SpikeGadgets

*Pixie 384 Headstage Manual*

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## Pixie 384 Headstage

## Introduction

The Pixie384 is a high channel-count, high sampling-rate chronic electrophysiology system which can be used for both tethered acquisition onto a computer and untethered (no cable) datalogging onto an SD card. This headstage leverages the power and flexibility of the Neuropixels 1.0 384-channel Neural Recording Integrated Circuit (NRIC) chip to acquire 384

channels of dual-band (AP & LFP) neural data and is compatible with most passive electrode arrays. Pixie384 features the SpikeGadgets Janus chip; a custom-designed ASIC logic chip, optimized for high channel count, low-power consumption data logging to achieve the longest recordings possible at the lowest weight.

The Pixie384 can record for 3 hours using a 400mAh battery (~25 grams). The system is compatible with larger battery options for longer sessions.

The connections on the Pixie384 are to 7x 60-pin Molex 2049270601 connectors. SpikeGadgets offers a 384-channel electrode interface board and other adaptors for this headstage.

The Pixie384 works in conjunction with the Logger Dock 2 or the MCU via the Trodes software suite. The Dock is used to start and stop recordings and facilitates wireless communication with the Pixie384 for headstage status, environmental sync, and battery status monitoring. Additionally, the MCU can be used for tethered streaming.

Neural data logged to the Pixie384 is synced with any environmental data recorded using the Logger Dock, MCU, or ECU digital and analog IOs.

Table 1 Pixie384 Headstage Specifications

| | |
|---|---|
| Channel Count | 384 Channel |
| Dimensions | 35 x 28 x 17.5 mm |
| Weight | 15 grams<br>~25 grams with 400mAh battery |
| Record Time* | 3 hours (with 400mAh battery) |
| RF Range | 6 meters |
| Sampling Rate | Dual band: 30 kHz (AP band); 2.5 kHz (LFP band) |
| Bit Depth | 10-bit |
| Gain | Programmable: 50-3000x |
| Sensors | 3-axis gyroscope; 3-axis accelerometer; |
| Data Acquisition | Neuropixels 1.0 384 channel NRIC chip |

**Recording time is dictated by battery health, which slowly changes with use over time. This results in an expected but modest decrease in recording time over the lifespan of the battery.*

## Pixie384 Headstage Dimensions

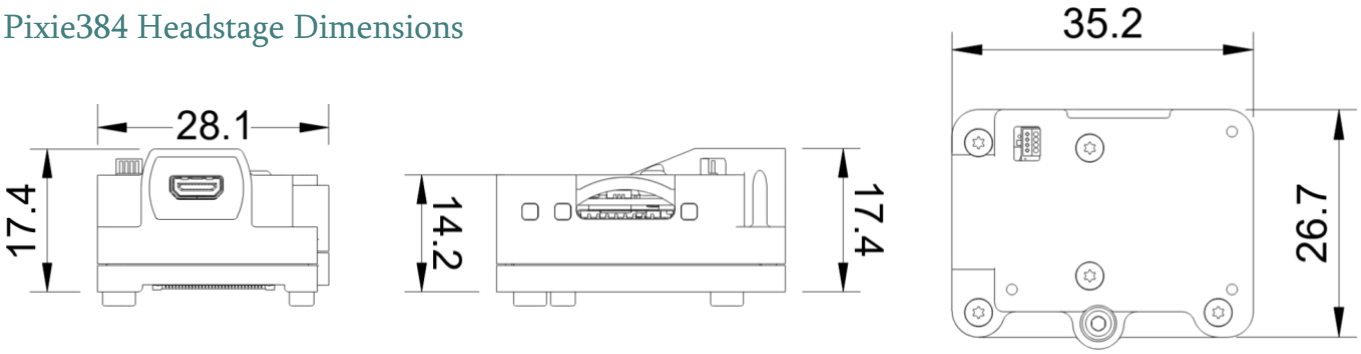



*Figure 1 Pixie384 dimensions (front, side, top views from left to right).*

## Headstage Connections

The Pixie384 has a variety of connection options:

1. **microHDMI** - For powering and streaming out live data in tethered experiments and power input in untethered experiments.

2. **Omnetics PZN** - Can be used in untethered experiments to power an external device (e.g LED array for head-tracking) or to power the headstage from a lithium-polymer battery.

3. **SD Card slot** - This is used for untethered recordings where neural and sensor data is saved directly to the SD card.

4. **Analog input connectors** - These connectors take in 384ch of low-amplitude analog neural data, and are used to interface with EIBs and probes (Molex-2049270601).

