Introduction

This application was designed as a data analyzer for nanogenerators. It is especially useful when several signals need to be synchronized and studied together. Data processing has three main windows: signal processing, creator of dataset batch and splitter peaks analyzer. Also, we must mention the first window (Fig. 1) where you can open an empty dataset or a batch of already created datasets.

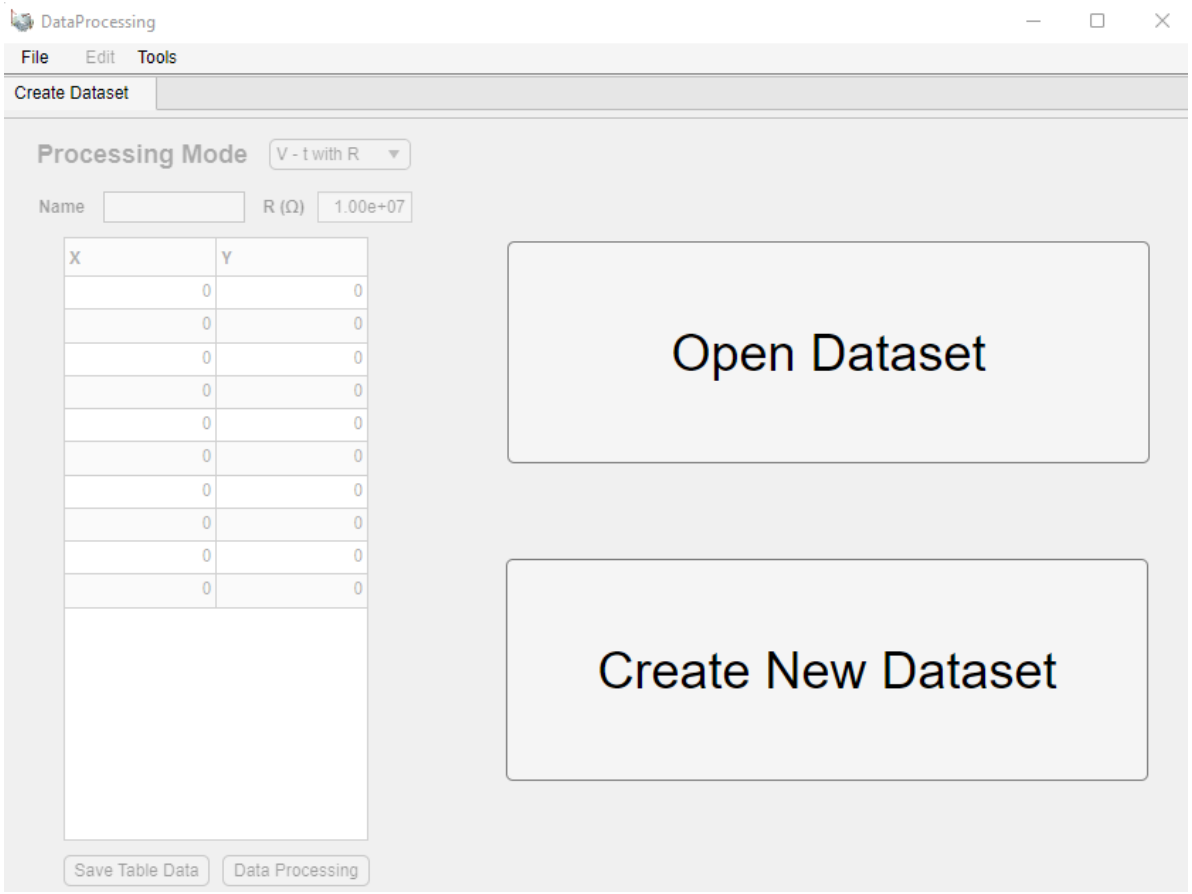
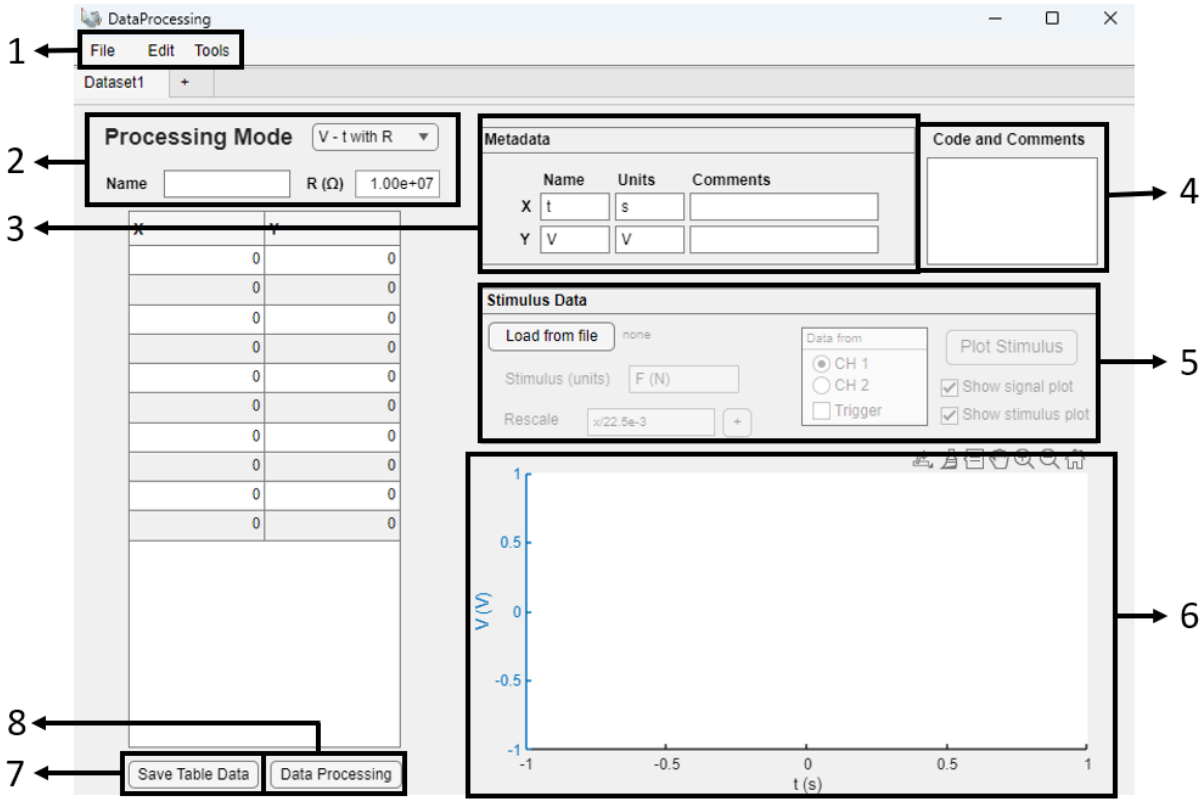


