



高中職學生參與衛星科學任務

IVM 量測電路與實習

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2017-07-02



大綱

- 基礎電路概論
- 運算放大器
- 阻滯電位分析儀



基礎電路概論



準確度、精密度

- 準確度: 平均值與理論的差距
- 精密度: 各實驗量測結果與其平均值的差距
- 量測儀器需同時具備高準確度與高精密度



電壓、直流電壓源

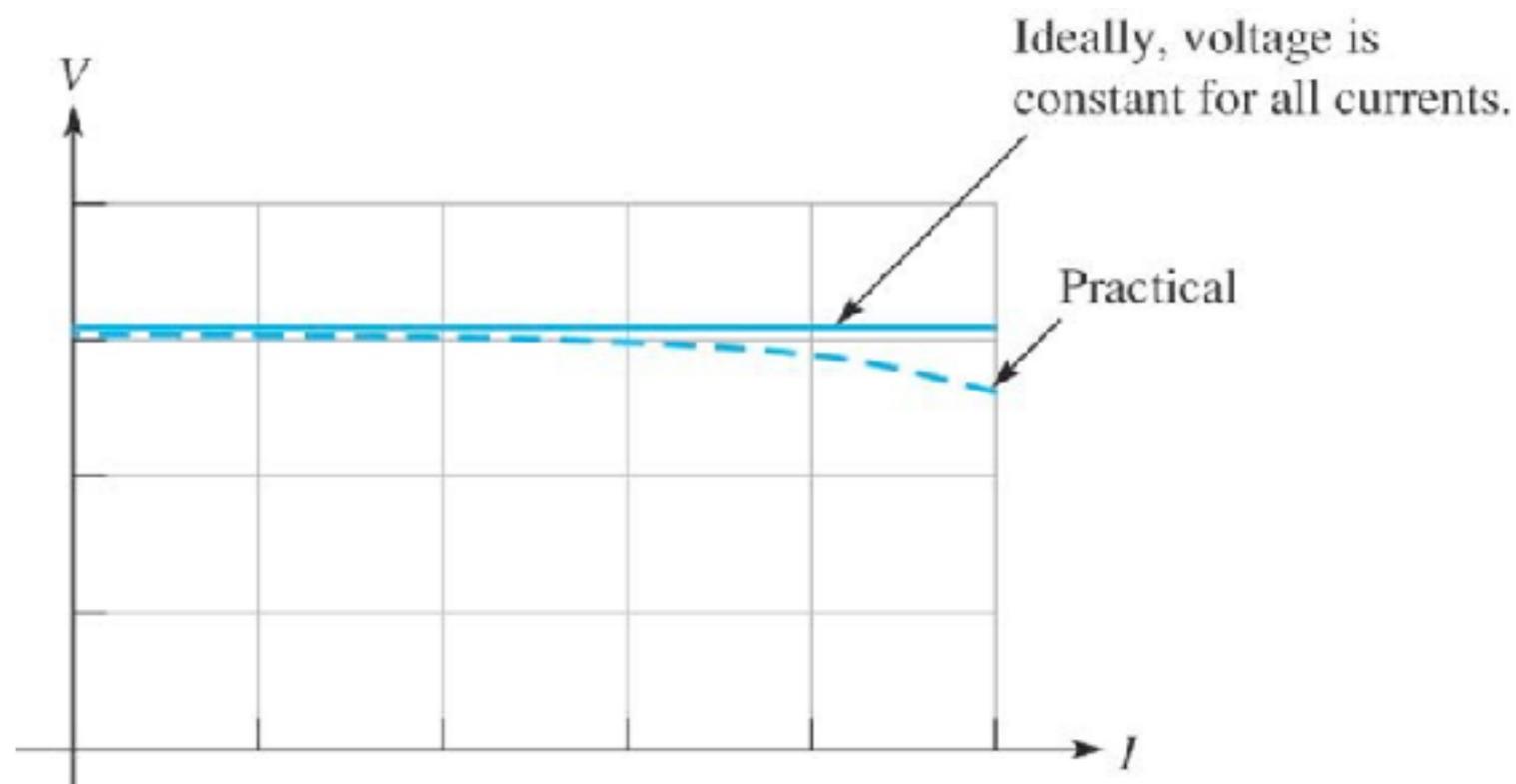
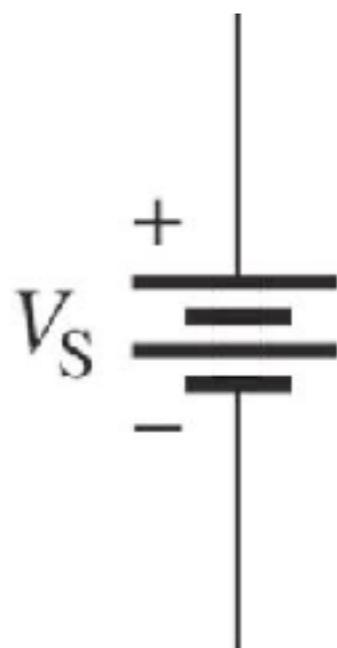
- 對一庫倫的電荷做一焦耳的功等於一伏特

$$V = \frac{W}{q}$$

- 直流電壓源:



Agilent triple output power supply





電流、直流電流源

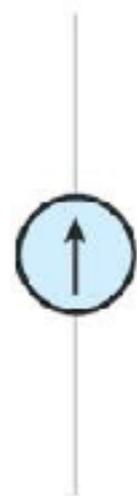
- 每秒通過一庫倫的電荷等於一安培

$$I = \frac{Q}{t}$$

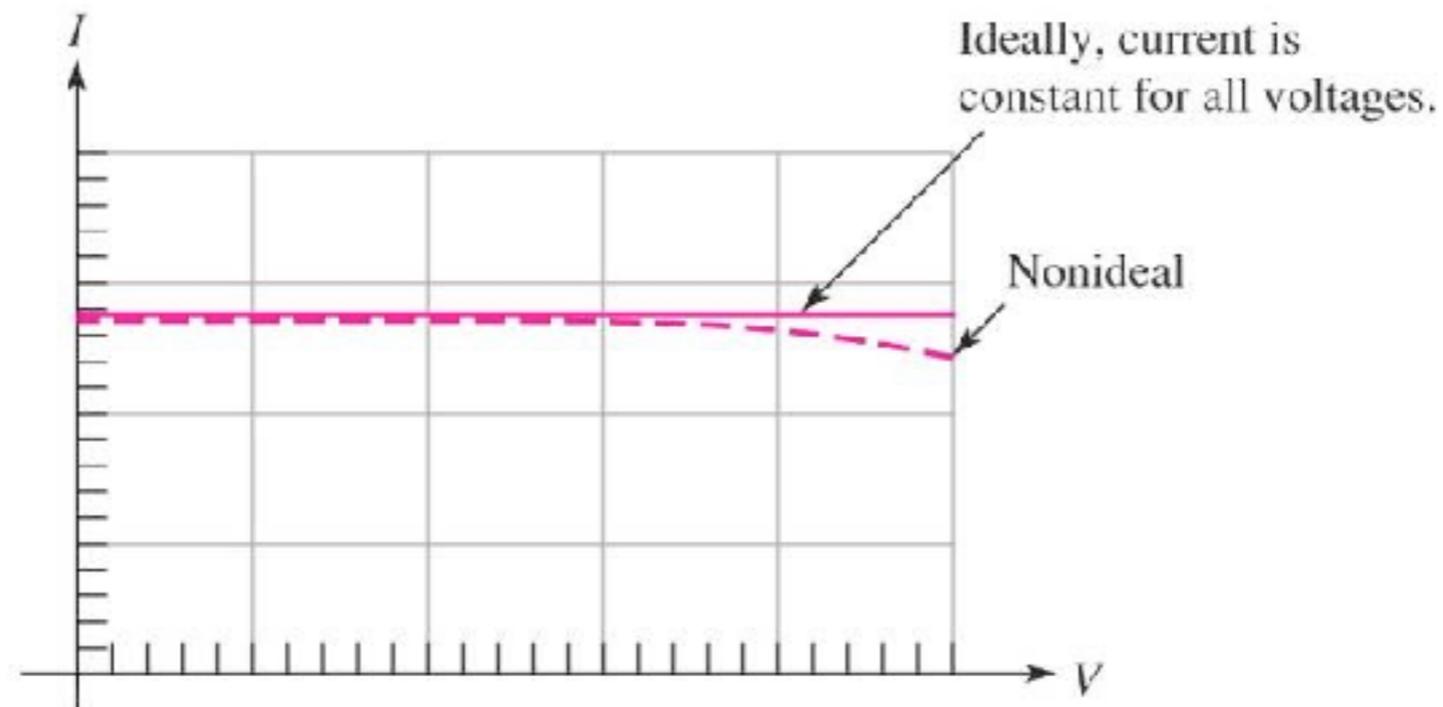
- 直流電流源:



Keithley micro current source



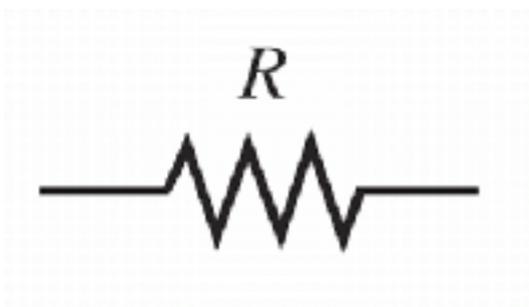
(a) Symbol



(b) *IV* characteristic



電阻的符號以及種類



(a) Carbon-composition



(b) Metal film chip resistor



(c) Chip resistor array



(d) Resistor network (simm)



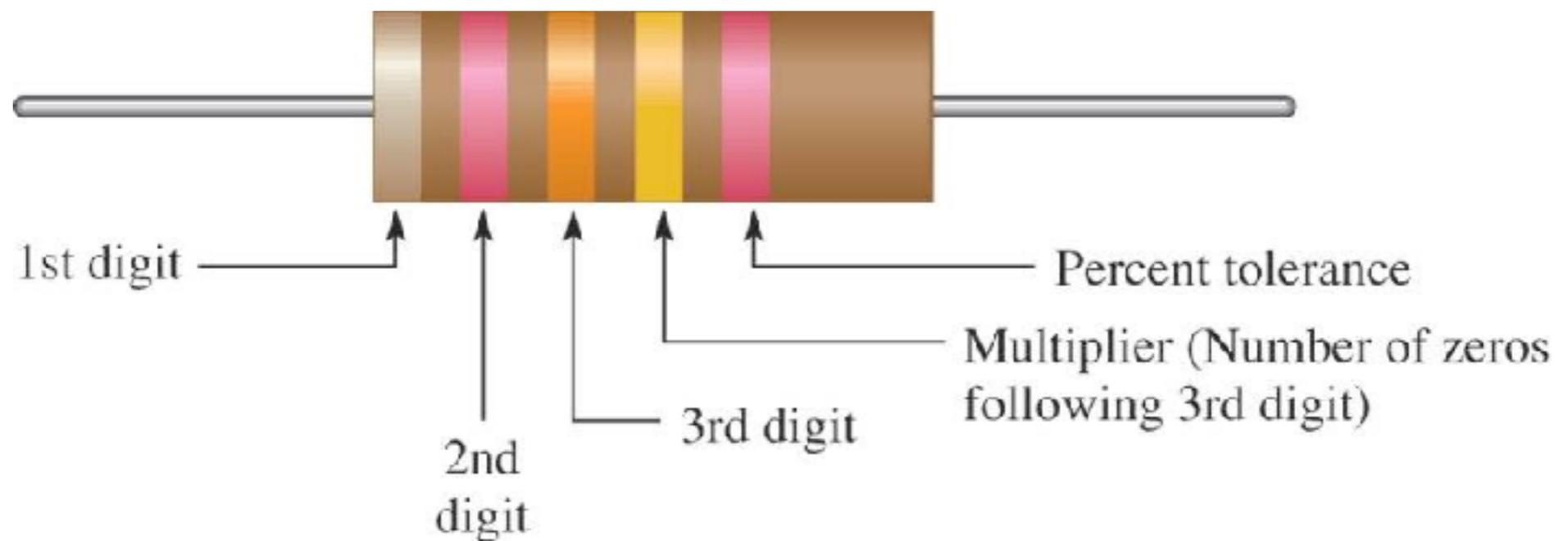
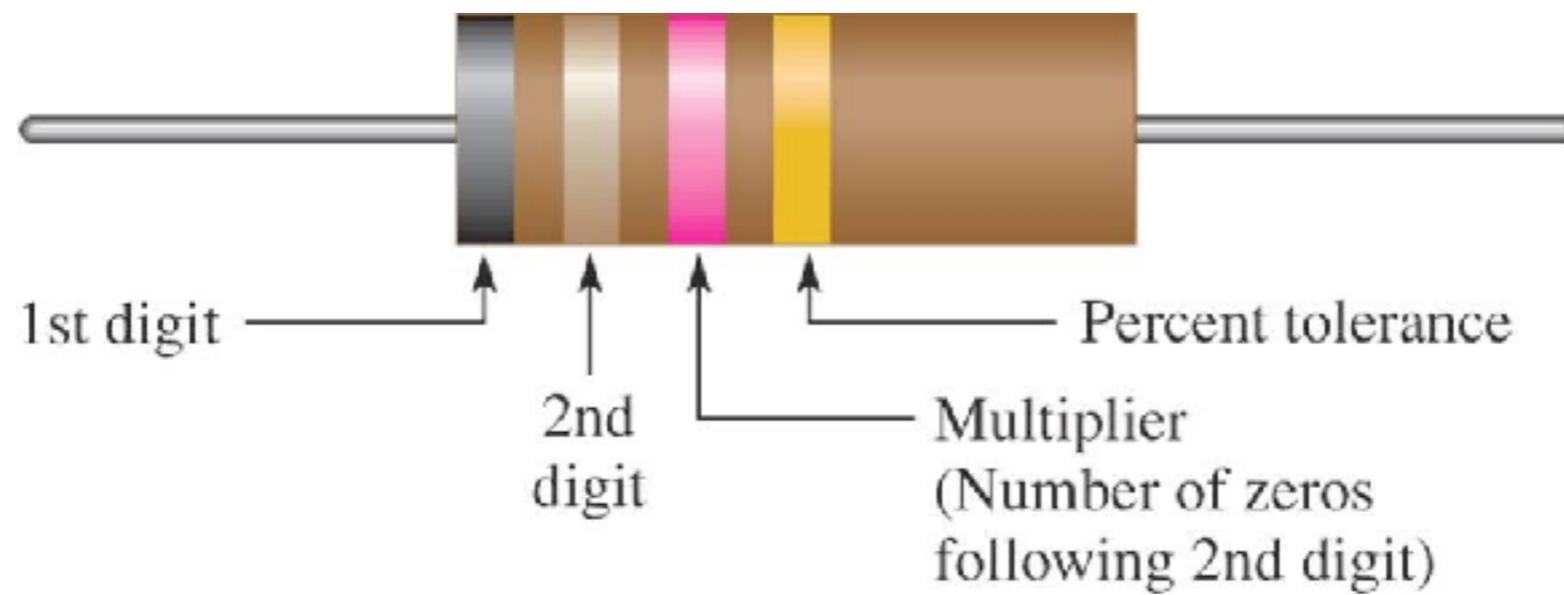
(e) Resistor network (surface mount)



(f) Radial-lead for PC board insertion



電阻值色條表示方法



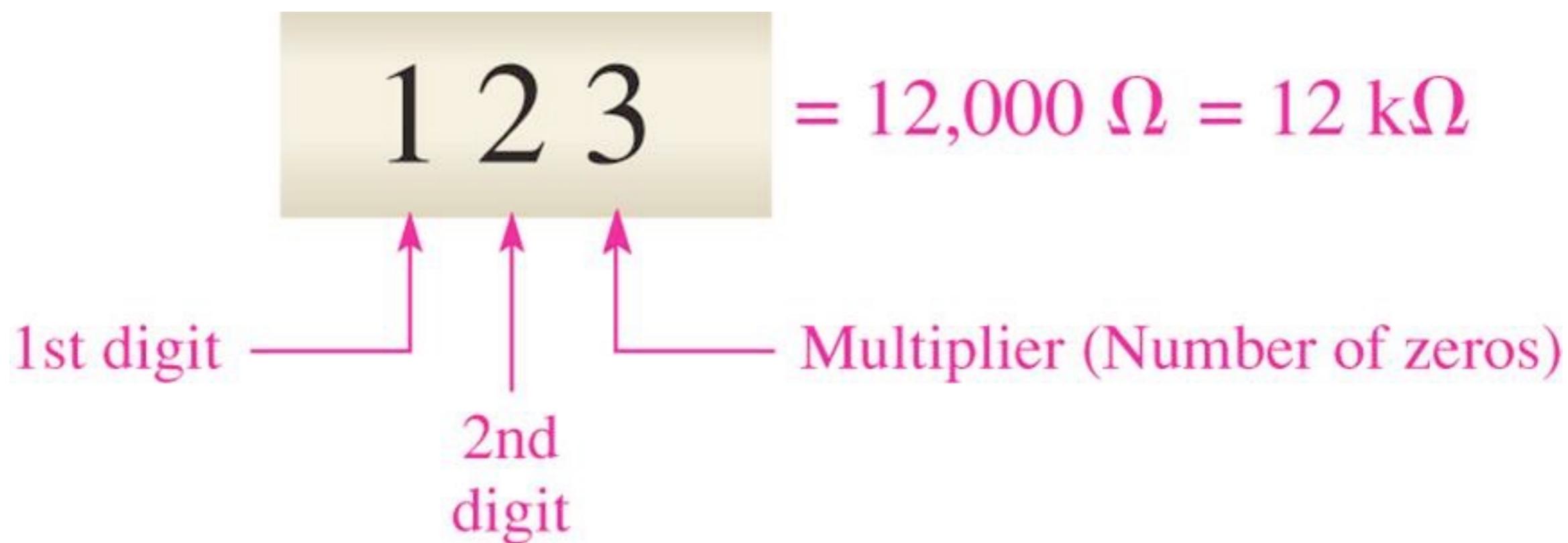


電阻值色條表示方法

	Color	Digit	Multiplier	Tolerance
	Black	0	10^0	
	Brown	1	10^1	1% (five band)
	Red	2	10^2	2% (five band)
	Orange	3	10^3	
	Yellow	4	10^4	
	Green	5	10^5	
	Blue	6	10^6	
	Violet	7	10^7	
	Gray	8	10^8	
	White	9	10^9	
	Gold	$\pm 5\%$	10^{-1}	5% (four band)
	Silver	$\pm 10\%$	10^{-2}	10% (four band)
	No band	$\pm 20\%$		

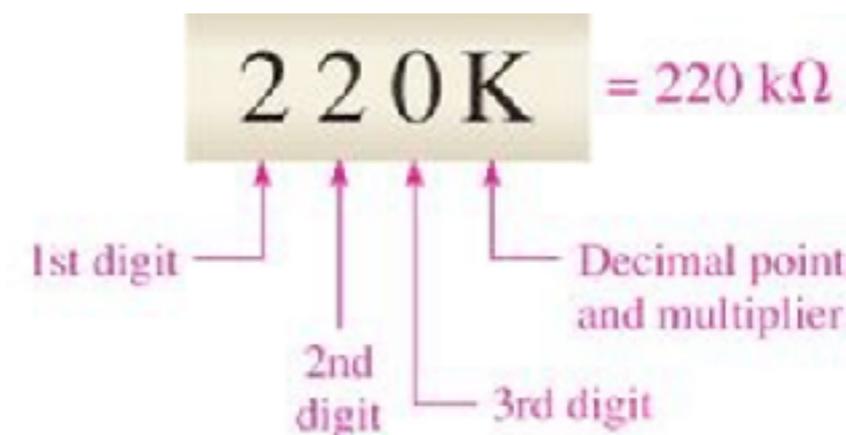
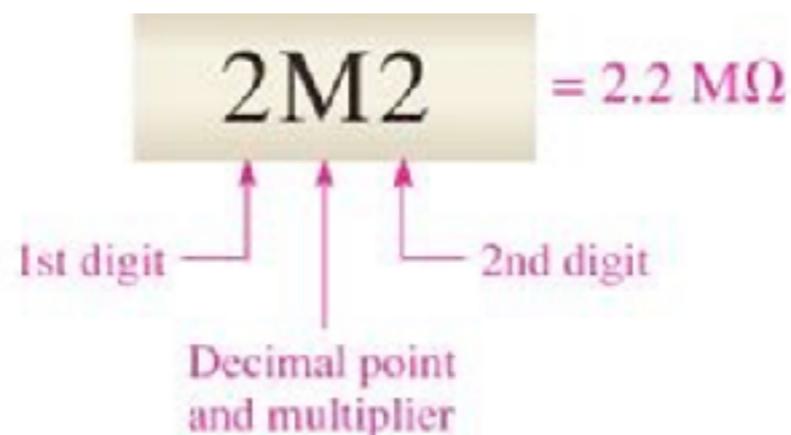
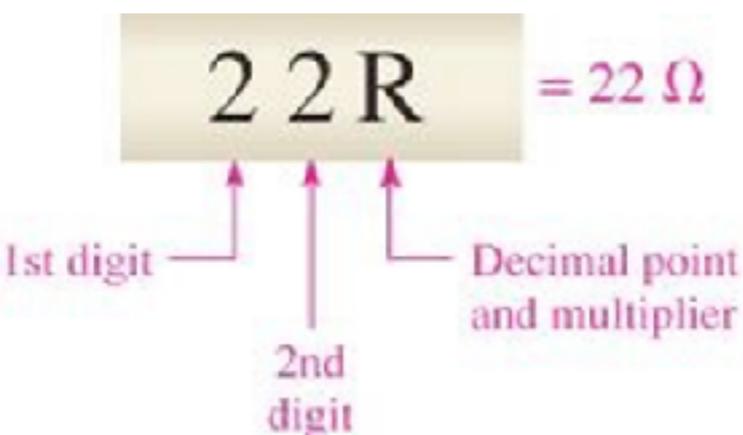


電阻值表示方法





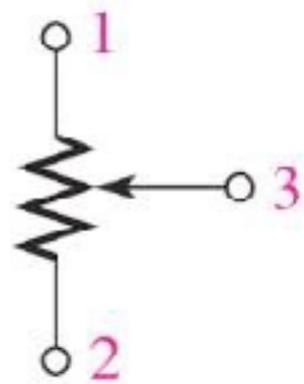
電阻值表示方法



Letter	Multiplier	Letter	Tolerance
R	x 1	F	$\pm 1\%$
K	x 10^3	G	$\pm 2\%$
M	x 10^6	J	$\pm 5\%$



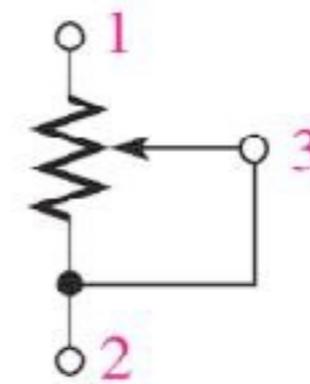
可變電阻的符號以及種類



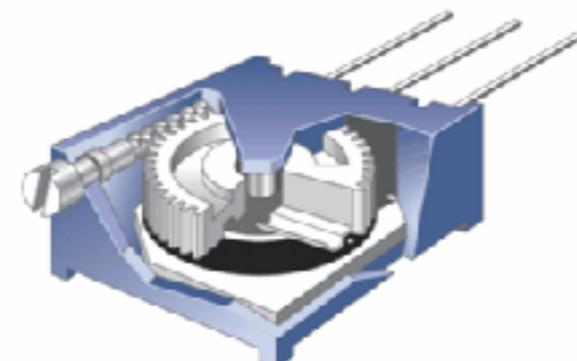
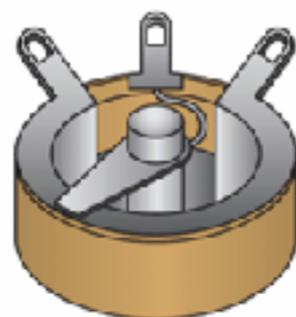
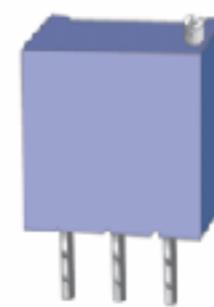
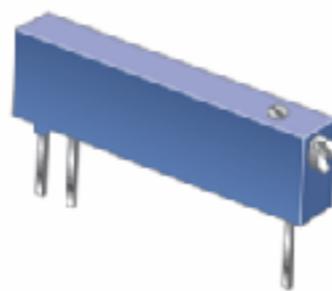
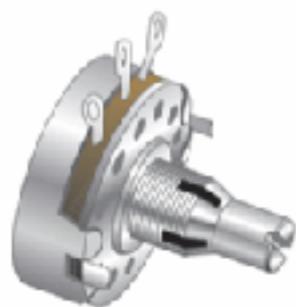
(a) Potentiometer



(b) Rheostat



(c) Potentiometer connected as a rheostat





三用電表



(a) Digital multimeter

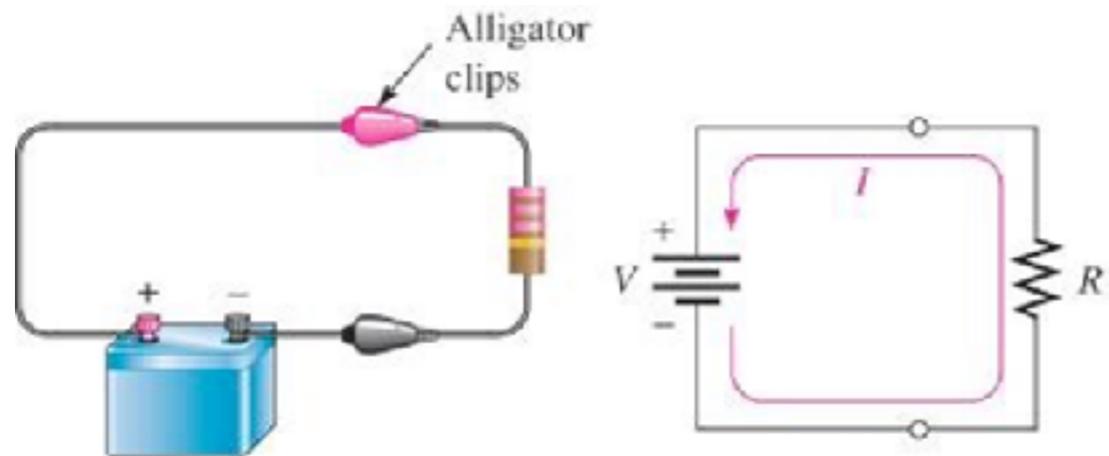


(b) Analog multimeter

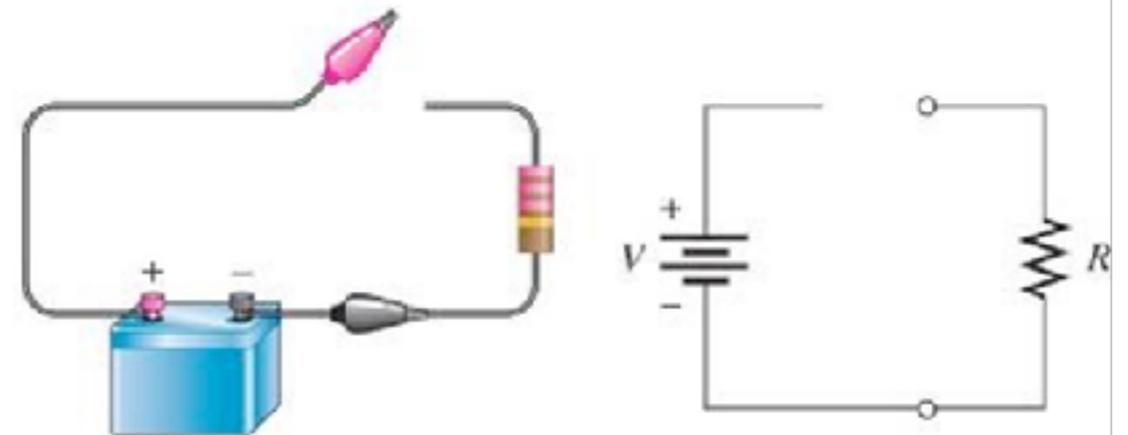
三用電表哪三用？
量電壓、量電流、以及量電阻



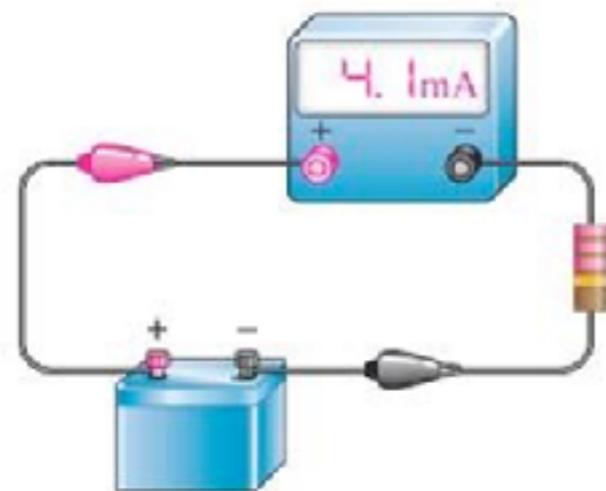
量測電流的方式



(a) Circuit in which the current is to be measured



(b) Open the circuit either between the resistor and the positive terminal or between the resistor and the negative terminal of source.

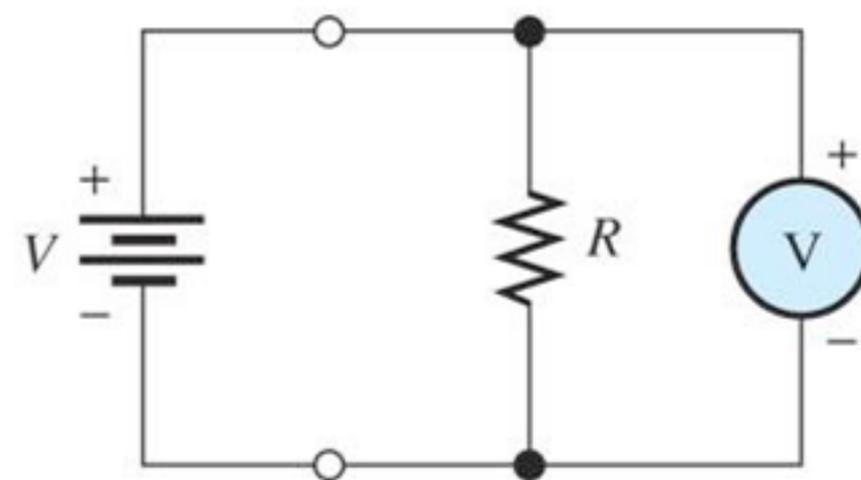
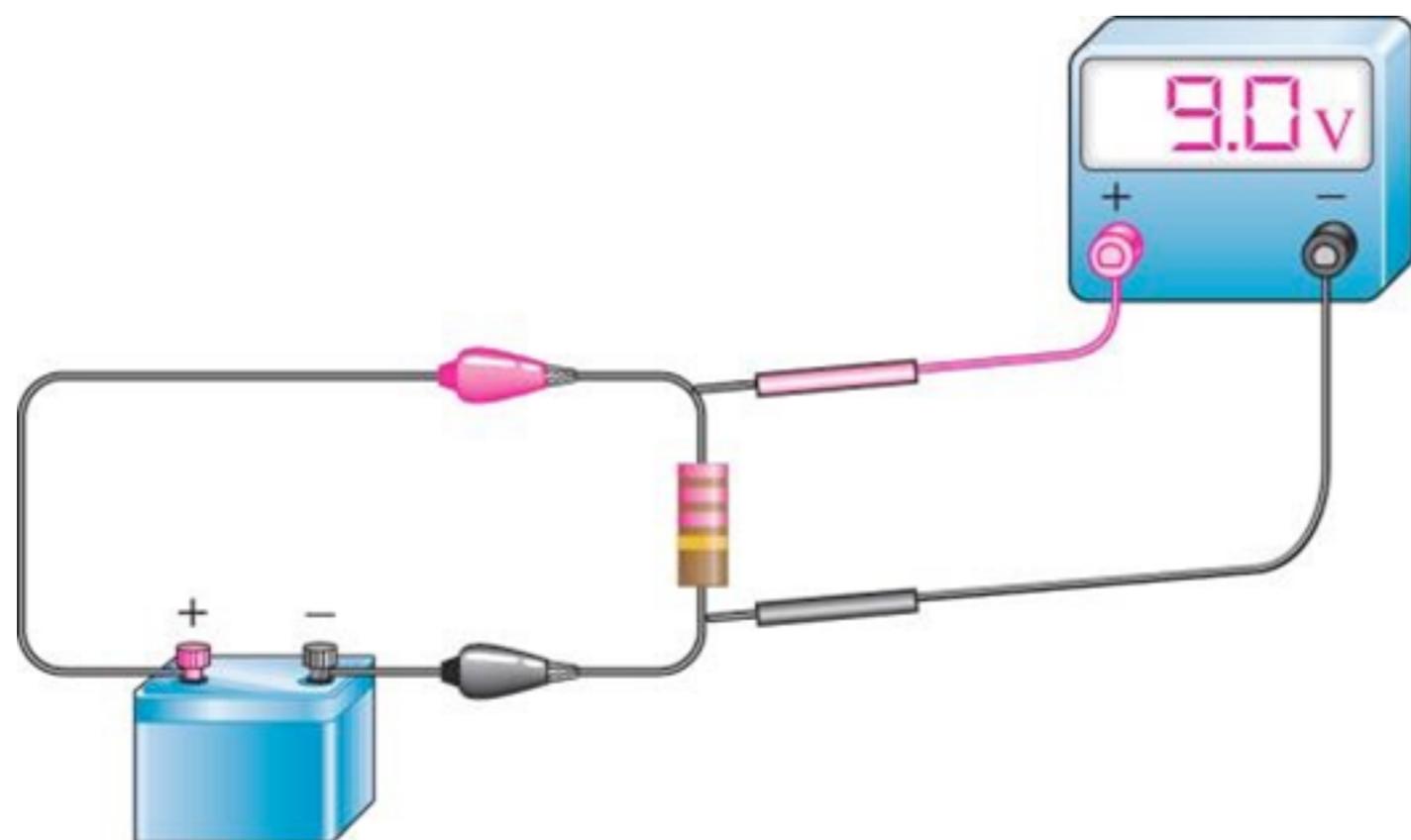


(c) Install the ammeter in the current path with polarity as shown (negative to negative, positive to positive).

