



Neuropixels 1.0 Headstage

Beta testing version



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Neuropixels Headstage



Figure 1 Front and back view of Neuropixels Headstage

Introduction

The SpikeGadgets Neuropixels headstage is designed to optimize the power and density of Imec's Neuropixels probes with the power and flexibility of SpikeGadgets' products. The headstage records neural signals from up to three Neuropixels probes with 2880 selectable neural channels. The headstage can operate in a tethered live streaming version where up to 1152 of the available 2880 channels may be selected or in an untethered, data-logging version where up to 400 channels across the three probes may be selected and the data is recorded locally to a microSD card.

Please make sure to also familiarize yourself with the Neuropixels user manual before recording with this headstage. The manual is located here-
https://e2f49b05-3010-45e2-a7bf-b8f67811425a.filesusr.com/ugd/832f20_ce2feed52995400a9b77f79ca92b019b.pdf.

Neuropixels Headstage Specifications

Number of Neuropixels Probes (not included)	Up to 3
Channel count	
Selectable	(up to) 2880
Streamable (via tether)	1152 (across 3 probes) or 384/probe
Wireless data logging	400 (across 3 probes) or 384/probe
Weight (without probes)	
Headstage + cone	19.2g
Headstage+ cone + 400mAh battery	31g
Record time (with 400mAh battery, 1 probe)	2.5 hours
Power consumption (1 probe)	160mAh
Dimensions- untethered recording (with cone and battery)	
Length	45mm
Width	25mm
Height	55mm
Dimensions tethered streaming (with cone,)	
Length	35mm
Width	25mm
Height	45mm
Sampling rate	30 kHz
Bit depth	10-bit
Connection to commutator	microHDMI
Sensors	Accelerometer, gyro
LED Array	6 LED (3 green, 3 red)

Headstage Connection

The Neuropixels probes connect directly into the headstage via a TE Connectivity Amp Connector (manufacturer part number 1-2013496-8).



Figure 2- TE Connectivity Amp Connector

Surgery, Probe Connection, and Assembly

The cone portion of the Neuropixels headstage must be placed around the Neuropixels probe(s) and glued to the top of the head. Once that is done, open the hinge on the bottom connector of the headstage (see photo below) to insert the probe. Each probe must be connected to the system by sliding the flex PCB into the hinge connector and closing the hinge. The probe must be completely inserted all the way into the connector.



Figure 3 Connectors on the bottom of the headstage, the bottom connector shown is the first connector



Figure 4 Probe and cone connection to the headstage

MCU Configuration

Once the MCU is connected to a Windows machine (see the MCU setup guide and manual for more details), run the MCU firmware. Locate the subfolder 'tool/windows/bin' which contains programs that can be run from the command line console on Windows. Select one of these programs to run when the headstage is connected to the MCU. Then run "set_MCU_RF_recordID_mode -i".

Probe Configuration

Imec Calibration

The Imec Neuropixels probes will need to be programmed with the probe calibration data provided by IMEC before it can be used. If the headstage detects

a probe without calibration data then the yellow LED will be solid as the headstage is turned on.

To accomplish this, use the SpikeGadgets probConfig program (Windows compatible only):

1. Plug a probe into one of the available slots on the headstage
2. Run the program specifying the slot (i.e. "probeConfig 1" if the probe to configure is in slot 1)

The program reads the probe ID, looks for a probe calibration file that match the probe ID in the same directory as the probeConfig program, and if found it will apply it to the probe. If not found it will ask if the probe should be configured using a default calibration data instead.

