JOINT INSTITUTE FOR NUCLEAR RESEARCH

Dzelepov Laboratory of Nuclear Problems

FINAL REPORT ON THE

SUMMER STUDENT PROGRAM

Reduction of long-term noise in 24-bit ADC DT9824 for Precision Laser Inclinometer

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ABSTRACT

At this work was explored daily noise of 24-bit ADC DT9824 in conditions of an office room and in conditions of heat stabilized and radio isolated laboratory. Also dependence of ADC noise on sample time was explored. The values of spectral destiny of ADC noise in the heat stabilized and radio isolated laboratory were obtained on frequency ~10^{-5} Hz. For the ADC DT9824 with the sample time 0,1 sec this value is equal to $4\cdot10^{-6}$ V/Hz$^{1/2}$.

Usage of the thermally stable and radio isolated conditions allows to stabilize ADC noise by a factor of 240 in the frequency range of 1,25·10^{-5} Hz.

The method of registration of temperature change in the ADC indications was offered. Point of this method is subtraction of indications of the one channel from indications of the other channels. *The main achievement of this method use is very significant increase by a factor of 13 of the rms value of ADC relative resolution in frequency range of [10^{-5};10^{-4}] was increased.*

The *Precision Laser Inclinometer is a unique new generation instrument* and it will measure with 10^{-9} rad accuracy the microseismic ground motion making possible to improve the space stabilization of the colliding beams parameters in the collision area leading to luminosity increase and improving the momentum and angular measurement precision.

INTRODUCTION

For many years Joint Institute for Nuclear Research (JINR) and CERN are developing methodology of the Precision Laser Inclinometer. In fact, PLI is an angular seismograph which allows one to observe the basic seismic effects: far happened earthquakes, microseismic peaks, industrial seismic effects [1-4].

Using data obtained by PLI – network allows us to visualize landscape changes induced by influence of surface seismic waves. These data could help us to stabilize modern accelerators – colliders from angular microseisms which will allow the luminosity increase.

Frequency range of PLI is about 10^{-6} Hz. One of the main problems with using PLI is parameters stabilization in low frequency fields (10^{-6} – 10^{-4} Hz). In PLI measuring circuit 24-bit ADC DT9824 is used. To obtain high sensitivity of PLI in low-frequency field it is necessary to stabilize the parameters of ADC and develop the method of noise reduction.

In precision measurements of electric signals what were obtained by temperature sensors, strain gauge in low frequency range, limiting factor is residual instability of noise induced by temperature variation and electromagnetic fields, detected by ADC [4-6]. Detection and reduction of ADC noise in low frequency range is an actual problem.

At this work a problem of long-term noise reduction in ADC DT9824 will have researched.

RESEARCH OF THE 24-BIT ADC DT9824 NOISE

Modern 24-bit ADC has a value of noise pollution about 10^{-6} V. The variation range of an input level is ±10 V. It means that the ADC allows to measure signals with the relative resolution of 10^{-7} what is the main factor in precision measurements in modern physical experiment.

As a rule, noise level measurements need to be taken in a short time (less than 1 hour). But while registering signals longer than for 1 hour you can see an ADC noise level change. These changes have the character of a quasi AC long-term drifting. The reason of this phenomenon could be defined due to change of external temperature or other physical factors: heightened high-frequency electromagnetic field, solar activity etc.

Daily ADC DT9824 noise measurement of four channels is shown in Figure 1. Sampling time is equal to 0,1 sec. The measurements have been taken in the conditions of office room with day/night variation of temperature.

