Calibration of Dallas sensors

Mariusz Sapinski
INFN Sezione di Roma1 – Roma, Italy
(April 2006)

1. Objectives

The goal of this work is to perform a calibration of Dallas sensors.
Nine Dallas sensors are glued in different places of the mechanical structure of box S of the gas system of the AMS Transition Radiation Detector. These sensors provide temperature measurement with an accuracy of about 0.5 °C [1]. They are glued to the structure with epoxy glue of unknown thermal conductivity.
The thermometers used to perform calibration of Dallas sensors are platinum thermometers. They provide accuracy of 0.01 °C. Their readout is via RP7000 digitizer connected via GBIP to a PC with LabView. These thermometers were glued with use of black electrical scotch tape, as close to Dallas sensors as possible. Nevertheless the distance between platinum thermometer and Dallas sensor were usually about 0.5 cm, what is a source of a systematic error discussed later.
The whole setup is placed in laboratory with air-conditioning and cannot be moved to another place, what means that a local heaters must be used to perform the calibration. The air-conditioning cannot be regulated. It keeps the room temperature of about 21 °C and it has a characteristic working cycle of about 50 minutes. The amplitude of temperature changes during the cycle, measured by platinum thermometers is about 0.2 °C. Additional, smaller temperature variations appear with a period of 24 h.
In such conditions, even if the frame of the setup is made of thermally well conductive aluminum, the heat distribution leads to temperature gradients, which can be only roughly estimated.
The calibration strategy is to take the measurements in at least two temperature points and fit a straight line:

$$T_{Dallas} = p_1 T_{Pt} + p_0$$

For every temperature point, in order to minimize the influence of temperature fluctuations, an average over many measurements is taken.
The error of the Dallas sensor measurement is simply equal to accuracy i.e. 0.5 °C. The error of the platinum thermometer measurement is estimated as a standard deviation of the chosen set of measurements.

2. Sensors close to Xenon and CO_2 bottles

The grip handles of the CO_2 and Xe bottles are equipped with build-in heaters. These heaters have power of about 10 W and are build-in into aluminum block. Their location provide good heat dispersion. They are able to heat-up the block by about 10 °C. The unique sensor addresses are: 10F6528E00080097 (CO_2 bottle) and 10B45B8E0008007F (Xe bottle). The typical heating process for sensor 10F6528E00080097 is shown in Figure 1.

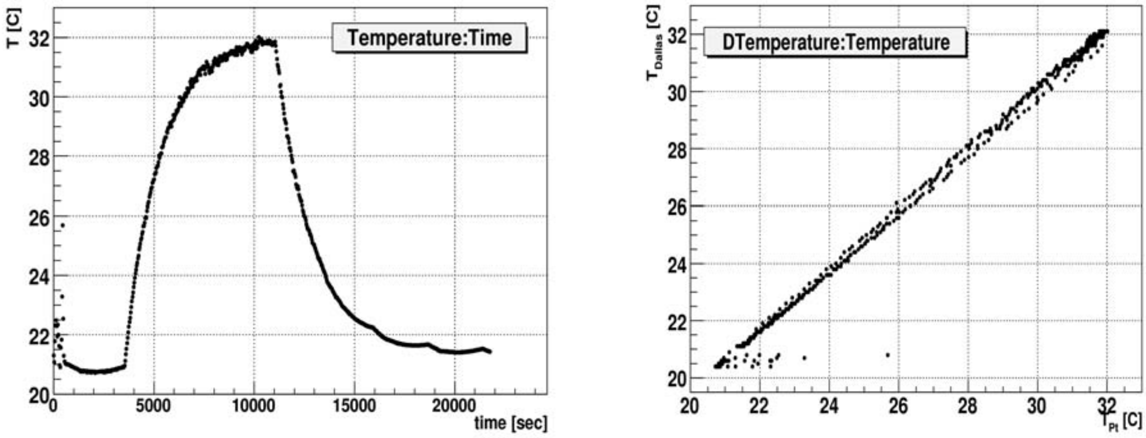

Figure 1: Left plot: example of heating cycle for Pt thermometer placed near Dallas sensor 10F6528E00080097. Right plot: hysteresis for the same sample.

This heating is performed using 250 heating cycles of 30 s each with duty factor of 70%. The readout was performed every 30 s. The initial heating rate is about 0.18 °C/min. The resulting temperature difference between cold and hot point is about 10 centigrades. In Figure 2 the determination of the calibration parameters with a linear fit is presented.

