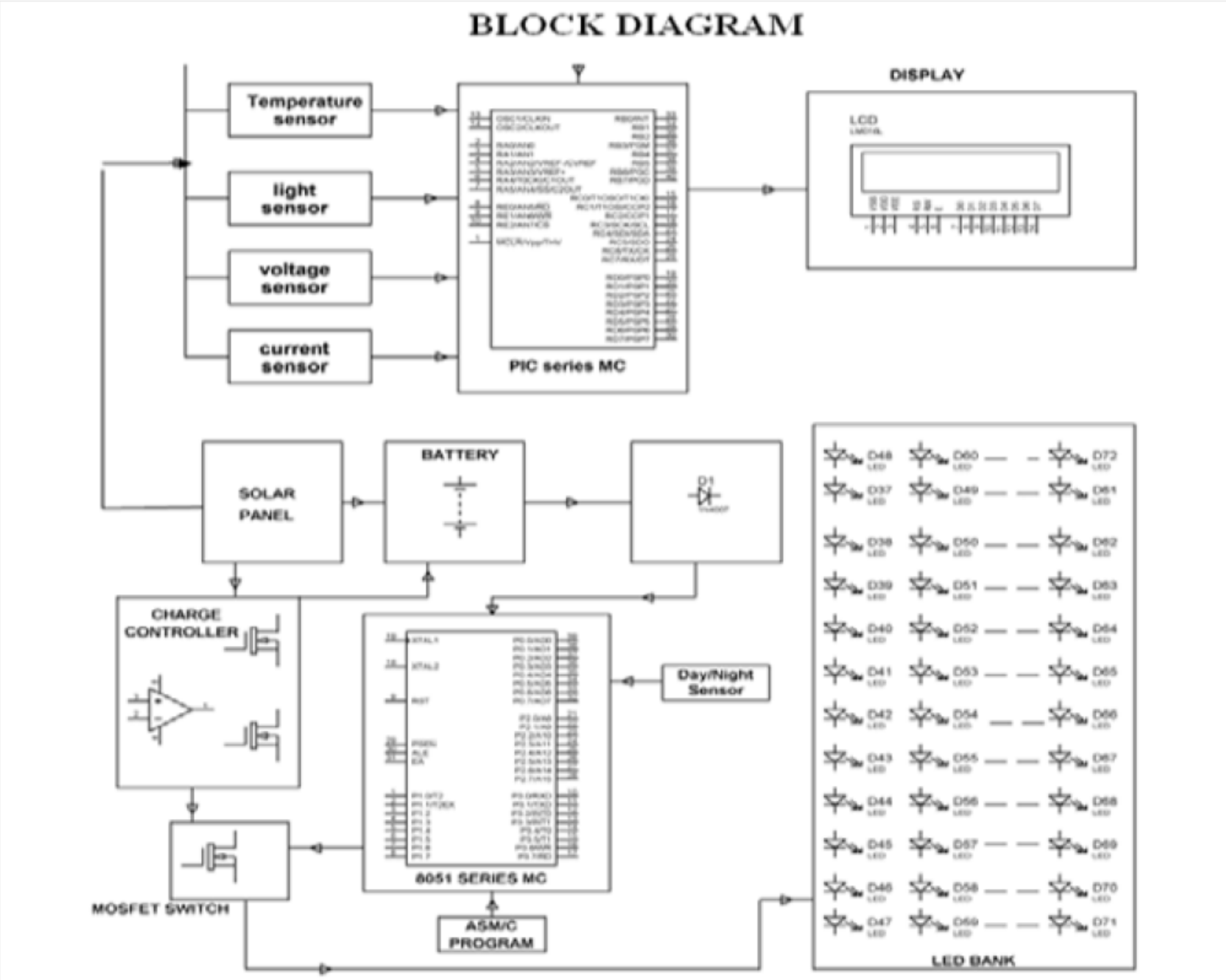
CHAPTER THREE

3. DESIGN METHODOLOGY

This circuit consists of a battery charge controller circuit that is charged by the solar panel. The battery gives supply to the micro-controller which is programmed to work as a PWM connected to the LDR which gives high/low signal based on the light intensity. When the microcontroller gives a high signal to the MOSFET the LED is OFF. Once the MOSFET gets a low signal it turns ON and the LED glows. The circuit also consists of measurement circuit for the measurement of photovoltaic power and the variation of light for the amount of sunlight obtained. The current is sensed by the current sensor, and temperature by the temperature sensor and voltage is noted by the potential divider circuit.

WORKING



3.1 Solar Panel Section

Figure (10) A BLOCK DIAGRAM OF INTERCONNECTED CABLES

Battery B1 is charged via D10 and fuse. When battery gets fully charged Q1 conducts from output of comparator. This results Q2 to conduct and divert the solar power through D11 and Q2 such that battery is not over charged. We use IC LM324 having 4 op-amps used as comparators that is U1: A, B, C, D. U1:A is used for sensing over charging of the battery to be indicated by action of U1:B output fed D1(red)and D12(green) for indicating battery status. Diodes D5 to D8 all connected in series are forward biased through R14 and D3 .This provides a fixed reference voltage of 0.65*4= 2.6v at anode point of D8 which is fed to pin 2 U1:A through R11, pin 13 of of U1:D, pin 6 of U1:B via R9 and pin 10 of U1:C via 5K variable resistor. While the battery is fully charged the voltage at cathode point of D10 goes up. This results in the set point voltage at pin 3 of U1:A to go up above the reference voltage. This will switch 'ON' the transistor Q1. MOSFET is triggered to drive a led D1 indicating battery is being fully charged. During overload U1:C going low to remove the drive to the gate of MOSFET Q2 that disconnects the load. The correct operation of the load in normal condition is indicated by D9 while the MOSFET Q2 conducts.

