Neuroelectrics User Manual

– Part 3. NIC2 –

CAUTION: INVESTIGATIONAL DEVICE
Limited by United States law to investigational use.

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Software version:

NIC2 v2.1.0

About the NIC User Manual

The **NIC User Manual** is **Part III** of the Neuroelectrics User Manual.

The **Neuroelectrics User Manual** includes three parts:

- **Part I:** Enobio User Manual or Starstim User Manual
- **Part II:** Electrode User Manual
- **Part III:** NIC User Manual

Before you use the Enobio or Starstim system, read the three parts of the Neuroelectrics User Manual. The NIC User Manual does not negate the need of reading the Enobio/ Starstim and Electrode parts.

The PDF version of all parts of the Neuroelectrics User Manual can be found under the Manual section of Neuroelectrics webpage:

www.neuroelectrics.com/documentation

Change Record

Issue	Date	Changes made
1.0	2016.10.04	First version of the manual for NIC2 (v2.0.2)
1.1	2016.11.08	NIC2.0.3 update
1.2	2016.12.05	NIC2.0.4 update
1.3	2017.02.28	NIC2.0.5 update
1.4	2017.07.25	NIC2.0.6 update
1.5	2018.03.01	NIC2.0.9 update
1.6	2018.10.26	NIC2.0.10 update
2.0.11_1.0	2019.05.27	NIC2.0.11 update
2.1.0_1	2022.03.08	NIC2.1.0 update

Table of Contents

I. Introduction

NIC stands for Neuroelectrics Instrument Controller. NIC is the application that allows a computer to interact with Neuroelectrics' devices. NIC is prepared for both wired and wireless connections to control the devices.

NIC allows EEG data to be streamed and analyzed in real-time with both Enobio and Starstim devices. It provides a secure way to define the stimulation parameters for Starstim units. NIC is a powerful platform that is equipped with basic and advanced modes to design and monitor any experiment involving electroencephalography (EEG) and/or non invasive brain stimulation with transcranial electrical stimulation (tES).

NIC2 corresponds to the second version of the former NIC. NIC2 has a completely new interface that provides a unique experience to both clinicians and researchers in Neuroscience departments. The new graphical user interface (GUI) simplifies the interaction with the advanced technology embedded in Neuroelectrics devices.

Enobio 8

Starstim 32

I.1
System Requirements

NIC2 is only compatible with Neuroelectrics devices. NIC2 must be used to control your device. In case you need your device to interact with a third-party software, contact Neuroelectrics support team for assistance.

The following devices are compatible with NIC2:

- Enobio (8/20/32) *
- Enobio (8/20/32) 5G
- Enobio Research (8/20/32)
- Starstim 8 *
- Starstim 8 5G
- Starstim tES *
- Starstim 20
- Starstim 32

* Former versions of these devices (shipped until October 2014; with firmware < 1251) are not compatible with NIC2. Contact our sales team if you would like to benefit from NIC2 features.

The computer used to install NIC2 needs to have the following system requirements (minimum):

- Operating systems compatible:
  - Windows (Vista / 7 / 8 /10)
  - Mac OS X (> Snow Leopard & x86_64 processors)
- Processor: 1.6 GHz
- RAM: 2 GB
- Interface: USB, or WiFi
- Screen resolution: 1280 x 768

I.2

Installation

Installation files

The latest version of NIC2 can be downloaded from the Software section of Neuroelectrics® website: www.neuroelectrics.com/downloads/

Alternatively, the installation files can also be found in the USB stick included in the package wherein the device was shipped.

To install NIC2, first choose the installation file according to the operating system of the computer where the software is intended to run. For Windows computers choose the *.exe file and follow the installation instructions; for MAC OS X choose the *.zip file and unzip it.

In Mac OS X

The installation in computers running Mac OS X is simple and straightforward. Double click on the unzipped NIC2 application file and follow the installation instructions. The installation should not take longer than a few minutes.

The user might need to first allow the computer to install programs from unidentified developers. For that, go to System Preferences / Security & Privacy and choose Anywhere in the Allow apps downloaded from. Administrator credentials are required to modify these settings.

The WiFi™dongle provided with the system is not compatible with Mac OS X system. Do not use the WiFi™dongle with a computer running Mac OS X.

In Windows

If using the cable connection option, a few steps are needed to install the USB drivers in Windows, before using NIC2. After installing NIC2, follow the instructions below:

In Windows 7, with the device switched on and connected via cable, go to the Control Panel definitions and select Device Manager. Righ-click on CDC Virtual COM and choose Update Driver Software. Select the driver location as: C:\Program Files\NeuroElectrics\NIC2\usbdriver. After this, you may launch NIC2 and proceed as described in the next page.

In Window 8, with the device switched on and connected via cable, go to C:\Program Files\NeuroElectrics\NIC2\usbdriverwin8. Execute and install the driver driver-atmel-bundle-7.0.888. After this, you may launch NIC2 and proceed as described in the next page.

In Windows 10 there is no need to install any drivers. NIC2 will be ready to use as soon as the installation is completed.

For wireless connections with Windows systems, it is recommended to use the – WiFi™– dongle provided with the system.

I.3

NIC2: Home Pane

NIC2 displays the **Home** pane when launched.

In NIC2 window, the left-side bar is always visible and it contains the Neuroelectrics® icon, the unlocked NIC2 panes and the version of NIC2 installed.

1 By clicking and dragging the Neuroelectrics® icon, NIC2 window can be moved.

2 The Pane bar shows all the active panes.

3 The installed version of NIC2 is indicated in the Pane bar below the active panes. Make sure you have the latest version installed to get the best of your device. The latest NIC2 version is available on the download section of Neuroelectrics website:
https://www.neuroelectrics.com/downloads/

4 **Access to user manuals**. By clicking the icon on the bottom left corner, you have access to the manuals of your device, electrodes and NIC2. For NIC2 to know which is the proper manual for your device it is necessary to get the device connected.

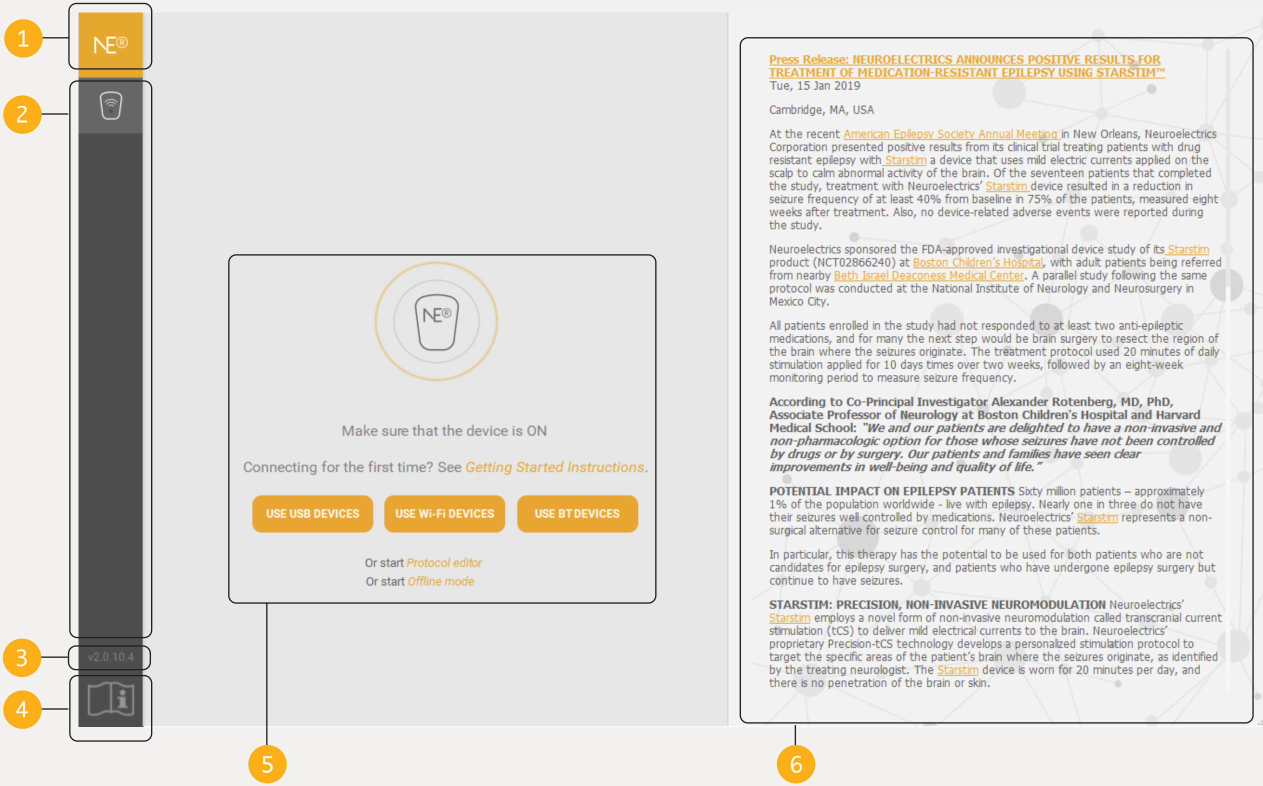
5 **Connection Type**. The first thing to do after launching NIC2 is to choose the type of connection to interact with the device. NIC2 is prepared to interact with Neuroelectrics® devices that use WiFi™ and/or USB. Select the type of connection compatible with your device.

Alternatively, it is possible to proceed without connecting to any device by either clicking on the Protocol editor command or the Offline mode one. In the first case, NIC2 will allow protocols to be created based on the features of the last device paired with NIC2. In the second case, NIC2 will allow loading previously recorded files to check the EEG signals within.

Read the **My Devices** chapter (pp. 14-15) to learn on how to establish the connection between NIC2 and your device.

6 **News**. The latest news shown on Neuroelectrics® website are also displayed in NIC2. Make sure that the computer has Internet connection to have the news updated.

NIC2 Home Pane



II. My Devices

After selecting the type of connection, you are directed to the **My Devices** section. The general settings can be defined before pairing the device with NIC2.

1 Click on the **scan for devices** button to command NIC to search for devices. NIC only finds devices that are switched on and using the connection type selected in the **Home** pane.

2 Select your device from the list of devices detected. The available wireless devices indicate the corresponding MAC address. When connected, NIC2 detects the type of device, the firmware version and the battery percentage level.

3 You may lock/unlock TCP connections to and from NIC (p.45), activate double blind mode (p. 58), enable the synchronizer, or invert the polarity of the EEG signal for visualization.

4 Activate the line noise filter to remove main line artifacts from the EEG data. Choose the 50 Hz option in Europe, and the 60 Hz filter for North America. Both options affect the data visualization. If the **Enable at recording** button is active, the filtering is also applied to the recorded data.

5 Choose the frequencies of the visualization filter, to be applied only for EEG visualization.

6 For stimulation, choose the type of Impedance Check (p. 55) between DC (default) and AC modes.

7 For advanced stimulation protocols, it is possible to load a custom waveform (pp. 54-55).

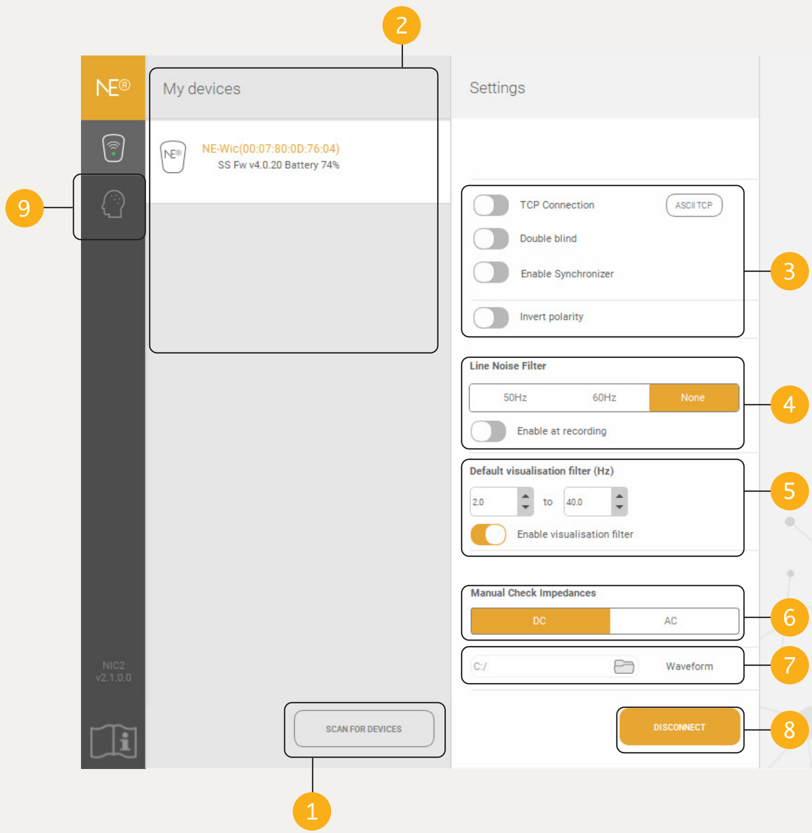
8 Finally, click on the **use this device** button to connect NIC2 with the device when all the previous settings are defined. When paired, the button will be replaced by the **Disconnect** button.