Figure 1. Initial window.

If you click on **"Open Dataset"** your files folder will be open and you must select the dataset you would like to be run (Go to section 2 for more information). If you click **"Create New Dataset"** you will see the following window **Cyclic signal processor** (Go to section 1).

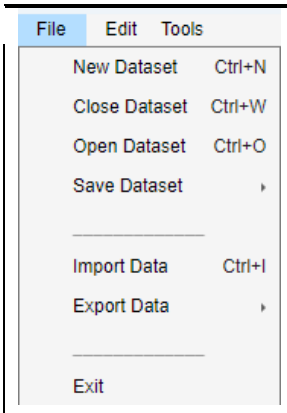
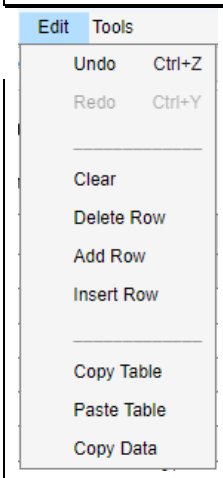
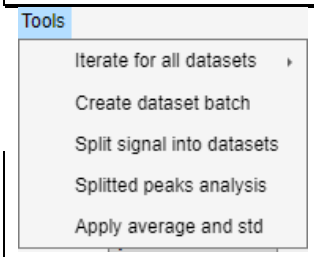
1. Cyclic signal processor

As its name suggests, the point is to process periodic signals as pyro, tribo or piezo signals. In the next board, the main sections of the cyclic signal processor are summarized.



1. **Toolbar**. (Go to 1.1 section)
2. **Processing Mode** and **dataset name**. (Go to 1.2 section)
3. **Metadata:** In this section, you can define the names of your variables and their units. Also, you can add comments in case you want to export to Origin. These variables can be changed by coding.
4. **Code and Comments:** This box was thought for code lines and comments about a dataset.
5. **Stimulus data**. (Go to 1.3 section)
6. **Graphics**. (Go to 1.4 section)
7. **Save table data**: this button exports the data contained in the table above.
8. **Data Processing**. (Go to section 3.)

1.1. TOOLBAR

User interface	Feature	Description
	**New Dataset**	Open a new dataset.
	Close Dataset	Close the current dataset.
	Open dataset	Open an already created dataset.
	Save dataset:	You can choose: ▪ Save the current dataset. ▪ Save all datasets (which are open).
	Import Data:	After choosing your data folder, **"Import Wizard"** opens (go to section 3).
	Export Data:	You can choose: ▪ Export the current dataset. ▪ Export all datasets. ▪ Export all to Origin.
	Exit	To close the program.
	**Undo**	Go back to the previous step. This action can be repeated up to 10 times.
	Redo	Go back to the next step. This action can be repeated up to 10 times.
	Clear	Delete all the data.
	Delete row	Delete a row from the table.
	Add row	Add a row to the table.
	Insert row	Insert a row into the table.
	Copy table	Copy the table data into the clipboard.
	Paste table	Paste data from the clipboard to the table.
	Copy data	Copy the plotted data into the clipboard.
	**Iterate for all dataset**	Apply denoising to all the datasets opened (go to section 3 to know what is denoising). Apply integration to all the datasets opened (go to section 3 to know what is integration).
	Create dataset batch	Go to section 4.
	Spit signal into the dataset	Go to section 5.
	Splitter peaks analysis	Go to section 6.
	Apply average and std.	Go to section 7.

1.2. Processing Mode

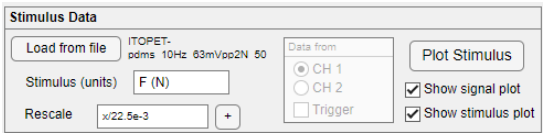
In the "Processing Mode" drop-down list there are four different modes that will define your variables:

- **V-t signal**: for temporal voltage measurement without external impedance (i.e. open circuit).
- **I-t signal**: for temporal current measurement without external impedance (i.e. short circuit).
- **V-t with R**: for temporal voltage measurement with external impedance. In this mode, you can calculate the mean power and energy per cycle.
- **I-t with R**: for temporal current measurement with external impedance. In this mode, you can calculate the mean power and energy per cycle.

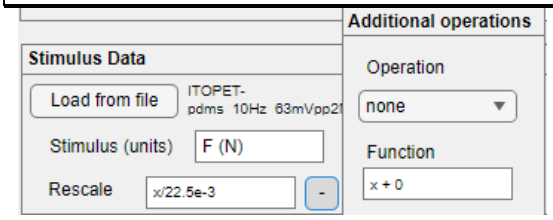
Below this drop-down button, you can name your dataset in **"Name"**, and write down the external impedance in case you need it in **"R (Ω)"**. The algorithm for power calculation will consider this value.

