Tikrit university

Collage of Engineering Shirqat

Department of Electrical Engineering

Fourth Class- Semester-2

Control Engineering

Chapter 12

Lecture 10

Design of Control Systems

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11-6 PID Controller Design

proportional-plus-integral-plus-derivative (PID) controller: A PID controller is shown in Figure 11.28. Its transfer function is

$$G_c(s) = K_1 + \frac{K_2}{s} + K_3 s = \frac{K_1 s + K_2 + K_3 s^2}{s} = \frac{K_3\left(s^2 + \frac{K_1}{K_3}s + \frac{K_2}{K_3}\right)}{s} \qquad 11.18$$

which has two zeros plus a pole at the origin. One zero and the pole at the origin can be designed as the ideal integral compensator; the other zero can be designed as the ideal derivative compensator.

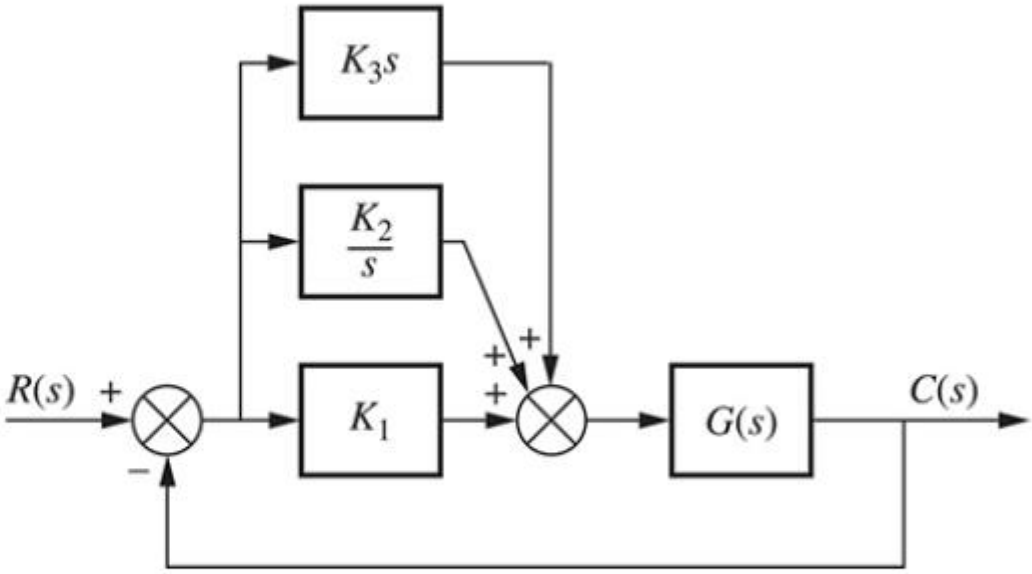

Fig 11.28 PID controller

The design technique, which is demonstrated in Example 11.7, consists of the following steps:

1. Evaluate the performance of the uncompensated system to determine how much improvement in transient response is required.
2. Design the PD controller to meet the transient response specifications. The design includes the zero location and the loop gain.
3. Simulate the system to be sure all requirements have been met.
4. Redesign if the simulation shows that requirements have not been met.
5. Design the PI controller to yield the required steady-state error.
6. Determine the gains, K1, K2, and K3, in Figure 11.28.
7. Simulate the system to be sure all requirements have been met.
8. Redesign if simulation shows that requirements have not been met.

Example 11.7

PROBLEM:

Given the system of Figure 11.29, with dominant poles $-5.415 \pm j10.57$. 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 to get and with zero steady-state error for a step input and KV= 5.7163sec^{-1} and final K=4.6.

