Ahsanullah University of Science & Technology

(Lab Manual)

(Open Ended Lab Project)

Course No: EEE 4106

Course Title: Control System I

Experiment Name: Designing of a PD compensated system which can operate with a peak time that is (2/3) times of the uncompensated system operating at 20% overshoot.

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Name of Experiment: Designing of a PD compensated system which can operate with a peak time that is (2/3) times of the uncompensated system operating at 20% overshoot.

Objective:

- ✓ Design a physical PD controller using the concept of the root locus method.
- ✓ Compensate the present system to get the desired response.
- ✓ Observe the response in SISOTOOL, Simulink, and for practical circuits in Waveforms (Analog Discovery 2).

A PD controller, also known as a Proportional-Derivative controller, is a control system commonly used in engineering and automation to regulate and stabilize systems. It combines two control actions: proportional control and derivative control. The PD controller aims to improve the transient response of a system while reducing the effects of overshoot and oscillation

Proportional Control (P): The proportional control action is based on the current error, which is the difference between the desired setpoint and the actual process variable (output of the system). The PD controller multiplies this error by a constant factor known as the proportional gain (K_p) to calculate the control output. The higher the error, the larger the control output.

Derivative Control (D): The derivative control action considers the rate of change of the error. It calculates the derivative of the error concerning time and multiplies it by a derivative gain (K_d). This helps to predict the future behavior of the error. If the error changes rapidly, the controller will take stronger corrective actions to counteract the change.

In mathematical terms, the output of a PD controller can be represented as:

$u(t)=K_p \cdot e(t)+K_d \cdot de(t)/dt$.

- $u(t)$ is the control output at time t.
- K_p is the proportional gain.
- K_d is the derivative gain.
- $e(t)$ is the error at time t, calculated as the difference between the desired setpoint and the actual process variable.
- $de(t)/dt$ is the derivative of the error with respect to time.

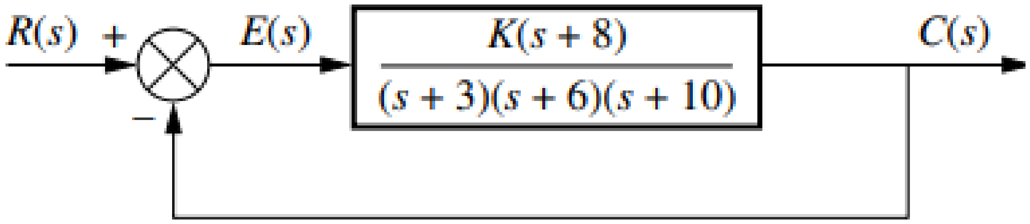


Fig1 : Given uncompensated feedback control system

Here the overshoot is given (20%). First, we have to analyze the uncompensated system to find necessary parameters.

Steps to design the PD compensator:

Step 1:

$$\omega_n = \frac{\omega_d}{\sqrt{1-\zeta^2}} \qquad \zeta = \sqrt{\frac{1}{1+\left[\frac{\pi}{\ln(overshoot\ ratio)}\right]^2}}$$

$$T_P = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$$

Using the following equations, the value of the Damping ratio and the peak time before compensation is evaluated.

Step 2: Evaluate the uncompensated system operating at 20% overshoot. Searching along the 20% overshoot line (Damping ratio=0.45) the dominant poles can be found to be -5.415 ± j10.57 with a gain of 121.5. A third pole,

which exists at -8:169, is found by searching the region between -8 and -10 for a gain equivalent to that at the dominant poles.

