DESIGN AND DEVELOPMENT OF A PHOTOVOLTAIC POWER SYSTEM FOR AUTOMATIC BEAN SPROUT

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MUHAMMAD NURZUHAILI BIN ZAINUDI

A report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Electrical Engineering (Power System)

Faculty of Electrical and Electronics Engineering
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JUNE 2012

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Date : 21 JUNE 2012

DEDICATION

Special dedication to my beloved parents; Ibu and Ayah, my uncle and my cousin.
Thank you for your unlimited support.

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And finally, I also offer profuse thanks to my loving family and friends for their constant encouragement.

ABSTRACT

Nowadays, the use of renewable energy has been increasingly widespread. One of the renewable energy that is now gaining attention is the use of solar power. In Malaysia, the use of solar power is particularly suitable for our country due to the equatorial climate in which our country is experiencing summer and humid throughout the year. There are a lot of applications in solar power that can be implemented. One of which is in the agricultural industry. Most crops require intensive care to produce quality results, while giving considerable returns to operators. Among the factors that influence the quality of the production of crops such as bean sprout, are sources of water. Bean sprout need plenty of water resources to produce good growth. An irrigation system to watering the seeds regularly is needed and at the same time to make sure the seeds are enough of water resources. This project concerns in designing an automatic system for bean sprout which integrate with the solar power system. The development of hardware consists of charging circuit, relay circuit which will integrate with microcontroller for controlling the water pump. The software is the development of PIC 18F4550 micro-controller software program that performs delays which will control the operation of water pump.

ABSTRAK

Pada masa kini, penggunaan tenaga boleh diperbaharui telah semakin meluas. Salah satu daripada tenaga boleh diperbaharui yang kini mendapat perhatian ialah penggunaan tenaga solar. Di Malaysia, penggunaan tenaga solar adalah amat sesuai kerana negara kita beriklim khatulistiwa iaitu mengalami musim panas dan lembap sepanjang tahun. Terdapat banyak aplikasi dalam tenaga solar yang boleh dilaksanakan. Salah satu daripadanya ialah dalam industri pertanian. Kebanyakan tanaman memerlukan penjagaan yang rapi untuk menghasilkan pengeluaran yang berkualiti di samping memberikan pulangan yang lumayan kepada para pengusaha. Antara faktor yang mempengaruhi kualiti pengeluaran tanaman seperti taugeh, adalah sumber air. Taugeh memerlukan sumber air yang banyak untuk menghasilkan pertumbuhan yang baik. Sistem pengairan untuk menyiram taugeh diperlukan dan pada masa yang sama perlu memastikan taugeh mendapat sumber air yang mencukupi. Projek ini melibatkan rekabentuk satu sistem automatik untuk siraman taugeh yang menggunakan sistem kuasa solar. Bahagian pertama adalah terdiri daripada mengecas litar, geganti litar yang akan disambung pada mikropengawal untuk mengawal pam air. Manakala bahagian kedua adalah berkaitan dengan penulisan program untuk PIC 18F4550 yang berfungsi sebagai mengawal tempoh operasi pam air.

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LIST OF SYMBOLS

AC	-	Alternating Current
ADC	-	Analog to Digital Converter
AH	-	Ampere Hour
DC	-	Direct Current
EEPROM	-	Electrically Erasable Programmable Read Only Memory
EMF	-	Electro Motive Force
F	-	Fahrenheit
g	-	gram
ICSP	-	In Circuit Serial Programming
IV	-	Current and Voltage
kg	-	kilogram
PIC	-	Peripheral Interface Controller
PV	-	Photovoltaic
PWM	-	Pulse Width Modulation
RM	-	Ringgit Malaysia
SDRAM	-	Synchronous Dynamic Random Access Memory
Si	-	Silicon

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Bean sprout is a food which produced through seeds germination. Studies have shown that production of been sprout is an area of viable business enterprises. The factors which influence the production of sprouts should be considered and viewed on every stage of their production process. The conventional method of growing bean sprout is manually watering the bean during daylight and also watering the seeds at night. But inconsistent volume of water and non-uniform patent in watering the seeds will result in imperfect sprouting. Due to that, it will influence the temperature inside the container thus will reduce the quality of the bean sprouts.

This project is based on how to produce an automatic system for the production of bean sprouts. The system will watering the seeds base on predetermines time period. By integrating the photovoltaic power system with the machine, it will become more efficient in term of power energy saving and reduce the use of man power.

Research has shown that by using the automated bean sprouts machine, it will helps in increase the production of the sprouts. By providing the automatic system in process of watering the seeds, it can helps in shorting the period for the seeds to sprout.

The AC motor water pump is used in this project for watering process. In order to run the motor, it required a high current inverter and to turn ON the inverter, 12 volt input DC supply is needed which will be supply from the lead-acid battery. This battery will be charged by the solar systems that require a controller which will manage the power that produced from the solar to store in the lead-acid battery.

1.2 Objective

The objectives of this project are:

i. To develop a system that helps in watering the seeds automatically. The watering process will be doing automatically base on predetermine time period which will control the water pump.

ii. To develop a system that will help the production of the bean sprout. By watering the seeds for a certain periods, thus avoid wastage of water and excessive watering.

iii. To develop a systems that use photovoltaic power systems. The solar module will placed at open area so that it will expose to the high intensity sun radiation. This radiation will be used by solar module to charge the battery thus will provide power for the system.

1.3 Scope of project

The works undertaken in this project are limited to the following aspects:

i. Develop solar charger circuit to charge the battery thus powering the system.

ii. Develop software for microcontroller in order to interface the microcontroller to control the output for watering the seeds.

CHAPTER 2

LITERATURE REVIEW

2.1 Bean Sprout Machine

A bean sprout growing machine in which automatic means is provided for spraying hot water at a predetermined temperature and at predetermined time periods and for a given length of time for each period to cause beans to sprout and grow [1]. If the length of period for watering the seeds is three to four hours, the production of bean sprout will be 5.3kg to 6.4kg but if watering the seeds with the length of period is two hours, the production will be 8.7kg [4]. Other methods that can influence the good quality of bean sprout is spray the seeds with the hot water at about 80°F for four to five minutes [1]. The second methods is maintained the temperature and humidity within the container by making a path (holes) inside the container for draining the water.

Other than that, water which has been used for spraying the seeds can be reused. This is because by reusing the recycling water, some of the unknown growth factor released during the germination and can be resupplied thus can be used for stimulation of growth [2]. It also prevents the nutrients from washing away and it can help to maintain constant temperature for sprouting and growing [2]. The suitable condition of the sprout to growth is in the moist area and also there is no access for the light or sunshine can go through the container. The seeds will take four to six days to growth and then it ready to eat or cook.

2.2 Solar / Photovoltaic Power System

Photovoltaic (PV) is the most direct way to convert solar radiation into electricity [5]. Light striking solar cells is transformed into electric energy. This occurs according to a norm called the 'photo-electric effect' [4]. A PV cell is a semi-conductor device consists of a p-n junction that has a built-in Electro-Motive-Force (EMF) [4]. As light of suitable quanta of energy reaches the p-n junction, electrons (-) are freed and holes (+) are formed. These are then determined by the EMF to the sides of the p-n junction. When connected to an outer conducting path, the circuit is complete thus providing useful electric energy for powering up an electric load [4].

Figure 2.1: Photovoltaic Module [12]

Majority of the PV cell is made by the semi-conductor type silicon (Si) [4]. Therefor from this semi-conductor it has developed two type of PV cell such as crystalline and thin film. From crystalline type, it was divided into two cells such as mono-crystalline and poly-crystalline. Mono-crystalline refers to cell which was cut from single crystal of silicon [5]. On the other hand, poly-crystalline refers to cells made from many crystals. Thin film also known as amorphous silicon is made from non-crystalline silicon that is deposited on the back of glass or other substrates [5]. Most popular application of PV cells is mono-crystalline and poly-crystalline due to the cell efficiency to absorb the sunlight radiation.

For solar PV cell or module, there is a factor that will affect the output of PV cells. It is a temperature effect. When exposed to the sun, the module temperature gets elevated. Thus it will decrease the output of the PV cells. Figure 2.2 shows the effect of temperature variation.

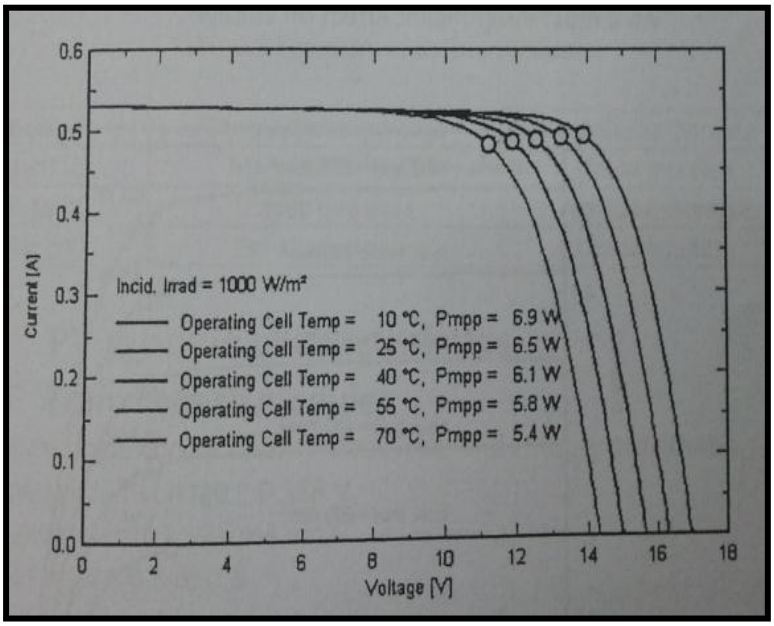


Figure 2.2: Effect of temperature variation on IV curve [3]

The higher of cell temperature, the lower it become for output of the PV cells. It will produce less power as they get hotter. Thus in PV system design, temperature of the cell in operation must be given serious attention. The changing of the weather will cause the inconstantly in producing the output power or voltage. Usually in PV stand- alone system, there will need a storage supply such as batteries. Normally in solar system, it will use the lead-acid type of battery. The output of the PV cell is used to charge the battery but due to the changing of weather which will produce the inconsistent output, the system needs solar charger controller.

2.3 Charge Controller

Charge controller or charge regulator is a device used to manage the energy that flow in the solar power systems. One of the successful factors of the solar system is the long-term performance of the batteries. For a system to operate well and have long lifespan, the batteries must be charged properly and kept in a high state of charge. Over several months, the energy entering the batteries during the day (i.e. the solar charge) must be roughly equivalent to the energy being discharge from the batteries at night by the load [4]. This device will ensures the batteries always in good condition by preventing it from overcharging and also avoid from deep discharging or discharging below their cut-off voltage.

Generally, there are two types of charge controller. There are linear charge controller and switching charge controller [4]. Linear charge controller used to continuously adjust the charge supplied the battery at any given moment to maintain the optimum voltage. It operates by using a voltage-controlled current source to force a fixed voltage to appear at the charge controller output terminal [4]. On the other hand, switching charge controller normally used for high power applications and systems where efficiency is important. For this type of controller, an active device such as a switching transistor is used to cut the input voltage or current to meet the load desires. This is accomplished by varying the duty cycle of the switching transistor [4].

2.4 Solar Water Pumping System

This system consists of two basic components. These are PV panels and pumps. Water pump is a type of motor that used to move fluids or water from one place to another place for various reasons. There are many types of water pump which are design with the different purpose. The reason is to make the system more efficient by using appropriate water pump. There are two types of water pump. One is DC water pump which getting supply from the DC sources such as rechargeable battery and the other one AC water pump which is power up by the AC source. DC water pump is commonly use in the solar water pumping system because of the output from the solar panel is in DC so that it can operate without using any additional component. In order implement the system on the large scale, the high pressure and horse power of DC water pump will be needed thus it also need the big solar panel to produce more power and will become more costly. This is because most of the large power DC water pump is more expensive compare to the AC water pump [11].

Usually most of this system is applied at the agricultural industry such as crop production and livestock, also for domestic use. The water pumping system is one of the appropriate uses for photovoltaic. A solar-powered pumping system is generally in the same price range as a new windmill but tends to be more reliable and require less maintenance [7].

