Internet of Things: Theory and Applications

Module 2: ESP32 based IoT Systems – Part B

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Assignment – Module 2 – Part B

Internet of Things: Theory and Applications

Theoretical Questions

- Mention the usage of interrupts and timers in ESP32 project and why it is important?
- How does the ESP32 interface with an LCD display, and what are the common communication protocols used for this purpose?
- How can an IR sensor be used to detect objects, and what is the principle behind its operation?
- How can PWM signals be generated using the ESP32, and what are the main factors to consider when configuring PWM?
- Discuss the principle behind matrix keypads and how they can be interfaced with the ESP32 for user input.

ESP32 Project – Problem 1

- Design a Smart Door system using ESP32, a servo motor, and an analog IR sensor to enable automatic door opening and closing based on the presence of a person. The system should detect a person using the IR sensor and control the servo motor to open the door and rotate from 0 to 180 and stop at 180. After a specified time or when no person is detected, the door should automatically close and return from 180 to 0 then stops at 0.
- Bonus: Schematic
  - Design: Create a clear schematic diagram of the Smart Door system using Fritzing or similar software.
  - Simulation: Simulate the project on Tinkercad to ensure proper functionality.

ESP32 Project – Problem 2

- Design a project that allows users to control the rotation of an SG90 servo motor to specific angles (e.g., 45°, 90°, 60°, 30°, 120°, 180°) using a keypad connected to an ESP32 microcontroller. The keypad should have buttons for each predefined angle, allowing users to select the desired angle for the servo motor's rotation.
- The system should include the following features:
- Keypad Interface: Interface a keypad with the ESP32 to receive user input for selecting the desired servo motor angle.
- Servo Motor Control: Connect the SG90 servo motor to the ESP32 and program it to rotate to the specified angle when the corresponding button on the keypad is pressed.
- Stop Button: Implement a "Stop" button on the keypad that halts the servo motor's movement at its current position.
- Reset Button: Include a "Reset" button that brings the servo motor back to the 0° position.
- BONUS: Custom Angle Button: Provide an additional button to allow users to input a custom angle (e.g., 18°) for the servo motor rotation from the serial monitor.

ESP32 Project – Problem 3

- Design a project to use an analog IR sensor with an ESP32 microcontroller to obtain real-time readings of infrared sensor output reading and measured distance from 1mm to 25mm. The objective is to display the IR sensor readings on an LCD screen continuously. Additionally, the system should detect when the IR sensor is not connected or has a poor connection and display a warning message on the LCD, such as "No input detected, please connect the sensor."
- The project should include the following components and functionalities:
- Analog IR Sensor: Connect the analog IR sensor to the ESP32.
- Real-Time Display: Implement code to continuously read the analog IR sensor's value and display it on the LCD in real-time along with the measured distance.
- LCD Interface: Interface an LCD screen with the ESP32 to show the IR sensor readings.
- Error Handling: Detect when the IR sensor is not connected or has a poor connection, and display the appropriate warning message on the LCD.

Quick Bonus

- Use OLED display with ESP32 to print IR analog sensing readings.
- Interface with an optical encoder to control servo angle upon the encoder interrupt.
- Interface with ESP32 the MQ4 smoke sensor to read methane concertation with LED and buzzer alarm on any threshold value.
- Interface with a digital humidity and temperature sensor and run a LED and buzzer alarm on any threshold value.
- Interface with MPU2050 and write read values of linear and angular acceleration on a LCD.
- Interface with flex or force sensor and move servo motor upon any threshold value.
- Interface with rain sensor and open a servo upon its detection of any water.

Bonus

- Design and implement a Smart Home Automation system using an ESP32 microcontroller that integrates various sensors, including an LDR (Light Dependent Resistor), piezo buzzer, an analog IR sensor, and a potentiometer, along with a SG90 servo motor and an LED. The system aims to automate window control based on ambient light conditions and detect the presence of a person to provide enhanced security and convenience.
- **Requirements:**
- **LDR Integration:** Interface the LDR with the ESP32 to detect ambient light conditions. When it detects darkness (low light intensity), the system should activate the servo motor to open the window to its maximum (180 degrees). Conversely, when the LDR detects light (high light intensity), the servo motor should close the window and return to the 0-degree position.
- **IR Sensor Integration:** Connect the IR sensor to the ESP32 to detect the presence of a person. When a person is detected, the system should light up the LED and run the buzzer to indicate the presence and simultaneously open the servo motor to the 180-degree position. When no person is detected, the servo motor should return to the 0-degree position and switch off the LED and stops the buzzer.
- **Potentiometer Control:** Utilize a potentiometer to provide manual control over the servo motor's angle. The user can rotate the potentiometer to adjust the window position within the range of 0 to 180 degrees.
- **Double Bonus:** Add a reset push button that get the servo to 0 degrees, switch off the LED, and the buzzer when pressed.

