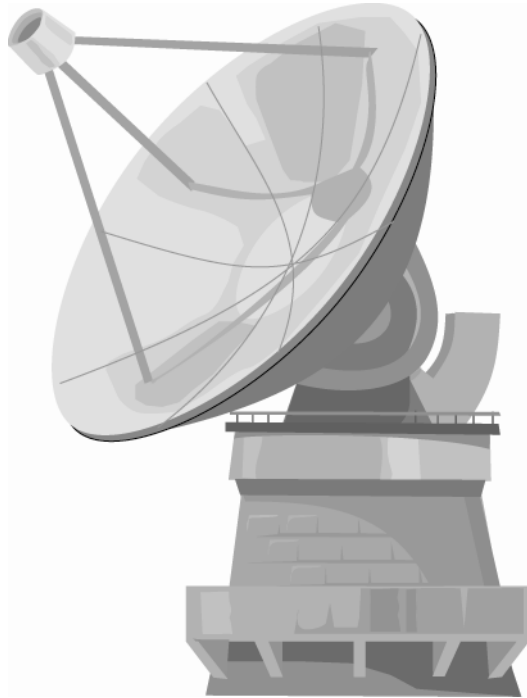
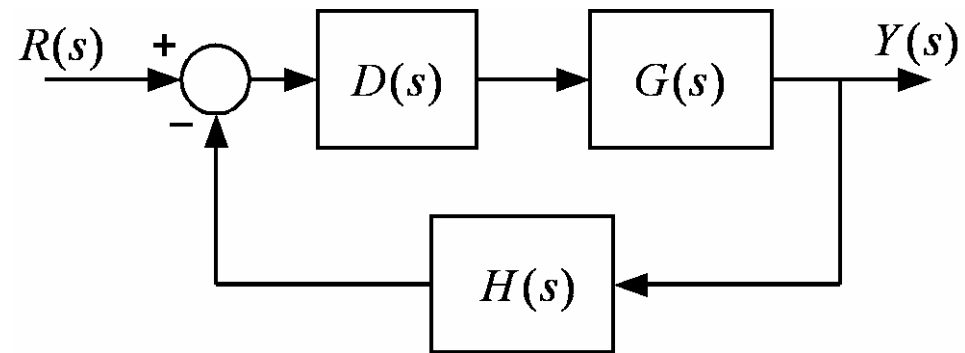


7. 주파수 영역에서의 제어기 설계



제어 시스템의 구조

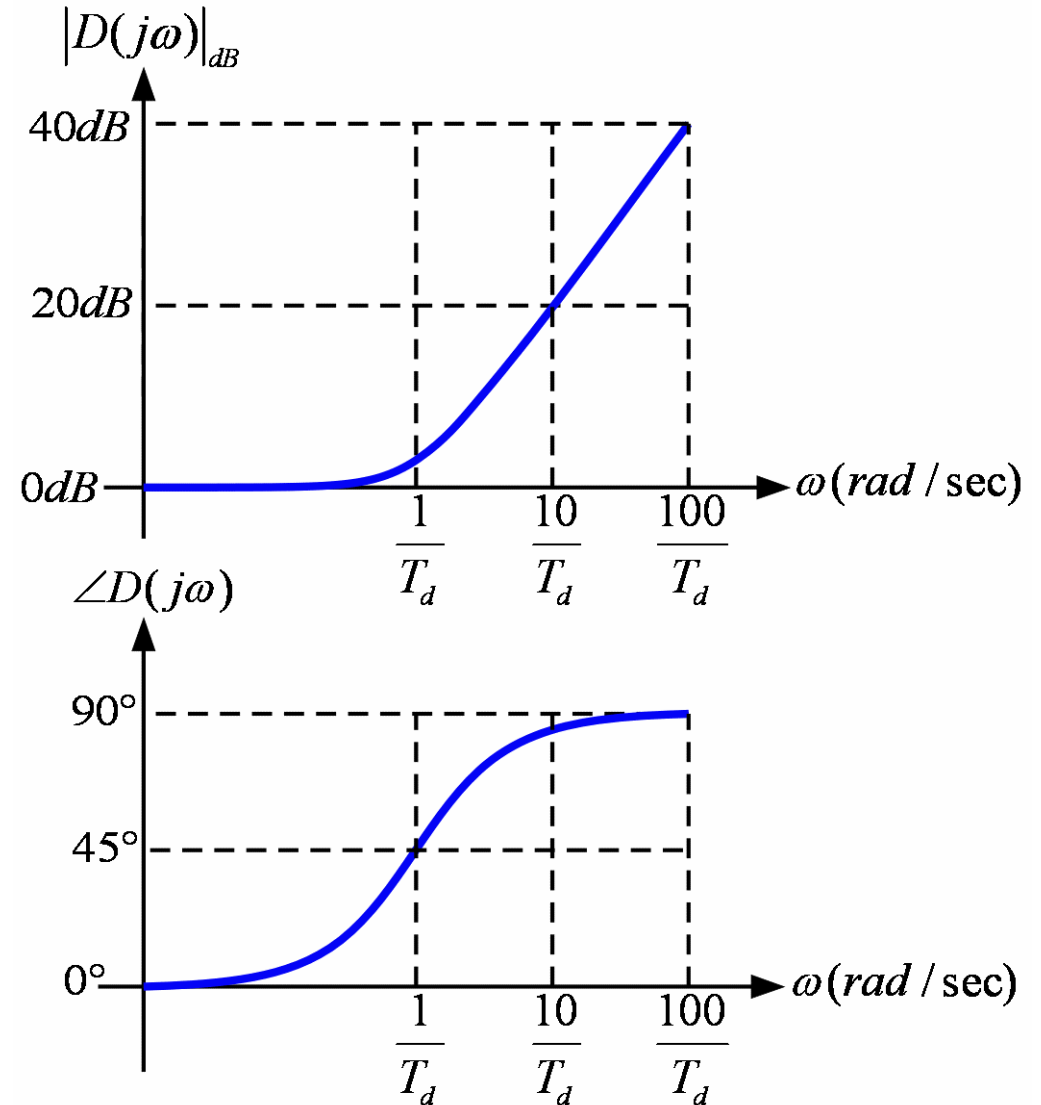


제어기 설계 과정

- 제어 시스템의 요구 사항 설정
- 센서와 구동기의 선정
- 제어 대상의 모델링
- 제어기의 설계
- 제어 시스템의 시뮬레이션
- 제어 시스템의 실험

