PHYSICS
A.Y. 2022/2023

Scientific Data Acquisition And Process

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Experimental experience n° 3:

Signal and noise

Date 21/11/2022

Dalle ore 10:30 alle ore 13:30

Purpose:

Analyze a signal affected by noise and check if:

- the noise is “white noise”
- the standard deviation of the mean decreases as the square root of the number of acquisitions N

Noise:

- In experimental measurements it is a component joined to a signal.

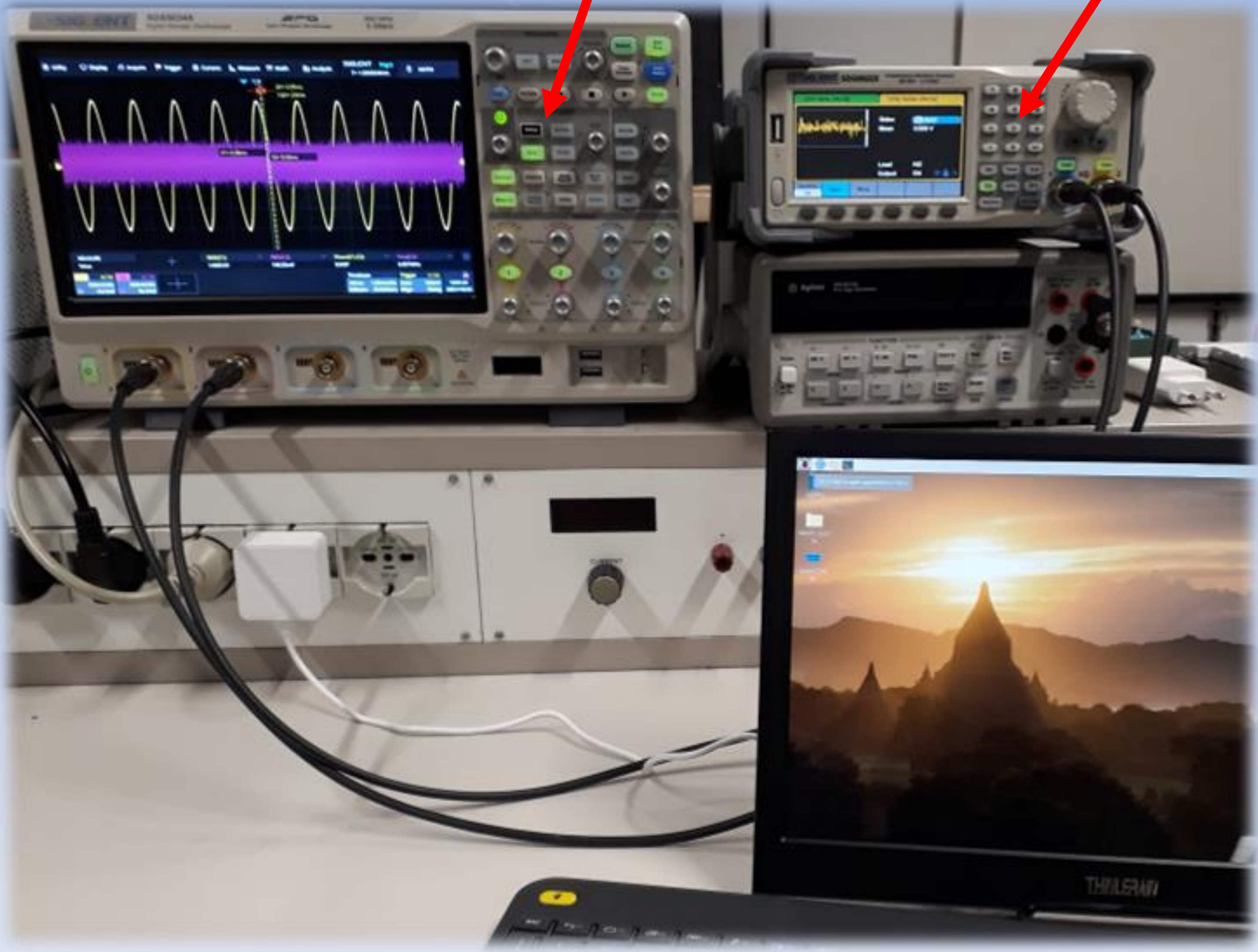
- It can never be completely eliminated.

- It is distributed on all frequencies in a uniform way.