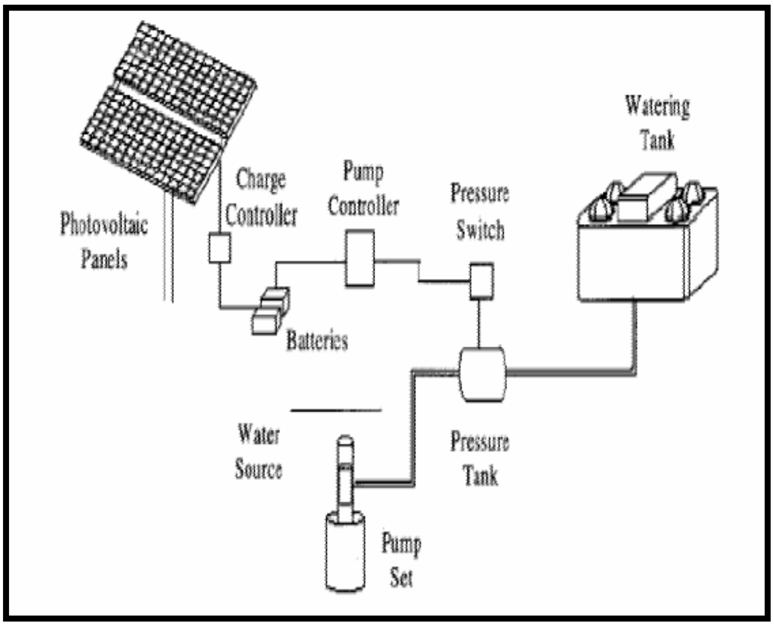


Figure 2.3: Battery-coupled solar water pumping system [7]

PV panel produced the electric current during the daylight hours charges the batteries and then supply power to the pump at any time it need. The use of battery is for providing the constant supply to the pump. Thus, during the night or a low light period, the system can still deliver a constant of water for livestock.

CHAPTER 3

METHODOLOGY

3.1 Project Development

In this project, it consist a lot of electronic hardware that will be used in order to create this system. It can be dividing into two parts which are design and non-design hardware. The design hardware are solar charging circuit for the car lead acid battery and write the coding for microcontroller that will be used to control the ON and OFF of the AC water pump. On the other hand, the non-design hardware is power inverter. In this section, the basic idea of designing the electronic hardware will be discussed.

Overall of the system is show in Figure 3.1. As for the input component, it consists of two types. It will be the 240V AC supply which getting from our daily supply and the second supply is getting from the 12V lead acid or car battery. During the daylight, the system will be support by the AC supply. Switching circuit will turn ON the AC water pump for watering the seed.

On the other hand, we will use the solar radiation during the daylight to charge the battery. As for the night operation, the system will be provided by the DC supply which is from the 12V battery. The night operation will be same as daylight operation except it used battery and inverter. The implementation of microcontroller will be used in this project. It used to control the timing and period for turning ON and OFF the AC water pump.

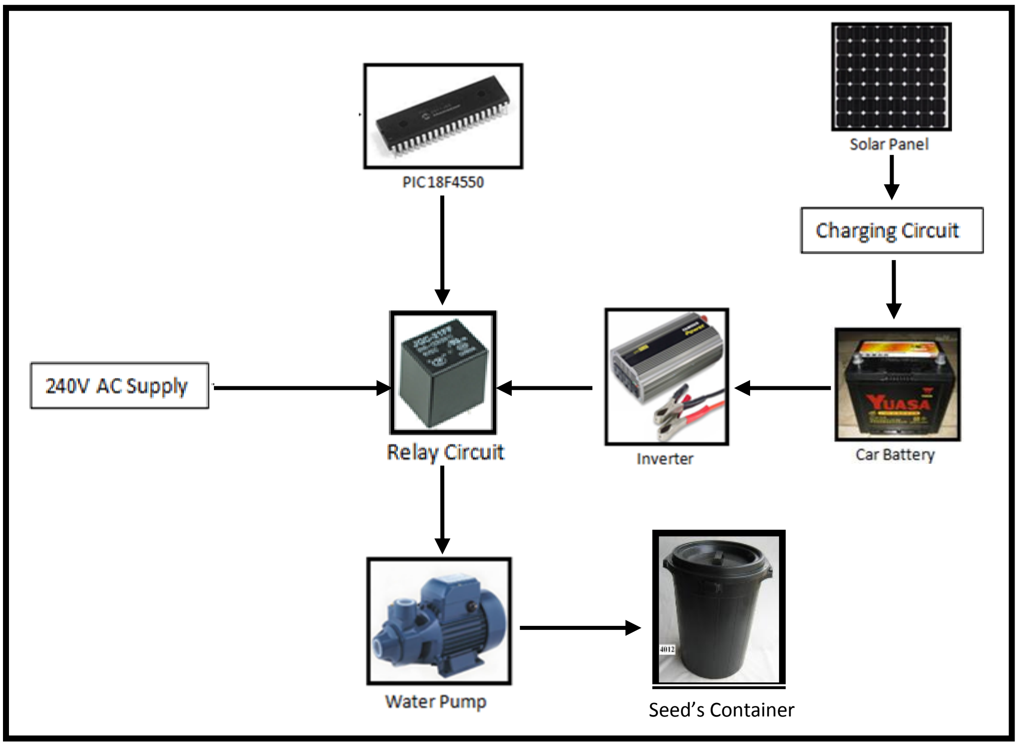


Figure 3.1: Overall System

3.2 Solar Charging Circuit

Voltage regulator LM338 is used in this charging circuit. The LM338 is the main component in this charging system. It can provide variable output voltage from the range of 1.2V to 32V and at the same time rating for constant output current which can pass through regulator around 5A. Due to this features, it suitable to use it in charging circuit that used to charge lead acid battery which have a large capacity of storage. In order to limit or adjust the output voltage, variable resistor is needed which will connect at the adjustment terminal of LM338. This charger will use the input voltage getting from the solar panel thus will use to charge the battery.

A TIP122 Darlington NPN Transistor is use in this circuit. It used to cut off the circuit when the battery is fully charged. TIP122 Darlington Transistor will go into full conduction with a maximum capacity of V_{BE} is 2.5V. The TIP122 is able to withstand high current and voltage which current can go through collector terminal up to 5A with a maximum voltage 100V. When TIP122 conducts, the adjustment terminal will directly connected to ground thus inhibits the working of regulator LM338. It will make the current at output terminal goes to zero. The connection of the charging circuit is shown in Figure 3.2.

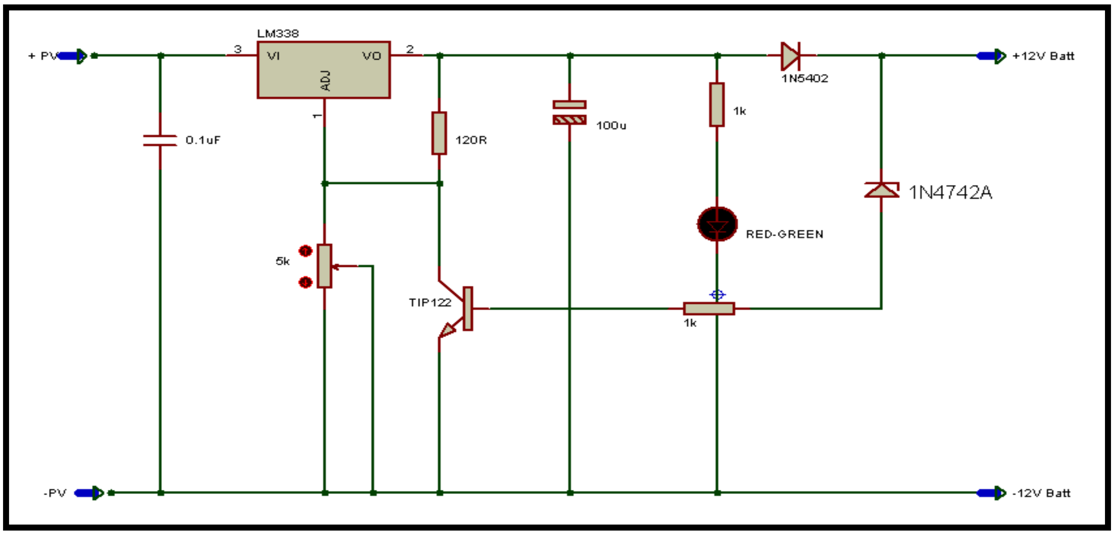


Figure 3.2: Charger Circuit Schematic Diagram

3.3 PIC 18F4550

For the controller itself, PIC18F4550 microcontroller is chosen in order to control the system. PIC18F4550 microcontroller is one of the families of microcontroller produced by Microchip Technology Inc. Figure 3.3 shows the pin diagram for PIC18F4550. The features of this microcontroller includes 2048 bytes of SDRAM and 256 bytes of EEPROM data memory, 32kbytes of Flash program memory, 10 bit resolution of Pulse Width Modulation (PWM), 13 channel of Analog to Digital Converter (ADC) module, single supply 5V In-circuit Serial Programming (ICSP) and etc. This several features of PIC will be needed in order to develop the controller of the system.

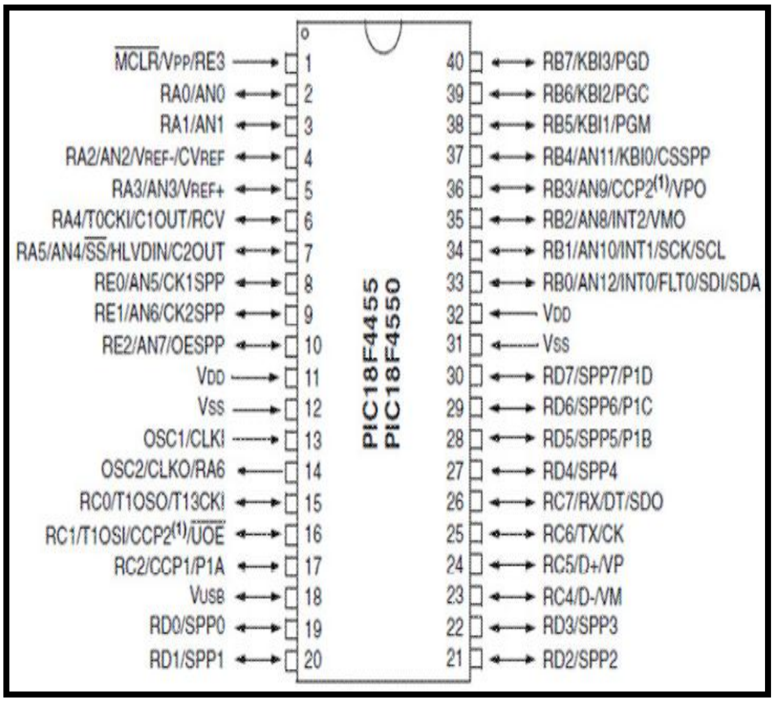


Figure 3.3: PIC18F4550 Pin Diagram

3.3.1 PIC Start-Up Kit

PIC Enhanced 40 pins Start-Up Kit is used for this project. This board is used to interface the PIC18F4550 with the relay circuit. It is easy to load a program or erase the program. This board was design with the basic element in order to introduce the user to begin project development. It is also suitable and fit with 40 pins 16F and PIC 18F. Figure 3.4 shows the PIC Enhanced 40 pins Start-Up Kit.

