A guide for testing and using the electronic coupling system for data transmission over an ionic medium

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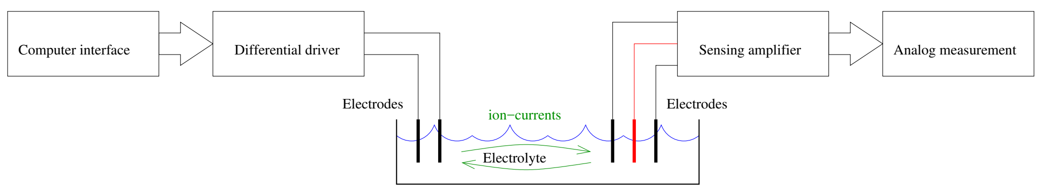
Introduction

This document is intended to describe how to test the electronic coupling system and to guide for setting up a first experiment on data transmission over an ionic medium, or more specifically, biological tissues.

System description

The coupling system consists on differential driver and a sensing amplifier. In a nutshell, the differential driver converts electronic pulses from a computer into ion-currents inside the electrolyte medium. These currents produce voltage at the far (not too far) electrodes of the sensing amplifier which elevates it so that it can be read by an analog measurement device, such as an oscilloscope. The following diagram depicts the whole scenario.



Unless you have already used an electrocardiograph amplifier or something similar, the following questions might arise from the diagram analysis:

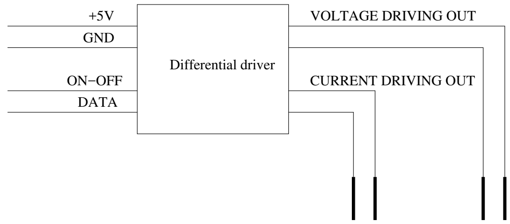
1. why is there a third (red) electrode on the sensing amplifier?
2. why is not there a computer interface on the amplifier side, but an analog measurement device instead?

The answers for both question are almost the same. The sensed voltage by the amplifier electrodes (black) is usually as low as 0.5 mV, superimposed to a DC component produced by the electrical-chemical interface, which can reach 100 mV (200 times higher! Yes, it is not a miscalculation), and is highly variable with temperature, electrodes positions, and other (almost random) factors.

Moreover, the high impedance featured by the electrode-electrolyte interface allows easy coupling of electrical interference to the conducting medium. The power-line interference usually coupled to the electrolyte medium can be as high as 1 V. As can be seen, retrieving the 0.5 mV pulses from such a hostile medium is not a simple task, and in order to reduce the electrical pollution, a driven common-mode rejection circuit is commonly applied (most of time referred as driven right-leg circuit due to its first usage for electrocardiography devices) which requires a third electrode. Nevertheless, the sensed voltage is amplified together with residual interference and noise, so that its conversion to digital pulses must be accomplished through some intelligence. An adaptive threshold comparison method should be a good starting choice. The more distant the sensing electrodes are from the driving ones, the worse the data recovering process.

Differential driver

The following block diagram shows the differential driver connections.



IMPORTANT: unless battery powered, including the computer connected to the driver, this circuit must not be used in humans. Electric shock hazard!

`+5V` and `GND` are the power-supply input. A well regulated 500 mA 5 V power supply must be used. A low-ripple one is strongly recommended.

`ON-OFF` is a 5 V compatible input for turning off the output driver. When it is at high level (output turned off), there is no current at the current driving out or differential voltage at the voltage driving out. **It protects the tissue against excessive power dissipation. It is not intended for reducing power consumption.** Although it is a logic input, it must be 5 or 0 V. It doesn't work for 3.3 V logic or a voltage apart from 5 V. Use a CMOS voltage-level converter if necessary. TTL devices may present a voltage drop at 5 V output.

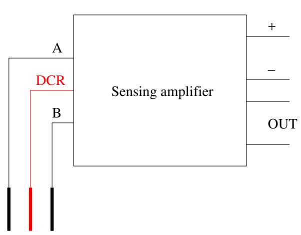
`DATA` is also a 5 V compatible input for changing the driver output polarity. As `ON-OFF`, **it is an analog input**, which means the voltage level must be at the nominal values.

`VOLTAGE DRIVING OUT` provides a ± 1 V differential voltage. This output is for testing purposes and must not be used in living tissues. There is no electric current control. Although the employed circuitry can not operate with currents much higher than 100 mA, it's far too larger than the adopted 1 mA recommended for safety.

