E Bike Speed Controller Using STM 32

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***Abstract*—This project presents the design and implementation of an e-bike speed controller using the STM32 microcontroller. The proposed system utilizes the STM32's advanced features, such as PWM generation and motor control, to regulate the speed of an electric bicycle. The speed controller uses a Hall effect sensor to detect the motor's rotational speed and adjusts the PWM signal accordingly to achieve the desired speed. The system also incorporates a user interface, allowing riders to set their desired speed and monitor the e-bike's status. The STM32's 32-bit processing capabilities and real-time operating system ensure reliable and efficient control of the e-bike's speed. The proposed system provides a cost-effective, efficient, and reliable solution for e-bike speed control, enhancing the overall riding experience.**

Keywords: E-bike speed controller, STM32 microcontroller, PWM generation, motor control, Hall effect sensor.

I. INTRODUCTION

The increasing demand for environmentally friendly and sustainable transportation solutions has led to a significant rise in the popularity of electric bicycles (e-bikes). E-bikes offer a convenient, cost-effective, and eco-friendly alternative to traditional fossil fuel-based transportation methods. However, the performance and efficiency of e-bikes rely heavily on the effectiveness of their speed control systems.

1. Background: Conventional e-bike speed controllers often suffer from limitations such as poor efficiency, limited adjustability, and inadequate reliability. These limitations can result in reduced riding comfort, decreased battery life, and increased maintenance costs. To address these challenges, this project aims to design and develop an advanced e-bike speed controller using the STM32 microcontroller

2. Objective: The primary objective of this project is to create a high-performance, efficient, and reliable e-bike speed controller using the STM32 microcontroller. The proposed system will utilize the STM32's advanced features, such as PWM generation and motor control, to regulate the speed of an electric bicycle. The system will also incorporate a user interface, allowing riders to set their desired speed and monitor the e-bike's status.

3.Scope: The scope of this project includes the design, development, and testing of the e-bike speed controller using the STM32 microcontroller. The project will involve the following tasks:

Hardware design and development

2. Software development and programming

3. Testing and validation

4. Performance evaluation and optimization

Expected Outcomes

The expected outcomes of this project include:

1. A high-performance, efficient, and reliable e-bike speed controller

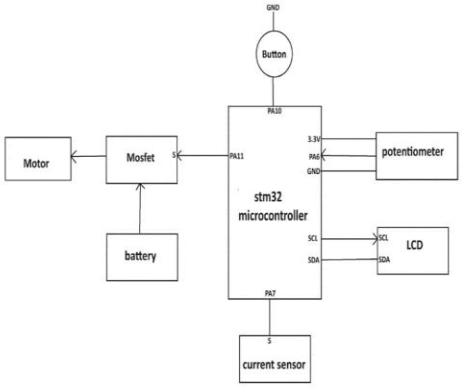
2. Improved riding comfort and experience

3. Increased battery life and reduced maintenance costs

4. A user-friendly interface for setting desired speed and monitoring e-bike status.

II.ORGANIZATION OF THE PAPER

This paper would discuss the basic idea of this research in section III “System Overview” with the aid of a block diagram. Further, the associated software and hardware is discussed in section IV. And then the findings of the research have been explained in section V "Results". And finally the paper concludes in the final section.



III. SYSTEM OVERVIEW

The block diagram of whole methodology has been shown in Fig.1. This diagram explains the methodology of the research conducted. In this study, the e-bike speed controller is a digital control system designed to regulate the speed of an electric bicycle. The system utilizes the STM32 microcontroller as its core component, which provides advanced features such as motor Regulate the speed of the e-bike based on user input and sensor feedback.

Regulate the speed of the e-bike based on user input and sensor feedback.

Optimize power consumption to maximize battery life and minimize heat generation. Ensure reliable operation and safety features, such as overcurrent protection and thermal monitoring.

STM32 Microcontroller Provides motor control, sensor interfaces, and communication protocols.

