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Self-Balancing Robot Project Proposal

# Project Description and Justification

We are designing a self-balancing two-wheeled robot using an ESP32 microcontroller, an MPU6050 IMU, two 6V DC gear motors (Pololu 3701), and a dual H-bridge motor driver (L298N). The robot will maintain balance using PID control, with real-time feedback from the IMU mounted near the wheel axle to sense pitch angle and angular velocity. All control logic and sensor processing will be executed on the ESP32, powered through a buck converter. A second buck converter powers the motor driver logic separately.

The robot is powered by a 12V Li-ion battery pack, chosen to provide sufficient headroom for torque delivery. The L298N introduces a voltage drop of approximately 2V, meaning motors effectively receive ~10V. At this voltage, the selected gear motors can deliver up to 2.0 kg·cm stall torque. Our torque calculations indicate that to correct a forward tip of 5 degrees with our estimated 1 kg robot (0.6 kg electronics below axle, 0.2 kg figurine above axle), approximately 0.024 Nm (2.45 kg·cm) of total torque is required. With two motors, each motor needs to provide around 1.2 kg·cm of torque, which is well within the motors’ performance range when overdriven safely at 10V. The use of 5-inch wheels ensures good ground contact and stability, while the low placement of the battery and electronics counterbalances the raised decorative figurine.

At its core, this project aims to explore the challenge and elegance of balancing a robot on just two wheels — a feat that captures the essence of modern control systems. Achieving upright stability using only sensor feedback and dynamic motor control illustrates how theory translates into practical, physical behavior. It's an exciting demonstration of how real-time physics, electronics, and programming converge into a functioning, responsive system.

This project is worthwhile as it combines essential control systems concepts such as feedback, PID tuning, real-time actuation, and dynamic stabilization. It gives us hands-on experience with nonlinear system control, sensor fusion, and system modeling—key competencies in control engineering.

# Feasibility and Planning

We have studied self-balancing robot implementations and PID control techniques using MPU6050 and ESP32 platforms. We are implementing complementary filtering or Kalman filtering to obtain a stable pitch estimate. Motor speed and direction will be controlled via PWM signals generated by the ESP32 and routed through the L298N. All hardware components have been selected to match our physical requirements and torque targets. We understand the limitations of the L298N and have compensated by using a 12V battery with dedicated buck converters to provide stable 5V and 3.3V outputs for the ESP32 and driver logic respectively.

# Timeline and Milestones

* 📆 Week 1 (Apr 21 – Apr 27): Finalize software structure, write low-level drivers for ESP32, and implement IMU communication and filtering. Finalize CAD design for robot chassis and mounts. Test buck converters and individual hardware modules.
* 📆 Week 2 (Apr 28 – May 4): Assemble mechanical frame and install all electronic components. Test full power distribution and PWM-based motor control. Begin integrating IMU data into balance logic.
* 📆 Week 3 (May 5 – May 11): Tune PID controller and verify balance behavior. Perform rigorous testing with weight distribution and evaluate robustness. Finalize report, demonstration, and documentation.