`CURRENT DRIVING OUT` provides a ± 1 mA current at the electrodes. This is the main output and the preferred way of driving living tissues for safety reasons.

Sensing amplifier

It consists on DC-coupled amplifier with a 1000 gain and an active common-mode rejection circuit. Its frequency range spans from 1 Hz to 10 kHz. The following block diagram shows the sensing amplifier connections.



`+` and `-` are the power supply inputs and may be directly connected to a 9 V alkaline battery. **Do not connect with the wrong polarity. The circuit may be irreversibly damaged.**

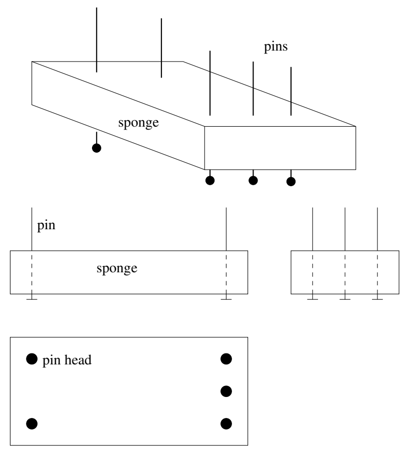
`OUT` is the signal output and must be connected to an analog measurement instrument.

`A` and `B` are the sensing electrode inputs.

`DCR` is the common-mode rejection output, and must be connected to the third electrode, which must be between electrodes A and B.

Setup and test procedure

A minimum test setup can be accomplished by using saline 0.9%, a washing sponge, a glass or plastic tray and some sewing pins (metallic heads). At first, introduce the pins in the sponge as depicted below.

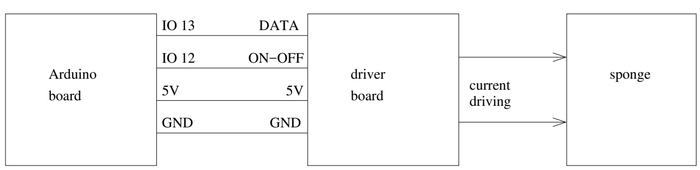


The greater the distance between pins, the higher the voltage at the sensing amplifier. I suggest 20 mm for driven and sensing pins. The DCR electrode must be located at the mid-point between electrodes A and B, for best common-mode rejection performance.

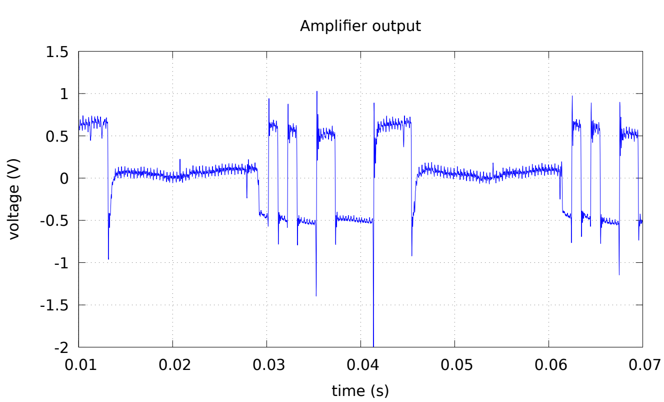
Place the apparatus (pin heads to the bottom) in the tray and fill it with saline. A quarter of sponge thickness is enough. Let the sponge soak part of the liquid. If necessary, put a little more saline in the tray.

Time to attach the coupling boards: amplifier first. Connect the input cables A and B to the corresponding pins. Turn on the sensing amplifier and plug its output to an oscilloscope. Adjust the vertical scale to 500 mV/div and the horizontal to 5 ms/div. The display must exhibit zero voltage with some added noise. If not, check pin connections and if the pin heads are touching the saline.

A data generator will be necessary at the driver side. I have programmed an Arduino Uno board with a minimal sequence generator. The code is available at `deathstar.zapto.org`. Connect the wires as illustrated below.



Turn on the Arduino board, which will feed the driver with energy and data. The generated sequence is, `0101001100001111` and it is repeated forever after an interval of 16 ms. If everything is working fine, the oscilloscope will display a waveform like the depicted above.



If not, check the wires and the data generator. The voltage at the electrodes is extremely sensitive to movements. Avoid long cables; keep the alligator clips as much stable as possible; stay away from power cords.

Good luck and have fun!