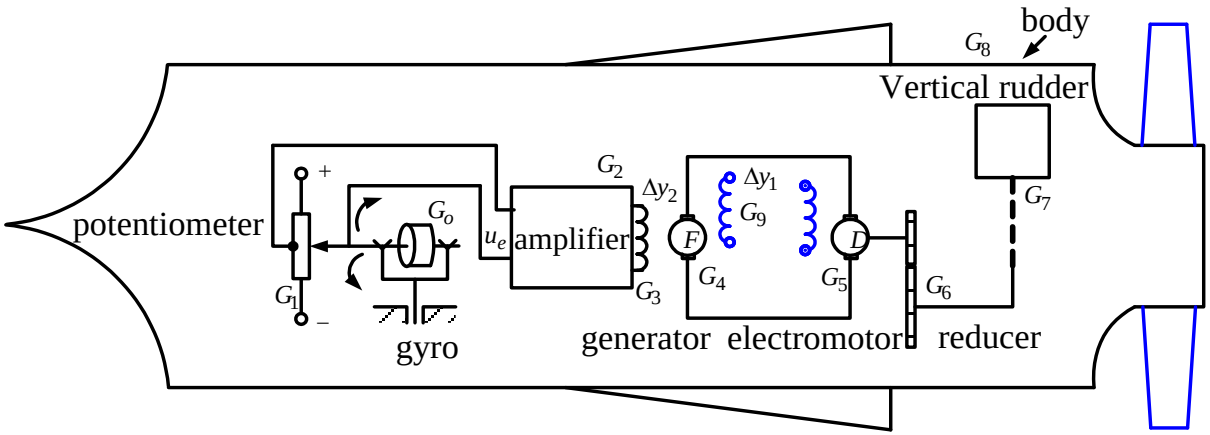
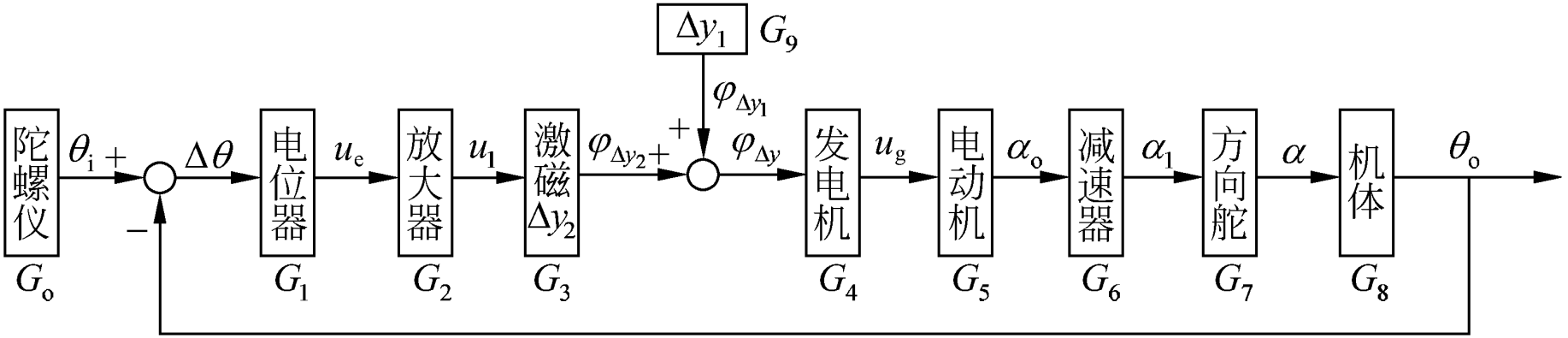
2.3 方块图

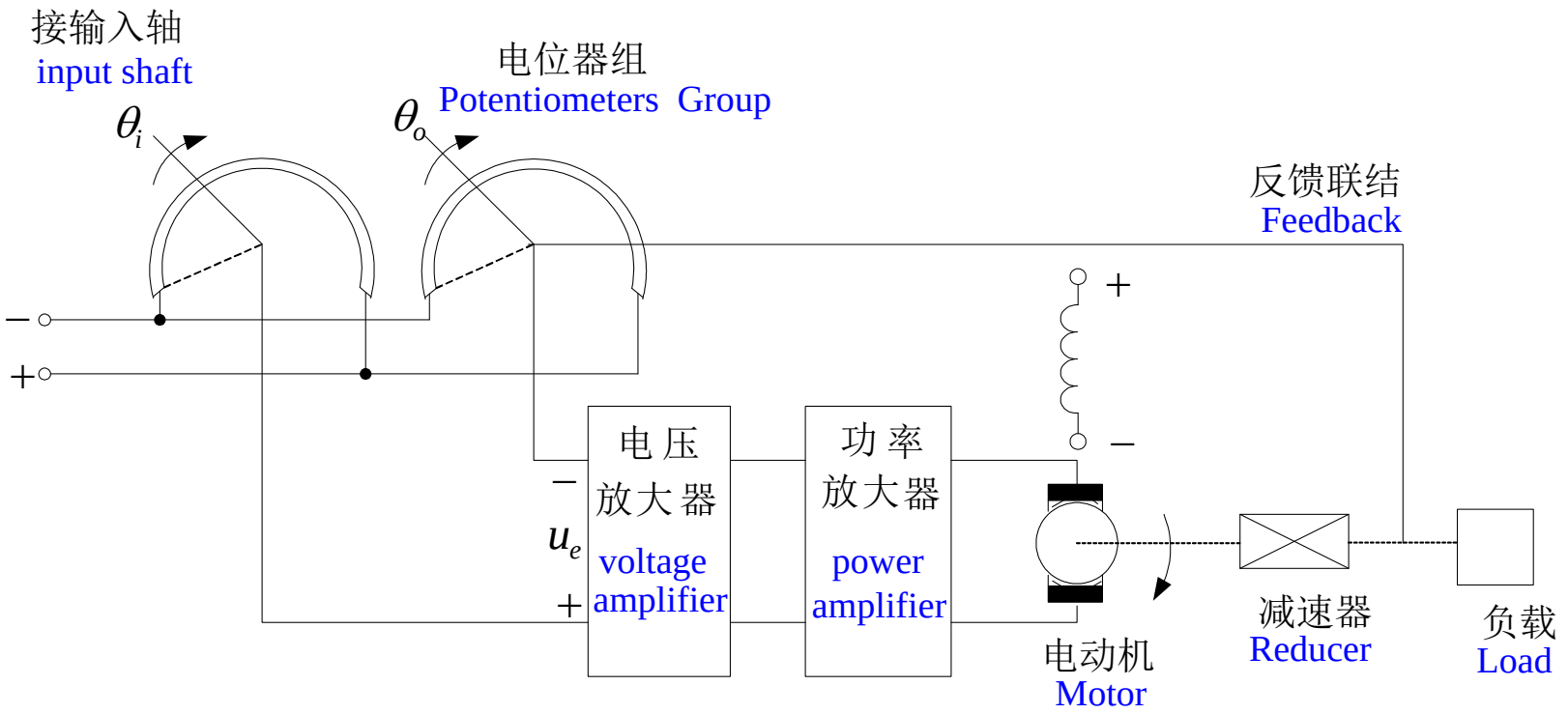
2.3.1 方块图的组成

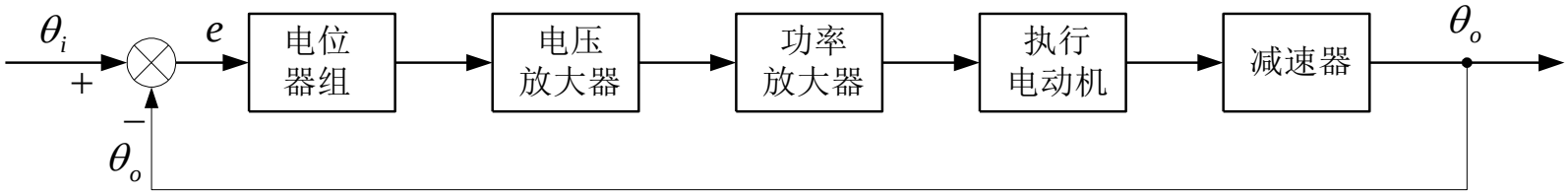
2.3.2 方块图的等效变换和绘制

2.3.3 闭环系统的传递函数

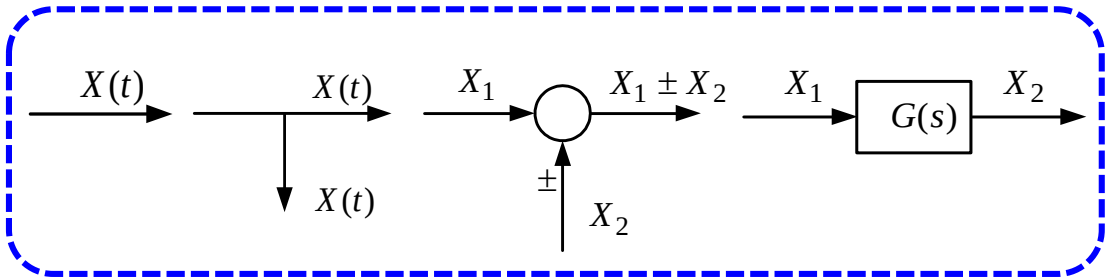

body
G_8
Vertical rudder
G_7
potentiometer
G_o
u_e
amplifier
G_2
Δy_2
G_3
Δy_1
G_9
F
D
G_4
G_5
G_6
G_1
gyro
generator
electromotor
reducer

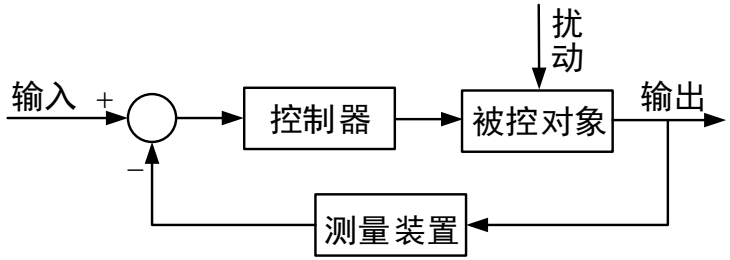

Δy_1
G_9
$\varphi_{\Delta y1}$
陀螺仪
G_o
θ_i
$\Delta\theta$
电位器
G_1
u_e
放大器
G_2
u_1
激磁 Δy_2
G_3
$\varphi_{\Delta y2}$
$\varphi_{\Delta y}$
发电机
G_4
u_g
电动机
G_5
α_o
减速器
G_6
α_1
方向舵
G_7
α
机体
G_8
θ_o

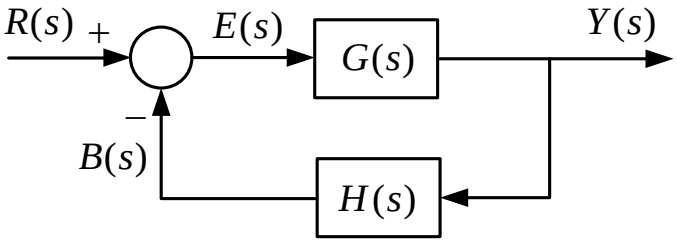

接输入轴
input shaft
θ_i
电位器组
Potentiometers Group
θ_o
反馈联结
Feedback
−
+
电压
放大器
voltage
amplifier
u_e
功率
放大器
power
amplifier
+
−
电动机
Motor
减速器
Reducer
负载
Load

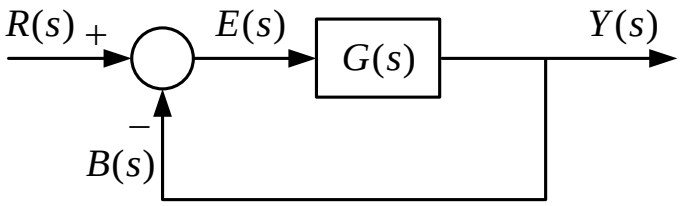

θ_i
+
−
θ_o
e
电位
器组
电压
放大器
功率
放大器
执行
电动机
减速器
θ_o

2.3.1 方块图的组成

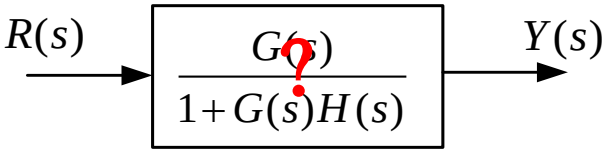


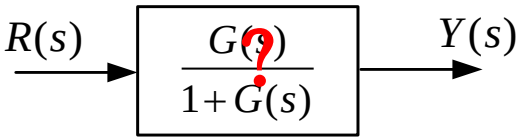






$$M(s)=\frac{G(s)}{1+G(s)H(s)}$$





$G(s)$: the forward-path transfer function.

$G(s)H(s)$: the open loop transfer function.

$H(s)$: the feedback transfer function.

$M(s)$: the closed-loop transfer function.

2.3.2 方块图的等效变换和绘制

[定义]：在方块图上进行数学方程的运算。

[类型]：①环节的合并；

--串联

--并联

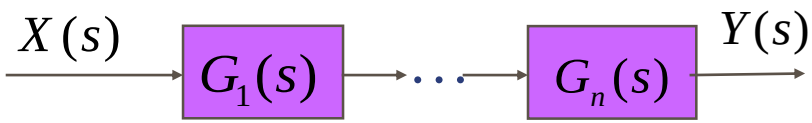
--反馈连接

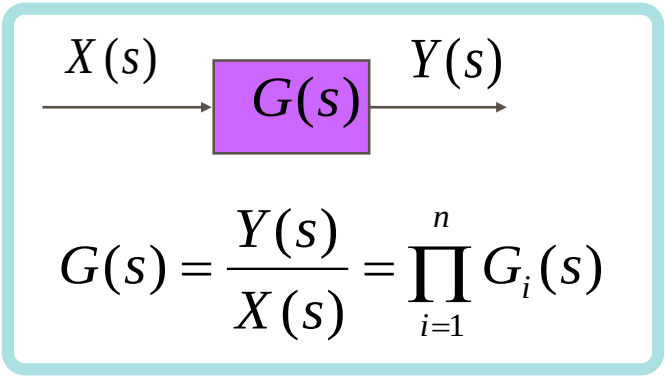
②信号分支点或相加点的移动。

[原则]：变换前后环节的数学关系保持不变。

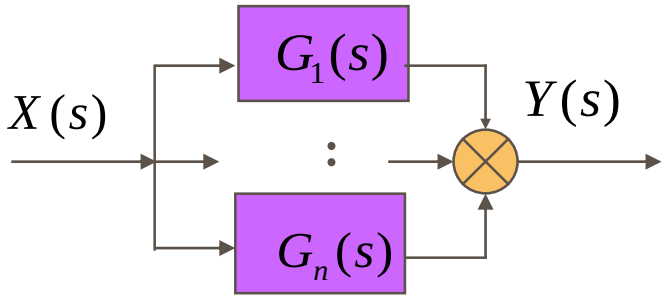
1. 环节的合并：有串联、并联和反馈三种形式。

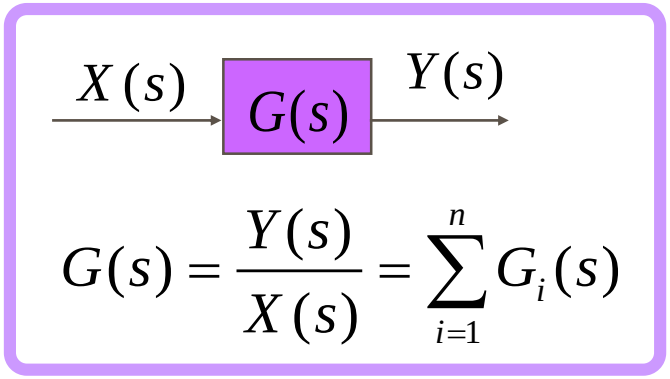
1） Combining blocks in cascade:



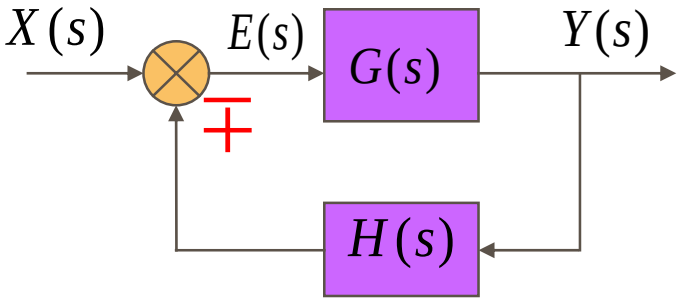


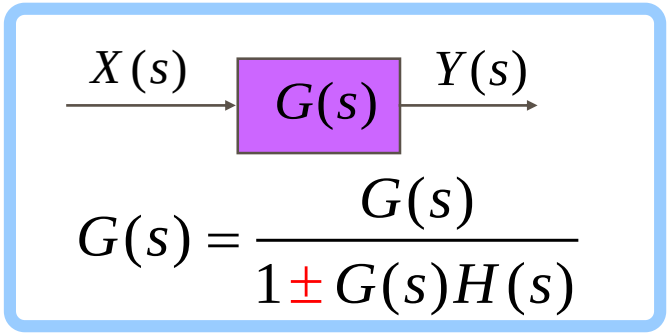
2） Combining blocks in parallel :





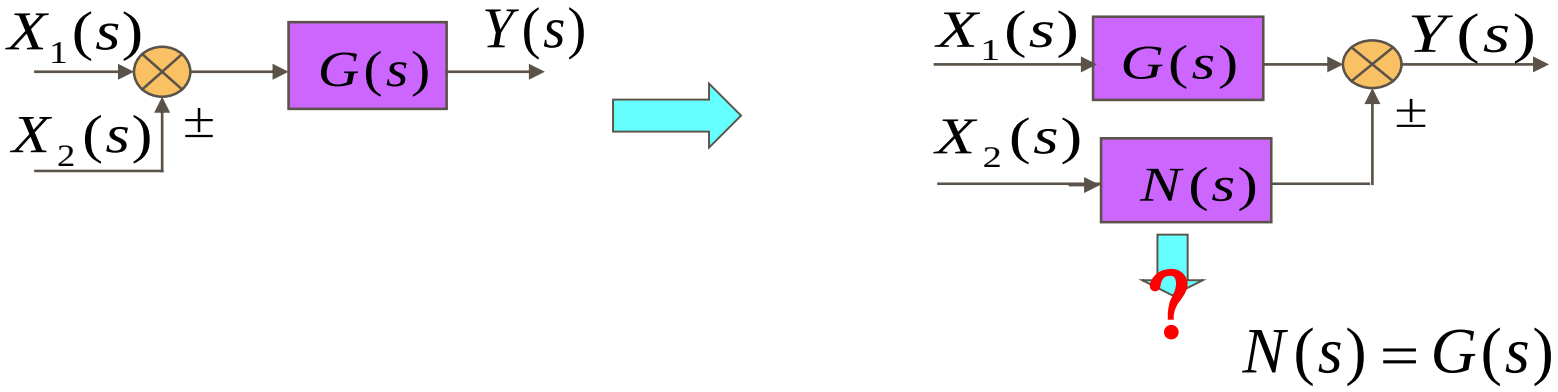
3） Combining blocks in feedback:



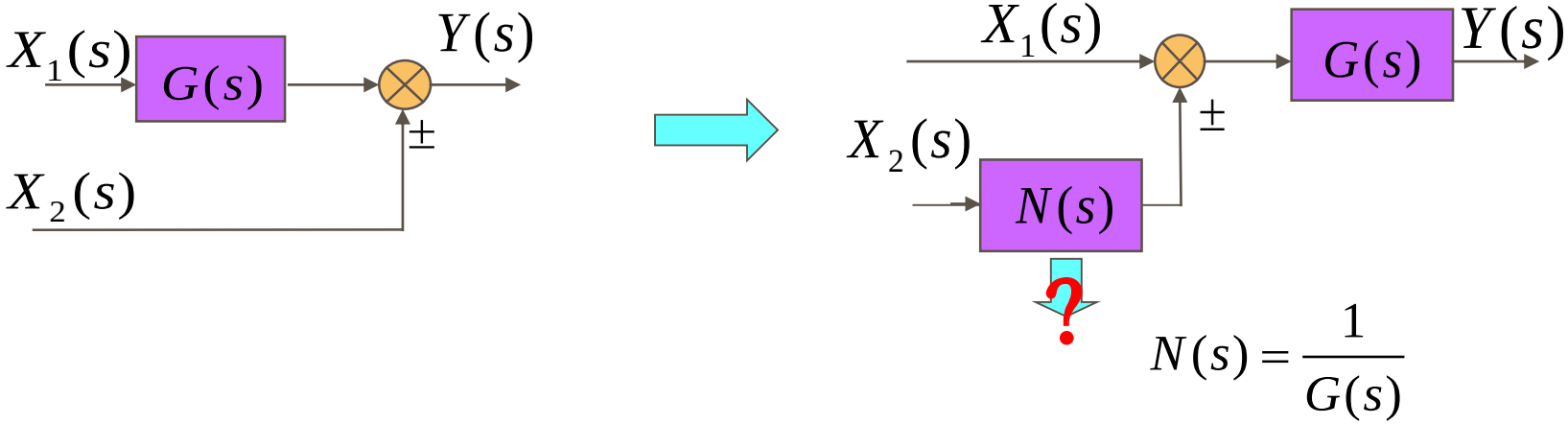


2．信号相加点和分支点的移动和互换：

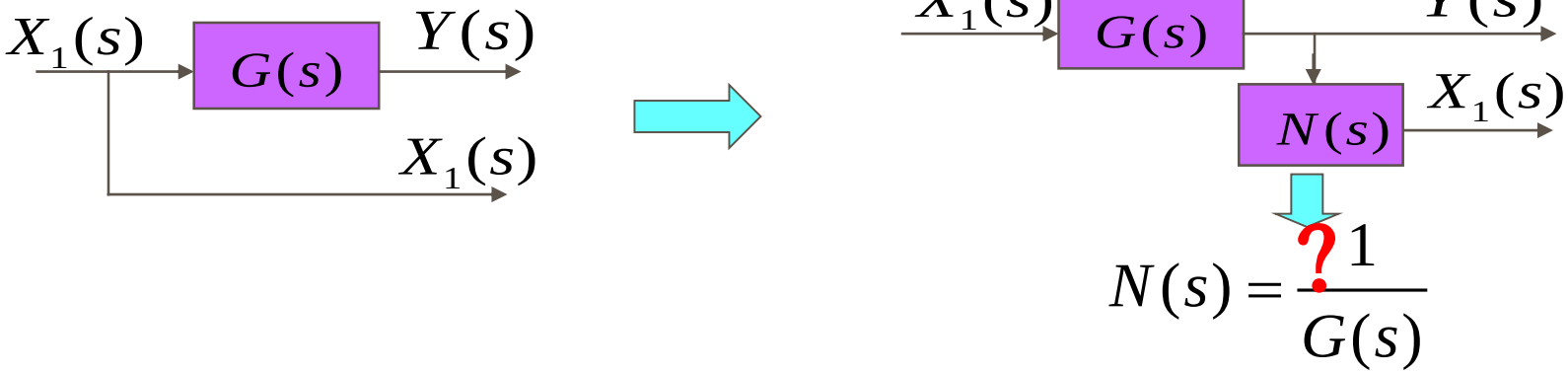
1） Moving a summing point behind a block:



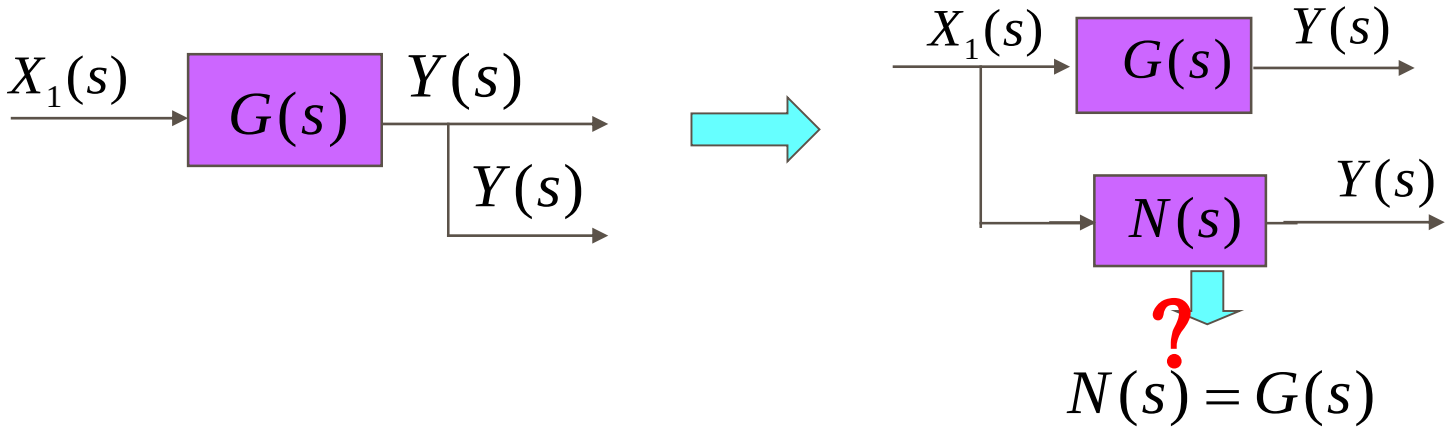
2） Moving a summing point ahead of a block:



3) Moving a pick off point behind a block:

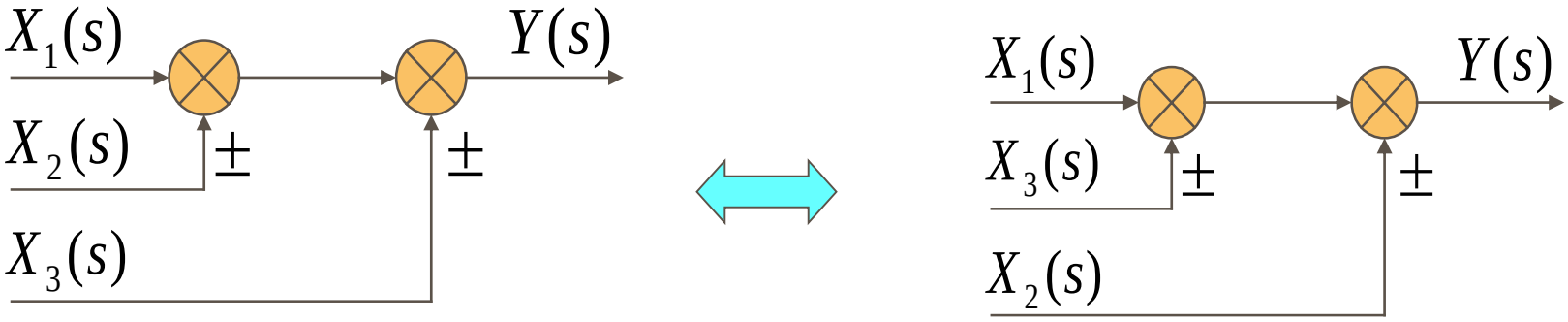


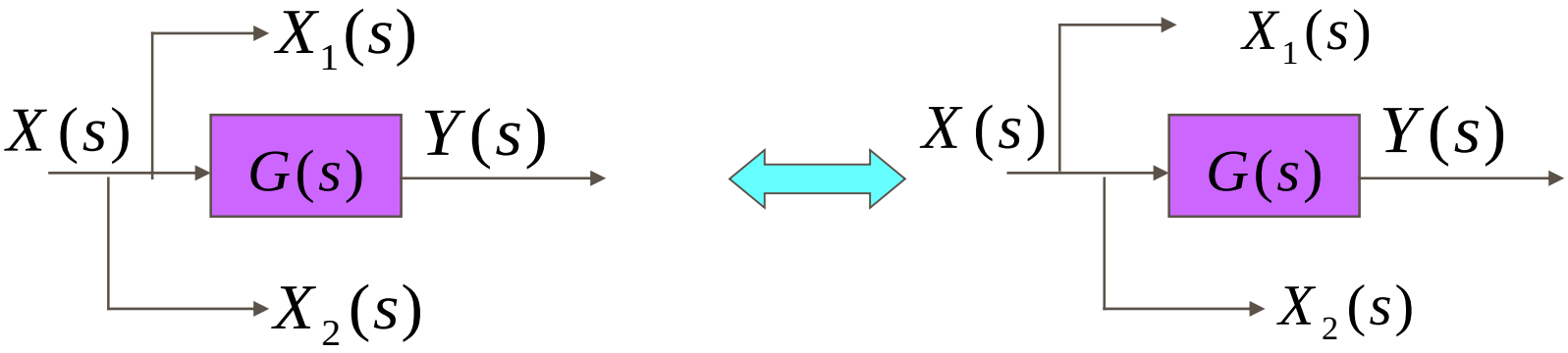
4) Moving a pick off point ahead of a block :

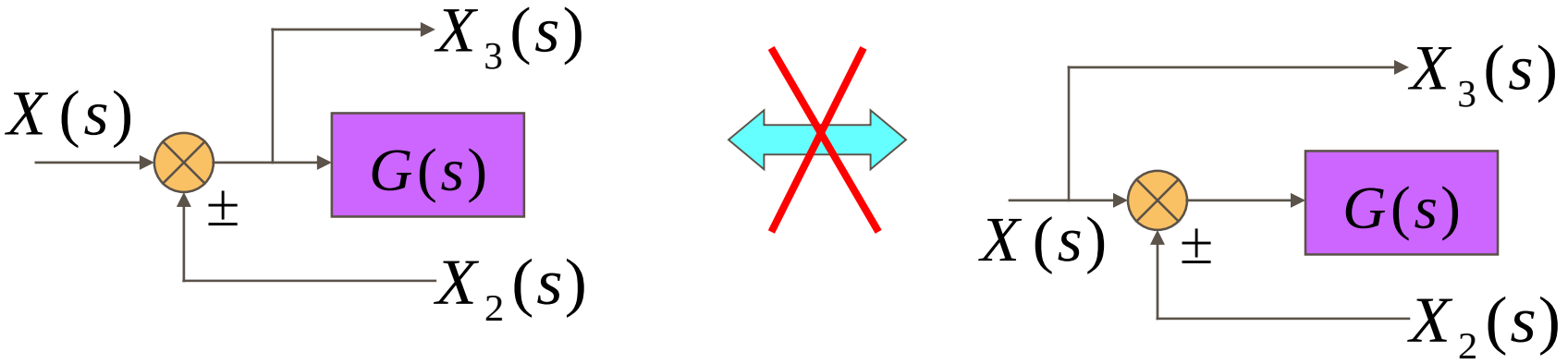


[Notice]:

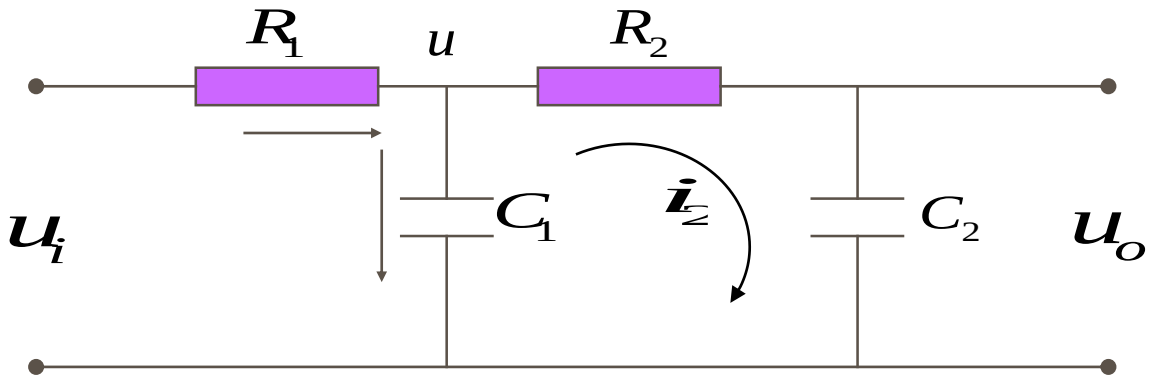
Exchange the position of the summing points:




$X_1(s)$
$X(s)$
$G(s)$
$Y(s)$
$X_2(s)$
$X_1(s)$
$X(s)$
$G(s)$
$Y(s)$
$X_2(s)$


$X_3(s)$
$X(s)$
$G(s)$
$\pm$
$X_2(s)$
$X_3(s)$
$X(s)$
$G(s)$
$\pm$
$X_2(s)$

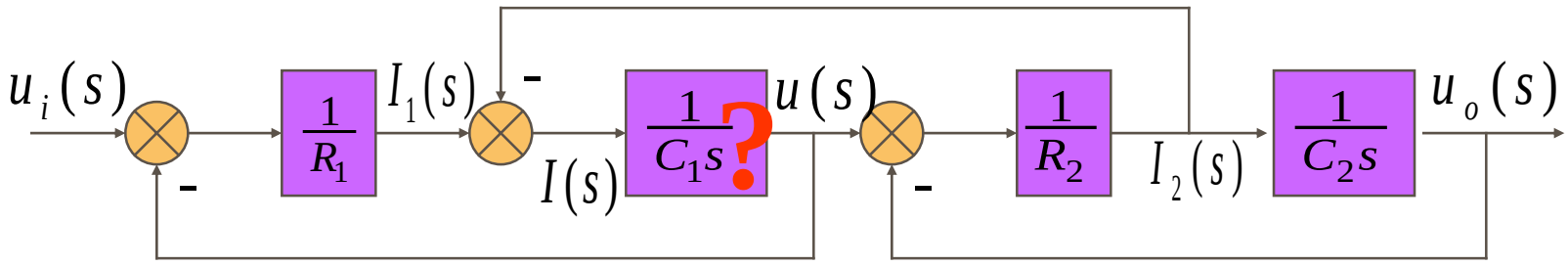
例： 利用方块图等效变换讨论两级RC串联电路的传递函数。



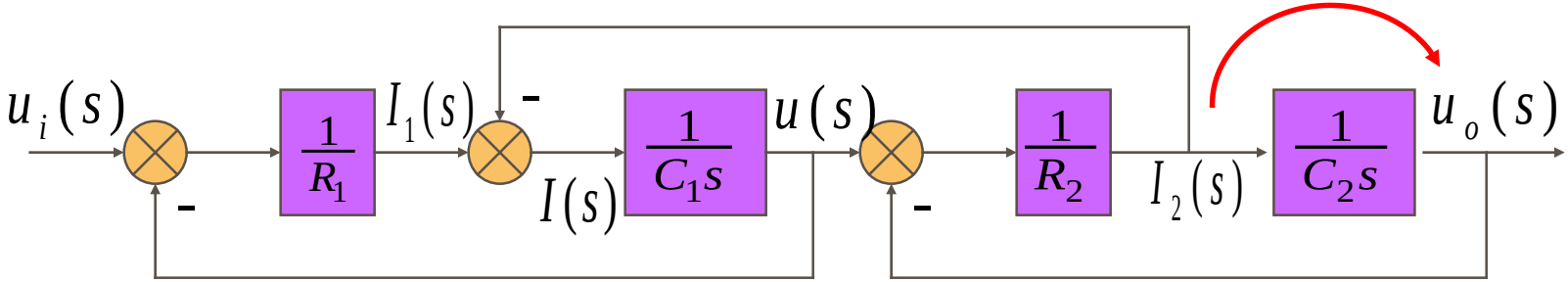
$$\frac{1}{[(1+R_1C_1s)(1+R_2C_2s)]}$$

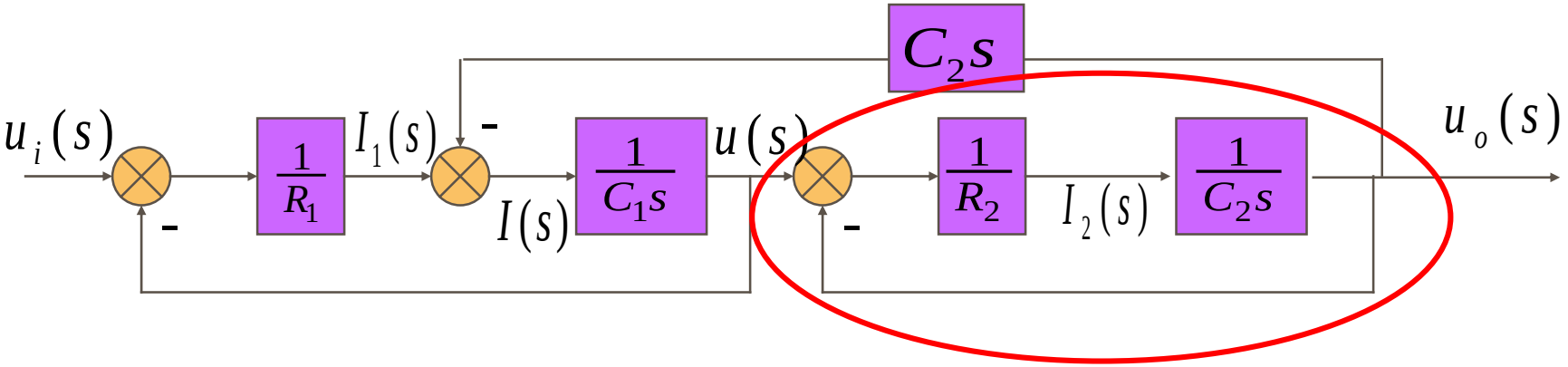
$$\frac{U_0(s)}{U_i(s)}=\frac{1}{(1+R_1C_1s)(1+R_2C_2s)+R_1C_2s}$$

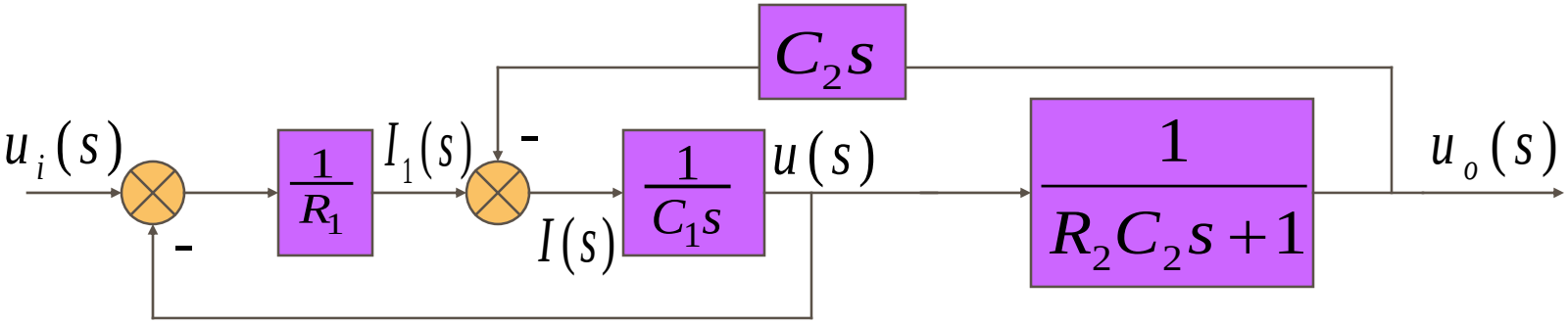
总的方块图如下：

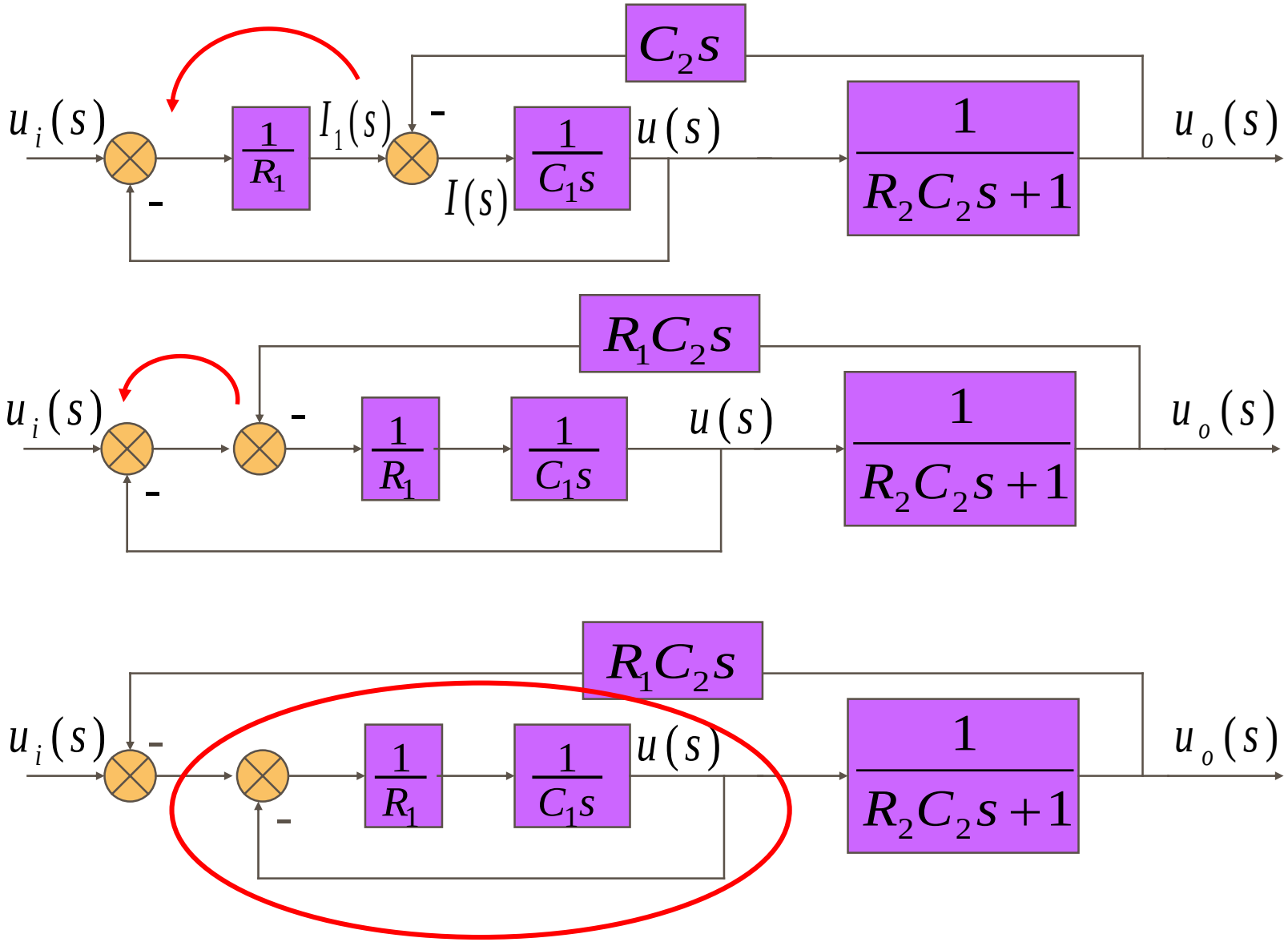


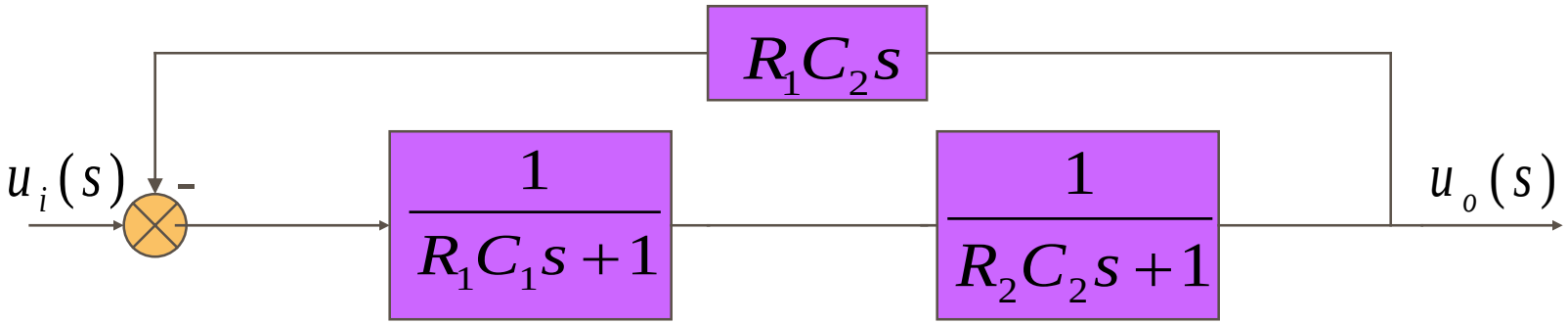
总的方块图如下：


$u_i(s)$
$\frac{1}{R_1}$
$I_1(s)$
$I(s)$
$\frac{1}{C_1 s}$
$u(s)$
$\frac{1}{R_2}$
$I_2(s)$
$\frac{1}{C_2 s}$
$u_o(s)$


$C_2 s$
$u_i(s)$
$\frac{1}{R_1}$
$I_1(s)$
$I(s)$
$\frac{1}{C_1 s}$
$u(s)$
$\frac{1}{R_2}$
$I_2(s)$
$\frac{1}{C_2 s}$
$u_o(s)$

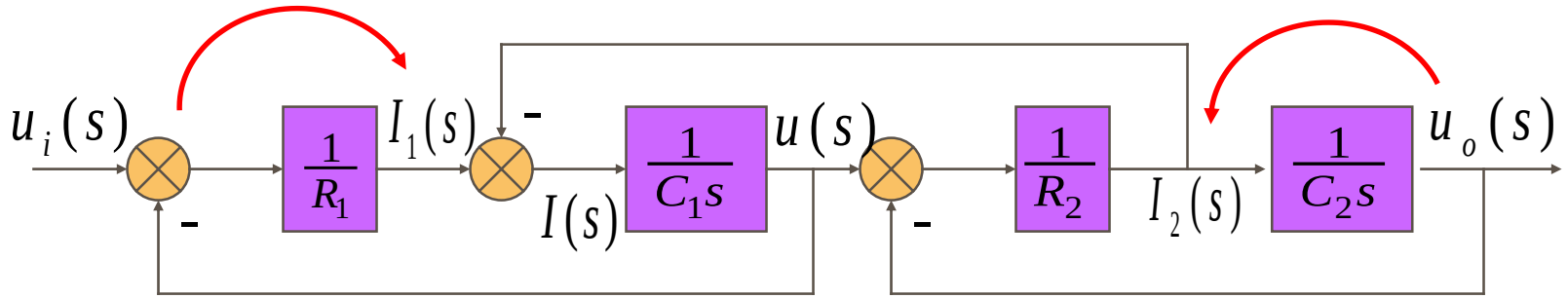

$C_2 s$
$u_i(s)$
$\frac{1}{R_1}$
$I_1(s)$
$I(s)$
$\frac{1}{C_1 s}$
$u(s)$
$\frac{1}{R_2 C_2 s+1}$
$u_o(s)$

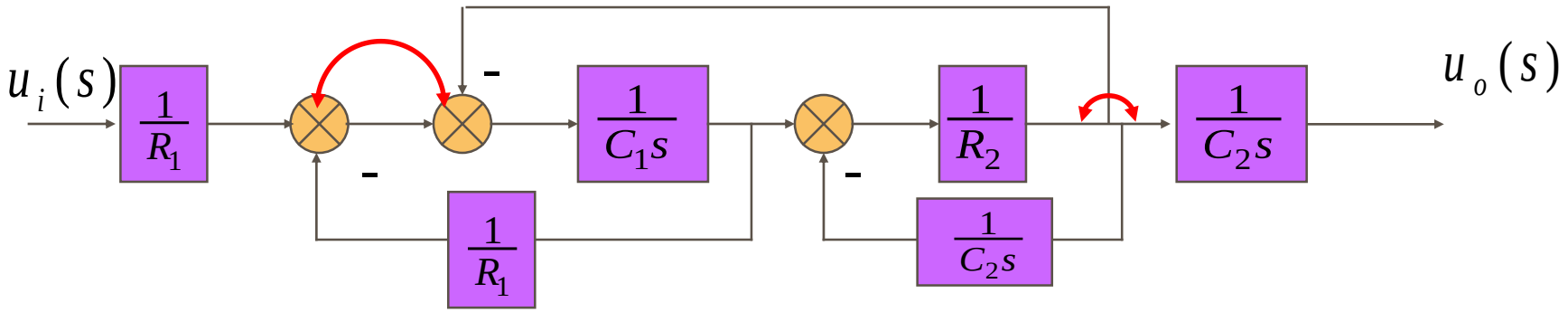

$C_2 s$
$u_i(s)$
$\frac{1}{R_1}$
$I_1(s)$
$I(s)$
$\frac{1}{C_1 s}$
$u(s)$
$\frac{1}{R_2 C_2 s+1}$
$u_o(s)$
$R_1 C_2 s$
$u_i(s)$
$\frac{1}{R_1}$
$\frac{1}{C_1 s}$
$u(s)$
$\frac{1}{R_2 C_2 s+1}$
$u_o(s)$
$R_1 C_2 s$
$u_i(s)$
$\frac{1}{R_1}$
$\frac{1}{C_1 s}$
$u(s)$
$\frac{1}{R_2 C_2 s+1}$
$u_o(s)$

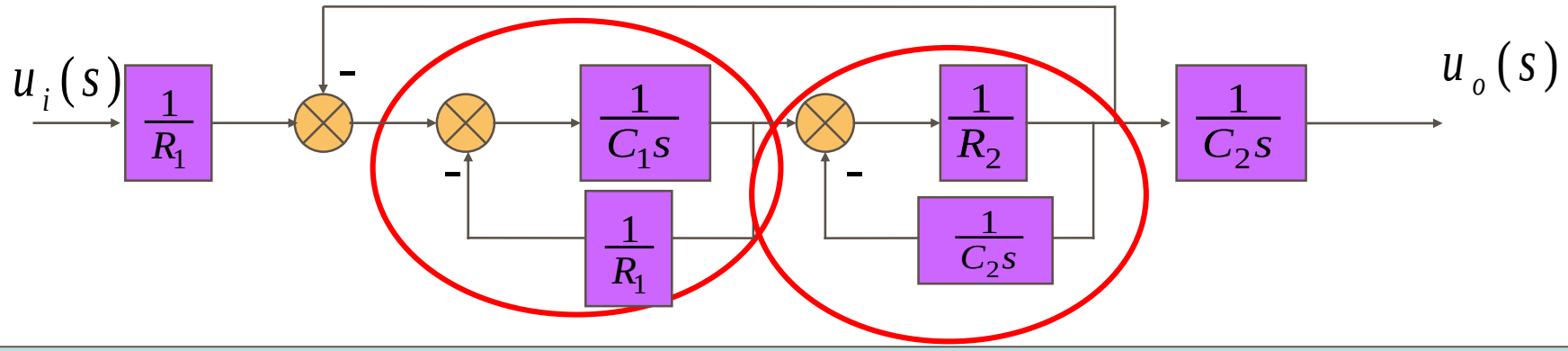


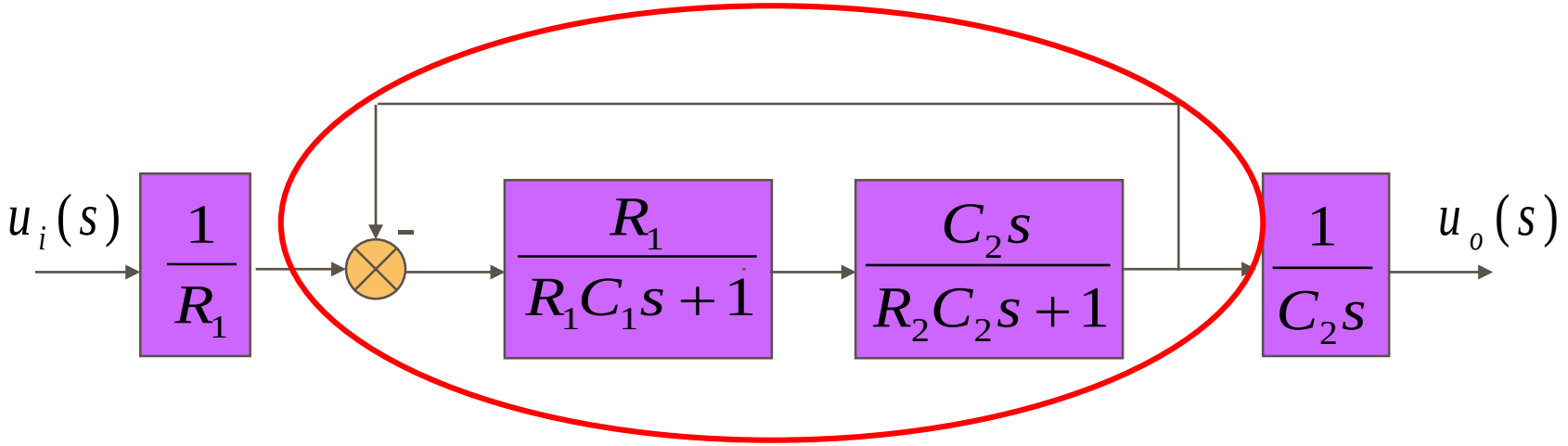
$$\therefore G(s)=\frac{u_o(s)}{u_i(s)}=\frac{\dfrac{1}{(R_1C_1s+1)(R_2C_2s+1)}}{1+\dfrac{R_1C_2s}{(R_1C_1s+1)(R_2C_2s+1)}}=\frac{1}{(R_1C_1s+1)(R_2C_2s+1)+R_1C_2s}$$

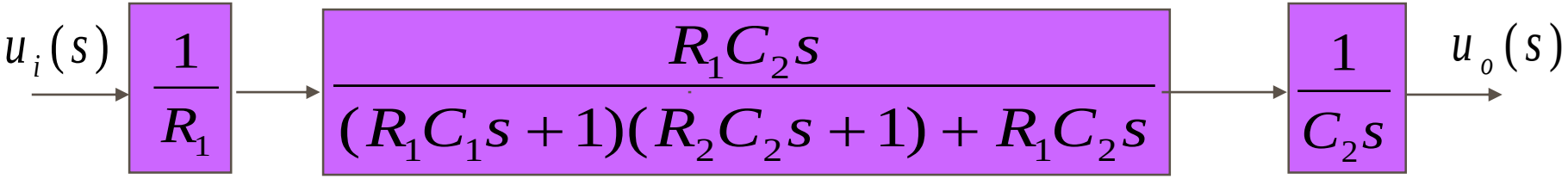
解法二：


$u_i(s)$
$\frac{1}{R_1}$
$I_1(s)$
$I(s)$
$\frac{1}{C_1 s}$
$u(s)$
$\frac{1}{R_2}$
$I_2(s)$
$\frac{1}{C_2 s}$
$u_o(s)$


$u_i(s)$
$\frac{1}{R_1}$
$\frac{1}{C_1 s}$
$\frac{1}{R_2}$
$\frac{1}{C_2 s}$
$u_o(s)$
$\frac{1}{R_1}$
$\frac{1}{C_2 s}$

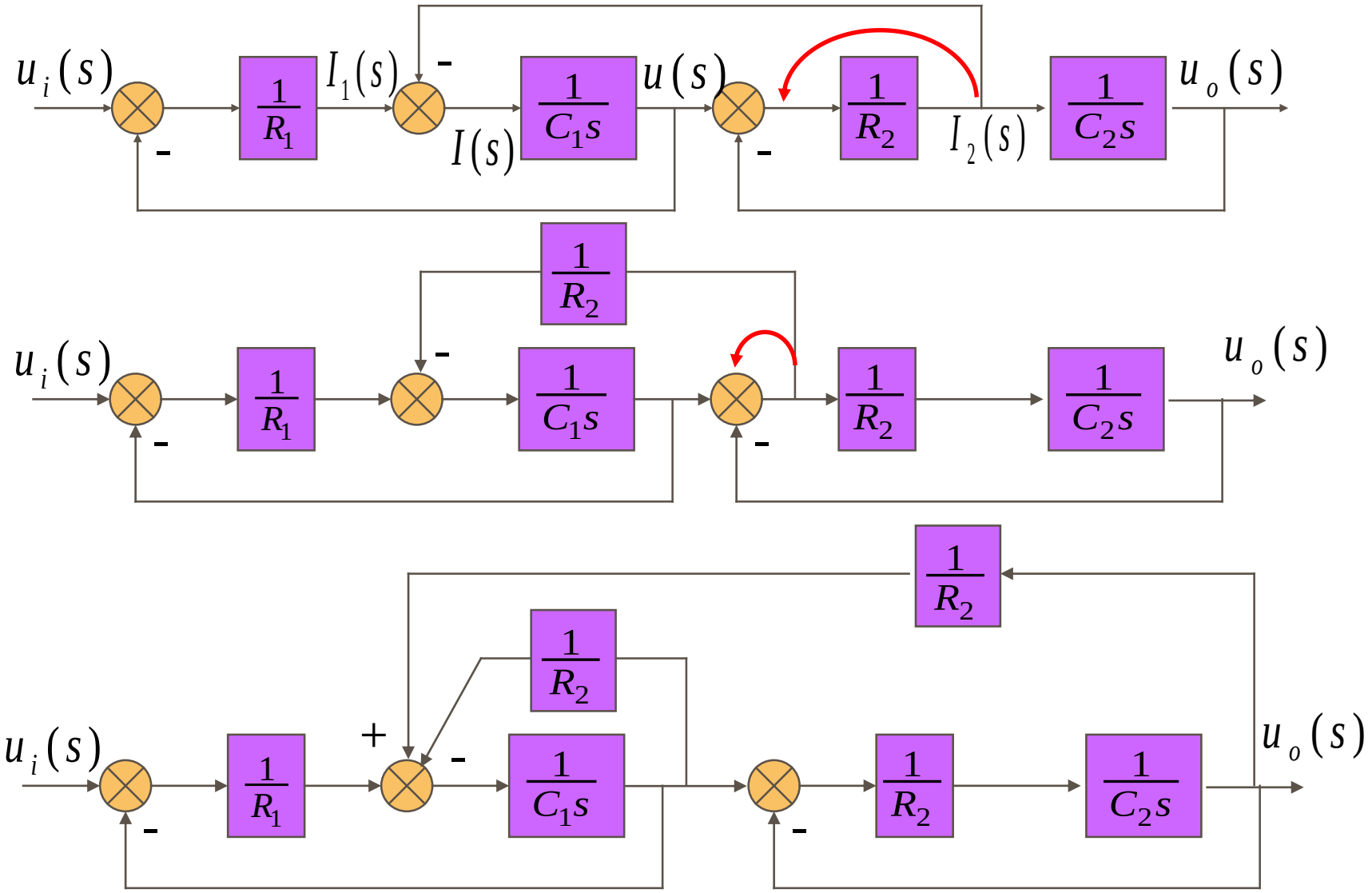

$u_i(s)$
$\frac{1}{R_1}$
$\frac{1}{C_1 s}$
$\frac{1}{R_2}$
$\frac{1}{C_2 s}$
$u_o(s)$
$\frac{1}{R_1}$
$\frac{1}{C_2 s}$

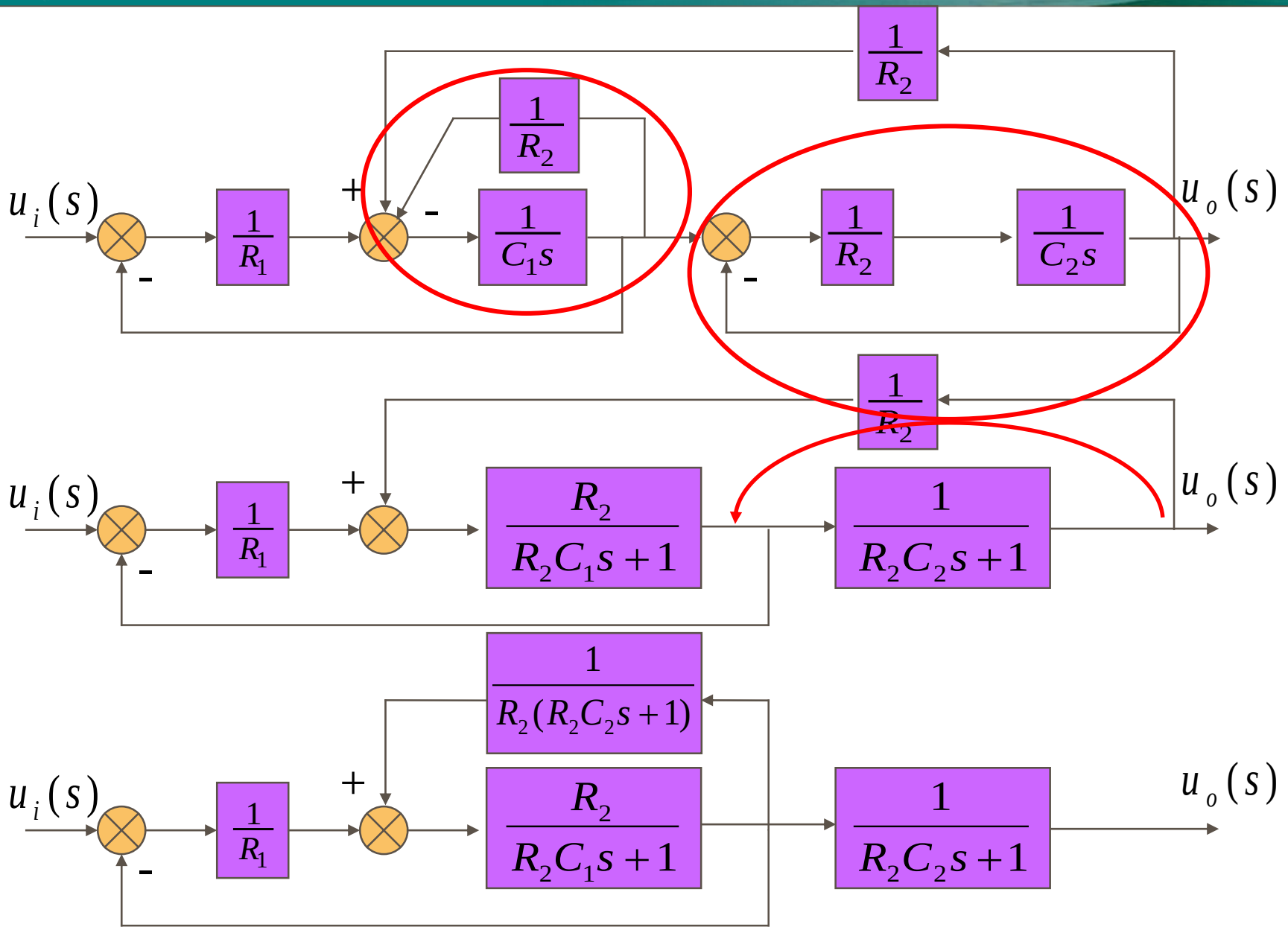


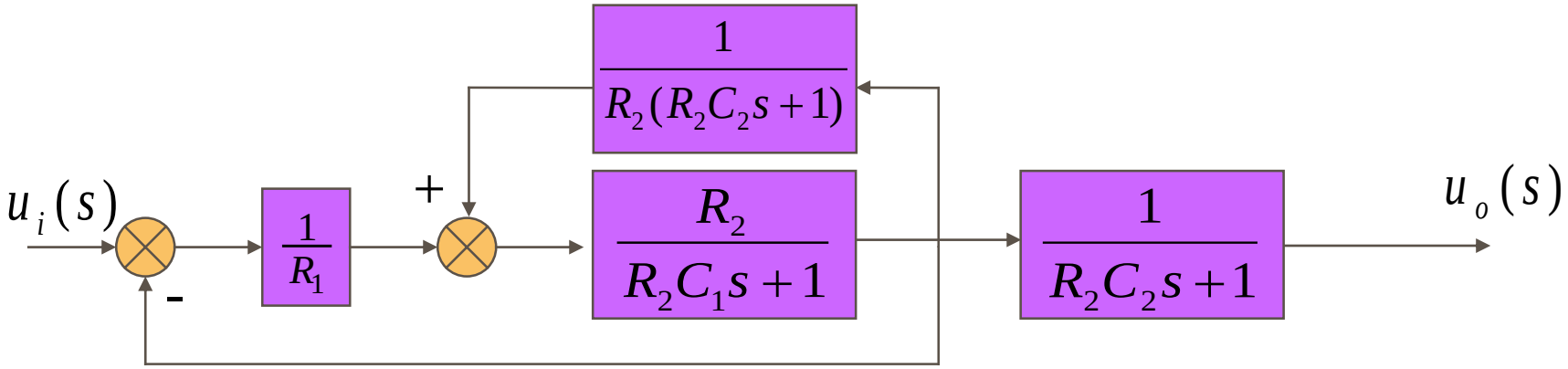


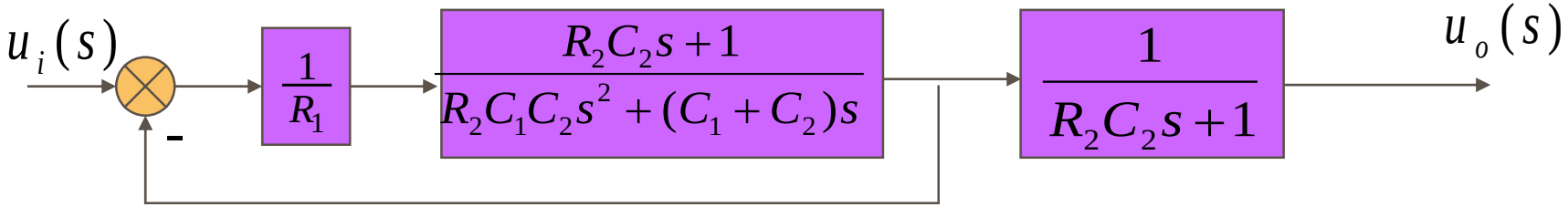
$$\therefore G(s)=\frac{u_o(s)}{u_i(s)}=\frac{1}{(R_1C_1s+1)(R_2C_2s+1)+R_1C_2s}$$

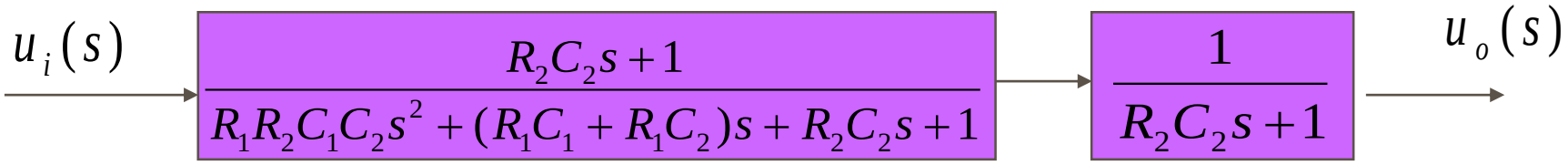
解法三：




$u_i(s)$
$\frac{1}{R_1}$
+
-
$\frac{1}{R_2}$
$\frac{1}{C_1 s}$
$\frac{1}{R_2}$
$\frac{1}{C_2 s}$
$u_o(s)$
$\frac{1}{R_2}$
$u_i(s)$
$\frac{1}{R_1}$
+
$\frac{R_2}{R_2C_1s+1}$
$\frac{1}{R_2C_2s+1}$
$u_o(s)$
$\frac{1}{R_2}$
$\frac{1}{R_2(R_2C_2s+1)}$
$u_i(s)$
$\frac{1}{R_1}$
+
$\frac{R_2}{R_2C_1s+1}$
$\frac{1}{R_2C_2s+1}$
$u_o(s)$

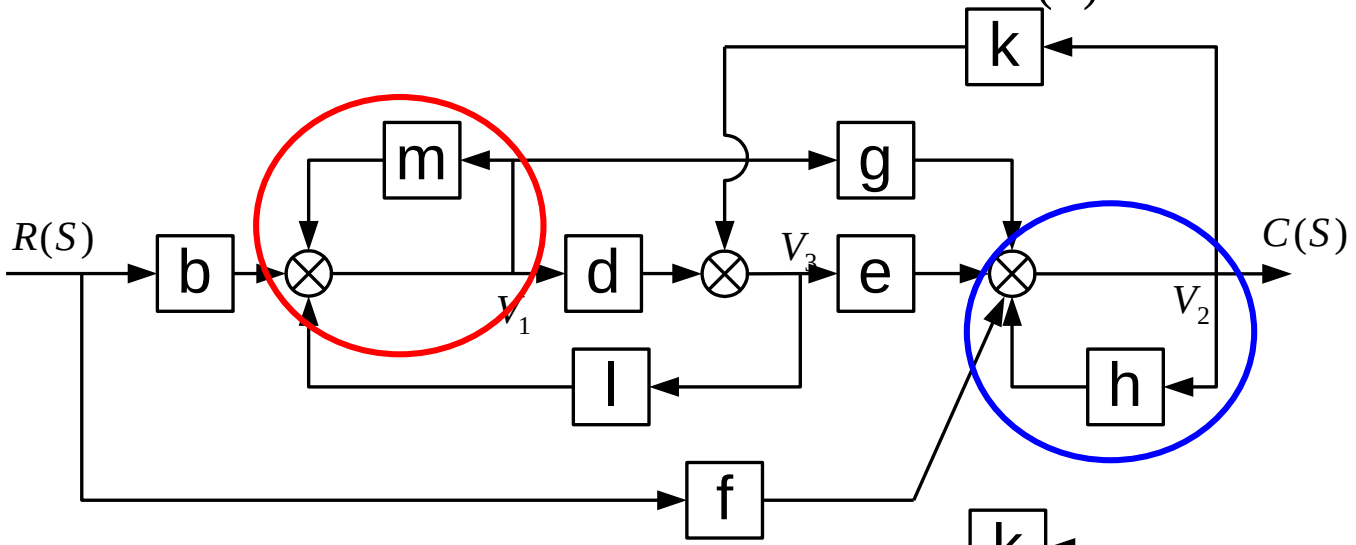


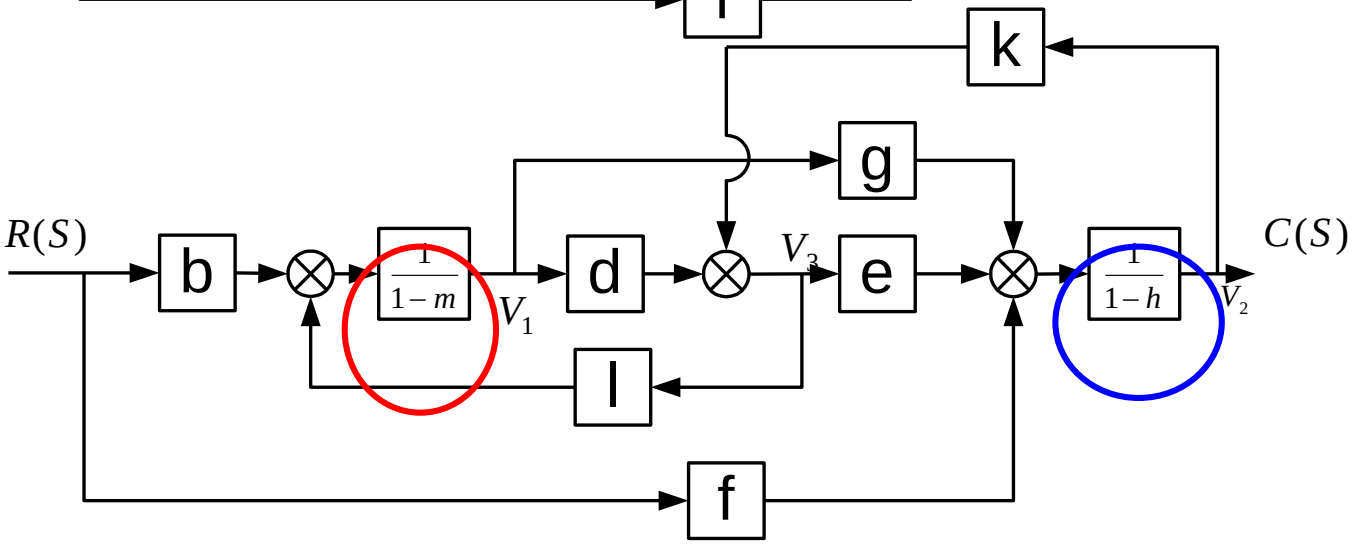


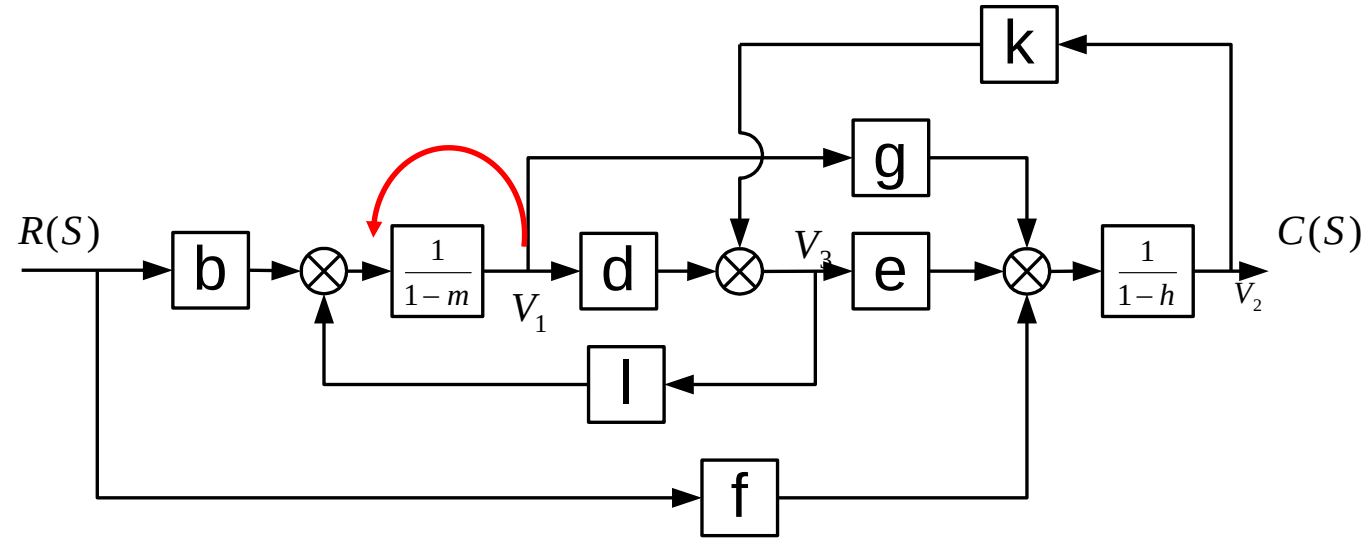


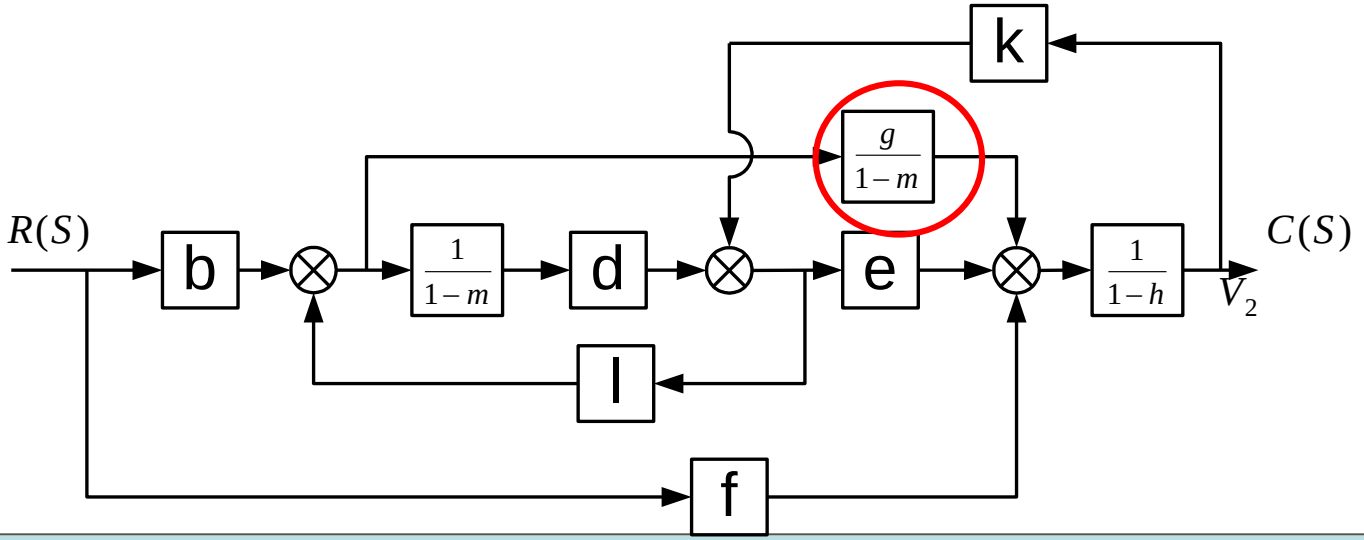
$$\therefore G(s)=\frac{u_o(s)}{u_i(s)}=\frac{1}{(R_1C_1s+1)(R_2C_2s+1)+R_1C_2s}$$

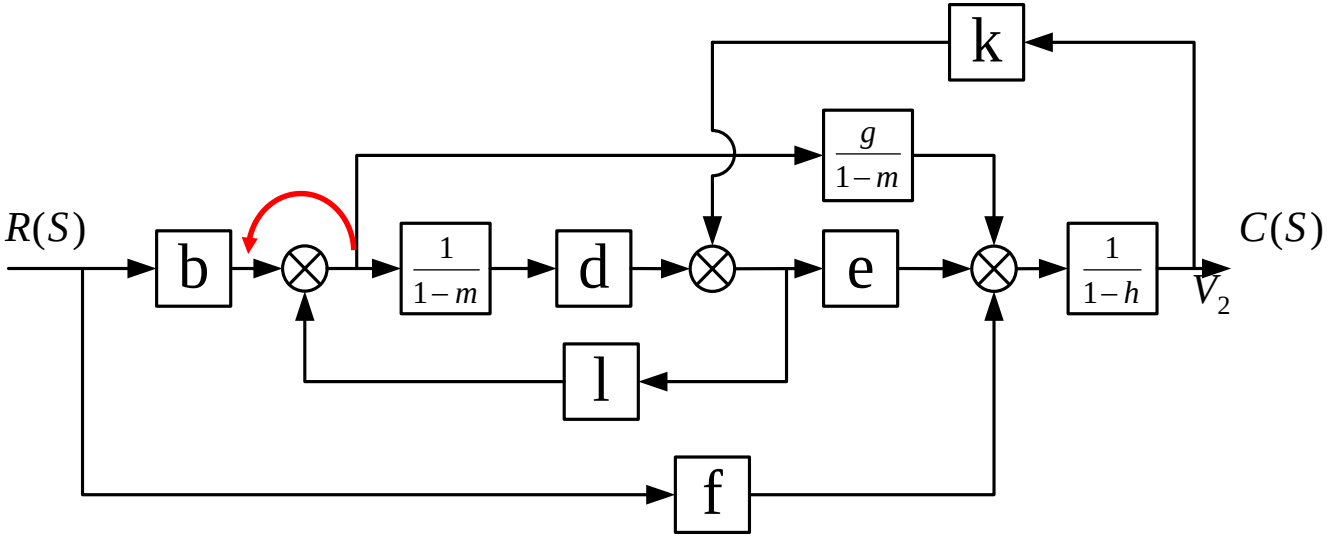
例： 系统方块图如下，求传递函数$G(s)=\dfrac{C(s)}{R(s)}$。

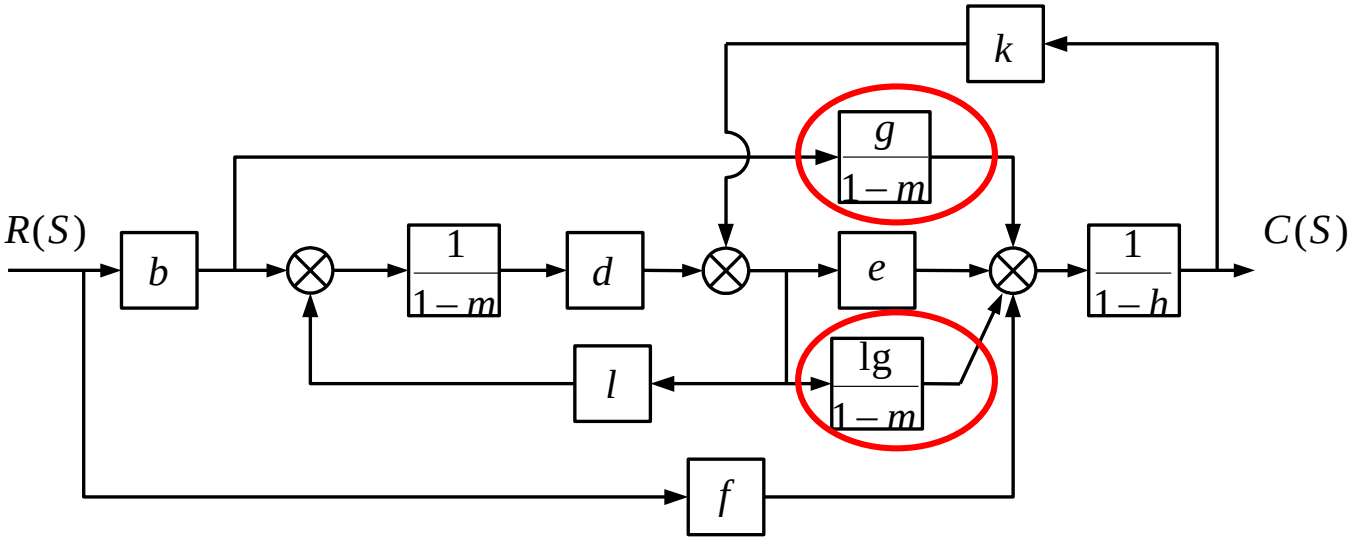


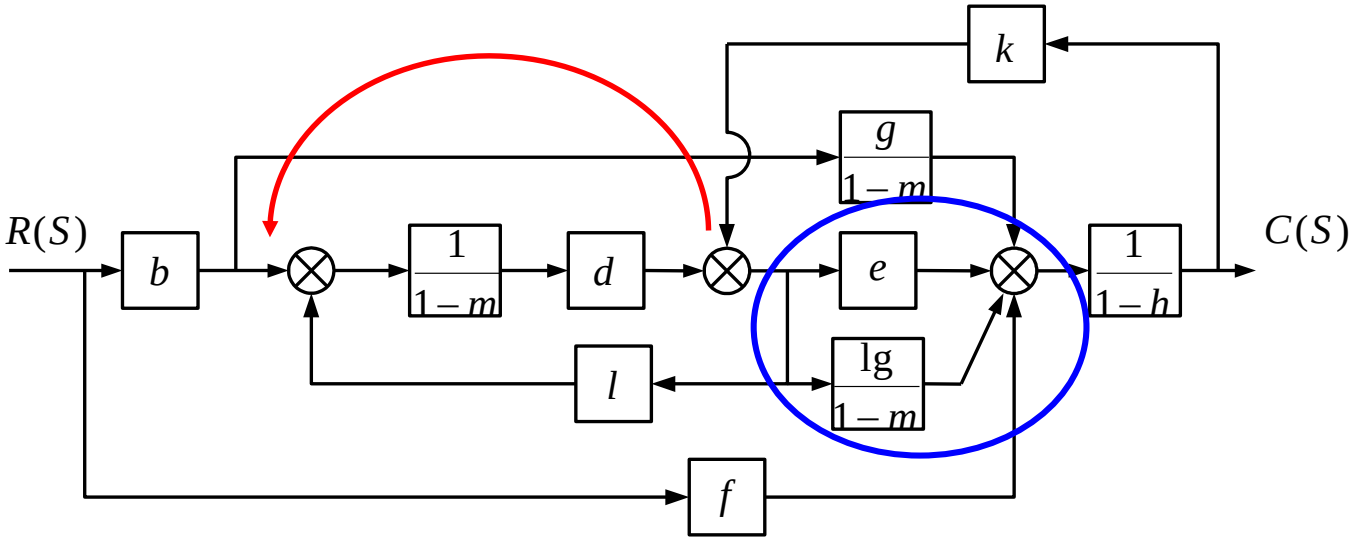


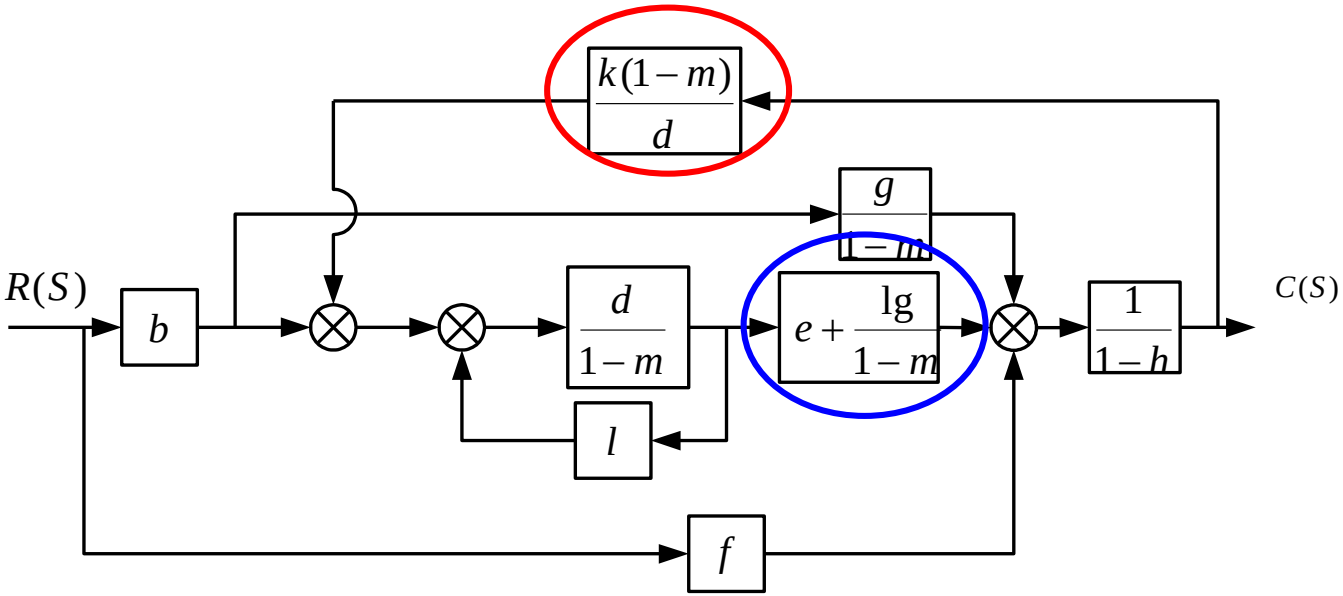

k
g
R(S)
b
1/(1−m)
V1
d
V3
e
1/(1−h)
C(S)
V2
l
f

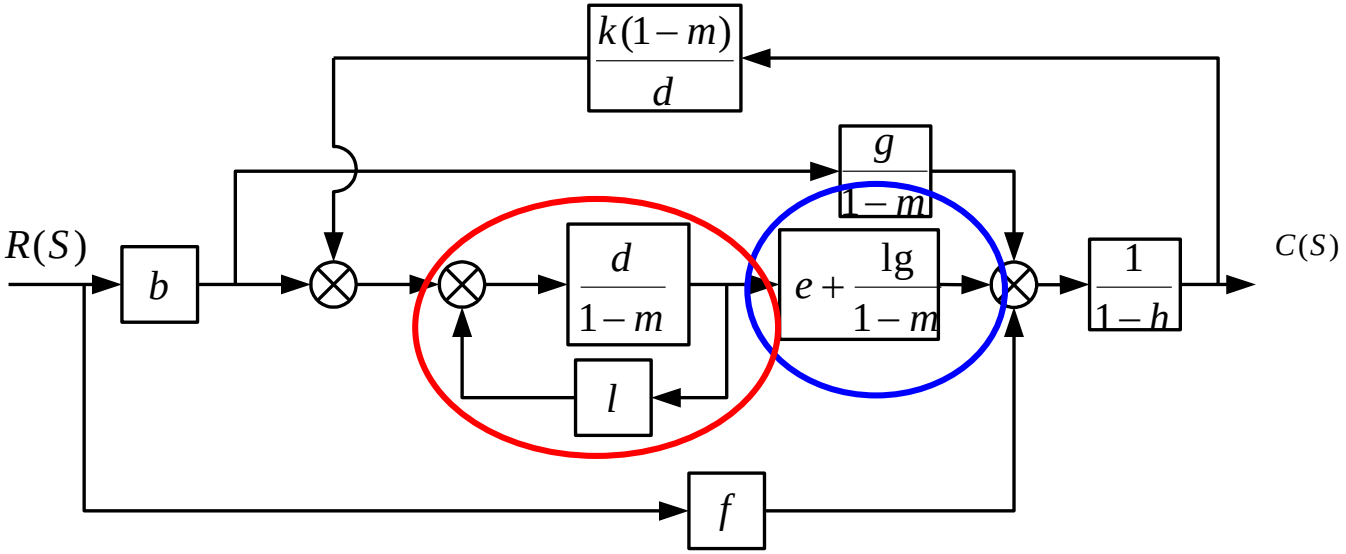

k
g/(1−m)
R(S)
b
1/(1−m)
d
e
1/(1−h)
C(S)
V2
l
f

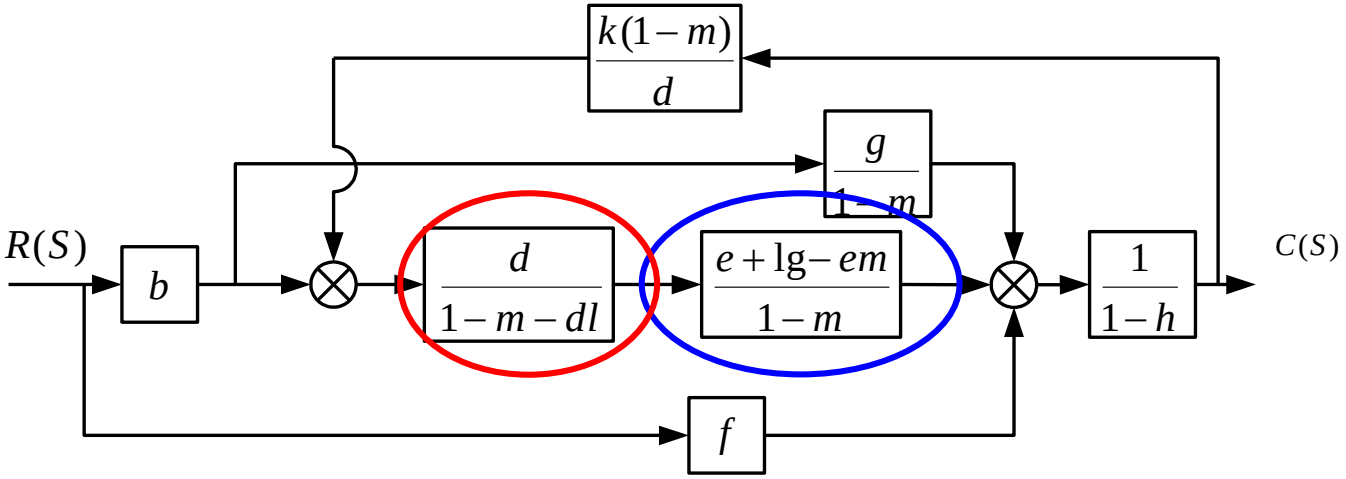

k
g/(1−m)
R(S)
b
1/(1−m)
d
e
1/(1−h)
C(S)
V2
l
f

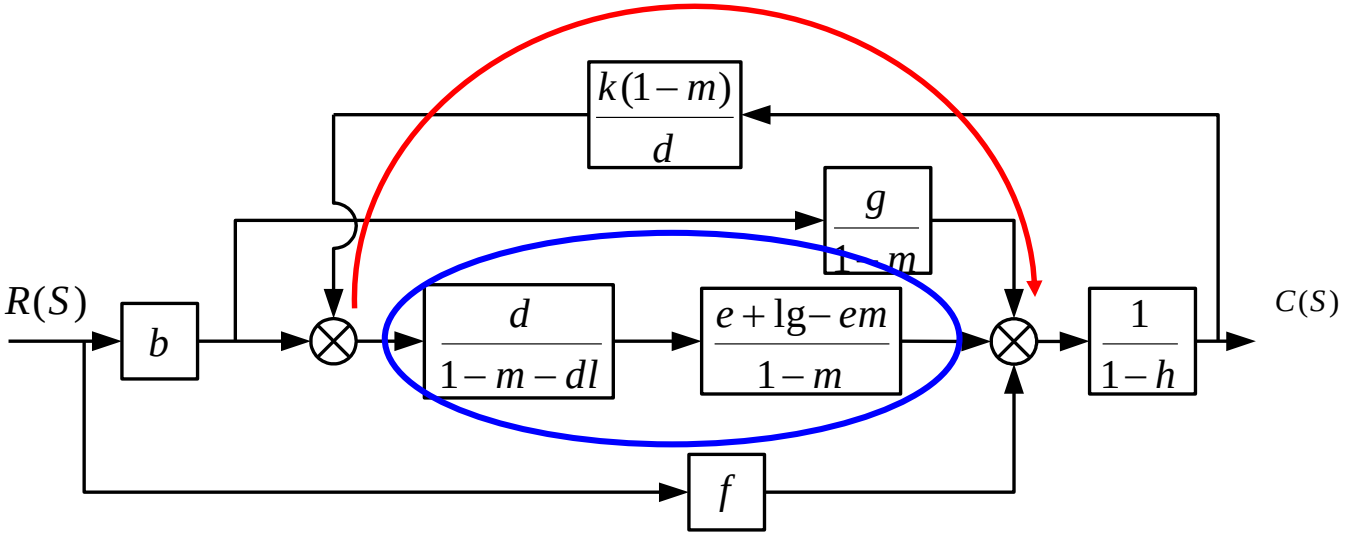

k
g/(1−m)
R(S)
b
1/(1−m)
d
e
1/(1−h)
C(S)
l
lg/(1−m)
f

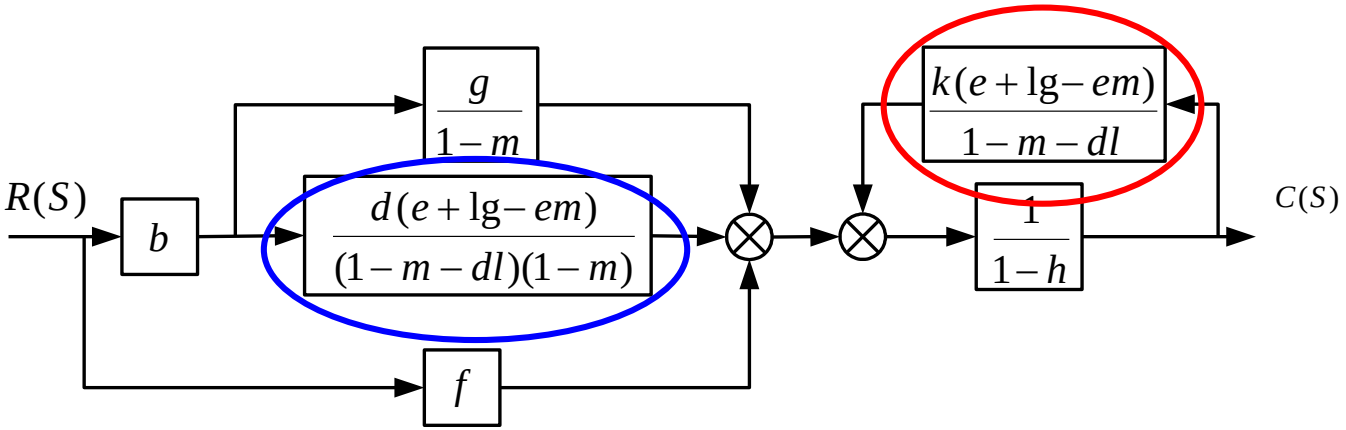

k
g/(1−m)
R(S)
b
1/(1−m)
d
e
1/(1−h)
C(S)
l
lg/(1−m)
f

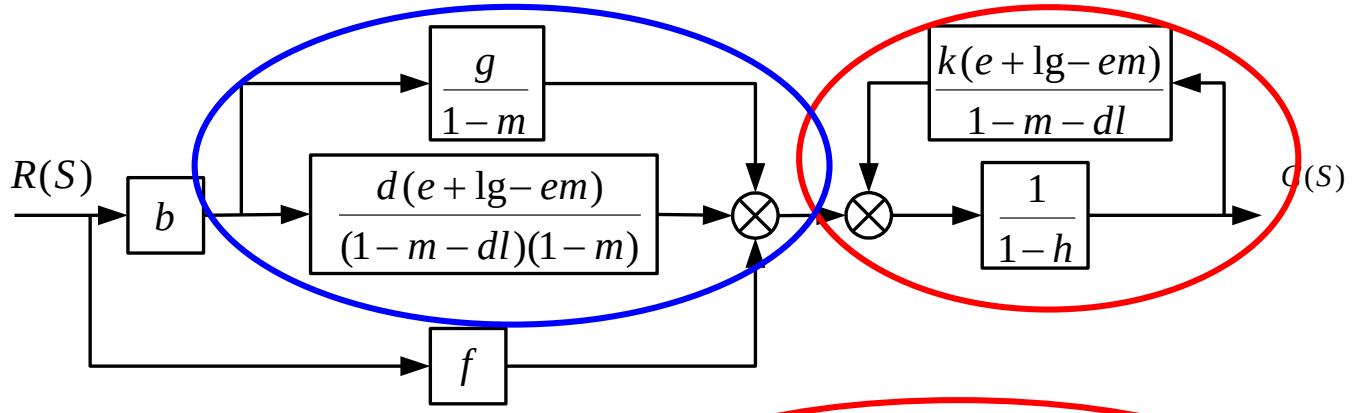

k(1−m)/d
g/(1−m)
R(S)
b
d/(1−m)
e+lg/(1−m)
1/(1−h)
C(S)
l
f

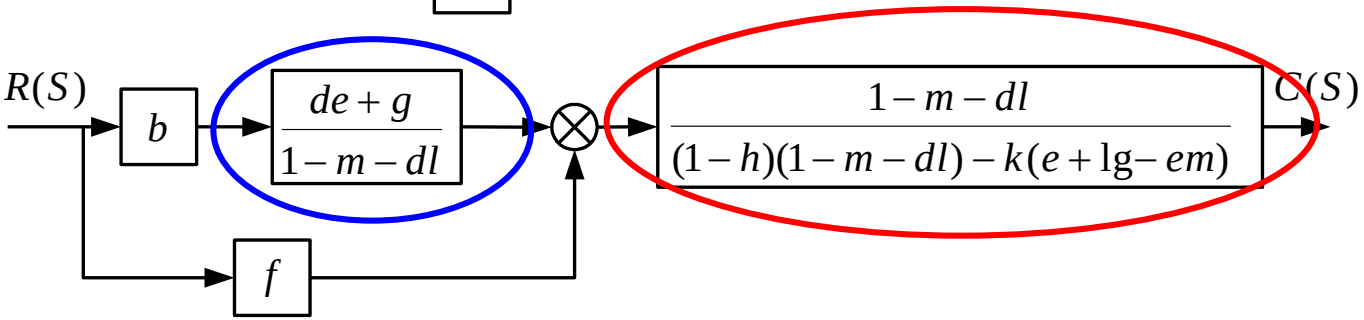

$\frac{k(1-m)}{d}$
$\frac{g}{1-m}$
$R(S)$
b
$\frac{d}{1-m}$
$e+\frac{\lg}{1-m}$
$\frac{1}{1-h}$
$C(S)$
l
f

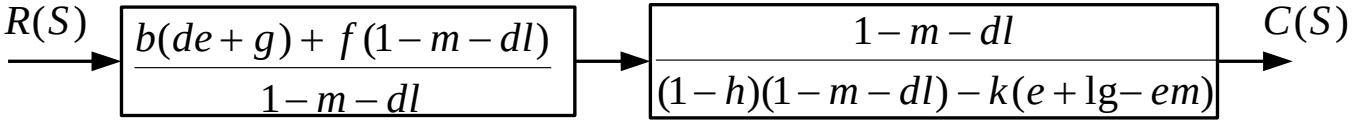

$\frac{k(1-m)}{d}$
$\frac{g}{1-m}$
$R(S)$
b
$\frac{d}{1-m-dl}$
$\frac{e+\lg-em}{1-m}$
$\frac{1}{1-h}$
$C(S)$
