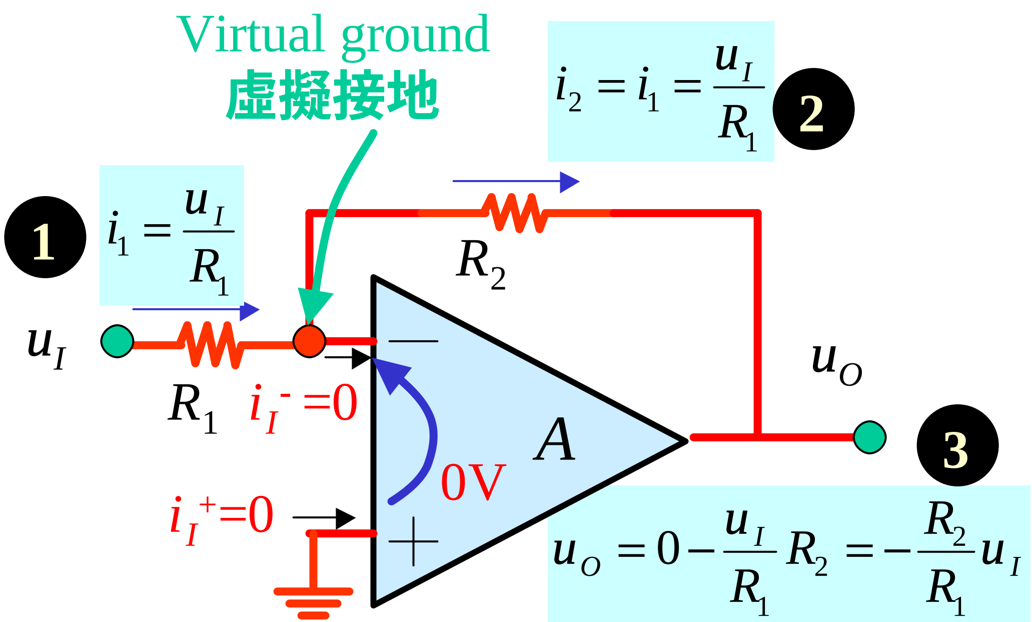
簡易運算放大器電路

反相放大器（inverting amplifier)