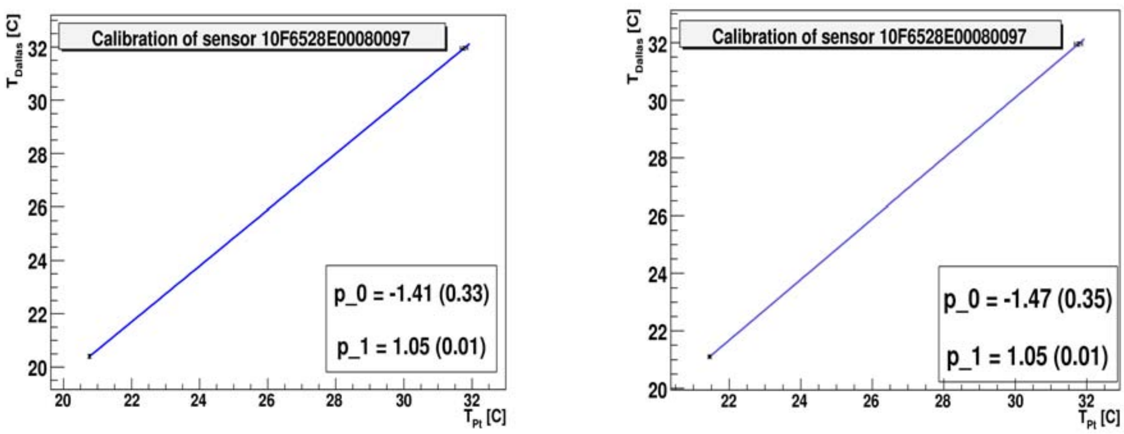

Figure 2: Calibration of the sensor 10F6528E00080097 during heating (left plot) and during cooling down (right plot).

The results during heating and during cooling down are compatible within errors. As the final result the one with smaller statistical errors has been chosen.

3. Sensor on the mixing vessel

The mixing vessel is made of thin steel so it behaves thermally in a different way than other parts of the gas mechanical structure which are made of aluminum.

There are no internal build-in heaters on the mixing vessel so an external heater was placed on the vessel in the neighborhood of platinum thermometer and Dallas sensor (approximately in the same distance from both of them). The heater was an electric resistance heater of with power of 4 W. An example of a heating curve for this sensor is shown in Figure 3.

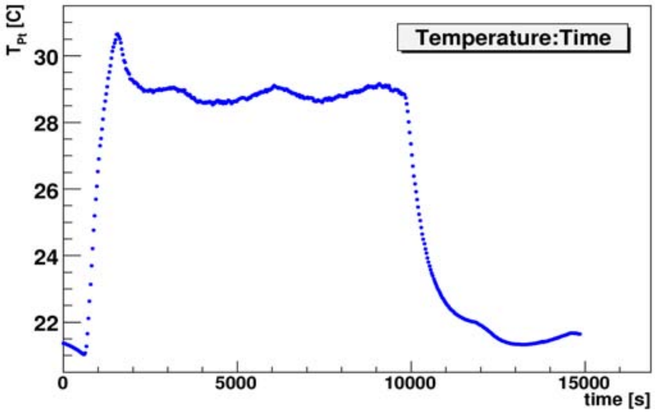

Figure 3. Heating curve for the sensor on the mixing vessel (106F4A8E000800F2). The initial peak is due to over heating and it was excluded from the analysis.

With respect to heating curve of the sensors close to build-in heaters we notice that the heating is much faster (0.5 °C/min). Another difference is a visible influence of the air-conditioning on the temperature measurements from the Pt thermometer. This is probably due to lower power of the heater.

4. Sensors on the aluminum structure

Finally a calibration for two Dallas sensors glued to flat parts of the aluminum structure has been performed. The aluminum structure is large and thin so the heat dissipation is much stronger than in case of previous measurements. This is a reason of larger errors for these measurements. The temperature difference between the cold and warm calibration point is of the order of only 4 centigrades. An example of the heating cycle for one of the sensors is shown in Figure 4.

The periodic behavior due to air-conditioning is visible. Averaging over a few periods were done in order to avoid systematic error.

The four sensors which have not been calibrated are glued in places where it was not possible to put platinum thermometers close to the sensors. The accuracy of the calibration of these sensors would suffer from very large and difficult to estimate systematic error.