3. If using more than one probe, repeat for additional probes

```
n
$ probeConfig 1
Sending get probe id command...
Found probe: Probe ID 18408410302
Probe configuration values found on probe. Overwrite with new values ? (yes or no) yes
Looking for calibration file 18408410302_ADCCalibration.csv... fund it!
Sending set probe settings command... success!
Writing probe configuration data to probe 18408410302
Continue? (yes or no) yes
Sending probe programming command... success!
```

Figure 5 Example run of probeConfig progra

LED Indicators

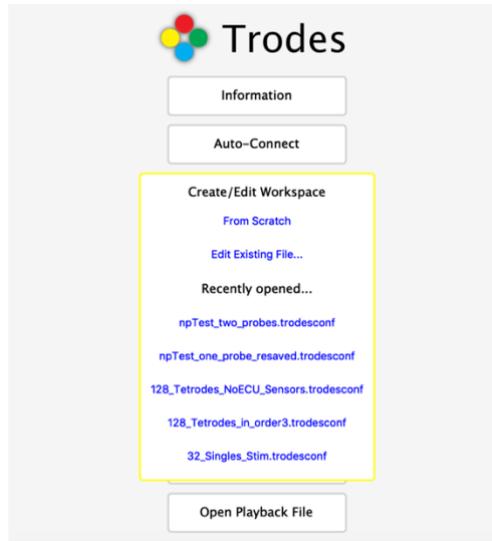
Example probe detection indicator: https://spikegadgets.com/wp-content/uploads/2020/08/IMG_5762.mov (Probe 1 and 2 detected, 3 is not)

Light Indicator	Meaning
Red	
Solid	No probe detected OR Cannot perform frame sync from a detected probe, indicating bad signal connection to the ZIF connector (headstage conducts a brief data stream test from the probes at power up) OR Lost frame sync from a probe while streaming data
Blink at start up	Order is the probe number, red indicates probe in corresponding slot not detected (see example video above)
Very fast blink (8Hz)	Bad data connection detected
Fast blink (4Hz)	SD card not enabled for writing
Slow blink (2Hz)	Cannot mount the SD card at power up
Breathing	SD card is full
Yellow	
Solid	Detected probe is not configured (see Imec calibration section)
Blink at start up	Order is the probe number, yellow indicates probe in corresponding slot detected (see example video above)
4 Blinks	Data streaming started
Blink while datalogging	Indicates RF signal received from dock, pulse sent every 10 seconds from MCU or every .5 seconds from Logger Dock
Breathing	SD card has been mounted and erased, ready for recording to start
Red and Yellow Blink	Power is on, occurs at start up

