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Course Code/ Course Title: 19ECE344 Embedded Systems
Academic Year: 2025–26 (Odd Semester)

Embedded Systems (19ECE344)

Semester Term Project Report

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Title of the Assignment

Intruder Alert System

• Sensor: PIR motion sensor (GPIO)

• Peripherals: GPIO, Buzzer, UART

• RTOS: Task detects motion, task triggers buzzer, task logs.

• Application: Smart security.

1. Introduction and Problem Definition (CO2)

The project titled 'Intruder Alert System' aims to design and implement a smart embedded security application that detects motion using a PIR (Passive Infrared) motion sensor and alerts through a buzzer while logging events over UART. The system is based on the STM32 Nucleo-F446RE microcontroller board using FreeRTOS for task scheduling and concurrency.

The system falls under the domain of Smart Home and IoT-based Security Systems. The inputs are obtained from the PIR sensor (digital GPIO input), and outputs are provided through a buzzer (GPIO output) and UART terminal for serial communication logging. The primary design goal is to achieve real-time detection of intrusions with task-based modularity and concurrent operation between sensing, alerting, and logging.

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2. System Design and Architecture (CO3)

The system consists of three main modules interconnected under the STM32 Nucleo-F446RE microcontroller:
• PIR Motion Sensor (input): Connected to a GPIO pin configured as digital input.
• Buzzer (output): Connected to a GPIO pin configured as digital output.
• UART Communication: Connected to a serial terminal (PuTTY) to display system logs.

The microcontroller runs FreeRTOS with two independent tasks:
1. PIR Detection Task: Periodically samples the PIR sensor pin to detect motion.
2. Buzzer Task: Activates the buzzer when motion is detected.
   UART Logging Task: Sends 'Intruder Detected!!!' via UART when motion is detected.

Peripheral configuration:
• GPIOA configured for PIR input and buzzer output.
• USART2 configured at 115200 bps for UART communication.

• FreeRTOS kernel configured with preemptive scheduling and 1 ms system tick.

The design ensures deterministic task response by separating sensing, alerting, and communication into independent tasks that synchronize through shared flags or queues.

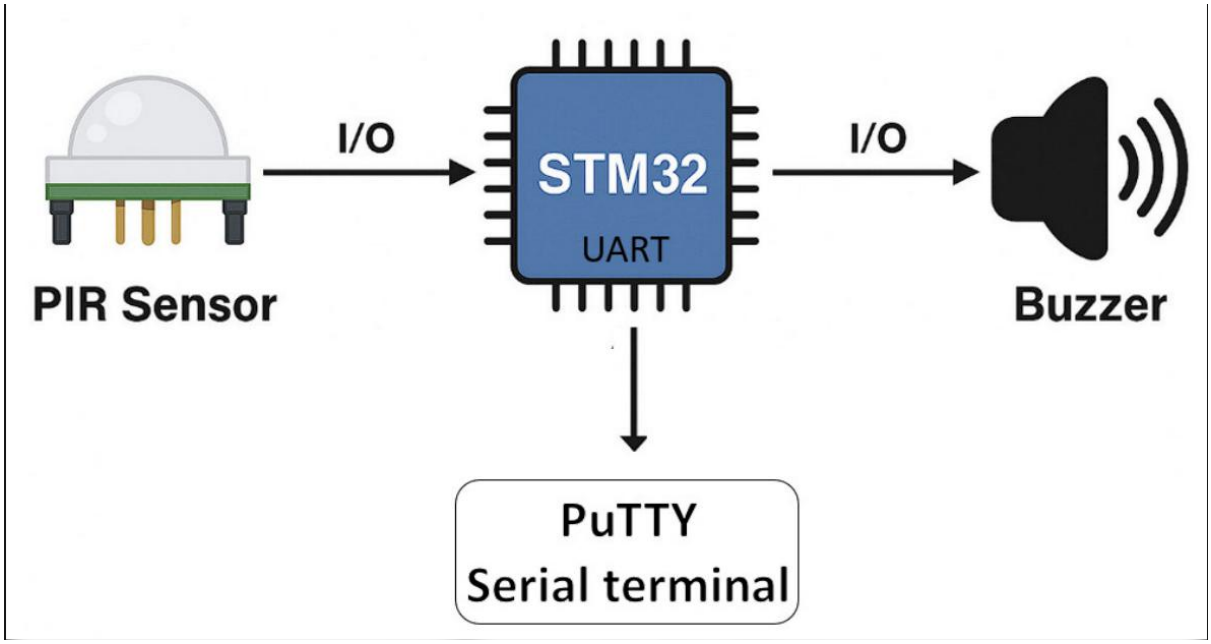

Fig 1: Block Diagram

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3. Implementation and RTOS Integration (CO3)

Hardware Used:
• STM32 Nucleo-F446RE Development Board
• PIR Motion Sensor
• Buzzer
• UART Interface with PuTTY terminal

Software Tools:
• STM32CubeIDE (integrated STM32CubeMX + FreeRTOS)
• FreeRTOS kernel for real-time task scheduling

RTOS Task Structure:
• PIR Detection Task: Periodic task that reads the PIR sensor GPIO pin.
• Buzzer Task: Waits for a semaphore signal from the PIR task to activate the buzzer.
UART Logging Task: Waits for the same event to log messages to PuTTY via UART.

