

# **BATTERY ALARM MONITORING SYSTEM**

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering  
in Partial Fulfillment of the Requirements  
for the Degree  
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(Electrical & Electronic Engineering)

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**CERTIFICATION**

# **CERTIFICATION OF APPROVAL**

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A project dissertation submitted to the  
Department of Electrical & Electronic Engineering  
Universiti Teknologi PETRONAS  
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(Electrical & Electronic Engineering)

Approved:

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Project Supervisor

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TRONOH, PERAK

August 2013

## **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.

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MOHD SYARMIZI BIN ZOLKIFLEE

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## **ABSTRACT**

Battery is used to supply the power to the load and is widely used in electrical appliances such as uninterruptable power source (UPS). UPS will supply the power during emergency or power failure. This project will explore battery monitoring system in UPS. Battery Alarm Monitoring System (BAMS) is designed to monitor the battery voltage and reduced the cost for monitoring the battery in UPS. The focus of this monitoring system is to identify the bad batteries in real time. This project is able to reduce the cost and time for preventive maintenance and avoid battery breakdown. The background of the project is discussed to get a clear view of the project. Furthermore, the problem statement of this project will be stated to address the main purpose and significance of conducting this project. The objective of this project and also the scope of study will be touched in detail. Next, the detailed of literature review will be presented. The concept and basic understanding of the project is discussed for better understanding. Moreover, the methodology, design and simulation as well as the key milestones are presented in detail. The project prototype is produced with discussion of results obtained. Lastly, the conclusion and recommendation for the project are concluded and proposed.

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## **CHAPTER 1 PROJECT BACKGROUND**

### **1.1 Problem Statement**

UPS is an electrical apparatus that supply power to the load when the main power source is fail. Power failure in IT data center will result in data loss and financial loss [1]. Battery is among the main and critical component in UPS. Batteries are connected in series have a lifespan that is stated by the manufacturer. Usually, battery has 5 years lifespan but it may fail before reaching it. The bad battery is changed to prevent from affecting the other good batteries in the string to fail. The service maintenance is done frequently to maintain the battery in good condition. Monitoring system to monitor the floating voltage of the battery using voltage sensor in the market is used but very expensive to install.

### **1.2 Objective**

The objective of this project is to design the cost effective battery alarm monitoring system (BAMS) for UPS system.

### **1.3 Scope of Study**

In this study, the main subjects under investigation are:

- i) Circuit for alarm monitoring system
- ii) Battery
- iii) Microcontroller

And the aspects being studied are:

- i) Voltage comparator
- ii) Voltage divider
- iii) Software coding

## **CHAPTER 2 LITERATURE REVIEW**

### **2.1 Uninterruptable Power Supply (UPS)**

UPS is a piece of equipment that is used to back up the power source when the main power supply fails [2]. Usually the generator will be used for back up, but generator need some time to fully function. During that time, the apparatus will be shut down and some data will lost. UPS have 3 categories and there are, on-line, line interactive and standby.

#### **2.1.1 On-line UPS**

AC voltage at the input is rectify to DC then passing through the battery inverting back to AC voltage for powering the equipment

#### **2.1.2 Line interactive**

A line-interactive UPS maintains the inverter in line. During power failure occur at the main source, it will redirect the battery's DC voltage from the normal charging mode.

#### **2.1.3 Standby (offline) UPS**

The standby UPS only will function when the incoming voltage falls below a range that has been fixed. The internal DC-AC inverter circuitry that is powered from an internal storage battery will be triggered to function.

### **2.2 Battery**

A battery is made up of interconnected cells. Usually nickel cadmium batteries as shown in Figure 1 and lead acid batteries in Figure 2 are used in UPS [3]. The nickel–cadmium is a type of rechargeable battery. It use nickel oxide hydroxide and metallic cadmium as electrodes [4]. Lead acid battery is also a rechargeable and low cost if compared to nickel cadmium battery.

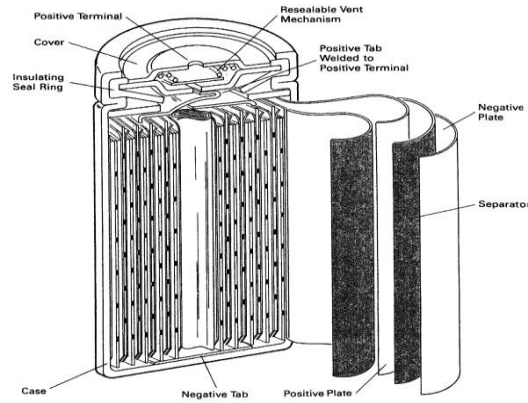


FIGURE 1. Nickel Cadmium Battery

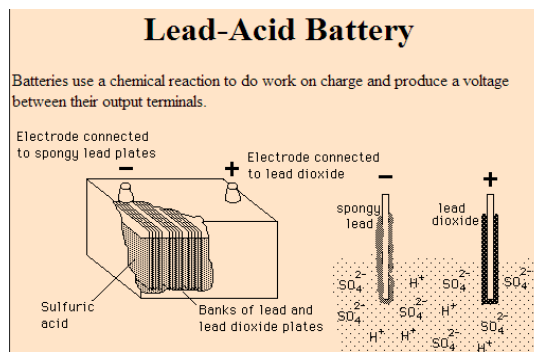


FIGURE 2. Lead Acid Battery

### 2.3 Monitoring System

Monitoring system is used to monitor the equipment or apparatus that is linked to the system [5]. The objective of monitoring system is to make sure the condition of the equipment that are monitored in good condition and function well.

#### 2.3.1 Ultra Electronics battery monitoring system (BMS)

Ultra Electronics BMS as shown in Figure 3 has been specifically designed for use on military vehicles [6]. BMS is able to measure conductance, voltage, current and temperature. The battery terminal is connected to the Ultra Electronics BMS to be monitored as shown in Figure 4.

The advantage of BMS:

- i) Power consumption monitoring
- ii) Critical power threshold alerts
- iii) Reduced life cycle cost



FIGURE 3. Ultra Electronics BMS

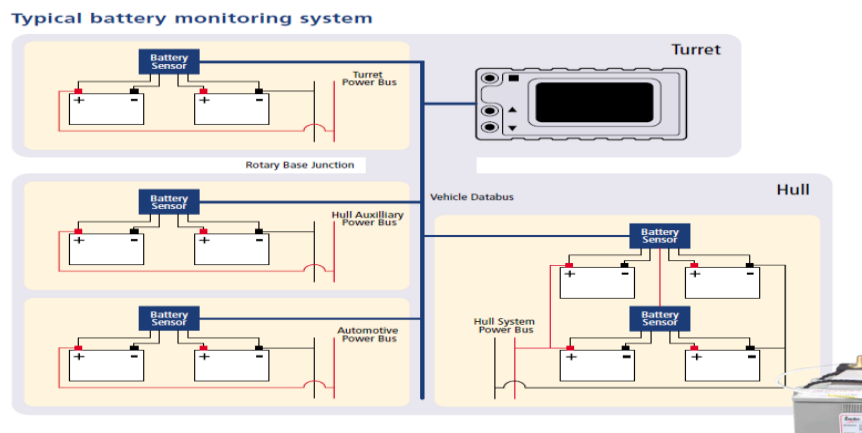


FIGURE 4. Battery Monitoring System

## 2.4 Microcontroller

Microcontrollers are used in automatically controlled products and devices such as embedded systems that functions like a small computer [7]. It is a single integrated circuit (IC) containing a processor core, memory and programmable input/output peripherals [8]. It can be used as interface to link the device with the computer.

The advantage of using microcontroller is:

- 1) High speed performance
- 2) Low-cost
- 3) Programming flexibility

## 2.4.1 Face Recognition Based on Auto-Switching Magnetic Door Lock System

In this project, face recognition system is used for security application. It involved the development of Graphical User Interface (GUI) based on face recognition system and Peripheral Interface Controller (PIC) [9]. The PIC functions as an input/output carrier to switch on/off magnetic lock for door lock security system. The microcontroller consists of CPU, ROM, I/O ports and timer that are designed to execute single specific task to control a single system as shown in Figure 5. The system has database for face recognition and the verification process is done by comparing the face of the user with the information in database. The flow chart of the system is shown in Figure 6.

