ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

INGENIERO ELECTROMECÁNICO

DYNAMO LED BIKE SAFETY LIGHTS

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Madrid
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DYNAMO LED BIKE SAFETY LIGHTS

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RESUMEN DEL PROYECTO

1. Introducción

Actualmente, montar en bicicleta puede acabar en accidentes debido a la falta o al mal uso de luces tanto en la parte frontal como trasera de la bicileta. Por esa razón, el objetivo de este proyecto es implementar un sistema que permita al ciclista ser visto durante la noche. Además, este sistema contará con un mecanismo de señalización (derecha, izquierda, parada) al tener el ciclista en la parte delantera unos interruptores para avisar a los demás de que dirección va a tomar.

Hoy en día, existen en el mercado luces para la bicicleta, pero o no están siempre encendidas o no indican que dirección va a ser tomada por el ciclista. Asimismo, hay sistemas instalados en las bicicletas que permiten indicar que dirección va a tomar el ciclista, pero funcionan con baterías, por lo que el sistema puede dejar de funcionar con más facilidad ya que las baterías se agotan o se deterioran.

El objetivo de este proyecto es diseñar un mecanismo que permita instalar luces en las bicicletas sin la utilización de baterías, y que, incluso cuando el ciclista esté parado en un stop (no habría energía disponible, ya que esta energía provendrá de una dinamo para la bicicleta), los LEDs y el microprocesador funcionarán por un tiempo razonable. Como se ha dicho anteriormente, el punto principal de este proyecto es aportar visibilidad y seguridad para prevenir accidentes en los ciclistas. En conclusión, este proyecto mejorará la seguridad de ciclistas en ciudades y campus, y, al no usar baterías, ni contaminan ni dañan el medio ambiente.

La idea principal es usar una dinamo para la bicileta que permitá la correcta visualización de los ciclistas por la noche. Esto será implementado con un microprocesador y dos paneles de luces, uno en la parte frontal y otro en la parte trasera. Este producto funcionará con "energía gratis", ya que la energía será generada por la dinamo. Además, esta energía será almacenada usando supercondensadores, en vez de baterías recargables. Esto será utilizado para tener un mecanismo de señalización incluso cuando el ciclista esté parado en una señal de stop o en un semáforo. La razón por el uso de los supercondensadores en vez de baterías, es debido a su rapidez de carga y a la larga duración que ofrecen ya que pueden soportar muchos ciclos de carga y descarga. Finalmente, se usarán LEDs muy brillantes de bajo coste de mantenimiento.

2. Metodología

En la figura 1 podemos ver el diagrama de bloques del proyecto. Todos los bloques mostrados en esta figura funcionarán como se explica después para cumplir los objetivos mencionados anteriormente.

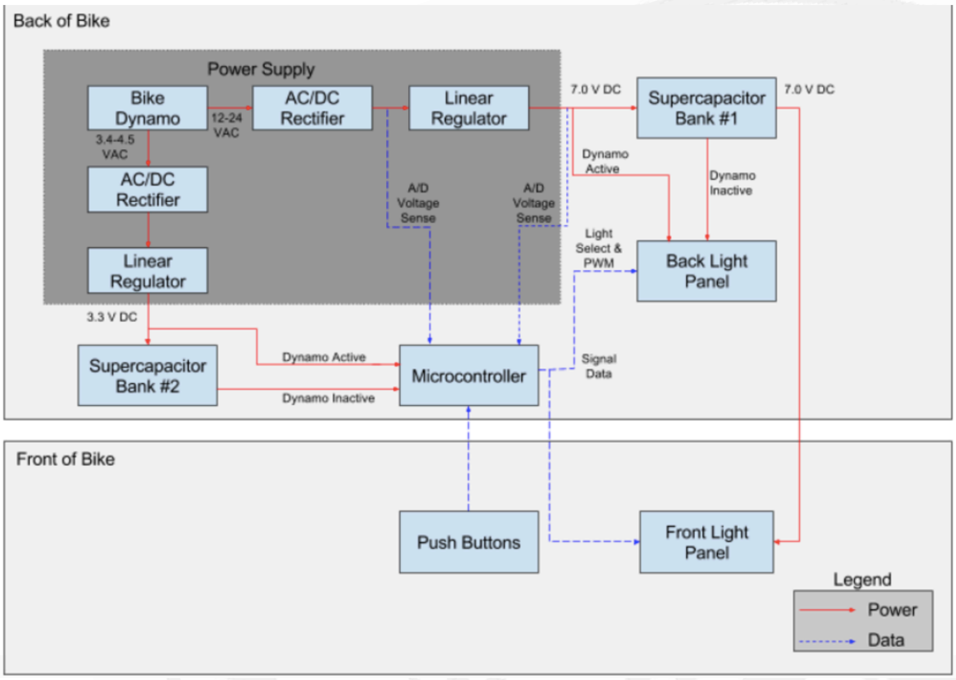


Figura 1: Diagrama de bloques

2.1 Dinamo

La dinamo para la bicicleta será usada como fuente de generación de energía en este diseño. Esta dinamo está tasada para 6 W, y dos voltajes de salida de corriente alterna de valor 12 y 3.4 Vrms. Los voltajes de salidas son dependientes de la velocidad del ciclista, siendo el valor entre 24 y 4.2 Vrms, respectivamente.

2.2 Rectificador CA/CC

Cada voltaje de entrada de alterna alimentará a un rectificador de diodos de puente completo que tendrá un condensador de salida para producir un voltaje de continua. Este rectificador tendrá dos funciones principales: la primera, suministrar voltaje de entrada al regulador linear y la segunda, saber que el microprocesador funciona bien.

2.3 Reguladores lineales

El uso de los reguladores lineales es necesario para hacer que el microprocesador y los paneles, tanto frontales como traseras, funcionen. Además, es el encargado de cargar los bancos de supercondensadores #1 y #2.

2.4 Bancos de supercondensadores

Dos bancos de supercondensadores serán usados para almacenar energía y luego, ser usada cuando no hay energía disponible, es decir, cuando el ciclista está parado en una señal de stop o en un semáforo (en estos momentos, la dinamo está inactiva). Además, los supercondensadores serán utilizados para mantener el sistema funcionado.

El primer banco de supercondensadores será tres 2.5 V, 10 F supercondensadores en serie, por lo que la capacidad total será de 3.33 F, tasado a 7.5 V. Este banco será usado para que los paneles con las luces funcionen.

El segundo banco de supercondensadores se implementará con un 3.6 V 1 F condensador. El objetivo principal de este banco es que el microprocesador funciona cuando la dinamo esté inactiva.

2.5 Paneles de luces

Para este proyecto, dos paneles de luces serán usados para asegurar la visibilidad. El voltaje de salida de 7 V del regulador lineal sumistrará energía cuando la dinamo esté activa, y, cuando esté inactiva, esta energía será suministrada por los bancos de supercondensadores. El uso de los BJT será necesario ya que actua como un interruptor de corriente controlada, y también para el diseño, ya que el microprocesador no sería capaz de encender todos los LEDs.

2.6 Microprocesador

El microprocesador es el cerebro del diseño. Dos importantes tareas serán desempeñadas por este bloque: la primera, detectando tanto como el voltaje de entrada como el de salida del regulador lineal; la segunda, recibir voltaje de entrada para pulsar los interruptores y determinar que dirección el ciclista va a tomar.

3. Resultados

Todos los requisitos de este proyecto han sido complidas cuando el producto final fue acabado. El tiempo de carga de los supercondensadores es de 60 segundos cuando el ciclista va a una velocidad media de 11 mph. Además, el sistema funciona por cinco minutos, mucho más de lo que está parado un ciclista en un semáforo o en una señal de stop, cuando está totalmente cargado.

Debido a la simplicidad del diseño, el producto fue pulido. Esto incluyo la optimización de la PCB con componentes de superficie y del tamaño adecuado. Por último, el tamaño de la placa ha sido determinada por un contenedor, para que el producto sea resistente al agua.

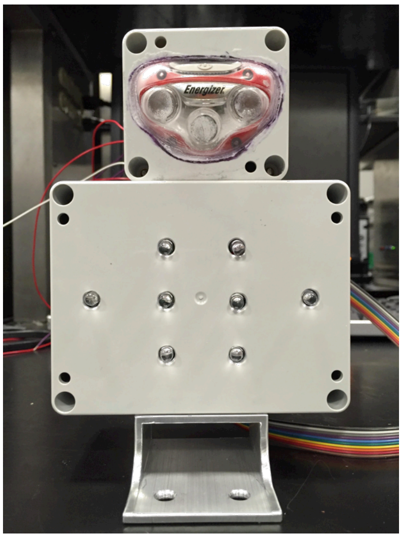


Figura 2: Producto finalizado

4. Conclusión

Hay muchos productos que pueden conseguir los objetivos de este proyecto. Por lo contrario, este producto tiene unas funciones que lo pueden distinguir de los productos que se venden hoy en día, ya que estos no tienen sistemas de señalización y usan baterías en vez de supercondensadores. Además, este proyecto es asequible económicamente: si compramos un producto parecido en Amazon, costaría $32.64, mientras que este producto ha costado hacerlo $41.29, pero, si las piezas se piden en masa, el producto pasaría a costar $22.92. Como resultado, estas LEDs para la bicileta es un producto que aporta un panel frontal y otro trasero, que comparado con otros que necesitan paneles separadas y usan baterías, es económico y efectivo.

DYNAMO LED BIKE SAFETY LIGHTS

SUMMARY OF THE PROJECT

1. Introduction

Nowadays, riding a bicycle could end up in an accident or bike injuries due to the lack of or improper use of headlights and tail lights in the bike. For that reason, this project aims to implement a system that will allow the rider to be visible at night. Besides, this system will have a signaling sytem (left, right, stop) as the cyclist will have push buttons in the front such that he can make others aware of their intended action.

Currrently, there are bike lights on the market, but they are simply always lit and do not indicate any intent from the bicyclist. In addition, there are signaling systems on the market but these are battery powered that the lights could go out at any time.

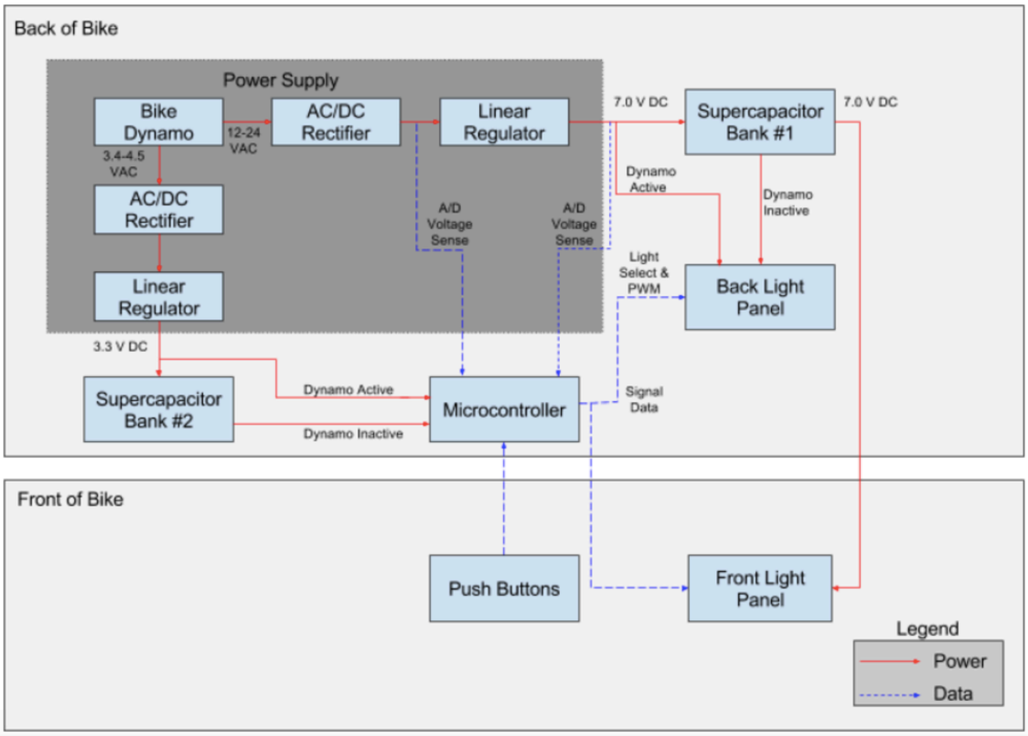
The goal of this project is to make a cost effective, self-sustainble LED lights that even at a complete stop (no generation available, as the energy will come from a bike dynamo), the LED’s and the microcontroller will stay powered for a reasonable amount of time. As it was mentioned before, the main key point of this porject is to provide increased visibility and safety in order to prevent cyclist injuries from occuring. Overall, this project will enhance bike safety in cities and campuses while also leaving a green footpint, and it will end up in happy cyclists.

The main idea is to use a bike dynamo to power a system that will allow the rider to be visible at night. This will be done with a microcontroller and two light panels, one in the front and one in the back. This product will work with “free energy”, as this energy will be generated from the dynamo. This energy will be stored using supercapacitors, as opposed to rechargeable batteries. This will be used to have a signal system also when the cyclist is stopped at a stop signal or a traffic light. The reason of using supercapacitors instead of battery is due to its lower charging times and the great lifetime they offer as they can withstand many charge/discharge cycles. Finally, low maintenance super bright LED lights wil be used.

2. Methodology

Figure 1 shows the block diagram of the project. As we can see in the figure, there a lot of blocks that will work in order to fulfill the project's goals.

Figure 1: Block Diagram



2.1 Bike Dynamo

A bike dynamo will be used as the source of generation in the design. This dynamo is rated for up to 6 W and outputs two AC voltages, 12 Vrms and 3.4 Vrms. The output voltage is dependent upon the speed of the rider, being between 24 Vrms and 4.2 Vrms, respectively.

2.2 Power supply- AC/DC rectifier

Each AC input will be fed into a separate full-bridge diode rectifier with an output capacitor to produce a DC voltage The AC/DC rectifier will be used for two main functions: the first one, to supply input to the linear regulator and the second one, to sense the microcontroller.

2.3 Power supply-Linear Regulator

The use of a linear regulators is needed to power the microcontroller and the front and back lights; in addition, to charge the supercapacitor bank #1 and #2.

2.4 Supercapacitor banks

Two supercapacitor banks will be used to store energy and then use it when there is no generation available, in other words, when the cyclist is stopped in a stop signal or traffic light (in these moments, the dynamo is inactive). In addition, supercapacitors will be used to maintain system functionality.

The first supercapacitor bank will be three 2.5 V, 10 F supercapacitors in series, so the total capacity will be 3.33 F, rated at 7.5V. This bank will be used to provide the necessary power to make the panel work.

For the second supercapacitor bank, it was implemented with a 3.6 V 1 F panasonic capacitor. The main purpose for this capacitor is to power the microcontroller when the dynamo is inactive.

2.5 Light panel

For this project, two light panels will be used to ensure visibility. Either the 7 V output from the linear regulator when the dynamo is active or the supercapacitor bank will supply power when the dynamo is inactive. The use of BJT will be necessary in order to act as a current controlled switch, and also it is necessary for the design since the microcontroller would not be able to source enough current to adequately light all the LEDs.

2.6 Microcontroller

The microcontroller is the brains of the operation. Two important tasks will be performed by the microcontroller. The first will be voltage sensing at the input and output of the linear regulator. The second task will be to receive input from the push buttons and determine which action the rider chooses to take.

3. Results

All the requirements of this project were fulfill as the final product was finished. The charge time of the supercapacitors is 60 seconds while the rider bikes at average speed of 11 mph. In addition, the system functions for five minutes, much longer than any trafic light, once full charge is reached.

Due to the simplicity of the design, the product was polished. This included: optimizing the PCB with surface mount components, providing test pads on the board, and sizing components appropriately. Ultimately, the board size was determined by the size of the container, as the product could be waterproof.

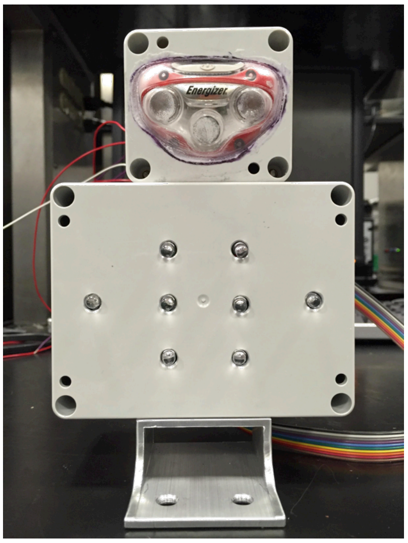


Figure 2: Final package product

4. Conclusion

There are a lot of products that can accomplish the goals of this project. However, this product has some functions that distinguish it for the products that sell nowadays, as the ones sold don't have turning signal lights or uses batteries instead of supercapacitors. In addition, the Illini Bike LED is affordable. If we buy this product in Amazon, it will cost $32.64. On the other hand, this product will cost $41.29 and if we buy it in a bulk order, it will cost $22.92. To sum up, Illini LED Bike Dynamo is a cost effective product that provides both front and back safety lights compared to the other ones, which requires a battery and a separate headlight.

Table of Contents

Figure Index

Table Index

PART 1:REPORT

CHAPTER 1: INTRODUCTION

In this chapter, there is an introduction of the project and also, the goals and benefits this project wants to accomplish. In the next chapter, it will be explained how this project is going to work, with the block diagram and an explanation of the function of each block in order to achieve all the project's benefits. Besides, in the third chapter, some calculations about the components used can be found in that part. In the last chapters we can see the requirements and verifications table, the simulations and the parts used.

In the second part of this project, in future work, it will be discused all the work that can be done after this project to improve the design and the efficiency of the project.

In the third part, we can find the conclusion of the project and in the last one, all the references we have used along the project.

