ABSTRACT

In the pursuit of creating smarter and more interactive environments, embedded systems provide robust solutions for sophisticated, automated control. This project details the development of an advanced proximity-based welcome system utilizing the LPC1768 microcontroller. The system integrates an ultrasonic sensor for high-precision distance measurement, a 16x2 character LCD for dynamic user feedback, an 8-bit LED bar graph for visual proximity indication, a separate PWM-controlled LED for smooth fade effects, and a buzzer for audible alerts.

The system is designed to measure the distance to an object (e.g., a hand) in real-time. When a user approaches within a predefined near threshold (10 cm), the system activates: it displays a "WELCOME" message on the LCD, illuminates a corresponding number of LEDs on the bar graph based on proximity, and smoothly fades in the PWM LED.

Conversely, when the user moves away (beyond 12 cm), the system initiates a departure sequence. It fades out the PWM LED, turns off the bar graph, and emits a brief beep from the buzzer. It then calculates and displays the duration of the user's presence on the LCD, followed by a "GOOD BYE" message, before returning to its idle state. This project showcases a multi-modal approach to user interaction, combining distance sensing with layered visual and audible feedback to create an energy-efficient and intelligent automated system.

INTRODUCTION

The increasing demand for automation and energy conservation in modern infrastructure has propelled the development of intelligent systems that can respond dynamically to their environment. Proximity-based control systems are a cornerstone of this technological shift, finding applications in automatic doors, smart lighting, touchless kiosks, and public utilities. By accurately detecting the presence and distance of a user, these systems can optimize energy usage and enhance user experience.

This project moves beyond simple motion detection to implement a sophisticated, distance-aware interactive system. Using the powerful LPC1768 ARM Cortex-M3 microcontroller, the system provides nuanced feedback based on precise distance data acquired from an HC-SR04 ultrasonic sensor. Unlike binary IR sensors, the ultrasonic sensor allows the system to quantify *how near* a user is.

The primary objective is to design a multi-functional system that provides layered feedback. When a user is detected nearby, the system provides a rich "welcome" experience: a text greeting on the LCD, a discrete visual level on the LED bar graph, and a smooth, analog fade-in of an indicator LED. When the user leaves, the system provides a "goodbye" sequence, including an audible beep and a display of the interaction time, demonstrating data logging and state management.

This project integrates several key peripherals of the LPC1768:

- Timer/Capture (Timer0): To precisely measure the echo pulse-width from the ultrasonic sensor.
- GPIO: To control the ultrasonic trigger, the 8-bit LED bar graph, the buzzer, and the LCD data/control lines.
- PWM (PWM1): To drive a single LED for smooth, analog fade-in and fade-out effects, separate from the bar graph.
- Interrupts (TIMER0_IRQn): To handle the ultrasonic echo capture asynchronously.

The resulting system is a robust and feature-rich prototype suitable for applications in smart homes, interactive displays, or energy-saving automation, demonstrating the powerful capabilities of the LPC1768 in managing multiple real-time tasks.

