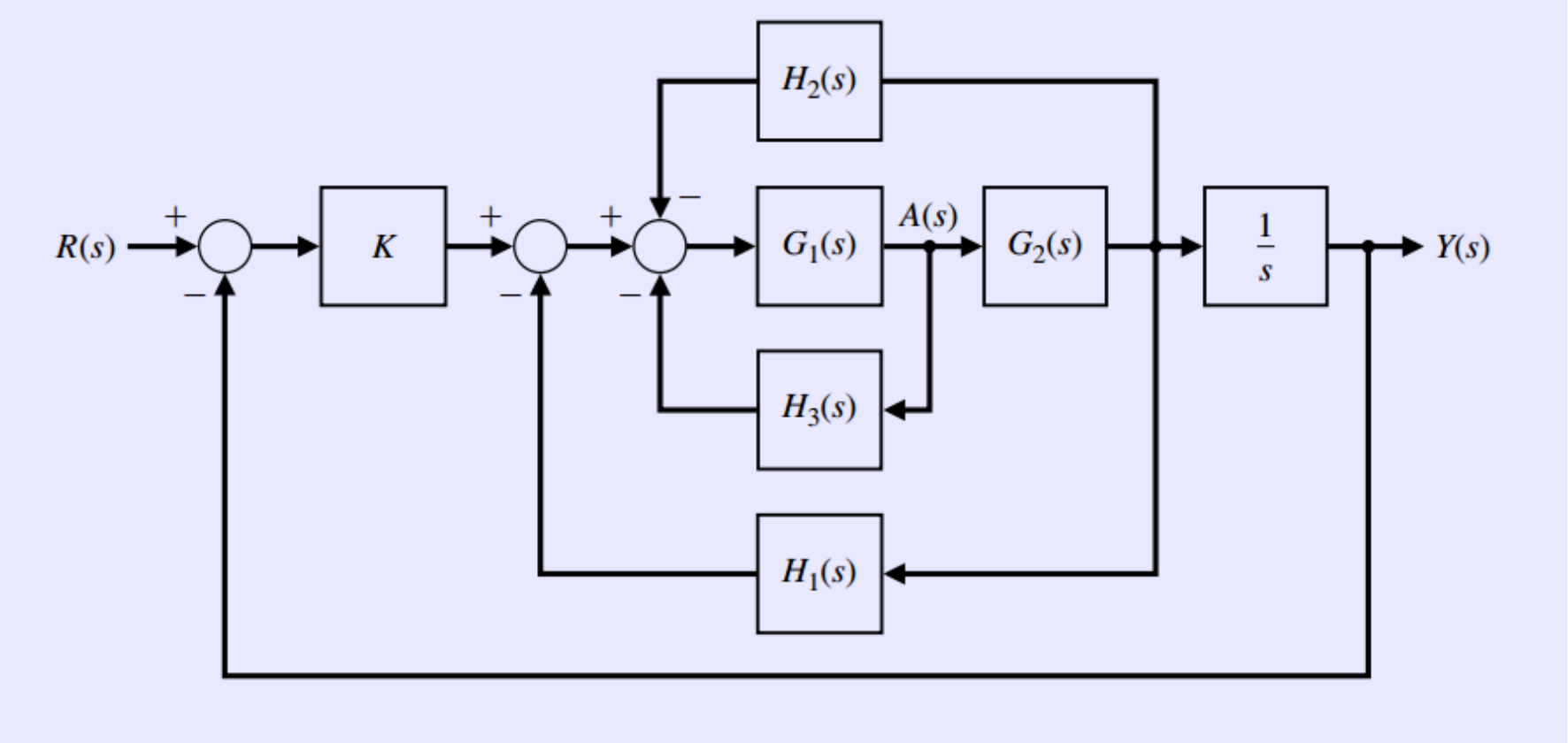
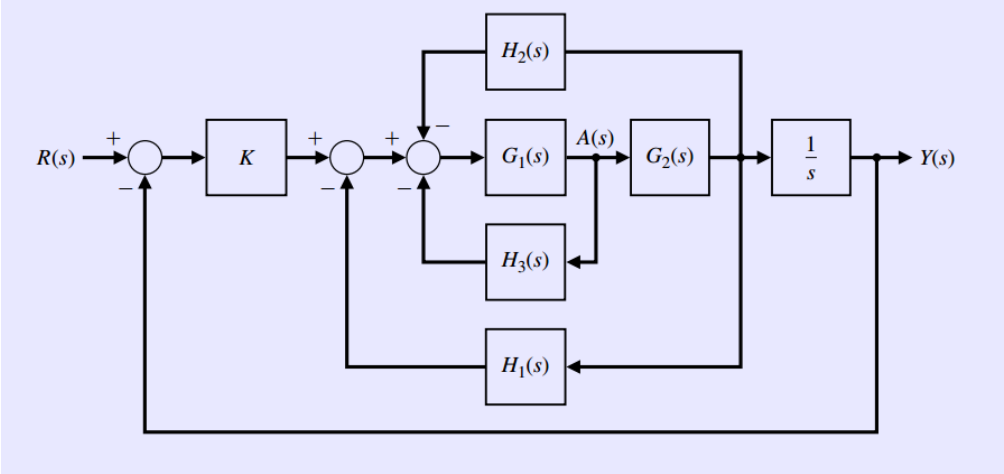
习题1 下图为1930s控制工程师N.Minorsky为美国海军设计的军舰航向习题；

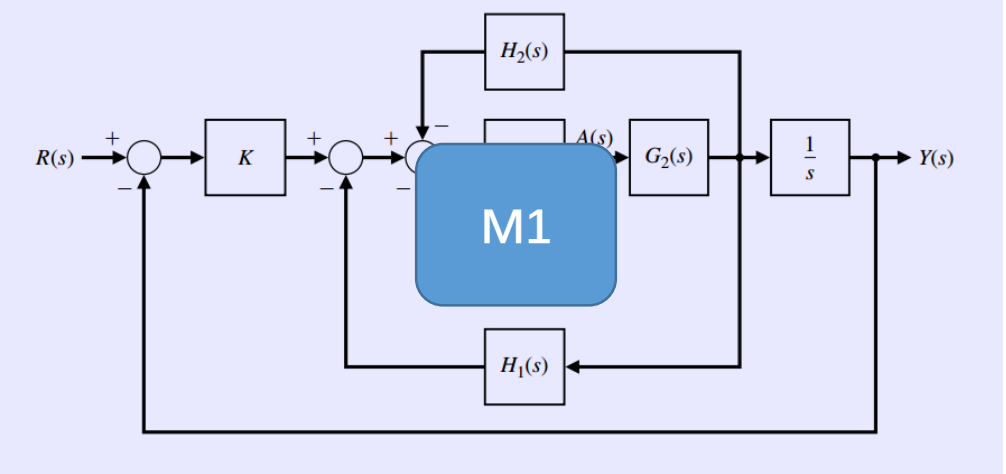
其中Y(s)为船的航线，R(s)为期望航线；A(s)是方向舵偏角。求传函Y(s)/R(s)。

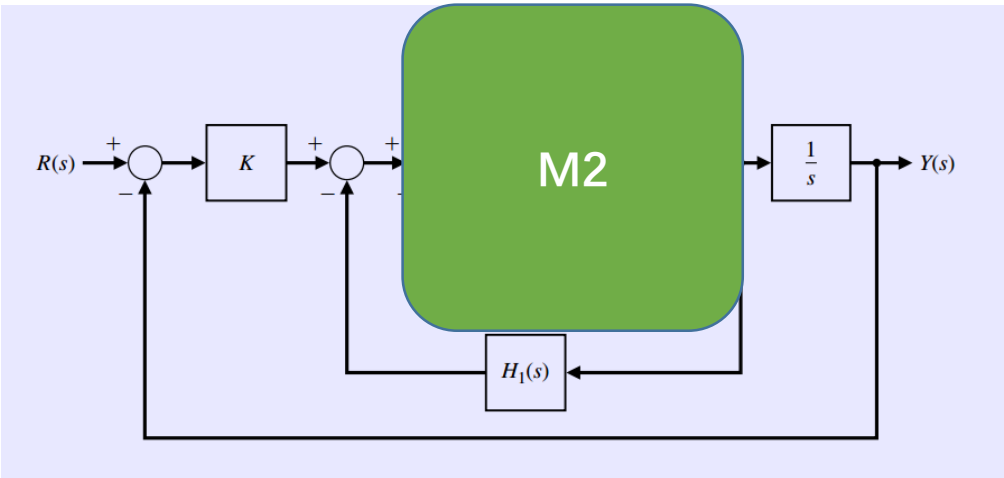


解法1 框图等效变换

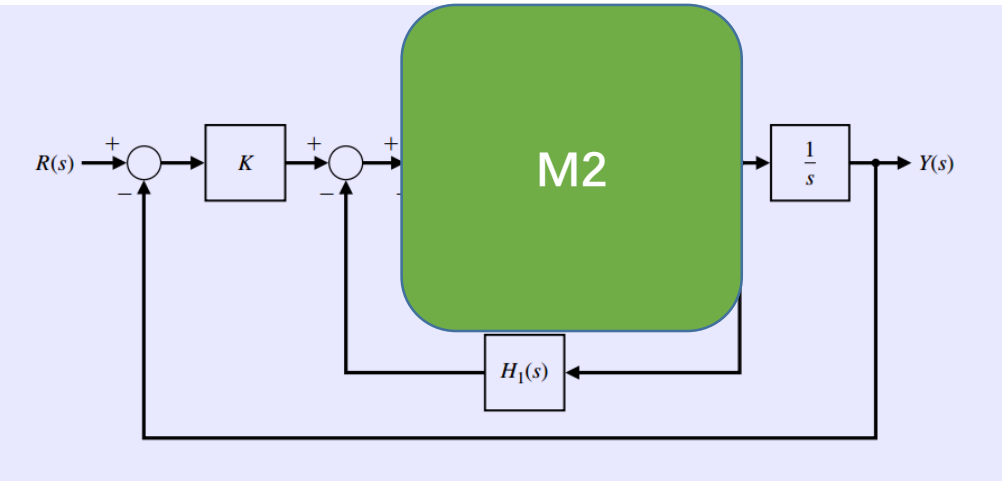
$$M_1 = \frac{G_1}{1+G_1H_3}$$

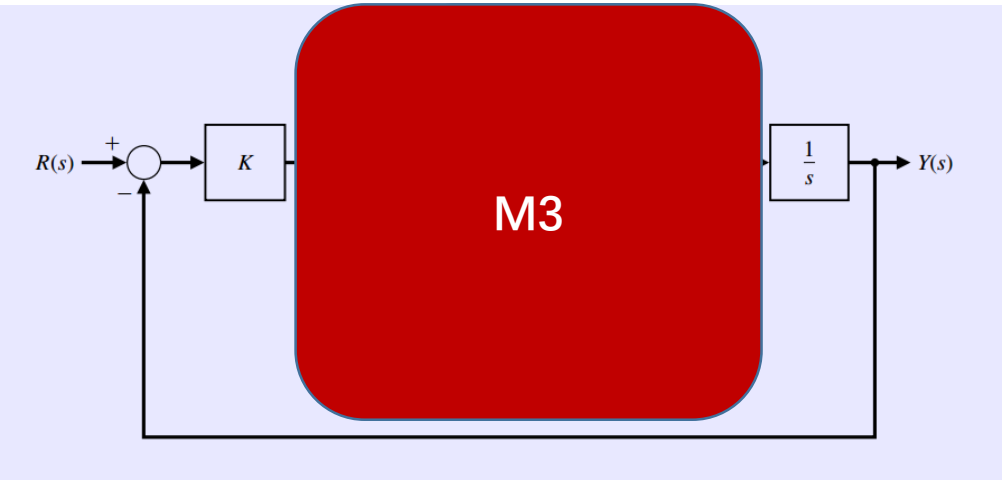






$$M_2 = \frac{G_2M_1}{1+G_2H_2M_1} = \frac{G_2G_1}{1+G_1H_3+G_2H_2G_1}$$

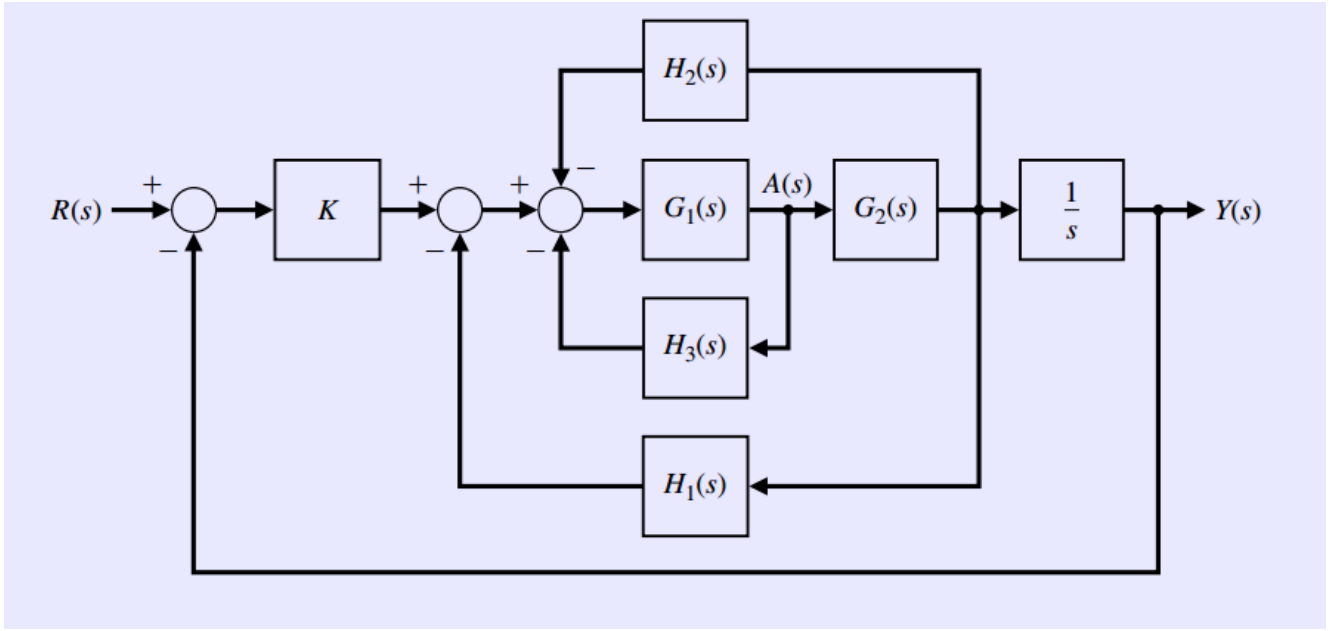


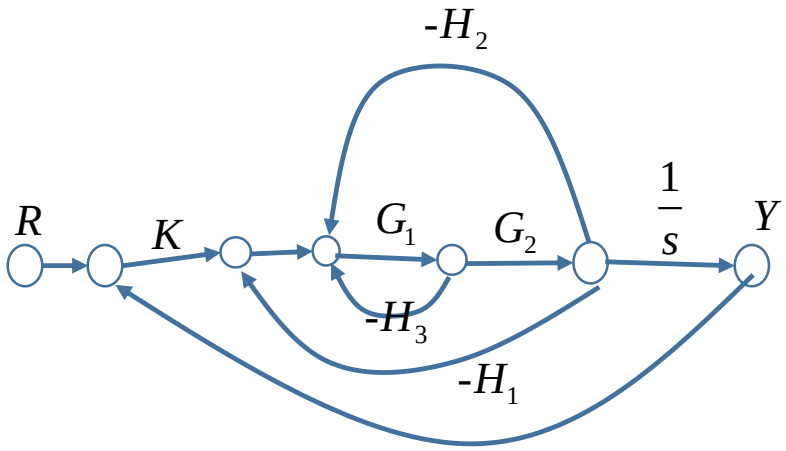


$$M_3 = \frac{M_2}{1+H_1M_2} = \frac{G_2G_1}{1+G_1H_3+G_2H_2G_1+H_1G_2G_1}$$

$$\frac{Y(s)}{R(s)} = \frac{KM_3\frac{1}{s}}{1+KM_3\frac{1}{s}} = \frac{KM_3}{s+KM_3} = \frac{KG_2G_1}{s\left(1+G_1H_3+G_2H_2G_1+H_1G_2G_1\right)+KG_2G_1}$$

解法2 梅森增益公式





1、四个单独回路

$$L_1=-G_1H_3 \qquad L_2=-G_1G_2H_2 \qquad L_3=-G_1G_2H_1 \qquad L_4=-KG_1G_2\frac{1}{s}$$

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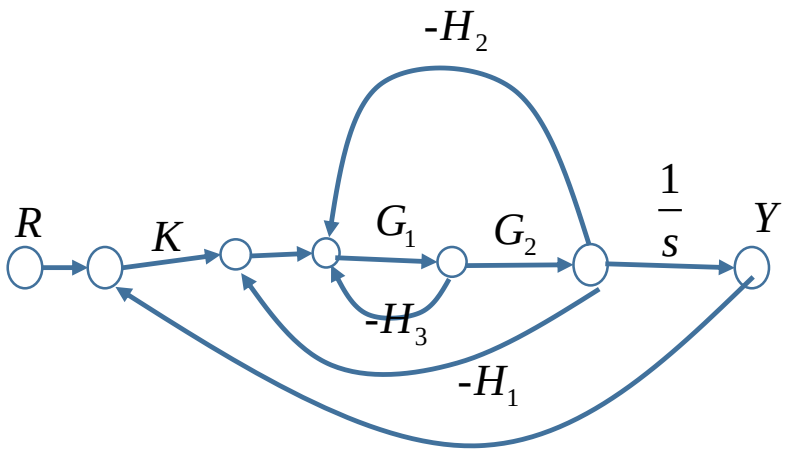


2、没有互相接触回路

$$\Delta=1-\left(L_1+L_2+L_3+L_4\right)$$

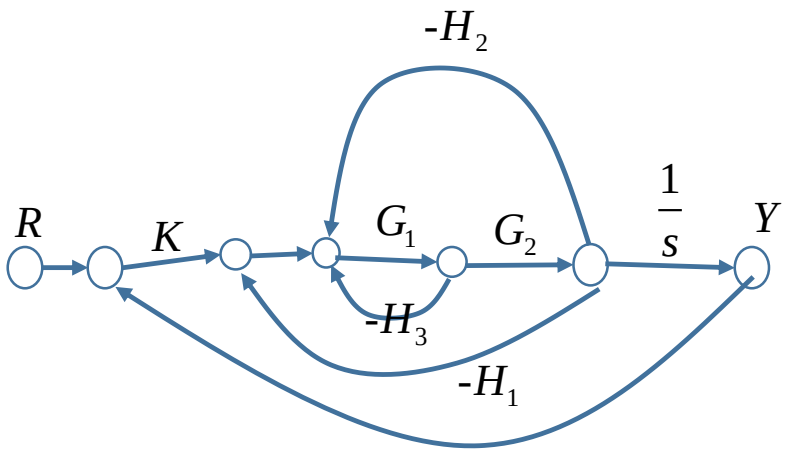
$$=1+G_1H_3+G_1G_2H_2+G_1G_2H_1+KG_1G_2\frac{1}{s}$$

3、一条前向通路，总增益为

$$p_1=KG_1G_2\frac{1}{s}$$

4、所有回路均与前线同路接触

$$\Delta_1 = 1$$

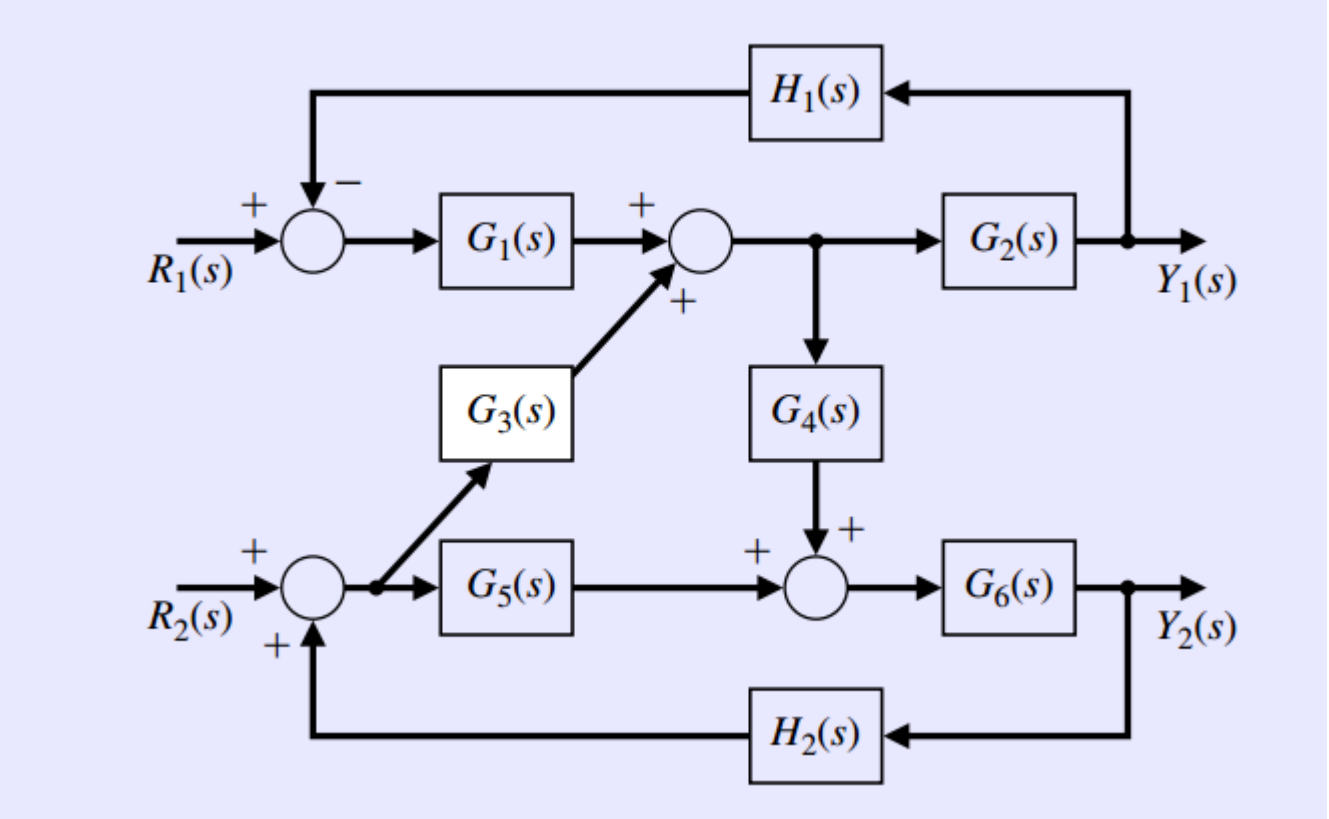


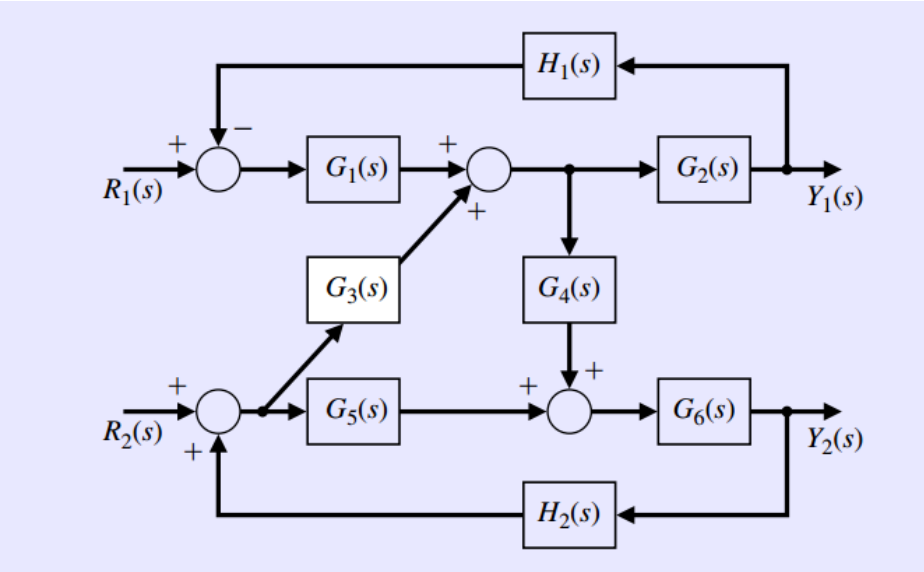
5、利用梅森增益公式