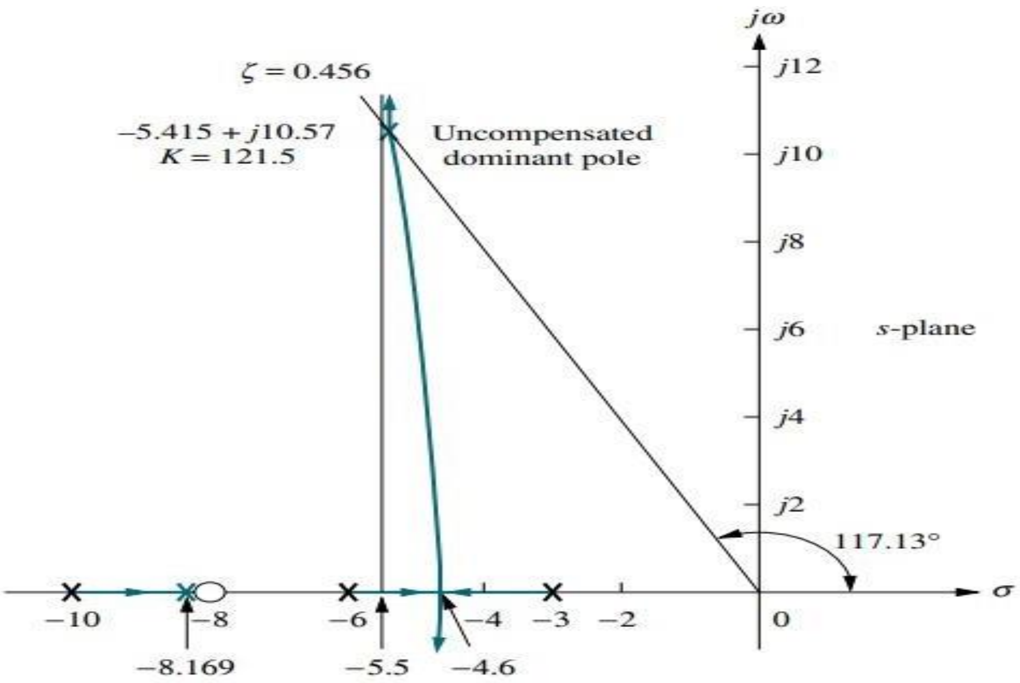


Fig 2: Evaluating dominant pole from root locus of the system.

Step 3: 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

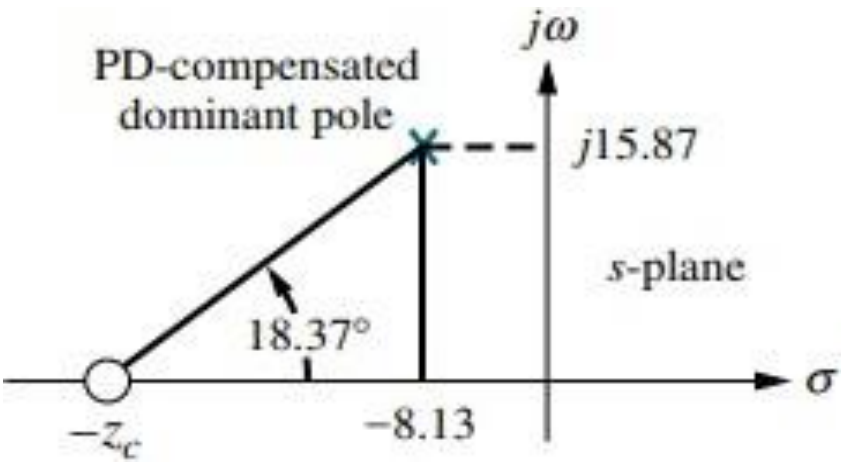
$$\omega_d = \frac{\pi}{T_p} = \frac{\pi}{(2/3)(0.297)} = 15.87$$

Thus, the real part of the compensated dominant pole is

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

Step 4:

Next design the compensator. Using the geometry shown below, calculate the compensating zero's location. Using the root locus program, find the sum of angles from the uncompensated system's poles and zeros to the desired compensated dominant pole which is -198:37°. Thus, the contribution required from the compensator zero is (198:37°-180°) =18:37°.



Assume that the compensator zero is located at -Zc. Since-

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

Then, Zc =55:92;

Thus, the PD controller is

$$G_{PD(s)}=(S+55:92).$$

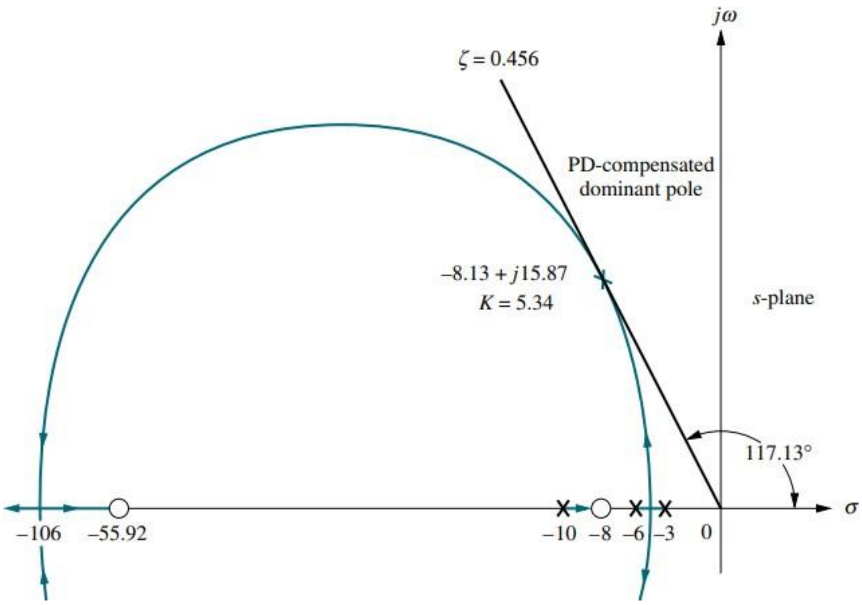


Fig 3: Root locus of PD compensated system.