When a device is successfully connected, the type of device, the firmware version and the battery level become visible. A successful connection also lights up the LED of the device icon on the lateral pane bar. Each color of the LED has a different meaning related to the battery level:

- **grey:** device not connected
- **red:** [0 - 33] %
- **orange:** [33 - 66] %
- **green:** [66 - 100] %

9 After defining the general settings and connecting to the device, proceed to the **Protocol** pane.

My Devices



Warning:

The synchronizer should be enabled during experiments when the timing synchronization of the device with the computer and/or other external devices is required (e.g. Event-related potentials – ERPs).

When enabled, the application will perform two synchronisation processes: the first is very short and is carried out before a protocol is loaded. The second is performed afterward, while the EEG is received. It prevents starting a recording until synchronisation accuracy between the Necbox and NIC2 is accurate enough. This procedure may take a few minutes (1-3 min).

III. Protocols

With NIC2, all the experiments are managed with the protocol structure. Each protocol corresponds to one experiment, and each experiment may contain one or more steps.

Within the **Protocol** pane, all the parameters regarding the experiment can be defined. Three types of experiments can be created: EEG monitoring experiments; stimulation-only experiments, or hybrid experiments that include both EEG & stimulation.

Enobio devices only allow for EEG protocols. Starstim tES devices only allow for stimulation protocols. Starstim 8/20/32 allow for all types of protocols (EEG-only, tES-only and combined EEG & tES).

1 **Protocol List.** When NIC2 is launched for the first time, there are no protocols listed. If NIC2 has been used before, it may contain previous protocols that were saved. By clicking on a specific protocol, NIC2 displays the protocol summary in Protocol Workspace on the right side of the page.

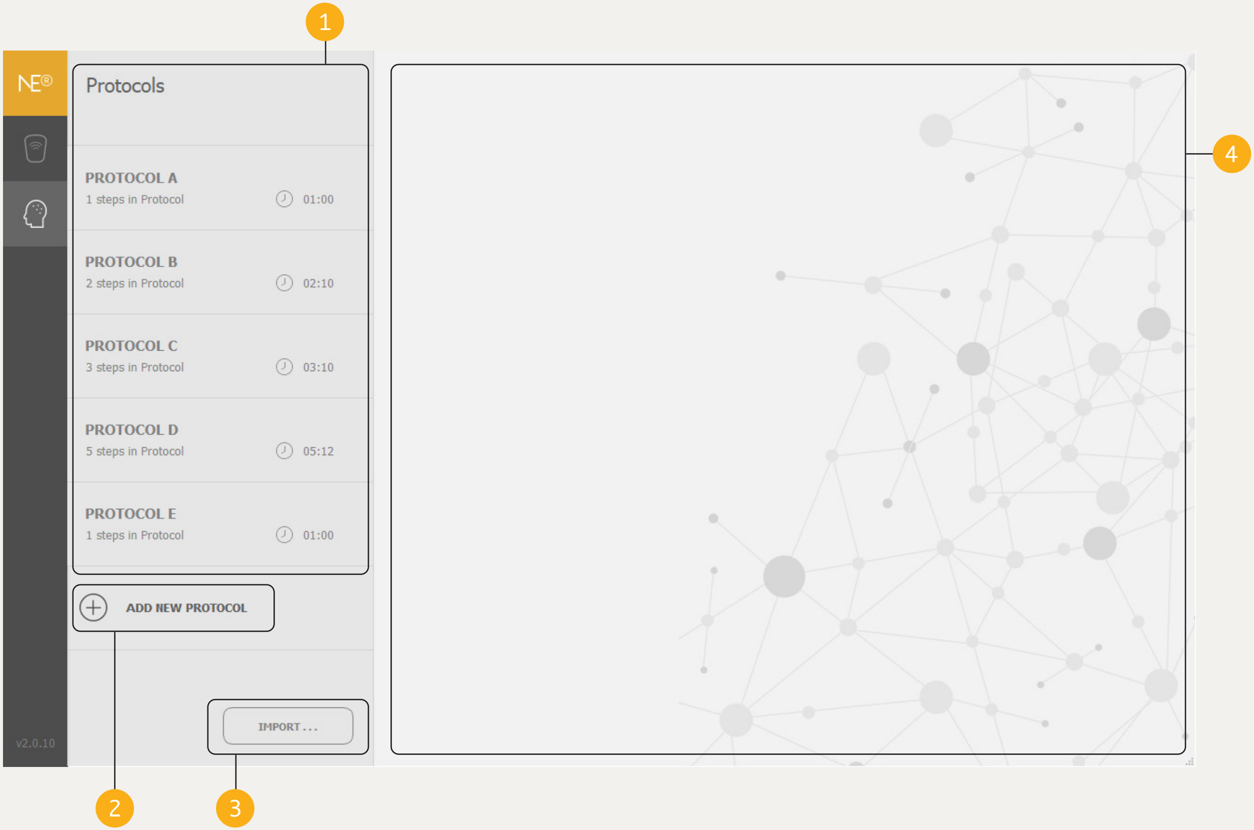
2 **Add New Protocol.** To create a new protocol, click on the **Add New Protocol** button. Consult the Protocol Design sub-chapter (pp. 18-19) to read the protocol creation instructions.

3 **Import Protocols.** NIC2 allows protocols to be imported. If a protocol is imported, any protocol with the same name will be overwritten. NIC2 is not compatible with protocols/templates created with former NIC.

4 **Protocol Workspace.** The Protocol Workspace is used for:

- Protocol Design (pp. 18-19)
- Protocol Summary (pp. 20-21)
- Stim Preview (pp. 24-25)

Protocols



1
NE®
Protocols
PROTOCOL A
1 steps in Protocol
01:00
PROTOCOL B
2 steps in Protocol
02:10
PROTOCOL C
3 steps in Protocol
03:10
PROTOCOL D
5 steps in Protocol
05:12
PROTOCOL E
1 steps in Protocol
01:00
ADD NEW PROTOCOL
IMPORT ...
v2.0.10
2
3
4

III.1
Protocol Design

Follow the next steps to create a new protocol from scratch:

1 **Protocol Name.** Start by defining the protocol name, the name should be unique. This is a case sensitive field.

2 **Step List.** Define the name and the duration of each step of the protocol. Multi-step protocols can be created, but the mount must be the same for all the steps of the same protocol, regardless of the function set to each channel. Steps can be copied and re-ordered using the dedicated buttons.

3 **Template & Mount.** With 8-channel devices, the template option is set to User defined. For 20-/32-channel devices, choose between User defined and Standard mount. The former option allows any of the 76 scalp map positions (or EOG1, EOG2, ECG and EXT) to be assigned to the channels of the device; whilst the latter locks the positions to the predefined mount of the system.

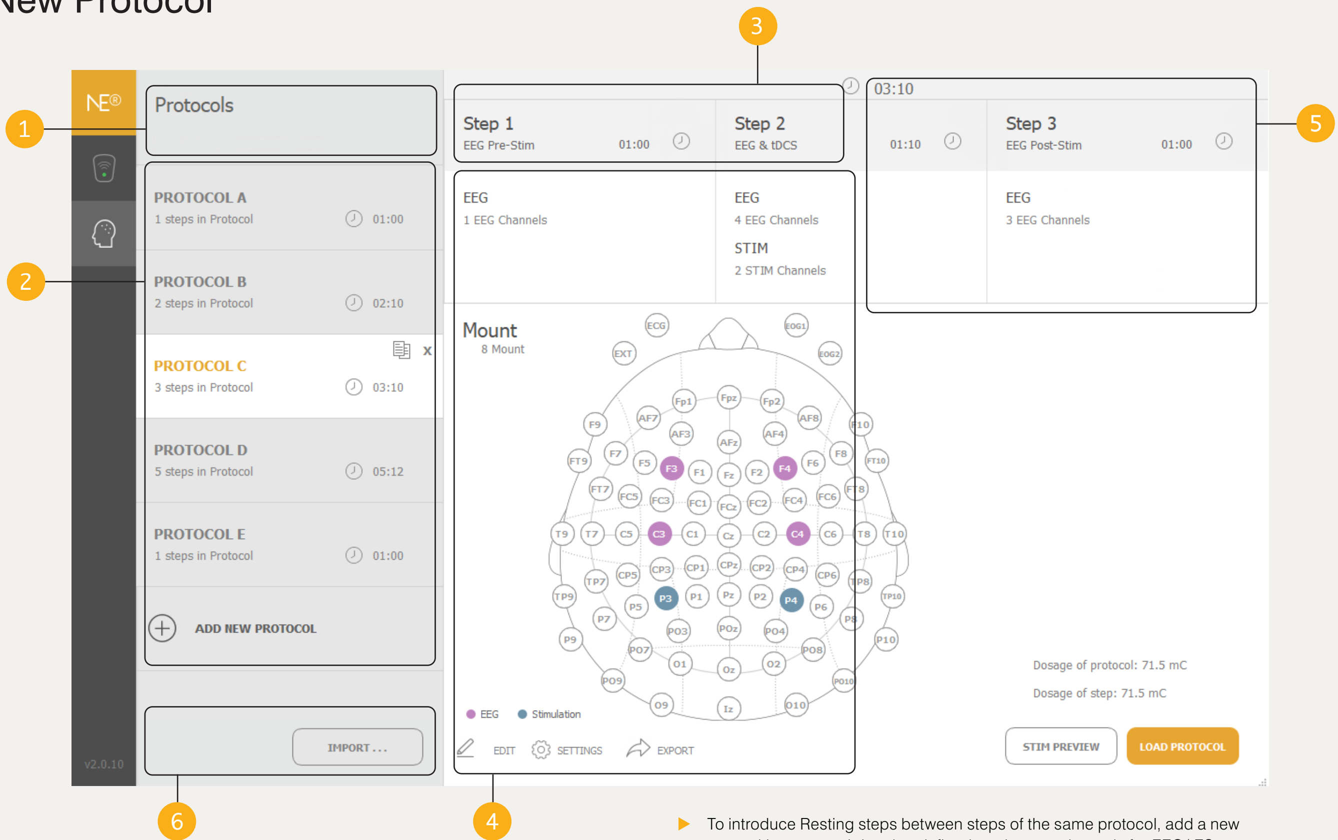
4 **Head Diagram.** The diagram shows a subset of the 10-10 EEG coordinate system. The color code identifies the channels and their function/status:

- **green:** positions available with the current template/mount.
- **blue**: channels assigned to stimulation during the current step.
- **purple**: channels assigned to EEG during the current step.
- **circled green**: available positions that are assigned to EEG and/or Stimulation in other steps of the same protocol.
- **white**: positions unavailable in the standard mount templates.

5 **Design.** The design area allows the user to build the electrode montage. To assign the EEG or Stimulation function to a specific channel, first click on the corresponding **EEG** or **Stimulation** button, then click on the desired scalp position and drag it from the Head Diagram to the workspace on the right. Alternatively, double click on the desired position, and choose between EEG and Stim functions.

