



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

DESIGN VIA ROOT LOCUS AND COMPENSATION TECHNIQUES

PD CONTROLLER DESIGN

DR ANIL KUMAR

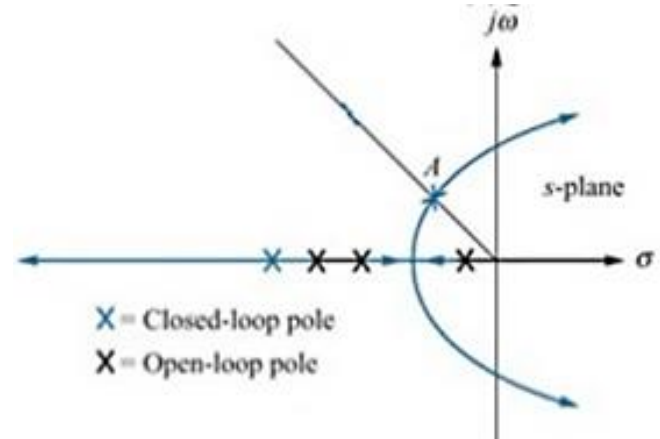
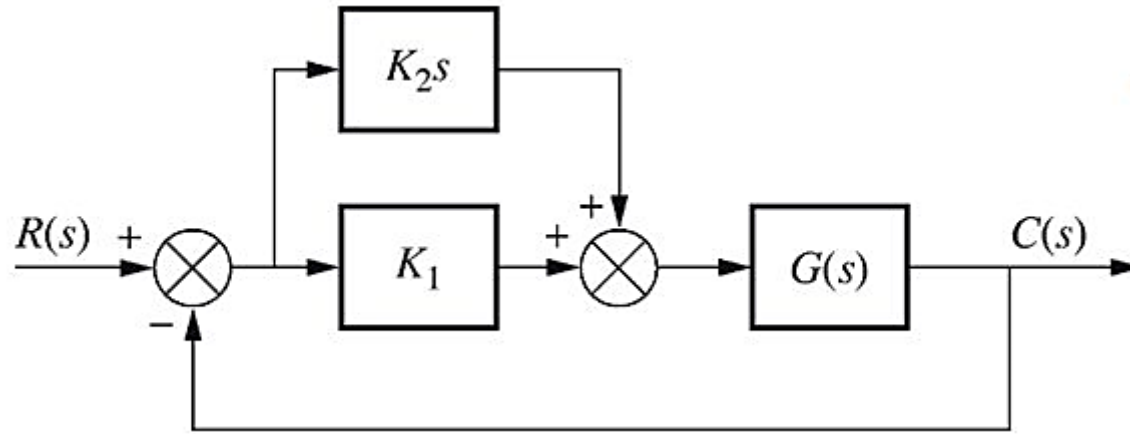
DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING



IDEAL DERIVATIVE COMPENSATION (PD)

- Improve the transient response TR
- Design a response that has a desirable percent overshoot and a shorter settling time than the original system
- The TR can be selected by choosing an appropriate closed-loop pole location on the s-plane
- If this point is on the RL, a simple gain adjustment is required
- If this point is not on the RL, then the RL must be reshaped (compensated)
- Add a single zero to the forward path: $G_c(s) = K(s+z_c)$
- **Proportional-plus-derivative (PD) controller**

IDEAL DERIVATIVE COMPENSATION (PD)