PD 제어기의 설계

$$D(s) = K(1 + T_d s)$$



예제 7-1

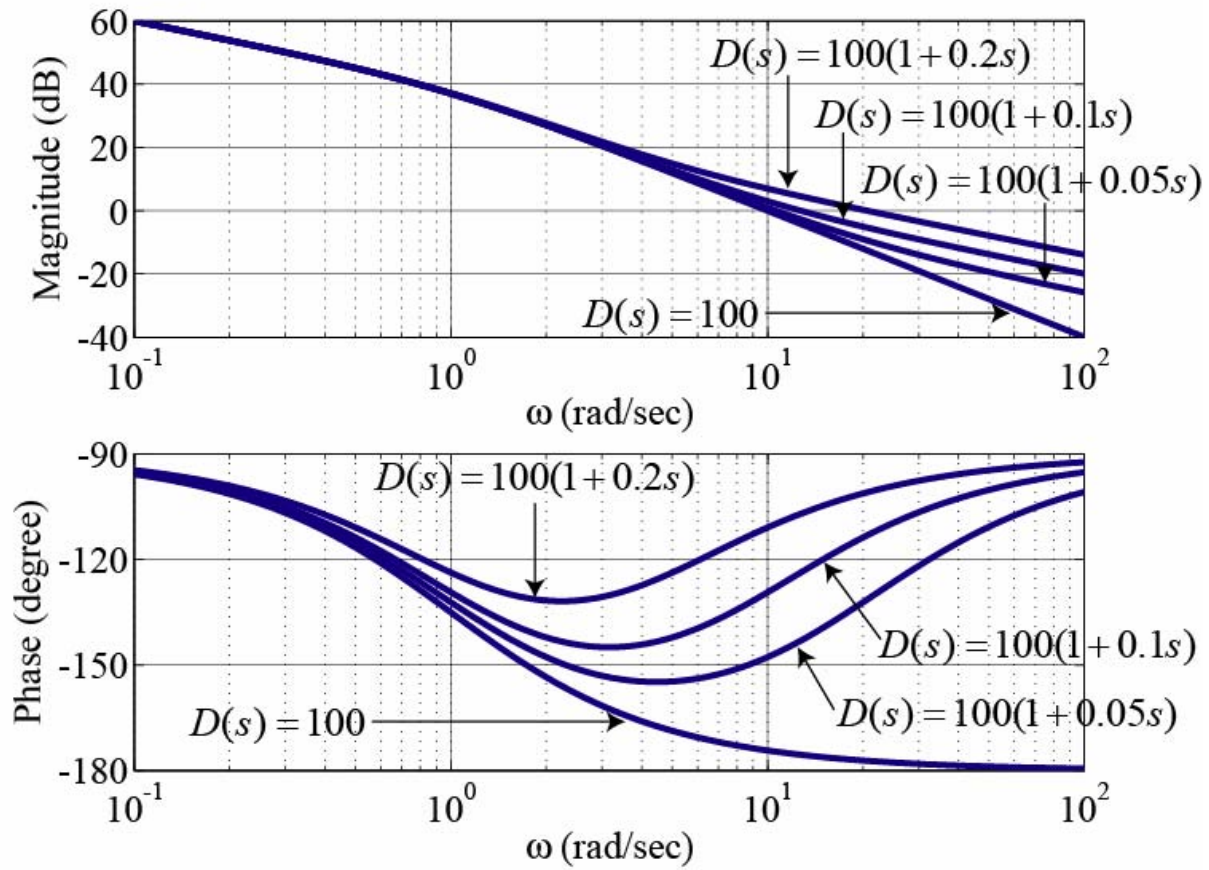
$$G(s) = \frac{1}{s(s+1)}$$

$$K_v = \lim_{s \rightarrow 0} s \frac{K}{s(s+1)} = K$$

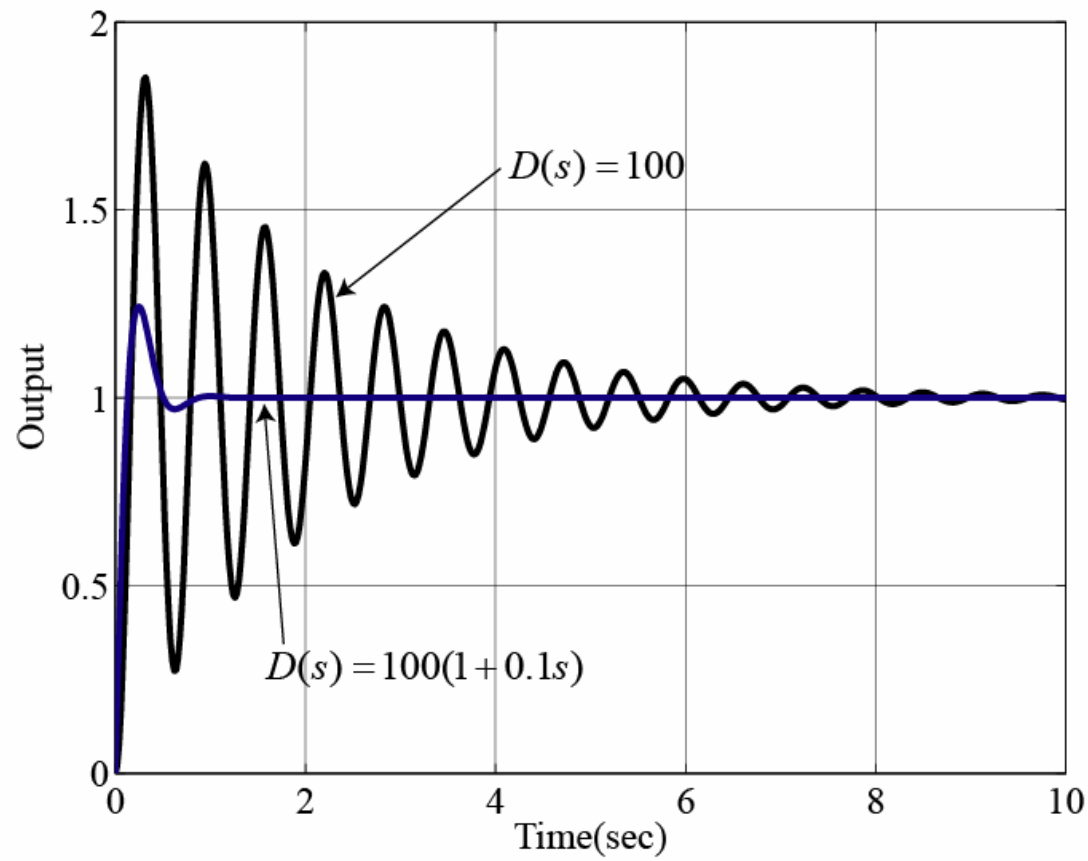
$$e_{ss} = \frac{1}{K_v} = \frac{1}{K}$$

$$D(s) = 100(1 + 0.1s)$$

예제 7-1

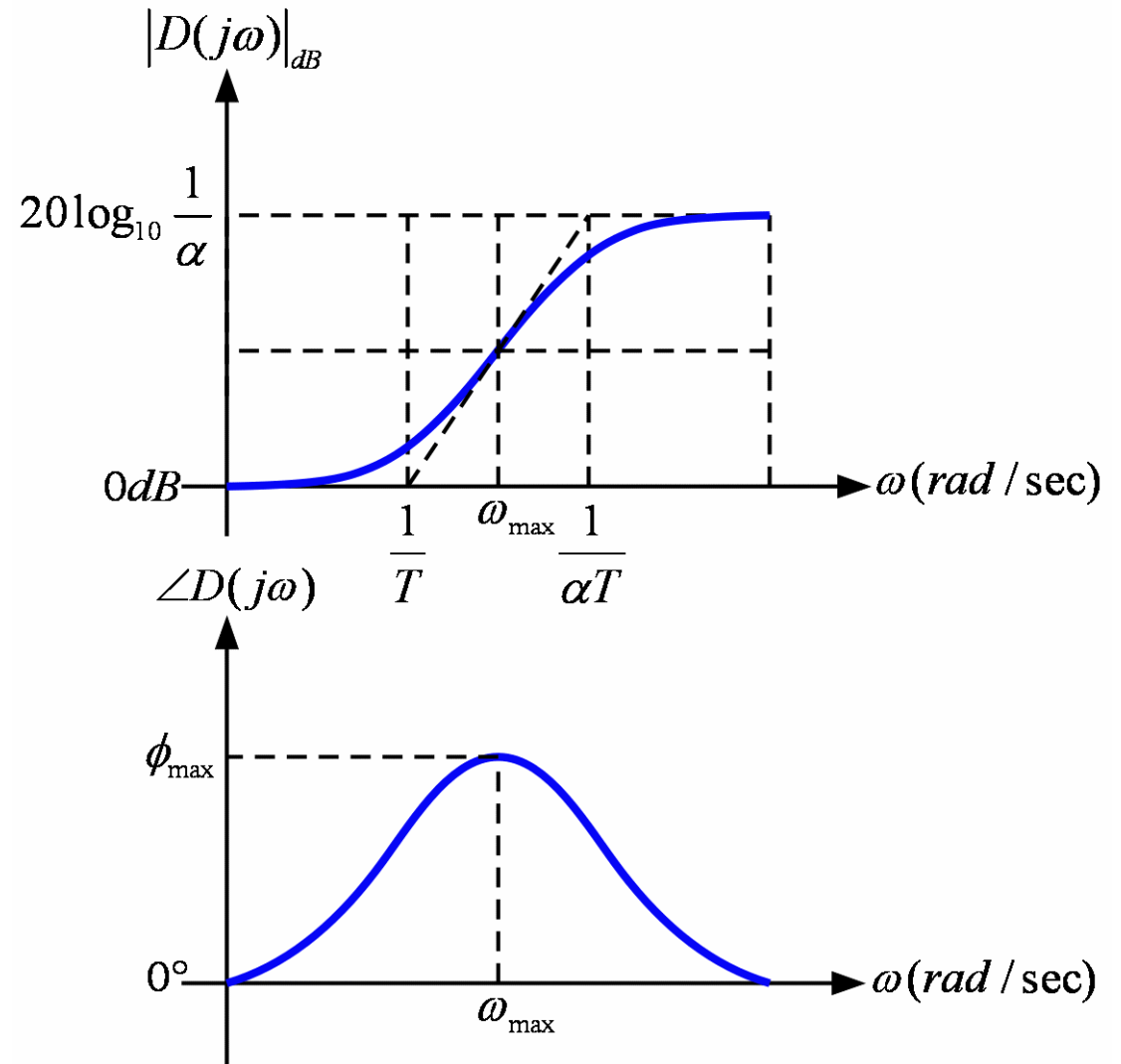


예제 7-1



진상 제어기의 설계

$$D(s) = K \frac{Ts + 1}{\alpha Ts + 1}$$



진상 제어기의 설계

$$\phi = \angle \left(\frac{jT\omega + 1}{j\alpha T\omega + 1} \right) = \tan^{-1}(T\omega) - \tan^{-1}(\alpha T\omega)$$

$$\log_{10} \omega_{\max} = \frac{1}{2} \left(\log_{10} \frac{1}{T} + \log_{10} \frac{1}{\alpha T} \right) \quad \omega_{\max} = \frac{1}{T\sqrt{\alpha}}$$

