

Chapter 9. 理想操作放大器及其電路

9.5 操作放大器的應用

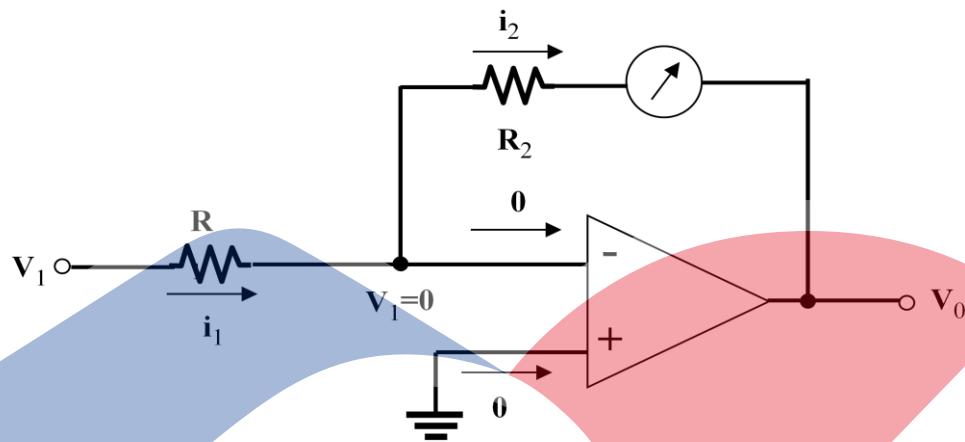
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9.5 操作放大器的應用

1. 轉換器(I-V Converter)

