



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

DESIGN VIA ROOT LOCUS AND COMPENSATION TECHNIQUES

LEAD AND LAG-LEAD COMPENSATION

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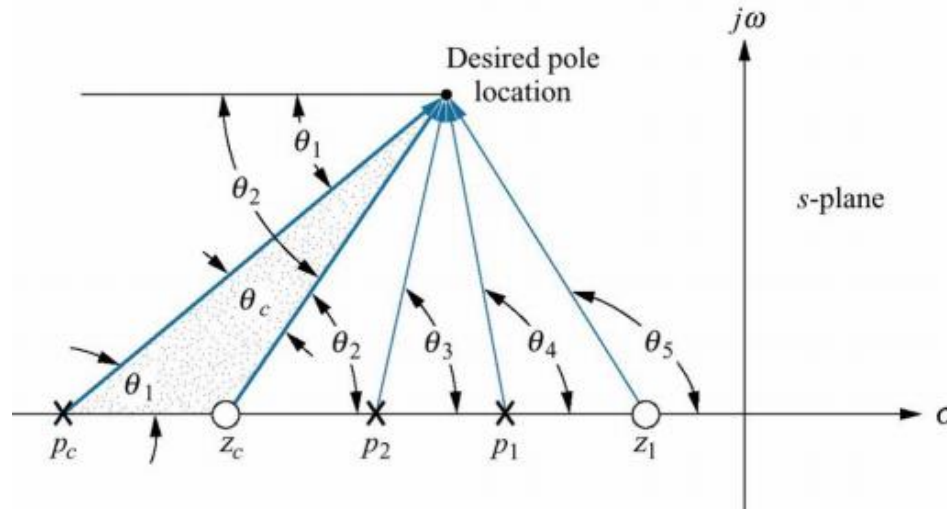
DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING



LEAD COMPENSATION

- An active ideal derivative compensator can be approximated with a passive lead compensator
- When passive networks are used, a single zero cannot be produced; rather a compensator zero and a pole result
- However, if the pole is farther from the imaginary axis than the zero, the angular contribution of the compensator is still positive and thus approximates an equivalent single zero

LEAD COMPENSATION



$$\theta_2 - \theta_1 - \theta_3 - \theta_4 + \theta_5 = (2k + 1)180^\circ$$

where $\theta_1 - \theta_2 = \theta_c$ is the angular contribution of the compensator

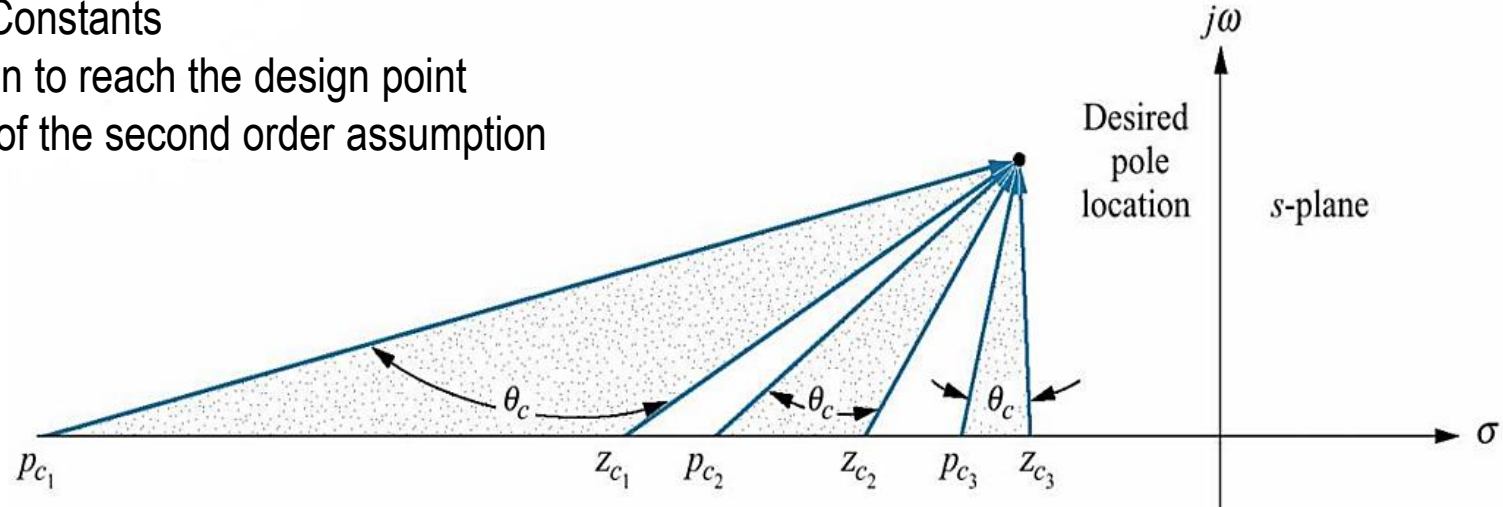
Ref: N. S. Nise: Control Systems Engineering, 6th Ed., Wiley, 2013

