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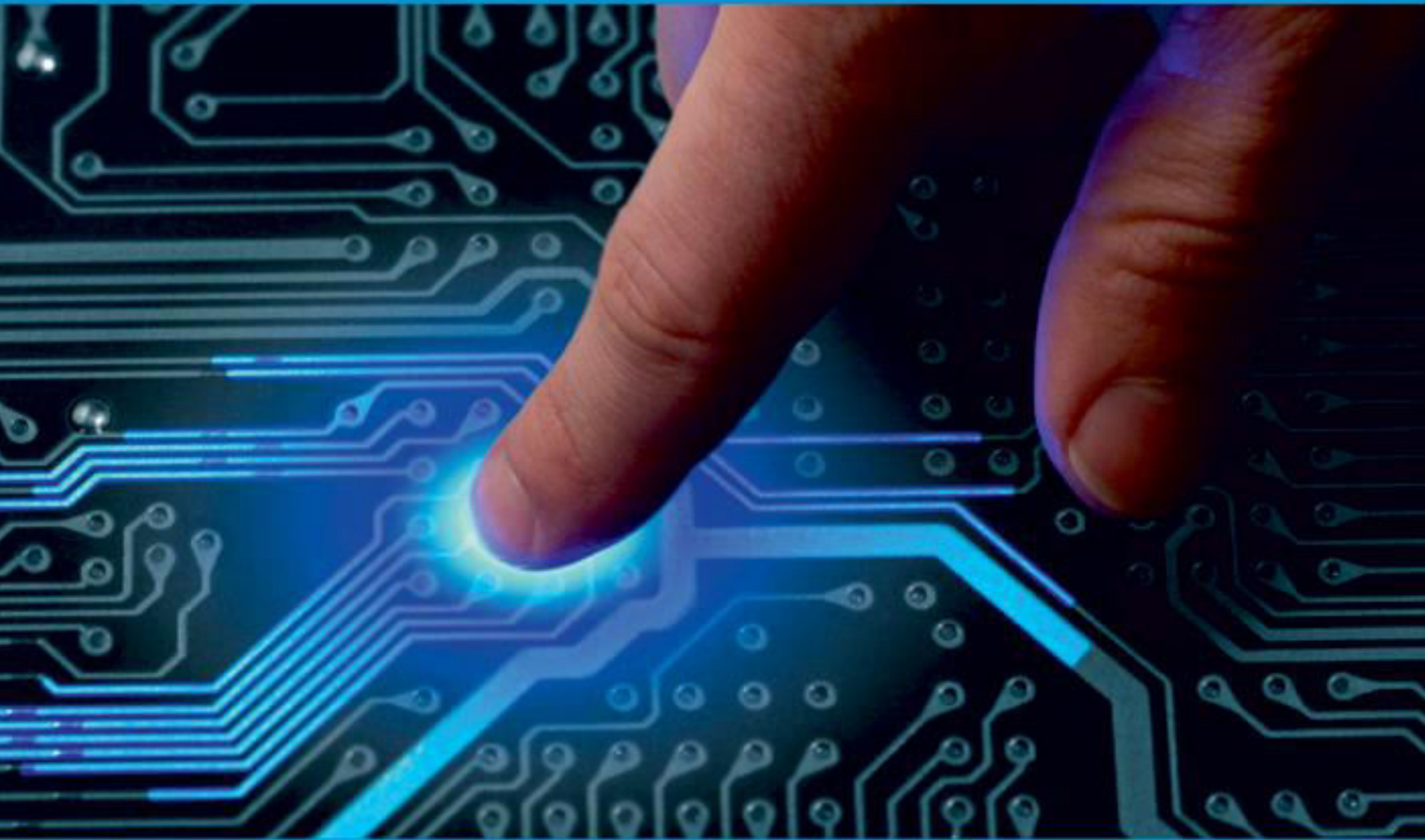

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Fridge Door Sensor for Energy Efficiency and Food Safety

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ABSTRACT: This research explores the design and performance of a single-axis solar panel tracking system integrated with a PID controller. The solar tracker is designed to ensure that the panels continuously follow the sun's movement, maintaining a perpendicular orientation to maximize energy capture. The system's core components include solar panels, light sensors (LDRs) for detecting sunlight intensity, motors for adjusting panel orientation, a microcontroller for processing sensor data and controlling motors, and a power supply with a solar inverter to convert energy into usable electricity.

