Semiconductor thermometer is accurate over wide range

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Reducing the circuit complexity and simplifying the calibration of thermometers that use the base-emitter drop of a transistor to detect temperature changes, this circuit provides readings accurate to within ±2°C over the range of −40°C to +150°C. Using the low-offset, low-drift characteristics of National's micropower LM-10 operational amplifier and Motorola's MTS-102 temperature sensor, the thermometer will compete with the more expensive platinum-resistance units.

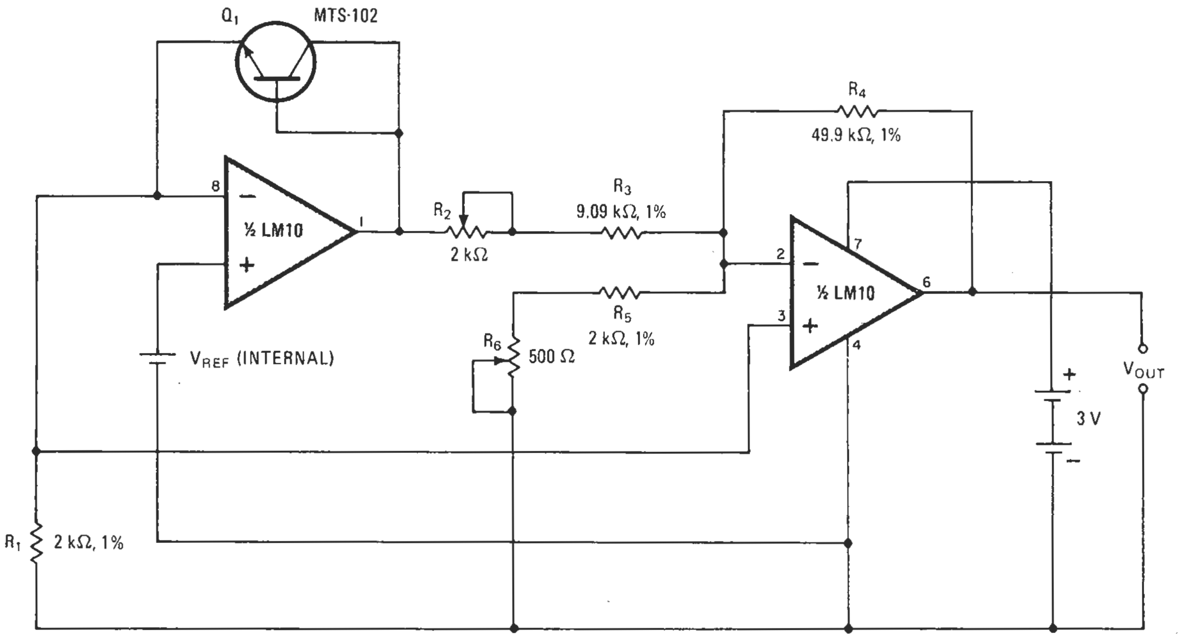
The LM-10 is used to bias, scale, and zero the MTS-102 sensing transistor, thereby removing the need for a separate constant-current bias source for the sensor and an additional scaling and nulling circuit. Further, the well-defined characteristics of the MTS-102 permit single-point calibration of the thermometer.

The MTS-102, Q_1, is placed in the feedback loop of the LM-10 reference amplifier. A constant-current bias is created by V_{ref} across resistor R_1 giving I_{bias} = 0.2 V/2kΩ = 100 μA. The voltage at the output of the reference amplifier will thus be $V_{ref} + V_{be}$. The second stage of the LM-10 is configured to provide a gain that is constant with respect to the temperature coefficient of the V_{be} drop and to subtract V_{ref} and V_{be} from the output at any desired reference temperature.

For a typical MTS-102, the V_{be} is 600 millivolts at 25°C, and its temperature coefficient is −2.25 mV/°C. The actual temperature coefficient for a particular device is thus $TC = -2.25 + 0.0033(V_{be}' - 600)$ mV/C, where V_{be}' is the measured base-emitter drop for the given sensor at 25°C. A corresponding offset voltage therefore appears at the output of A_1.

The gain-controlling elements of A_2, resistors R_2–R_4, can be set so that the circuit's output-voltage-to-temperature slope will be correct for any sensor. The actual gain will be $R_4/(R_2+R_3)$. Once the gain is set, R_5 and R_6 are adjusted to null the offset and yield the desired output voltage at any calibration temperature within the operating range of the circuit.

For very accurate calibration, a reference temperature source should be used to keep Q_1 at 25°C. The V_{be} of Q_1 can then be measured with a digital voltmeter and R_2 and R_3 set to null the offset. R_5 and R_6 are then set to yield an output voltage corresponding to the value that should be measured at 25°C. Using this technique, the calibration will be accurate to within ±1°C.



(R_2, R_3, R_5, AND R_6 NOMINAL VALUES FOR TEMPCO = 10 mV/°C, 0°C = +1 V OUT)

Hot number. Micropower op amp and semiconductor made specifically for temperature-sensing applications reduce complexity and calibration procedure of thermometers that use V_{be} of transistors to detect temperature changes. Accuracy of device, no worse than ±2°C over the range of −40°C to +150°C, and its simplicity enable it to compete with much more expensive units.

A simpler alternative is to set R_2 and R_3 to correspond with TC associated with the nominal V_{be} of the particular MTS-102 device used, zeroing the circuit at a reference temperature provided by an ice bath. Each MTS device is marked with their respective $V_{be} \pm 2$ mv. This technique will provide calibration accuracy to ±2°C. Either technique will provide accuracy to 4°C for all interchanged devices marked with the same V_{be}. But interchangeability accuracy will vary to a greater degree with the MTS-103 and MTS-105 devices.

The circuit will also work with a conventional silicon transistor, such as a 2N3904, but for calibration purposes, its V_{be} should be measured between at least two points because it is not a specified parameter. The circuit is relatively insensitive to power supply voltage and it will operate satisfactorily over 2-to-40-v range. □