ECE 220-203

Lab 1

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ECE 220-203

Objective

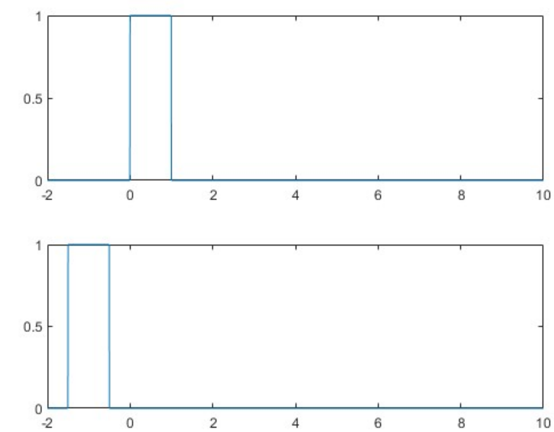
The purpose of this lab is to better understand the linear and time-invariant system properties. We will use MATLAB to better visualize them.

MATLAB Code

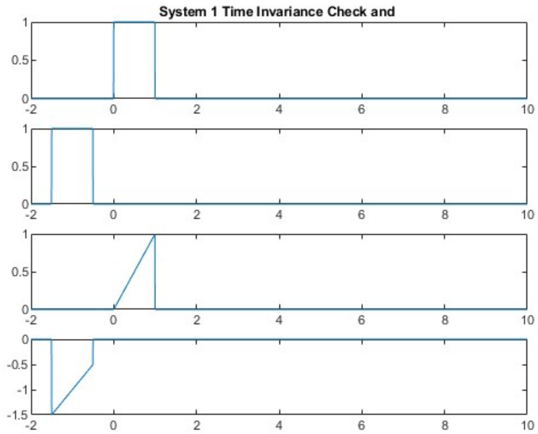
See Appendix A.