1.3. Stimulus data

In this section, you can import the stimulus signal.



Load Stimulus Data	Go to Section 2.
Rescale	Sometimes, the instrument that supplies the stimulus does not show the data in the correct unit. Then, you need calibration, which normally is provided by the instrument suppliers. Here, you can add it.
Data from	In order to synchronize the stimulus and the data, a trigger signal simultaneous to the stimulus can be used to define the data acquisition interval. The channel number of the stimulus data must be defined. Trigger checkbox activated allows the detection of the change in the trigger data from LOW to HIGH and takes it as the zero time point.
Plot Stimulus	This signal will be plotted by clicking on. The plot will take into account rescaling, operations and trigger synchronization.



Operation	You can choose: – None: nothing is applied. – Derivation: to differentiate the stimulus signal. – Integration: To integrate the stimulus signal. – Denoising: GUI denoising is applied for the stimulus signal.
Function	Additional mathematical operations can be added using 'x' as the variable name.

1.4. Graphics

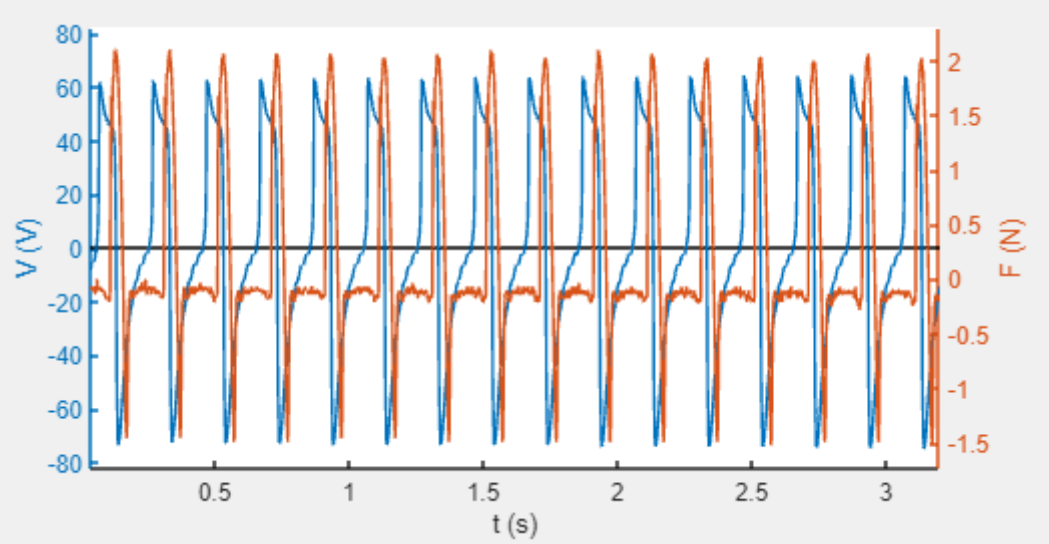


Fig 2: Measured signal (blue) and stimulus (orange) versus time.

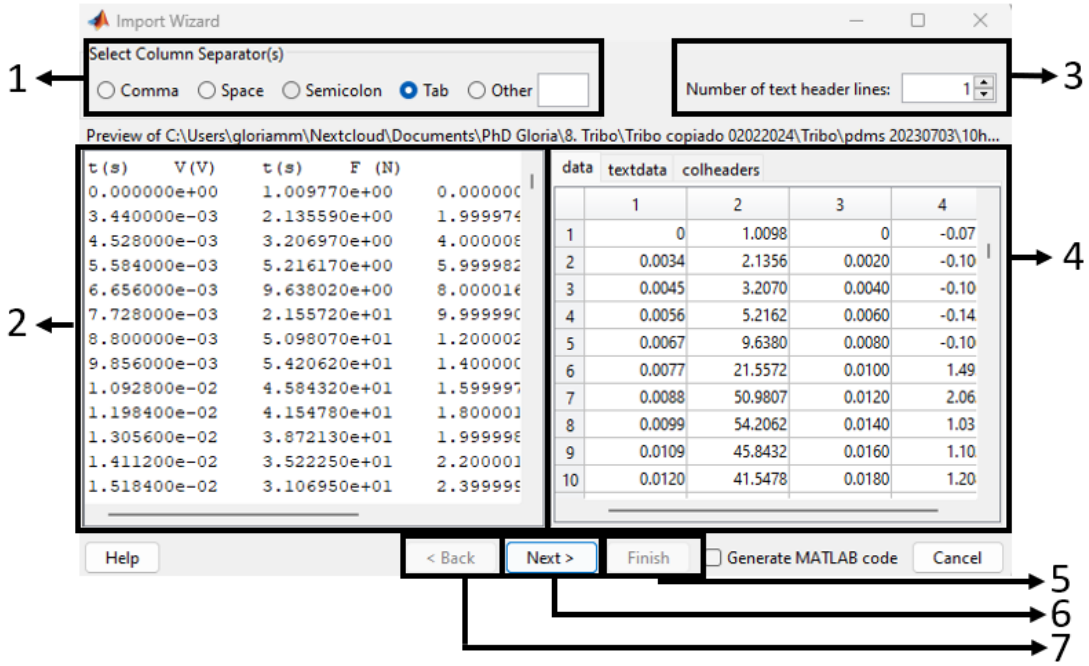
The plot of the data signal (in blue) and the stimulus (in orange) appears in the axis. While you are modifying the signal in the "**Data Processing**" section (Go to section 3), the modified signal is plotted in yellow. You can find a toolbar with the icons shown in the table below, at the top right corner in every graph axis of the application:

Icon	Name	Description
	Save As	It allows to save the figure as an image file choosing the format, .png, .jpg, etc.
	Copy as image	It will copy the image in the clipboard for a further use in other program or location using "Paste".
	Copy as Vector Graphic	• Like "Copy as Image," but ensure that you are working with vector graphics. • Some programs may have a specific option or format for copying as a vector graphic.
	Brush data	This refers to manipulating brush settings in a drawing or design program. • Click the point you want to deselect and click on the "Brush Data" icon.
	Data tips	Once clicked, it may display additional information, or tooltips related to the data or elements in your workspace. • Click on the "Data Tips" icon. • This may display additional information, or tooltips related to the data or elements in your workspace.

