DEVELOPMENT OF SOLAR FLUORESCENT LAMP

MOHD HAFIZUDDIN BIN ABDUL RAZAK

\

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **DEVELOPMENT OF SOLAR FLUORESCENT LAMP**

SESI PENGAJIAN: 2006/2007

Saya **MOHD HAFIZUDDIN BIN ABDUL RAZAK (870815-03-5167)**
(HURUF BESAR)

mengaku membenarkan tesis (Sarjana Muda/~~Sarjana~~ /~~Doktor Falsafah~~)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

[ ]	**SULIT**	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
[ ]	**TERHAD**	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[√]	**TIDAK TERHAD**	

Disahkan oleh:

(TANDATANGAN PENULIS) (TANDATANGAN PENYELIA)

Alamat Tetap:

LOT 818 KAMPUNG MACHANG BUBOK
16400 PERINGAT KOTA BHARU
KELANTAN

RUHAIZAD BIN ISHAK
(Nama Penyelia)

Tarikh: **24 NOVEMBER 2009** Tarikh: : **24 NOVEMBER 2009**

CATATAN:
* Potong yang tidak berkenaan.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai atau TERHAD.
♦ Tesis dimaksudkan sebagai tesis bagi Ijazah doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

Signature : ______________________

Name : RUHAIZAD BIN ISHAK

Date : 24 NOVEMBER 2009

DEVELOPMENT OF SOLAR FLUORESCENT LAMP

MOHD HAFIZUDDIN BIN ABDUL RAZAK

This thesis is submitted in fulfillment of the
requirements for the award of the Bachelor Degree of
Electrical Engineering (Power System)

Faculty of Electrical & Electronic Engineering
Universiti Malaysia Pahang

NOVEMBER 2009

“All the trademark and copyright use herein are property of their respective owner. Reference of information from other sources are quoted accordingly; otherwise the information presented in this report is solely word of the author,”

Signature : ___________________________

Author :MOHD HAFIZUDDIN BIN ABDUL RAZAK

Date :24 NOVEMBER 2009

Dedicate to my beloved family and friends
who always give me a courage to finish this thesis

Also to those people who have been supportive through all this time.
Thank you for the kindness and advices that have been given.

God Bless you all,
–amin-

ACKNOWLEDGEMENT

First of all, I would like to thank God for his bless towards myself. Without his blessing I could not be able to finish my final year project. My project title is "Development of Solar Fluorescent Lamp". I able to complete this project in time of the requirement of the degree of Bachelor Engineering (Electric Power System).

Secondly, I would like to thank to all people had assisted me either directly or indirectly in completing my final year project. My special thank to Mr. Ruhaizad B. Ishak, my intelligent supervisor for the project whom had given her support, knowledge, advice and also guidance that I need. He had been guiding me from the beginning of the project until the final thesis has been done. With his support, I had learned a lot of knowledge regarding to this project, many thing that I can use in my future especially the experience in making this project. Without him, I not expect that I will finish this project same as the University requirement. Thank again to Mr. Ruhaizad.

A million thank also to other lecturers who had teach and helped me in completing this project. Not to forget, I would like to thank to all my friends in support and their co-operation especially my roommates. They had never hesitated to help me in sharing and discuss about this project. May God bless them always, Amin.

Last but not least, my very special thank to my beloved parents and also to all my siblings who had given me a support while I was struggling with this project.

ABSTRACT

Solar cells are common examples in this category of electricity generation. They are also known as photovoltaic cells. A combination of individual PV cells forms the Photovoltaic module. A collection of photovoltaic modules, which are tied together with a wire and are so designed to install it in a field readily, is known as photovoltaic panels or simply solar panels. The installation includes the photovoltaic modules, an inverter, a battery all linked to each other with a wire.

Since this technology is still new in Malaysia especially in UMP. The using of solar as electric source is limited. So, in this case, I need to develop a system that uses solar panel as a basic supply for the Fluorescent Lamp. This project is mainly concerned in design a charger that uses solar as source to charge the battery 12 V. This project also designs the inverter from 12VDC to 240VAC. The inverter could be supply power to the load that we use in this project. The load is a Fluorescent Lamp. This project will be divided into two main parts which are hardware design and software development. The hardware includes the charger and the inverter. The charger will take the energy from the solar source and store it in battery. After that the battery will give supply to the inverter circuit to convert the direct current into alternating current. The most important thing in this project is to convert direct current DC into alternating current AC. By using suitable controller, it will change from square wave into sine wave. The controller can produce the waveform that we need. Lastly when we get the suitable power, voltage and current, we connect it to the Fluorescent Lamp as a load in this project.

ABSTRAK

Sel suria adalah salah satu kategori dalam penghasilan elektrik. Ia juga dikenali sebagai sel fotovoltan. Kombinasi satu sel PV akan menghasilkan module fotovoltan. Pengumpulan modul, merangkumi bersama satu rekabentuk yang hendak dipasang dikenali sebagai panel fotovoltan atau dengan erti kata lain panel suria. Pemasangan akan dilengkapi dengan panel suria, satu penyongsang, satu bateri and akan disambung dengan satu wayar.

Walaubagaimanapun, teknologi ini masih baru di Malaysia terutamanya di UMP. Penggunaan suria elektrik agak terhad. Jadi dalam hal ini, saya perlu mencipta satu sistem yang menggunakan panel suria sebagai pembekal utama untuk lampu Fluorescent. Projek ini akan tertumpu pada mencipta pengecas dari sumber suria untuk mengecas bateri 12 V. Projek ini juga mencipta penyongsang dari 12 NDC kepada 240 VAC. Penyongsang ini akan membekalkan kuasa kepada beban yang digunakan. Bebennya adalah lampu Fluorescent. Projek ini akan terbahagi kepada dua bahagian iaitu “hardware design” dan jalan kira untuk penggunaan kuasa. “Hardware” akan merangkumi pengecas dan juga penyongsang. Pengecas akan mengambil kuasa daripada suria dan menyimpannya kedalam bateri. Selepas itu bateri akan membekalkan kuasa untuk litar penyongsang supaya menukar arus terus kepada arus ulang alik. Apa yang paling penting dalam projek ini adalah untuk menukar arus terus DC kepada arus ulang alik AC. Dengan menggunakan pengawal litar yang sesuai, ia akan menukar “square wave” kepada “sine wave”. Akhir sekali, bila dapat nilai kuasa, voltan dan arus yang sesuai, sambungkan ia kepada lampu Fluorescent sebagai beban dalam projek ini.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Solar panel described two types of devices that collect energy from the sun. It is solar photovoltaic modules and solar thermal collector. Solar photovoltaic modules are use solar cells to convert light from sun into electricity. Solar cells are common examples in this category of electricity generation. An electric power can be converting from one form to another by using electronic devices. The function of the electronic circuit by using semiconductor devices is to switching and modifying or controlling a voltage. It will convert electrical energy from one form to another form.

1.2 Background

Normally power electronic systems consist of two parts. It is power processor and power controller. Power process that handle power transfer from input to output and power controller that tell how the process need to do to get the output compared to input. It is shown in Figure 1.1.

In order to save energy from common use (TNB), we use another source to get the electricity. For example, use energy from solar. By using this energy, we just get the direct current DC. Is not suitable to our equipment that using alternating current AC. That means we need to converts DC to AC power by switching the DC input voltage (or current) in a pre-determined sequence so as to generate AC voltage (or current) output. By convert the input direct current DC to alternating current AC, it is suitable to our equipments. Figure 1.2 shown the inverter that converting DC input to AC output.

Application of power electronic range from low-power conversion equipment, for examples AC devices. Convertion of DC input from the battery to get AC output is shown in Figure 1.2. This DC-AC converter is also specifically classfied as a inverter. In order to get the power in AC, the power need to follow the specification of the equipment that we use. The voltage must be 240V at no load and not less than 220V at load. The frequency must be 50-60Hz. Lastly we need to consider the output power for the load. Therefore, this project is assigned as to design and build a suitable inverter for the load that we used. The load is Fluorescent Lamp. The power that load needed is about 5-20W. in order to get the pure sine wave, we need to add the filter circuit after we get the full wave of square wave. After passing the filter circuit, the output will change in sine wave. The block diagram of the filter is shown in Figure 1.3.

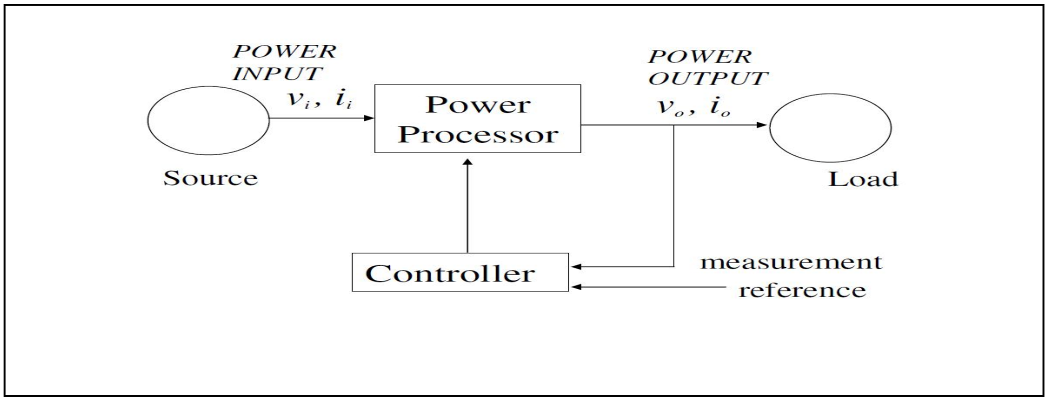


Figure 1.1: Basic Controller

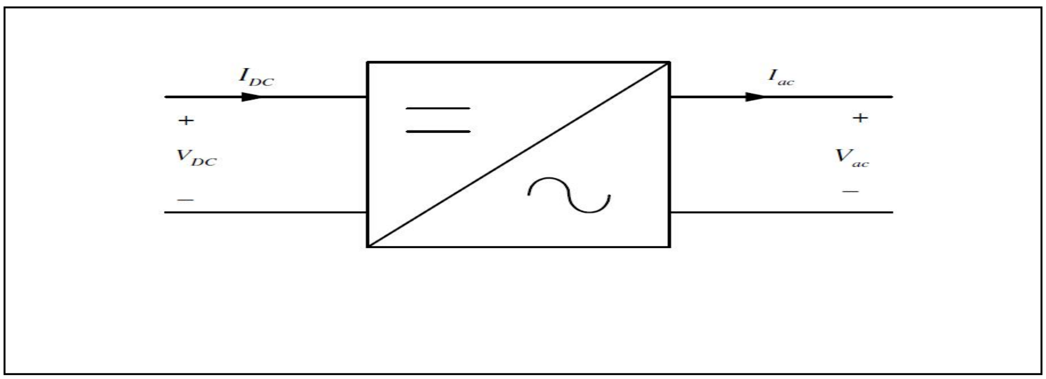


Figure 1.2 : Basic DC/AC

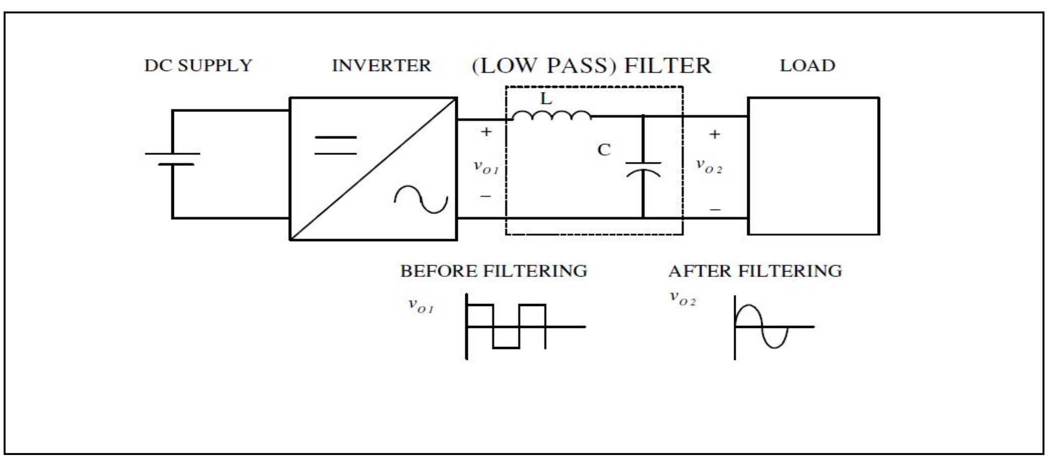


Figure 1.3: Filtering Diagram

1.3 Objectives

The main point of this project is to store the energy from the sun into the battery and to convert the DC voltage to AC voltage by using power electronic devices. In order to achieve the single phase AC voltage, it is required to design and create the suitable inverter for the load by using the source from the sun energy. Besides that, it is the objective of this project also to design and build the solar charger that can taking energy from the sun and store it into the battery 12V. To achieve all the objectives of this project, a lot of work must be consider before the project done. There are as stated below:

i. To develop a system that uses solar panel as a basic supply

ii. To design a suitable inverter to integrate with low power load

iii. To apply all the theory has been studied practically

1.4 Scopes

In this project, it will be focus on two parts; it is the hardware development and calculation of power consumption. The main scope of this project is to generate electricity from the sun energy (solar panel) and then store it to battery (12Vdc) by control with charger circuit.

For this project, the power consumption will be calculated manually. The battery used only 12V in constant voltage. After that the inverter produced only suitable for the load. The load in this project is Florescent Lamp and the inverter must be turn on the lamp after the control circuit is on.

In addition to this project, the external switches to control and protect the system from damage or short circuit. There are as stated below:

i. Generate electricity from the sun energy (solar panel) and then store it to battery (12VDC) by control with charger
ii. Only used 12V battery in constant voltage to supply to the inverter
iii. The inverter that will be used is 12DC-240AC/5-20W
iv. Get stabilized voltage for used at lower voltage devices
v. Additional circuit for control the system work properly.

1.5 Problem Statement

Today, the system that using the solar panel as a source for the fluorescent lamp is very hard to found, especially at the bus stop. In easy word is no installation of solar fluorescent lamp at bus stop in Malaysia. Today, technology is very important and very useful to us. So we need to find way to improve ourselves. For example, generate the electricity using energy from the sun light. That we call is the solar photovoltaic modules. Because of that, we not hope electricity from TNB only but we can make it ourselves.

That's why this system is designed. The problem here is we cannot produces constant supply for the load, so the charger needs to be design to store the energy to the battery. The output will stable when supply from battery is constant. Normally, the inverter is very hard to design because the input in DC and the output is AC, it is easy to burn. So the component must be suitable for higher temperature and higher efficiency. Nowadays, a lot of product used for DC load only, but this system is designed for load in AC

1.6 Thesis Organization

There are all five chapters being structure in this thesis and every chapter will elaborate in details about this project. Chapter 2 is about the literature review. The data and the theory will be taking from this part before move to the next chapter. Chapter 3 is all about the methodology. This chapter will be discussing about the flow or the method that applied into this project. All detail explanation about the project in this chapter. Chapter 4 is displaying the result and discussing about the project after all the circuit finish. Chapter 5 in overall will discuss about the conclusion and summary of the project. This chapter also states the problem and recommendation for the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to perform this project, literature review has been made from various sources like journals, books, articles and others. All of this will be references for this project and also make idea to produce suitable circuit or inverter for the charger and also the inverter. A review of the article was performed to identify studies that relevant to the topic. A combination of the following keywords was used to identify relevant material. The Solar Fluorescent Lamp concept is integrated the solar charger, battery, inverter and the sensor to switch ON the fluorescent lamp.

2.2 Solar Energy

A solar energy and electric lighting system wherein when the solar energy is available as in the day-time, it is utilized for lighting through conventional electric lamps, but when no solar energy is available the lamp are turned on [2]. Using the light sensor to detect weather no solar energy or not. The solar power source is suitable for powering outdoor advertising signs. Generally, the solar power source has application in any environment where the constant power source was desired [3]. It is suitable to apply to bus stop.

2.3 Solar Panel

Solar panel which is also known as photovoltaic is a device that receives the energy from the sun and then converts it to electrical energy. Solar panel has several types according to their size and output. It will produce DC voltage [4]. Its output which is 17Vdc 5A must be store to a battery. The present invention relates to means for concentration solar energy on solar cells, optimizing the utilization of solar energy [5]. Outdoor solar energy lamp with luminescence efficiency relates to lamp, and more particularly to an outdoor solar energy lamp that uses environmental solar energy as power source and has luminescence function to prolong lamp lighting [6]. By using the environmental source we get to generate the electricity and give the supply to the fluorescent lamp.

2.3.1 Solar Panel Specification

Model	Sunmodule SW80 mono/RSE
Rated Max. Power, Pmax(W)	80(±5%)
Open Circuit Voltage, Voc(V)	21.9
Rated Voltage, Vrated(V)	17.5
Short Circuit Current, Isc(A)	5.00
Rated Current, Irated(A)	4.58
Maximum System Voltage, (V)	715AC

Table 2.1: Solar Panel Specification

2.4 Battery

Nowadays maintenance-free lead-acid batteries are common in vehicles, inverters and UPS systems. If the battery is left in a poor state of charge, its useful life is shortened. It also reduces the capacity and recharge ability of the battery [13]. We use the lead-acid battery in this system or project because it is suitable to use for the inverter system.

2.4.1 Battery Specification

Figure 2.1: Battery

A lead-acid battery is a electrical storage device that uses a reversible chemical reaction to store energy. It uses a combination of lead plates or grids and an electrolyte consisting of a diluted sulphuric acid to convert electrical energy into potential chemical energy and back again. The electrolyte of lead-acid batteries is hazardous to your health and may produce burns and other permanent damage if you come into contact with it.

Voltage is an electrical measure which describes the potential to do work. The higher voltage will risk to you and your health. Systems that use voltages below 50V are considered low-voltage and are not governed by an as strict (some might say arcane) set of rules as high-voltage systems.