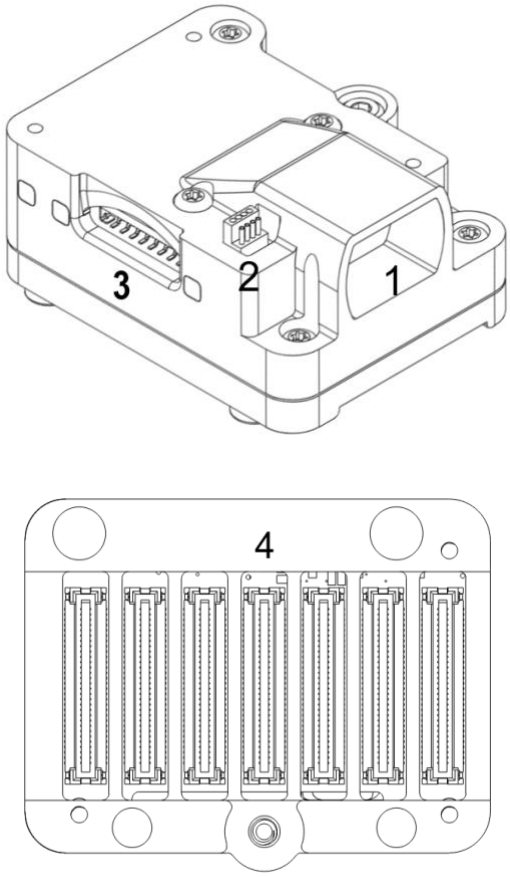



*Figure 2 Pixie384 connectors: microHDMI (1), Omnetics PZN (2), SD Card slot (3), Analog input connectors (4)*

## Analog Input Interface and Mapping

The analog input interface uses four posts to ensure proper alignment and orientation of the headstage. There is a captive screw on the system that can be used to bolt the headstage to the corresponding adapter.

Below are some illustrations of the Pixie384 channel map and specifications of the *adapter* side of the interface in order to facilitate custom designs.

