ATCSJ
Applied Technology and Computing Science Journal
Open Access **p-ISSN 2621-4458 | e-ISSN 2621-4474**
Available online to journal2.unusa.ac.id
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Journal Page is available to https://journal2.unusa.ac.id/index.php/ATCSJ

A Simple Electronic System of Security for a 24-Hour Grocery Store

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Article history:

Received 26 June 2023
Revised 10 July 2023
Accepted 29 July 2023
Available online 30 July 2023

Keywords:

Grocery stores,
Motion sensor analysis,
Motion detection,
Electronic security system,
Notification.

Abstract

Grocery stores, commonly found in cities, represent the latest model of retail establishments offering a diverse range of daily essentials and groceries while operating 24/7 for added convenience. However, these stores often encounter security challenges, such as employee lapses like falling asleep or leaving their posts unattended, which can jeopardize safety. To address this issue, we have developed a simple yet effective tool to enhance store security, utilizing an analysis of detection and sensor error rates. This security system relies on analog circuits to process signals from motion sensors, triggering a buzzer notification upon detecting movement. Through this research, the aim of the research is to quantify the level of detection accuracy and sensor error magnitude, as well as determine the optimal sound level for the generated notification. The results of this research contribute to bolstering safety and vigilance in these grocery stores.

I. INTRODUCTION

A grocery store, often referred to as a basic food store, is a vital retail establishment that offers a diverse range of daily necessities and staple items. These stores play a crucial role in providing essential products such as rice, sugar, cooking oil, instant noodles, salt, coffee, tea, milk, and other daily[1]. With their wide assortment of goods, grocery stores have become a ubiquitous sight, particularly in urban areas like Surabaya. In this bustling city, these shops serve as lifelines for residents, catering to their everyday needs and contributing significantly to the local economy. It's exploring the significance and prevalence of grocery stores in Surabaya, shedding light on their crucial role in meeting the everyday demands of the city's population.

Figure 1. Model situation grocery at 5a.m

Most retail establishments provide a wide array of essential daily needs and groceries, and what sets them apart is their 24-hour accessibility[2]. However, with such extended operating hours, these stores often face security challenges, such as instances of employees dozing off or leaving their post for brief periods, which can compromise safety.

To address these issues and bolster store security, the need for system security with a simple yet highly effective tool based on a comprehensive analysis of detection and sensor error rates. So, in this research we developed an innovative security system that relies on analog circuits to process signals from motion sensors, promptly triggering a buzzer notification in response to any detected movement. By implementing this system, it is necessary to enhance safety and vigilance within these grocery stores.

II. RELATED WORKS

This Grocery stores face various risks, including intense competition, price fluctuations, availability and stock management challenges, theft, and loss incidents, shifts in consumer habits, and changes in regulations and policies[3]–[5]. Despite these risks, small-scale grocery retail shops can achieve economic resilience due to a healthy financial turnover, especially when operating 24 hours[4], [5]. One specific risk that requires attention is theft and loss, as grocery stores' locations near roads and their round-the-clock operations can make them attractive targets for thieves both from within (guards, customers) and outside the premises.

To mitigate the risk of theft and enhance store security, different sound-based security systems can be implemented:

1. Sound Alarm: This system utilizes motion detection sensors to trigger an alarm or loud sound in response to suspicious activity, alerting occupants, and startling potential intruders[6].
2. Voice Announcements: Sound responses in the form of voice announcements can be activated when motion is detected, delivering pre-recorded messages like "Property under system control" or "You have violated the authority of a restricted zone," potentially deterring intruders[7].
3. Security Intercom: This system incorporates security intercom facilities, enabling direct communication with people outside the property or in the detected area, facilitating identification and providing warnings or instructions[7]–[9].
4. Voice Notification Systems: Modern security systems can connect with smart devices via Wi-Fi or the internet, sending sound notifications to users' devices when motion is detected[10].
5. Sound Detection Systems: In addition to motion sensors, security systems may utilize sound detection sensors to recognize suspicious noises such as broken glass or forced entry, audio-based accident, audio-crime detection, triggering loud warnings or notifications[8], [11], [12].

