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Automatic Hair Dryer with Temperature and Speed Control

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Abstract - This project develops a wirelessly connected hair drying system that automatically adjusts airflow speed based on real-time hair moisture detection through integration with existing hair dryer units. The system employs ESP32 microcontroller as the central processing unit with built-in Wi-Fi capability for cloud connectivity and mobile application interface. Capacitive moisture sensors continuously monitor hair wetness levels and transmit data to the ESP32 which processes the information through adaptive algorithms. DS18B20 temperature sensors monitor thermal output while solid-state relays control the heating element through PWM signals. Motor speed regulation utilizes to modulate AC motor performance across three operational levels high speed for very wet hair conditions, medium speed for moderately damp hair and low speed for nearly dry hair conditions. The touch control interface integrates mounted on the dryer surface for manual operation while the mobile application communicates through Firebase cloud platform enabling remote parameter adjustment. An OLED display module presents real-time operational data including moisture levels and temperature readings. The integration process involves mounting the moisture sensor near the dryer nozzle, installing temperature sensors adjacent to heating elements and housing the ESP32 module within the dryer handle.

Keywords— Capacitive moisture sensor, DS18B20 sensor, ESP32, Heating element.

I. INTRODUCTION

Hair dryers are widely used personal care appliances in domestic and commercial environments for drying hair efficiently. Conventional hair dryers operate based on manual control, where users adjust temperature and speed settings without any feedback regarding hair moisture or temperature conditions. This often results in excessive heat exposure, leading to hair damage, discomfort, and unnecessary energy consumption. With increasing awareness of energy efficiency and personal safety, there is a growing demand for intelligent personal care appliances that can adapt their operation according to real-time conditions.

Recent advancements in embedded systems and sensor technologies have enabled the development of smart control systems capable of monitoring environmental and physical parameters accurately. Sensors such as temperature sensors and moisture sensors provide real-time data that can be processed by microcontrollers to assist in decision-making. In particular, temperature monitoring is crucial in appliances involving heating elements, as uncontrolled heat can cause material degradation and safety hazards. Similarly, moisture sensing helps determine the actual drying requirement, preventing overuse of heat once the desired dryness is achieved.

The ESP32 microcontroller has emerged as a powerful and cost-effective platform for smart appliance control due to its high processing capability, low power consumption, and support for multiple peripherals. When combined with reliable sensors such as the DS18B20 temperature sensor and capacitive moisture sensors, ESP32-based systems can effectively monitor and regulate appliance operation. Although fully automatic systems exist, manual intervention is still preferred in many household devices for safety, simplicity, and user confidence.

This project proposes an Automatic Hair Dryer with Temperature and Speed Control that integrates sensor-based monitoring with manual speed selection. The system continuously measures hair moisture and air temperature and provides guidance for selecting low or high speed using a manual switch. This hybrid approach ensures user control

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while improving safety, efficiency, and drying performance. By minimizing excessive heat exposure and optimizing drying time, the proposed system contributes to improved hair care and reduced energy consumption. The design is simple, economical, and suitable for practical implementation in household appliances.

Fig. 1: Illustration of the impact of Hair dryer

II. LITERATURE REVIEW

Chen W et al., (2023) introduced their work on Temperature Monitoring and Control System Using DS18B20 Sensor for Industrial Applications to Journal of Instrumentation and Control Engineering. This study focuses on the implementation of the DS18B20 digital temperature sensor for accurate temperature monitoring in industrial environments. The authors highlight the sensor's high precision, digital communication capability, and resistance to noise, making it suitable for harsh conditions. A microcontroller-based control system was developed to regulate temperature automatically based on sensor feedback.

Boureima et al., (2025) developed Experimental Study of a Direct Solar Dryer with an Automatic Temperature Control System to International Journal of Research and Review. This research presents the design and experimental analysis of a solar dryer equipped with automatic temperature control to improve drying efficiency. The study emphasizes the importance of maintaining optimal temperature levels to achieve uniform drying while minimizing energy usage. By incorporating sensors and control logic, the system adjusts operating conditions based on real-time feedback. Although the application focuses on solar drying, the underlying concept of temperature-controlled drying is directly applicable to hair dryers.

