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Design and Implementation of a Real-Time Embedded Automation System for Industrial Sorting Applications

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Abstract: ***This paper describes the development of a real-time embedded automation system designed for small to medium-sized industrial settings. It uses an ARM Cortex-M4-based microcontroller to manage a sensor-driven sorting mechanism on a conveyor system. Real-time task management is achieved with FreeRTOS. The system supports remote data monitoring through IoT using NodeMCU and the MQTT protocol. This solution reduces manual effort, improves sorting accuracy, and boosts overall production efficiency.***
Keywords: Embedded Automation, Real-Time Systems, ARM Cortex, FreeRTOS, IoT, MQTT, STM32, Industrial Sorting.

I. INTRODUCTION

Industrial environments increasingly rely on automation to ensure consistent output and minimize human error. Embedded systems are ideal for controlling these operations because of their low power consumption and quick response times. This project presents a real-time automation solution for sorting materials based on sensor feedback. The system integrates FreeRTOS for task scheduling and IoT for remote monitoring, making it suitable for modern industrial uses.

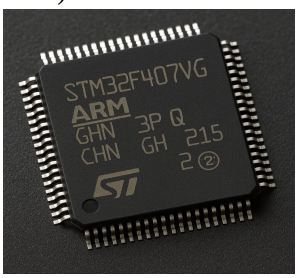
II. BACKGROUND AND MOTIVATION

Previous automation solutions have effectively managed temperature, motion, and robotic systems. However, many lacked accurate real-time control or the ability to monitor system performance from a distance. This work addresses that gap by combining a real-time operating system with a lightweight IoT communication protocol, improving both responsiveness and connectivity.

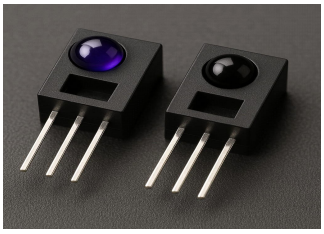
III. SYSTEM OVERVIEW

A. Hardware Components

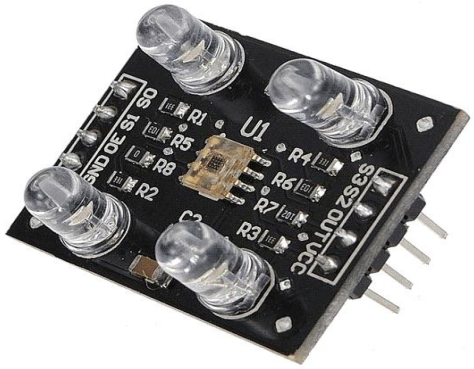
- STM32F407VG microcontroller (ARM Cortex-M4 core)



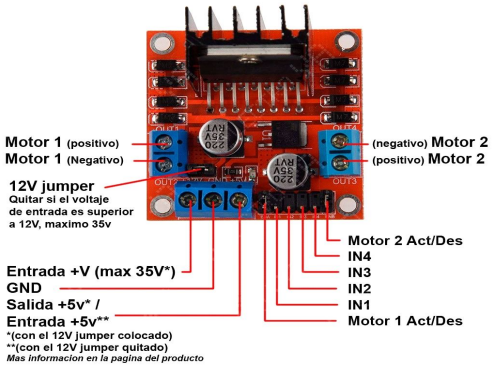
- Infrared proximity sensors



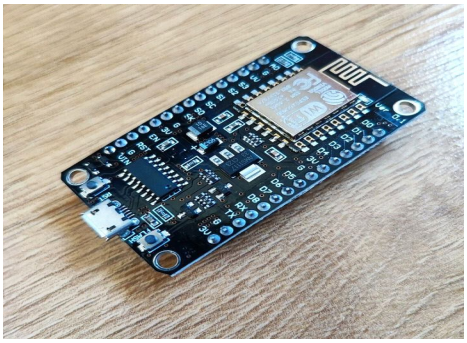
- TCS3200 color sensor



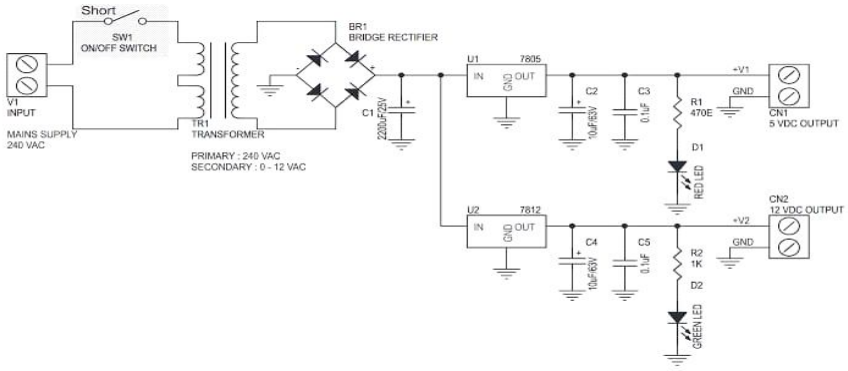
- DC motors with L298N motor driver



- ESP8266 (NodeMCU) for Wi-Fi connectivity



- 12V regulated power supply



B. Software Tools

- FreeRTOS (for real-time task scheduling)
- STM32CubeIDE (for firmware development)
- Arduino IDE (for NodeMCU programming)
- MQTT Dashboard (for remote monitoring)