While voice security systems can serve as an added layer of security, their optimal effectiveness lies in integration with other security measures such as motion sensors, surveillance cameras, and secure door or window locks. By combining these technologies, grocery store owners can create a comprehensive security solution that enhances protection and provides early warnings, helping to safeguard their premises and assets[13].

A. Sound intensity

The sound intensity with the buzzer component is measured in decibels (dB). The dB scale indicates the sound power level. Depending on the buzzer type and specifications, the decibel level generated by an active buzzer may vary. Buzzers generally have a lower decibel range value compared to the sound produced by audio devices or musical instruments or other audio devices. The decibel range of an active buzzer is usually between 70 dB and 120 dB. However, it should be noted that the decibel level generated by the buzzer can also be affected by factors such as voltage and control circuitry. Using a resistor voltage divider or a variable volume control can help control the loudness of the buzzer. Before implementing a security system with a buzzer, the focus is on examining the technical specifications of the buzzer that will be used to obtain more specific information about the decibel level generated by the buzzer.

B. PIR

The PIR sensor (Passive Infrared) is a light sensor utilized to detect changes in temperature by sensing the infrared radiation emitted by objects in its vicinity. Primarily employed in security system applications, such as residential properties, the PIR sensor triggers actions in response to movements or temperature variations, which can stem from human or animal activity.

The functioning of the PIR sensor is straightforward. It consists of several detector elements that are highly sensitive to temperature changes[14]. Whenever any movement occurs within the sensor's coverage area, such as a person walking through a room where the sensor is installed, the ambient temperature surrounding the sensor alters[15]. The PIR sensor promptly identifies this temperature shift and generates an output signal. One of the key advantages of the PIR sensor is its power efficiency. These sensors typically consume minimal power and only activate when a significant temperature change is detected, making them well-suited for security applications where motion detection is crucial.

Figure 2. PIR sensor

The PIR The PIR (Passive Infrared) sensor requires careful consideration of several parameters, including:

1. Detection Distance: This refers to the maximum range at which the PIR sensor can detect motion, and it varies depending on the sensor type and model[16].

2. Detection Angle: The PIR sensor's viewing angle determines its capability to detect motion, typically ranging from about 90 to 180 degrees.
3. Delay Time: After detecting motion, the sensor remains active for a certain duration before returning to an idle state. Users can adjust this delay time through the sensitivity setting or potentiometer on the sensor.
4. Sensitivity: The sensitivity setting allows users to customize the PIR sensor's response to changes in temperature, tailoring its performance to suit specific application needs.

PIR sensors are commonly integrated with microcontrollers or other electronic systems to trigger actions based on motion detection. This can involve activating alarms, auto-lighting, or sending notifications to smart devices via wireless connections[17]–[19]. To ensure proper usage and optimize motion detection performance, it is essential to refer to the technical specifications and user manual of the specific PIR sensor being utilized.

It's important to note that PIR sensors do not measure absolute temperature; instead, they detect changes in temperature conditions or significant temperature differences in the surrounding environment. By measuring infrared radiation emitted by objects, PIR sensors can identify substantial temperature changes, which subsequently trigger an output signal.

PIR sensors are primarily employed for detecting human or animal movement, as the temperature changes produced by the bodies of living beings can be effectively sensed by these sensors. However, PIR sensors are not suitable for precise temperature measurements of objects or ambient conditions. For more accurate temperature readings, specialized temperature sensors such as thermistors or infrared temperature sensors designed explicitly for temperature measurement purposes may be more appropriate. In PIR sensor usage, the primary focus lies in detecting substantial temperature changes as an indicator of motion presence, rather than providing exact temperature measurements.

C. *Analog circuit sensor*

Analog PIR (Passive Infrared) sensor is a sensor that is used to detect motion based on analog circuits by using mode switching through transistor components to regulate current flow while motion recognition technology uses infrared radiation emitted by objects. Analog PIR sensors output an analog signal relating to the presence or absence of movement in the vicinity.

