Thermistor Interfacing

Chapter 9

Thermistors are low-cost sensitive devices capable of operating over a moderate temperature range and available in a wide variety of standard resistance values (@ 25°C & negligible dissipation). They are discussed in Chapters 1 and 5. Many applications in measurement and control require reasonable degrees of accuracy and linearity; consequently, linearized composite thermistors, with guaranteed specifications, are preferred by many instrument designers to the lower-cost naked devices (which require more attention). Most of the applications discussed here involve linearized thermistors. Although one manufacturer's devices have received the lion's share of the mention, comparable devices are available from other thermistor manufacturers.

SIMPLE INTERFACE CIRCUITS

Linearized thermistors may be used in two ways: either as resistors, with resistance proportional to temperature, or as voltage dividers, with the ratio proportional to temperature. As expected, the former are two-terminal devices, the latter are three-terminal devices.

In Figure 9-1, a linearized thermistor is used as the feedback resistor of an op amp. A current, developed by an AD580 precision voltage reference and a series resistor, is transduced into voltage by the thermistor's resistance. The output voltage is summed passively with a constant offset and amplified. The net output voltage is proportional to temperature (10°C/V), over the range 0° to 100°C.

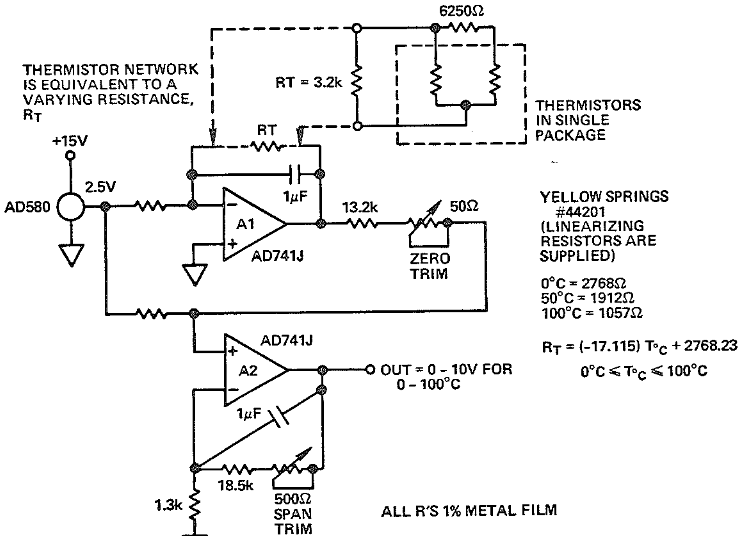

Figure 9-1. Instrumenting linearized thermistors with op amps—resistance mode

In Figure 9-2, which is functionally similar to 9-1, the same thermistor type is used potentiometrically. Both the sensor and the offset network are supplied by a 2.5V IC reference. The difference of the voltages (in essentially a linear bridge circuit) is read out by an instrumentation amplifier, which may be connected for the desired gain and output configuration (see Chapter Four).

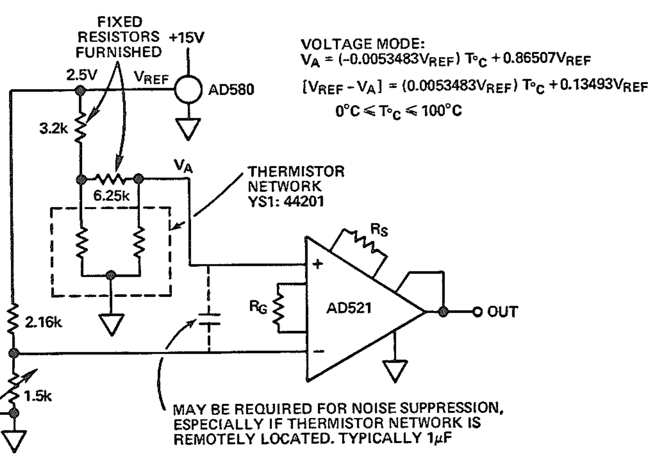

Figure 9-2. Instrumenting linearized thermistors—voltage mode

DIFFERENTIAL THERMOMETER

In Figure 9-3, two linear thermistor composites are used potentiometrically to measure a temperature difference (for example, in a temperature control system, in gradient and thermal flow studies, in calorimetry, in chemical process monitoring, and a host of other operations). A 2B31 signal-conditioning module is used to provide excitation, precise differential-voltage measurement, amplification with adjustable gain, and (if needed) filtering.