Comprises power MOSFETs, motor, and other power components. Includes Hall effect sensors, current sensors, and voltage sensors. Consists of LCD display, push buttons, and LED indicators. Provides regulated power to the system components.

The user sets the desired speed using the push buttons.

The sensor suite provides feedback on motor speed, current, and voltage. The STM32 microcontroller executes a control algorithm to regulate the motor speed. The STM32 microcontroller controls the power stage to adjust the motor speed.

The system monitors for faults and protects against overcurrent, overvoltage, and thermal overload.

Optimized power management for extended battery life. Reliable operation and protection against faults. Precise speed control and smooth acceleration. Intuitive user interface for easy operation.

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IV. HARDWARE AND SOFTWARE IMPLEMENTATION

A. Circuit and Logic

Fig.2 shows the STM32 microcontroller to power MOSFET(PWM signals)

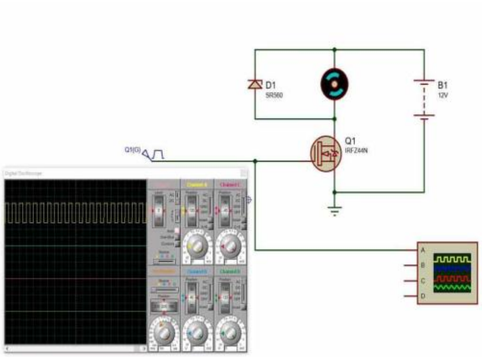

Fig.2. PMW Signal

Fig.3. shows the Power MOSFETs to motor (power stage)

Optimized power management for extended battery life. Reliable operation and protection against faults. Precise speed control and smooth acceleration. Intuitive user interface for easy operation.

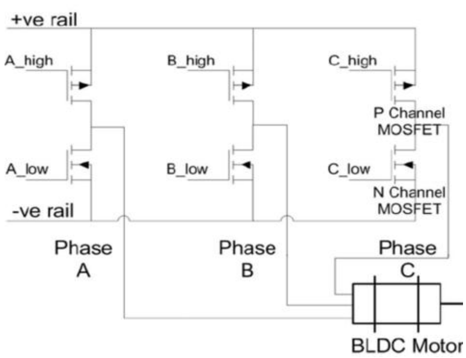

Fig.3. MOSFETS in the power stage

The conditions required to achieve MOSFET activation are as follows (A phase is taken as an example)

For N Channel MOSFET activation: VA_low V-ve_rail + VGS(th) where VGs(th) is the Gate-Source threshold voltage given in the MOSFET data sheet.

For P Channel MOSFET activation: VA_high≤V+ve_rail - VSG(th) to accomplish the required voltage on the P Channel from a TTL control circuit, an extra driving circuit is required for this MOSFET. This circuit consists of a BJT (bi-polar transistor) shown in Fig. 3. Consists of LCD display, push buttons, and Fig.4. shows the Hall effect sensors to STM32 microcontroller (motor position and speed feedback)

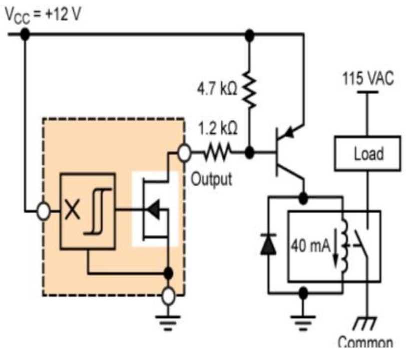

Fig.4.Hall effect sensors

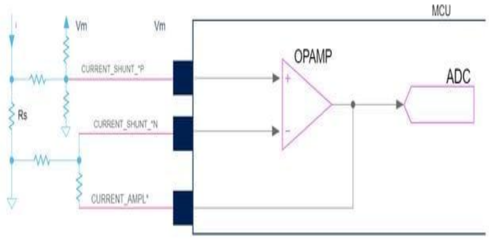

Fig.5. Current sensors

Fig.6. Shows the Voltage sensor to STM32 microcontroller (battery voltage feedback)

