Precision temperature controller has thermal-gradient compensation

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Accurate and stable temperature control is necessary for effectively using many thermally sensitive components and sensors, such as semiconductor lasers and optical detectors. An industry has grown up in response to provide thermal-control devices, such as TECs (thermoelectric coolers), temperature sensors, and both monolithic and hybrid application-specific driver ICs, to facilitate the associated designs. This availability eases the implementation of high-performance thermostasis electronics with good dynamic behavior, because it allows you to assemble feedback loops with flexible and sophisticated control characteristics—PID (proportional-integral-differential) feedback loops, for example—with nothing more than appropriate choices of shunt resistance and capacitance. Unfortunately, achieving good static stability is sometimes more difficult because the thermal properties of a system, rather than the electronics, often cause limited temperature-control-loop static stability.

Every thermal-control system incurs nonzero thermal impedances in the heat-transfer paths between the source of heating, cooling, or both. These paths include the thermal load, which is the object of thermostasis; the temperature sensor—the thermistor, for example; and the ambient temperature. If the ratios of these impedances don't balance well, which, unfortunately, is usually the case, then

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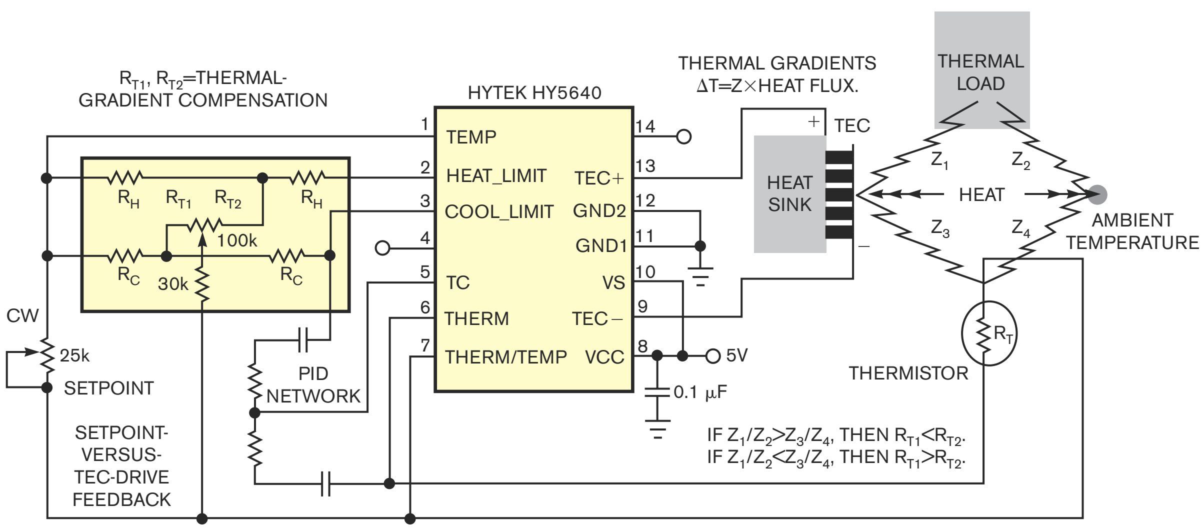

Figure 1 This circuit partially cancels the effects of thermal gradients in the load's thermal impedances. It works by providing an adjustable positive- or negative-feedback path from the TEC-drive level that couples changes in ambient temperature into compensating changes in the thermistor setpoint.

even perfect thermostasis of the sensor doesn't equate to adequate stability of the load's temperature (**Figure 1**).

For example, if Z_1/Z_2 is greater than Z_3/Z_4, where Z is the impedance, then rising ambient temperatures will cause the temperature of the load to rise, whereas falling ambient temperatures will cool the load. By contrast, if Z_1/Z_2 is less than Z_3/Z_4, then rising ambient temperatures will cause the temperature of the load to fall and vice versa (**Figure 2**). Reducing the parasitic impedances with tighter thermal coupling and better insulation can reduce but seldom eliminate the gradient and magnitude of the error.

The circuit in **Figure 1** provides a different solution: an electronic workaround to at least partially cancel the effects of thermal gradients in the impedances. It works by providing an adjustable positive- or negative-feedback path from the TEC-drive level that couples changes in ambient temperature and, therefore, in TEC drive into compensating changes in the thermistor-setpoint temperature. The implementation in **Figure 1** uses a popular hybrid TEC controller. Two signal nodes that track TEC drive, COOL_LIMIT and HEAT_LIMIT, are inputs to an adjustable bridge circuit that comprises R_{T1}, R_{T2}, the potentiometer, and associated circuitry. With correct adjustment of R_{T1} and R_{T2}, a test determined that the thermistor setpoint must move either with or in opposition to ambient temperature, so that net stability of the load results. A version of this concept flew as part of two tunable-diode laser spectrometers in the science package of the 1999 Mars Polar Lander (**Reference 1**).EDN

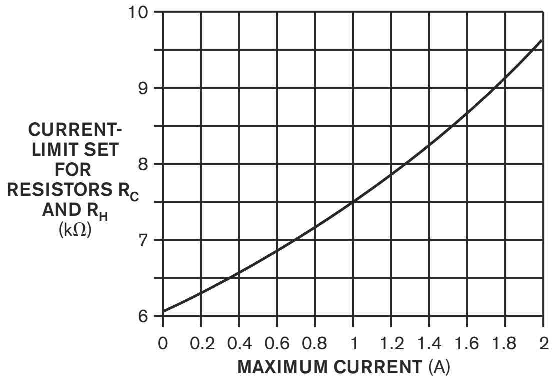

Figure 2 The TEC's maximum-drive heat- and cool-current ratings determine the selection of current-sampling resistors R_C and R_H.

REFERENCE

1 May, Randy D, Siamak Forouhar, David Crisp, W Stephen Woodward, David A Paige, Asmin Pathare, and William V Boynton, "The MVACS tunable diode laser spectrometers," American Geophysical Union, *Journal of Geophysical Research*, Volume 106 (E8), 2001, pg 17,673, www.agu.org/pubs/#journals.