Current is a measure of how many electrons are flowing through a conductor. Current is usually measured in amperes (A). Current flow over time is defined as ampere-hours (a.k.a. amp-hours or Ah), a product of the average current and the amount of time it flowed. Lastly, Power is the product of voltage and current and is measured in Watts. Power over time is usually defined in Watt-hours (Wh), the product of the average number of watts and time. Your energy utility usually bills you per kiloWatt-hour (kWh), which is 1,000 watt-hours[17].

2.4.2 Acid Lead Specification

Model	Lead Acid 12V 7Ah
Battery Technology	Lead Acid
Energy Storage	7 Ah
Output Voltage	12 V
External Depth/Length/Width	65mm/97.5mm/151mm
Weight	2,65 kg

Table 2.2: Acid Lead Specification

2.5 Charger

The function of the charger circuit is to regulate the power flowing from a photovoltaic panel into the rechargeable battery. The energy from the sun will be taking and store it into the battery 12V. The charger will be charge the battery in certain time in order to make the battery full back. After the battery full, battery can be use for the inverter circuit. The goal of the circuit design was to make a charge controller with analog simplicity, high efficiency and reliability. A medium power solar system can be built with 12V solar panel up to 10 Amp [16].

2.5.1 TLC2272

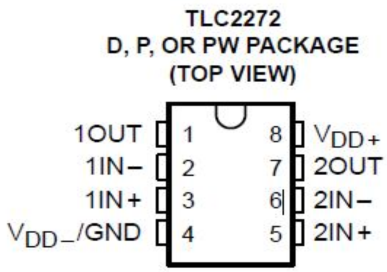


Figure 2.2: TLC2272

A TLC2272 is an operational amplifier IC and it can make a comparator either the voltage can flow trough it or not. Depend on this type the function in the charger circuit is to on and activated the transistor to allow the charge into the battery. This IC also makes the comparator based on the trigger oscillator to make the solar turn on and off.

2.5.2 IRF9Z34N

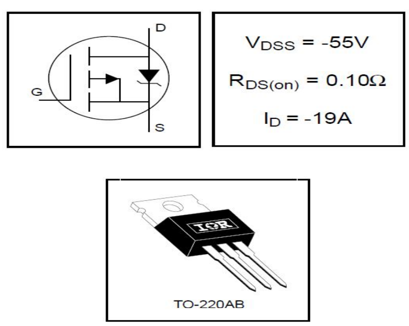


Figure 2.3: IRF9Z34N

A IRF9Z34N is a power mosfet or rectifier. When the transistor on, this mosfet will pass trough the voltage to the battery in high voltage. In other word this device can step up the voltage or current.

2.5.3 Voltage Regulator 78L05

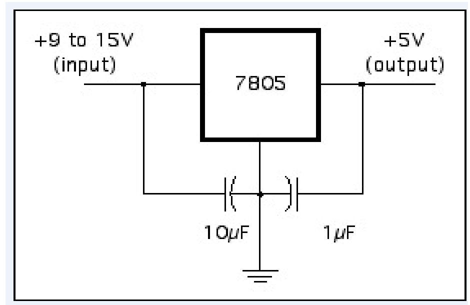


Figure 2.4: Voltage Regulator 78L05

A voltage regulator is an electrical regulator designed to automatically maintain the voltage level. This device can step up or step down the voltage to the value that we need.

2.6 DC and AC Current

In the world today there are currently two forms of electrical transmission, Direct Current (DC) and Alternating Current (AC), each with its own advantages and disadvantages. DC power is simply the application of a steady constant voltage across a circuit resulting in a constant current. A battery is the most common source of DC transmission as current flows from one end of a circuit to the other. Most digital circuitry today is run off of DC power as it carries the ability to provide either a constant high or constant low voltage, enabling digital logic to process code executions [7]. The idea is use the DC supply from the battery and any devices that used today is in AC current. In this project, charge the battery by using the solar panel.

2.7 Inverter

Lastly this statement are taken from futures planning of a company that produce the solar energy product and equipment, collect sunshine by solar panel directly to DC power, through the solar charge controller to charge the battery adjustably. Via DC to AC inverter, the energy which stored in the battery will be used in AC220V/110V loading [14]. This statement gives me more confident to make this project. That is Solar Fluorescent Lamp.

2.7.1 Modified Sine Wave

A modified sine wave is similar to a square wave but instead has a “stepping” look to it that relates more in shape to a sine wave [8]. The waveform is easy to produce because it is just the product of switching between 3 values at set frequencies, thereby leaving out the more complicated circuitry needed for a pure sine wave. The modified sine wave inverter provides a cheap and easy solution to powering devices that need AC power. It does have some drawbacks as not all devices work properly on a modified sine wave, products such as computers and medical equipment are not resistant to the distortion of the signal and must be run off of a pure sine wave power source.

2.7.2 Pure Sine Wave

Pure sine wave inverters are able to simulate precisely the AC power that is delivered by a wall outlet. Usually sine wave inverters are more expensive then modified sine wave generators due to the added circuitry [9]. In order to use the equipment today, we need to consider all the specification of the equipment. The output from the inverter must be suitable for the load. This can be seen in Figure 2.1, which displays how a modified sine wave tries to emulate the sine wave itself.

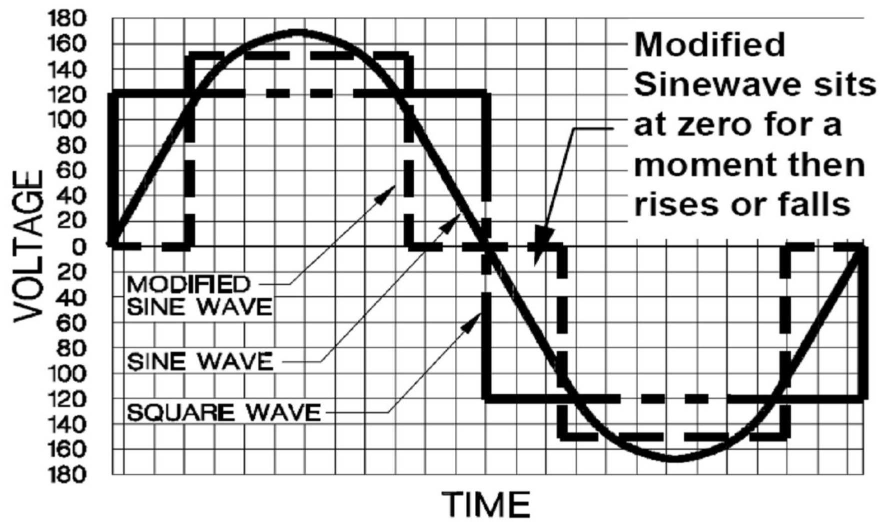


Figure 2.5: Modified Wave

2.8 Fluorescent Lamp

Portable Fluorescent Lamp and inverter there for , and more particularly to a fluorescent lamp operated on high-frequency alternating current produced from battery direct current by a transistor inverter [10]. Transistor inverter use to convert DC to AC in high frequency and supply to the fluorescent lamp. There are many applications where it is desirable to have a light source that is capable of operating from a convenient dc power source, such as battery. The incandescent lamp is often used as a means of converting electrical power from a battery into light power [11].

Fluorescent lamp lighting device more particularly to such a lighting device of the type in which a fluorescent lamp is lit with a dc power source [12]. By using 12V battery we supply to the fluorescent lamp after invert the current from dc to ac by inverter. Fluorescent lamp may be controlled in accordance with the amount of ambient light incident, or falling upon, at least a part of area in which the fluorescent lamp is located [13]. The suitable device to detect light is the light sensing detector and applies this to the project to switch ON the fluorescent lamp automatically.

A fluorescent lamp lighting arrangement with an integral motion detector and light sensing detector for controlling the light intensity of fluorescent lamp [14]. But in this project we use the light sensing detector for switching the fluorescent lamp. Light control fluorescent lamp and more particularly to a compact type fluorescent lamp which can be automatically turned on and off in accordance with the brightness of external environment and a light control circuit integrated therewith [15]. This statement will be produce into this project.

2.8.1 Fluorescent Lamp Specification

Type	Cool Daylight (Screw-in)
Power	8/9 Watt
Voltage	220-240V AC
Frequency	50Hz

Table 2.3: Fluorescent Lamp Specification

2.9 Summary

In this chapter, a new idea is found for designed the suitable circuit for this project. All of the selecting devices were shown in this chapter. Few methods have been discovering to relate it to the researcher's study. In the next chapter will present the concept, framework and all about this project completely.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, will discuss about the project flow and also explain everything about the circuit that use in this project. Like before, in this project is divided by two parts. It is the hardware design and the calculation about the power consumption. There are several steps to be applied in designing a charger and the inverter. The relevant information is gathered through literature review. First of all, define the solar panel that suitable for this project. After get the solar panel, collect the data to design the charger hardware. After collect the data, testing the circuit either the circuit can transfer the solar energy to the battery. After the circuit complete, the circuit of inverter has been design after collect the data and analysis. If necessary, test the circuit by using the software OrCad P-Spice and make the comparison about the circuit. A lot of circuit has been tried into the software. Lastly, develop the hardware according to the design. Figure 3.1 shows the block diagram of the methodology that has been applied. Figure 3.2 shows the overall flow chart of this project.

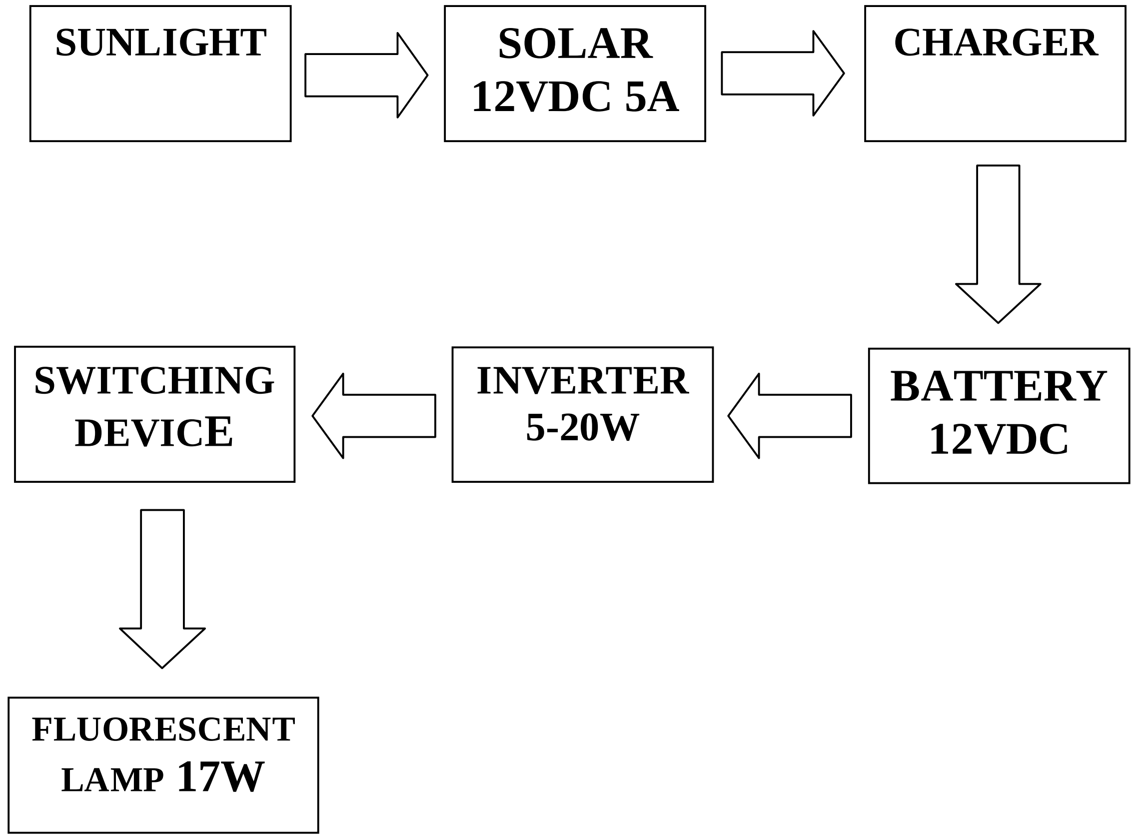


Figure 3.1: Block Diagram of the System

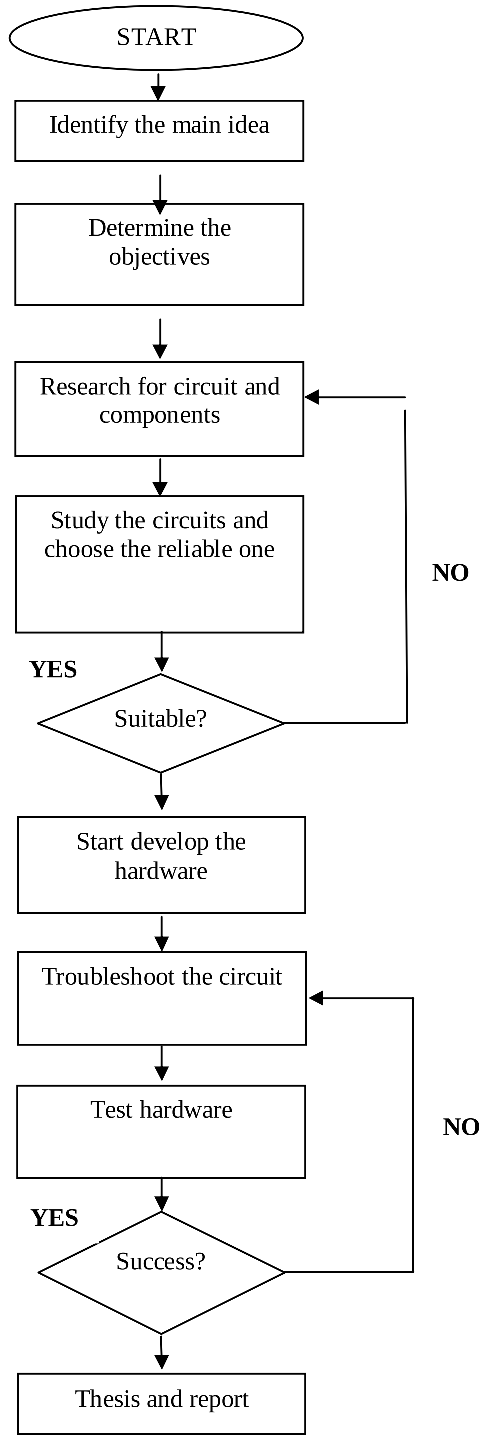


Figure 3.2: Flow Chart of the Project

3.2 Literature Review and Background Study

In this project, basic knowledge about the circuit design is obtained from the literature review. All the circuit of charger and inverter is obtained trough it. It same like the chapter before. From the study, the related information is discussed with the project supervisor. It is to make sure that the project can proceed to the next level. So, there are two circuit has been design. It is the charger circuit and the inverter circuit.

3.3 Theoretical Design

This part is very important to make sure that the circuit can be proceeding. After that the project is started. In this part, the ideas are combined and then discuss implementation details specific to the research.

3.3.1 Power Supply

First of all, the charger circuit needs to interface with the basic or common power supply. It is the solar panel. The solar panel is collected the sun energy and transfer to the charger circuit. The charger is collected the energy and store it into the battery until the battery full of charge. The connection between the solar panel and the charger will be shown in Figure 3.3. The current will be flow to the charger circuit and the charger directly connects to the battery. There take several times to make the battery full charge. The solar panel will be a power supply to the charger circuit and after this the battery will be a power supply to the inverter. The calculation about the sizing solar panel will be show below.

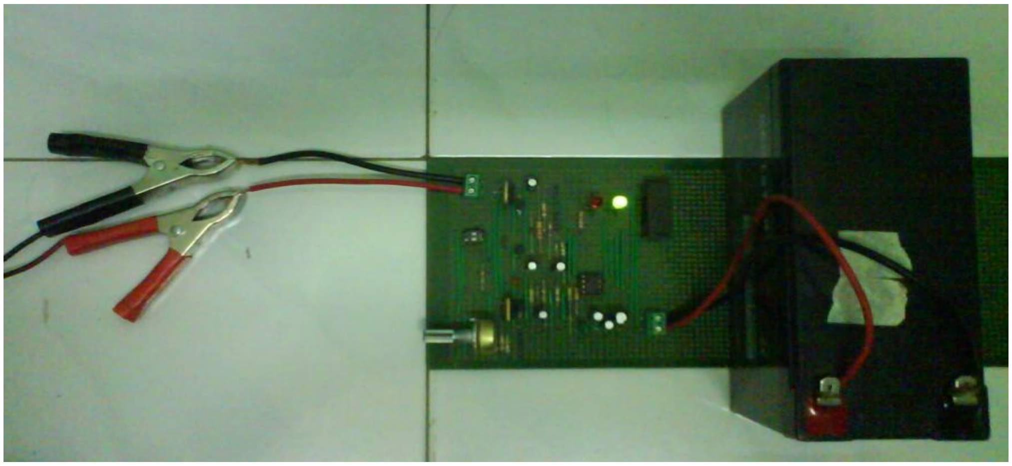


Figure 3.3: Connection Solar Panel to Charger

Your location:	26300 Gambang, Pahang, Malaysia
Using data from **Kuantan (AFB) weather station**	
Min. solar irradiation per day	3.58 kWh / m^2
Average solar irradiation per day	5.19 kWh / m^2
Max. solar irradiation per day	5.97 kWh / m^2

Table 3.1: **Solar Irradiation Information**

Energy usage (per day)	0.075 kWh
Maximum (Peak) load	15 W
Power from other sources (wind, hydro, etc)	0 Ah a day at 12 V

Table 3.2: **Energy**

System voltage	12 V
Current required (factoring loss)	7 Ah at 12 V
Solar Panels	2 × Suntech Solar Panel 20Watt 12Volt Multi-crystalline)
Solar Charge Controller	1 × Morningstar Sunguard 12Volt 4.5Amp Regulator
Inverter	1 × Selectronic 200Watt 12volt True Sinewave Inverter
Days of battery backup	7 days
Battery depth of discharge	20 %
Battery bank required (factoring loss)	260 Ah 2 × Trojan Flooded Lead Acid Battery 6V 260Ah

Table 3.3: **Solar System**

Calculation:

Sizing Solar Panel

Let say,
5 hour peak sunshine for Malaysia

Solar panel input = 90/5 hour peak sunshine
= 18 Watt

Select solar panel and regulator

Solar panel in lab = 80Watt*
Unit of Solar = 18/80 …… solar panel input divide by solar panel used
= 0.225 unit
≈1 unit

Short Circuit Current, Isc = 5.00A*
Regulator need to handle 5.00A Isc

This calculation will be combining with others to get the sizing of the battery used.

