Micro-LED Optoelectrode and Interface System

µLED-12-32 Optoelectrode

Features
- 12 µLEDs with dimensions 10 x 16 µm each, 3 per shank
  - Emission Peak $\lambda = 460$ nm and FWHM $= 40$ nm
  - Typical irradiance @ 100µA is 125 mW/mm$^2$, recommend maximum
- 32 recording channels, 8 per shank
  - Electrode impedance of 100 - 1500 kΩ at 1 kHz
  - Noise floor $\leq 5\mu$V$\text{rms}$ using an Intan RHD2132 Amplifier Board
- PCB dimension 10 x 20 mm, weight < 2 g
- 36-pin Omnetics connector for recording and 18-pin Omnetics connector for stimulation

Description
The µLED-12-32 optoelectrode integrates the smallest LED technology with high-density recording electrodes. The silicon substrate makes a convenient form factor for animal research with use in many labs. The recording channels are connected to an Omnetics 36-ch connector and works with most recording systems on the market. We recommend a current source with resolution of 1 µA and a range of up to 100 µA. While many configurations are possible of electrode and µLED position, this version is a 4-shank layout as shown above. The shank length is 5 mm and center-center spacing is 250 µm. Each probe is connected to the PCB via a flexible cable and is microdrive compatible. The electrodes are on a 20-µm vertical pitch.

Two versions currently available

µLED-12-32-A
µLED-12-32-F (flexible)

Questions? ContactMINT@umich.edu
For samples, complete order form at mint.engin.umich.edu/technology-platforms/#optoelectrodes
Recording System Compatibility

Pre-amplifiers are required to ensure low-noise and are widely available. Any 36-pin Omnetics male headstage is compatible with the µLED-12-32 recording electrode. All testing to date has used an Intan RHD2132 amplifier board (www.intantech.com). Also any other amplifier board with this connector would work including products from Ripple, TDT, Plexon, Neuralynx, Triangle Biosystems, etc.

Applications

- optogenetic-control of local neural circuits in awake behaving studies
- square-wave excitation for precise timing control
- sine-wave excitation for graded modulation
- chronic optogenetics where a microdrive is used to fine-tune position
- example of typical tissue depth when driving with 100 µA (right)
- References: Mendrela et. al, IEEE BioCAS, 2018; English, et. al, Neuron 2017; Wu et. al, Neuron 2015

Microdrive

- Optional for chronic use where position control is desired
- Total travel –
- Mouse – 2.6 mm
- Rat – 5.7 or 8.9 mm
- Resolution, distance per turn – 280 µm
- 3D printable CAD files are available for download at this GitHub page
- A video demonstrating its use in an animal surgery can be found here on GoogleDrive

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Typical System Configuration

Description

The passive µLED-12-32 allows for greater compatibility. Internally we use an Intan RHD2132 pre-amp headstage and RHD2000 interface board. We recognize many labs use other commercial systems and software. Please contact to discuss your application. Control of the OSC1-36 can be done through Matlab via a USB connection. A link for all required software will be made available on our website mint.engin.umich.edu and hosted on GitHub.

OSC1-36 µDriver

Features

- 36-channel independent drivers
- Current range 1 µA - 1024 µA (10-bit res)
- Customizable waveforms at an update rate of 11.72 kHz
- Trigger in/out available via DB connector
- USB 2.0 communication with PC
- PCB dimensions 10 x 20 cm, 9VDC
- Easy-to-use software interface

Description

This optical stimulation chip provides 36 current drivers all independently controlled through an easy-to-use GUI or with external triggers. The level of precision provided by this driver is critical for precise illumination of local neurons in optogenetic experiments. Download a stand-alone executable or the MatLab code at our GitHub page. An example of the GUI is shown below.

