Lab 5

ECE 380 W21

Group 8

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Declaration of Authorship

We acknowledge and promise that:

a) We are the sole authors of this lab report and associated simulation files/code.
b) This work represents our original work.
c) We have not shared detailed analysis or detailed design results, computer code, or Simulink diagrams with any other student.
d) We have not obtained or looked at lab reports from any other current or former student of ECE/SE 380, and we have not let any other student access any part of our lab work.
e) We have completely and unambiguously acknowledged and referenced all persons and aids used to help us with our work.

Student1 Name and Signature:

Arjun Bawa

Student2 Name and Signature:

Andrew Tran

5.1

```
1/(1+K) <= 0.02 ==> 1/0.02 - 1 <= K ==> K = 49
```

5.2

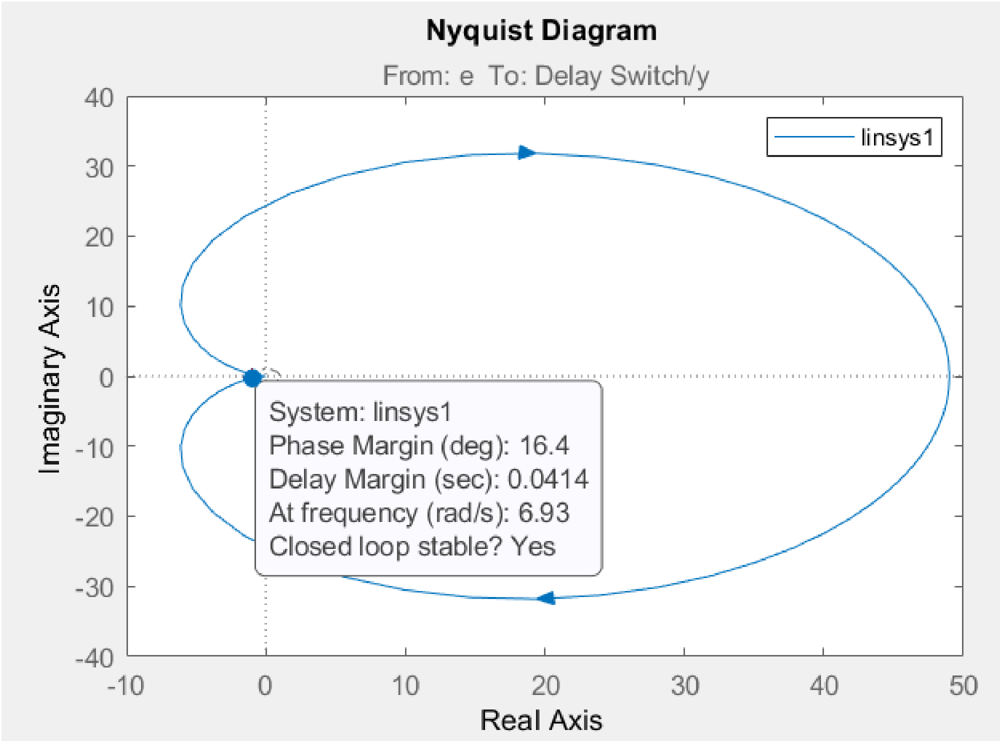


Figure 1 No delay

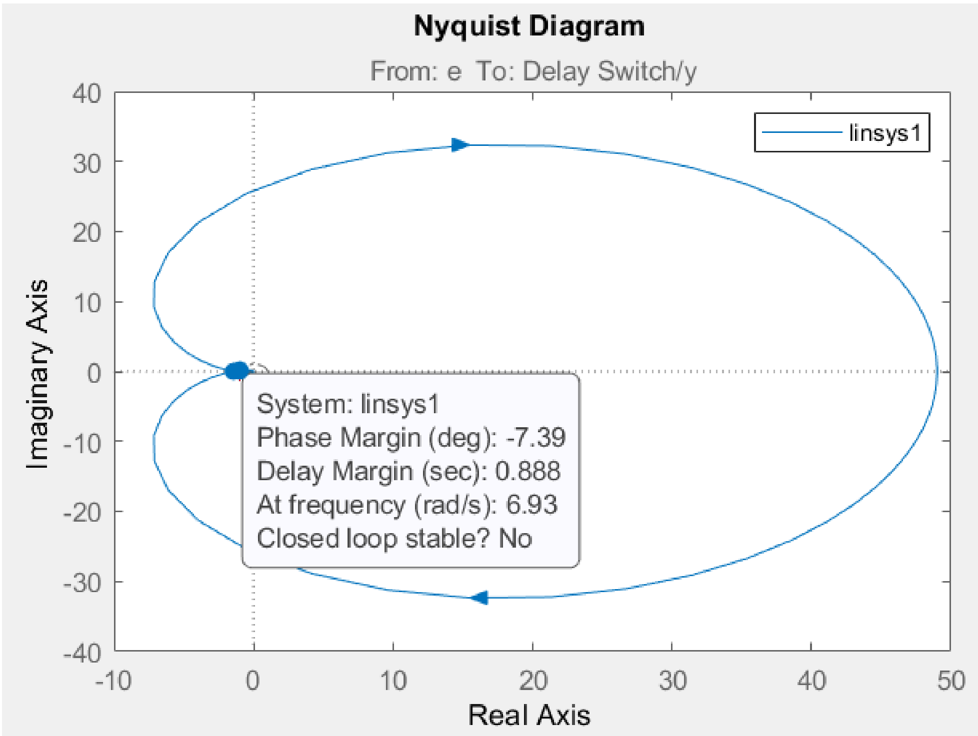
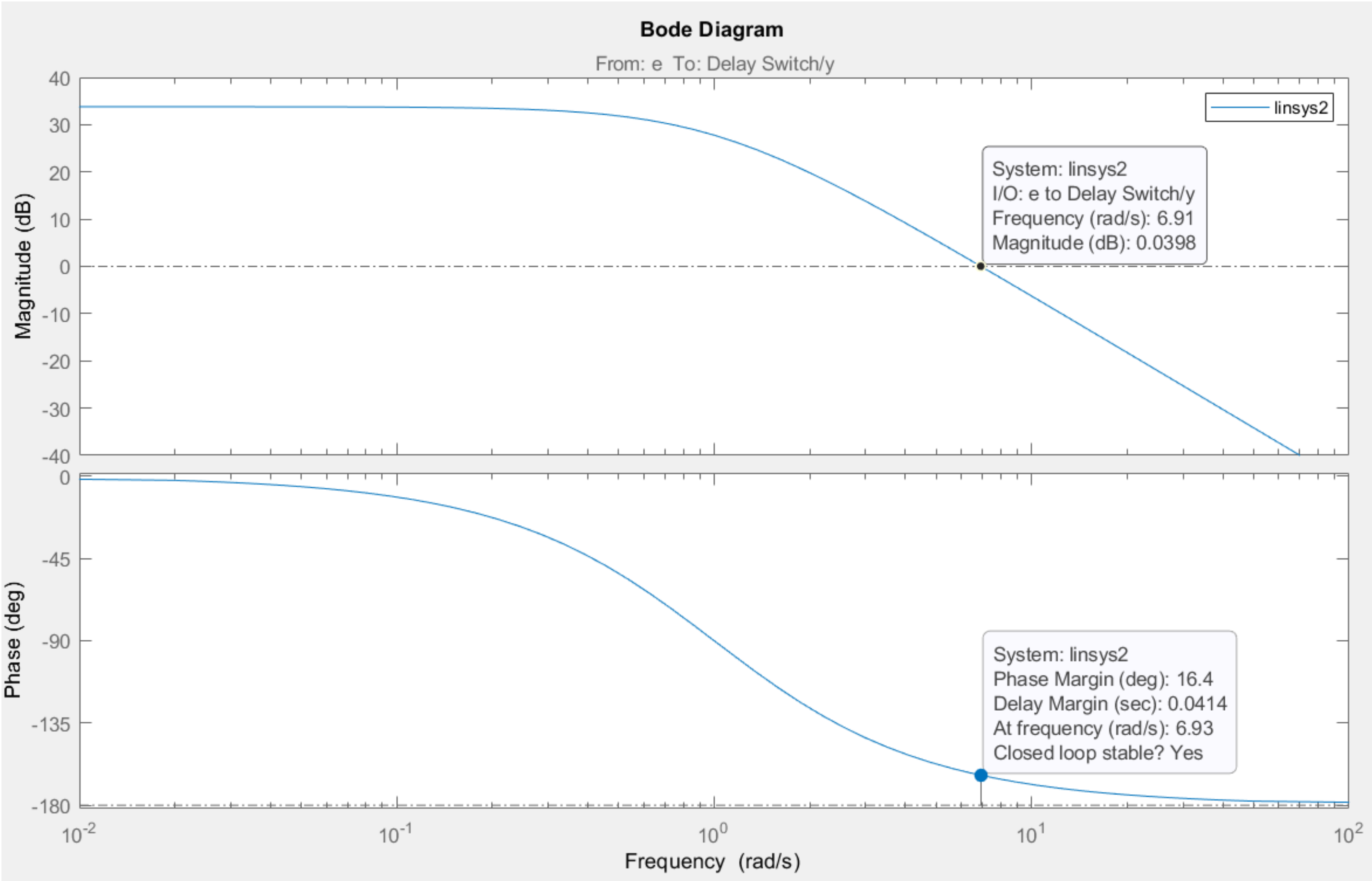


