Noise reduction in AD24USB

A differential low noise amplifier with bipolar operational amplifiers is on input of a USB measuring module AD24USB. Noise of any amplifier increases when frequency decreases – there is 1/f noise which limits noise performance for DC measurements. For this reason, high-performance nanovoltmeters use AC modulation (“chopping”) for removing 1/f noise component and achieving the lowest possible noise. The disadvantage of chopper amplifier is greater complexity and longer settling time, so the chopper amplifier is not suitable for applications with multiplexed inputs.

A different approach is used in the AD24USB. A dual switch is in front of the input amplifier that allows input swapping, but output demodulation and filtration are implemented digitally in a microcontroller – the AD24USB takes two input samples for both input polarity and these samples are subtracted. These subtractions are accumulated and averaged with a variable number of samples. The result is the same as with normal chopper amplifier, but this arrangement has several advantages: There is no analogue demodulation and analogue low pass filter. Averaging act as a tunable low pass digital filter, a number of averaged samples can be easily changed and sets total conversion time and resulting noise. Fast input multiplexing is also possible with no delay.

Optimal integrating time of the AD converter for the AC modulation is 20 ms. This integrating time gives modulation frequency approximately 24 Hz. Longer integrating times can be used, but modulation frequency decreases below 10 Hz and 1/f noise increases. When shorter integrating times are used, the resolution of the AD24USB decreases and interference 50 Hz isn't rejected. As mentioned, 1/f noise is eliminated, so total noise is set by the number of averages and can be easily computed from the total conversion time, the peak-peak value of noise u [nV] is given:

$$u = 15\sqrt{t}$$

where t is total conversion time in sec.

The AC modulation - “chopping”- reduces noise and eliminates input offset, but doesn´t reduce another important error source – parasitic thermoelectric voltages at input terminals. The AD24USB has chopped current or voltage source for eliminating these voltages.

The voltage source is suitable for measurements with resistive bridges – a typical example is a strain gauge. The current source is suitable for accurate measurements of small resistors like Pt100 or HALL sensors etc. Signal offset voltages in input wires are eliminated due to modulation of the excitation and total offset is below 10 nV.

AC modulation can be realized only with the differential version of the AD24USB, SE version has no modulation, but its noise is $\sqrt{2}$ times lower thanks to a simpler input amplifier. If even lower noise levels are required, custom modifications of input amplifier are possible and noise can be up to two times reduced, for more information contact manufacturer.

Values of the noise of the AD24USB without modulation and with both types of modulation were measured and are presented. Measurements were realized with program AD24control which is supplied with the AD24USB. Total measured time was 30 s. Measured data shows that noise without modulation is 210 nVpp for integrating time 320 ms - fig. 1. When AC modulation is used with the same measurement period, noise is reduced to 30-33 nVpp, (7.1-7.3 nVef) see fig.2-3. Also notice that when output modulation is used, the input offset is reduced from 613nV to 1.6nV. Fig 4 shows that when measurement time is increased to 1 s, noise is reduced to 13 nVpp (3 nVef). Fig. 5 and 6 show noise on ranges +-49 a 128 mV. Warning! Due to stochastic nature of noise, peak to peak values of noise can vary significantly with variance up tens of percent! Effective values are more repeatable.