** Due to limited supply, we recommend that most labs refer to our list of commercially available options for multi-channel drivers below. We are not affiliated nor promoting any of these vendors. Please let us know if these products lack compatibility and still require the OSC1-36.
Example of OSC1-36 µDriver Software Interface

<table>
<thead>
<tr>
<th></th>
<th>Plexon PlexStim</th>
<th>Pulse Pal v2</th>
<th>OSC1-36 (for reference)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vendor</strong></td>
<td>Plexon</td>
<td>Sanworks, Inc.</td>
<td>NeuroNex MINT</td>
</tr>
<tr>
<td><strong># Channels</strong></td>
<td>16</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td><strong>Current/Voltage</strong></td>
<td>Current</td>
<td>Voltage</td>
<td>Current</td>
</tr>
<tr>
<td><strong>LED Protection Circuit</strong></td>
<td>Yes</td>
<td>Contact vendor</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Isolation Circuit</strong></td>
<td>Yes</td>
<td>Contact vendor</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Output Range</strong></td>
<td>100nA – 1mA</td>
<td>±10V</td>
<td>1µA – 1mA</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>16 bit</td>
<td>12 bit</td>
<td>12 bit</td>
</tr>
<tr>
<td><strong>Arbitrary waveform</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
<td>1µs</td>
<td>100µs</td>
<td>100µs</td>
</tr>
<tr>
<td><strong>TTL input/output</strong></td>
<td>In/Out</td>
<td>In only</td>
<td>In/Out</td>
</tr>
<tr>
<td><strong>Software control</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>$8500</td>
<td>$595</td>
<td>$1000 (MTA)</td>
</tr>
</tbody>
</table>
µLED-12-32 Connectors

Recording system connector is the 36-pin Omnetics (A79024-001/NPD-36-AA-GS, pictured at right)

Stimulation connector is the 18-pin polarized Omnetics (PZN-18-AA)

µLED-12-32 Mapping Details

Optoelectrode tip top view

PCB rear view

Suggested connection w/ Intan headstage

Intan channel mapping w/ suggested connection

Frequently Asked Questions

Q: I am seeing a stimulation artifact whenever I pulse the LEDs. Can this be avoided?

Stimulation artifacts can occur in the recordings at the beginning (stimulation onset) and the end (stimulation end) of the voltage / current pulse to the micro-LEDs in a shape of high-frequency, high-amplitude swing of the signal. Stimulation artifact is typically observed on the recording channels on the same shank of the LED being

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stimulated, but it is possible that it occurs on all the recording channels. The artifact amplitude and pulsewidth varies depending on position relative to the LED and the impedance of the given electrode.

The cause is mostly dominated by the photovoltaic effect for which we hope to have a solution available in 2019. Whether artifacts can ever be completely eliminated is yet to be proven but we have reason to be hopeful. Fortunately, there are ways to deal with it when it occurs, namely pulse shaping and subtraction methods.

Pulse shaping, i.e. slowing the slew rate (or rate of change) of the pulse signal provided to the LEDs, will reduce the artifact amplitude. Driving your LED with a sine wave is an extreme form of pulse shaping. In standard CMOS drivers, the turn-on period is in nanoseconds. It has been observed that sinusoidal or gaussian off-to-on and on-to-off transitions exhibit stimulation artifacts of smaller amplitudes than that of (high-speed) ramp. It has also been observed that ramp transitions with rise (and fall) times as long as a few milliseconds can also greatly reduce the stimulation artifact.

Another pulse shaping method to reduce the artifact is to reduce the total step change in the voltage required to drive the LED. Choose a low voltage where current is effectively zero, usually 2V works well, and program that to be off state for the LED. The ON state would be as it was before but in this situation the dV/dt is reduced and so is the artifact. Similar argument works for a current driver but this requires very high resolution, e.g. choose 100 nA.