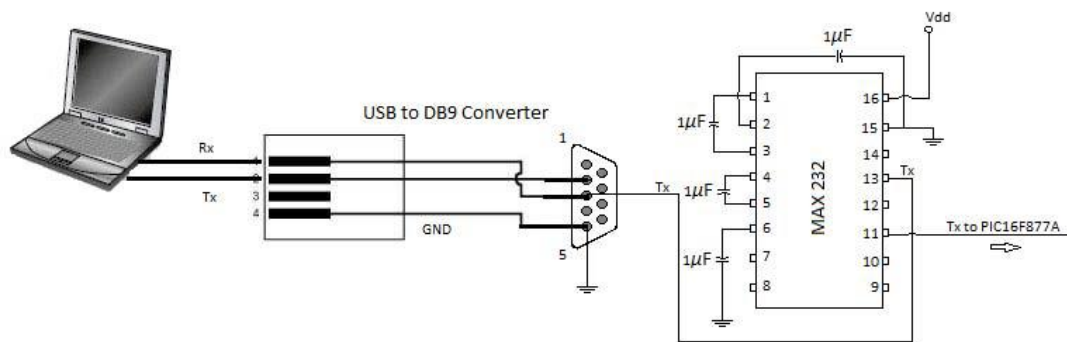


FIGURE 5. Auto Switching Magnetic Door Lock System

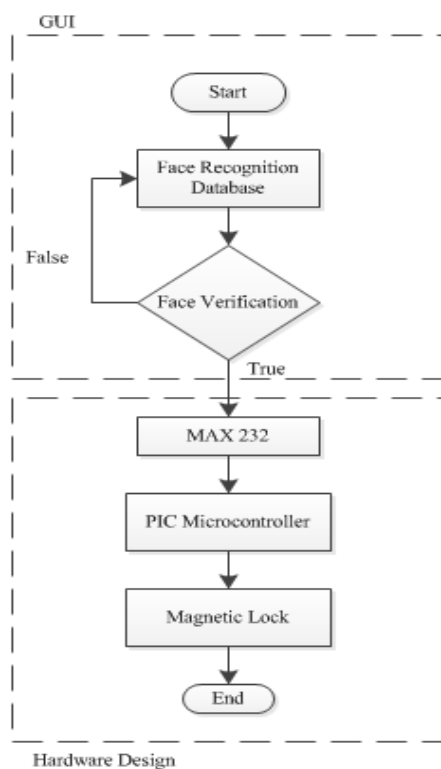


FIGURE 6. Flow Chart

## 2.4.2 Arduino Leonardo (microcontroller board)

The Arduino Leonardo is a microcontroller board that can be powered via the USB connection or with an external power source [10]. The configuration of the Arduino Leonardo board is shown in Figure 7. It can operate on an external supply approximately from 6 to 20 Volts. It also can be programmed with the Arduino software and the feature of this microcontroller board is:

- 1) 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analog inputs)
- 2) 16 MHz crystal oscillator
- 3) A micro USB connection
- 4) A power jack
- 5) An ICSP header
- 6) A reset button

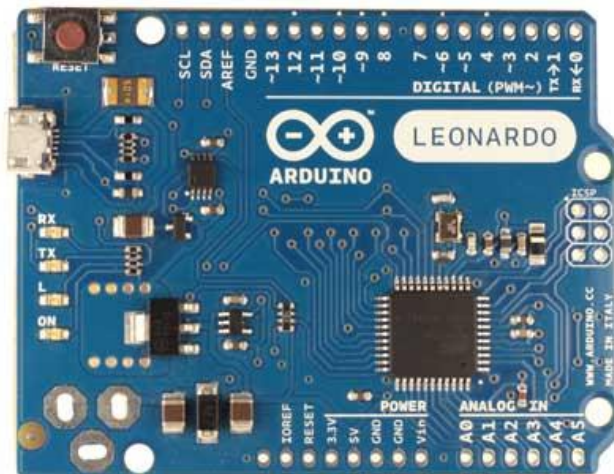


FIGURE 7. Arduino Leonardo Board

## CHAPTER 3 METHODOLOGY

### 3.1 Research Methodology and Project Activities

The methodology to conduct the research for the project is exploration and discovery. The relevant and importance input are gathered from the literature review. To solve the problem, an investigation and information gathering are conducted. The experience during internship is fully utilized to get the basic idea and information. The circuit design for the monitoring system is explored. After the circuit is designed, the simulation is done to validate and test the efficiency of the design. Lastly, the circuit will be designed to produce a real prototype. The summary of this general approach is shown in Figure 8.

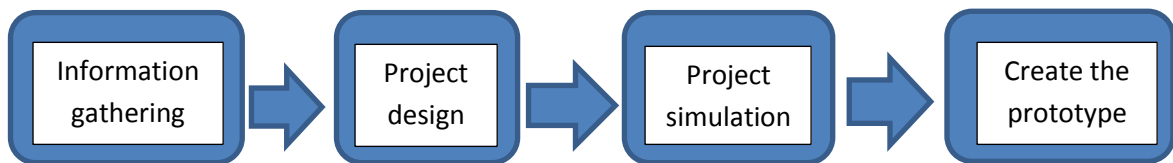


FIGURE 8. Schematic diagram for general approach

#### 3.1.1 Information Gathering

Information for the project are gathered by:

- 1) Get the information from internet source
- 2) Research from book and journal
- 3) Experience and log book during internship
- 4) Consultation with the expert

#### 3.1.2 Project Design

The project is designed by using Multisim software. The material to be used for the project is identified during the design process. First, the comparator window to monitor the voltage of the battery is designed as shown in Figure 9 [11]. Each comparator is constructed using an Op Amp. The comparator circuit has 3 inputs that are  $V_i$ ,  $V_{refh}$ ,  $V_{refl}$  and 1 output that is ( $V_o$ ). The window width is set by the  $V_{refh}$  and  $V_{refl}$ , such that a logic '0' is the result at  $V_o$  if the voltage value of  $V_i$  is within the window range else  $V_o$  will be set to logic '1' [12].

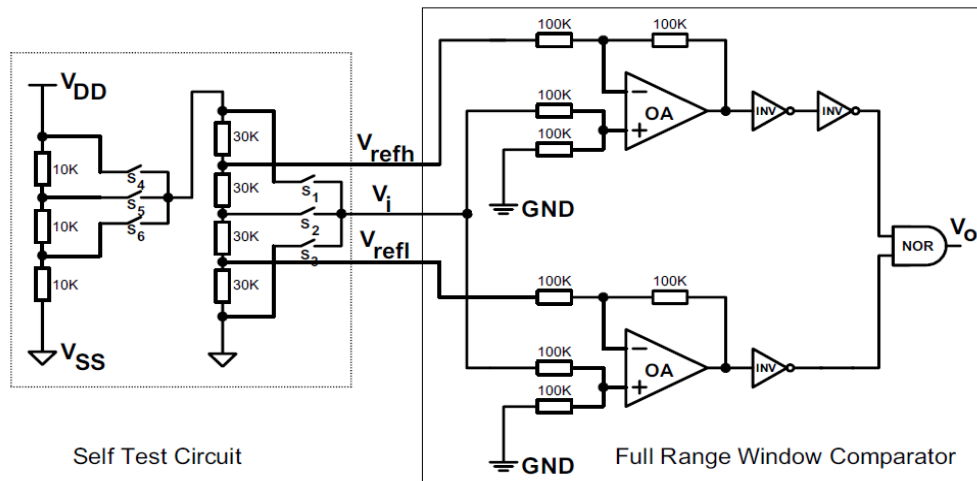


FIGURE 9. Window Comparator

An alarm device system is designed to give an audible, visual or other form of alarm signal under certain conditions [13]. In this project, an LED is used as an alarm and will be ON if the voltage of the battery is out of the range that is set as shown in Figure 10.

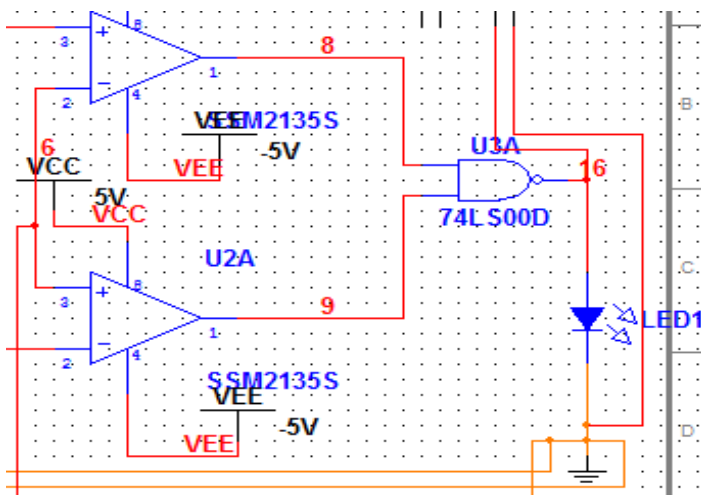


FIGURE 10. Alarm System

Finally, the comparator window and alarm system are combined as shown in Figure 11. The comparator window will send the information to the alarm system about the battery voltage range. Then, the alarm system will function according to the information that is sent by the comparator window.