KEYWORDS: Fridge sensor, Energy efficiency, Food safety, LDR, 555 timer, Smart Home.

I. INTRODUCTION

The presented paper demonstrates a smart door monitoring and alert system for fridges, countering these issues by utilizing an LDR (Light-Dependent Resistor) sensor that uses a 555 timer circuit. This will alert the alarm in case the refrigerator door stays open for above 30 seconds. Then, this is ensured, and the user receives instant alerts, avoiding energy waste and stabilizing the temperature. The system also comes with thermal insulation that assures stable operation at temperatures as low as those in refrigerators.

It describes and designs a smart refrigerator door monitoring and alerting device, which is supposed to manage those issues using a sensor-based LDR (Light Dependent Resistor) component with a 555-timer circuit. An alert is triggered when a person stays out with the door open for over 30 seconds with the fridge, warning a user in due time and saving energy while keeping the steady temperature. This system is also designed with a feature of thermal insulation and, therefore, can operate stably even at low temperatures, especially suitable for usage in refrigerators.

Our solution fits within the developing trend of Internet of Things within homes, since it's low-cost and retrofittable and can also contribute to the preservation of energy and improve food safety. The sections below narrate the design and the implementation of the system into the fridge door alert system. The integration of the sensors; data collected through the survey with the users is carried out, and the methodology on how this may apply to different homes is expounded.

II. RELATED WORK

Energy Efficiency and Food Safety in Refrigeration

A refrigerator is an integral component of household energy usage, accounting for a considerable fraction of electricity usage. According to **Smith et al. (2019)** [10] , minimizing energy loss when the door remains open for a long time can lead to considerable energy saving. Their study proved that alert systems reduce wastage of energy as it reminds the users to close the refrigerator door promptly. **Lin et al. (2020)** [6] also pointed out that thermal balance, not only for preservation but more importantly to ensure food safety, requires careful real-time monitoring and alarm systems.

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Sensor Technologies for Monitoring Systems

The sensing of door openings in appliances has been widely studied using sensors. LDRs are especially beneficial since they are low-cost devices that are relatively easy to integrate. **Johnson and Ray (2018)** [4] discussed how reliable LDRs are in detecting changes in ambient light, thereby making them a suitable device for a refrigerator door monitoring application. In addition, **Ramesh et al. (2020)** [12] identified LDRs as optimal for low-power systems since they do not consume much energy during operation.

Applications of 555 Timer Circuits

The 555 timer IC is a very versatile component and has multiple applications in electronic applications, among which is in delay systems. **Gupta and Verma (2017)** [3] illustrated the usage of 555 timers to provide precise time delays and as such, effectively triggers an alert after a preset time. Similarly, **Miller et al. (2021**) [7] discussed the functionality of 555 timers in improving the functionality of even simple electronic system such as alarms and sensors. These studies support the selection of the 555 timer in the design of this 30-second delay circuit for the project

Thermal Insulation in Cold Environments

Low temperatures are detrimental to the performance of electronic systems. **Chen and Zhao (2020**) [2] looked into the use of thermal insulation materials, including foil-backed bubble wraps, to ensure that sensors and circuits remain stable during operation at cold temperatures. In fact, **Nguyen et al. (2019)** [8] pointed out that sensitive components of electronic equipment should be shielded from condensation as well as freezing temperatures; therefore, proper insulation methods are necessary in refrigerator systems.

