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Design and Implementation of an IOT-Based Anti-Theft Mat Using Arduino Nano, ESP32 Camera, and Piezo Sensors

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Abstract: ***As urbanization and crime rates surge, conventional anti-theft security systems face vulnerabilities. This project introduces an innovative solution – the IoT-based Anti-theft Flooring System utilizing ESP32 camera and Arduino Nano. By monitoring floor movement, the system ensures comprehensive security. Activated when occupants leave, the system detects intruders through a secure flooring tile, triggering an alert via IoT. The ESP32 & Arduino Nano powered setup includes a Piezo sensor. Upon detecting an intruder, the system captures and transmits images. This novel approach enhances home security by counteringevasion tactics and providing real-time images to homeowners.***

Keywords: IoT, Security System, Anti-Theft, Pressure Sensor, ESP Camera, Arduino Nano.

I. INTRODUCTION

With the rapid advancement of IoT technologies, the concept of interconnected devices has permeated various domains, including security systems. Traditional security measures, although effective to some extent, often lack real-time monitoring and proactive response capabilities. In response to thischallenge, we introduce an IoT-based anti-theft mat designed to bolster security measures by employing a combination of hardware components and intelligent software algorithms. The anti-theft mat serves as a vigilant guardian, detecting unauthorized access attempts and promptlynotifying the user, thereby enhancing overall security and peace of mind.

II. SYSTEM ARCHITECTURE

The proposed anti-theft mat consists of three primary components: Arduino Nano microcontroller, ESP32 camera module, and piezo sensors. The Arduino Nano serves as the central processing unit, responsible for sensor data acquisition, threshold-based decision making, and signaling to the ESP32 camera module. The ESP32 camera module, equipped witha camera, captures visual evidence upontriggering and communicates with the uservia Telegram messaging service. Piezo sensors embedded within the mat detectpressure changes, indicative of potentialintrusion attempts.

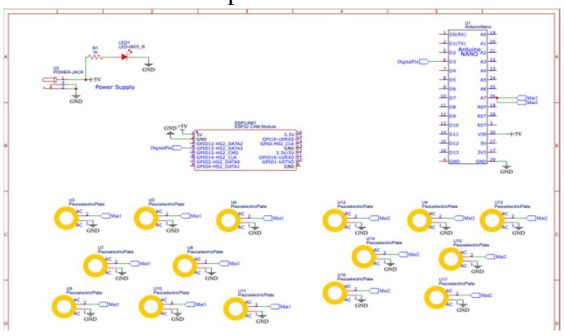


Figure 2.1 System Architecture

III. KEY COMPONENTS

A. Hardware Components

1) Arduino Nano

The Arduino Nano stands out as a closely packed and flexible micro controller board centered around the ATmega328P micro controller chip. It is a vita part of the Arduino family of development boards, renowned for its ease of use and wide-ranging applications in electronics prototyping and projects.

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The Arduino Nano is ideal for projects where space is limited and its small form factor allows for flawless amalgamation into various devices and applications, making it suitable for projects with space constraints or those requiring portability. Despite its compact size, the Nano retains most of the features found in its larger counterparts, such as the Arduino Uno, including digital and analog input/output pins, PWM (Pulse Width Modulation) o results, UART (Universal Asynchronous Receiver-Transmitter) communication, andI2C(Inter-Integrated Circuit)and SPI (Serial Peripheral Interface) interfaces.Furthermore, the Arduino Nano can be programmed effortlessly using the Arduino IDE (Integrated Development Environment), allowing users to write, compile, and upload code easily to the board. Its affordability, versatility, and ease of programming make the Arduino Nano a popular choice among hobbyists, students, and professionals for a wide range of electronic projects, from robotics and automation to IoT (Internet of Things) applications and beyond.

The Arduino Nano serves as a vital component in the anti-theft flooring mat system, contributing to data processing and control functions. As the central processing unit, the Arduino Nano processes signals received from the piezo sensors and coordinates the activation of the ESP32 Camera module. Its role encompasses interpreting sensor data, executing predefined algorithms for intrusion detection, and triggering alerts when unauthorized activity is detected. Additionally, the Arduino Nano facilitates communication between the piezo sensors,ESP32 Camera module.