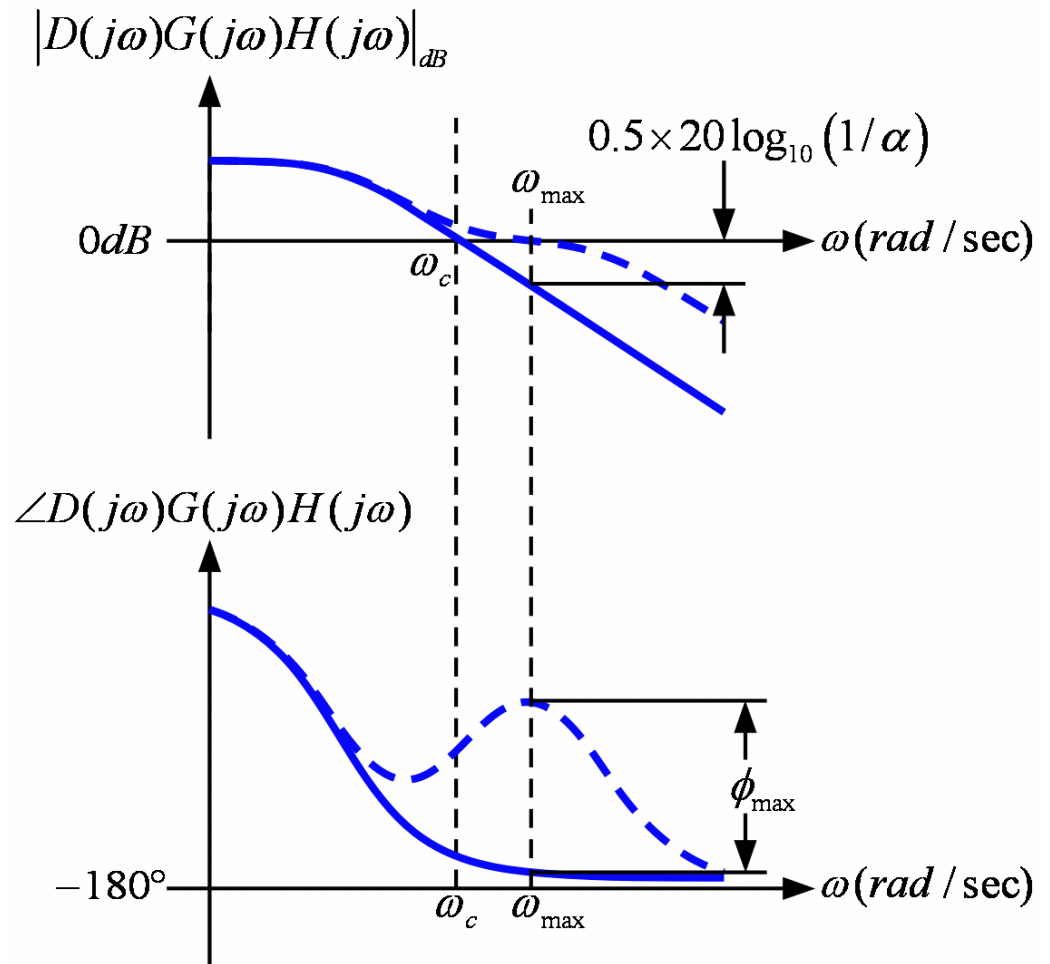
$$\phi_{\max} = \tan^{-1} \frac{1}{\sqrt{\alpha}} - \tan^{-1} \sqrt{\alpha}$$

$$\tan \phi_{\max} = \frac{1 - \alpha}{2\sqrt{\alpha}} \quad \sin \phi_{\max} = \frac{1 - \alpha}{1 + \alpha} \quad \alpha = \frac{1 - \sin \phi_{\max}}{1 + \sin \phi_{\max}}$$

진상 제어기의 설계

$$20\log_{10} |KG(j\omega_{\max})H(j\omega_{\max})| = -0.5 \times 20\log_{10} \frac{1}{\alpha}$$

$$T = \frac{1}{\omega_{\max} \sqrt{\alpha}}$$



예제 7-2

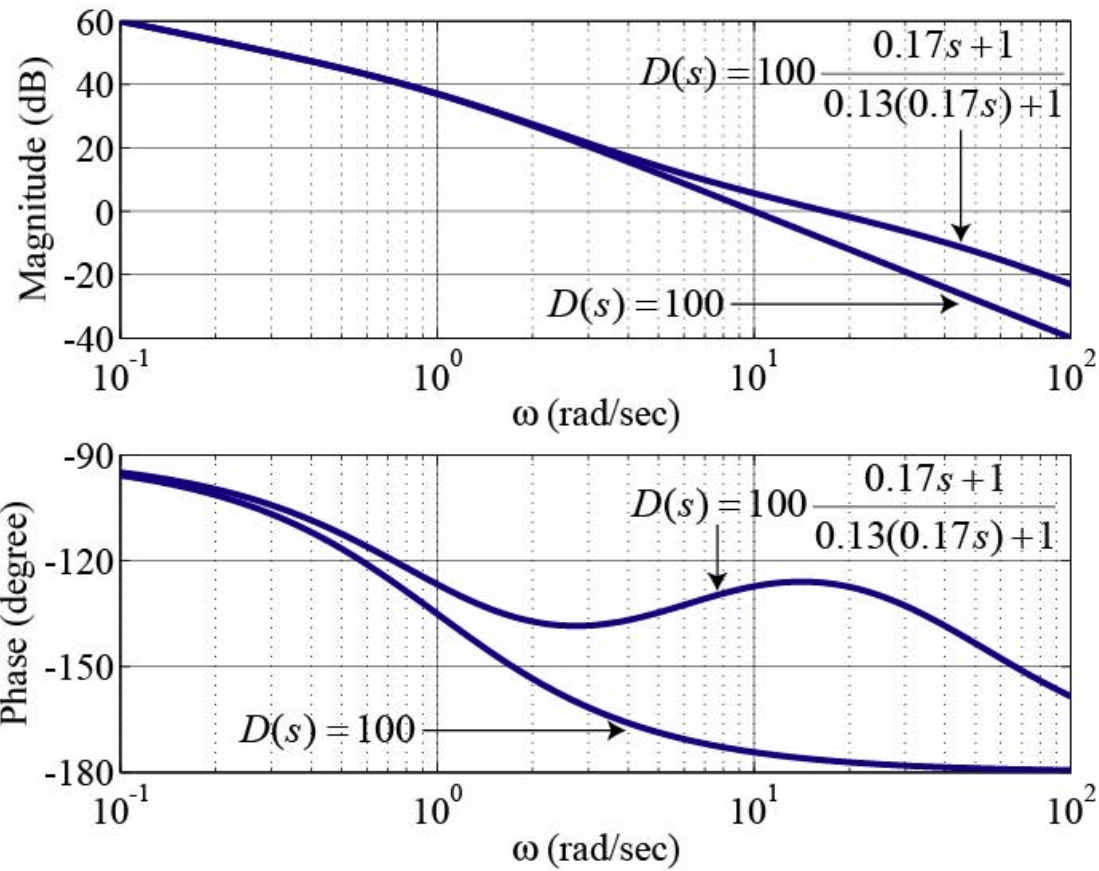
$$\phi_{\max} = 50^\circ \quad \alpha = 0.13$$

$$0.5 \times 20 \log_{10} (1/\alpha) = 9 \text{ dB}$$

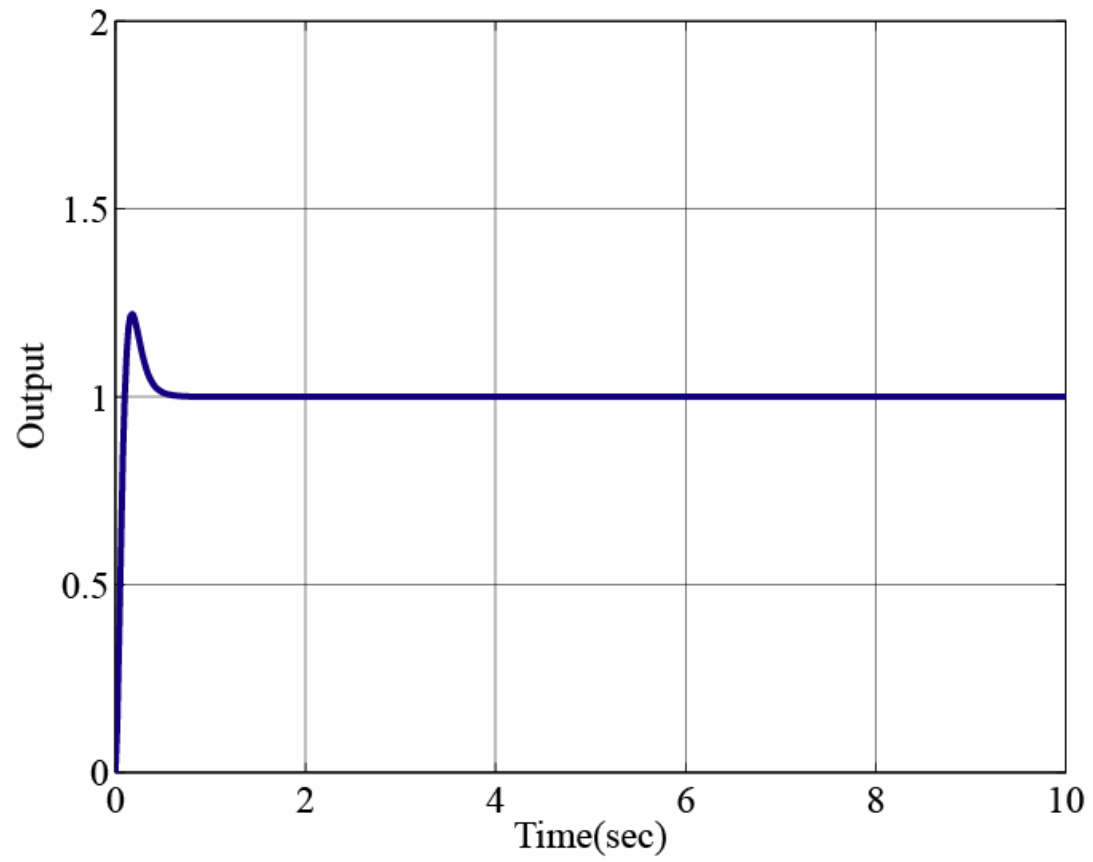
$$T = \frac{1}{\omega_{\max} \sqrt{\alpha}} = \frac{1}{16.7 \sqrt{0.13}} = 0.17$$

