WHITEPAPER

VX Instruments
the test solutions provider

Measuring accuracy and measuring ranges in dynamic AC measuring applications

If you are working in measurement technology, you cannot avoid measurement errors and measurement inaccuracies. In our whitepaper we show the effects of errors in the case of dynamic AC measurement.

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In our whitepaper "The sum of measurement uncertainty and measurement error", we presented the influences of a measuring instrument on measurement inaccuracy and measurement errors in the case of static DC measurement. In addition, we demonstrated the advantage of measuring instruments with a higher number of measuring ranges in terms of measurement uncertainty.

In this whitepaper, we discuss the effects of measurement uncertainty in the case of dynamic AC measurement. It was stated in the last whitepaper that measurement accuracy represents the sum of measurement uncertainty and measurement error.

Measurement uncertainty occurs with both dynamic AC measurements and static measurements, so the values given in the data sheets must be taken into account. In dynamic AC measurements, a measurement error caused by the measuring instrument itself not only affects the internal ohmic resistance, but also the parallel internal capacitance (Figure 1).
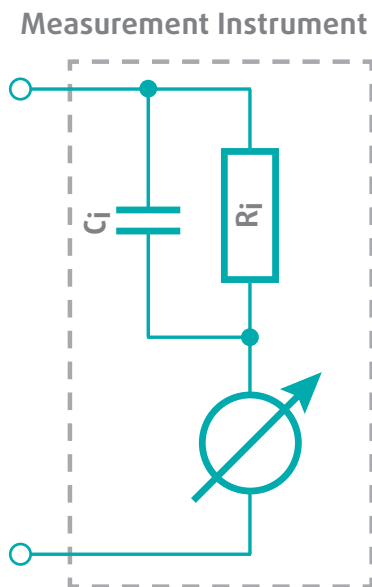
Measurement Instrument

Figure 1: A basic representation of the input impedance.

1. INPUT INPEDANCE – PARALLEL CONNECTED OHMIC RESISTOR OR CAPACITOR

The input impedance of an oscilloscope, digitizer, or multimeter is therefore usually defined as the parallel connection of an ohmic resistor and a capacitor. Typical values for digital multimeters are 10 MOhm and capacities from 20 to 300 pF (see whitepaper "How to select oscilloscope, digitizer and DMM"). For oscilloscopes, 1 MOhm and 20 pF can be expected. In the example of measurement on a voltage divider, a sinusoidal source signal of $24\,V_{AC}$ is fed in. Figure 2 shows the unloaded system with the ideal output voltage of $12\,V_{AC}$.

If a measuring instrument is connected to measure the voltage via R2, as in this dynamic measurement case, the combination of a parallel-connected resistor and a parallel-connected capacitor is effective. This can be seen in Figure 1 in an equivalent circuit diagram. This results in an impedance Zi, which is connected in parallel to the resistor to be measured, and thus generates a frequency-dependent measurement error. The impedance Zi is calculated as in Figure 2.
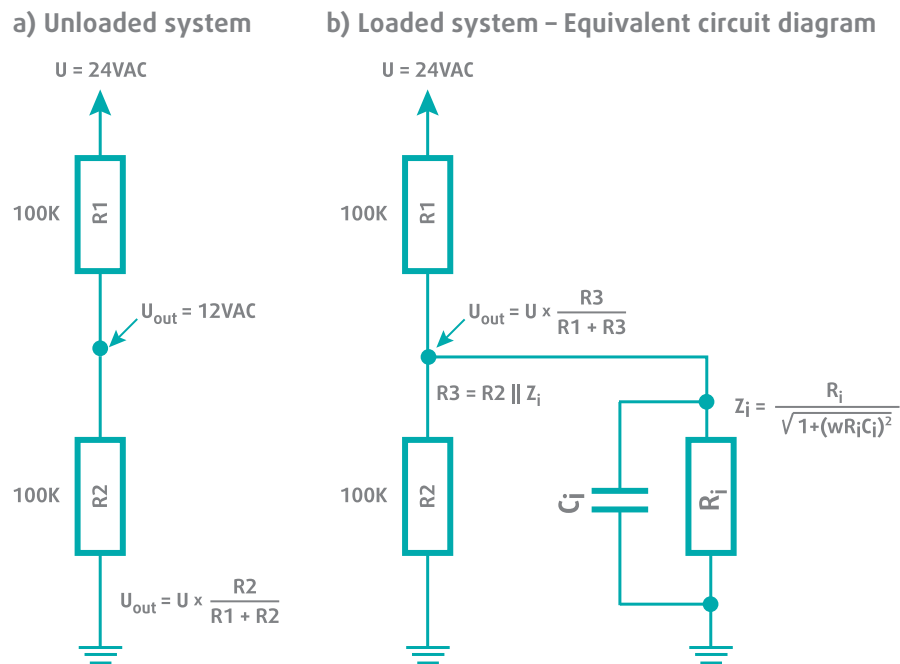
a) Unloaded system