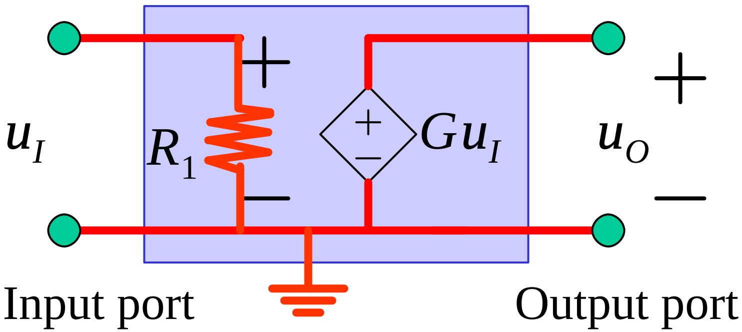


$$G = \frac{u_O}{u_I} = -\frac{R_2}{R_1}$$

輸入阻抗 $R_i = \frac{u_I}{i_1} = R_1$

輸出阻抗 $R_0 = 0$

等效電路可畫為

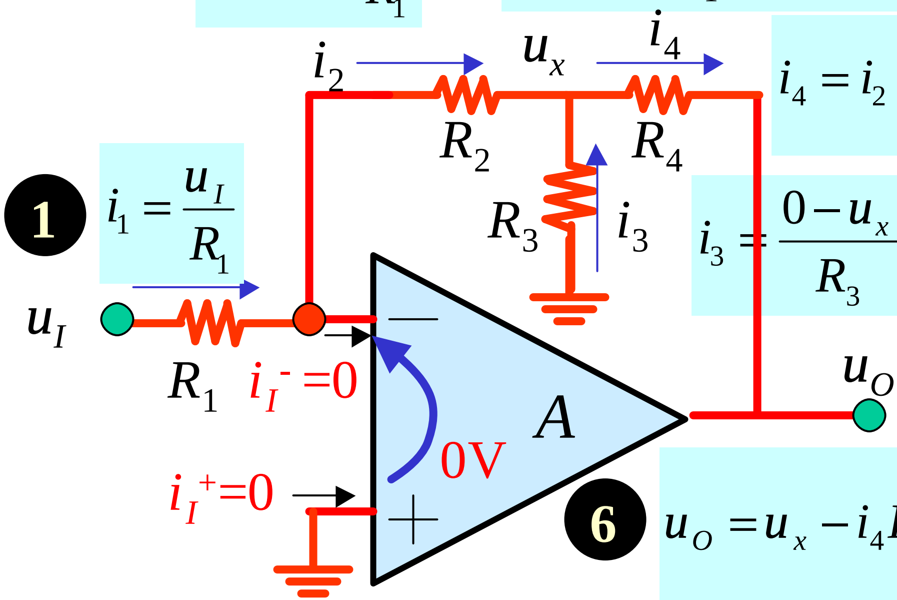


考慮finite open-loop gain A

$$G = \frac{u_O}{u_I} = -\frac{R_2 / R_1}{1 + (1 + R_2 / R_1) / A}$$

（自行練習）

用T型回授網路的反相放大器（inverting amplifier with a T-network)



1 $$i_1 = \frac{u_I}{R_1}$$

2 $$i_2 = i_1 = \frac{u_I}{R_1}$$

3 $$u_x = 0 - \frac{u_I}{R_1} R_2 = -\frac{R_2}{R_1} u_I$$

4 $$i_3 = \frac{0 - u_x}{R_3} = \frac{R_2}{R_1 R_3} u_I$$

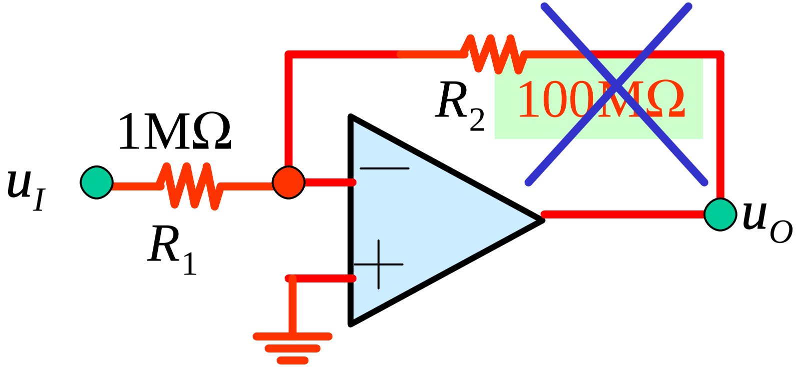
5 $$i_4 = i_2 + i_3 = \frac{u_I}{R_1} + \frac{R_2}{R_1 R_3} u_I$$

6 $$u_O = u_x - i_4 R_4 = -\frac{R_2}{R_1} u_I - \left(\frac{u_I}{R_1} + \frac{R_2}{R_1 R_3} u_I \right) R_4$$

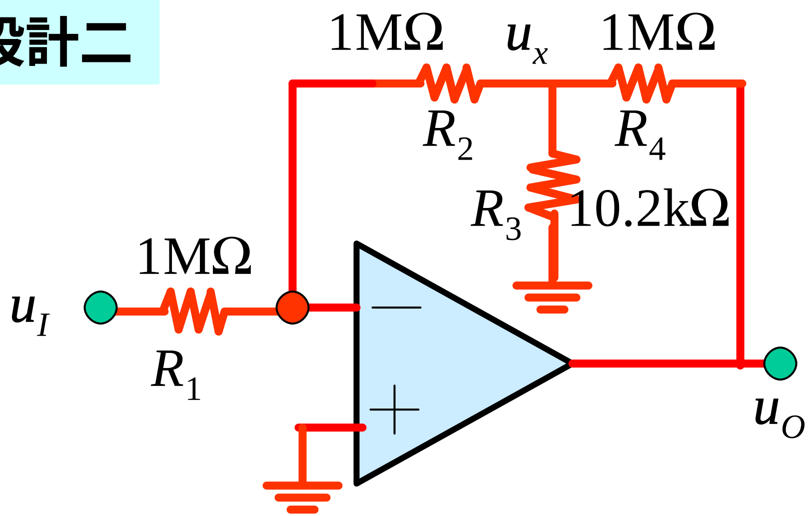
$$G = \frac{u_O}{u_I} = -\frac{R_2}{R_1} - \frac{R_4}{R_1}\left(1 + \frac{R_2}{R_3}\right) = -\frac{R_2}{R_1}\left(1 + \frac{R_4}{R_2} + \frac{R_4}{R_3}\right)$$

