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ARDUINO BASED SOLAR TRACKING SYSTEM

SATHIS A/L VATUMALAI

Report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Engineering (Hons.) in Mechatronics Engineering

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

June 2016

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering (Honours) in Mechatronics Engineering.

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Name of Supervisor : DR. ARSHED ABDULHAMEED OUDAH
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DEDICATION

I dedicated this to my family and friends. Thanks for your unconditional love, support and guidance through the hardships while completing this course. Thanks God for meeting me with these beautiful people.

ACKNOWLEDGEMENTS

ABSTRACT

This thesis proposes the dual axis solar tracker for optimum solar cell implementation using dc-dc boost converter controlled by fuzzy logic controller with the maximum power point tracking (MPPT) method. The objectives of this project are to track and optimize the maximum output power of the solar panel by designing and implementing the fuzzy logic controller using microcontroller as well as to regulate the output voltage of the solar panel using dc-dc boost converter. The system includes a solar panel, DC-DC boost converter, the fuzzy logic controller implemented on Arduino Uno for controlling on/off time of MOSFET of the boost converter, voltage divider and optocoupler circuit as a driver for MOSFET. Tracking and detecting the angle of the sun to locate the surface plate of solar cell at the position and the angle where it can get maximum amount of energy. The solar panel must have sensors that can detect the position of the sun and dc motors act as free moving neck to make it easier to move freely depending on the angle detected. The light dependent resistor (LDR) will be used as sun tracking. The photocell panel will detect the existing of sun and the surface plate of photocell panel will move horizontal and vertical axis depending on the value of LDR detected to follow the angular degree of sun in order to get maximum and best result of absorbing energy. Moreover, this project presents a fuzzy logic real time code in Arduino language for ATmega328 microcontroller at Arduino Uno board. The result obtained from the Arduino coding is the variation of duty cycle of PWM signal according to the voltage of solar panel. The final result obtained from dc-dc boost converter showed that the output voltage has been regulated. Overall, the designed system increases the efficiency of the solar panel based on experimental results.

ABSTRAK

Tesis ini mencadangkan dua paksi tracker solar pelaksanaan sel solar yang optimum menggunakan rangsangan penukar arus terus yang dikawal oleh pengawal logik kabur dengan kaedah pengesanan titik kuasa maksimum. Objektif projek ini adalah untuk mengesan dan mengoptimumkan kuasa panel solar dengan merekabentuk dan melaksanakan pengawal logik kabur dengan menggunakan mikropengawal serta untuk mengawal voltan keluaran panel solar menggunakan rangsangan penukar arus terus. Sistem ini mengandungi panel solar, penukar rangsangan arus terus, pengawal logik kabur yang dilaksanakan dengan Arduino Uno untuk mengawal "MOSFET" yang terdapat dalam rangsangan penukar, pembahagi voltan dan litar "optocoupler" sebagai pemandu "MOSFET". Penjejakan dan mengesan sudut matahari untuk mencari plat permukaan sel solar pada kedudukan dan sudut di mana ia boleh mendapatkan jumlah maksimum tenaga. Panel solar mesti mempunyai sensor yang boleh mengesan kedudukan matahari dan dc motor bertindak memusingkan panel tersebut bergerak bebas untuk membuat ia lebih mudah untuk bergerak bebas bergantung kepada sudut yang dikesan. Perintang peka cahaya (LDR) akan digunakan sebagai pengesanan cahaya matahari. Panel photocell akan mengesan matahari yang sedia ada dan plat permukaan panel photocell akan bergerak pada paksi mendatar dan menegak bergantung kepada nilai LDR dikesan untuk mengikuti kedudukan sudut matahari untuk mendapatkan cahaya maksimum dan terbaik hasil daripada menyerap tenaga. Projek ini juga membentangkan kod masa sebenar logik kabur dalam bahasa Arduino untuk mikropengawal "ATmega328" yang terdapat di papan Arduino Uno. Keputusan yang diperolehi daripada pengekodan Arduino adalah variasi isyarat kitar tugas nadi lebar modulasi mengikut voltan panel solar. Keputusan akhir yang diperolehi daripada rangsangan penukar arus terus menunjukkan bahawa voltan keluaran dari panel solar telah dikawal dan dioptimumkan. Secara keseluruhannya, sistem yang direka telah meningkatkan kecekapan panel solar berdasarkan keputusan eksperimen.

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LIST OF SYMBOLS

D   Duty cycle/ratio

E   Error

CE   Change of error

f_s Switching frequency

I_{MPP} Rated current

I_{SC} Short circuit current

P_{max} Maximum power

R_1 First resistor

R_2 Second resistor

t_{on} Switch on time

t_{off} Switch off time

T_s Switching period

V_d Input voltage of DC-DC boost converter

V_{in} Input voltage of the voltage divider

V_{MPP} Rated voltage

V_O Output voltage of DC-DC boost converter

V_{OC} Open circuit voltage

V_{out} Output voltage of the voltage divider

V_{PV} Photovoltaic voltage

V_{REF} Reference voltage

LIST OF ABBREVIATIONS

AC   Alternative current

ADC   Analog-to-digital converter

DC   Direct current

DSO   Digital Storage Oscilloscope

FIS   Fuzzy inference system

FLC   Fuzzy Logic Controller

GUI   Graphical User Interface

IDE   Integrated development environment

I/O   Input or output

LCD   Liquid-crystal display

LDR   Light Dependent Resistor

LED   Light-emitting diode

MOSFET Metal-oxide-semiconductor field-effect transistor

MPPT   Maximum power point tracking

PV   Photovoltaic

PWM   Pulse-width modulation

CHAPTER 1

INTRODUCTION

1.1   BACKGROUND OF THE STUDY

Recently, solar energy has given more and more attention, it is a clean and renewable energy sources. The Photovoltaic (PV) cells are attained to convert solar energy from the sunlight directly to electrical energy. This energy can be utilized in many applications, like lighting, heating and performing different devices. The sun powered cell is containing semiconductor physical which utilizing the photovoltaic impact. At the point when the daylight is opposite to exterior of the PV sun powered board, can acquire higher efficient system; therefore, maximum potential electrical energy can be established. Many experimentations have been done to boost the efficiency of the solar cell.

Few decades ago, solar cell modules have been created and have been invented by arranging in series to optimise the output voltage. Solar tracking system categorizes as a control system that consists of sensors to detect either the sunlight is upright to the PV panel or not, and a controller that deliver signals to one or more actuator for changing the panel to the maximum targeted position. Nowadays dual axis solar tracker mechanism gained interest in R&D field due to the evidence of gain at the efficiency of the PV panel. Presently the researchers practising the usage of dc-dc support converter to coordinate the yield voltage as well as boost the lower voltage from system of photovoltaic. The purpose of using dc-dc boost converter is to boost low output voltage to high output voltage and also avoids the reverse current flow by blocking diode.

Furthermore, the Pulse-width Modulation (PWM) approach is also providing by researchers to regulate the dc-dc support converter. The Extreme Power Point Tracking or MPPT method obtains maximum extreme potential force from sun oriented boards. An intelligent controller is required to support the proficiency of the control framework of PV together with mechanical model of tracking structure. One of the MPPT method is fuzzy logic controller which is very reliable for photovoltaic array because fuzzy logic technique is promoted better and rapid tracking effectiveness for different optimal operating points. It supports to record optimum power under weather surroundings changing and gain great strength plus feedback amount is big. Progressively, data acquisition (DAQ) is process of recording or storing the data of output voltage from solar panel to compare with different weather conditions.

1.2 PROBLEM STATEMENT

Usually, a solitary sun based cell can't be connected straightforwardly to the heap on the grounds that it has less output voltage and less energy conversion efficiency. Furthermore, the output voltage covers by solar emission and temperature as well. Many solar cells that build in series to generate the maximum output voltage leads to high expenses to fix the photovoltaic system. In conjunction, large surface area is required for sufficient electricity and competence system. The data of output voltage from solar panel is required to record the different weather conditions.

1.3 OBJECTIVES OF THE STUDY

i.   To design the model of sun tracking scheme.
ii. To execute the fuzzy logic controller using Arduino to trace and create extreme output power of the sun powered cell also used for managing output voltage by dc-dc boost converter.
ii. To record effective data of output voltage from solar panel.

1.4   SCOPES OF THE STUDY

i.   The monocrystalline silicon solar panel is the solar panel selected for the project.

ii. The boost converter obtains developed using MOSFET, diode and more convenient components.

iii. The performance of the fuzzy logic controller by using the Arduino Uno Rev3.

iv. The Arduino terminology which is set in C or C++ created the fluffy rationale programming in order to build equipment.

v.   The data acquisition system is designed by voltage sensor and current sensor.

CHAPTER 2

LITERATURE REVIEW

2.1   INTRODUCTION

The overview of theory and elements applied to reach the objective for this project is stated in this section. This outline could support to master the concept and application on appliances relevant to this project. This section will discuss on the construction of dual axis tracker, material required and mechanism to develop fuzzy logic of this project.

2.2   SOLAR ENERGY

Solar energy is getting more attention as it is a clean and renewable energy especially in electricity production due to lack and contamination of fossil fuels (Yingue, Yeguang, Shengdong, Gang and Jinguang, 2014). Solar energy will be one of the most dominating energy assets in nations where hot atmosphere is overwhelming. Solar energy can extricate from sun rays as heat and electricity. Consistently, too many electrical appliances and gadgets are invented and utilized all over the world, including remote areas by extremely valuable solar powered generators. Much proficient and practical will consequently proceed when utilization of solar power increase and the research continuously make solar power developing system.

2.3   PHOTOVOLTAIC TECHNOLOGY

The biggest sufficient and user-friendly origin of sustainable energy act solar radiation utilized by sun powered cells. The elemental of the solar structure is sun

powered cells. "Photo" defines ray and "voltaic" known as producing electricity appear from the word photovoltaic. Hence, the photovoltaic process is "producing electricity directly from sunlight". The yield power like a sun-powered cell relies on the quantity of light forecasted on the cell. Duration of the day, weather, position of panel and orientation are considerate for the yield power. Photovoltaic cells are the littlest part of a solar panel. Sun powered cells provide optimum yield power when sun is straightly perpendicular along the panel (Vijandran, 2014).

2.4   DUAL AXIS TRACKER SYSTEM

Double hub trackers contains flexibility for two degrees which work like a turn of revolution as shown in the Figure 2.1. Dual support solar trackers, equally recommend, manage turn concurrently in vertical together with horizontal orientations, including capable via spot precisely toward sun in any location consistently (Shrivastava, 2013). Double pivot trackers recognize evolution pairs along the azimuthally and elevation-axes. Those capturing structures generally produce the outstanding achievement, given that peripherals gain large sufficient efficiency too. Double pivot trackers are counted for both seasonal and daily motions.
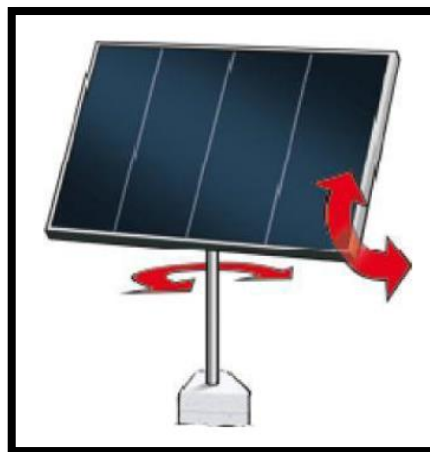
Figure 2.1: Dual axis solar tracker

Source: Shrivastava (2013)

2.5   DC-DC BOOST CONVERTER

The DC-DC boost converter boosts the input voltage into a greater output voltage. This converter also can be called as step-up converter. It used to regulate the dc power supplies. This converter only needs four external components which are diode, capacitor, electronic switch and output inductor. The diode is reversed biased when the switch is on. This will isolate the output voltage as well as the input will supply energy to the inductor. Meanwhile, the output stage will receive energy from the inductor and also the input when the switch is off (Mohan, Underland & Robbins, 2002).
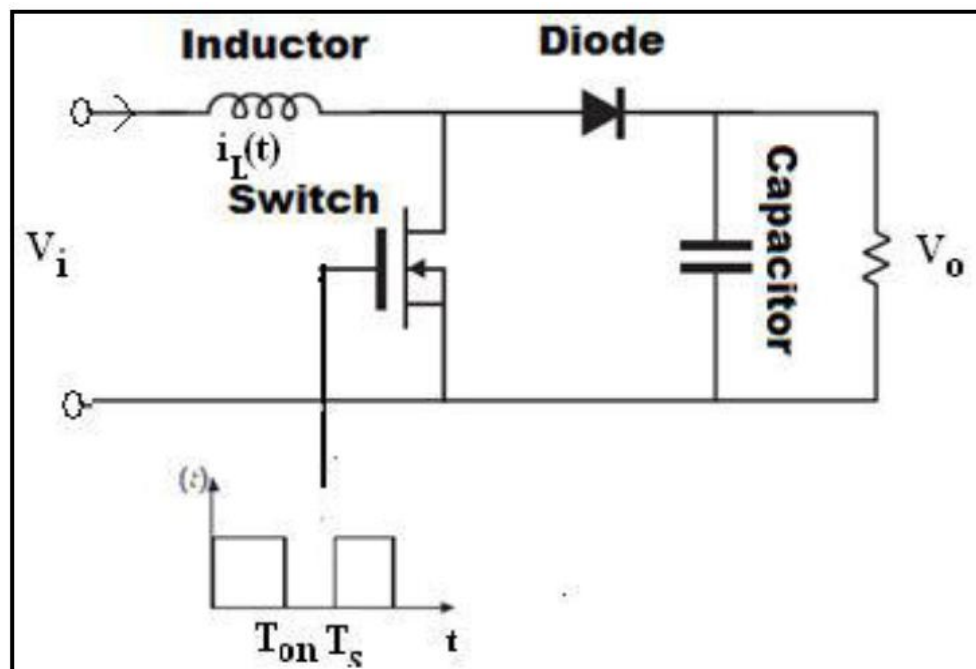
Figure 2.2: Boost converter

Source: Mitulkumar R. Dave & K.C. Dave, (2012)

2.5.1   Continuous-Conduction Mode

The time integral of the inductor voltage must be zero over one-time period in the steady state. Thus, the steady state equation is as below: -

$$V_d t_{on} + (V_d - V_0)t_{off} = 0 \qquad (2.1)$$

where V_d acts as initial voltage, V_0 acts as average final voltage, t_{on} is the switch on time and t_{off} is the switch off time. Dividing both sides by T_s gives,

$$\frac{V_0}{V_d} = \frac{T_s}{t_{off}} = \frac{1}{1-D} \qquad (2.2)$$

as T_s, switching period and D is duty cycle (Mohan et al., 2002).
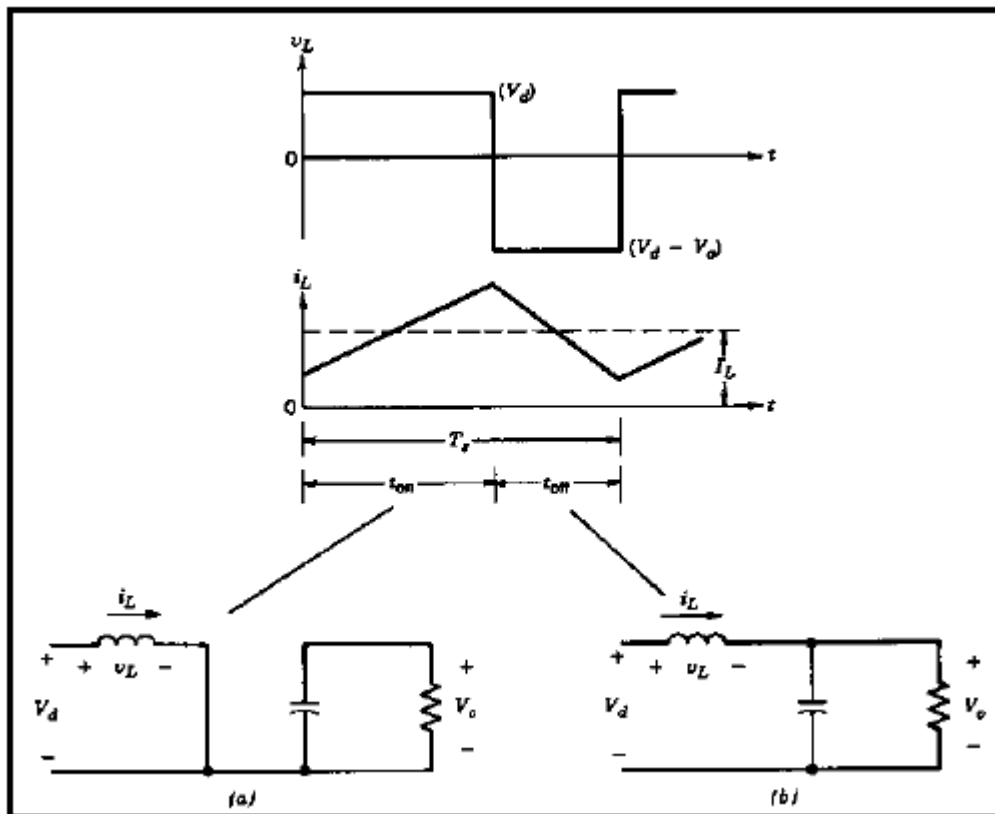
Figure 2.3: Continuous conduction mode; (a) switch on; (b) switch off

Source: Mohan et al., (2002)

2.6   PULSE WIDTH MODULATION

Pulse width modulation can be defined as the variation of the on duration ratio to the switching time period. By analysing a signal-level control voltage, $V_{control}$

including an over and over waveform, the knob regulates indication that dominates on and off condition for knob is developed. Presently a PWM control, switching frequency f_s is kept constant. With time proportional to the switching regularity, the amplified fault indication adjusts very calmly. The switch turns on whenever the switch regulation becomes huge, which is happened if sawtooth waveform is lower than signal of amplified fault. The knob is off if sawtooth waveform is higher than the signal of amplitude fault. That knob obligation proportion and switching frequency perhaps disclosed respectively during the time below (Mohan et al., 2002).

$$f_s = \frac{1}{T_s} \qquad (2.3)$$

$$D = \frac{t_{on}}{T_s} \qquad (2.4)$$

where t_{on} is the switch on time and T_s is the total of switch on and switch off time.
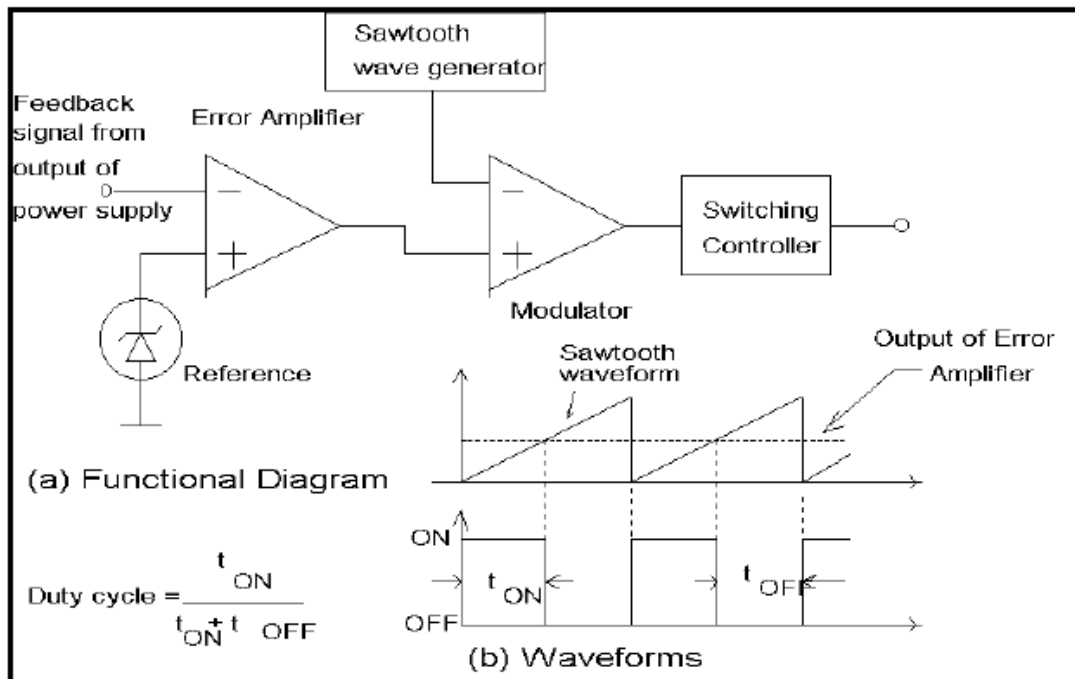
Figure 2.4: Pulse-width modulator: (a) block diagram; (b) comparator signals

Source: Mohan et al., (2002)

2.7   MAXIMUM POWER POINT TRACKING

In order to increase the efficiency and to maintain the operating point at an optimum maximum power point of the PV power generation system, Maximum Power Point Tracking (MPPT) is used. To record the new changed greatest force point in its comparing bend when MPPT method is utilized at whatever point the variety in the temperature or illumination happens. It can be seen from P-V power characteristics curve; Figure 2.5, that the increment, or decrement of the voltage increases, or decreases the power when the operating point is on the left of the Maximum Power Point (MPP), and decreases, or increases the power when being on the right of the MPP. The process is repeated periodically until the MPP is reached.
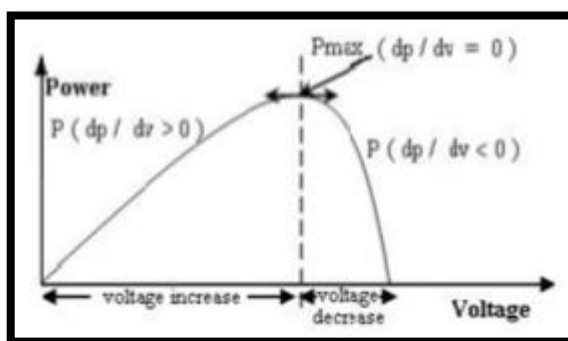
Figure 2.5: P-V characteristic curve

Source: Bawa and Patil (2013)

In order to maintain the operating point at an optimum value a power conditioner or a DC-DC converter is added as an interface between the source and the load. It extracts the maximum power from the source and transfers it to the load by stepping up (boost) or stepping down (buck) as per the requirement at the load side. The power transfer is carried out in accordance to the maximum power value by varying the on/ off duty cycle of switch of the DC-DC converter. (Bawa and Patil, 2013).