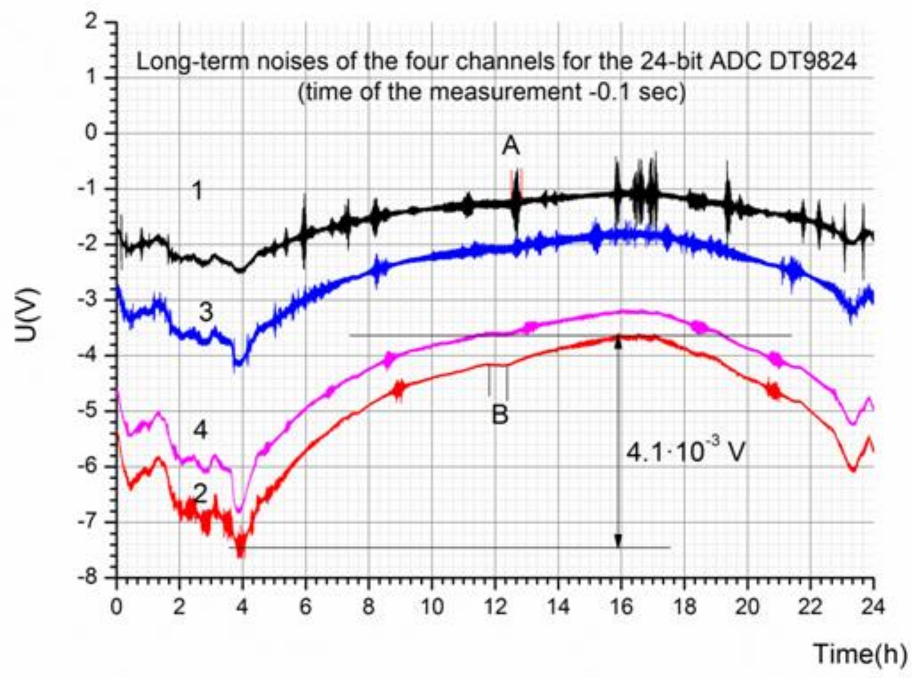

Fig. 1. Long-term noise record for 4 channels

As shown in Figure 1, there are both the long-term noise changes and short-term (10-15 min) noise rising (A).

Rms of minimal noise for the period of 20 minutes (B) is equal to $5 \cdot 10^{-6}$ V. Short-term noise rising (A) increases the rms of minimal noise to $165 \cdot 10^{-6}$ V. Variation of noise amplitude change reached $4{,}1 \cdot 10^{-6}$ V per day. Daily root mean squares of channels were as follows: 1st channel – $0{,}4 \cdot 10^{-3}$ V; 2nd channel - $1{,}1 \cdot 10^{-3}$ V; 3rd channel - $0{,}6 \cdot 10^{-3}$ V; 4th channel - $0{,}9 \cdot 10^{-3}$ V.

As shown in Figure 1, channels 1, 2, 3, 4 have a matched drift. And besides, each channel has one's own scaling factor relatively the channel with maximal variation of noise amplitude. Scaling factors for the 1st, 3rd, and 4th channels relatively the 2nd channel were determinate experimentally. Also rms σ_i of noise variations for 1-4 channels in low-frequency field ($10^{-5} – 10^{-4}$ Hz) were determined. After that we determine the scaling factors $K_i = \frac{\sigma_2}{\sigma_i}$ relatively the 2nd channel. For data shown on Figure 1 scaling factors were as follows: K_1 = 2,9; K_2 = 1,8; K_4 = 1,2. After multiplication by these factors we got a data with approximately equal noise change for all channels.

In Figure 2 there are normalized graphs of ADC noise variation for 4 channels.

