SpikeGadgets

Griffin

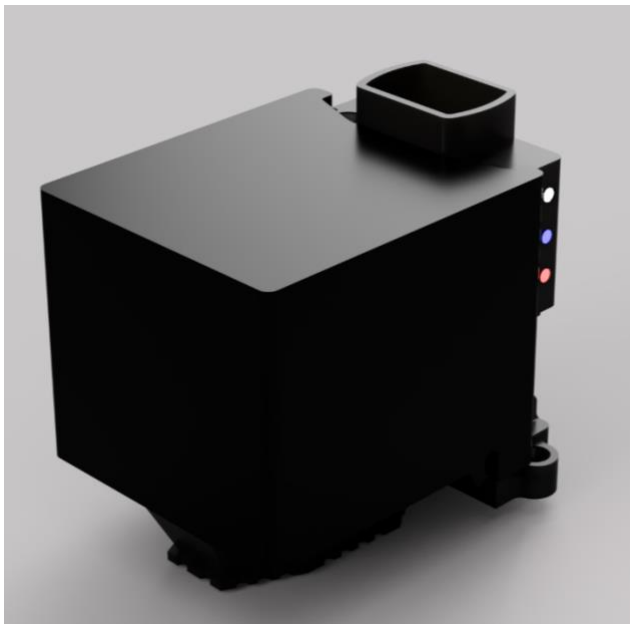


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Introduction

The Griffin is a modular, scalable head-mounted electrophysiology system capable of simultaneously recording up to 512 channels of neural data. It achieves this by combining the Griffin processor with up to four probe connectors, supporting either 64- or 128-channel CMOS Diagnostic Biochips or Cambridge Neurotech probes, for a total channel count between 64 and 512 channels in 64- or 128-channel increments.

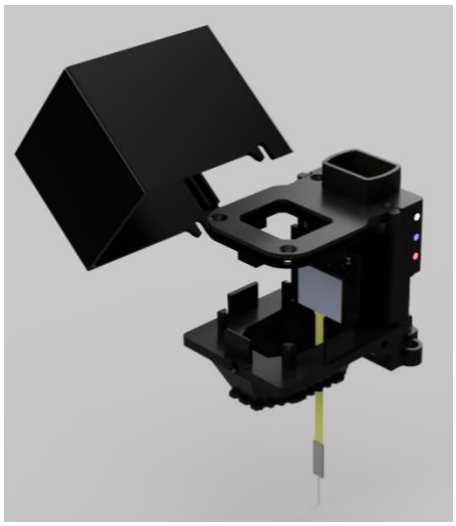


Figure 1 | Griffin

The Griffin supports two recording modes. In tethered mode, the Griffin connects to the Main Control Unit (MCU) via micro HDMI, streaming up to 512 channels to a local computer through Trodes. In untethered logging mode, the Griffin runs on battery power and records to a removable onboard micro SD card — up to 384 channels at 30kHz or up to 512 channels at 20kHz. In this mode, the headstage is controlled via RF signal transmitted by the Logger Dock 2, which also synchronizes neural data with any event data recorded to the local computer.

The Griffin connects to implanted Diagnostic Biochips or Cambridge Neurotech probes via a 12-pin Omnetics connector (A79622-001). An optional cone cover slides onto the Griffin processor to cover the probes (Fig. 2); note that when the cone cover is used, the Griffin is intended to remain on the animal for the duration of the implant.