3.3.2 Charger

In this part, everything about the charger will be discussed completely. How it work and also how the charger can charge the battery in several time. Like stated before, the charger is taken several time to charge the battery. The charger required a DC input to charge the DC battery. In this project the acid lead battery has been used.

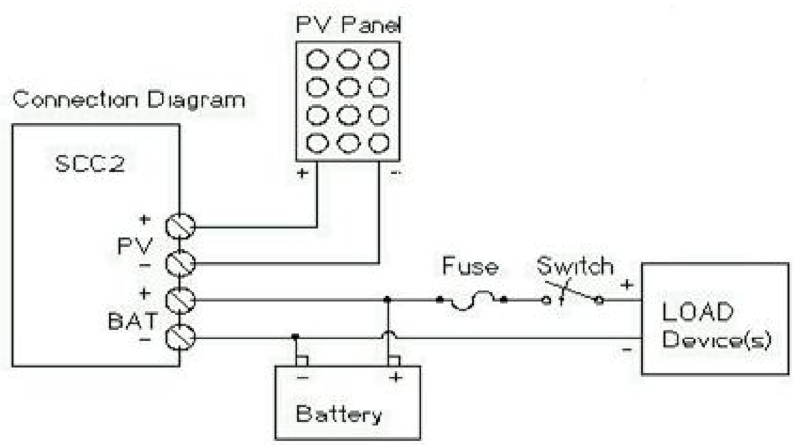


Figure 3.4: Basic Connection of Charger

In the charger circuit show in Appendix, the PV Panel directly connects to the charger circuit and the current will control by using the 10 Amp fuse. The flow of voltage and current in this circuit has been control by using semiconductor devices. The output for this circuit will be connecting to the lead acid battery 12V. The capabilities of the battery depend on what type used. It will be shown in calculation after this part. After that charge, the battery connects parallel with the load. The load in this project used for the inverter. Inverter used for convert the DC current to AC current. The details explanation about the charger circuit will be shown below.

Refer to the Appendices A, it shows the circuit diagram of the solar charger. That circuit acts as a medium power DC between the PV and the battery.

From that circuit Diode D1 prevents reverse night time current flow from the battery back to the PV panel. When the PV voltage is high enough to charge the battery, zener diode D2 conducts and turns on transistor Q2. Q2 switches the power for the rest of the circuit on. IC2 provides a 5 volt regulated voltage to power the comparator circuits. It also provides a reference voltage for comparator IC1a.

When the battery voltage is below the desired full voltage and needs charging, comparator IC1a turns on and activates Q1 and Q3, this allows the solar charging current to flow into the battery. Note that Q3 is a P-channel mosfet, this allows the circuit to be wired with a common ground for the solar panel and battery. The solar current loop is drawn in heavy lines on the schematic.

When the battery reaches the full charge point, IC1a operates as a comparator based schmidt trigger oscillator, it switches the solar current off and on. The switching causes the battery voltage to oscillate a few tens of millivolts above and below the desired set point. A rail-to-rail op-amp is required for proper operation, 741 style op-amps will not work in this circuit.

The red/green charging/full LED is driven between the output of IC1a and IC1b. IC1b has an inverted version of the IC1a signal. Pin 5 of IC1b only needs an approximate center point to work as an on-off comparator. It is connected to the varying IC1a pin 2 so that it does not require another reference divider circuit.

The resistors and thermistor on the input side of IC1a form a resistive bridge circuit that is used to compare the battery voltage to a reference voltage coming from IC2/R8/R9. The potentiometer adjusts the voltage point around which the circuit will oscillate on full charge. Resistor R7 adds positive feedback to IC1a for a schmidt trigger characteristic. The thermistor provides thermal compensation, as the temperature goes down, the full voltage goes up.

The equalize switch, S1a, forces the circuit on for intentional overcharging. Switch S1b and R1 can be used to select a different float voltage range, typically R1 should be greater than 1M.

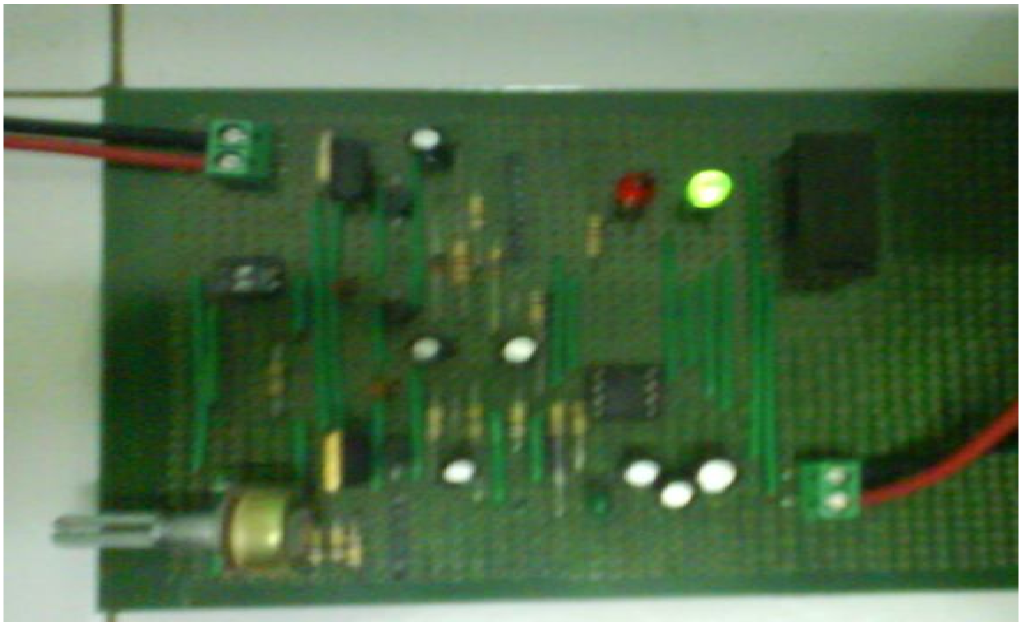


Figure 3.5: Charger Circuit

3.3.3 Battery

Battery is the power supply in direct current. The type battery used in this project is Acid Lead 12V 7Ah. It is depend on the load use. If the load used the large current, the battery must be replaced. For example using 12V 40Ah or something more than that. The important thing here is the voltage must be 12V only and the ampere per hour is depending on the load. The ampere per hour (Ah) means the charge in the battery decrease and sold in one hour if used it straightly. For example if the battery use is 7Ah, the battery sold if current use 7 Amp straightly in one hour.

Calculation:

Sizing Battery
Load = 40Wh per day
Ampere hour per day = total load per day divide by Rated Voltage*
= 40/17.5
= 2.29 Ah
Energy loss = 20%
Ampere hour per day = 2.29 + 20%
= 2.75Ah per day
Battery required = 2.75/0.2 Energy loss
= 13.75Ah x 7 days backup no sun light
= 96.25 Ah for a week

Selected of battery = 12V 40Ah Lead Acid Battery
Unit of battery = 3 units

3.3.4 Inverter

Inverter is the important part in this project. It is convert the direct current DC from the battery to the alternating current AC. The DC wave is in straight line and need the device that can be convert the wave into the square wave. Firstly, the wave will be divided to two waves. It is the half square wave. The second half wave could not be same with the first half wave. There need to shift in 180 degree. After both wave produced, the waves will be combine to get the full wave square wave. It is very difficult to get both of waves because there is more interruption to the wave. Because of that, there push to tried more than one circuit of inverter and make the comparison of the result. There have 5 inverter circuits has been tried and will be shows after this.

3.3.4.1 DC/AC Pure Sine Wave Inverter

This inverter actually uses concepts of Pulse Width Modulation PWM. First of all, the input DC will be divided in two parts. First part is to produce the Sine Wave reference and the second part is to produce Triangle Wave reference. After that the reference sine wave will be trough to the non-inverting amplifier to get the square wave. The reference triangle wave will go to the summing to separate the wave into two parts. It is positive and negative part. After that, the square wave will be combining with the low frequency square wave from the input reference in MOSFET Driver 1. Then the triangle will be combining with the sine wave reference in MOSFET Driver 2. Actually the combination will be produced the Pulse Width Modulation and after trough the snubber circuit, there will get the full wave sine. To get pure sine wave for this circuit, it added filter circuit to filter the wave if having the interruption after through the Power Mosfet. Refer to the result; the pure sine wave **could not** be produced because the Driver is very sensitive with the interruption. Because of that this circuit could not be precede in this project. The basic connection shows in Figure 3.6 below.

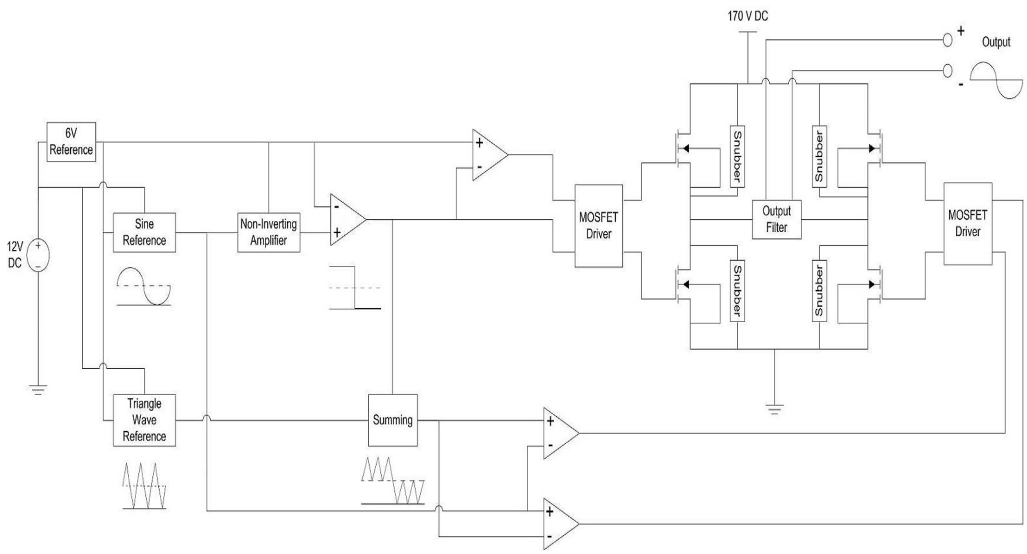


Figure 3.6: Basic Connection Pure Sine Wave Inverter

3.3.4.2 12VDC Fluorescent Lamp

In this part, the inverter produced the square wave and suitable for low power load only. It designs for the fluorescent lamp only. By using the 555 Timer, it can produce the square wave by using the suitable or correct device. The special thing about this IC is it can vary the frequency. And for this inverter the frequency is 50 Hz. There have the calculation about the time duration and the frequency. But this circuit could not be proceeding because the current produce is very low. The square wave is produced but the output from this circuit is very low power. When the load is connecting, the load will blinking and the maximum load reach to 3 Watt only. The circuit diagram of this part shows below complete with calculation of time duration and frequency.

Calculation for 555 Timer:

The frequency of operation of the astable circuit is dependent upon the values of R1, R2, and C. The frequency can be calculated with the formula:

f = 1/(0.693 x C x (R1 + 2 x R2))

f = 1/t or t = 1/f

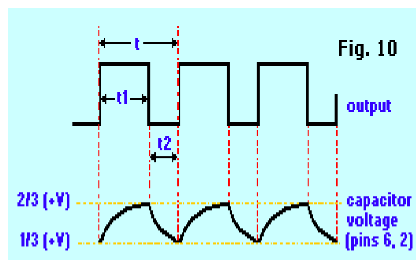


Figure 3.7: Time Duration Wave

The total period (t) is t1 + t2 (See Figure 3.7)

Duty Cycle,

D = t1/t = (R1 + R2) / (R1 + 2R2)

From that we get t1 and t2,

t1 = 0.693(R1+R2) C

t2 = 0.693 x R2 x C

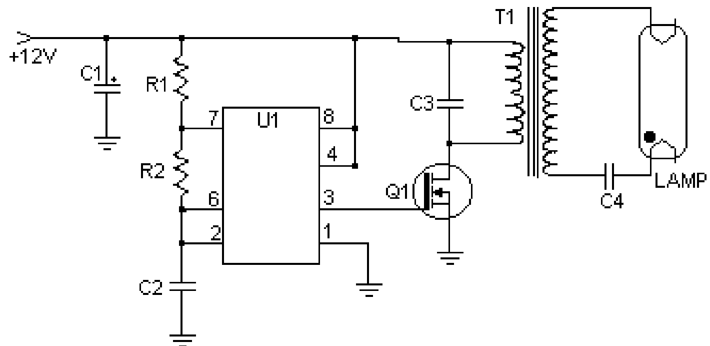


Figure 3.8: Circuit Diagram for 12VDC Fluorescent Lamp

3.3.4.3 DC to AC Inverter

This inverter is same concept with the previous inverter. It uses the 555 Timer as a controller. But in this part, the output of 555 Timer will be divided into two parts. It for the power mosfet before go to the transformer. But this circuit also could not be proceeding because the output from the transformer also low power. The load happen same with previous inverter. The calculation of the duty cycle and frequency same with the previos inverter and the circuit diagram shows in Figure 3.9 below.

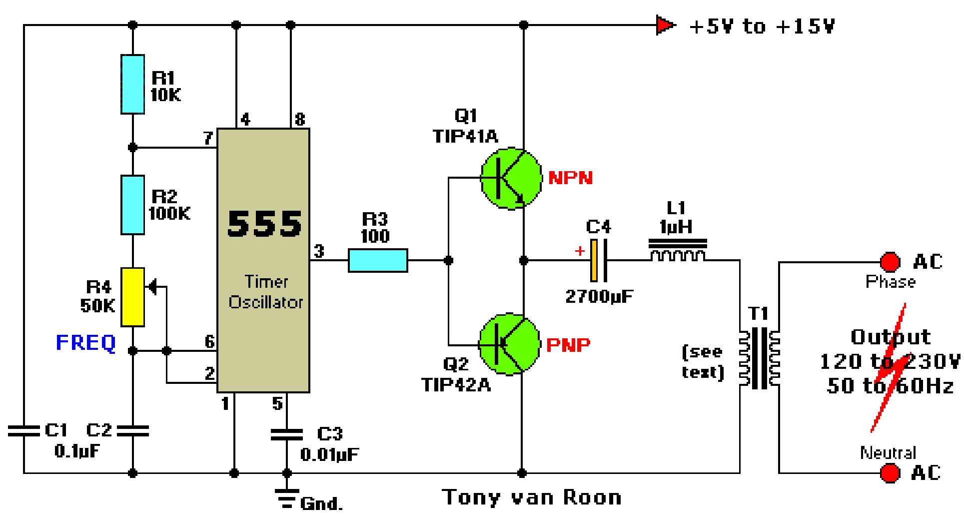


Figure 3.9: Circuit diagram for DC to AC Inverter

3.3.4.4 Mosfet Power Inverter

This inverter has 2 IC that using comparator concept. LM358 consist of two independent, high gains, internally frequency compensated operational amplifier. The output from this amplifier will go to the CD4001 to separate into two parts. Expected output from this CD4001 is square wave and then go to power mosfet to step up the voltage or current. The output from the power mosfet will connect to the reverse transformer to step up voltage from 12V to 220/240VAC. But the result from this circuit could not be proceeding because no output detected from LM358. But all the circuit will be make comparison after this. The circuit diagram of this part shows in Figure 3.10 below.

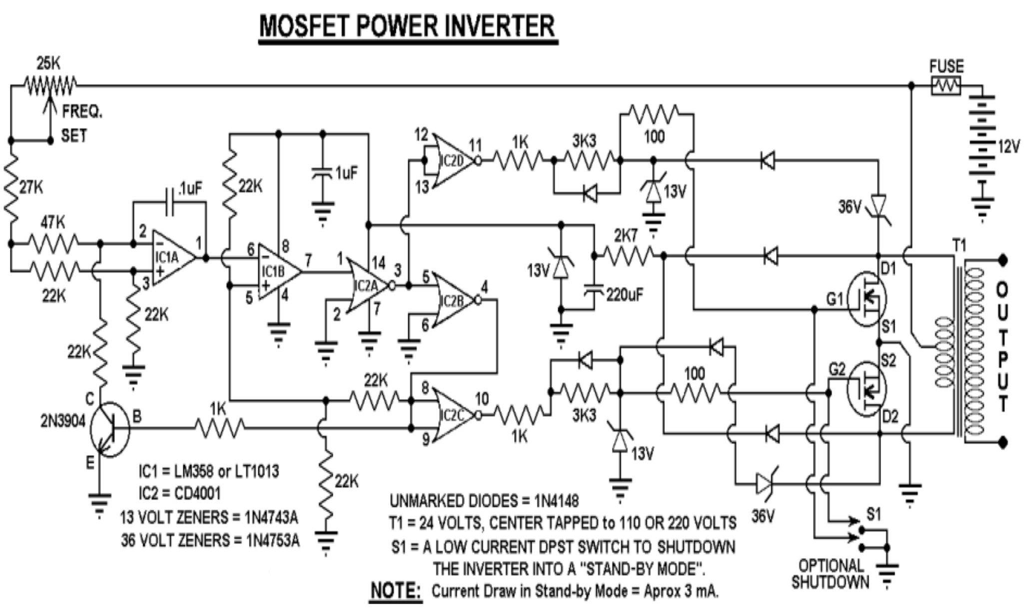


Figure 3.10: Circuit Diagram for Power Mosfet Inverter

3.3.4.5 Power Inverter

In this inverter consists gatable astable multivibrator. This CD4047 used because the output from this IC will be square wave. There is a lot of connection. The external at Pin 1, 2, 3 will be the important part because it will be decided either this IC will be function or not. But this multivibrator is very sensitive and the output will be 50% loss. It depend on type of the CD4047.after get the output from CD4001, it will go to the Power Mosfet IRF540 because the output must be step up before trough to the reverse transformer. From this circuit, it will give the result but some modification was made for the connection and devices. The circuit diagram shows in Figure 3.11 below.