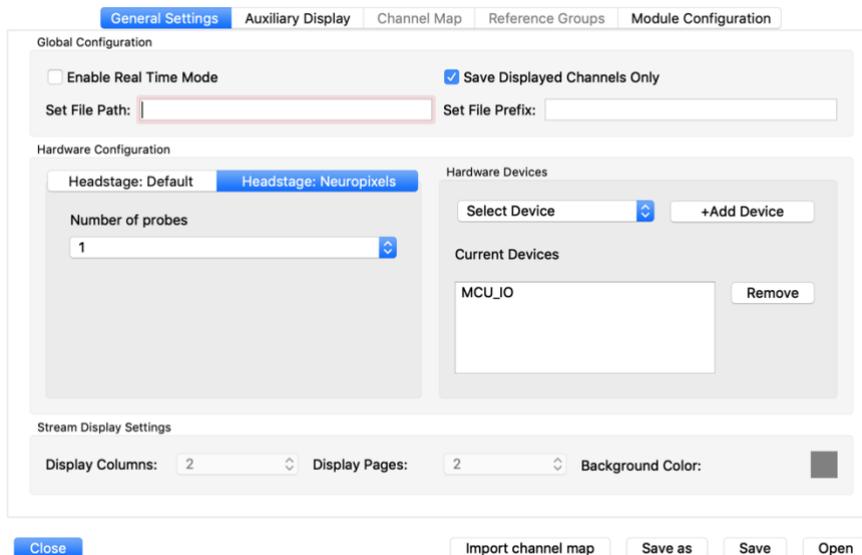
Trodes

Creating a Neuropixels Workspace

1. In the main menu, choose "Create/Edit Workspace" and "From Scratch"



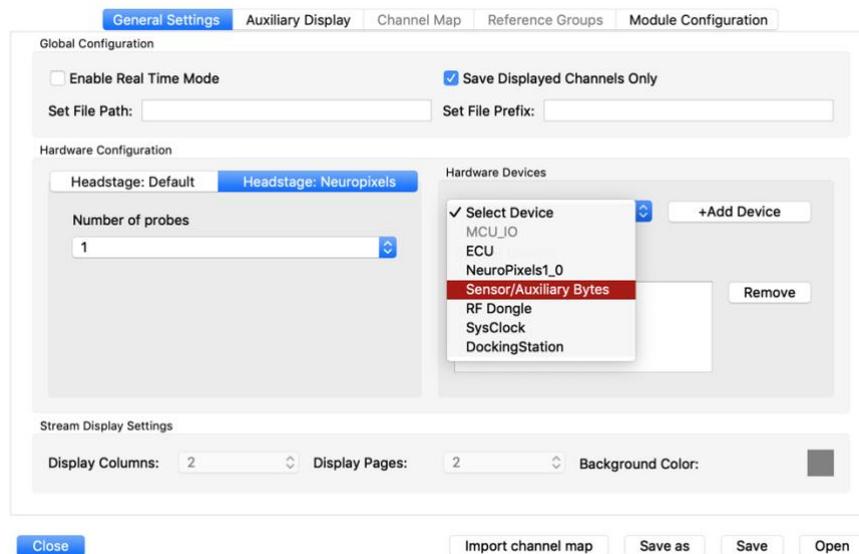
2. From the Workspace Editor, under "Hardware Configuration" select the "Headstage: Neuropixels" tab.



3. In the drop-down menu, select the number of probes that are connected to the headstage (1, 2, or 3)
4. Under "Hardware Devices" select "Sensor/Auxiliary bytes" from the drop-down menu and click "Add Device" If an ECU is connected to the system, the ECU device should also be added.
5. Click "Open"

Selection Tool

There is a limit to the number of channels that may be recorded from the Neuropixels probes. For tethered live streaming data may be recorded for up to 1152 channels across 3 probes (384 channels per probe). A total of four hundred



channels across three probes may be selected for untethered live streaming with a selection of no more than 384 channels from any one probe. Use the Trodes GUI to select the Neuropixels channels for recording.

To run the Neuropixels selection tool in Trodes open or create a workspace (see instructions above) and click: *Connection>Specific Source code>Neuropixels*

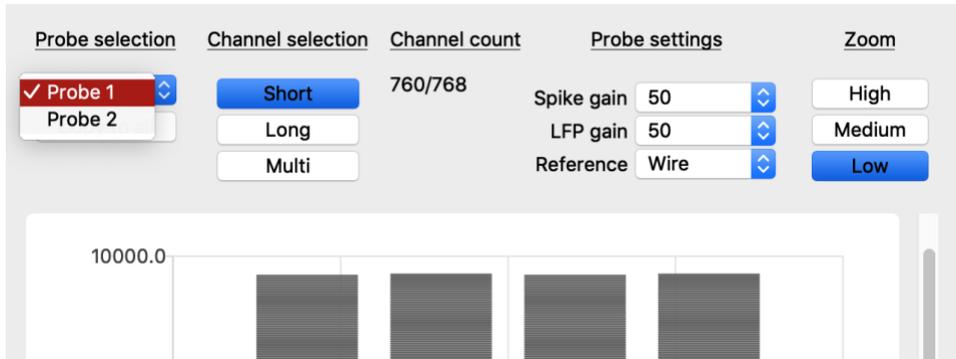


Figure 6 Neuropixels Selection Tool Menu

Probe Selection- Choose the probe for formatting

Channel Selection- This menu item facilitates channel selection. A total of 384 channels per probe may be selected for a total of up to 1152 channels across 3 probes. **Note:** *Untethered recording supports a maximum of 400 channels across all 3 probes regardless of the total listed in the “Channel count” of the GUI.*

Short- The short feature selects exactly 384 consecutive channels across the probe.

