



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

DESIGN VIA ROOT LOCUS AND COMPENSATION TECHNIQUES

PID CONTROLLER DESIGN

DR ANIL KUMAR

DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING

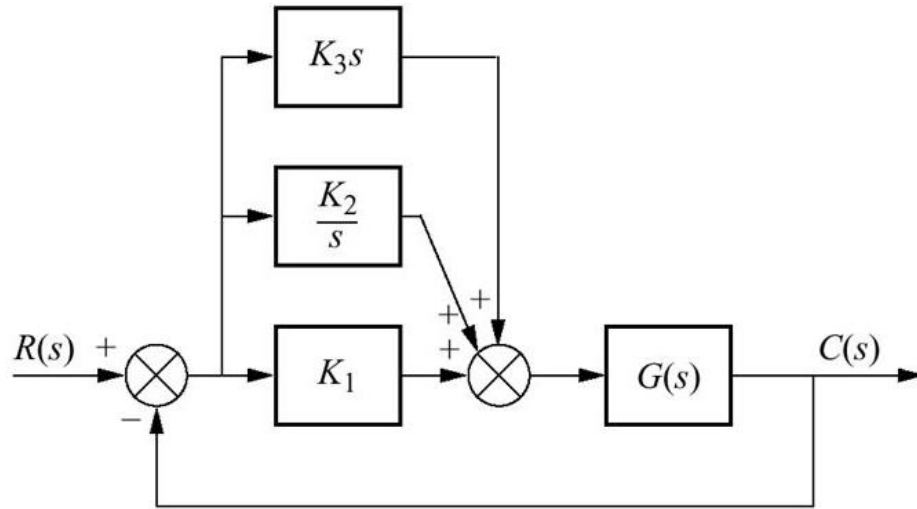


PID CONTROLLER

- If we design an active *PD* controller followed by an active *PI* controller
- It is called a *Proportional-plus-integral-plus-derivative (PID)* controller



PID CONTROLLER DESIGN



$$G_c(s) = K_1 + \frac{K_2}{s} + K_3s$$

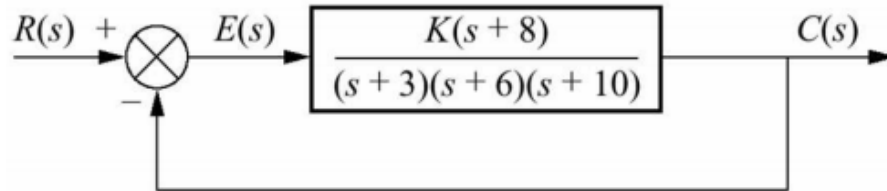
$$G_c(s) = K_1 + \frac{K_2}{s} + K_3s = \frac{K_1s + K_2 + K_3s^2}{s} = \frac{K_3(s^2 + \frac{K_1}{K_3}s + \frac{K_2}{K_3})}{s}$$

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

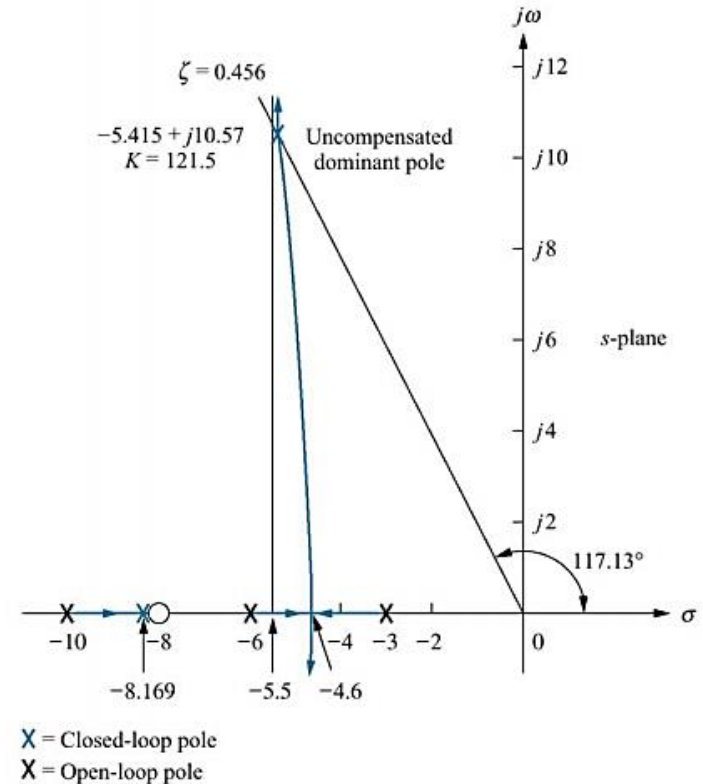
PID CONTROLLER DESIGN STEPS

- Evaluate the performance of the uncompensated system to determine how much improvement in TR is required: desired pole location
- Design the *PD controller* to meet the TR specifications. The design includes the zero location and the loop gain
- Simulate the system to be sure all requirements have been met
- Redesign if the simulation shows the requirements have not been met
- Design the *PI controller* to yield steady state error performance.
- Combine PD and PI to obtain K_1, K_2, K_3
- Simulate the system to be sure all requirements have been met
- Redesign if simulation shows that requirements have not been met

