Fundamentals of Microelectronics II

فصل ۱۲- فیدبک

(قسمت دوم- آرایش های فیدبک و ...)

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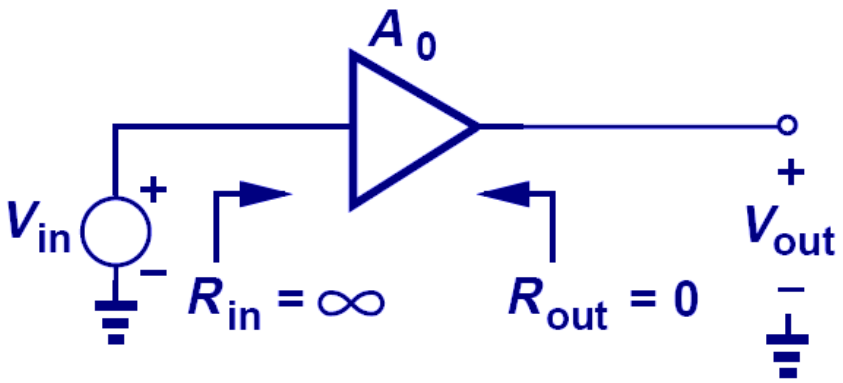
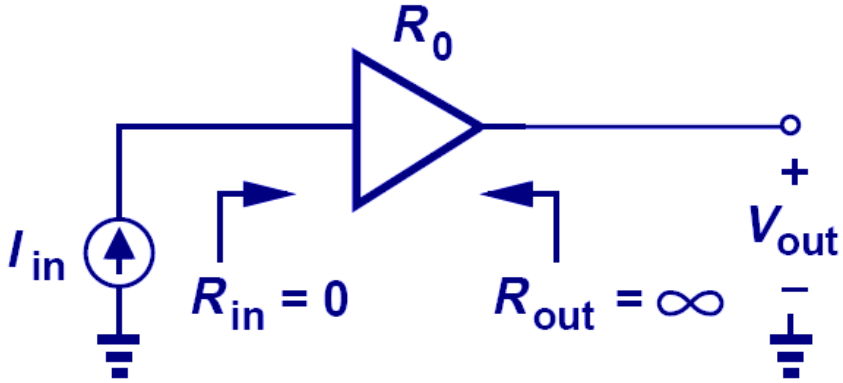
Chapter 12 Feedback

- 12.5 Feedback Topologies
- 12.6 Effect of Finite I/O Impedances
- 12.7 Stability in Feedback Systems

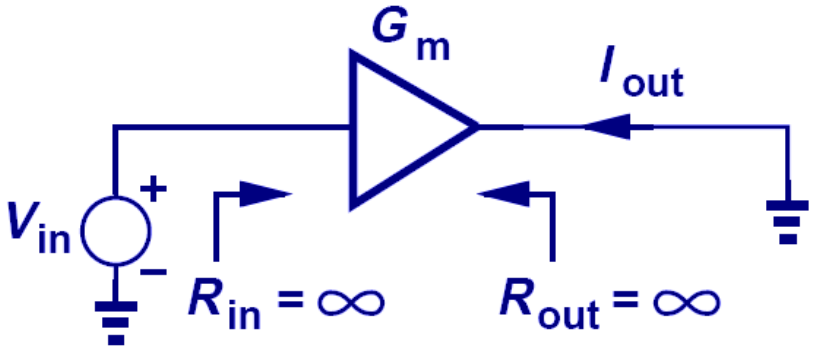
Four Types of Amplifiers

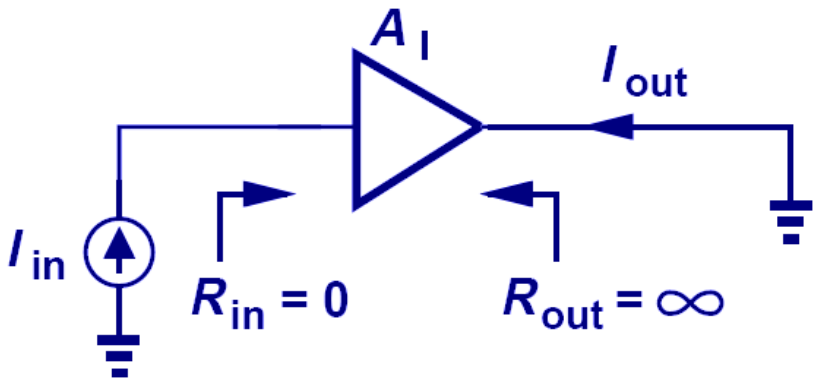


(a)

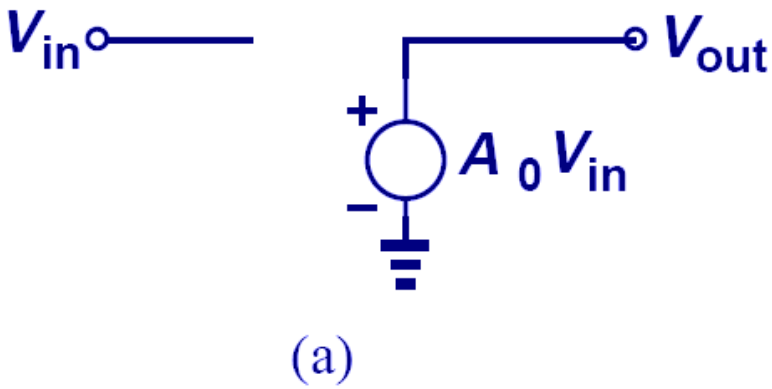


(b)

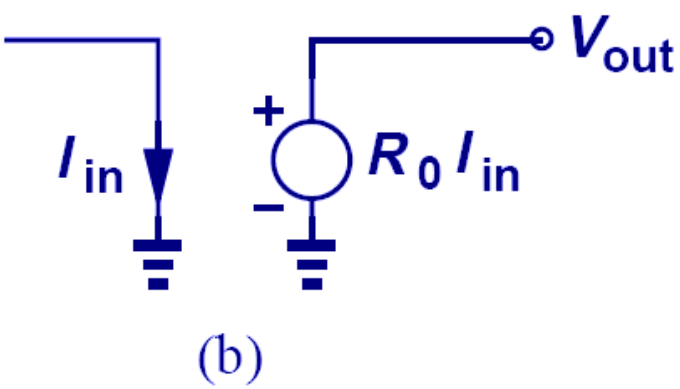




Ideal Models of the Four Amplifier Types



(a)



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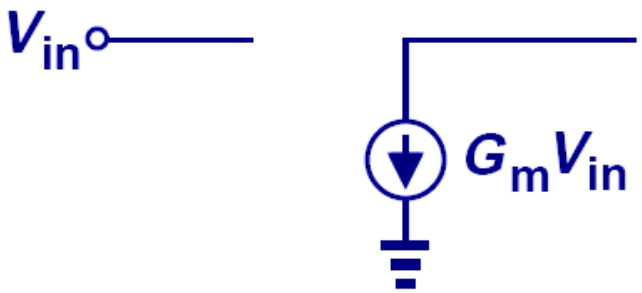

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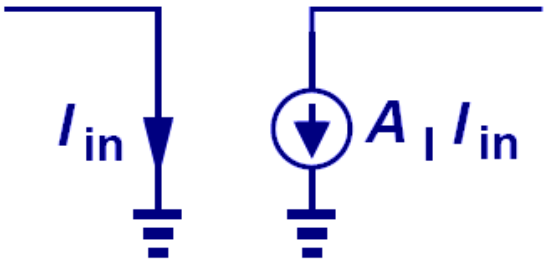
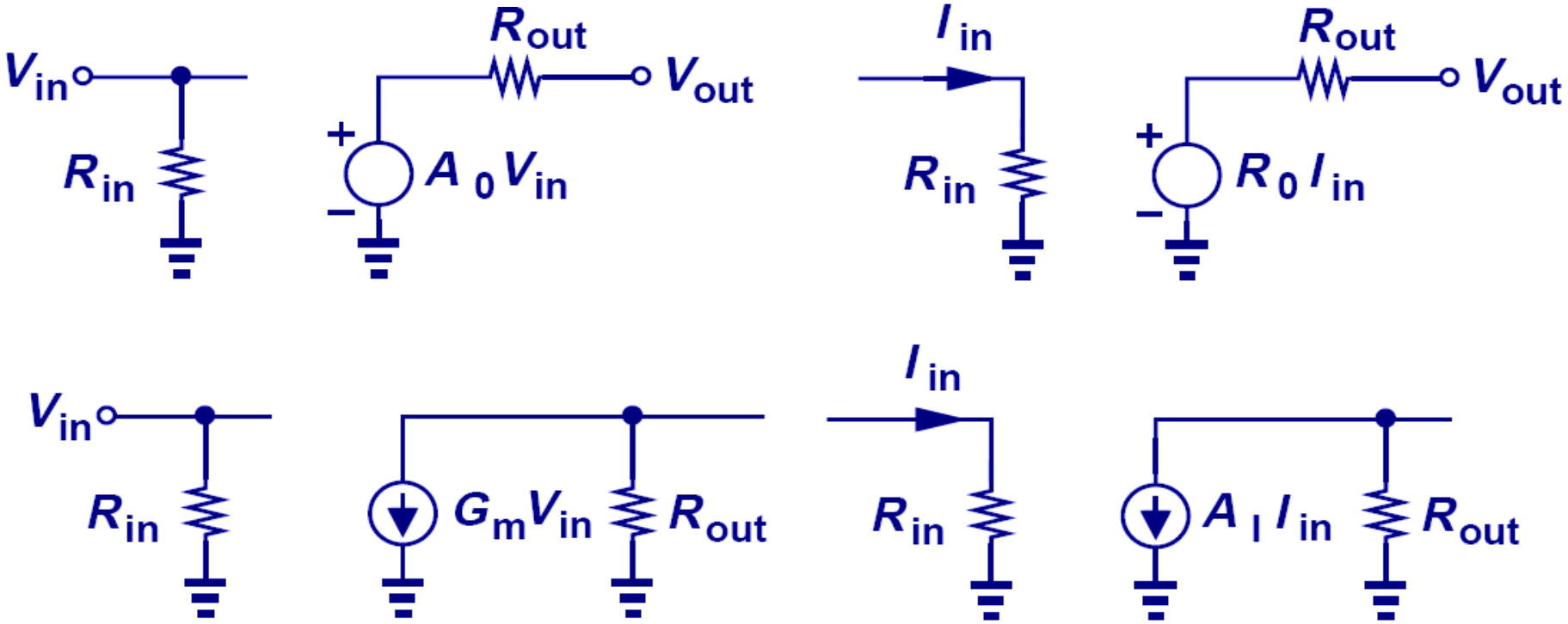


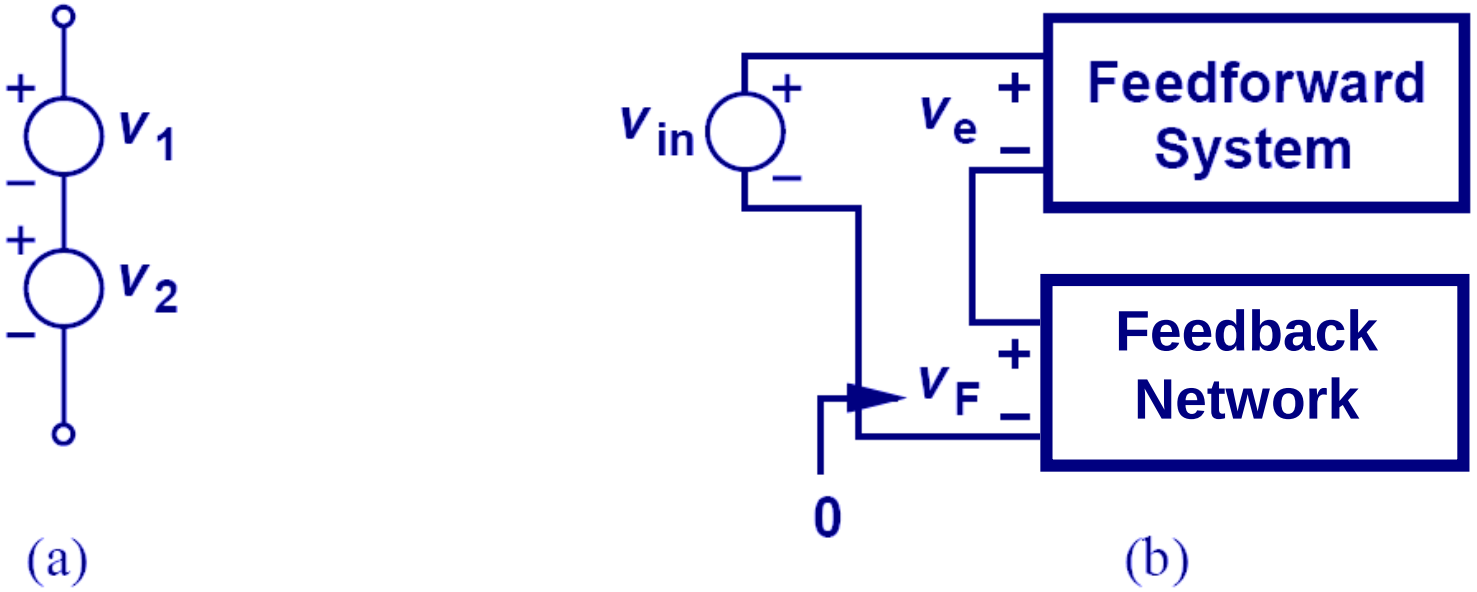
(d)

Realistic Models of the Four Amplifier Types



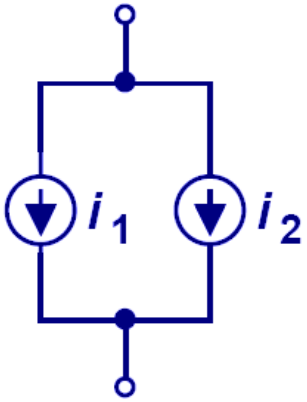
ردیف	نوع تقویت کننده	شرایط مورد استفاده		R_{in}	R_{out}	A_O
		R_s	R_L			
۱	ولتاژ	0=کم	∞= زیاد	∞= زیاد	0=کم	$A_V=V_{out}/V_{in}$
۲	جریان	∞= زیاد	0=کم	0=کم	∞= زیاد	$A_i=I_{out}/I_{in}$
۳	هدایت انتقالی	0=کم	0=کم	∞= زیاد	∞= زیاد	$A_o=G_m=I_{out}/V_{in}$
۴	مقاومت انتقالی	∞= زیاد	∞= زیاد	0=کم	0=کم	$A_o=R_m=V_{out}/I_{in}$

Addition of Two Voltage Sources

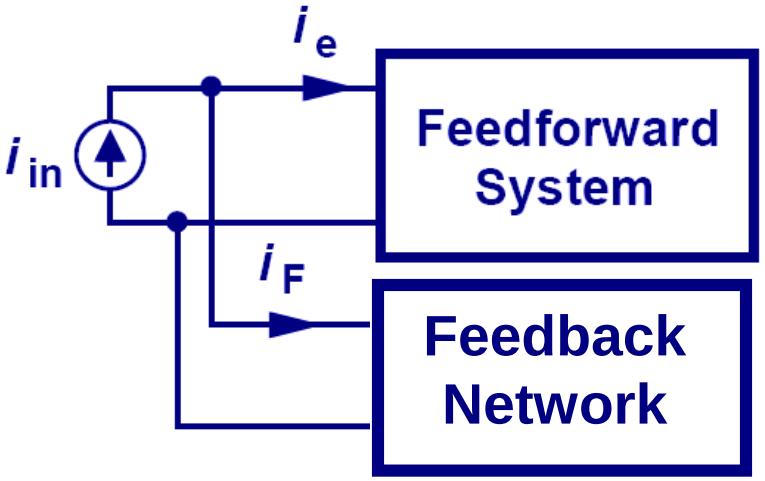


- **In order to add or substrate two voltage sources, we place them in series. So the feedback network is placed in series with the input source.**

Addition of Two Current Sources



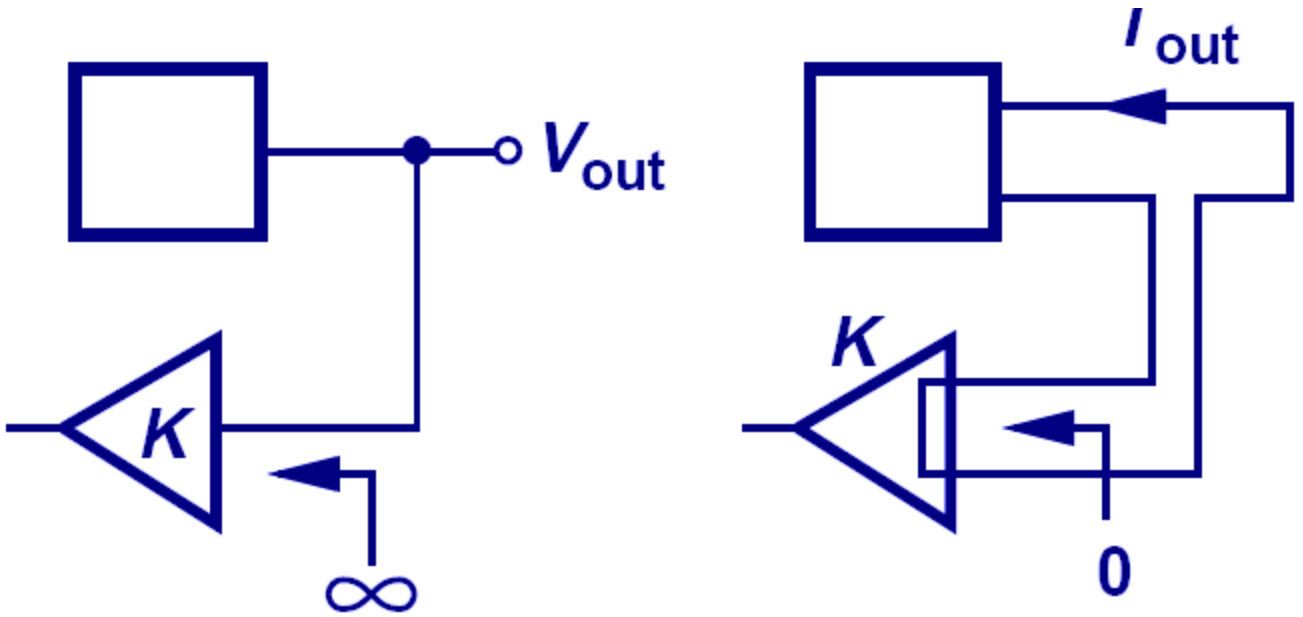
(a)



(b)

- **In order to add two current sources, we place them in parallel. So the feedback network is placed in parallel with the input signal.**

Input Impedance of an Ideal Feedback Network



- **To sense a voltage, the input impedance of an ideal feedback network must be infinite.**
- **To sense a current, the input impedance of an ideal feedback network must be zero.**

انواع تقویت کننده

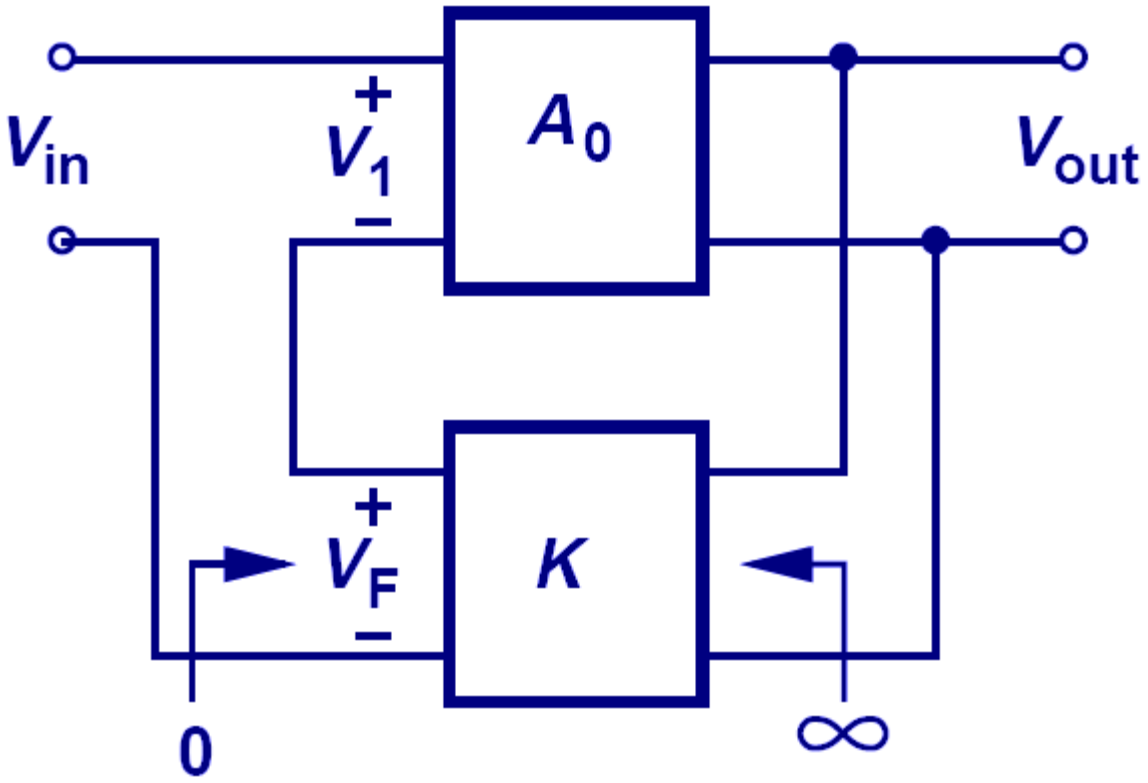
ردیف	نوع تقویت کننده	شرایط مورد استفاده		R_{in}	R_{out}	A_O
		R_s	R_L			
۱	ولتاژ	0=کم	∞= زیاد	∞= زیاد	0=کم	$A_V=V_{out}/V_{in}$
۲	جریان	∞= زیاد	0=کم	0=کم	∞= زیاد	$A_i=I_{out}/I_{in}$
۳	هدایت انتقالی	0=کم	0=کم	∞= زیاد	∞= زیاد	$A_o=G_m=I_{out}/V_{in}$
۴	مقاومت انتقالی	∞= زیاد	∞= زیاد	0=کم	0=کم	$A_o=R_m=V_{out}/I_{in}$

انواع فیدبک

ردیف	نوع فیدبک	تقویت شاخص	ضریب فیدبک K	$A_{(f)}$, $R_{in(f)}$, $R_{out(f)}$
۱	فیدبک ولتاژ- ولتاژ فیدبک ولتاژ- سری فیدبک سری- موازی	بهره ولتاژ $A_o=A_v=V_{out}/V_{in}$	$K= V_f/V_{out}$ | ...	$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}.(1+KA_o)$ $R_{out(f)}=R_{out}/(1+KA_o)$
۲	فیدبک جریان- جریان فیدبک جریان- موازی فیدبک موازی- سری	بهره جریان $A_o=A_i=I_{out}/I_{in}$	$K=I_f/I_{out}$ | ...	$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}/(1+KA_o)$ $R_{out(f)}=R_{out}.(1+KA_o)$
۳	فیدبک جریان-ولتاژ فیدبک جریان- سری فیدبک سری-سری	هدایت انتقالی $A_o=G_m=I_{out}/V_{in}$	$K=V_f/I_{out}$ | ...	$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}.(1+KA_o)$ $R_{out(f)}=R_{out}.(1+KA_o)$
۴	فیدبک ولتاژ-جریان فیدبک ولتاژ- موازی فیدبک موازی- موازی	مقامت انتقالی $A_o=R_m=V_{out}/I_{in}$	$K=I_f/V_{out}$ | ...	$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}/(1+KA_o)$ $R_{out(f)}=R_{out}/(1+KA_o)$

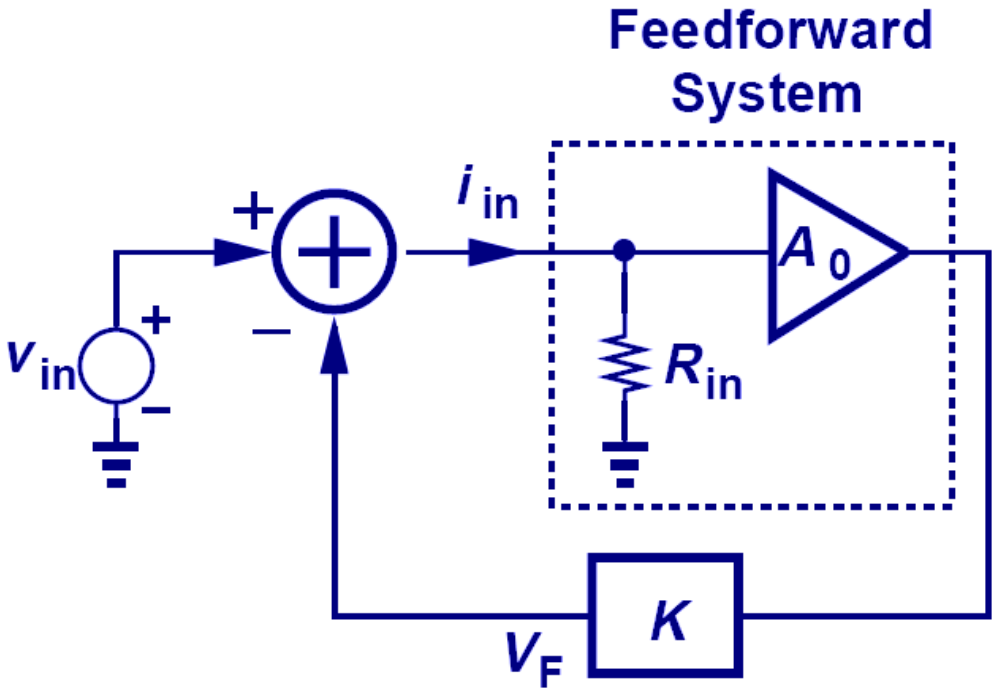
Voltage-Voltage Feedback

$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}.(1+KA_o)$ $R_{out(f)}=R_{out}/(1+KA_o)$	$K=V_f/V_{out}$ | …	$A_o=A_v=V_{out}/V_{in}$ بهره ولتاژ	فیدبک ولتاژ- ولتاژ فیدبک ولتاژ- سری فیدبک سری- موازی



$$\frac{V_{out}}{V_{in}}=\frac{A_0}{1+KA_0}$$

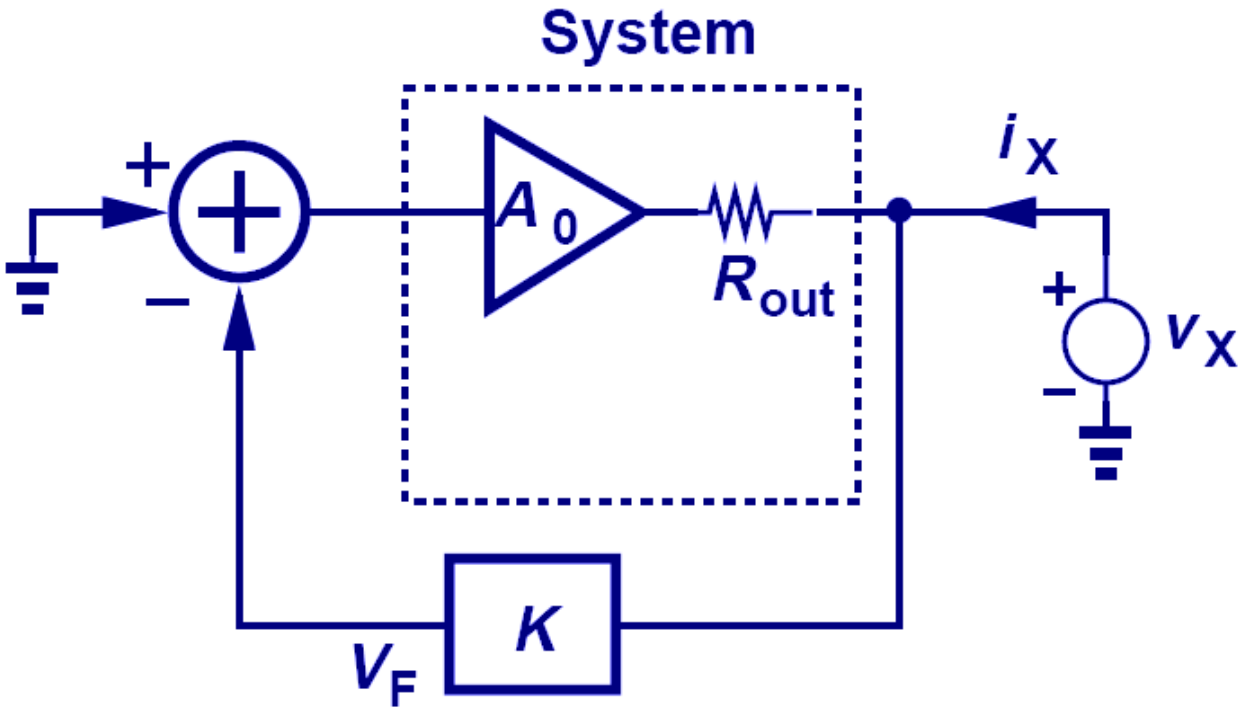
Input Impedance of a V-V Feedback



$$\frac{V_{in}}{I_{in}} = R_{in}(1+A_0K)$$

- **A better voltage sensor**

Output Impedance of a V-V Feedback

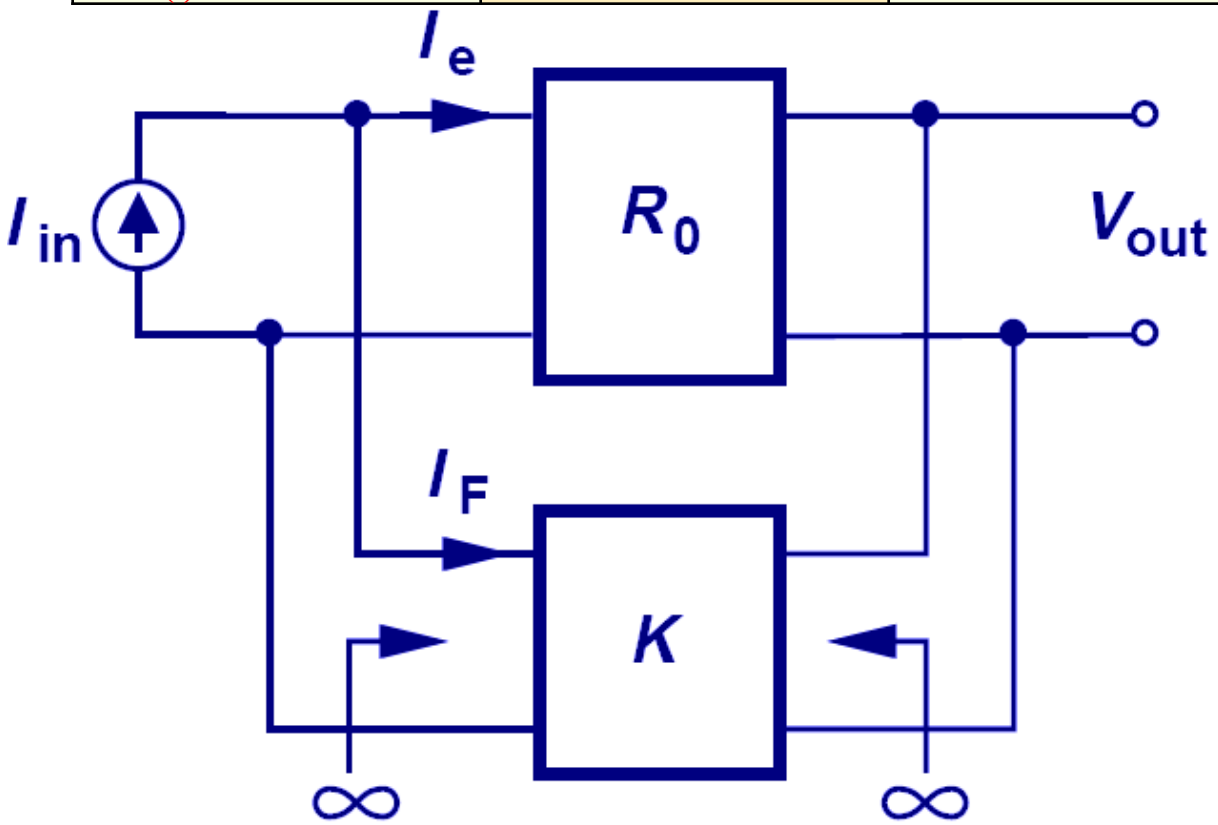


$$\frac{V_X}{I_X} = \frac{R_{out}}{(1+KA_0)}$$

- **A better voltage source**

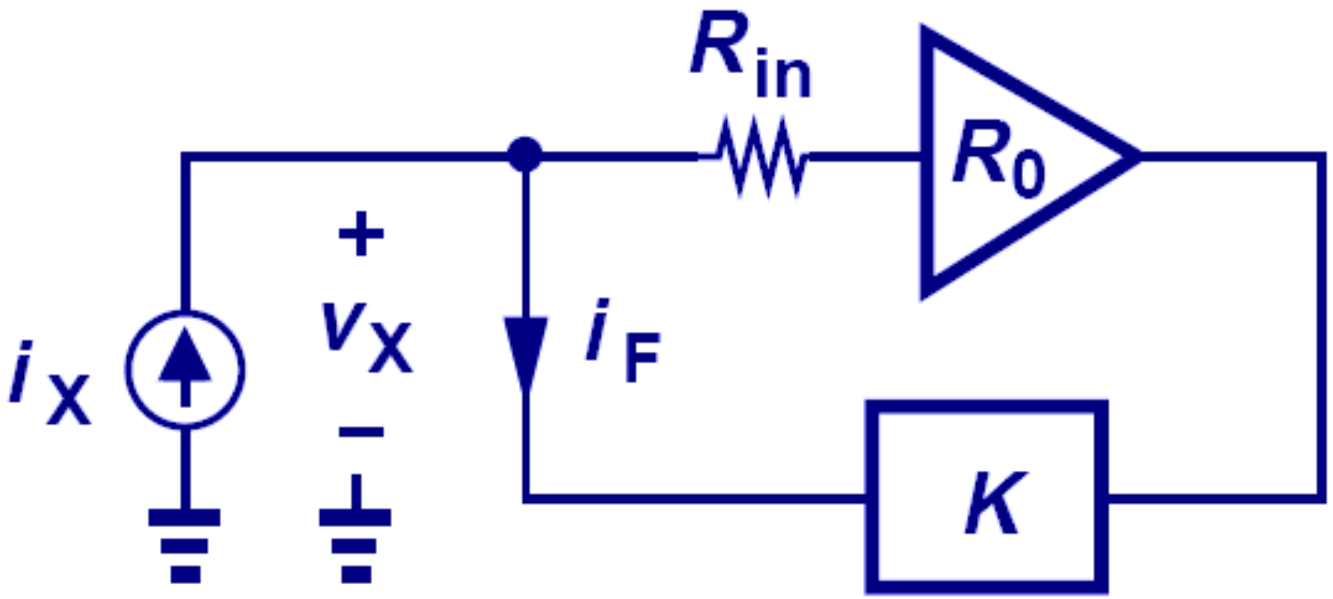
Voltage-Current Feedback

$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}/(1+KA_o)$ $R_{out(f)}=R_{out}/(1+KA_o)$	$K=I_f/V_{out}$ | …	$A_o=R_m=V_{out}/I_{in}$ مقامت انتقالی	فیدبک ولتاژ-جریان فیدبک ولتاژ- موازی فیدبک موازی- موازی



$$\frac{V_{out}}{I_{in}}=\frac{R_O}{1+KR_O}$$

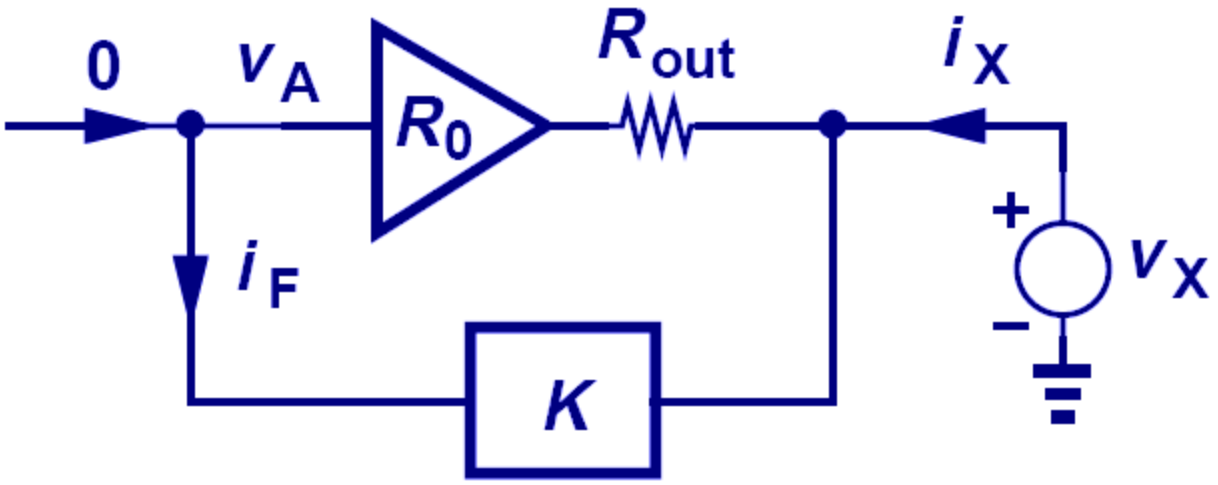
Input Impedance of a V-C Feedback



$$\frac{V_X}{I_X} = \frac{R_{in}}{1 + R_0 K}$$

- **A better current sensor.**

Output Impedance of a V-C Feedback

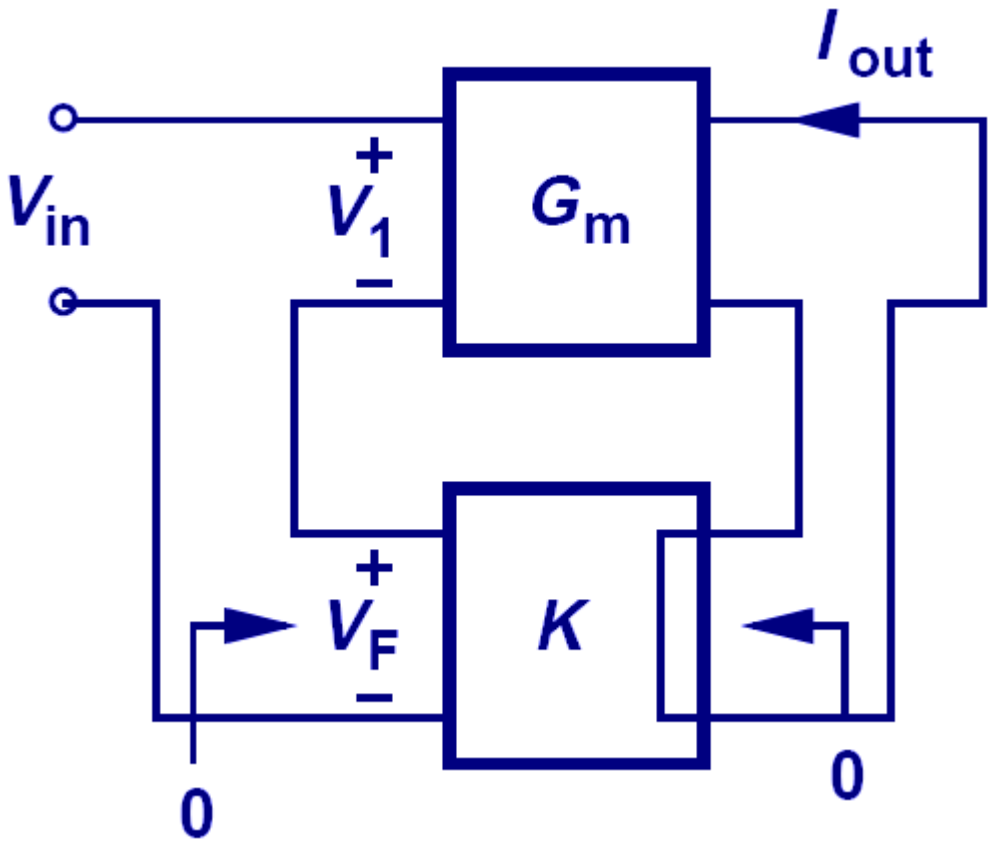


$$\frac{V_X}{I_X} = \frac{R_{out}}{1 + R_0 K}$$

- **A better voltage source.**

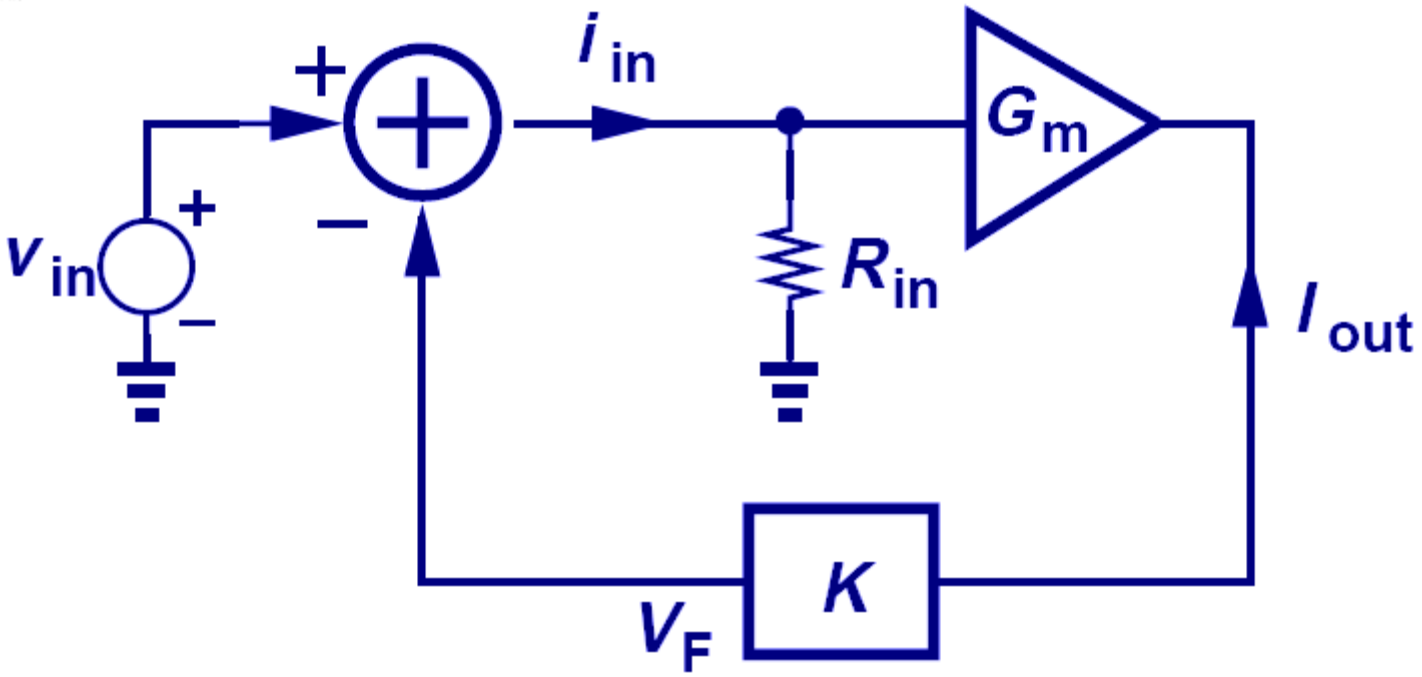
Current-Voltage Feedback

$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}.(1+KA_o)$ $R_{out(f)}=R_{out}.(1+KA_o)$	$K=V_f/I_{out}$ | …	$A_o=G_m=I_{out}/V_{in}$ هدایت انتقالی	فیدبک جریان-ولتاژ فیدبک جریان- سری فیدبک سری-سری



$$\frac{I_{out}}{V_{in}} = \frac{G_m}{1+KG_m}$$

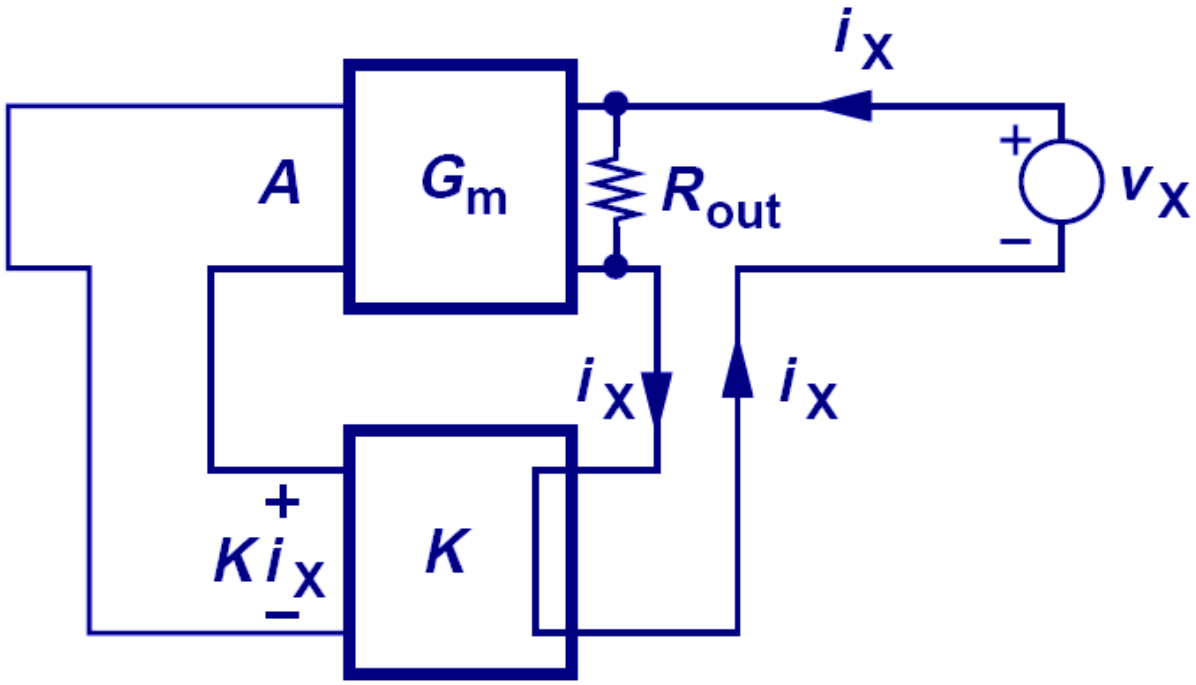
Input Impedance of a C-V Feedback



$$\frac{V_{in}}{I_{in}} = R_{in}(1+KG_m)$$

- **A better voltage sensor.**

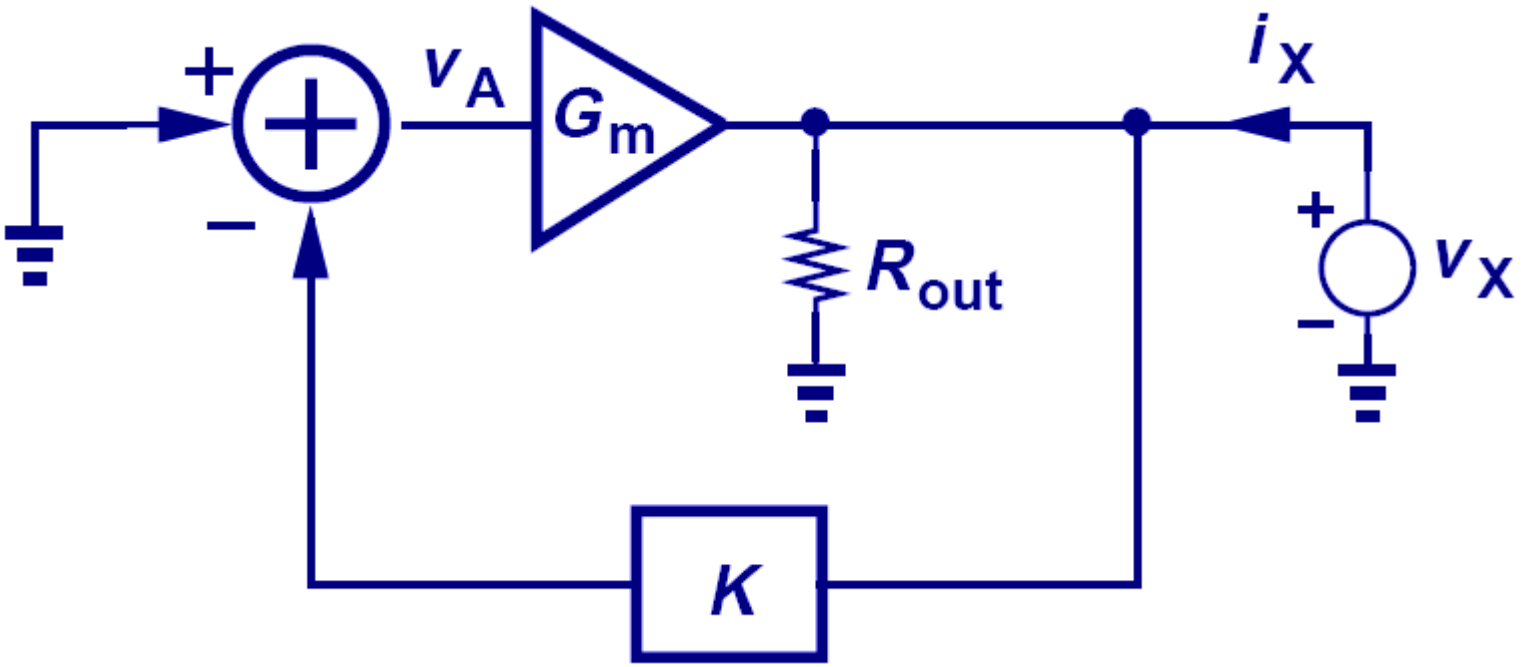
Output Impedance of a C-V Feedback



$$\frac{V_X}{I_X} = R_{out}(1 + KG_m)$$

- **A better current source.**

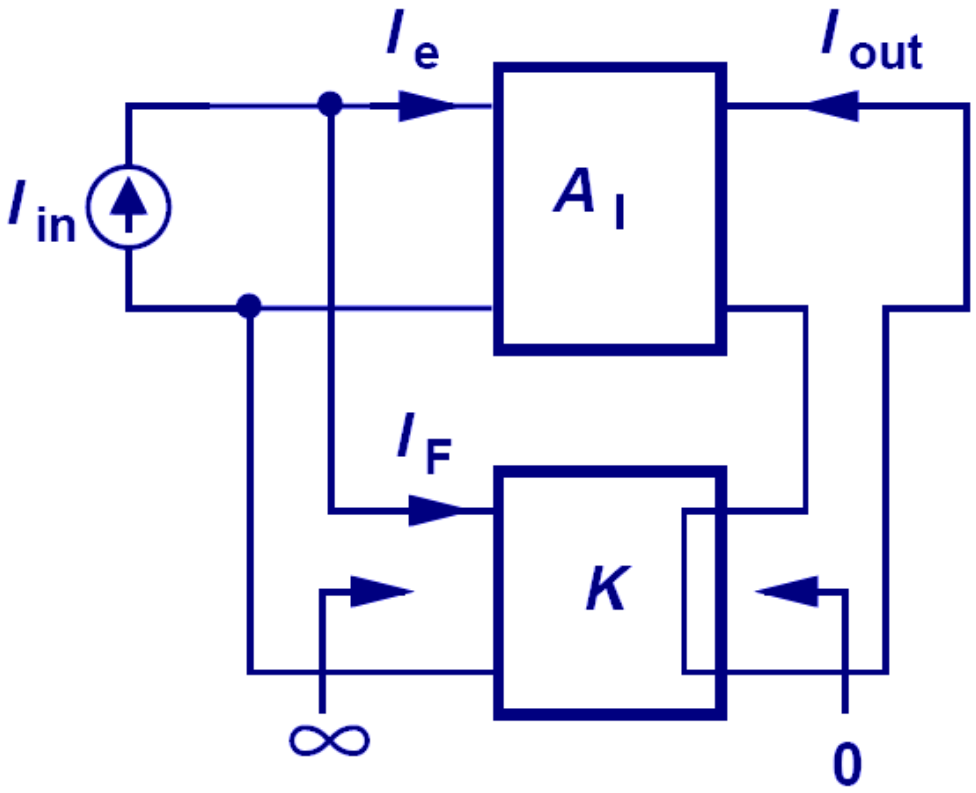
Wrong Technique for Measuring Output Impedance



- If we want to measure the output impedance of a C-V closed-loop feedback topology directly, we have to place V_X in series with K and R_{out}. Otherwise, the feedback will be disturbed.

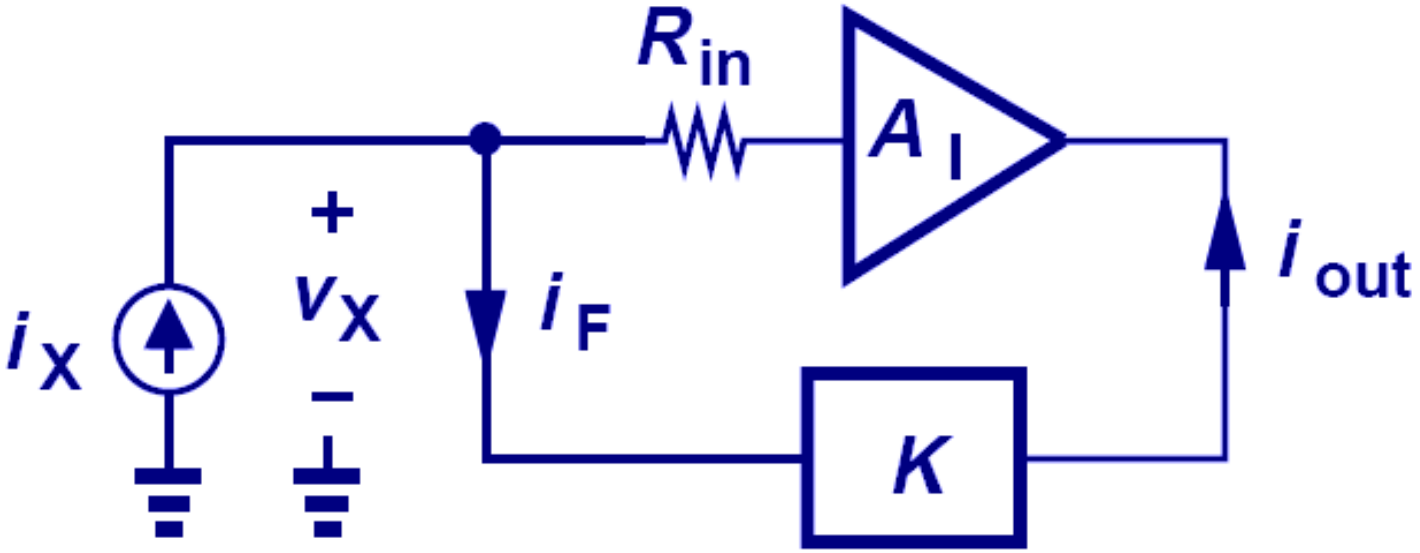
Current-Current Feedback

$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=Rin/(1+KA_o)$ $R_{out(f)}=R_{out}.(1+KA_o)$	$K=I_f/I_{out}$ | …	$A_o=A_i=I_{out}/I_{in}$ بهره جریان	فیدبک جریان- جریان فیدبک جریان- موازی فیدبک موازی- سری



$$\frac{I_{out}}{I_{in}}=\frac{A_I}{1+KA_I}$$

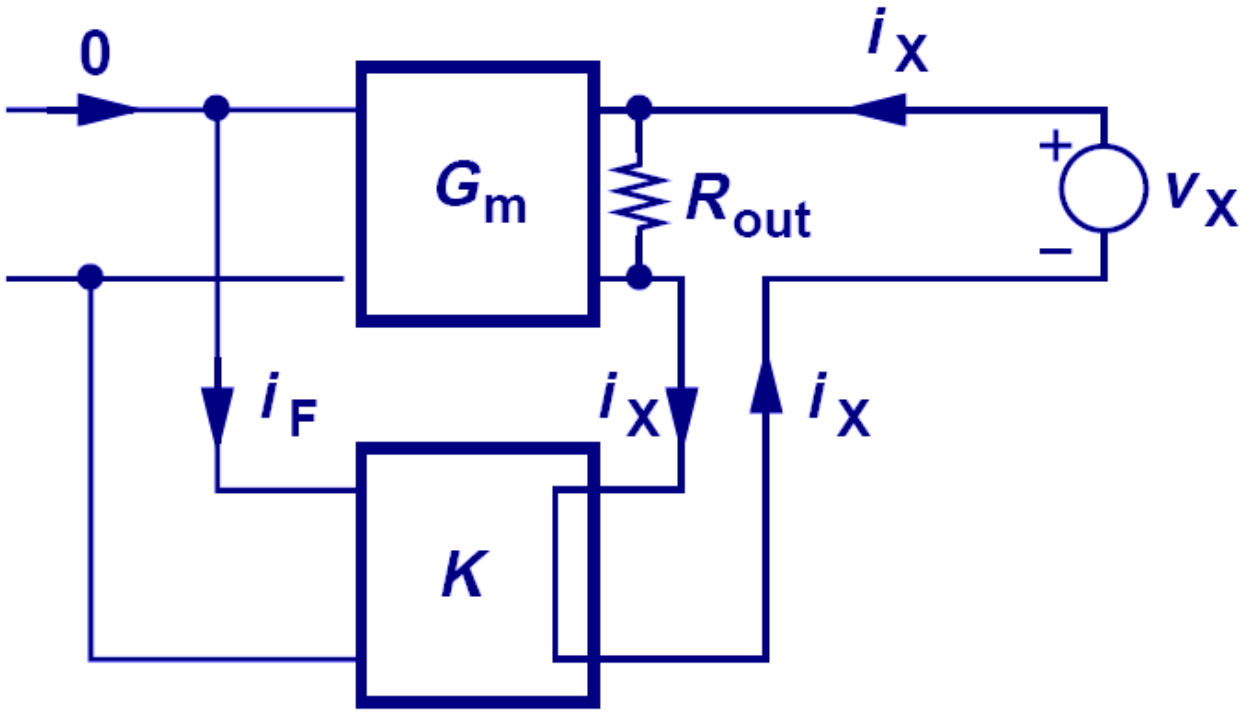
Input Impedance of C-C Feedback



$$\frac{V_X}{I_X} = \frac{R_{in}}{1 + KA_I}$$

- **A better current sensor.**

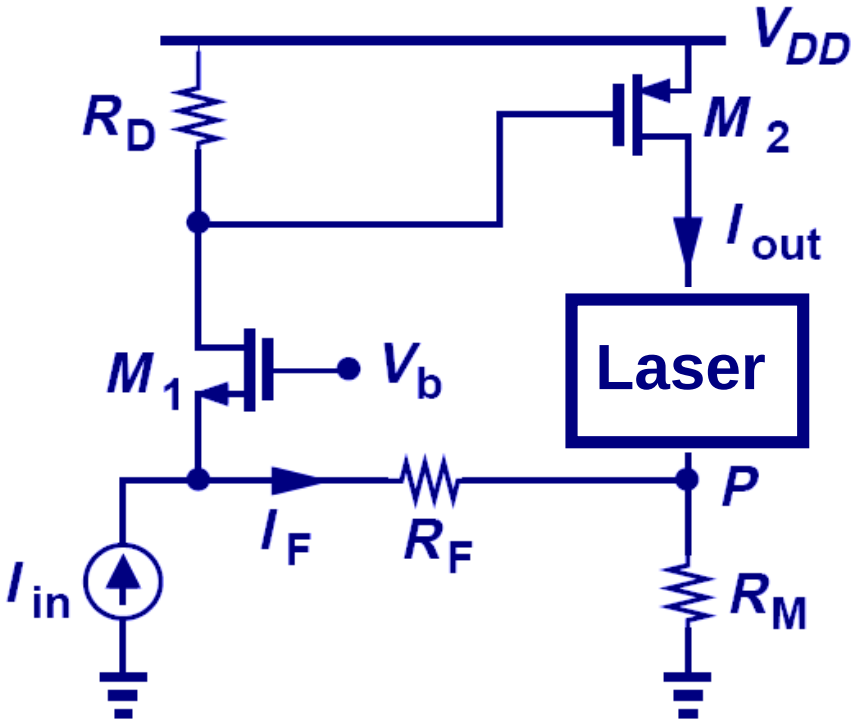
Output Impedance of C-C Feedback



$$\frac{V_X}{I_X} = R_{out}(1 + KA_I)$$

- **A better current source.**

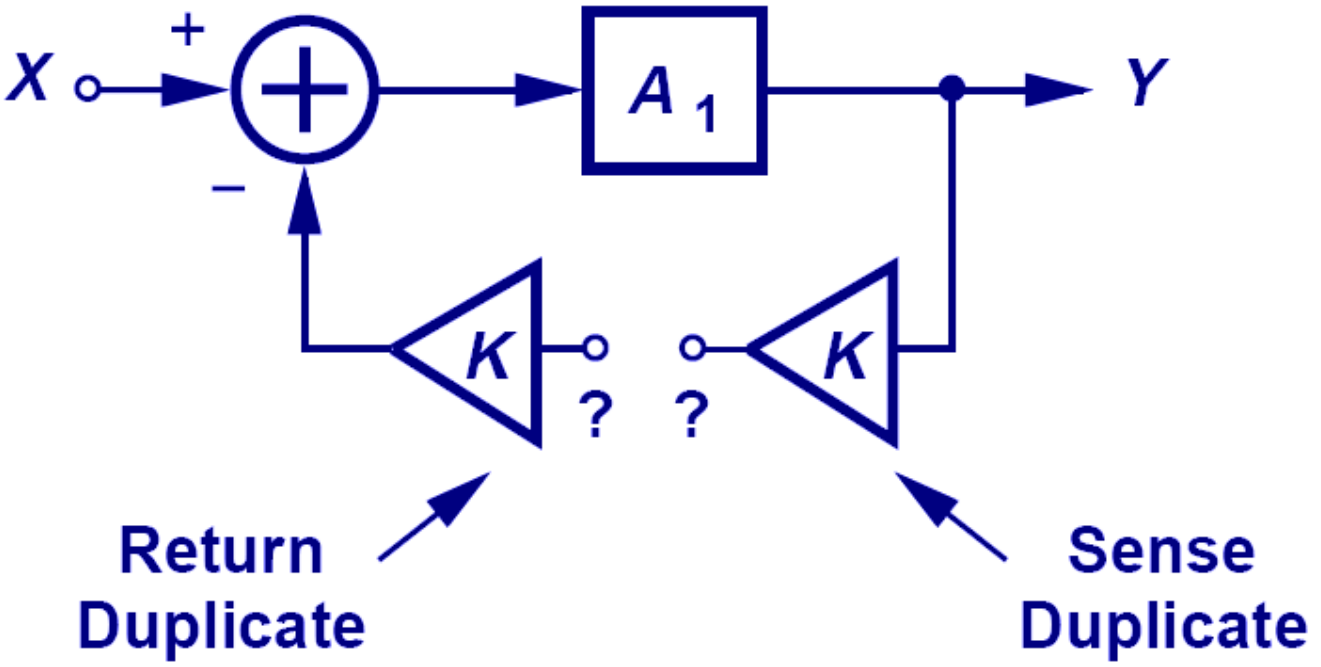
Example: Test of Negative Feedback



$$I_{in} \uparrow \Rightarrow V_{D1} \uparrow, I_{out} \downarrow \Rightarrow V_P \downarrow, I_F \uparrow \Rightarrow V_{D1} \downarrow, I_{out} \uparrow$$

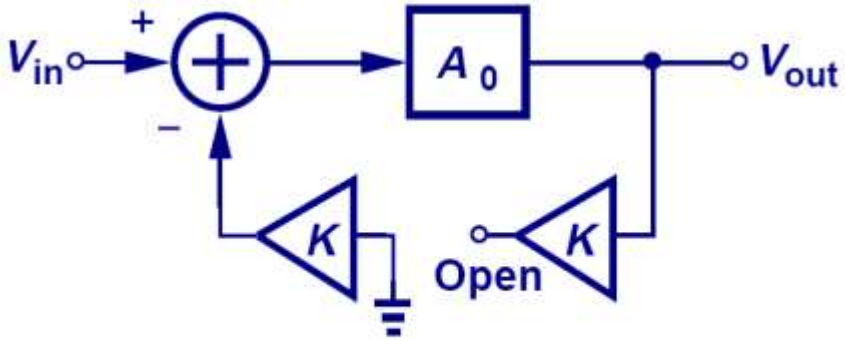
Negative Feedback

How to Break a Loop

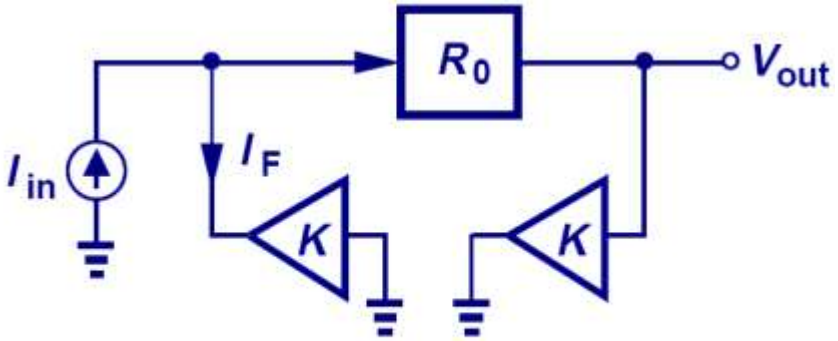


- The correct way of breaking a loop is such that the loop does not know it has been broken. Therefore, we need to present the feedback network to both the input and the output of the amplifier.

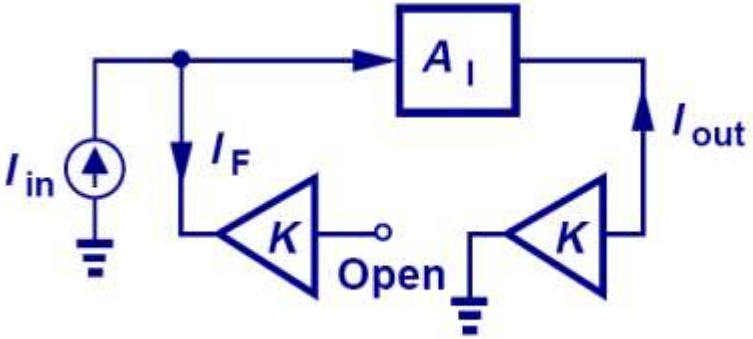
Rules for Breaking the Loop of Amplifier Types



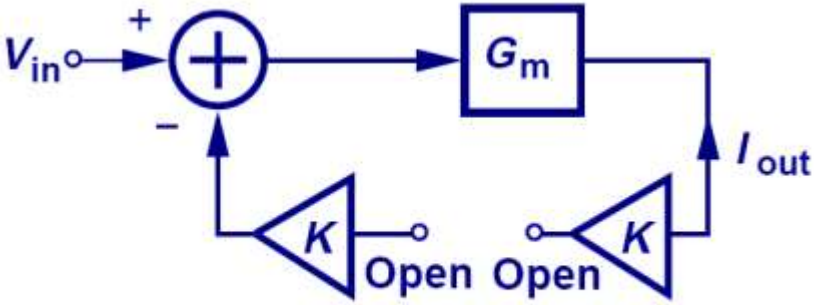
(a)



(b)

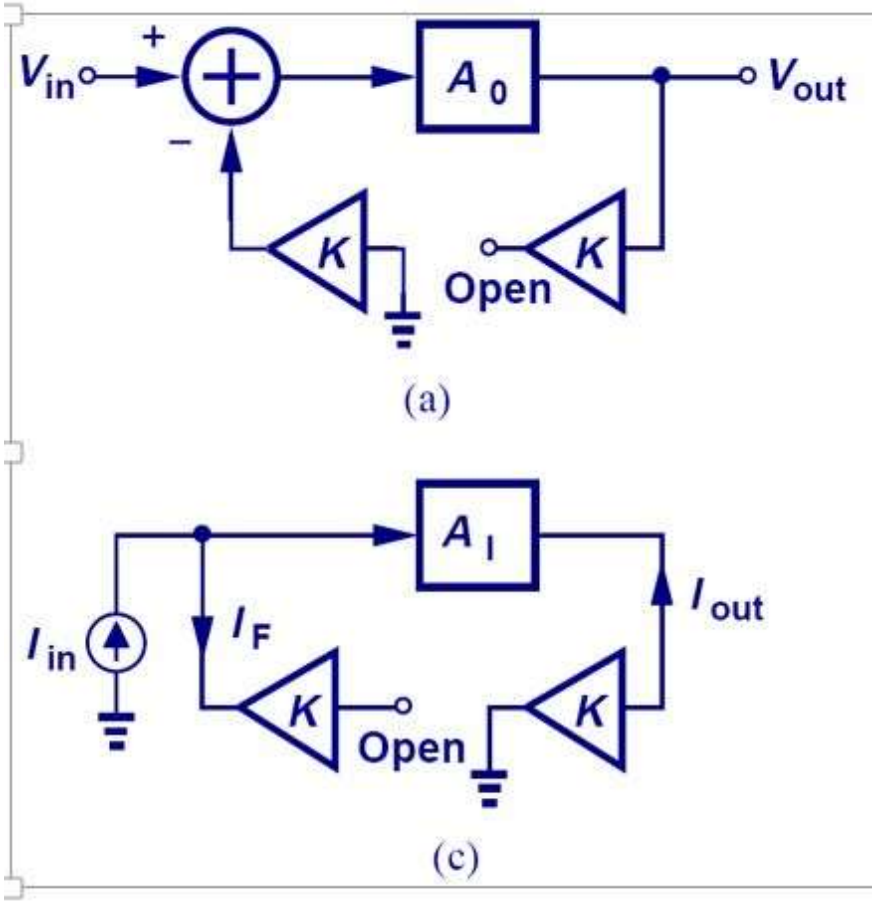


(c)



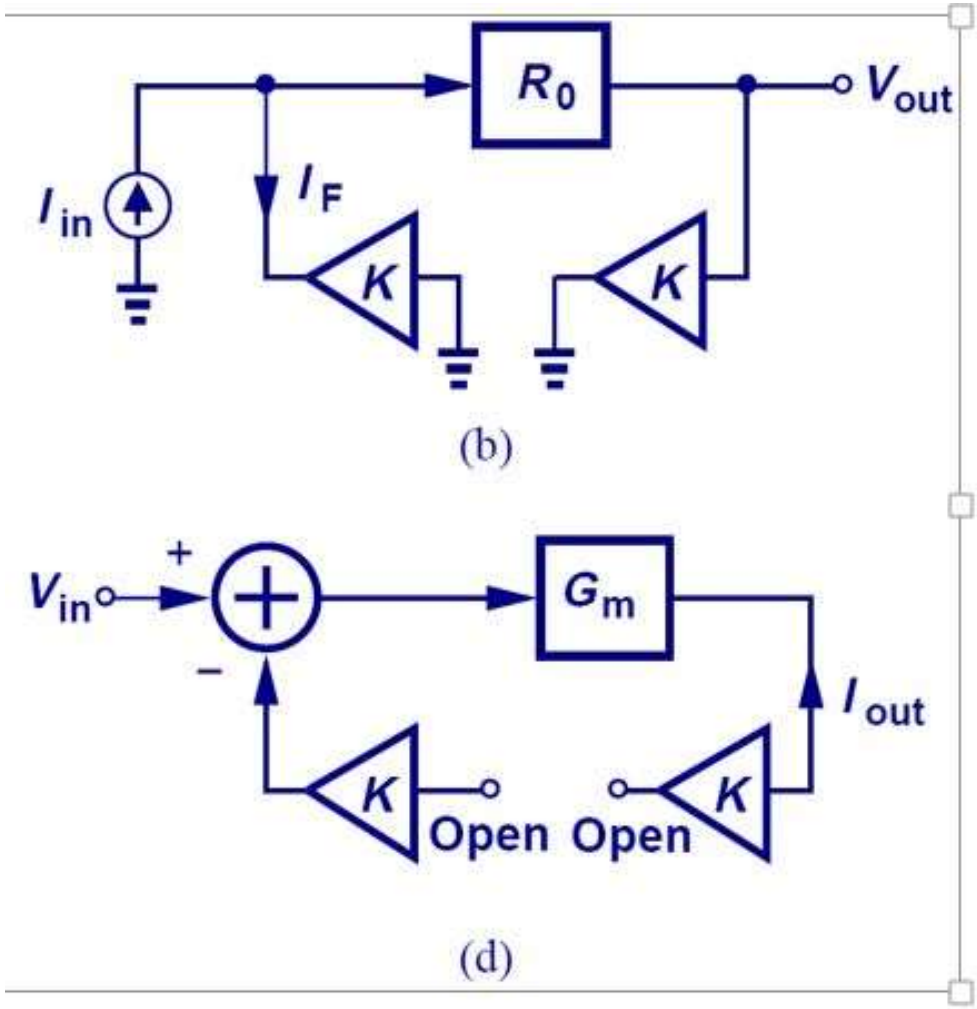
(d)

Rules for Breaking the Loop of Amplifier Types



نوع فیدبک
فیدبک ولتاژ- ولتاژ
فیدبک ولتاژ- سری
فیدبک سری- موازی
فیدبک جریان- جریان
فیدبک جریان- موازی
فیدبک موازی- سری

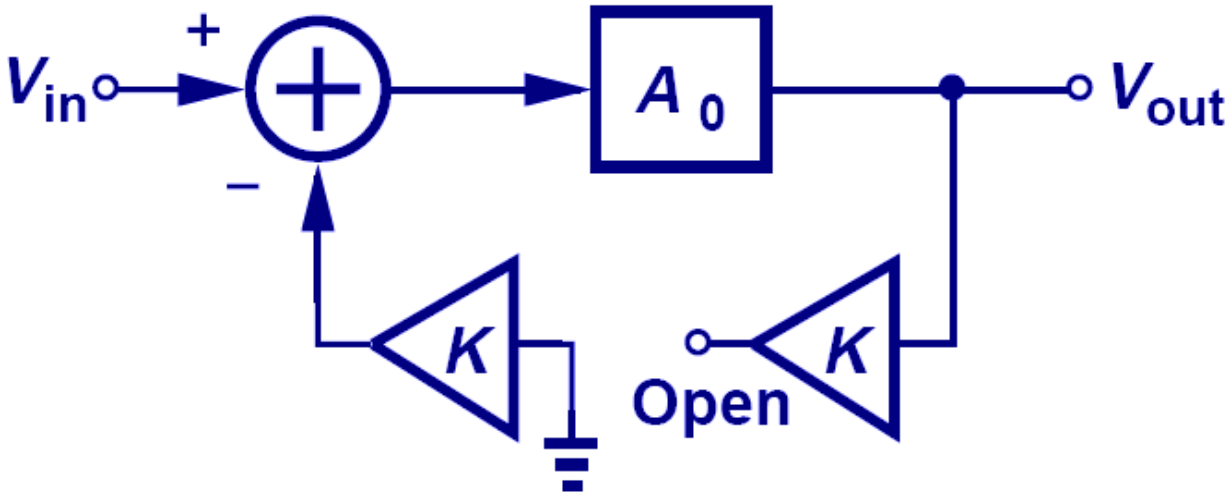
Rules for Breaking the Loop of Amplifier Types



نوع فیدبک
فیدبک ولتاژ-جریان
فیدبک ولتاژ- موازی
فیدبک موازی- موازی
فیدبک جریان-ولتاژ
فیدبک جریان- سری
فیدبک سری-سری

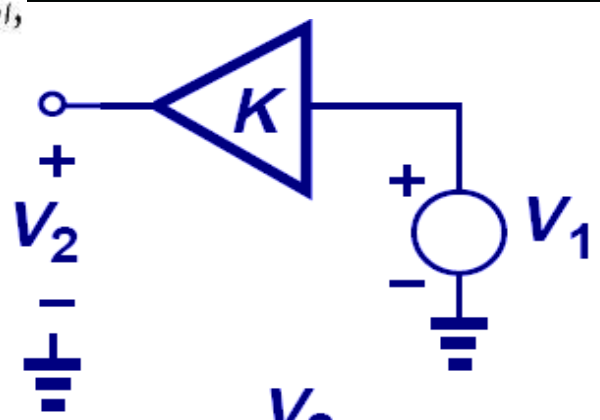
Intuitive Understanding of these Rules

Voltage-Voltage Feedback

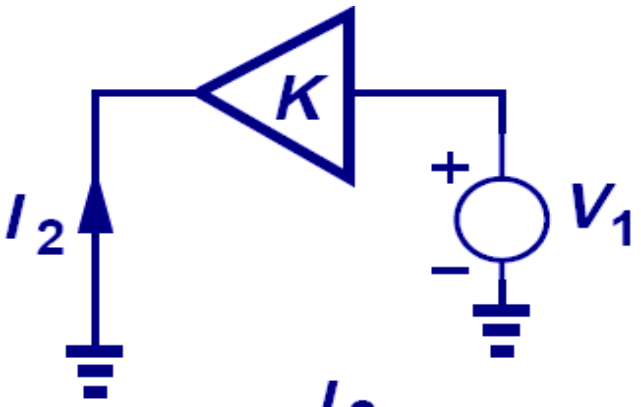


- Since ideally, the input of the feedback network sees zero impedance (Z_{out} of an ideal voltage source), the return replicate needs to be grounded. Similarly, the output of the feedback network sees an infinite impedance (Z_{in} of an ideal voltage sensor), the sense replicate needs to be open.
- Similar ideas apply to the other types.

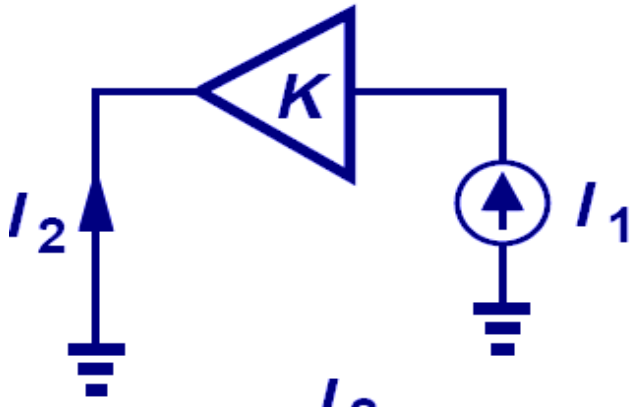
Rules for Calculating Feedback Factor



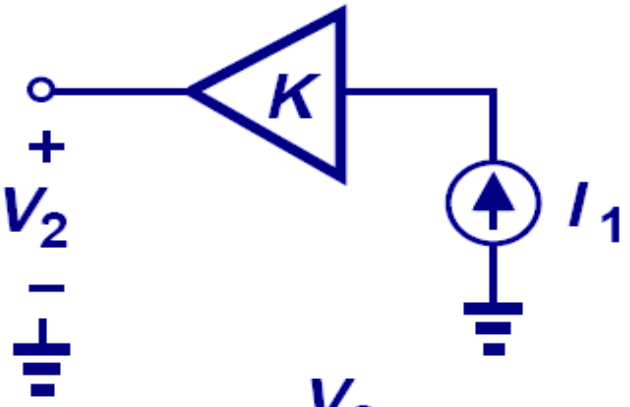
$$K = \frac{V_2}{V_1}$$



$$K = \frac{I_2}{V_1}$$



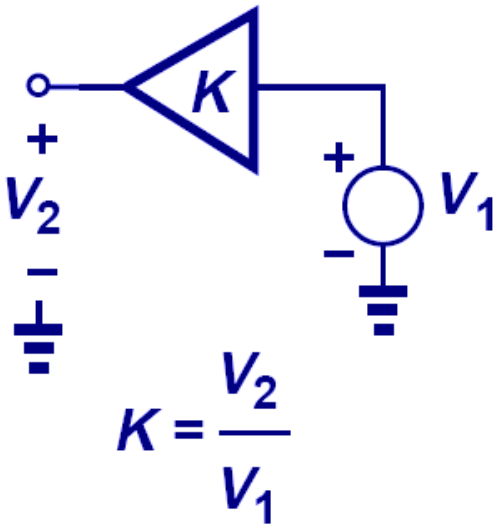
$$K = \frac{I_2}{I_1}$$



$$K = \frac{V_2}{I_1}$$

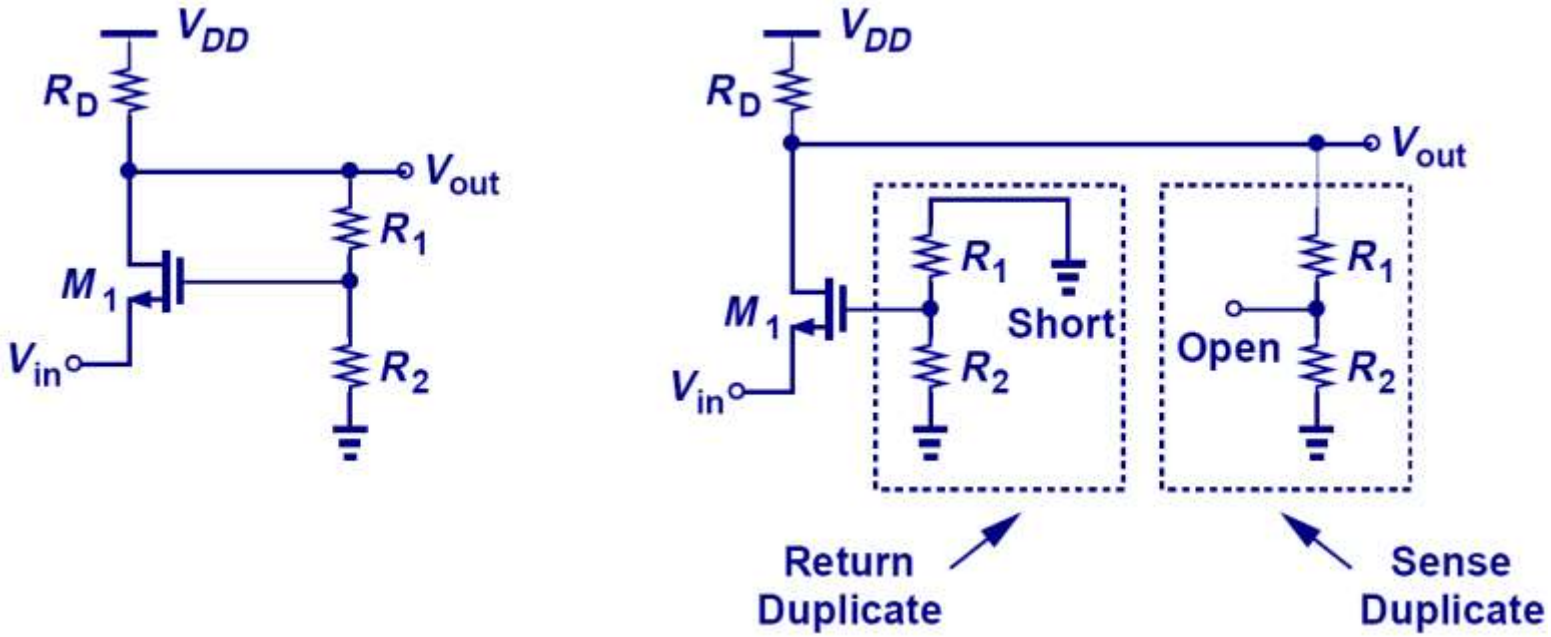
Intuitive Understanding of these Rules

Voltage-Voltage Feedback



- Since the feedback senses voltage, the input of the feedback is a voltage source. Moreover, since the return quantity is also voltage, the output of the feedback is left open (a short means the output is always zero).
- Similar ideas apply to the other types.

Breaking the Loop Example I

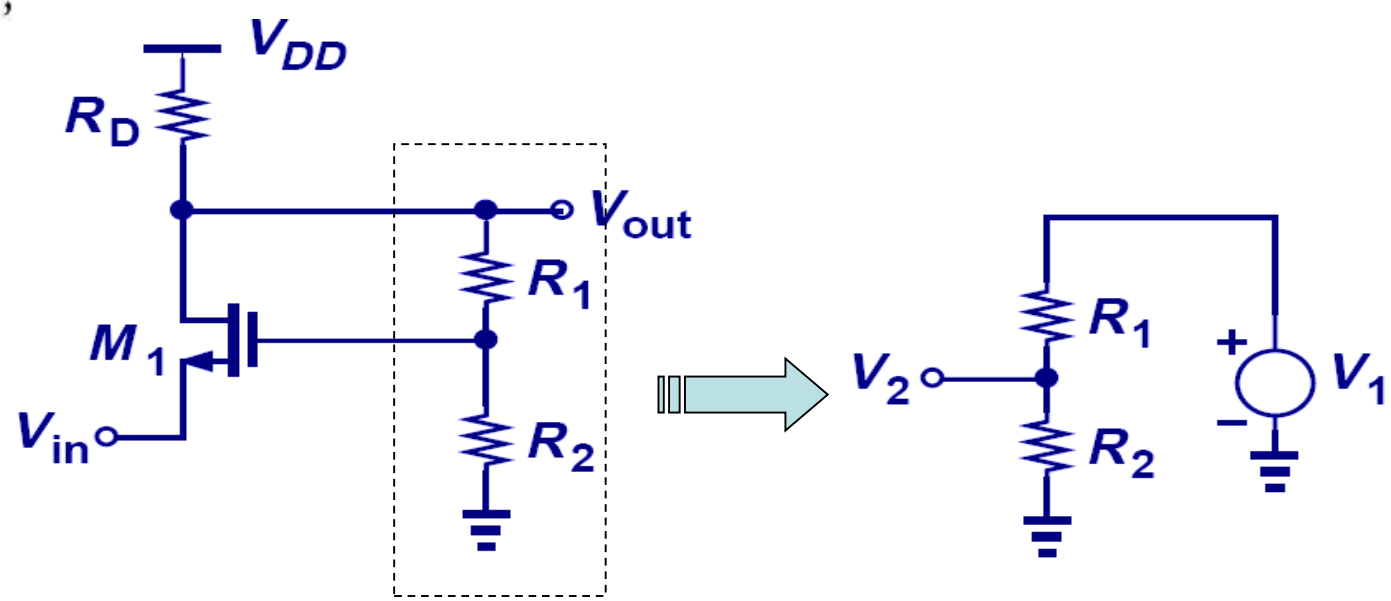


$$A_{v,open} = g_{m1}\left[R_D \parallel (R_1 + R_2)\right]$$

$$R_{in,open} = 1/g_{m1}$$

$$R_{out,open} = R_D \parallel (R_1 + R_2)$$

Feedback Factor Example I



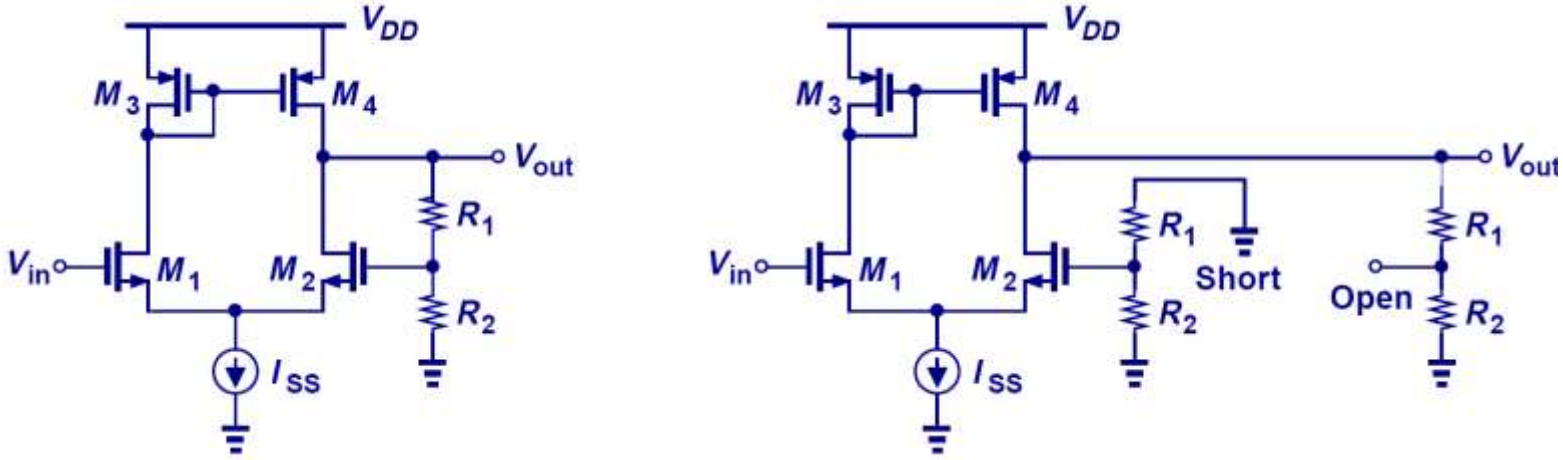
$$K = R_2 /(R_1 + R_2)$$

$$A_{v,closed} = A_{v,open} /(1 + KA_{v,open})$$

$$R_{in,closed} = R_{in,open}(1 + KA_{v,open})$$

$$R_{out,closed} = R_{out,closed} /(1 + KA_{v,open})$$

Breaking the Loop Example II

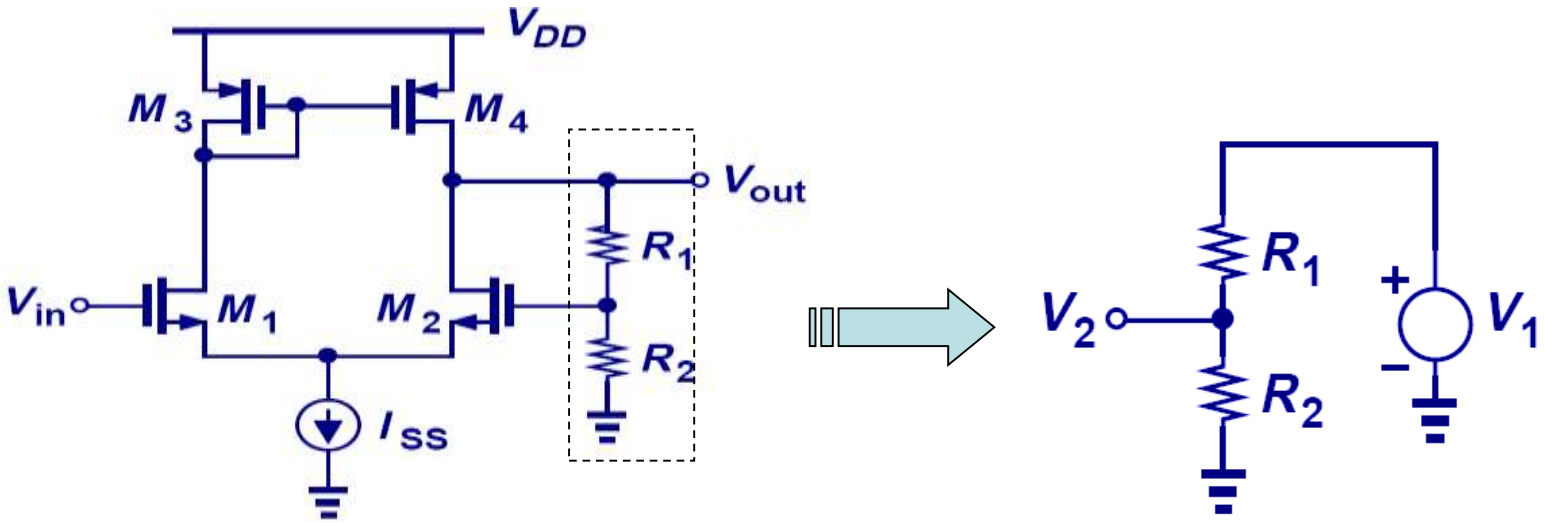


$$A_{v,open} = g_{mN}\left[r_{ON} \parallel r_{OP} \parallel (R_1 + R_2)\right]$$