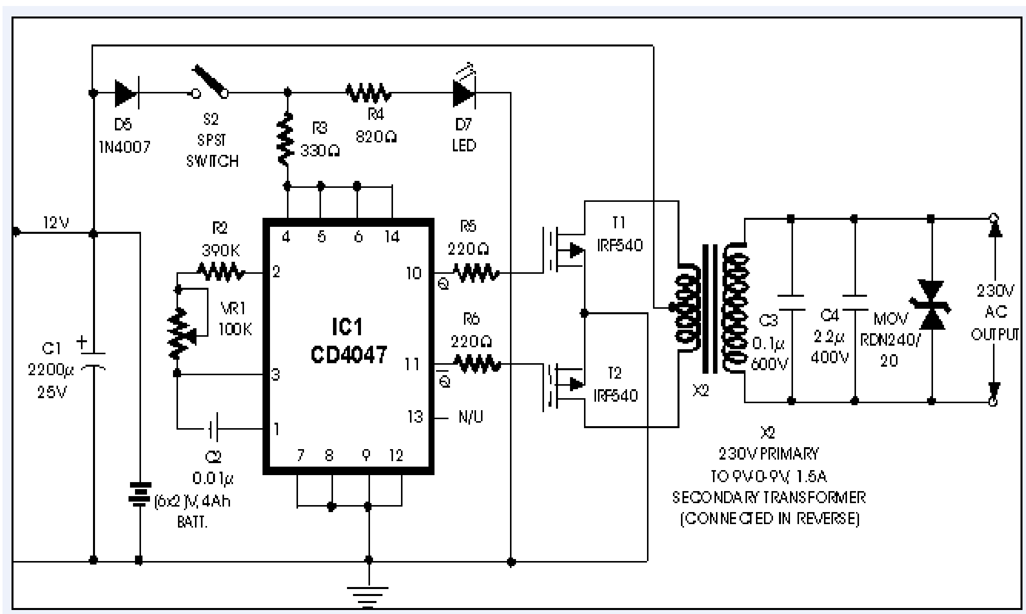


Figure 3.11: Circuit Diagram for Power Inverter

Calculation:

Inverter

Efficiency = 80%
Load = 48Wh per day

48/0.8 = 60Wh per day
Inverter Power = 60/5hours
= 12 Watt

Selected of inverter for 25 Watt
Reason: To apply with another appliance and to decrease power losses

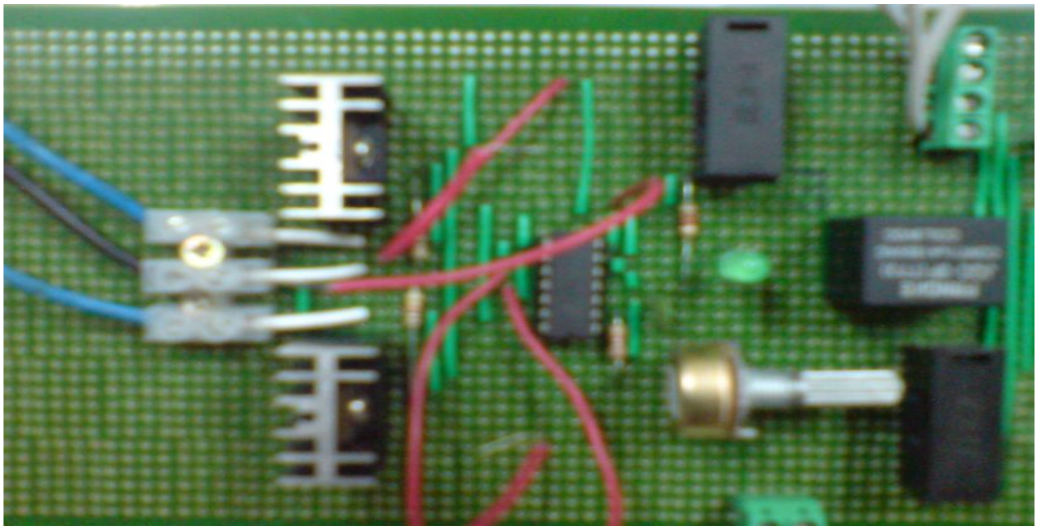


Figure 3.12: Inverter Circuit

3.3.5 Load

The load in this project is Fluorescent Lamp. There is several type of this lamp. The power consumption of this lamp also has many. The calculation about this load will be shows after this. The table for the type of this lamp will be shows below. But for this project, the load will use is Fluorescent Lamp 5-20 Watt only. The most important part in this project is the inverter. If the inverter can produce suitable power for the output, the load will be no matters. The load specification in this project will be show in Table 3.3 below.

Type	Philip Cool Daylight Lamp
Power	8/9 Watt
Voltage	220-240V AC
Frequency	50Hz
Current	33.33mA

Table 3.4: Lamp Specification

Figure 3.13: Actual Load Used

Calculation:

Total load per day

Load lamp = 8W
Unit= 2
Total power = 2 x 8 x 5 hour per day
= 80Wh per day

Energy loss = 20%
= 20/100 x 80
= 16 Wh

Total load power = Total power + 20% Energy loss
= 96Wh per day

This calculation will be combining to the previous calculation to get the quantity of the battery used in this project.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This chapter discuss about all the result obtained and the limitation of the project. This includes all the result from hardware and also the calculation about the output power. All the related result will be include also in this chapter.

4.2 Hardware Design

The hardware in this project is divided by two parts. It is the charger circuit and inverter circuit. In Figure 4.1 below shows the complete hardware. It is include also the control circuit. The control circuit design to control the overall circuit.

The control circuit will be switching devices to all the function in this project hardware. Switch 1 will be control the charging and using of the battery. Switch 2 is to control the AC input to the load directly. Switch 3 is to control the DC input to the inverter and the load will be function by using the DC current. The relay will be a protection control. To make sure that the input for the load in one source only. When the DC input, the AC input will be cut of and when the AC input, the DC input will be cut off automatically. Switch 4 is standby mode for the inverter. When this switch on, the output from the inverter will be use for the load. Refer Appendix A and B for the circuit diagram of Charger and Inverter.

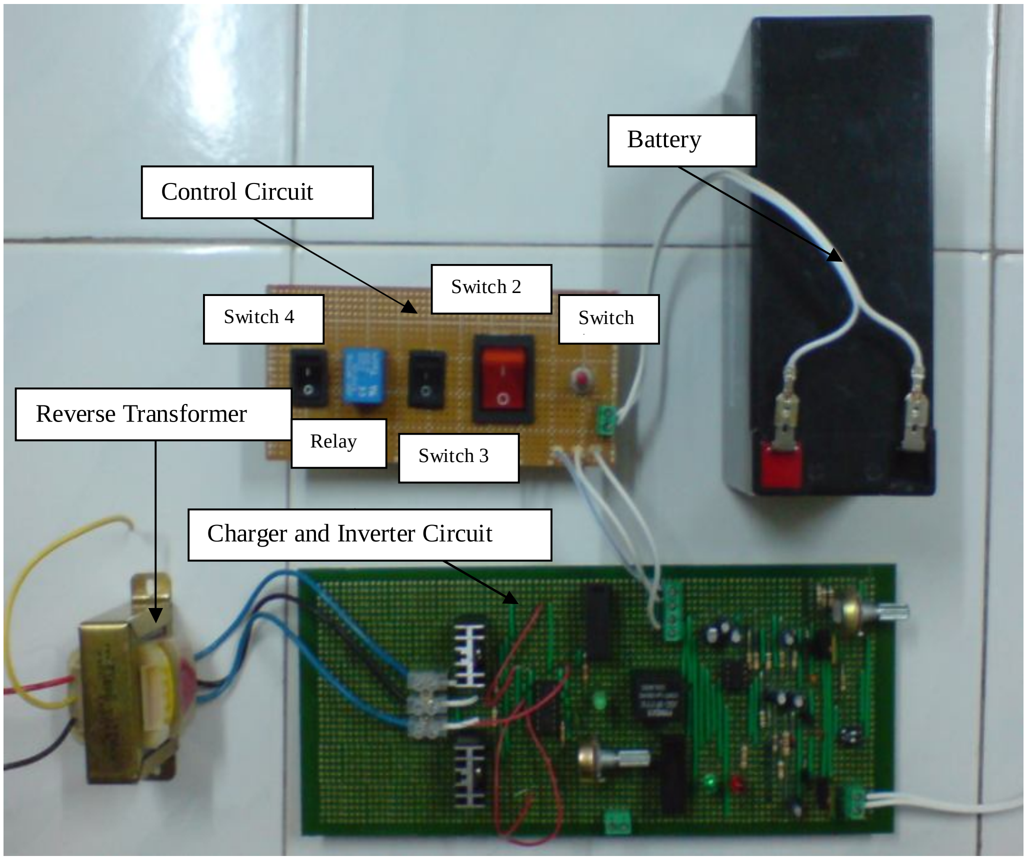


Figure 4.1: Complete Hardware

Label	Notification
Battery	7Ah acid lead battery
Switch	Control the incoming solar through the charger circuit
Switch 2	Direct AC from TNB (Socket Outlet)
Switch 3	Control either use Inverter or direct AC from TNB
Switch 4	Turn On the output from the Inverter
Relay	Change the output either use Inverter or direct from TNB
Transformer	Reverse Transformer from 12-240 AC

Table 4.1 : Notification Circuit Label

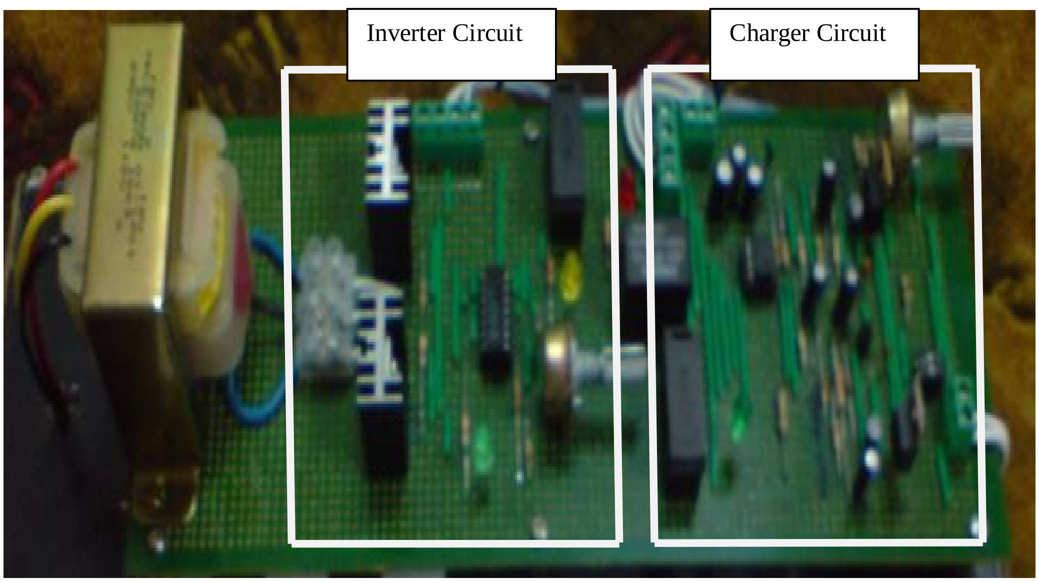


Figure 4.2: Charger and Inverter Circuits

4.3 Result and Discussion

Data result from the Inverter:

Reading	Duration (Hours)	`Voltage (Volt)
1	0	12.51
2	1	11.53
3	2	11.04
4	3	8.81
5	4	3.98

Table 4.2: Voltage Drop for 8 Watt Load

This result showed the voltage drop of the 7Ah battery. The load used for this result is 8 Watt Philips Lamp. When the voltage decrease to 3.98 V, the lamp will be turn off. It shown the voltage from the battery could not support anymore. The inverters need 12 VDC in order to get the output 240 VAC. Theoretically the voltage can stay till 10 hours and 27 minutes, but practically the battery can support below than 4 hours. It is because the battery is not in full charge and the power loss in the circuit.

Reading	Duration (Minutes)	Voltage (Volt)
1	0	12.06
2	15	11.85
3	30	11.64
4	45	11.46
5	60	11.23
6	75	9.81
7	90	9.10
8	105	6.52
9	118	5.46

Table 4.3: Voltage Drop for 17 Watt Load

Table 4.3 showed the voltage drop of the 7Ah battery. The load used for this result is combination 2 lamps and the combination power is 17 Watt. When the voltage decrease to 6.52 V, one of the lamps (9 Watt) will be turn off. It shown the voltage from the battery could not support for high load. Another lamp still on because the output from the inverter still produces enough voltage only for one load (8 Watt). Theoretically the voltage can stay below than 4 hours, but practically the battery can support below than 2 hours. It is because the battery is not in full charge and the power loss in the circuit. In order to get more hour, increase the capacity of the battery. More current can produce from the battery, its more hour lamp will be turn on.

Data result from the Charger:

Reading	Duration (Minutes)	Voltage (Volt)
1	0	3.50
2	5	8.37
3	10	10.64
4	15	11.75
5	20	11.97
6	25	12.16
7	30	12.50
8	35	12.65

Table 4.4: Charging Battery

Figure 4.3: Reading During Charging

Result from the Inverter:

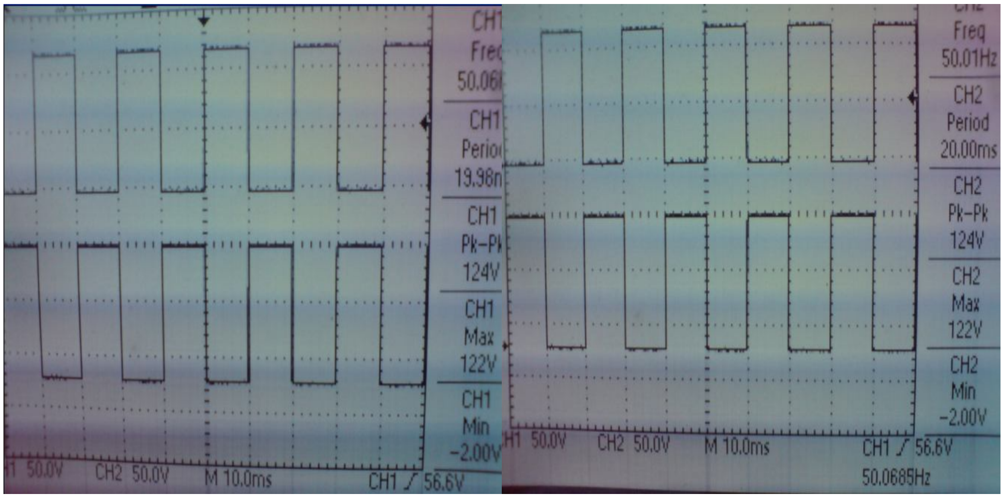


Figure 4.4 Output Signal from CD4047

Figure 4.4 showed the difference wave between two Channels of the Oscilloscope. Output wave for Channel 1 is upper side and the output for Channel 2 is lower side. This figure showed the same output produced by IC CD4047. The frequency, period, peak to peak voltage, maximum voltage and minimum voltage is nearest each other. From theoretically, the frequency can be calculated by using the period produced. The maximum voltage must be 120 V but in practically get 122 V. But the minimum voltage showed in figure is -2 V, and when 122-2V, we get 120 V. It’s same with theoretically calculation. Actually the output frequency of this circuit can be control change the value of the Resistor or Capacitor at CD4047 used and the calculation will be shown below.

Calculation:

Frequency, f = 1/T

T = 4.40 RC

C = 0.01 uF

R = 350 kΩ – 450kΩ

If used, R = 350 kΩ

T = 4.40 (350k)(0.01u) = 0.0154 s

f = 1/0.0154 = **64.93 Hz**

If used, R = 450 kΩ

T = 4.40 (450k) (0.01u) = 0.0198 s

f = 1/0.0198 = 50**.51 Hz**

Note: 4.40 is the constant for Astable Mode Design, and constant for Monostable Mode Design is 2.48.

Thus, the resistor can use in this circuit CD4047 is 350 kΩ connected series with variable resistor 100 kΩ in order to get variable frequency.

Figure 4.5: Output Voltage from Power Mosfet

Figure 4.5 showed the reading output voltage from the IRF540 Power Mosfet by using Digital Multimeter. Actually the result shown 12 V for AC current produced. Output from the CD4047 will be trough the power mosfet to step up the current before go trough the Transformer. Transformer used in this project is 240-12 VAC, but the transformer connects reversely in order to step up the voltage.

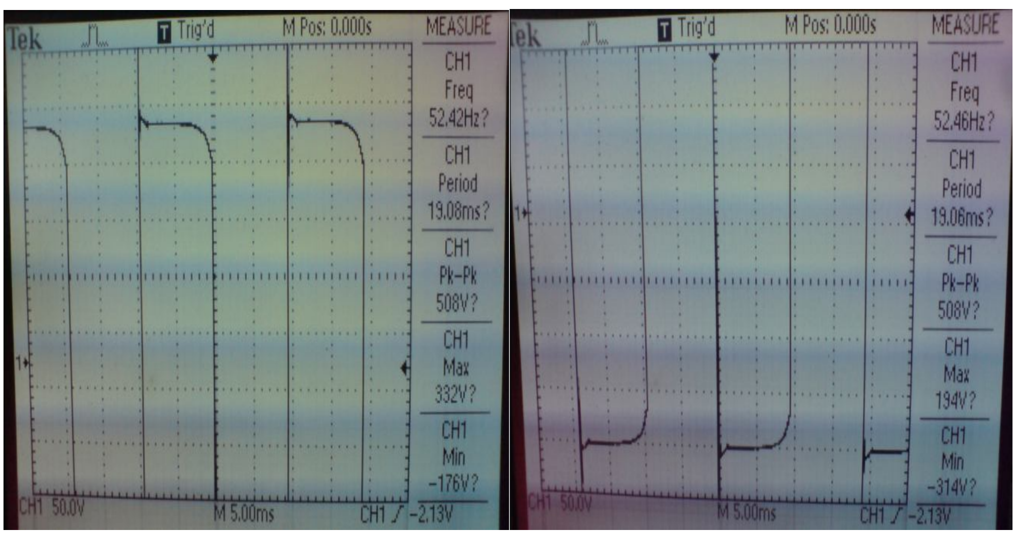


Figure 4.6: Output Signal from Transformer

Figure 4.6 showed the output voltage produced by inverter. The left hand side picture shown the wave at maximum voltage and the right hand side picture shown the wave at minimum voltage. Actually the signal in same Channel of Osciloscope but the signal could not see when combine both of it. That’s why the result showed in two side. It is because the signal produced in high duration time. To get the signal with the figure, change the multiple of the probe into 10X not 100X. Adjust the duration untill get the wave same like the figure shown. But the wave produced is not pure sine wave because the output produced from the CD4047 is square wave only. The CD4047 is function to shift the input signal by 180 degree and separate it into two output of square wave. Then the signal will be combine by using the power mosfet IRF540 to get the full square wave. By using reverse Transformer, the voltage will be step up from 12 VAC to 240 VAC. Figure below will show the output from the Transformer connected with Socket Outlet and the reading voltage produced by the inverter.

