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Advancements in Autonomous Battery Monitoring: A System with Auto-Return Home Integration

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Abstract:

As the adoption of autonomous systems continues to proliferate in various industries, the need for reliable and efficient battery monitoring solutions becomes increasingly crucial. This paper presents the development and implementation of an innovative Autonomous Battery Monitoring System (ABMS) equipped with Auto-Return Home Integration (ARHI). The proposed system addresses the limitations of existing battery monitoring technologies by combining real-time data analysis, autonomous decision-making, and the ability to return autonomously to a charging station when necessary. Furthermore, the ABMS incorporates adaptive charging algorithms that optimize the charging process based on historical usage patterns, reducing energy waste and extending battery lifespan. Additionally, the system offers remote monitoring and control capabilities, allowing operators to oversee multiple autonomous systems equipped with ABMS from a centralized interface. In practical applications, the ABMS with ARHI integration has demonstrated significant improvements in the reliability and autonomy of battery-powered systems, particularly in industries such as unmanned aerial vehicles (UAVs), robotics, and autonomous ground vehicles. The ability to proactively address battery issues and seamlessly integrate autonomous return-to-base functionality enhances operational safety, reduces operational costs, and extends the overall lifespan of battery packs. Atmega328 microcontroller, wireless data module HC-12 model is used with transmitter and receiver and system application. The microcontroller control or handles the analog to digital conversion, the wireless module handles data transmission between transmitter and receiver, while the system application collects, store the continue data entrance to the receiver into Microsoft excel, display the data in system screen and also, plot graph with the stored data.

Keywords — **Microcontroller, Voltage Divider Network, Transmitter, Receiver, Wireless Data Module, VB.NET app. USB Serial Port**

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I. INTRODUCTION

Autonomous Battery Monitoring System (BMS) is a technology designed to monitor, control, and optimize the performance of batteries used in various applications. With the widespread use of batteries in devices such as electric vehicles (EVs), drones, renewable energy systems, and backup power systems or portable electronic systems, there is a growing need for efficient battery management systems. BMS plays a critical role in ensuring the safety, longevity, and performance of batteries by monitoring and controlling various parameters such as temperature, voltage, state of charge and discharge. Autonomous battery monitoring system comprises of several components that work together to monitor and control the performance of batteries which include: A battery Management Unit (BMU) is the central component of a BMS and is responsible for collecting data from various sensors and controlling the battery's performance. The BMU is typically equipped with a microcontroller, memory, the communication interfaces: The communication interface is used for transmitting data from the BMU to external devices such PC system or human machine interface (HMI), or a battery management software. Human-machine interface is graphical user interface that permits or allow the operator to view and control the performance and battery current status, while the battery is in use. HMI also have ability to display various parameters such as voltage, temperature, current, state of charge and discharge in real-time.

Today, the use of drone for various application has been widely embraced by developing and developed nations and this cannot be unconnected to its ability to be fly using renewable energy battery, ability to be fly and be control without on board pilot, ability to maneuver easily, ability to fix on board camera and also, ability to travel to high altitude (Agha, S. et al., 2022) but the major constraint in the use of drone today, is the limitation in its battery power source and the monitoring aspect of its battery capacity while it is engaged in flight mode. (Arada, G. P. et al., 2014).

For most drone accident disasters, are usually caused by the system components, which may include, sudden, transmission signal cut-off between the transmitter and the receiver, faulting BLDC motor or battery voltage drop while in the drone is in flight mission. Generally, the overall functionality of a drone is highly dependent to battery capacity and its maintenance during its usage (Conference, N. et al., 2019). The common type of the battery used today in drones are lithium polymer battery. This type of battery is made up of cells e.g., 2s, 3s, or 5s. the higher the number of the cells the higher the amount of voltage and current it can produce (Corral, L. et al., 2016). One of the major advantages of lithium polymer battery, is that, its cells have about four times the energy density of a nickel cadmium or nickel metal hydride (Grey, C. et al., 2020). Lithium polymer battery is introduced to enable portable electronics, such that, it can be use in drones to serve as source of its power and its efficiency can be determine or maintain through or by observing the state of charge (SOC), state of discharge (SOD) and temperature variation while it's in state of used (Khofiyah, N. et al., 2019). Therefore, this research work focuses, on designing and development of automatic battery monitoring system with auto-return home, when the battery voltage threshold has drop to the level that cannot sustain or guarantee the safety of the drone with may lead to crashing, during flight mission.