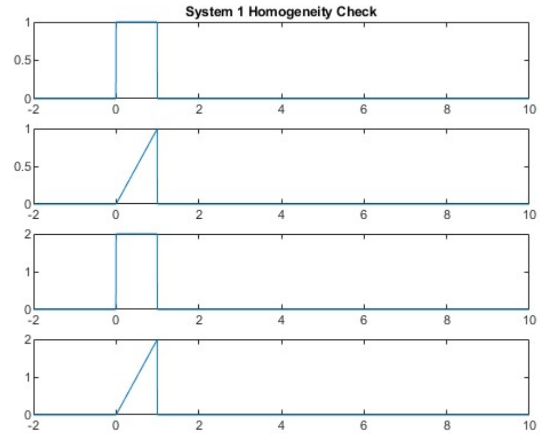
Results

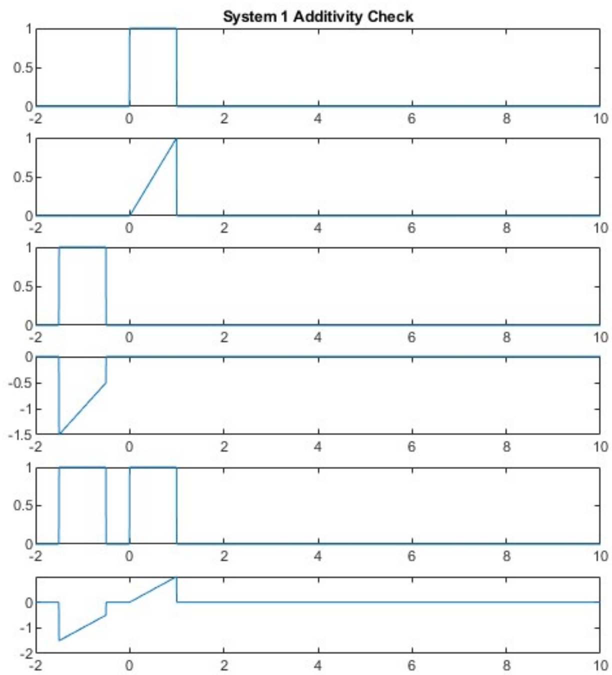
Original Test Signals



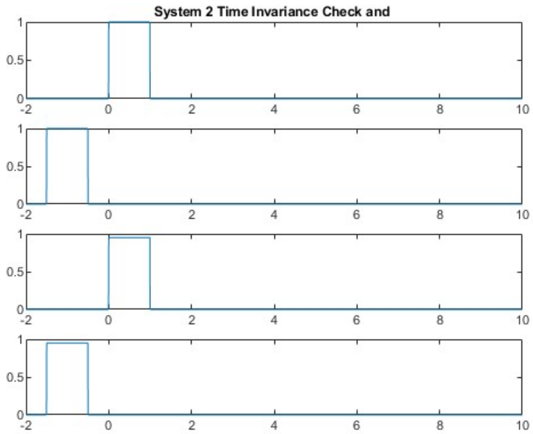
System 1

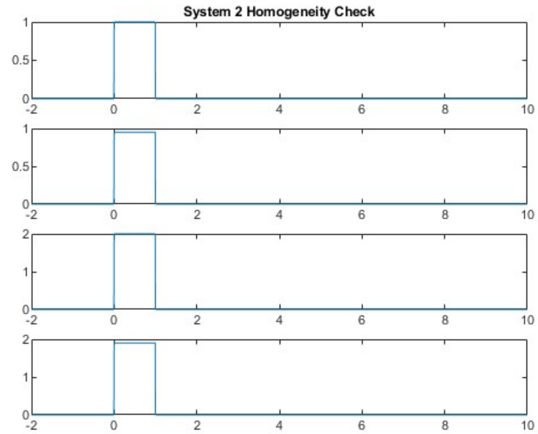

System 1 Time Invariance Check and

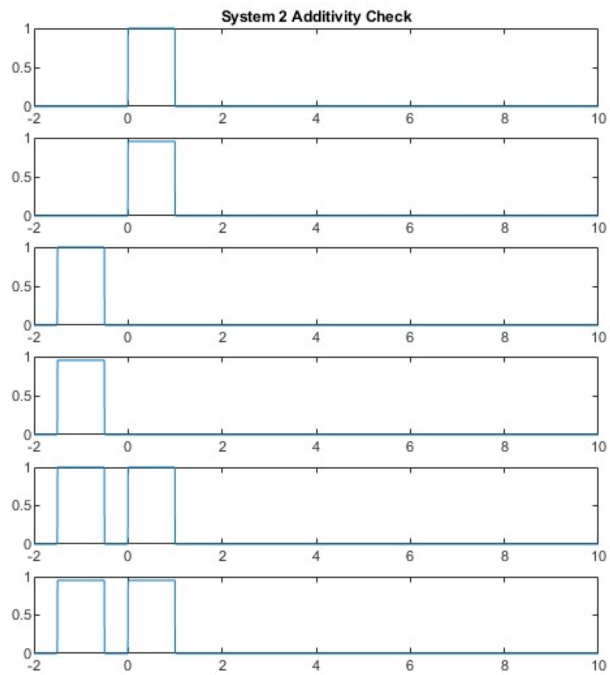

System 1 Homogeneity Check


System 1 Additivity Check

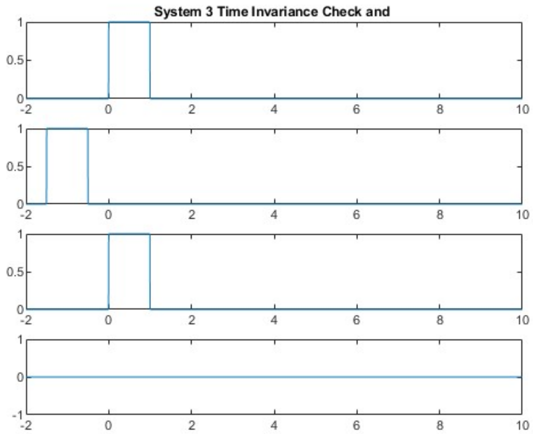
System 2

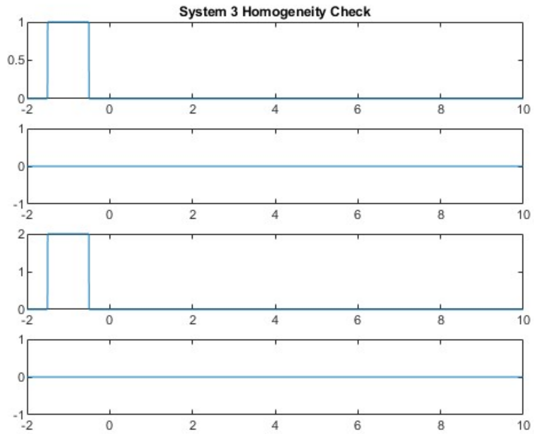

System 2 Time Invariance Check and
1
0.5
0
-2
0
2
4
6
8
10

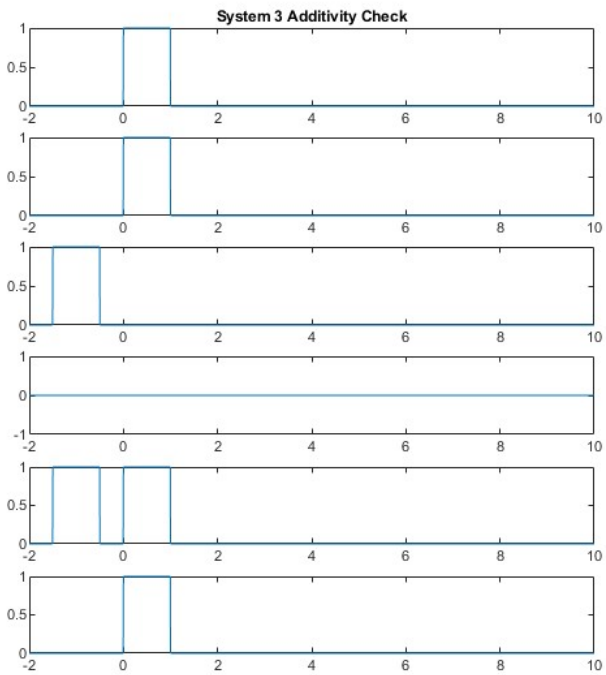

System 2 Homogeneity Check
1
0.5
0
2
1
-2
0
2
4
