Video Article

Design and Construction of a Cost Effective Headstage for Simultaneous Neural Stimulation and Recording in the Water Maze

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Abstract

Headstage preamplifiers and source followers are commonly used to study neural activity in behavioral neurophysiology experiments. Available commercial products are often expensive, not easily customized, and not submersible. Here we describe a method to design and build a customized, integrated circuit headstage for simultaneous 4-channel neural recording and 2-channel simulation in awake, behaving animals. The headstage is designed using a free, commercially available CAD-type design package, and can be modified easily to accommodate different scales (e.g. to add channels). A customized printed circuit board is built using surface mount resistors, capacitors and operational amplifiers to construct the unity gain source follower circuit. The headstage is made water-proof with a combination of epoxy, parafilm and a synthetic rubber putty. We have successfully used this device to record local field potentials and stimulate different brain regions simultaneously via independent channels in rats swimming in a water maze. The total cost is < $30/unit and can be manufactured readily.

Video Link

The video component of this article can be found at https://www.jove.com/video/2155/

Protocol

1. Headstage Design and Fabrication Overview

A completed headstage pre-amplifier system consists of the following components:

1. A computer designed integrated circuit board with four channels of recording and two channels of stimulation.
2. Electrodes that relay the recordings and stimulation channels to the appropriate connectors on the animals head stage.
3. A tether cable and interface that relays the recording and stimulation channels to a slip-ring commutator.
4. Two forms of waterproofing on the head stage and on the integrated circuit.

2. Design and Layout of the Headstage

We designed a printed integrated circuit board with 4 source followers and 2 pass through stimulation channels using a commercially available software CAD package (www.expresspcb.com). One headstage is designed, and the design pattern is tiled across a larger sheet of circuit board to provide many headstages at a lower cost. The CAD file is transmitted to the printed circuit board (PCB) manufacturing service where double sided, two layer boards are printed using top and bottom copper layers with all holes plated through. The boards use tin/lead solder plated traces and pads that correspond to industry standard FR-4 laminate. The PCB can be ordered and shipped the next business day. Individual headstages are cut from the large tiled PCB sheet and electronic components are connected with solder. An example layout of the headstage used in this protocol is shown (Figure 1). Please see the manufacturer website for detailed instructions and tips on designing a PCB.

3. Preparation and Soldering of Electronic Components

All electronic components used in this protocol are of the Surface Mount Device (SMD) type. The footprint of each device type (resistor, capacitor, etc.) was chosen to minimize wasted space on the headstage, but larger SMD components may be used if necessary.

1. Organize your components on the circuit board and prepare them for soldering.
2. Place a small amount of solder on the tin/lead pad to be soldered and bring the tip of the soldering iron close to melt and adhere the solder to the pad.
3. Solder the capacitors first, resistors next, and then the operational amplifiers.

4. The op-amps can be destroyed by over heating. We used a variable heat soldering gun and the lowest heat necessary to melt the solder. Minimize the heating time used to make a good solder joint. We found it convenient to create a small reservoir of solder that flows into the footprint pad by applying solder along the communication or power traces.
5. Test that the resistance across your resistors meets the expected value using an ohmmeter.
6. Inspect each pad closely to ensure that no solder is connecting or bridging adjacent pads. If there is a solder bridge, heat and melt the solder and use a tweezer to break the bridge.

4. Assembly and Fabrication of Implant and Tether Interfaces

1. Insert a 23 Ga hypodermic tubing into one of the unused ports of the 9pin ABS socket for mechanical support.
2. Cut six 1 cm length pieces of insulated magnetic wire for connecting the female amphenol pins to the ABS socket.
3. Solder the female pins to the magnetic wire using a small amount of solder in each pin, and by heating the pin from the tip.
4. Solder the other end of each magnetic wire into the ABS sockets.
5. Position the male - female MillMax pins over the pads on the tether side of the headstage, and squeeze the pins over the PCB to ensure a pressure fit. Then, solder each pin to each pad in order.
6. Position the ring nut over the neural implant connector and push all the female pins into the desired slots on the plastic base.
7. Apply acrylic glue (krazy glue) to the top of the ABS socket connector and secure it to the base of the headstage. Glue the 23Ga tube to the tether side of the headstage for support.

