TEMPERATURE CORRECTION METHOD APPLIED ON ZIGBEE MEASUREMENT DATA TRANCEIVER

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In the presented paper a cheap and effective solution for temperature correction of the measuring results is described; it is especially well suited for distributed measuring systems. The method is based on previous mathematic analyze which is used for obtaining relations for the temperature influence over the parameters on the used electronic components. The obtained equations are further used for software correction of the measuring results. This solution is practically verified by using experimental design of a system intended for measurement data transmission, which uses IEEE 802.15.4 ZigBee protocol and unites several existing standards such as serial asynchronous transmission, and industrial standards 4-20mA and 0-5V.

Keywords: measurement data transceiver, temperature correction, ZigBee

1. INTRODUCTION

In many measurement systems there is a necessity for transmission measurement signals over quite long distances from the point of measurement to the place where the signals are recorded or used in a process control system. The transmission can be done in different ways, and by using different methods which significantly have influence on the performance, quality, accuracy and the economical aspect of the solution. The problems of the measurement data transmission are getting bigger in the systems designed for measurement of different physical quantities on a rotating, movable or hard to reach places. In such cases, very often the circuits for signal conditioning are affected by electromagnetic influence or temperature variations, so it is necessary to find a way for their correction.

In this paper we propose a software approach for temperature compensation by measuring the ambient temperature of the signal conditioning circuits and correction of the temperature dependent parameters. The solution is practically verified by using experimental design of a system intended for measurement data transmission, which uses IEEE 802.15.4 ZigBee protocol and unites several existing standards such as serial asynchronous transmission, and industrial standards 4-20mA and 0-5V. The analyses of the measurement data is done by using the LabView software.

2. STRUCTURE OF THE EXPERIMENTAL SYSTEM

The experimental system is based on a MaxStream XBee RF module which fulfills the unique needs of low cost, low power wireless sensor networks. The modules operate within the ISM (Industrial, Scientific & Medical) 2.4GHz frequency band require minimal power and provide reliable delivery of data between devices in range from 30 to 100m. The system uses the ZigBee 802.15.4 protocol and unites several existing standards, such as serial asynchronous transmission and the industrial standards 4-20mA and 0-5V.

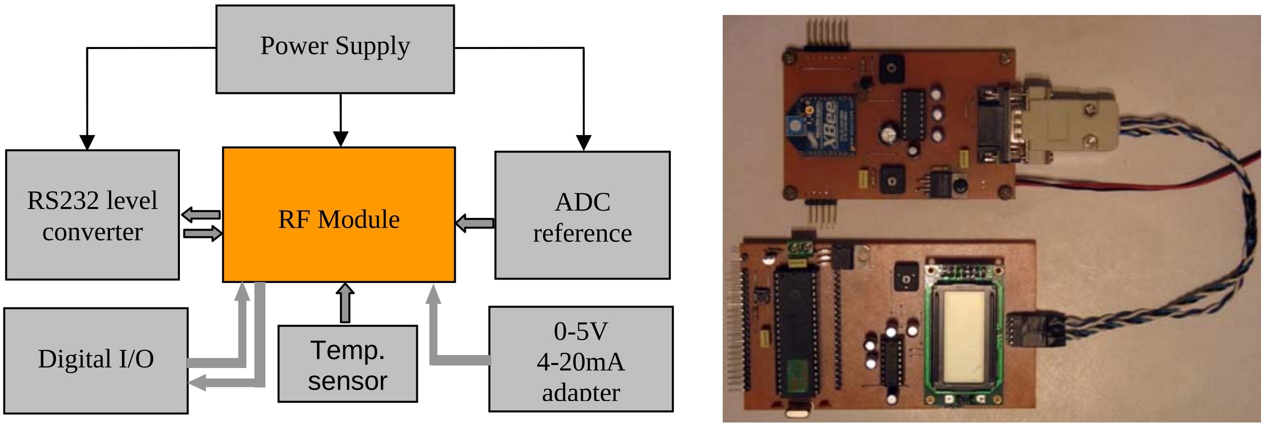


Fig.1 (experimental ZigBee measurement data transceiver)

The communication between the XBee module and the host is realized through a logic-level asynchronous serial port. Through this port, the module can communicate with any logic and voltage compatible UART (Universal Asynchronous Receiver Transmitter) or through a level translator to any serial device.

