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TD-11-***

Evaluation of the National Instruments Dynamic Signal Acquisition Module PXI-4462

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Outline

1 Introduction

Most test stands at Magnet Test Facility (MTF) utilize old hardware instrumentation and old software based on the CHISOX system. Created more than a decade ago, the CHISOX system now is nearly unsupportable and has become a limiting factor for the further upgrade or improvement of test stands. CHISOX replacement project was launched recently at Technical Division. Several hardware upgrade projects were also initiated in parallel, for example to design and build new signal conditioner device and signal integrator for magnetic measurements. Evaluation of Dynamic Signal Acquisition (DSA) devices is a part of the hardware upgrade at MTF.

The National Instruments (NI) data acquisition modules are widely used at Fermilab because of a very convenient hardware and software support they provide. A unified platform of the NI modules allows expansion of the existed test setup with minimal expenses. Search for new hardware was started with ADC based DSA devices. The NI PXI-4462 DSA module was selected for further investigation based on characteristics provided by manufacturer.

Main goal of an evaluation test is to verify most important parameters of the DSA module, like stability and linearity of the output signal. Based on the test results we will decide if PXI-4462 is good for future magnetic measurement systems. Hardware requirements are mostly defined by different type of measurements performed at test stands.

ADC should satisfy requirements listed below:

- Easy reading interface
- High precision of measurement
- High frequency of measurement
- Stability to environmental factors such as temperature change and magnetic field

1.1 ADC NI PXI 4462 description

NI PXI-4462 is a high-accuracy data acquisition module specifically designed for sound and vibration applications. This module includes the hardware and software needed to make precision measurements with microphones, accelerometers, and other transducers that have very large dynamic ranges. ADC developed for NI PXI crate, compatible with hybrid or PXIe (express) slots.

Basic parameters are listed below:

ADC resolution:	24bit
Form Factor	PXI Platform
Sample Rate	204.8 kS/s
Max Voltage Range	-42.4 V, 42.4 V
Max Voltage Range Sensitivity	5.05 µV
Min Voltage Range	-316 mV, 316 mV
Min Voltage Range Sensitivity	37.7 nV
Gain range	-20dB, 30dB
On-Board Memory	2047 samples

Detail specification on NI website http://www.ni.com/pdf/manuals/372125e.pdf

2 Evaluation test

2.1 Experimental setup

Experimental setup is based on the NI modules in PXIe format. For DSA evaluation tests we used several electronics devices:

- PXI crate NI PXIe-1082
- Digital multimeter Agilent 3458A
- Waveform generator Agilent 33120A
- Voltage calibrator DVC 8500
- Temperature Logger NI PXI 4351
- Terminal Block for Thermocouples TBX-68T
- RTD pt-102

2.2 Software

Software was developed within the LabView frame. Following packages and drivers were used:

- NI Labview 10 (2010)
- NI DAQmx device drivers
- NI DAQ traditional drivers

2.3 Test plan

DSA module evaluation test included:

1. Offset stability test
2. Linearity & resolution test
3. AC test
4. Crosstalk between channels
5. Temperature influence
6. Warming up test
7. Short time drift test

All tests made after calibration routine.

2.4 Test results PXI-4462

2.4.1 Offset stability test

Goal of this test is to investigate the output offset and its deviation from the average estimated during the long time period of data taking.

Test conditions.

- Test duration – 12 hours
- Sampling rate – 1 kHz, 2 kHz, 5 kHz, 50 kHz
- Taking data – each 0.5s per 30s

Output data

- Flow of raw signals
- Histogram count of events per voltage
- FFT from raw signals
- PSD from raw signals
- Histogram of PSD

All experimental data collected in ASCII files at one directory. User set directory by himself.

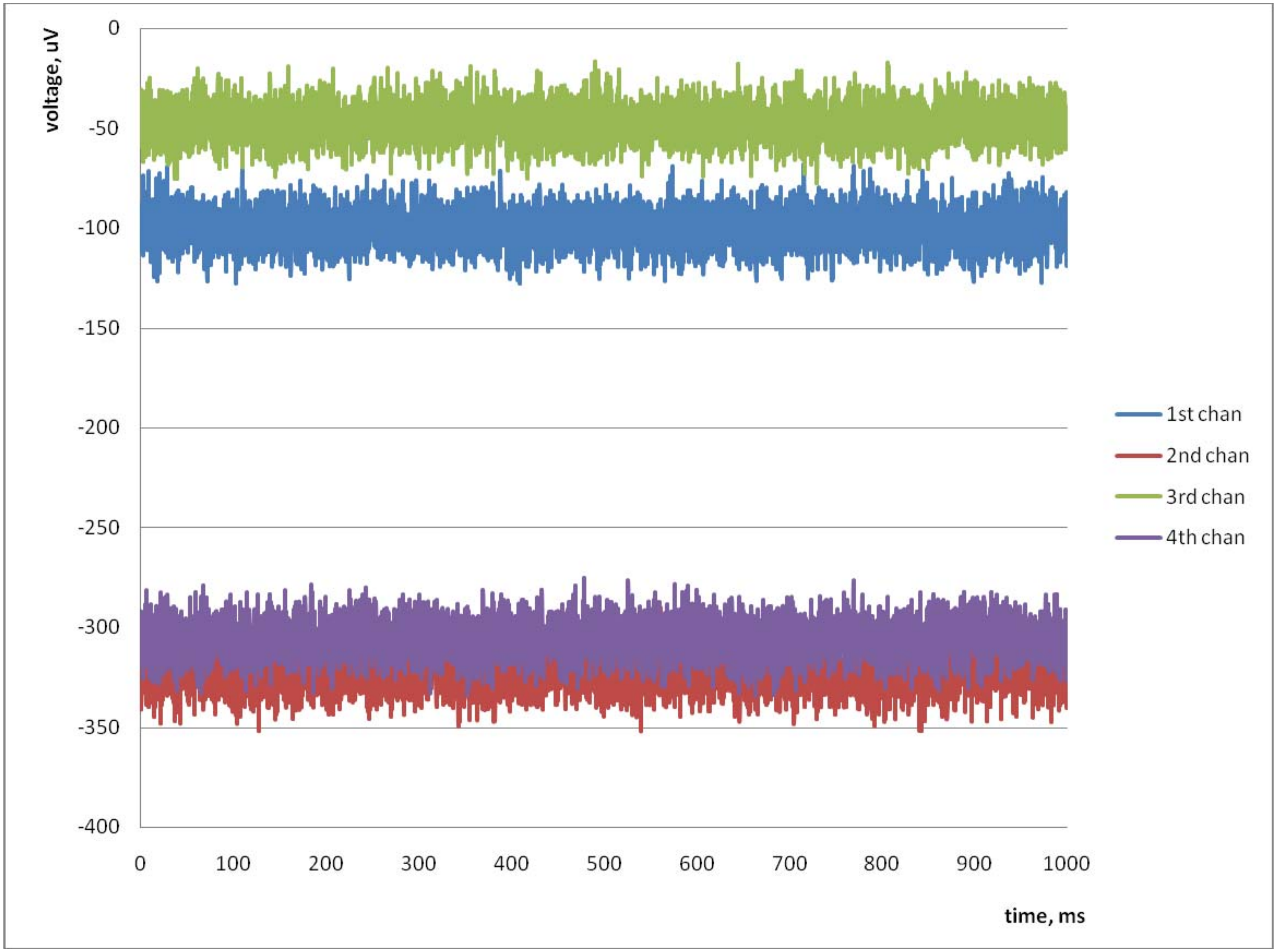

Figure 1. Flow of raw signals (50k samples, shot pulses 10ohm)

