LCR-Meter Basic Test Theory

基本量測原理

Training course D

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R&D Engineering

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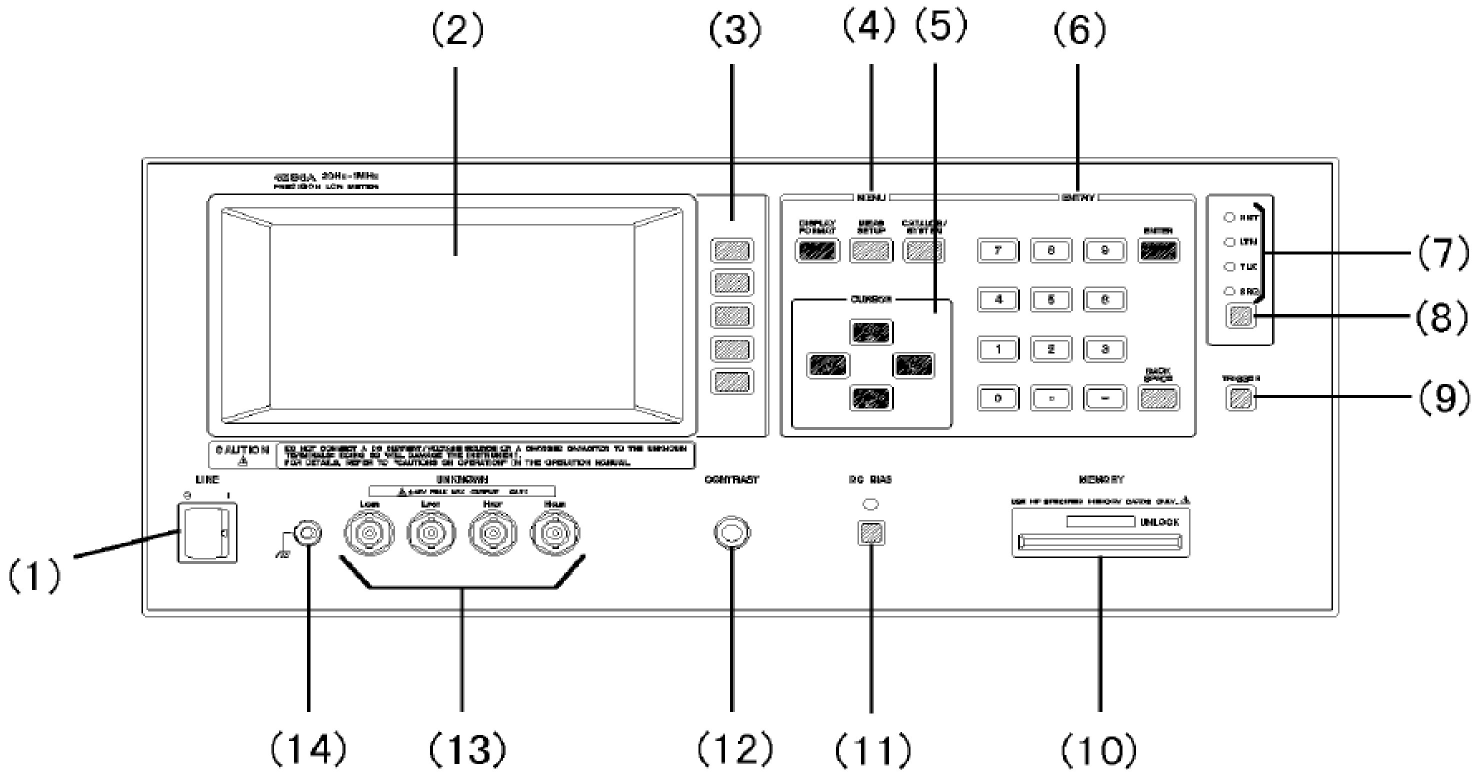
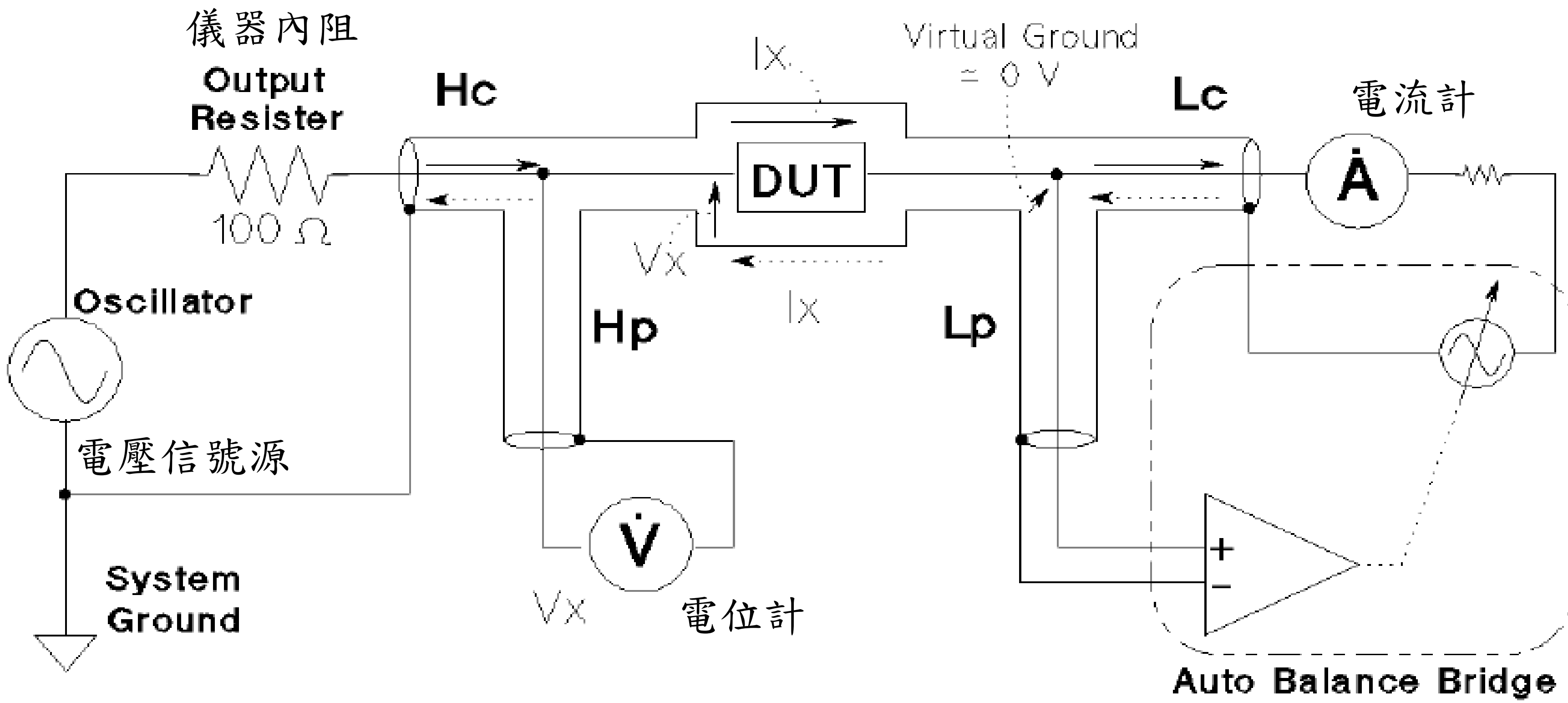
• HP4284A Front Panel:



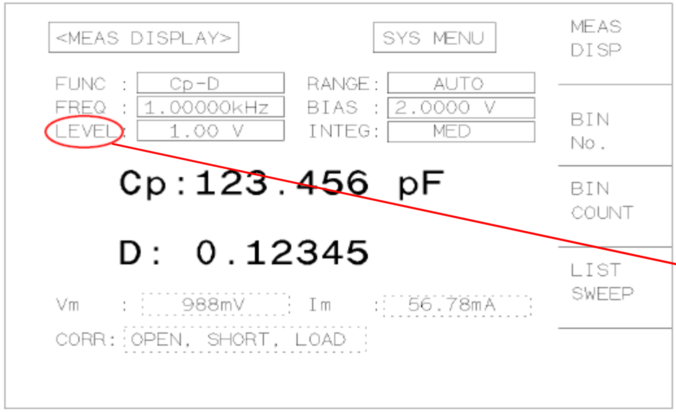
1:電源開關；2:LCD幕面；3:控制與參數功能選項鍵；4:菜單選項鍵；5:LCD幕面參數功能移動選擇鍵；6:輸入鍵；7:HP-IB介面狀態顯示燈；8:電腦程控鍵(僅限HP-IB介面功能啟動下)；9:手動觸發鍵；10:記憶卡帶插槽；11:直流偏壓鍵；12:LCD幕面對比調鈕；13:四端子量測治具接頭；14:接地保險接頭