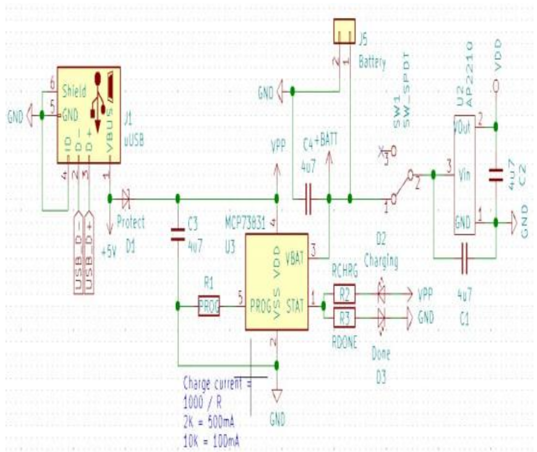

Fig.6. Voltage sensors

Fig.7. Shows the LCD display to STM32 microcontroller (display interface)

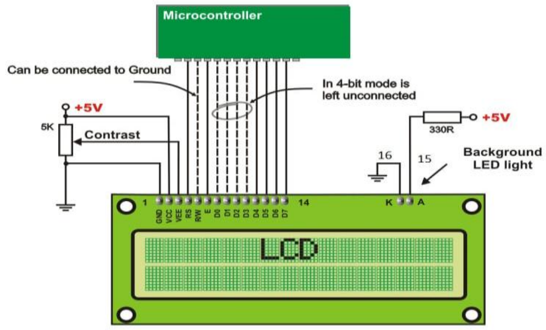

Fig.7 .LCD display

Fig.8. Shows the Push buttons to STM32 microcontroller (user controller)

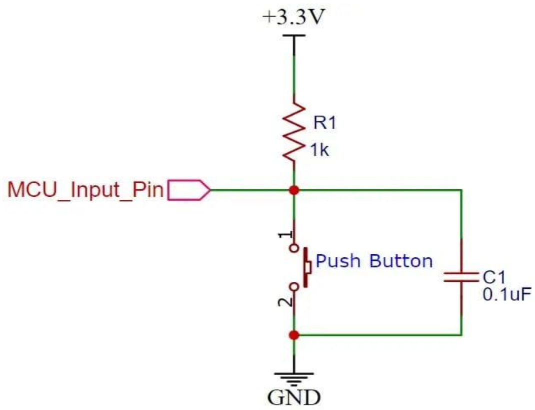

Fig.8. Push buttons STM32 microcontroller

B. Battery state of Charge Estimation:

Battery SOC estimation is a critical component of an e-bike speed controller, as it enables the system to accurately determine the remaining battery capacity and prevent over-discharge.

Methods for Battery SOC Estimation

There are several methods for battery SOC estimation, including. This method involves measuring the charge and discharge currents and calculating the accumulated charge.

This method involves measuring the battery voltage and estimating the SOC based on the voltage-charge relationship.

This method involves using a Kalman filter algorithm to estimate the SOC based on the battery voltage, current, and temperature. This method involves using machine learning algorithms to estimate the SOC based on historical data. Implementation on STM32

For the e-bike speed controller using STM32, we will implement a Coulomb counting-based SOC estimation method.

A current sensor (e.g., ACS758) is required to measure the charge and discharge currents.

A voltage sensor (e.g., TLV6001) is required to measure the battery voltage. Initialize the SOC to a default value (e.g., 100%).Measure the charge and discharge currents using the current sensors .Calculate the accumulated charge by integrating the current over time. Update the SOC based on the accumulated charge and the battery capacity. Effects on the battery capacity. STM32 Code Snippet code snippet in C that demonstrates the Coulomb counting-based SOC estimation method on STM32 sensors, current sensors, and voltage sensors.

