ELECTRICAL & COMPUTER ENGINEERING
TEXAS A&M UNIVERSITY

Pre-Lab 5: Operational Amplifiers
Part 3

Kylan Lewis
UIN: 719001131
ECEN 325 -501
TA: Jian Shao

Date: 9/21/2020

Pre-Lab

Calculations:

Lossy Integrator

1. For the lossy integrator in Fig. 2, derive the time-domain equation for the output in terms of the input.

$$V_o = -\left(\frac{\frac{R_2}{R_1}}{1+sR_2C}\right)Vi$$

$$V_o(t) = V_i(t)\frac{R_1}{R_1+R_2}e^{\frac{-t}{\tau}}\ ;\ \tau = \frac{R_1R_2C}{R_1+R_2}$$

$$V_o(t) = V_i(t)\frac{R_1}{R_1+R_2}e^{\frac{-t(R_1+R_2)}{(R_1R_2C)}}$$

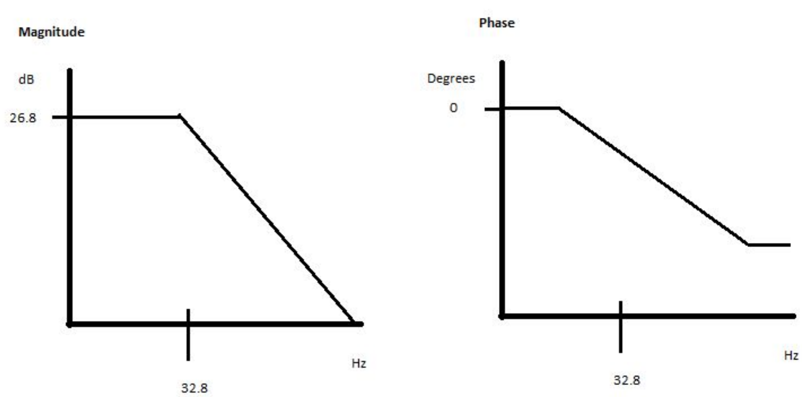
2. Find R1 to have a low-frequency gain of -22 if R2 = 22kΩ and C = 220nF, and calculate the 3-dB frequency

$$V_o = \frac{-R_2}{R_1}\frac{1}{1+sR_2C}V_i \Rightarrow \frac{V_o}{V_i} = \frac{-R_2}{R_1}\frac{1}{1+sR_2C}$$

$$Low\ frequency\ gain:\ -\frac{R_2}{R_1} = -22 = \frac{-22k}{R_1} \Rightarrow R_1 = 1k\Omega$$

$$3dB - frequency:\ \frac{1}{2\pi R_fC} = \frac{1}{2\pi\cdot 22k\cdot 220n} = 32.88Hz$$

3. Sketch the magnitude and phase Bode plots for the transfer function Vo /Vi . 20 log(22) = 26.8



dB

4. Calculate Vo (t) for Vi(t) = 0.5 sin(2π1000t).

$$32.88\ Hz = 206.6\ rad/s$$

$$\frac{V_o}{V_i} = -\left(\frac{\frac{R_2}{R_2}}{1 + sR_2C}\right) = -\left(\frac{\frac{22k}{1k}}{1 + s(22k)(220nF)}\right) = \frac{-22}{1 + 4.84 \cdot 10^{-3}s}$$