Setup:

Oscilloscope

Function Generator



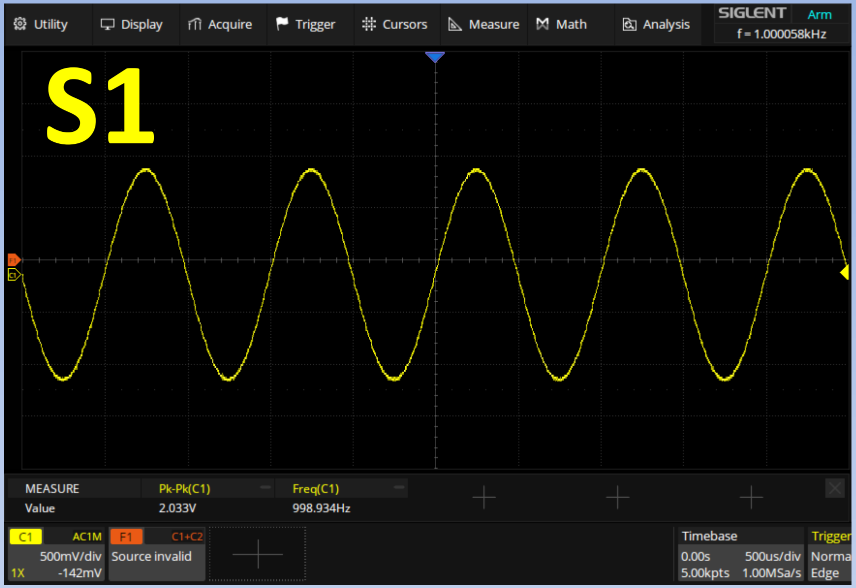
How to proceed :

1. Generate a sinusoidal signal with 1KHz frequency and 2Vpp amplitude (OUTPUT 1).

2. Using the OUTPUT 2 and the "noise" function of the function generator, generate the noise fixing the amplitude at 100mV.

3. Add or subtract the two signals.

4. Acquire the data of the obtained signal.



+

=

S1+S2

Signal
to acquire

How to proceed :

