Ultracapacitor As A Backup Power Supply

by

Khairul Izuan Bin Mohd Shah
10263

A project dissertation
submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

MAY 2011

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
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Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved:

____

Puan Azizan binti Zainal Abidin
Project Supervisor

UniversitiTeknologi PETRONAS
Tronoh, Perak

MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

KHAIRUL IZUAN BIN MOHD SHAH

ABSTRACT

Today, power supply is the most important thing in our daily life. All appliances need power supply to ensure the appliances can operate properly. Most people have problems with the power supply especially when the power disturbances occur. There are many types of power disturbances such as voltage dips and surges, harmonics, or voltage spikes. Interruptions of power disturbances cause difficulties and great monetary causes especially for those who are doing the businesses at home such as internet business. These groups of people depend on internet and computer to generate their income. Modem and computer need a power supply before they can use it. However, their business will ruin if power disturbances occur. This problem burdens them and cause great monetary causes. The objective of this project is to design a backup power supply prototype for the home usage. In other words, backup power supply that will be designed is the mini Uninterruptable Power Supply (UPS) system. This system will use the bank of ultracapacitors as the energy source. Ultracapacitors can replace UPS batteries because it is able to store more energy like a battery. They have extremely high energy densities and exhibits low Equivalent Series Resistance (ESR). Ultracapacitor are very strong in power density, safety, environmental and performance efficiency. Ultracapacitor can accept charges at high rate without degradation and can deliver power when needed. The main tools of electronic components that will be used in this project are UPS system design as the system to backup power, ultracapacitors to store the energy, voltage regulator to maintain constant voltage level and bulb as the load. There are two methods that can use; by placing the ultracapacitors in parallel and placing the ultracapacitors in series. Both methods have the advantages and disadvantages. When placing the ultracapacitors in parallel, the capacitance is bigger but voltage rating is smaller. However, when placing the ultracapacitors in series, the capacitance is smaller but the voltage rating is bigger. Small capacitance means the discharging time is faster

compared to the bigger Farad which means the discharging time is slower. Both of the circuits can be used but it depends on the application. In this project, it will use twenty ultracapacitors and build it as an ultracapacitor bank. This ultracapacitor bank will combine with the mini UPS system as the backup power for the system.

ACKNOWLEDGEMENT

In the name of Allah, Most Gracious, Most Merciful. All the praises are due to Allah, the Lord, The Cherisher of the Worlds. First and foremost, I would like to express my thanks and great gratitude to Him for guiding me to complete my final year project. Indeed, without His help and will, nothing is accomplished.

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My sincere thank you to my parents, family members and also to those who are very close to my heart. Without their guidance and support, I would not have made this far in my life. Every moment with them will be cherished and also motivates me to go further into a new dimension in this life. Thank you again to all my family members.

Last but not least, I would like to express my gratitude to all who are directly and indirectly supported and helped me out all this while to make this project possible.

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INTRODUCTION

1.1 Background of Study

Electrical power supply disturbances can appear in a range of forms such as voltage dips and surges, harmonics, or voltage spikes. These disruptions can cause serious harm to sensitive electrical equipment especially during the critical processing or production stages of an operation. Uninterruptible Power Supply (UPS) systems are often incorporated in electrical networks to reduce the risk of power supply disturbances. Uninterruptable Power Supply (UPS) can provide power when the primary power source is temporarily disabled of supplying high quality electrical power to a load. Manufacturers of electronic power supplies provide reliable and high-quality power flow for sensitive electrical load equipment. This UPS system commonly uses in industrial processing applications, medical facilities, emergency equipment, telecommunications, and computerized data systems. A UPS system can be a helpful tool for ensuring proper power supply performance [1].

1.2 Problem Statement

Most people today choose to work at home compared to work with the company. They are willing to work alone at home than work at office which is need to deal with clients and many paper works. Housewife also can work at home to help their husband to increase their family income. However, they got a problem to work when the blackout occurs. These people, who are doing the internet businesses, are the major group that will be affected. These people are depends on internet to generate their income. As an example, one housewife is selling the shoes through internet. Every day, she has the customers from inside and outside the country. One day, unfortunately blackout was occurs. She cannot use the internet unless she has a backup power supply for her internet. Internet needs a power supply to work. She had suffered a loss during that day. This example shows that power supply is the major problem when the blackout occurs for those who are doing the internet businesses at home.

1.3 Objective

The objective of this project is to design a backup power supply prototype for the home usage. In other words, backup power supply that will be designed is the mini Uninterruptable Power Supply (UPS) system. This system will use the bank of ultracapacitors as the energy source. The ultracapacitor is acting as a charge conditioner. The ultracapacitor is storing the energy from the AC supply and can be used during the blackout for the load usage. As overall, this project will use ultracapacitor in the mini UPS as the energy storage because it has the capability to store the energy, rapid charging and environmental friendly compared to the battery.

1.4 Scope of the Study

This project is focusing on developing backup power supply which is Uninterruptable Power Supply (UPS) for the home usage. Gaining information is the most important thing. The study on power supply, ultracapacitor and UPS system is needed to get the better understanding and information about the subject matter. More experiment must be done to find the better ultracapacitors combination for the circuit to get the most efficiency result. In addition, the information about the case study must be very good. Hard work is needed to finish the prototype within the expected time and to ensure the prototype is working.

1.4.1 Relevancy of the Project

Based on a quick survey done, backup power is needed for the home usage. The flexibility offered by the UPS system will be very useful for this kind of usage. In addition, the project is also focusing on using ultracapacitor as the storage medium because it is environmental friendly.

CHAPTER 2

LITERATURE REVIEW

2.1 Uninterruptable Power Supply

An Uninterruptable Power Supply or UPS is a device that has an alternate source of energy that can provide power when the primary power source is temporarily disabled of supplying high quality electrical power to a load without interruptions. The switchover times must be small enough which is not to cause disruptions in the operation of the loads [2].

A standby generator is not considered as a UPS system. Although diesel generator can generate the electricity, in the event when the power outage or disturbance, there will always be an interval between the power failing and the standby generator is starting up. The break in power supply will occur and this may result in significant financial losses. UPS is needed for the continuous power supply without disruptions. UPS is not only provide protection against all types of power supply failure but it also capable of filtering a vast range of power disturbances found in the mains power supply [3].

There are several incidents that can cause power disturbances. Below is showing the power disturbances cause:

i. Storm activity – lightning, wind, ice

ii. Objects coming in contact with power line and tripping breaker – tree branches, animals, other

iii. Utility fault clearing

iv. Construction activity

v. Accidents – motor vehicle

vi. Equipment failure

vii. Overloading

viii. Load switching

ix. Non-linear loads

x. Poor grounding

In other words, it is very important having a UPS system to protects against multiple types of power disturbances. UPS system also is the only device that protects against an outage. UPS system also offers protection against equipment not operating properly, computer and equipment damage and data loss [4].

UPS system will work when the primary power source is temporarily disabled. UPS system is placed between the incoming mains power supply and the load. In the UPS system, there are batteries or backup power source to provide the electrical power when the primary power supply fails to work. The time length that the load can be supported fully depends on the size of the UPS battery. UPS system provides enough time to shut down essential computer system and safe the important data from being loss. It also gives a time to standby generator to be started up to support the load. When the mains power fails, UPS system switches with the backup UPS batteries to ensure the load keep working without having any disturbances [5].

There are many design approach are used to implement UPS system, depends on the application. The examples of design approaches are Standby UPS, Line Interactive UPS, Standby-Ferro UPS, Double Conversion On-Line UPS and Delta Conversion On-Line UPS. Line Interactive UPS is the common design used for UPS system.

Line Interactive is the common design used for UPS system. In this design, the battery is always connected to the load. Between the battery and the AC load, there is an inverter which is to convert from DC supply to AC supply. When the AC power is normal, the AC supply will charge the battery through the rectifier. Rectifier converts the AC power to DC power. The transfer switch is open when the input power fails and the power flows from the battery to the UPS output. This design provides additional filtering, with the inverter is always on and connected to the output to reduce switching transients [6].

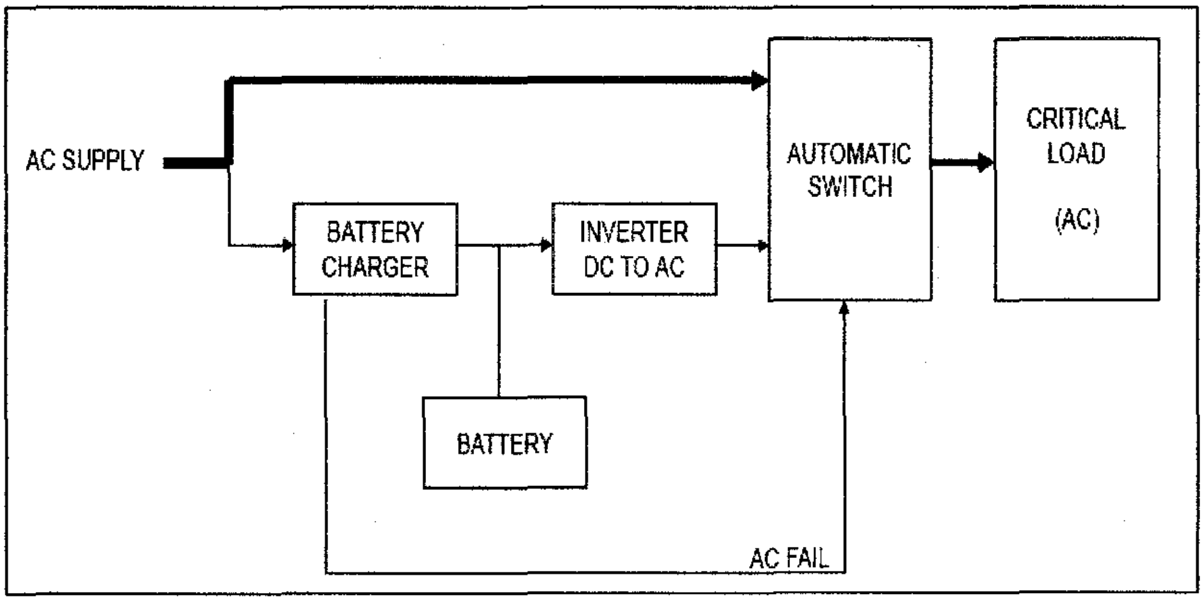

Figure 1: Block diagram Line Interactive UPS

2.2 Ultracapacitor

Ultracapacitor is also known as supercapacitor is an electric double layer capacitor. Ultracapacitor is based on ceramic have an extremely high specific surface area and metallic substrate. These characteristics make the ultracapacitor have extremely high energy densities and exhibits low Equivalent Series Resistance (ESR). The combination of low ESR and extremely low inductance provides ultracapacitor with a very high power density and fast rise time [7].

