Quick Guide

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EMCR - Graphical User Interface and Basic Commands

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Revision History

Date	Version	Description
01/10/2024	0.3.0	Added digital filters, Irms, release notes, button to rearrange floating windows, reference to scripts to work with saved files
20/08/2024	0.2.0	Added spectrum, added event detection, added measurement overview, refactor of central widgets, refactor of offset correction
11/04/2024	0.1.0	First version of document

Key terms

GUI: Graphical user interface.

Widget: A widget is a single, combined element made from several standard graphical objects like buttons or text fields. It simplifies the interface by bundling related controls together in one place.

Expanded traces/channels: list of channels that are visible in the central widget. See **Channels overview** for more information.

SR: Sampling rate.

DUT: Device under test, i.e., the sensor connected to the amplifier's input.

FIR: Finite impulse response, i.e., a digital filter that only uses the filter input (the raw data) to compute the output.

IIR: Infinite impulse response, i.e., a digital filter that reinjects also the computed output filter in previous time steps to compute subsequent filter outputs.

Introduction

The default GUI is organized in multiple widgets all embedded in a single window; however single widgets can be removed from the main window and split in different windows to be placed where preferred on the screen.

Click on the **View** menu to select which widgets should be shown or hidden.

Common features

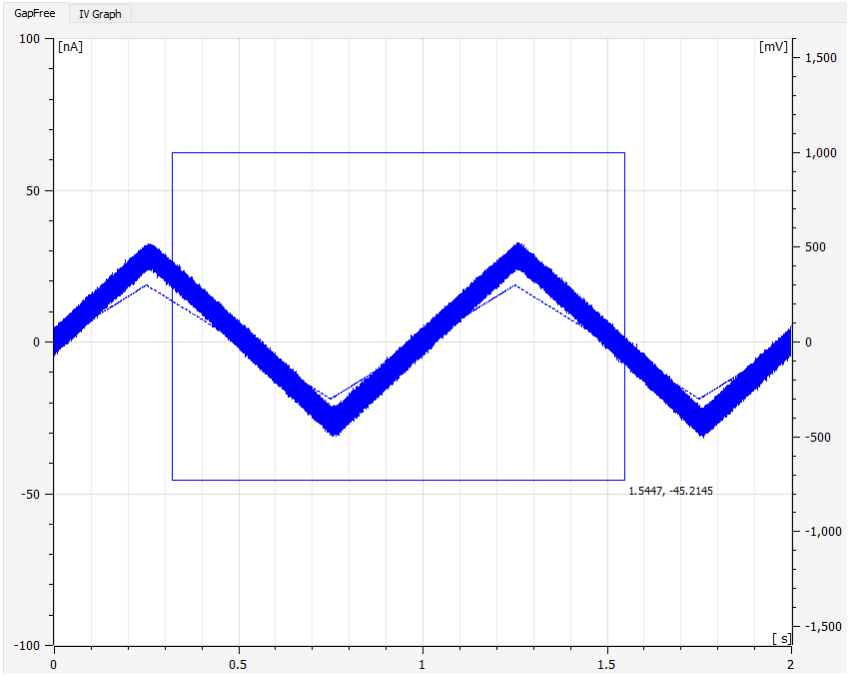
Zoom and offset

You can zoom vertically using **CTRL + Mouse** wheel and horizontally with **SHIFT + Mouse** wheel.

The offset can be modified using the mouse scroll wheel.

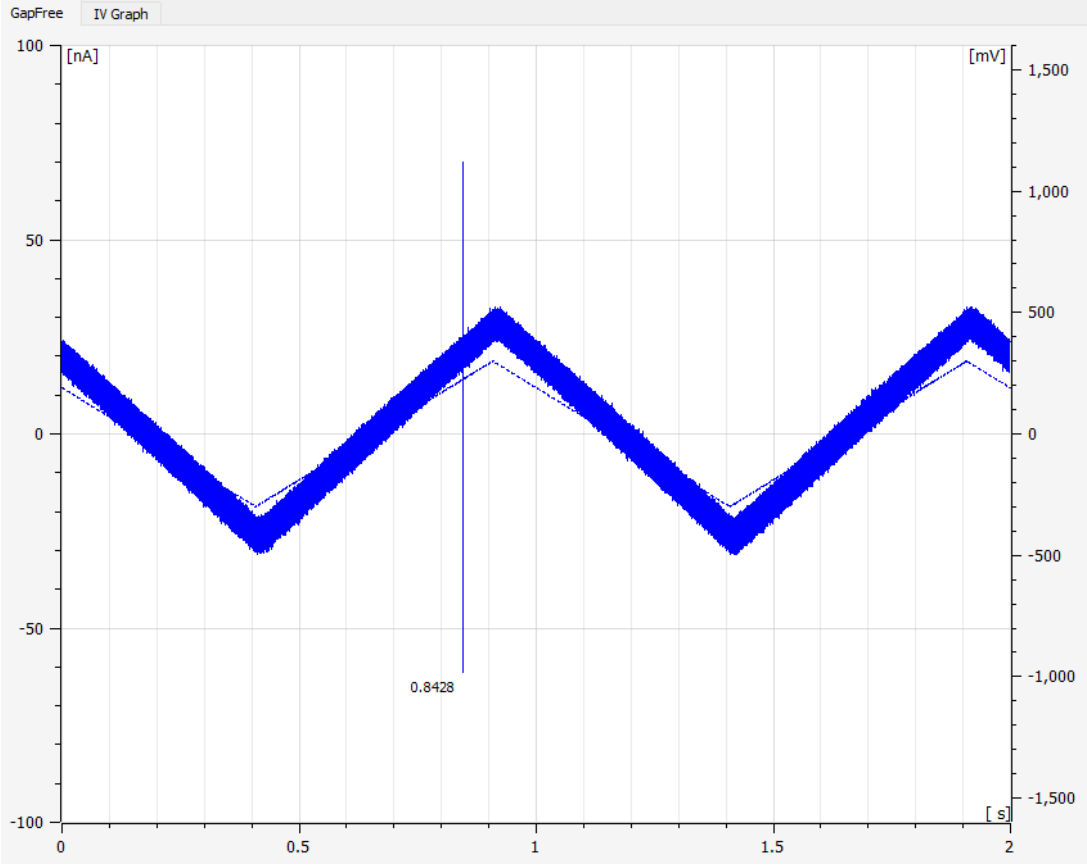
The CTRL + Mouse wheel and wheel control change the scale and the offset respectively of the current plot if the mouse cursor is on the left half of the plot. Conversely, the voltage plot is controlled if the cursor is on the right half of the plot.

