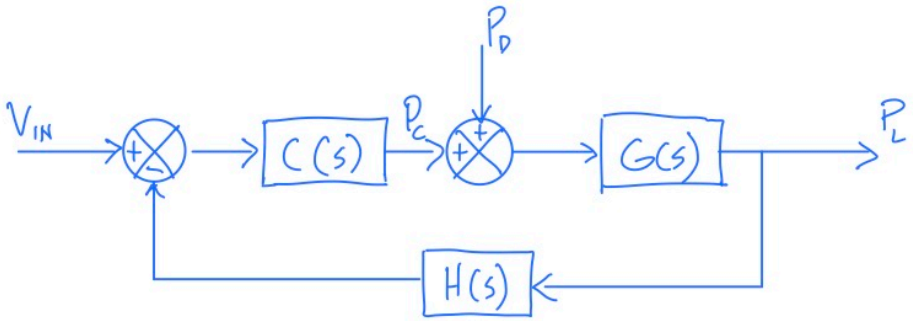
BME 444
Mechanical Respirator Controller
May 2, 2023

Lesson 23 Student Exercise - Due by May 5 Midnight

Tuning a Controller with PID Tuner

In this exercise, we re-visit the infant warmer as a model for designing an optimum controller. Instead of randomly picking values for a controller, you will learn to use the PID tuner in MATLAB.

In lesson 21 we modeled an infant warmer as a unity feedback system. Now, we also incorporate disturbances in the system. The new diagram looks like:



where $C(s)$ is the controller, $G(s)$ is the plant (the thermal characteristics of the infant), and $H(s) = 1$ is a sensor in the feedback loop. Assume that

$$G(s) = \frac{1.2}{5000s^3 + 2700s^2 + 102s + 1}$$

Your goal is to create and tune a PID controller for this system.

1. Read the documentation on how to tune a PID controller here: https://www.mathworks.com/help/control/getstart/tune-pid-controller-to-balance-tracking-and-disturbance-rejection.html
2. Start with a PI Controller for the infant warmer.
3. Add an Input Disturbance Rejection plot.
4. Briefly explain what the Reference Tracking plot shows. Do not answer, “Reference tracking is the response at y to signals at r” because that does not explain anything. Use your own words.

5. Briefly explain what the Input Disturbance Rejection plot shows. Do not answer, "Disturbance rejection is a measure of the suppression at y of signals at d". Use your own words.
6. Explore the different buttons on the menu until you figure out how to display Rise Time, Settling Time, Overshoot, Gain Margin and Phase Margin.
7. Adjust the transient response to improve disturbance rejection. How do you know it worked? Include a screenshot of your plots and justify your answer using numbers (e.g., from the system characteristics).
8. Now, adjust the transient response to minimize settling time in the Reference Tracking plot. How do you know it worked? Include a screenshot of your plots and quantitatively justify your answer.
9. Reset the design and then change your controller to a PID.
10. Research online to discover the difference between PID and PIDF controllers in Matlab. What is the difference?
11. Without making any adjustments, how has switching to a PID controller changed the reference tracking response and the input disturbance response? Did it improve/make worse one or both? Include a screenshot of your plots and quantitatively justify your comments.
12. Make your Tuned Response the new Baseline Response.
13. What effect does changing the Response Time have on the controller parameters (i.e., if you make the response time slower, does it increase/decrease K_P, K_I, and K_D)?
14. What effect does changing the Transient Behavior have on the controller parameters (i.e., if you make the transient behavior aggressive, does it increase/decrease K_P, K_I, and K_D)?
15. Reset the design.
16. Adjust Response Time and Transient Behavior until you have a system with the following specifications:
    1. %OS = 0%, and
    2. Rise Time < 20 seconds, and
    3. Settling Time < 35 seconds

    Hint: use the up and down arrows next to the numbers to precisely adjust the values.

17. Include a screenshot of your plots from #16.
18. What is the approximate damping coefficient ζ of your tuned system?
19. What K_P, K_I, and K_D resulted from your tuning in #16?
20. What effect did the tuning from #16 have on input disturbance rejection?