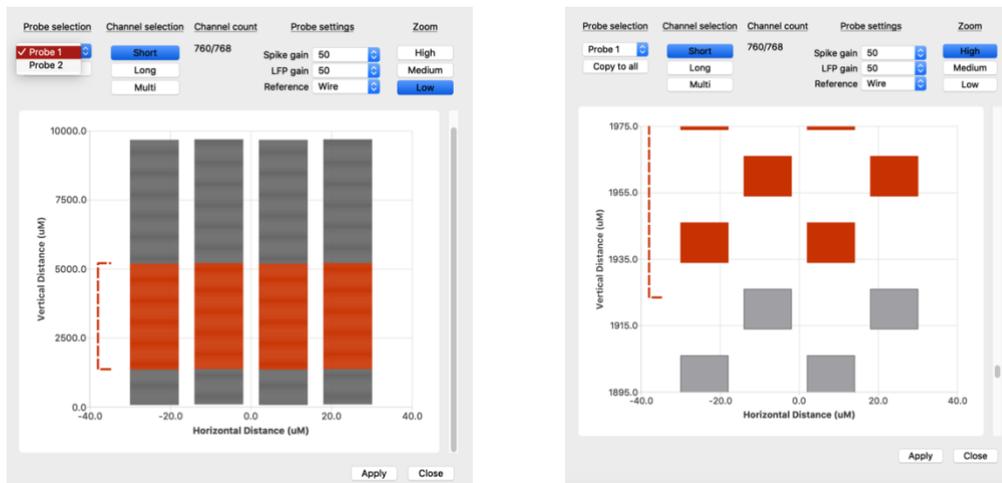


Figure 7 Short channel selection with low and high zoom views

Long- Similar to the short feature, select 384 channels consecutive channel across the probe but with every other channel activated. Covers an area twice as wide

with half the density of the short selection. The density is roughly equivalent to that of a tetrode.

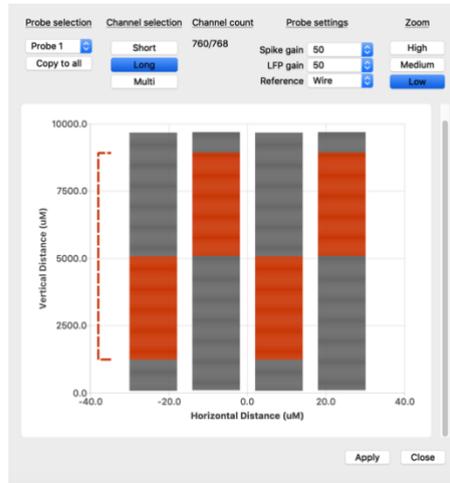


Figure 8 Long channel selection at low zoom

Multi- Individually select the channels the probe will record. With the multi-channel selection and the high zoom options specific channels may be turned on/off. Multi-channel selection patterns may be copied to other probes with the “copy to all” probe selection button under the Probe Selection menu. Additionally, the length of any range marker may be changed by right clicking on the range marker and selecting “set length.”

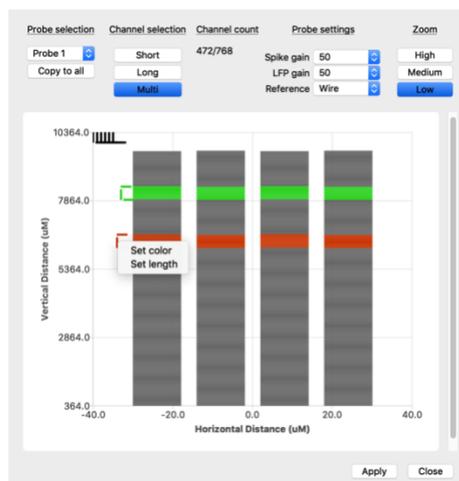


Figure 9 Multi channel selection at low zoom

Probe Settings- Probe settings allow the user to select the spike gain, LFP gain, and reference of the probes. The probe splits LFP data and spike data allowing users to have different gains for each one. It's highly recommended to use the same probe settings across all probes for consistency and clarity.

