Equipos de medida

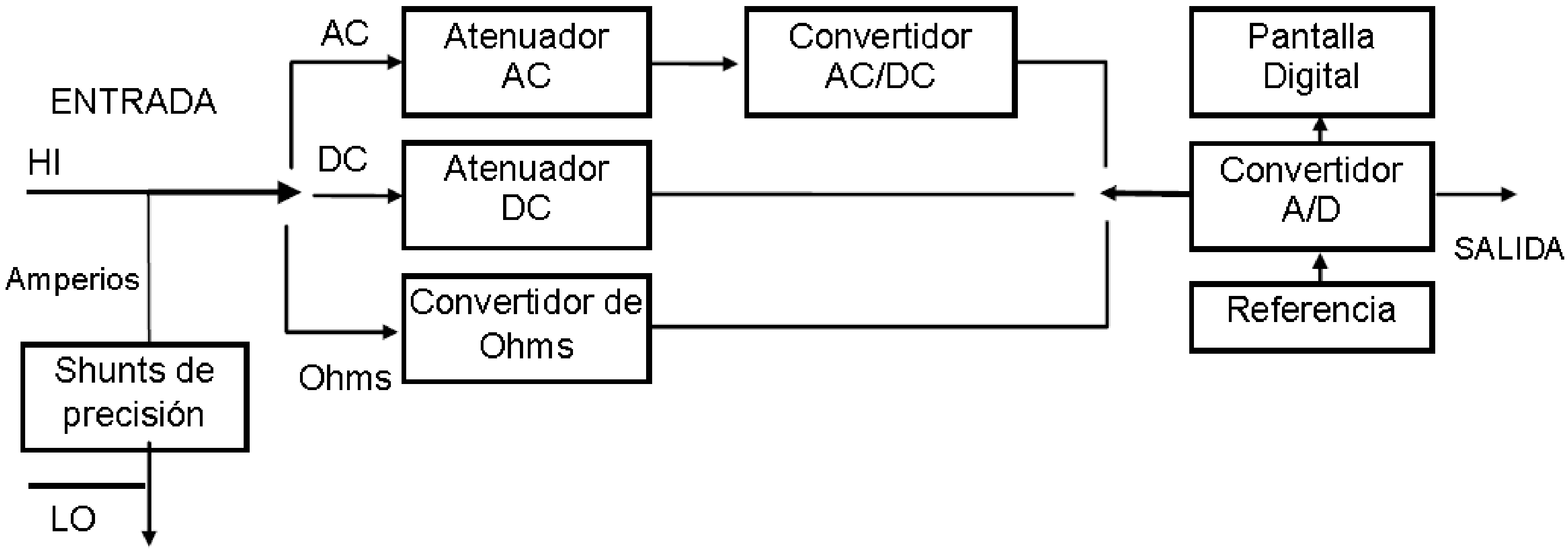
- Multímetro Digital (DMM)
- Medidor vectorial de impedancias

Equipos de medida
Multímetro digital:

- **Equipo para medida digital de magnitudes típicas de:**
  - Tensión continua: 1 mV a 1000V
  - Tensión alterna: 10mV a 1000V (10 Hz a 1 Mhz)
  - Intensidad continua: 1mA a 20ª (10Hz a 10KHz)
  - Intensidad alterna: 1mA a 20 A
  - Resistencia: 1Ω a 100 MΩ
- **En muchos casos la lectura digital se puede enviar a varios puertos de salida GPIB, RS232, USB etc.**

Equipos de medida
Multímetro digital:

- **Bloques básicos**

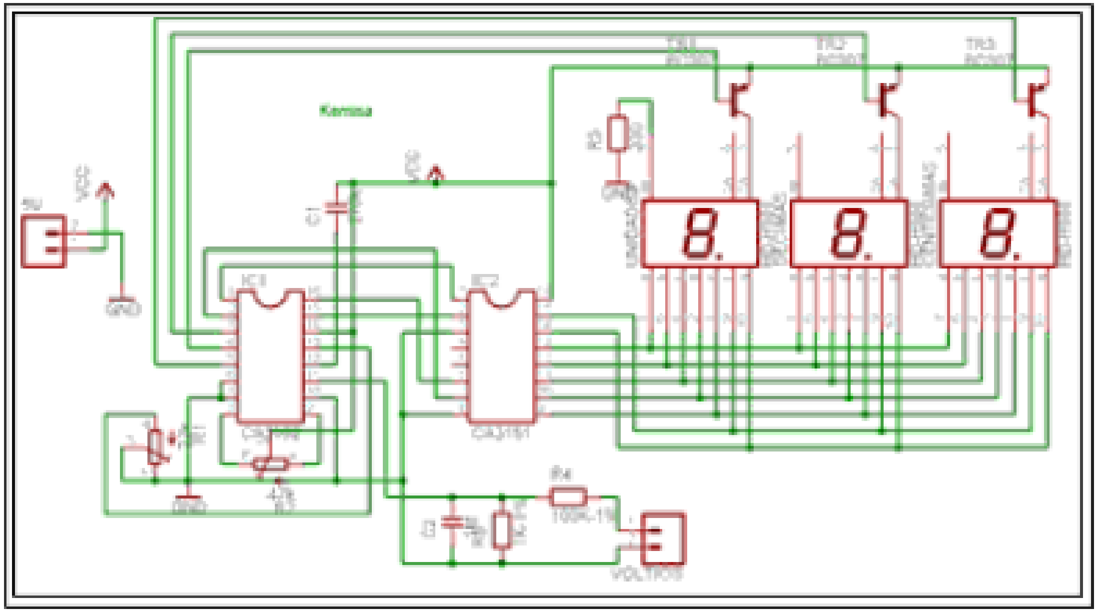


El sistema básico de medida lo constituye el **Voltímetro digital** (Convertidor A/D- Pantalla digital) las restantes medidas se fundamentan en esta.

Equipos de medida

Multímetro digital:

- **Voltímetro digital**
  - **Convertidor A/D**
  - **Decodificador a display "7segmentos"**
  - **Display 7 segmentos (típicamente 31/2, 41/2, 51/2 dígitos de resolución)**