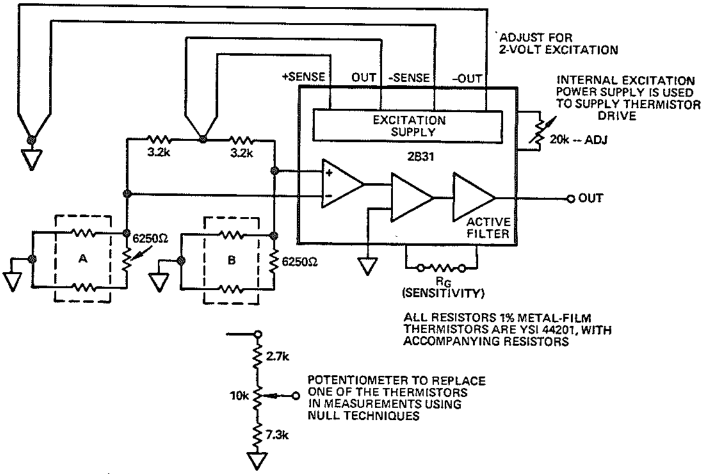

Figure 9-3. Differential thermometer using linearized thermistors

For precision temperature measurement using null techniques, one of the thermistors can be replaced by a ten-turn potentiometer and associated scaling resistors (inset). At balance, the temperature can be determined from the potentiometer reading. The gain of the 2B31 determines the sensitivity of the null.

HIGH-RESOLUTION DIFFERENTIAL THERMOMETER

In the circuit of Figure 9-4, temperature differences can be measured to tenths of a millidegree using a precision potentiometer—employing a Kelvin-Varley divider with 5-decade resolution; a floating chopper amplifier as a high-resolution null indicator; and an isolation amplifier to provide low-impedance readout at system level, as well as providing isolated power to float the chopper amplifier.

Two kinds of measurement can be performed: the differential temperature between thermistors A and B, and the temperature

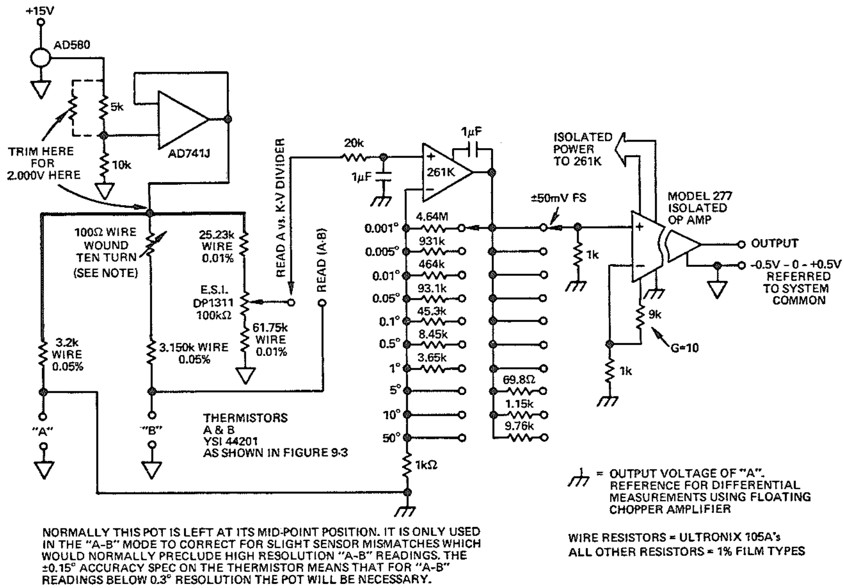

Figure 9-4. High-resolution differential thermometer

of thermistor A. The former is a precision measurement, similar to that shown in Figure 9-3, in which the 261K chopper amplifier reads the voltage across the bridge formed by the two thermistors. Because the 261K floats, it can perform differential voltage measurements with high common-mode rejection. The temperature at thermistor A is measured by forming a bridge with the precision divider, and adjusting the divider output for a null, again reading the output via the 261K. A number of gain steps are provided to permit the sensitivity of the measurement to be increased to the maximum needed. The 100Ω variable resistor is used to standardize the outputs of the two thermistors at the same temperature for measurements with better than 0.3° resolution.