Ultracapacitor is based on the existing hundred year old technologies that posses a very high power density compared with electrolic capacitors. Ultracapacitor are very strong in power density, safety, environmental and performance efficiency. Ultracapacitor can accept charge at high rate without degradation and can deliver power when needed [8].

Ultracapacitor attracted many companies to do the research and develop the component because it is very useful in future. First patents date of back to 1957 where a capacitor based on high surface area carbon was described by Becker. In 1969, the device was firstly attempts to market and it was undertaken by SOHIO. However, the ultracapacitor became famous in the nineties because it was used for hybrid electric vehicles. A DOE ultracapacitor development program was initiated in 1989 for short terms and 1998 until 2003 for the long terms goal.

Today, several companies such as Maxwell Technologies, Siemens Matsushita, NEC, Panasonic, ELNA and TOKIN are invest in ultracapacitor development. The applications are principally boost components supporting batteries or replacing batteries primarily in electric vehicles [9]. Below is shown the example of 1.0 Farad ultracapacitor.

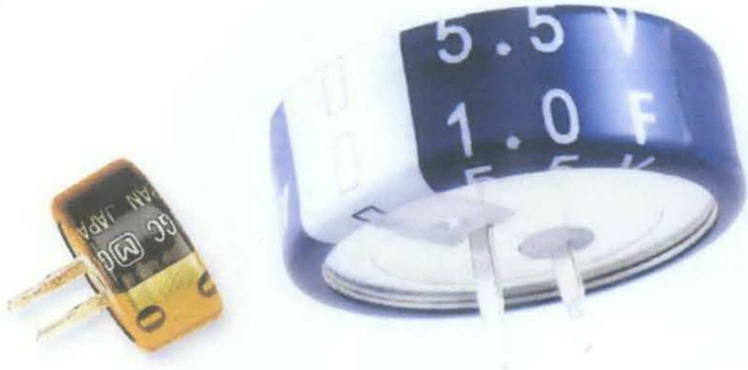

Figure 2: 1.0 Farad ultracapacitors

The characteristics of ultracapacitor are very useful for this project. The ultracapacitor is conjunction with batteries by acting as a charge conditioner, storing energy from other sources for balancing purpose and using the excess energy to charge the batteries. Besides, the ultracapacitor is also rapid charging, it can be charge in seconds. Table 1 compares the attributes between ultracapacitors and batteries.

Table 1: Ultracapacitors vs. batteries [10]

Attribute	Ultracapacitors	Batteries
Environmental	Green	Hazardous disposal
Shelf life	Years	Months
Charge time	Seconds	Hours
Weight	Lighter	Heavier
Operating temperature	Up to 70 °C	60°C maximum
Operating life	Up to 10 years	1 to 3 years
Maintenance	None	Replace every 1-2 years
Conditioning	None	Initial and periodic

2.3 Voltage Regulator

Voltage regulator or known as charge controller is an electrical regulator which is designed to automatically maintain a constant voltage level. Voltage regulator can monitor the battery state of charge. It is very important to ensure the battery is charging and not over charging. Voltage regulator may use an electromechanical mechanism, passive or active electronic components.

The voltage regulator rating must base on the amount of amperage they can process from the adjustable adapter. As an example, if the voltage regulator is rated at 30amps, the rating current for the adjustable adapter should be equal or less than 30amps. Pulse Width Modulation (PWM) is referred by most advanced voltage controllers which are utilizing the charging principle. This is to ensure battery charging efficiency and to extend the battery life [11].

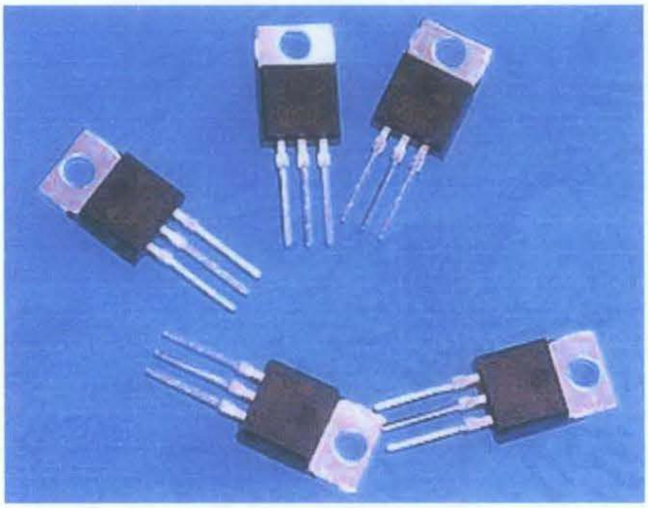

Figure 3: Voltage regulator

CHAPTER 3

METHODOLOGY

This project is all about to design a backup power supply or mini Uninterruptable Power Supply (UPS) system prototype for the home usage. The ultracapacitor will be the main component that will be use for this project. There are two ways to use the ultracapacitor. Firstly, put the ultracapacitor parallel with the batteries. This method is suitable to gain the high power or high energy. The other way is to remove the batteries and put the ultracapacitor alone. However, this method is limited to applications that require only a few seconds of operation between charging [12]. This project use ultracapacitor to change the UPS battery as the storage medium for this UPS system.

The first stage of this project is to test the connection method for ultracapacitor, either in parallel or in series. The first experiment was done by putting the ultracapacitors in parallel with each other. For this method, the input voltage is limited according to the ultracapacitor voltage rating. In this project, 1.0 Farad ultracapacitor will be used and the voltage rating for 1.0 Farad ultracapacitor is 5.5V. Thus, the total capacitance in experiment one:

Total capacitance for experiment one:

$$C_T = C_1 + C_2 + C_3 + C_4 + C_5 + C_6 + C_7 + C_8$$

$$C_T = 1F + 1F + 1F + 1F + 1F + 1F + 1F + 1F$$

$$C_T = 8F$$

The time constant calculation is needed to calculate the charging and discharging time of ultracapacitors. Time constant (TC) is the time required to charge a capacitor to 63.2 percent of full charge or to discharge it to 36.8 percent of its initial [13]. Below is shown the time constant for this circuit:

Time constant = R x C

$= 10\Omega \times 8.0F$

$= 80$ seconds

The second experiment also was done by putting the ultracapacitors in series. This method used to obtain the backup power that have a high voltage. The maximum voltage rating for 1.0 Farad ultracapacitor is 5.5V. If the ultracapacitor is putting in series, the ultracapacitor voltage rating input is increase until 11V. Thus, the total capacitance in experiment two:

Total capacitance in experiment two:

$$\frac{1}{C_{T1}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C_{T1}} = \frac{1}{1F} + \frac{1}{1F}$$

$$C_{T1} = 0.5F$$

$$C_{T1} = C_{T2} = C_{T3} = C_{T4} = 0.5F$$

Four sets of ultracapacitors in parallel:

$C_{Total} = 2.0F$

The time constant calculation is needed to calculate the charging and discharging time of ultracapacitors. Time constant (TC) is the time required to charge a capacitor to 63.2 percent of full charge or to discharge it to 36.8 percent of its initial [14]. Below is shown the time constant for this circuit:

Time constant = R x C

= 10Ω x 2.0F

= 20 seconds

Both experiment one and two were using Science Workshop750 Interface for the simulation part. The simulation graphs for voltage is obtained by connect the Science Workshop 750 Interface across ultracapacitors while simulation graphs for current is obtained by connect the Science Workshop 750 Interface in series with ultracapacitors.

The second stage for this project is to build a prototype, which is to combine the suitable ultracapacitor connection method circuit with the mini Uninterruptable Power Supply (UPS) circuit. According to the experiment one and two, the first method which is the combination of all ultracapacitors in parallel will be used. This method is used to get the voltage rating up to 5.5V. Thus, the total capacitance for ultracapacitor bank for UPS system:

Total capacitance in this circuit:

$$C_T = C_1 + C_2 + C_3 + \cdots + C_{20}$$

$$C_T = 20F + 1F + 1F + \cdots + 1F$$

$$C_T = 20F$$

The time constant calculation is needed to calculate the charging and discharging time of ultracapacitors. Time constant (TC) is the time required to charge a capacitor to 63.2 percent of full charge or to discharge it to 36.8 percent of its initial [15]. Below is shown the time constant for this circuit:

Time constant = R x C

= 10Ω x 20.0F

= 200 seconds

The dc voltage from the adjustable adapter is 5V. The mini UPS was designed to produced output dc which is 5V. This mini UPS input and output is in dc, just to show the mechanism and principle of UPS system applied for the home usage.