	Pan	• Drag the canvas or workspace to navigate around.
	Zoom in	Use the zoom tool to click and zoom into a specific area. You can also zoom in with the scroll wheel of the mouse (hold down Ctrl or Command while scrolling).
	Zoom out	Use the zoom tool to click and zoom out of a specific area. It can also allow zooming out with the scroll wheel of the mouse (hold down Ctrl or Command while scrolling).
	Restore view	This icon usually resets the view to the default or original settings.

2. IMPORT WIZARD

This window appears when you try to import data. This functionality helps the application to read the folders correctly.



1. **Select Column Separator.**
2. **Window Data.** What the program reads.
3. **Number of text header lines.** It lets the application know which lines of the file are not data, but headers.
4. **Preview of imported data.**
5. **Finish:** To finish the importation.
6. **Next:** To preview what is going to be imported.
7. **Back:** To return to the previous step

Caution: Data must be formatted with point "." as the decimal separator. Comma is only eligible as number separator.

3. Data Processing Tool

The **data processing** button allows to access to the **denoising** and **integration tools**. Once clicked, the data processing interface will appear (Figure 3b). This part of the application allows to perform noise removal post-processing operations, as well as to calculate typical parameters used to measure nanogenerators efficiency, this is the mean power and the energy per cycle.

a) b)

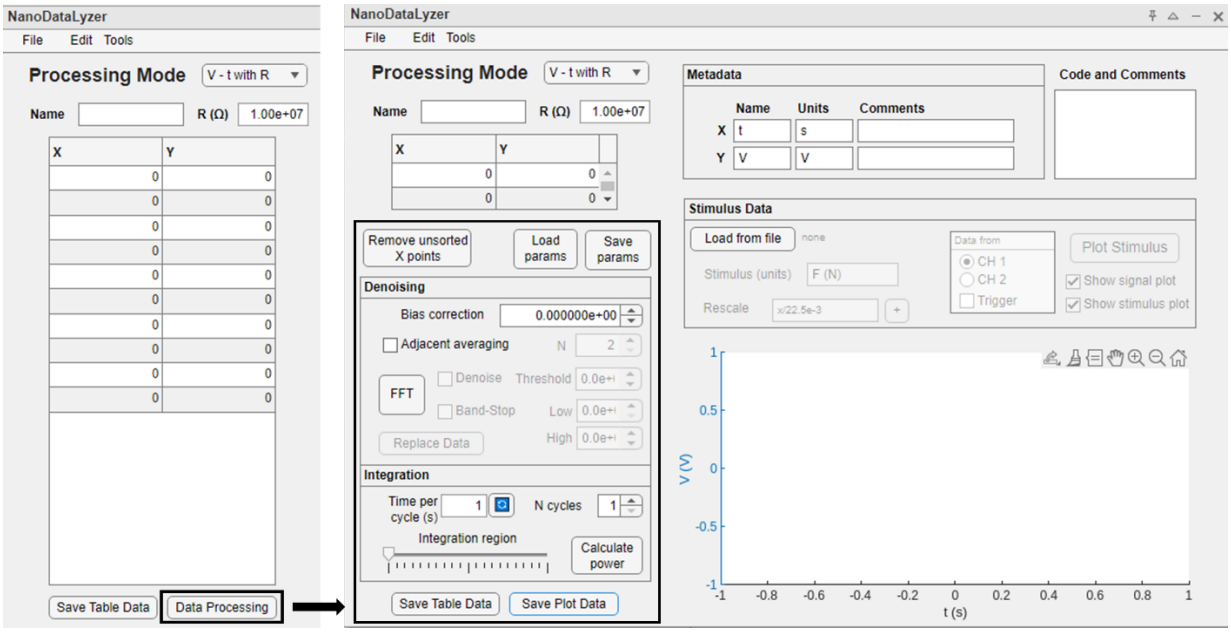
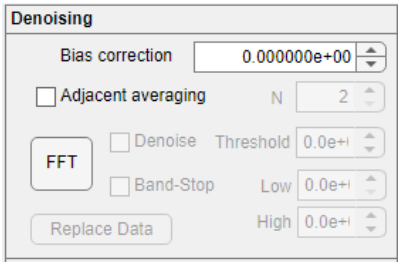
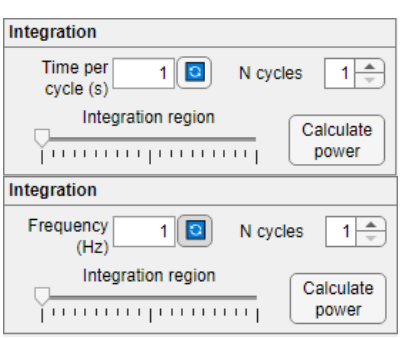
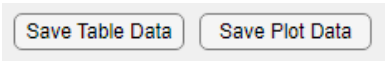


Figure 3. Access to Data Processing Tool.

The "Data Processing Tool" offered functionalities are explained in Table 2.

