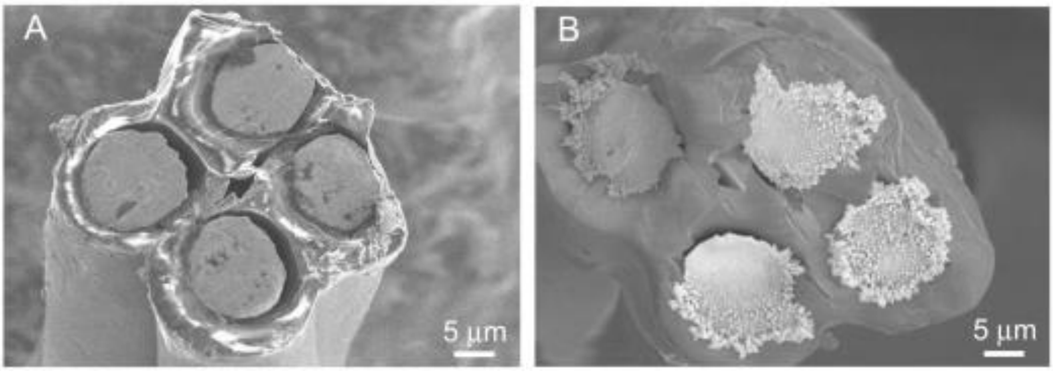
Responsable Dr. Esteban Valverde	IFIBIO "Houssay" UBA-CONICET Tetroplater for intracranial microelectrodes	Ticket # 20220420
Start date: 20/04/2022		End date: 26/12/2022

A tetrode is a set of four micro-wires that can record from multiple neurons simultaneously into the brain of a free-moving animal. Tetrodes are usually electro-deposition with some metal to reduce impedances from 2-3 MΩ to 200-500 kΩ (measured at 1 kHz), which increases the signal-to-noise ratio and allows the recording of small amplitude signals.

Plating causes the deposition and growth of gold particles (gold-plating) at the tips of the tetrode micro-thread, which increases its effective surface areas and reduces its impedances.

A Tetraplate is a device that performs this operation, in our particular case, by means of electrolytic deposition of gold particles, and which is used for measurements of brain recordings in rats.

