Self-balancing robot

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Introduction:

Self-balancing robots represent a remarkable intersection of engineering disciplines, including electronics, mechanics, and control systems. Inspired by the principles of inverted pendulum dynamics, these robots remain upright by continuously adjusting their orientation through feedback control mechanisms. This capability demonstrates the practical implementation of core principles in robotics, such as stability, motion control, and sensor integration.

The objective of this project is to design and develop a self-balancing robot that can maintain its equilibrium on two wheels. This requires a careful combination of hardware components like sensors, actuators, and microcontrollers, as well as software algorithms for real-time data processing and control. Central to the operation of such a robot is the use of feedback control systems, specifically Proportional-Integral-Derivative (PID) controllers, to process data from gyroscopes and accelerometers, ensuring precise balance and movement.

In addition to demonstrating fundamental engineering principles, self-balancing robots have broader applications, including in personal transport devices, autonomous delivery systems, and humanoid robotics. The project also provides a platform to explore the challenges of integrating software with hardware and optimizing performance under dynamic conditions.

This report details the design, implementation, and testing of a self-balancing robot. It discusses the theoretical framework, hardware configuration, software architecture, and experimental results, highlighting the key challenges encountered and solutions developed.

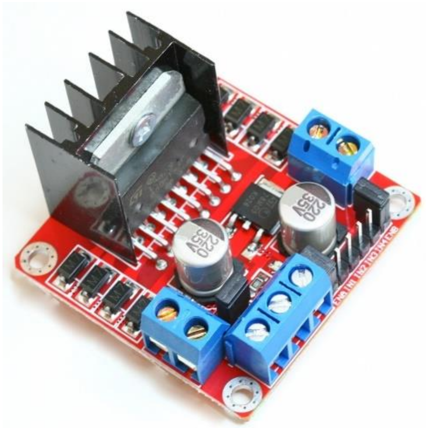
components:

- Arduino uno

- IMU (MPU6050)

- (DC motors) x 2

- Motor driver (L298)

