Error de Método

Ing. Pablo De Césare
2025

Error de Método

- Se caracterizan porque el sistema de medición altera el sistema a medir.
  - Absorción de energía.
  - Desadaptación impedancias.

Error de Método

Nomenclatura

X_i : valor indicado de la magnitud a medir

$\bar{X}$: valor más probable o "valor verdadero"

El error absoluto de la medición

$$\Delta X_i = X_i - \bar{X}$$

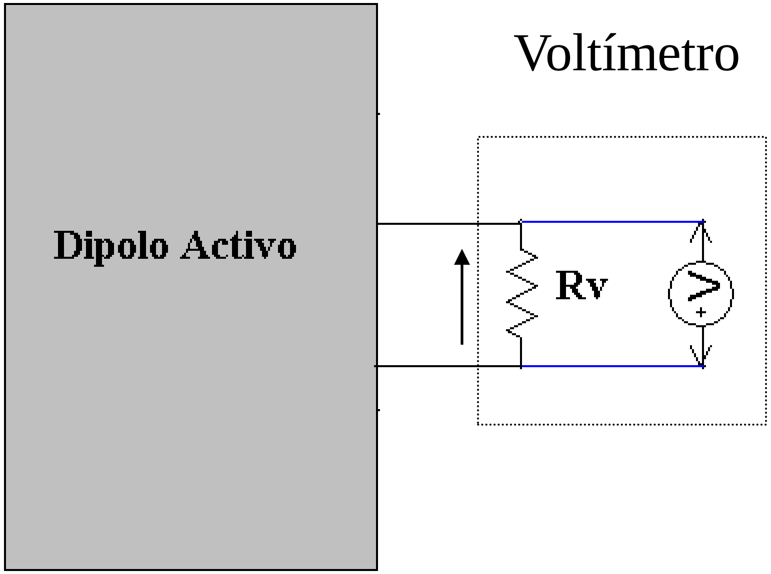
Error relativo

$e_i = \Delta X_i / X_i$ ó $e_i\% = \Delta X_i / X_i$

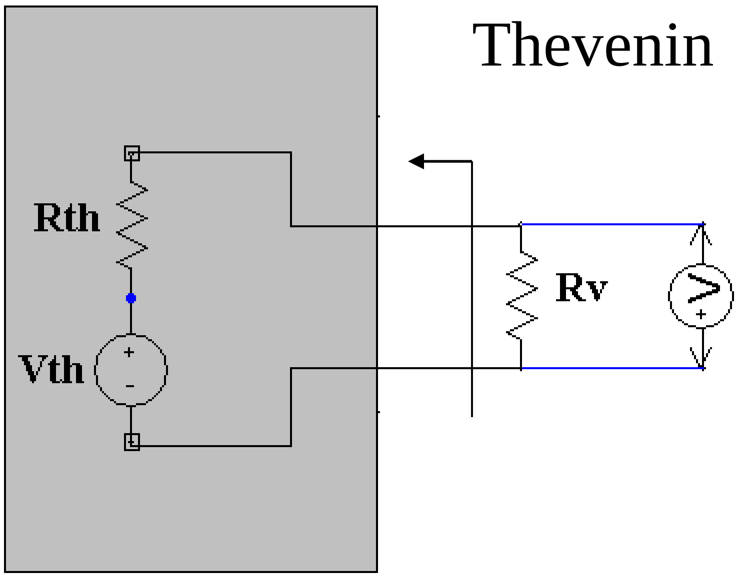
$$e_i = \frac{X_i - \bar{X}}{\bar{X}} = \longrightarrow \boxed{\bar{X} = \frac{X_i}{1 + e_i}}$$