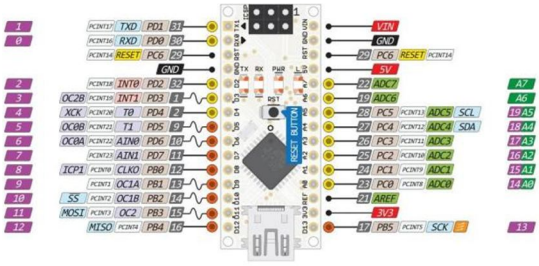


Figure 3.1 Arduino Nano

2) ESP32 Camera

The ESP32 Camera is an integrated module that combines the capabilities of the ESP32 microcontroller with a camera sensor. It allows users to capture images or videos and perform image processing tasks directly on the ESP32 microcontroller. The ESP32 Camera module includes a high-resolution camera sensor, along with necessary interfaces for connecting to the ESP32 microcontroller. This integration enables developers to create IoT applications that involve image capture, recognition, surveillance, and more, all within a single compact module.



Figure 3.2 ESP 32 Camera

The ESP32 Camera module is widely used in projects ranging from security systems and surveillance cameras to smart home devices and industrial monitoring applications.

The ESP32 Camera module serves as the primary sensor for detecting and recordingunauthorized movement on the mat's surface. Its functionality includes capturing high-resolution images upon activation by the pressure sensors embedded within the mat and sending the images to the House owner via Telegram. These images provide visual evidence of potential intrusions and facilitate immediate assessment and response by thehomeowner.

3) Piezo Sensors

Piezo sensors, short for piezoelectric sensors, are devices that produce an electrical charge in feedback to mechanical stress or pressure. They utilize the piezoelectric effect, which is the characteristics of certain materials to produce an electric potential when subjected to mechanical distortion. Piezo sensors consist of a piezoelectric material sandwiched betweentwo conductive electrodes.

When pressure or force is applied to the piezo sensor, it causes the piezoelectric material to deform, resulting in a change in electrical voltage or current across the electrodes. This change in voltage or current can be measured and one can use to discern the timing and magnitude of the applied force.Piezo sensors are commonly used invarious applications, includingtouch-sensitive input devices, vibration detection, acoustic sensing, pressure monitoring, and impact detection. Due to their high sensitivity, fast response time, and rugged construction, piezo sensors are used for applications where precise and reliable sensing of mechanical stimuli isrequired.



Figure 3.3 Piezo Sensors

The Piezo sensors are strategically embedded throughout the mat's surface, typically arranged in a grid pattern to ensure comprehensive coverage. When pressure is applied to the mat, such as by footsteps or movement, the piezo sensors generate electrical signals proportional to the applied force.
These signals serve as triggers foractivating the ESP32 Camera module,prompting it to capture images of the detected movement. By accurately sensingpressure variations, piezo sensors enable
the system to reliably detect and respondto potential security threats.

IV. HARDWARE IMPLEMENTATION

The hardware implementation involves integrating the Arduino Nano, ESP32 camera module, and piezo sensors into a cohesive system. The piezo sensors are strategically placed within the mat to detect pressure variations caused by footsteps or physical tampering. The Arduino Nano facilitates analog signal processing from the piezo sensors and controls the signaling to the ESP32 cameramodule based on predefined thresholdvalues.

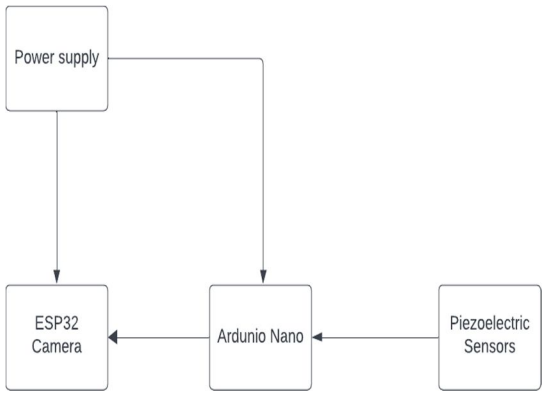


Figure 4.1 Block Diagram

The ESP32 camera module captures images upon receiving a trigger signal from the Arduino Nano and communicateswith the user via Telegram API for real-time notifications.