$$H(w) = \frac{-4545.45}{jw + 206.6}\ ;\ w = 2\pi 1000$$

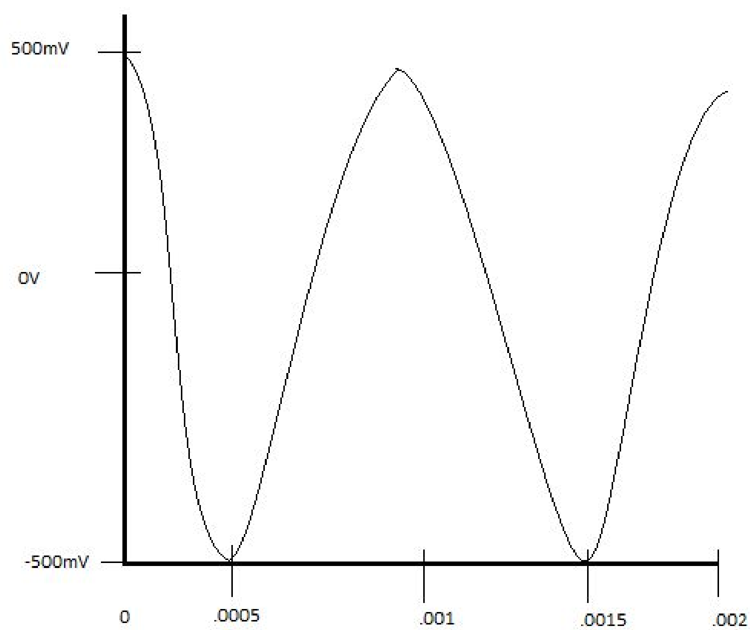
$$\frac{V_o}{V_i} = -0.024 + j0.723 = 0.73 \angle 91.88°\ ,\ V_i = 0.5\sin(2\pi 1000t) = 0.5\angle 0°$$

$$V_o = 0.73 \angle 91.88°\ (0.5\angle 0°) = 0.3615 \angle 91.88°$$

$$V_o(t) = 0.3615\ \sin(2\pi 1000t + 91.88°)\ V$$

5. Sketch the output waveform if the input is a 500mV 1kHz square wave signal.

Tried to make the sketch accurate but it is hard in paint.



Pseudo Differentiator

1. For the first order high-pass filter in Fig. 4, derive the time-domain equation for the output in terms of the input.

$$V_o(t) = \frac{R_2}{R_1 + R_2} V_i(t)$$

$$V_o(t) = V_i(t) \cdot \frac{R_2}{R_1 + R_2} e^{\frac{-t}{\tau}} \; ; As\ t \to \infty \; , \; V_o = 0 \; and \; \tau = \left(R_1 + R_2\right) C$$

$$V_o(t) = V_i(t) \cdot \frac{R_2}{R_1 + R_2} e^{\frac{-t}{\left(R_1 + R_2\right) C}}$$