$$R_{in,open} = \infty$$

$$R_{out,open} = r_{ON} \parallel r_{OP} \parallel (R_1 + R_2)$$

Feedback Factor Example II



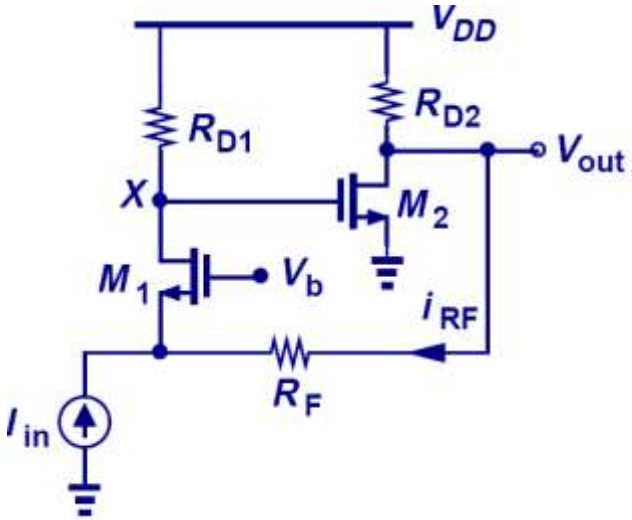
$$K = R_2 /(R_1 + R_2)$$

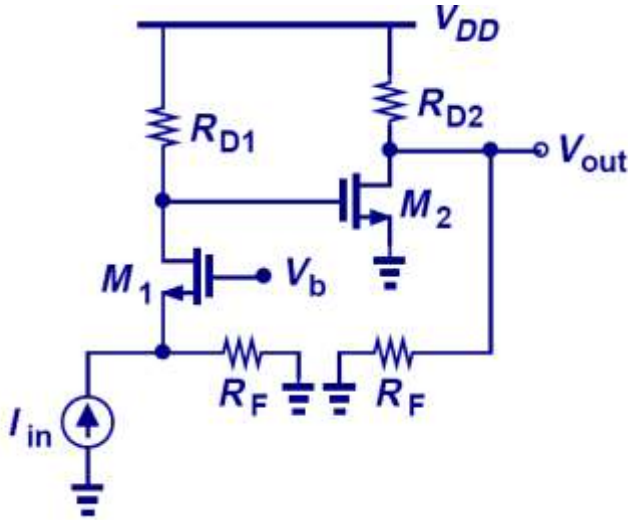
$$A_{v,closed} = A_{v,open} /(1 + KA_{v,open})$$

$$R_{in,closed} = \infty$$

$$R_{out,closed} = R_{out,open} /(1 + KA_{v,open})$$

Breaking the Loop Example IV



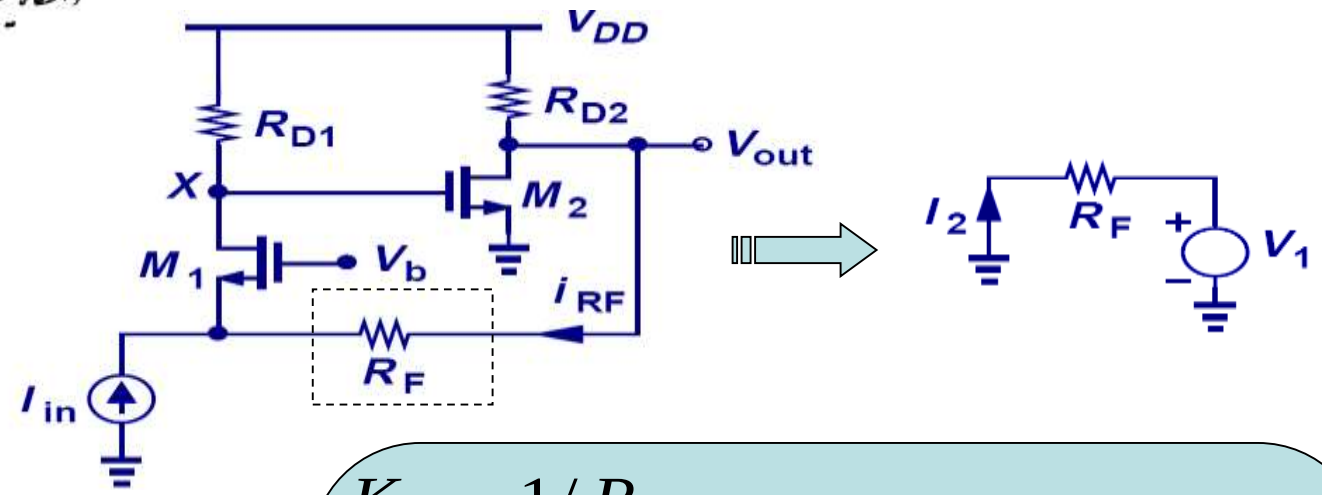


$$\frac{V_{out}}{I_{in}}\Big|_{open} = \frac{R_F R_{D1}}{R_F + \dfrac{1}{g_{m1}}} \cdot \left[-g_{m2}\left(R_{D2} \parallel R_F\right)\right]$$

$$R_{in,open} = \frac{1}{g_{m1}} \parallel R_F$$

$$R_{out,open} = R_{D2} \parallel R_F$$

Feedback Factor Example IV



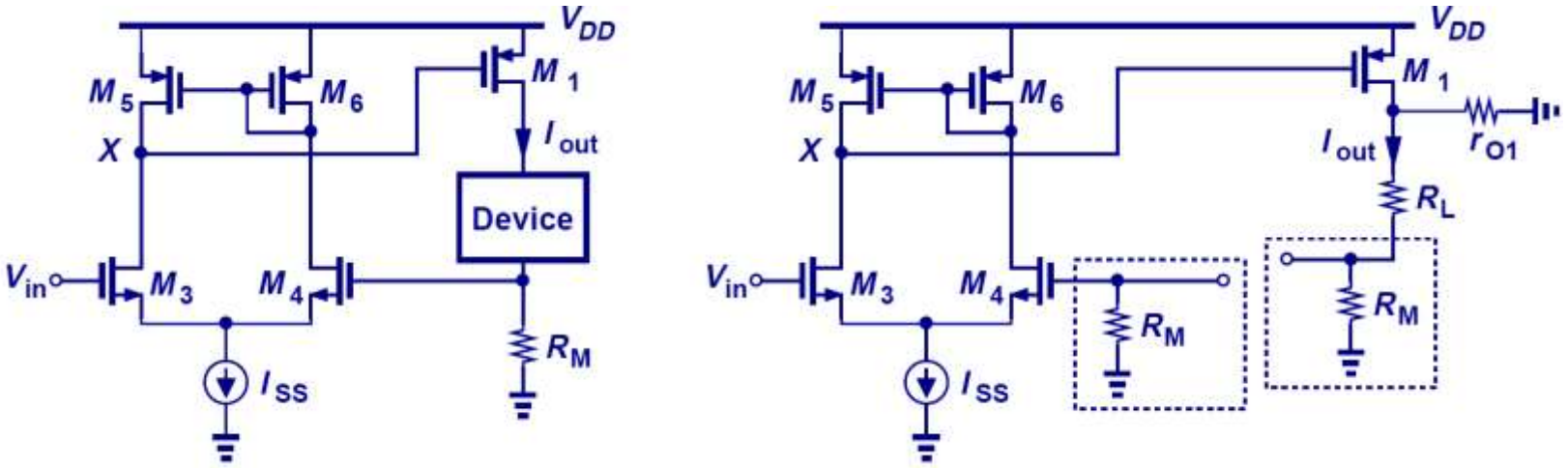
$$K = -1/R_F$$

$$\frac{V_{out}}{I_{in}}\Big|_{closed} = \frac{V_{out}}{I_{in}}\Big|_{open} /\left(1 + K\frac{V_{out}}{I_{in}}\Big|_{open}\right)$$

$$R_{in,closed} = R_{in,open} /\left(1 + K\frac{V_{out}}{I_{in}}\Big|_{open}\right)$$

$$R_{out,closed} = R_{out,open} /\left(1 + K\frac{V_{out}}{I_{in}}\Big|_{open}\right)$$

Breaking the Loop Example V

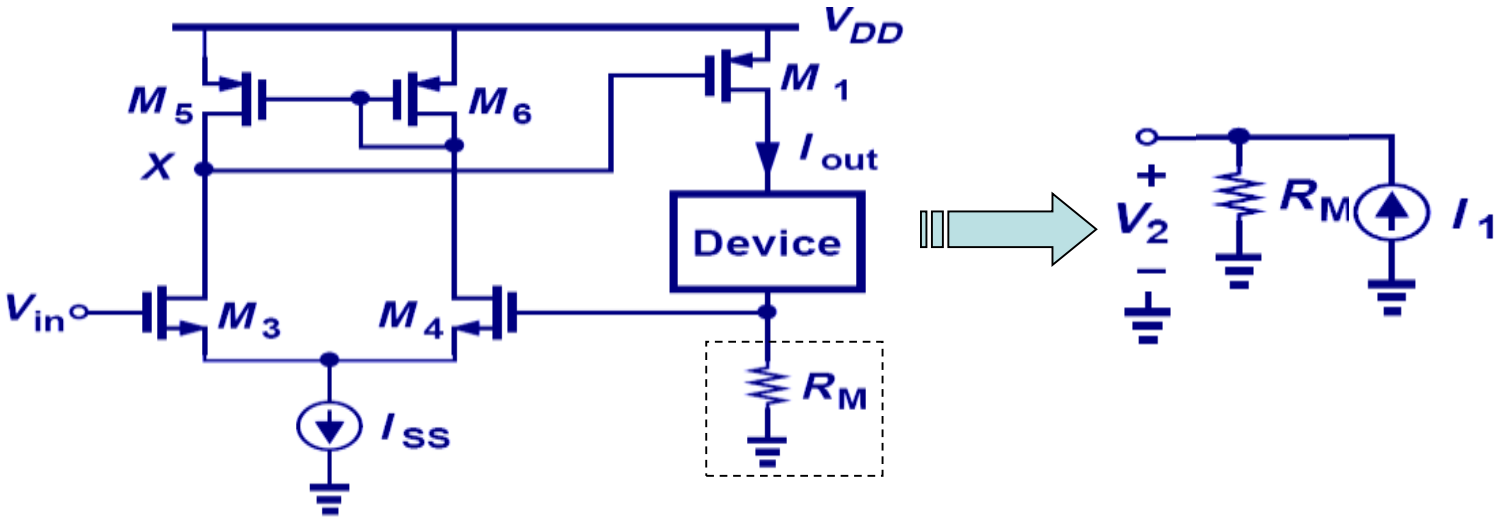


$$\left.\frac{I_{out}}{V_{in}}\right|_{open} = \frac{g_{m3}(r_{O3} \parallel r_{O5})g_{m1}r_{O1}}{r_{O1} + R_L + R_M}$$

$$R_{in,open} = \infty$$

$$R_{out,open} = r_{O1} + R_M$$

Feedback Factor Example V



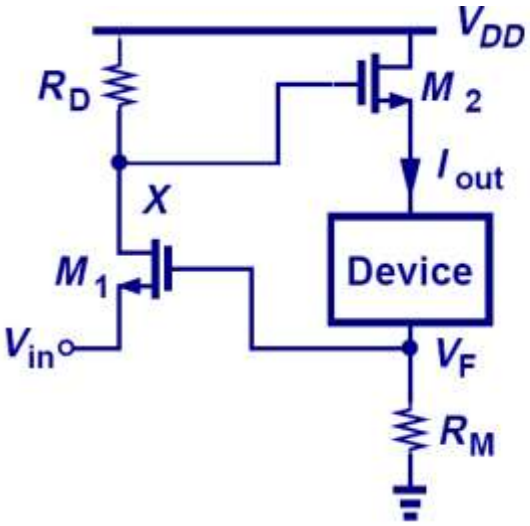
$$K = R_M$$

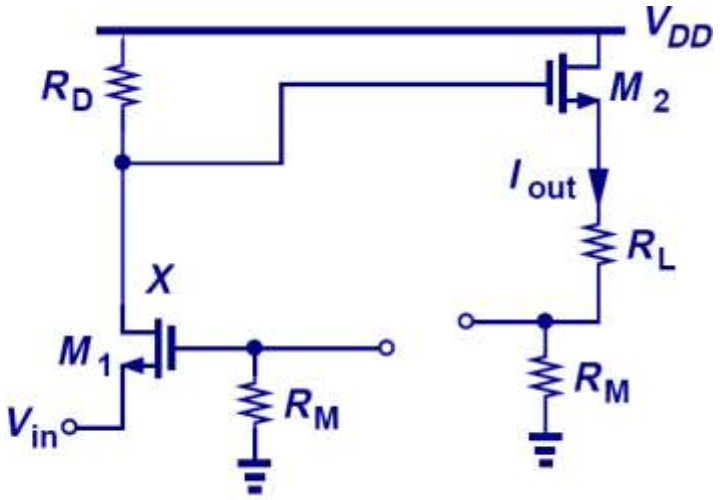
$$(I_{out}/V_{in}|_{closed}) = (I_{out}/V_{in}|_{open})/[1+K(I_{out}/V_{in})|_{open}]$$