Kumar A Patel R Singh M (2024) developed ESP32-Based IoT Framework for Home Automation and Remote Monitoring Systems to International Journal of Advanced Computer Science and Applications.This paper explores the use of the ESP32 microcontroller as a central controller for smart home automation systems. The authors discuss ESP32's processing power, flexibility, and ability to interface with multiple sensors and actuators. The system architecture demonstrates reliable sensor data acquisition and real-time decision-making. Although IoT connectivity is emphasized, the core contribution of this work is the effective utilization of ESP32 for embedded control applications. This research supports the selection of ESP32 for the proposed hair dryer system, as it efficiently handles sensor inputs such as temperature and moisture values while controlling output devices like relays or motor drivers.

Patel et al., (2023) presented PWM-Based Motor Speed Control Using Microcontroller for Energy Efficient Systems to International Journal of Electrical and Electronics Engineering. This paper discusses the use of PWM techniques for controlling motor speed efficiently using microcontrollers. The authors demonstrate how speed control reduces power consumption and improves system performance. Although the proposed hair dryer uses discrete low and high speed control with manual switching, the principles of controlled motor operation discussed in this study are applicable. The research highlights the importance of matching motor speed with actual requirements, which supports the moisture-based speed selection approach used in the proposed system.

Sharma et al., (2022) investigated Solid-State Relay Applications in Smart Home Heating Control Systems to IEEE Transactions on Consumer Electronics. This research focuses on the use of solid-state relays for controlling heating elements in smart home applications. The study highlights advantages such as fast switching, reliability, and electrical isolation. This work is relevant to the proposed hair dryer system, where relays or solid-state devices are required to control high-power AC loads safely. The findings support the safe integration of microcontroller-based control with heating appliances.

Thompson et al., (2023) analyzed Heat Damage Prevention in Hair Care through Intelligent Temperature Regulation to International Journal of Cosmetic Science. This study examines the effects of excessive heat on hair structure and emphasizes the importance of intelligent temperature regulation in hair care devices. The authors conclude that controlled temperature exposure significantly reduces hair damage and improves user comfort. This research directly supports the motivation for the proposed project, as it highlights the necessity of monitoring and controlling temperature in hair dryers. The findings validate the use of temperature sensors and controlled operation to enhance hair safety and overall appliance performance.

III. DESCRIPTION OF THE EXISTING SYSTEM

The existing hair dryer system operates purely on manual control. Users select low or high speed and temperature settings using mechanical switches without any feedback regarding hair moisture or temperature levels. The heating element continues to operate as long as the dryer is switched on, regardless of whether the hair is already dry. This lack of feedback makes the system inefficient and highly dependent on user judgment. Additionally, traditional hair dryers do not include any safety mechanisms to regulate temperature dynamically. Continuous operation at high temperature may cause hair damage and discomfort to the user. Energy consumption is also higher due to unnecessary heating, making the existing system inefficient and outdated.

IV. CHALLENGES IN THE EXISTING SYSTEM

One of the major challenges in the existing system is the absence of moisture detection, which leads to over-drying of hair. Excessive heat exposure can weaken hair structure and cause long-term damage. Another challenge is energy wastage due to continuous heating even after drying is complete. Manual operation also increases the risk of overheating, especially when users are unaware of optimal drying conditions. Safety concerns arise due to the lack of real-time temperature monitoring. The system does not adapt to environmental changes or user requirements, making it inefficient. These challenges highlight the need for an improved system that incorporates intelligent monitoring and control features.

V. PROPOSED SYSTEM

The proposed system is an Automatic Hair Dryer with Temperature and Speed Control designed to overcome the limitations of conventional manual hair dryers by incorporating sensor-based monitoring and embedded control. The system aims to enhance user safety, improve energy efficiency, and prevent hair damage by regulating the drying process based on real-time temperature and moisture conditions while retaining manual speed selection for reliability and ease of use.