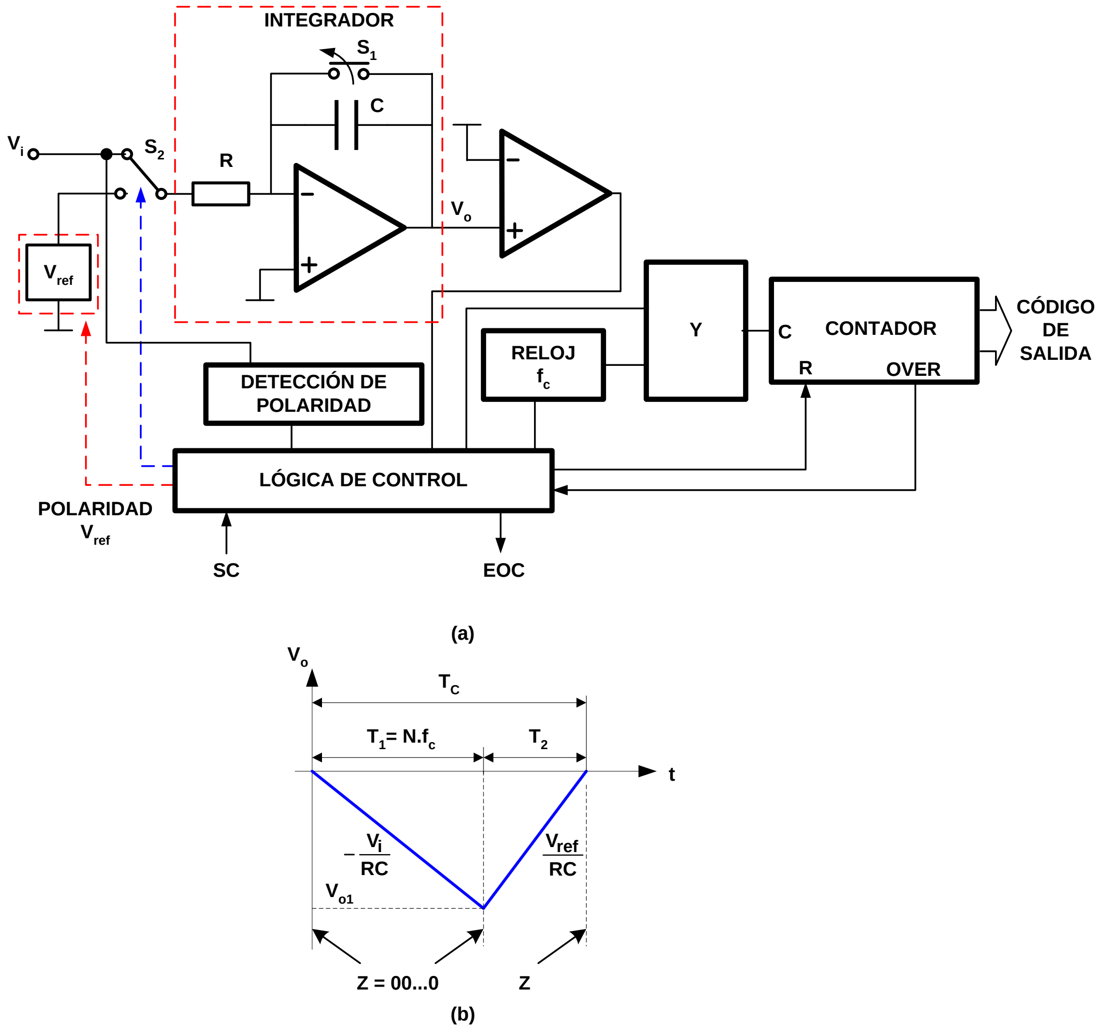


Ejemplo de circuito impreso de un voltímetro de 3 digitos

Equipos de medida

Multímetro digital:

- **Convertidores A/D usuales en DMM: doble rampa**



$$Z = \frac{T_2}{T_1} \cdot 2^n$$

$$\frac{\overline{V_i}}{R \cdot C} \cdot T_1 = \frac{V_o}{R \cdot C} \cdot T_2$$

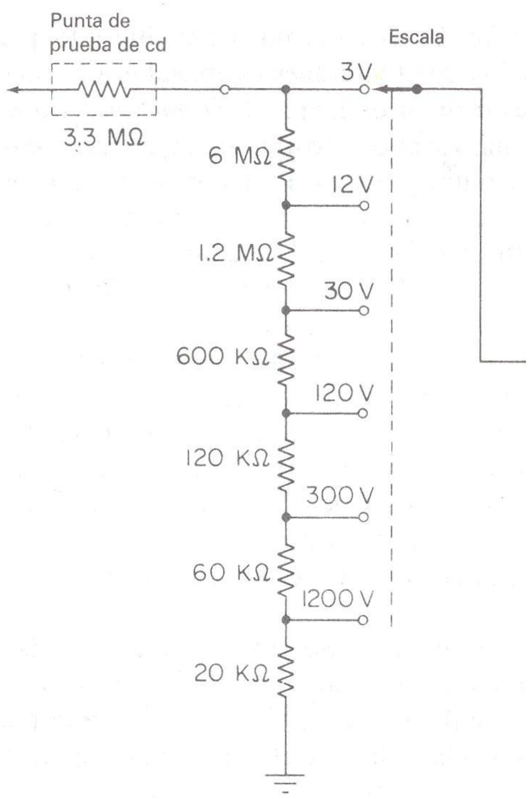
$$T_2 = T_1 \cdot \frac{\overline{V_i}}{V_{ref}}$$

$$Z = \frac{2^n}{V_{ref}} \cdot \overline{V_i}$$

Equipos de medida

Multímetro digital:

- **Atenuador de entrada (Rangos)**

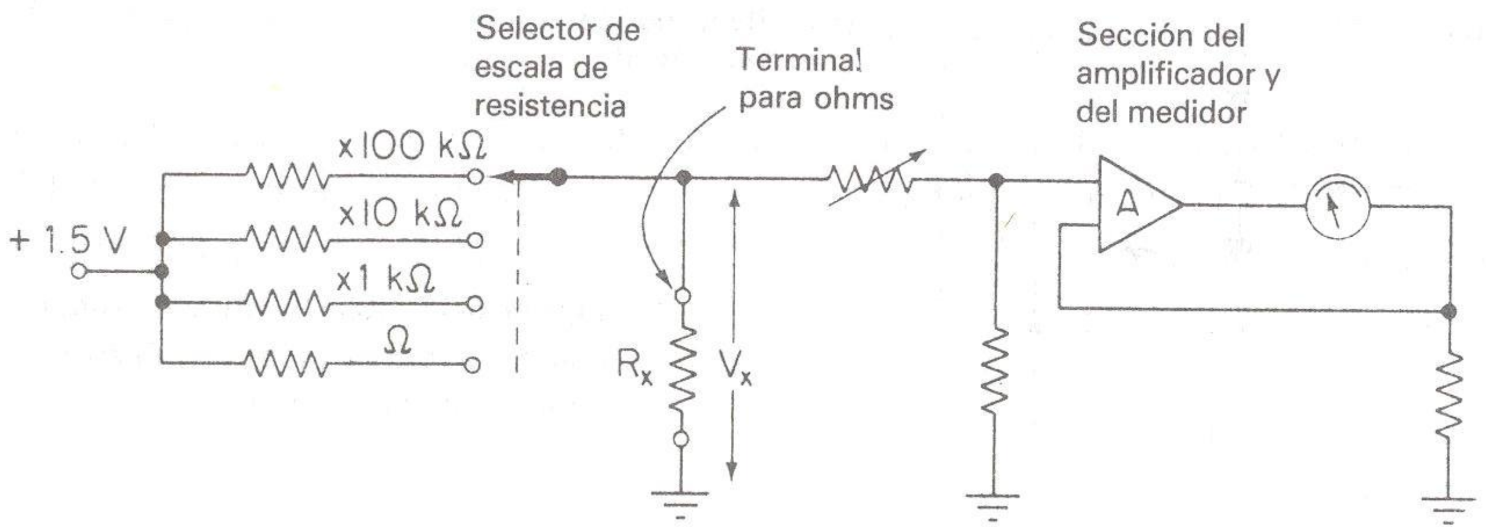


Permite la selección de las escalas de tensión

Equipos de medida

Multímetro digital:

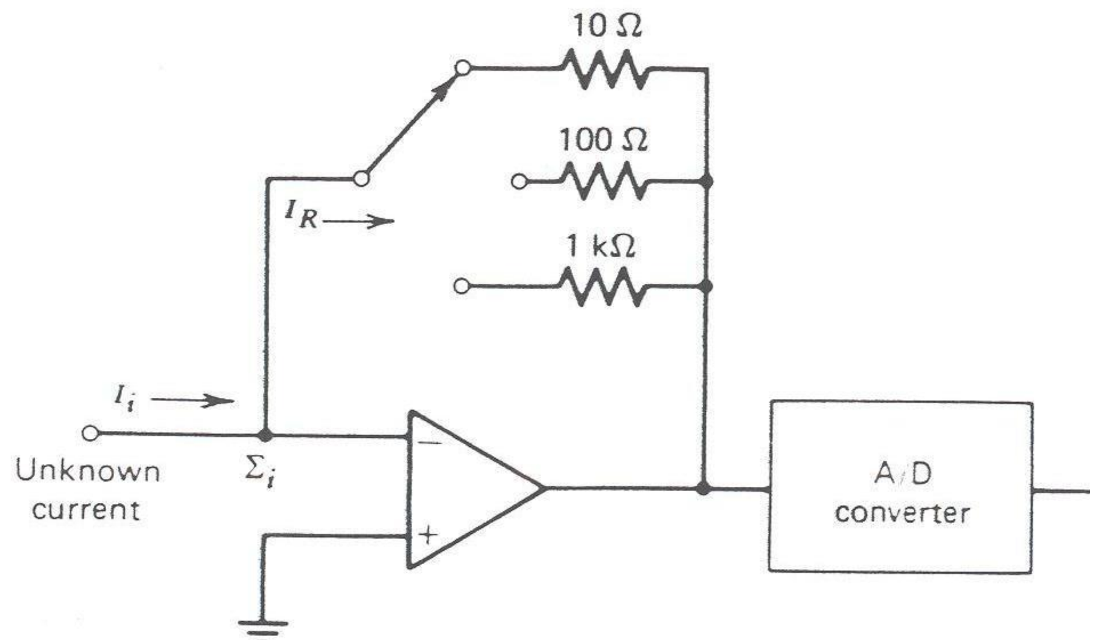
- **Ejemplo de convertidor de ohmios (R/V)**



El instrumento dispone de una fuente de tensión continua que se aplica a la resistencia a medir. La tensión resultante con los atenuadores se mide con el voltímetro digital.

Equipos de medida
Multímetro digital:

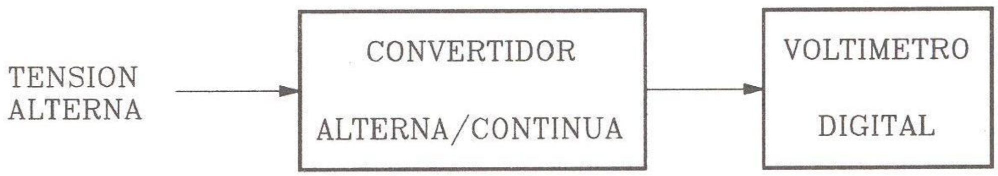
- **Shunts de precisión, convertidor I/V**



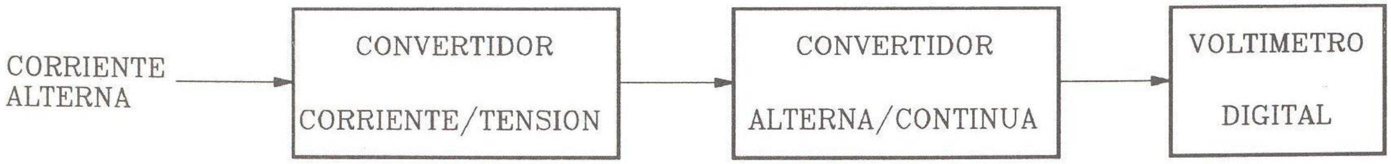
Equipos de medida

Multímetro digital:

- **Medidas de V y I alternas**



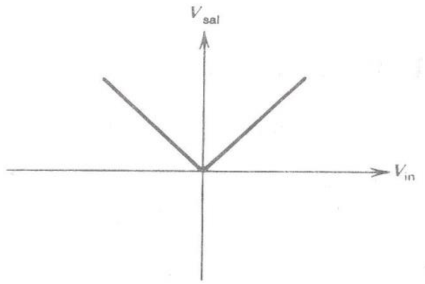
Voltímetro de alterna digital

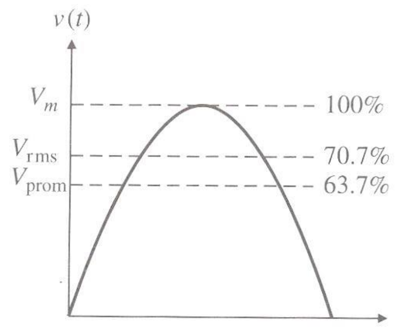


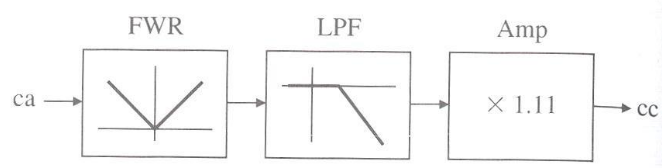
Amperímetro de alterna digital

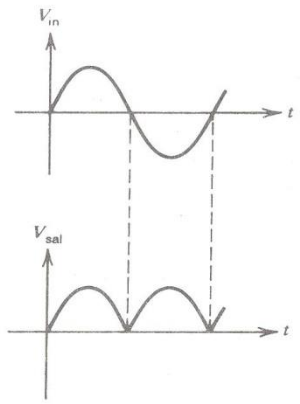
Equipos de medida
Multímetro digital:

- **Convertidores Alterna/Continua**
  - De valor de pico o de **valor medio d**e la señal rectificada
    - Válido para **señales sinusoidales**









(b)

$$V(t) = V_m \left(\frac{2}{\pi} - \frac{4}{3\pi}\cos 2\omega t + \frac{4}{15\pi}\cos 4\omega t - ....\right)$$

$$V_{LPF} = \frac{2V_m}{\pi} \quad \text{señal dc "valor medio"}$$

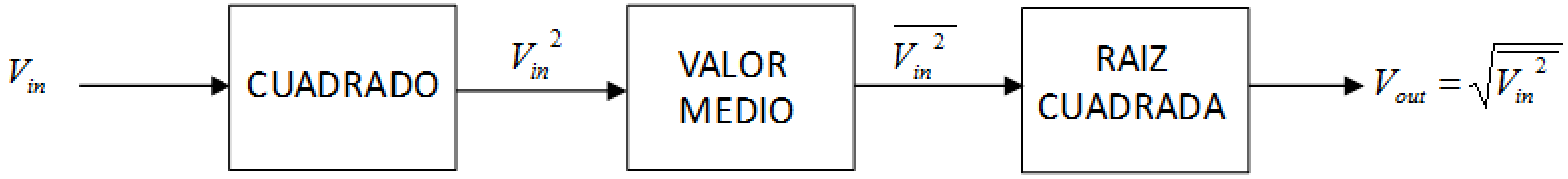
$$V_{rms} = V_{LPF}\left(\frac{\pi}{2\sqrt{2}}\right) = 1{,}11 V_{LPF}$$

Equipos de medida

Multímetro digital:

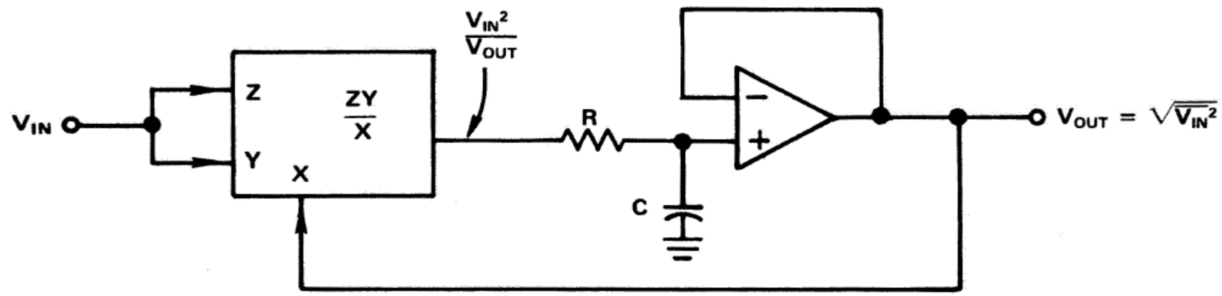
- **Convertidores Alterna/Continua**
  - Analógicos de **verdadero valor eficaz** (rms)
    - Válidos para **cualquier forma de onda,** implementan directamente la definición de valor eficaz de una señal V(t)