3.2 Control of Street Lighting Circuit

Here we use a LDR to sense the daylight, based on that we switch ON the LEDs. As we made a potential divider with 100K and LDR. While in the daylight light falls on LDR its resistance will go down, as resistance go down voltage drop across it will go down. voltage drop across 100K go increase. The voltage drop across LDR will go to 39th pin of MC as LOW logic. When night falls there will be no light on LDR so resistance of LDR go increase so voltage drop across will increase, this voltage drop goes to MC as HIGH logic sensing as Night. Based on light intensity falling on LDR decided the duty cycle of output LEDs . The MOSFET switches ON between its drain and source that completes its path of current flow through the LEDs. Therefore with varying duty cycle from 90% to 10% the current flowing through the LEDs reduces that result in lesser intensity as described earlier.

3.3 **Measurement of Solar Photovoltaic Power Circuit**

In the measurement circuit the Voltage from the solar panel is fed to the MC pin no 4 through a potential divider comprising of R4 & R5. A resistance is used as load in series with another resistor R7 of 10ohm, 10W. The voltage drop across the resistor R7 is proportional to the load current which is fed to pin 5 of MC. Light input is sensed by LDR which is fed to MC pin 2. A temperature sensor LM35(U3) is connected to pin 3 of MC. Thus, four analog varying voltage parameters are fed to the internal ADC of the MC out of total availability of 8 channels. A LCD is used to display all the output parameters such as light intensity, temperature, voltage and current of solar panel.

3.4 **Smart street light system with energy saving function based on the sensor network**

here are some attempts being made to reduce the energy wastes of street lamps, such as, a sensor light which will be controlled by a light sensor and optionally a motion sensor are used. But there is a delay in switching on the light using the motion sensor because the person or vehicle should be in close proximity to the street lamp instead it should switch on before the desired object comes close so that it lights up the street. Some companies and universities have developed central systems to control the street lights smartly using one central computer. These systems are suitable for controlling street lamps on large scale and are not at all suitable for small scale project.