Figure 2 With delay

5.3



Bode Diagram
From: e To: Delay Switch/y
Magnitude (dB)
Phase (deg)
Frequency (rad/s)
linsys2
System: linsys2
I/O: e to Delay Switch/y
Frequency (rad/s): 6.91
Magnitude (dB): 0.0398
System: linsys2
Phase Margin (deg): 16.4
Delay Margin (sec): 0.0414
At frequency (rad/s): 6.93
Closed loop stable? Yes

Figure 3

$\boxed{5.4}$ Lag

$K = 49$

PM (from deliverable 5.3, Bode Plot)

$= 16.4^\circ$

spec: $PM_{desired} > \frac{12\,\omega_{gc}}{100} \Rightarrow \frac{12(6.91)}{100}$

$+10^\circ$ buffer $\Rightarrow PM_{desired} > \frac{12(6.91)(180)}{100\pi} + 10$

This $PM_{desired}$ occurs when

$\angle P(j\omega) = PM_{desired} - 180^\circ = -169.74^\circ$

$\Rightarrow \omega = 10.6\ \frac{rad}{s}$ (see Bode Plot below),

$|P(j\omega)| \doteq 7.23\text{ dB}$ @ $\omega = 10.6\ \frac{rad}{s}$

$\Rightarrow k_c \doteq 10^{-\frac{7.23}{20}} = 0.435$ $\left(C_{lag}(s) = K_c\beta\frac{(\beta p)^{-1}s+1}{p^{-1}s+1}\right)$

$K = k_c\beta \Rightarrow \beta = \frac{K}{K_c} \doteq 112.64$

$\Rightarrow \boxed{\alpha \doteq 8.8778 \times 10^{-3}}$

$z = \beta p = \frac{10.6}{10} = 1.06 \Rightarrow p = \frac{1.06}{\beta} \doteq 9.41 \times 10^{-3}$

