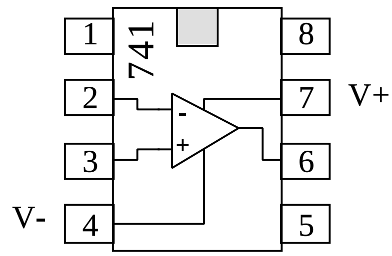
Laboratory 8.2	**Operational Amplifiers**
Name	**Section**

PURPOSE

1. Investigate an active differentiator.
2. Investigate a two-pole active filter.



SPECIAL EQUIPMENT

A single 741 op amp is needed for this lab. An improved version should not be substituted in Part A since several of the observations depend on the high frequency limitations of the 741. However, if an improved type is available, you might find it illuminating to duplicate the observations with both devices.

Section B also makes use of a 74123 TTL multivibrator .

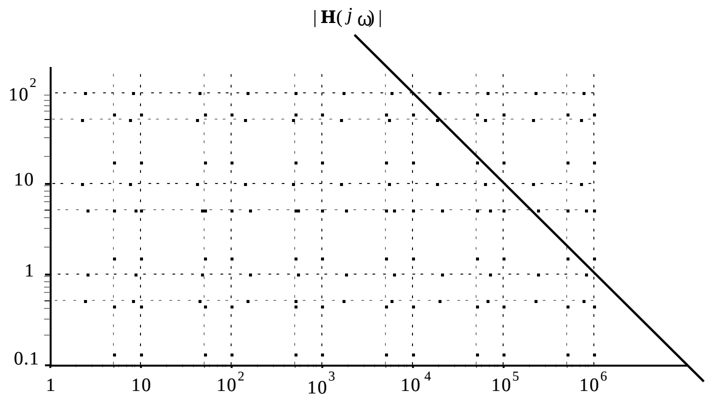
A. Differentiator

1. Preliminary design work

Do the work in this entire section before you come to lab.

a. Sketch the basic op amp differentiation circuit below. Show your signal generator modified to have less than 100 Ω of output impedance.

b. The following graph shows the open loop gain of the 741 op amp at high frequency. Plot the closed loop gain curves G for your differentiation circuit on this plot for two choices of *R* and *C*: 1 kΩ with 0.001 μF, and 10 kΩ with 0.01 μF.



c. Refer to the text discussion in Section 8.6.2, and on each of the above |**G**| curves, indicate whether you expect the design to be slightly under damped, slightly over damped, strongly under damped, or strongly over damped.

2. Build the differentiator.

a. Build each of these circuits, ending up with the one which displays the most ringing when driven by a low frequency square wave from a signal generator with 100 Ω or less output impedance. For both circuits, record the order of magnitude values of any decay times or frequencies that are evident. Use low amplitude signals so as not to exceed the slew rate of the 741 op amp.

Circuit 1: t = f = ω =

Circuit 2: t = f = ω =

b. Add a second resistor to the circuit to achieve critical damping of the differentiated signal. From problem 8.22, the condition for critical damping is found to be $R_2 = 2(R/\omega_1 C)^{1/2}$. Try values on either side of this prediction to find the R_2 that yields an impulse response that is most like a delta function. You may find it convenient to use one of the potentiometers on your breadboard. Your lab instructor can measure its value at various settings.

Predicted for critical damping R_2 =

Measured at best delta function R_2 =

Note that a slightly smaller than critical R_2 implies a slightly under damped solution which typically gives the "best looking" impulse response.

3. View differentiated signals.

You have worked with the square wave up to now, but the following questions use the other waveforms of your signal generator. Don't be afraid to experiment!

a. Start off with a 1 kHz sine wave and display both input and output. Note the phase relationship. Explain how and why your output signal differs from the correct derivative. If you think about it the square wave has the same problem!

b. Sweep your sine wave to higher frequencies, and note how the output changes relative to the input when you move beyond the frequency region where $|\mathbf{G}|$ applies. What happens?

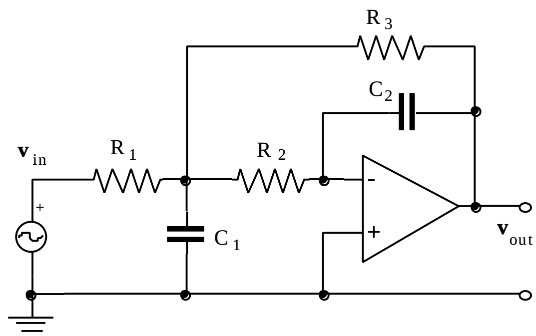
c. If your signal generator has a triangle wave, experiment with that input as well.

B. Two-pole Active Filter

1. Preliminary design work

Do the work in this section before you come to lab.

a. Refer to the discussion in Section 8.3.6 of the low-pass active filter shown at the right. Take $R_1 = R_2 = R_3 = 5$ kΩ, and $C_1 = 0.1$ μF and determine the value of C_2 needed to make a Butterworth filter as in Example 8.3.



$C_2 =$

b. What corner frequency do you expect for this filter.

$\omega_c =$ $f_c =$

From Example 8.3 in your text, evaluate the pole locations using this corner frequency. (Note there is a missing minus sign on the first $1/\sqrt{2}$.

$\sigma =$ $\omega = \pm$

c. The impulse response of this filter should be proportional to $e^{\sigma t}\sin(\omega t)$. Make a table of the value of this function at 45° intervals in ωt out to $\sin(\omega t) = 1$.

2. Build the circuit.

a. Add a 100 Ω resistor to your signal generator to reduce its output impedance as described in the introduction to this manual, then build the Butterworth filter and apply a sine wave from this modified filter.

b. Locate the corner frequency of your filter. It should closely match your prediction.

f_c = ω_c =

3. Observe the impulse response.

a. Build the multivibrator impulse generator described in the introduction to this manual.

b. Apply the impulse source as input to the filter and observe the impulse and the impulse response. Determine the zero-crossing time of the impulse response, measured from the falling edge of the impulse, and see if ω from the poles predicts a zero at this time.

t_{zero} = $\sin(\omega t_{zero})$ =

c. Increase the value of C_1 by approximately a factor of 10 and again observe the impulse response. Sketch it here and indicate the frequency of the oscillation.

f_{osc} =

d. Switch back to the sine wave input and scan the low frequency spectrum. Sketch the magnitude of the observed transfer function and record the frequency of any resonant peak you find. It should be close to f_{osc}.

f_r =