ELEC 2120-005
Lab 6 – System Linearity TIMS
Sam Servick

INTRODUCTION
The main objective of this lab was to understand system linearity and be able to determine if a system is linear or not. This includes determining if a system is scalable and/or additive.

PART A
Part A focused on determining the linearity of systems. In part A, the voltage-controlled oscillator (VCO) was used which provides a sinusoidal output with frequency dependent on the input voltage.

A.1 Comparator
The VCO sin(t) output was connected to the buffer amplifier input A, as well as to the frequency counter. The buffer amplifier output, k1A was connected to the utilities module COMPARATOR input and to Scope ChA. The CLIPPER output was connected to Scope ChB. The scope settings were adjusted and the VCO frequency was adjusted to 1000 Hz. The gain k1 was adjusted so the input had a 1Vpp. The corresponding output Vpp was then measured. This process was repeated up 10Vpp input in 1V increments. A plot of Output Vpp vs Input Vpp is shown below in Figure 1.

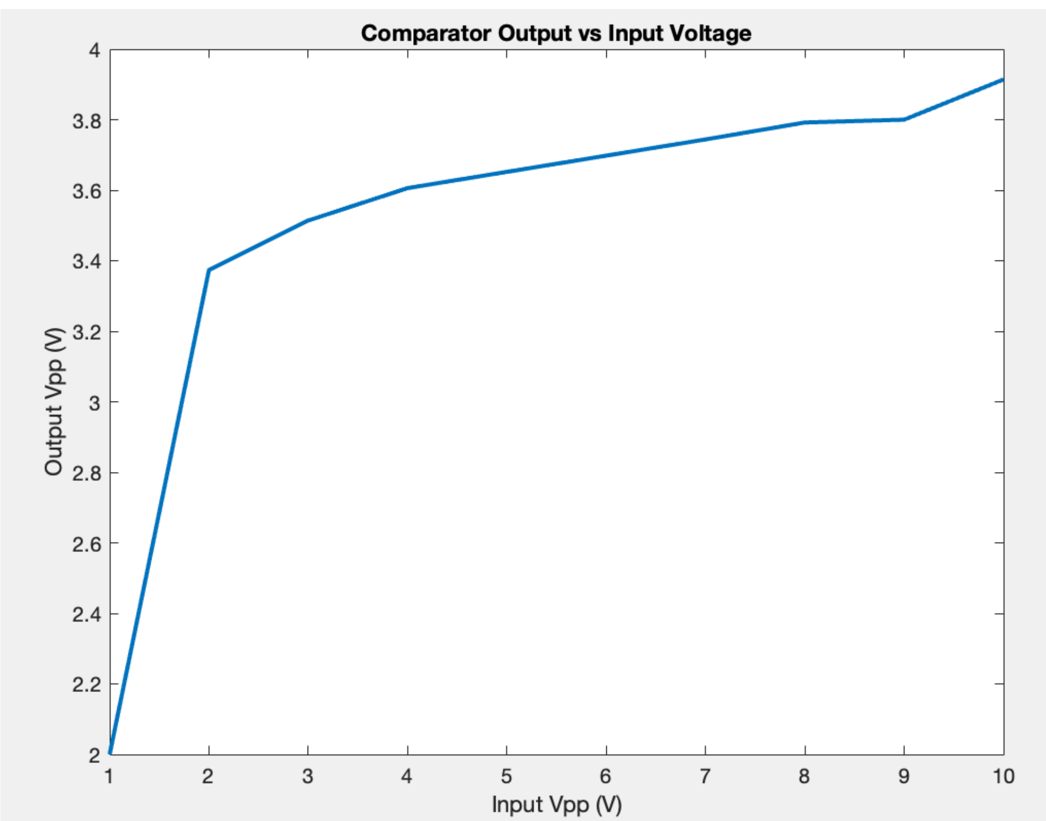

Figure 1. Comparator Output vs Input Voltage

Looking at Figure 1, it is clear the comparator system output is nonlinear because the system cannot be scaled and still produce a linear output. Evident by the plateau seen in the plot.

A.2 Rectifier

Next, the rectifier system was studied. All connections from the previous exercise were left except the buffer amplifier output k1A was connected to the rectifier input along with Scope ChA, and Scope ChB was connected to the rectifier output. The scope settings were set, and the input signal was set to 1000Hz and 1Vpp. The same process of plotting output Vpp vs input Vpp was repeated, and the result is shown below in Figure 2.

