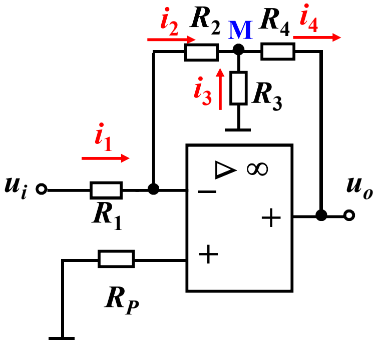
E.g.: Find A_u=?



虚短路

$u_+ = u_- = 0$ 虚开路

$i_1 = i_2$ 虚开路

$$v_M = \frac{\frac{u_o}{R_4}}{\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}}$$

$$i_2 = \frac{-v_M}{R_2} = i_1 = \frac{u_i}{R_1}$$

$$v_M = \frac{\frac{u_o}{R_4}}{\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}} \qquad i_2 = \frac{-v_M}{R_2} = i_1 = \frac{u_i}{R_1}$$

$$A_u = \frac{u_o}{u_i} = -\frac{R_2\left(\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right)}{\frac{R_1}{R_4}} = -\frac{R_2\left(\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right)}{\frac{R_1}{R_4}}$$

$$= -\frac{R_2}{R_1}\left(\frac{R_4}{R_2}+\frac{R_4}{R_3}+1\right)$$

该放大电路，在放大倍数较大时，可避免使用大电阻。但R_3的存在，削弱了负反馈。

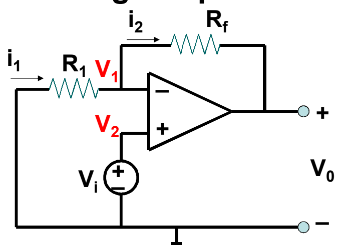
5.5 Noninverting Amplifier

1. The figure and property

2. A voltage follower

Noninverting Amplifier

1.



Application of KCL at the inverting terminal gives

$$i_1 = i_2 \qquad \Rightarrow \frac{0 - V_1}{R_1} = \frac{V_1 - V_o}{R_f}$$

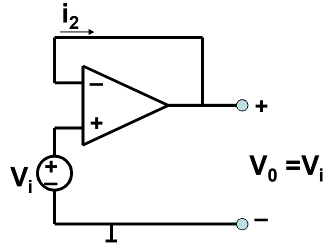
But $V_1 = V_2 = V_i$. Equation (1) becomes

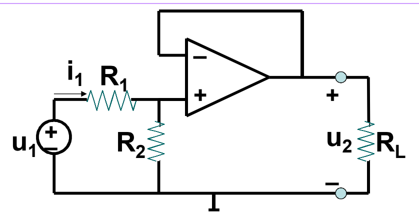
$$\frac{-V_i}{R_1} = \frac{V_i - V_o}{R_f}$$

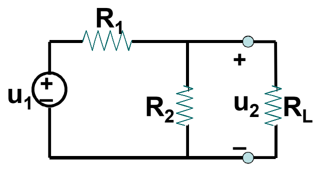
$$\therefore \quad V_o = \left(1 + \frac{R_f}{R_1}\right) V_i$$

A noninverting amplifier is an op amp circuit designed to provide **a positive voltage gain.**

2. If feedback resister R_f=0 (short circuit) or R_1=∞ (open circuit) or both, the gain becomes 1. Under these conditions (R_f=0 and R_1=∞), the circuit is called **a voltage follower** (or **unity gain amplifier**) because the output follows the input.







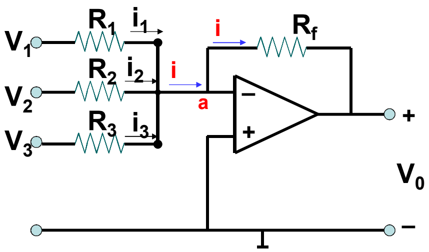
$$u_2 = \frac{R_2}{R_1 + R_2} u_1$$

5.6 Summing Amplifier

-------- The figure and property

Summing Amplifier

A summing amplifier is an op amp circuit that combines several inputs and produces an output that is the weighted sum of the inputs.