Maintaining voltage within the required range is critical for long-term reliability of the ultracapacitors. The charger voltage must be controlled to ensure it does not exceed the rated voltage of the cells. Having voltages above rating will reduce the life of the cell proportional to the overage. If overage is high enough, cell failure may occur rapidly [16].

3.1 Project Workflow

The project workflow for FYP1:

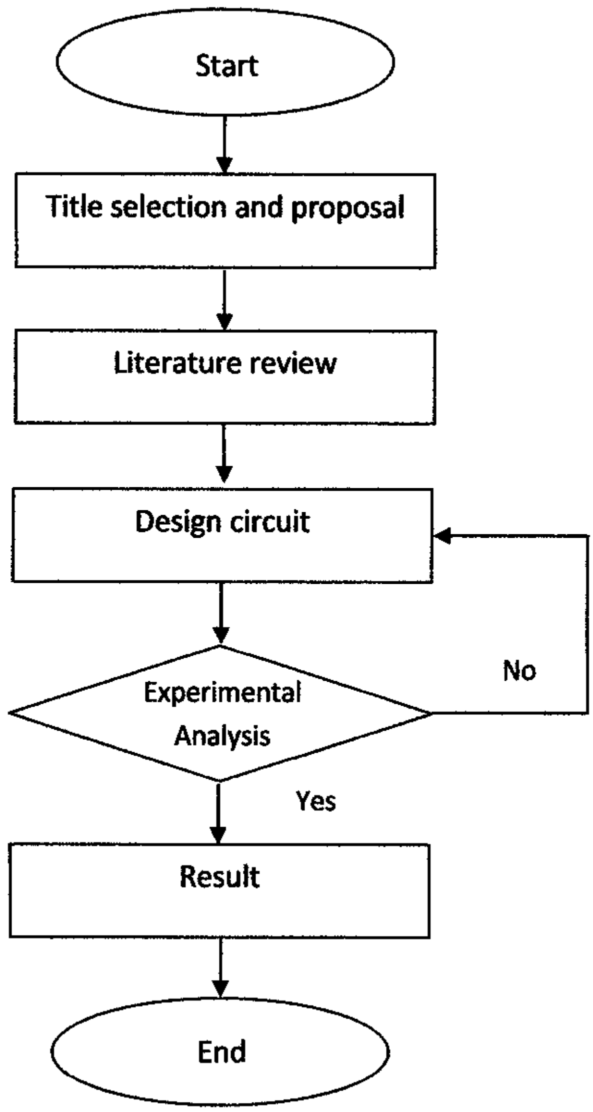

Figure 4: Project Activities Flow Chart FYP1

The project workflow for FYP2:

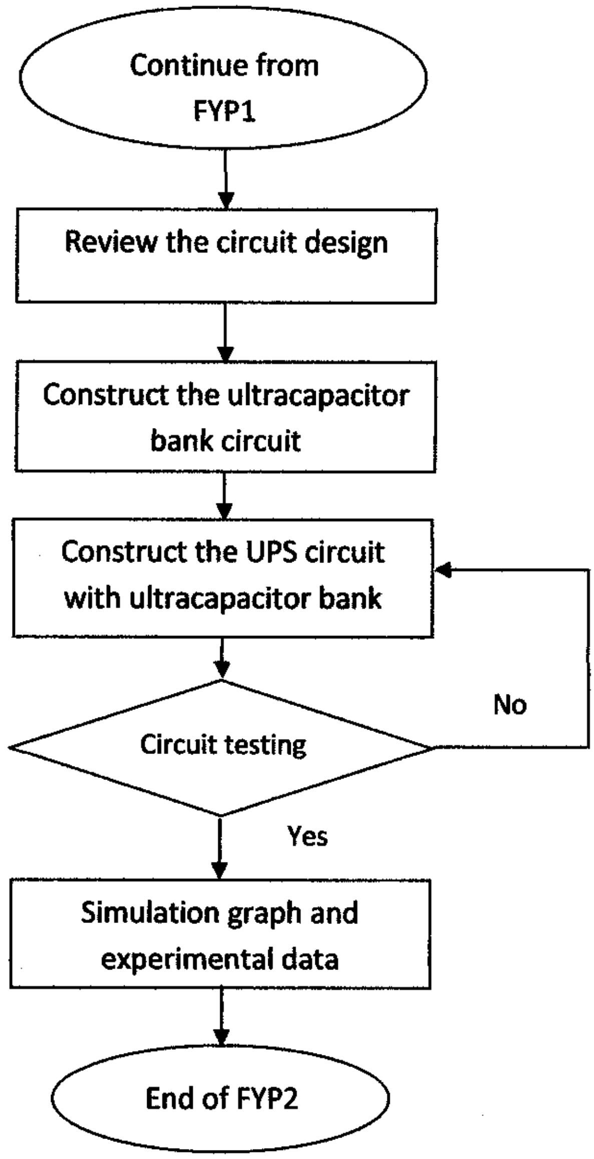

Figure 5: Project Activities Flow Chart FYP2

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results

The results here is showing the construction of mini Uninterruptable Power Supply (UPS) system circuit and the basic principle of the ultracapacitor and the capability of the ultracapacitor to increase the voltage to certain level. However, the voltage of the power supply must be in a range of ultracapacitor rating to prevent ultracapacitor from being damage. The selection of the ultracapacitor capacity is very important to determine the better result of the experiment.

Two experiments have been done to see the ultracapacitor performance. One of the experiments is running by putting all eight ultracapacitors in parallel while the other two experiments are running by putting four sets of two ultracapacitors in series in parallel. This mini UPS will used one of this combination of ultracapacitors. Below is showing the result for the experiment.

4.1.1 Experiment 1

The first experiment is performing with eight 1.0 Farad ultracapacitors by putting all the ultracapacitors in parallel. This experiment is using 12V supply voltage. 12V supply voltage will go through voltage regulator L7805ABV in order to gain 5V voltage output. The function of this voltage regulator is to stabilize the input voltage. Some calculation on the resistance is done to get the suitable resistor value for the circuit.

Below is shown the simple calculation to get the resistor value from the experiment.

4.1.1.1 Calculation

In this experiment, the circuit is use 12V input voltage as the power supply. However, there is a voltage regulator in the circuit to maintain the voltage output around 5V. In order to avoid the Light Emitting Diode (LED) from burn, some resistor must be put in the circuit. The calculation for the resistor is shown below.

After 12V voltage go through voltage regulator L7805ABV, the voltage output value is 5V. Thus,

$V_1 = 12V$

$V_2 = 5V$

We will use V_2 to calculate the resistor value.

For longest lifetime, maximum current can through LED is only 25mA. There are three LEDs in this circuit and the connection is in parallel. So,

25mA x 3 = 75mA

To calculate the minimum resistor, use the ohm's law. Thus,

$$V = IR$$

$$R = \frac{V}{I}$$

$$R = \frac{5}{75m}$$

$$= 66.6667\ \Omega$$

The minimum resistance is 66.6667 Ω. So, the researcher chooses to use 100 Ω resistors.

Below is shown the circuit for experiment one.

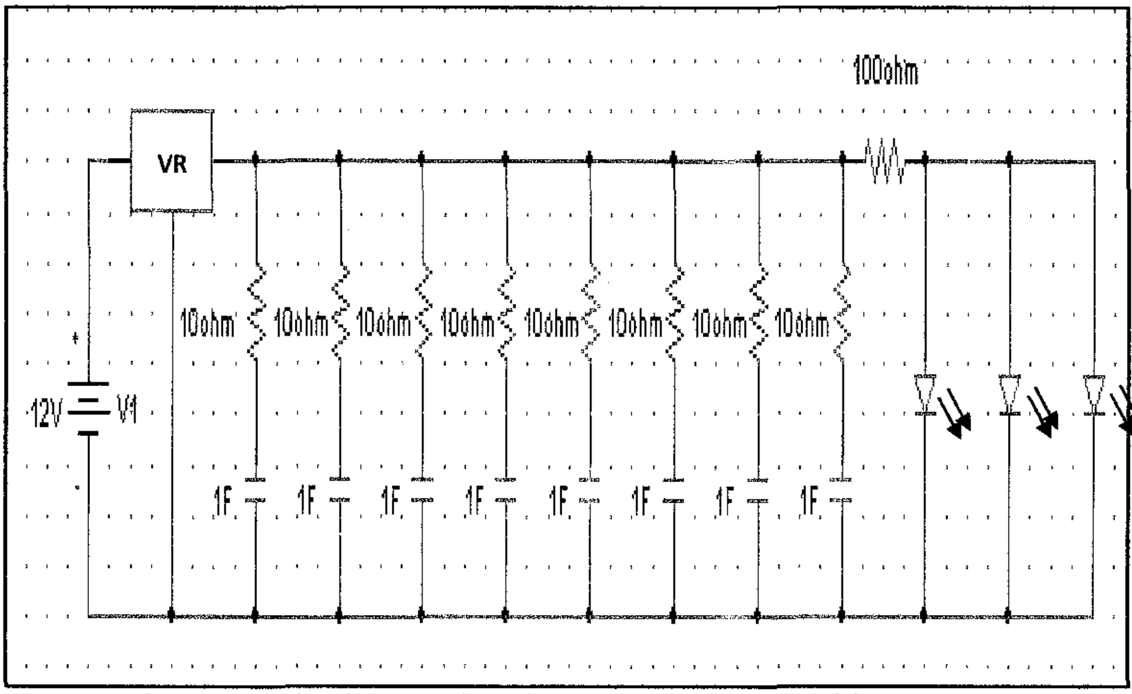

Figure 6: Eight ultracapacitors in parallel connection with LED as the load

After the circuit design is done, the author starts the experiment to get the charging and discharging graph for ultracapacitors. Below is shown the result of the experiment one.

