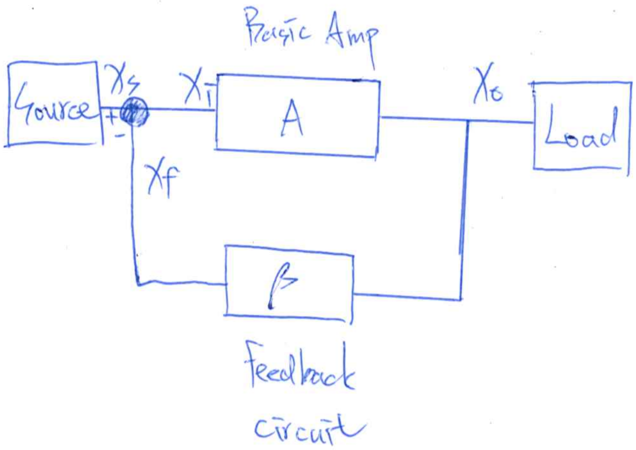
Chapter 9 Feedback Lec 12

§ negative feedback.



$$\begin{cases} X_i = X_s - X_f \\ X_o = A X_i \\ X_f = \beta X_o \end{cases}$$

$$\Rightarrow X_o = A(X_s - X_f)$$
$$= A(X_s - \beta X_o)$$
$$X_o(1+\beta A) = A X_s$$

$$\Rightarrow \boxed{\frac{X_o}{X_s} = \frac{A}{1+\beta A}}$$

→沒有回授的 A_{vo}

$1+\beta A \gg 1$ （$1+\beta A$ 是正号且通常大於1），增益会下降

gain is reduced

loop gain.

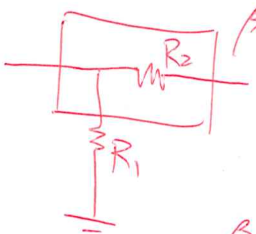
再算一下：$X_f = \beta X_o = \beta \dfrac{A}{1+\beta A} X_s = \dfrac{\beta A}{1+\beta A} X_s$

→ 迴授回来的信号 会等於 input 信号源(X_s) 再 × $\dfrac{\beta A}{1+\beta A}$

若 $\beta A \gg 1$

$$\Rightarrow \begin{cases} X_f \cong X_s \\ A_f = \dfrac{A}{1+\beta A} \cong \dfrac{1}{\beta} \end{cases}$$

→ 閉迴路增益 $A_f = \dfrac{1}{\beta}$



$\beta = \dfrac{1}{10}$

$\beta = \dfrac{R_1}{R_1+R_2}$

$= 1 + \dfrac{R_2}{R_1}$

independ of A

Semiconductor parameter

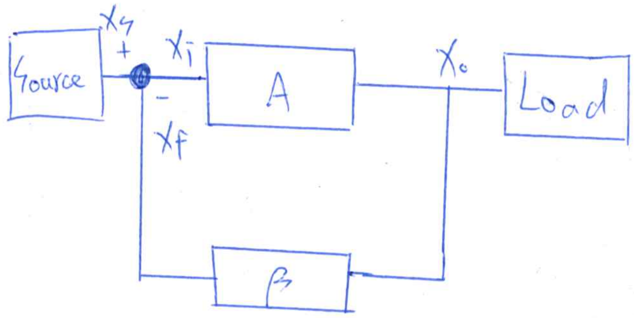
跟温度有関 → 不好控制

→ $f(Temp)$

⇒ 負回授時，增益只和β有関，和半導体無関了

電子學(三) Lec 13

§ Negative feedback.