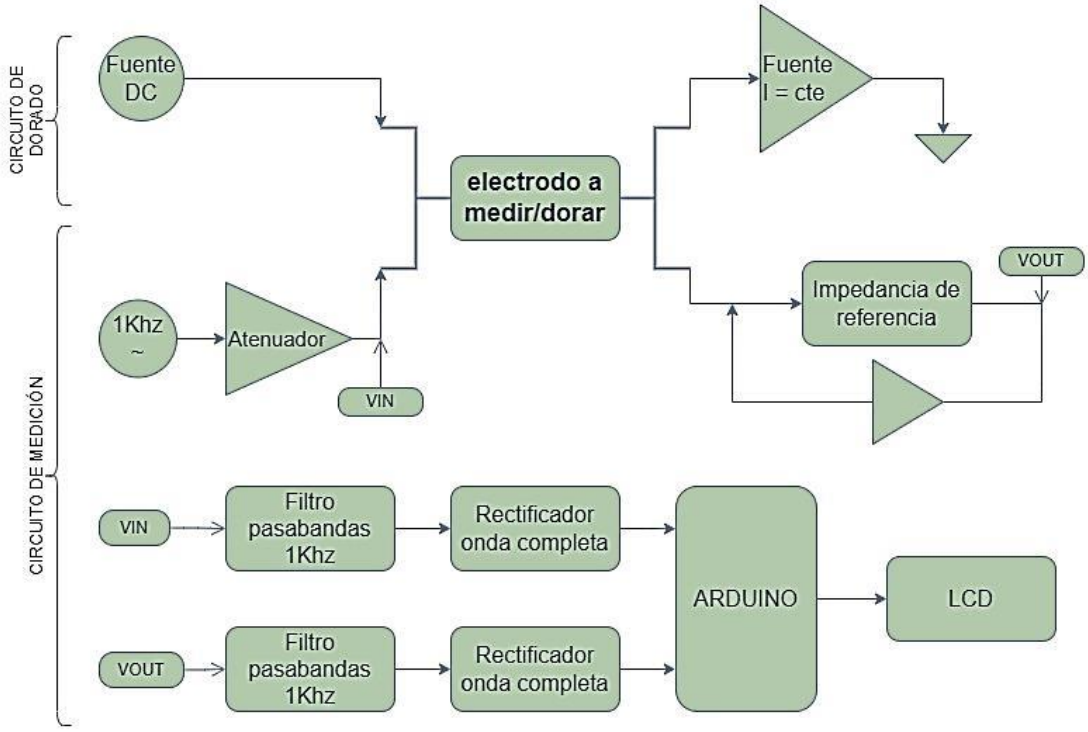


After the construction of the tetrode (4 tungsten threads with sheath), the oxidation/reduction process is carried out in order to gild the visible end of the tetrodes, with the intention of decreasing their impedance. The gilding is done by immersing the tip of the tetrode in a bath containing gold to which a continuous current is circulated for a few instants of time.

The figure above shows a microscopic image of a tetrode before (A) and after (B) the electrodeposition process.

Working Principle of Tetroplate

The general block diagram of Tetroplate is as follows



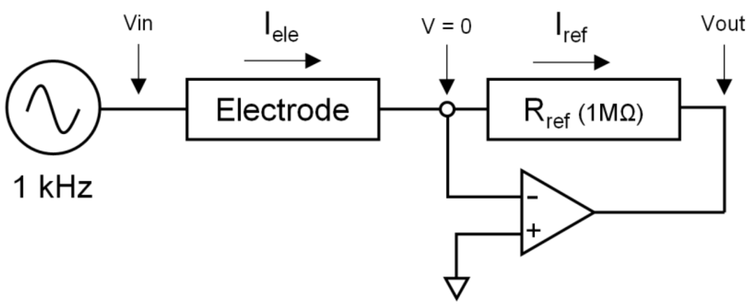
From this diagram, there are two main blocks. One is the electrode impedance measurement system. This system is basically shown in the figure below

Tetrodo Golden Circuit

A direct current of 2.5uA is circulated through the bath/tetrode (with the direction of current from the bath to the tetrode), which has a gold solution for the electrodeposition of the electrodes. This is achieved by applying pulses of direct current through the tetrode, and as it browns, its impedance decreases. After each pulse of current (on the order of one second), the impedance must be checked to know when the gilding process is finished.

Tetrode Measuring Circuit

The general impedance measurement diagram of the tetrode is shown in the following figure



A pure sinusoidal source is used at a frequency of 1Khz. It is important that this source does not have a continuous component because this component would still perform the gilding process during the measurement.

To verify the electrode resistance value, a sinusoidal voltage of 1Khz (30~40 mVpp) is applied, in order to comply with the previous circuit. Considering virtual ground at the negative input of the op-amp, it is true that

$$V_{IN} / R_{ELE} = V_{OUT} / R_{REF} \quad (1)$$

Then you get

$$R_{ELE} = R_{REF} \times V_{IN} / V_{OUT} \quad (2)$$

In this way, the impedance value of the electrode during the gilding process can be estimated by measuring the amplitudes of the sine waves at the input and output of the circuit and then applying the above equation. Consequently, the measurement of the impedance of the tetrode is indirect and the calculation of the above equation must be performed.

Checking the Current Circuit

A measurement of the current circuit was made for two values of resistances (in equivalent "electrode" modes), and it was verified that the current through each resistor remains constant (around 2.5mA, which is stipulated in the design). It is also observed that the rest of the parameters of the current circuit (different measured voltages) are correctly adapted in each case. Table 1 is a summary of the one found in the annex, "Constant Current Source".

R_L [KΩ]	V_{RL} [V]	V_{DS} [V]	I_D [μA] (calculado)
217	0.534	8.57	2.46
993	2.275	6.53	2.29

Table 1: Measured Values in the Current Circuit for Different Resistors

Verification of the measuring circuit

In order to test the effectiveness of the circuit measurement, measurements were made on resistors of known value (in equivalent "electrode" modes), previously measured with a multimeter. Figure 1 shows a linear response, but with an overestimation of the real value of the resistors as their value increases. Figure 2 also shows the relative error expressed as $\Delta = (Z - R) / R$.

