



# **Fiberless and Wireless Optogenetically Synchronized Electrophysiology System**

User Manual

Version 2.1.0

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## System Overview

### 1.1 Fiberless Wireless Electrophysiology System

The Doric *Optogenetically Synchronized Electrophysiology System (OSE)* combines optogenetics with electrophysiological recordings. The system allows the delivery of optical signal to the region of interest as well as the detection of electrical signals and fields from neural activity.

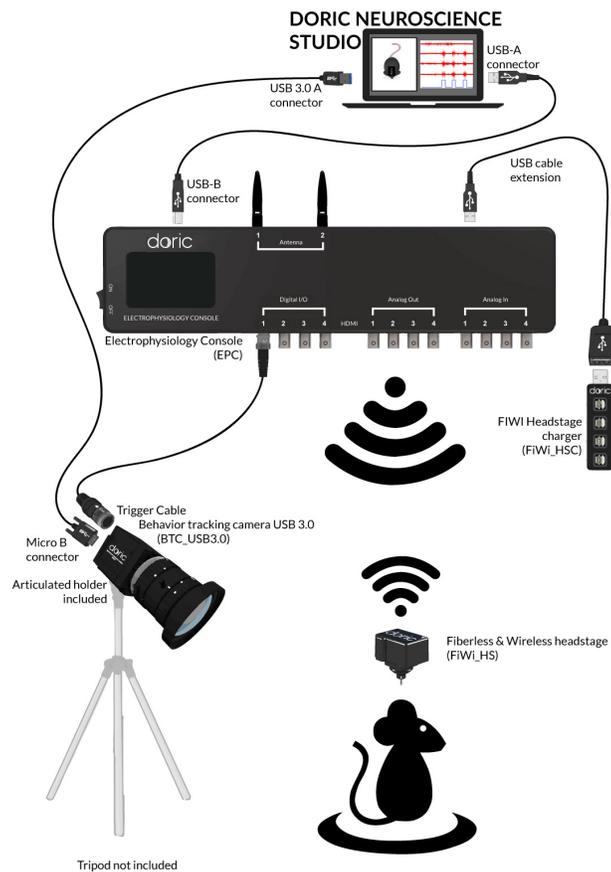


Figure 1.1: *Optogenetically Synchronized Electrophysiology System Layout*

The system uses a *Fiberless & Wireless Headstage* to connect the *Electrophysiology Console* and the *Fi-Wi Opto-electric Canula* using wireless signal. This allows small animal subjects high mobility while performing optogenetic and electrophysiological recording experiments. The system can easily be integrated alongside other *Doric Lenses* products, including our *Behavior Tracking Camera*. A standard OSE system (Fig. 1.1) contains the following elements.

- The *Fiberless & Wireless Headstage*.

- The *Fi-Wi Opto-electric cannula*.
- The *Electrophysiology Console*.
- The *Dummy Headstage*.
- The *USB Charger*.
- The *Test Cannula*.
- The *Implantation Holder*.
- The *Behavior tracking camera* (optional).

### 1.1.1 Fiberless & Wireless Headstage



Figure 1.2: *Fiberless & Wireless Headstage*

The *Fiberless & Wireless Headstage* (Fig. 1.2) is an electronic device that creates the link between the opto-electric cannula and the electrophysiology console. Its primary use is to record, amplify and digitize the electrophysiological signal. This is done using the **Intan RHD 2132** chip. Its secondary use is as an LED driver. It sends pulse sequences to the stimulation LED contained in the cannula. The headstage also contains a battery that powers the LED as well as all wireless transmissions. The headstage is secured to the cannula using a snap-on connector.

- The **Antenna** is a small ridge on the side of the headstage used to transmit wireless electrical signal.
- The **Headstage connector**, found on the underside of the headstage, links it to the cannula transmitting data and power.

### 1.1.2 Fi-Wi Opto-electric Cannula

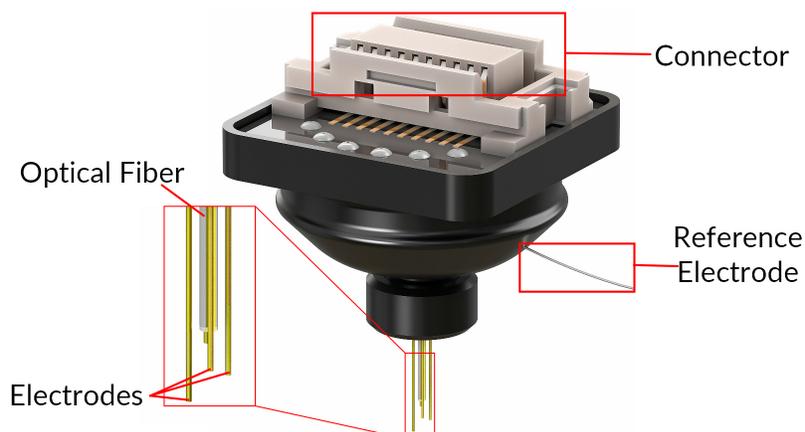


Figure 1.3: *Fi-Wi Opto-electric Cannula*

The *Fi-Wi Opto-electric cannula* (Fig. 1.3) contains an LED connected to a single optical fiber, allowing light to be sent into the region of interest. The cannula also contains the electrodes, positioned around the optical fiber, up to a maximum of 4. Electrode-only and optical-only cannulas are available on request.

- The **Cannula connector** (Fig. 1.3) links the cannula and the headstage, transmitting data and power.
- The **Recording Electrodes** receive electrical signal from the brain region in which their tips are located.
- The cannula also includes a single **Reference electrode** that can be intra- or extra-cranial.
- The **Optical Fiber** guides light from an LED integrated into the cannula.

Much care should be taken when unpackaging the **Fi-Wi Opto-electric Cannula**. The **Electrodes** and the **Optical Fiber** are very fragile. While removing the protective cap, ensure the movement used is parallel to the axis of the **Optical Fiber**. Removing the cap with a gentle unscrewing motion can help keep the cap in the right orientation.

### 1.1.3 Electrophysiology Console

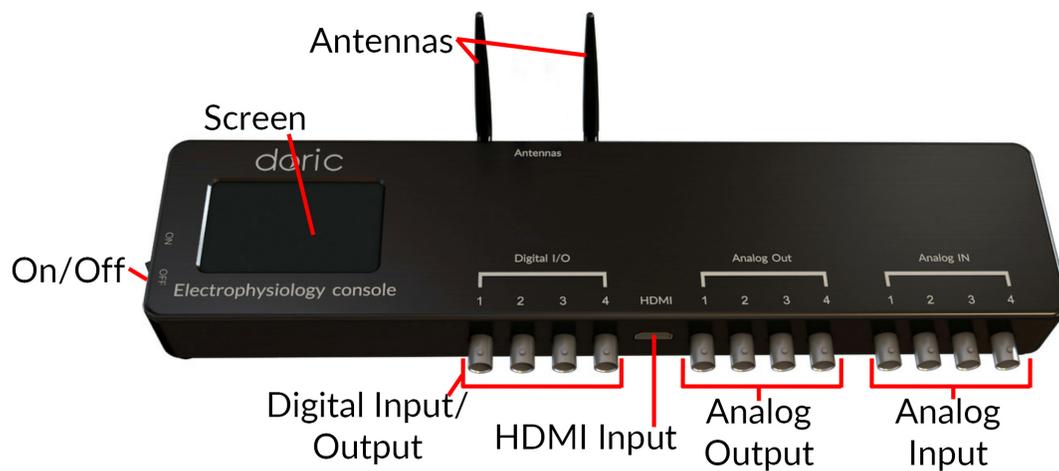


Figure 1.4: *Electrophysiology Console, Front*

The *Electrophysiology Console* (Fig. 1.4) allows control of the different elements, as well as reception and transmission of information from the control computer.

- The **ON/OFF** (Fig. 1.4) switch activates the console.
- The **LCD Screen** (Fig. 1.4) shows the status of the system's channels.
- The **DIGITAL I/O** (Fig. 1.4) ports control, send and receive 0-5 V TTL signals.
- The **HDMI** (Fig. 1.4) port acquires digital signals and digital communications via a custom pinout HDMI connector.
- The **Analog-Out** (Fig. 1.4) ports send a variable  $\pm 5$  V signal.
- The **Analog-In** (Fig. 1.4) ports acquire analog signals coming from various inputs.
- The two **Antennas** (Fig. 1.4) connect to the **SMA Connectors** (Fig. 1.5) and allow wireless connection to the headstages.
- The **12 VDC power input** (Fig. 1.5) connects to the 12 VDC power supply.
- The **USB Computer Connection** (Fig. 1.5) port allows connection to a computer using a USB-A/USB-B cable.
- The **USB Charging Port** (Fig. 1.5) is used by the *Fi-Wi Headstage Charger* to recharge the headstage battery. It is best to connect the charger to the console using the *USB-A Male/Female cable*.
- The **Service** (Fig. 1.5) port is a USB-B input through which the firmware of the device can be updated.



Figure 1.5: *Electrophysiology Console, Rear*

### 1.1.4 Fi-Wi Headstage Charger

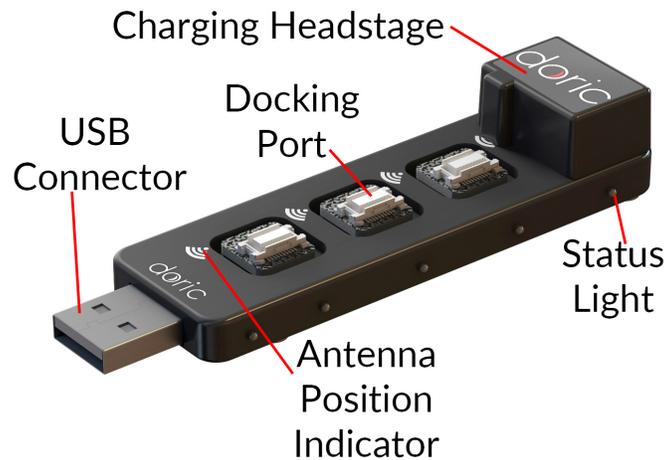


Figure 1.6: *USB Charger*

The *Fi-Wi Headstage Charger* (Fig. 1.6) is used to recharge the headstage batteries and shut down the wireless connection. During the pairing process, all unused headstages must be on the charger, as otherwise they could be detected instead of the one currently in use. The charger uses the same snap-in connectors as the cannula.

- The **USB Connector** connects the charger to the console or directly to a computer. It is recommended to use a USB Cable (Male/Female) to connect the *USB Charger*.
- The **Docking Ports** are used to recharge headstages connected to them. When a headstage is connected to a **Docking Port**, its wireless connection is shut down.
- The **Status Lights**, on the side of the charger, show the status of connected headstages. The one closest to the connector is blue when the charger is ready for usage. The others are yellow when a headstage is charging on a corresponding docking port. Once a headstage battery is fully charged, the light goes from yellow to green.
- The **Antenna Position Indicator** shows the proper placement of the antenna when docking a headstage to recharge the battery.

### 1.1.5 Test cannula

The *Test Cannula* is a simplified version of the *Fi-Wi cannula* that is used to test headstage performance. It can be used to test illumination sequences and ensure proper wireless connectivity, as the headstage alone provides no external indicators of activity. It otherwise has all the same functions as the *Fi-Wi cannula*, with the exception that it is not designed to be implanted.

### 1.1.6 Dummy Headstage

The *Dummy Headstage* is a simplified version of the *Fi-Wi Headstage* that is used to habituate an animal subject to the weight of the headstage. It contains no electronics or other valuable components, and will not function as a *Fi-Wi Headstage*.

### 1.1.7 Implantation Holder

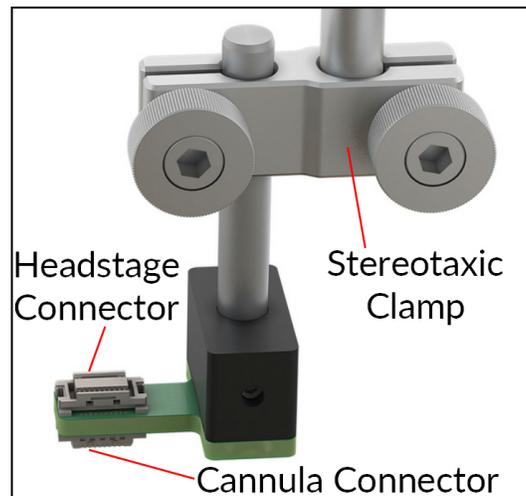


Figure 1.7: *Fi-Wi Cannula Implantation Holder*

The *Implantation Holder* is used to hold the *Fi-Wi Cannula* during implantation. The holder is made to be integrated within a stereotaxic apparatus. The holder has the following elements.

- The **Stereotaxic Clamp** is used to attach the holder to a rod in a stereotaxic apparatus.
- The **Headstage Connector** is used to hold a *Fi-Wi Headstage*. A headstage in this position will be able to send/receive signals from a cannula connected to the **Cannula Connector**.
- The **Cannula Connector** is used to hold a *Fi-Wi Cannula*. A cannula in this position will be able to send/receive signals from a headstage connected to the **Headstage Connector**.

### 1.1.8 Behavior Tracking Camera



Figure 1.8: *Behavior Tracking Camera*

The **Behavior Tracking Camera** (Fig. 1.8) is an optional addition that allows the observation of the subject in real-time. See the [Behavior Tracking Camera User Manual](#) for more information.

## Operations Guide

### 2.1 System Setup

The following steps assume the *Fi-Wi Opto-electric Cannula* is already implanted in the region-of-interest of the animal's brain (Fig. 2.1). The process of implantation is not described in this document.