The artifact can also be subtracted out before your spike sorting/PCA analysis. Given your timestamps for each ON and OFF event, remove the signal recorded for a 1 ms period at the stimulation onset. This should be repeated at the stimulation OFF event. The missing signal is then replaced with a linear interpolation. This has been done in English, McKenzie, et al., “Pyramidal cell-interneuron circuit architecture and dynamics in hippocampal networks”, Neuron, 2017.

**Q: I am wondering if my LEDs are still working properly. What is the best way to test them?**

Micro-LEDs can be damaged due to extended exposure to high current. It is recommended that the micro-LEDs are not exposed to current higher than 100 μA for multiple stimulation cycles. If suspicious about proper operation, you can measure the current-to-voltage (I vs. V) characteristics of the potentially damaged micro-LED and compare that to the original characteristics as that can be used as a good indicator for the operation of the micro-LED. You can also measure the optical power output using an optical power meter (although measurement using optical power meters is not as accurate as the integrating sphere we use internally). This allows you to compare the radiant flux-to-voltage (E vs. V) or the radiant flux-to-current (E vs. I).

For current measurement, you can use a sourcemeter or a combination of a DC voltage source and a multimeter (with microampere resolution). For optical power measurement, you can use an optical power meter which uses calibrated silicon-based sensor and set the wavelength at 470 nm.

**Q: Are the micro-LEDs ESD protected?**

ESD can permanently damage the micro-LEDs. Currently, there is no ESD protection circuitry integrated to the PCBs to protect the micro-LEDs on the optoelectrode. It is important that you discharge yourself before handling the micro-LED optoelectrode PCBs, especially when handling them in dry environment. It is also recommended that you use ESD protection equipment (e.g. ESD-safe mats and wrist straps) and ESD-safe (dissipative) tools for handling if available.

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**Q: Can I drive the LEDs with voltage driver instead of a current driver?**

Current drivers are generally a safer way to use your µLEDs but if you choose to use a voltage driver follow the I-V curve carefully and consider placing a high precision resistor in series and monitor current as well. Any oscilloscope or voltmeter would work well across your resistor in this case and ensure you know the current. This is also a simple way to make your own I-V curve if you want to evaluate the µLEDs on your own.

**Q: Can you recommend commercial current drivers for the uLEDs?**

We do not want to endorse particular commercial products but we will gladly share our experience with products as we learn more. Plexon, for example, has begun testing our µLEDs with their Plexon PlexStim system. We will share that information in Google Group forum and encourage EVERYONE to share their own experience so the community can learn.

**Q: How do I interpret the I-V curves for the micro-LEDs?**

A turn-on voltage between 2.8V and 7V is considered usable, although near 3V is typical. If the I-V curve is flat, i.e. there is no current at any voltage, then the LED is open. Please do not use. If the turn-on is higher than 7V, it is also considered damaged. If the I-V curve is linear (I=a*V) then there is a short and that too is faulty.

**Q: What is a normal working range for impedance values at 1 kHz frequency?**

A normal working range is 100 kΩ to 1.5 MΩ. Outside of that, you are not likely to see spiking activity.

**New Questions?**

Please post to this forum—**Michigan-Optoelectrodes**!

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**Useful Links**

- Want to request µLED samples? [This link](#) will help us complete an outgoing MTA for you to receive 2 samples. It is not a formal commitment but will get the process started.
- [Video hosted on GoogleDrive](#) showing surgical techniques for implanting the uLED array with a microdrive and even re-using the array.
- [Michigan-Optoelectrodes](#) is a Google Group / Forum for exchanging tips and ideas on how these can be used, re-used, driven, implanted, etc. Please post questions and answer a colleagues question here!
- Registration with MINT can quickly be completed [here](#) – this helps us track researcher interest and improve our communication.
- Github link at [YoonGroupUmich](#) where you can find our code for the OSC1 software and microdrive information described above.
- MINT website with the latest datasheet on optoelectrodes [here](#).
- Interested in learning about other NSF NeuroNex tools? [www.neuronex.org](#)

**References**


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