Lab Week 4: Liquid Level Control System

0. Objectives

- Analyze a system and create a block diagram

1. Overview

This multi-week lab consists of using MATLAB Simulink and Arduino microprocessors to control a liquid level system. The system operates by manipulating the outlet valve to maintain a desired water height regardless of inlet flowrate.

2. System Description

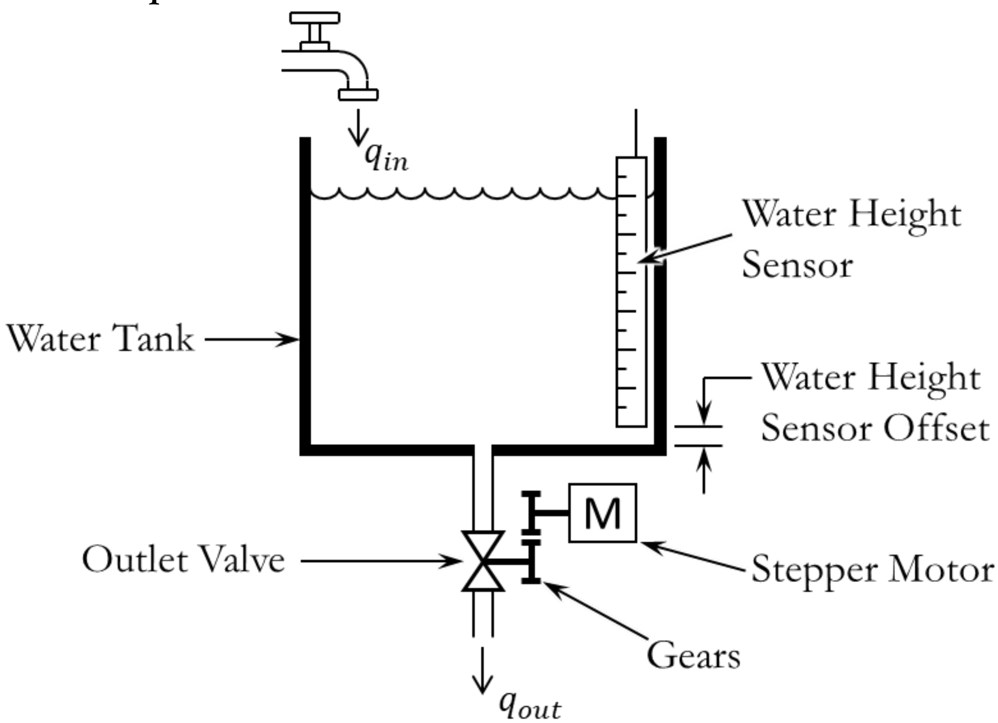

Figure 1: Mixing tank schematic

2.1 Main System Components:

- Outlet valve: controls outlet flowrate to maintain desired water height
- Stepper Motor
  - Opens and closes outlet valve via gears
  - When outlet valve is fully closed, the stepper motor position is 'steps = 0'
  - When outlet valve is fully open, the stepper motor position is 'steps = 1020'
- Water height sensor
  - Detects water height
  - Also referred to as an eTape sensor
- Water tank

2.2 Main system variables:

- Inlet flowrate (q_{in})
    - Inlet flowrate of water
    - Value of flowrate is unknown, uncontrollable, and can vary
    - Units: cm^3/s
- Outlet flowrate (q_{out})
    - Outlet flowrate of water
    - Flowrate will vary depending on outlet valve position **<u>and</u>** actual water height
    - Initial outlet flow rate is 0 cm^3/s
    - Units: cm^3/s
- Outlet valve position (X_{valve})
    - Fully closed position = 0 steps
    - Fully open position = 1020 steps
    - The valve position can be anywhere between 0 steps and 1020 steps
    - Initial valve position is 0 steps
    - Units: steps
- Water tank cross-sectional area (A_{tank})
    - Assume constant
    - 643 cm^2
    - Units: cm^2
- Setpoint water height ($h_{setpoint}$)
    - The desired water height
    - Units: cm
- Actual water height (h_{actual})
    - This is the output variable; the variable we want to control
    - The setpoint water height will be specified. By adjusting the outlet valve, the actual water height will change until it matches the setpoint water height
    - The initial actual water height is 0 cm
    - Units: cm
- Sensor water height (h_{sensor})
    - This is the output/reading of the water height sensor
    - Units: cm
- Water height sensor offset (h_{offset})
    - 3.5 cm
    - Units: cm

3. Objectives

Using MATLAB Simulink and Arduino microprocessors, a liquid level system will be controlled by manipulating the outlet valve to maintain a desired water level regardless of inlet flowrate. The basic steps for completing the multi-week lab are as follows:

1. Create a block diagram of the full system simulation model
2. Characterize and model system components
3. Build simulation model of full system using Simulink
4. Run simulation model to optimize controllers and predict behavior
5. Build physical system control model
    - Create new block diagram that will be used for the physical control model
6. Compare simulated results and experimental results

4. Background: create block diagram of full system simulation model

Before creating a simulation model within Simulink, it is helpful to start out by creating a block diagram for the full liquid level system. Figure 2 and 3 provides a starting point for your block diagram.