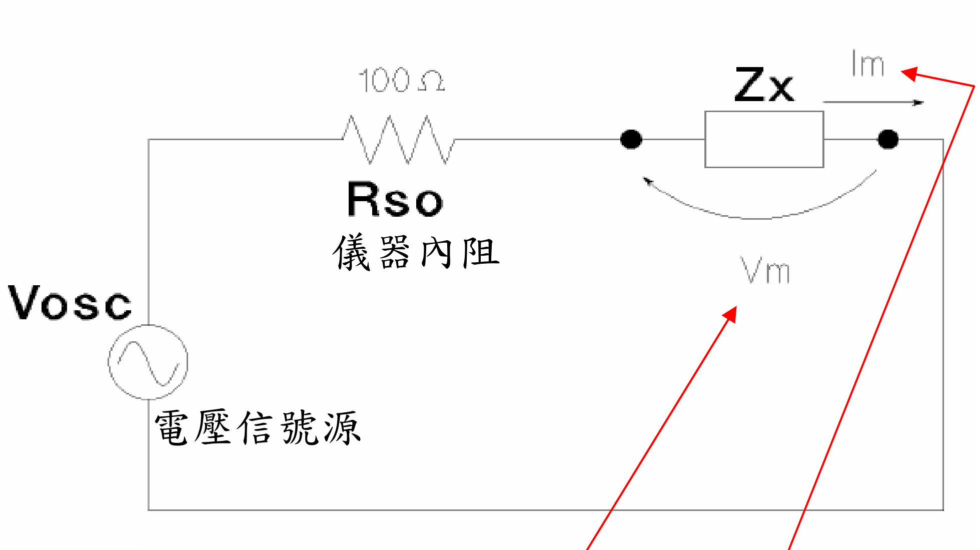
• Four-Terminal Pair Measurement Principle:



DUT: Device Under Test (待測物)

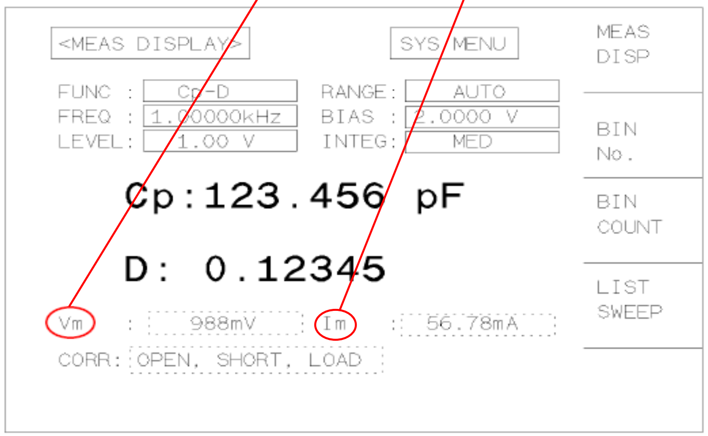
- Simplified Model of Signal Level & DUT:





$$|V_m| = \frac{|Z_x|}{|R_{so} + Z_x|} \times |V_{osc}|$$

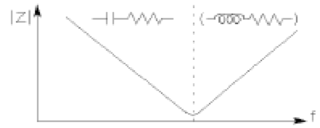
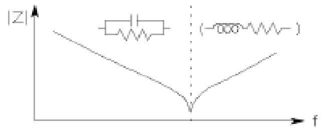
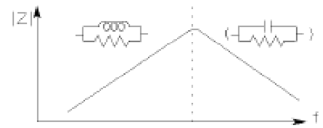
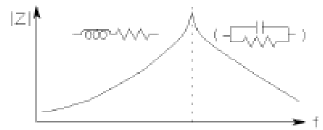
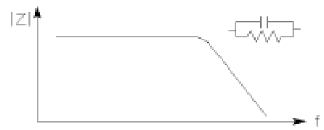
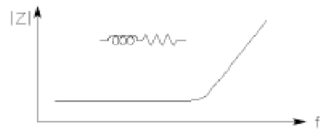
$$|I_m| = \frac{|V_{osc}|}{|R_{so} + Z_x|}$$



Where, $|V_{osc}|$: oscillator voltage level of the 4284A,
R_{so} : Source resister of the 4284A (= 100 Ω),
$|V_m|$: Signal voltage level applied on DUT,
$|I_m|$: Signal current level flowed in DUT,
$|Z_x|$: Impedance of DUT.

V_m: 待測物跨接端電壓(rms)
I_m: 通過待測物之電流(rms)

• Typical Characteristics of Components:

DUT	Characteristics Example	Measurement Functions
Large C		Cs−Rs, Cs−D, Cs−Q, R−X, |Z|−θ
Small C		Cp−D, Cp−G, G−B, |Y|−θ
Large L		Lp−Rp, Lp−D, Lp−Q, G−B, |Y|−θ
Small L		Ls−Rs, Ls−D, Ls−Q, R−X, |Z|−θ
Large R		Cp−Rp, G−B, |Y|− θ
Small R		Ls−Rs, R−X, |Z|− θ

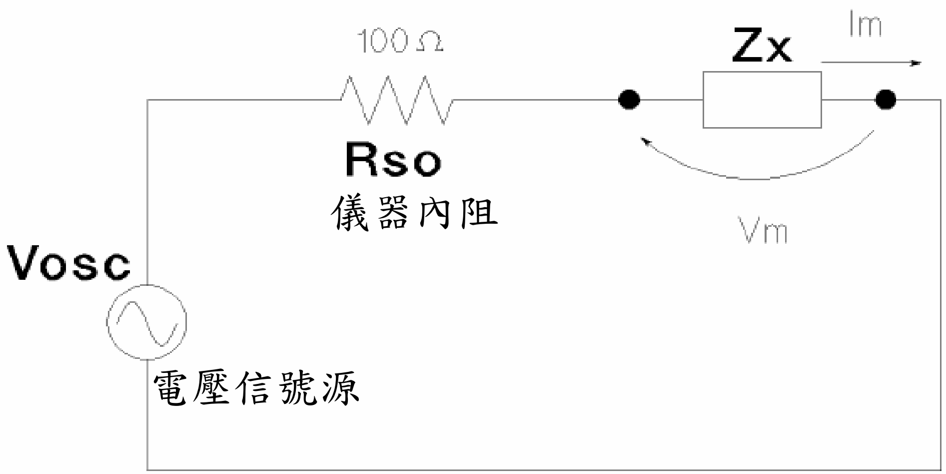
- LCR-meter 之基本量測參數: V_m, I_m and θ

V_m 是由儀器內的電位計量得

I_m 是由儀器內的電流計量得

θ 是電壓與電流的零點相位差

* 電壓信號源為正弦波



量測等效線路圖

待測物總阻抗 $|Zx| = \dfrac{V_m}{I_m}$ (Ohm's law)

