Cover Page

EE 316-08
Electric Circuits & Electronics Design Lab

Lab 3: Integrator and Differentiator Circuits

By: Nolan Anderson

Lab Date: 02/08/2021

Lab Due: 02/09/2021

1. Introduction and objectives

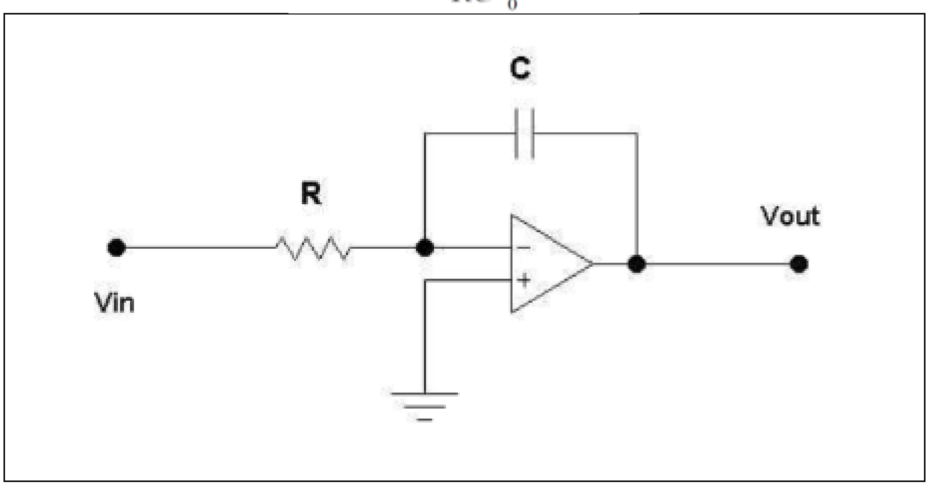
Laboratory 3 examines the characteristics of Op-Amp Integrator and Differentiator circuits. Continually, we will familiarize ourselves with these circuits by examining the gain, the input output phase relationship, as well as plotting the waveforms as a product of constructing the circuits in Multisim. We will first look at the theory behind Integrators and Differentiators, simulate the two in Multisim (with results), and finally discuss our findings.

2. Theoretical Analysis

2.1 Integrators

In it’s most basic definition, an Op-Amp Integrator simply performs Integration. Knowing this, we can cause an Integrator’s output to react to changing input voltages. This output voltage is proportional to the integral of the input voltage. Replacing a resistor in a negative feedback loop with a capacitor renders a simple Integrator circuit (see circuit 1 below). Initially, the uncharged capacitor’s resistance is low enough to cause a short circuit allowing maximum current to flow via the input resistor. As the capacitor begins to charge, the output signal grows closer to the input signal until they are directly flipped from one another.
An integrators output voltage:

$$V_{OUT}(t) = -\frac{1}{RC}\int_0^t V_{IN}(t)\,dt$$



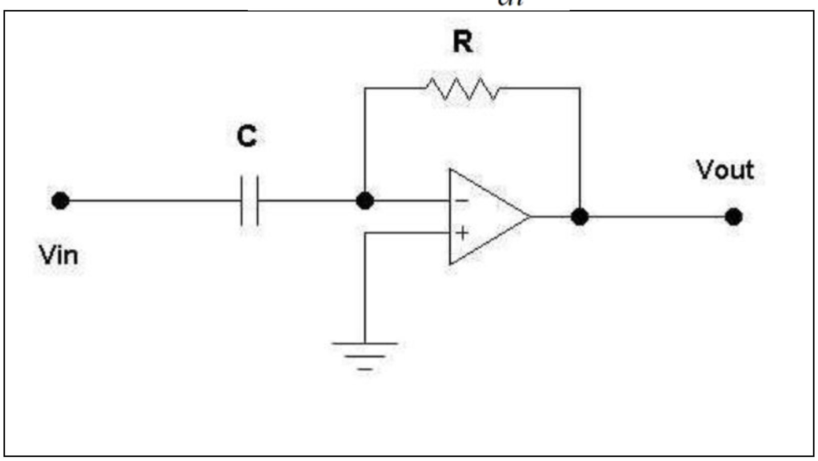
Circuit 1: Basic Integrator

2.2 Differentiators

In it's most basic definition, an Op-Amp Differentiator simply performs a differential. Knowing this, we can cause a Differentiators output to react to changing input voltages. This output voltage is directly proportional to the input voltage rate of change with respect to time. Replacing the input resistor with a capacitor renders a simple Differentiator circuit (see circuit 2 below). Initially, the uncharged capacitor renders zero output voltage. As the capacitor begins to charge, however, the output signal becomes unstable and will begin to oscillate. We can see this effect in section 3.2.

A differentiators output voltage:

$$V_{OUT}(t) = -RC\,\frac{dV_{IN}(t)}{dt}$$



Circuit 2: Basic Differentiator

3. Simulations

3.1 Integrator Simulation and Wave Forms

Section 3.1 constructs an Integrator in Multisim, see figure 1. Next, it answers the laboratory questions on gain and input / output phase relationship, see 3.1b. Sections 3.1a and 3.1c represent the waveforms calculated from Multisim.

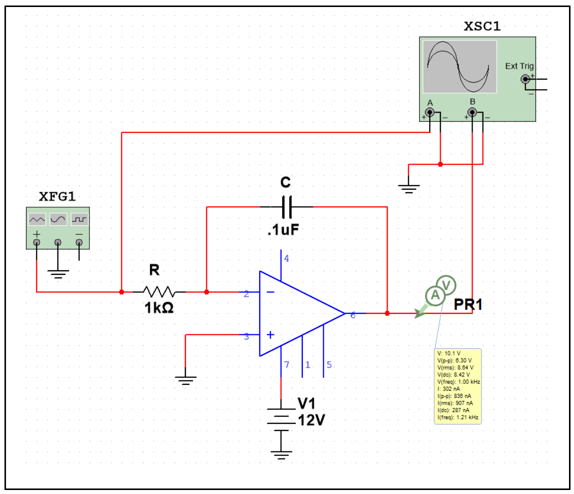


Figure 1: Integrator in Multisim

R = 1kΩ, C = 0.1 µF, f = 1 kHZ

V_{IN} = 2Vpp sinusoidal, triangle, square

3.1a Plot the input and output waveforms on the same graph for two complete cycles.

- **See Figures 2-4**

3.1b Comment on the gain and input-output phase relationship.

i. Figure 2 – Gain is 1.635 V/v – Input is sine and output is gain * cosx
ii. Figure 3 – Gain is 1.239 V/v – On max / min input, output is 0.
iii. Figure 4 – Gain is 2.472 V/v – When input changes direction, output is max / min.
iv. Figure 5 – Gain is 0.164 V/v – Input is out of phase wrt output.
v. Figure 6 – Gain is 0.133 V/v – On max / min input, output is 0.
vi. Figure 7 – Gain is 0.234 V/v – When the input is changing, output is max / min.