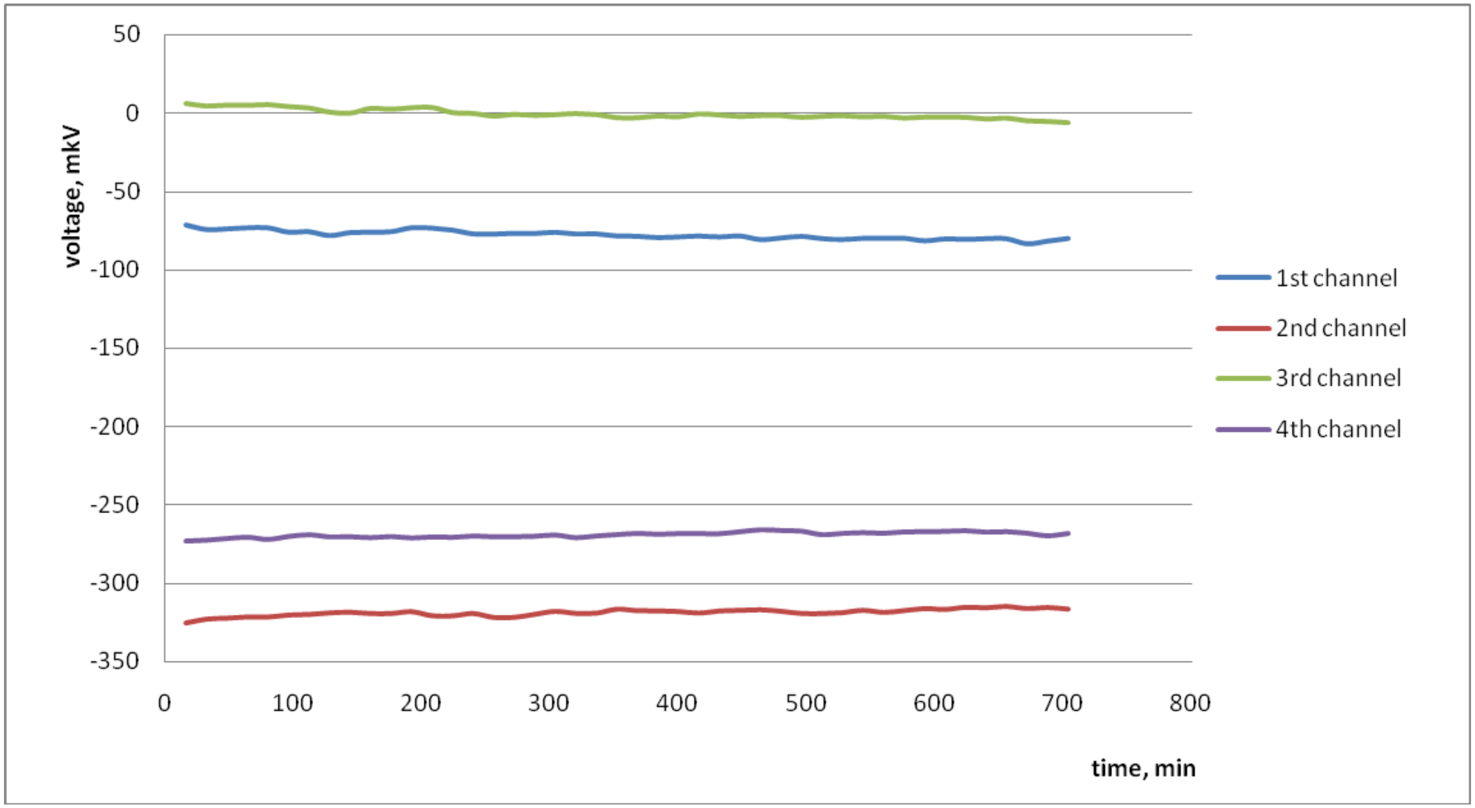

Figure 2. Flow of raw signals (50k samples, shot pulses 10ohm) 12 hour set

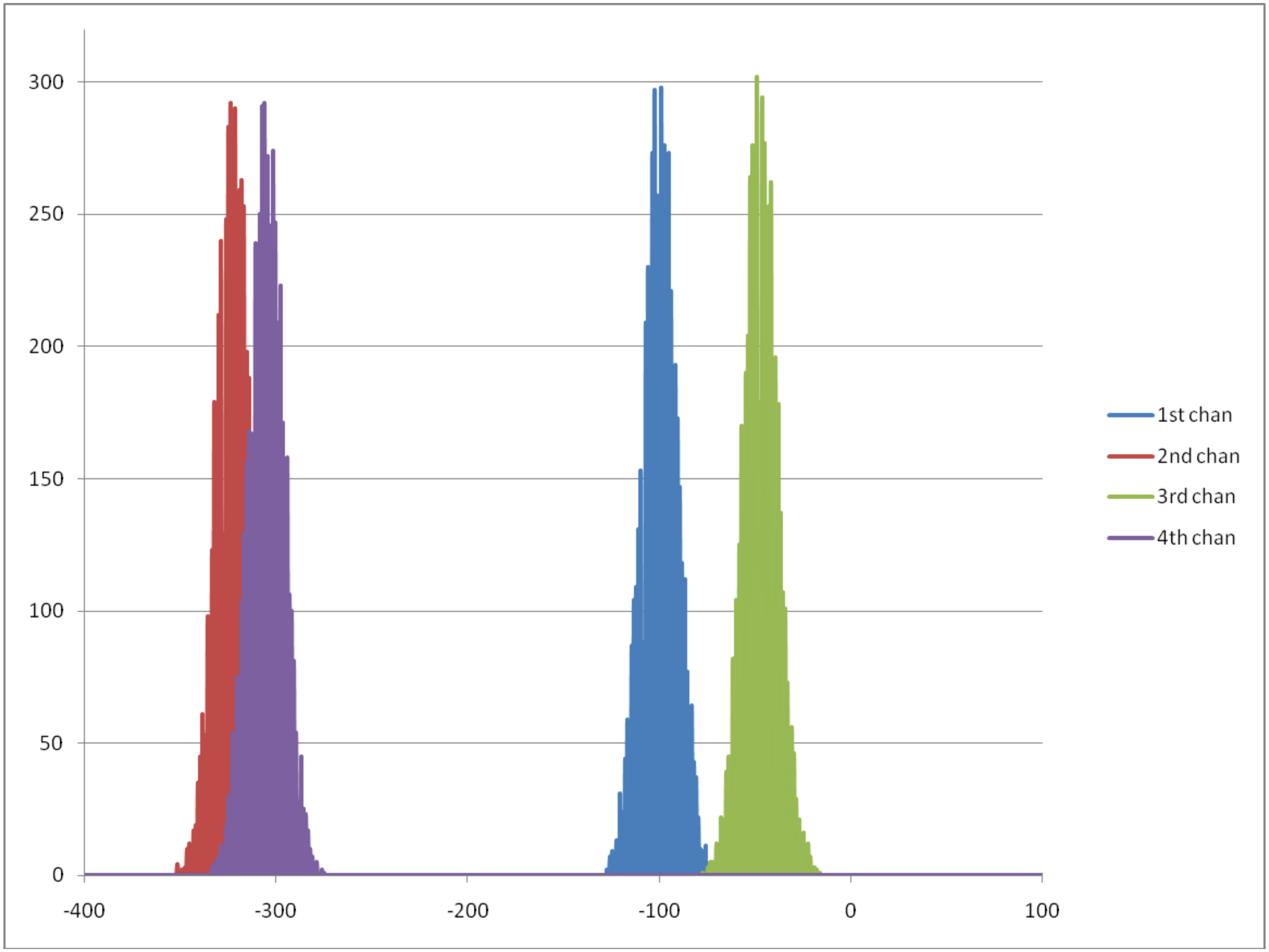

Figure 3. Histogram count of events per voltage (50k samples, shot pulses 10ohm).