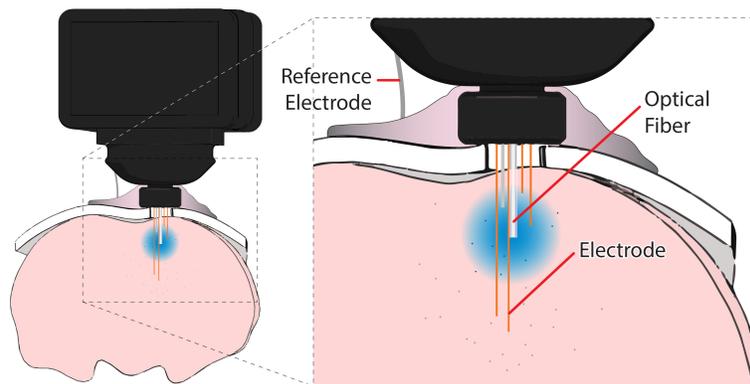


Figure 2.1: *Implanted Fi-Wi Opto-electric Cannula*

#### 2.1.1 Electrophysiology Console Setup

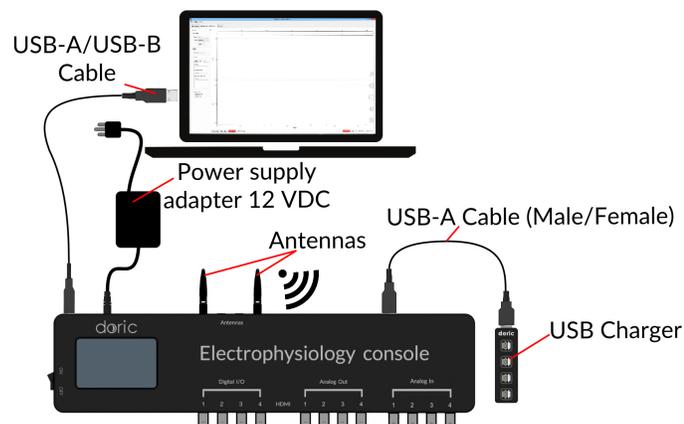


Figure 2.2: *Electrophysiology Console Setup*

1. Screw each antenna into the **SMA Connector**. Fold the antenna upwards for optimal reception.

2. Connect the console to the **12 VDC power supply** and turn the console **ON**. **THIS MUST BE DONE BEFORE CONNECTING THE CONSOLE TO THE COMPUTER.**
3. Connect the *Fi-Wi Headstage Charger* to the **USB Docking Port** using the USB-A (male/female) cable. Install the headstage(s) onto the charging port.
4. Connect the console to the computer using the **USB-A/USB-B Cable**.
5. When the console is **OFF**, disconnect the **USB-A/USB-B Cable** before turning it back **ON**. Once the console is **ON**, reconnect the cable.

### 2.1.2 Software setup

The following section details how to set up a measurement sequence using *Doric Neuroscience Studio*. Further detail for each software feature is found in section 3.

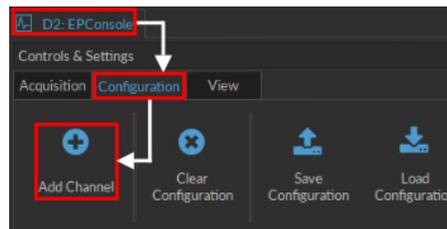
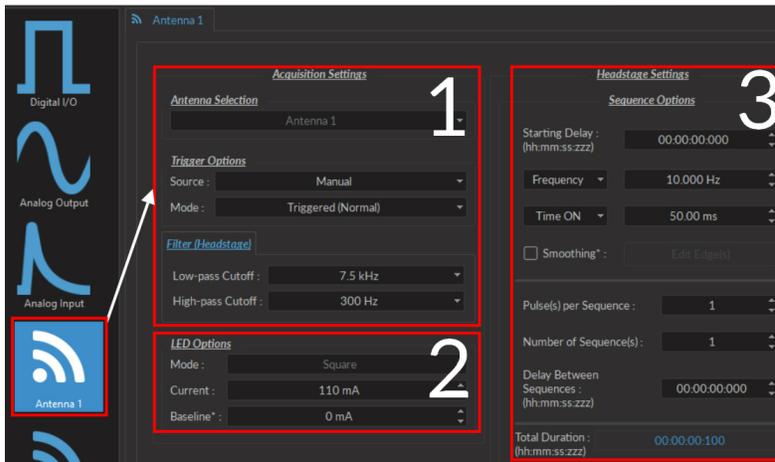
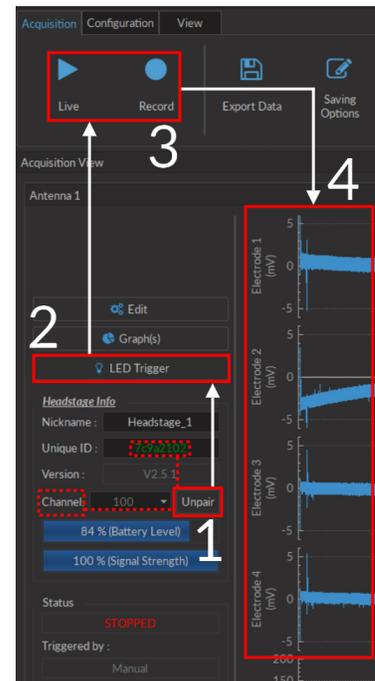


Figure 2.3: Antenna Channel Configuration

1. With the console properly connected, open the *Doric Neuroscience Studio*. Once open, the electrophysiology console tab (Fig. 2.3) will appear. Select the **Configuration** tab in the **Control & Settings** box, then select the **Add configuration** button to open the **Channel configuration** window.
2. In the **Channel configuration** window (Fig. 2.4), there are 2 **Antenna** channels available. When one is selected, the channel can be configured.
  - The **Acquisition settings** box (Fig. 2.4a-1) is used to define how electrophysiological data is acquired. This includes triggering options, as well as frequency filters.
  - The **LED Options** box (Fig. 2.4a-2) is used to define the cannula LED current and the current baseline.
  - The **Headstage settings** box (Fig. 2.4a-3) is used to define the pulse sequence emitted by the cannula LED. While the standard pulse sequence is square, the **Smoothing Edges** function can allow specific rise/fall times.
3. Once your channel is configured, it can be controlled using the **Acquisition** control tab and the tools in the **Acquisition view**.
  - Once the headstage is charged and off the charging station, click the **Pair/Unpair** button (Fig. 2.4b-1), which will connect it to the console. Its **Unique ID** will be indicated right above the button. The wifi **Channel** is shown beside the **Unpair** button; if multiple headstages are in use, each must have a different channel separated by at least 10 increments.
  - Once the headstage is paired, the LED sequence is triggered by the beginning of an acquisition sequence. The sequence progression can be seen on the **LED Trigger** window (Fig. 2.4b-2).
  - Once everything is ready, the **Live/Record** buttons (Fig. 2.4b-3) will start the acquisition sequence.
  - With the acquisition sequence started, recorded signal will be shown in the **Graphs Box** (Fig. 2.4b-4).



(a) Channel configuration window setup



(b) Acquisition setup

Figure 2.4: Headstage startup elements

### 2.1.3 Fiberless & Wireless Headstage Setup

The *Fiberless and Wireless Headstage* is the bridge between the *Fi-Wi Opto-electric Cannula* and the *Electrophysiology Console*. Some preparation is required for optimal use.

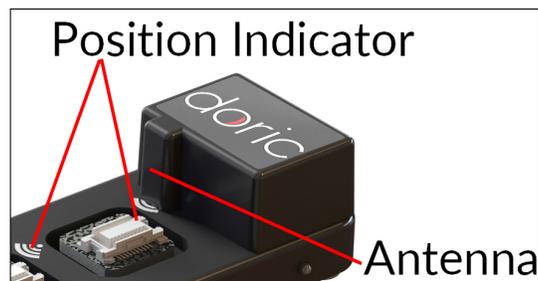


Figure 2.5: Headstage charger installation

1. The *Fiberless and Wireless Headstage* must first be charged. Place a headstage onto the *USB Charger* so the antenna is on the position indicator.
  - The console must be **ON** for the headstage to recharge, which requires > 60 min.
  - The headstage cannot connect wirelessly while being charged.
  - While recharging, the **Status Lights** of each **docking port** are yellow. These turn green once the headstage has sufficient charge to be used, which will typically take approximately an hour.
2. Remove a headstage from the *USB Charger*.
3. Click the **Pair** button in the **Wireless Settings**. Once properly paired, the section will display the **Headstage ID**, the **Battery Level** and the **Signal Strength**.



Figure 2.6: Headstage placement

4. The headstage is connected to the cannula using a snap-on connector. For the two elements to connect properly, the headstage antenna ridge must be oriented towards the front of the cannula, as shown in Figure 2.6.
5. Connect the headstage to the **Test Cannula** and place it inside the experimental space. Test your **Signal Strength** and the LED to ensure proper function of the headstage. This is used to validate transmission quality between the headstage and the console during an experiment.
6. The headstage can then be installed onto the *Fi-Wi Opto-electric Cannula* for experimental use. Ensure the protective cap is removed from the cannula using a motion that is parallel to the **Optical Fiber**, as described in section 1.1.2.
7. After use, place the **Fiberless and Wireless Headstage** back onto the **USB Charger** to reset the wireless connection.
8. To ensure optimal transmission:
  - The experimental subjects should be on the same plane as the console antenna.
  - Avoid placing metallic objects between the console and the **Headstage**. For proper transmission, the vertical faces of the animal cage must be non-metallic.
  - If signal is not received properly, change the wireless **Channel**. Wi-Fi signal can interfere with transmission.
  - Ensure the antenna is fully screwed into the **SMA Connector** (Fig. 1.5).
  - Before use in an experiment, place the *Fi-Wi Headstage* in the experimental area to verify transmission quality.
9. It is possible to connect a second **Fiberless and Wireless Headstage** to the console at the same time. When using a second headstage, ensure that each headstage is using a **Channel** at least 10 increments from the other.

## Doric Neuroscience Studio

### 3.1 Fiberless and Wireless Optogenetically Synchronized Electrophysiology

Optogenetically Synchronized Electrophysiology (OSE) systems require delivery of appropriate optical signals to the point of interest within neural tissue as well as detection and processing of the electrical signals from neural activity. The Wireless OSE module incorporates different functions to control our Doric Fiberless & Wireless OSE system. The core of the system is the Fiberless & Wireless Headstage. This device controls a *Wireless cannula* containing several electrophysiological probes and an LED light source. This cannula is implanted into the brain of an animal and records electrophysiological data while sending pulse sequences of light. This headstage is controlled from the **Electrophysiology Console**, which transfers data between the headstage and the computer.



Figure 3.1: Electrophysiology console user interface

### 3.1.1 Channels

As the electrophysiology console has 4 different channel types. As it shares its basic architecture with our photometry consoles, the 3 first channel types (**Digital I/O**, **Analog Output** and **Analog Input**) are described in section 3.2. The **Antenna** channels are used to control the fiberless and wireless headstage (section 3.1.1).

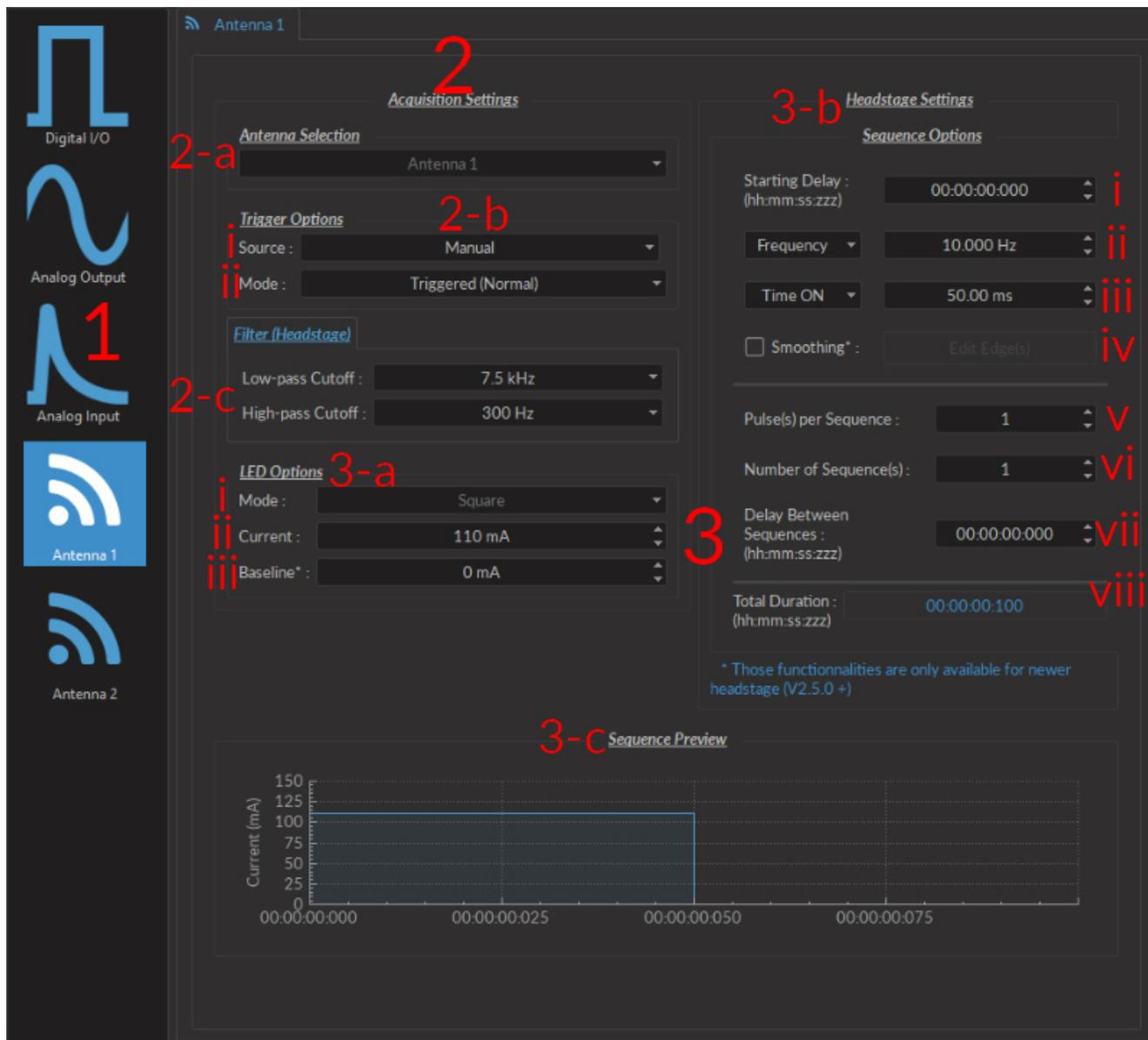


Figure 3.2: Electrophysiology channel configuration window

1. The **Channel Types** (Fig. 3.2) are selected on the left side of the window. Selecting the channel icon will display the parameters of each respective **Channel type**.
2. The **Wireless settings** (Fig. 3.2) are used to select recording and transmission settings.
  - a) The **Antenna selection** (Fig. 3.2) box shows the currently selected antenna.
  - b) The **Trigger options** (Fig. 3.2) box allows the selection of trigger parameters for data acquisition.
    - i. The **Trigger source** can either be **Manual**, or can come from the **Digital I/O** channels.
    - ii. The **Trigger mode** can be one of two types. In **Triggered** mode, the measurement sequence starts when a trigger signal is received, and continues even if the trigger signal stops. In **Gated** mode (currently in

development), the measurement sequence when a high TTL signal (>4 V) is detected, and will stop when a low TTL signal (<0.4 V) is detected.