Because the 261K floats across the bridge, it provides high common-mode rejection and 100nV/°C ambient drift performance, permitting extremely high gains to be used. On the most-sensitive gain setting, and when instrumented with all appropriate precautions, the circuit will allow stable resolution of 100 *micro-degree* (C) temperature changes at the sensor.

SMALL-DEVIATION THERMISTOR BRIDGE

Figure 9-5 suggests a means of measuring small (m°C) temperature changes. The active element in the bridge is a thermistor without linearization. A potentiometer, connected between the power-supply rails, provides an adjustable offset by injecting current into the fixed leg of the bridge, with offset sensitivity determined by a switched series resistor. Because the bridge excitation is provided by a pair of symmetrical or tracking supplies, the dc common-mode level is near-zero.

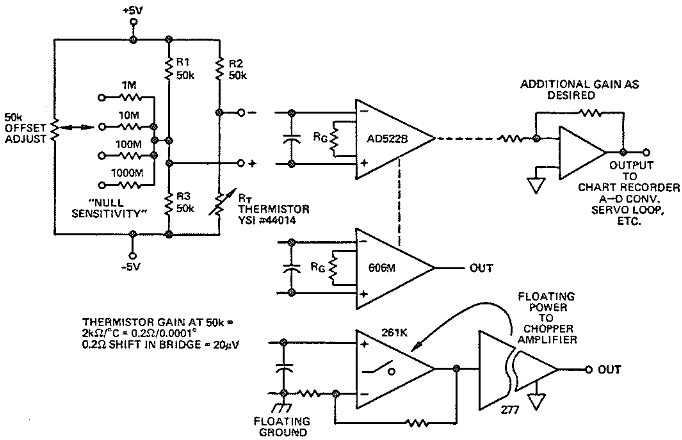

Figure 9-5. Alternative readouts for small-deviation thermistor bridge

At the initial temperature (near 60°C, in this case), the bridge is brought into balance by adjustment of the offset-adjust pot for zero output at an appropriate null sensitivity level. Then, when the temperature at the sensor has changed to the new value, the output voltage will be a linear function of the temperature change.*

For the YSI 44014 thermistor, which has a resistance of 50kΩ at 66°C, the temperature coefficient is approximately 2kΩ/°C (or 2Ω/m°C) at that point. The bridge can resolve temperature changes smaller than 100μ°C when implemented and used with care (and a sufficiently sensitive amplifier). Typical amplifiers might include the AD522B IC instrumentation amplifier, the 606M low-drift instrumentation amplifier, and the combination suggested in Figure 9-4: the low-drift 261 chopper amplifier isolated by a 277—which provides gain, low-impedance readout, and isolated power. Because of the high resistance values, amplifier offset-current tempco is as important a consideration as offset voltage tempco.

*For doubled sensitivity, replace R1 by a matched thermistor.

Another application of this circuit might be to determine when the measured temperature has changed by a prescribed small amount. In that case, an offset would be preset, and the amplifier would be followed by a zero-biased comparator, to detect the crossing through zero difference between the preset temperature and the actual temperature.

CURRENT TRANSMITTERS

Thermistor measurements can be transmitted via 4 to 20mA (or other standard) current loops. The output voltage from a thermistor-bridge amplifier (see Figure 9-2, for example) can be applied to the input of a voltage-to-current converter, such as the 2B20 common-supply current generator or the 2B22 isolated current transmitter, described elsewhere in this book (see Figure 5-4).

THERMISTOR-TO-FREQUENCY CONVERSION

The output of a thermistor-bridge amplifier can be applied at the input of a voltage-to-frequency converter for high-noise-immunity transmission, with the possibility of optical or pulse-transformer isolation, and conversion to a digital code at the destination.