2.8 ARCHITECTURE OF FUZZY CONTROLLER

Fuzzy logic is similar to the feeling of human beings and inference process. Fuzzy logic control is a range to point or range to range control which is efficient than the classical control strategy. This is because classical control strategy is point to point control only. The classical set has a sharp boundary with two elements, 0 and 1. Meanwhile, fuzzy set has a smooth boundary compared with a classical set (Ying Bai & Dali Wang, 2006).

2.8.1 Fuzzy Sets

The components have a place with fuzzy set with a sure level of participation is the fundamental thought of the fluffy set hypothesis. It implies that suggestion is could be genuine or false, thus rather might be incompletely valid or somewhat faulty to any magnitude. Those magnitudes will be undertaking in between of the real number, 0 to 1. Crisp set theory is the classical set theory that uses genuine or faulty and that philosophy can't be meant ambiguous concepts. Meanwhile, fluffy set is fit for giving effortless moves which over the limit unlike the crisp set theory (Michael Negnevitsky, 2011). For instance, the speed has been taken as an example. The speed is divided into three categories which are low, medium and high. Figure 2.6 shows the velocity range in control of fuzzy logic (Chuen Chein Lee, 1990).
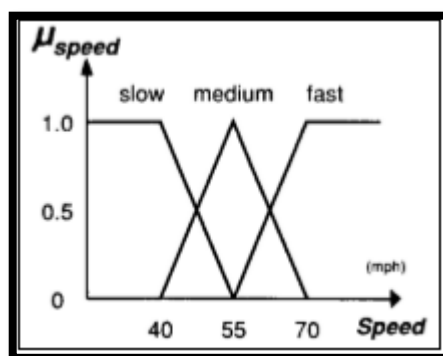
Figure 2.6: Level of participation of the velocity in fuzzy

Source: Chuen Chein Lee, (1990)

2.8.2 Rules for fuzzy

A fluffy tenet is a contingent explanation that in the structure,

IF y is C
THEN z is D

where y and z are alphabet elements as well as C and D are alphabet values which are determines by the fluffy series on the nature of talks Y and Z separately (Michael Negnevitsky, 2011).

2.8.3 Fuzzy Inference

A process of mapping from an input to an output which using the theory of fuzzy sets called as a fuzzy inference (Michael Negnevitsky, 2011).

i. Fuzzification
    Fuzzification is the first step to take the crisp inputs and determine the degree to which these inputs belong to the appropriate fuzzy sets.

ii. Rule evaluation
    This procedure is to collect fuzzified inputs and execute them into antecedents of the fluffy rules.

iii. Aggregation regarding that guideline yields
     This is the process of unification of the outputs of all rules.

iv. Defuzzification
    This process is the last step for the fuzzy inference. The final output of a fuzzy system should be a crisp number. The aggregate output of the fuzzy sets will become the input for the defuzzification process and a single number will become the final output.
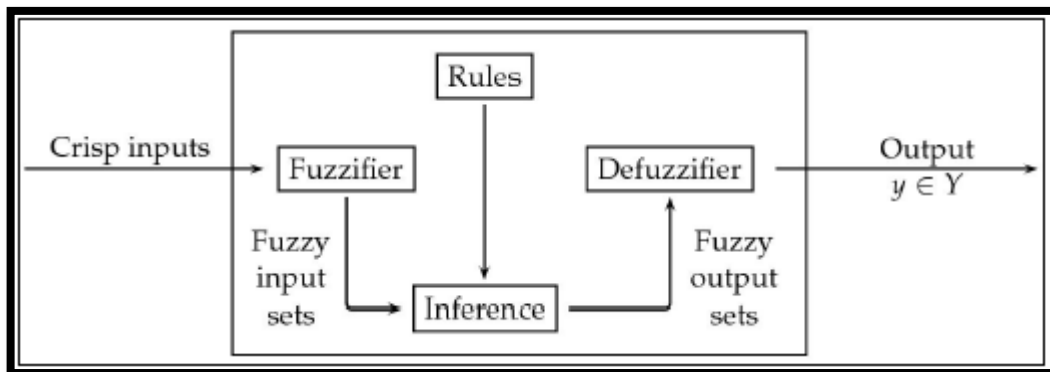
Figure 2.7: Block diagram of fuzzy logic system

Source: Sohail Iqbal, Nora Boumella & Juan Carlos Figueroa, (2012)

Figure 2.8: Example of fuzzy logic controller rule base

Source: Jana Paulusova, (2010)

2.9 SOLAR PANEL

A gadget that convert over daylight straightforwardly into power from the photo cell impacts is called sun oriented cell. PV cells come in many shapes and sizes,

different size of cells absorb different amount of solar energy. Large PV cells will give higher voltage and power output (Vijandran,2014).

Figure 2.9: Solar Panel

Source: Vijandran (2014)

2.10   LEAD-ACID BATTERY

A conversion of electrical energy from a stored chemical inside a battery is an oxidation/reduction reaction. Electrochemical reaction takes place when equipment is linked to a battery that outcomes electrical energy (Vijandran, 2014). The energy efficiency of this type of battery is higher compared to nickel cadmium.

2.11   LIGHT DEPENDENT RESISTOR (LDR)

On the surface of solar panel, 4 LDR sensors are installed. With the Arduino Uno simple pins, it is associated (Zakariah, Jamian and Yunus, 2015). The LDR are put on the south, north, west and east **s**ides of sun powered PV board. The sort of sensor demonstrates in Figure 2.10.

Figure 2.10: LDR sensor

Source: Zakariah, Jamian and Yunus (2015)

Those sensor contrasts the force simple quality and a 10 kΩ varying resistor which goes as a relative controller and identifies the power of the daylight. At the point when the episode daylight force expands, V_{out} likewise ascends to a greater quality. The yield voltage of the sensor is ascertained by potential difference divider mathematical statement:

$$V_{out} = V_{in} \times \frac{R_2}{R_{LDR} + R_2}$$

(2.5)

2.12 MICROCONTROLLER

A microcontroller can be defined as a small computer with a single integrated circuit which contains a processor core, memory and also programmable input or output peripherals. It can be said as a self-contained system and able to use as an embedded system. The switches, relays, LEDs, LCD displays, solenoids, radio frequency and also sensors for temperature, humidity or light level data become the typical input and output devices for the microcontroller. The embedded system normally has no keyboard, disks, screen and other recognizable input or output devices of personal computer.

Regularly, microcontrollers are utilized for naturally controlled gadgets (Afiqah and Sasikala, 2015). Microcontrollers can be customized in different abnormal state programming dialects, for example, C programming. Most of the microcontrollers have

at least two kinds of memory which are non-volatile memory for firmware storage and read write memory for temporary data.

2.13 PROGRAMMING OF MATLAB

Matlab is useful software which has fourth-generation programming language. It is developed by MathWorks. This software can be used for plotting of functions and data, matrix manipulation, creation of user interface, implementation of algorithms as well as interfacing with programs written in other languages which is C, C++, Java and Fortran.

SIMULINK is a Matlab toolbox which is designated for the dynamic simulation of the linear and non-linear systems. There is toolbox especially for fuzzy logic which allows the manipulation of fuzzy systems and membership functions. Furthermore, Matlab is very efficient for neural net, fuzzy systems and genetic algorithm (Afiqah and Sasikala, 2015).

2.14 CONCLUSION

Overall, this chapter had discussed about all the blocks or parts of this project separately with detailed description, figures and tables. The sources that were used for this chapter had stated clearly with the citations. This chapter is mainly to improve the understanding on variables involved in this project. Fuzzy logic reflects the thinking of people and models our common sense. It also models our decision making and the sense of words.

CHAPTER 3

METHODOLOGY

3.1   INTRODUCTION

This chapter explains the methods and techniques to accomplish the objectives of this project. Furthermore, this chapter also discusses the process flow of the project which is about the solar cell power optimisation system with the relevant steps. The explanations of the software development and hardware development with the electrical circuit diagrams also included in this chapter.

3.2   DESIGN OF SOLAR TRACKER MODEL

The objective is to design a model prototype and test dual axis rotation sun tracking system for solar panel. In order to start a design, a basic design concept and draft the design out. The figure below is the draft design; it consists a PV solar panel, support of four aluminium profile and connected to an aluminium rod that allow the PV solar panel to rotate freely.
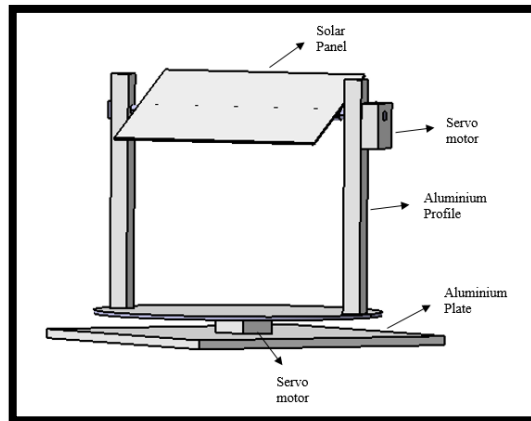
Figure 3.1: Draft model of dual axis solar tracker system
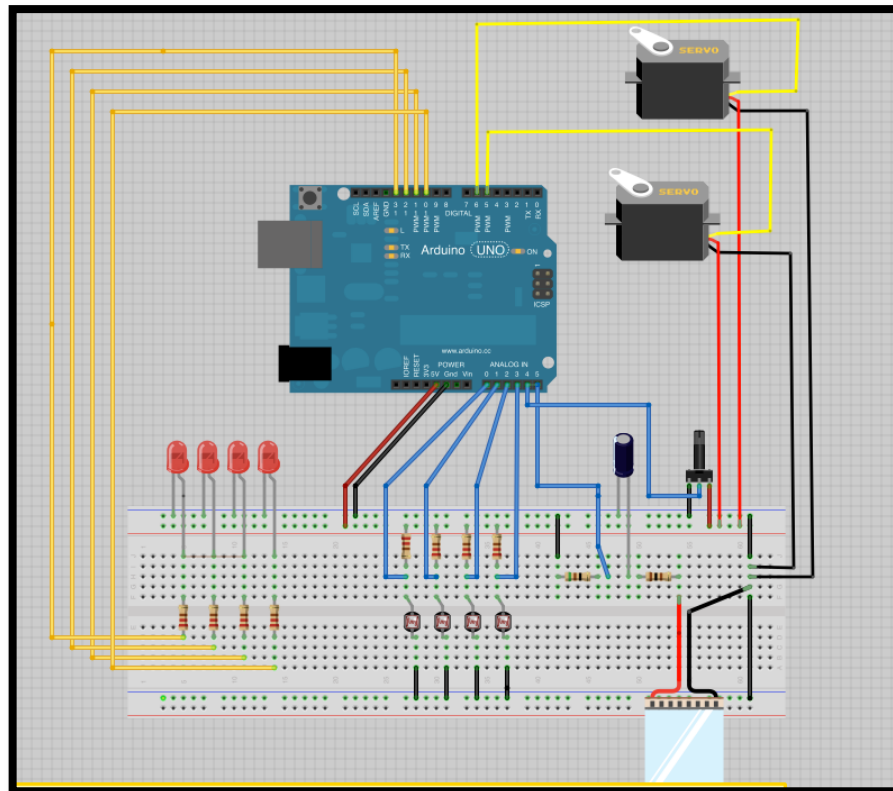
Figure 3.2: Complete design in fritzing software

This model will track the sun concurring the light force of the LDRs and pivot from 180 degrees East to West and North to South. The following is the flow chart of the model.
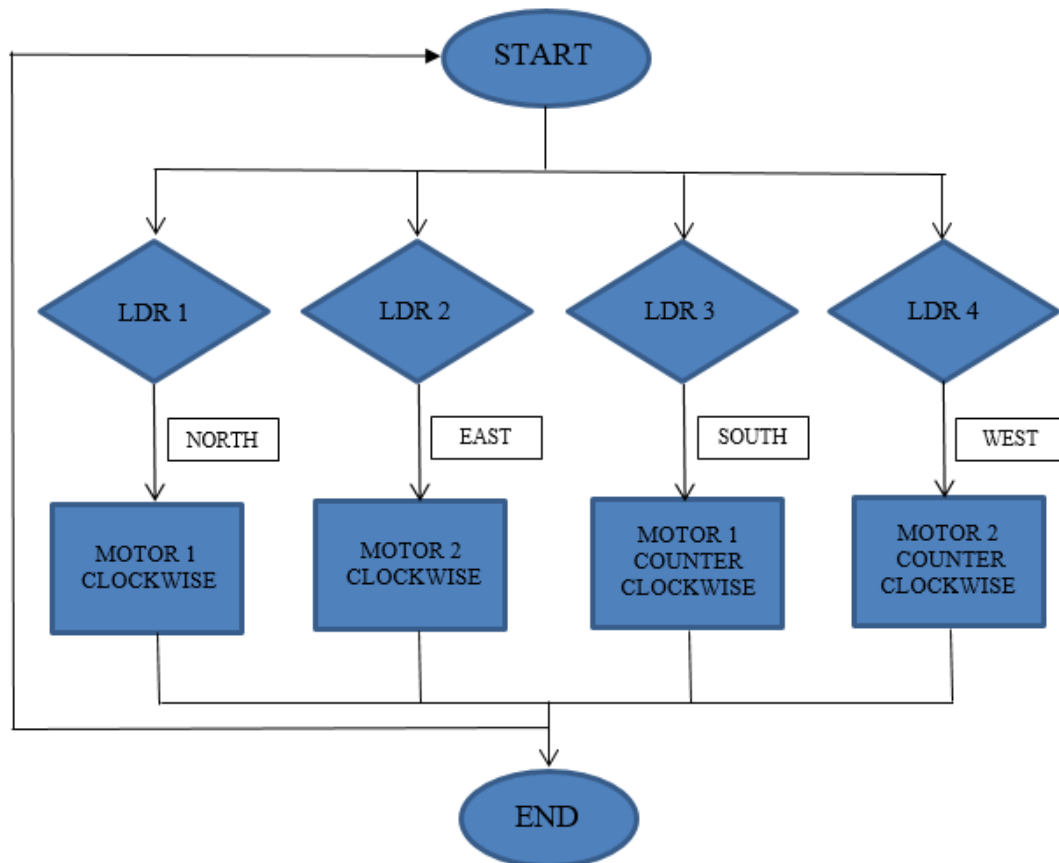
Figure 3.3: Flow chart of design model

3.3   MOTOR

Motor is the important part which needs to be considered since without motor, no movement will be made. The motor that been utilized are servo motor. A circuit to keep up the position of the engine turn is made to maintain a strategic distance from it pivots unreservedly relentless. Also, different things that should be advised are the size and limit of the servo engine. This is because solar panel has its own weight. Thus, servo engine that will be utilized must have the ability to pivot with the heaviness of the sun powered board. Servo engine is controlled by sending an electrical beat of variable width, or heartbeat width tweak (PWM). A servo engine can just turn 90 degrees in either bearing for an aggregate of 180-degree development. The PWM sent to the motor decides position of the pole, and in light of the term of the beat sent through the control wire; the rotor will swing to the sought position.

Figure 3.4: Servo motor

3.4   FLOWCHART OF THE PROJECT

First of all, create and design the fuzzy rules for the solar cell power optimisation. The software development used to create the fuzzy rules is the Fuzzy Logic Toolbox in MATLAB/SIMULINK. However, MATLAB was only used for optimised the membership function of the fuzzy logic controller by using hit and trial method. The Arduino language code was written for the implementation of FLC in hardware. After that, design the complete electrical circuit of the system. The software development used for the circuit design is the ISIS Proteus. Some parts of the electrical circuits had undergone simulation in that software. The next step is constructing the hardware of the electrical circuit. Some part of the circuit had undergone testing. After that upload the fuzzy logic Arduino language code in the ATmega328 microcontroller present in the Arduino board and connect the solar panel with the complete electrical circuit. Finally, test the prototype and improve it if needed.
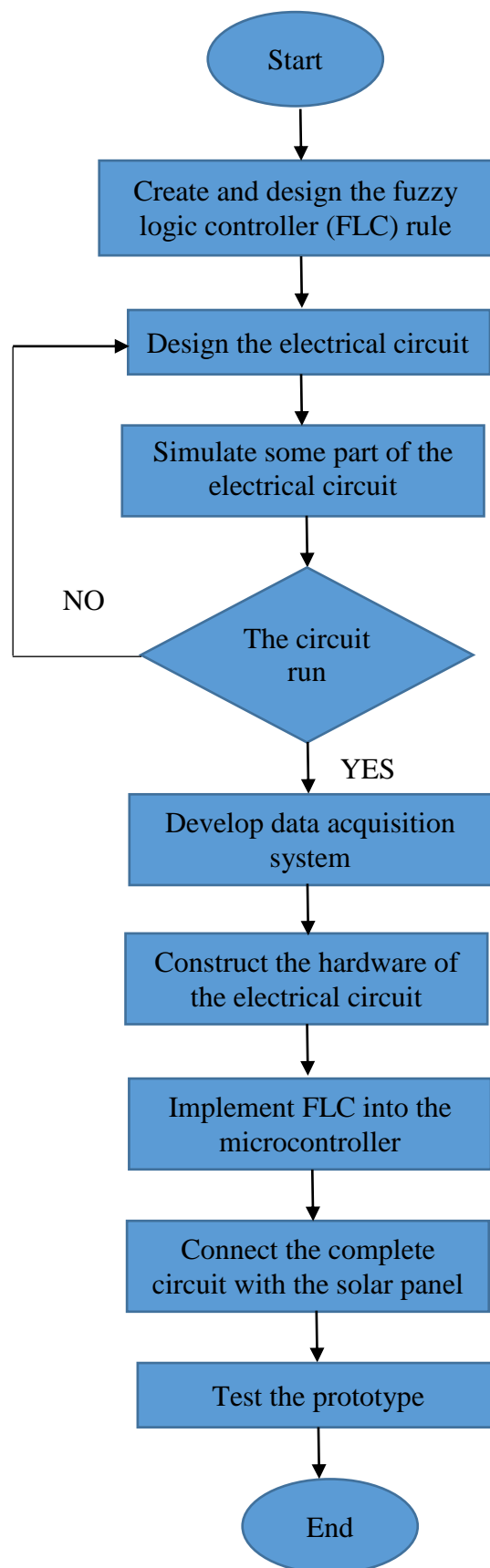
Figure 3.5: Flow chart of project