1.3c Repeat for C = 1 *µF and compare to your results with C = 0.1 µF.*

- ***See Figures 5-7***

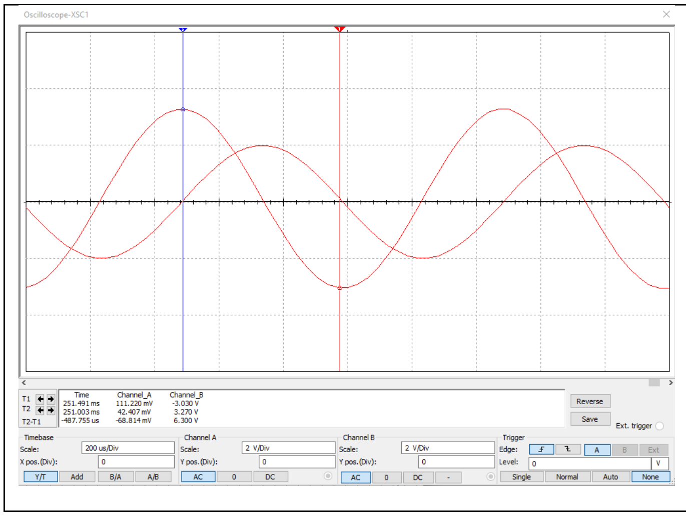


Figure 2: Integrator with sine wave R = 1kΩ, C = 0.1μF

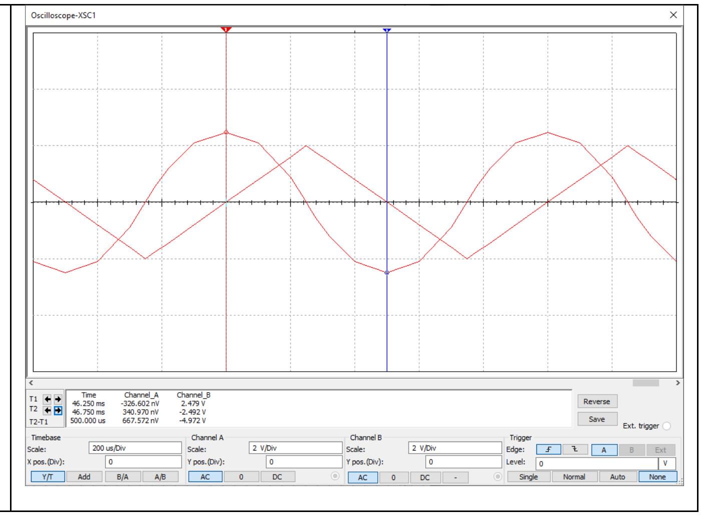


Figure 3: Integrator with triangle wave R = 1kΩ, C = 0.1μF

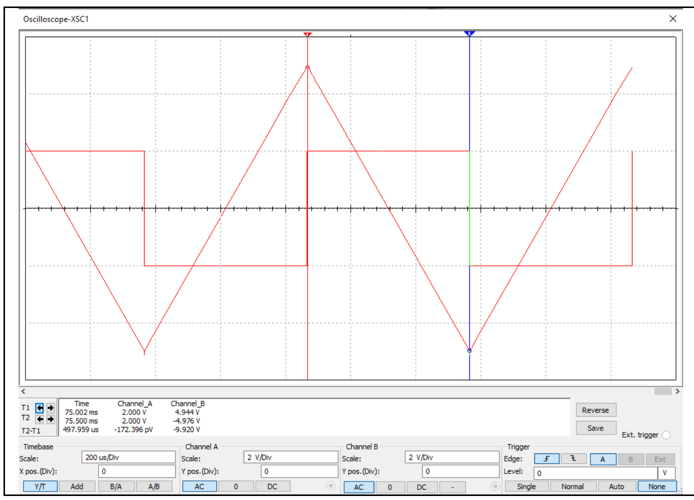


Figure 4: Integrator with square wave R = 1kΩ, C = 0.1μF

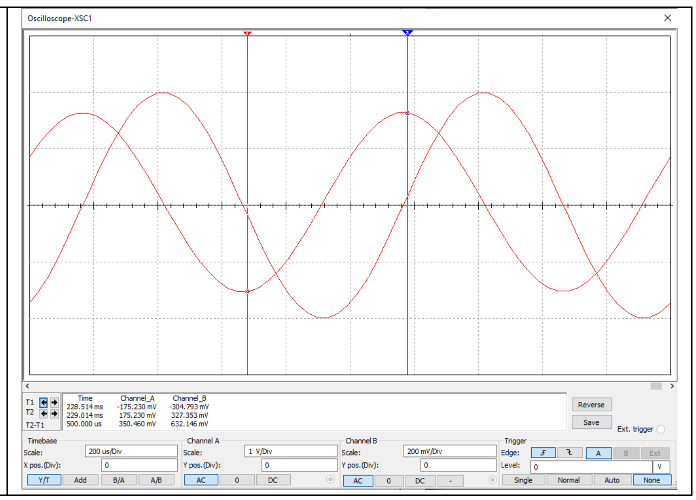


Figure 5: Integrator with sine wave R = 1kΩ, C = 1μF

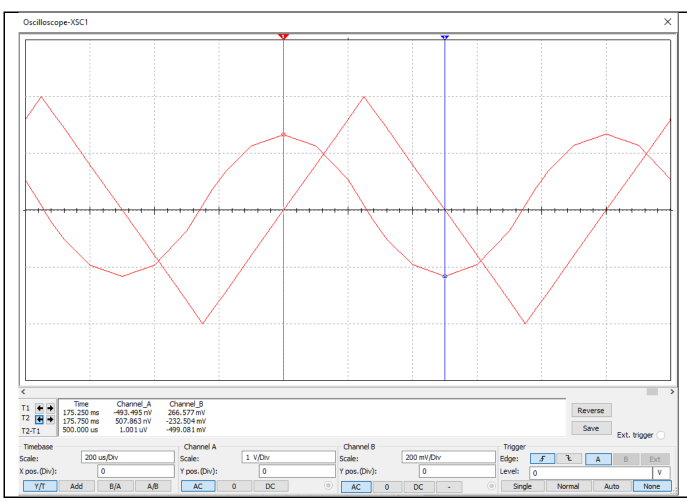


Figure 6: Integrator with triangle wave R = 1kΩ, C = 1μF