$$D(s) = K \frac{Ts + 1}{\alpha Ts + 1} = 100 \frac{0.17s + 1}{0.13(0.17s) + 1}$$

예제 7-2



예제 7-2



예제 7-3

$$G(s) = \frac{1}{s(s+1)(s/5+1)}$$

$$K_v = \lim_{s \rightarrow 0} s \frac{K}{s(s+1)(s/5+1)} = K$$

$$e_{ss} = \frac{1}{K_v} = \frac{1}{K}$$

$$\phi_{\max} = 55^\circ$$

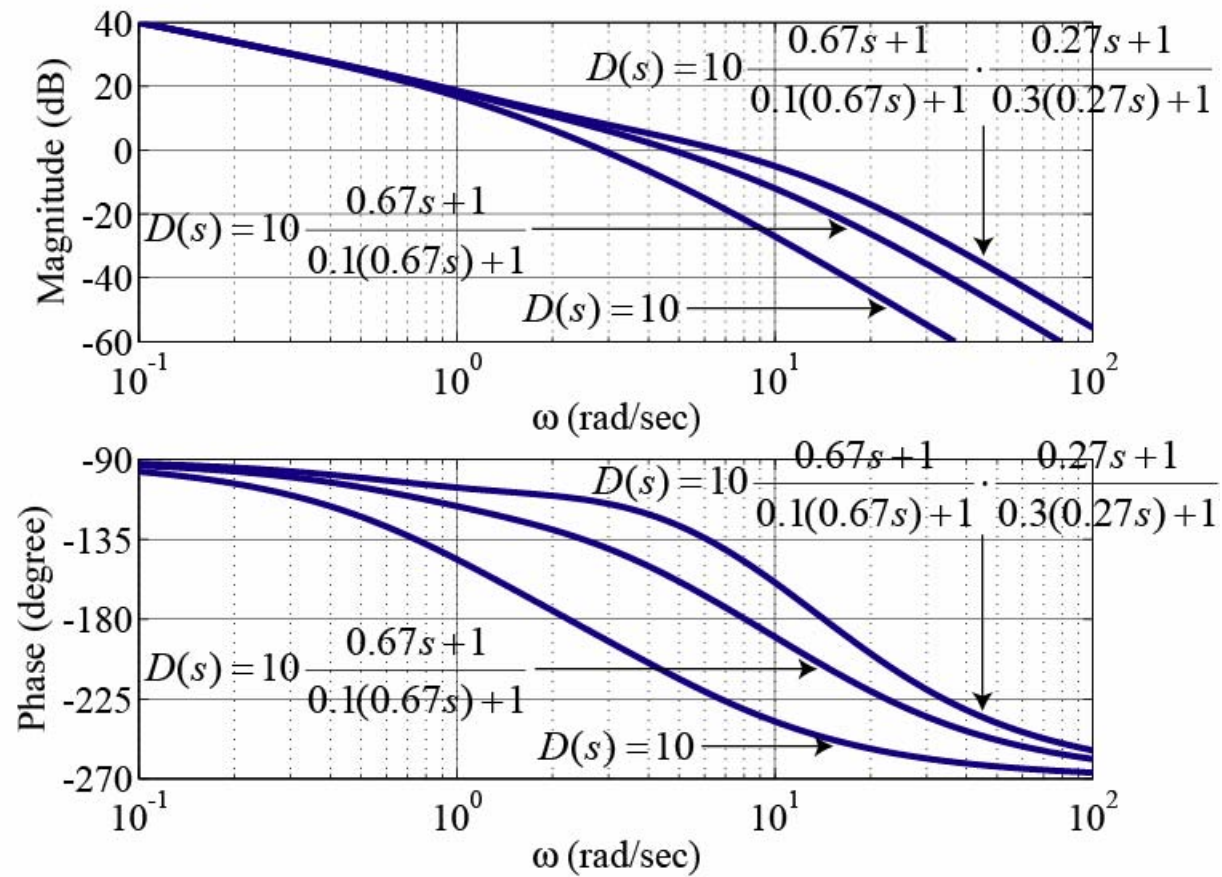
$$\alpha = 0.1$$

$$0.5 \times 20 \log_{10} (1/\alpha) = 10dB$$

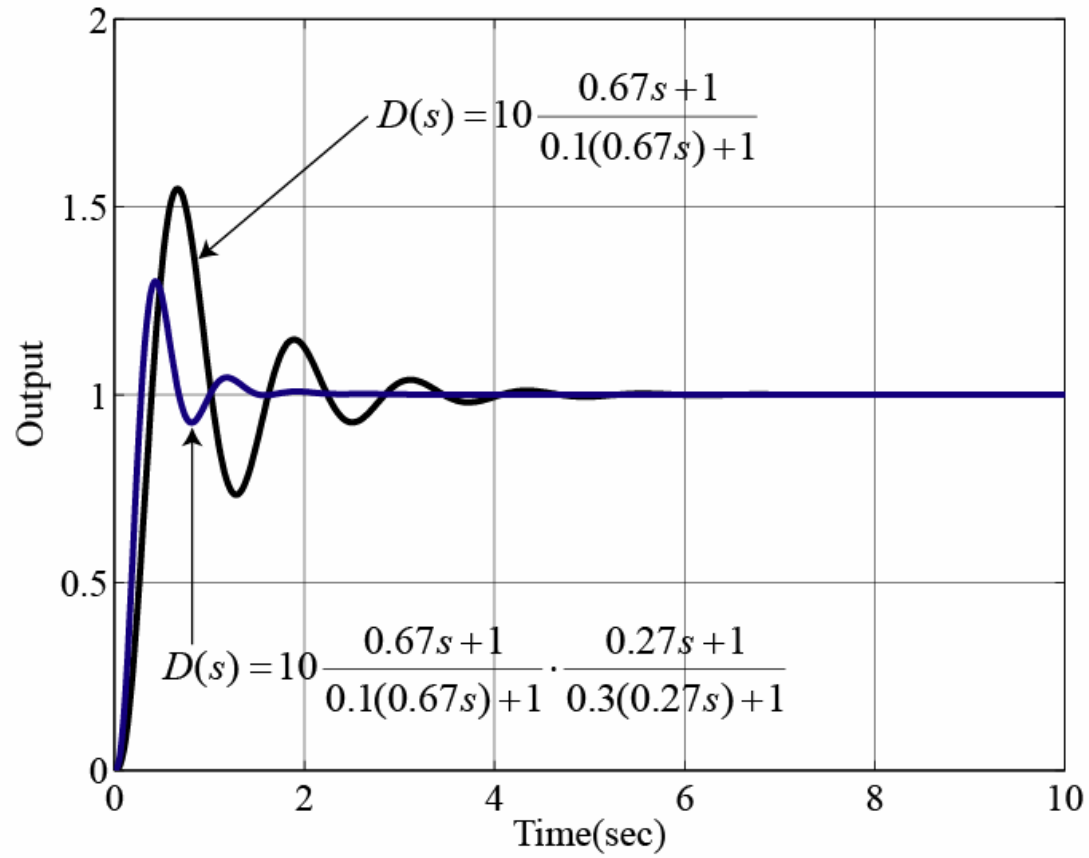
$$T = \frac{1}{\omega_{\max} \sqrt{\alpha}} = \frac{1}{4.73 \sqrt{0.1}} = 0.67$$