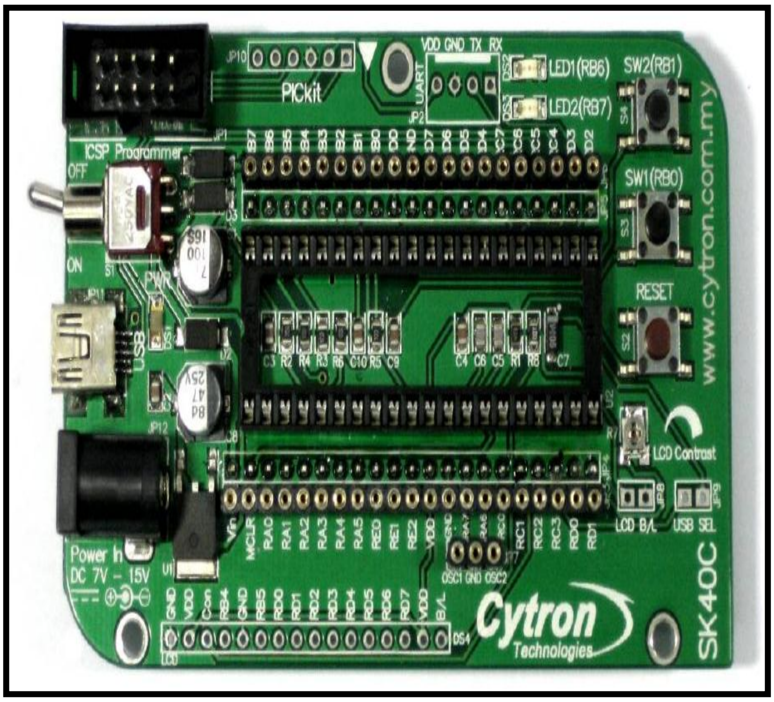


Figure 3.4: PIC Enhanced 40 pins Start-Up Kit

3.4 Relay Circuit

Relay that used in this project was DC 5 Volt relay. This type of relay can permit 6A with 250V for AC and 12A with 28V for DC. Figure 3.6 show the DC 5V Relay. In this project, the relay will be used to permit 240V AC through it at the switching side. Two relays will be used in this project. This relay will be used as switching component that will connected with transistor from PIC 18F4550. Once the PIC has sent the signal through the transistor, the relay will energized thus will provide a power source to turn ON the AC water pump. The water pump will turn ON according to the predetermined period. The connection of the circuit is shown in Figure 3.5.

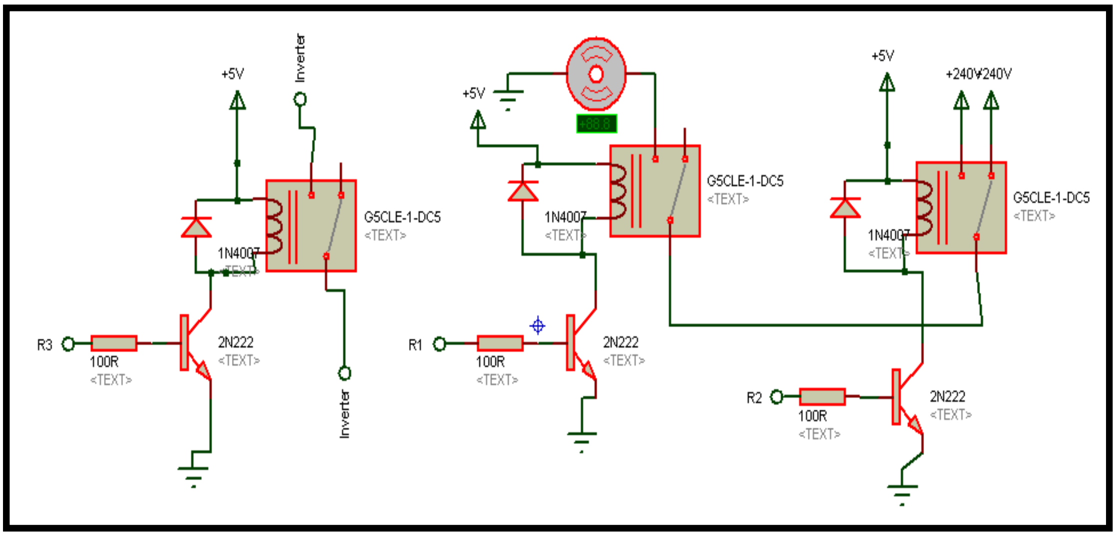


Figure 3.5: Relay Circuit Schematic Diagram

3.5 Controller System

As the system is ON, it will start a delay along four hours. After four hours it will turn ON the water pump for five minutes. The system will start to count base on internal counting that has been set. If it not achieved the value of internal counting, then it will back to initial condition which is having a delay for two hours. Once it certified the internal counting, the system will be turn OFF. According to this project, the water pump will be turn ON base on the period that needed to sprouting the seeds. If four days is needed, then this controller will turn ON the water pump for a several times until it match with the four days periods. Figure 3.6 shows the controller system flow chart.

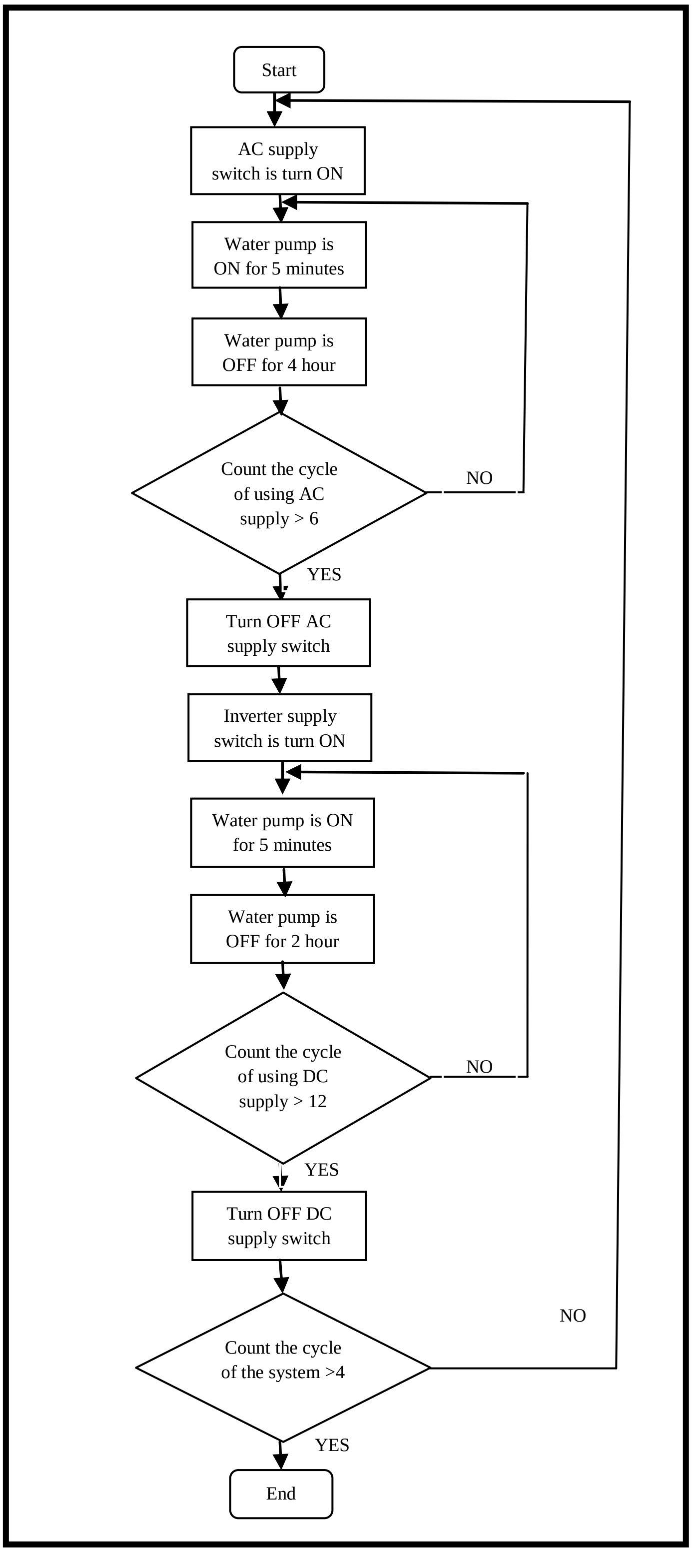


Figure 3.6: Controller System Flow Chart

3.6 Software Development

The software development of this project is constructed using CCS PCW C Compiler as shown in Figure 3.7(a). The programming language used for the microcontroller is in C language where it is one of the high-level languages. To program the PIC18F4550, PICkit2 Programmer is used. The compiled code from the CCS PCW C Compiler is programmed to the PIC18F4550 using UIC000A programmer through ISCP connection of the PIC. Figure 3.7(b) shows the PICkit2 programming software where Figure 3.7(c) shows the UIC000A programmer.

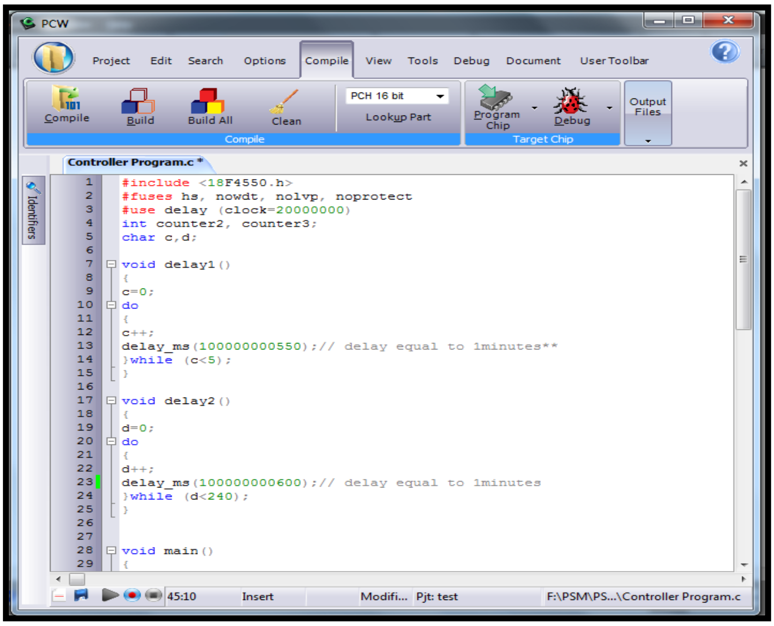
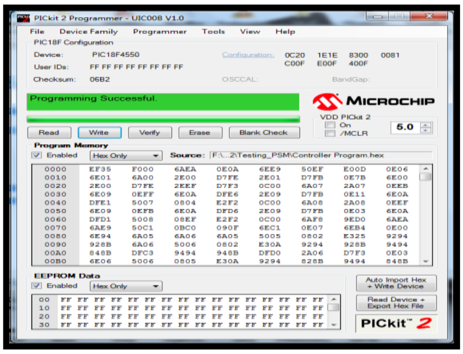


Figure 3.7(a): CCS PCW C Compiler



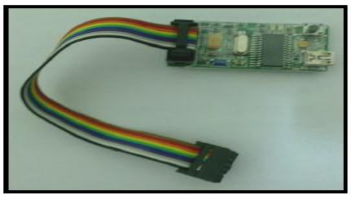


Figure 3.7(b): PICkit2 Programming Software **Figure 3.7(c):** UIC000A Programmer

3.7 Power Inverter

The principle operation of inverter is to convert the DC supply to AC supply. 1000 watt Power Inverter is used to turn ON AC water pump. This inverter is 12V DC types which can be turn ON by using lead acid battery or 12V car battery. The inverter will start to function if the battery is above 12V or equal to 12V. This inverter comes with the safety system. The purpose is to prevent the load from damage by having an over or low voltage supply. It will cut off the supply to the load if it sense the level of the battery is nearly 11V or below than 11V. Figure 3.8 show the 1000 watt Power Inverter.

Figure 3.8: 1000 watt Power Inverter

CHAPTER 4

RESULT AND DISCUSSION

Extensive testing has been conducted on the controller. All the data will be recorded based on the various test and will be discussed in this chapter. The several test conducted are done in order to test the functionality of the controller. It includes testing the controller circuit and charging circuit. The full system is tested in real condition where the solar module is exposed under the sunlight while the controller will turning ON and OFF the AC water pump for watering the seeds.

4.1 Battery Charger Module

The battery charger design is for charging lead acid battery. The battery used to power the system is 12V30AH lead acid battery. The charger will charge the battery with according to the charging logarithm. Figure 4.1(a) shows the setting condition of the charger. During charging state, the charger will charge the lead acid batteries with constant current of 3A as shown in Figure 4.1(b). At the end of charging state, the charger will reduce the current flow to the battery as shown in Table 4.2 (Refer Appendix A). The state of charge for lead acid battery is shown in Table 4.1. From the Table 4.2, the battery is in full charge state at 12.71V.