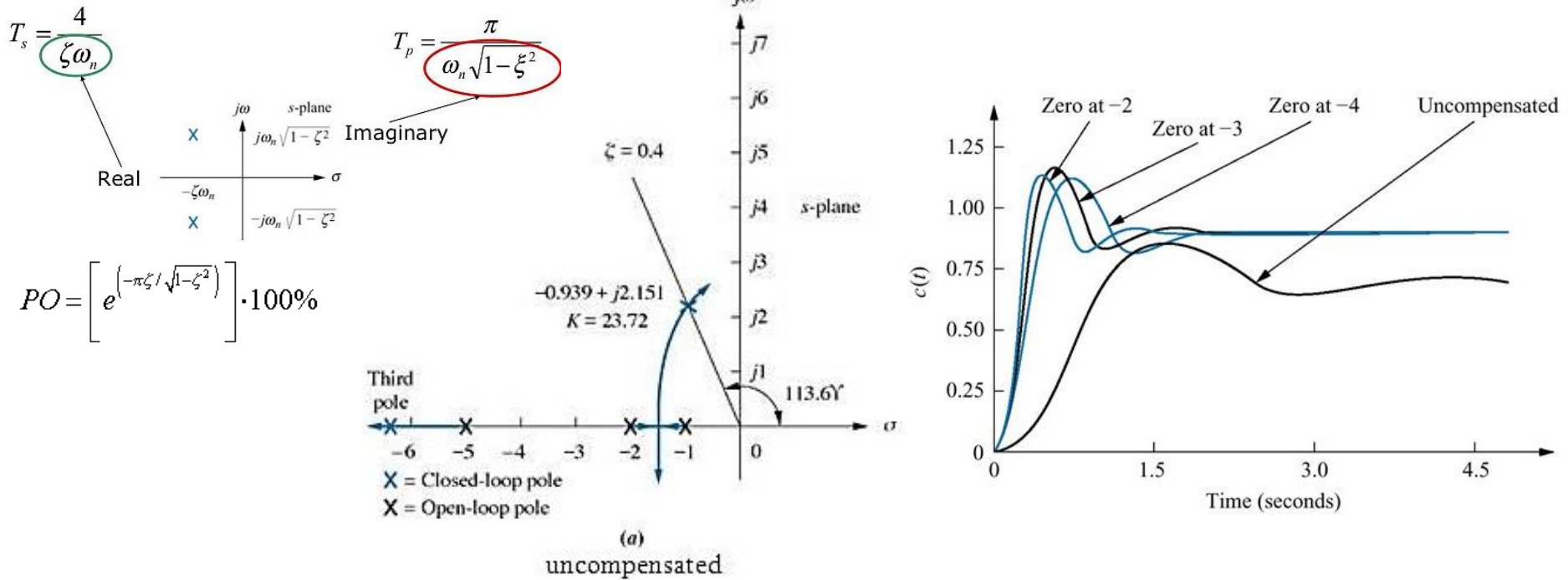
$$G_c(s) = K_2s + K_1 = K_2\left(s + \frac{K_1}{K_2}\right).$$

Annotations:

- loop-gain value. (pointing to K_2)
- equal the negative of the compensator zero. (pointing to $\frac{K_1}{K_2}$)

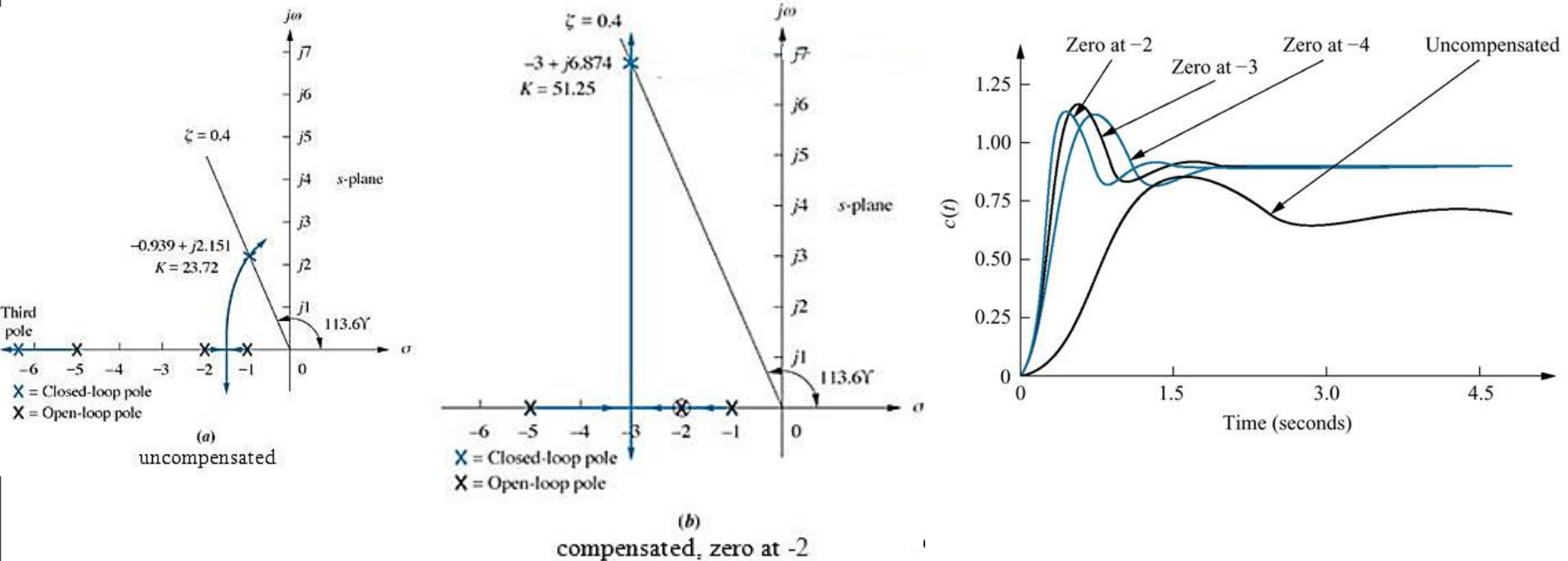
Ref: N. S. Nise: Control Systems Engineering, 6th Ed., Wiley, 2013