This source can either be **Manual**, or from one of the four **Digital I/O** channels. The **Trigger Mode** can be either **Triggered** or **Gated**.

- c) The **Pre-processing** (Fig. 3.2) filters define the high and low-pass frequency cutoff for electrical signal received by the headstage.
3. The **LED options** (Fig. 3.2) are all parameters used to control the light source of the cannula connected to the *Fi-Wi* headstage.
    - a) The **Channel options** (Fig. 3.2) are used to control the LED mode and current.
      - i. The **Mode** (Fig. 3.2) allows the selection of the pulse sequence mode. At time of writing, only **Square** mode is available.
      - ii. The **Maximum current** (Fig. 3.2) defines the current sent to the cannula LED. For proper function of the cannula, the current should always be greater than 10 mA.
      - iii. The **Baseline** (Fig. 3.2) leaves a small offset to the current sent to the LED. It is recommended to use a small offset, as a complete shut-down of the LED will induce a spike in the electrical acquisition signal.
    - b) The **Sequence options** (Fig. 3.2) box is where LED pulse sequence parameters are defined.
      - i. The **Starting Delay** (Fig. 3.2) sets the delay (in hh:mm:ss:zzz format) before the first pulse.
      - ii. The **Frequency/Period** (Fig. 3.2) sets the frequency (in Hz) or period (in ms) for the pulse sequence. For example, a signal at 10 Hz (frequency) will output one pulse every 100 ms (period), whereas a pulse sequence at 0.5 Hz (frequency) will output one pulse every 2000 ms (period).
      - iii. The **Time ON/Duty Cycle** (Fig. 3.2) sets the time (in ms) or the duty cycle (in %) for each pulse. The **Time ON** must be lower than  $(1/\text{frequency})+0.005$  ms, while the **Duty cycle** must be below 100 %. These squares will appear red should an impossible **Frequency/time ON** be selected.
      - iv. The **Smoothing** option is used to change the pulse slope in square pulse sequences. The **Edit Edges** button opens the **Smoothing Edge(s)** window (Fig. 3.3).

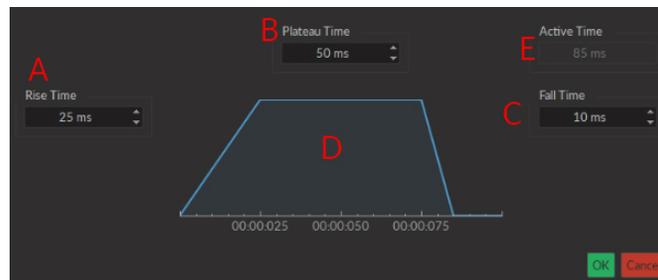


Figure 3.3: Light Source Smoothing Edge(s) Window

- A. The **Rise Time** box is used to define the duration to rise from 0 to the pulse maximum.
  - B. The **Plateau Time** box is used to defined the duration the pulse is at its maximum value.
  - C. The **Fall Time** box is used to define the duration to descend from the pulse maximum to 0.
  - D. The **Pulse Graph** displays the pulse shape.
  - E. The **Active Time** box displays the total duration of the pulse. While the **Smoothing** option is active, the **Time ON** is fixed at this value.
- (need to include section)
- v. The **Pulses per sequence** (Fig. 3.2) sets the number of pulses per sequence. If it is set to 0, the pulse will be repeated indefinitely.
  - vi. The **Number of sequences** (Fig. 3.2) sets the number of times that the sequence will be repeated. If it is set to 0, the sequence will be repeated indefinitely.
  - vii. The **Delay between sequences** (Fig. 3.2) sets the delay (in hh:mm:ss:zzz format) between each sequence if the **Number of Sequences** is greater than 1.
  - viii. The **Total Duration** (Fig. 3.2) displays the total time of the experiment. The different values can be *Inf* for infinite, a valid time value or *Err* if the **Time ON** value is greater than  $1/\text{frequency}$ .
- c) The **Preview** box shows a preview of the pulse sequence.

### 3.1.2 Control and Settings tabs

The three **Control and settings tabs** are used to manage different parts of the software, and are described in section 3.2.2.

### 3.1.3 Acquisition View

The **Acquisition View** box displays all information concerning active channel. Each channel chosen using **Add Channel** is displayed on the window, occupying a rectangular box. Each **Channel box** shows a number of basic elements, described in section 3.2.3. Elements uniquely associated with the **Antenna** channel are described here.

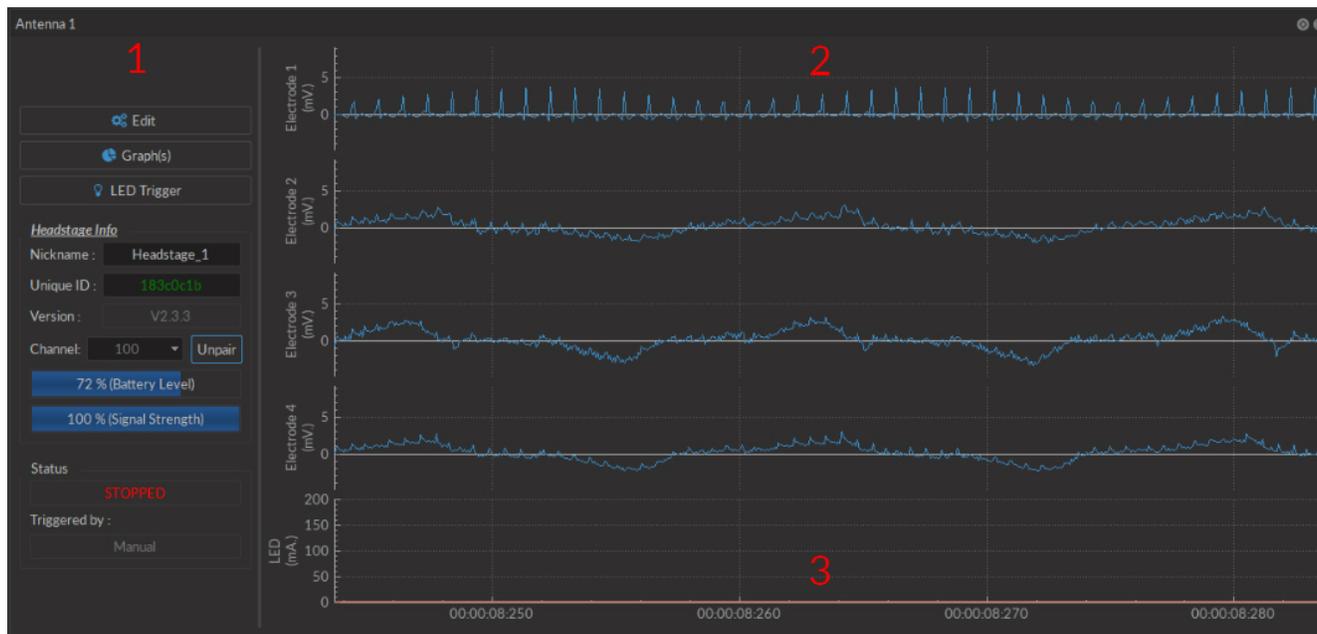
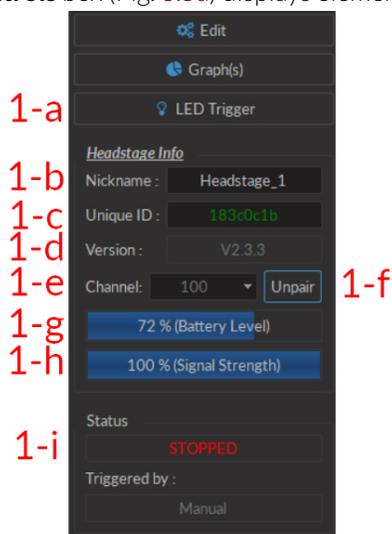
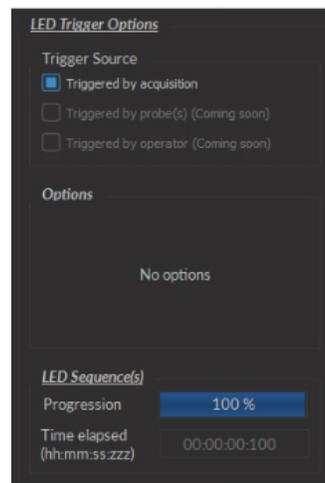


Figure 3.4: Electrophysiology acquisition view, Antenna box

1. The **Controls** box (Fig. 3.5a) displays elements to control and monitor the wireless headstage.



(a) Acquisition View, Controls



(b) LED Trigger-Triggered by Acquisition Window

Figure 3.5: Acquisition View Interfaces

- a) The **LED trigger** buttons opens the **LED trigger options** window. In this window, the **Triggered By Acquisition** option is available; other options are still in beta, and will be made available at a later date. Sequences can be activated/shut down while this window is open.
    - The **LED Triggered by acquisition** (Fig. 3.5b) mode activates the LED when an acquisition sequence is started. This includes the moment the **Headstage** is initially activated, and when a recording session is started using one of the **Ephys Trigger Options**.
  - b) The **Nickname** box allows the user to change the name used for the connected headstage.
  - c) The **Unique ID** box displays the unique ID sequence associated with the headstage currently in use.
  - d) The **Version** box displays the headstage firmware version.
  - e) The **Channel** drop-down list shows the channel currently in use by the headstage. When using two headstages, the channel must be different for each headstage.
  - f) The **Pair** button is used to pair an active headstage to a console. When a headstage is paired, it becomes the **Unpair** button, which unpairs the active headstage associated with the given antenna.
  - g) The **Battery Level** bar displays the headstage battery level, in %, at all times.
  - h) The **Signal strength** bar displays the signal strength. If the signal strength is acceptable (100-76%) the bar appears **blue**. If the signal strength is low (75-50%), it will appear **yellow**. If the signal strength is critically low (<50%), it will appear **red**.
  - i) The **Status** bar displays acquisition status. **STOPPED** is displayed when the acquisition is inactive, and **STARTED** when acquisition is active.
2. The **Electrode Traces** (Fig. 3.4) displays the signal detected by the cannula electrodes, in numbered order.
  3. The **LED Trace** (Fig. 3.4) displays the current being sent to the cannula LED.

## 3.2 Acquisition Console

The heart of the *Electrophysiology console* is the acquisition console, an FPGA based data acquisition unit which synchronizes the output control and the input data of the acquisition. The interface provides different functionalities for multi-channel experiments. It enables control over the excitation light pulses, or the sinusoidal waveform trig of an external source (i.e. Doric LED driver) with 4 TTL and 4 analog voltage outputs. The module interface displays real-time recordings of up to 4 input signals and performs basic signal processing. The system is controlled using 3 **Control and Settings** tabs. Separate channel windows are used to define output/input specifications.