3.5 FLOWCHART OF PROCESS AND SYSTEM BLOCK DIAGRAM
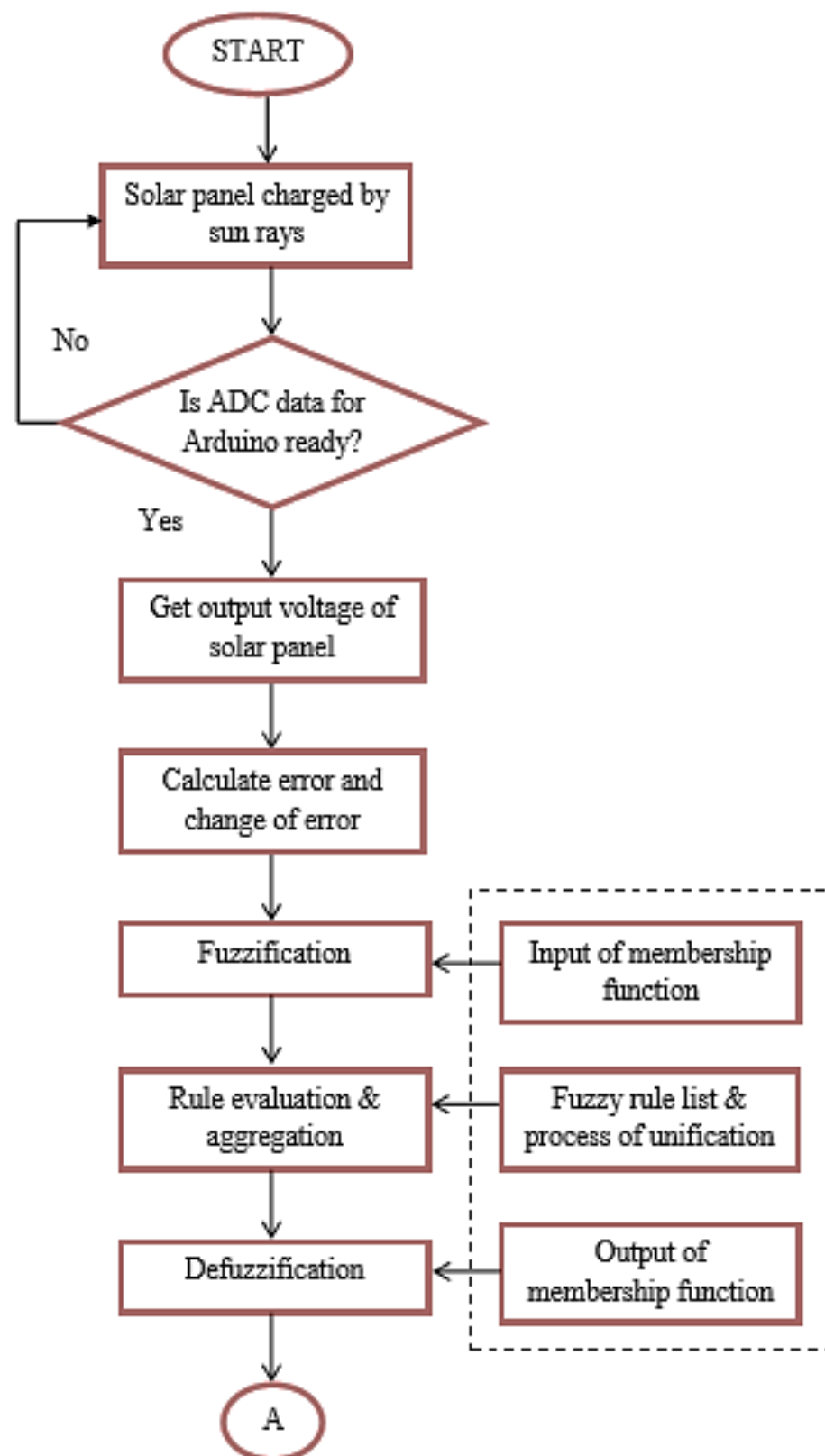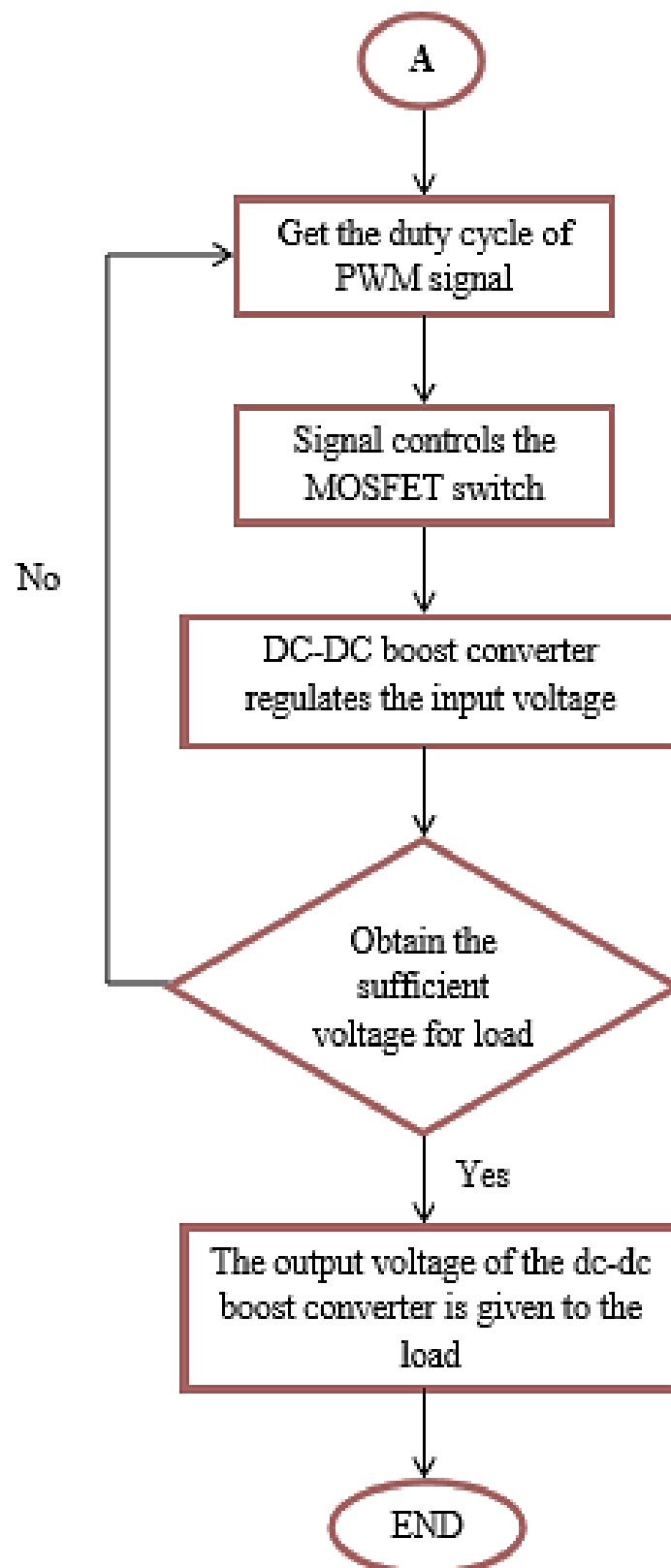
Figure 3.6: Flowchart of process for complete system
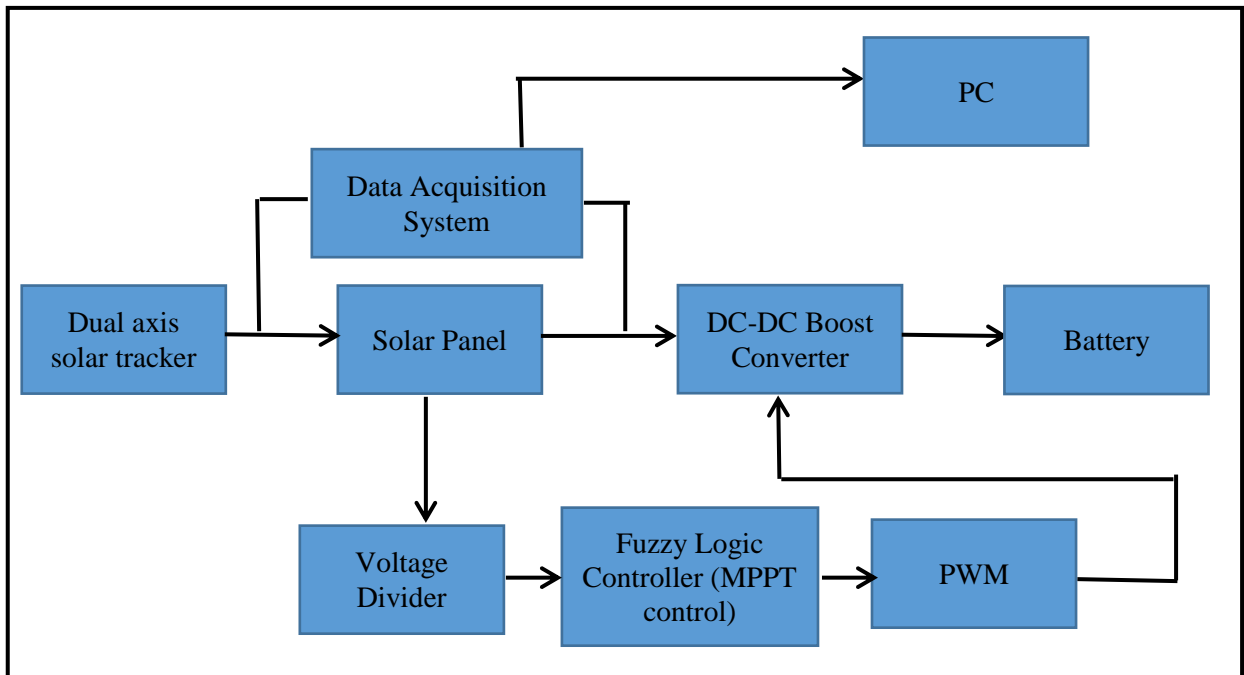
Figure 3.7: Designed system with block diagram

3.6   FRAMEWORK CIRCUIT OF COMPLETED SYSTEM
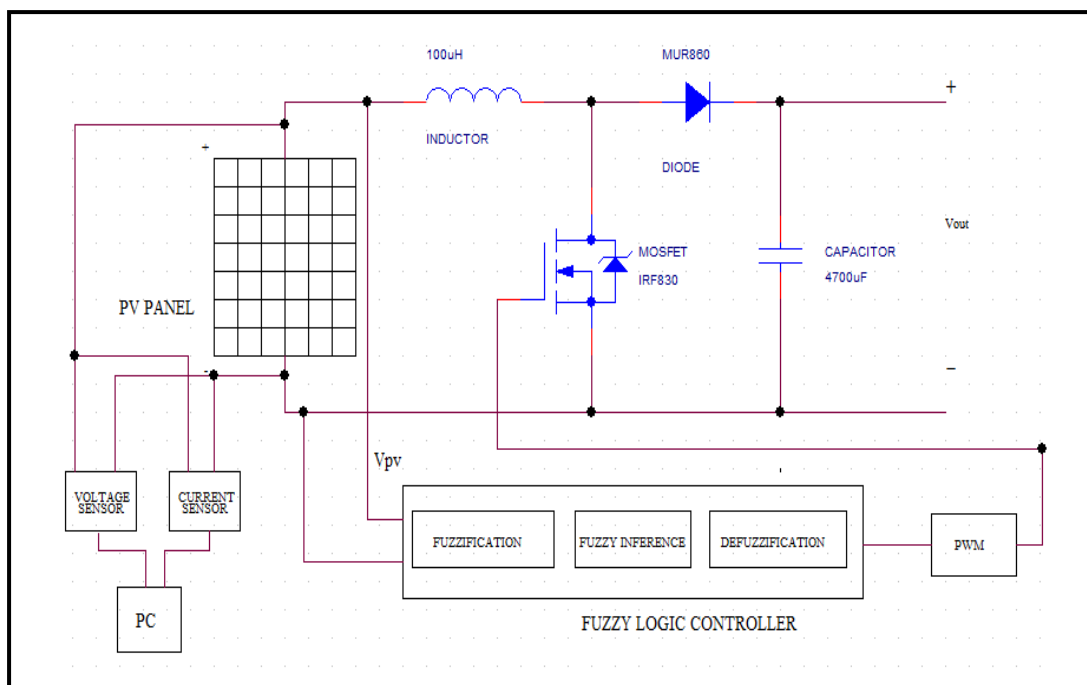
Figure 3.8: Framework circuit of overall system

3.7 FUZZY LOGIC TOOLKIT ALONG FLUFFY LOGIC METHOD ARCHITECTURE IN MATLAB

Most importantly, the fluffy rationale calculation ought to be outline as per the venture. The fluffy rationale calculation is contrasting for each framework. Since this anticipate is about enhancing the most extreme force of the sunlight based cell, then the sun based cell attributes ought to be investigated. As MOSFET, the inputs of the fluffy rationale controller for this anticipate are the blunder and change of mistake while the yield is the PWM obligation cycle.

The current vs. voltage bend in Figure 3.9 beneath demonstrates the most extreme current and voltage of the sun oriented board. The most extreme force point (MPP) can be computed with greatest voltage and current.
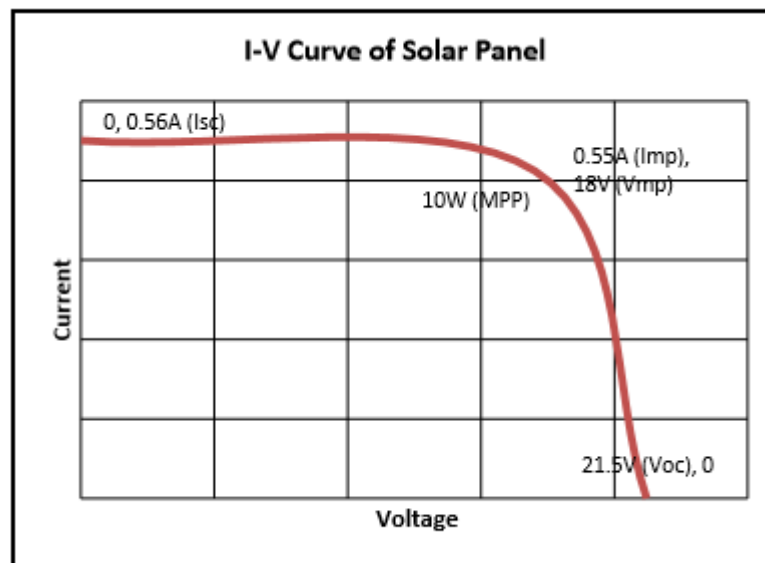
Figure 3.9: I-V bends of solar module

Moreover, the principles of fluffy rationale can be configuration with the assistance of power vs. voltage bend of the sun based board.
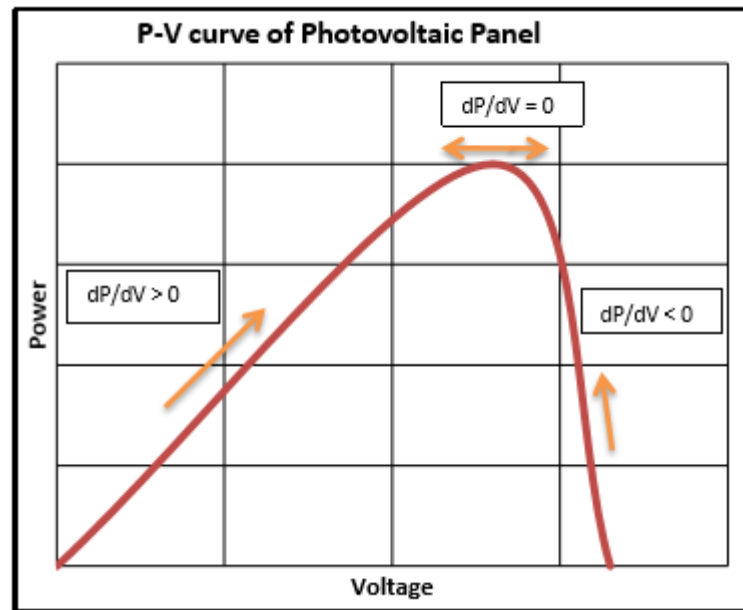
Figure 3.10: P-V bends of solar panel

The standards can be configuration as per the dp/dv. Whenever dp/dv > 0, thus the controller prefers adjustment of obligation cycle in order to build the voltage until the force achieves the greatest quality or dp/dv = 0. In addition, if dp/dv < 0, thus the controller prefers adjustment of obligation cycle to less the voltage until the force achieves its most extreme worth. In that matter, another straightforward strategy separated from the technique clarified previously. The most extreme force of the PV board has the greatest voltage. Along these lines, the obligation cycle can be changed as per the yield voltage by making a voltage of reference.

The fluffy rationale toolkit in MATLAB programming will outline the fluffy guidelines and participation elements of Fuzzy Logic Controller. It contains Editor of FIS which is a compiling User Interface of Graphical apparatus that rearranges the configuration of FLC. The FIS manager contains Editor of Membership, Editor of Rule, Viewer of Rule and Viewer of Surface. Those Editor of Membership and Editor of Rule have been utilized to plan fluffy rationale calculations. The Viewer of Rule and Viewer of Surface demonstrate the perspective of enrolment capacities as surface and principle separately.

The fluffy rationale control encloses three groups of principle work which are fuzzification, surmising system and defuzzification. This FLC utilizes the Mamdani technique which is generally acknowledged for catching master learning in fluffy tenets. It permits client to depict the ability in a human-like way not at all like the Sugeno strategy which is computationally compiling and works with streamlining and versatile strategies.

3.7.1 Fuzzification

The fuzzification is to convert the crisp inputs into the linguistic variables by means of fuzzy subsets. In this manner, the participation capacity qualities are communicated by phonetic variables utilizing fluffy subsets which are Z (zero), P (positive) and N (negative). A voltage of reference is altered and the yield voltage of the sunlight based board is computed by FLC. The error, E and the adjustment of error, CE are ascertained utilizing the voltage of reference and yield voltage of sun powered board.

The initial values of FLC are E and CE also depend on numeral changeable that have their scope of qualities and are utilized to adjust the fluffy parameter to enhance the framework operation. This E worth is standardized by and data scaling variable such that the info qualities are at intervals of - 1 to 1. The preferred equation for calculating of E and CE as per the following:

$$\text{Error} = V_{REF} - V_{PV}$$

$$\text{Change of Error} = E(h) - E(h-1)$$

where V_{REF} and V_{PV} are the voltage of reference and yield voltage of photovoltaic panel appropriately. At the same time, E (h) and E (h − 1) are error values at the moment (h) and (h-1).

3.7.2 Mechanism of Inference

Fluffy inference can be characterized as a procedure of mapping from the initial value to a yield which is utilizing the fluffy sets hypothesis. Principle assessment and conglomeration of the guideline yields incorporated into the fluffy deduction too. Guideline base has been composed with the fluffy subsets. The fluffy control is executed with the triangular participation capacities. The obligation cycle has been altered by yield voltage of the sun oriented board. For example, if the error and change of error is positive, it means the output voltage of solar panel is low. In this manner, the obligation cycle must be expanded to get a most extreme voltage. The complete principle base can be found in the Table 3.1 beneath.

Table 3.1: Rule source

CE / E	N	Z	P
N	N	N	Z
Z	N	Z	P
P	Z	P	P

Enrolment elements of inputs, mistake (E) and change of blunder (CE) and the yield, Duty proportion (D) are as take after.
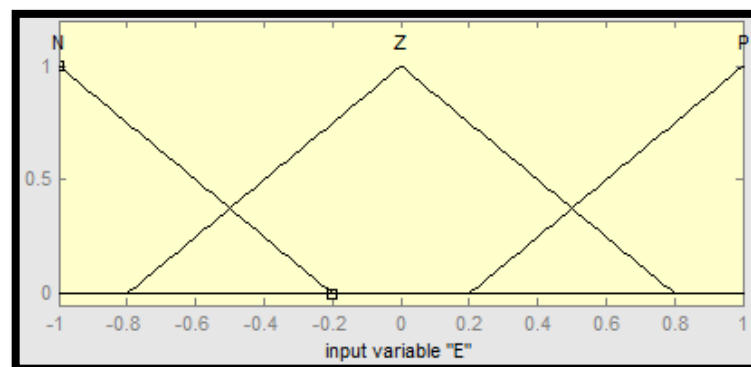
Figure 3.11: Error, E
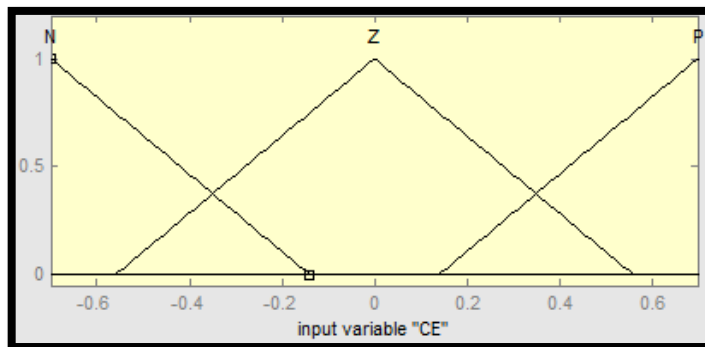
Figure 3.12: Change of error, CE
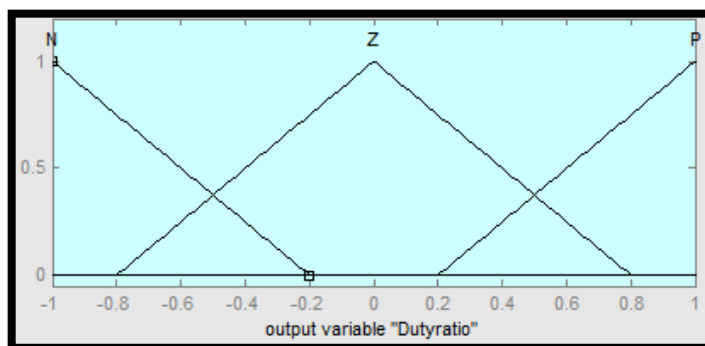
Figure 3.13: Duty ratio

The viewer of rule of 1 output and 2 inputs are as observe as below:
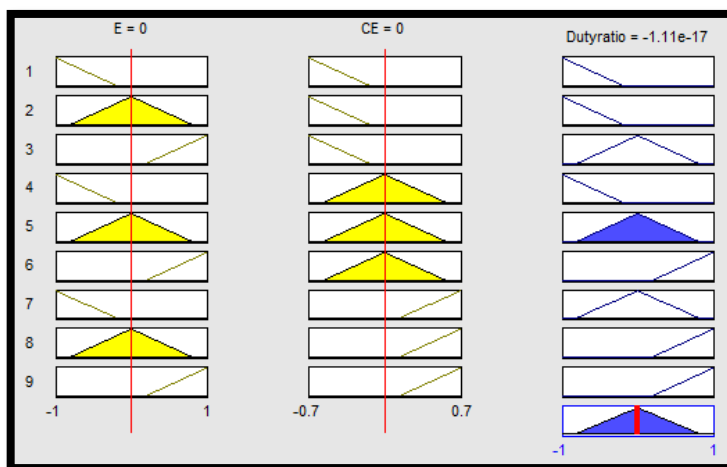
Figure 3.14: Viewer of rule

The Figure 3.15 below displays the viewer of surface of the enrolment elements.
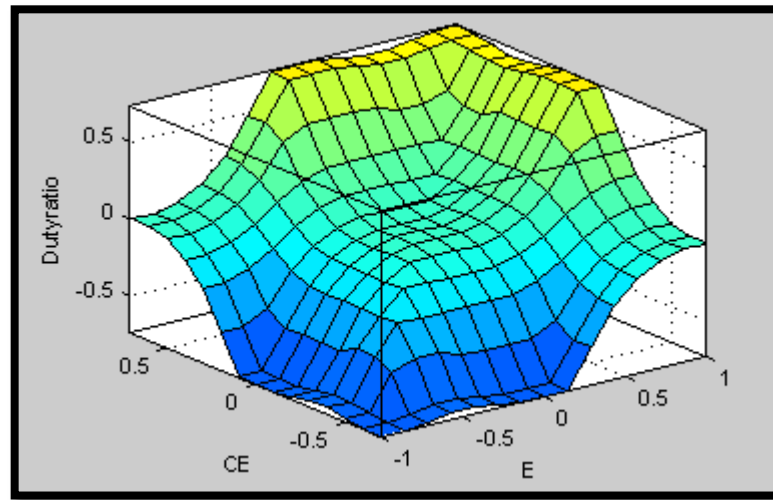
Figure 3.15: Viewer of surface

3.7.3   Defuzzification

The defuzzification changes over the surmising system into the genuine yield which is crisp number with the procedure. Mamdani strategy is been actualized in the observation that can be created by the centroid technique. The yield of fluffy rationale controller and obligation proportion, D is contrasted with waveform of sawtooth to create a heartbeat for switch of MOSFET in dc-dc support converter.