串聯整個迴路



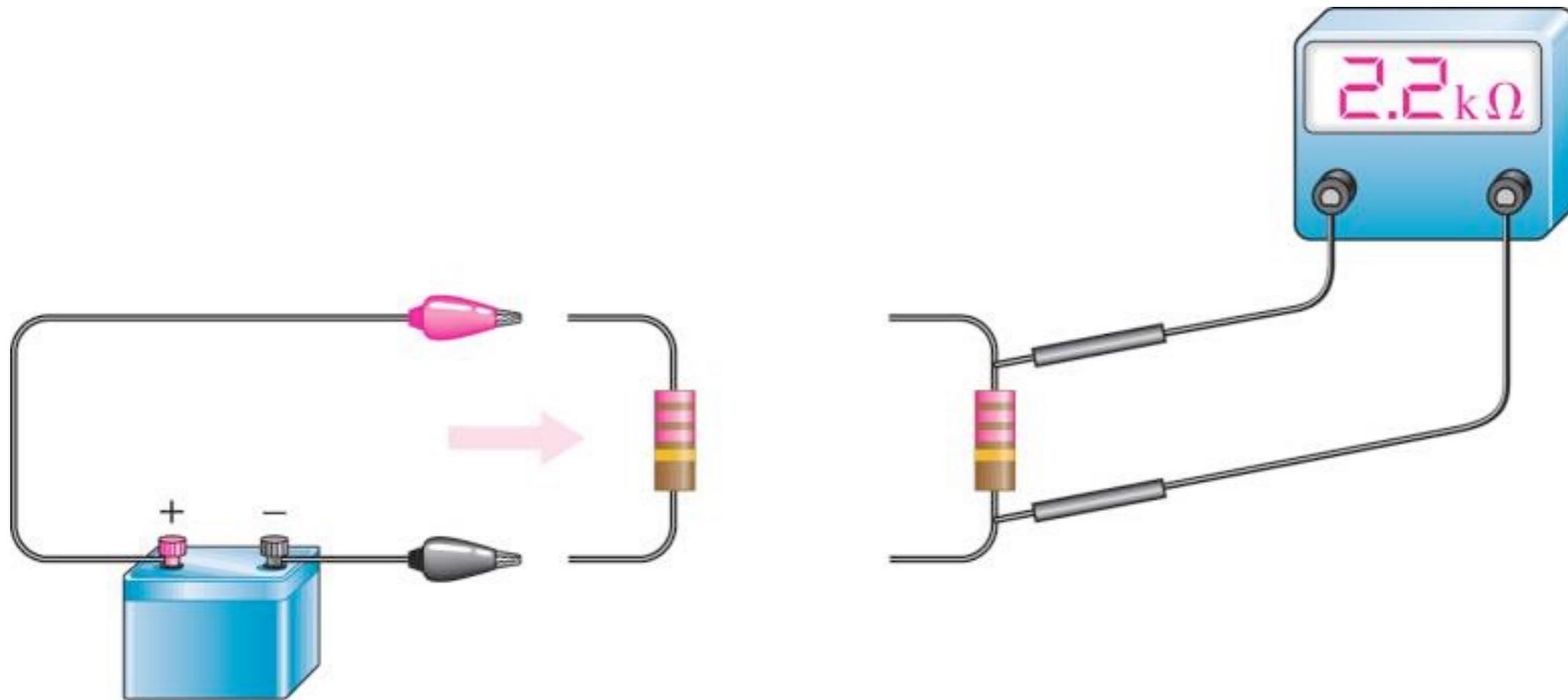
量測電壓之方式



並聯待測源



量測電阻值的方法



(a) Disconnect the resistor from the circuit to avoid damage to the meter and/or incorrect measurement.

(b) Measure the resistance.
(Polarity is not important.)

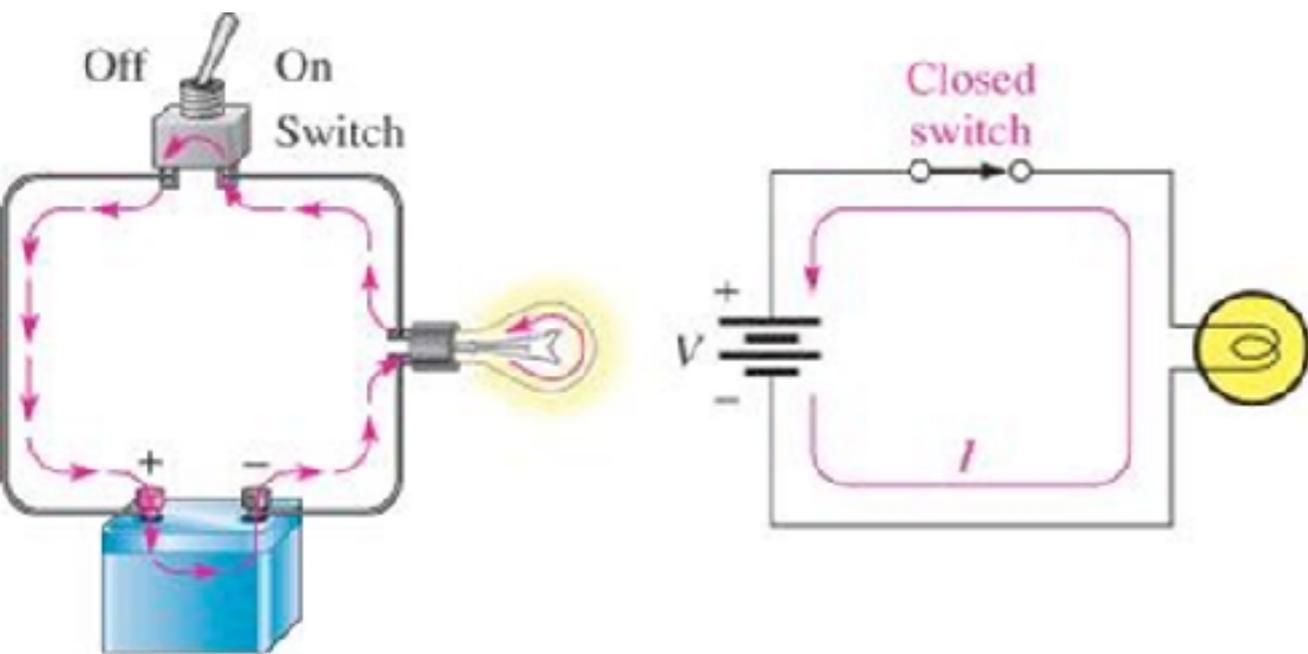
並聯待測電阻



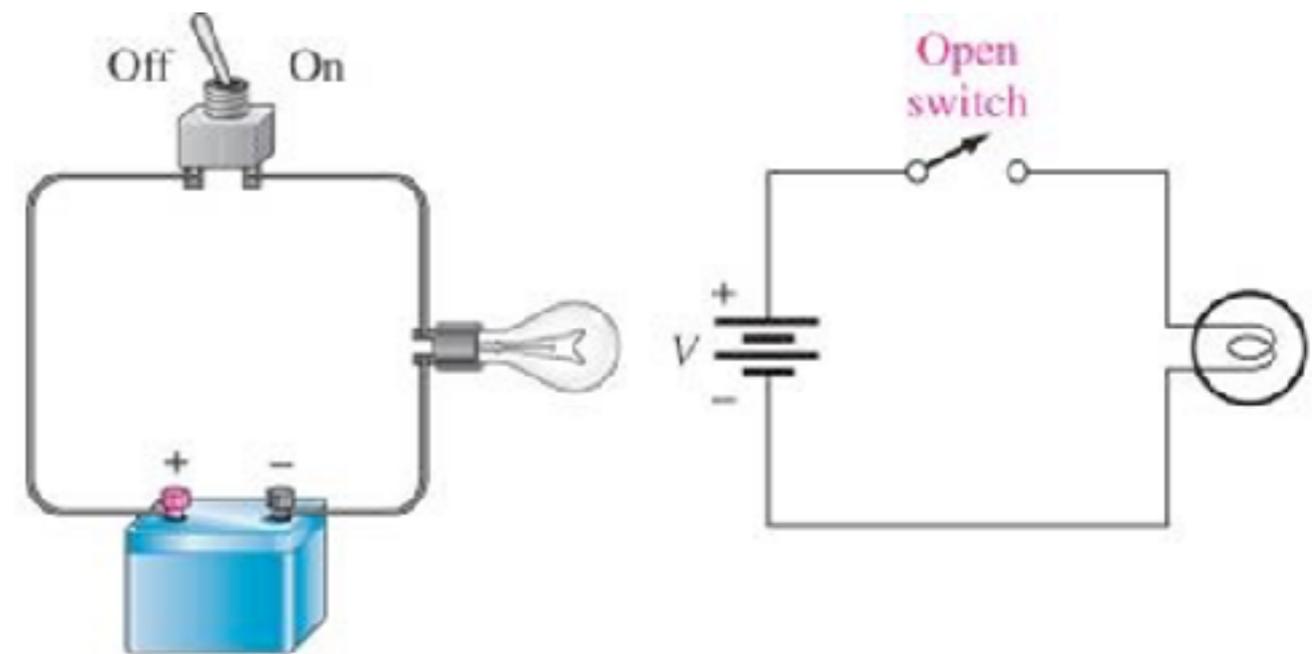
短路電路以及開路電路

短路：電阻無限小

開路：電阻無限大



(a) There is current in a *closed* circuit because there is a complete current path (switch is ON or in the *closed* position). Current is always indicated by a red arrow in this text.



(b) There is no current in an *open* circuit because the path is broken (switch is OFF or in the *open* position).



接地符號



(a)



(b)

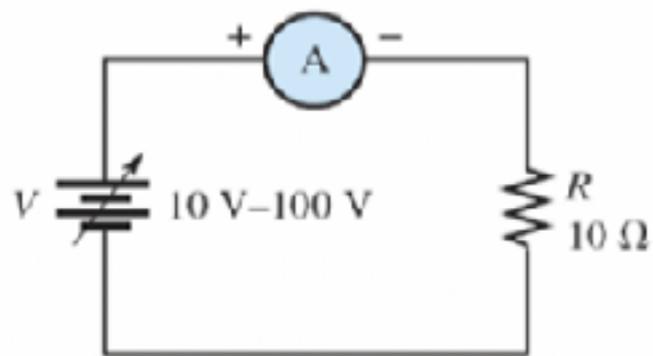


(c)

3 種接地的符號，我們定義**接地**就代表該節點電壓為 **0** 伏特



歐姆定律

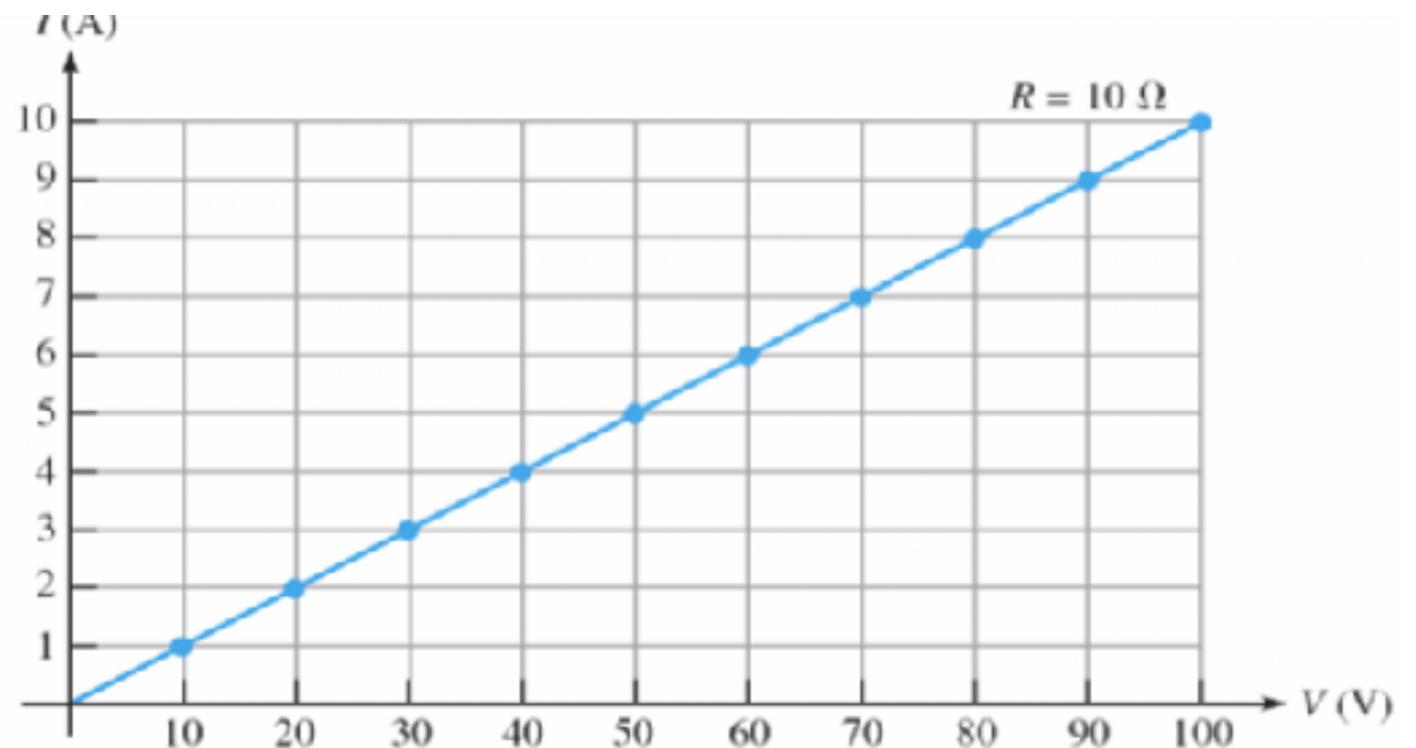


(a)

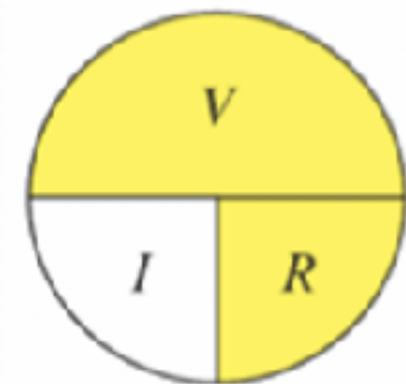
V	I
10 V	1 A
20 V	2 A
30 V	3 A
40 V	4 A
50 V	5 A
60 V	6 A
70 V	7 A
80 V	8 A
90 V	9 A
100 V	10 A

$$I = \frac{V}{10 \Omega}$$

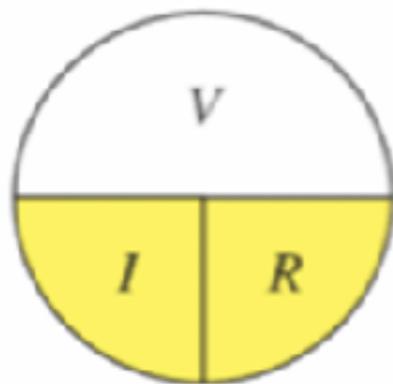
(b)



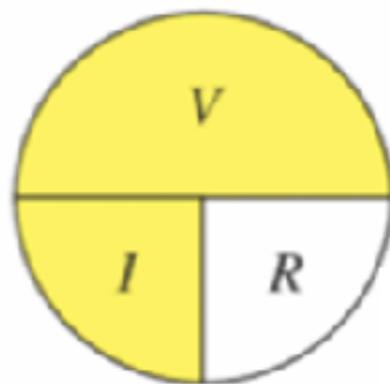
(c)



$$I = \frac{V}{R}$$



$$V = IR$$

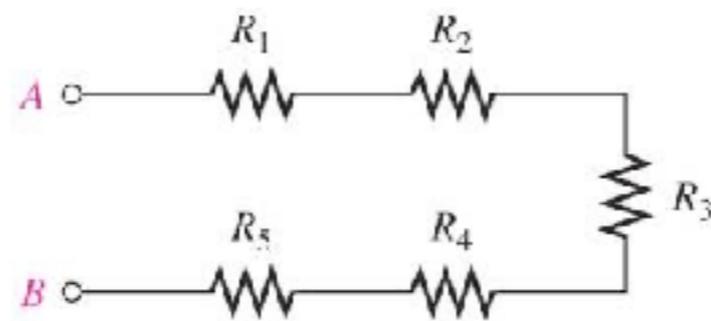
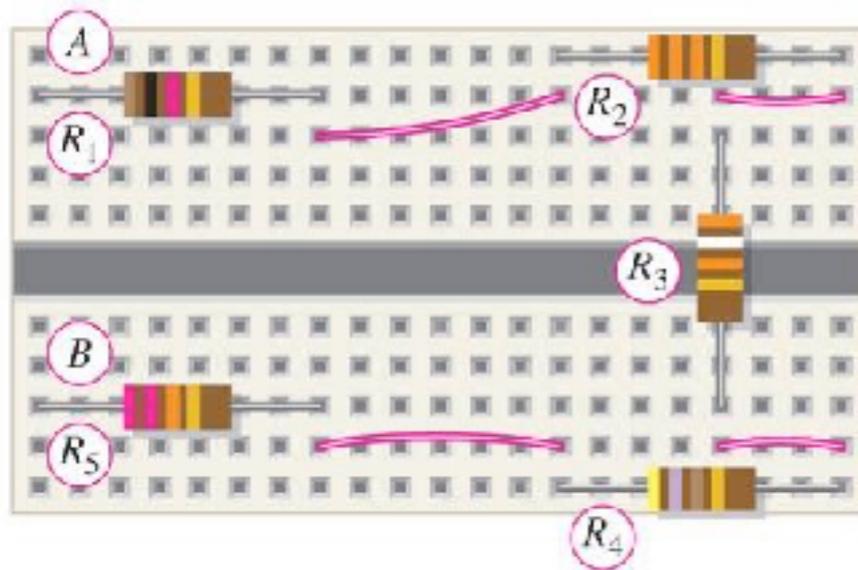
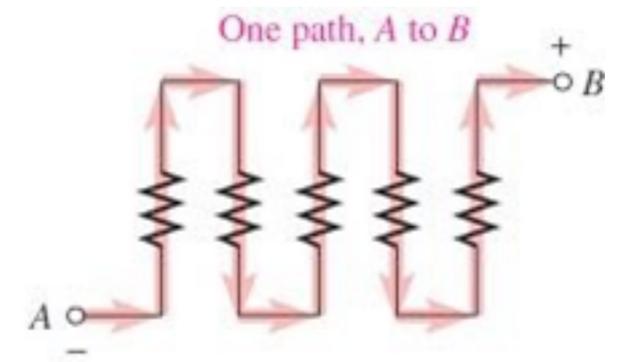
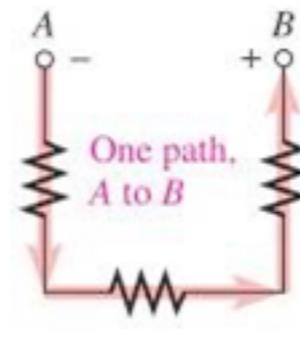
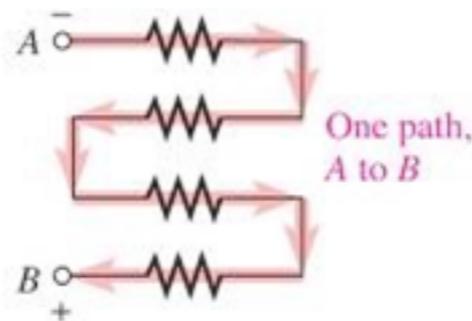
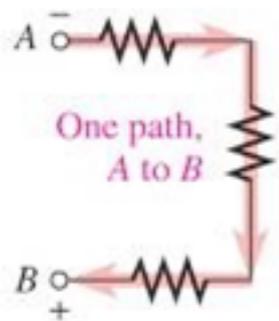
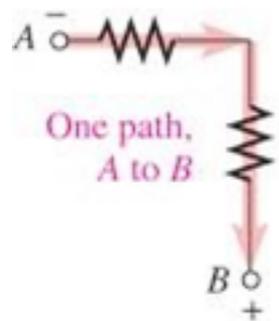
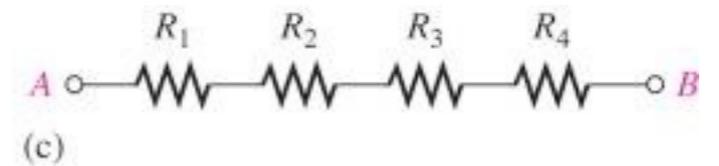
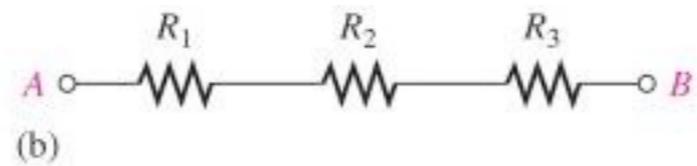


$$R = \frac{V}{I}$$

電阻值固定，流過電阻兩端的電流與施加於電阻兩端的電壓呈正比，此為歐姆定律。



電阻串聯



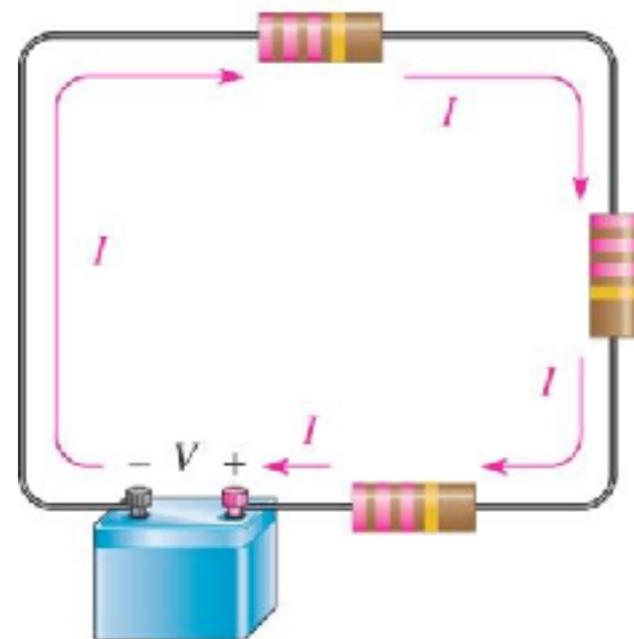
(a) Assembly diagram

(b) Schematic

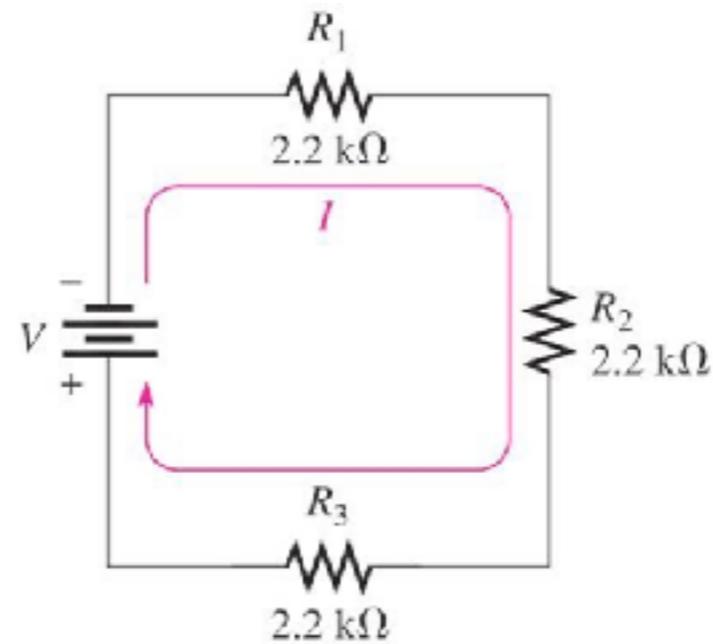
電阻串聯，總電阻值為各電阻值之和 $R_T = R_1 + R_2 + R_3 + \dots + R_n$



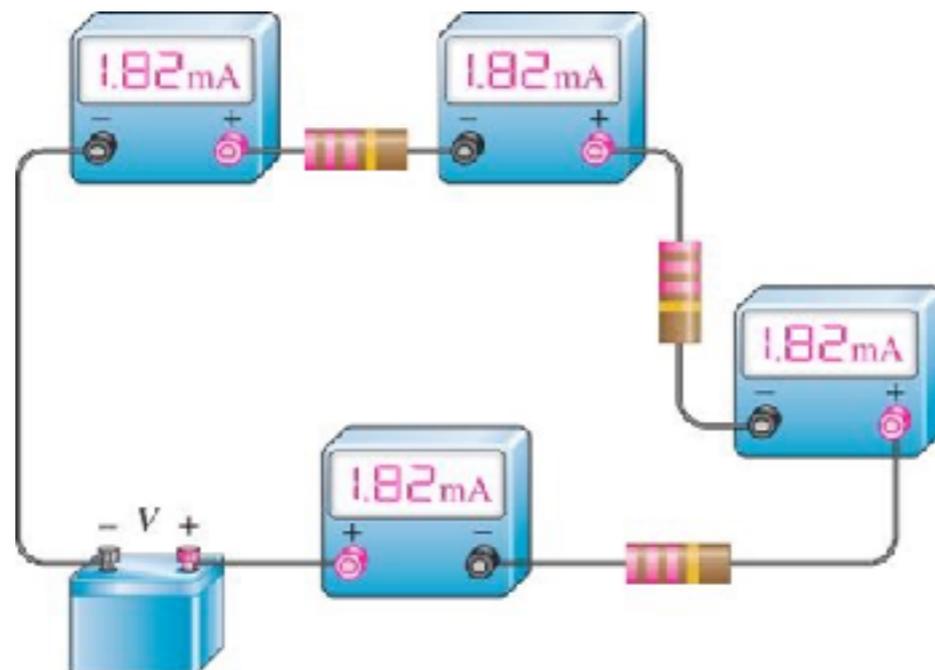
串聯電路電流相等



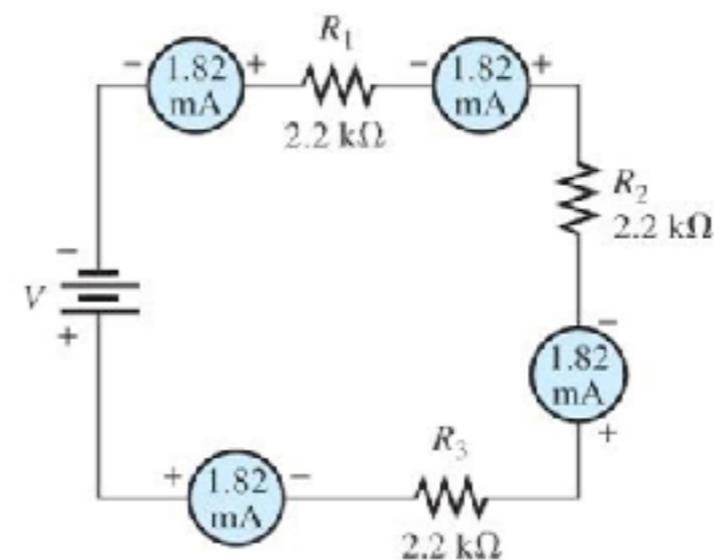
(a) Pictorial



(b) Schematic



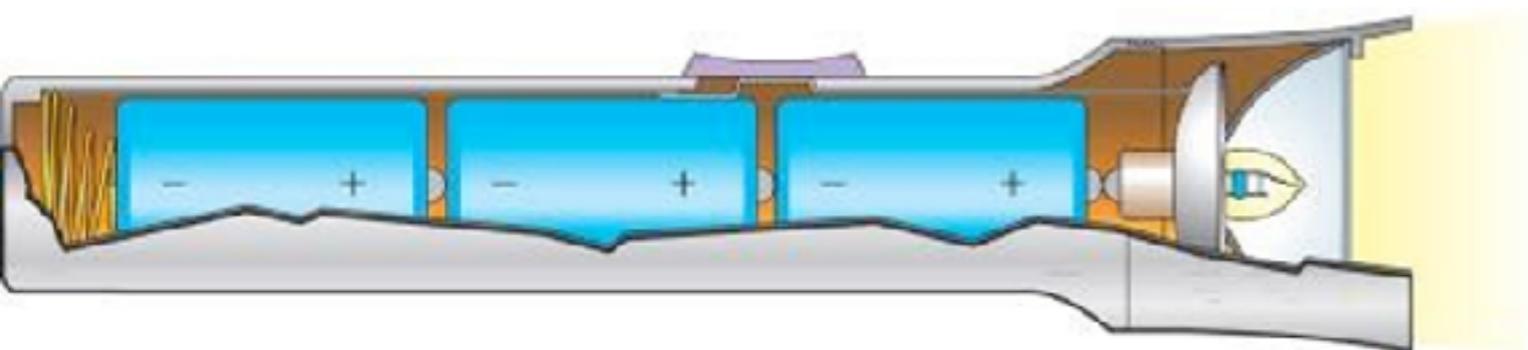
(a) Pictorial



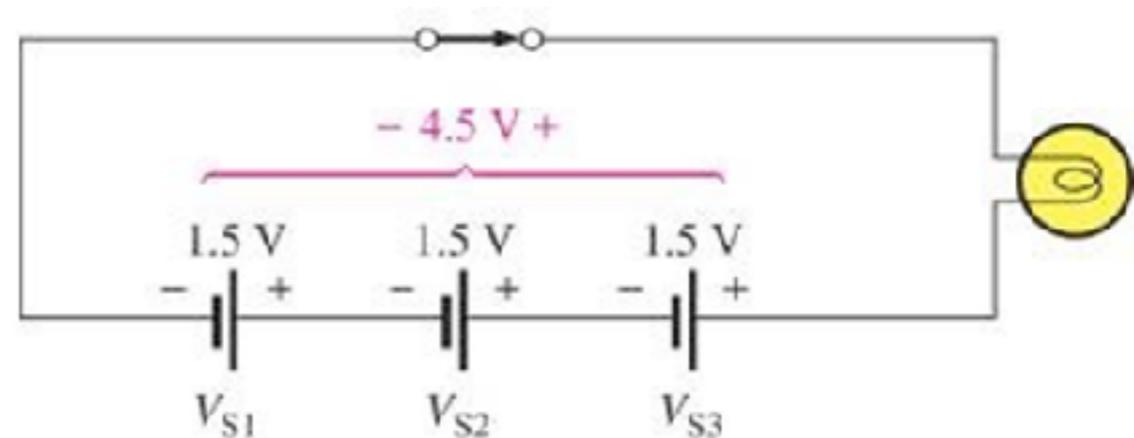
(b) Schematic



電壓串聯

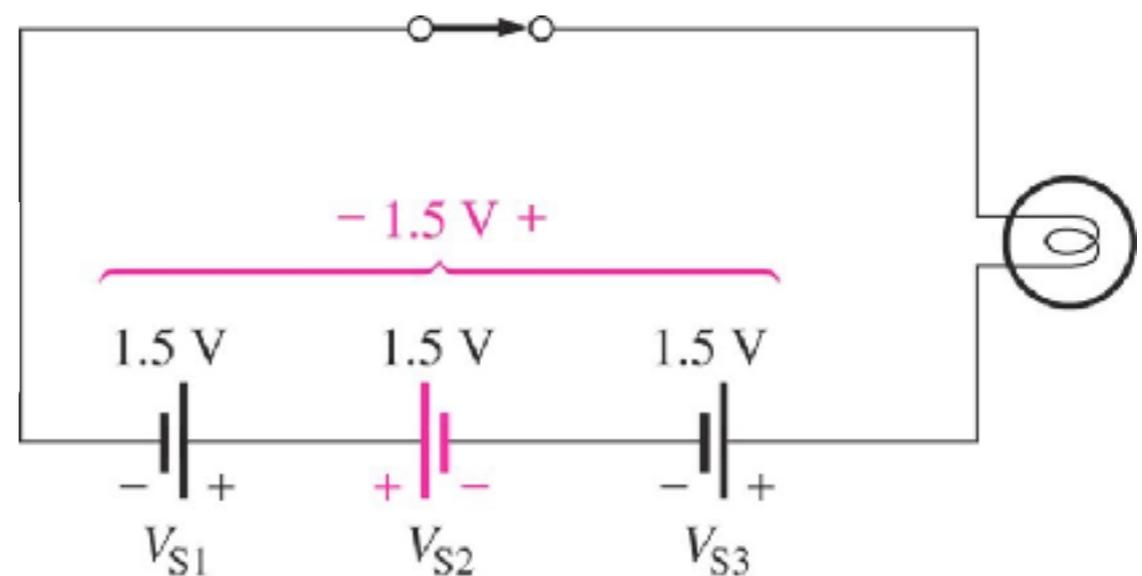


(a) Flashlight with series batteries



(b) Schematic of flashlight circuit

電壓源串聯，總電壓值為各電壓源之和

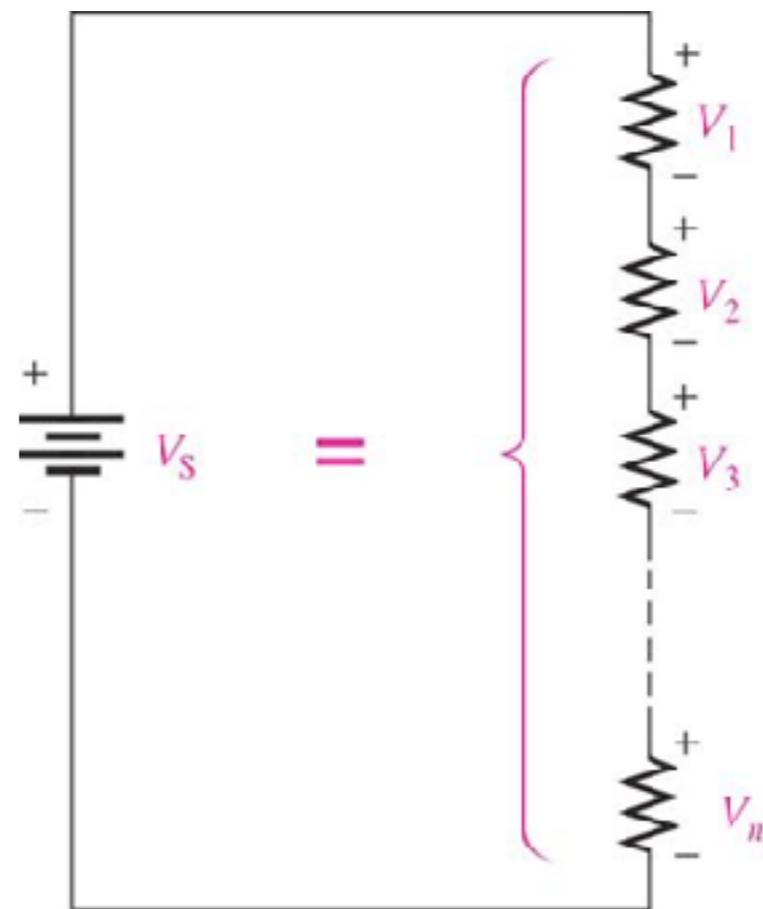
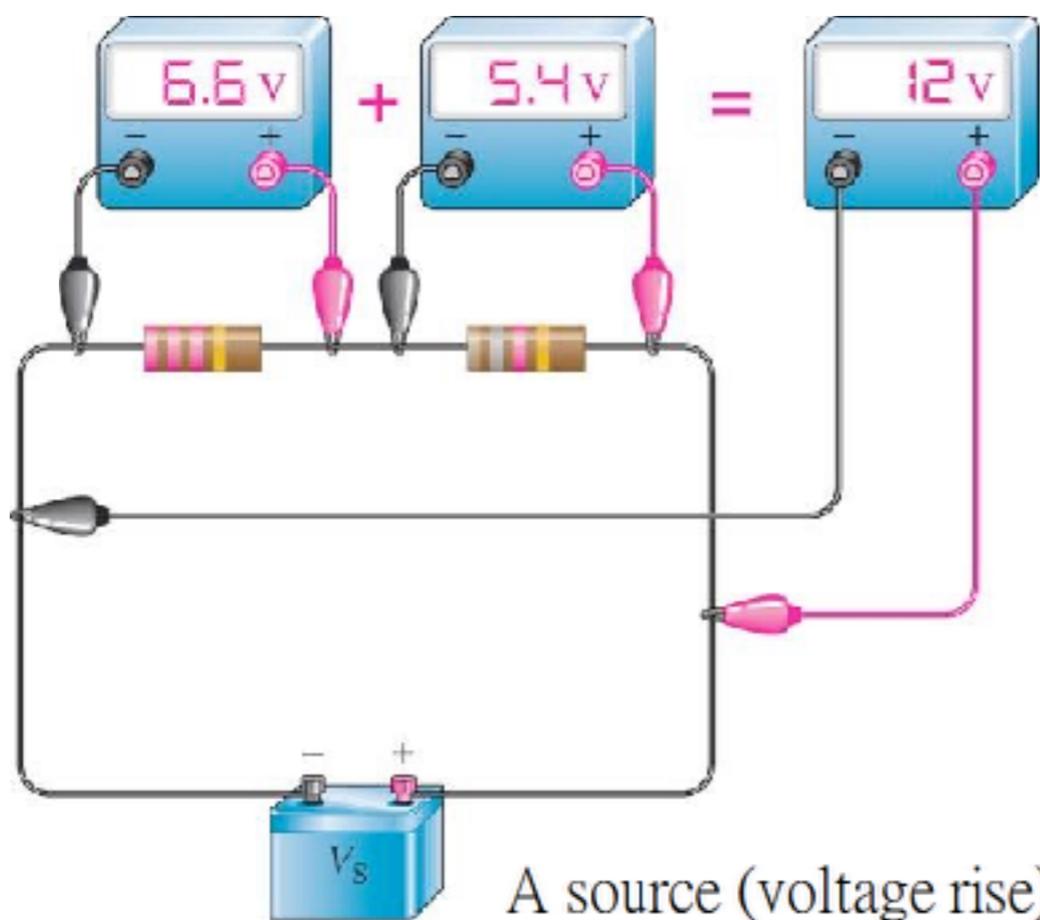