The process of analog to digital conversion is preformed by using A/D converter with resolution of 10 bits and accurate voltage reference with maximum deviation of 2% under temperature influence. The temperature is measured by using thermistor connected to an unbalanced Whitstone bridge in a range from 0 to 100°C.

3. THEORETICAL ANALYZE OF INDUSTRIAL STANDARDS 4-20mA AND 0-5V

The 4-20mA current loop is a very effective and robust method for sensor signal conditioning. Current loops are ideal for data transmission because of their inherit insensitivity to electrical noise. The measuring quantity through appropriate sensor and measuring amplifier is converted in to a current proportional to the quantity that is being measured. The current flowing through receiver produces a voltage that is easily measured by an analog input of a controller.

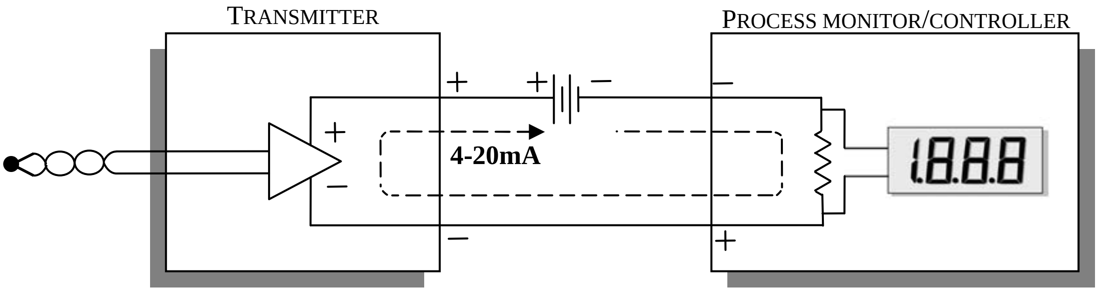


Fig.2 (4-20mA current loop transmission)

The total uncertainty is a sum of several parameters, such as current resistor uncertainty δ_R, A/D conversion error δ_{ADC}, reference voltage δ_{Vref} and random errors δ_S. It is expressed with the relation:

$$\delta_e = \delta_R + \delta_{ADC} + \delta_{Vref} + \delta_s \tag{1}$$

Random errors are related to the probability laws, by doing statistical analyze to this kind of errors we estimate the random component of the measurement uncertainty; actually we do estimation of the true value of the measuring quantity. The A/D conversion errors are sum of several effects, such as offset, unlinearities and temperature drifts of the used A/D converter. From the other site these errors are defined in certain extent given by the producer, so it can be considered that there is a high probability that the measuring results would be in this extent. What can be done in this case is a choice of an A/D converter with higher resolution. For the errors of the current resistor and the reference voltage can be written:

$$\delta_{Vref} = \delta_{Vref\,0} + \delta_{Vref\,(T)} \tag{2}$$

$$\delta_{R_L} = \delta_{R_L\,0} + \delta_{R_L\,(T)} \tag{3}$$

Actually these errors consist of the voltage and resistance nominal value deviations and the temperature influence. By using precise measuring instrumentation, the first part of the equations can be minimized, but for decreasing of the temperature deviation errors a suitable correction should be done.

