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Development Arduino Data Logger using INA219 Sensor for Battery Capacity Monitoring

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ABSTRACT

Abstract *- A battery, also known as an accumulator, is an electrical cell that can reverse an electrochemical process with high efficiency. It is essential in the use of electrical systems as storage devices. It has two critical parameters: current and voltage. These parameters can affect the battery's behavior, which leads to battery usage. As a result, a battery monitoring instrument is required to monitor the battery's current and voltage while it is in use. The researchers designed a monitoring instrument with an Arduino Pro Mini 5V microcontroller as the main processor, INA219 as a current and voltage sensor, RTC DS3231 as a time reader, micro-SD card module as a data logger, and OLED SH1106 to display the current, voltage, and time readings. The calibration of the INA219 sensor has a current reading accuracy of 91.43% and a voltage reading accuracy of 99.87%. RMSE was measured at 227.65 mA and 0.0146 V. The device was tested with a BSB DB 12-55Ah battery connected to 30W PJU lamps. In the results of this test, we experienced voltage drop and current ripple in the battery performance. The battery usage capacity was 49.71 Ah. Based on this research, the device built can monitor battery conditions.*

Keywords: *Current, Voltage, Monitoring, INA219 sensor, Data logger*

1. INTRODUCTION

A battery, also known as an accumulator, is an electrical cell that undergoes an electrochemical process that is reversible and highly efficient. There are two kinds of batteries: primary batteries and secondary batteries. A *lead acid battery* is a secondary battery that uses lead acid as a chemical. The advantages of this battery are that it can be used and recharged multiple times [1]. The battery has several essential parameters, including current and voltage [2]. The parameters can be used to determine the battery's behavior, one of which leads to battery usage [3]. Therefore, a battery monitoring system is required.

Previous research has identified battery consumption and battery performance conditions related to the battery usage monitoring system using the ACS712 sensor for current readings and the voltage sensor for voltage readings [4]. Other researchers have used the INA219 sensor for current and voltage readings in battery monitoring and control systems. The INA219 sensor's reading accuracy is precise and suitable, allowing the system to function correctly [5][6]. Therefore, research is required to implement a battery monitoring system. In this paper, Researchers designed a monitoring system using the INA219 sensor, which functions as a current and voltage reader. An Arduino Pro mini5V microcontroller serves as a data processor in this system. This monitoring system also includes an RTC DS3231 time reader. A data logger uses the Micro SD card Module as a data storage device in this monitoring system. The system also displays direct current, voltage, and time reading data against the SH1106 OLED. The current and voltage monitoring results can be seen in the amount of power consumed on such batteries based on the load used.

2. RESEARCH METHOD

This research was conducted at the Renewable Energy Laboratory of the Faculty of Engineering, Raja Ali Haji Maritime University, on 10 – 12 March 2022. The battery monitoring system uses seven main components to support this research: The system input consists of an INA219 sensor as a current and voltage reader and a Real-Time Clock DS3231 as a time reader. The system is processed as a data processor on an Arduino Pro mini 5V. The output of this system is stored in the Micro SD Card Module, and the data is displayed in the OLED SH1106 display. The 18650 Battery and the TP4056 Charging Module provide the energy for this system's monitoring battery (Figure 1).

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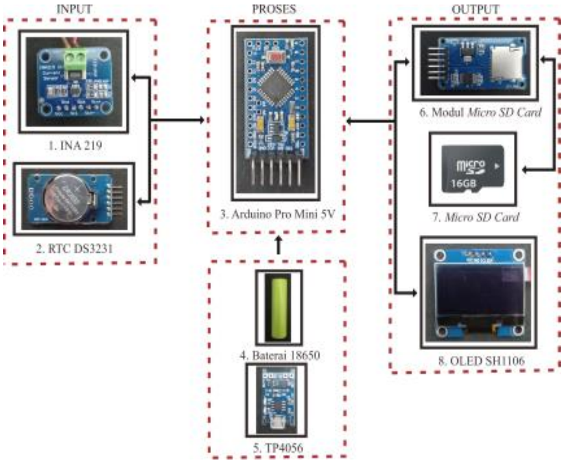

Figure 1. Battery monitoring system

2.1 Firmware Design

In this research, an instrument has been designed and built to measure Current and Voltage from the INA219 sensor, obtain dates and times from Real-Time Clock DS3231, store the data in micro-SD, and display the data in SH1106 OLED. The firmware of this microcontroller was developed using Arduino IDE. This instrument measures the Current and Voltage every second. Flowcharts of this system are shown in Figure 2.

