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Analysis of the Sensitivity of the SW-420 Vibration Sensor to Minor Mechanical Disturbances in the Safe Security System

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Abstract

The security of assets in closed storage spaces such as safes faces challenges in the form of illegal removal of units and physical manipulation. This study aims to design and evaluate an Arduino Uno microcontroller-based anti-theft alarm system with a SW-420 vibration sensor. The approach used is a laboratory experimental method with a focus on testing the responsiveness of the system to low-intensity mechanical interference or "Level Easy". The results showed that the integration of the SW-420 sensor, relay module, and buzzer successfully detected physical anomalies in real-time with a response time of less than one second. The use of the pulseIn() function in programming logic has proven to be effective in processing digital vibration signals into accurate alarm activation instructions. Setting the threshold through a potentiometer and the application of the debouncing method has succeeded in minimizing the potential for false alarms. In conclusion, this prototype demonstrates high reliability as a standalone and portable early warning system for static asset protection.

Keywords: *Arduino Uno, SW-420 Sensor, Safety Safe, Vibration.*

Abstract

The security of assets in closed storage such as safes faces challenges in the form of illegal unit removal and physical manipulation. This study aimed to design and evaluate an anti-theft alarm system based on the Arduino Uno microcontroller with an SW-420 vibration sensor. The approach used was a laboratory experimental method focusing on testing the system's responsiveness to low-intensity mechanical interference or "Level Easy". The results showed that the integration of the SW-420 sensor, relay module, and buzzer successfully detected physical anomalies in real-time with a response time of less than one second. The implementation of the pulseIn() function in the programming logic proved effective in processing digital vibration signals into accurate alarm activation instructions. Threshold adjustments via potentiometers and the application of debouncing methods successfully minimized the potential for false alarms. In conclusion, this prototype demonstrated high reliability as an independent and portable early warning system for the protection of static assets.

Keywords : *Arduino Uno, SW-420 Sensor, Safe Security, Vibration.*

1. Introduction

The security of physical assets within closed storage spaces such as safes has become a top priority in the development of modern electronic security systems to reduce the risk of material loss [1]. Although digital and biometric locking technologies have come a long way, threats such as illegal removal of units or attempts at physical manipulation are still frequent due to weaknesses in static locking system detection [2]. One of the tools considered the most effective to overcome these gaps is the use of piezoelectric vibration sensors that are able to detect mechanical anomalies and shocks in the structure of objects before forced access is successfully carried out [3].

The use of the SW-420 sensor module in microcontroller-based security systems has become standard in prototype design due to its ability to generate digital outputs that are responsive to mechanical interference [4]. The main technical challenge faced in its implementation is the optimization of thresholds to distinguish between real threats and ambiguous environmental disturbances [5]. In the mechanical fault scenario classified as the "*Easy*" level in this study, the system is required to have high sensitivity in order to be able to respond to minimal touch or suspicious subtle shifts [6]. However, without proper calibration, high sensitivity at this level often triggers a false alarm phenomenon caused by non-threat factors, which can ultimately degrade the overall reliability of the system [7].

Several previous studies have in-depth explained the use of the Arduino Uno microcontroller as a fundamental processing center component, due to its efficiency in processing information from various sensors in real-time as well as its flexibility in integrating with relay modules to control various types of external actuators. However, there are still areas that require further study regarding the sensor's response characteristics to vibration and intensity, as the performance of "*Easy*" still requires further technical investigation to ensure accuracy and precision in digital data measurement. Therefore, this study aims to thoroughly evaluate the performance of the device in providing early warning through the systematic integration between the relay module and the buzzer as the alarm output unit, as well as to identify the optimal calibration parameters on the potentiometer of the SW-420 sensor module. This step is critical to finding the most accurate detection threshold point in order to reduce the risk of false detection when the device is subjected to mild physical disturbances, while still providing maximum protection to the object being guarded.