1.1 STATEMENT OF PURPOSE

Riding a bicycle can be a dangerous endeavor, especially during the night when visibility is low [ILLI09]. With an increasing number of bicyclists in today's society, the ability to be seen on the road is very important. However, many current products on the market require frequent maintenance or do not provide visibility when stopped. The Meilan X5 Safety Light is a wirelessly operated signal system that provides rear visibility. However, this product uses rechargeable batteries that will only last four hours at full brightness for every full charge. A dynamo bike light set harnesses the tire rotation to power safety lights, yet does not provide any means to signal nor does it work when motionless. This project aims to implement a batteryless, dynamo driven lighting and signal system that will function both when riding and when stopped. By harnessing the power produced by the rider, the project can leave a green footprint while simultaneously enhancing the safety of the rider.

In addition to producing a functional product, the aim was also to produce a very polished product due to the simplicity of the design. This encompassed reducing costs through component selection, sizing the board such that it could be placed in a pick and place machine, and creating test pads on the finalized board for easy debugging. On the mechanical side, the product was required to have a waterproof housing such it could withstand the harshest conditions.

Supercapacitors are indeed a viable means of energy storage for low power brownout applications. In addition, supercapacitors do not need a complex charging circuit which allowed the design to be simple and compact on the PCB. For the project, the aim was to create a battery-less bike light system complete with front headlights and rear turn signals that are push button operated. In order to generate the power necessary to fulfill the goals we used a bike dynamo that will ride along the bike tire. The dynamo produces energy that is stored in two separate supercapacitor banks: one to power the light panel and one to power the microcontroller that will be discussed later in Chapter 2. For thar reason, when the rider is stopped, the lights should continue to provide visibility, that it will be store in the supercapacitor banks, for the average stop light time of around 45 seconds.

1.2 OBJECTIVES

1.2.1 GOALS AND BENEFITS

As it was mentioned in 1.1 Statement of Purpose, the main goal of this project is to be seen while riding a bike in order to decrease the number of accidents, as 22% of the 48,000 cyclists injuries reported in 2013 occured during 6 and 9 pm, when there is less visibility [PEDE14].

Nowadays, you can buy tons of bike lights that will accomplish this goal, but none of them will last more than 4 hours at full brightness for every full charge. For that reason, this product will use two supercapacitors bank so it will have low maintenance and it will be self-sustainable. In addition, as a dynamo will be employed, the power necessary to lighten the LEDs will be providen by the dynamo without using any type of battery, so it will leave a green footprint.

1.2.2 FUNCTIONS AND FEATURES

As it was mentioned in 1.1 Statement of Purpose, in this project, instead of using a battery that will store energy to lighten the lights, the energy will be harnessed by a bike dynamo. When the cyclist will stop in a stop signal or in a traffic light, the dynamo will harness no energy, so the energy used to lighten the LEDs will come from two supercapacitor banks that will store this energy while the cyclist is pedaling. Besides, a turn signal system will be implemented to know what direction the cyclist is going to take (right, left or if he/she is going to stop). This system will be installed with low maintenance super bright LED safety lights.

CHAPTER 2: DESIGN

2.1 BLOCK DIAGRAM

Figure 1 shows the block diagram of the project. Both parts of the project, front and back panel, will be connected by a bundle of 8 wires that would be used to transmit data and power.

As we can see in figure 1, in the front panel the product will have push buttons in order to always know what directions the cyclist is going to take. In addition, two super bright white LEDs will be always lighten so the cyclist can be seen from the front part of the bike.

On the other hand, in the back of the bike, the energy harnessed by the bike dynamo will power two AC/DC rectifiers, depending the two output voltage this dynamo has. Each of these rectifiers will be used to store energy in the supercapacitor banks passing through linear regulators. Two supercapacitor banks will be used: the firt one to ligten the front and back light panel, and the second one to make the microcontroller work. This will be explained with more details in the block descriptions listed after.

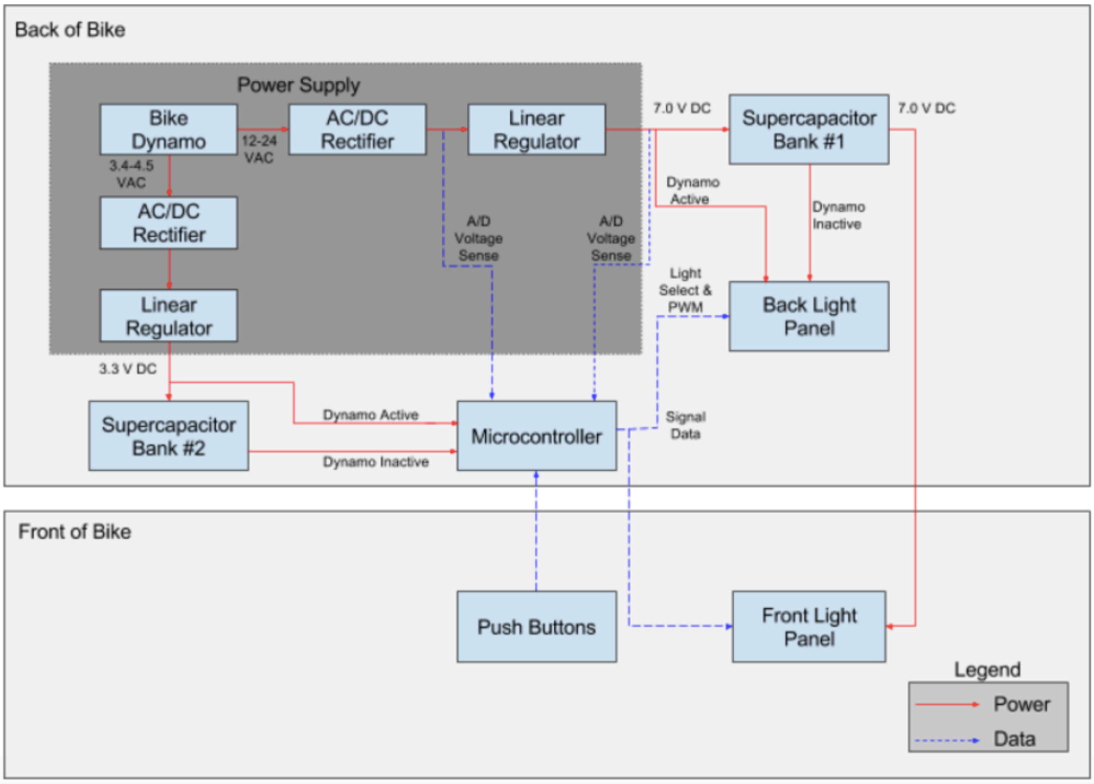


Figure 1. Block Diagram

Figure 2 shows the initial block diagramthat was going to use to implement the goals. While the core of the design remained intact, instead of using a bundle of eight wires, a wireless portion was intended to provide response to the push buttons. This would also eliminate the coin cell battery and second microcontroller and resulted in significant cost savings. Another change to the block diagram was the replacement of the DC/DC converter with another linear regulator: after extensive testing and debugging, the problem was narrowed down to noise in the feedback loop due to PCB layout which led to improper output. For this reason, this converter was switch to a linear regulator. The dynamo could provide suficient power for the circuit thus eficiency was not a concern. Lastly, the linear regulator was much cheaper and simpler than the buck converter IC which resulted in decreased cost and simpler PCB layout.

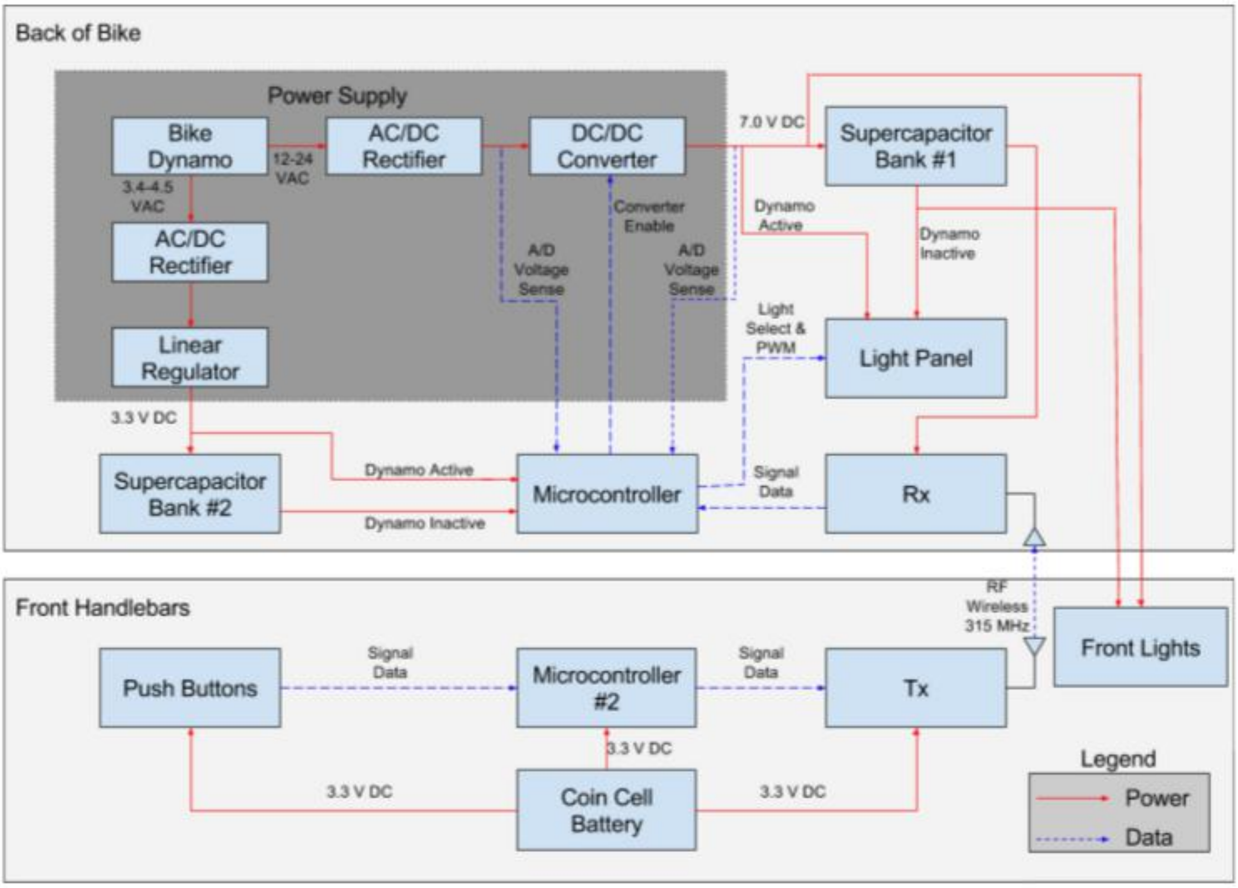


Figure 2. Original System Block Diagram

2.2 BLOCK DESCRIPTIONS

2.2.1 POWER SUPPLY- BIKE DYNAMO

A bike dynamo will be used as the source of generation in the design. This dynamo is rated for up to 6 W and outputs two AC voltages, 12 Vrms and 3.4 Vrms. After receiving the dynamo and performing preliminary tests, it is noted that the dynamo may output a voltage as high as 24 Vrms and 4.2 Vrms, respectively. The output voltage is dependent upon the speed of the rider. For example, at 12 MPH the dynamo outputs 13 Vrms and 3.5 Vrms.

2.2.1.1 Bike Dynamo Self Study

The dynamo purchased from Amazon had very little electrical data so it was necessary to perform tests to characterize the dynamo. Figure 3 shows the test set up where the generator on the left is attached via a belt to the motor on the right. This set up will allow the project to easily simulate the dynamo riding on the rubber tire of the bike without having to physically bike around.

Figure 4 shows multiple I-V curves for varying load. This test was done for the high side only, as it will need to supply enough current to charge the supercapacitors quickly. The supercapacitors drew about 500 mA when the voltage output of the high side was 17 V. Figure 5 shows how the two voltages produced by the dynamo increase proportionally with increasing bike speed. The maximum voltages we would expect are 10 V for the low side and 38 V for the high side. The choice was to use linear regulators that could handle these maximum ratings.

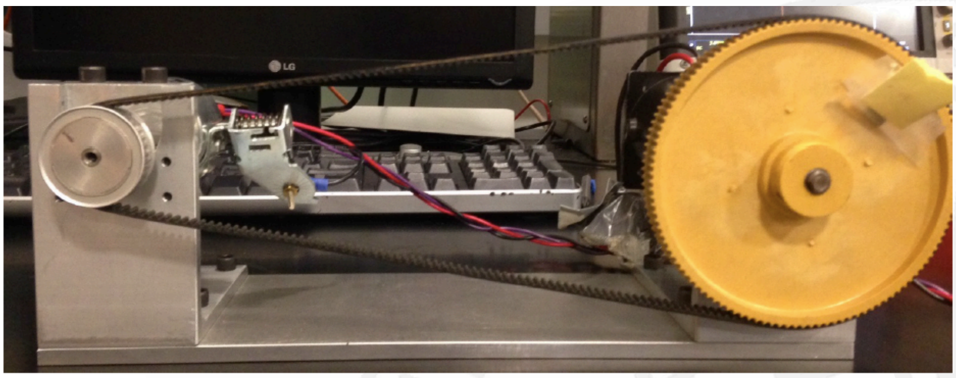


Figure 3. Dynamo Motor Test Setup

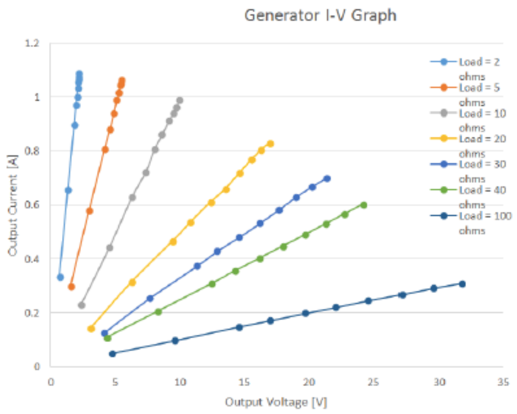


Figure 4. Generator I-V Curves

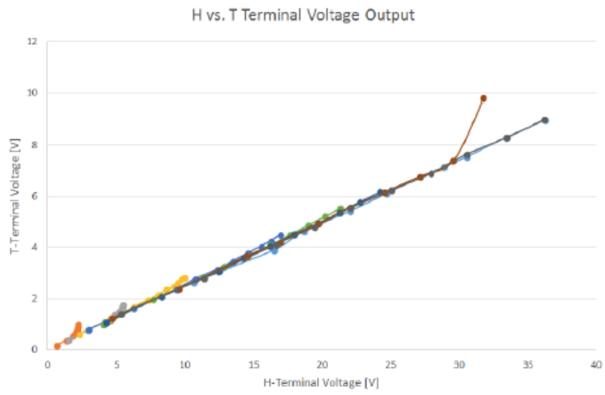


Figure 5.Generator High vs. Low Voltage

Figure 6 shows how the motor RPM equates to the biker speed in mph. Table 1 shows how the input voltage to the motor relates to the motor RPM. The average biker speed of about 11 mph would equate to about a 7 V input to the motor. To obtain the MPH estimate, the motor RPM is multiplied by the gear ratio of 3.5 and the circumference of the dynamo as seen in equation 1. A sample calculation is shown below for the 7 V input.

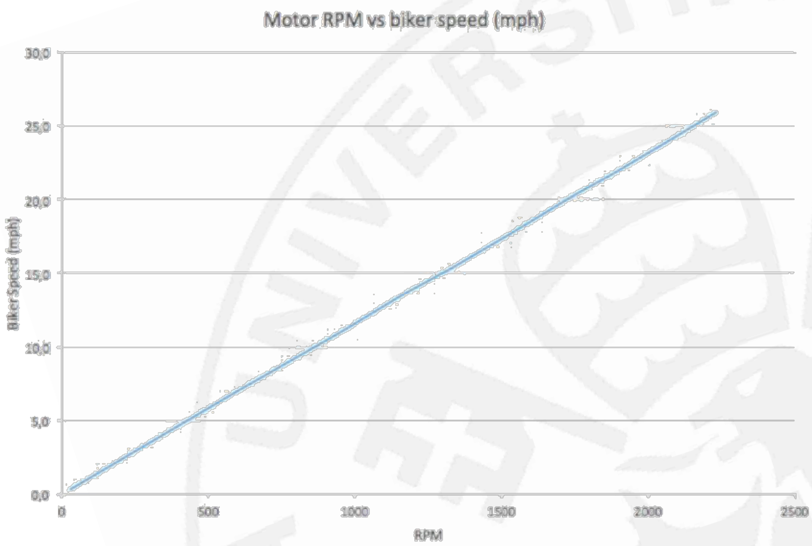


Figure 6. Motor RPM vs Bike Speed (mph)

$$mph = \frac{revolutions}{minute} * 3.5 * \frac{.3\,ft}{revolution} * \frac{1\,mile}{5280\,ft} * \frac{60\,minutes}{hour}$$

$$956 * 3.5 * \frac{.3\,ft}{revolution} * \frac{1\,mile}{5280\,ft} * \frac{60\,minutes}{hour} = 11.4\,mph \quad (1)$$

Table 1: Input Motor Voltage and Motor RPM

Input Voltage	Motor RPM
3	28
5	600
7	956
8	1153
9	1327
10	1536
11	1760
12	1870
13	2070
14	2230

2.2.2 POWER SUPPLY- AC/DC RECTIFIER

Each AC input will be fed into a separate full-bridge diode rectifier with an output capacitor to produce a DC voltage equal to the peak of the AC voltage produced by the dynamo. The AC/DC rectifier will be used for two main functions: the first one, to supply input to the linear regulator and the second one, to sense the microcontroller.

