Application Report

SLOA123 – January 2007

Low-Cost, Noise-Immune, Isolated Thermocouple Signal Processor

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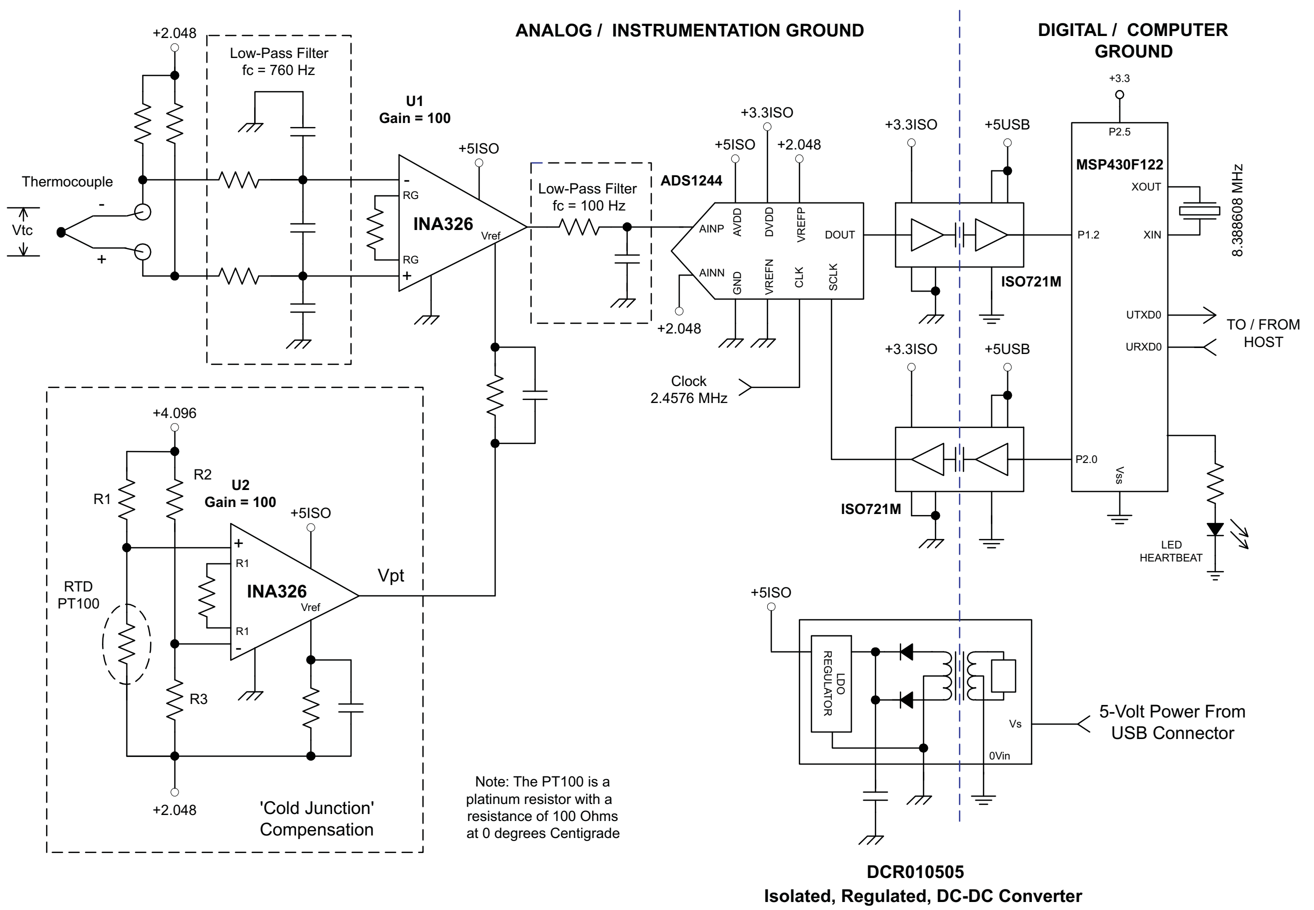
ABSTRACT

This application report describes a low-cost, thermocouple-based, temperature measurement system featuring high-noise immunity and electrical isolation between the analog and digital circuits. Unlike conventional designs employing analog *cold junction* compensation, in this design the thermocouple is connected directly to the differential inputs of a INA326 instrumentation amplifier. This configuration takes advantage of the high (>90 dB) CMRR (common mode rejection ratio) of the instrumentation amplifier.



A thermocouple is a simple device, consisting of two wires of dissimilar metallic composition connected at one point. The point at which the wires connect forms a junction. A small voltage is produced that is proportional to the difference in temperature between the *shorted* and the *open* ends of the thermocouple leads. Typically this voltage, commonly called the *Seebeck Coefficient*, ranges from 30 μV to 60 μV per °C, depending on the metals used. For a K-type thermocouple, these metals are nickel/chromium and nickel, and the Seebeck Coefficient is approximately 39.4 μV per °C.

Because the voltage produced by the thermocouple is proportional to the difference in temperature between its leads, it is necessary to accurately know the temperature of the connector where the thermocouple attaches to the measurement system. In this design, a platinum RTD (resistance temperature detector) is used to make this measurement.