$\boxed{T = p^{-1} \doteq 106.265}$

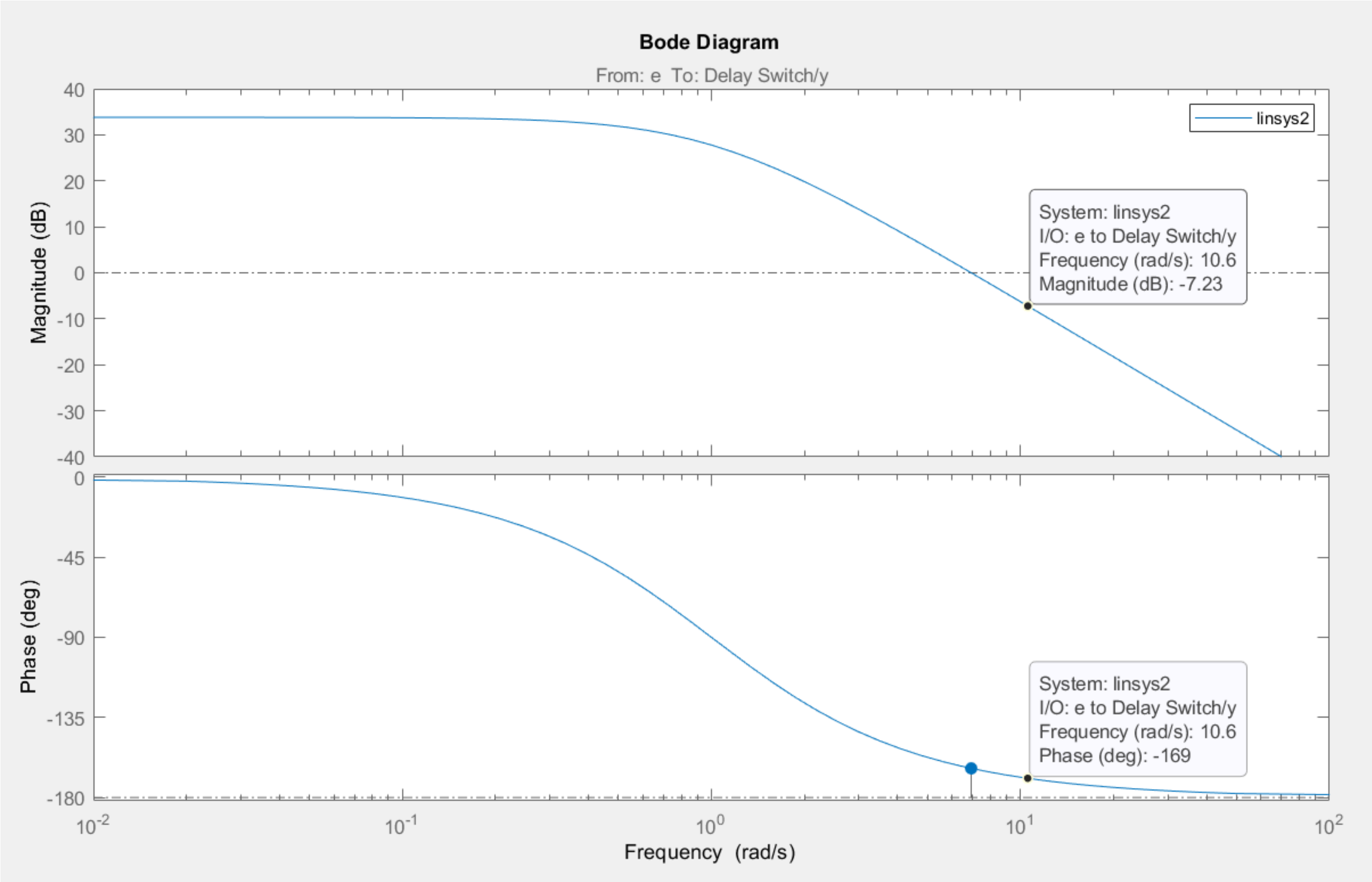

Bode Diagram
From: e To: Delay Switch/y
linsys2
System: linsys2
I/O: e to Delay Switch/y
Frequency (rad/s): 10.6
Magnitude (dB): -7.23
System: linsys2
I/O: e to Delay Switch/y
Frequency (rad/s): 10.6
Phase (deg): -169
Magnitude (dB)
Phase (deg)
Frequency (rad/s)

