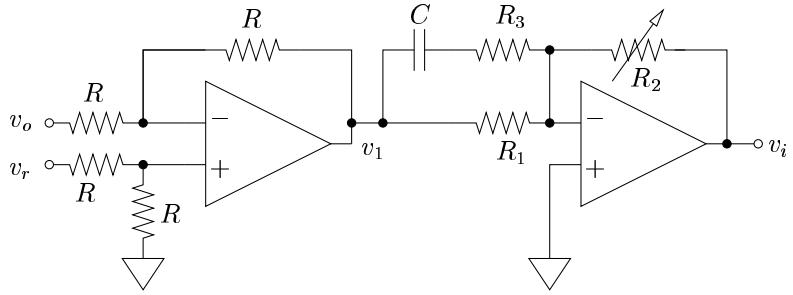
In this lab, we will examine the effects of closed-loop control on the second-order "plant" of Labs 3 and 4. The op-amp circuit shown below will allow us to implement proportional and lead controllers with an adjustable gain.



We have constructed the ciruit with $R_1 = 68$ kΩ and left off R_3 and C. (You will add them later to make a lead compensator.)

1. Set the function generator to produce a square wave of approximately 300 mV. By turning the adjustment screw on the potentiometer R_2, reduce the gain to essentially zero. Give the system an initial displacement and measure the 10-90% rise time. This is the rise time of the open-loop system.

2. Now increase the gain so that the rise time is approximately 1/2, 1/4, 1/6, 1/8, and 1/10 (in turn) that of the open-loop system. At each setting, estimate the location of the poles, and plot them on an s-plane. At each setting, be sure to give the system a disturbance by hand and feel the action of the controller.

3. If the system goes unstable, turn down the amplitude of the square wave, and try to stabilize the system with your hand.

4. Reduce the gain to zero and add the capacitor $C = 0.47$ μF and resistor $R_3 = 6.8$ kΩ to obtain a lead compensator. Again, gradually increase the gain to obtain rise times of 1/2, 1/4, 1/6, 1/8, and 1/10 that of the open-loop system. Estimate the location of the poles. Add them to the s-plane plot you made for the proportional controller.