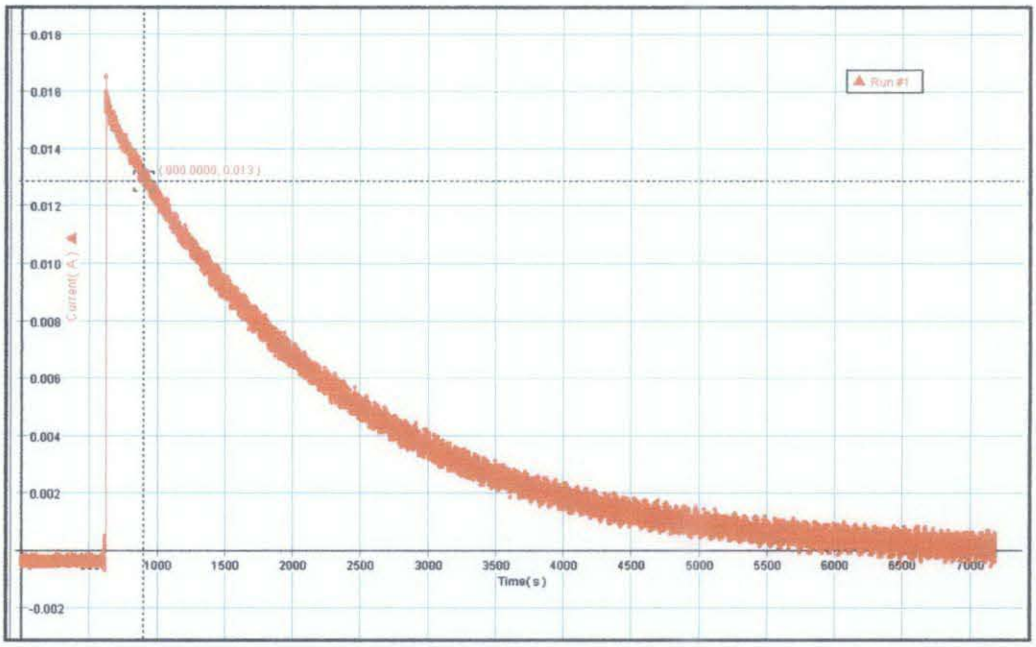

Figure 7: Current (A) versus time (m) during discharging mode for experiment one

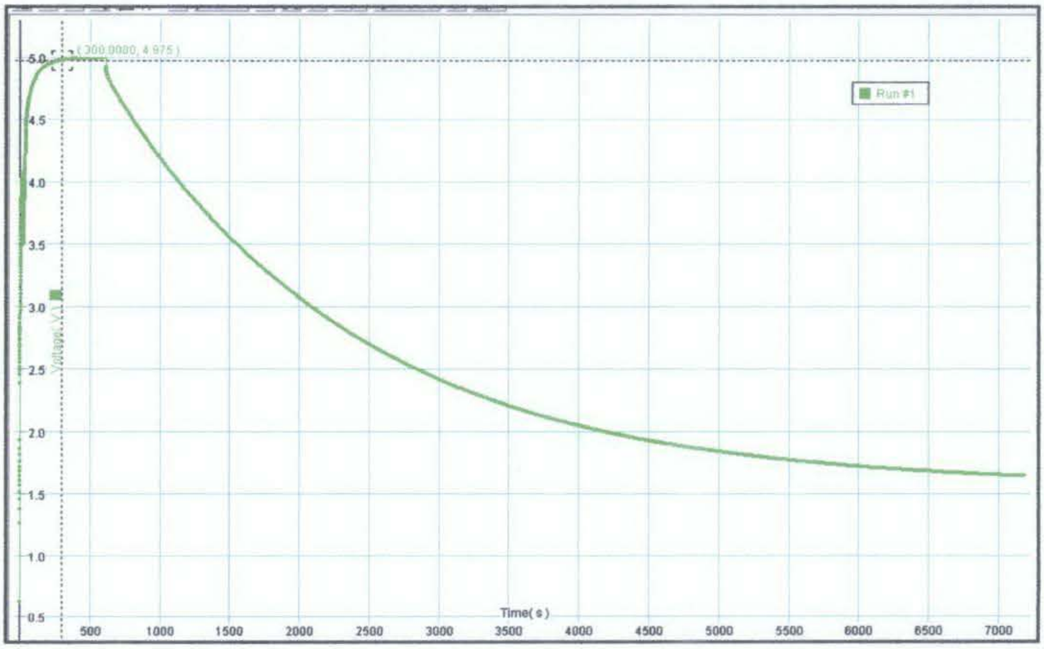

Figure 8: Voltage (V) versus time (m) during charging and discharging mode for experiment one

4.1.2 Experiment 2

The second experiment is performing with eight 1.0 Farad ultracapacitors by placing four sets of two ultracapacitors in series. Then, the four sets of ultracapacitors are placing in parallel. This experiment is using 15V supply voltage. 15V supply voltage will go through voltage regulator L7809CV in order to gain 9V voltage output. The function of this voltage regulator is to stabilize the input voltage. Some calculation on the resistance is done to get the suitable resistor value for the circuit.

Below is shown the simple calculation to get the resistor value from the experiment.

4.1.2.1 Calculation

In this experiment, the circuit is use 15V input voltage as the power supply. However, there is a voltage regulator in the circuit to maintain the voltage output around 9V. In order to avoid the Light Emitting Diode (LED) from burn, some resistor must be put in the circuit. The calculation for the resistor is shown below.

After 15V voltage go through voltage regulator L7809CV, the voltage output value is 9V. Thus,

$V_1 = 15V$

$V_2 = 9V$

We will use V_2 to calculate the resistor value.

For longest lifetime, maximum current can through LED is only 25mA. There are three LED's in this circuit and the connection is in parallel. So,

25mA x 3 = 75mA

To calculate the minimum resistor, use the ohm's law. Thus,

$$V = IR$$

$$R = \frac{V}{I}$$

$$R = \frac{9}{75m}$$

$$= 120\ \Omega$$

The minimum resistance is 120 Ω. So, the researcher chooses to use 150 Ω resistors.

Below is shown the circuit for experiment two.

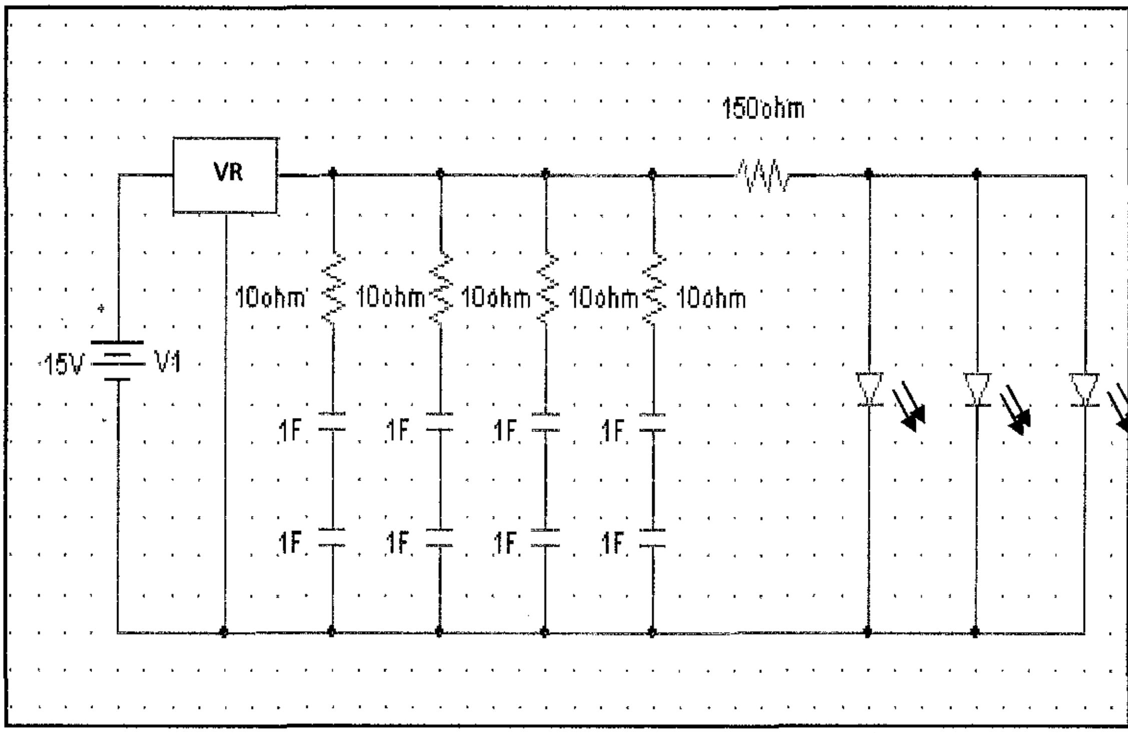

Figure 9: Four sets of two 1.0 Farad ultracapacitors are placing in series. Then, the four sets of ultracapacitors are placing in parallel

After the circuit design is done, the author starts the experiment to get the charging and discharging graph for ultracapacitors. Below is shown the result of the experiment two.

