BUCK-BOOST CONVERTER FOR PV SOLAR SYSTEM

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BUCK-BOOST CONVERTER FOR PV SOLAR SYSTEM

MOHD FIRDAUS BIN ZAINAL ABIDIN

Thesis submitted in fulfilment of the requirements
for the award of the degree of
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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of degree of Bachelor of Engineering Technology in Electrical.

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I hereby declare that the work in this thesis is my own except for quotations and summaries in which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

The PV solar system is a promising technology of harnessing renewable energy to be used in this world. However, the major drawback of PV solar system is the output generated is fluctuated within time. Thus, the buck-boost converter with arduino microcontroller used to regulate the voltage output from the solar panel. The arduino microcontroller is instructed to control the desired voltage output.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

cm	Centimeter
°C	Degree Celsius
e^-	Electron
g	Gram
H^+.	Hydrogen ion
kPa	Kilopascal
kV	Kilovolt
L	Liter
MPa	Megapascal
M^0	Metal colloid
M^+	Metal ion
m	Meter
µg	Micro gram
µl	Micro Liter
µm	Micro meter
ml	Milliliter
mm	Millimeter
min	Minute

LIST OF ABBREVIATION

ATP	Adenosine-5'-triphosphate
ANOVA	Analysis of variance
B-B	Box-Behnken
s-CNC	Cellulose nanocrystals
CCD	Central Composite Design
CFU	Colony Forming Unit
DNA	Deoxyribonucleic acid
EDX	Energy dispersive X-ray spectrometer
EPA	Environment Protection Authority
EC	Epicatechin
ECG	Epicatechin-3-gallate
EGC	Epigallocatechin
EGCG	Epigallocatechin-3-gallate
E. coli	Escherichia coli
FESEM	Field emission scanning microscope
FDA	Food and Drug Administration
FTIR	Fourier transform infrared spectroscopy
FFD	Full Factorial Design
GC	Gallocatechin
HPMC	Hydroxypropyl methylcellulose
ICDD	International Centre for Diffraction Data
MNP	Metal nanoparticles

OFAT	One factor -at-a-time
PHB	Poly(3hydroxybutyrate)
PCL	Poly(e-caprolactone)
PGA	Poly(glycolic acid)
PEG	Polyethylene glycol
PLA	Polylactic acid
ROS	Reactive oxygen species
RSM	Response surface methodology
AgNP	Silver nanoparticles
SNP	Silver nanoparticles
$AgNO_3$	Silver nitrate
SS	Sum of squares
SPR	Surface plasmon resonance
SERS	Surface-enhanced Raman scattering scattering
TEM	Transmission electron microscopy
XRD	X-ray diffraction

PROJECT BACKGROUND

1.1 Introduction

The concern of environmental issue nowadays causing rising in demand of renewable energy that is cheaper and sustainable with less emission. Solar energy is an option that offered promising result in cater on the problem. PV system is module used to harness solar energy. PV system that built in form of array solar panel where harnessing solar energy take place.

As generally recognized, many applications require voltage bucking boosting converters, such as portable devices, car electronic devices, etc. This is because the battery has quite large variations in output voltage, and hence, the additional switching power supply is indispensable for processing the varied input voltage so as to generate the stabilized output voltage. There are several types of non isolated voltage buck boosting converter such as buck–boost converter, single ended primary inductor converter ,Cuk converter, Zeta converter, Luo converter and its derivatives, etc. (Jeevan Naik, 2014)

A non-inverting buck-boost converter is essentially a cascaded combination of a buck converter followed by a boost converter, where a single inductor-capacitor is used for both . As the name implies, this converter does not invert the polarities of the output voltage in relation to the polarities of the input. This converter requires the use of two active switches and is designed by combining a buck converter and boost converter design in the same topology. (Lipika Nanda and Sushree Sibani Das, 2013)

A MPPT is utilized for removing the greatest power from the sunlight based PV module and exchanging that energy to the load. A dc-dc converter (step up or stepdown) fills the need of exchanging maximum power from the sunlight based PV module to the load. A dc/dc converter goes about as an interface between the load and the module .

However, the PV system is facing problems with the insulating and varying climate issues that causing inefficiency and vary in generated power output of the system [1-2]. The sensitivity of certain electrical appliance toward variation of power input generated by solar energy not suitable to be used as power source. Because of that, DC-DC converter is needed in order to regulate the power output from the PV system.

1.2 Problem statement

The worlds are seeking for alternative energy power source for better living nowadays which known as renewable energy. It is because renewable energy sources are abundance and natural. As a result, the energy is cheaper and suitable with the environment. For instance, solar energy is energy that harnessed from the sun light using PV system and it can be considered as the best renewable energy option existed nowadays.

However, there is two major problems that may related with PV system. First, the efficiency of solar electric power generation is low especially when system is exposed to low irradiation conditions. Second, the amount of electrical power generated by solar PV system is vary according to weather conditions. These problem occurred because of unstable weather condition or the light intensity that exposed to the solar panel is changed by time. These situations can affect the viability of the solar system to be used for certain electrical appliance, because of these appliances sensitivity towards the change in power input.

For an effective PV solar system, it need to build with buck-boost converter with micro controller. It is because, buck-boost converter is a dc-dc converter that can amplified and lowered the amount of power output by changing duty cycle. By having the buck-boost converter system, it will help in controlling the power output from the PV solar system which is vary depends on light intensity exposed. As a result, the power generated by the PV solar system can be used by the electrical appliances according to its suitable power input.

1.3 Objective

The main objective of this project is to develop an efficient PV system using buck boost converter with arduino controller. To accomplish that, the aim to achieve the following project the specific objectives is

1) To design and develop a buck boost converter for maximum power point tracking of PV system.
2) To design and implement an arduino microcontroller for the developed buck boost converter.
3) To analyse the performance of the developed system using both simulation and prototype.

1.4 Project scope

The scope of this project is to control the power output from the PV Solar System via Buck-Boost Converter. This is the important aspect needed to be taken as to make a Desired PV Solar System. The power output of the PV Solar system is essential role as for powering certain sensitive electrical appliances. In order to control the power output, the duty cycle of the buck-boost converter need to regulate. Other than that, the microcontroller is needed in the system, in order to analyse the power output from the buck-boost converter and regulate the duty cycle when needed. The microcontroller is Arduino Uno. In order to use this microcontroller, the specific programming language is required.

LITERATURE REVIEW

2.1 Introduction

In this chapter, the fundamental of The PV Solar System will be explained more with comparison of the PV solar system ratings and the voltage yield percentage. The output voltage of the PV solar system is concerned most in this research. In this chapter also will cover the detail about type of voltage sensitive electrical equipment load, it will cover on the required voltage input to the load. Other than that, this chapter will include the details about DC-DC Converter which will differentiate between Buck converter, Boost converter and Buck-Boost converter in term of basic mechanism with advantages of the converter. It will study about voltage increment and decrement situation according to fixed desired output. Lastly, in this chapter will cover on Pulse with Modulator (PMW) system that is act as microcontroller in the converter to control the increment or decrement of desired output voltage

2.2 PV Solar System

The PV solar system is a system that converting sun energy into electricity. The sun irradiance is strike the solar panel of the solar system, then converted into electricity. A solar panel is a packaged connected assembly of photovoltaic cells. Photovoltaic (PV) cells made up of semiconductor p-n junction that after stroke by sun light and it will absorb the light energy, as a results, the population of charge carriers will increase with a potential related to the band gap and also into cell heating which degrades the performance (K.Arun kumar , B.W.Vijaykumar, B.Subba Reddy, 2014**)**.

A typical solar system consists of a 0.2mm thick mono crystalline silicon which built in two layers that represent the difference in electrical properties. As a results have enhance doping of the electron with impurities then creating an electric field at the junction area. When sunlight is strike on the solar cell the energy from the photons creates free charges that are separated by the electrical field, creating a potential so when a load is placed between the terminals a photo current is created (Parimita Mohanty, Tariq Muneer, Eulalia Jadraque Gago and Yash Kotak, 2016).

Electrical connections are made in series to achieve a desired output voltage and or in parallel to provide a desired current capability The most common material used in photocells today is silicon (Si) divided in mono crystalline, polycrystalline, and amorphous. The amount of energy they can deliver changes depending on the material of the cell and the incidence of sunlight (A.M.K. El-Ghonemy, 2012**)**. Figure 2.1 show the example image of Mono crystalline silicon solar panel.

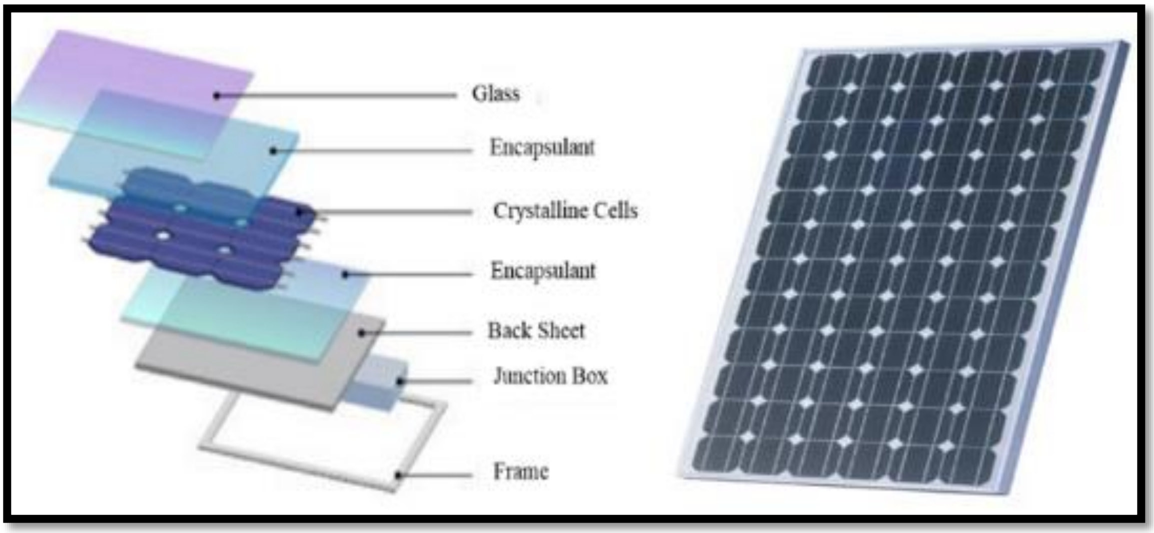

Figure 2.1: Cut way of Monocrystalline Solar Panel

PV solar systems are generally classified according to their functional and operational requirements, their component configurations, and the structure of the PV system is connected to other power sources and electrical loads. The PV solar system can be classified into two which are grid-connected systems and stand-alone systems**.**

Firstly, the Grid-connected are designed to operate in parallel with directly connected to the electric utility grid. The primary component in grid-connected PV systems is the inverter, and known as power conditioning unit (PCU). The role of PCU is to converts the DC power produced by the PV array into AC power. The value need to be fixed with the voltage and power quality requirements by the utility grid. The system will automatically stops supplying power to the grid when the utility grid is not energized (Florida Energy Centre 2014).

A bi-directional interconnection is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance. This allows the AC power produced by the PV system to either supply directly to the electrical loads. The electric can be flow back-feed the grid when the PV system output is greater than the on-site load demand. At night and during other periods when the electrical loads are greater than the PV system output, the balance of power required by the loads is received from the electric utility. Figure 2.2 show diagram of Grid-connected PV solar system (Florida Energy Centre 2014).

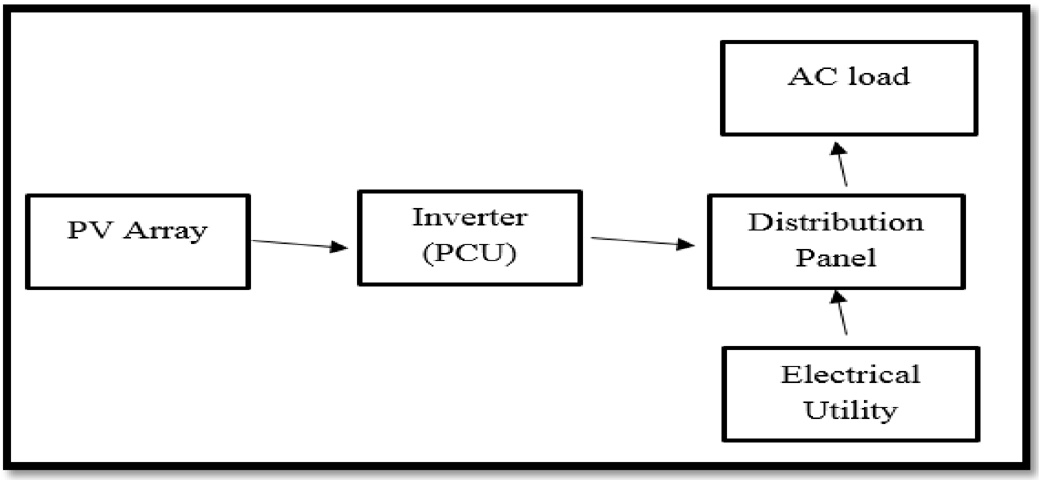

Figure 2.2: Diagram of Grid-connected PV solar system

Secondly, Stand-alone PV systems are designed to operate independently as the electric utility grid, and it usually designed and sized to supply certain DC and/or AC electrical loads from the beginning of the production process. These types of systems may be powered by a PV array only, or may use other power generation tool to support the power generated, for instance an engine-generator or utility power as an auxiliary power source in. This system is named by PV-hybrid system. The simplest type of stand-alone PV system is a direct-coupled system. The system work when DC output of a PV array is directly connected to a DC load as shown in figure 2.3. there is no electrical energy storage like battery is connected, thus the load only operates during day where there is sun light. It makes the direct-coupled designs are suitable for common applications such as ventilation fans, water pumps, and small circulation pumps for solar thermal water heating systems (Florida Energy Centre 2014).