$$D(s) = K \frac{Ts+1}{\alpha Ts+1} = 10 \frac{0.67s+1}{0.1(0.67s)+1}$$

예제 7-3



예제 7-3



예제 7-3

$$\phi_{\max} = 32^\circ \qquad \alpha = 0.3$$

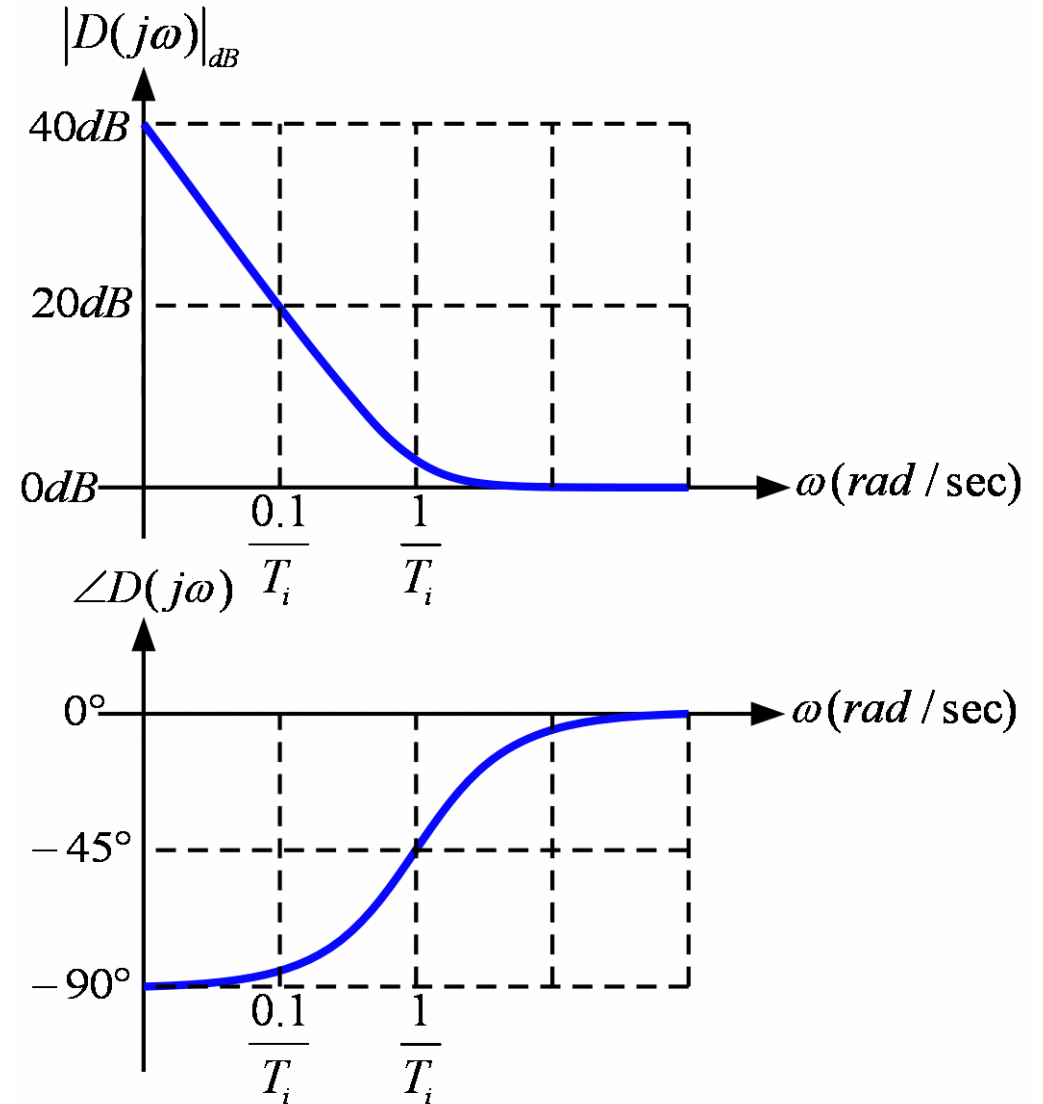
$$0.5 \times 20 \log_{10} (1/\alpha) = 5.2 \text{ dB}$$

$$T = \frac{1}{\omega_{\max} \sqrt{\alpha}} = \frac{1}{6.75 \sqrt{0.3}} = 0.27$$

$$D(s) = 10 \frac{0.67s + 1}{0.1(0.67s) + 1} \cdot \frac{0.27s + 1}{0.3(0.27s) + 1}$$

