

Rarely Asked Questions

Strange but true stories from the call logs of Analog Devices

Resistors (and old ladies) have hidden depths

Q. You recently discussed the thermal noise of resistors. They seem to be such straightforward components with just two connections and one simple property: resistance. Do they have more traps for the unwary?

A. I recently attended the 80th birthday of a charming white-haired old lady. In conversation, I was amazed to learn of her teenage years in the French Resistance blowing up Nazi ammunition trains.

The other sort of resistance can fool you, too. A resistor's value, and its tolerance, are obvious properties. Power dissipation is also specified, and, occasionally, breakdown voltage.

But there are many other characteristics which may need to be considered. Matching two or more resistors can be critically important to high precision analog circuitry. Precision on its own may be insufficient; two resistors matched at one temperature will be matched at another only if their temperature coefficients (TCs) are also matched. And if their temperatures differ, because of self-heating or other causes, matched TCs will not help (although very low TCs will). Resistors whose matching is important should be on a single substrate: ceramic or glass for separate resistor networks or silicon for precision thin film resistors integrated on an IC. This ensures matching of resistance, TC, and temperature.

Resistors usually consist of resistive material and copper connections. Two dissimilar conductors in contact form a thermocouple, which produces a voltage due to the Seebeck Effect. This is about $40 \mu\text{V}/^\circ\text{C}$ for copper/nichrome, and can exceed $400 \mu\text{V}/^\circ\text{C}$ for carbon resistances. So, if there is a temperature difference between the ends of a resistor there will be a voltage between them, adding a dc error to the circuit. If this matters, we must minimize temperature

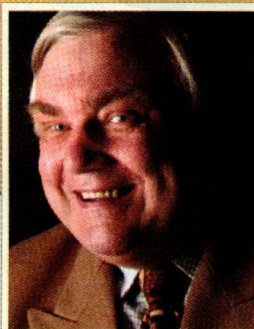


differentials and perhaps use (expensive!) resistors with low thermoelectric emf.

Resistors have capacitance and inductance as well as resistance. Precision resistors that are wire-wound or have a spiral thin film structure have quite large (many μH) inductance. Even when inductance minimizing techniques are used, the resulting structure does not have very low inductance. At high frequencies, reactance matters and must be considered.

The resistance of many high value ($\geq 50\text{M}\Omega$) resistors varies with applied voltage, causing distortion. This can also occur with poor quality resistors of lower value. Such resistors may also have current dependent noise in addition to thermal noise.

Like my friend, resistors are more complex than they first appear; your circuits will benefit if you understand them thoroughly.



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