For the high side, the maximum expected voltage will be 38 V and for the low side, it will be 10 V.

Shown in Figure 7, we can see the schematic for the full-bridge rectifier. Schottky diodes were used rated for 40 V and 2 A due to their low forward voltage drop. Not pictured in the schematic are the output capacitors to smooth the rectified waveform to a near DC output. For the high side, it was used a 680 uF capacitor rated for 40 V and for the low side we used one 47 uF capacitor rated for 10 V. The pads in the schematic are for test pads that will be used to probe intermediate points of interest on the PCB for easy debugging.

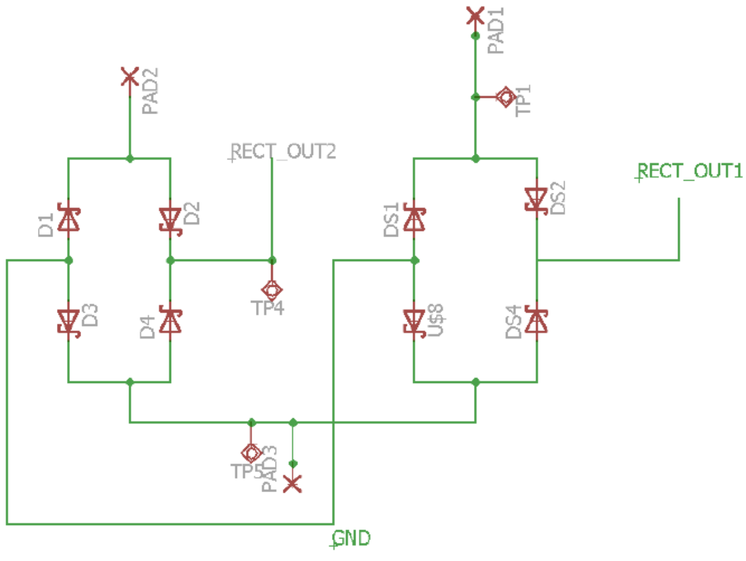


Figure 7. Full Bridge Rectifier

2.2.3 POWER SUPPLY- LINEAR REGULATOR (3.3 V)

When the dynamo is active, the linear regulator will accept a DC voltage anywhere from 4.81 to 5.94 V and output a 3.3 V DC voltage. This DC voltage comes from the AC/DC rectifier. We have to use a linear regulator to ensure a consistent voltage output due to the sensitivity of the microcontroller. The 3.3 V output is needed to power the microcontroller as well as charge supercapacitor bank 2 which consists of one 1 F 3.6 V supercapacitor.

In figure 8, we can see the LD1117, an adjustable and fixed low drop positive voltage regulator, which has an input between 3 and 40 V and an output of 3.3 V. This linear regulator is used for supercapacitor bank #2.

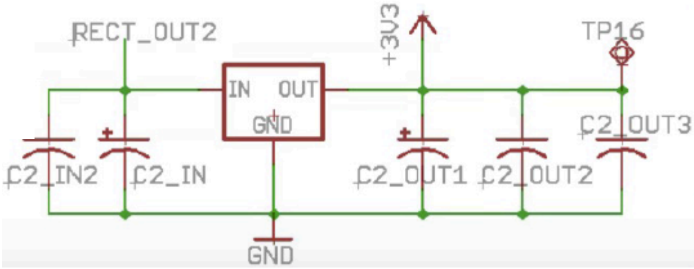


Figure 8. 3.3 V Linear Regulator

2.2.4 POWER SUPPLY- LINEAR REGULATOR (7 V)

The linear regulator must accept an input voltage up to 38 V and have an output of 7.0 +/- .1 V. The 7 V output will be used to power the front and back lights as well as charge supercapacitor bank #1. The LM317, a three-pin adjustable regulator, can take an input voltage up to 40 V and has an adjustable output voltage, setting this voltage to be 7 V as will be shown in the following section.

Shown in Figure 9 is the schematic for the feedback portion of the LM317. From the datasheet, the feedback resistors are set using equation 2 [STMI14].

$$Vo = 1.25(1 + \frac{FB1}{FB2})$$
$$Vo = 1.25\left(1 + \frac{1000}{215}\right) = 7.064\,V \tag{2}$$

The LM317 proved to be a viable and cost efective alternative to the buck converter as mentioned previously. The output voltage stayed within the tolerance of 7 .1 V for varying dynamo inputs.

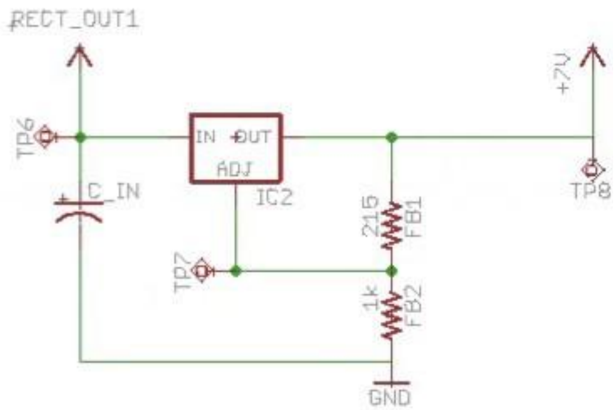


Figure 9. LM317 Feedback Schematic

2.2.5 SUPERCAPACITOR BANK #1

Two supercapacitor banks will be used to store energy and then use it when the dynamo is inactive. In addition, supercapacitors will be used to maintain system functionality. The first supercapacitor bank will be three 2.5 V, 10 F supercapacitors in series, so the total capacity will be 3.33 F, rated at 7.5V. This bank will be used to provide the necessary power to make the panel work. The target is for the supercapacitors to discharge steadily, powering the system for up to 45 seconds while there is no generation. The bank will charge when the dynamo is active, (i.e. the rider is pedaling).

In order to extend the lifetime of the capacitors for a brownout period, as well as alert any trafic the rider is stopped, the back LED's will be ashed with a 50% duty cycle. The current draw was anticipated and designed to be 68 mA (halved when stopped) from the back lights and 17 mA from the front lights for a total of 51 mA (when stopped) during brownouts. Equation 3 shows the estimation of light length for an assumed constant current of 51 mA and capacitor voltage remaining above 6 V. This exceeds the 45 s target time.

For supercapacitor bank #1, each LED array will draw a maximum of 19 mA to light 2 LEDs in series. We will have four such arrays in parallel so the total maximum current will be 4x19mA = 76 mA. During brownout we will blink at a 50% duty cycle effectively halving the current to 38 mA.

The supply voltage of the capacitor must not decay below 6.0 V which accounts for the scenario of two 2.0 V drops in the LED's, a voltage drop across the collector-emitter junction of about .4 V, and a 3.6 V drop across a 160 Ω resistor. Assume this current stays constant for the entire 45 seconds, the capacitor will need to supply = .64 mAh. Thus the capacitor must be able to discharge at a rate of 51 mA for longer than 45 s without its voltage dropping below 6.0 V.

$$I = C\frac{dv}{dt}$$

$$dt = \frac{C * dv}{I} = 3.33 * \frac{1}{.051} = 65.2\ s \tag{3}$$

Now the tolerance on each capacitor is -20% to 80%. An increased capacitance will be of no issue but let us assume that each capacitor is actually 20% less than the rated value of 10 F. Three 8 F capacitors in series would amount to a 2.67 F total. Solving for the time change at a 51 mA constant current draw, it is found that the voltage will be maintained above 6 V which again exceeds the requirement as we can see in equation 4.

$$dt = \frac{C*dv}{I} = 2.67 * \frac{1}{.051} = 48.54\ s \tag{4}$$

The reason the specification in the capacitor voltage remain above 6 V in the R

& V requirements was due to the voltage drop across each LED of 2 V. It was assumed that as the capacitor voltage fell the lights would fade rather quickly due to diminishing current. However, the LEDs purchased performed better than expected and had a strong luminosity at very low currents. From full charge, the back lights remained visible for approximately 20 minutes.

In figure 10, we can see supercapacitor bank #1, with three capacitors of 10F, 2.5 V each and a RC resistor to vary charging time of 1 Ohm, 1W.

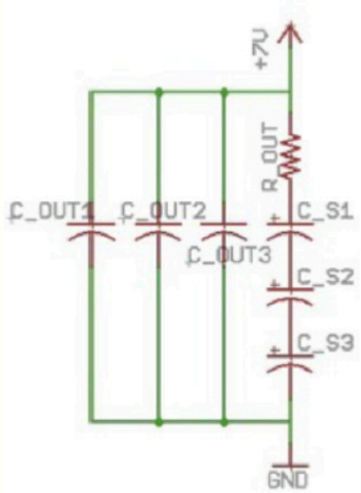


Figure 10. Supercapacitor bank #1

2.2.6 SUPERCAPACITOR BANK #2

For the second supercapacitor bank, it was implemented with a 3.6 V 1 F panasonic capacitor. The main purpose for this capacitor is to power the microcontroller when the dynamo is inactive. This capacitor was placed at the output of the 3.3 V linear regulator and thus overvoltage would not be an issue due to the .3 V buffer. A similar estimation of lifetime is made in equation 5. It is desired the microcontroller voltage remain between 3-3.3 V as the ADC reference voltage must be as consistent as possible.

$$I = C\frac{dv}{dt}$$

$$dt = \frac{C * dv}{I} = 1 * \frac{.3}{.001} = 300\ s \tag{5}$$

Again, three hundred seconds is more than suficient for the purposes. Additionally, one might argue that less capacitance could be used since the target time was only 45 s. However, as mentioned previously, we wished that the ADC reference voltage remain as constant as possible so the less fluctuation in voltage the better.

In figure 11, we can see supercapacitor bank #2, with a capacitor of 1F, 3.6 V.

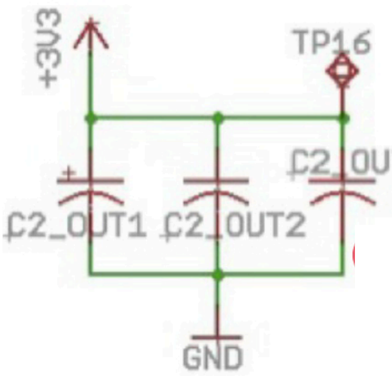


Figure 11. Supercapacitor bank #2

2.2.7 LIGHT PANEL

The back light panel will consist of four series strings of 2 LED's (8 total), current limiting resistor, and a BJT. Power will be supplied by either the 7 V output from the linear regulator when the dynamo is active or the supercapacitor bank when the dynamo is inactive. Each string will be controlled by one output pin from the microcontroller by means of a BJT. The BJT will act as a current controlled switch, and is necessary for the design since the microcontroller would not be able to source enough current to adequately light all the LEDs. A high output of 3.3 V from the microcontroller will inject current into the base causing current to flow from collector to emitter. The collector emitter current should be maintained between 14-19 mA to ensure visibility. With four strings, it will be able to signal left, right, and straight. Power consumption will be a large factor for this module, especially during times when no generation is available and the supercaps are providing system power.

Shown in Figure 13 is the schematic for the back light panel. Resistor values were chosen using the value of 100 from the BJT datasheet and a desired collector current of 17 mA [DIOD16]. Equations 6, 7 and 8 show the calculations for the base resistor as well as the series resistor [SEDR10], as we can see in chapter 3. Voltage drops of .4 V, .7 V and 2 V were assumed for the collector-emitter junction, base-emitter junction, and LED forward voltage, respectively.

For the final PCB, it was used values of 160 and 15 k as those were readily available. Using DC power supplies the current draw for all four branches was veried to be 68 mA, or 17 mA per branch. In addition, in figure 12, we can see the final front light panel, using the same values for the resistors as used in the back one, but only with one array with two LEDs, as the cyclist do not have to show what direction is taking from the front panel.

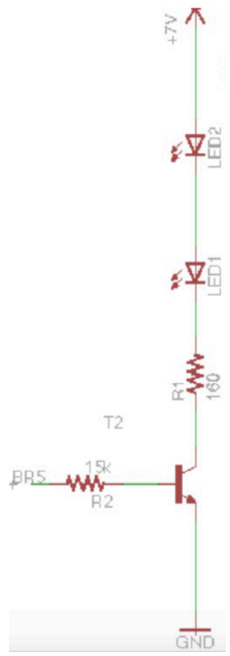


Figure 12. Front Light Panel Schematic

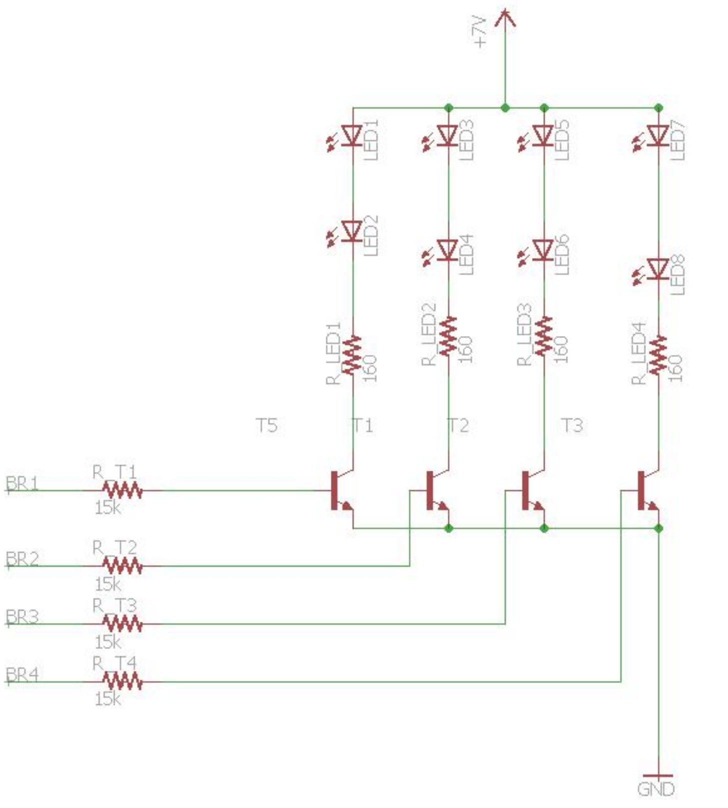


Figure 13. Back Light Panel Schematic

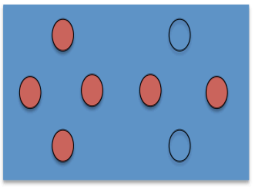


Figure 14.1. Left turn signal

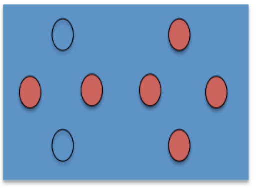


Figure 14.2: Right turn signal

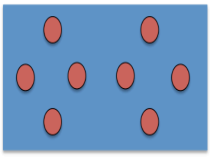


Figure 14.3: Stop

2.2.8 MICROCONTROLLER

The microcontroller is the brains of the operation. Because this system is limited in terms of available generation, the best option for the low power is PIC16F877A. Power will be provided by a 3.3 V linear regulator when the dynamo is active, and a supercapacitor rated for 3.6 V, 1 F when the dynamo is inactive. Two important tasks will be performed by the microcontroller. The first will be voltage sensing at the input and output of the linear regulator. If input voltage is not sensed, then the lights will blink to alert trafic the rider is stopped and conserve life. It is important that the voltage rating on supercapacitors is not exceeded as overvoltage on an electrolytic can shorten its lifetime or permanently damage the charging capability. The second task will be to receive input from the push buttons and determine which action the rider chooses to take.

Figure 15 depicts the pin-out for the microcontroller. There are four input pins used for push button communication, five output pins used for BJT switching, and two pins used for A/D conversion. A 16 MHz crystal oscillator was used for the microcontroller clock.