Error de Método

1º analizaremos el caso de medir la tensión de salida de un dipolo activo

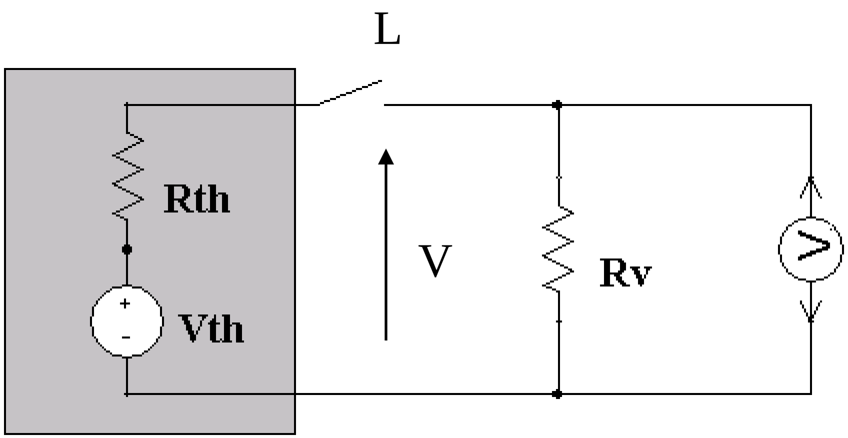


Error de Método



El dipolo activo se puede reducir a fuente Vth con una Rth

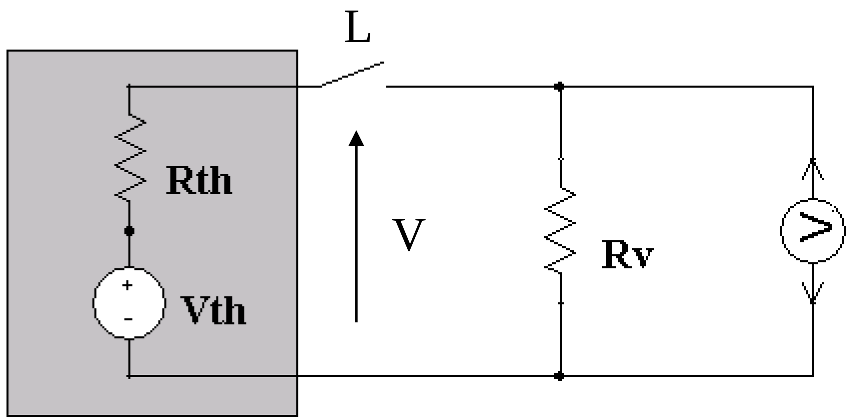
Error de Método



Con L abierta : V = Vth

Con L cerrada : ??

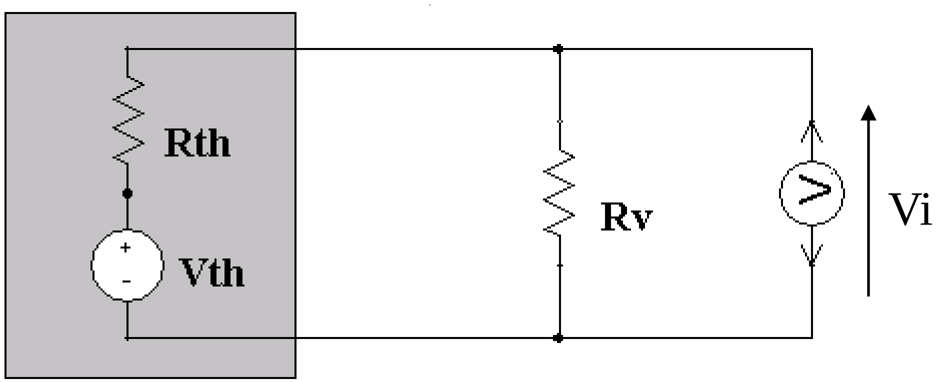
Error de Método



Con la llave cerrada la tensión indicada por el voltímetro Vi es distinta Vth

$$V = Vth$$

Al cerrar la llave



$$Vi = \frac{V}{Rth + Rv} \cdot Rv$$

$$Vi = \frac{V}{1 + \frac{Rth}{Rv}}$$

Error de Método

$$Vi = \frac{V}{1 + \frac{Rth}{Rv}}$$

$Vi = Vth$ cuando

$Rth = 0$
$Rv = \infty$

<u>Calculo del error de método</u>

$\Delta Vi = Vi - V$ remplazamos a expresión de Vi

$$\Delta Vi = \frac{V}{1 + \frac{Rth}{Rv}} - V$$

$$e_m = \Delta Vi / V \longrightarrow \boxed{e_m = \frac{1}{1 + \frac{Rth}{Rv}} - 1}$$

