Controlled Opening/Retraction Triggered by Illumination and Natural-light Analysis

Universidade de Aveiro(*UA*)

Departamento de Electrónica, Telecomunicações e Informática(*DETI*)

Mestrado em Engenharia de Computadores e Telemática (*MECT*)

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Authors

Anderson Lourenço - 108579
aaokilourenco@ua.pt

António Almeida - 108250
ant.almeida@ua.pt

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Chapter 1

Abstract & Introduction

1.1 Abstract

This project presents C.O.R.T.I.N.A (Controlled Opening/Retraction Triggered by Illumination and Natural-light Analysis), a cost-effective DIY smart home solution for automated curtain control. The system addresses the accessibility limitations of expensive commercial smart home systems by combining affordable components with intelligent automation capabilities. C.O.R.T.I.N.A utilizes an ESP32-C3 microcontroller, TMC2208 stepper driver, NEMA 17 motor, and BH1750 light sensor to create a dual-mode operation system that automatically adjusts curtain position based on ambient light conditions while providing remote manual control through ESP RainMaker cloud integration. The software architecture implements a FreeRTOS dual-task design with automatic light-based control with hysteresis to prevent oscillation, alongside manual override capabilities accessible via mobile applications. Testing demonstrated reliable system operation with smooth motor control, consistent sensor readings, and responsive cloud connectivity with sub-second command latency. The systematic component-by-component development methodology proved highly effective, achieving stable integration without critical failures.

1.2 Introduction

Smart homes are experiencing unprecedented growth in popularity, with an increasing number of consumers seeking wireless control and automation solutions for everyday household tasks. However, the high cost of commercial smart home systems significantly limits their accessibility to the average consumer. DIY solutions emerge as a compelling alternative, offering more affordable and flexible options for individuals looking to build custom smart home setups tailored to their specific needs and budgets.
C.O.R.T.I.N.A (Controlled Opening/Retraction Triggered by Illumination and Natural-light Analysis) presents an alternative for automation of window coverings through intelligent light-based control. By combining ESP32 microcontroller technology with cloud connectivity through ESP RainMaker, Controlled Opening/Retraction Triggered by Illumination and Natural-light Analysis (C.O.R.T.I.N.A) is able to achieve such solution.

Chapter 2

Design and Implementation

2.1 Hardware Architecture

The C.O.R.T.I.N.A system utilizes an ESP32-C3 microcontroller for it's fast computational power and integrated WiFi connectivity essential for cloud-based remote control functionality. The motor control subsystem features a NEMA 17 stepper motor paired with a TMC2208 stepper driver. This combination delivers precise positioning control with smooth operation.

Environmental sensing is accomplished through a BH1750 digital light sensor, which provides accurate luminance measurements essential for the automatic control algorithm. The sensor communicates via I2C protocol, offering reliable data transmission while minimizing pin usage on the microcontroller. The system architecture emphasizes modularity, allowing for individual component testing and validation during development. This approach facilitates troubleshooting and enables incremental system integration, reducing development complexity and improving overall reliability.

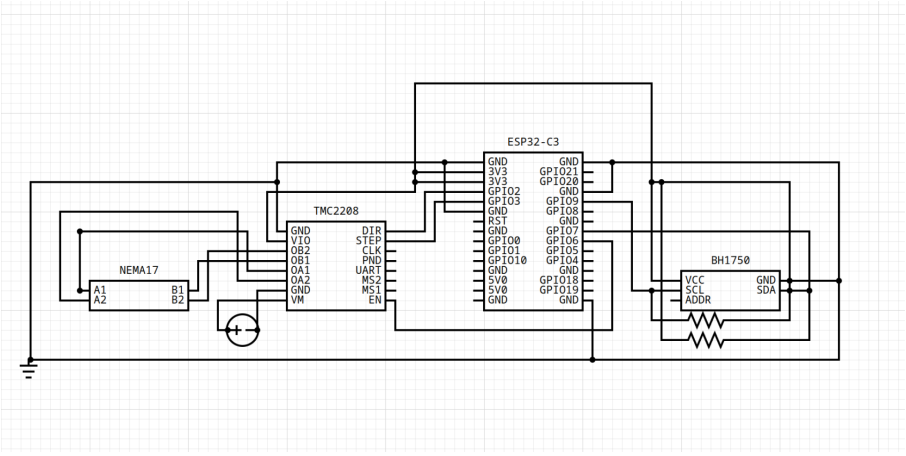

Figure 2.1: Eletric Scheme

2.2 Software Architecture

The software architecture implements a dual-task FreeRTOS design combining cloud connectivity, sensor monitoring, and motor control. The main thread manages ESP RainMaker integration through callback functions, implements a state machine for automatic/manual control modes, and handles I2C communication with the BH1750 light sensor. A separate stepper task provides independent motor control with position tracking and safety limits, ensuring responsive operation across all system functions.