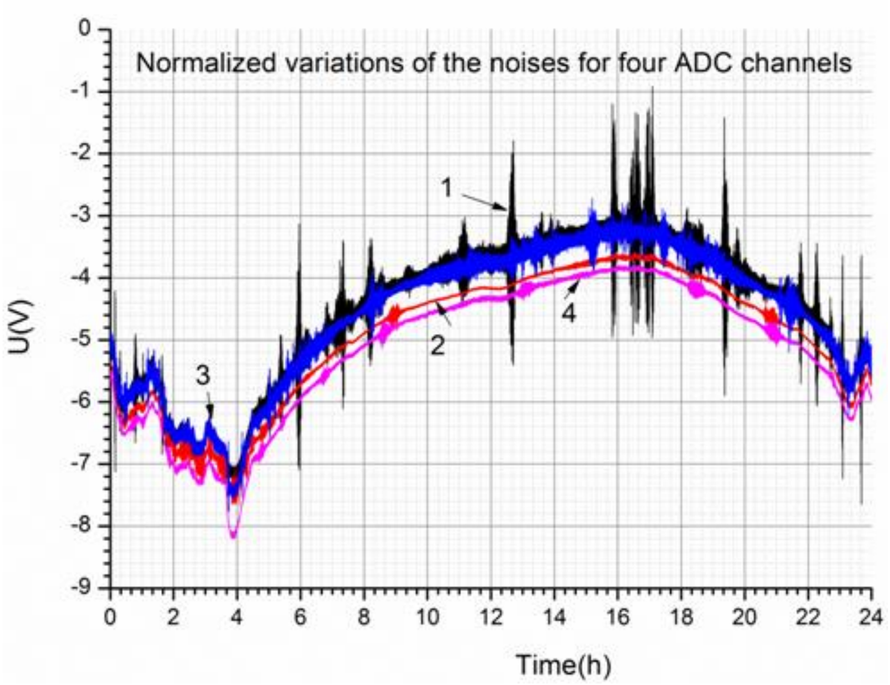

Fig. 2. Normalized noise variations for 4 channels of ADC DT9824.

For reduction of daily noise we use one of the channels as fiducial channel and subtract value of this channel from other channels. As a result we have of 3 out of 4 informational channels with reduced noise variation.

In Figure 3 there are values of noise variation for 3 out of 4 channels after subtracting from this channel's normalized data a data of the 4^{th} channel.

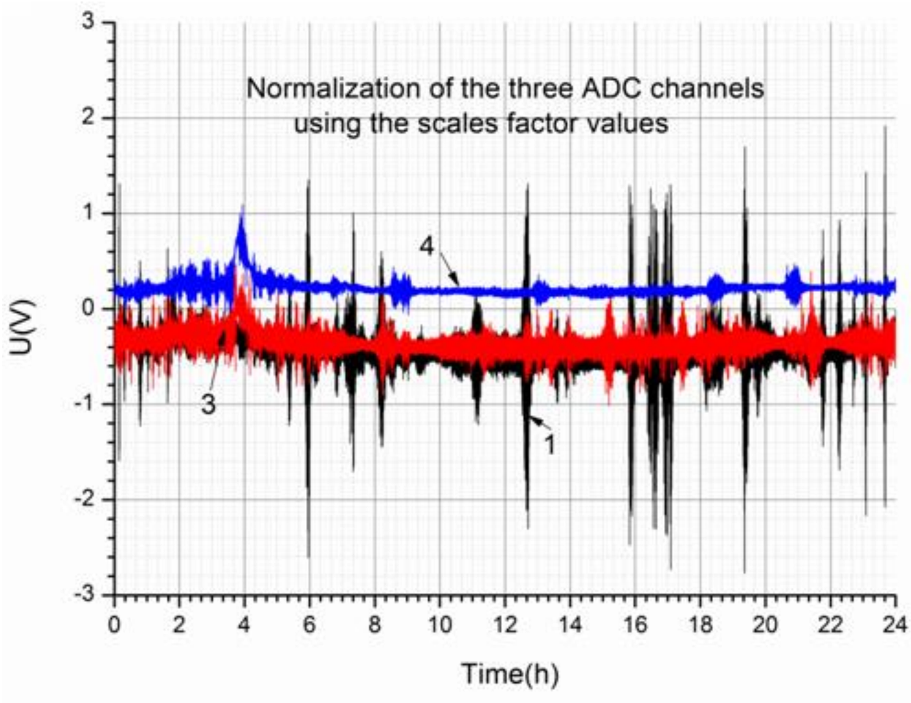

Fig.3. Compensation of the 1, 3 and 4 channel's noise using the 2^{nd} channel signal.

Daily values of rms for normalized channels were as follows: 1st channel – $1{,}4 \cdot 10^{-4}$ V; 3rd channels - $8 \cdot 10^{-5}$ V; 4th channel - $7 \cdot 10^{-5}$V.