3.8   OVERVIEW OF HARDWARE

3.8.1   Data Acquisition System

Parallax Data Acquisition apparatus (PLX-DAQ) programming include for Microsoft Excel secures until 26 channels of information from whatever Parallax microcontrollers and put the numbers into sections as they appear. PLX-DAQ gives simple spreadsheet investigation of information gathered in the area, lab examination of sensors and ongoing gear checking. For this project, it is done by using Arduino voltage

sensor and current sensor to collect data in PLX DAQ for each seconds that appears in Microsoft Excel with the real time data graph.

Figure 3.16: Parallax data acquisition system

3.8.2   Arduino Voltage Sensor

This module is based on the design principles of the resistor divider, enabling the terminal interface input voltage narrow five times, Arduino analogue input voltage up to 5V, then the input voltage of the voltage detection module cannot be greater than $5V \times 5 = 25V$ (3.3V if used system, the input voltage cannot exceed 3.3Vx5 = 16.5V). Because Arduino AVR chips used in 10 AD, so the simulation resolution of this module is 0.00489V (5V / 1023), so the minimum input voltage detection module detects voltage $0.00489V \times 5 = 0.02445V$.

Figure 3.17: Voltage sensor

3.8.3 Arduino Current Sensor

The ACS712 Current Sensor Module is a simple sensor that gives exact estimation of AC and DC streams. Current sensors are utilized to screen the measure of force or a torque. This present sensor module can deal with AC or DC streams up to 5A. A solitary simple yield signal interfaces with your microcontroller to give the sensor readings. This module works at 5V.

Figure 3.18: Current sensor

3.8.4   Solar Panel

Solar panel that was used for this project is the Photovoltaic (PV) panel and the type of the panel that was chosen is a monocrystalline silicon PV panel. The electrical specifications of the solar panel are shown in the Table 3.2. This PV panel are made up by two semiconductors layer which are photons and electrons. The PV panel is based on p-n diode. When a photovoltaic panel exposes to the sunlight, the photons from the sun rays will be absorbed.

If there are enough photons from the sunlight that has been absorbed by the negative layer, then the excited electrons are free from negative layer and move to the positive layer which create a voltage differential. When the load is connected with two layers, the electrons will flow to the load from positive to negative layer. This process will continue until the panel has sufficient amount of electrons and sunlight.

Table 3.2: Electrical particulars of the 10W photovoltaic panel of monocrystalline silicon

Parameter	Abbreviation	Value
Maximum Power	P_{max}	10W
Rated Voltage	V_{MPP}	18V
Rated Circuit	I_{MPP}	0.55A
Open Circuit Voltage	V_{OC}	21.5V
Short Circuit Current	I_{SC}	0.56A

3.8.5   Light Dependent Resistor

Light Dependent Resistor (LDR) is known as photo resistors. It works precisely like a variable resistor; however, the resistance relies upon the power of light. The resistance of the LDR is conversely relative to the power of light. The two LDR is installed on the surface of the solar panel PV panel. The both LDRs were separated by plastic board and its height adjusted to required sensitivity to the tracking system as shown in figure 3.19 (I). The engine turns clockwise if the simple sign from LDR 1 is more noteworthy than LDR 2 and against clockwise if the other way happened. The engine continues turning until the both LDRs simple signs are equivalent and stop as

appeared in Figure 3.19 (III). The sun based following framework takes after the quickly suns movement at constantly.
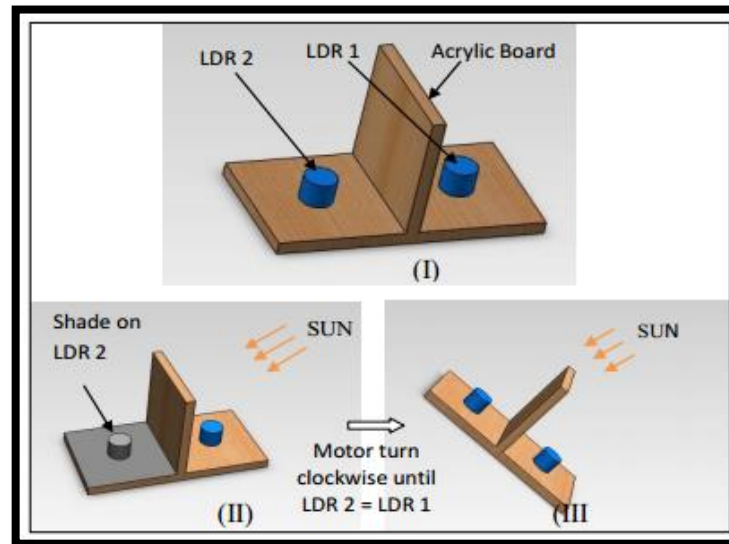
Figure 3.19: (I, II, III) LDR based tracking system

3.8.6 Lead-Acid Battery

12V lead-acid battery has been selected because of its large capacity and often available in many places. Lead-acid battery seems the commonly used battery for energy charging. 12V battery has standby use of 13.5V – 13.8V, so it shows that the battery can charge up to 13.8V. When the battery voltage is in the range of 13.5V to 13.8V during charging process, it means that the battery has reached its full energy capacity. Thus the charging process will be automatically cut-off during this state.

Figure 3.20: Lead-acid battery

3.8.7   Application of Fuzzy Logic Controller

Fluffy rationale controller is known as primary part of the venture framework. It tracks and advances the most extreme yield force of the sun oriented board. The controller is utilized as a part of this anticipates in the Arduino Uno Rev3. The enhanced enrolment capacity information made with MATLAB Fuzzy Rationale Toolkit had been utilized as a part of composing Arduino dialect code and transferred in the microcontroller of ATmega328 in the Arduino board. The product utilized for composing the code by version 1.0.5 of Arduino IDE.

a)   Arduino Uno Rev3

The Arduino Uno Rev3 is a solitary board microcontroller in view of the ATmega328. The ATmega328 is categorized as 8-bit AVR processor of Atmel. The board has 6 simple data pins and 14 computerized information/yield pins of which 6 can be utilized as Pulse-Width Modulation (PWM) yields.

The board likewise has a 16 MHz precious stone oscillator, a USB association, a force jack, a header of ICSP and a reset catch. Also, it consists everything expected to bolster a processor. The panel can be beginning by just associate it to a PC with a USB link or additionally can be force the board with an AC-to-DC connector/battery. The other data of the Arduino Uno board is expressed in the table underneath.

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Figure 3.21: Particulars for Rev3 board of Arduino Uno
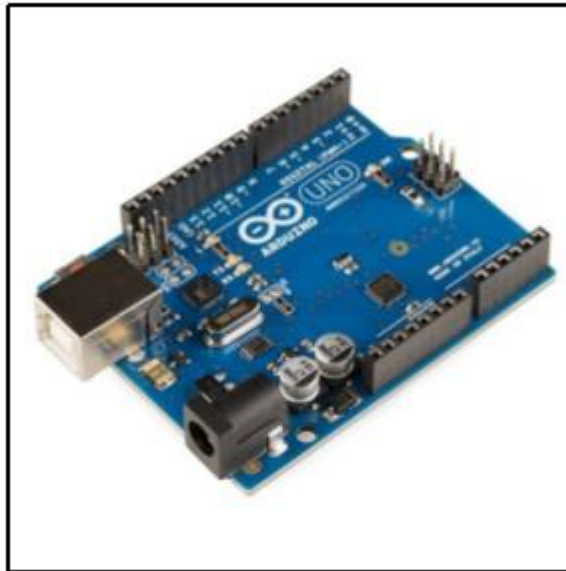
Figure 3.22: The Rev3 board of Arduino Uno
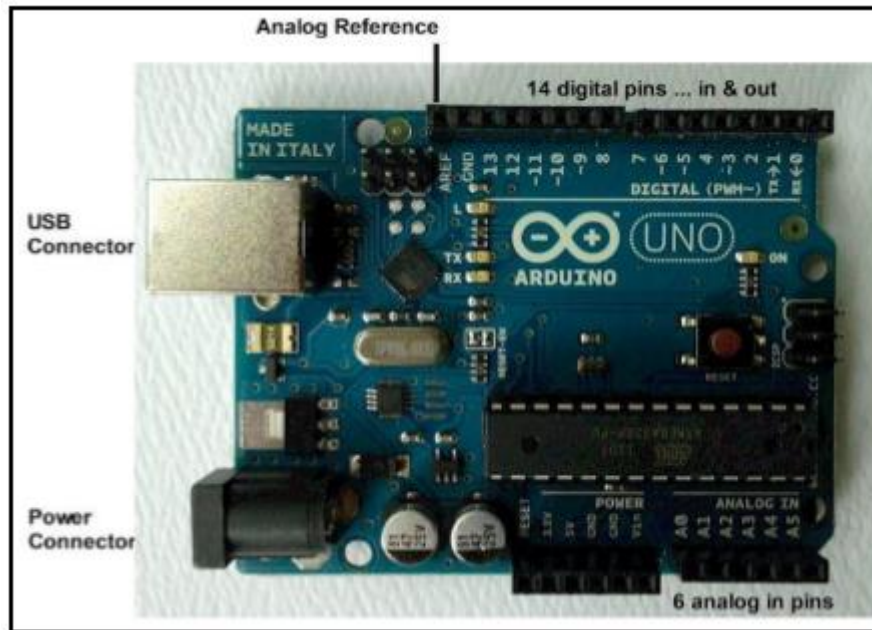
Figure 3.23: The description of I/O locations for Arduino Uno
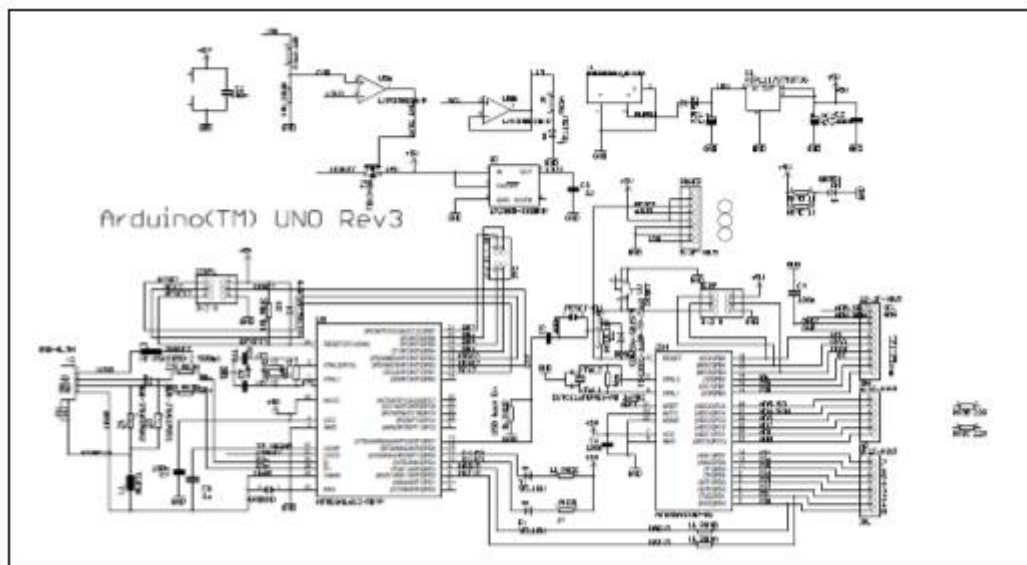
Figure 3.24: Arduino Uno Rev3 circuit diagram

b) **The IDE Software for Arduino**

Arduino IDE variant 1.0.5 is the product utilized for this anticipates composing the source rule for controller of Arduino. IDE well-known as Integrated Development Environment that keeps running on customary PCs and in addition it permits composing

programs/codes for Arduino utilizing C/C++. The open-source Arduino environment makes it easy to write code and upload it to the I/O controller board. Nature is composed in Java taking into account Processing, avr-gcc and other free source programming. It is equipped for aggregating and transferring projects to panel with just a solitary snap. Moreover, a system composed for Arduino is termed as "representation".

The code which composed for this anticipates is the fluffy rationale with one output and two inputs. The code is attached in the Appendix for guidance. Two capacities must be characterized to generate possible cyclic official projects which are loop and setup.

3.9   DESIGN OF ELECTRICAL CIRCUIT

3.9.1   Voltage Divider

A potential divider is otherwise called a voltage divider. This is a direct circuit which delivers a yield voltage that is a small amount of its data voltage. Voltage division allowed to the gain of a potential difference among the divider segments. The division of voltage is ordinarily used to make a voltage of reference or to obtain a small voltage signal relative to the measured voltage. Furthermore, a voltage divider may be sufficiently accurate if made with only resistors for direct current and relatively low frequencies. The relation between the input voltage and yield voltage can be constructing by implementing Ohm's Law.

$$V_{out} = \frac{R_2}{R_1 + R_2} . V_{in}$$

where V_{in} and V_{out} is initial and yield voltage of the potential divider appropriately while the resistors are R1 and R2.

The potential divider which intended for this anticipates is demonstrated as follows. This potential divider system is utilized as a sensor for voltage between the

sunlight based board and controller. 180kΩ and 47kΩ resistors were gotten the output voltage of most extreme 5V from the input voltage, 25V in this divider. The output voltage of the system is utilized as a maximum input voltage to the A/D transformation for controller.
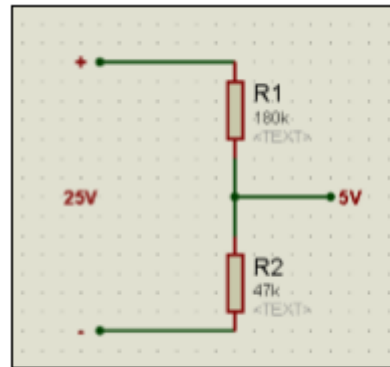
Figure 3.25: Potential divider

3.9.2   DC-DC Boost Converter

The dc-dc boost converter step ups the low output voltage which has gain from the solar panel as well as regulates the voltage. The output voltage of the solar panel will be the input voltage of the dc-dc boost converter. Fuzzy logic PWM signal will control the on/off time of the MOSFET switch of the DC-DC boost converter. The dc-dc boost converter acts as a charge controller where it is controlled by software based on fuzzy logic. The fuzzy logic control will track the output voltage of the solar panel and finds out the maximum power as well as controls the boost converter.

The duty cycle (D) of the MOSFET is adjusts with the fuzzy logic controller by generating the PWM signal. The voltage gets from the boost converter will be the final output voltage and it will be send to the load. The dc-dc boost converter had been designed to get a higher output voltage. The input voltage of the dc-dc boost converter will be varied from 0 to 21.5V; however, the maximum power point voltage of the solar panel is 18V:

$$\frac{V_o}{V_d} = \frac{1}{1-D}$$

where V_d is the initial voltage, V_o is yield voltage and duty cycle will be D.
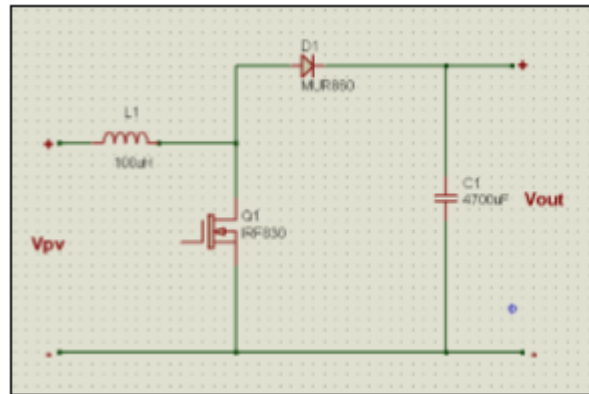
Figure 3.26: The DC-DC boost converter circuit

3.10   CONCLUSION

Overall, this chapter had discussed the design of overall system of the project in terms of electronic circuits and hardware overview of solar panel. It also elaborated and explained the design of fuzzy logic algorithm for Maximum Power Point Tracking (MPPT) of solar panel with the Arduino.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1   INTRODUCTION

The results and analysis of project are described in this chapter. Dual axis mechanism, data monitoring system and controller design of fuzzy logic are discussed in depth for this project. The model has been trained and a portion of the information from the equipment was gathered. Fuzzy logic controller and double axis tracker are optimised the extreme power point. The software of Arduino IDE use Arduino language to design the fluffy rationale programming. The output of the controller is the PWM obligation cycle and yield voltage of sun powered board has been alternated and regulated by duty cycle of PWM.

4.2   SOLAR TRACKER MECHANISM

The data collected for both dual axis tracking with and without system on a clear sky. The comparison and performance of both mechanisms were included. The data was recoded for every one hour, starting at 8.00 AM until 6.00 PM. Each value of solar panel voltage and output voltage were measured using Multimeter and PLX Data Acquisition System.

4.2.1 Dual Axis Solar Tracker without System

Table 4.1: Solar Panel Voltage and Output Voltage (I)

Time (Hour)	Solar Panel Voltage (V)	Output Voltage (V)
8.00 AM	8.55	8.55
9.00 AM	9.57	9.57
10.00 AM	10.20	10.20
11.00 AM	10.90	10.90
12.00 PM	11.78	11.78
1.00 PM	13.01	13.01
2.00 PM	14.15	14.15
3.00 PM	14.35	14.35
4.00 PM	13.90	13.90
5.00 PM	12.57	12.57
6.00 PM	11.27	11.27

The table 4.1 shows the voltage from PV solar panel voltage and output voltage. From this data, the graph of dual axis solar tracker without system was obtained in order to analyse the results.
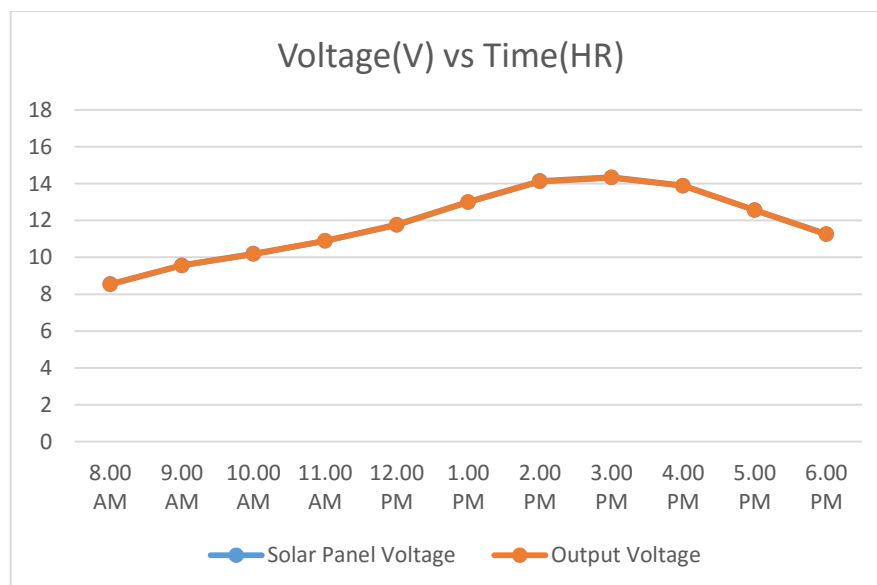
Figure 4.1: Solar panel voltage and output voltage (I)

Figure 4.1 shows results of the experiment of output voltage and solar panel voltage against time hour. Every one hour the data shows different result in term of input voltage of a solar panel and output voltage of a battery. This happens because the solar panel receive bright sunlight ray for each one hour during experiment. At 8.00AM to 9.00AM, the input voltage starts to increase; this is because the sun light is getting brighter. The charging process runs because 10V to 12V DC supply was enough to flow through the charging circuit and power supply circuit. At 3.00PM, the maximum voltage input was recorded at 11.89V near to the value of 12V.

The voltage began to increase at the peak hour starting at 10.00AM till 3.00PM. This is because there was no cloudy environment as it was cleared sky. From the peak voltage, the time that is effective for charging process was around 10.00AM to 3.00PM. However as for daily use, the same results can't be obtained because sometimes it might be cloudy or raining depends on the weather and sky conditions. Another thing that can affect the sun light ray from passing to earth is cloud which sometime blocks the sun light. As per experiment, the voltage drops slightly and not stable for the output voltage.

4.2.2 Dual Axis Solar Tracker with System

Table 4.2: Solar Panel Voltage and Output Voltage (II)

Time (Hour)	Solar Panel Voltage (V)	Output Voltage (V)
8.00 AM	8.45	18
9.00 AM	9.97	18
10.00 AM	10.15	18
11.00 AM	11.65	18
12.00 PM	12.42	18
1.00 PM	13.01	18
2.00 PM	13.97	18
3.00 PM	14.35	18
4.00 PM	14.15	18
5.00 PM	13.95	18
6.00 PM	12.39	18

The table 4.2 shows the voltage from PV solar panel voltage and output voltage. From this data, the graph of dual axis solar tracker with system was obtained in order to analyse the results.
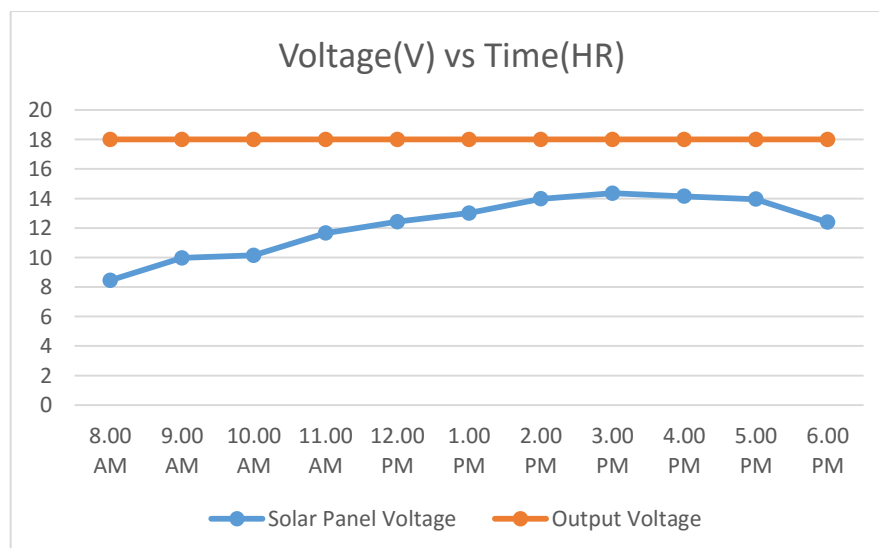
Figure 4.2: Solar panel voltage and output voltage (II)

The dual axis solar tracker with system gives the maximum and stable output voltage that a solar panel does. This shown that the solar panel in this system works at full efficiency. Eventhough the weather and sky conditions affects the solar rays, the output voltage always reach 18V and stable with FLC and DC-DC boost converter.