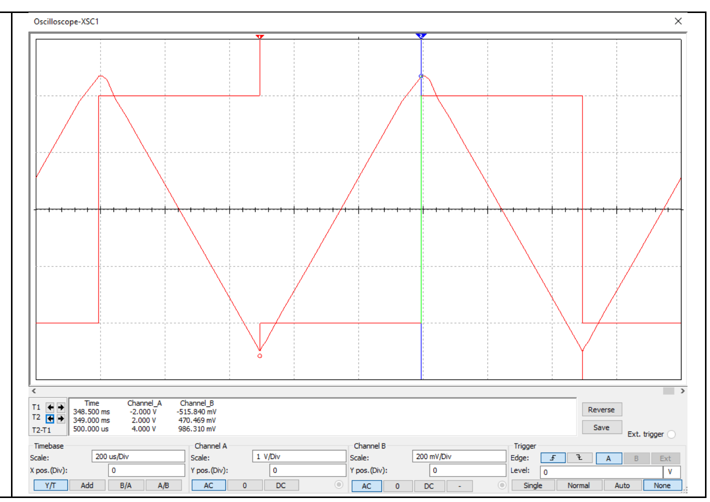


Figure 7: Integrator with square wave R = 1kΩ, C = 1μF

3.2 Differentiator Simulation and Wave Forms

Section 3.2 constructs a Differentiator in Multisim, see figure 8. Next, it answers the laboratory questions on gain and input / output phase relationship, see 3.2b. Sections 3.2a and 3.2c represent the waveforms calculated from Multisim.

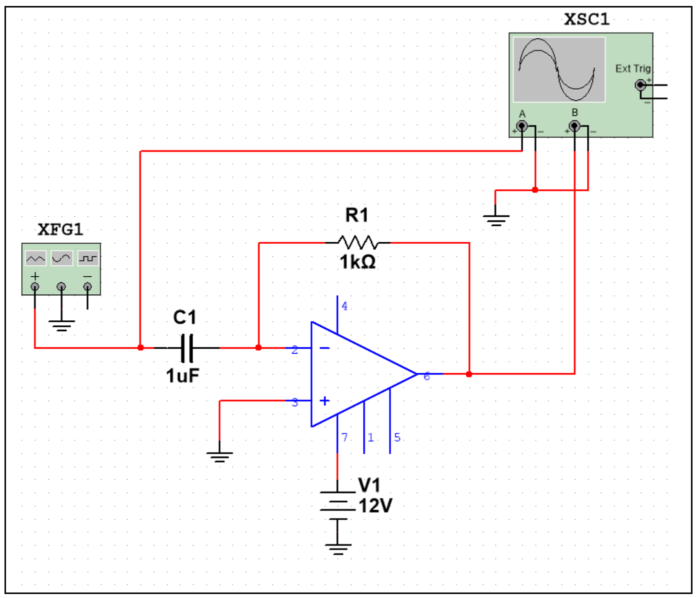


Figure 8: Differentiator in Multisim

R = 1kΩ, C = 0.1 µF, f = 1 kHZ

V_{IN} = 2Vpp sinusoidal, triangle, square

3.2a Plot the input and output waveforms on the same graph for two complete cycles.