回授基本公式

$$\begin{cases} X_i = X_s - X_f \\ X_o = AX_i \\ X_f = \beta X_o \end{cases}$$

$$X_o = A(X_s - X_f)$$

$$\Rightarrow \frac{X_o}{X_s} = \frac{A}{1+\beta A}$$

$$X_f = \frac{\beta A}{1+\beta A} X_s$$

$\left(ex: A = 100, \beta = \frac{1}{10} \Rightarrow A\beta = 10 \right)$

A 是放大器

β 是簡單的串阻分壓 or 分流电路

若 $\beta A >> 1$,

$$\frac{X_o}{X_s} = \frac{A}{1+\beta A} \cong \frac{1}{\beta}$$

$\Rightarrow$ indep of A!! 可得穩定的增益

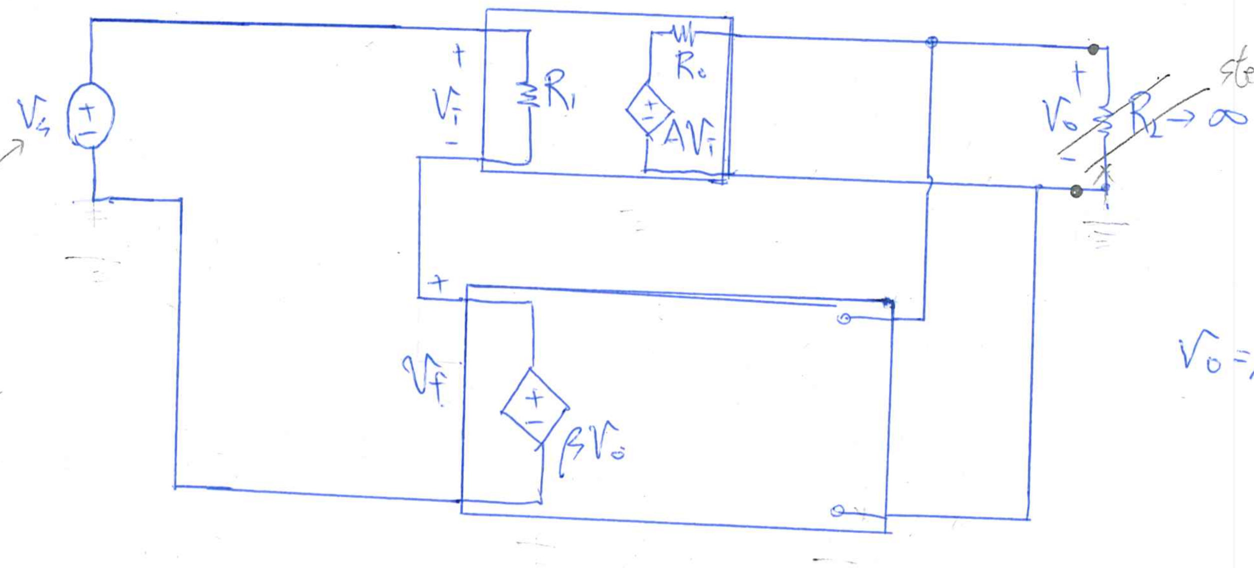
☆ X: can be v or i

depends on feedback method $\Rightarrow$ 4種方式

$$\begin{cases} v - v \\ v - i \\ i - v \\ i - i \end{cases}$$

5 V-V

此 Basic Amp 可放任一模型，此挑 V-V Amp model



假設訊號源內阻=0

$V_o = AV_i$

step1: 畫框架

step2: 畫 Amp 模型

step3: $R_L \to \infty$，改改開路

step4: 畫理想 β 模型.

step5: 滿足回授三條件 → 故 $A_f = \frac{A}{1+\beta A}$ 可以用!

