Autonomous Car

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Overview

The project aims to develop a real-time operating system (RTOS) with a non-preemptive scheduler that manages various tasks to control an autonomous light-tracking car. This RTOS is designed to efficiently allocate processor resources, including processing time and hardware peripherals, among different tasks. The primary objective is to implement a scheduler that schedules tasks based on their periodicities, allowing the car to respond to environmental conditions while adhering to a predefined schedule.

The autonomous light-tracking car is equipped with several sensors and components to enable its functionality:

1. **Photo-Resistors (LDRs):** Two photo-resistors are used to detect and measure the illumination levels in the car's surroundings.

2. **Ultrasonic Sensor Module HC-SR04:** This sensor is employed to measure distances to obstacles in front of the car.

3. **On-board Temperature Sensor:** The car features a temperature sensor to monitor environmental temperature.

4. **LCD Display:** An LCD screen is integrated into the car to provide real-time feedback and data visualization.

5. **Motors and Motor Drivers:** The car is equipped with four motors and two motor drivers to control its movement.

The car's operation is governed by the following rules:

- **Motor Control:** The car's motors are activated using one of two on-board switches.

- **Car Movement:** When the motors are started, the car moves and navigates towards the area with the highest illumination.

- **Data Display:** The car displays temperature, the difference in illumination levels as detected by the LDRs, and elapsed time on the LCD screen.

- **Obstacle Avoidance:** If the car approaches an obstacle within a range of 10 centimeters, the ultrasonic sensor triggers, causing the car to reverse its direction and then rotate by 90 degrees to avoid the obstacle.

The heart of this system is the scheduler, which plays a central role in orchestrating these actions. It operates based on a counter incremented in the SysTick handler.

The scheduler relies on the SysTick timer to implement a straightforward non-preemptive scheduling mechanism. To maintain modularity, the scheduler's implementation is separated into files (e.g., scheduler.c and scheduler.h). Key components of the scheduler include:

1. **Task Control Block (TCB) Struct:** This struct contains two members, a pointer to the task and the task's periodicity.

2. **create_task Function:** It allows the creation of tasks with specific periodicities using the `create_task(void (*Task)(), uint32_t ms_periodicity)` function.

3. **tasks_scheduler Function:** This function is the core of the scheduler, executing a loop that scans the periodicities of tasks and schedules them accordingly.

Tasks:

Initially, tasks do not include an infinite while(1) loop. There are three primary tasks to implement:

1. **ldr_swing_car:** This task manages the car's swinging motion based on input from the LDRs, directing the car toward areas with higher illumination.

2. **lcd_display:** Responsible for displaying data on the LCD screen, including temperature, LDR readings, and elapsed time.

3. **avoid_obstacle:** This task handles obstacle avoidance when the ultrasonic sensor detects an obstacle within a 10-centimeter range.