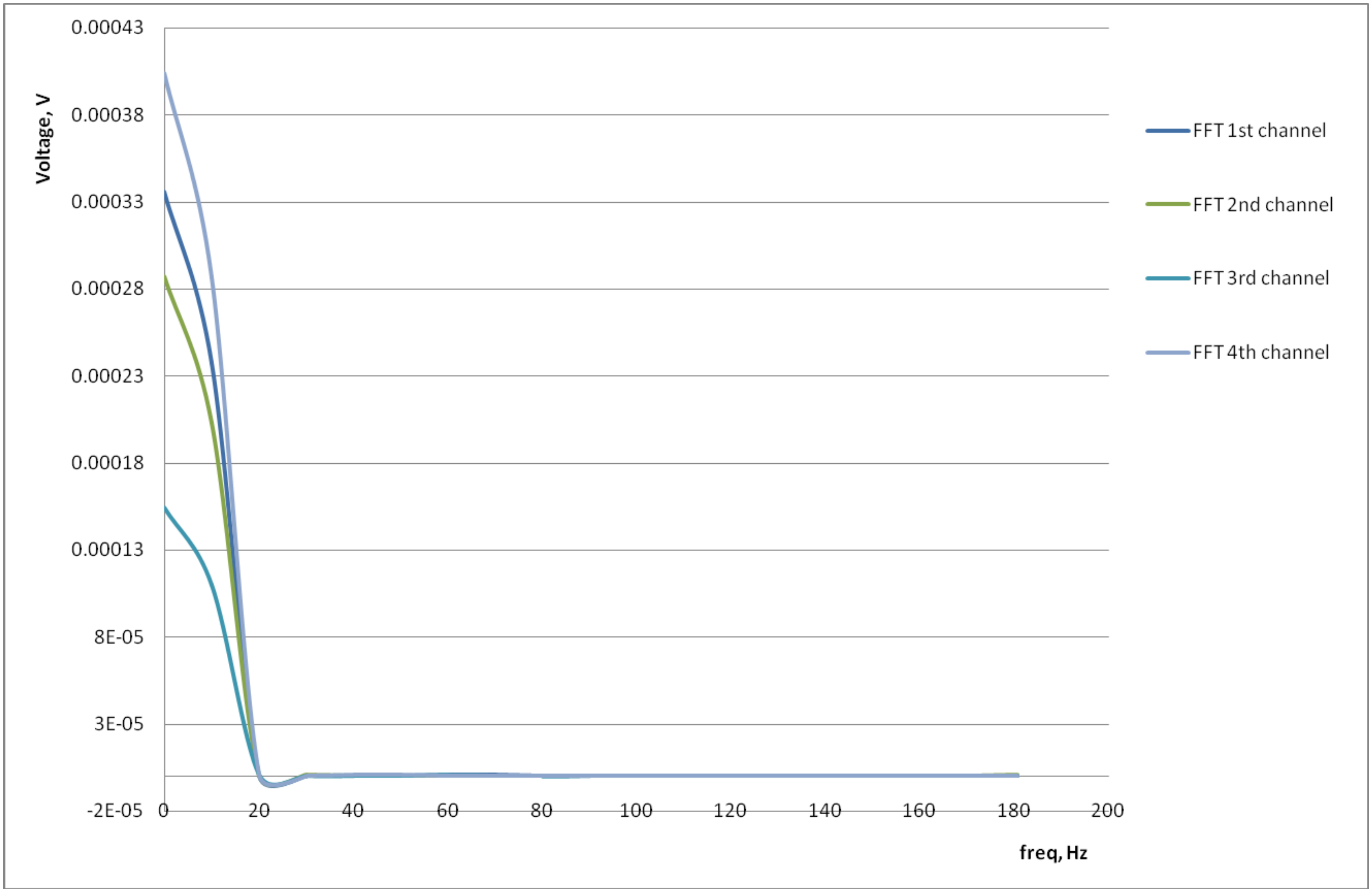

Figure 4. FFT from raw signals (50k samples, shot pulses 10ohm)

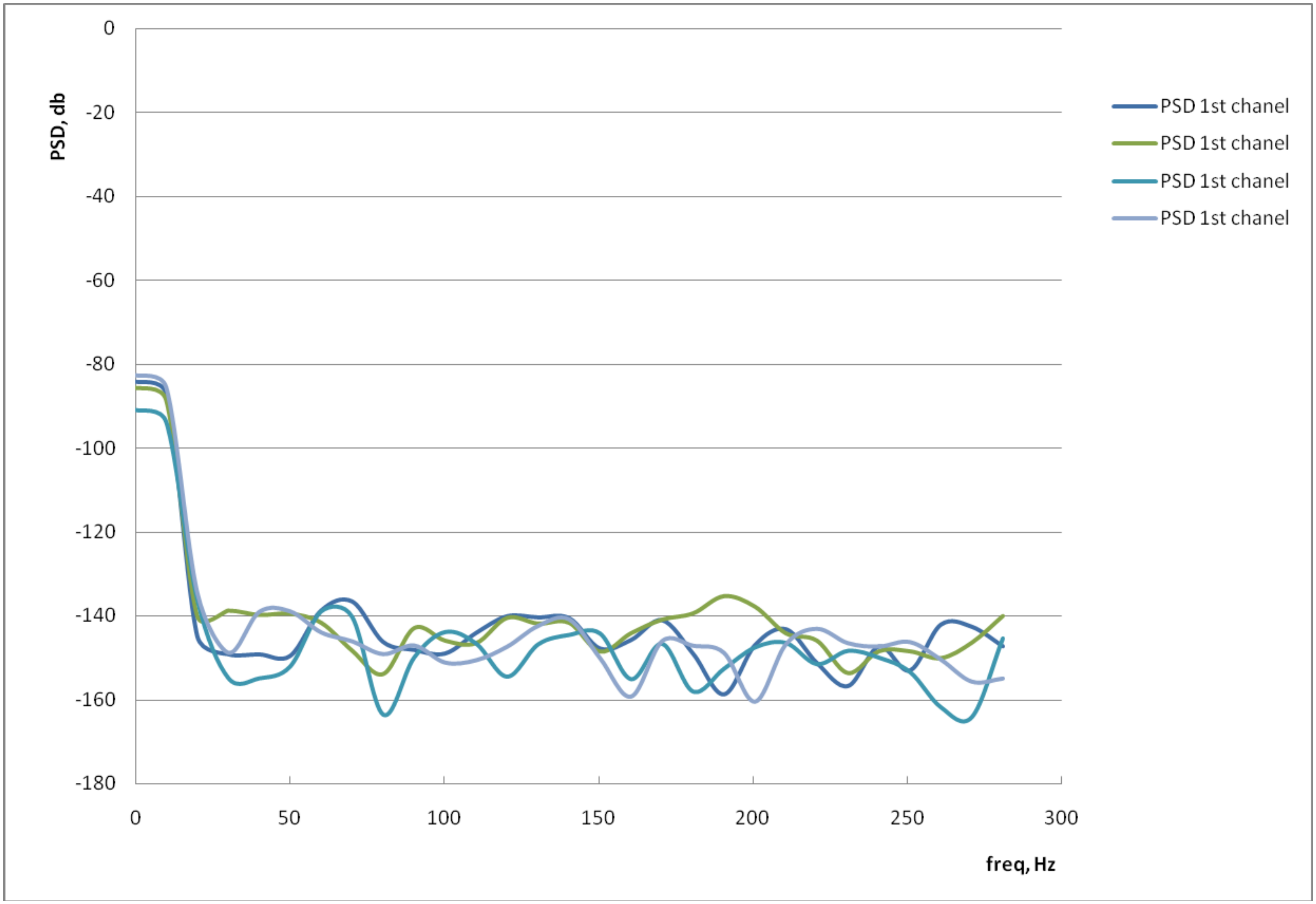

Figure 5. PSD from raw signals (50k samples, shot pulses 10ohm)

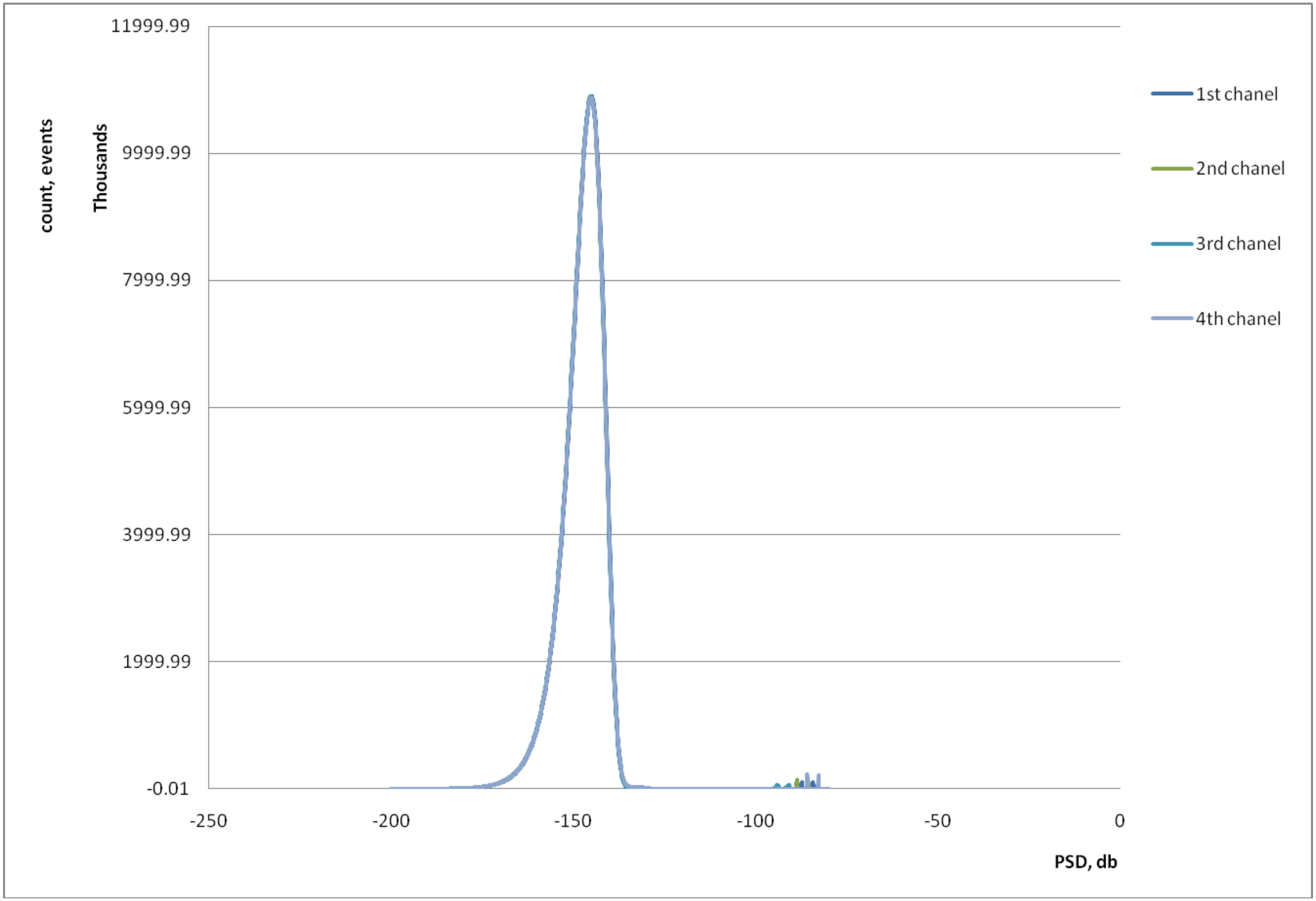

Figure 6. Histogram of PSD (50k samples, shot pulses 10ohm)

Offset stability test summary, voltage in µV

	mean				variance			
	1k	2k	5k	50k	1k	2k	5k	50k
1st chan	- 90.913	- 93.029	- 77.8719	- 100.259	4.63	5.09	4.71	9.38
2nd chan	- 306.371	- 305.486	- 318.936	- 330.807	3.8	4.36	4.19	9.76
3rd chan	- 22.756	-33.985	- 7.643	- 51.027	4.01	5.57	4.72	9.49
4th chan	- 476.833	- 432.124	- 268.891	- 306.975	2.89	3.22	4.01	9.33

Table 1. Offset stability test. Voltage and variance

2.4.2 Linearity and resolution test.

This test shows linearity of DSA output with linear increase of input signal. We used Voltage Calibrator DVC 8500 as a voltage source and DVM Agilent 3458A for precise voltage measurement.