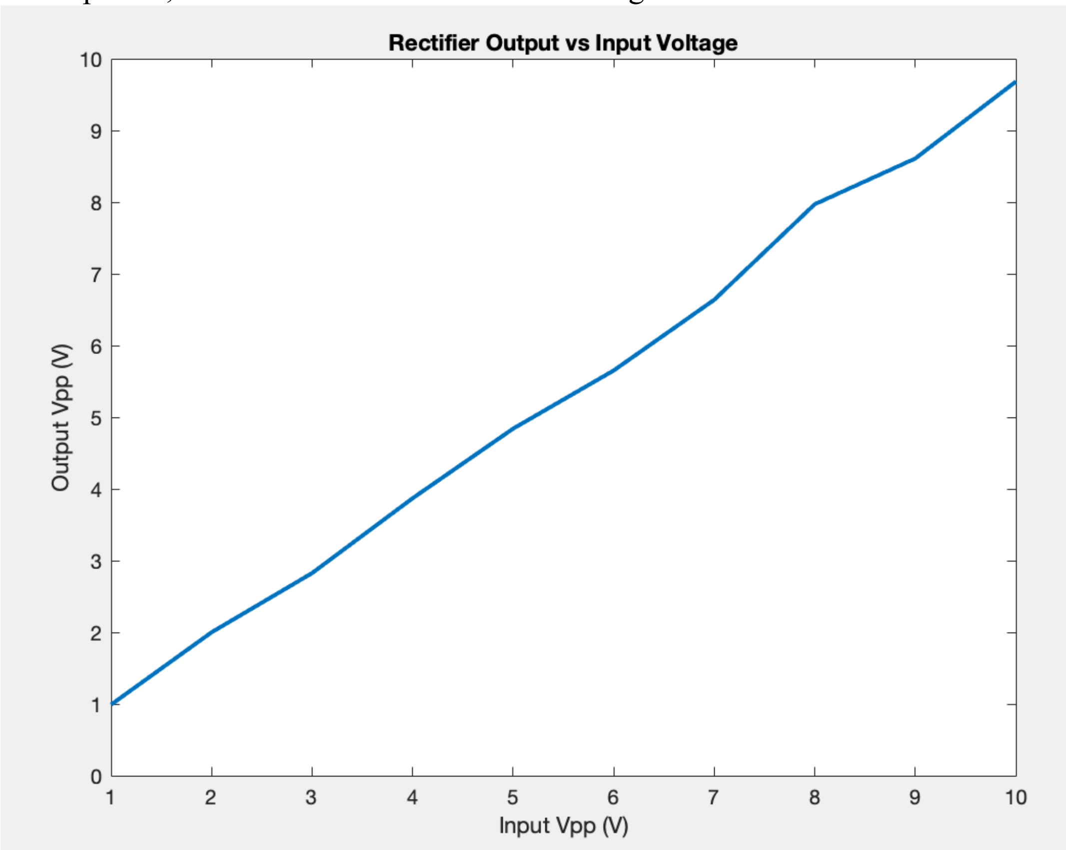

Figure 2. Rectifier Output vs Input Voltage

From Figure 2, the rectifier system appears to be linear because as the input voltage is increased (i.e. the input is scaled) the output voltage increases linearly.

A.3 Multiplier

The last part of Part A focused on the additivity property of linear systems. To start, the MULTIPLIER module was inserted in the TIMS rack. The VCO output was connected to the buffer amplifier input and frequency counter. The VCO signal was adjusted to 1 kHz. The buffer amplifier output was connected to both inputs if the MULTIPLIER and Scope ChA. The MULTIPLIER output was connected to Scope ChB. Scope settings were set, and the input signal was adjusted to 1Vpp (0.5V amplitude). The output amplitude was then measured. This process was repeated up to 4.0V input amplitude. These results are shown below in Table 1 with the plot of Table 1 shown in Figure 3.

Table 1. Input vs Output amplitude for MULTIPLIER system

Input Amplitude (V)	Output Amplitude (V)
0.5	0.1235
1.0	0.5276
1.5	1.17
2.0	2.112
3.0	4.791
4.0	8.333