◇ 電壓到電流轉換器



Floating 浮接法

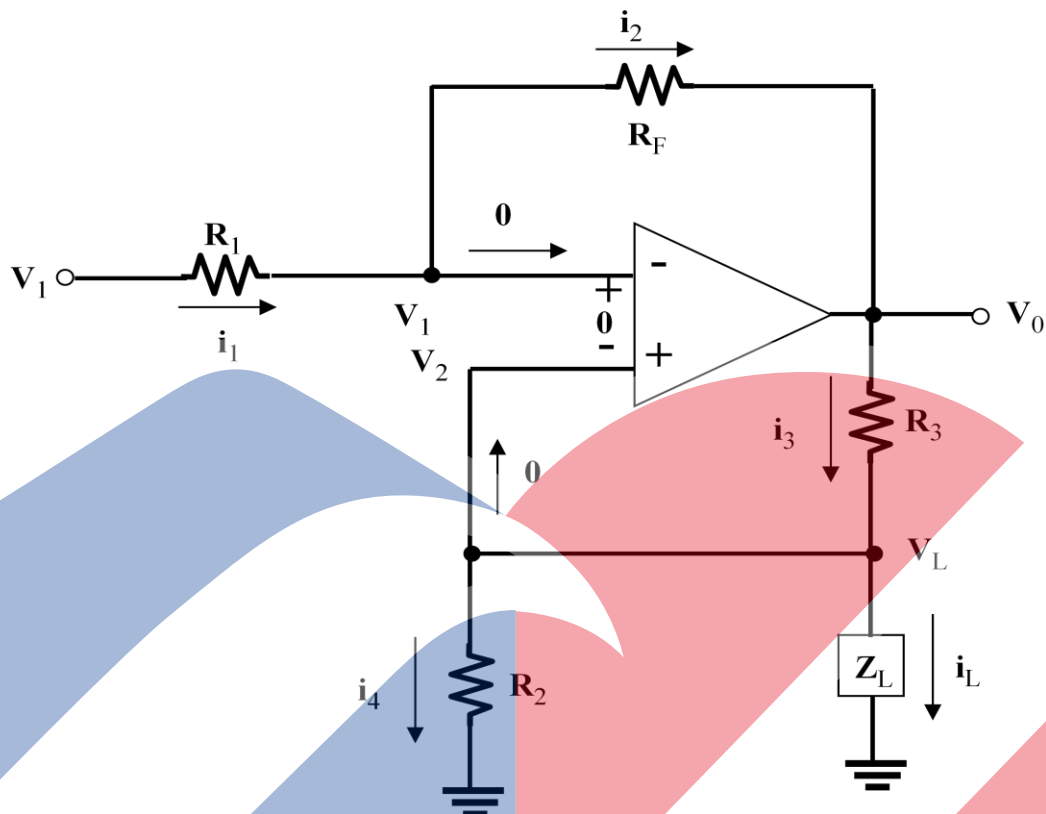
$$i_1 = \frac{V_1 - 0}{R_1}$$

$$i_1 = i_2 = i_0$$

$$i_0 = \frac{V_1}{R_1}$$

$$v_o = -\frac{R_2}{R_1} v_1$$

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接地法

\therefore Virtual ground $\rightarrow v_{(+)} = v_{(-)} = i_L Z_L$

$$i_1 = \frac{v_i - v_1}{R_1} = \frac{v_i - i_L Z_L}{R_1} = i_2 \quad \textcircled{1}$$

$$i_4 = \frac{i_L Z_L}{R_2}$$

由 V_2 點 KCL 得:

$$i_4 + i_L = i_3$$

$$\frac{i_L Z_L}{R_2} + i_L = i_3 \quad \textcircled{2}$$

$$v_o = v_1 - i_2 R_F$$

$$= i_L Z_L - \frac{v_i - i_L Z_L}{R_1} R_F = i_L Z_L \left(1 + \frac{R_F}{R_1} \right) - \frac{R_F}{R_1} v_i$$

$$i_3 = \frac{v_o - v_1}{R_3} = \frac{v_1 - i_2 R_F - v_1}{R_3}$$

$$\text{代入 } \textcircled{1} \text{ 得 } i_3 = -\frac{R_F}{R_3} \left[\frac{v_i - i_L Z_L}{R_1} \right] = \frac{i_L Z_L R_F}{R_1 R_3} - \frac{v_i R_F}{R_1 R_3} \quad \textcircled{3}$$

$$\textcircled{2} = \textcircled{3}$$

$$\frac{i_L Z_L}{R_2} + i_L = \frac{i_L Z_L R_F}{R_1 R_3} - \frac{v_i R_F}{R_1 R_3}$$

$$i_L \left[\frac{Z_L R_F}{R_1 R_3} - 1 - \frac{Z_L}{R_2} \right] = \frac{v_i R_F}{R_1 R_3}$$

$$i_L = \frac{\frac{v_i R_F}{R_1 R_3}}{\frac{Z_L R_F}{R_1 R_3} - 1 - \frac{Z_L}{R_2}}$$

$$\text{When } \frac{R_F}{R_1 R_3} = \frac{1}{R_2}$$

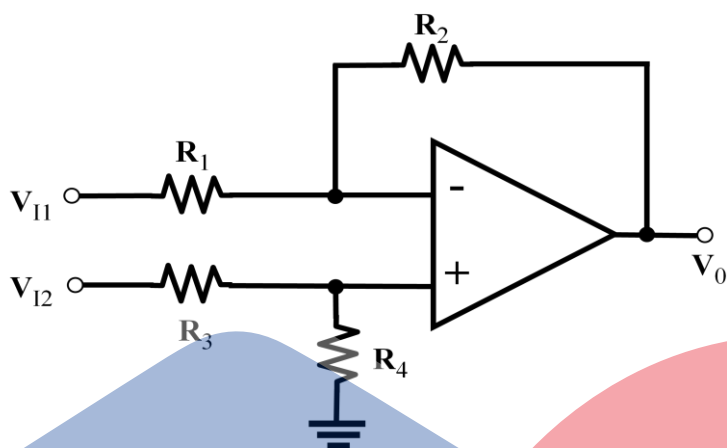
$$\frac{R_F}{R_1} = \frac{R_3}{R_2} \text{ 成立時}$$

$$i_L = -\frac{R_F}{R_1 R_3} v_i$$

The logo of Southern Taiwan University is a stylized, abstract design. It consists of several overlapping, curved shapes in shades of blue, red, and white, forming a central white space. The overall shape is reminiscent of a stylized 'S' or a traditional Chinese knot.