At the core of the system is the ESP32 microcontroller, which functions as the main control and processing unit. The ESP32 continuously collects data from two sensors: a DS18B20 digital temperature sensor and a capacitive moisture sensor. The temperature sensor is positioned to measure the hot air temperature near the hair dryer outlet, ensuring that the temperature remains within safe operating limits. The capacitive moisture sensor detects the moisture level in the hair, allowing the system to identify whether the hair is wet, partially dry, or nearly dry.

The sensor data acquired by the ESP32 is processed in real time and displayed on a serial monitor connected to a laptop. This provides clear feedback to the user regarding current temperature and moisture conditions. Based on the moisture level, the system assists the user in selecting the appropriate operating mode. High-speed operation is recommended when the moisture level is high to enable faster drying, while low-speed operation is suggested when the moisture level decreases to prevent excessive heat exposure. Unlike fully automatic systems, speed control in the proposed design is achieved through a manual switch. Electrical isolation between the low-voltage control circuitry and the high-voltage AC load is ensured through this switching arrangement.

Overall, the proposed system combines intelligent sensing with manual control to provide a practical, economical, and user-friendly solution for modern hair drying applications. The design reduces energy consumption, minimizes hair damage, and improves overall drying efficiency, making it suitable for both domestic and professional use. Duty cycle modulation. The driver's internal protection features including over- temperature shutdown and fly back diodes protect both the motor and control electronics from voltage spikes generated during motor switching operations.

VI. BLOCK DIAGRAM

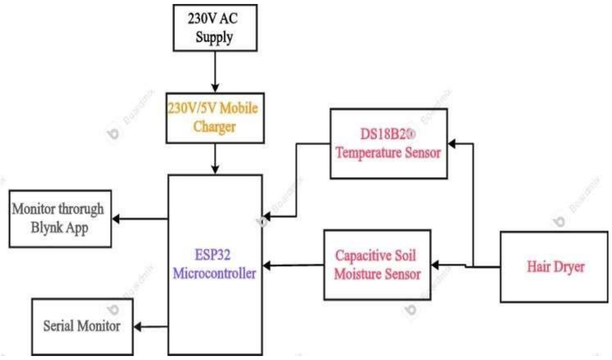

Fig.2. Block Diagram of the Proposed System

Hardware Implementation

Below mentioned hardware components are used for the development of the Proposed System of Automated Water tank cleaning system using ESP32 Controller
ESP32
DS18B20 Temperature Sensor
Capacitive Moisture Sensor
Connecting Wires

ESP32
The ESP32 is a powerful, low-cost microcontroller with built-in Wi- Fi and Bluetooth capabilities. It serves as the central processing unit of your water tank cleaning system. Operates at 3.3V logic level, can be powered via 5V input. The ESP32 development module is a powerful, low-cost microcontroller featuring a dual-core 32-bit operating at frequencies up to 240 MHz, providing exceptional processing capabilities for IOT applications.

DS18B20 Temperature Sensor

DS18B20 Temperature Sensor
The DS18B20 is a digital temperature sensor known for its high accuracy and stability. It uses a one-wire communication protocol, allowing easy interfacing with the ESP32 using a single data line. The sensor provides precise temperature measurements, which are essential for preventing overheating in hair dryers. Its digital output minimizes noise and ensures reliable temperature monitoring throughout operation.

DS18B20 Temperature Sensor

Capacitive Moisture Sensor
The capacitive moisture sensor is used to detect moisture content without direct electrical contact with water. It operates based on changes in capacitance caused by moisture presence. In this project, the sensor helps identify whether the hair is wet or dry. Moisture detection enables optimized drying by assisting in selecting appropriate speed levels, reducing over-drying and heat damage.

Capacitive Moisture Sensor
Connecting Wires
A jump wire, also known as a jumper, jumper wire, jumper cable, DuPont wire, or cable, is an electrical wire or cable with connectors or pins at each end. It's primarily used to interconnect components on a breadboard or prototype for testing purposes. In electronics and computing a jumper refers to a short length of conductor that closes opens or bypasses part of an electronic circuit.