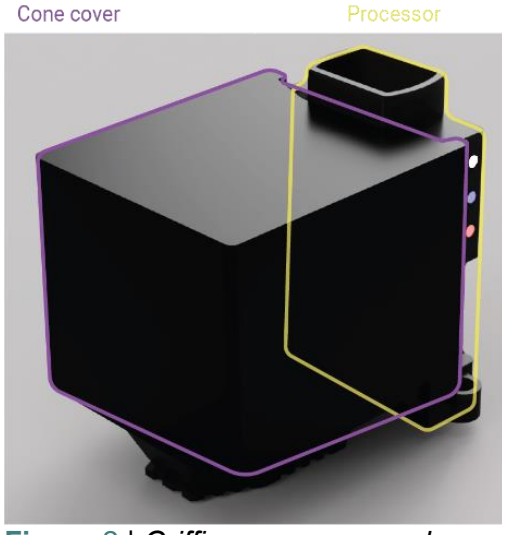


Figure 2 | *Griffin cone cover and processor*

Specifications

Channel Count	Scalable 64 to 512 channels
Intended Experimental Applications	Freely-moving tethered or untethered recording
Connector to Probe	1x A79622-001 Omnetics connector per Probe Board
Sampling Rate	30kHz, 20kHz & 2kHz supported
Bit Depth (ADC's)	16-bit and 12-bit supported
Input-referred Noise	2.4-2.8 µV RMS (as reported by Intan)
Connector to MCU	Micro HDMI
Input Range	±5 mV
Dimensions	
Length	41 mm
Width	28 mm
Height	34 mm
Weight	17g (without probes)
Battery Life	Varies based on battery capacity.
Sensors	3-axis accelerometer, 3-axis-gyro
Radio synchronization range	10-20 meters

Onboard Sensors

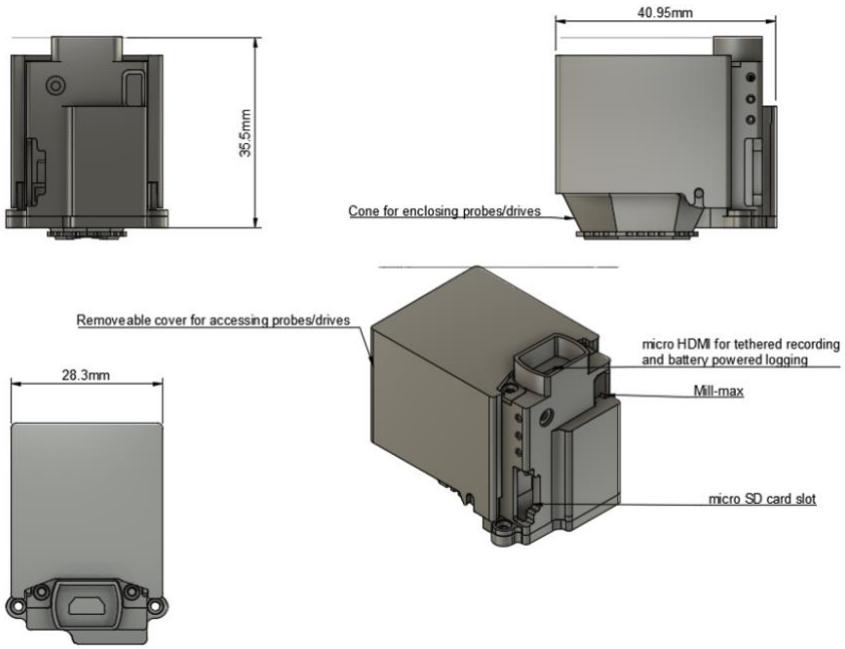
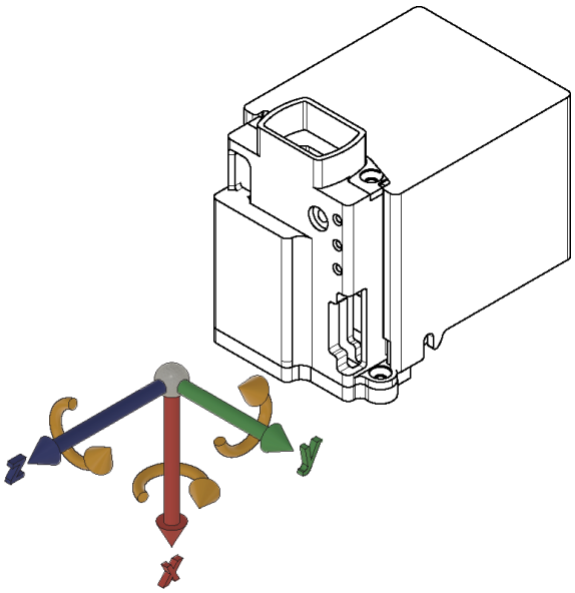


Figure 3 | *Griffin scale*

The headstage has an integrate accelerometer and gyroscope. The diagram below shows the orientation of these sensors.