LEAD COMPENSATION

There are infinitely many choices of z_c , p_c providing same θ_c .

The choice from infinite possibilities affects:

- Static Error Constants
- Required gain to reach the design point
- Justification of the second order assumption



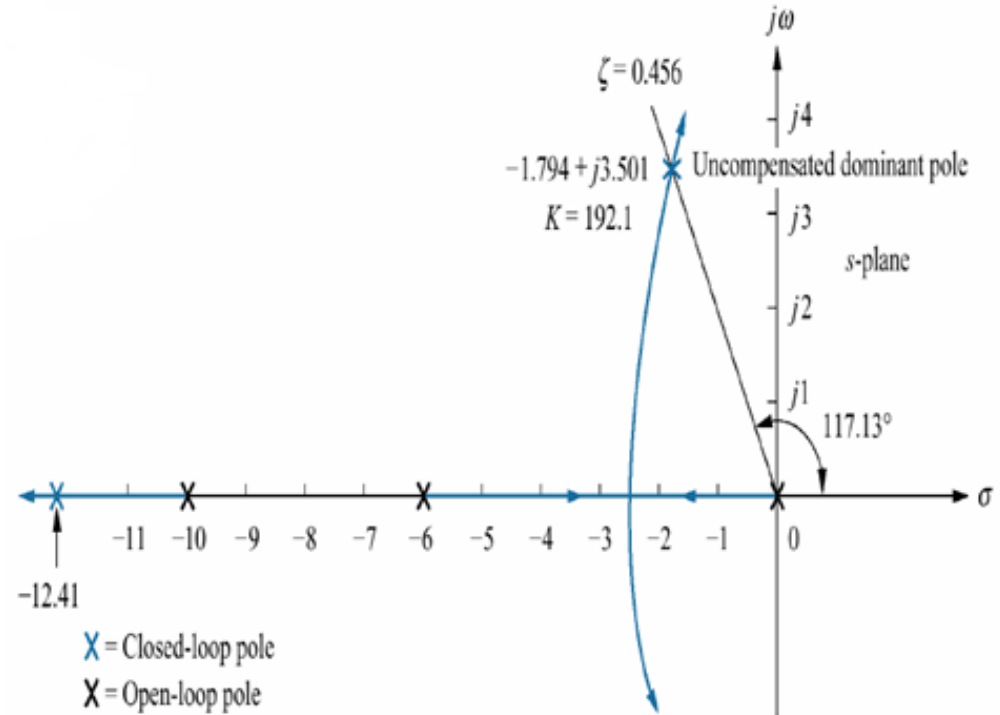
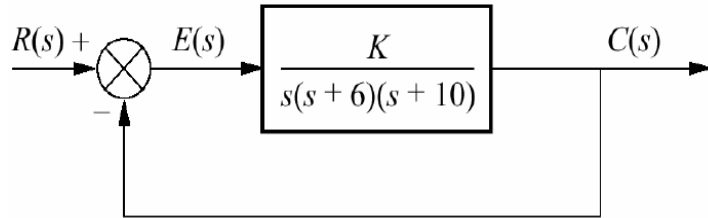
Ref: N. S. Nise: Control Systems Engineering, 6th Ed., Wiley, 2013

LAG-LEAD COMPENSATION

- Determine the desired pole location based on specifications
- Design the lead compensator to meet the TR specifications. The design includes the zero location, pole location, and the loop gain
- Simulate the system to be sure all requirements have been met
- Redesign if the simulation shows that requirements have not been met
- Evaluate the SS error performance of the lead compensated system to determine how much more improvement in SS error is required
- Design the lag compensator to yield the required SS error
- Simulate the system to be sure all requirements have been met
- Redesign if the simulation shows that requirements have not been met