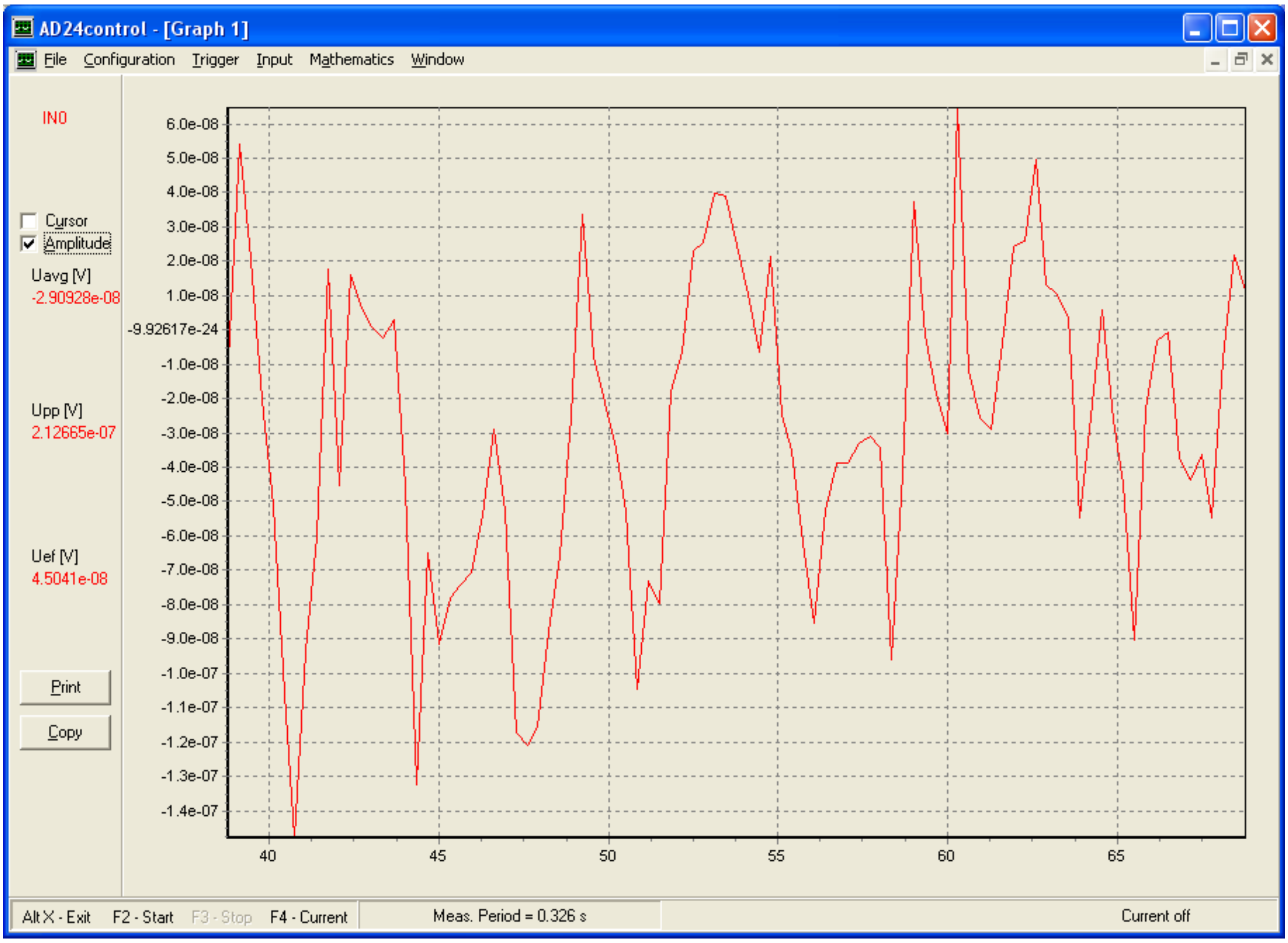
