MBD

REPORT ON TANK CONTROLLER MODELS

Stephen Power (20093364)

Model-Based Development

Report on Tank Controller Models

Stephen Power (20093364)

Project Title:	Tank Controller Models
Student Name:	Stephen Power
Student Number:	20093364
Start Date:	November 17, 2022

Description:	This document reports the implementation of a PID controller and a sequential controller for a tank control system. The objective is to design these controller models in order to control the level of liquid in the tank. The tank control system is developed in Simulink.

Contents

1. Closed Loop Control

1.1 PID Controller

A PID (Proportional Integral Derivative) controller is an instrument used in control applications to regulate process variables. PID controllers are an example of closed loop control which use control loop feedback mechanisms to control process variables. There are three pieces of gain that work to correct or reduce the error in the PID method:

- Kp (Proportional Gain)
- Ki (Integral Gain)
- Kd (Derivative Gain)

Y(t) = Kp.e + Ki.∫e.dt + Kd.d(e)/dt, where e is the error signal (setpoint – actual value). Kp is the proportional gain (P), Ki is the integral gain (I), and Kd is the derivative gain (D). The Kp, Ki, and Kd values are chosen to give the desired system response.

The proportional gain Kp influences the response time of the system. Generally, the larger the value, the faster the response will be. Although if the Kp value is too large, this may lead to unstable oscillations and a large overshoot. The integral gain Ki reduces the residual error between process variable and set point over time. The controller has to compensate as long as an error exists. Too large of an integral gain causes overshoot. The derivative gain Kd is used to reduce the overshoot. The derivative gain value is always very small otherwise noise in the process variable will cause oscillations.

The ideal system response of a PID controller would be a critically damped system. The system should react quickly, minimise energy usage, and contain no overshoot. The below figure illustrates the difference between a desired critically damped response in comparison to an underdamped and overdamped response.

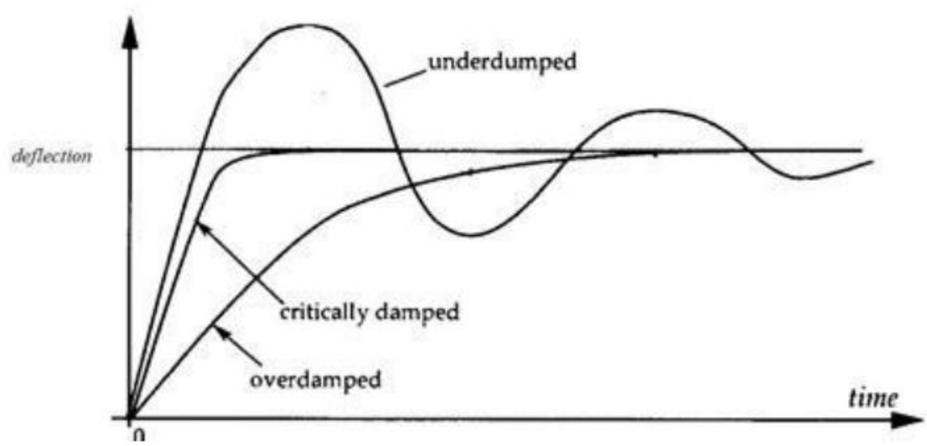

Figure 1: Illustration of a Critically Damped Response

1.2 Ziegler-Nichols Method

The Ziegler-Nichols method is used to determine the three gain values for a PID controller. The Ziegler-Nichols method states that Ki and Kd should initially be set to zero. Kp is increased until the system shows constant oscillations. The proportional gain value that produces the constant oscillations is known as K_{MAX}. The frequency of oscillation at K_{MAX} is recorded as f_O. 1 is divided by the time period value between two peaks is in order to get f_O. Kp, Ki, and Kd are set according to the following:

- Kp = 0.6 K_{MAX}
- Ki = 2.0 f_O
- Kd = 0.125 / f_O

Once the PID values are set according to the Ziegler-Nichols method, a somewhat desired response should be produced. The method won't result in perfect responses, but it will act as a base line for further tuning to perfect a desired response.

1.3 PID Tuning Procedure

Firstly, the Ziegler-Nichols method was carried out to get a base line for the tuning. The integral and derivative gain values were set to zero. The proportional gain value was varied until constant oscillations were found. Constant oscillations could be seen when the P value was set to 8.25.