The PT100 RTD is connected to a separate instrumentation amplifier (U2), set to the same gain as the instrumentation amplifier connected to the thermocouple (U1). The PT100 has a resistance of 100 Ω at 0°C. Its resistance is a linear function of temperature, with a coefficient of 0.385% per °C. Voltage Vtc is therefore a function of temperature and the current through the RTD. The value of resistor R1 (20 kΩ) is chosen such that the temperature coefficient of voltage Vpt matches that of a K-type thermocouple (39.4 μV per °C). The value of resistor R2 is set equal to that of R1 and the value of R3 is set to 100 Ω, so that Vtc is 0 at 100°C.

The *Reference* input on U1 provides an easy way to sum Vpt (the temperature-dependent voltage from the platinum RTD) and Vtc (the temperature-dependent voltage from the thermocouple).

tp = probe (junction) temperature in °C

ta = ambient (card) temperature °C

Vtc = thermocouple generated voltage in mV

$V(PT100) \approx 10.19 + 0.0395 \times ta$ (millivolts)

$Vtc \approx 0.0395 \times (tp - ta)$

$Vpt = 100 \times (V(PT100) - 10.19) + 2048 \approx 2048 + 3.95 \times ta$ millivolts

$ADCVIN = 100 \times Vtc + Vpt \approx 2048 + 3.95 \times (tp - ta) + 3.95 \times ta \approx 2048 + 3.95 \times ta$ (millivolts)

The ADS1244 is a 24-bit A/D converter with an effective resolution of 20 bits (7.8 μV, as connected). The DCR10505 is an isolated DC-to-DC converter with an internal voltage regulator, and supplies the 5 volts to the analog circuits. Two digital signals (Data Out and Clock) connect the ADS1244 to the MSP430F122 ultralow power microcontroller. The ISO721Ms provide ground isolation between the analog and digital grounds. Note that electrical isolation is maintained between *analog ground* (circuits to the left of the blue dashed line in the figure) and *digital ground* (circuits to the right of the blue dashed line).

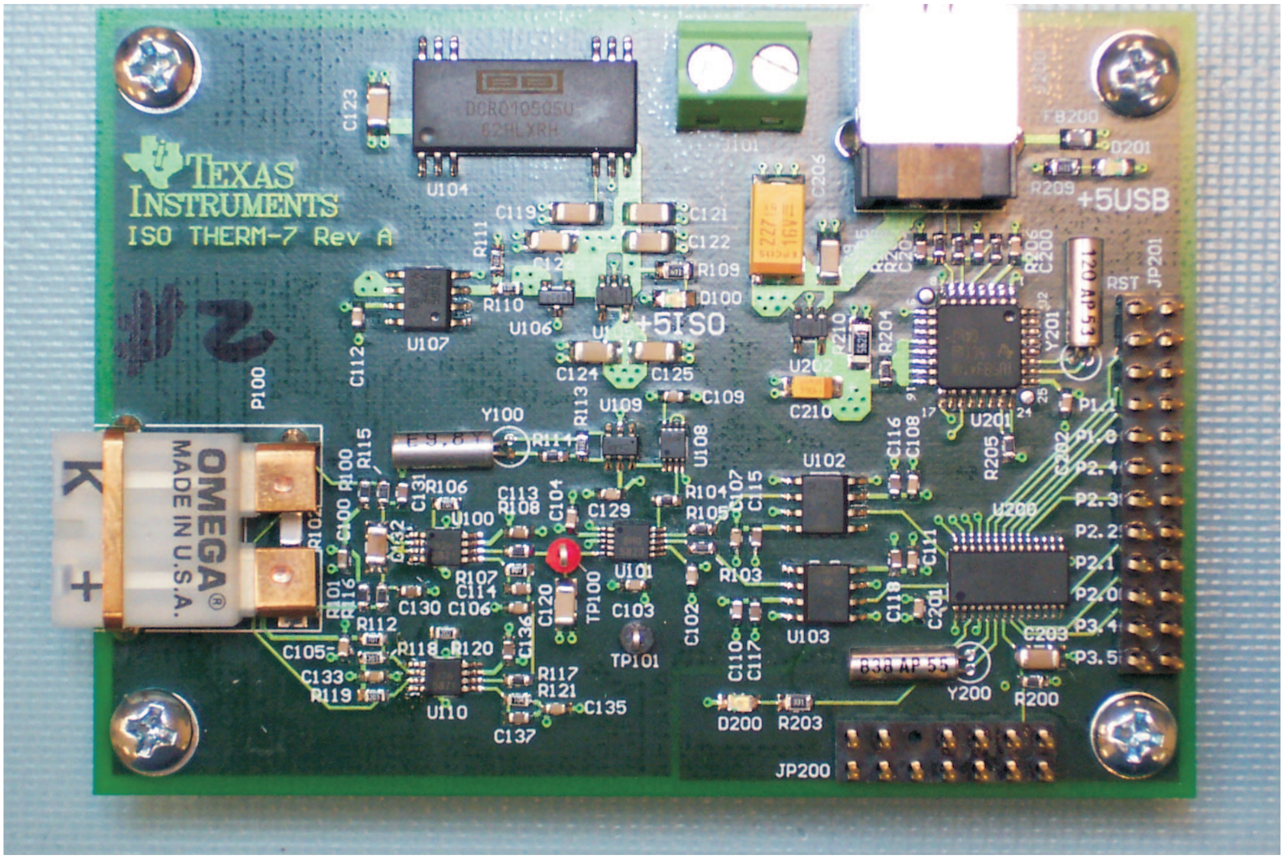


Figure 1. Example Card

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