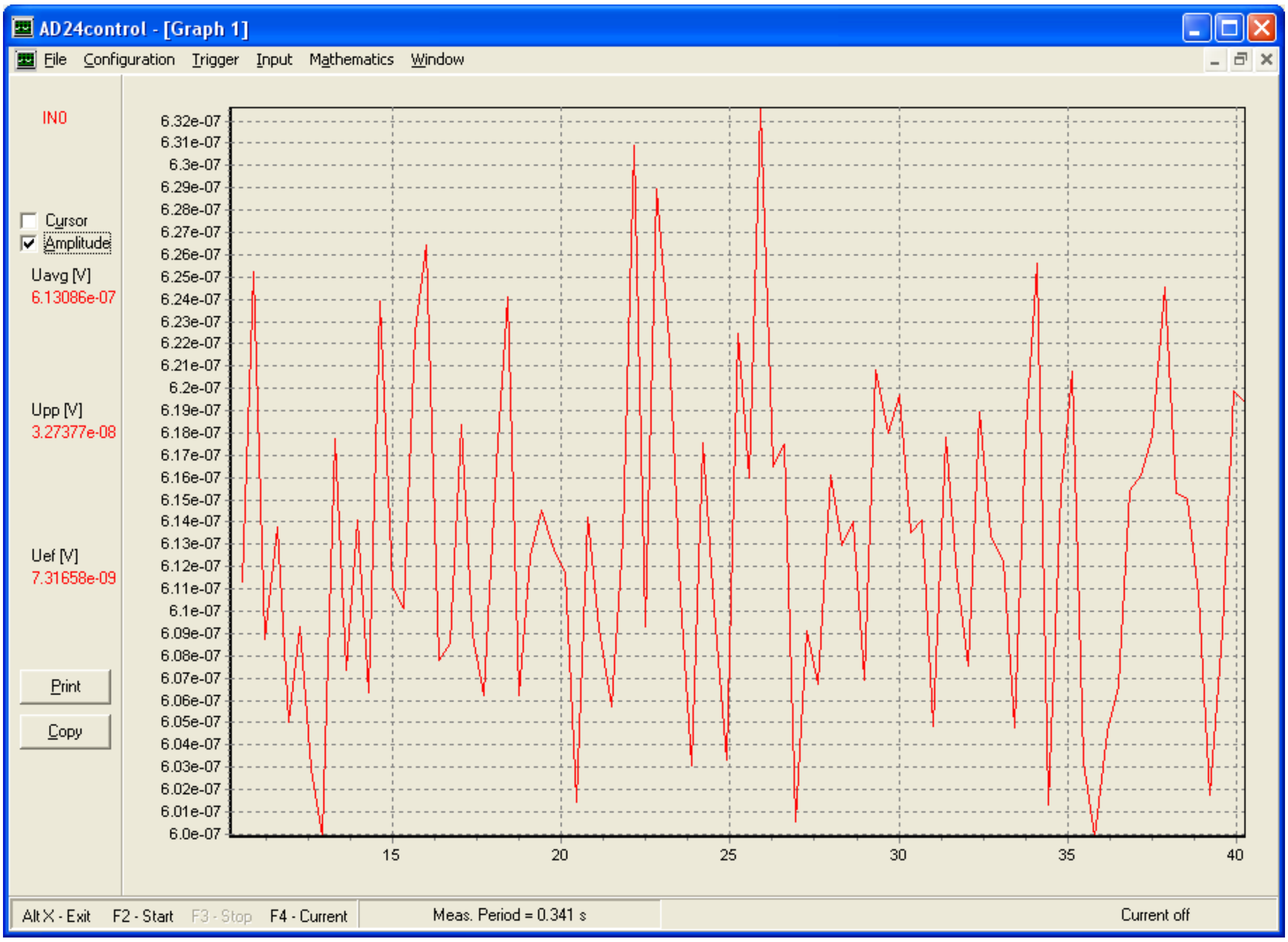