IDEAL DERIVATIVE COMPENSATION (PD)



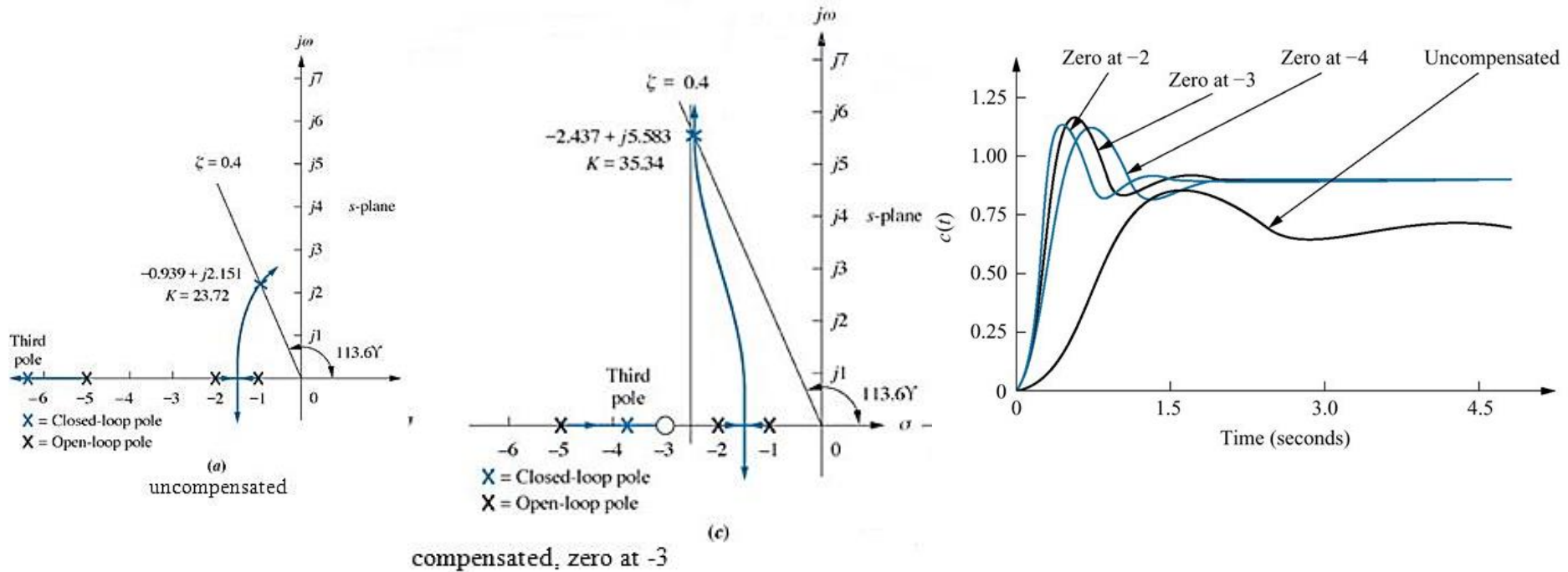
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IDEAL DERIVATIVE COMPENSATION (PD)