V. SOFTWARE DESIGN

The software design encompasses firmware development for Arduino Nano and ESP32 camera modules. The Arduino firmware includes algorithms for analog signal processing, threshold-based decision making, and serial communication for debugging purposes. The ESP32 firmware integrates camera control functionalities, Telegram bot API for message transmission, and logic for handling user commands. Furthermore, the software implements mechanisms for system calibration, error handling, and power management to ensure reliable operation.

VI. SYSTEM OPERATION

Upon deployment, the anti-theft mat continuously monitors its surroundings for any suspicious activities. When a pressure variation exceeding the predefined threshold is detected by the piezo sensors, the Arduino Nano triggers the ESP32 camera module to capture images of the intruder. Simultaneously, the system sendsan alert message to the user's mobile device via the Telegram messaging service, providing real-time notification of the security breach. The user can then take appropriate actions, such as contacting authorities or remotely accessing the camera feed for further assessment.

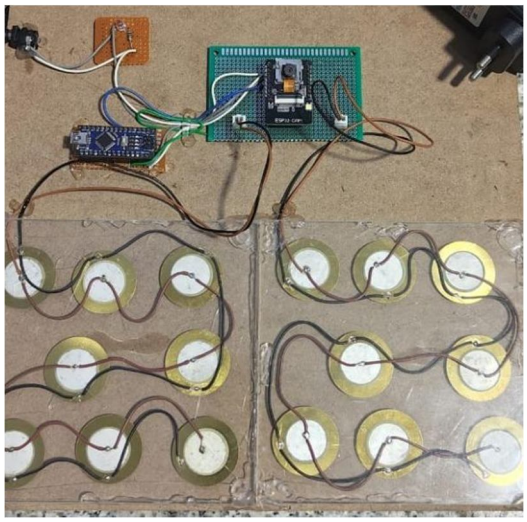


Figure 6.1 Prototype

VII. PERFORMANCE EVALUATION

To assess the performance and reliability of the anti-theft mat, extensive testing is conducted under various environmental conditions and intrusion scenarios. The system's response time, accuracy indetecting intrusions, and robustnessagainst false alarms are evaluated rigorously. Additionally, power consumption, network connectivity, and overall system stability are scrutinized to ensure optimal performance in real-world deployment scenarios.

