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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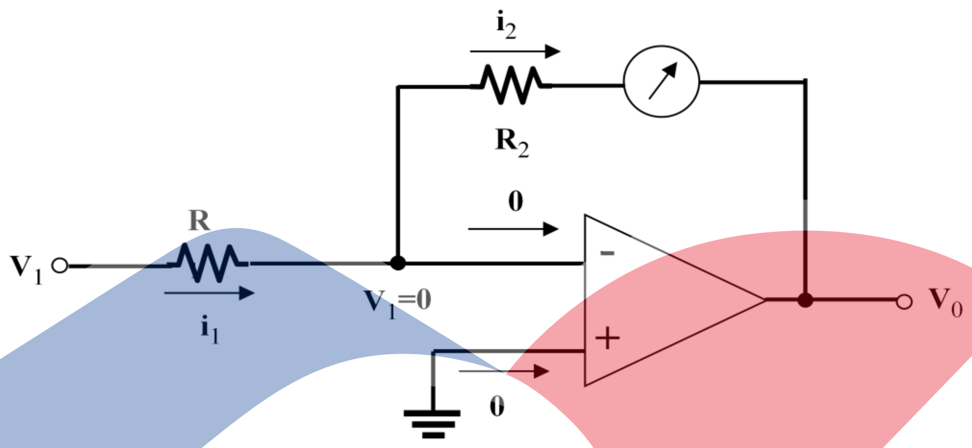
1. 轉換器(I-V Converter)

✧ 電壓到電流轉換器



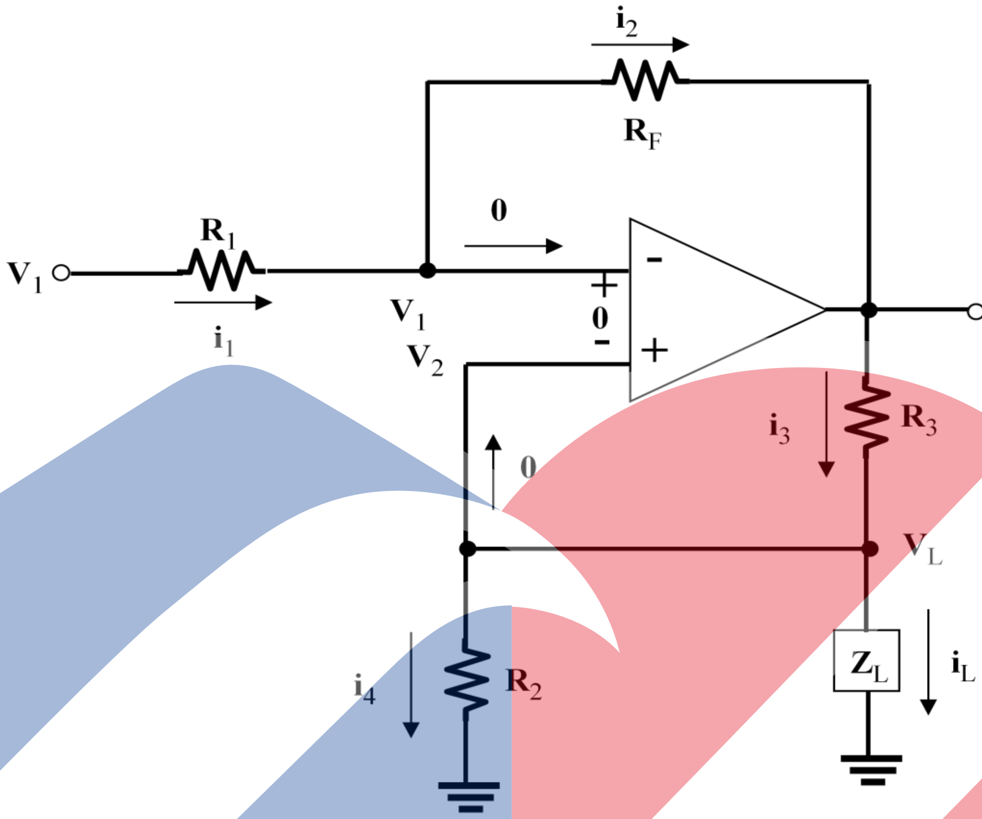
Floating 浮接法

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

$$i_1 = i_2 = i_0$$

$$i_o = \frac{v_I}{R_1}$$

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



接地法

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

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

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

由V_2點 KCL 得:

$$i_4 + i_L = i_3$$

$$\frac{i_L Z_L}{R_2} + i_L = i_3 - \text{②}$$

$$v_o = v_1 - i_2 R_F$$

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

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

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

② =③

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

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

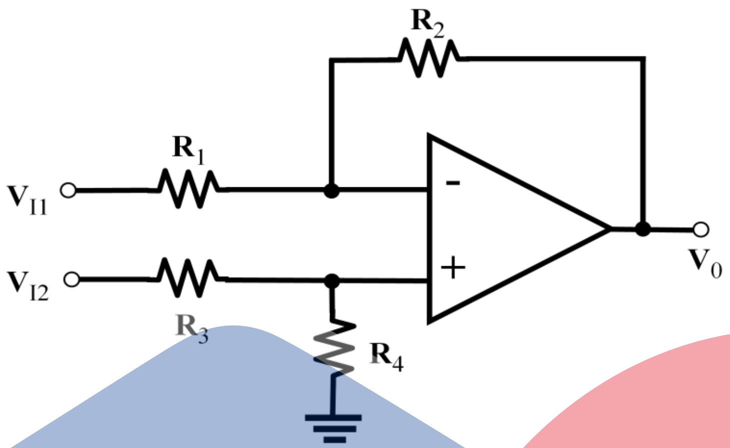
$$i_L = \frac{\frac{v_i R_F}{R_1 R_3}}{\frac{Z_L R_F}{R_1 R_3} - 1 - \frac{Z_L}{R_2}}$$

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

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

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

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}，$v_{I1} = 0$

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

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

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

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

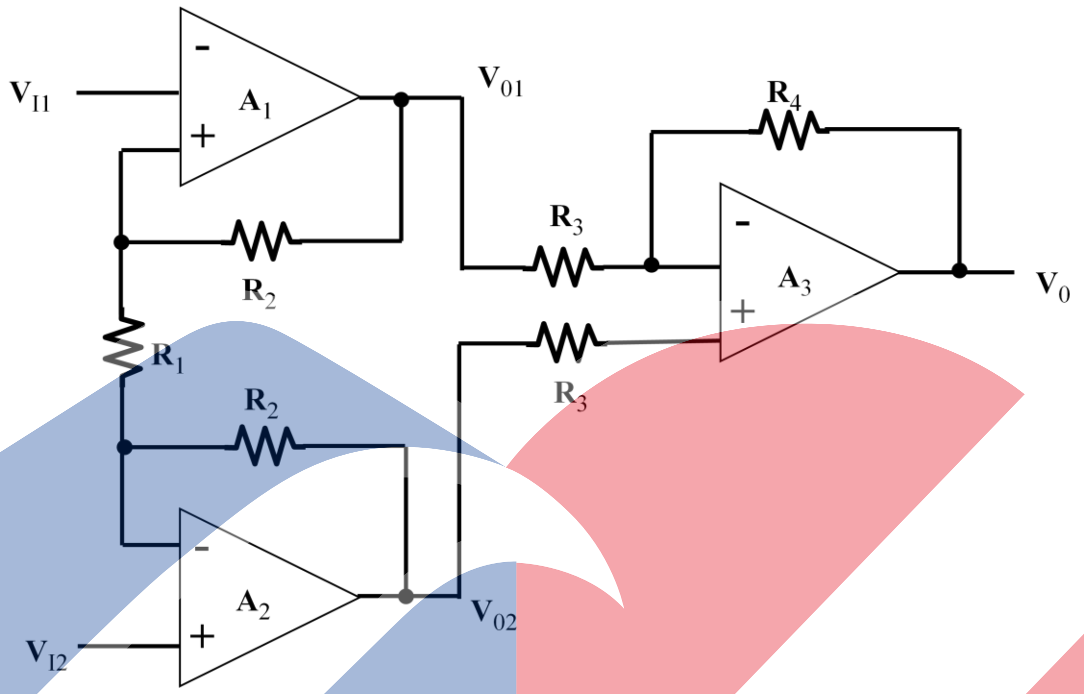
$$= -\frac{R_2}{R_1} v_{I1} + \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_3}\right) v_{I2}$$

