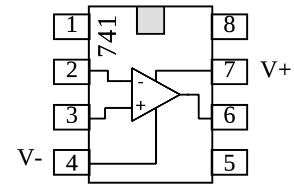
Laboratory 8.3:	**Operational Amplifiers**
Name	**Section**

PURPOSE

1. Investigate the Negative Impedance Converter
2. Build and Operate a Wien Bridge Oscillator



SPECIAL EQUIPMENT

A 741 or similar operational amplifier and the inductor from Lab 2.1 are needed for this lab.

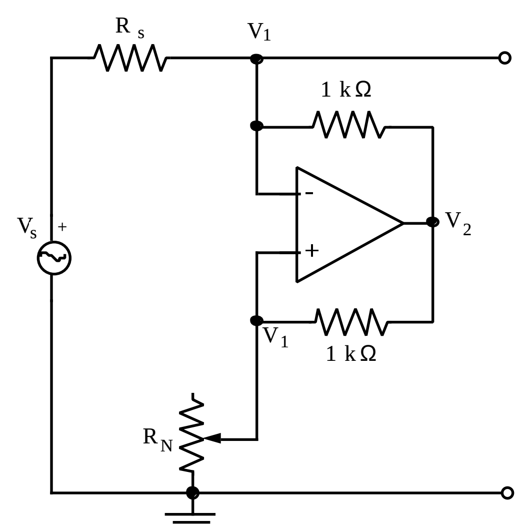
A. The Negative Impedance Converter

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

a. Sketch a two resistor voltage divider and derive the transfer function when the grounded resistor (R_2) has a negative resistance -R_N. Write an expression for the voltage gain of this circuit in terms of R_s and R_N. Label the input signal to this divider as $\mathbf{v}_s$ and the output as $\mathbf{v}_1$.

2. Build and test an NIC amplifier.

a. This circuit works like the voltage divider with two series resistors: R_s and a negative resistance -R_N. When building this circuit, increase the output impedance of your signal generator R_s until it is about half of the maximum impedance of your potentiometer: something like 5 kΩ and a 10 kΩ pot works well. The circuit shown is stable ONLY when $R_N < R_s$: when $R_N > R_s$ you must reverse the plus and minus op amp inputs.



b. With the in-circuit part of potentiometer R_N set to about 1/4 of its maximum resistance, apply a low amplitude sine wave of about 1 kHz and compare the output at $\mathbf{v}_s$ to that at $\mathbf{v}_1$ and $\mathbf{v}_2$. If the device appears to be functioning, slowly increase the resistance R_N while observing $\mathbf{v}_s$ and $\mathbf{v}_1$. Near the mid-range of the potentiometer you should see the output distort and ultimately lock at one power supply. Adjust the potentiometer (and the offset control of your signal generator) for the maximum usable gain (a sine wave output), then with power off, disconnect the potentiometer and measure what was its in-circuit resistance.

At maximum useable gain with R_s = R_N =

c. Reverse the input terminals to the op amp and repeat the previous step except that now you should start with R_N near its maximum value.

At maximum useable gain = R_N =

3. Build and test the Q-enhanced LCR circuit.

a. Before you come to lab, sketch a series *R*, *L*, *C*, NIC circuit.

b. Build this circuit with miminum series resistance (only the intrensic resistances of the signal generator and the inductor) and a potentiometer that will allow you to cancel this resistance.

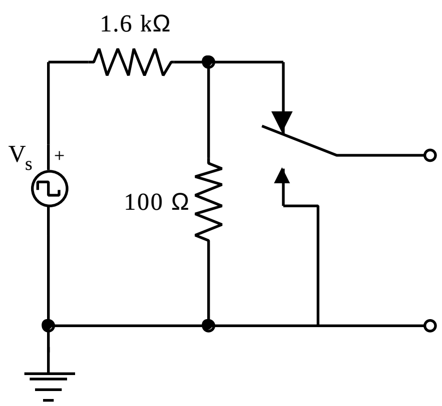
c. With the potentiometer set to zero, apply a low frequency square wave and observe the ringing response at the inductor-capacitor junction. Slowly increase the potentiometer and note how the response changes. (Remember that a high *Q* circuit should ring for a long time.) Measure and record the potentiometer setting when you have achieved maximum *Q* and compare it with the series resistance.

R_N = $R_s + R_L$ =

B. The Wien Bridge Oscillator.

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

a. The following drawing shows an impedance modified signal generator connected to a single-pole, double-throw (SPDT) switch. Complete this circuit by adding a Wien bridge oscillator connected so that this switch can be used either to short the inputs as shown in Fig. 8.17a, or to provide signal generator source driving the oscillator. Use the notation of Fig. 8.17a to label the circuit elements and voltages on your schematic.



2. Build and test the circuit.

a. Build the circuit with the components R = 10 kΩ, C = 0.1 μF, and R_2 = 30 kΩ. For a sine wave oscillator R_1 should be half of R_2, but when you build the circuit use a 10 kΩ potentiometer as part (5 kΩ worth) of R_1.

b. Drive this circuit with a low frequency square wave and adjust the potentiometer (or the fixed resistors making up R_1) until the poles are on (or slightly to the right of) the imaginary axis. Record the total R_1 in your circuit (estimate or remove and measure the potentiometer).

R_1 =

c. What is the frequency (Hz) of the oscillation that you observe?

T = f =

d. Draw your actual circuit from the switch to the negative op amp input and label the individual component values that make up R_1.

e. Now use the switch to short the inputs to the Wein bridge oscillator (removing the signal generator from the circuit) and adjust the potentiometer if necessary to obtain a sine wave output. (With a 741 op amp this circuit seems to be stable, presumably because of nonlinearities within the amplifier.) Did the potentiometer setting remain essentially the same as in Section b?

f. Measure the frequency of the oscillation you observe and compare it with the frequency predicted by Equation 8.41. Your measurements should match those in Section c.

T = f =

ω = $\omega_{predicted} = 1/RC$ =

g. In Section b you adjusted an amplifier so that its impulse response (actually a step response) was a sinusoid, then in part e you applied an input signal that was zero (a shorting wire) and converted the amplifier to a sine wave oscillator. However the oscillator can still be described as an amplifier that is generating its impulse response function in response to some single event disturbance.

Now suppose that the signal generator output impedance had been 1.6 kΩ instead of less than 100 Ω. How would you expect the potentiometer setting to change between Section b and Section e? Explain with words and pictures.