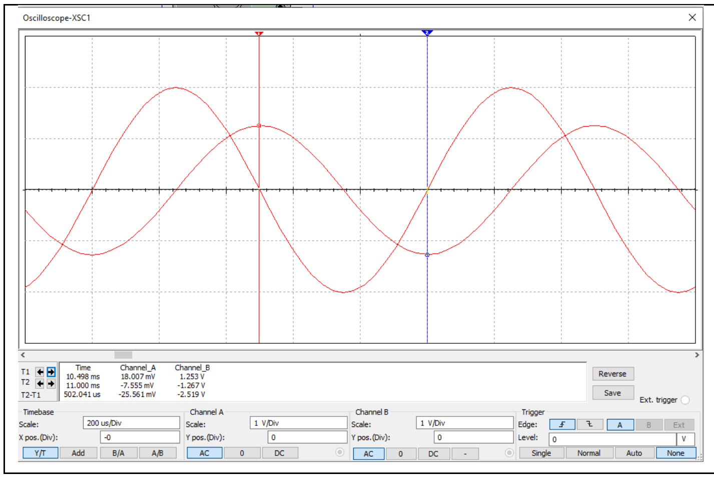
- **See Figures 9-11**

3.2b Comment on the gain and input-output phase relationship.

i. Figure 9 – Gain is 0.73 V/v – When input is sin, output is gain * cos
ii. Figure 10 – Gain is 1.07 V/v – When input inc / dec, output is damped oscillator.
iii. Figure 11 – Gain is 5.60 V/v – When input changes direction, output is max / min.
iv. Figure 12 – Gain is 5.41 V/v – The input is out of phase with output.
v. Figure 13 – Gain is 5.18 V/v – When input is at a minimum, output is decreasing.
vi. Figure 14 – Gain is 5.48 V/v – Output decreases as a reaction to the input gaining.

3.2c Repeat for C = 1 µF and compare to your results with C = 0.1 µF.

- **See Figures 12-14**



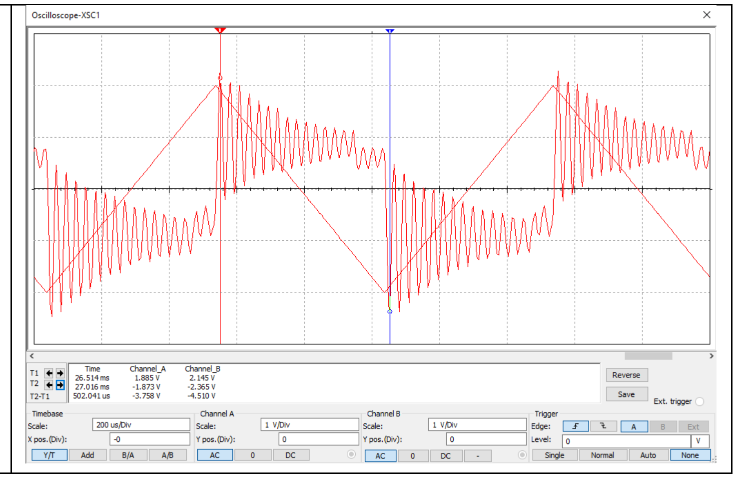
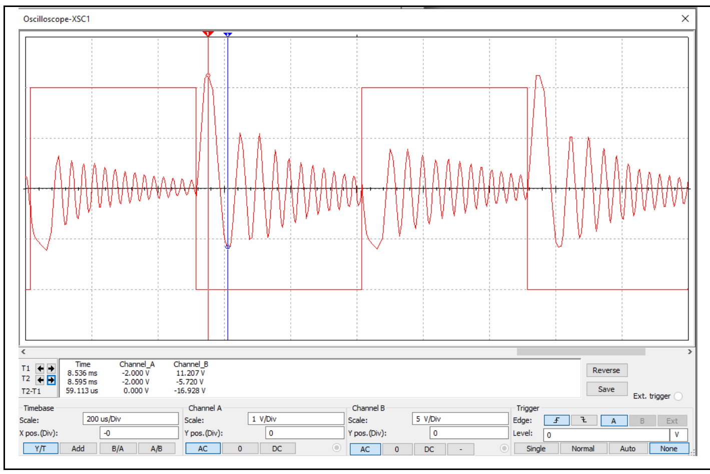