In general, 'gain' refers to how much the signal is amplified before being digitized. 'Reference' refers to how amplifiers work. Amplifiers work like this:

$$\text{output signal} = \text{GAIN} * (\text{input voltage} - \text{reference voltage})$$

The input voltage is on the electrodes of the probe. The reference voltage can come from one of the three available sites.

Neuropixels notes, "The standard recording configuration is to short the external reference with the ground, and connect these to a saline bath (or agar) above the craniotomy for acute implants, or connect them to a skull screw for chronic implants." In our interface this is the "wire" reference. Probes may be configured with different settings so be sure to ensure all probes are set to the same gain and reference unless unique settings are intended.

More information on gain settings and references can be found here:

https://github.com/cortex-lab/neuropixels/wiki/Gain_settings

<https://github.com/cortex-lab/neuropixels/wiki/Referencing>

Zoom- Channel view of the probes. High density zoom allows for individual channel view. The view displayed of 4 columns and its individual tabs is always for the 1 probe that is selected.

Important note: All channels are routed to one of three output channels. If certain channels are not able to connect it is likely because they are routed to the same output channel. See the Neuropixels manual for more details or choose an alternate range of channels.

Channel formatting- Channel selections may be color coded by right clicking on any range marker and choosing "set color." The length of the marker may also be changed in the multi-channel selection format by right clicking the range marker.

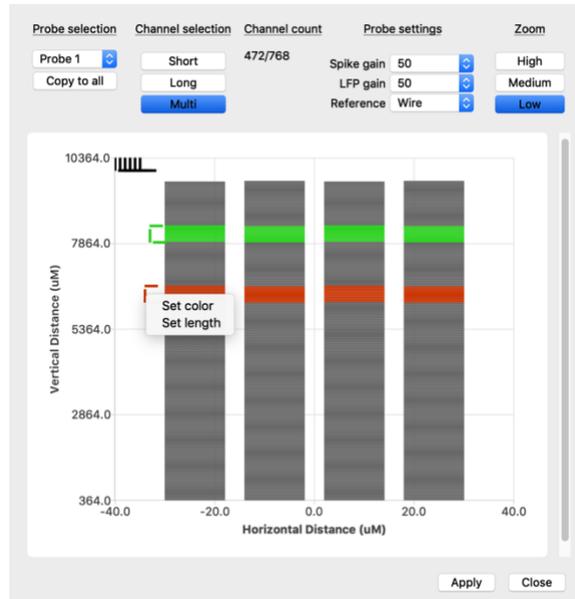


Figure 10 Setting color and length of range markers

Once all of the desired channels are selected, click “Apply” to save the configuration. This will save the channel selections to the headstage itself for untethered recording or tethered streaming.

Tethered Recording

Configuration with the MCU

In tethered mode, an HDMI to micro HDMI plug is used to power the headstage and stream data to the MCU. Slide the cable into the kitten case until the connector is fully inserted. If the headstage is properly detected by the MCU, the MCU power indicator will turn green. Otherwise it will blink orange. Data streaming is started using the Trodes software or the record button on the MCU (in standalone mode).

Headstage settings can be modified using Trodes and saved onto the headstage after it is powered off and will also be applied to untethered recordings. Settings can only be modified once a connection is made to the MCU from the computer, but not while data is actively streaming. On the Neuropixels headstage, the following settings are available and can be modified:

- **Smart Referencing** (on/off) This feature is not currently supported by the Neupixels headstage so it's recommended to turn it off.
- **3-axis accelerometer** (on/off)
- **3-axis gyro** (on/off)

Workspace Setup in Trodes

Tethered Recording

All headstages

Step 1: Record

Computer and headstage

In Trodes open final workspace for recording.

Begin Recording:
Connection>Stream from Source

Type of file: final.rec

Figure 11 Tethered streaming workspace flowchart

Untethered data logging



Figure 12 Neuropixels Headstage with battery

The Neuropixels Headstage can operate without a tether, logging all data to an onboard microSD card. It utilizes a wireless link to communicate with the MCU (start/stop commands and synchronization commands are sent through the wireless link).