PI 제어기의 설계

$$D(s) = K \left(1 + \frac{1}{T_i s} \right)$$



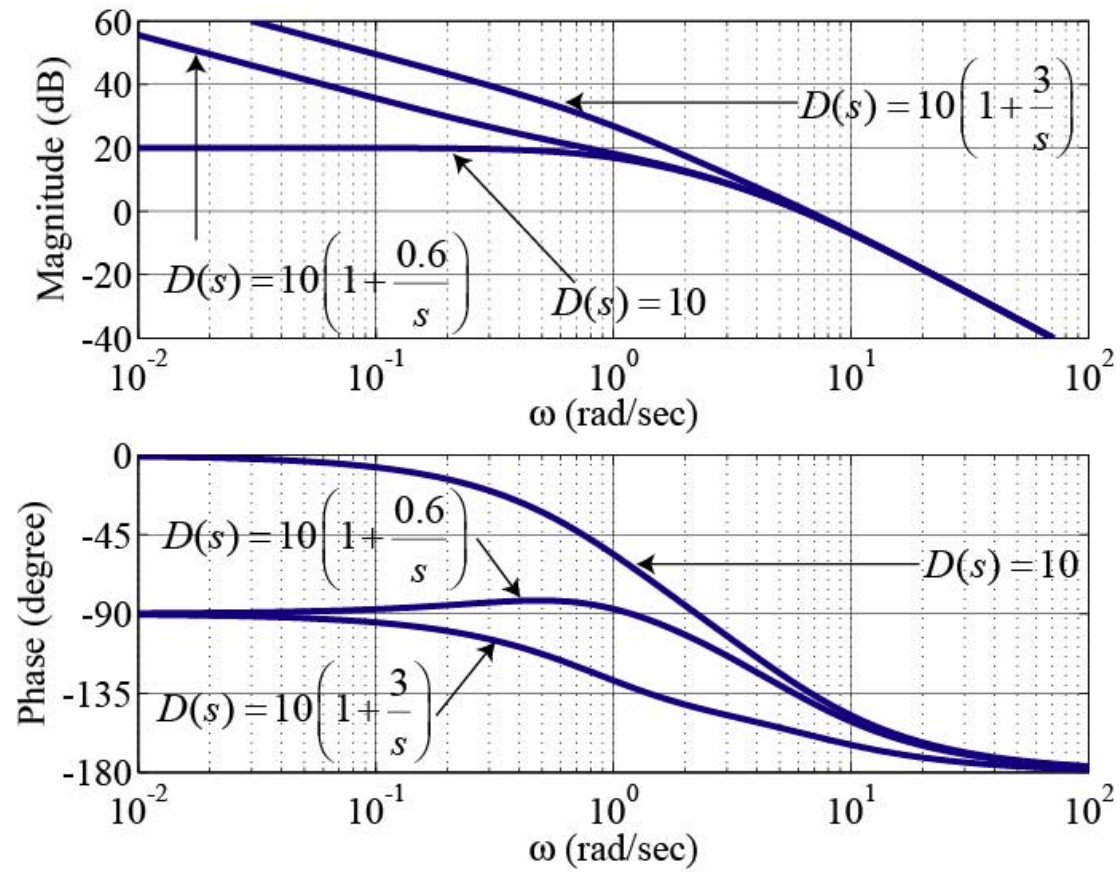
예제 7-4

$$G(s) = \frac{1}{(s+1)(s/5+1)}$$

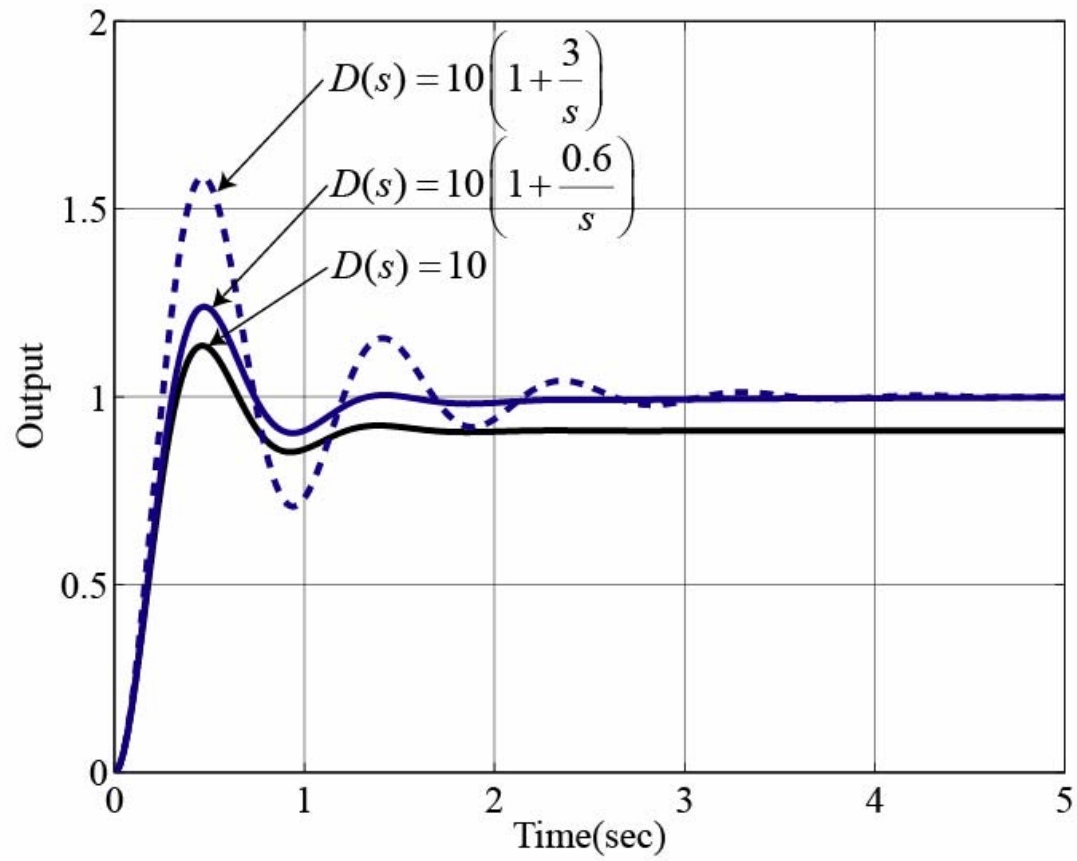
$$D(s) = 10 \left(1 + \frac{0.6}{s} \right)$$

$$D(s) = 10 \left(1 + \frac{3}{s} \right)$$

예제 7-4



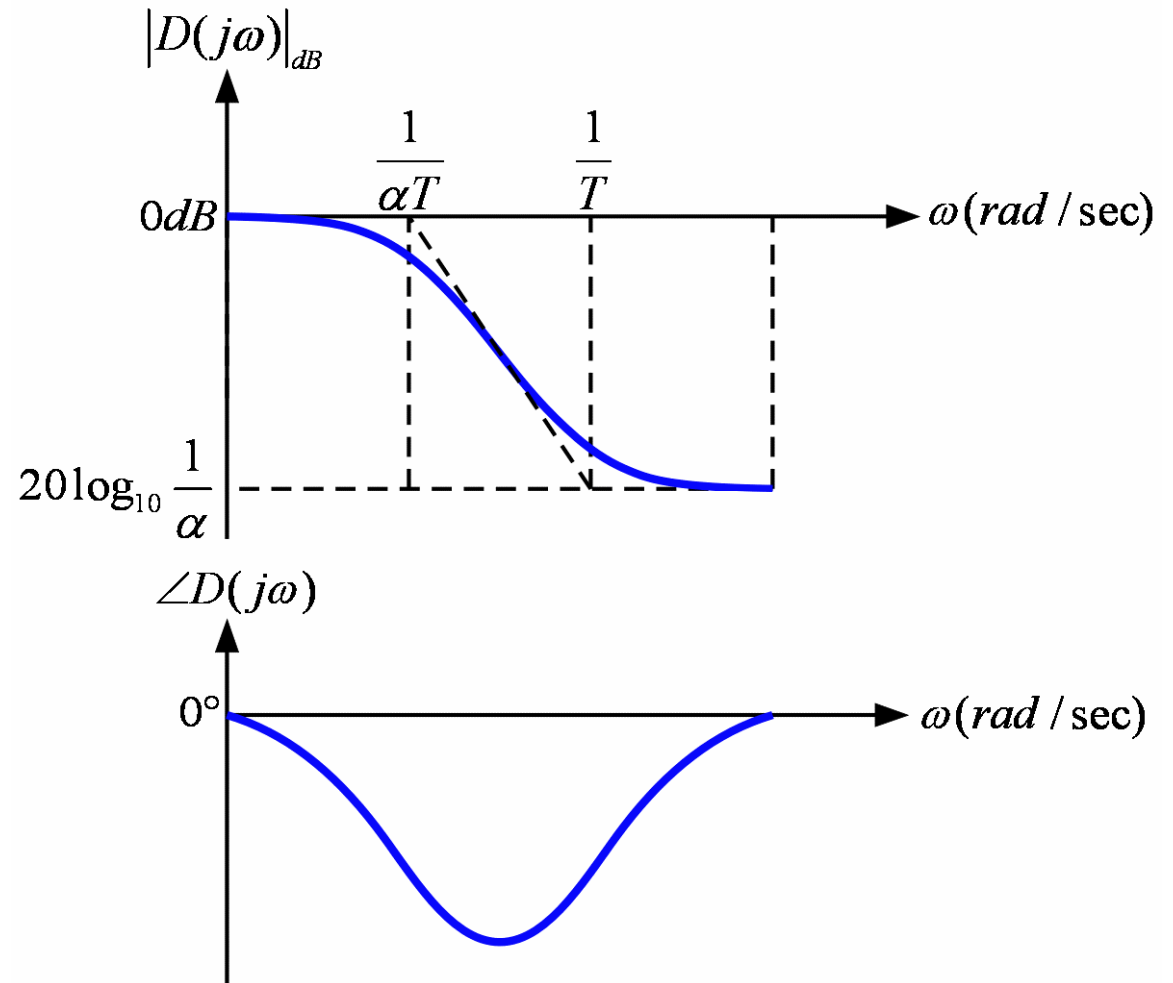
예제 7-4



지상 제어기의 설계

$$\phi = \angle \left(\frac{jT\omega + 1}{j\alpha T\omega + 1} \right) = \tan^{-1}(T\omega) - \tan^{-1}(\alpha T\omega)$$

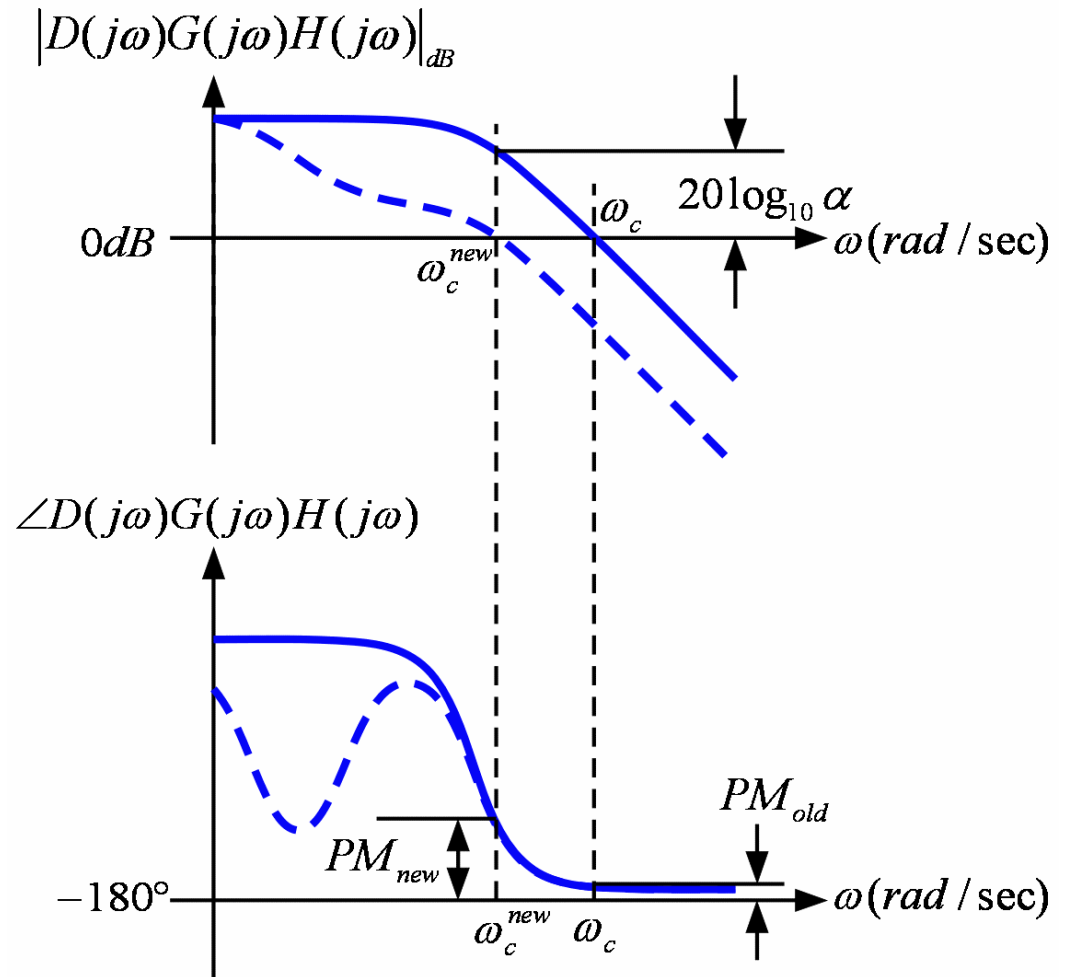
$$D(s) = K \frac{Ts + 1}{\alpha Ts + 1}$$