Figure 9: Differentiator with sine wave R = 1kΩ, C = 0.1µF

Figure 10: Differentiator with triangle wave R = 1kΩ, C = 0.1µF



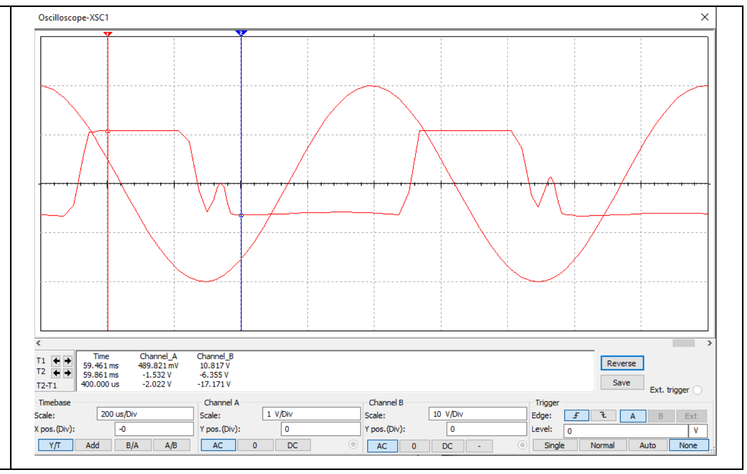
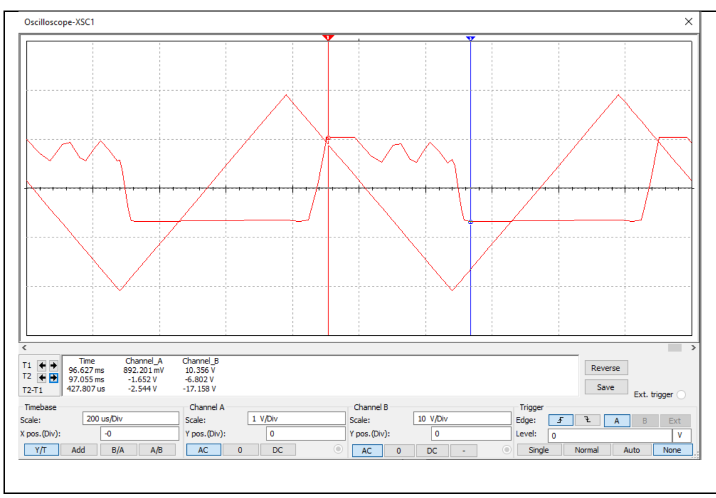


