ECE214: Electrical Circuits Laboratory

Lab #4 — Basic OpAmp Circuits

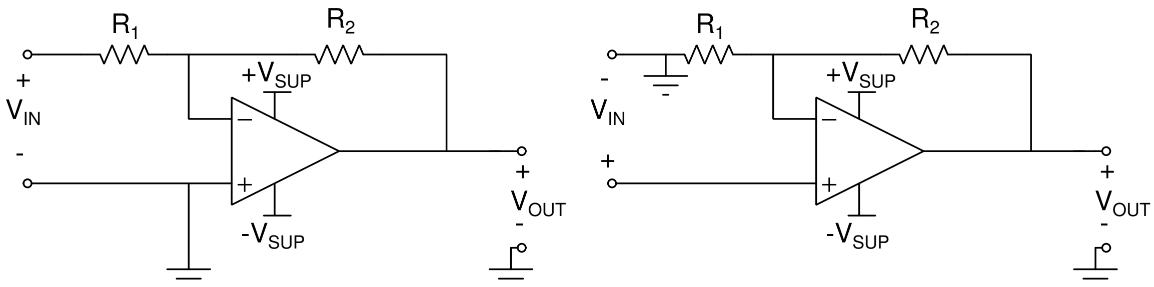
Week of 10 February 2015

1 Introduction

The TL082 Operational Amplifier (OpAmp) and the Texas Instruments "Analog System Lab Kit Pro" evaluation board are used to explore basic OpAmp circuits using negative feedback. The input coupling and triggering functions of the scope are used.

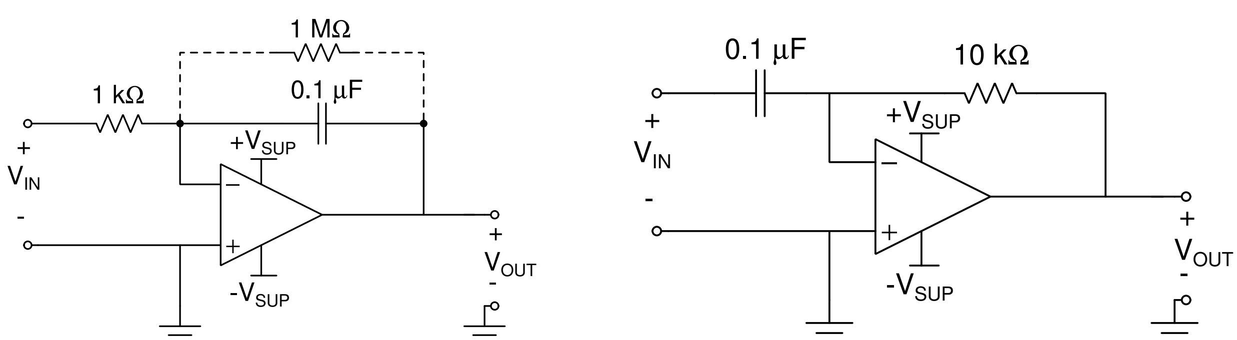
2 Pre-lab

1. Review ideal OpAmp circuits from ECE 210. For each of the four OpAmp configurations shown below, make sure you can calculate both the voltage gain and output response $V_{OUT}(t)/V_{IN}(t)$. Each configuration makes use of negative feedback to achieve amplification within the active region of operation. Make sure you understand why these amplifiers is configured to use negative 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. You can review the YouTube video "How to use an oscilloscope." `https://www.youtube.com/watch?v=CzY2abWCVTY` but you probably already know most of what is covered. Make sure you understand the difference between AC and DC coupling and the concept of triggering — especially the role of the trigger slope, trigger level, and the difference between internal and external triggering.

3 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 with the "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 OpAmp's behavior at frequencies below 10 kHz (down to at least 100Hz). Does the gain or phase shift change? Now look at frequencies above 10 kHz (up at least into the MHz range). 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^o to -225^o ($+135^o$). 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^o to -45^o. 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.

13. Connect a 1 Vp sine wave signal with a frequency of 1kHz 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? What is the expected gain of this circuit? 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. Build the inverting differentiator shown in Figure 2b.

17. Connect a 1 Vp sine wave signal with a frequency of 1kHz to the input of the differentiator. What does the output signal look like? What is the expected gain of this circuit? Is the amplitude and phase what you expect? Record the results in your notebook.

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

4 Post-Lab

Use Micro-cap to simulate the behavior of the inverting integrator (Figure 2) when the input is a sine wave, square wave, triangular wave, and sawtooth wave. Record the results from the Micro-cap simulation in your notebook and label the page number of this graph in the table of contents. How do these results compare with the experimental results from lab?