6
8
10


System 2 Additivity Check
1
0.5
0
-2
0
2
4
6
8
10

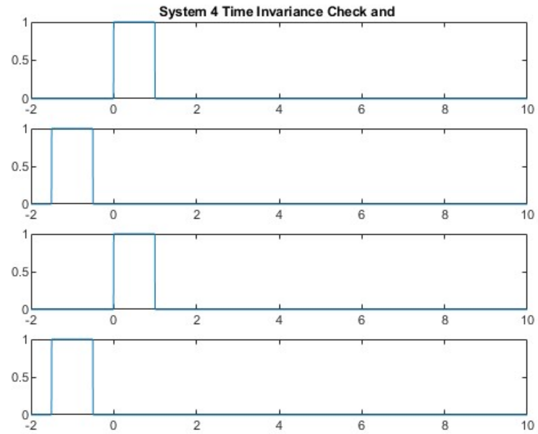
System 3

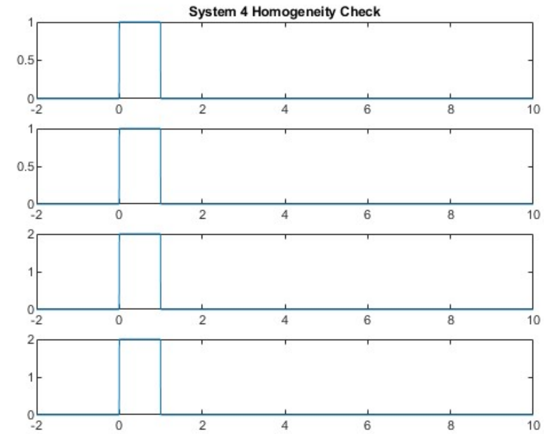

System 3 Time Invariance Check and

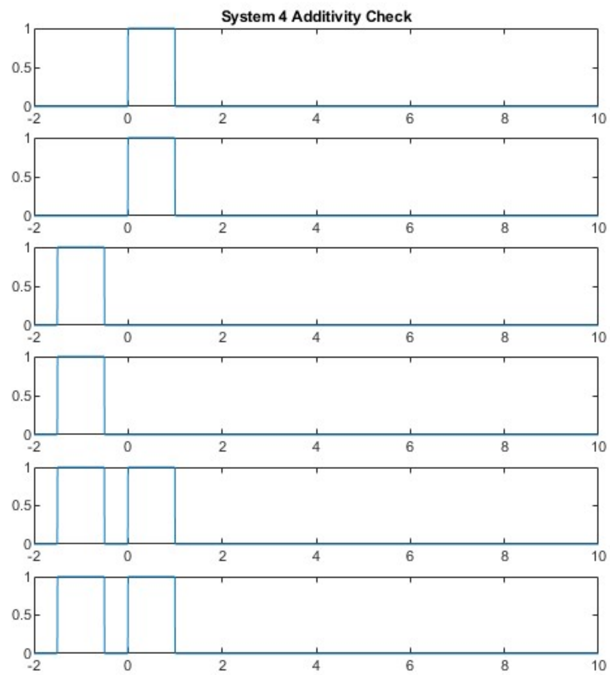

System 3 Homogeneity Check


System 3 Additivity Check

System 4


System 4 Time Invariance Check and


System 4 Homogeneity Check


System 4 Additivity Check

Questions

1)

a) System 1: $y(t) = t \,.\!*\, x(t)$
System 2: $y(t) = \sin\left(\frac{3\pi}{5}\right) * x(t)$
System 3: $y(t) = x(t) \,.\!*\, t\,; t \geq 0$
System 4: $y(t) = x(t)\,.\,\hat{}\;2$