PONTIFICIA UNIVERSIDAD CATÓLICA ARGENTINA

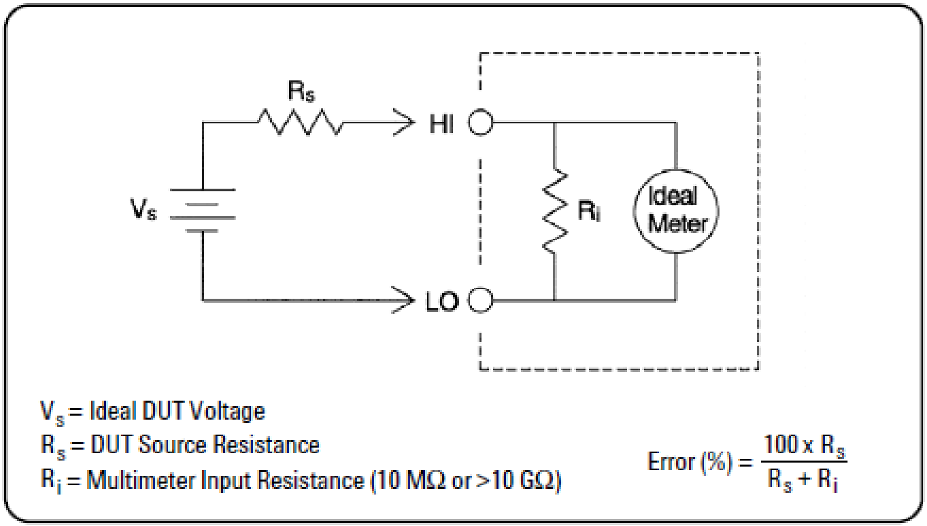
Error de Método

$$e_m = \frac{1}{1 + \frac{R_{th}}{R_v}} - 1$$

$$V = \frac{V_i}{1 + e_m}$$

PONTIFICIA UNIVERSIDAD CATÓLICA ARGENTINA

Ya lo dicen las notas de aplicación



Loading Errors Due to Input Resistance — Measurement loading errors occur when the resistance of the DUT is an appreciable percentage of the multimeter's own input resistance. Figure 7 shows this error source.

To reduce the effects of loading errors, and to minimize noise pickup, set the Agilent 34401A's input resistance to greater than 10 GΩ for the 100 mVdc, 1 Vdc, and 10 Vdc ranges. The input resistance is maintained at 10 MΩ for the 100 Vdc and 1000 Vdc ranges.

Application Note AN 1389-1

Calibrador DMM

Pioneer/Instrumentation

CALIBRATOR MODEL **450A**

PORTABLE PRECISION VOLTAGE SOURCE

- FOUR OUTPUT VOLTAGES . . . 10 VDC, 1.0 VDC, 100mVDC, and 10mVDC
- ±0.05% ACCURACY . . . 10 V, 1V, and 100mV OUTPUTS
- ±0.1% ACCURACY 10mV OUTPUT
- LOW OUTPUT RESISTANCE
- SHORT CIRCUIT PROOF OUTPUTS
- BATTERY POWERED
- PROVISION FOR EXTERNAL SUPPLY
- LED BATTERY CONDITION INDICATOR
- LOW COST

DESCRIPTION

The Quik-E® is a portable precision DC voltage source which was designed to provide a convenient means of checking and adjusting voltage measuring equipment.

The performance of the Model 450A is intended to complement that of precision digital instruments, but its low output resistance gives it the versatility required for use as a universal calibration tool.

The exceptional accuracy and stability of the Quik-E® are achieved using a solid state voltage reference and precision voltage divider.