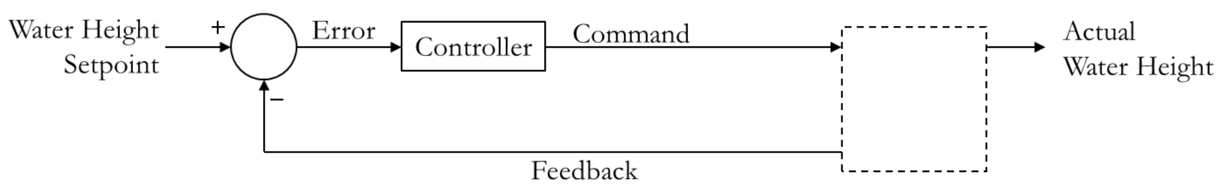

Figure 2: Block diagram of system

4.1 Block diagram – water height control

Water height control uses desired water height as the setpoint. This value is compared with the feedback variable (i.e., actual water height) and produces an error signal. This error signal is used by the controller to generate a command signal. The controller used for water height regulation <u>must be</u> either a PID, phase-lag, phase-lead, or lag-lead controller (as discussed in Chapter 5 of the textbook). The output of the controller (i.e., command signal) will control the outlet valve which affects the output flowrate.

When creating a block diagram, it is important keep track of the signal flow arrows/lines. What are the units represented in each flow arrow (e.g., cm, cm^3/s, steps)? What are the physical properties represented in each flow arrow (e.g., water height, net flow rate, actual valve position)? When making your block diagram it is helpful to label each signal flow arrow with its physical property and its units.

For simplicity, do not use any A/D or D/A blocks in your block diagram. In Figure 3, the setpoint has units of cm and the feedback variable (actual water height) also has units of cm. Even though the feedback variable comes from the water height sensor, assume that the output of the water height sensor is cm. Furthermore, you will still need the 'water height sensor' block in your block diagram.

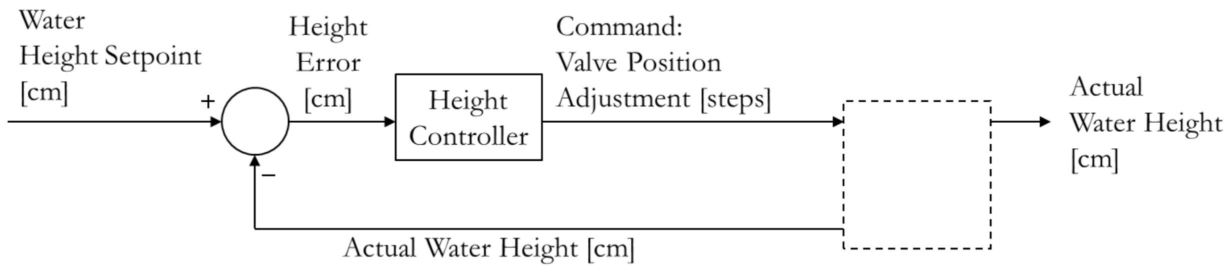

Figure 3: Block diagram of system

When keeping track of flow arrow physical properties and units, note that the output of your controller can have **<u>any</u>** units that you desire. For example, Figure 3 shows that height error [cm] enters the controller and valve position adjustment [steps] exits the controller. Another example showing how units change is shown in Figure 4. Volume [cm^3] is multiplied by {1/cross sectional area} and results in height [cm]. As you build your block diagram, pay attention to units and the actual physical properties. Also, remember that each flow arrow only represents one single variable or physical property.

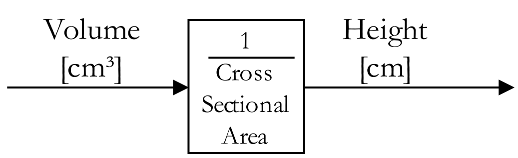

Figure 4: Volume changes to height

Using Figure 3 as a starting point, how will you go from 'valve position adjustment [steps]' to 'actual water height [cm]'?

5. Assignment

- Using Figure 3 as a starting point, create a block diagram of the liquid level system
    - Think through the process of controlling water height
        - Measure current water height and calculate error
        - Send error to controller which produces controller command
        - Valve position is adjusted which affects outlet flow rate
        - The current water height also affects outlet flow rate
        - The difference between the inlet flow rate and the outlet flowrate results in a net flowrate
        - Net flowrate affects water volume in the tank
        - Water volume is directly linked to water height
- Answer the questions below. By thinking through and answering these questions, you will be better able to accurately create your block diagram
    1. How will the command signal be used to adjust the outlet valve?
    2. How will you translate error signal information into outlet valve adjustments?
    3. If your error is negative, what should the valve do?
    4. If your error is negative, do you have too much water in the tank or not enough?
    5. If your error is negative, should the valve position adjustment be positive or negative?
    6. If your error is positive, what do you want the valve to do?
    7. If your error is positive, do you have too much water in the tank or not enough?
    8. If your error is positive, should the valve position adjustment be positive or negative?

6. Deliverables

- Completed block diagram
    - Include proper labels on all transfer functions
    - Include proper labels and units on all signal flow arrows
    - Create the block diagram using computer software
        - The block diagram cannot be hand-drawn
        - Software examples include PowerPoint, Word, Visio, etc.
- Answer questions 1 – 8 in Part 5. Type answers in a numbered list.
- Don't forget a cover sheet; coversheet guidelines are posted on Blackboard