Figure 4

5.5

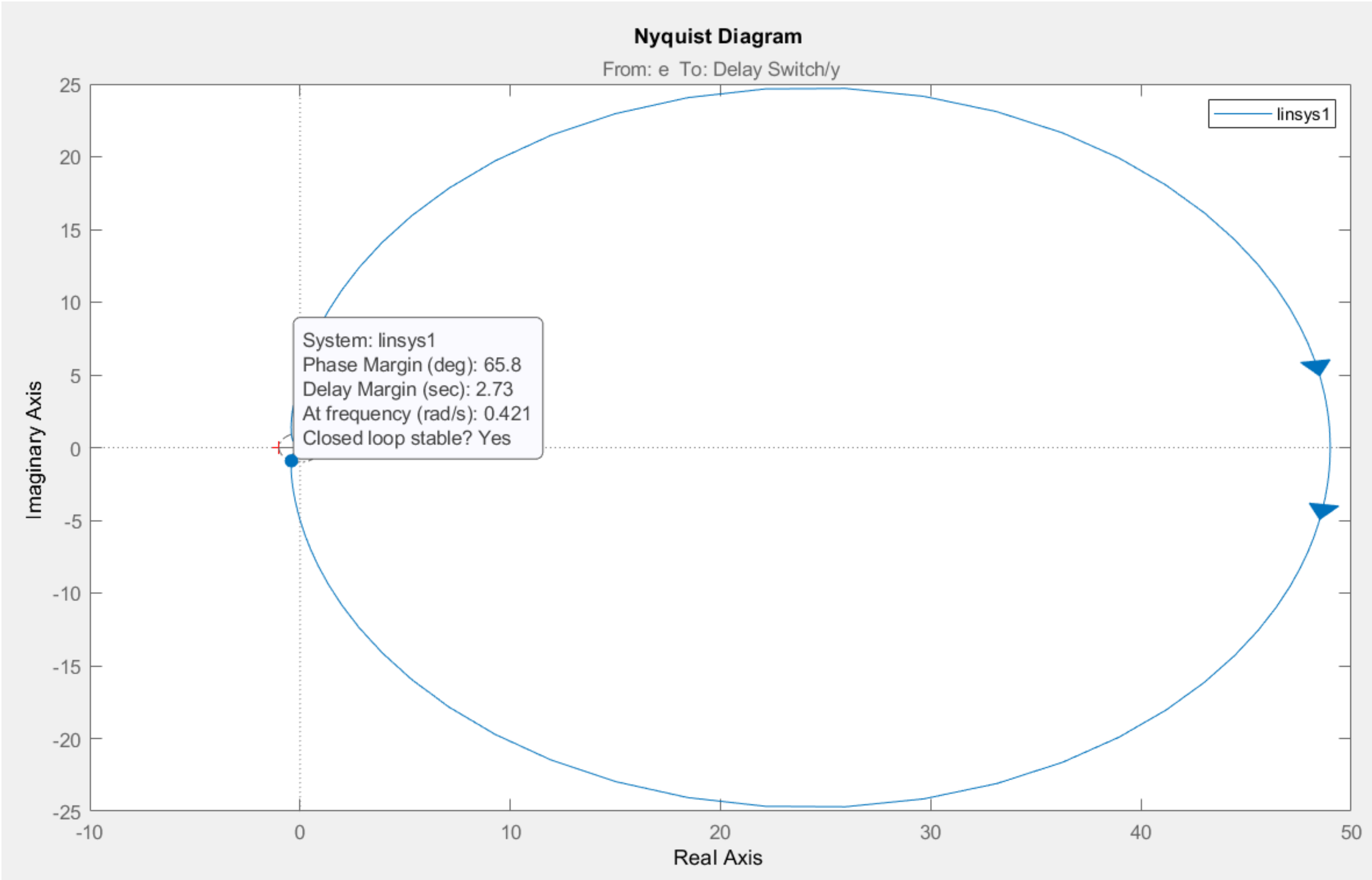


Figure 5 Lag compensated with delay

$\boxed{5.6}$ Lead

$K = 49$

PM (from deliverable 5.3, Bode Plot)