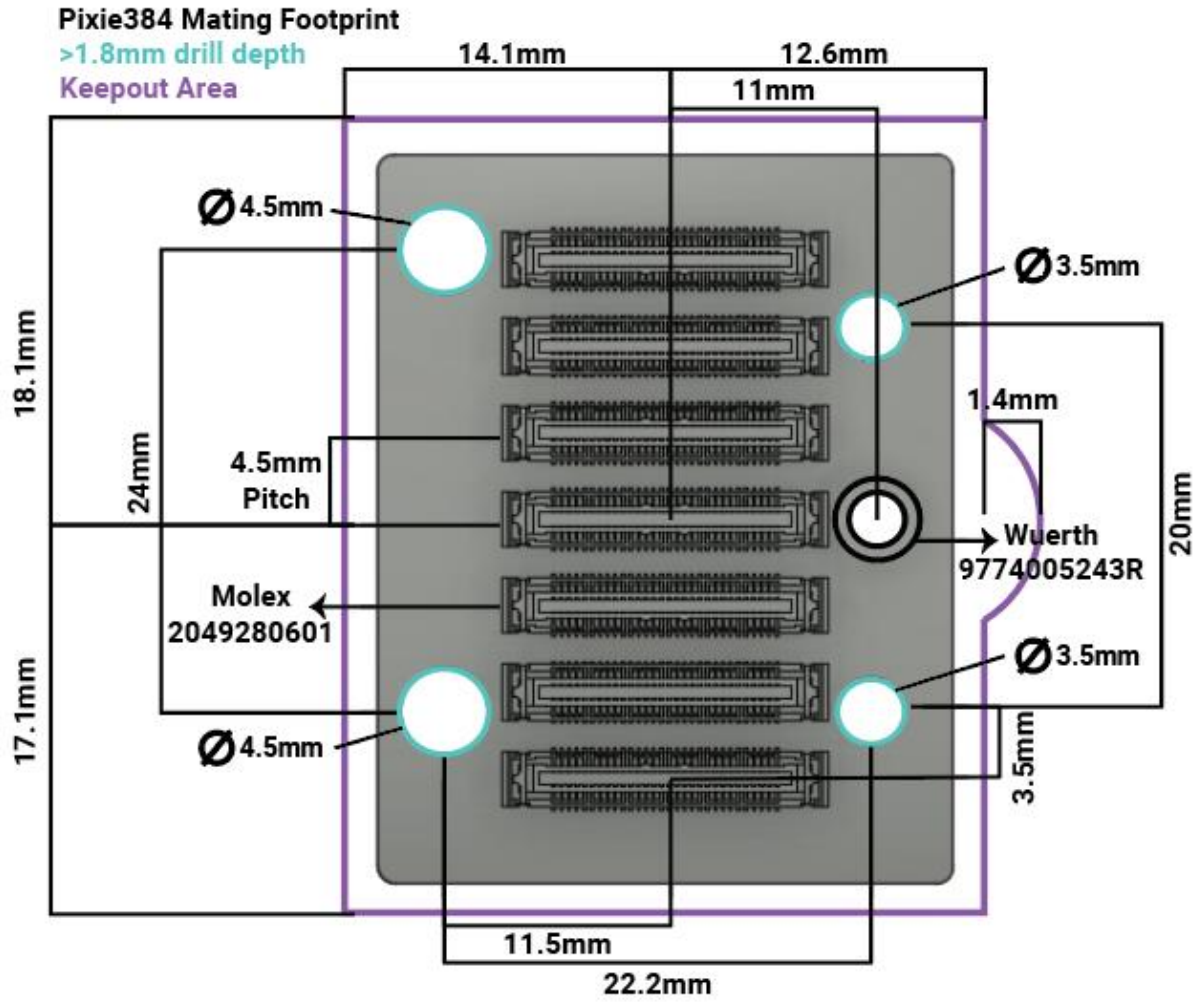



*Figure 3 Pixie384 adapter interface*

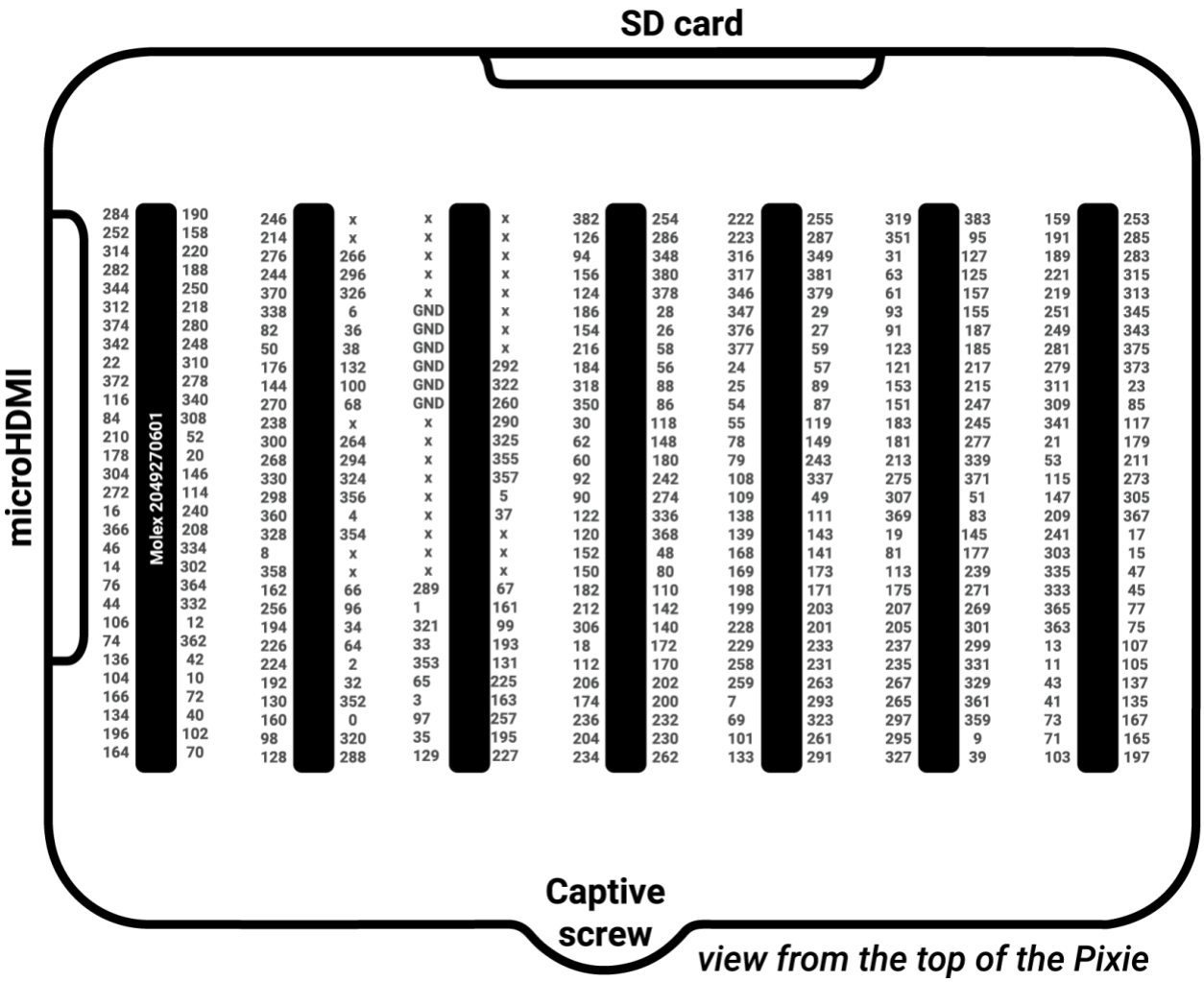



*Figure 4 Pixie384 hardware mapping*

## Grounding and Reference

By default, the Pixie384 amplifier references are tied to electrical ground. This means that a skull screw or equivalent will serve as a local reference to the amplifiers *and* tie the animal to building ground in a tethered recording and will tie the animal to the negative battery terminal in an untethered recording.

## Headstage Powering and Standby

**Low Power States:** During an untethered recording, if the Pixie 384 is powered on with less than 10% battery power remaining, the headstage's Hardware Status LED will show yellow illumination to warn the user that the battery needs to be charged. A recording cannot be initiated in this state.

### Standby Mode

When powered by a battery, the Pixie384 features a standby mode for untethered datalogging. After completing initialization and system checks, the headstage enters standby mode to await wireless commands from a paired Logger Dock. Standby mode has been optimized for low power consumption. One hour in this mode will drain ~1% of a 400mAh battery, resulting in a similar percentage decrease in the overall possible record time.

When a user pauses an active datalogger recording, the headstage will enter standby until the recording is resumed, enabling recording bouts over extended timeframes. As long as there is sufficient battery power (>10%) and SD card space the recordings may be paused and resumed for extended recording on an animal.

### Securing a Battery

The SpikeGadgets Battery Mount Adapter (included in the datalogging bundle) enables secure attachment of any external 3.7V lithium-polymer battery to any SpikeGadgets logging headstage. Users have the flexibility to choose the mounting location for each part of the adapter on both the headstage and the battery. After peeling off the protective layer from the acrylic foam tape, each half is permanently bonded to the headstage and battery. After installation, the battery mount can be slid into and out of the headstage mount. The two components are then fastened together using the small M1.6 x 3mm socket screw.