克希荷夫電壓定律

- 在一個封閉迴路中，總電壓降等於此封閉迴路總電壓源
- 在一個封閉迴路中，沿同一方向走一圈，電壓總和為0

$$V_1 + V_2 + V_3 + \dots + V_n = 0$$

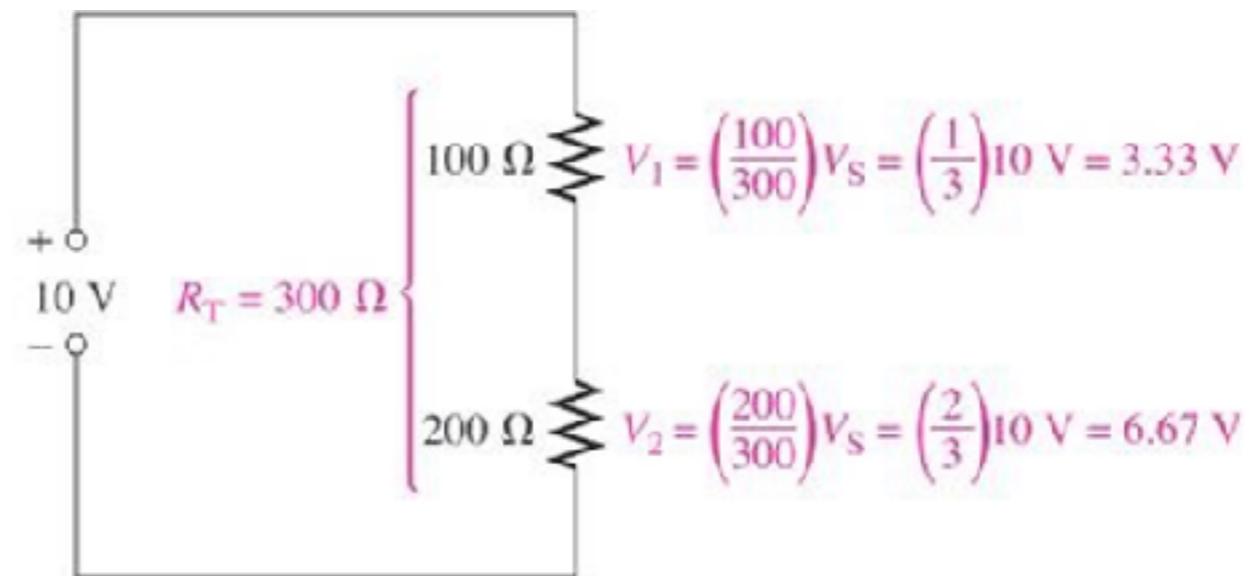
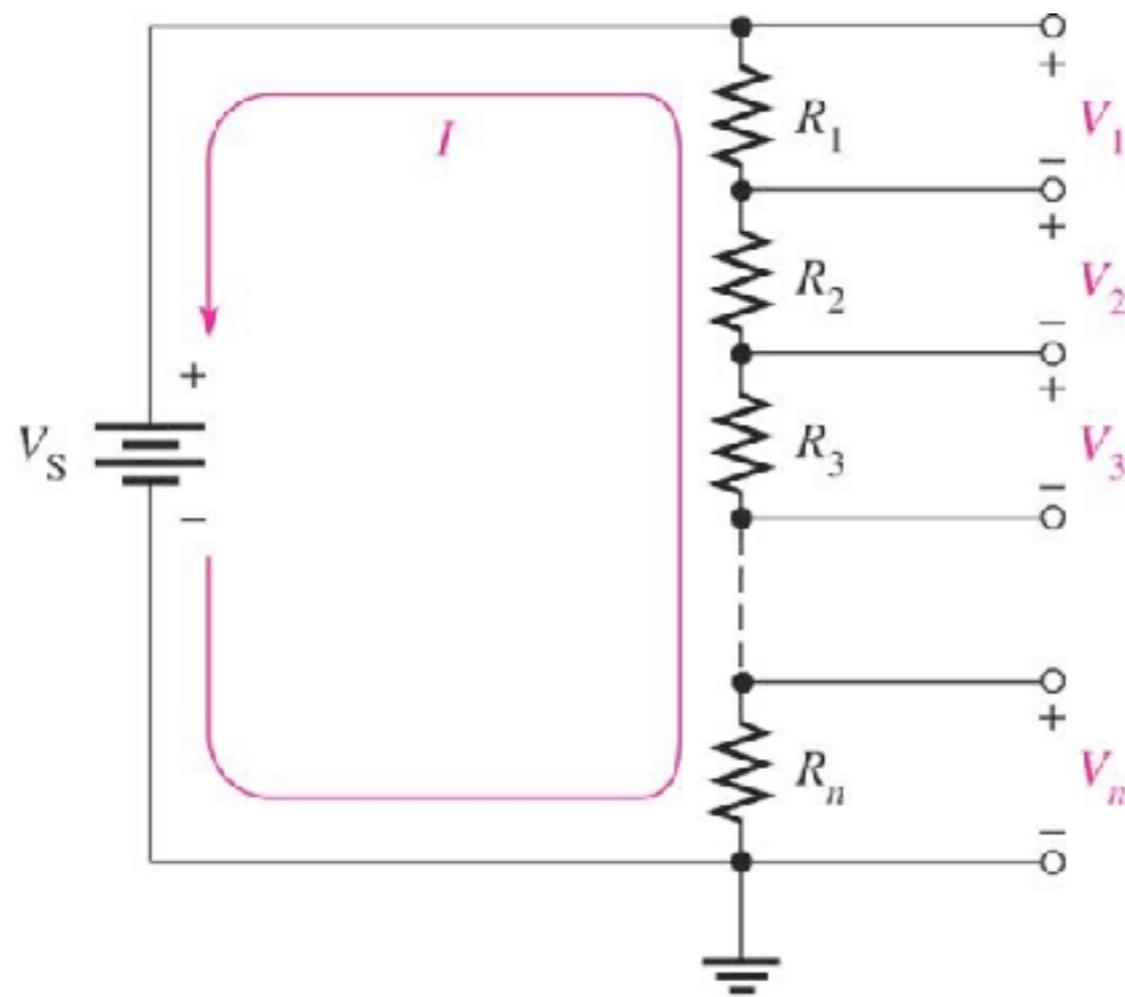


$$V_s = V_1 + V_2 + V_3 + \dots + V_n$$



電阻分壓

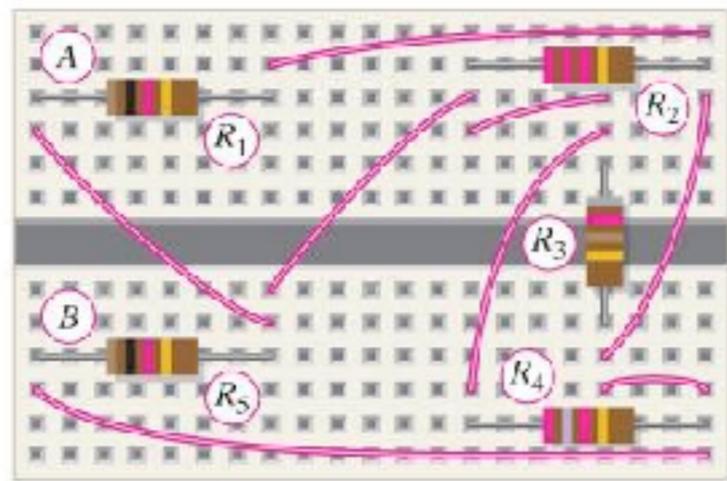
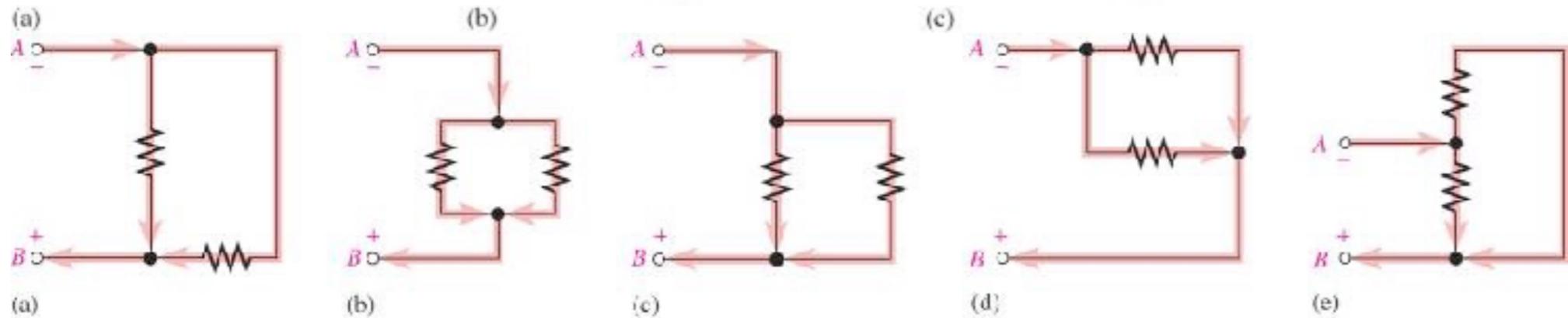
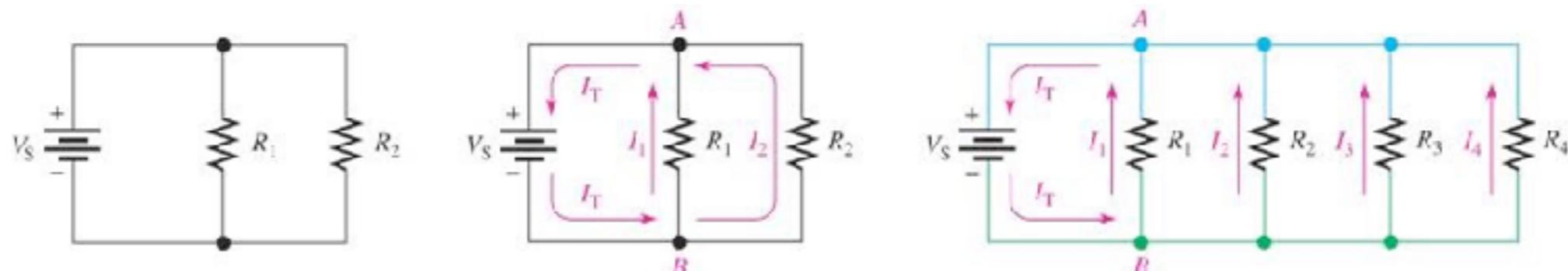
- 串聯電路中，經過一電阻的電壓降與電壓源之比值等於此電阻與迴路總電阻之比值



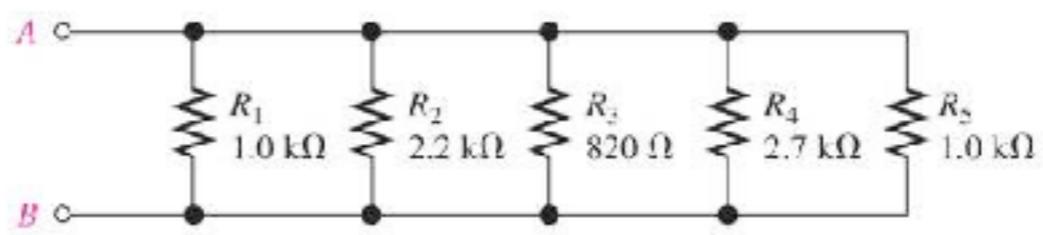
$$V_x = \left(\frac{R_x}{R_T} \right) V_S$$



電阻並聯



(a) Assembly wiring diagram



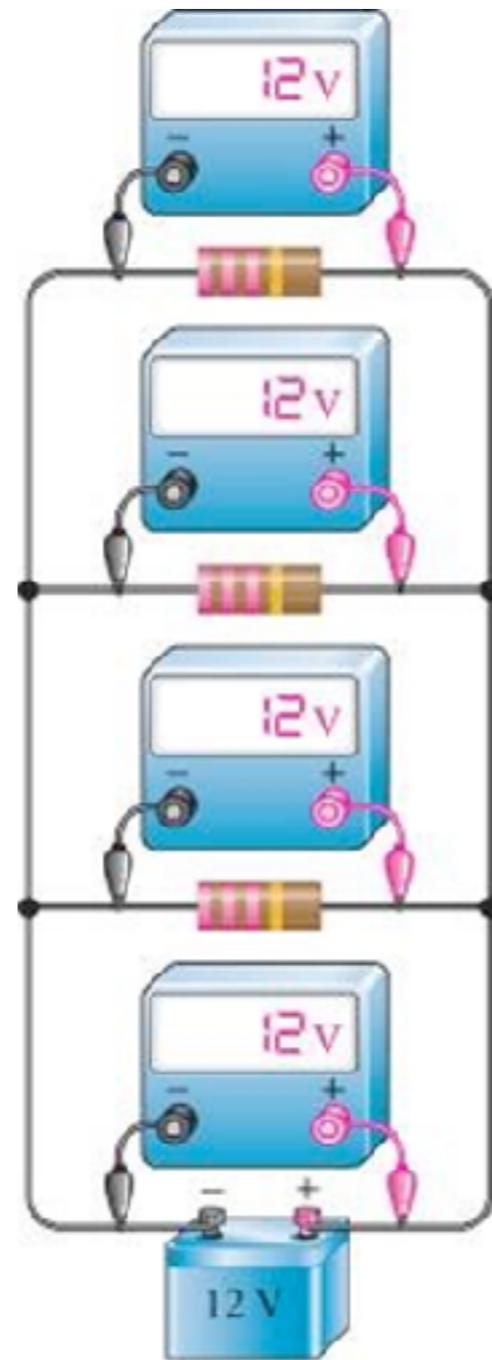
(b) Schematic

電阻並聯，總電阻值為各電阻值倒數和的倒數

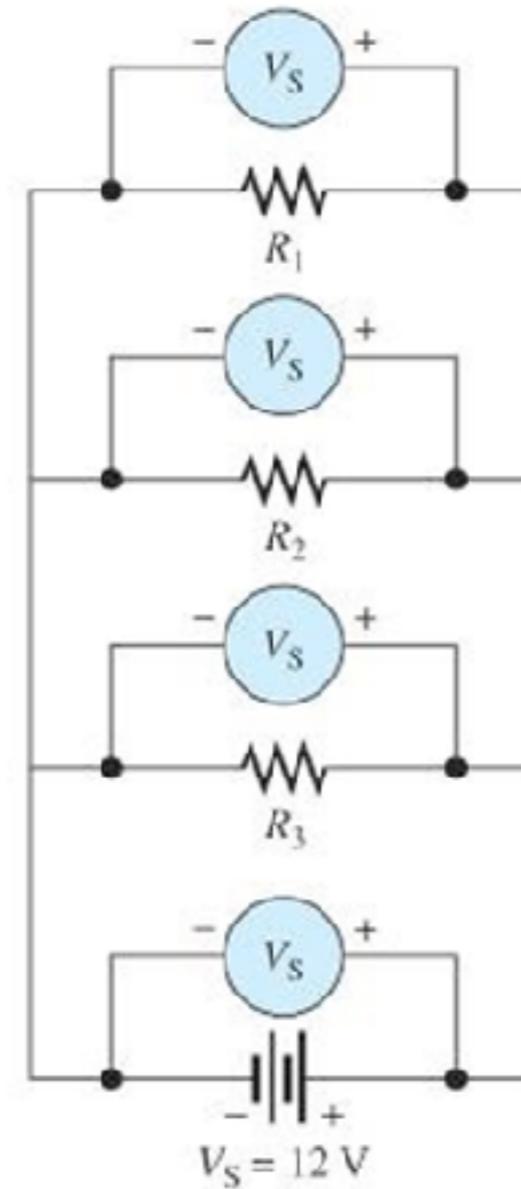
$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}}$$



並聯電路電壓相等



(a) Pictorial

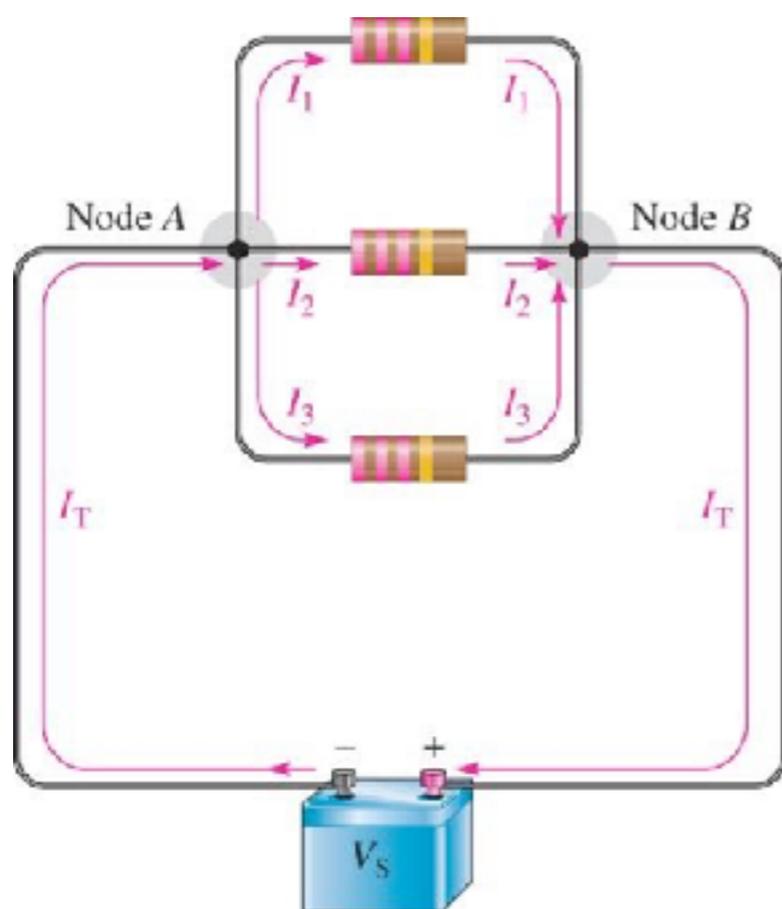


(b) Schematic

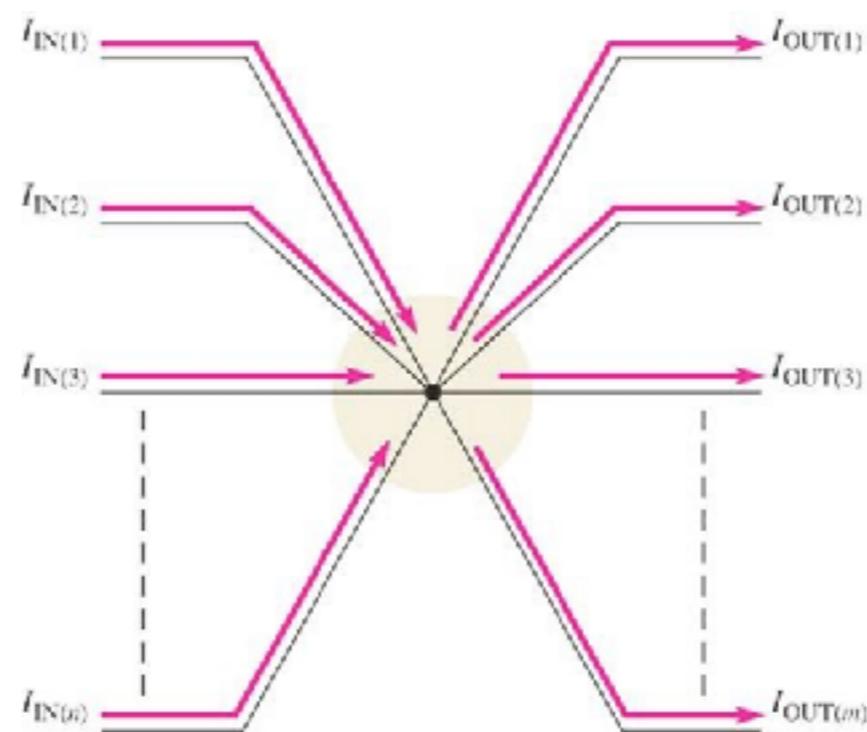


克希荷夫電流定律

- 流入電路中任一節點的電流和等於流出此節點的電流和
- 電路中任一節點所有流入與流出電流和為0



$$I_T = I_1 + I_2 + I_3$$



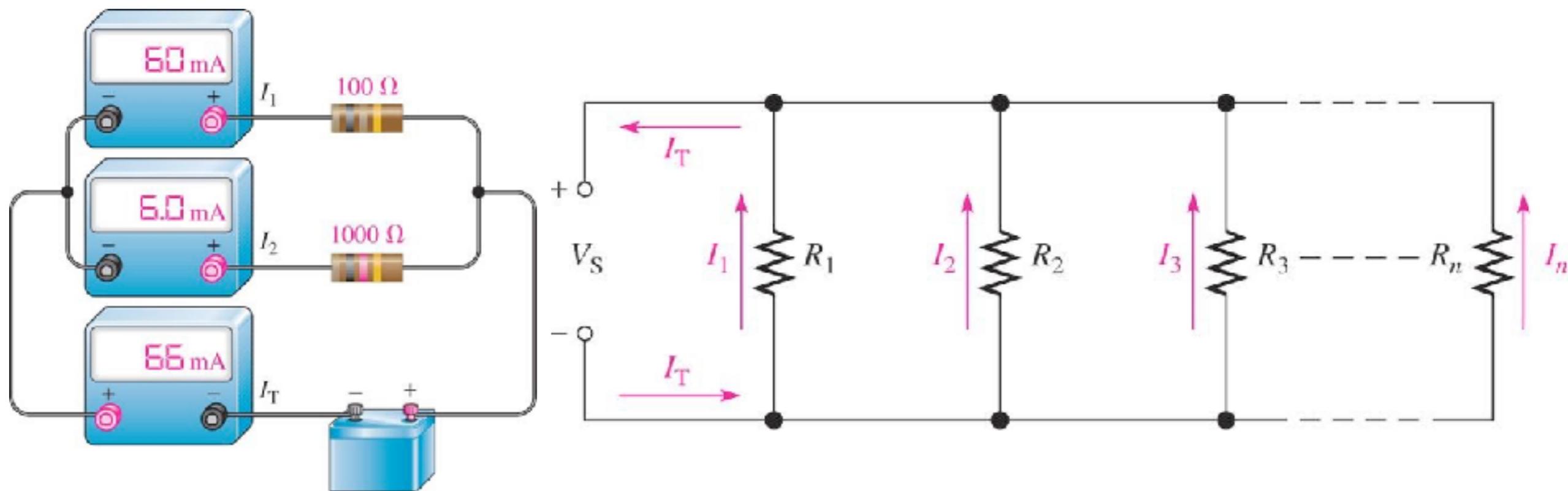
$$I_{IN(1)} + I_{IN(2)} + I_{IN(3)} + \dots + I_{IN(m)} = I_{OUT(1)} + I_{OUT(2)} + I_{OUT(3)} + \dots + I_{OUT(m)}$$

$$\sum_{i=1}^k I_i = 0$$



電阻分流

- 並聯電路中，經過任一電阻電流與其電阻值成反比

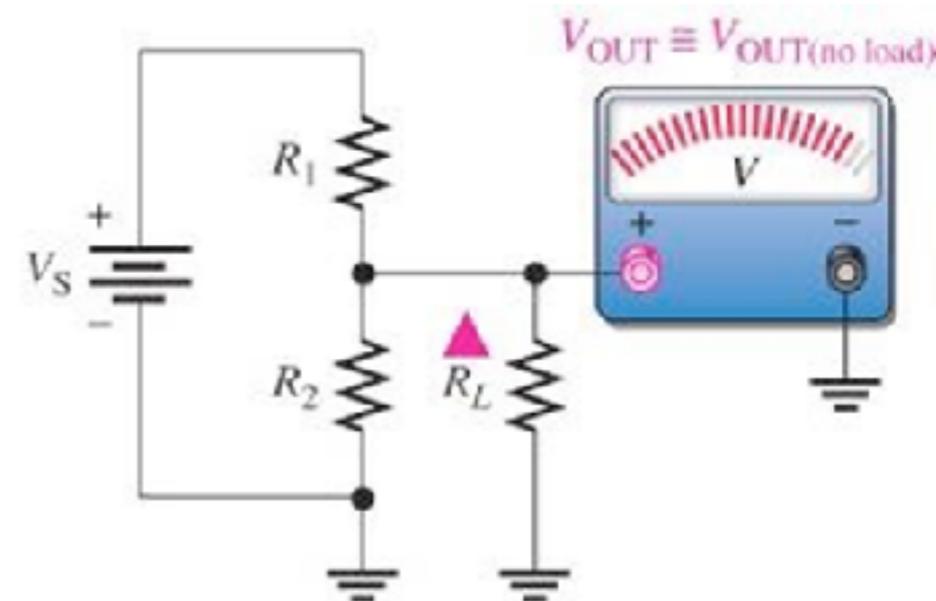
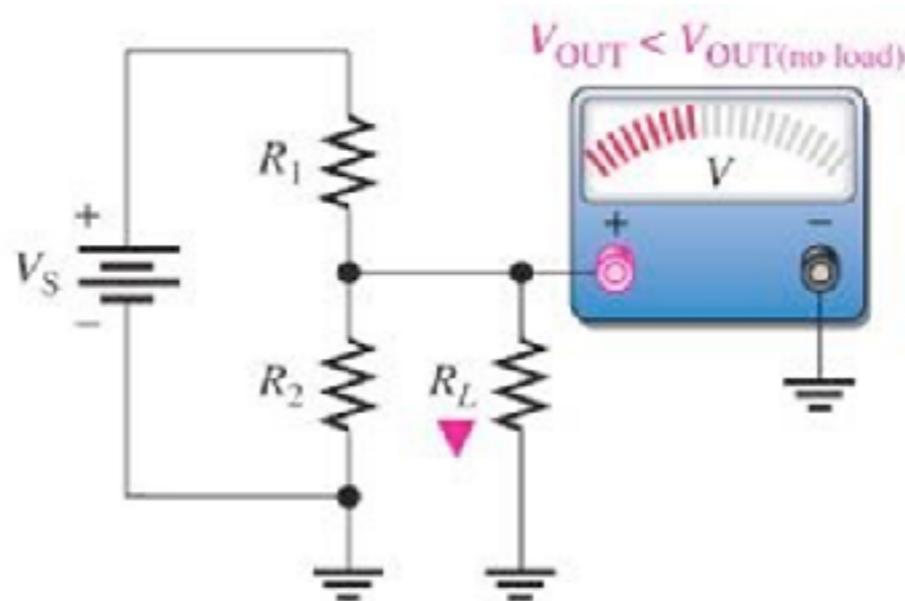
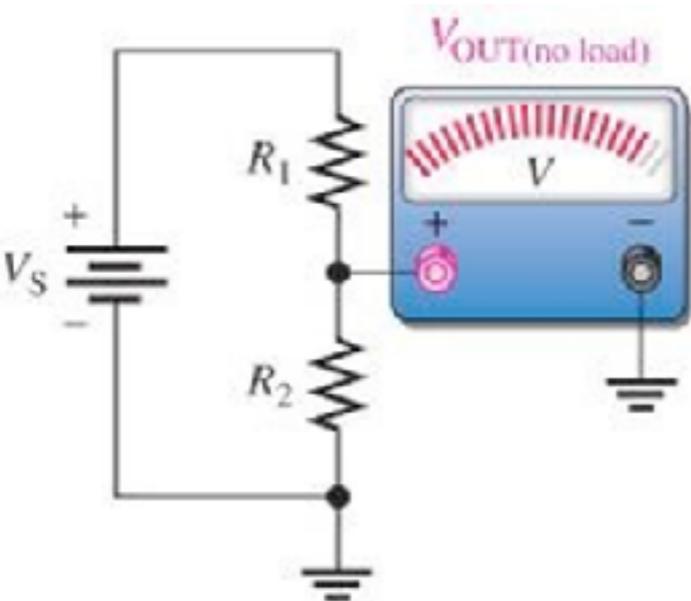
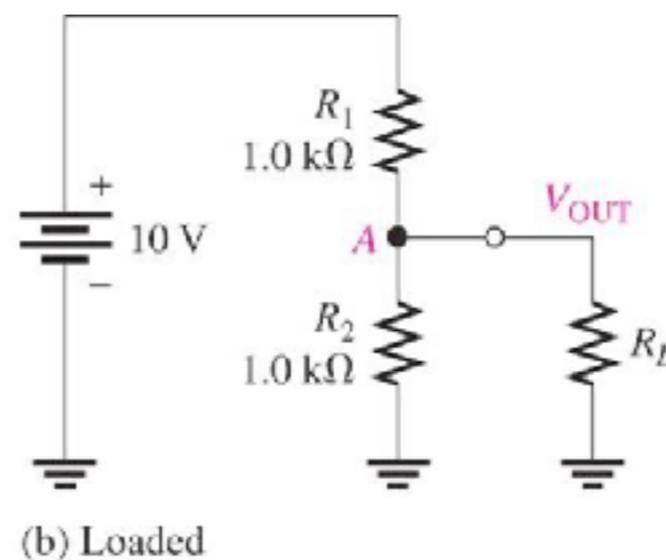
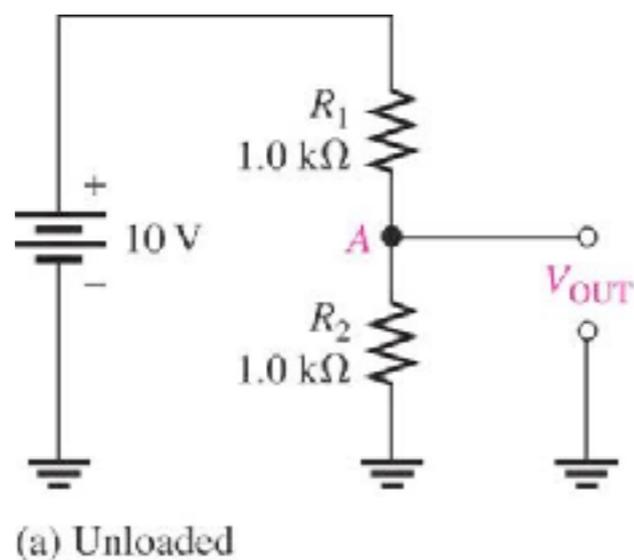


$$I_x = \frac{V_S}{R_x} = \frac{I_T R_T}{R_x} = \left(\frac{R_T}{R_x} \right) I_T$$