step6: 改畫実際电路的狀況，改接地

和実際的 BJT, MOSFET 較像

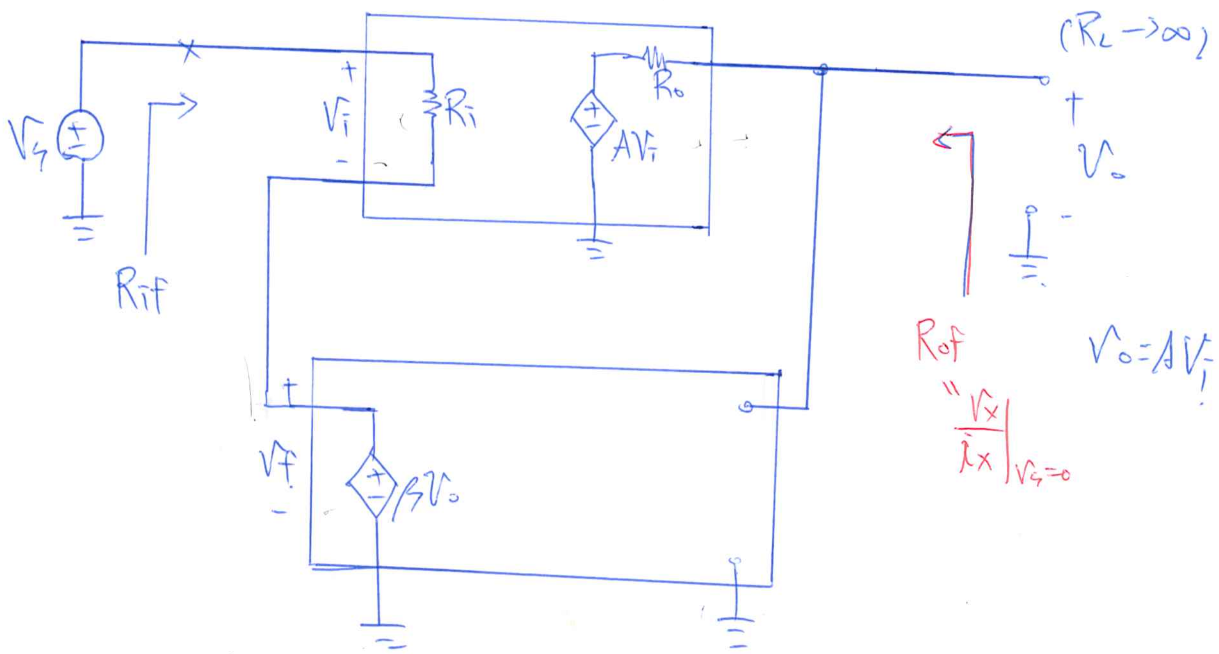
step7: 求 R_{if}

$V_i = V_s - V_f$

$V_f = \beta V_o$

Step 6: 重整模型

series shunt
V - V



* $R_{if} = \frac{V_s}{V_i/R_i} = \frac{V_s R_i}{V_i} = \frac{V_s R_i}{V_s - V_f} = \frac{V_s R_i}{V_s - \beta V_o} \xrightarrow{\frac{V_o}{V_s} = \frac{A}{1+\beta A}} \frac{\cancel{V_s} R_i}{\cancel{V_s} - \beta\left(\frac{A}{1+\beta A}\cancel{V_s}\right)} = \frac{R_i}{1 - \frac{\beta A}{1+\beta A}}$

上下×(1+βA)

$= (1+\beta A) R_i$

電阻變大了!!

從 input 看進去，
看到"串聯" ⇒ R 変大

* $R_{of} = \frac{V_x}{i_x}\Big|_{V_s=0}$ → 逆 V_x 送 i

V_s 短路 ⇒ $V_i = -V_f$ ⇒ $AV_i = A(-V_f) = A(-\beta V_x)$ ⇒ $i_x = \frac{V_x - A(-\beta V_x)}{R_o} = \frac{V_x(1+\beta A)}{R_o}$