Rectangular zoom



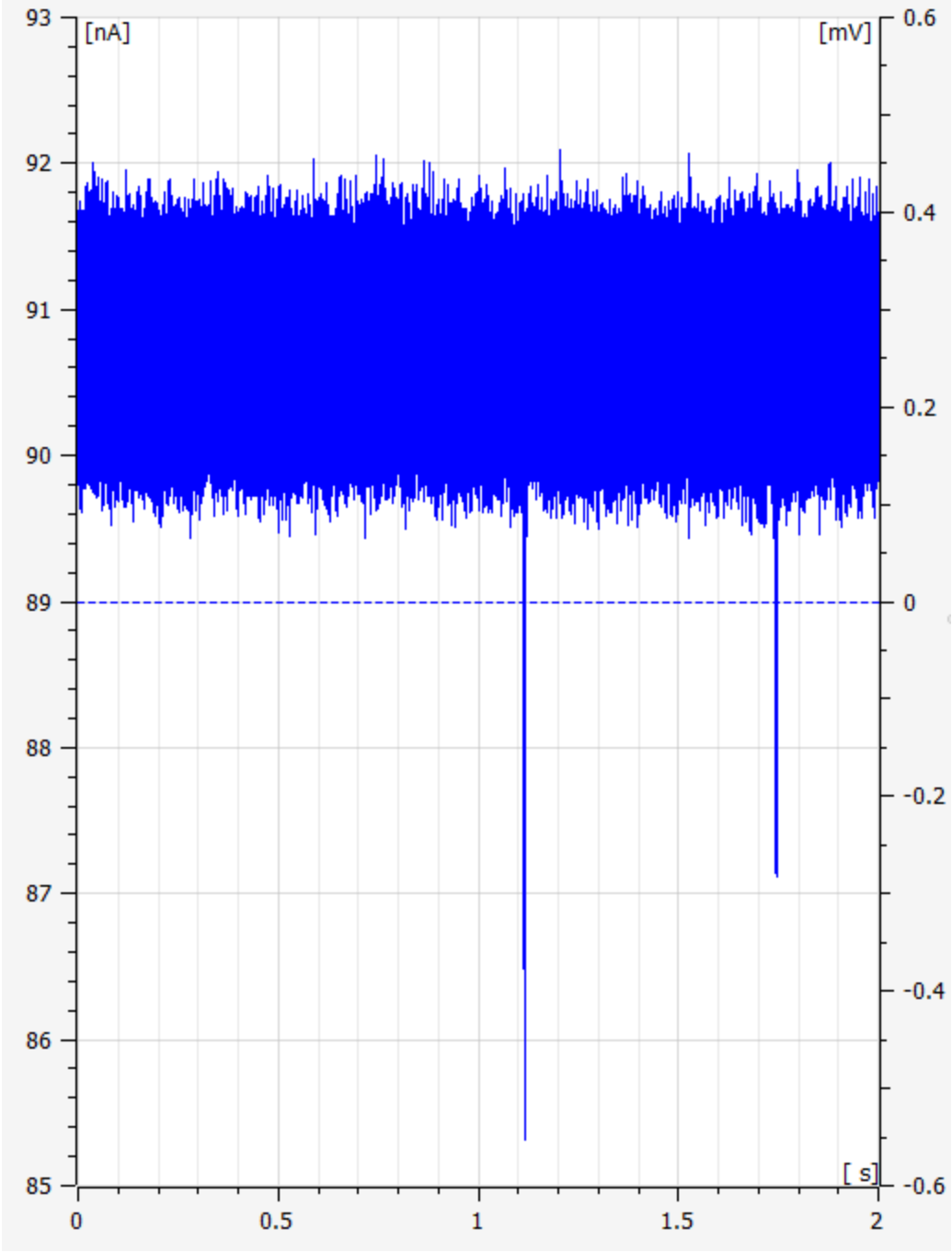
It is also possible to select a rectangular area to zoom manually. Simply left click in one corner of the rectangular area you want to zoom, drag the mouse cursor to the opposite corner of the area and finally release the left button of the mouse.

In order to zoom only along the x-axis or y-axis draw a thin rectangle, elongated along the horizontal or vertical axes, respectively. When done properly, the rectangle will become a horizontal or vertical line.



To go back to the **previous zoom** setting, **right click** anywhere within the plot areas.

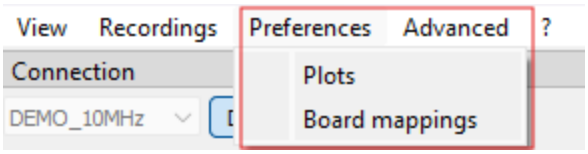
To **reset the zoom** level to the default one for the specified current/voltage range, perform a **double right click**

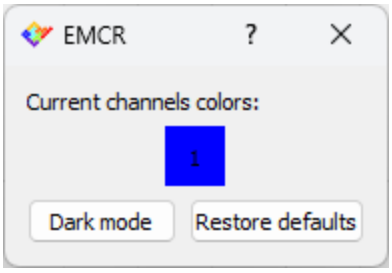


Most plots have also an auto zoom button  that tries to figure out the best visualization for the data currently acquired.

Visualization options

In order to change the color of traces or to switch between dark and light mode, select Plot from the Preferences menu.





Expandable views

Most of the widgets in the central part of the application will display three dots. By dragging them left or right, you can modify the amount of space taken from a plot and the other controls. To maximize the plot visibility, just move the dots all the way to the right: the other commands will disappear leaving you only with the plot. To make the controls appear again, just move the three dots to the left until they pop up.

Copyable tables

The content of tables can be copied by selecting the desired cells and clicking **CTRL + C**. The copied content can then be pasted in other programs, such as spreadsheets or text editors, by using the shortcut **CTRL + V** or the **paste** command from the contextual menu.

Central Widgets

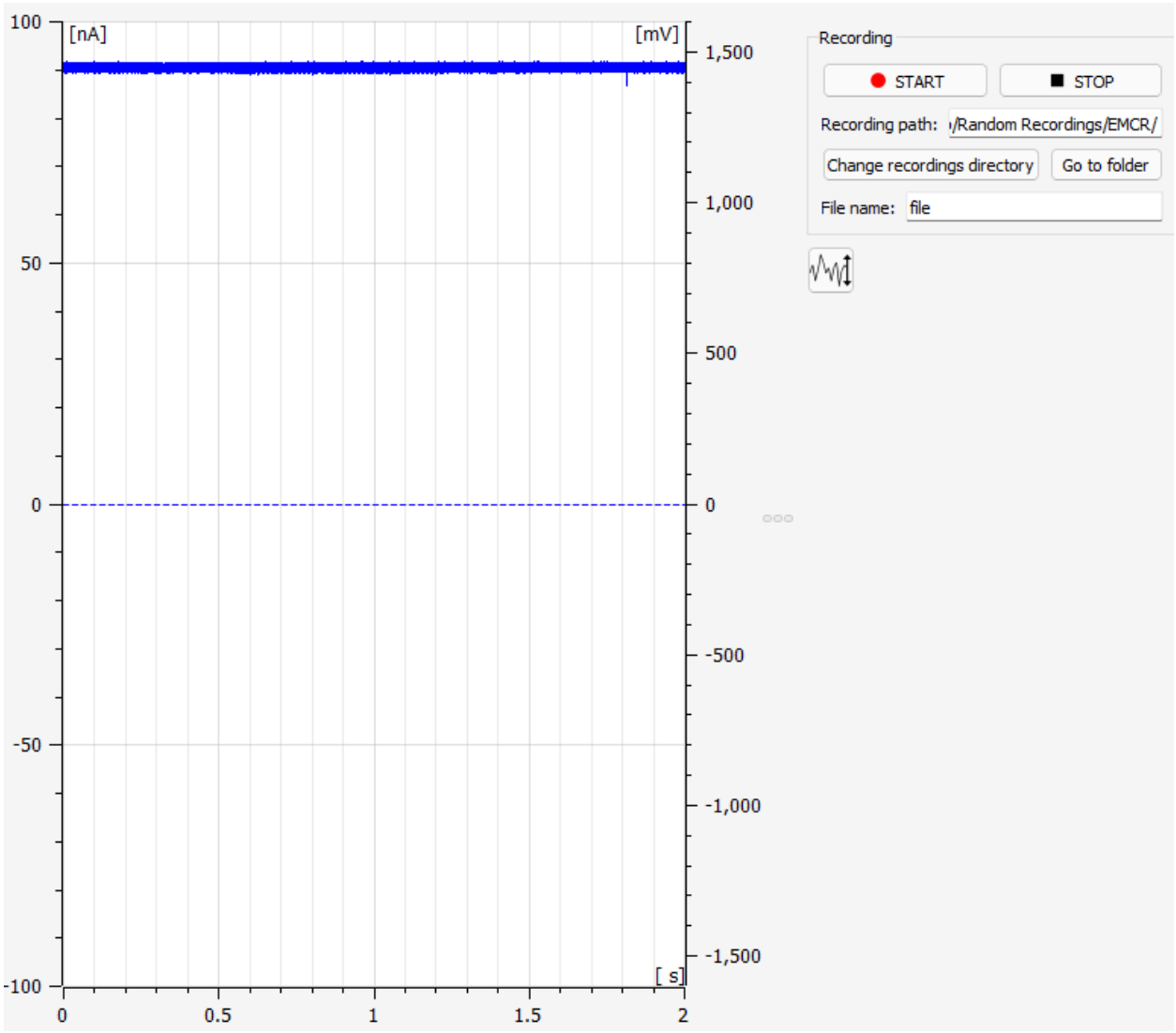
The central part of the software can display the acquired data in several formats:

- Gapfree
- IV Graph
- Event Detection
- Spectrum

Only one of these options can be selected at a time, and only the Expanded channels are shown. Each acquisition modality has some controls on the right side. Most of these controls display a help tooltip by hovering the mouse onto a specific button.

By default the trace for channel 1 will be Expanded at the startup.

Gapfree



The central window of the Graphical User Interface displays the acquired input current channel (or channels for multichannel devices) and the control voltage in an oscilloscope-like fashion.

The currents are shown as solid lines, while the voltages are dotted lines.

You will be able to interact with the current plot while the cursor is on the left part of the graph and with the voltage when the cursor is on the right.

