Micro-Mouse Design Report

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Student number: LNGLUL002

Brief description of design task (max. 600 characters)

A short outline of the task identified and the problem it is intended to solve.

The task was to design a gyro-based orientation control system for the Micromouse to maintain accurate straight-line motion and execute precise 90° turns. The system addresses drift and misalignment caused by uneven wheel speeds and surface friction. Using the z-axis readings of the gyro sensor, the design calibrates offset, computes heading, and applies PID-based corrections to the motors, ensuring reliable navigation through the maze environment.

Visual aids for this report

Any figures, images, or other graphics can be placed in this section and be referred to in the rest of the text. This can include excerpts of Stateflow or Simulink block diagrams. Note that you can only insert a single graphic file here, so prepare your content separately, convert to an image, and insert as required.

Figure 1: Simulink Block Diagram of the Gyro Control System

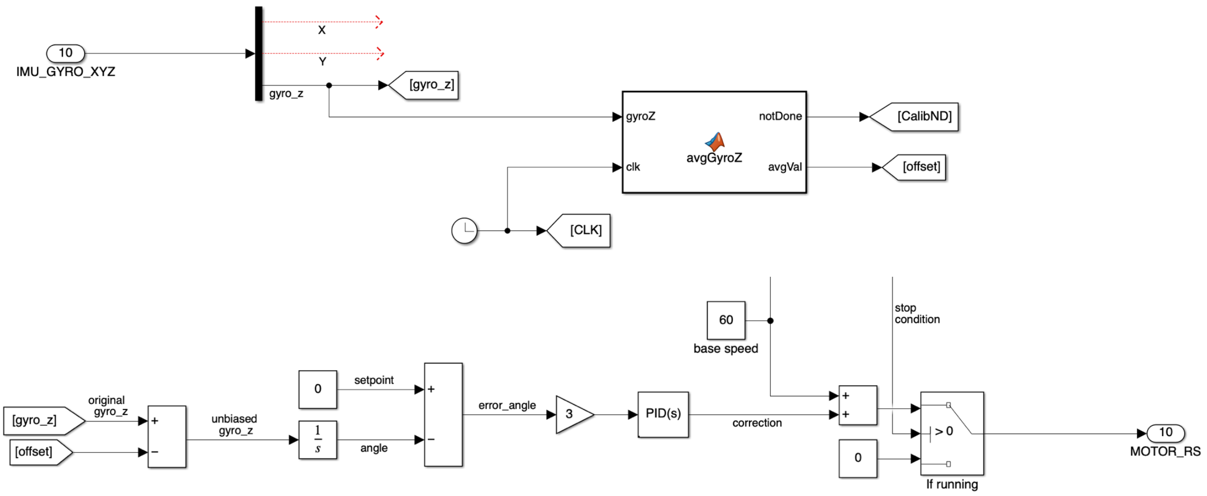


Figure 2: Simulink Block Diagram of the 90˚ Turn Procedure

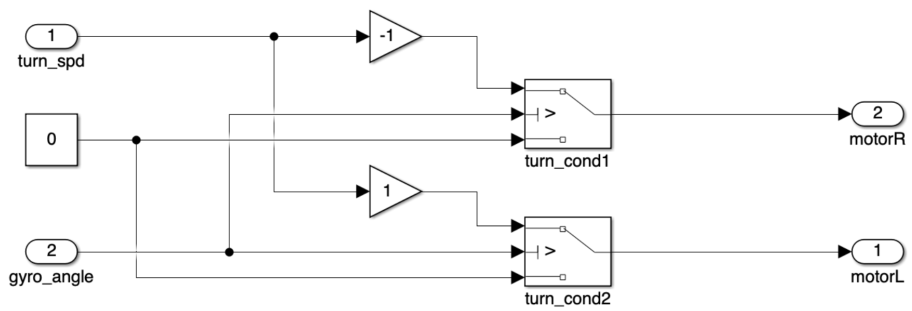
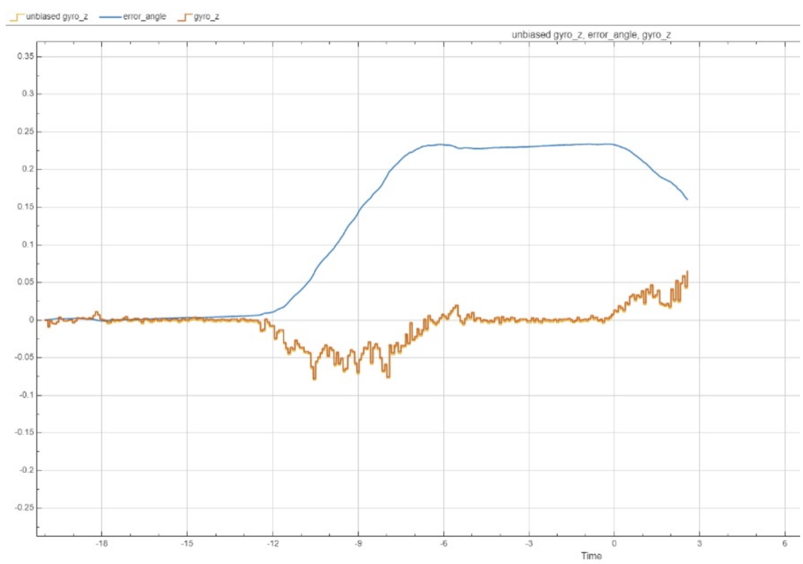


Figure 3: Raw & Unbiased Gyro Z Readings and Error Angle (during Straight-line Movement & After 90˚ Right Turn)



Design criteria and constraints (max. 1000 characters)

These are fundamental elements in the engineering design process. Criteria are the desired features, functions, and performance standards that a design must meet, while constraints are the limitations or restrictions that must be considered during the design process.

