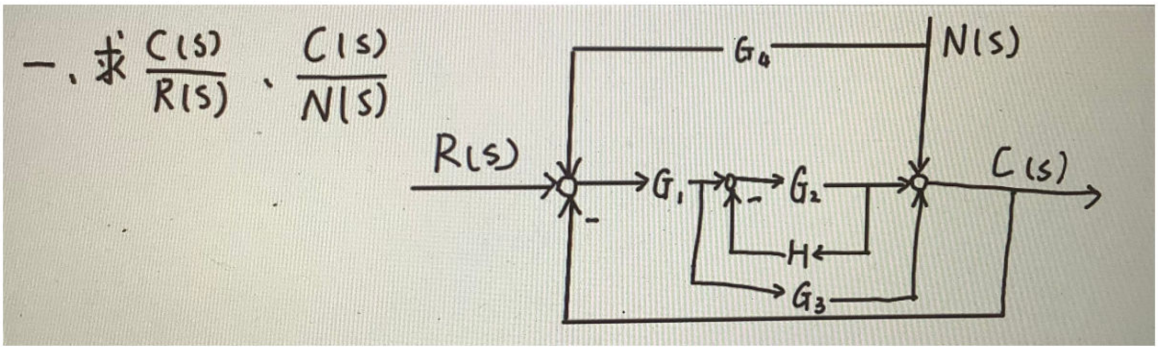


$\frac{C(s)}{R(s)}$: $L_1 = -G_2H$ $L_2 = -G_1G_2$ $L_3 = -G_1G_3$

$$\Delta = 1 + G_2H + G_1G_2 + G_1G_3 + G_1G_2G_3H$$

$P_1 = G_1G_2$ $\Delta_1 = 1$ $P_2 = G_1G_3$ $\Delta_1 = 1 + G_2H$

$$\frac{C(s)}{R(s)} = \frac{G_1G_2 + G_1G_3(1+G_2H)}{1+G_2H+G_1G_2+G_1G_3+G_1G_2G_3H}$$

$\frac{C(s)}{N(s)}$: $P_1 = 1$ $\Delta_1 = 1 + G_2H$ $P_2 = G_1G_2G_4$ $\Delta_2 = 1$

$P_3 = G_1G_3G_4$ $\Delta_3 = 1 + G_2H$

$$\frac{C(s)}{N(s)} = \frac{1+G_2H+G_1G_2G_4+G_1G_3G_4(1+G_2H)}{1+G_2H+G_1G_2+G_1G_3+G_1G_2G_3H}$$

二. 单位负反馈开环 $G(s)=\dfrac{k}{s(s+3)(s+5)}$，系统特征根实部不大于-1，求k取值范围。

$$\Phi(s)=\frac{k}{s(s+3)(s+5)+k}$$

$$(s-1)(s+2)(s+4)+k=0$$

$$(s^2+s-2)(s+4)+k=0$$

$$s^3+4s^2+s^2+4s-2s-8+k=0$$

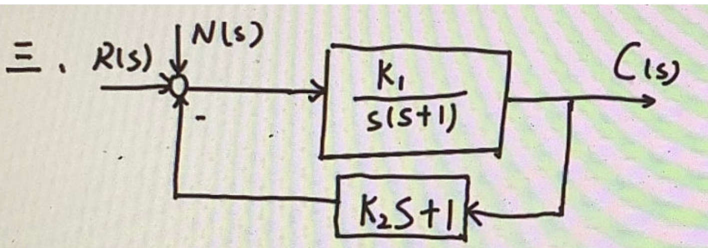
$$s^3+5s^2+2s+k-8=0$$

s^3	1	2
s^2	5	$k-8$
s^1	$\frac{18-k}{5}$	0
s^0	$k-8$	

$\frac{18-k}{5}\geq 0$ 且 $k-8>0$

$8<k\leq 18$

三、



(1) $t_p=0.5s$，$\sigma\%=2\%$，求 K_1，K_2。

(2) $K_2=0$，求R(s)和N(s)均为单位阶跃时的稳态误差 e_{ss}。

(1) $G(s)H(s)=\dfrac{k_1(k_2s+1)}{s(s+1)}$ $=\dfrac{k_1}{s^2+(k_1k_2+1)s+k_1}$

$\Phi(s)=\dfrac{\frac{k_1}{s(s+1)}}{1+\frac{k_1(k_2s+1)}{s(s+1)}}=\dfrac{k_1}{s(s+1)+k_1(k_2s+1)}$