For the digital represent of A/D converter input voltage can be written

$$N = \frac{V_{ADC} - V_{ref(-)}}{V_{ref(+)} - V_{ref(-)}} 2^n \tag{4}$$

If $V_{ref(-)}=0$, and with inserting the temperature influence, the equation will become:

$$N = 2^n I_S \frac{R_L(T)}{V_{ref}(T)} \tag{5}$$

The temperature dependence of the current resistor can be represented with the equation:

$$R_L(T) = R_{L0}[1 + \alpha(T - T_{ref})] \tag{6}$$

And the temperature dependence of the reference voltage is expressed with the equation:

$$V_{ref}(T) = V_{ref\,0} X(T) \tag{7}$$

By inserting the relations (6) and (7) in relation (5) we will obtain:

$$N = 2^n \frac{I_S R_{L0}}{V_{ref\,0}} \frac{1 + \alpha(T - T_{ref})}{X(T)} = K I_S \frac{1 + \alpha(T - T_{ref})}{X(T)}, \text{ where } K = 2^n \frac{R_{L0}}{V_{ref\,0}} \tag{8}$$

The temperature dependence of the current resistor can be minimized with use of resistor composed by material with low temperature coefficient such as Manganin or Constantan, and the reference voltage temperature dependence by suitable hardware compensation. In our case, the idea is to solve this problem by using software temperature correction at the receiver side. In that way lower cost of the solution and simpler hardware realization is achieved. Such approach asks for measurement of temperature at the transmitter side, and also alternating transmission of one measurement data byte and one temperature byte. The measurement data correction is realized at the receiver side by the use of a microcontroller or computer.

For the industrial standard 0-5V a suitable attenuation needs to be done, actually the signal has to be attenuated in extent of the allowed input voltage of the used A/D converter. The simplest solution of this problem is the use of passive resistive voltage divider.

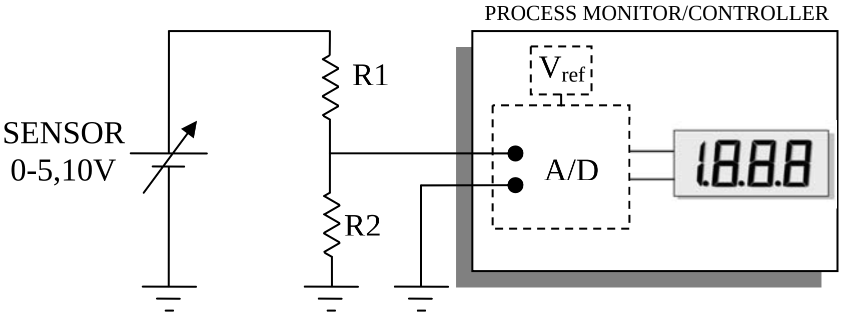


Fig.3 (0-5V transmission)

For the digital represent of A/D converter input voltage can be written:

$$N = \frac{V_S R_1(T)}{[R_1(T) + R_2(T)]V_{ref}(T)} 2^n \tag{9}$$

If one considers that resistors R_1 and R_2 are in the same ambient conditions, and that they are fabricated from the same materials with equal temperature coefficient, relation (9) will become:

$$N = 2^n \frac{V_S}{V_{ref0}} \frac{R_1}{R_1 + R_2} \frac{1}{X(T)} = KV_S \frac{1}{X(T)}, \text{ where } K = 2^n \frac{V_S}{V_{ref0}} \tag{10}$$

In this case, the temperature variations do not cause voltage deviations on the output of the divider, so it is necessary to make correction only of the temperature dependence of the reference voltage.

4. EXPERIMENT

In the test we use three analog channels, one for 4-20mA standard, channel for the standard 0-5V, and one channel for temperature measurement. The channels are sampled with frequency of 100Hz where 10 samples for each channel are successively taken and averaged. The temperature is measured by using the thermistor KTY81-122 connected to an unbalanced Whitstone bridge in a range from 0 to 100°C with maximum deviation of ± 0.5°C. The unlinear characteristic of the termistor (Fig.4.a) is approximated by using the least square method. TL431 is a programmable shunt voltage reference with guaranteed temperature stability over the entire temperature range of operation. The voltage reference provides maximum deviation of 2% under temperature influence; this characteristic is approximated by using the least square method (Fig4.b).