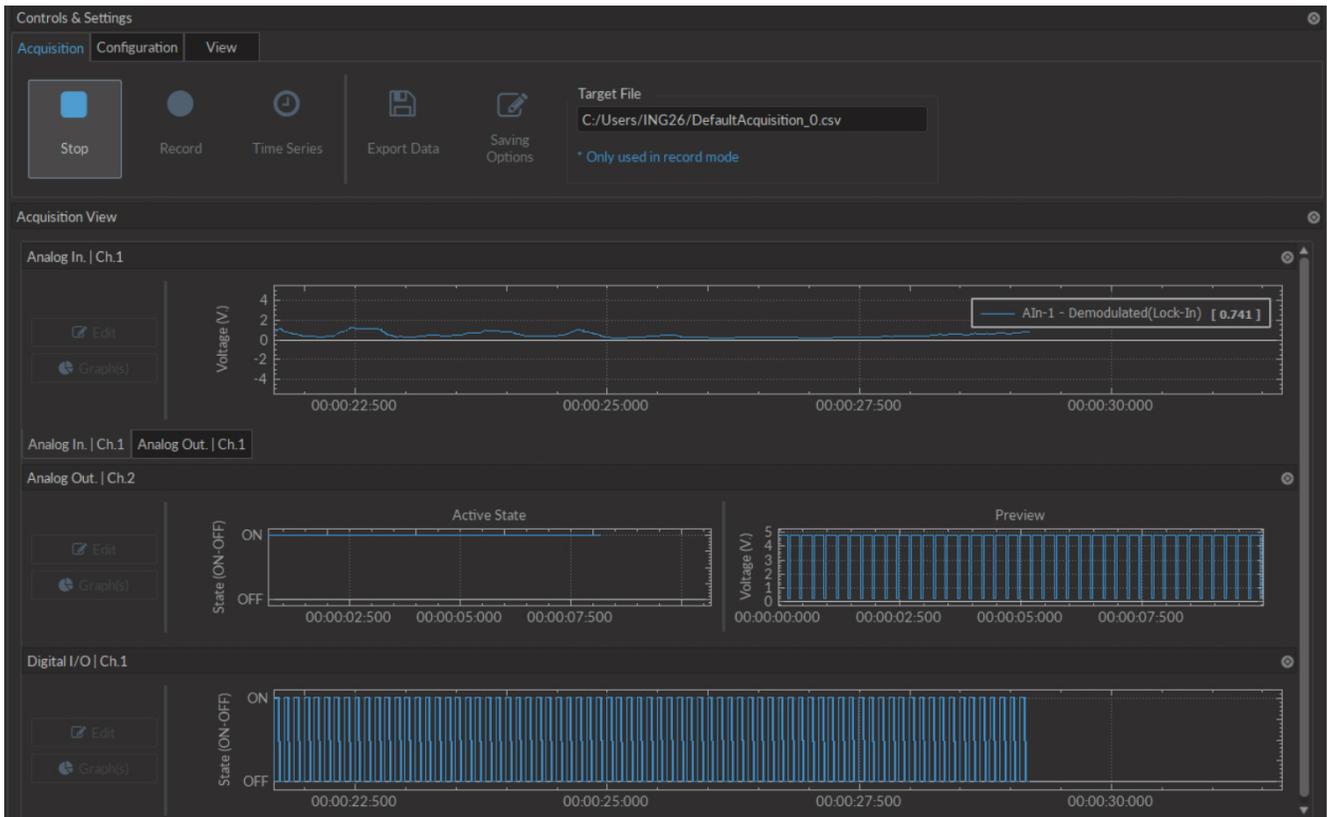


Figure 3.6: Console User Interface

### 3.2.1 Channels

The console has three different types of channels. The **Digital I/O** (Section 3.2.1) channels allow the input and output of TTL signals. The **Analog Output** (Section 3.2.1) channels allow the output of analog signals. The **Analog Input** (Section 3.2.1) channels allow the input of analog signals. Any number of channels may be added using the **Add channel** button on the **Configuration** tab (Section 3.2.2). The **Channel(s) configuration** window contains the following elements shared by most channel types.

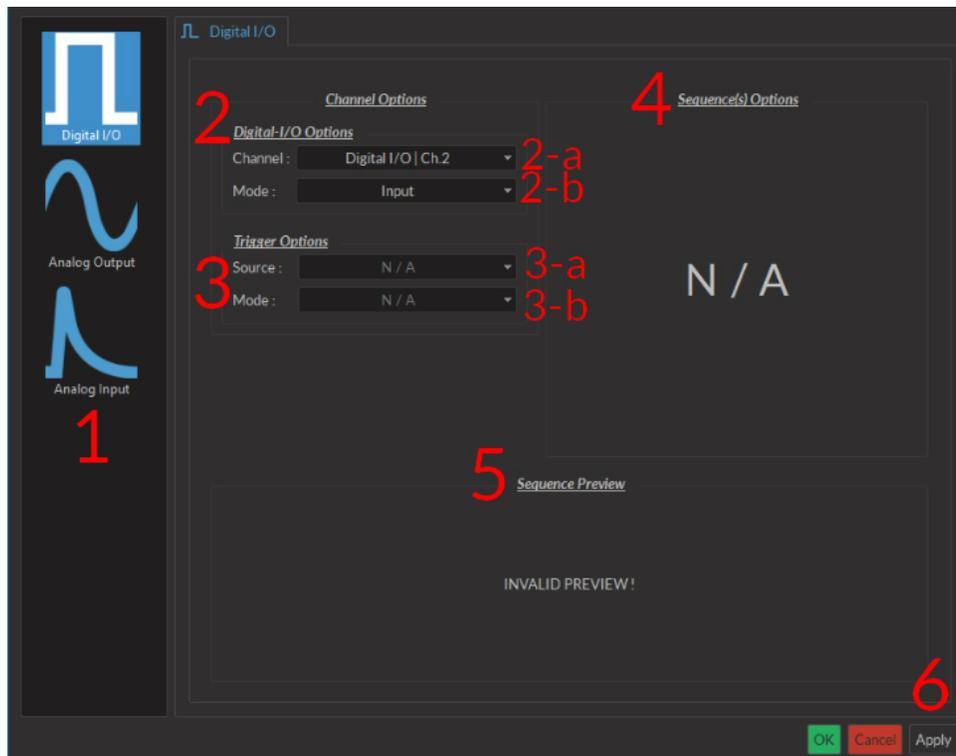


Figure 3.7: Channel(s) configuration window, Digital I/O input

1. The **Channel Types** (Fig. 3.7) are selected in the box on the left side of the window. Selecting the **Digital I/O** , **Analog-Out** or **Analog Input** icons will display the parameters to each respective **Channel type** on the right side of the window.
2. The **Channel Options** (Fig. 3.7) include the **Channel** drop-down list and the channel **Mode** list.
  - a) The **Channel** identifies which of the 4 channels available for each channel type is currently being modified. The channel can be changed by selecting a new one from the drop-down list.
  - b) The **Mode** identifies the type of signal sent (for output channels) or the way the signal is measured (for input channels). The specifics of these choices are defined in the section for each channel type.
3. The **Trigger Options** (Fig. 3.7) define the trigger methods. These options include the trigger **Source** and **Mode**.
  - a) The **Source** trigger option allows the choice of a **Manual Trigger** (activated by a user) or an **Input** trigger, coming from an input on a **Digital I/O** channel.
  - b) The **Mode** defines how the trigger activates a sequence. This includes input sequences, which can be triggered/gated by an outside source.
    - In **Triggered** mode, the sequence is started manually or by a trigger source from another digital input channel. Once the trigger source is received, the sequence will continue until the end or until **Stop** is pressed.
    - In **Gated mode**, the sequence will play as long as there is a high TTL signal (4 V or more) on the input modulation BNC. This signal comes from a different light source or device driver. When the TTL signal is

low (0.4 V or less), the sequence stops and waits for another high TTL signal to continue. This mode will cut pulses, with a new pulse restarting once the high signal returns.

4. The **Sequence Options** (Fig. 3.7) define the parameters of each pulse sequence for output channels. These parameters are defined with each channel type. Should a parameter chosen be impossible to apply to a sequence (For example, a **Time ON** greater than  $1/\text{Frequency}$ ), the color of the option boxes will turn **RED**.
5. The **Sequence Preview** (Fig. 3.7) section allows visualization of the output sequence that will play by selecting the channel in the graph.
6. The **Apply** button (Fig. 3.7) will generate the defined channel OR update an already configured channel with any changes.

## Digital I/O Channels

With the **Digital I/O** channels, each digital channel can be configured as an output or an input and create TTL (On/Off) pulse sequences. Each numbered channel corresponds to the same number digital channel on the console. Pulse sequences have different parameters depending on the **Channel Mode**, which can be **Continuous** or **Square** for output sequences and **Input** for input signals. The **Channels Configuration** window contains the following elements for a Digital I/O channel.

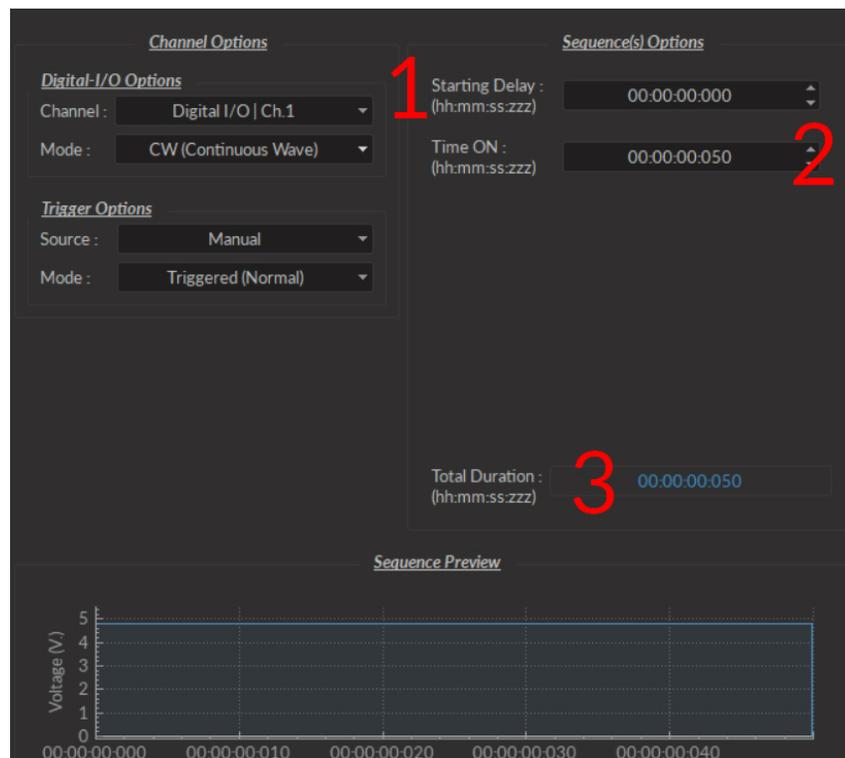


Figure 3.8: Channel(s) configuration window, Digital I/O CW

- The **CW(Continuous Wave)** channel mode (Fig. 3.8) allows the creation of a continuous TTL pulse sequence. The following elements appear in the **Sequence Options** box.
  1. The **Starting Delay** defines the time between the activation of the pulse sequence and the beginning of the signal.
  2. The **Time ON** defines the length of time the continuous signal is active. Should the time chosen be 0, the signal will continue until the pulse sequence is stopped manually.
  3. The **Total Duration** shows the total expected duration of the pulse sequence. Should the duration be infinite, the box will display  $\infty$ . If there is an error in parameter selection, this box will display **N/A**.

- The **Square** channel mode (Fig. 3.9) allows the creation of a square TTL pulse sequence. This includes all sequence options as the **CW** mode, with the following additions.
  1. The **Frequency** sets the frequency (in Hz), which is the number of pulses per second. The frequency can also be changed to the **Period**. For example, a signal at 10 Hz (frequency) will output one pulse every 100 ms (period), whereas a signal at 0.5 Hz (frequency) will output one pulse every 2 seconds (period).
  2. The **Time ON** defines the length of a single pulse. This time can also be converted to a **Duty Cycle**, which indicates the % of the period the pulse duration corresponds to.
  3. The **Pulse(s) per sequence** set the number of pulses per sequence. If it is set to 0, the number of pulses will be infinite.
  4. The **Number of sequence(s)** sets the number of times that the sequence will be repeated.
  5. The **Delay between sequences** sets the delay between each sequence.
- The **Input** mode (Fig 3.7) receives a signal that is translated to 0 (**Off**) or 1 (**On**). The channel can then be used as a trigger source for all the other channels of the console. No **Sequence Options** or **Sequence Previews** are available for this mode.

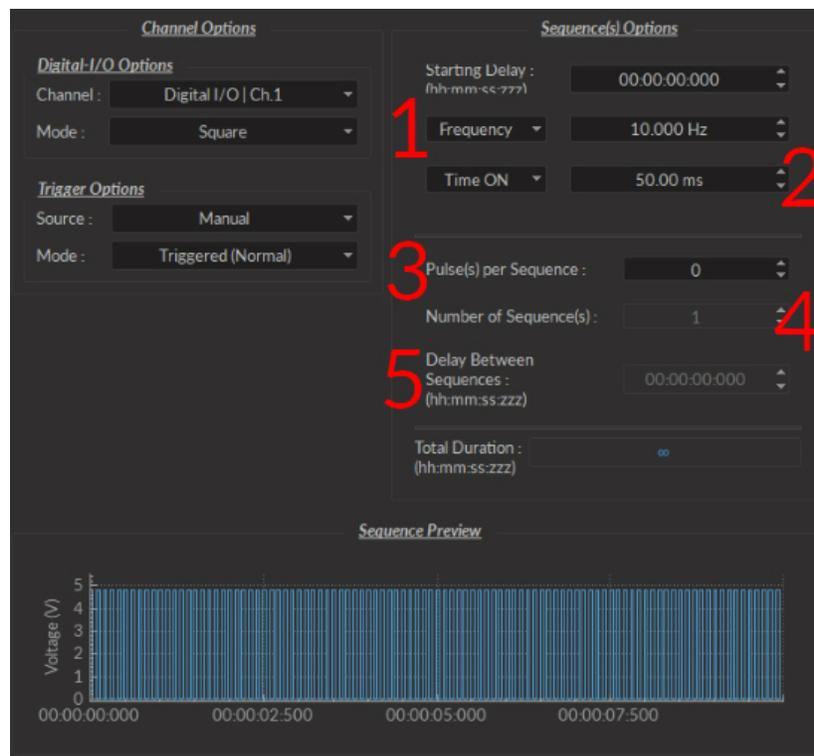


Figure 3.9: Channel(s) configuration window, Digital I/O square

## Analog Output

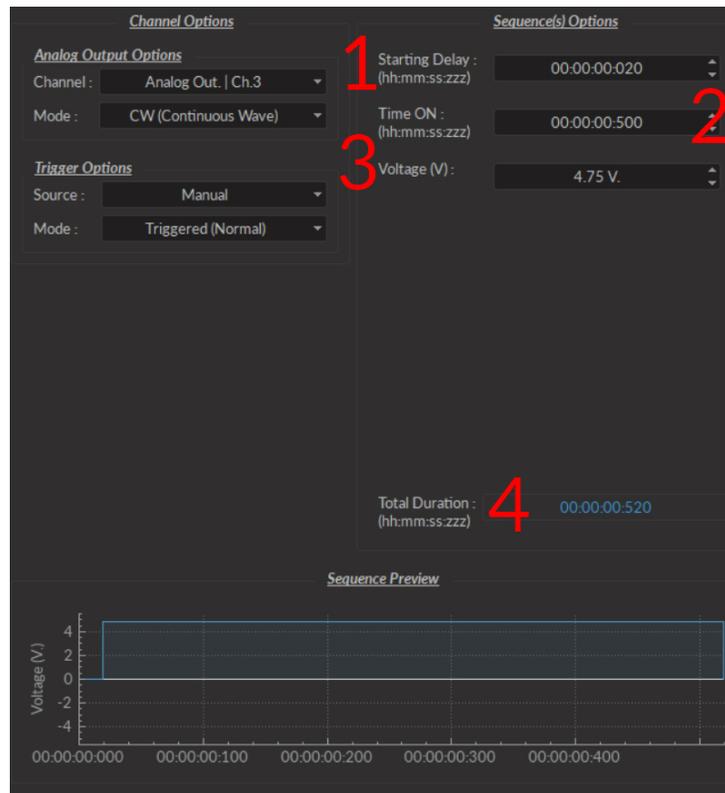


Figure 3.10: Channel(s) configuration window, Analog Output CW

The **Analog Output** channel type creates analog pulse sequences. Each numbered channel corresponds to the same number analog channel on the console. Pulse sequences have different parameters depending on the channel **Mode**, which can be **Continuous**, **Square** or **Sine**. The **Channels Configuration** window contains the following elements for an analog channel.