As we can see there is a significant achievement: the long-term ADC noise reduction by a factor of 13.

One of the reasons of drift change of the ADC noise is a variation of external temperature. To proof this hypothesis the researches were repeated in the conditions of heat stabilized and radio isolated laboratory with daily temperature instability better than 0,01 ºC [9]. In the Figure 4 there is an ADC noise in thermally stable and radio isolated conditions.

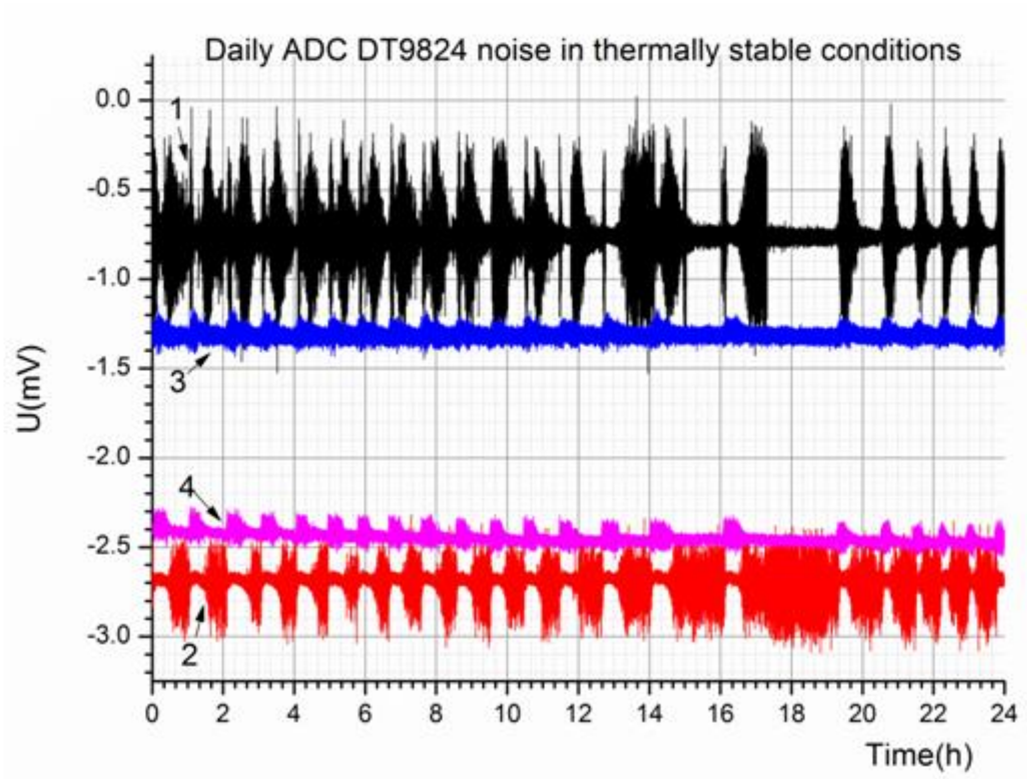

Fig. 4. The long-term ADC noise measurement in conditions of heat stabilized and radio isolated laboratory.

As it shown in the Figure 4 there are periodic and coincident with the work of an air conditioner noise bursts. The air conditioner is located in laboratory for supporting a constant temperature.

The reason of this noise is quite obvious – this is an influence of an electromagnetic field induced by the air conditioner on the ADC. The metal box was used for isolation of the ADC from the influence of the air conditioner.

In the Figure 5 there are ADC noise changes in the isolated from the influence of the air conditioner conditions.