The battery then powers the headstage through a JST-to-microHDMI adapter plugged into the microHDMI port.

## LED Indications

The Pixie384 displays recording readiness using 3 different LEDs. When all 3 LEDs are blue, untethered recording can be initiated!

**Hardware Status** - Indicates the overall status of the headstage hardware. This includes the hardware systems responsible for digitization and amplification, data processing, and system control.

**Wireless Status** - Indicates RF connection status with the Logger Dock.

**SD Card Status** - Indicates the SD card readiness to record. Before each session the SD card must be

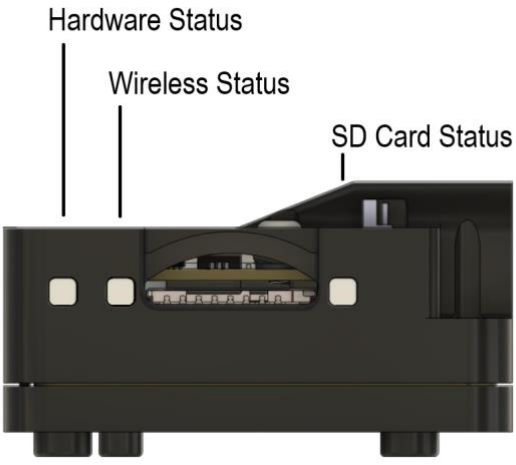



*Figure 5 Pixie384 Status indication LEDs.*

enabled for recording. The SD status LED will indicate if the SD card is not enabled or cannot be mounted. Data extraction and SD card enabling is discussed in more detail in a later section.

## Initialization and Startup

When the Pixie is powered on, all 3 status LEDs will blink white simultaneously. This indicates the headstage has completed initialization and is now in the active state. The headstage status LEDs will now report system readiness to record using the following color-coded indications:

*Table 2 LED Code Indicators*

| LED Color | Hardware Status LED | Connection Status LED | SD Card Status LED |
|---|---|---|---|
| **Blue** | Hardware OK | Connection to Dock OK | SD card ready |
| **Yellow** | Battery charge <10% | Waiting for RF communication from Dock | SD card not enabled for recording |
| **Red** | Hardware error detected; contact Support | - | No SD card detected **OR** SD card error |
| **None** | Connected to MCU | Connected to MCU | Connected to MCU |

## Recording Indications

When a recording is started, all status LEDs will flash white (4x) simultaneously to indicate the Start command has been received. Status LEDs will remain off for the duration of the recording. Status LEDs will flash white (4x) again when the Stop command is received.