6 **Cancel, Finish & Save.** These buttons allow the user to save the last modifications of the protocol and leave the editing area, or cancel and leave without applying the last changes.

New Protocol



▶ To introduce Resting steps between steps of the same protocol, add a new step, with name and duration defined, and set no channels for EEG/tES.

III.2
Protocol Summary

Within the **Protocol** pane, it is possible to have the general information about each protocol.

1 **Protocol List.** The number of steps and the total duration of each protocol is shown for all the protocols in the list. Select the protocol in which you are interested. On the right side of the window, the Protocol Workspace will display the summary of the selected protocol.

When a protocol is selected, the copy icon becomes visible. By clicking on it, a new protocol is added to the list, identical to the original protocol and with "_Copy" appended to the name.

2 **Protocol Sequence.** This section summarizes the selected protocol and briefly describes each of its steps. The top bar displays the duration of the entire protocol, and the table below contains basic data of each step: name, duration, number of EEG channels, and number of stimulation (STIM) channels. The mount diagram below refers to the step selected.

3 **Mount.** The mount diagram identifies the 10-10 position coordinate of the EEG and STIM channels used for the pre-selected step of the protocol. If no step is selected, the Mount refers to the first step of the protocol. The user is also informed about the stimulation dosage of each step and of the total protocol. More information about the dosage can be found on page 56.

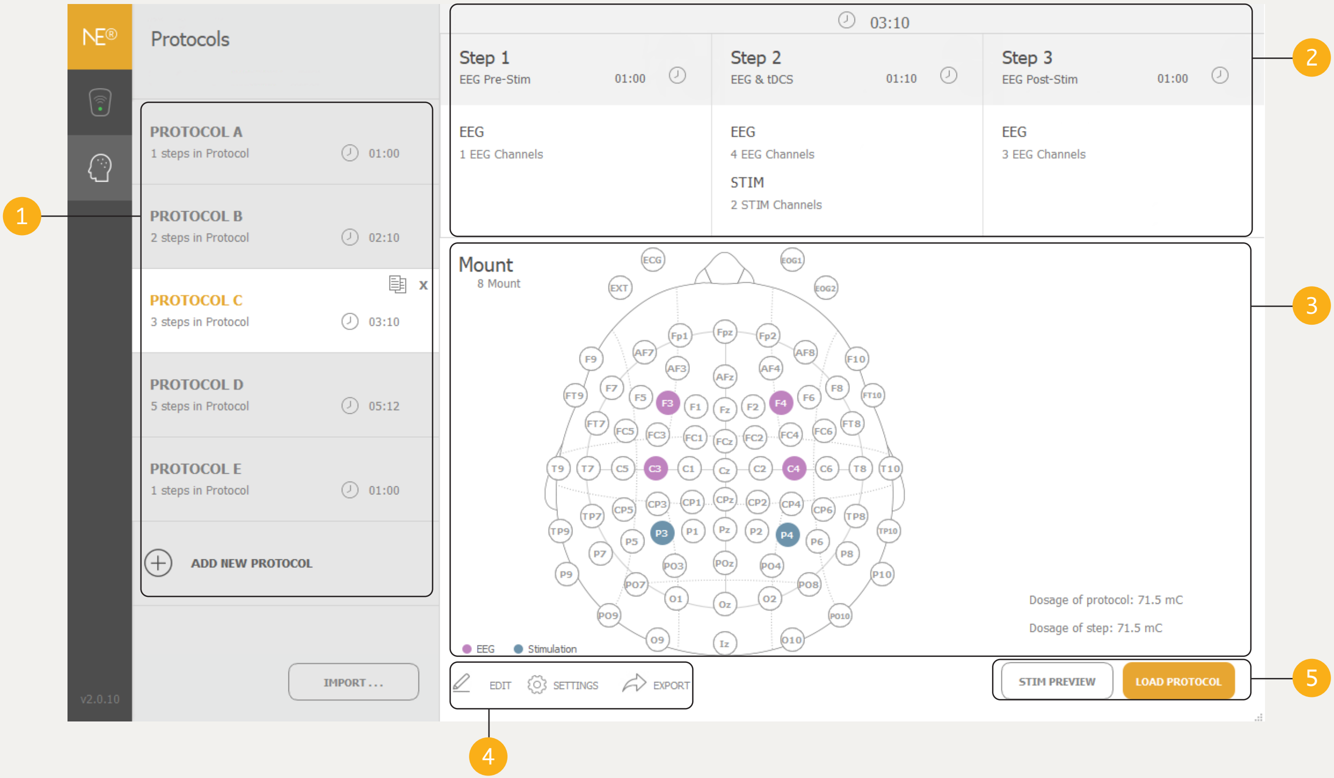
4 **Action Buttons.** Three actions can be performed regarding the selected protocol:

- Edit: redirects the user to the Protocol Design (pp. 18-19) so the protocol can be modified.
- Settings: general settings regarding the file format, markers and data streaming can be defined (pp. 22-23).
- Export: the user may export the protocol data to a *.txt file.

5 **Stim Preview and Load Protocol**

- Stim Preview (pp. 24-25)
- Load Protocol (pp. 26-27).

Protocol Summary



III.3
Protocol Settings

The protocol settings are defined for all protocols and they are applied to all their steps.

1 **File formats & Directory.** NIC2 allows five types of file to be saved. :

- *.nedf : binary file with an *.xml header
- *.easy : ASCII file saved during EEG recording.
- *.edf : The EDF extension stands for the European Data Format (EDF). The EDF+ is the standard binary file format for EEG data.
- *.sdeeg : binary EEG file stored in the SD card during offline recording.

The user may choose which file types to be recorded. More information about the NIC files can be found on pages 59-60. Then they should specify the path in the directory where those files should be saved.

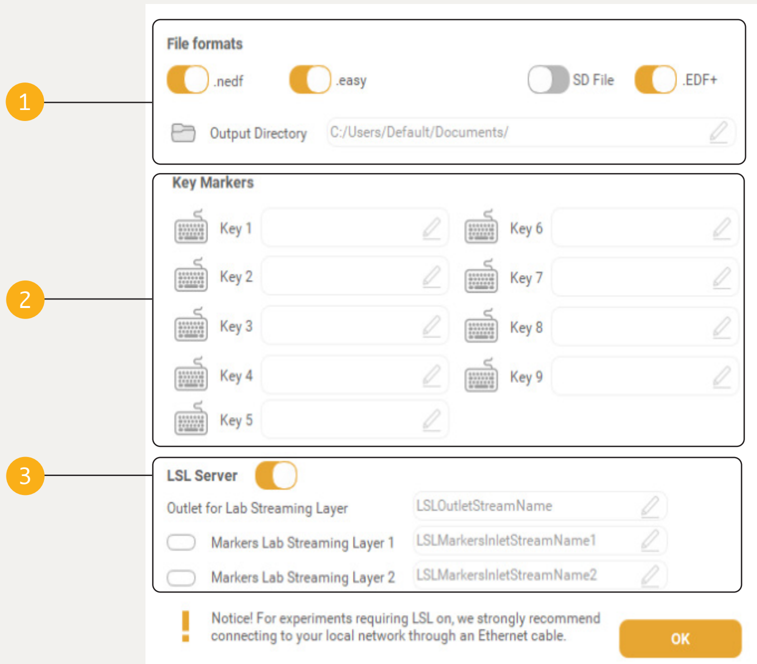
Warning: The *.nedf file format has 24-bit resolution, while the *.edf format has 16-bit resolution. The DC component is filtered when *.edf files are created.

2 **Markers.** Up to 9 markers can be assigned to the keys 1 to 9 of the keyboard. When those keys are pressed during the experiment, the marker number is added to the corresponding sample.

3 **Data streaming.** NIC2 allows data to be streamed and receive markers from third party software applications running on the same network by using Lab Streaming Layer (LSL) connections.

Warning: Since version 2.1, connectivity using the LSL protocol is disabled by default. Once enabled, LSL functionality will remain active unless manually disabled in protocol settings.
LSL is a data intensive streaming service. When requiring LSL, to prevent it from interfering with the device connectivity, we strongly recommend connecting to your local network through an Ethernet cable.

Protocol Settings



III.4

Stim Preview

The **Stim Preview** pane is only available for Starstim devices. In Stim Preview, the electric field generated in the brain, that results from the stimulation montage of each step of a stimulation protocol, is displayed in a 3D standardized model.

It is recommended to use the Stim Preview visualization as a confirmation step before loading a stimulation protocol.

1 Interact with the 3D model and choose what to be displayed:

- White and grey matter options
- Electric potential V, electrical field magnitude ||E||, and its normal E_n and tangential E_t components
- Left, right or both hemispheres
- Automated anatomical labeling (ALL) regions
- Show electrodes used for stimulation
- Male or female brain model
- Snapshot the 3D model

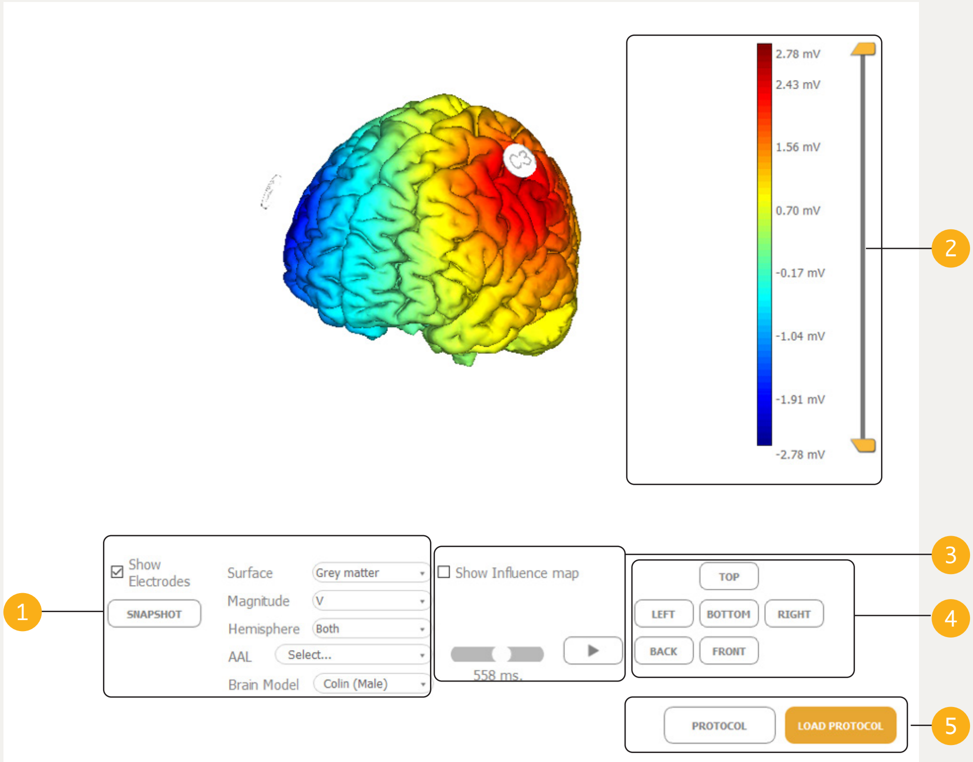
2 The upper and lower limits of the color map can be changed on the vertical scale.

3 For tACS protocols, it is possible to visualize the variations of the electric field over time. Press the **Play** button to see the oscillatory effects. Additionally, it is possible to visualize the influence map of tACS montages, which identifies the areas of the cortex that are the most/ less affected by tACS overtime.

4 The six buttons allow the user to display the brain surface according to any of the six orthogonal views.

5 Go back to the protocol summary, or load the protocol.

Electric Field Visualization



IV. Liveview

When a protocol is loaded, the **Liveview** panes are unlocked. To load a protocol, click on the **Load Protocol** button, available within the Protocol Summary and the Stim Preview sections.

1 Liveview Home. The Liveview Home is the NIC2 pane that must be used to control both EEG and tES experiments. This pane cannot be customized.

2 Liveview Customization. NIC2 allows users to create Liveview panes according to their preferences. The Liveview Customization pane is the NIC2 section where the user can select and combine different tools to analyse EEG data in real-time.