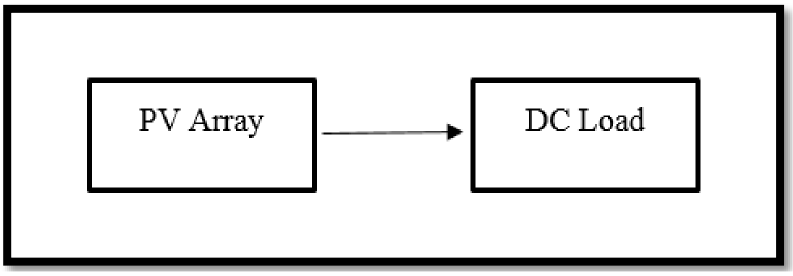

Figure 2.3: Diagram of Direct-Coupled System

Other than that, there is also Stand-alone PV system design that involving electrical energy storage like battery. It usually uses to power an AC electrical appliances, thus the system is involving also AC/DC inverter to convert the DC power generated into AC power to be use as. Figure 2.4 show the diagram of Stand-alone PV system with electrical energy storage. These systems are suitable for home electrical appliances such as Washing machine, microwave, refrigerator and AC air-conditioner.

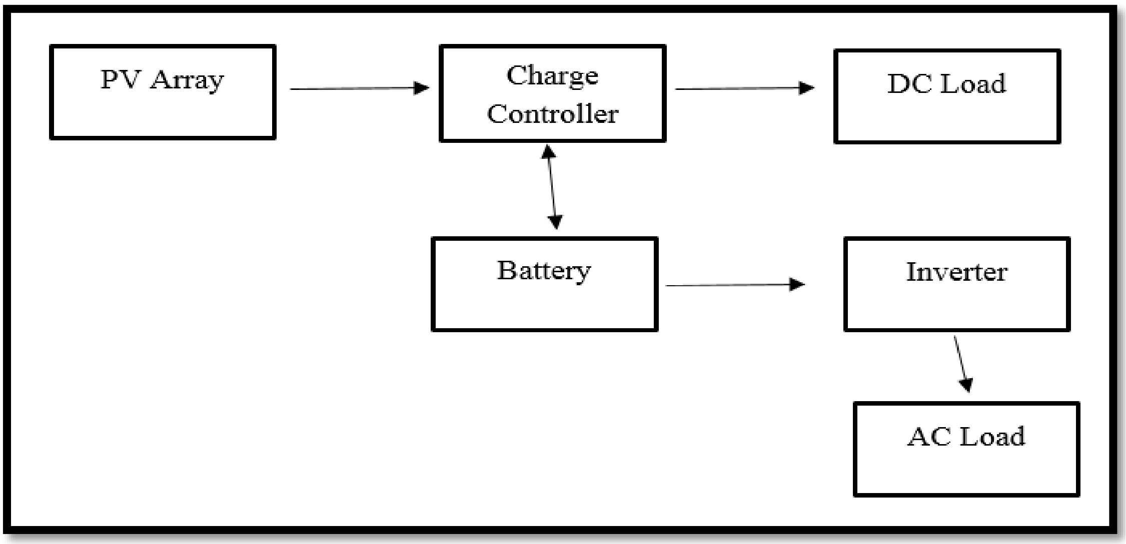

Figure 2.4: Diagram of stand-alone PV system with battery storage powering DC and AC loads.

There are numerous PV solar systems that reconstruct based on basic mechanism of solar energy in order to achieve better efficiency. The efficiency of the solar system is encompassing the ability to convert direct solar energy from sun into electricity and also the ability to achieve fixed parameter study from that particular solar generation system. To differentiate the efficiency of the solar system, it involving a system called solar system rating. According to Daryl Myers (2009). In United State of America (USA). The common test that conducted to evaluate and rate the PV solar system is called standard test condition (STC) (Daryl Myers, 2009).

Basically the STC is use to analyse the solar rating power generated yield by on condition the parameter study is fixed. STC test is conducted on three major condition which is temperature of the cell, fixed solar irradiance and mass of the air. The temperature it set to be 25°C. The Solar Irradiance need to be 1000 W/m^2. It is amount of sunlight emit on certain period of time per area at specific area study. Next, mass of the air need to be 1.5, These correspond to the irradiance and spectrum of sunlight incident on a clear day upon a sun-facing 37°-tilted surface with the sun at an angle of 41.81° above the horizon. The result of the STC is a standard use to rate the PV solar panel worldwide. The electrical characteristics that focused on this STC are maximum power produced P_{MAX}, which measured in W, open circuit voltage (V_{OC}), short circuit current I_{SC}, which measured in ampere, maximum power voltage , V_{MPP}, maximum power current I_{MPP}, peak power W_p, and solar panel efficiency which calculate in percentage (Mustapha I, Dikwa M. K, Musa B. U and Abbagana M, 2013)

Open circuit voltage $V_{OC,}$ is the maximum voltage that the panel can produce when not connected to an electrical circuit or system. The peak power rating W_p, is the maximum output under standard test conditions. Typical panel, which could measure, will be rated from as low as 75 W to as high as 350 W, depending on their efficiency. At the time of testing, the test panel are binned according to their test results, and a typical manufacturer might rate their modules in 5 W increments, and either rate them at +/- 3%, +/-5%, +3/-0% or +5/-0% (Mustapha I, Dikwa M. K, Musa B. U and Abbagana M, 2013).

$$\eta_{th} \equiv \frac{W_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}}$$

η_{th} = Efficiency of the PV solar panel

W_{out} = Power produced

Q_{in} = Energy irradiance emit by sunlight

Q_{out} = Electrical produced by the solar

According to Azhar Ghazel and Abdul Malik Abdul Rahman (2011) who conducted a research with title The Performance of Three Different Solar Panels for Solar Electricity Applying Solar Tracking Device under the Malaysian Climate Condition. There is difference in solar power yield with different Semi-conductor type. In the research they use poly-crystalline, mono-crystalline and amorphous silicon as the solar panel. And it shows, the best solar Semi-conductor is poly-crystalline in term of power generation yield. However, the price of the poly-crystalline is expensive, which can cost up to RM 2000 per solar panel. Based on these finding, for these project, the most suitable PV solar panel to be use in this project is Monocrystalline solar panel. It is having maximum 17 V power output, with reasonable price and moderate percentage yield of voltage generated. There are three essential formulae that used in their research. The formulae are shown bellows (Azhar Ghazel and Abdul Malik Abdul Rahman, 2011).

$$\eta_P = (P_{mea} / P_{max}) \times 100\%$$

η P = Power output efficiency (%)

Pmea = Average power output (W) measured on site in the given period

Pmax = Maximum power output (W) of panel

$$\eta_{eve} = \frac{P_{eve\text{-}mea}}{PV_A \cdot H} \times 100\%$$

ηeve = Average module efficiency (%)

Peve mea = Average power output (W) measured on site in the given period

H = Average incident radiation (W/m^2) on site in the given period

PVA = Surface area (m^2)

$$PR = \frac{P_{eve\text{-}mea}}{P_{max}} / \frac{H}{G_{STC}}$$

PR = Performance Ratio

Peve mea = Average power output (W) measured on site in the given period.

Pmax = Maximum power output (W) of panel.

H = Average incident radiation (W/m^2) on site in the given period.

GSTC= Irradiance at STC (W/m^2) = 1000W/m^2

2.3 Sensitive Load Toward Regulated Voltage

There is numerous electrical appliance that used in daily life. To power up these appliances, the essential element is Current (I) and Voltage (V). The common appliances that use at home usually need 230 VC voltage Excessive fluctuations of the supplied voltage may cause the appliance to malfunction or get irreparably damage. Voltage surges and spikes in excess of kilovolts and hundreds of amperes in very short duration of microseconds (figure 2.5), power outages, brownouts, mains under- and over-voltage conditions can cause unprotected appliances either in the home or office to malfunction. (A.A. Willoughby, W. Ayara, and N. Obafemi, 2014)

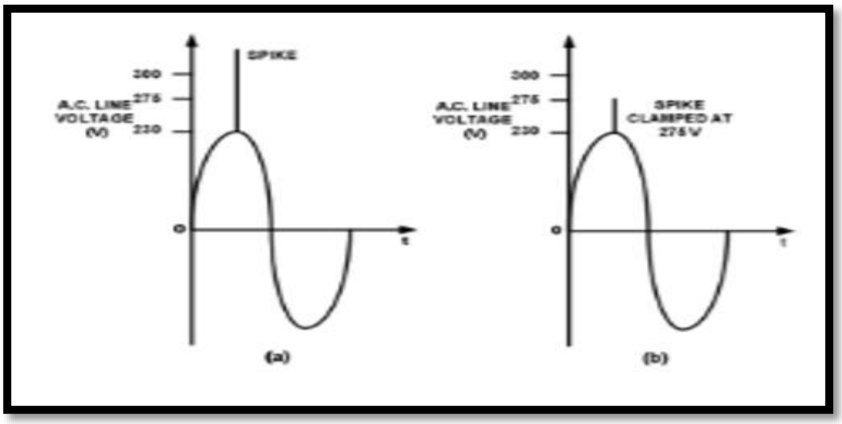

Figure 2.5: Line Voltage (a) Spike (b) Clamped

According to A.A. Willoughby, W. Ayara, and N. Obafemi (2014) which conducting a research with title an Automatic Mains Voltage Switch Protector for Domestic Appliances. The research conducted is to invent an automatic main voltage switch protector (AVS). The AVS can senses undesirable and harmful fluctuations in mains voltages and disconnects the appliance whenever the mains voltage supply goes above or below tolerable limits. The appliance is automatically reconnected when mains power returns to normal within that circuits. (A.A. Willoughby, W. Ayara, and N. Obafemi, 2014)

2.4 Buck Boost Converter

2.4.1 DC-DC Converter

A dc-dc converter is a vital part of alternative and renewable energy conversion, portable devices, and many industrial processes. It is essentially used to achieve a regulated DC voltage from an unregulated DC source which may be the output of a rectifier or a battery or a solar cell etc. Nevertheless, the variation in the source is significant, mainly because of the variation in the line voltage, running out of a battery etc., but within a specified limit. (Abhinav Dogra and Kanchan Pal, 2014)

DC-DC converters are one of the important electronic circuits, which are widely used in power electronics. (Matsuo M, Matsui K, Yamamoto L. and Ueda F, 2000). The main problem with operation of DC-DC converter is unregulated power supply, which leads to improper function of DC –DC converters. There are various analogue and digital control methods used for dc-dc converters and some have been adopted by industry including voltage- and current-mode control techniques. (Rashid M.H,2003). The DC-DC converter inputs are generally unregulated dc voltage input and the required outputs should be a constant or fixed voltage. Application of a voltage regulator is that it should maintains a constant or fixed output voltage irrespective of variation in load current or input voltage. Various kinds of voltage regulators with a variety of control schemes are used to enhance the efficiency of DC-DC converters. Today due to the advancement in power electronics and improved technology a more severe requirement for accurate and reliable regulation is desired. This has led to need for more advanced and reliable design of controller for dc-dc converters. (Sujata Verma, S.K Singh and A.G. Rao, 2013)

Basically, two inductors are used for feeding the load by two independent switches. One inductor charges up by load voltages and another inductor discharges its energy into load during this time. The output power is almost like doubled where the ripple voltage is reduced by factor of two when compared to the conventional DC to DC converter. If the supply side matter is concern for application purpose then it includes Switched mode power supply and flyback converter with KA3524 SMPS controller. And according to the design parameters and results, simulation is done for getting reference values for the hardware implement with Micro Controller.

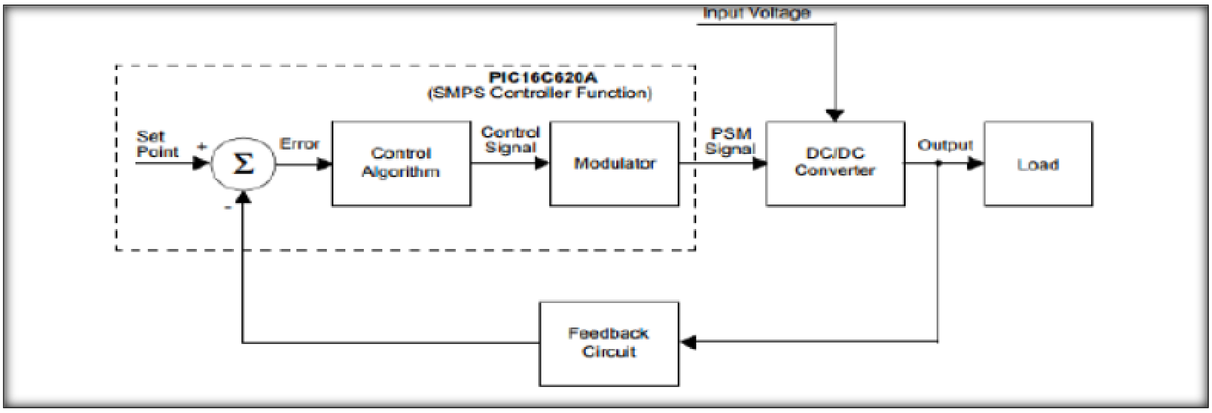

Figure 2.6 : The system of DC-DC Converter

2.4.2 Buck Converter

A buck converter is a step down dc-dc converter consisting primarily of inductor and two switches generally a transistor switch and diode for controlling inductor. It fluctuates between connection of induction to source voltage to mount up energy in inductor and then discharging the inductor's energy to the load.

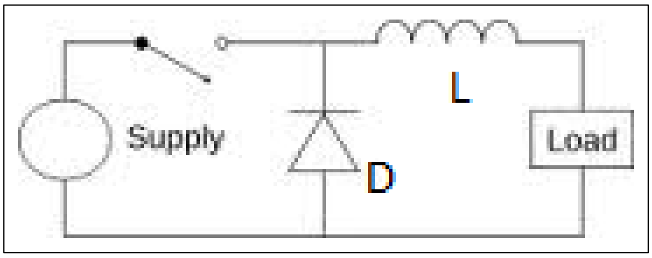

Figure 2.7 : Connection of Buck Converter circuit.