The transfer function of the PD compensated system-

$$C(S)=\frac{K'(S+8)(S+55.92)}{(S+3)(s+6)(s+10)}$$

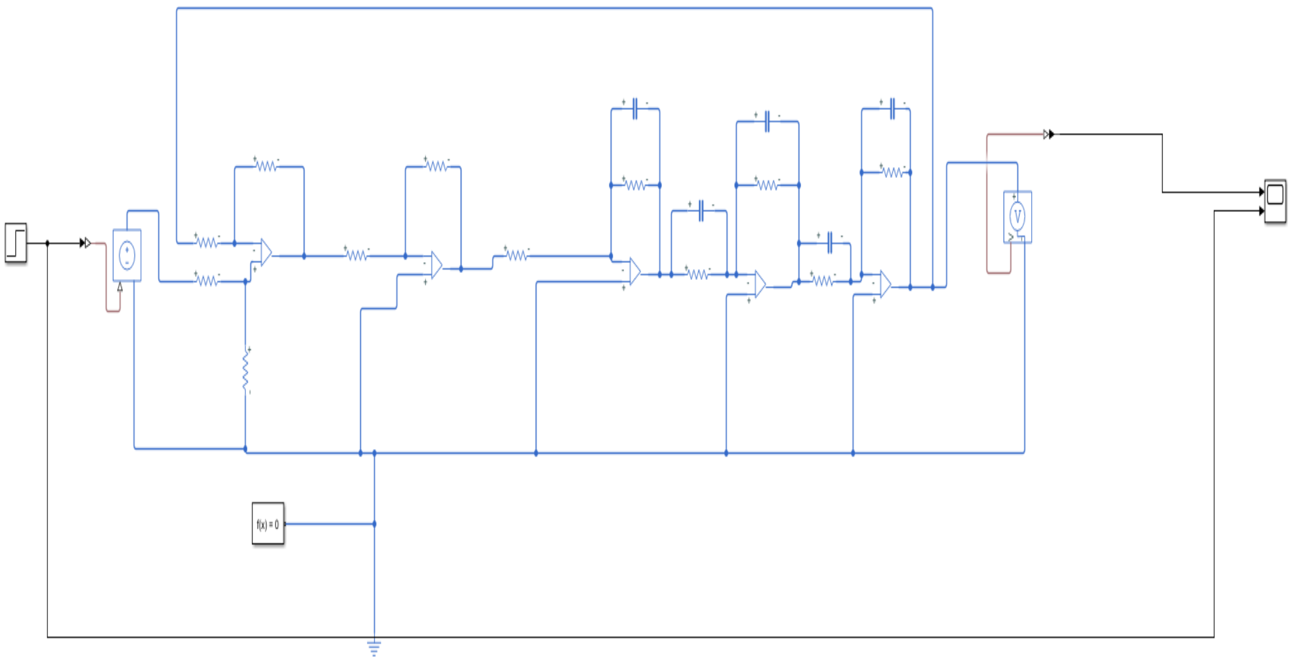
Step 5: Find the gain of the compensated system in dominant pole. K′=10.886

Now,

$$C(S)=\frac{5.34(S+8)(S+55.92)}{(S+3)(s+6)(s+10)}.$$

Step 6: Using the necessary values design the physical circuit diagram as well as observe the output in waveforms software(using Analog Discovery device)

Physical Circuit Diagram:



Calculations:

R_i=	R_{i1}=	R_{f1}=	C_{f1}=	C_{i2}=
R_f=	R_{i2}=	R_{f2}=	C_{f2}=	C_{i3}=
	R_{i3}=	R_{f3}=	C_{f3}=	

Assignments:

1. Observe the output response in SISOTOOL.

2. Design the physical circuit in simulation environment.

3. Compare the values of the output response in SISOTOOL, Simulink and Waveforms software. (Hardware circuit)