The QuadTech Tutor

Resistance Measurements: Ac vs Dc

Q. Can ac measurements be used for testing resistor tolerances?

A. Yes, in almost all cases.
Although most MIL and EIA specs call for dc measurements, it can be easily shown that low-frequency ac measurements give the same results for almost all composition and film resistors and even most wire-wound resistors. If simple precautions are made, the differences between the ac and dc values is usually substantially smaller than the accuracy of the measuring instrument. These precautions are:

1. use a low frequency, 1kHz or less, 100 Hz is suggested,
2. measure the ***series*** resistance of low-valued resistors, less than about 1 kilohm (this removes the effect of series inductance), and
3. measure the ***parallel*** resistance of high values, > 1kilohm (this removes the effect of lumped, shunt capacitance).

Q. How can I be sure?

A. Test the resistor at two frequencies, say 100 Hz and 1 kHz. If the difference is small, the ac/dc error at the lower frequency, 100Hz, will be substantially less than the measured difference. Most changes with frequency vary as f^2, but some can vary more slowly. To be conservative we might assume that the ac error is proportional to frequency in which case the error at 100 Hz is 1/9th of the difference between the 100Hz and 1kHz values.

Q. What are the exceptions?

A. Some resistors will have ac/dc differences even at 100 Hz.

1. Very high-valued resistors.
   Very high-valued resistors have ac errors caused by distributed stray capacitance along the body of the resistor. If this capacitance is to guard it will slightly increase the value, if not it will decrease it. Carbon composition resistors have internal distributed capacitance (the Boella Effect). In some resistors dielectric loss in the insulating coating can also reduce the value. A rule of thumb for the ac-dc error for composition resistors is

   (R in Megohms)x(Frequency in MHz)*100%

   This gives an error of .01% for 1 Meg at 100 Hz. The error for physically-small, film resistors is usually much less. Single-layer wire-wound resistors wound on a flat cards are also good, but multi-layer wire-wound resistors can be much worse.
2. Very low-valued resistors.
   Resistors made of thick wire are subject to Skin Effect errors, but this error is rare in commercial resistors except for heavy current shunts. Moreover, very-low-valued resistors rarely have tight tolerances.
3. Resistors wound on conducting materials.
   Magnetic coupling to nearby metal will cause Eddy Current errors. This greatly affects the resistance of iron-cored chokes and transformers (which also have hysteresis loss) but rarely affects resistors unless they are wound on metal heat sinks.

Q. Can ac be used for precision measurements in the Standards Lab?

A. Yes, it can and is used. The ac errors in precision resistors, including single-layer wire-wound types, can be less than 1 ppm for values up to 100 kohm or more at 100 Hz. Moreover, if the frequency error is known it can be corrected for. Larger errors may occur in high-valued standards made up of several resistors is series such as decades or "transfer boxes". Their errors can be determined by comparison to small film resistors at two frequencies because one can assume that the frequency error in film type is substantially smaller.

Q. Can ac be better than dc?

A. Yes. Dc resistance measurements are subject to thermoelectric voltages (Seebeck Effect) in the connecting leads or the test instrument which can cause large errors when measuring low resistances unless a high test current is used. The error in percent is

$$\frac{\text{Thermal Voltage in volts}}{\text{(Ix in amperes)*(Rx in ohms}} * 100\%$$

This error can be very large for low-valued resistors that use "copper clad" leads or those with any junctions of dissimilar metals. Moreover, dc measurements are subject to 1/f noise and other sources of drift in the voltage-sensing device. Both these errors are reduced by "zeroing" measurements or averaging measurements made with the polarity of the dc reversed, the more quickly the better. But if the dc source is reversed quickly, is it dc or is it ac?