LAG-LEAD COMPENSATION

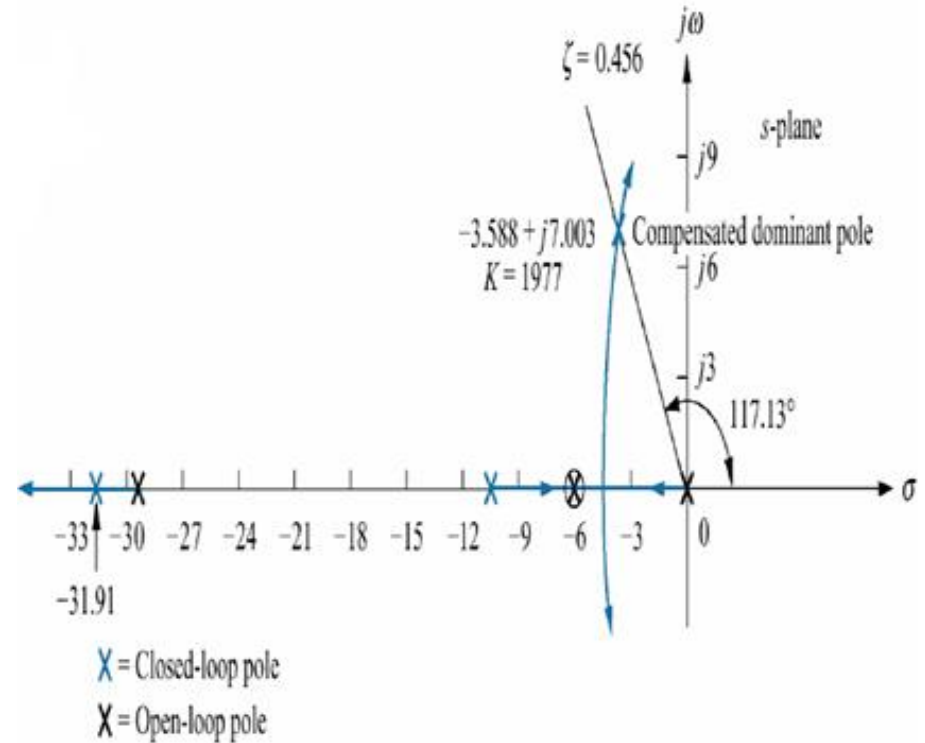
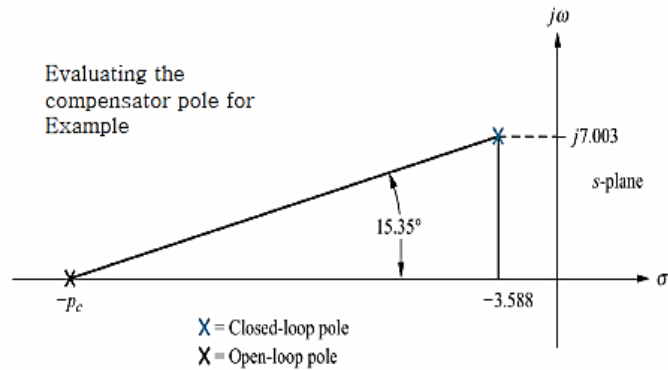
For the given system, design a lag-lead compensator so that the system can operate with 20 % overshoot and a twofold reduction in settling time. Further, the compensated system can exhibit a tenfold improvement in steady-state error for a ramp input.