4.2.3 Comparison for Output Voltage of with and without System
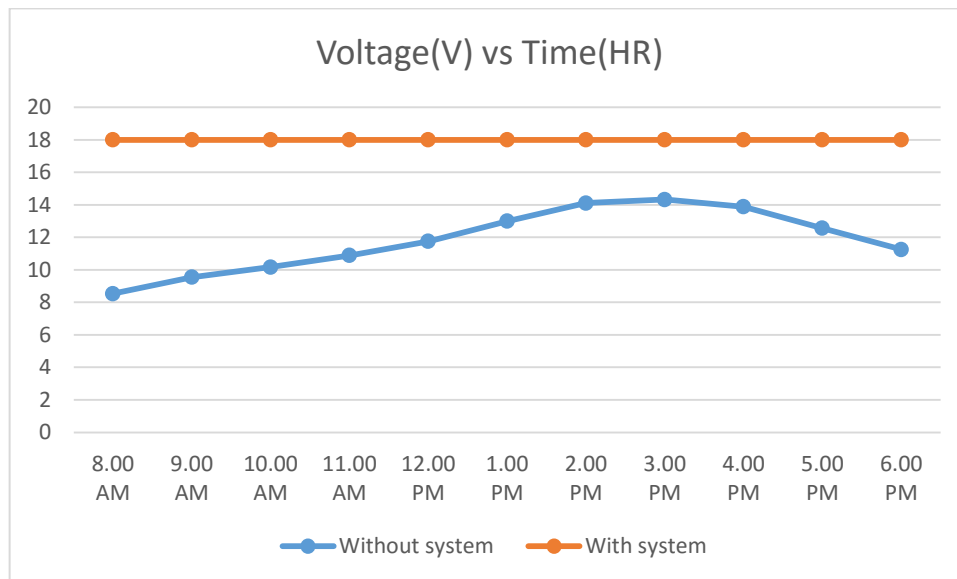
Figure 4.3: Comparison of output voltage of with and without system

Figure 4.3, shows the output voltage of both with and without system against time for each one hour. Output voltage for dual axis solar tracker with system constantly increase and stable compared to the dual axis solar tracker without system during daylight.

4.3 VOLTAGE DIVIDER IN THE ROLE OF VOLTAGE SENSOR

For solar or sun powered cells, voltage divider acted as sensor of voltage. The ceramic resistors of 180kΩ and 47kΩ are peripherals that can stand suitable until 10W. It is utilized for potential difference divider. This segment has barrier to have maximum 5V for yield voltage of solar powered cells.

Because of the optimum input potential difference for controller of Arduino Uno is 5V itself, the potential difference from sunlight based board has been ranged to 0-5V. The input potential difference of controller is the yield voltage of this segment. In Table 4.3, the potential difference collected subsequently the segment is appeared. Additionally, the genuine circuit of potential difference divider can found in Figure 4.4.

Table 4.3: Comparison of solar panel input voltage and divider output voltage

V_{pv} (V)	V_{out} from Divider (V)
0.0	0.000
3.6	0.751
8.2	1.693
18.0	3.670
21.5	4.380
25.0	5.130
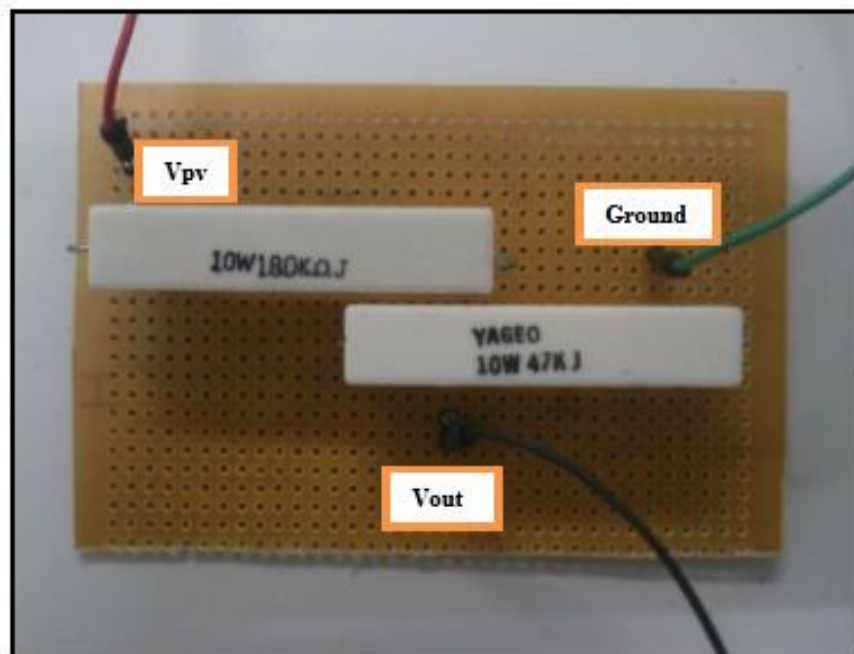
Figure 4.4: Potential difference divider

4.4 CONVERTER FOR BOOST

The circuit for dc-dc help converter is intended to regulate the yield voltage of sunlight based board. IRF 830 MOSFET, 4700uF Capacitor, MUR860 diode, 100uH

radial inductor, resistors of 1kΩ and 6.2kΩ. The help converter had directed the voltage of the sun based board as indicated by the estimation of obligation cycle which can be getting from the fluffy rationale controller where the obligation cycle will be deliver to MOSFET.

The DC-DC support converter decided for PV framework since it is minimal effort, straightforward and high proficient too. Additionally, it is embraced as a controller for this framework. The Figure 4.5 demonstrates the genuine circuit of the help converter which was outlined in a solder board.
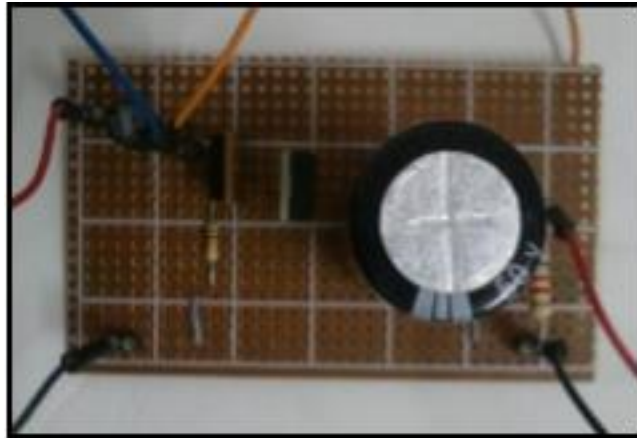
(a)
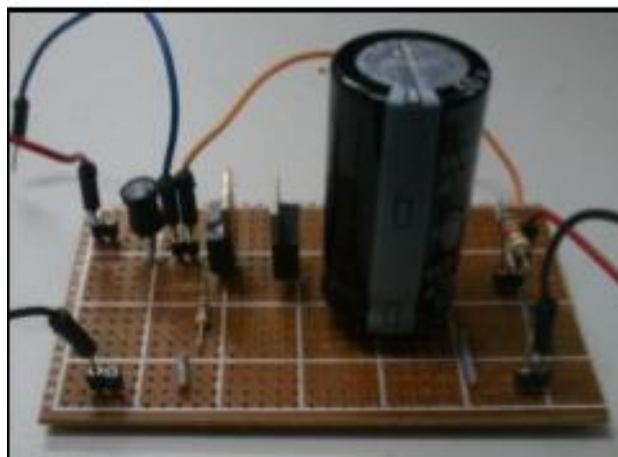
(b)

Figure 4.5: DC-DC boost converter in (a) top view and (b) side view

4.5   OPTOCOUPLER

From the controller of Arduino, the circuit of optocoupler is used as MOSFET driver to build the crest voltage, Vpp as signal of PWM. 5V of Vpp only can give by Arduino. On the grounds that the base exchanging voltage of the IRF830 MOSFET, the driver required in the DC-DC support converter is 10V and with Vin of controller of Arduino, optocoupler can operate as far as 12V. Optocoupler of 4N25, resistors of 10kΩ and 150Ω are built in this circuit.
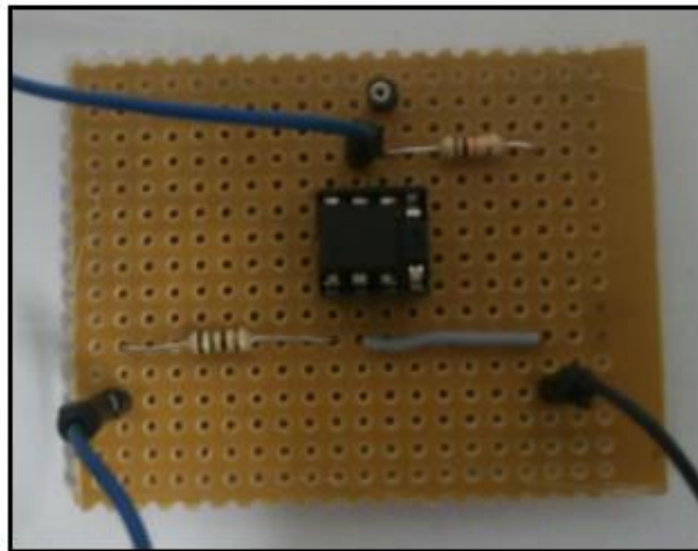
Figure 4.6: Circuit of optocoupler

4.6   MICROCONTROLLER CONCERNING FUZZY LOGIC

The microcontroller used in this project is the ATmega328 which is included in the Arduino Uno Rev3 board. The Arduino Uno has been used to upload a fuzzy logic C program where the program can optimise the power of the solar by controlling the duty cycle of MOSFET in boost converter according to the output voltage of the solar panel. The first input of the controller is the output voltage of solar panel. The second input is the reference voltage. The inputs for the fuzzy logic program are the error and change of error.

The calculations for these inputs have been written in methodology. The output of the controller and also fuzzy logic program is the PWM duty cycle for the MOSFET. Before connect the controller with solar panel and boost converter, it is connected with DC power supply for the input voltage and Digital Storage Oscilloscope (DSO) for checking the PWM output. The required debugging was done to see the final PWM output at DSO. The Figure 4.7 shows the Arduino Uno controller with those connections mentioned above.
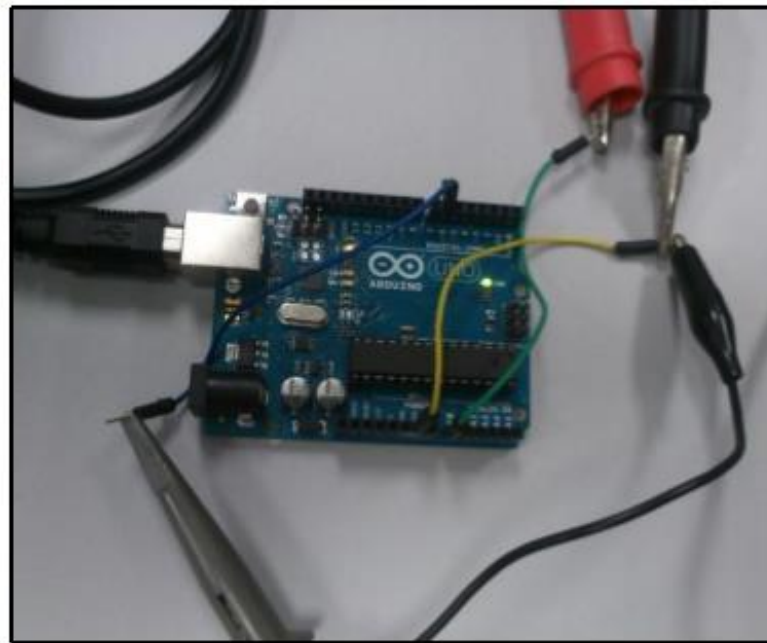
Figure 4.7: The relation of DSO and power supply with Arduino Uno

4.7   FUZZY LOGIC CONTROLLER WITH OUTPUT

Table 4.4 demonstrates the information gathered from the controller of Arduino Uno utilizing the Power Supply of DC for the information voltage supplied the sunlight based board and also DSO to demonstrate the PWM reaction with the estimation of obligation cycle. This strategy has been directed to check the fluffy rationale coding or program. The obligation cycle had changed by estimation of mistake and change of blunder.

Table 4.4: Using fuzzy logic coding and controller to collect data

V_{pv} (V)	V_{ref} (V)	Error	Change of Error	Duty cycle Digital Value (0-255)
9.40	18	0.48	0.48	220
14.05	18	0.22	-0.26	96
7.40	18	0.59	0.37	205
3.65	18	0.80	0.21	254
20.00	18	-0.11	-0.91	0
20.00	18	-0.11	0.00	127
16.95	18	0.06	0.17	136
13.05	18	0.28	0.22	150

In a DSO, the Arduino Uno caught PWM yield signal. As declare some time recently, the obligation cycle had fluctuated by mistake and change of blunder of the fluffy rationale while from the controller, the PWM reactions were varied by obligation cycle. Figure 4.8, 4.9 and 4.10 demonstrates a few reactions for various obligation cycle rate systems.
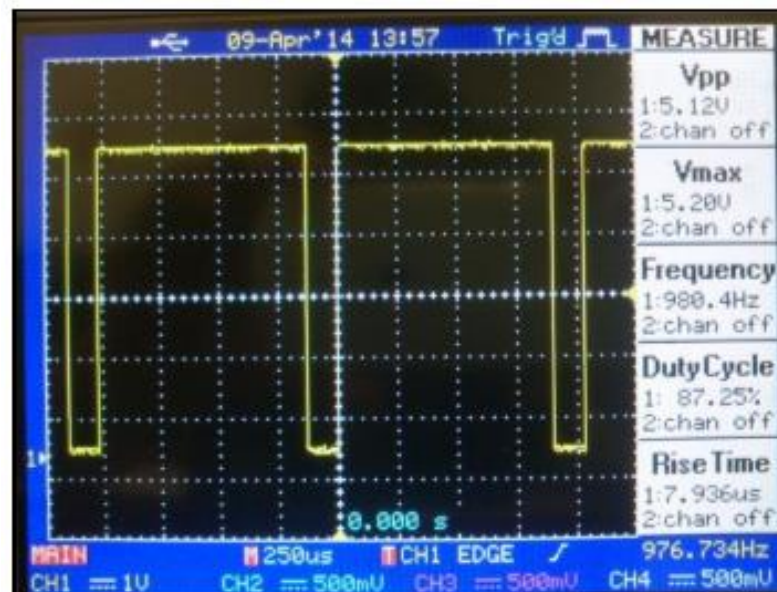
Figure 4.8: High obligation cycle of PWM output (87.25%)
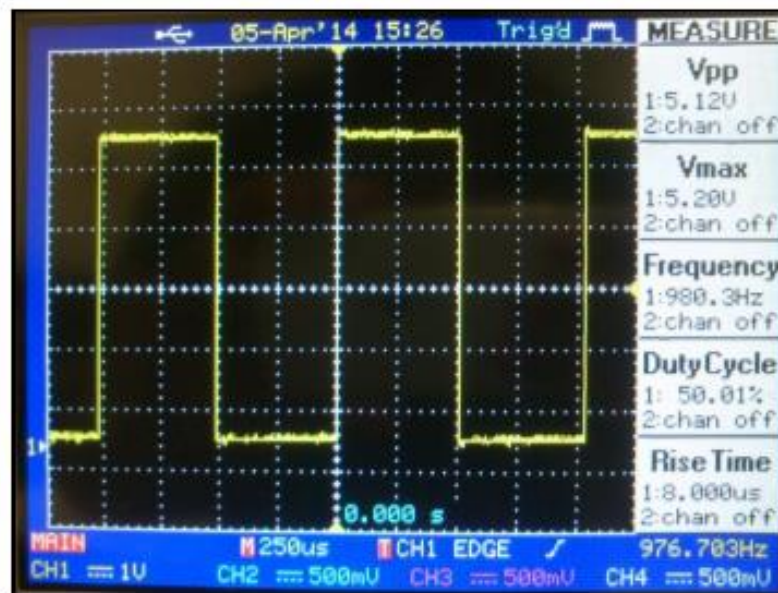
Figure 4.9: Average obligation cycle of PWM output (50.00%)
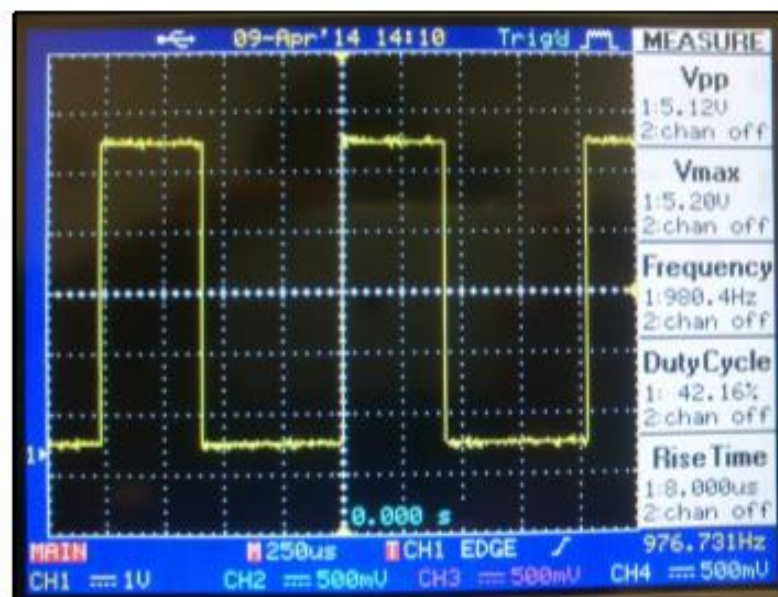
Figure 4.10: Low obligation cycle for PWM output (42.16%)

4.8   OPTOCOUPLER OUTPUT

The top voltage of PWM sign has been expanded by the optocoupler to a roughly 12V. This voltage can turn on the MOSFET. The reaction got from the circuit of optocoupler can be found in Figure 4.11, 4.12 and 4.13.
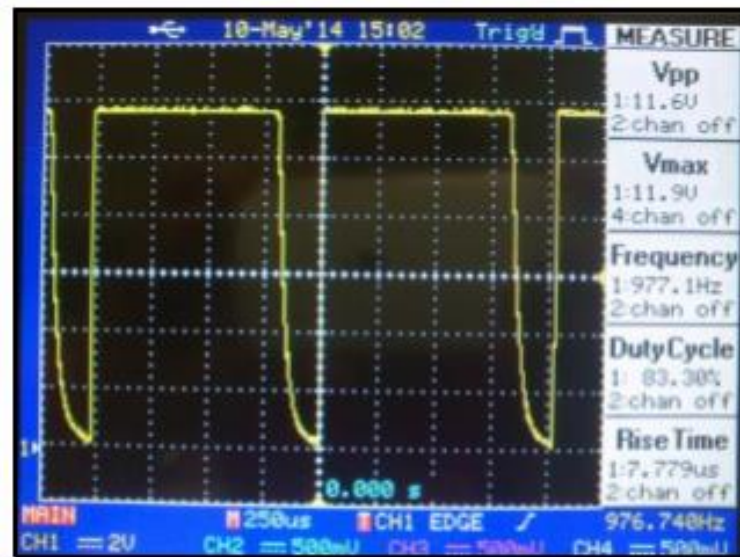
Figure 4.11: High obligation cycle of PWM output
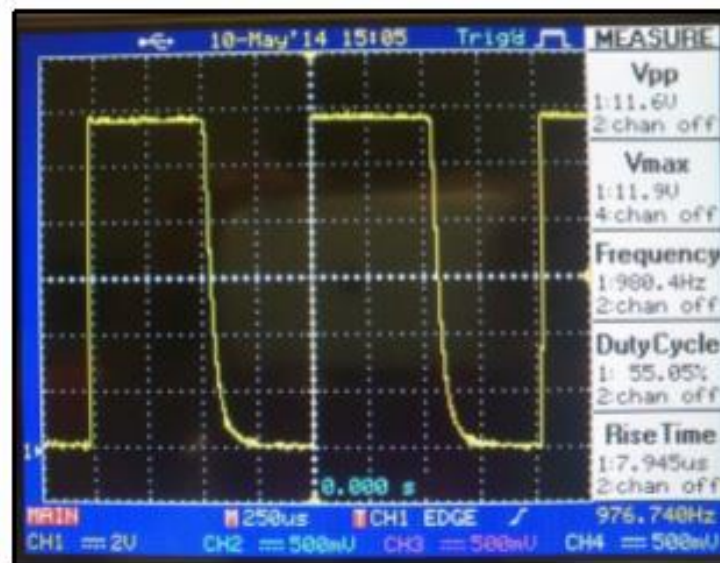
Figure 4.12: Medium obligation cycle of PWM output
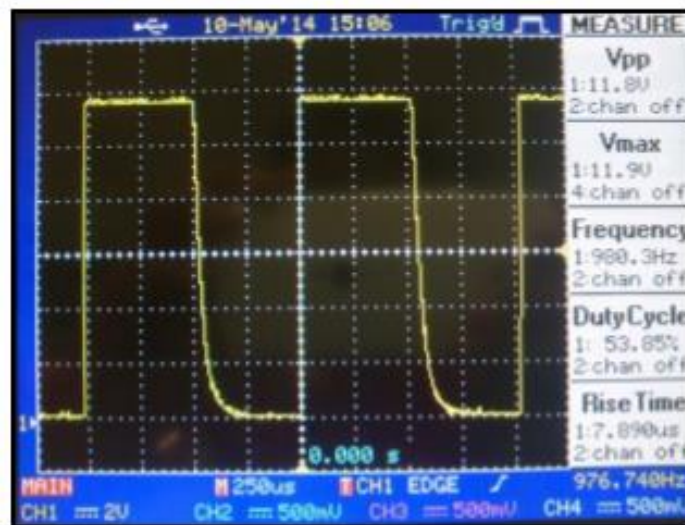
Figure 4.13: Low obligation cycle of PWM output

4.9   TESTING COMPLETE PROTOTYPE

The Figure 4.14 demonstrates the experimentation which accomplished for the complete planned framework. The yield voltage acquired against full framework and the yield voltage got straightforwardly from the sun oriented board was caught and thought about in DSO. The output voltage obtained from the designed system has been more stable than the output voltage obtained directly from the solar panel.