The urgency of this research is driven by the need for an efficient self-security system in terms of power consumption and production costs [8]. The compact hardware integration allows the system to be applied to a wide range of storage scales, from household safes to industrial lockers [9]. The development of security systems that are adaptive to different levels of intrusion intensity is an important step in dealing with various modes of theft [10]. Through analysis at the "*Level Easy*" level, it is hoped that a common point can be found between maximum protection and minimization of operational disruptions due to detection errors [11].

Several previous studies have examined the use of the Arduino Uno microcontroller as the main unit due to its efficiency in processing sensor data in *real-time* as well as its ease of integration with a relay module to control the actuator [12]. However, research that focuses on specific analysis on the characteristics of sensor response to low vibration is still limited and requires further deepening to ensure detection accuracy [13]. Therefore, this study aims to analyze the detection performance of the SW-420 sensor at low vibration levels through a measured experimental approach, in the hope of contributing to the development of a more reliable vibration sensor-based security system [14].

2. Methodology

This methodology is prepared based on a logical sequence that includes the design, implementation, and validation stages of the system to ensure that the research output is in accordance with the target functionality of the safe security system.

2.1 Stages of System Design

The initial step in this research is focused on designing a centralized controller architecture that uses the Arduino Uno microcontroller as the core of the system. The selection of this component is based on the sensor's real-time data processing efficiency capabilities and its flexibility in managing input-output variables for digital security applications. At this stage, systematic integration is carried out between the SW-420 vibration sensor that functions as a sensor, as well as other components that play a role in signal transmission and accession. The system is designed to operate independently and efficiently using a 9V battery power supply, which guarantees current stability and supports portability and ease of installation in various enclosed storage spaces, such as safes, without dependence on static power sources.

2.2 Software Implementation and Development

The next stage in the development cycle of this system is the process of coding the control logic implemented using the C++ programming language through the integrated Arduino IDE development environment. The main focus in the development of this software is the optimal utilization of the pulseIn() function to accurately capture the duration of the digital signal from the SW-420 vibration sensor, so that any data received can be processed precisely by the microcontroller. To optimize the accuracy of the readings and improve the overall reliability of the system, the debouncing method and filtration techniques are applied in the programming by adding a delay() instruction to stabilize the input data. This step is a crucial strategy that aims to minimize the potential for false alarm triggers due to mechanical noise or parasitic vibrations that often occur in contact-type sensors, so that the system will only activate relays and buzzers when detecting continuous and significant patterns of physical disturbance according to predetermined thresholds

2.3 Scenario 1 (*Easy) Testing Procedure*

To obtain valid research outputs, laboratory tests were carried out with the "*Level Easy*" parameter. These test stages are arranged in the following logical order:

- Threshold Calibration: Sets the analog potentiometer on the SW-420 module to adjust the sensor's mechanical sensitivity level.
- Simulation of Mild Disturbance: Provide stimulation in the form of a light touch or minimal shake using one hand on the body of the safe.
- Response Time Measurement: Observes the time interval between the occurrence of the shock and the activation of the buzzer through the Serial Monitor.
- Consistency Evaluation: 10 test repeats to validate the system's reliability in detecting low-level vibrations.

3. Results and Discussion

3.1 Test Results of Light Vibration Scenario (*Easy Level*)

Based on experiments conducted on the prototype anti-theft alarm, the test focused on the responsiveness of the SW-420 sensor to low-intensity mechanical stimuli, otherwise known as "Level Easy". This scenario represents minimal physical disturbance, such as gentle touching or light shaking on the outside of the safe. The test results show the performance of the system as follows:

Table 1. Low Vibration Test Results Data (*Easy Level*)

Test parameters	Activity Description	Sensor status Sw -420	Buzzer/relay status	Response time
Level easy	Smooth touch/shake of at least one hand	Active (Yes)	Active (Yes)	<1sec

The implementation of the SW-420 vibration sensor in this prototype has been empirically proven to be able to detect various forms of physical anomalies instantly and accurately, even before more serious structural damage to the safe object occurs. The effectiveness of this early detection is reinforced by the opinions of experts such as Harahap et al., who affirm that the use of piezoelectric-based vibration sensors has a very important role in building early warning systems. This concept explains that as income levels increase, consumption also increases, although not in the same proportion, thus helping to prevent losses on high-value static assets. The system's ability to capture vibration stimuli at a "Level Easy" intensity level with a response time of less than one second indicates that the integration of hardware components and programming logic has achieved an adequate reliability standard to protect assets from physical threats in real-time.