Consists of LCD display, push buttons, and LED

C. Process Flow:

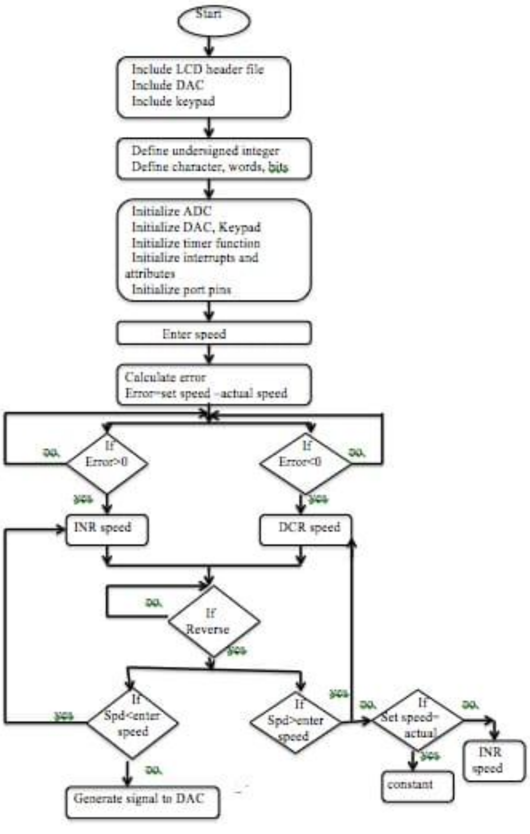

Fig.9. Flow chart of Speed Control System

Fig 9 shows the flow chart of speed control system. The system powers on, and the STM32 microcontroller initializes. The STM32 microcontroller configures the clock settings.

The STM32 microcontroller initializes the peripherals, such as the GPIO, TIM, and ADC.

The STM32 microcontroller configures the interrupts.

The user inputs the desired speed using the throttle or pedals. The system reads the sensor data, including:

- Motor speed and position (Hall effect sensors)
- Motor current (current sensors)
- Battery voltage and temperature (voltage and temperature sensors)

The STM32 microcontroller executes the control algorithm, which includes:

- Speed control (PID or FOC)
- Current limiting
-Battery management (SOC estimation, charging/discharging control) The STM32 microcontroller generates the PWM signals to control the motor speed. The PWM signals are sent to the motor controller, which drives the motor.

The TIM ISR is triggered at regular intervals (e.g., 1 kHz) to update the motor control algorithm. The ADC ISR is triggered when the ADC conversion is complete to update the sensor readings. The UART ISR is triggered when data is received from the user interface throttle or pedals The system powers off, and the STM32 microcontroller shuts down. The STM32 microcontroller disables the peripherals.

D. Battery Modelling:

Battery modeling is a critical component of an e-bike speed controller, as it enables the system to accurately estimate the battery's state of charge (SOC), state of health (SOH), and remaining capacity. Battery Model Types

There are several types of battery models, including, These models represent the battery as a circuit of resistors, capacitors, and voltage sources.

These models simulate the electrochemical reactions within the battery. These models use experimental data to estimate the battery's behavior.

Battery Model Parameters

The battery model. The voltage across the battery terminals when it is not connected to a load. The resistance within the battery that affects its ability to supply current.

The total amount of charge that the battery can store.

The percentage of the battery's capacity that is currently available. Battery Modeling Using STM32

To implement battery modeling using STM32, you can follow these steps:

Select a suitable battery model based on your requirements. Measure or estimate the model parameters, such as OCV, Ri, C, and SOC.