Gapfree Controls

- Start, stop and configure recordings (the topic of recordings is better described in the following paragraph)
- Auto zoom the y axis

Recording

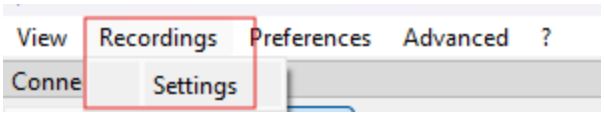
By pressing the **START** button, a recording of the selected channels will begin.

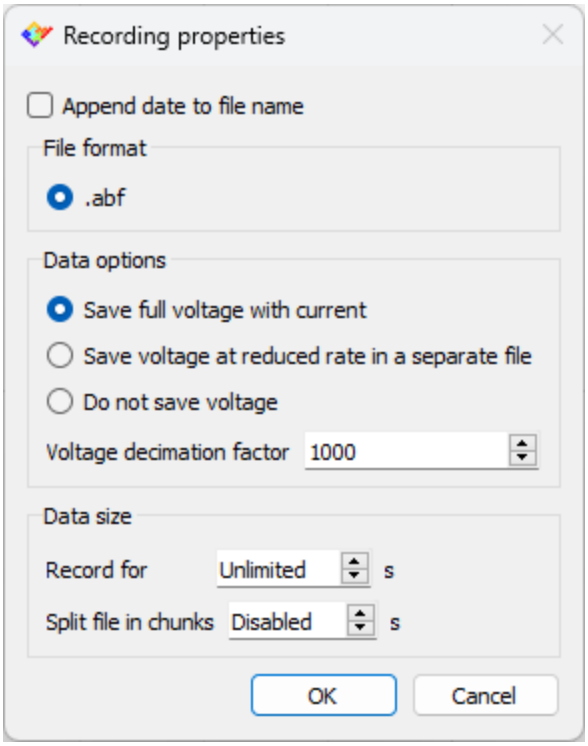
You can stop the recording manually by pressing the **STOP** button.

The **Recording path** is the base directory in which all the recordings will be stored, you can change it by clicking the **Change recordings directory** or navigate to it by pressing the **Go to folder** button.

To edit the file name, simply change the content next to the file name label.

Other recording options can be found in the **Recordings** menu.





NOTE: Certain devices have a very high throughput. Since both currents and voltages are saved in the same file by default, the user can choose not to save the voltages (making the files 50% smaller), or to downsample the voltages (making them practically irrelevant in size but still usable for analysis).

NOTE: in order to have the **Unlimited** and **Disabled** options for the **Record for** and **Split file in chunks** respectively, set the numeric field to 0.

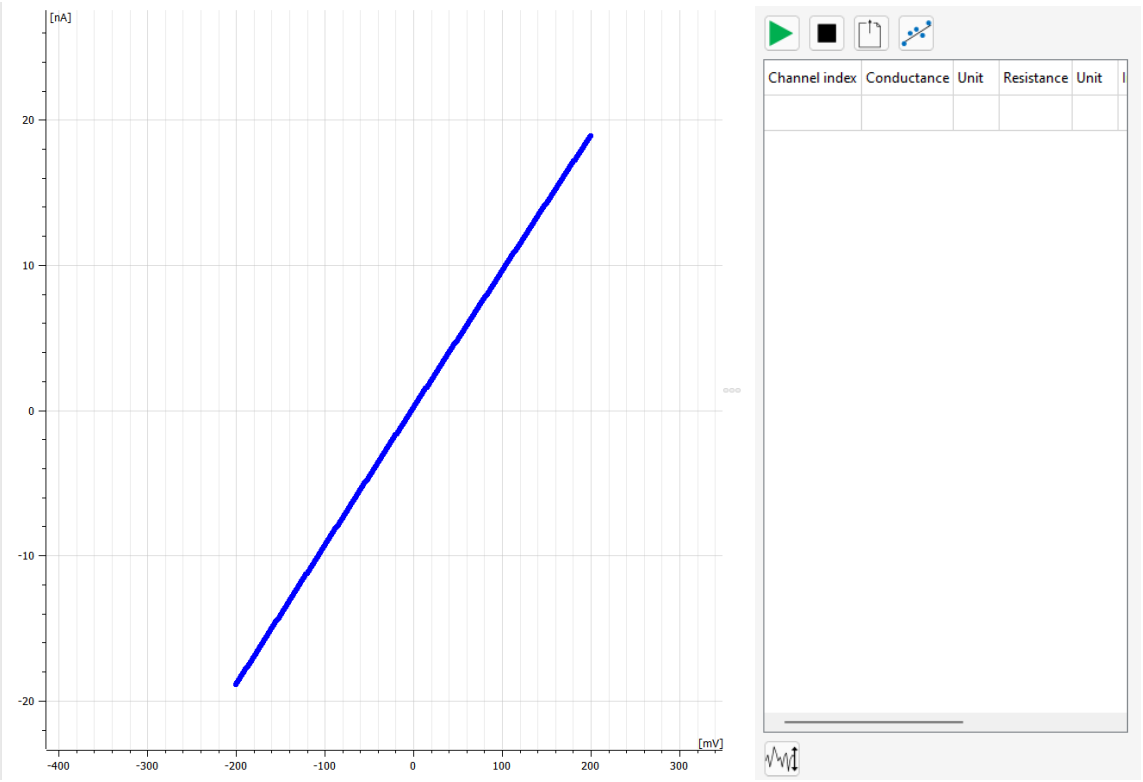
Scripts

In the EMCR installation folder (default path: C:\Program Files (x86)\Elements - EMCR) there's a script/abf folder which contains some simple Matlab and Python scripts that show how to load and plot the data from an .abf file.

IV Graph

The IV graph will display a plot that has currents on the y axis and voltages on the x axis.

It is important to note that this kind of analysis **only works on channels that are Expanded**.



IV Graph Controls

- Start the IV graph analysis: a reinitialization of the data will be performed to discard old data from previous protocols.
- Stop the analysis: stop the data flow from the device, the plot will not be updated anymore (until the start analysis button is pressed again)
- Export the data: export the plotted points to a CSV file of your choice
- Least square line: approximates the IV graph data with a line and populates a table with useful information. You can copy these values and paste them in a file of your choice; they will be tab separated in order to enable the user to open them as a spreadsheet
- Auto zoom the x and y axis.

IV Graph Algorithm

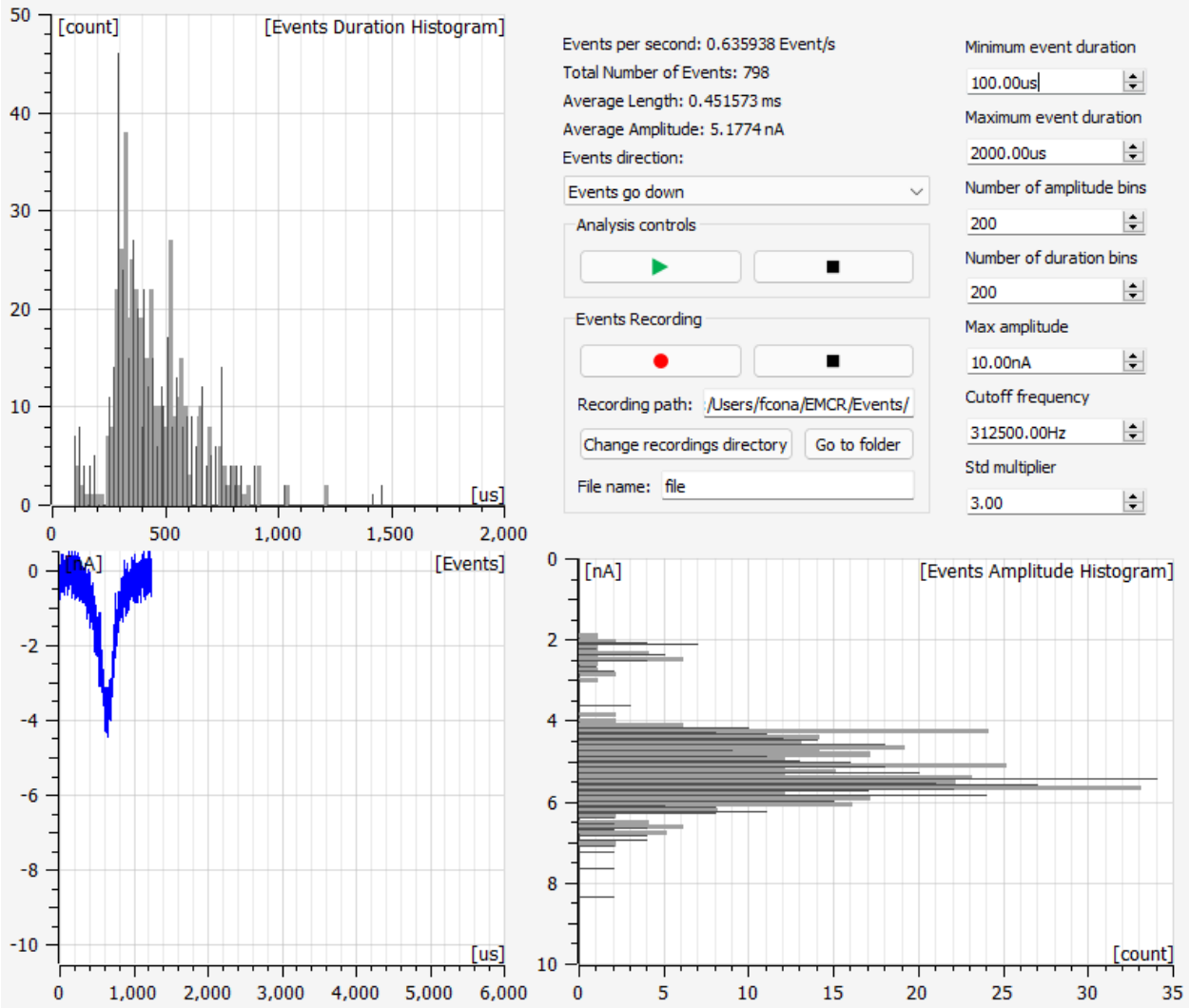
The IV Graph analysis monitors the voltage value and for each value computes the average current. Currently the x axis is divided into **3200 voltage bins**, so for example if a device can apply voltages in the range ±1600mV the resolution on the x axis will be 1mV, it won't be possible to appreciate changes smaller than this value.

