CSE411: Real-Time and Embedded Systems Design

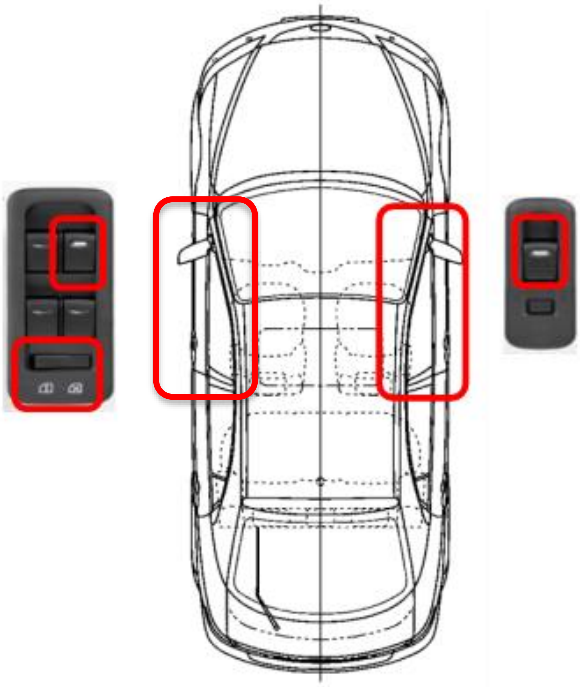
Spring 2025

Project Description – Idea 1

Advanced Power Window Control System

Project Overview

This project aims to develop an advanced power window control system using the Tiva C Series TM4C123GH6PM microcontroller and FreeRTOS for real-time task management. The system will control a front passenger door window, featuring manual and automatic operation, obstacle detection, window lock functionality, and precise position tracking. The implementation emphasizes safety, reliability, and efficient resource utilization.



Key Features

1. **Manual and Automatic Window Operation**
    - Manual Mode: The window moves up or down while the respective switch is held.
    - One-Touch Auto Mode: A short press fully opens or closes the window without requiring continuous input.
2. **Obstacle Detection and Safety Measures**
    - IR sensors detect obstacles during auto-close operation.
    - If an obstacle is detected, the window immediately stops and reverses downward for 0.5 seconds to prevent injury or damage.
    - Upper and lower limit switches ensure safe operation by preventing over-travel.
3. **Position Control with Encoder Feedback**
    - An incremental encoder provides precise window position feedback.
    - Position tracking enables additional features like partial window opening.
4. **Window Lock Functionality**
    - A window lock switch allows the driver to disable passenger-side controls.
    - When activated, only the driver can operate the passenger window.
    - Status is displayed on an LCD screen
5. **Power Management**
    - The system enters low-power mode when idle, reducing energy consumption and improving efficiency
6. **Real-Time Task Scheduling with FreeRTOS**
    - The system is structured into independent FreeRTOS tasks for:
        - Manual and automatic window control
        - Obstacle detection and response
        - Position tracking and safety monitoring
        - System status updates (LCD, LED, buzzer alerts)
    - Synchronization is handled using semaphores and message queues to ensure reliable task execution.

Hardware Components

- Microcontroller: TM4C123GH6PM (Tiva C Series)
- Motor and Driver: DC motor with an H-bridge motor driver
- Sensors:
    - IR Sensor for obstacle detection
    - Incremental encoder for position tracking
    - Limit switches for limits of window
- User Interface:
    - Push buttons for window control
    - ON/OFF switch for window lock
    - LCD display for status updates
    - Buzzer and RGB LED for audible/visual alerts

Project Deliverables

1. Hardware Setup: A fully functional prototype with all components integrated.
2. Software Implementation: Well-structured, modular FreeRTOS-based firmware.
3. Live Demonstration: Showcasing all features in real-time operation.
4. Project Report including but not limited to:
    - System design and architecture
    - FreeRTOS implementation details
    - Challenges and solutions
    - Future improvements

Project CHECKLIST

MARKS	ACTIVITIES
2	Manual Mode from both sides
2	Automatic Mode from both sides
2	Obstacle Detection and Jam Protection
2	Encoder feedback
2	Upper/lower limit switches
1	LCD displays window’s position accurately
1	Lock switch disables passenger-side control properly
1	Driver retains full control when lock is enabled
1	Sleep mode when idle
1	Tasks are created and scheduled correctly
1	Tasks priorities are assigned properly
1	Semaphores/mutexes for resource management
1	Queues for passing data between tasks
2	Full Technical Report
5	Individual Assessment
25	Total Project

