WHEN YOU NEED RESISTANCE FAR BEYOND MEGOHMS, CONVENTIONAL TECHNIQUES MAY NOT CUT IT.

Unique process takes your resistance to the max

By Bill Schweber, Executive Editor

FOR MANY DESIGNERS, extremely low resistance is an important design attribute. Low resistance, in the milliohm range, is the key to efficient power buses, effective ground planes, and low switching-component IR loss. But in some applications, a far different set of resistance priorities exists, in which megohm and greater values are the talk of the design-review meeting. As these applications and their associated circuitry advance, mere megohms are not enough. Instead, you need to search for gigaohm ($10^9\Omega$) and even teraohm ($10^{12}\Omega$) components. This situation dramatically demonstrates the dynamic range—a span of 10^{-3} to $10^{12}\Omega$, or 15 decades—that engineers must deal with in their designs.

Why would anyone need these extreme values? Several situations require them. For example, the popular piezoelectric transducer that you use to sense vibration, pressure, and strain is a current-output device that wants to see very little loading. Its sourcing capabilities are low, and this capability has gotten even lower as the size of the piezo element, like so much else in electronics, has shrunk. As the transducer capacitance decreases, the resistor that makes up the other half of its RC pairing needs to increase in value to maintain a meaningful time constant, usually on the order of a few seconds. Other high-resistance-challenged applications include charge amplifiers and high-resolution electrometers, in which each electron flowing through the circuit is an event that you want to note.

Figure 1

By writing, not screening, a thick-film serpentine pattern on a ceramic substrate, resistor values of as much as 10 TΩ are available for your sensitive designs.

In the past, such smaller, lower-output piezo devices weren't really useful, because any associated signal-conditioning front-end circuitry strayed too far from the mythical perfect op amp. Their minute but unavoidable deficiencies, such as excessive bias current, effectively swamped the improvement in the transducer itself. However, newer analog circuitry provides input performance of femtoamps, so the potential of these transducers can actually be useful if you properly design the circuitry and layout. This situation reminds designers that great designs are wonderful, but if no one makes the real-world parts you need, you can't realize the full benefits of those concepts.

SOME NEW IDEAS ARE NEEDED

You can build a high-value resistor using the well-established thick-film technology screened onto a substrate, but the short current path somewhat compromises various performance parameters. You could also use thin-film techniques, but the range of values you can get is limited.

Instead of conventional thin- or thick-film and screening approaches, Ohmcraft Inc (www.ohmcraft.com) uses the Micropen, a proprietary-pen-and-orifice system, to literally write the resistor pattern on a ceramic substrate. A computer plans and implements the thickness, width, and length of the line that the Micropen draws to provide the desired resistance value, which can reach 10 TΩ. Interestingly, although the system is proprietary, it uses standard thick-film inks from vendors such as DuPont. These inks are available with maximum resistivities of 1 GΩ/square. Although each gigaohm or teraohm resistor is made to order, there is no hard tooling associated with each design and production run.

UNLIKE CONVENTIONAL THIN- OR THICK-FILM AND SCREENING APPROACHES, THE MICROPEN LITERALLY WRITES THE RESISTOR PATTERN ON A CERAMIC SUBSTRATE.

The pen draws the resistor as a serpentine pattern with a typical line width of 4 mils, but different orifices that produce different line widths are also available (**Figure 1**). The pattern provides several attributes. It minimizes inductance, which is important in some applications. The relatively long trace results in reduced internal voltage gradients, so the final device can handle intermittent voltage spikes and ESD better than conventional designs. For applications in which resistance values are critical, you can design the serpentine trace with special areas, such as loops or "top hats," to provide different areas of both high and low trim sensitivity, unlike standard thick-film trimming, which usually uses single notch or plunge cuts.

For many applications, the absolute resistance value is less critical than stability and repeatability. Many final system implementations are less sensitive to static error, or you can calibrate them to accommodate such error (which ranges from 5 to 30%, depending on grade). In contrast, it is much more difficult to calibrate your instrument to correct for drift and other nonfixed errors. Ohmcraft measures the resistance, the TCR (temperature coefficient of resistivity), and the VCR (voltage coefficient of resistivity) in a dry-room atmosphere at 25°C. In addition, Ohmcraft measures VCR at both 10 and 100V. Typical available VCR is 100 to 300 ppm/V, depending on grade, compared with 5000 to 10,000 ppm/V for conventional thick-film-resistor techniques; TCR is less than 500 ppm/°C. However, the higher VCR approaches are less expensive, so you face the common engineering conundrum of greater cost for greater performance, and you'll have to look at your error-versus-cost budgets. For many of these extreme-performance applications, cost is secondary to performance.

The final gigaohm or teraohm device is housed in a sealed package with a metal top, which is then backfilled with nitrogen gas to maintain the dry, inert atmosphere. A typical leaded device costs about $20; you can also get chip versions for about $1.50, but with reduced performance specifications, due to the absence of the hermetic package.

If you plan to use any high-value resistors, you must be prepared. You can't simply check their values by measuring them with a digital ohmmeter clipped across their leads. More important, you need to mount them on Teflon standoffs, rather than directly on the pc board, and keep the surrounding surfaces clean. Standard FR-4 pc-board material has surface resistance of about one-tenth of a teraohm, which would effectively short-circuit the resistor.

Although in theory you could draw ever-longer lines with the pen-on-substrate technique and thus achieve even higher resistance values, the engineer's eternal enemy of noise comes into the picture. Johnson noise increases with resistance, although Ohmcraft claims that its design has a much lower noise figure than competitive approaches. It's difficult to measure noise of such high-value components, and the meaning of the measurement can be a somewhat philosophical question, because noise is a function of charge carriers, and higher-value resistors have far fewer such carriers.□

You can reach Executive Editor Bill Schweber at 1-617-558-4484, fax 1-617-558-4470, e-mail bill.schweber@cahners.com.