Every time a voltage value is applied, the software calculates which bin better approximates that voltage and the corresponding current is accumulated. Then the average is calculated to draw a [V, I] pair dot in the plot. If a previously observed voltage value is acquired again, the dot

corresponding to the same voltage bin is updated with the new current values, taking the average of the new and old current values.

Event Detection

The **Event detection** is a feature that enables users to extract pulses that diverge from the noise or baseline of the signal they are acquiring.



Its main goal is to help scientists to extract only significant information from the signal, discarding the baseline, reducing the overall data size and providing them with meaningful and aggregated information.

The result of the Event detection is an HDF5 file whose structure can be found in Appendix A of this document.

The HDF5 file format is free and open source, and the files can be opened using the free software **HDFView**.

Event Detection Controls

- Start the event detection analysis: a reinitialization of the data will be performed to discard old data from previous protocols
- Stop the analysis: stop the data flow from the device, the plot will not be updated anymore (until the start analysis button is pressed again)
- Start, stop and configure recordings (the topic of recordings is better described in the following paragraph)
- Set the analysis parameters: see the event detection algorithm paragraph
- Have a quick overview of the events statistics

Recording

By pressing the **START** button, a recording of the selected channels will begin.

You can stop the recording manually by pressing the **STOP** button.

The **Recording path** is the base directory in which all the recordings will be stored, you can change it by clicking the **Change recordings directory** or navigate to it by pressing the **Go to folder** button.

To edit the file name, simply change the content next to the file name label.

Scripts

In the EMCR installation folder (default path: C:\Program Files (x86)\Elements - EMCR) there's a script/events hdf5 folder which contains some simple Matlab and Python scripts that show how to load and plot the events from an .hdf5 file.

Event Detection Algorithm

Objectives

The algorithm is designed to:

- Be memory efficient
- Be computationally efficient
- Use less space than a raw recording
- Extract a baseline for the signal

The algorithm is **not** designed to:

- Be 100% accurate
- Yield accurate results with a fast changing stimulus

Explanation

To extract the events the raw signal is filtered twice.

The first time the signal is filtered with a Butterworth first order IIR filter with a 500Hz cutoff frequency.

The result of this filter will be used as the baseline.

The baseline is then subtracted from the current values in order to have zero-centered current values (this is useful because it allows the user to appreciate the real amplitudes of the events without any offsets introduced by the applied voltages).

The resulting signal is then filtered again with the user input cutoff frequency to reduce the high frequency noise. Such cutoff frequency heavily depends on the SR of the experiment. If the user does not know what frequency should be set, a good rule of thumb is to choose **SR/4**, so that the reduction in noise is low but the risk of neglecting real events is minimized.

Each current value is then compared to a threshold value, calculated as **STD*N** where N is the user input parameter Std multiplier, and STD is the estimated standard deviation of the current signal. Greater values for N will lead to less more evident events, while lower values will identify more events but could also save noise instead of real events.

A candidate event is effectively confirmed (and saved to file when the recording is activated) if its duration lies between the input parameters Minimum events duration and Maximum events duration, and if its amplitude is less than the input parameter Max amplitude.

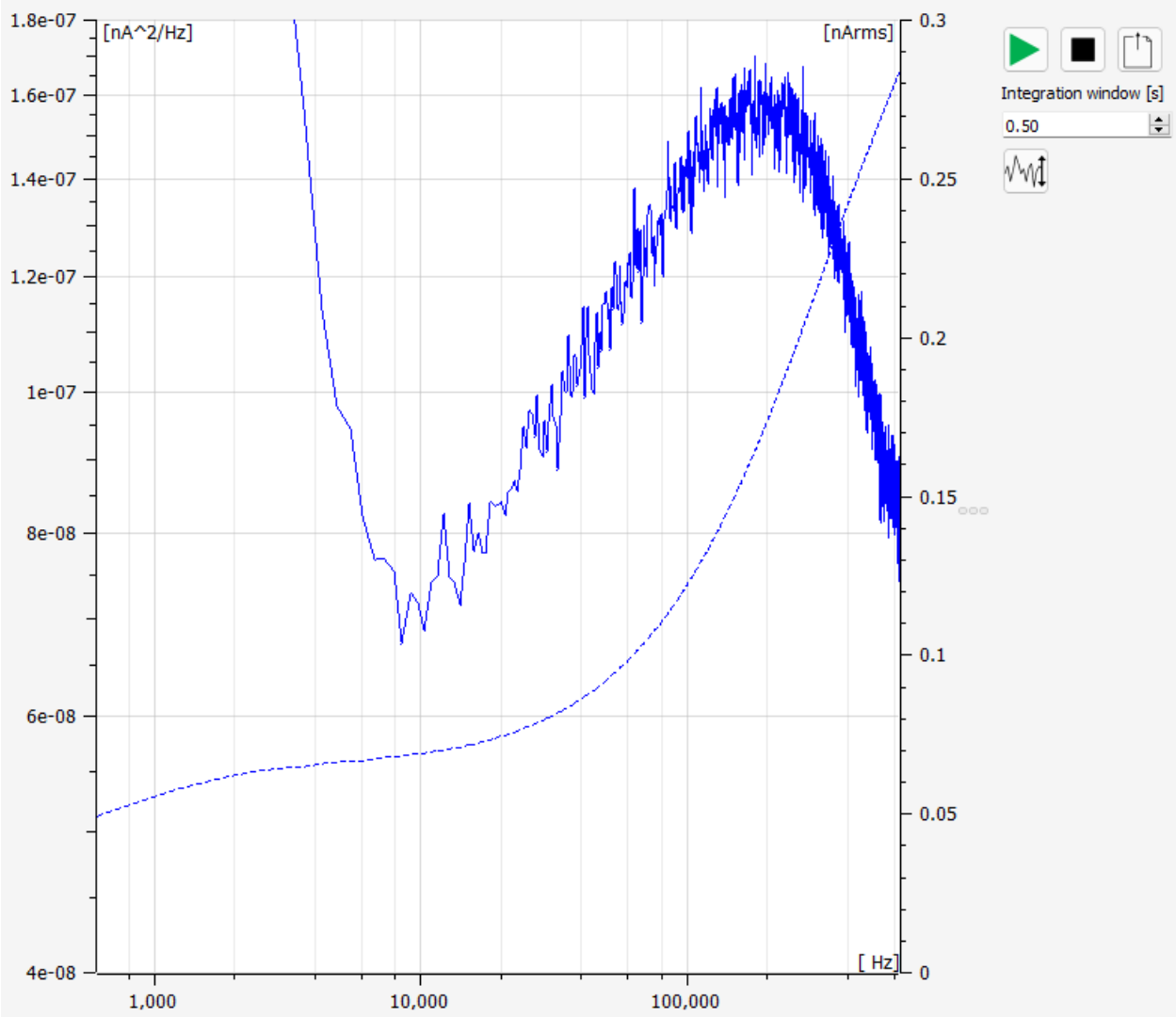
Confirmed events are used to update the events statistics and histograms. To compute the Events Duration Histogram, the time range [0, Maximum event duration] is divided into Number of duration bins (input parameter) subsets. For each duration subset the number of events with the duration such subset are counted and the number is represented with a vertical column. Analogously, to compute the Events Amplitude Histogram, the range [0, Max amplitude] is divided into Number of amplitude bins (input parameter) subsets, and a horizontal line is drawn to represent the events count for each amplitude subset.