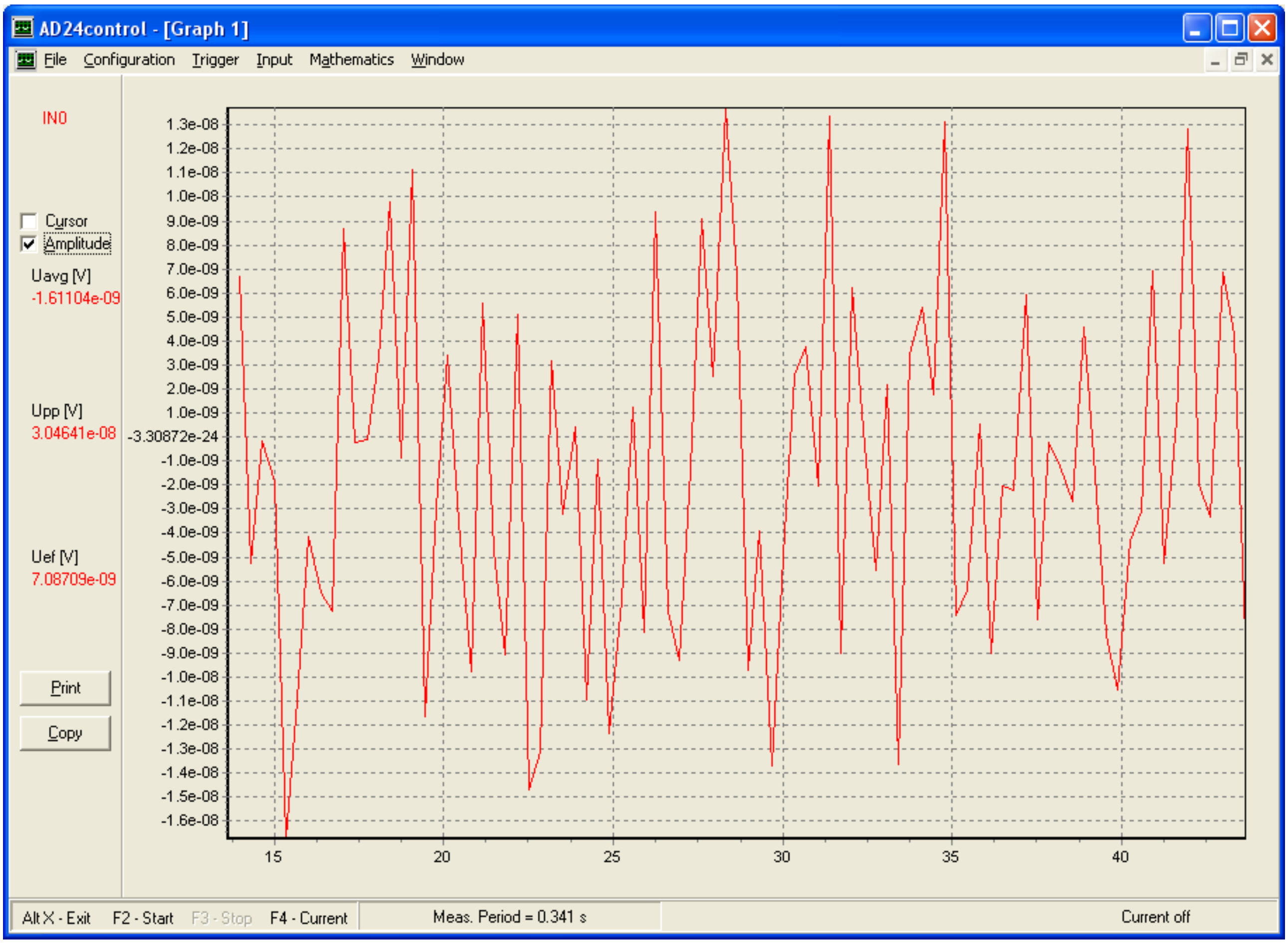