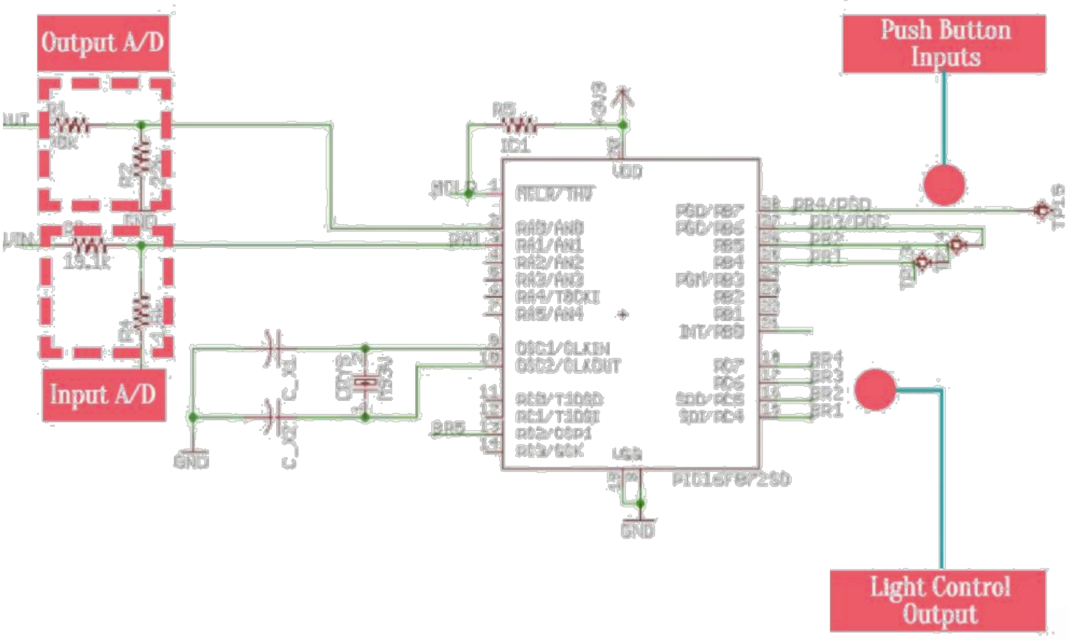


Figure 15. Microcontroller Schematic

CHAPTER 3: CALCULATIONS

3.1 LIGHT PANEL

The light panel will consist of a current limiting resistor, 2 LED's, and a BJT. The BJT will act as a switch, enabling current to flow when output is high from the microcontroller. The panel will be powered by the 7 V output from the linear regulator when the dynamo is active. When the dynamo is inactive, the supercapacitor will supply the light panel with a decaying voltage. The desired current is 17 mA and the BJT V_{be} will be estimated to be .7 V. The current into the base of the BJT will govern the collector-emitter current as shown in equation 6. Assuming β = 100 (this will vary slightly based on each individual BJT).

$$Ic = \beta * Ib \rightarrow Ib = \frac{17\ mA}{100} = 170\ \mu A \tag{6}$$

Then, the base resistor can be calculated as in equation 7.

$$Rb = \frac{Von - Vbe}{Ib} \rightarrow Rb = \frac{(3.3 - .7)V}{170\ \mu A} = 15.2\ k\Omega \tag{7}$$

A resistor of 15 kΩ will be chosen for the base. Next, the series resistor value will be determined. It will be assumed a .4 V_{ce} and we will use the measured voltage drop across the chosen LED's of 1.98 V. Equation 8 shows the calculation for R_S. We will choose a 160 Ω resistor for R_S.

$$Rs = \frac{Vlinreg - 2 * Vdiode - Vce}{Ib} \rightarrow Rs = \frac{7 - 2 * 1.98 - 0.4V}{170\ \mu A} = 155.29\ \Omega \tag{8}$$

3.2 BIKE DYNAMO

The dynamo is rated for up to 6 W and has two AC terminals - 12 Vrms and 3.4 Vrms. The lower voltage terminal, "T" is intended for taillights and the higher voltage terminal, "H" for headlights. With preliminary testing, the "H" terminal produces an AC voltage of 12.72Vrms, whereas the "T" produces 3.68 Vrms at no load with bike speed of approximately 11 miles per hour. However, once some load is put onto the generator (25 ohms), approximately going about the same speed at 11 miles per hour, it was measured on the high side voltage to be 11.67 Vrms and, on the low side voltage, 2.98Vrms, producing 4.67W at the high side and 0.28W at the low side. The frequency of the both AC waveforms was 83.33Hz for output load of 25 ohms and 95.3Hz at no load. The power produced depends on the overall resistance of the output load and how well the load is matched to the dynamo's internal resistance. With internal resistance of 9.3 ohms and internal inductance of 17.7mH, it is easy to calculate the current at 25 ohm load as we can see in equation 10.

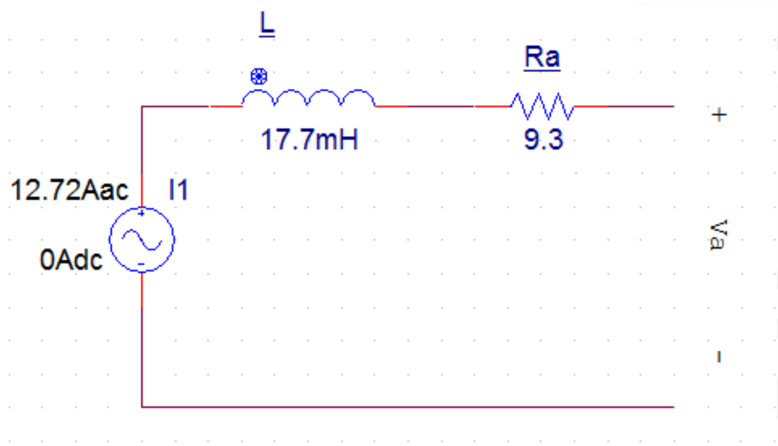


Figure 16. AC Single-phase Synchronous Generator Equivalent Circuit

Open circuit and short circuit testing indicated the values of the following parameters:

$$Eaf = 12.72\ Vrms, Ls = 17.7mH, Ra = 9.3\ \Omega, Rl = 25\ \Omega$$

$$Eaf = Ia(Ra + jXs + Rl) = Ia(Ra + jwLs + Rl), where\ w = 2\Pi f \tag{9}$$

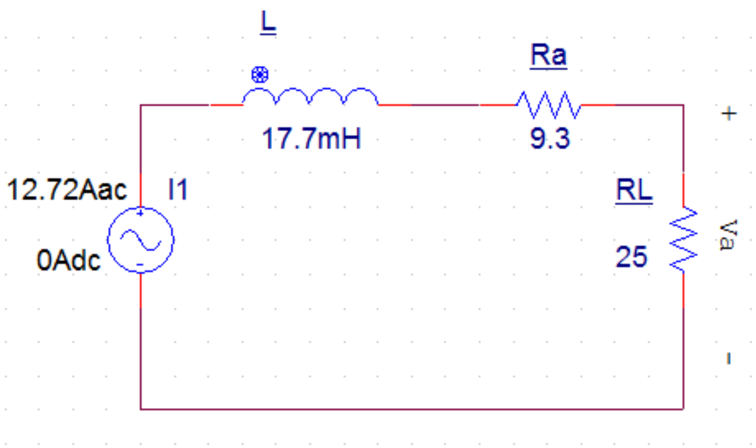


Figure 17. Equivalent Circuit Synchronous Generator with 25load

Using the above circuit diagram we can calculate the current through the load:

$$12.72V = Ia(9.3 + j(2\Pi * 83.33 * 0.0177) + 25)$$

$$12.72\ V = Ia(34.5 + j9.26) = Ia(35.5\ < 15.1°) \tag{10}$$

$$Ia = \frac{12.72}{35.5} = 0.36\ A$$

However, during the preliminary testing with output load of 25 ohms, the current measured through the output load was 0.46A. Using the above theoretical value, the percent error between the theoretical value and the actual experimental value is calculated using the formula below, shown in equation 11:

$$\%error = \frac{0.36 - 0.46}{0.36} * 100 = 28.2\% \tag{11}$$

Table 2 summarizes and compares the testing and calculation results at no load and at 25 output load.

Table 2: AC Synchronous Generator Voltage, Current & Power Comparison with no load vs. 25

Terminal	@ 11mph	No load	Load= 25Ω
H	V_{pp} [V]	36 [V]	33 [V]
	V_{rms} [V]	12.72 [V]	11.67 [V]
	I_1 [A]	0 [A]	0.467 [A]
	P_1 [W]	0 [A]	5.45 [W]
	f_1 [Hz]	95.3 [Hz]	83.33 [Hz]
L	V_{pp} [V]	10.4 [V]	8.43 [V]
	V_{rms} [V]	3.68 [V]	2.98 [V]
	I_2 [A]	0 [A]	0.095 [A]
	P_2 [W]	0 [W]	0.28 [W]
	f_2 [Hz]	95.3 [Hz]	83.33 [Hz]

CHAPTER 4: REQUIREMENTS AND VERIFICATIONS

Table 3: Requirements and Verifications plan

Requirements	Verification Procedure
1. Bike dynamo I. The bike dynamo provides two AC output voltajes: 12 +/- 1 and 3.4 +/- 1 Vrms and produces 6 +/- 0.5 W of power at speed of 12 mph	**Verification process for item I:** a. Use a DC motor to rotate bike generator at 12 mph. b. Apply voltage across the motor and measure output voltage and current. c. Ensure voltajes read than 12 +/- 1 and 3.4 +/- 1 Vrms. d. Attach a 25 ohm power resistor to 12 V lead and 3.4 V leads. e. Measure power dissipated at each terminal f. Ensure sum of power is > 6 +/- 0.5 W.
2. AC/DC Rectifier and DC/DC converter I. Input is 12-24 Vrms AC and output is 7.0 V +/- 0.1 V DC for 0.857 A load	**Verification process for item I:** a. Attach electronic load in current mode set for 0.86 A at linear regulator output. b. Attach oscilloscope across load c. Sweer voltage from 12-24 vrms AC d. Ensure output voltage remains between 6.9 and 7.1 V
3. AC/DC Rectifier and 3.3 V DC linear regulator	**Verification process for item I:** a. Attach 660 Ω load resistor

I. Input is 3.4-4.5 Vrms AC and output is 3.3 V +/- 0.1 V DC for 5 mA load.	b. Attach oscilloscope across load c. Sweep voltage from 3.4-7 Vrms AC d. Ensure output voltage remains between 3.2 and 3.4 V
4. Light Panel I.8 LEDs with luminous intensity such that they can be viewed from 500 feet away when powered from constant 7 V source [SEDR10]. II.8 LEDs with luminous intensity such that they can be viewed from 500 feet away when powered from 7.5 V, 3.3 F capacitor bank charged to 7 V for 45 seconds [SEDR10].	**Verification process for item I:** a. Wire a 160 Ω resistor, two LED's, and a BJT in series. b. Power the series branch with a 7.0 V power supply. c. Wire a 15 k Ω resistor at base of BJT and power with a 3.3 V power supply. d. Use Lux-meter and ensure measurement is 30-80 lux from 1 foot. **Verification process for item II:** a. Put a 160 Ω resistor, two LED's, and a BJT in series. b. Power the series branch with a 7.0 V 3.3 F capacitor c. Put a 15 k Ω resistor at base of BJT and power with a 3.3 V power supply. d. Use Lux-meter and ensure measurement is 30-80 lux from 1 foot for 45 seconds.
5. Front lights I.2 white LEDs with luminous intensity such that they can be viewed from 500 feet away when powered from constant 7 V source [SEDR10].	**Verification process for item I:** a. Wire a 80 Ω resistor and two White LED's in series b. Power the series branch with a 7.0 V power supply c. Use Lux-meter and ensure easurement is 30-80 lux from 1

II. 2 white LEDs with luminous intensity such that they can be viewed from 500 feet away when powered from a 7.5 V, 3.3 F capacitor bank charged to 7 V for 45 seconds [SEDR10].	foot. **Verification process for item II:** a. Wire a 80 Ω resistor and two White LED's in series b. Power the series branch with a 7.0 V 3.3 F capacitor c. Use Lux-meter and ensure measurement is 30-80 lux from 1 foot for 45 seconds
6. Supercapacitors I.Supercapacitor Bank 1- supply 0.64 mAh of charge with the capacitor bank maintaining its voltage between 7.0-6.0 V. II.Supercapacitor Bank 2- supply up to 37.5 uAh of charge with the capacitor maintaining its voltage between 3.3-3 V.	**Verification process for item I:** a. Charge supercapacitor bank to 7 V. b. Attach a 120 Ω load resistor c. Measure the current draw at 5 second intervals in addition to monitoring the capacitor voltage with a multimeter d. Stop test after 180 seconds or when capacitor voltage reaches 6 V e. Integrate average current over time interval to calculate capacity in mAh f. Ensure capacity is > 0.64 mAh. **Verification process for item II:** a. Charge supercapacitor bank to 3.3 V. b. Attach a 1.1 kΩ load resistor c. Measure the current draw at 10 second intervals in addition to monitoring the capacitor

	voltage with a multimeter d. Stop test after 180 seconds or when capacitor voltage reaches 3 V e. Integrate average current over time interval to calculate capacity in mAh f. Test passes if capacity is > 37.5 uAh.
7. Microcontroller Light Panel Control I.Microcontroller can control light panel to indicate left turn by setting pins S1 and S2 high at 3.3 +/- 0.1 V II.Microcontroller can control light panel to indicate right turn by setting pins S3 and S4 high at 3.3 +/- 0.1 V III.Microcontroller can control light panel to indicate straight bike path by setting pins S2 and S3 high at 3.3 +/- 0.1 V IV.Microcontroller can turn off lights/shut down when rider arrives home.	**Verification process for item I:** a. Power microcontroller with 3.3 V b. Run program simulating left turn signal received c. Measure voltage with multimeter at S1 and S2 (pins 16 and 17) to ensure output is high at 3.3 +/- 0.1 V. d. Measure voltage with multimeter at S3 and S4 (pins 18 and 19) to ensure low output of 0 +/- 0.1 V. **Verification process for item II:** a. Power microcontroller with 3.3 V b. Run program simulating right turn signal received c. Measure voltage with multimeter at S3 and S4 (pins 18 and 19) to ensure output is high at 3.3 +/- 0.1 V. d. Measure voltage with multimeter at S1 and S2 (pins 16 and 17) to ensure low output of 0 +/- 0.1 V.

	Verification process for item III: a. Power microcontroller with 3.3 V b. Run program simulating straight signal received c. Measure voltage with multimeter at S2 and S3 (pins 17 and 18) to ensure output is high at 3.3 +/- 0.1 V. d. Measure voltage with multimeter at S1 and S4 (pins 16 and 19) to ensure low output of 0 +/- 0.1 V. **Verification process for item IV:** a. Power microcontroller with 3.3 V b. Run program simulating off signal received c. Measure voltage with multimeter at S1 and S4 (pins 16 and 19) to ensure output is high at 3.3 +/- 0.1 V. d. Measure voltage with multimeter at S2 and S3 (pins 17 and 18) to ensure low output of 0 +/- 0.1 V.

CHAPTER 5: DESIGN VERIFICATION

The R & V requirements can be found in Chapter 4. These requirements were able to be satisfied and demonstrated a fully functional product. The charge time of the supercapacitors is 60 seconds while the rider bikes at average speed of 11 mph. This charge time will change depending on the speed of the rider. In addition, the system functions for five minutes, much longer than any trafic light, once full charge is reached.

Due to the simplicity of the design, the product was polished. This included: optimizing the PCB with surface mount components such that it can be used with a pick-and-place machine, providing test pads on the board, and sizing components appropriately. Figures 18, 19 and 20 show the board layout and soldered components. A 10 pin connector will be used to run wires from the front panel to the back panel. Figure 18 is the bottom side of the PCB in figure 19. On the bottom right in figure 18, there is a PICKIT 2 connector. This feature allows for on board programming which is useful if the duty cycle of the lights needs to be changed or if any new control strategies need to be implemented [MICR08]. SMD 0603 resistors were used in order to achieve a very small footprint. Because the 10 F supercapacitors are through-hole, they can be folded sideways on the board. Ultimately, the board size was determined by the size of the container as the product could be waterproof.

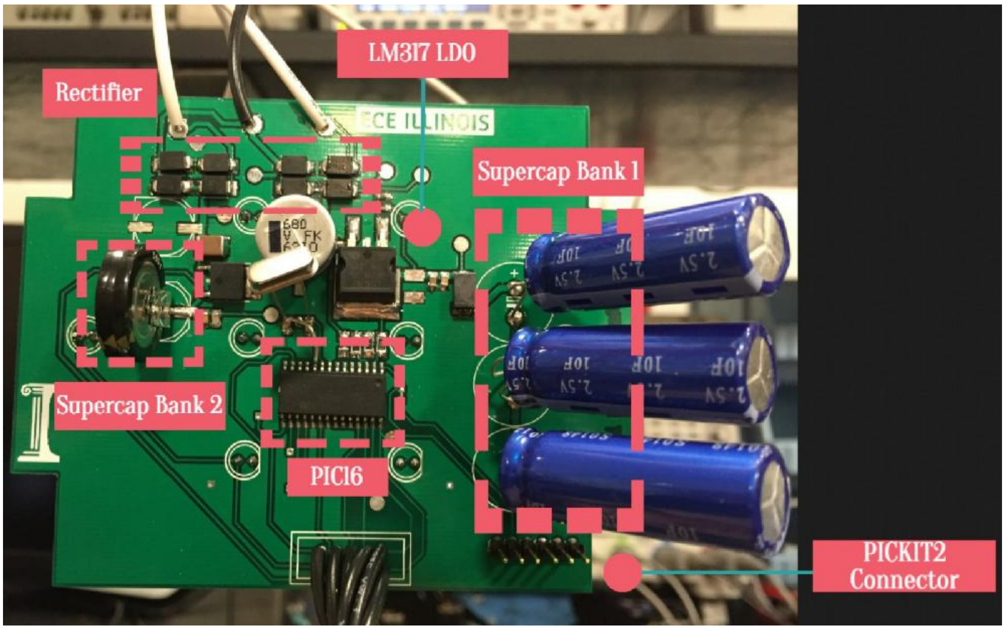


Figure 18. Final Soldered PCB

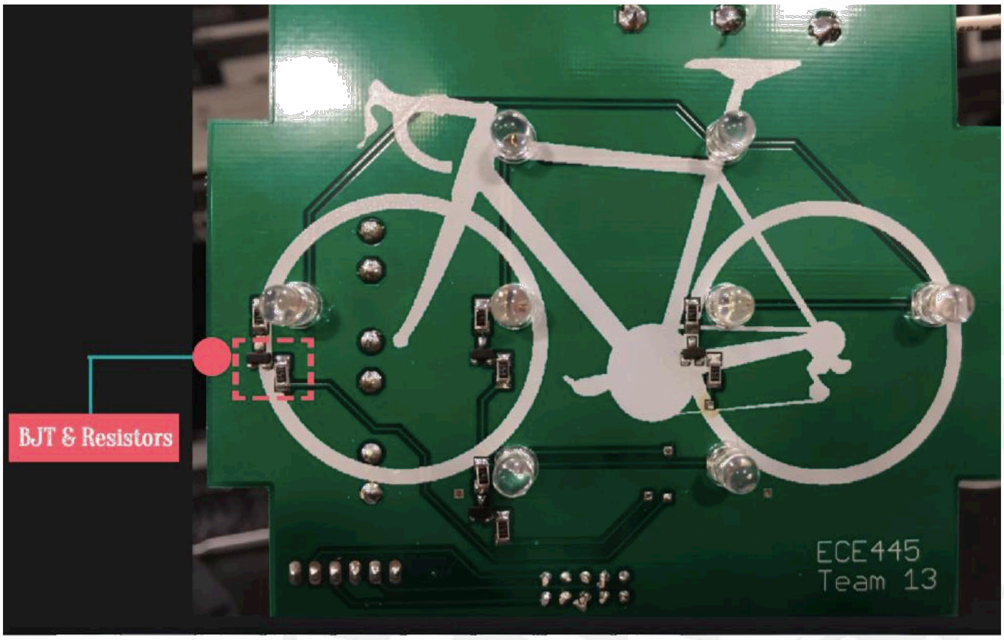


Figure 19. Back Lights

Figure 20 shows the PCB that will be mounted on the front handlebars. Push buttons will face the rider while two white LEDs will face towards the riders intended path.