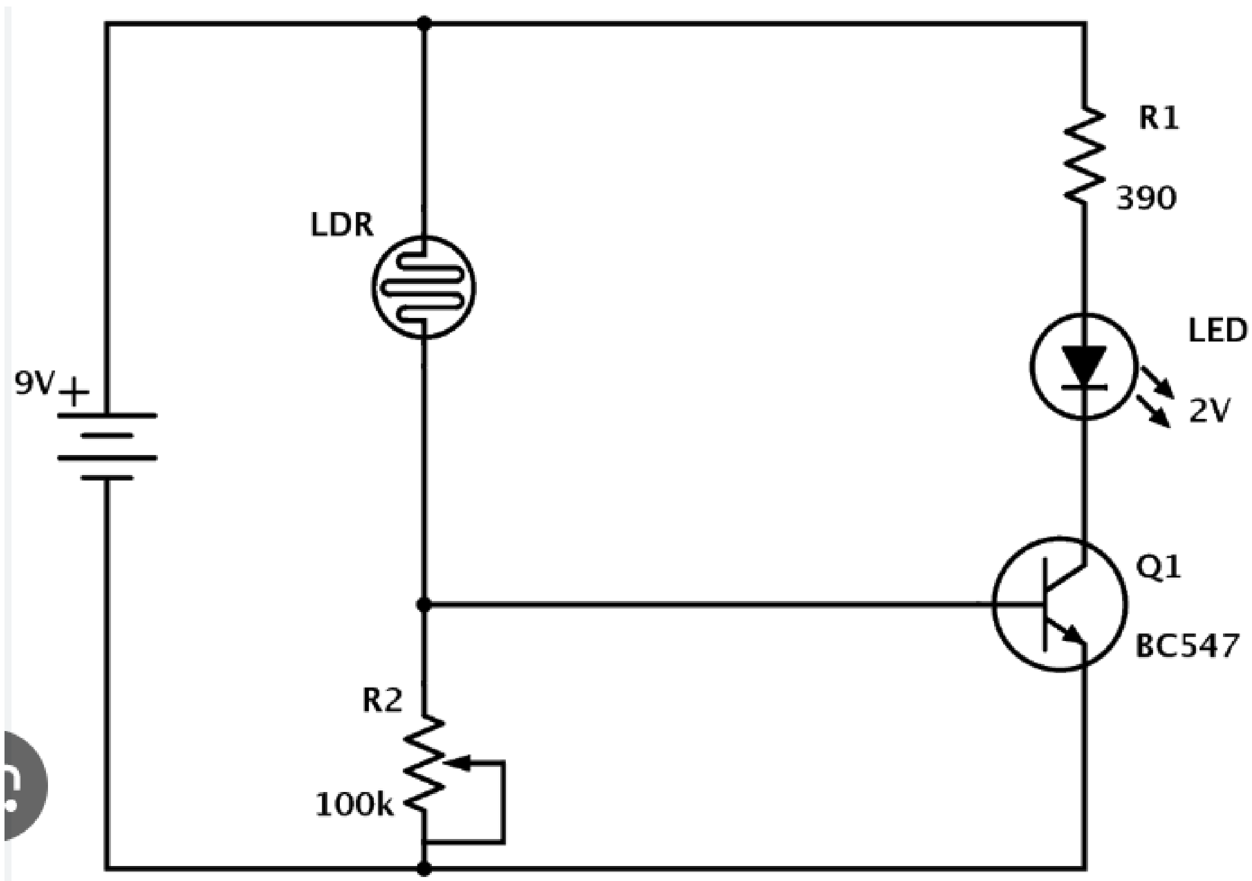
In summary, this project focuses on building an RTOS with a non-preemptive scheduler to manage tasks for an autonomous light-tracking car. The system responds to environmental cues, providing a practical demonstration of real-time embedded systems and sensor integration in autonomous vehicles.

Sensors

In our autonomous car project, we utilize various sensors to gather data from the car's environment, enabling it to navigate and make decisions. Below is a quick overview of the sensors used in our project, along with their associated circuit topologies:

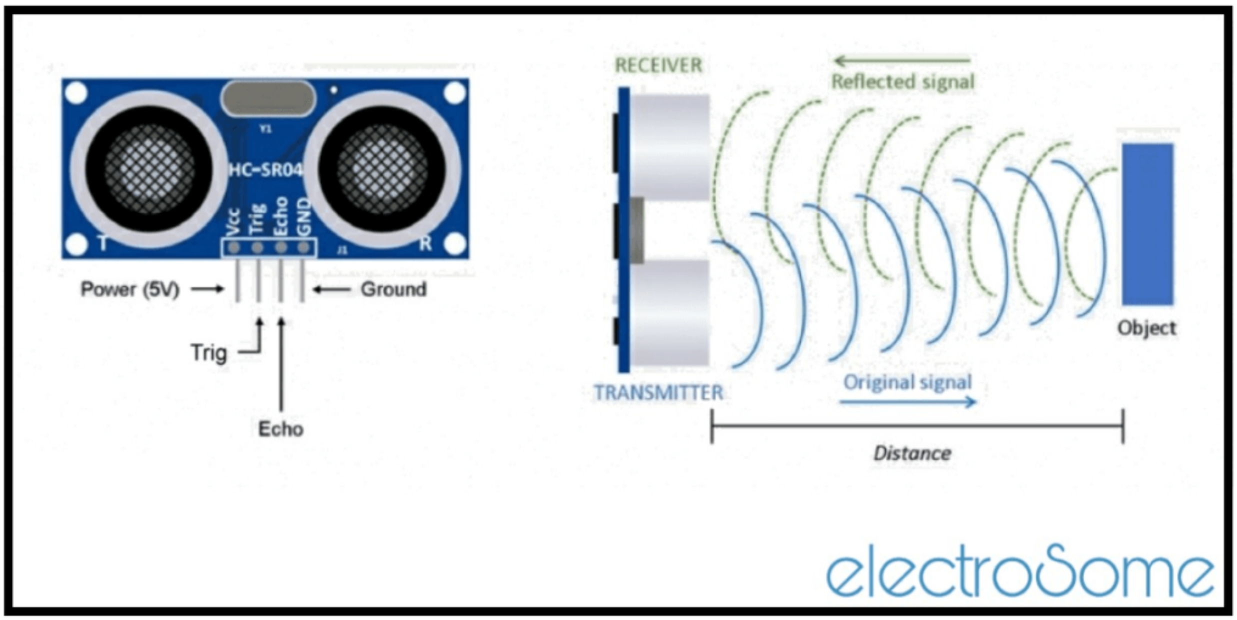
1. **Photo-Resistors (LDRs):**

- **Sensor Overview:** Photo-resistors, or Light Dependent Resistors (LDRs), are light-sensitive devices that change their resistance based on the intensity of incident light. They are commonly used to detect ambient light levels.
- **Circuit Topology:** LDRs are typically used in voltage divider circuits. One end of the LDR is connected to the ground, and the other end is connected to a voltage source. The voltage at the junction between the LDR and a fixed resistor varies with light intensity and is used as an input to the microcontroller's analog-to-digital converter (ADC).



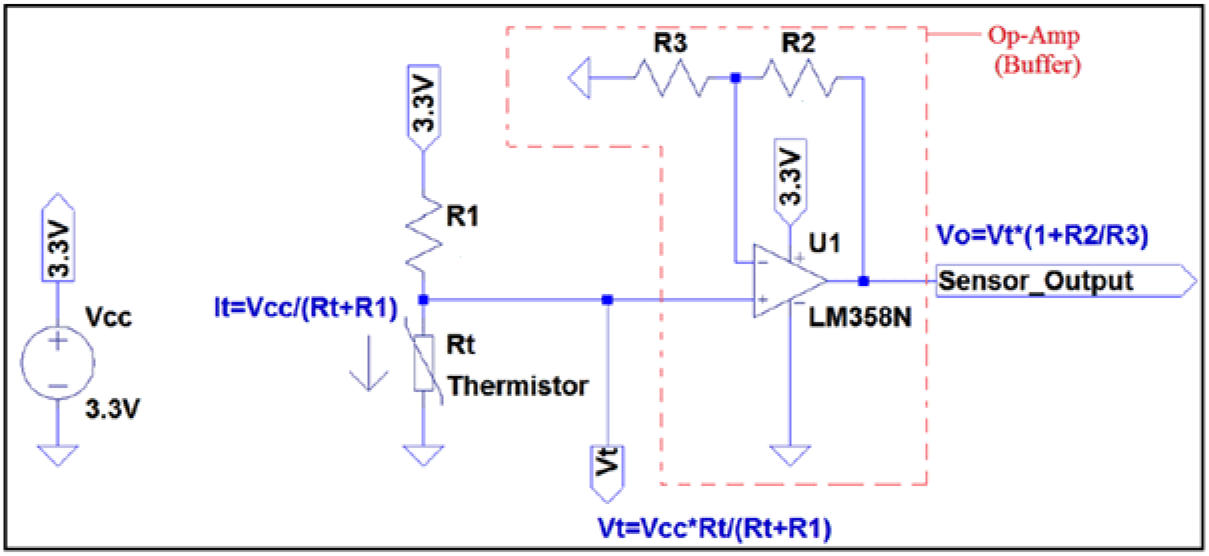
2. **Ultrasonic Sensor Module HC-SR04:**

- **Sensor Overview:** The HC-SR04 is an ultrasonic distance sensor that uses sound waves to measure distances to objects. It emits ultrasonic pulses and calculates the time it takes for the pulses to bounce back to determine the distance.
- **Circuit Topology:** The HC-SR04 sensor is straightforward to interface with microcontrollers. It requires two pins, one for triggering the ultrasonic pulse and another for receiving the echo. The sensor generates a pulse on the trigger pin, and the microcontroller measures the time it takes for the echo pulse to return.