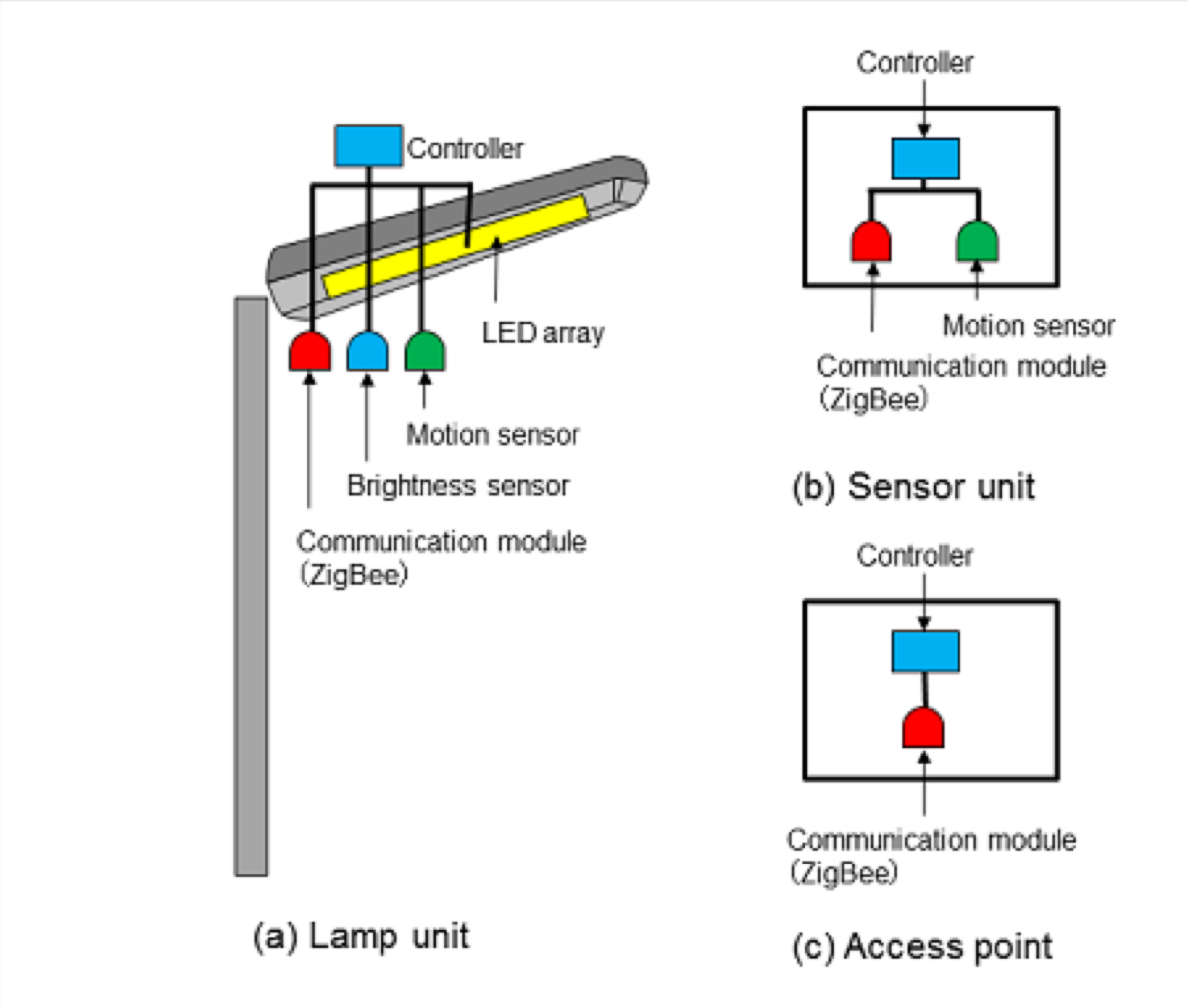


Figure 11: Components for the Smart Street Light

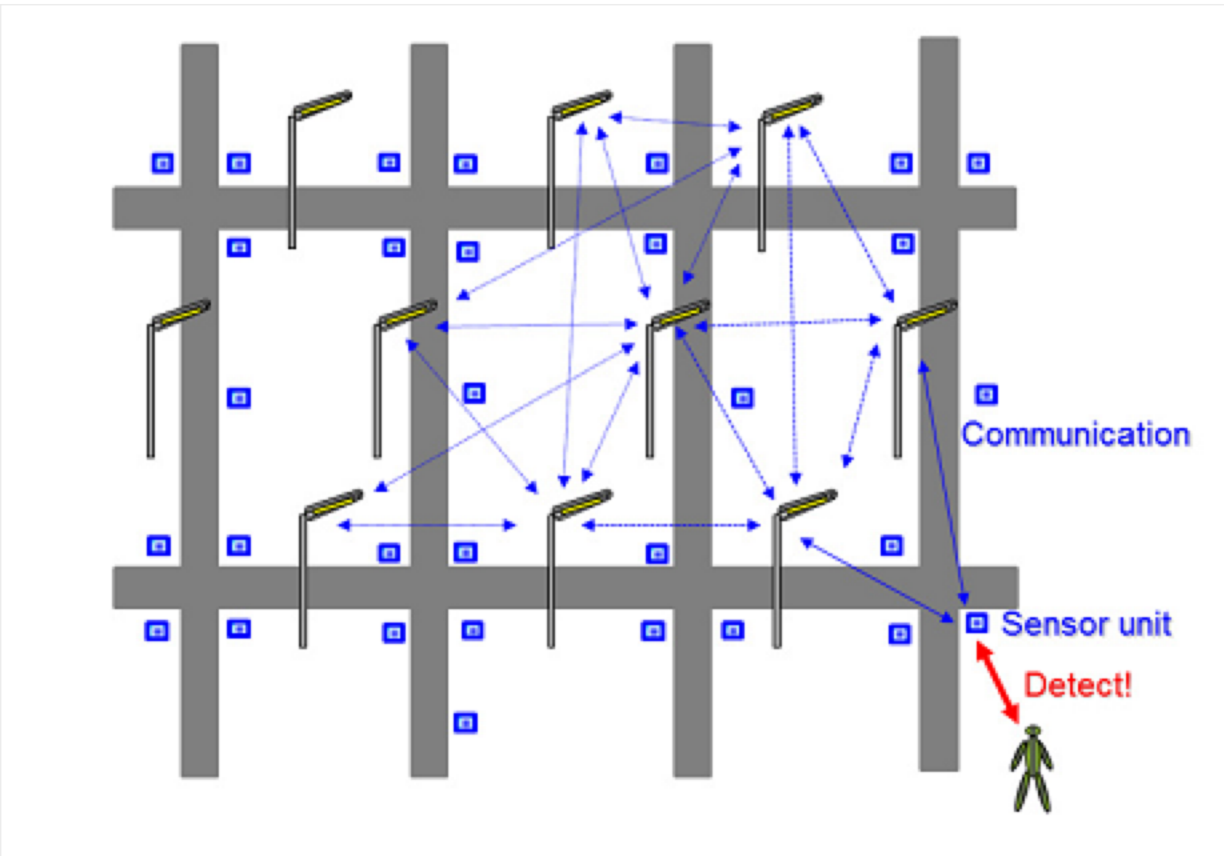


Figure 12: Object Detection Network

3.5Assumptions and Dependencies

In this project, our team is proposing a green and efficient solution for AUS campus street lighting. This solution saves energy by consuming less power and saves annual expenses of the country. After comparing different light sources, our team agreed upon using LEDs lamps because there are several advantages over the other types. The design of this project involves a solar system to save energy and power, LEDs to help in producing dimmable lightning and higher life span, and a motion sensor to control the switch ON/OFF of the system at night I different periods.