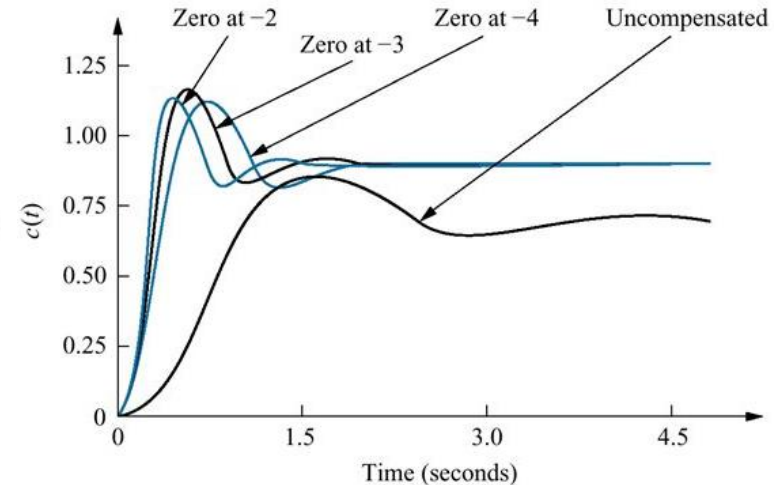
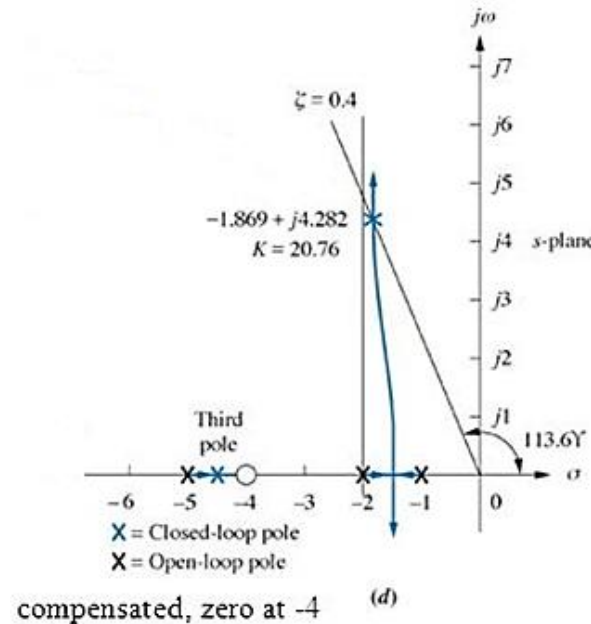
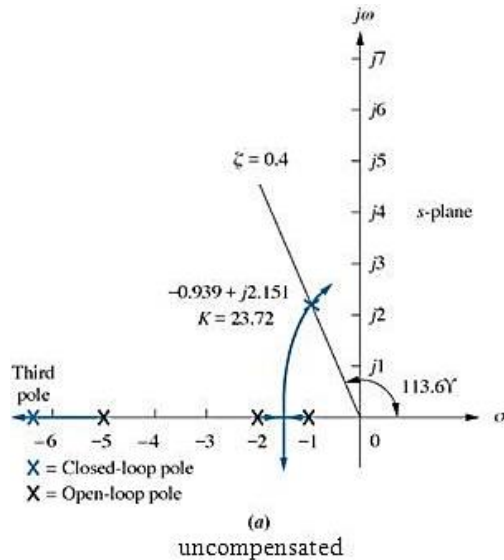
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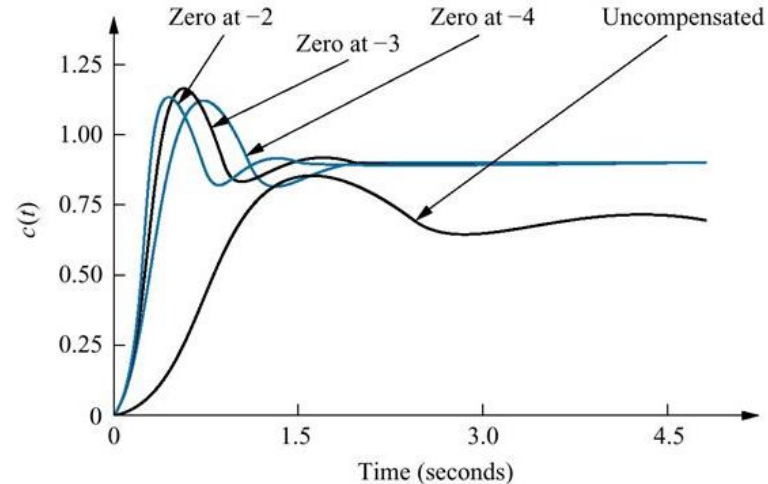
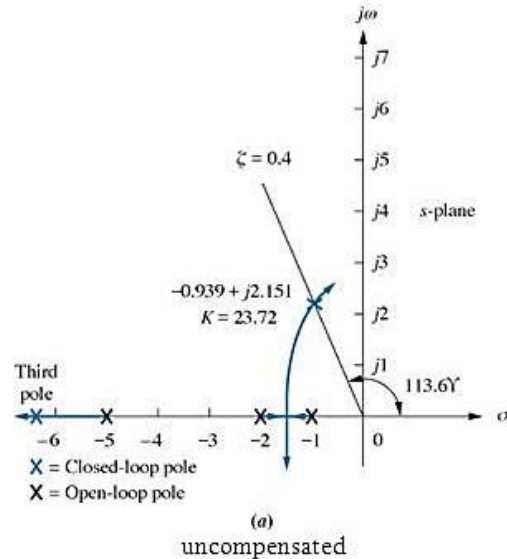
IDEAL DERIVATIVE COMPENSATION (PD)



