Chapter 9. 理想操作放大器及其電路

9.2 反相放大器(Inverting Amplifier)

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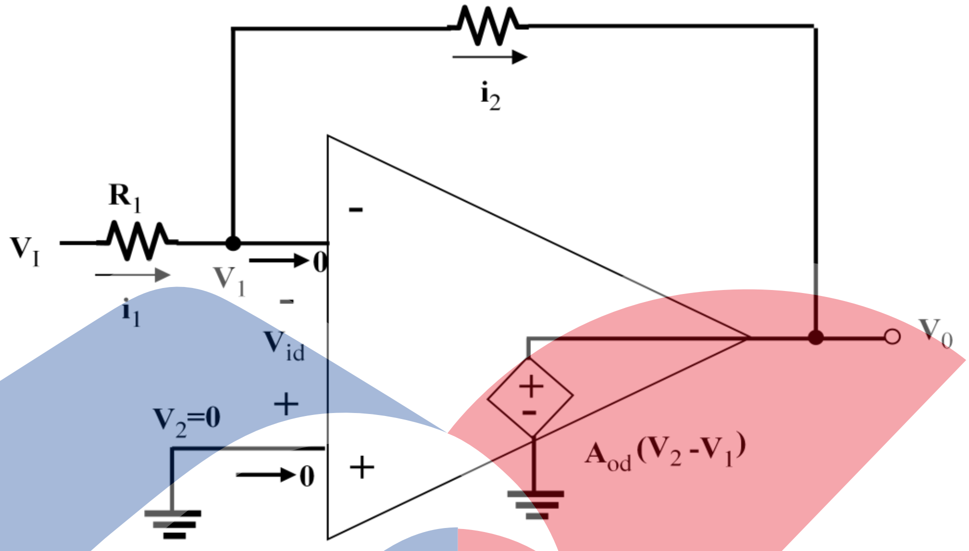
1. 基本放大器



對V_1使用 KCL　　$i_1 = i_2$

∵Virtual ground → $v_1 = v_2 = 0$

$$i_1 = \frac{v_i - 0}{R_I}$$

$$i_2 = \frac{0 - v_o}{R_F}$$

$$\frac{v_i - 0}{R_I} = \frac{0 - v_o}{R_F}$$

$$v_o = \frac{-R_F}{R_I} v_i$$

$$A_V = \frac{v_o}{v_i} = \frac{-R_F}{R_I}$$

$R_{in} = R_I$

$R_{out} = 0$

2. 非理想操作放大器的特性

當考慮非理想 OP 放大器時

$A_{od} \neq \infty$、$Z_{in} = \infty$、$Z_{out} = 0$

$$i_1 = \frac{v_i - v_1}{R_I}$$

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

$\because Z_{in} = \infty$

對V_1使用 KCL　$i_1 = i_2$

$$\frac{v_i - v_1}{R_I} = \frac{v_1 - v_o}{R_F}$$

$$v_o = \left(1 + \frac{R_F}{R_I}\right) v_1 - \frac{R_F}{R_I} v_i - ①$$

$\because A_{od} \neq \infty$ 故$v_o = A_{od}(v_2 - v_1)$

$=A_{od}(0 - v_1)$

$=-v_1 A_{od}$

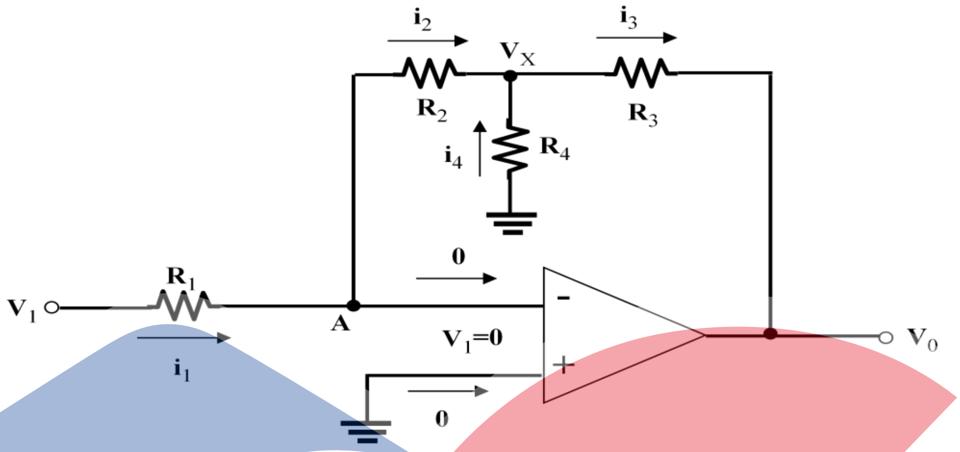
$$v_1 = \frac{-v_o}{A_{od}} - ②$$

② 代入 ① $\rightarrow v_o \left(1 + \frac{R_F}{R_I}\right) \frac{-v_o}{A_{od}} - \frac{R_F}{R_I} v_i$

$$v_o = \frac{-\frac{R_F}{R_I} v_i}{1 + \frac{+}{A_{od}}\left(1 + \frac{R_F}{R_I}\right)}$$

當$A_{od} \rightarrow \infty$　$A_V = -\frac{R_F}{R_I}$

3. 具有 T-網路(T-Network)的放大器



$$A_V = \frac{v_o}{v_I}$$

$\because Z_{in} = \infty$、$i_{(+)} = 0$

對 A 點使用 KCL

$$i_1 = i_2$$

$$i_1 = \frac{v_i - 0}{R_1} = i_2 = \frac{0 - v_X}{R_2} - ①$$

$$i_4 = \frac{0 - v_X}{R_4} = \frac{-v_X}{R_4}$$

對v_X點使用 KCL

$$i_2 + i_4 = i_3$$

$$\frac{-v_X}{R_2} - \frac{v_X}{R_4} = i_3$$

$$-v_X\left(\frac{1}{R_2} + \frac{1}{R_4}\right) = i_3 - ②$$

$$\frac{v_X - v_o}{R_3} = i_3 - ③$$

② = ③

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

$$v_X\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) = \frac{v_o}{R_3}$$

$$v_o = R_3\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)v_X - ④$$

由①得

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

將④代入上式

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

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