2. Find R2 to have a high-frequency gain of -22 if R1 = 1kΩ and C = 33nF, and calculate the 3-dB frequency.

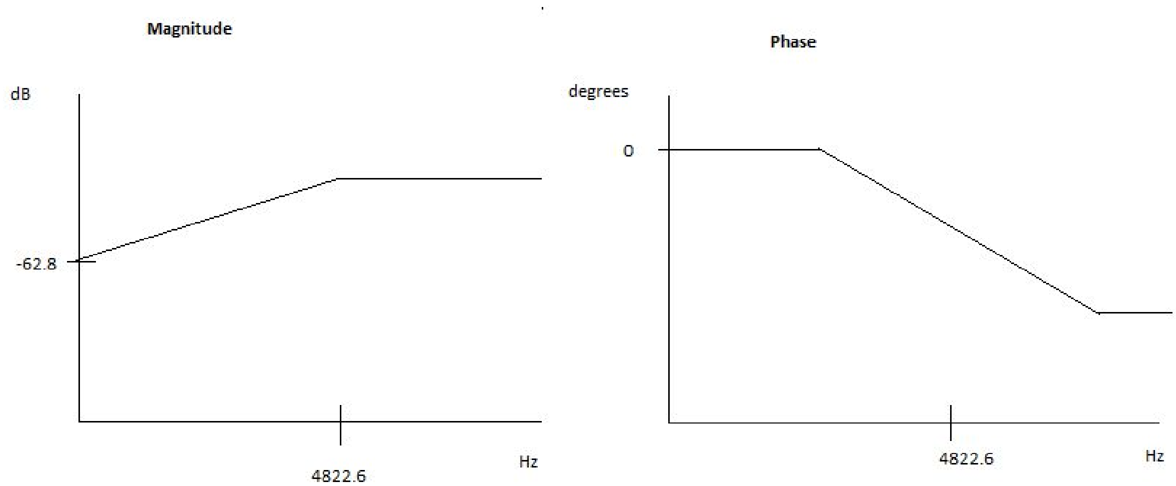
$$High\ f\ requency:$$

$$-22 = -\frac{R_2}{R_1} = -\frac{R_2}{1k} \; ; R_2 = 22k\Omega$$

$$3dB\ f\ requency:$$

$$\frac{1}{R_1 C} = \frac{1}{1k\Omega \cdot 33nF} = 30303\ rad/s = 4822.88\ Hz$$

3. Sketch the magnitude and phase Bode plots for the transfer function Vo /Vi .



4. Calculate Vo (t) for Vi(t) = 0.1 sin(2π1000t).

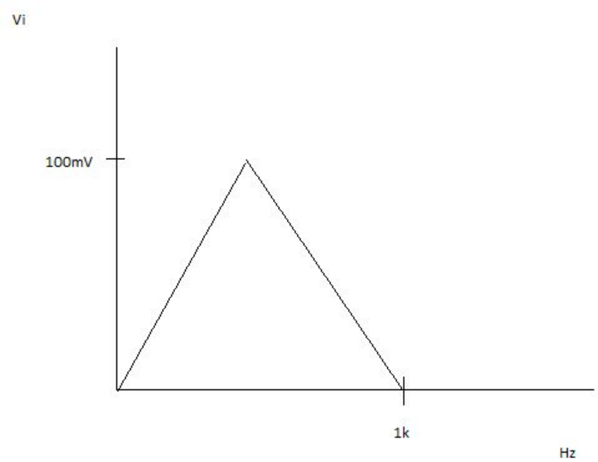
$$\frac{V_o}{V_i} = \frac{-sCR_2}{1+sCR_1} = \frac{7.26\cdot 10^{-4}w}{\sqrt{1+\left(7.59\cdot 10^{-4}w\right)^2}}$$

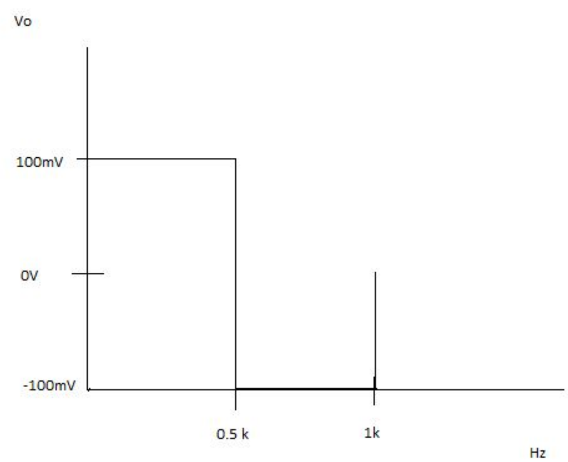
$$|H(jw)| = \frac{7.26\cdot 10^{-4}(2\pi 1000)}{\sqrt{1+\left(7.59\cdot 10^{-4}(2\pi 1000)\right)^2}} = 0.936$$

$$\&\ \angle H(jw) = 90^\circ - \tan^{-1}\left(7.59\cdot 10^{-4}(2\pi 1000)\right) = 11.84^\circ$$

$$V_o(t) = 0.1\angle 0^\circ\ (0.936\angle 11.84^\circ) = 0.0936 \sin(2\pi 1000t + 11.84^\circ)$$

5. Sketch the output waveform if the input is a 100mV 1kHz triangular wave signal.





Finite GBW Limitations

1. For the non-inverting amplifier in Fig. 5, assume R1 = 1kΩ. Find the values of R2 to set the low-frequency gain to 23, 57, and 83.