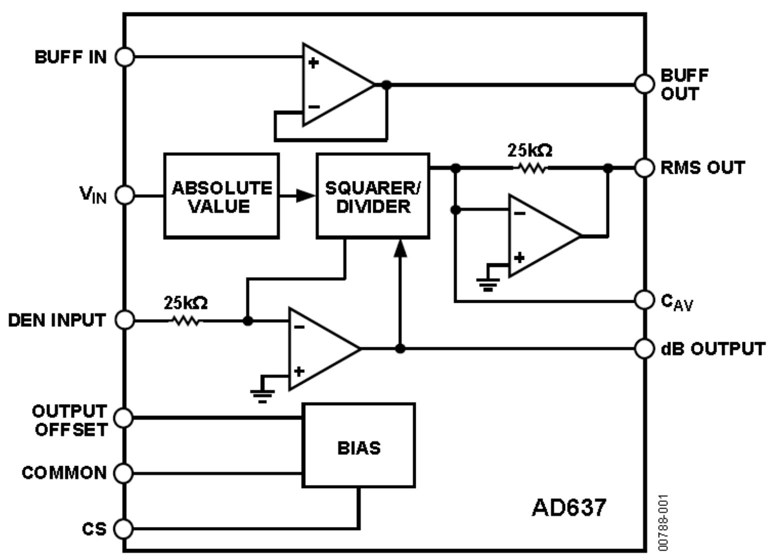
$$\mathrm{Vrms} = \sqrt{\frac{1}{T}\int_0^T V^2(t)\,dt} = \sqrt{\overline{V^2(t)}}$$



Equipos de medida
Multímetro digital:

- **Convertidores Alterna/Continua**
  - Analógicos de **verdadero valor eficaz** (rms). Ejemplo C.I. AD637





High accuracy
- 0.02% maximum nonlinearity, 0 V to 2 V rms input
- 0.10% additional error to crest factor of 3

Wide bandwidth
- 8 MHz at 2 V rms input
- 600 kHz at 100 mV rms

Computes
- True rms
- Square
- Mean square
- Absolute value

dB output (60 dB range)

Chip select/power-down feature allows
- Analog three-state operation
- Quiescent current reduction from 2.2 mA to 350 µA

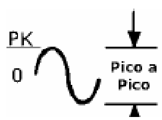
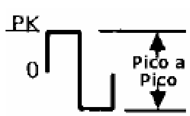
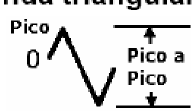
14-lead SBDIP, 14-lead low cost CERDIP, and 16-lead SOIC_W

Equipos de medida

Multímetro digital:

- **Convertidores Alterna/Continua**

Tabla de coeficientes para el cálculo de señales no senoidales según el tipo de multímetro

Tipo de Señal	La lectura de un Multímetro de Promedio Calibrado en RMS senoidal, se multiplica por:			La lectura de un Multímetro de Verdadero RMS, se multiplica por:		
	Vpp: Valor pico a pico	Vp: Valor pico	Verdadero Valor Eficaz	Vpp: Valor pico a pico	Vp: Valor pico	Verdadero Valor Eficaz
Senoidal pura 	2,828	1,414	1	2,828	1,414	1
Onda cuadrada 	1,80	0,90	0,90	2	1	1
Onda triangular 	3,6	1,80	1,038	3,464	1,732	1

Equipos de medida

Multímetro digital:

Ejemplo: modelos 8845A y 8846A de FLUKE de 6 ½ dígitos.

Fluke 8845A

Características

	8845A	8846A
Pantalla	VFD doble de matriz de puntos	
Resolución	6,5 dígitos	
Velocidad de medición (lecturas/seg)	1.000	
Pruebas de continuidad/diodos	Sí	
Funciones analíticas	Estadísticas, histograma, TrendPlot™, comparación de límites	
Funciones matemáticas	Cero, Mín/Máx, dB/dBm	
Puerto USB	-	Puerto para dispositivo de memoria USB
Reloj en tiempo real	-	Sí
Interfaces	RS232, IEEE-488.2, Ethernet	
Lenguajes de programación/ Modos de emulación	SCPI (IEEE-488.2), Agilent 34401A, Fluke 45	
Seguridad	diseñado conforme a IEC 61010-12000-1, ANSI / ISA-S82.01-1994, CAN / CSA-C22.2 No.1010.1-92 1000V CATI / 600V CATII	

Especificaciones

(Visite nuestra página web para ver más detalles)

Función*	8845A			8846A		
	Rango	Resolución	Precisión* (%)	Rango	Resolución	Precisión* (%)
Tensión CC	1000 V	100 nV	0.0035	1000 V	100 nV	0.0024
Tensión CA (Frec. 300 Hz)	750 V	100 nV	0.06	1000 V	100 nV	0.06
Resistencia (método 2 y 4 hilos)	100 MΩ	100 μΩ	0.01	1 GΩ	10 μΩ	0.01
Corriente CC	10 A	100 pA	0.05	10 A	100 pA	0.05
Corriente CA (Frec. 3 Hz-10 kHz)	10 A	1 μA	0.10	10 A	10 nA	0.10
Frecuencia/período	300 kHz	1 μHz	0.01	1 MHz	1 μHz	0.01
Capacidad	-	-	-	1 nF a 0,1 F	1 pF	1
Temperatura RTD	-	-	-	-200 a +600°	0,001°	0,06

* Precisión =+/- (% de la lectura)

Equipos de medida
Multímetro digital:

- **Convertidores Alterna/Continua**
  - **Convertidores térmicos**
    - Valor rms de una señal es la tensión continua que aplicada a una misma resistencia disipa la misma energía en el mismo tiempo.
    - Su funcionamiento se basa en la comparación ente la potencia eléctrica de la señal ac y de una tensión dc mediante transformación en calor. Válidos para cualquier forma de onda-
    - Permiten comparar la energía de calentamiento entre ac y dc en 0,1 ppm
    - Se utilizan también como estándar para señales ac entre 10Hz y 1MHz y existen cuatro tipos:
      - SJTC (Single-Juction Thermal Converters) desarrollados en la década de 1950
      - MJTC (Multijunction Thermal converters) 1970-1980
      - Thin-Film (Planar) MJTC
      - Semiconductors rms sensor

Equipos de medida
Multímetro digital:

- **Convertidores Alterna/Continua**
  - **Convertidores térmicos**

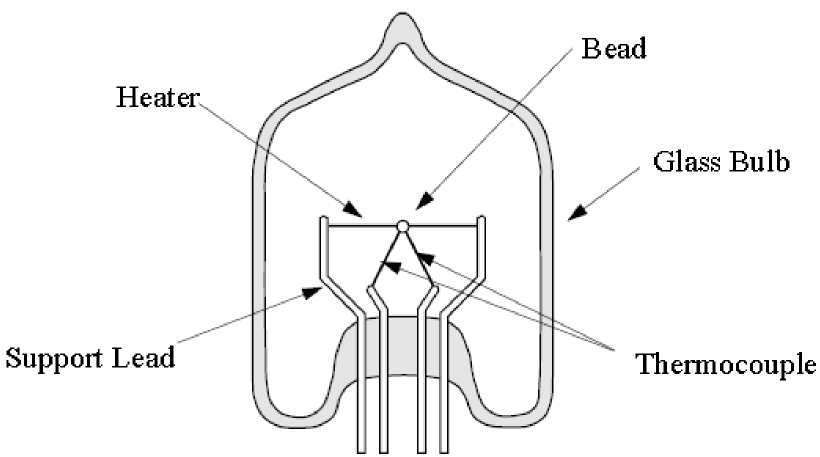


Figure 1.3 Construction of a typical SJTC element. A thin filament-heater and a thermocouple are inserted in a vacuum-shielded glass bulb. A thermocouple is attached to the heater at the midpoint of the heater using a bead made of glass or ceramics.