U = 24VAC

100K — R1

U_{out} = 12VAC

100K — R2

$U_{out} = U \times \dfrac{R2}{R1 + R2}$

b) Loaded system – Equivalent circuit diagram

U = 24VAC

100K — R1

$U_{out} = U \times \dfrac{R3}{R1 + R3}$

R3 = R2 ∥ Z_i

100K — R2

C_i

R_i

$Z_i = \dfrac{R_i}{\sqrt{1+(wR_iC_i)^2}}$

Figure 2: Measurement at a voltage divider; left as an unloaded system and right as an equivalent circuit diagram.

As a practical example, a measuring instrument with a low input capacitance of 20 pF, such as the Multi Measurement Device PXMe7820, and an exemplary measuring instrument with a standard capacitance value of 300 pF are assumed. Both devices are based on an ohmic input resistance of 10 MOhm. This shows the effect of different input capacitances on the total impedance (Figure 3).

Input Impedance
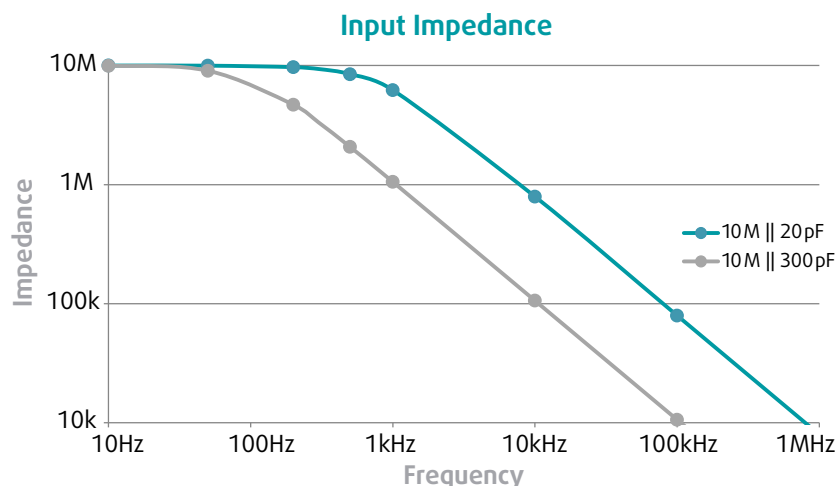

Legend: 10 M ∥ 20 pF / 10 M ∥ 300 pF

Figure 3: The input impedance for both instruments.

Even at low frequencies above 100 Hz, this leads to a significant difference in the manipulation of the measurement signal, i. e. the generated measurement error. In the example given here, it results in the measurement error for both measuring instruments shown in Figure 4. Even at a frequency of <1 kHz, a clear difference between the two devices can be seen. A measurement error of more than 5 percent is not acceptable for most applications.
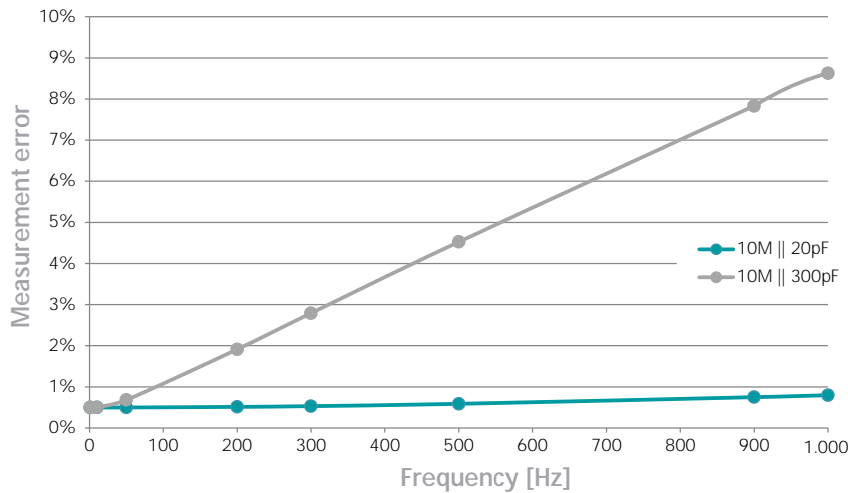
Measurement error up to 1kHz

Figure 4: A measurement error up to 1 kHz.