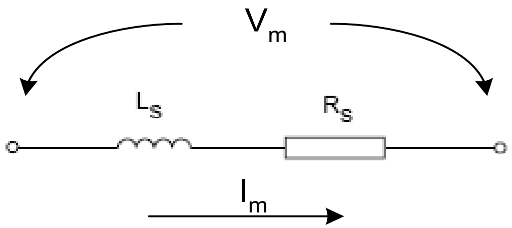
- LCR-meter 串聯模式(series mode) 之電感量測原理：

$$Zx = R_s + j\omega L_s$$

$$\omega = 2\pi f$$

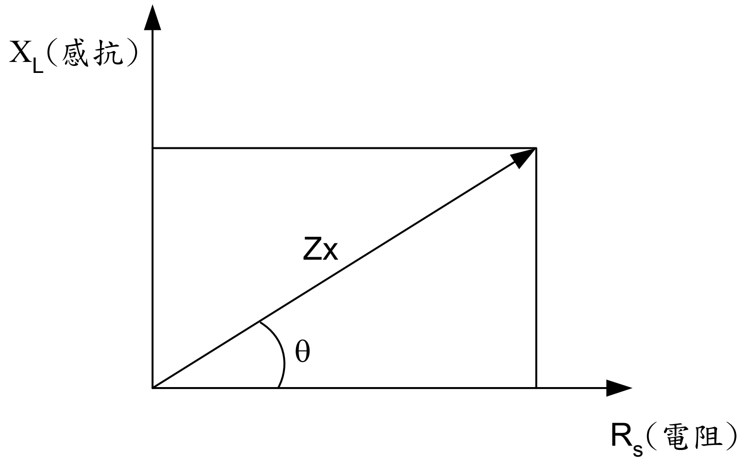
f： 測試頻率

繞線產品的等效電路 —



串聯模式(series mode)

電路複數阻抗之向量圖 —



$$R_s = |Zx| \cdot \cos\theta$$

$$X_L = \omega L_s = |Zx| \cdot \sin\theta$$

- LCR-meter 並聯模式(parallel mode) 之電感量測原理：

$$\frac{1}{Zx} = \frac{1}{R_p} + \frac{1}{j\omega L_p}$$

$\omega = 2\pi f$　　f： 測試頻率

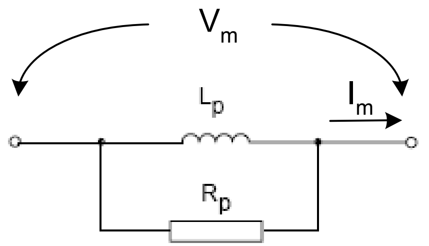
$$Y = G - jB_L$$

導納 $Y = \dfrac{1}{Zx}$

電導 $G = \dfrac{1}{R_p}$

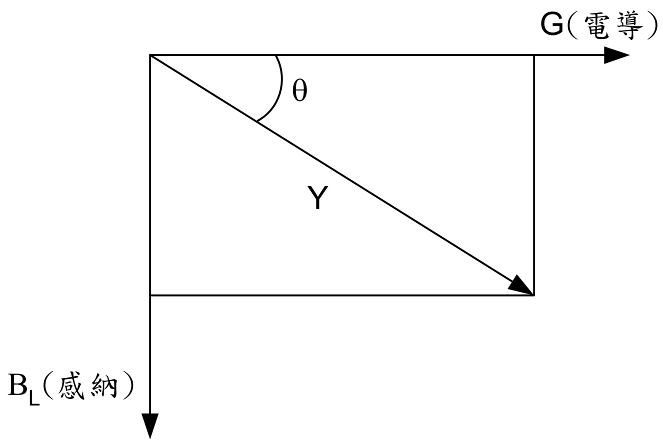
電感納 $B_L = \dfrac{1}{\omega L_p}$

繞線產品的等效電路 —



並聯模式(parallel mode)

電路複數導納之向量圖 —



- LCR-meter 並聯模式與串聯模式之對應：

$$\frac{1}{Zx}=\frac{1}{R_p}+\frac{1}{j\omega L_p}$$

經由代數分數的計算…

$j=\sqrt{-1};\ j^2=-1$

$$Zx=\underbrace{\frac{\omega^2 R_p L_p^2}{R_p^2+\omega^2 L_p^2}+j\frac{\omega R_p^2 L_p}{R_p^2+\omega^2 L_p^2}}_{\text{並聯模式下的參數}}=\underbrace{R_s+j\omega L_s}_{\text{串聯模式下的參數}}$$

$$\therefore Q=\frac{\omega L_s}{R_s}=\frac{R_p}{\omega L_p}$$

Thank you for listening!