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Designing with temperature sensors, part four: thermocouples

Thermocouples offer distinct advantages over other temperature sensors, such as thermistors, RTDs (resistance-temperature detectors), and silicon sensors. Thermocouples respond to the widest temperature range. Different environment requirements, such as vibration resistance or corrosion resistance, can help determine the correct thermocouple type for your application.

You can construct a thermocouple with two wires of dissimilar metals or alloys, such as iron and constantan (Type J). A weld bead bonds the two dissimilar metals on one end of both wires. If there is a temperature difference between the bead and the open end of the thermocouple wires, an EMF (electromotive-force) voltage appears between the open end of the two wires. This EMF voltage changes proportionally with temperature without voltage or current excitation. The temperature range of the thermocouples may vary depending on the types of metals being used. **Table 1**, available with the Web version of this article at www.edn.com/111215bb, presents types of thermocouples whose temperature ranges vary, depending on the types of metals used. The Seebeck coefficient is the first derivative of the thermocouple's EMF voltage as a function of temperature.

Thermocouples produce a voltage that ranges from a few microvolts to tens of millivolts. This voltage is repeatable but nonlinear through changes in temperature. Because all thermocouples are nonlinear, the value of this Seebeck coefficient changes with temperature. To account for this nonlinearity, designers typically use look-up tables in their microcontrollers or processors.

Figure 1 shows an example of a single-supply thermocouple application using a J-type thermocouple. The J-type thermocouple wires are soldered to the PCB copper, which creates thermocouples J_2 and J_3.

In any thermocouple application, the variables at work are the EMF voltage change versus the temperature of the thermocouple's bead versus the open-ended wires, the absolute temperature at the near site (B), and the absolute temperature at the far site (A). The thermocouple manufacturer provides a table of the EMF voltage versus temperature for the thermocouple bead. This information leaves two unknowns: the temperature at A and the temperature at B. In finding the temperature at site B, the isothermal block in **Figure 1** is a plane that contains J_2, J_3, and the temperature sensor, which is inside the ADS1118 chip. The accuracy of the ADS1118's temperature sensor typically is 0.2°C, with a minimum and maximum of ±0.5°C. Careful layout techniques allow you to keep the entire ADS1118, J_2, and J_3 at the same temperature on the isothermal block.

To find the temperature at site A, measure and then convert the temperature of the isothermal block to its equivalent EMF voltage by performing a reverse look-up on the table of the J-type thermocouple. Then add the equivalent EMF isothermal voltage and the J_1 EMF measured voltage. Finally, convert the total voltage to temperature with the J-type thermocouple's look-up table.

The price of thermocouples may vary, depending on the accuracy rating, the purity of metals, the integrity of the weld bead, and the quality of the wire insulation. Regardless, thermocouples are less expensive than other varieties of temperature sensors. Thermocouples have their advantages when you use them in harsh, high-temperature applications. They are rugged and impervious to hostile environments.

Read parts one, two, and three of this series at http://bit.ly/rpSnOp, http://bit.ly/s6Llbu, and http://bit.ly/u4zJs7, respectively. EDN

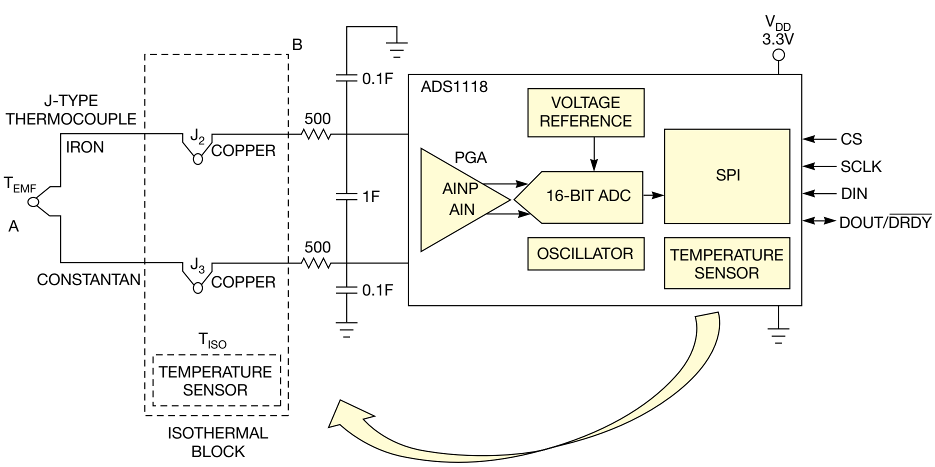

Figure 1 This single-supply thermocouple application uses a J-type thermocouple.