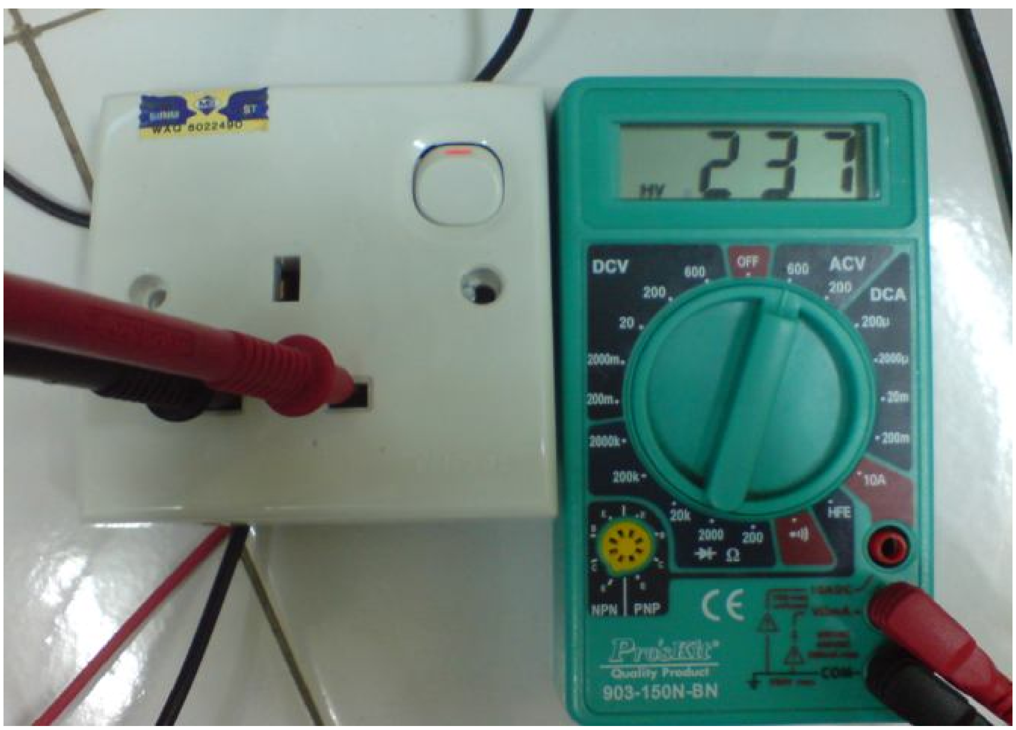


Figure 4.7: Output Voltages Produced

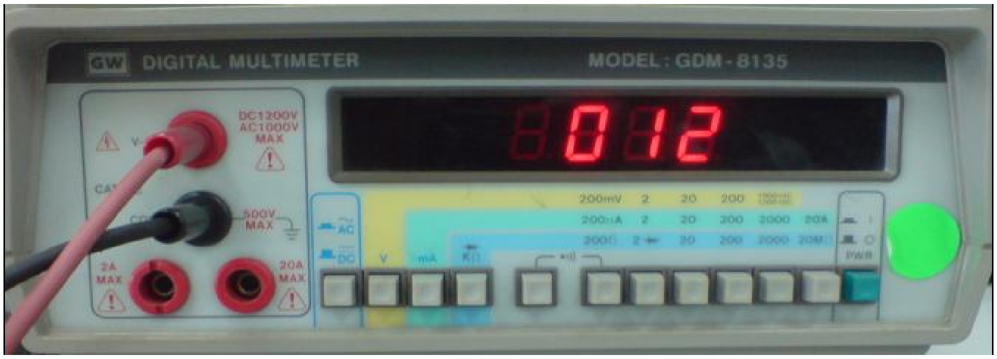


Figure 4.8: Reading at Low Voltage Transformer

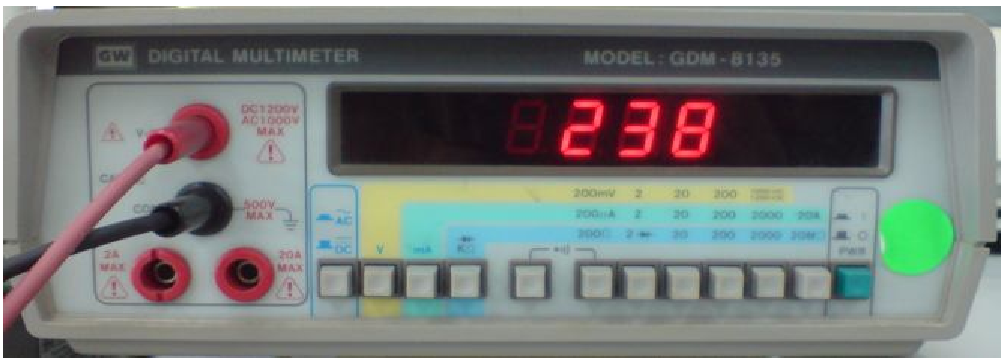


Figure 4.9: Reading at High Voltage Transformer

Figure 4.10: Reading for Input DC

4.4 Calculation

In this part, calculation about the illumination of the lamp produced. Illumination is the light falling of the surface, which also called incident radiation. But some of the value must be assuming in order to get that illumination. For example the area that we need to installed this lamp. The lumen is the flow of light which is radiated from the source. The lumen will be showed at the lamp itself or at the lamp specification. The important thing is the percent of the light reach the surface or the working plane. This value also we need to assume in order to get the illumination. Two lamps are use is 2U Screw-in Fluorescent Lamp 8Wattand the Lumen of the lamp is 435 lumen.

Assume: Length = 5 m, Width = 3 m and 90% output lamp reach to the surface area.

Total lumen output	= 2 x 435 lumen
	= 870 lumen
Light reaching surface	= 90% x 870
	= 783 lumen
Surface area	= 5 m x 3 m
	= 15 m^2

Thus,

Illumination, E	= Incident light/Surface area
	= 783/12
	= 52.2 = 52 lux

From that calculation, we know that this project suitable for area that need the illumination about 50 Lux only. Refer to Appendix G, the suitable area is living room, bedroom and garage.

4.5 Discussion

The whole circuit that had been constructed shows in Figure 4.11. All the circuit combines into that figure. The charger reading shows in the Table 4.3 and Figure 4.3 showed the reading of the charger during charging condition. All output reading shows in figures above. The result here is the square wave, not the pure sine wave. The Figure 4.11 below will show the inverter can generate suitable output for the load to turn on in stable. Both of the lamps showed in that figure will be on when the switch at the socket outlet turn on.

Figure 4.11: Complete Hardware Produced

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Summary of the Project

The charger and the inverter circuit have been discussed in previous chapter. The theory about all the circuit has been discussed and the result shows everything about this project. The inverter circuit is most important thing in this project. A lot of inverter circuit has been show and their relative advantages and disadvantages also have been discussed.

The inverter in this project acts like a heart because the controller CD4047 is very sensitive. The result is fully depending on that controller. If the signal not produced at pin 10 and 11, the inverter will be not produced for the output. In order to get the suitable value at the output, make sure the CD4047 is not burn and the important things here is do not connect the battery in wrong polarity.

The load used in this project is two pieces screw-in fluorescent lamp cool daylight 8 and 9 Watt. It is also call the Energy Saving Lamp. The duration of the load will be stay by using 7Ah acid-lead battery same like I said before and it shown in the result above.

Through this project, the ability of the inverter to convert the DC current to the AC current has been done. The charger can take the sun energy from the sun and store into the battery. The DC current could be converting to the AC current by using the inverter. The load used in this project also suitable with the main title of this project. For the conclusion, this project is achieving all the objectives.

5.2 Future Recommendation

The future recommendation for this project is more studies about the related information especially to the other candidates. There is maybe some modification for the circuit to make this project look more interesting and flexible for the other users. The recommendation is suggested is:

i. Change the controller CD4047 for the inverter into the other type or other controller that more efficient and more stable than this controller.

ii. Design the other inverter that can produce more power than inverter in this project and flexible with more than one load.

iii. Resize the size of the hardware so it is more interesting, reasonable, and compact and make it easy for all users.

iv. Use larger battery if want to use larger load.

5.3 Commercialization

In this part, this project can be commercialized if adding several devices. For example change the large capacity of the battery in order to get more hour of lamp to on. This project can be installed to our home but the inverter produced low power. To solve this problem, do not connect the load more than three load depend on the power used. Let say we want to installed it for 36W electronic fluorescent lamp, we need larger battery and it necessary only for one load. Refer to result that we get in this project, if used 8W load the battery can generate in four hours and if used 17W load the battery can generate only two hours. This happen because use 7Ah battery. If use 40Ah battery, it can generate power for more load. For the conclusion better installed this hardware for lower load only.

5.4 Component List

The total components and the prices for Cascaded Multilevel Inverter is summarized in the Table 5.1.

Components/devices	Specifications	Quantity	Price (RM)	Total (RM)
MOSFET	IRF540	2	3.50	7.00
IC	CD4047	1	3.50	3.50
IC	TLC2272	1	3.00	3.00
Transistor	2N3904	1	1.50	1.50
Voltage regulator	LM7805	1	2.50	2.50
Variable Resistor	100k	2	1.50	3.00
Resistor	2.2k	1	0.0	0.30
Resistor	10k	1	0.10	0.10
Resistor	100k	5	0.10	0.50
Resistor	750	2	0.10	0.20
Resistor	180k	1	0.10	0.10
Resistor	200k	2	0.10	0.10
Resistor	300k	1	0.10	0.10
Resistor	4.7M	1	0.10	0.10
Resistor	100	1	0.10	0.10
Resistor	1k	3	0.10	0.30
Resistor	22k	1	0.10	0.10
Resistor	3.3k	1	0.10	0.10
Resistor	4.7k	1	0.10	0.10
Capacitor	0.1uF	6	0.15	0.90
Capacitor	0.01uF	3	0.15	0.45
Capacitor	47uF	1	0.15	0.15
Zener diode	12V	1	2.00	2.00
Schottky diode	90SQ045	1	4.00	4.00
LED	-	4	0.50	2.00
Fuse	10A	2	1.00	2.00
Connecter	-	8	1.00	8.00
Heat sink	-	2	1.00	2.00

IC base	8 foot	1	0.50	0.50
IC base	14 foot	1	0.50	0.50
Vera board	-	2	3.50	7.00
Wire jumper	-	0.3m	2.00	1.00
Wire	-	0.2m	0.50	1.00
Switch	-	5	3.00	15.00
Relay	-	2	1.50	3.00
Socket Outlet	3 Pin	1	1.50	1.50
Lamp	Screw-in	2	7.00	14.00
Total				87.70

Table 5.1: List of component

REFFERENCES

[1] Kei Mori, 3-16-3-501, Kaminoge, Setagaya-ku, *Solar Light Energy and Electric Lighting System*, http://www.freepatent.com.

[2] William E. Rogers, San Antonio, Tex, *Solar Power For Lighting System*, http://www.freepatents.com.

[3] Dr. Zainal Salam, Reka Bentuk & Pembangunan Penyongsang Dwi Hala Berprestasi Tinggi Untuk Aplikasi Photovolataic,UTM Skudai, http://eprints.utm.my/2934/1/74104.

[4] Renata Reisfeld, Samuel Neuman, Collector For Solar Energy, 4 Jan 1983, http://www.freepatent.com.

[5] Kuang-Huang Kao, Outdoor Solar Energy Lamp, 25 September 2007, http://www.freepatent.com.

[6] John Lovine, *PIC Microcontroller Project Book*, http://books.google.com.my/books/piccontroller.

[7] Robert P. Fuller, Larry A. Nordstrom, Fluorescent Lamp Circuit, 17 Dec 1985,
http://www.freepatent.com.

[8] Yoshinobu Inchinose, Fluorescent Lamp Lighting Device, 31 Jan 1978 http://www.freepatent.com.

[9] Stefan F. Szuba, Fluorescent Lamp Controlling Arrangement, 21 Jan 1992, http://www.freepatent.com.

[10] Stefan F. Szuba, Fluorescent Lamp Lighting Arrangement For “Smart Building”,
15 Jun 1993, http://www.freepatent.com.

[11] Onn Fah Foo, Light Control Fluorescent Lamp and Circuit Thereof, 23 Aug 2007, http://www.freepatent.com.

[12] D. Mohan Kumar, Lead-Acid Battery Charger With Voltage Analyser, March 2003, http://www.freepatent.com.

[13] http://www.cirkits.com/das1/das1specs.html

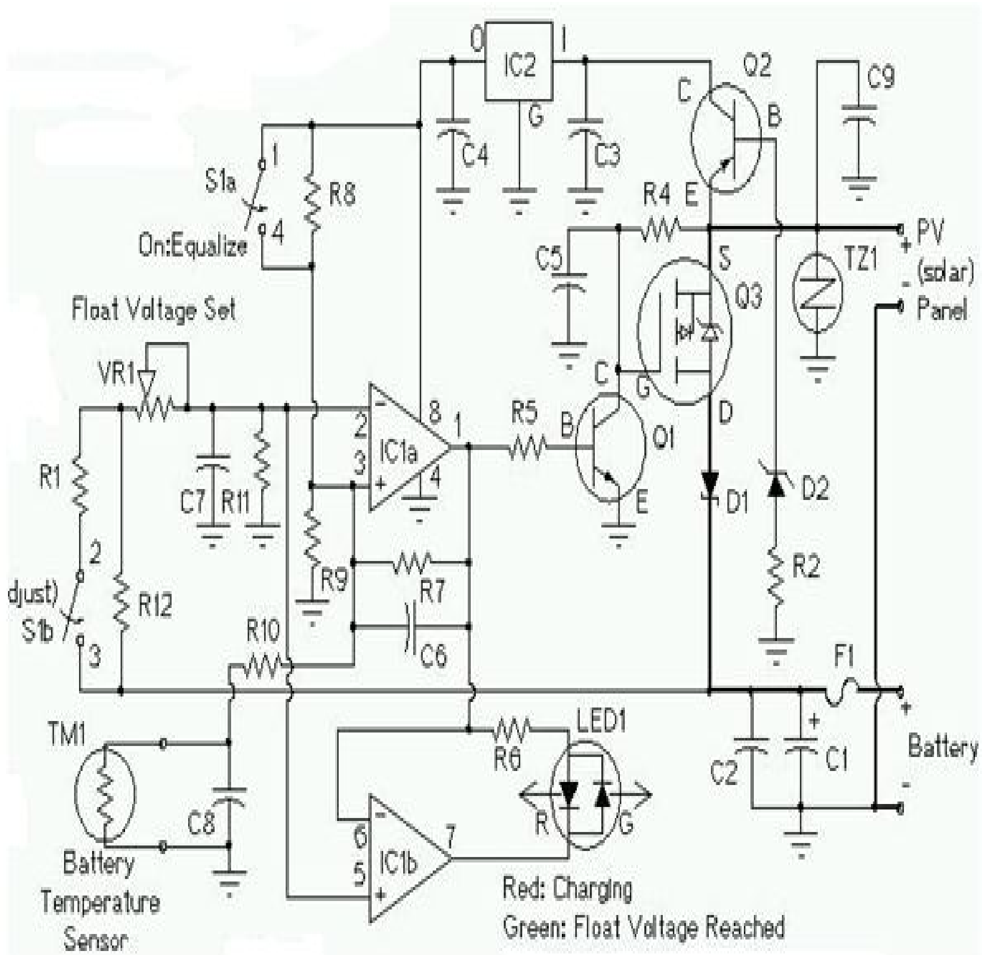
[14] http://www.merisitechnologies.com/products.html

[15] http:// www.wikipedia.org

[16] http://www.energymatters.com.au/climate-data/saps-electricity-usage.php

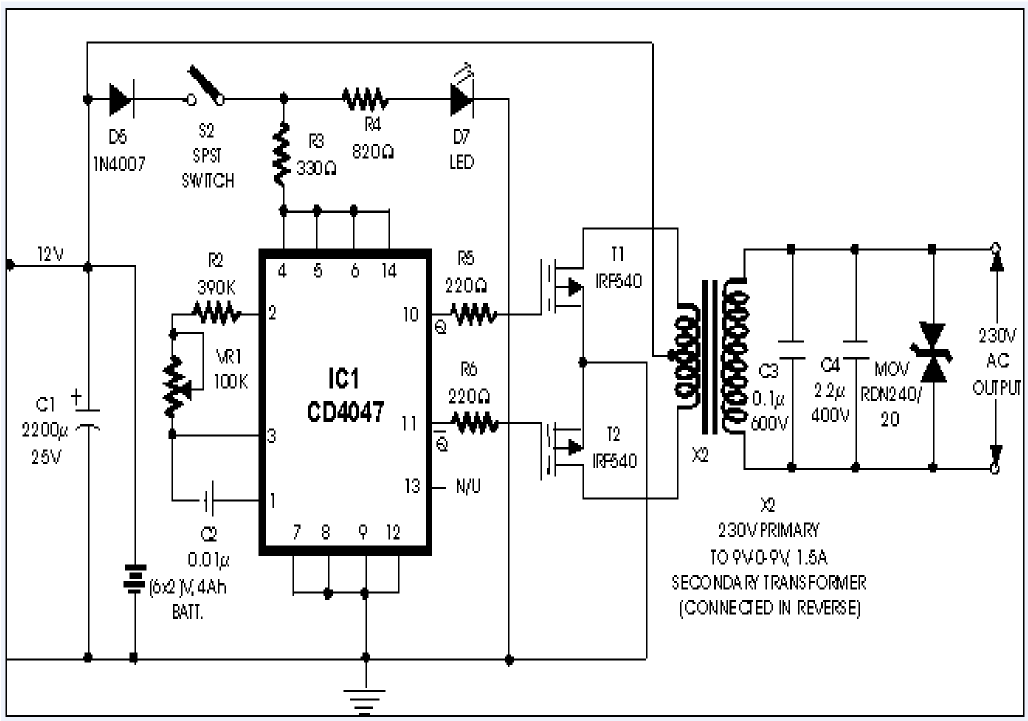
[17] Jim Doucet, Dan Eggleston, Jeremy Shaw "DC/AC Pure Sine Wave"2006-2007.