The program begins with serial communication initialization. Then the microcontroller will check the Micro SD. Next, the microcontroller will check the Micro SD Card. If the Micro SD card is not connected, the microcontroller turns the LED on to indicate a Micro SD error. If the micro-SD card checking was successful, the microcontroller will check the file inside the Micro SD Card and make a new file INALog.txt. Next, the microcontroller will read the current and voltage data using the INA219 sensor and time using Real-Time Clock DS3231. The data Current, Voltage, and Time will be displayed on SH1106 OLED and stored inside the micro-SD card.

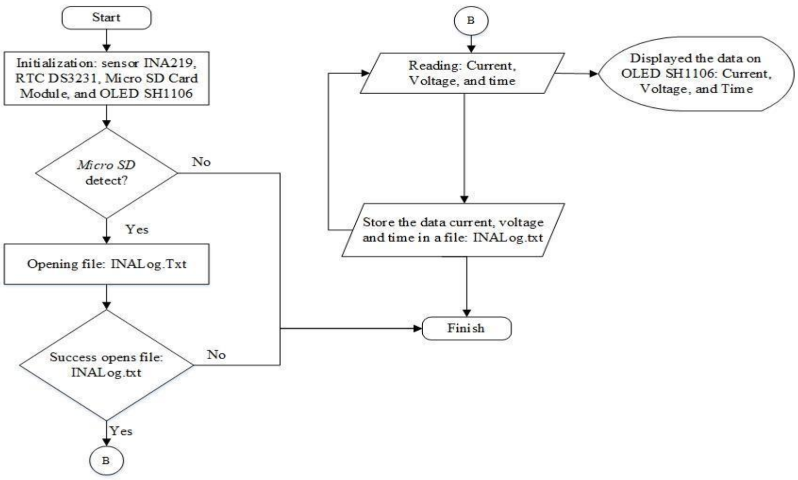

Figure 2. Flowchart of battery monitoring system

2.2 Data Analysis

The INA219 sensor will be measured several times, and the results will be compared to a multimeter as a reference. Calibration is performed to ensure that the measurement results are accurate and precise by looking for error, accuracy, and root mean square error (RMSE) values from the INA219 sensor. The relative error is the ratio of absolute error to the true value. The absolute error is the difference between the actual and estimated values [7]. Equations 1–3 show the error and accuracy value formulas.

$$error = |x_b - x_a| \tag{1}$$

$$\%\,error = \frac{error}{x_b} \times 100\% \tag{2}$$

$$A = 100\% - \%\,error \tag{3}$$

Description:
Error = Relative error
% error = Percentage error
A = Percentage accuracy
x_a = Value measurement of Sensor INA219
x_b = Value measurement calibrator

The Root Mean Square Error (RMSE) is an equation that can calculate the average error value of a measuring instrument. The lower the RMSE value, the more accurate the measurement results [8]. Equation 4 can be used to calculate the RMSE.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(x_b - x_a)^2}{n}} \tag{4}$$

Description:
$RMSE$ = Value RMSE
x_a = Value measurement of Sensor INA219
x_b = Value measurement calibrator
n = number of readings

Linear regression is a predictive analysis used to determine relationships between two or more variables [8]. Equations 5 – 7 can be used to calculate the value of linear regression.

$$Y = a + bX \tag{5}$$

$$a = \frac{(\sum Y)(\sum X^2) - (\sum X)(\sum XY)}{(n \sum X^2) - (\sum X)^2} \tag{6}$$

$$b = \frac{(n \sum XY) - (\sum X)(\sum Y)}{(n \sum X^2) - (\sum X)^2} \tag{7}$$

Description:
Y = Response variable
X = Predictor variable
a = Constanta

Battery capacity is calculated by multiplying the current flowing by the battery's usage time [9]. Therefore, equation 8 can be used to calculate the capacity of a battery.

$$C = I.T \tag{8}$$

Description:
C = Capacity (Ah)
I = Current (A)
T = Time (Hour)

3. RESULT AND DISCUSSION

3.1 Device Design

The monitoring device was designed using the SketchUp 2020 software. This monitoring device has an ABS (Acrylonitrile Butadiene Styrene) plastic box with a transparent cover. The box measures 130 mm in length, 80 mm in width, and 70 mm in height. The other components include an Arduino Pro Mini 5v, an INA219 sensor, an RTC DS3231, a micro-SD card module integrated into the PCB, and a battery 18650 as the power source for the monitoring device installed in the box. OLED SH1106 is on the surface of the box cover. The monitoring device design can be seen in Figure 3.