$$\frac{V_o}{V_i} = \frac{G_o}{1+\frac{s}{w_o}}; \; G_o = 1+\frac{R_2}{R_1}, \; w_o = \frac{w_t}{G_o}$$

$$Gain = 23$$

$$23 = 1+\frac{R_2}{1k} \Rightarrow R_2 = 22k\Omega$$

$$Gain = 57$$

$$57 = 1+\frac{R_2}{1k} \Rightarrow R_2 = 56k\Omega$$

$$Gain = 83$$

$$83 = 1+\frac{R_2}{1k} \Rightarrow R_2 = 82k\Omega$$

2. Find the transfer function Vo /Vi(s) for each gain value.

$$Gain = 23$$

$$\frac{V_o}{V_i} = \frac{23}{1+\frac{s}{\frac{w_t}{23}}} = \frac{w_t}{s+\frac{w_t}{23}}$$

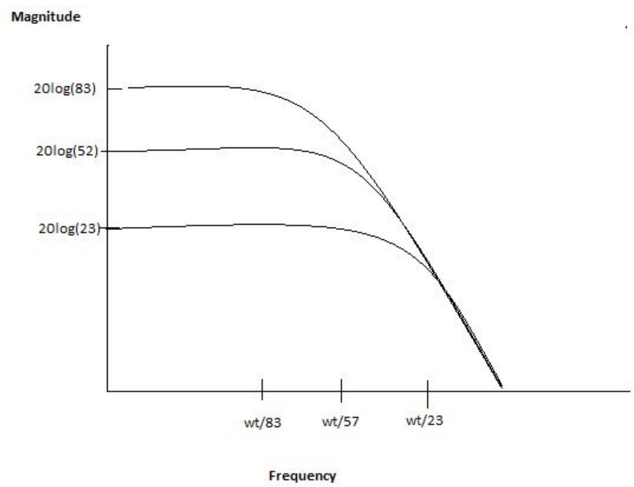
$$Gain = 57$$

$$\frac{V_o}{V_i} = \frac{w_t}{s+\frac{w_t}{57}}$$

$$Gain = 83$$

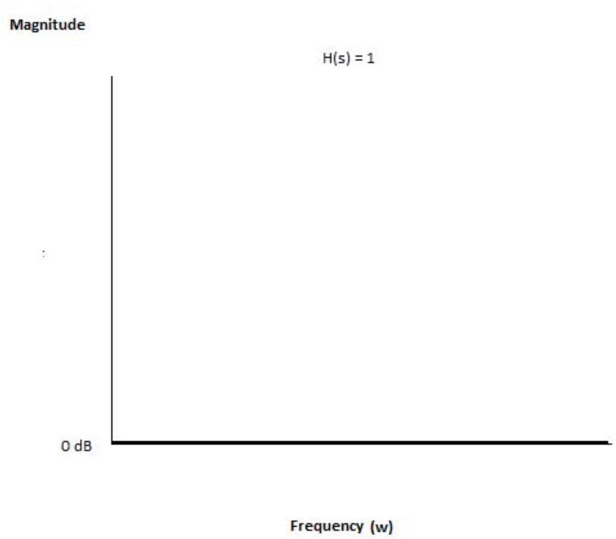
$$\frac{V_o}{V_i} = \frac{w_t}{s+\frac{w_t}{83}}$$

3. Sketch the magnitude Bode plots of the three transfer functions on the same plot.



Slew Rate Limitations

1. For the unity-gain buffer in Fig. 6, find the transfer function Vo /Vi(s), and sketch the magnitude Bode plot



2. If the slew rate of the opamp is 0.5V/μs, find the maximum frequency of the 1V sine wave input signal before the output is distorted

$$slew\ rate\ = 0.5v/\mu s\ = 0.5 \cdot 10^6\ v/s$$

$$v_i\ = 1\ \sin(\ t)$$

$$v_o = v_i = 1\ \sin(\ t)\ \ \&\ v_{o,\ max} = \sqrt{2}$$

$$f_{max} = \frac{0.5 \cdot 10^6}{2\pi \cdot \sqrt{2}} = 56269.8\ Hz$$

3. If the slew rate of the opamp is 0.5V/μs, find the maximum amplitude of the 75kHz sine wave input signal before the output is distorted.