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

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)



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

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

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

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

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

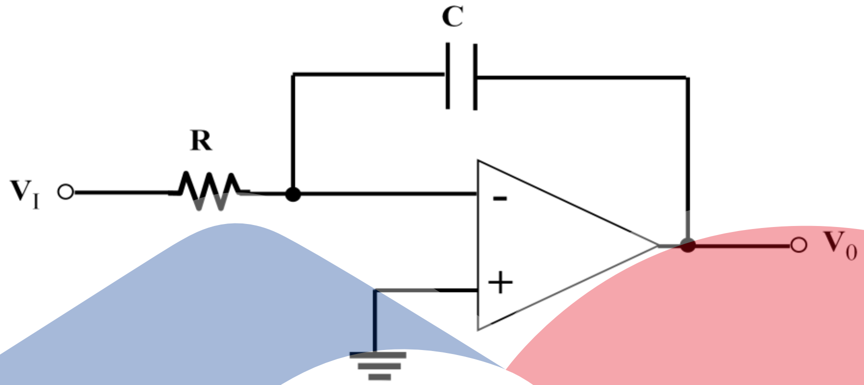
$$= \frac{v_{I2} - v_{I1}}{R_1}(2R_2 + R_1)$$

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

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

4. 積分器與微分器

✧ 積分器



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

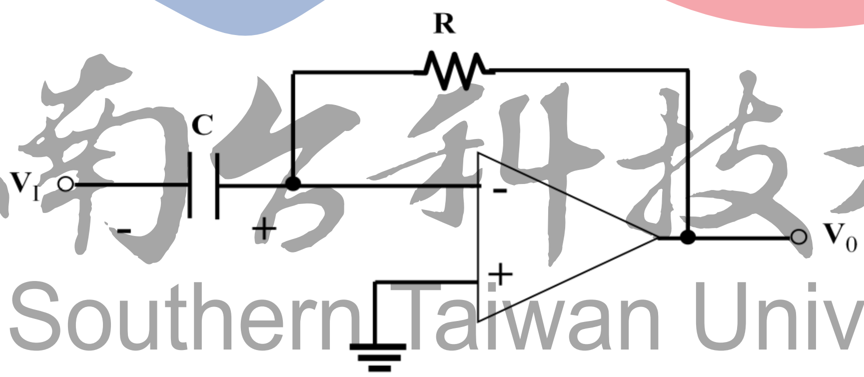
$$v_o(t) = -\int_0^{t'} \frac{1}{RC} v_i(t)dt + c - ①$$