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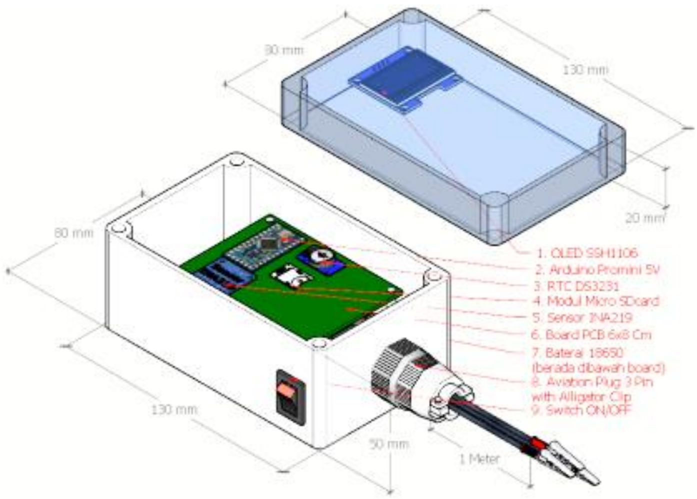

Figure 3. The monitoring device design

Component integration is the process of combining pre-designed components. The integration component schematic can be seen in Figure 4. The components combined in Figure 5 include Arduino Pro mini microcontroller, RTC DS3231, Micro SD Card Module, INA219 Sensor, and power supplied by a 18650 battery built into the PCB bottom box.

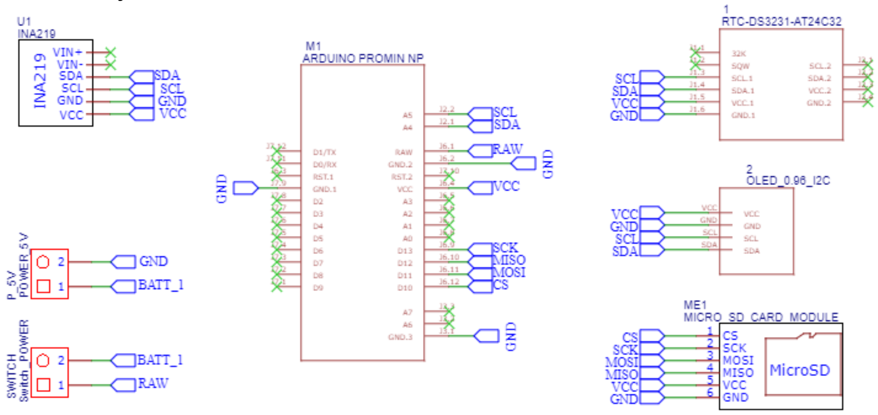

Figure **4.** Integration components schematic

Figure 5. The monitoring device

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3.2 INA219 Sensor Calibration

Calibration INA219 sensor done using a multimeter as calibrator. The measured voltage value starts from 5V – 12V. The voltage measurement on the INA219 sensor is carried out every one second for 1 minute and calibration was carried out at 15 different voltage values. The graph of the voltage calibration results can be seen in Figure 6.

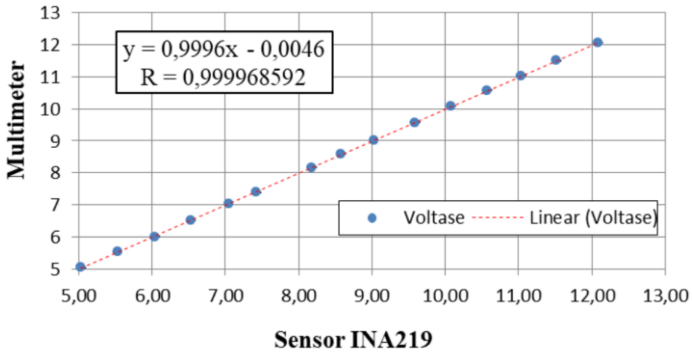

Figure 6. Voltage calibration between INA219 sensor and multimeter

Based on this calibration, the INA219 correlation coefficient obtained is 0,99. Therefore, the average accuracy of the INA219 sensor is 99.87%, with an error percentage of 0.13% and an RMSE of 0.0146 V. From the three sensor calibration results, the INA219 sensor has a very high level of accuracy. Hence, in these results, the sensor INA219 is very well used for voltage measurement.

As for current calibration, the INA219 sensor was calibrated using a BSB DB 12-55Ah battery connected with a lamp with different power. The measured lights have different power levels ranging from 4W to 39W. The multimeter was used as the calibrator. The current measurement on the INA219 sensor is carried out every second for 1 minute, and calibration was carried out at 17 different current values. The graph of the voltage calibration results can be seen in Figure 7.

