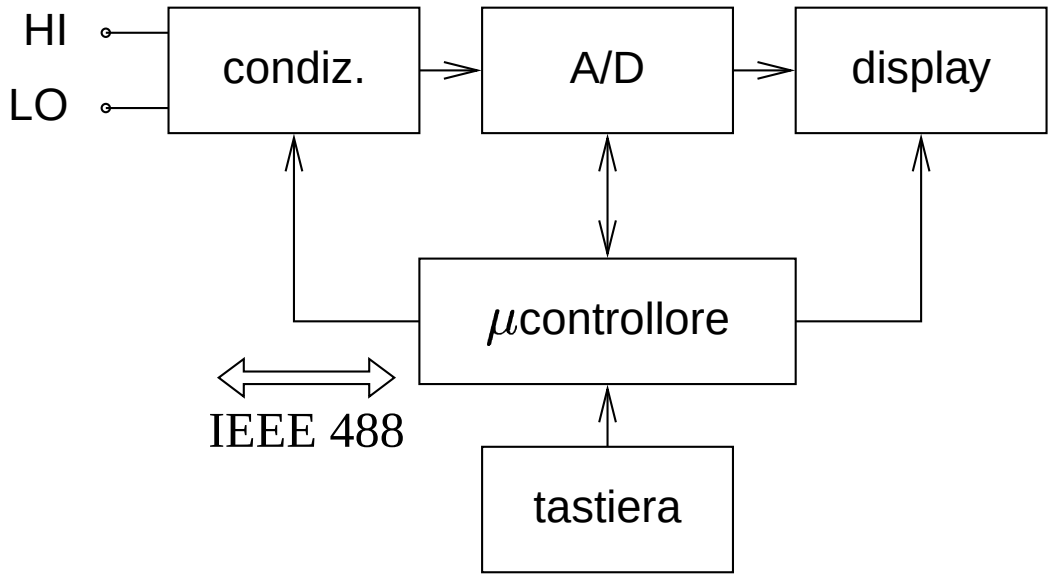
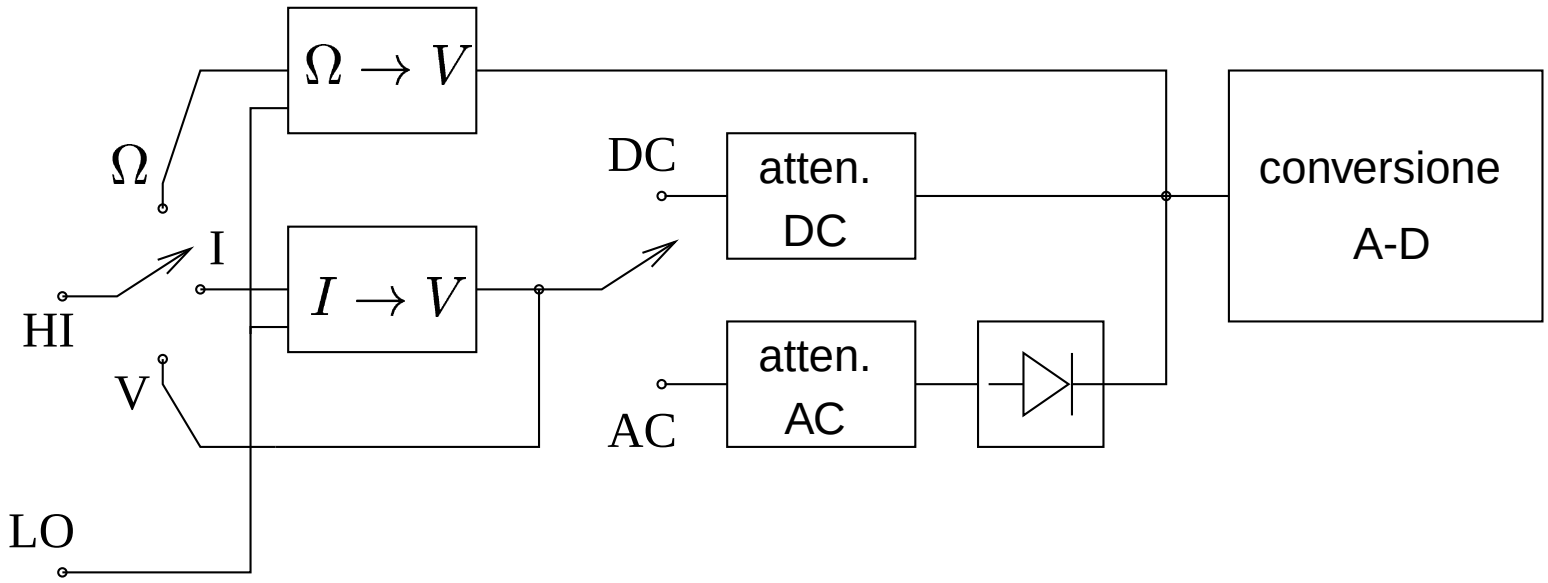
Multimetro digitale - schema a blocchi



- accuratezza e precisione maggiori rispetto a uno strumento elettromeccanico;
- possibilità di interfacciamento con Personal Computer;
- consentono misure di tensione e corrente (AC e DC) e di resistenza;
- anche misure di continuità, provadiodi, frequenza, periodo, temperatura (con sonde dedicate).

Multimetro digitale - condizionamento del segnale in ingresso



- conversione resistenza-tensione;
- conversione corrente-tensione;
- attenuazione (DC e AC);
- raddrizzamento.

Multimetro digitale

Principali caratteristiche:

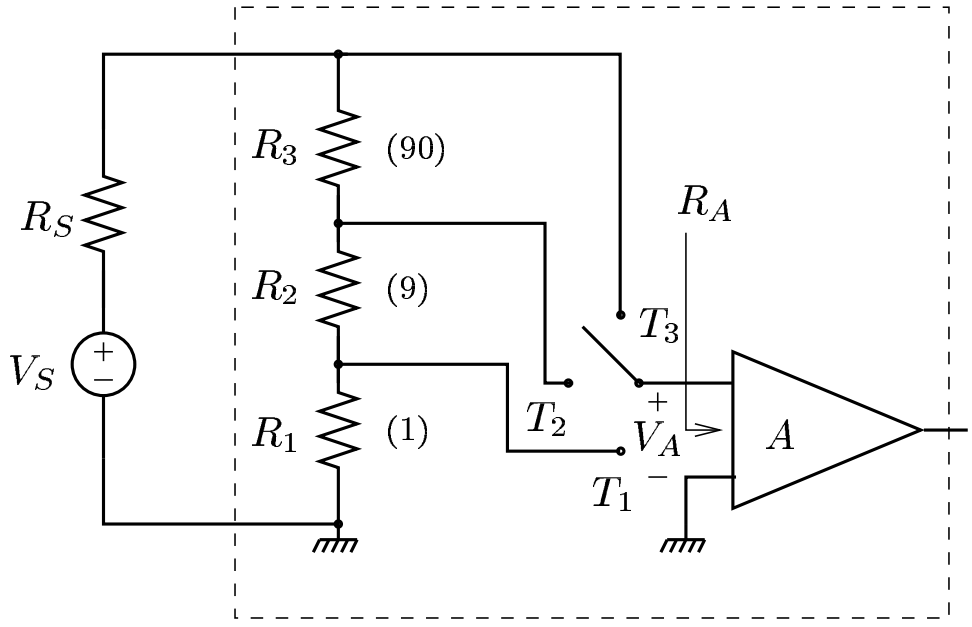
- Accuratezza;
- Sensibilità;
- n. cifre del display (es.: 5 1/2).