d) **System 1: Non-Linear and Non-Time-Invariant**
Proof: System $= t \,.\!*\, x(t)$
The linearity check tests homogeneity and additivity and the plots show the system has homogeneity $\left(kx(t) \rightarrow ky(t)\right)$, but not additivity $\left(x_1(t) + x_2(t) \rightarrow y_1(t) + y_2(t)\right)$; therefore, this system is non-linear.
The time-invariance check tests if the output remains the same, but with a delay of -1.5. The plot shows y2, whose input is $x(t) < 0$, is not the same as the original $x(t)$. Also, the system relies on t directly for its output, so inversing the polarity of t would affect the output. Therefore, this system is non-time-invariant.
System 2: Linear and Time-Invariant
Proof: System $= \sin\left(\frac{3\pi}{5}\right) * x(t)$
The linearity check tests for homogeneity and additivity and the plots show the system has homogeneity $\left(kx(t) \rightarrow ky(t)\right)$ and additivity $\left(x_1(t) + x_2(t) \rightarrow y_1(t) + y_2(t)\right)$; therefore, this system is linear.
The time-invariance check tests if the output remains the same, but with a delay of -1.5. The plot shows y2, whose input is $x(t) < 0$, is the same as the original $x(t)$. Also, this system does not rely on t directly for its output. Therefore, this system is time-invariant.
System 3: Non-Linear and Non-Time-Invariant
Proof: System $= x(t) \,.\!*\, t\,; t \geq 0$
The linearity check tests for homogeneity and additivity and the plots show the system does not have homogeneity $\left(kx(t) \rightarrow ky(t)\right)$, but has additivity $\left(x_1(t) + x_2(t) \rightarrow y_1(t) + y_2(t)\right)$; therefore, this system is non-linear.
The time-invariance check tests if the output remains the same, but with a delay of -1.5. The plot shows y2, whose input is $x(t) < 0$, is not the same as the original $x(t)$. Also, the system relies on t directly for its output, so inversing the polarity of t would affect the output. Therefore, this system is non-time-invariant.
System 4: Linear and Time-Invariant
Proof: System $= x(t)\,.\,\hat{}\;2$
The linearity check tests for homogeneity and additivity and the plots show the system has homogeneity $\left(kx(t) \rightarrow ky(t)\right)$ and additivity $\left(x_1(t) + x_2(t) \rightarrow y_1(t) + y_2(t)\right)$; therefore, this system is linear.
The time-invariance check tests if the output remains the same, but with a delay of -1.5. The plot shows y2, whose input is $x(t) < 0$, is the same as the original $x(t)$.

Also, this system does not rely on t directly for its output. Therefore, this system is time-invariant.

Discussions/Conclusion

This lab went smoothly and was completed without issue. The most challenging part of this lab was proving if a system was linear and time-invariant for all inputs. I had to re-familiarize myself with the exact relationships used to prove system properties because a "gut feeling" did not cut it for mathematical proof. The relationships $kx(t) \rightarrow ky(t)$ and $x_1(t) + x_2(t) \rightarrow y_1(t) + y_2(t)$ were used in every linearity check to see if the systems had both homogeneity and additivity, the two requirements for linearity. It was difficult to see in some systems because they might have had homogeneity, but not additivity and vice-versa. However, you need both properties to claim linearity. Time-invariance was less involved and was just a check to see if delays in the signal, positive or negative, would change the output. This came down to mostly if t was directly affecting the output (i.e. $y(t) = t * x(t)$). I believe my results to be accurate and I found no errors when writing my MATLAB script.

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Appendix A

```
%Define test signals
t = -2:.005:10;
x1 = (t>=0 & t<1);
x2 = (t>=-1.5 & t<-0.5);

%subplot(211), plot(t, x1);
%subplot(212), plot(t, x2);

x = 1;

%Time Invariance Check
figure(1)
y1=lab2systems(t, x1, x);
y2=lab2systems(t, x2, x);

subplot(411), plot(t, x1), title(['System ',num2str(x) ,' Time Invariance
Check and ']);
subplot(412), plot(t, x2);
subplot(413), plot(t, y1);
subplot(414), plot(t, y2);


%Linearity Check
figure(2)
y1=lab2systems(t, x1, x);
y2=lab2systems(t, x2, x);

subplot(411), plot(t, x1), title(['System ',num2str(x) ,' Homogeneity
Check']);
subplot(412), plot(t, y1)
subplot(413), plot(t, (2*x1));
subplot(414), plot(t, (2*y1));

figure(3)
subplot(611), plot(t, x1), title(['System ',num2str(x) ,' Additivity
Check']);
subplot(612), plot(t, y1)
subplot(613), plot(t, x2)
subplot(614), plot(t, y2)
subplot(615), plot(t, (x1 + x2));
subplot(616), plot(t, (y1 + y2));
```