Scheduling Algorithm: Fixed Priority Preemptive Scheduling (FreeRTOS default)

This modular RTOS design enables each task to execute independently without blocking others, ensuring responsiveness and predictability.

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4. Experimental Results and Analysis (CO3, CO4)

The system was successfully implemented and tested on the STM32 Nucleo-F446RE board. When the PIR sensor detected motion, the buzzer was activated, and the UART terminal displayed the message 'Intruder Detected!!!'. The UART logs were observed on PuTTY configured at 115200 baud rate.

Results Summary:
• Motion detected
• Buzzer activated
• UART log transmission verified without data loss.
• System response was consistent and stable across multiple tests.

Serial output confirmed correct task synchronization and timing behavior under FreeRTOS. We also used the live expressions feature present in the STMCube IDE to view the values of the variables.

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5. Discussion and Inference (CO4)

The project demonstrates an efficient implementation of a smart embedded security system using an RTOS. By employing task-based design, the system achieves modular separation between sensing, alerting, and logging. FreeRTOS allows each component to operate concurrently with deterministic timing.

Advantages of using FreeRTOS:
• Simplified concurrency management through tasks and semaphores.
• Enhanced reliability and responsiveness.
• Easy scalability for adding new features like GSM alerts or camera integration.

Limitations and Future Scope:
• Currently detects only motion, not identity.
• Future integration with IoT or mobile alerts possible.
• Logging can include timestamps or SD card data storage.

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6. Conclusion

This project successfully demonstrates the design and implementation of an Intruder Alert System on STM32 using FreeRTOS. The integration of multiple concurrent tasks provided efficient real-time performance. Through this project, students gained practical exposure to RTOS task management, GPIO interfacing, and UART communication. The system fulfills its objective by reliably detecting motion and providing both audible and serial alerts in real time.

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7. References

[1] P. Chodon, D. M. Adhikari, G. C. Nepal, R. Biswa, and S. Gyeltshen, "Passive Infrared (PIR) Sensor-Based Security System," *International Journal of Electrical, Electronics and Computer Systems (IJEECS)*, vol. 14, no. 2, pp. 23-27, 2013.

[2] D. Ramegowda, S. R. Nayak, and M. S. Reddy, "Energy Efficient Mixed Task Handling on Real-Time Systems," *Journal of Systems Architecture*, vol. 135, pp. 102808, 2022.

[3] I. Zagan, L. Smarandache, and C. Ionescu, "BIoT Smart Switch-Embedded System Based on STM32," *Buildings*, vol. 14, no. 10, pp. 3076, 2024.

[4] FreeRTOS Documentation, Available: https://www.freertos.org

[5] STMicroelectronics, *STM32F446RE Datasheet and Reference Manual*, 2024.