Funzioni accessorie:

- Autorange: selezione automatica della portata;
- Autopolarità: selezione automatica della polarità;
- Autozero: azzeramento di un eventuale *offset*;
- Calibrazione: ripristino (automatico) delle condizioni di funzionamento ideale.

⚠ : non presenti in tutti gli strumenti!

Attenuatori in C.C. (1)



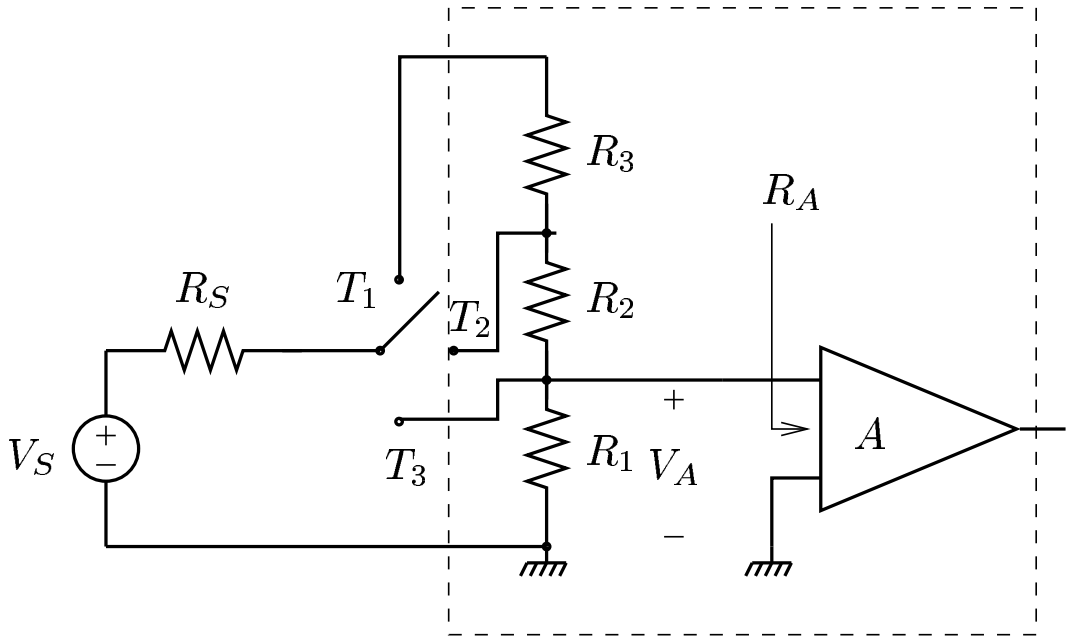
$$R_A \gg R_1 + R_2 + R_3$$
$$R_S \ll R_1 + R_2 + R_3$$
$$\Downarrow$$

$$T_1: \quad V_A = \frac{R_A \| R_1}{R_S + (R_A \| R_1) + R_2 + R_3} V_X \simeq \frac{R_1}{R_1 + R_2 + R_3} V_X (= 0.01 V_X)$$

$$T_2: \quad V_A = \frac{R_A \| (R_1 + R_2)}{R_S + [R_A \| (R_1 + R_2)] + R_3} V_X \simeq \frac{R_1 + R_2}{R_1 + R_2 + R_3} V_X (= 0.1 V_X)$$

$$T_3: \quad V_A = \frac{R_A \| (R_1 + R_2 + R_3)}{R_S + [R_A \| (R_1 + R_2 + R_3)]} V_X \simeq V_X$$

Attenuatori in C.C. (2)



$$R_A \gg R_1$$
$$R_S \ll R_1$$

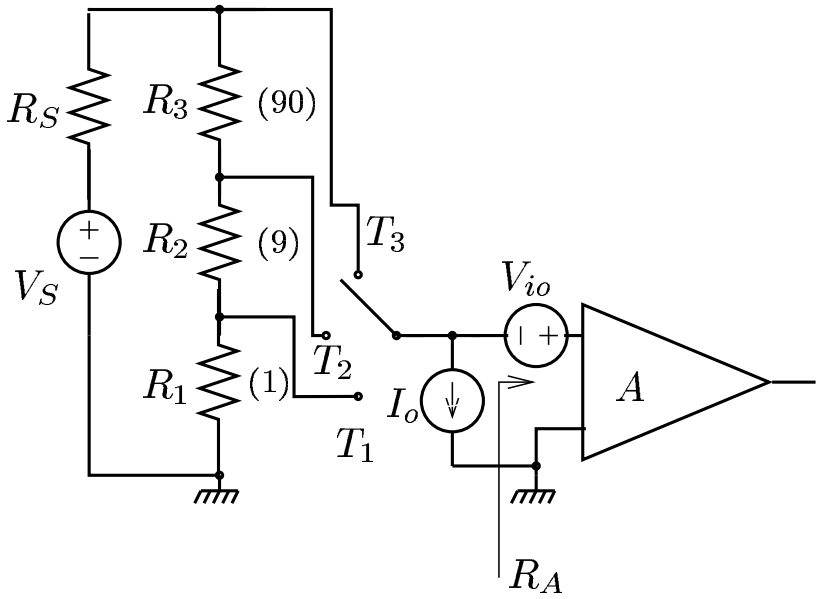
$$\Downarrow$$

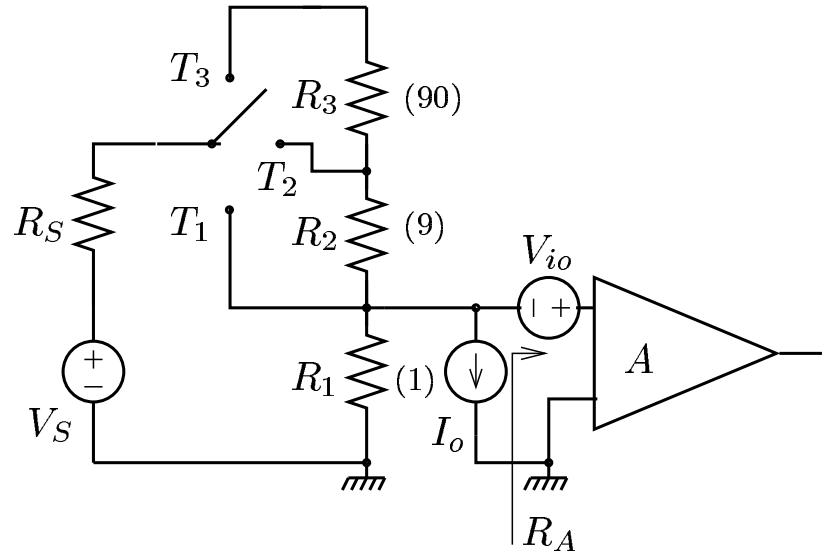
$$T_1: \quad V_A = \frac{R_A \| R_1}{(R_A \| R_1) + R_2 + R_3 + R_S} V_X \simeq \frac{R_1}{R_1 + R_2 + R_3} V_X$$