$\begin{cases}\omega_n^2=k_1\\2\zeta\omega_n=k_1k_2+1\end{cases}$ $\begin{cases}t_p=\dfrac{\pi}{\omega_n\sqrt{1-\zeta^2}}=0.5\\e^{-\frac{\pi\zeta}{\sqrt{1-\zeta^2}}}=0.02\end{cases}$ $\begin{cases}\omega_n=10.03\\\zeta=0.780\end{cases}$

$k_1=100.741$ $k_2=0.145$

(2) $e_{ss1}=\dfrac{1}{1+k_p}$

$k_p=\lim\limits_{s\to 0}G(s)H(s)=\infty$

$e_{ss1}=0$

$E_N(s)=-\dfrac{N(s)G(s)}{1+G(s)H(s)}=-\dfrac{1}{s}\cdot\dfrac{\frac{k_1}{s(s+1)}}{1+\frac{k_1}{s(s+1)}}=-\dfrac{1}{s}\cdot\dfrac{k_1}{s^2+s+k_1}$

$$e_{ss_2} = \lim_{s \to 0} sE_{1N}(s) = -1$$

$$e_{ss} = -1$$

四、单位负反馈 $G(s)=\dfrac{(s+k)(s+4)}{s(s^2+s-3)}$

(1) 绘制闭环根轨迹 $(k: 0\to\infty)$

(2) 输入单斜坡信号，使稳态误差 $|e_{ss}|\le 1$，求 k 的取值范围。

(1)

$$s^3+s^2-3s+s^2+4s+ks+4k=0$$

$$s^3+2s^2+s+k(s+4)=0$$

$$G^*(s)=\frac{k(s+4)}{s^3+2s^2+s}=\frac{k(s+4)}{s(s+1)^2}$$

$p_1=0$ $p_2=-1$ $p_3=-1$ $z_1=-4$

$n=3$ $m=1$

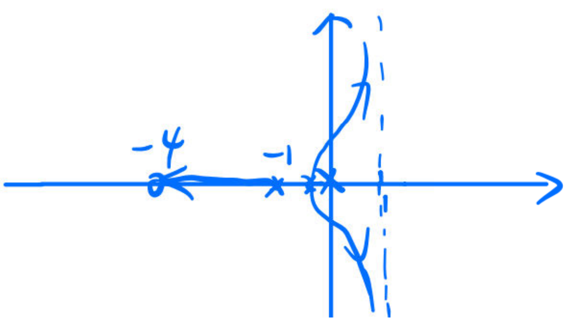
3条分支数 2条渐近线

$$\varphi_a=\frac{(2k+1)\pi}{2}=\pm 90^\circ$$

$$\sigma_a=\frac{\Sigma p-\Sigma z}{2}=1$$

分离点：$\Sigma\dfrac{1}{d-z}=\Sigma\dfrac{1}{d-p}$ $\dfrac{1}{d}+\dfrac{1}{d+1}+\dfrac{1}{d+1}=\dfrac{1}{d+4}$

$$\frac{1}{d}+\frac{2}{d+1}=\frac{1}{d+4}\qquad d=-0.354$$



(2) $e_{ss} = \frac{1}{K_v}$

$$K_v = \lim_{s \to 0} s G(s) H(s) = \lim_{s \to 0} \frac{(s+k)(s+4)}{s^2+s-3}$$

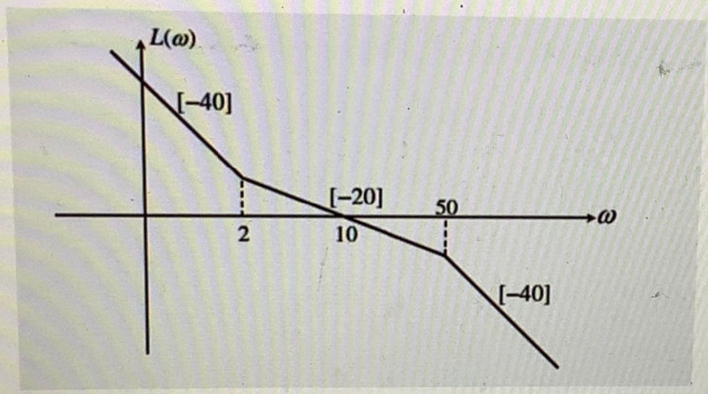
$$= \frac{4k}{-3} = -\frac{4k}{3}$$

$$|e_{ss}| = \left| -\frac{3}{4k} \right| \le 1$$

$$k \ge \frac{3}{4}$$

五.(1)写出开环单位负反馈 $G(s)H(s)$

(2)绘制开环的幅相特性曲线，用奈氏判断系统稳定性。



(1) $$G(s)H(s)=\frac{k(T_1s+1)}{s^2(T_2s+1)}$$ $T_1=\frac{1}{2}$ $T_2=\frac{1}{50}$