II. REVIEW OF RELATED LITERATURE

Today battery monitoring system can be deployed for monitoring a renewable energy system, back-up power station, electric vehicle and also in portable electronic devices such as in drones by using a wireless data transmission approach. The result or the output obtained from the performance evaluation shows that, the research work was remarkable and interesting one because, the system designed, was able to monitor, control and transmit data in real-time from one point to another but the challenge is in the area of data transmission range. The system was only able to transmit data effectively, only when within 10meters apart (Mattada, M. et al., 2022). The assessment and control of a back-up power system as always being a challenge of all times. (Pham, N. N. et al., 2022) developed an automated battery monitoring system with a transmitter and receiver, the major achievement of the designed was that, the transmitter and the receiver were able to communicate effectively, without data lost but the constraint of the designed is that, the electronic circuit used for the system was not properly soldered and arranged, which over time will affect, the entire system functionality.

The use of drone today, for various applications has quiet achieved many significant but the major challenge to its use, is the ease in the probability of it to crash. (Roslan, N. F et al., 2020) designed and implemented an IOT base battery monitoring system with CAN BUS. The author, used distributed topology approach, allowing the slave module to monitor and protect multi-cell battery pack. The battery temperature, state of discharge, battery current and battery voltage were successful monitored and sent to the master module simultaneously. The design, lack an inbuild system application that can keep recording and saving of the battery reading parameters. The system built by (Series, C. 2020) Arduino uno microcontroller ADC port to convert analog battery voltage to its digital equivalence. The system was tested and fully implemented in electric vehicle and the result obtained was compared to that of multimeter direct measurement, which was found the same. This shows that, the objectives of the design were achieved as planned. For the creation of an effective and dynamic uninterrupted power supply, (Sharif, S. et al., 2015) constructed a smart power management system for uninterrupted power supply, by using microcontroller based intelligent uninterrupted power supply.

The system designed was used in a LAB viz, to monitor and control the switching of electrical appliance automatically, according to the available voltage in the UPS, during power failure. During performance evaluation test, the result achieved was satisfactory, because the power consumption rate reduces drastically and more energy is saved. The limitation of the work is that, there was a battery voltage fluctuation. Remote monitoring and control is the one of the most important requirements for maximizing process plant requirement (Wild, G. et al., 2017). For a diagnostic and data entrance monitoring purposes, in a battery monitoring system, the use of an indicator, that shows the continuous data coming in or receiving, compliment the system design. (Kumar, M. R. et al., 2018) implement a battery monitoring system, using a peripheral interface controller as a control unit with a universal asynchronous receiver/transmitter (UART) device. The major breakthrough of the design is that, the author, uses a liquid crystal display and a light emitting diode to show and display the measured parameters such as the battery state of discharge, current and voltage respectively but the design does not include the use of a prolific USB serial communication channel, which will enable the receiver to send onward data to PC system in order to achieve fast and reliable data deliver.

III. MATERIALS AND METHOD

This section deals with the entire system design analysis, material selection and system construction.

A. *Required Components*

The components required for this project is divided into hardware and software. The hardware part used include the following; Microcontroller (atmega328), HC_12 wireless Module, Voltage Regulator, Capacitor, Resistor and PCB Circuit. The software part includes; integrated Atmel Microchip programming software, VB.NET Programming Software and Proteus software.

B. *Methods*

Figure 1 shows the electric circuit diagram of the entire system hardware components used. The circuit illustrates how the reference battery voltage is connected to the transmitter circuit that handles the conversion of analog battery voltage to its digital equivalence. The microcontroller, sent the converted value to the wireless data module, which also sent same data to the receiver via air. The receiver is connected to the PC system by using prolific USB cable via PC serial port, for onward delivery of data to PC system. The VB.NET application, allowed for data collection, display, saved the said data and also permits or allowed data plotting through the use of Microsoft excel sheet. Following the required sequential steps, the microcontroller code was uploaded to the controller.