例題 利用運算放大器設計一個反相放大器，輸入阻抗1MΩ，增益100，但電路中不得使用大於1MΩ的電阻。

設計一



設計二



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

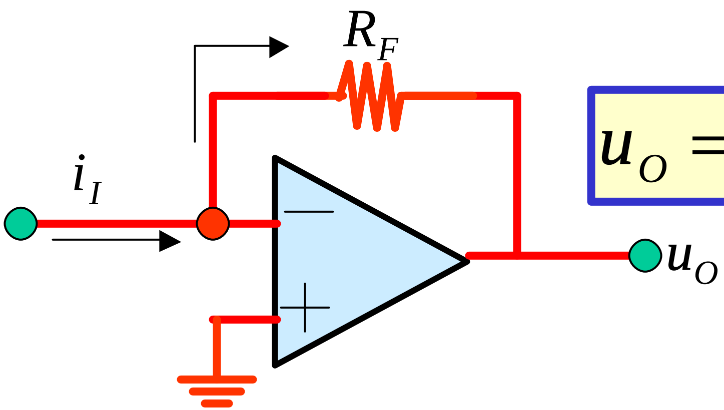
98

1 1

100

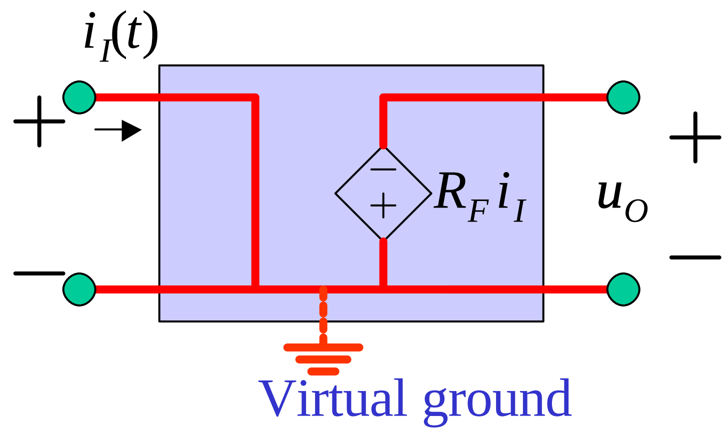
R_3 =1MΩ/98=10.2kΩ

Current-to-Voltage Converter (CCVS)