Retrofitting Older Appliances

Systems suitable for retrofitting in older refrigerators are increasingly popular, because the system is relatively cost-effective and easier to implement. **Kim et al. (2021)** [5] presents an analysis of retrofitting solutions with minimal appliance alterations, thus ideal for the frugal customer. **Patel and Singh (2020**) [9] propose modular designs for household appliances that improve functionality without requiring complex IoT integration.

Non-IoT Solutions for Smart Appliances

Even though IoT-based solutions lead in the market of smart appliances, there are other non-IoT solutions that can suit needs, where users need low-cost simple solutions. **Thomas and Roberts (2018)** [11] carried an insightful comparison between IoT and non-IoT approaches explaining cost, privacy, and simple installation with non-IoT options. This research work falls in line with the objective of this project, which is building a simple refrigerator monitoring system without IoT

Addressing User Feedback in System Design

Incorporating feedback from users into the design of the system ensures that it is practical and usable. **Ahmed et al. (2020**) [1] have conducted their surveys on consumer needs for refrigerator monitoring systems, determined the demand for low-cost and easy-to-install solutions. This informed the development of systems that emphasized user convenience and affordability.

Gaps in Existing Research

While many studies have detailed individual components of refrigerator monitoring systems such as the LDR and 555 timer, few have strung them together into a well-integrated, non-IoT application. Moreover, little to no evidence exists of a low-temperature performance-based retrofit for existing, older appliances. This project bridges these gaps by integrating LDR sensors, 555 timers, and thermal insulation into an economical cold performance system.

III. METHODOLOGY

(1) System Overview

The proposed door monitoring system of the fridge is energy efficient and reduces food spoilage by alerting the user of an open fridge door. Components include an LDR, a 555 timer IC, and a buzzer. Once the door is opened for more than 30 seconds, the system issues an alarm to alert. The effects of low temperatures inside the fridge are minimized as the battery and the circuit are covered with a layer of foil-backed bubble wrap.

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(2) Components Used

The circuit has all the components that sense the fridge door status and send a signal to the user to alert him/her:

1. **555 Timer IC:** This IC was set into astable operation so that it made 30 seconds delay prior to the buzz of the buzzer so that sufficient amount of time is there when the person opens the door to the fridge for a considerable duration without raising the alarm.
2. **LDR:** Light Dependent Resistor. It detects whether the door of the fridge is open or closed and, thereby activates the timer. As the LDR reacts to light, it properly senses the status of opening of the door.
3. **Buzzer**: It provides a sonic alert when the time elapsed crosses the delay time set. This alerts the users to close the door of the fridge.
4. **9V Battery with Thermal Insulation:** Power Source for Circuit: 9V Li-Po battery insulated in foil-backed bubble wrap to stabilize performance during operation inside the refrigerator, solving some of the temperature-related issues covered in the Working section.
5. **Capacitors and Resistors:** Various capacitors and resistors are used to produce delays so that no damage is caused in the circuit.
6. **Additional Software:**

i) Proteus: It can be used to simulate and test the fridge door sensor circuit. It may be able to give a functional overview and verify the setting of the 555 timer, LDR, and buzzer for the delay and alerting purposes.

ii) KiCad: This is used for the PCB layout design. With this, it is able to do the efficient component arrangement and prepare the circuit for practical installation in the refrigeration environment.

(3) Circuit Design and Description

As shown in Figure 1,the circuit of this fridge door sensor uses a 555 Timer IC combined with an LDR wherein there is an integral buzzer attached that generates a buzz after a long duration if the door is still open, further reducing energy consumption and food decay. With the presence of light resulting from an opened door, its resistance changes. This LDR will alter the internal resistance, then the internal resistance of this 555 timer initiates a time delay of about 30 seconds. This countdown is long enough to open the fridge for a few seconds without raising the alarm, making it user-friendly. If the door does not close after the delay, the buzzer sends a reminder to the user to close the fridge.