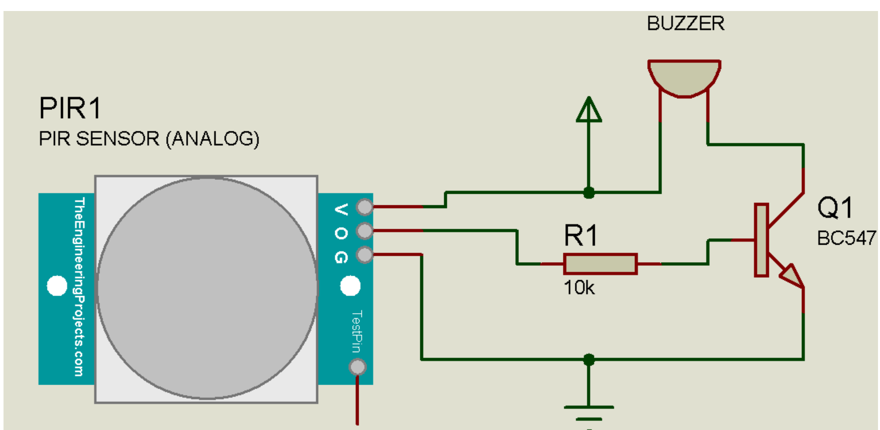

Figure 3. PIR schematic circuit

In figure 2 the voltage from the PIR sensor at the pin out is connected to the base pin on the transistor, the transistor component as a switch mode to activate the output on the PIR sensor. If using a direct circuit from the PIR sensor to activate the buzzer, the output signal is not able to quickly activate the buzzer.

III. METHODS

To create a PIR security sensor, the following methodology is employed:

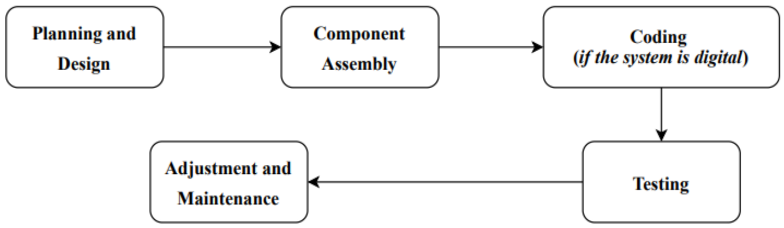

Figure 4. Methodology Research

A. Planning and Design

1. Identify the specific needs and objectives of the PIR security system to be developed.
2. Determine the area or room that requires surveillance using the PIR sensor.
3. Select a suitable type and model of the PIR sensor that aligns with the identified requirements.
4. Design circuits and connection schemes for the security system.
5. Create a physical layout of the PIR security system, outlining the placement of the PIR sensor and other supporting components.

B. Component Assembly

1. Gather the necessary components, including a microcontroller (if used), buzzer, resistors, jumper cables, etc.
2. Carefully connect the components according to the designed connection scheme.
3. Ensure proper and secure connectivity between all components.

C. Coding (if the system is digital)

1. If a microcontroller is used, write a program or code to govern motion detection and the corresponding actions when motion is detected.
2. The program may involve tasks such as reading PIR sensor status, activating a buzzer, sending notifications, or implementing other security measures.

D. Testing

1. Conduct thorough testing of the PIR security system once the assembly and coding are complete.
2. Verify motion detection by moving within the PIR sensor's coverage area.
3. Ensure that the PIR sensor effectively detects motion and activates the desired actions, such as producing a sound or triggering notifications.

E. Adjustment and Maintenance

1. If any inaccuracies in motion detection or actions taken are identified during testing, make necessary adjustments to the sequences or coding.
2. Perform routine maintenance tasks on the PIR security system, including checking connections, cleaning sensors, and replacing batteries as needed.

E-ISSN:*2621-4474, ISSN:2621-4458.*

Throughout the entire process, it is essential to consult the documentation and user manual for the components utilized, such as the PIR sensor and microcontroller. Additionally, always adhere to applicable policies and legal requirements concerning the use of security systems.

