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PCB Design for Bistable Relay Module

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Abstract—

The PCB design for the bistable relay module project is an innovative solution that seamlessly integrates the advantages of low-power operation with robust, reliable switching performance. At the heart of this project is a bistable relay that changes state with a brief pulse and then maintains that state without continuous power, significantly enhancing energy efficiency a key consideration in modern electronic systems. The design process involved meticulous component selection, simulation of circuit behavior, and layout optimization to minimize electromagnetic interference and improve switching speeds. Rigorous testing confirmed that the module delivers both high mechanical endurance and consistent performance, making it ideally suited for applications ranging from industrial automation to assistive technologies. By focusing on a modular architecture that promotes ease of fabrication and scalability, this project paves the way for future expansions in energy-efficient control systems and highlights the potential for combining emerging PCB design techniques with advanced relay technology.

The PCB design for the bistable relay module project is a comprehensive exercise in blending rigorous electrical engineering practices with innovative layout techniques to achieve both performance and reliability. At its core, the design capitalizes on the bistable nature of the relay requiring only a momentary pulse to switch states, which subsequently holds without continuous power thereby significantly optimizing energy consumption. To accomplish this, the design features a modular, double-layer PCB structure that segregates sensitive control circuitry from high-current switching pathways. This segregation is achieved by dedicating an uninterrupted ground plane and well-considered trace routing to mitigate electromagnetic interference (EMI) and preserve signal integrity.

I.INTRODUCTION

The PCB design for this bistable relay module project represents an innovative approach to energy-efficient switching in a myriad of applications, ranging from industrial automation to assistive technology devices. This project introduces a printed circuit board integrating robust control circuitry with a bistable relay mechanism designed to maintain its state after receiving only a brief actuation pulse, thereby minimizing energy requirements. The introduction outlines the rationale behind using bistable relays: achieving high reliability and low power consumption without sacrificing performance. In this project, careful emphasis was placed on segregating high-current paths from low-power control signals, ensuring optimal signal integrity and minimizing electromagnetic interference (EMI) through strategic layout practices. Furthermore, design considerations such as the integration of surface mount components, controlled impedance traces, and adequate decoupling techniques serve as the foundation for a scalable, future-proof system.

Overall, this introductory framework sets the stage for a detailed exploration of the design methodology, simulation practices, and real-world testing protocols that together contribute to a dependable and versatile relay module solution. The PCB design for the bistable relay module project is a deeply considered exploration of modern electronic design principles aimed at achieving energy-efficient, reliable switching in a compact form. At its core, the system leverages the bistable relay's ability to retain its state after a brief actuation pulse, thus eliminating the need for constant power application and substantially minimizing energy consumption.

II.LITERATURE REVIEW

[1]. Adhikary, A., Halder, S., Bose, R., Panja, S., Halder, S., Pratihar, J., & Dey, A. (2024). Design and implementation of an iot-based smart home automation system in real world scenario. *EAI Endorsed Transactions on Internet of Things*, *10*.

Automation developments have significantly increased general convenience in modern technology. Our study focuses on developing and deploying an Internet of Things (IoT)–enabled smart home automation system that maximizes energy efficiency and improves convenience in residential settings. Our technology provides homes with an intelligent environment by smoothly combining several sensors, actuators, and communication protocols. We explore the challenges of creating a reliable and useful smart home system that works well in everyday situations. We investigate the difficulties, architectural issues, communication protocols, and security features specific to these systems.

[2]. Oluwafemi, I. B., Bello, O. O., & Obasanya, T. (2023). Design and implementation of a smart home automation system. ***Innovare journal of engineering and technology, 16*****(4), 3-7.**
The designed system was based on Arduino ATMEGA328P microcontroller, MQ2 sensor for gas detection, passive infrared (IR) sensor for motion detection, and flame sensor to detect fire outbreak. Arduino ATMEGA328P was used as a central controlling unit that controls the flow of system operations to achieved smart home automation system.