$$T_2: \quad V_A = \frac{R_A \| R_1}{(R_A \| R_1) + R_2 + R_S} V_X \simeq \frac{R_1}{R_1 + R_2} V_X$$

$$T_3: \quad V_A = \frac{R_A \| R_1}{(R_A \| R_1) + R_S} V_X \simeq V_X$$

Attenuatori - effetti dei generatori di offset





$V_{io} \rightarrow -AV_{io}$

I_o:

$T_1: \; -AI_o[R_1 \| (R_2 + R_3 + R_S)]$

$T_2: \; -AI_o[(R_1 + R_2) \| (R_3 + R_S)]$

$T_3: \; -AI_o[(R_1 + R_2 + R_3) \| R_S]$

$V_{io} \rightarrow -AV_{io}$

I_o:

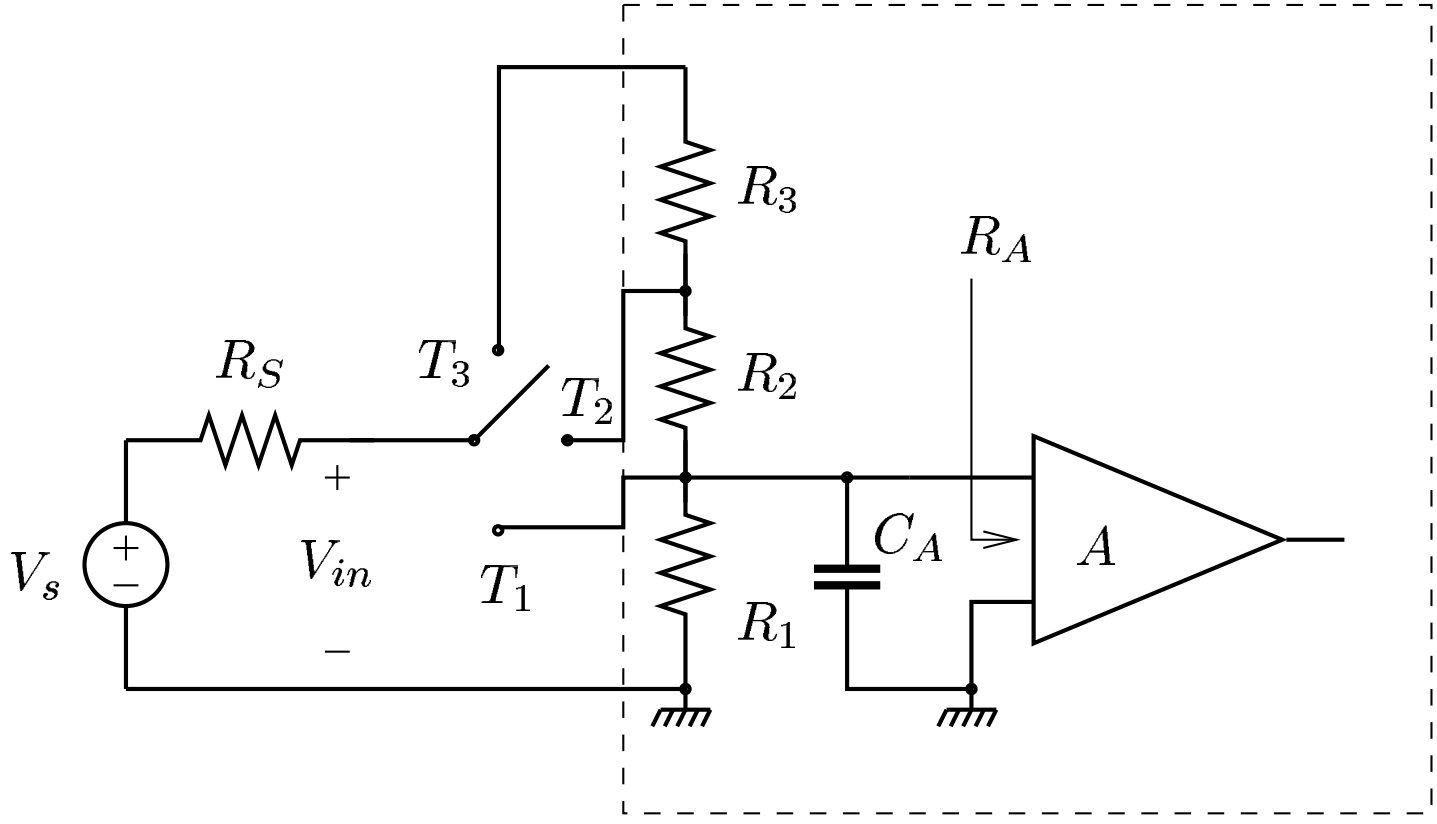
$T_1: \; -AI_o(R_1 \| R_S)$

$T_2: \; -AI_o(R_1 \| (R_S + R_2)$

$T_3: \; -AI_o(R_1 \| (R_S + R_2 + R_3)$

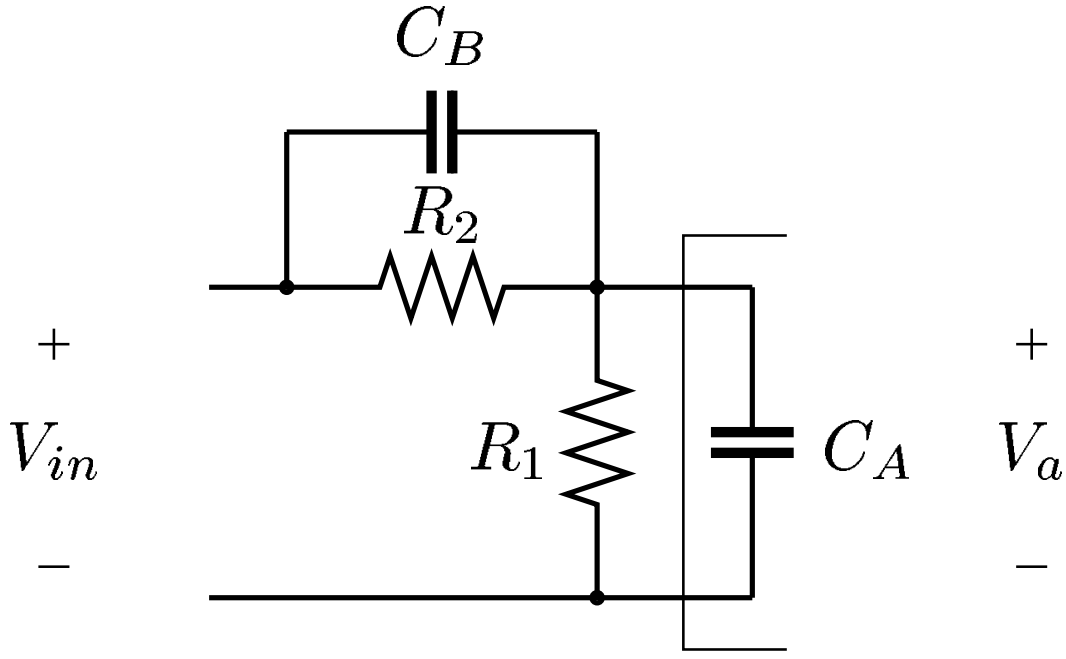
(meno dipendente da R_S)