APPENDIX A
Circuit Diagram for Charger



IC2
0
I
G
C4
C3
C9
Q2
C
B
E
R4
S1a
1
4
On:Equalize
R8
C5
S
Q3
TZ1
PV
(solar)
Panel
Float Voltage Set
VR1
C
G
D
2
3
IC1a
8
1
4
R5
B
Q1
E
R1
C7
R11
D1
D2
djust)
S1b
R12
R9
R7
R2
R10
C6
F1
TM1
R6
LED1
C2
C1
Battery
C8
R
G
6
7
5
IC1b
Battery
Temperature
Sensor
Red: Charging
Green: Float Voltage Reached

APPENDIX B
Circuit Diagram for Inverter



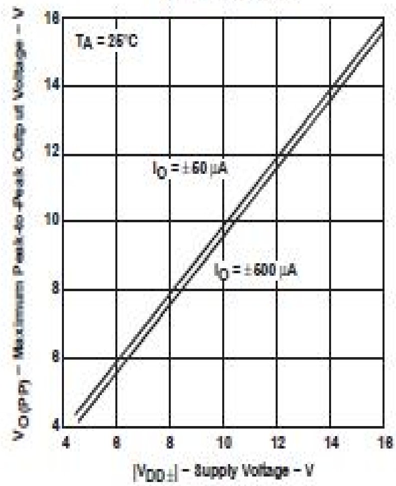
D6
1N4007
S2
SPST
SWITCH
R3
330Ω
R4
820Ω
D7
LED
12V
R2
390K
VR1
100K
IC1
CD4047
C1
2200μ
25V
C2
0.01μ
(6x2)V, 4Ah
BATT.
R5
220Ω
R6
220Ω
N/U
T1
IRF540
T2
IRF540
X2
C3
0.1μ
600V
C4
2.2μ
400V
MOV
RDN240/
20
230V
AC
OUTPUT
X2
230V PRIMARY
TO 9V-0-9V, 1.5A
SECONDARY TRANSFORMER
(CONNECTED IN REVERSE)

APPENDIX C
Datasheet TLC2272

- Output Swing Includes Both Supply Rails
- Low Noise . . . 9 nV/√Hz Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Both Single-Supply and Split-Supply Operation
- Common-Mode Input Voltage Range Includes Negative Rail
- High-Gain Bandwidth . . . 2.2 MHz Typ
- High Slew Rate . . . 3.6 V/µs Typ
- Low Input Offset Voltage 950 µV Max at T_A = 25°C
- Macromodel Included
- Performance Upgrades for the TS272, TS274, TLC272, and TLC274
- Available in Q-Temp Automotive
  HighRel Automotive Applications
  Configuration Control / Print Support
  Qualification to Automotive Standards

description

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE



The TLC2272 and TLC2274 are dual and quadruple operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC227x family offers 2 MHz of bandwidth and 3 V/µs of slew rate for higher speed applications. These devices offer comparable ac performance while having better noise, input offset voltage, and power dissipation than existing CMOS operational amplifiers. The TLC227x has a noise voltage of 9 nV/√Hz, two times lower than competitive solutions.

The TLC227x, exhibiting high input impedance and low noise, is excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micro-power dissipation levels, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature, with single- or split-supplies, makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLC227xA family is available with a maximum input offset voltage of 950 µV. This family is fully characterized at 5 V and ±5 V.

The TLC2272/4 also makes great upgrades to the TLC272/4 or TS272/4 in standard designs. They offer increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442 devices.

If the design requires single amplifiers, see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

TLC2272 AVAILABLE OPTIONS

T_A	V_{IO}max At 25°C	PACKAGED DEVICES					
		SMALL OUTLINE† (D)	CERAMIC LCC (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP‡ (PW)	CERAMIC FLAT PACK (U)
0°C to 70°C	950 µV 2.5 mV	TLC2272ACD TLC2272CD	— —	— —	TLC2272ACP TLC2272CP	TLC2272ACPW TLC2272CPW	— —
−40°C to 125°C	950 µV 2.5 mV	TLC2272AID TLC2272ID	— —	— —	TLC2272AIP TLC2272IP	— TLC2272IPW	— —
	950 µV 2.5 mV	TLC2272AQD TLC2272QD	— —	— —	—	TLC2272AQPW TLC2272QPW	— —
−55°C to 125°C	950 µV 2.5 mV	TLC2272AMD TLC2272MD	TLC2272AMFK TLC2272MFK	TLC2272AMJG TLC2272MJG	TLC2272AMP TLC2272MP	—	TLC2272AMU TLC2272MU

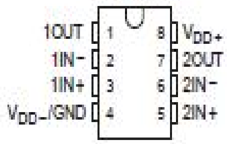
† The D packages are available taped and reeled. Add R suffix to the device type (e.g., TLC2272CDR).
‡ The PW package is available taped and reeled. Add R suffix to the device type (e.g., TLC2272PWR).
§ Chips are tested at 25°C.

TLC2274 AVAILABLE OPTIONS

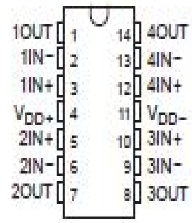
T_A	V_{IO}max AT 25°C	PACKAGED DEVICES					
		SMALL OUTLINE† (D)	CERAMIC LCC (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP‡ (PW)	CERAMIC FLAT PACK (W)
0°C to 70°C	950 µV 2.5 mV	TLC2274ACD TLC2274CD	—	—	TLC2274ACN TLC2274CN	TLC2274ACPW TLC2274CPW	—
−40°C to 125°C	950 µV 2.5 mV	TLC2274AID TLC2274ID	—	—	TLC2274AIN TLC2274IN	TLC2274AIPW TLC2274IPW	—
	950 µV 2.5 mV	TLC2274AQD TLC2274QD	—	—	—	—	—
−55°C to 125°C	950 µV 2.5 mV	TLC2274AMD TLC2274MD	TLC2274AMFK TLC2274MFK	TLC2274AMJ TLC2274MJ	TLC2274AMN TLC2274MN	—	TLC2274AMW TLC2274MW

† The D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2274CDR).
‡ The PW package is available taped and reeled.
§ Chips are tested at 25°C.

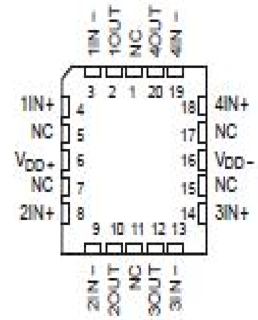
TLC2272
D, JG, P, OR PW PACKAGE
(TOP VIEW)



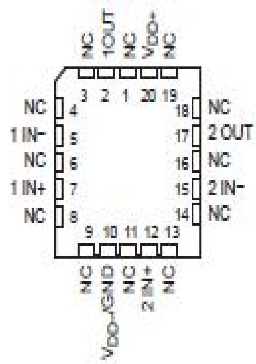
TLC2274
D, J, N, PW, OR W PACKAGE
(TOP VIEW)



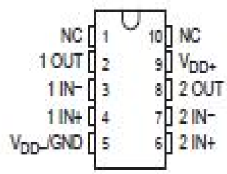
TLC2274
FK PACKAGE
(TOP VIEW)



TLC2272
FK PACKAGE
(TOP VIEW)



TLC2272
U PACKAGE
(TOP VIEW)



NC – No internal connection

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD+} (see Note 1) . . . . 8 V
Supply voltage, V_{DD-} (see Note 1) . . . . –8 V
Differential input voltage, V_{ID} (see Note 2) . . . . ±16 V
Input voltage range, V_I (any input, see Note 1) . . . . V_{DD-} – 0.3 V to V_{DD+}
Input current, I_I (any input) . . . . ±5 mA
Output current, I_O . . . . ±50 mA
Total current into V_{DD+} . . . . ±50 mA
Total current out of V_{DD-} . . . . ±50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3) . . . . unlimited
Package thermal impedance, θ_{JA} (see Notes 4 and 5): D package (8 pin) . . . . 97.1°C/W
D package (14 pin) . . . . 86.2°C/W
N package . . . . 79.7°C/W
P package . . . . 84.6°C/W
PW package (8 pin) . . . . 149°C/W
PW package (14 pin) . . . . 113°C/W
Package thermal impedance, θ_{JC} (see Notes 4 and 5): FK package . . . . 5.6°C/W
J package . . . . 15.1°C/W
U package . . . . 14.7°C/W
Operating free-air temperature range, T_A: C suffix . . . . 0°C to 70°C
I, Q suffix . . . . –40°C to 125°C
M suffix . . . . –55°C to 125°C
Storage temperature range . . . . –65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, P or PW package . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J or U package . . . . 300°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{DD+} and V_{DD-}.
2. Differential voltages are at IN+ with respect to IN–. Excessive current will flow if input is brought below V_{DD-} – 0.3 V.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.
4. Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
5. The package thermal impedance is calculated in accordance with JESD 51-7 (plastic) or MIL-STD-883 Method 1012 (ceramic).

recommended operating conditions

	C SUFFIX		I SUFFIX		Q SUFFIX		M SUFFIX		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{DD\pm}$	±2.2	±8	±2.2	±8	±2.2	±8	±2.2	±8	V
Input voltage, V_I	V_{DD-}	V_{DD+} – 1.5	V_{DD-}	V_{DD+} – 1.5	V_{DD-}	V_{DD+} – 1.5	V_{DD-}	V_{DD+} – 1.5	V
Common-mode input voltage, V_{IC}	V_{DD-}	V_{DD+} – 1.5	V_{DD-}	V_{DD+} – 1.5	V_{DD-}	V_{DD+} – 1.5	V_{DD-}	V_{DD+} – 1.5	V
Operating free-air temperature, T_A	0	70	–40	125	–40	125	–55	125	°C

TLC2272C electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	T_A†	TLC2272C MIN	TLC2272C TYP	TLC2272C MAX	TLC2272AC MIN	TLC2272AC TYP	TLC2272AC MAX	UNIT
V_{IO}	Input offset voltage	V_{IC} = 0 V, $V_{DD}\pm$ = ±2.5 V, V_O = 0 V, R_S = 50 Ω	25°C		300	2500		300	950	μV
			Full range			3000			1500	
α_{VIO}	Temperature coefficient of input offset voltage		25°C to 70°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.002			0.002		μV/mo
I_{IO}	Input offset current		25°C		0.5	60		0.5	60	pA
			Full range			100			100	
I_{IB}	Input bias current		25°C		1	60		1	60	pA
			Full range			100			100	
V_{ICR}	Common-mode input voltage	R_S = 50 Ω, $\|V_{IO}\|$ ≤ 5 mV	25°C	0 to 4	−0.3 to 4.2		0 to 4	−0.3 to 4.2		V
			Full range	0 to 3.5			0 to 3.5			
V_{OH}	High-level output voltage	I_{OH} = −20 μA	25°C		4.99			4.99		V
		I_{OH} = −200 μA	25°C	4.85	4.93		4.85	4.93		
			Full range	4.85			4.85			
		I_{OH} = −1 mA	25°C	4.25	4.65		4.25	4.65		
			Full range	4.25			4.25			
V_{OL}	Low-level output voltage	V_{IC} = 2.5 V, I_{OL} = 50 μA	25°C		0.01			0.01		V
		V_{IC} = 2.5 V, I_{OL} = 500 μA	25°C		0.09	0.15		0.09	0.15	
			Full range			0.15			0.15	
		V_{IC} = 2.5 V, I_{OL} = 5 mA	25°C		0.9	1.5		0.9	1.5	
			Full range			1.5			1.5	
A_{VD}	Large-signal differential voltage amplification	V_{IC} = 2.5 V, V_O = 1 V to 4 V, R_L = 10 kΩ‡	25°C	15	35		15	35		V/mV
			Full range	15			15			
		V_{IC} = 2.5 V, V_O = 1 V to 4 V, R_L = 1 MΩ‡	25°C		175			175		
r_{id}	Differential input resistance		25°C		10^{12}			10^{12}		Ω
r_i	Common-mode input resistance		25°C		10^{12}			10^{12}		Ω
c_i	Common-mode input capacitance	f = 10 kHz, P package	25°C		8			8		pF
z_o	Closed-loop output impedance	f = 1 MHz, A_V = 10	25°C		140			140		Ω
CMRR	Common-mode rejection ratio	V_{IC} = 0 V to 2.7 V, V_O = 2.5 V, R_S = 50 Ω	25°C	70	75		70	75		dB
			Full range	70			70			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	V_{DD} = 4.4 V to 16 V, V_{IC} = V_{DD}/2, No load	25°C	80	95		80	95		dB
			Full range	80			80			
I_{DD}	Supply current	V_O = 2.5 V, No load	25°C		2.2	3		2.2	3	mA
			Full range			3			3	

† Full range is 0°C to 70°C.
‡ Referenced to 0 V

NOTE 6: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

APPENDIX D
Datasheet CD4047

TEXAS INSTRUMENTS

Data sheet acquired from Harris Semiconductor
SCHS044

CD4047B Types

CMOS Low-Power Monostable/Astable Multivibrator

High Voltage Types (20-Volt Rating)

■ CD4047B consists of a gatable astable multivibrator with logic techniques incorporated to permit positive or negative edge-triggered monostable multivibrator action with retriggering and external counting options.

Inputs include +TRIGGER, −TRIGGER, ASTABLE, $\overline{\text{ASTABLE}}$, RETRIGGER, and EXTERNAL RESET. Buffered outputs are $\overline{Q}$, Q, and OSCILLATOR. In all modes of operation, and external capacitor must be connected between C-Timing and RC-Common terminals, and an external resistor must be connected between the R-Timing and RC-Common terminals.

Astable operation is enabled by a high level on the ASTABLE input or a low level on the $\overline{\text{ASTABLE}}$ input, or both. The period of the square wave at the Q and $\overline{Q}$ Outputs in this mode of operation is a function of the external components employed. "True" input pulses on the ASTABLE input or "Complement" pulses on the $\overline{\text{ASTABLE}}$ input allow the circuit to be used as a gatable multivibrator. The OSCILLATOR output period will be half of the Q terminal output in the astable mode. However, a 50% duty cycle is not guaranteed at this output.

The CD4047B triggers in the monostable mode when a positive-going edge occurs on the +TRIGGER-input while the -TRIGGER is held low. Input pulses may be of any duration relative to the output pulse.

If retrigger capability is desired, the RETRIGGER input is pulsed. The retriggerable mode of operation is limited to positive-going edge. The CD4047B will retrigger as long as the RETRIGGER-input is high, with or without transitions (See Fig. 34).

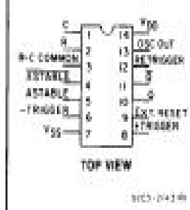
An external countdown option can be implemented by coupling "Q" to an external "N" counter and resetting the counter with the trigger pulse. The counter output pulse is fed back to the $\overline{\text{ASTABLE}}$ input and has a duration equal to N times the period of the multivibrator.

A high level on the EXTERNAL RESET input assures no output pulse during an "ON" power condition. This input can also be activated to terminate the output pulse at any time. For monostable operation, whenever V_{DD} is applied, an internal power-on reset circuit will clock the Q output low within one output period (t_M).

The CD4047B-Series types are supplied in 14-lead hermetic dual-in-line ceramic packages (D and F suffixes), 14-lead dual-in-line plastic packages (E suffix), and in chip form (H suffix).