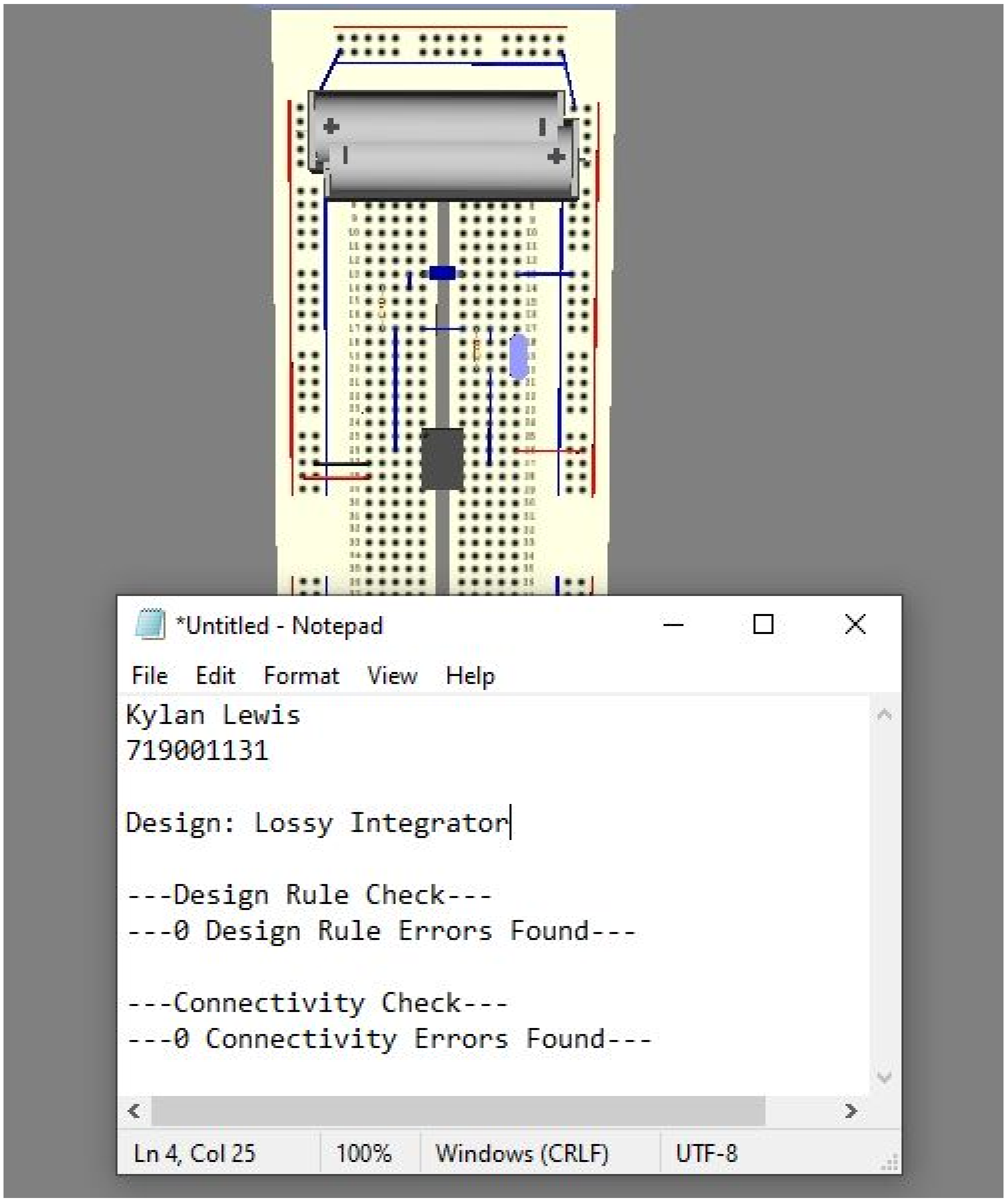
$$slew\ rate\ = 0.5 \cdot 10^6\ v/s$$

$$f_{max} = 75kHz$$