5. Waterproofing the Headstage

1. To waterproof the headstage, encase the entire integrated circuit and any exposed metal surfaces with 5 minute epoxy. Allow 5-10 minutes for initial drying, and 60 minutes for permanent drying.
2. Poster Tack putty should be applied to the surface the 9 pin ABS socket around the female pins protruding from the animal end.
3. For maximal waterproofing, the ABS socket and ABS plug should be mated and the ring nut should be tightened. A small strip of parafilm should be wrapped around the interface to prevent water from contacting the pin connectors.

Secrets to Success

1. When soldering the operational amplifier, do not overheat the plastic package. If there is visible burning or melting, remove the op-amp and replace it. Applying too much heat may damage the op amp without visible melting. Test each channel with a function generator after soldering.
2. Make sure there are no stray connections or solder bridges on the headstage. Solder wick can be used to remove components or stray solder.

6. Representative Results

A good recording will follow an input source signal without cutting in and out during movement. To test the headstage, the user should use a function generator as an input to each recording pin and evaluate the waveforms at the Mill Max header output end. Physically moving the headstage should not influence the shape of recorded waveforms.

A. B.

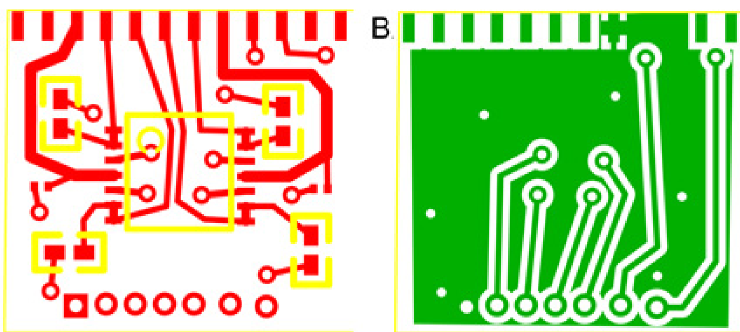

Figure 1. (A) Schematic view of top layer of printed circuit board (PCB). Red lines indicate copper traces. Yellow lines indicate optional silkscreen layer for positioning of electronic parts. Shown are the operational amplifier placement (central yellow square), resistors (smaller yellow squares) and capacitors (smallest yellow squares). **(B) Schematic view of bottom layer of PCB.** Green lines indicate copper traces. Large green filled area represents ground plate. A model file of this schematic is provided for download.

Discussion

Water maze based behavioral tasks provide effective tools to probe animals' cognitive abilities and representations in real time [1]. The use of lightweight and cost effective headstage preamplifiers is especially critical in behavioral neurophysiology applications involving the water maze. Because escaping the cold water provides intrinsic motivation for animals in these tasks, their behavior can be tested in repeated trials without the difficulties of motivating animals on dry mazes. The low cost headstage preamplifier device described here will allow scientists to test hypotheses of neural function in water tasks without the worry of damaging costly equipment.

This protocol is meant to serve as a starting point for custom headstage design. The schematic provided is easily adaptable to include more recording or stimulation channels and can be scaled according to the desires of the experimenter. In particular, by incorporating commercial pin connector setups, one can build headstages that can mate with commercially available electrode interface boards. Although the example provided in this protocol provides unity gain source following on each channel, the interested reader may adjust this amplification by changing the configuration of resistors and capacitors (please see [2] for a detailed review of data acquisition systems).

Although the techniques related to electrode implantation and positioning are beyond the scope of this article, we have used the following setup to record from fixed depth electrodes (Shirvalkar *et al.* in press, 2010). Further details of how to build and implant movable electrodes for chronic recording can be found here: [3].

Disclosures

No conflicts of interest declared.

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