$= 16.4°$

spec: $PM > \frac{12\,\omega_{gc}}{100} \Rightarrow \frac{12\,(6.91)}{100}$

$\Rightarrow \phi_{max} = \frac{12\,(6.91)}{100} \times \frac{180}{\pi} - 16.4 + 10$

$\Rightarrow \tilde{\alpha} = \frac{1 - \sin\phi_{max}}{1 + \sin\phi_{max}}$ $\left(C_{lead}(s) = K \frac{(\tilde{\alpha} p)^{-1} s + 1}{p^{-1} s + 1} \right)$

$\Rightarrow \alpha = \frac{1}{\tilde{\alpha}}$

$W_{gc} \doteq 6.91 \; \frac{rad}{s}$

$\Rightarrow \omega_{max} = 6.91 \; \frac{rad}{s}$

$\Rightarrow p = \frac{\omega_{max}}{\sqrt{\tilde{\alpha}}}$ $\Rightarrow T = \frac{1}{p}$

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spec: $PM > 0.8292 \rightarrow \phi_{max} \doteq 41.11°$

$\Rightarrow \tilde{\alpha} \doteq 0.207 \Rightarrow \alpha = \tilde{\alpha}^{-1} = 4.84$

$\Rightarrow p = \frac{\omega_{max}}{\sqrt{\tilde{\alpha}}} \doteq 15.202 \rightarrow T = p^{-1} \doteq 0.0658$

