Implementation of a Differential Thermometer using the ADS1248

Im Yun-Taek[a*], Song Jae-Ha[a], Shin Jin-Won[a], Kim Hyung-Kyoo[a], and Choi Young-San[a]
[a] *Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 34057, Korea.*
HANARO Management Division.
[*] *Corresponding author: ytim@kaeri.re.kr*

1. Introduction

Thermal power, or rate of heat transfer, is directly proportional to the differential temperature between the inlet and outlet of a heat exchanger as shown in Fig. 1 [1]. If a measurement of this differential temperature varies according to a noise signal in a steady state, it would be incorrect to try to estimate thermal power. Therefore, measuring accurate temperature difference in the heat exchanger of a plant is important to find out the rate of heat transfer.

Most COTS (commercial off-the-shelf) digital thermometers offer variety of functions and are inexpensive, and reliable. On the other hands, size, measurement range, accuracy, and output signals of the equipment are so variously required in industry, and some components, such as the 6B13, are discontinued due to rapid digital technology development [2]. Also, it is often necessary for an electronic engineer to design unique requirements for individual environment with customizing. For these reasons, COTS products are occasionally preferable, but all COTS products are not the best solution.

In this paper, differential thermometer using an ADS1248 is presented [3] for a special purpose of error reduction, and several design considerations regarding measurement error reduction are described.

2. Differential Thermometer

2.1 Design Considerations

The first design consideration is whether the sensor is a 4-wire RTD or a 3-wire RTD. Since a 3-wire technique for sensing resistance assumes that the lengths of lead wires are equal, a small mismatch of a lead-wire resistance of a 3-wire RTD can result in a measurement error. Instead, a 4-wire RTD isolates the excitation path of the RTD from the sensing path to provide the highest accuracy [4], [5]. So, to reduce measurement error, a 4-wire RTD should be used.

Table I: System Specifications

RTD Sensor	ADS1248 (4-Wire)
ADC Resolution	24 [Bit]
Number of Channels	2 (A/B)
Measurement Range	T_A (or T_B) : 0.00~100.00 [℃]
	Int($\Delta T_{B\text{-}A}$) : 0 ~ 50 [℃]
	Fra($\Delta T_{B\text{-}A}$) : 0.00~ 0.99 [℃]
Current Loop Resolution	T_A (or T_B) : < 16 [mA] / 100.0 [℃]
	Int($\Delta T_{B\text{-}A}$) : 16 [mA] / 50.00 [℃]
	Fra($\Delta T_{B\text{-}A}$) : 0.16 [mA] / 0.01 [℃]
Current Loop Accuracy	< ± 0.005%

The second design consideration is whether two parts of a loop current should be used to transmit it accurately. Because the fractional part is vulnerable to noise signal (a small variation in the loop due to noise signal can cause a measurement error), a designer may choose to separate analog signals of the integer part and the fractional part in order to reduce the vulnerability of the fractional part to noise signal. Equations (1) and (2) show analog output signals that represent the integer part and the fractional part of the differential temperature. The integer parts covers 0~50 [℃], and the fractional part covers 0.00~0.99 [℃]. Accordingly, the corresponding analog output signals are 4~20 [mA], and 4.00~19.84 [mA], respectively.

$$I_{Int(\Delta T_{B-A})} = 4 + 16 \times \frac{Int(\Delta T_{B-A})}{50.0} [mA] \qquad (1)$$

$$I_{Fra(\Delta T_{B-A})} = 4 + 16 \times \frac{Fra(\Delta T_{B-A})}{1.00} [mA] \qquad (2)$$

The third design consideration is whether the analog output signals of the integer part and the fractional part should be quantized. Since an additive noise increases uncertainty associated with SRSS (square-root-sum-squares) [6], quantization of current loop signals is another manner to reduce noise signal. Current loop receivers of the monitoring system shown in Fig. 2 should be aware of the discrete level, so that it can ignore any noise level that is less than the current loop resolution listed in Table I.