Features:

- *Low power consumption: special CMOS oscillator configuration*
- *Monostable (one-shot) or astable (free-running) operation*
- *True and complemented buffered outputs*
- *Only one external R and C required*
- *Buffered inputs*
- *100% tested for quiescent current at 20 V*
- *Standardized, symmetrical output characteristics*
- *5-V, 10-V, and 15-V parametric ratings*
- *Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for Description of 'B' Series CMOS Devices"*



Terminal Diagram

Monostable Multivibrator Features:

- *Positive- or negative-edge trigger*
- *Output pulse width independent of trigger pulse duration*
- *Retriggerable option for pulse width expansion*
- *Internal power-on reset circuit*
- *Long pulse widths possible using small RC components by means of external counter provision*
- *Fast recovery time essentially independent of pulse width*
- *Pulse-width accuracy maintained at duty cycles approaching 100%*

Astable Multivibrator Features:

- *Free-running or gatable operating modes*
- *50% duty cycle*
- *Oscillator output available*
- *Good astable frequency stability: Frequency deviation:*
  = ±2% + 0.03%/°C @ 100 kHz
  = ±0.5% + 0.015%/°C @ 10 kHz
  (circuits "trimmed" to frequency V_{DD} = 10 V ± 10%)

Applications:

Digital equipment where low-power dissipation and/or high noise immunity are primary design requirements:

- *Envelope detection*
- *Frequency multiplication*
- *Frequency division*
- *Frequency discriminators*
- *Timing circuits*
- *Time-delay applications*

RECOMMENDED OPERATING CONDITIONS

For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges:

CHARACTERISTIC	LIMITS		UNITS
	MIN.	MAX.	
Supply-Voltage Range (For T_A = Full Package-Temperature Range)	3	18	V
NOTE: IF AT 15 V OPERATION A 10 MΩ RESISTOR IS USED THE OPERATING TEMPERATURE SHOULD BE BETWEEN −25°C and 100°C			

MAXIMUM RATINGS, *Absolute-Maximum Values:*

DC SUPPLY-VOLTAGE RANGE, (V_{DD})
Voltages referenced to V_{SS} Terminal) .... −0.5V to +20V
INPUT VOLTAGE RANGE, ALL INPUTS .... −0.5V to V_{DD} +0.5V
DC INPUT CURRENT, ANY ONE INPUT .... ±10mA
POWER DISSIPATION PER PACKAGE (P_D):
For T_A = −55°C to +100°C 500mW
For T_A = +100°C to +125°C .... Derate Linearly at 12mW/°C to 200mW
DEVICE DISSIPATION PER OUTPUT TRANSISTOR
FOR T_A = FULL PACKAGE-TEMPERATURE RANGE (All Package Types) 100mW
OPERATING-TEMPERATURE RANGE (T_A) .... −55°C to +125°C
STORAGE TEMPERATURE RANGE (T_{stg}) .... −65°C to +150°C
LEAD TEMPERATURE (DURING SOLDERING):
At distance 1/16 ± 1/32 inch (1.59 ± 0.79mm) from case for 10s max .... +265°C

CD4047B FUNCTIONAL TERMINAL CONNECTIONS
NOTE: IN ALL CASES EXTERNAL RESISTOR BETWEEN TERMINALS 2 AND 3▲
EXTERNAL CAPACITOR BETWEEN TERMINALS 1 AND 3▲

FUNCTION	TERMINAL CONNECTIONS TO V_{DD}	TO V_{SS}	INPUT TO	OUTPUT PULSE FROM	OUTPUT PERIOD OR PULSE WIDTH
Astable Multivibrator:					
Free Running	4,5,6,14	7,8,9,12	—	10,11,13	t_A (10,11) = 4.40 RC
True Gating	4,6,14	7,8,9,12	5	10,11,13	t_A (13) = 2.20 RC#
Complement Gating	6,14	5,7,8,9,12	4	10,11,13	
Monostable Multivibrator:					
Positive-Edge Trigger	4,14	5,6,7,9,12	8	10,11	
Negative-Edge Trigger	4,8,14	5,7,9,12	6	10,11	t_M (10,11) = 2.48 RC
Retriggerable	4,14	5,6,7,9	8,12	10,11	
External Countdown*	14	5,6,7,8,9,12	—	10,11	

▲ See Text.

\# First positive ½ cycle pulse-width = 2.48 RC, see Note on Page 3-134.

* Input Pulse to Reset of External Counting Chip External Counting Chip Output To Terminal 4

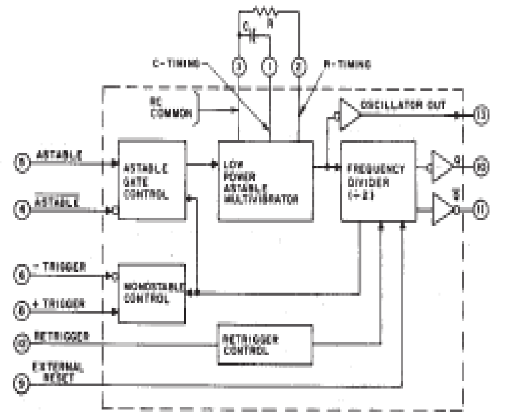


Fig. 1—CD4047B logic block diagram.

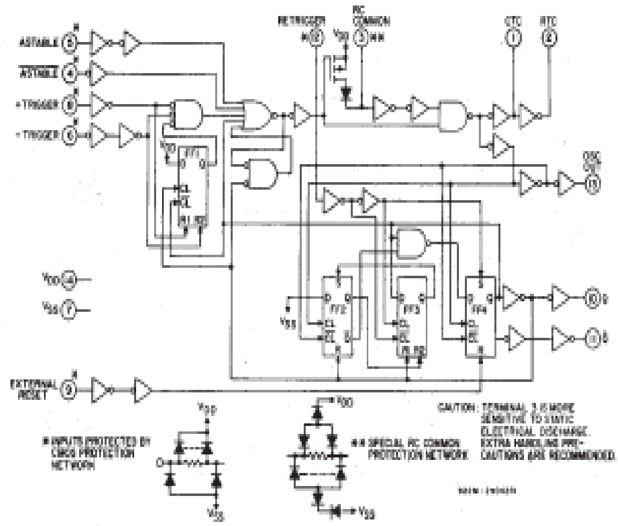


Fig. 2—CD4047B logic diagram.

STATIC ELECTRICAL CHARACTERISTICS (CONTINUED)

CHARACTERISTICS	CONDITIONS V_O (V)	V_{IN} (V)	V_{DD} (V)	LIMITS AT INDICATED TEMPERATURES (°C) −55	−40	+85	+125	+25 Min.	+25 Typ.	+25 Max.	UNITS
Output Voltage: High-Level, V_{OH} Min.	—	0,5	5	4.95				4.95	5	—	V
	—	0,10	10	9.95				9.95	10	—	
	—	0,15	15	14.95				14.95	15	—	
Input Low Voltage, V_{IL} Max.	0.5,4.5	—	5	1.5				—	—	1.5	V
	1,9	—	10	3				—	—	3	
	1.5,13.5	—	15	4				—	—	4	
Input High Voltage, V_{IH} Min.	0.5,4.5	—	5	3.5				3.5	—	—	
	1,9	—	10	7				7	—	—	
	1.5,13.5	—	15	11				11	—	—	
Input Current I_{IN} Max.	—	0,18	18	±0.1	±0.1	±1	±1	—	$\pm10^{-5}$	±0.1	µA

DYNAMIC ELECTRICAL CHARACTERISTICS *at T_A = 25°C; Input t_r, t_f = 20 ns, C_L = 50 pF, R_L = 200 kΩ*

CHARACTERISTIC	V_{DD} (V)	LIMITS MIN.	TYP.	MAX.	UNITS
Propagation Delay Time, t_{PHL}, t_{PLH} Astable, $\overline{Astable}$ to Osc. Out	5	—	200	400	ns
	10	—	100	200	
	15	—	80	160	
Astable, $\overline{Astable}$ to Q, $\overline{Q}$	5	—	350	700	
	10	—	175	350	
	15	—	125	250	
+ or - Trigger to Q, $\overline{Q}$	5	—	500	1000	
	10	—	225	450	
	15	—	150	300	
Retrigger to Q, $\overline{Q}$	5	—	300	600	
	10	—	150	300	
	15	—	100	200	
External Reset to Q, $\overline{Q}$	5	—	250	500	
	10	—	100	200	
	15	—	70	140	
Transition Time, t_{THL}, t_{TLH} Osc. Out, Q, $\overline{Q}$	5	—	100	200	
	10	—	50	100	
	15	—	40	80	
Minimum Input Pulse Width, t_W + Trigger, - Trigger	5	—	200	400	
	10	—	80	160	
	15	—	50	100	
Reset	5	—	100	200	
	10	—	50	100	
	15	—	30	60	
Retrigger	5	—	300	600	
	10	—	115	230	
	15	—	75	150	
Input Rise and Fall Time, t_r, t_f All Trigger Inputs For + Trigger: t_r t_f only is unlimited	5	—	270	—	µs
	10	—	18	—	
	15	—	9	—	
For - Trigger: t_f t_r only is unlimited	5	—	325	—	
	10	—	9	—	
	15	—	4	—	
Q or $\overline{Q}$ Deviation from 50% Duty Factor	5	—	±0.5	±1	%
	10	—	±0.5	±1	
	15	—	±0.1	±0.5	
Input Capacitance, C_{IN}	Any Input	—	5	7.5	pF

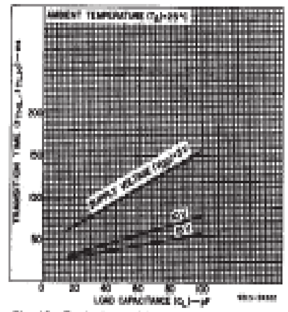


Fig. 10—Typical transition time as a function of load capacitance.

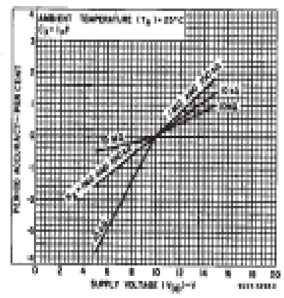


Fig. 11—Typical astable oscillator or Q, $\overline{Q}$ period accuracy vs. supply voltage.

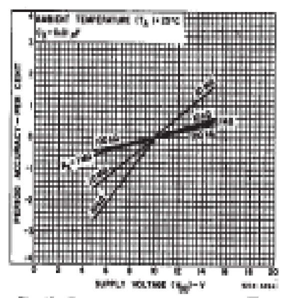


Fig. 12—Typical astable oscillator or Q, $\overline{Q}$ period accuracy vs. supply voltage.

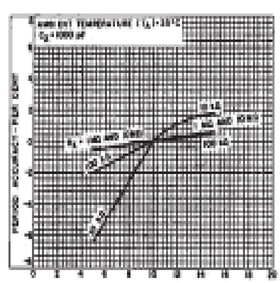


Fig. 13—Typical astable oscillator or Q, $\overline{Q}$ period accuracy vs. supply voltage.

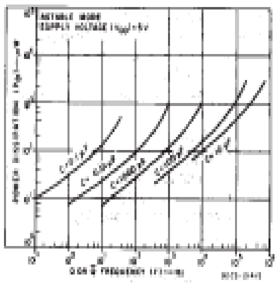


Fig. 26—Typical power dissipation vs. output frequency (V_{DD} = 5 V).

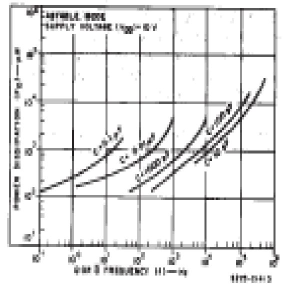


Fig. 27—Typical power dissipation vs. output frequency (V_{DD} = 10 V).

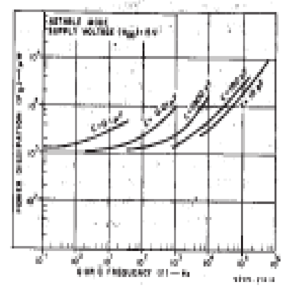


Fig. 28—Typical power dissipation vs. output frequency (V_{DD} = 15 V).

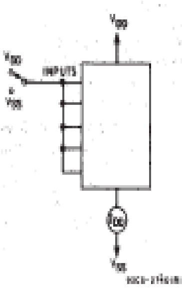


Fig. 29—Quiescent device current test circuit.

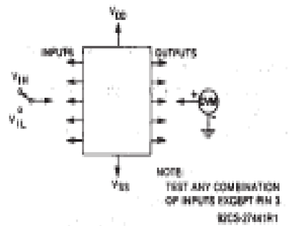


Fig. 30—Input-voltage test circuit.

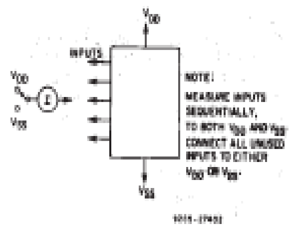


Fig. 31—Input-leakage current test circuit.

1. Astable Mode Design Information

A. Unit-to-Unit Transfer-Voltage Variations — The following analysis presents variations from unit to unit as a function of transfer-voltage (V_{TR}) shift (33%—67% V_{DD}) for free-running (astable) operation.

Fig. 32—Astable mode waveforms.

$$t_1 = -RC \ln \frac{V_{TR}}{V_{DD} + V_{TR}};$$

typically, t_1 = 1.1 RC

$$t_2 = -RC \ln \frac{V_{DD} - V_{TR}}{2V_{DD} - V_{TR}};$$

typically, t_2 = 1.1 RC

$$t_A = 2(t_1 + t_2)$$

$$= -2\,RC \ln \frac{(V_{TR})(V_{DD} - V_{TR})}{(V_{DD} + V_{TR})(2V_{DD} - V_{TR})}$$

Typ: V_{TR} = 0.5 V_{DD}	t_A = 4.40 RC
Min: V_{TR} = 0.33 V_{DD}	t_A = 4.62 RC
Max: V_{TR} = 0.67 V_{DD}	t_A = 4.62 RC

thus if t_A = 4.40 RC is used, the variation will be +5%, −0% due to variations in transfer voltage.

B. Variations Due to V_{DD} and Temperature Changes — In addition to variations from unit to unit, the astable period varies with V_{DD} and temperature. Typical variations are presented in graphical form in Figs. 11 to 18 with 10 V as reference for voltage variations curves and 25°C as reference for temperature variations curves.

II. Monostable Mode Design Information

The following analysis presents variations from unit to unit as a function of transfer-voltage (V_{TR}) shift (33% — 67% V_{DD}) for one-shot (monostable) operation.

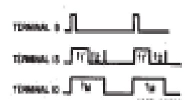


Fig. 33—Monostable waveforms.

$$t_1' = -RC \ln \frac{V_{TR}}{2V_{DD}}$$

typically, t_1' = 1.38 RC

$$t_M = (t_1' + t_2)$$

$$t_M = -RC \ln \frac{(V_{TR})(V_{DD} - V_{TR})}{(2V_{DD} - V_{TR})(2V_{DD})}$$

where t_M = Monostable mode pulse width. Values for t_M are as follows:

Typ: V_{TR} = 0.5 V_{DD}	t_M = 2.48 RC
Min: V_{TR} = 0.33 V_{DD}	t_M = 2.71 RC
Max: V_{TR} = 0.67 V_{DD}	t_M = 2.48 RC

thus if t_M = 2.48 RC is used, the variation will be +9.3%, −0% due to variations in transfer voltage.

Note:

In the astable mode, the first positive half cycle has a duration of t_M; succeeding durations are $t_A/2$.

In addition to variations from unit to unit, the monostable pulse width varies with V_{DD} and temperature. These variations are presented in graphical form in Fig. 19 to 26 with 10 V as reference for voltage-variation curves and 25°C as reference for temperature-variation curves.

III. Retrigger Mode Operation

The CD4047B can be used in the retrigger mode to extend the output-pulse duration, or to compare the frequency of an input signal with that of the internal oscillator. In the retrigger mode the input pulse is applied to terminal 12, and the output is taken from terminal 10 or 11. As shown in Fig. 34 normal monostable action is obtained when one retrigger pulse is applied. Extended pulse duration is obtained when more than one pulse is applied.

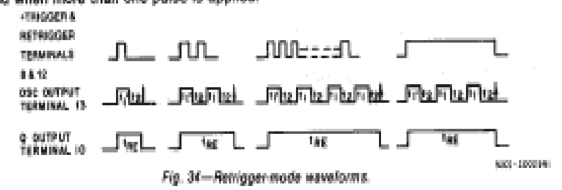


Fig. 34—Retrigger-mode waveforms.

For two input pulses, $t_{RE} = t_1' + t_1 + 2t_2$. For more than two pulses, the output pulse width is an integral number of time periods, with the first time period being $t_1' + t_2$, typically, 2.48RC, and all subsequent time periods being $t_1 + t_2$, typically, 2.2RC.

IV. External Counter Option

Time t_M can be extended by any amount with the use of external counting circuitry. Advantages include digitally controlled pulse duration, small timing capacitors for long time periods, and extremely fast recovery time. A typical implementation is shown in Fig. 35. The pulse duration at the output is

$$t_{ext} = (N - 1)(t_A) + (t_M + t_A/2)$$

where t_{ext} = pulse duration of the circuitry, and N is the number of counts used.

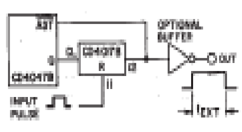


Fig. 35—Implementation of external counter option.

V. Timing-Component Limitations

The capacitor used in the circuit should be non-polarized and have low leakage (i.e. the parallel resistance of the capacitor should be at least an order of magnitude greater than the external resistor used). There is no upper or lower limit for either R or C value to maintain oscillation.

However, in consideration of accuracy, C must be much larger than the inherent stray capacitance in the system (unless this capacitance can be measured and taken into account). R must be much larger than the CMOS "ON" resistance in series with it, which typically is hundreds of ohms. In addition, with very large values of R, some short-term instability with respect to time may be noted.

The recommended values for these components to maintain agreement with previously calculated formulas without trimming should be:

$C \geq 100$ pF, up to any practical value, for astable modes;

$C \geq 1000$ pF, up to any practical value for monostable modes.

$10\ k\Omega \leq R \leq 1\ M\Omega$

VI. Power Consumption

In the standby mode (Monostable or Astable), power dissipation will be a function of leakage current in the circuit, as shown in the static electrical characteristics. For dynamic operation, the power needed to charge the external timing capacitor C is given by the following formulas:

Astable Mode:

$P = 2CV^2f$. (Output at terminal No. 13)

$P = 4CV^2f$. (Output at terminal Nos. 10 and 11)

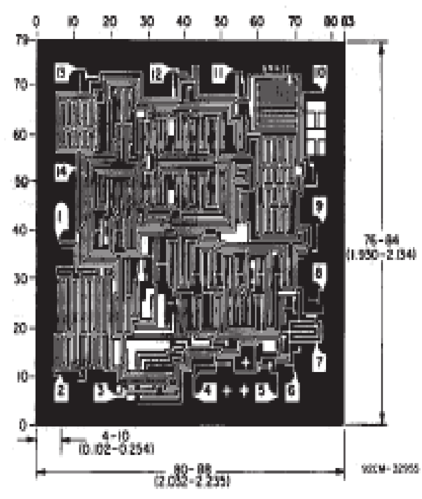
Monostable Mode:

$$P = \frac{(2.9CV^2)\ (\text{Duty Cycle})}{T}$$

(Output at terminal Nos. 10 and 11)

The circuit is designed so that most of the total power is consumed in the external components. In practice, the lower the values of frequency and voltage used, the closer the actual power dissipation will be to the calculated value.

Because the power dissipation does not depend on R, a design for minimum power dissipation would be a small value of C. The value of R would depend on the desired period (within the limitations discussed above). See Figs. 27, 28, and 29 for typical power consumption in astable mode.



Chip dimensions and pad layout for CD4047B

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated. Grid graduations are in mils (10^{-3} inch).