User interface	Feature	Description
	**Remove unsorted X points**	Remove faulty points that are not part of the measurement, i.e. different points with same x value.
	Save params	Allows you to save denoising and integration parameters as a configuration for future measurements.
	Load params	Load a previously saved measurement parameters configuration.
	Bias correction	Allows to shift the measured signal along the y axis for a bias correction. The real-time changes are shown in the graph window placed on the left.
	Adjacent averaging	Applies a moving average smooth filter to the measured signal. It returns a new

		dataset in which each value is the average of a local N-point region of the original data set. When selected, the N parameter is enabled.
	FFT	Applies a Fast Fourier Transform to the signal. The measured signal represented in the frequency domain, is then displayed on the right side, above the graph axis. When clicked, the denoise and band-stop features are enabled.
	Denoise	Allows to perform threshold denoising. This functionality will remove the signal data points whose value is below the entered threshold.
	Band-Stop	By choosing low and high values, enabled by clicking on band-stop box, allows to select frequency ranges to apply band-pass, band-stop, high-pass, and low-pass filters to the measured signal.
	Replace data	Once clicked, the data modifications made using the denoise operations shown in the graph, are confirmed into the graph.
	**Time per cycle (s)**	Time per cycle of a periodic measured signal. It will be used as integration time.
	Frequency (Hz)	Frequency of the measured signal.
	N cycles	For selecting the number of cycles to which the integration will be applied.
	Integration region	The slide allows you to select the region that will be integrated.
	Calculate power	Allows to calculate the Mean Power and the Energy per Cycle values. When clicked, the calculated values are shown in a new window, these can be copied to clipboard or appended to a created .txt file.
	**Save Table Data**	Saves the original measured data in a new ascii file.
	Save Plot Data	Saves the processed measured data and the stimulus data in a new ascii file.

4. Batch creator tool

4.1. Overview

The batch creator tool in "**NanoDataLyzer**" allows to selectively choose signals for further cyclic data stability and device performance with the external load resistance.

Accessing Steps for Create Dataset batch

i. Navigate to the NanoDataLyzer application home page.
ii. Go to "**Tool**" in the toolbar menu.
iii. Select "**Create dataset batch**".

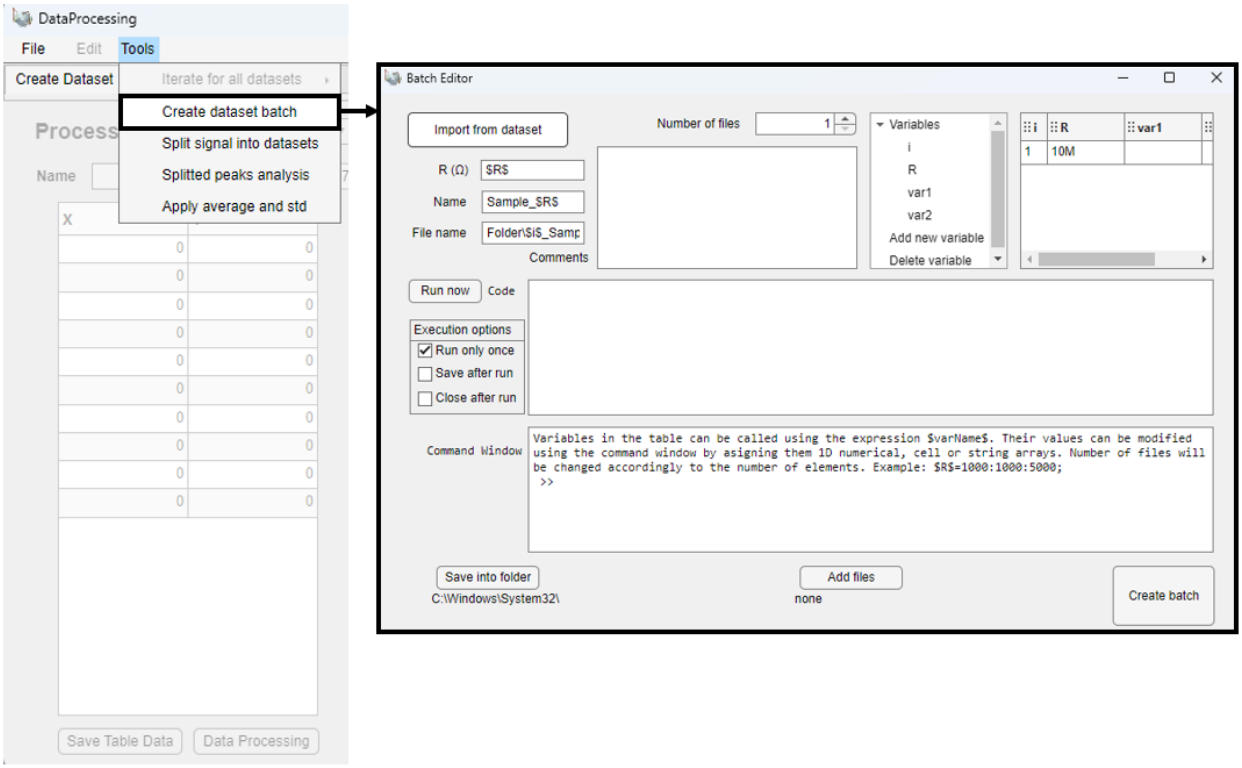
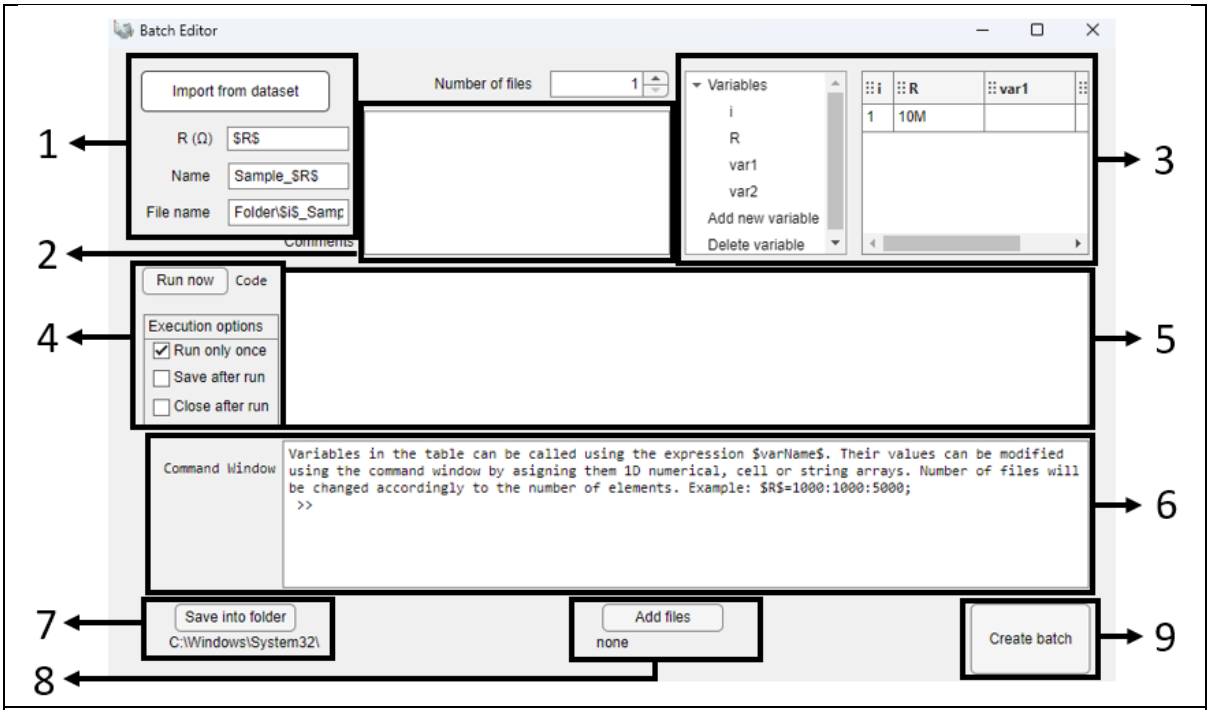