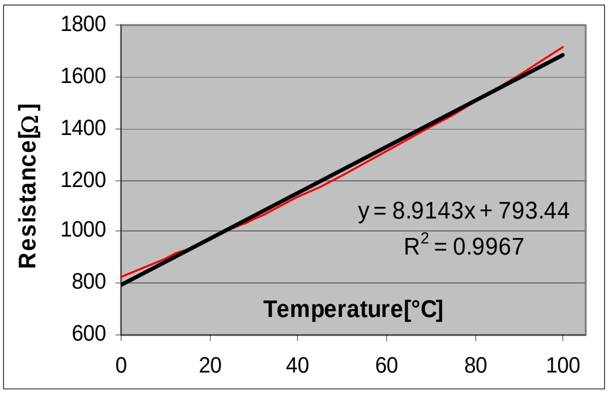


Fig.4.a (KTY81-122 least square approximation)

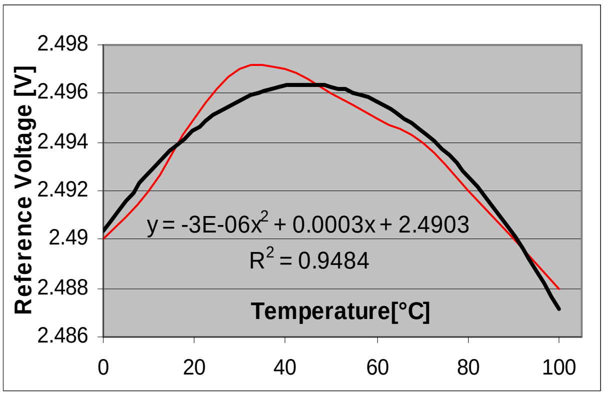


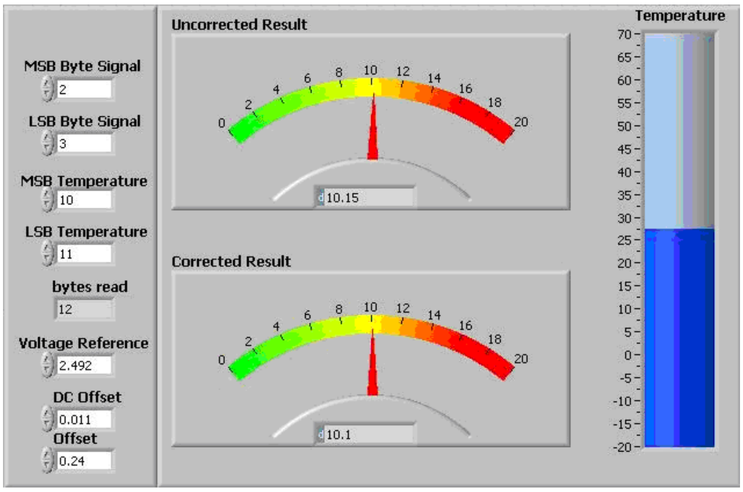
Fig4.b (TL431 least square approximation)

Wirewound resistor elements offer excellent temperature stability and high power dissipation abilities with acceptable resolution limits so they can be a satisfactory choice for precision measurement. For our experiment we use a 120Ω/5W wirewound resistor with temperature coefficient of 300ppm, but in order to compensate the temperature rise due to the dissipation all temperature dependent components must be placed on a common plate. Using this data and having in mind relation (8), correction of the measurement results is done by using the relation:

$$Is = \frac{N}{K}\frac{1 + 0.0003(T - T_{ref})}{0.0000012T^2 + 0.00012T + 0.9993} \tag{11}$$

Similar, the relation for 0-5V measurements is:

$$V_S = \frac{N}{K}\frac{1}{0.0000012T^2 + 0.00012T + 0.9993} \tag{12}$$



MSB Byte Signal 2
LSB Byte Signal 3
MSB Temperature 10
LSB Temperature 11
bytes read 12
Voltage Reference 2.492
DC Offset 0.011
Offset 0.24
Uncorrected Result 10.15
Corrected Result 10.1

Fig.5.a (experimental software)