When the switch pictured above is closed, On-state, the voltage across the inductor is VL= Vi- Vo. The current flowing through inductor linearly rises. The diode doesn't allow current to flow through it, since it is reverse-biased by voltage. For Off case when switch pictured above is opened, diode is forward biased and voltage is VL= - Vo (neglecting drop across diode) across inductor. The inductor current which was rising in ON case now decreases.

In a buck converter, the average output Va is less than the input voltage, Vs. The circuit diagram of a buck regulator has shown below and this is like a step-down converter.
The freewheeling diode D conducts due to energy stored in the inductor; and the inductor current continues to flow through inductor (L), capacitor (C), load and diode (D). The inductor current falls until transistor S is switched on again in the next cycle.

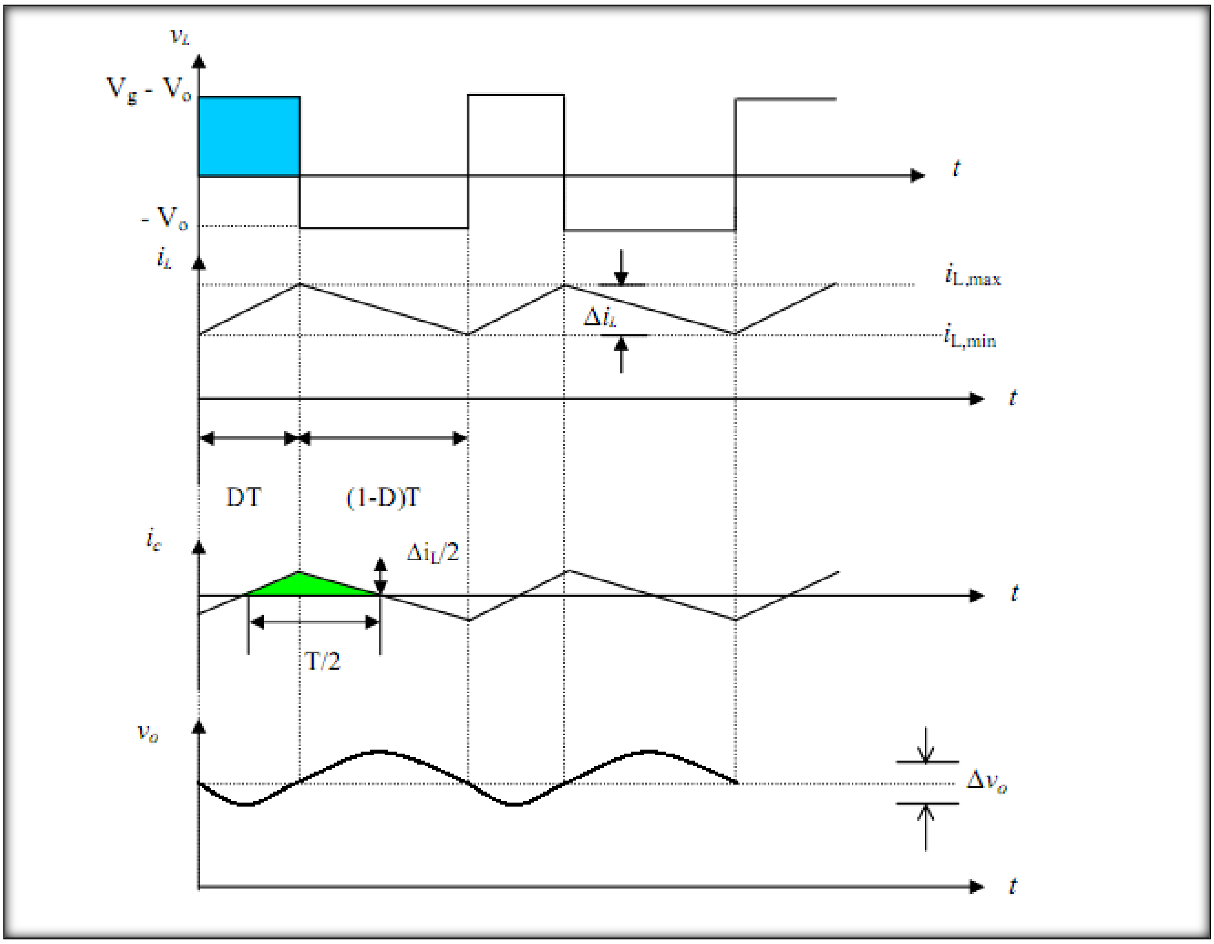

Figure 2.9 : Graph of buck converter

The waveforms for voltage and current are shown in for continuous load current assuming that the current rises or falls linearly. For a constant current flow in the inductor L, it is assumed that the current rises and falls linearly. In practical circuits, the switch has a finite, nonlinear resistance. Its effect can generally be negligible in the most applications depending on the switching frequency, filter inductance, and capacitance, the inductor current could be discontinuous.

2.4.2 Boost Converter

A boost converter is a step up converter, as its name suggest step up the input DC voltage value and provides at output. This converter contains mostly a diode, a transistor as switches and at least one energy storage element. Capacitors are usually added to output so as to perform the function of removing output voltage ripple and sometimes inductors are also combined with.

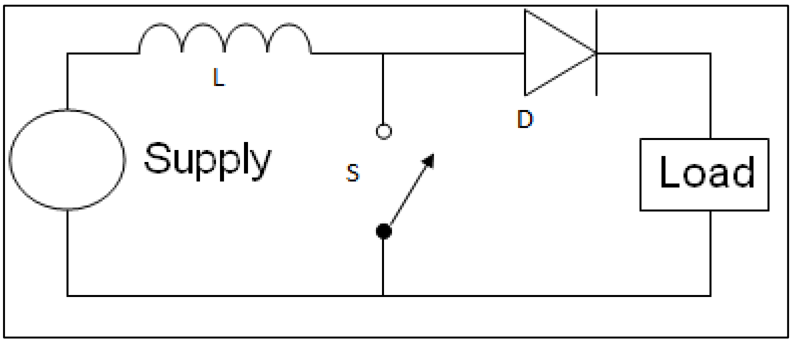

Figure 2.10 : Connection of boost converter

Its operation is generally of two separate states,

1) During the ON period, switch is made to close its contacts which results in increase of inductor current.
2) During the OFF period, switch is made to open and thus the only path for inductor current to flow through the fly-back diode ‘D’ and the parallel combination of capacitor and load. This enables capacitor to transfer energy gained by it during ON period.

In a boost regulator the output voltage is larger than the input voltage hence the name ‘boost’. A boost regulator using a power MOSFET .

2.4.3 Buck Boost converter

A buck-boost converter provides an output voltage that may be less than or greater than the input voltage hence the name buck-boost; the output voltage polarity is opposite to that of the input voltage. This converter is also known as inverting regulator. The circuit arrangement of a buck-boost converter is shown is figure 2.31.

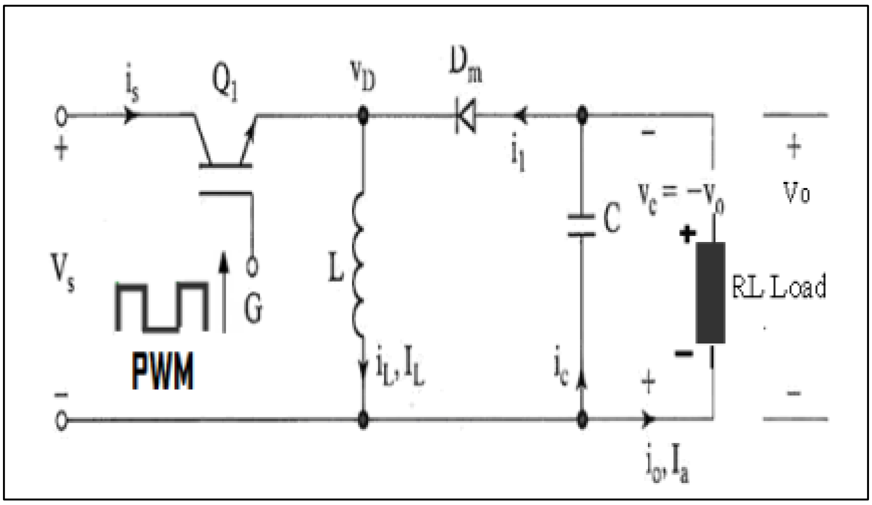

Figure 2.11 : Connection of buck boost converter circuit

The circuit operation divided into two modes. During mode 1, transistor Q1 is turned on and the diode Dm is reversed biased. The input current, which rises, flows through inductor L and transistor Q1. During mode 2, transistor Q1 is switched off and the current, which was flowing through inductor L, would flow through L, C, Dm, and the load. The energy stored in inductor L would be transferred to the load and inductor current would fall transistor Q1 is switched on again in the next cycle. The equivalent circuits for the modes are shown in figure 2.11. The waveforms for steady-state voltages and currents of the buck-boost regulator are shown in figure 2.12 for a continuous load current.

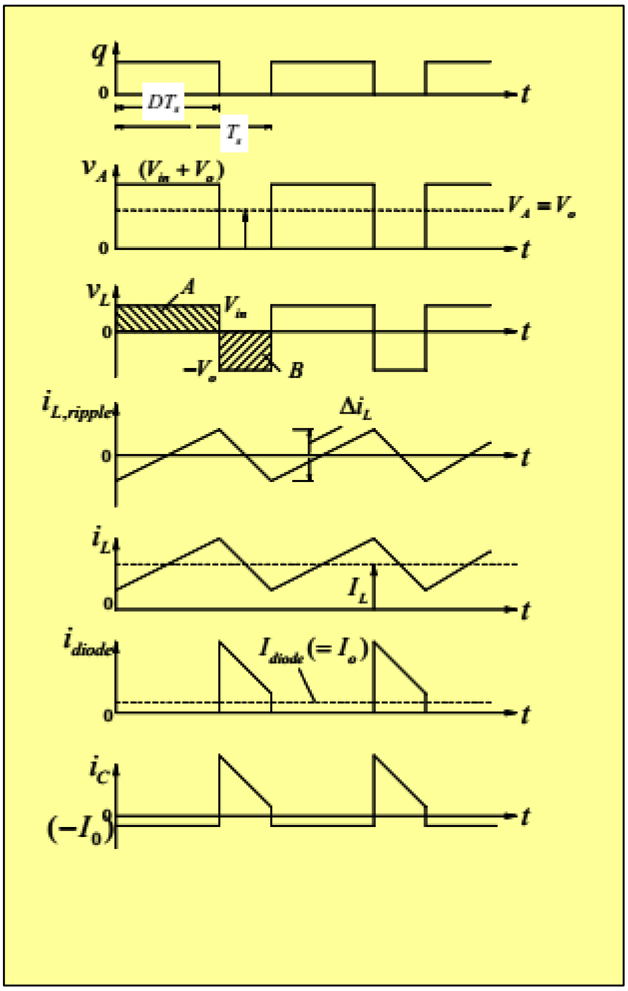

Figure 2.12 : Graph of buck boost converter

Boost mode is when the PV panel's voltage is lower than the instantaneous reference voltage, it will operate in boost mode, in which S will be switched ON and OFF with the duty cycle 0.5<K<1 which can be found from equation (1) .Buck mode is when the PV panel's voltage is higher than the instantaneous reference voltage, it will operate in buck mode, in which S will be switched ON and OFF with the duty cycle 0<K<0.5 which can be found from eq. (1). (Bhavesh Dave , 2010)

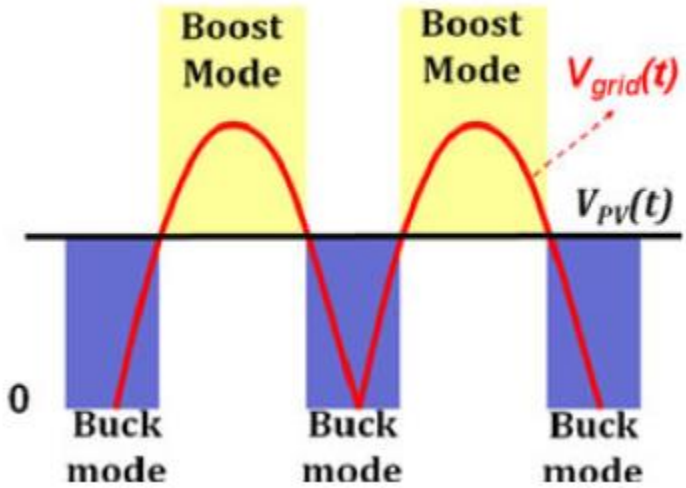

Figure 2.13 : Graph operation mode if buck boost converter

Thus, if the PV panel’s voltage is lower than the system’s peak voltage, the PV inverter will switch between buck mode and boost mode depending on the instantaneous system voltage as shown in Figure 2.12. However, if the PV panel’s voltage is higher than the system’s peak voltage, it will always run at buck mode. Instead of a dc bus in the middle, the voltage across the capacitor C in boost/buck PV inverter varies with the system, if PV panel’s voltage is lower than the System’s peak voltage as shown in Figure 2.13. However, if PV panel’s voltage is higher than system’s peak voltage, C ’s voltage will be the same as the PV panel’s voltage.

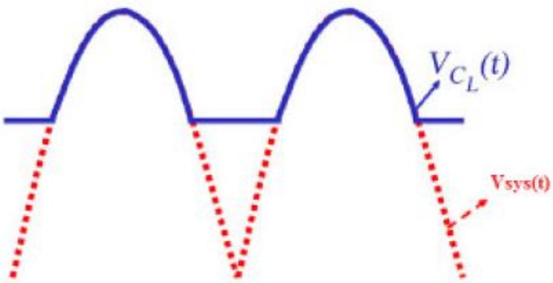

Figure 2.14 : Capacitor’s C voltage

2.5 Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328 . Arduino is a microcontroller which is simpler and can be programmed by the user. Since arduino capable to read the analog value and provide the PWM output accordingly, it is one of the compatible controllers for buck boost circuit .It has 14 digital input and output pins which 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. (T.K. Sethuramalingam and M. Karthighairasan, 2012). Besides, Arduino is also low cost controller.