Table 4.1: Standard estimation charge state for lead acid battery [8]

Open circuit voltage	State of charge
12.65V	100%
12.45V	75%
12.24V	50%
12.06V	25%
11.89V or less	Discharged

Figure 4.1 (a): Charging State

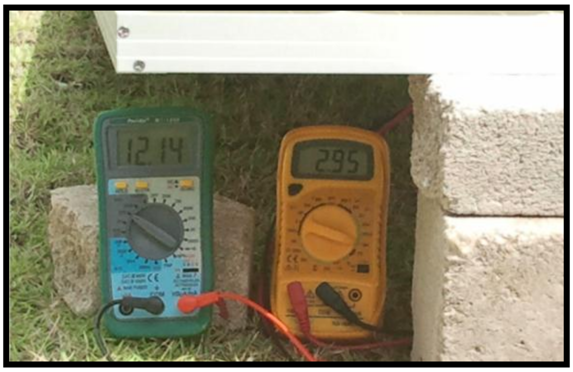


Figure 4.1 (b): Voltage (left) and Current (right) Value

4.2 Circuit Controller for Watering System

Figure 4.2 shows the circuit controller system board. It is the main board of the system which was used to control the water pump base on the predetermined period for the pump to turn ON and OFF. The controller system boards consist of PIC Start-up Kit and the relay circuit.

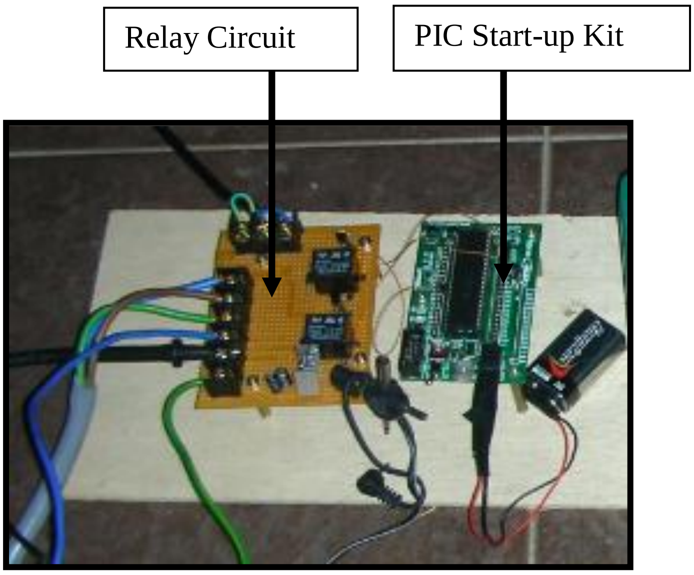


Figure 4.2: Circuit Controller System Board

4.3 Switching the DC Supply and AC Supply

This result was collected according to the five minutes period of watering (water pump is ON) and five minutes period of the water pump is in OFF condition. Figure 4.3 (b) shows as for the starting for the watering system, the AC power will be used to supply the power to turn ON the water pump. Figure 4.3 (c) shows the water pump is getting supply from the DC source which was from 12V battery.

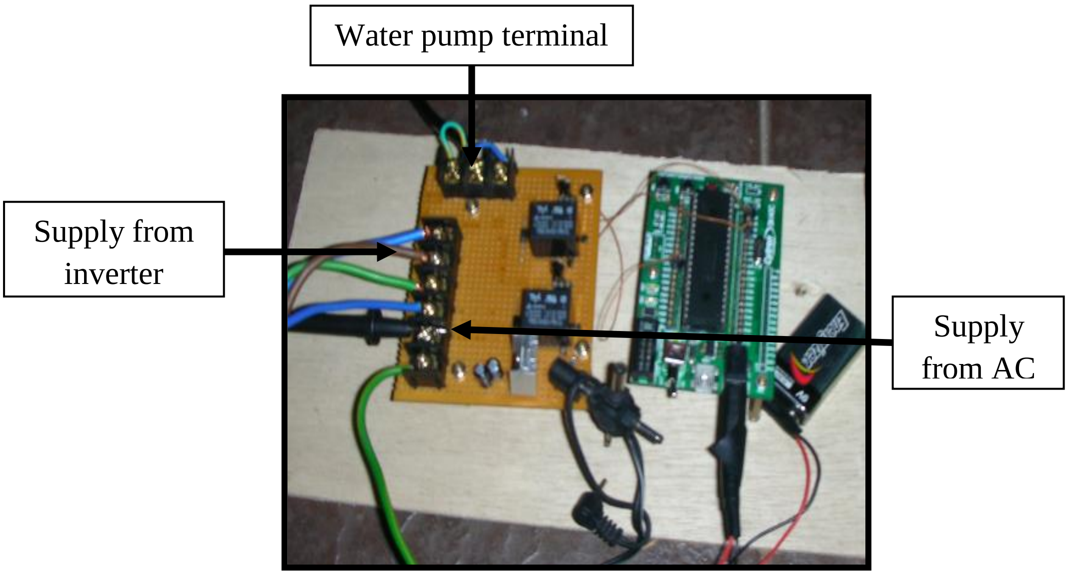


Figure 4.3 (a): Circuit Controller System Board

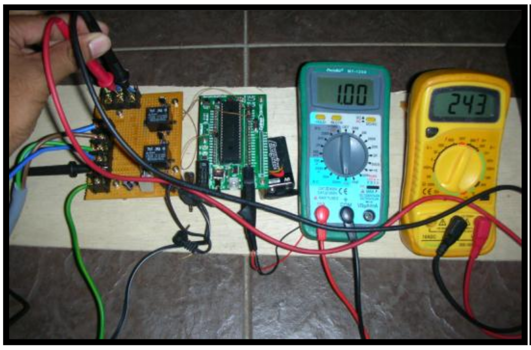


Figure 4.3(c): Using AC power supply

Figure 4.3 (b): Using DC power supply

4.4 Integrated System

The integrated system is tested to collect relevant data. Figure 4.4 shows the full view of the system. The system is connected all together and exposed under the sunlight for a period of time. This system has been tested for four days which is same as the period for the seeds to sprout.

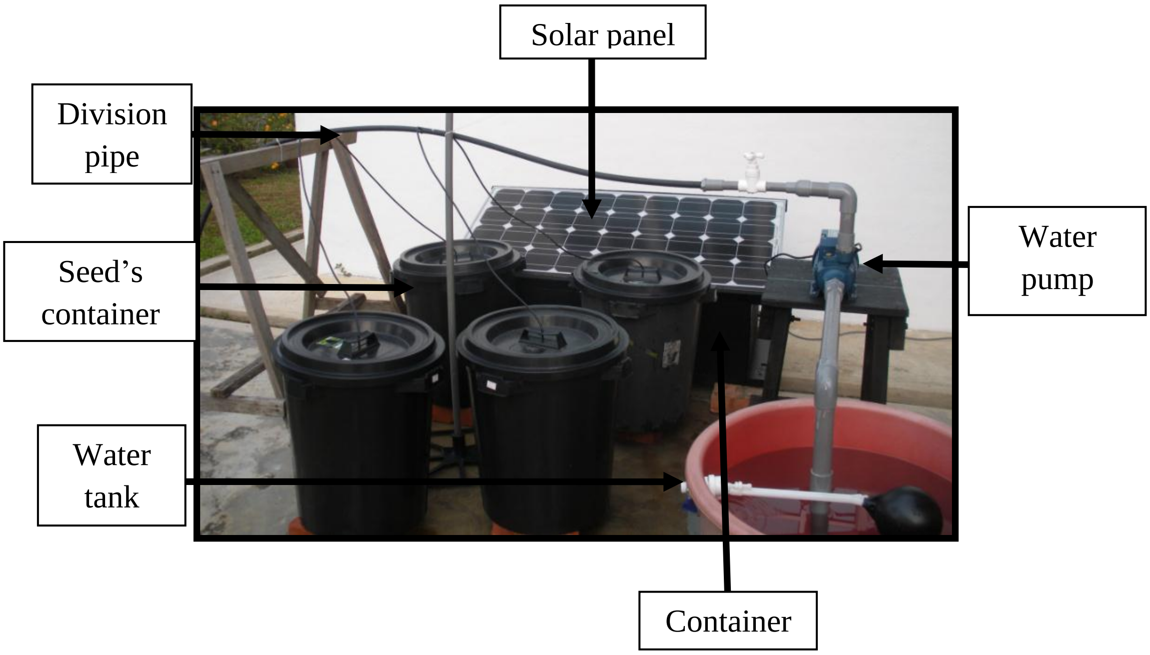


Figure 4.4: Full view of the system

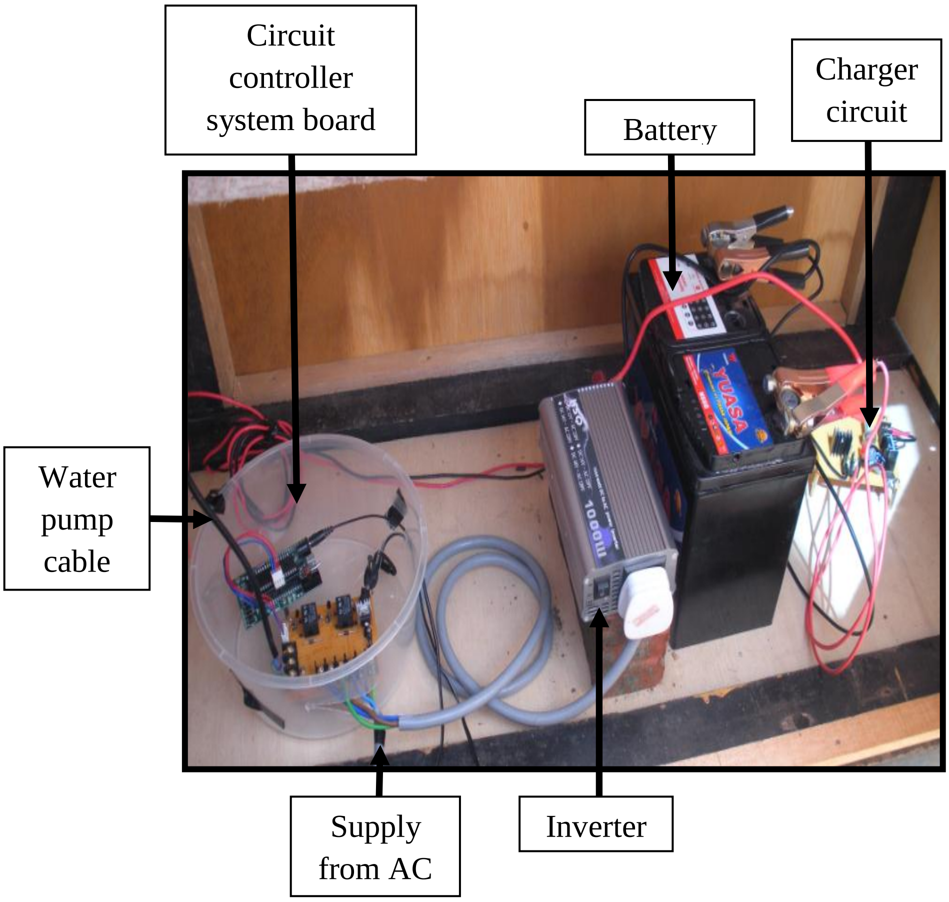


Figure 4.5: View inside the container

Figure 4.5 shows the inside view of the container which is containing the battery, inverter, charging circuit and controller circuit. The solar panel was connected to the charging circuit and the output of the circuit will connected to the battery. The inverter is used in order to give a supply to the water pump by having a source from the battery.

Data have been collected during the sunny day, starting from 11.30 AM until 4.30 PM which was about six hours. The measurement has been taken after each one minutes of the times and was written in the Table 4.2 (refer Appendix A).