3 Customized Liveviews. After creating a customized Liveview, the user can load it. The user can load up to 4 customized Liveviews simultaneously. The loaded customized Liveviews are added to the Pane bar on the left of the NIC2 window. At anytime, the user can remove (i.e. unload) a customized Liveview. Click on the cross on the superior right corner of the Liveview icon to close it.

4 Monitoring bar. The top monitoring bar is common to all Liveview panes, and it contains the basic commands:

- Protocol name and total number of steps
- Impedance Check (p. 56)
- Timing info and Play/Pause/Quit button (p. 27)
- Set ID of the saved files.
- Progress bar with step identification and stimulation profiles.
- Channel bar with signal quality (EEG channels, p. 42-43) and impedance (STIM channels, p. 56) values.
- Configuration bar – choose the reference channel for visualization, and adjust the voltage (μV) and time (s) scales. The voltage scale can be set to Auto so it adjusts to the amplitude of the signals.

5 Main EEG Plot. The multi-channel signal is plotted for all the positions defined in the mount template in the Protocol Design pane. Stimulation channels typically display a flat line. To add/remove channels to/from the Main EEG Plot, click on the circle label on the Channel Bar.

Liveview Home

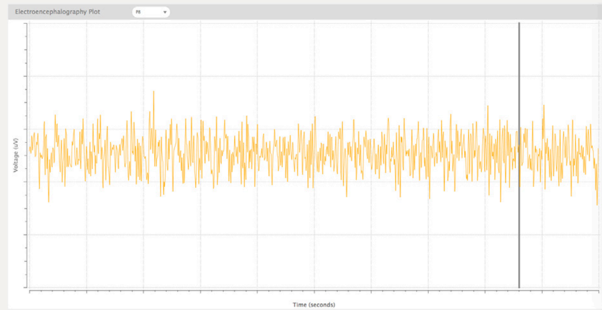
- Click on the Play/Pause button to start or stop the protocol (EEG or Stimulation) at any time.
- Click the Play/Pause button to pause the protocol.
- Click and hold the Play/Pause button for 3 seconds to stop and re-start the protocol from 0.

IV.1
Liveview Plots

The customizable Liveview panes allow the user to combine different types of EEG analysis plots. There are seven Liveview plots in NIC2 that can be used for real-time EEG monitoring. Below, you may find a description of each plot type.

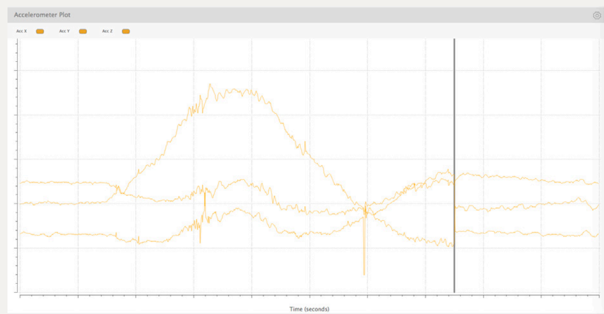
EEG Plot

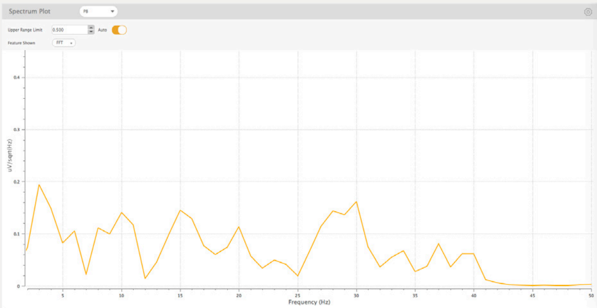
Choose one EEG channel to be plotted. Any chanel can be selected from the list of channels selected for EEG in the protocol in use.



Accelerometer

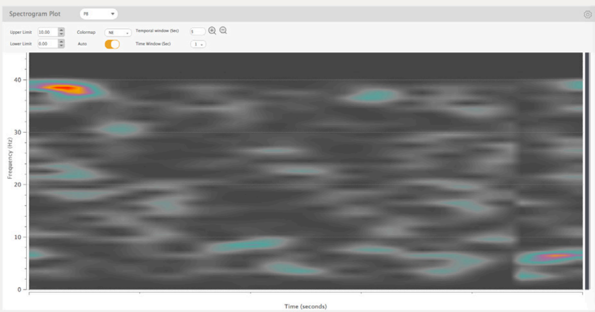
The 3-axis accelerometric data can be displayed in real time. By clicking on the gear symbol (upper right corner), it is possible to choose which accelerometric components (x, y, z) to be visualized.





Spectrum

This window displays the Fast Fourier Transform (FFT) or the Power Spectrum Density (PSD) of the selected channel. The upper range limit (vertical scale) can be set to auto or defined by the user. Click on the gear symbol on the top-right corner to modify such parameters.



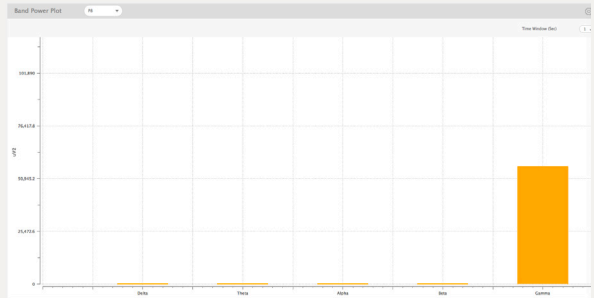
Spectrogram

The power spectrogram displays the online frequency contents of the signal of a specific EEG channel over time. The temporal window (horizontal scale), time window (used to compute the signal spectrum to be plotted), the colormap, and the spectrum limits maybe adjusted. Click on the gear symbol on the top-right corner to modify such parameters.

IV.1
Liveview Plots

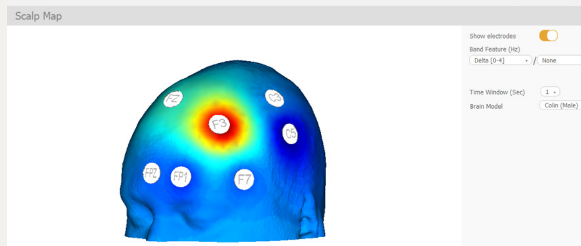
Band Power

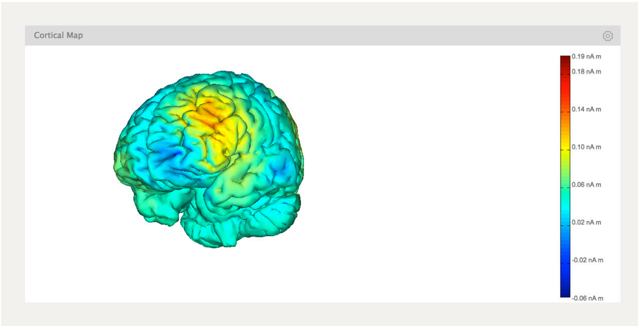
The power of the different EEG bands (Delta, Theta, Alpha, Beta, Gamma) can be computed in real-time for any specific channel. It is possible to adjust the time window (1, 2 or 4 seconds) used to compute band power values. Click on the gear symbol on the top-right corner to modify such parameters.



Scalp Map

The scalp map displays a color code to spatially represent the power distribution μV^2 for the band, or band ratio, selected. The electrodes can be made visible or not. Male or female brain model can be selected. Click on the gear symbol on the top-right corner to modify such parameters.





Cortical Map

The cortical map uses backward problem solving to compute the density of electric dipoles (nA m) on the brain surface. This source localization tool allows active brain areas to be identified, on both white and grey matter surfaces, based on the electric potential values measured by the scalp sensors. This is only available for devices with 20 and 32 channels using the standard mount.

IV.2
Liveview Design

The Liveview Customization pane allows the user to create and customize new Liveviews. The Liveview plots are organized in grids, and NIC2 allows groups up to 5 rows and 2 columns – a total of 10 plots. To create a new Liveview, follow the steps:

1 Click on the **Add New Analysis Template** button.

2 Define the name of your new Liveview. The name should be unique.

3 Click on **Add New Analysis Plot**.

4 Choose, from the drop-down list, the type of EEG Analysis Plot to add to the view:

- EEG Plot
- Accelerometer (Acc) Plot
- Spectrum
- Spectrogram
- Band Power
- Scalp Map
- Cortical Map

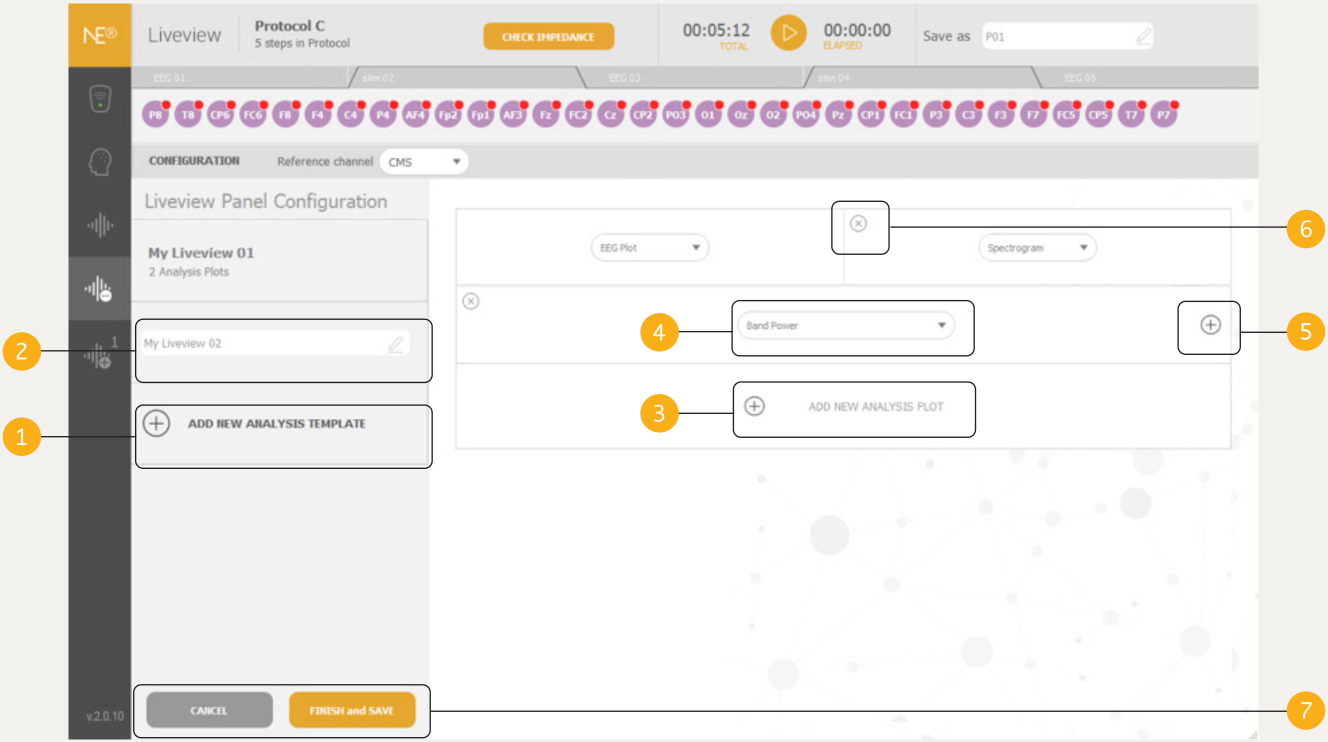
5 Click on the plus sign to add a second column in the corresponding row. The plus sign is located on the right side of the plot slot. A second drop-down menu will appear Repeat steps 3-5 to add more rows to the customized Liveview.

6 To remove any plot from the grid, click on the cross sign located on the top left corner of each slot.

7 Click on the **Finish & Save** button when the new Liveview is complete. Alternatively, you may proceed without saving the changes applied to the Liveview by clicking on the **Cancel** button.

When the Liveview is saved, it is automatically loaded. When returning to the Liveview Design, the edit option allows the user to modify the Liveview grid structure and plots of the customized Liveviews. The **Load** button directs the user to the Customized Liveview pane. NIC2 is capable of loading up to 4 customized Liveviews simulatenously.