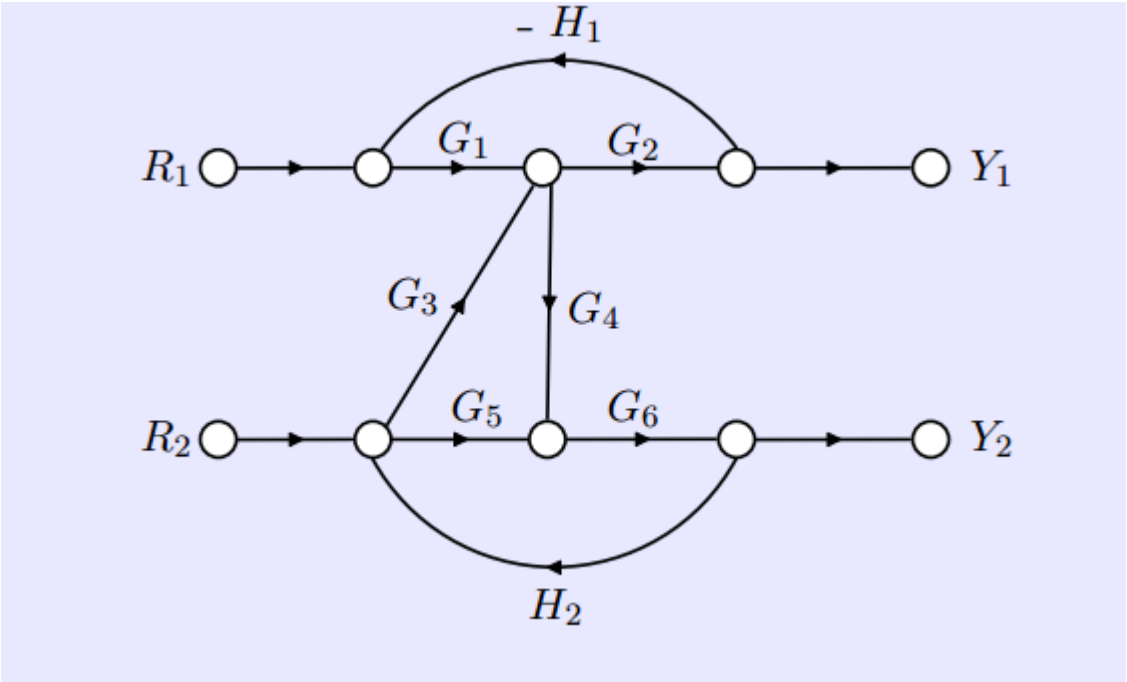
$$\frac{Y(s)}{R(s)} = \frac{p_1\Delta_1}{\Delta} = \frac{KG_1G_2\dfrac{1}{s}}{1+G_1H_3+G_1G_2H_2+G_1G_2H_1+KG_1G_2\dfrac{1}{s}}$$