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Figure.6. Connecting Wires

Working Of Proposed System

The working of the proposed Automatic Hair Dryer with Temperature and Speed Control is based on continuous sensing of temperature and moisture conditions using sensors interfaced with the ESP32 microcontroller and assisting the user in selecting the appropriate speed through manual switching. The system operates in a structured and safe manner by separating low-voltage control circuitry from the high-voltage hair dryer circuit.

Figure.7. Proposed System

Operation Proposed System

When the system is powered ON, a regulated 5 V supply is provided to the ESP32 microcontroller and sensors. The ESP32 initializes all configured GPIO pins and prepares the system for operation. The capacitive moisture sensor is connected to GPIO 34, which is an analog input pin of the ESP32. This pin continuously reads the analog voltage from the moisture sensor, which varies according to the moisture content present in the hair. Higher moisture levels produce higher analog values, indicating wet hair conditions. The DS18B20 temperature sensor is interfaced with the ESP32 using a single data line along with a 4.7 kΩ pull-up resistor connected between the data line and 3.3 V supply. This resistor ensures reliable one-wire communication between the ESP32 and the temperature sensor. The DS18B20 measures the real-time temperature of the hot air produced by the hair dryer and sends accurate digital temperature values to the ESP32.

The ESP32 continuously processes the moisture and temperature data and displays these values on the serial monitor connected to a laptop. Based on the moisture sensor reading, the system determines the drying stage. When the moisture value indicates a wet condition, the system recommends high-speed operation. When the moisture value falls below a predefined threshold, indicating partially dry or dry hair, the system recommends low-speed operation to prevent overheating and hair damage. Speed control is implemented using two relay control outputs. The user selects the appropriate speed using a manual switch based on the system's guidance. During operation, the ESP32 continuously monitors the temperature value from the DS18B20 sensor. If the temperature exceeds a predefined safe limit, the system alerts the user through the serial monitor and restricts prolonged high-speed operation. This ensures thermal safety and prevents damage to hair and the appliance. The drying process continues with continuous monitoring until the moisture sensor indicates a fully dry condition. The user can then manually switch OFF the hair dryer. Thus, the proposed system provides efficient drying, improved safety, and optimized energy usage by combining sensor-based monitoring with ESP32-controlled relay operation.

VII. RESULTS AND DISCUSSIONS

The Automatic Hair Dryer with Temperature and Speed Control was successfully designed, implemented, and tested using an ESP32 microcontroller, a DS18B20 temperature sensor, and a capacitive moisture sensor. During testing, the system was able to accurately sense real-time temperature and moisture values and display them on the serial monitor connected to a laptop. The ESP32 effectively processed sensor data through GPIO 34 for moisture sensing. When the moisture sensor detected high moisture levels, the system correctly indicated the wet condition and assisted the user in selecting high-speed operation. As the moisture level gradually decreased, the system identified partially dry and dry conditions and recommended low-speed operation. This ensured a smooth transition between speed modes, preventing excessive heat exposure.

VIII. CONCLUSION

This project successfully demonstrates the design and implementation of an Automatic Hair Dryer with Temperature and Speed Control using embedded systems and sensor technology. By integrating a capacitive moisture sensor and a DS18B20 temperature sensor with an ESP32 microcontroller, the system provides real-time monitoring and assisted speed control for hair drying applications. The hybrid approach of sensor-based guidance combined with manual speed selection ensures safety, simplicity, and reliability. The proposed system effectively addresses the limitations of conventional hair dryers by preventing over-drying, reducing excessive heat exposure, and optimizing energy consumption. Electrical isolation using relay-based switching enhances operational safety, making the system suitable for household and salon use. The results validate that intelligent monitoring improves drying performance without increasing system complexity or cost. In conclusion, the Automatic Hair Dryer with Temperature and Speed Control offers a practical and efficient solution for modern personal care appliances. The system can be further enhanced with full automation, advanced power control techniques, and user interface improvements, making it a strong foundation for future smart appliance development.

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