APPLICATIONS

- Calibration of Digital Voltmeters and Multimeters
- Calibration of VOM's
- DC Calibration of Oscilloscopes
- Portable Voltage Reference
- Calibration of Chart Recorders

Pioneer/Instrumentati

DIVISION OF PIONEER-STANDARD ELECTRONICS
4800 EAST 131ST STREET / CLEVELAND, OHIO
(216) 58

SPECIFICATIONS

Output Voltages: 10mVDC, 100mVDC, 1.0VDC 10.0VDC

Output Resistance: 5 ohms typical for 10mVDC
50 ohms typical for 100mVDC
500 ohms typical for 1.0 VDC
1000 ohms typical for 10.0VDC

Note: Specific output resistance on each unit.

Guaranteed Accuracy: ±0.05% (15 to 35°C) on 100 mV, 1.V, 10.V Outputs
±0.1% (15 to 35°C) on 10 mV Output

Temp. Coefficient: 10 PPM/°C typical 0 – 50°C

Output Stabilization Time: 30 seconds to rated accuracy.

Power Required: Self contained batteries (2 Mallory MN 1604 alkaline cells, 9 VDC, or equivalent) or external 15 to 20 VDC supply at approximately 15 MA

Battery Life: Minimum of 10 hours @ continuous duty Approximately 6 months @ normal intermittent duty.

Weight: Approximately 16 ounces with batteries

Dimensions: 3½" wide, 6" long, 2" deep

OPERATING INSTRUCTIONS

STANDARD AND INTERMEDIATE OUTPUTS:

In standard operation the desired output range is connected to the instrument to be calibrated. Intermediate output voltages are available by using combinations of the positive output terminals. In this mode of operation the resultant output voltage is a subtractive function of the lower from the higher value.

ACCURACY AND LOADING CONSIDERATIONS:

The Quik-E® calibrator is designed to provide rated accuracy into high input resistance instruments such as digital panel meters and test equipment. When instruments of lower input resistance are calibrated, and where it is desirable to know the specific effect of loading on the Quik-E® the following formula can be utilized.

$$E_a = \frac{R_{in}}{R_{in} + R_q} \times \text{rated output}$$

where: E_a = actual output
R_{in} = load resistance
R_q = Quik-E output resistance

EXAMPLE: In the case of an instrument of 20,000 ohms per volt sensitivity calibrated on the 10.0 VDC output of the Quik-E® calibrator, the actual output voltage based on loading is 9.95 VDC.

$$E_a = \frac{200{,}000}{200{,}000 + 1{,}000} \times 10.0 = 9.95 \text{ VDC}$$

EXTERNAL SUPPLY OPERATION:

The Quik-E® calibrator can be operated from an external bench supply or with the AC adapter when continuous operation or conservation of battery life is desirable.

The external supply of 15 to 20 VDC is connected to the "EXT PWR" jacks. This provides a continuous output from the Quik-E for use as a standard reference.

Protection is provided in the external supply input to protect the device from damage due to accidental polarity reversal of the supply.

BATTERY CONDITION INDICATOR:

A Light Emitting Diode is provided on the front panel to indicate the presence of sufficient battery voltage for accurate operation. The relative intensity of this LED is indicative of battery strength. As long as there is visible indication from this LED, regardless of the intensity, the Quik-E® calibrator will operate within rated accuracy specifications.

NORMAL MAINTENANCE CONSIDERATIONS:

Battery Replacement is accomplished by removing the 4 mounting screws on the cover plate and carefully removing the cover and foam material covering the battery cavity. The old batteries should be removed and discarded and replaced with two Mallory MN 1604 alkaline cells or their equivalent.

Periodic Calibration Checks are recommended for reliable operation. These should be performed on a 6 month interval. It is recommended that recalibration, when required, be performed by Pioneer/Instrumentation, or a qualified instrument laboratory, utilizing differential measurement techniques.

A Statement of Calibration traceable to the National Bureau of Standards can be provided allowing the Quik-E® calibrator to be utilized as a secondary standard where portability and ruggedness are required.

The statement of calibration furnished lists the actual output values of the unit calibrated.

REPRESENTATIVE

Ordering Information -- Specify

Model 450A Quik-E® Calibrator . $99.50

Model PS45A-AC Adapter Accessory for 110 VAC Line Operation. . $25.00

Statement of Calibration traceable to National Bureau of Standards . $15.00

UCA
PONTIFICIA UNIVERSIDAD CATÓLICA ARGENTINA

Que pasa en AC?