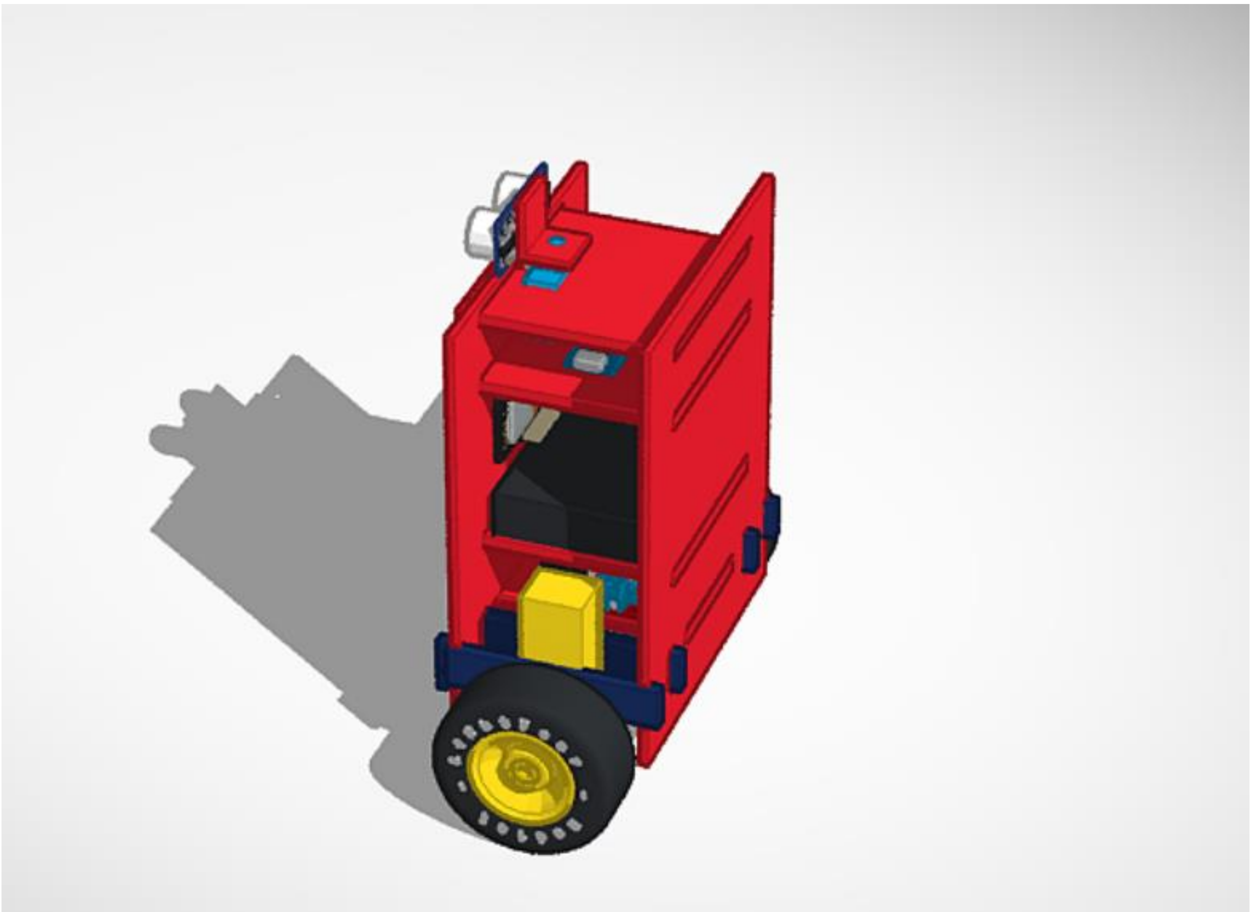


- (Batteries) x 3

- wooden sheets for the body

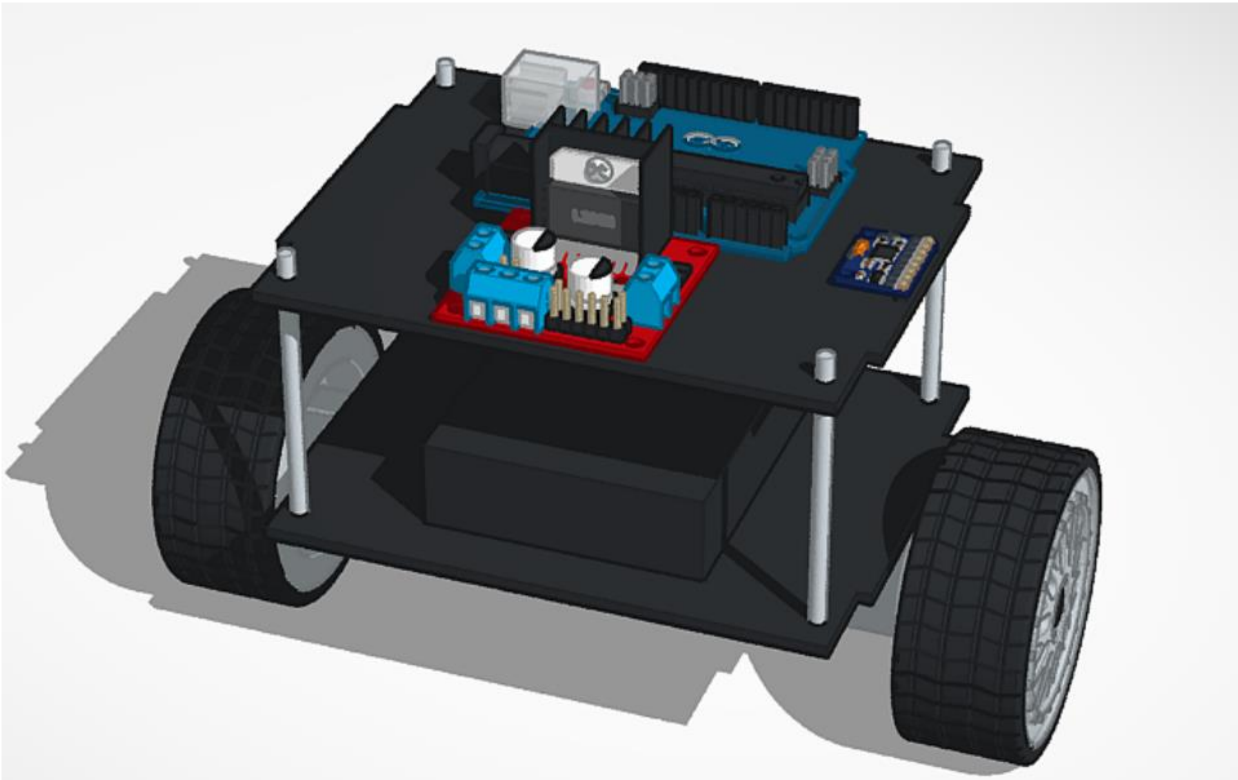
Mechanical design:

Design#1



This design faced two significant challenges. The first was the robot's height, which made maintaining balance more difficult due to the higher center of gravity. The second challenge was the initial choice of motors, which lacked the necessary power to support the robot's weight effectively, leading to suboptimal performance.