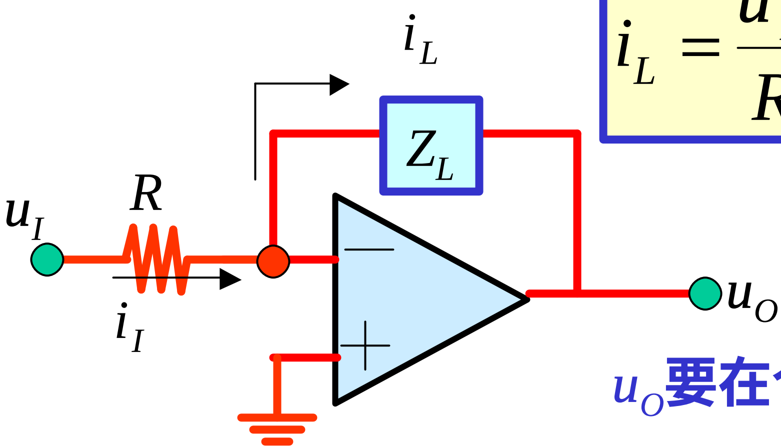


$$u_O = -R_F i_I$$

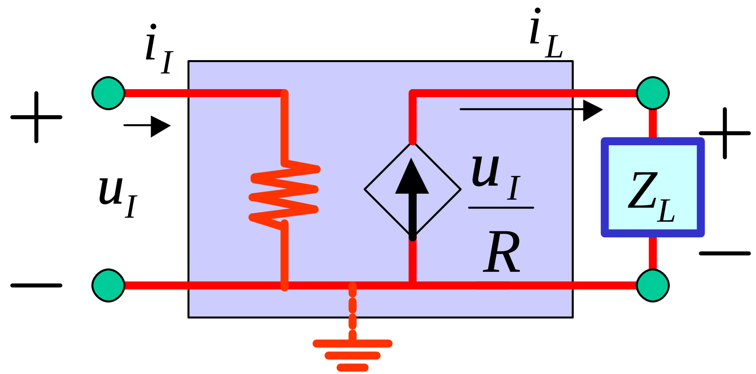
Transresistance Amplifier



Voltage-to-Current Converter (VCCS)