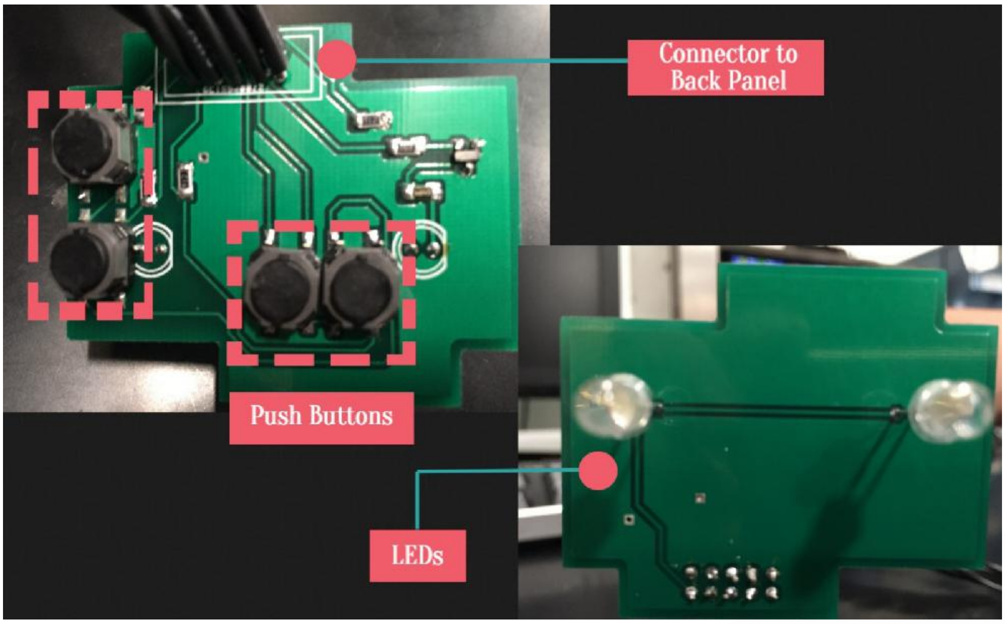


Figure 20. Front Lights and Push Buttons

Figure 21 shows the final product in its casing. The ribbon cable connector can be seen in the bottom right. The casings are waterproof and any area that was drilled through would be sealed with silicone.

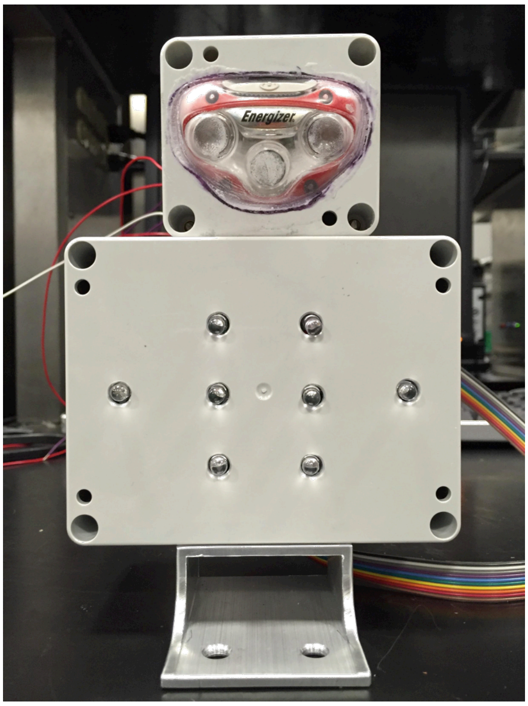


Figure 21. Finalized Packaged Product

In the next figures (figures 22 and 23), we can see the design of the PCB with all the block descriptions we have discuss in Chapter 2.

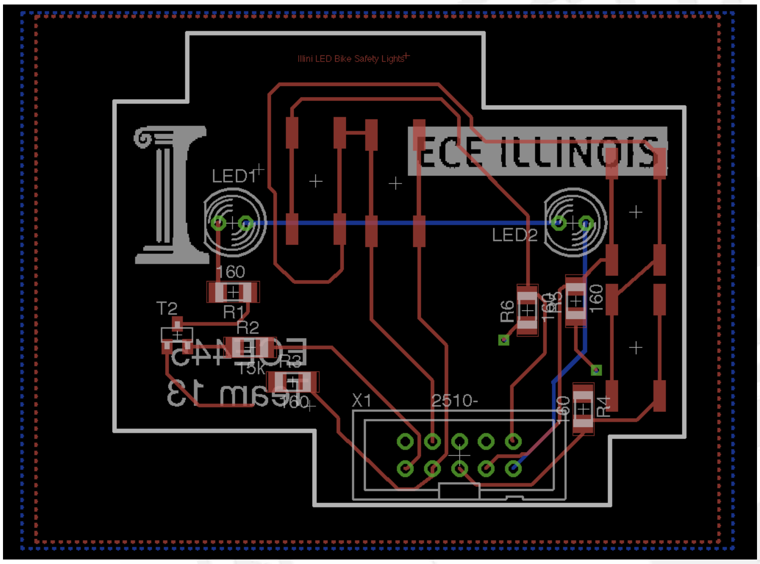


Figure 22. PCB Design of the front light panel

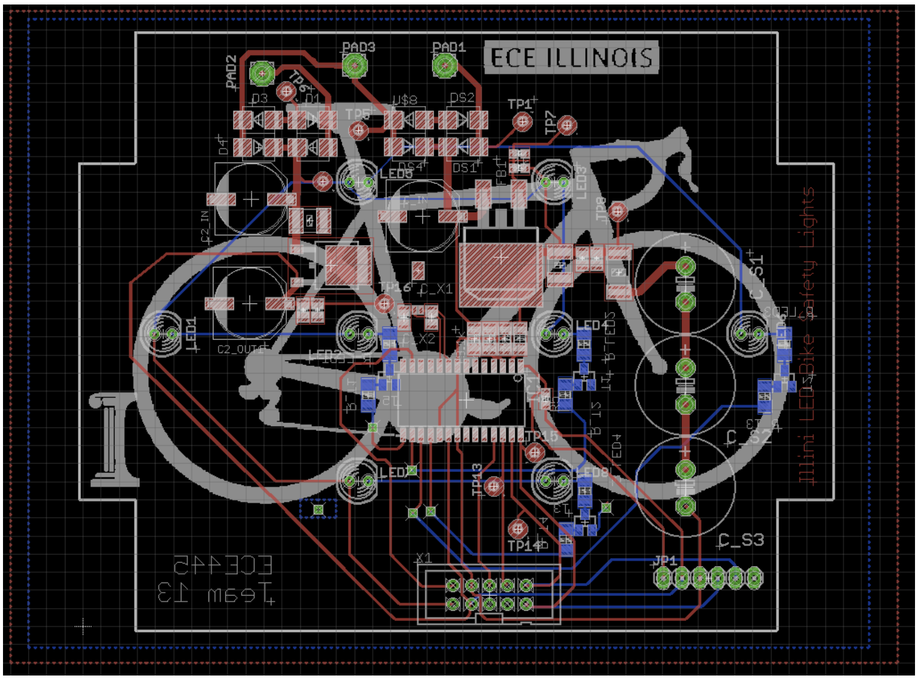


Figure 23. PCB Design of the back light panel

CHAPTER 6: SIMULATIONS

6.1 BIKE DYNAMO

As the dynamo was purchased in Amazon, it was important and necessary to test it in order to know that one of the main components of this project was working as it should be; remember that the dynamo will harnessed the energy from the bike wheels as this prohect is going to be implemented is batteryless.

In figure 24, we can see the bike dynamometer studies that have been done to verify the efficiency of the product purchased.

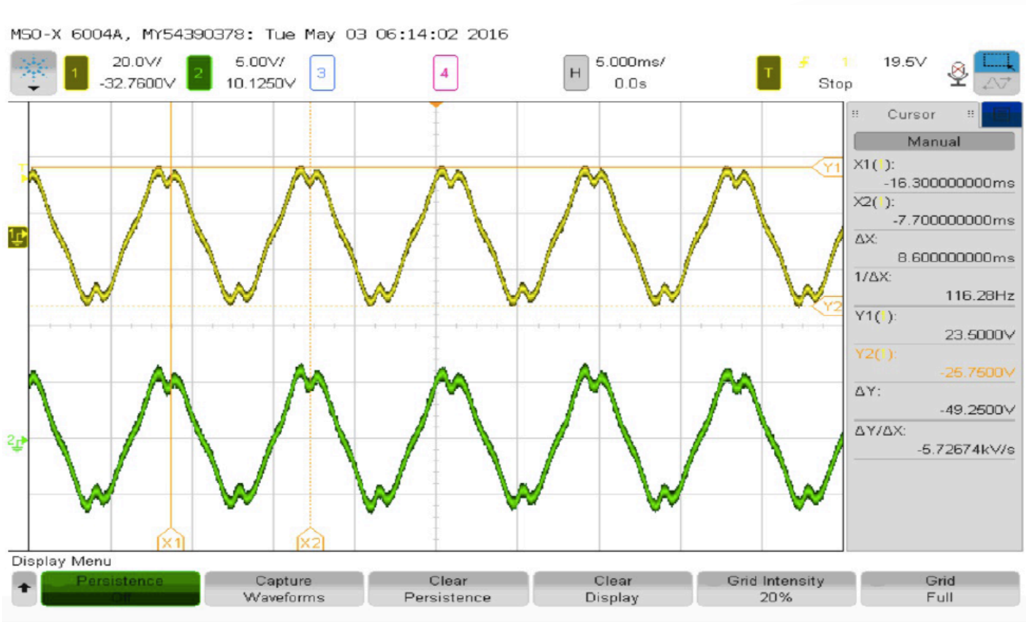


Figure 24. Bike dynamometer studies

6.2 SUPERCAPACITORS

As the project was being developed, it was necessary to know how the supercapacitor banks were working, so some tests were perfomed. As we can see in figure 25, the front panel charges faster than the back one, as the discharge time. This is due the back light panel is much more complex than the front one, so the charging time is more than the back one, but as the discharge time.

As we can see the front light panel charges more or less in 30 seconds and discharges in 5 minutes. Besides, the back one charges in 50 seconds and discharges in 20 minutes, so with this product we have plenty of time to be seen from the front and back (five minutes versus twenty). In addition, this time is much greater than any stop in a stop signal or in a traffic light. In conclusion, we can say that the product developed has achieved its goals.

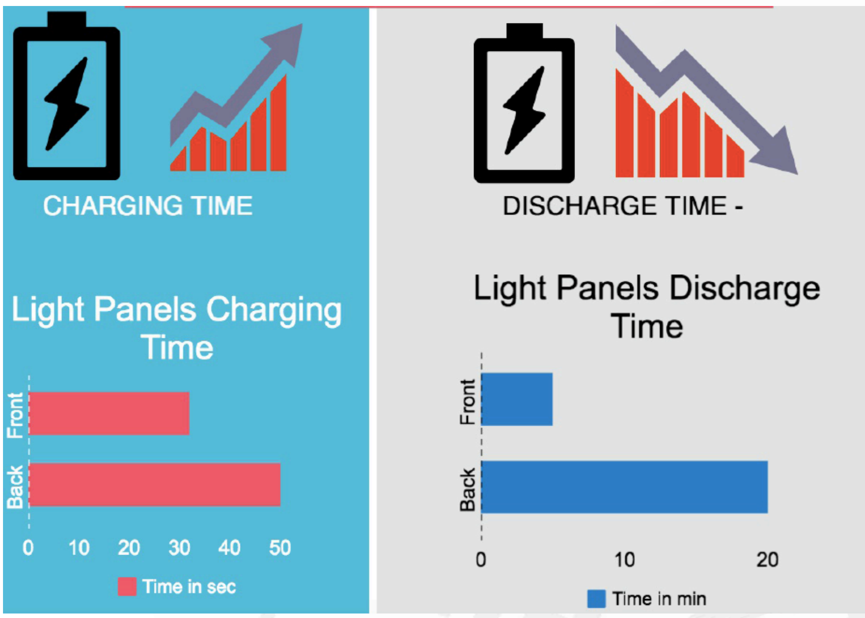


Figure 25. Charging and discharging time of the supercapacitors

Also, in figure 26, we can see the capacitor discharge rate that we have discussed before.

Figure 26. Capacitor discharge rate.

CHAPTER 7: PARTS

Table 4 shows the complete parts list for the product. In total. there are 62 components necessary for the system to function.

Table 4: Parts List for Final Product

Part	Manufacturer	Part No.	Quantity
Supercapacitors 10 F	Suntan	TS12SR	3
Supercapacitor 1 F	Panasonic	RG	1
LEDs	China Young Sun LED Tech	YSLR531R3CA13	10
9 k resistors	Panasonic	SMD 0603	4
15 k resistors	Panasonic	SMD 0603	5
160 ohm	Panasonic	SMD 0603	3
66 ohm	Panasonic	SMD 0603	1
1.5 k	Panasonic	SMD 0603	1
18.1 k	Panasonic	SMD 0603	1
22.1 k	Panasonic	SMD 0603	1
28 k	Panasonic	SMD 0603	1
5 k	Panasonic	SMD 0603	1
1 ohm 1 W	Vishay	WSC25151R000FEA	1
4.7 uF	Panasonic	SMD 0603	4
16 mHz xtal	Abracon LLC	ABLS-16.000MHZ-B2-T	1
22 pF caps	Panasonic	SMD 0603	2
SM PIC	PIC16F872	microchop	1
Push Buttons	Panasonic	EVQ-Q1E06K	4
47 uF cap	Kemet	T491B476K010AT	1
680 uF cap	Panasonic	EEV-FK1V681Q	1
LM317	STMicroelectronics	LM317D2T-TR	1
3.3 V Linear Voltage	STMicroelectronics	LD1117V33	1

Regulator			
diodes	Diodes Incorporated	APD240KDTR-G1	8
bjts	Diodes Incorporated	MMBT3904-7-F	5
Totals			62

7.1 COSTS

Table 5 shows the breakdown of component expenses. To build one unit, it will cost $ 41.56. However, if we were to purchase parts for 10^5 units, the cost would decrease significantly to $ 22.92 per unit. The LEDs were the most expensive item so maybe it is possible to reduce this price further by choosing LEDs with similar current and voltage ratings but reduced brightness. The current LEDs were so bright that it hurt to look directly at them, so this trade-off would not alter product performance.

Table 5: Cost Analysis for One Unit and 10^5 units

Part	Quantity	Price (1unit)	Total	Price (10^5units)	Total
Supercapacitors 10 F	3	$ 3.47	$10.41	$ 1.56	$ 4.68
Supercapacitor 1 F	1	$ 2.70	$ 2.70	$ 2.09	$ 2.09
LEDs	10	$ 0.95	$ 9.50	$ 0.86	$ 8.60
9 k resistors	4	$ 0.10	$ 0.40	$ 0.03	$ 0.10
15 k resistors	5	$ 0.10	$ 0.50	$ 0.03	$ 0.13
160 ohm	3	$ 0.10	$ 0.30	$ 0.01	$ 0.02
66 ohm	1	$ 0.10	$ 0.10	$ 0.01	$ 0.01
1.5 k	1	$ 0.10	$ 0.10	$ 0.03	$ 0.03
18.1 k	1	$ 0.10	$ 0.10	$ 0.03	$ 0.03
22.1 k	1	$ 0.10	$ 0.10	$ 0.03	$ 0.03
28 k	1	$ 0.10	$ 0.10	$ 0.03	$ 0.03

5 k	1	$ 0.10	$ 0.10	$ 0.03	$ 0.03
1 ohm 1 W	1	$ 1.30	$ 1.30	$ 0.56	$ 0.56
4.7 uF	4	$ 0.15	$ 0.60	$ 0.03	$ 0.12
16 mHz xtal	1	$ 0.47	$ 0.47	$ 0.22	$ 0.22
22 pF caps	2	$ 0.10	$ 0.20	$ 0.03	$ 0.06
SM PIC	1	$ 2.97	$ 2.97	$ 2.56	$ 2.56
Push Buttons	4	$ 1.20	$ 4.80	$ 0.51	$ 2.02
47 uF cap	1	$ 0.53	$ 0.53	$ 0.09	$ 0.09
680 uF cap	1	$ 1.44	$ 1.44	$ 0.41	$ 0.41
LM317	1	$ 0.78	$ 0.78	$ 0.26	$ 0.26
3.3 V Linear Voltage Regulator	1	$ 0.55	$ 0.55	$ 0.16	$ 0.16
diodes	8	$ 0.37	$ 2.96	$ 0.08	$ 0.65
bjts	5	$ 0.11	$ 0.55	$ 0.01	$ 0.06
Totals	62		$41.56		$22.92

CHAPTER 8: SAFETY STATEMENT

Supercapacitors are the main point of safety in the circuit as they will retain charge for a long duration, and thus we must ensure the circuit is properly enclosed in a container such that a user will not accidentally be shocked. Extreme caution must be also exercised when making changes to the circuit, even after power has been cut off. The circuit will be suitable for all weather conditions and the regulators will ensure that overvoltage not occur as supercapacitors will fail spectacularly in the event of overvoltage.