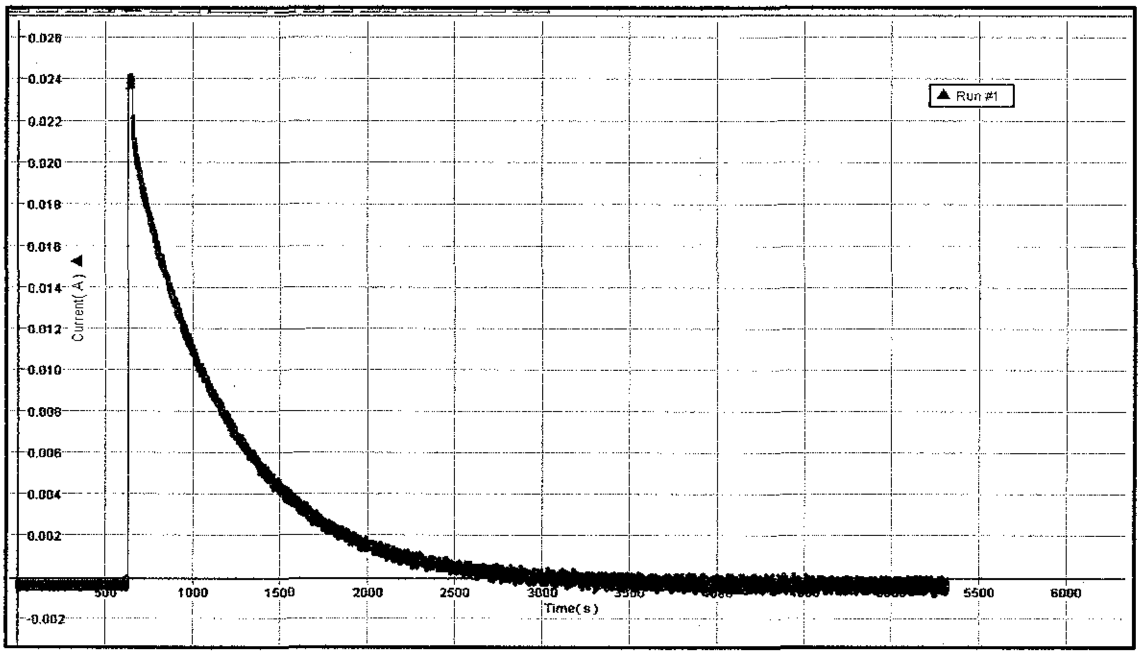

Figure 10: Current (A) versus time (m) during discharging mode for experiement two

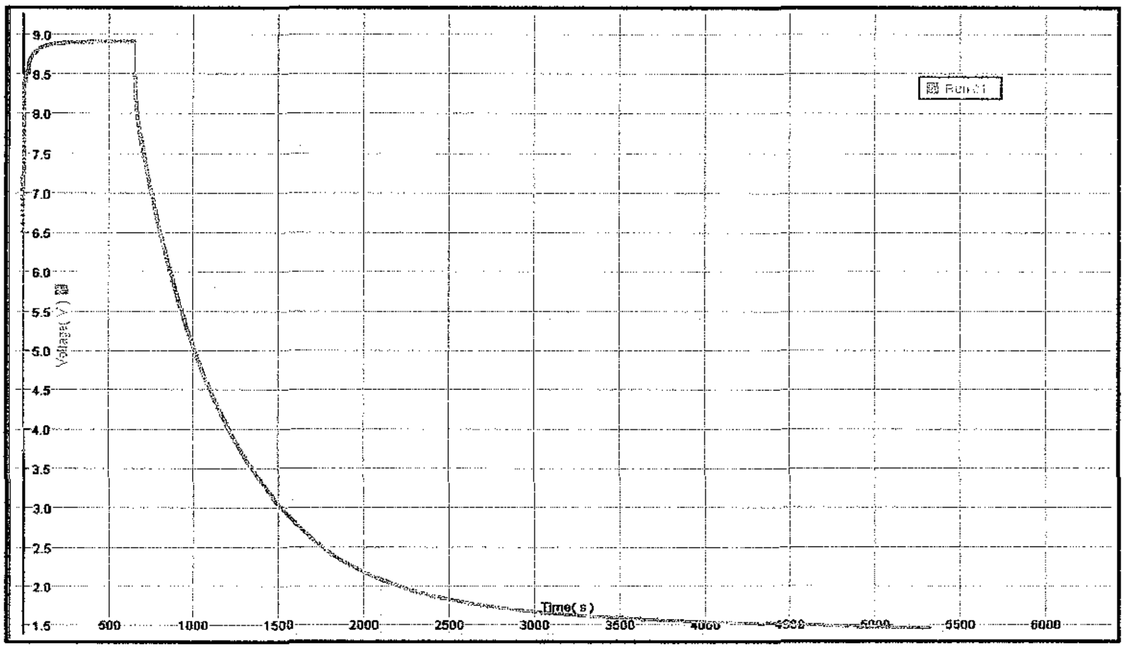

Figure 11: Voltage (V) versus time (m) during discharging mode for experiement two

4.1.3 Mini Uninterruptable Power Supply (UPS)

The mini Uninterruptable Power Supply (UPS) system for this project is using 5V as its supply. Below is shown the circuit diagram of the mini UPS system.

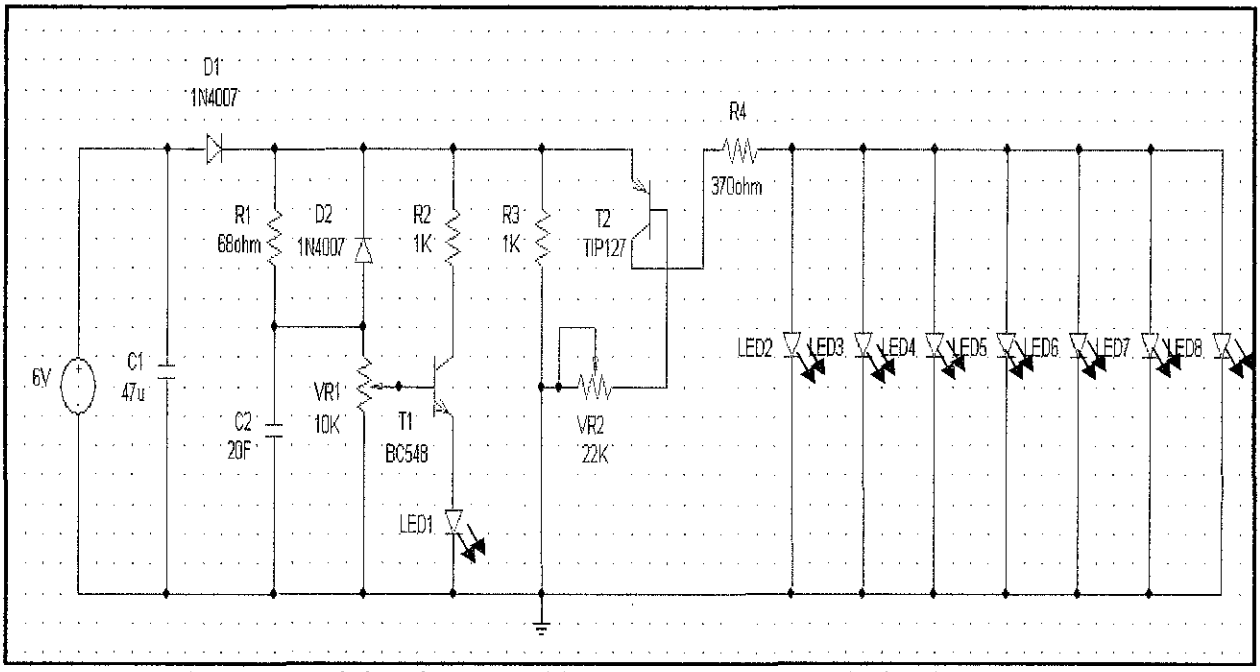

Figure 12: Mini Uninterruptable Power Supply (UPS) circuit

This mini UPS battery will be replaced with the bank of ultracapacitors because the capability of ultracapacitor to store the energy and its capability to charge in seconds. After doing the two experiments, the combination of ultracapacitors in parallel is chosen to be constructing together with the mini UPS circuit. Below is shown the circuit diagram of ultracapacitors bank.

