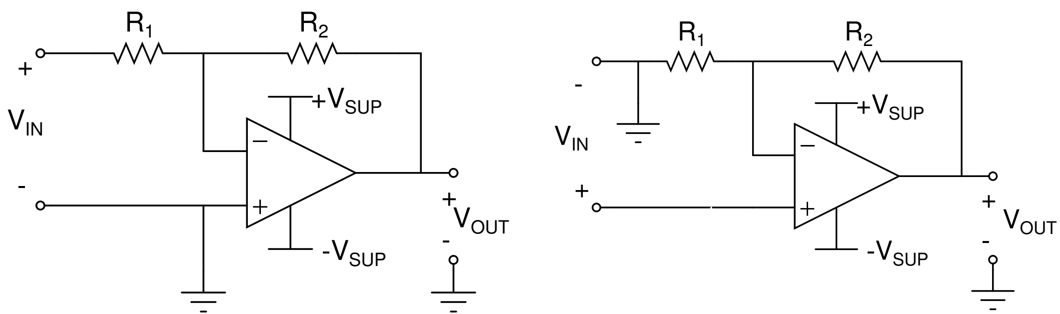
ECE 214 - Lab #4 — Basic OpAmp Circuits

16 February 2016

Introduction: The TL082 Operational Amplifier (OpAmp) and the Texas Instruments "Analog System Lab Kit Pro" evaluation board are used to explore basic OpAmp circuits. Negative feedback is used to generate the inverting, non-inverting, inverting integrator and inverting differentiator OpAmp configuration. Additional features of the oscilloscope including the input coupling and triggering settings are also utilized.

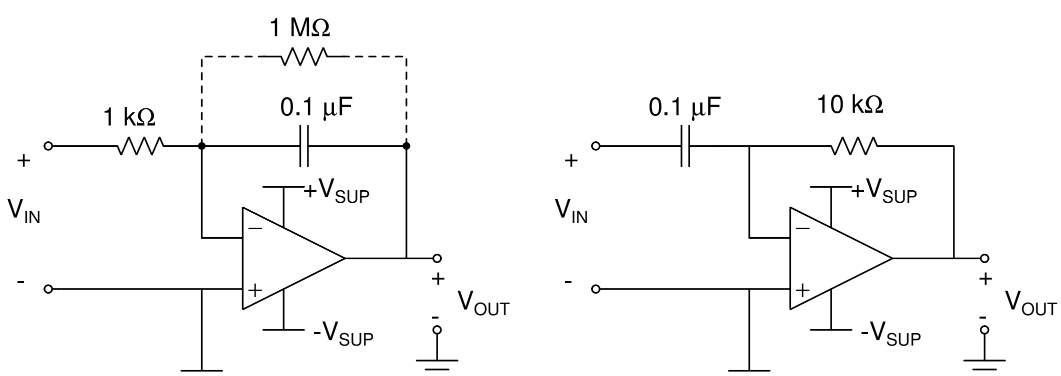
Pre–Lab:

1. Review ideal OpAmp circuits from ECE 210. Make sure you can calculate both the voltage gain and output response $V_{OUT}(t)/V_{IN}(t)$ for each of the four OpAmp configurations shown below. Each OpAmp configuration uses negative feedback to achieve amplification within the active region of operation. Make sure you understand why each of these amplifiers is configured to use negative feedback and how to distinguish between negative and positive feedback.



(a) Inverting OpAmp circuit. (b) Non–inverting OpAmp circuit.

Figure 1: Inverting and non–inverting OpAmp circuits.



(a) Inverting integrator OpAmp circuit. (b) Inverting differentiator OpAmp circuit.

Figure 2: Inverting integrator and inverting differentiator OpAmp circuits.

2. Watch the videos titled: "Tutorial - How to use an oscilloscope" Parts 1, 2 and 3 located at `http://ece214.eece.maine.edu/?page_id=379`. You are already be familiar with much

of this information. However, make sure you understand the differences between AC input coupling and DC input coupling. Also, pay attention to the concept of triggering, especially the role of the trigger slope and the trigger level, and the difference between internal and external triggering. The input coupling and triggering features of the scope will be utilized in this and future labs.