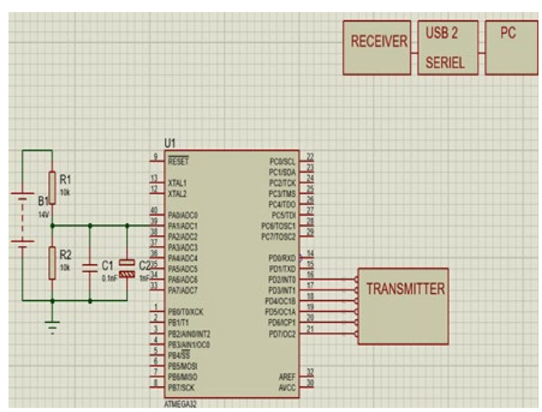

Figure 1: System Electric Circuit

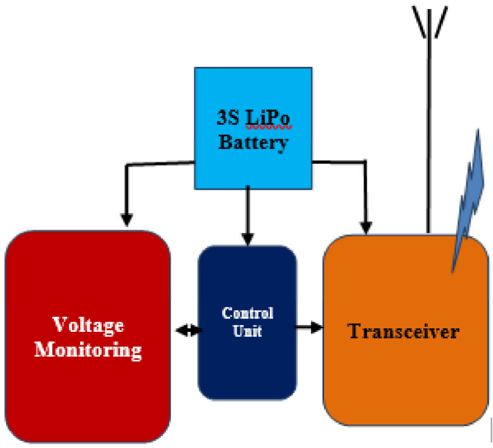

Figure 2: System Block Diagram

C. *System Construction Procedures*

The wireless data module VCC (power), GND (ground) are connected to 4.2volts via a diode and the module RX and TX pins are respectively connected to the microcontroller serial communication protocol in order to allow effective data transmission.

D. *System's Algorithm*

The Figure 3 is the algorithm of the system showing step by steps of how the system works. According to the flowchart, the Atmega ADC port sample the reference battery voltage, convert, and send to receiver. The receiver then, send to PC system and PC display the result through the use of VB.NET application.

E. *MATLAB Virtual Simulation Model of Analog to Digital Conversion (ADC)*

In the Battery state monitoring, the simulation model accurately captures the behaviour of the monitored battery, providing real-time data on parameters such as voltage, current, temperature, state-of-charge (SOC), and state-of-health (SOH). Figure 4 depicts the virtual simulation of the system designed; ADC toolbox MATLAB Simulink was used.

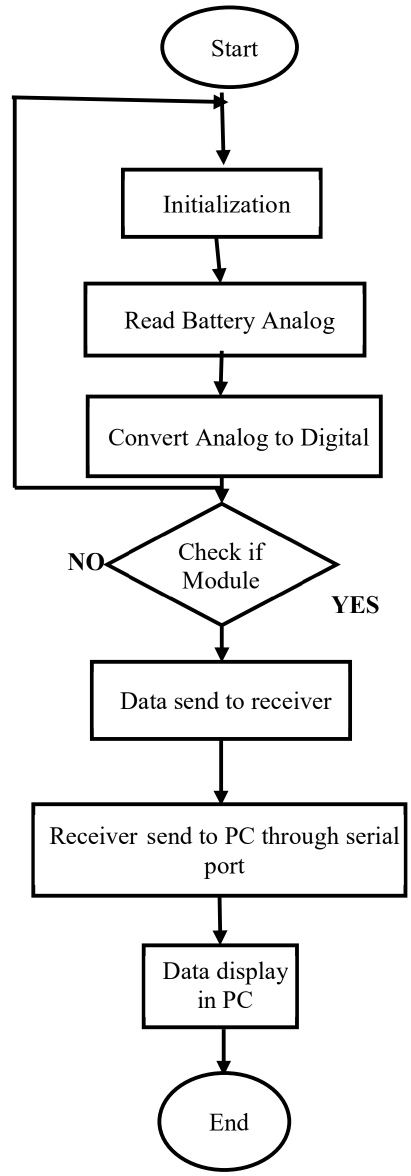

Figure 3: System Flowchart Diagram

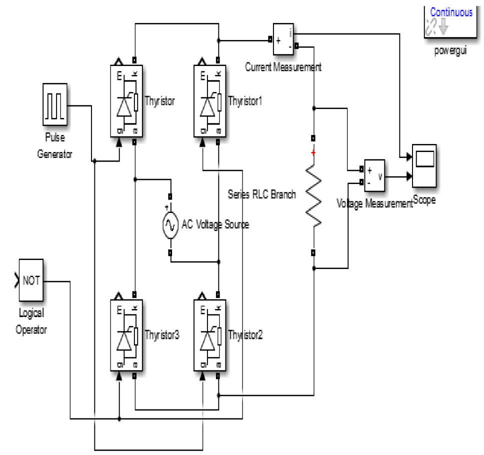

Figure 4: MATLAB Battery Simulink Model

F. VB.NET User Graphic Interface Application Design

Figure 5 depicts the VB.NET User graphic interface application design, it enables user for data collection, display store and graph plot.