負載效應

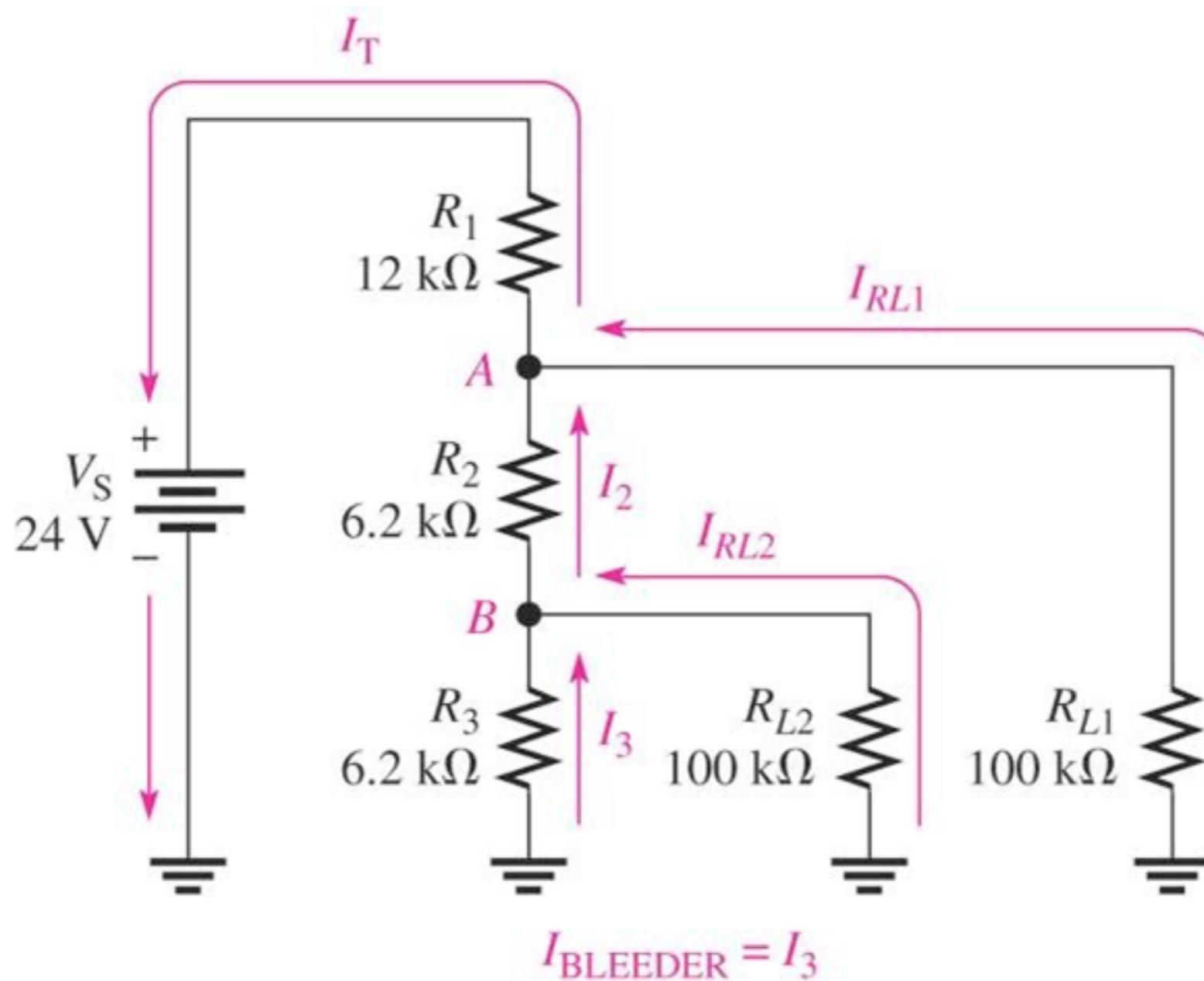
- 當分壓電路的輸出接到一負載電阻時，輸出電壓將會減少





練習題#1

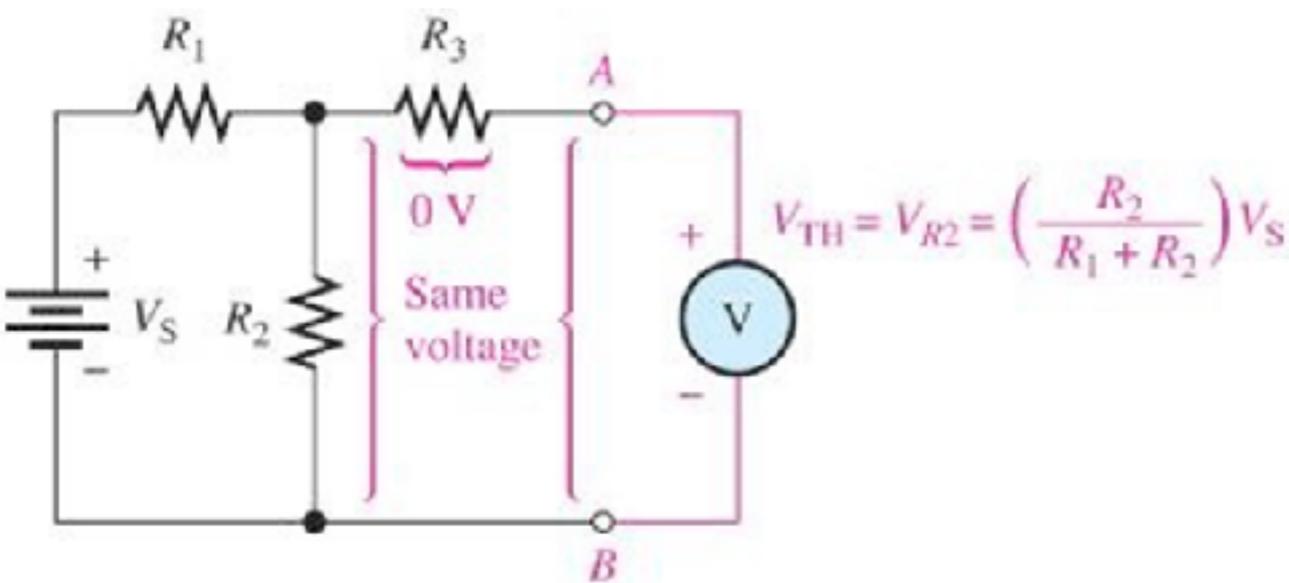
- 計算下圖電路中 I_{RL1} 、 I_{RL2} 、 I_3 電流值。



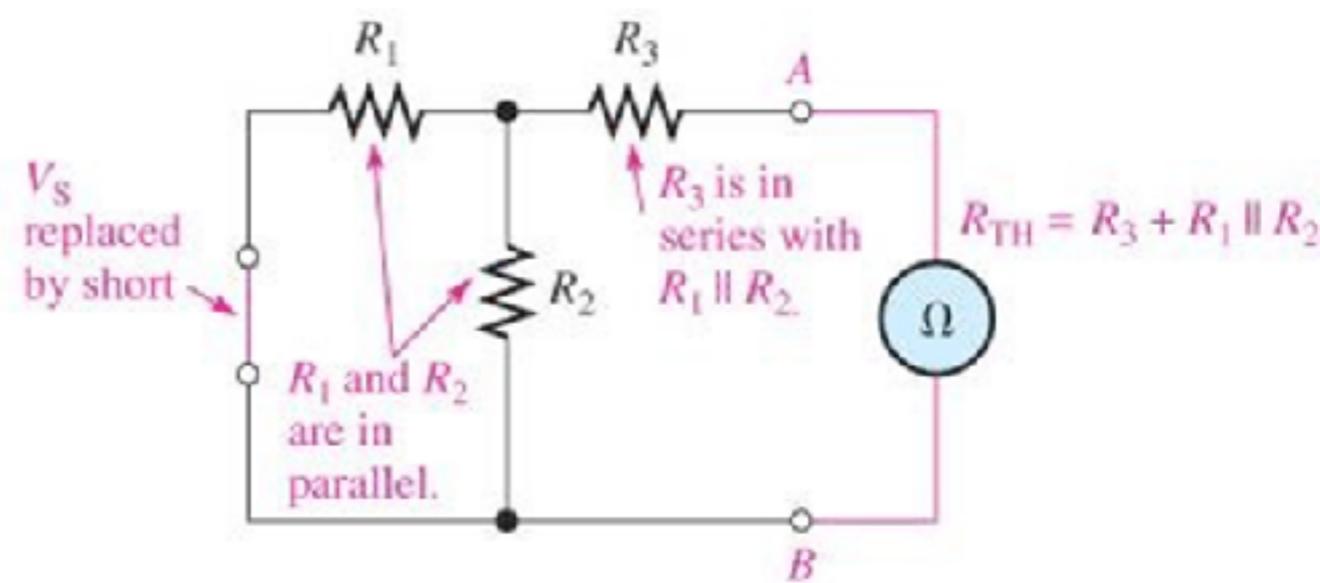


戴維寧定理

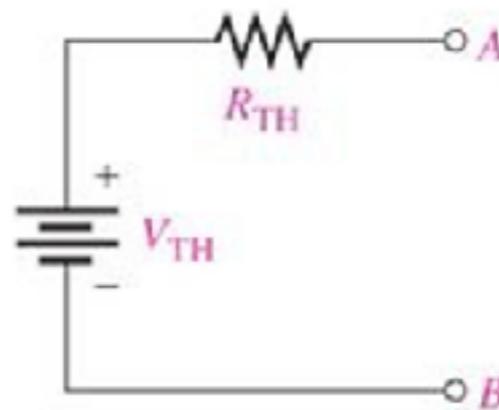
- 從含有電壓源之電阻電路的兩端點看入，可用一電壓源串聯一個電阻來等效。



(a) Finding V_{TH}



(b) Finding R_{TH}

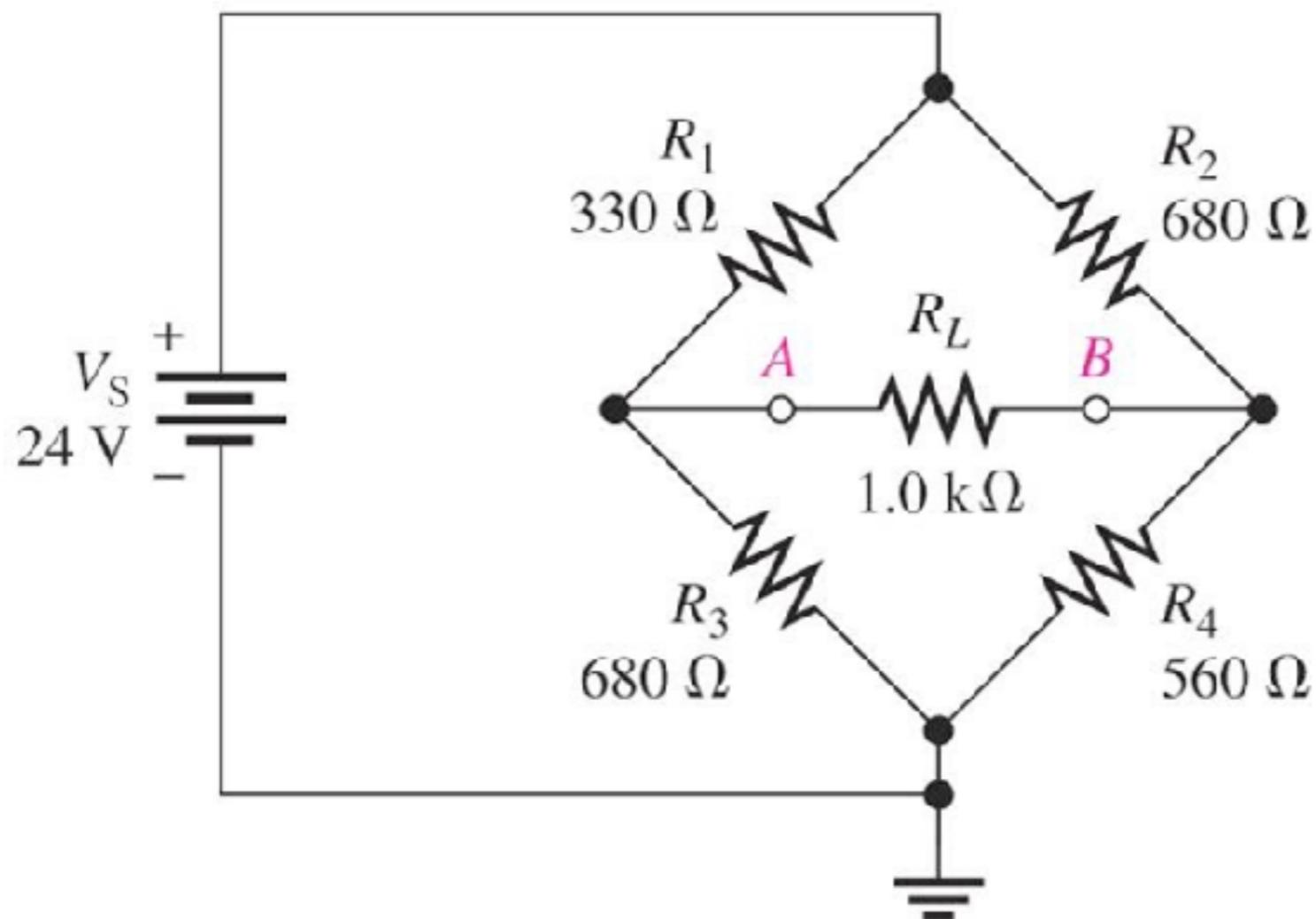


(c) Thevenin equivalent circuit



練習題#2

- 試計算下圖電路中經過 R_L 之電壓與電流值。





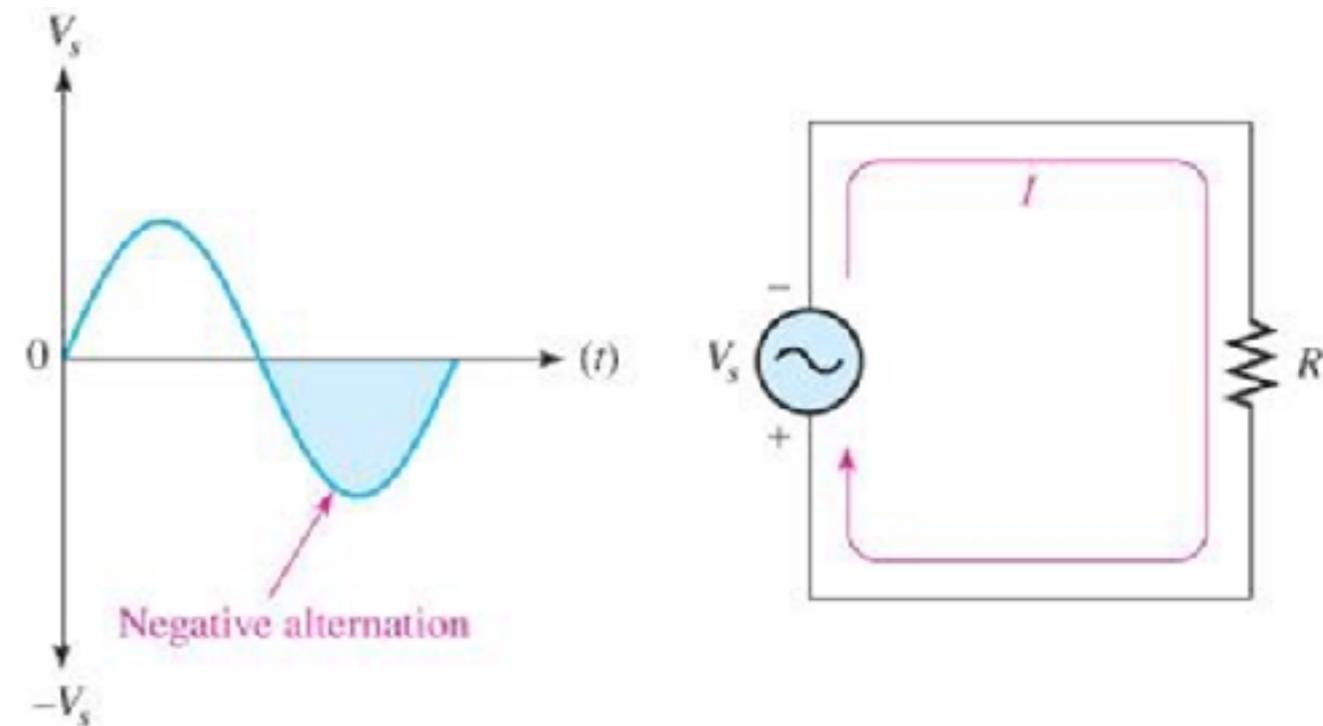
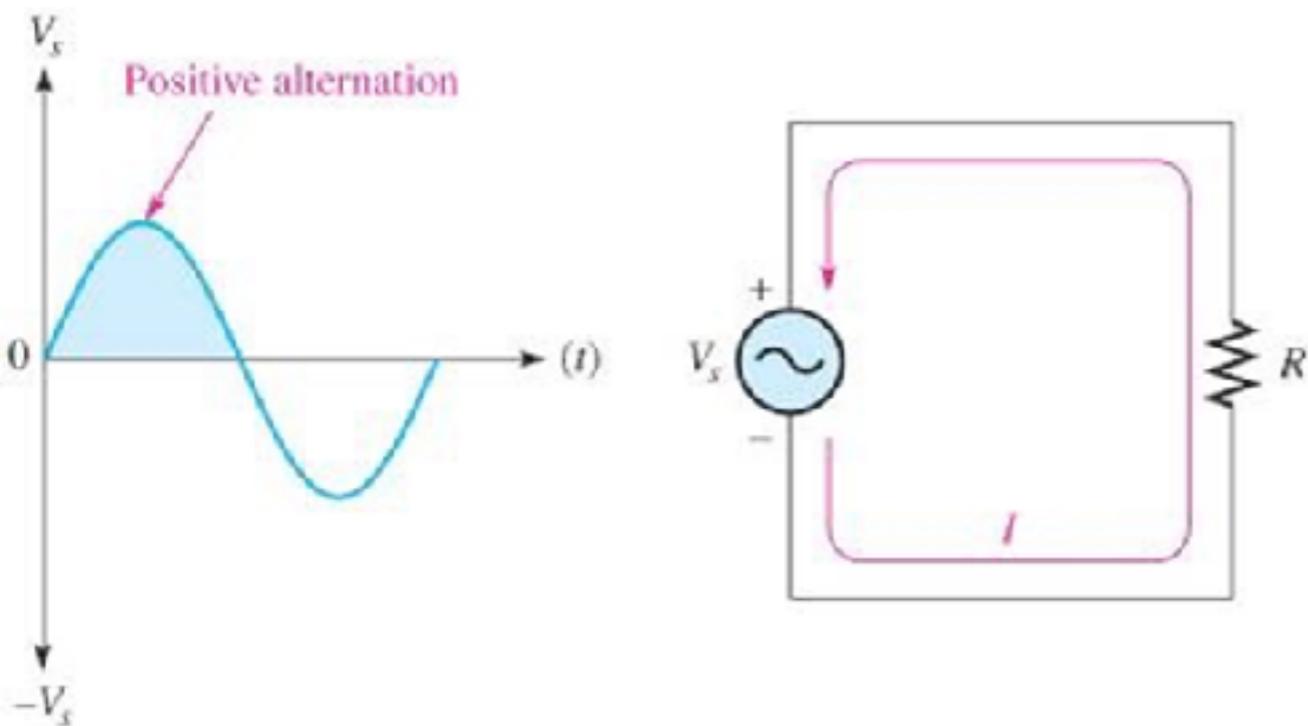
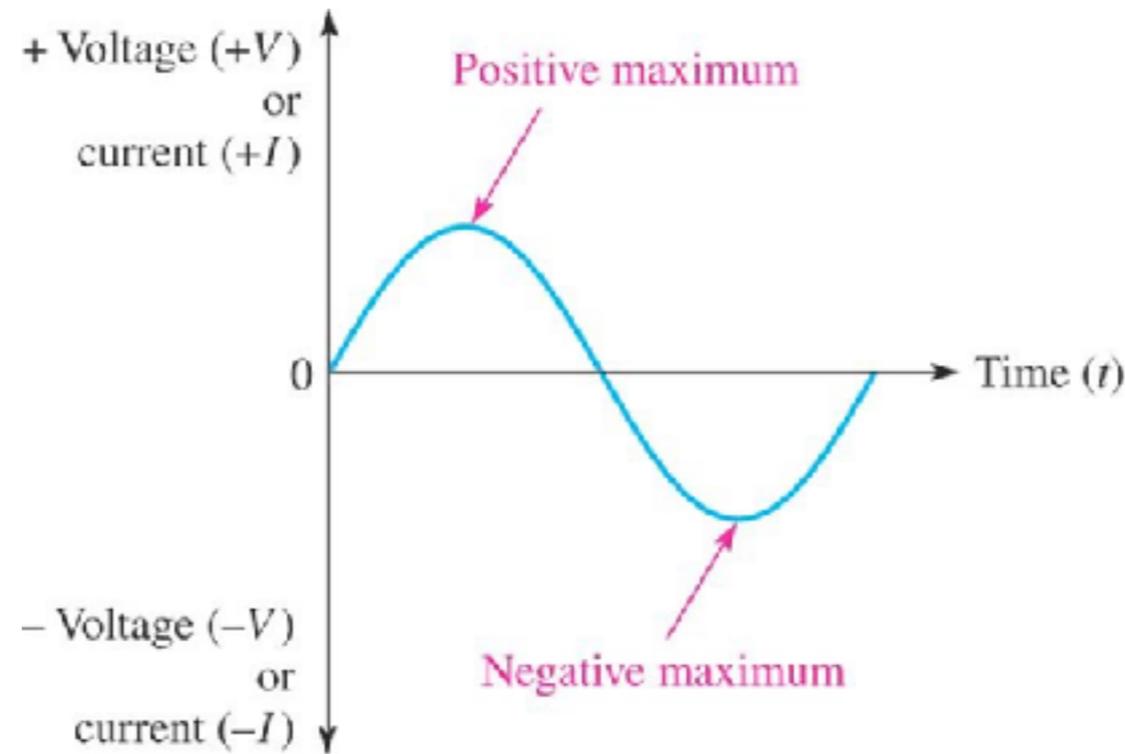
交流電源



(a) Examples of function generators



(b) A typical arbitrary waveform generator



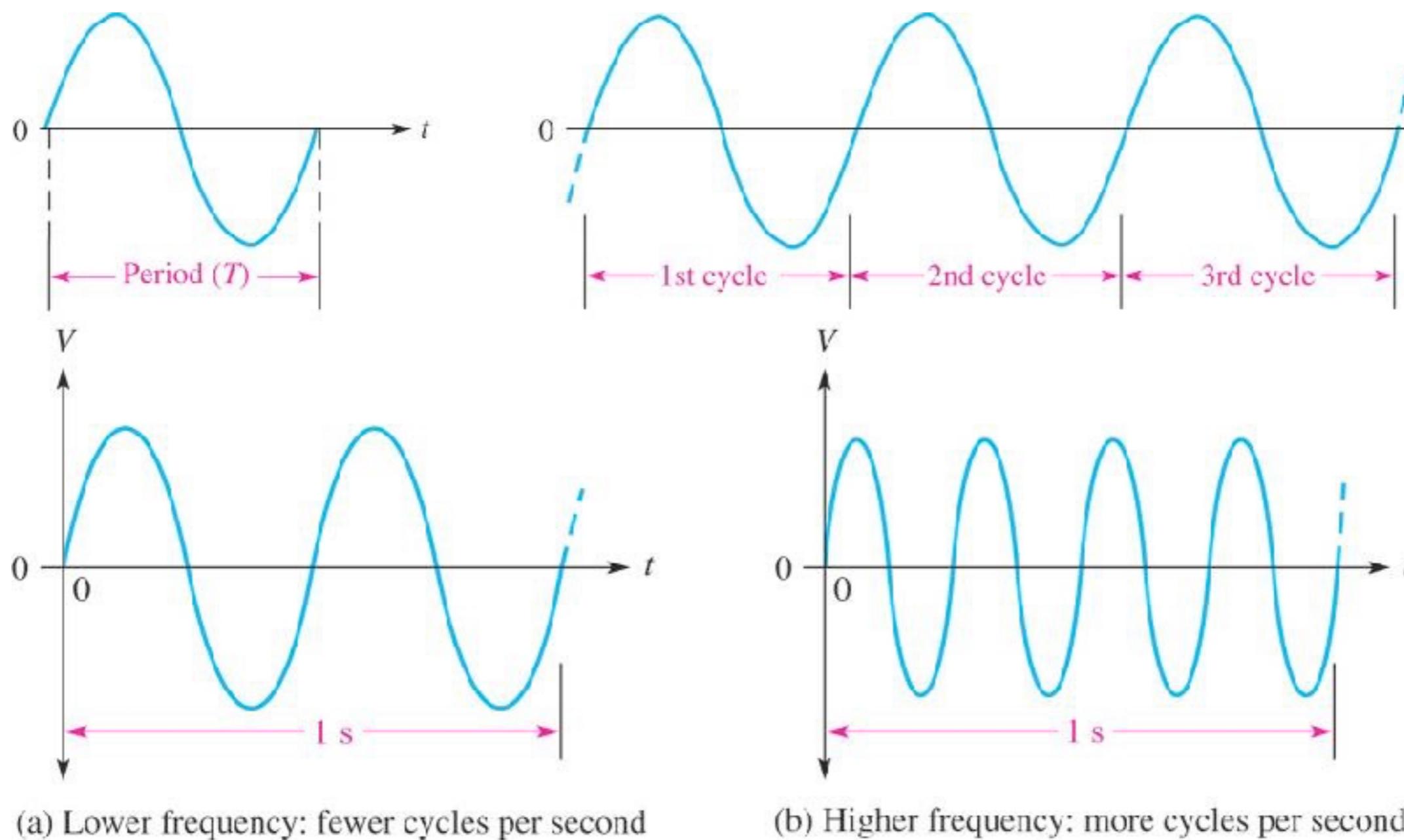
(a) During a positive alternation of the voltage, current is in the direction shown.

(b) During a negative alternation of the voltage, current reverses direction.

一個正弦函數交流電壓源的時間與輸出關係圖



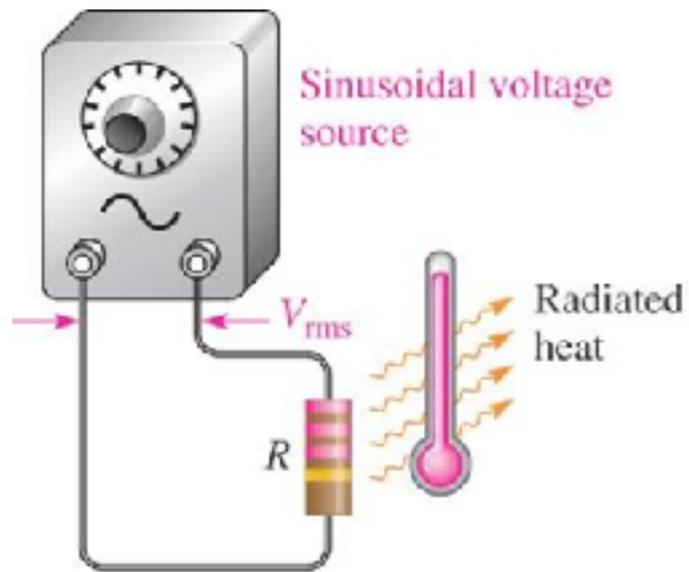
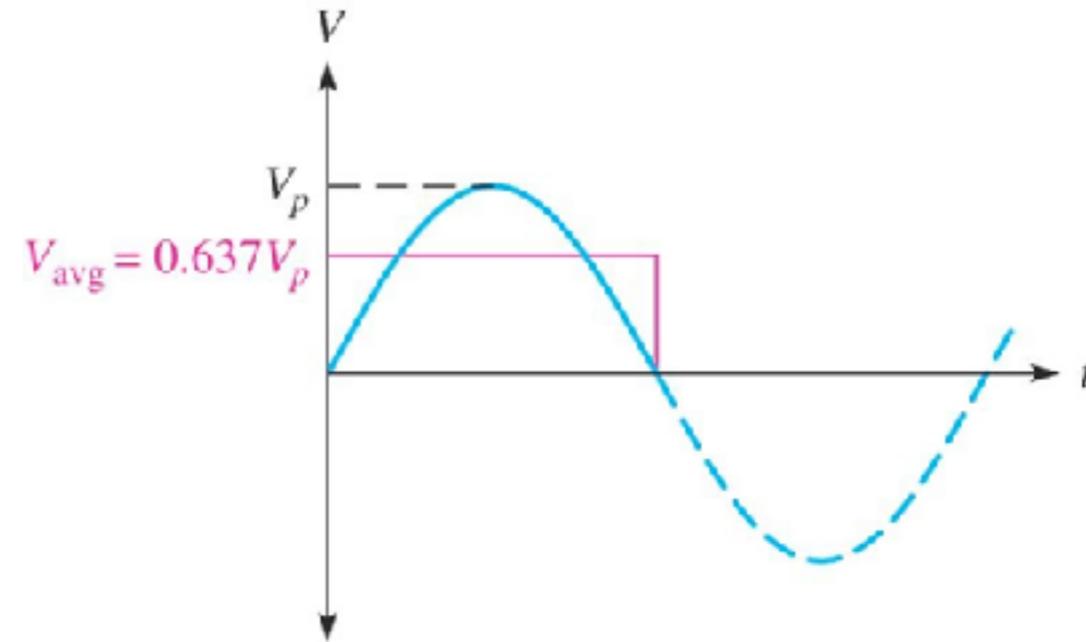
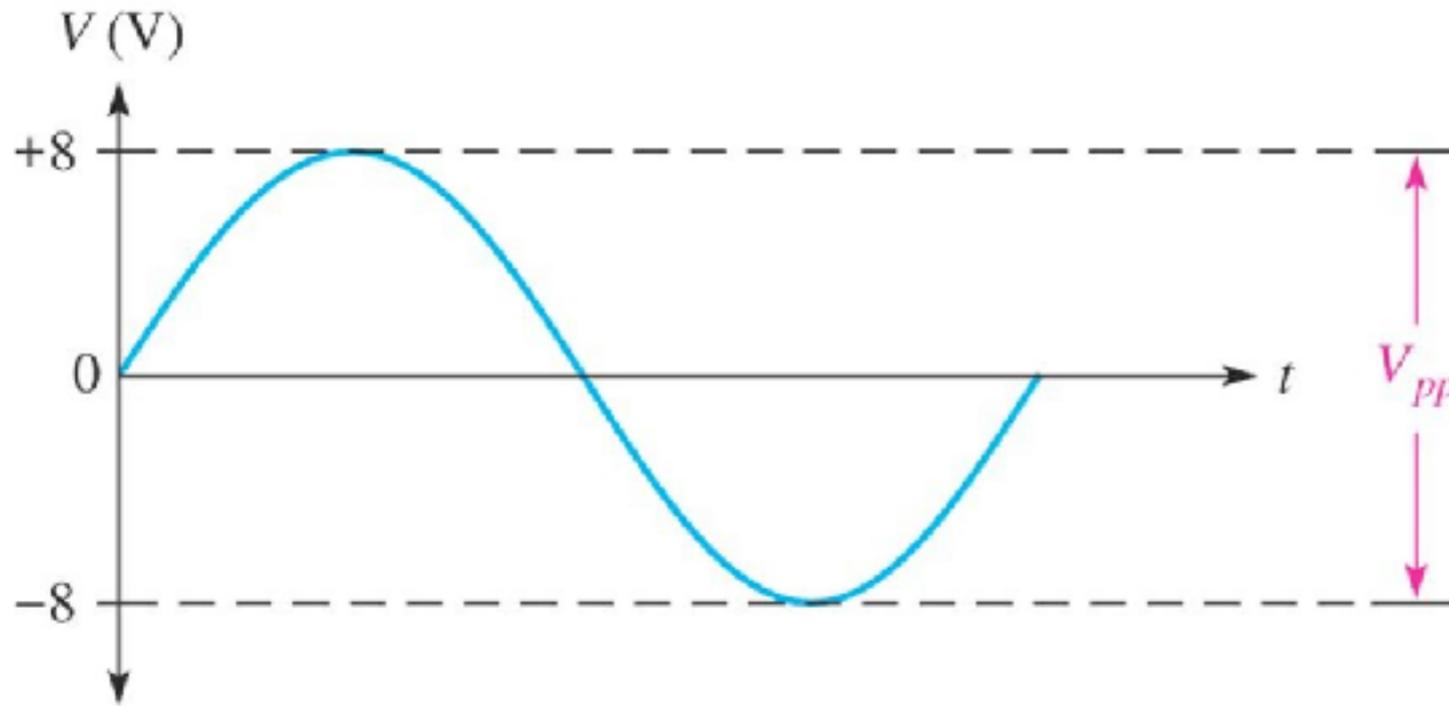
週期、頻率



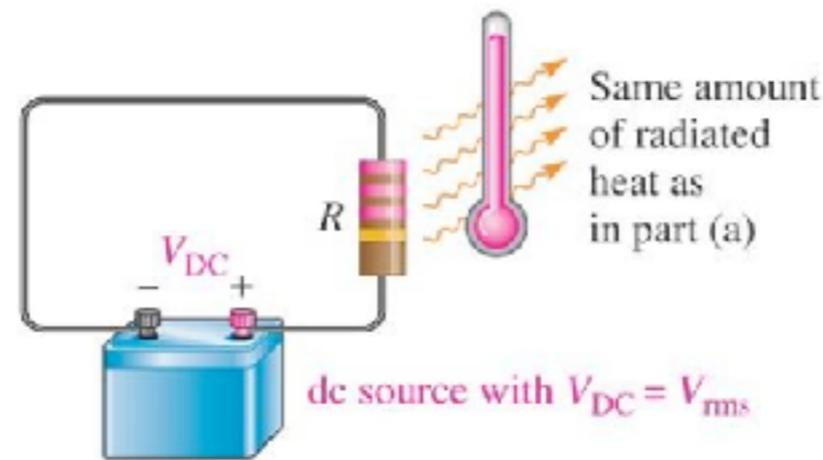
週期為 T 、頻率為 f
 $f = 1 / T$



V_{pp} 、 V_{rms} 、 V_{avg}



(a)