- **Perform multiple samplings (e.g. 16) of the values of V (t)** (sum or difference of the two signals).

An acquisition is made up of 5000 points [t, V (t)].

We will see later how to save the data and how to use this new instrumentation.

Data processing 1:

Check if the noise is "white noise"

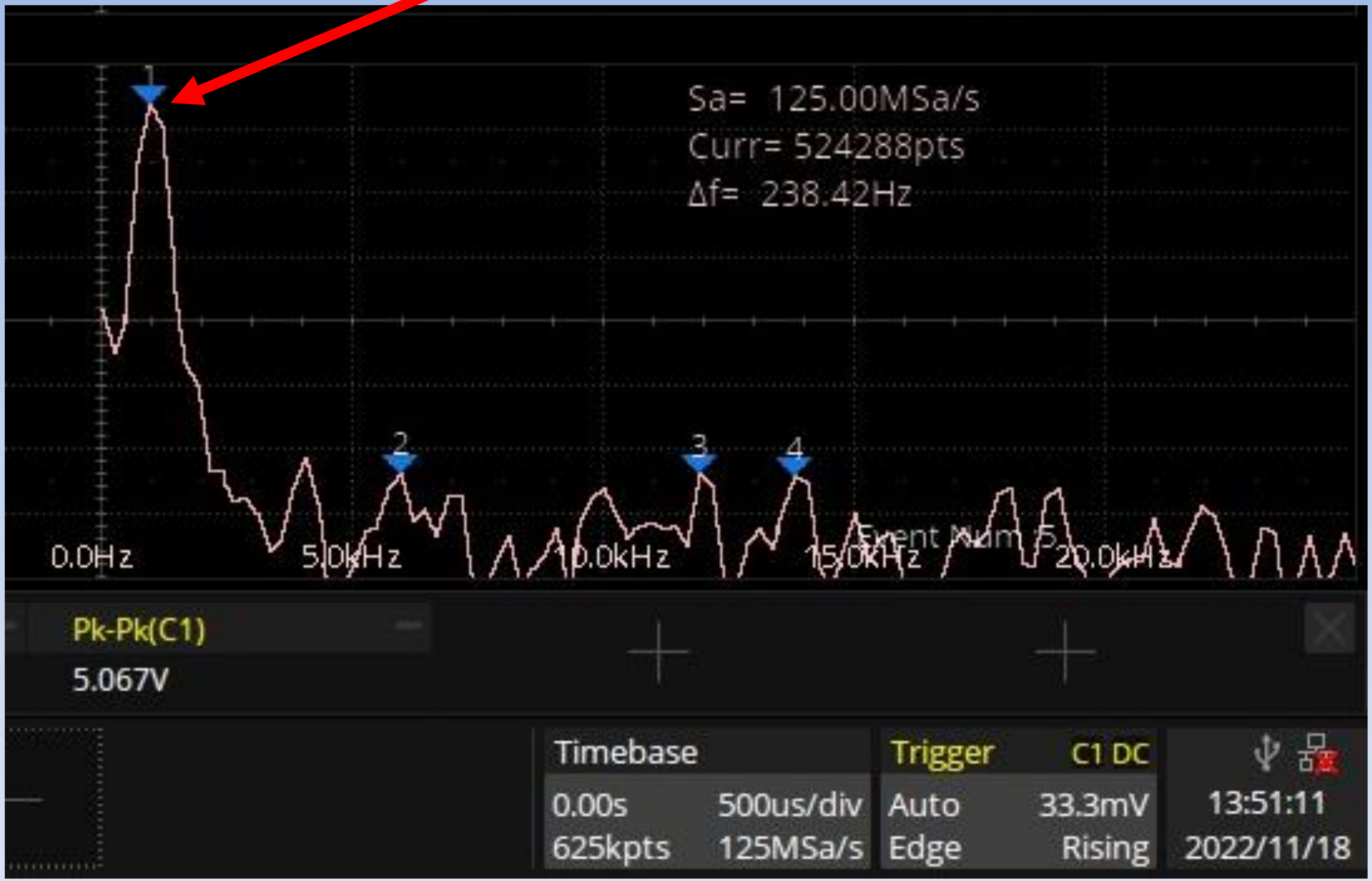
1. Use a suitable software to do the FFT (Fast Fourier Transform) of the data (only the first sampling).