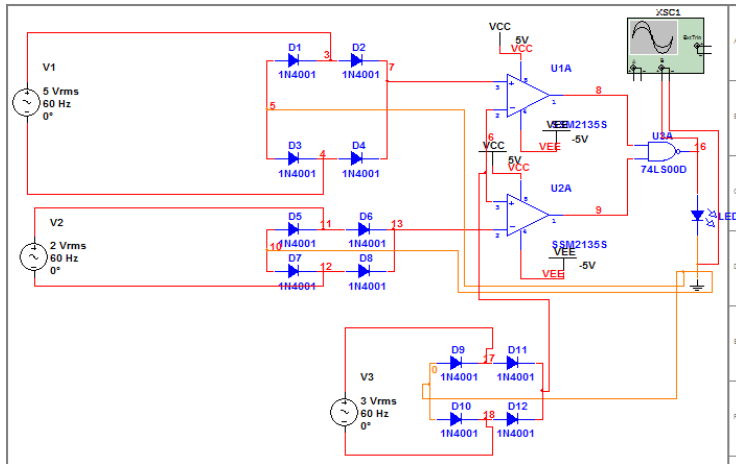


FIGURE 11. Window Comparator and Alarm System

### 3.1.3 Project Simulation

After the design is finalized, the project is simulated by using Multisim software. Multisim has oscilloscope function for simulation as shown in Figure 12. The project is simulated to show that the concept of the project is feasible. The oscilloscope will show the output voltage waveform to identify whether the output voltage is at logic 1 or logic 0 [14] as shown in Figure 13.

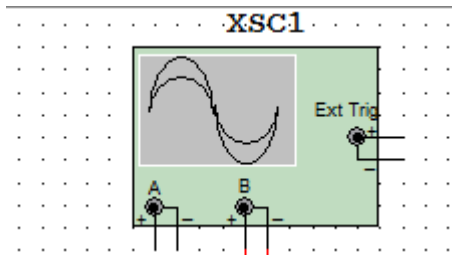


FIGURE 12. Oscilloscope Function

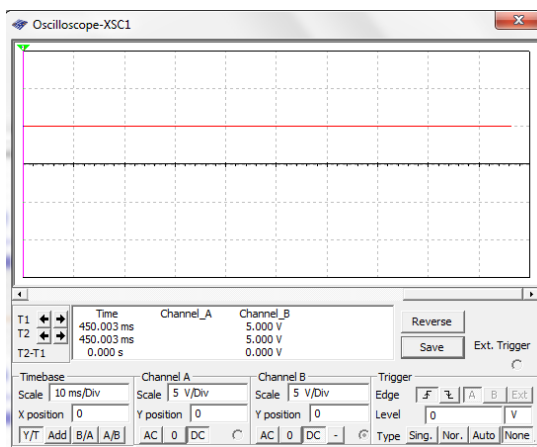


FIGURE 13. Output Voltage Waveform

### 3.1.4 Prototype

The prototype is created based on the project design in Multisim software. Initially the project is done on the breadboard. The comparator window is implemented by using Integrated Circuit (IC) LM339N. The output from the comparator window is connected to the input of the NAND gate. Then the NAND gate will send the output to the microprocessor and LED for the alarm. Microprocessor is used to transfer the information from the breadboard to the computer and vice versa.

The battery terminal is connected and become input voltage to the comparator window. The value of  $V_{refh}$  and  $V_{refl}$  input are set by using voltage divider as shown in Figure 14. The value of  $V_{refh}$  and  $V_{refl}$  will determine the voltage range of the monitoring system [15]. The output from the comparator window is connected to the microprocessor board and LED for alarm system.

Microcontroller will send the information from the board to the laptop. The circuit is linked to the microcontroller board. The microcontroller board has specific value of voltage requirement in order to function. If the value of the output voltage is too low, voltage booster is used. If the value of the output voltage is too high, the voltage divider will be used [16].

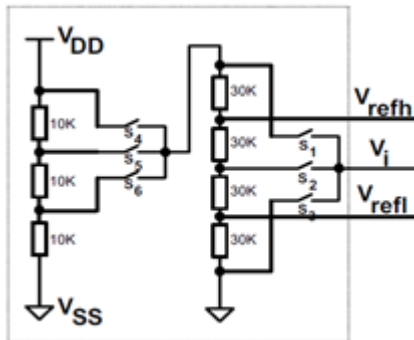


FIGURE 14. Voltage Divider

## 3.2 Materials

The materials to be used are identified based on the circuit design in software. Research on the material are conducts to know more about the feature and characteristics of the materials.

### 3.2.1 Window Comparator IC (LM339N)

The basic idea of window comparator is to produce a voltage range for monitoring system. The circuit is built by using LM 339N single supply Op Amp comparators. The polarity of the op-amp output circuit depends on the polarity of the difference

between the two input voltages. A window comparator usually used two comparators with one output indicating the input is between the two limits. The comparator calculates an error signal and is a measure of the difference between the actual and desired outputs.

### 3.2.2 AND Gate (74LS00D)

The AND gate is a basic digital logic and behaves according to the truth table in Figure 15. A HIGH output result is achieved only when both the inputs to the gate are HIGH. If only one input to the gate is HIGH, it will produce a LOW output result. The output from comparator window is connected to the AND gate and is used as the input to the LED in alarm system.

INPUT		OUTPUT
A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

FIGURE 15. AND Gate's Truth Table

### 3.2.3 Resistor

A resistor is a passive two-terminal electrical component and is used as an electrical resistance in the circuit. Resistor is used to protect the component in the circuit from over current. It is also used in voltage divider at the input of comparator window.

### 3.2.4 Breadboard

A breadboard is usually a construction base for prototyping or experimenting of electronics circuit. In the project, it is used for creating temporary prototypes and experimenting with circuit design.

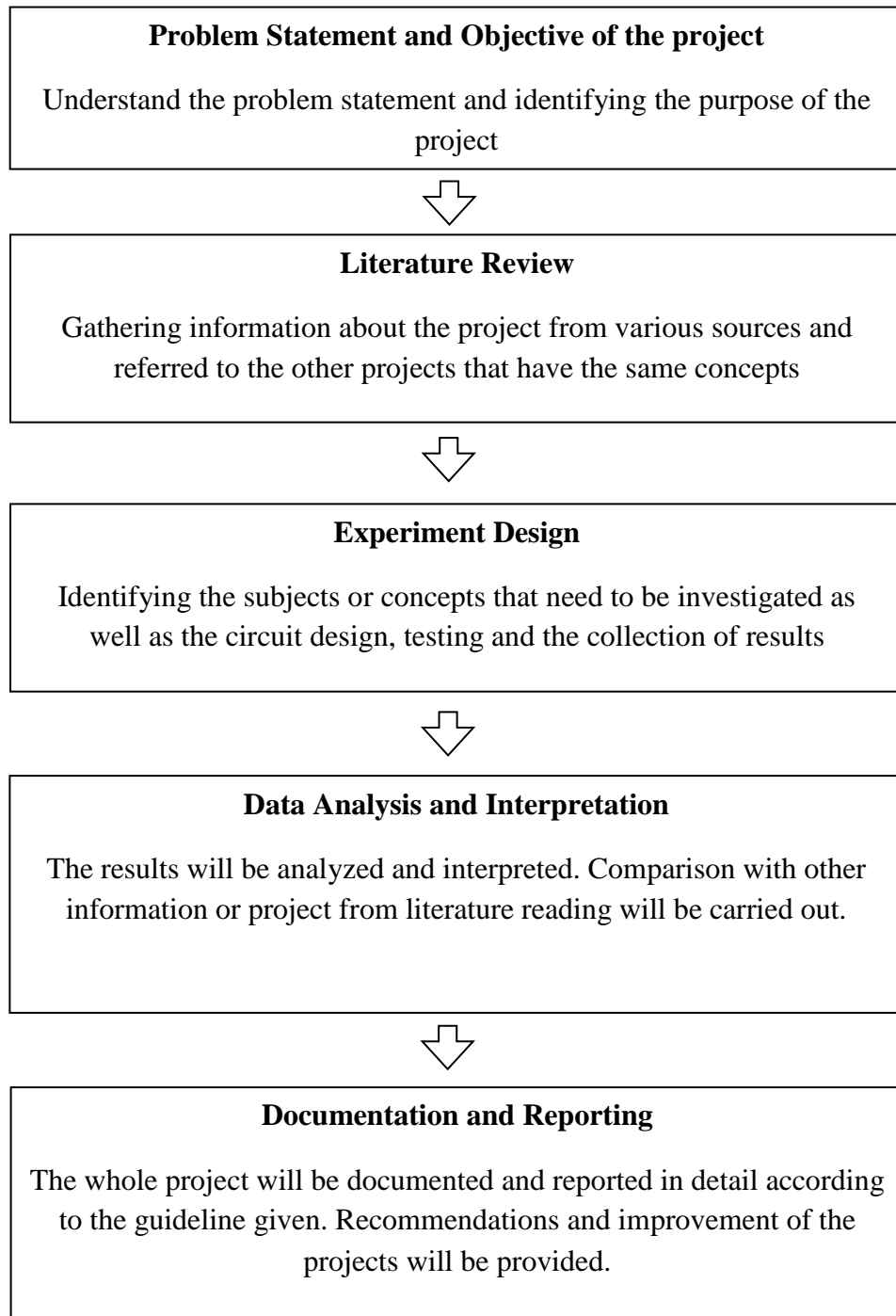
### 3.2.5 Microcontroller (Arduino-Leonardo)

Microcontroller is a single integrated circuit (IC) containing a processor core, memory and programmable input/output peripherals. Arduino Leonardo is a type of

microcontroller board and is used to transfer the input or output from the computer to the circuit or from the circuit to the computer.