Test description:

We put voltage on one of the channels and see it value after ADC proceeds. It consists of 100 steps in each voltage range (ADC have 6 ranges).

- 30 db ±0.316 V
- 20 db ±1.00 V
- 10 db ±3.16 V
- 0 db ±10.0 V
- –10 db ±31.6 V
- –20 db ±42.4 V

Test was done for gains 0, 10, 20, 30, because voltage source range was only ±20V.

Try -10 and -20 db and check linearity for +/- 20 V range.

Plots:

1st channel ADC. 0db gain.

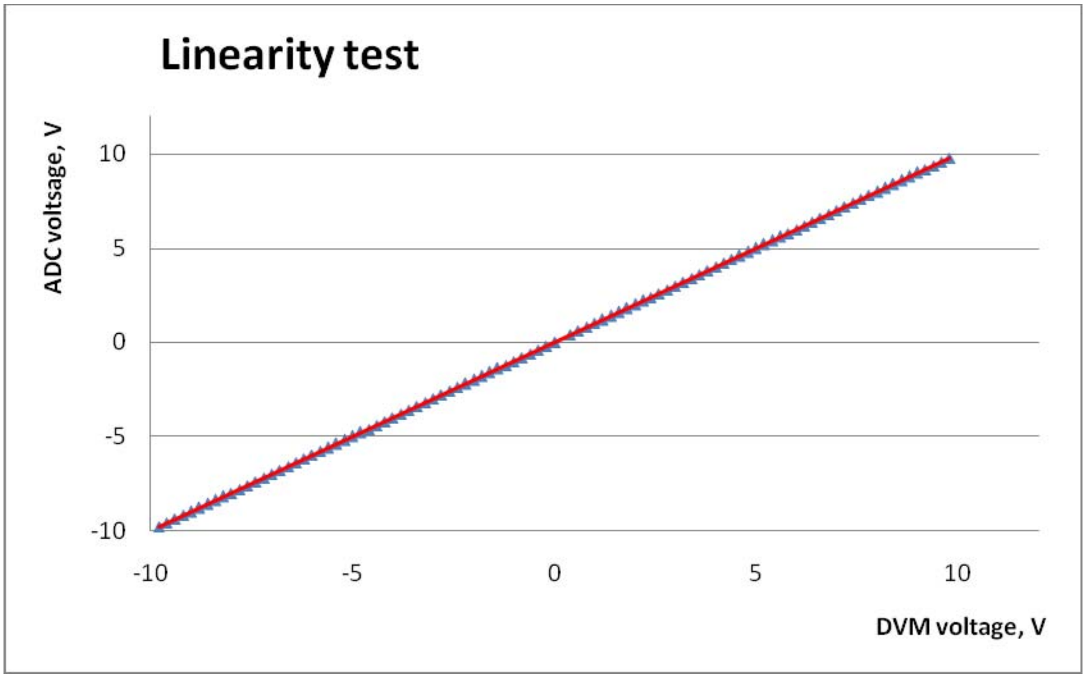

Figure 7. Linear plot, 1st channel, 0db gain

Linear fit y=0.998951*x - 0.000068

Deviation from linearity 0.000145

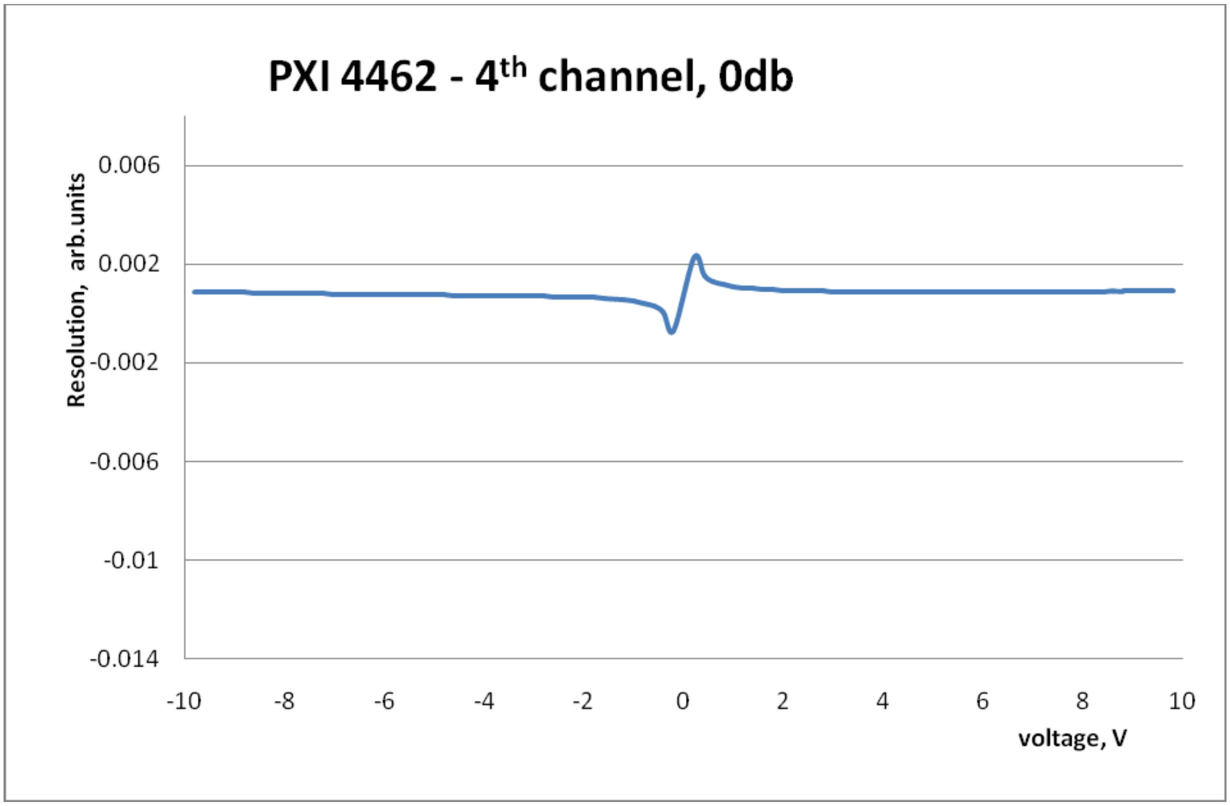

Figure 8. Resolution plot, 1st channel, 0db gain

Data:

Line fit $Y = a \cdot X + b$

		Linear fit				Deviation from linearity			
gain		0db	10db	20db	30db	0db	10db	20db	30db
1st channel	Slope	0.998951	0.998918	0.850419	0.999000	0.000145	0.000044	0.150336	0.000005
	Intercept	0.000068	0.000091	0.015539	0.000083				
2nd channel	Slope	0.998985	0.999034	0.999100	0.999060	0.000143	0.000044	0.000002	0.000005
	Intercept	0.000186	0.000063	0.000043	0.000035				
3rd channel	Slope	0.999190	0.999192	0.998678	0.999180	0.000757	0.000048	0.000466	0.000005
	Intercept	0.000038	0.000029	0.000015	0.000020				
4th channel	Slope	0.999511	0.999345	0.999127	0.999332	0.011404	0.000044	0.000734	0.000005
	Intercept	0.001984	0.000113	0.000052	0.000008				

Table 2. Linear test, slopes and …

Summary:

In all dynamic ranges output voltage was pretty close to source, which confirms by linear fits of data. Also deviation from linearity is small, which shows good linear characteristics of ADC.

2.4.3 AC test

This test shows how ADC distorts sine function from source state. We used sine function wave generated by the LabView because of problems with voltage generator reading through GPIB interface.

Test description:

We put sine signal on one of ADC channel. We compare output signal from ADC and signal with same parameters (freq, amplitude) generated by LabView. By this data software estimate mean of deviation, rms and variations.