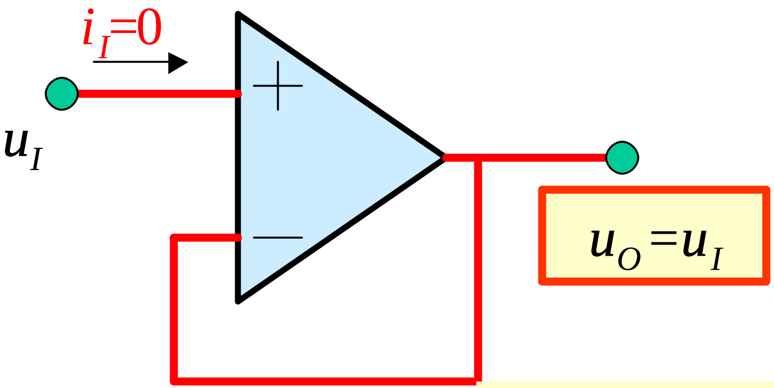


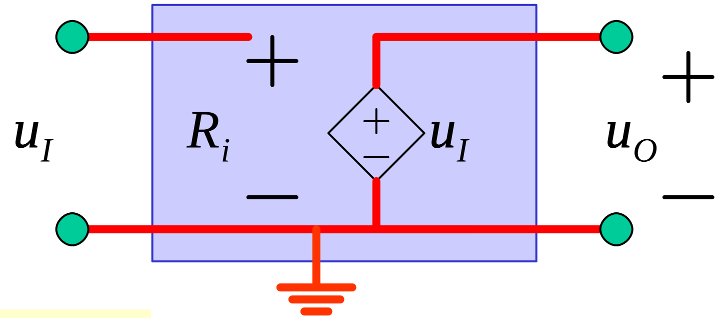
$$i_L = \frac{u_I}{R}$$



u_O要在合理範圍

Voltage Follower (Buffer) 耦隨器（緩衝器）





$G=1$、 $R_i \to \infty$、 $R_o \to 0$

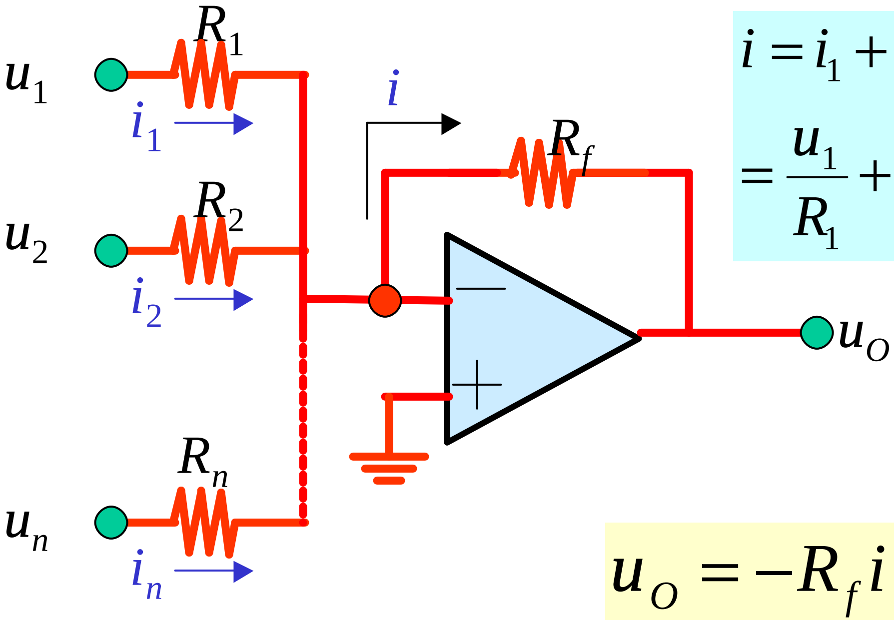
用途：

1.**改善負載效應**
2.**快速，寬頻**
3.**通常可提供大電流給負載**
4.**特別適用於高輸出阻抗的訊號源**

注意事項：
不是每一種運算放大器都可接成緩衝器。有些會產生高頻振盪，這是由於高頻時，開路增益的相位達180º，且增益大小大於1，形成正回授。

Weighted Summer (加權加法器)

Summing amplifier



$$i = i_1 + i_2 + \cdots + i_n = \frac{u_1}{R_1} + \frac{u_2}{R_2} + \cdots + \frac{u_n}{R_n}$$

$$u_O = -R_f i = -R_f\left(\frac{u_1}{R_1} + \frac{u_2}{R_2} + \cdots + \frac{u_n}{R_n}\right) = -\left(\frac{R_f}{R_1}u_1 + \frac{R_f}{R_2}u_2 + \cdots + \frac{R_f}{R_n}u_n\right)$$