There is virtually no limit in the file size generated from this analysis and no overhead when processing them. However, if you need to modify them, make sure to save a copy before any change, otherwise all the data will be overwritten.

Spectrum

The spectrum of a signal and the integral rms (Irms) noise can be estimated and visualized in real time by clicking on the **Spectrum** tab. The spectrum is plotted with a solid line, while the IRms is plotted with a dashed line.

It is important to note that this kind of analysis **only works on channels that are Expanded**.



Spectrum Controls

The right part of this widget will allow the user to perform the following operations:

- Start the spectrum analysis: a reinitialization of the data will be performed to discard old data from previous protocols.
- Stop the analysis: stop the data flow from the device, the plot will not be updated anymore (until the start analysis button is pressed again)
- Export the data: export the plotted points to a CSV file of your choice
- Parameters: see the spectrum algorithm paragraph
- Auto zoom the y axis

Spectrum Algorithm

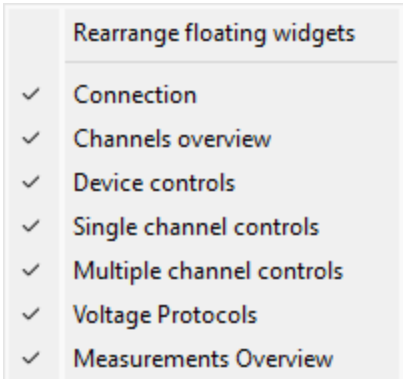
The spectrum is estimated using the periodogram method. An amount of data corresponding to at least the defined integration window is collected. The data is then divided into blocks of 2048 samples each. An FFT is computed for each block and the spectrum is obtained as the average of the squared amplitudes of all the FFTs[1].

The Irms is derived from the spectrum by taking the cumulative sum of the spectrum[2] and then the square root of each component. The last value of the Irms should match the rms value computed by the Measurement overview widget, with a small tolerance due to the fact that the 2 analyses don't necessarily use the same chunks of data.

Dockable widgets

The software makes a great use of dockable widgets. Such widgets can be displayed, closed, moved around or embedded in one of the borders of the Graphical user interface.

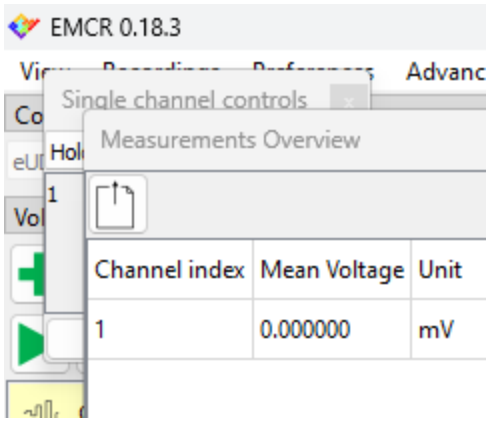
They can be enabled or disabled by using the **view** menu in the upper left corner.



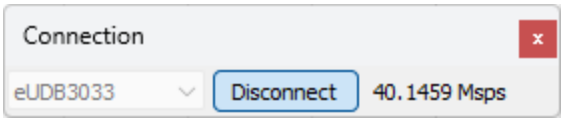
Rearrange floating widgets

This functionality helps in retrieving floating widgets that may have gone partially out of the screen and cannot be dragged manually. By clicking all floating widgets are sorted near the upper left corner of the main interface

[1] A scaling factor has to be applied for the spectrum to have physical sense. The scaling factor equals 2/N where N is the total number of samples used for a single estimation, i.e. the number of samples corresponding to the integration window.
[2] The DC component of the spectrum (null frequency) is not taken into consideration for the computation of the Irms.



Connection

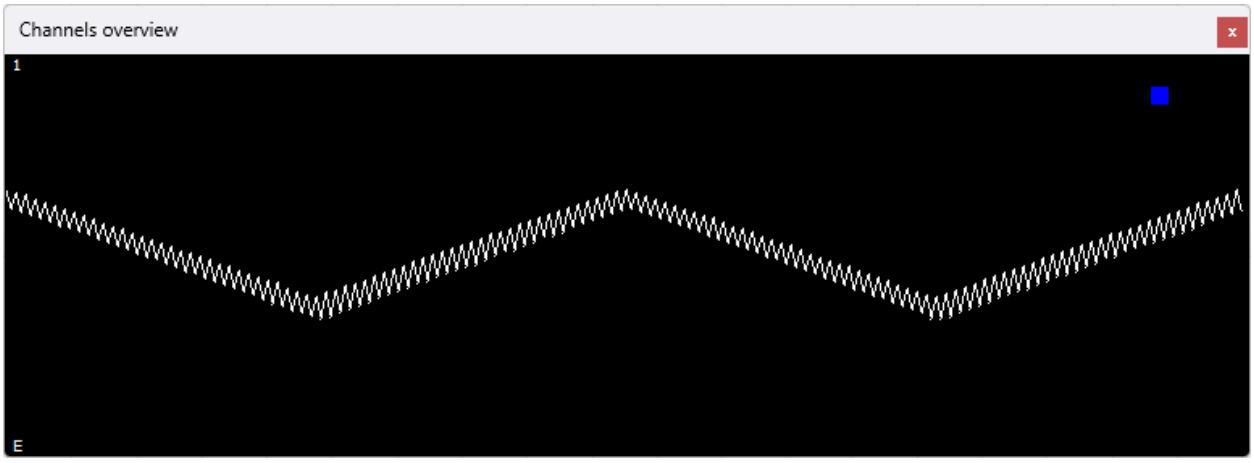


The connection widget will show the serial number of the connected device, together with an estimation of the sampling rate measured as **Samples per second**.

Voltage protocols

The voltage protocols are slightly more complex than the other features described here. For this reason a complete guide on this topic can be found on the resource page of our website.

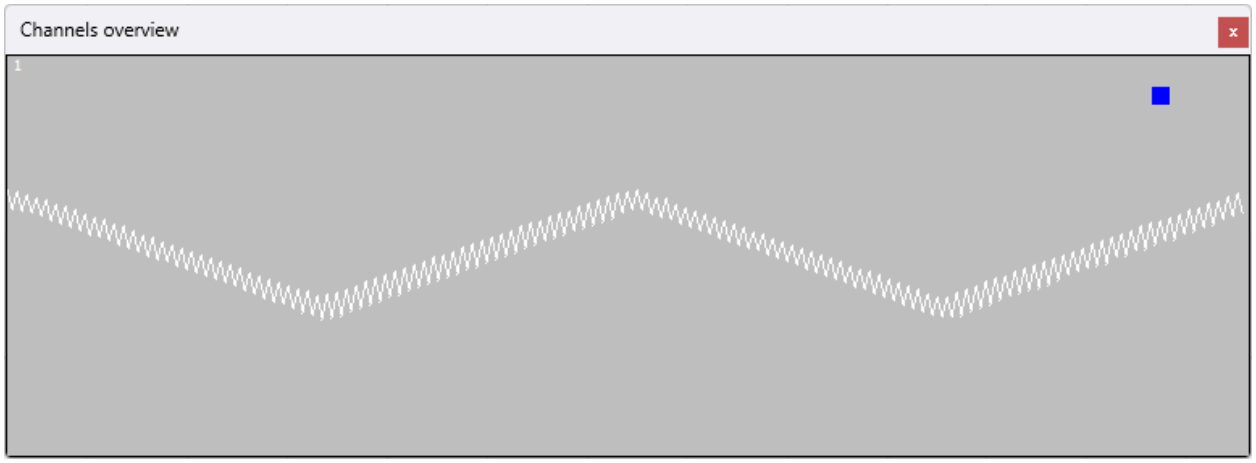
Channels overview



The **Channels overview** is designed to provide an overview of all the channels of a device.