Headstage Functions

Griffin Processor

The Griffin utilizes an integrated processor (FPGA) to achieve scalability, flexibility and modularity. The processor flexibly communicates with up to four 64- or 128-channel Diagnostic Biochips or Cambridge Neurotech probes simultaneously, combining their output into one high-speed data stream. In tethered recording mode, this allows for real-time streaming of up to 512 channels of data simultaneously via a single cable tether.

In untethered data-logging mode, this allows up to 384 channels of data (recorded at 30KHz, 16-bit) or 512 channels (recorded at 20kHz, 12-bit) to be written directly to onboard micro-SD card. The lower untethered sampling rate for the higher channel count is due to the write speed restrictions of micro-SD card.

Removing the cone cover from the processor will give access to the implant area and drives (if applicable) through the opening at the top of the processor case and adapter board (Fig.4). The cone cover is held in place by two #0-80 3/16”screws.
The Griffin adapter board is designed for use with Diagnostic Biochips or Cambridge Neurotech CMOS 64- or 128-channel probes. Probes interface with the adapter board via an A79622-001 Omnetics connector.
The Griffin’s global hardware channel mapping is zero-based and can be determined using the channel mapping of a given probe and the position (1 – 4, see Fig.4) of the probe on the adapter board. When connecting multiple probes, the global identity of a given channel can be found using the following equation:

Hardware channel = n + (64 or 128*the number of preceding probe on the adapter board)*

Where n is dependent on the channel mapping of the given probe.

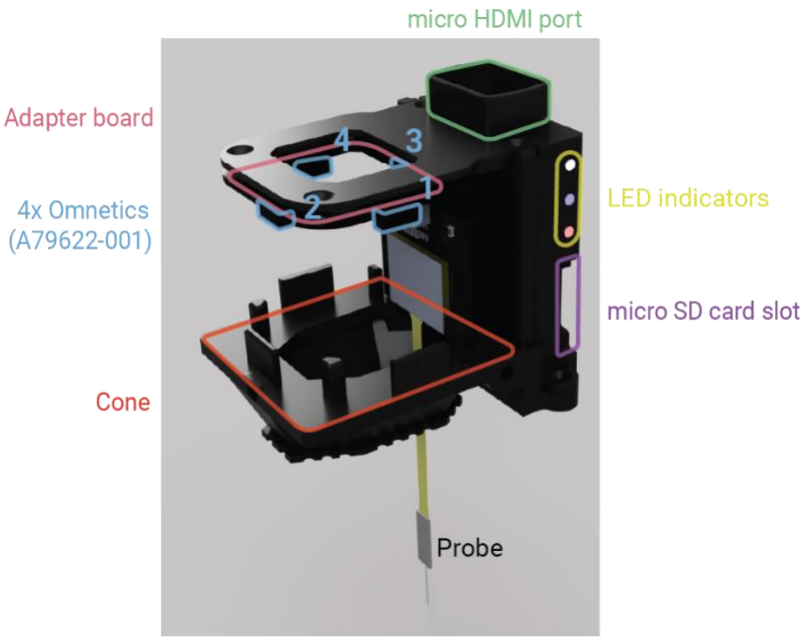


Figure 4 | *The micro-HDMI port is used for tethered recording and battery powered logging – during which the micro-SD card is pushed into the card slot. The three LED indicate hardware, RF and SD card functionality. The cone can be separated into two halves to ease the mount of probes, drives and the cone during surgery. Up to four either 64- or 128-channel probes can be mounted. To note, position 1 needs to be mounted with a probe before 2, 2 before 3 and 3 before 4 (e.g. only mounting a probe in position 4 will not be possible).*

Probe Interfacing

During surgery the cone can be separated into two halves (left and right) to ease the placement of the probes and if applicable drives. One #0-80 1/8” screw and one #0-80 5/32” screw hold the two halves together. As soon as the surgery is complete and the cone is cemented, the probe(s) can be connected to the adapter board and the processor lowered down onto the cone and screwed in place (two #0-80 1/8” screws).