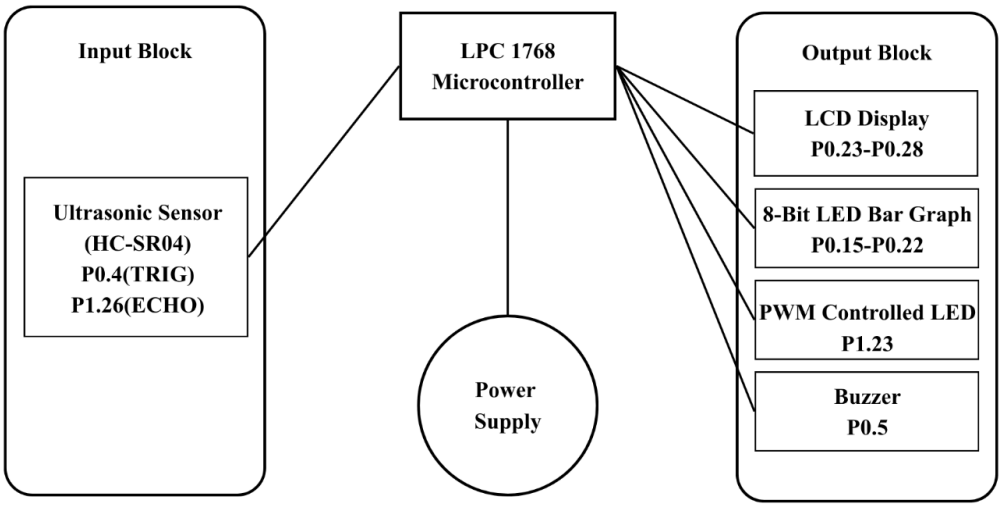
METHODOLOGY

a. Components Required

- LPC1768 Microcontroller: The ARM Cortex-M3-based development board, serving as the system's central controller.
- Ultrasonic Sensor (HC-SR04): Provides distance measurement by emitting an ultrasonic pulse (Trig) and measuring the time until the echo is received (Echo).
- LCD Display (16x2): A character liquid-crystal display used to show text-based messages like "WELCOME", "Time: X sec", and "GOOD BYE".
- 8-bit LED Bar Graph: An array of 8 LEDs used to provide a discrete, visual representation of the user's proximity (e.g., more LEDs light up as the user gets closer).
- Single LED (with resistor): A separate LED controlled by a PWM signal to provide smooth dimming and brightening effects.
- Buzzer: An active or passive buzzer to provide a single, audible beep during the departure sequence.
- Connecting Wires and Breadboard: For establishing electrical connections between all components.
- Power Supply: To provide regulated 5V and 3.3V power to the microcontroller and peripheral components.

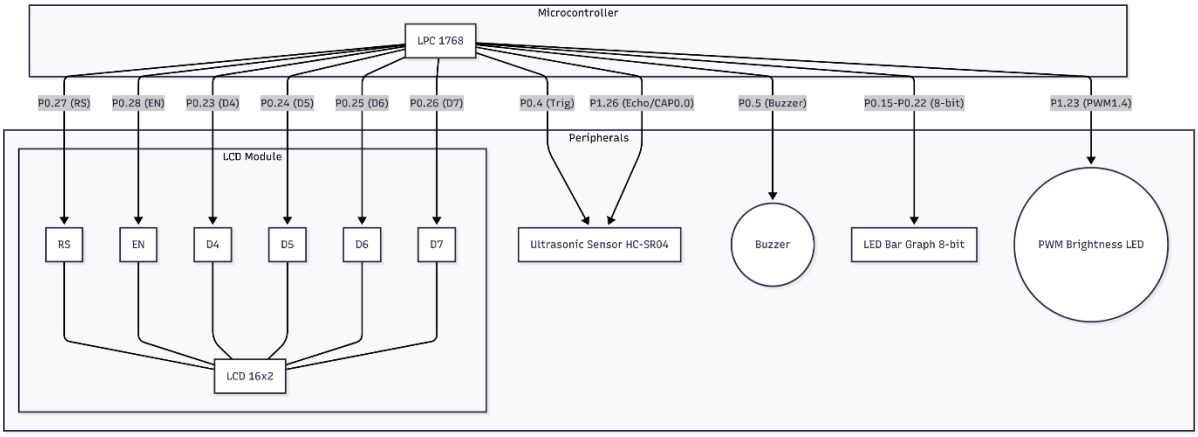
b. Block Diagram

The system is centered around the LPC1768. The microcontroller sends a trigger pulse to the ultrasonic sensor and captures the returning echo pulse using a timer. Based on the calculated distance, it simultaneously controls four output peripherals: it sends commands and data to the LCD, sets the appropriate bits for the 8-LED bar graph, adjusts the duty cycle of the PWM-controlled LED, and activates the buzzer when required.



c. Connection Description

- LCD Display (16x2):
    - Interfaced in 4-bit mode.
    - RS_CTRL (Register Select) connected to P0.27.
    - EN_CTRL (Enable) connected to P0.28.
    - Data lines D4-D7 connected to P0.23, P0.24, P0.25, and P0.26.
- Ultrasonic Sensor (HC-SR04):
    - TRIG_PIN (Trigger) connected to P0.4 (GPIO Output).
    - ECHO_PIN (Echo) connected to P1.26 (Timer0 Capture Input - CAP0.0).
- 8-bit LED Bar Graph:
    - The 8 LED pins (LED_PINS) are connected to GPIO port 0: P0.15, P0.16, P0.17, P0.18, P0.19, P0.20, P0.21, and P0.22.
- PWM-Controlled LED:
    - The single LED for fading is connected to P1.23 (PWM1.4 Output).
- Buzzer:
    - The BUZZER_PIN is connected to P0.5 (GPIO Output).
- Power and Ground:
    - All components share a common ground (GND). The LPC1768, LCD, and other peripherals are powered by the appropriate 3.3V or 5V supply lines.