Figure 4. Access to batch creator tool.

A new window will appear with "**Batch Editor**" which promptly provides you access to the batch editor.



1. Go to section 4.2.
2. Go to section 4.2.4.
3. Go to section 4.2.5.
4. Run button. To test your code once before measurement. You can save or close it after running.
5. Go to section 4.2.6.
6. **Comand window.** Go to section 4.2.7.
7. **Save into a folder.** Save code and batches into a folder.
8. **Add files** . In case you need some extra file in your code.
9. Create batch button.

4.2. Signal processing details

This will allow easier steps to check the device's stability, durability performances and load resistance behavior. So, follow the below steps.

4.2.1. First, import the program from the top panel named "I**mport from dataset**"1.2. Type the name of the variable e.g., Resistance **"R".**

4.2.2. Type the name of the sample e.g., **XYZ_R.**

4.2.3. Type the name of the folder or path e.g., **data analysis**\XYZ_R.

4.2.4. There is space provided for any comments for analysis (2 in Figure above).

4.2.5. The number of files and variables can be modified from the top panel (3 in the Figure above).

For example, in the image above 3 files and correspondingly 3 data sheets will be displayed in the right corner for analysis.

Similarly, 3 variables will be displayed: R, var1, var2. You can add more variables or delete them as well.

4.2.6. This application also provides the analysis for any coding, so here (5 in the figure above) you can create code and then run it now (4 in the figure above). Then a new window will appear with the results.

After that, a new window will appear which demonstrates the given input credentials as shown in Figure 8.

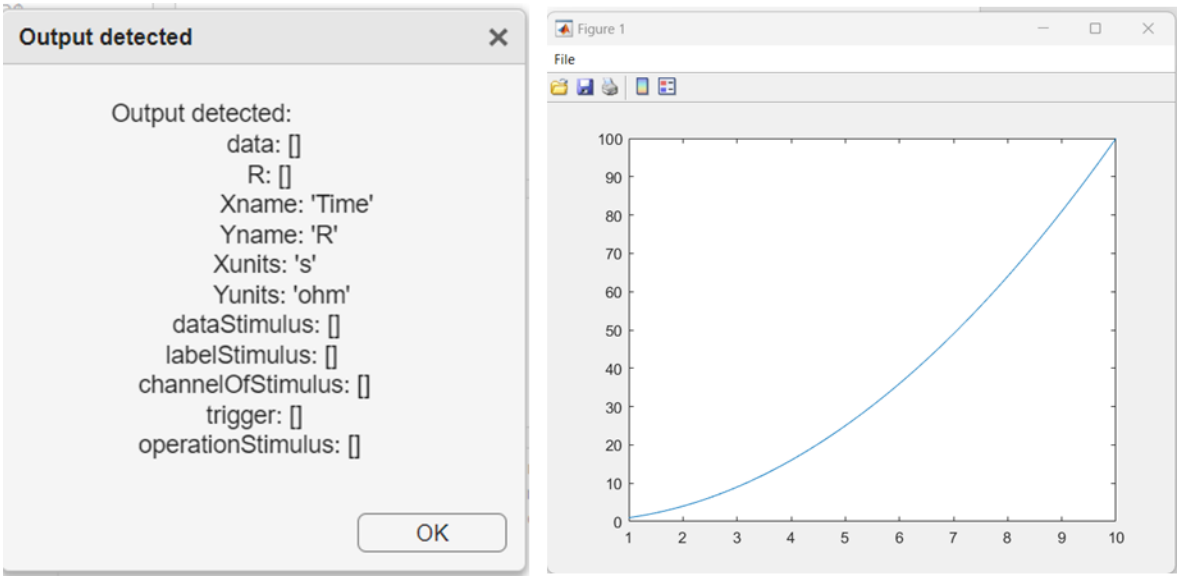


Figure 5. Output detected and graph.

