

EECS 216 Winter 2008
 Lab 4: Control
 Part II: In-lab & Post-lab Assignment
 ©Kim Winick

The lab has been designed so that you can complete both in-lab and post-lab portions *during* the three-hour lab.

1 Laboratory Work (In-lab)

All the circuits constructed as part of this laboratory use the 741 operational amplifier.

1.1 Circuit & Protoboard Layout

The following three figures illustrate the circuits and their protoboard layout for the present lab. Figure 1.1.1 shows the op-amp circuit realization of the PD controller, where the plant, $P(s)$ appears as a separate component in the circuit. Further details about $P(s)$ are given in Figure 1.1.2, which provides the appropriate op-amp circuit. Finally, Figure 1.1.3 provides a schematic for the overall layout of the protoboard.

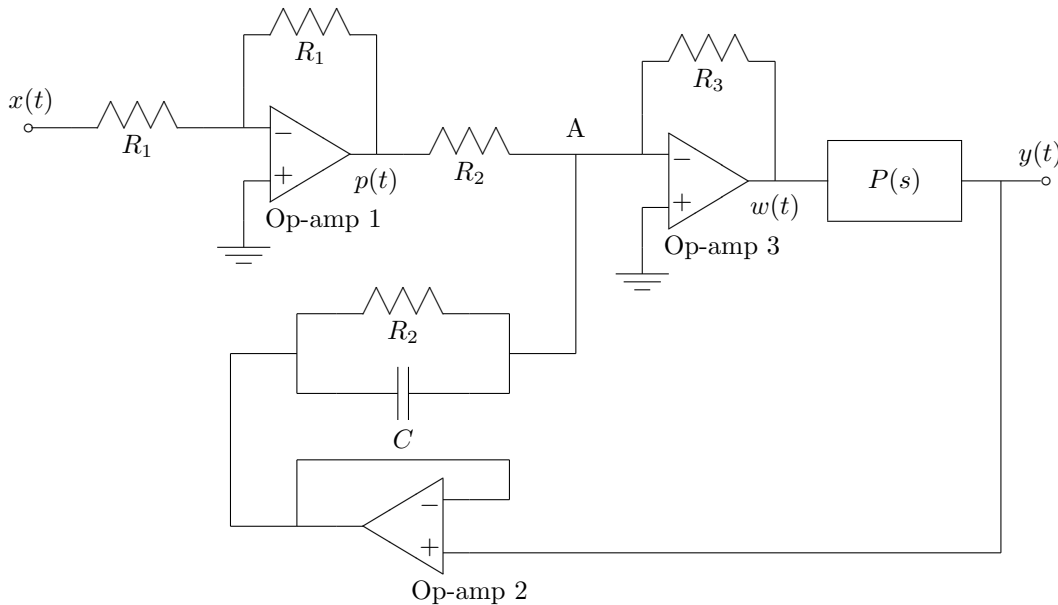


Figure 1.1.1: Op-Amp Realization of PD Controller With 2-Degrees of Freedom

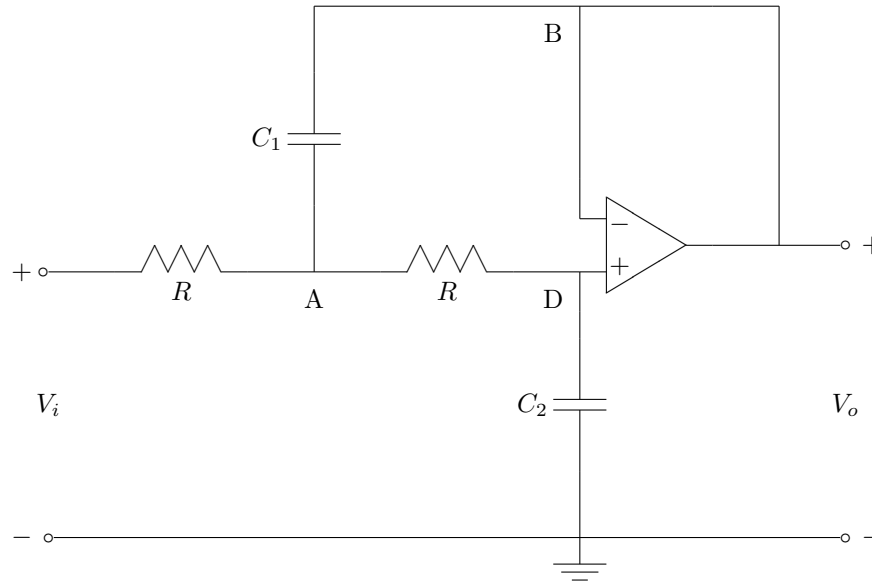


Figure 1.1.2: Op-Amp Circuit for Plant

1.2 Plant Response

- (a) Examine the circuit of the plant on your protoboard and fill in the values for the resistor and capacitors below:

$$R = \qquad C_1 = \qquad C_2 =$$

- (b) Isolate the plant from the PD circuit. Use the signal generator to apply a unit step input, i.e., $v_i(t) = u(t)$, to the plant and observe on the oscilloscope both the input step (scope channel 1) and output step response, $v_o(t)$, (scope channel 2). Store these scope traces (plot and both channels of data) on the computer for later use. Note: The output step response should be of the form $v_o(t) = A + Be^{-\alpha t} \cos(\omega t + \phi)$.
- (c) Using the oscilloscope, measure the oscillation frequency, ω , and the decay rate, α , of the step response signal $v_o(t)$. Use this data to compute the location of the complex poles of the transfer function $Q(s) = \frac{V_o(s)}{V_i(s)}$. Fill in the values you found below:

$$\omega =$$

$$\alpha =$$

$$s_1 =$$

$$s_2 =$$

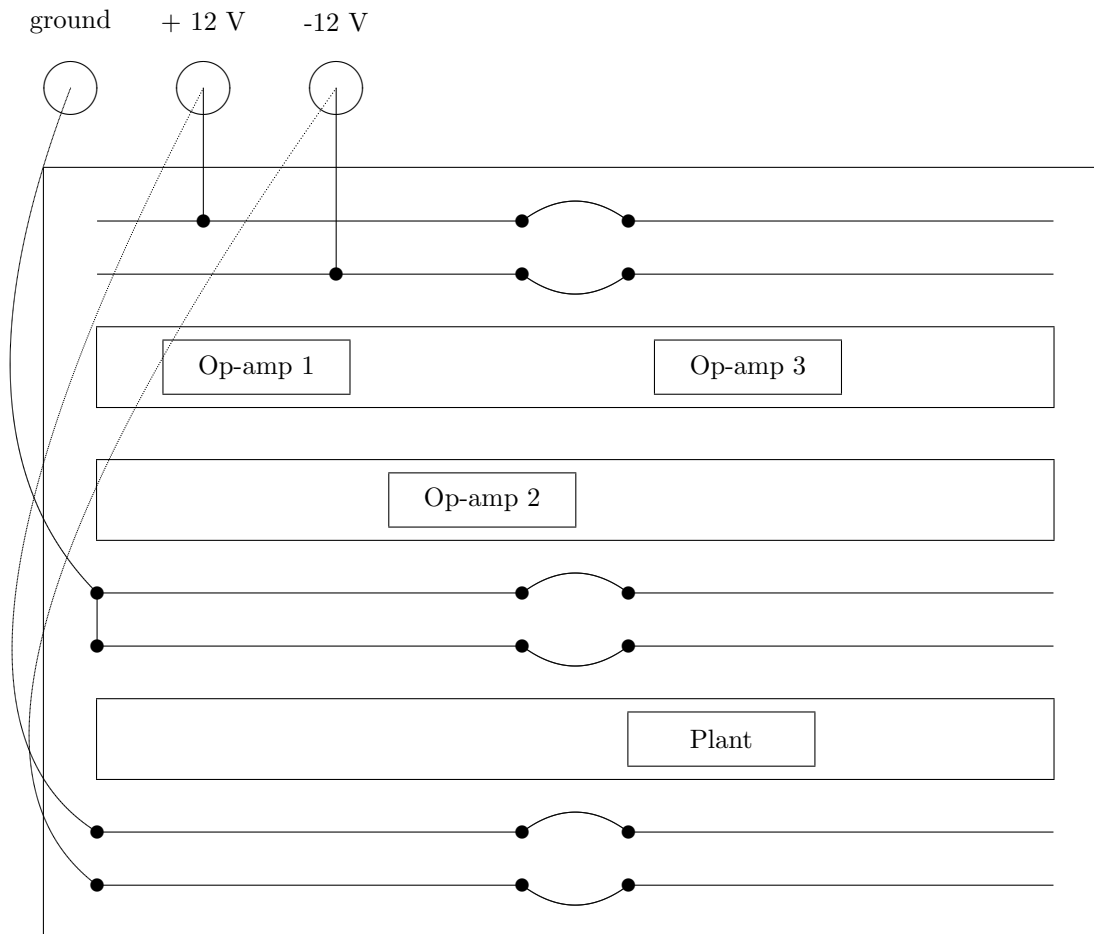


Figure 1.1.3: Protoboard Layout

Do your results agree with the values given as part of question 3.1.2 in Section 3.1 of the Pre-lab? (See also question 3.1.3 of Section 3.1) Fill in the values you found below:

Yes or No? [Justify your answer.]