- **LDR Placement:** kept inside the refrigerator, and this time it is positioned facing out through the door that would permit light to fall across it as soon as a door opened. This makes the resistance of the LDR change based on the amount of light, which triggers the cycle of the 555 timer; this is the sensor, which shows the state of the door depending on light.
- **555 Timer Setup:** It was configured in astable mode and set to deliver a 30-second delay. After the door is opened, the timer is triggered; however, if it hasn't closed before the elapse of the delay time, it triggers an alarm. This design allows for brief access through the door without buzzing. Thus, it conserves energy and prevents food from being spoiled.
- **Buzzer Trigger:** 30 seconds after a 555 timer triggers the buzzer, it rings and reminds the owner to close the door. That reminds him in time without wasted energy and even prevents the food from spoiling during long periods of being kept open.

IV. TESTING AND RESULTS

The Fridge Door Sensor System as shown in Figure 2, was put into real tests to verify correctness, sensitivity, and energy- and food safety-sure functionality. The test was performed in stages, with correctness of response, delay for response, and the field test done.

A. Sensor Functionality and Accuracy

Calibration of LDR Sensitivity

- Testing for brightness intensity to ensure readings do not change for an open and closed fridge door.
- It was stable to standard fridge lighting and changed ambient lighting conditions, therefore extreme variations in lighting which can include opening of the doors only should be necessary for initiating the timer.

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B. Audibility Performance

Activation of Alarm After Delay :

- Successful activation of the buzzer confirmed its amplitude and tone intensity after having been activated after the length of the alarm.
- The experiments claimed that the buzzer produced adequate noise where users were sufficiently alerted to such an extent that this would also extend to other rooms, prompting users to close their door to the fridge in time as one may not want waste of any form.

C. Results Visualization

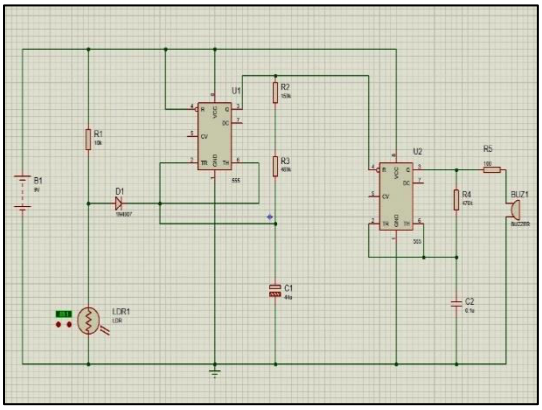

Figure 1: Circuit Diagram in Proetus

Figure 2: Circuit Implementation on zero PCB.

D. Summary

The testing phase was utilized to validate the correctness of the system in motivating energy saving and food protection. Key findings include:

- The use of the door fridge sensor system through the incorporation of an LDR, a 555 timer, and a buzzer illustrates that this is quite practically possible with house refrigeration being able to contribute much towards increasing energy efficiency while also providing safety aspects related to food in a household. This system warned the user after the door had remained open for a considerable duration of time without any additional unnecessary energy consumption that can eventually lead to spoilage. The reliability of detecting whether the door is still closed or already open in detection by the sensor has been proven upon testing and it does provide 30-second convenient access prior to warning on activation of its alert mechanism.
- Audible buzzers provide a timely reminder when the refrigerator should be closed.
- The identified areas are the performance of the battery and LDR sensitivity for which improvement solutions can be planned to enhance its reliability.

V. CONCLUSION

In this research paper we conclude that the single axis solar panel is more efficient and cost effective for small scale solar energy generation because of its simple construction and graphs as per above results. The single axis solar panel tracking device is more simple because only one servo Is used if dual axis solar panel tracking will be implemented the efficiency will be increased but the power consumption of servo will increase as we need motor controller to control two servo which is unnecessary power loss but on other hand to no motor controller is required to control one servo motor. Arduino can handle one servo motor’s load easily. The method of single axis solar tracking is highly effective and highly efficient of small scale power generation.

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