No inventamos nada tampoco

AC Loading Errors — In the ac voltage function, the input of the Agilent 34401A appears as a 1MW resistance in parallel with 100 pF of capacitance. The cabling used to connect signals to the multimeter will also add additional capacitance and loading. Figure 2 shows the multimeter's approximate input resistance at various frequencies.

Input Frequency	Input Resistance
100 Hz	1 MW
1 kHz	850 kW
10 kHz	160 kW
100 kHz	16 kW

Figure 2.

For Low Frequencies:

$$\text{Error (\%)} = \frac{-100 \times R_s}{R_s + 1M\Omega}$$

Additional error for high frequencies:

Where:

$$\text{Error (\%)} = 100 \times \left[\frac{1}{\sqrt{1 + (2\pi \times F \times R_s \times C_{in})^2}} - 1 \right]$$

R_s = Source Resistance

F = Input Frequency

C_{in} = Input Capacitance (100 pF) plus Cable Capacitance

Note: *Be sure to use low-capacitance cable when measuring high-frequency signals.*

Especificaciones de Impedancia de Entrada típicas

DC Voltage

Measurement Method:
Continuously integrating multi-slope III A-D converter

A-D Linearity:
0.0002% of reading + 0.0001% of range

Input Resistance:
10 MΩ or 0.1 V, 1 V, 10 V ranges:
Selectable > 10,000 MΩ

100 V, 1000 V ranges: 10 MΩ ±1%

Input Bias Current: < 30 pA at 25°C

Input Protection: 1000 V all ranges

dcV:dcV ratio accuracy:
V_{input} Accuracy + $V_{relevance}$ Accuracy

True RMS AC Voltage

Measurement Method:
AC-coupled true rms-measures the ac component of the input with up to 400 Vdc of bias on any range.

Crest Factor:
Maximum of 5:1 at full scale.

Additional Crest Factor errors (non-sinewave):
Crest factor 1-2: 0.05% of reading
Crest factor 2-3: 0.15% of reading
Crest factor 3-4: 0.30% of reading
Crest factor 4-5: 0.40% of reading

Input Impedance:
1 MΩ ± 2% in parallel with 100 pF

Input Protection: 750 Vrms all ranges

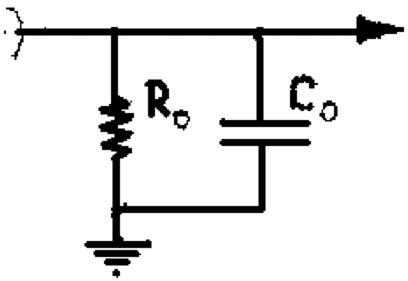
Model 187 & 189
Manual de Uso

Impedancia de entrada

Función	Impedancia de entrada (Nominal)
Voltios, mV	10 MΩ, < 100 pF

PONTIFICIA UNIVERSIDAD CATÓLICA ARGENTINA

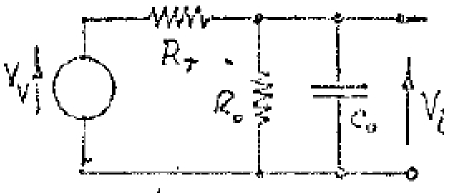
Un osciloscopio es peor!!!



Sensibilidad	1 mV a 5 V/DIV , 12 pasos en secuencia 1-2-5
Exactitud	5mV a 5V/DIV ≤ 3% , 1 mV –2 mV/DIV ≤ 5% (10ºC a 35ºC)
Sensibilidad del Vernier	A 1 / 2,5 o menos del valor indicado en el Panel
Ancho de Banda	5 mV a 5 V/DIV DC a 50 MHz
	1mV – 2 mV /DIV DC a 15 MHz
	Acoplado en AC , la frecuencia de corte inferior es 10 Hz (- 3 dB con referencia a 8 div a 100 KHz)
Rise Time	5 mV – 5 V/DIV = 7 nS 1 mV – 2 mV/DIV = 23 nS
Impedancia de Entrada	1 MOhm ± 2 % // Aprox. 25 pF
Características de respuesta para Onda Cuadrada	Sobreimpulso : ≤ 5% (Sensibilidad en 10 mV/DIV) Otras distorsiones para otros rangos : agregar 5 % al valor indicado anteriormente (10 ºC a 35 ºC)
Desplazamiento del Balance de CC	5 mV a 5 V/DIV : ± 0.5 DIV , 1 mV – 2mV/DIV : ± 2.0 DIV
Linealidad	< ± 0.1 DIV de cambio de amplitud cuando una señal de 2 DIV de amplitud , centrada en la gratícula , es movida verticalmente