$$= \frac{KG_1G_2}{s\left(1+G_1H_3+G_1G_2H_2+G_1G_2H_1\right)+KG_1G_2}$$

习题2 下图为双输入双输出系统，求 $R_2 = 0$ 时， Y_1 / R_1 及 Y_2 / R_1

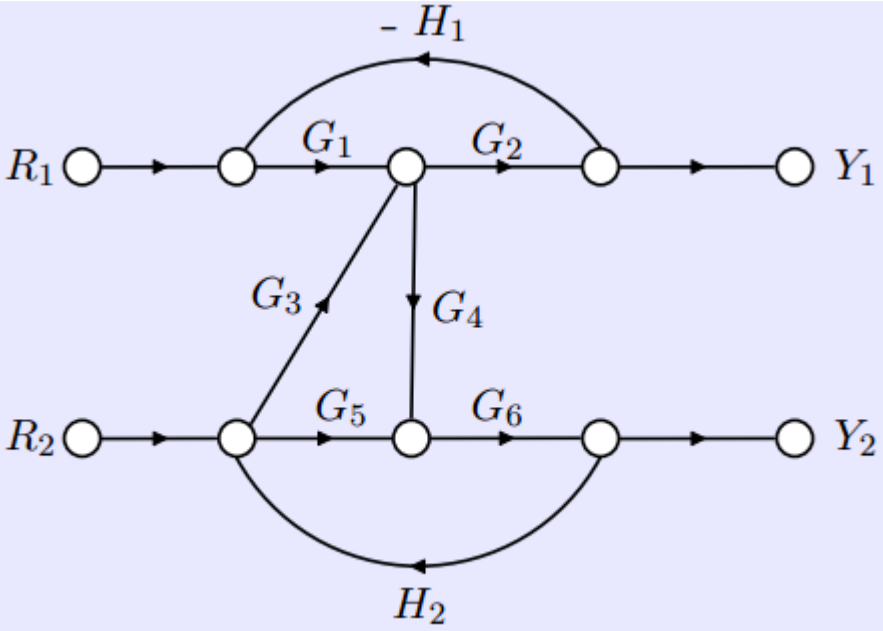






1、三个单独回路

$$L_1 = -G_1G_2H_1; \quad L_2 = G_4G_6H_2G_3; \quad L_3 = G_5G_6H_2$$



$$L_1 = -G_1G_2H_1; \quad L_2 = G_4G_6H_2G_3; \quad L_3 = G_5G_6H_2$$

2、回路L1与L3不接触，特征式子为

$$\Delta = 1 - L_1 - L_2 - L_3 + L_1L_3$$

3、R1至Y1的前向通道为1条，且与L3不接触

$$p_1 = G_1G_2, \Delta_1 = 1 - L_3$$

4、R1至Y2的前向通道为1条，且与所有回路接触

$$p_1' = G_1G_4G_6, \Delta_1' = 1$$

$$\frac{Y_1(s)}{R_1(s)} = \frac{P_1\Delta_1}{\Delta}$$
$$\frac{Y_2(s)}{R_1(s)} = \frac{P_1'\Delta_1'}{\Delta}$$

习题3 判断下列特征方程为稳定还是不稳定，如果不稳定，写出其不稳定根的数目

$$s^3 - 4s^2 + 6s + 100 = 0.$$

$$s^4 - 6s^3 - s^2 - 17s - 6 = 0.$$

$$s^2 + 6s + 3 = 0.$$

$$s^3 - 4s^2 + 6s + 100 = 0.$$

特征方程系数不同号，不稳定；

s^3	1	6
s^2	-4	100
s^1	31	0
s^0	100	

变号1次，有一对不稳定的根

$$s^4 - 6s^3 - s^2 - 17s - 6 = 0.$$

特征方程系数不同号，不稳定；

s^4	1	-1	-6
s^3	-6	-17	0
s^2	$-\frac{23}{6}$	-6	
s^1	$-\frac{175}{23}$	0	
s^0	-6		

有一个不稳定的实根

$$s^2 + 6s + 3 = 0.$$

s^2	1	3
s^1	6	0
s^0	3	0

稳定