2. Note, in the graph of FFT, the presence of a peak that corresponds to the frequency of the signal used.

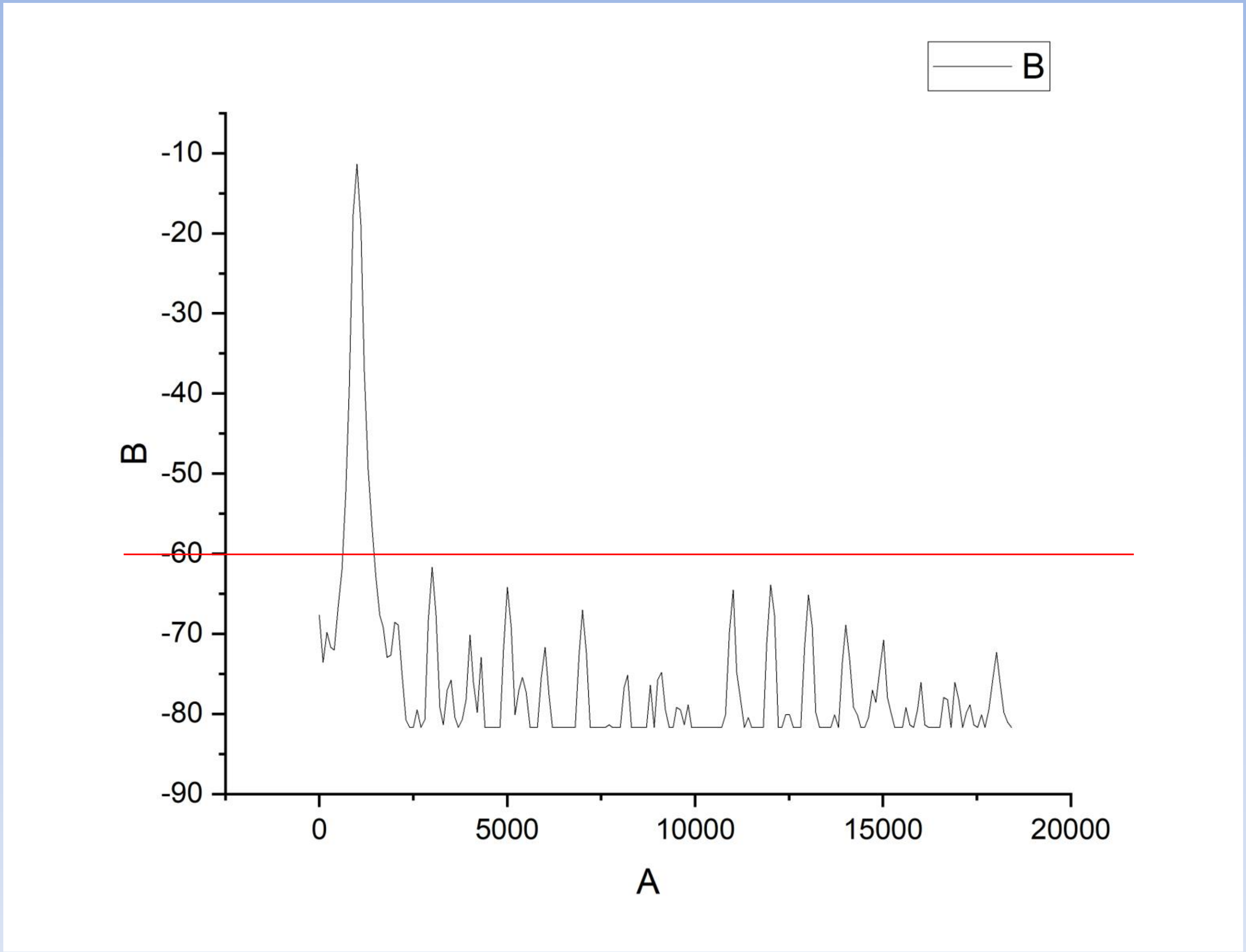
3. Eliminate this peak by substituting zero (expected average value) for those frequency values that generate the peak.

