# Design of an Automatic Battery Swapping System for E-Bikes with LCD Voltage Monitoring and Dual Battery Management

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**Abstract -** In recent years, electric bikes (e-bikes) have emerged as an eco-friendly and cost-effective alternative to conventional vehicles. A crucial challenge in the development of e-bikes is the management of battery life, as the limited charge capacity of a single battery may cause the vehicle to stop unexpectedly. This paper proposes an automatic battery swapping system for e-bikes, designed to seamlessly switch between two batteries to ensure continuous operation. The system monitors the battery voltage and automatically switches from Battery 1 to Battery 2 when the voltage level of Battery 1 drops below a pre-defined threshold. Additionally, an LCD display provides real-time battery voltage feedback to the rider. This approach not only maximizes battery life but also ensures that the e-bike runs smoothly with minimal rider intervention, as the batteries are only charged when their charge level falls below 20%. The circuit employs an Arduino microcontroller, voltage sensors, a relay, and an LCD display to manage and monitor the batteries.

***Key Words***: E-bike, Automatic Battery Swapping, Arduino, Dual Battery Management, LCD Display, Battery Voltage, Voltage Sensing, Relay Circuit, Battery Life, Renewable Energy.

## 1.INTRODUCTION

The growing popularity of electric vehicles, particularly electric bikes, is attributed to their efficiency, reduced environmental impact, and cost-effectiveness. However, one of the key concerns with e-bikes is the limited capacity and life span of their batteries. Typically, e-bike batteries have a limited range, which can affect their usability, especially for long-distance riders. A practical solution to address this issue is the implementation of a dual-battery system with an automatic switching mechanism. This system enables the e-bike to run continuously by switching to an alternative battery once the primary battery's charge level becomes insufficient.

This paper outlines the design and development of an automatic battery swapping circuit for e-bikes, leveraging Arduino-based control to manage the battery switching based on voltage levels. The system ensures that the e-bike operates efficiently while maintaining the health of the batteries by only charging them when their charge falls below a threshold.

## 2. LITERATURE REVIEW

Several studies and designs have explored different methods to improve the efficiency and longevity of e-bike batteries. One common approach is to use Battery Management Systems (BMS), which help monitor the voltage, temperature, and state of charge of a battery pack. However, these systems often focus on managing a single battery.

Dual-battery setups with manual switching have been explored, but there is limited research on fully automated systems that manage dual-battery configurations based on real-time voltage monitoring.

A study by M. Li et al. (2018) proposed a power management system for electric vehicles based on multiple battery packs, but the system required manual intervention. In contrast, a design by A. ElShafie et al. (2021) introduced an automated system that uses microcontrollers to monitor battery conditions and switch between battery packs.

These solutions laid the groundwork for this proposed design, which adds an LCD display for better user interaction and real-time monitoring of battery status.

## 3. PROPOSED SYSTEM

The proposed system utilizes an Arduino microcontroller (such as the Arduino Uno) as the central controller.

The circuit is designed to manage two batteries, automatically switching between them when the first battery's voltage falls below a certain threshold. The system consists of the following main components:

Arduino Microcontroller: Controls the system's logic and battery switching operation.

Voltage Sensors: Monitor the voltage levels of both batteries.

Relay: Acts as a switch to change the power source from one battery to another.

LCD Display: Provides real-time information on the battery voltage to the rider.

Power Supply Circuit: Ensures the Arduino and other components receive adequate power.

The core function of the system is to monitor the voltage levels of Battery 1 and Battery 2. When Battery 1's voltage drops below a set threshold (e.g., 20% charge), the system automatically switches to Battery 2 to maintain continuous power supply to the e-bike.

## 4. METHODOLOGY

The methodology for designing the automatic battery swapping system for e-bikes involves several steps, starting with the selection of key hardware components and progressing through the circuit design, programming, and integration of the system.

The central control unit is an Arduino microcontroller, chosen for its flexibility and ease of integration with various sensors and actuators. Voltage sensors are connected to the Arduino to continuously monitor the charge levels of two batteries. These sensors provide analog signals that the Arduino converts into digital values to assess the state of charge of each battery.

The system is designed to automatically switch from Battery 1 to Battery 2 when the voltage of Battery 1 falls below a pre-defined threshold, ensuring uninterrupted power supply for the e-bike. A relay is used to facilitate this battery switching, activated by the Arduino when the threshold is breached.

Additionally, an LCD display is integrated to provide real-time voltage readings of both batteries to the rider, allowing them to monitor battery performance. The Arduino program continuously reads the voltage from both batteries, compares it against the threshold, and triggers the relay to switch to Battery 2 when necessary.