d. Method / System Logic

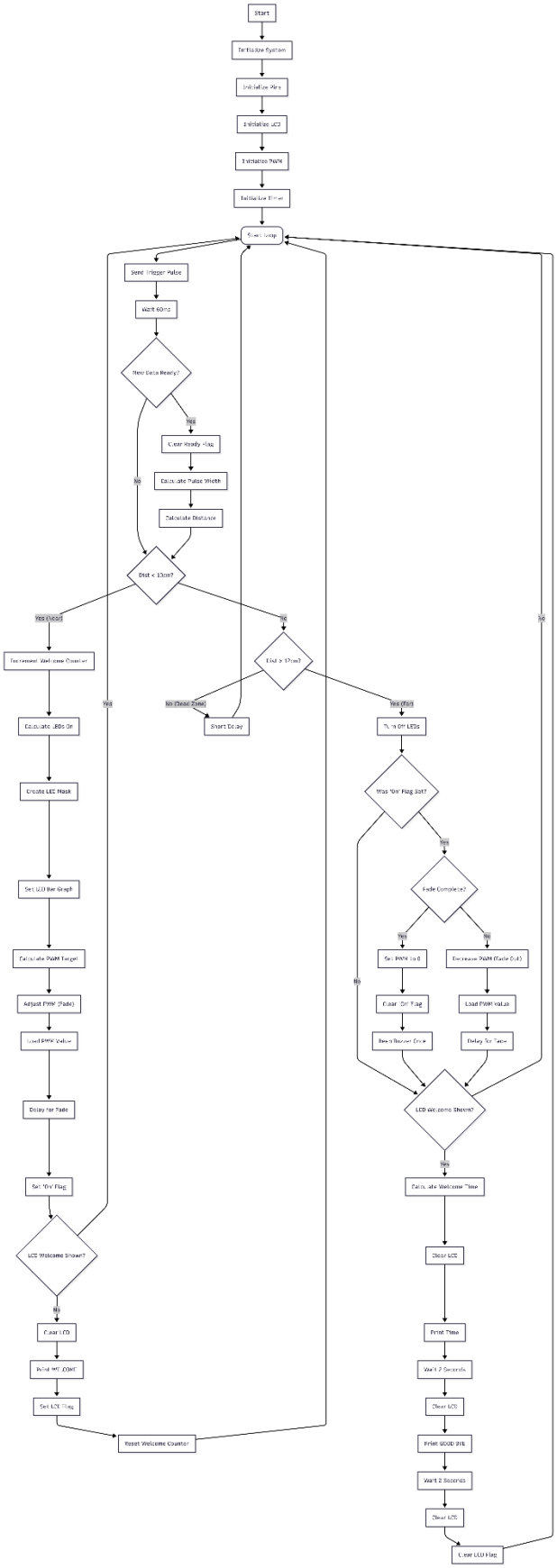
The system's logic is implemented as a state machine within an infinite loop, with a hysteresis band to prevent flickering.

1. Initialization:

- The SystemInit() function configures the microcontroller clock.
- All peripherals (GPIO, PWM, Timer/Capture) are initialized.
- lcd_init(): The LCD is initialized with its specific command sequence.
- pwm_init(): PWM1 channel 4 is configured with a frequency (MR0 = 30000) and the duty cycle (MR4) is set to 0.
- timer_init(): Timer0 is configured in capture mode to interrupt on both rising and falling edges of the P1.26 (ECHO) pin.

2. Continuous Measurement Loop:
    - The while(1) loop continuously calls send_trigger_pulse(), which sends a 10µs pulse to the sensor's TRIG pin.
    - The TIMER0_IRQHandler() interrupt service routine runs in the background. It captures the rising_time (start of echo) and falling_time (end of echo) from the LPC_TIM0->CR0 register.
    - The main loop checks if a new_measurement_ready flag is set by the ISR. If so, it calculates pulse_width and converts it to distance_cm (pulse_width / 58).
3. State 1: Object is Near (distance < 10 cm)
    - LCD: If not already displayed, the LCD is cleared and "WELCOME" is printed. A welcome_duration_counter is started.
    - LED Bar Graph: The number of LEDs to turn on (leds_on) is calculated based on the distance (e.g., 9cm = 8 LEDs, 2cm = 1 LED). The GPIO pins P0.15-P0.22 are set accordingly.
    - PWM LED: A target_brightness is calculated (inversely proportional to distance). The code smoothly increments the PWM duty cycle (MR4) towards this target, creating a "fade-in" effect.
4. State 2: Object is Far (distance > 12 cm)
    - LEDs: The 8-bit LED bar graph is immediately turned off (FIOCLR).
    - PWM LED: The code smoothly decrements the PWM duty cycle (MR4) towards 0, creating a "fade-out" effect.
    - Buzzer & LCD: When the fade-out is complete (MR4 reaches 0), the beep_buzzer() function is called once. The welcome_duration_counter is stopped, and the elapsed time is calculated and printed to the LCD (e.g., "Time: 5 sec"). After a 2-second delay, this is replaced by "GOOD BYE" for another 2 seconds. The LCD is then cleared, and the system is fully reset for the next interaction.
5. State 3: Hysteresis Zone (distance 10-12 cm)
    - To prevent the system from rapidly switching states if an object hovers at the threshold, this "dead zone" is created.