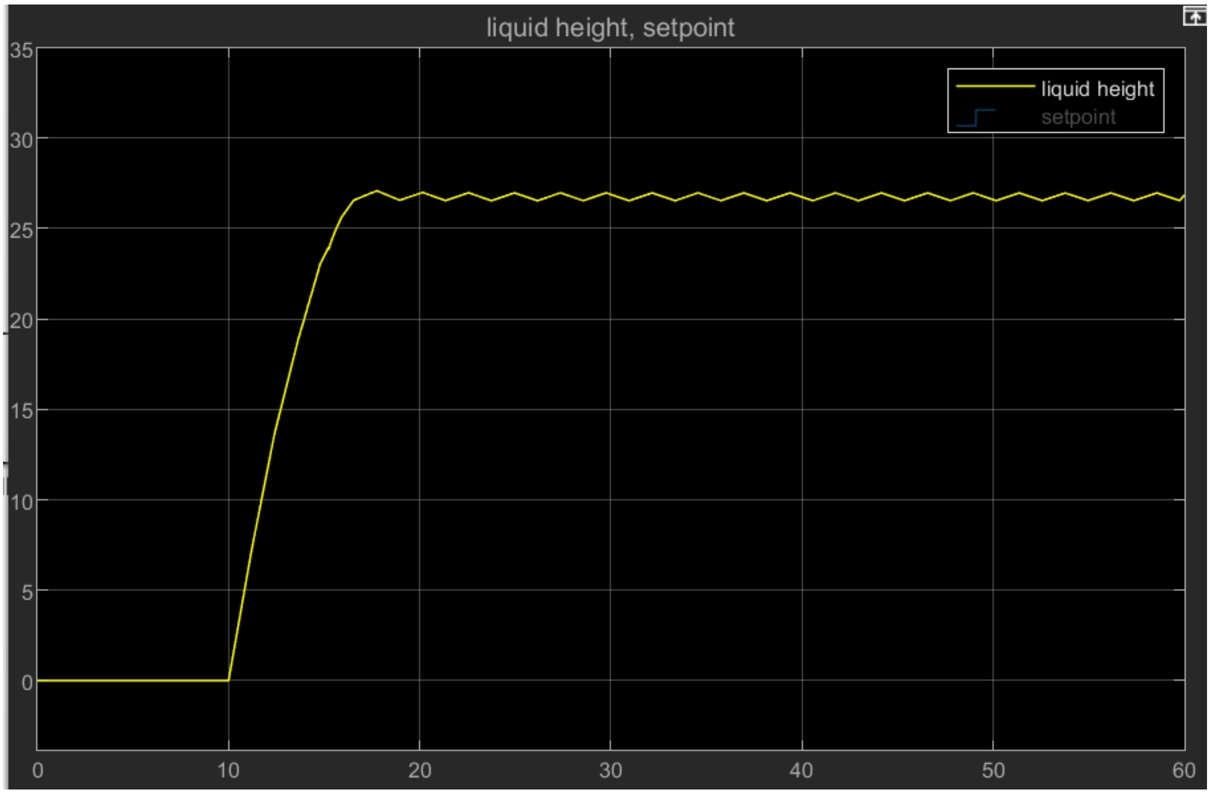

Figure 2: Constant Oscillations

Once K_{MAX} was determined as 8.25, the gain values could be set to get a resulting response. The frequency value was found to be $\frac{1}{2.3}$ as the time between the peaks of the oscillations was 2.3 seconds. The following PID values were set accordingly using the Ziegler-Nichols method:

- Kp = 0.6 x 8.25
- Ki = 2.0 x $\frac{1}{2.3}$
- Kd = 0.125 / $\frac{1}{2.3}$

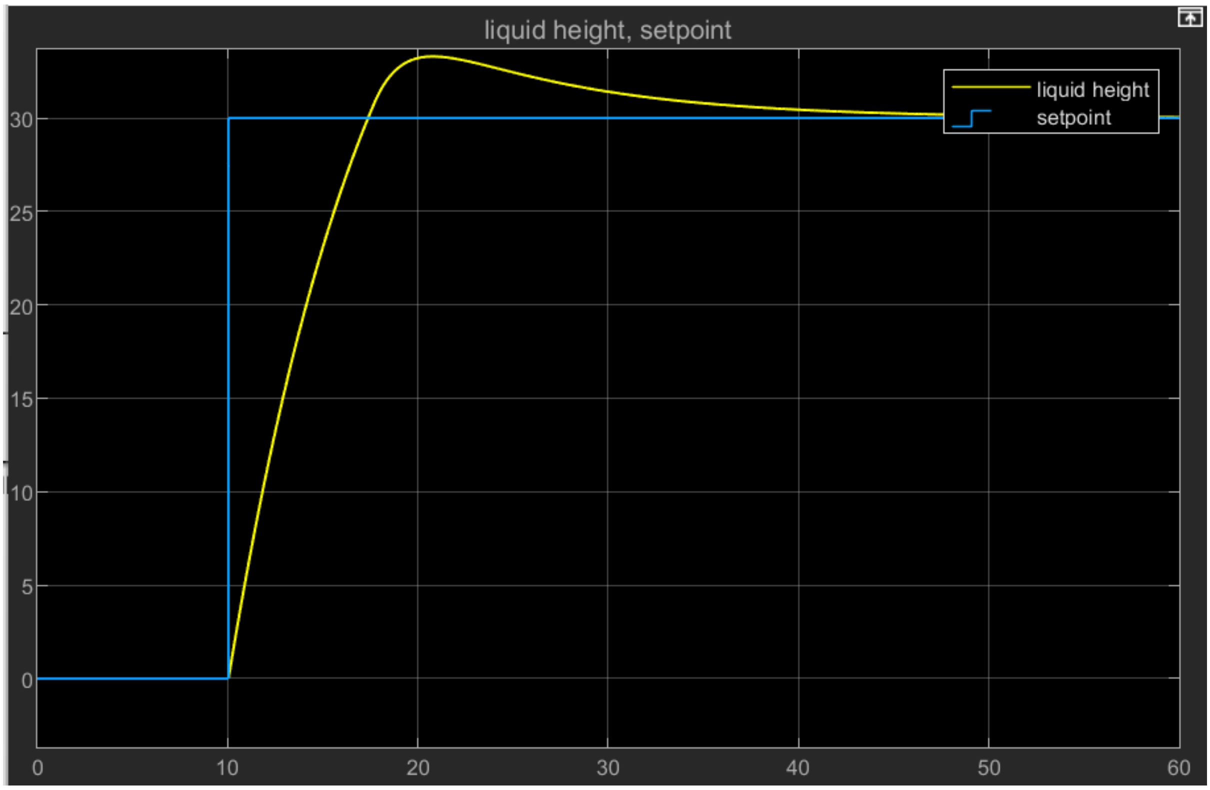

Figure 3: Ziegler-Nichols Method Response

The resulting graph (Figure 3) gives a reasonable response, but there is a fairly large overshoot. The Ziegler-Nichols method gave a good foundation to work upon. As the overshoot is quite large, this was the effect of a large integral gain. The integral gain value was set to '2.0 x $\frac{1}{2.3}$' after implementing the Ziegler-Nichols method. By modifying the integral parameter slightly, a critically damped response was found. The integral gain was set to '2.0 x $\frac{1}{6.5}$' while the proportional and derivative gains remained the same as their original Ziegler-Nichols method values. The modified PID values (Figure 4) produced a critically damped response (Figure 5) where there is a quick response time and no overshoot.