Up to four 64- or 128-channel Diagnostic Biochips or Cambridge Neurotech probes can be mounted. It is important to note **that it is not possible to interleave 64- and 128-channel probes, only one type of probe can be used at a time.**

The four probe positions can only be used in a specific sequence. For example, mounting a probe in position 2 and not 1 is not possible. The probe positions (1-4) are indicated on the adapter board (Fig.4).

Referencing and Grounding

All probes connected to the Griffin share a common ground line that serves as the amplifier reference for the system. Probe-specific ground or references are not internally connected in the Griffin to avoid the risk of creating ground-loops.

When preparing your setup for recording, proper grounding is crucial. This can be achieved using the hardware configuration shown above. In this configuration, a single ground line is connected from the headstage's adapter board to the experimental subject (often to an implanted skull screw). This ground is then shared amongst all connected probes (Fig.5). This avoids ground loops and helps prevent amplifier artifacts that can arise from using multiple reference lines.

Importantly, when grounding equipment such as a faraday cage to the MCU, this must be connected to the 2mm ground jack in the rear of the MCU, not the MCU case**. NOTE: The MCU and computer should be powered using the same circuit when possible. If this is not possible, connecting with only Ethernet may reduce grounding issues.**

External Ports

The Griffin is equipped with externally accessible ports for both routine and custom

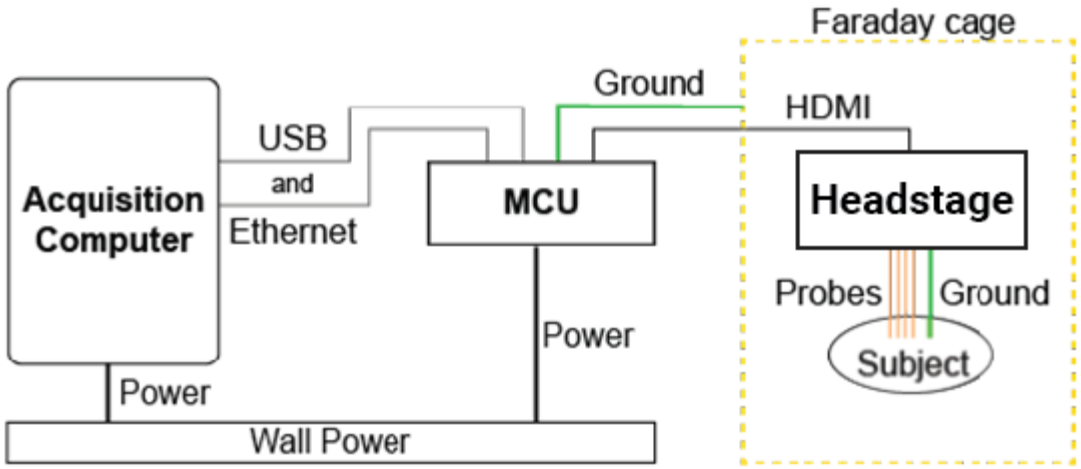


Figure 5 | *Recording setup grounding diagram*

applications (Fig.6).

Micro-HDMI: When using the Griffin for tethered recordings, the headstage is connected to the MCU via the micro-HDMI port. This allows data to be streamed and saved to the local computer using Trodes.

When recording untethered, the headstage is powered using an external battery connected to the micro-HDMI port using the SpikeGadgets battery adaptor.

Micro-SD: When recording untethered, the micro-SD card used to save data is inserted into this slot.

NOTE: Tethered data streaming in Trodes cannot be initiated while a SD card is mounted in the MCU or connected headstage.