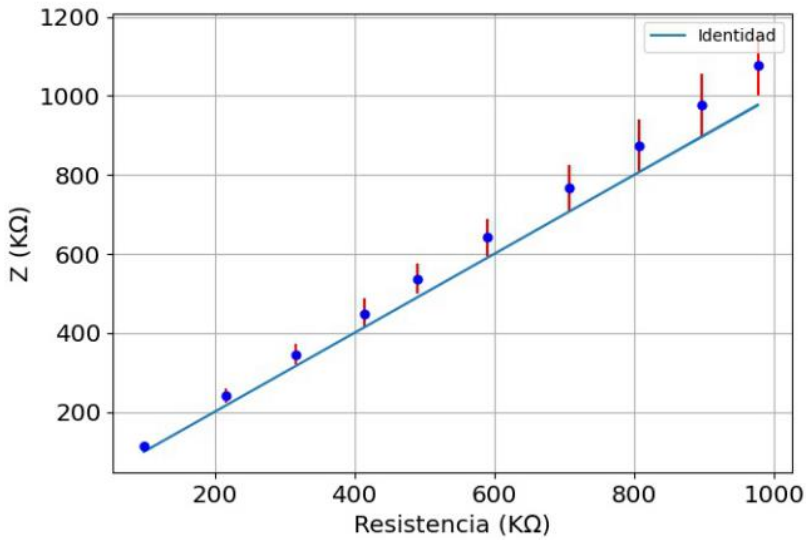


Figure 1: Measurements obtained with different resistance values, previously measured with a multimeter. On the abscissa axis, the value of the resistors is observed, and on the ordinate axis, the values obtained with the Tetraplater measurement circuit. The vertical bars correspond to the error of the instrument

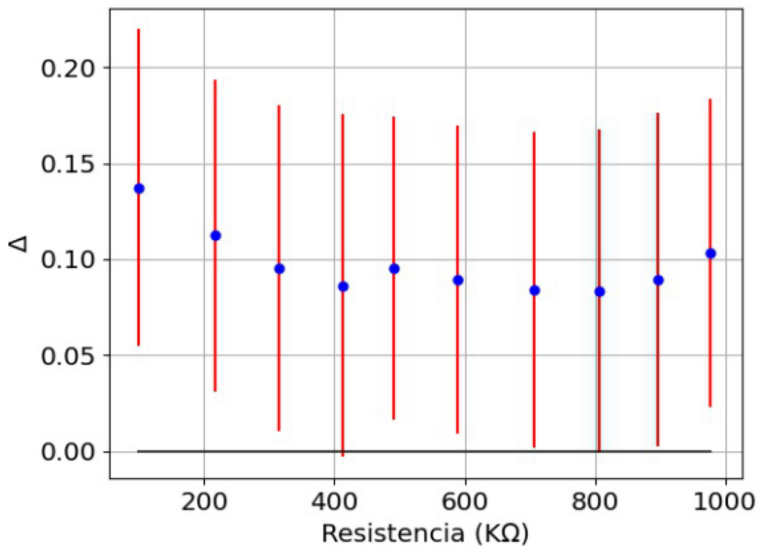


Figure 2: Error in the measurement of resistance values. The vertical bars correspond to the error of the instrument

Tetraplate Verification with Real Electrodes

In order to verify the complete circuit, different tetrodes were manufactured and the measurements of the same, before and after gilding, were contrasted with the ad-hoc device found in the IFIBIO laboratory.