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2. 差值放大器



利用重疊定理: Virtual ground $\rightarrow v_{(+)} = v_{(-)}$

I. 考慮 v_{I1} , $v_{I2} = 0$

$$v_{o1} = -\frac{R_2}{R_1} v_{I1}$$

II. 考慮 v_{I2} , $v_{I1} = 0$

$$v_{(+)} = -\frac{R_4}{R_3 + R_4} v_{I2}$$

$$v_{o2} = \left(1 + \frac{R_2}{R_1}\right) v_{(+)}$$

$$= \left(1 + \frac{R_2}{R_1}\right) \left(\frac{R_4}{R_3 + R_4}\right) v_{I2}$$

$$v_o = v_{o1} + v_{o2}$$

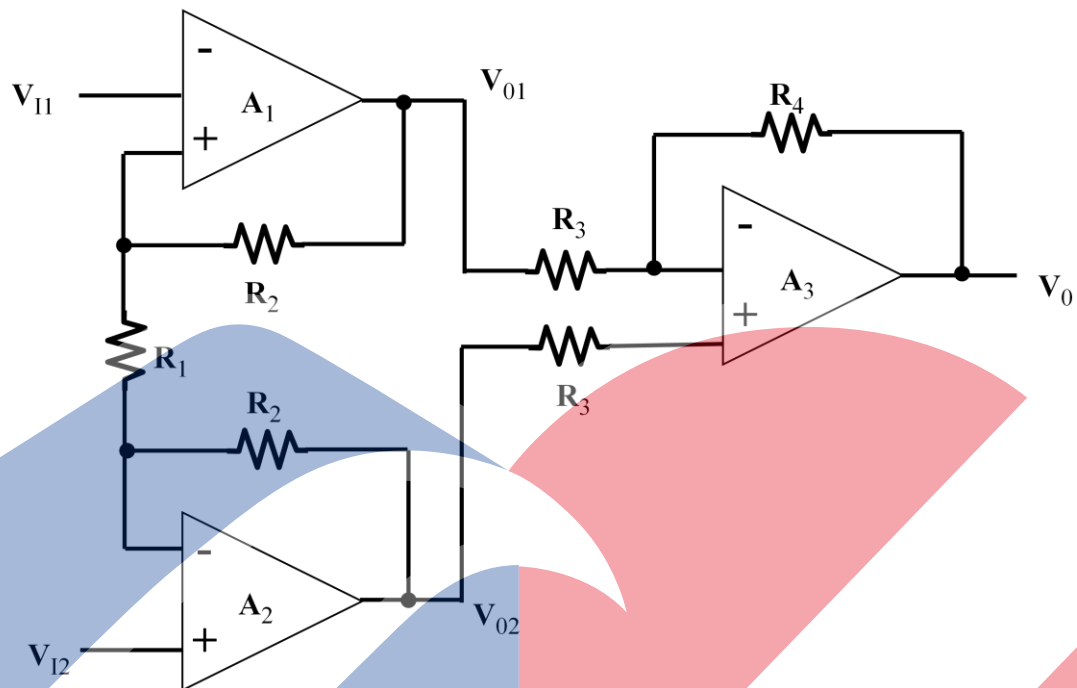
$$= -\frac{R_2}{R_1} v_{I1} + \left(1 + \frac{R_2}{R_1}\right) \left(\frac{R_4}{R_3 + R_4}\right) v_{I2}$$

$$v_o = -\frac{R_2}{R_1} v_{I1} + \left[\frac{R_4}{R_3} \left(\frac{1 + \frac{R_2}{R_1}}{1 + \frac{R_4}{R_3}}\right)\right] v_{I2}$$

When $\frac{R_2}{R_1} = \frac{R_4}{R_3}$ 成立

$$v_o = \frac{R_2}{R_1} (v_{I2} - v_{I1})$$

3. 儀表放大器(Instrument Amplifier)



$$v_o = -\frac{R_2}{R_1}v_{o1} + \left[\frac{R_4}{R_3} \left(\frac{1 + \frac{R_2}{R_1}}{1 + \frac{R_4}{R_3}}\right)\right]v_{o2}$$