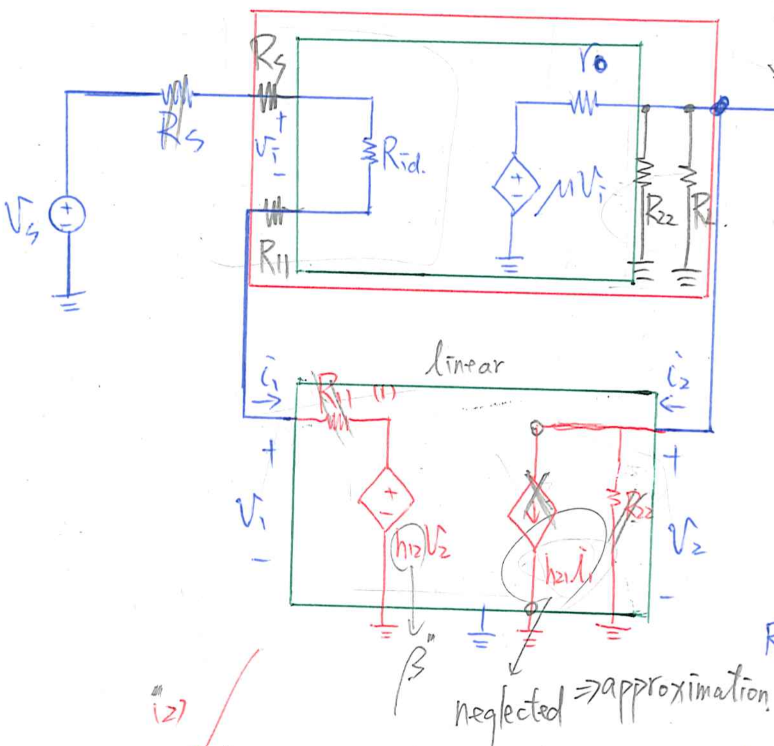
$V_o = V_x$

⇒ $R_{of} = \frac{V_x}{i_x}\Big|_{V_s=0} = \frac{R_o}{1+\beta A}$ ⇒ 從 output 看進去，看到"並聯" ⇒ R 变小

* $\frac{V_o}{V_s} = \frac{A}{1+\beta A}$ → 知道 β 和 A 即可得增益

畫実際电路

practical. 実際电路一定有訊號源內阻，一定有負載，回授电路也沒這麼簡單，不只βV_o可能有好几个电阻在裡面）



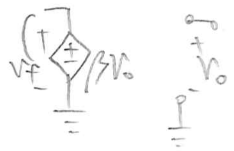
任何 linear 电路都可从此形式表示 (4种)

$$\begin{cases} V_1 = R_{11} i_1 + h_{12} V_2 \\ i_2 = h_{21} i_1 + \frac{1}{R_{22}} V_2 \end{cases}$$

$$R_{12} = \left.\frac{V_1}{i_1}\right|_{V_2=0} \qquad h_{21} = \left.\frac{i_2}{i_1}\right|_{V_2=0}$$

$$h_{12} = \left.\frac{V_1}{V_2}\right|_{i_1=0} \overset{(2)}{=} \beta \qquad R_{22} = \left.\frac{V_2}{i_2}\right|_{i_1=0}$$

(2) 想辦法換成理想形式



⇒ ①觀察可得 h_{12} 就是 β

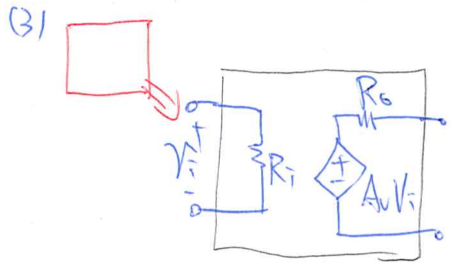
⇒ ②把 R_{11} 移去外面

③把 R_{22} 移去外面

④剩 $h_{21} i_1$ ……忽略!! (变 open)

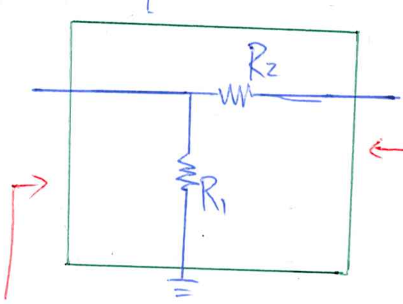
⑤把 R_s，R_L 移進去，看成新的放大器 A，再把 R_{if}, A, R_{of} 求出 (新的)

(3)



⟶求 R_{11}, R_{22}, β, 新R_{if}, A, R_{of} ⇒破關!!!

舉个例子! β network



$\boxed{R_{22}} = \frac{v}{i}\Big|_{i_1=0} = R_1+R_2$ #

$\boxed{R_{11}} = \frac{v}{i}\Big|_{v_2=0}$

$= R_1 // R_2$ #

$\beta = \frac{V_f}{V_o}\Big|_{i_1=0}$ $\Rightarrow V_o \times \frac{R_1}{R_1+R_2} = V_f$, $\boxed{\frac{V_f}{V_o}} = \frac{R_1}{R_1+R_2}$ # β

$\Rightarrow$ 求得 R_{11}, R_{22}, β! #

*求 R_i:

$\boxed{R_i} = R_s + R_{id} + R_{11}$ #

*求 A: $A = \frac{V_o}{V_i} \Rightarrow \mu V_i \times \frac{(R_{22}//R_L)}{r_o+(R_{22}//R_L)} = V_o$ $R_{22} = R_1+R_2$

$V_i = V_s \times \frac{R_{id}}{R_s+R_{id}+R_{11}}$

(新放大器的輸入電压V_i就是V_s!!!)