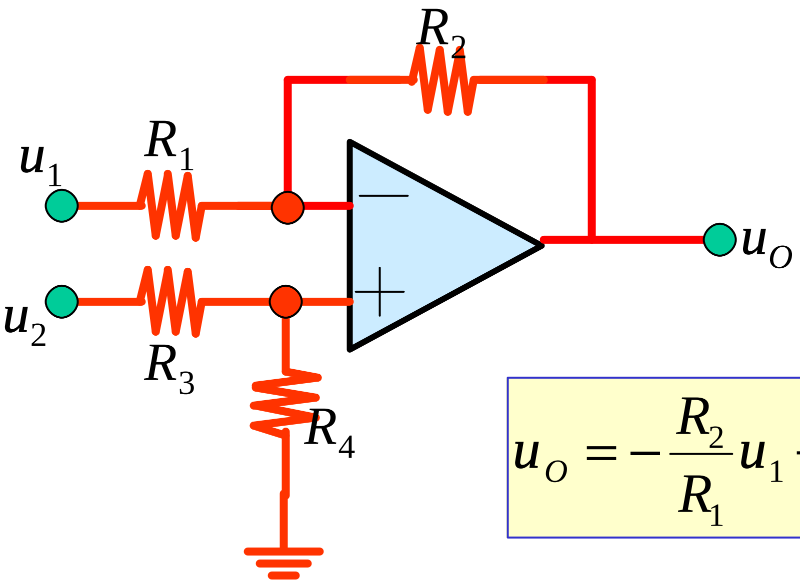
差動放大器（difference amplifier）

差動放大器有兩個輸入訊號，利用線性疊加法：

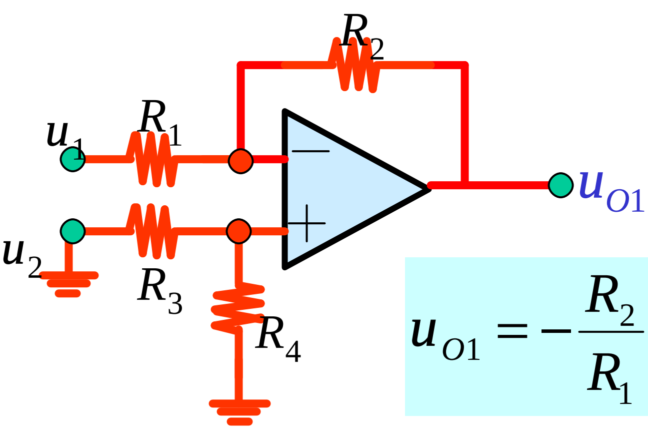
先令 $u_2=0$，得輸出 u_{O1}

再令 $u_1=0$，得輸出 u_{O2}

然後 $u_O=u_{O1}+u_{O2}$

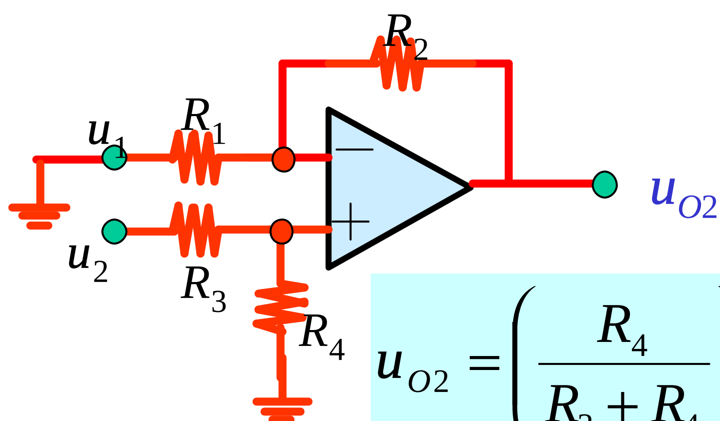


$$u_O=-\frac{R_2}{R_1}u_1+\frac{1+R_2/R_1}{1+R_3/R_4}u_2$$



$$u_{O1}=-\frac{R_2}{R_1}u_1$$

$$R_{in1}=R_1$$



$$u_{O2}=\left(\frac{R_4}{R_3+R_4}\right)\left(1+\frac{R_2}{R_1}\right)u_2$$

$$R_{in2}=R_3+R_4$$

$$u_O = -\frac{R_2}{R_1}u_1 + \frac{1+R_2/R_1}{1+R_3/R_4}u_2$$

我們希望輸入只有共模訊號u_{CM}，無差模訊號u_d時，輸出愈小愈好。

令$u_1 = u_2 = u_{CM}$

$$u_O = \left(-\frac{R_2}{R_1} + \frac{1+R_2/R_1}{1+R_3/R_4}\right)u_{CM} \to 0$$