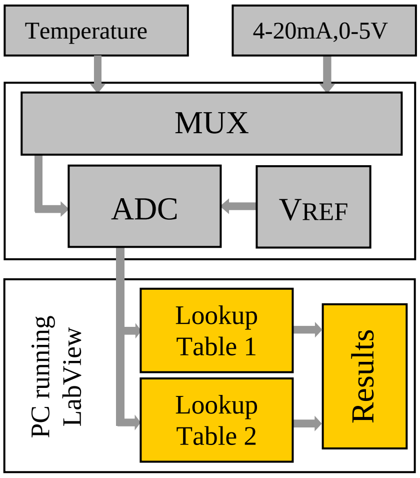


Fig5.b (block diagram)

The inclusion of a temperature driven look-up table in the signal conditioning architecture adds a great deal of flexibility to the system and can simplify the calculation process substantially. Using this method, the A-D count is simply used to correlate to the temperature recorded in the table. In the experiment we use two lookup tables, one for calculation of temperature, and one for calculation of the relations (11) and (12). All calculations can be done by using microcontroller or a computer. In this experiment we use a PC and specially designed software in LabView environment.

5. RESULTS

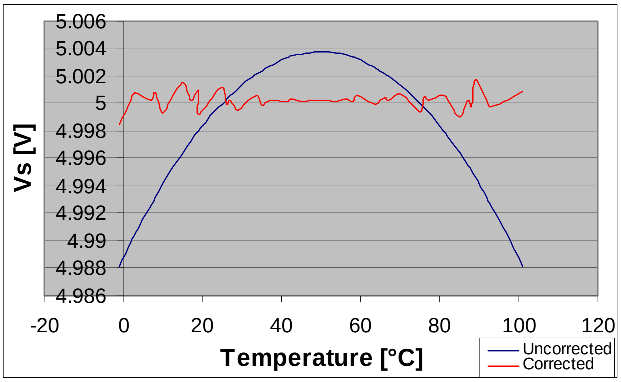


Fig 6.a (0-5V measurement results)

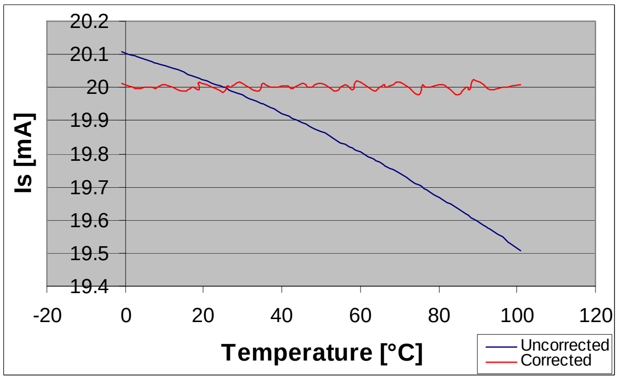


Fig 6.b (4-20mA measurement results)

The results are obtained by using precision calibrator source FLUKE 5500A for temperature rise from 0 to 100°C. For measurement data correction a lookup table with 2 °C step is used. The calculations are done with PC and specially designed software in LabView environment. From the obtained result graphs can be clearly seen that the application of this method significantly approves temperature stability of the measurement results. The accuracy of the temperature drift error compensation is determined by the accuracy of the predicted temperature curves, the accuracy of the temperature sensor and the lookup table step size.

6. CONCLUSION

Temperature correction method based on ambient temperature measurements was described in this paper. This method was applied on an experimental ZibBee based measurement data transceiver which supports the industrial standards 4-20mA and 0-5V. All experiments were made for temperature rise from 0 to 100°C. The measuring results are obtained by using specially designed software in LabView environment with a use of correction lookup table. This concept combines therefore the advantages of a digital approach (flexibility through programmability) and the benefits of an analog solution (reduction of total error). The available options and combinations help to select best fitting solution for a given system. In comparison with the classical hardware temperature compensation methods it allows much simpler hardware solution and lower price.

7. REFERENCES

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