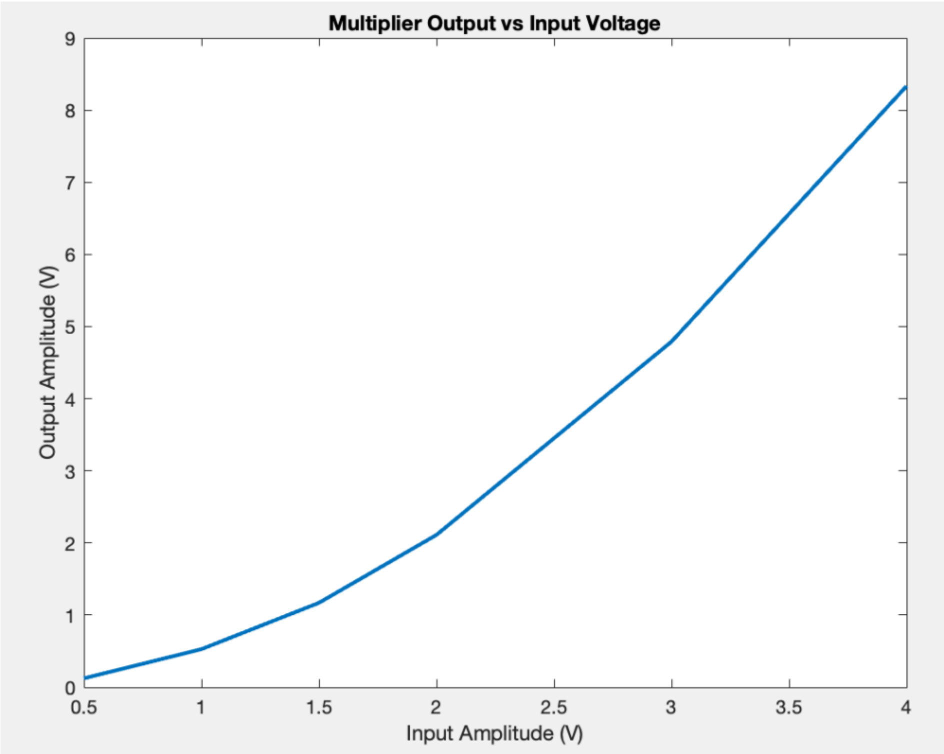

Figure 3. Multiplier Output vs Input Voltage

The system does not exhibit linearity based on Figure 3. The rate at which the output voltage is increasing as the input increases is growing which does represent a linear system which would have a constant rate of change (or appear as a line). In fact, the curve looks quadratic. This corresponds with the expected result due to the half angle formula, A^2sin^2(t) = ½ A^2(1-cos(2t)). When looking at this equation at a consistent point in time (i.e. time where signal is peaked) the 1-cos(2t) term is a constant and the graph of the output amplitude as a function of the input amplitude looks like a quadratic equation of the form y = 1/2x^2 which is very similar to the observed curve in Figure 3.

PART B

B.1 DC Control

Part B examined the VCO as a system. The first part looked at its DC control characteristics. The VARIABLE DC output was connected to the VCO input and Scope ChB. The VARIABLE DC output can deliver a steady DC voltage ranging from -2 to 2V. The VCO output was connected to the frequency counter and Scope ChA. The signal frequency of the output was then measured as the input voltage was varied from -2 to 2V. These results are shown below in Table 2. Figure 4 shows the plot of the data in Table 2.

Table 2. VCO Output Frequency as DC input varied

DC value (V)	Signal frequency (Hz)
-2	17,680
-1	14,070
0	10,210
1	6,210
2	2,640

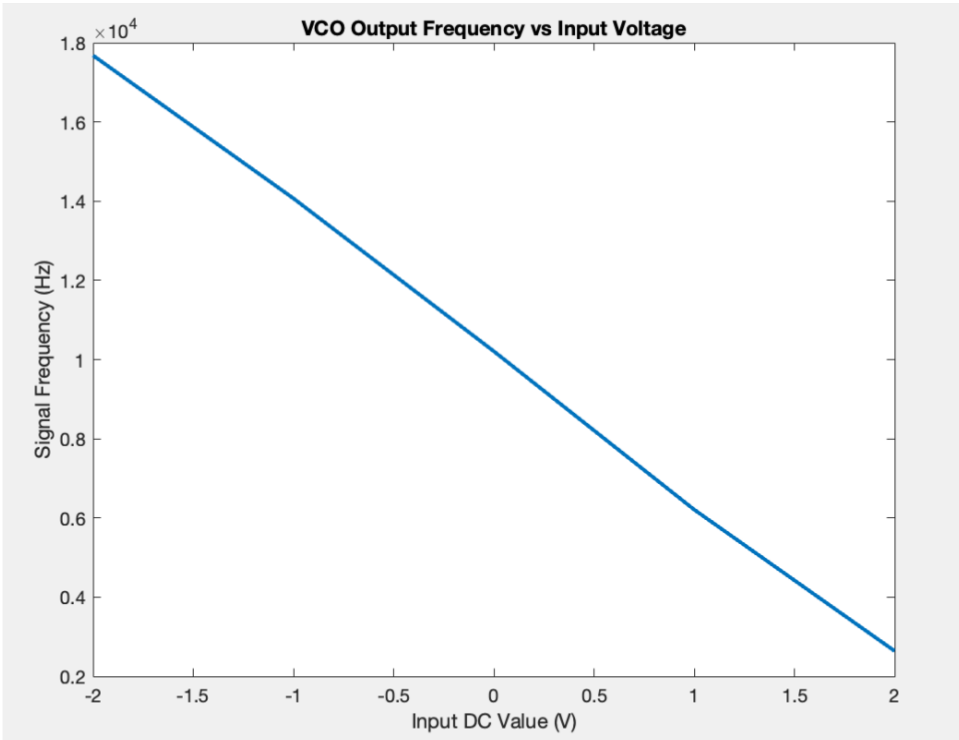

Figure 4. VCO Output Frequency vs Input Voltage

From Figure 4, the VCO system appears to be linear as a change in the input results in a linear change in the output.