- In this state, no changes are made. The system maintains its current state (either "WELCOME" or "GOOD BYE") until the distance firmly crosses one of the thresholds.

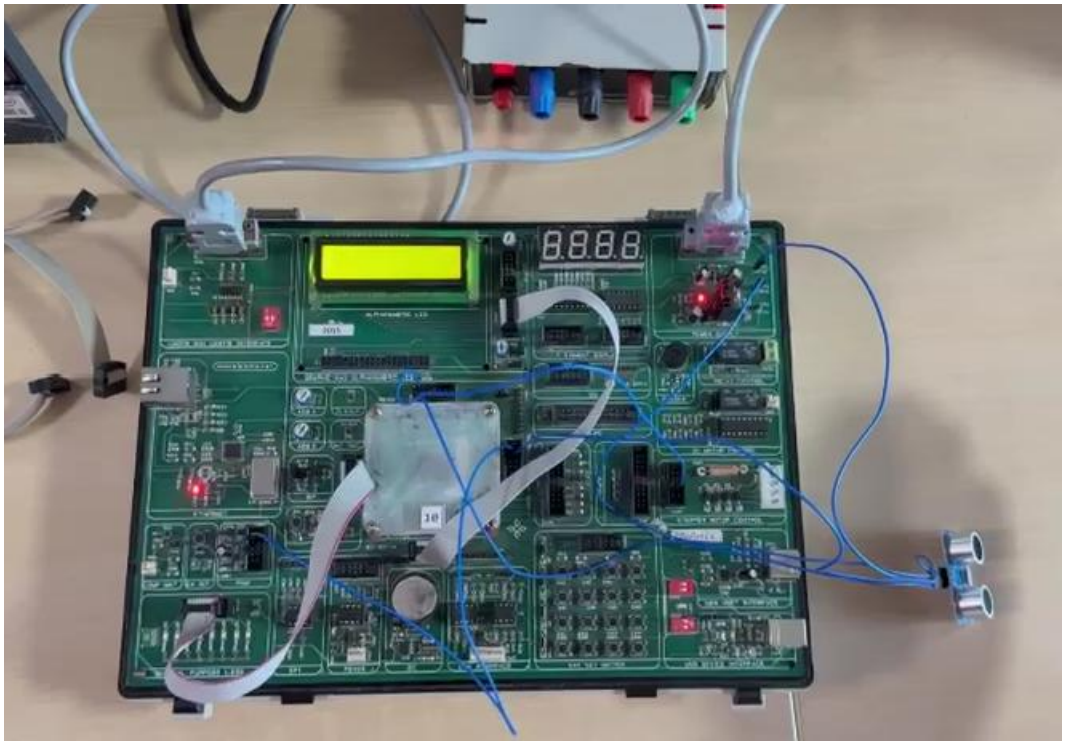


RESULTS AND DISCUSSION

The system successfully integrates multiple sensors and actuators to create a responsive and interactive user experience.

- Distance Measurement: The ultrasonic sensor and Timer0 capture module provide reliable and accurate distance measurements, forming the core of the system's logic.
- Multi-Modal Feedback: The use of four distinct feedback mechanisms (LCD, 8-bit Bar Graph, PWM LED, and Buzzer) provides clear and layered information to the user. The bar graph gives an intuitive, "analog" sense of distance, while the LCD provides specific text-based information.
- Smooth Aesthetics: The use of PWM for fading the indicator LED, rather than just turning it on or off, significantly improves the user's perceived quality of the system, making the transitions feel less abrupt.
- State Management: The system correctly manages its state, using flags (lcd_displayed, flag) and a counter (welcome_duration_counter) to track the user's presence and display the interaction duration. The hysteresis band (10-12 cm) proved effective in preventing unwanted state "flickering" at the boundary.

This project serves as a strong foundation for more advanced smart systems. It could be expanded for applications in access control (logging entry/exit times), energy-saving (controlling room lights based on occupancy duration), or as an interactive display in a public kiosk.



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