Variable voltage source has independently adjustable TC

by Nathan O. Sokal
Design Automation Inc., Lexington, Mass.

A reference voltage source, which is built around a suitably stable general-purpose operational amplifier, offers an adjustable output-voltage magnitude, as well as an adjustable output-voltage temperature coefficient. Both the voltage magnitude and the temperature coefficient may be varied independently of each other.

The output voltage can be positive or negative, and it is continuously variable from 0.7 to 13 v. The temperature coefficient is also continuously variable, from −0.3%/°C to +0.3%/°C. For the circuit shown in the figure, the output voltage is positive. To obtain a negative voltage, the polarities of all the diodes and the supply (except to the op amp) are simply reversed.

The temperature coefficients of the zener-diode voltage, the resistance values, the op-amp input offset voltage, the op-amp input bias and offset currents, and the power-supply voltage need not all be zero. Rather, their values as functions of temperature must be stable with time and retrace well with temperature cycling. This is also true of the V-I characteristics of diodes D_1 and D_2. Moreover, these two diodes do not have to be matched.

If a narrower range of output voltage is adequate, part of resistance R_1 should be a stable fixed resistor. Likewise, if a narrower temperature-coefficient range is satisfactory, part of resistance R_2 should be a stable fixed resistor. Resistances R_1, R_2, and R_3 should be multi-turn potentiometers if both wide-range adjustment and high resolution are desired. Or they should be combinations of potentiometers and fixed resistors if a narrow adjustment range will do. Or they should be only fixed resistors when the desired output voltage and temperature coefficient need not be adjusted.

The fixed resistors used in this circuit should be film or wire-wound types for good long-term stability. A reference-type zener diode, such as the 1N4894, will improve voltage stability still further. All the resistors and semiconductor devices should be thermally coupled to each other for a good transient response to changes in ambient temperature.

A simple procedure can be followed to adjust the circuit to desired operating conditions. First, set potentiometers R_1 and R_2 approximately at their mid-range positions. Then adjust potentiometer R_3 until the voltage across R_2 is zero at the reference temperature. This is the temperature at which it must be possible to adjust the temperature coefficient without changing the output voltage. Next, position potentiometer R_1 to give the desired output voltage at the reference temperature.

The last step is to adjust potentiometer R_2 for the desired temperature coefficient. This adjustment, which should not affect the output voltage at the reference temperature, can be made by heating or cooling the entire circuit to some temperature other than the reference temperature and then adjusting R_2 to obtain the desired output voltage at that temperature.

As a precaution, the circuit's output voltage should be checked for changing temperature. If it is not within the desired tolerance, repeat all the adjustment steps but the first one. Usually no such repetition will be needed.

More output current can be obtained from this reference voltage source by adding an npn power transistor, wired as an emitter-follower, at the circuit's output. The output from the op amp goes to this transistor's base, and resistor R_1 is then connected to the transistor's emitter, which becomes the circuit output. If the output voltage is negative, a pnp emitter-follower should be used. Without an emitter-follower, the output current can be as large as 10 milliamperes for most general-purpose op amps. □

Stable voltage source. The output voltage of this reference voltage source can be adjusted from 0.7 to 13 volts. And the circuit's output-voltage temperature coefficient is also adjustable, from −0.3%/°C to +0.3%/°C. These two adjustments are independent of each other. Potentiometer R_1 sets the output voltage, potentiometer R_2, the temperature coefficient, and potentiometer R_3, the reference temperature.