3. **On-board Temperature Sensor:**

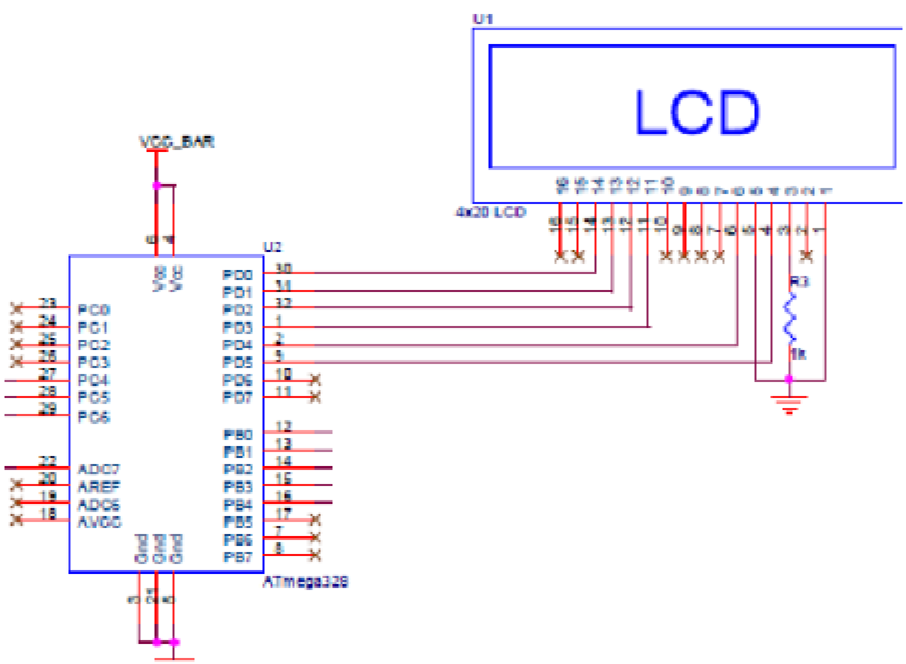
- **Sensor Overview:** The on-board temperature sensor is used to measure the ambient temperature in the car's environment.
- **Circuit Topology:** Temperature sensors are often connected to analog pins of the microcontroller. The output voltage of the sensor varies with temperature, and the microcontroller's ADC is used to convert this voltage into a temperature reading.



4. **LCD Display:**

- **Sensor Overview:** While not a traditional sensor, the LCD display serves as an output device to provide visual feedback from the car's system, including temperature, light readings, and elapsed time.

- **Circuit Topology:** LCD displays are commonly interfaced with microcontrollers through parallel data connections. They require connections for power, ground, data lines, and control signals to display information.