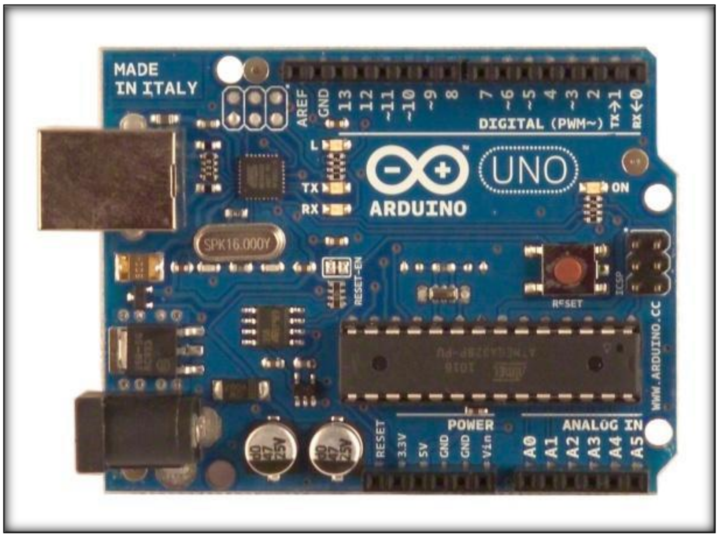

Figure 2.15 : Arduino Uno

Arduino is an open - source single board microcontroller, intended to formulate a process of exploiting electronics in multidisciplinary projects more accessible. The hardware comprises of a simple open hardware devise for the Arduino board with an Atmel processor and on-board I/O support. The software comprises of a standard programming language and also the boot loader that runs on the board.

The analog reader, which is port A0, A1, A2, A3, A4, and A5 is suitable to read the output voltage of the buck boost converter which will be functioning as a feedback control to PWM control system. The digital output port is for PWM output from arduino. It can be modified in order to have high switching frequency throughout the programming technique and fast PWM mode.

Microcontroller	Atmega328
Operating Voltage	5 Volt
Input Voltage	7-12V
Digital I/O Pins	14
Analog Input Pin	6
DC Current per I/O pin	40Ma
DC Current for 3.3V Pin	50Ma
Flash memory	32KB(Atmega328)
SRAM	2KB (Atmega328)
EEPROM	1KB (Atmega328)
Clock Speed	16Hz

Table 2.1 : Basic details of Arduino Uno

2.6 Electrical appliance as a load

There is a lot of electrical appliance that very sensitive toward inconstant input voltage. According to Mohd Faiz Bin Zamri that involve in research with title Buck-Boost Converter for Light Emitting Diode (LED) driver circuit with Arduino PMW control stated that, LED is a sensitive component towards changes of voltage. A small change of voltage will cause high amount of current changes in LED. The LED that suitable for lighting application usually has a big power dissipation compared to ordinary LED and it is called as power LED. Usually, the range of power dissipation in power LED is around 1 W to 5 W. LED is using DC power supply. (Mohd Faiz Bin Zamri, 2015)

Other than that, there is a lot of other electrical appliance that sensitive with non-constant voltage input. Figure 2.6 show the load or appliance that sensitive to voltage input. These informations gathered from electrical appliances manufacturer.

Equipment	Voltage Input Required	Power value	Current required	Image
Light Emitting Diode (LED)	3.8 Volt DC	3 Watt	0.79 A	
Compact Fluorescent Lamp (CFL)	12 volts AC	30 watt	2.5 A	
Incandescent Light Bulb	12 volts DC	60 Watt	5 A	

Table 2.2 : The Load that Sensitive to Fluctuation of Voltage Input.

METHODOLOGY

3.1 Introduction

In the introduction, the flow of the project methodology will be explained briefly. Selection of the PV solar panel is according to desired output for designing the buck-boost converter. The selection of buck-boost converter in term of the design. The process of designing buck-boost converter can be divided into two stages, which are formulation theory and simulation. In the formulation theory stages the value of capacitor, inductor and the switching frequency are determined based on finding from literature review on the equation that derived. Next in simulation stages, based on the value gathered in formulation stages, the simulation will be conduct in order to observe the characteristic of output formed by using the data from the simulation part. When the simulation gives positive result, then the hard ware can be fabricated using the data that gained from the simulation.

3.2 Selection of PV Solar Panel

The project objective which wanted to build a buck-boost converter that act as voltage regulator which use PV solar output as the voltage input of the buck-boost converter that need to be regulate. In this part, the PV Solar panel selection will focus few elements, which are first, the maximum voltage output that can be generated by the PV solar panel. This is the essential element that need to be focus on, as the output of the selected PV solar panel will be use as voltage input by the buck-boost converter. The value of the conductor, inductor and switching frequency component will be determined according to value of maximum voltage output of the PV system. Second, the maximum power that can be generated, this element concerned for the designing buck-boost circuit. Thirdly, the price and the availability of the solar panel in Malaysia market. Finally, the element that concerned is the size and the weight of the solar panel. This element is important during designing the overall project. Figure 3.1 show the table of available solar panels that meet the requirements in Malaysia market. This data gathered from company element14 Sdn Bhd which deal as trader of electrical equipment in Malaysia. The manufacturer of the solar panel is Ralos Gmbh, Camdenboss electronics and BP Solar

PV Solar Panel Model	Maximum Voltage Output	Power Rating	Price per panel	Weight	Manufacturer
SR50-36	17 V	5 W	RM 214.34	4.5 Kg	Ralos Gmbh,
MSX-005F	3.3V	500mW	RM 146.38	5.2 Kg	Camdenboss electronics
MSX-01F	7.5 V	1.2 W	RM 192.51	4.5 Kg	Camdenboss electronics
CBSPGF/100	19.3 V	100 W	RM 1382.25	7.5 Kg	BP Solar

Figure 3.1: The table of details of available solar panels in Malaysia market

Based figure 3.1, the PV solar panel that suits with this buck-boost converter project will SR50-36 manufactured by Raloss GMBH. It is because, the value of maximum voltage output is 17 V, and it easy to suit the criteria of calculating the conductor, inductor and switching frequency of the buck-boost converter to be build. Figure 3.2 shows the Standard Test Condition (STC) of the solar panel provided by manufacturer company. Based on the figure 3.2 the Voltage maximum,Vm is 17.50V. and it meet the criteria of PV solar panel Selection.

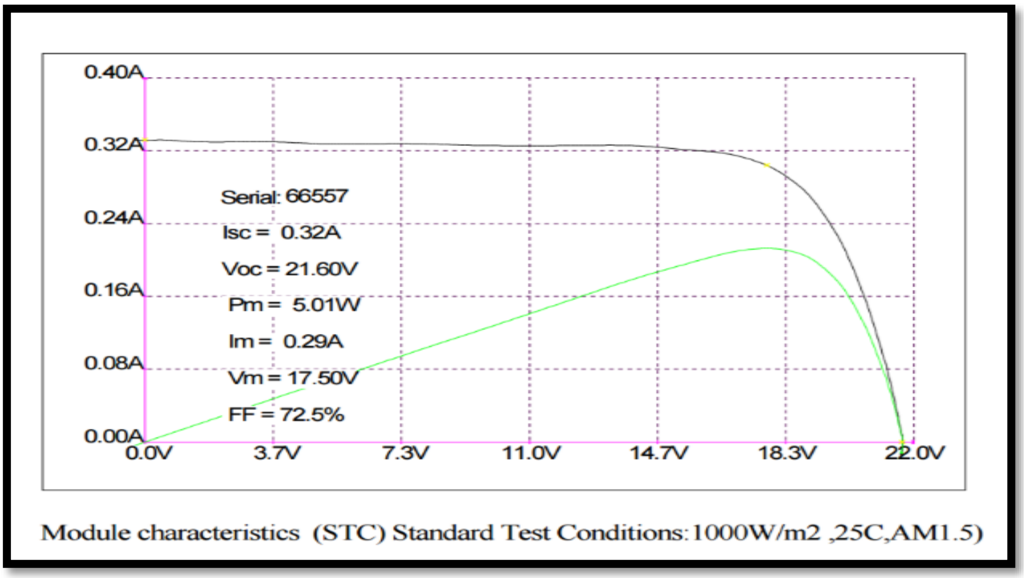

Figure 3.2: The STC result for solar panel SR50-36

3.3 Designing the buck-boost converter

In this part, will be explain more about the component selection with complete formula and simulation.

The buck boost converter consist of energy storage element which is capacitor and inductor. However, this two energy storage component should be choosen by doing calculation due to the quality of the output power. The value of capacitor and inductor will affect the ripple voltage and current respectively.

In this project, the power desired of the output is 180W for 3 incandescent light bulb connected in series, the rating voltage for one power incandescent light bulb is 12V and current for one power incandescent light bulb is 5A. Assuming 720mA and 60W for output current and output power respectively. Thus, the resistance for load that we have is

$$R = Po/ Io2 = 5\ \Omega$$

First of all, the switching duty cycle,D is determined by,

$$D=0.24$$

While for minimum inductor value, L_{min}, consider

$$L\ min = \frac{(1-D)2 \text{ x } R}{2f} = 24.06\ \mu H$$

By assuming the value of *f* which is 30khz, we can determine the value of L_{min} which is the value is **value Lmin**. The inductor value taken must be greater than minimum inductor, Lmin. Therefore, the value of inductor that has been chosen is 10uH. The voltage output ripple will be affected by capacitor. Hence, the ripple factor ,r, has to be decided in order to determine the capacitor value. The desired value of ΔVout is 5V and output voltage,Vout is equal to 12V. So, the ripple factor will be,

$$r = \frac{\Delta Vout}{Vout} = 2.4$$

With the value of ripple factor now, the value of the capacitor can be determined. The capacitor vale can be determined by using calculation which is

$$C = \frac{D}{rRf} =$$

The capacitor's value calculated from equation 3.04 is the minimum value the capacitor that can be used. The value of capacitor is 67huF since it is available at local market.

3.4 Circuit simulation using MULTISIM

The simulation are ready to run after the value of all component in the buck boost circuit was calculated by using the formula. The configuration of the circuit was shown in the Figure 3.1. The time delay is det as 0s. Means, the time rise and time fall is set for 20ns. The switching frequency is set at 30kHz, the period is 16.67Us.The value of pulse width is equal to duty cycle times with the

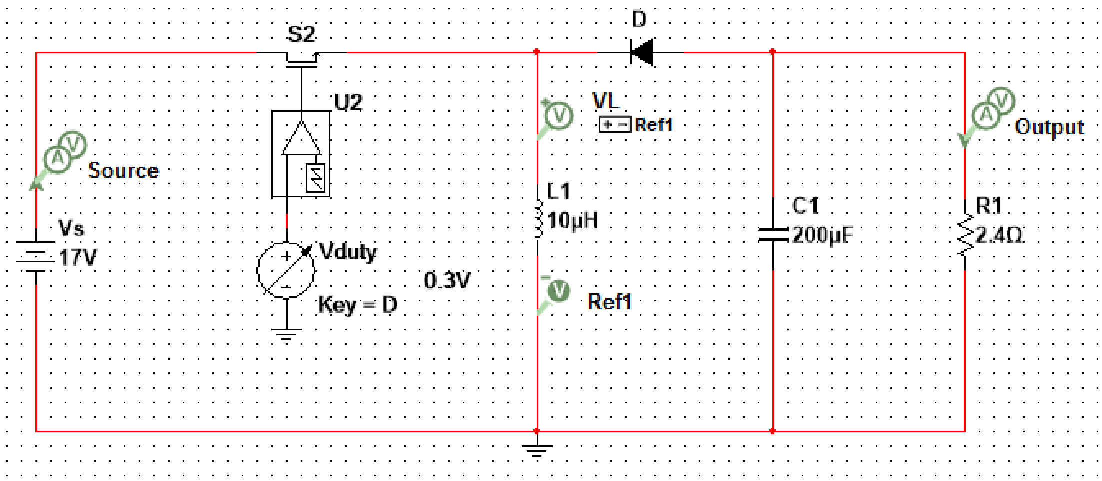

Figure 3.1 ; Circuit configurations in MULTISIM

The suitable value of the component for the hardware implementation, we can decide by doing simulation using Multisim. The specification for the hardware is shown in table below.

Component	**Value**
Capacitor	68uF
Inductor	10uF
MOSFET	IRF540N
Diode	MUR450

Table 3.1 : The value for every component

PROJECT MANAGEMENT

4.1 Budget & Cost Analysis

No	Items	Model	Quantity	Price
1	Solar Panel	Raloss, SR5-36, 17V rating	1	RM214.34
			Total	RM214.34

Table 4.1 : Energy Part Cost Analysis

No	Items	Model	Quantity	Price
1	Arduino Uno	UNO R3 ATMEGA328P	1	RM147.35
2	LCD Display(16x2)		1	RM19.08
3	Set Breadboard		1	RM50.00
4	Capacitor	470 uF	100	RM24.70
5	Resistor	Mixed Ohm	30	RM1.50
6	Inductor	0.5W Assorted colour wheel inductor kit 105 tolerance set	200	RM17.23
7	Potentiometer	100k, 50mW	3	RM15.45
8	Diode	IN4004, 400V 1A Axial Lead Silicon Rectifier Diode	25	RM16.58
9	Transistor	IRF540N N-Channel MOSFET	2	RM43.00
			Total	RM334.89

Table 4.2 : Electrical Budget Cost

No	Particular	Amounts
1	Energy Part Budget Cost	RM214.34
2	Electrical Budget Cost	RM334.89
	Total	RM549.23

Table 4.3 : Total Cost Analysis

4.2 Project Planning

4.2.1 Gantt Chart

Project Task	SENIOR DESIGN PROJECT 1 (SDP 1) WEEK														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Understanding the project scope															
Gathering information															
Clarify objectives															
Chapter 1 submission															
Learn the basic of Arduino source code writing															
Design the circuit of buck boost converter															
Slide preparation															
Presentation															
Proposal writing															
Submission of Proposal															
Submission purchasing list															

Table 4.4 : Gantt Chart

4.3 Group Interaction

Our team as well distributes work well and fairly for each other based on capabilities and learning opportunities so that everyone in the same has a role to play and learn to work together as a team. In order to coordinate well with the project advisor, the team will have weekly meeting with the advisor to ensure the project is on time, progress in correct orientation, and both sides have common understanding about the project. Open communication is encouraged in the team, anyone in the team has the right to speak up whenever an issue is occurred and needed to be resolved. Project advisor will sometimes play the role as the coordinator for open discussion. In term of authorship, there is no specific project leader elected as all team members are working under the supervision of the advisor, thus everyone has the same role to play.