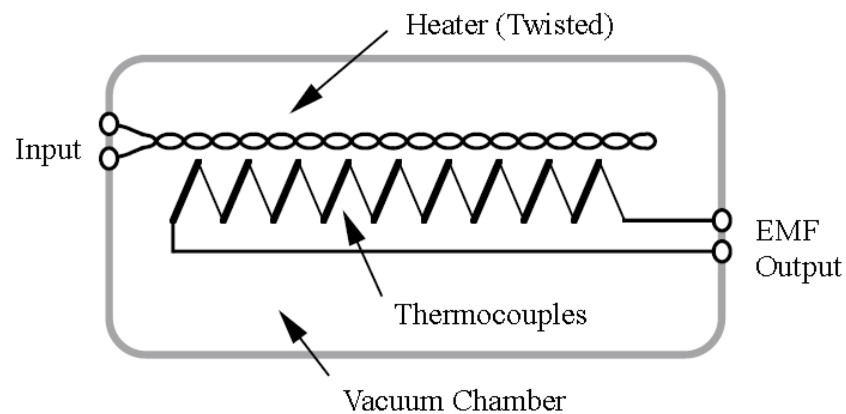


Figure 1.4 Construction of a Wilkins-type MJTC. Use of many numbers of thermocouples and the twisted bifiler heater is for compensating the thermoelectric effects.

Equipos de medida

Multímetro digital:

- **Convertidores Alterna/Continua**
  - **Convertidores térmicos**

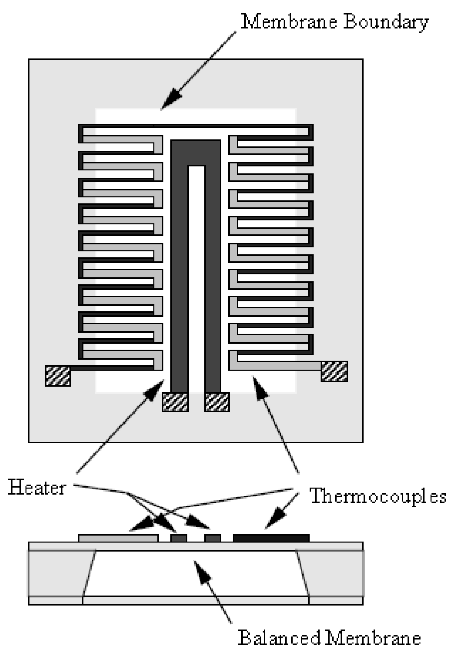
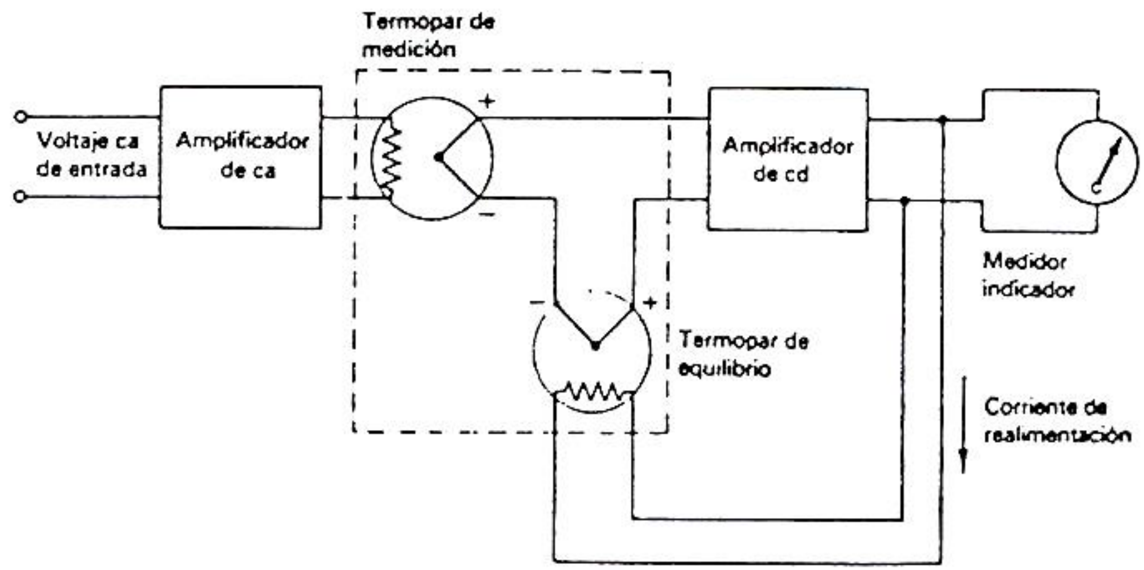


Figure 1.5 Construction of a thin-film MJTC developed at PTB. The heater and the hot-junctions of the thermocouples are formed on SiO_2/Si_3N_4 sandwich membrane made with an isotropic etching.



- **Arquitectura y características usuales**
- Rango de 100 µV a 300V
- 10Hz a 10 MHz
- Factor de cresta 100/1

Equipos de medida

Medidor vectorial de impedancias:

- **Introducción**

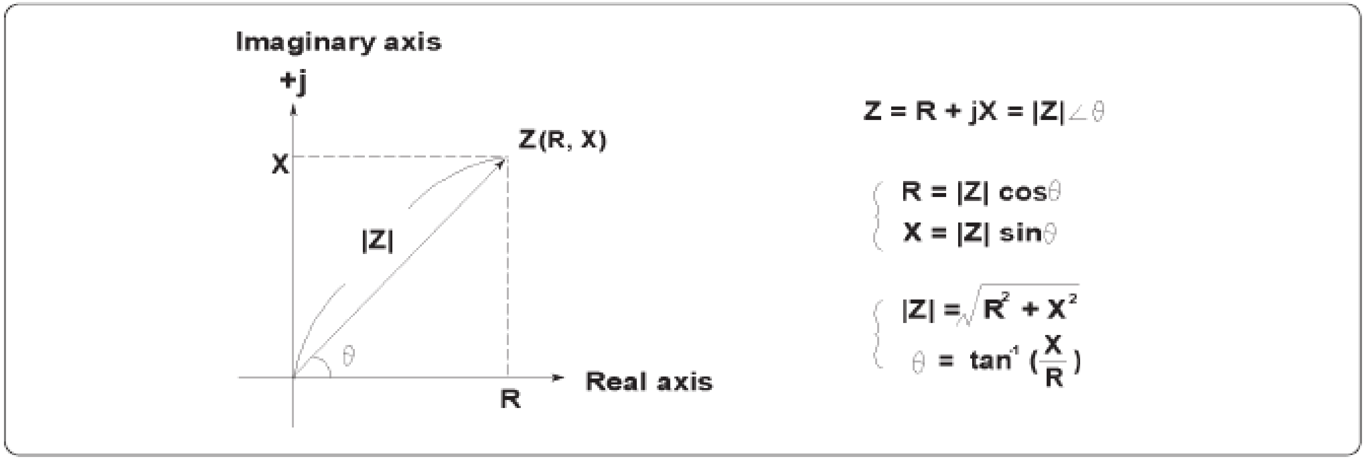


Figure 1-1. Impedance (Z) consists of a real part (R) and an imaginary part (X)