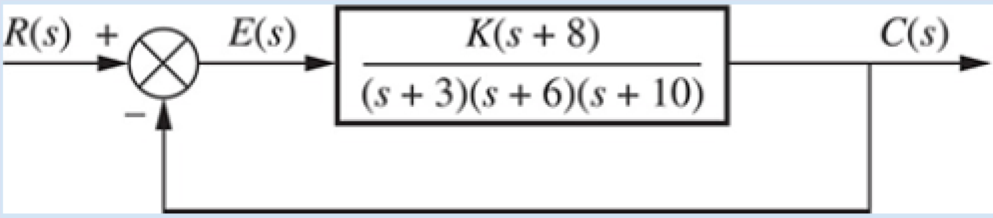

Fig 11.29 Uncompensated feedback control system for Example 11.7

Step 1 Let us first We estimate that the uncompensated system has a peak time of 0.297 second at 20% overshoot.

$$Tp = \frac{\pi}{\omega_d} = \frac{\pi}{10.57} = 0.297$$

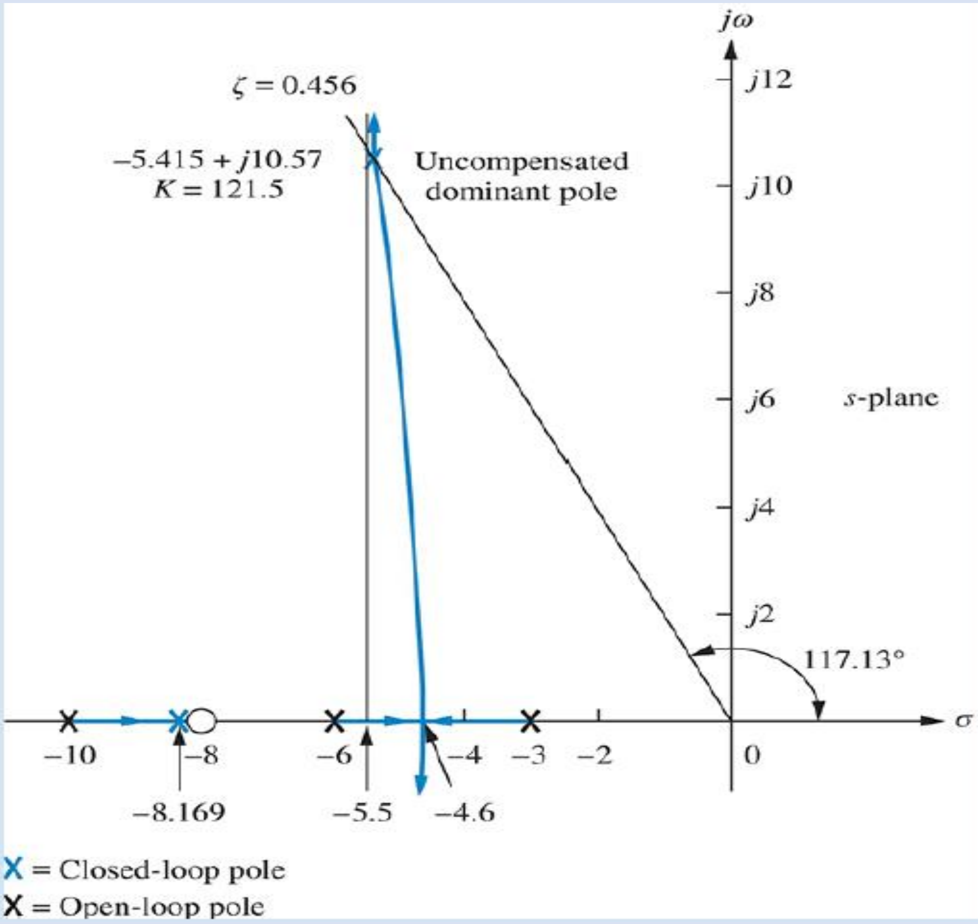

Fig 11.30 Root locus for the uncompensated system of Example 11.7

Step 2 To compensate the system to reduce the peak time to two-thirds of that of the uncompensated system, we must first find the compensated system's dominant pole location. The imaginary part of the compensated dominant pole is

$$\omega_d = \frac{\pi}{T_p} = \frac{\pi}{(2/3)\,(0.297)} = 15.87$$

Thus, the real part of the compensated dominant pole is

$\theta = \cos^{-1}\zeta = 62.87 \;\rightarrow\; \sigma = wd/(180-\theta) =$

$$\sigma = \frac{\omega_d}{\tan 117.13^\circ} = -8.13$$

Next we design the compensator. We calculate the compensating zero's location. Using the root locus characteristic,

$$\angle \left.\frac{K(S+8)}{(S+3)(S+6)(S+10)}\right|_{s=-8.13+j15.87} = -198.37^\circ$$

the compensator zero is 198.37° −180° = 18.37°. Assume that the compensator zero is located at $-z_c$, as shown in Figure 11.31. Since