This setup ensures that the e-bike operates smoothly, with minimal rider intervention, while preserving the longevity of the batteries by only charging them when their voltage falls below 20%. The system is designed to be simple, cost-effective, and user-friendly, automating battery management and enhancing the overall performance and efficiency of the e-bike.

## 5. FLOW CHART

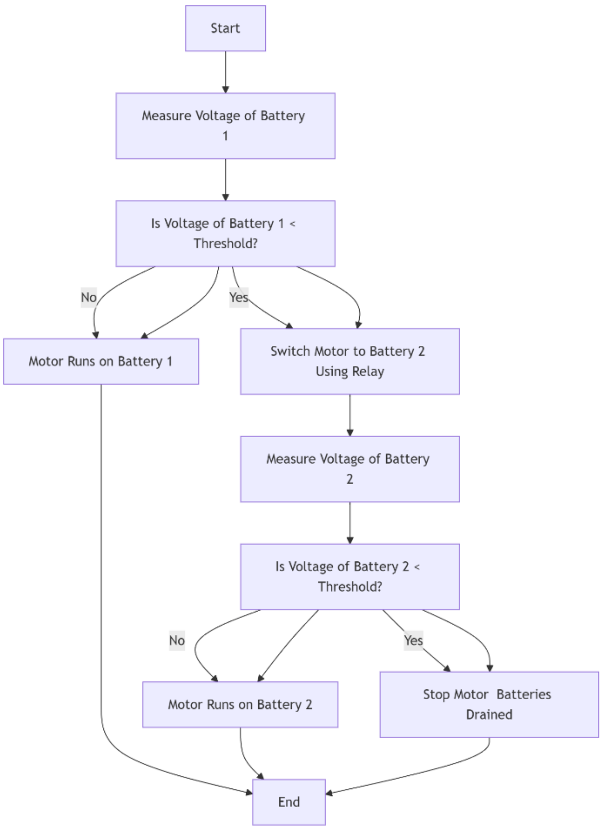



**Fig -1**: Figure

## 6. WORKING

The automatic battery swapping system for e-bikes works by continuously monitoring the voltage levels of two batteries using voltage sensors connected to an Arduino microcontroller.

The Arduino reads the voltage of Battery 1 and Battery 2 through analog-to-digital conversion. If the voltage of Battery 1 falls below a pre-defined threshold (e.g., 3.2V per cell), the system triggers a relay to switch the power source from Battery 1 to Battery 2, ensuring the e-bike continues to run without interruption.

The relay is activated by the Arduino, which uses its digital output pin to control the switching mechanism. At the same time, an LCD display shows real-time voltage readings of both batteries, providing visual feedback to the rider. This allows the rider to monitor the current status of the batteries. The system operates autonomously, automatically switching to Battery 2 when needed, without requiring manual intervention.

The battery switching process is seamless and transparent to the rider, helping prevent the e-bike from stopping unexpectedly due to a depleted battery. The system also contributes to preserving battery life by ensuring that batteries are only charged when their charge drops below 20%, optimizing their performance over time.

The continuous voltage monitoring and automatic switching ensure that the e-bike runs efficiently and reliably, enhancing the rider’s experience.