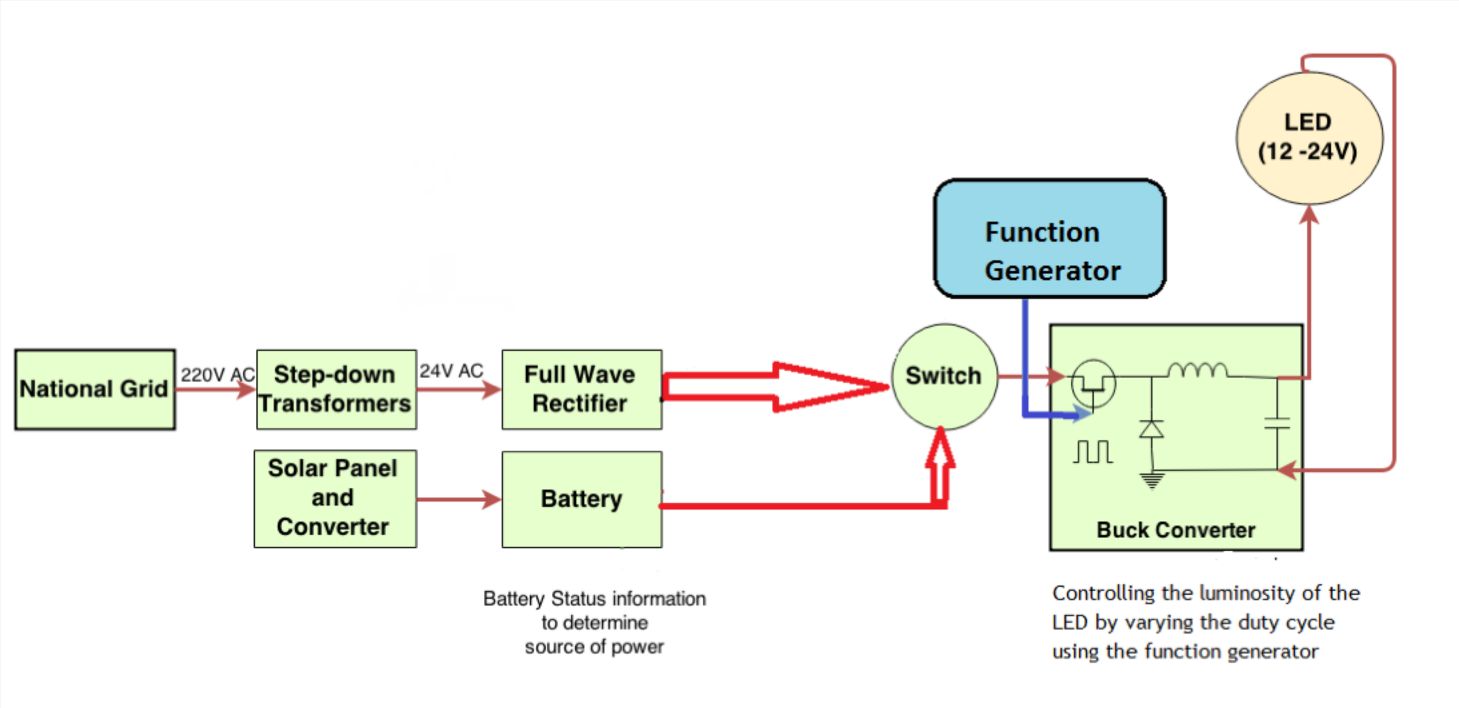


Figure 13: (Overall System)

3.6 System Decomposition

The following are the main parts used for the SSL project:

1. Solar Panel

Solar panel is one of the most important parts of solar street lights, as solar panel will convert solar energy into electricity. There are 2 types of solar panel: mono-crystalline and poly-crystalline. Conversion rate of mono-crystalline solar panel is much higher than poly-crystalline.

2. Lighting Fixture

LED (Light Emitting Diode) is a solid state semiconductor device which can convert electrical energy into visible light. It is usually used as lighting source of modern solar street light. It is because of the fact that it has small size, low power consumption ad long service life. The spectrum of the LED is mostly concentrated in the visible light spectrum, so it has a high luminous efficiency. Also the energy consumption of LED fixture is at least 50% lower than HPS (High Pressure Sodium) fixture which is widely used as lighting source in traditional street lights. Another advantage is that LED lacks warm up time that adds to its efficiency.

3. Rechargeable Battery

The electricity from solar panel is stored in the battery during the day and it provides energy to the fixture during night. The life cycle of the battery is very important to the lifetime of the light and the capacity of the battery will affect the backup days of the lights. A battery convert's energy stored in the chemical bonds of a material into electrical energy via a set of oxidation/reduction (redox) reactions. Redox reactions are chemical reactions in which an electron is either required or produced. For primary batteries, this is a one-way process – the chemical energy is converted to electrical energy, but the process is not reversible and electrical energy cannot be converted to chemical energy.

4. Controller

It is the controller which decides the switch on /off, charging and lighting and the dimming of the (SLSL). Solar Charge controller can be configured to stop the flow of current to the battery when the rated current level of the battery is reached. Charge controllers can also be referred to as Charge Regulators. A series charge controller or series regulator disables further current flow into batteries when they are full. A shunt charge controller or shunt regulator diverts excess electricity to an auxiliary or "shunt" load, such as an electric water heater, when batteries are full, Simple charge controllers stop charging a battery when they exceed a set high voltage level, and re-enable charging when battery voltage drops back below that level. Pulse width modulation (PWM) and maximum power point tracker (MPPT) technologies are more electronically sophisticated, adjusting charging rates depending on the battery's level, allow charging closer to its maximum capacity. Charge controllers may also monitor battery temperature to prevent overheating. Some charge controller systems also display data, transmit data to remote displays, and data logging to track electric flow over time

5. Pole

Strong Poles are necessary to all street lights, especially to solar street lights as there are components mounted on the top of the pole: Fixtures, Panels and sometime batteries. And wind resistance should also be taken into consideration when choosing the pole.