4. Do the IFFT (Inverse Fast Fourier Transform).

Peak to be removed



0	-67,625
100,1001	-73,5625
200,2002	-69,8125
300,3003	-71,6875
400,4004	-72
500,5005	-66,6875
600,6006	-62
700,7007	-52,3125
800,8008	-39,1875
900,9009	-17,625
1001,001	**-11,375**
1101,1011	-18,875
1201,2012	-37,3125
1301,3013	-49,5
1401,4014	-56,6875
1501,5015	-62,9375
1601,6016	-67,625
1701,7017	-69,1875
1801,8018	-72,9375
1901,9019	-72,625
2002,002	-68,5625
2102,1021	-68,875
2202,2022	-75,125
2302,3023	-80,75
2402,4024	-81,6875
2502,5025	-81,6875
2602,6026	-79,5
2702,7027	-81,6875
2802,8028	-80,75
2902,9029	-68,25
3003,003	-61,6875
3103,1031	-67,625



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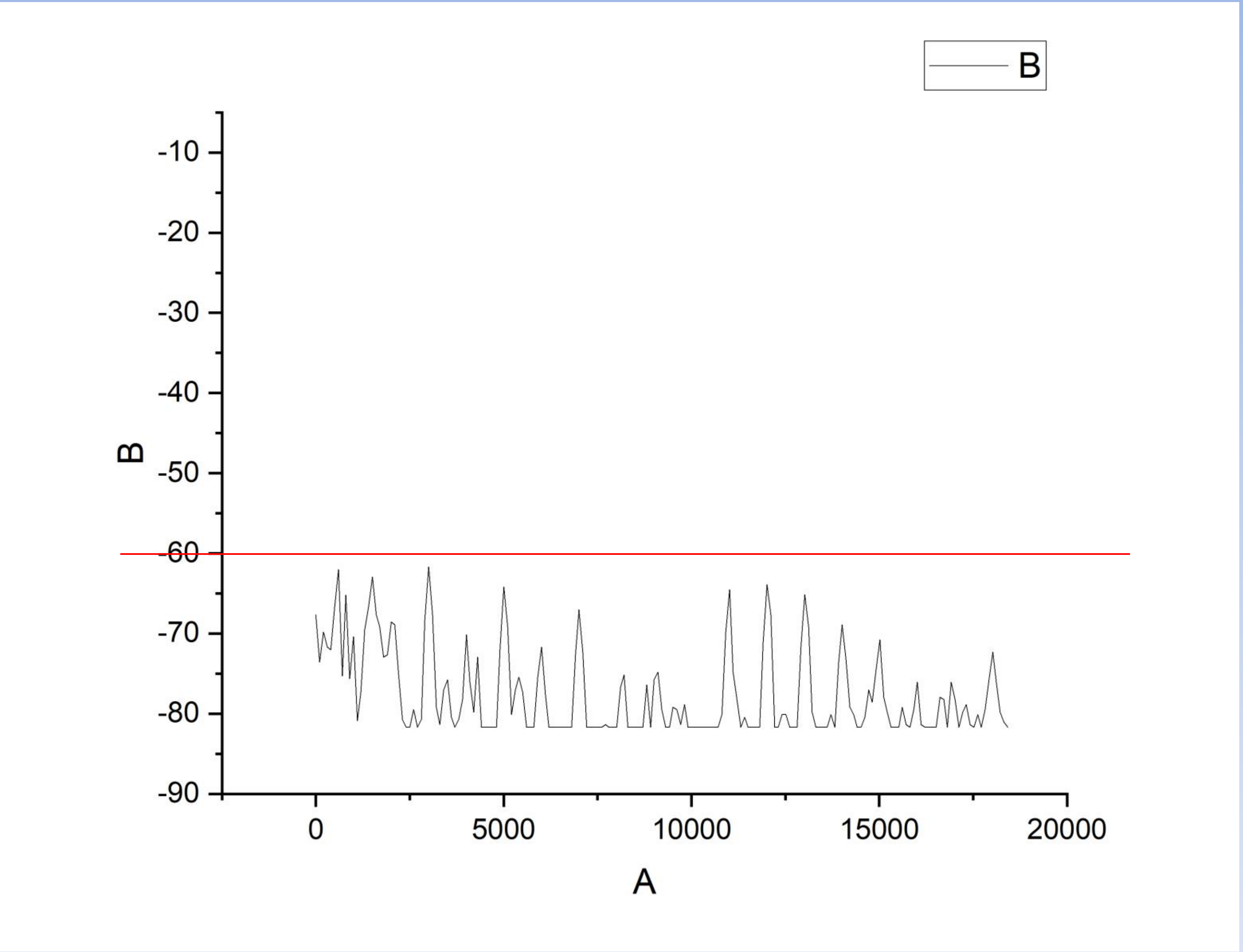


Data processing 1:

Check if the obtained values (noise) are distributed in a Gaussian way (if it is white noise).

- Make the histogram;
- Calculate the average value <V>;
- Calculate the standard deviation σ_V ;
- Using the Chi-square test, compare the distribution obtained with the theoretical one.

(All this for a single acquisition).

Data processing 2:

In this second part we will see how the random error can be reduced (but not eliminated) by increasing the number of acquisitions.

$$\boxed{\sigma_V = \frac{k}{\sqrt{N}}}$$

Data processing 2:

- Isolate the noise for all other files.

- Add the noise files dot-by-dot in groups of 2, 4, 8, and 16.

(NB: the number of points in a file remains the same)

For each new grouping proceed as above:

- Calculate the average value <V>;