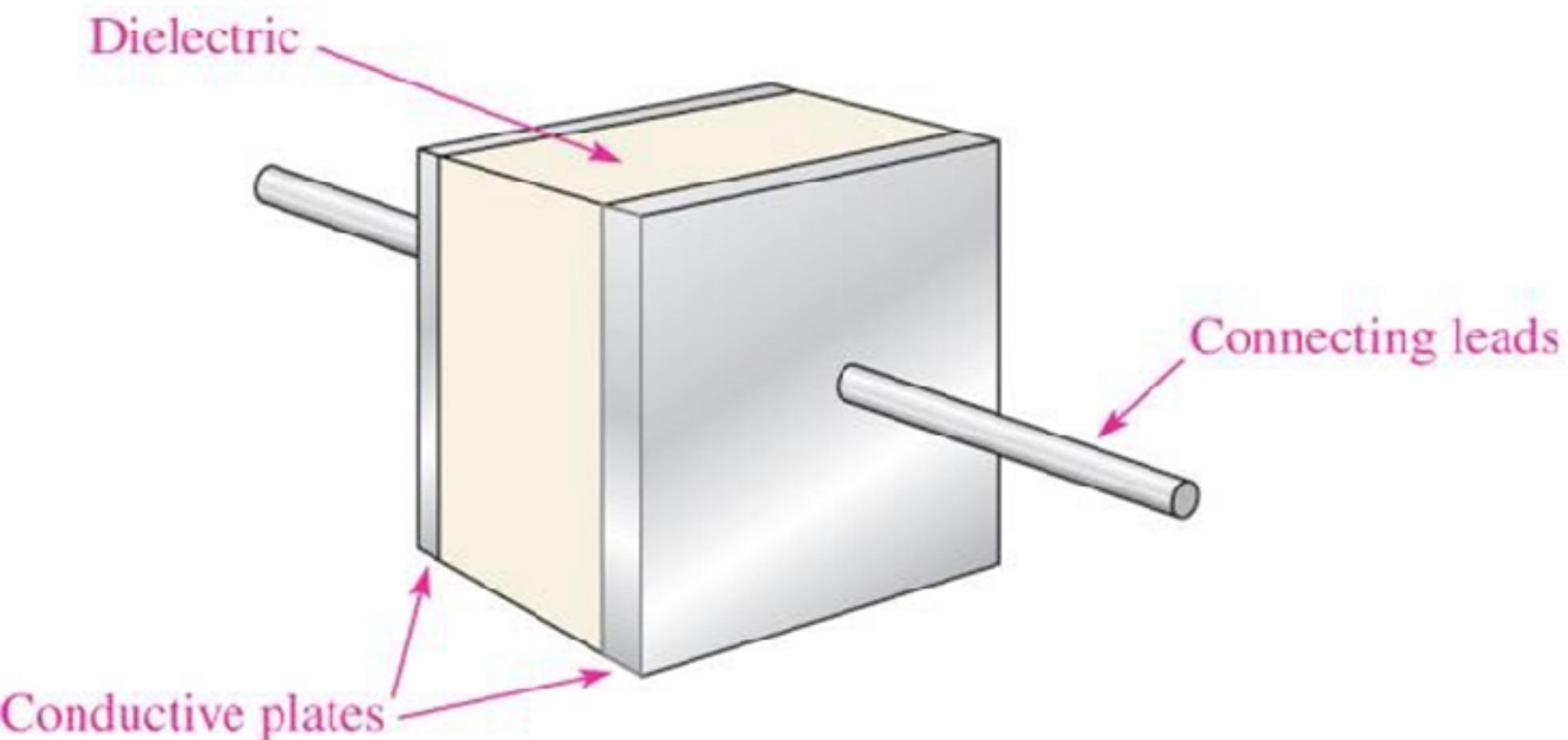


(b)

$$V_{rms} = \frac{1}{\sqrt{2}} V_p$$



電容



(a) Construction

$$C = \frac{Q}{V}$$

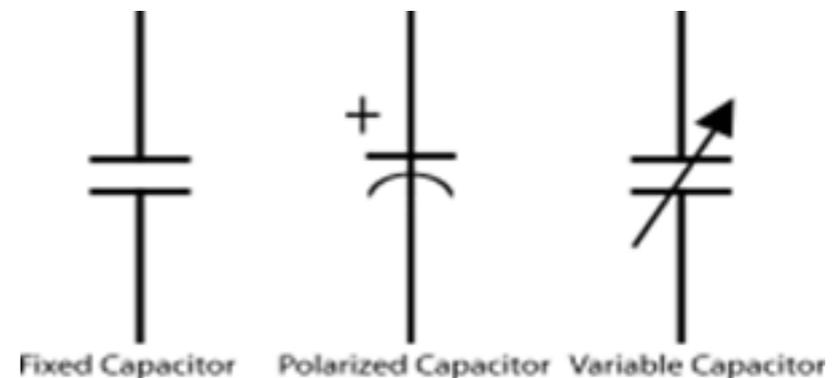
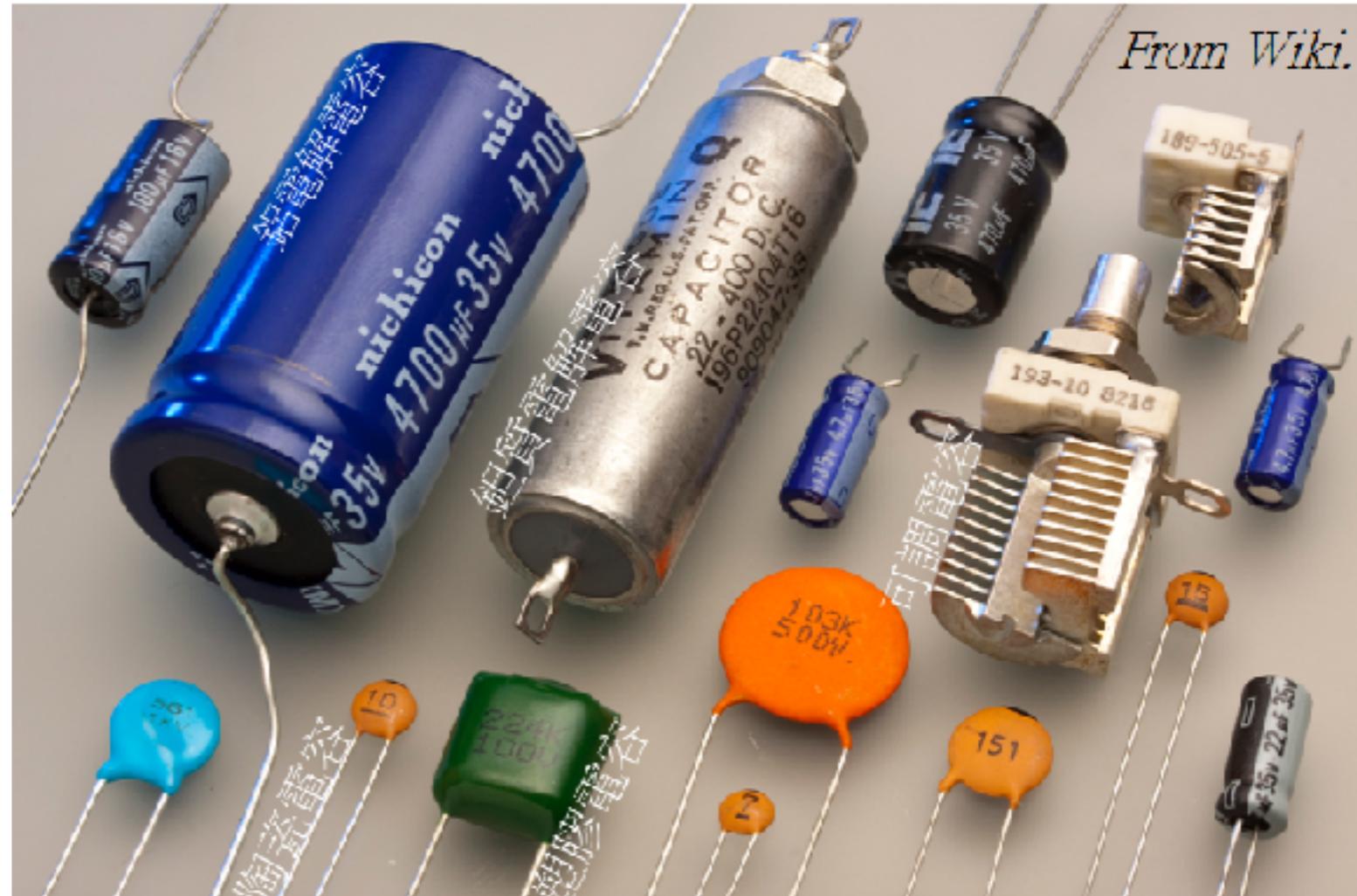


(b) Symbol



電容種類

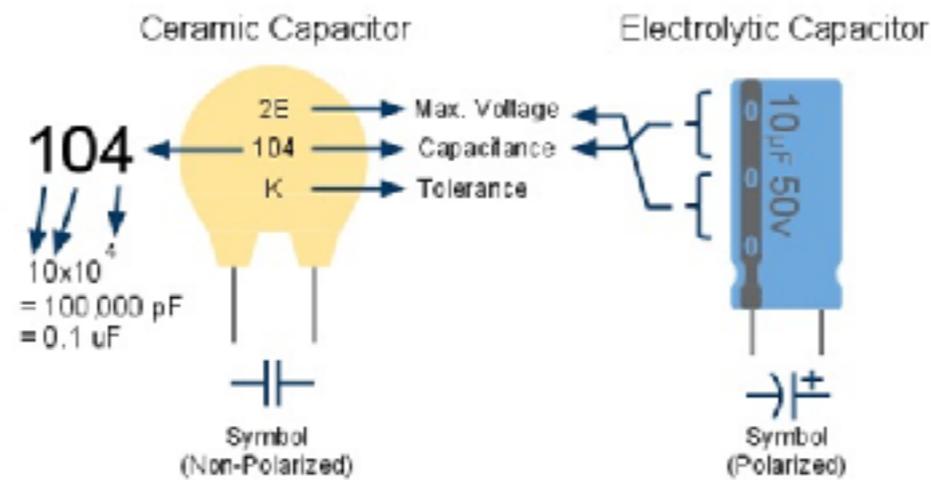
- 常見的電容：
- 雲母電容
- 塑膠電容
- 陶瓷 / 積層陶瓷電容
- 鋁電解電容
- 鉮質電解電容
- 可調電容





電容值表示方法

Capacitors



Max. Operating Voltage	
Code	Max. Voltage
1H	50V
2A	100V
2T	150V
2D	200V
2E	250V
2G	400V
2J	630V

Capacitance Conversion Values

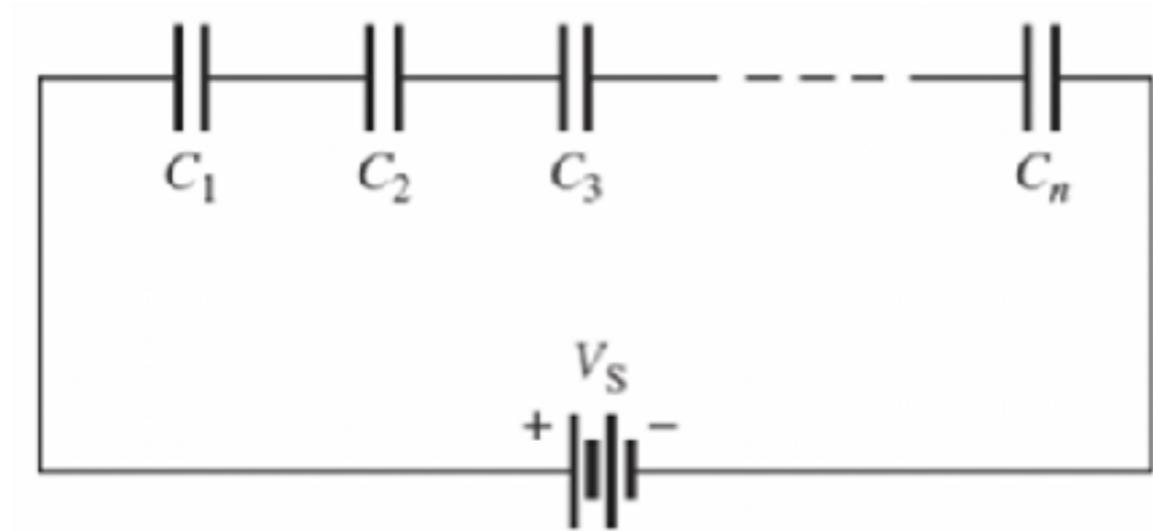
Microfarads (µF)	Nanofarads (nF)	Picofarads (pF)
0.000001 µF	0.001 nF	1 pF
0.00001 µF	0.01 nF	10 pF
0.0001 µF	0.1 nF	100 pF
0.001 µF	1 nF	1,000 pF
0.01 µF	10 nF	10,000 pF
0.1 µF	100 nF	100,000 pF
1 µF	1,000 nF	1,000,000 pF
10 µF	10,000 nF	10,000,000 pF
100 µF	100,000 nF	100,000,000 pF

Tolerance

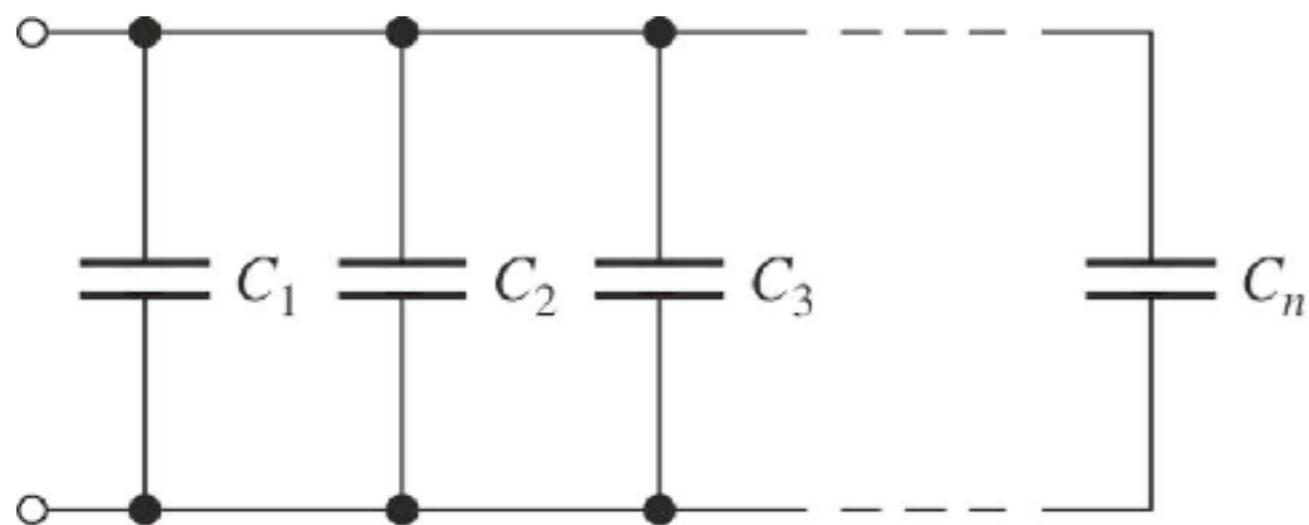
Code	Percentage
B	± 0.1 pF
C	±0.25 pF
D	±0.5 pF
F	±1%
G	±2%
H	±3%
J	±5%
K	±10%
M	±20%
Z	+80%, -20%



電容串聯、並聯



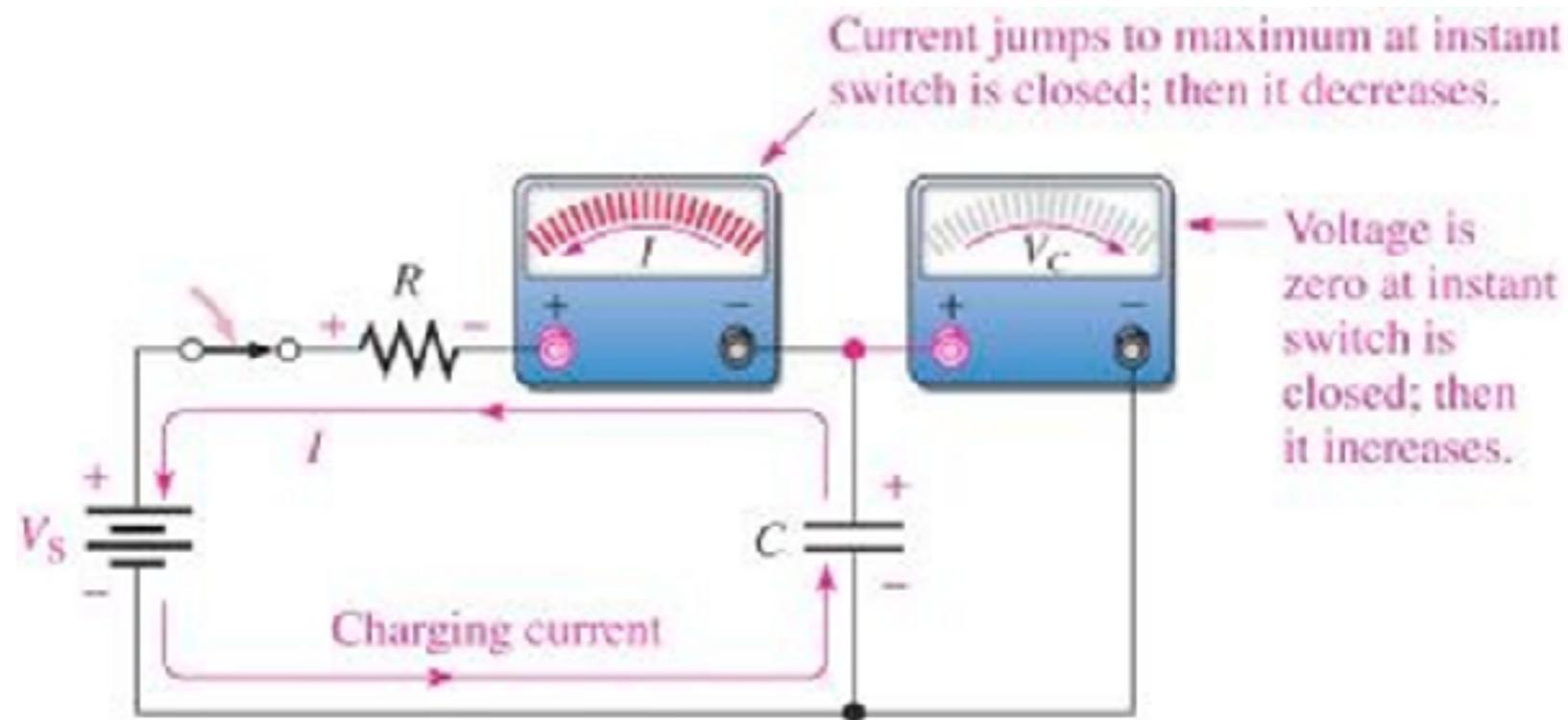
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}$$



$$C_T = C_1 + C_2 + \dots + C_n$$



電容充電

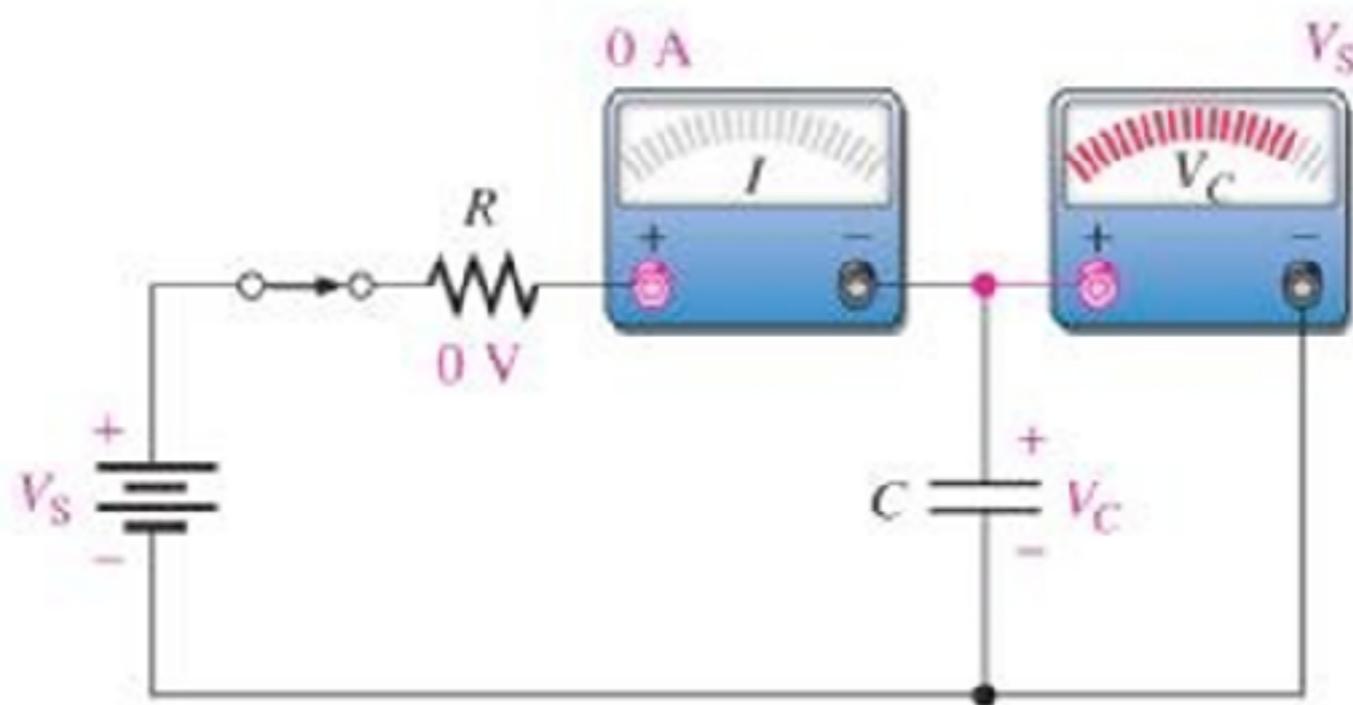


(a) Charging: Capacitor voltage increases as the current and resistor voltage decrease.

$$V_C(t) = V_S \left(1 - e^{-\frac{t}{RC}} \right)$$



電容充飽電

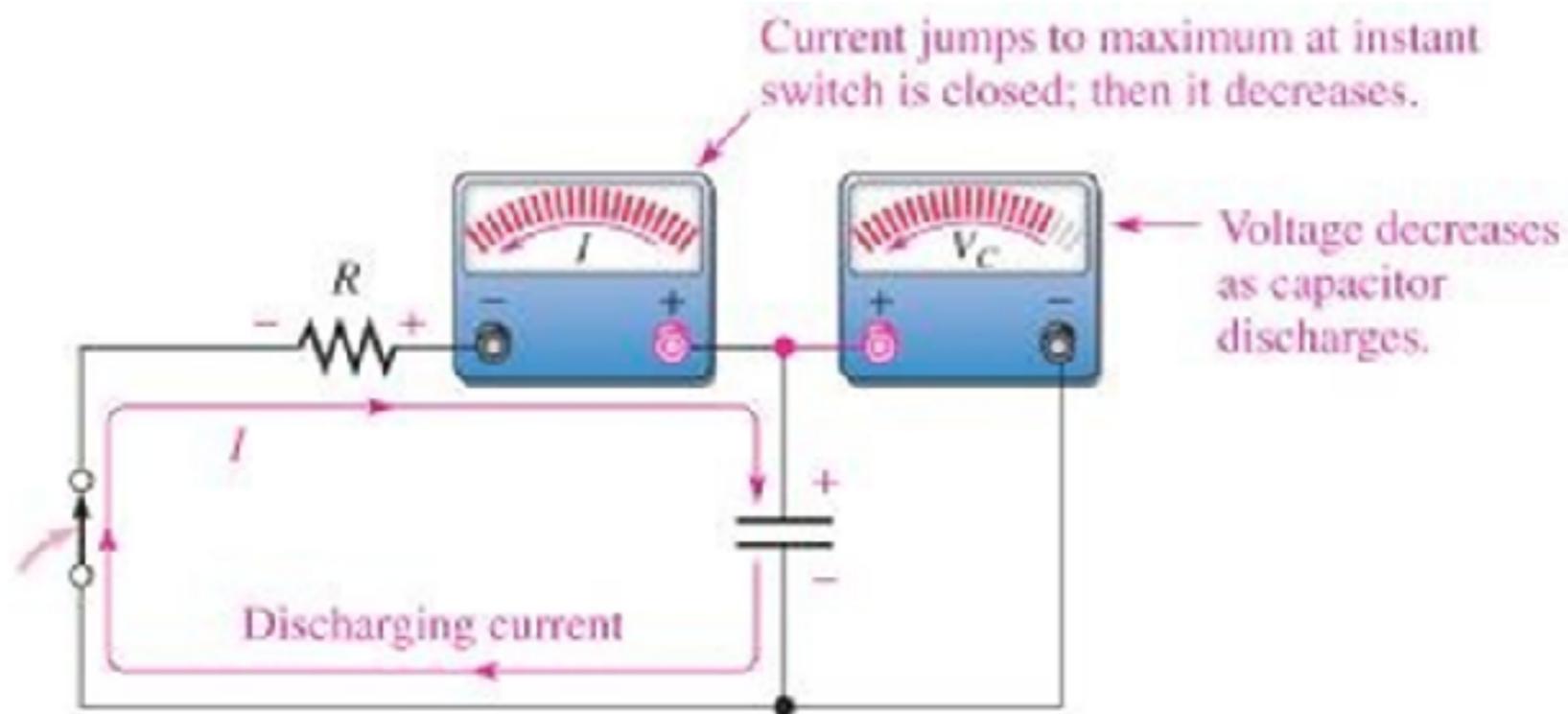


(b) Fully charged: Capacitor voltage equals source voltage.
The current is zero.

$$V_C(\infty) = V_S \left(1 - e^{-\frac{\infty}{RC}} \right) = V_S$$



電容放電

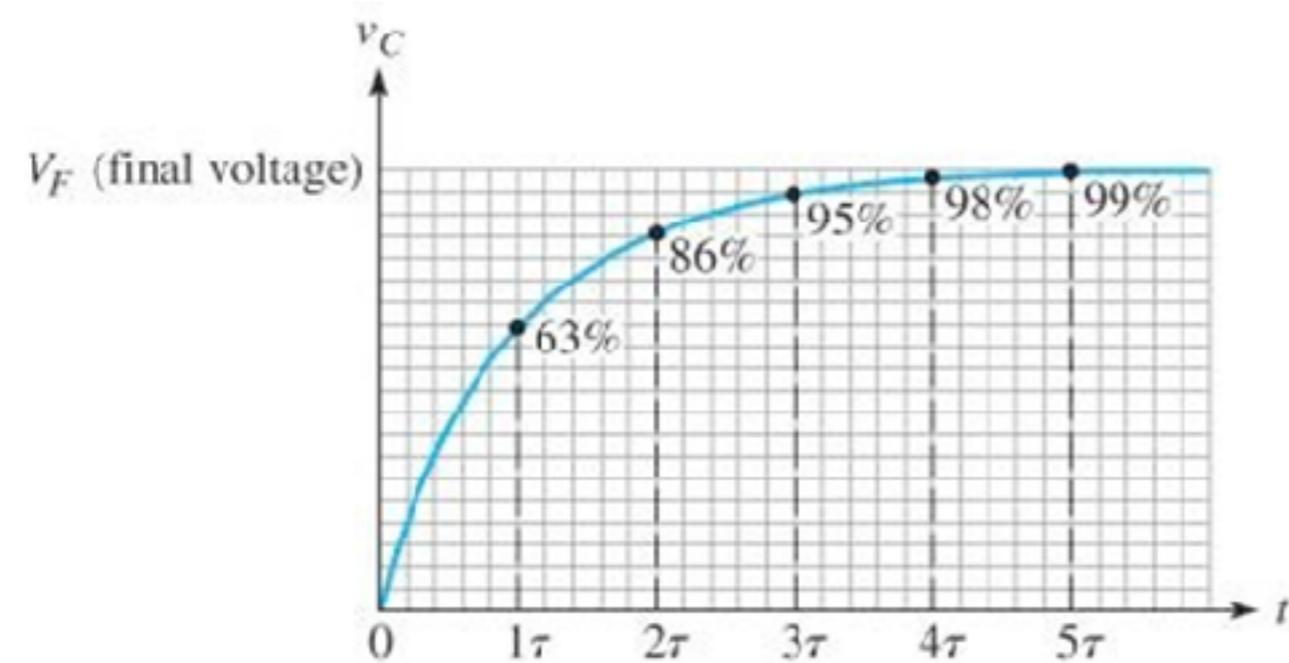


- (c) Discharging: Capacitor voltage, resistor voltage, and the current decrease from their initial maximum values. Note that the discharge current is opposite to the charge current.

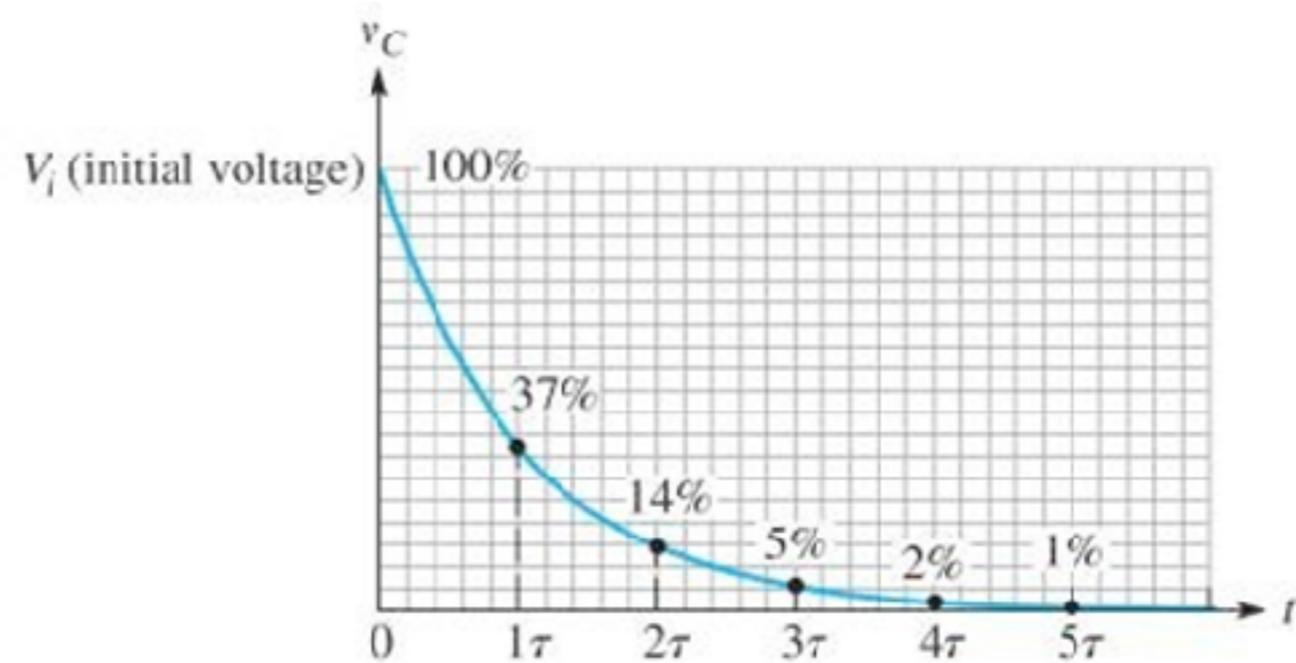
$$V_c(t) = V_s e^{-\frac{t}{RC}}$$



電阻電容時間常數



(a) Charging curve with percentages of the final voltage



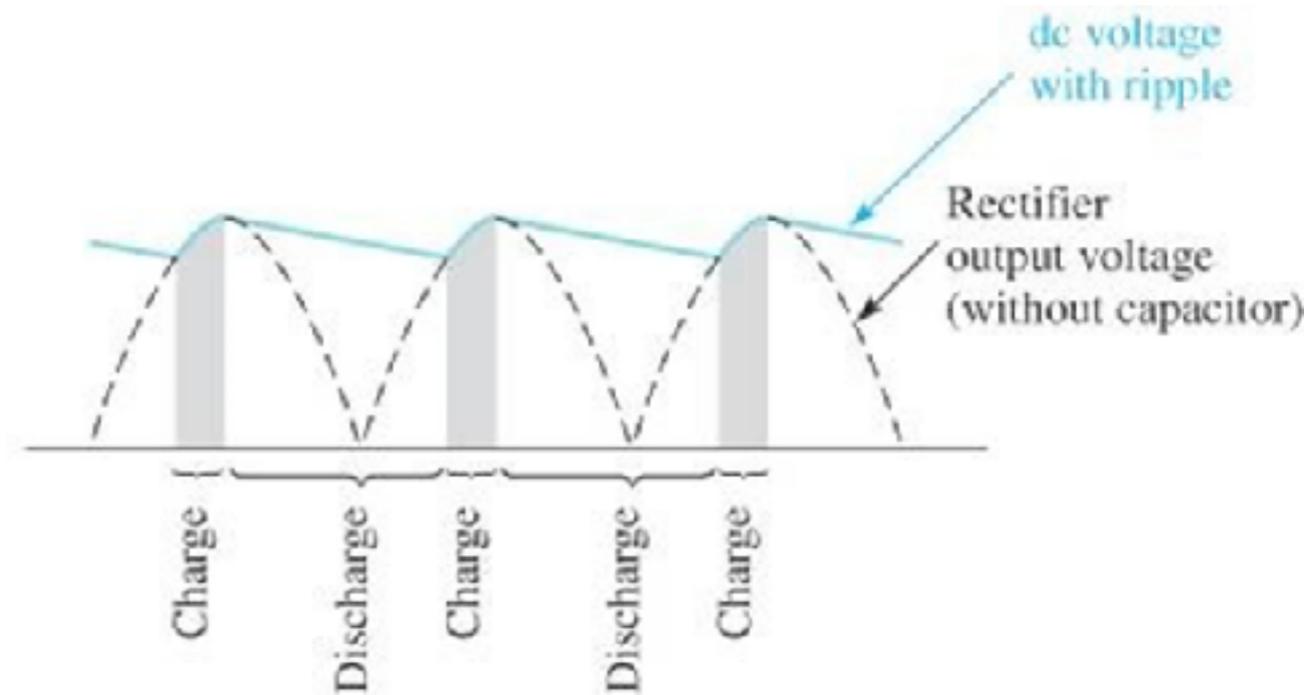
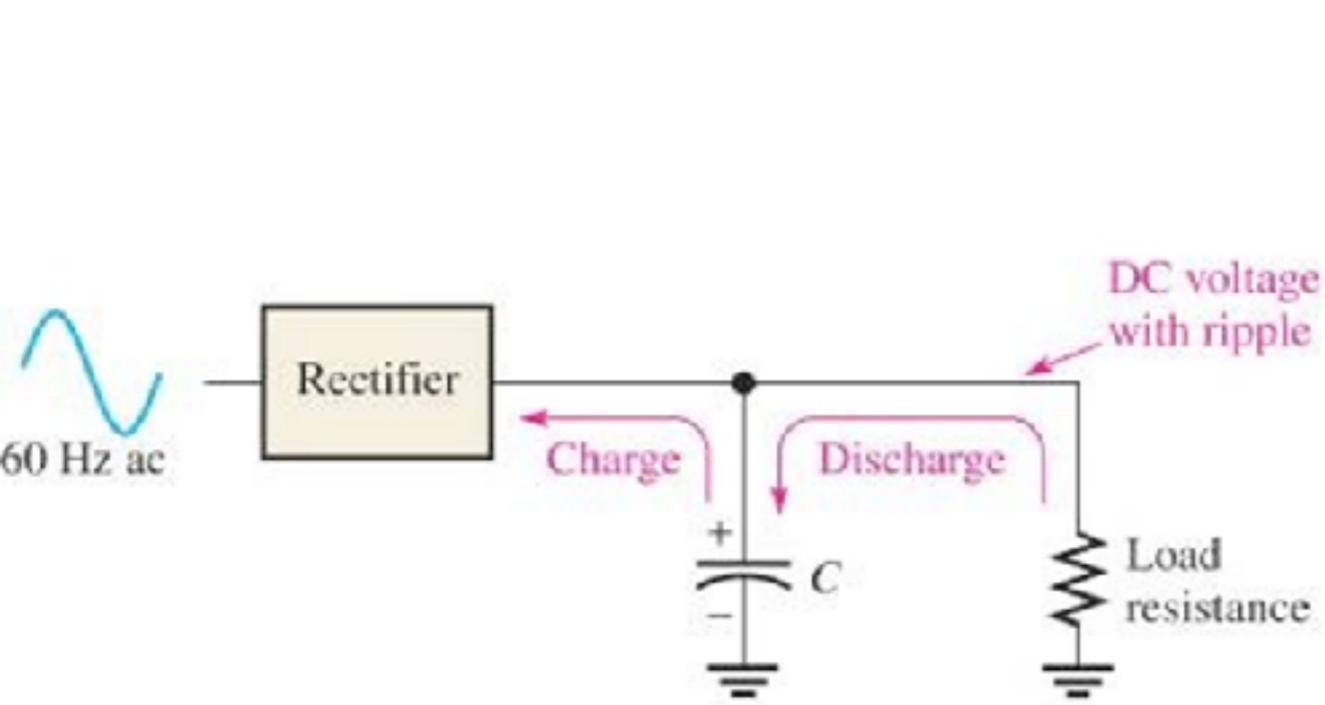
(b) Discharging curve with percentages of the initial voltage