$\Rightarrow \boxed{A} = \frac{\mu(R_{22}//R_L)}{r_o+(R_{22}//R_L)} \times \frac{R_{id}}{R_s+R_{id}+R_{11}}$ #

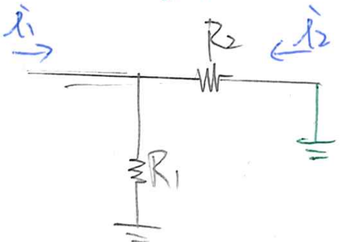
*求$\boxed{R_o}$ = (輸入V短路 $\Rightarrow \mu V_i = 0 \Rightarrow$ 看到r_o, R_{22}, R_L並联)

$R_o = r_o // R_{22} // R_L$ #

☆ 破關了! $R_{if} = R_i(1+\beta A)$, $R_{of} = \frac{R_o}{1+\beta A}$, $A_f = \frac{A}{1+\beta A}$ #

證明一下, why $h_{21} i_i$ 可忽略:

$h_{21} = \frac{i_2}{i_1}\Big|_{V_2=0}$



$i_1 \times \frac{R_1}{R_1+R_2} = -i_2$

$\frac{i_2}{i_1} = \frac{-R_1}{R_1+R_2}$

$\frac{h_{21} i_i}{\frac{1}{R_{22}} \times V_2} = \frac{\frac{-R_1}{R_1+R_2} \times \frac{V_s}{(R_s+R_{id}+R_{11})(1+\beta A)}}{\frac{\frac{A}{1+\beta A} V_s}{R_1+R_2}}$ $(i_i = \frac{V_s}{R_{if}})$

$V_2 = V_o = \frac{A}{1+\beta A} V_s$

比大小而已, 負号不看了 $= \frac{R_1}{[R_s+R_{id}+(R_1//R_2)]A}$

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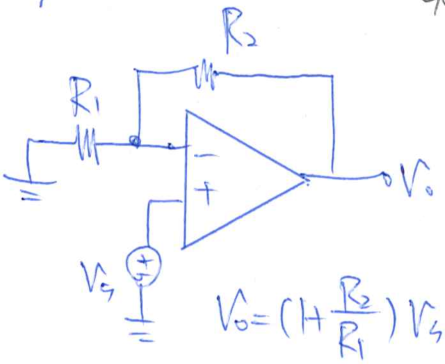
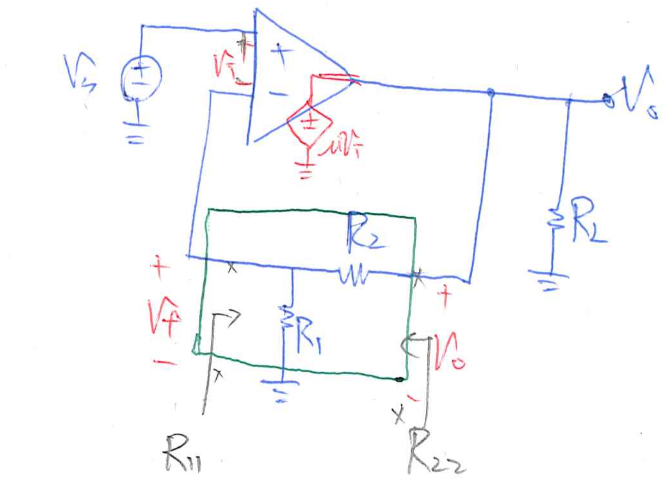
§ Negative Feedback V-V series shunt



$V_o = (1+\frac{R_2}{R_1}) V_s$ ⇒

設 $R_i \to \infty$, $R_o = 0$



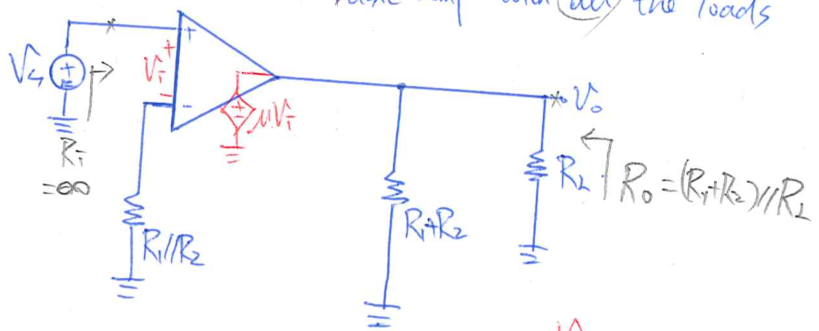
β網路的

$\beta = \frac{V_f}{V_o}\Big|_{\text{input open}} = \frac{R_1}{R_1+R_2}$

$R_{11} = R_1 // R_2$ (output short)