In this plot only current values are drawn with a very low resolution, in order to reduce the computational requirements for updating this plot.

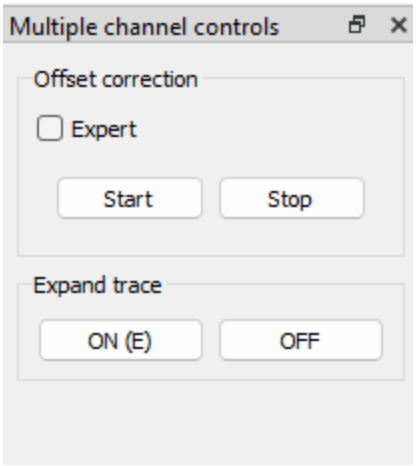
A channel can either be **SELECTED** or **NOT SELECTED**. A selected channel will have a black background while a not selected channel will have a gray background, as the one shown in the following figure.



The controls in the **Multiple channels controls** widget are applied only to selected channels.

This widget also provides useful information about the channel status, represented by the label at the bottom left corner. E.g., in the first figure of this section the label E specifies an expanded channel (i.e., a channel visible in the main plot). In the upper right corner, the colored square indicates the channel color within the central plot.

Multiple channels controls



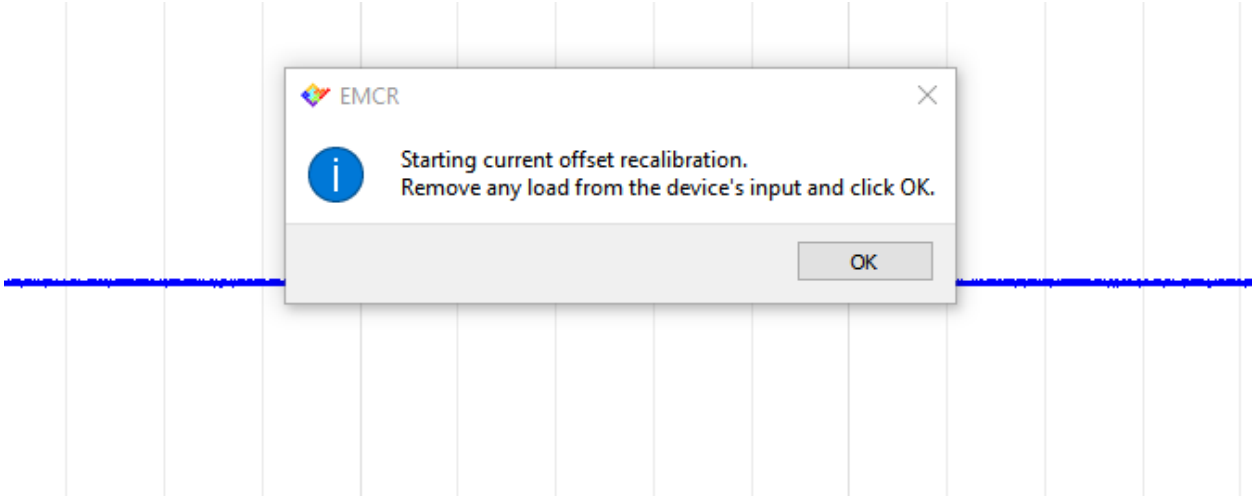
The buttons in the **Multiple channels controls** widget operate on all channels selected in the **Channels overview**.

Offset correction

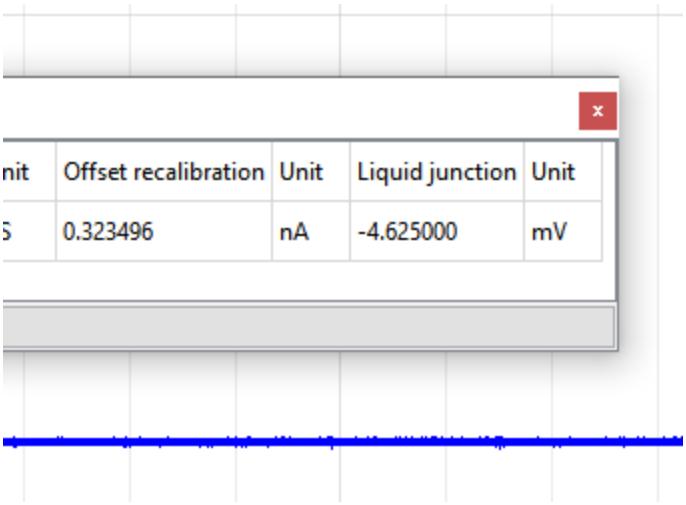
Both the current and the voltage offset of a device can be corrected by using the **Offset correction** controls. This control comes with a basic and an expert version

Basic

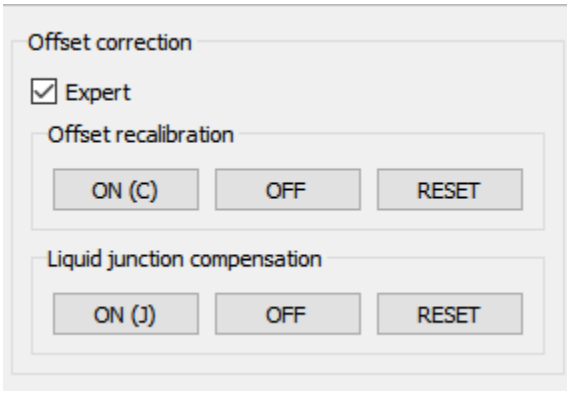
The basic version works as a wizard, so when the start button is pressed, a set of instructions will pop up in order, to guide the user through the recalibration of the current and the voltage offset. This procedure calls in a specific order the same controls that are available in the expert version and that are described in the next paragraph.



At the end of the procedure the results will be shown in the Measurement overview widget.



Expert (Offset recalibration)



Pressing the **ON** button will activate the offset recalibration procedure on the selected channels (and will append the letter C to their labels in the **Channels Overview**). This procedure has to be performed in open circuit, i.e. with no load connected to the amplifier's input. The offset recalibration estimates the current offset and subtracts it, so that the current in open circuit is as close to 0 as possible.

The procedure will stop by itself, or the user can interrupt it using the **OFF** button.

The **RESET** button will discard the corrected offsets.

The corrected offsets can be viewed and modified in the Single channel controls widget.

Expert (Liquid junction compensation)

Pressing the **ON** button will activate the liquid junction compensation procedure on the selected channels (and will append the letter J to their labels in the **Channels Overview**). This procedure

has to be performed with a resistive load connected to the amplifier's input. The liquid junction compensation modifies the voltage applied to the DUT in order to compensate for electrode voltage offset. This way, when the user applies 0 V the actual potential applied on the DUT is tuned to compensate for the electrode potential, so that the net current flowing is as close to 0 as possible.

The procedure will stop by itself, or the user can interrupt it using the **OFF** button.

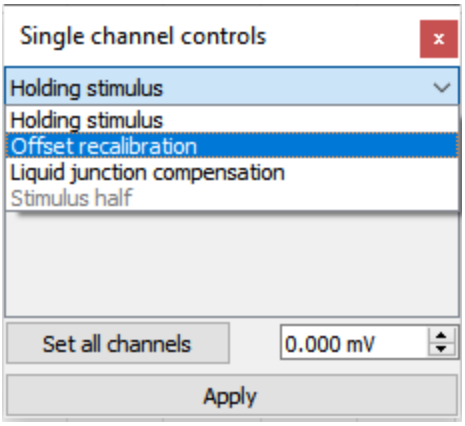
The **RESET** button will discard the compensated voltages.

The compensated voltages can be viewed and modified in the Single channel controls widget.

Expand trace

Pressing the **ON** button will make the selected traces visible in the central plot and append the letter E to their labels in the **Channels Overview.** Pressing the **OFF** button will remove the plots from the central plot.

Single channel controls



This widget provides information about the current status of the device and lets the user apply a certain degree of control on the specified channels.

Holding stimulus

By selecting **Holding stimulus** the user will be able to apply a specific voltage to each channel independently. Such voltage is added on top of the selected voltage protocol. The **Set all channels** button and the corresponding spinbox, can be used to set all the voltages at once. The voltages will be applied when the **Apply** button is pressed or **RETURN / ENTER** is pressed on the keyboard.