$$\tau = RC$$



電源濾波

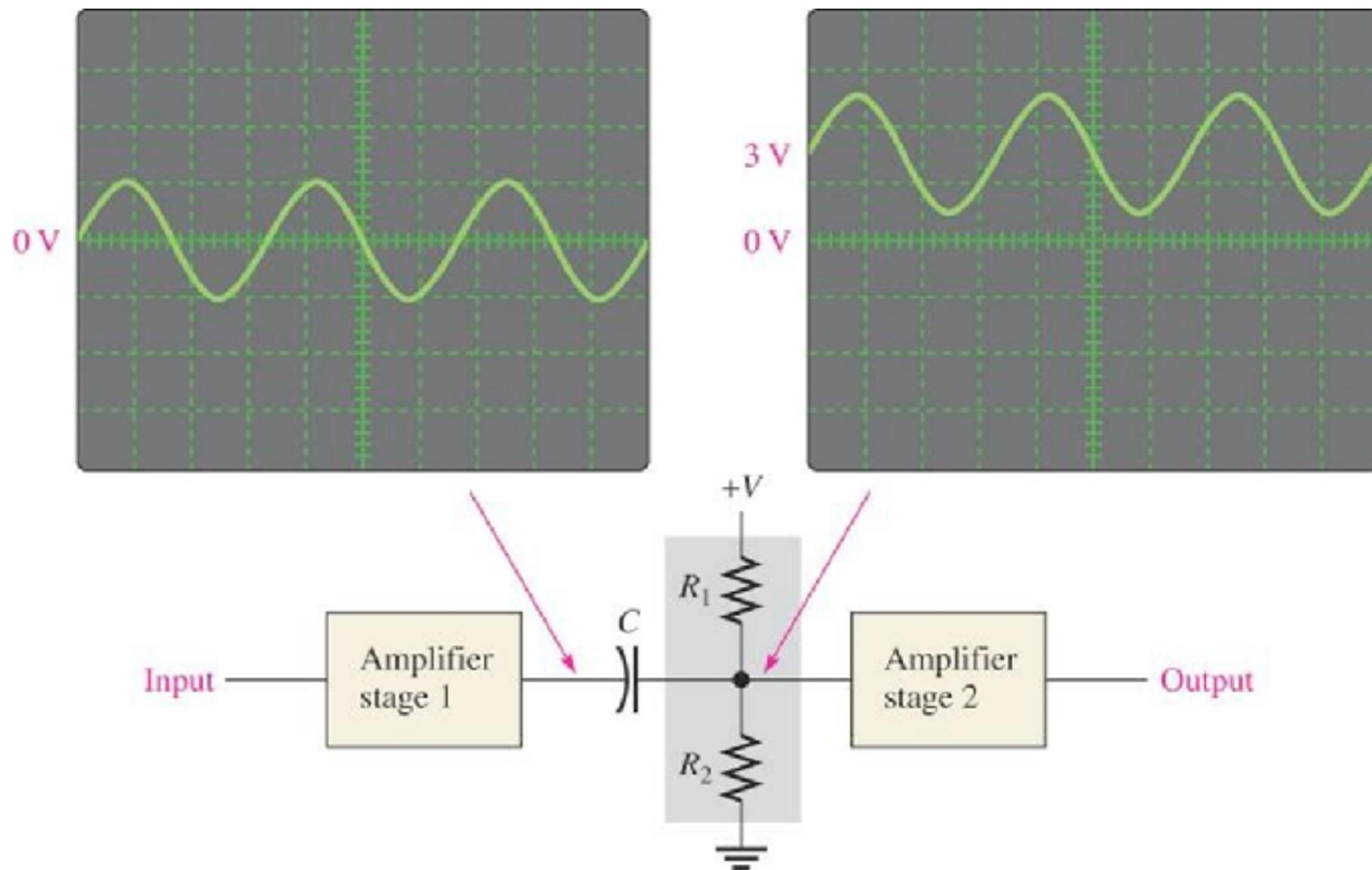
- 透過電容濾波將整流器的輸出電壓轉為直流電壓
- 越良好的電源供應器，產生的擾動越小





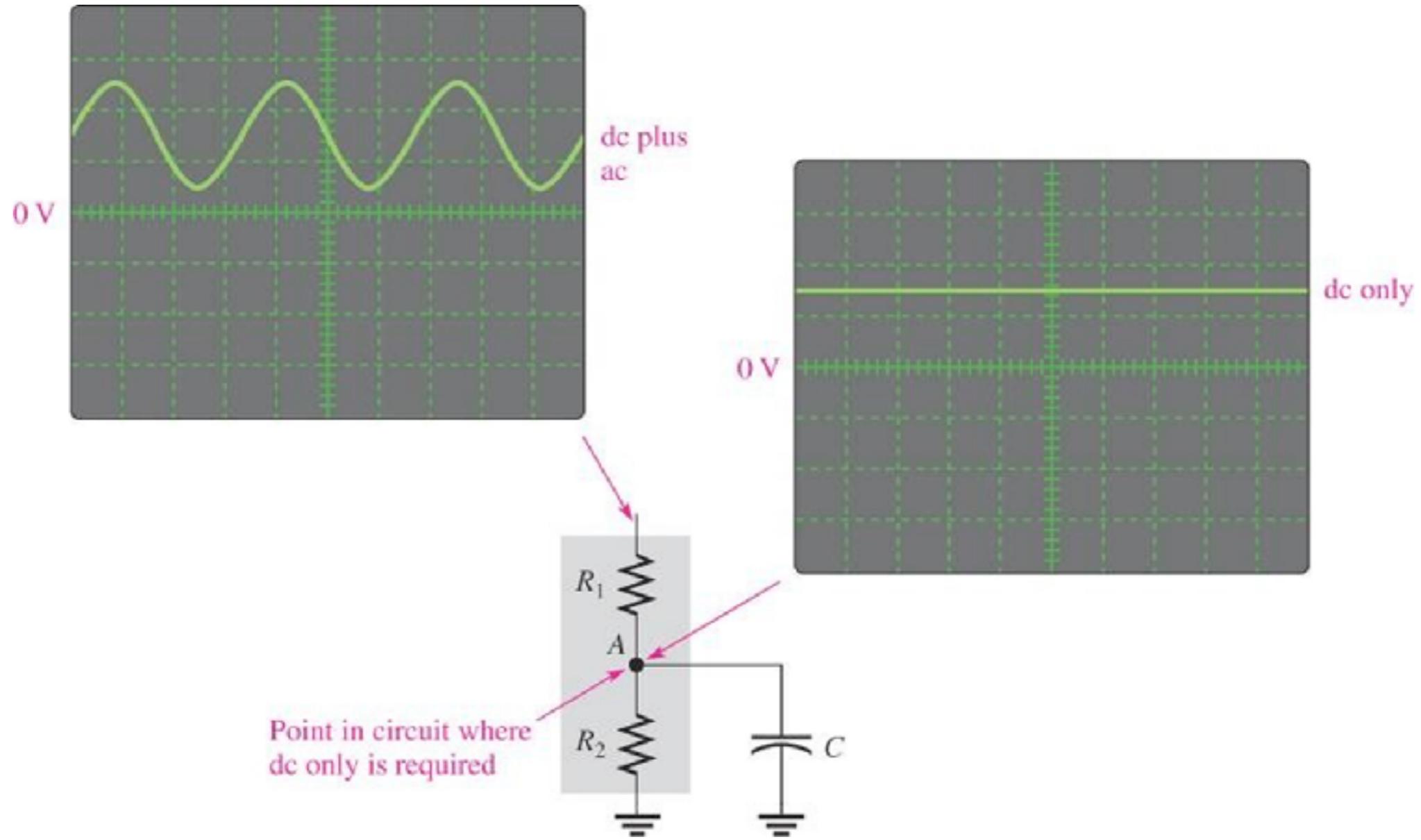
電容濾波

- 開路直流訊號
- 短路交流訊號



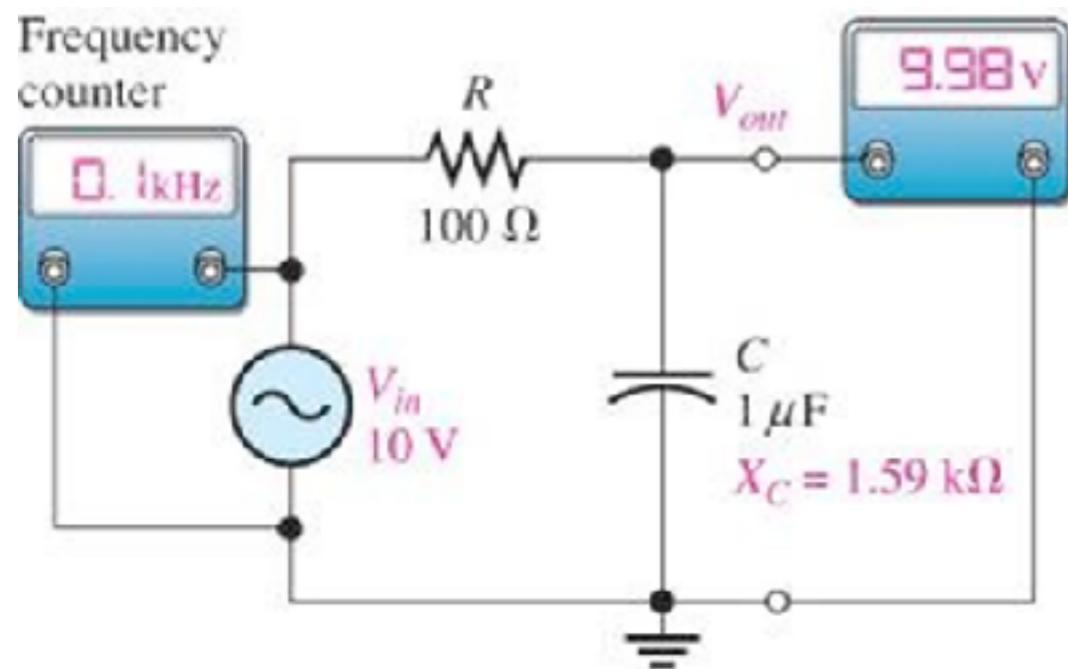


電容濾波

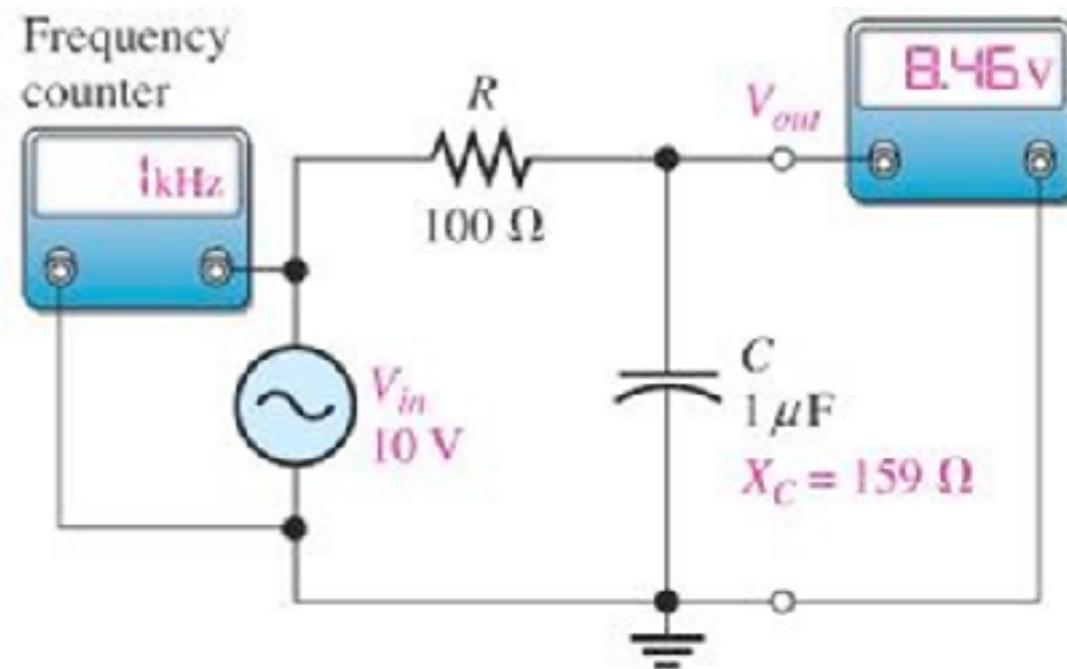




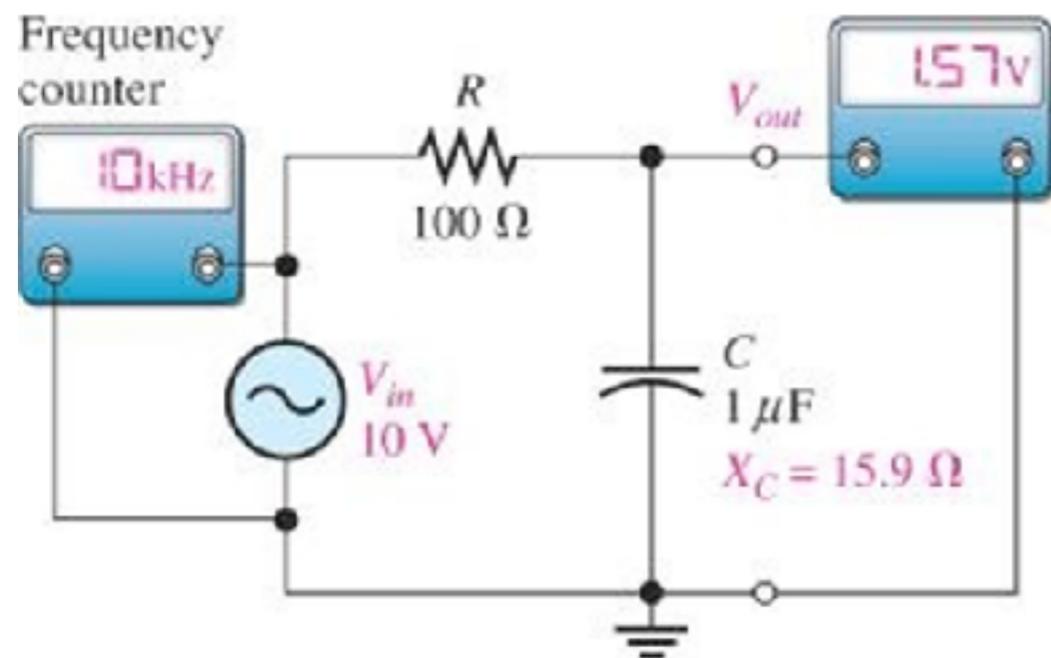
低通濾波器



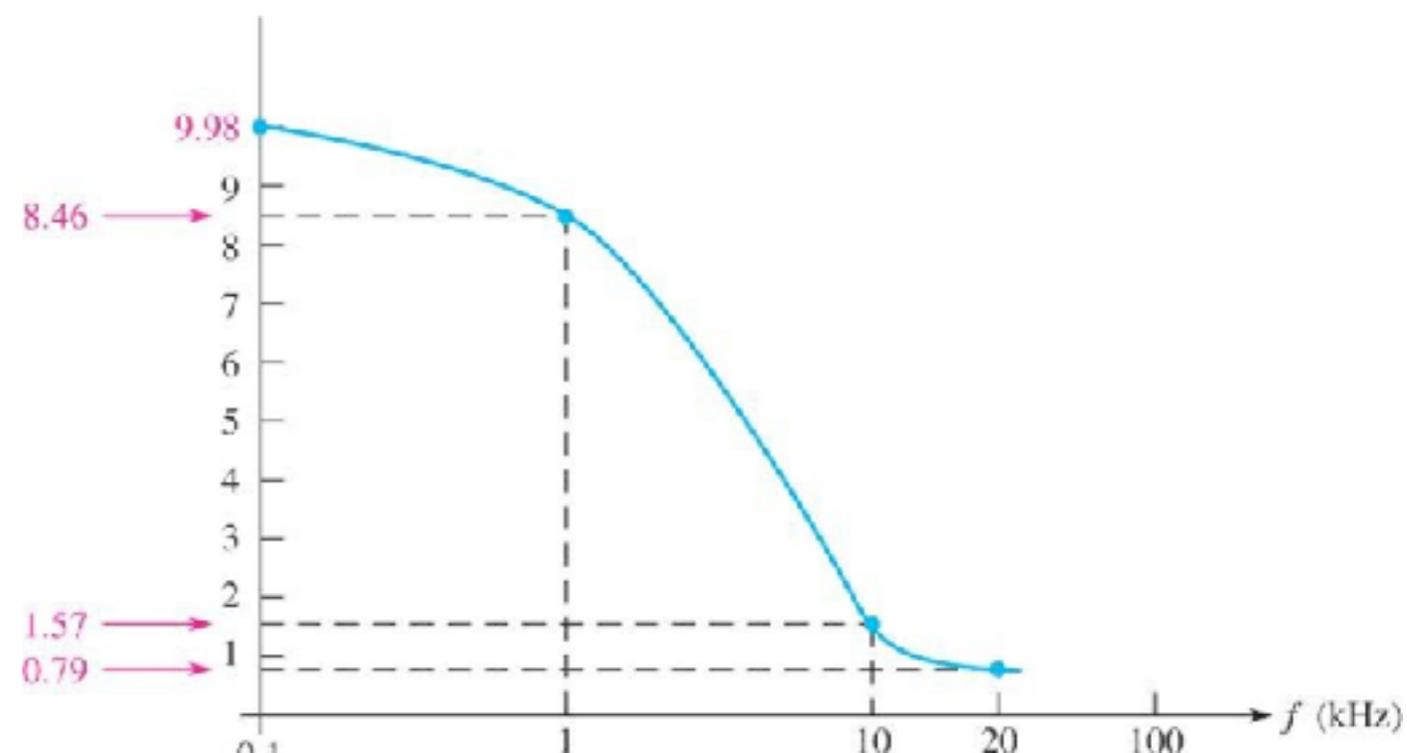
(a) $f = 0.1\ \text{kHz}$, $X_C = 1.59\ \text{k}\Omega$, $V_{out} = 9.98\ \text{V}$



(b) $f = 1\ \text{kHz}$, $X_C = 159\ \Omega$, $V_{out} = 8.46\ \text{V}$

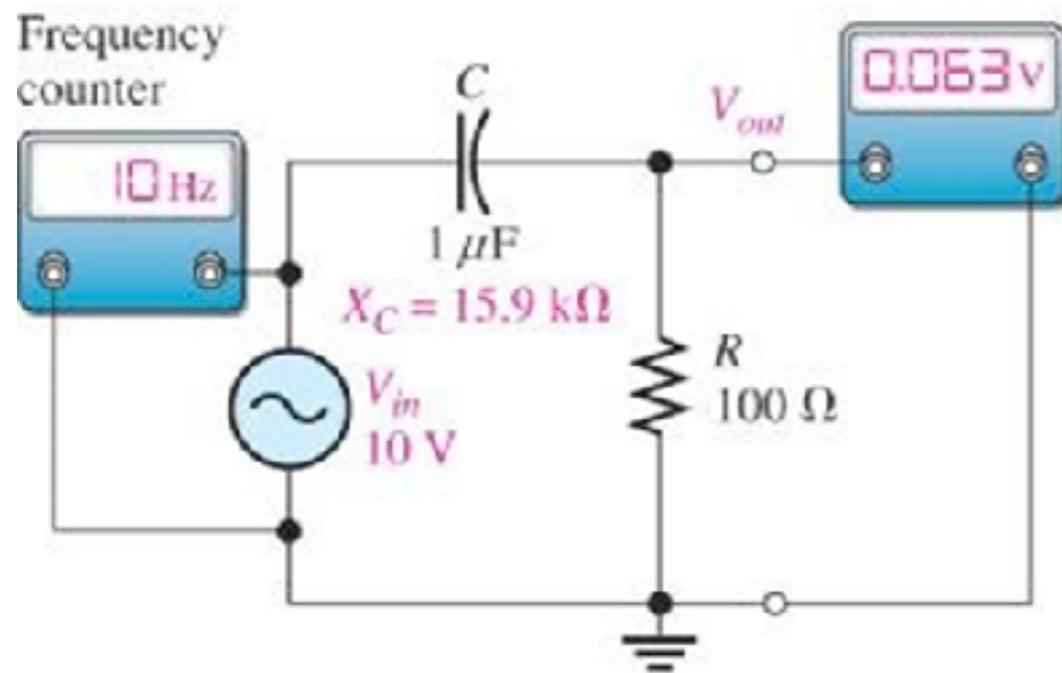


(c) $f = 10\ \text{kHz}$, $X_C = 15.9\ \Omega$, $V_{out} = 1.57\ \text{V}$

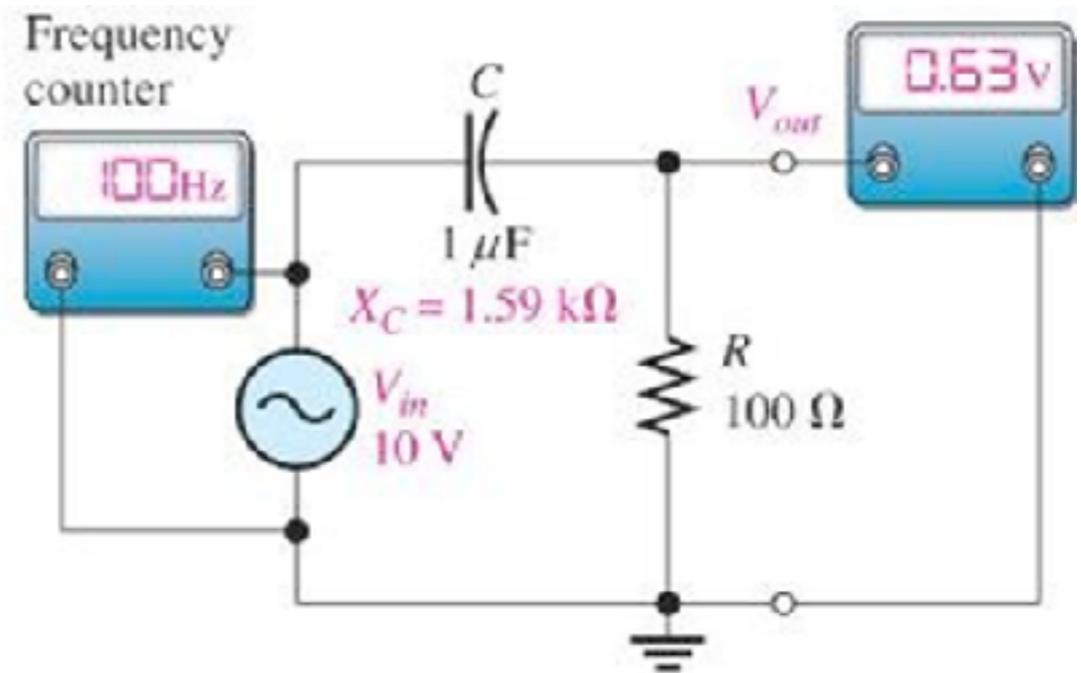




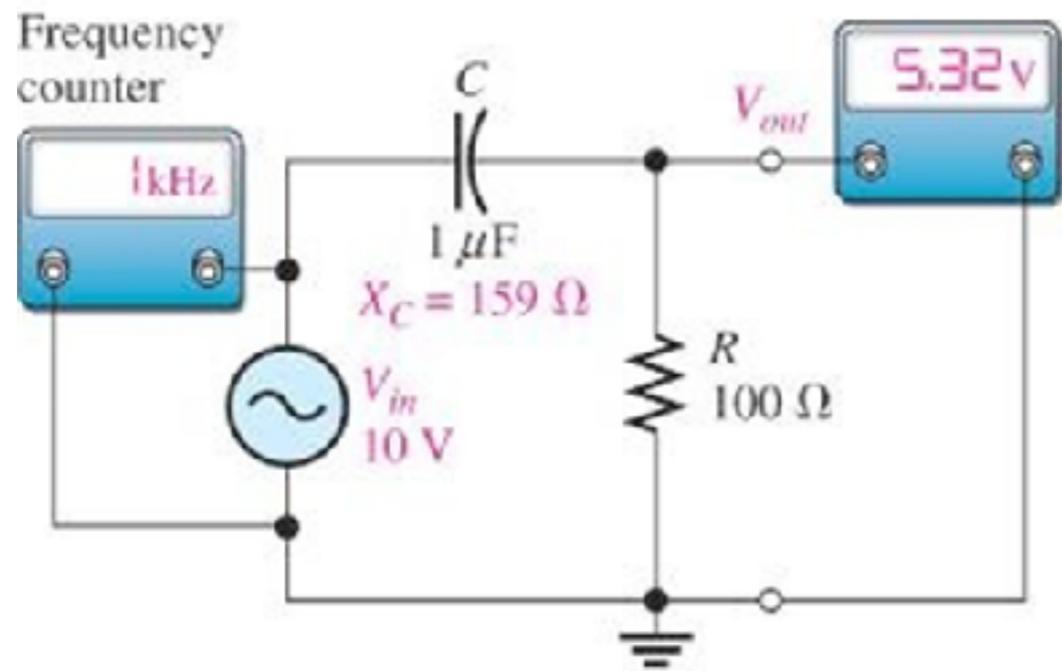
高通濾波器



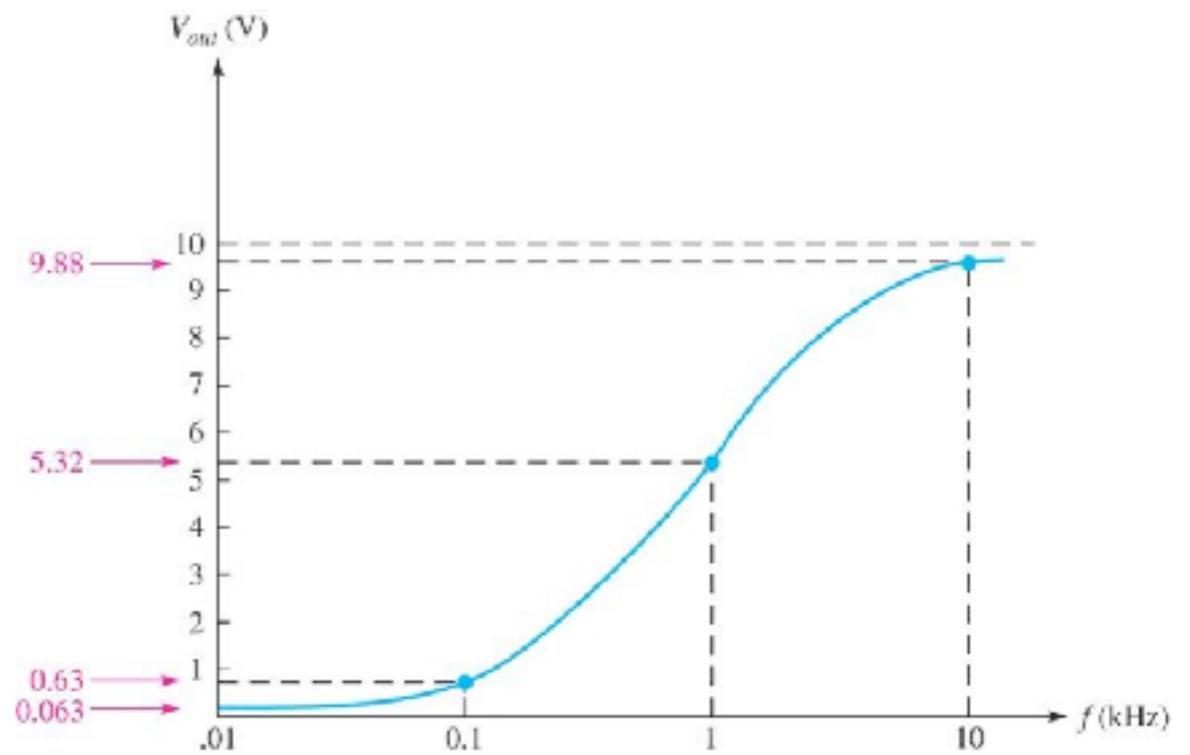
(a) $f = 10 \text{ Hz}$, $X_C = 15.9 \text{ k}\Omega$, $V_{out} = 0.063 \text{ V}$



(b) $f = 100 \text{ Hz}$, $X_C = 1.59 \text{ k}\Omega$, $V_{out} = 0.63 \text{ V}$