## 7. ARDUINO CODE

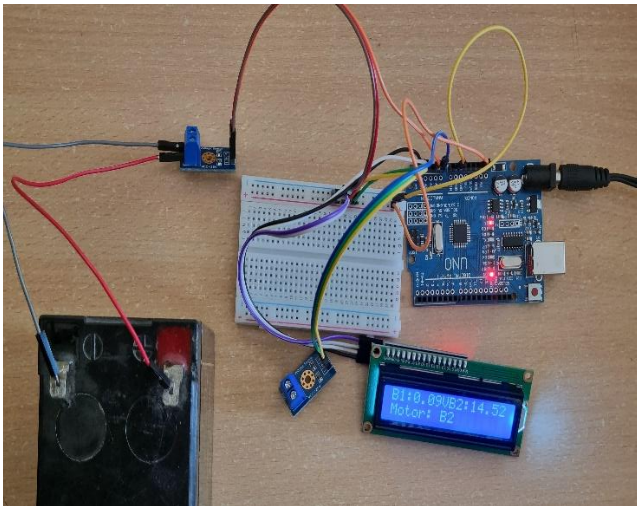
```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
// Initialize the LCD with I2C address 0x27, 16 columns, and
2 rows
LiquidCrystal_I2C lcd(0x27, 16, 2);
// Pin definitions
#define BATTERY_1_PIN A0
#define BATTERY_2_PIN A1
#define WARNING_PIN 7
// Voltage sensor calibration (adjust based on actual resistor
values)
const float VOLTAGE_DIVIDER_RATIO = 4.4;  // Adjust
this to match your voltage divider calculation
const float MAX_ADC_VALUE = 1023.0;       // 10-bit ADC
const float REF_VOLTAGE = 5.0;            // Arduino
reference voltage
const float LOW_VOLTAGE_THRESHOLD = 11.0; //
Voltage threshold for warning

void setup() {
  Serial.begin(9600);  // Start serial communication for
debugging
  pinMode(WARNING_PIN, OUTPUT);
  digitalWrite(WARNING_PIN, LOW);  // Ensure warning
signal is off initially
  // Initialize the LCD
  lcd.init();
```

```
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("Battery Monitor");
  delay(2000);
  lcd.clear();
}
void loop() {
  // Read analog values from sensors
  int sensorValue1 = analogRead(BATTERY_1_PIN);
  int sensorValue2 = analogRead(BATTERY_2_PIN);
  // Convert ADC values to voltage using adjusted calibration
factor
  float voltage1 = (sensorValue1 * REF_VOLTAGE /
MAX_ADC_VALUE) * VOLTAGE_DIVIDER_RATIO;
  float voltage2 = (sensorValue2 * REF_VOLTAGE /
MAX_ADC_VALUE) * VOLTAGE_DIVIDER_RATIO;
  // Display battery voltages on LCD
  lcd.setCursor(0, 0);
  lcd.print("B1:");
  lcd.print(voltage1, 2);
  lcd.print("V ");
  lcd.setCursor(8, 0);
  lcd.print("B2:");
  lcd.print(voltage2, 2);
  lcd.print("V ");
  // Set output pin based on Battery 1 voltage
  if (voltage1 >= LOW_VOLTAGE_THRESHOLD) {
    digitalWrite(WARNING_PIN, HIGH);  // Set output pin
HIGH
    lcd.setCursor(0, 1);
    lcd.print("Motor: B1       ");
  } else if (voltage2 >= LOW_VOLTAGE_THRESHOLD) {
    digitalWrite(WARNING_PIN, LOW);  // Set output pin
LOW
    lcd.setCursor(0, 1);
    lcd.print("Motor: B2       ");
  } else {
    digitalWrite(WARNING_PIN, LOW);  // Ensure warning
pin is LOW
    lcd.setCursor(0, 1);
    lcd.print("Charge Batteries");
  }
  // Debugging output
  Serial.print("Battery 1 Voltage: ");
  Serial.println(voltage1);
  Serial.print("Battery 2 Voltage: ");
  Serial.println(voltage2);
  Serial.print("Output Pin State: ");
  Serial.println(digitalRead(WARNING_PIN) ? "HIGH" :
"LOW");
  delay(1000);  // Update display every 2 seconds
```

## 9. FLOW CHART EXPLAINATION

1. Initialization (setup() function)
   - The LCD display is initialized to show messages to the rider.
   - The relay pins (relay1 and relay2) are set as output to control battery switching.
   - Battery 1 is initially active, so relay1 is set to HIGH (connected) and relay2 is set to LOW (disconnected).
   - The LCD prints "Battery 1 Active" at the start.
2. Loop Execution (loop() function)
   - The voltage of Battery 1 and Battery 2 is continuously monitored using analogRead().
   - Voltage Calculation:
     The analogRead() function gives a value between 0-1023, which is converted into actual voltage using the formula: Voltage=(Analog Read Value×5.01023.0)× 4.2\text{Voltage} = \left(\frac{\text{Analog Read Value} \times 5.0}{1023.0}\right) \times 4.2Voltage=(1023.0Analog Read Value×5.0 )×4.2
   - The calculated voltage values are displayed on the LCD screen.
3. Battery Switching Logic
   - If Battery 1 voltage drops below the threshold (e.g., 11.0V):
     - The system switches to Battery 2 by setting relay1 LOW and relay2 HIGH.
     - LCD updates to "Battery 2 Active".
   - Else, Battery 1 continues to power the motor, and the LCD keeps displaying "Battery 1 Active".
4. Final Condition (Both Batteries Drained)
   - If Battery 2 also falls below the threshold, the e-bike stops running as both batteries are depleted.
   - The system prevents deep discharge by switching off the motor when both batteries reach the low voltage threshold.

## 10. PHOTOGRAPH OF MODEL




## 11. CONCLUSION

The design of the automatic battery swapping system for e-bikes ensures uninterrupted operation by automatically switching between two batteries. The Arduino-based system provides a simple, cost-effective solution for managing dual-battery configurations.

By monitoring the battery voltage and switching at the appropriate threshold, the system also helps in preserving the battery life, as the batteries are only charged when their charge falls below 20%. This system enhances the overall usability and longevity of e-bikes, contributing to more sustainable electric transportation solutions.

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