IV. Results And Discussions

The result of this motion detection circuit system produces a sound when there is a change in temperature due to a moving object. The wavelength of the "Passive Infrared" PIR sensor (infrared passive), depends on the type or type of PIR sensor used. In general, PIR sensors usually work in the far infrared (far infrared) wavelength range between 8 and 14 micrometers (µm). This range is known as the "far infrared" or "far infrared", while the discussion in this study refers to the working ability of the system being tested, including the ability to make sounds, sensor accuracy, sensor range to detect objects.

SPL (Sound Pressure Level) is a measure of sound intensity expressed in decibels (dB) relative to a standard reference sound pressure level. The sensitivity specification of the buzzer in the form of SPL at short distances with the provisions of 80 to 100db has a sensitivity of 86 dB SPL at a distance of 1 meter which means that the buzzer produces a sound pressure level of 86 dB SPL when measured at a distance of 1 meter from the buzzer.

The sensitivity of the buzzer at a certain distance is also determined by the component manufacturer based on standard test conditions, such as the location of the storeroom or environment and the measuring equipment used. This sensitivity may vary depending on the characteristics of the building insulation model, power level, positioning, and ambient noise conditions.

The dB drop level with the inverse formula of the law of sound emission is as follows:

$$L2 = L1 - 20\ logs\left(\frac{r2}{r1}\right) \tag{1}$$

In the formula:

L2 is the decibel level at a second distance (farther distance from the sound source).
L1 is the decibel level at the first distance (the distance that is closer to the sound source).
r1 is the first distance from the sound source.
r2 is the second distance from the sound source.

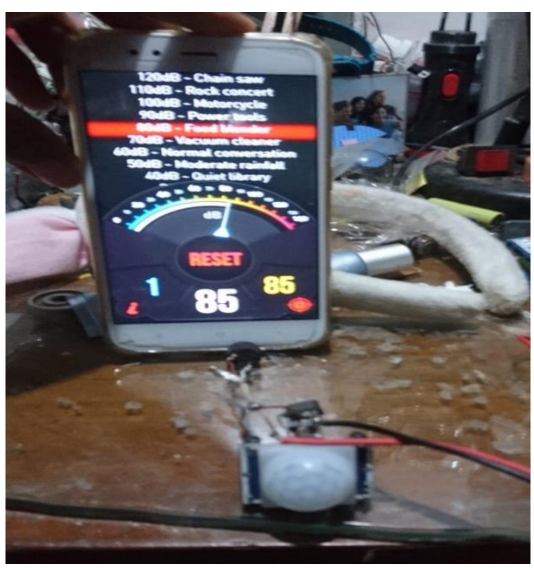

Figure 5. Signal level measurement tool

To calculate the signal level at different distances from the sound source, we have the decibel level of the buzzer at a distance of 1 meter (*L1*) as 86 dB SPL. Now, let's find the decibel level at a distance of 3 meters (*L2*) from the sound source.

Given data:

L1 = 86 dB SPL (decibel level at 1 meter distance)
r1 = 1 meter (first distance)
r2 = 3 meters (second distance)
Using the inverse square law formula equation (1) for sound emission:

$$L2 = L1 - 20 \text{ logs } (r2/r1)$$
$$L2 = 86 - 20 \text{ logs } (3/1)$$
$$L2 = 86 - 20 \text{ logs } (3)$$
$$L2 \approx 86 - 9.54$$
$$L2 \approx 76.46 \text{ dB SPL}$$

Therefore, the projected decibel level of the buzzer at a distance of 3 meters away from the sound source, with an initial decibel level of 86 dB SPL at 1 meter distance, is approximately 76.46 dB SPL. If the shop is of the shop house type, with a length ranging from 10 to 15 meters, and the shopkeeper is positioned at a distance of 10 meters away, without considering building insulation, the decrease in sound level according to the inverse square law at this distance can be calculated as follows:

$$L2 = L1 - 20 \text{ logs } (r2/r1)$$
$$L2 = 86 - 20 \text{ logs } (10/1)$$
$$L2 = 86 - 20 \text{ logs } (10)$$
$$L2 \approx 86 - 20 \times 1$$
$$L2 \approx 66 \text{ dB SPL}$$

So, the approximate decibel level of the buzzer at 10 meters from the sound source with an initial decibel level of 86 dB SPL is about 66 dB SPL.