$$= \frac{R_4}{R_3}(v_{o2} - v_{o1}) \quad \text{--- (1)}$$

∵ Virtual ground $\rightarrow v_{(+)} = v_{(-)}$

$$i_{R1} = \frac{v_{I2} - v_{I1}}{R_1}$$

$$v_{o2} - v_{o1} = i_{R1}(R_2 + R_1 + R_2)$$

$$= \frac{v_{I2} - v_{I1}}{R_1}(2R_2 + R_1)$$

$$= (v_{I2} - v_{I1})\left(1 + \frac{2R_2}{R_1}\right) \quad \text{--- (2)}$$

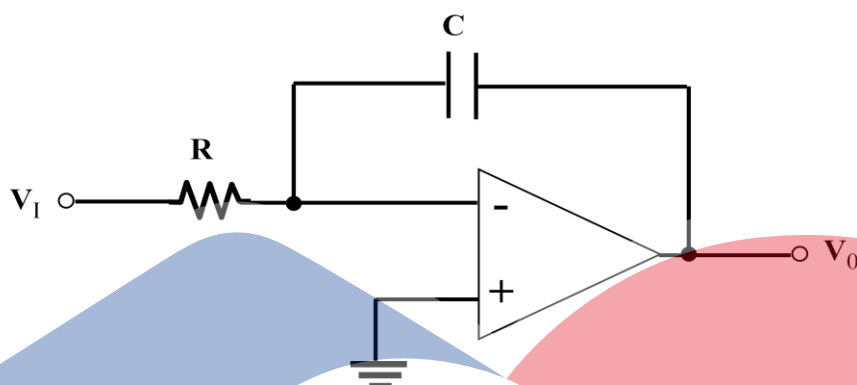
②代入① $v_o = \frac{R_4}{R_3}(v_{I2} - v_{I1})\left(1 + \frac{2R_2}{R_1}\right)$

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4. 積分器與微分器

◇ 積分器



$$v_o = -\frac{1}{SC} v_i = -\frac{1}{SRC} v_i$$

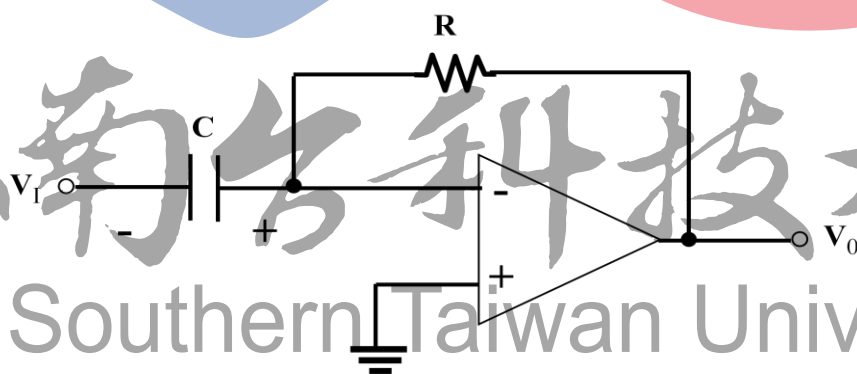
$$v_o(t) = -\int_0^{t'} \frac{1}{RC} v_i(t) dt + c \quad \text{①}$$

