Department of Mechanical Engineering

2.14 ANALYSIS AND DESIGN OF FEEDBACK CONTROL SYSTEMS

Laboratory 8: PID Position Control

Introduction: In the previous laboratory, you constructed an op-amp circuit to provide closed-loop proportional-integral (PI) control for the rotational velocity of the servo motor. Compared with proportional control, PI control resulted in lower steady-state error and better disturbance rejection.

In this session we examine the effect of derivative action by constructing and evaluating a PID position controller.

Laboratory Objectives:

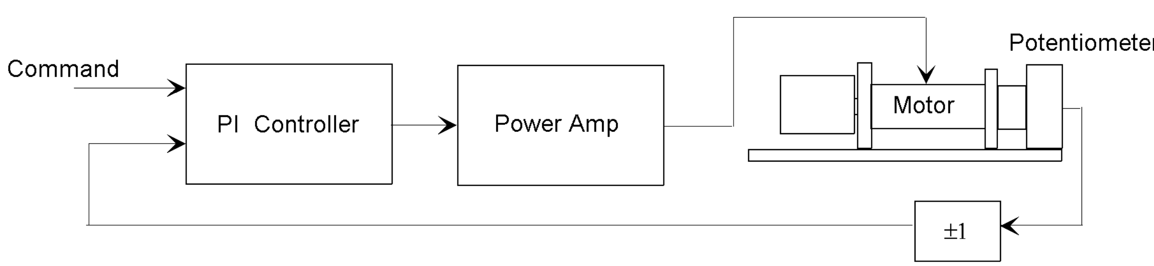
(i) The construction and evaluation of an op-amp differentiator.

(ii) The construction of a PID controller.

(iii) Measurement of the effect of derivative action on a position control system.

Set Up and Test your PI Controller as a Position Controller:

In Lab 7 you constructed a PI controller to control the angular velocity of the motor shaft. It worked well, and eliminated steady-state errors. Now connect the PI controller as a position controller by using the potentiometer as the sensor.



Use the function generator and the oscilloscope to record the step response of this system. Explain your observations in terms of a root-locus.

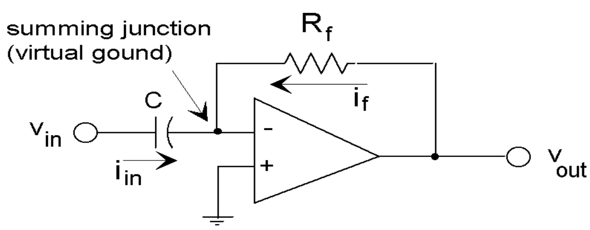
Hint: Recall that the plant $G_p(s)$ and controller $G_c(s)$ transfer functions are of the form

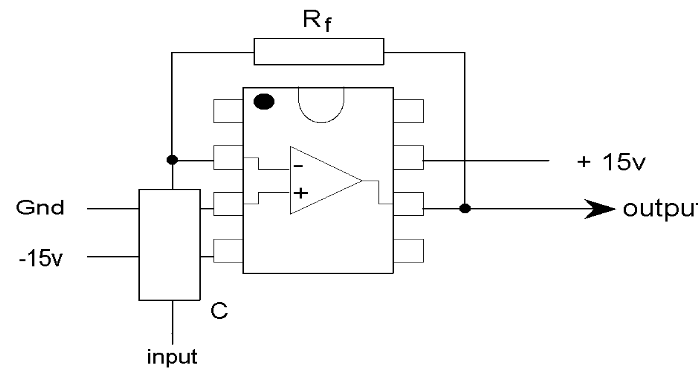
$$G_p(s) = \frac{K_1}{s^2} \qquad \text{and} \qquad G_c(s) = K\left(1 + \frac{K_i}{s}\right)$$

where K, K_1, and K_i are constants.

Build an Op-amp Based Differentiator:

(1) Construct an op-amp differentiator as shown below:



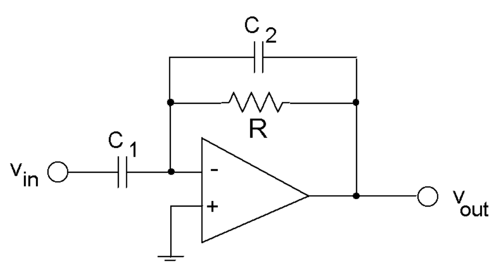


Use a 4.7 μF capacitor and a 10K resistor. Compute the transfer function of the differentiator.

(2) Before connecting the differentiator to the rest of the circuit,test its respone to sine wave, sawtooth wave, and square wave inputs, and monitor its output. Does the differentiator live up to its name?

(3) Is the differentiator output “noisy”? What is the origin of the noise? (Hint: Think about the nature of a computer generated waveform)

(4) Practical differentiators are rarely in the form shown above. They usually include an extra pole to “roll-off” the high frequency response. Consider the modified circuit below:



The transfer function is now

$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{sRC_1}{sRC_2 + 1}$$

Make a sketch of the Bode plots for this transfer function.

Add a capacitor of value 0.47 μF to your differentiator and repeat part (2) above. Is the waveform less noisy?

