Progress 4

Complex Engineering Activity

Mechatronics System Design

Water Level in a Tank

Group Members (Names & IDs)

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Abstract

In our "Water Tank Level" project, we aim to develop an automated water control system with a strong focus on sustainability. The system integrates crucial components, including a feedback controller (such as PID), sensors for measuring water levels, and actuators to regulate water flow. Mathematical models for control elements, sensors, actuators, and controllers will be created, and MATLAB will be employed for PID tuning. The hardware implementation prioritizes sustainability by utilizing recycled materials. It includes mechanical components for the tank structure, electronic elements for sensing and actuation, and a microcontroller (Arduino) to execute the PID control algorithm. While the water tank itself is not an electronic device, it is an integral part of the system, interacting with electronic components to achieve automated water management. This project aims to contribute to water conservation efforts by ensuring efficient and automated water control, blending principles of control theory with sustainable design practices.

Contents

Objectives

1. To design and implement a system that can accurately monitor the water level in a tank.
2. To incorporate a PID controller for maintaining the desired water level.
3. To implement the controller using a microcontroller, integrating sensors and actuators.
4. To promote sustainability by using recycled materials wherever possible.
5. To make a GUI in MATLAB to see the status of the Tank.

The Project

The "Water Tank Level" project aims to create an automated water control system, utilizing a precise monitoring system for tank water levels. Integration of a PID controller ensures efficient maintenance of the desired water level, supported by a mathematical model of the water tank for controller tuning. The project seamlessly merges control theory and electronics through the implementation of the PID controller using a microcontroller. Further optimization based on the system's response enhances stability and overall performance. A key focus is on sustainability, achieved by incorporating recycled materials into the project's hardware components. This holistic approach combines technical precision with environmental consciousness, contributing to responsible water management practices.

Figure 1: Proposed project; Water Level in a Tank

Design Methodology

To develop the "Water Level in a Tank" system, we employed a systematic design methodology encompassing hardware selection, software development, and simulation. Initially, we chose key components including an Arduino UNO, an HC-SR04 ultrasonic sensor, a mini submersible pump, and a 5V relay. The ultrasonic sensor measures the water level, while the Arduino controls the pump based on this input. We wrote an Arduino IDE code to activate the pump when the water level drops below a set threshold and to turn it off once the desired level is reached. The code continuously reads distance values from the sensor and makes real-time decisions to manage the pump, ensuring optimal water levels. To enhance the system's performance, we integrated a PID controller to regulate the pump operation more smoothly and efficiently. We then transitioned to Simulink for modeling and simulation, creating a comprehensive representation of the system. This included blocks for setpoint definition, error calculation, and the PID controller, along with subsystems for simulating the ultrasonic sensor and pump dynamics. By running simulations, we visualized and refined the system's behavior, adjusting the PID parameters for optimal performance. This methodology ensured a robust, responsive, and efficient water level control system.

Modeling & Simulation of the System

Plant

In the process of creating a Simulink model for the "Water Tank Level" project, we encountered challenges due to the absence of the Arduino library in MATLAB. Despite successfully tuning a pre-defined water tank model using PID blocks, the integration of an ultrasonic sensor and a servo motor proved challenging. Efforts to attach these components were hindered by the unavailability of the necessary Arduino library. We attempted to explore MATLAB's add-ons and support packages, but unfortunately, specific libraries for the ultrasonic sensor and servo motor were not readily accessible.

PID controller

Having employed a pre-defined tuning option, I successfully fine-tuned the PID controller for the water control system in Simulink, employing a scope to visualize the system's response. The graphical representation exhibited a distinctive contrast between the blocked response, depicted as a dotted line, and the tuned response, represented by a marker line. The blocked response likely represents the system's initial, untuned state, while the tuned response showcases the improved performance achieved through the tuning process. This visual comparison provides a comprehensive understanding of the impact of PID tuning on the system's behavior, affirming its effectiveness in enhancing stability and response as intended.