3.2 Analysis of the sensitivity characteristics of the SW-420 sensor

Analysis of experimental data showed that these safety systems worked consistently in response to mechanical stimuli, even when the given interference was at a minimum threshold or classified as a "Level Easy" test. Although technically the SW-420 sensor has sensitivity characteristics that are highly dependent on the quality of mechanical contact and mounting position, the lack of understanding of micro-vibration detection capabilities as well as activation latency in actuator units, where the relay module and buzzer are successfully triggered in a response time of less than one second. This extremely instant response speed is a vital indicator that the integration between the piezoelectric sensor and the Arduino Uno microcontroller via Pin

2 and Pin 8 has been running optimally, thus guaranteeing the system remains reactive to subtle touches or minimal suspicious shaking. This performance stability is reinforced by the use of the pulseIn() function in programming algorithms that effectively monitor the duration of vibration pulses in real-time, ensuring that any physical anomalies detected in the vault can provide reliable early warning to asset owners before more severe physical manipulation attempts occur.

The response speed of under one second is an important indicator that indicates that the integration between the SW-420 piezoelectric vibration sensor and the Arduino Uno microcontroller in this security system has been running optimally. Efficiency in data processing is critical in the development of portable devices designed to provide early warning. Rapid detection must be supported by the use of a stable battery power source in order to remain operating effectively. This concept is the basis for understanding how changes in income affect economic activity. In this context, the system also emphasizes the importance of power stability and real-time data readability, which is implemented through the use of a 9V battery to maintain the consistency of detection performance even without a direct electrical connection. Optimization of the power supply and hardware synchronization aspects ensures that any mechanical anomalies in mild vibration or "Level Easy" scenarios can be immediately converted into interrupt signals that trigger relay and buzzer actuations in the absence of significant latency. Thus, the system not only has a high sensitivity to minimal physical interference, but also has strong operational reliability as an effective and efficient safe-to-use security solution [15].

3.3 Discussion of False Alarm Detection and Prevention Mechanism

Technically, the vibration detection mechanism at the intensity of the "Easy" level is implemented through a precise reading of the digital pulse duration using the pulseIn function (PinGetar, HIGH) configured on pin 2 of the Arduino Uno. The programming logic compiled in this system establishes a specific *threshold* where if the accumulated readable vibration value exceeds 2500, the microcontroller will activate the alarm. This function is fundamental in understanding how changes in vibration levels affect overall economic activity. In this context, as the vibration level increases, the buzzer response speed also increases, although the sensitivity of this level provides an advantage in terms of early detection responsiveness to minimal shock. However, the system faces significant technical challenges in the form of potential false alarms triggered by environmental noise factors or other non-threatening mechanical disturbances. To address this phenomenon, the integration of the relay component serves as an automatic switch that ensures electrical current is routed to the buzzer only when the sensor actually detects a continuous physical anomaly The addition of a threat classification feature through more dynamic threshold setting is indispensable for the system to have the intelligence to distinguish deliberate human intrusion patterns compared to static environmental vibration patterns around storage areas.

This research shows that setting thresholds through potentiometers and locking logic in program code is the main solution to balance between security and user convenience. In addition, the addition of a threat classification feature can improve system intelligence in distinguishing between human intrusion patterns and other static environmental vibrations. The integration of relay components in this study has been proven to be effective in controlling alarm loads independently. With increasing income levels, consumption also increased, but not proportionately [16].