Figure 11: Differentiator with square wave R = 1kΩ, C = 0.1µF

Figure 12: Differentiator with sine wave R = 1kΩ, C = 1µF



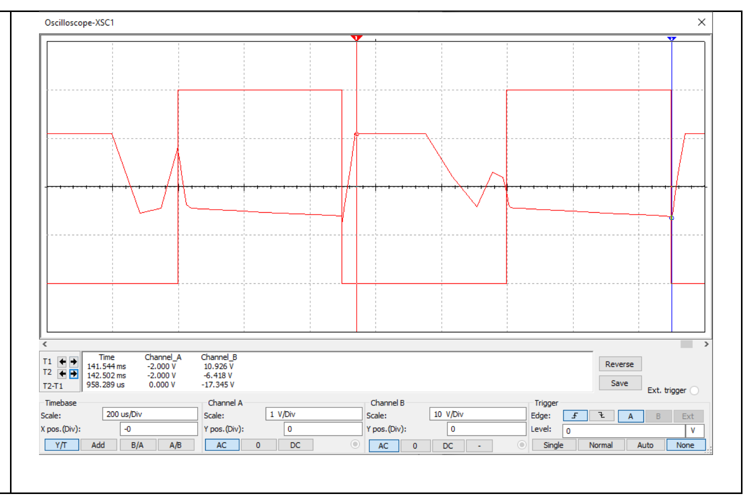
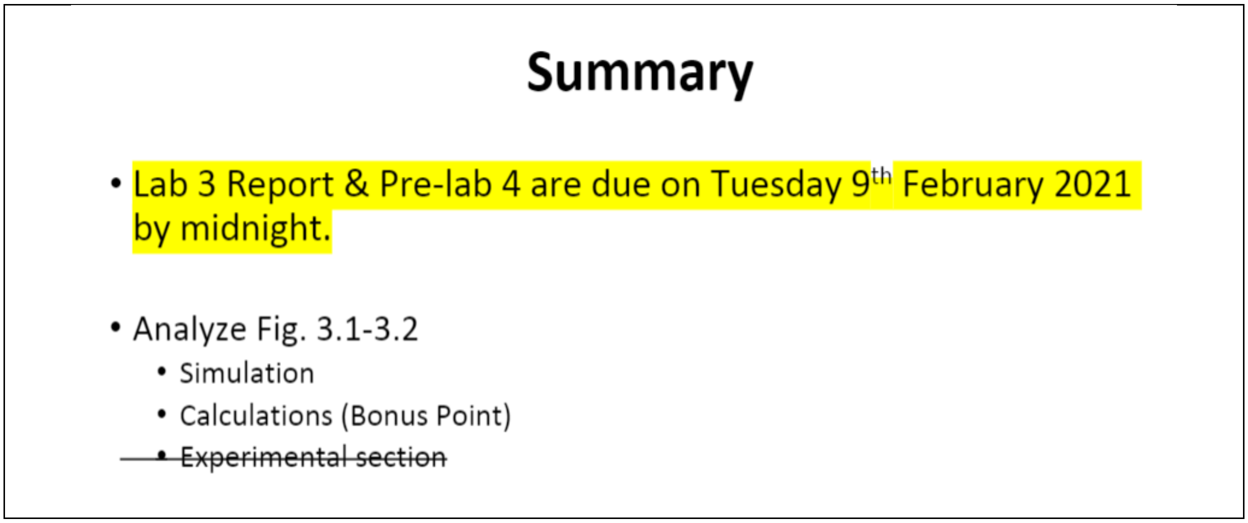


Figure 13: Differentiator with triangle wave R = 1kΩ, C = 1µF

Figure 14: Differentiator with square wave R = 1kΩ, C = 1µF

~~4. Experimental:~~

We were not instructed to provide experimental results for this lab, see the following screenshot.



5. Results and Discussion:

When analyzing the waveforms and gains in section 3, we can see that the circuits implemented in this lab closely resemble the intended effect of Integrators and Differentiators. As seen in section 3.2b, over time the output of the differentiator circuit begins to grow as the capacitor does. The circuit waveform also becomes more unstable and begins to oscillate. A similar effect and output can be seen on the Integrator in section 3.1b. Overall, the results taken from Multisim seem to be accurate enough for a proper analysis, albeit some margin of error when recording data.

6. Conclusion:

Lab 3 useful in understanding and practicing with Integrators and Differentiators. While the prelab was rather tedious, it showed how these circuits act over time with different input wave signals. Most important, however, was seeing in real time an implementation of these circuits with simulated results.

7. Appendix:

Figure A1: Inputs calculated by hand