4.2.7. In a command window section, we can also create a program to run the existing files as per the given command (6 in Figure above)

4.2.8. At the lower panel of the application (7, 8 and 9 in the figure above) there are multiple options like save, add files, and create batch to control our signals.

5. Data Splitter Tool

The **Data Splitter Tool** in "**NanoDataLyzer**" empowers you to selectively choose signals/events for analysis or remove them from consideration. The **Data Splitter Tool** enhances your data analysis capabilities by allowing you to tailor your dataset according to your specific needs. Efficiently manage signals and events to derive meaningful insights from your data. This guide will walk you through the steps to access and utilize this feature seamlessly.

Accessing the Data Splitter Tool:

i. Navigate to the **NanoDataLyzer** front panel.
ii. Locate the "**Tool**" menu in the toolbar.
iii. Click on "**Tool**" to reveal the dropdown menu.

iv. Choose "**Split Signals into Dataset**" from the available options.

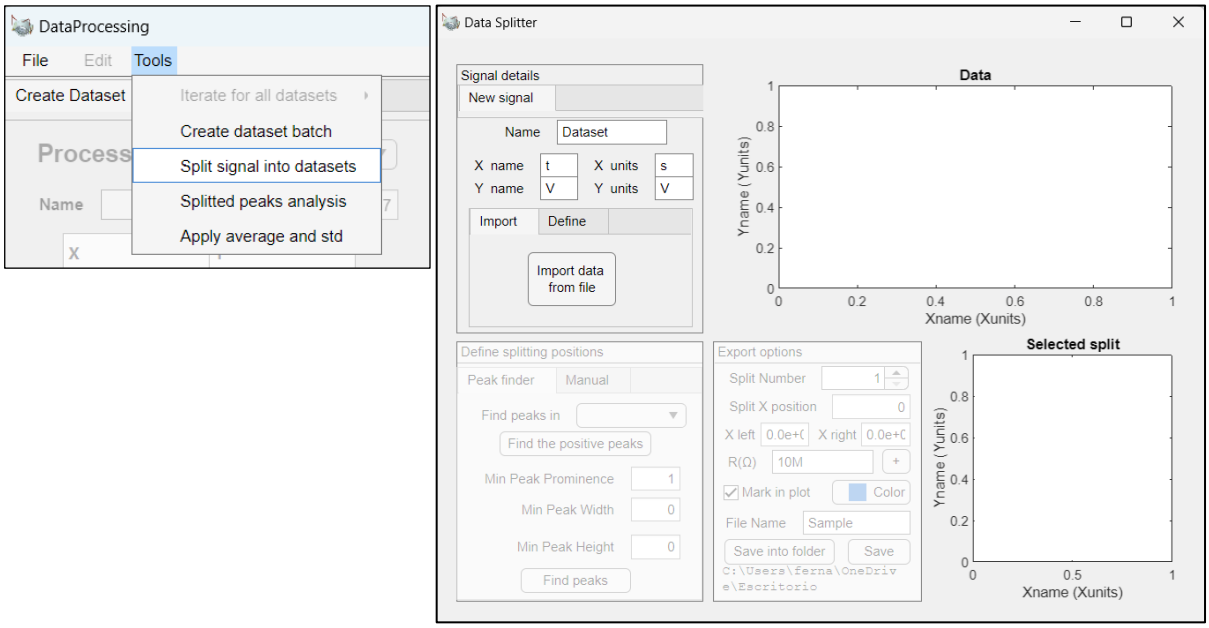
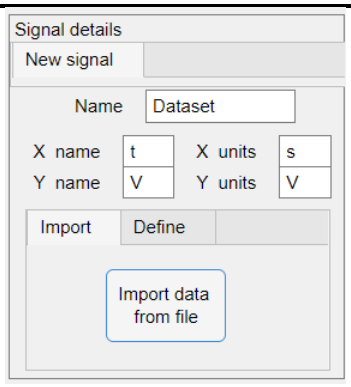
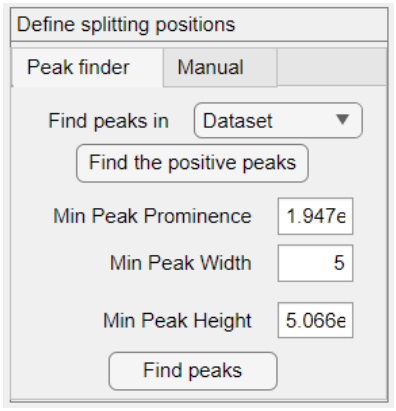
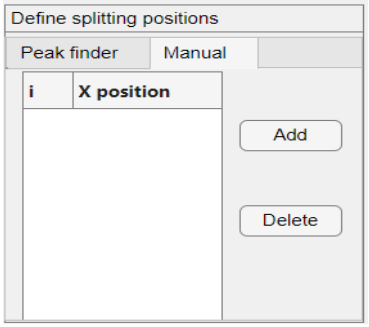
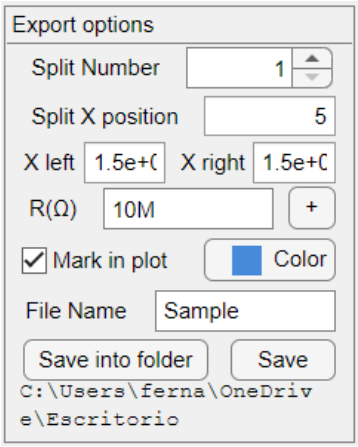
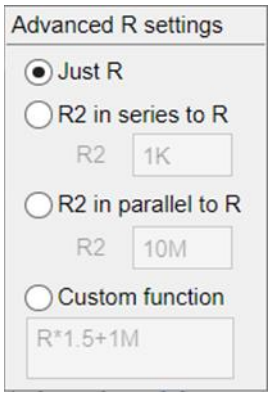
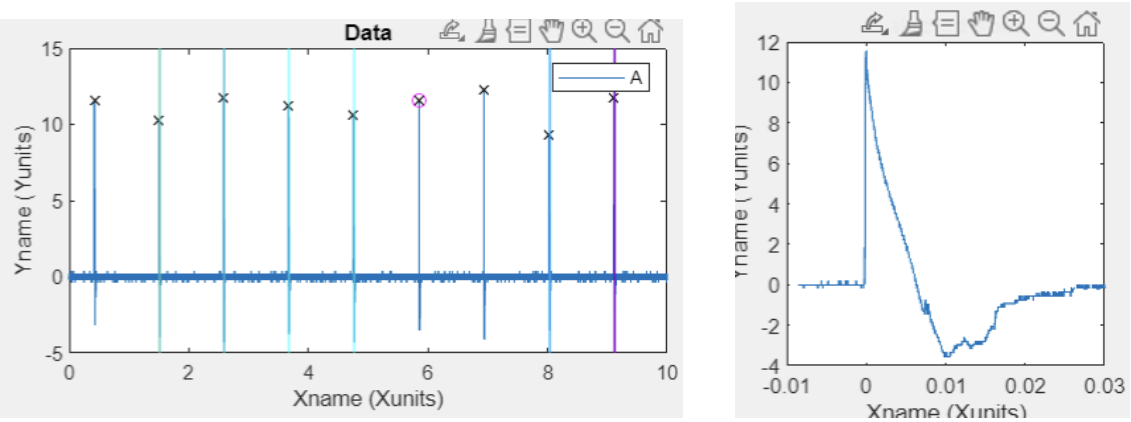