Offset recalibration

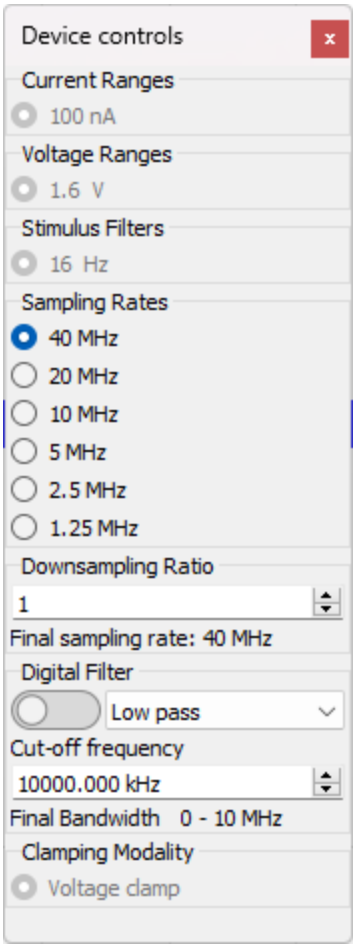
The **Offset recalibration** displays the exact current that has been corrected to recalibrate the offset. Such value can be manually tuned, in case the value automatically returned by the recalibration algorithm was not satisfying.

Liquid junction compensation

The **Liquid junction compensation** gives the exact voltage that has been applied to compensate for the electrodes. Differently from the **Holding stimulus**, the value applied with this control is not reflected in the acquired voltage trace, since this control acts as a recalibration of the voltage offset.

Other options could be available (e.g. Stimulus half) for certain device families, and are grayed out for devices that do not support such features.

Device controls



This widget is used to control various device global settings. Different devices will have different options.

Sampling rate and Downsampling ratio

The sampling period of the device can be modified via the **Sampling rate** and **Downsampling ratio** controls. Both of these controls do basically the same two things, that is:

- Apply a low pass anti-aliasing filter with cutoff frequency equal to SR/4 where SR is the final sampling rate
- Decimate the data in order to get the desired sampling rate

With these two controls combined, the final sampling rate equals the **Sampling rate** control divided by the **Downsampling ratio**. The main difference between the two is that the **Sampling rate** control sets the sampling period of the device, so reducing this value actually reduces the amount of data per time unit received by the computer and the computational resources required to process the data. On the other hand the **Downsampling ratio** is a software feature, so even if the ratio is increased the computer still receives the same amount of data, so the computational resources do not benefit much from a reduction of the sampling period obtained this way.

Digital Filter

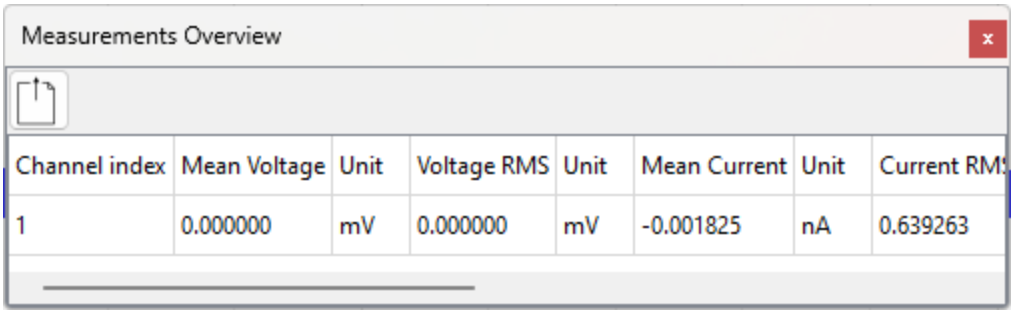
The digital filter allows the user to enable a simple 1st order IIR digital filter.

The filter type can be either low pass or high pass, and the cutoff frequency can be set between 1Hz and SR/4.

When the downsampling ratio is activated (value greater than 1), the digital filter works also as anti aliasing filter for the decimation, so its behavior changes in the following ways:

- The filter is always active
- The filter is always low pass
- The cutoff frequency range goes from 1Hz to SR/(4*downsampling ratio)

Measurements overview

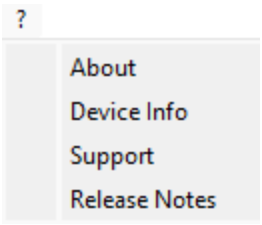


The **Measurement Overview** gives a brief summary of the most relevant acquisition figures, such as the mean current or the RMS noise.

Please notice that the conductivity is estimated by simply dividing the mean current by the mean voltage, so if the offsets are not properly corrected the value might not be reliable[3]. In order to get better results the I/V graph can be used.

The information in the table can be exported in a CSV file by clicking the **export** button  .

The ? menu

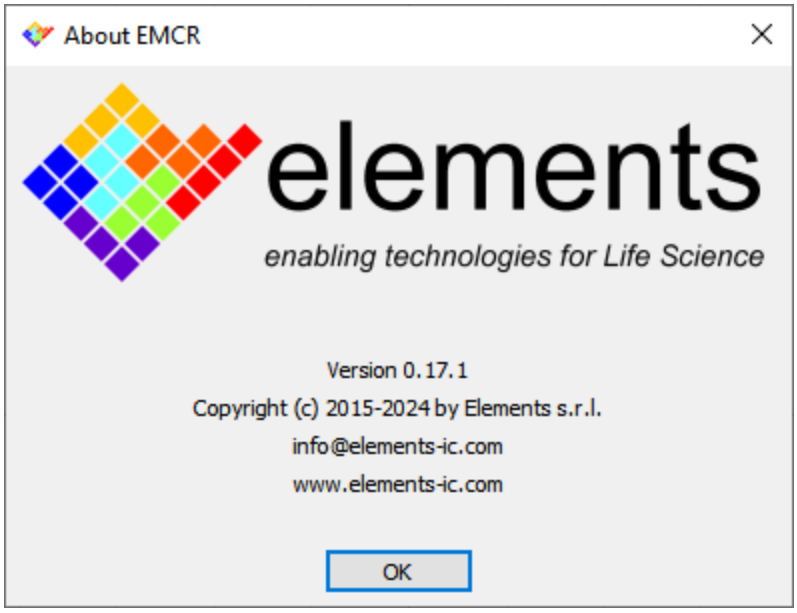


The **?** menu gives access to some information about the software or the device.

About

The About window will show some general information about the software.

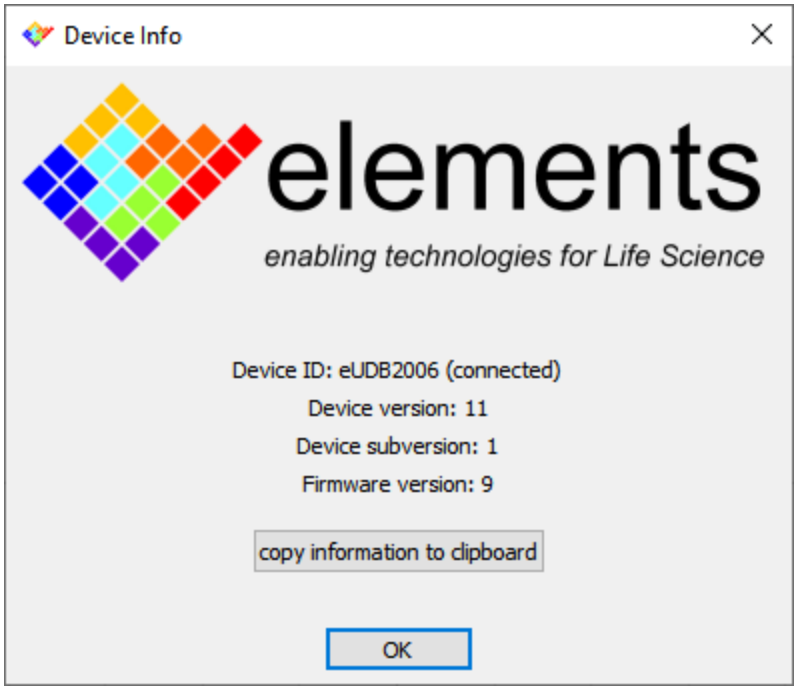
[3] If the estimated value is negative a generica -1 is displayed.