Recordings ended due to low battery or an error state will be signaled as described below.

*Table 3 Recording Indications*

| LED Color | Hardware Status LED | Connection Status LED | SD Card Status LED |
|---|---|---|---|
| **Yellow** | Remaining battery charge below 5% | - | - |
| **Red** | Hardware error detected; contact Support | - | • No SD card detected<br>• SD card error<br>• SD card full |

# Trodes

## Creating a Pixie 384 Workspace

1. From the Trodes main menu, choose **Create/Edit Workspace** then select **From Scratch**. This will open the Workspace editor.

2. From the Workspace editor, under **Hardware Configuration** select **Headstage: Neuropixels 1.0 NRIC Chip**.

3. If an Environmental Control Unit (ECU) is connected to the system, the ECU device should be added under **Hardware Devices**. To do this, select **ECU** from the **Select Devices** dropdown menu, then click **+Add Device**.

4. Click **Open**.

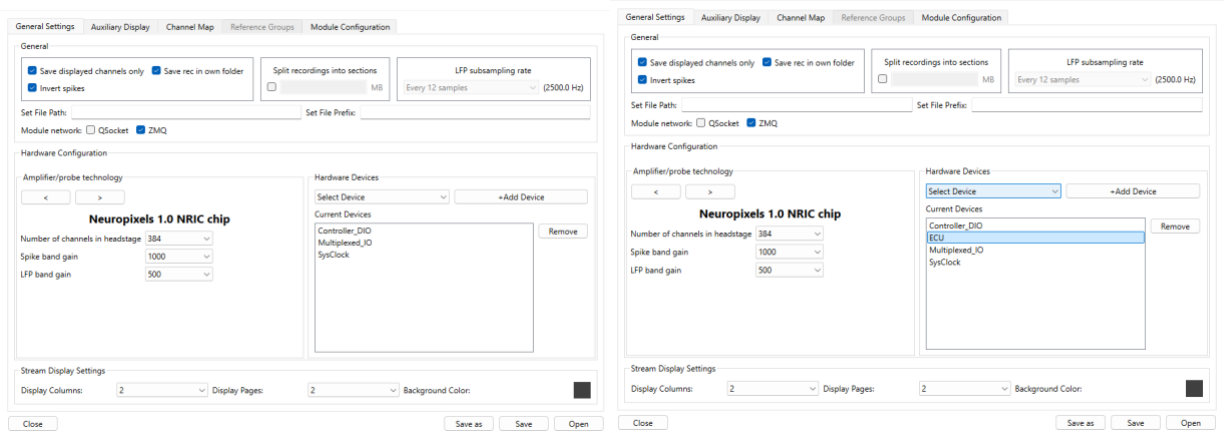



*Figure 6 Workspace hardware selection dropdown menu (left), and selecting ECU from the Hardware Devices dropdown menu (Right)*

## Tethered Configuration and Recording

When recording in tethered mode, the headstage is powered and data is streamed via the HDMI cable connecting the headstage to the Main Control Unit (MCU). When the headstage is properly connected to the MCU, the rightmost LED on the front of the MCU will change from blinking orange to solid green. When connecting the MCU to your computer, USB can theoretically stream up to 400 channels, but **Ethernet is strongly recommended for all tethered recordings.**

**NOTE:** Any SD card inserted into the headstage must be removed before tethered streaming can be initiated.

The following settings are available under the Headstage Settings menu:

- **3-axis accelerometer (on/off) –** The accelerometer range is +/- 2g, encoded in signed 16-bit integers, sampled at 500Hz. This means each step is 2/32767g or 0.000061g.
- **3-axis gyro (on/off) –** The gyro range is +/- 2000 degrees/second at 16 bits, or 0.061deg/sec per step, sampled at 500Hz.

The accelerometer and gyro each refresh their internal registers at 104 Hz. When both sensors are enabled, the system oversamples the sensors at 500 Hz. When only one sensor is enabled, it is oversampled at 1kHz.

Auto Settle, Sample Sequence Correction and reduced bit depth options are not supported by the Pixie384

### Initiating a Tethered Recording

1. Open Trodes and your Pixie384 Workspace.
2. Connect your headstage to the MCU via HDMI, and link your MCU to Trodes using the **Connection** dropdown menu via: *Source* > *SpikeGadgets* > *Ethernet*
3. Configure your probe and channel settings if you have not done so already and hit **Apply** to save the setting to your headstage.
4. Begin streaming by clicking **Stream from source** under the Connections dropdown menu.
5. Create a new recording file by selecting **New recording** under the **File** dropdown menu.
6. Set your recording directory using the file explorer pop-up window.

