Experiment 4

**Submission Template**

# The following should be included in your experimental checklist. Everything should be labeled and easy to find. Credit will be deducted for poor labeling or unclear presentation. ALL PLOTS SHOULD INDICATE WHICH TRACE CORRESPONDS TO THE SIGNAL AT WHICH POINT AND ALL KEY FEATURES SHOULD BE LABELED.

**Hand written schematics are required for physically built circuits, ONLY!!!**

# Part A – (14 pts)

 A.1 Include the following plots:

1. LTspice transient of inverting amplifier with input amplitude of 200mV and both traces marked. (2 pt)
2. LTspice transient of inverting amplifier with input amplitude of 1V and both traces marked. (2 pt)
3. M2K/Analog Discovery picture of input and output voltages for the inverting amplifier circuit. (2 pt)

A.2 Answer the following questions:

1. What is the theoretical gain of your inverting amplifier? What gain did you find with LTspice when the input amplitude was 200mV? How close are these? (2 pt)

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1. What was the actual gain you got for the inverting amplifier you built? How did this compare to the theoretical gain? How did this compare to the LTspice gain? (2 pt)

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1. What value did you get for the saturation voltage of the 741 op-amp in LTspice? What value did you get for the saturation voltage of the real op-amp in your circuit? How do they compare? (2 pt)

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1. At what input voltage did the op-amp in the amplifier you built on the protoboard begin to saturate? (2 pt)

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# Part B – (10 points)

B.1 Include the following plots:

1. LTspice transient of the voltage divider with 100Ω load and no voltage follower. (1 pt)

1. LTspice transient of the voltage divider with 100Ω load and a voltage follower. (1 pt)
2. LTspice transient of the voltage divider with 1Ω load and a voltage follower. (1 pt)
3. LTspice AC sweep of the input impedance for the voltage follower. (2 pt)

B.2 Answer the following questions:

1. Compare the transients of the output with and without the buffer circuit in place. What is the function of the buffer circuit? (2 pt)

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1. Why is the follower unable to work properly with a small load resistor? (1 pt)

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1. What is the typical value of the input impedance of the voltage follower when it is working properly at low frequencies? (1 pt)

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1. Is the magnitude of the input impedance of the voltage follower high enough at high frequencies for it to work effectively? (1 pt)

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# Part C – Integrators and Differentiators (38 points)

C.1 Include the following plots:

1. LTspice transient plot of the integrator. (1 pt)
2. AC sweep of amplitude (with three experimental points marked) and phase (with three experimental points marked.) The frequency at which the phase gets close to ideal should also be marked. (3 pt)
3. AC sweep plot of the integrator voltage and -Vin/ωRC with the location of fc and the place where the voltage gets close to ideal indicated. (2 pt)
4. LTspice plots of the integrator with DC source with slope and theoretical slope (if any) indicated on plot. One should be when C2=1uF and the other for C2=0.01uF (2 plots) (2 pt)
5. M2K/Analog Discovery pictures of your circuit trace (input vs. output) at 100Hz, 1kHz and 5kHz. (3 plots) (3 pt)

1. M2K/Analog Discovery pictures of your integrator input and output with sine wave, triangular wave and square wave inputs (input vs. output) (3 plots) (3 pt)
2. M2k/Analog Discovery plot of the ideal integrator (without feedback resistor) (1 pt)
3. M2K/Analog Discovery picture of your differentiator output with sine wave, triangular wave and square wave inputs (input vs. output) (3 plots) (3 pt)

C.2 Answer the following questions:

1. Using the rules for analyzing circuits with op-amps, derive the relationship between Vout and Vin for the integrator circuit. (3 pt)

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1. Why is the integrator also called a low-pass filter? Take the limits of the transfer function at high and low frequencies to demonstrate this. (3 pt)

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1. What are the features of the AC sweep and transient analysis of an integrator that show it is working more-or-less as expected according to the transfer function? For about what range of frequencies does it act like an inverting amplifier? For about what range of frequencies does it act like an integrator? (3 pt)

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1. Consider the phase shift and the change in amplitude of the output in relation to the input when the circuit is behaving like an integrator. Use the expected change in phase and amplitude (from the ideal equation) to demonstrate that the circuit is actually integrating. (3 pt)

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1. Why would we prefer to use the 0.01uF capacitor in the feedback loop even though the circuit does not integrate quite as well over as large a range? (1 pt)

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1. In the hardware implementation, you used a square-wave input to demonstrate that the integrator was working approximately correctly. If it were a perfect integrator, what would the output waveform look like? Is it close? (3 pt)

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1. What happens when we try to use an ideal integrator? (1 pt)

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1. When we built the differentiator, what did the output waveform look like for the square-wave input? What did the differentiator circuit output look like for a triangular wave input? If it were a perfect differentiator, what would the output waveform look like? Is it close? (3 pt)

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# Part D – Using Op-Amps to Add and Subtract Signals (10 points)

D.1 Include the following plots:

1. Transient simulation of the output of the adder with both input resistors set to 1k. (1 pt)
2. Transient simulation from LTspice with R2 modified. (1 pt)

D.2 Answer the following questions:

1. Demonstrate that the original adder circuit (figure D-3) works as expected. (3 pt)

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1. Demonstrate that the modified adder circuit (modified figure D-3) works as expected. (3 pt).

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1. Give an example of a system (electrical, mechanical, chemical or some combination) with negative feedback and an example of a system with positive feedback. (2 pt)

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**Overall (8 points)**

1. Material should be in logical order, easy to follow and complete. (6pt)

**List group member *responsibilities (0 to -4 pts)*.**  Note that this is a list of *responsibilities* as you reported in Exp 1, 2 and 3. This isn’t the personal efforts as reported for Project 1. It is very important that you divide the responsibility for each aspect of the experiment so that it is clear who will make sure that it is completed. Responsibilities include, but are not limited to, reading the full write up before the first class; collecting all information and writing the report; building circuits and collecting data (i.e. doing the experiment); setting up and running the simulations; comparing the theory, experiment and simulation to develop the practical model of whatever system is being addressed, etc.

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**Summary/Overview** (0 to -10 pts) There are two parts to this section, both of which require revisiting everything done on this experiment and addressing broad issues. Grading for this section works a bit differently in that the overall report grade will be reduced if the responses are not satisfactory.

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***Experiment 4***

***Checklist w/ Signatures for Main Concepts***

INSERT SIGNED COPY OF CHECKLIST BELOW (OR ADD SCANNED PDF VERSION)

***Experiment 4***

***Hand Drawn Schematics***

INSERT HAND DRAWN SCHEMATICS FOR ALL CIRCUITS BUILT