- The **CW (Continuous wave)** channel mode (Fig. 3.10) allows the creation of a continuous analog signal. The following elements appear in the **Sequence Options** box.
  1. The **Starting Delay** (Fig. 3.10) defines the time between the activation of the pulse sequence and the beginning of the signal.
  2. The **Time ON** (Fig. 3.10) defines the length of time the continuous signal is active. Should the time chosen be 0, the signal will continue until the pulse sequence is stopped manually.
  3. The **Voltage** (Fig. 3.10) defines the voltage of the continuous signal, in volts. The signal cannot go beyond  $\pm 4.75$  V.
  4. The **Total Duration** (Fig. 3.10) shows the total expected duration of the pulse sequence. Should the duration be infinite, the box will display  $\infty$ . If there is an error in parameter selection, this box will display **N/A**.

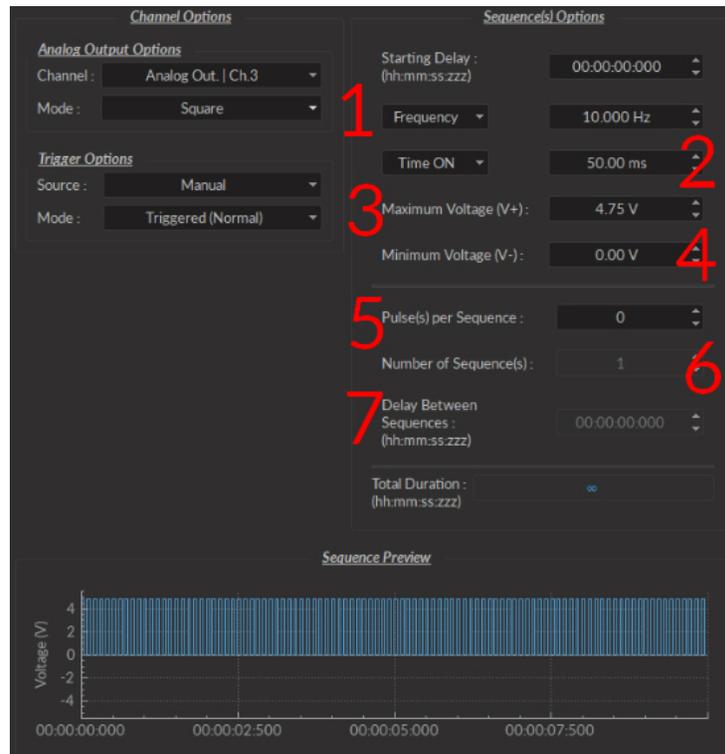


Figure 3.11: Channel(s) configuration window, Analog Output Square

- The **Square** channel mode (Fig. 3.11) creates a sequence of pulses with the minimum of the pulses at **V-** and the maximum of each pulse at **V+**. This includes all sequence options as the **CW** mode, with the following additions.
  1. The **Frequency** (Fig. 3.11) sets the frequency (in Hz), which is the number of pulses per second. The frequency can also be changed to the **Period**. For example, a signal at 10 Hz (frequency) will output one pulse every 100 ms (period), whereas a signal at 0.5 Hz (frequency) will output one pulse every 2 seconds (period).
  2. The **Time ON** (Fig. 3.11) defines the length of a single pulse. This time can also be converted to a **Duty Cycle**, which indicates the % of the period the pulse duration corresponds to.
  3. The **Maximum Voltage (V+)** (Fig. 3.11) defines the maximum voltage of each pulse, in volts. The signal cannot go beyond +4.75 V.
  4. The **Minimum Voltage (V-)** (Fig. 3.11) defines the minimum voltage of each pulse, in volts. The signal cannot go beyond -4.75 V.
  5. The **Pulse(s) per sequence** (Fig. 3.11) set the number of pulses per sequence. If it is set to 0, the number of pulses will be infinite.
  6. The **Number of sequence(s)**(Fig. 3.11) sets the number of times that the sequence will be repeated.
  7. The **Delay between sequences** (Fig. 3.11) sets the delay between each sequence.

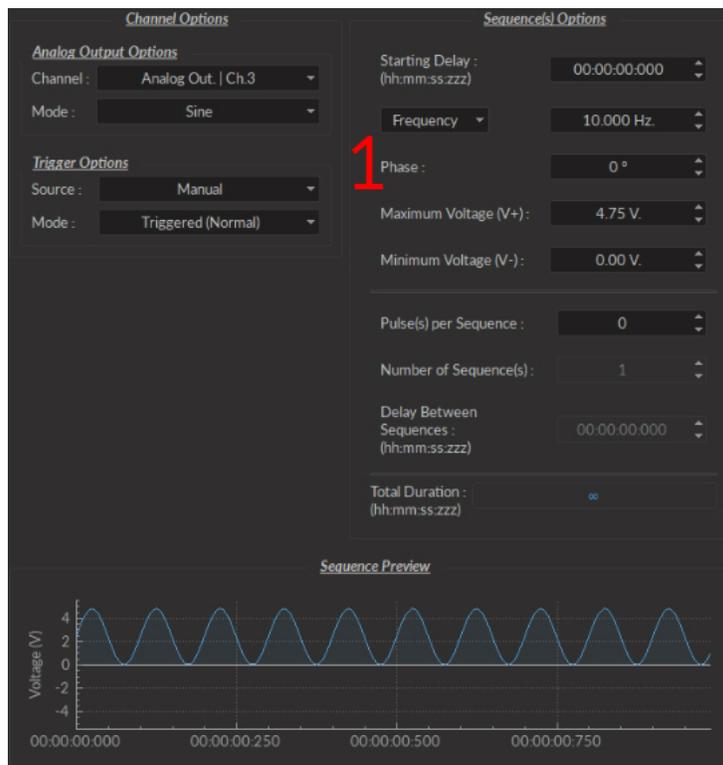


Figure 3.12: Channel(s) configuration window, Analog Output Sine

- The **Sine** mode (Fig. 3.12) creates a sinusoidal pulse sequence with peaks at **V+** and **V-**. This includes all sequence options as the **CW** and **Square** mode, save the following.
  - The **Time ON** option is changed for the **Phase** option (Fig. 3.12). This allows the choice of the sine wave phase, in degrees.

## Analog Input

The **Analog Input** channels (Fig. 3.13) acquire from the **Analog Input** BNC connector ports. For these channels, **Sequence Options** are replaced by **Global Options** concerning the acquisition of data. These **Global Options** are applied to all **Analog input** channels. They use different **Channel Modes** unique to the **Analog Input** channels.

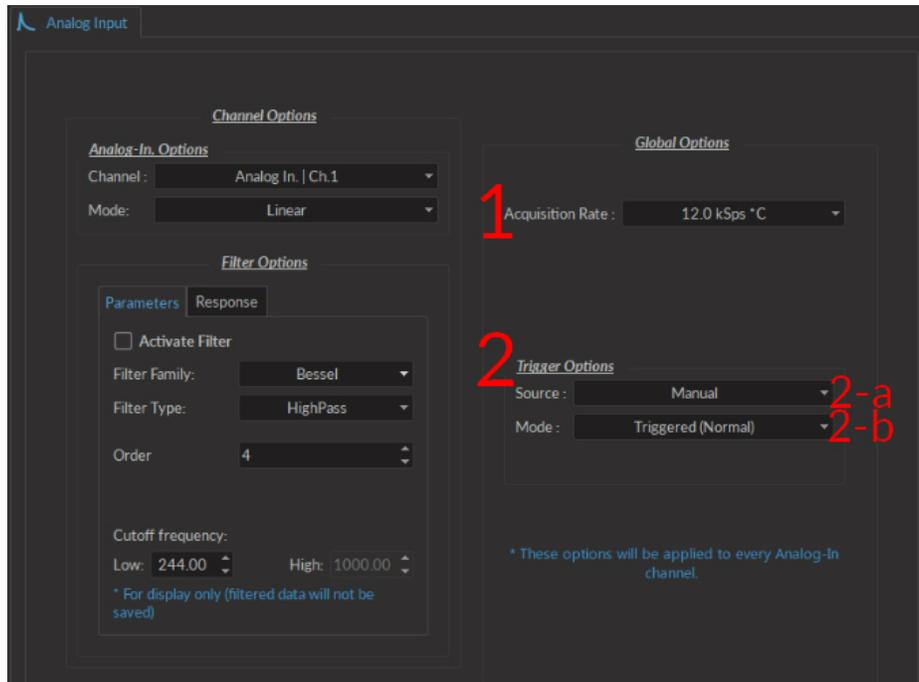


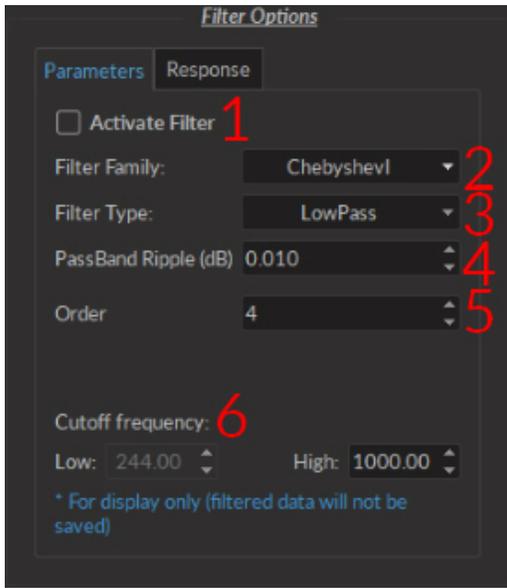
Figure 3.13: Channel(s) configuration window, Analog Input Linear

There are two **Global Options** available to all **Analog-in Modes**.

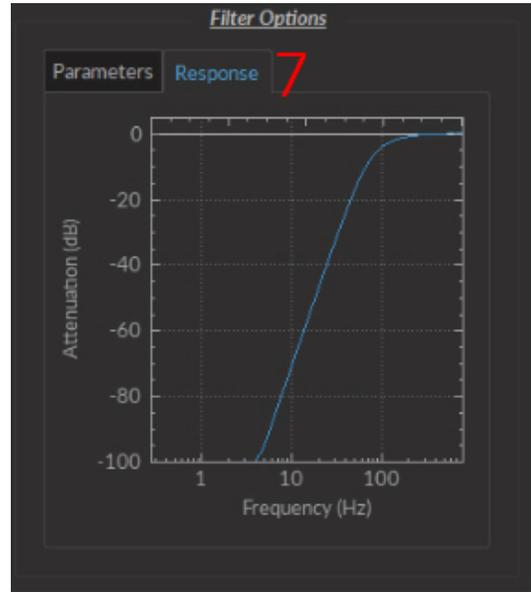
1. The **Acquisition Rate** (Fig. 3.13) is measured in kilosamples per second. A rate of 1 kSps will acquire 1,000 samples per second per channel. During an acquisition, a maximal amount of  $3.6 * \text{rate} [\text{in kSps}] \text{ MB/min}$  of data are created.
2. The **Trigger Options** defines the trigger source and mode.
  - a) The **Trigger Source** is either **Manual** or a **Digital I/O** channels.
  - b) The **Trigger Mode** is either **Triggered** or **Gated**. **Gated** mode is only available when the trigger source isn't **Manual**.

Each **Analog-In Mode** has a specific set of parameters. The function of each **Mode** is described here.

- The **Linear** channel mode (Fig. 3.13) allows the direct measurement of signal received by a channel. The linear mode has the option of a frequency filter, found in the **Filter Options** box.
  1. When the **Activate Filter** checkbox is selected, the defined filter is applied on all input data and displayed on a new trace. The filtered data is for display only, and will not be saved.
  2. The **Filter Family** drop-down list is used to choose the filter type. These include **Bessel**, **Butterworth** and **Chebyshev (I ad II)** filters.
  3. The **Filter Type** drop-down list allows the choice of a filter type from **High-Pass**, **Low-Pass**, **Band-Pass** and **Band-Stop**.
  4. The **Ripples** box is only available for **Chebyshev** filters. The ripple (either in the passband, or in the stopband) defines the acceptable filter response ripples. The higher the ripples, the sharper the filter response.
  5. The **Order** selector is linked to filter sharpness; a higher order will provide a sharper filter.
  6. The **Cutoff Frequency** boxes are used to define the low/high cutoff values for the filter, depending on the type used. The cutoff frequency must be less than half of the sampling rate.



(a) Filter Tab



(b) Response Tab

Figure 3.14: Linear Mode Filter Options

7. The **Response Tab** displays the filter response (attenuation) according to frequency.

### 3.2.2 Control and Settings tabs

The three **Control and settings tabs** are used to manage the different parts of the software. There are three tabs, **Acquisition**, **Configuration** and **View**.

#### Acquisition Tab

The **Acquisition** tab allows the activation of pulse and recording sequences. Three **Live**, **Record** and **Time Series** buttons are used for activation and will not function if no channels are configured. This includes the saving of data accumulated by these pulse sequences.