共模增益為0

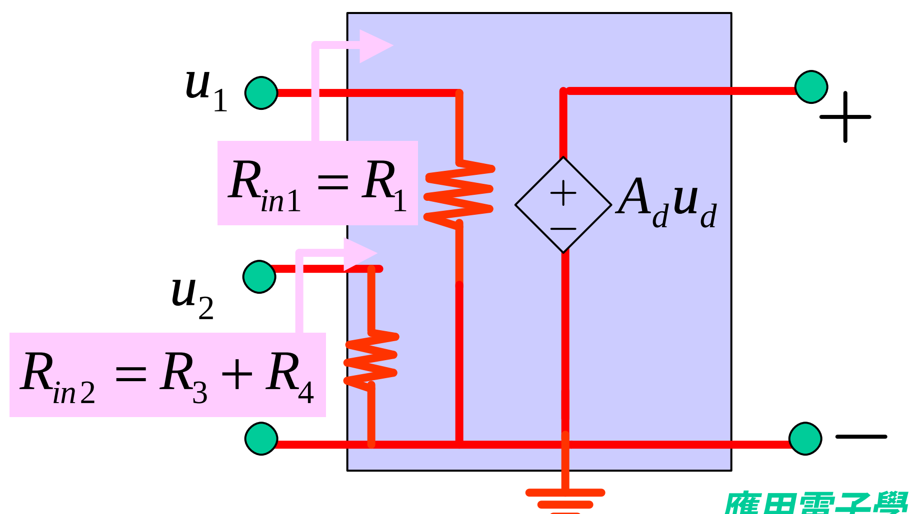
CMRR→∞

$$\Rightarrow \frac{R_2}{R_1} = \frac{R_4}{R_3}$$

一般選擇$R_1=R_3$**，**$R_2=R_4$

$$\Rightarrow u_O = -\frac{R_2}{R_1}u_1 + \frac{1+R_2/R_1}{1+R_1/R_2}u_2$$

$$u_O = \frac{R_2}{R_1}(u_2 - u_1)$$

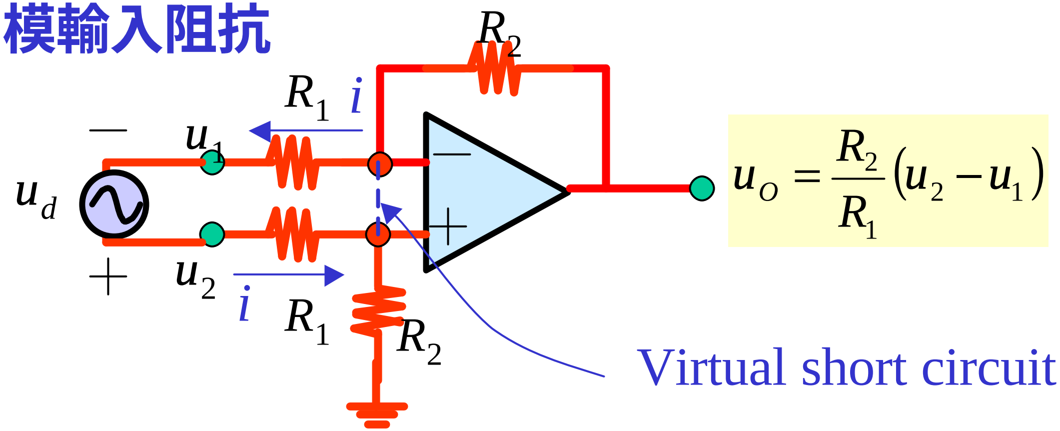


適當的選擇電阻後，

$A_c=0$，$A_d= R_2/R_1$

差模與共模的輸入阻抗

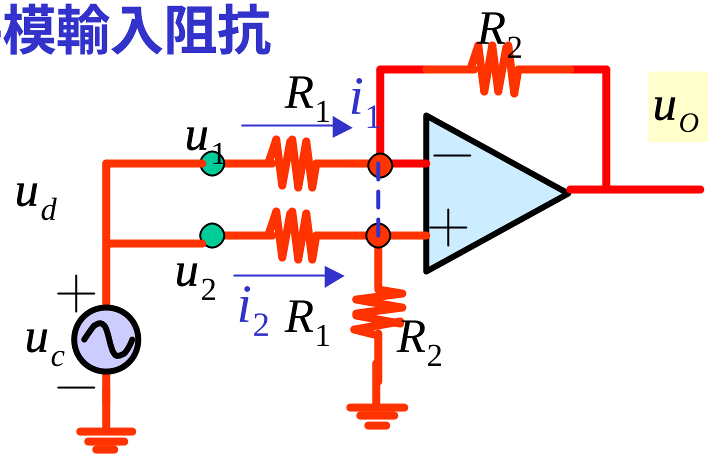
差模輸入阻抗



$$u_O = \frac{R_2}{R_1}(u_2 - u_1)$$

$$R_d = \frac{u_d}{i} = 2R_1$$