Fig 1. AD24USB noise without modulation for Tint 320 ms, range +-10 mV



Obr. 2. Noise with input AC modulation 16 x 20 ms, range +-10 mV



Obr. 3. Noise with output AC modulation 16 x 20 ms, range +-10 mV

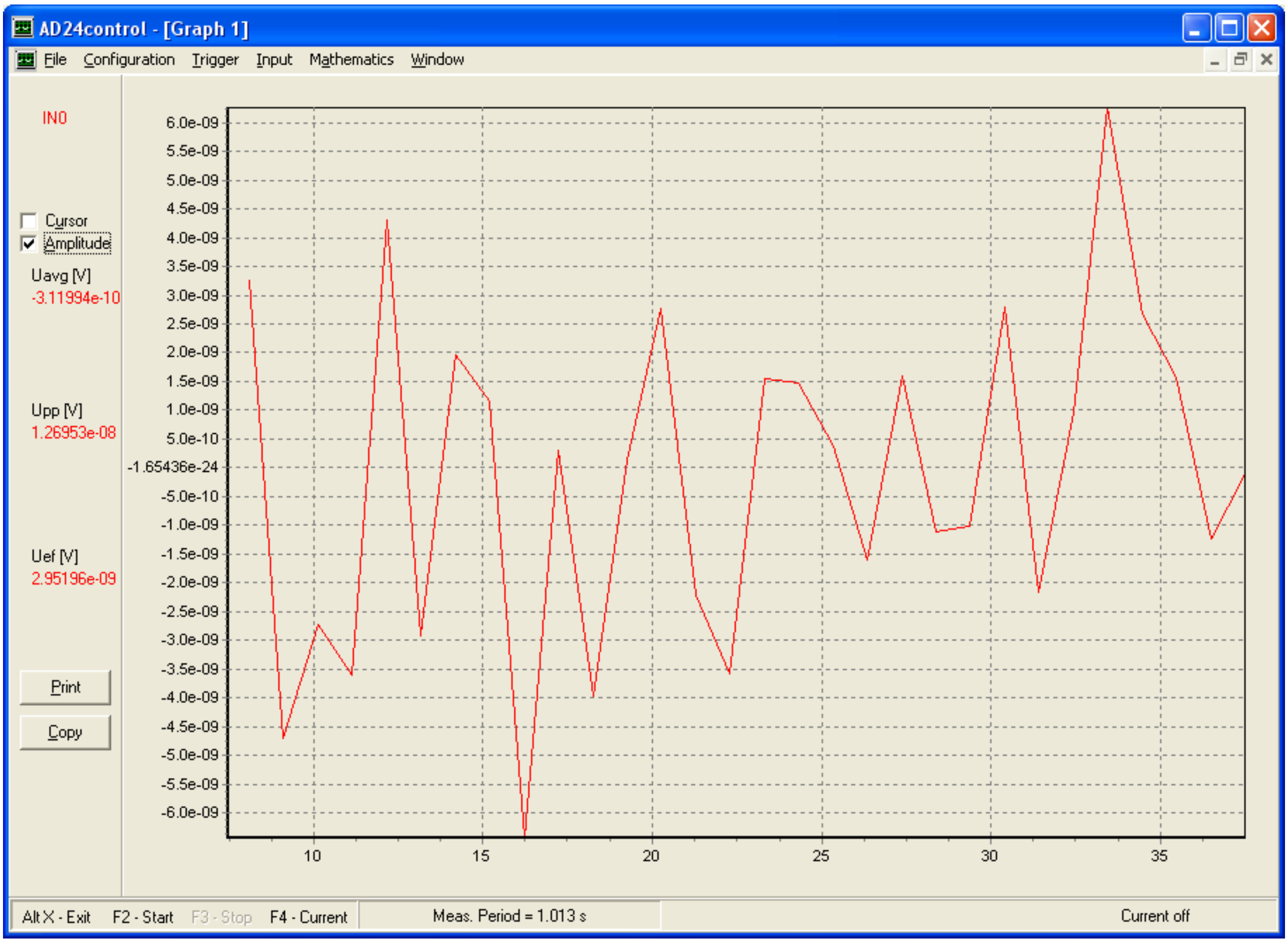


Fig. 4. Noise with output AC modulation 48 x 20 ms, range +-10 mV