Complete Circuit & Calibration

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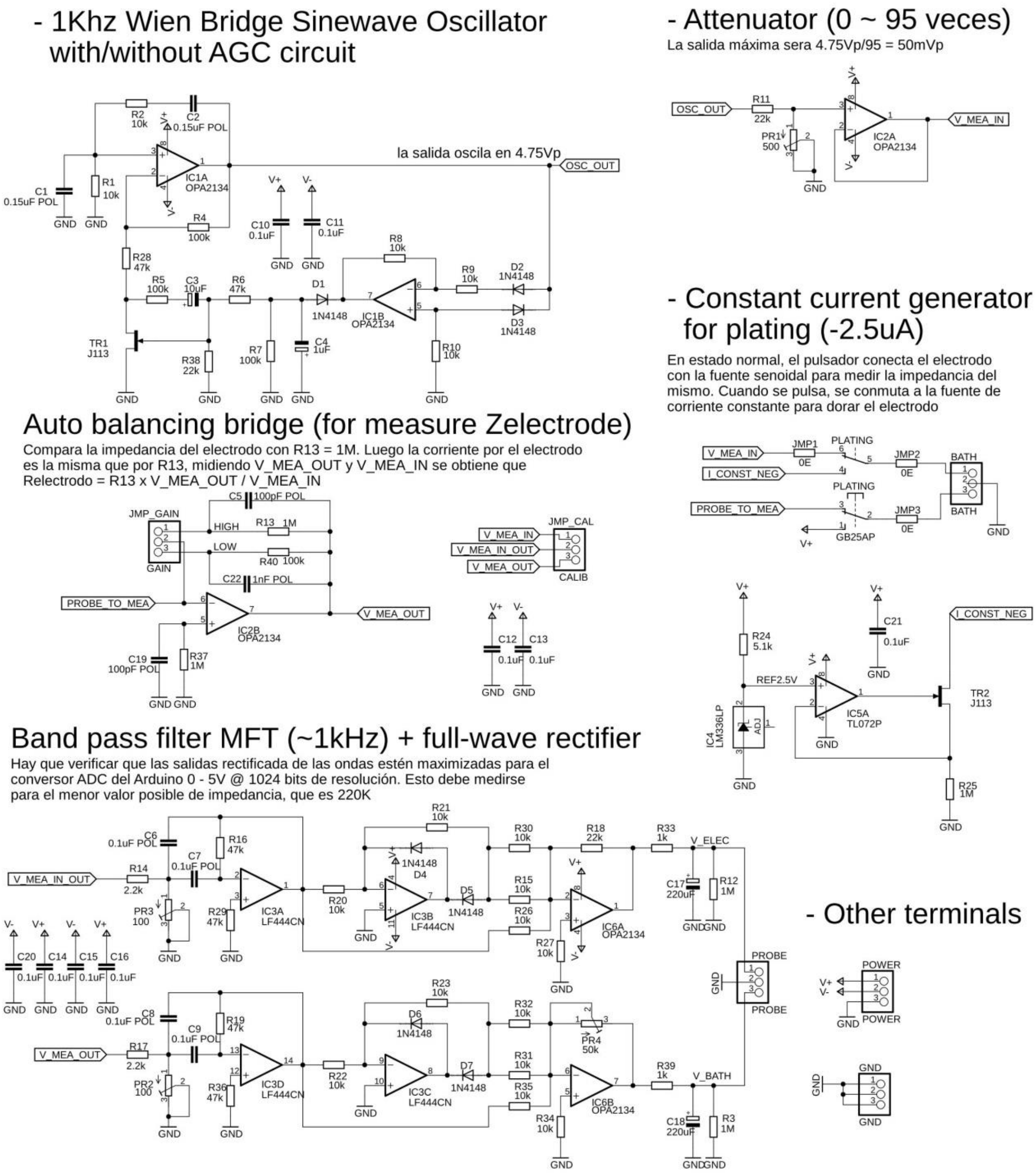

Steps for Calibration

1. Place the jumper JMP_CAL in the V_MEA_IN position so that both channels are connected to the fader output.
2. Adjust PR2 and PR3 so that both channels show a maximum output of IC3-1 and IC3-14 (bandpass filter setting to 1KHz), and that both sinusoidal signals are perfectly superimposed.
3. Measure in IC6-1 and IC6-7 the rectified outputs of both channels (full-wave rectifier and amplifier) and regulate PR4 until both registers coincide in amplitude.

4. Verify on pins 1 and 3 of the PROBE connector that the continuous waves have exactly the same amplitude
5. Connect the jumper JMP_CAL in the V_MEA_OUT position to complete the calibration and be able to measure
6. Connect a resistor between 220K and 470K of known value and verify that approximately the same reading is observed on the device's display.

Annexes

The attached files describe in detail the circuits and equations that govern each stage of the Tetroplate and the final report of the students.