(d) Use the function generator to generate the following input signal:

$$V_{in}(t) = [u(t) - u(t - 1)] + 2(t - 1.1)[u(t - 1.1) - u(t - 1.6)] \text{ V}$$

Hint: This waveform has been pre-programmed into the generator by your GSI and was also used in Lab 1 to demonstrate linearity and time invariance. To create this signal using the function generator, press Arb, "Select Wform," "Stored Wforms," make sure ARB_1 is highlighted and press "SELECT"

ARB.” Change the following settings for the wave form: Period 7 s, HiLevel 1 V, and LoLevel 0 V. Apply this input to the plant and observe on the oscilloscope both the input (scope channel 1) and output response (scope channel 2).

Store these scope traces (plant and both channels of data) on the computer for later use. Note: you’re on the right track if the output response initially looks similar to the step response and then changes when the ramp input occurs.

1.3 Closed-loop Unit Step Response of PD Controller

- (a) Examine the 2 degree-of-freedom PD controller shown in Fig. 1.1.1. Based on the circuit, fill in the values for R_1 , R_2 , R_3 , and C below:

$$R_1 = \qquad R_2 = \qquad R_3 = \qquad C =$$

- (b) Re-connect the controller as indicated in Fig. 1.1.1 to the plant.
- (c) Compute the values of K_p and K_D using your answer for Pre-lab question 3.4.5 in Section 3.5 of the Pre-lab. Using the results that you derived in Section 3.4 of the Pre-lab, determine whether this closed-loop system is over-damped, critically-damped or under-damped. Fill in the values you found below:

$$K_p =$$

$$K_D =$$

Over-damped, critically-damped or under-damped? [Justify your answer.]

- (a) Use the signal generator to apply a unit step input, i.e., $x(t) = u(t)$, to the entire system (input applied at input of controller). Observe on the oscilloscope both the input step (scope channel 1) and output-closed loop step response, $v_o(t)$, (scope channel 2). Store these scope traces (plot and both channels of data) on the computer for later use.
- (b) Use the oscilloscope to measure the steady-state error, i.e. $\lim_{t \rightarrow \infty} (x(t) - y(t))$. Fill in the blank below.

Steady-state error =

- (f) Use the oscilloscope to measure the 90% rise time of the response, i.e., the time it takes for $y(t)$ to reach 90% of its final value. Fill in the value below:

90% rise time =

- (g) Replace the $4.7 \mu\text{F}$ capacitor in the controller with a $10 \mu\text{F}$ capacitor, and repeat parts (c)-(f) above. Fill in the values you found below:

$$\frac{K_p R_3}{R_2} =$$

$$K_D =$$

Over-damped, critically-damped or under-damped?

Steady-state error =

90% rise time =

Has the measured 90% rise time increased or decreased with this change in the capacitor value? Fill in your answer below:

Increased or decreased?

Is this the expected result?

- (h) Use the signal generator to apply the same input as in 1.2(d), i.e.,

$$x(t) = [u(t) - u(t - 1)] + 2(t - 1.1)[u(t - 1.1) - u(t - 1.6)],$$

to the entire system (input applied at input of controller). Observe on the oscilloscope both the input (scope channel 1) and output-closed loop step response, $v_o(t)$, (scope channel 2). Visually compare the input and output of the closed-loop system and note their similarity, although the output may not reach quite as high of voltage levels as the input. Store these scope traces (plot and both channels of data) on the computer for later use.

2 Post-lab

2.1

The GSI's have stored the calculated responses for the open-loop and closed-loop systems on your lab computer so you can hand-in a completed Lab 4 before you leave the lab. So, your remaining tasks are to

- complete the following questions
- print out your results
- add a filled-in Lab cover sheet to the *front* of your completed In-Lab document and the figures you generate for the Post-lab to the *back*
- staple the stack of papers
- hand your completed assignment to your GSI

Cheers!

2.2 Plant Response

- (a) Plot the measured step response of the plant together with the computed step response (see question 3.1.3 in the Pre-lab, Section 3.1) on a single graph. Use the Matlab axis command `axis([0 6 0 2])`.
- (b) On a separate figure, plot both the measured input (Ch 1) and the measured response (Ch 2) of the plant to ARB_1. Use the Matlab axis command `axis([0 5 -1 2])`.

2.3 Closed-Loop PD Controller Response to Step Input

- (a) How does your measured result for the steady-state error compare with the predicted quantity $\frac{1}{K_p+1}$ when $C = 4.7 \mu\text{F}$? When $C = 10 \mu\text{F}$?
- (b) Plot the measured (see In-lab Section 1.3 part (d) with $C = 4.7 \mu\text{F}$) and theoretically predicted closed-loop unit step responses on a single graph. Repeat with $C = 10 \mu\text{F}$. You should get pretty good agreement between theory and measurement.
- (c) On a separate figure, plot both the measured input (Ch 1) and the measured closed-loop response (Ch 2) of the closed-loop system to input ARB_1. Use the Matlab axis command `axis([0 5 -0.2 1.2])`.