Furthermore, the fuzzy logic controller has optimized the system by providing high duty cycle when the output voltage from the solar panel is lower than V_{MPP} and low duty cycle when the output voltage from the solar panel is higher than V_{MPP}.
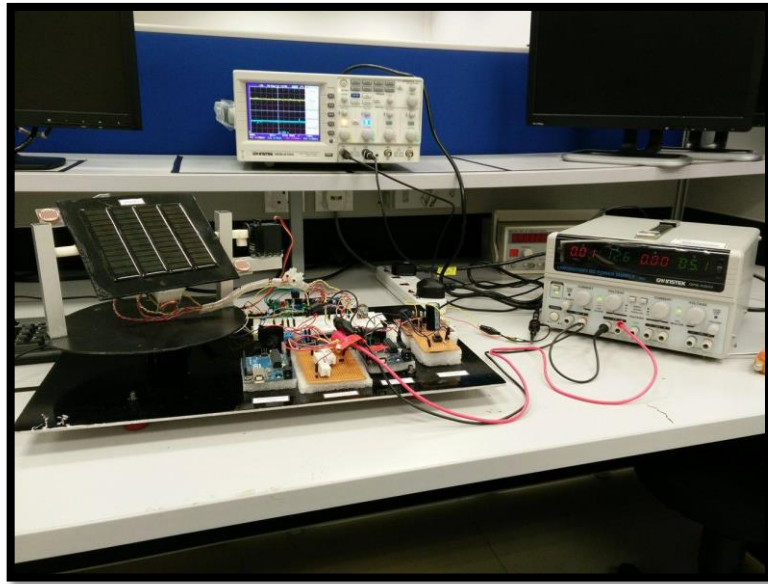
Figure 4.14: Output measuring for boost converter
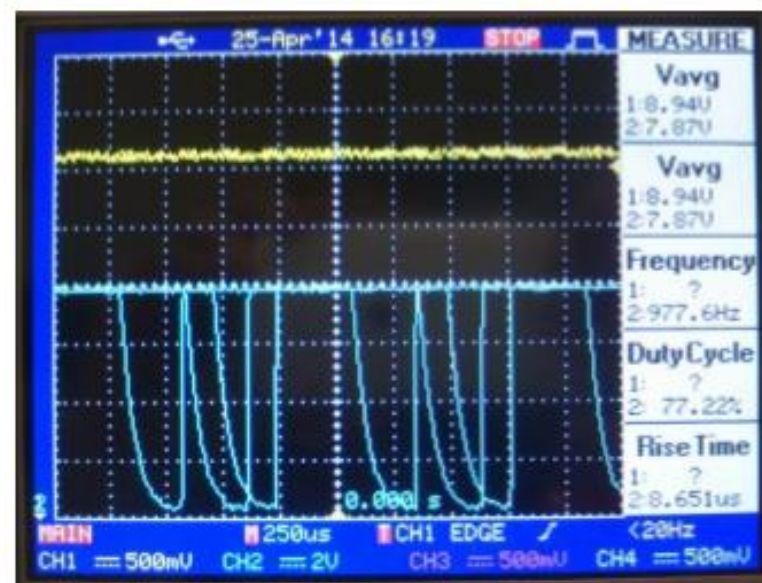
(a)
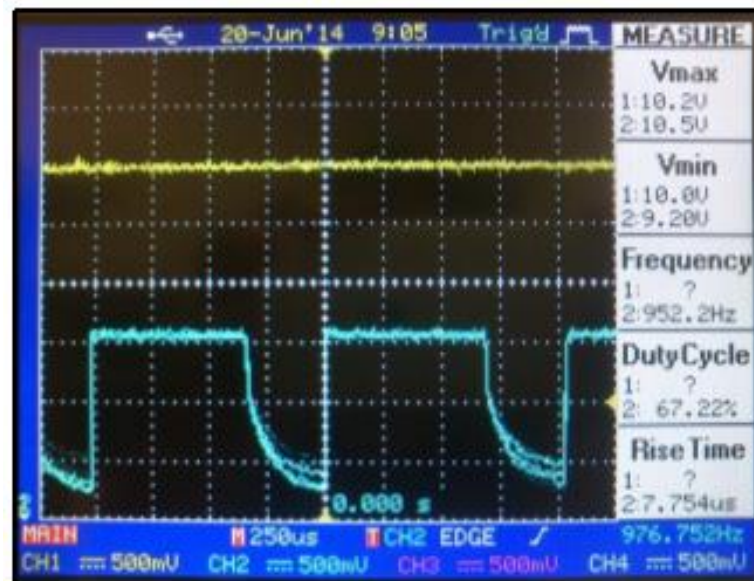
(b)

Figure 4.15: Comparison with solar powered board direct yield voltage (blue) and solar powered board with FLC and boost converter yield voltage (yellow) with variable warmth condition, (a) and (b)

4.10 CONCLUSION

In general, this section has clarified about every circuit in the framework and in addition it demonstrated the genuine circuits independently. The output from each circuit also had been discussed. The yield from the controller which was acquired with the coding of Arduino was appeared in this part shrewdly by shifting the potential difference. The entire model had been tried with the daylight vitality. The information of the last yield voltage of sun oriented board is Fuzzy Logic Controller with the support converter and the yield voltage specifically from sun based board was analysed.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 OVERVIEW

This chapter concludes all the significant findings of this project. This chapter also gives some recommendations and suggestions for the future improvement of the project.

5.2 CONCLUSION

Definitively, the targets of this anticipate were accomplished. The model of the ideal sun based cell execution utilizing dc-dc help converter controlled by fluffy rationale controller was effectively outlined and created. The model can be used to enhance the productivity of the sun powered board.

The framework consists of three primary parts which are sun powered board, DC-DC help converter and fluffy rationale controller. The controller can control the obligation cycle of the PWM signal also deliver to MOSFET. Also, the support converter can manage the potential difference of sun powered board as per MOSFET signal. Overall, the prototype had optimised the efficiency of solar panel.

5.3   RECOMMENDATIONS FOR THE FUTURE STUDY

This anticipates had effectively outlined. In any case, there are a few enhancements that can actualize for a superior effective framework later the current composed framework. The following are a few proposals for the future upgrades.

i.   Utilize a greater sunlight based board with high most extreme energy to acquire a superior result.

ii.   Expand the phonetic variables in participation elements of fluffy rationale inputs and yield to get a more successful variety of obligation cycle.

iii.   The tracking system can be installed with DC to AC inverter where it can convert the DC current to AC current and electrical appliances.

iv.   The battery should be replaced with the battery which has larger capacity and power for more efficiency.

REFERENCES

Bai, Y., Zhuang, H. and Wang, D. 2006. *Advanced Fuzzy Logic Technologies in Industrial Applications*. London: Springer-Verlag London Limited.

Bawa, D., and Patil, C. Y. 2013. Fuzzy control based solar tracker using Arduino uno, *International Journal of Engineering and Innovative Technology (IJEIT)*. **2**(12): 179–187.

Basil, M.H., El-Moghany and Mohammed S. 2012. Fuzzy Controller Design using FPGA for Photovoltaic Maximum Power Point Tracking. *International Journal of Advanced Research in Artificial Intelligence (IJARAI)*. **1**(3): 14-21.

Ibrahim, H.E.A., and Ibrahim, M. 2012. Comparison Between Fuzzy and P&O Control for MPPT for Photovoltaic System using Boost Converter. *Journal of Energy Technologies and Policy*. **2**(6): 1-11.

Iqbal, S., Boumella, N. and Figueroa, J.C. 2012. Fuzzy Controllers Recent Advances in Theory and Applications (online). www.intechopen.com (15 January 2016).

Kargarnejad, A., Taherbaneh, M. and Kashefi, A.H. 2013. A New Fuzzy-Based Maximum Power Point Tracker for a Solar Panel Based on Datasheet Values. *International Journal of Photoenergy Volume*, 1-9.

Khan, S.A. and Hossain, M.I. 2010. Design and Implementation of Microcontroller Based Fuzzy Logic Control for Maximum Power Point Tracking of a Photovoltaic System. *6th International Conference on Electrical and Computer Engineering*. 322-325.

Koide, N., Islam, A., Chiba, Y. and Han, L. 2006. Improvement of Efficiency of Dye-Sensitized Solar Cells Based on Analysis of Equivalent Circuit. *Journal of Photochemistry and Photobiology A: Chemistry*. **182**: 296-305.

Maniam, V. 2014. *Model Prototype of Photovoltaic Tracking System and Photovoltaic Battery Storage*. Degree. Thesis. University Malaysia Pahang, Malaysia.

Mitulkumar, R.D. and Dave, K.C. 2012. Analysis of Boost Converter using PI Control Algorithms. *International Journal of Engineering Trends and Technology*. **3**(2): 71-73.

Mohan, N., Tore, M.U., and William, P.R. 2002. *Power Electronics: Converters, Applications, and Design*. 3rd ed. New York: Wiley.

Negnevitsky, M. 2011. *Artificial Intelligence*: *A Guide to Intelligent Systems*. 3rd ed. England: Pearson Education Limited.

Nhivekar, G.S., Nirmale, S.S., and Mudholker, R.R. 2011. Implementation of fuzzy logic control algorithm in embedded microcomputers for dedicated application. *International Journal of Engineering, Science and Technology.* **3**(4): 276-283.

Patcharaprakitia, N., Premrudeepreechacharnb, S. and Sriuthaisiriwong, Y. 2005. Maximum Power Point Tracking Using Adaptive Fuzzy Logic Control for Grid-Connected Photovoltaic System.1-18.

Pattnaik, D., Sahu, B. and Samantaray, D. 2013. *Microcontroller Based Implementation of a Fuzzy Knowledge Based Controller*. Degree. Thesis. Department of Electrical Engineering, National Institute of Technology, Rourkela.

Rahmani, R., Seyedmahmoudian, M., Mekhilef, S. and Yusof, R. 2013. Implementation of Fuzzy Logic Maximum Power Point Tracking Controller for Photovoltaic System. *American Journal of Applied Sciences*, **10**(3), 209-218.

Shrivastava, S.M. 2013. *Dual Axis Solar Tracker*. Degree. Thesis. Raj Kumar Goel Institute of Technology, Lucknow.

Siddik, A.A. and Shangeetha, M. 2012. Implementation of Fuzzy Logic Controller in Photovoltaic Power Generation using Boost Converter and Boost Inverter. *International Journal of Power Electronics and Drive System (IJPEDS).* **2**(3): 249-256.

Sivanandam, S.N., Sumathi, S., & Deepa, S.N. 2007. *Introduction to fuzzy logic using MATLAB*. Tamil Nadu, India: Springer.

Yao, Y., Hu, Y., Gao, S., Yang, G., and Du, J. 2014. A multipurpose dual-axis solar tracker with two tracking strategies. *Renewable Energy*. 72: 88–98 (online). http://doi.org/10.1016/j.renene.2014.07.002 (16 January 2016).

Zainal, N.A. and Ganaisan, S. A. 2015. Optimum Solar Panel Implementation Using DC-DC Boost Converter Controlled by Fuzzy Logic Controller. In *Applied Mechanics and Materials*. Vol. 793: pp. 378-382. Trans Tech Publications.

Zakariah, A., Jamian, J. J., & Yunus, M. A. 2015. Dual-Axis Solar Tracking System Based on Fuzzy Logic Control and Light Dependent Resistors as Feedback Path Elements. *IEEE Student Conference on Research and Development (SCOReD)*. 139–144.

APPENDIX A

ARDUINO CODE FOR SOLAR TRACKER

```
#include <Servo.h>
Servo servo_Vertical;      // create servo object to control a servo (Vertical)
Servo servo_Horizonal;     // create servo object to control a servo (Horizontal)
int val_Vertical=90;       // variable to read the value from the analog pin
int val_Horizonal=90;      // variable to read the value from the analog pin
//==========================================================
const int referenceVolts = 5;
const float R1 = 51000.0;    //Resistor #1 (51K)
const float R2 = 100000.0;   //Resistor #2 (100K)
const float Ratio = (R1/R2);


const float resistorFactor = ((referenceVolts/Ratio)/1023.0);  // eq 0.014471088
const int TolarencePin = A4;  // Use Potentiometer for Tolarence Settings
const int solarPin = A5;      // +V from Solar Panel connected to analog pin
float v = 0;
//
const int LDR_1_Left = A0;      // LDR connected to Analog Pin 0 Left
const int LDR_2_Right = A1;     // LDR connected to Analog Pin 1 Right
const int LDR_3_Down = A2;      // LDR connected to Analog Pin 2 Down
const int LDR_4_Up = A3;        // LDR connected to Analog Pin 3 Up
//
int LDR_1_Left_val = 0;
int LDR_2_Right_val = 0;
int LDR_4_Up_val = 0;
int LDR_3_Down_val = 0;
//
//LEDs 10=UP; 11=Right; 12=Left; 13=Down
int ledPins[] = {10,11,12,13};
//
int dtime = 25;
```

```
int Tolarence = 0;

void setup()
{
servo_Vertical.attach(5);  // attaches the servo on pin 5 (Elevation) to the servo object
servo_Horizonal.attach(6); // attaches the servo on pin 6 (Horizontal) to the servo
object

//Setup LED Pins as OUTPUT
for (int x = 0; x < 4; x++){
pinMode(ledPins[x], OUTPUT);
}
Serial.begin(9600);
}



void loop()
{
reset_leds();
read_potentiometer();
read_voltage();
read_LDRs();
adjust_Servos();

display_status();
delay(dtime);                    // waits for the servo to move
}


//============================================================
// Subs....
//============================================================
void reset_leds(){
for (int x = 0; x < 4; x++){
```

```
digitalWrite(ledPins[x], LOW);

}

}

//==============================================================

void read_potentiometer(){

// Use Potentiometer for Tolarence Settings

Tolarence = analogRead(TolarencePin)/4;

}


//==============================================================

void read_voltage(){

v = analogRead(solarPin);

v *= resistorFactor;

} // end read_voltage


//==============================================================

void read_LDRs(){

// Set the LDRs in an x config and label the LDRs from 1-4

//   \ 4 /

//   1 X 2

//   / 3 \

///arduino LDR Pins 10=UP; 11=Right; 12=Left; 13=Down

 LDR_1_Left_val = analogRead(LDR_1_Left);

 LDR_2_Right_val = analogRead(LDR_2_Right);

 LDR_3_Down_val = analogRead(LDR_3_Down);

 LDR_4_Up_val = analogRead(LDR_4_Up);

} //end read_LDRs


//==============================================================

void adjust_Servos(){

int avg_Left_Top =    (LDR_1_Left_val +  LDR_4_Up_val) / 2;      // average value
Left_Top

int avg_Left_Botton =  (LDR_1_Left_val +  LDR_3_Down_val) / 2;     // average
value Left_Botton
```

```
int avg_Right_Top =    (LDR_2_Right_val + LDR_4_Up_val) / 2;        // average
value Right_Top
int avg_Right_Botton = (LDR_2_Right_val + LDR_3_Down_val) / 2;      // average
value Right_Botton


int dvert = (avg_Left_Top + avg_Right_Top) - (avg_Left_Botton +
avg_Right_Botton);
// check the diffirence of up and down
int dhoriz = (avg_Left_Top + avg_Left_Botton) - (avg_Right_Top +
avg_Right_Botton);// check the diffirence og left and rigt


// Using the tolarence value stop servo seeking
// Check Vertical
if (-1*Tolarence > dvert || dvert > Tolarence){ // check if the diffirence is in the
tolerance else change vertical angle
if ((avg_Left_Top + avg_Right_Top) > (avg_Left_Botton + avg_Right_Botton)){
//adjust Vertical Servo Down
digitalWrite(ledPins[3], HIGH); //Blink the Bottom LED
val_Vertical = ++val_Vertical;
if (val_Vertical > 179){
val_Vertical = 179;
}
}


else if ((avg_Left_Top + avg_Right_Top) < (avg_Left_Botton + avg_Right_Botton)){
//adjust Vertical Servo Up
val_Vertical= --val_Vertical;
digitalWrite(ledPins[0], HIGH); //Blink the Top LED
if (val_Vertical < 1){
val_Vertical = 1;
}
}
servo_Vertical.write(val_Vertical);
}
```

```
//Check Horizonal
if (-1*Tolarence > dhoriz || dhoriz > Tolarence){ // check if the diffirence is in the
tolerance else change horizontal angle
if ((avg_Left_Top + avg_Left_Botton) > (avg_Right_Top + avg_Right_Botton)){
//adjust Horizonal Servo Left
val_Horizonal = --val_Horizonal;
digitalWrite(ledPins[1], HIGH); //Blink the Left LED
if (val_Horizonal < 1){
val_Horizonal = 1;
}
}
else if ((avg_Left_Top + avg_Left_Botton) < (avg_Right_Top + avg_Right_Botton)){
//adjust Horizonal Servo Right
val_Horizonal = ++val_Horizonal;
digitalWrite(ledPins[2], HIGH); //Blink the Right LED
if (val_Horizonal > 179){
val_Horizonal = 179;
}
}
else if ((avg_Left_Top + avg_Left_Botton) == (avg_Right_Top +
avg_Right_Botton)){
// nothing
}
servo_Horizonal.write(val_Horizonal);
}
} // end adjust servos


//===========================================================
void display_status(){
Serial.print("Solar Panel Volts: ");
Serial.print(v);

Serial.print("  Servo Horizontal: ");
Serial.print(val_Horizonal);
```

```
Serial.print("  Servo Vertical: ");
Serial.print(val_Vertical);

Serial.print("  LDR_1_L: ");
Serial.print(LDR_1_Left_val);
Serial.print("  LDR_2_R: ");
Serial.print(LDR_2_Right_val);
Serial.print("  LDR_3_D: ");
Serial.print(LDR_3_Down_val);
Serial.print("  LDR_4_U: ");
Serial.print(LDR_4_Up_val);

Serial.print("  Tolarence: ");
Serial.println(Tolarence);
} //end display status
```

APPENDIX B

ARDUINO CODING FOR FUZZY LOGIC CONTROLLER

```
#define Rf 3.6
#define In A1
#define Out 5
float Ref; // Reference value
float voltage; // Voltage from PV Panel
float vol; // Real voltage value after convert from 0-1023 to 0-5V
float e; // Error (Input 1 for fuzzy logic controller)
float ce; // Change of Error (Input 2 for fuzzy logic controller)
float dat[2]={0,0}; // Storage variable for error values of k and k-1
float dutyRatio; // Output of the fuzzy logic controller
boolean i=false;
// The setup routine runs once when you press reset:
void setup()
{
Serial.begin(9600);
// Initialize the analog pins for input
// Set pin as input for reference voltage
pinMode(Rf, INPUT);
// Set pin as input for voltage of PV panel
pinMode(In, INPUT);
// Initialize the analog pin for output
// Set pin as output for MOSFET dutyratio
pinMode(Out, OUTPUT);
//Read the reference value from the input, Rf
Ref=Rf*1023/5;
Serial.print("The Reference value = ");
Serial.println(Ref);
}
// The loop routine runs over and over again forever:
void loop()
```

```
{
// Read the output voltage of PV panel
voltage = analogRead(In);
vol=((float)voltage*5/1023);
Serial.print("The actual voltage of PV panel = V");
Serial.println(vol);
// Calculate the error by comparing the vol with Ref and finally normalized it
e=(float)(Ref-voltage)/3.6;
e=(e*5)/1023;
Serial.print("The Error value = ");
Serial.println(e);
dat[i]=e;
// Calculate the Change of Error by comparing current error and the the previous error
ce=dat[i]-dat[!i];
i=!i;
Serial.print("The Change of Error value = ");
Serial.println(ce);
// Apply fuzzy logic system
dutyRatio= PVpower_optimization(e,ce);
// Obtain the crisp value of the output from the fuzzy logic controller
dutyRatio=(dutyRatio+1)*255/2;
// Get the output value from the fuzzy logic system
analogWrite(Out, (int)dutyRatio);
// Send the PWM output
Serial.print("The crisp value of dutyratio = ");
Serial.println((int)dutyRatio);
delay(1000);
}
// Fuzzy Inference
float PVpower_optimization(float er,float cer)
{
float x0[3],x1[3],x2[3];
float dutyRatio;
float aggre;
```

```
// Fuzzification & Rule Evaluation
for(int i=0;i<3;i++)
{
x0[i]=0;
x1[i]=0;
x2[i]=0;
}
// Input 1(Error)
if(er<-0.8)
{
x0[0]=-1.25*er-0.25;
}
if((er>-0.8) && (er<-0.2))
{
x0[0]=-1.25*er-0.25;
x0[1]=1.25*er+1;
}
else if((er>-0.2) && (er<0))
{
x0[1]=1.25*er+1;
}
else if((er>0)&&(er<0.2))
{
x0[1]=-1.25*er+1;
}
else if((er>0.2) && (er<0.8))
{
x0[1]=-1.25*er+1;
x0[2]=1.25*er-0.25;
}
else if((er>0.8) && (e<1))
{
x0[2]=1.25*er-0.25;
}
```

```
// Input2(Change of Error)
if((cer>-0.7) && (cer<-0.56))
{
x1[0]=-1.786*cer-0.25;
}
if((cer>-0.56) && (cer<-0.14))
{
x1[0]=-1.786*cer-0.25;
x1[1]=1.786*cer+1;
}
else if((cer>-0.14) && (cer<=0))
{
x1[1]=1.786*cer+1;
}
else if((cer>0) && (cer<0.14))
{
x1[1]=-1.786*cer+1;
}
else if((cer>0.14) && (cer<0.56))
{
x1[1]=-1.786*cer+1;
x1[2]=1.786*cer-0.25;
}
else if((cer>0.56) && (cer<0.7))
{
x1[2]=1.786*cer-0.25;
}
// Aggregation
// Output
for(int i=0;i<3;i++)
{
for(int j=0;j<3;j++)
{
if((x0[i]!=0 )&& (x1[j]!=0))
```

```
{
if((i+j)<2)
{
aggre=x2[0];
x2[0]=x0[i]<x1[j]?x0[i]:x1[j];
x2[0]=aggre>x2[0]?aggre:x2[0];
}
else if((i+j)==2)
{
aggre=x2[1];
x2[1]=x0[i]<x1[j]?x0[i]:x1[j];
x2[1]=aggre>x2[1]?aggre:x2[1];
}
else if((i+j)>2)
{
aggre=x2[2];
x2[2]=x0[i]<x1[j]?x0[i]:x1[j];
x2[2]=aggre>x2[2]?aggre:x2[2];
}
}
}
}
// Defuzzification
dutyRatio=((-1*x2[0])+(0*x2[1])+(1*x2[2]))/(x2[0]+x2[1]+x2[2]);
return dutyRatio;
}
```