3.7 Operation principle

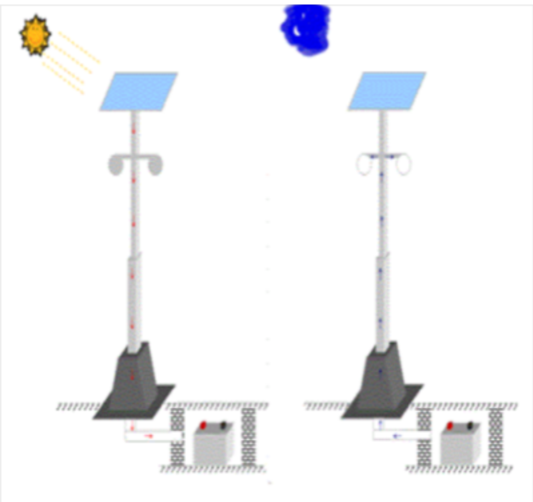
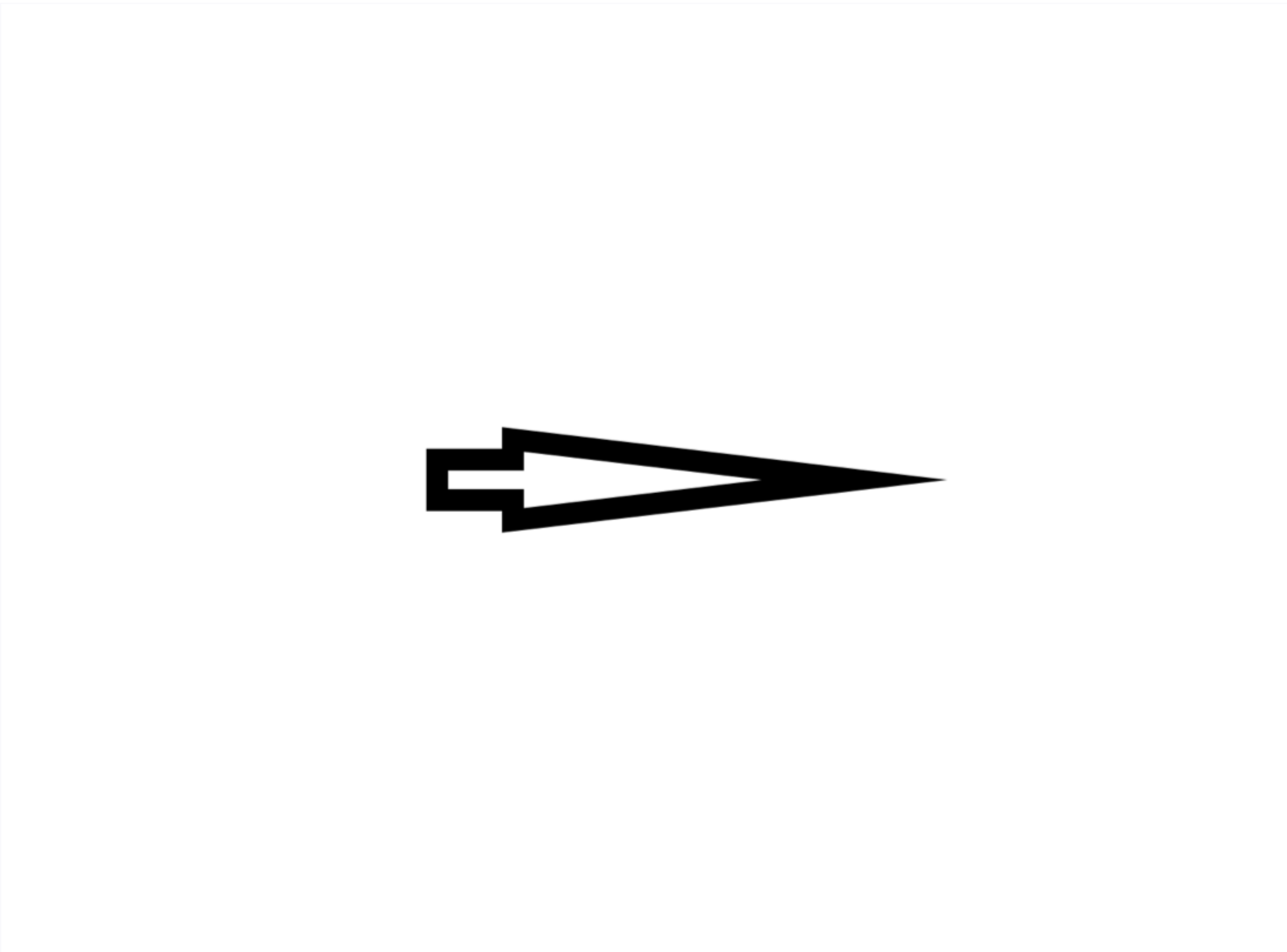


Figure 14: Operation Principle

Solar Panel



Controller
LED
Battery

Figure 15: System Work Flow

According to principle of photovoltaic effect, the solar panels receive solar radiation during the day time and then convert it into electrical energy through the charge and discharge controller, which is finally stored in the battery. When the light intensity reduced to about 10 lx during night and open circuit voltage of the solar panels reaches at a certain value, the controller has detected voltage value and then acts. The battery offers the energy to the LED light to drive the LED emits visible light at a certain direction.
Battery discharges after certain time passes, the charge and discharge controller will act again to end the discharging of the battery in order to prepare next charging or discharging again