Liveview Design



IV.3
Custom Liveview

When a new Liveview is loaded, all the plots are generated and plotted in NIC2 window.

The example given on page 35 corresponds to a Liveview created with the following grid structure (2 x 2).

The Liveview plots can be further adjusted:

1 To modify the height of the rows, drag vertically the horizontal border between them.

2 To adjust the column width of slots of the same row, drag the vertical border between both columns.

3 For the EEG, Spectrum, Spectrogram, and Band Power plots, the user can choose the channel, from the used mount, to reference the EEG data being plotted. The reference for the Cortical Map plot is Cz and can not be modified.

4 Each plot allows the user to define specific configurations. For instance, the Scalp Map plot allows the option to show/hide the electrodes from the model, and also to plot a band ratio instead of a standard brainwave band. It is up to the user to set those parameters.

Customized Liveview

V.EEG Experiments

V.1
EEG Protocol

An EEG protocol is typically one-step protocol. Preparing the EEG protocol is a simple process. Follow the steps below based on the example shown on pages 18-19.

1 Name the Protocol (e.g. EEG Protocol)

2 Optionally, name the protocol step (e.g. EEG01).

3 Define the duration of the EEG recording (e.g. 10 min). Note that wireless Enobio systems have a limited battery duration. Make sure the battery is charged before loading long protocols.

4 Define the template mount. Place the cursor above the available positions (**green**) and drag them to the EEG workspace. Make sure the selected positions become **purple**.

5 Optionally, define the EOG Training settings (i.e. EOG channels and EOG Training duration)

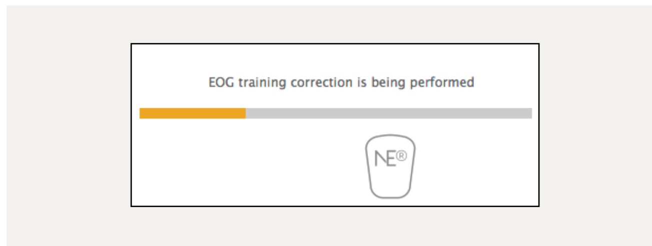
6 Save the protocol and, then, load it.

Note: The stimulation related parameters (i.e. ramp-up/down times, Sham activation, and dosage information) are not visible when using Enobio. When using a Starstim 8/20/32 for an EEG-only protocol, those fields should not be used, because they will have no effect.

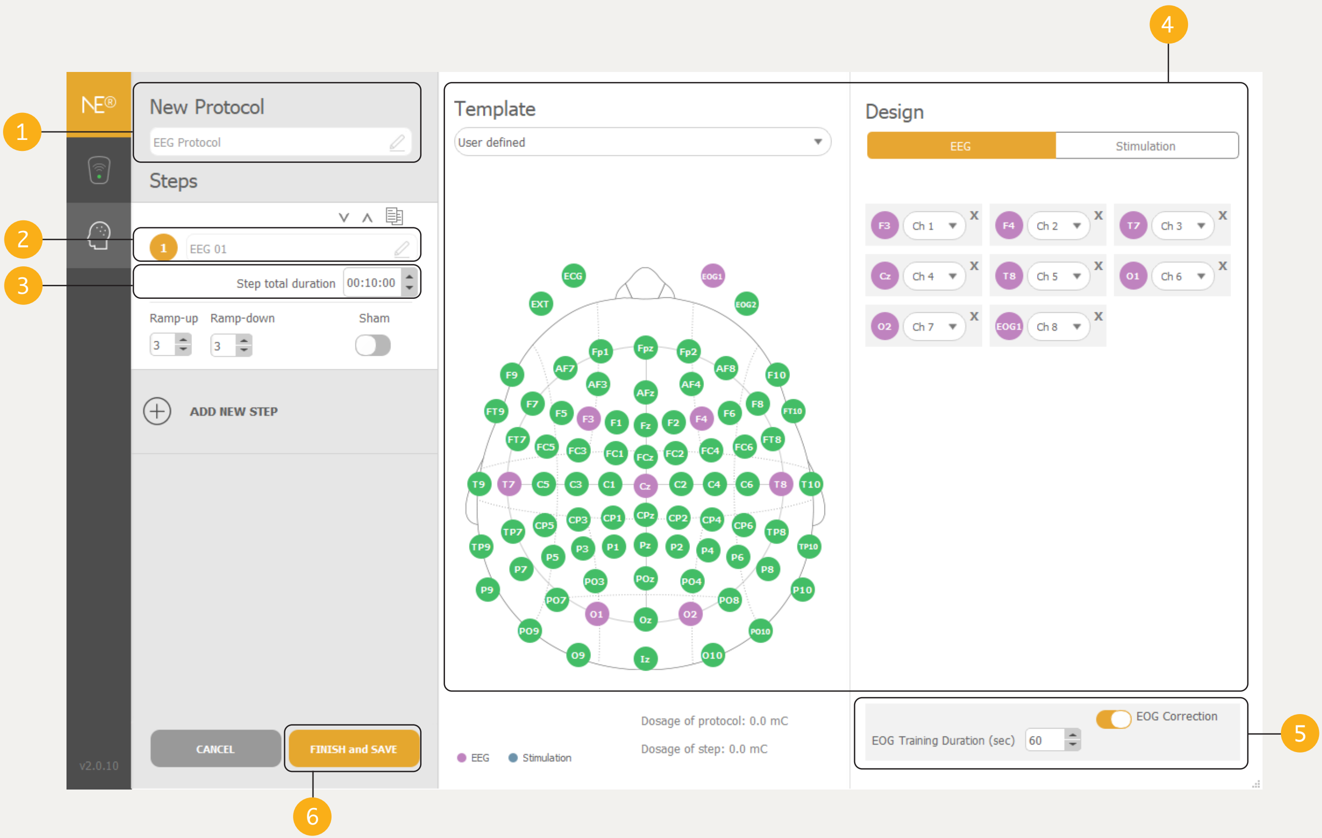
EOG Correction

The EOG correction feature allows artifacts, associated to the eye movement, to be removed from the EEG signal. The EOG correction requires one or two channels to be assigned to the EOG function. Those channels should be associated to adhesive electrodes placed near the eye to better detect the ocular movements.

To activate the EOG correction, first assign one or two channels of the mount to the EOG labels shown on the Head Diagram. Select the duration of the EOG training which corresponds to the time period during which the EOG channels learn the signals associated to the movement of the eyes. When the EEG protocol starts, the EOG training will start and, when finished, the EEG recording begins. EOG correction will be applied only during visualization.



EEG Protocol



V.2
EEG Monitoring

When an EEG protocol is loaded and the Play button is pressed, the recording starts. If EOG training is activated, the EOG training window will pop-up before the recording starts. During the EEG monitoring, pay attention to the filters, the reference system, and the plot scales. Make use of the Liveview panes (pp. 26-35) for real-time EEG analysis and visualization.

Data Filtering

NIC2 allows EEG data to be filtered. The 50 Hz (Europe) and the 60 Hz (US) filters can be enabled/disabled in the **My Devices** pane (pp. 14-15). Both line noise filters are applied for the visualization and they can be optionally applied for the recorded data.

Additionally, the user may define a visualization filter (pp. 14-15). These filters are applied to the EEG plots in NIC2, but they do not affect the data recorded. A possible band-pass filter can be 2 Hz - 40 Hz, since it removes the offset of the channels and line noise.

EEG Reference

During the monitoring, the operator may select the reference channel. By default, all channels are plotted in reference to the CMS channel. Optionally, the signals can be also referenced to the average of all EEG channels. Bipolar and banana referencing options are available for 20-/32-channel systems using the standard mount template.

Warning: Note that the chosen reference is only for visualization purposes. All the recorded EEG data is referenced to the CMS channel.

Time & Voltage scales

Both time and voltage scales can be adjusted. The standard time scale is set to 10 seconds, whilst the voltage scale is initially set to Auto. Use a vertical scale $< 100\ \mu$V, to be able to properly visualize the EEG signals and their quality.

EEG Monitoring

V.3
EEG Signal Quality

In NIC2, the quality of the EEG signals is assessed via the quality index (QI). The QI is computed every 2 seconds, and it depends on four parameters as described by **Equation 1**:

- **Line Noise:** power (μV^2) of the signal in the standard line noise frequency band (EU: 50±1 Hz; US: 60±1 Hz).
- **Main noise:** signal power of the standard EEG band (1–40Hz)
- **Offset**: mean value of the waveform
- **Drift:** the drift is measured but not included in the QI computation because it has a high inter-subject variability. A high drift does not imply bad signal.

During EEG monitoring, place the cursor above the superscripted quality circles, to see the values of drift, offset, main noise, line noise and QI. The parameter in bold is the one affecting the signal the most.

The quality indicator is meant to be used as a guidance, it does not need to be taken very strictly; visual inspection of the EEG signal is equally important. If the signal looks good and the quality indicator is **orange**/**green**, you may proceed with the experiment. If the indicator becomes **red** at some point, there is no need to immediately stop recording.

Each EEG channel displays a color code based on its QI:

- **green** (QI: 0.0 - 0.5)
- **orange** (QI: 0.5 - 0.8)
- **red** (QI: 0.8 - 1.0)

First visually inspect the signal and wait until it becomes orange or green again. Read the Electrode manual to learn how to improve the signal quality. The signal quality depends on the type of EEG electrode and on the CMS reference channel. If that does not happen, several reasons may explain that:

Examples of EEG signals

Page 43 contains examples of EEG signals:

- Normal EEG signal.
- Signal with artifacts derived from repetitive chewing movements.
- Multichannel EEG with one signal with high drift.

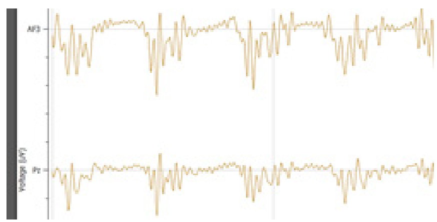
Equation 1:

$$QI(t) = \tanh\left(\sqrt{\left(\frac{Offset(t)}{WeightOffset}\right)^2 + \left(\frac{MainNoise(t)}{WeightMainNoise}\right)^2 + \left(\frac{LineNoise(t)}{WeightLineNoise}\right)^2}\right)$$

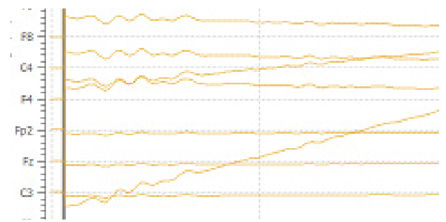
- $WeightOffset = 280\ mV$
- $WeightLineNoise = 100\ \mu V$
- $WeightMainNoise = 250\ \mu V$

Warning: The quality index (QI) is not an Impedance Check measurement. The Impedance Check feature is available, only for stimulation channels.

Normal EEG signal



Signal with chewing artifacts



Signal with drift

V.4

EEG Analysis

NIC2 allows real-time data analysis via Liveview panes (pp. 26-35). Nevertheless, the processed data is not stored, only displayed. In order to post-process data, Neuroelectrics® provides TCP/LSL streams. This option makes EEG data available for advanced processing with third-party applications.

Neuroelectrics® also provides a plugin to allow EEG data from NIC2 to be imported into the EEGLAB MATLAB (MathWorks®) toolbox (www.sccn.ucsd.edu/eeglab/).

Data streaming

EEG data can be read and processed with third-party softwares, such as MathWorks® MATLAB. Both Lab Streaming Layer (LSL) and Transmission Control Protocol (TCP) options are available in NIC2. To activate the LSL and/or TCP streams, go to the Protocol Settings (pp. 22-23).

To activate the LSL go to the Protocol Settings (pp 22-23) and provide a name for the LSL Outlet. NIC2 will use this name to provide 4 different outlets: provided_name-EEG, provided_name-Accelerometer, provided_name-Quality, provided_name-Markers. A third-party application can connect to them to receive information regarding EEG streaming, accelerometer, quality and markers data respectively.