To end, the product will conform to the Illinois Laws regarding bike lights such the user will be visible from safe distance when riding at night [ILLI09].

CHAPTER 9: ETHICAL CONSIDERATIONS

The main goal of this project is to use a batteryless, dynamo driven lighting and signal system to be seen while riding a bike. With this project, it is important to implement a new way to try to decrease bikes accidents with the lighting system that will work when riding and when stopped. By stating the purpose of this project, the first code of IEEE Code of Ethics can be stated as: “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”.

Working along through this project, a lot of decisions have been in order to know what materials should be the best ones to accomplish the goal; looking at datasheets have been an important key point as the components have been selected and in addition, knowing the time available for making the project have stated the things we were capable of doing in that period of time. In this point, the second code of IEEE Code of Ethics states: “to be honest and realistic in stating claims or estimates based on available data”.

During all the process of building and developing the project, the profesor was able to help and to improve all the details of the project. For that reason, feedback was given by this profesor in order to achieve the goals and besides, to see different points of view. In this aspect, the sixth code of the IEEE Code of Ethics says: “to seek, accept, and o er honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others”. [IEEE16]

PART II: FUTURE WORK

In the future, it is possible to add an automatic signal to the product to turn off such as in a motor vehicle. This would be implemented by incorporating a gyroscope that would sense the direction of travel and relay that information to the microcontroller. Additionally, another key point is to focus on cost reduction as mentioned previously. This can be done by replacing the current LEDs and monitoring performance. Lastly, a better designed casing would be necessary for marketability of the product. The current case is big, bulky, and not very sleek. A better designed case with focus films for thelights would enhance the functionality and aesthetics of this project.

Another aspect is to minimize the size of the boxes by making a custom fit to the LED light panels. Besides, the packaging size can be optimized via multiple layer PCBs with smaller surface mount components. This can be implemented by a hand gesture coordinated light signaaling patterns in the near future.

PART III: CONCLUSION

Upon completion of the project, a working prototype was design and it was able to verify all the design choices made through the semester. In addition, the project helped demonstrate the usefulness of supercapacitors for low current brownout applications. Years ago capacitor technology might not have allowed for a battery-less bike light system; however, with the advent of supercapacitor technology the project was able to be completed and even exceed the expectations made at the beginning of this project. Supercapacitors are simple to charge (there is no charging circuit required) and will last for thousands of charge/discharge cycles.

As it was mentioned in chapter 1: goals and benefits, the main goals were:

- ✓ Make cost effective, self-sustainble LED lights.
- ✓ Provide increased visibility and safety.
- ✓ Prevent cyclist injuries from occuring.

As a conclusion, by increasing visibility and safety of cyclists, the LED Bike Dynamo project can help reduce the number of bike injuries due to lack of or improper use of headlights and tail lights.

Besides, how this project works? With three main key points:

- ✓ "Free energy", as the electricity is generated by a bike dynamo.
- ✓ It is bateryless, in other words, the energy is stored via supercapacitors.
- ✓ The LED lights have a low maintenance super bright LED lights, they will have a luminosity intensity of 80,000 mcd.

In addition, as we mentioned before, there are a lot of products that can accomplish the goals of this project. However, this product has some functions that distinguish it for the products that sell nowadays. In addition, we have to ask ourselves if the Illini Bike LED is affordable. If we buy this product in Amazon, it will cost \$32.64. On the other hand, this product will cost \$41.29 and if we buy it in a bulk order, it will cost $22.92. To sum up, Illini LED Bike Dynamo is a cost effective product that provides both front and back safety lights compared to Melian Smart Tail Light, which requires a battery and a separate headlight.

PART IV: REFERENCES

[ILLI09] Illinois Statutes Regarding Bicycles, Active Transportation Alliance. March 2009. https://www.activetrans.org/sites/files/Illinois%20statutes.pdf

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[STMI14] STMicroelectronics., "1.2 V to 37 V Adjustable Voltage Regulator", LM317D2T-TR datasheet, March 2014.

[DIOD16] Diodes Inc., "40 V NPN Small Signal Transistor in SOT23", MMBT3904 datasheet, April 2016.

[SEDR10] A. Sedra and K. Smith, Microelectronic Circuits. 6th ed. New York: Oxford University Press, 2010.

[MICR08] Microchip Technology Inc., "PICkit 2 Programmer/Debugger User's Guide", datasheet, 2008.

[IEEE16] IEEE Code of Ethics, IEEE Advancing Technology for Humanity.

PART V: AWARD

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

ECE 445 HALL OF FAME

AREA AWARD: ELECTROMECHANICAL DESIGN

Team 13 – Dynamo LED Bike Safety Lights

presented to

GREGORY PLAUCK, ISABEL MARTIN MONTEMAYOR,
AND LEELE GILL

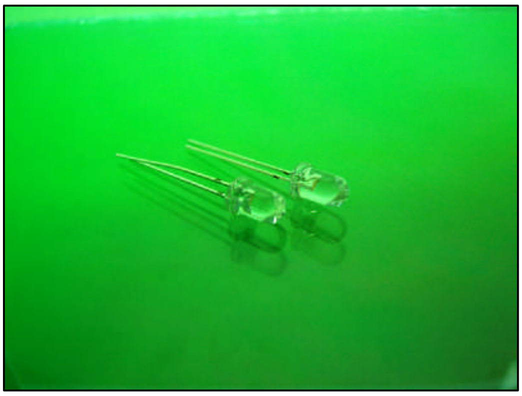
Awarded May 5, 2016

WILLIAM H. SANDERS	RAKESH KUMAR	JONATHAN MAKELA	THOMAS GALVIN	JACKSON LENZ
DEPARTMENT HEAD	FACULTY	FACULTY	FACULTY	TEACHING ASSISTANT

PART VI: DATASHEETS

深 圳 市 昱 申 科 技 有 限 公 司
CHINA YOUNG SUN LED TECHNOLOGY CO., LTD.
TEL: (86) 755-28079401 28079402 28079403 28079404 28079405
FAX: (86) 755-28079407 E-mail: info@100LED.com Web: www.100LED.com

Model No.: YSL-R547W2C-A13



Applications:

- Decorations
- Illuminations
- Advertising Sign
- Traffic Lights
- Indicators
- Flashlights

Absolute Maximum Ratings: (Ta=25 ℃) .

ITEMS	Symbol	Absolute Maximum Rating	Unit
Forward Current	I_F	20	mA
Peak Forward Current	I_{FP}	30	mA
Suggestion Using Current	I_{su}	16-18	mA
Reverse Current (VR=5V)	I_R	10	uA
Power Dissipation	P_D	105	mW
Operation Temperature	T_{OPR}	-40 ~ 85	℃
Storage Temperature	T_{STG}	-40 ~ 100	℃
Lead Soldering Temperature	T_{SOL}	Max. 260℃ for 3 Sec. Max. (3mm from the base of the expoxy bulb)	

Absolute Maximum Ratings: (Ta=25 ℃)

ITEMS	Symbol	Test condition	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F=20mA	3.2	---	3.4	V
Wavelength (nm) or TC(k)	Δ λ	I_F=20mA	6000	---	8000	K
*Luminous intensity	I_V	I_F=20mA	8000	---	10000	mcd
50% Viewing Angle	2 θ 1/2	I_F=20mA	---	---	10	deg

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TEL: (86) 755-28079401 28079402 28079403 28079404 28079405
FAX: (86) 755-28079407 E-mail: info@100LED.com Web: www.100LED.com

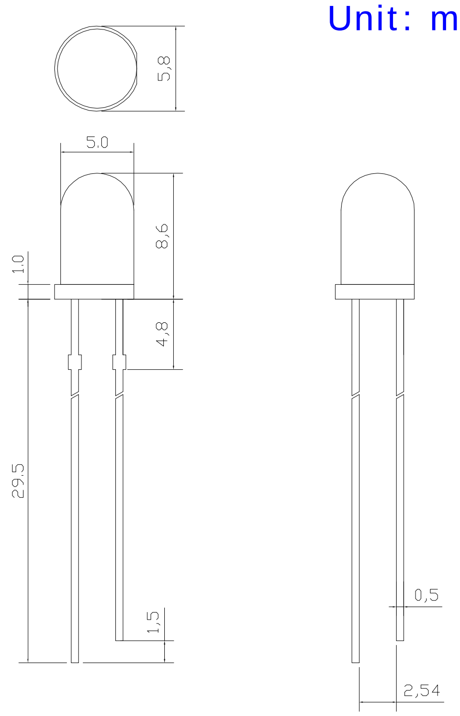
Light Degradation in mcd: (IF=20mA)

Hours / Colors	Light Degradation in mcd after Different Hours					
	216 Hrs	360 Hrs	792 Hrs	1104 Hrs	1992 Hrs	2328 Hrs
Red	1.52%	-1.22%	-3.10%	-4.68%	-5.72%	-8.27%
Yellow	-1.71%	-2.97%	-5.93%	-8.13%	-8.90%	-11.10%
Blue	3.13%	-0.33%	-3.84%	-8.23%	-21.32%	-24.92%
Green	-8.02%	-9.78%	-14.25%	-17.37%	-20.79%	-22.30%
Hours	48 Hrs	168 Hrs	336 Hrs	360Hrs	720 Hrs	1008 Hrs
Cool White	10.56%	6.72%	-2.29%	-7.68%	-17.32%	-22.48%
Pure White	13.66%	8.22%	-1.45%	-8.50%	-19.52%	-25.26%
Warm White	3.02%	-4.38%	-15.18%	-21.15%	-27.19%	-29.97%

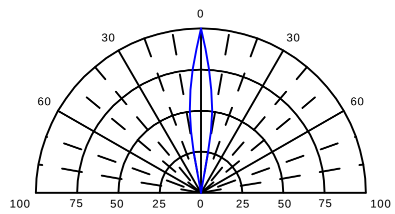
Mechanical Dimensions:

- All dimension are in mm, tolerance is ±0.2mm unless otherwise noted
- An epoxy meniscus may extend about 1.5mm down the leads.
- Burr around bottom of epoxy may be 0.5mm Maximum

Unit: mm



Viewing Angle Drawing



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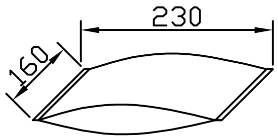
FAX: (86) 755-28079407 E-mail: info@100LED.com Web: www.100LED.com

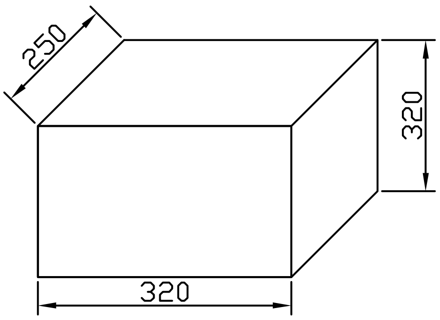
Packing Information:

1. Anti-static bag



Unit: mm

- 200 - 500pcs per bag
- With 1 little bag of drier inside

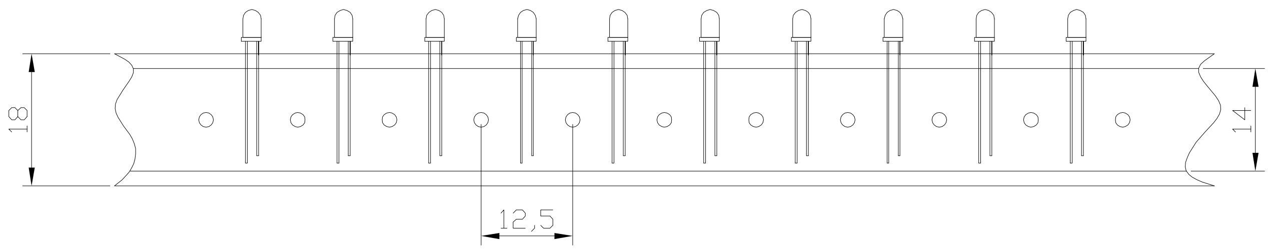


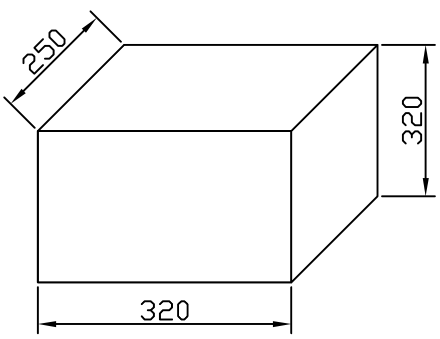
Middle Box

- 30 - 40 bags per box
- 15-20K pcs per box

Anti-static Tube Packaging Information:

Unit: mm





Middle Box

- Taping dimension can be adjusted to customer's requirements.
- 8-10 Layers per box
- 16K-20K pcs per box

TEL: (86) 755-28079401 28079402 28079403 28079404 28079405
FAX: (86) 755-28079407 E-mail: info@100LED.com Web: www.100LED.com

Code System:

YSL-R547W2C-A13

1 2 3 4 5 6 7 8 9 10

1. Company Code, short for Young Sun
2. Code for LED series.
3. Code for LED Type.
   R: Round B: Bullet C: Columnar O: Ovai
   H: Helmet Q: Square V: Concave P: Pagoda
   S: Strawhat D: Special
4. Code for LED Lens Type.
5. Code for Lead Frame of LED
6. Code for Lead Frame Code of LED
7. Code for Wavelength Color
8. Code for Lens color

   C: Water Clear W: White Diffused D: Color Diffused T: Color Transparent
9. Code for Viewing Angle

   A: 1-10 B: 10-20 C: 20-30 D: 30-40 E: 40-60 F: 60-90 G: 90-120 H: >120
10. Luminous Intensity Grade:

1: 1-50mcd	4: 200-300mcd	7: 800-1000mcd	10: 2000-3000mcd	14: 10000-13000mcd
2: 50-100mcd	5: 300-500mcd	8: 1000-1500mcd	11: 3000-5000mcd	15: 13000-15000mcd
3: 100-200mcd	6: 500-800mcd	9: 1500-2000mcd	12: 5000-8000mcd	16: 15000-20000mcd
			13: 8000-10000mcd	17: 20000~mcd

Warrantee:

- In order to make the LEDs lifespan longer, please set the input Current below 20mA.
- Electrical & Optical Characteristics consistency of same items all shippments.

Notes:

- Please use LEDs based on our datasheet.
- LED is senstive to statics, be sure your equipments are anti-static when you use our LEDs.
- Pay more attention to your heat dissipation system when you use it, the better heat dissipation, the longer LED lifespan.

40V NPN SMALL SIGNAL TRANSISTOR IN SOT23

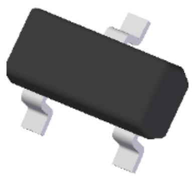
Features

- Epitaxial Planar Die Construction
- Complementary PNP Type Available (MMBT3906)
- Ideal for Medium Power Amplification and Switching
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **Qualified to AEC-Q101 Standards for High Reliability**
- **PPAP Capable (Note 4)**

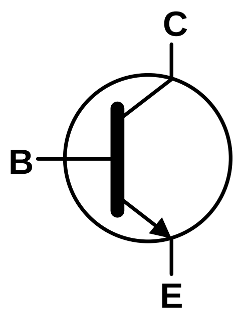
Mechanical Data

- Case: SOT23
- Case Material: Molded Plastic, "Green" Molding Compound; UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads; Solderable per MIL-STD-202, Method 208 e3
- Weight: 0.008 grams (Approximate)

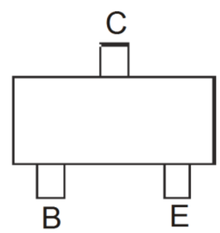
SOT23



Top View



Device Symbol



Top View
Pin-Out

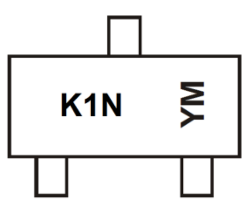
Ordering Information (Notes 4 & 5)

Product	Status	Compliance	Marking	Reel Size (inches)	Tape Width (mm)	Quantity Per Reel
MMBT3904-7-F	Active	AEC-Q101	K1N	7	8	3,000
MMBT3904Q-7-F	Active	Automotive	K1N	7	8	3,000
MMBT3904-13-F	Active	AEC-Q101	K1N	13	8	10,000

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
2. See http://www.diodes.com/quality/lead_free.html for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen and Antimony free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
4. Automotive products are AEC-Q10x qualified and are PPAP capable. Automotive, AEC-Q101 and standard products are electrically and thermally the same, except where specified. For more information, please refer to http://www.diodes.com/quality/product_compliance_definitions/.
5. For packaging details, go to our website at http://www.diodes.com/products/packages.html.

Marking Information

SOT23



K1N = Product Type Marking Code
YM = Date Code Marking
Y or $\overline{Y}$ = Year (ex: D = 2016)
M or $\overline{M}$ = Month (ex: 9 = September)

Date Code Key

Year	2014	2015	2016	2017	2018	2019	2020	2021
Code	B	C	D	E	F	G	H	I

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Code	1	2	3	4	5	6	7	8	9	O	N	D

Absolute Maximum Ratings (@T_A = +25°C, unless otherwise specified.)

Characteristic	Symbol	Value	Unit
Collector-Base Voltage	V_{CBO}	60	V
Collector-Emitter Voltage	V_{CEO}	40	V
Emitter-Base Voltage	V_{EBO}	6	V
Collector Current	I_C	200	mA

Thermal Characteristics (@T_A = +25°C, unless otherwise specified.)