The gyro-straightening system must maintain a stable heading with minimal drift and enable accurate 90° turns within a small error margin (aiming for ±3° of the intended angle). The mechanism should operate in real time, using the gyro's z-axis readings to detect angular velocity, calibrate its offset during startup, and integrate the unbiased signal to determine orientation. Corrections are applied through a proportional–integral–derivative (PID) controller that adjusts wheel speeds to minimize heading error.

Constraints include limited processing capacity on the STM32 microcontroller, sensor noise, drift due to long-term integration, and unequal motor performance caused by surface friction or wheel slip. The design also had to ensure that offset calibration completes reliably before motion begins, and that gain and PID tuning balance responsiveness with smooth movement without overshooting.

Main design assumptions with justification (max. 1000 characters)

Design assumptions are fundamental beliefs or statements about a system, its environment, or its users, that are taken as true without proof during the design process. Justification involves providing reasons and evidence to support these assumptions, explaining why they are reasonable and necessary for the design to proceed.

It was assumed that the gyro's z-axis output is stable enough after calibration to represent accurate angular velocity, and that the average of the first 100 samples provides a reliable offset for drift correction. The integration of the unbiased gyro signal was assumed to produce a sufficiently accurate estimate of angular position over short time intervals. It was also assumed that motor response to speed adjustments is approximately linear and consistent between wheels, allowing PID corrections to effectively align the robot's heading. The maze surface was assumed to provide uniform traction, and environmental vibration was considered negligible as there are no active physical disturbances. These assumptions simplify the design while remaining reasonable for the controlled testing environment used in the micromouse operation.

Design process description (max. 1000 characters)

The design process is a structured approach, often iterative, used to solve problems and develop solutions. It typically involves identifying a need, researching the problem, brainstorming ideas, creating prototypes, testing, and refining the design until it meets the desired outcome.

The design process began with identifying the need for accurate heading control, as small drift errors caused the Micromouse to veer off course under normal operation. To address this, a gyro-based correction system was developed in Simulink. The z-axis of the IMU was isolated and used to compute an average offset over the first 100 samples to remove bias. The unbiased signal was then integrated to estimate angular position. A PID controller adjusted the right wheel's speed based on heading error, with gains tuned experimentally for stable correction without oscillation. For 90° turns, the integrated angle was monitored until $\pm\pi/2$ was reached, at which point the motors stopped. Iterative testing refined calibration duration, gain values, and control timing to balance accuracy and responsiveness under hardware constraints.

Design implementation (max. 1000 characters)

Design implementation describes the process of translating a design into a functional reality. It's the stage where the theoretical design is brought to life, whether it's a software application, a physical product, or a system.

The final design was implemented in Simulink and deployed to the STM32 microcontroller of the Micromouse. The Simulink model of the gyro-straightening mechanism is shown in Figure 1, illustrating the data flow from gyro input to motor speed correction through the PID controller. The IMU's gyro outputs were read continuously, with the z-axis data demultiplexed and passed to the avgGyroZ MATLAB function to compute the initial offset during calibration before the Micromouse started moving. Once the offset was locked, the unbiased gyro signal was integrated to determine orientation. The resulting angle was compared to a zero set-point to compute heading error, amplified through a gain block and fed into a PID controller. The PID output dynamically adjusted the right wheel's speed to maintain straight motion. For turns, the integrated gyro angle triggered motor stop conditions once $\pm\pi/2$ was reached. The 90° turn control logic, implemented using gyro angle integration and motor stop conditions, is shown in Figure 2. The complete system was executed in simulation and in real time to ensure smooth transitions between calibration, straightening, and 90° rotation phases.

Design evaluation and testing (max. 1000 characters)

Evaluation and testing is crucial for ensuring a design meets its objectives and user needs. This process involves assessing a design's feasibility, desirability, and viability, and identifying areas for improvement before it gets deployed.

The gyro-straightening mechanism was first evaluated during Milestone 1, where the Micromouse was required to travel 2 m in a straight line. The system successfully maintained a stable heading with minimal deviation, validating the offset calibration and PID-based correction approach. The 90° turn procedure was then validated both through simulation and physical testing. Figure 3 shows the raw and unbiased gyro z-axis readings, along with the computed error angle, during straight-line motion and after a 90° right turn. In simulation, the integrated gyro angle produced consistent turn angles within ±3° of the target, and these results were confirmed on the actual robot. The design assumptions regarding gyro stability and motor symmetry held true under normal operating conditions. Overall, the implementation demonstrated reliable straight-line motion and precise rotational control, meeting the intended performance criteria.