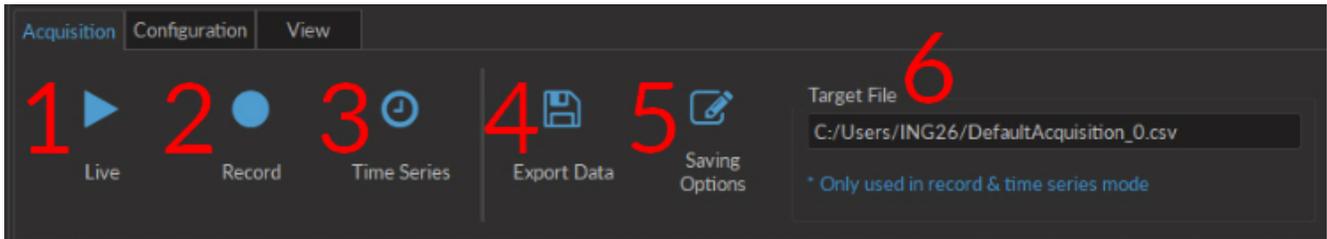


Figure 3.15: Acquisition Tab

1. The **Live** button (Fig. 3.15) activates all prepared channels. This mode does not automatically save data, keeping only the most recent 700 000 data points in memory. This mode is not recommended for long or critical measurement sequences.
2. The **Record** button (Fig. 3.15) activates all prepared channels while periodically saving recorded data to the disk. This mode is recommended for long measurement sequences.

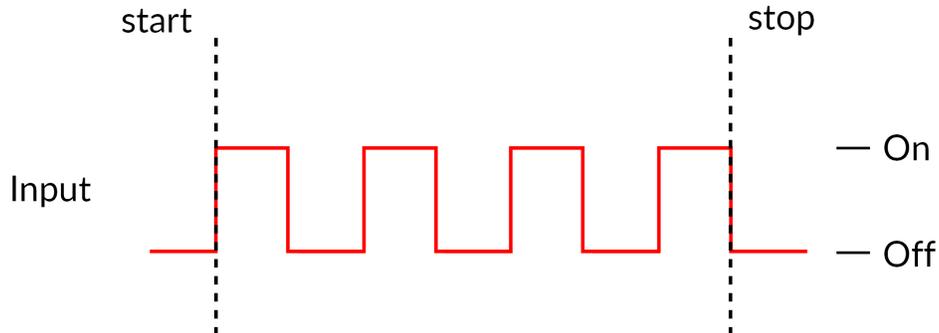


Figure 3.16: Time Series Acquisition Timing Diagram

3. The **Time Series** button (Fig. 3.15) opens the **Time Series Window** (Fig 3.17). This window allows the organisation of timed activation using the following parameters. Each **Time series** sequence is automatically saved to the same .csv file as defined in **Saving Options**.
  - The **Settings** box contains the series settings.
    - The **Number of series** defines the amount of times the series is repeated.
    - The **Time ON** defines the duration of the series.
    - The **Interval Between Series** defines the amount of time between each series, if the **Number of series** is greater than 1.
    - The **Total Duration** displays the total duration of all series.
  - The **Progression** box includes the **Progression bar**, which indicates the progression of the series (in %), while the **Time Elapsed** counter indicates the progression of the series.

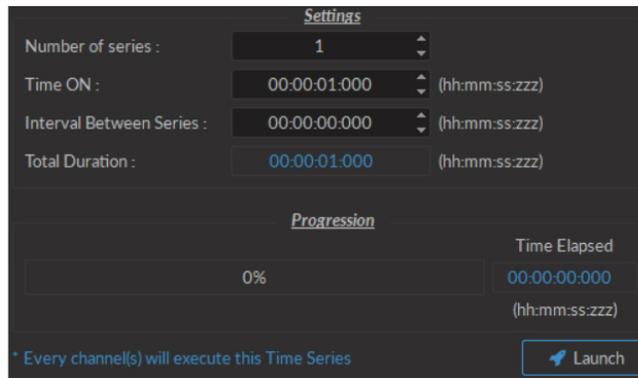


Figure 3.17: Time Series Window

- The **Launch** button start the series. While the series is active, it is impossible to add channels or change the configuration, though **View** settings can be modified.
4. The **Export Data** button (Fig. 3.15) will export all data in the **Acquisition view** into a .csv file. This is the only way to export data obtained will using the **Live** acquisition mode.
  5. The **Saving Options** (Fig. 3.15) button opens the **Saving Menu** window (Fig. 3.18).

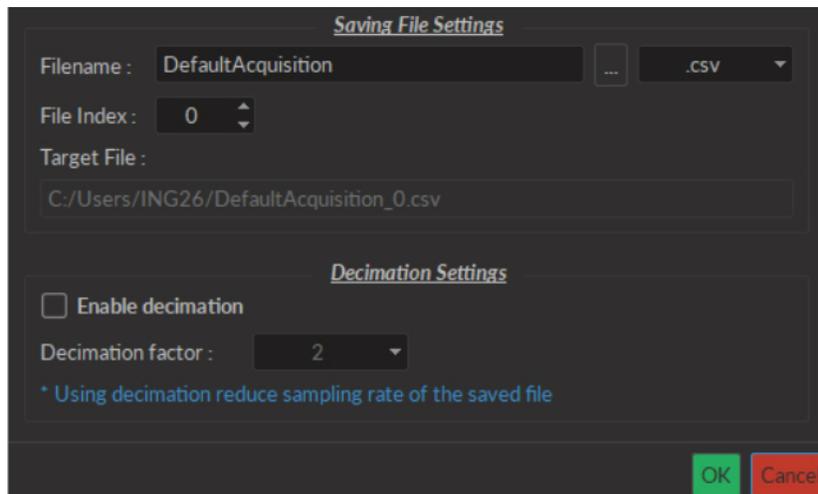


Figure 3.18: Saving Menu Window

- The **Save file settings** box is used to define how and where the file is saved. The name is taken from the **Filename** box, while the save location can be chosen by clicking the **...** button. The **File Index** box is used to define the current indexation number used for multiple files saved during the same measurement session. All this information is summarized in the **Target File** box.
  - The **Decimation Settings** allow the reduction of file sizes. This method conserves points averaged over a number of data points equal to the **Decimation Factor**<sup>1</sup>. When the **Enable decimation** checkbox is selected, the **Decimation factor** box is used to define the number of points averaged.
6. The **Target File** box (Fig. 3.15) displays the save location and name used for files obtained using **Record**.

### Configuration Tab

The **Configuration** tab is used to configure which channels are used, as well as saving and loading the configuration of the console software.

<sup>1</sup>For a data set of 10 points, saved with a **Decimation Factor** of 2, the first two points (1,2) will be averaged, the second two points (3,4)... This produces a file of 5 points of data

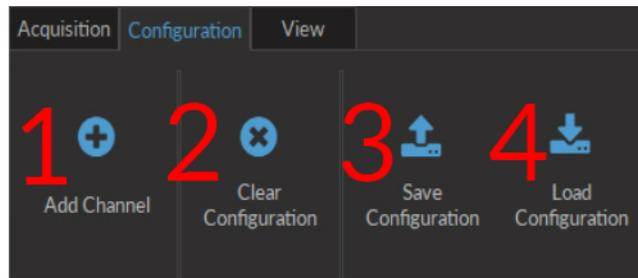


Figure 3.19: Configuration Tab

1. The **Add Channel** button (Fig. 3.19) opens the **Channels configuration** window. This window is detailed in section 3.2.1.
2. The **Clear configuration** button (Fig. 3.19) resets the acquisition view and all other parameters set. Any configurations already set will be lost.
3. The **Save configuration** button (Fig. 3.19) allows a console configuration to be saved in the **.doric** format. This file will only preserve the configuration of each current channel.
4. The **Load configuration** button (Fig. 3.19) allows a console configuration in **.doric** format to be loaded.

### View Tab

The **View Tab** (Fig. 3.20) is used to modify the presentation of graphs in the **Acquisition view**.



Figure 3.20: View Tab

1. The **Autoscrolling** button (Fig. 3.20), when clicked, makes the graphs scroll as new data appears. The duration (in seconds) kept on display is defined in the box beside the button.
2. The **Reset Zoom** button (Fig. 3.20) sets the graph zoom to a pre-defined value. This value is defined using the **Zooming menu** (Fig. 3.21), accessed using the **Gear** button.

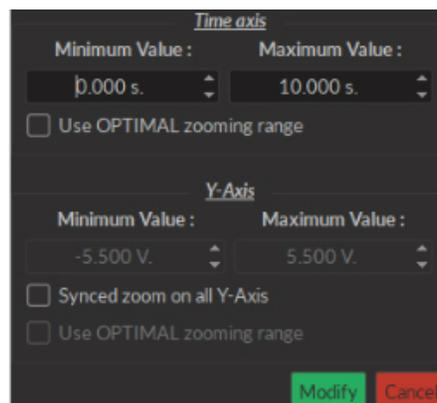


Figure 3.21: Zooming Menu Window

- The **Time axis** box is used to define the minimum and maximum values of the horizontal axis. If the **Use OPTIMAL zooming range** checkbox is selected, these values will be set to display all data currently in memory.
  - The **Y-Axis** box is used to define the minimum and maximum value of the vertical axis. If the **Synced zoom on all Y-Axis** checkbox is selected, these values can be changed. This only allows the **Voltage** axes to be changed, to the same value for all. The **Use OPTIMAL zooming range** will set the axes to a value displaying all data points in memory.
  - The **Modify** button will apply any changes to the axis values. The **Cancel** button cancels all changes.
3. The **Show Legend** button (Fig. 3.20) will open the **Legend** window (Fig. 3.22). This window display each configured **Channel**, as well as its **Name**, its **Channel Mode**, **Trigger Mode** and **Trigger Source** if applicable. Selecting the button while a window is open will close the window.

Channel	Name	Type	Trigger Mode	Trigger Source
▼ Digital I/O   Ch.1	Digital I/O   Ch.1	-	N / A	N / A
▼ Graph(s)				
DI/O-1		Input	-	-
▶ Digital I/O   Ch.2	Digital I/O   Ch.2	-	Triggered (Normal)	Manual
▼ Analog Out.   Ch.4	Analog Out.   Ch.4	-	Triggered (Normal)	Manual
▶ Graph(s)				
▼ Analog In.   Ch.1	Analog In.   Ch.1	-	Triggered (Normal)	Manual
▼ Graph(s)				
Aln-1		Physical	-	-

Figure 3.22: Legend Window

4. The **Show Notes** button (Fig. 3.20) will open the **Note Viewer** window (Fig. 3.23). Selecting the button while a window is open will close the window.

Note(s) List			Note Information
Title	Time	Graph	Title
Note_0005	00:00:03:042	Aln-1 - Raw	Note_0005
Note_0006	00:00:05:363	Aln-1 - Raw	
<div style="border: 1px solid gray; height: 20px; width: 100%;"></div>			Time (hhmm:ss:zzz) 00:00:03:042
<div style="border: 1px solid gray; height: 40px; width: 100%;"></div>			Note Text Spike
Delete			Apply

Figure 3.23: Note Viewer Window

- The **Note(s) List** displays the **Title**, **Time** and **Graph** on which a note is marked. Selecting the **Delete** button will delete any note selected on the list.
- The **Note Information** box displays the information of a note selected in the **Note(s) List**. The **Title**, **Time** and **Note Text** can be edited. The **Apply** button applies these changes to the graph.

### 3.2.3 Acquisition View

The **Acquisition View** box displays all information concerning active channels. Each channel chosen using **Add Channel** is displayed in this window, occupying a rectangular box.

Each **Channel box** shows the following basic elements, with additional elements available for specific channel types.



Figure 3.24: Acquisition View Box

1. The **Channel name** is located on the upper left of the **Channel box** (Fig. 3.24), identifying the type of channel and its number, corresponding to that on the console. This name can be modified in the **Graph options** window.
2. The **Edit** button (Fig. 3.24) allows the editing of channel parameters, opening the channel configuration windows. For further information, see section 3.2.1.

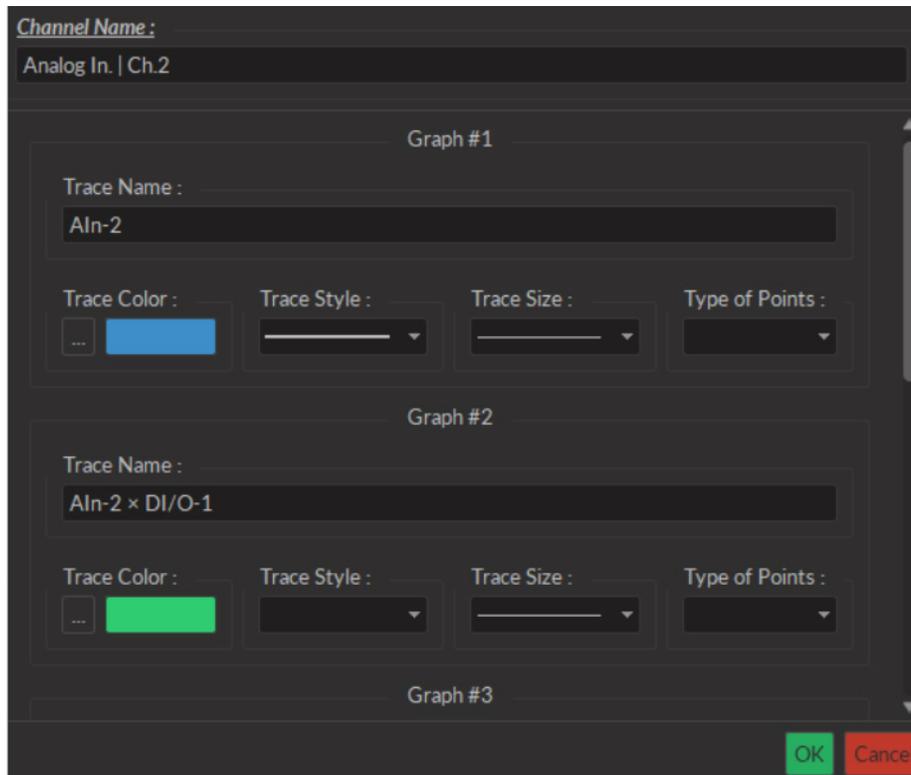


Figure 3.25: Graphs Window

3. The **Graph(s)** (Fig. 3.24) button opens the **Graph Options** window.

- The **Channel Name** (Fig. 3.25) is indicated in the upper left.
- The **Trace # X** box (Fig. 3.25) (where **X** is the number of the trace) show the visual options available for a single trace on the graph. A trace box appears for each trace on the graph.
  - The **Trace Name** box contains a standard name generated by the software. The name can be changed here.
  - The **Trace Color** button (...) opens the **Color Select** window (Fig. 3.26), which allows the selection of a trace color from a wide palette. The **Pick screen color** in this window allows the selection of any color displayed on the computer screen.