PID CONTROLLER DESIGN: EXAMPLE

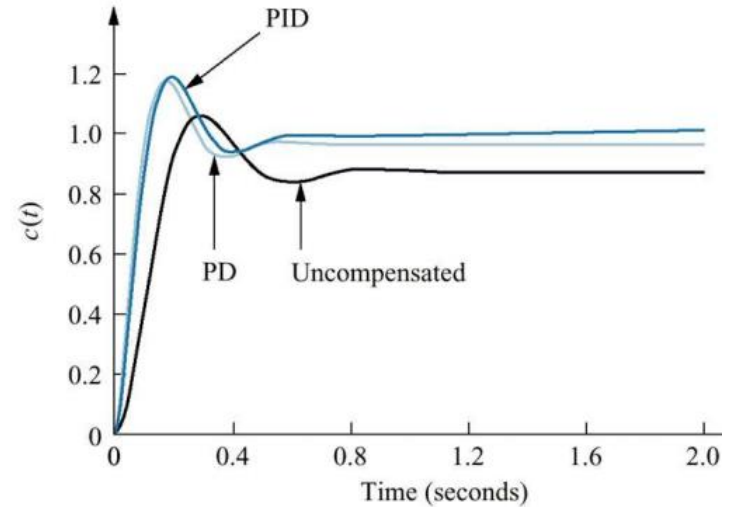
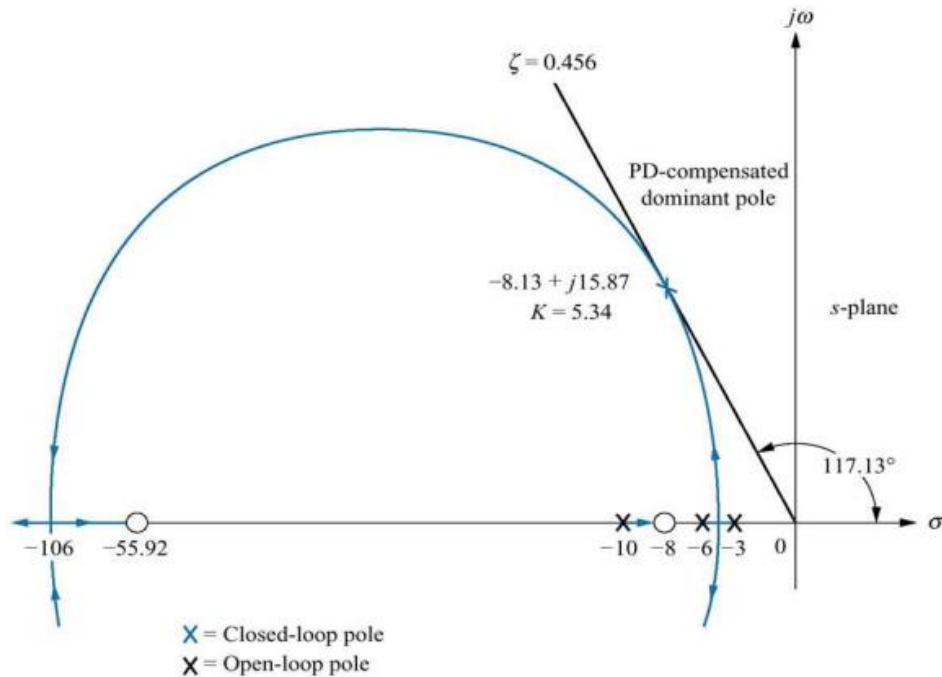


For the given system, design a PID controller so that the system can operate with a peak time that is two-thirds that of the uncompensated system at 20 % overshoot and with zero steady-state error for a step input.