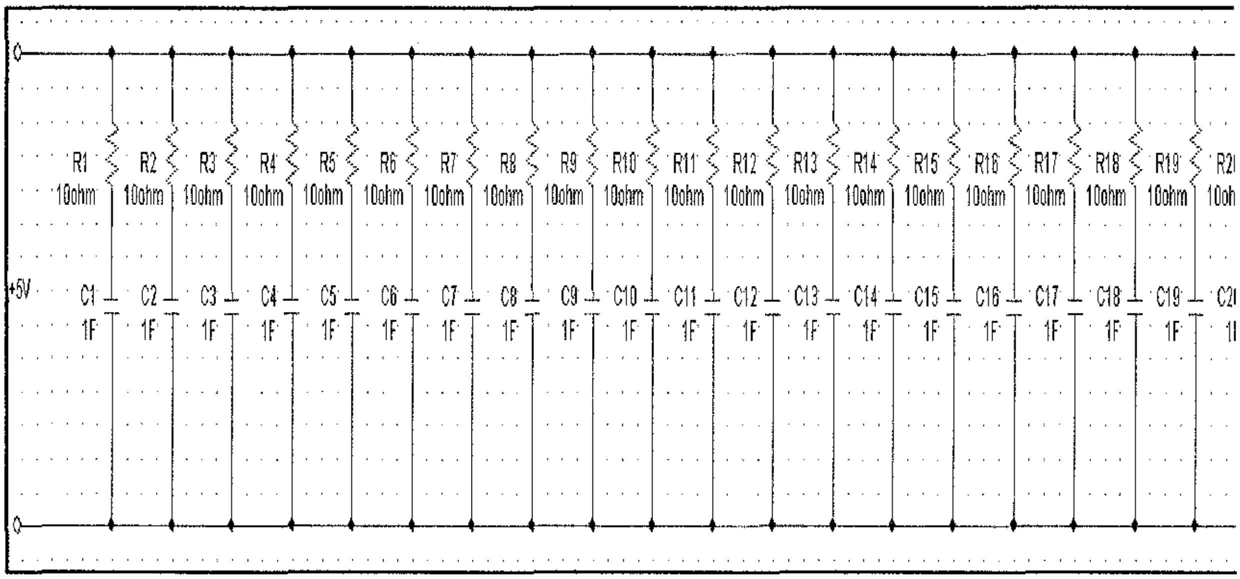

Figure 13: Ultracapacitor bank circuit for mini UPS system

The mini UPS circuit is combining with the ultracapacitors bank. After the circuit is constructing, the author starts the experiment to get the charging and discharging graph for this UPS system. Below is shown the result for the system.