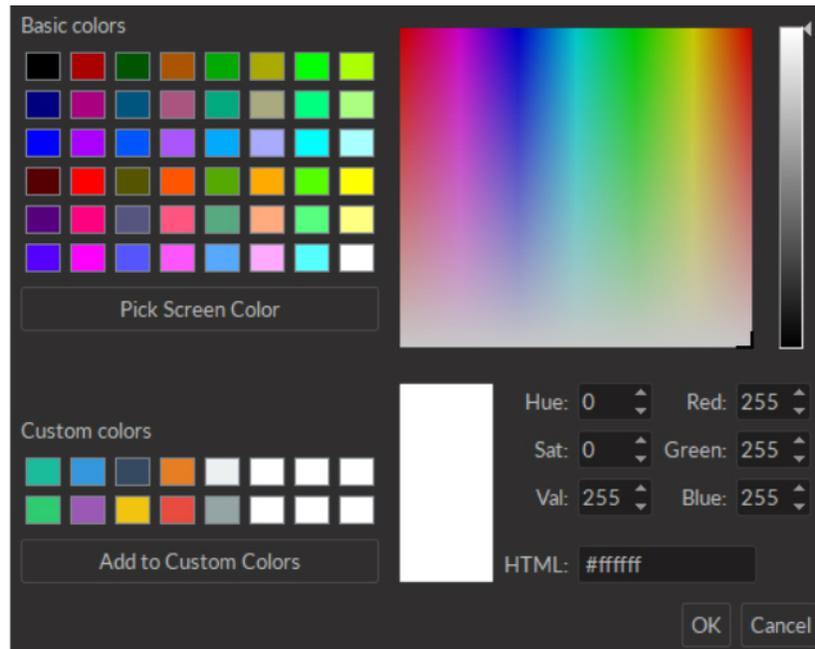


Figure 3.26: Select Color Window

- The **Trace style** drop-down list allows the selection of the type of trace, from full to dashed lines. If the style chosen is empty, the trace will not be displayed.
  - The **Trace size** drop-down list allows the selection of the trace size. Using a bigger **Trace size** than the default may result in slower display and performance degradation.
  - The **Type of points** drop-down list allows the selection of what type of point used to indicate data points on the trace. Using different point types than the default (none) may result in slower display and performance degradation.
4. The **Graph** (Fig. 3.24) box displays the graph of a channel, with **Voltage** or **State** as the vertical axis and **Time** as the horizontal axis. Double-clicking either axis will open a **Change Axis Range** window that allows the axis limits to be changed, as in the **Zooming Menu**. Any changes done on a horizontal axis will change the axis limits for each channel.
  5. The **Instant values** box (Fig. 3.24) can be activated by right-clicking the **Input graph** box and selecting **Show instant values**. This box shows the current value detected by the console for each trace on the selected channel. This box cannot be activated on **Preview graphs**.
  6. The **Channel tabs** (Fig. 3.24) appear in certain input modes (such as **Interleaved** and **Lock-in**) where the input automatically sets the output values on separate channels. It is possible to create a **Channel tab** by undocking one channel and moving it above another until it turns blue, then releasing it.
  7. Analog output channels display an **Active state** graph (Fig. 3.24). This graph displays whether the channel is outputting a signal (On,  $V \neq 0$ ) or not (Off,  $V = 0$ ).
  8. Output channels display a **Preview** graph (Fig. 3.24), showing a preview of the pulse sequence.

### 3.3 Electrophysiology Analysis Module

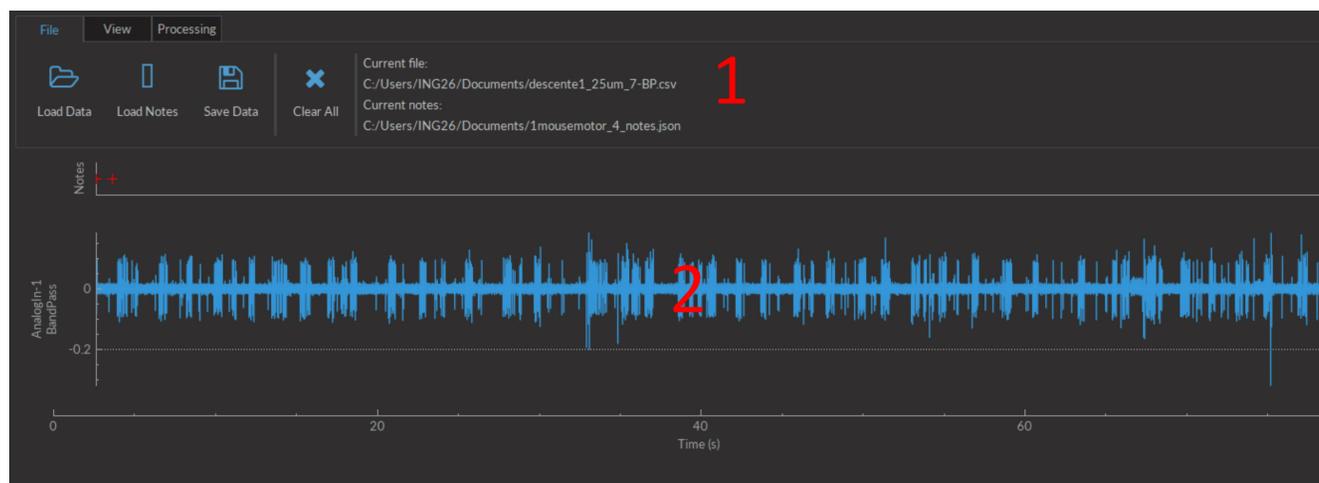


Figure 3.27: Electrophysiology Analysis Module

The **Electrophysiology analysis module** (Fig 3.27) is designed to process electrophysiological data. The module is separated into two main sections.

1. The **Control box** contains all controls, separated into the **File**, **View** and **Processing** tabs.
2. The **Graph box** contains all currently displayed graphs as well as timestamped notes.

#### 3.3.1 File

The **File** tab allows the loading and saving of data.

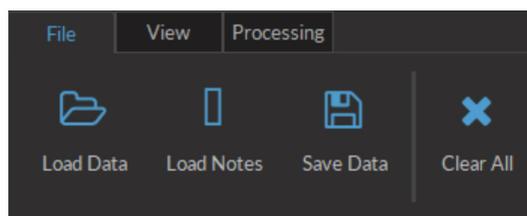


Figure 3.28: File Tab

- The **Load data** button allows the loading of a .csv file. The file must contain time and signal data.
- The **Load notes** allows the loading of a .json file contained timestamp-associated notes. Both the .csv and .json files must have the same time series.
- The **Save data** button saves graph data in a .csv file.
- The **Clear data** button deletes all data currently in the module. This data cannot be recovered, so ensure the data is properly saved before clearing it.
- The **Current File** box displays the files currently loaded into the analysis module.

### 3.3.2 View

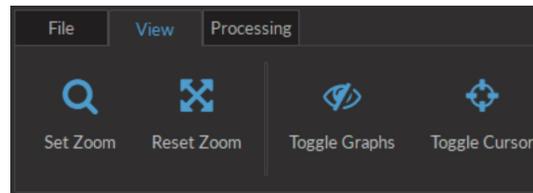


Figure 3.29: View Tab

The **View** tab (Fig. 3.29) is used to adjust the view in the **Graphs box**.

- The **Set Zoom** button opens the **Zoom window** (Fig. 3.30). The minimum and maximum values of each axis can be defined. The **Automatic** checkbox chooses axis values to fully display the entire data set.

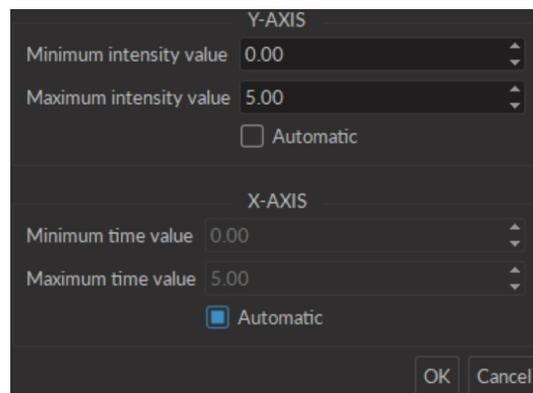


Figure 3.30: Set Zoom Window

- The **Reset zoom** button resets the axis values to those defined in **Set zoom**.
- The **Toggle graphs** button opens the **Show/hide graphs** window (Fig. 3.31). Any checked data sets will be displayed in the **Graph box**.

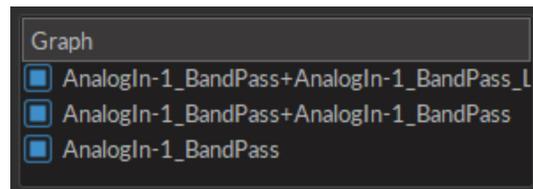


Figure 3.31: Show/hide Graphs Window

- The **Toggle cursor** button, when clicked, activates a red cursor in the **Graphs box**. This cursor can be moved to any part of a graph by clicking the location, showing the coordinates of the chosen point. The cursor will be positioned at the same temporal location on each graph.

### 3.3.3 Processing

The **Processing** tab (Fig. 3.32) is used to process data sets loaded into the module.

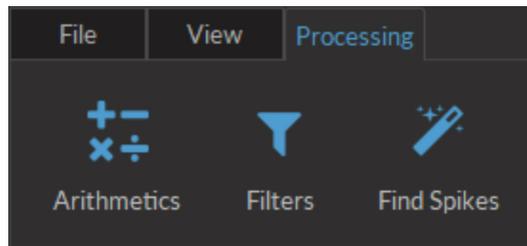


Figure 3.32: *Processing Tab*

- The **Arithmetics** button opens the arithmetic window (Fig. 3.33). From this window simple arithmetic operations (+, -, ×, ÷) can be performed on any two data sets currently in the module. This includes data sets that have already been processed.

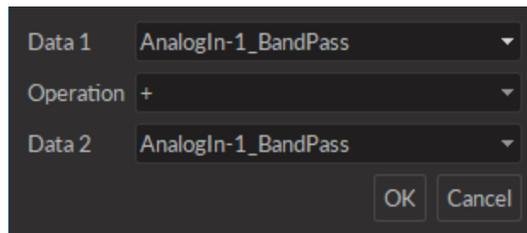


Figure 3.33: *Arithmetic Window*

- The **Filter** button is used to filter the frequency of data sets. After selecting the data set to be filtered, the filter window (Fig. 3.34) is opened. This allows a choice of filter type and variables.

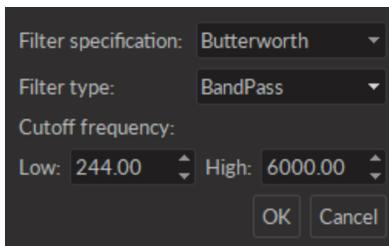


Figure 3.34: *Filter Window*

- The **Filter specification** allows the selection of a filter model.
- The **Filter type** defines whether the filter is low-pass, high-pass or bandwidth limited.
- The **Cutoff frequency** defines which frequencies are filtered. Which values are accessible depends on the **Filter type**.
- The **Find spikes** button allows the automated identification of spikes in the data set. See section 3.3.4 for more details.

### 3.3.4 Find Spikes Function

The **Find spikes** function is used to automatically identify and classify spikes in electrophysiological signal. Clicking the **Find spikes** button prompt the selection of a dataset, followed by the **Spike finder settings**(Fig. 3.35) window, showing the following variables.