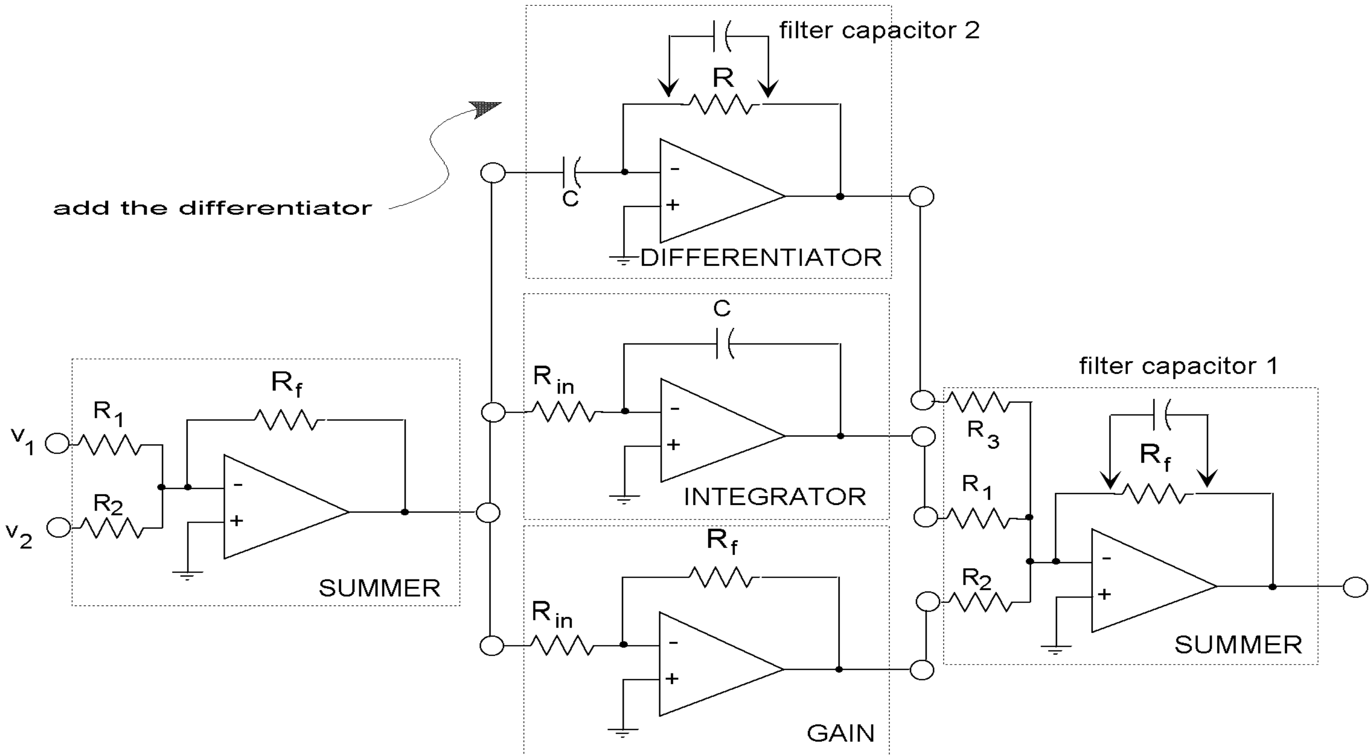
Build a PID Controller:

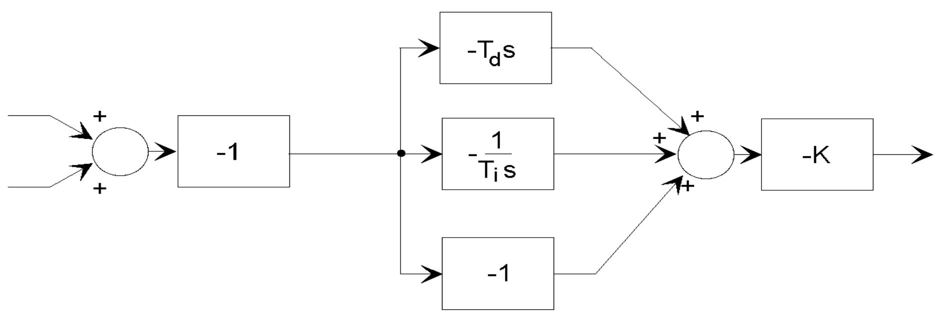
(1) The full PID controller is shown on the next page. (You may need to change some of your component values as shown.) Determine the transfer function of the controller with these values. Connect the differentiator into the system, and measure the step response. What happens? Does the performance of the controller improve?

(2) Measure the step response. Measure the rise time, estimate the percent overshoot, and the settling time. Compare the results with the corresponding results using PI control. Has the performance of the system improved?

(3) Vary the derivative gain (by changing the value of R_3 in the output summer), and measure the step response. What is the effect of the derivative action?

(4) Based on your observations, what is the best control strategy for the system?





Use the following component values:

Input Summer	$R_1 = R_2 = 10$ kΩ $R_f = 1$ kΩ
Proportional Gain:	$R_{in} = 1$ kΩ $R_f = 10$ kΩ
Integrator:	$R_{in} = 5$ kΩ $C = 10\ \mu$F
Differentiator:	$C = 1\ \mu$F $R = 50$ kΩ
Output summer:	$R_1 = 25$ kΩ $R_2 = 20$ kΩ $R_3 = 3$ kΩ $R_f = 100$ kΩ