지상 제어기의 설계

$$20\log_{10} |KG(j\omega_c^{new})H(j\omega_c^{new})| = 20\log_{10} \alpha$$

$$\frac{1}{T} = \frac{\omega_c^{new}}{10}$$



예제 7-5

$$G(s) = \frac{1}{(s+1)(s/5+1)}$$

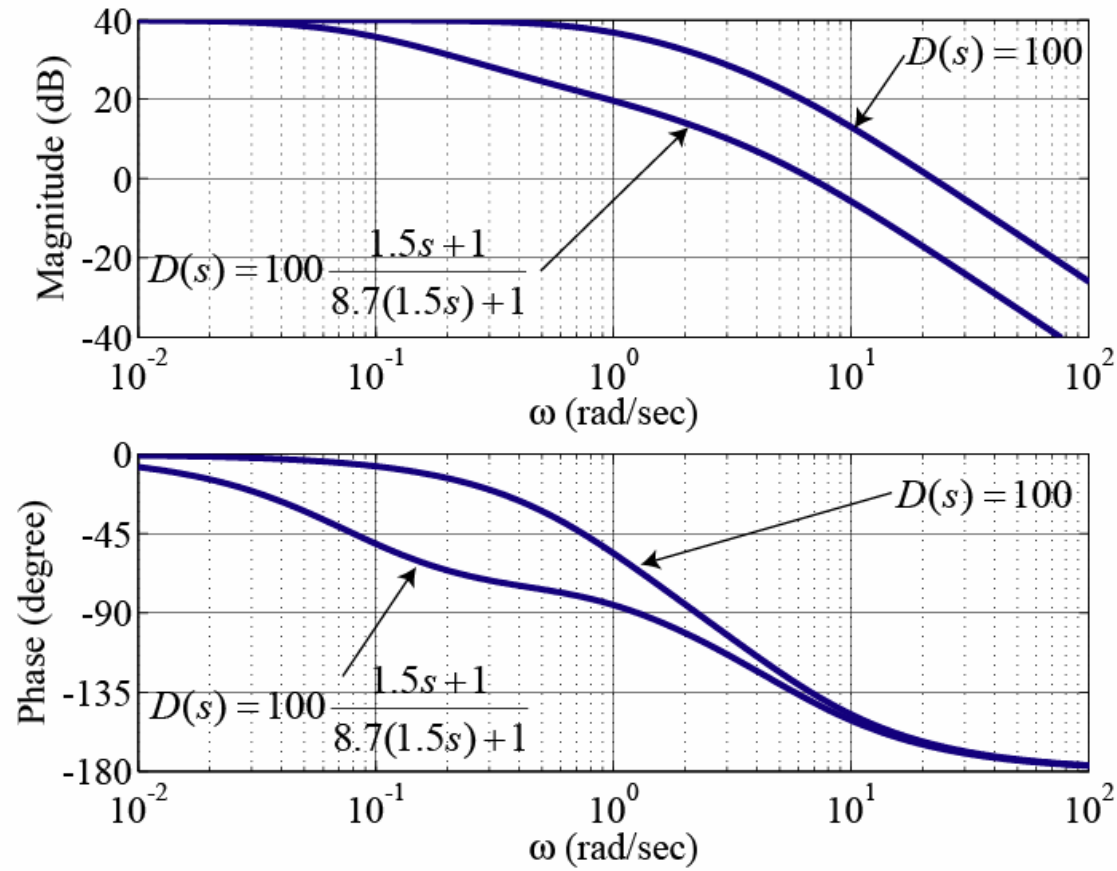
$$18.8 = 20 \log_{10} \alpha$$

$$\alpha = 10^{(18.8/20)} = 8.7$$

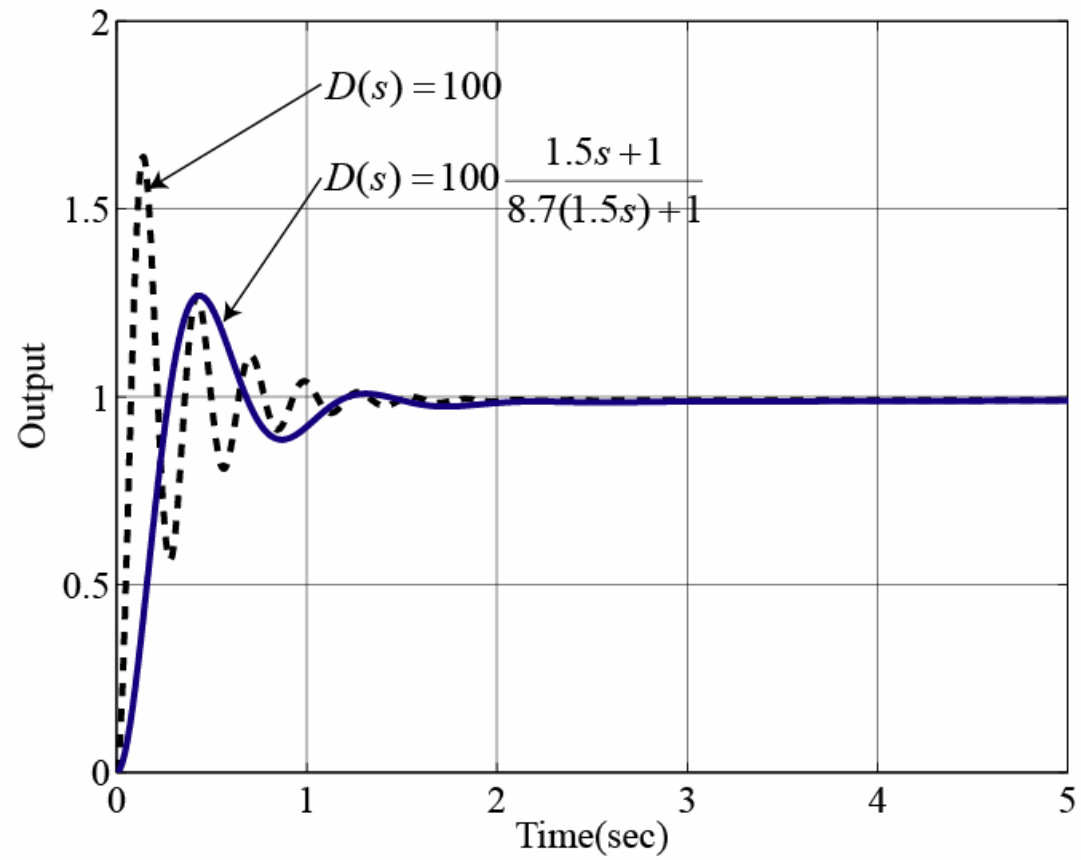
$$T = \frac{10}{\omega_c^{new}} = \frac{10}{6.75} = 1.5$$