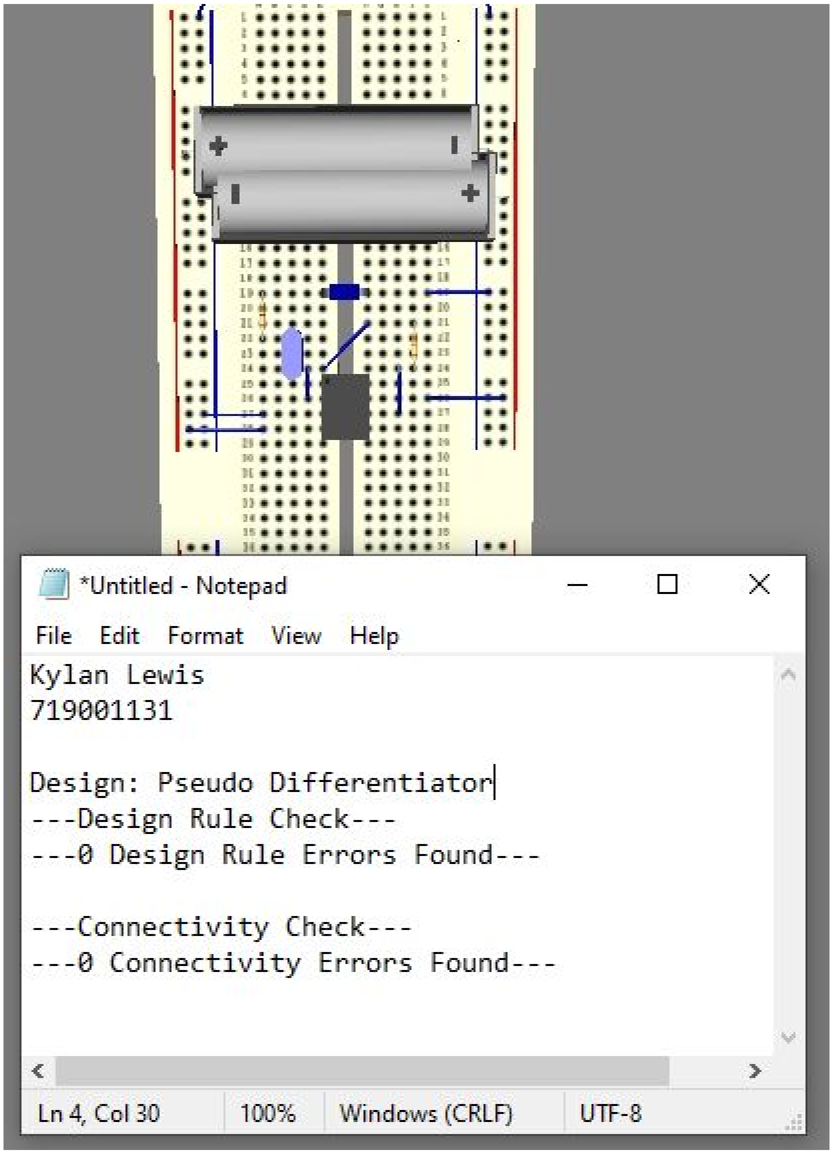
$$v_{o,\ max} = \frac{0.5 \cdot 10^6 v/s}{2\pi \cdot 75k} = 1.06\ v$$

Multisim Breadboard Wiring:

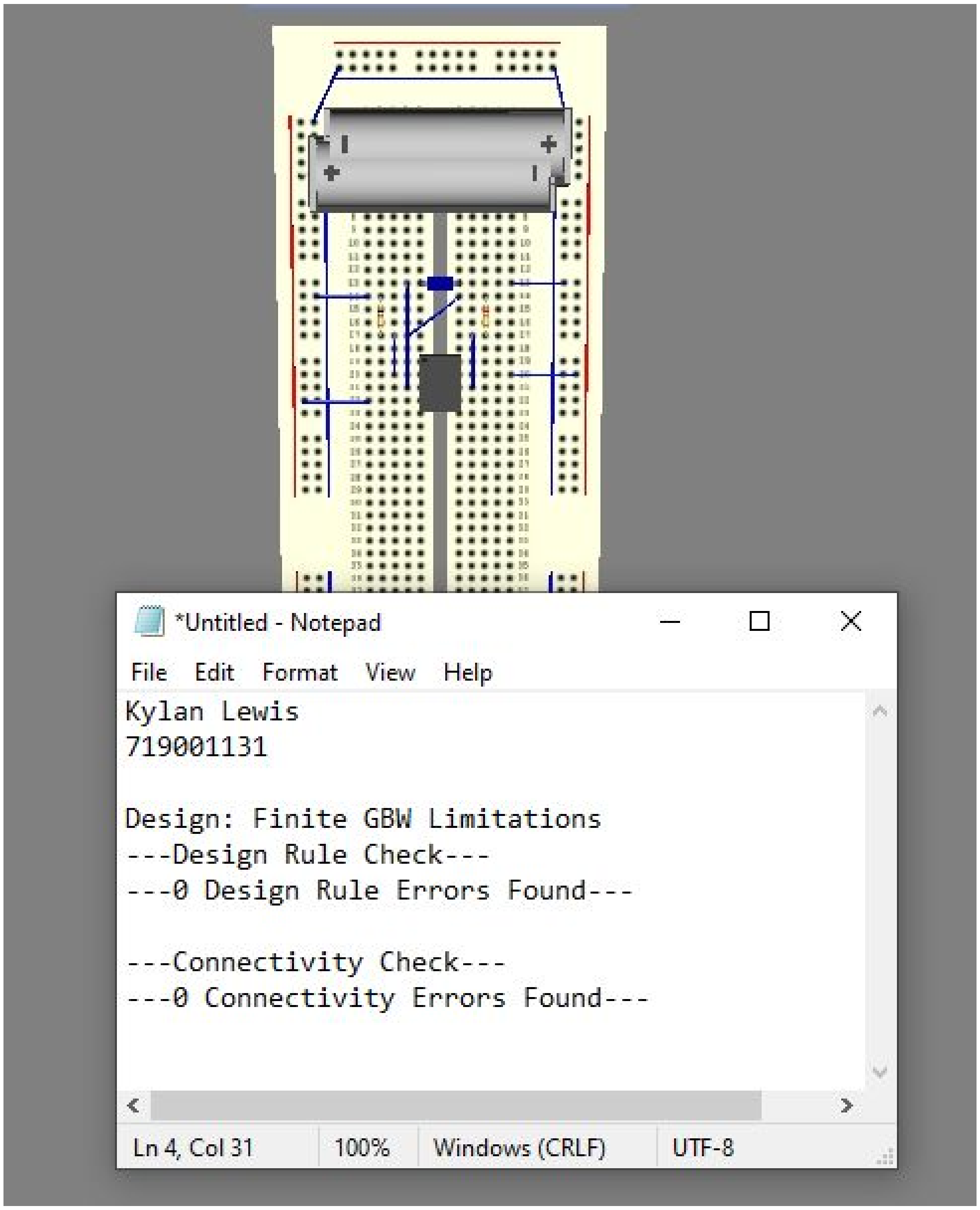
Lossy Integrator:



Pseudo Differentiator:



Finite GBW Limitations:



Slew Rate Limitation: