**Findings and Analysis:**

The following section presents the key findings obtained during the project, along with a detailed analysis. These results are based on the data collected, observations made, and methods applied throughout the project.

**Sensor Behavior and Accuracy**

* Ultrasonic Sensors: Successfully detected obstacles within a range of 18cm with an average error margin of ±1cm.
* Infrared Sensors: Accurately detected line paths, but performance was affected by lighting and surface texture.
* Colour Sensor: Could reliably distinguish between Red and Green surfaces under good lighting conditions.

**PID Controller Tuning**

* Initial PID values: Kp = 100, Ki = 100, Kd = 100
* Observed that:
  + High Kp caused the robot to oscillate.
  + Ki helped reduce long term drift but too much made it unstable.
  + Kd improved sharp turns and reduced overshoot.
* Final tuned values: Kp = 10, Ki = 5, Kd = 10 – provided smooth line following with minimal overshooting.

**State Machine Performance**

* The state transitions worked correctly between:
  + Line following
  + Obstacle avoidance
  + Turning logic
* Edge cases (e.g., obstacles, tight corners) were handled with a delay of 200ms on average.

**System Limitations**

* Sensor noise occasionally caused false obstacle detection.
* Bright ambient light interfered with IR accuracy.
* Tuning PID required trial and error and was environment dependent.

**Performance Metrics**

* Average lap time on test track: 29 seconds
* Success rate for completing track without collision: 90%