2. ESTIMATION WITH AN IMPEDANCE DIAGRAM

A quick estimation of the input impedance according to the frequency can be stated in an impedance diagram or a RF wallpaper (Figure 5).

To estimate the impedance at a given frequency, first select this point on the x-axis. This can be 10 kHz, for example. Then follow an imaginary line in the y-direction until this line intersects the diagonal at the appropriate capacitance value with, for example, 10 pF.

By projecting this intersection point in the horizontal direction on the y-axis, the searched impedance, in our example a value of approximately 1.4 MOhm, is obtained. Thereby, the double logarithmic representation shown in enlarged form in the right part of Figure 5 is to be considered.

You can download a LCR Diagram as an example with the following link: www.vxinstruments.com/rf-wallpaper
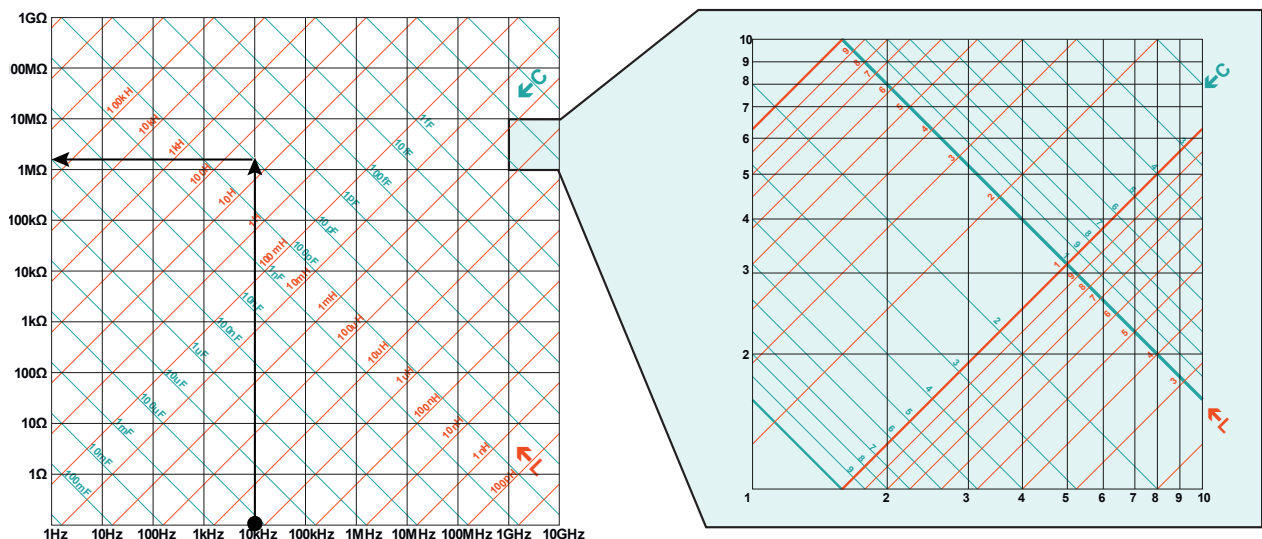
LRC DIAGRAM

Figure 5: For a quick estimation of the input impedance of a measuring instrument according to the frequency, the so-called impedance diagram or HF wallpaper helps.

Low input capacitance is indispensable when precise AC measurements are required. Depending on the application, this can play an important role in the achievable accuracy even at very low frequencies.

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PXI System Alliance
VX Instruments is one of nine Executive Members (total over 60 members) in the PXI System Alliance, the consortium, which defines and develops the PXI standard. Here we enjoy voting privileges and have direct access to the technical committee.

LXI Consortium
The LXI Consortium is promoting the development and adoption of the LXI Standard, an open, accessible standard identifying specifications and solutions relating to the test and measurement industry.

PCI-SIG
The PCI-SIG is a community, which develops and maintains the standardized approach to PCI data transfers.

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