### 3.3 Milestones

The flow chart below shows the key milestones for the research project.



### 3.4 Planning Gantt chart

Key Milestones/Project activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Submission of Progress Report															
Pre-SEDEX / SEDEX															
Draft Report															
Final Report															
Viva															
Submission of Hard Bound Copy of The Project															
Phase 1															
Phase 2															
Phase 3															

Phase 1: Experiment the prototype on the breadboard

Phase 2: Build the experimental prototype

Phase 3: Finishing work

## CHAPTER 4 RESULT AND DISCUSSION

### 4.1 Simulation

The preliminary circuit is designed by using Multisim software to simulate the function of BAMS. Normally, the LED is ON when the battery input voltage ( $V_i$ ) that is presented by B1 (for battery 1) and B2 (for battery 2) are out of the range. In this simulation, the voltage range is set at 13.2V to 13.8V. The oscilloscope function shows the results by measuring the output voltage ( $V_o$ ) at each BAMS. The summary of the voltage range:

$13.2V < V_i < 13.8V$ ,  $V_o = 0V$  and the LED will OFF

$13.2V > V_i > 13.8V$ ,  $V_o = 5V$  the LED will ON

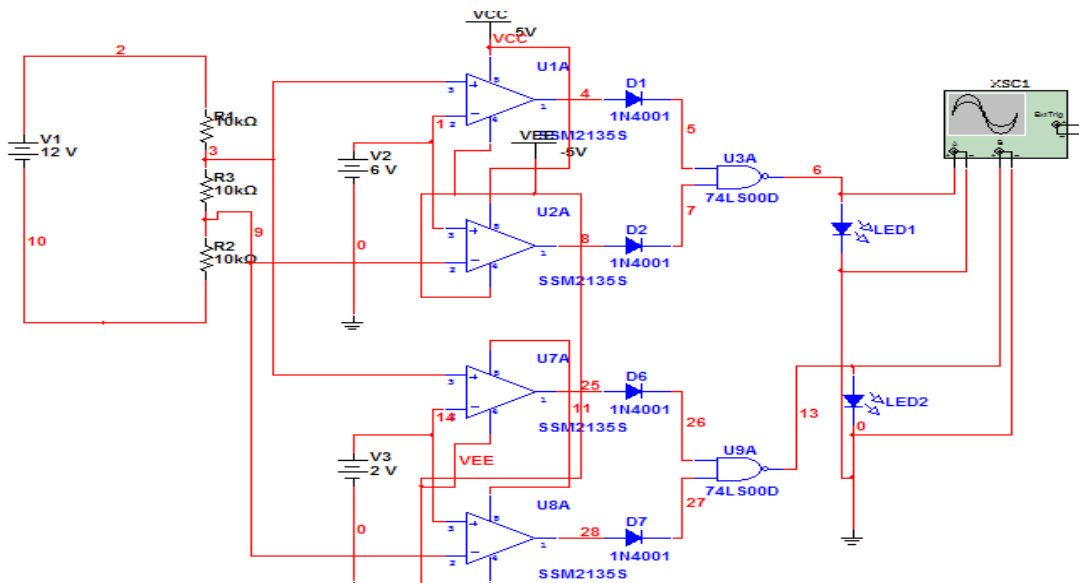


FIGURE 16. Circuit of BAMS

Figure 16 shows the circuit for BAMS that is design by using Multisim. There are two set of battery alarm monitoring system in the circuit.

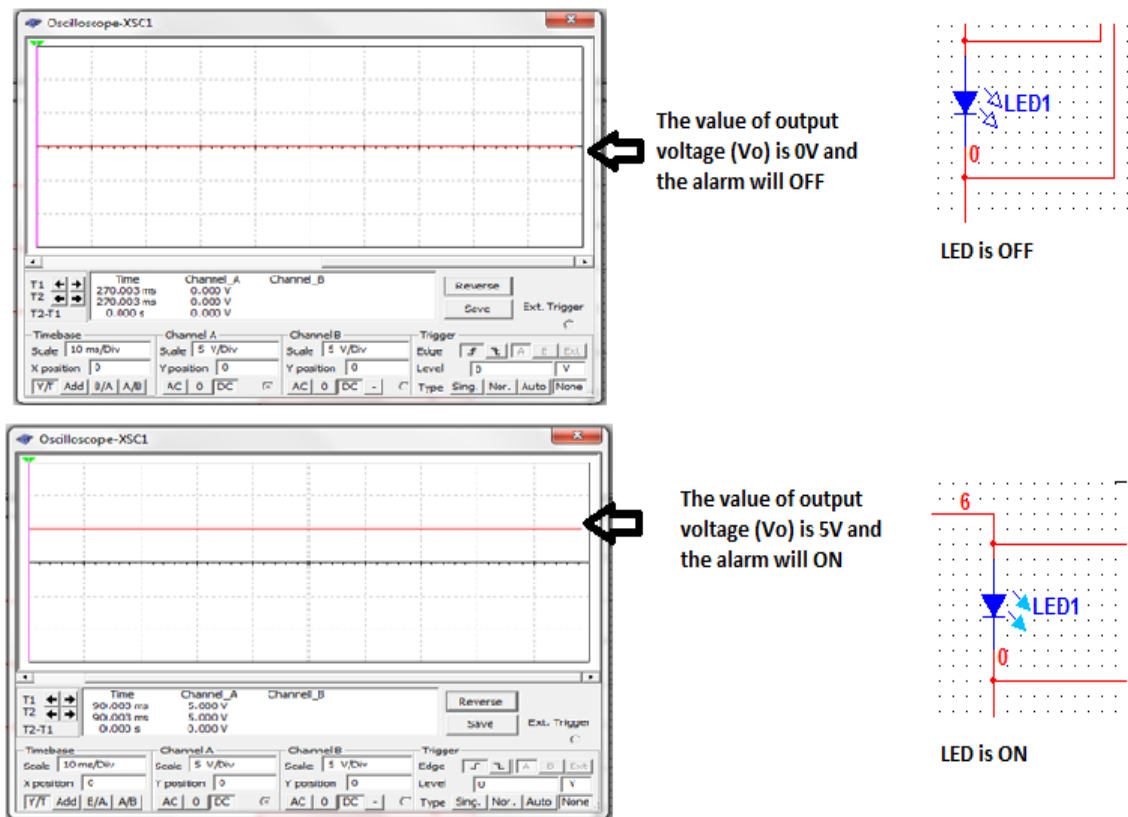


FIGURE 17. Oscilloscope function

Figure 17 shows the oscilloscope function to show the voltage waveform of  $V_o$  in BAMS. If the value of  $V_o$  is 5V, the alarm will ON and if the value of  $V_o$  is 0V, the alarm will OFF.

Experiments were carried out to check the function of the circuit design in Multisim software. Different value of B1 and B2 are used to check whether the alarm is functioning correctly. The results of the experiment are shown in Table 1. Figure 18 until Figure 28 shows the voltage waveform of  $V_o$  in BAMS for 11 experiments. The value of B1 and B2 is put from 13.0V until 14.0V to check whether the alarm will be ON if the value is out of the range.

TABLE 1. Result of experiment conducted on circuit design in Multisim

No. of Test	Vin (B1)	LED (ON/ OFF)	Status	Vin (B2)	LED (ON/ OFF)	Status
1	13.0V	ON	Out Of The Range	13.0V	ON	Out Of The Range
2	13.1V	ON	Out Of The Range	13.1V	ON	Out Of The Range
3	13.2V	OFF	In The Range	13.2V	OFF	In The Range
4	13.3V	OFF	In The Range	13.3V	OFF	In The Range
5	13.4V	OFF	In The Range	13.4V	OFF	In The Range
6	13.5V	OFF	In The Range	13.5V	OFF	In The Range
7	13.6V	OFF	In The Range	13.6V	OFF	In The Range
8	13.7V	OFF	In The Range	13.7V	OFF	In The Range
9	13.8V	OFF	In The Range	13.8V	OFF	In The Range
10	13.9V	ON	Out Of The Range	13.9V	ON	Out Of The Range
11	14.0V	ON	Out Of The Range	14.0V	ON	Out Of The Range

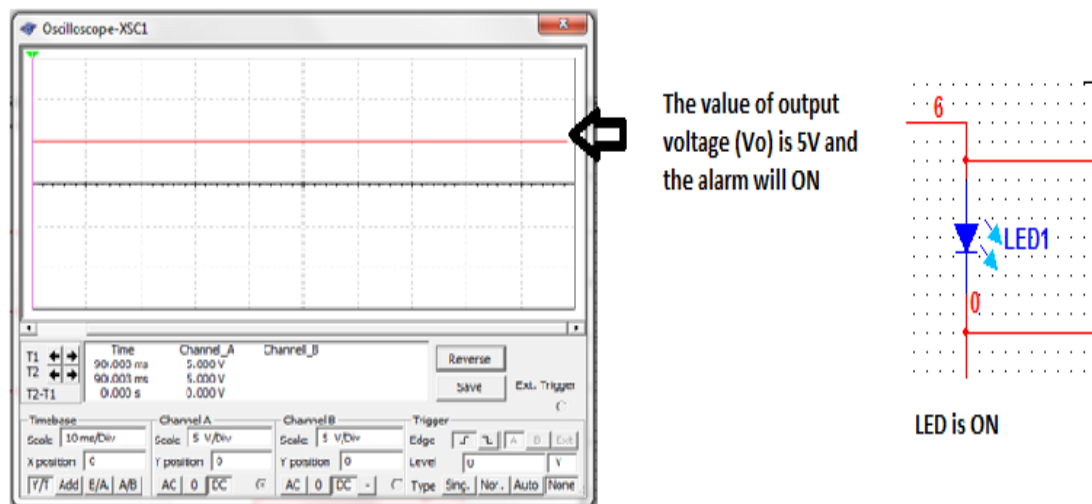


FIGURE 18. Experiment 1

Figure 18 shows the result for experiment 1. In experiment 1, the value for B1 and B2 are set to 13.0V. The voltage for B1 and B2 are out of the range and LED for both batteries are ON.