Data:

	Mean			deviation			RMS		
freq.	***5Hz***	***10Hz***	***20Hz***	***5Hz***	***10Hz***	***20Hz***	***5Hz***	***10Hz***	***20Hz***
1st Channel	179	183	161	0.033246	0.007993	0.008579	0.033163	0.007975	0.008558
2nd Channel	297	298	299	0.070946	0.063371	0.054433	0.070769	0.063213	0.054298
3rd Channel	491	270	300	0.040492	0. 011497	0.054544	0.040393	0.011468	0.054407
4th Channel	705	426	429	0.069558	0.039142	0.057840	0.069387	0.039046	0.057697

Table 3. AC test data summary.

Resume:

In all dynamic ranges output voltage was pretty close to source, which confirms by linear fits of data. Also deviation from linearity is small, which shows good linear characteristics of ADC.

2.4.4 Crosstalk between channels.

This test shows influence of AC current on adjacent channels.

Test description:

We put AC voltage on one of the channels and take date from others. We will see dependence in measurement (or independence) by set input on one of channel. We use Agilent 33120A AC generator for this test. Input was

- 10 V ~AC
- 50 Hz

We receive 12 hours set of data by put AC voltage on each channel with four different sampling rates. Data type was same as in “offset stability test”.

Data:

	mean				variance			
	1k	2k	5k	50k	1k	2k	5k	50k
1st chan	- 92.752	- 95.589	- 79.863	- 102.358	4.8	5.15	5.52	9.33
2nd chan	- 298.556	- 301.896	- 315.562	- 329.681	3.97	4.6	4.8	9.82
3rd chan	- 23.125	-35.568	- 8.657	- 52.173	4.05	6.01	6.12	9.64

4th chan	- 477.904	- 435.125	- 266.85	- 304.569	2.71	3.35	4.12	9.35

Table 4. Crosstalk test, mean and variance.

Summary:

After proceed date we got result staying to close with offset stability test. That's mean ADC do not have big influence from one channel to another by getting 10V AC on one of channel.

2.4.5 Warming up test

This test verifies DSA output change after long time period of cooling.

Test description:

We turn off ADC for period of time, and after that turn on and read data from all channels during 30 minutes.

Data:

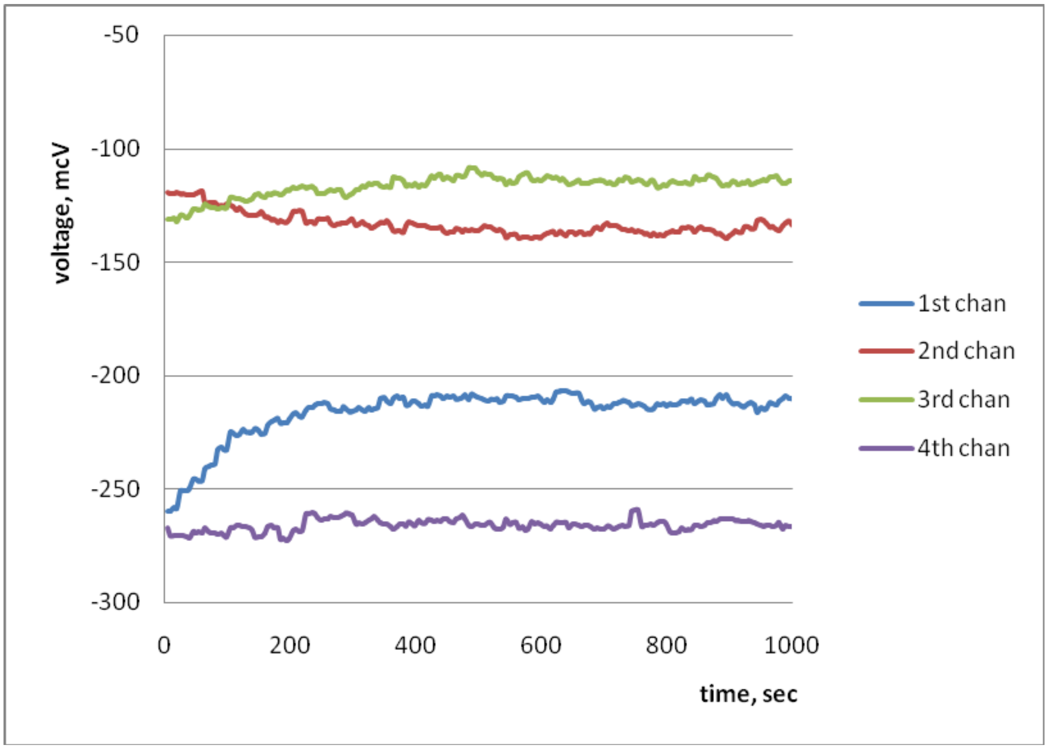

Figure 9. Warming up after 1hr cooling.

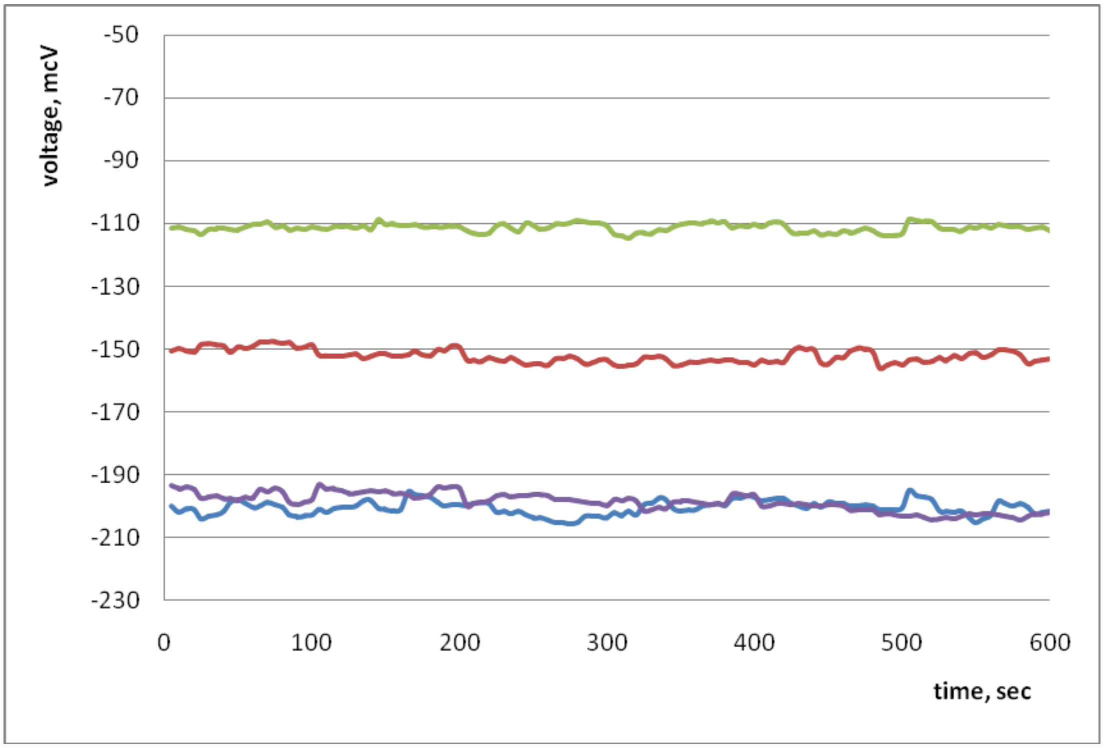

Figure 10. Warming up after 0.5hr cooling.

Summary:

As you can see, there is no such influence after half hour cooling. We observe influence after 1 hour cooling, but it was only by 3 minutes. It's ok for making any tests.

2.4.6 Temperature measurement

By this test we want to see work stability of ADC during long period of time. And it need to determine how temperature changes influence on ADC work.

Test description:

Test goes in same way like a offset stability test, but here we also measure temperature inside crate. We used standard RTD connected to crate by TBX-68T terminal block.

Data:

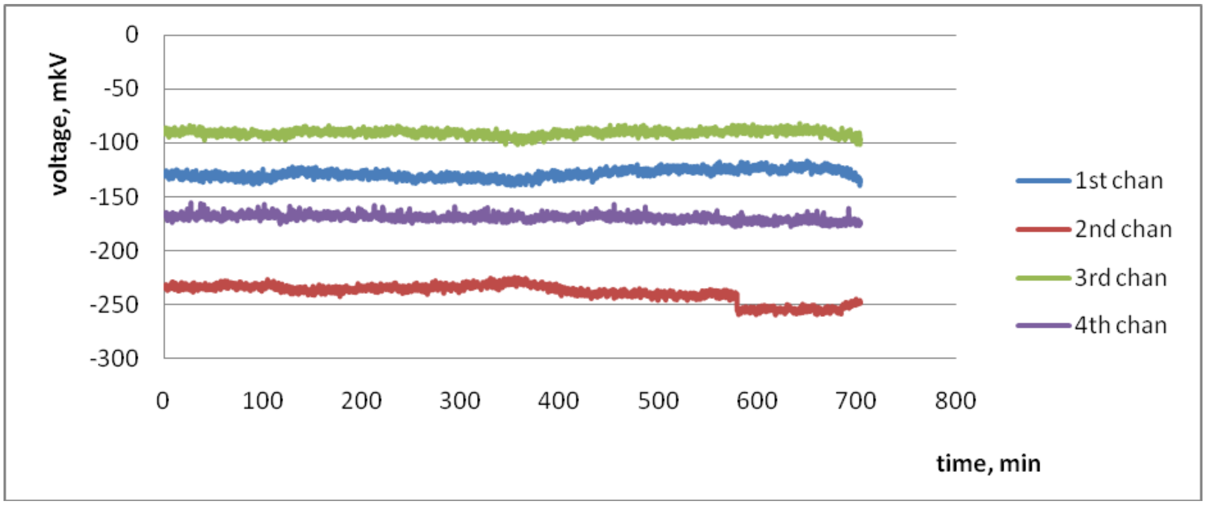

Figure 11. Voltage measurement on temperature dependence test.

