Fetrode™ Interfacing Guidelines

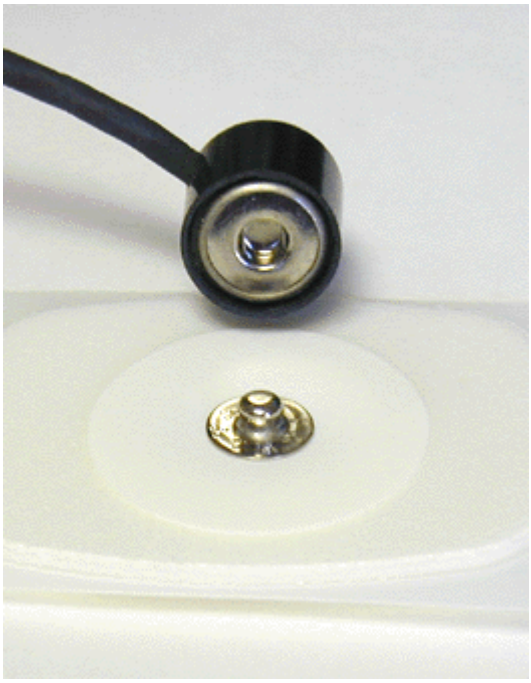
Overview

The UFI Fetrode™ is a temperature-compensated buffer amplifier with an extremely high input impedance and a very low output impedance. The surface-mount circuitry is built into a miniature enclosure which can be snapped onto any high quality electrode. This innovation places signal buffering directly on active electrode sites, thereby minimizing artifacts produced by cable movement and static electricity. (These artifacts can be especially troublesome where the electrode contact impedance is very high.)

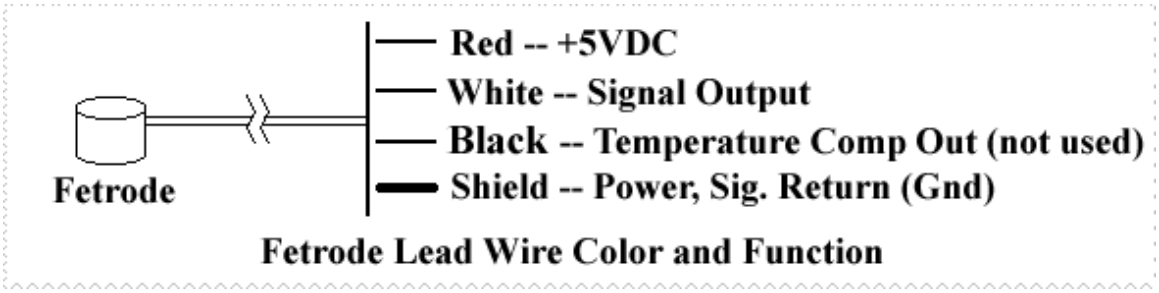
This technical article addresses various aspects of interfacing our Fetrode™ technology to your signal conditioner circuitry. If you find this discussion helpful, please let us know. And please send us your suggestions for improvements!

Electrical connections to the Fetrode™

The Fetrode™ snap provides both mechanical attachment to the standard patch electrode as well as an electrical connection.



The Fetrode™ cable contains three conductors enclosed by a shield. The identification and functions of the conductors are shown in the illustration below and described in the text that follows.



Fetrode Lead Wire Color and Function

The RED wire should be connected to a +5-volt DC supply. The voltage should be well decoupled using appropriate capacitors and should be stable, preferably regulated. Supply voltages higher than +5 volts can be used -- up to +15 volts – but may introduce additional noise.

The WHITE wire carries the buffered, millivolt-level signal output. A 10K resistor is required between this wire and the shield (ground) to complete the buffer circuit. The small signal level put out by a Fetrode™ actually "rides" on a DC *offset* voltage of about +2 volts. Signal conditioning downstream from the Fetrode™ must take this offset voltage into account.

The BLACK wire is a temperature-compensation output, is generally *not* used, and so is left unconnected. (Care must be taken to prevent this lead from shorting to other leads, however.) Our experience has shown that even very low frequency EGG signals do not require the temperature-compensation output. However, if you feel your application may require the stability offered by temperature compensation, contact UFI for instructions.

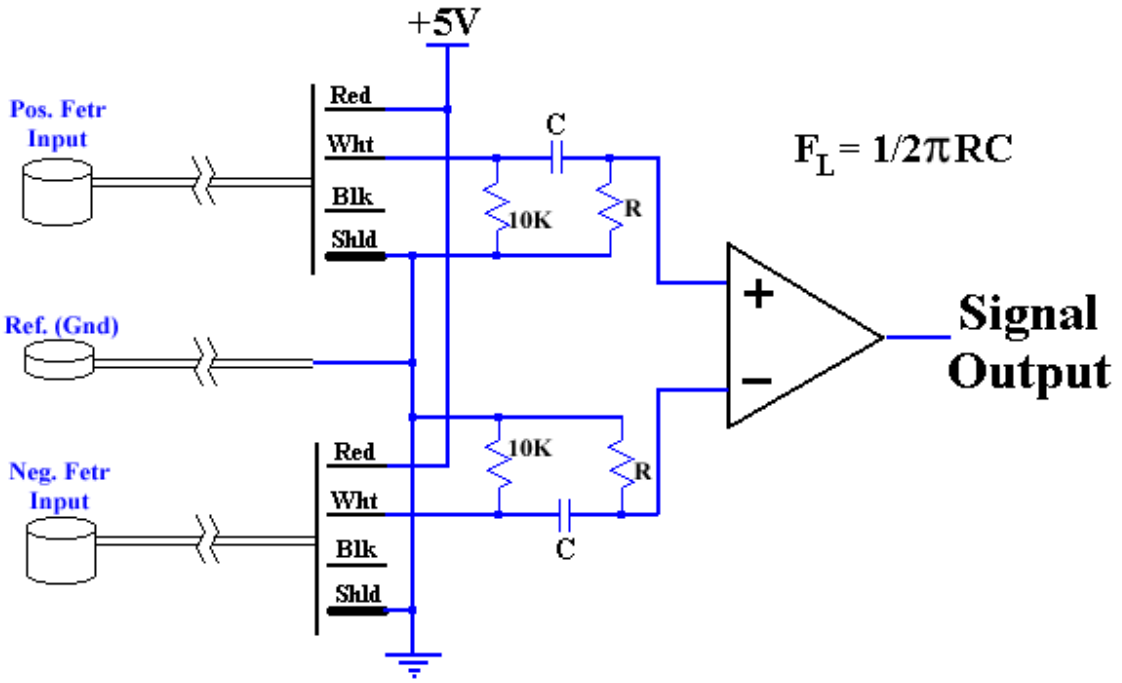
The SHIELD is the signal return (ground) for both the +5V supply and the signal output.