[3]. Yunardi, R. T., Firdaus, A. A., Abdulloh, M. N., Nahdliyah, S. D. N., & Putra, K. T. (2022, November). Relay module IoT devices for remote controlling of home automation system. In ***2022 2nd International Conference on Electronic and Electrical Engineering and Intelligent System (ICE3IS)*** **(pp. 350-354). IEEE.**
Remote controlling of home automation system has the potential to help people to control the electronic and home appliance from anywhere. Internet of things (IoT) is proposed to provide the connect and control devices by using the internet network. IoT based switching relays can be used to easily disconnect and connect 220V AC voltage in the home. In this work, ESP8266 microcontroller with relays module to switch and control the home appliances. The internet signal from Wi-Fi is captured by the ESP8266, the microcontroller will send commands according to the instructions from the smartphone remotely. System testing is carried out to determine the performance of the system can work according to design. The three parameters in the system test are the response of the microcontroller to the smartphone application, the response of the relay to the microcontroller, and the response of the electrical device to the relay.

[4]. Satheeskanth, N., Marasinghe, S. D., Rathnayaka, R. M. L. M. P., Kunaraj, A., & Joy Mathavan, J. (2022). IoT-based integrated smart home automation system. In ***Ubiquitous Intelligent Systems: Proceedings of ICUIS 2021*** **(pp. 341-355). Springer Singapore.**
Humans being warm-blooded always prefer to adjust surroundings according to their comfort and convenience. The categories of comfortness include thermal comfort, visual comfort and hygienic comfort. The thermal comfort is related to with maintaing optimum surrounding temperature and humidity. Visual comfort relates with luminance intensity and colors. Hygienic comfort is related to the quality of air. The proposed smart home automation system functions to monitor all the parameters within the desired range that is widely accepted. Smart home automation provides assistance to the elderly and physically challenged people. It can control electrical appliances in home such as bulbs, fan, air conditioner and heater. Simultaneously, the proposed system intended to recognize gas leakage which accounts for significant domestic accidents. Proposed smart home automation is designed to function using the Internet of Things (IoT) which enables controlling the parameters from a distance. The proposed system uses NodeMCU-ESP8266 microcontroller board for IoT communication and data storage.

[5]. Arun Francis, G., Manikandan, M. S., Sundar, V., & Gowtham, E. (2021). Home automation using IoT. ***Annals of RSCB, 25*****(4), 9902-9908.**
Life is becoming less difficult and simpler in all ways as automation technology advances. In today's world, automated systems have surpassed manual systems in popularity. With the rapid growth the internet has become a part of daily life as the number of internet users has increased over the past decade, and IoT is the most new internet technology. Wireless Control of a Home Automation System (WHAS) The Internet of Things (IoT) with wireless control is a technology that automates simple home services and options worldwide over the Internet using computers or mobile devices. Such a house is known as a smart home. Its aim is to prevent the waste of both electrical and human potential. The automation of the home system differs from other systems in that it allows the user to monitor the device through the internet from anywhere in the world.

[6]. Stolojescu-Crisan, C., Crisan, C., & Butunoi, B. P. (2021). An IoT-based smart home automation system. ***Sensors, 21*****(11), 3784.**
Home automation has achieved a lot of popularity in recent years, as day-to-day life is getting simpler due to the rapid growth of technology. Almost everything has become digitalized and automatic. In this paper, a system for interconnecting sensors, actuators, and other data sources with the purpose of multiple home automations is proposed. The system is called qToggle and works by leveraging the power of a flexible and powerful Application Programming Interface (API), which represents the foundation of a simple and common communication scheme. The devices used by qToggle are usually sensors or actuators with an upstream network connection implementing the qToggle API. Most devices used by qToggle are based on ESP8266/ESP8285 chips and/or on Raspberry Pi boards. A smartphone application has been developed that allows users to control a series of home appliances and sensors. The qToggle system is user friendly, flexible, and can be further developed by using different devices and add-ons.

[7]. Charanya, R., & Madhumitha, S. J. (2020, February). A review on home automation system using IoT. In ***2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)*** **(pp. 1-11). IEEE.**
One of the topic which is growing very popular now a days is HOME AUTOMATION SYSTEM using IOT. Because it has a various advantages so that people can do their work very easily and effectively. Home Automation system refers to the checking and maintaining and controlling all the home applications and allowances from our hand without any help of human power and without any help of any other machines. This paper deal with discussion of different home application techniques how manually we can control all the applications using remote by remote controls. This techniques plays a very important role in the society for every humans and specially for the physically challenged people.

