**Term Project Report – Line Following Car**

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1. **Introduction**

Line-following robots are a fundamental application in robotics, combining concepts of automation, sensor technology, and control systems. These robots are designed to navigate along a predefined path, typically marked by a black line on a white surface, utilizing sensors to detect and react to changes in the environment. The underlying principle involves real-time feedback from sensors that guide the robot's motors to ensure it stays on track. This project demonstrates the practical implementation of such concepts by constructing a robot car capable of autonomously following a black line while adjusting to curves and intersections.

The robot car utilizes two photo light sensors to detect the contrast between the black line and the white background. These sensors relay data to a microcontroller, which interprets the signals and generates appropriate motor commands. To achieve smooth and efficient navigation, the car adjusts the speed of its two rear motors dynamically based on sensor readings. This design enables the robot to perform precise turns and corrections, showcasing the importance of sensor-based control in real-world applications such as automated vehicles, warehouse robots, and industrial automation.

This report details the development process, starting from hardware assembly to programming and testing. It examines the robot’s design considerations, including sensor placement and motor control logic, and evaluates its performance under varying path complexities. The goal is to provide an understanding of how robotics principles can be applied to create autonomous systems capable of adapting to dynamic environments.

1. **Functionality and correctness**

The primary functionality of the line-following robot car is to autonomously navigate along a black line on a white surface by dynamically controlling its motors based on input from two photo light sensors. The sensors detect the contrast between the black line and the white background, and this information is processed by the microcontroller to determine the appropriate motor actions. The car adjusts its movement through motor speed modulation and directional control, ensuring that it remains on the path, handles turns smoothly, and corrects deviations effectively. The core logic is implemented in the main function, which evaluates sensor readings and applies control commands to the motors using the Motor\_SetSpeed function.

The correctness of the implementation lies in the integration of precise sensor readings with dynamic motor control. The algorithms sensor\_algorithm1 and sensor\_algorithm2 measure threshold values that represent the presence or absence of the black line under each sensor. These thresholds are then compared to pre-defined values to determine the car's position relative to the line. For instance, when both sensors detect low thresholds, the car moves forward, indicating it is aligned with the line. When one sensor deviates, the corresponding motor adjusts speed to steer the car back on track. The motor control functions, motor\_control\_1 and motor\_control\_2, configure the necessary GPIO pins and timers to enable smooth and accurate pulse-width modulation (PWM) for speed control, ensuring a seamless response to changes in sensor inputs.

This modular approach to functionality allows for adaptability and reliable performance, as the system continuously evaluates sensor data and adjusts motor actions in real-time. The use of alternate functions for GPIO pins and precise timer configurations ensures the hardware operates efficiently. The design emphasizes robustness by accounting for various scenarios such as sharp turns and intersections, demonstrating the system's correctness in adhering to the desired path.

1. **Pre-lab**

There was no official prelab, but we did break the code into smaller/more manageable pieces. We first worked on the sensor code and once we knew the sensor worked, we moved on to the motors. Once the motor code was working, we then worked on the final implementations for the final project.

1. **Post-Lab**

No post-lab assignment.

1. **Conclusion**

The line-following robot car project successfully demonstrated the integration of sensor-based control systems, motor control logic, and real-time decision-making to achieve autonomous navigation. By utilizing two photo light sensors and a microcontroller, the robot was able to detect and respond to variations in the environment, ensuring it stayed aligned with the black line. The implementation of motor speed modulation and dynamic adjustments for turns and intersections showcased the practical application of embedded systems principles in robotics. The use of PWM signals to control motor speed provided smooth and efficient movement, while the modular structure of the code ensured adaptability and scalability.

This project highlights the importance of combining hardware and software to solve engineering challenges. The robot's performance under various conditions demonstrated the robustness and correctness of the design, but it also identified areas for potential improvement, such as refining sensor calibration for more precise threshold detection and optimizing motor control for tighter turns. Overall, the project served as an effective platform for understanding real-world embedded systems applications, fostering skills in microcontroller programming, sensor integration, and system debugging. This foundation provides a pathway for future advancements in autonomous systems, with potential applications in industries ranging from transportation to manufacturing.