Controlled system

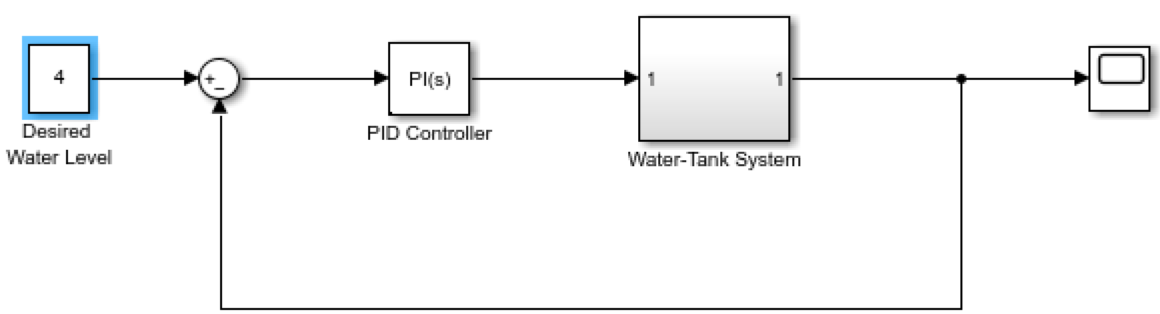


Figure 2: Water Level Simulink Model

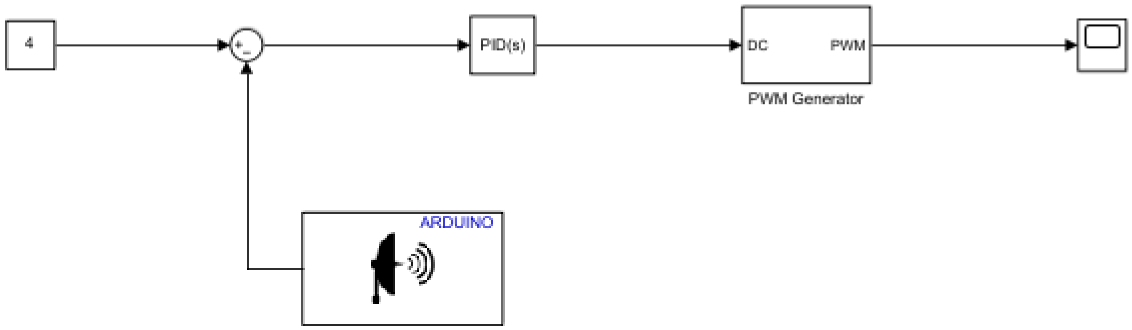


Figure 3: Water Level with PID Controller

Simulation & Results

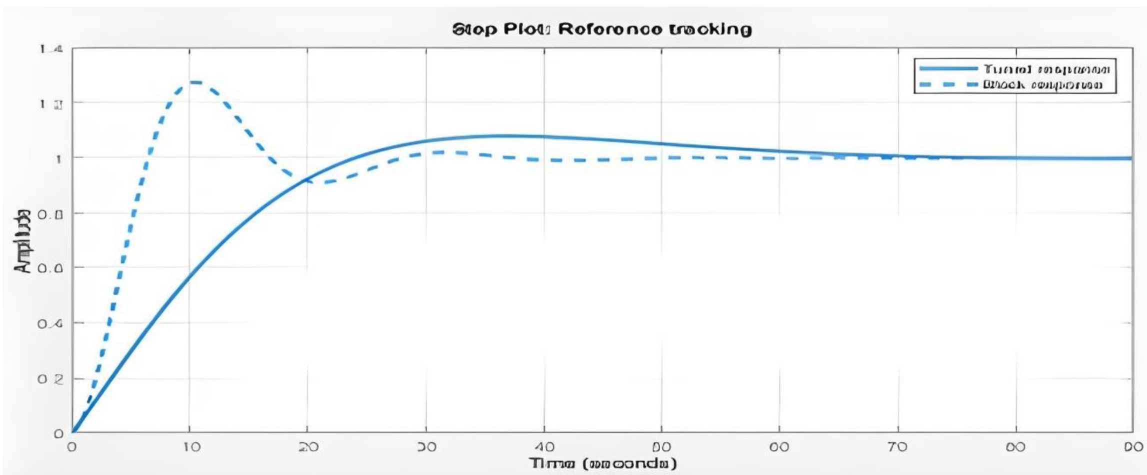


Figure 4: Reference Tracking

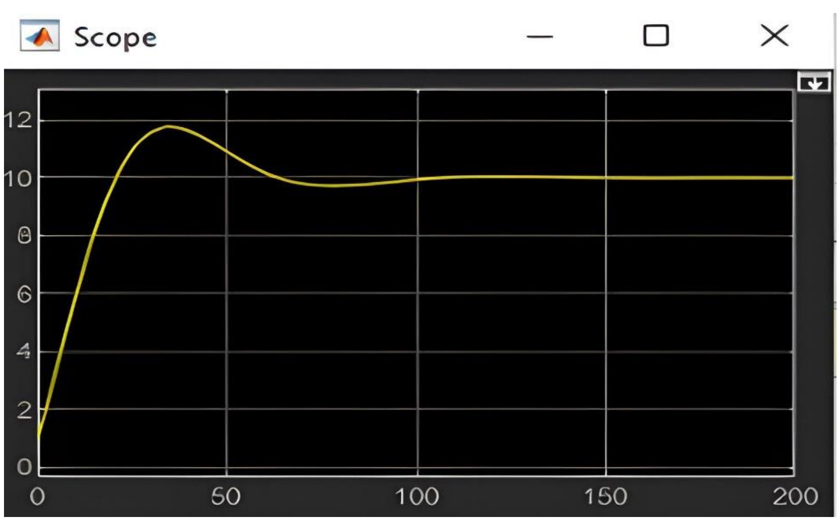


Figure 5: Scope Results

Controller Parameters

	Tuned	Block
P	0.26752	1.5993
I	0.026736	0.079967
D	-0.1943	-7.5257
N	0.18905	0.20121

Performance and Robustness

	Tuned	Block
Rise time	17.3 seconds	4.5 seconds
Settling time	61.6 seconds	26.6 seconds
Overshoot	7.86 %	27.5 %
Peak	1.08	1.27
Gain margin	Inf dB @ NaN rad/s	Inf dB @ NaN rad/s
Phase margin	69 deg @ 0.0891 rad/s	40.6 deg @ 0.285 rad/s
Closed-loop stability	Stable	Stable

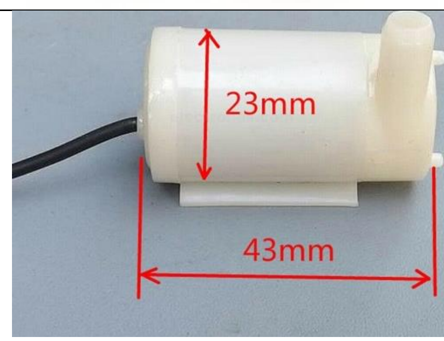
Figure 6: Controlled Parameters.