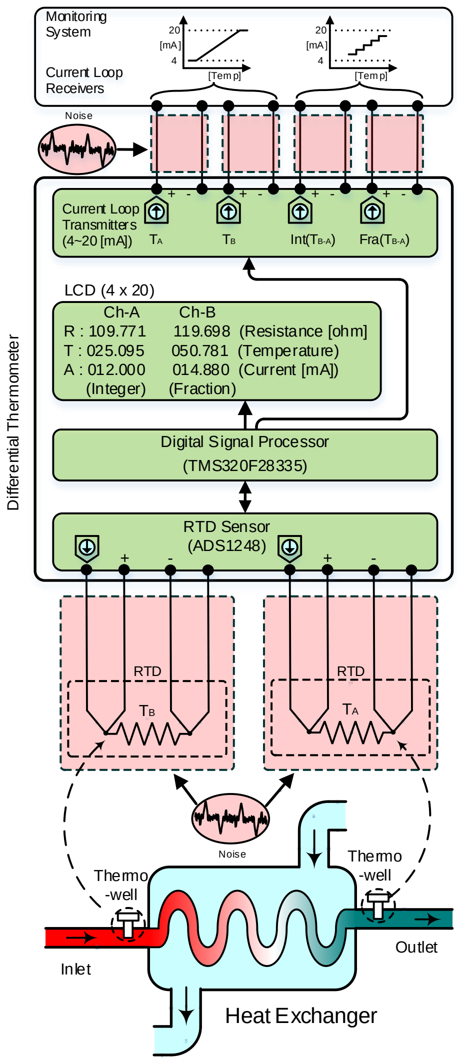
2.2 Implementation

A differential thermometer is implemented by the ADS1248. Fig. 2(a) shows all the relevant system modules. The RTD sensor is capable of reading two channels of a 4-wire RTD with 24-bit resolution. The measurement range for each such channel is 0 to 100 [℃], and the corresponding analog signals linearly vary with respect to temperature according to IEC-60751 [7]. Further, the differential temperature is divided into integer and fractional parts. The outputs of the current loop transmitter are optimized by a least square approximation approach [8]. To reduce error due to noise, the current loop signals of both the fractional part and the integer part are quantized for reading temperature in the current loop receiver with a resolution of 0.01 [℃].

Fig. 2(b) shows the LCD screen during measurement of resistances in two channels. The input values of the two considered channels are approximately 110 [ohm] and 120 [ohm], and the corresponding current loop signals of the integer and fractional parts are 12.00 [mA] and 14.88 [mA], respectively.

3. Conclusions

Estimation of thermal power in a plant requires accurate measurement of temperature. COTSs digital thermometers are a possible solution. However, it may sometimes be necessary to use a customized solution for special purposes. A differential thermometer has been realized using the ADS1248 with 4-wire RTD configuration, and a method to separate the differential signal into two parts has been introduced while quantizing the current loop signals to reduce noise signal. The proposed system will be suitable for the measurement of the differential temperature in a heat exchanger.



Fi g. 1. Block diagram of the differential thermometer.

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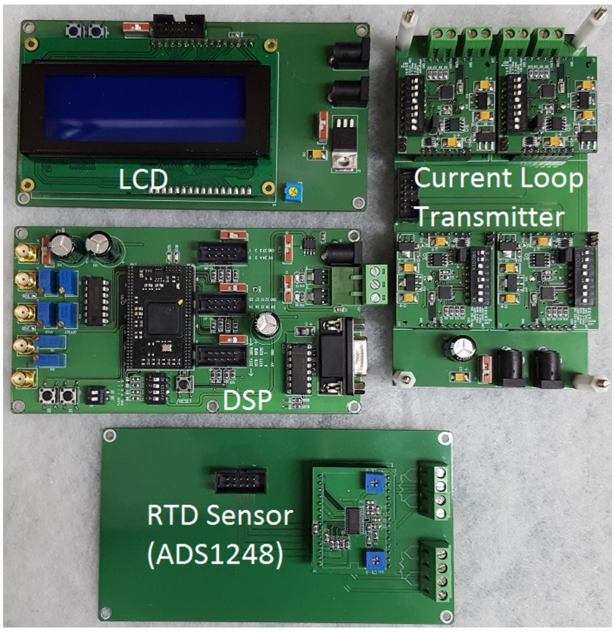
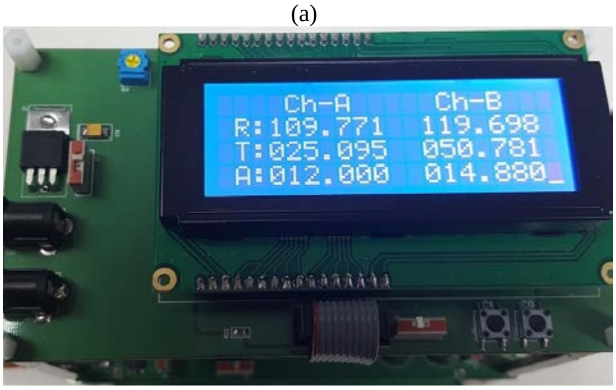


(a)



(b)

Fig. 2. (a) The implemented system (b) LCD screen display during test.