ESP RainMaker Integration: The system creates a "Cortina" device with a dropdown parameter for direction control (Up, Down, Auto, Stop). The write_cb callback function processes cloud commands by updating the global user_value variable, which drives the main control state machine. This approach enables seamless cloud-to-device communication without complex threading issues.

Control State Machine: The main loop implements a switch-case structure based on user_value: Auto mode (0) reads the BH1750 sensor via I2C and compares against LIGHT_THRESHOLD_HALF (60 lux, a teoretical value for the perfect room illumination) with HISTERESIS (5 lux) to prevent oscillation, setting motor direction and enable flags accordingly. Manual modes (1-2) directly control direction, while Stop mode (3) disables the motor via the enable flag.

Motor Control: The stepper_task continuously monitors the enable flag and direction variable set by the main thread. It implements position tracking through step_count with defined limits (UPPER_LIMIT 10000, LOWER_LIMIT 0) to prevent mechanical damage. Step generation uses precise timing with esp_rom_delay_us(STEP_DELAY_US) for smooth 1ms pulse intervals.

I2C Sensor Communication: The bh1750_read_light function implements the BH1750 protocol by first sending a continuous high-resolution mode command (0x10), waiting 180ms for conversion, then reading the 2-byte result and converting to lux units by dividing the raw value by 1.2, providing accurate ambient light measurements for the control algorithm.

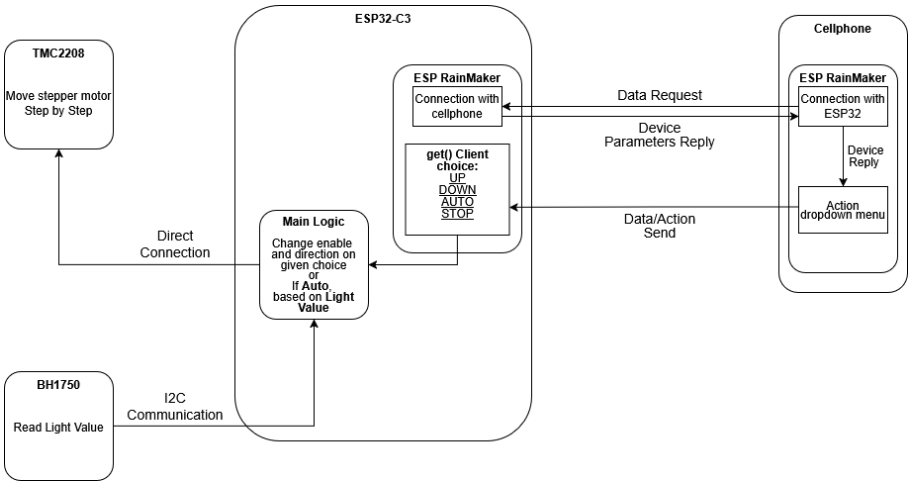

Figure 2.2: Software Block Diagram

Chapter 3

Results & Conclusion

3.1 Results

The C.O.R.T.I.N.A system successfully demonstrates that DIY smart home solutions can deliver a good functionality while maintaining cost-effectiveness and customization flexibility.

The TMC2208/NEMA 17 combination delivered smooth motor control and the BH1750 sensor provided consistent luminance measurements via I2C communication.

ESP RainMaker cloud integration exceeded expectations, offering responsive remote control through mobile applications with robust WiFi connectivity with automatic reconnection capabilities.

The automatic light-based control operates reliably across various lighting conditions, rising when light is too low, lowering when it's too bright, stooping in the perfect position. The Hysteresis works as expected, adding a layer of longevity to the components,reducing unnecessary movement. Further tests for the perfect room light need to be conducted, as the theoretical point was only defined in order to test the capability of automatization.

System reliability proved excellent throughout testing with no critical failures, although the structure that's holding all the project could be better, as it proved too light, moving as the curtain rose, and not very practical in the real world for the average consumer.

3.2 Conclusion

C.O.R.T.I.N.A works as intended, successfully providing automated curtain control based on ambient light conditions while offering comprehensive remote control capabilities through ESP RainMaker API. The system demonstrates reliable operation from automatic light-based adjustments to manual user commands, with consistent performance and no critical system failures. The project successfully achieved its primary objectives of creating the beginning of an affordable DIY smart home solution that tries to rival commercial alternatives.

The combination of ESP32-C3 microcontroller, TMC2208 stepper driver, NEMA 17 motor, and BH1750 sensor delivers professional-grade functionality while maintaining cost-effectiveness and customization flexibility that commercial systems cannot match.

Further improvements such as faster stepper motor speeds, cross-network accessibility for remote control beyond local WiFi, and better enclosure design are necessary to transform C.O.R.T.I.N.A from a successful proof-of-concept into a market-ready product.

Overall, C.O.R.T.I.N.A achieved it's main objective of being a cheap alternative for more expensive Curtain risers.