Design#2

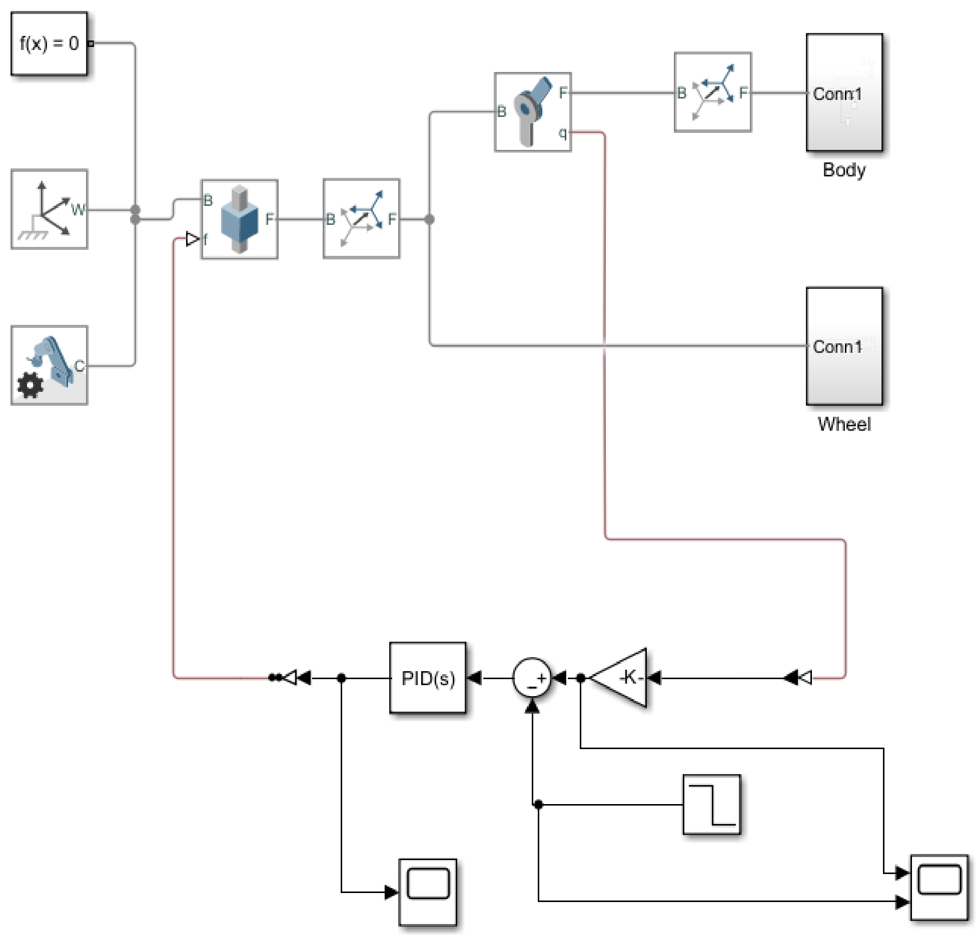


In the second design, we addressed stability issues by making the robot shorter and wider, which lowered its center of gravity and improved its ability to balance. We also replaced the original motors with more powerful ones, ensuring they could handle the robot’s weight effectively and deliver optimal performance.

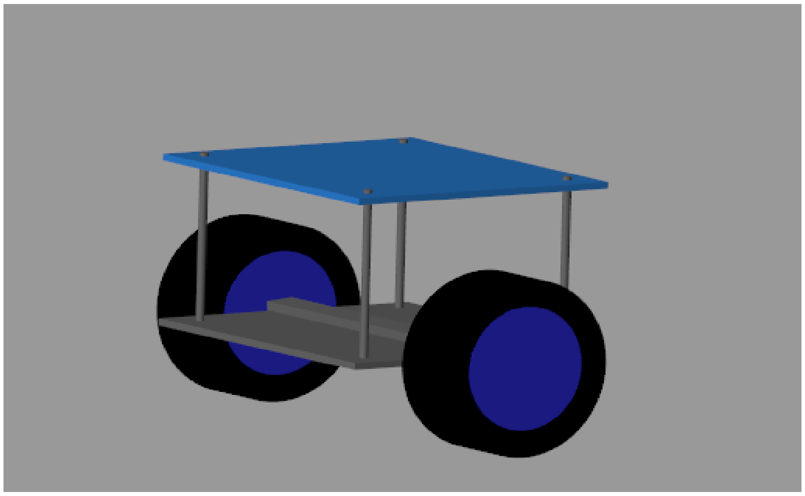
Simulation:

We utilized MATLAB Simscape to simulate and analyze the robot's physical performance, allowing us to evaluate its behavior and optimize the design before physical implementation.