IV. MATHEMATICAL EQUATION

1. Motor Voltage:

$$V_m = R_m * I_m + L_m * (dI_m/dt) + E_m$$

where:
V_m = motor voltage
R_m = motor resistance
I_m = motor current
L_m = motor inductance
E_m = motor back-EMF

2. Motor Torque:

$$T_m = K_t * I_m$$

where:
T_m = motor torque
K_t = motor torque constant

Speed Control
The speed control algorithm can be represented by the following equations:

1. Speed Error:

$$e = \omega_{ref} - \omega_m$$

where:
e = speed error
ω_{ref} = reference speed
ω_m = motor speed

2. PI Controller

$$u = K_p * e + K_i * \int e \, dt$$

where:
u = control output
K_p = proportional gain
K_i = integral gain

Battery Model

The battery model can be represented by the following equations:

1. Battery Voltage

$$V_b = OCV - R_i * I_b$$

where:
V_b = battery voltage
OCV = open-circuit voltage
R_i = internal resistance
I_b = battery current

2. Battery State of Charge (SOC)

$$SOC = (1 - (V_b - OCV) / (R_i * I_b)) * 100$$

where:
SOC = state of charge (%)

STM32 Implementation
The above equations can be implemented on the STM32 microcontroller using C code. The implementation involves
Reading data from sensors such as motor current, motor speed, and battery voltage.
Calculating the control output using the PI controller equation.
Updating the motor control signals based on the control output.
Displaying data such as motor speed, battery voltage, and SOC on an LCD display.

V. RESUILTS

A. Simulation output

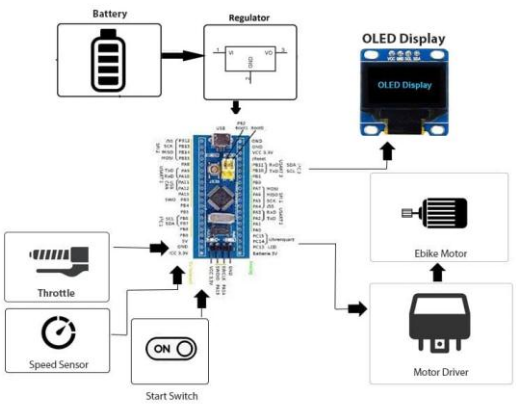

Fig.10. E-bike speed controller system using STM 32

The system detects the speed of the vehicle in which the controller act as the main source to restrict the vehicle's speed. This project deals with controlling the speed through the throttle. The input power will cut off when the vehicle reaches the speed limit. This leads to an efficient energy management system. In addition to it, the battery range will increase. The power drain system of the vehicle is also upgraded using the stm32.

B. Hardware output

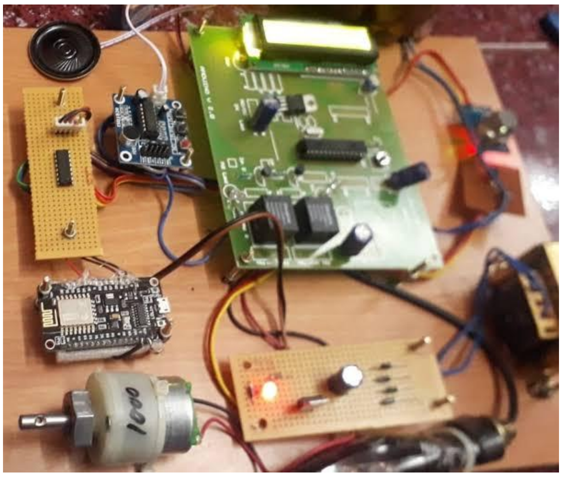

Fig.11. Hardware output

VI. CONCLUSION AND FUTURE IDEAS

Thus, The Throttle signal is processed by the controller, and it then operates the motor through the motor driver. The motor voltage is varied as per throttle values to control its power and speed. Also, the controller constantly monitors speed sensor values. The speed sensor works on the Hall Effect principle to constantly transmit the wheel RPM. This RPM value is displayed on the LCD by the controller. The motor speed and sensor monitoring are turned off when the main switch is turned off. The complete process restarts the switch is turned on. Thus, we successfully develop and test our own E-bike controller using STM32. This project can he broken down into five separate categories: the lithium-ion battery, the DC-DC boost converter, the solar panel, the motor, and the motor controller Each of these will be built upon and improved further by future students, one category at a time. The hope is that this design can become very efficient, cost-effective, and one day mass-produced, especially in developing countries where automotive transportation is impossible.

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