APPENDIX C

ARDUINO CODING FOR DATA ACQUISITION SYSTEM

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
int delayData = 80; // Set a delay period for the data transferred to Excel and attempt
to reduce data volumes
int sample2=0.0;
float current;
float x;
float sample1=0.0;
float vout = 0.0;
float vin = 0.0;
float R1 = 10000.0; // resistance of R1 (100K) -see text!
float R2 = 1000.0; // resistance of R2 (10K) - see text!
int value = 0;
float Power=0;
int y=0;
int row = 0; // Set the starting Excel row

void setup (){
Serial.begin(9600);
Serial.println("CLEARDATA"); //clears any residual data
Serial.println("LABEL, Time, Voltage, Current, Power");

lcd. begin (20, 4);
lcd.print ("DC VOLTMETER");
}
void loop () {
// read the value at analog input
//value = analogRead(analogInput);
for (int i=0; i<250; i++)
{
```

```
sample1+=analogRead (0); //read the voltage from the sensor
delay (2);
}
sample1=sample1/250;


vout = (sample1* 4.40) / 1024; // see text
vin = (vout / (R2/(R1+R2))-0.20);
if (vin<0.14) {
vin=0.0;//statement to quash undesired reading!
}


/////current measurement////////
for (int j=0; j<250; j++)
{
sample2+= (analogRead (2)-511); //read the voltage from the sensor


delay (2);
}
sample2=sample2/250;
x=sample2;
current = ((x)*5/1024/0.04-0.04) +0.13;


if (sample2<2)
{
current=0;
}
Power=current*vin;
lcd. setCursor(0,0);
lcd.print ("Voltage: ");
lcd.print(vin,2);
lcd.print (" V");
Serial.println(vin);
lcd. setCursor (0,1);
lcd.print ("Current: ");
```

```
lcd.print(current,2);
lcd.print(" A");
Serial.println(current,2);
lcd.setCursor(0,2);
lcd.print ("POWER: ");
lcd.print(Power,2);
lcd.print (" W");
Serial.println(Power,2);
Serial.print("DATA, TIME,"); Serial.print(vin); Serial.print(",");
Serial.print(current,2); Serial.print(","); Serial.println(Power);
row++;
y++;
// MyPlot.SendData("Voltage", vin);
// MyPlot.SendData("Current", current);
// MyPlot.SendData("Power", Power);
//delay (500);
}
```

APPENDIX D

SERIAL MONITOR DATA FROM ARDUINO


```
The Error value = 0.48
The Change of Error value = 0.48
The crisp value of dutyratio = 220
The actual voltage of PV panel = V2.81
The Error value = 0.22
The Change of Error value = -0.26
The crisp value of dutyratio = 96
The actual voltage of PV panel = V1.48
The Error value = 0.59
The Change of Error value = 0.37
The crisp value of dutyratio = 205
The actual voltage of PV panel = V0.73
The Error value = 0.80
The Change of Error value = 0.21
The crisp value of dutyratio = 254
```

```
The Error value = -0.11
The Change of Error value = 0.00
The crisp value of dutyratio = 127
The actual voltage of PV panel = V4.00
The Error value = -0.11
The Change of Error value = 0.00
The crisp value of dutyratio = 127
The actual voltage of PV panel = V4.00
The Error value = -0.11
The Change of Error value = 0.00
The crisp value of dutyratio = 127
The actual voltage of PV panel = V3.39
The Error value = 0.06
The Change of Error value = 0.17
The crisp value of dutyratio = 136
```