Lab Procedure:

1. Locate the “OpAmp Type II Full” circuit on the TI evaluation board. Use this circuit for all measurements described below.
2. Design and build an inverting OpAmp circuit with a gain of -4.7. (Use only components that are available “OpAmp Type II Full” circuit on the TI evaluation board.)
3. Turn on the Dual Voltage Supply (PS) and turn all voltages down to zero. Set the Tracking Ratio knob fully clockwise till it clicks. Attach the ends of extra long wires between (a) the PS common, adjustable +20, and adjustable -20 volt terminals and (b) the “Main Power” GND, +10V, and -10V terminals on the TI evaluation board.
4. Monitor the voltage on the display and adjust the voltage to +10. If none of the components on your board gets hot and no smoke appears, things are going well. The power LEDs on the evaluation board should be illuminated. Use a DVM to verify that the correct voltages have been established at the rails of the OpAmp.
5. Connect the function generator (FG) to the input of the OpAmp circuit. Adjust the FG to output a sine wave of 500 mVp at a frequency of 10 kHz. Connect one channel of the oscilloscope to the FG output and the other channel to the output of the OpAmp. What are the gain and phase shift of the output with respect to the input? How do these results compare with theoretical predictions? Record the results in you notebook.
6. Increase the amplitude of the input signal until the OpAmp saturates. What does the output signal look like when the input signal is too large? Sketch the output of the OpAmp in saturation in your notebook. What is the maximum and minimum output voltage from the OpAmp? Record the results in your notebook.
7. Reduce the input signal back to 500mVp and examine the OpAmps behavior at frequencies below 10 kHz. Does the gain or phase shift change? Now look at frequencies above 10 kHz. Briefly describe the results in your notebook as the frequency is decreased and increased.
8. Increase the frequency until the phase shift goes from $-180°$ to $-225°(+135°)$. Lissajous patterns might help in determining this frequency. What is the gain at this frequency? Record the frequency and gain in your notebook. Reference this result in your table of contents.
9. Design and build a non-inverting OpAmp circuit with a gain of +11. (Use only components that are available on the TI evaluation board.)
10. Repeat steps 5 through 7 above.
11. Increase the frequency until the phase shift goes from $0°$ to $-45°$. What is the gain at this frequency? Record the frequency and gain in your notebook.

12. Build the inverting integrator shown in Figure 2a. The 1 MΩ resistor across the capacitor provides a DC path from the output to ground. What is the expected gain of this circuit?

13. Connect a 1 Vp sine wave signal with a frequency of 1K Hz to the input of the integrator. Use the DC offset on the FG to stabilize the DC component of the output signal. What DC offset voltage was needed to keep the output signal centered around 0 V? What does the output signal look like? Is the amplitude and phase what you expect? Record the results in your notebook.

14. Increase the frequency of the input signal. Explain and record in your notebook what happens to the output signal. You may need to utilize AC coupling and ensure you trigger the scope from the sine wave input signal, or use external triggering, to obtain a stable output signal.

15. Experiment with square, triangular and sawtooth waves as inputs to the integrator. Does the circuit integrate properly? Record the input and output signals in your notebook.

16. Design and build a non-inverting integrator circuit with the same gain as above. (Use only components that are available on the TI evaluation board.) Apply a 1 kHz square wave to the input of the circuit and verify the output is correct. Make sure to record the circuit along with scope images in your notebook. Make a reference to the circuit schematic and output waveforms in the table of contents of your notebook.

17. Build the inverting differentiator shown in Figure 2b. What is the expected gain of this circuit?

18. Connect a 1 Vp sine wave signal with a frequency of 1K Hz to the input of the differentiator circuit. What does the output signal look like? Is the amplitude and phase what you expect? Record the results in your notebook.

19. Input a triangular signal into the differentiator circuit. Does the circuit differentiate properly? Record the input and output signals in your notebook.

Post Lab:

Simulate the behavior of the inverting integrator using Micro-cap when the input to the integrator is a sine wave, square wave, triangular wave, and sawtooth wave. Record the Micro-cap circuit and simulation results in your notebook and label the page number(s) of this information in the table of contents. Compare the simulated results to the experimental results from this lab?