Fooled by a thermocouple

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During the development of a medical product requiring noninvasive temperature sensing of fluid passing through ⅜-in. medical plastic tubing, the design team I was working with selected a miniature infrared optical temperature sensor. The cylindrical sensor measured ¼ in. in diameter by 1 in. long. The sensor had a 1-to-1 field of view. The tubing we needed to sense was within the disposable component of the system. The sensor, spring-loaded to maintain slight pressure against the tubing when the disposable was clamped to the device, was centered on a U-shaped channel on the device to align with and "receive" the tubing.

We used the "heat-balance" method that the vendor recommended to accomplish temperature sensing. This method requires pressing the tubing against the sensor, which permits the sensor to convert the infrared energy that the fluid emits but ignores the effects of the tubing material or the disposable housing. To our surprise, this method seemed to work well in early breadboarding experiments to track the actual temperature, which we measured using standard thermocouples in contact with the fluid within a ±1°C tolerance of error. The method also tracked rapid changes in the fluid's temperature with only a few seconds of delay.

The vendor advertised that the sensor behaves as a K-type thermocouple at 37°C and is relatively accurate within our temperature range of interest: 10 to 50°C. In other words, its output should resemble the output of a contact thermocouple at the same temperature. We implemented a "cookbook" input circuit for a standard K-type thermocouple, expecting that it would perform perfectly. The breadboard prototype performed well, requiring only the addition of an offset adjustment to compensate for variations in components. We used the same conditioning circuit in the final design for both the optical infrared sensors and the standard-contact thermocouple sensors.

Once we implemented the design in the device, we noticed some odd behavior. With all sensors reading correctly and temperatures stabilized throughout the system, the optical thermocouples' output would rise significantly to as much as 5°C higher if anyone approached or touched any of the exposed metal parts on the device. The manufacturing operators also had a difficult time of adjusting the offset circuit for the infrared sensors with any repeatability, a fact that was no doubt related to the sensor's undocumented "proximity-sensing feature." The standard-contact thermocouple outputs did not change. This situation was, of course, unacceptable. A lot of head-scratching ensued!

After some investigation, we discovered that the optical infrared sensors had a measured impedance across their leads of nearly 20 kΩ! A standard thermocouple would normally appear as a short circuit. Apparently, this mismatch of impedance at the output of the infrared sensor and the input of the conditioning circuit was amplifying any minute sources of noise—in this case, induced ground noise—to an untenable level.

The cure was to place a 20-kΩ resistor across the input leads of the conditioning circuits of only the optical infrared sensors. The proximity-sensing feature and the difficulty in adjustment of the offset circuits miraculously disappeared! A review of the optical-sensor data sheets confirmed that they never mentioned this "output impedance." I suppose, in this case, a K-type "thermocouple" wasn't really a K-type thermocouple. EDN

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