PROJECT ABSTRACT

Ball and Beam Balancing System with PID Control

A ball-and-beam balancing rig: an ultrasonic sensor tracks a steel ball on a servo-tilted aluminium beam, with a student-tuned PID loop on Arduino. Delivered built-to-order with assembled rig, firmware, tuning guide, report, PPT and viva kit.

Project type: Hardware

Availability: Built to order

Suitable branches: Mechanical

Technologies: Arduino Uno, ultrasonic position sensor, servo motor, aluminium beam, PID firmware, 5V supply, tuning procedure

Price: Request a quotation

Prepared by Projectech · projectech.in — for academic project reference.

01. Title

Ball and Beam Balancing System with PID Control

02. Introduction / Background

The ball and beam is the canonical unstable control-system plant: a steel ball rolls freely on a beam, and the controller must tilt the beam fast enough to keep the ball at the setpoint — a task with no stable resting state, like balancing a broom on a palm. It is the standard teaching rig for PID control because every term of the controller is visible in the ball's behavior: too little proportional gain and the ball wanders, too much derivative and it jitter; integral windup sends it rolling off. This project builds the rig — aluminium beam on a pivot, servo-driven tilt linkage, ultrasonic ball-position sensing — and walks the student through tuning a real PID loop on their own hardware.

03. Problem Statement

Control theory is usually taught with simulations where the plant never misbehaves. The project addresses this with a physical ball-and-beam rig where the student implements and tunes a PID controller on an Arduino, observing each term's effect on a genuinely unstable plant — and documents the tuning method, final gains and step-response behavior in a complete report.

04. Objectives

- Build a ball-and-beam rig: pivoted aluminium beam, servo tilt linkage, steel ball.
- Sense ball position with an ultrasonic sensor at the beam end.
- Implement a PID control loop on an Arduino driving the tilt servo.
- Provide a student tuning procedure (manual method plus documented starting gains).
- Demonstrate setpoint tracking and disturbance rejection (a tap on the beam).
- Deliver the complete student kit: rig, firmware, tuning guide, report, PPT and viva Q&A.;

05. Proposed Methodology

The rig is assembled from an aluminium beam on a central pivot, a servo driving the tilt through a linkage arm, and an ultrasonic sensor at one beam end measuring ball position. The Arduino runs the PID loop at a fixed sample rate: position error feeds the controller, whose output sets the servo angle. The student tunes the loop using the included procedure — starting from documented gains, adjusting P for response, D for damping and I for steady-state error — and records the final gains and the observed step response and disturbance recovery in the report.

06. System Architecture / Working

Each control cycle, the ultrasonic sensor measures the ball's distance from the beam end — the process variable. The PID firmware computes the error against the setpoint and outputs a beam-tilt command to the servo; tilting the beam accelerates the ball toward the setpoint. The loop repeats at approximately 20 Hz: proportional action drives the ball to target, derivative action damps oscillation, and integral action removes steady-state offset. A tap on the beam demonstrates disturbance rejection as the controller re-centers the ball.

07. Hardware / Software Requirements

- Arduino Uno (ATmega328P)
- Ultrasonic distance sensor (HC-SR04 class)
- Standard servo motor with tilt linkage
- Aluminium beam with center pivot and base
- Steel ball (approx. 25 mm)
- 5 V regulated supply

- Arduino IDE (C/C++ firmware)
- PID tuning procedure document

08. Expected Outcomes

- A working rig that balances the ball at the setpoint.
- Student-tuned PID gains with a documented tuning procedure.
- Observed step-response and disturbance-rejection behavior in the report.
- A complete report, PPT and viva Q&A; on PID control and unstable plants.

09. Applications

- Teaching PID control on a classic unstable plant.
- Control-systems laboratory demonstrations.
- A platform for comparing PID with advanced controllers (future student work).

10. Future Scope

- Cascade control with an inner beam-angle loop.
- LQR or fuzzy-logic controller comparison on the same rig.
- Vision-based ball tracking as a sensor upgrade.
- Remote tuning dashboard over serial/Wi-Fi.