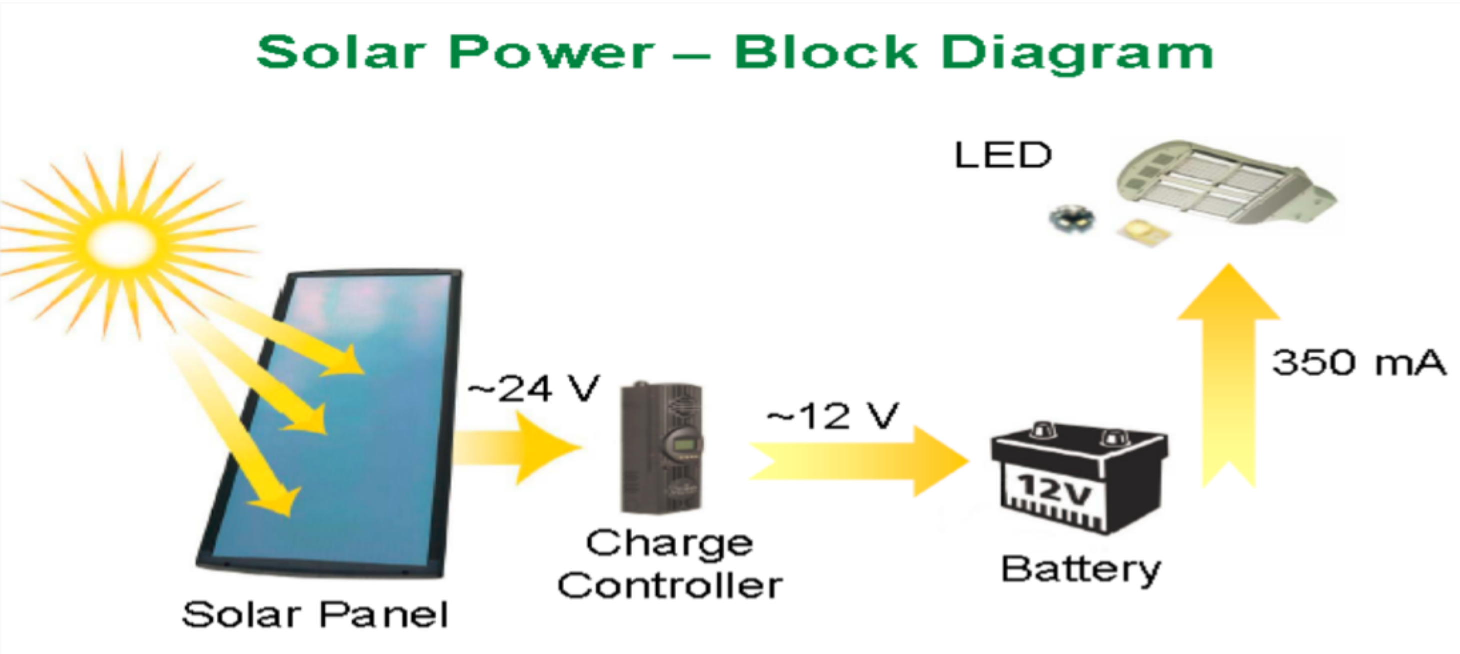


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Figure 16: Solar Power- Pictorial Diagram

Requirement Specifications

Therefore to select an appropriate LED we had to know their technical specifications in order to quote them to a company. By thorough research we found companies which would suit our requirements to implement for the real time model. The UAE Solar Energy is one of the leading companies in LED industry which fulfills the standard requirement. The following shows the specifications of the street light.

Product Details:
1. Model JNYT-40W -Solar panel
2. Max power 18v/65W
3. Life time 25 years
4. Battery type : Lithium-FePo4battery
5. Capacity 12.8V/30AH
6. Life time 5 years
7. LED Lamp
8. Max power :12V/40W
9. Led chip :Bridge lux from USA
10. Lumen (LM) :4800-5200lmlm
11. Led chip :40pcs
12. Life time :50000hours

Product Parts:
1) Solar Panel
2) Li-Fe Battery
3) LED
4) MPPT controller
5) Human intelligence induction System

Product Properties:
1. Angle 120 degrees
2. Charging by sun light :7 hours
3. Full power more than 10hours
4. Half power more than 20hours
5. Work temp range (*C) : 30-70
6. Color temp range(k) :3000-6000
7. Height range (m):4-5m
8. Space range (m) :8-10m
9. Material aluminum alloy
10. Certificate CE / ROHS/ IP65
11. Warranty 2 years

3.8 Implemented Model Details

We wanted to implement the real system in our project, but due to the high cost of an actual system we decided to build a scaled down model on which we can implement our lighting control and mobile application. The cost of one entire set is AED 3500 and this was beyond the allowed range for us students. However, when the university is buying it in bulk, the cost reduces and also the university has to afford only its initial cost of setting up the solar powered LED. Because once it is set up, the LED then completely works on solar power, thus reducing the overall power consumption .The following are the details of our miniature model. Electrical students had to build the buck convertor on their own to interface the buck converter with the rest of the model.

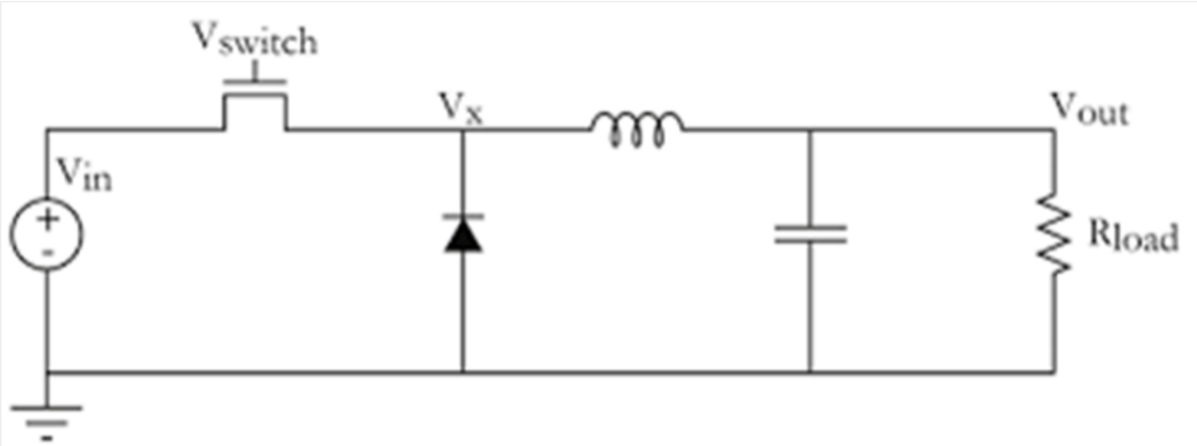


Figure 17: (Simple Buck Converter Circuit)

The figure [17] above shows a basic buck converter circuit. The buck converter is used in our project to control the dimming function of the LED light using a power MOSFET. The MOSFET works as a switching regulator. In other words, the MOSFET voltage depends on the time of the duty cycle in order to have the solar panels voltage (input voltage) to vary by turning the MOSFET ON/OFF in order to control the voltage transferred to the load. Our system is made up of a solar panel that supply energy of 12 volts and store it in a battery, the battery discharge this energy to the buck converter input voltage. The switching voltage of the MOSFET is a control signal that control the duty cycle. When the input voltage is high, the MOSFET turns ON allowing the input voltage to pass which is greater than the output voltage. Then the current through the inductor starts to increase and charges the capacitor. When the MOSFET turns OFF the current through the inductor
starts pass through the diode producing a voltage equals to approximately zero. This voltage is less than the output voltage. Then the current through the inductor decreases and the capacitor starts to supply current to the load. This will produce a controllable buck converter in which it reduces the input voltage to any required output voltage for the load.