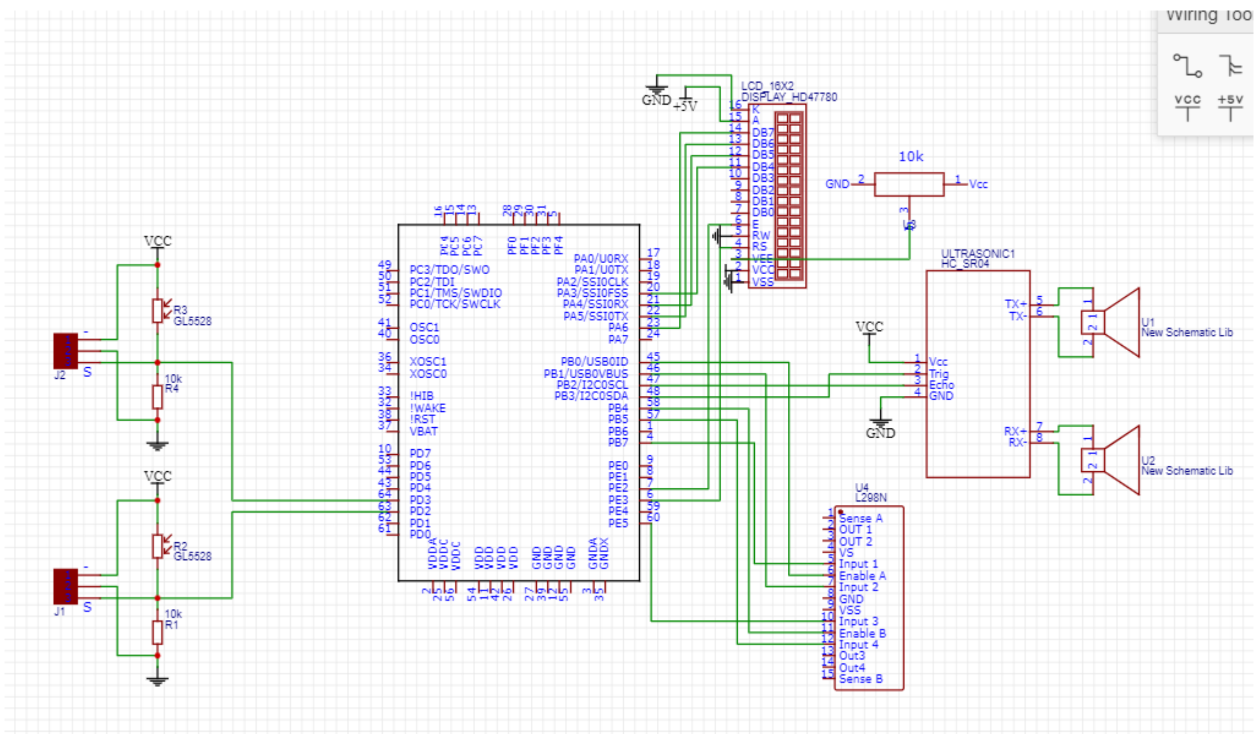
5. **Motors and Motor Drivers:**

- **Sensor Overview:** Motors are used for controlling the car's movement, and motor drivers are used to interface these motors with the microcontroller.

- **Circuit Topology:** Motor drivers, such as H-bridges, are typically used to control the direction and speed of motors. They take input signals from the microcontroller and provide the necessary power to the motors. The control signals include direction (forward/backward) and PWM (Pulse Width Modulation) signals for speed control.

Project Components Layout

In autonomous car project, the layout of components and their interconnections is critical to the proper functioning of the system. Here, I'll describe the layout of the project's major components and how they are connected to each other.



Features and delimitations.

Features:

1. **Real-time Operating System (RTOS):** The project incorporates an RTOS, which efficiently manages multiple tasks, allowing for seamless coordination of the car's actions. This real-time system ensures timely responses to sensor inputs and precise control of the car's movements.

2. **Non-preemptive Scheduler:** The system employs a non-preemptive scheduler that schedules tasks based on their periodicities. This approach ensures predictable and deterministic behavior, as tasks are executed to completion before switching to the next task.

3. **Light Tracking:** The car is equipped with two photo-resistors (LDRs) that detect light levels in the environment. The car autonomously navigates towards areas with higher illumination, making it suitable for applications like line-following or light-tracking scenarios.

4. **Obstacle Avoidance:** An ultrasonic sensor (HC-SR04) is used to detect obstacles in front of the car. If an obstacle is detected within a specified range, the car reverses and rotates by 90 degrees to avoid the obstacle, ensuring safe navigation.

5. **Temperature Monitoring:** The project includes an on-board temperature sensor that measures and displays the ambient temperature. This feature can be valuable for applications where temperature data is relevant, such as environmental monitoring.

6. **LCD Display:** A liquid crystal display (LCD) provides real-time feedback, displaying information such as temperature, light readings, and elapsed time. This visual feedback enhances the user's understanding of the car's behavior.

7. **Motor Control:** The car is equipped with four motors and motor drivers, allowing precise control over its movements. The motors can be started and stopped using on-board switches, giving the user manual control over the car's operation.