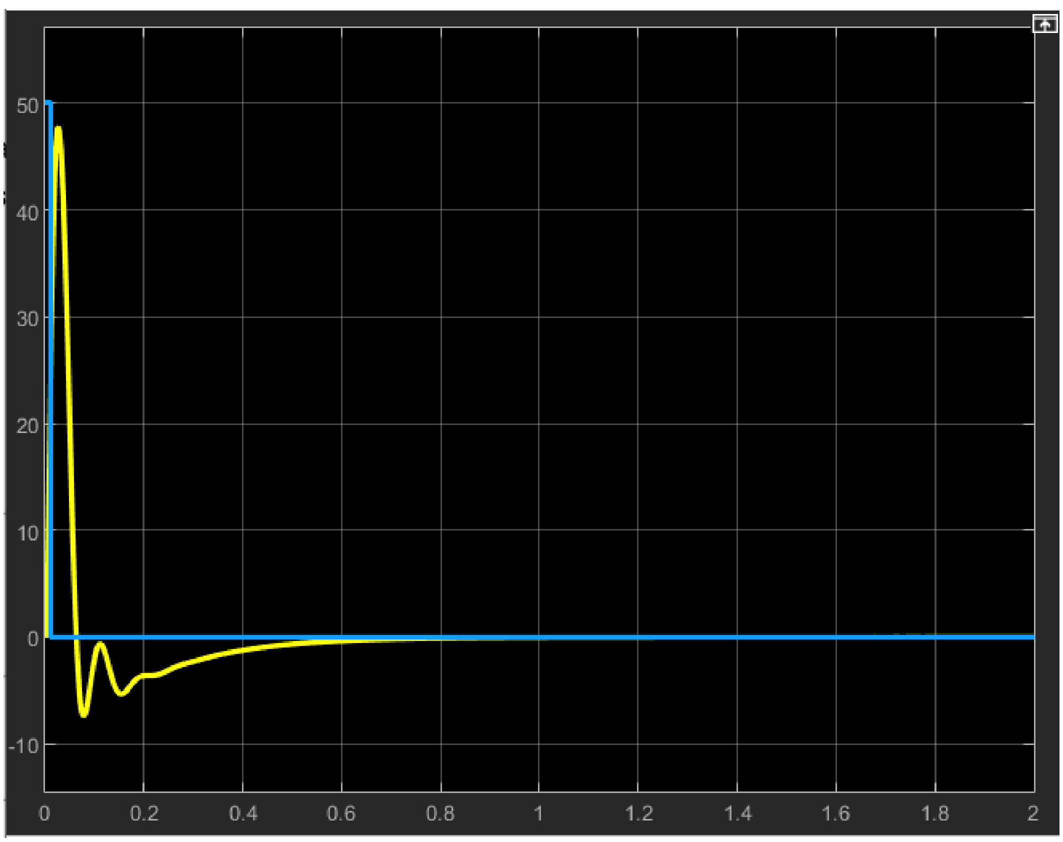
- Simscape model:



- Robot 3D model:



- Simulation output:



Software implementation:

We used the MPU6050 sensor to accurately measure the pitch angle of the robot, providing real-time data on its orientation. To maintain the robot in an upright position, we designed a PID controller that dynamically adjusts the motor speeds based on the sensor readings. This control system ensures that the robot remains balanced by continuously correcting deviations from its vertical alignment.

For the tuning process, we began with the initial PID values obtained from the simulation as a starting point. These values were then refined through a trial-and-error approach, adjusting them incrementally while closely observing the system's response. This iterative method allowed us to optimize the controller settings and achieve the best performance for maintaining the robot's balance.

Bill of materials:

Arduino uno	400 LE
IMU (MPU6050)	125 LE
(DC motors) x 2	700 LE
Motor driver (L298)	80 LE
(Batteries) x 3	100 LE
Robot body	541 LE
Total	1946 LE