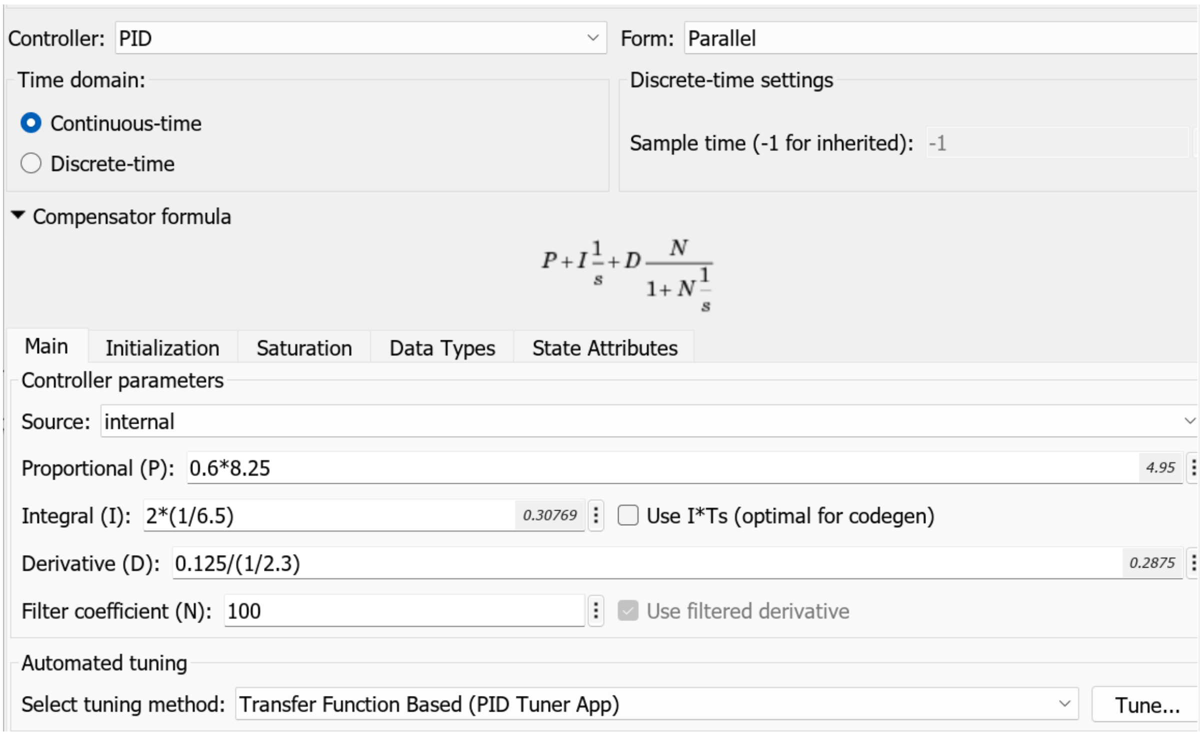

Figure 4: PID Controller Values

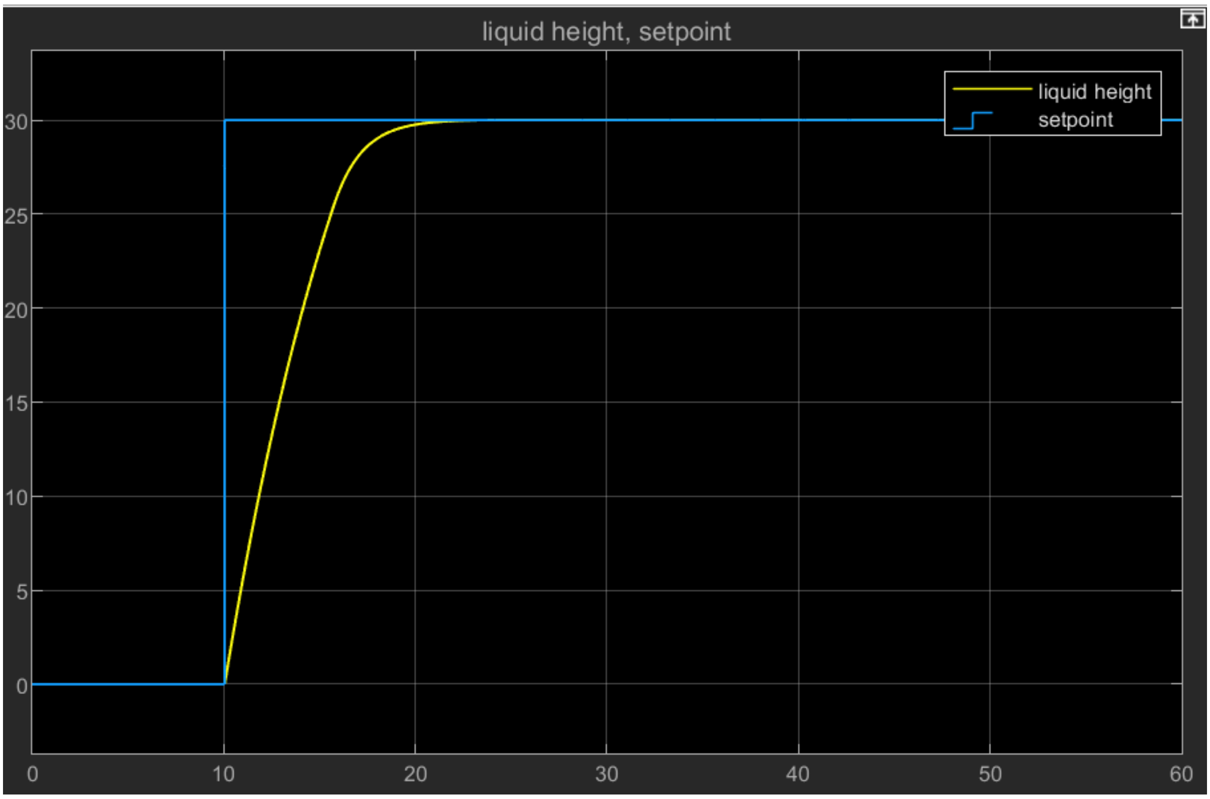

Figure 5: Critically Damped Response

2. Sequential Controller Design

2.1 Controller Design

The sequential controller model was set up to use a Stateflow state chart that would work with the PID controller in order to control the level of liquid in the tank. Three pre-defined set points were set up:

- Low Level = 2
- Medium Level = 8
- High Level = 16

The desired set point block can be connected to the set point input in the Stateflow block. The set point level sets the required level of liquid in the tank. The Stateflow chart was set up to contain three states: Initial state, Boosted state, and Empty state.