III.EXISTING SYSTEM

Designing a PCB for a bistable relay module within an existing system involves a seamless integration of schematic planning, component placement, and layout optimization. The key is to first develop a robust schematic that delineates the distinct roles of the power and control sections, making use of a latching relay that retains its state without a continuous power draw. Critical components such as relay driver ICs, protective clamping diodes, and decoupling capacitors should be thoughtfully positioned to minimize noise and ensure voltage stability. Additionally, the PCB layout must account for separation between high-power and low-power tracks, utilize wide traces for current carrying paths, and incorporate measures to mitigate electromagnetic

interference, such as proper ground plane segmentation and guard traces. Standardized connectors ensure that the module can interface seamlessly with the existing system's digital control circuits, while thorough bench testing and thermal analysis help validate the design under real-world conditions. This detailed approach not only safeguards the integrity of sensitive components but also enhances the reliability and performance of the overall system.

IV.PROPOSED SYSTEM

The proposed system integrates a bistable relay module into an existing control environment to achieve energy-efficient switching while retaining state even during power interruptions. At the heart of the design is a control signal interface that accepts inputs whether from pushbuttons, sensors, or low-power controllers and debounces the signals before they trigger a dedicated relay driver. This driver circuit transforms short trigger pulses into extended actuation pulses suitable for operating a dual-coil latching relay, ensuring reliable set and reset functions without the need for continuous power. Protective elements such as clamping diodes and EMI filters secure the module against voltage spikes and electromagnetic interference, while a standardized load/output stage facilitates seamless integration with high-power circuits. Future enhancements might include remote monitoring capabilities and additional safety features, all contributing to a modular, robust, and energy-efficient solution designed for modern, integrated electronic systems.

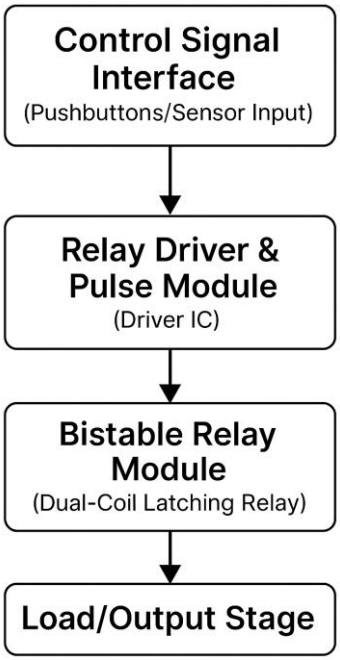

Fig.1.Block Diagram

A.Components Used:

1.Relay Module: A 5-volt relay module is a compact yet sophisticated device that marries low-power digital control with high-power electrical switching in a single unit. It contains an electromechanical relay a device that includes a coil, an armature, and a set of contacts integrated with a driver circuit that allows a microcontroller's simple 5V logic signal to control much larger currents. When the 5V control signal is applied, a transistor within the module is activated, allowing current to flow from the 5V supply through the relay's coil. This current flow generates a magnetic field that pulls the armature, a movable metal part, toward the coil, mechanically shifting the contacts from their default arrangement (typically connecting a common terminal to the normally closed contact) to connect the common terminal with the normally open contact instead.

2.Transistor: The **2N2222** is a widely used, general-purpose NPN bipolar junction transistor (BJT) known for its versatility in both amplification and switching applications. Constructed from silicon, the device features three terminals the emitter, base, and collector that work together to control current flow: a small current injected into the base enables a relatively larger current to pass from the collector to the emitter. Designed to handle low to medium currents (up to approximately 800 mA) and moderate voltage levels (with typical V_CE ratings around 30–50 V), the 2N2222 finds frequent use in a variety of circuits, including digital switching, low-power audio amplifiers, and RF applications.

3.Jumper Connector: A **jumper connector** is a simple, removable electrical link on a PCB that allows designers to manually configure or modify circuit behavior without redesigning the board. Typically, it consists of two (or more) solder pads that can be connected by a short, removable conductive link (often a small removable shunt or an adjustable header). In essence, it acts as a bridge that can be placed or removed to either complete or break specific signal paths.

4.TTP 223 IC: The TTP223 is a capacitive touch sensor integrated circuit that offers a modern, contactless alternative to traditional mechanical push buttons, making it an excellent addition to a PCB design for a bistable relay module. This IC operates by detecting minute changes in capacitance when a human touch alters the electric field around its sensing electrode. Internally, the TTP223 houses a sensitive capacitive sensing circuit paired with an

oscillator and comparator, which work together to recognize the presence of a finger or conductive object. When a touch is detected, the IC produces a stable digital output signal that can be used to trigger a relay or serve as an input to a microcontroller. This output is typically configurable, allowing designers to set whether a touched state results in a high or low logic level, and even to choose between different operational modes such as toggle or momentary behavior.