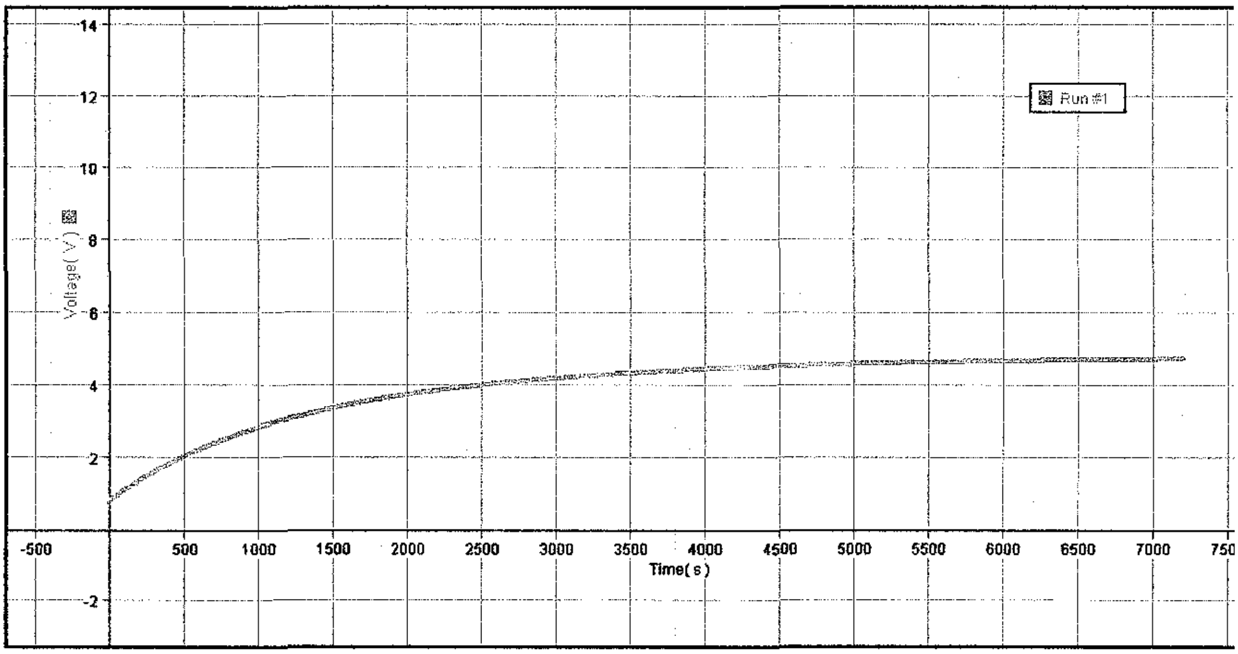

Figure 14: Voltage (V) versus time (m) during charging mode for UPS system

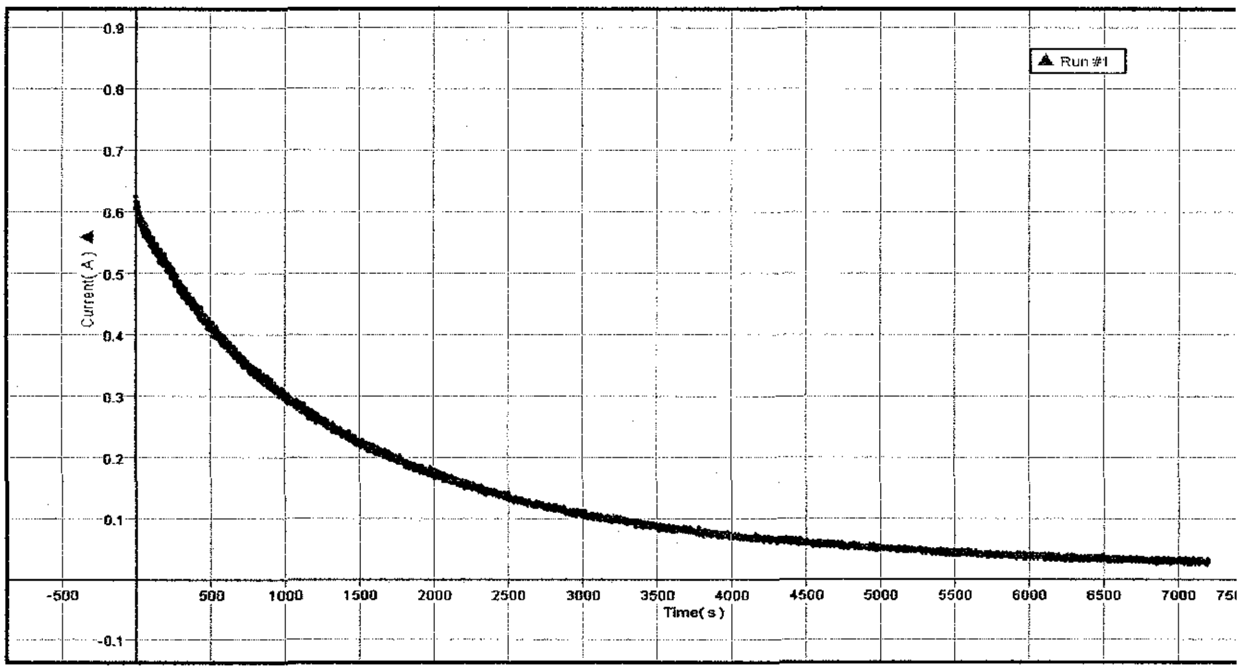

Figure 15: Current (A) versus time (m) during charging mode for UPS system

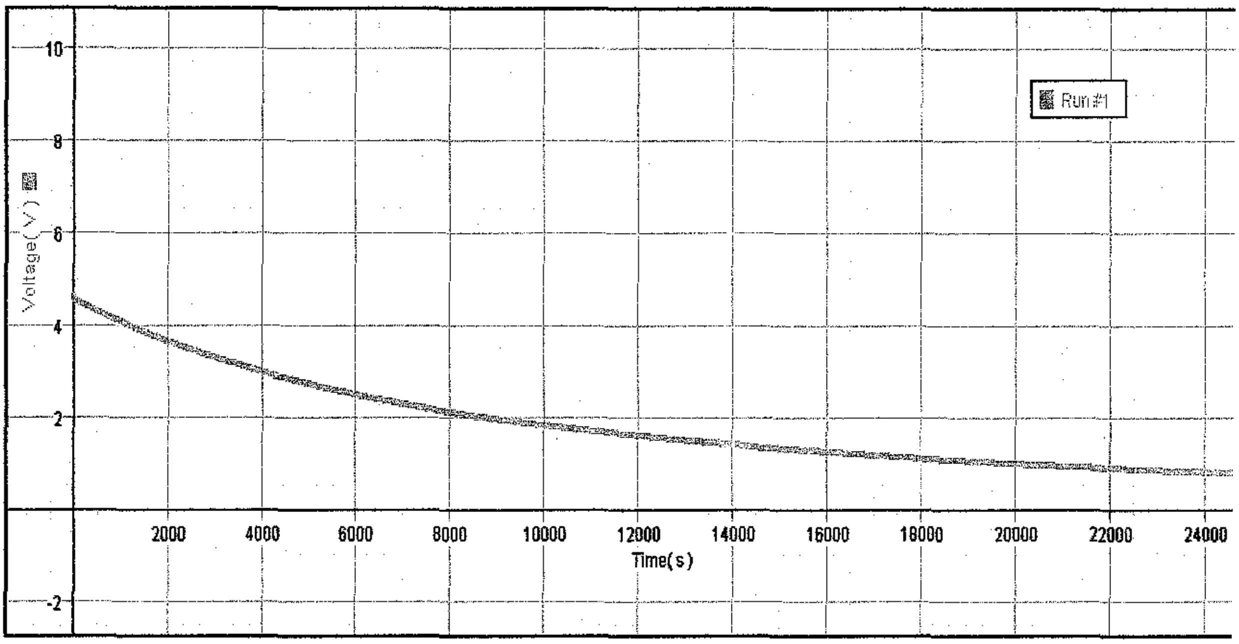

Figure 16: Voltage (V) versus time (m) during discharging mode for UPS system

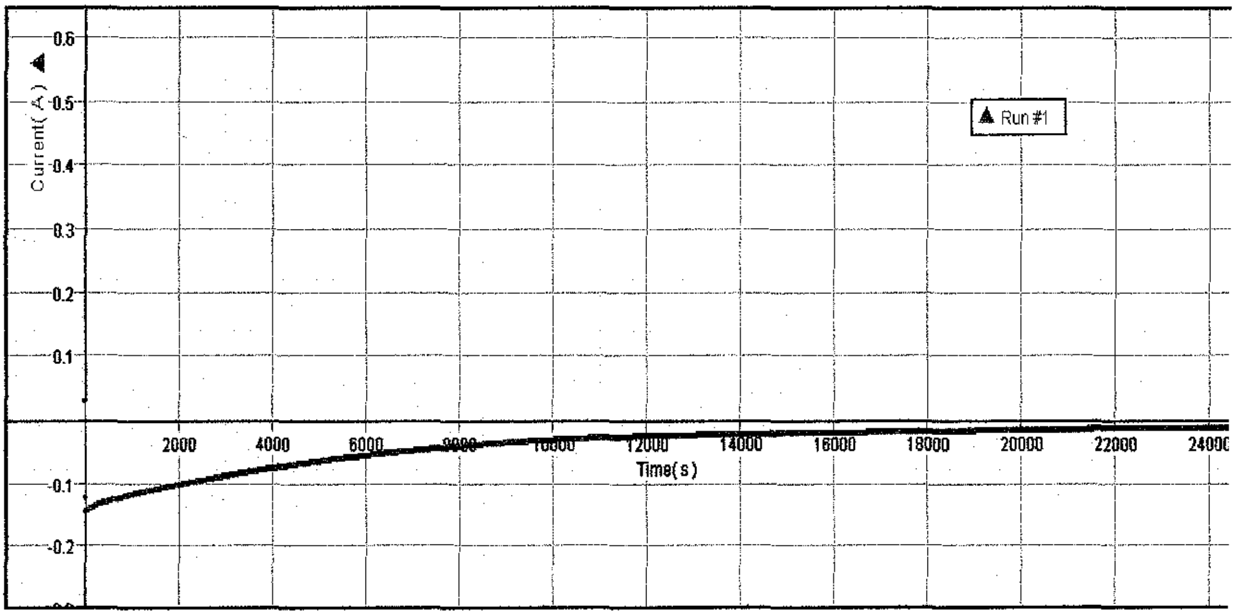

Figure 17: Current (A) versus time (m) during discharging mode for UPS system

Below is shown the construction of the mini UPS system with the ultracapacitors bank as its backup power for the system.

1. The complete mini UPS circuit

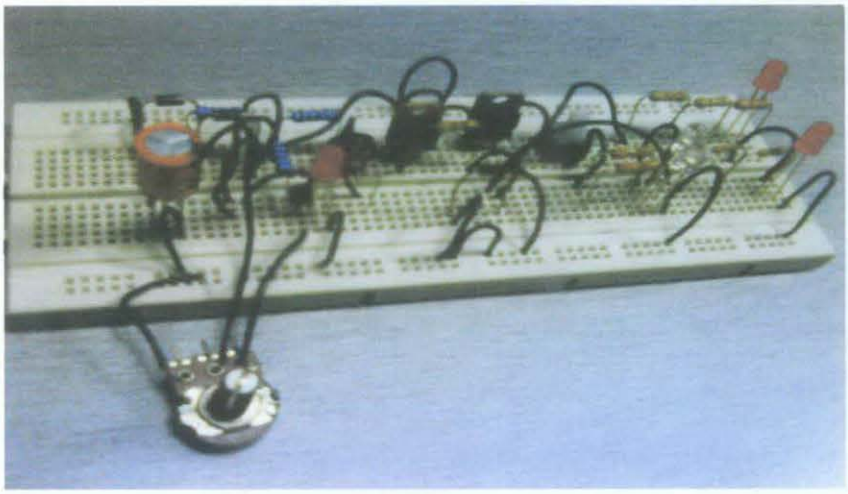

Figure 18: Mini UPS circuit without ultracapacitors bank

2. Ultracapacitor bank for mini UPS

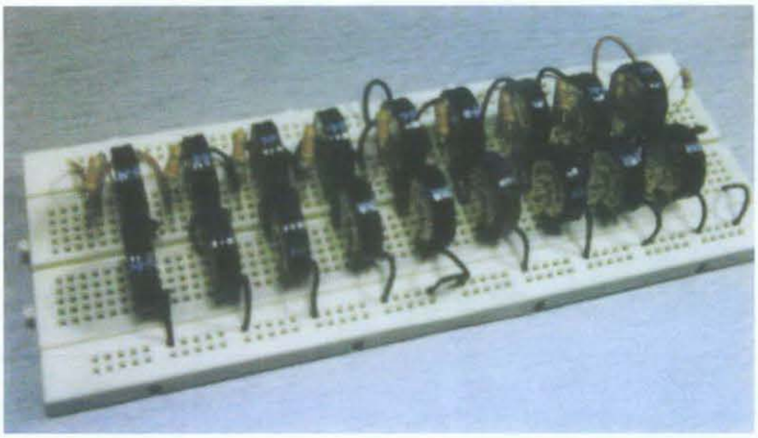

Figure 19: 20 Farad ultracapacitors bank

3. Mini UPS circuit calibration before connect it to the ultracapacitors bank

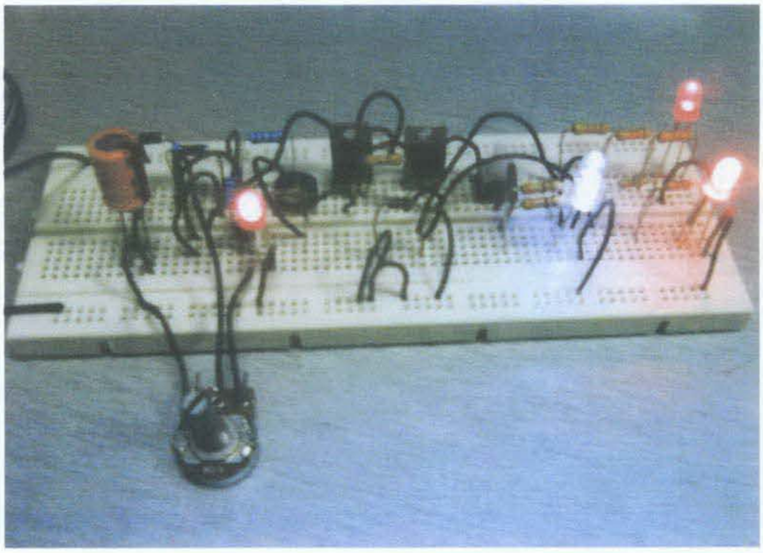

Figure 20: Circuit calibration

4. Mini UPS and ultracapacitor bank connect together

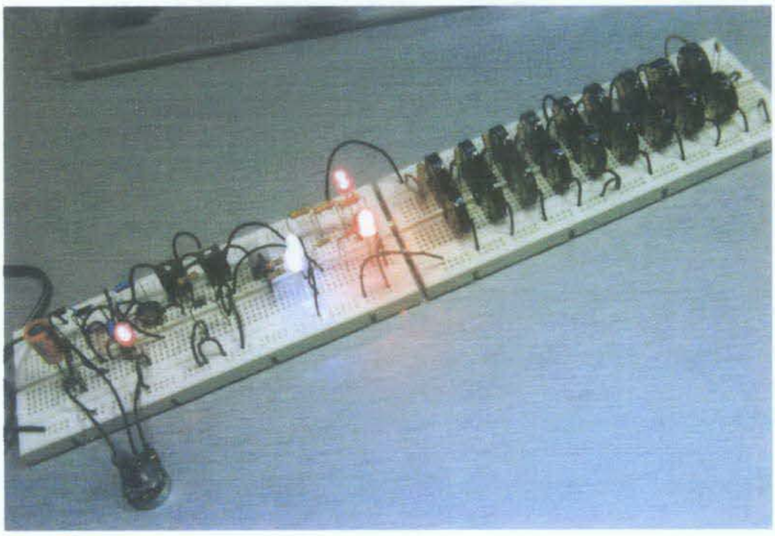

Figure 21: Mini UPS with 20 Farad ultracapacitors bank

5. Mini UPS system build together with ultracapacitors bank

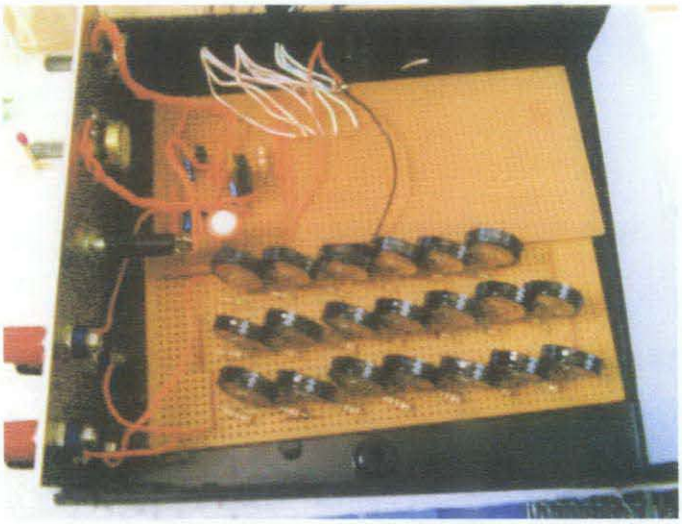

Figure 22: Mini UPS combine with 20 Farad ultracapacitors bank

6. Prototype of Mini UPS system

Figure 23: Mini UPS system prototype

4.2 Discussions

The experiment had been done by using ultracapacitors. The purpose of this experiment is to see the ultracapacitors performance by connect ultracapacitors in series and parallel. Below is the explanation for the experiments.