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IDEAL DERIVATIVE COMPENSATION (PD)

- Gain K is chosen such that PO is same
- Compensated poles have more negative real and imaginary parts: smaller T_s and T_p



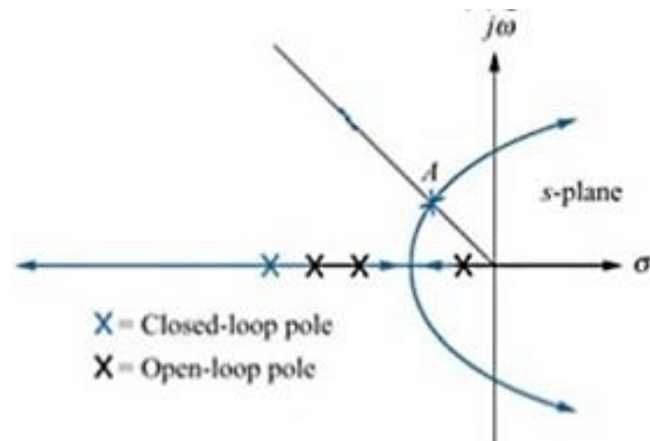
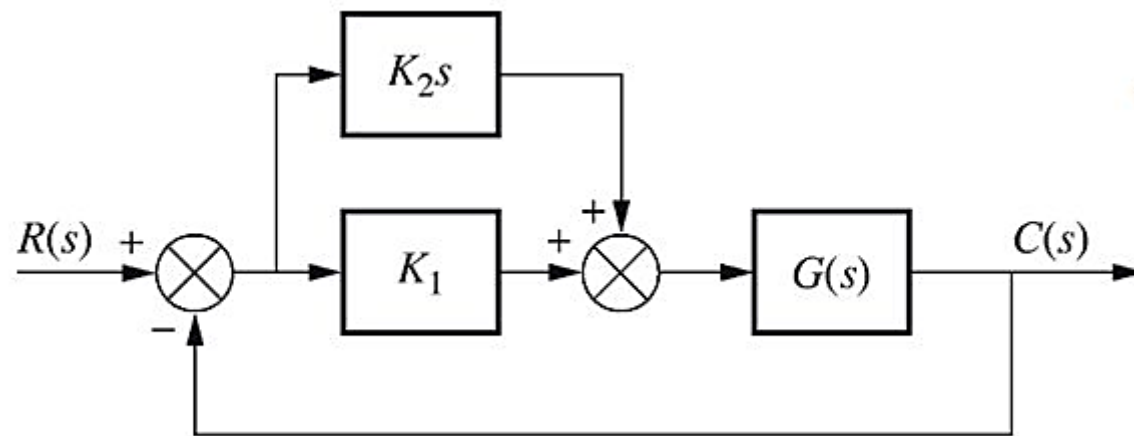
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IDEAL DERIVATIVE COMPENSATION (PD)

	Uncompensated	Compensation b	Compensation c	Compensation d
	K	$K(s+2)$	$K(s+3)$	$K(s+4)$
Plant and compensator	$(s+1)(s+2)(s+5)$	$(s+1)(s+2)(s+5)$	$(s+1)(s+2)(s+5)$	$(s+1)(s+2)(s+5)$
Dom. poles	$-0.939 \pm j2.151$	$-3 \pm j6.874$	$-2.437 \pm j5.583$	$-1.869 \pm j4.282$
K	23.72	51.25	35.34	20.76
ζ	0.4	0.4	0.4	0.4
ω_n	2.347	7.5	6.091	4.673
%OS	25.38	25.38	25.38	25.38
T_s	4.26	1.33	1.64	2.14
T_p	1.46	0.46	0.56	0.733
K_p	2.372	10.25	10.6	8.304
$e(\infty)$	0.297	0.089	0.086	0.107
Third pole	-6.123	None	-3.127	-4.262
Zero	None	None	-3	-4
Comments	Second-order approx. OK	Pure second-order	Second-order approx. OK	Second-order approx. OK

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IDEAL DERIVATIVE COMPENSATION (PD)



$$G_c(s) = K_2s + K_1 = K_2\left(s + \frac{K_1}{K_2}\right).$$

← loop-gain value.
← equal the negative of the compensator zero.

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IDEAL DERIVATIVE COMPENSATION (PD): DRAWBACK

- It requires an active circuit to perform the differentiation
- Differentiation is a noisy process. The level of the noise is low but the frequency of the noise is high
- Differentiation of high frequencies can lead to large unwanted signals or saturation of amplifiers and other components
- The *lead compensator* can be used to overcome the disadvantages of PD controller

REFERENCE BOOKS

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