In Figure 9-6, the differential output of a bridge circuit employing a YSI 44018 linearized thermistor is amplified by an AD522 instrumentation amplifier and converted to frequency by a 452L 100kHz-full-scale V/f converter. The circuit has fast response, millidegree resolution, and a temperature range of 0° to 100°C, with accuracy to within 0.15°C. An analog output is available, normalized to 10°/V, and the frequency output may be optionally gated on and off by a level at precisely determined intervals, so

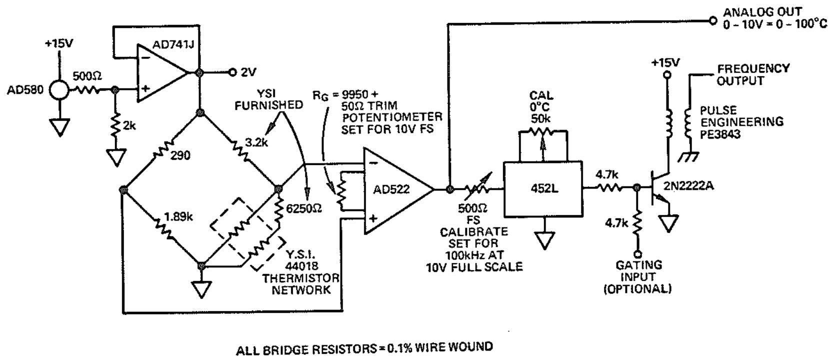

Figure 9-6. Thermistor-to-frequency converter

that a remote asynchronous counter may be used. The frequency output drives a pulse transformer, which provides galvanic isolation and off-ground operation.

LINEAR THERMISTOR THERMOMETER

A digital panel meter, such as the AD2026, can be used to read the output of a thermistor-bridge amplifier, simply and at low cost, in engineering units. Where more than one channel must be measured, the AD2037 six-channel scanning digital voltmeter, introduced in Figure 8-6, is a useful adjunct.

Figure 9-7 shows how the AD2037 would be connected to instrument a number of linearized thermistors (YSI 44201). Excitation for the thermistors is provided from the AD2037's reference voltage, attenuated to the 1.0000V level and stiffened by an AD741K op amp. The thermistors are read out potentiometrically and multiplexed by the meter's switching circuitry. Although the thermistors are excited in common and read with reference to the meter's input circuitry, they are isolated from the digital system circuits.

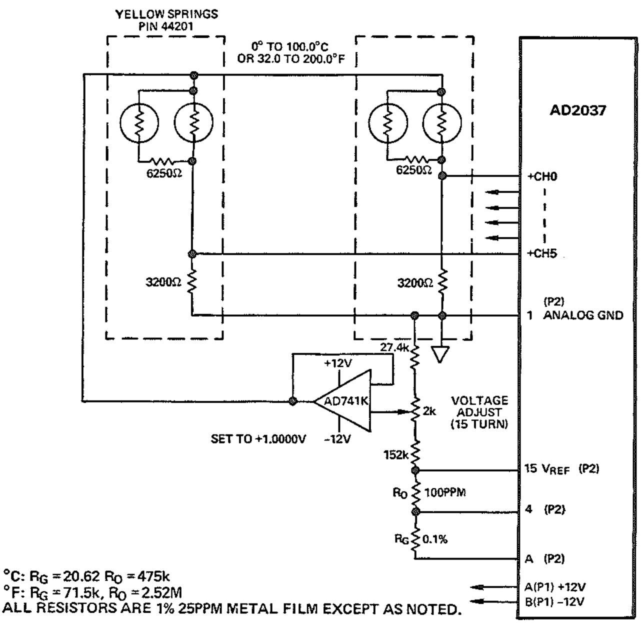

Figure 9-7. Thermistor instrumentation with the AD2037 scanning DPM

In this application, the temperatures being measured are in the range 0° to 100°C or 32.0° to 200.0°F. The ranges are selected by the choice of resistors R_O (offset) and R_G (span), connected to the meter's internal precision op amp.

The digital properties of the AD2037, e.g., its conversion, display, and scanning schemes, are the same as those of the AD2036, described in relation to Figure 7-10.