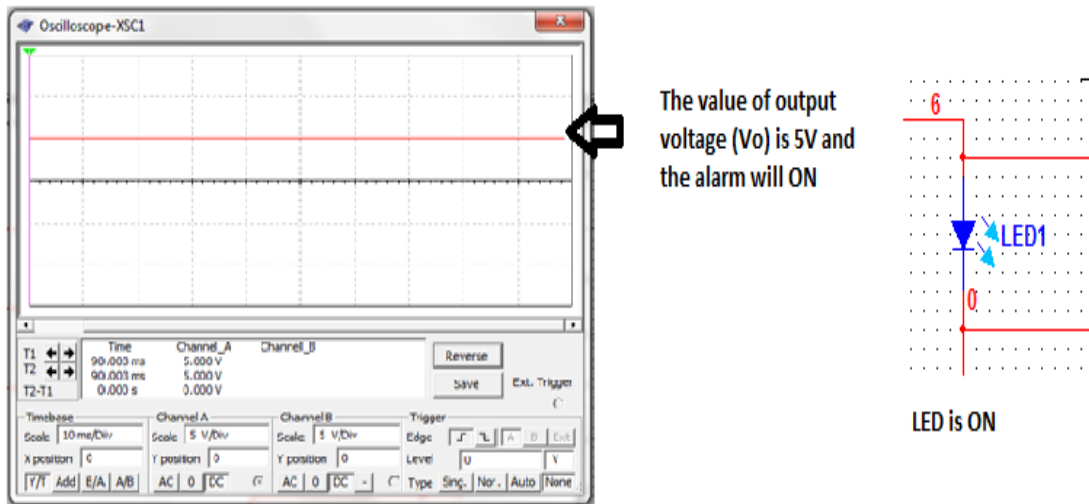


FIGURE 19. Experiment 2

Figure 19 shows the result for experiment 2. In experiment 2, the value for B1 and B2 are set to 13.1V. The voltage for B1 and B2 are out of the range and LED for both batteries are ON.

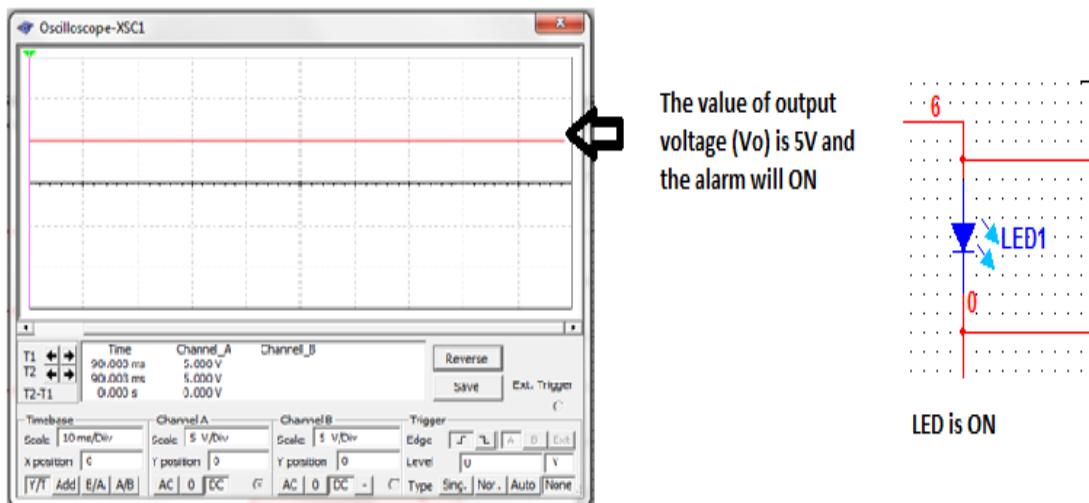


FIGURE 20. Experiment 3

Figure 20 shows the result for experiment 3. In experiment 3, the value for B1 and B2 are set to 13.2V. The voltage for B1 and B2 are out of the range and LED for both batteries are ON.

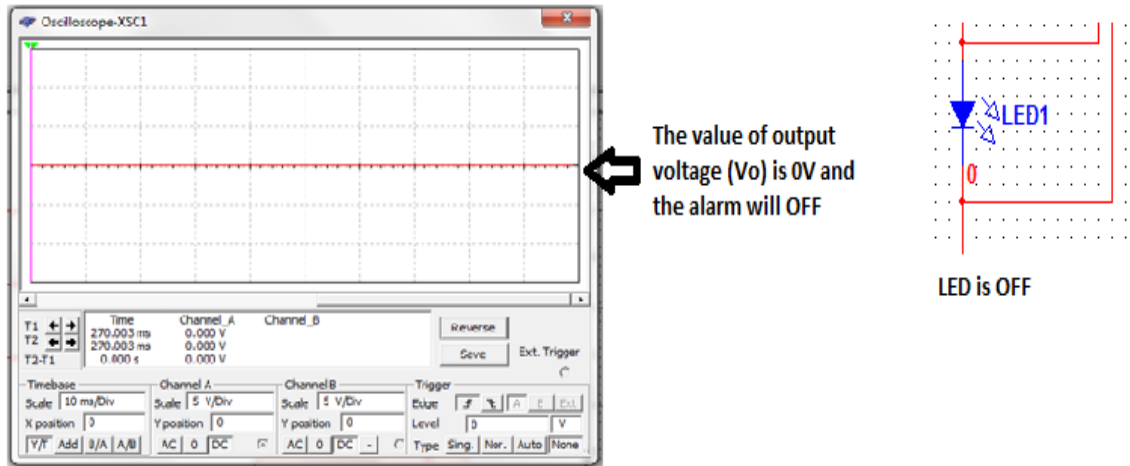


FIGURE 21. Experiment 4

Figure 21 shows the result for experiment 4. In experiment 4, the value for B1 and B2 are set to 13.3V. The voltage for B1 and B2 are in the range and LED for both batteries are OFF.

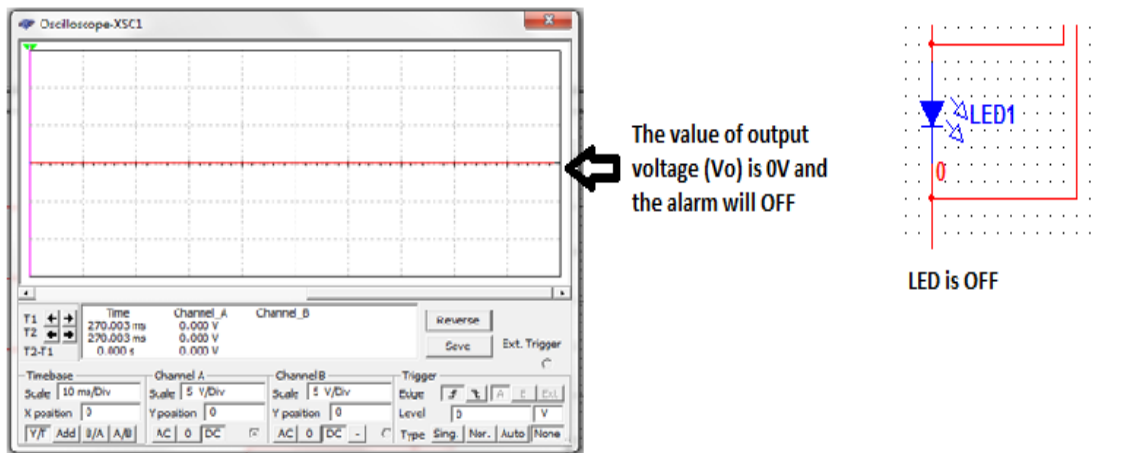


FIGURE 22. Experiment 5

Figure 22 shows the result for experiment 5. In experiment 5, the value for B1 and B2 are set to 13.4V. The voltage for B1 and B2 are in the range and LED for both batteries are OFF.