Table 1: This is table 1

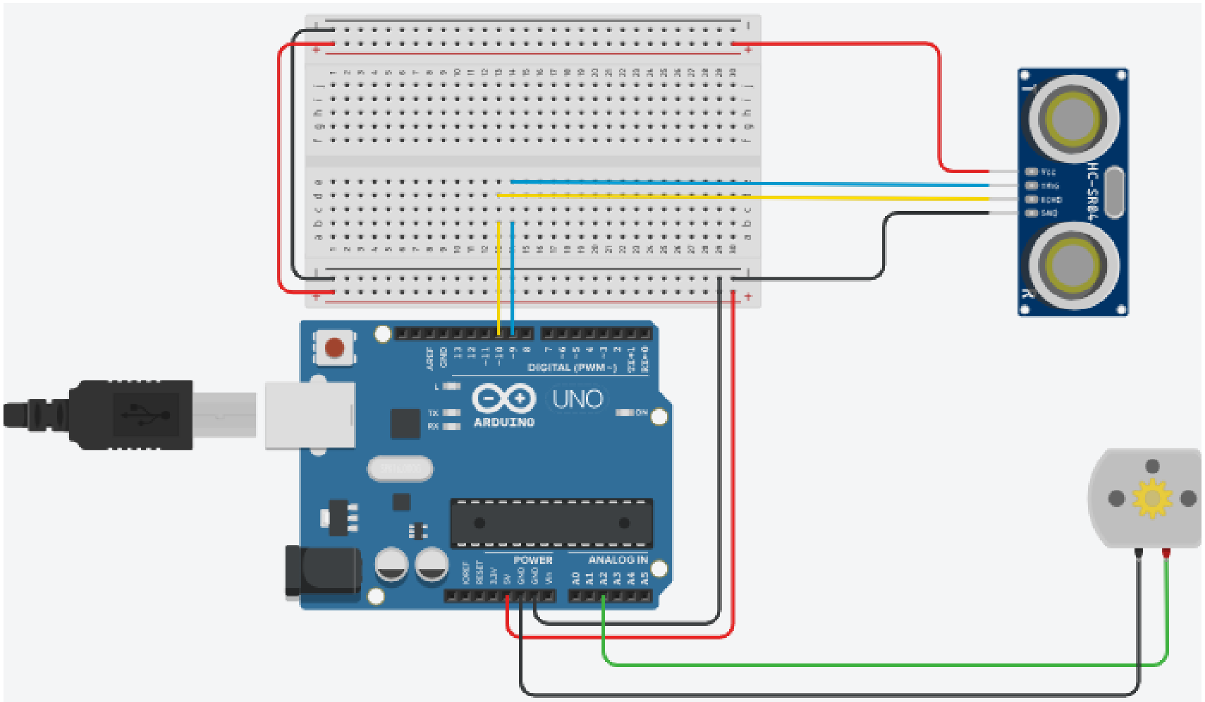
1.	Microcontroller	Arduino UNO
2.	Ultrasonic senor’s level threshold	4.0 cm
3.	PID Values	P=2, I=5, D=1
4.	Relay	5V single phase

Hardware

Material arranged

Circuit diagrams

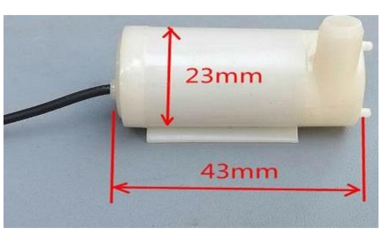


In this circuit diagram, we have connected a 5V Relay with a Mini-Submersible Pump to Analog pin A2 and the trigger pin of Ultrasonic sensor to Digital pin 09 and the Echo pin to Digital pin 10 of the Arduino UNO.

Modular operation

This is the microcontroller we used, the Arduino UNO, for its capacity to hold and manage the things in a proper way.

This is used to measure the waters level in the Tank. Upon that sensor data, the microcontroller will turn on and turn off the mini submersible pump.



This is used to fill up the tank when it is running low.

Hardware Development

Results

The results based on the water level in a tank are same as that of the physical hardware system in which the water in tank will be filled up upon the sensors data fed up into the tank.

Conclusion

the "Water Level in a Tank" project successfully demonstrated effective control of water levels using an Arduino-based system. By integrating an HC-SR04 ultrasonic sensor and a mini submersible pump with a PID controller, we achieved precise and automated water level management. The Arduino code and Simulink model effectively controlled the pump, maintaining the tank's water level near the desired setpoint. This project highlights the synergy between hardware, software, and simulation tools in developing a reliable and efficient water management solution for practical applications.