Es importante ver que la impedancia de entrada esta dada con un error de ±2%.
Es de esperar que el error de método también tenga asociado un error

Error de método en ORC



$$Vi = \frac{\frac{R0 * (\frac{-j}{wc})}{R0 - j\,\frac{1}{wc}}}{\frac{R0 * (\frac{-j}{wc})}{R0 - j\,\frac{1}{wc}} + Rt} V$$

Sacando denominador común $R0 - j\,\frac{1}{wc}$

$$Vi = \frac{R0 * (\frac{-j}{wc})}{R0 * (\frac{-j}{wc}) + Rt * (R0 - j\,\frac{1}{wc})} V$$

T= $\frac{Vi}{V}$

$$T = \frac{)\ -jR0}{-jR0 + RtR0wc - jRt)}$$

Multiplicando y dividiendo por $\frac{j}{Ro}$

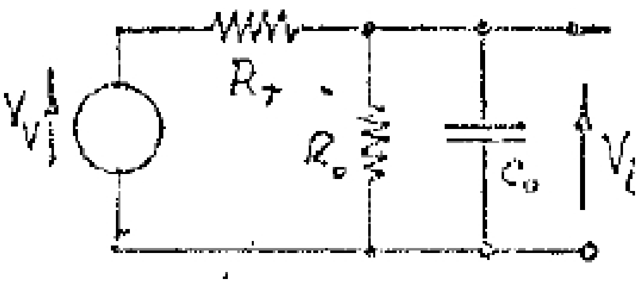
$$T = \frac{1}{1 + jRtwc + \frac{Rt}{R0}}$$

$$T = \frac{1}{\sqrt{(\frac{Rt}{R0} + 1)^2 + (Rtwc)^2}}$$

El error de método es: $Em = \frac{\Delta Vi}{V} = \frac{Vi - V}{V} = \frac{Vi}{V} - \frac{V}{V} = T - 1$