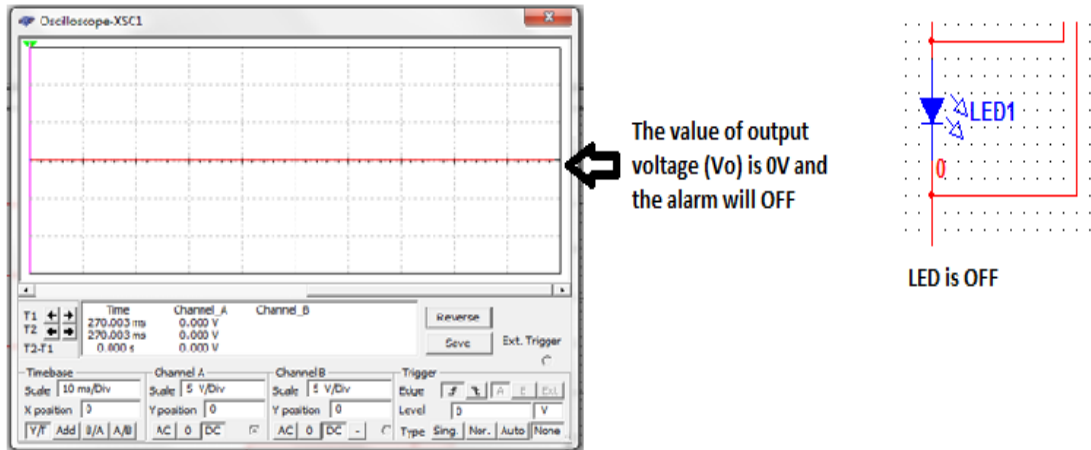


FIGURE 23. Experiment 6

Figure 23 shows the result for experiment 6. In experiment 6, the value for B1 and B2 are set to 13.5V. The voltage for B1 and B2 are in the range and LED for both batteries are OFF.

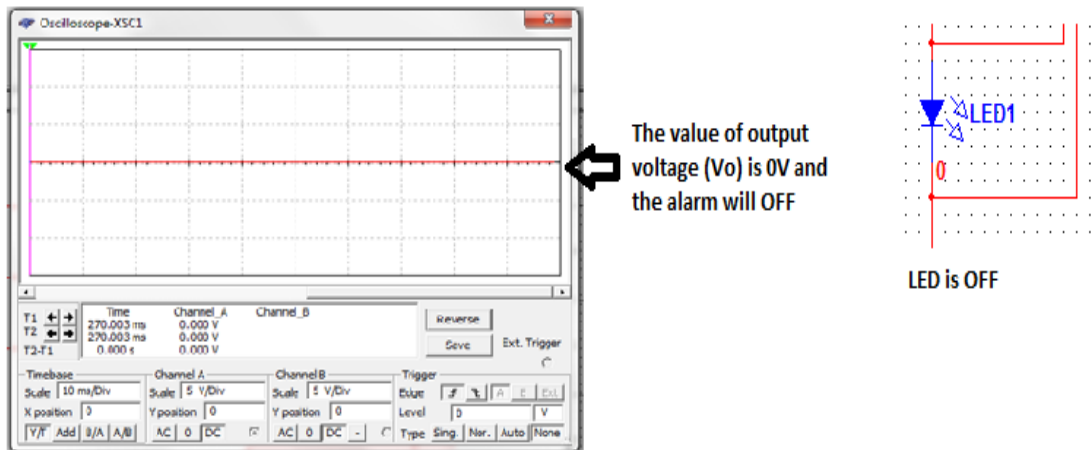


FIGURE 24. Experiment 7

Figure 24 shows the result for experiment 7. In experiment 7, the value for B1 and B2 are set to 13.6V. The voltage for B1 and B2 are in the range and LED for both batteries are OFF.

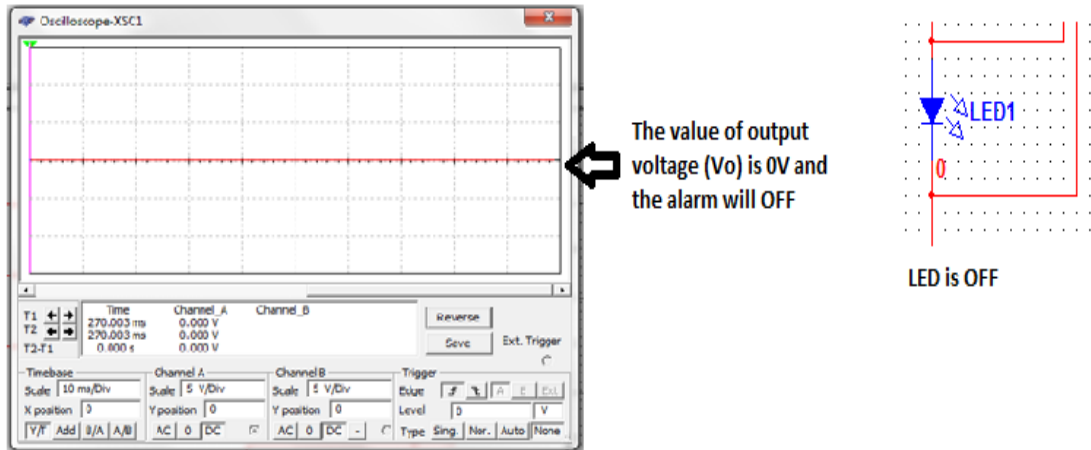


FIGURE 25. Experiment 8

Figure 25 shows the result for experiment 8. In experiment 8, the value for B1 and B2 are set to 13.7V. The voltage for B1 and B2 are in the range and LED for both batteries are OFF.

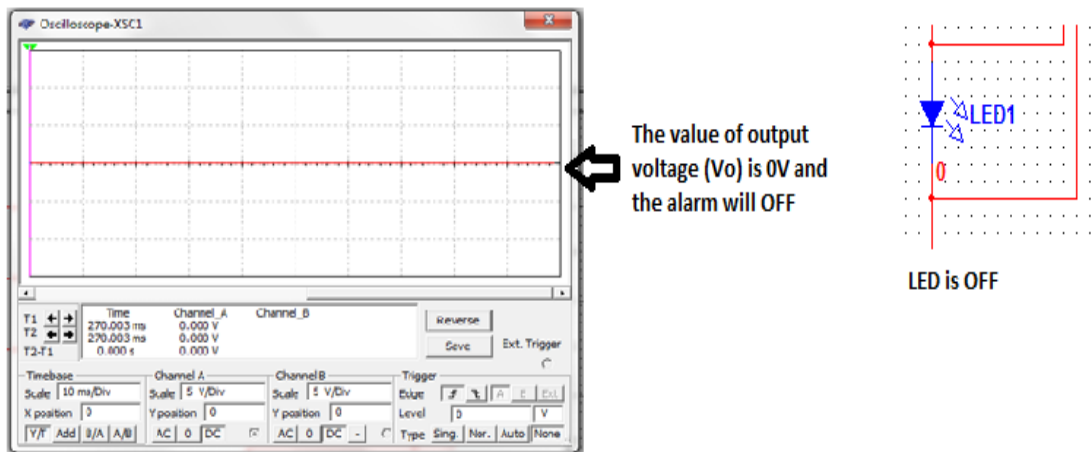
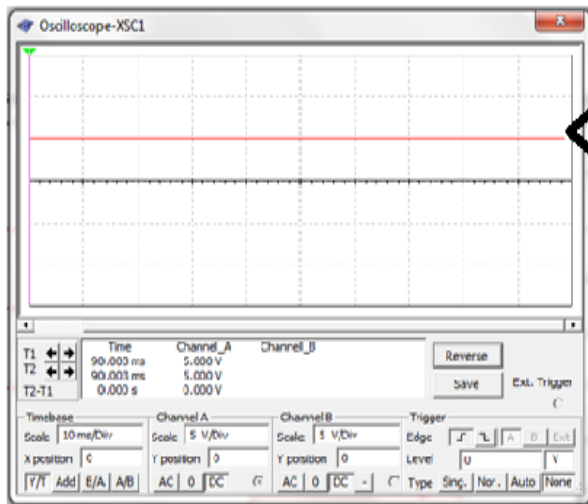
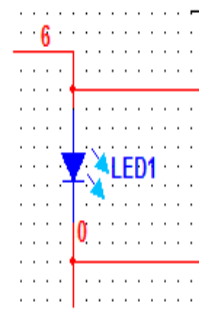


FIGURE 26. Experiment 9

Figure 26 shows the result for experiment 9. In experiment 9, the value for B1 and B2 are set to 13.8V. The voltage for B1 and B2 are in the range and LED for both batteries are OFF.