7. Begin recording by hitting the **Record** button.

8. To end your recording, click the **Pause** button, and disconnect your stream.

## Batteries and Charging for Untethered Recording

When recording untethered, the Pixie384 is powered using rechargeable 3.7V Li-po batteries. Attempting to power the headstage using a different battery type is not recommended and can result in damage to the headstage or connected probes. For most applications a capacity of 400 mAh is recommended.

Batteries can be charged using either the SpikeGadgets Battery Charger, or a 3rd party charging device. When charging batteries with any device, it is important that the selected charge rate setting does not exceed the battery specification (e.g. a 400mAh battery should be changed using a 400mAh charge setting or lower). Charging at a rate below the battery spec will result in a longer charge time but will still fully charge the battery.

**IMPORTANT NOTE:** *Li-po battery connector polarity varies based on vendor. SpikeGadgets' battery uses the same standard as Sparkfun and Adafruit, but many battery vendors use the reverse polarity.*
*Please confirm the polarity of your 3rd party batteries with the SpikeGadgets team before connecting to your headstage!*

## SD Card Setup for Untethered Recording

Before an SD card can be used for untethered recording, it must be enabled. This can be done using the MCU or Logger Dock, or using Direct Access (Trodes 2.5.0 or later).

**MCU:** Place the microSD card in an SD adaptor, mount to MCU and press and hold the left MCU button. The LED will flash red rapidly then turn solid green. The button can be released when the LED turns green, indicating the card has been enabled.

**IMPORTANT NOTE:** SD cards ***should only be mounted to the MCU when being read or enabled and should be removed following the action***. The MCU cannot read or enable the SD card while streaming, and streaming cannot be initiated while an SD card is mounted.

### Enabling SD via the Control Unit

- Mount the SD card into the card reader slot on either the MCU or Logger Dock, then press and hold the left button on the front of the control unit. The indicator LED will rapidly flash red indicating the card is being enabled. When the LED turns green the

card has been enabled and it is safe to release the button. (MCU requires firmware version 3.19 or later)

### Enabling SD via the Logger dock using the DataLoggerGUI

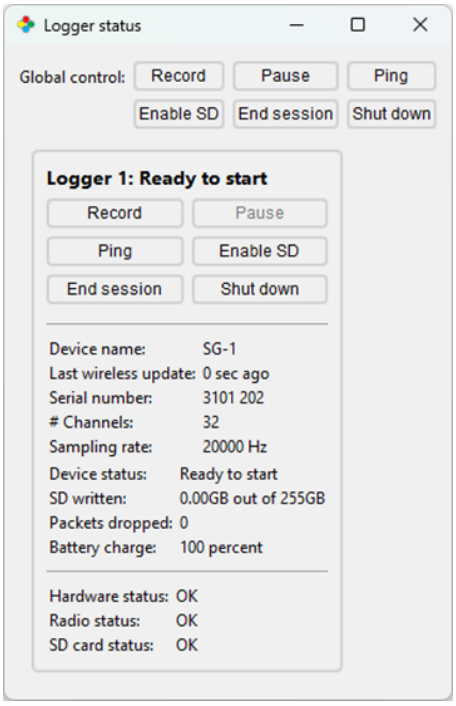
- Mount the SD card into the card reader slot on either the MCU, Logger Dock, or a direct access card reader, then open the DataLoggerGUI application. The SD card will be listed as a storage device with the status, "*not enabled for recording*." Simply select the device in the list and hit **enable for recording**.

### Enabling SD via 2-Way RF using Trodes

- To enable the SD card mounted to a paired Pixie384, simply click the **Enable SD** button in the Logger Status menu (described in the **2-way Radio Link** section below) for the corresponding logger. Trodes must be streaming from the connected dock and the logger must be powered on and operating wirelessly. This feature is disabled when the logger is connected via USB. The Enable SD Global command enables all SD cards mounted to paired and connected devices. This command should be used with caution.

**IMPORTANT NOTE:** SD cards cannot be read or enabled by the Logger Dock while streaming, and streaming cannot be initiated while an SD card is mounted. As such, SD cards should be unmounted once they have been read and/or enabled.

## 2-way Radio Link




Pixie384 features headstage status and battery monitoring facilitated by 2-way radio link. This enables back-and-forth communication between the headstage and control unit. This provides detailed real-time information about the status of all connected headstages and empowers the user to make informed experimental decisions on the fly. The Logger Status window is accessed by clicking the **Remote Control** button in the upper left of the Trodes interface.