B.2 Frequency Control

The next part of Part B examined the frequency control of the VCO system. The audio oscillator's sin(t) output to Input A of the buffer amplifier and to the frequency counter's analog input. The audio oscillator's sin(t) output was set to 300 Hz. Buffer amplifier k1A output to VCO Vin input and Scope ChB. The VCO sin(t) output to Scope ChA. The scope settings were adjusted. The scope output showed a signal whose frequency was dependent on the phase of the input sinusoid. When sinusoid is negative, frequency increases, when sinusoid is positive, frequency decreases. One obvious application of a signal of this type is FM radio transmission.

PART C

Part C looked at the Laplace V2 module and its integration capabilities.

C.1 The Integrator

The audio oscillator sin(t) output was connected to the COMPARATOR input, and to the frequency counter's analog input. The audio oscillator frequency was set to 1 kHz. The UTILITIES output was connected to the LAPLACE V2's S1in and Scope ChB. Laplace V2's S1out was connected to Scope ChA. The scope output demonstrates the integrator because the input, which looks like a series of unit step functions, is integrated to a series of ramp functions which is what would be expected.

C.2 Feedback System

For the final part of Part C, the ARB2 signal is used as the system input. The signal from Lab 3 was chosen. The signal appears as a series of unit step functions. The triple adder on the SFP window was set such that gain b1 = 1 and gain b2 = -1. Next, ARB2 output was connected to Scope ChA and to the b1 input of the TRIPLE ADDER. Output B of the TRIPLE ADDER V2 module was connected to S1in of LAPLACE V2 module. S1out of the Laplace V2 module was connected to the b2 input of the TRIPLE ADDER V2 module. The TRIPLE ADDER output B was connected to Scope ChB. The scope output is shown below in Figure 5.

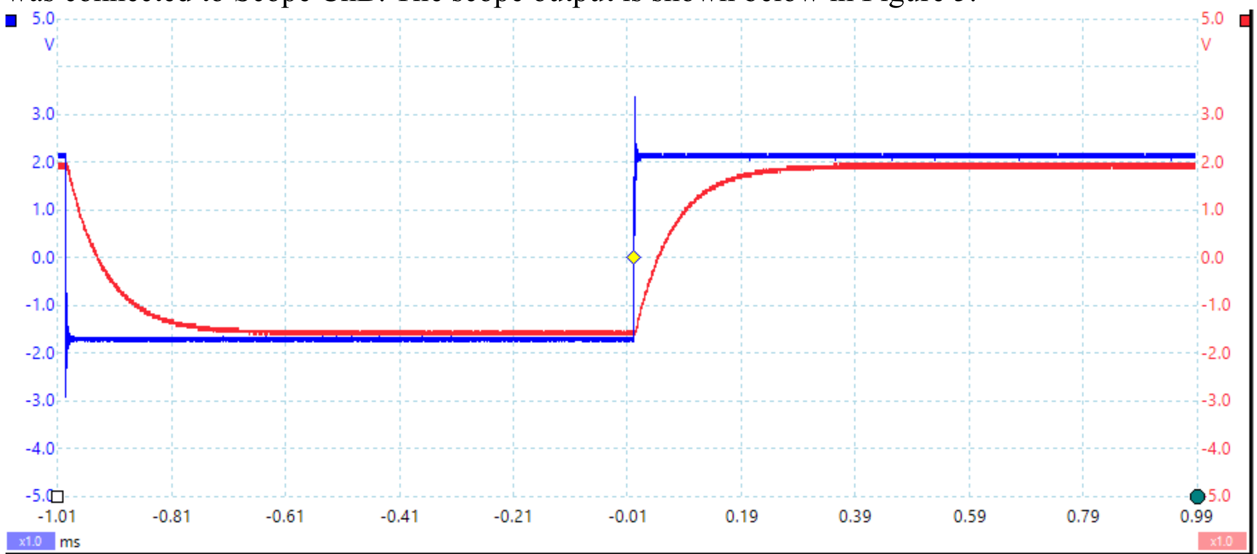

Figure 5. Scope Output for Triple Adder and Laplace system

The time for the exponential curve to decrease to e^-1 of its top value (time constant) was 65.493µs.

CONCLUSION

I enjoyed testing the linearity of various systems in the lab. Using MATLAB to plot the results was also enjoyable since I was able to use the skills I built from the previous lab. There were no major issues for the lab and no major improvements to be made.