第五章 模拟运算电路

5.3 加法/减法电路

加法/减法电路

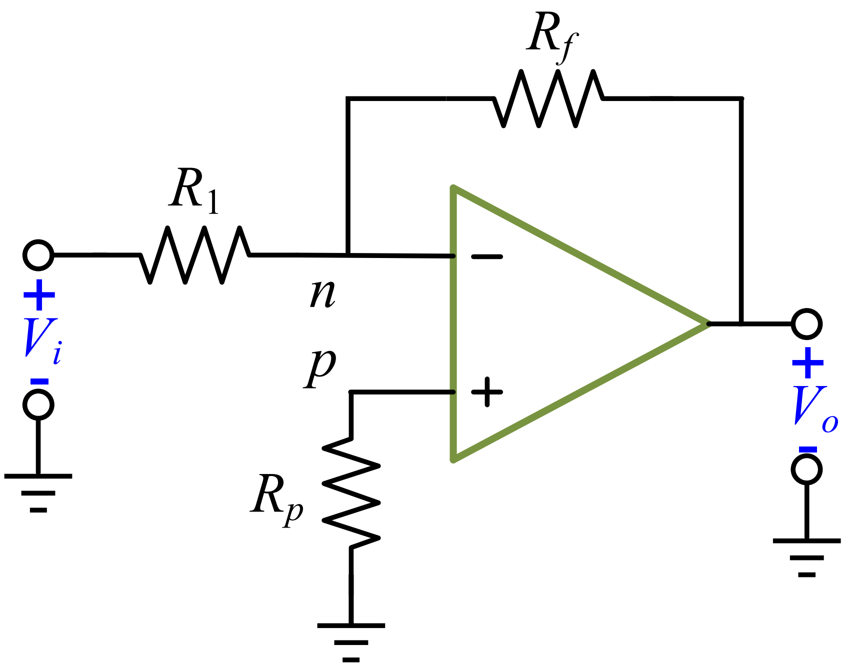
- 加法电路
  - 反相加法电路
  - 同相加法电路

- 减法电路

反相放大器

- 增益

$$A_f = \frac{V_o}{V_i} = -\frac{R_f}{R_1}$$

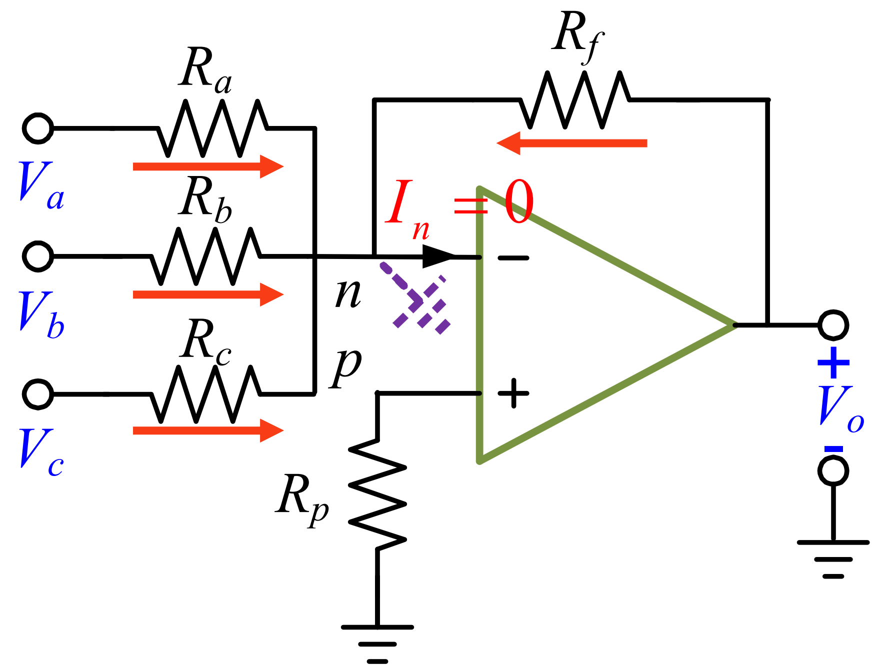


反相加法电路

- 3个输入
- 节点n虚地，同时 $I_n = 0$
- 围绕节点n列写KCL方程

$$\frac{V_a}{R_a}+\frac{V_b}{R_b}+\frac{V_c}{R_c}+\frac{V_o}{R_f}=0$$

$$V_o=-R_f\left(\frac{V_a}{R_a}+\frac{V_b}{R_b}+\frac{V_c}{R_c}\right)$$



$$\boxed{R_a = R_b = R_c = R_f \quad V_o = -\left(V_a + V_b + V_c\right)}$$

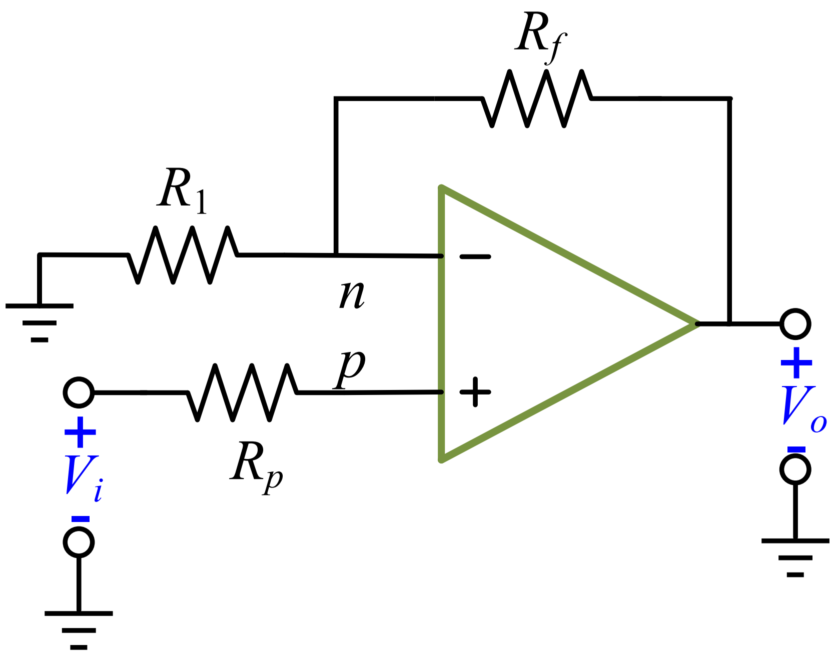
反相加法

同相放大器

- 增益

$$A_f = \frac{V_o}{V_i} = 1 + \frac{R_f}{R_1}$$

$$V_o = \left(1 + \frac{R_f}{R_1}\right) V_i$$

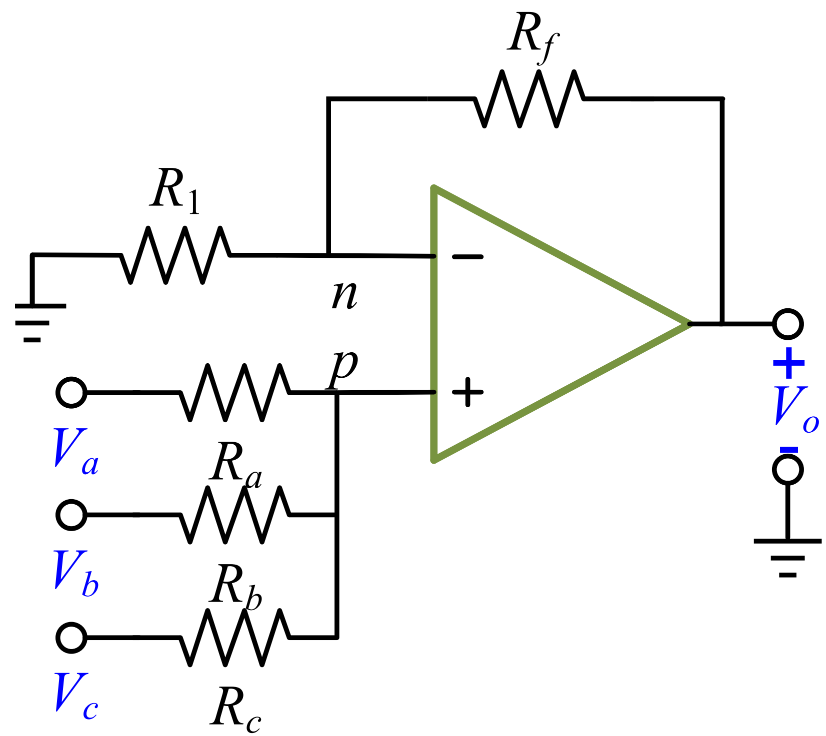


同相加法电路

- 3个输入

求解思路：

1. 分别计算V_a、V_b、V_c单独作用产生的输出
2. 利用叠加原理得到总的输出

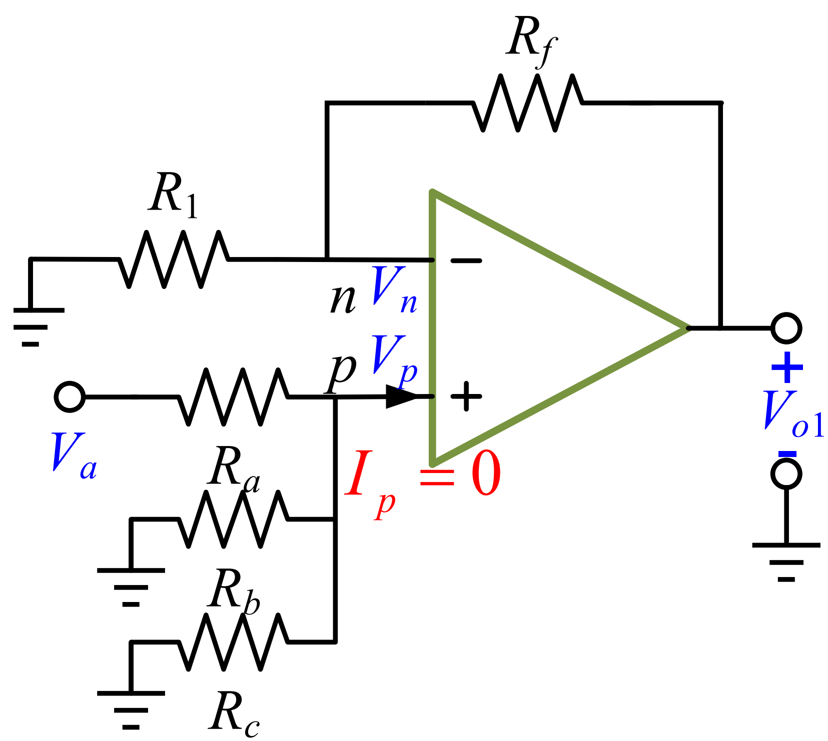


同相加法电路

- 假设V_a单独作用， $V_b=0$， $V_c=0$

$$V_p = V_a \frac{R_b \| R_c}{R_a + R_b \| R_c}$$

$$V_n = V_p$$



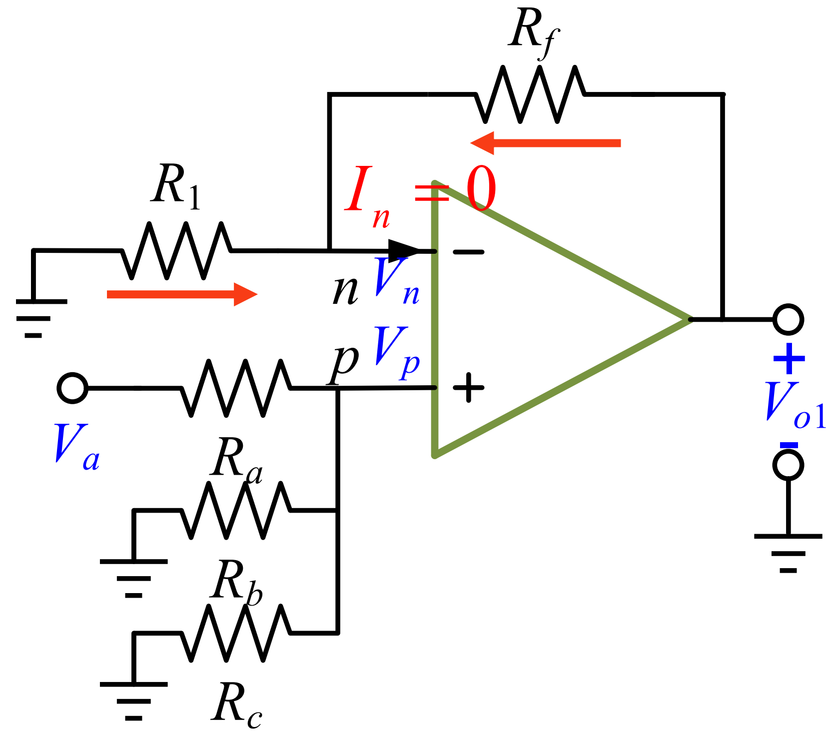
同相加法电路

- V_a单独作用

$$V_p = V_a \frac{R_b \| R_c}{R_a + R_b \| R_c}$$

$$V_n = V_p$$

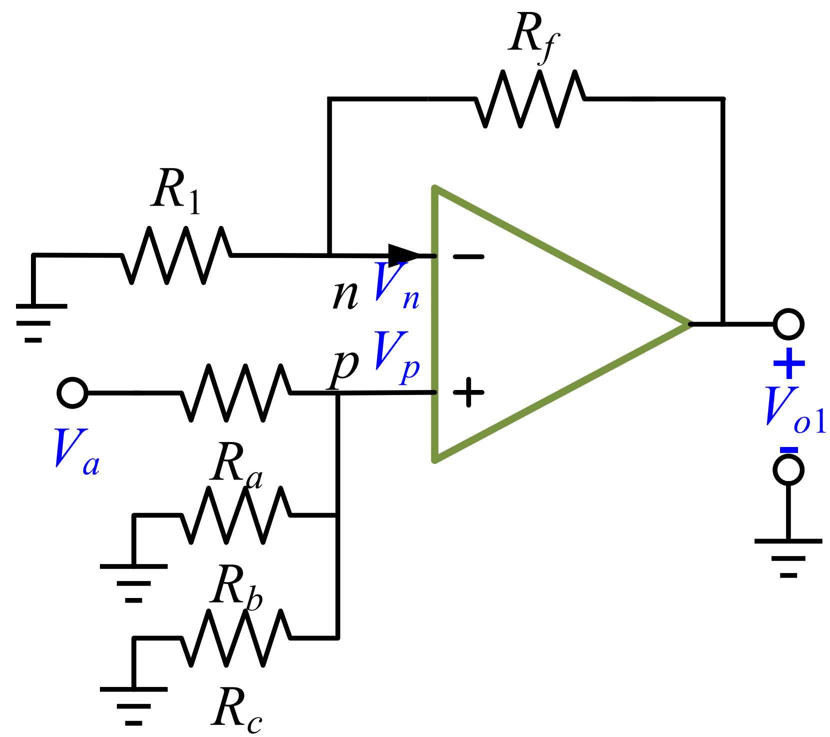
$$-\frac{V_n}{R_1} + \frac{V_{o1} - V_n}{R_f} = 0$$



同相加法电路

- V_a单独作用

$$V_{o1}=(1+\frac{R_f}{R_1})\frac{R_b\|R_c}{R_a+R_b\|R_c}V_a$$



$$R_a=R_b=R_c$$

$$V_{o1}=\frac{1}{3}(1+\frac{R_f}{R_1})V_a$$

同相加法电路

- V_a单独作用

$$V_{o1} = \frac{1}{3}(1+\frac{R_f}{R_1})V_a$$

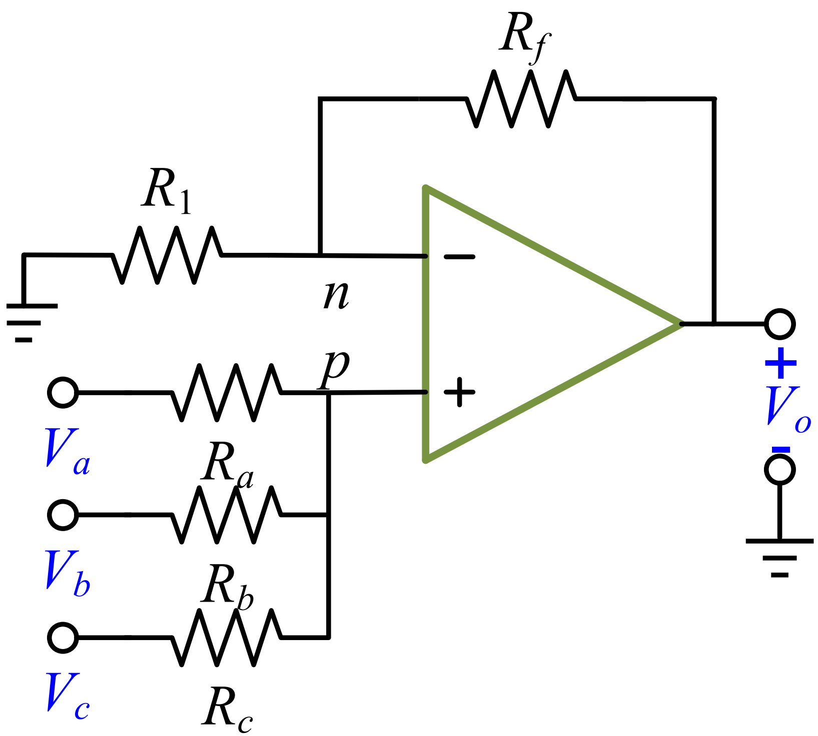
- V_a、V_b、V_c同时作用

$$V_o = \frac{1}{3}\left(1+\frac{R_f}{R_1}\right)(V_a+V_b+V_c)$$

$$R_f = 2R_1$$

$$V_o = V_a+V_b+V_c$$

同相加法



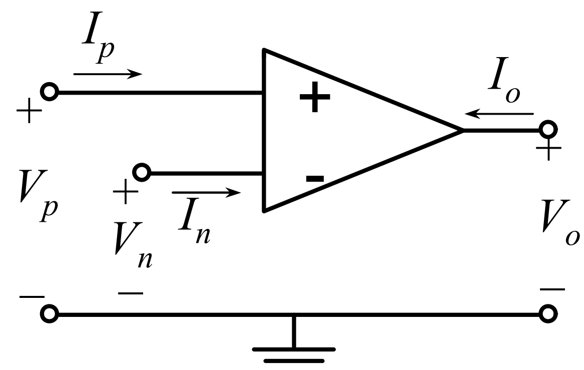
减法电路

理想运放就是减法放大器

$$V_o = A\left(V_p - V_n\right)$$

$$-V_{CC} \le V_o \le V_{CC}$$

$$-\frac{V_{CC}}{A} \le V_p - V_n \le \frac{V_{CC}}{A}$$

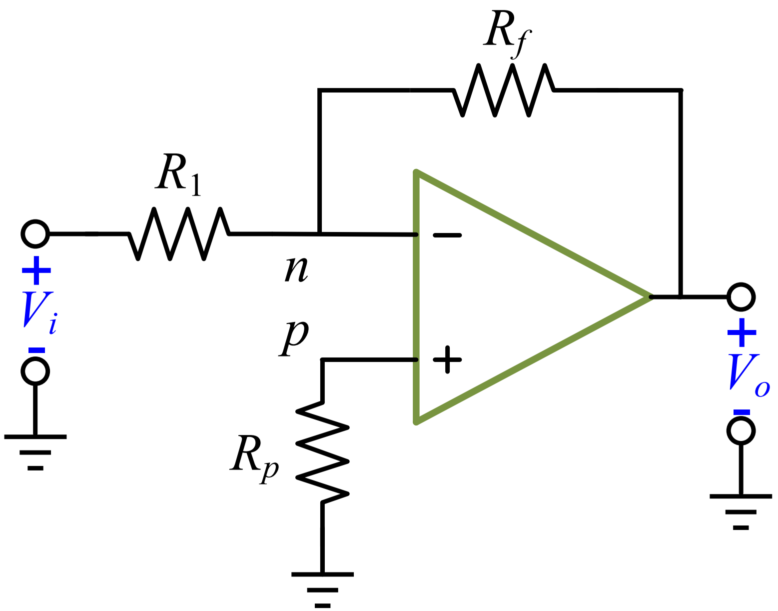


线性工作范围太小

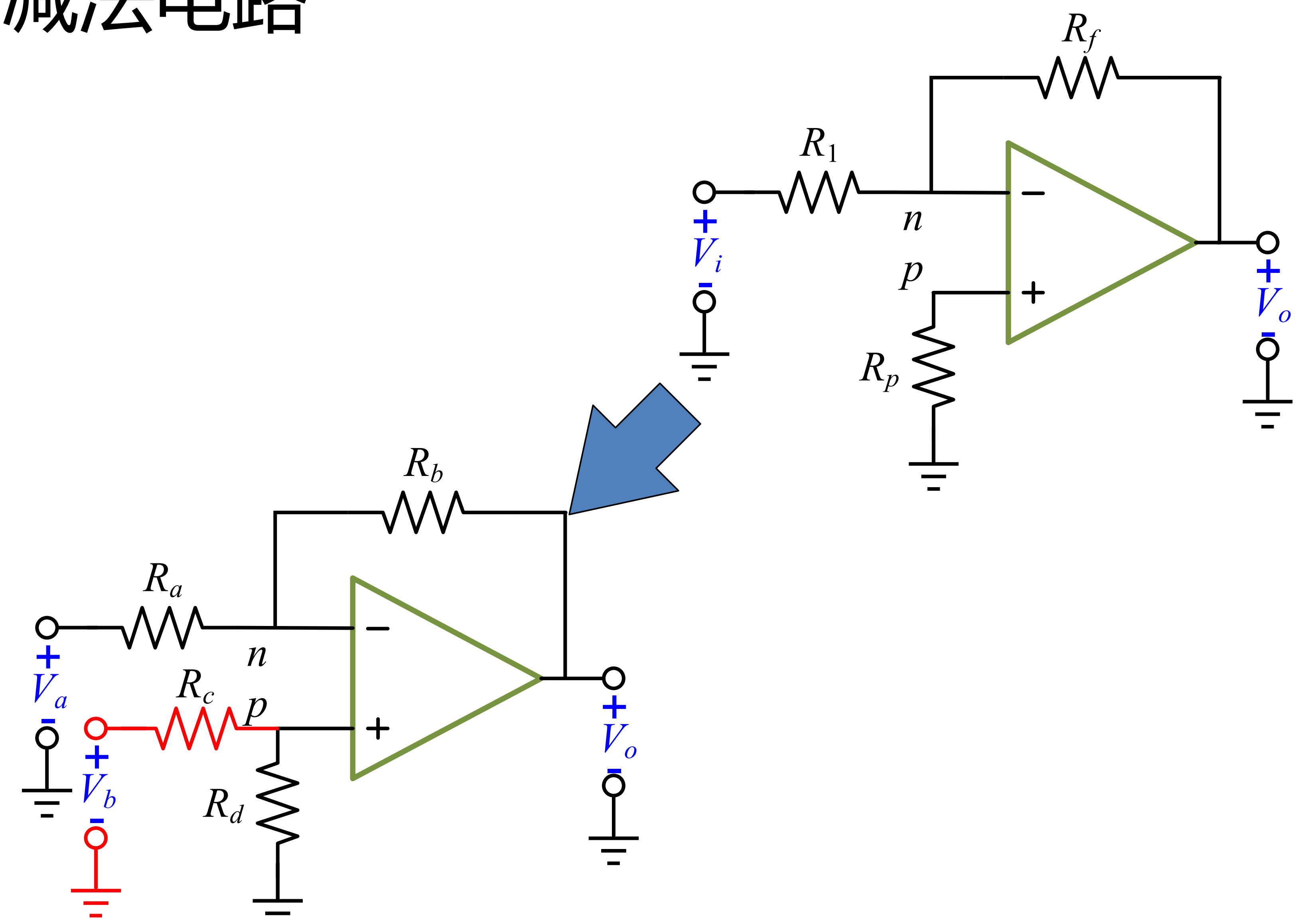
反相放大器

- 增益

$$A_f = \frac{V_o}{V_i} = -\frac{R_f}{R_1}$$



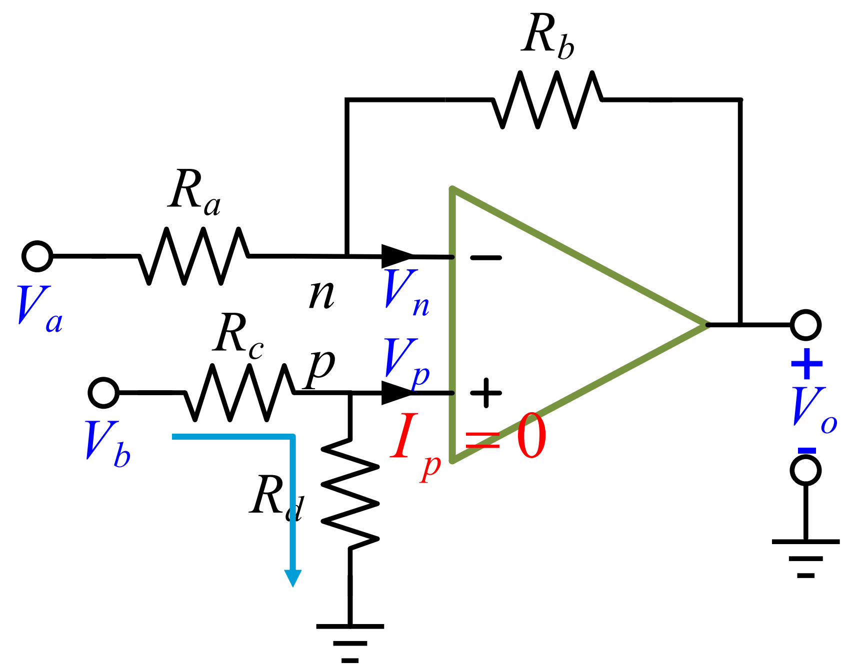
减法电路



减法电路

$$I_p = 0, \quad I_n = 0, \quad V_n = V_p$$