The Buck Convertor Specifications:
I. Output Power: P = 7 Watts
II. Input Voltage : Vinput = 12V
III. Current through one Led: I led = P / V = 7/12 = 0.5833A
Here we assume the load has 4 LEDs: Total current through
the load:

I. Current (I) through load =4*0.5833= 2.5 A
II. Duty Cycle: D = 0.5
III. Vout = D* Vin =6 V
IV. Ripple Current: Ir =30% * I load =0.75A
V. L=(Vin-Vout)*D)/Iripple*Frequency)
Assuming frequency to be 6Khz
I. L≥0.77mH
II. Vripple =100mV
III. Capacitance=((1-D)*I load*D*T)/Vripple >= 1.04mF
IV. Diode should be able to handle current greater than 2.5A
V. Mosfet >= 3* Vin => More than 30V
VI. Capacitance = ((1-D)*I load*D*T)/Vripple >= 1.04mF
a. Diode should be able to handle current greater than 2.5A
b. MOSFET >= 3* Vin => More than 30V

3.9 COST analysis
1. Sodium lamps (Current system)
2. Energy Consumption for 705 lamp posts each with 4 lamps:

a. 705 x 250W x 4 bulbs = 705 kW Per day consumption:

b. 705kW x (12 hours/day) = 8460 kW.hr

3. Annual consumption in MW.hr:
a. 8460 x (365days) = 3087.8 MW.hr

4. Annual consumption in AED, per fils rate 0.45 fils/KW.hr
5. Cost = AED 1,389,510 / annum

LED's (proposed solution):
1. Energy Consumption for 705 lamp posts each with 4 lamps:
2. 705 x 40 W x 4bulbs = 112.8 kW
3. Per day consumption
4. 112.8kW x (12hours/day) = 1353.6 kW.hr
5. Annual consumption in MW.hr
6. 1353.6kW.hr x (365 days) = 494.064 MW.hr
7. Annual consumption in AED, per fils rate 0.45 fils/KW.hr
8. Cost = AED 222,328.8 / annum
9. This cost estimation leads us to a ratio of 1: 6.24
10. Cost of electrical components which includes lamp post, control box, solar panel, LEDs and battery = AED 3500[14]

11. Initial Cost of setting up 705 Led lamp posts = AED 3500*705 = AED 2,467,500

Implemented Model Cost:

1. Solar Panel with the controller and the battery = AED 500
2. LED (7 W- Dc Dimmable) = AED 70
3. Buck Convertor Components = AED 40
4. Total Cost = AED 610

3.10 **Simulations:**

During the second phase of the project (ELE 491), we build the buck convertor and interfaced with solar charged battery and function generator and tested the ON/OFF as well as dimming of the 7 Watts Led. The only problem we faced was the heating up of the mosfet. The problem was solved by using a heat sink with the mosfet.