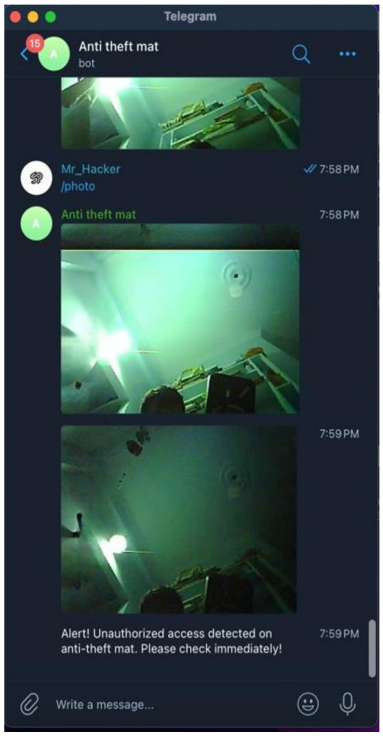


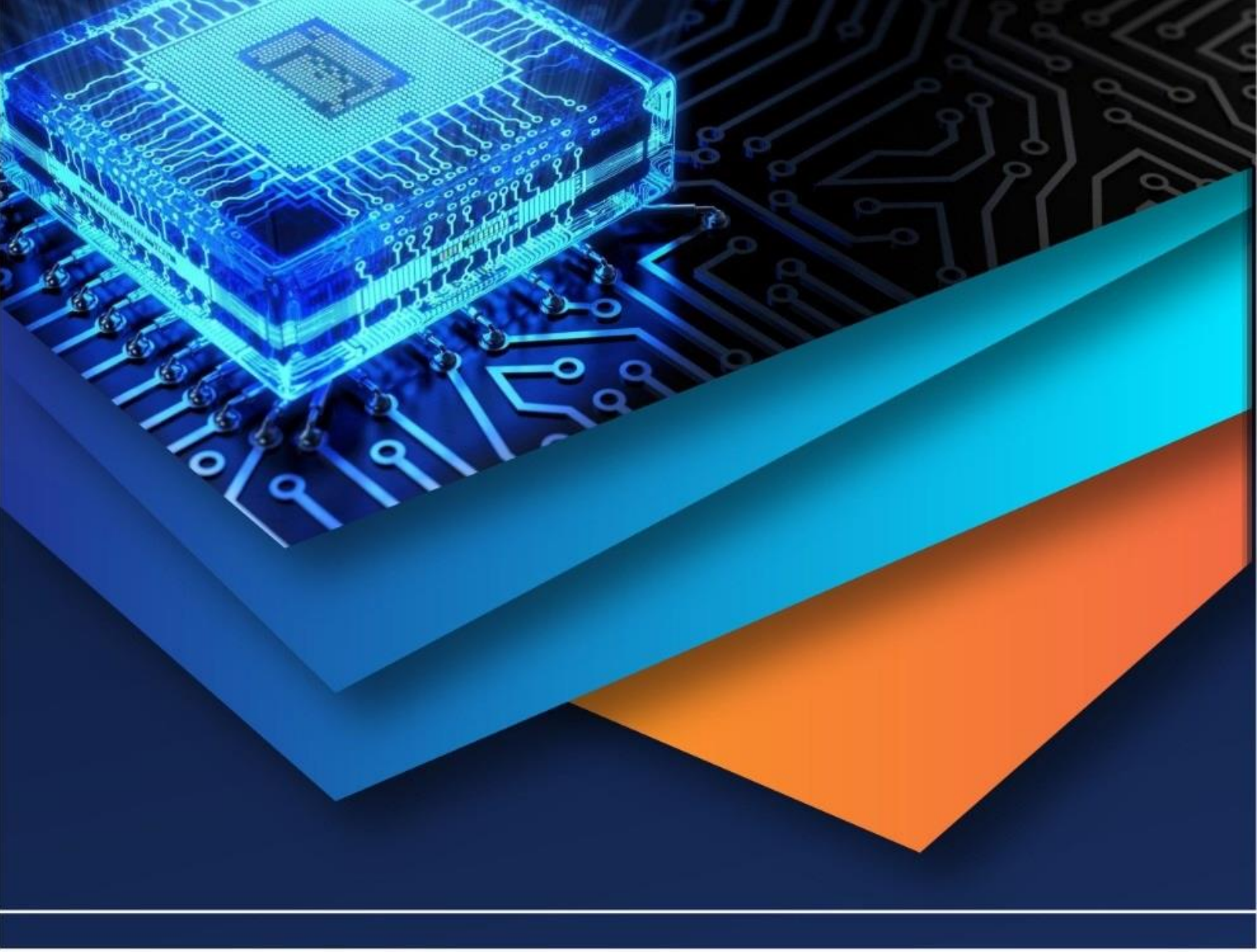
Figure 7.1 Results

VIII. CONCLUSION

In conclusion, the proposed IoT-based anti-theft mat offers an effective solution for enhancing security measures in residential and commercial premises. By leveraging the capabilities of Arduino Nano, ESP32 camera module, and piezo sensors, the system provides real-timeintrusion detection and timely notificationsto the user, enabling proactive response to potential security threats. Future enhancements may include integration with cloud-based surveillance platforms, machine learning algorithms for anomaly detection, and scalability to accommodate larger deployment environments.

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