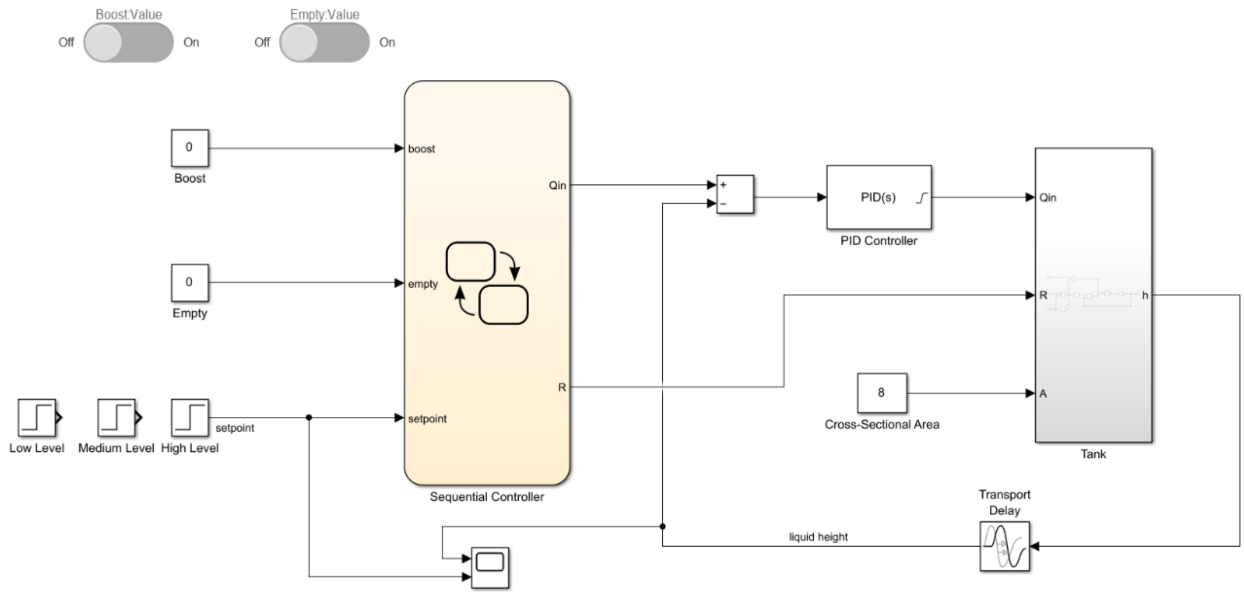

Figure 6: Controller Model

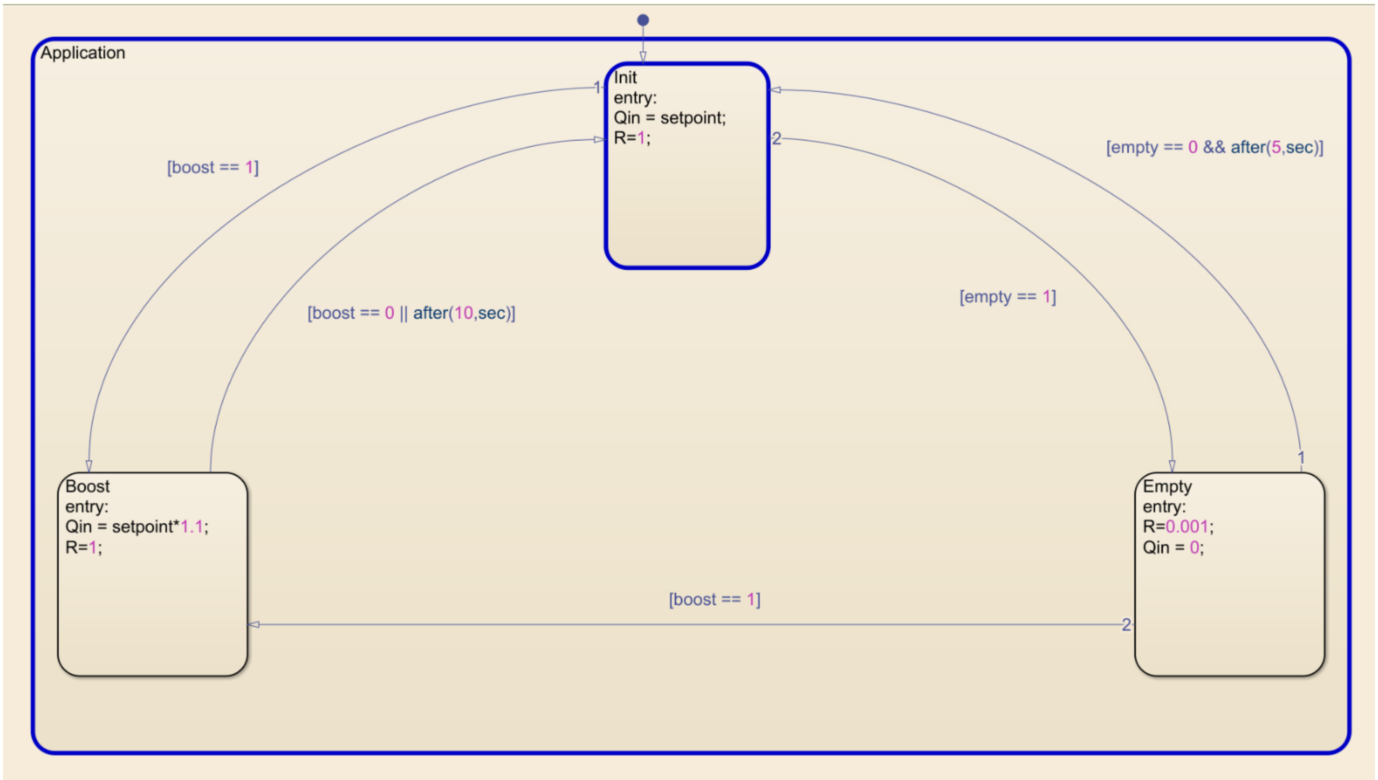

Figure 7: Stateflow State Chart

2.2 Booster Button

A constant block was used to connect to the boost input in the Stateflow block. If the constant block is set to 1, the boost button would activate. If the active state is either the 'Init' or 'Empty' state and boost is activated, the state chart will switch states to the 'Boost' state.

The 'Boost' state is used to boost the height of the liquid by 10% for a period of 10 seconds before it returns to the 'Init' state. The resistance value is set to 1. If the boost button is set to 0 before the 10 seconds has elapsed, the state chart will switch to the 'Init' state.

2.3 Empty Button

A constant block was also used in order to connect to the empty input in the Stateflow block. The empty button activates when the constant block is set to 1. If the active state is 'Init' and empty is activated, the state chart will switch to the empty state after 5 seconds. If empty is activated while in the 'Boost' state, the state chart needs to leave the 'Boost' state back to the 'Init' state before switching to the 'Empty' state.

The 'Empty' state sets the R value to 0.001 (valve closed) and sets Qin to 0. This state is used to empty the tank and close the valve.