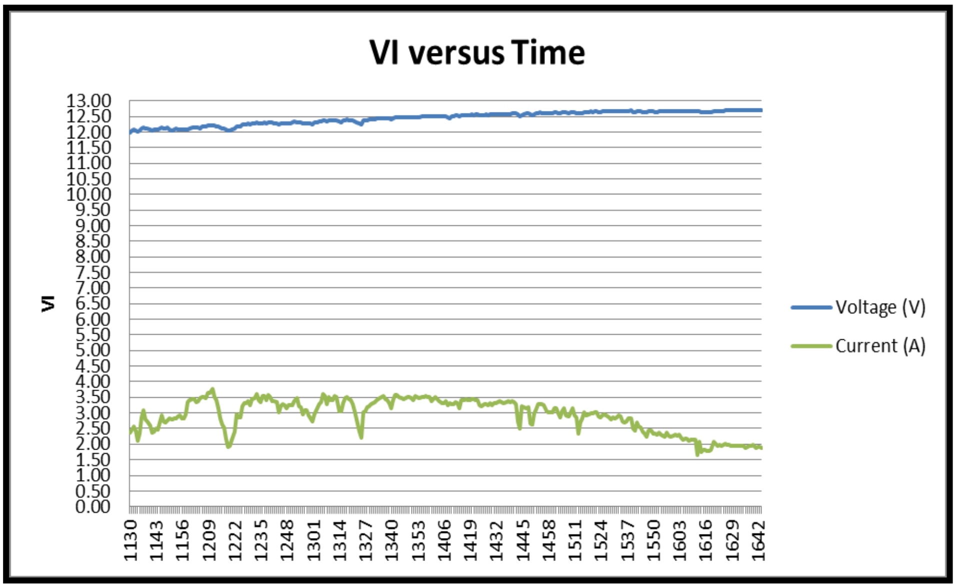


Figure 4.6: Graph Battery Voltage and Current versus Time

Figure 4.6 shows the battery voltage and current through the period of charging state. The charging current is increasing and decreasing due to the charging state of the battery charger. If the intensity of the sunlight is not high, the battery charger could not charge the battery with the rated charging current.

Table 4.3: Discharging Voltage and Current

DC Voltage (V)	DC Current (A)	AC Current (A)
11.92	20.60	1.18
11.88	20.80	1.20
11.86	20.80	1.19
11.83	20.80	1.19
11.82	20.50	1.18
11.79	20.30	1.19
11.76	20.70	1.19
11.74	20.70	1.18
11.72	20.80	1.19
11.70	20.60	1.19
11.68	20.70	1.18
11.67	20.60	1.18
11.65	20.50	1.18
11.62	20.60	1.18
11.60	20.70	1.18
11.58	20.60	1.18
11.56	20.70	1.18
11.54	20.50	1.18
11.52	20.80	1.18
11.49	20.60	1.18
11.47	20.50	1.18
11.46	20.50	1.18
11.44	20.70	1.18
11.41	20.70	1.18
11.39	20.60	1.18
11.37	20.60	1.18
11.35	20.60	1.18
11.33	20.70	1.17
11.31	20.60	1.18
11.29	20.50	1.18
11.27	20.50	1.18
11.24	20.50	1.17
11.22	20.30	1.17
11.21	20.30	1.17
11.18	20.40	1.17
11.16	20.20	1.17
11.13	20.10	1.17
11.11	20.00	1.17
11.07	20.10	1.17
11.05	20.10	1.17
11.02	20.10	1.17
11.00	19.90	1.17
10.96	19.90	1.17
10.93	19.90	1.17
10.88	20.00	1.17

The data was recorded during the discharging process. The measurement of AC current, DC current and DC Voltage was written in the Table 4.3. The controller was programmed to turn ON the water pump for five minutes and then will turn OFF for 120 minutes. This repetition cycle was held for four days.

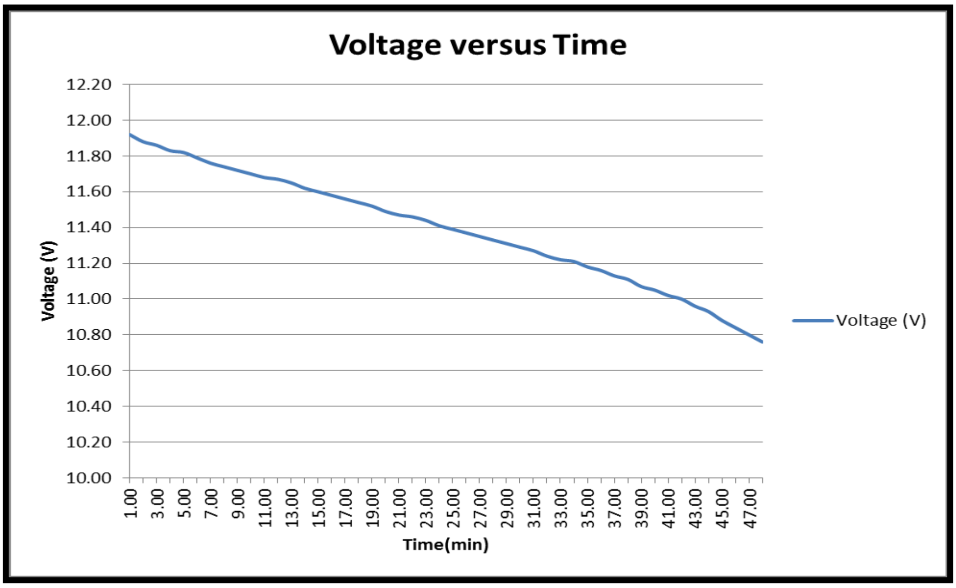


Figure 4.7: Graph Battery Voltage versus Time

According to the Figure 4.7, it shows that the battery can be last long for 45 minutes which is means, the watering system can used the battery for nine times of the cycle for watering process. Based on this project, during the daylight the watering system will be power up by the AC supply and during the night, it will operate using the DC supply which is from the 12V battery.

A 2kg seed has been tested in this project. By using four seed's container, the seed was divided into four and each container was filled up with 500g. The process for the seeds to growth and became the bean sprout was recorded. Figure 4.8 shows the process of the seeds to growth from day one until day four. Figure 4.8 (a) shows the result of seeds which were soaked for a night.

Figure 4.8 (a): Day one

Figure 4.8 (b): Day two

Figure 4.8 (c): Day three

Figure 4.8 (d): Day four

One seed's container produced around 3.4 to 3.5kg bean sprout. Total for the four containers was around 14kg. From two kilograms of seed had produced 14kg of bean sprout.

4.5 Usage of Electrical Energy in Bean Sprout System

The total amount of the electrical energy use in this system is shown in the Table 4.4. It shows the comparison of using two power supplies which are AC and DC source in this project. Both of these tables show the amount of charge for the system to be running for four days which is from the initial germination process until the sprouts. In table 4.4(a), it shows the total charge that can be saved if the system using battery as a supply during night operation.

Table 4.4 (a): Total electrical usage using AC supply and battery

Total Unit (kWh)	33.1344
Rates (RM)	0.218
Amount (RM)	7.22

For Table 4.4(b), it shows the amount of charge for this project if the system using fully AC supply.

Table 4.4(b): Total electrical usage using AC supply

Total Unit (kWh)	66.2688
Rates (RM)	0.218
Amount (RM)	14.44

The calculation for this table can be referring to Appendix C. The different amount between these two tables is RM 7.22 which is the amount of charge that can be saving in the bills for four days. If the system keeps functioning according to the system at Table 4.4 (a) for 28 days, the amount of charge that can be saving is RM 50.54.

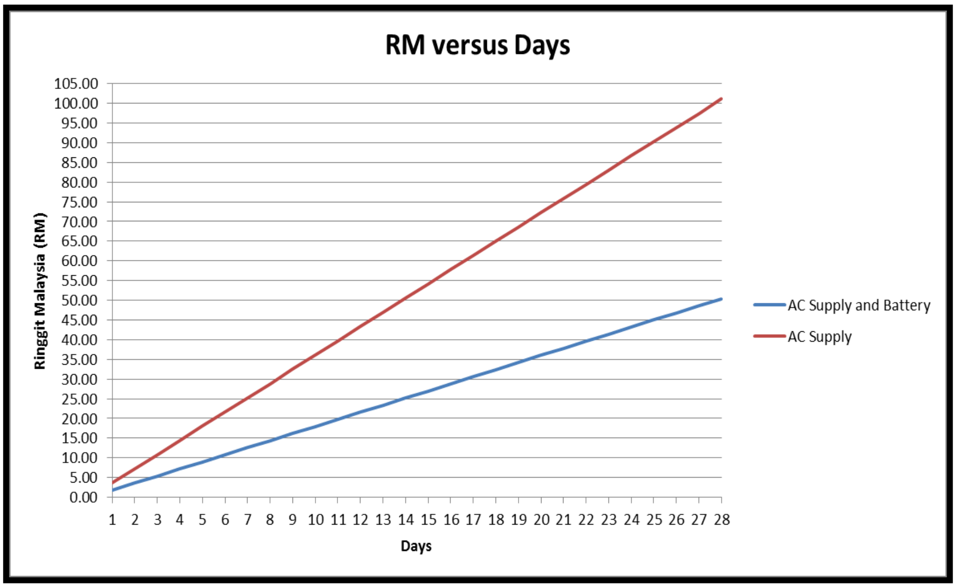


Figure 4.9: Graph Ringgit Malaysia (RM) versus Days

Base on the calculation at the Appendix C, total charge for one day is RM 1.80 if using AC supply and battery but if using fully AC supply the total charge will be RM3.61. Figure 4.9 shows the comparison of the estimation cost on the electrical usage for 28 days between using fully AC supply and using AC supply with battery. Total charge for 28 days is RM 50.40 for using AC supply and battery. But compare to the using fully AC supply, total charge is RM 101.08. Half of the price for using fully AC supply can be reduce if running the system using AC supply and battery.

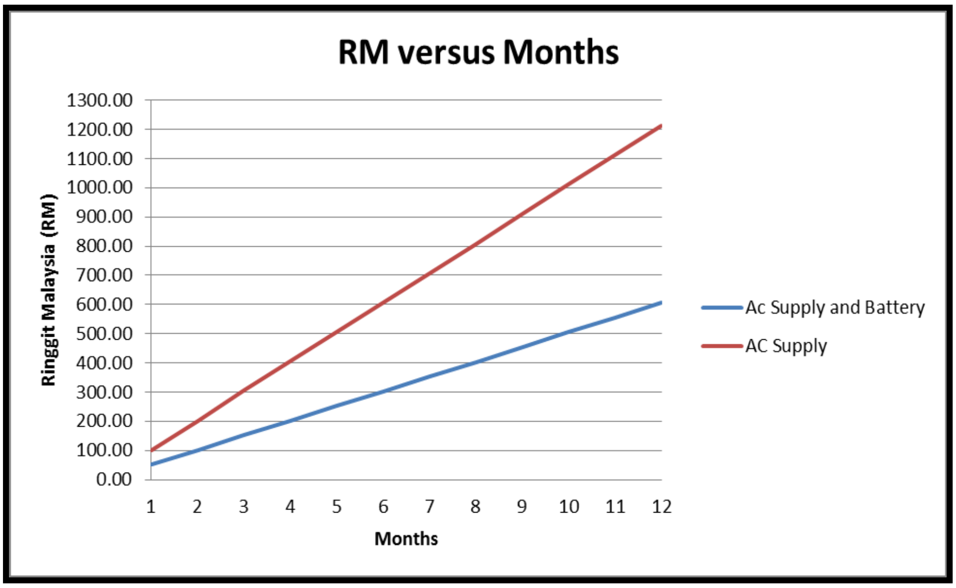


Figure 4.10: Graph Ringgit Malaysia (RM) versus Months

Figure 4.10 shows the comparison of the estimation cost on the electrical usage for 12 months between using fully AC supply and using AC supply with battery. Total charge for 12 months is RM 604.80 for using AC supply and battery. Compare to the total charge using fully AC supply is RM 1212.96. The difference cost is RM 608.16 and it shows that a lot of energy and cost can be saving if using AC supply and battery for the automatic bean sprout system.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main objectives of this project has been achieved where the system is able to run in automatic mode by develop a software for the microcontroller and interface it with the water pump which used to watering the seeds base on predetermines time period. Overall of the system consist of two type power source which are AC and DC supply. AC supply will be used during the day light and at the same time solar panel used to charge the 12V battery and provide power to the system during the night operation.