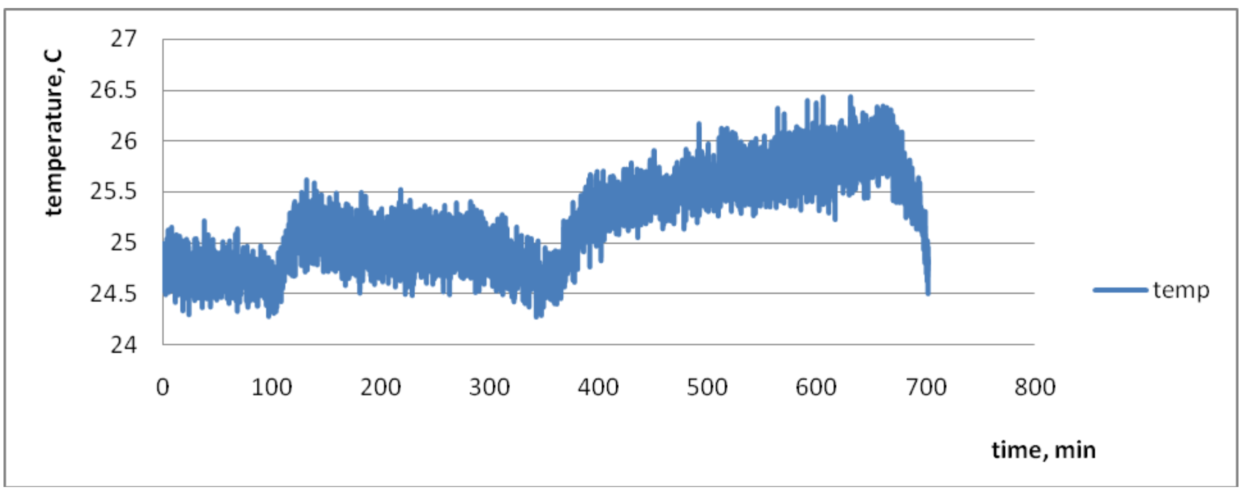

Figure 12. Temperature measurement on temperature dependence test.

You can see, what temperature drift from 24 to 26 C, but it's not influence on ADC reading.

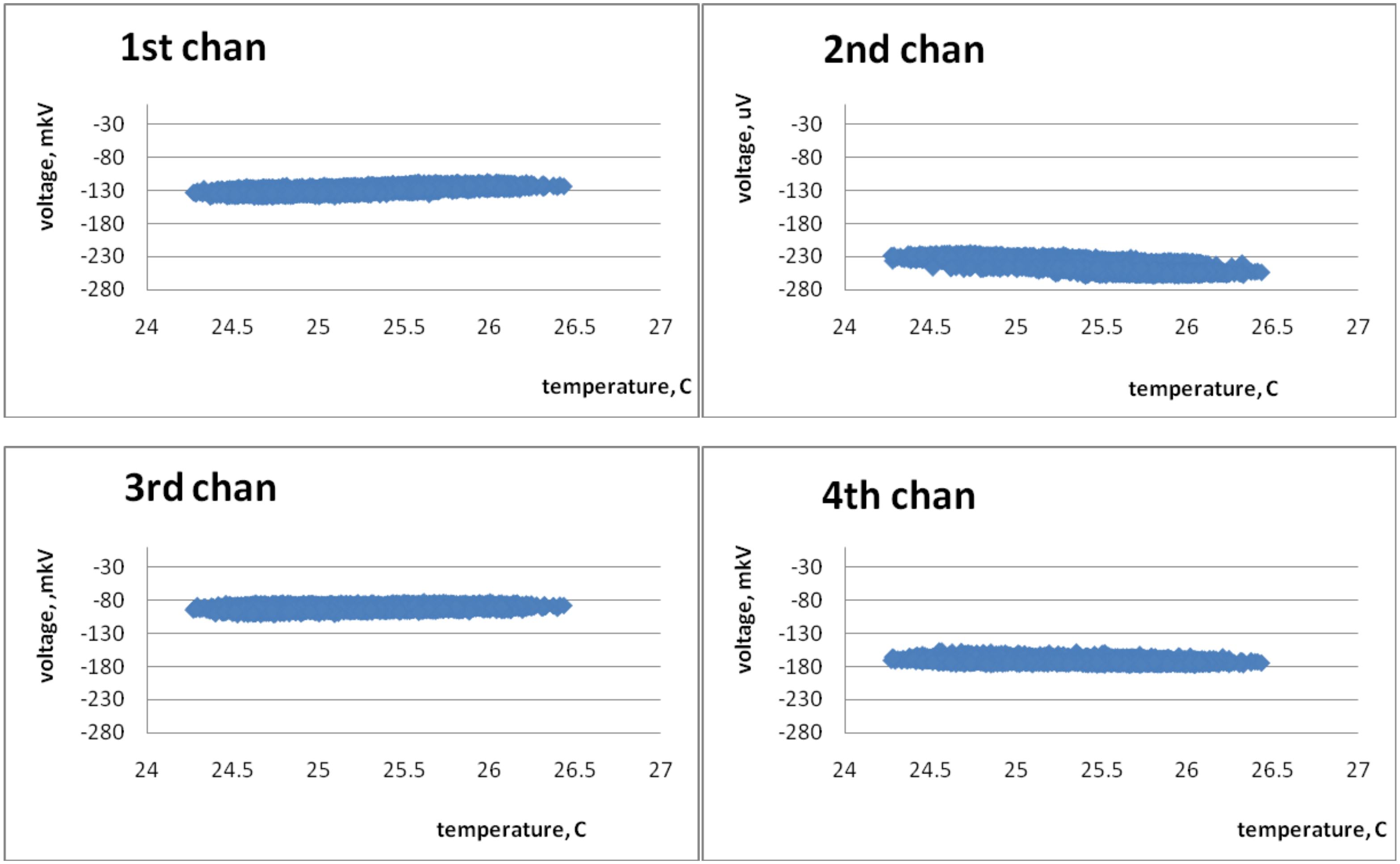

Figure 13. Dependence of voltage floating on temperature.

These plots show dependence "voltage on temperature" by each channel of ADC. Also we didn't observe any relation between these parameters. You can see some fall on 2^{nd} channel, but it stay in range of allow error.

Resume:

Test didn’t show any influence of ADC reading by temperature changes in day-night cycle (range 2-3 deg C).

2.4.7 Short time offset drift

This test shows us summarizing of offsets during short time period (20 sec).

Test description:

We collect data continuously during 20 sec without any breaks. For example on long time test we digitize only half second during 30 seconds data set.

Data:

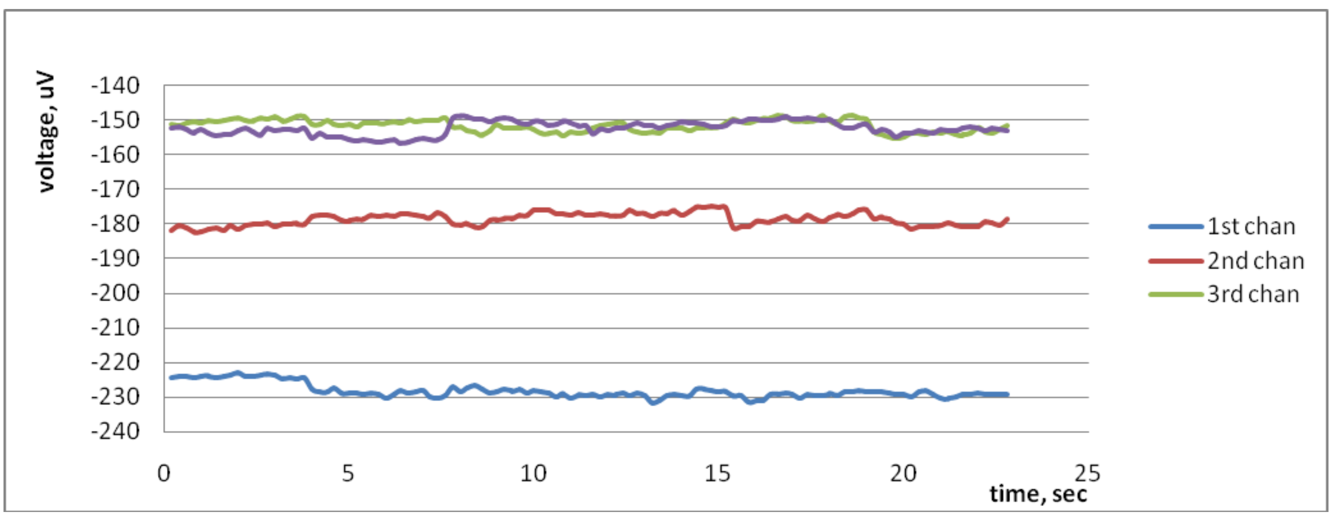

Figure 14. Short time offset voltage drift.