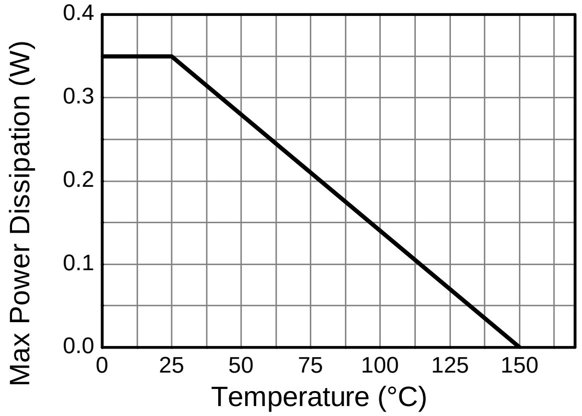
Characteristic		Symbol	Value	Unit
Power Dissipation	(Note 6)	P_D	310	mW
	(Note 7)		350	
Thermal Resistance, Junction to Ambient	(Note 6)	$R_{\theta JA}$	403	°C/W
	(Note 7)		357	
Thermal Resistance, Junction to Leads	(Note 8)	$R_{\theta JL}$	350	°C/W
Operating and Storage Temperature Range		T_J, T_{STG}	-55 to +150	°C

ESD Ratings (Note 9)

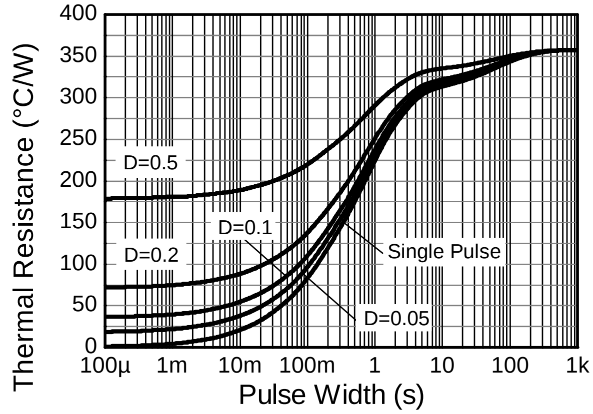
Characteristic	Symbol	Value	Unit	JEDEC Class
Electrostatic Discharge - Human Body Model	ESD HBM	4,000	V	3A
Electrostatic Discharge - Machine Model	ESD MM	400	V	C

Notes:
6. For a device mounted on minimum recommended pad layout 1oz copper that is on a single-sided FR4 PCB; device is measured under still air conditions whilst operating in a steady-state.
7. Same as Note 6, except the device is mounted on 15 mm x 15mm 1oz copper.
8. Thermal resistance from junction to solder-point (at the end of the leads).
9. Refer to JEDEC specification JESD22-A114 and JESD22-A115.

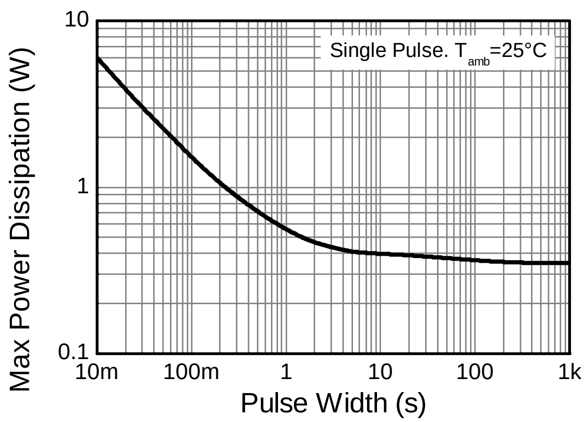
Thermal Characteristics and Derating Information



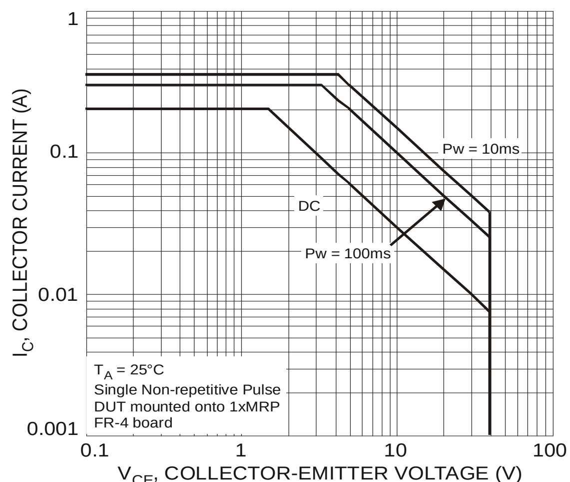
Derating Curve



Transient Thermal Impedance



Pulse Power Dissipation



Typical Collector Current
vs. Collector-Emitter Voltage

Electrical Characteristics (@T_A = +25°C, unless otherwise specified.)

Characteristic	Symbol	Min	Max	Unit	Test Condition
OFF CHARACTERISTICS					
Collector-Base Breakdown Voltage	BV_{CBO}	60	—	V	I_C = 10µA, I_E = 0
Collector-Emitter Breakdown Voltage (Note 10)	BV_{CEO}	40	—	V	I_C = 10mA, I_B = 0
Emitter-Base Breakdown Voltage	BV_{EBO}	6.0	—	V	I_E = 10µA, I_C = 0
Collector Cut-Off Current	I_{CEX}	—	50	nA	V_{CE} = 30V, $V_{EB(OFF)}$ = 3.0V
Base Cut-Off Current	I_{BL}	—	50	nA	V_{CE} = 30V, $V_{EB(OFF)}$ = 3.0V
Emitter Base Cut-Off Current	I_{EBO}	—	50	nA	V_{EB}=6V
Collector-Base Cut-Off Current	I_{CBO}	—	50	nA	V_{CB}=48V
ON CHARACTERISTICS (Note 10)					
DC Current Gain	h_{FE}	40 70 100 60 30	— — 300 — —	—	I_C = 100µA, V_{CE} = 1.0V I_C = 1.0mA, V_{CE} = 1.0V I_C = 10mA, V_{CE} = 1.0V I_C = 50mA, V_{CE} = 1.0V I_C = 100mA, V_{CE} = 1.0V
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	—	0.20 0.30	V	I_C = 10mA, I_B = 1.0mA I_C = 50mA, I_B = 5.0mA
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	0.65 —	0.85 0.95	V	I_C = 10mA, I_B = 1.0mA I_C = 50mA, I_B = 5.0mA
SMALL SIGNAL CHARACTERISTICS					
Output Capacitance	C_{obo}	—	4.0	pF	V_{CB} = 5.0V, f = 1.0MHz, I_E = 0
Input Capacitance	C_{ibo}	—	8.0	pF	V_{EB} = 0.5V, f = 1.0MHz, I_C = 0
Input Impedance	h_{ie}	1.0	10	kΩ	V_{CE} = 10V, I_C = 1.0mA, f = 1.0kHz
Voltage Feedback Ratio	h_{re}	0.5	8.0	x 10^{-4}	
Small Signal Current Gain	h_{fe}	100	400	—	
Output Admittance	h_{oe}	1.0	40	µS	
Current Gain-Bandwidth Product	f_T	300	—	MHz	V_{CE} = 20V, I_C = 10mA, f = 100MHz
Noise Figure	NF	—	5.0	dB	V_{CE} = 5.0V, I_C = 100µA, R_S = 1.0kΩ, f = 1.0kHz
SWITCHING CHARACTERISTICS					
Delay Time	t_d	—	35	ns	V_{CC} = 3.0V, I_C = 10mA, $V_{BE(off)}$ = - 0.5V, I_{B1} = 1.0mA
Rise Time	t_r	—	35	ns	
Storage Time	t_s	—	200	ns	V_{CC} = 3.0V, I_C = 10mA, I_{B1} = I_{B2} = 1.0mA
Fall Time	t_f	—	50	ns	

Note: 10. Measured under pulsed conditions. Pulse width ≤ 300µs. Duty cycle ≤ 2%.

Typical Electrical Characteristics (@T_A = +25°C, unless otherwise specified.)

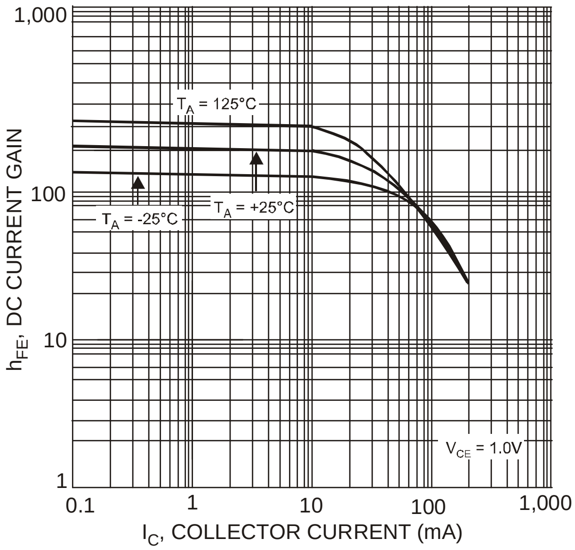


Fig. 1 Typical DC Current Gain vs. Collector Current

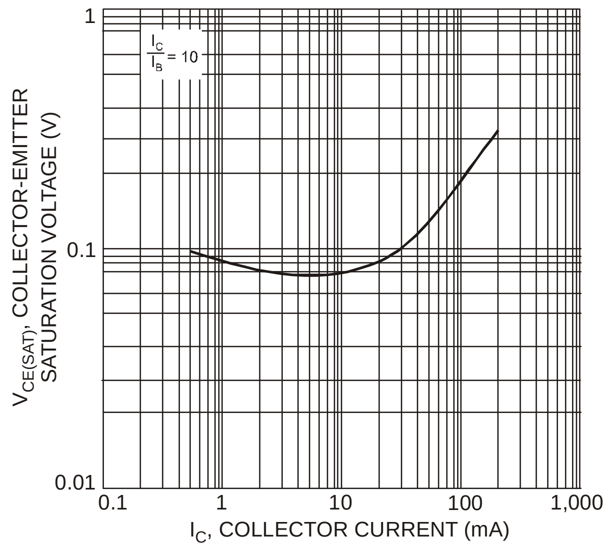


Fig. 2 Typical Collector-Emitter Saturation Voltage vs. Collector Current

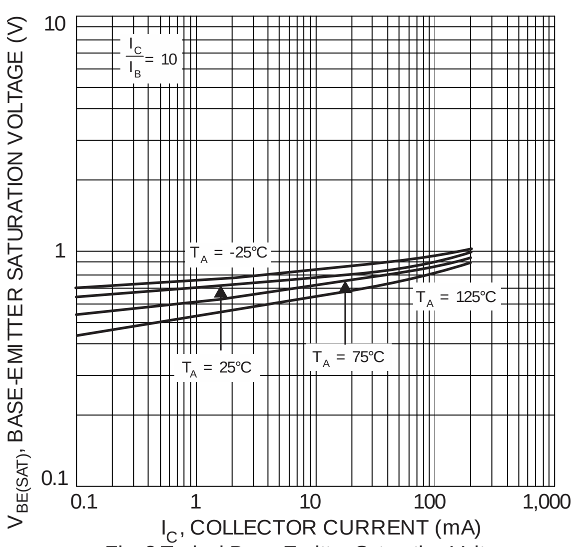


Fig. 3 Typical Base-Emitter Saturation Voltage vs. Collector Current

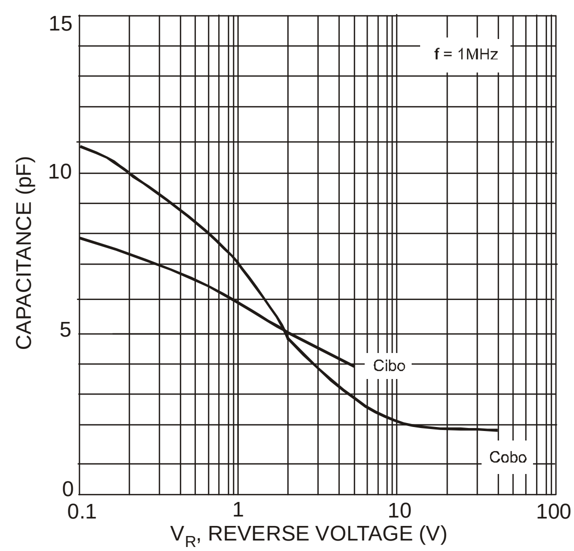
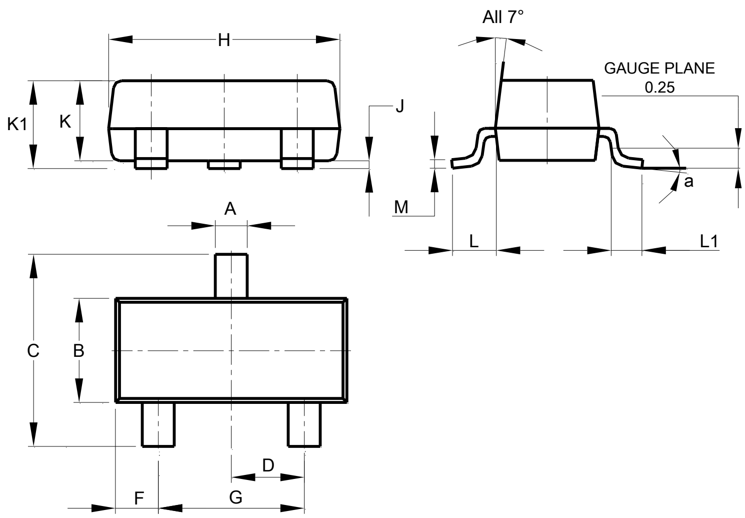


Fig. 4 Typical Capacitance Characteristics

Package Outline Dimensions

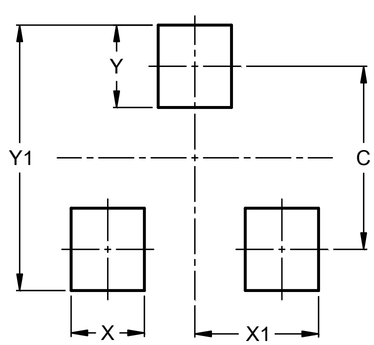
Please see http://www.diodes.com/package-outlines.html for the latest version.



SOT23			
Dim	Min	Max	Typ
A	0.37	0.51	0.40
B	1.20	1.40	1.30
C	2.30	2.50	2.40
D	0.89	1.03	0.915
F	0.45	0.60	0.535
G	1.78	2.05	1.83
H	2.80	3.00	2.90
J	0.013	0.10	0.05
K	0.890	1.00	0.975
K1	0.903	1.10	1.025
L	0.45	0.61	0.55
L1	0.25	0.55	0.40
M	0.085	0.150	0.110
a	0°	8°	--
All Dimensions in mm			

Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.



Dimensions	Value (in mm)
C	2.0
X	0.8
X1	1.35
Y	0.9
Y1	2.9

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2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

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www.diodes.com

Suntan

ELECTRIC DOUBLE LAYER CAPACITOR-GOLD CAPACITOR

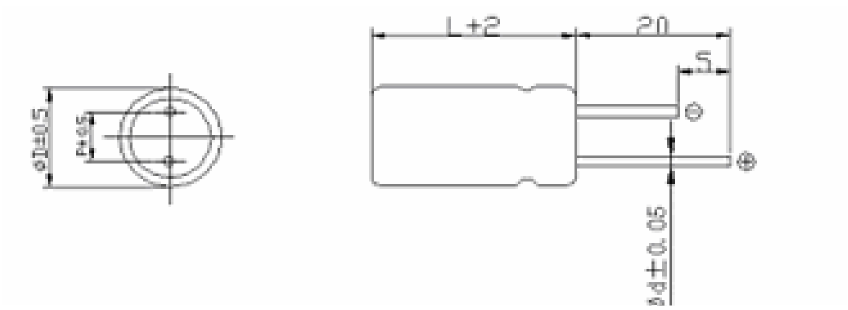
TS12S-R

FEATURES

Radial & Snap-in type
large capacity, VENT case.

SPECIFICATIONS

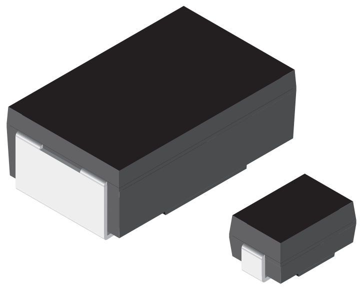
Operating temperature	-40～+70℃
Rated voltage	2.5VDC
Surge Voltage	3.0VDC
Capacitance tolerance	-20%～+80%
Characteristics at Temperature	+70℃｜△C/C｜≤30%,IL≤ 300% time of specified value at 25℃ -40℃｜△C/C｜≤≤40%,ESR≤ 300% time of specified value at 25℃
Characteristics at Low Temperature	+70℃±2 加 5.5V 1000h 后，｜△C/C｜≤30% IL≤ 200% specified value，ESR≤ 400% specified value
Moisture Resistance	+50℃±2, 90～95%RH，500 hours at 2.5V, same as Characteristics at Temperature
Life	100,000 time life at 2.5V & -40～+70℃



Rated Capacitance	Rated Current	Max. Current	ESR	Max. Internal Resistance	Size	P (mm)	Φd (mm)
0.7F	85	364	600	750 (0.1A)	Φ8×15	4+-0.5	0.6
1.0F	170	600	245	400 (0.1A)	Φ8×15	4+-0.5	0.6
2.0F	400	1480	130	180 (0.1A)	Φ10×18	5+-0.5	0.6
3.3F	720	2200	80	120 (0.1A)	Φ10×18	5+-0.5	0.6
4.7F	980	3000	50	100 (0.1A)	Φ13×21	5+-0.5	0.6
8.0F	1585	4150	45	90 (0.1A)	Φ13×21	5+-0.5	0.6
10F	1750	4500	40	80 (3A)	Φ13×33.5	5+-0.5	0.6
20F	3530	11200	18	35 (3A)	Φ16×33.5	8+-0.5	0.8
30F	5300	16800	14	31 (3A)	Φ16×33.5	8+-0.5	0.8
50F	8800	28000	14	21 (3A)	Φ18×33.5	8+-0.5	0.8
90F	15200	47600	14	21 (3A)	Φ22×46.5	9+-0.5	1.6
120F	21000	67000	14	21 (3A)	Φ25×46.5	10+-0.5	1.6

90F & 120F is Snap-In type, other is Radial type.