5.2 Recommendation

This project has successfully demonstrated an automatic bean sprout system using solar panel. Future work on this project may include:

- Use the humidity sensor in order to maintain the temperature and moisture inside the seeds container.
- Use high horse power of water pump for using in the large scale of growing the bean sprout.
- Use intelligent charging circuit for charging the battery.
- Fully operation of the system will be power up by the solar system

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APPENDIX A

TABLE OF RESULT

Table 4.2: Charging Voltage and Current

Time (H)	Voltage (V)	Current (A)
1130	11.99	2.36
1131	12.04	2.48
1132	12.07	2.57
1133	12.06	2.44
1134	12.02	2.10
1135	12.04	2.34
1136	12.12	2.87
1137	12.15	3.07
1138	12.12	2.80
1139	12.11	2.72
1140	12.09	2.60
1141	12.06	2.37
1142	12.07	2.39
1143	12.08	2.50
1144	12.08	2.47
1145	12.11	2.68
1146	12.14	2.92
1147	12.12	2.72
1148	12.12	2.69
1149	12.13	2.77
1150	12.08	2.81
1151	12.05	2.79
1152	12.07	2.83
1153	12.10	2.84
1154	12.07	2.89
1155	12.09	2.91
1156	12.08	2.84
1157	12.07	2.83
1158	12.08	2.97
1159	12.09	3.36
1200	12.12	3.40
1201	12.13	3.45
1202	12.14	3.46
1203	12.13	3.34
1204	12.13	3.38
1205	12.11	3.49
1206	12.16	3.50
1207	12.19	3.51
1208	12.19	3.49
1209	12.21	3.65
1210	12.21	3.65
1211	12.22	3.77
1212	12.20	3.52
1213	12.19	3.40

1214	12.16	3.16
1215	12.13	2.84
1216	12.11	2.64
1217	12.10	2.52
1218	12.07	2.17
1219	12.03	1.90
1220	12.04	1.96
1221	12.08	2.13
1222	12.12	2.41
1223	12.17	2.94
1224	12.18	2.87
1225	12.19	2.86
1226	12.23	3.22
1227	12.25	3.30
1228	12.25	3.30
1229	12.26	3.37
1230	12.25	3.26
1231	12.27	3.43
1232	12.27	3.48
1233	12.29	3.61
1234	12.27	3.42
1235	12.26	3.35
1236	12.28	3.53
1237	12.29	3.54
1238	12.28	3.40
1239	12.29	3.56
1240	12.29	3.50
1241	12.29	3.38
1242	12.28	3.38
1243	12.28	3.35
1244	12.25	3.03
1245	12.27	3.23
1246	12.28	3.29
1247	12.28	3.24
1248	12.27	3.16
1249	12.28	3.24
1250	12.28	3.24
1251	12.30	3.26
1252	12.33	3.39
1253	12.32	3.47
1254	12.29	3.22
1255	12.29	3.17
1256	12.27	2.96
1257	12.28	3.10
1258	12.28	3.08
1259	12.27	2.91
1300	12.26	2.83

1301	12.25	2.73
1302	12.30	2.97
1303	12.31	3.16
1304	12.33	3.29
1305	12.34	3.35
1306	12.37	3.61
1307	12.36	3.53
1308	12.34	3.29
1309	12.37	3.51
1310	12.36	3.41
1311	12.36	3.42
1312	12.38	3.55
1313	12.38	3.52
1314	12.33	3.06
1315	12.32	3.05
1316	12.36	3.30
1317	12.38	3.48
1318	12.39	3.52
1319	12.38	3.43
1320	12.38	3.41
1321	12.38	3.28
1322	12.35	3.05
1323	12.32	2.79
1324	12.28	2.40
1325	12.25	2.21
1326	12.36	3.03
1327	12.36	3.04
1328	12.38	3.19
1329	12.39	3.22
1330	12.40	3.29
1331	12.41	3.32
1332	12.41	3.33
1333	12.42	3.40
1334	12.43	3.47
1335	12.44	3.52
1336	12.44	3.53
1337	12.44	3.46
1338	12.43	3.42
1339	12.42	3.32
1340	12.40	3.14
1341	12.44	3.42
1342	12.46	3.57
1343	12.46	3.57
1344	12.46	3.50
1345	12.46	3.47
1346	12.46	3.45
1347	12.46	3.47

1348	12.47	3.51
1349	12.47	3.51
1350	12.47	3.47
1351	12.47	3.41
1352	12.48	3.55
1353	12.48	3.50
1354	12.48	3.49
1355	12.49	3.51
1356	12.49	3.51
1357	12.50	3.54
1358	12.50	3.52
1359	12.50	3.52
1400	12.49	3.38
1401	12.50	3.46
1402	12.51	3.51
1403	12.50	3.46
1404	12.50	3.39
1405	12.50	3.31
1406	12.50	3.30
1407	12.49	3.37
1408	12.46	3.26
1409	12.45	3.30
1410	12.49	3.28
1411	12.50	3.27
1412	12.52	3.33
1413	12.52	3.32
1414	12.50	3.14
1415	12.53	3.42
1416	12.53	3.40
1417	12.54	3.44
1418	12.54	3.42
1419	12.54	3.41
1420	12.55	3.45
1421	12.54	3.43
1422	12.55	3.42
1423	12.55	3.40
1424	12.54	3.25
1425	12.53	3.20
1426	12.54	3.29
1427	12.55	3.29
1428	12.54	3.25
1429	12.55	3.30
1430	12.55	3.26
1431	12.56	3.32
1432	12.56	3.30
1433	12.57	3.36
1434	12.58	3.37

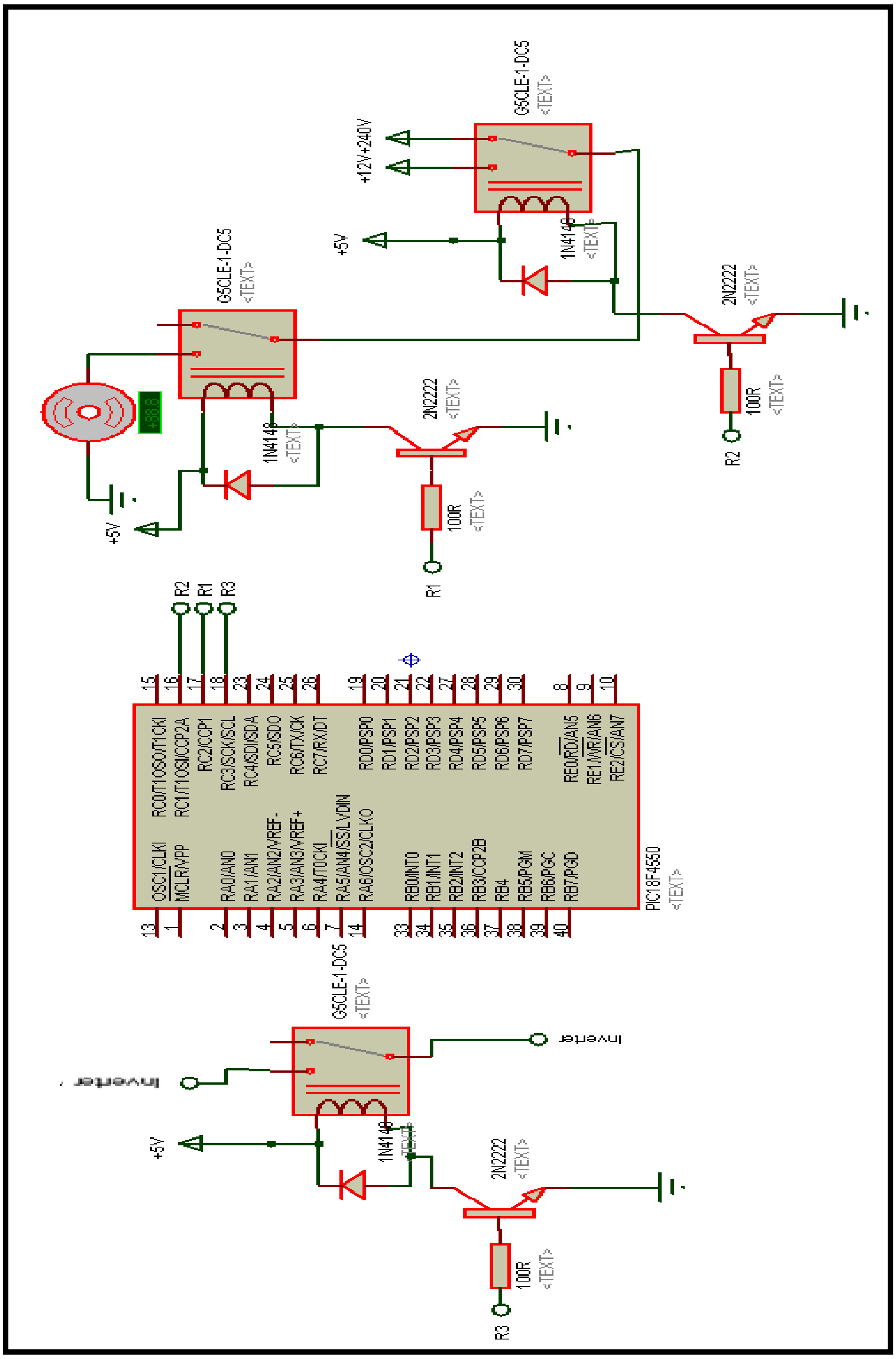
1435	12.57	3.34
1436	12.58	3.32
1437	12.58	3.34
1438	12.58	3.37
1439	12.58	3.36
1440	12.59	3.37
1441	12.59	3.35
1442	12.59	3.27
1443	12.56	2.72
1444	12.50	2.51
1445	12.54	3.21
1446	12.58	3.19
1447	12.59	3.15
1448	12.61	3.19
1449	12.55	2.65
1450	12.53	2.64
1451	12.57	2.98
1452	12.60	3.11
1453	12.61	3.28
1454	12.62	3.29
1455	12.61	3.29
1456	12.61	3.24
1457	12.61	3.06
1458	12.60	3.01
1459	12.60	3.03
1500	12.61	3.02
1501	12.63	3.14
1502	12.63	3.15
1503	12.61	2.98
1504	12.60	2.86
1505	12.62	3.06
1506	12.63	3.16
1507	12.62	2.93
1508	12.59	2.90
1509	12.63	3.02
1510	12.64	3.14
1511	12.62	2.91
1512	12.61	2.87
1513	12.61	2.35
1514	12.60	2.71
1515	12.60	2.83
1516	12.64	3.02
1517	12.62	2.92
1518	12.63	2.97
1519	12.65	2.99
1520	12.64	2.99
1521	12.66	3.03

1522	12.65	3.01
1523	12.64	2.88
1524	12.64	2.85
1525	12.65	2.91
1526	12.66	2.96
1527	12.66	2.93
1528	12.65	2.87
1529	12.65	2.80
1530	12.66	2.86
1531	12.65	2.83
1532	12.66	2.86
1533	12.67	2.92
1534	12.67	2.89
1535	12.66	2.73
1536	12.65	2.69
1537	12.65	2.72
1538	12.66	2.81
1539	12.68	2.84
1540	12.63	2.51
1541	12.63	2.44
1542	12.66	2.69
1543	12.66	2.58
1544	12.65	2.53
1545	12.64	2.39
1546	12.63	2.34
1547	12.63	2.23
1548	12.65	2.45
1549	12.65	2.42
1550	12.65	2.33
1551	12.64	2.32
1552	12.64	2.30
1553	12.65	2.36
1554	12.65	2.31
1555	12.65	2.27
1556	12.65	2.25
1557	12.66	2.37
1558	12.65	2.27
1559	12.65	2.24
1600	12.65	2.26
1601	12.66	2.29
1602	12.66	2.27
1603	12.66	2.29
1604	12.66	2.19
1605	12.65	2.15
1606	12.66	2.17
1607	12.66	2.16
1608	12.66	2.12