APPENDIX E
Datasheet IRF540

FAIRCHILD SEMICONDUCTOR®

NOT RECOMMENDED FOR NEW DESIGNS
POSSIBLE SUBSTITUTE PRODUCT
IRF540N

IRF540, RF1S540SM

January 2002

28A, 100V, 0.077 Ohm, N-Channel Power MOSFETs

These are N-Channel enhancement mode silicon gate power field effect transistors. They are advanced power MOSFETs designed, tested, and guaranteed to withstand a specified level of energy in the breakdown avalanche mode of operation. All of these power MOSFETs are designed for applications such as switching regulators, switching convertors, motor drivers, relay drivers, and drivers for high power bipolar switching transistors requiring high speed and low gate drive power. These types can be operated directly from integrated circuits.

Formerly developmental type TA17421.

Ordering Information

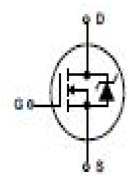
PART NUMBER	PACKAGE	BRAND
IRF540	TO-220AB	IRF540
RF1S540SM	TO-263AB	RF1S540SM

NOTE: When ordering, use the entire part number. Add the suffix 9A to obtain the TO-263AB variant in the tape and reel, i.e., RF1S540SM9A.

Features

- 28A, 100V
- $r_{DS(ON)} = 0.077\Omega$
- Single Pulse Avalanche Energy Rated
- Nanosecond Switching Speeds
- Linear Transfer Characteristics
- High Input Impedance
- Related Literature
  - TB334 "Guidelines for Soldering Surface Mount Components to PC Boards"

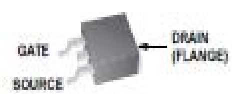
Symbol



Packaging

JEDEC TO-220AB

JEDEC TO-263AB



Absolute Maximum Ratings $T_C = 25^oC$, Unless Otherwise Specified

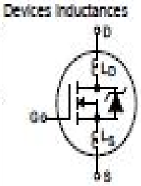
		IRF540, RF1S540SM	UNITS
Drain to Source Breakdown Voltage (Note 1)	V_{DS}	100	V
Drain to Gate Voltage (R_{GS} = 20kΩ) (Note 1)	V_{DGR}	100	V
Continuous Drain Current	I_D	28	A
$T_C = 100^oC$	I_D	20	A
Pulsed Drain Current (Note 3)	I_{DM}	110	A
Gate to Source Voltage	V_{GS}	±20	V
Maximum Power Dissipation	P_D	120	W
Dissipation Derating Factor		0.8	$W/^oC$
Single Pulse Avalanche Energy Rating (Note 4)	E_{AS}	230	mJ
Operating and Storage Temperature	T_J, T_{STG}	-55 to 175	^oC
Maximum Temperature for Soldering			
Leads at 0.063in (1.6mm) from Case for 10s	T_L	300	^oC
Package Body for 10s, See Techbrief 334	T_{pkg}	260	^oC

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

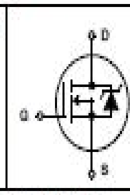
NOTE:

1. $T_J = 25^oC$ to $T_J = 150^oC$.

Electrical Specifications $T_C = 25^oC$, Unless Otherwise Specified

PARAMETER	SYMBOL	TEST CONDITIONS		MIN	TYP	MAX	UNITS
Drain to Source Breakdown Voltage	BV_{DSS}	$I_D = 250\mu A$, $V_{GS} = 0V$ (Figure 10)		100	-	-	V
Gate to Threshold Voltage	$V_{GS(TH)}$	$V_{GS} = V_{DS}$, $I_D = 250\mu A$		2	-	4	V
Zero Gate Voltage Drain Current	I_{DSS}	$V_{DS} = 95V$, $V_{GS} = 0V$		-	-	25	µA
		$V_{DS} = 0.8 \times$ Rated BV_{DSS}, $V_{GS} = 0V$, $T_J = 150^oC$		-	-	250	µA
On-State Drain Current (Note 2)	$I_{D(ON)}$	$V_{DS} > I_{D(ON)} \times r_{DS(ON)\,MAX}$, $V_{GS} = 10V$ (Figure 7)		28	-	-	A
Gate to Source Leakage Current	I_{GSS}	$V_{GS} = \pm 20V$		-	-	±100	nA
Drain to Source On Resistance (Note 2)	$r_{DS(ON)}$	$I_D = 17A$, $V_{GS} = 10V$ (Figures 8, 9)		-	0.060	0.077	Ω
Forward Transconductance (Note 2)	g_{fs}	$V_{DS} \geq 50V$, $I_D = 17A$ (Figure 12)		8.7	13	-	S
Turn-On Delay Time	$t_{d(ON)}$	$V_{DD} = 50V$, $I_D = 28A$, $R_G = 9.1\Omega$, $R_L = 1.7\Omega$ MOSFET Switching Times are Essentially Independent of Operating Temperature		-	15	23	ns
Rise Time	t_r			-	70	110	ns
Turn-Off Delay Time	$t_{d(OFF)}$			-	40	60	ns
Fall Time	t_f			-	50	83	ns
Total Gate Charge (Gate to Source + Gate to Drain)	$Q_{g(TOT)}$	$V_{GS} = 10V$, $I_D = 28A$, $V_{DS} = 0.8 \times$ Rated BV_{DSS}, $I_{g(REF)} = 1.5mA$ (Figure 14) Gate Charge is Essentially Independent of Operating Temperature		-	38	59	nC
Gate to Source Charge	Q_{gs}			-	8	-	nC
Gate to Drain "Miller" Charge	Q_{gd}			-	21	-	nC
Input Capacitance	C_{ISS}	$V_{DS} = 25V$, $V_{GS} = 0V$, f = 1MHz (Figure 11)		-	1450	-	pF
Output Capacitance	C_{OSS}			-	550	-	pF
Reverse Transfer Capacitance	C_{RSS}			-	100	-	pF
Internal Drain Inductance	L_D	Measured From the Contact Screw on Tab To Center of Die	Modified MOSFET Symbol Showing the Internal Devices Inductances 	-	3.5	-	nH
		Measured From the Drain Lead, 6mm (0.25in) from Package to Center of Die		-	4.5	-	nH
Internal Source Inductance	L_S	Measured From the Source Lead, 6mm (0.25in) From Header to Source Bonding Pad		-	7.5	-	nH
Thermal Resistance Junction to Case	$R_{\theta JC}$			-	-	1.25	$^oC/W$
Thermal Resistance Junction to Ambient	$R_{\theta JA}$	Free Air Operation		-	-	80	$^oC/W$
	$R_{\theta JA}$	RF1S540SM Mounted on FR-4 Board with Minimum Mounting Pad		-	-	62	$^oC/W$

Source to Drain Diode Specifications

PARAMETER	SYMBOL	TEST CONDITIONS		MIN	TYP	MAX	UNITS
Continuous Source to Drain Current	I_{SD}	Modified MOSFET Symbol Showing the Integral Reverse P-N Junction Diode		-	-	28	A
Pulse Source to Drain Current (Note 3)	I_{SDM}			-	-	110	A
Source to Drain Diode Voltage (Note 2)	V_{SD}	$T_J = 25^oC$, $I_{SD} = 27A$, $V_{GS} = 0V$ (Figure 13)		-	-	2.5	V
Reverse Recovery Time	t_{rr}	$T_J = 25^oC$, $I_{SD} = 28A$, $dI_{SD}/dt = 100A/\mu s$		70	150	300	ns
Reverse Recovery Charge	Q_{RR}	$T_J = 25^oC$, $I_{SD} = 28A$, $dI_{SD}/dt = 100A/\mu s$		0.2	1.0	1.9	μC

NOTES:

2. Pulse test: pulse width ≤ 300μs, duty cycle ≤ 2%.
3. Repetitive rating: pulse width limited by maximum junction temperature. See Transient Thermal Impedance curve (Figure 3).
4. $V_{DD} = 25V$, starting $T_J = 25^oC$, $L = 440\mu H$, $R_G = 25\Omega$, peak $I_{AS} = 28A$.

Typical Performance Curves Unless Otherwise Specified

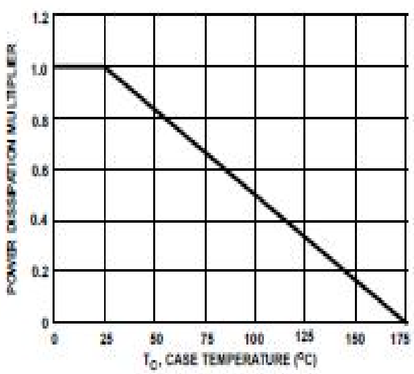


FIGURE 1. NORMALIZED POWER DISSIPATION vs CASE TEMPERATURE

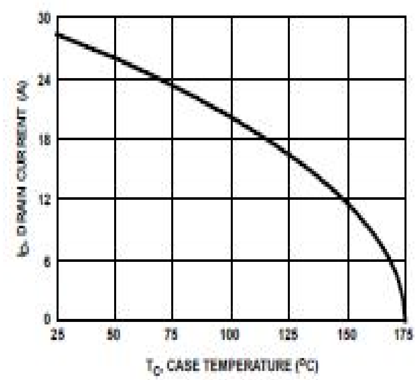


FIGURE 2. MAXIMUM CONTINUOUS DRAIN CURRENT vs CASE TEMPERATURE

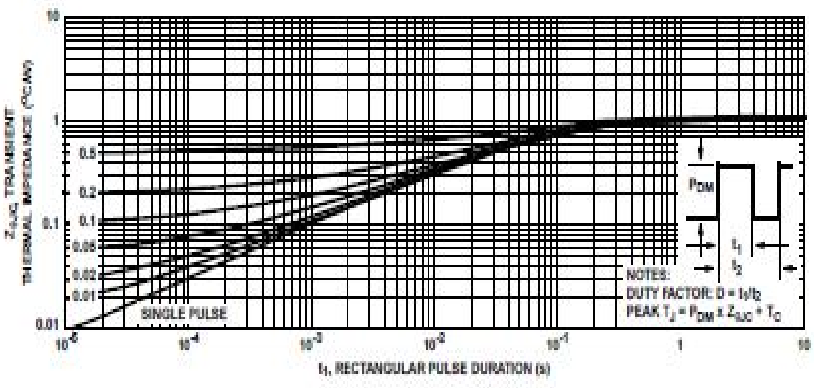


FIGURE 3. MAXIMUM TRANSIENT THERMAL IMPEDANCE

Appendix F
Datasheet IRF9Z34

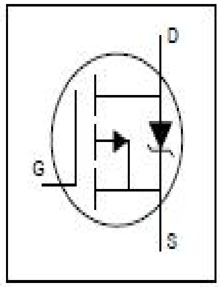
International
IOR Rectifier

PD - 9.1485B

IRF9Z34N

HEXFET® Power MOSFET

- Advanced Process Technology
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- P-Channel
- Fully Avalanche Rated



V_{DSS} = -55V

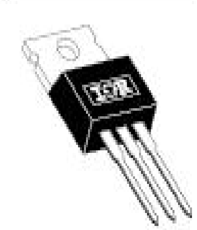
$R_{DS(on)}$ = 0.10Ω

I_D = -19A

Description

Fifth Generation HEXFETs from International Rectifier utilize advanced processing techniques to achieve extremely low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET Power MOSFETs are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications.

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



TO-220AB

Absolute Maximum Ratings

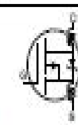
	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ -10V	-19	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ -10V	-14	
I_{DM}	Pulsed Drain Current ①	-68	
P_D @ T_C = 25°C	Power Dissipation	68	W
	Linear Derating Factor	0.45	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
E_{AS}	Single Pulse Avalanche Energy②	180	mJ
I_{AR}	Avalanche Current①	-10	A
E_{AR}	Repetitive Avalanche Energy①	6.8	mJ
dv/dt	Peak Diode Recovery dv/dt ③	-5.0	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting torque, 6-32 or M3 screw	10 lbf•in (1.1N•m)	

Thermal Resistance

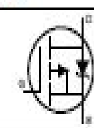
	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	2.2	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.50	—	
$R_{\theta JA}$	Junction-to-Ambient	—	62	

8/25/97

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	-55	—	—	V	V_{GS} = 0V, I_D = -250µA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	-0.05	—	V/°C	Reference to 25°C, I_D = -1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	0.10	Ω	V_{GS} = -10V, I_D = -10A ④
$V_{GS(th)}$	Gate Threshold Voltage	-2.0	—	-4.0	V	V_{DS} = V_{GS}, I_D = -250µA
g_{fs}	Forward Transconductance	4.2	—	—	S	V_{DS} = 25V, I_D = -10A
I_{DSS}	Drain-to-Source Leakage Current	—	—	-25	µA	V_{DS} = -55V, V_{GS} = 0V
		—	—	-250		V_{DS} = -44V, V_{GS} = 0V, T_J = 150°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS} = 20V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS} = -20V
Q_g	Total Gate Charge	—	—	35	nC	I_D = -10A
Q_{gs}	Gate-to-Source Charge	—	—	7.9		V_{DS} = -44V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	16		V_{GS} = -10V, See Fig. 6 and 13 ④
$t_{d(on)}$	Turn-On Delay Time	—	13	—	ns	V_{DD} = -28V
t_r	Rise Time	—	55	—		I_D = -10A
$t_{d(off)}$	Turn-Off Delay Time	—	30	—		R_G = 13Ω
t_f	Fall Time	—	41	—		R_D = 2.6Ω, See Fig. 10 ④
L_D	Internal Drain Inductance	—	4.5	—	nH	Between lead, 6mm (0.25in.) from package and center of die contact 
L_S	Internal Source Inductance	—	7.5	—		
C_{iss}	Input Capacitance	—	620	—	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	—	280	—		V_{DS} = -25V
C_{rss}	Reverse Transfer Capacitance	—	140	—		f = 1.0MHz, See Fig. 5

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	—	—	-19	A	MOSFET symbol showing the integral reverse p-n junction diode. 
I_{SM}	Pulsed Source Current (Body Diode) ①	—	—	-68		
V_{SD}	Diode Forward Voltage	—	—	-1.6	V	T_J = 25°C, I_S = -10A, V_{GS} = 0V ④
t_{rr}	Reverse Recovery Time	—	54	82	ns	T_J = 25°C, I_F = -10A
Q_{rr}	Reverse RecoveryCharge	—	110	160	nC	di/dt = -100A/µs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L_S+L_D)				

Notes:

① Repetitive rating; pulse width limited by max. junction temperature. (See fig. 11)

② Starting T_J = 25°C, L = 3.6mH R_G = 25Ω, I_{AS} = -10A. (See Figure 12)

③ I_{SD} ≤ -10A, di/dt ≤ -290A/µs, V_{DD} ≤ $V_{(BR)DSS}$, T_J ≤ 175°C

④ Pulse width ≤ 300µs; duty cycle ≤ 2%.

Appendix G
Standard Illumination Table

GENERAL BUILDING AREAS	IES Standard Service illuminance LUX	JKR Standard illuminance Lux	Position of measurement	Colour Appearance of light	Notes
HOMES					
Garages	50	50	Floor	Intermediate	Illuminance must be increased 50 — 100% above recommendations for homes. Particular attentions must be paid to avoid glare and to reveal steps and obstructions. Two way switches should be illstalled for through ways, stair etc.
(HOME OLD PEOPLES)					
INDOOR SPORTS AND RECREATIONAL BUILDING					
MULTI PURPOSE SPORTS HALLS					
Athletics, basketball, Bowls, Judo gymnastics, hockeyball	300 700	200 500	Floor	Instrument of warm	For some sports side lighting or localized lighting (e.g. at the net in badminton) is preferred. Arrange switching to give illuminance appropiate to activity.
BADMINTON COURTS	300	300	Floor	"	Avoid glare from overhead lighting.
BILLIARD ROOMS					
General	100	150	Floor		
Table	special lighting				
CARD ROOMS	300	300	cable	"	
GYMNASIA GENERAL	500	300	Floor	"	Impact resistant luminance required. Proof luminance required, Acess to luminance must be considered. Window and luminance must be located to avoid glare to swimmers, divers and spectators by direct view and by reflections at water surface.
SWIMMING POOL					
TOP POOL	500	300	water level	"	
Spectator areas	150	150	seated level	"	
Club recreational	300	200	water level	"	
GENERAL					
Changing rooms showers, cookers rooms	150	150	Floor	"	
TABLE TENNIS					
Club	300	200	Table top	"	
Recreational	200	200	"	"	

GENERAL BUILDING AREAS	IES Standard Service illumi-nance LUX	JKR Standard illumi-nance LUX	Position of measur-ement	Colour Appearan-ce of light	Notes
Shelves	150		Verticle plane at lowest shelf	-	
Reception general	300	200	working plane	-	
Enquiry desk	500	300	Desk	-	
Laboratories	500	300	Bench	-	
Operating theatre suits general	400	400	Trolley height	Inter-mediate or warm	Hose proof luminaires maybe required.
Operating area	—	—			Special lighting
Recovery room and intensive care units	30-50	Bedhead	Inter mediate or warm		400 LUX to be available on bed for supervision only.
X-ray department radio. diagnostic and rooms fluores copy	500	500	couch	Inter-mediate or warm	Dimming required
HOSPITAL					
Radio therapy rooms	300	300	Position of measur-ement	Inter-mediate or warm	Decorations required
Dental surgeries	-	-			Special lighting
HOMES					
Living rooms general	50	50	working plane	Inter-mediate or warm	In all home areas, attention should be given to the lighting of room surfaces. Luminance should be selected and posi-tioned to give occupants a compromise between attractive sparkle and unwanted glare. Dimming is useful for changing. atmosphere. Addi-tioal mirror lighting required in bedrooms. Additional mirror lighting required Enclosed luminaires should be used
Casual reading	150	150	-	-	
Sewing and darningsrudies Desk and protuged	300	300	-	-	
Bedrooms general	50	50	Floor	-	
Bedlead kitchen	150	150	Bed	-	
Kitchen working areas				-	
Bathrooms	100	100	Floor	-	
Hall and landings	150	150	Floor	-	
Stairs	100	100	Tread	-	High luminance spacing should be screened from view when ascending or descending stairs.
Workshops	300	200	Bench	-	