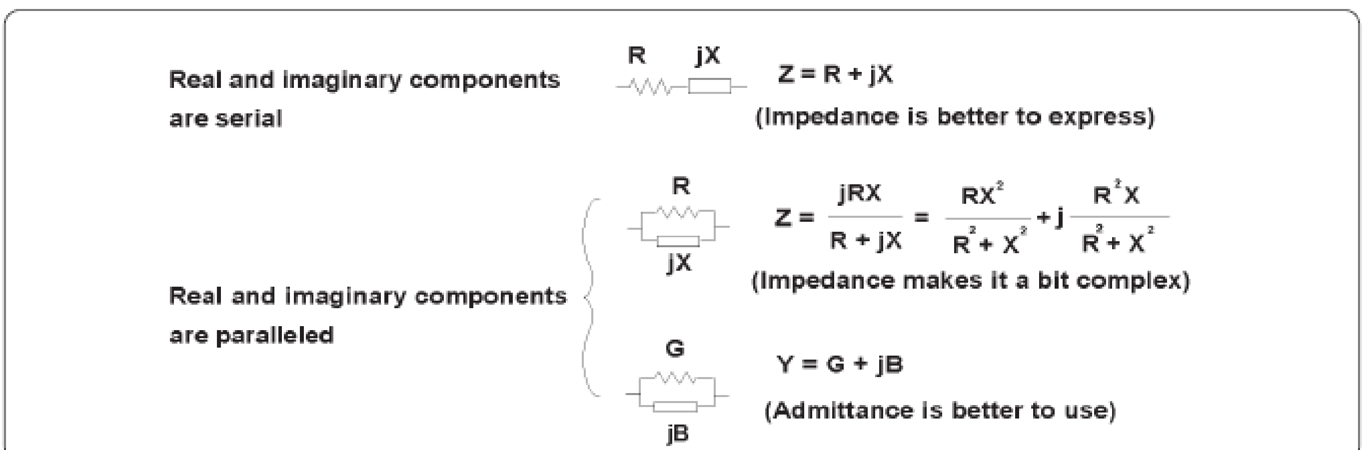


Figure 1-2. Expression of series and parallel combination of real and imaginary components

Equipos de medida

Medidor vectorial de impedancias:

- **Introducción**
- Para la medida de la impedancia a una frecuencia se necesita medir al menos dos valores debido a que la impedancia es compleja.
- En muchos equipos se mide la parte real e imaginaria del vector impedancia y se deducen los demás parámetros: $|Z|$, θ, $|Y|$, R, X, G, B, C y L.
- Los valores medidos de impedancia de un componente dependen principalmente de las siguientes condiciones de medida:
  - **Frecuencia**; esta dependencia es común en todos los componentes reales debido a la existencia de elementos parásitos .
  - **Nivel de la señal** de test de medida: afecta al resultado de la medida en muchos componentes. P.e. condensadores cerámicos , componentes semiconductores etc.
  - **Polarización dc**: muy común en medidas de componentes semiconductores como diodos o transistores y condensadores cerámicos.
  - **Temperatura:** La mayor parte de los componentes dependen de la temperatura. El coeficiente de variación con T es una importante especificación para resistencias, condensadores e inducciones

Equipos de medida

Medidor vectorial de impedancias:

- **Introducción**

Table 1-1. Measurement circuit modes

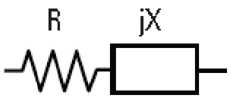
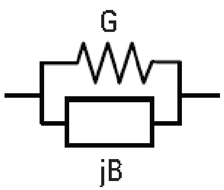
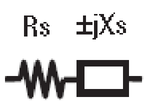
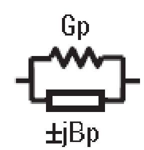
Equivalent circuit models of component		Measurement circuit modes and impedance parameters
Series		Series mode: Cs, Ls, Rs, Xs
Parallel		Parallel mode: Cp, Lp, Rp, Gp, Bp

Table 1-2. Definitions of impedance parameters for series and parallel modes

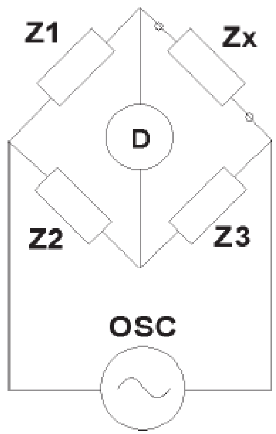
Series mode		Parallel mode	
	$\lvert Z \rvert = \sqrt{Rs^2 + Xs^2}$ $\theta = \tan^{-1} (Xs/Rs)$		$\lvert Y \rvert = \sqrt{Gp^2 + Bp^2}$ $\theta = \tan^{-1} (Bp/Gp)$

Equipos de medida

Medidor vectorial de impedancias:

- **Métodos de medida:**

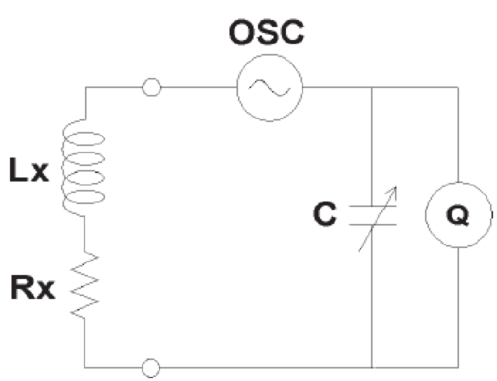
Bridge method



$$Zx = \frac{Z1}{Z2} Z3$$

When no current flows through the detector (D), the value of the unknown impedance (Zx) can be obtained by the relationship of the other bridge elements. Various types of bridge circuits, employing combinations of L, C, and R components as the bridge elements, are used for various applications.

Resonant method



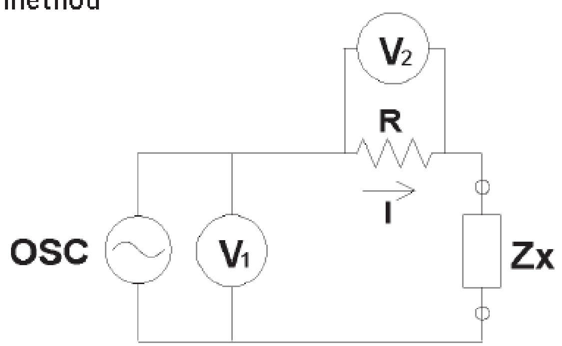
When a circuit is adjusted to resonance by adjusting a tuning capacitor (C), the unknown impedance Lx and Rx values are obtained from the test frequency, C value, and Q value. Q is measured directly using a voltmeter placed across the tuning capacitor. Because the loss of the measurement circuit is very low, Q values as high as 300 can be measured. Other than the direct connection shown here, series and parallel connections are available for a wide range of impedance measurements.

Equipos de medida

Medidor vectorial de impedancias:

- **Métodos de medida:**

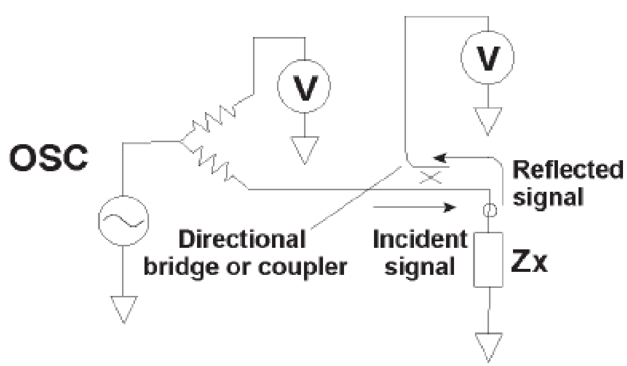
I-V method



$$Zx = \frac{V_1}{I} = \frac{V_1}{V_2} R$$

The unknown impedance (Zx) can be calculated from measured voltage and current values. Current is calculated using the voltage measurement across an accurately known low value resistor (R.) In practice a low loss transformer is used in place of R to prevent the effects caused by placing a low value resistor in the circuit. The transformer, however, limits the low end of the applicable frequency range.