$R_{22} = R_1 + R_2$ (input open)

Basic Amp with all the loads



$\frac{V_o}{V_s} = A = \mu$ #

$\Rightarrow \frac{V_o}{V_s} = \frac{A}{1+\beta A} = \frac{\mu}{1+\frac{R_1}{R_1+R_2}\mu}$ #

$R_{if} = (1+\beta A) R_i = \infty$ #

$R_i \to \infty$

$R_{of} = \frac{(R_1+R_2)//R_L}{1+\frac{R_1}{R_1+R_2}\mu}$ #

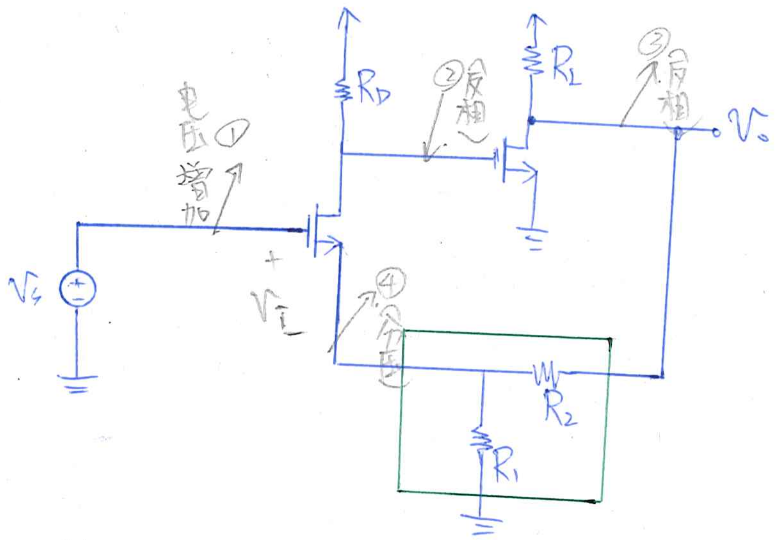
如果μ很大, $\frac{V_o}{V_s} = 1 + \frac{R_2}{R_1}$

$R_{of} \to 0$ (有負載沒差, R_{of}一樣是0)

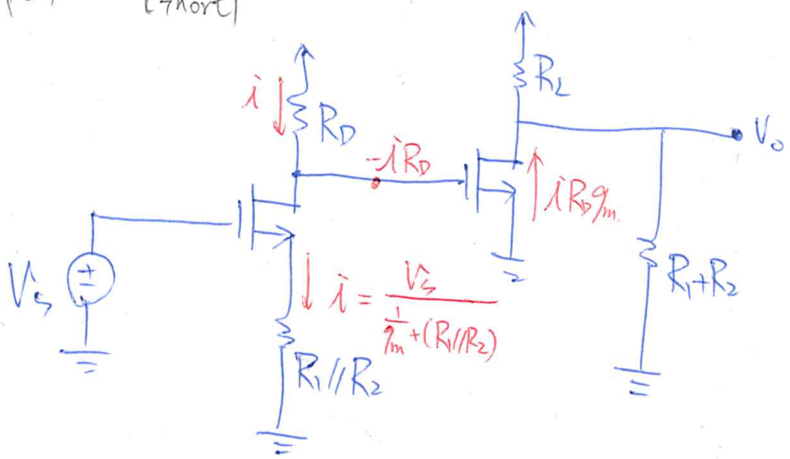
沒有負載效應!!!

§ Negative feedback V-V (再舉一个例子!)