Device Info

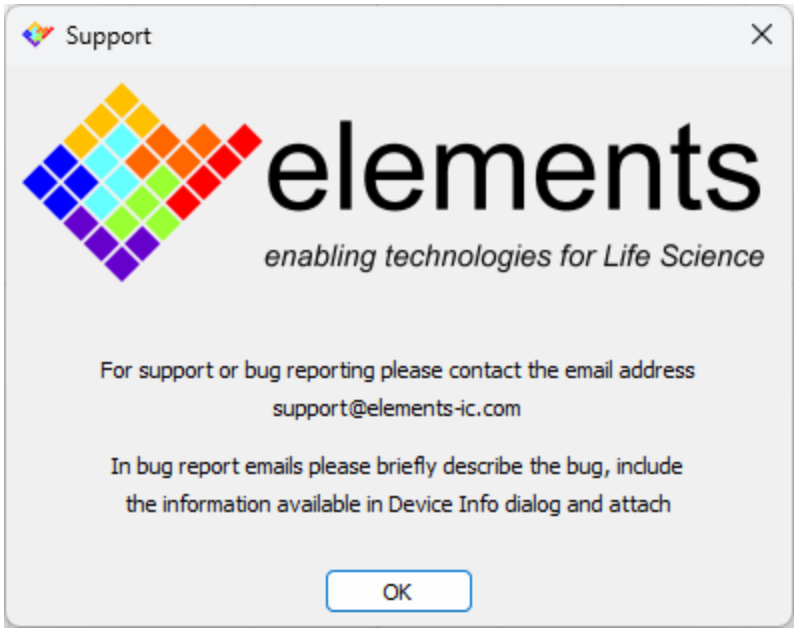
The Device Info window shows detailed information about the device currently connected (or the selected device if the connect button has not been pressed yet), such as the device ID (i.e., the device Serial Number), the device version and the firmware version.

This information is very useful especially when requiring support, so the bottom button will conveniently copy the information to the clipboard, so that it can be pasted in an email.



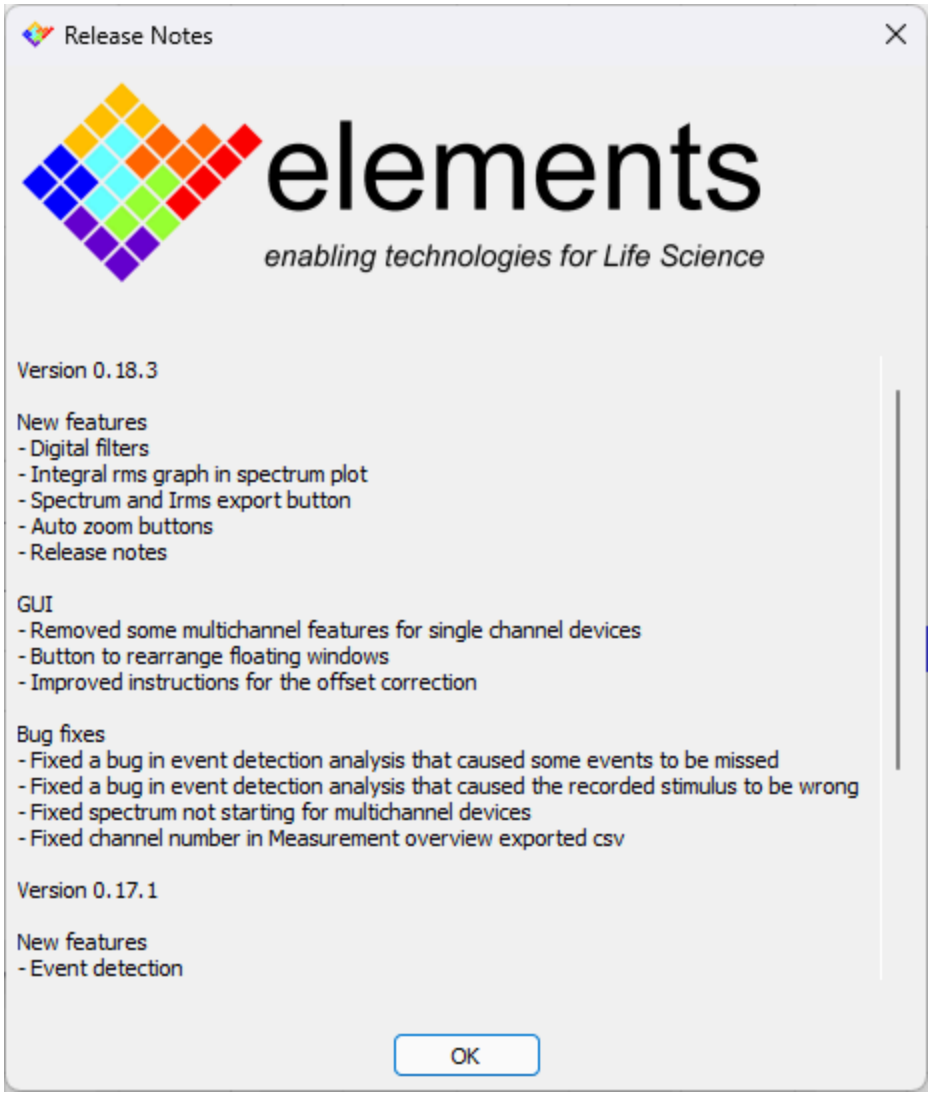
Support

The support window contains information on how to contact the technical support and what kind of information you should provide to make the support service more efficient.



Release Notes

Gives an overview of the main changes of every official software release



Notes on performances

The software is designed to use as little resources as possible.

If you notice that the software performance starts deteriorating (for example if the estimated sampling rate does not match the selected one) you could try some of the following tricks to improve the speed of the software.

Close unnecessary programs

If you're using a browser, listening to music or using any other program beside EMCR, consider closing them to minimize the amount of open processes which the operating system needs to run.

Remove all the expanded plots

The process of drawing the plots and in general producing the data needed by the plot is computationally demanding. When no data is plotted the software can stop processing the corresponding data, freeing some resources.

Close the channels overview

If the Channels Overview is not needed, consider closing its widget, so that the software can stop producing unnecessary data, thus freeing resources.

Close the measurement overview

Even though the measurement overview could be pretty useful, it can be computationally intensive, especially with multichannel devices. Therefore keep it closed if you don't need to continuously monitor the values displayed there.

Appendix A: Elements HDF5

Misc

This Dataset will be common to all the different kinds of recordings

Version 1

Compatible with

- Events v1
- Gapfree v1
- Episodic v1

Structure

- Misc
    - Date time
    - Version : 1
    - Acquisition modality (Gapfree, Episodic, events)
    - Device type
    - Device name
    - Device serial number
    - Clamping modality: (Current clamp, voltage clamp)
    - Acquisition sw

Events

Version 1

- ch0
    - Baseline
        - Current Uom
        - Current resolution
        - Current multiplier
        - Voltage Uom
        - Voltage resolution
        - Voltage multiplier
        - I: Dataset

            - Sampling rate (Hz)
            - Sampling period (s)
        - V: Dataset
            - Sampling rate (Hz)
            - Sampling period (s)
    - Events
        - Current Uom: the unit of measurement
        - Current Resolution: the resolution of each data
        - Current Multiplier: multiply by this number to go to the base unit of measurement (ie: 1e-9 for nA)
        - Voltage Uom
        - Voltage resolution
        - Voltage multiplier
        - Sampling rate (Hz)
        - Sampling period (s)
        - ev0: Readout Dataset
            - Sample offset: the position measured in samples from the beginning of the recording
            - Stimulus: the value of the stimulus (assumed constant) for the event
        - ev1
        - ..
        - evn
- ch1
- ..
- chn

Gapfree

Version 1

Electrophysiology Channels:

- ch0
    - Current Uom
    - Current resolution
    - Current multiplier
    - Voltage Uom
    - Voltage resolution
    - Voltage multiplier

        - I: Dataset
            - Sampling rate (Hz)
            - Sampling period (s)
        - V: Dataset
            - Sampling rate (Hz)
            - Sampling period (s)
- ch1
- ..
- chn

Other measurements

- channel_name_0: could be different things (Temperature, light intensity, buffer pressure...)
    - Measurement Uom
    - Meas resolution
    - Meas multiplier
    - Meas: Dataset
        - Sampling rate (Hz)
        - Sampling period (s)
- channel_name_1
- ..
- channel_name_n

Episodic

Version 1

- ch0
    - Sweeps
        - Current Uom: the unit of measurement
        - Current Resolution: the resolution of each data
        - Current Multiplier: multiply by this number to go to the base unit of measurement (ie: 1e-9 for nA)
        - Voltage Uom
        - Voltage resolution
        - Voltage multiplier
        - Sampling rate (Hz)
        - Sampling period (s)

        - sw0: Current-Voltage Dataset (multidimensional array with current in the first line and voltage in the second)
            - Sample offset: the position measured in samples from the beginning of the recording
        - sw1
        - ..
        - swn
- ch1
- ..
- chn