Figure 6. Split Signals into Dataset access and interface

User interface	Feature	Description
	**Name**	File name of your dataset.
	X and Y name	Label of the X and Y axis in order to be defined in the plot.
	X and Y units	Units of the X and Y axis in order to be defined in the plot.
	Import data from file	It allows to import a dataset from a pre-existing file.
	**Find peaks in**	Choose the dataset to be analyzed.
	Find the positive peaks	Choose if you want to find the positive or negative peaks.
	Min peak Prominence	Set the minimum prominence required for a peak to be considered and identified.
	Min Peak Width	Specify the minimum width a peak should have to be recognized by the analyzer.
	Min Peak Height	Define the minimum height threshold that a peak must meet for accurate detection.
	Find peaks	After selecting all the parameters pressing this button to find the peaks which fulfil the specifications.

<table>
<tr><td rowspan="4"> 
</td><td>Manual</td><td></td></tr>
<tr><td>Add</td><td></td></tr>
<tr><td>Delete</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="10"> 
</td><td>Split Number</td><td>It refers to the number of the peak/event already splitted from the dataset in order to move through the data</td></tr>
<tr><td>Split X position</td><td>It refers to the position in X axis where the splitted peak/event is.</td></tr>
<tr><td>X left and X right</td><td>It refers to the part of the signal selected before and after the peak/event of interest.</td></tr>
<tr><td>R (Ohms)</td><td>This functionality facilitates the inclusion of a resistor within the circuit mode, such as that of the measuring instrument. Users can opt to introduce an additional resistor and specify its arrangement, choosing between series, parallel, or custom configurations.</td></tr>
<tr><td>Mark in Plot</td><td></td></tr>
<tr><td>Color</td><td>This functionality allows mark in color some peaks/event with a defined characteristic.</td></tr>
<tr><td>File name</td><td>In order to save the splitted peak/event you can introduce the name of the file.</td></tr>
<tr><td>Save into folder</td><td>It allows to select the folder to save the data.</td></tr>
<tr><td>Save</td><td></td></tr>
<tr><td rowspan="4"> 
</td><td>Just R</td><td>Do not add any extra resistance.</td></tr>
<tr><td>R2 in series to R</td><td>Series Configuration: Position the resistor in series with the existing circuit elements.</td></tr>
<tr><td>R2 in parallel to R</td><td>Parallel Configuration: Place the resistor in parallel with the existing circuit components.</td></tr>
<tr><td>Custom function</td><td>Custom Configuration: Tailor the placement of the resistor based on specific user-defined requirements.</td></tr>
</table>

5.1. Graphics



6. Splitted peak analysis tool

Once you have already saved a series of data divided by events or peaks, you can automatically analyze the main characteristics of these events or peaks. The Splitted peak analysis tool allows you to make some calculations regarding the shape of these events. This tool does not have a graphical interface as such, instead it will ask for the folder where all the splitted datasets are saved generates a .txt file with the following parameters for each peak:

- **R (Ohm):** The load resistance at which this peak has been obtained
- **Max V+ (V)**: The maximum value of the positive Y axis for the peak.
- **Max V- (V)**: The maximum value of the negative Y axis for the peak.
- **MaxPower(W)**: Instantaneous power measured for each peak.
- **FWHM+(s)**: Full width at half maximum of the peak.
- **FWHM-(s):** Full width at half maximum of the peak.
- **t+(s):** Position of the positive peak in t .
- **t-(s):** Position of the negative peak in t.

7. Apply average and std tool

This tool is useful for statistical calculations on the output of “Splitted peak analysis” tool or “Calculate power” feature in “Data Processing” section. It inputs a txt file with tab-separated parameters and outputs a new txt file with the unique values of the first parameter (usually R) and the average value and standard deviation of all the elements with that same value of the first parameter.