CHAPTER IV

RESULT AND DISCUSSION

5.1 Introduction

In the Chapter 5 result and discussion chapter, the element that will be discussed is the result of the voltage output produced by the solar PV system with time frame, the result of buck and boost process with different input voltage and the result of buck and boost by using solar panel output voltage as the sources.

5.2 PV Solar Panel Voltage Output

The PV solar panel used it this project is 17V rating, the predicted voltage output produced from the solar panel is about 10 V-17 V with high exposure to sun radiation condition. In this project, the voltage output of the solar panel is analyse with time frame. From the solar panel used, the maximum voltage output produced recorded is 15.3 V and the lowest voltage output is 3V. The lowest output voltage recorded is when the solar panel is stored in the room with no exposure to sunlight. The voltage output recorded in this project show in table 4.1

Time	Temperature, ^{0}C	Output Voltage, V
10 am	28	12.5
11 am	27	11.6
12 pm	29	13.2
1 pm	30	15.3
2 pm	28	14.2

Table 5.1 the solar panel voltage output recorded with time frame

Based on the data, it can show that the peak temperature of the day is between 12 pm- 1 pm. The solar output voltage show an increment as the temperature is peak. The voltage output is fluctuate within time. Figure 5.1 show the PV solar panel is tested.

Figure 5.1 : The testing of PV solar panel output

5.3 The buck-boost converter for different input voltage

The purpose of this part is to evaluate the performance of the buck-boost converter circuit in performing buck and boost processes, the desired output from the buck boost converter is 12V. There are 3 different input voltage used in this experiment, which are 9 V, 12 V, 17.2 V. The objective is to obtained the desired output voltage which is 12 V. The output voltage will be measured using voltage multimeter

The first voltage input use is 9 V, the process that involve in obtaining the desired output is boost process. The output result from the buck-boost converter recorded is 11.90 V and the duty cycle is 57.2%. Figure 5.2 show the reading of output voltage by the buck-boost converter and the duty cycle recorded.

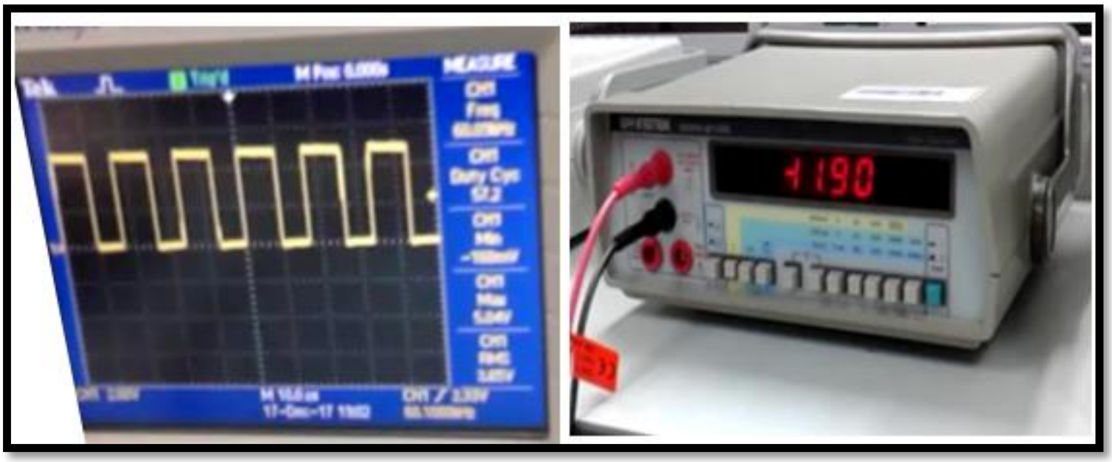

Figure 5.2 : The reading of output voltage by the buck-boost converter and the duty cycle for 9 V

The second voltage input use is 12 V, as the input voltage is equal with desired output voltage, the test is to evaluate the effect of buck boost converter to voltage output recorded. The output result from the buck-boost converter recorded is 11.60 V and the duty cycle is 50.1%. Figure 5.3 show the reading of output voltage by the buck-boost converter and the duty cycle recorded.

Figure 5.3 : The reading of output voltage by the buck-boost converter and the duty cycle for 12V

The third voltage input use is 17.2 V, the process that involve in obtaining the desired output is buck process. The output result from the buck-boost converter recorded is 14.07 V and the duty cycle is 40.6%. Figure 5.3 show the reading of output voltage by the buck-boost converter and the duty cycle recorded.

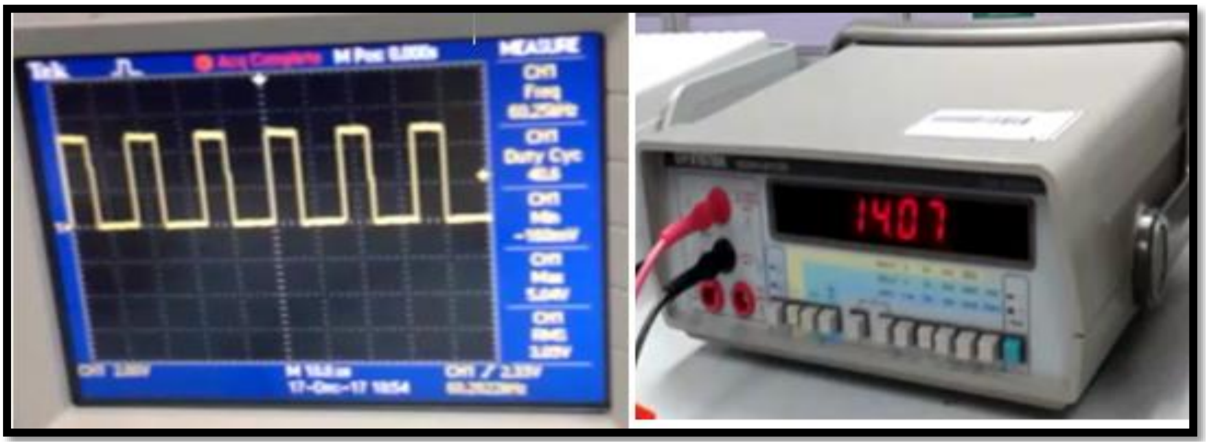

Figure 5.4 : The reading of output voltage by the buck-boost converter and the duty cycle for 17.2V

5.4 The buck-boost converter connected to PV solar Panel

The voltage output generated by the PV solar panel will be connected to the buck-boost converter as its voltage input. Basically, the buck-boost converter will experience either buck or boost process as to meet the desired output. the duty cycle of the process is self-determined by the circuit. The output result from the buck-boost converter recorded is 0.11 V. Figure 5.5 show the reading of output voltage by the buck-boost converter.

Figure 5.4 : The reading of output voltage by the buck-boost converter connected to PV solar system

5.5 Discussion

Referring to chapter 4.2 the voltage output generated by the PV solar panel with time framed. It shows that, the voltage output generated does changing overtime. It is because of the solar radiation received by the solar panel, and it is influenced by the weather condition at that specific time. Basically in Malaysia, the amount of radiation of sunlight received is high as it located near the equator. However the cloud formation that influenced by the natural land structure can limit the amount of solar radiation received, compared to places located in Siberian and Mediterranean dessert. The amount of solar radiation received is very high as the amount of cloud formed is low.

Based on table 5.1, it shows that as the temperature high the Voltage output generated by the PV solar system is high, and the temperature peak is at 29-30 ^{0}C at time 12 pm – 1 pm, the voltage output generated is about 15 V. While the lowest output generated by the solar panel is 11.6 V approximately at 11 am with temperature of 27^{0}C. The reason of this fluctuation situation happen is because, the location of the sunlight or can be interpret as the angle of the sunlight to the solar panel plate is different within time. During the peak, the angle of the sunlight can be considered as almost 90^0 to the solar panel plate and at 11 am the angle of the sunlight is either lower or higher to the solar panel plate. This situation effect the amount of solar radiation received and also voltage output generated by the PV solar system. It is the one of the main reason, the fluctuation of voltage output of the solar panel.

Referring to the chapter 5.3 the buck-boost converter for different input voltage, based on the result shows that the buck-boost converter able to perform boost process. When the input voltage of 9 V is connected to the buck-boost circuit the output voltage obtained is 11.90 and it is almost 12 V as the desired result. However when the input voltage is increase to 17.2 V the voltage output obtained is 14.7 V. Based on the result, it indicates that the buck process is performed, as the input voltage is reduced to 14.7 V from 17.2 V. However it not meet the desired output which is 12 V. The problem may come from the duty cycle of the circuit. It is because the role of duty cycle of the transistor is controlling the voltage output. Referring to chapter 5.4, the buck-boost converter connected to PV solar system. The result shows that the buck booster converter is not performing the role to boost the input voltage to desired output. It once again indicate that the duty cycle of the buck-boost circuit is set correctly in order to perform buck or boost processes.

CHAPTER VI

CONCLUSION AND RECOMENDATION

6.1 Conclusion

In this project, the buck-boost converter circuit is managed to be built, and it able to perform boost process of voltage input to desired output voltage. However the buck-boost converter is unable to perform buck process as the duty cycle of the transistor is not determined and controlled well. It same goes when the buck boost converter is connected to the PV solar module. The buck-boost converter unable to regulate the voltage to desired output. The simulation of the buck-boost converter is made. And it is compared to the actual buck-boost circuit.

6.2 Recommendation

The main concerned of this project is to regulate the output voltage of the solar PV system. In order to perform this process the buck-boost converter need to control the output by regulate the duty cycle of the transistor by using arduino microcontroller. The arduino microcontroller must be control by installing the instruction using the coding. As for recommendation, the proper coding of the microcontroller is very important in instructing the buck-boost converter to control its duty cycle in order to achieve the desired output and it is need to be improved. Other than that, usually for the commercial use of the PV solar system, the solar panel output is used to charge the battery. The battery output then use for other electrical appliances. Thus, for recommendation the output of the PV solar system need to be regulated by buck-boost converter before used to charge the battery. The reason of people using solar panel is power up electrical appliances and One of the main element in powering up an electrical appliances is current, A. The output current of PV solar system can be 0 at certain time, thus the point of using PV solar system is mislead. It need storage to store the current made by the solar panel, because of that the buck-boost converter need to be use in charging the battery before being use to power up any electrical appliances.