$$D(s) = 100 \frac{1.5s+1}{8.7(1.5s)+1}$$

예제 7-5



예제 7-5



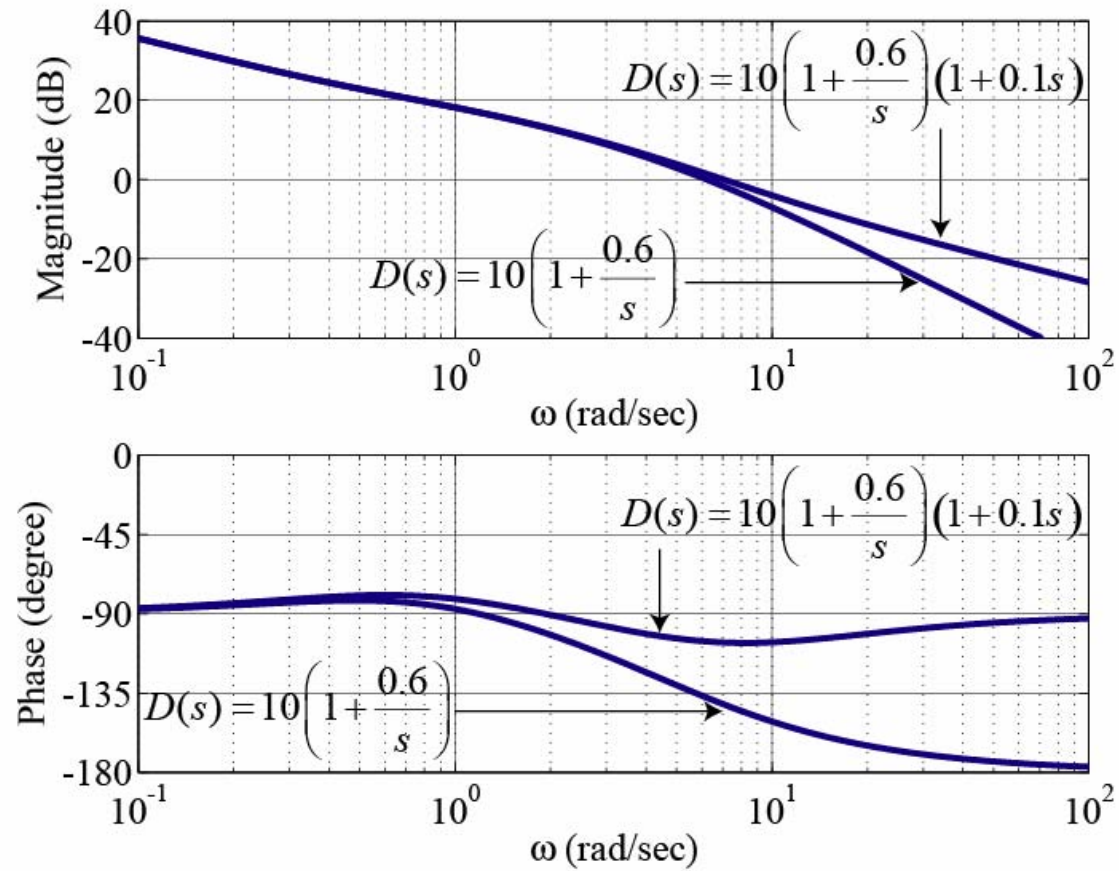
PID 제어기와 진상-지상 제어기

$$D(s) = K + \frac{K_i}{s} + K_d s$$

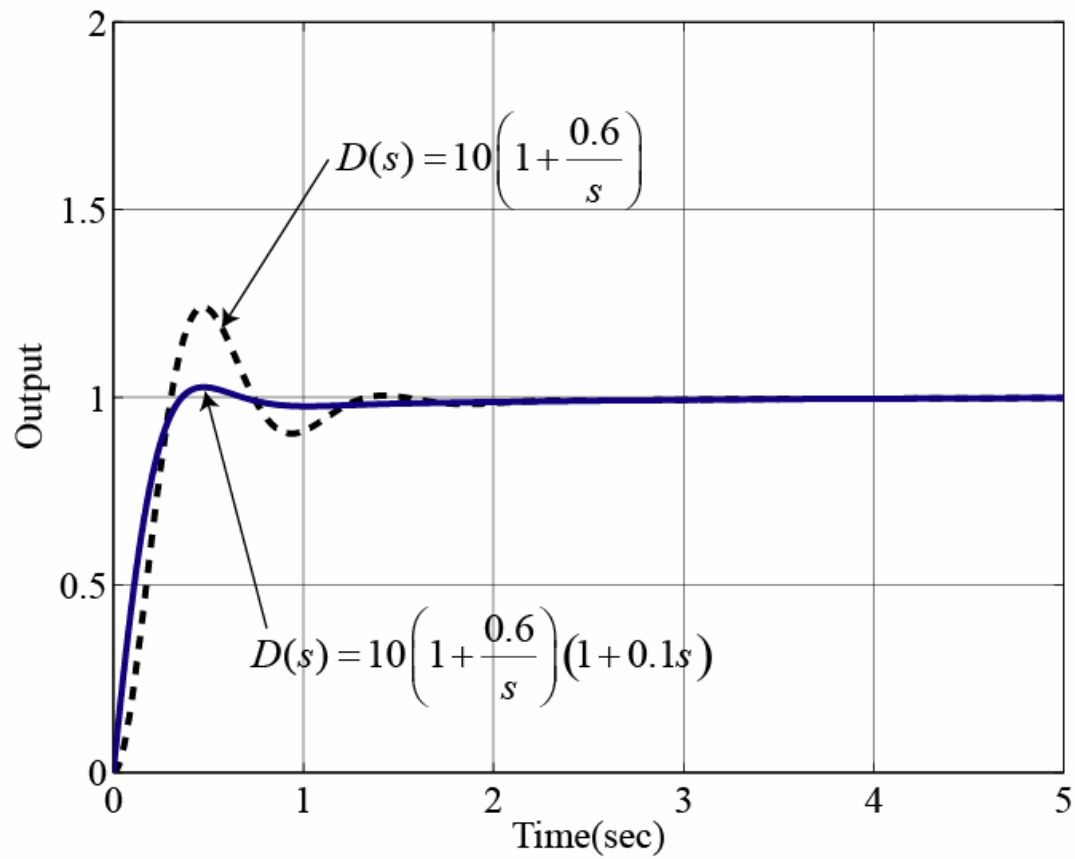
$$D(s) = K \left(1 + \frac{1}{T_i s} \right) (1 + T_d s)$$

$$D(s) = K \frac{T_1 s + 1}{\alpha_1 T_1 s + 1} \cdot \frac{T_2 s + 1}{\alpha_2 T_2 s + 1}$$

예제 7-6



예제 7-6



예제 7-7

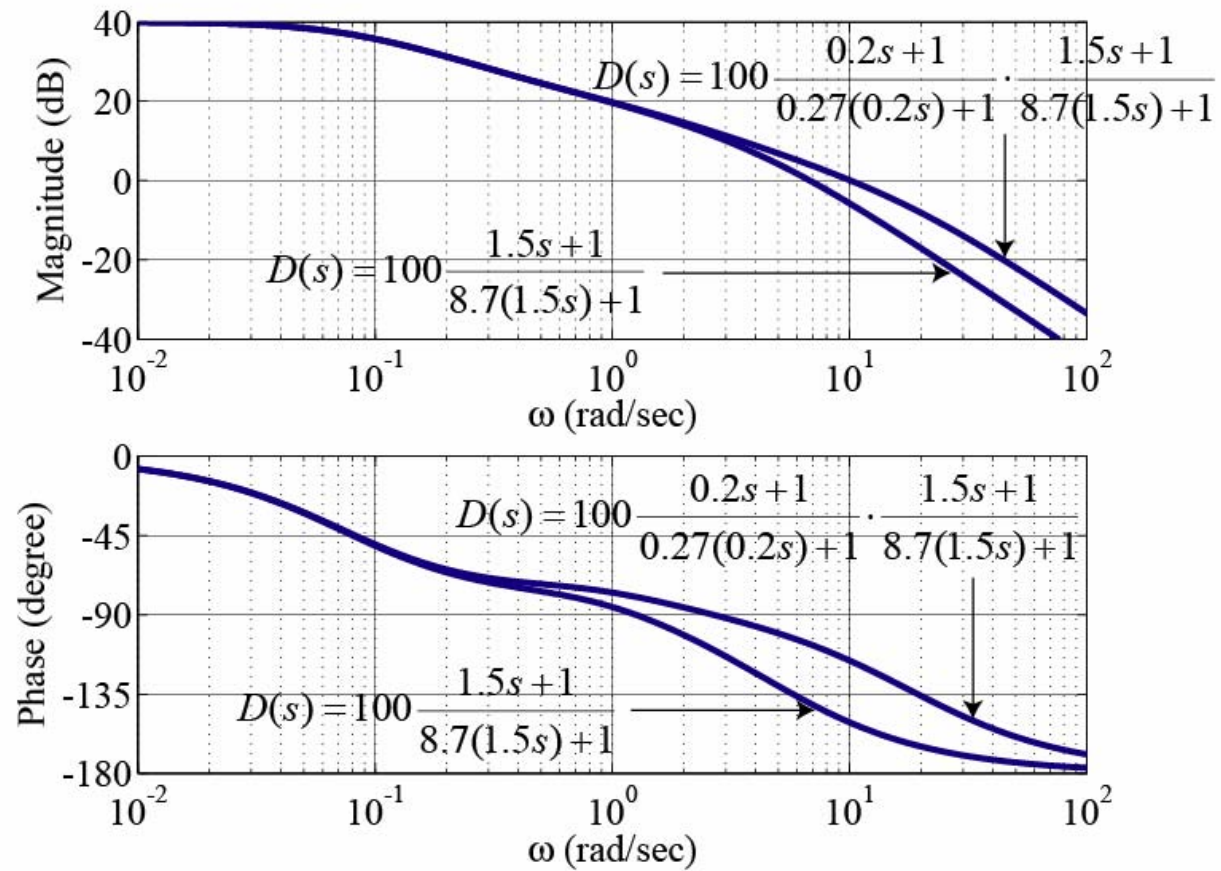
$$\phi_{\max} = 35^\circ \quad \alpha = 0.27$$

$$0.5 \times 20 \log_{10} (1/\alpha) = 5.7 \text{ dB}$$

$$T = \frac{1}{\omega_{\max} \sqrt{\alpha}} = \frac{1}{10\sqrt{0.27}} = 0.2$$

$$D(s) = 100 \frac{0.2s + 1}{0.27(0.2s) + 1} \cdot \frac{1.5s + 1}{8.7(1.5s) + 1}$$

예제 7-7



예제 7-7