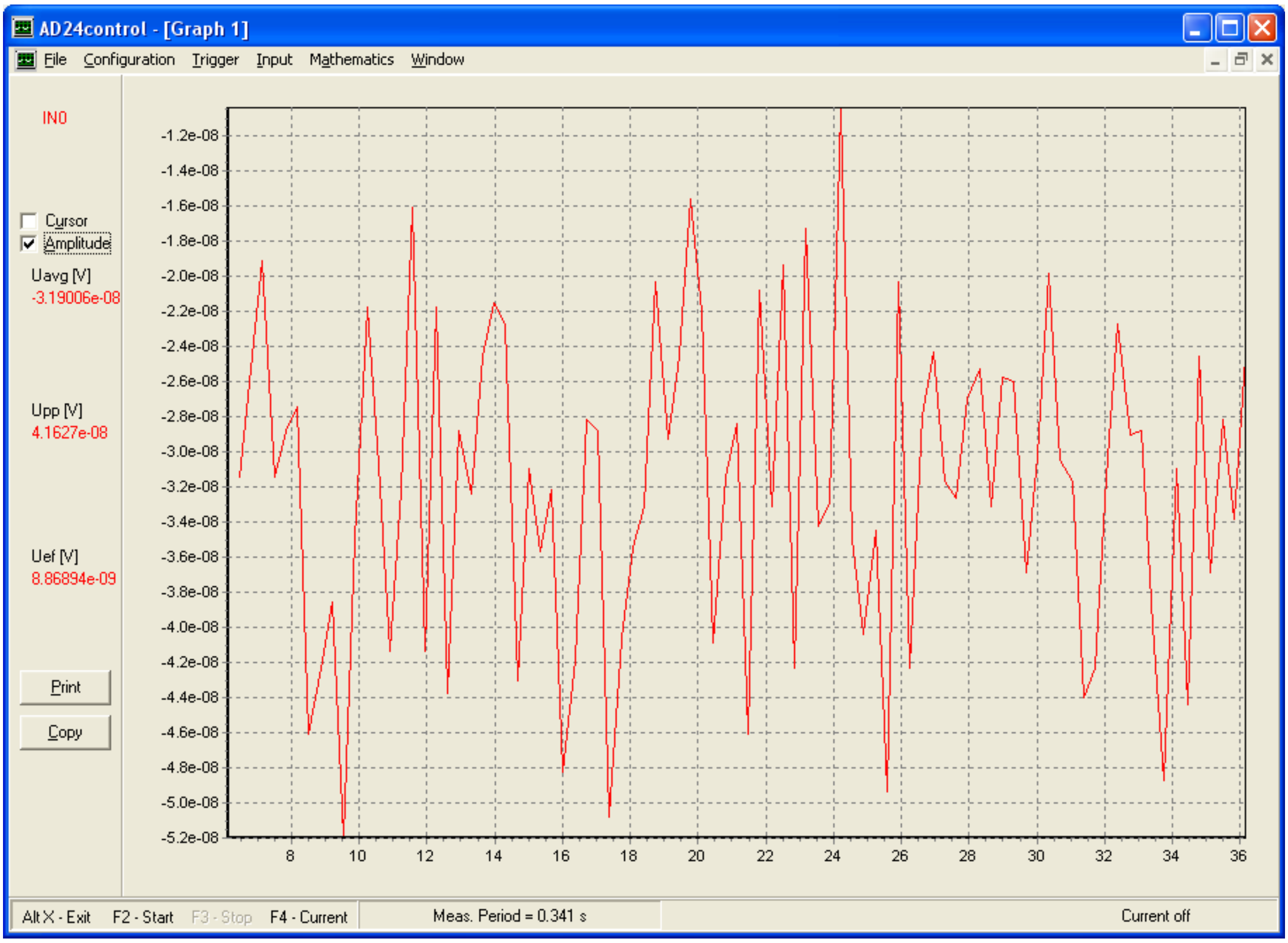


Fig. 5. Noise with output AC modulation 16 x 20 ms, range +-49 mV

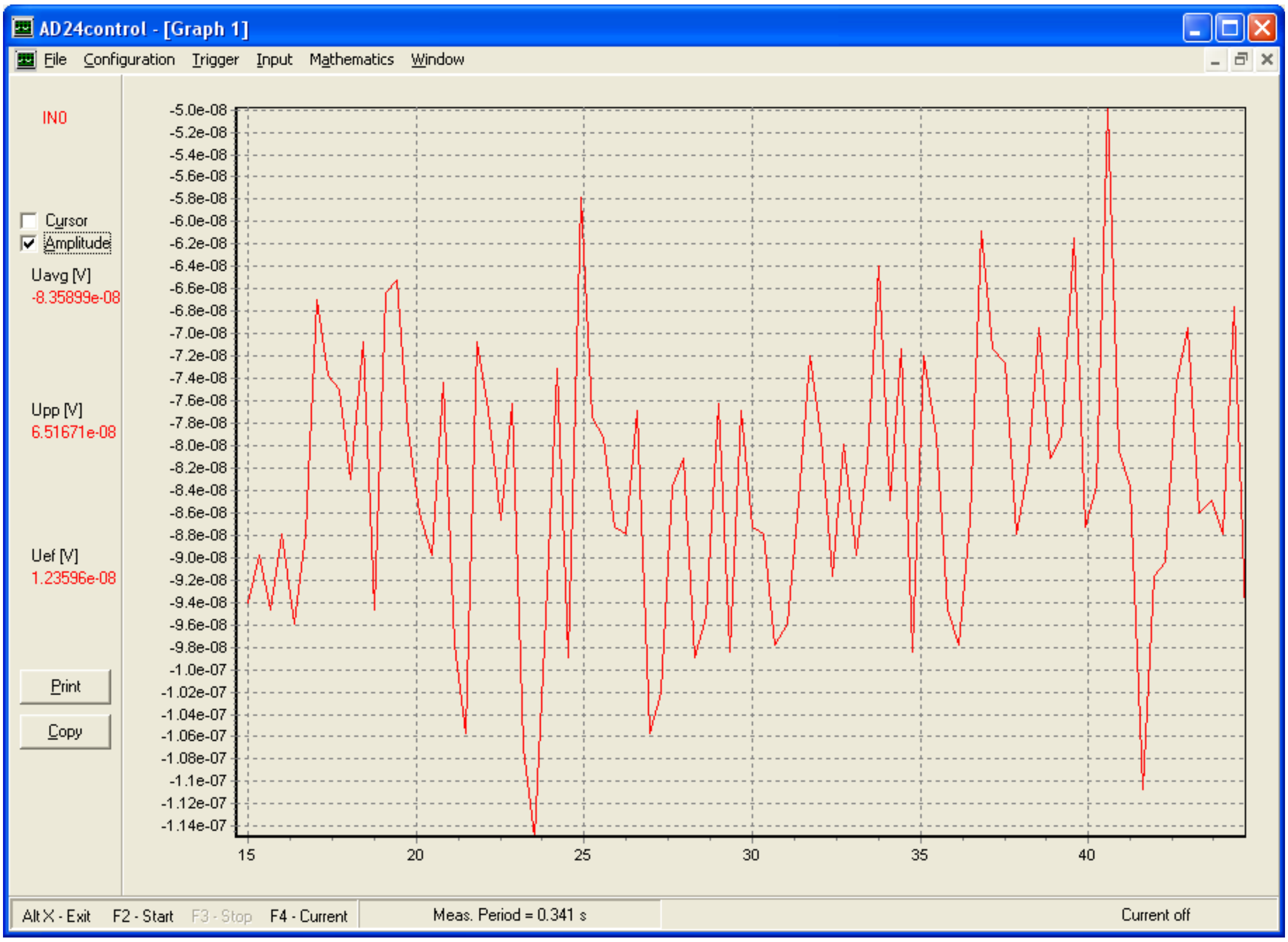


Fig. 6. Noise with output AC modulation 16 x 20 ms, range +-128 mV

Fig.7 shows noise of temperature measurement with Pt100. Pt100 was replaced by the stable resistor 200 Ohm, excitation current was 0.5 mA with output modulation enabled. The graph shows that noise is 0.00028 °Cpp or 0.00005 °Cef. Warning! It is achievable resolution, not accuracy! Accuracy is given mainly by the sensor itself.