Each paired and connected headstage will have its own info card in the Logger Status window, and the window will expand based on the number of connected loggers. Devices are always displayed in order based on pairing slot assignment.

Each connected logger is controlled individually using the command buttons within its designated info card (as seen in Figure 5 Pixie384 Status indication LEDs.).

Additionally, commands can be issued to all connected devices simultaneously using the Global control buttons found at the top of the Logger Status window.

*Figure 7 Trodes Logger Status Window*

The headstage Ping command causes the logger's LEDs to illuminate briefly for easy visual identification of one or all connected devices with a single button press.

Headstage Pause leverages the low power standby mode to enable multiple recording epochs within a single session with minimal impact on overall record time.

**NOTE:** Streaming in Trodes is required for 2-way communication with the logger. This means the Dock must be powered and connected and Trodes must be streaming from source before status can be viewed or commands can be issued. Powering down the Logger Dock will immediately end the recording session for any connected devices.

## Headstage Pairing

Initial headstage pairing requires a hardware connection with the control unit. During pairing, each headstage is assigned a specific "slot" in Trodes (1-8). The slot assignment is selected by the user and saved to the headstage for future recording sessions. Once paired, the logger will automatically be recognized by the Dock and Trodes. Slot assignment and device pairing can be updated by the user at any time.

The following hardware and software are required for 2-way Radio Link:

- Pixie384 & Logger Dock 2

- Trodes 2.6.0

## Pairing and Hardware Settings

1. Open Trodes and create a new Workspace with no neural data.

2. Connect Pixie384 to the Logger Dock 2 using the provided USB to microHDMI cable.

3. Connect to your Dock in Trodes by selecting the following from the **Connections** dropdown menu:

*Source > SpikeGadgets > Logger Dock > USB*

4. Open the **Hardware Settings** window under the **Settings** dropdown menu.

5. Select the **2-way** checkbox.

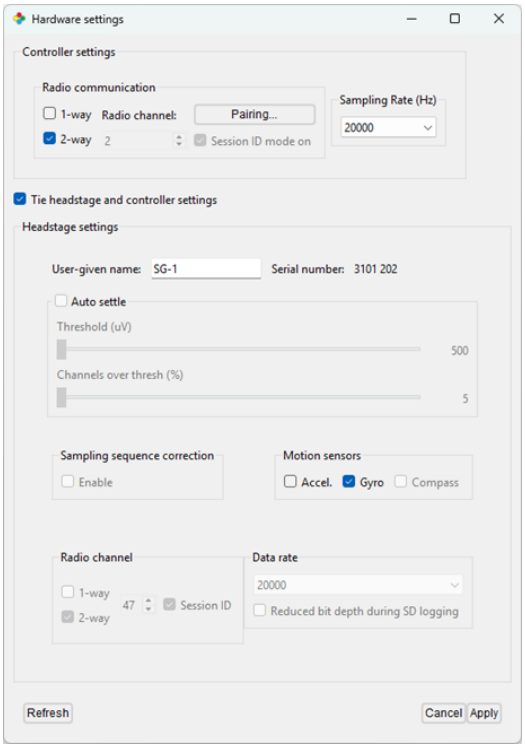



*Figure 8 Trodes hardware settings.*

Selecting the **Tie headstage and controller settings** checkbox is recommended as this ensures consistent settings for both the environmental and neural recordings.

6. Hit **Apply** to save settings to the headstage.

7. Open the **Pairing** menu using the **Pairing** button and select the preferred headstage slot by clicking **Add/replace**. Paired headstages can also be pinged or disconnected using this menu.

**Additional note:** The Pixie384 can also store a user-given name. The name is saved to the logger and persists through power cycling. Headstage name can be up to 12 characters and may be changed at any time.

