 BY JOHN LINSTROM • S&K ELECTRONICS AND SUNSPOT

What color is 10 kΩ?

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In the '80s, I worked for a company that made industrial computers in an STDBus format. (It soon went to a single-board-computer format.) My first major project was to migrate the ADC on its ADC/DAC multi-I/O card from 12 to 14 bits. The card design was flexible: It could handle 16 single-ended or eight differential inputs, each over a range of 0 to 5V, 0 to 10V, ±5V, or ±10V, with an onboard cold junction for thermocouples. The ADC inputs and eight-output, 12-bit DAC were individually strap-programmable. Conversions and updates were in the 100-kHz range, all under the control of an 8051 with a 64-kbyte EEPROM and 32-kbyte SRAM. So far, so good.

I found a multisourced ADC and did some front-end work—the input amps were LM324s, and the error budget was wide. There were many choices for lower-offset and lower-temperature-drift parts at nearly the same price. The layout of the programming straps was not intuitive, and the user manual got a few tweaks. We went through an artwork spin and prototype build just fine, but when we fired up the board, it gave us 11 bits of solid data, maybe 12 on a good day. I finally narrowed down the problem to microprocessor churning during analog-to-digital-conversion cycles. We switched to a CMOS 8051, put the digital side to sleep, and let the "end-of-conversion" flag wake up the microprocessor. Now, the team had 13 to 14 bits of solid data over the whole input range and could honestly brag about greater resolution in the trade magazines. Orders followed, salesmen were happy, and life was good.

It was good, that was, until we couldn't properly test and calibrate the first batch of 25 boards. Now, the eager customers and smiling salesmen started turning up the heat. The team scoped, metered, substituted parts, studied the artwork, and checked the golden board—following the drill every design engineer knows by heart—all for naught. My handmade board worked great, but all the production copies tested in the weeds.

We used 4051-style data latches for the channel selects, and I had normalized-gain-set resistors with values of approximately 10 kΩ. The value was high enough to swamp any changes in switch resistance, low enough to keep down resistor noise, and high enough to keep bias currents and self-heating low. Plus, it made the math easy. (In those days, we still used through-hole parts.)

Staring at the good and bad boards finally gave me the "smack upside the head." The 10-kΩ-resistor code, as every good design engineer knows, is brown-black-orange followed—you hope—by a tolerance band. The bad boards were stuffed with a mix of 10-kΩ and 300Ω resistors! I had stared at the problem so long, expecting something immense, that I had blown right by the obvious. Backtracking the trail of destruction unraveled the whole tale. The people who built the units didn't know resistor codes from Morse code; they stuffed in whatever was in the correct pick bins. The stockroom used kits from bins that incoming inspection filled. My computer bought from reputable distributors but reserved incoming tests for items more costly than 2-cent resistors. I checked the stocking bins and found a 60/40% mix of 10-kΩ and 300Ω resistors. We were thankful that no other bins fell prey to the same confusion. We had a heart-to-heart talk with the buyers, engineering staff, and production team. I don't think anyone learned the resistor color code that didn't already know it, but everyone learned how to identify correct parts. EDN

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