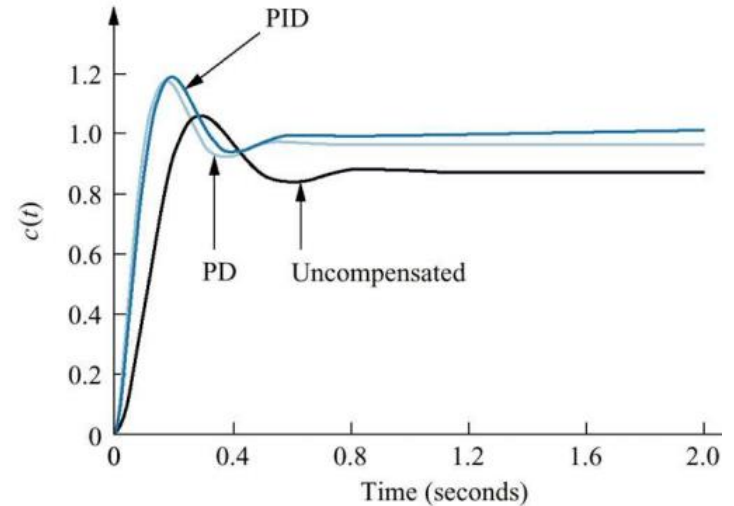
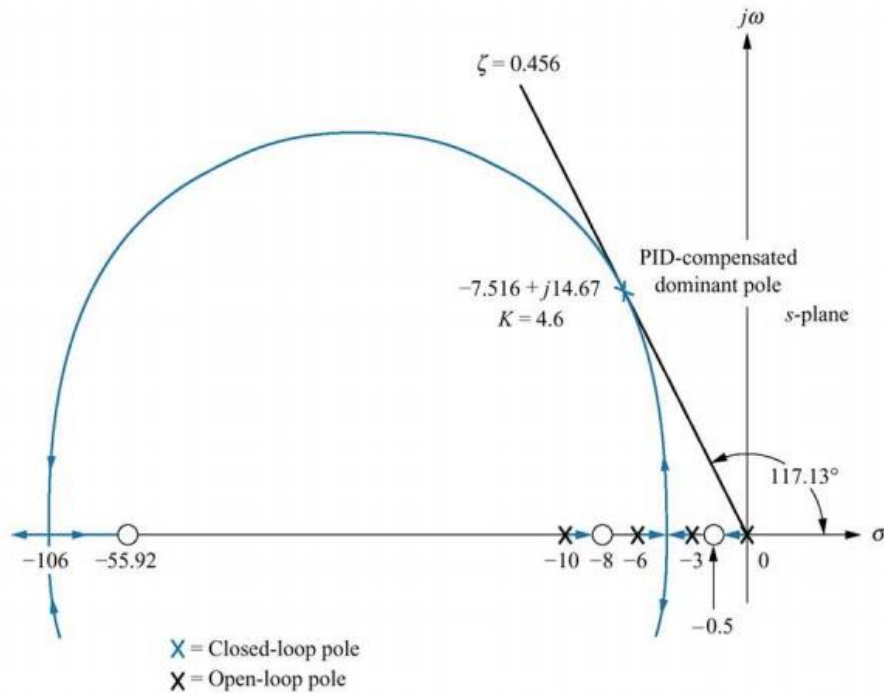
Ref: N. S. Nise: Control Systems Engineering, 6th Ed., Wiley, 2013

PID CONTROLLER DESIGN: PD



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

PID CONTROLLER DESIGN: PD+PI



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

PID CONTROLLER DESIGN: PD+PI

	Uncompensated	PD-compensated	PID-compensated
Plant and compensator	$\frac{K(s+8)}{(s+3)(s+6)(s+10)}$	$\frac{K(s+8)(s+55.92)}{(s+3)(s+6)(s+10)}$	$\frac{K(s+8)(s+55.92)(s+0.5)}{(s+3)(s+6)(s+10)s}$
Dominant poles	$-5.415 \pm j10.57$	$-8.13 \pm j15.87$	$-7.516 \pm j14.67$
K	121.5	5.34	4.6
ζ	0.456	0.456	0.456
ω_n	11.88	17.83	16.49
%OS	20	20	20
T_s	0.739	0.492	0.532
T_p	0.297	0.198	0.214
K_p	5.4	13.27	∞
$e(\infty)$	0.156	0.070	0
Other poles	-8.169	-8.079	-8.099, -0.468
Zeros	-8	-8, -55.92	-8, -55.92, -0.5
Comments	Second-order approx. OK	Second-order approx. OK	Zero at -55.92 and -0.5 not canceled

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



PID CONTROLLER DESIGN

Which one to improve first: TR or SS error ?

First TR then SS error

- Slight decrease in the speed of the response when the SS error is improved

First SS error then TR

- Improvement in TR in some cases yields deterioration in the improvement of the SS error, which was designed first
- In other cases, improvement in TR yields further improvement in SS error. Thus a system can be overdesigned w.r.t. SS error
- Overdesign is not a problem unless it affects cost or produces other design problems

REFERENCE BOOKS

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