Variance by channels (3.65, 3.57, 3.48, 3.59) uV

Average by channels (-228.2, -178.6, -151.6, -152.4) uV

Summary:

Shot time offsets parameters (variance and average) looks same as offsets, what we get on regular offset tests.

3 Compare ADCs PXI 4462 & PXI 4472

Magnet system group use for tests 8 channels ADC NI PXI 4472. We should compare main parameters and test results for make a decision about ability to use new ADC for tests.

3.1 Main parameters

	PXI 4462	**PXI 4472**
Channels	4	8
Resolution	24 bits	24 bits
Sample Rate	204.8 kS/s	102.4 kS/s
Max Voltage	42.4 V	10 V
Maximum Voltage Range	-42.4 V , 42.4 V	-10 V , 10 V
Minimum Voltage Range	-316 mV , 316 mV	-10 V , 10 V
Minimum Voltage Range Sensitivity	37.7 nV	1.19 µV
Number of Ranges	6	1
On-Board Memory	2047 samples	1023 samples

This table shows main parameters of each ADC. It's clear, what voltage range of PXI 4462 much wider when PXI 4472. Also PXI 4462 have two times more sampling rate diapason.

3.2 Comparing test results

3.2.1 Offset stability test

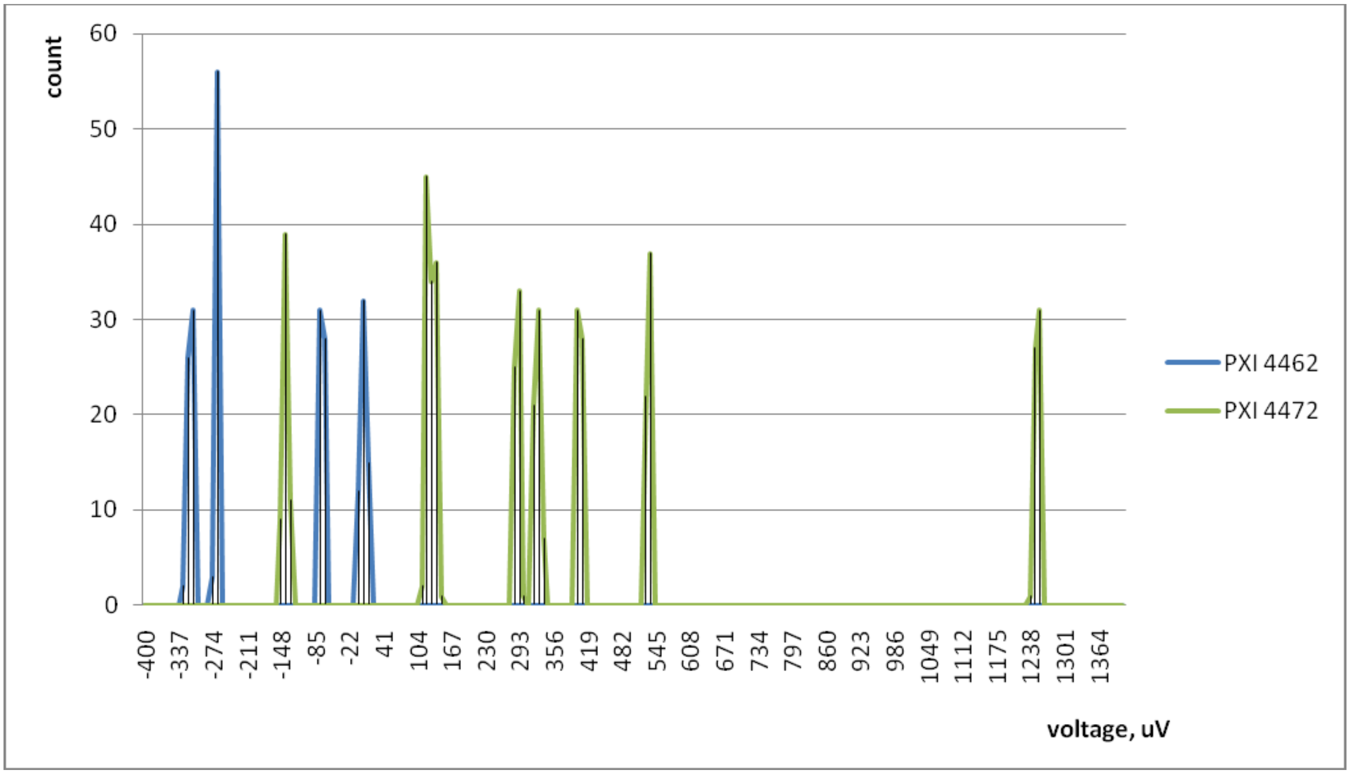

Figure 15. Voltage histogram for PXI 4462 and PXI 4472

Histo shows us offsets range of each ADC, it's clear, what range of PXI 4462 more than two times less, than range of PXI 4472.

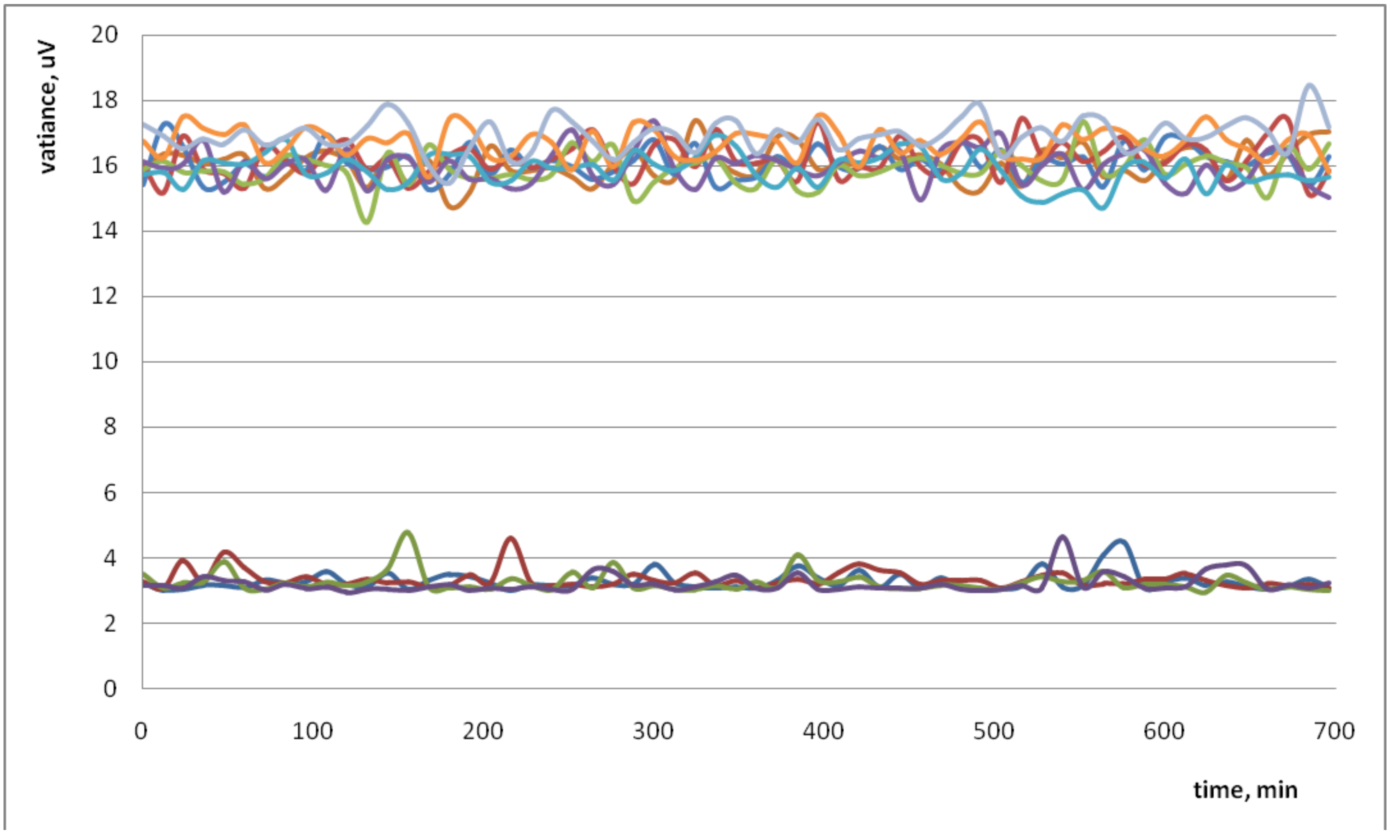

Figure 16. Variance for PXI 4462 and PXI 4472

Upper set – variance for PXI 4472

Lower set – variance for PXI 4462

Summary table for offset test data

	mean				variance				
	PXI 4472		PXI 4462		PXI 4472		PXI 4462		
	5k	50k	5k	50k	5k	50k	5k	50k	100k
1st chan	520.451	504.23	- 77.8719	- 100.259	17.31	18.78	4.71	9.38	13.35
2nd chan	110.739	117.152	- 318.936	- 330.807	16.9	18.81	4.19	9.76	12.71
3rd chan	310.385	304.64	- 7.643	- 51.027	17.11	19.01	4.72	9.49	12.72
4th chan	110.284	89.782	- 268.891	- 306.975	17.44	18.74	4.01	9.33	13.20

Table 5. Voltage and variance for PXI 4462 and PXI 4472.

