Department of Mechanical Engineering

2.010 CONTROL SYSTEMS PRINCIPLES

Laboratory 7: PI Control

Introduction:

In the previous laboratory sessions, you constructed an op-amp controller to provide proportional and velocity feedback control for the rotational plant. In this laboratory, you will extend the op-amp circuit to construct a proportional + integral (PI) controller. You will investigate the properties of the resulting circuit as a velocity control.

Laboratory Objectives:

(i) Construction and testing of an op-amp integrator circuit.

(ii) Construction of a PI controller using op-amps.

(iii) Investigation of the closed-loop behavior of a PI velocity controller.

Preparation:

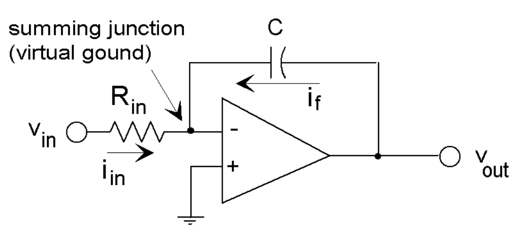
(a) Review PI control, and the reasons for including the integral action.

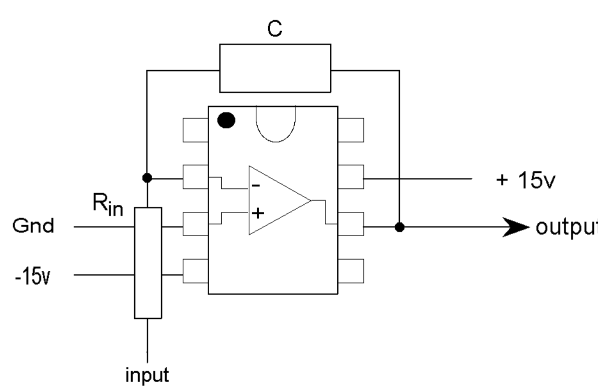
(b) Review the actions of op-amps as described in the handout.

(b) Review your report for Laboratory 3 (Proportional Velocity Control), including sugestions for wiring circuits on the breadboard.

Procedure:

Step 1: Build an Integrator



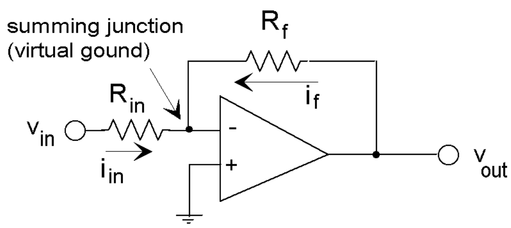


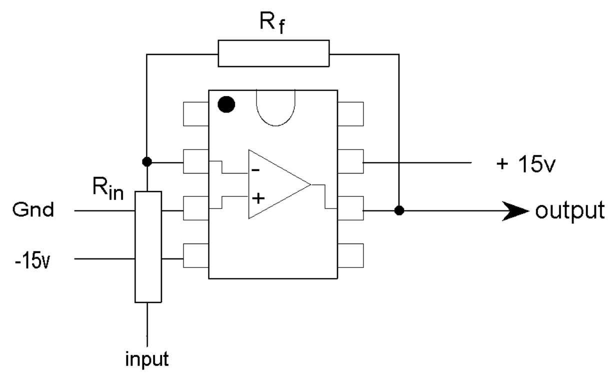
Build an integrator using the above schematic and suggested layout. The integrator obeys the equation:

$$v_{out} = -\frac{1}{R_{in}C}\int_0^t v_{in}(t)dt + v_out(0)$$

Use $R_{in} = 10$ kΩ and $C = 10$ μF. Test the integrator by using the function generator to supply the integrator with (a) a square-wave input, (b) a sawtooth input, (c) a sine input. Print the outputs and include them with you report. Make sure that you understand the integral action for each waveform - does the integrator live up to its name?

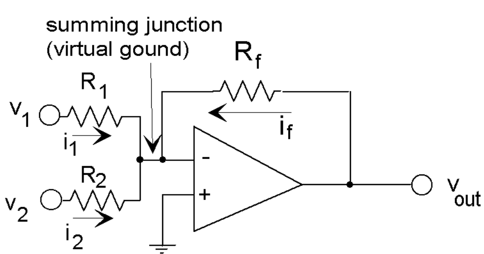
Step 2: Build a Unity Gain Inverting Amplifier

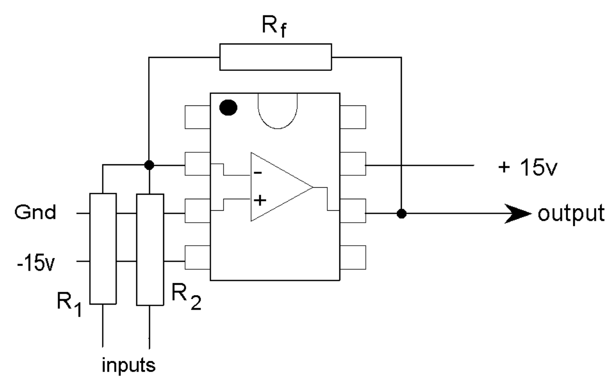




This should be easy now! Use 10 kΩ resistors for R_{in} and R_f.