4.2.1 Experiment 1

In experiment 1, the researcher use 12V as the supply voltage. The 12V will go through L7805ABV voltage regulator to get 5V output voltage. The function of voltage regulator in this experiment is to get constant output voltage. This is due to the input voltage from the adapter which is not constant. The input voltage that through this voltage regulator must be 12V in order to get 5V output voltage.

5V is supply to the circuit to charge the ultracapacitors. This circuit is recharging about 10minutes. After 10minutes, 5V supply is removed from the circuit. Then, ultracapacitors starts to discharge. Based on the result, the LED's are lighting up about two hours. However, the LED's become dimmer when the discharging time is increase. This is because the voltage and current is decreasing due to time.

4.2.2 Experiment 2

In experiment 2, the researcher use 15V as the supply voltage. The 15V will go through L7809CV voltage regulator to get 9V output voltage. The function of voltage regulator in this experiment is to get constant output voltage. This is due to the input voltage from the adapter which is not constant. The input voltage that through this voltage regulator must be 15V in order to get 9V output voltage.

9V is supply to the circuit to charge the ultracapacitors. This circuit is recharging about 10minutes. After 10minutes, 9V supply is removed from the circuit. Then, ultracapacitors starts to discharge. Based on the result, the LED's are lighting up about one hour. However, the LED's become dimmer when the discharging time is increase. This is because the voltage and current is decreasing due to time.

4.2.3 Analysis

Based on the result in experiment 1, total capacitance is 8.0 Farad and in experiment 2, total capacitance is 2.0 Farad. Small capacitance means the discharging time is faster compared to the bigger Farad which means the discharging time is slower. This can be approved from the experiment. The discharging time for voltage in experiment 1 is slower compared with experiment 2. This is because both experiments have different ultracapacitors arranging. In experiment 1, eight ultracapacitors are placing in parallel. In experiment 2, four sets of two ultracapacitors are placing in series and all four sets of ultracapacitors are placing in parallel.

The time constant for experiment 1 is 80 seconds and the time constant for experiment 2 is 20 seconds. Time constant is the time required to charge a capacitor to 63.2 percent of full charge or to discharge it to 36.8 percent of its initial. Based on the calculation, the charging time for experiment 1 is slower compared to experiment 2.

According to the experiments result, the researcher decides to use the ultracapacitors combination in parallel to construct with the mini UPS circuit. However, the voltage rating for the UPS circuit is only 5.5V but the system can work for a longer time.

4.2.2 Mini UPS system

This circuit provides a mini Uninterruptable Power Supply (UPS) to operate 5V DC at up to 1A current. The backup source which is ultracapacitor bank takes up the load without spikes or delay when the mains power gets interrupted. LED1 indication is showing the full charge voltage level of the ultracapacitor bank. LED2, LED3, LED4, LED5, LED6, LED7 and LED8 represent as the output for the UPS system.

The adjustable adapter provides 5V of DC source to the circuit. Capacitor C1 provides ripple-free DC to charge the battery. Diode D1 gets forward biased to charge the battery when the mains power is on. Resistor R1 limits the charging current. Variable resistor, VR1 (10k) with transistor, T1 acts as the voltage comparator. The battery is fully charged when LED1 is glowing; indicate a full voltage level of 5V.

Diode D1 gets reverse biased and D2 gets forward biased when the mains DC source fails. The ultracapacitor bank automatically takes up the load without any delay. The output voltage, 5V is ready to run the load when the mains power is available. In contrast, when the mains power is down, output voltages can run the load only when the battery is fully charged. The indication by LED1 represents the battery is fully charged. This mini UPS system has one output, which is 5V through the diode. The output lamp uses seven super-bright white LEDs (LED2 until LED8) with current limiting resistor R4.

Before connecting the circuit to the ultracapacitor bank and mains DC source, calibration is needed by connect the circuit to a variable power supply. Provide 5V DC and VR1 is adjusted until LED1 is glowing. After that, adjust VR2 until the output trips off. After that, remove the variable power supply and connect a fully-charged ultracapacitor bank to the terminals and ensure that LED1 is on. After making all the adjustments, connect the circuit to the ultracapacitor bank and mains DC source.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

During FYP1, two experiments on ultracapacitors were successfully done. The first experiment is about the connection of all ultracapacitors are placing in parallel. Based on the calculation, the total capacitance for the ultracapacitors is 8.0 Farad. More Farad is very useful in this circuit because the discharging time will be slower. However, the voltage input cannot bigger than the voltage rating for the ultracapacitors which is 5.5V. The voltage that is bigger that 5.5V may damaged the ultracapacitors. The second experiment is about the four sets of two 1.0 Farad ultracapacitors are placing in series. Then, the four sets of that ultracapacitors are placing in parallel. Based on the calculation, the total capacitance for the ultracapacitors is 2.0 Farad. The discharging time for this circuit will be faster compared with the experiment 1 because the total Farad is lower. However, the voltage input can be two times greater than the ultracapacitors voltage rating; thus, the maximum input voltage is 11V.

After the experiment is done, the suitable ultracapacitors connection for mini Uninterruptable Power Supply (UPS) system is the combination of ultracapacitors parallel. This is the right combination because this combination can work for a longer time. In conclusion, ultracapacitor is very suitable for mini UPS system because of its capability to recharge on seconds, it is lightweight and environmental friendly.

5.2 Recommendations

Some improvement can be done for this project by:

1. Use big DC power supply such as 12-15V to get the big voltage supply.
2. With 12-15V DC power supply, it is possible for the UPS to operate with three outputs which is 12V, 9V and 5V.
3. Use the inverter at the output to convert from DC to AC for other applications.

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APPENDICES

APPENDIX

GANTT CHART

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Research on UPS																				
2	Construct capacitor bank																				
									M												
3	Construct mini UPS system								I												
									D								S		E		
4	Submission of Progress Report																T		X		
									S								U		A		
5	Construct the small house								E								D		M		
									M								Y				
6	Wiring the house with mini UPS system								E												
									S								W		W		
7	Pre EDX (Poster Presentation)								T								E		E		
									E								E		E		
8	Draft Report								R								K		K		
9	Submission of Final Report								B												
									R												
10	Submission of Technical Report								E												
									A												
11	Oral Presentation								K												

Stacked Coin Type

Series: **SG**

■ Features

- Endurance : 70 °C 1000 h
- Maximum height of 6 mm (H Terminal)
- RoHS directive compliant

■ Recommended Applications

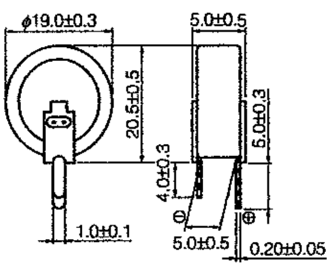
- Memory back-up for video and audio equipment, cameras, telephones, printers, data terminals, rice cookers and intelligent remote controls

■ Specifications

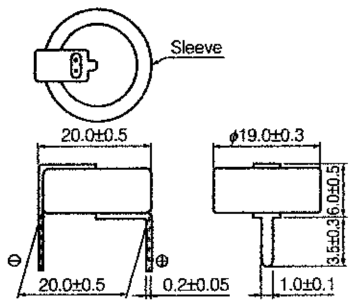
Category Temp. Range	-25 °C to +70 °C	
Maximum Operating Voltage	5.5 V.DC	
Nominal Cap.Range	0.47 F to 1.5 F	
Characteristics at Low Temperature	Capacitance change	±30 % of initial measured value at +20 °C (-25 °C to +70 °C)
	Internal resistance	≤5 times of initial measured value at +20 °C (at -25 °C)
Endurance	After 1000 hours application of 5.5 V. DC at +70 °C, the capacitor shall meet the following limits.	
	Capacitance change	±30 % of initial measured value
	Internal resistance	≤4 times of initial specified value
Shelf Life	After 1000 hours storage at +70°C without load, the capacitor shall meet the specified limits for Endurance.	

■ Dimensions in mm(not to scale)

Terminal: V



Terminal: H



■ Standard Products

Maximum Operating Voltage (V.DC)	Capacitance (F)	Capacitance range (F)	Internal resistance (Ω) at 1kHz	Part number	Min. Packaging Q'ty (pcs)
5.5	0.47	0.376 to 1.41	≤ 30	EECS5R5( )474	100
	1.0	0.80 to 1.80	≤ 30	EECS5R5( )105	100
	1.5	1.20 to 2.70	≤ 30	EECS5R5( )155	100

( ) Please use V or H, to indicate the terminal style.

Note : Do not use reflow soldering. (IR, Atmosphere heating methods, etc.)

Please refer to P197 "Mounting Specifications".