```
The actual voltage of PV panel = V3.39
The Error value = 0.06
The Change of Error value = 0.17
The crisp value of dutyratio = 136
The actual voltage of PV panel = V3.39
The Error value = 0.06
The Change of Error value = 0.00
The crisp value of dutyratio = 127
The actual voltage of PV panel = V2.61
The Error value = 0.28
The Change of Error value = 0.22
The crisp value of dutyratio = 150
```

Figure D.1: Serial Monitor Data from Arduino

APPENDIX E

PHOTOS OF PROTOTYPE
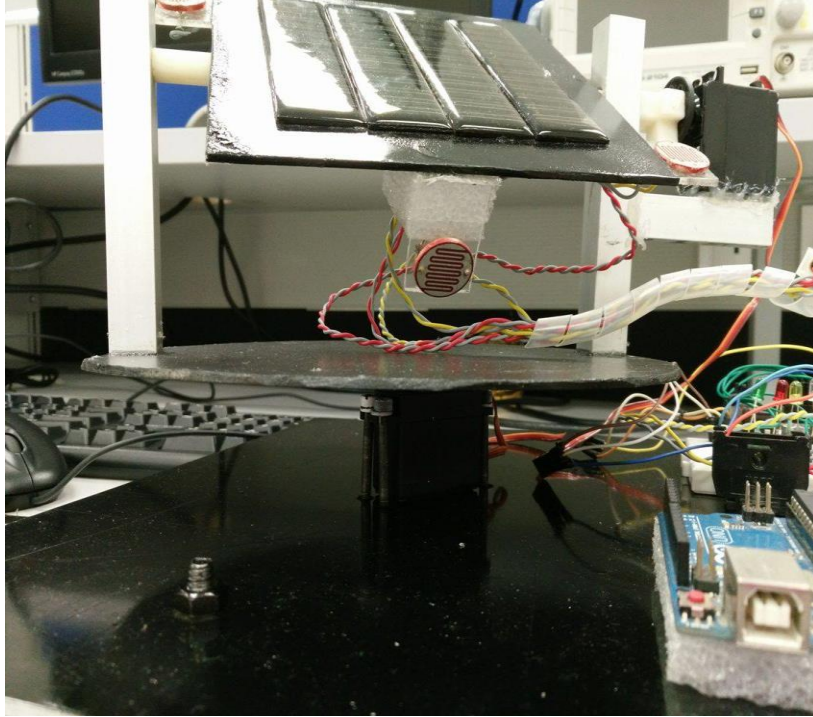
Figure E.1: Side view of solar tracker
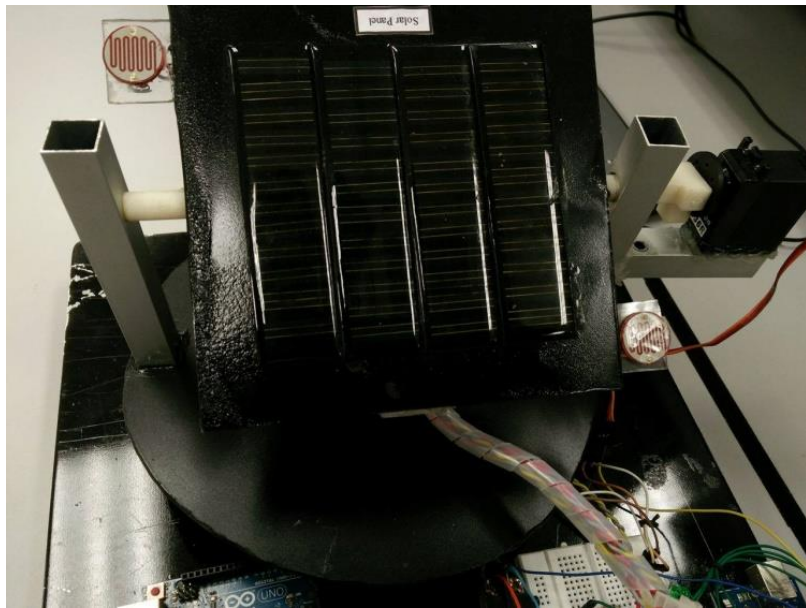
Figure E.2: Top view of solar tracker
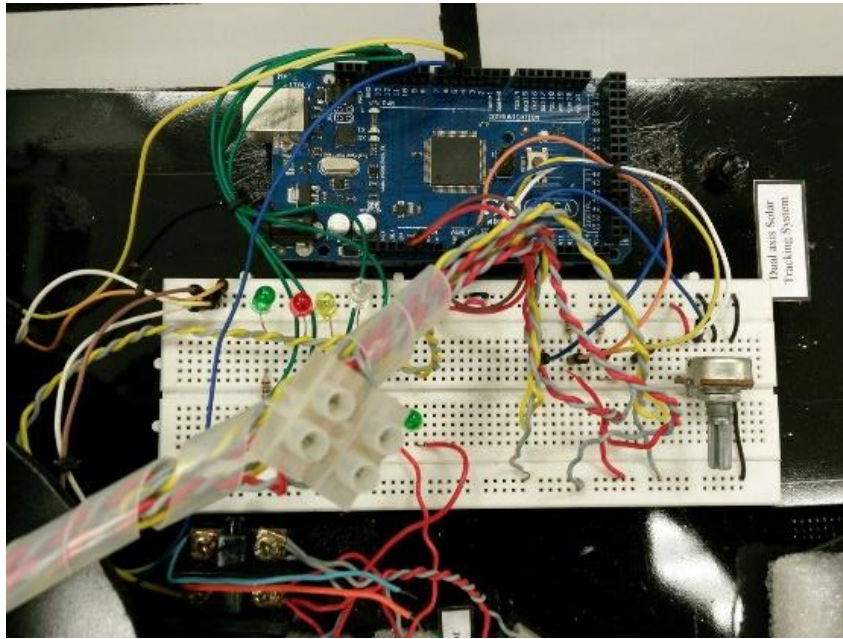
Figure E.3: Circuit of Solar Tacker
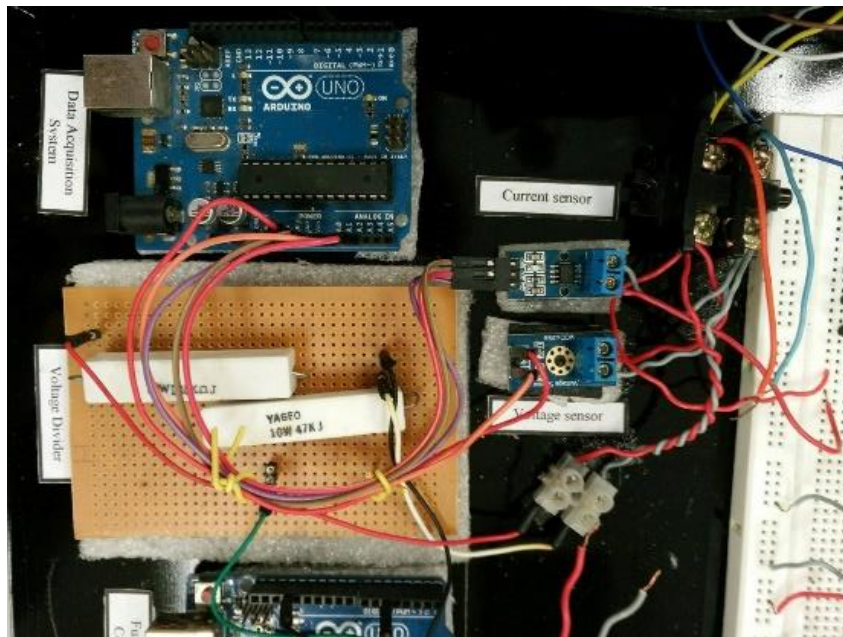
Figure E.4: Circuit of Voltage divider and Arduino Uno for FLC
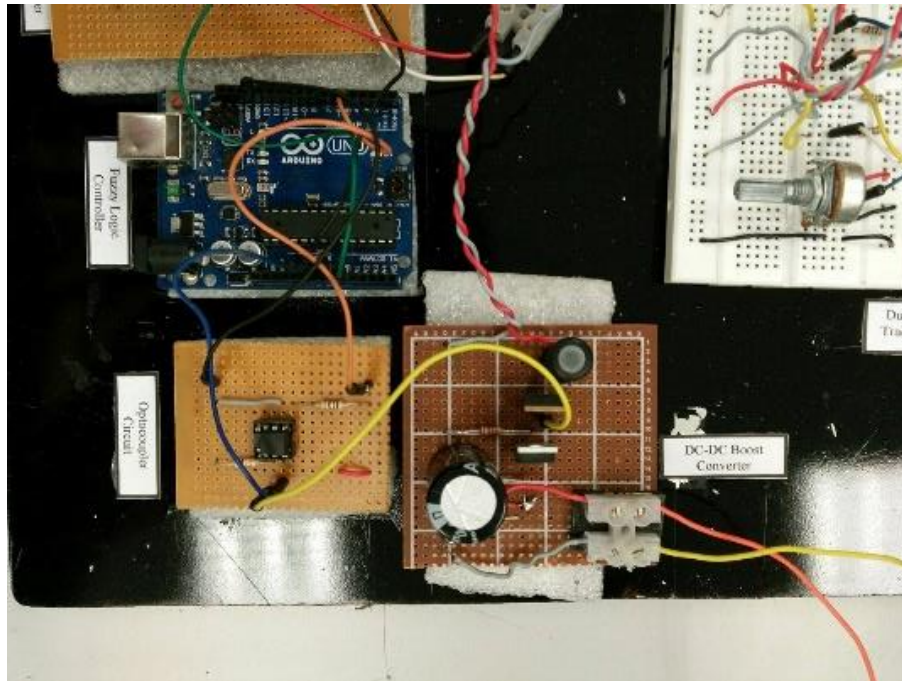
Figure E.5: Circuit of DC-DC Boost Converter and Optocoupler

APPENDIX F

DATASHEET OF SOME IMPORTANT ELECTRONIC COMPONENTS

Figure F.1: Arduino Uno

Technical Specification

EAGLE files: arduino-duemilanove-uno-design.zip Schematic: arduino-uno-schematic.pdf

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

the board
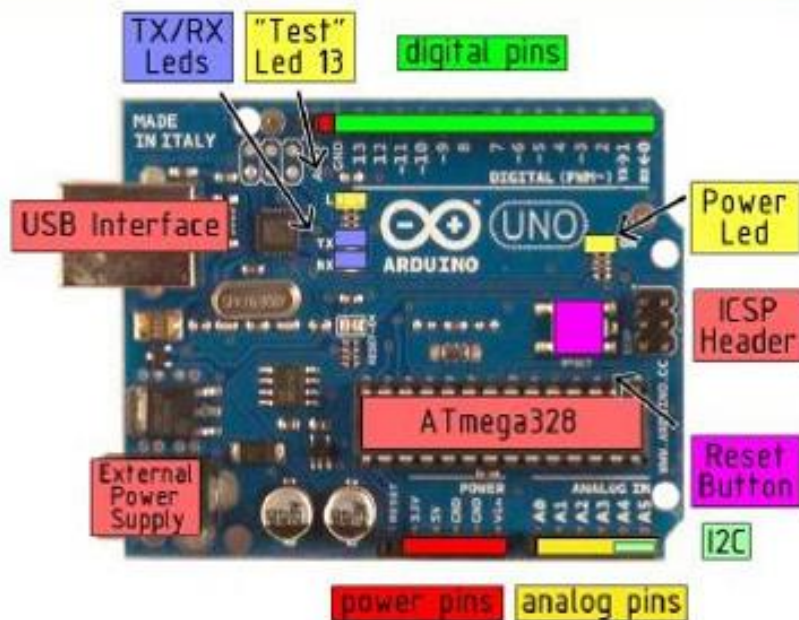
Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The Atmega328 has 32 KB of flash memory for storing code (of which 0,5 KB is used for the bootloader); it has also 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. TThese pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip .
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.

- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- I²C: 4 (SDA) and 5 (SCL). Support I²C (TWI) communication using the Wire library.

There are a couple of other pins on the board:

- AREF. Reference voltage for the analog inputs. Used with analogReference().
- Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the mapping between Arduino pins and Atmega328 ports.

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an *.inf file is required..

The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Uno's digital pins.

The ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. To use the SPI communication, please see the ATmega328 datasheet.

Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno w/ ATmega328" from the Tools > Board menu (according to the microcontroller on your board). For details, see the reference and tutorials.

The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

The ATmega8U2 firmware source code is available . The ATmega8U2 is loaded with a DFU bootloader, which can be activated by connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader).

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

How to use Arduino

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, MaxMSP).

Arduino is a cross-platform program. You'll have to follow different instructions for your personal OS. Check on the Arduino site for the latest instructions. http://arduino.cc/en/Guide/HomePage

Linux Install   Windows Install   Mac Install

Once you have downloaded/unzipped the arduino IDE, you can Plug the Arduino to your PC via USB cable.

Blink led

Now you're actually ready to "burn" your first program on the arduino board. To select "blink led", the physical translation of the well known programming "hello world", select

File>Sketchbook>
Arduino-0017>Examples>
Digital>Blink

Once you have your skecth you'll see something very close to the screenshot on the right.

In Tools>Board select

Now you have to go to
Tools>SerialPort
and select the right serial port, the one arduino is attached to.

Press Compile button
(to check for errors)

Upload

TX RX Flashing

Blinking Led!

Dimensioned Drawing
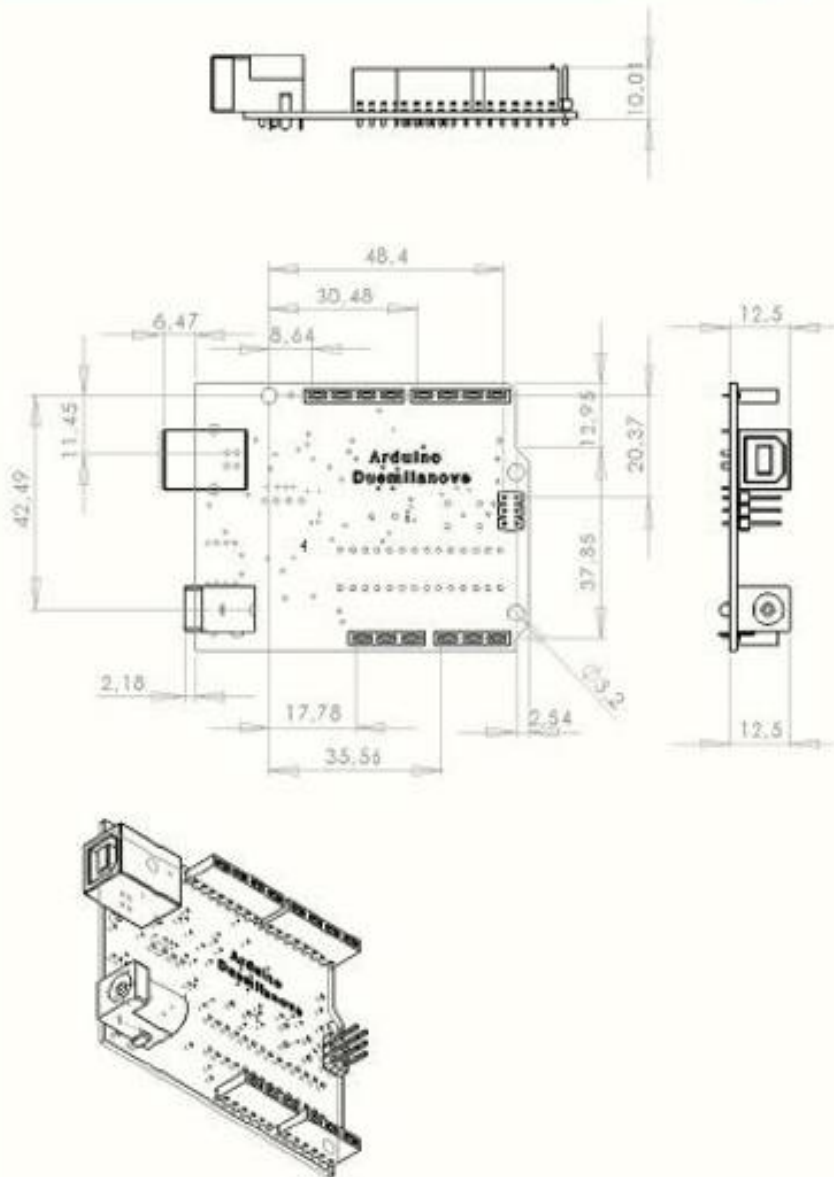
Terms & Conditions

1. Warranties

1.1 The producer warrants that its products will conform to the Specifications. This warranty lasts for one (1) years from the date of the sale. The producer shall not be liable for any defects that are caused by neglect, misuse or mistreatment by the Customer, including improper installation or testing, or for any products that have been altered or modified in any way by a Customer. Moreover, The producer shall not be liable for any defects that result from Customer's design, specifications or instructions for such products. Testing and other quality control techniques are used to the extent the producer deems necessary.

1.2 If any products fail to conform to the warranty set forth above, the producer's sole liability shall be to replace such products. The producer's liability shall be limited to products that are determined by the producer not to conform to such warranty. If the producer elects to replace such products, the producer shall have a reasonable time to replacements. Replaced products shall be warranted for a new full warranty period.

1.3 EXCEPT AS SET FORTH ABOVE, PRODUCTS ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." THE PRODUCER DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING PRODUCTS, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

1.4 Customer agrees that prior to using any systems that include the producer products, Customer will test such systems and the functionality of the products as used in such systems. The producer may provide technical, applications or design advice, quality characterization, reliability data or other services. Customer acknowledges and agrees that providing these services shall not expand or otherwise alter the producer's warranties, as set forth above, and no additional obligations or liabilities shall arise from the producer providing such services.

1.5 The Arduino™ products are not authorized for use in safety-critical applications where a failure of the product would reasonably be expected to cause severe personal injury or death. Safety-Critical Applications include, without limitation, life support devices and systems, equipment or systems for the operation of nuclear facilities and weapons systems. Arduino™ products are neither designed nor intended for use in military or aerospace applications or environments and for automotive applications or environment. Customer acknowledges and agrees that any such use of Arduino™ products which is solely at the Customer's risk, and that Customer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

1.6 Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products and any use of Arduino™ products in Customer's applications, notwithstanding any applications-related information or support that may be provided by the producer.

2. Indemnification

The Customer acknowledges and agrees to defend, indemnify and hold harmless the producer from and against any and all third-party losses, damages, liabilities and expenses it incurs to the extent directly caused by: (i) an actual breach by a Customer of the representation and warranties made under this terms and conditions or (ii) the gross negligence or willful misconduct by the Customer.

3. Consequential Damages Waiver

In no event the producer shall be liable to the Customer or any third parties for any special, collateral, indirect, punitive, incidental, consequential or exemplary damages in connection with or arising out of the products provided hereunder, regardless of whether the producer has been advised of the possibility of such damages. This section will survive the termination of the warranty period.

4. Changes to specifications

The producer may make changes to specifications and product descriptions at any time, without notice. The Customer must not rely on the absence or characteristics of any features or instructions marked "reserved" or "undefined." The producer reserves these for future definition and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them. The product information on the Web Site or Materials is subject to change without notice. Do not finalize a design with this information.

Enviromental Policies

The producer of Arduino™ has joined the Impatto Zero® policy of LifeGate.It. For each Arduino board produced is created / looked after half squared Km of Costa Rica's forest's.

VISHAY.

IRF830, SiHF830

Vishay Siliconix

Power MOSFET

PRODUCT SUMMARY

V_DS (V)		500
R_DS(on) (Ω)	V_GS = 10 V	1.0
Q_g (Max.) (nC)		36
Q_gs (nC)		5.8
Q_gd (nC)		22
Configuration		Single

TO-220AB

N-Channel MOSFET
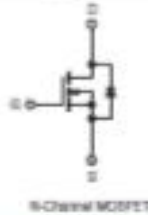
FEATURES
- Dynamic dV/dt Rating
- Repetitive Avalanche Rated
- Fast Switching
- Ease of Paralleling
- Simple Drive Requirements
- Compliant to RoHS Directive 2002/95/EC

RoHS* COMPLIANT

DESCRIPTION

Third generation Power MOSFETs from Vishay provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness.

The TO-220AB package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 W. The low thermal resistance and low package cost of the TO-220AB contribute to its wide acceptance throughout the industry.

ORDERING INFORMATION

Package	TO-220AB
Lead (Pb)-free	IRF830PbF
	SiHF830-E3
SnPb	IRF830
	SiHF830

ABSOLUTE MAXIMUM RATINGS (T_C = 25 °C, unless otherwise noted)

PARAMETER			SYMBOL	LIMIT	UNIT
Drain-Source Voltage			V_DS	500	V
Gate-Source Voltage			V_GS	± 20	
Continuous Drain Current	V_GS at 10 V	T_C = 25 °C	I_D	4.5	A
		T_C = 100 °C		2.9	
Pulsed Drain Current[a]			I_DM	18	
Linear Derating Factor				0.56	W/°C
Single Pulse Avalanche Energy[b]			E_AS	280	mJ
Repetitive Avalanche Current[a]			I_AR	4.5	A
Repetitive Avalanche Energy[a]			E_AR	1.4	mJ
Maximum Power Dissipation	T_C = 25 °C		P_D	74	W
Peak Diode Recovery dV/dt[c]			dV/dt	3.5	V/ns
Operating Junction and Storage Temperature Range			T_J, T_stg	- 55 to + 150	°C
Soldering Recommendations (Peak Temperature)	for 10 s			300[d]	
Mounting Torque	6-32 or M3 screw			10	lbf · in
				1.1	N · m

Notes

a. Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11).
b. V_DD = 50 V, starting T_J = 25 °C, L = 34 mH, R_G = 25 Ω, I_AS = 4.5 A (see fig. 12).
c. I_SD ≤ 4.5 A, dI/dt ≤ 75 A/µs, V_DD ≤ V_DS, T_J ≤ 150 °C.
d. 1.6 mm from case.

* Pb containing terminations are not RoHS compliant, exemptions may apply

Figure F.2: MOSFET (IRF830)

IRF830, SiHF830

Vishay Siliconix

VISHAY.

THERMAL RESISTANCE RATINGS

PARAMETER	SYMBOL	TYP.	MAX.	UNIT
Maximum Junction-to-Ambient	R_{thJA}	-	62	
Case-to-Sink, Flat, Greased Surface	R_{thCS}	0.50	-	°C/W
Maximum Junction-to-Case (Drain)	R_{thJC}	-	1.7	

SPECIFICATIONS (T_J = 25 °C, unless otherwise noted)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
Static						
Drain-Source Breakdown Voltage	V_{DS}	V_{GS} = 0 V, I_D = 250 µA	500	-	-	V
V_{DS} Temperature Coefficient	$\Delta V_{DS}/T_J$	Reference to 25 °C, I_D = 1 mA	-	0.61	-	V/°C
Gate-Source Threshold Voltage	$V_{GS(th)}$	V_{DS} = V_{GS}, I_D = 250 µA	2.0	-	4.0	V
Gate-Source Leakage	I_{GSS}	V_{GS} = ± 20 V	-	-	± 100	nA
Zero Gate Voltage Drain Current	I_{DSS}	V_{DS} = 500 V, V_{GS} = 0 V	-	-	25	µA
		V_{DS} = 400 V, V_{GS} = 0 V, T_J = 125 °C	-	-	250	
Drain-Source On-State Resistance	$R_{DS(on)}$	V_{GS} = 10 V, I_D = 2.7 A	-	-	1.5	Ω
Forward Transconductance	g_{fs}	V_{DS} = 50 V, I_D = 2.7 A	2.3	-	-	S
Dynamic						
Input Capacitance	C_{iss}	V_{GS} = 0 V,	-	610	-	pF
Output Capacitance	C_{oss}	V_{DS} = 25 V,	-	160	-	
Reverse Transfer Capacitance	C_{rss}	f = 1.0 MHz, see fig. 5	-	16	-	
Total Gate Charge	Q_g		-	-	38	nC
Gate-Source Charge	Q_{gs}	V_{GS} = 10 V, I_D = 3.1 A, V_{DS} = 400 V, see fig. 6 and 13	-	-	5.8	
Gate-Drain Charge	Q_{gd}		-	-	20	
Turn-On Delay Time	$t_{d(on)}$		-	8.2	-	ns
Rise Time	t_r	V_{DD} = 250 V, I_D = 3.1 A	-	18	-	
Turn-Off Delay Time	$t_{d(off)}$	R_G = 12 Ω, R_D = 79 Ω, see fig. 10	-	40	-	
Fall Time	t_f		-	15	-	
Internal Drain Inductance	L_D	Between lead, 6 mm (0.25") from package and center of die contact	-	4.5	-	nH
Internal Source Inductance	L_S		-	7.5	-	
Drain-Source Body Diode Characteristics						
Continuous Source-Drain Diode Current	I_S	MOSFET symbol showing the integral reverse p - n junction diode	-	-	4.5	A
Pulsed Diode Forward Current	I_{SM}		-	-	18	
Body Diode Voltage	V_{SD}	T_J = 25 °C, I_S = 4.5 A, V_{GS} = 0 V	-	-	1.6	V
Body Diode Reverse Recovery Time	t_{rr}	T_J = 25 °C, I_F = 3.1 A, di/dt = 100 A/µs	-	329	640	ns
Body Diode Reverse Recovery Charge	Q_{rr}		-	1.0	2.0	µC
Forward Turn-On Time	t_{on}	Intrinsic turn-on time is negligible (turn-on is dominated by L_S and L_D)				

Notes

a. Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11)

b. Pulse width ≤ 300 µs; duty cycle ≤ 2 %.

FAIRCHILD
SEMICONDUCTOR®

MUR840, MUR860, RURP840, RURP860

Data Sheet   November 2013

8 A, 400 V - 600 V, Ultrafast Diodes

Description

The MUR840, MUR860, RURP840, RURP860 is an ultrafast diode with low forward voltage drop. This device is intended for use as freewheeling and clamping diodes in a variety of switching power supplies and other power switching applications. It is specially suited for use in switching power supplies and industrial application.

Features

- Ultrafast Recovery t_{rr} = 70 ns (@ I_F = 8 A)
- Max Forward Voltage, V_F = 1.5 V (@ T_C = 25°C)
- 400 V, 600 V Reverse Voltage and High Reliability
- Avalanche Energy Rated
- RoHS Compliant

Applications

- Switching Power Supplies
- Power Switching Circuits
- General Purpose

Ordering Information

PART NUMBER	PACKAGE	BRAND
MUR840	TO-220AC-2L	MUR840
RURP840	TO-220AC-2L	RURP840
MUR860	TO-220AC-2L	MUR860
RURP860	TO-220AC-2L	RURP860

NOTE: When ordering, use the entire part number.

Packaging

JEDEC TO-220AC

Symbol

Absolute Maximum Ratings T_C = 25°C, Unless Otherwise Specified

		MUR840 RURP840	MUR860 RURP860	UNIT
Peak Repetitive Reverse Voltage	V_{RRM}	400	600	V
Working Peak Reverse Voltage	V_{RWM}	400	600	V
DC Blocking Voltage	V_R	400	600	V
Average Rectified Forward Current (T_C = 150°C)	$I_{F(AV)}$	8	8	A
Repetitive Peak Surge Current (Square Wave, 20kHz)	I_{FRM}	16	16	A
Nonrepetitive Peak Surge Current (Halfwave, 1 Phase, 60Hz)	I_{FSM}	100	100	A
Maximum Power Dissipation	P_D	75	75	W
Avalanche Energy (See Figures 10 and 11)	E_{AVL}	25	25	mJ
Operating and Storage Temperature	T_{STG}, T_J	-65 to 175	-65 to 175	°C
Maximum Lead Temperature for Soldering				
Leads at 0.063 in. (1.6mm) from case for 10s	T_L	300	300	°C
Package Body for 10s, see Tech Brief 334	T_{PKG}	260	260	°C

Figure F.3: Diode (MUR860)

MUR840, MUR860, RURP840, RURP860

Electrical Specifications T_C = 25°C, Unless Otherwise Specified

SYMBOL	TEST CONDITION	MUR840, RURP840			MUR860, RURP860			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
V_F	I_F = 8 A	-	-	1.3	-	-	1.5	V
	I_F = 8 A, T_C = 150°C	-	-	1.0	-	-	1.2	V
I_R	V_R = 400 V	-	-	100	-	-	-	µA
	V_R = 600 V	-	-	-	-	-	100	µA
	V_R = 400 V, T_C = 150°C	-	-	500	-	-	-	µA
	V_R = 600 V, T_C = 150°C	-	-	-	-	-	500	µA
t_{rr}	I_F = 1 A, dI_F/dt = 200 A/µs	-	-	60	-	-	60	ns
	I_F = 8 A, dI_F/dt = 200 A/µs	-	-	70	-	-	70	ns
t_a	I_F = 8 A, dI_F/dt = 200 A/µs	-	32	-	-	32	-	ns
t_b	I_F = 8 A, dI_F/dt = 200 A/µs	-	21	-	-	21	-	ns
Q_{rr}	I_F = 8 A, dI_F/dt = 200 A/µs	-	195	-	-	195	-	nC
C_J	V_R = 10 V, I_F = 0 A	-	25	-	-	25	-	pF
$R_{\theta JC}$		-	-	2	-	-	2	°C/W

DEFINITIONS

V_F = Instantaneous forward voltage (pw = 300 µs, D = 2%).

I_R = Instantaneous reverse current.

t_{rr} = Reverse recovery time (See Figure 9), summation of $t_a + t_b$.

t_a = Time to reach peak reverse current (See Figure 9).

t_b = Time from peak I_{RM} to projected zero crossing of I_{RM} based on a straight line from peak I_{RM} through 25% of I_{RM} (See Figure 9).

Q_{rr} = Reverse recovery charge.

C_J = Junction Capacitance.

$R_{\theta JC}$ = Thermal resistance junction to case.

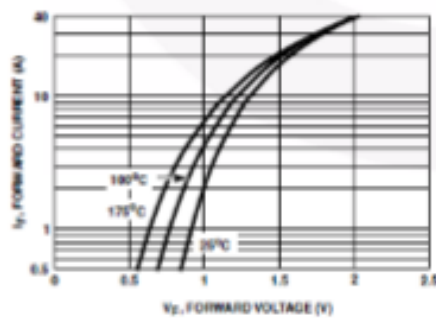pw = pulse width.

D = duty cycle.

Typical Performance Curves
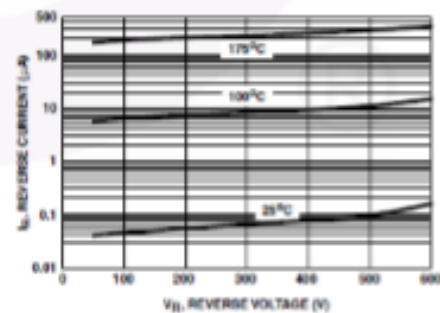

FIGURE 1. FORWARD CURRENT vs FORWARD VOLTAGE

FIGURE 2. REVERSE CURRENT vs REVERSE VOLTAGE
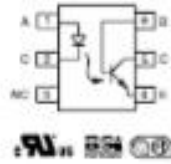
4N25, 4N26, 4N27, 4N28

Vishay Semiconductors

VISHAY.

Optocoupler, Phototransistor Output, with Base Connection

FEATURES
- Isolation test voltage 5000 V$_{RMS}$
- Interfaces with common logic families
- Input-output coupling capacitance < 0.5 pF
- Industry standard dual-in-line 6 pin package
- Compliant to RoHS directive 2002/95/EC and in accordance to WEEE 2002/96/EC

APPLICATIONS
- AC mains detection
- Reed relay driving
- Switch mode power supply feedback
- Telephone ring detection
- Logic ground isolation
- Logic coupling with high frequency noise rejection

AGENCY APPROVALS
- UL1577, file no. E52744
- BSI: EN 60065:2002, EN 60950:2000
- FIMKO: EN 60950, EN 60065, EN 61335

DESCRIPTION
The 4N25 family is an industry standard single channel phototransistor coupler. This family includes the 4N25, 4N26, 4N27, 4N28. Each optocoupler consists of gallium arsenide infrared LED and a silicon NPN phototransistor.

ORDER INFORMATION

PART	REMARKS
4N25	CTR > 20 %, DIP-6
4N26	CTR > 20 %, DIP-6
4N27	CTR > 10 %, DIP-6
4N28	CTR > 10 %, DIP-6

ABSOLUTE MAXIMUM RATINGS [1]

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
INPUT				
Reverse voltage		V_R	5	V
Forward current		I_F	60	mA
Surge current	t ≤ 10 µs	I_{FSM}	3	A
Power dissipation		P_{diss}	100	mW
OUTPUT				
Collector emitter breakdown voltage		V_{CEO}	70	V
Emitter base breakdown voltage		V_{EBO}	7	V
Collector current		I_C	50	mA
	t ≤ 1 ms	I_C	100	mA
Power dissipation		P_{diss}	150	mW

Figure F.4: Optocoupler (4N25)

VISHAY.

4N25, 4N26, 4N27, 4N28

Optocoupler, Phototransistor Output, Vishay Semiconductors
with Base Connection

ABSOLUTE MAXIMUM RATINGS [1]

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
COUPLER				
Isolation test voltage		V_{ISO}	5000	V_{RMS}
Creepage distance			≥ 7	mm
Clearance distance			≥ 7	mm
Isolation thickness between emitter and detector			≥ 0.4	mm
Comparative tracking index	DIN IEC 112/VDE 0303, part 1		175	
Isolation resistance	$V_{IO} = 500$ V, $T_{amb} = 25$ °C	R_{IO}	10^{12}	Ω
	$V_{IO} = 500$ V, $T_{amb} = 100$ °C	R_{IO}	10^{11}	Ω
Storage temperature		T_{stg}	− 55 to + 125	°C
Operating temperature		T_{amb}	− 55 to + 100	°C
Junction temperature		T_j	125	°C
Soldering temperature [2]	max. 10 s dip soldering distance to seating plane ≥ 1.5 mm	T_{sd}	260	°C

Notes
[1] $T_{amb} = 25$ °C, unless otherwise specified.
Stresses in excess of the absolute maximum ratings can cause permanent damage to this device. Functional operation of the device is not implied at these or any other conditions in excess of those given in the operational sections of this document. Exposure to absolute maximum ratings for extended periods of this time can adversely affect reliability.
[2] Refer to reflow profile for soldering conditions for surface mounted devices (SMD). Refer to wave profile for soldering conditions for through hole devices (DIP).

ELECTRICAL CHARACTERISTICS [1]

PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
INPUT							
Forward voltage [2]	$I_F = 10$ mA		V_F		1.3	1.5	V
Reverse current [2]	$V_R = 3$ V		I_R		0.1	100	μA
Capacitance	$V_R = 0$ V		C_0		25		pF
OUTPUT							
Collector base breakdown voltage [2]	$I_C = 100$ μA		BV_{CBO}	70			V
Collector emitter breakdown voltage [2]	$I_C = 1$ mA		BV_{CEO}	30			V
Emitter collector breakdown voltage [2]	$I_E = 100$ μA		BV_{ECO}	7			V
Icc (dark) [2]	$V_{CE} = 10$ V (base open)	4N25			5	50	nA
		4N26			5	50	nA
		4N27			5	50	nA
		4N28			10	100	nA
Icc (dark) [2]	$V_{CE} = 10$ V, (emitter open)				2	20	nA
Collector emitter capacitance	$V_{CE} = 0$		C_{CE}		5		pF
COUPLER							
Isolation test voltage [2]	Peak, 60 Hz		V_{ISO}	5000			V
Saturation voltage, collector emitter	$I_C = 2$ mA, $I_F = 50$ mA		V_{CEsat}			0.5	V
Resistance, input output [2]	$V_{IO} = 500$ V		R_{IO}	100			GΩ
Capacitance, input output	f = 1 MHz		C_{IO}		0.5		pF

Notes
[1] $T_{amb} = 25$ °C, unless otherwise specified.
Minimum and maximum values are testing requirements. Typical values are characteristics of the device and are the result of engineering evaluation. Typical values are for information only and are not part of the testing requirements.
[2] JEDEC registered values are 2500 V, 1500 V, 1500 V, and 500 V for the 4N25, 4N26, 4N27, and 4N28 respectively.

2200R Series
Radial Lead Inductors

C&D TECHNOLOGIES
POWER ELECTRONICS DIVISION

SELECTION GUIDE

FEATURES
- RoHS compliant
- Radial format
- Up to 1.62A Idc
- 10µH to 68mH
- Low DC resistance
- Miniature size
- PCB mounting
- MIL-I-23053/5 class I sleeving
- Fully tinned leads
- Supplied in bags of 100
- Compatible with RoHS soldering systems
- Backward compatible with Sn/Pb soldering systems
- Custom parts available

DESCRIPTION

The 2200R Series is a general purpose range of inductors suitable for low to medium current applications. Their small footprint makes them ideal for high density applications where a chip inductor will not cope with the power requirement.

TYPICAL CORE/WIRE CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS

SOLDERING INFORMATION

RoHS COMPLIANT 2002/95/EC

www.cd4power.com

MAGNETIC PRODUCTS

Figure F.5: Radial Inductor (100uH)

APPENDIX G

GANTT CHARTS

Project Activities		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Verify the title	PLAN	█									m					
	ACTION	█									i					
Verify the supervisor	PLAN		█								d					
	ACTION		█													
Discuss about the title with supervisor	PLAN			█							t					
	ACTION			█							e					
Literature and theoretical study	PLAN				█	█					r					
	ACTION				█	█					m					
Complete the proposal for project	PLAN						█	█	█	█						
	ACTION						█	█	█		b					
Verify the panels	PLAN									█	r					
	ACTION									█	e					
Submission of proposal	PLAN										a	█				
	ACTION										k	█				
Proposal Presentation	PLAN												█			
	ACTION												█			
Complete the final report(chapter 1,2,3)	PLAN													█	█	
	ACTION													█	█	
Final report Submission	PLAN															█
	ACTION															█

Figure G.1: Gantt chart of FYP 1

Project Activities		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Hardware design	PLAN	█	█													
	ACTION	█	█													
Construction of hardware	PLAN			█	█	█	█		m							
	ACTION			█	█	█	█		i							
Collection of data by testing	PLAN							█	d							
	ACTION							█								
Modification and Evaluation	PLAN								t	█						
	ACTION								e	█						
Complete the chapter 4 (Result and Disccusion)	PLAN								r		█					
	ACTION								m		█					
Complete the chapter 5 (Conclusion and Recommendation)	PLAN											█				
	ACTION								b			█				
Submit all the chapters to supervisor and panels	PLAN								r				█			
	ACTION								e				█			
Corrected and compile as full thesis	PLAN								a					█		
	ACTION								k					█		
Final Presentation	PLAN														█	
	ACTION														█	
Final thesis submission	PLAN															█
	ACTION															█

Figure G.2: Gantt chart of FYP 2