Double Bonus

- Design and implement a Smart Home Automation system using the ESP32 module, integrating various sensors, including an MQ4 gas sensor, a PIR motion sensor, a digital temperature and humidity sensor, along with an SG90 servo motor, an LED, a buzzer, and an LCD display. The system aims to monitor methane gas concentration, display temperature and humidity readings, detect motion, and provide enhanced security and alerts in case of any intrusion detected by the motion sensor.
- **Requirements:**
- **MQ4 Gas Sensor:** Interface the MQ4 gas sensor with the ESP32 to detect methane gas concentration. Display the real-time gas concentration value on the LCD and run LED and Buzzer alarm on any assumed threshold value.
- **Digital Temperature and Humidity Sensor:** Connect the digital temperature and humidity sensor to the ESP32 to measure and display temperature and humidity readings on the LCD and run LED and Buzzer alarm on any assumed threshold value.
- **Motion Sensor:** Integrate the motion sensor with the ESP32 to detect any human presence. When motion is detected, display "Motion Detected" on the LCD for a short time and move the SG90 servo motor to a predefined position as a smart door then run a LED and buzzer alarm for this intrusion for short time and stop them.
- **Servo Motor Control:** Program the ESP32 to control the SG90 servo motor's movement in response to motion sensor inputs and return it to its initial position after a specified time.
- **LED and Buzzer Alarm:** Implement code on the ESP32 to activate the LED and buzzer as an alarm when motion is detected, alerting occupants of possible intrusion, upon threshold methane gas concentration detected, and threshold temperature and humidity sensor detected.

Double Bonus

- Design and implement a Smart Home Automation system using the ESP32 module, integrating various sensors, including a Flame sensor, an Ultrasonic sensor, a digital temperature and humidity sensor, along with an SG90 servo motor, an LED, a buzzer, and an LCD display. The system aims to monitor flame detection, measure temperature and humidity, detect obstacles using the Ultrasonic sensor, and provide enhanced security and alerts in case of critical temperature and humidity values.
- **Requirements:**
- **Flame Sensor:** Interface the Flame sensor with the ESP32 to detect flames or high-temperature sources. When a flame is detected, activate the LED and buzzer as an alarm for immediate response and send a warning message to the LCD.
- **Digital Temperature and Humidity Sensor:** Connect the digital temperature and humidity sensor to the ESP32 to measure and display real-time temperature and humidity readings on the LCD and run a threshold LED and buzzer alarm on any assumed threshold values.
- **Ultrasonic Sensor:** Integrate the Ultrasonic sensor with the ESP32 to detect obstacles or proximity to objects. Display the distance measurements on the LCD, and open and close servo based on a threshold value detected along with running LED and buzzer alarm when this threshold value exceeded and print a warning message on the LCD and stop real time data when this happen.
- **Servo Motor Control:** Program the ESP32 to control the SG90 servo motor's movement based on the Ultrasonic sensor's distance measurements.
- **LED and Buzzer Alarm:** Implement code on the ESP32 to activate the LED and buzzer as an alarm when a flame is detected or when critical temperature and humidity values are measured or threshold ultrasonic sensor values is detected.

Triple Bonus - Design of Autonomous Wheel Robot with Sensing and Avoidance Capabilities

- Using the following component design and implement a autonomous wheel robot with sensing and avoidance capabilities
- **ESP32:** The brain of the robot, controlling various functions, sensors, and actuators.
- **Chassis:** A robot platform with two wheels and a cluster wheel for stability.
- **Motors:** Two DC motors for wheel propulsion.
- **L298N Motor Driver:** To control and drive the DC motors.
- **Power Source:** Power bank for the main power supply and a separate 9V battery for the L298N motor driver and control panel (CP) to manage power efficiently.
- **Flame Sensor:** To detect flames or high-temperature sources.
- **Methane Gas Sensor:** To detect methane gas concentration.
- **Digital Temperature and Humidity Sensor:** To measure temperature and humidity.
- **Ultrasonic Sensor:** For obstacle avoidance and distance measurements.
- **Servo Motor:** To rotate and scan for obstacles.
- **LCD Display:** To show real-time sensor readings and system status.
- **LED and Buzzer:** For alarm notifications.
- **Keypad:** For user input and robot control.

Triple Bonus - Design of Autonomous Wheel Robot with Sensing and Avoidance Capabilities

- **Functionalities**:
- Movement: The robot moves on its two wheels and cluster wheel using the two DC motors, controlled by the L298N motor driver.
- Sensing: The robot constantly reads values of methane concentration, flame, temperature, and humidity using their respective sensors every second.
- Display: The LCD display shows the real-time sensor readings, including methane concentration, flame detection, temperature, and humidity.
- Alarm: If any of the sensor readings exceed predetermined threshold values, an LED and buzzer alarm will be triggered to notify the user.
- Obstacle Avoidance: The robot uses an Ultrasonic sensor and a SG90 Servo motor to detect obstacles and avoid collisions by rotating and scanning its surroundings.
- User Control: The robot can be controlled using a keypad attached to the control panel (CP). Upon user input, the robot can stop, rotate to four different angles at various speeds, and perform other actions.

Triple Bonus - Design of Autonomous Wheel Robot with Sensing and Avoidance Capabilities

- **Power Management:**
- The main power source is a power bank, providing power to the main robot components.
- To manage power more efficiently, the L298N motor driver and CP are powered separately using a 9V battery, allowing independent control of motor and sensing systems.
- **Restart Capability:**
- The robot has a restart button located on its back. When pressed, it will restart all systems, providing a quick and convenient way to reset the robot if needed.
- **Safety Considerations:**
- The robot should be designed with safety features, such as proper insulation and casing for electrical components, to avoid any hazards.
- All sensor readings should be carefully monitored to prevent hazardous situations, especially when dealing with methane gas and flames.