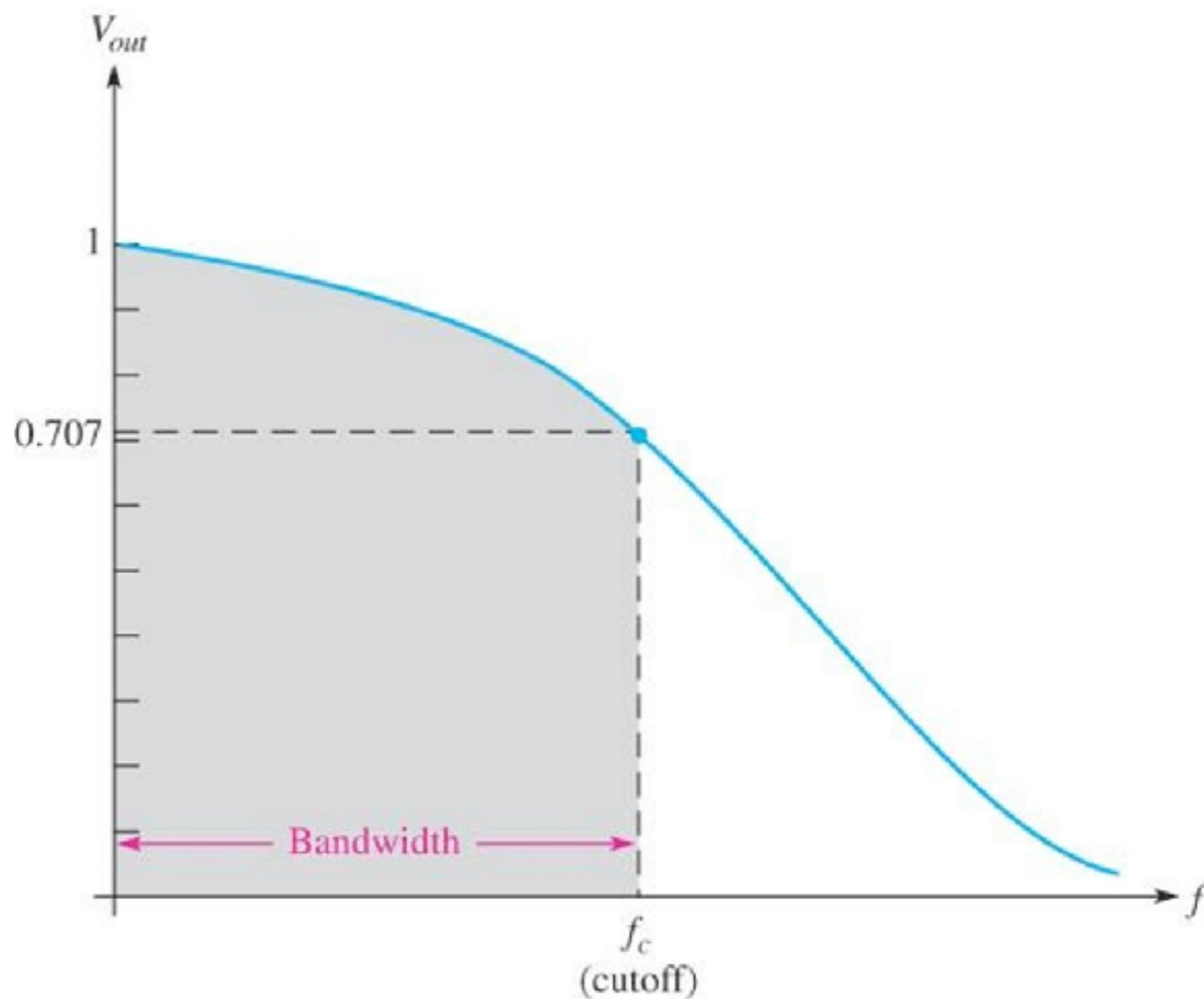


(c) $f = 1 \text{ kHz}$, $X_C = 159 \Omega$, $V_{out} = 5.32 \text{ V}$





截止頻率與頻寬



$$f_c = \frac{1}{2\pi RC}$$



運算放大器

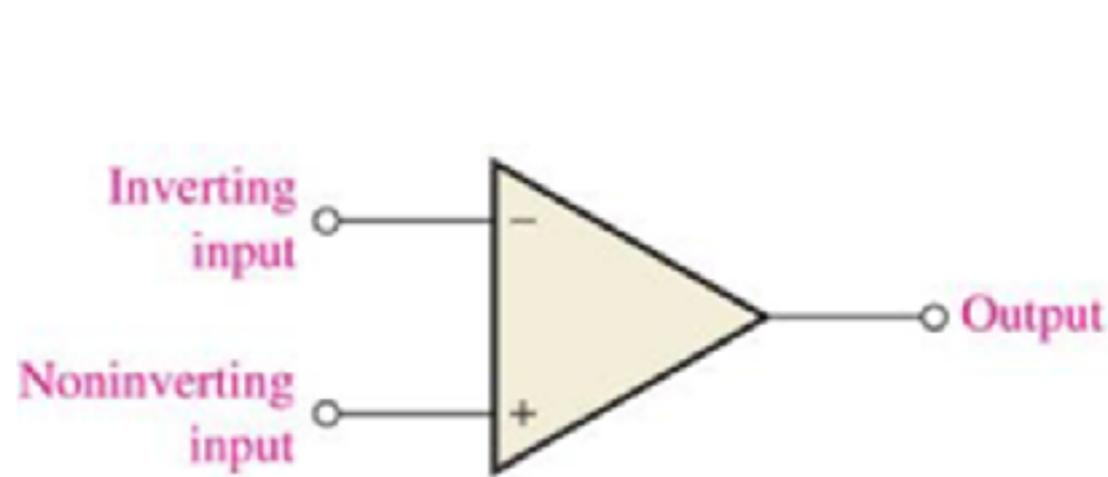


運算放大器

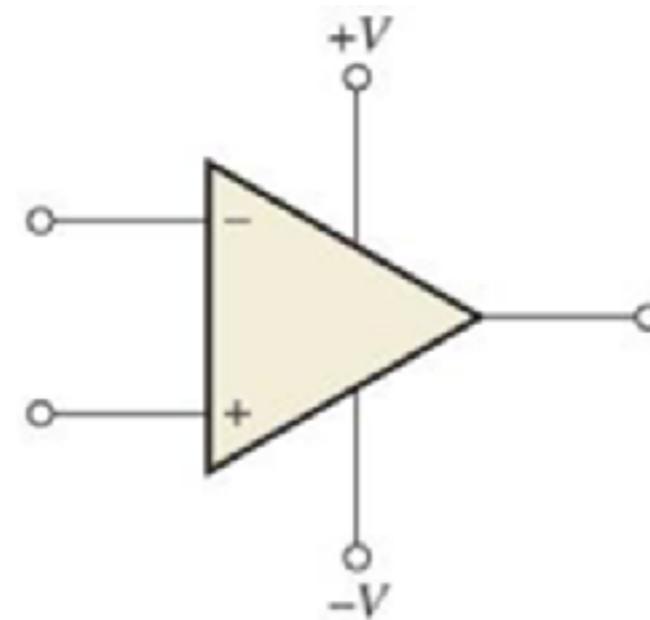
- 運算放大器 (op-amp) 為一種多功能的積體電路 (IC) 。運算放大器需要電源才能正常運作。
- 運算放大器最基本的電路為負回授 (negative feedback) 組態。



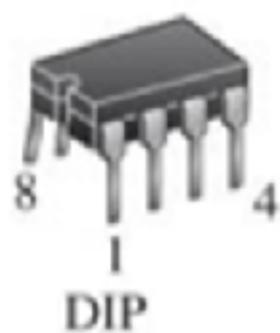
運算放大器的符號表示與多種封裝



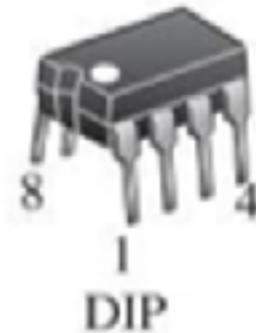
(a) Symbol



(b) Symbol with dc supply connections



DIP



DIP



SOIC



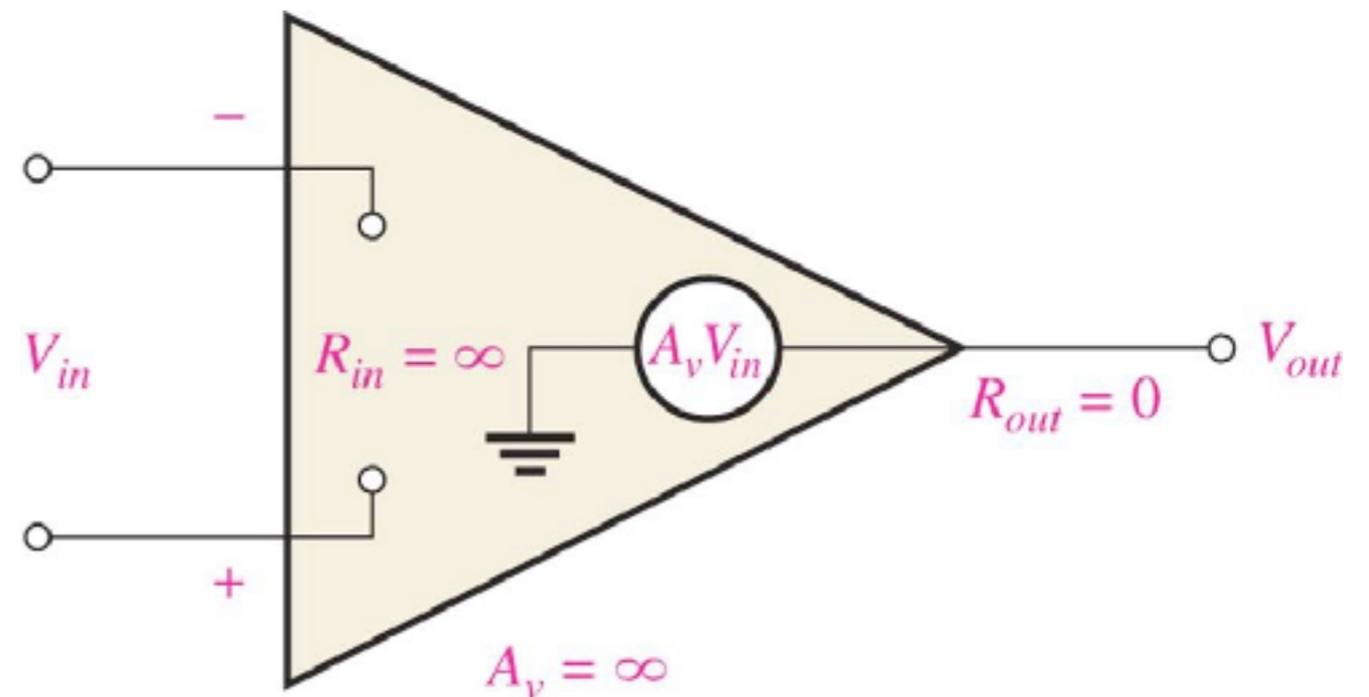
PLCC

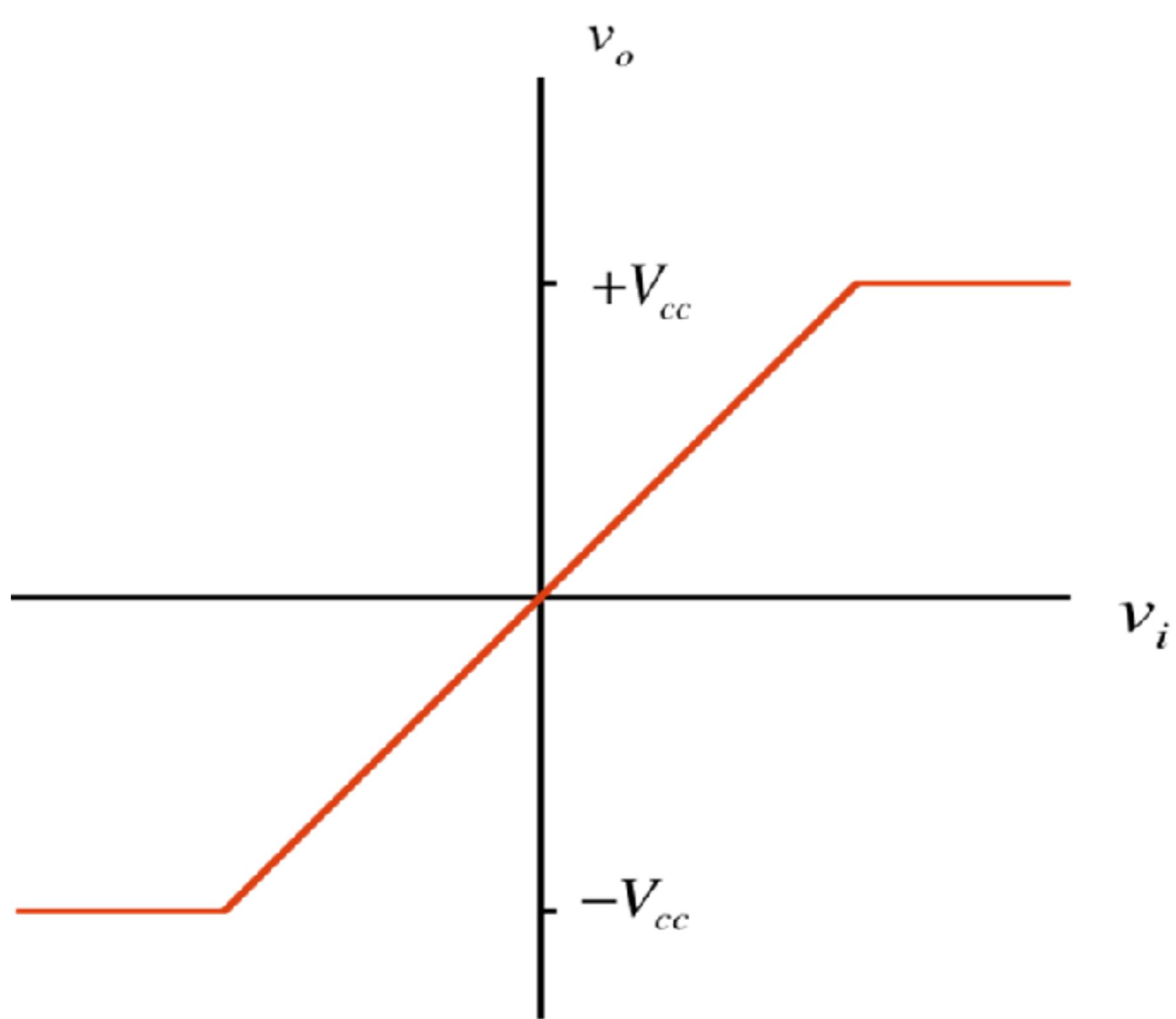
(c) Typical packages. Looking from the top, pin 1 always is to the left of the notch or dot on the DIP and SOIC packages. The dot indicates pin 1 on the plastic-leaded chip carrier (PLCC) package.



理想的運算放大器

- 理想的運算放大器，其兩個輸入端 (V_+ 、 V_-) 不會有電流流入或流出。
- 輸出阻抗等於0
- 運算放大器的輸出電壓 (V_{OUT}) 永遠會被其電源所限制。

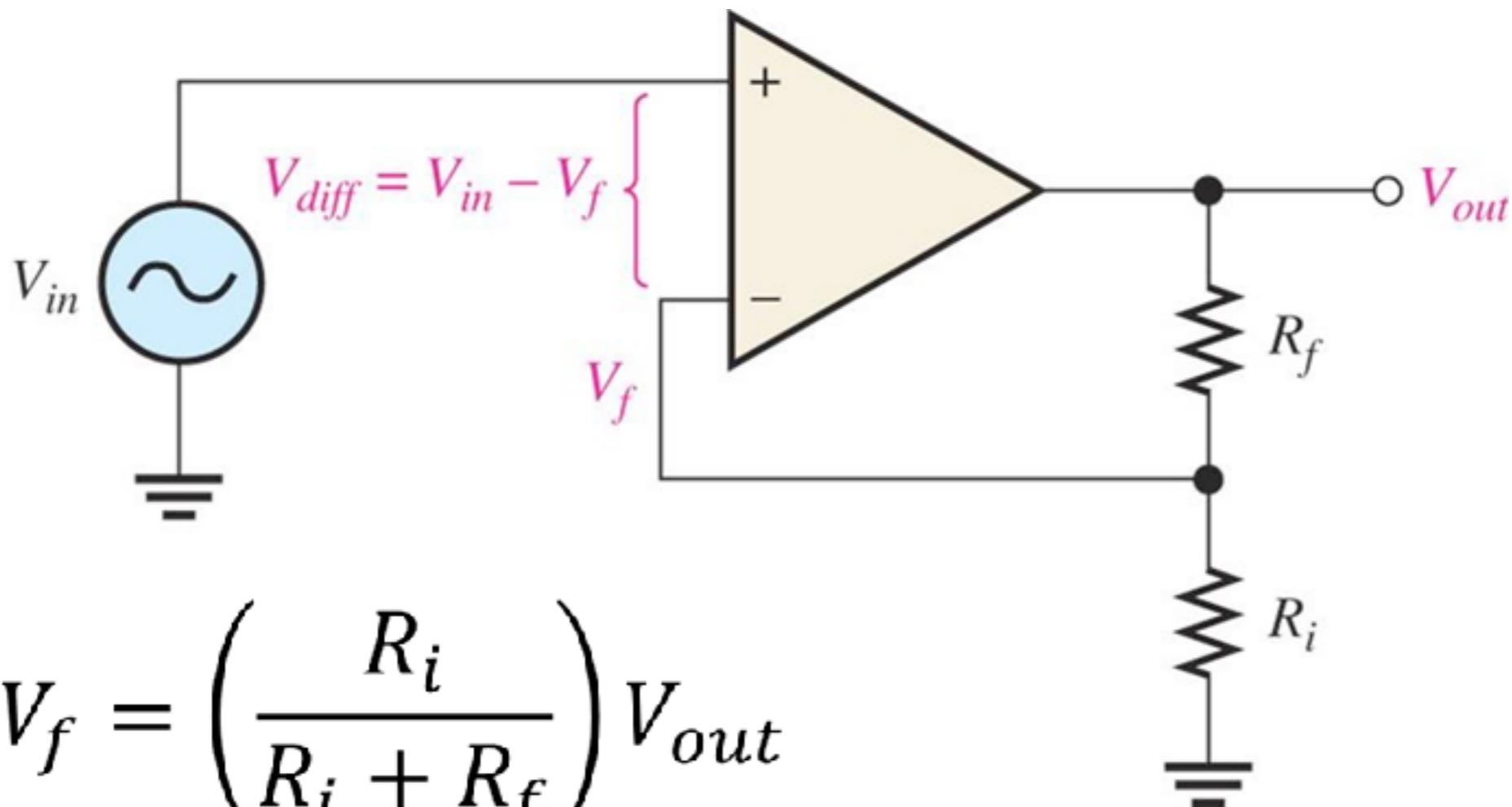




- 理想運算放大器的輸出極限受到其電源的影響



非反向放大器



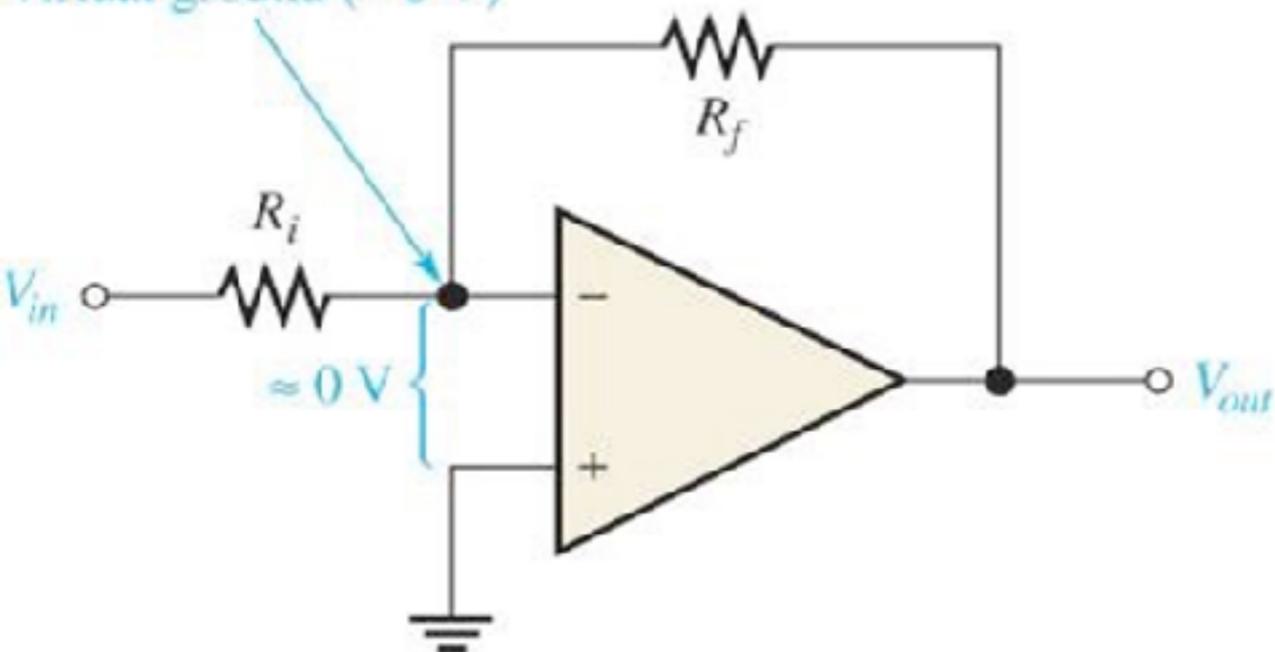
$$V_{in} \sim V_f = \left(\frac{R_i}{R_i + R_f} \right) V_{out}$$

$$V_{out} = \frac{R_i + R_f}{R_i} V_{in} = \left(1 + \frac{R_f}{R_i} \right) V_{in}$$

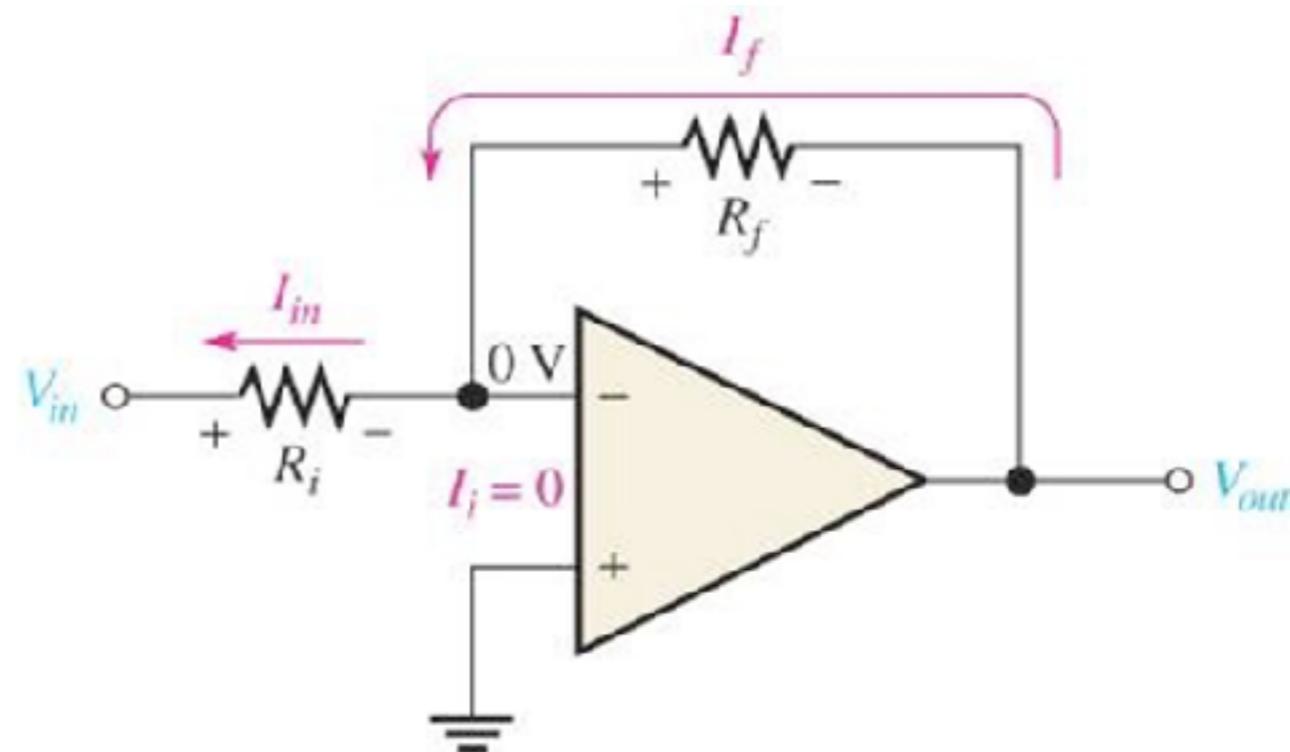


反向放大器

Virtual ground ($\approx 0\text{ V}$)



(a) Virtual ground



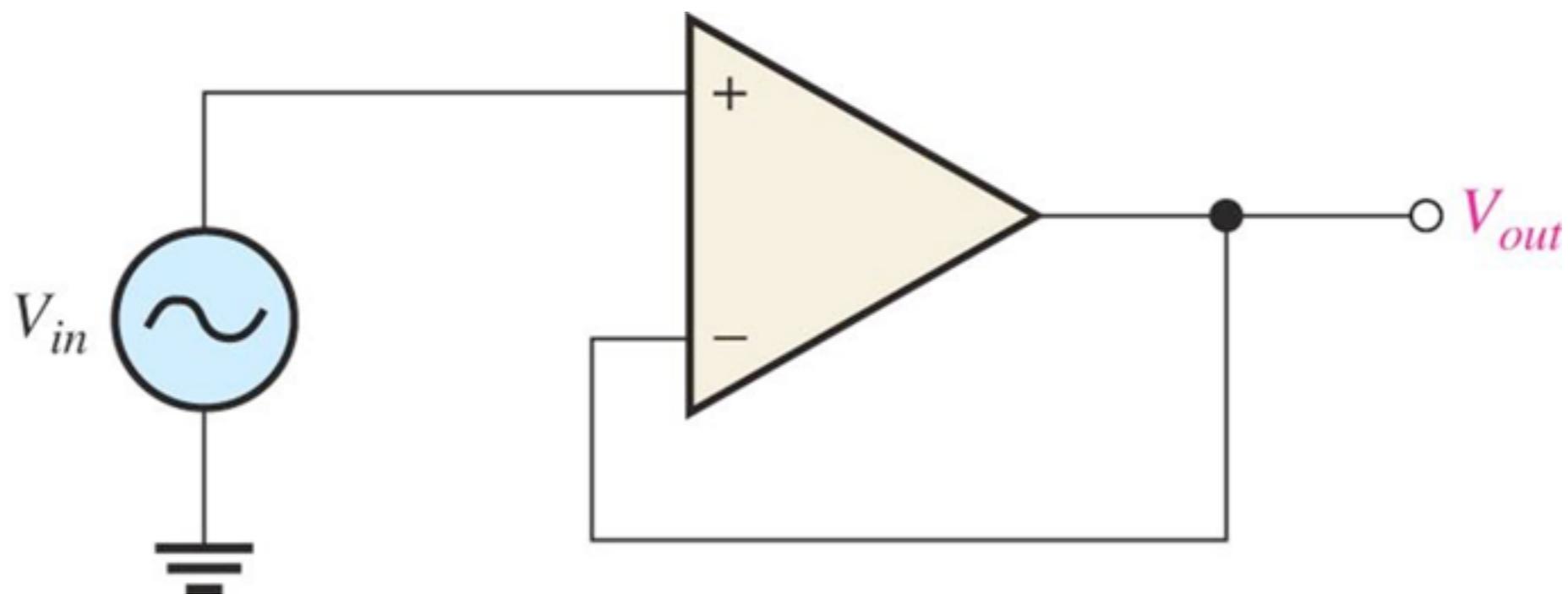
(b) $I_{in} = I_f$ and current at the inverting input, $I_i = 0$

$$I_{in} = I_f \rightarrow \frac{V_{in}}{R_i} = -\frac{V_{out}}{R_f}$$

$$V_{out} = -\frac{R_f}{R_i} V_{in}$$



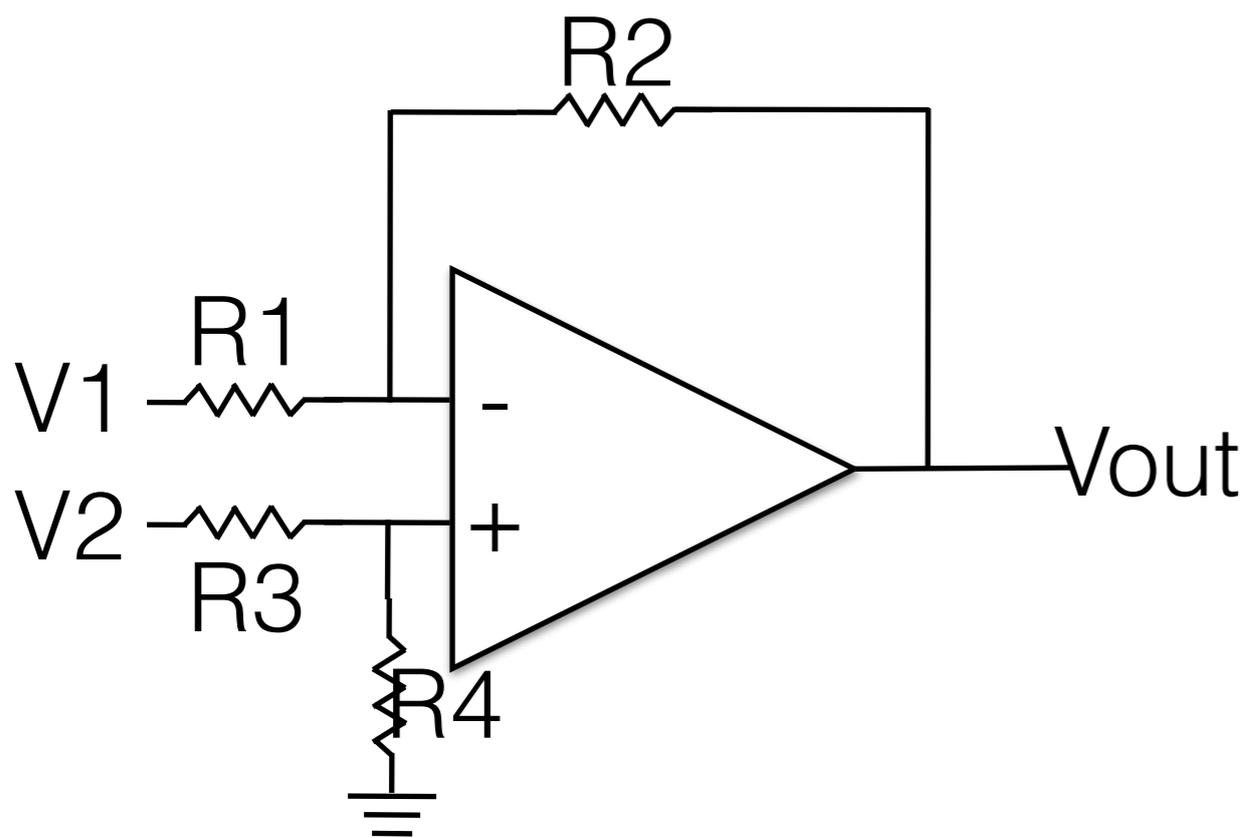
電壓追隨器 (緩衝器)



$$V_{out} = V_{in}$$



差值放大器



$$V_+ = \frac{R_4}{R_3 + R_4} V_2 = V_-$$

$$V_{OUT} - V_- = -\frac{R_2}{R_1} (V_1 - V_-)$$

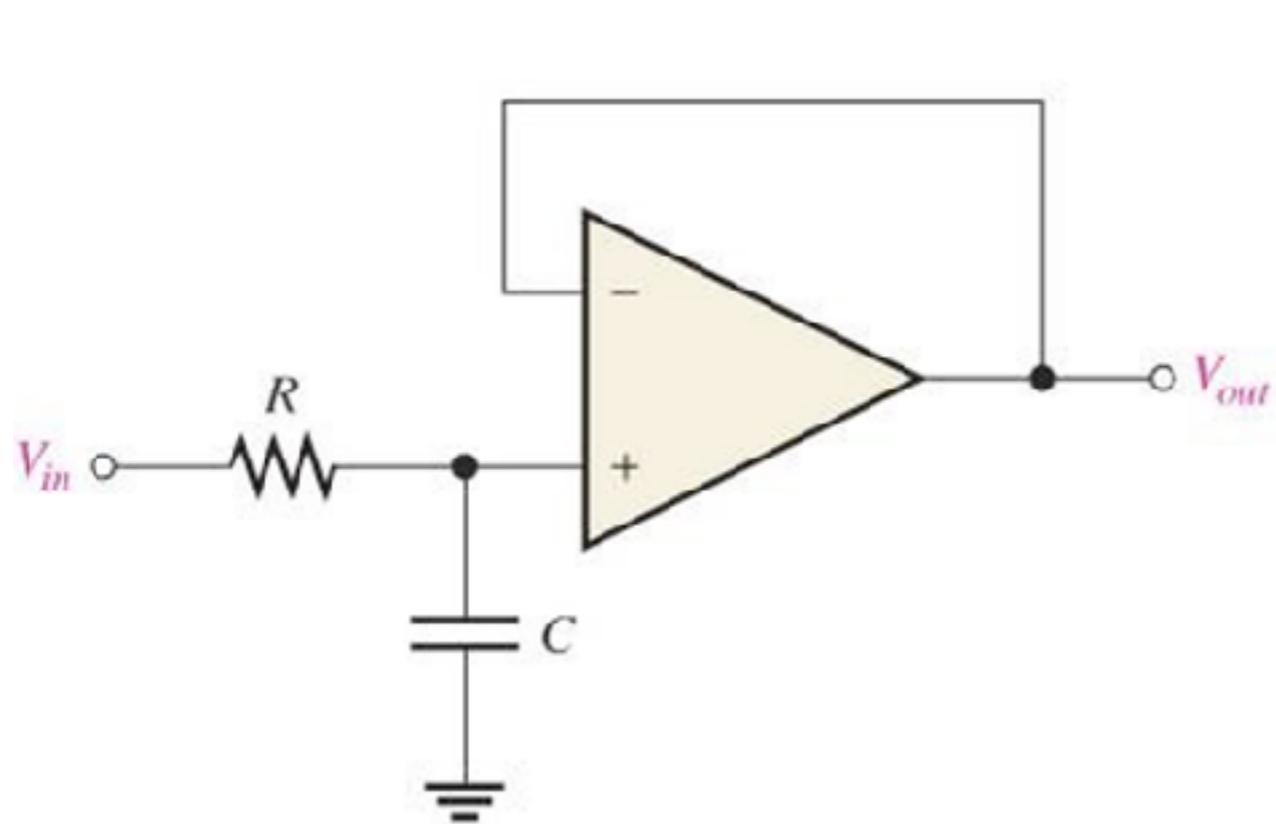
$$\Rightarrow V_{OUT} = \frac{R_1 + R_2}{R_1} V_- - \frac{R_2}{R_1} V_1$$

$$\text{Replace } V_- : V_{OUT} = \left(\frac{R_1 + R_2}{R_3 + R_4} \right) \frac{R_4}{R_1} V_2 - \frac{R_2}{R_1} V_1$$