The value of output voltage ( $V_o$ ) is 5V and the alarm will ON



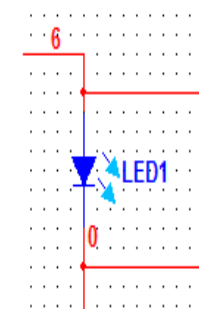
LED is ON

FIGURE 27. Experiment 10

Figure 27 shows the result for experiment 10. In experiment 10, the value for B1 and B2 are set to 13.9V. The voltage for B1 and B2 are out of the range and LED for both batteries are ON.



The value of output voltage ( $V_o$ ) is 5V and the alarm will ON



LED is ON

FIGURE 28. Experiment 11

Figure 28 shows the result for experiment 11. In experiment 11, the value for B1 and B2 are set to 14.0V. The voltage for B1 and B2 are out of the range and LED for both batteries are ON.

From the experiment's result in Table 1 and the oscilloscope display in Figure 18 to Figure 28, the comparator window and alarm system are functioning correctly. The alarm will be ON if the voltage of the battery is out of the range and the alarm will be OFF if the voltage of the battery is in the range.

#### 4.2 Prototype

After the simulation in Multisim software is proven, the circuit for comparator window is experimented on the breadboard as shown in Figure 29. Then, the experimented prototype of BAMS is done as shown in Figure 30.

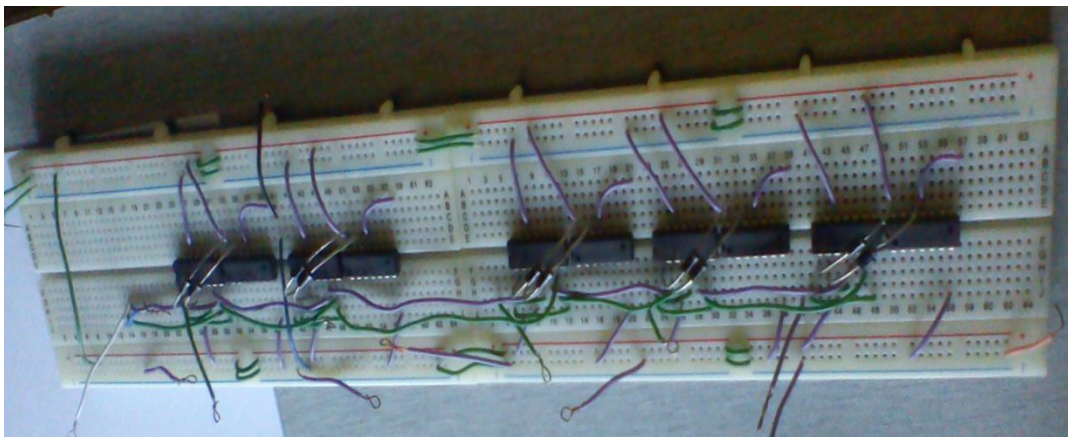


FIGURE 29. BMS Circuit on Breadboard

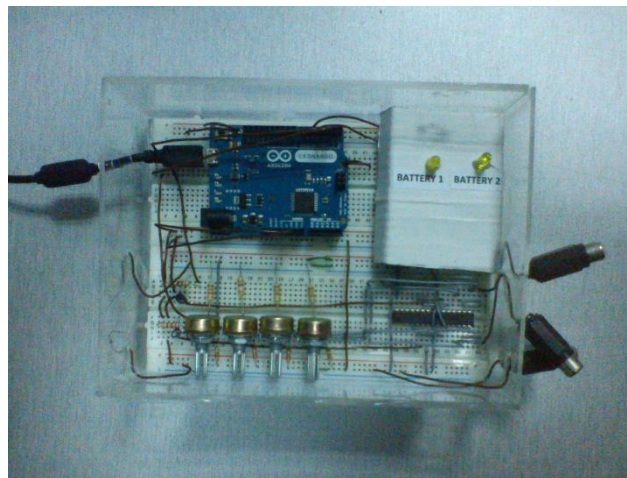


FIGURE 30. Prototype Design of BAMS

The same experiment as in Multisim software is conducted to the experimental prototype of BAMS. The  $V_o$  from the circuit is measured and the alarm system is tested as shown in Figure 31. The value of  $V_o$  is 0V if  $V_{in}$  is in the range and the LED will be OFF. If the value of  $V_{in}$  is out of the range, the value of  $V_o$  is 4.24V and the LED will be ON. The value of  $V_o$  is not 5V as in the simulation because the voltage drop at LED when the light is ON. The experimental prototype functions as simulation in Multisim. The result of the experiment is shown in Table 2.

The microprocessor updated the battery condition to the computer correctly. The programming code for the microprocessor is shown in Appendix A. It will update the status of input voltage for battery1 and battery2 whether it is in the range or out of the range as shown in Appendix B.

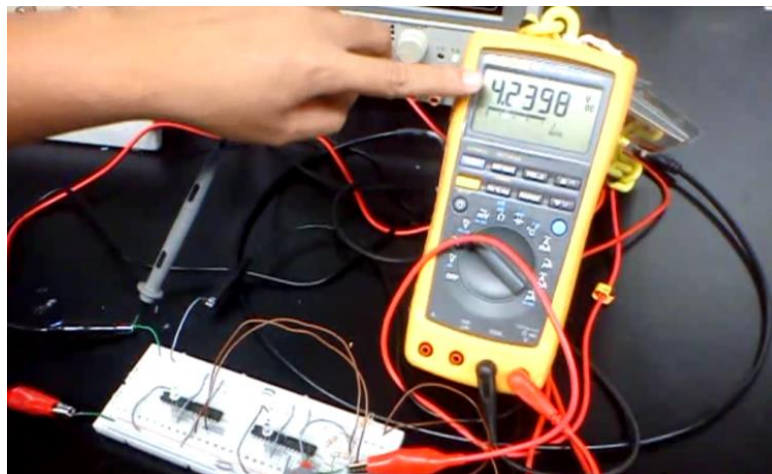


FIGURE 31. Experiment is conducted at the prototype design of BAMS

TABLE 2. Result of Test on Experiment Prototype

No. of Test	$V_{in}$	LED (ON/ OFF)	Status
1	13.0V	ON	Out Of The Range
2	13.1V	ON	Out Of The Range
3	13.2V	OFF	In The Range
4	13.3V	OFF	In The Range
5	13.4V	OFF	In The Range
6	13.5V	OFF	In The Range
7	13.6V	OFF	In The Range
8	13.7V	OFF	In The Range
9	13.8V	OFF	In The Range
10	13.9V	ON	Out Of The Range
11	14.0V	ON	Out Of The Range



### 4.3 Cost

In this project, the BAMS is designed to reduce the cost for monitoring the battery in data center. This project is designed to monitor 2 batteries and the cost of BAMS is compared with the cost of Arduino voltage sensor as shown in Figure 32. The cost for monitoring 2 batteries by using Arduino voltage sensor and BAMS are shown in Table 3 and Table 4.



FIGURE 32. Cost of Arduino Voltage Sensor

TABLE 3. Cost for monitoring by using voltage sensor

Item	Price/each (RM)	Quantity	Total (RM)
1) Voltage Sensor	18.5	2	37
			<b>37</b>

From Table 3, the total cost to monitor two batteries by using Arduino voltage sensor is RM37.



TABLE 4. Cost for monitoring by using BAMS

Item	Price/each (RM)	Quantity	Total (RM)
1) Voltage comparator IC	1	1	1
2) Resistor	0.8	10	8
3) Variable Resistor	1	4	4
4) Transistor NPN	0.8	4	3.6
			<b>16.6</b>

From Table 4, the total cost to monitor two batteries by using BAMS is RM16.60. The cost for monitoring 2 batteries by using BAMS is cheaper than Arduino voltage sensor and can save RM20.40.

The line graph in Figure 33 shows the cost to monitor 2 batteries up to 16 batteries by using Arduino voltage sensor and BAMS. The cost for monitoring batteries can be reduced significantly by using BAMS.