Applying KCL at node a gives $i=i_1+i_2+i_3$

But $$\frac{V_a - V_o}{R_f} = \frac{V_1 - V_a}{R_1} + \frac{V_2 - V_a}{R_2} + \frac{V_3 - V_a}{R_3}$$

We note that $V_a=0$, and we get

$$\frac{-V_o}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

$$V_o = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

If we assume $R_1=R_2=R_3=R_f$

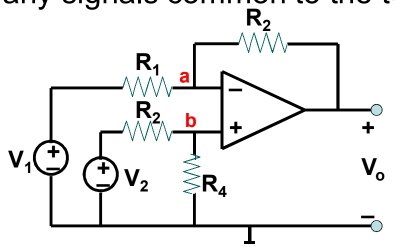
$$V_o = -(V_1 + V_2 + V_3)$$

5.7 Difference Amplifier

1. The figure and property
2. Applications
   - (a) Integrator
   - (b) Differentiator

Difference Amplifier

A difference amplifier is a device that amplifies the difference between two inputs but rejects any signals common to the two inputs.



Applying KCL to node a, $\frac{V_1 - V_a}{R_1} = \frac{V_a - V_o}{R_2}$

or $V_o = (\frac{R_2}{R_1} + 1)V_a - \frac{R_2}{R_1}V_1 \qquad (1)$

Applying KCL to node b, $\frac{V_2 - V_b}{R_3} = \frac{V_b - 0}{R_4}$

or $V_b = \frac{R_4}{R_3 + R_4}V_2 \qquad (2)$

But V_a=V_b. Substituting Eq.(2) into Eq.(1) yields

Electric Circuits

$$V_o = (\frac{R_2}{R_1} + 1)\frac{R_4}{R_3 + R_4}V_2 - \frac{R_2}{R_1}V_1$$

or

$$V_o = \frac{R_2}{R_1} \cdot \frac{1 + \frac{R_1}{R_2}}{1 + \frac{R_3}{R_4}}V_2 - \frac{R_2}{R_1}V_1$$

Since a difference amplifier must reject a signal common to the two inputs, the amplifier must have the property that V_O=0 when V_1=V_2. This property exists when R_1/R_2=R_3/R_4.

Electric Circuits

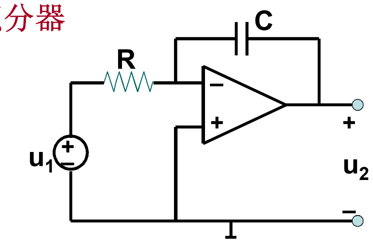
$$\therefore V_o = \frac{R_2}{R_1}(V_2 - V_1)$$

If R_2=R_1 and R_3=R_4, the difference amplifier becomes a subtractor, with the output

$$V_o = V_2 - V_1$$

Electric Circuits

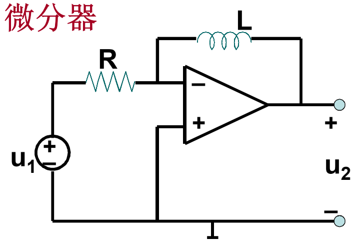
Integrator 积分器



$$\frac{u_1}{R} + C\frac{du_2}{dt} = 0 \qquad \Rightarrow \frac{du_2}{dt} = -\frac{1}{RC}u_1$$

$$\Rightarrow u_2 = -\frac{1}{RC}\int_{-\infty}^{t} u_1 dt$$

Differentiator 微分器



$$\frac{u_1}{R}+\frac{1}{L}\int_{-\infty}^{t}u_2dt=0 \qquad or \qquad u_2=-\frac{L}{R}\frac{du_1}{dt}$$