共模輸入阻抗



$$u_O = 0$$

$$R_c = \frac{u_c}{i_1 + i_2} = \frac{R_1 + R_2}{2}$$

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

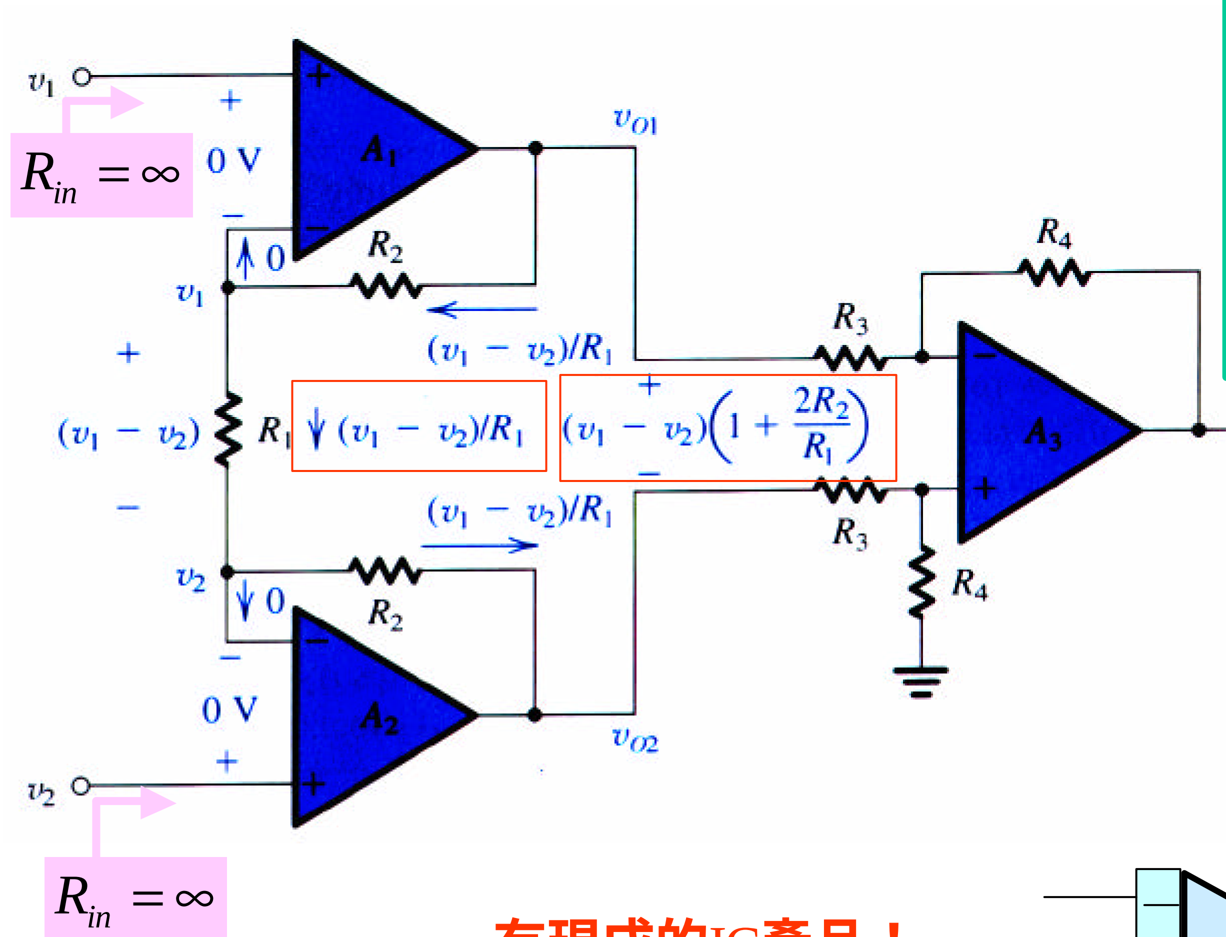
此差動放大器的缺點：

1.**增益不容易調整**

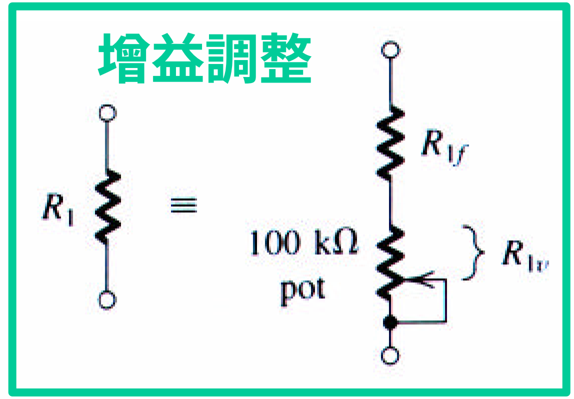
2.**輸入阻抗小**

3.**正負輸入端不對稱**

儀器放大器（instrumentation amplifier)



$$v_O = -\frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)(v_1 - v_2)$$



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