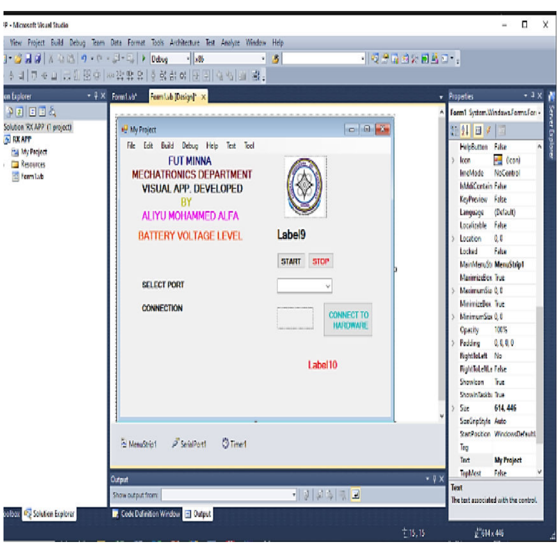

Figure 5: User Graphic Interface

IV. RESULTS AND DISCUSSION

Using the circuit diagram in Figure 1, a prototype of a battery monitoring system was developed. The system's design is depicted in Figure 6. It encompassed the voltage network divider to step down the reference battery voltage, the microcontroller to programmatically control every aspect of the system, a voltage regulator to control the voltage supply to the microcontroller, a transmitter and receiver for wireless signal communication, and a user graphic interface for data collection and storage.

Figure 6: System after final packaging

The Atmega328 ADC port pin enables the ADC sampling from the battery source and convert it to its digital equivalence through the transmitter and the result data is then send to the receiver through the use of wireless module. The final battery voltage reading is depicted in Figure 7 and is shown on a PC system using a VB.NET program. The continuous battery voltage reading value can also be recorded using the VB.net in an Excel spreadsheet, where the obtained values are plotted on a graph.

Figure 8 shows the analog to digital conversion. The amplitude of the graph represents the sine wave of the analog signal and the discrete part of the graph represent the analog digital equivalence. The signal was continuously sample, quantify and then produce its digital form equivalence.

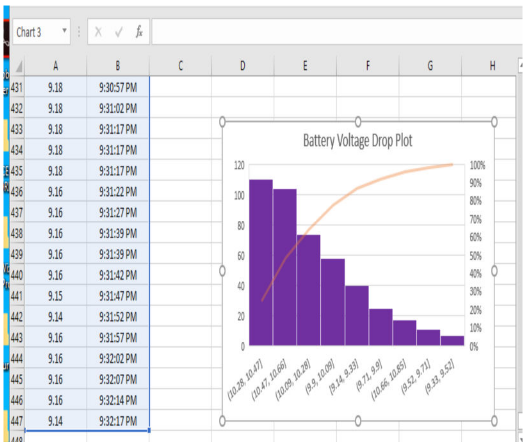

Figure 7: Battery Voltage Drop Plot

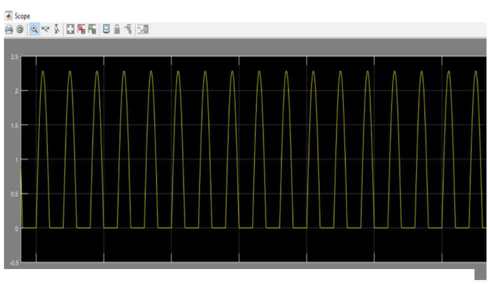

Figure 8: ADC Signal Conversion

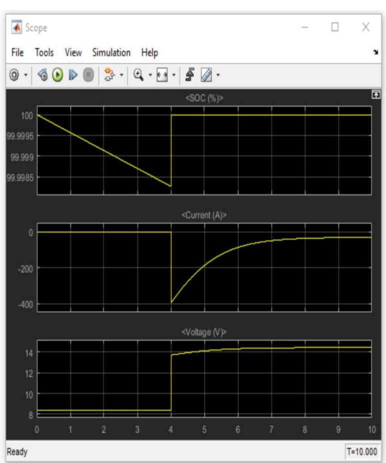

Figure 9: Battery Modelling

The charge state and discharge rate are shown in Figure 9. The first plot represents the battery status with a voltage amplitude of 100 volts, which indicates a charged battery, and over time it continues to slope downward as a result of the load connected to it. The second plot represents the current percentage and it maintains a steady state of 45% before it starts to drop downward, indicating that in the future, there will be a need for recharging. The final graphic displays the voltage state, by the chart, the voltage increases when the load is added from 0 to 100 percent and then gradually falls.

IV. CONCLUSION

As the use of drones to complete complex tasks has increased recently, it is crucial to make sure that the DC battery, which serves as the system's source of power, is a primary concern. The design and development of automatic battery monitoring with an auto-return home was carried out successfully by the earlier stated objectives.

To produce a fully working system design, each component of the system, including the transmitter, receiver, VB.NET app, and wireless data module, was all successfully interfaced.

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