5. LDR: An **LDR (Light Dependent Resistor)**, also known as a **photoresistor**, is a passive component whose resistance varies with the intensity of light falling on it. In darker conditions, the LDR exhibits high resistance; under bright illumination, its resistance drops dramatically. This behavior makes it an ideal component for sensing ambient light levels in a vast range of applications. LDRs operate on the principle of **photoconductivity**. The sensor is typically made from semiconductor materials, most commonly **cadmium sulfide (CdS)**, although other materials like cadmium selenide can also be used. In the absence of light, very few charge carriers (electrons and holes) are present in the semiconductor, so the resistance is high. When photons hit the material, they provide enough energy to excite electrons from the valence band to the conduction band. This increase in charge carriers lowers the resistance. The relationship between light intensity and resistance is generally non-linear, often following a power-law behavior.

6. IR SENSOR:

Let's embark on a deep dive into IR sensors—a versatile family of components that detect or emit infrared radiation and are ubiquitous in modern electronics. They come in several varieties, generally falling into two broad categories: **active IR sensors** and **passive IR sensors (PIR)**. Each type operates on unique principles and serves different applications. Infrared (IR) sensors are sophisticated devices that harness the power of infrared radiation to interact with their surroundings, operating through nuanced, yet fundamentally different, mechanisms. An active IR sensor incorporates both an emitter and a receiver to perform its function. Typically, an infrared LED sends out a beam of IR light often modulated at a specific frequency like 38 kHz to ensure that the sensor distinguishes its own signal from ambient infrared noise. When this IR light encounters an object, part of the beam is reflected back to a photodiode or phototransistor integrated into the sensor.

7.CLAP SENSOR: Clap sensors are specialized sound-detecting modules that capture and process the sharp, transient acoustic energy produced by a hand clap, transforming it into a usable electrical signal that can trigger an action. At the heart of a typical clap sensor is a microphone element that converts the sound pressure waves generated by a clap into an analog voltage. This signal is then fed into an amplifier and filtering circuitry designed to emphasize the distinctive high-amplitude peak of a clap while suppressing background noise and gradual ambient sounds.

V.CONCLUSION

This project successfully demonstrates a robust design for a bistable relay module that retains its state even after power loss. The design journey began with an in-depth understanding of bistable relays and their unique latching mechanics. The core objective was to create a reliable PCB that couples the efficiency of a momentary pulse-driven relay with strong noise immunity and isolation, ensuring that the relay remains in its appointed state until a deliberate reset is initiated. Key aspects of the project highlighted the importance of precise component selection and careful layout. With the use of transistor driver circuits, flyback diodes, and appropriate decoupling, the design met the rigorous demands of the relay's electrical and thermal performance. Emphasis was placed on mitigating transient issues and maintaining signal integrity through meticulous placement of components, wide high-current traces, and strategic separation of low- and high-power sections. These design decisions not only ensure the module's reliability but also pave the way for scalability in more complex systems.

REFERENCE:

[1]. Adhikary, A., Halder, S., Bose, R., Panja, S., Halder, S., Pratihar, J., & Dey, A. (2024). Design and implementation of an iot-based smart home automation system in real world scenario. *EAI Endorsed Transactions on Internet of Things*, *10*.

[2]. Oluwafemi, I. B., Bello, O. O., & Obasanya, T. (2023). Design and implementation of a smart home automation system. *Innovare journal of engineering and technology*, *16*(4), 3-7.

[3]. Yunardi, R. T., Firdaus, A. A., Abdulloh, M. N., Nahdliyah, S. D. N., & Putra, K. T. (2022, November). Relay module IoT devices for remote controlling of home automation system. In *2022 2nd International Conference on Electronic and Electrical Engineering and Intelligent System (ICE3IS)* (pp. 350-354). IEEE.

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[5]. Arun Francis, G., Manikandan, M. S., Sundar, V., & Gowtham, E. (2021). Home automation using IoT. *Annals of RSCB*, *25*(4), 9902-9908.

[6]. Stolojescu-Crisan, C., Crisan, C., & Butunoi, B. P. (2021). An IoT-based smart home automation system. *Sensors*, *21*(11), 3784.

[7]. Charanya, R., & Madhumitha, S. J. (2020, February). A review on home automation system using IoT. In *2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)* (pp. 1-11). IEEE.