To activate the connection through TCP go to the My Device Settings (pp 14-15) and activate the TCP Server option. Click on the gear symbol to modify parameters such as:

1 The network adapter where the server will be listening

2 Activate/deactivate server for raw EEG data

3 Inclusion of received marker on the raw EEG data server

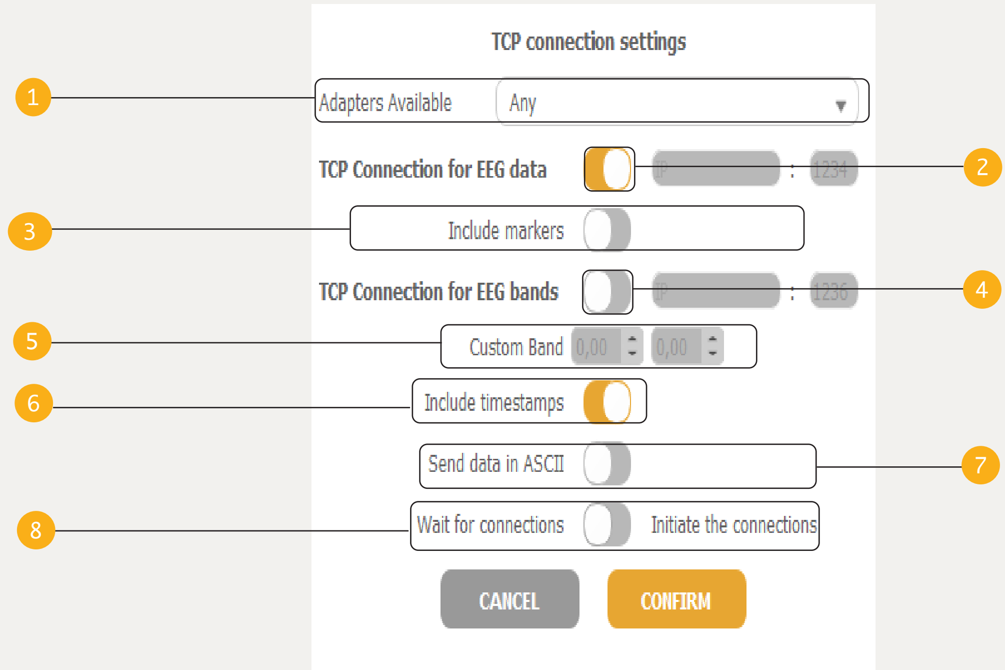
4 Activate/deactivate server for EEG power in bands data

5 Definition of a custom band to be sent on the EEG power in bands server

6 Inclusion of timestamps

7 Option to send the information in ASCII format rather than binary

8 Option to make NIC2 wait for incoming connections (default) or to actively initiate a connection to the provided IP addresses to send data


TCP connection settings
Adapters Available
Any
TCP Connection for EEG data
IP
1234
Include markers
TCP Connection for EEG bands
IP
1236
Custom Band
0,00
0,00
Include timestamps
Send data in ASCII
Wait for connections
Initiate the connections
CANCEL
CONFIRM
1
2
3
4
5
6
7
8

V.5
Holter Mode

NIC allows Enobio devices to enter in Holter Mode. The data will be stored in the SD card inserted into the Enobio amplifier so the EEG system is completely wireless and wearable. Check your firmware version to make sure it is supported for this function.

How to enter Holter Mode:

1 Insert the SD card in the SD card slot (Enobio lateral side) and configure the desired protocol with the total duration the recording shall last.

2 Enable the SD Card file (Go to Protocol Settings page 23 and check the picture on the right.)

3 Load the protocol and press the start button for EEG acquisition. Note that message with the exact amount of free space in the SD card that is needed to carry out the recording will appear. If there is no such free space, the device will rapidly blink for a few seconds indicating that the recording could not be started in the SD card. The same behaviour occurs when the SD card is not present.

4 Once the recording has started, close NIC2. Here, NIC2 asks for permission to enter in Holter Mode so press Yes.

5 The data recorded is stored for the time the protocol has been configured in NIC2. Note that the device will blink while the recording in the SD card is happening and that will get back to the idle state when it stops recording.

Technical Specifications:

For optimal performance, fast micro SDHC (Micro Secure Digital High-Capacity) cards are recommended (UHS-I or higher, Class 10.)
As a recommendation, the SD card should not be protected against writing. The battery level is read every 5 minutes and it records data to SD Card every 10 minutes

VI. Stimulation Experiments

Warning: During stimulation with Starstim, NIC2 needs to maintain continuous communication with the device. If communication is lost, the stimulation is automatically aborted.

VI.1

Stimulation Protocols (1/4)

Many types of tES studies can count on NIC2 to be implemented. NIC2 allows for bipolar anodal/cathodal montages, multi-electrode templates, and even combined EEG&tES protocols. In addition NIC2 includes three types of tES:

- transcranial Direct Current Stimulation (tDCS)
- transcranial Alternate Current Stimulation (tACS)
- transcranial Random Noise Stimulation (tRNS)

Due to the complexity that stimulation protocols can reach in NIC2, it is highly important that one understands how to implement such protocols.

NIC2 protocols for stimulation can be created in Basic or Advanced modes. The former allows only one channel for stimulation and one or multiple return channels; whilst the latter allows for multiple stimulation channels and only one return. In addition, the advanced mode allows the user to combine tDCS, tACS and tRNS for each channel, independently.

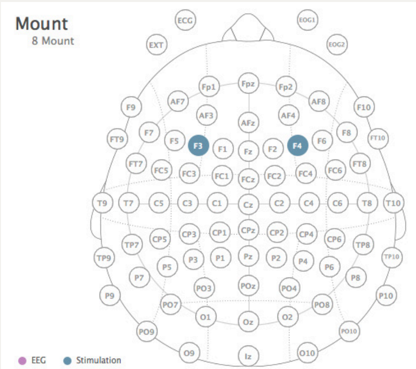
Depending on the complexity of the protocol to be created, the user should choose the most appropriate mode.

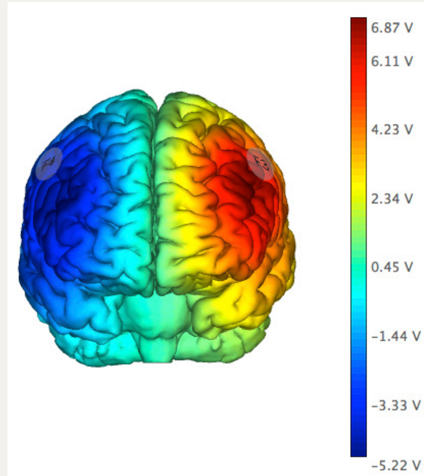
Bipolar Montages

The Basic mode is suitable for simple bipolar montages. To create an anodal tDCS protocol, go to the Protocol Design section in NIC2 and follow the steps below. An example of a Bipolar Montage tDCS can be found on p.49:

1. Select Stimulation under the Design workspace.
2. Select the Basic mode, and choose tDCS.
3. Define the anode
   - **Drag the channel position F3 from the Head Diagram to the Design/Stimulation workspace.**
   - **Choose the Stimulation function for this channel, and select Anodal.**
   - **Type the desired current amplitude, 1000 μA (= 1mA).**
4. Define the cathode
   - **Drag the channel position F4 from the Head Diagram to the Design/Stimulation workspace.**
   - **Choose the Return function for this channel, and type the return percentage, 100%.**

Bipolar Montage
tDCS, 1mA





The stimulation protocol will use the positions located at F3 and F4 as indicated in the mount diagram.

F3 channel is defined as anode, with a current intensity of 1mA. The total amount of current (100%) will return at F4 (cathode).

Stim Preview confirms that the chosen montage will target the desired brain area, with anode over F3 and cathode over F4.

VI.1

Stimulation Protocols (2/4)

High-definition Montages

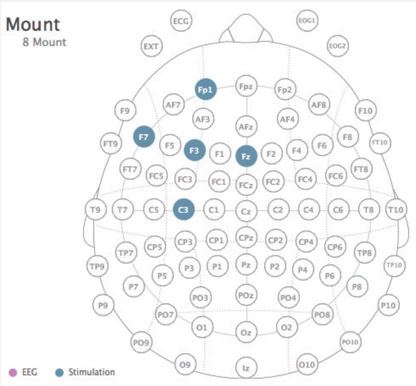
The Basic mode is also suitable to create high-definition tDCS montages. The term high-definition tDCS—or multi-polar tDCS— describes the concept of having a central electrode over the target area, and a set of return electrodes arranged in a ring around the central electrode.

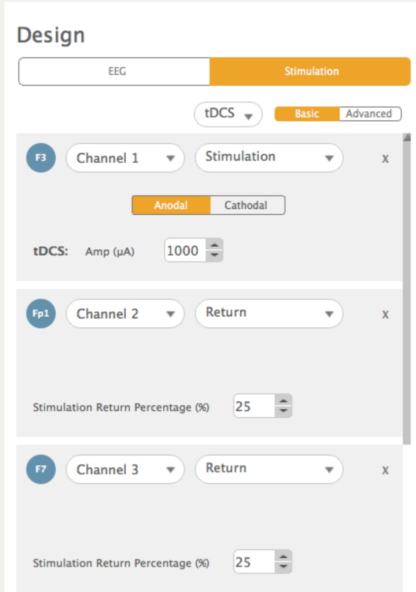
Neuroelectrics® Starstim products are suitable for multi-polar tDCS montages. The multi-polar montages can be formed with the conventional ring of 4 cathodes or with more than 4 return channels to minimize the current under the cathodes.

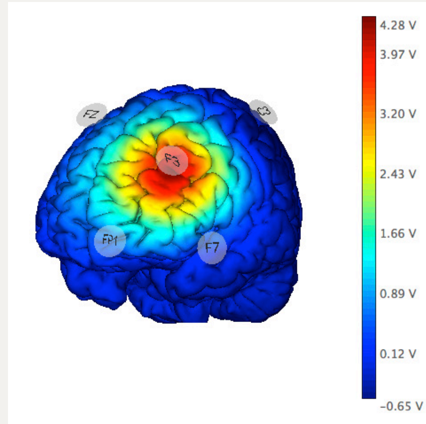
To create a multi-polar tDCS protocol, with a ring of 4 return channels as illustrated with the images on the right, follow the steps below, in the Protocol Design section:

1. Select Stimulation under the Design workspace.
2. Select the Basic mode, and choose tDCS.
3. Define the Anode
   - Drag the channel position F3 from the Head Diagram to the Design/Stimulation workspace.
   - Choose the Stimulation function for this channel, and select Anodal.
   - Type the desired current amplitude, 1000 μA (= 1mA).
4. Define the ring of cathodes
   - Drag the channel positions that form the ring – Fp1, F7, Fz and C3 – from the Head Diagram to the Design/Stimulation workspace.
   - Choose the Return function for this channel, and type the return percentage of 25% for each of the four channels.

Multi-polar Montage
tDCS, 1mA







The stimulation protocol will use the main location F3, with 4 channels around the positions located at F3 and F4 as indicated in the mount diagram.

F3 channel is defined as anode, and four cathodes (Fp1, F7, Fz and C3) are used to disperse the return current effects.

Stim Preview confirms that the chosen montage will target the desired brain area, with anode over F3, without the reverse effect on the counter side.

VI.1
Stimulation Protocols (3/4)

Complex waveforms: tDCS, tACS & tRNS

NIC2 can combine tDCS, tACS and tRNS in order to produce more complex waveforms that result from the linear combination of those. In the Advanced mode, more than one channel can be used for stimulation and their currents can be independently defined.

The stimulation current per channel can be defined as a linear combination of tDCS, tACS and tRNS. The following five parameters can be independentely chosen for each channel:

1 DC amplitude: Amp_{tDCS} (μA)

2 AC amplitude: Amp_{tACS} (μA)

3 AC frequency: F_{tACS} (Hz)

4 AC phase: P_{tACS}(^{o})

5 Random noise amplitude: Amp_{tRNS} (μA)

Warning: Note that the currents of all stimulation channels should add zero. Alternatively, one, and only one, of the channels can be defined as **return**. The current in the return channel is set through the current conservation law.