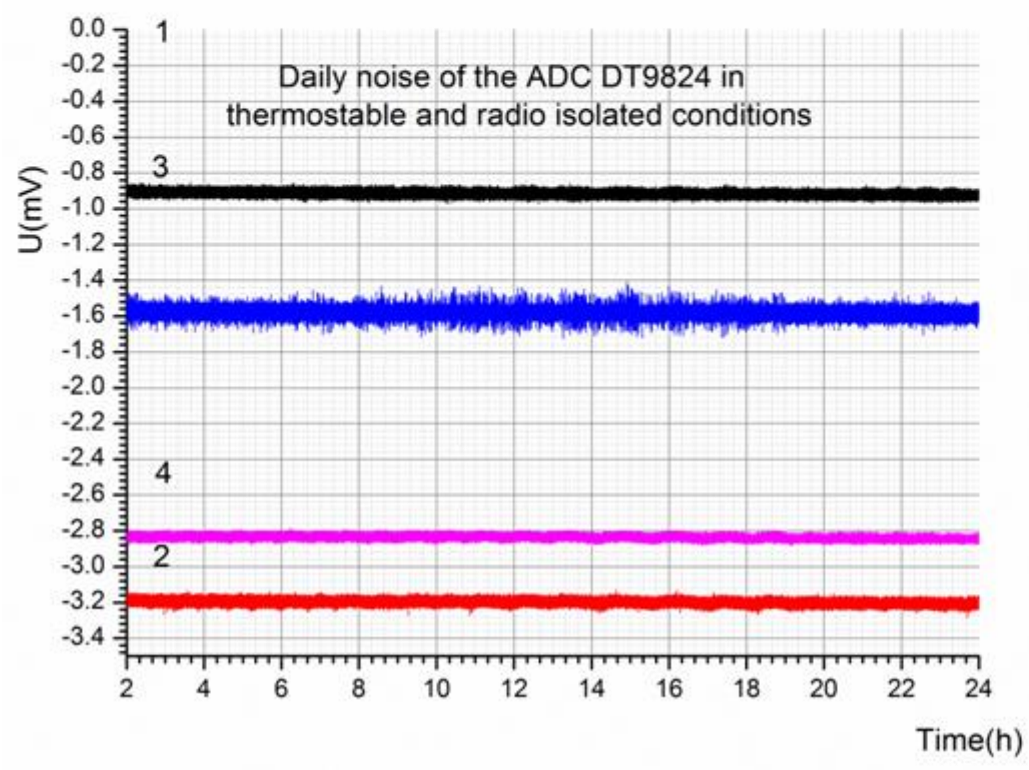

Fig. 5. The long-term ADC noise measurement in the thermally stable, radio isolated and isolated from the influence of the air conditioner conditions.

As we can see, the hypothesis about the influence of external devices on the work of the ADC was completely confirmed. The daily rms of channels were as follows: 1st channel – $1{,}2\cdot10^{-5}$ V; 2nd channel – $1{,}3\cdot10^{-5}$ V; 3rd channel – $1{,}9\cdot10^{-5}$ V; 4th channel - $1\cdot10^{-5}$ V.

Let's define the frequency range of the limiting resolution of the ADC in the different conditions of work. To define the frequency range we need to make a Fourier – analysis of the data from 4th channel which is shown in the Fig.1 and in the Fig. 5.

At the Figure 6 there is Fourier – analysis of the data from 4th channel in office room and thermally stable and radio isolated laboratory.