判别是否負回授



V - V
series - shunt
(open) (short)



$$V_o = \frac{V_s}{\frac{1}{g_m}+(R_1//R_2)} \times R_D \times g_m \times [R_L // (R_1+R_2)] \Rightarrow \frac{V_o}{V_s} = \frac{1}{\frac{1}{g_m}+(R_1//R_2)} \times R_D\, g_m [R_L // (R_1+R_L)]$$

$A =$

$$\beta = \frac{R_1}{R_1+R_2}$$

$$R_{if} = R_i(1+\beta A) \to \infty$$

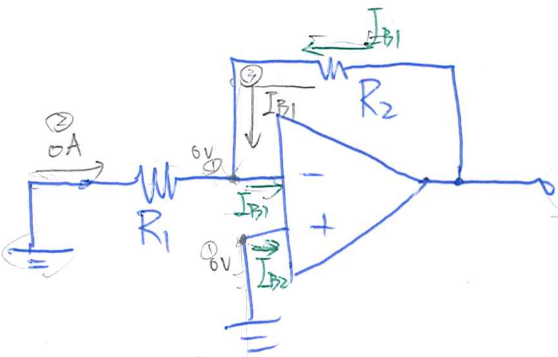
$$R_o = R_L // (R_1+R_2)$$

$$R_{of} = \frac{R_o}{1+\beta A}$$

$$\frac{V_o}{V_s} = \frac{A}{1+\beta A}$$

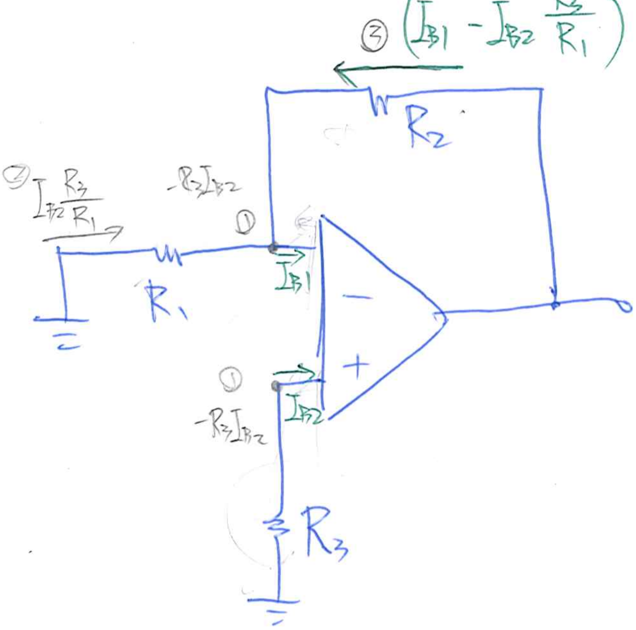
OPA - 考慮 Input Bias Current (DC Imperfections) 電子學(一) Lec 10

($\cong 100nA$)



$V_o = I_{B1} R_2 = \underbrace{I_B}_{100nA} \times \underbrace{R_2}_{100k} \cong 0.01\,V$

偏移一直流準位



$V_o = -R_3 I_{B2} + R_2\left(I_{B1} - I_{B2}\frac{R_3}{R_1}\right)$

$= R_2 I_{B1} - I_{B2}\left(R_3 + \frac{R_2 R_3}{R_1}\right)$

(假設 $I_{B1} = I_{B2} = I_B$。欲使 V_o 直流偏移為 0)

$R_2 = R_3 + \frac{R_2 + R_3}{R_1}$

$R_2 = R_3\left(1 + \frac{R_2}{R_1}\right)$ $\cancel{\Rightarrow R_3}$

$R_3 = \dfrac{R_2}{1 + \frac{R_2}{R_1}}$

$\Rightarrow R_3 = \frac{R_1 R_2}{R_1 + R_2} = R_1 // R_2$ #

$= \dfrac{R_2}{\frac{R_1 + R_2}{R_1}}$

$= \dfrac{R_1 R_2}{R_1 + R_2}$

現考慮 $I_{B1} \neq I_{B2}$，

則 $I_{B1} - I_{B2} = I_{os}$ ($\cong 10nA$)

$V_o = R_2 \underbrace{I_{B1}}_{I_{B2} + I_{os}} - I_{B2}\left(R_3 + \frac{R_2 R_3}{R_1}\right)$，若 $R_3 = R_1 // R_2$，則

$V_o = I_{os} R_2$ #