Ref: N. S. Nise: Control Systems Engineering, 6th Ed., Wiley, 2013

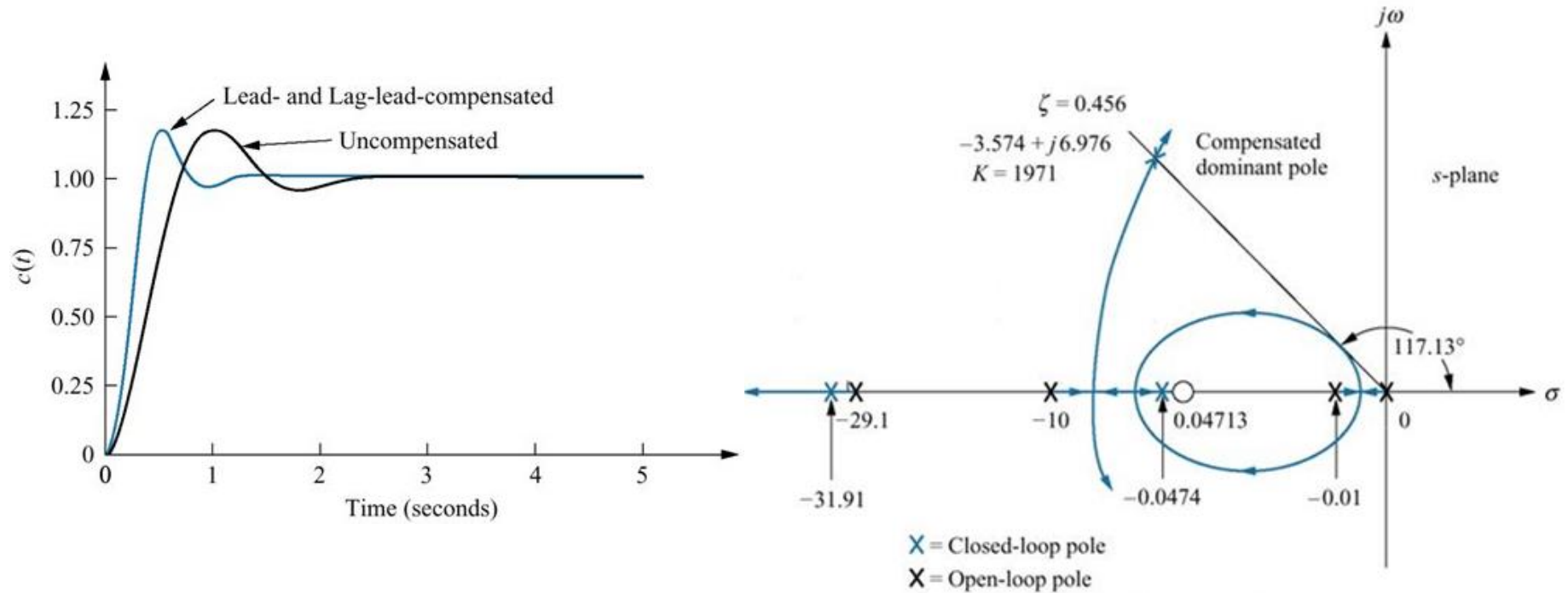
LAG-LEAD COMPENSATION

Evaluating the compensator pole for Example



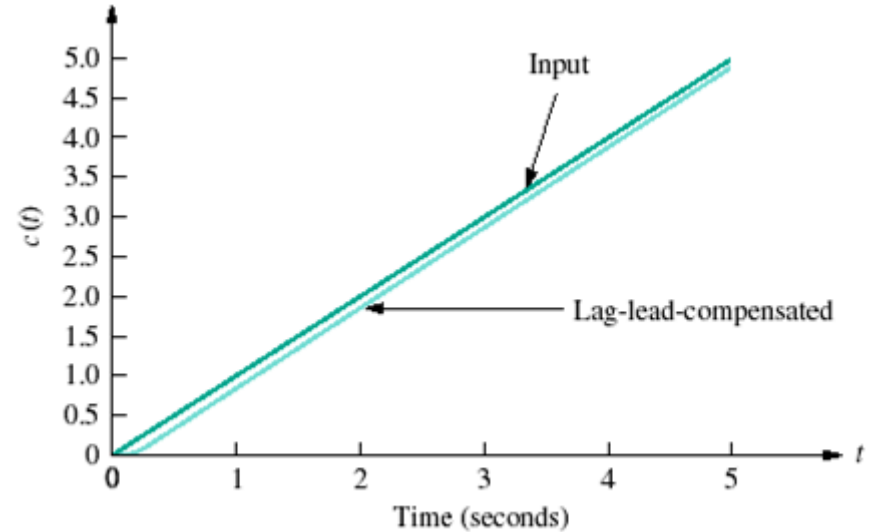
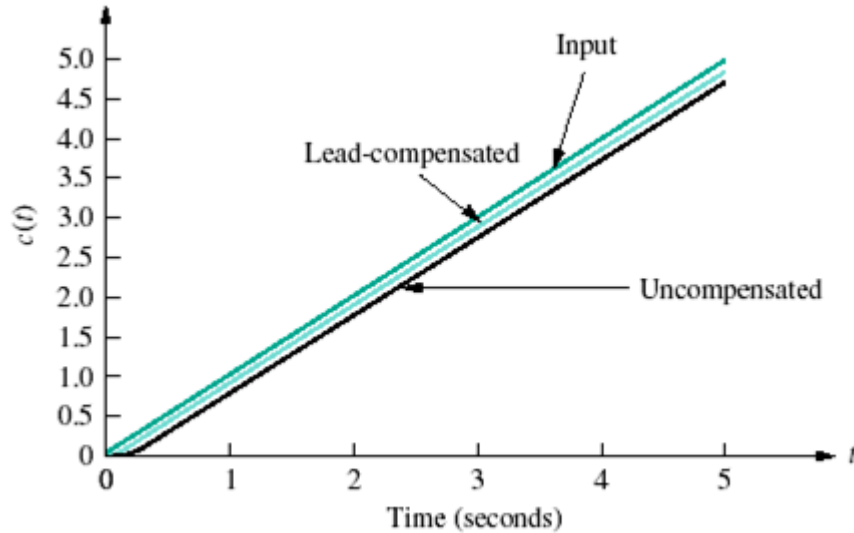
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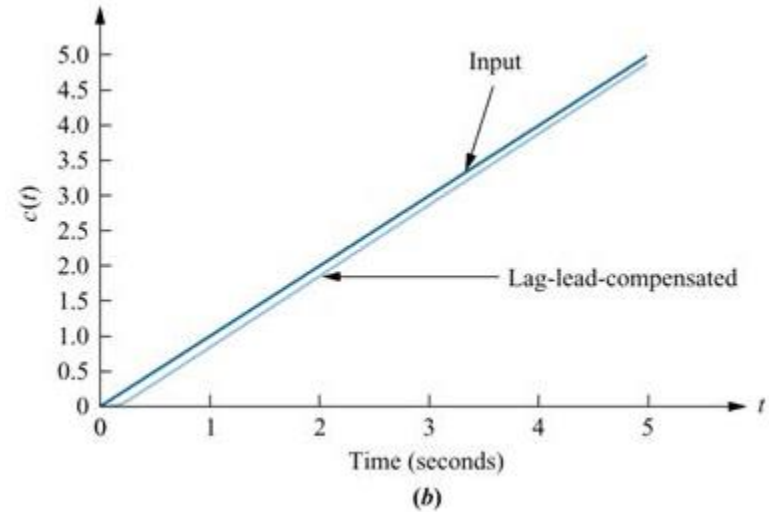
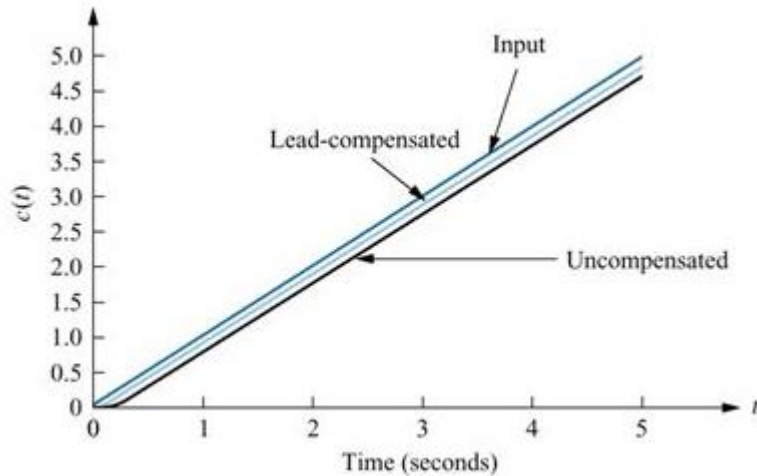
LAG-LEAD COMPENSATION

	Uncompensated	Lead-compensated	Lag-lead-compensated
Plant and compensator	$\frac{K}{s(s+6)(s+10)}$	$\frac{K}{s(s+10)(s+29.1)}$	$\frac{K(s+0.04713)}{s(s+10)(s+29.1)(s+0.01)}$
Dominant poles	$-1.794 \pm j3.501$	$-3.588 \pm j7.003$	$-3.574 \pm j6.976$
K	192.1	1977	1971
ζ	0.456	0.456	0.456
ω_n	3.934	7.869	7.838
%OS	20	20	20
T_s	2.230	1.115	1.119
T_p	0.897	0.449	0.450
K_v	3.202	6.794	31.92
$e(\infty)$	0.312	0.147	0.0313
Third pole	-12.41	-31.92	-31.91, -0.0474
Zero	None	None	-0.04713
Comments	Second-order approx. OK	Second-order approx. OK	Second-order approx. OK

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LAG-LEAD COMPENSATION



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REFERENCE BOOKS

- Norman S. Nise, Control Systems Engineering, Wiley, 2013
- Katsuhiko Ogata, Modern Control Engineering, Prentice Hall, 2010.