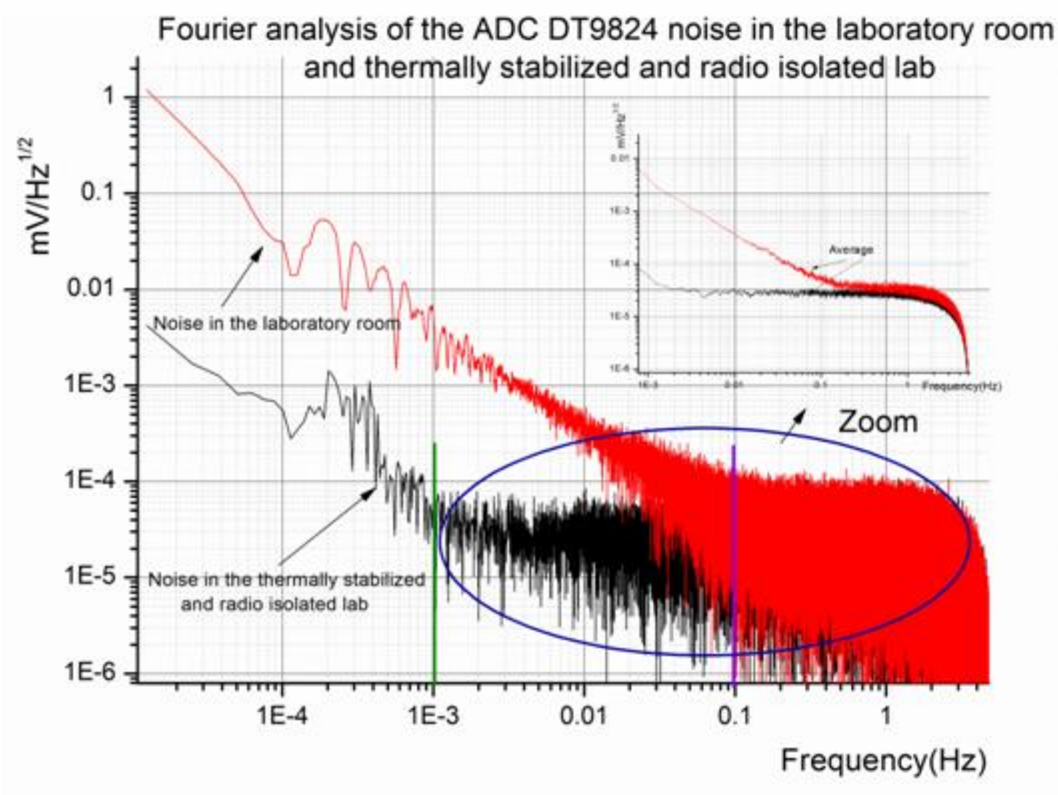

Fig.6. The Fourier – analysis of the ADC DT9824 noise in the conditions of the office room and the thermally stable and radio isolated laboratory.

As it shown in the Figure 6, the limit resolution of the ADC at the level of $6\cdot10^{-7}$ $Hz^{1/2}$ is achieved when the ADC works in the office room with 0,1 Hz. For the case when there are conditions of thermally stable and radio isolated laboratory this value is equal to 0,001 Hz. *Usage of the thermally stable and radio isolated conditions allows to stabilize ADC noise by a factor of 240 in the frequency range of* $1{,}25\cdot10^{-5}$ *Hz.* It also allows to obtain a resolution of the ADC at the level of $4\cdot10^{-6}$ $V/Hz^{1/2}$.

DETERMINATION OF THE NOISE DEPENDENCE ON THE SAMPLE TIME FOR THE 24-BIT ADC DT9824

While measuring at the high frequency (10^{-3} Hz), it is important to determinate a value of a noise reduction in the conditions of thermally stability and radio isolation.

In the Figure 7 there are graphs of the noise variation in the conditions of the office room. The sample time is different.