f

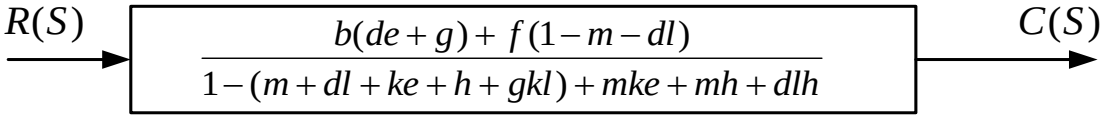

$\frac{k(1-m)}{d}$
$\frac{g}{1-m}$
$R(S)$
b
$\frac{d}{1-m-dl}$
$\frac{e+\lg-em}{1-m}$
$\frac{1}{1-h}$
$C(S)$
f


$\frac{k(e+\lg-em)}{1-m-dl}$
$\frac{g}{1-m}$
$R(S)$
b
$\frac{d(e+\lg-em)}{(1-m-dl)(1-m)}$
$\frac{1}{1-h}$
$C(S)$
f


R(S)
b
g / (1−m)
d(e+lg−em) / (1−m−dl)(1−m)
f
k(e+lg−em) / (1−m−dl)
1 / (1−h)
C(S)

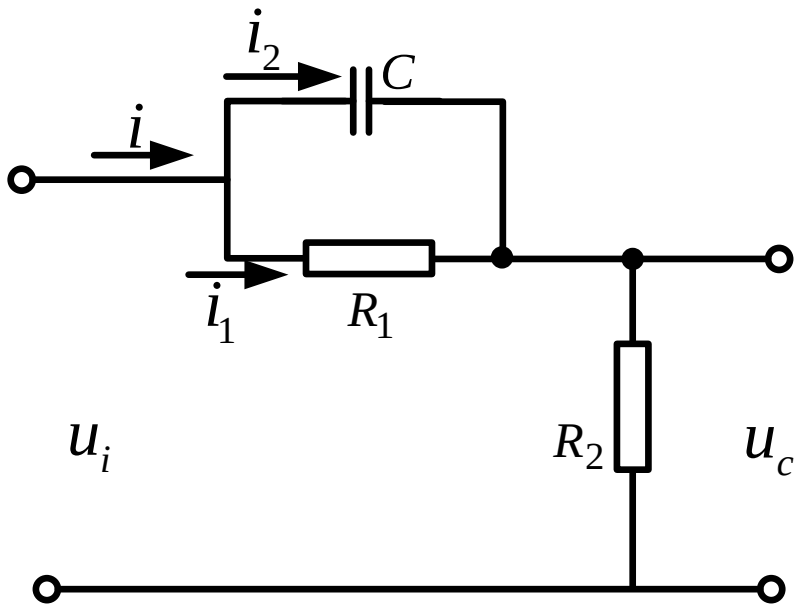

R(S)
b
de+g / (1−m−dl)
f
(1−m−dl) / [(1−h)(1−m−dl)−k(e+lg−em)]
C(S)


R(S)
b(de+g)+f(1−m−dl) / (1−m−dl)
(1−m−dl) / [(1−h)(1−m−dl)−k(e+lg−em)]
C(S)


R(S)
b(de+g)+f(1−m−dl) / [1−(m+dl+ke+h+gkl)+mke+mh+dlh]
C(S)

方块图的绘制

例1



$$i_1 = \frac{u_i - u_c}{R_1}$$

$$i_1 R_1 = \frac{1}{c}\int i_2 dt$$

$$i = i_1 + i_2$$

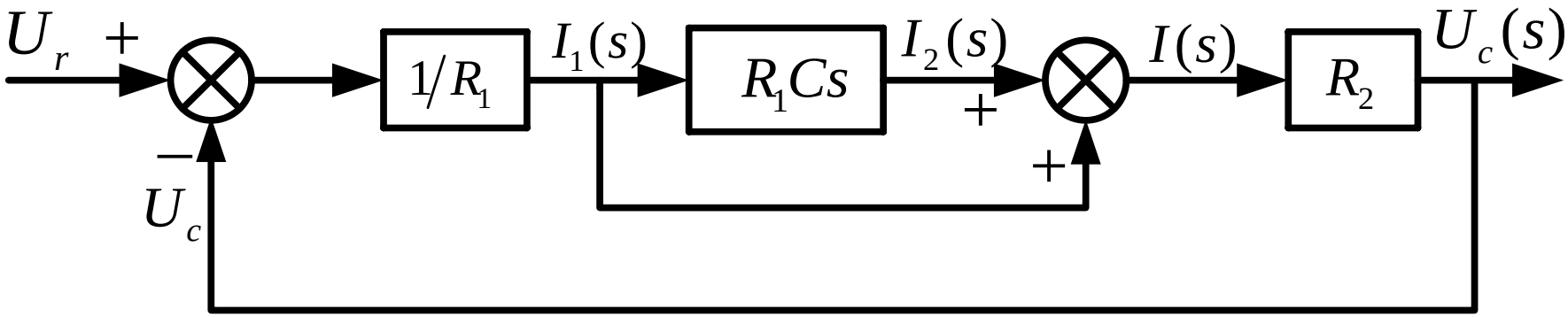
$$u_c = R_2 i$$

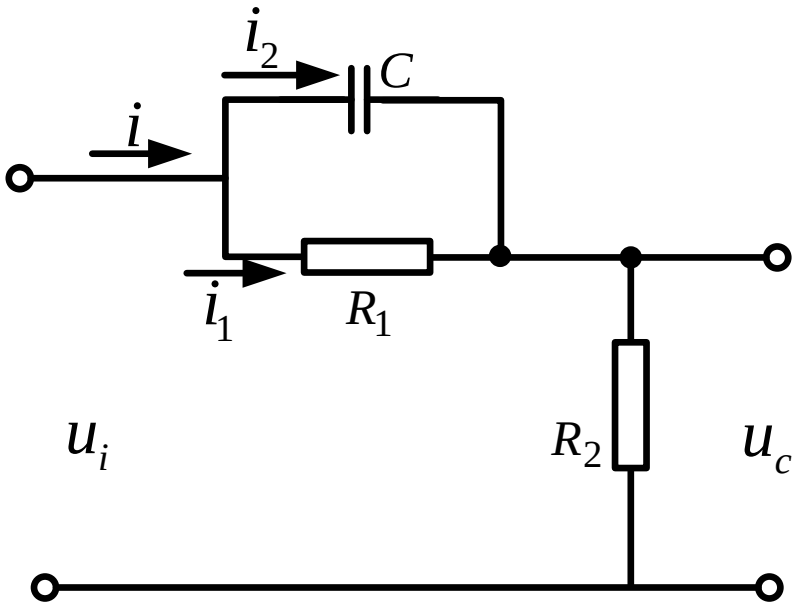
$$I_1(s) = \frac{U_i(s) - U_c(s)}{R_1}$$

$$\frac{1}{cs} I_2(s) = R_1 I_1(s)$$

$$I(s) = I_1(s) + I_2(s)$$

$$U_c = R_2 I(s)$$





系统的方块图

是不是唯一的?