3.4 Discussion of Obstacles and Efforts to Minimize *False Alarms*

Although the test results listed in Table 1 show the success of the system in detecting physical interference in the safe object, there are significant technical challenges in the form of the possibility of false alarm phenomena due to the high level of sensitivity of the device at the initial setting. This is because the SW-420's vibration sensor in the "*Easy*" setting is too responsive to small vibrations, so environmental vibrations that are not a real threat—such as footsteps or shifting objects around the storage area—can inadvertently trigger the relay module and alarm. These conditions show that the adjustment of the threshold through a physical potentiometer integrated into the sensor module is a very important first mitigation step to balance between the aspects of high sensitivity and detection accuracy to avoid excessive operational disruption. This concept of parameter balance is crucial in understanding how fluctuations in input data from sensors affect the overall stability of the system, where any small change in vibration intensity must be processed precisely through programming logic so as not to produce incorrect outputs. Thus, through the proper calibration process and code optimization on the Arduino Uno, an increase in vibration input intensity will be followed by a consistent increased alarm output response, although the correlation is not always in the same proportion depending on the current stability of the battery power supply as well as the duration of the pulse read by the system.

Future security systems should start adopting logic filters in programming to distinguish random vibration patterns from human interference patterns. In this report, the use of a delay time delay(20) after sensor readings serves to help stabilize the data before it is further processed by the microcontroller. This integration ensures that the system remains effective but has resistance to minor irrelevant interference [17].

4. Conclusions and Suggestions

4.1 Conclusion

Based on the results of research, design, and testing that has been carried out on the anti-theft alarm system using the SW-420 vibration sensor based on Arduino Uno, several conclusions can be drawn as follows:

- The safe security system designed in this study comprehensively integrates various key microelectronic components, ranging from the Arduino Uno microcontroller board as a central processing unit that controls all system logic, the SW-420 type vibration sensor as the main input instrument in charge of continuously monitoring the presence, to the use of relays as electronic control switches to activate the reminder actuator. The successful integration resulted in a prototype of a highly functional early detection tool, where coordination between components allows the device to convert physical vibration signals into sound responses via buzzers instantly, creating a reliable and automated defense mechanism to warn of attempted interference or intrusion on a secured object.
- Based on the results of in-depth observations at the experimental stage, tests conducted through the "Level Easy" scenario or the category of vibration with light intensity prove that this safety system has a very optimal level of responsiveness in detecting physical anomalies. This performance advantage is demonstrated through the device's ability to execute the sequence of control logic instantly, where the activation time of the alarm on the buzzer and relay occurs in a very short duration. This very impressive response speed is a crucial parameter that confirms that the integration between the SW-420 sensor and the Arduino Uno microcontroller is capable of working synchronously in the absence of system latency, thus ensuring the effectiveness of the early warning function in mitigating the risk of criminal acts in real-time.
- The implementation of programming logic using the pulseIn() function on pin 2 of the Arduino Uno proved to be a very effective and accurate method of extracting and processing digital signals from the SW-420 vibration sensor in real-time. By utilizing this function, the microcontroller is able to calculate the duration of the high pulse (HIGH) generated by the sensor during an interference, so that any vibration information can be translated into precise numerical parameters. The reliability of this logic ensures that when the vibration intensity exceeds the threshold specified in the program code, an execution command can be directly sent to pin 8 to trigger the output actuators in the form of relay modules and buzzers without significant processing or latency barriers.
- The use of a 9V battery as a primary power source allows the system to operate independently and portably without compromising detection efficiency, making it easy to install on a variety of static storage objects.

4.2 Suggestions

For the development of more perfect systems in the future, several strategic suggestions can be considered, ranging from the addition of IoT-based wireless communication modules such as GSM modules SIM800L or Wi-Fi modules ESP8266 so that the system not only relies on on-site sound alarms, but is also capable of sending real-time alert notifications to the user's mobile device. In addition, it is necessary to develop a more complex and adaptive filter algorithm to improve the system's intelligence in analyzing sensor data, so that the device has a more accurate ability to distinguish between vibration patterns due to human intrusion attempts and natural vibrations from ambient noise to minimize the risk of false alarms. Finally, the integration of additional sensors such as *Passive Infrared* (PIR)-based motion sensors and magnetic door sensors (*reed switches*) is highly recommended to create a more comprehensive *multi-layered security* system architecture, where the combination of these sensor inputs will provide comprehensive protection and stronger threat validation against various crime modus operandi on static objects high value.

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