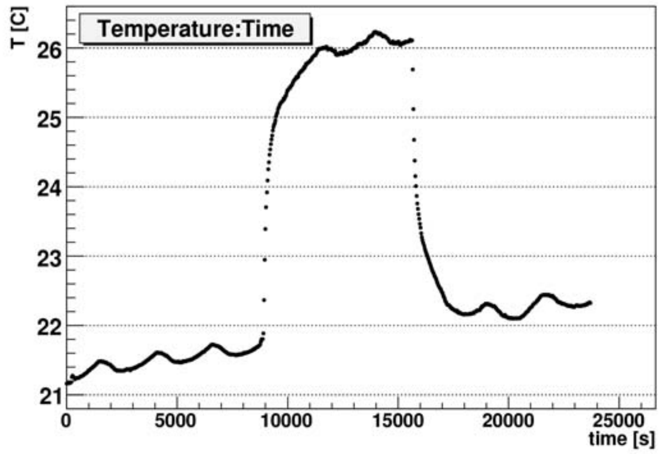

Figure 4: Example of a heating curve for the sensor 10A64A8E000800FB.

5. Results

The results of the calibration are presented in Table 1. In the second column the calibration constant (p_0) is shown and in the third one the calibration coefficient (p_1). The errors presented there are statistical, obtained from linear regression.

Additional systematical error should be added to p_0 parameter due to the heat flow. This error has been estimated using the approximative values.

Assume that the aluminum frame temperature is T_0. The temperature of the Dallas sensor is expressed:

$$T_{Dallas} = T_0 - (Q \cdot d / A \cdot \lambda)$$

where: Q – heat flow, d – distance between heater and Dallas sensor, A – surface of the contact between sensor and the mechanical structure, λ- thermal conductivity of the contact between sensor and surface.

A similar statement can be written for platinum thermometer, but as platinum thermometers are pressed to the surface without any glue it is a good approximation to assume that the thermal conductivity for platinum thermometers is much larger than in case of Dallas sensors ($T_{pt}=T_0$).

For typical values : Q = 1 W, d = 5 mm, A = 0.1 cm^2, λ= 10 (W/m·K)

$$T_{Dallas} - T_{Pt} = 0.5\ °C$$

This difference is an estimation of the systematic error of the calibration constant due to heat flow.

It should also be remarked that in all tested configurations the temperature of the Dallas sensor during the heating were higher than during the cooling down. But this effect is probably due to 9-bit readout of the Dallas sensors (sensor stays in different state after heating).

sensor address	***p_0 [°C]***	***p_1***	***remarks***
10F6528E00080097	-1.4 (1.3)	1.05 (0.07)	CO_2 bottle
10B45B8E0008007F	-2.4 (2.6)	1.12 (0.10)	Xe bottle
106F4A8E000800F2	-1.5 (2.4)	1.05 (0.10)	Mixing vessel
10A64A8E000800FB	0.7 (3.6)	0.95 (0.15)	
1075738E00080011	-0.4 (7.1)	1.00 (0.31)	Very large statistical errors

Table 1: Results of the calibration for five Dallas sensors. Statistical errors are shown in brackets.

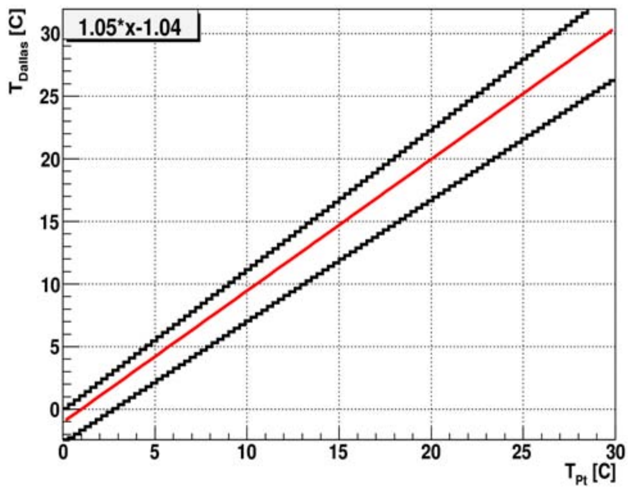

Figure 5. Accuracy of the calibration of sensor 10F6528E00080097 as a function of temperature. The black lines designate calibration error.

6. Conclusions

The calibration of Dallas sensors has been performed however the conditions of the calibration lead to large statistical and systematic errors. Within the obtained accuracy the Dallas sensors are linear with calibration coefficient in a range 0.9-1.1. The calibration constant is found to be in the range -5 to 4.3 °C.

One of the sensor has errors of the calibration two times larger than other sensors.

The main difficulties in reaching a better accuracy of calibration were impossibility to assure stable temperature conditions especially for the second temperature point (warm).

To obtain the calibration of the Dallas sensors with accuracy of 0.5 °C we suggest to perform it before gluing the sensors to the structure.

Bibliography

1. Dallas sensors specification (http://pdfserv.maxim-ic.com/en/ds/DS18S20.pdf)