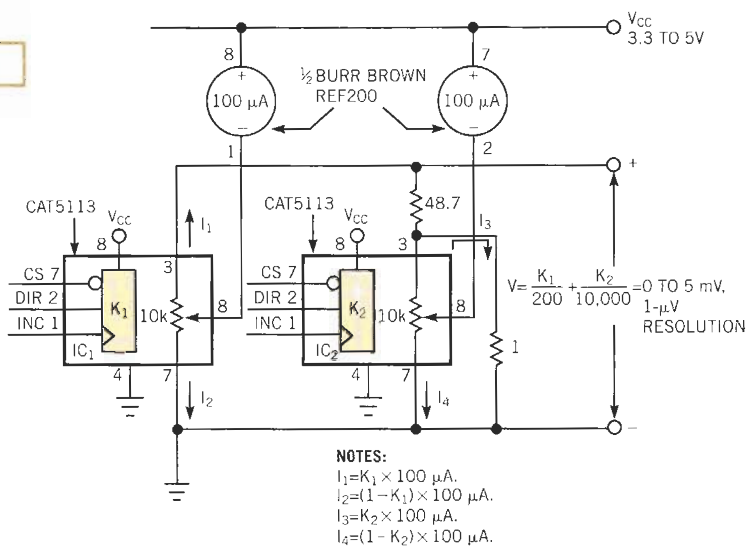
DPPs make nonvolatile microvolt DAC

Stephen Woodward, University of North Carolina, Chapel Hill, NC

THE AVAILABILITY of a seemingly limitless variety of monolithic DAC chips makes it easy to implement most digital-to-analog-conversion applications with a single off-the-shelf device. Sometimes, an unusual set of requirements necessitates a multichip approach, however. One example of such a requirement is the need for nonvolatility of the DAC's setting in power-up and -down cycles. Another example is the need for output resolution and stability at less than 1 μV. The circuit in **Figure 1** combines inexpensive DPPs (digitally programmed potentiometers) from Catalyst Semiconductor (www.catsemi.com) with precision current references from Burr-Brown (www.ti.com) to achieve both nonvolatility and less-than-1-μV performance. Accurate simulation of the signals from high-temperature platinum-rhodium-based thermocouples requires less-than-1-μV performance. These temperature sensors have Seebeck coefficients of only 6 μV/°C. Therefore, only voltage sources with 1-μV-level stability and precision can simulate such sensors.

Figure 1



Digitally programmed potentiometers combine to form a novel, microvolt-level DAC.

To achieve such low output drift would normally require the use of active circuit elements, such as chopper-stabilized amplifiers, with offset temperature coefficients not much higher than 1 nV/°C. The circuit in **Figure 1** takes a different approach by using current division and a passive and, therefore, inherently drift-free output that needs no amplifiers. Each half of the REF200 sources a 100-μA reference current. The twin currents each connect to the wiper of DPPS, IC_1 and IC_2. There, they split into two currents (for example, I_1 and I_2) in a wiper-to-total ratio, K_1, which the programmed setting of the DPP determines. $I_1=K_1\times100$ μA, and $I_2=(1-K_1)\times100$ μA. I_1 passes through the series combination of the 48.7Ω resistor and the 1Ω output resistor and thereby generates the output voltage: $V=K_1(50\Omega\times100\ \mu A)=0$ to 5 mV as K_1 varies from 0 to 1. The operation is straightforward and drift-free. Unfortunately, the resolution with a single potentiometer is inadequate for many precision applications.

IC_1, a CAT5113, like other DPPs, offers the versatility of an uncommitted resistance element and nonvolatility of the setting. Its resolution, however, is only 100 steps, which is slightly worse than 7 bits and equivalent to 50 μV in this circuit. You therefore incorporate a second DPP, IC_2, in the converter. IC_2's output current acts into the 1Ω load for a 50-to-1 resolution enhancement over IC_1 alone. IC_2 thus adds a 0- to 100-μV contribution to V. Hence, the composite output is $V=K_1/200+K_2/10{,}000$ with a 5-mV span and 1-μV resolution. The circuit is an ideal approach for such applications as the simulation of thermocouple signals in precision temperature-measurement and -control systems.

Is this the best Design Idea in this issue? Select at www.edn.com.

Publish your Design Idea in *EDN*. See the What's Up section at www.edn.com.