The Griffin is also equipped with an externally accessible 4 pin female Mill-max connector (1.27mm pitch) for connecting external devices and components as seen in Fig. 6.

5V input: The 5V input can be used to power the headstage in situations where the micro-HDMI connection is inaccessible or an alternative power source is needed.

NOTE: connecting a battery to the 5V input while powering the system via HDMI should be avoided.



Figure 6 | *External ports*

AUX: The auxiliary port is currently inactive but retained for future development.

GND: The ground input is connected to the unified headstage ground to ensure a single ground line for any connected devices.

5V OUT: The 5V output can be used to power external components of devices such as LED arrays for headtracking applications.

Note: An important distinction between the 5V IN and 5V OUT is that the 5V OUT is disabled when the headstage enters low-power standby, ensuring peripherals such as LED arrays are off until the recording begins.

LED Indications

Griffin simplifies headstage status signaling and streamlines setup by displaying recording readiness for each logger system using three different LEDs (Fig.7).

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 enabled for recording. If the SD card is not enabled, the SD Status LED will indicate this. Data extraction and SD card enabling is discussed in more detail in a later section.

Initialization and Startup

When the Griffin is powered on, all three 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:

LED Color	Hardware Status LED	Wireless 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

All LED must show a blue indication before a recording can be initiated. Once this occurs, the LEDS will stay on briefly, then turn off to conserve power. **NOTE:** Logger system statuses are displayed hierarchically. This means that a status issues must be resolved sequentially as follows: Hardware Status issues must be addressed before Wireless Status can be addressed, and Wireless Status must be OK before an SD Status issue can be resolved.

In practical terms, this means that if the Wireless Status LED is yellow (waiting for RF signal), enabling your SD card will not cause the SD Card status LED to change until the Wireless Connection is established.

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 remain off for the duration of the

recording. Status LEDs will flash white (2x) again when the Stop command is received. LEDs will remain off unless a hardware or SD cards state change is detected.

LED Color	Hardware Status LED	Connection Status LED	SD Card Status LED
Red	Hardware error detected; contact Support	-	No SD card detected SD card error SD card full

Standby Mode

When using the Griffin for untethered recording, battery life is a key consideration. To maximize recording time, the Griffin saves battery life by entering standby mode until a recording is initiated*. When in standby mode, the headstage can receive radio frequency (RF) commands from control units (Logger Dock 2), but most other headstage functions remain dormant.

In standby mode, when the Griffin receives a start command from the control unit, the headstage runs a brief boot-up sequence checking all headstage functions before initiating recording. This ensures that all systems are functional before recording begins. The Griffin re-enters standby mode when it receives a stop command from the control unit.

NOTE: When in standby mode, the 5V OUT is unpowered. This means that any external devices or components powered by this port, such as LED arrays for headtracking, will not receive 5V power until the recording is initiated.

*Standby mode is present in all headstages running firmware version 4.4.1-1.1.2 or later.

Headstage Configuration and Recording

Headstage Configurations

In tethered mode, an HDMI to micro-HDMI cable is used to power the headstage and stream data to the MCU. Once connected via micro-HDMI, if the headstage is properly detected by the MCU, the MCU's power indicator LED will change from blinking amber to solid green. Data streaming is controlled by the Trodes application via the MCU. More information about this can be found in the Trodes wiki.

For both tethered and untethered recording modes, headstage settings are modified using Trodes and saved to the headstage's onboard flash memory. The Griffin must be configured in Trodes while connected to the MCU via HDMI before recording in untethered mode. To modify settings, the MCU connection to your computer must be enabled in Trodes, but streaming should not be initiated. Settings cannot be saved to the headstage while streaming data. Headstage setting specific to untethered recording will be discussed below.