Delimitations:

1. **Simplified Obstacle Avoidance:** The obstacle avoidance mechanism implemented in the project has certain limitations. It primarily relies on ultrasonic sensor data to detect obstacles and react. More complex obstacle avoidance algorithms or additional sensors (e.g., infrared or lidar) could enhance the car's obstacle detection capabilities.

2. **Non-Preemptive Scheduling:** While the non-preemptive scheduling approach simplifies task management, it may not be suitable for applications requiring higher degrees of responsiveness or where certain tasks must be interrupted immediately. For such cases, a preemptive scheduler may be more appropriate.

3. **Limited Sensor Suite:** The project employs a basic set of sensors, including LDRs, an ultrasonic sensor, and a temperature sensor. More advanced autonomous car systems may incorporate a broader range of sensors, such as cameras, GPS, or IMUs, to provide richer perception and navigation capabilities.

4. **Simplified Task Set:** The project outlines three primary tasks (light tracking, LCD display, and obstacle avoidance). In a real-world autonomous car application, there would likely be a more extensive set of tasks and decision-making processes to handle complex scenarios, including path planning, traffic detection, and control algorithms.

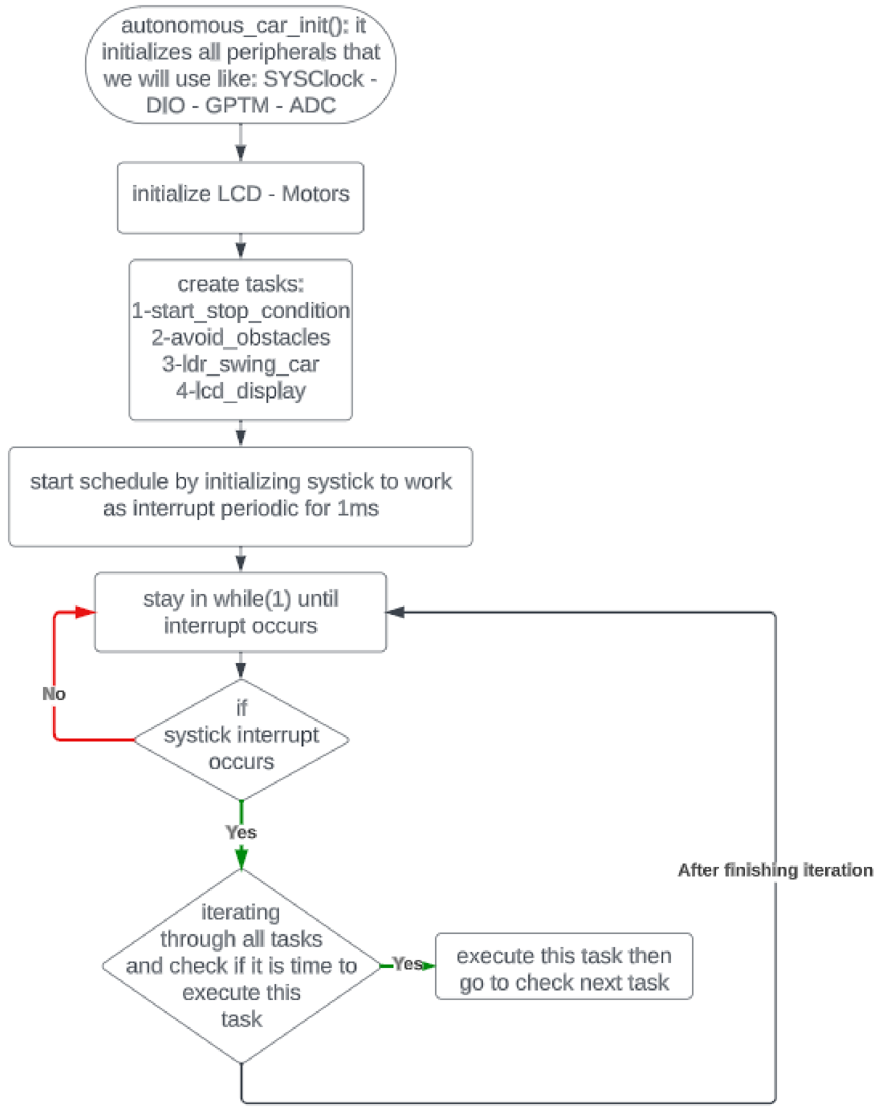
5. **Manual Motor Control:** While the car's motors can be manually started and stopped using switches, the project does not include autonomous decision-making regarding motor control based on environmental conditions. More advanced autonomous cars would incorporate automatic control algorithms for navigation and movement.