Network analysis method



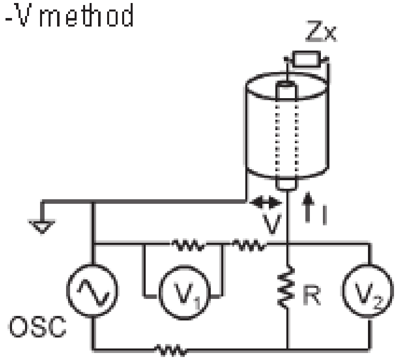
The reflection coefficient is obtained by measuring the ratio of an incident signal to the reflected signal. A directional coupler or bridge is used to detect the reflected signal and a network analyzer is used to supply and measure the signals. Since this method measures reflection at the DUT, it is usable in the higher frequency range.

Equipos de medida

Medidor vectorial de impedancias:

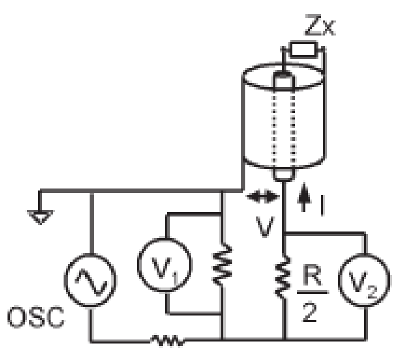
- **Métodos de medida:**

RF I-V method



Low impedance type

$$Zx = \frac{V}{I} = \frac{2R}{\frac{V_2}{V_1} - 1}$$



High impedance type

$$Zx = \frac{V}{I} = \frac{R}{2}\left(\frac{V_1}{V_2} - 1\right)$$

While the RF I-V measurement method is based on the same principle as the I-V method, it is configured in a different way by using an impedance-matched measurement circuit (50 Ω) and a precision coaxial test port for operation at higher frequencies. There are two types of the voltmeter and current meter arrangements that are suited to low impedance and high impedance measurements.

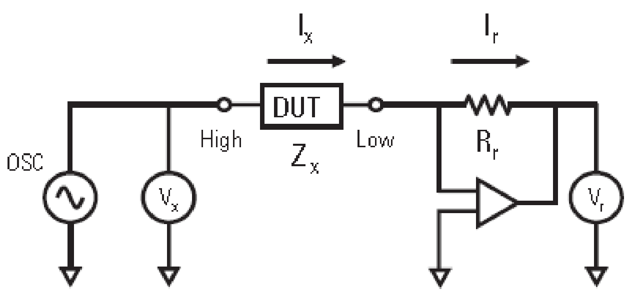
Impedance of DUT is derived from measured voltage and current values, as illustrated. The current that flows through the DUT is calculated from the voltage measurement across a known R. In practice, a low loss transformer is used in place of the R. The transformer limits the low end of the applicable frequency range.

Equipos de medida

Medidor vectorial de impedancias:

- **Métodos de medida:**

Auto-balancing bridge method



$$\frac{V_x}{Z_x} = I_x = I_r = \frac{V_r}{R_r}$$

$$\longrightarrow Z_x = \frac{V_x}{I_x} = R_r \frac{V_x}{V_r}$$

The current Ix balances with the current Ir which flows through the range resistor (Rr), by operation of the I-V converter. The potential at the Low point is maintained at zero volts (thus called a virtual ground.) The impedance of the DUT is calculated using the voltage measured at the High terminal (Vx) and across R_r (Vr).

Note: In practice, the configuration of the auto-balancing bridge differs for each type of instrument. Generally, an LCR meter, in a low frequency range typically below 100 kHz, employs a simple operational amplifier for its I-V converter. This type of instrument has a disadvantage in accuracy at high frequencies because of performance limits of the amplifier. Wideband LCR meters and impedance analyzers employ the I-V converter consisting of sophisticated null detector, phase detector, integrator (loop filter), and vector modulator to ensure a high accuracy for a broad frequency range over 1 MHz. This type of instrument can attain to a maximum frequency of 110 MHz.

Equipos de medida

Medidor vectorial de impedancias:

- **Métodos de medida:**

Table 2-1. Common impedance measurement methods

	Advantages	Disadvantages	Applicable frequency range
Bridge method	• High accuracy (0.1% typ.) • Wide frequency coverage by using different types of bridges • Low cost	• Needs to be manually balanced • Narrow frequency coverage with a single instrument	DC to 300 MHz
Resonant method	• Good Q accuracy up to high Q	• Needs to be tuned to resonance • Low impedance measurement accuracy	10 kHz to 70 MHz
I-V method	• Grounded device measurement • Suitable to probe-type test needs	• Operating frequency range is limited by transformer used in probe	10 kHz to 100 MHz
RF I-V method	• High accuracy (1% typ.) and wide impedance range at high frequencies	• Operating frequency range is limited by transformer used in test head	1 MHz to 3 GHz
Network analysis method	• High frequency range • Good accuracy when the unknown impedance is close to the characteristic impedance	• Recalibration required when the measurement frequency is changed • Narrow impedance measurement range	300 kHz and above
Auto-balancing bridge method	• Wide frequency coverage from LF to HF • High accuracy over a wide impedance measurement range • Grounded device measurement	• Higher frequency ranges not available	20 Hz to 110 MHz

Equipos de medida

Medidor vectorial de impedancias:

- **Métodos de medida: Diagrama de bloques de puente autobalanceado representativo.**