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8. Appendix

GitHub repository : https://github.com/StevenInfinity/IntruderAlert

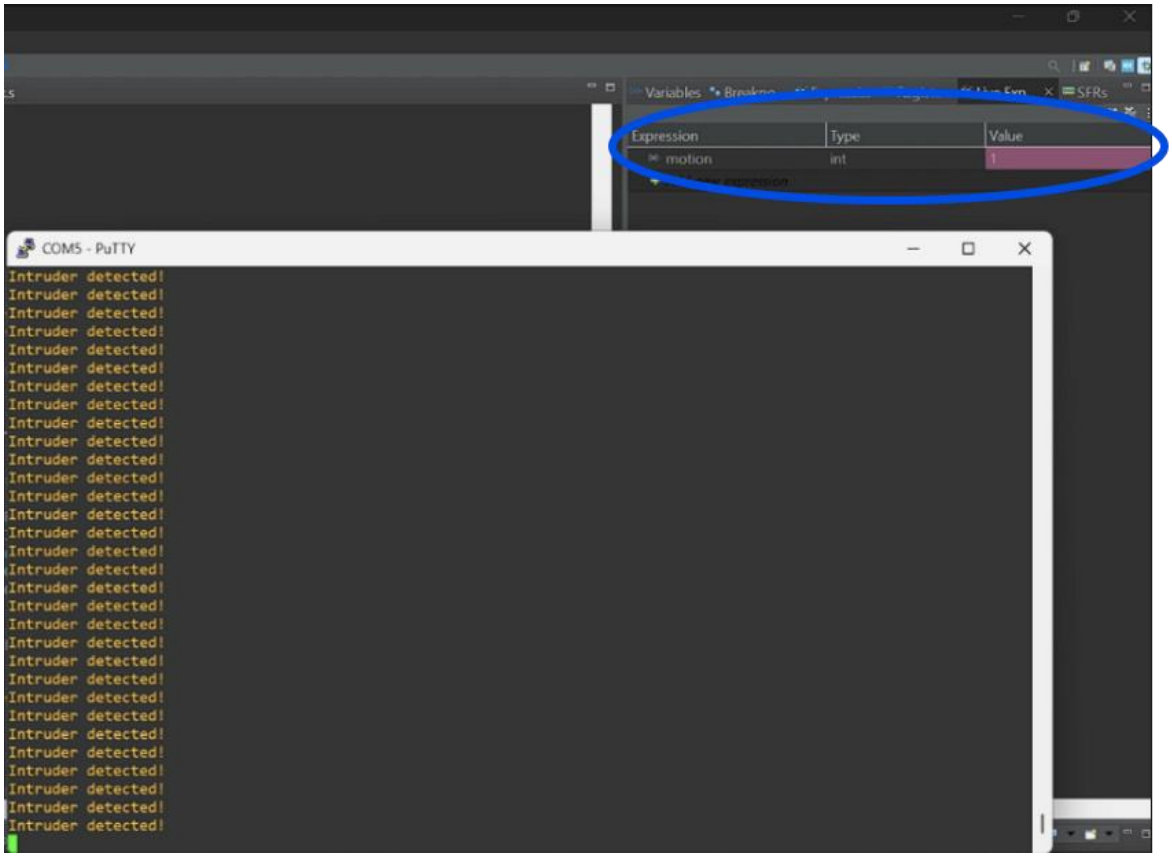

Fig 2: PIR Sensor Value is 1 and UART says “Intruder detected!”

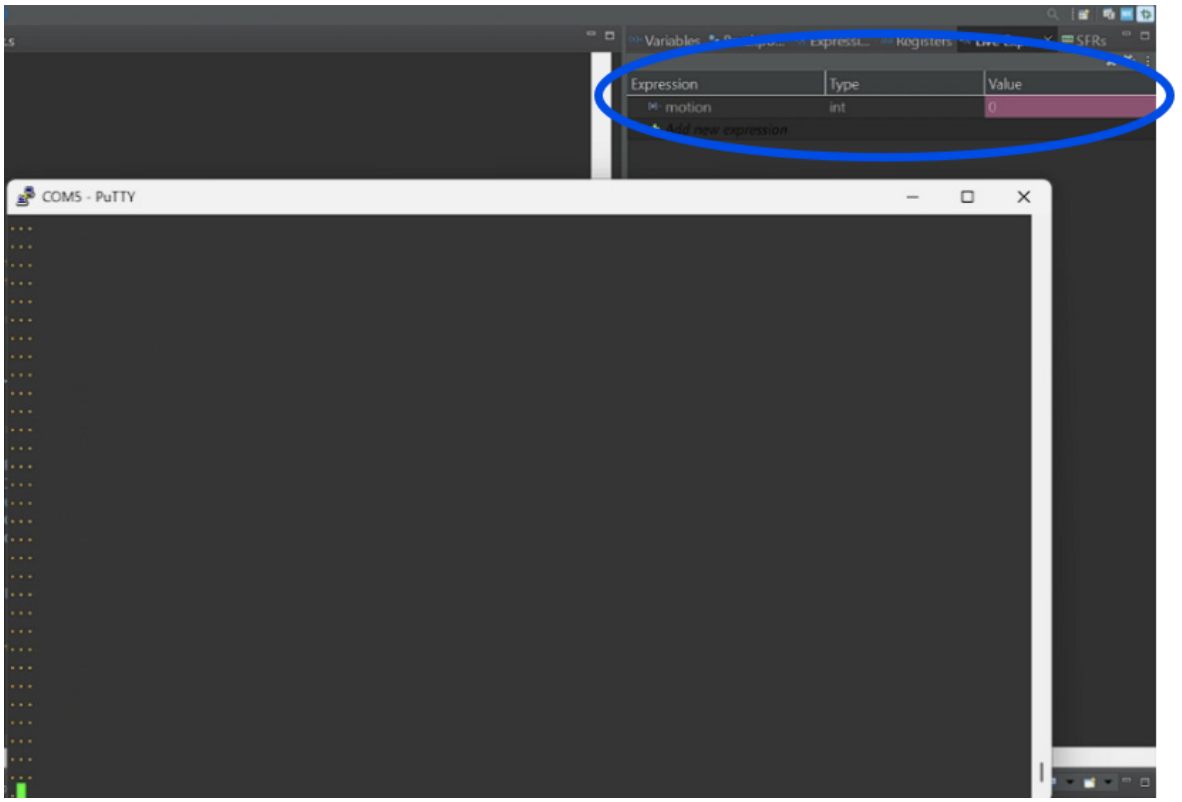

Fig 3: PIR Sensor Value is 0 and UART says “...”