5.7

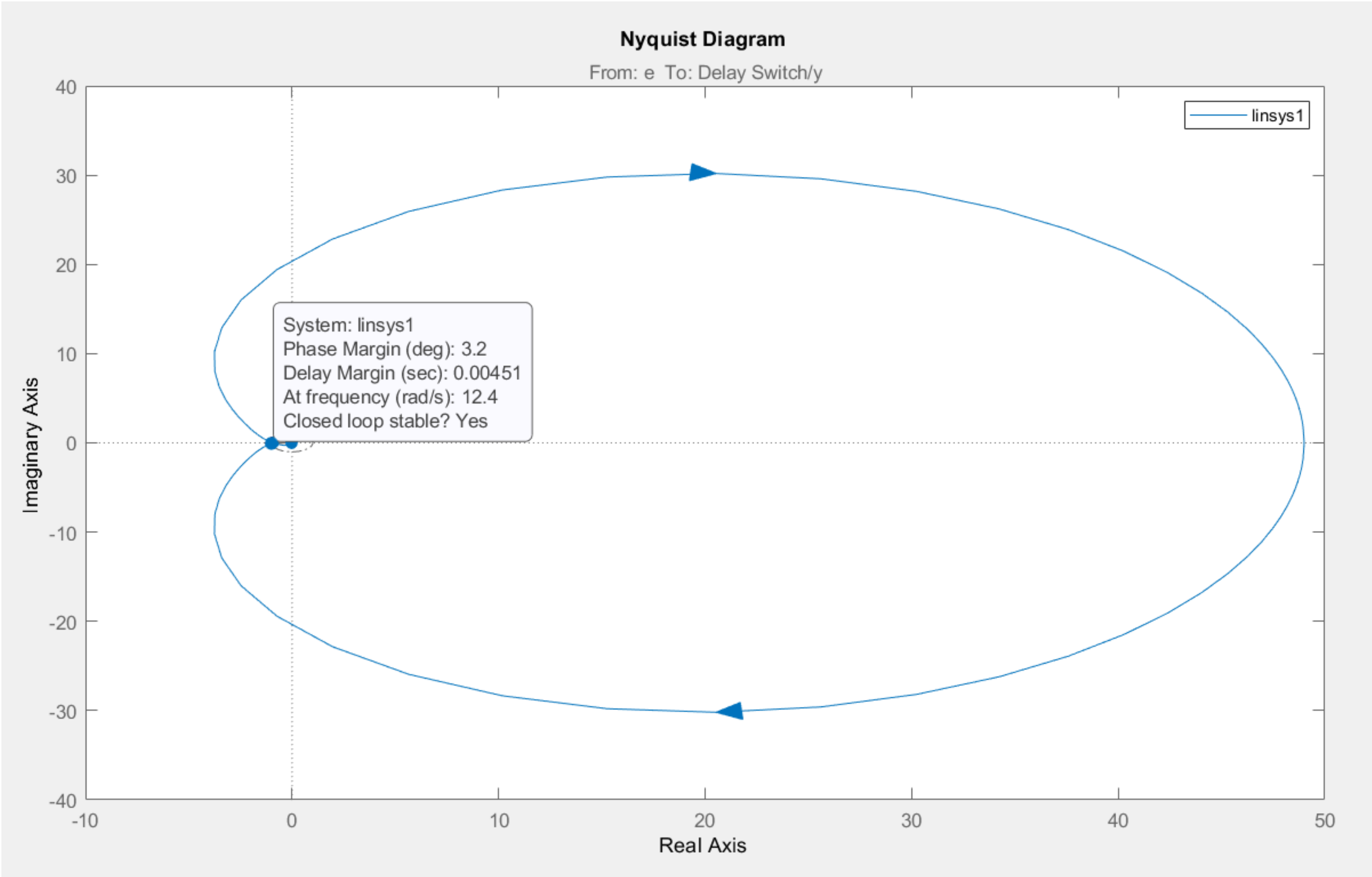

Figure 6 Lead compensated with delay

5.8

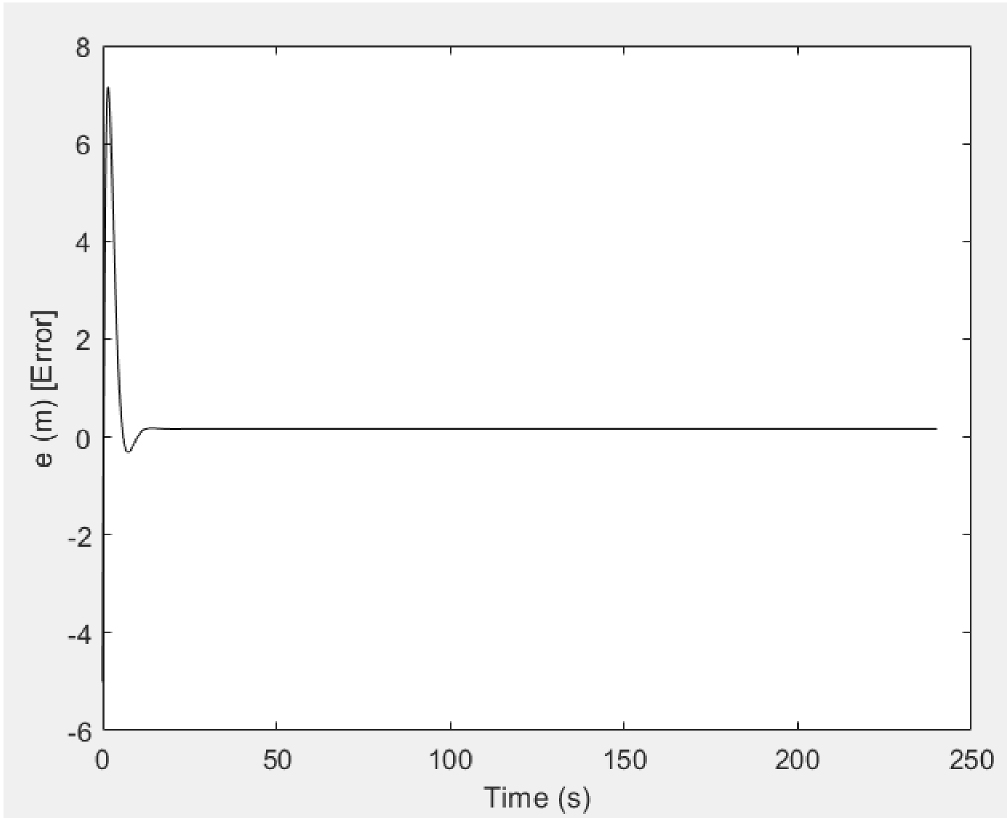

Figure 7

5.9

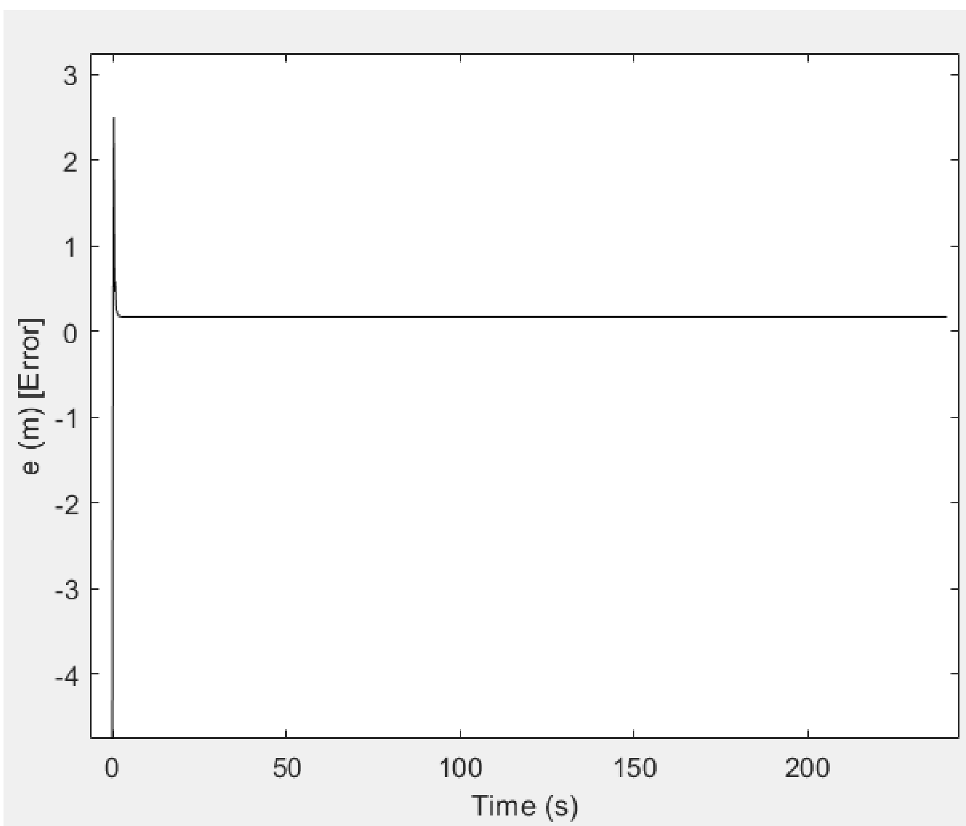

Figure 8

5.10

1

Wherever the phase margin is targeted and increased/decreased the magnitude of the bode plot will become more/less flat. This implies that it is essential for the output of the compensators to have a consistent magnitude for both lead and lag compensators. The effect of a lead controller on a system is that the system has a faster response time and has the w(cg) value shifted to the right whereas for a lag controller the systems response is slowed down and has w(cg) shifted to the left.

2

From the plots the lead compensator exhibits a significantly lower amount of overshoot, peak times, and settling time, however the there is a higher steady state error value. In comparison to the lag controller, the value of the overshoot is higher, and exhibits a small amount of oscillation before the steady state value is reached. The advantage of having a lead compensator is that it settles faster but with the cost of a higher steady state error in comparison to the lag controller. Thus, there is a faster acceleration value for using a lead compensator which then causes the system to be less stable.

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