3.2.2 Linearity & resolution test

Linear plots

NI PXI 4462

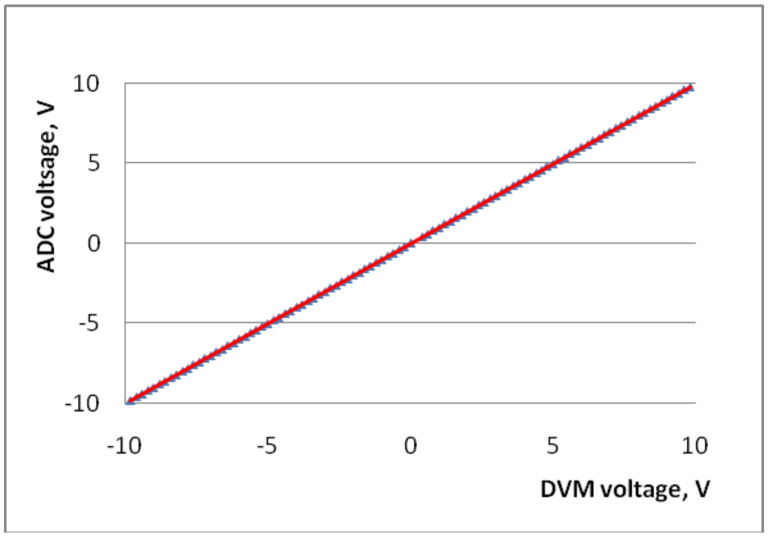

Figure 17. linear test plot for PXI 4462

Linear fit y=0.998951*x - 0.000068

Deviation from linearity 0.000145

NI PXI 4472

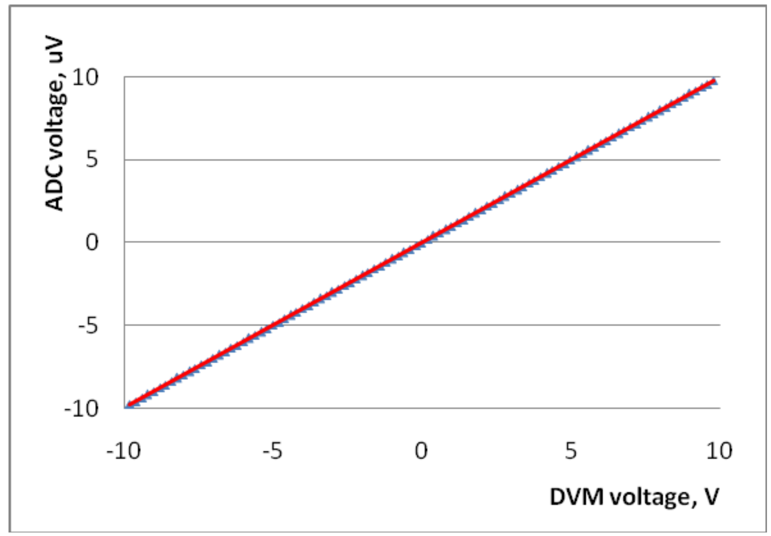

Figure 18. linear test plot for PXI 4472

Linear fit y=0.99603*x + 0.000557

Deviation from linearity 0.000326

Both of data set good fited by line, deviation from linearity by PXI 4472 bit more than same parameter by PXI 4462.

Resolution plots

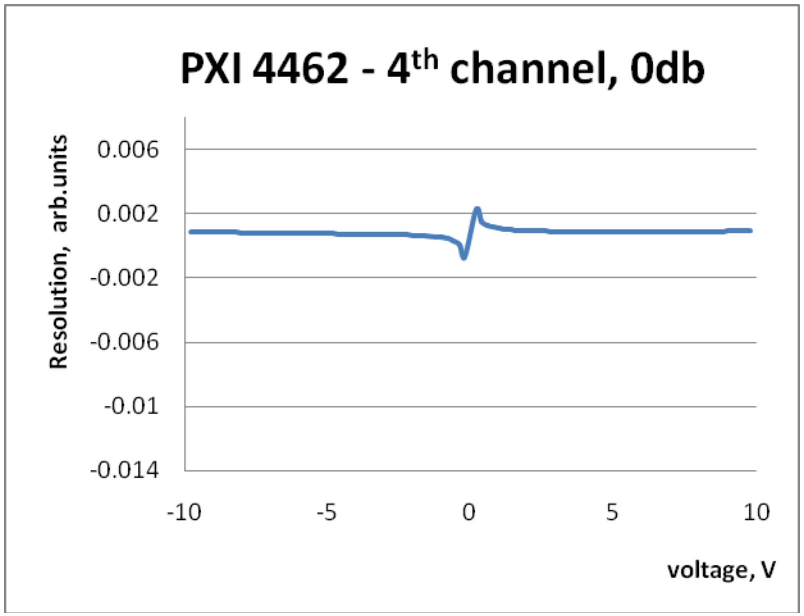

Figure 19.resolution plot for PXI 4462

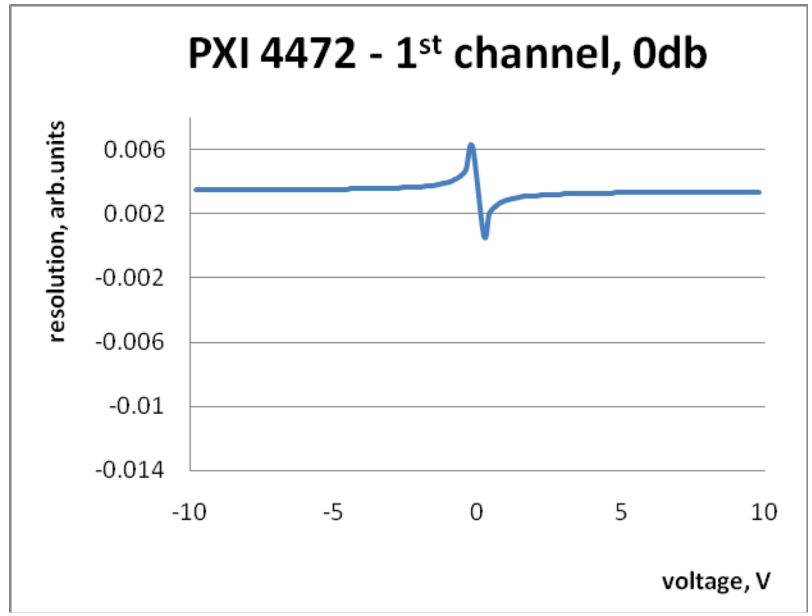

Figure 20. resolution plot for PXI 4472

Resolution range of PXI 4462 stay closer to zero, also it have smaller range than PXI 4472 have.

3.3 Summary

	PXI 4462		PXI 4472	
Variance	5 – 10 uV		15 - 17 uV	
Mean range	(-350; 10) uV		(-200; 1200) uV	
Linear test (line fit)	Slope	+ 0.998951	Slope	+0.99603
	Offset	- 0.000068	Offset	+0.000557
Resolution range	0 – 2 uV		2 – 6 uV	
Crosstalk	no influence		no influence	

By this table, it’s clear what ADC PXI 4462 is more accurate and have better range of offsets.

4 Conclusions

4.1 ADC NI PXI 4462

After all test we can see, what ADC correspond to all parameters gives by manufacturer. And it also satisfied to all us requirement for fast ADC.

4.2 Compare to NI PXI 4472

For former test magnet system group used ADC NI PXI 4472, it also good ADC, but PXI 4462 have in two times sampling rate for reading signal. Also it much accurate – it have less variance of measurement. PXI 4462 have 6 dynamic ranges instead one on PXI 4472. And only PXI 4462 have less channels for reading – only four instead 8, which have PXI 4472.

Final decision: ADC NI PXI 4462 by its parameters perfect fit for digitizing and collecting data in future magnet tests.