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Project Description – Idea 2
Automotive Smart Safety System
(Intelligent Door Lock + Rear Park Assist)

Project Overview

This project integrates two core automotive safety functionalities into a unified embedded system:

1. **Intelligent Car Door Locking** based on motion (speed detection) using a potentiometer
2. **Rear Parking Assistance System** using an ultrasonic sensor for obstacle detection

The system is implemented using the **TM4C123GH6PM microcontroller** and programmed with **FreeRTOS** to handle multiple tasks concurrently. The project simulates real-world automotive safety systems and demonstrates key embedded design principles such as modularity, task scheduling, real-time responsiveness, and sensor interfacing.

System Explanation

- Switches mimic the behavior of the vehicle gear shifter (Park, Drive, Reverse).
- A switch mimics the behavior of the vehicle driver door.
- The system uses a potentiometer to detect the motion of the vehicle and estimate speed. If the calculated speed exceeds a predefined threshold (e.g., 10 km/h), the system automatically **locks the doors**.
- When the **ignition switch** (simulated by a toggle input) is turned off, the doors automatically **unlock**, simulating driver shutdown behavior.
- Two **manual pushbuttons** allow the driver to **lock or unlock** the doors at any time, overriding the automatic logic.
- The **LCD display** shows the current system status (e.g., "Doors Locked", "Doors Unlocked", "Speed = X km/h").
- A **buzzer** gives audible alert when the vehicle is moving and driver door is open with message on LCD to indicate door is open.
- the system uses an **HC-SR04 ultrasonic sensor** mounted at the rear (simulated setup) to continuously measure the distance to nearby objects when in **reverse** gear.
- The closer the object is to the vehicle, the faster the **buzzer** beeps, alerting the driver to potential collisions.
- An RGB LED indicates proximity visually:
  - Green: Safe zone (> 100 cm)
  - Yellow: Caution zone (30–100 cm)
  - Red: Danger zone (< 30 cm)
- The **LCD display** updates in real time to show the exact distance measured by the ultrasonic sensor.
- The entire system runs under **FreeRTOS**, which ensures reliable and deterministic scheduling of:
  - Sensor data acquisition
  - Event-driven responses (e.g., lock activation, buzzer feedback)
  - Display updates

Tasks are coordinated using queues for sensor data, and semaphores/mutexes are used to safely access shared resources like the LCD and buzzer. This structure ensures real-time performance and modularity, while teaching students how to design and implement multitasking embedded applications.

Hardware Components

- Microcontroller: TM4C123GH6PM (Tiva C Series)
- Sensors:
  - Potentiometer
  - HC-SR04 Ultrasonic Sensor
  - Pushbutton or Limit switch module for vehicle door simulation
- User Interface:
  - Push buttons for manual lock/unlock
  - Switches to mimic gears.
  - Ignition Switch
  - RGB Led
  - LCD display for status updates
  - Buzzer for audible alerts

Project Deliverables

1. Hardware Setup: A fully functional prototype with all components integrated.
2. Software Implementation: Well-structured, modular FreeRTOS-based firmware.
3. Live Demonstration: Showcasing all features in real-time operation.
4. Project Report including but not limited to:
   - System design and architecture
   - FreeRTOS implementation details
   - Challenges and solutions
   - Future improvements

Project
CHECKLIST

MARKS	ACTIVITIES
1	Gear shifting operates correctly
2	Vehicle speed is measured accurately
2	Doors automatically lock upon crossing speed threshold
2	Doors automatically unlock when ignition is turned off
2	Manual locking and unlocking work reliably
2	Rear obstacle distance is measured accurately
1	Audible alert varies based on proximity to rear obstacles
1	RGB LED changes behavior based on obstacle distance
1	LCD accurately displays system status
1	Tasks are created and scheduled correctly
1	Tasks priorities are assigned properly
1	Semaphores/mutexes for resource management
1	Queues for passing data between tasks
2	Full Technical Report
5	Individual Assessment
25	Total Project