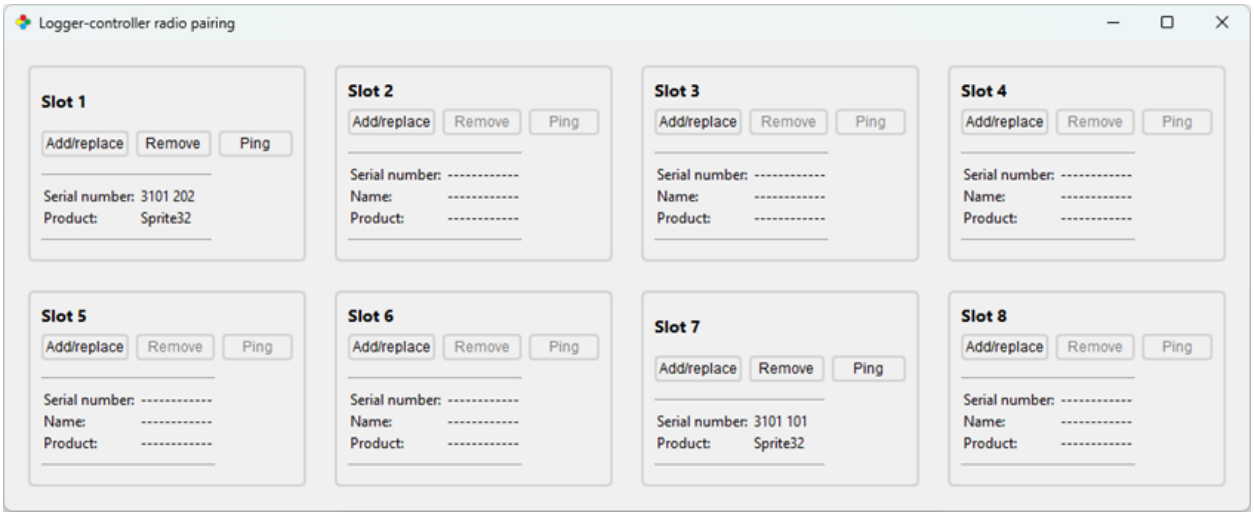



*Figure 9 Headstage pairing menu showing all 8 available slots*

The Trodes hardware settings menu is used for configuring both 1-way and 2-way radio link capable headstages. As such, not all settings in the menu apply to all headstages. For instance, Pixie384 does not support Auto Settle, Sample Sequence Correction or reduced bit depth during SD logging.

## Headstage Auxiliary Power Output

The Pixie384 is equipped with a 8-pin PZN Omnetics connector for powering accessory devices such as headtracking LEDs.

When the headstage is powered by the MCU via HDMI, the Supply Out provides 5V. When the headstage is operating under battery power, the output voltage is ~3.7V. The center pins are firmware programmable outputs but currently serve no function.

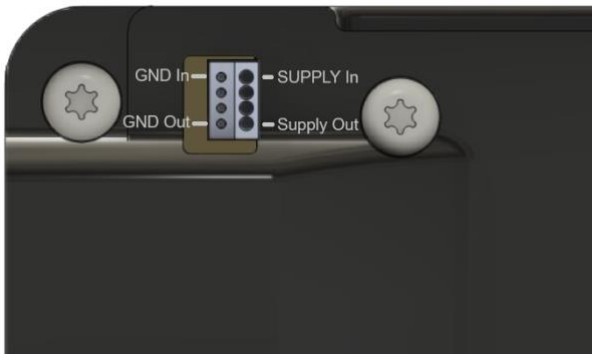



*Figure 10 Pixie Auxiliary Power connector (top view)*

## Synchronization

Synchronization between the environmental recording taken by Trodes on your local computer and the neural data recorded to SD on the Pixie384 is done via a 2-way radio link. Logger Dock 2 can be paired with up to 8 Pixie384 headstages simultaneously and sends sync signals at 80 Hz. The Dock sends sync signals to each headstage by cycling through each of the 8 pairing slots. This results in a 10 Hz sync signal for each headstage. Each sync signal is recorded by both the headstage and Logger Dock at the same sampling rate as the neural and environmental data.

During the data merging process, the sync signal timestamps recorded in both data files are aligned, and the sample count between signals is compared. If a difference in sample count is identified, small local adjustments are made to the environmental record to maintain alignment. This eliminates drift and results in high alignment precision throughout the merged recording.

## Transferring and Merging Data

### Merging Data with DataLoggerGUI and Logger Dock

In order to merge your data files into a single .rec file you will need the following:

1. The file containing the recorded neural data from the headstage SD card.
2. The file containing the environmental data recorded to your local computer by Trodes.
3. A Trodes workspace file to append to the merged file containing both environmental record settings as well as probe and channel setting as if the recording were taken in tethered mode. A step-by-step workspace creation tutorial video can be found here.

More information about merging your data files can be found in the data extraction subsection of the DataLoggerGUI documentation.

## Items Included with Shipment

*Table 4 Items Bundled with Pixie384 Headstage*

| Item | Description |
|---|---|
| Pixie384 Headstage | Data logger with amplification, digitization, and SD data storage |
| 45” HDMI A-D Cable (HDMI to micro HDMI) | HDMI tether for connecting headstage to MCU |

## 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.