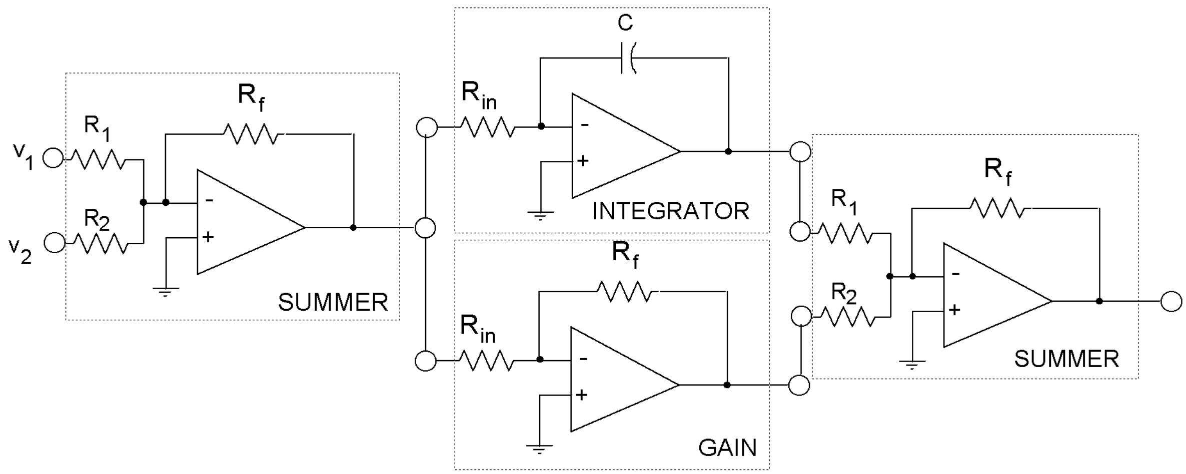
Step 3: Build a Summer:

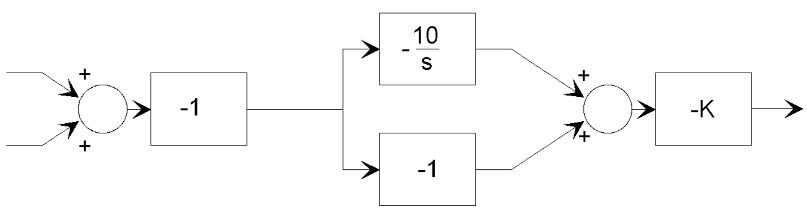




This will be similar to the summer you constructed in Lab. 3. You will vary the value of R_f to vary the overall loop gain.

Connect the Elements to Form a PI Controller Modify the op-amp circuit you used for the previous labs to be a summer as in Step 3. The complete circuit and its block diagram are shown below:

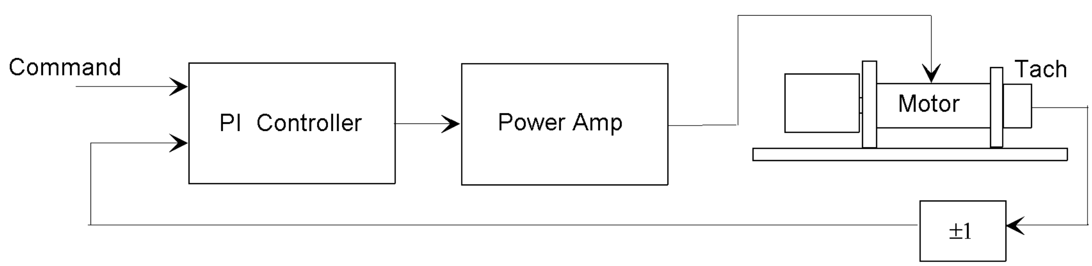




Now connect your PI controller to the plant:

(1) Make sure that the gears on the position sensor (potentiometer) are dis-engaged.

(2) Connect the system as a velocity controller as shown below:



(3) Use the function generator to drive the system, and connect the oscilloscope to monitor the command signal (from the function generator), the velocity response, and the error.

Test the PI Controller

(1) Turn on the power to the circuit and the function generator: supply a square-wave input. Turn on the power to the power amplifier. Make sure you have negative feedback!

(2) Observe the steady-state error behavior of the system. Disable the integrator (remove its output connection) and note the steady-state error behavior. Does the PI action eliminate any steady-state bevahior?

(3) Observe the disturbance rejection of the closed-loop system (under both P and PI action) by using your hand to supply a torque disturbance on the wheel. Can you feel the effect of the integral action as you attempt to slow down the motor?

(4) Discuss with your partner how integral action acts to eliminate steady-state errors.

(5) Investigate the step response of the closed-loop system. Use the function generator to supply a square wave with a sufficiently long period to allow the motor to come to a steady state. Print out the resulting oscilloscope trace. Using the cursors, measure and record the steady-state error, the settling time, and the period of any oscillatory component.

(6) Repeat Step 5 for gains $K = 0.5, 5, 10$. From your results, discuss what gain results in the 'best' control, as measured by disturbance rejection, steady-state error, and time constant? Justify your answer.