Attenuatori in C.A.



⚠ attenuazione dipendente dalla frequenza!

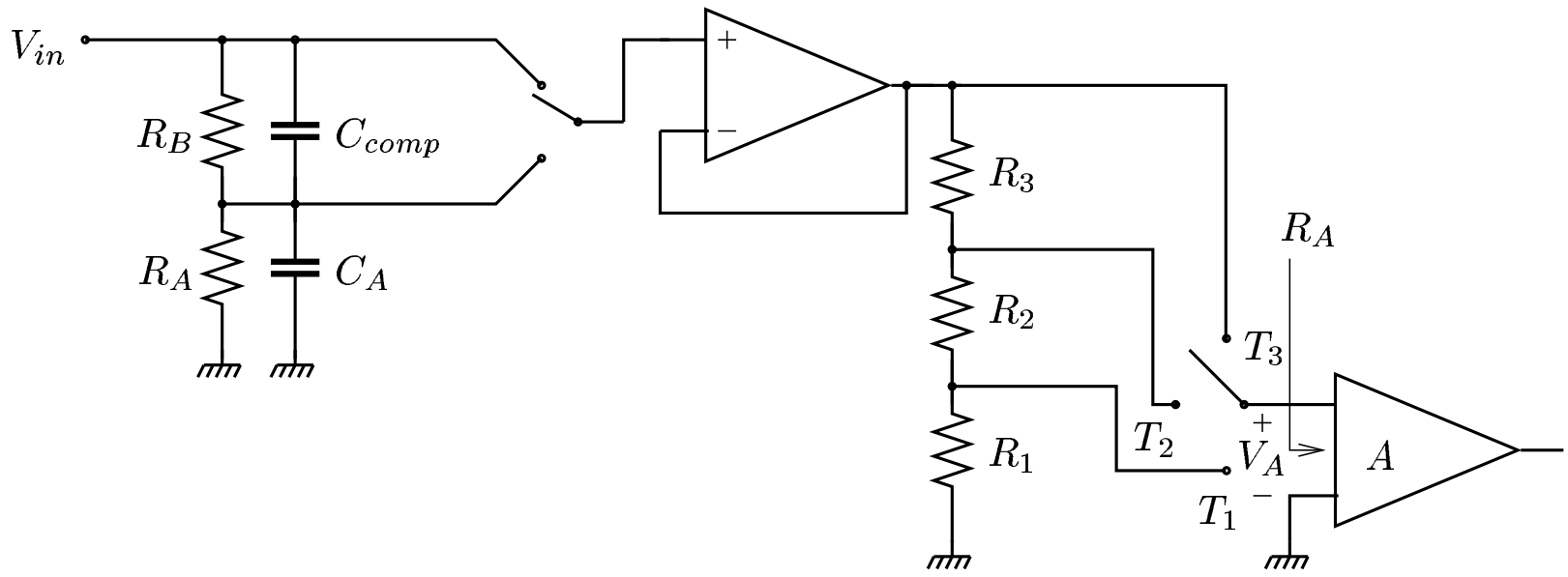
Partitore Compensato



$$W(0) = \frac{R_1}{R_1 + R_2}, \qquad W(\infty) = \frac{C_B}{C_A + C_B}$$

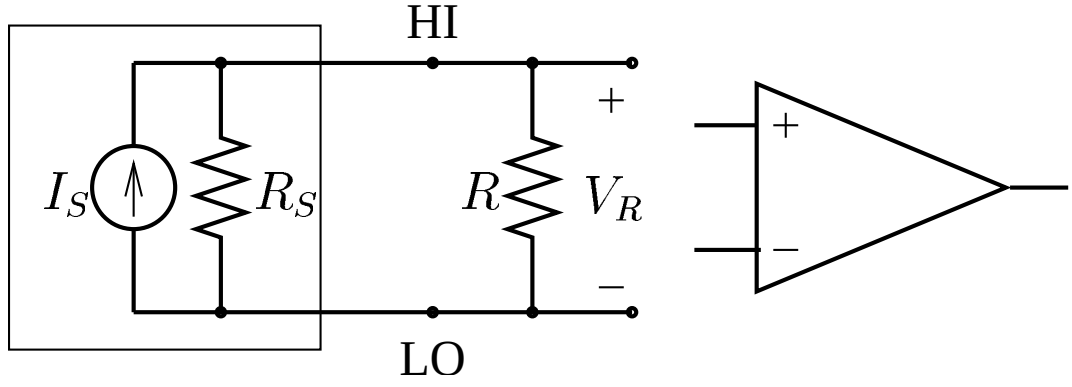
$$C_B = C_A \frac{R_1}{R_2} \quad \rightarrow \quad W(0) = W(\infty) = \text{cost.}$$

Partitore compensato a più stadi



Misure di corrente (1)