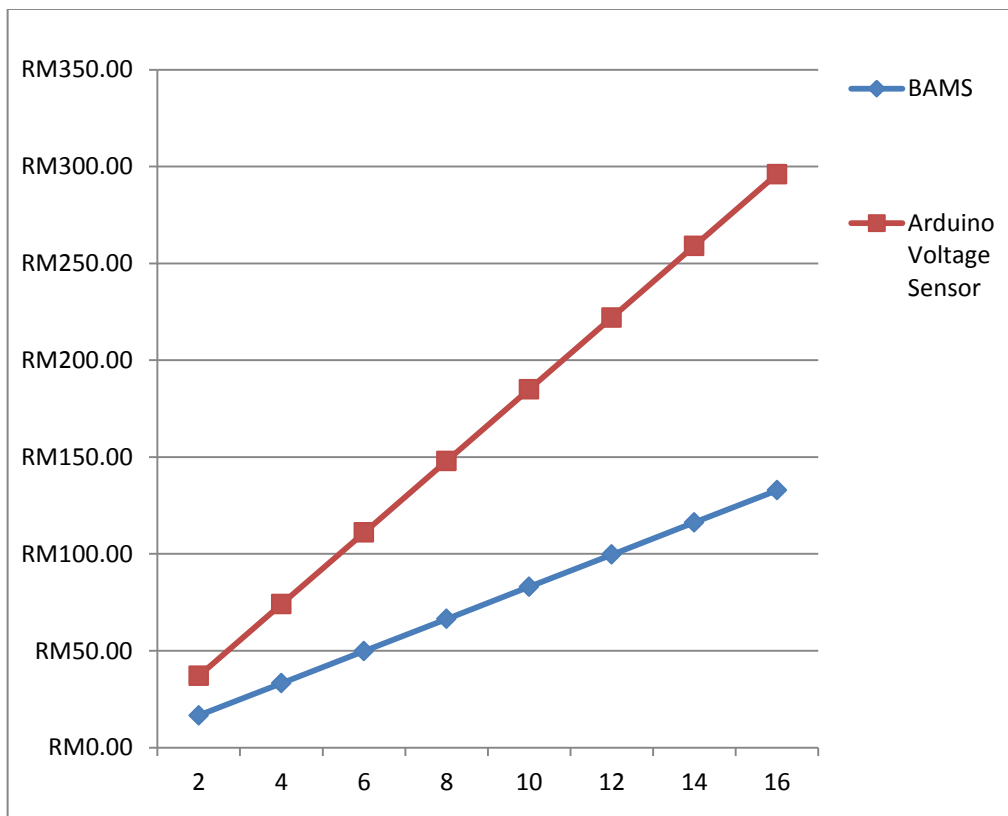


FIGURE 33. Cost Comparison

#### **4.4 Discussion**

The simulation is designed for two BAMS only because the limitation of the software. The software is not capable to run more than two BAMS. In data center, there are many batteries need to be monitored and sometimes up to 2000 batteries and maybe more. In this project, BAMS is designed to monitor two batteries to prove the concept of using voltage comparator to monitor the battery voltage.

The circuit is experimented on the breadboard and it functions as in simulation. The voltage range is set from 13.2V to 13.8V. This value is suggested by the manufacturer of the battery. If input voltage is in the range, the battery is considered in good condition. The voltage range must be accurate in order to monitor the battery voltage and for better battery monitoring system. Voltage divider is used to get the voltage range value. The resistor value must be accurate to get an accurate value for voltage range. Variable resistor is used to get an accurate value of resistor.

The microprocessor used can monitor at most 8 batteries because it has 8 input. If we were to monitor more than 8 batteries, we need to add the microprocessor board for another 8 batteries. Other alternatives, we need to used more advanced microprocessor board that have many inputs and can monitor more batteries. The cost for monitoring two batteries by using BAMS is cheaper than using Arduino voltage sensor by RM20.40.

## **CHAPTER 5 CONCLUSION AND RECOMMENDATION**

In conclusion, this project is about monitoring the battery in UPS system. BAMS is designed in Multisim software and it performed well in experiment and hence the objective of this project is achieved. The cost for battery monitoring by using BAMS is compared with Arduino voltage sensor and great amount of saving can be attained.

As recommendations, the concepts of monitoring by using comparator window can be used to monitor battery temperature. The battery temperature is also another indicator of their condition. If the distance between battery room and control room is far, long wire need to be used to connect the microprocessor board with the computer in control room. The wireless communication system is recommended to connect the microprocessor board in battery room with the control room. The battery condition also can be update through email or SMS in mobile phone.

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## APPENDICES

APPENDIX A  
Microprocessor Coding

```
/*  
  
  AnalogReadSerial  
  
  Reads a analog input on pin 2 and pin 3, prints the result to the serial monitor  
  
  This example code is in the public domain.  
  
  */  
  
// analog pin 2 and pin 3 has a pushbutton attached to it. Give it a name:  
  
int Battery1 = 2;  
int Battery2 = 3;  
int Output1 = 4;  
int Output2 = 5;  
  
// the setup routine runs once when you press reset:  
void setup() {  
  // initialize serial communication at 9600 bits per second:  
  Serial.begin(9600);  
  
  // make the pushbutton's pin an input:  
  pinMode(Battery1, INPUT);  
  pinMode(Battery2, INPUT);  
  pinMode(Output1, OUTPUT);  
  pinMode(Output2, OUTPUT);  
}  
  
// the loop routine runs over and over again forever:
```

```

void loop() {
    // read the input pin:
    int B1State = digitalRead(Battery1);
    int B2State = digitalRead(Battery2);
    // print out the state of the button:
    Serial.print("Battery 1:");
    Serial.print("\t");
    //Serial.print("Battery 1:");
    //Serial.print("\t");
    if (B1State == HIGH) {
        Serial.print("float voltage IN the range");
        digitalWrite (Output1,LOW);
    }
    else {
        Serial.print("float voltage OUT of the range");
        digitalWrite (Output1,HIGH);
    }
    Serial.print("\t");
    Serial.print("\t");
    Serial.print("\t");
    Serial.print("Battery 2:");
    Serial.print("\t");
    if (B2State == HIGH) {
        Serial.print("float voltage IN the range");
        digitalWrite (Output2,LOW);
    }
    else {

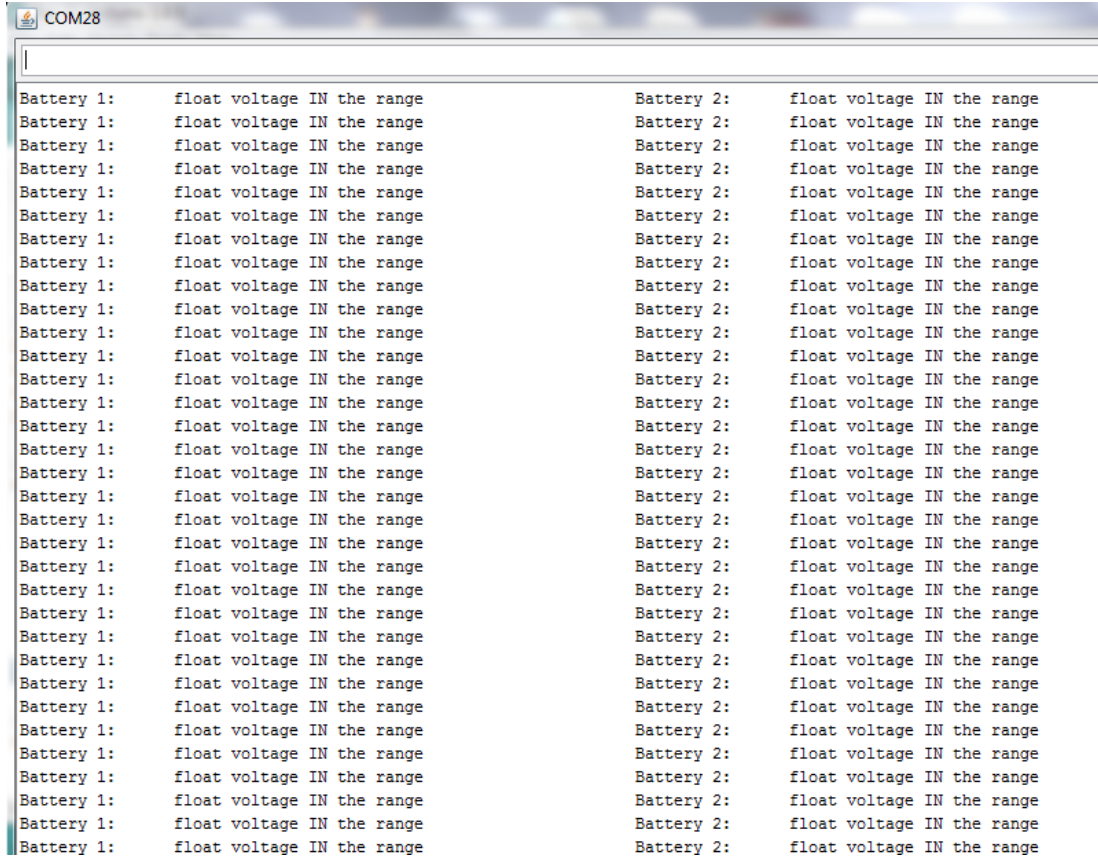
```

```
Serial.print("float voltage OUT of the range");  
digitalWrite (Output2,HIGH);  
}  
Serial.println("");  
delay(1000);    // delay in between reads for stability  
}
```



## APPENDIX B

### Microprocessor result



The screenshot shows a terminal window with the title 'COM28'. The output consists of two columns of text, each containing 25 identical entries. The left column is for 'Battery 1' and the right column is for 'Battery 2'. Each entry reads: 'float voltage IN the range'.

Battery 1:	float voltage IN the range	Battery 2:	float voltage IN the range
Battery 1:	float voltage IN the range	Battery 2:	float voltage IN the range
Battery 1:	float voltage IN the range	Battery 2:	float voltage IN the range
Battery 1:	float voltage IN the range	Battery 2:	float voltage IN the range
Battery 1:	float voltage IN the range	Battery 2:	float voltage IN the range
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