Escape Room - Digital Fort Project Report

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1 Introduction

The "Escape Room - Digital Fort" project is an innovative embedded system designed to simulate an interactive escape room experience using a PIC16F877A microcontroller. This project integrates a series of three challenges that a player must complete sequentially to "escape" a virtual locked room. Leveraging assembly language programming, the system processes inputs from switches, a potentiometer, and pushbuttons, and provides feedback through an LCD, a 7-segment display, LEDs, and a buzzer. The design showcases fundamental microcontroller concepts such as digital input handling, analog-to-digital conversion, interrupt-driven programming, and output control, making it a comprehensive demonstration of embedded systems engineering.

2 System Description

The system is structured around three distinct challenges, each testing different aspects of player interaction and system functionality:

- **Challenge 1: Prime Number Check** The player inputs a 4-bit number using switches connected to PORTB (RB4-RB7). The system evaluates whether this number is prime (3, 5, 7, 11, or 13). A green LED (CORR1, PORTE, RE2) indicates success, and the 7-segment display shows a specific pattern for pass or fail conditions.
- **Challenge 2: Potentiometer Range Matching** The player adjusts a potentiometer, providing an analog voltage input to the ADC on PORTA. The system converts this voltage to a digital value and determines its range (R1 to R5). If the value matches a predefined range (e.g., R3), the CORR2 LED (PORTE, RE1) lights up, and the LCD displays "You are correct." Adjacent ranges prompt "You are so close," while others show no message.
- **Challenge 3: Math Problem Solving** Upon pressing a Start button (PORTB, RB0), a random math problem from five predefined options (e.g., 1+1, 2-1) is displayed on the LCD. A 9-second countdown begins on the 7-segment display. The player inputs the solution via switches and presses a Finish button (PORTB, RB1). A correct answer within time lights the CORR3 LED (PORTE, RE0), while failure resets the system.

Upon completing all challenges, the system celebrates with flashing LEDs, a buzzer sound, and an LCD message: "YOU WIN! Escape." Failure at any stage resets the system to Challenge 1, displaying "Hard Luck" on the LCD.

3 Hardware System

The hardware design is tailored to support the interactive nature of the escape room:

- **Inputs:**
  - *Switches:* Four switches (PORTB, RB4-RB7) for binary input in Challenges 1 and 3.

  - *Potentiometer:* Connected to PORTA (RA0) as an analog input for Challenge 2.
  - *Pushbuttons:* Start (PORTB, RB0) and Finish (PORTB, RB1) buttons for Challenge 3 timing.

- **Outputs:**
  - *LCD:* Displays messages and math problems (connected via PORTD and control pins on PORTA).
  - *7-Segment Display:* Shows results and countdown (PORTC).
  - *LEDs:* Three green LEDs (PORTE, RE0-RE2) indicate challenge success.
  - *Buzzer:* Signals victory (assumed on a spare pin, e.g., PORTC).

The microcontroller initializes with TRIS registers configured for input (TRISB, TRISA) and output (TRISC, TRISD, TRISE) ports. The ADC is set up with ADCON0 and ADCON1 for right-justified 10-bit conversion, though only the upper 8 bits (ADRESH) are used for simplicity. Interrupts are enabled for ADC conversion completion, enhancing system responsiveness.

4 System Testing and Results

The system was rigorously tested using both unit and integration testing methodologies in MPLAB and Proteus:

- **Challenge 1 Testing:**
  - *Test Cases:* Inputs of 3, 5, 7, 11, 13 (prime) and 4, 6, 8, 10 (non-prime).
  - *Results:* CORR1 LED and 7-segment display correctly reflected prime status. Non-prime inputs triggered the "Hard Luck" message and reset.

- **Challenge 2 Testing:**
  - *Test Cases:* Potentiometer voltages corresponding to 0-51 (R1), 52-102 (R2), 103-153 (R3), 154-204 (R4), and 205-255 (R5).
  - *Results:* LCD messages and CORR2 LED activated correctly for R3 (predefined range), with "You are so close" for R2 and R4, and no output for R1 and R5. ADC interrupt handling was reliable.

- **Challenge 3 Testing:**
  - *Test Cases:* All five math problems (e.g., 1+1=2, 2-1=1) with correct and incorrect switch inputs, within and beyond 9 seconds.
  - *Results:* Countdown decremented correctly, CORR3 LED lit for timely correct answers, and system reset on timeout or errors.

- **Integration Testing:**
  - *Test Case:* Sequential completion of all challenges.

– *Results:* Victory sequence (flashing LEDs, "YOU WIN! Escape") executed flawlessly upon success, with resets functioning as expected on failures.

Minor timing adjustments were made to delays (e.g., DELAY_5S, DELAY_ONE_SECOND) to optimize user experience, ensuring smooth transitions and readable outputs.

5 Conclusion

The "Escape Room - Digital Fort" project successfully delivers an engaging escape room simulation using the PIC16F877A microcontroller programmed in assembly language. The team divided responsibilities efficiently: one member handled arithmetic logic (Challenge 1), another configured the ADC (Challenge 2), a third managed input handling (switches/buttons), and the fourth integrated the system with LCD and 7-segment outputs. Key challenges included tuning the countdown timer precision and ensuring consistent ADC readings under varying potentiometer inputs. This project deepened our understanding of low-level programming, hardware interfacing, and system debugging, culminating in a robust and interactive embedded solution.