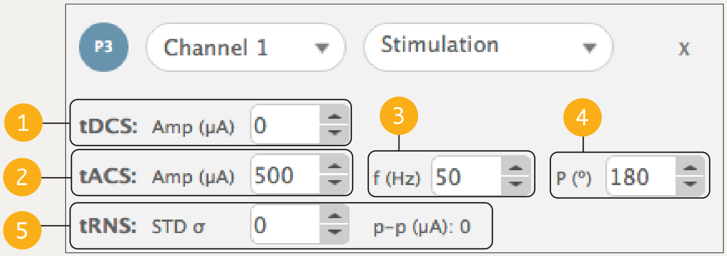
In **Design/Stimulation** workspace, the stimulation parameters can be defined as it follows:

- Click on the **Stimulation** button.
- Select the Advanced mode.
- Click on and drag the desired channel to the white area below.
- Insert the desired values of the stimulation parameters for the corresponding channel.

The injected current (I_{NIC}(t), μA) in the corresponding electrode position is given by **Equation 2**, where **t** is the time in seconds and **RNS** is white noise with an unitary variance Gaussian distribution.

6 The RNS waveform can be filtered using low, band or high pass filters. The cut-off frequencies can be defined by the user.

tDCS, tACS & tRNS

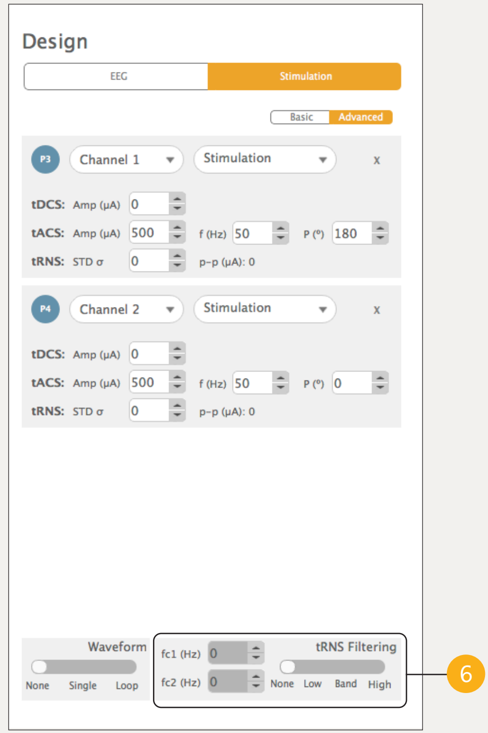


Equation 2:

$$\mathbf{I_{NIC}(t)} = \mathbf{Amp_{tDCS}} + \mathbf{Amp_{tACS}} * \sin(2\pi * \mathbf{F_{tACS}} * t + \mathbf{P_{tACS}}) + \mathbf{Amp_{tRNS}} * \mathrm{RNS}(t) \quad (\mu A)$$

Notice: The tACS current is defined as 0 to peak

Warning: Regardless of the values assigned, the current at any electrode never exceeds the maximum value allowed by the device at any given time. The maximum value is either 2 mA or 4 mA, depending on the version of the Starstim. Starstim limits the maximum injected current per channel and per system at any time instant.



VI.1
Stimulation Protocols (4/4)

Custom Waveforms

With NIC2, it is possible to customize waveforms that, due to their complexity, can not be created using a linear combination of tDCS, tACS and/or tRNS (eg. rectangular waveform). Follow the steps below to customize the stimulation waveforms for Starstim:

1 Create a text file (*.txt) that contains the samples of the stimulation waveforms that correspond to the multi-channel stimulation. The file should contain the following specifications:

- The number of columns should correspond to the number of stimulation channels used in the protocol.
- Each row corresponds to a multi-channel sample with a milisecond resolution (e.g. 1 second waveform requires a file with 1000 rows).
- The stimulation values are defined in micro-ampere (μA).
- For each row, the values must add a zero in order to respect the current conservation law at any time instant.
- Only integer numbers are allowed.
- Columns must be separated from each other (do not use comas, points, or more than one tabulation space).

2 In the **My Devices** pane (pp. 14-15) load the text file previously created. NIC2 will show an error message in case there is a problem with the file structure.

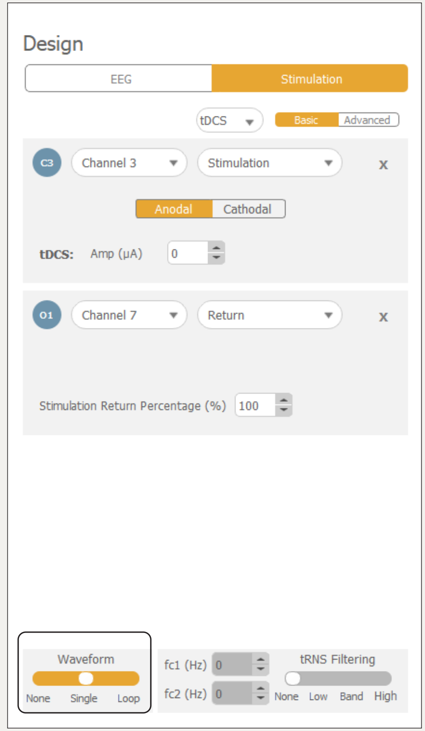
3 When creating the stimulation protocol, make sure that all the stimulation steps use the same number of stimulation channels, which equals to the number of columns of the loaded text file.

4 The protocol will not be compliant if the user defines tDCS, tACS, and/or tRNS parameters in Basic or Advanced configuration modes. The amplitude and frequency of the stimulation channels must be blank.

5 The user has the option to apply the custom waveform once (single) or repeated times (loop) during the total duration of the stimulation step.

Warning: The custom waveform feature is only available with the following devices: Starstim 8 5G and Starstim R20/32. To be compatible, Starstim 8 5G must have a firmware version equal or superior to 4016, and Starstim R20/32 must have a firmware version equal or superior to 3028.

Custom Waveforms



Warning: Regardless of the values assigned, the current at any electrode never exceeds the maximum value allowed by the device at any given time, that is 2 mA. Starstim limits the maximum injected current per channel and per system at any time instant.

VI.2
Impedance Check

The impedance of the stimulation channels can be measured by NIC2. This feature is available for Starstim devices, but not for Enobio devices.

The **Impedance Check** button is used to measure the impedance of the channels used for stimulation, including the return channel. The Impedance Check should be performed before launching any protocol with stimulation.

For each channel, the Impedance Check is computed via Ohm's law. NIC2 allows for two types of impedance check: with alternate current (AC) and with direct current (DC).

With the AC option, an alternating current of 300 μA amplitude and 30 Hz frequency is injected and the resulting voltage values are measured. The DC impedance is measured using a 300 μA constant current. Both methods measure the impedance values during 5 seconds per pair of channels.

The impedance bar appears below the icons of the stimulation channels and its color depends on the obtained value:

- **green**: [0 - 10] kΩ
- **orange**: [10 - 15] kΩ
- **red**: [15 - 20] kΩ

In the LiveView panes, by placing the cursor above the bar, a rectangle appears showing the actual impedance value. Those values are automatically saved on a text file too.

During a stimulation protocol, the impedance is monitored every second. At any instant, if the impedance exceeds 20 kΩ in any stimulation electrode, the stimulation protocol aborts to protect the subject from the high voltages generated.

How to improve the contact impedance

There are several ways to decrease the impedance of the stimulation electrodes and improve the contact with the scalp:

(a) part the hair underneath the electrode **(b)** clear the visible scalp using a cotton swab **(c)** add more conductive liquid between the electrode and the scalp.

VI.3
Dosage of the Stimulation

The stimulation dosage is defined as the amount of charge received by the subject during a tES session.

For each stimulation protocol, NIC2 computes the total dosage of the protocol, and the dosage of the each protocol step.

The dosage is calculated using the equation:

Equation 4:

$$Dose = \frac{1}{2} \sum_{n=1}^{N} \int_{0}^{T} |I_n(t)|\, dt$$

N = total number of stimulation channels

VI.4
Blind Modes

NIC2 is prepared to conduct single and double blind stimulation experiments. In both scenarios, the Sham mode is needed to control the placebo effect of the stimulation.

Single Blind: Sham

Conducting a Sham session implies that the subject undergoing the stimulation experiment should not be aware if a real tES protocol is being applied or if he/she is being submitted to a fake tES protocol. The Sham protocol should therefore be designed to provide the same sensation as a real stimulation without its effects. Sensations similar to those in tES are created by generating currents at the start and at the end of the stimulation, although it is possible to disable the sensations at the end of the session by activating the Single Ramp option.

To enable the Sham mode, activate the Sham slider when defining the name and duration of the stimulation step. After activating the Sham, set the duration of the Sham ramp. In this situation the current will increase and decrease at the beginning and at the end of the corresponding active stimulation experiment.

To disable the ramp-up/down at the end of the experiment, active the Single Ramp slider.

Double blind

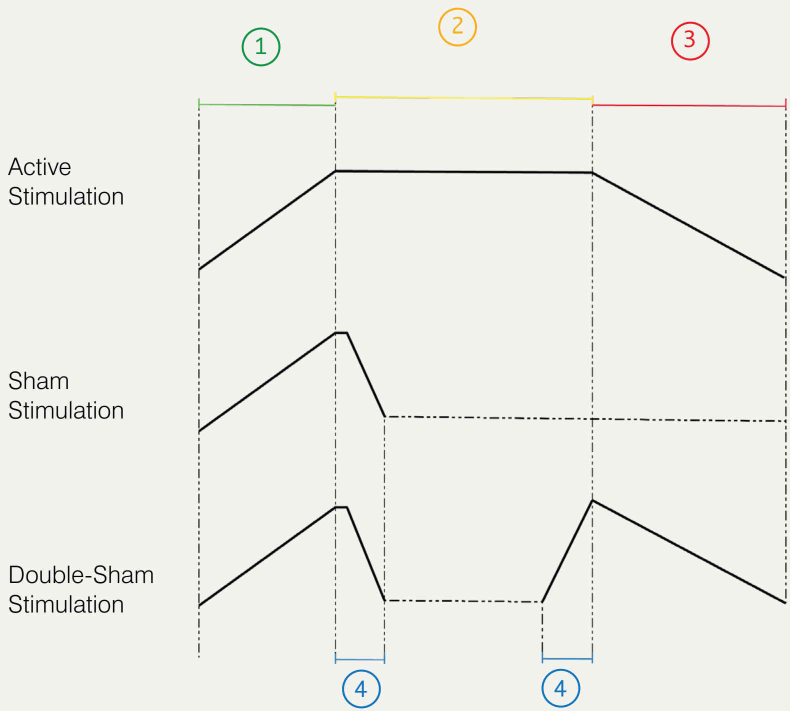
Before explaining how to activate the double blind mode, one needs to define the concept of administrator and operator. The administrator is the person who creates and manages the protocols. The operator only runs the experiments, and is not informed about which protocols refer to active stimulation and which protocols are in the Sham mode.

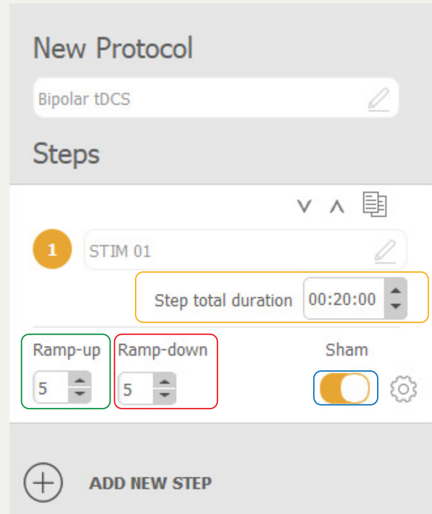
The protocols should be given a generic name (e.g. Protocol A1, Step A.1). The administrator should also prepare a list that assings a protocol to the corresponding subject.

The double blind mode is activated in NIC2 in the **My Devices** pane (pp. 14-15). NIC2 requests a password to activate the double blind mode. The administrator should activate the double blind mode, and the operator should not have access to the password. When the double-blind mode is activated, non-essential information is hidden.

Contact Neuroelectrics® in case you forget your password.

Active Stimulation and Sham Profiles





1. Stimulation Ramp-up
2. Stimulation Duration
3. Stimulation Ramp-down
4. Fade-out preceded by 5s Plateau / Fade-in

VII. NIC file formats

NIC2 works with files with distinct file formats.