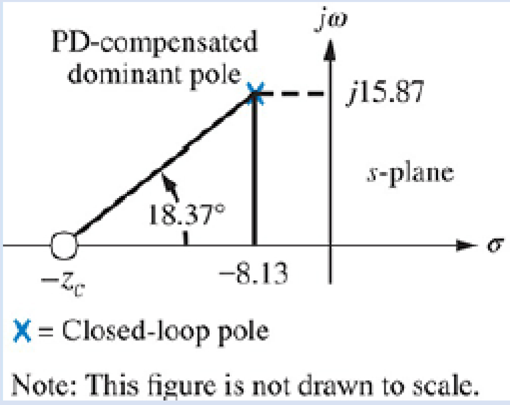

Fig 11.31 Calculating the PD compensator zero for Example 11.7

$$\frac{15.87}{z_c - 8.13} = \tan 18.37^\circ$$

zc = 55.92

Thus, the PD controller is

$$G_{\mathrm{PD}}(s) = (s + 55.92)$$

The complete root locus for the PD-compensated system is sketched in Figure 11.32.

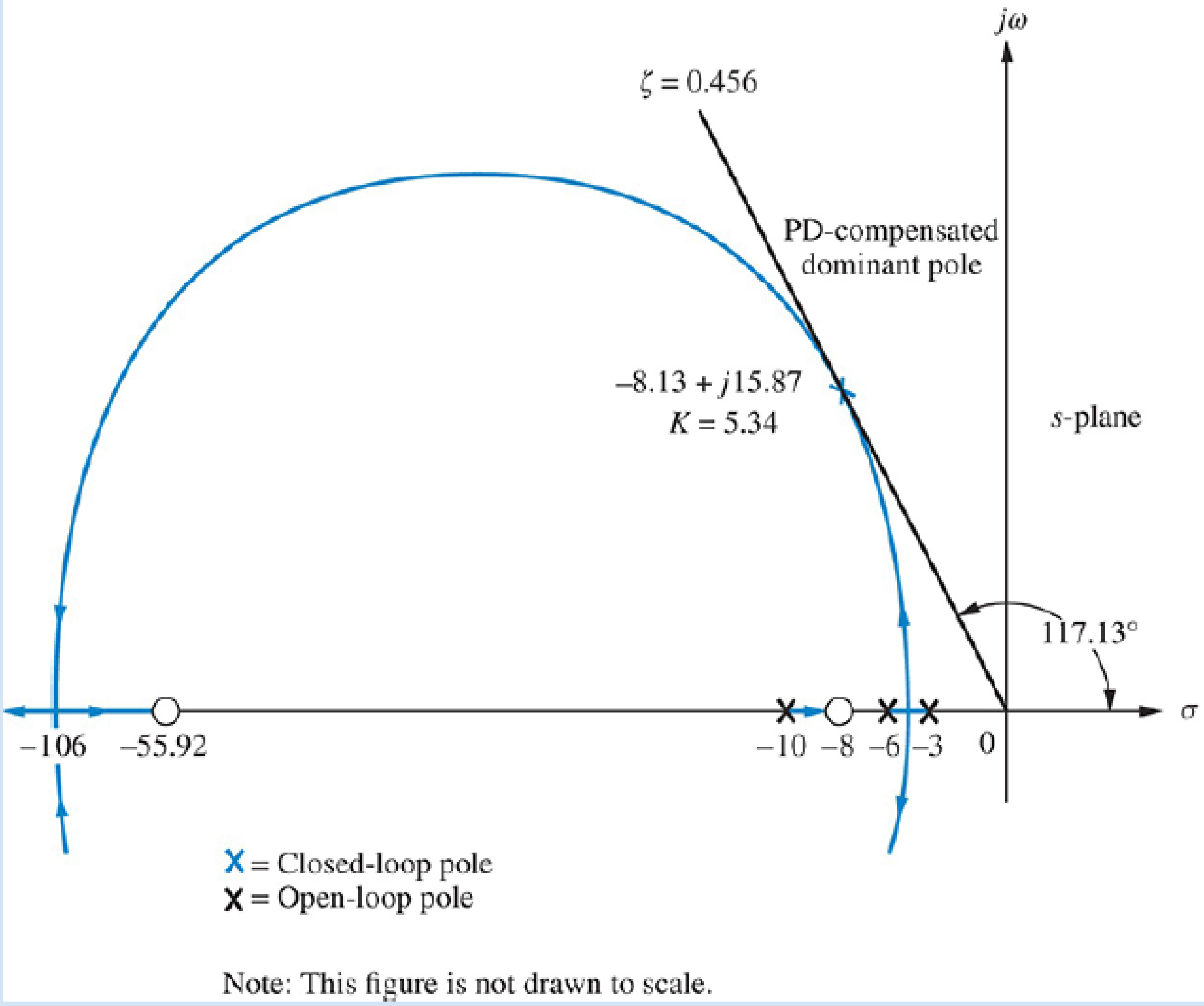

Fig 11.32 Root locus for PD-compensated system

Steps 3 & 4 We simulate the PD-compensated system, as shown in Figure 11.33. We see the reduction in peak time and the improvement in steady-state error over the uncompensated system.

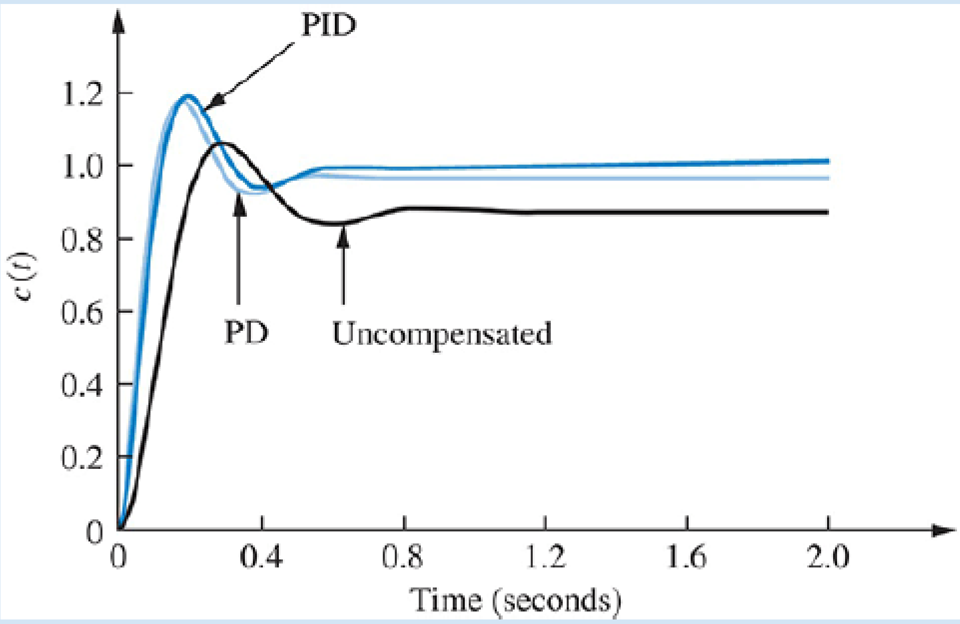

Fig 11.33 Step responses for uncompensated, PD-compensated, and PID-compensated systems

Step 5 After we design the PD controller, we design the ideal integral compensator to reduce the steady-state error to zero for a step input. Any ideal integral compensator zero will work, as long as the zero is placed close to the origin. Choosing the ideal integral compensator to be

Kv=$\lim_{S\to 0} S\,\frac{K\,(S+8)(S+55.92)(S+zi)}{S(S+3)(S+6)(S+10)}$= when K=4.6 and Kv =5.7163

Zi= 0.5

$\left|\frac{s+0.5}{s}\right|_{s=\,-8.13+j15.87}$=0.9875∠-1.45

Step 6 Now we determine the gains, K1, K2, and K3, in Figure 11.28. the product of the gain and the PID controller is

$$G_{\mathrm{PID}}(s)=\frac{K(s+55.92)(s+0.5)}{s}=\frac{4.6(s+55.92)(s+0.5)}{s}$$

$$=\frac{4.6\left(s^2+56.42s+27.96\right)}{s} \qquad 11.19$$

Matching Eqs. (11.18.) and (11.19), $K1$ = 259.5, $K2$ = 128.6, and $K3$ = 4.6.