Fetrode™ signal connections

Bioamplifiers generally have two active inputs, one for each subject electrode, and amplify the difference signal between them. For example, for ECG electrodes might be placed at both the sternum and on the left midline at the V6 level. For an EMG measurement, the electrodes might be placed at either end of a muscle group. For an EOG measurement, they might be attached above and below the eye. In each case, Fetrode™ signal conditioning requires a separate Fetrode™ for each of these two active inputs.

A third, “reference" electrode is also required; it should never be omitted. This reference electrode minimizes common-mode interference from external noise sources, and is *essential to proper performance*.

A typical Fetrode™ subject array thus involves three electrodes: one Fetrode™ for each of the two active inputs (“positive” and “negative”), plus a standard (non-buffered) electrode as the reference. The following schematic shows how to connect the Fetrodes™ and the reference electrode to a differential amplifier.



Typical Fetrode Interface Circuit

The +5V (RED) wires of both Fetrodes™ should be connected to a common +5V supply, preferably the same supply as for the rest of the signal conditioner circuitry.

The BLACK temperature-compensation outputs are generally not used, and should be left unconnected. They should be insulated carefully to prevent shorts.

Both Fetrode™ SHIELD leads should be connected to the reference lead. This common point becomes the "analog ground" for the subject, and should be connected to the ground for the rest of the signal conditioner circuitry.

The WHITE leads carry the buffered signals from the subject. Each lead must have its own 10K resistor to ground to complete the buffer circuitry.

Note that the Fetrode™ is just a buffer and so does *not* amplify the subject signal. However, the Fetrode™ output signal *will* carry a substantial DC offset to the original signal sensed by the Fetrode™ . This offset voltage may vary from one Fetrode to another.

Fetrode™ frequency response considerations

Most physiological signal conditioning does not require frequency response down to DC (0 Hz). In fact, some low-frequency "roll-off" (attenuation) is often welcome in order to eliminate frequencies below the band of interest, which are usually considered artifacts.

(EOG signals are an exception to this general rule: here very low frequency response is required. EOG uses a differential-input configuration similar to that shown, but without the RC filters described in the next paragraph. In addition, a correction to the signal baseline is incorporated into the next stage. Contact us for more information.)

The Fetrode™ outputs are shown above connected to simple RC high-pass filters that attenuate frequencies below the band of interest. These high-pass filters also block the DC offset voltages on the Fetrode™ outputs. Careful matching of the resistor and capacitor values used with one differential input to those used at the other will optimize common-mode rejection (CMR) and reduce noise.

We recommend that you connect Fetrodes™ to fixed-gain instrumentation amplifiers such as the micropower LT1101 made by Linear Technology. Use of an instrumentation amplifier (IA) chip simplifies the circuitry required for a true differential amplifier input connection. Gain stages and high-frequency filtering can follow the front-end IA as needed to provide the desired signal conditioner output signal. (Most physiological signals will require overall channel gains between 1,000 and 5,000 from subject to signal conditioner output.)

The single-pole RC filter shown above attenuates lower frequencies at a rate of only 6 dB/octave. For most physiological recording, this is not sufficiently “sharp.” UFI generally increases low-frequency roll-off to 12 dB/octave by inserting another single-ended RC filter between the first IA and the following gain stage. This second filter should have the same cut-off frequency as the front-end filters in order to supply a uniform roll-off. For best results, any downstream filtering added to the signal conditioner to attenuate *high* frequencies should also supply at least 12 dB/octave roll-off.

Multiple-Fetrode™ configurations; subject isolation

We frequently supply systems for which a number of Fetrode™ channels are connected to the same subject. These multiple Fetrode™ channels can usually function well with only one reference electrode, but some experimentation may be needed to identify the optimum location for this single reference. For example, EEG may require that the reference be placed on the forehead.

Sometimes it is desirable to have a single electrode of one polarity (e.g positive) deployed along with multiple electrodes of the other polarity (here, negative). In this array, each signal conditioner channel processes the difference between one of the negative electrodes and the (common) positive electrode. Fetrodes™ can be used with this "common-electrode star" configuration, but the reference electrode is still required. Contact UFI for more information.

Fetrode™ signal conditioning does involve -- via the reference electrode -- a direct electrical connection both to the subject and to the signal conditioner ground. Depending on the downstream components of the system to which the Fetrodes™ are connected, some sort of subject Isolation may be required. Again, contact UFI for assistance.