Connecting your MCU to your computer via Trodes is done under the Connection dropdown in your Trodes Workspace:

*Connection > Source > SpikeGadgets > USB **OR** Ethernet*

The following Griffin settings can be modified under Settings in your Trodes Workspace:

- **Auto Settle –** Large transient electrical events (caused by electrical stimulation, physical bumping, etc.) can cause extended amplifier ringing. The Auto settle function resets the amplifiers when this occurs and allows you to set a voltage and channel count threshold for triggering the reset.

IMPORTANT NOTE: Auto settle channel threshold should always be set to a value greater than zero. Failure to do this can result in high amplitude noise "ticks" occurring at a 500ms interval across all neural data channels.

- **Sampling Sequence Correction (on/off) –** Eliminates temporal referencing error associated with the sequential nature of how Intan channels are sampled. It is highly recommended to turn this on when using digital reference.

- **3-axis accelerometer (on/off) –** The accelerometer range is +/- 2g, encoded in signed 16-bit integers. 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.

The accelerometer and gyro sensors both refresh at 104 Hz. When both sensors are enabled, each sensor is sampled at 500 Hz. When only one sensor is enabled, it is sampled at 1kHz.

Initiating a Tethered Recording

For information about using Trodes and tethered recording, see the Trodes Wiki.

Untethered Configuration and Recording

In untethered data-logging mode, the Griffin records neural data directly to an onboard microSD card without the need of a cable tether. It does this under battery power by receiving wireless communication from the control unit (Logger Dock 2). The control unit sends start/stop and synchronization commands to the headstage via radio frequency (RF) wireless link.

The Griffin headstage draws approximately 135mA @4V with one 64-channel probe mounted and 152mA @4V with one 128-channel probe mounted. Each 64- or 128-channel probe adds roughly 18mA or 36mA, respectively. So, four 64- or two 128-channel probes will record for approximately 2h when using a 400mAh battery. Larger Ah batteries will allow for longer record durations.

For information about using Trodes and untethered recording, see the Trodes Wiki.

Batteries and Charging for Untethered Recording

When recording untethered, the Griffin Headstage is powered using rechargeable 3.7V Lithium-ion batteries with JST-PH connector. Attempting to power the headstage using a different battery type is not recommended and can result in damage to the headstage or connected boards or probes. Batteries may be purchased in the SpikeGadgets datalogging bundle or you can contact us via Slack or email to confirm compatibility.

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.

SD Card Setup

Before an SD card can be used for untethered recording, it must be enabled. This can be done using the MCU or Logger Dock 2, or using Direct Access (Trodes 2.5.0 or later).

MCU: Place the micro SD 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 Logger dock using the DataLoggerGUI

1. Once your SD card has been inserted into the Logger Dock or MCU, open the DataLoggerGUI application from the Trodes application directory.

2. Your SD card should be listed under "Detected Storage Devices." If you do not see your device listed, hit the refresh button.

3. Select the relevant device and hit the "Enable for recording" button to enable your SD card.

Synchronization

Synchronization between the environmental record recorded by Trodes on your local computer and the neural data recorded to SD on the headstage is done via a radio signal sent at regular intervals (10-second intervals for most setups). This signal is transmitted from the SpikeGadgets control unit that acquires your environmental data and connects

to your computer. Trodes connects to this control unit to display and save the environmental data during the recording session. Any video recordings taken using the Camera Module in Trodes are set up the same way they would be for tethered recording. Importantly, the neural data being recorded to SD cannot be accessed during recording. Once the recording session is done, there will be 2 data files that need to be merged. One data file contains the neural data and is saved to the headstage SD card, the other contains the environmental data saved to your computer. These two files will be aligned using the synchronization signals saved to both files and will be merged using the DataLoggerGUI.

For information about workspace creation, the DataLoggerGUI and data merging can be found under the Workspaces and DataLoggerGUI subsections of the Trodes Wiki.

Additional Resources

For information about getting started with your SpikeGadgets recording system, please visit the Trodes Wiki, which contains additional information and resources covering many basic and advanced topics about using SpikeGadgets recording systems. For new users, a good place to start is the Quickstart Guide.

Additional information and documentation about all our products and software can be found on our website.

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.