In the actual measurement at a distance of 4 meters, you get a value of 67db with two crossed wall partitions, whereas according to the formula, ignoring obstacles, you get a db value of 76.46db with no obstacles.

Figure 6. The recorded dB measurements were obtained from a distance of 4 meters.

while the test at a distance of 10 meters was obtained at 56.7 dB with three obstacles while in measurement or theory it was obtained at 66db.

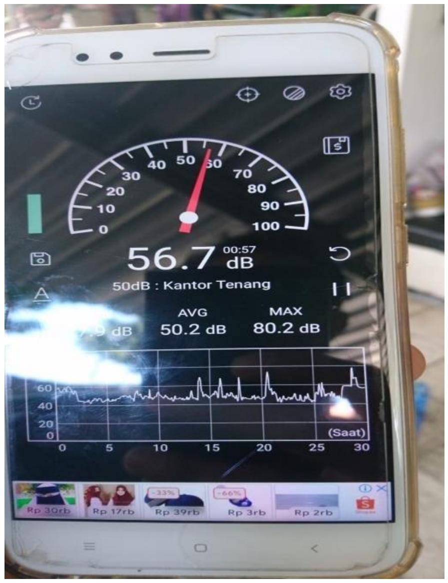

Figure 7. The recorded dB measurements were obtained from a distance of 10 meters.

The following are the results of measurements on sensors based on analyzing the level of detection and error rates of PIR sensors in Groceries Store security systems:

Table 1. The Result of Measurement PIR Sensors in Groceries Store Security Systems

Event Data	**Detect status**	**Actual state**
Event 1	Detected	Motion
Event 2	Detected	Gerakan Asli
Event 3	Detected	Gerakan Asli
Event 4	Not detected	No motion
Event 5	Detected	Motion
Event 6	Not Detected	No motion
Event 7	Detected	Motion
Event 8	Detected	Motion
Event 9	Not Detected	No motion
Event 10	Not Detected	No Motion

In the above example system, we have a number of n-events or 10 events that are observed by the PIR motion sensor sensor. Each event or occurrence is marked "Detected" or "Not Detected" based on the output of the PIR sensor. The actual status reflects the ability of the PIR sensor based on the level of the detection wave whether or not the movement is genuine in each event. From these data, we can calculate the detection rate and error rate of a system as follows:

- True Positive (TP): The number of events that the sensor correctly detected (detected and genuine motion). In this example, TP = 6.
- False Positive (FP): The number of false events detected (detected but no genuine moves). In this example, FP = 2.
- True Negative (TN): The number of events that were not correctly detected (no detections and no original moves). In this example, TN = 2.
- False Negative (FN): The number of events that were not detected incorrectly (not detected but there is genuine movement). In this example, FN = 0.

Using this information, we can calculate the detection rate (sensitivity) and error rate (specificity) as follows:

Detection Rate = TP / (TP + FN) = 6 / (6 + 0) = 1 (or 100%)

Error Rate = FP / (FP + TN) = 2 / (2 + 2) = 0.5 (or 50%)

In this example, the detection rate is 100%, which means the system can detect all of the original motions. However, the error rate is 50%, which means that a significant number of spurious events were detected. By analyzing, we can identify areas in the security system that need to be improved to reduce errors and increase accurate detection.

V. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the findings of this study hold significant economic value and demonstrate the effectiveness of the implemented security system. The results indicate that the system performs admirably at distances beyond the store's immediate monitoring area, as it produces a clear sound with a noise level of 30 dB that remains audible at a distance of 10 meters, even with building insulation considered. Furthermore, the sensors exhibit rapid responsiveness, effectively detecting movement and triggering the desired notifications. Additionally, the system's theoretical calculation error is within an acceptable margin of 10% of the nominal value. These positive outcomes affirm the practicality and reliability of the security system, underscoring its potential to enhance safety and vigilance in grocery stores while catering to various monitoring requirements.

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