Prepare the card for recording

Trodes contains a set of helper programs to interface with the SD cards. If command prompts are preferred for more advanced SD card settings, please see the end of this manual for those instructions. Trodes is available for download here: <https://bitbucket.org/mkarlss0/trodes/downloads/>

Synchronization

Synchronization between the environmental record and the data recorded on the headstage depends on a radio signal that is sent to the headstage at regular intervals (most setups use a 10-second interval). This signal originates from SpikeGadgets' hardware (there are multiple options) that also acquires environmental data and connects to your computer. Trodes connects to this hardware to display and saves the environmental data during the recording session. If video recording is also used, the camera module set up the same way as during tethered recordings.

There is not access to the neural data during the recording. After the recording session is done, there will be two files: one on the headstage SD card and one on the computer. These two files will be aligned and merged using the synchronization signals that were recorded in both files.

Workspace Setup in Trodes

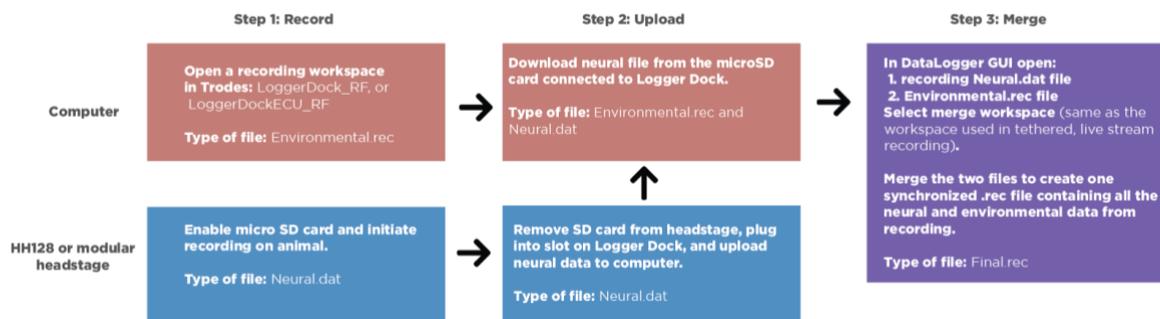


Figure 13 Untethered data logging workspace flowchart

Recording

Power on the headstage and make sure that the light indicators on the headstage indicate that it is ready to start recording and the correct number of probes register. The RF dongle should be plugged into the MCU. The system is now ready to record. Once data begins acquiring in Trodes, the MCU will send a “start” signal to the headstage to start recording. Next, create a new recording file from the Trodes menu and start recording. When the recording session is complete, stop the recording in Trodes and close the .rec file. Then, stop acquisition (this will also stop the headstage recording) and power off the headstage. At this point the .rec file on the computer will contain the environmental record. The SD card on the headstage will contain the neural data. Note: the SD card on the headstage will be locked from further recording in order to protect the existing recording from accidental erasing. After data has been transferred to the computer, the card must be enabled for recording again using the transfer utility. Transferring Data to Computer and Merging Files The following is needed to merge to the two files into a single .rec file:

1. the file from the SD card recording
2. the .rec file containing the environmental record
3. a workspace to append to the merged file

The workspace should be the same workspace that would have been used if the recording was performed in tethered mode. Note: this is NOT the same workspace used to collect the environmental record. We provide a graphical utility to perform the operations of transferring data from the SD card and merging the two files here:

Data Logger GUI (<https://bitbucket.org/mkarlsson/trodes/wiki/DataLoggerGUI>)

Data upload and battery charging

Data recorded from each untethered data logging session should be uploaded by inserting the microSD card from the Neuropixels headstage into the Logger Dock. The Logger Dock will also charge the battery. See the Logger Dock manual for more details.

About SpikeGadgets

SpikeGadgets is trying something new. Our hybrid approach is to design and sell powerful hardware that interfaces with an open-source software platform supported by a large community of scientists and developers. Our goal is to support the efforts of the open-source community in a commercially-sustainable way.

Technical Support

If you would like technical support, please email us at support@spikegadgets.com.