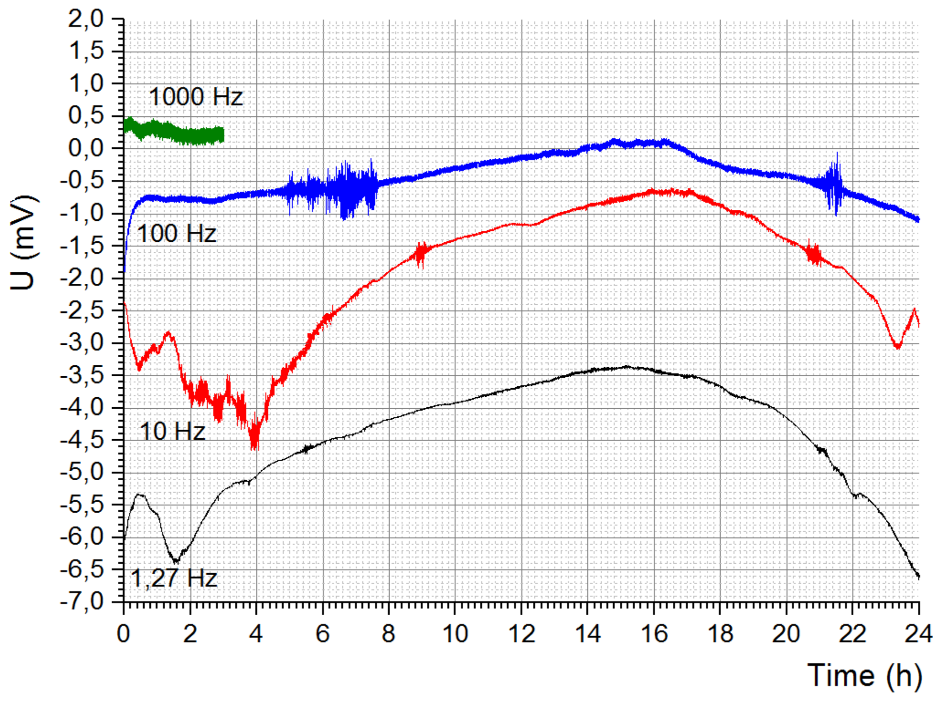

Fig.7. The noise variation for the different sample time in the office room.

As it shown in the Figure 7, there is an amplitude increase of the registered noise while the sample time decreasing.

In the Figure 8 there is a data of the noise variation for the dirrefent sample time in the thermally stable and radio isolated laboratory.

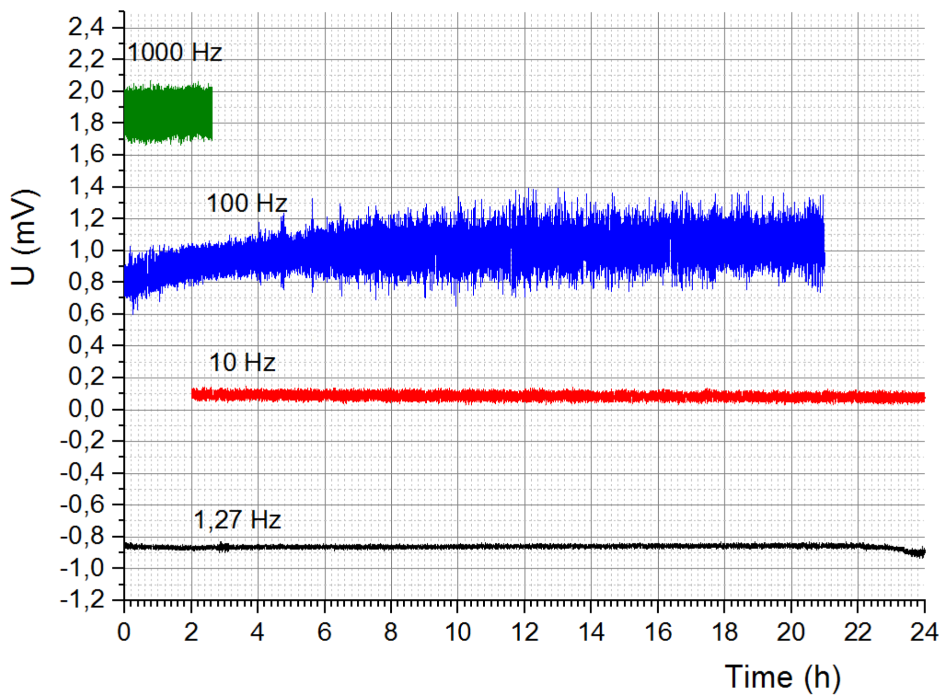

Fig. 8. The noise variation for the different sample time in the laboratory.

For the quantitative determination of noise reduction we need to determinate rms in the office room and thermally stable and radio isolated conditions.

In the Figure 9 there is the calculated rms of the ADC DT9824 noise in the office room and thermally stable and radio isolated conditions.