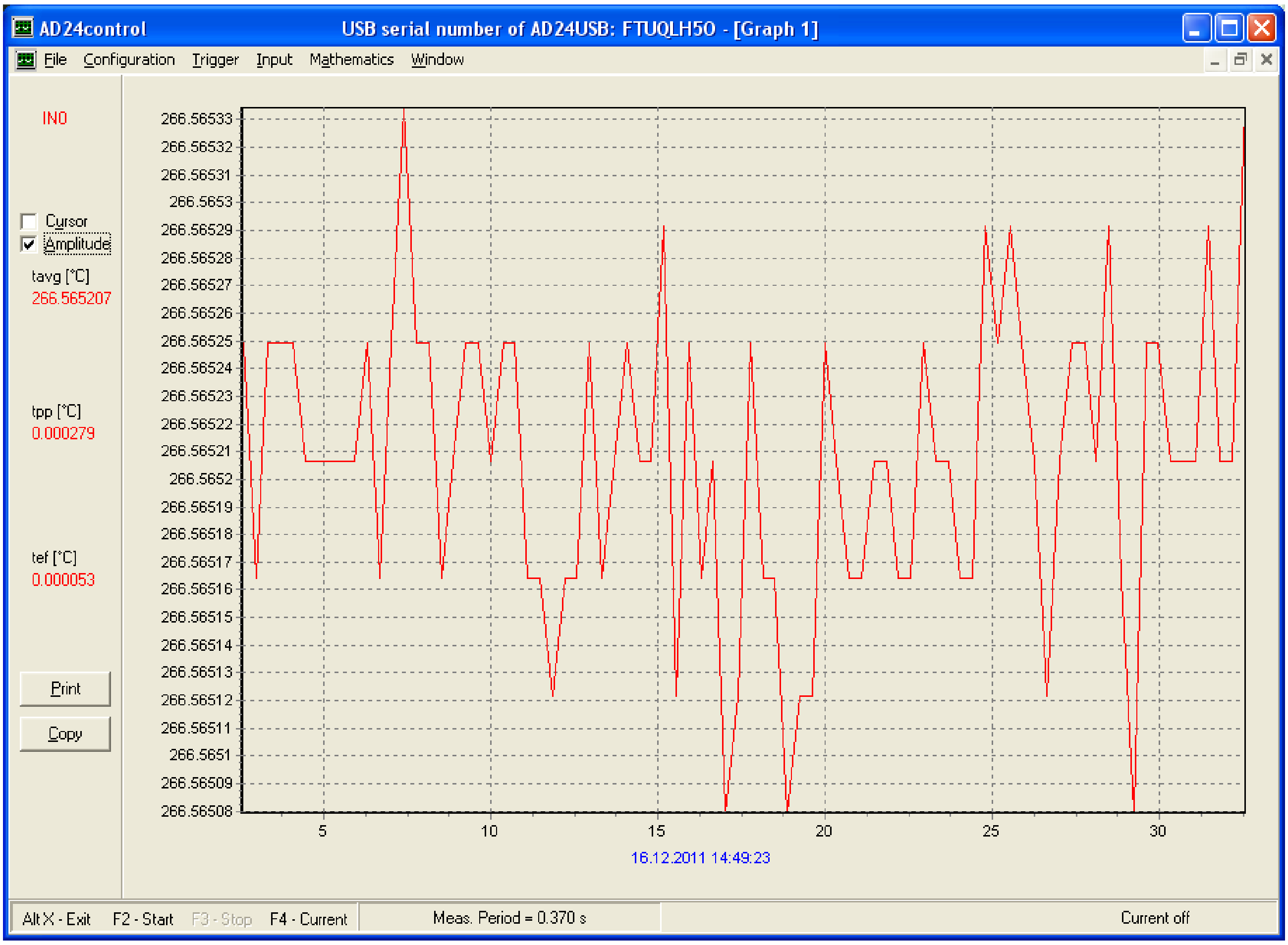


Fig. 7. Noise of temperature measurement with output AC modulation