6. **Limited User Interface:** The project does not include a comprehensive user interface for interacting with the car's functions. Advanced autonomous cars would typically have user-friendly interfaces for settings, monitoring, and control.

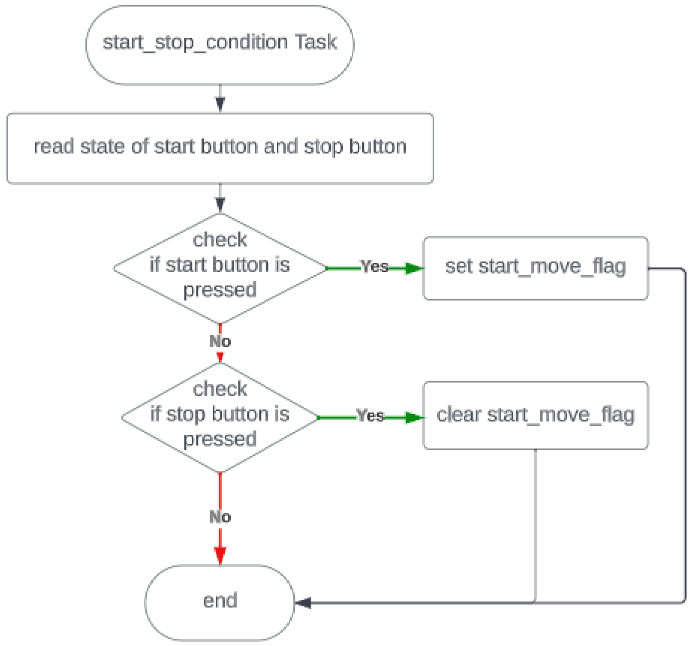
These features and delimitations define the scope and capabilities of the autonomous car project. While it provides a foundation for understanding and implementing essential autonomous car functionalities, it also highlights areas for potential expansion and improvement in more advanced autonomous systems.

Flowcharts.

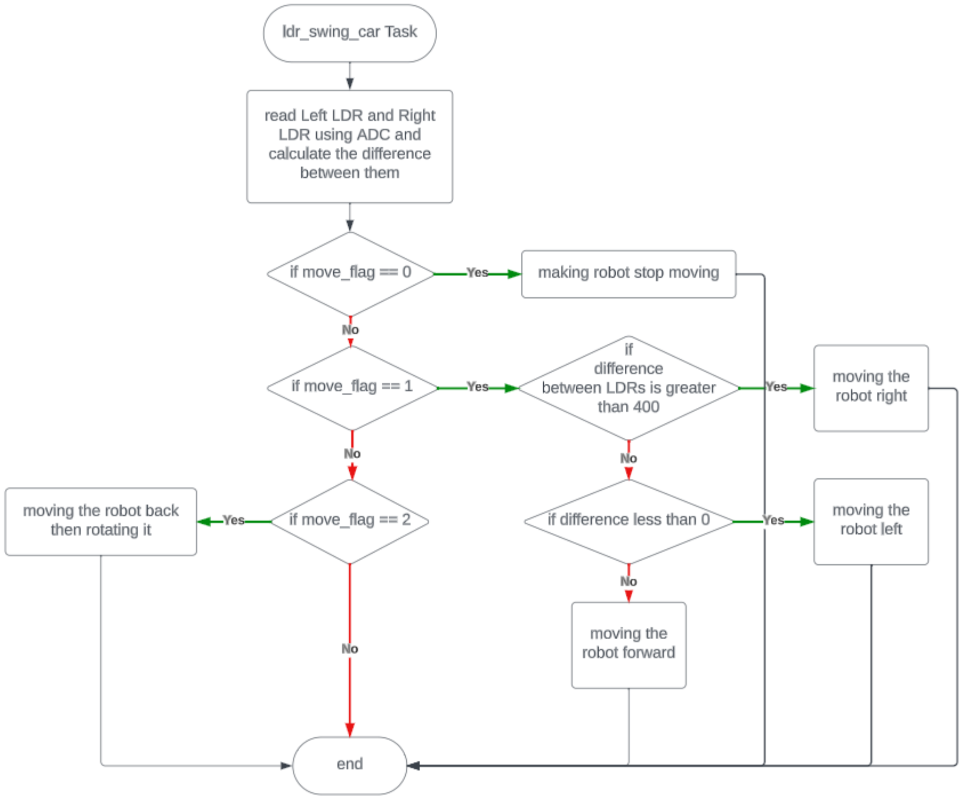
- Flow of Application:



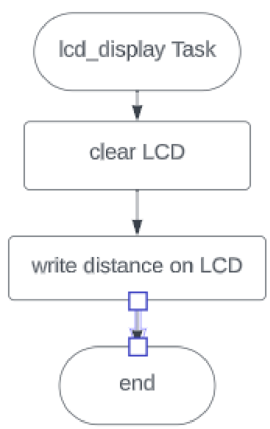
- Task: start_stop_condition():



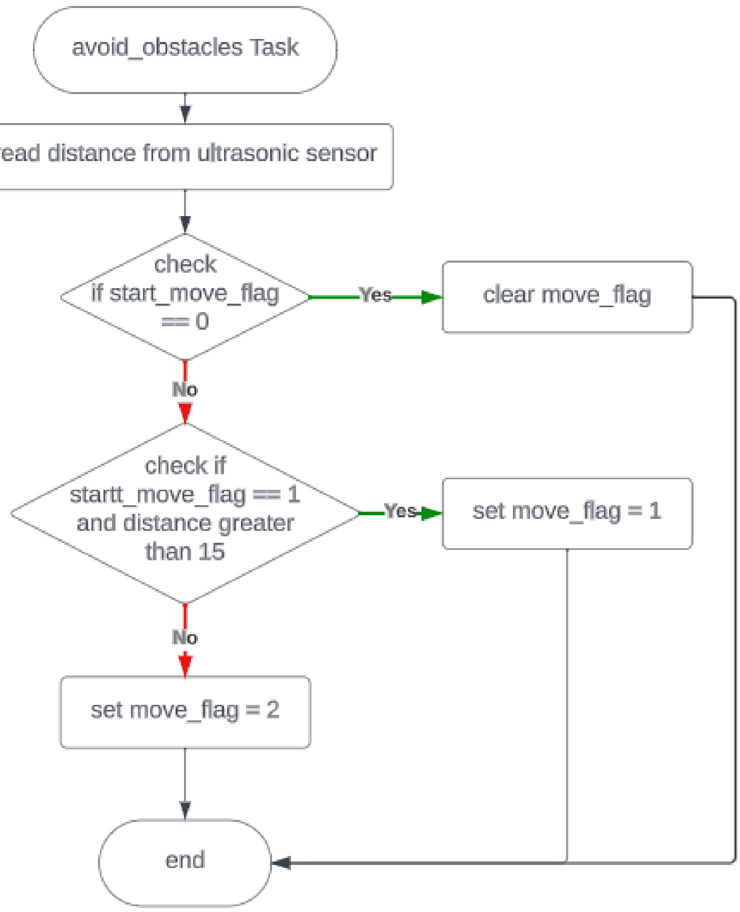
- Task: ldr_swing_car():



- Task: lcd_display():



- Task: avoid_obstacles();



Conclusion

In summary, this project has achieved the successful integration of sensors and a non-preemptive scheduler into an autonomous car system. It demonstrates the car's ability to autonomously track light, avoid obstacles, and display real-time data. The project highlights the importance of real-time operating systems in automation.

While successful, the project has some limitations. The obstacle avoidance system can be enhanced with advanced sensors and algorithms, and the task set can be expanded for more complex scenarios.

Overall, this project provides a solid foundation for exploring and applying basics concepts of automotive embedded systems