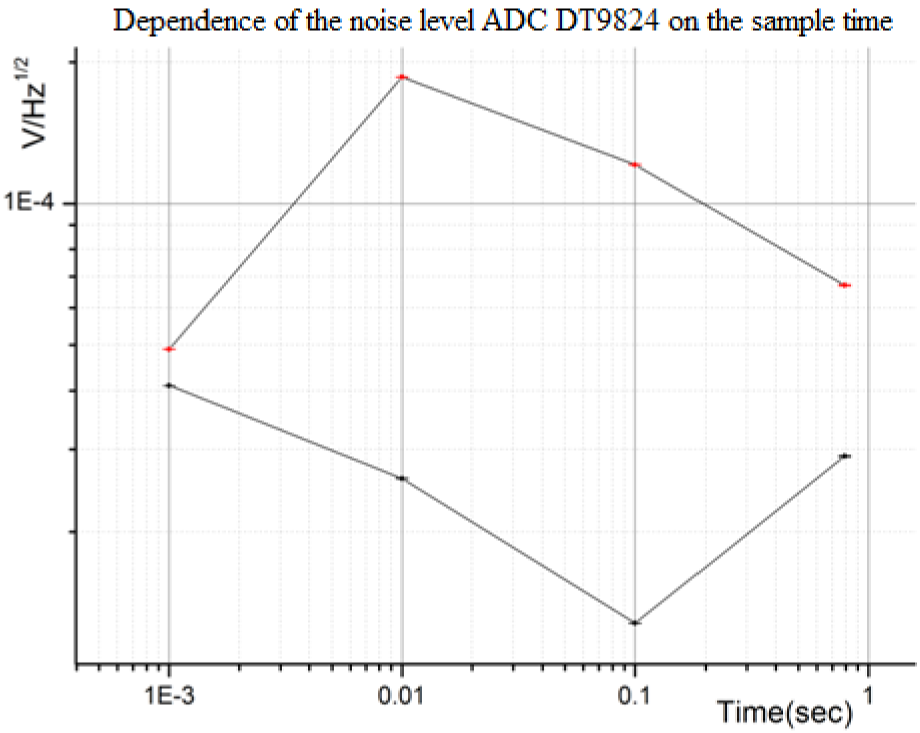

Fig. 9. Comparison of the rms of the daily ADC noise in the different conditions. The rms in depends on sample time.

As it shown in the Figure 9, there are decreasing of the noise difference in conditions of the office room and the laboratory. For ADC DT9824 the usage of laboratory conditions allows to reduce noise using the sample time up to 10^3 Hz.

CONCLUSION

At this work there was experimentally researched the 24-bit ADC DT9824 noise, also there were described the methods of this noise reduction. There were experimentally detected the noise causes which influence to the ADC indications. In the conditions of the office room these causes are both influence of external temperature variations in day/night period and industrial electromagnetic noise. In the conditions of thermally stable and radio isolated laboratory there was found a periodical internal noise, caused by work of the air conditioner which one supports the internal temperature with the daily temperature instability better than 0,01 ºC.

Two methods of noise reduction were offered, which results were as follows:

There was firstly used the method of registration of temperature change in ADC indications. *The innovative point of this method* is subtraction of the indication of the one channel from the indications of the other channels. *After using this method the rms value of ADC relative resolution in frequency range of [10^{-5};10^{-4}] was increased by a factor of 13.*

The second method is using the thermally stable and radio isolated laboratory for reducing the influence of the external temperature changes. Also to isolate the ADC from the influence of the air conditioner there was used the metal box. *Usage of the thermally stable and radio isolated conditions allows to stabilize ADC noise by a factor of 240 in the frequency range of $1{,}25\cdot10^{-5}$ Hz.* It also allows to obtain a resolution of the ADC at the level of $4\cdot10^{-6}$ V/Hz$^{1/2}$. Also we found that usage of laboratory conditions allows to reduce noise using the sample time up to 10^3 Hz.

The limit value of ADC resolution determined with the follows formula:

$$\Delta U_n = \frac{\Delta U}{2^{24}}$$

where ΔU is the maximal value of the registered signal. For the ADC DT9824 this value is equal to: ΔU = 10V - $\Delta U_{n2} = 6 \cdot 10^{-7}$ V.

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