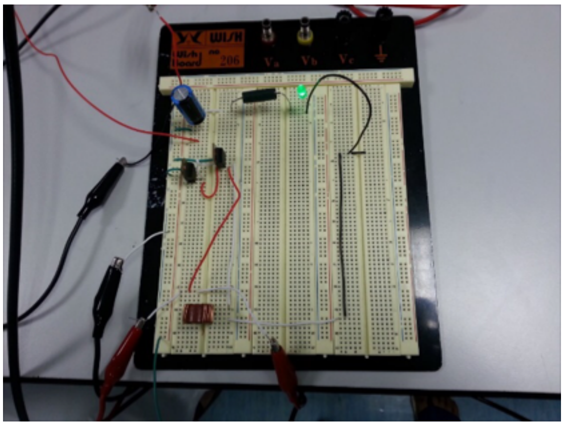
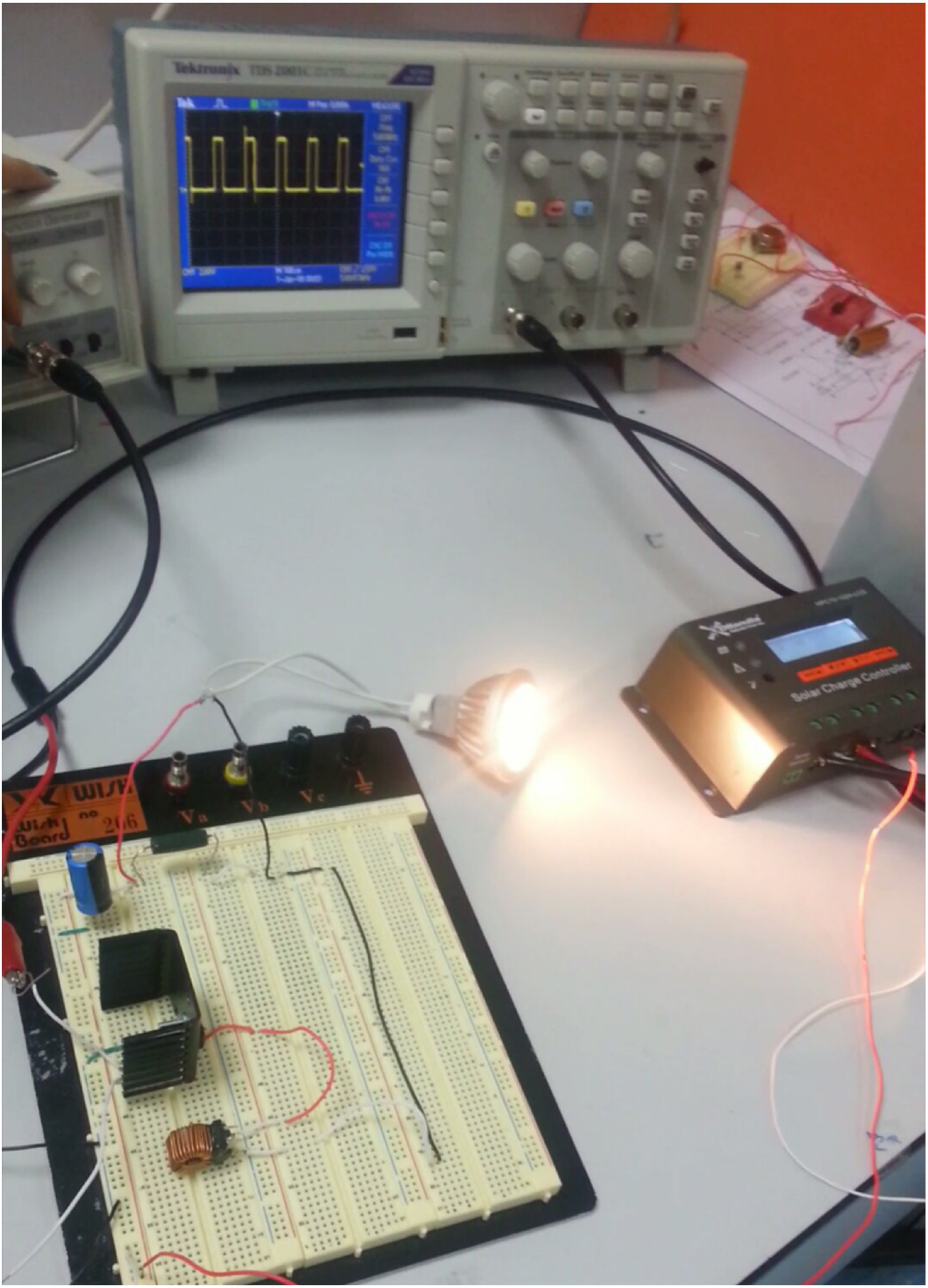


Figure 18: Buck Convertor with Small LED



Tektronix
TDS 2001C
Va
Vb
Vc
Solar Charge Controller

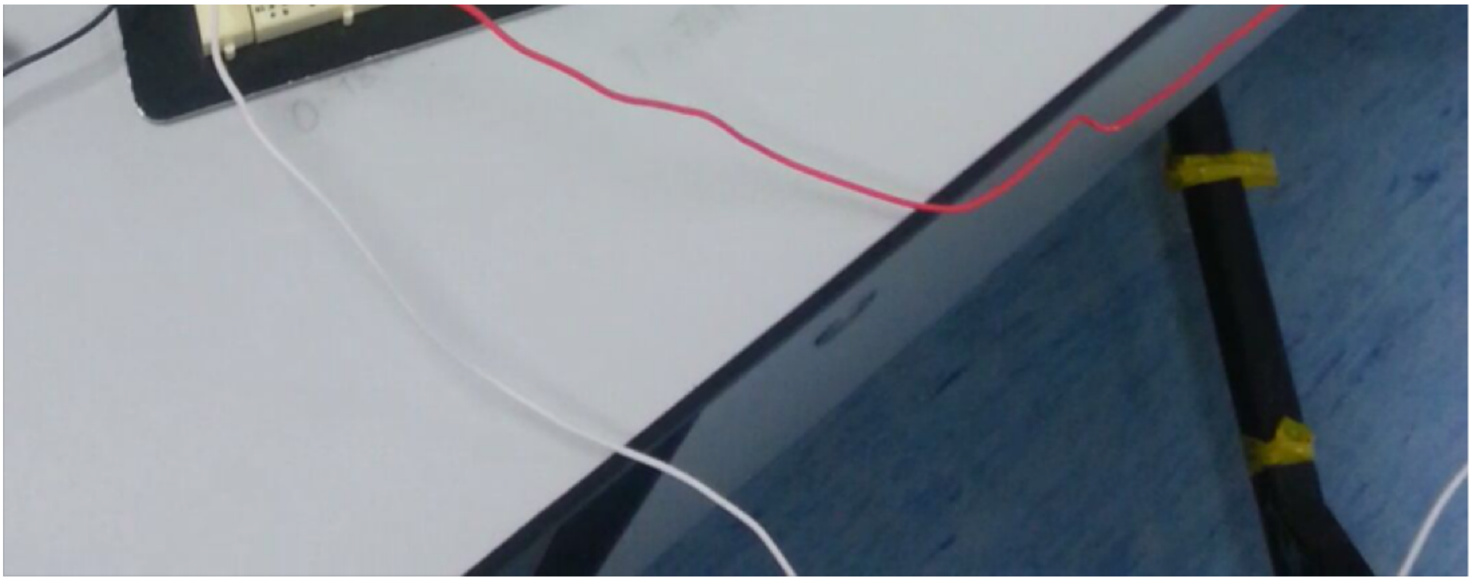


Figure 19: Dimming the 7Watt LED by Varying the Duty Cycle