During EEG recording, if the ***.easy** option is enable in the Protocol Settings (pp. 22-23), two ASCII files are created with the ***.info** and ***.easy** file extensions. The former corresponds to a text file that contains the metadata of the corresponding recording. Information, like the EEG sampling rate, the percentage of packet loss, the channel-position list, are written on this file. The latter is also a text file containing the data itself which is organized as it follows:

1 The first 8 (20 or 32) columns correspond to the voltage signal, in nanoVolts (nV), of the EEG channels. If stimulation has been simultaneously used, the stimulation channels will display, by convention, the value -1.

2 The three following columns will display the acceleration (a_x,a_y,a_z) in millimeters per second squared (mm/s^2).

3 The next column corresponds to the markers column and it displays mostly zeros. The numbered flags (0 to 9) are registered when the corresponding keys are pressed. The number 255 identifies the samples when data loss occurred. For stimulation protocols, the number 201 identifies when the ramp up begins, 202 when the ramp down begins, 203 when the stimulation starts and 204 when the stimulation stops.

4 The last column contains the Unix Time Stamp, in milliseconds (ms), for each sample. This time unit refers to the number of milliseconds since January 1, 1970.

1								2			3	4
-5704363	-3873234	-4539845	-4614389	-14385780	-18114187	-6415708	-10008899	-912	-343	9483	0	1440592136173
-5717174	-3884959	-4552492	-4625675	-14398126	-18101210	-6427910	-10020641	-912	-343	9483	0	1440592136175
-5723256	-3890647	-4557717	-4631479	-14405290	-18117905	-6434057	-10026971	-951	-343	9443	0	1440592136177
-5706770	-3873646	-4540178	-4615375	-14388744	-18120523	-6416069	-10010265	-951	-343	9443	0	1440592136179
-5707568	-3876536	-4543018	-4616238	-14390237	-18116380	-6418147	-10011408	-951	-343	9443	0	1440592136181
-5695222	-3863897	-4530062	-4604097	-14376906	-18105450	-6405817	-9998889	-951	-343	9443	0	1440592136183
-5721262	-3889150	-4555160	-4630930	-14403993	-18109140	-6432261	-10024138	-951	-343	9443	0	1440592136185

The ASCII files (***.info**, and ***.easy**) can be opened with, for instance, Notepad (Windows) or TextEdit (MAC OS).

Additionally, NIC2 also works with binary files: ***.edf**, ***.nedf** and ***.sdeeg**.

The ***.edf** extension stands for the European Data Format (EDF) which is a binary file format commonly used to exchange and store multichannel data from physiological signals. NIC2 produces the EDF+ files (extension of EDF) which is the standard binary file format for EEG data. The binary ***.nedf** files are propietary NIC files with an **xml** header, while the binary ***.sdeeg** file format is used when offline recording is used in a SD memory card.

VIII. Offline Mode

NIC2 can read files with distinct formats to inspect their EEG signals.

The **Offline Mode** can be accessed from the Home Pane by clicking on the Offline mode command. Files with *.easy, *.nedf, *info and *.sdeeg formats can be loaded. Once the file is fully read by NIC2 the EEG signals are presented in the Liveview Home pane. In Offline mode this pane is slightly changed.

1 Click on the ***Offline Mode*** button. A box will appear to load a new file. Make sure to select a file from your Directory.

2 Use Play/Pause and forwards/backwards button to inspect the EEG signals.

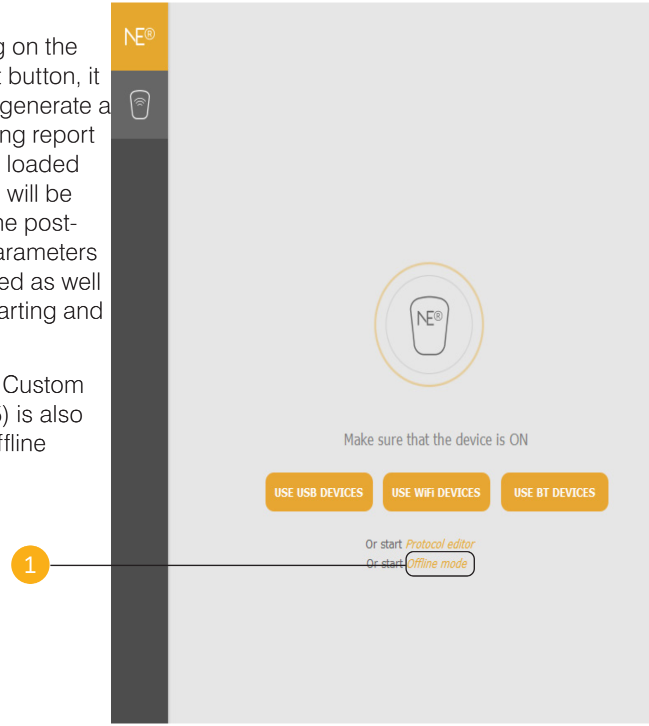
3 Drag and drop the time line bars to rapidly move to an exact time in the file

4 When the file contains markers, it is possible to select any type and navigate to where they are with the double-arrow buttons.

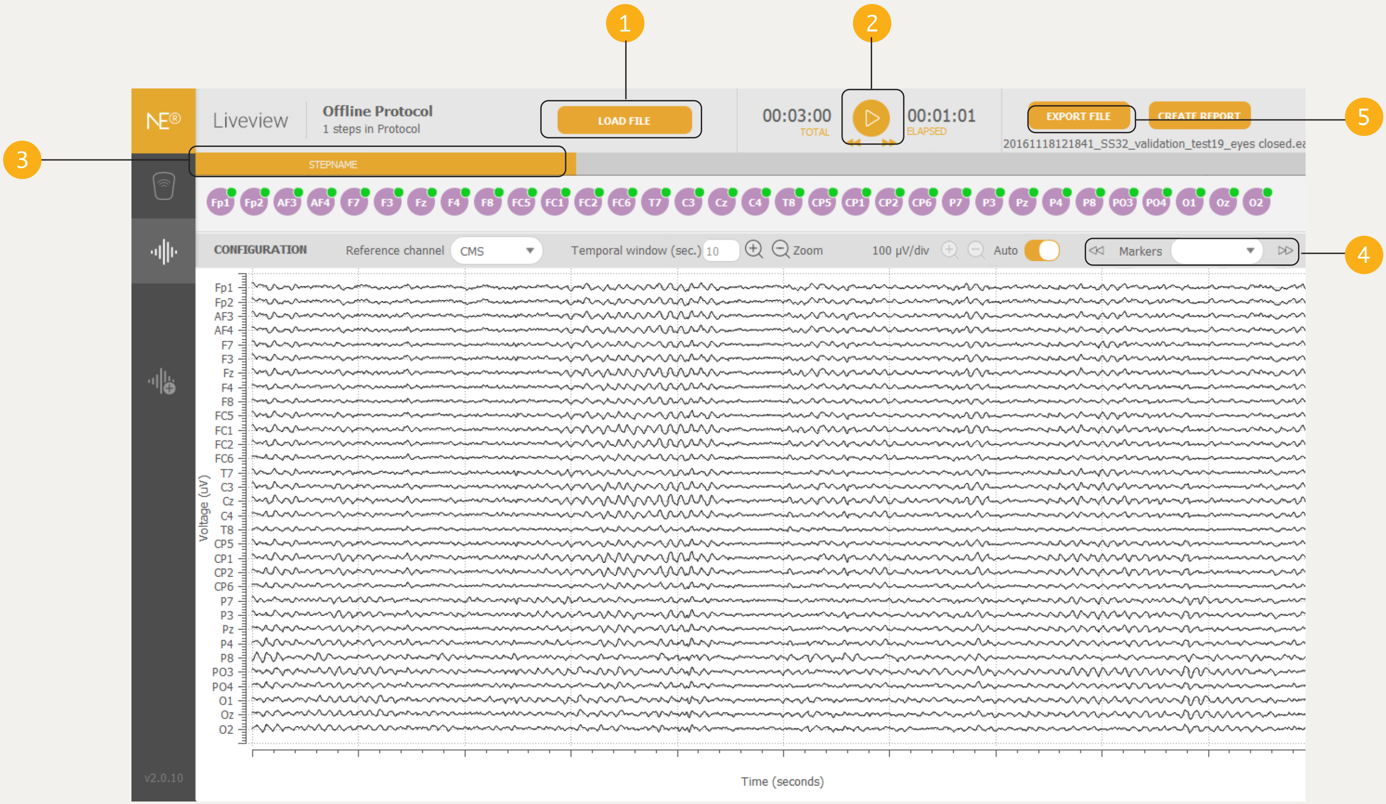
5 Click on the Export File button to convert the current loaded file to a different format (*.easy, *.nedf, *.edf) by clicking on the ***Export File*** button.

6 By clicking on the Create Report button, it is possible to generate a post-processing report on the current loaded data. A dialog will be open where the post-processing parameters can be adjusted as well as the data starting and finishing time.

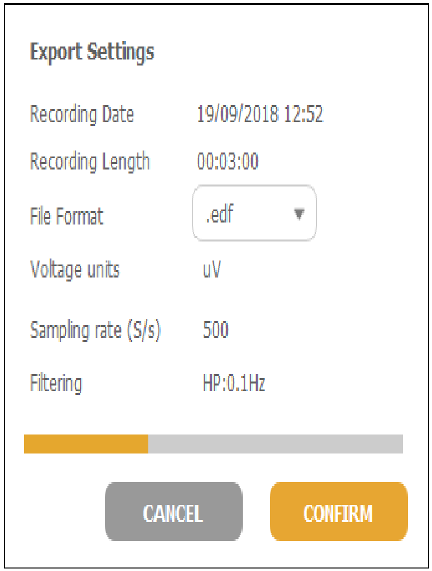
7 Access to Custom views (p28-35) is also available in Offline mode.



Offline Mode



Offline Mode



IX. WiFi Troubleshooting

Due to the nature of WiFi connectivity, communication issues can arise from time to time. However, this should not happen frequently. Detailed below are instructions which will help stabilise the WiFi connection.

Step 1: Connect via the WiFi panel

To form a more stable connection, establish it manually in Wi-Fi settings on your computer. If the device has been previously connected to the computer, forget it in your operating system WiFi settings. Once the Wi-Fi connection is formed, open the NIC software and try to connect it again.

Step 2: Update the NIC version

Ensure you are using the latest version of the Neuroelectrics Instrument Controller software (NIC). It is available on our website at the following link.
https://www.neuroelectrics.com/resources/software

Step 3: Use an internet connection via Ethernet

Use an Ethernet cable connection to connect your computer to the internet. Use the internal WiFi of the computer to connect with the device. Maintaining these two parallel connections will improve the stability of the WiFi connection with the Neuroelectrics device.

Step 4: Check LSL system

As described in section III.3, LSL is a data intensive streaming service. If your LSL is enabled and the protocol you are planning to apply does not require LSL, disable it in protocol settings (page 23). If you do require LSL, we strongly recommend connecting to your local network through an Ethernet cable.

Step 5: Use an internet connection via the USB WiFi dongle

Use the USB WiFi dongle provided in your Neuroelectrics kit to connect your computer to the internet. Connect the WiFi dongle to the local internet router and use the internal WiFi of the computer to connect with the Neuroelectrics device. Maintaining these two parallel connections will improve the stability of the WiFi connection with the Neuroelectrics device.

Step 6: Alter equipment being used and environment.

- Battery charge levels below 20% may lead to a weaker Wi-Fi signal. If you encounter Wi-Fi connectivity issues, try operating the device with a higher level of charge.

- It may be possible that the computer equipment being used is the source of disconnections. You can download NIC onto another computer and attempt to form a connection.
- It may be possible that the WiFi network in your physical environment is busy and causes disconnections. You can physically move your setup to another less busy location to improve the WiFi connection with the Neuroelectrics device. Another option is to limit the number of devices in your environment actively connecting with WiFi.
- WiFi connections are limited in terms of physical distance. Reduce the distance between the computer running the NIC software and the Neuroelectrics device to improve the WiFi connection.