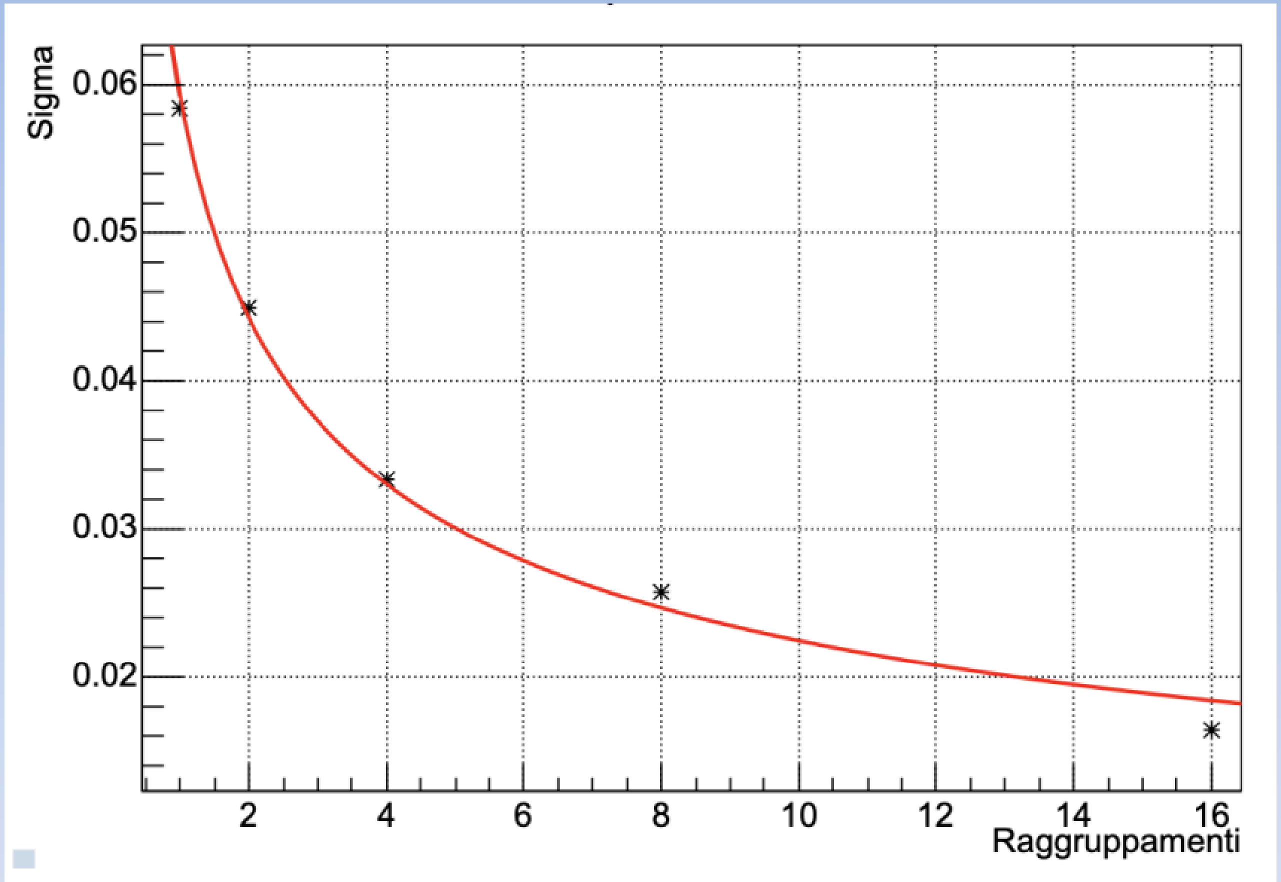
- Calculate the standard deviation σ_V .

Data processing 2:

N Groupings	<V>	<σ_v>
1	V_1	σ_{V1}
2	V_2	σ_{V2}
4	V_3	σ_{V3}
8	V_4	σ_{V4}
16	V_5	σ_{V5}

Report the obtained values of <V> and σ_v in a table (including those of the first sampling).

Data processing 2:



Plot σ_v as a function of N.

Data processing 2:

We combined measures belonging to different acquisitions in groups of 1, 2, 4, 8 and 16 elements.

It can be seen that the $<V_i>$ vary little (remain constant) while the $<\sigma_{Vi}>$ tend to become smaller.

We must verify that the standard deviation of the mean decreases according to a power law:

$$\boxed{\sigma_V = kN^{\alpha}}$$

Data processing 2:

σ_{Vi} and N are known values, we must find K e α.

Then we proceed with the linearization of the law:

$$\boxed{\sigma_V = \mathrm{k}\mathrm{N}^{\alpha}}$$

As in the previous experience:

$$\boxed{ln\sigma_V = \ln\mathrm{k}\,\alpha ln\mathrm{N}}$$

Least squares method :

The values obtained from the linearization must be reported on a graph ($\ln\sigma_v$ vs $\ln N$) and with the least squares method estimate the value of α.

We expect it to be (within the error) $\alpha = -\frac{1}{2}$ because

the standard deviation of the mean decreases as the square root of the number of acquisitions N.

SDS5034X Oscilloscope

The SDS5034X supports saving setups, reference waveforms, screen shots, and waveform data files to internal storage or external USB storage devices.

BMP
Saves the screen shot to external memory in *.bmp format.

JPG
Saves the screen shot to external memory in *.jpg format.

PNG
Saves the screen shot to external memory in *.png format.

SDS5034X Oscilloscope

Binary Data
Saves the waveform data to external memory in binary (*.bin) format.

CSV Data
Saves the waveform data to the external memory in ".csv" format (**Comma-separated values**).

Matlab Data
Saves the waveform data to external memory in *.dat format which can be imported by Matlab directly.

How to set the number of points to process:

1) ACQUIRE
2) Menu
3) Mem Depth
4) 5 K (or 10K)

How to define a function:

1) MATH
2) Menu
3) Trace: F1 or F2
4) Operation: ON
5) Function: C1+C2

How to save the data:

1) SAVE
2) Save path: external
3) Type: CSV
4) File Manager

END