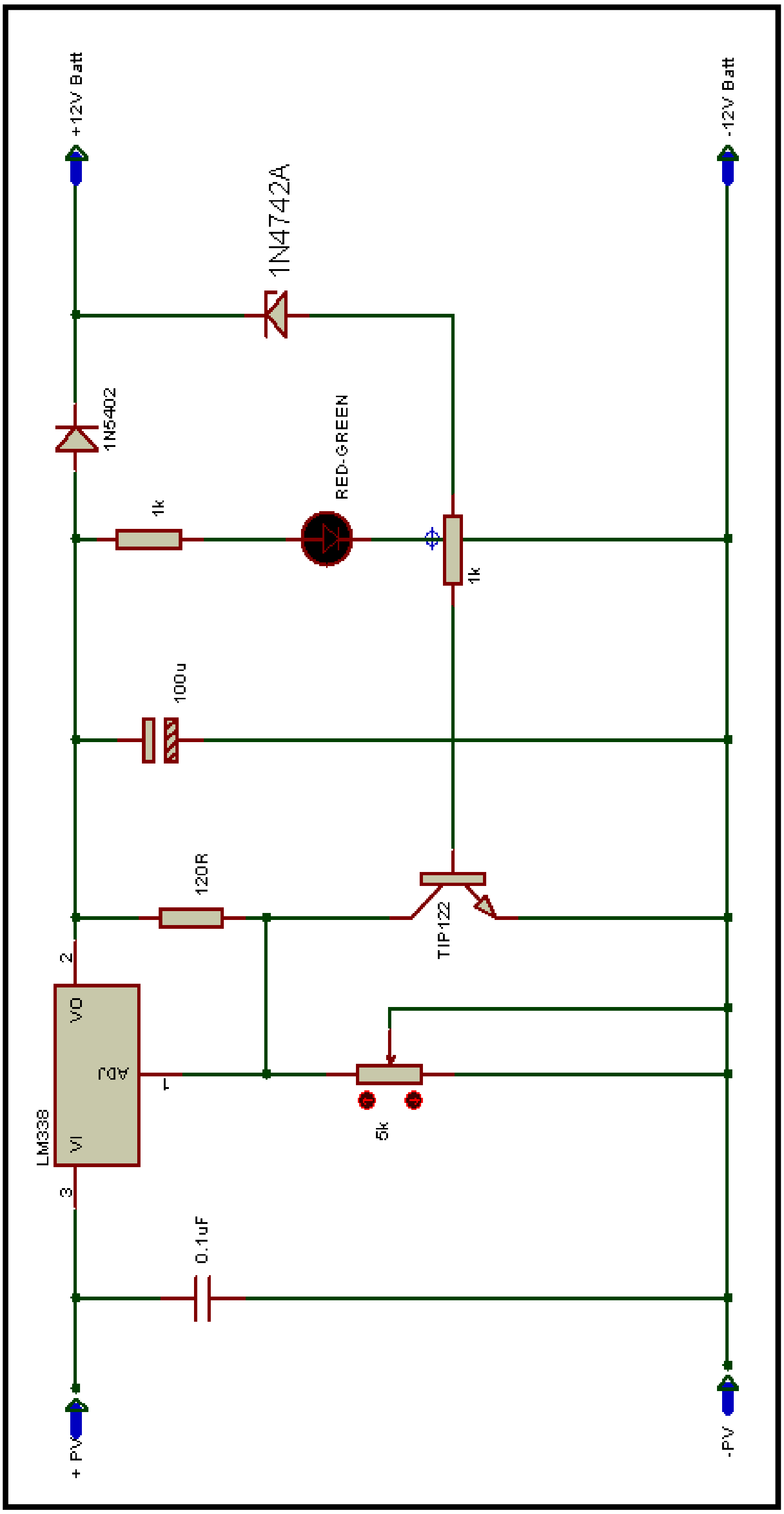
1609	12.66	2.13
1610	12.67	2.14
1611	12.67	2.13
1612	12.66	1.65
1613	12.66	2.07
1614	12.62	1.76
1615	12.62	1.81
1616	12.63	1.82
1617	12.62	1.77
1618	12.63	1.77
1619	12.62	1.80
1620	12.65	2.07
1621	12.66	2.00
1622	12.67	1.95
1623	12.67	1.98
1624	12.67	1.96
1625	12.67	1.97
1626	12.68	2.00
1627	12.68	1.99
1628	12.68	1.99
1629	12.68	1.95
1630	12.68	1.94

APPENDIX B

FULL CIRCUIT SCHEMATIC DIAGRAM



APPENDIX B1: Schematic Diagram of Controller System Board



APPENDIX B2: Schematic Diagram of Charger Circuit

APPENDIX C

CALCULATION FOR ELECTRICAL CHARGE

Power consumption of water pump:

1. Output AC current: 1.18A
2. Output AC voltage: 234V
3. Output Power: 1.18 x 234 = 276.12 Watt

Amount of electrical energy usage using AC supply and battery:

1. Usage of water pump for one day: 6 times
2. Period of time for the water pump is ON for one time: 5 minutes
3. Total time for water pump is ON for one day: 6 x 5 = 30 minutes
4. Amount of power consumption: 30 x 276.12 = 8.2836 kW
5. Total charged for one day: 8.2836 x 0.218 = RM 1.80
6. Total time for water pump is ON for four days : 4 x 30 = 120 minutes
7. Amount of power consumption: 120 x 276.12 = 33.1344 kW
8. Total charged for four days: 33.1344 x RM0.218 = RM 7.22

Amount of electrical energy usage using fully AC supply:

1. Usage of water pump for one day: 12 times
2. Period of time for the water pump is ON for one time: 5 minutes
3. Total time for water pump is ON for one day: 12 x 5 = 60 minutes
4. Amount of power consumption: 60 x 276.12 = 16.5672 kW
5. Total charged for one day: RM 3.61
6. Total time for water pump is ON for four days : 4 x 60 = 240 minutes
7. Amount of power consumption: 240 x 276.12 = 66.2688 kW
8. Total charged for four days: 66.2688 x RM0.218 = RM 14.44

APPENDIX D

PIC CODING

```
#include <18F4550.h>
#fuses hs, nowdt, nolvp, noprotect
#use delay (clock=20000000)
int counter2, counter3;
char c,d;
void main()
{set_tris_c(0x00);
counter2 =0; // day
counter3 =0; // day and night
for (counter2=0;counter2<4;counter2++)
{output_low(PIN_B0);
output_low(PIN_B2);
for (counter3=0;counter3<6;counter3++)
{output_low(PIN_B0);//confirm power relay is at off state
output_high(PIN_B1); // water pump ON
delay1();
output_low(PIN_B1); // water pump OFF
delay2();
}
for (counter3=3;counter3<12;counter3++)
{output_high(PIN_B0);// power relay is ON
output_high(PIN_B2);
output_high(PIN_B1);
delay1();
output_low(PIN_B1);
delay2();
}
output_low(PIN_B1);
output_low(PIN_B0);
}
}
```

APPENDIX E

DATASHEET

GOOD-ARK

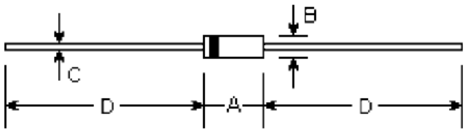
1N4728 THRU 1N4764

SILICON PLANAR POWER ZENER DIODES

Features

Silicon Planar Power Zener Diodes
for use in stabilizing and clipping circuits with high power rating. Standard Zener voltage tolerance is ± 10%. Add suffix "A" for ± 5% tolerance. Other tolerances available upon request.

DO-41



DIMENSIONS					
DIM	inches		mm		Note
	Min.	Max.	Min.	Max.	
A	-	0.169	-	4.3	
B	-	0.110	-	2.8	ф
C	-	0.031	-	0.8	ф
D	1.102	-	28.0	-	

Absolute Maximum Ratings (T_a=25℃)

	Symbols	Values	Units
Zener current see Table "Characteristics"			
Power dissipation at T_{amb}=25℃	P_{tot}	1 [1)]	W
Junction temperature	T_j	200	℃
Storage temperature range	T_S	-65 to +200	℃

Note:
(1) Valid provided that leads at a distance of 8 mm from case are kept at ambient temperature.

Characteristics at T_{amb}=25℃

	Symbols	Min.	Typ.	Max.	Units
Thermal resistance junction to ambient Air	R_{thA}	-	-	170 [1)]	K/W
Forward voltage at I_F=200mA	V_F	-	-	1.2	V

Note:
(1) Valid provided that leads at a distance of 8 mm from case are kept at ambient temperature.

Type	Zener voltage range [3]		Maximum Zener Impedance [1]			Reverse leakage current		Surge current at T_A=25℃	Maximum regulator current [2]
	V_{znom}	I_{ZT}	r_{zjT} and r_{zjk} at I_{ZK}			I_R at V_R		I_R	I_{ZM}
	V	mA	Ω	Ω	mA	uA	V	mA	mA
1N4728	3.3	76	10	400	1.0	150	1	1375	275
1N4729	3.6	69	10	400	1.0	100	1	1260	252
1N4730	3.9	64	9	400	1.0	100	1	1190	234
1N4731	4.3	58	9	400	1.0	50	1	1070	217
1N4732	4.7	53	8	500	1.0	10	1	970	193
1N4733	5.1	49	7	550	1.0	10	1	890	178
1N4734	5.6	45	5	600	1.0	10	2	810	162
1N4735	6.2	41	2	700	1.0	10	3	730	146
1N4736	6.8	37	3.5	700	1.0	10	4	660	133
1N4737	7.5	34	4.0	700	0.5	10	5	605	121
1N4738	8.2	31	4.5	700	0.5	10	6	550	110
1N4739	9.1	28	5.0	700	0.5	10	7	500	100
1N4740	10	25	7	700	0.25	10	7.6	454	91
1N4741	11	23	8	700	0.25	5	8.4	414	83
1N4742	12	21	9	700	0.25	5	9.1	380	76
1N4743	13	19	10	700	0.25	5	9.9	344	69
1N4744	15	17	14	700	0.25	5	11.4	304	61
1N4745	16	15.5	16	700	0.25	5	12.2	285	57
1N4746	18	14	20	750	0.25	5	13.7	250	50
1N4747	20	12.5	22	750	0.25	5	15.2	225	45
1N4748	22	11.5	23	750	0.25	5	16.7	205	41
1N4749	24	10.5	25	750	0.25	5	18.2	190	38
1N4750	27	9.5	35	750	0.25	5	20.6	170	34
1N4751	30	8.5	40	1000	0.25	5	22.8	150	30
1N4752	33	7.5	45	1000	0.25	5	25.1	135	27
1N4753	36	7.0	50	1000	0.25	5	27.4	125	25
1N4754	39	6.5	60	1000	0.25	5	29.7	115	23
1N4755	43	6.0	70	1500	0.25	5	32.7	110	22
1N4756	47	5.5	80	1500	0.25	5	35.8	95	19
1N4757	51	5.0	95	1500	0.25	5	38.8	90	18
1N4758	56	4.5	110	2000	0.25	5	42.6	80	16
1N4759	62	4.0	125	2000	0.25	5	47.1	70	14
1N4760	68	3.7	150	2000	0.25	5	51.7	65	13
1N4761	75	3.3	175	2000	0.25	5	56.0	60	12
1N4762	82	3.0	200	3000	0.25	5	62.2	55	11
1N4763	91	2.8	250	3000	0.25	5	69.2	50	10
1N4764	100	2.5	350	3000	0.25	5	76.0	45	9

Notes:

(1) The Zener Impedance is derived from the 60 Hz AC voltage which results when an AC current having an RMS value equal to 10% of the Zener current (I_{ZT} or I_{ZK}) is superimposed on I_{ZT} or I_{ZK}. Zener Impedance is measured at two points to insure a sharp knee on the breakdown curve and to eliminate unstable units.

(2) Valid provided that leads at a distance of 8 mm from case are kept at ambient temperature.

(3) Measured under thermal equilibrium and DC test conditions.

National Semiconductor

May 1998

LM138/LM338
5-Amp Adjustable Regulators

General Description

The LM138 series of adjustable 3-terminal positive voltage regulators is capable of supplying in excess of 5A over a 1.2V to 32V output range. They are exceptionally easy to use and require only 2 resistors to set the output voltage. Careful circuit design has resulted in outstanding load and line regulation — comparable to many commercial power supplies. The LM138 family is supplied in a standard 3-lead transistor package.

A unique feature of the LM138 family is time-dependent current limiting. The current limit circuitry allows peak currents of up to 12A to be drawn from the regulator for short periods of time. This allows the LM138 to be used with heavy transient loads and speeds start-up under full-load conditions. Under sustained loading conditions, the current limit decreases to a safe value protecting the regulator. Also included on the chip are thermal overload protection and safe area protection for the power transistor. Overload protection remains functional even if the adjustment pin is accidentally disconnected.

Normally, no capacitors are needed unless the device is situated more than 6 inches from the input filter capacitors in which case an input bypass is needed. An output capacitor can be added to improve transient response, while bypassing the adjustment pin will increase the regulator's ripple rejection.