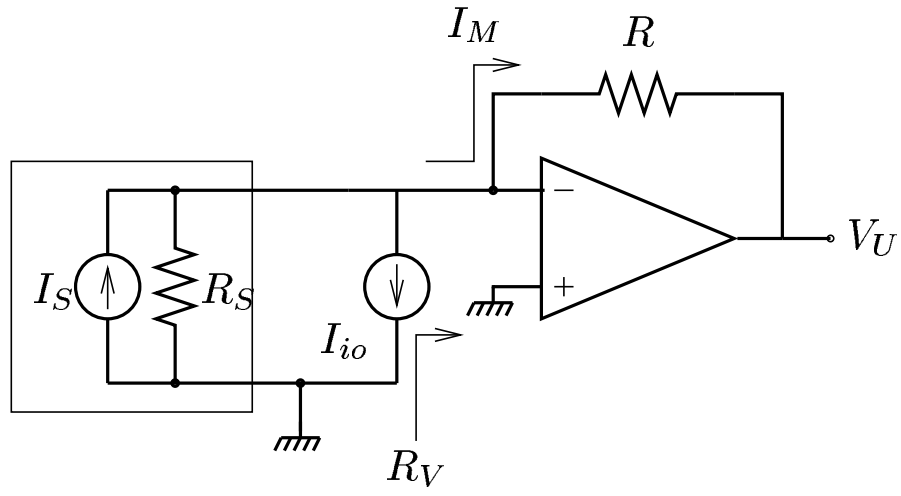
Resistenza di *shunt*



- effetto caricante
- (1)errore di misura $\varepsilon = I_S \dfrac{R}{R + R_S}$ (decresce con R)
- $R \| R_S$ introduce rumore termico: $S_{vn} = 4kT(R \| R_S)$
- (2)$SNR = \dfrac{I_S^2 (R \| R_S)^2}{4kT(R \| R_S)\Delta f} = \dfrac{I_S^2 (R \| R_S)}{4kT\Delta f} \simeq I_S^2 \dfrac{R}{4kT\Delta f}$ $(R \ll R_S)$; (decresce con R)
- (1) e (2) esigenze contrastanti!

Misure di corrente (2)

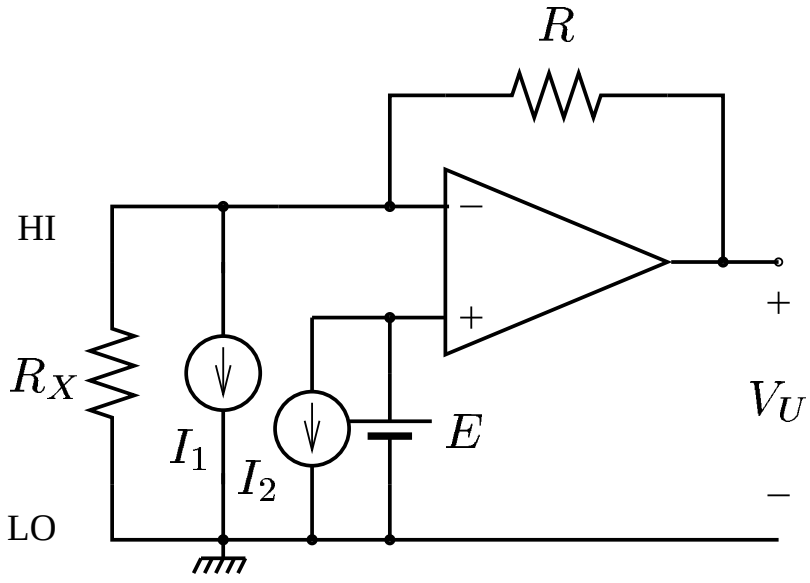
Conversione corrente-tensione



- $V_U = -RI_M$;
- errore di misura $\varepsilon = I_S \dfrac{R_V}{R_V + R_S}$;
- $R_V = \dfrac{R}{1 + A_{vol}}$
- $I_M \simeq I_S \quad \Rightarrow$ errore piccolo (effetto caricante molto contenuto)
- SNR come nel caso (1), ma R può essere di valore maggiore.

Misure di resistenza (1)

Metodo a tensione impressa



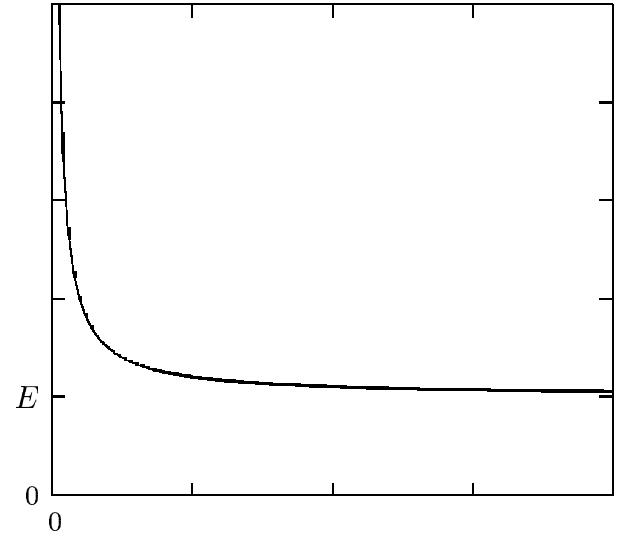
$$V_U = E\left(1 + \frac{R}{R_X}\right) + RI_1$$

(e V_{IO}?)

– max R_X misurabile: $RI_1 \ll E\dfrac{R}{R_X}$

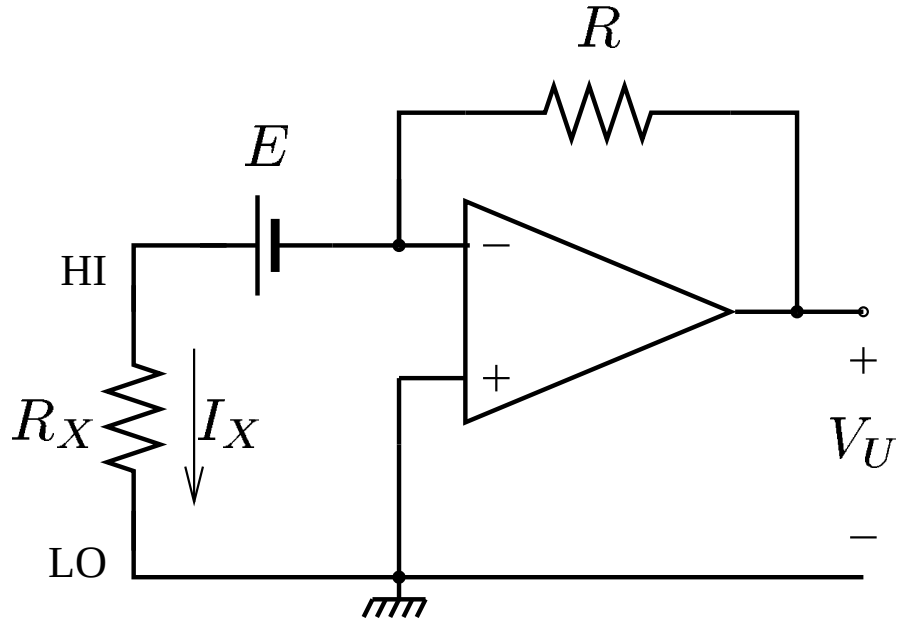
– $\Rightarrow \quad R_X \ll E/I_1$

– E è componente a modo comune!