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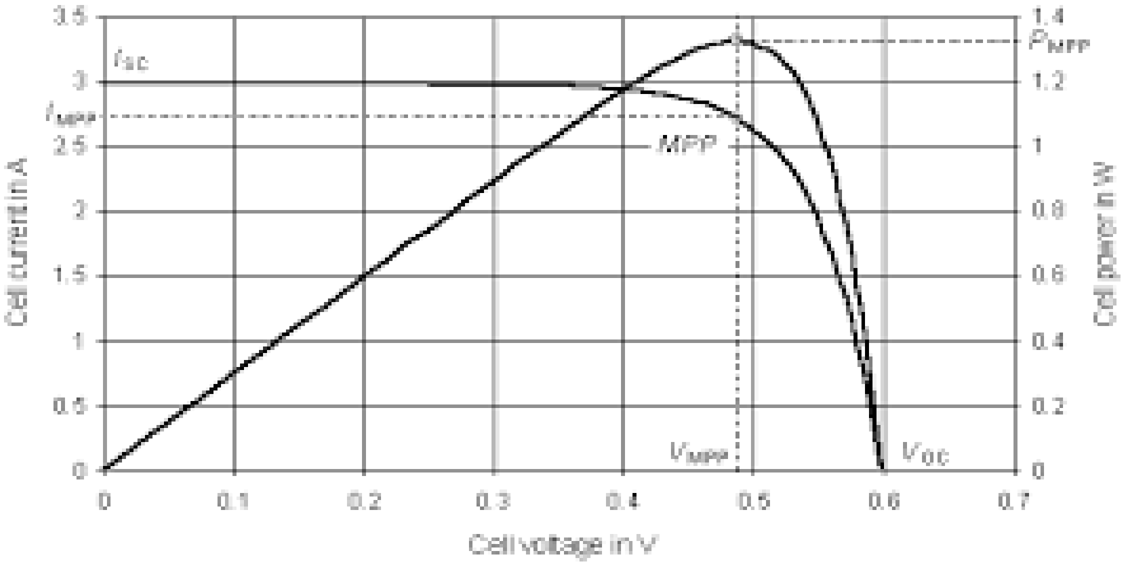
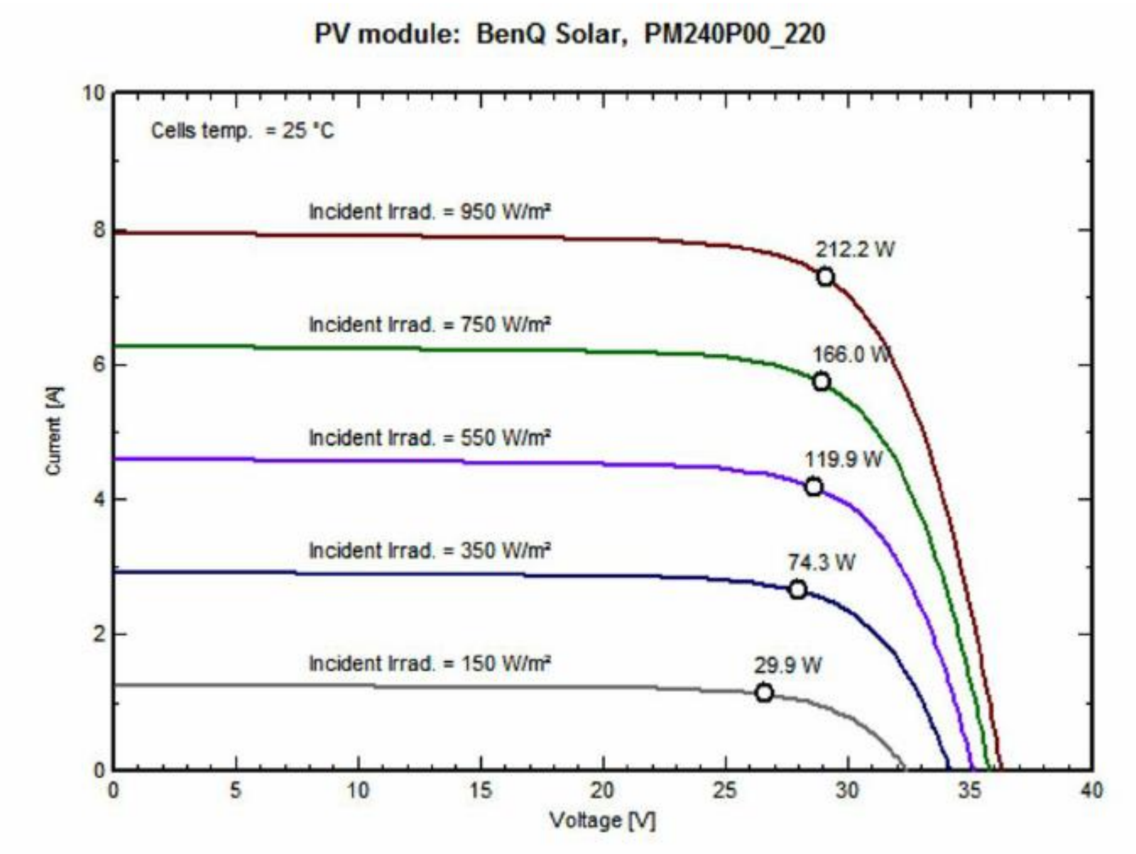
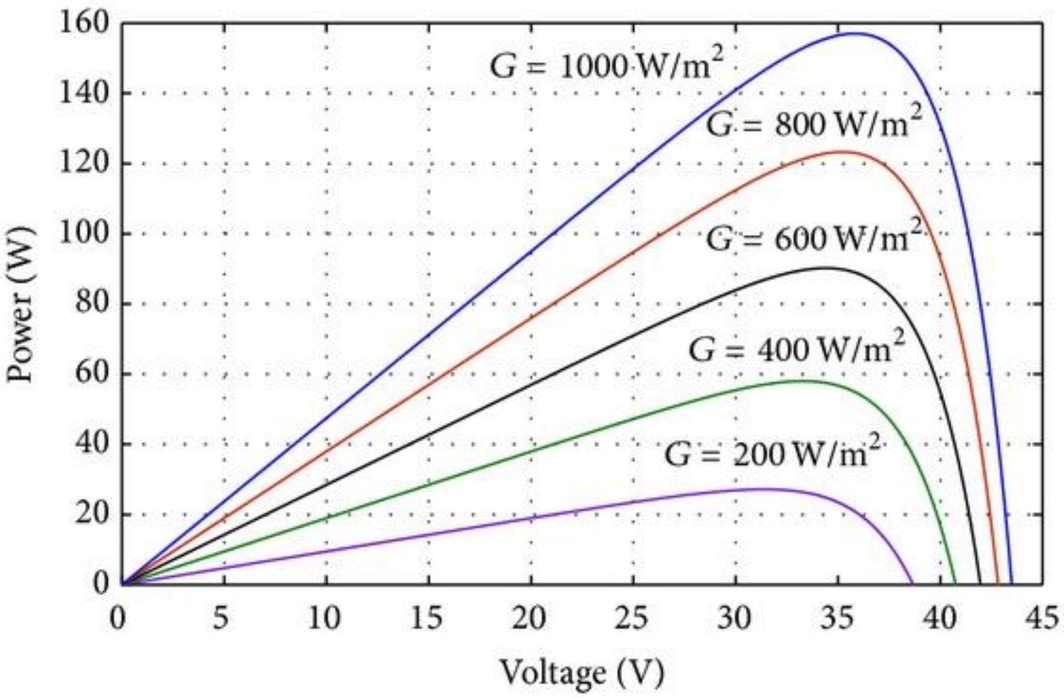
Appendix A

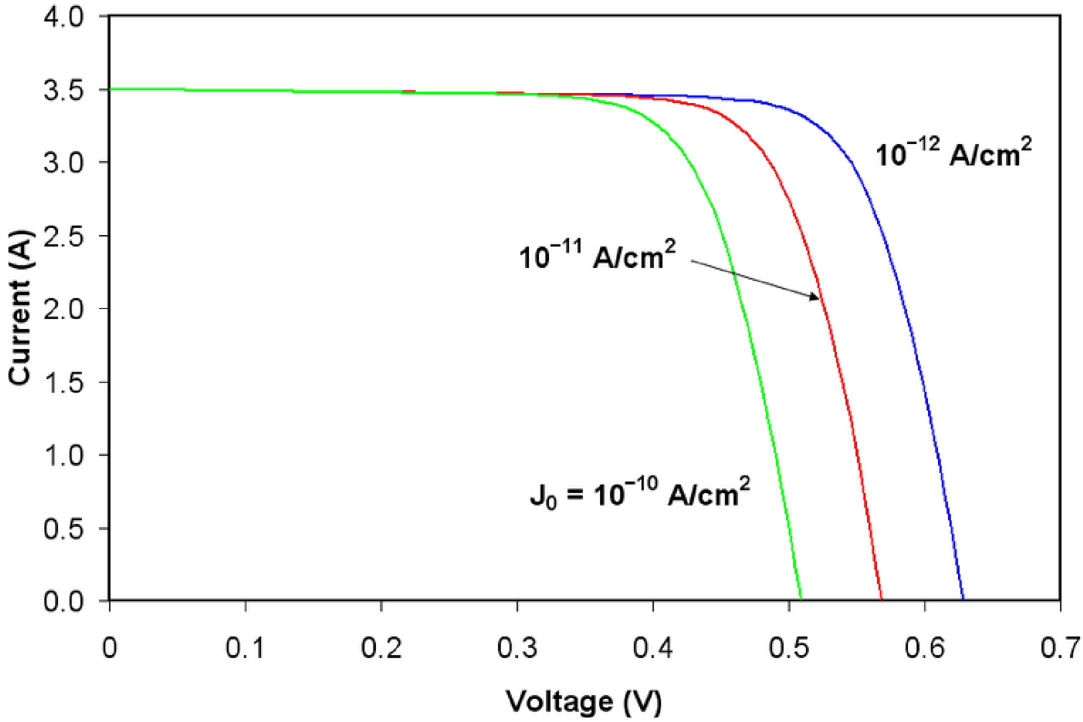
Major Solar PV Module Test Conditions Comparison

Testing Condition	Abbreviation	Irradiance (W/m²)	Module Temperature (°C)	Ambient Temperatue (°C	Air Mass (AM)	Wind Speed (m/s)	Module tilt angle (°C)
High Temperature Conditions	HTC	1000	75	/	1.5	0	/
Low Irradiance Conditions	LIC	200	25	/	1.5	0	/
Low Temperature Conditions	LTC	500	15	/	1.5	0	/
Normal Operating Cell Temperature	NOCT	800	/	20	1.5	1	45
PV-USA Test Conditions	PTC	1000	/	20	1.5	1	/
Standard Test Conditions	STC	1000	25	/	1.5	0	/




PV module: BenQ Solar, PM240P00_220
Cells temp. = 25 °C
Incident Irrad. = 950 W/m²
212.2 W
Incident Irrad. = 750 W/m²
166.0 W
Incident Irrad. = 550 W/m²
119.9 W
Incident Irrad. = 350 W/m²
74.3 W
Incident Irrad. = 150 W/m²
29.9 W
Current [A]
Voltage [V]


G = 1000 W/m²
G = 800 W/m²
G = 600 W/m²
G = 400 W/m²
G = 200 W/m²
Power (W)
Voltage (V)



4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Current (A)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Voltage (V)
10^-12 A/cm^2
10^-11 A/cm^2
J0 = 10^-10 A/cm^2

APPENDIX B

3mm LEDs

Optical and Electronic Characteristics								Max Continuous	Preferred Value Series Resistor (ohms) for		
Size (mm)	Viewing Angle (Degrees)	Colour	Lens	Wavelength, Chromatic (nm), Co-ordinates	IF Typical (mA)	VF Typical (V)	IV Typical (mcd)	IF Max (mA)	5VDC	9VDC	12VDC
3	45	Red	Diffused	650	15	2.3	40	15	180	470	680
3	15	Red	Waterclear	660	20	1.8	1500	30	160	360	510
3	20	Red	Waterclear	625	20	2.0	2100	50	150	360	510
3	15	Red	Waterclear	625	20	2.1	7000	30	150	360	510
3	45	Orange	Diffused	625	20	1.9	35	30	160	360	510
3	50	Yellow	Diffused	585	20	2.1	10	20	150	360	510
3	20	Yellow	Waterclear	588	20	2.0	3000	50	150	360	510
3	15	Yellow	Waterclear	588	20	2.2	6500	50	150	360	510
3	50	Green	Diffused	573	20	2.3	40	20	130	330	470
3	20	Green	Waterclear	568	20	2.1	500	30	150	360	510
3	20	Green	Waterclear	520	20	3.2	6000	20	91	300	470
3	15	Aqua	Waterclear	505	20	3.5	4000	30	75	270	430
3	15	Blue	Waterclear	465	20	3.3	1500	20	82	300	430
3	15	Blue	Waterclear	470	20	3.2	3700	30	91	300	430
3	15	White	Waterclear	0.31/0.32	20	3.2	1000	20	91	300	430
3	20	White	Waterclear	0.31/0.32	20	3.2	5000	30	91	300	430
3	15	White	Waterclear	0.31/0.32*	25	3.4	12000	25	62	220	360

	Hollywood Lights	Feit Workshop Light	Cree LS Series	Cree TW series T8 LED	Philips InstantFit	Hyperikon	T8 fluorescent
Type of light	Retrofit	Shop light	Integral lamp fixture	Replacement	Replacement	Retrofit	T8 ballasted fixture
CCT	3700K	4100K	3500K, 4000K, 5000K	2700K, 4000K	3000-5000K	4000K	3500K
CRI	90-92	83	92	91 (2700K model)	83	85	78
Lumens	1900 lm	3700 lm	4000 lm	1700 lm	1500 lm	1980 lm	2470 lm
Watts	19W	38W	44W	25W	14.5 W	18W	32W
Efficacy	100 lm/W	97 lm/W	91 lm/W	68 lm/W	103 lm/W	110 lm/W	77 lm/W
Power factor	0.97	0.98	N/A	N/A	N/A	0.95	N/A
Warranty	3-yr unlimited	5-yr	10-yr limited	5-yr	4-yr	5-yr	N/A
Claimed lifetime	75,000 hrs	50,000 hrs	50,000 hrs	50.000 hrs	50,000 hrs	45,000 hrs	24,000 hrs
Dimmable?	Yes: Triac	No	Yes: 0-10V	Yes: Ballast dimming	No	No	N/A
Price	$27	$32	$127	$22	$25	$19	$3

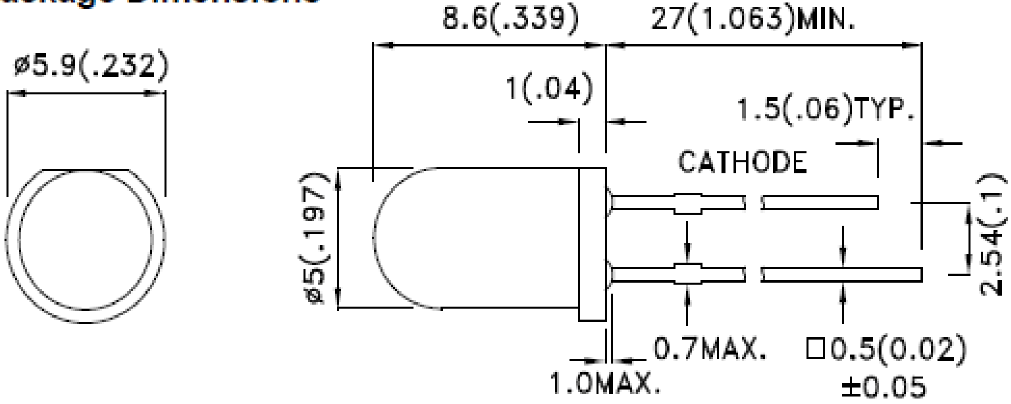
ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	**TEST CONDITION**	**SYMBOL**	**VALUE**	**UNIT**
Reverse voltage		V_R	5	V
Forward current		I_F	100	mA
Peak forward current	t_p/T = 0.5, t_p = 100 µs	I_{FM}	200	mA
Surge forward current	t_p = 100 µs	I_{FSM}	1.5	A
Power dissipation		P_V	160	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	- 40 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	t ≤ 5 s, 2 mm from case	T_{sd}	260	°C
Thermal resistance junction/ambient	J-STD-051, leads 7 mm soldered on PCB	R_{thJA}	230	K/W