Besides replacing fixed regulators or discrete designs, the LM138 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded, i.e., do not short-circuit output to ground. The part numbers in the LM138 series which have a K suffix are packaged in a standard Steel TO-3 package, while those with a T suffix are packaged in a TO-220 plastic package. The LM138 is rated for $-55^{\circ}C \leq T_J \leq +150^{\circ}C$, and the LM338 is rated for $0^{\circ}C \leq T_J \leq +125^{\circ}C$.

Features

- Guaranteed 7A peak output current
- Guaranteed 5A output current
- Adjustable output down to 1.2V
- Guaranteed thermal regulation
- Current limit constant with temperature
- P+ Product Enhancement tested
- Output is short-circuit protected

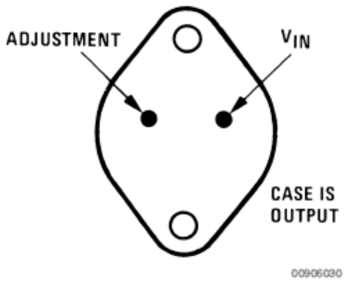
Applications

- Adjustable power supplies
- Constant current regulators
- Battery chargers

Connection Diagrams (See Physical Dimension section for further information)

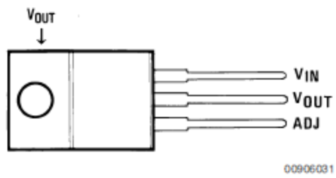
Connection Diagrams

(TO-3 STEEL)
Metal Can Package



Bottom View
Order Number LM138K STEEL or LM338K STEEL
See NS Package Number K02A

(TO-220)
Plastic Package



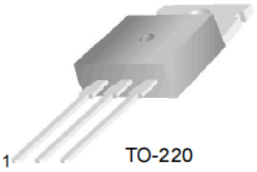
Front View
Order Number LM338T
See NS Package Number T03B

FAIRCHILD SEMICONDUCTOR®

October 2008

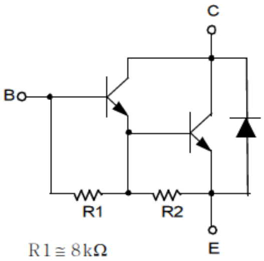
TIP120/TIP121/TIP122
NPN Epitaxial Darlington Transistor

- Medium Power Linear Switching Applications
- Complementary to TIP125/126/127



1.Base 2.Collector 3.Emitter

Equivalent Circuit



R1 ≅ 8kΩ
R2 ≅ 0.12kΩ

Absolute Maximum Ratings* T_a = 25°C unless otherwise noted

Symbol	Parameter	Ratings	Units
V_{CBO}	Collector-Base Voltage : TIP120 : TIP121 : TIP122	60 80 100	V V V
V_{CEO}	Collector-Emitter Voltage : TIP120 : TIP121 : TIP122	60 80 100	V V V
V_{EBO}	Emitter-Base Voltage	5	V
I_C	Collector Current (DC)	5	A
I_{CP}	Collector Current (Pulse)	8	A
I_B	Base Current (DC)	120	mA
P_C	Collector Dissipation (T_a=25°C)	2	W
	Collector Dissipation (T_C=25°C)	65	W
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	- 65 ~ 150	°C

* These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Electrical Characteristics* T_a=25°C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
V_{CEO}(sus)	Collector-Emitter Sustaining Voltage : TIP120 : TIP121 : TIP122	I_C = 100mA, I_B = 0	 60 80 100			 V V V
I_{CEO}	Collector Cut-off Current : TIP120 : TIP121 : TIP122	 V_{CE} = 30V, I_B = 0 V_{CE} = 40V, I_B = 0 V_{CE} = 50V, I_B = 0			 0.5 0.5 0.5	 mA mA mA
I_{CBO}	Collector Cut-off Current : TIP120 : TIP121 : TIP122	 V_{CB} = 60V, I_E = 0 V_{CB} = 80V, I_E = 0 V_{CB} = 100V, I_E = 0			 0.2 0.2 0.2	 mA mA mA
I_{EBO}	Emitter Cut-off Current	V_{BE} = 5V, I_C = 0			2	mA
h_{FE}	* DC Current Gain	V_{CE} = 3V,I_C = 0.5A V_{CE} = 3V, I_C = 3A	1000 1000			
V_{CE}(sat)	* Collector-Emitter Saturation Voltage	I_C = 3A, I_B = 12mA I_C = 5A, I_B = 20mA			2.0 4.0	V V
V_{BE}(on)	* Base-Emitter On Voltage	V_{CE} = 3V, I_C = 3A			2.5	V
C_{ob}	Output Capacitance	V_{CB} = 10V, I_E = 0, f = 0.1MHz			200	pF

* Pulse Test: Pulse Width≤300µs, Duty Cycle≤2%

2N2222 / 2N2222A

NPN Silicon Epitaxial Planar Transistor
for switching and AF amplifier applications.

The transistor is subdivided into one group according to its DC current gain. As complementary type the PNP transistor ST 2N2907 and ST 2N2907A are recommended.

On special request, these transistors can be manufactured in different pin configurations.

1. Emitter 2. Base 3. Collector

TO-92 Plastic Package
Weight approx. 0.19g

Absolute Maximum Ratings (T_a = 25 ^{O}C)

	Symbol	Value		Unit
		ST 2N2222	ST 2N2222A	
Collector Base Voltage	V_{CBO}	60	75	V
Collector Emitter Voltage	V_{CEO}	30	40	V
Emitter Base Voltage	V_{EBO}	5	6	V
Collector Current	I_C	600		mA
Power Dissipation	P_{tot}	625		mW
Junction Temperature	T_j	150		^{O}C
Storage Temperature Range	T_S	-55 to +150		^{O}C

2N2222 / 2N2222A

Characteristics at T_{amb}=25 ^{O}C

		Symbol	Min.	Typ.	Max.	Unit
DC Current Gain						
at I_C=0.1mA, V_{CE}=10V		h_{FE}	35	-	-	-
at I_C=1mA, V_{CE}=10V		h_{FE}	50	-	-	-
at I_C=10mA, V_{CE}=10V		h_{FE}	75	-	-	-
at I_C=150mA, V_{CE}=10V	ST 2N2222	h_{FE}	100	-	300	-
at I_C=500mA, V_{CE}=10V	ST	h_{FE}	30	-	-	-
	2N2222A	h_{FE}	40	-	-	-
Collector Cutoff Current	ST 2N2222					
at V_{CB}=50V	ST	I_{CBO}	-	-	0.01	μA
V_{CB}=60V	2N2222A	I_{CBO}	-	-	0.01	μA
Collector Base Breakdown Voltage						
at I_C=10μA	ST 2N2222	$V_{(BR)CBO}$	60	-	-	V
	ST	$V_{(BR)CBO}$	75	-	-	V
Collector Emitter Breakdown Voltage						
at I_C=10mA	ST 2N2222	$V_{(BR)CEO}$	30	-	-	V
	ST	$V_{(BR)CEO}$	40	-	-	V
Emitter Base Breakdown Voltage						
at I_E=10μA	ST 2N2222	$V_{(BR)EBO}$	5	-	-	V
	ST	$V_{(BR)EBO}$	6	-	-	V
Collector Saturation Voltage						
at I_C=150mA, I_B=15mA	ST 2N2222	$V_{CE(sat)}$	-	-	0.4	V
	ST	$V_{CE(sat)}$	-	-	0.3	V
at I_C=500mA, I_B=50mA	2N2222A	$V_{CE(sat)}$	-	-	1.6	V
	ST 2N2222	$V_{CE(sat)}$	-	-	1	V
Base Saturation Voltage						
at I_C=150mA, I_B=15mA	ST 2N2222	$V_{BE(sat)}$	-	-	1.3	V
	ST	$V_{BE(sat)}$	0.6	-	1.2	V
at I_C=500mA, I_B=50mA	2N2222A	$V_{BE(sat)}$	-	-	2.6	V
	ST 2N2222	$V_{BE(sat)}$	-	-	2.0	v
Gain Bandwidth Product						
at I_C=20mA, V_{CE}=20V, f=100MHz		f_T	250	-	-	MHz
Collector Output Capacitance						
at V_{CB}=10V, f=1MHz		C_{ob}	-	-	8	pF
Input Capacitance						
at V_{CB}=0.5V, f=1MHz		C_{ib}	-	-	30	pF

FAIRCHILD SEMICONDUCTOR®

September 2011

LM78XX/LM78XXA
3-Terminal 1A Positive Voltage Regulator

Features

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

General Description

The LM78XX series of three terminal positive regulators are available in the TO-220 package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

Ordering Information

Product Number	Output Voltage Tolerance	Package	Operating Temperature
LM7805CT	±4%	TO-220 (Single Gauge)	-40°C to +125°C
LM7806CT			
LM7808CT			
LM7809CT			
LM7810CT			
LM7812CT			
LM7815CT			
LM7818CT			
LM7824CT			
LM7805ACT	±2%		0°C to +125°C
LM7806ACT			
LM7808ACT			
LM7809ACT			
LM7810ACT			
LM7812ACT			
LM7815ACT			
LM7818ACT			
LM7824ACT			

Pin Assignment

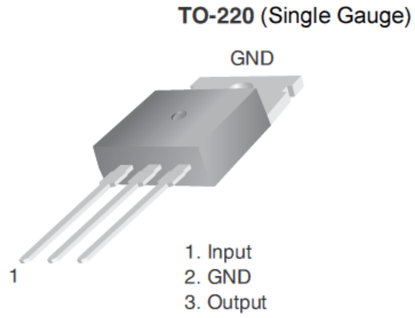


Figure 2.

Absolute Maximum Ratings

Absolute maximum ratings are those values beyond which damage to the device may occur. The datasheet specifications should be met, without exception, to ensure that the system design is reliable over its power supply, temperature, and output/input loading variables. Fairchild does not recommend operation outside datasheet specifications.

Symbol	Parameter		Value	Unit
V_I	Input Voltage	V_O = 5V to 18V	35	V
		V_O = 24V	40	V
$R_{\theta JC}$	Thermal Resistance Junction-Cases (TO-220)		5	°C/W
$R_{\theta JA}$	Thermal Resistance Junction-Air (TO-220)		65	°C/W
T_{OPR}	Operating Temperature Range	LM78xx	-40 to +125	°C
		LM78xxA	0 to +125	
T_{STG}	Storage Temperature Range		-65 to +150	°C

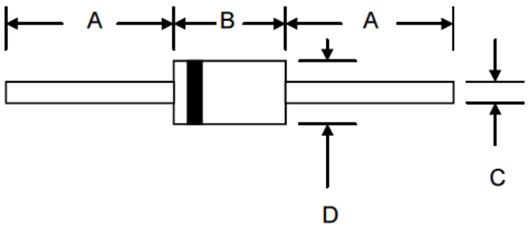
WTE
POWER SEMICONDUCTORS

1N5400 – 1N5408

3.0A SILICON RECTIFIER

Features

- Diffused Junction
- Low Forward Voltage Drop
- High Current Capability
- High Reliability
- High Surge Current Capability



Mechanical Data

- Case: Molded Plastic
- Terminals: Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Weight: 1.2 grams (approx.)
- Mounting Position: Any
- Marking: Type Number
- Epoxy: UL 94V-O rate flame retardant

DO-201AD		
Dim	**Min**	**Max**
A	25.4	—
B	8.50	9.50
C	1.20	1.30
D	5.0	5.60
All Dimensions in mm		

Maximum Ratings and Electrical Characteristics @T_A=25°C unless otherwise specified

Single Phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N 5400	1N 5401	1N 5402	1N 5404	1N 5406	1N 5407	1N 5408	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @T_A = 75°C	I_O	3.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms Single half sine-wave superimposed on rated load (JEDEC Method)	I_{FSM}	200							A
Forward Voltage @I_F = 3.0A	V_{FM}	1.0							V
Peak Reverse Current @T_A = 25°C At Rated DC Blocking Voltage @T_A = 100°C	I_{RM}	5.0 100							µA
Typical Junction Capacitance (Note 2)	C_j	50							pF
Typical Thermal Resistance Junction to Ambient (Note 1)	$R_{\theta JA}$	18							K/W
Operating Temperature Range	T_j	-65 to +125							°C
Storage Temperature Range	T_{STG}	-65 to +150							°C

***Glass passivated forms are available upon request**

Note: 1. Leads maintained at ambient temperature at a distance of 9.5mm from the case
2. Measured at 1.0 MHz and Applied Reverse Voltage of 4.0V D.C.