$$\boxed{Em = \frac{1}{\sqrt{(\frac{Rt}{R0} + 1)^2 + (Rtwc)^2}} - 1}$$

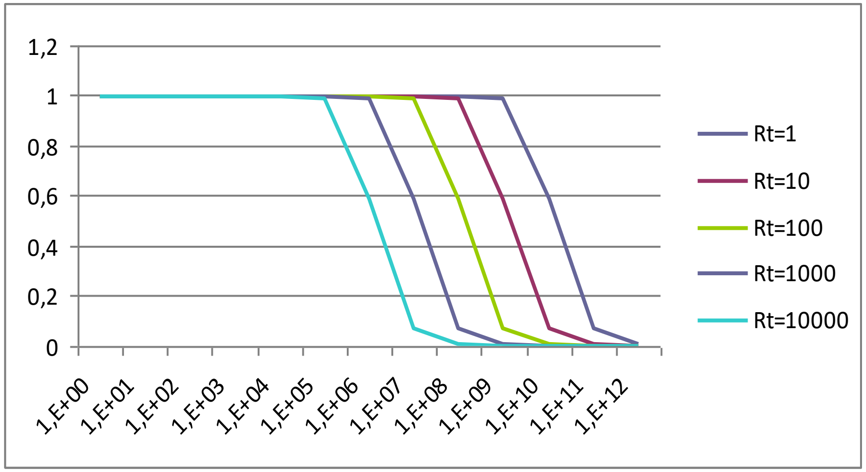
Transferencia de entrada



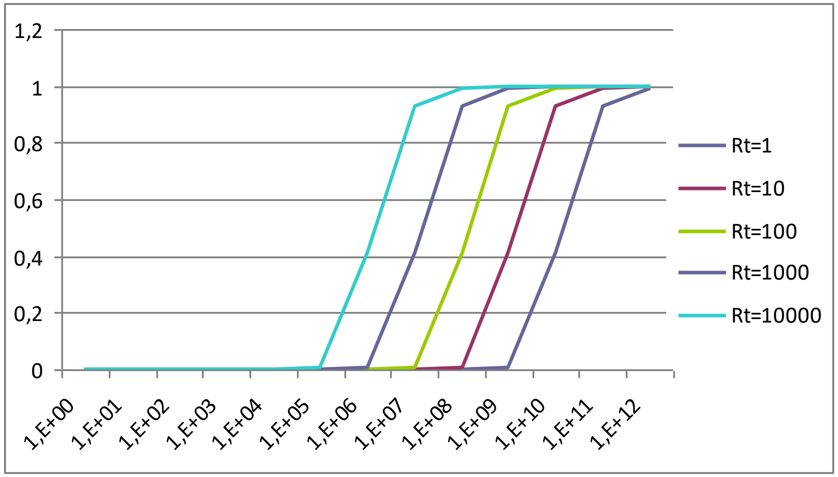
Ro = 1MΩ
Co = 22 pF

$$T = \frac{Vi}{Vv} = \frac{1}{\sqrt{\left(1 + \frac{Rt}{Ro}\right)^2 + \left(\omega^2 . Co^2 . Rt^2\right)}}$$

Transferencia



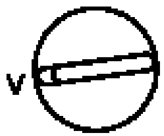
Em



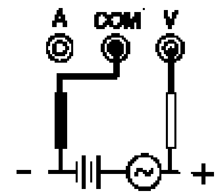
Error de Método

Vamos a analizar ahora el error que suelen cometer los voltímetros digitales que expresan la lectura en dBm

Multímetros digitales de RMS verdadero
TX-DMM™
TX1 y TX3



Mediciones de voltaje de dB y dBm

Medición	Tecla de menú	Conexión de cables	Pantalla principal	Pantalla superior
dB (sólo TX3)[1]	4 dB o dBm (pulse para alternar)		AC	dB
dBm (sólo TX3)[2]			AC	dBm

1 Lectura dB = 20 × log (lectura de la pantalla principal/ref), donde ref = 1 V es el valor predeterminado.

2 Lectura dBm = 10 × log (lectura de la pantalla principal ^{2}/R), donde R=600 Ω

PONTIFICIA UNIVERSIDAD CATÓLICA ARGENTINA

Error de Método

$$P[dBm] = 10.log\left(\frac{\frac{V^2}{R}}{1mW}\right)$$

$$1mW = \frac{V^2_{ref}}{600\Omega} \rightarrow V_{ref} = \sqrt{1mW.600\Omega} = 0.7746V$$

$$P[dBm] = 10.log\left(\frac{\frac{V^2}{R}}{\frac{(0.7746V)^2}{600\Omega}}\right)$$

$$P[dBm] = 10.log\left(\frac{\frac{V^2}{R}}{\frac{(0.7746V)^2}{600\Omega}}\right) = 20.log\left(\frac{V}{0.7746}\right) + 10.log\left(\frac{600\Omega}{R}\right)$$

Error de Método

$$P[dBm] = 20.log\left(\frac{V}{0.7746}\right) + 10.log\left(\frac{600\Omega}{R}\right)$$

Conversión que aplica el voltímetro para pasar de tensión a potencia en dBm

Error de método por ser distinta la impedancia sobre la cual se mide tensión

Con lo cual

P = Pi + Corrección por Error de método

Resumen
Error de Método

- La universalidad del problema!!

- ¿Siempre es necesario realizar la corrección por error de método?

- Es necesario fijar un criterio:

  - Que sea 10 veces menor que el error de lectura.

- Siempre que se realice una medición interpretar de que manera los instrumentos afectan al sistema, utilizando para ello su CONOCIMIENTO METROLOGICO razonando cada punto del procedimiento de medición.

PONTIFICIA UNIVERSIDAD CATÓLICA ARGENTINA