C. System Block Flow

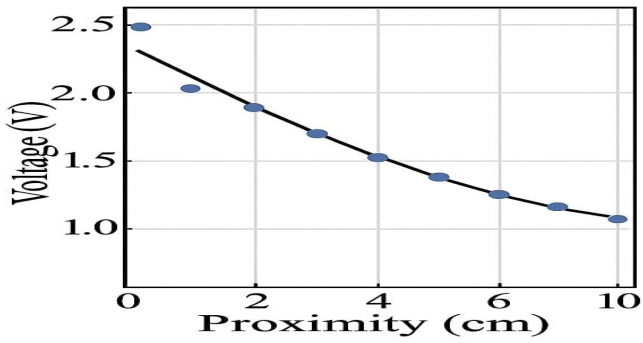
[IR + Color Sensors] → [STM32 MCU] → [Motor Driver & Actuators]
↓
[NodeMCU WiFi] → [MQTT Cloud Server]

IV. IMPLEMENTATION STRATEGY

1) Sensor Polling Task: Continuously reads data from the proximity and color sensors.
2) Sorting Task: Uses sensor inputs to control different motors and direct materials accordingly.
3) IoT Communication Task: Sends status information to an online MQTT broker at regular intervals.
4) FreeRTOS Scheduler: Manages execution timing to ensure tasks respond quickly and do not interfere with each other.

V. RESULTS

1) Maximum Latency: 50 milliseconds from object detection to actuation .
2) Sorting Accuracy: Achieved a 98.5% success rate in a test run of 200 samples .
3) IoT Monitoring: System status updates visible every 2 seconds through the MQTT dashboard .
4) Advantages: Real-time multitasking, modular design, remote access capability .



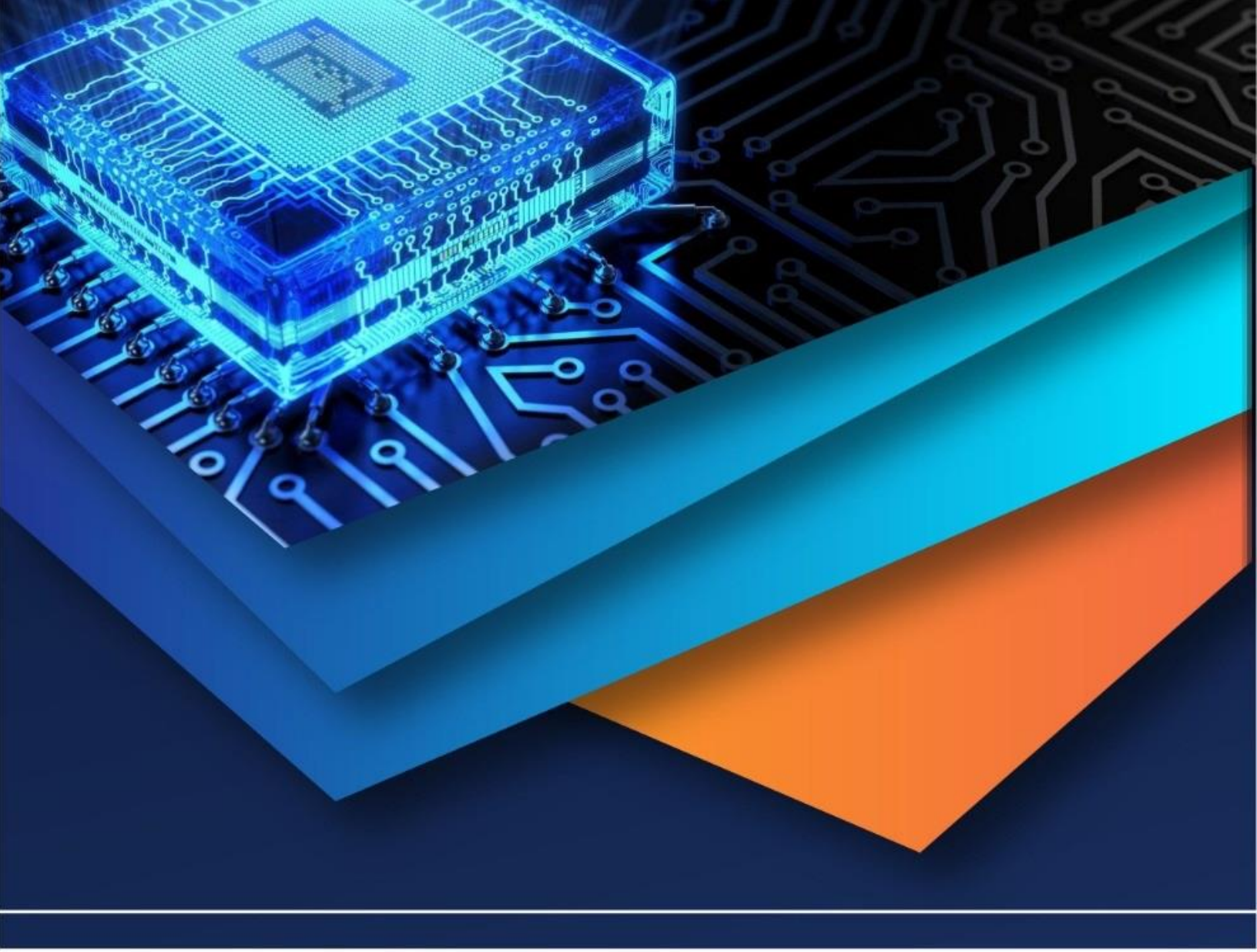
(c) Observed Data

VI. CONCLUSION

The proposed system illustrates how embedded technologies and real-time operating systems can improve industrial automation tasks. It successfully automates a sorting process with minimal human involvement while allowing for remote oversight. Future enhancements may include AI-based decision-making and networked nodes for larger systems.

REFERENCES

[1] FreeRTOS Documentation: https://www.freertos.org
[2] MQTT Protocol Info: https://mqtt.org
[3] STM32CubeIDE Documentation: https://www.st.com
[4] ESP8266 Community Resources: https://www.arduino.cc



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