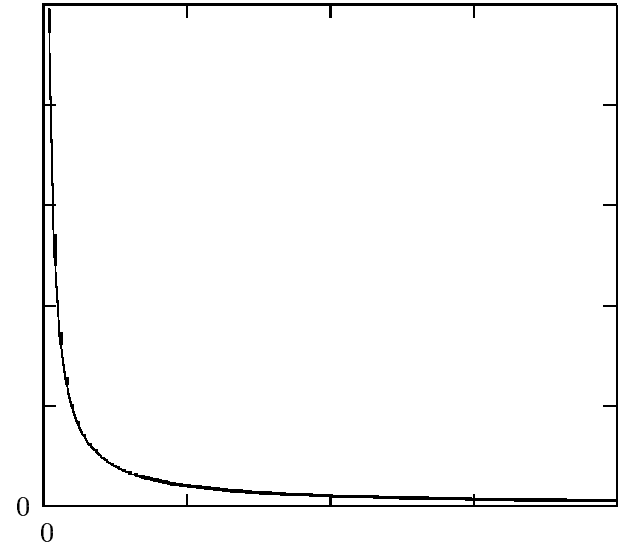


Misure di resistenza (2)

Metodo a tensione impressa (variante)

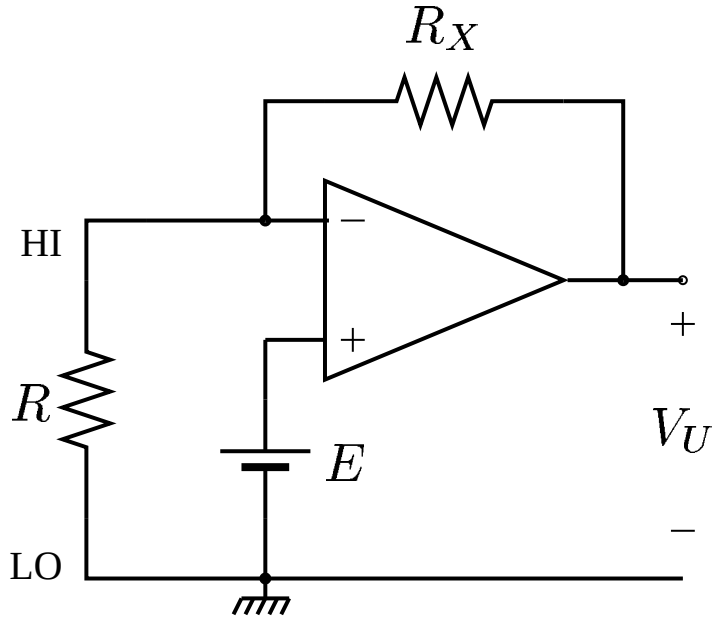


- $E - R_X I_X = 0 \quad \Rightarrow \quad I_X = E/R_X$
- $V_U = RI_X = E\dfrac{R}{R_X}$

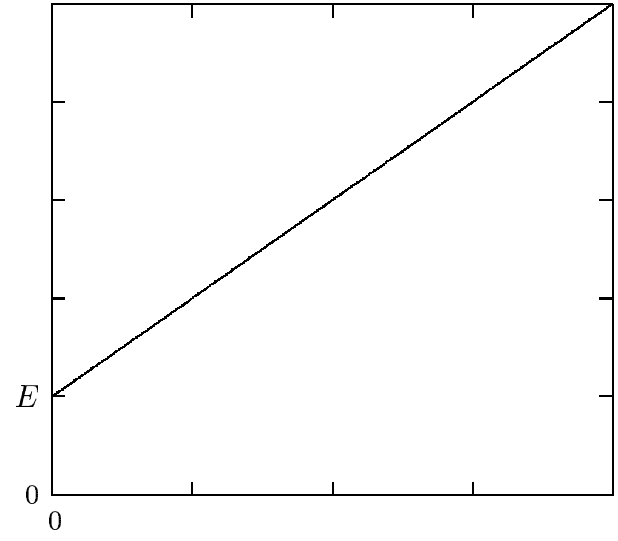


Misure di resistenza (3)

Metodo a corrente impressa

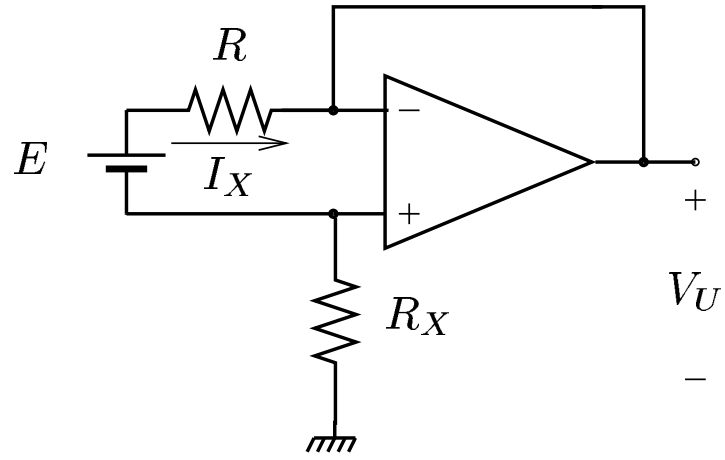


- $V_U = E\left(1 + \dfrac{R_X}{R}\right)$
- andamento lineare (+ offset)
- E è componente a modo comune

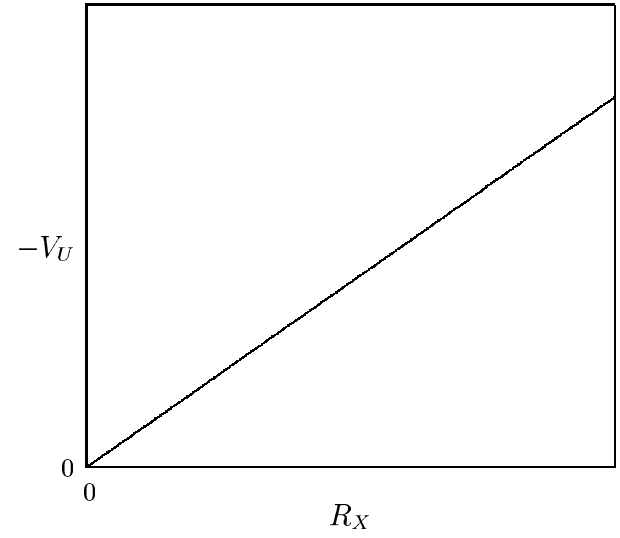


Misure di resistenza (4)

Metodo a corrente impressa (variante)