$$V_p = \frac{R_d}{R_c + R_d} V_b$$

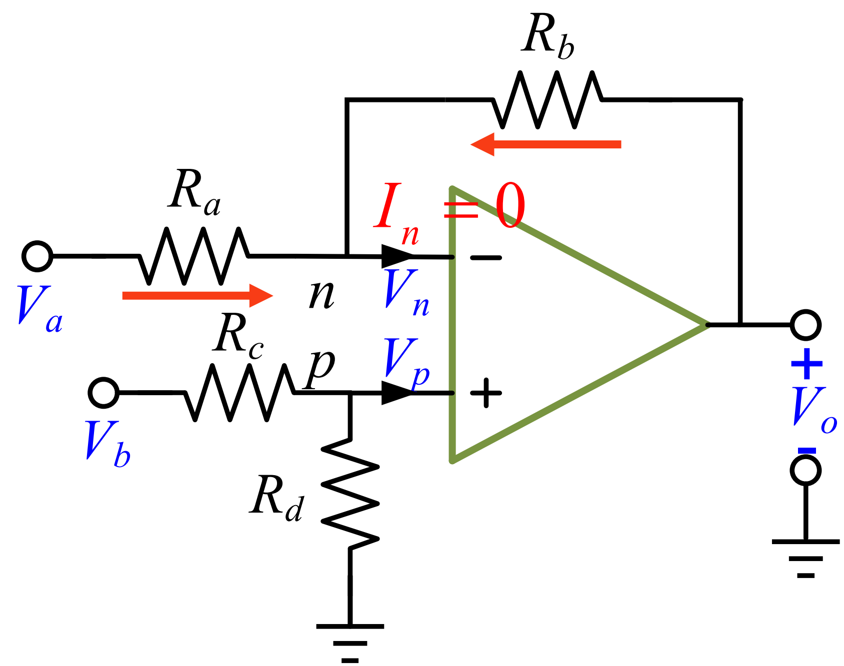


减法电路

$$I_p = 0, \quad I_n = 0, \quad V_n = V_p$$

$$V_p = \frac{R_d}{R_c + R_d} V_b$$

$$\frac{V_a - V_n}{R_a} + \frac{V_o - V_n}{R_b} = 0$$



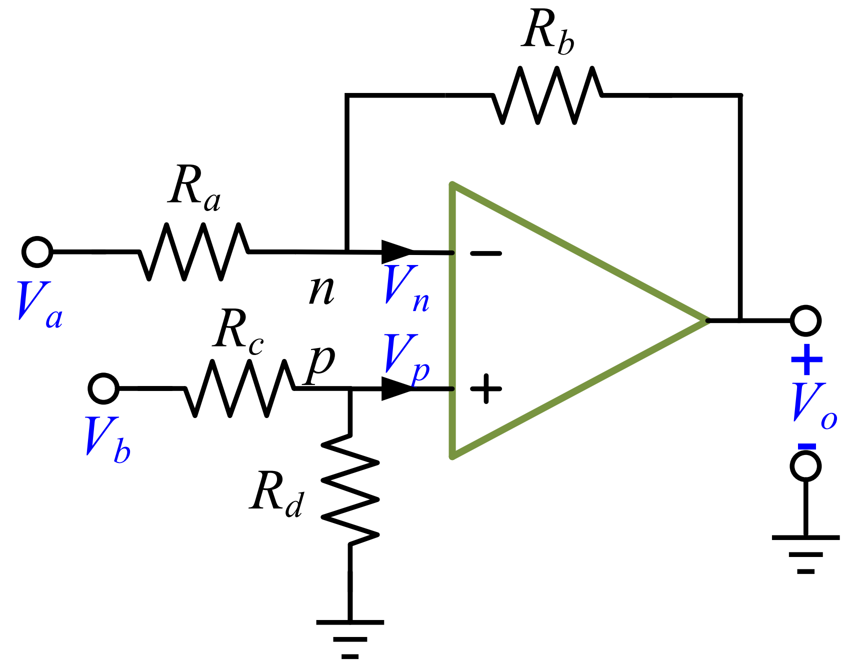
减法电路

$$I_p = 0, \quad I_n = 0, \quad V_n = V_p$$

$$V_p = \frac{R_d}{R_c + R_d} V_b$$

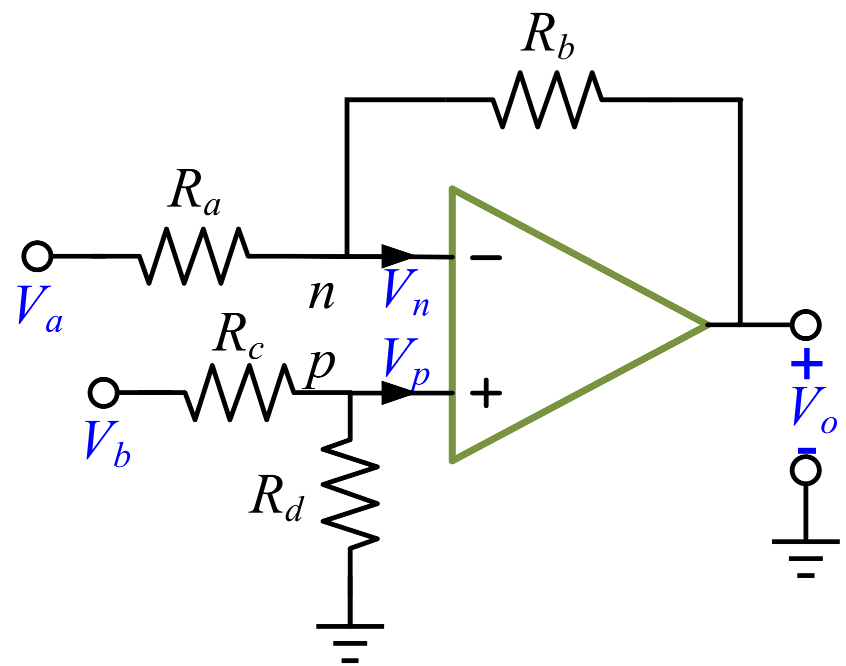
$$\frac{V_a - V_n}{R_a} + \frac{V_o - V_n}{R_b} = 0$$

$$V_o = \frac{R_d\left(R_a + R_b\right)}{R_a\left(R_c + R_d\right)} V_b - \frac{R_b}{R_a} V_a$$



减法电路

$$V_o = \frac{R_d\left(R_a + R_b\right)}{R_a\left(R_c + R_d\right)}V_b - \frac{R_b}{R_a}V_a$$



减法放大:

$$R_a = R_c, \quad R_b = R_d$$

$$V_o = \frac{R_b}{R_a}\left(V_b - V_a\right)$$

减法:

$$\left(R_a = R_c\right) = \left(R_b = R_d\right)$$

$$V_o = V_b - V_a$$