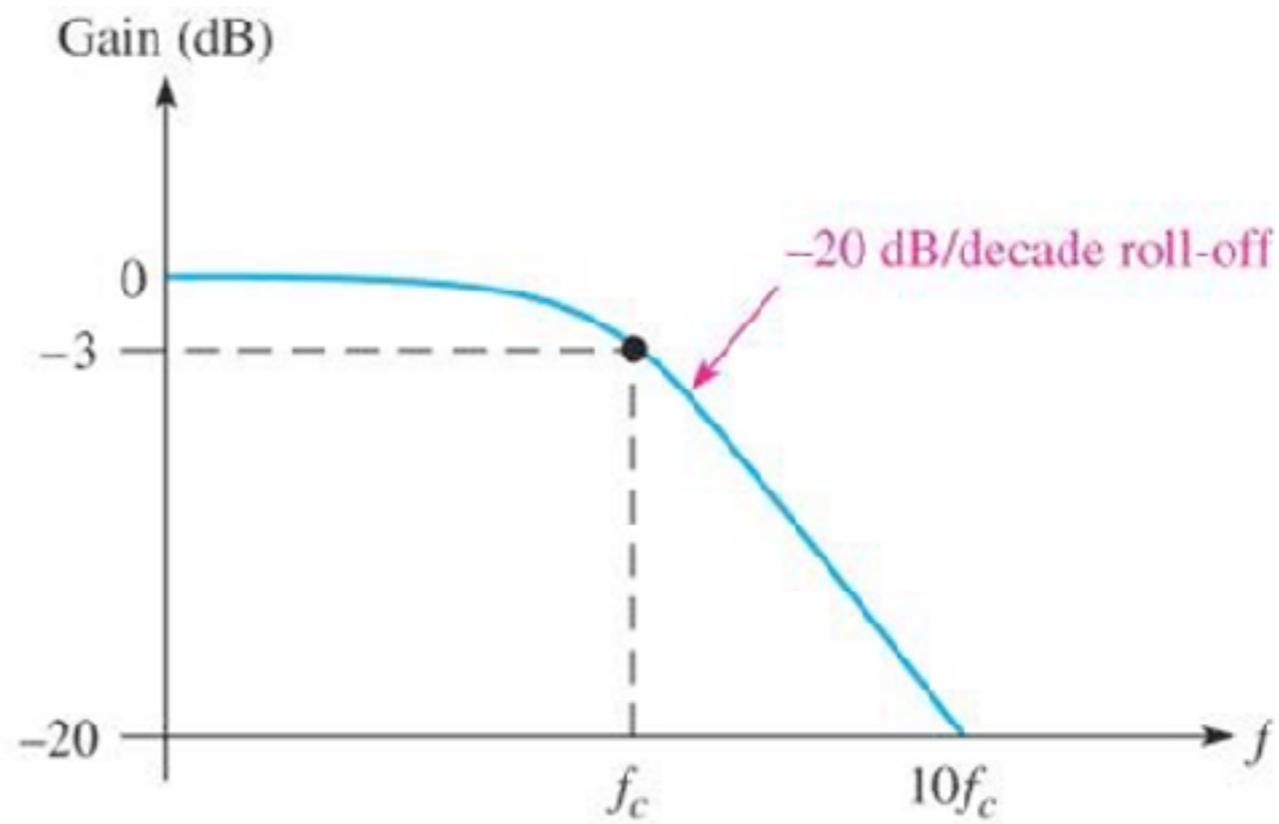
$$\text{set: } R_1 = R_3, R_2 = R_4 \rightarrow \frac{R_2}{R_1} (V_2 - V_1)$$



一階低通濾波器



(a)

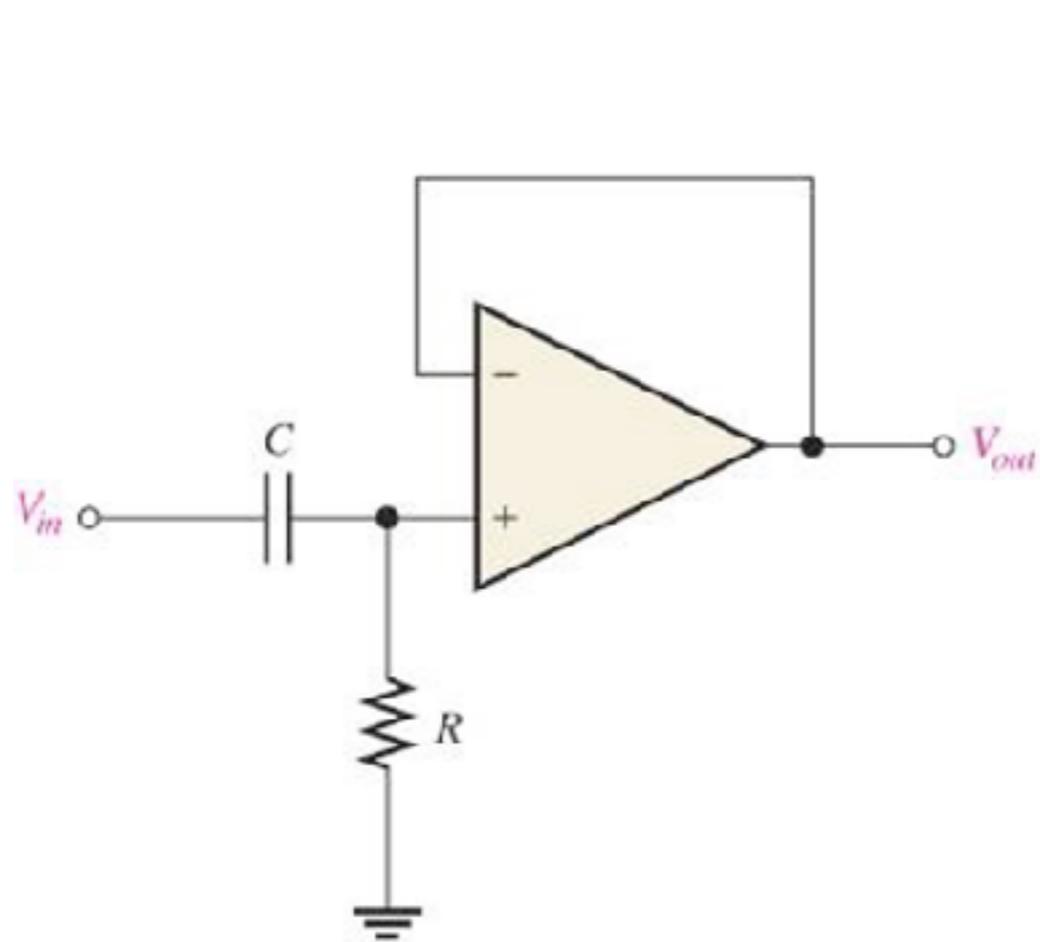


(b)

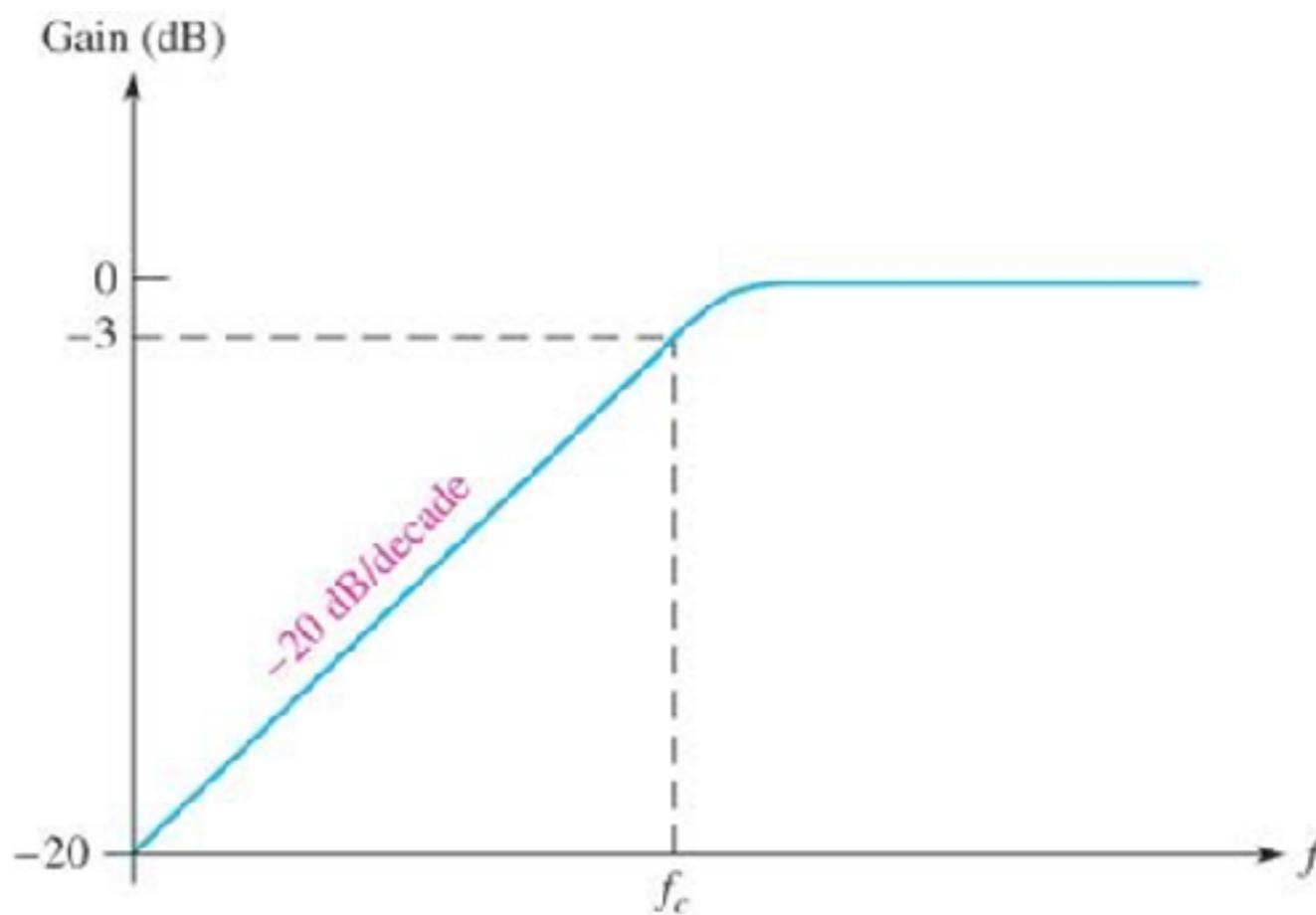
$$f_c = \frac{1}{2\pi RC}$$



一階高通濾波器



(a)

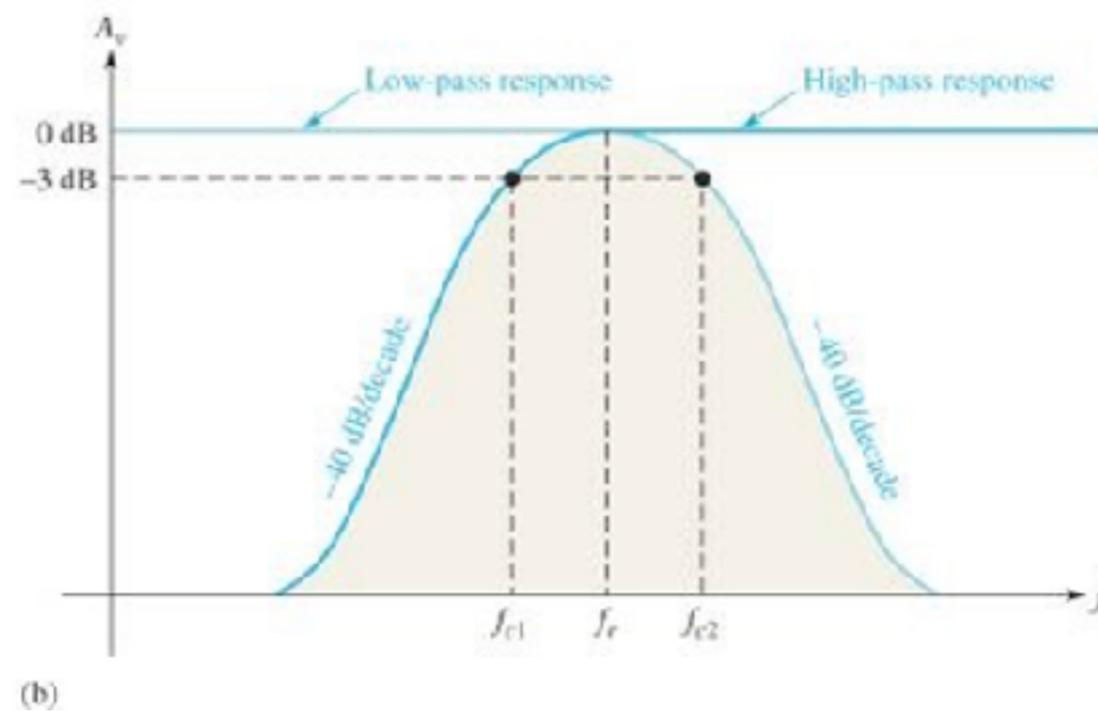
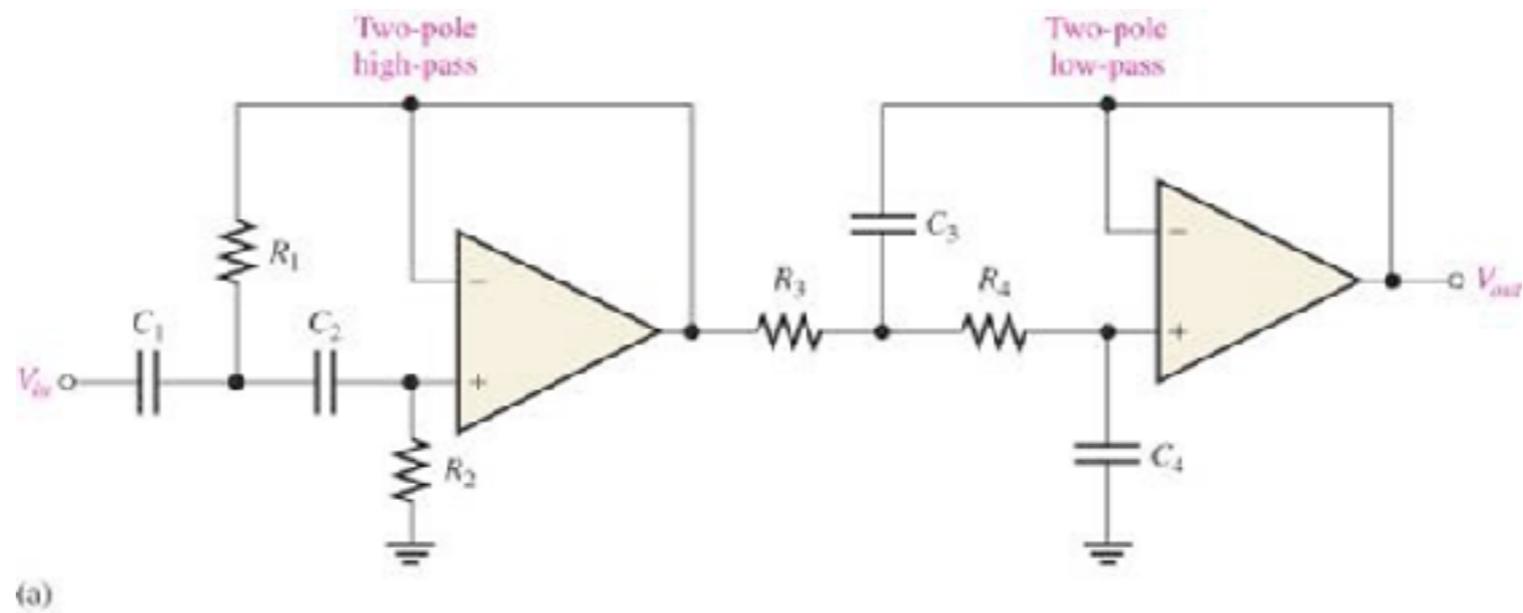


(b)

$$f_c = \frac{1}{2\pi RC}$$



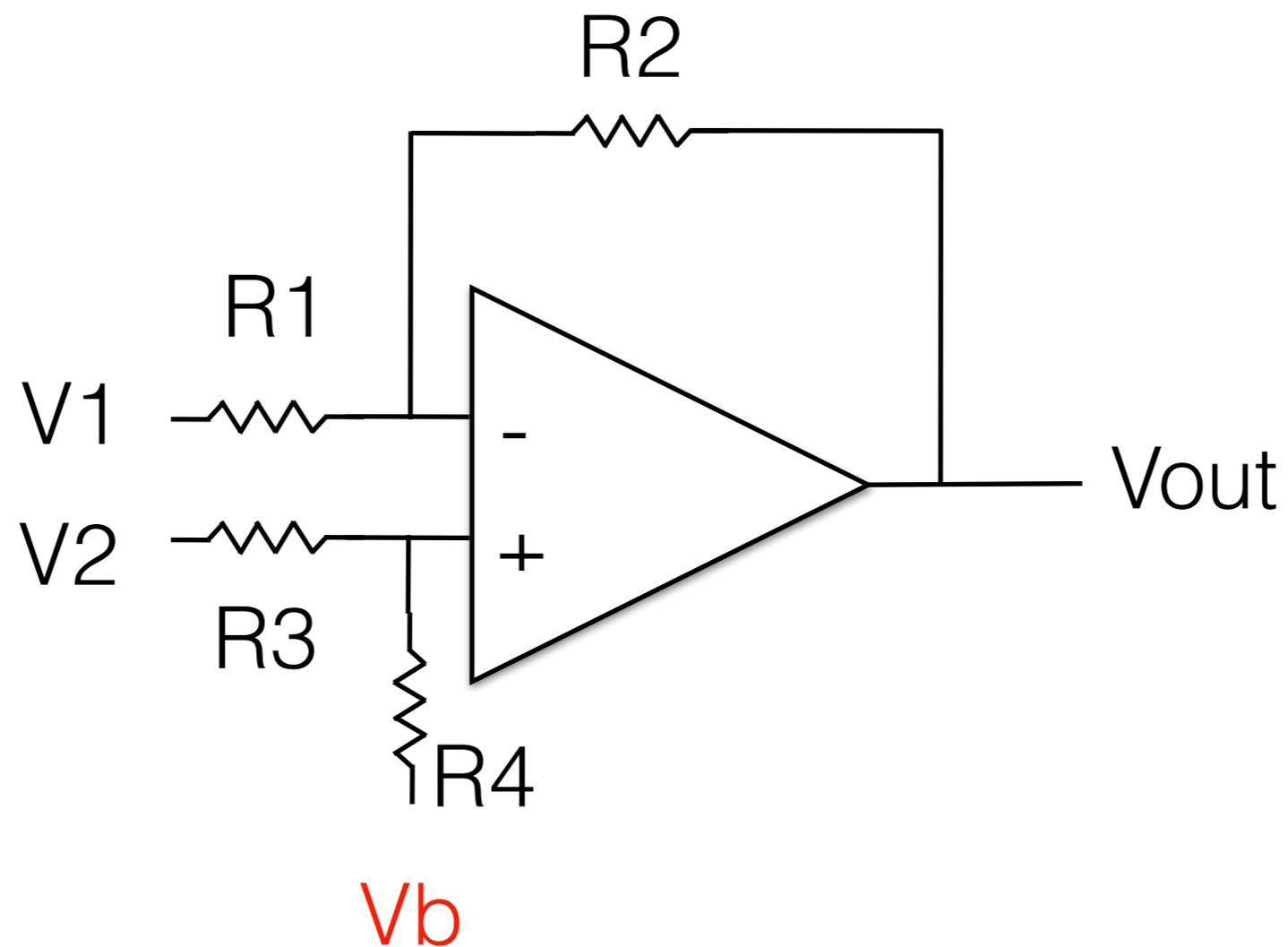
帶通濾波器





練習題#3

- 圖中為一差值放大器，若 $R4$ 之接地點電壓改為 V_b 。試推算兩輸入端點 $V1$ 、 $V2$ 與輸出 V_{OUT} 的關係？



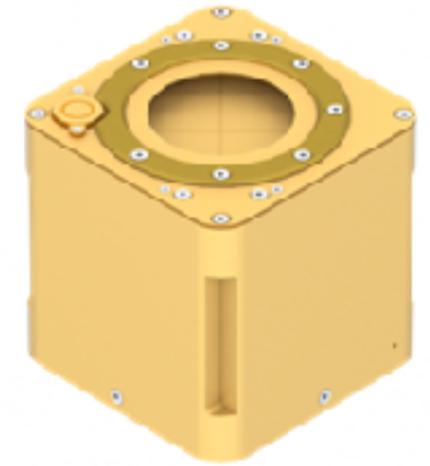


參考文獻

- Electric Circuits Fundamentals, the 8th edition, by Thomas L. Floyd



AIP 量測原理簡介



電漿探針電極

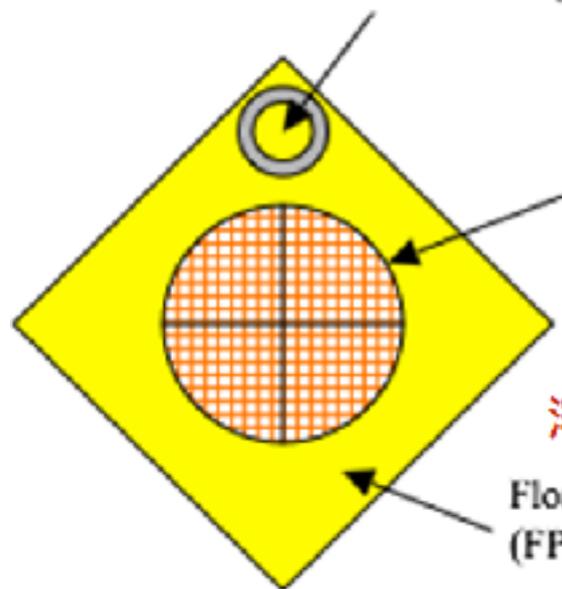
Planar Langmuir Probe
Electrode (PLP, -10 to +10 V)

電漿入口

Entrance
Opening

浮動電位裝置

Floating Potential Plate
(FPP, V_{FP})

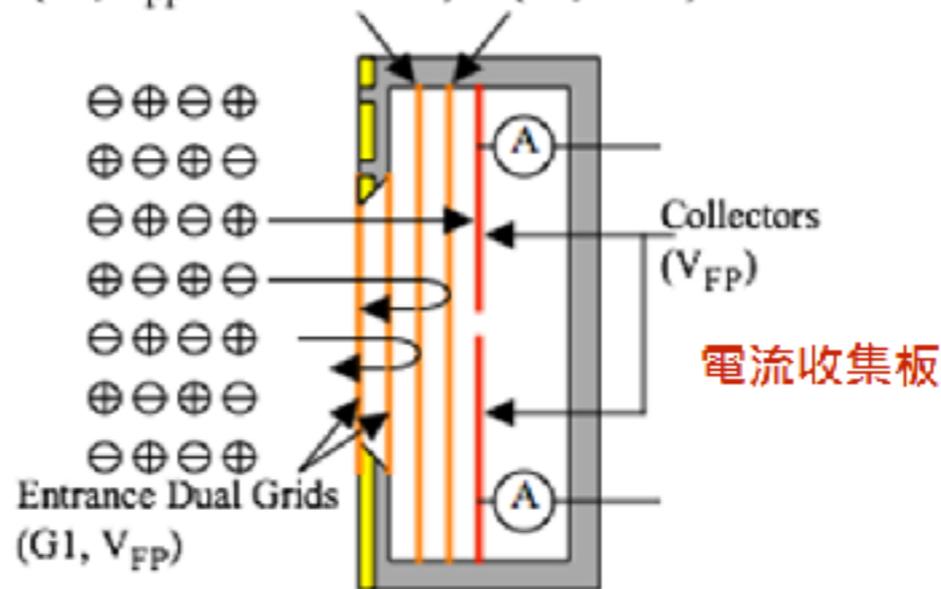


阻滯網

Retarding Grid
(G2, V_{FP} or -10 to +10 V)

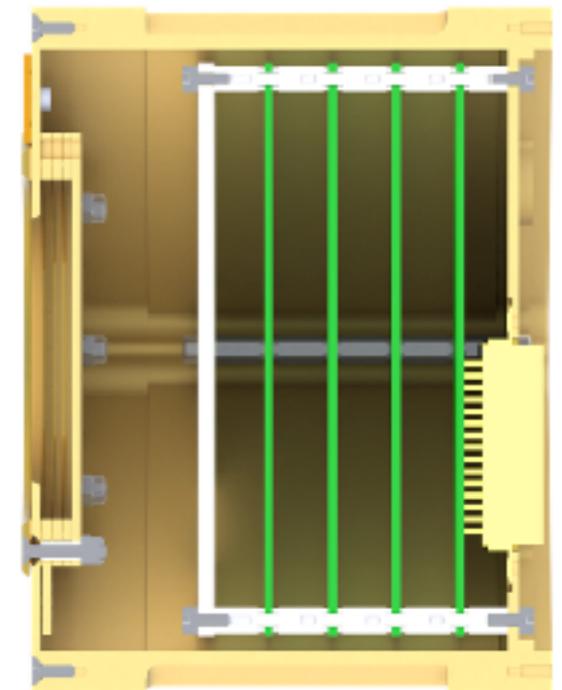
壓制網

Suppressor Grid
(G3, -15 V)



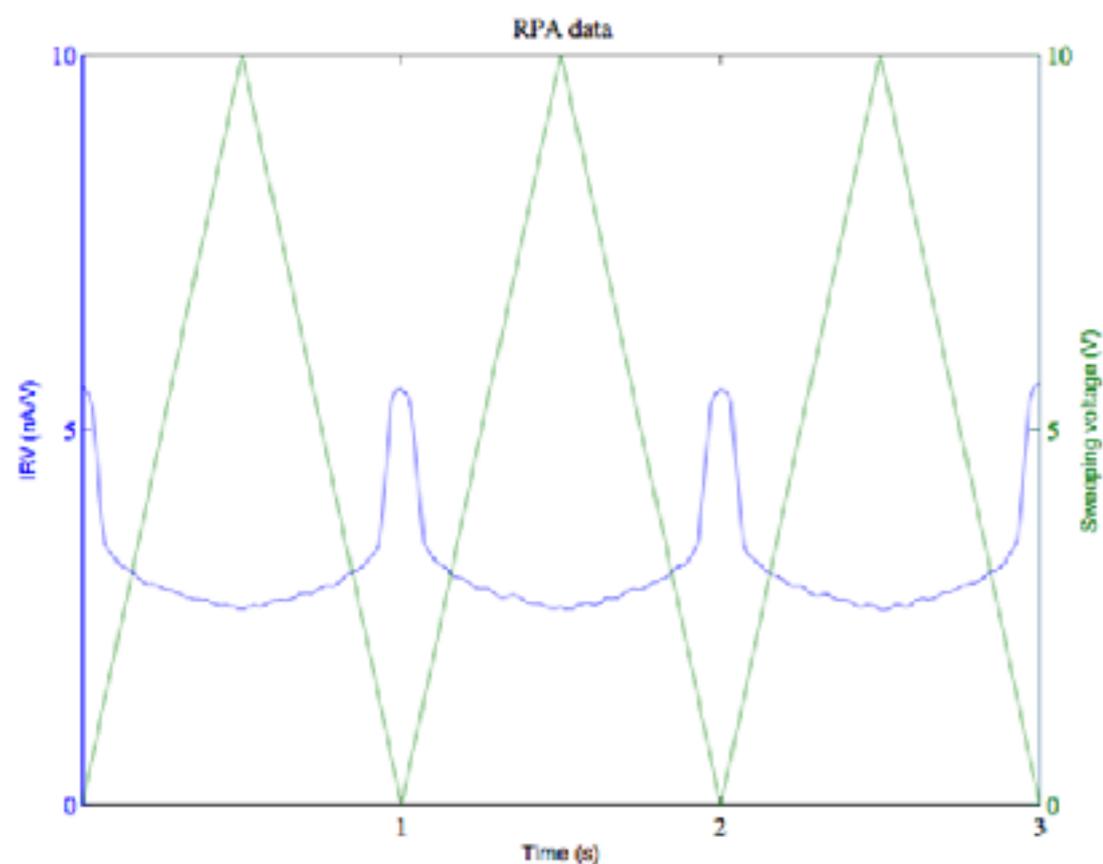
雙層入口網

電流收集板

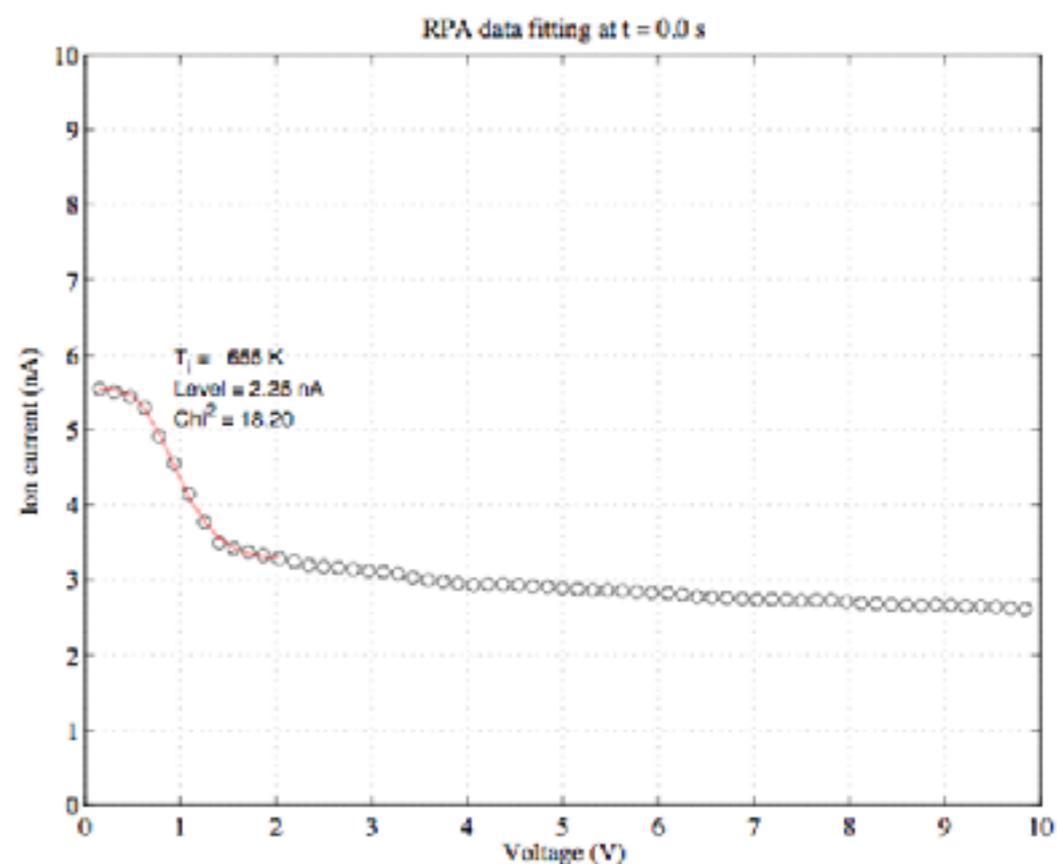




電流 / 電壓特性曲線



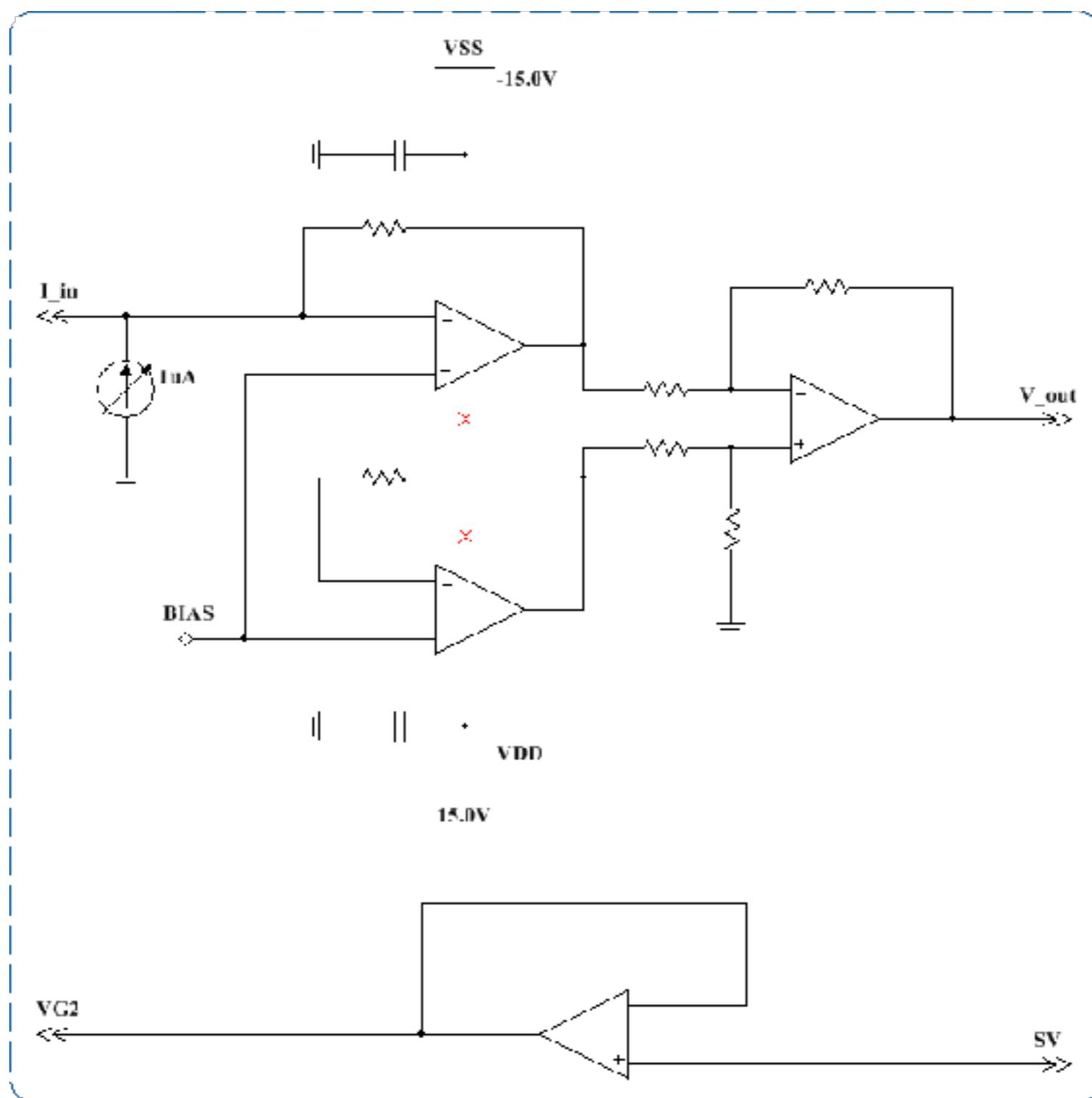
阻滯電位與收集電流



電流 / 電壓特性曲線



阻滯電位分析儀量測電路





作業

- 使用NI myRIO提供阻滯電位分析儀掃描電壓(0-10V)，並擷取其電流訊號，繪製電流/電壓特性曲線，顯示於人機介面。
- 儲存掃描電壓與收集到的電流訊號，於MATLAB繪製並分析其結果。