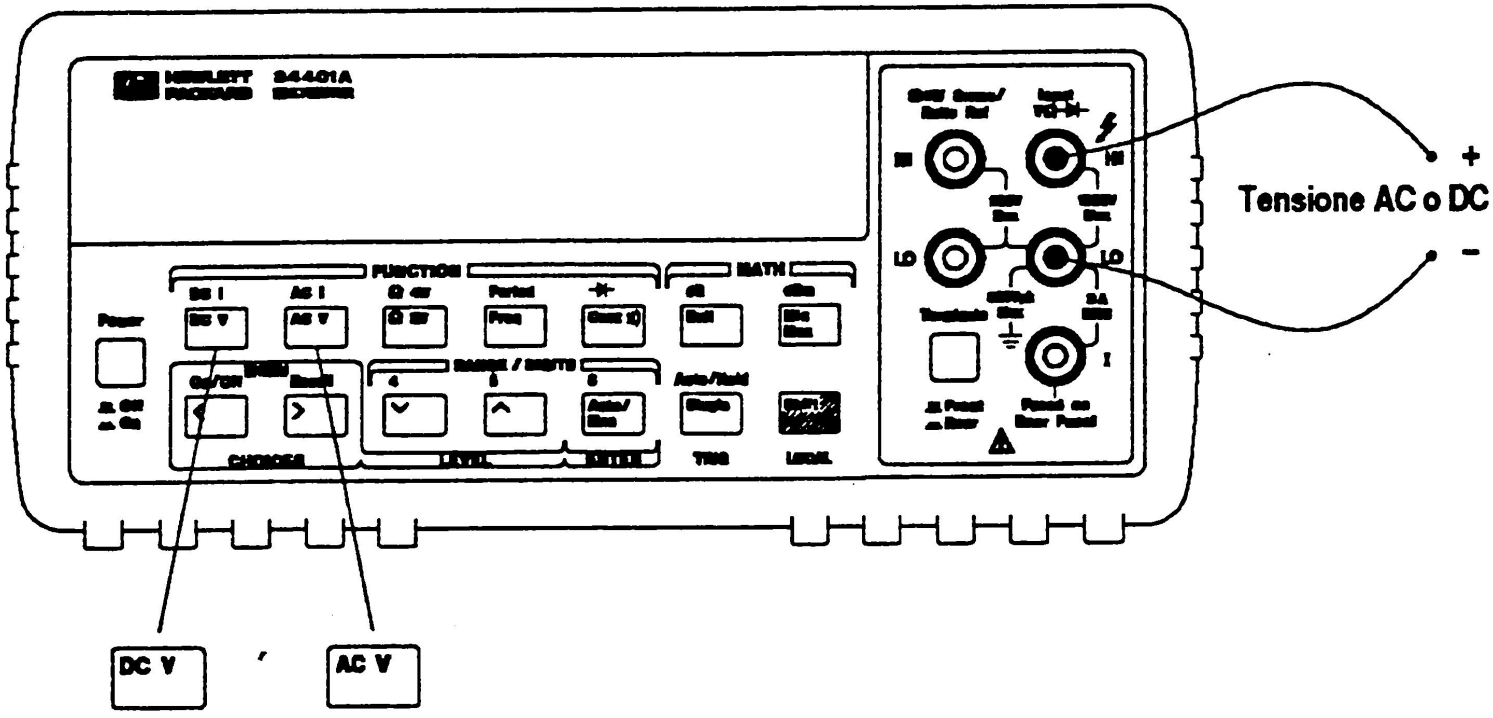
- $E - RI_X = 0 \quad \Rightarrow \quad I_X = E/R$
- $V_U = -R_X I_X = -E\dfrac{R_X}{R}$
- andamento lineare (senza offset)
- resistenza incognita riferita a “massa”



Multimetro digitale Agilent 34401A - specifiche (1)

Misure di tensione

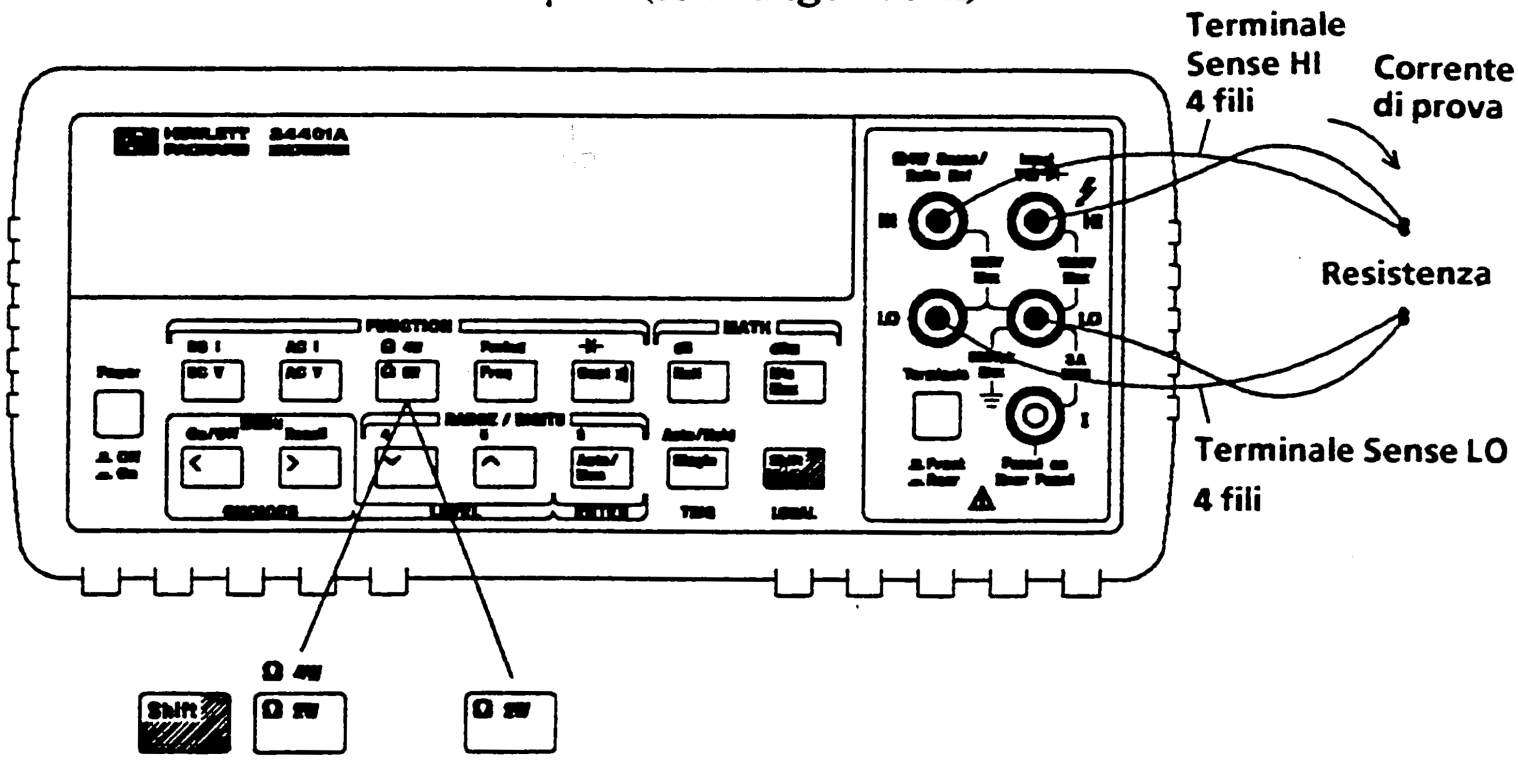
Range: 100 mV, 1 V, 10 V, 100 V, 1000 V (750 V AC)
Risoluzione massima: 100 nV (*con range 100 mV*)
Tecnica AC: RMS effettivo, accoppiamento AC