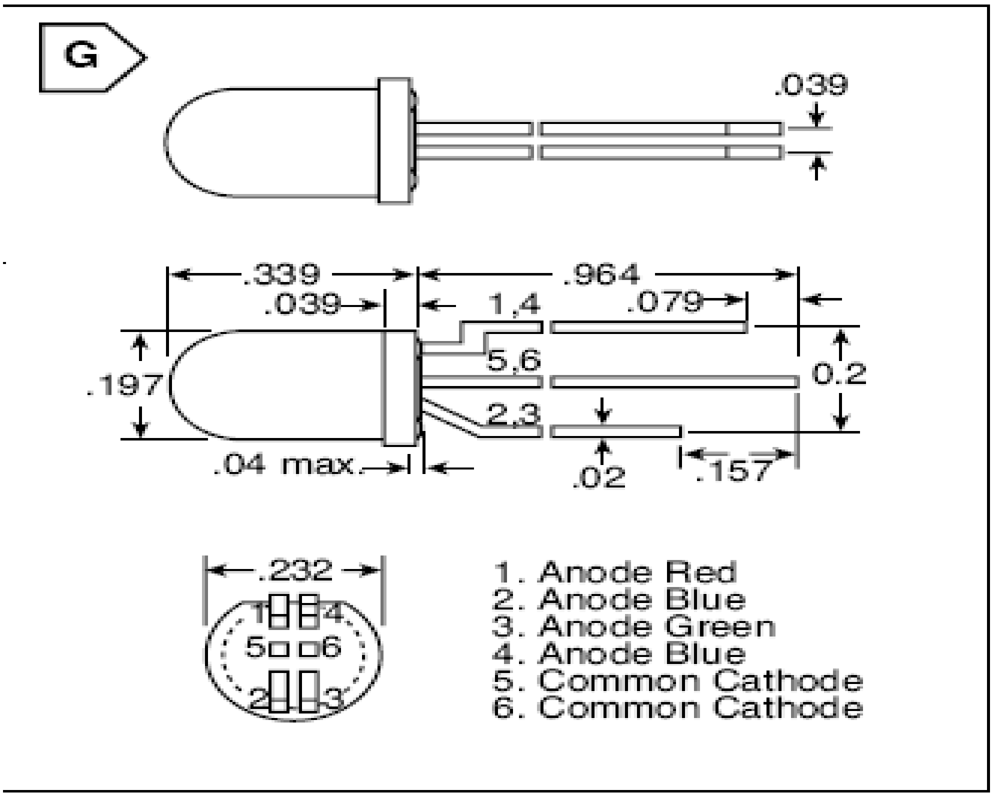
Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λpeak	Peak Wavelength	Super Bright Red	660		nm	I_F=20mA
λD [1]	Dominant Wavelength	Super Bright Red	640		nm	I_F=20mA
Δλ1/2	Spectral Line Half-width	Super Bright Red	20		nm	I_F=20mA
C	Capacitance	Super Bright Red	45		pF	V_F=0V;f=1MHz
V_F [2]	Forward Voltage	Super Bright Red	1.85	2.5	V	I_F=20mA
I_R	Reverse Current	Super Bright Red		10	uA	V_R = 5V

Notes:
1.Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.

Package Dimensions





APPENDIX C

SPECIFICATIONS:

ITEM	SPECIFICATION	LSVF5006SU64X	LSVF5006SU96X
GENERAL PERFOMANCE	Spacing Criteria	Available upon request	Available upon request
	Initial Lumens (using F32T8/800)	6400	9,600
	Efficiency (using F32T8/800)	67%	61%
	Number of Lamps (not Incl.)	2 X F32T8	3 X F32T8
ELECTRICAL	Ballast Type	Instant start electronic	Instant start electronic
	Ballast Factor	1.18	1.15
	Maximum THD	<= 13%	<= 13%
	Input Voltage	120-277V	120-277V
	Power Consumption (System Wattage)	74W	111W
PHYSICAL	Dimensions (L x W x H)	50" x 6" x 3.75"	50" x 6" x 3.75"
	Weight	8 lbs.	8.5 lbs.
	Housing	Glass-reinforced polyester	Glass-reinforced polyester
	Lens	Ribbed polycarbonate clear	Ribbed polycarbonate clear
	Mounting	Ceiling surface mount or wall mounted	Ceiling surface mount or wall mounted
	Operating Temperature	0°F to 104°F	0°F to 104°F
CERTIFICATION	Certification	cETLus,, FCC, LM79	cETLus,, FCC, LM79
	Material Usage	RoHS compliant, no mercury	RoHS compliant, no mercury
	Environment	Indoor / outdoor covered – wet, IP66	Indoor / outdoor covered – wet, IP66
	Warranty	1 year material and workmanship 3 years on ballasts	1 year material and workmanship 3 years on ballasts

Absolute Maximum Ratings (Ta = 25℃)

Items	Symbol	Absolute Maximum Rating	Unit
Forward Current	IF	0.7	A
Peak Forward Current*	IFP	0.8	A
Reverse Voltage	VR	5	V
Power Dissipation	PD	3	W
Electrostatic discharge	ESD	±2000	V
Operation Temperature	TOPR	-40~+80	℃
Storage Temperature	TSTG	-40~+100	℃
Lead Soldering Temperature*	TSOL	Max. 260℃ for 3sec Max.	

Advantages of LEDs

Feature	Light Emitting Diodes (LEDs)	Incandescent Light Bulbs	Compact Fluorescents (CFLs)
Life Span (Hours)	Typically above 50,000	1,000 – 2,000	8,000 – 10,000
Wattage (equivalent to 60 W Incandescent Bulb)	6 – 8 W	60 W	13 – 15 W
Temperature Sensitivity	None	Yes, Somewhat	Yes
Sensitive to humidity	No	Yes, Somewhat	Yes
Switching On/off Quickly	No Effect	Yes, Somewhat	Yes - lifespan can reduce drastically
Turns on instantly	Yes	Yes	No - takes time to warm up
Durability	Durable - Can handle jarring and bumping	glass or filament are fragile	glass can break easily
Toxic Mercury	No	No	Yes

Westinghouse

Specification Sheet

Professional Series PAR20 Dimmable LED Lamp

Item Number **03431**

Specifications

Energy Used (Watts)	8
Incandescent Equivalent Wattage	40
Domestic Code	8PAR20/LED/DIM/50
Volts	120
Brightness (Lumens)	410
Average Rated Hours	30,000
Life (in years)*	27.4
Beam Spread	25°
Light Appearance (Kelvin)	5000
CRI	80
CIE Chromacity	x.346,y.359
Efficacy (LPW)	48
PF	≥.7
Minimum Starting Temperature	-20°C/-4°F
Estimated Yearly Energy Cost**	$0.96
Country of Origin	China

Physical Characteristics

Finish	Cool White
Housing Material	Aluminum
Base	Medium
MOL	3 7/16"
MOD	2 5/8"

c UL us LISTED FC RoHS COMPLIANT 2002/95/EC DAMP

Limited Warranty

This lamp is warranted to be free from defects in material and workmanship for 3 years (based on using 3 hours per day). If the product fails during the warranty period, return defective product to retailer. Warranty terms and conditions of retailer apply. If replacement product is not available at retail store, please return product, original package and receipt to manufacturer at: 12401 McNulty Road, Philadelphia, PA 19154-1029.

Warning

- Turn power off before inspection, installation, or removal.
- Risk of electric shock - Do not use where exposed to water or weather.
- Suitable for Damp Locations - The lamp is suitable for use in wet locations when used in an outdoor rated fixture.
- Not for use in totally enclosed fixtures.
- Do not open – no user serviceable parts inside.
- This device is not intended for use with emergency exit fixtures or emergency exit lights
- This device complies with Part 15 of the FCC rules and has been tested and found to comply with the limits for a Class B digital device. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. Any changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

* Based on 3 hrs./day
** Based on 3 hrs./day 11¢/k/Wh - Cost depends on rates and use.

See reverse side for dimmer compatibility

SPECIFICATION SHEET

Omni-Directional LED Lamp

Item Number 03440

Specifications

Energy Used (Watts)	9
Incandescent Equivalent Wattage	60
Domestic Code	9OMNI/LED/30
Volts	120
Brightness (Lumens)	800
Average Rated Hours	40,000
Life (in years)*	36.5
Light Appearance (Kelvin)	3000
Beam Spread	220°
CRI	80
CIE Chromaticity	x.438, y.403
Efficacy (LPW)	89
PF	≥.7
Number of LED Modules	27
Minimum Starting Temperature	-20°C/-4°F
Estimated Yearly Energy Cost**	$1.08
Package Type	Card
Country of Origin	China

Physical Characteristics

Finish	Warm White
Housing Material	Plastic
Base	Medium
MOL	4.33"

Limited Warranty

This lamp is warranted to be free from defects in material and workmanship for 3 years (based on using 3 hours per day). If the product fails during the warranty period, return defective product to retailer. Warranty terms and conditions of retailer apply. If replacement product is not available at retail store, please return product, original package and receipt to manufacturer at: 12401 McNulty Road, Philadelphia, PA 19154-1029.

Warning

- Turn power off before inspection, installation, or removal.
- Risk of electric shock - Do not use where exposed to water or weather.
- Not for use in totally enclosed luminaires.
- Do not open – no user serviceable parts inside.
- This device is not intended for use with emergency exit luminaires or emergency exit lights.
- This device complies with Part 15 of the FCC rules and has been tested and found to comply with the limits for a Class B digital device. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. Any changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

* Based on 3 hrs./day
** Based on 3 hrs./day 11¢/kWh - Cost depends on rates and use.

Specifications are subject to change without notice, please visit www.westinghouselighting.com for latest information.

Call 1-800-999-2226 or visit www.westinghouselighting.com.

A Licensee of Westinghouse Electric Corporation

12w LED BULB SPECIFICATION

Product Name: LED BULB

Material: plastics +Glass

Color: White/warm white

Base: E27

Frequency: 50/60HZ

Input Voltage： AC100V-240V

Working Temperature： 14° - 140°

Lens Angles: 360°

LED Quantity: SMD 12W

Led driver current: 300MA

LED consumption: 12W

Power efficiency: >75%

Power factor (PF): >0.7

LED color index (CRI): Ra > 75

Projection Distance: 2-4M

Luminous flux：1080LM

Average lifetime: 20,000hrs

Gross Weight: 0.3KG

Certification: CE and ROHS and FCC

Products Warranty: See Website

Advantages:

1、Energy-saving 2、Environmental-protection 3、Long-life 4、less heat energy 5、Easily-install

LEDLight.com

23w LED BULB SPECIFICATION

Product Name: LED BULB

Material: plastics +Glass

Color: White/warm white

Base:E27

Frequency: 50/60HZ

Input Voltage: AC100V-240V

Working Temperature: 14°F - 140°F

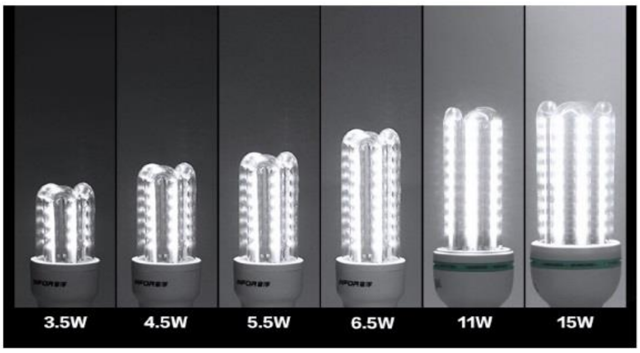
Lens Angles: 360°

LED Quantity: SMD 23W

Led driver current: 300MA

LED consumption: 23W

Power efficiency: >85%



Power factor (PF): >0.8

LED color index (CRI): Ra > 75

Projection Distance:3-6M

Luminous flux: 2000LM

Average lifetime: 20,000hrs

Certification: CE and ROHS and FCC

Products Warranty: See Website

Advantages:

1、 Energy-saving 2、Environmental-protection 3、Long-life 4、less heat energy 5、Easily-install

LEDLight.com

APPENDIX D

Maximum power (Pmax)	230W
Maximum power voltage (Vpm)	29.49 V
Maximum power current (Ipm)	7.80 A
Open circuit voltage (Voc)	37.20 V
Short circuit current (Isc)	8.39 A
Module efficiency (ηm)	14.3%
No. & type solar cells	60 in series/ 6"(156x156 mm) multicry
Maximum system voltage	TUV:DC 1000 V/UL:DC 600 V
Series fuse rating	15 A
Performance tolerance	±3%
Operating temperature	-40 to +90 ℃
Storage temperature	-40 to +90 ℃
Dimensions	1626 x 990 x 50 mm / 64 x 39 x 1.96 in
Weight	20.0 kg/44.09 lbs
Output Terminal(Tyco J-Box)	1394462-4(-)/6-1394461-2(+)