When $t=0$ $v_o(0) = v_c$ 代入①

$$v_o(0) = v_c = c$$

$$v_o(t) = v_c - \int_0^{t'} \frac{1}{RC} v_i(t) dt$$

◇ 微分器



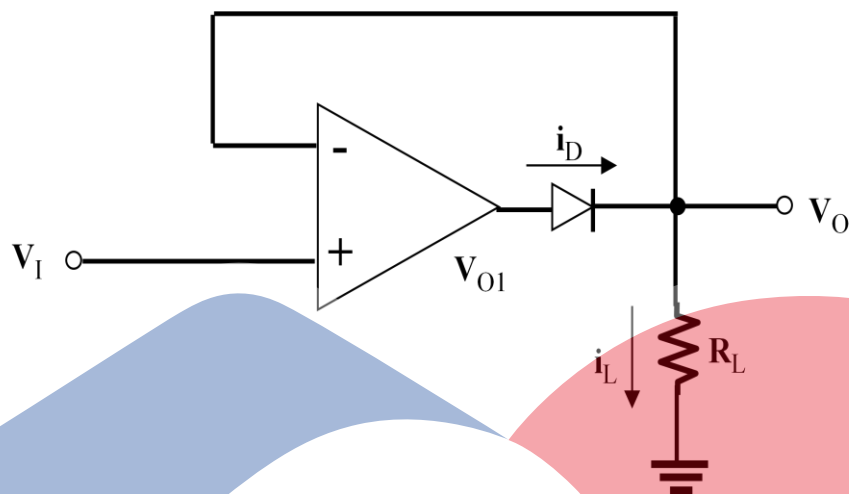
$$v_o = -\frac{R}{1} v_i = -RCv_i$$

$$v_o(t) = -RC \frac{dv_i}{dt}$$

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5. 非線性電路運用

◇ 精確半波整流器



When $v_{(+)} > v_{(-)}$

$$v_i > v_o$$

$v_{o1} = v_{sat}^+ \rightarrow D \text{ ON}$ 負迴授成立

$$v_{(+)} = v_{(-)}$$

$$v_o = v_i$$

When $v_{(+)} < v_{(-)}$

$$v_i < v_o$$

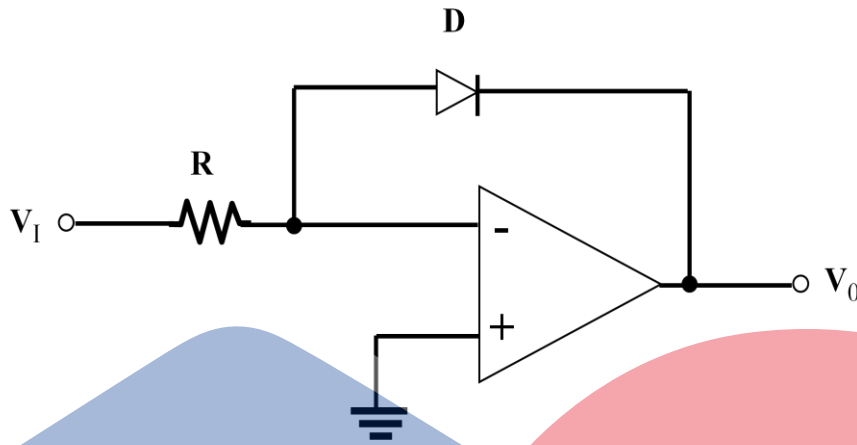
$v_{o1} = v_{sat}^- \rightarrow D \text{ OFF}$

$$v_o = 0$$

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◇ 對數放大器



When $v_i > 0 = v_{(+)}$

$$v_o = v_{sat}^-$$

D ON 負迴授成立

$$i_1 = \frac{v_i}{R_1} = i_D$$

$$\therefore v_o = -v_D$$

$$i_D = I_S(e^{\frac{v_D}{v_T}} - 1) \cong I_S e^{\frac{v_D}{v_T}}$$

$$\therefore v_D = -v_o$$

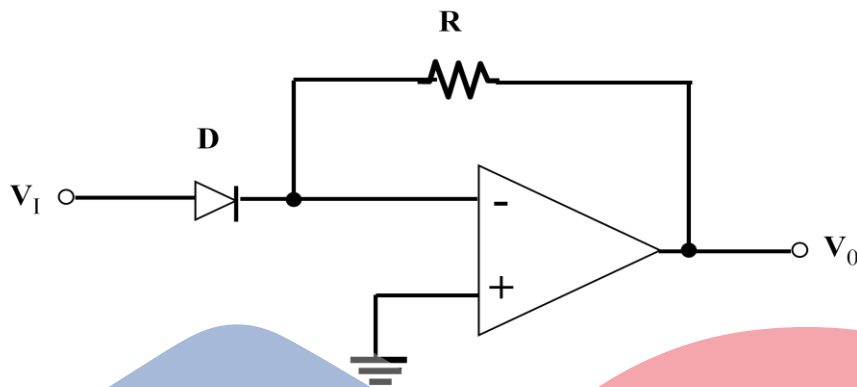
$$i_D = \frac{v_i}{R_1} = I_S e^{\frac{v_D}{v_T}} = I_S e^{\frac{-v_o}{v_T}}$$

$$\frac{v_i}{I_S R_1} = e^{\frac{v_o}{v_T}}$$

$$\ln\left(\frac{v_i}{I_S R_1}\right) = \frac{v_o}{v_T}$$

$$v_o = -v_T \ln\left(\frac{v_i}{I_S R_1}\right)$$

✧ 反對數或指數放大器



負迴授成立

$$v_{(+)} = v_{(-)} = 0$$

$$v_D = v_i$$

When $v_i > 0$

$$i_D = I_S(e^{\frac{v_D}{V_T}} - 1) \cong I_S e^{\frac{v_i}{V_T}}$$

$$v_o = -i_2 R$$

$$\because i_D = i_2$$

$$v_o = -I_S e^{\frac{v_i}{V_T}} R$$

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