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

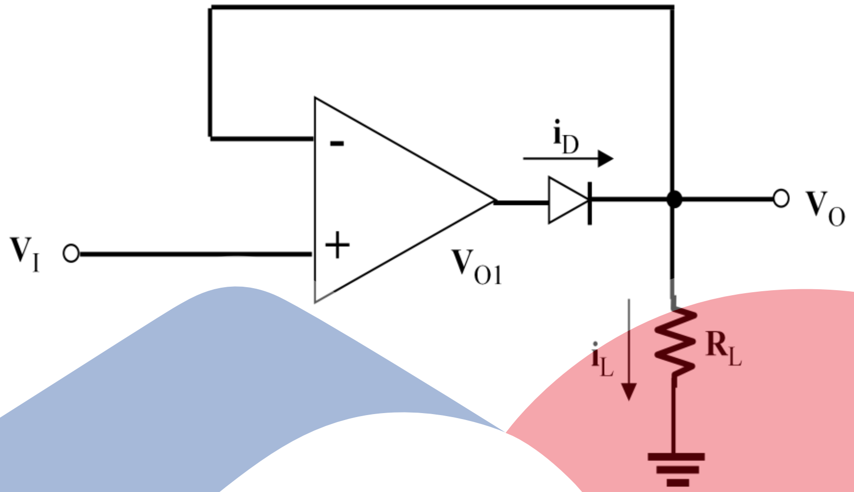


$$v_o = -\frac{R}{\frac{1}{SC}} v_i = -SRCv_i$$

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

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 ON 負迴授成立

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

$v_o = v_i$

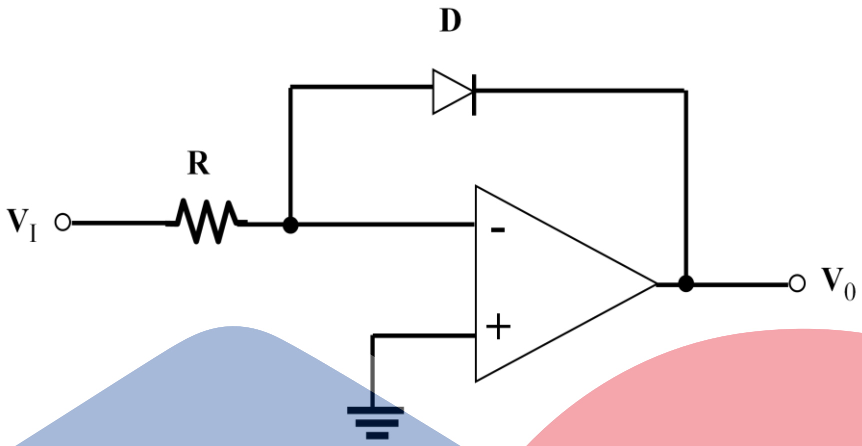
When $v_{(+)} < v_{(-)}$

$v_i < v_o$

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

$v_o = 0$

✧ 對數放大器



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

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

D ON 負迴授成立

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

$$\because v_o = -v_D$$

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

$$\because v_D = -v_o$$

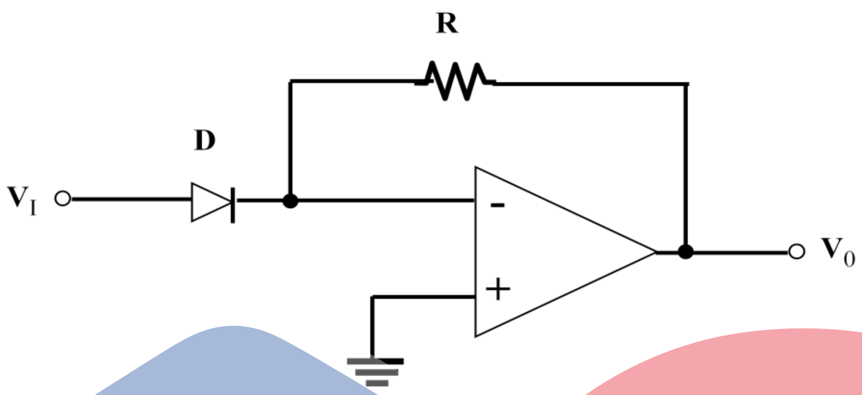
$$i_D = \frac{v_I}{R_1} = I_S e^{\frac{v_D}{v_T}} = I_S e^{\frac{-v_o}{v_T}}$$

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

$$\ln(\frac{v_I}{I_S R_1}) = \frac{v_o}{v_T}$$

$$v_o = -v_T \ln(\frac{v_I}{I_S R_1})$$

✧　反對數或指數放大器



負迴授成立

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

$v_D = v_i$

When $v_i > 0$

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

$v_o = -i_2 R$

$\because i_D = i_2$

$v_o = -I_S e^{\frac{v_I}{v_T}} R$