PCB Size	Operating Voltage	Operating Current	Power range	Material
35×35mm	0.5V-4V	30mA -200 mA	0.01W -0.1W	Mono/Poly
48×56mm	0.5V-5V	30mA -300 mA	0.015W-0.15W	Mono/Poly
49×59mm	0.5V-6V	30mA -400 mA	0.015W-0.15W	Mono/Poly
50×33mm	0.5V-4V	30mA -300 mA	0.01W-0.15W	Mono/Poly
53×22mm	0.5V-1V	30mA -250 mA	0.01W-0.13W	Mono/Poly
53×18mm	0.5V-2V	30mA -200 mA	0.01W-0.1W	Mono/Poly
53×19mm	0.5V-2V	30mA -200 mA	0.01W-0.1W	Mono/Poly
54.5×21.5mm	0.5V-2V	30mA -200 mA	0.01W-0.1W	Mono/Poly
54×54mm	0.5V-4V	30mA -600 mA	0.01W-0.3W	Mono/Poly
54×19mm	0.5V-2V	30mA -300 mA	0.01W-0.15W	Mono/Poly
37×64mm	0.5V-6V	30mA -500 mA	0.01W-0.25W	Mono/Poly
55×27mm	0.5V-4V	30mA -300 mA	0.01W-0.16W	Mono/Poly
150×33mm	0.5V-3V	30mA -700 mA	0.01W-0.35W	Mono/Poly
55×35mm	0.5V-2V	30mA -400 mA	0.01W-0.2W	Mono/Poly
50×55mm	0.5V-4V	30mA -500 mA	0.01W-0.32W	Mono/Poly
55×55mm	0.5V-4V	30mA -550 mA	0.01W-0.32W	Mono/Poly
47×65mm	0.5V-5V	30mA -600 mA	0.01W-0.3W	Mono/Poly
45×64mm	0.5V-5V	30mA -600 mA	0.01W-0.3W	Mono/Poly
60×60mm	0.5V-6V	30mA -700 mA	0.01W-0.35W	Mono/Poly
60×30mm	0.5V-2.5	30mA -300 mA	0.01W-0.175W	Mono/Poly
85×50mm	1V-6V	30mA -1000 mA	0.02W-0.5W	Mono/Poly
85×70mm	1V-9V	40mA -1200 mA	0.04W-0.6W	Mono/Poly
75×75mm	1V-6V	40mA -400 mA	0.04W-0.5W	Mono/Poly

Electrical Characteristics		
Maximum Power (Pmax)	170W	Watt
Power Tolerance	±5	%
Maximum Power Voltage (Vmp)	35.0	Volt
Maximum Power Current (Imp)	4.86	Ampere
Open circuit Voltage (Voc)	44.0	Volt
Short circuit Current (Isc)	5.36	Ampere
Maximum System Voltage	600V(U.S. & IEC 61215 rating) 750V (TüV Rheinland rating)	
Module Efficiency (η m)	13.3	%
Temp. coefficient Voc	-0.35±0.02	%/°C
Temp. coefficient Isc	+0.04±0.0015	%/°C
Temp. coefficient Power	-0.5±0.05	%/°C
Nominal operating cell temperature (NOCT)	47°C±2°C	°C

Cells		
Brand Name of Solar Cells	Sun-Earth	
Cell Type	Single Crystal Cell	
Cell Size	125*125	mm
Cell Shape	Quasi Square	
Number Cells	72	in series
Encapsulated Solar Cells Efficiency (η c)	15.9	%

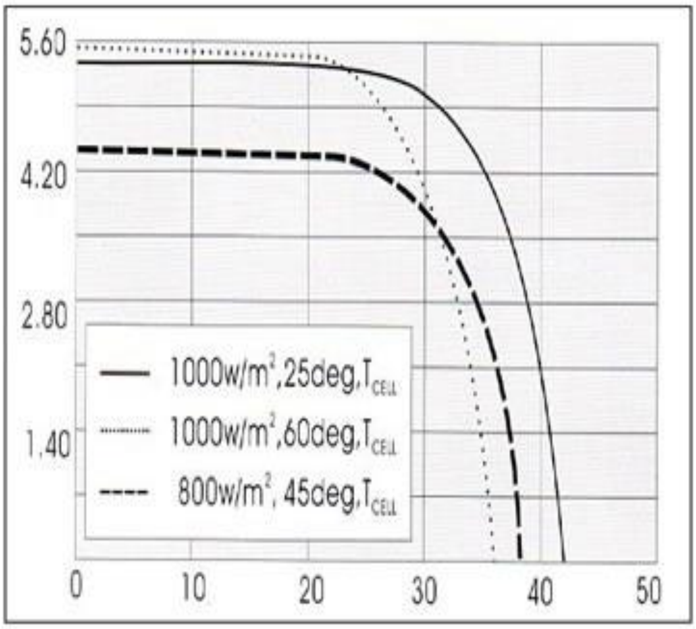
Standard Test Conditions	
AM	1.5
Irradiation	1000 W/m2
Tc	25 °C

Mechanical Characteristics			
Dimensions	Lenght (mm)	1580	mm
	Width (mm)	808	mm
	Depth (mm)	46	mm
Installation Dimensions	Lenght (mm)	1176	mm
	Width (mm)	737	mm
Weight(kg)		16	Kg
Frame structure (Material, Corners)		Aluminium	
Front side		Glass	
Front glass thickness		3.2	mm
Encapsulant		EVA	
Back side		TPT	
Junction Box		Sun-Earth	

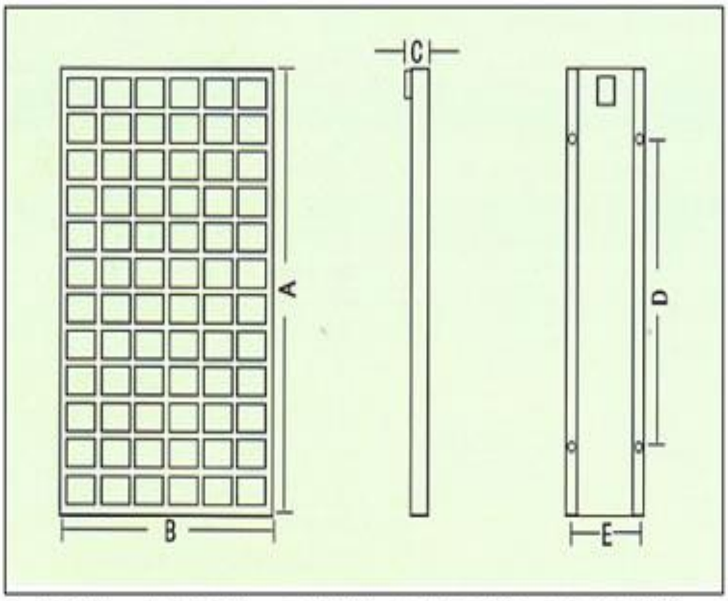
Packing/ Transport Information		
Packing configuration	10	pcs per carton
Size of Carton	1630*550*900	mm
Weight of Carton	9	Kg
Cartons per 20' container	24(x 10pcs)	cartons (x modules)
Cartons per 40' container	56(x 10pcs)	cartons (x modules)

Absolute Maximum Ratings		
Operating Temperature	-40℃～+90℃	°C
Storage Temperature	-40℃～+90℃	°C
Dielectric Isolation Voltage	1000	VDC max 1000V
Maximum Wind Resistance	60m/s	N/m2 or max Km/h
Maximum Load Capacity	200	Kg/m2
Maximum Hail diameter @ 80Km/h	25mm	@ 80Km/h

Current-Voltage Curves



Module Drawing with measures



A: 1580MM B: 808MM C:46MM D:1176±2MM E：737±2MM

BISOL BMU/214-245

BISOL

Multicrystalline Silicon Photovoltaic Modules

EU Made in Europe

Module presorting for a more profitable investment

10 10-year product warranty

+6W Strictly positive power output tolerances

Electrical Specifications @ STC (AM1.5, 1,000 W/m², 25° C):

Module Type		BMU/214	BMU/224	BMU/227	BMU/233	BMU/239	BMU/245
Maximum Power	P_{MPP} [W]	214	224	227	233	239	245
Short Circuit Current	I_{SC} [A]	8.15	8.30	8.35	8.45	8.56	8.65
Open Circuit Voltage	V_{OC} [V]	36.4	37.0	37.1	37.5	37.8	38.1
MPP Current	I_{MPP} [A]	7.50	7.70	7.80	7.90	8.00	8.15
MPP Voltage	V_{MPP} [V]	28.5	29.0	29.2	29.5	29.8	30.2
Solar Cell Efficiency	η_C [%]	14.7	15.3	15.5	16.0	16.4	16.8
Module Efficiency	η_M [%]	13.1	13.7	13.9	14.3	14.6	15.0

Additional power classes available on request.

Efficiency of modules at low irradiation (200 W/m²) decreases to 95.7 % of efficiency at STC.

Electrical Specifications @ AM1.5, 800 W/m², Cell Temperature 44° C:

Module Type		BMU/214	BMU/224	BMU/227	BMU/233	BMU/239	BMU/245
Maximum Power	P_{MPP} [W]	158	165	168	172	176	181
Short Circuit Current	I_{SC} [A]	6.62	6.74	6.78	6.86	6.95	7.03
Open Circuit Voltage	V_{OC} [V]	33.8	34.3	34.4	34.8	35.1	35.3
MPP Current	I_{MPP} [A]	6.06	6.23	6.31	6.39	6.47	6.59
MPP Voltage	V_{MPP} [V]	26.0	26.4	26.6	26.9	27.2	27.5
Solar Cell Efficiency	η_C [%]	13.5	14.2	14.3	14.7	15.1	15.5
Module Efficiency	η_M [%]	12.1	12.6	12.8	13.2	13.5	13.8

Electrical Specifications:

Solar Cell Type		Multicrystalline Silicon
Solar Cell Dimensions		156 mm x 156 mm (6+")
Number of Cells		60 in series
Power Output Tolerance		0/+ 6 W
Current Temperature Coefficient	α	+ 5.5 mA/° C
Voltage Temperature Coefficient	β	- 120 mV/° C
Power Temperature Coefficient	γ	- 0.40 %/° C
Maximum System Voltage		1,000 V (IEC 61730)
NOCT		44° C
Limiting Reverse Current		No external voltage higher than V_{OC} should be applied

www.bisol.com

ZNSHINESOLAR

MAP environmental

ZNSHINESOLAR Photovoltaic Modules

Tel: 01622 722280 Web: www.mapenvironmental.co.uk

250W Mono-Crystalline PV Module

<Model No. ZX250(48)M5)>

SPIB ZURICH CHARTIS

5 inch Gallium cells used in manufacturing process.

- Power output is maximised through the highly efficient Gallium 'small angle' solar cells used.
- Low Iron Tempered Glass: The glass applied to the panels is designed to transmit power at a high rate and is coated with an anti-reflecting substance which increases panel efficiency.
- Waterproof Multi-function Junction Box with MC4 connectors.
- Long Lifespan: >=25 years with 90% efficiency.
- Power Tolerance: 0 to +3%
- Full BBA approval for wind uplift and weather tightness.
- Resistant to adverse weather conditions such as hailstones.
- Effective at resisting moisture and corrosion.
- Certificate issued by MCS, BBA, TUV, CE and IEC.
- Insurance backed by Chartis, SPIB and Zurich.

TÜV IEC CE BBA

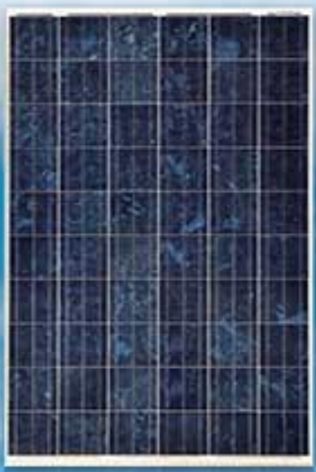
PV Module Characteristics

Electrical Characteristics	Physical Characteristics	Temperature Coefficients(TCs)	Absolute Maximum Limits
Pmax: 250W **Vmp:** 49.08V **Imp:** 5.09A **Voc:** 60.36V **Isc:** 5.56A **Eff:** 14.7%	**Cell Material:** Gallium mono-crystalline 125*125 (R165) **Cell Array:** 6*12/125*125 **Dimensions:** 1575mm*1082mm*45mm **Weight:** 22Kg	**Current TCs:** 0.0241 (%/K) **Voltage TCs:** -0.2904 (%/K) **Power TCs:** -0.4183 (%/K)	**Max System Voltage:** 1000V DC **Operating Temp:** -40°C~+85°C **Noct(DEGC):** 47°C±2°C

25 Year Performance Graph

ahead renewable energy

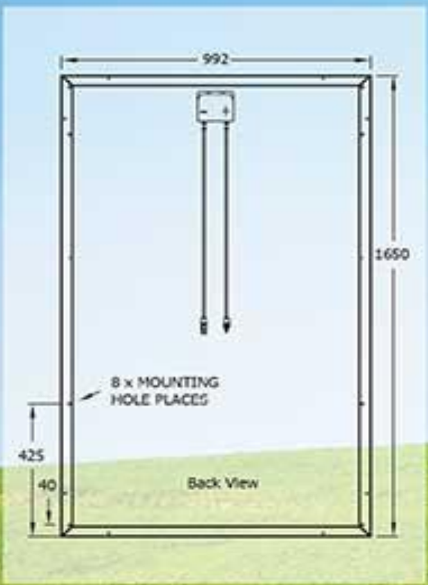
Photovoltaic Module PowerPro Poly AHAJ60P-250W



Mechanical and Physical Characteristics	
Cells	60pcs (6×10), 156×156mm/poly
Weight	19.0kg
Dimensions	L x W x D (mm) 1650×992×40
Glass	3.2mm thickness
Frame	40mm anodised aluminium alloy
Maximum load	2400Pa/5400Pa
Cable size	(area, length) $4mm^2$, 900mm
Junction box	IP65 with MC4 connectors

Specifications may be subject to change without notice.
Information published 01.01.13

diagram and dimensions



Electrical Characteristics AHAJ60P-250W	
Maximum Power (Pmax)	250W
Power output tolerance (%)	+5%, -0%
Voltage at Pmax (Vmp)	29.98 V
Current at Pmax (Imp)	8.34 A
Open-Circuit Voltage (Voc)	37.54 V
Short-Circuit Current (Isc)	8.84 A
Module Efficiency (%)	15.29
Standard Test Conditions	Air Mass AM1.5, Irradiance $1000W/m^2$, Cell Temperature 25°C
NOCT	47°C
Temperature coefficient of Isc (%/°C)	+0.06
Temperature coefficient of Voc (%/°C)	-0.33
Temperature coefficient of power (%/°C)	-0.45
Maximum series fuse rating (A)	15
Maximum system voltage (Vdc)	1000
Operating temperature (°C)	-40/+85
Number of bypass diodes	6

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Certifications and standards
Module certified to IEC61215, IEC61730, IEC62716