Wirewound Resistors, Precision Power, Surface Mount



Note
(1) Flame retardance test may not be applicable to some resistor technologies.

FEATURES

- All welded construction
- Molded encapsulation
- Wraparound terminations
- Excellent stability at different environmental conditions
- High power ratings (up to 3 W)
- Superior surge capability
- Available in non-inductive styles with Ayrton-Perry winding (WSN in lieu of WSC, maximum resistance is one-half WSC range)
- AEC-Q200 qualified available (1)
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

AUTOMOTIVE GRADE
Pb-free Available
e3
RoHS* Available
HALOGEN FREE Available
GREEN (5-2008) Available

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	HISTORICAL MODEL	SIZE	POWER RATING $P_{70\ °C}$ W	RESISTANCE RANGE Ω	TOLERANCE ± %	WEIGHT (typical) g/1000 pieces	ENCAPSULATION
WSC01/2	WSC-1/2	2012	0.5	0.1 to 4.99	0.5, 1, 5	90	Epoxy
WSC0001 (3)	WSC-1	2515	1	0.1 to 2.77K	0.5, 1, 5	165	Thermoplastic (2)
WSC2515	WSC2515	2515	1	0.1 to 2.5K	0.5, 1, 5	165	Thermoplastic
WSC0002	WSC-2	4527	2	0.1 to 4.92K	0.5, 1, 5	760	Thermoplastic (2)
WSC4527	WSC4527	4527	2	0.1 to 4.92K	0.5, 1, 5	760	Thermoplastic
WSC6927	WSC6927	6927	3	0.1 to 8K	0.5, 1, 5	1675	Thermoplastic

Notes
- Part marking: 1/2 W - DALE, value; 1 W - model, value, tolerance, date code; 2 W and 3 W - DALE, model, value, tolerance, date code.

(2) As of 1/1/2010, the WSC0001 and WSC0002 are molded with thermoplastic in lieu of epoxy. Reference PCN-DR-002-2009 and PCN-DR-003-2009
(3) As of February 19, 2016, the WSC0001 was obsoleted by PCN-DR-013-2015; the WSC2515 is a drop-in replacement. You may contact your sales representative or submit an inquiry via ww2bresistors@vishay.com for supporting information.

TECHNICAL SPECIFICATIONS

PARAMETER	UNIT	WSC01/2	WSC2515	WSC0002	WSC4527/WSC6927
Temperature Coefficient	ppm/°C	± 50 = 1.0 Ω to 4.99 Ω; ± 90 = 0.1 Ω to 0.99 Ω	± 20 = 26.51 Ω and above; ± 50 = 1.0 Ω to 26.5 Ω; ± 90 = 0.31 Ω to 0.99 Ω; ± 150 = 0.1 Ω to 0.3 Ω	± 20 = 10.0 Ω and above; ± 50 = 1.0 Ω to 9.9 Ω; ± 90 = 0.1 Ω to 0.99 Ω	± 20 = 10 Ω and above; ± 50 = 1.0 Ω to 9.9 Ω; ± 90 = 0.31 Ω to 0.99 Ω; ± 150 = 0.1 Ω to 0.3 Ω
Dielectric Withstanding Voltage	V_{AC}	> 500			
Insulation Resistance	Ω	> 10^9			
Operating Temperature Range	°C	-65 to +175	-65 to +275		
Maximum Working Voltage	V	$(P \times R)^{1/2}$			

GLOBAL PART NUMBER INFORMATION

Global Part Numbering example: WSC2515R7000FEA (visit www.vishay.net Vishay Dale parts numbering manual for all options)

W	S	C	2	5	1	5	R	7	0	0	0	F	E	A		

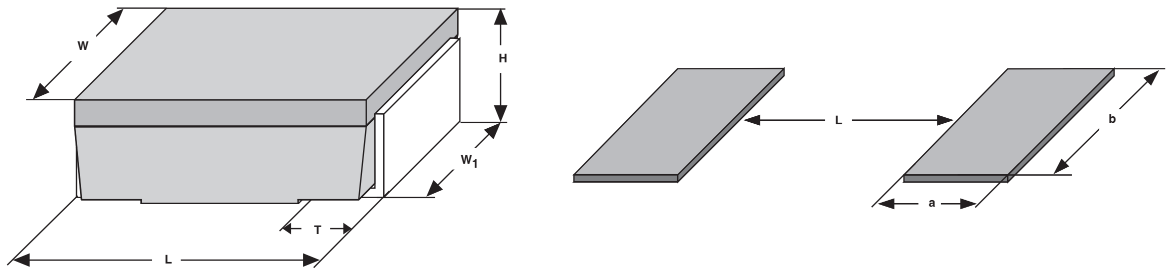
GLOBAL MODEL	SIZE	VALUE	TOLERANCE	PACKAGING	SPECIAL
WSC **WSN**	**01/2** **2515** **0002** **4527** **6927**	**R** = decimal **K** = thousand **R7000** = 0.70 Ω **1K500** = 1.5 kΩ	**D** = ± 0.5 % **F** = ± 1.0 % **G** = ± 2.0 % **H** = ± 3.0 % **J** = ± 5.0 % **K** = ± 10 %	**EA** = lead (Pb)-free, tape / reel **EK** = lead (Pb)-free, bulk **TA** = tin / lead, tape / reel (R86) **BA** = tin / lead, bulk (B43)	(dash number) (up to 2 digits) from **1 to 99** as applicable

Historical Part Numbering example: WSC-2 0.7 Ω 1 % R86

WSC-2	**0.7 Ω**	**1 %**	**R86**
HISTORICAL MODEL	RESISTANCE VALUE	TOLERANCE	PACKAGING

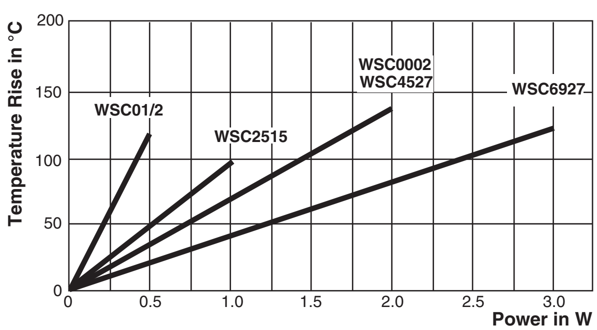
Note
- Packaging code: EB (lead (Pb)-free) and TB (tin / lead) are non-standard packaging codes designating 1000 piece reels. These non-standard packaging codes are identical to our standard EA (lead (Pb)-free) and TA (tin / lead), except that they have a package quantity of 1000 pieces.

DIMENSIONS in inches (millimeters)

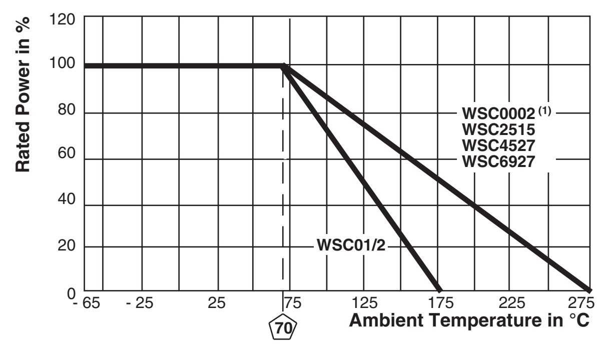


GLOBAL MODEL	DIMENSIONS					SOLDER PAD DIMENSIONS		
	L	H	T	W	W_1	a	b	L
WSC01/2	0.200 ± 0.020 (5.08 ± 0.508)	0.096 ± 0.015 (2.44 ± 0.381)	0.040 ± 0.010 (1.02 ± 0.254)	0.125 ± 0.005 (3.18 ± 0.127)	0.050 ± 0.010 (1.27 ± 0.254)	0.085 (2.16)	0.070 (1.78)	0.080 (2.03)
WSC2515	0.250 ± 0.020 (6.35 ± 0.508)	0.110 ± 0.015 (2.79 ± 0.381)	0.045 ± 0.010 (1.14 ± 0.254)	0.150 ± 0.005 (3.81 ± 0.127)	0.098 ± 0.005 (2.49 ± 0.127)	0.090 (2.29)	0.115 (2.92)	0.120 (3.05)
WSC0002	0.455 ± 0.020 (11.56 ± 0.508)	0.167 ± 0.010 (4.24 ± 0.254)	0.100 ± 0.010 (2.54 ± 0.254)	0.275 ± 0.005 (6.98 ± 0.127)	0.215 ± 0.005 (5.46 ± 0.127)	0.155 (3.94)	0.230 (5.84)	0.205 (5.21)
WSC4527	0.455 ± 0.020 (11.56 ± 0.508)	0.167 ± 0.010 (4.24 ± 0.254)	0.100 ± 0.010 (2.54 ± 0.254)	0.275 ± 0.005 (6.98 ± 0.127)	0.215 ± 0.005 (5.46 ± 0.127)	0.155 (3.94)	0.230 (5.84)	0.205 (5.21)
WSC6927	0.690 ± 0.032 (17.53 ± 0.813)	0.280 ± 0.015 (7.11 ± 0.381)	0.100 ± 0.010 (2.54 ± 0.254)	0.275 ± 0.005 (6.98 ± 0.127)	0.215 ± 0.015 (5.46 ± 0.381)	0.155 (3.94)	0.235 (5.97)	0.470 (11.94)

TEMPERATURE RISE



DERATING



Note

(1) As of 1/1/2010, WSC0002 will be molded with thermoplastic and have the higher 275 °C temperature derating.

PERFORMANCE

TEST	CONDITIONS OF TEST	TEST LIMITS
Thermal Shock	-55 °C to +150 °C, 1000 cycles, 15 min at each extreme	± (0.5 % + 0.05 Ω) Δ*R*
Short Time Overload	5 x rated power for 5 s	± (0.2 % + 0.05 Ω) Δ*R*
Low Temperature Storage	-65 °C for 24 h	± (0.2 % + 0.05 Ω) Δ*R*
High Temperature Exposure	1000 h at + 275 °C (+175 °C for WSC01/2)	± (0.5 % + 0.05 Ω) Δ*R*
Bias Humidity	+85 °C, 85 % RH, 10 % bias, 1000 h	± (0.2 % + 0.05 Ω) Δ*R*
Mechanical Shock	100 *g*'s for 6 ms, 5 pulses	± (0.1 % + 0.05 Ω) Δ*R*
Vibration	Frequency varied 10 Hz to 500 Hz in 1 min, 3 directions, 9 h	± (0.1 % + 0.05 Ω) Δ*R*
Load Life	1000 h at rated power, +70 °C, 1.5 h “ON”, 0.5 h “OFF”	± (1.0 % + 0.05 Ω) Δ*R*
Resistance to Solder Heat	+260 °C solder, 10 s to 12 s dwell, 25 mm/s emergence	± (0.5 % + 0.05Ω) Δ*R*

PACKAGING

MODEL	REEL			
	TAPE WIDTH	DIAMETER	PIECES/REEL	CODE
WSC01/2	12 mm/embossed plastic	330 mm/13"	2000	EA/TA
WSC2515	16 mm/embossed plastic	330 mm/13"	2000	EA/TA
WSC0002/WSC4527	24 mm/embossed plastic	330 mm/13"	1200	EA/TA
WSC6927	32 mm/embossed plastic	330 mm/13”	725	EA/TA

Note

- Embossed Carrier Tape per EIA-481.

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Please note that some Vishay documentation may still make reference to RoHS Directive 2002/95/EC. We confirm that all the products identified as being compliant to Directive 2002/95/EC conform to Directive 2011/65/EU.

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WSC01\21R210FTB WSC45272K000FEB WSC0001R2500FTB WSC2515243R0FTA WSC00021K500FTA
WSC00022R200FTA WSC00022R000FTA WSC00022R700FTA WSC00022R800FTA WSC00022R500FTA
WSC00022R430FTA WSC00022R490FTA WSC00022R740FTA WSC0002200R0FTA WSC000122R00FTB
WSC000115R00FTB WSC4527400R0FEB WSC000120R00FTB WSC000147R00FBA WSC000113R70FBA
WSC452720R00DBA WSC45271R000FEB WSC000249R90FBA WSC01\21R000FTB WSC00024K530FTA
WSC25151R000FEB WSC45275R000FEB WSC000225R00FTA WSC000222R00FTA WSC000224R00FTA
WSC0001180R0FTB WSC000220R00FTA WSC00015R110FTB WSC01\22R700FTB WSC01\22R300FTB
WSC01\2R1500FTB WSC00021K000FTA WSC00022K000FTA WSC000213R70FTA WSC00021K740FTA
WSC00023K740FTA WSC000241R00JTA WSC000211R00JTA WSC00021R210FTA WSC0002R5000FTA
WSC45271K000FEB WSC000216R20FTA WSC0002820R0FTA WSC00028R200FTA WSC0002866R0FTA
WSC00011K000FTB WSC00026R800FTA WSC00026R900FTA WSC00026R000FTA WSC0002604R0FTA
WSC0002649R0FTA WSC0002665R0FTA WSC000222R10FTA WSC000210R40FTA WSC00021K210FTA
WSC00022K340FTA WSC2515R1000FEB WSC251510R00FEB WSC69271K000FEA WSC00023R010FTA
WSC000240R20FTA WSC00011K500FTB WSC000290R90FTA WSN00014R700FBA WSC000239R00FTA
WSC000230R00FTA WSC000275R00FTA WSC00024R120FTA WSC01\2R5000FTB WSC01\2R1000FTB
WSC01\2R2000FTB WSC01\2R3000FTB WSC45272R000FEB WSC01\23R900FTB WSC000239R20FTA
WSC00024K750FTA WSC01\2R3010FTB WSC01\21R000FEB WSC452720R00FEB WSC25151K000FEB
WSC0002820R0JTA WSC0002R1500FTA WSC0001R2490FEB WSC25155R110FEB WSC251549R90FEB

Stacked Coin Type

Series : **RG**

Features

- Endurance : +85 °C 2000 h
- Can be discharged mA current
- RoHS compliant

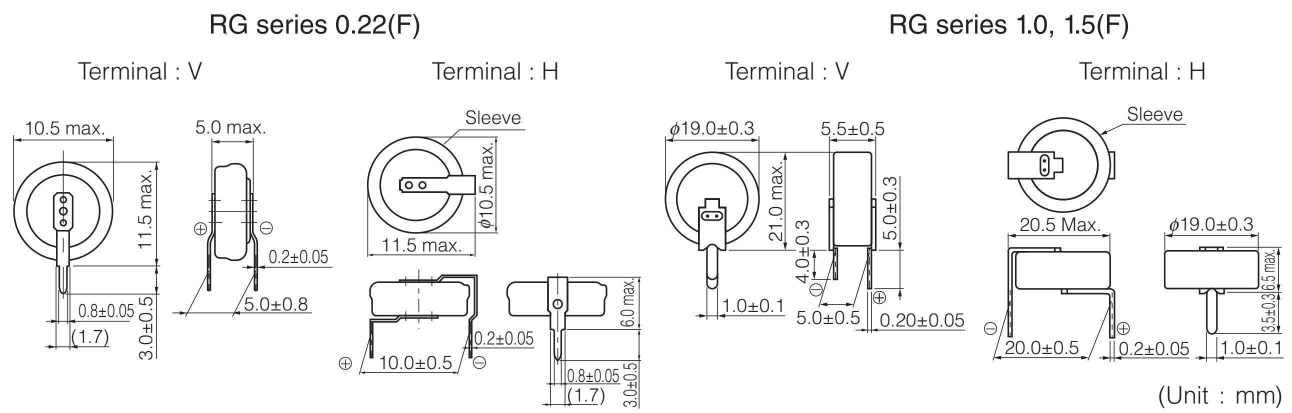
Recommended applications

- Backup of data/RTC of base station, electronic meter, and industrial equipment
- For assist of rapid load change

Specifications

Category temp. range	–25 °C to +85 °C	
Maximum operating voltage	3.6 V.DC	
Nominal capacitance	0.22 F	1.0 F, 1.5 F
Characteristics at low temperature	Capacitance change	±30 % of initial measured value at +20 °C (at –25 °C)
	Internal resistance	≦5 times of initial measured value at +20 °C (at –25 °C)
Endurance	After 2000 hours application of maximum operating voltage at +85 °C	
	Capacitance change	±30 % of initial measured value at 20 °C
	Internal resistance	100 Ω or less (0.22 F) 40 Ω or less (1.0 F, 1.5 F)
Shelf life	After 2000 hours storage at +85 °C without load (voltage)	
	Capacitance change	Capacitance change shall meet the specified limits for Endurance
	Internal resistance	Internal resistance shall meet the specified limits for Endurance

Dimensions in mm(not to scale)



(Unit : mm)

Characteristics list

Maximum operating voltage (V.DC)	Capacitance (F)	Capacitance tolerance (F)	Internal resistance (Initial specified value) (Ω) at 1 kHz	Recommended discharge current (mA)	Parts number	Mass (Reference value) (g)	Min. packaging q'ty (pcs)
3.6	0.22	0.176 to 0.396	≦50	1 or less	EECRG0V224( )	1.0	200
	1.0	0.8 to 1.8	≦20	20 or less	EECRG0V105( )	4.1	100
	1.5	1.2 to 2.7	≦20	20 or less	EECRG0V155( )	4.2	100

Do not use reflow soldering. (IR, Atmospherheating methods, etc.) Please refer to the page of “Application guidelines”.
( ) : Please use V or H to indicate terminal type.
The recommended discharge current is a reference value. Please design your equipment(circuit) in consideration of IR dorop.