$$\frac{y_0}{\lg 2-\lg 10}=-20$$

$$-20(\lg 2-1)=y_0$$

$$y_0=20(1-\lg 2)$$

过 $(1, 20\lg k)$ $(2, 20(1-\lg 2))$

$$\frac{20-20\lg 2-20\lg k}{\lg 2-\lg 1}=-40$$

$k=$

$$\frac{1-\lg 2-\lg k}{\lg 2}=-2$$

$$-2\lg 2=\lg\frac{10}{2k}$$

$$(2)^{-2}=\frac{10}{2k}$$

$$\frac{1}{4}=\frac{10}{2k} \qquad k=20$$

$$G(s)H(s)=\frac{20\left(\frac{1}{2}s+1\right)}{s^2\left(\frac{1}{50}s+1\right)}$$

(2) $$G(j\omega)H(j\omega)=\frac{20\left(\frac{1}{2}j\omega+1\right)}{-\omega^2\left(\frac{1}{50}j\omega+1\right)}=$$

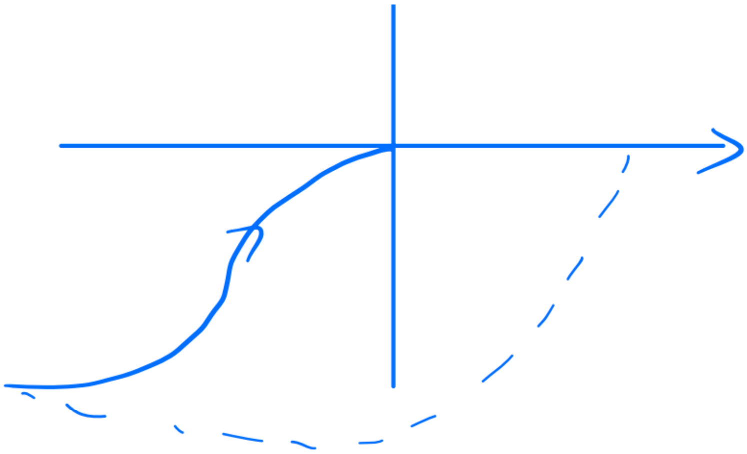
$$|G(j\omega)H(j\omega)|=\frac{20\sqrt{\frac{\omega^2}{4}+1}}{-\omega^2\sqrt{\frac{\omega^2}{2500}+1}}$$

$$\angle(G(j\omega)H(j\omega))=\arctan\frac{\omega}{2}-180^\circ-\arctan\frac{\omega}{50}$$

$\omega\to 0$ $A=\infty$ $\varphi=-180^\circ$

$\omega\to\infty$ $A=0$ $\varphi=-180^\circ$

稳定



六、单位负反馈 $G(s)=\dfrac{K}{s(1+0.1s)(1+s)}$

(1) 求幅值裕度为 20 dB 时的 K 值

(2) 求相位裕度为 60° 时的 K 值

(1) $G(j\omega)=\dfrac{K}{j\omega(1+0.1j\omega)(1+j\omega)}$ $\quad \dfrac{jK\omega(1-0.1j\omega)}{-\omega^2}$

$$|G(j\omega)|=\frac{K}{\omega\sqrt{0.01\omega^2+1}\cdot\sqrt{\omega^2+1}}$$

$$\angle G(j\omega)=-90^\circ-\arctan 0.1\omega-\arctan\omega=-180^\circ$$

$$1-0.1\omega^2=0$$

$$\omega=\sqrt{10}$$

$$h=\frac{\sqrt{10}\cdot\sqrt{1.1}\cdot\sqrt{11}}{K}=20$$

$$K=\frac{11}{20}$$

(2) $180^\circ-90^\circ-\arctan 0.1\omega_c-\arctan\omega_c=60^\circ$

$$\arctan 0.1\omega_c+\arctan\omega_c=30^\circ$$

$$\frac{1.1\omega_c}{\qquad}=\frac{\sqrt{3}}{\cdot}$$

$1-0.1\omega_c^2$ 　 3

$$3.3\omega_c = -0.1\sqrt{3}\,\omega_c^2+\sqrt{3}$$

$$0.1\sqrt{3}\,\omega_c^2+3.3\omega_c-\sqrt{3}=0$$

$$\omega_c=0.511$$

$$\frac{K}{0.511\sqrt{0.01\times0.511^2+1}\cdot\sqrt{0.511^2+1}}=1$$

$$K=0.575$$