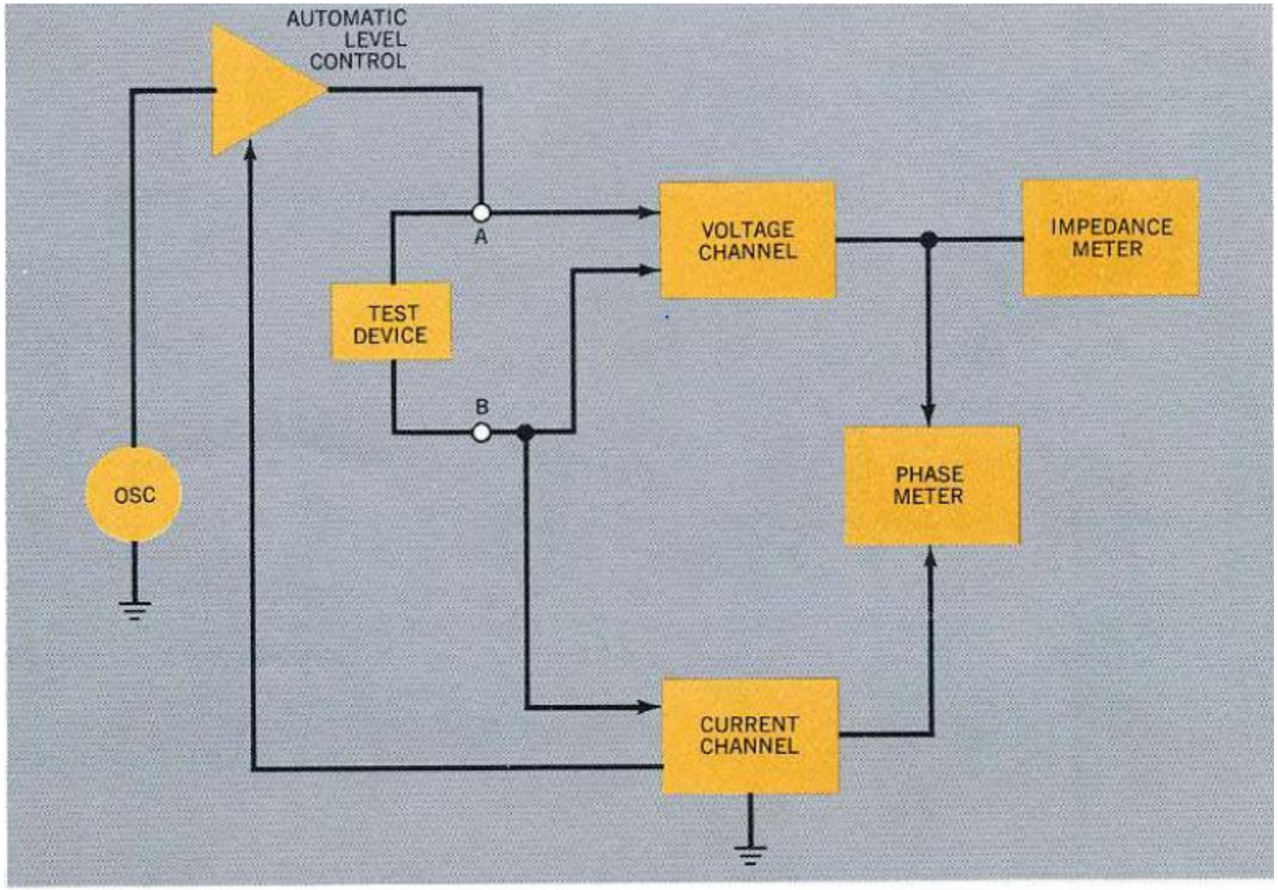
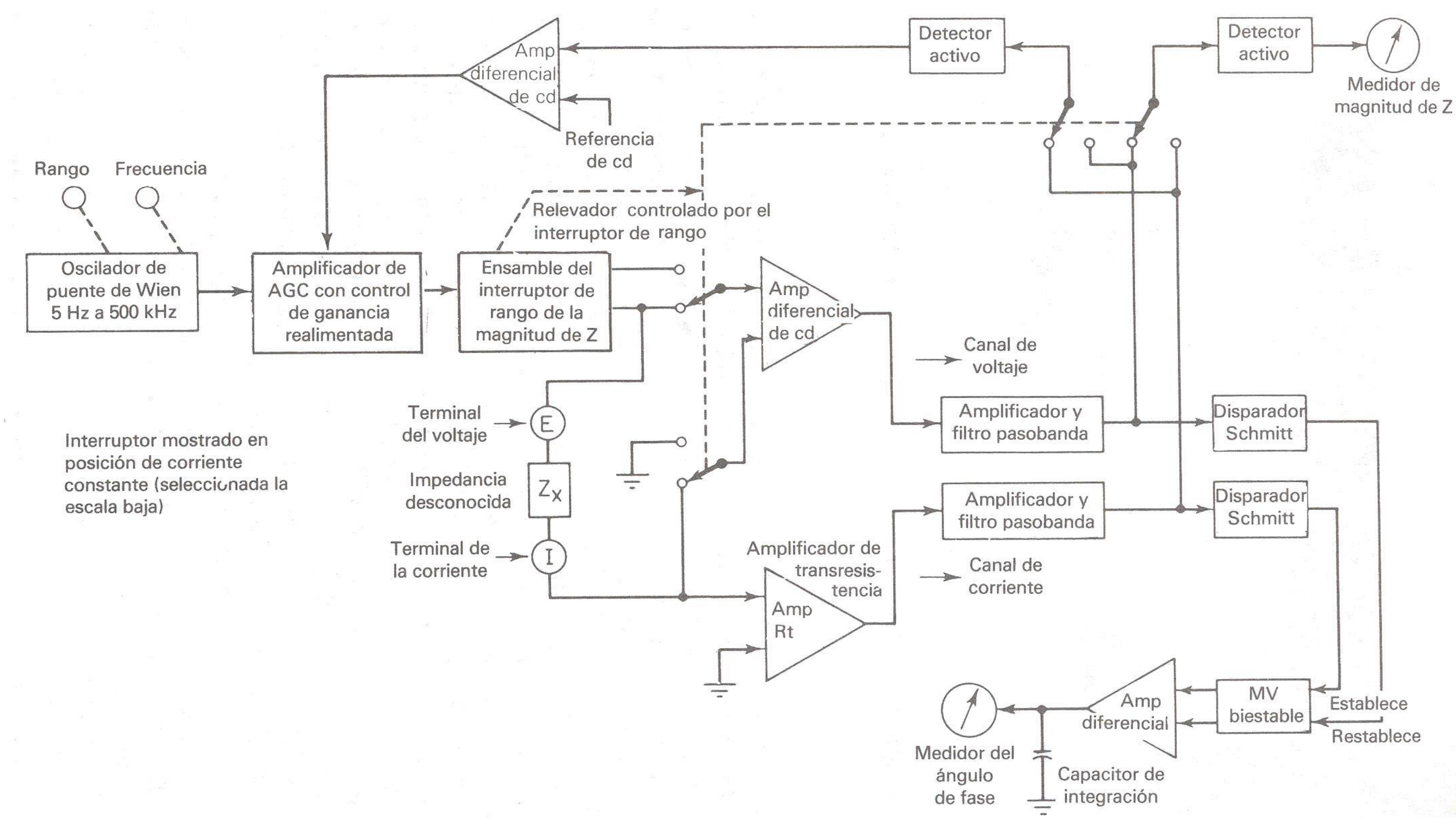


Fig. 1. Simplified Block Diagram — Vector Impedance Meters.

Equipos de medida

Medidor vectorial de impedancias:

- **Métodos de medida: Diagrama de bloques de puente autobalanceado representativo.**



Equipos de medida

Medidor vectorial de impedancias:

- **4294A de Agilent**

Key Features & Specifications

Basic accuracy

- Basic impedance accuracy: +/- 0.08 %

Frequency

- 40 Hz to 110 MHz

More features

- Accurate measurement over wide impedance range and wide frequency range
- Powerful impedance analysis function
- Ease of use and versatile PC connectivity

Description

The 4294A precision impedance analyzer is an integrated solution for efficient impedance measurement and analysis of components and circuits. The 4294A covers a broader test-frequency range (40 Hz to 110 MHz) with Basic impedance accuracy:+/-0.08 %. Excellent High Q/Low D accuracy enables analysis of low-loss components. The wide signal-level ranges enable device evaluation under actual operating conditions. The test signal level range is 5m V to 1 Vrms or 200 uA to 20m Arms, and the DC bias range is 0 V to +/-40 V or 0m A to +/-100m A. Advanced calibration and error compensation functions eliminate measurement error factors when performing measurements on in-fixture devices. The 4294A is a powerful tool for design, qualification and quality control, and production testing of electronic components. Circuit designers and developers can also benefit from the performance/functionality offered.

Equipos de medida

- **Referencias:**
- Multímetro digital (DMM): [8] pag. (131-159), [3] pag. (657-662)
- Medidor vectorial de impedancias: [8] pag. (159-185); http://cp.literature.agilent.com/litweb/pdf/5950-3000.pdf - Impedance Measurement Handbook- pag. (1-1,1-14), (2-1,2-8); [8] pag. (159-185)