$$R_{in,closed} = \infty$$

$$R_{out,closed} = R_{out,open}[1+K(I_{out}/V_{in})|_{open}]$$

Breaking the Loop Example VI



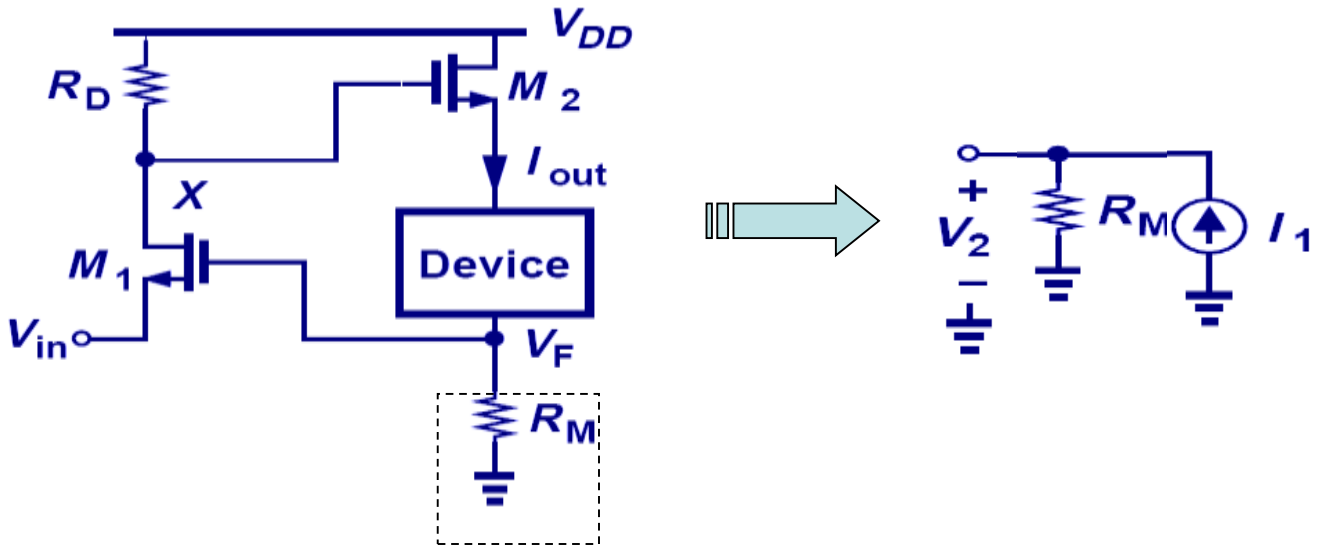


$$\left.\frac{I_{out}}{V_{in}}\right|_{open} = \frac{g_{m1}R_D}{R_L + R_M + 1/g_{m2}}$$

$$R_{in,open} = 1/g_{m1}$$

$$R_{out,open} = (1/g_{m2}) + R_M$$

Feedback Factor Example VI



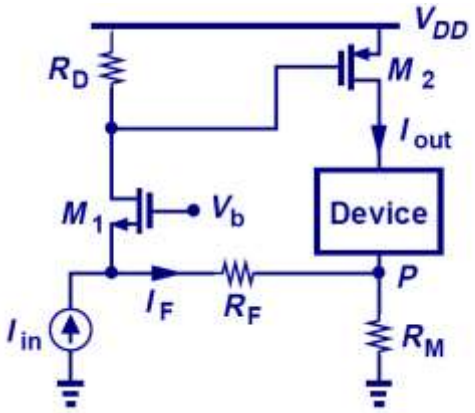
$$K = R_M$$

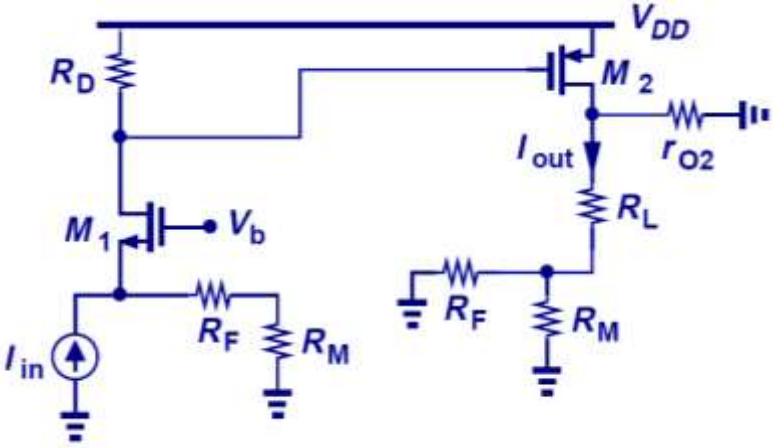
$$(I_{out}/V_{in}|_{closed}) = (I_{out}/V_{in}|_{open})/[1+K(I_{out}/V_{in})|_{open}]$$

$$R_{in,closed} = R_{in,open}[1+K(I_{out}/V_{in})|_{open}]$$

$$R_{out,closed} = R_{out,open}[1+K(I_{out}/V_{in})|_{open}]$$

Breaking the Loop Example VII



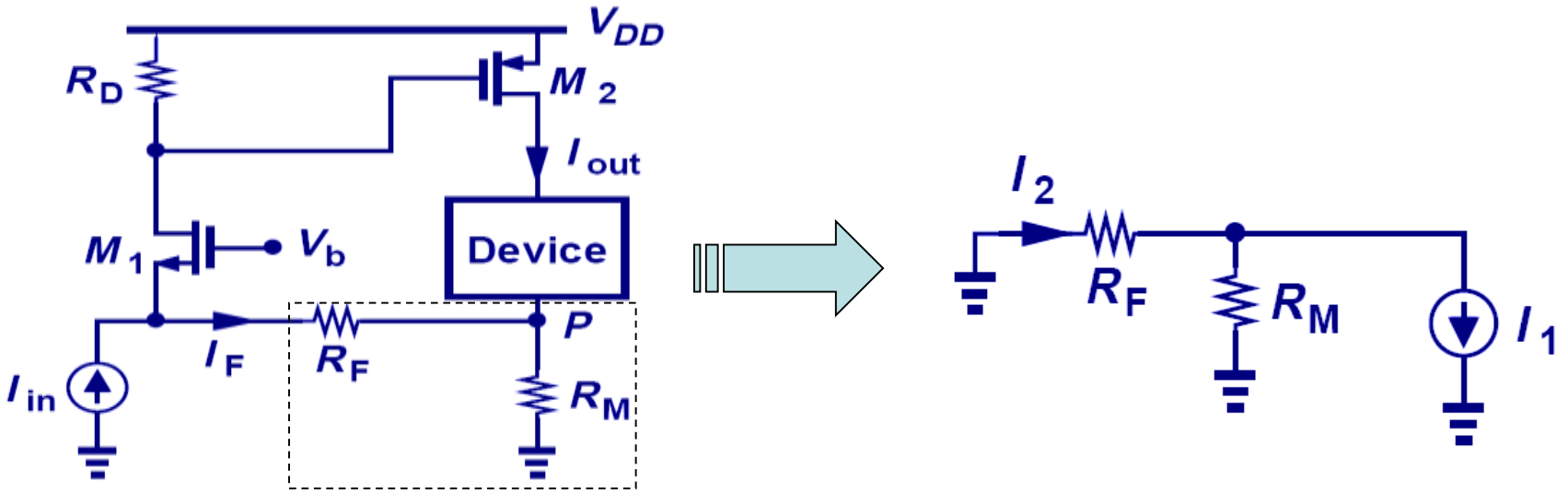


$$A_{I,open} = \frac{(R_F + R_M)R_D}{R_F + R_M + \dfrac{1}{g_{m1}}} \cdot \frac{-g_{m2}r_{O2}}{r_{O2} + R_L + R_M \parallel R_F}$$

$$R_{in,open} = \frac{1}{g_{m1}} \parallel (R_F + R_M)$$

$$R_{out,open} = r_{O2} + R_F \parallel R_M$$

Feedback Factor Example VII



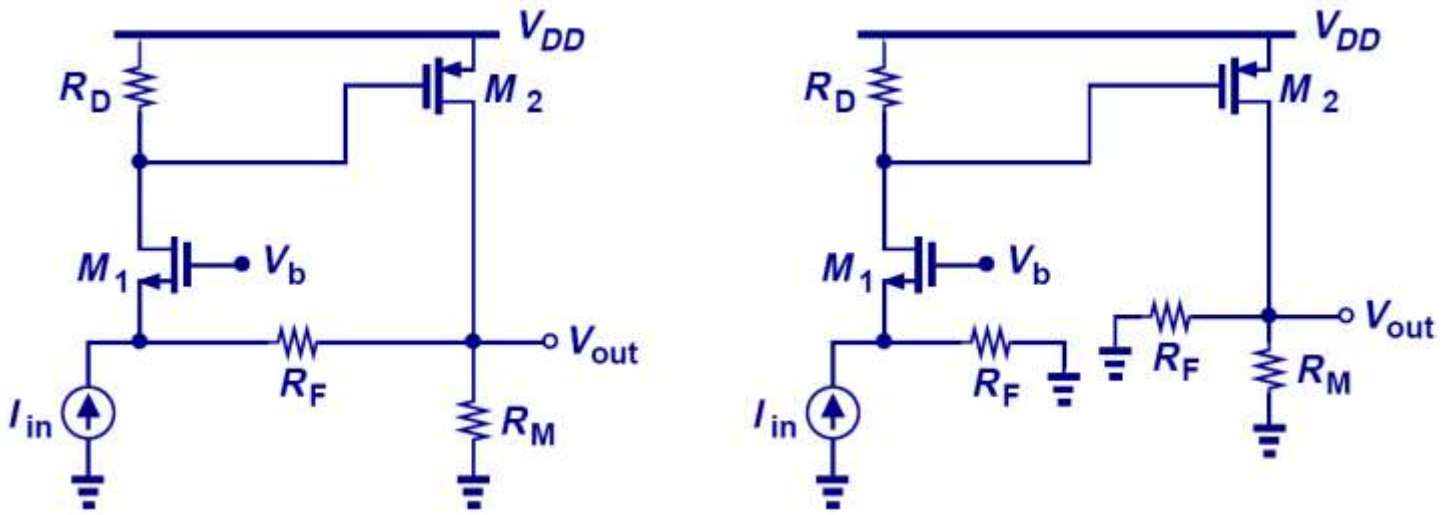
$$K = -R_M /(R_F + R_M)$$

$$A_{I,closed} = A_{I,open} /(1 + KA_{I,open})$$

$$R_{in,closed} = R_{in,open} /(1 + KA_{I,open})$$

$$R_{out,closed} = R_{out,open}(1 + KA_{I,open})$$

Breaking the Loop Example VIII

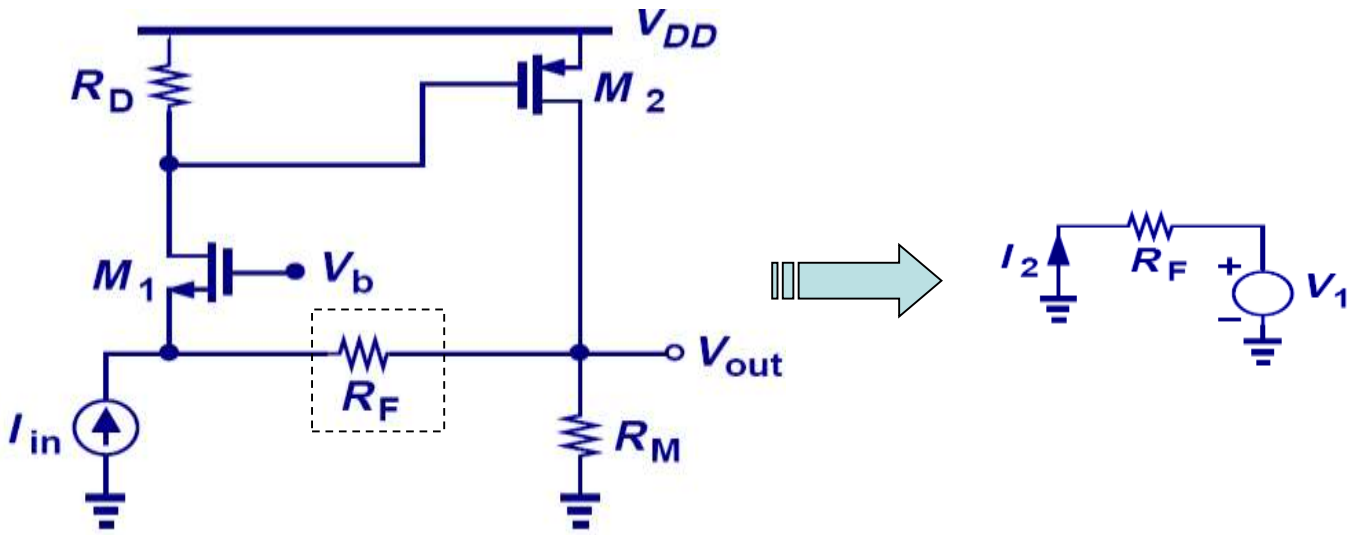


$$\frac{V_{out}}{I_{in}}\Big|_{open} = \frac{R_F R_D}{R_F + 1/g_{m1}}[-g_{m2}(R_F \parallel R_M)]$$

$$R_{in,open} = \frac{1}{g_{m1}} \parallel R_F$$

$$R_{out,open} = R_F \parallel R_M$$

Feedback Factor Example VIII



$$K = -1/R_F$$

$$(V_{out}/I_{in})|_{closed} = (V_{out}/I_{in})|_{open}/[1+K(V_{out}/I_{in})|_{open}]$$

$$R_{in,closed} = R_{in,open}/[1+K(V_{out}/I_{in})|_{open}]$$

$$R_{out,closed} = R_{out,open}/[1+K(V_{out}/I_{in})|_{open}]$$

انواع فیدبک

ردیف	نوع فیدبک	تقویت شاخص	ضریب فیدبک K	$A_{(f)}$, $R_{in(f)}$, $R_{out(f)}$
۱	فیدبک ولتاژ- ولتاژ فیدبک ولتاژ- سری فیدبک سری- موازی	بهره ولتاژ $A_o=A_v=V_{out}/V_{in}$	$K= V_f/V_{out}$ | ...	$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}.(1+KA_o)$ $R_{out(f)}=R_{out}/(1+KA_o)$
۲	فیدبک جریان- جریان فیدبک جریان- موازی فیدبک موازی- سری	بهره جریان $A_o=A_i=I_{out}/I_{in}$	$K=I_f/I_{out}$ | ...	$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}/(1+KA_o)$ $R_{out(f)}=R_{out}.(1+KA_o)$
۳	فیدبک جریان-ولتاژ فیدبک جریان- سری فیدبک سری-سری	هدایت انتقالی $A_o=G_m=I_{out}/V_{in}$	$K=V_f/I_{out}$ | ...	$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}.(1+KA_o)$ $R_{out(f)}=R_{out}.(1+KA_o)$
۴	فیدبک ولتاژ-جریان فیدبک ولتاژ- موازی فیدبک موازی- موازی	مقامت انتقالی $A_o=R_m=V_{out}/I_{in}$	$K=I_f/V_{out}$ | ...	$A_{(f)}=A_o/(1+KA_o)$ $R_{in(f)}=R_{in}/(1+KA_o)$ $R_{out(f)}=R_{out}/(1+KA_o)$