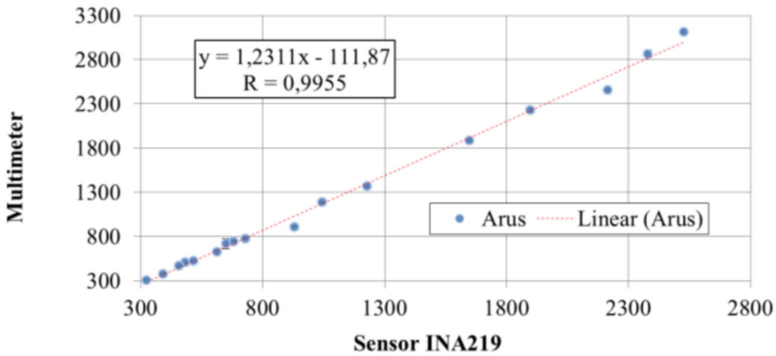

Figure 7. Current calibration between INA219 sensor and multimeter

The current calibration results show the R-value (correlation coefficient) is 0.9955 with a percentage of 99.55%. This calibration indicates the INA219 sensor has an average accuracy of 91.43%, with an error percentage of 8.57% and an RMSE of 227.65 mA. So, the INA219 sensor has a very high level of accuracy and is very well used for current measurement.

3.3 Experimental Result

The experiment was carried out at the Renewable Energy Laboratory, Faculty of Engineering, Raja Ali Haji Maritime University. The experiment was conducted to collect data on the current and voltage of battery usage with a 30W PJU lamp load. In this test, the BSB DB 12V-55Ah battery was used. This BSB DB 12V-55Ah battery has been extensively tested and measured. Therefore, this battery monitoring device is connected to a BSB DB 12V-55Ah battery and a 30W PJU lamp (Figure 8).

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Figure 8. Experiment battery monitoring device at renewable energy laboratory

This experiment was carried out from 11-12 March 2022 with a total test time of 12 hours 58 minutes (12.98 hours). The current and voltage graph in this experiment can be seen in Figure 9. The battery experiment with a 30W PJU lamp load stored 46,724 data. The battery's voltage and initial current were 11.29 V, and 3.83 A. Voltage drop patterns were observed to decrease slowly and consistently until 12 hours 21 minutes (12.36 hours) experienced a voltage drop until the experiment ended at 12 hours 58 minutes (12.98 hours). The voltage drop ends at 8.00 V. Furthermore, the current pattern connected to the 30W lamp load produces a stable current output. After that, it experienced a current ripple at 12 hours and 30 minutes (12.5 hours) until the experiment ended. The results of the calculation of battery capacity for 3 PJU 30W lamp usage in the third field test can be seen in Equation 8. According to equation 8, the capacity of the BSB DB 12V-55Ah battery at the use of 30W PJU lamps for 12 hours 58 minutes (12.98 hours) with an average current of 3.83 A was 49.71 Ah.

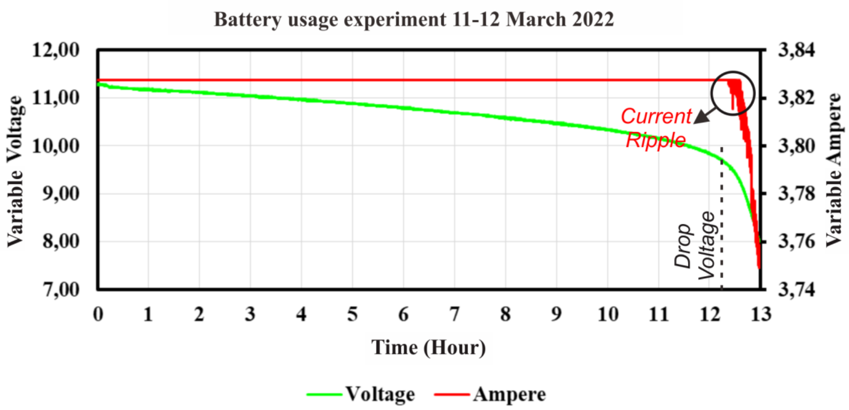

Figure 9. Battery usage experiment result

3.4 Discussion

The phenomenon of voltage drops and current ripple was experienced in this test. The Drop Voltage occurs when changes in the inside of the battery that cause changes in voltage. The effect of inner polarization on the battery causes a reduced change in voltage level. Electrochemical reactions cause this polarizing effect. As a result of these effects, the temperature in the battery rises, causing the voltage to drop rapidly to the final voltage [10].

The Current Ripple phenomenon is caused by a decrease in performance over time due to active material degradation, heating, and battery corrosion [11]. If this phenomenon repeatedly occurs during battery use (discharging), the battery's life will be shortened. The battery experiment using BSB

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DB12V-55Ah batteries revealed that the batteries used in this test were good quality. The current and voltage graphs show that the battery is in good condition.

4. CONCLUSION

Based on the research, it is possible to conclude that this monitoring device was a success. This device uses Arduino Pro Mini 5V, INA219 Sensor, Real-Time Clock DS3231, Micro SD Card Module, and OLED SH1106 to monitor current and voltage. Based on the test, this monitoring device can assess the battery condition of 30W lamps as a load. This measurement resulted in a battery capacity of 49.71 Ah. Therefore, according to this research, the BSB DB 12V-55Ah battery is in good condition.

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