Multimetro digitale Agilent 34401A - specifiche (2)

Misura di resistenza

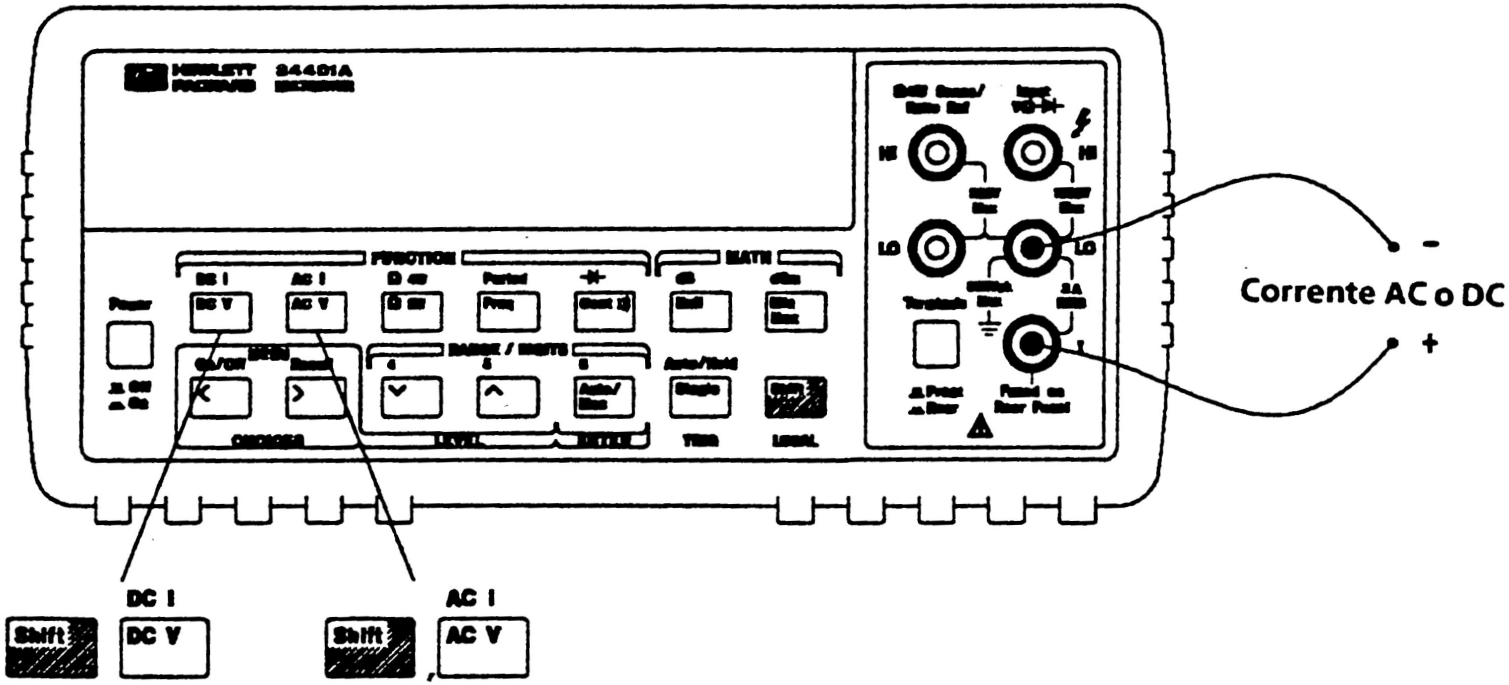
Range: 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, 1 MΩ, 10 MΩ, 100 MΩ
Risoluzione massima: 100 μΩ (*con range 100 Ω*)



Multimetro digitale Agilent 34401A - specifiche (3)

Misure di corrente

Range: 10 mA (solo DC), 100 mA (solo DC), 1 A , 3 A
Risoluzione massima: 10 nA (*con range 10 mA*)
Metodo AC: RMS effettivo, accoppiamento AC



Multimetro digitale Agilent 34401A - specifiche (4)

■ Specifiche DC

Caratteristiche di precisione ± (% della lettura + % del range) [1]

Funzione	Range [3]	Corrente di prova o tensione di carico totale	24 ore [2] 23°C ± 1°C	90 giorni 23°C ± 5°C	1 anno 23°C ± 5°C	Coefficiente di temperatura 0°C – 18°C 28°C – 55°C
Tensione DC	100.0000 mV		0.0030 + 0.0030	0.0040 + 0.0035	0.0050 + 0.0035	0.0005 + 0.0005
	1.000000 V		0.0020 + 0.0006	0.0030 + 0.0007	0.0040 + 0.0007	0.0005 + 0.0001
	10.00000 V		0.0015 + 0.0004	0.0020 + 0.0005	0.0035 + 0.0005	0.0005 + 0.0001
	100.0000 V		0.0020 + 0.0006	0.0035 + 0.0006	0.0045 + 0.0006	0.0005 + 0.0001
	1000.000 V		0.0020 + 0.0006	0.0035 + 0.0010	0.0045 + 0.0010	0.0005 + 0.0001
Resistenza [4]	100.0000 Ω	1 mA	0.0030 + 0.0030	0.008 + 0.004	0.010 + 0.004	0.0006 + 0.0005
	1.000000 kΩ	1 mA	0.0020 + 0.0005	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	10.00000 kΩ	100 µA	0.0020 + 0.0005	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	100.0000 kΩ	10 µA	0.0020 + 0.0005	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	1.000000 MΩ	5 µA	0.002 + 0.001	0.008 + 0.001	0.010 + 0.001	0.0010 + 0.0002
	10.00000 MΩ	500 nA	0.015 + 0.001	0.020 + 0.001	0.040 + 0.001	0.0030 + 0.0004
	100.0000 MΩ	500 nA // 10 MΩ	0.300 + 0.010	0.800 + 0.010	0.800 + 0.010	0.1500 + 0.0002
Corrente DC	10.00000 mA	< 0.1 V	0.005 + 0.010	0.030 + 0.020	0.050 + 0.020	0.002 + 0.0020
	100.0000 mA	< 0.6 V	0.01 + 0.004	0.030 + 0.005	0.050 + 0.005	0.002 + 0.0005
	1.000000 A	< 1 V	0.05 + 0.006	0.080 + 0.010	0.100 + 0.010	0.005 + 0.0010
	3.000000 A	< 2 V	0.10 + 0.020	0.120 + 0.020	0.120 + 0.020	0.005 + 0.0020
Continuità	1000.0 Ω	1 mA	0.002 + 0.010	0.008 + 0.020	0.010 + 0.020	0.001 + 0.002
Test diodi	1.0000 V	1 mA	0.002 + 0.010	0.008 + 0.020	0.010 + 0.020	0.001 + 0.002