#### Spike Finder Settings Window

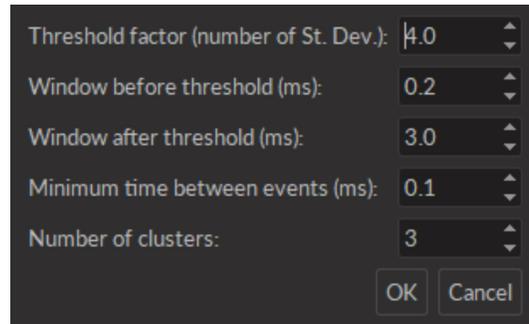
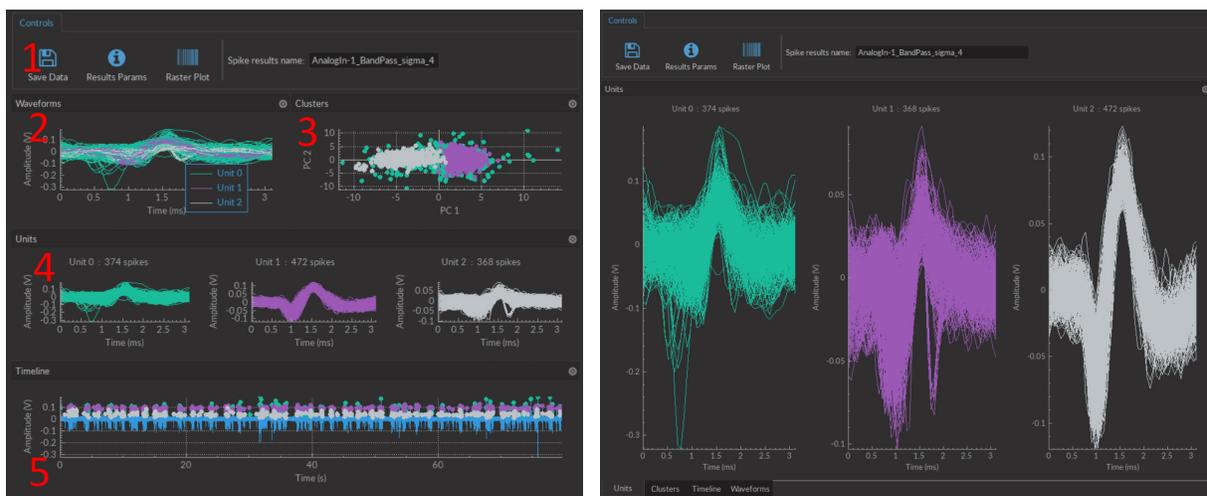


Figure 3.35: Spike Finder Settings Window

- The **Threshold factor** defines the number of standard deviations above the average the amplitude must have to be identified as a spike. A low threshold factor will give more false positives, while a high threshold factor can reject good spikes.
- The **Window before/after threshold** defines the time recorded (in ms) before/after the point identified as a spike.
- The **Minimum time between events** defines the minimum time (in ms) between two different spikes.
- The **Number of units** defines the number of different spike waveforms (also called **units**) searched for.

#### Spike Finder Results Window

The results provided by the spike finder algorithm are displayed in the **Spike finder results window** (Fig. 3.36a). The window is separated into several boxes. Each box can be undocked from the main window. Each box can be clicked and dragged onto each other; this converts each box into a tab (Fig. 3.36b, lower left).



(a) Spike Finder Results Window, Full display

(b) Spike Finder Results Window, Tab Mode

Figure 3.36: Spike Finder Results Window

1. The **Control box** (Fig. 3.37) displays options usable in the window.

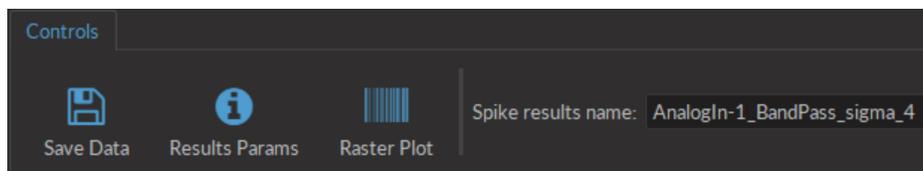


Figure 3.37: Spike Finder Control Box

- The **Save data** button records data in this window in the *.HDF5* format. The data can be added to a pre-existing database.
- The **Results Params** button opens a window displaying the **Spike finder settings**. The settings cannot be changed in this window.
- The **Raster Plot** button opens the **Raster plot window** (Fig. 3.38). The window displays the raster plot of all spikes over time, with each color corresponding to a single cluster. This window can be kept active over multiple uses of the **Spike finder**, with all raster plots displayed within.



Figure 3.38: Raster Plot Window

- The **Spike results name** shows the filename used to save the spike results.
2. The **Waveform box** (Fig. 3.39) shows a superimposed view of all different spike waveforms recovered. Each different color corresponds to a different unit, as shown on the legend.

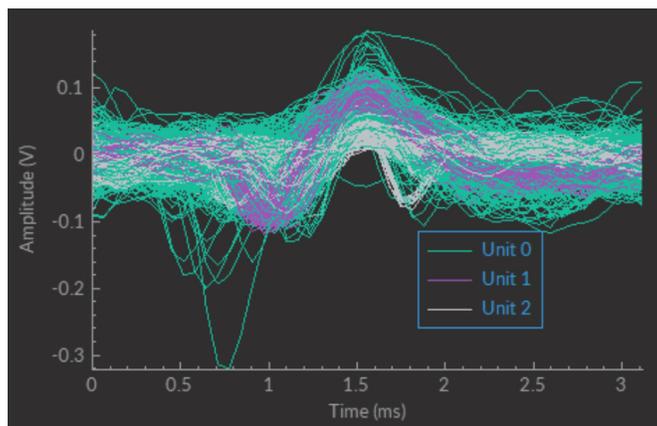


Figure 3.39: Waveform box

3. The **Clusters** box shows a scatter plot of all spikes. Each color corresponds to a different unit.

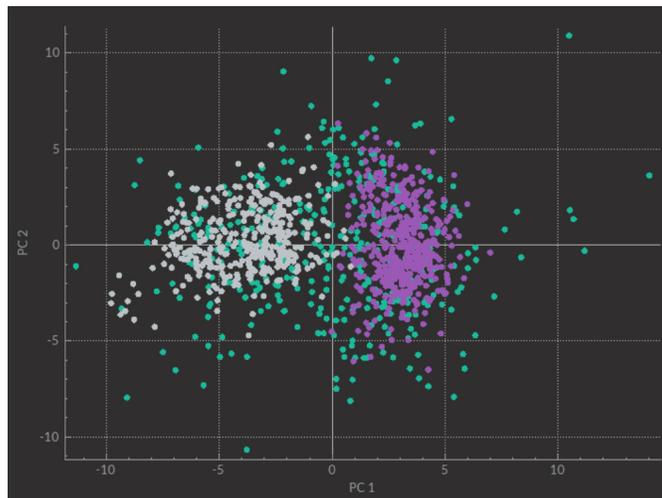


Figure 3.40: Clusters box

4. The **Unit box** shows a superimposed view of all different spikes associated with each individual unit.

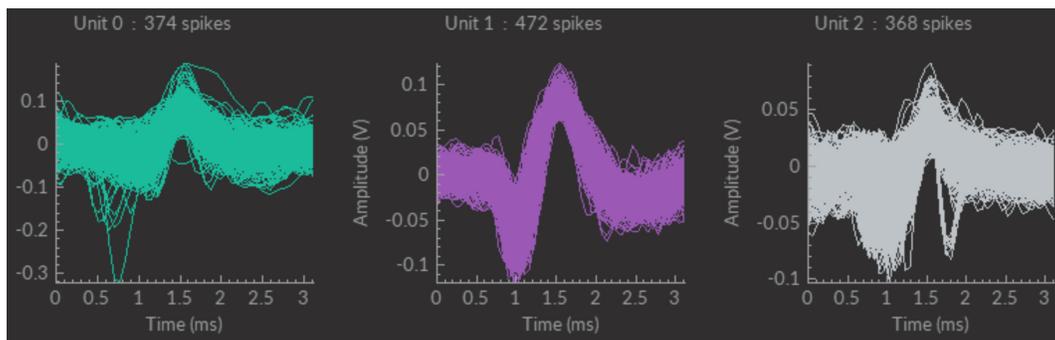


Figure 3.41: Unit box

5. The **Timeline box** shows the original graph with each spike identified. Each color indicates a given unit, as defined in the legend of the **Waveform box**.

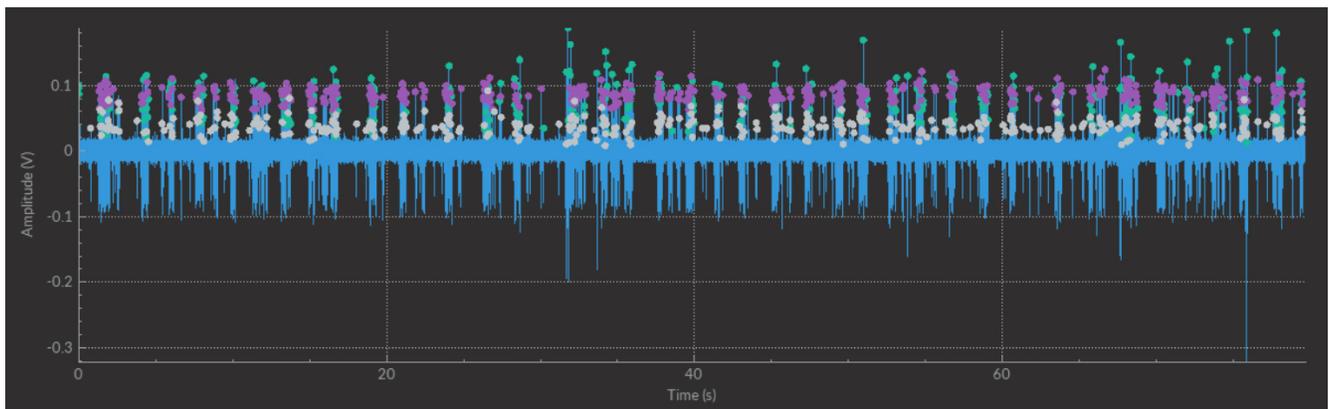


Figure 3.42: Timeline box

## Specifications

Table 4.1: *Fi-Wi Opto-electric Cannula General Specifications*

<b>SPECIFICATIONS</b>	<b>VALUE</b>	<b>NOTES</b>
Peak optical output	8 mW	with blue (465 nm wavelength) LED
Input current	Min: 0, Max: 150 mA	
Dimensions	7.5 x 9.7 x 9.7 mm	Without fiber and electrodes
Mass	0.4 g	
Electrodes material	Tungsten	
Electrodes diameter	25 or 50 $\mu\text{m}$	
Optical fiber NA	0.66	
Optical fiber core diameter	200 or 400 $\mu\text{m}$	

Table 4.2: *Fiberless & Wireless Headstage General Specifications*

<b>SPECIFICATIONS</b>	<b>VALUE</b>	<b>NOTES</b>
Dimensions	9.6 x 14.9 x 18.6 mm	
Mass	2.8 g	Including 40 mAh battery
Transmission Frequency	2.400 to 2.525 GHz	
RF Data Speed	2 Mbps	
Electrophysiology Sampling Rate	14 kHz	On each channel
Operation distance	0-3 m	For optimal performance
High-pass frequency filter loss	-30 dB/decade	
Low-pass frequency filter loss	-40 dB/decade	
Battery charge duration	90 min	60 mA current at 10% duty cycle, 4 channels recording
Battery recharge time	> 60 min	

Table 4.3: Electrophysiology Console General Specifications

SPECIFICATIONS	VALUE	NOTES
Power supply	110-240 VAC ; 50-60 Hz	Power supply adapter included
DC Power supply	12 VDC	
Dimensions	360 x 140 x 37 mm	Including connectors
TTL input voltage	0 to +5 V	Min Hi Level: 4 V; Max Low Level: 0.55 V
TTL output voltage	0 to +5 V	
TTL input impedance	3 k $\Omega$	
TTL output impedance	30 $\Omega$	
TTL time propagation delay	4.6 ns	
TTL time input resolution	82 $\mu$ s	
TTL time output resolution	10 $\mu$ s	
Analog output voltage	$\pm$ 4.75 V	
Analog output sample frequency	25 MS/s	
Analog output max. frequency	10 khz	
Analog output impedance	6 $\Omega$	
Analog time propagation delay	20 ns	
Analog input voltage	$\pm$ 5 V	
Analog Input voltage	$\pm$ 10 V	
Analog input sample frequency	15 kS/s	
Channel-to-channel isolation	110 dB	
Analog input impedance	100 to 124 k $\Omega$	

Table 4.4: Console Analog input noise and resolution specifications with chopping mode<sup>1</sup> enabled

Data rate	Real Rate	Time resolution	- 3dB Frequency	RMS noise	Effective resolution <sup>2</sup>
0.3 kSps *C	372 Hz	2686 $\mu$ s	200 Hz	9.6 $\mu$ V	20.0 bits (9.5 $\mu$ V/bit )
1.0 kSps *C	1 001 Hz	999 $\mu$ s	520 Hz	15.5 $\mu$ V	19.3 bits (15.5 $\mu$ V/bit )
2.5 kSps *C	2 534 Hz	395 $\mu$ s	1 300 Hz	26.1 $\mu$ V	18.5 bits (27.0 $\mu$ V/bit )
6.0 kSps *C	6 041 Hz	166 $\mu$ s	3 100 Hz	46.0 $\mu$ V	17.7 bits (47.0 $\mu$ V/bit )
12. kSps *C	12 166 Hz	82 $\mu$ s	6 300 Hz	120 $\mu$ V	16.3 bits (123.9 $\mu$ V/bit )

Table 4.5: Console Recommended Environmental Specifications

DESCRIPTION	OPERATION	STORAGE
Use	Indoor	Indoor
Temperature	0-40 ° C	0-40 ° C
Humidity	40-60% RH, non condensing	40-60% RH, non condensing

<sup>1</sup>Chopping Enabled: This mode provides very low noise with lower output rates. Chopping does not eliminate the offset error and drifts caused by input resistors. Noise performance depends on the selected analog input range and the chopping mode. The analog input is always operated with chopping mode in order to optimize the offset drift and to allow a better noise performance. When starting an acquisition, input data rate (Samples per second) can be selected according to the needs of each test. Higher data rate provides higher RMS noise. Analog inputs are reversed and then calculated as an average of two conversions in order to reduce the offset error.

<sup>2</sup>Effective resolution for linear mode at  $\pm$  10 V input range. Input resolution is 16 bits (0.152 mV). Lower data rates provides higher effective resolution. The lock-in mode allows higher effective resolution. In this case, effective resolution is higher than RMS noise for every listed frequency.

## Support

### 5.1 Maintenance

The product does not require any maintenance. Do not open the enclosure. Contact Doric Lenses for return instructions if the unit does not work properly and needs to be repaired.

### 5.2 Warranty

This product is under warranty for a period of 12 months. Contact Doric Lenses for return instructions. This warranty will not be applicable if the unit is damaged or needs to be repaired as a result of improper use or operation outside the conditions stated in this manual. For more information, see our [Website](#).

### 5.3 Contact us

For any questions or comments, do not hesitate to contact us by:

**Phone** 1-418-877-5600

**Email** [sales@doriclenses.com](mailto:sales@doriclenses.com)



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