One transistor senses, heats in temperature regulator

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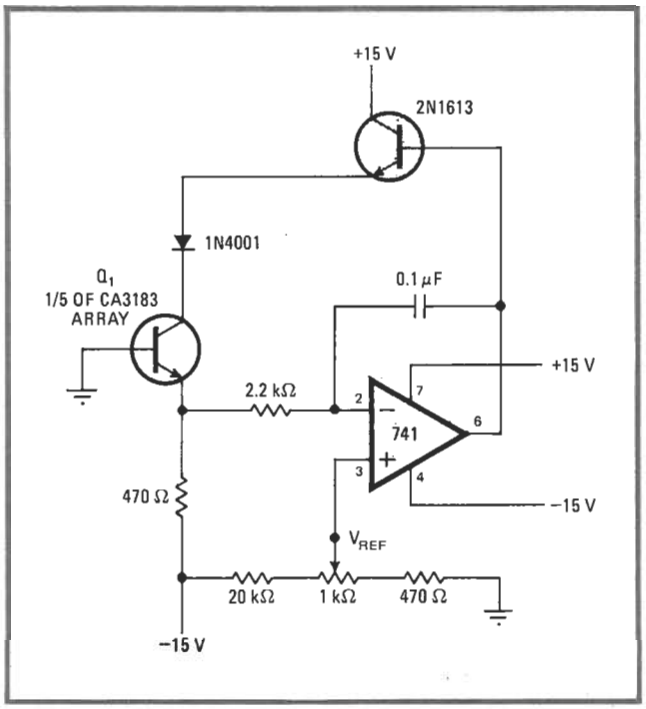
Most circuits for regulating the temperature of a substrate employ at least two transistors—one for sensing the temperature, and another for generating heat. But the designer can make a single transistor serve as a combination sensor and heater by exploiting the fact that the voltage drop across a silicon junction changes by −2 millivolts per °C change of temperature. As a result, he is free to use, for example, a matched dual transistor



Double duty. Transistor Q_1 serves as both temperature sensor and heater element in this circuit for regulating substrate temperature. Reference voltage is set to the value that a base-emitter junction has at the desired substrate temperature. The op amp senses the difference between the reference level and the actual V_{BE} of Q_1, and it drives current through the transistor to bring it to that temperature.

as a temperature-independent logging element or to use all but one of the transistors in an array for purposes other than temperature regulation.

In the accompanying circuit diagram, transistor Q_1 is connected as a current source. The grounded-base configuration permits the base-to-emitter junction voltage V_{BE} to be easily monitored by the operational amplifier. The op amp compares V_{BE} to a preset reference voltage, V_{ref}, that is equal to the junction voltage at the desired substrate temperature. Unbalanced voltage at the op-amp inputs causes it to drive more current through Q_1, thus changing the junction temperature and voltage.

To calibrate the regulator, the collector of Q_1 is initially grounded so that the emitter-to-collector voltage is essentially zero, and, therefore, power dissipation in the transistor is zero. The base-to-emitter voltage is then measured, preferably to the nearest millivolt. This reading, V_O, is the junction voltage at ambient temperature. If the ambient temperature is, for example, 23°C and the desired junction (substrate) temperature is 63°C, the V_{ref} must be set to V_O − [2 mV × (63 − 23)]. When the op amp is then reconnected to the collector of Q_1, the servo action will maintain enough collector dissipation in Q_1 to keep its junction at 63°C.

Although a small-signal transistor in an array is shown as Q_1 here, this same principle can of course be applied to larger transistors, such as the 2N3055. To enable the op amp to source more current, an emitter follower can be added to the circuit, in the line connecting the emitter of the 2N1613 to the anode of the 1N4001 diode. □