SUPPORTING INFORMATION

HunStat – a Simple and Low-Cost Potentiostat for Analytical and Educational Purposes

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Details on the HunStat Hardware. Even the simplest potentiostat ought to incorporate operational amplifiers depicted in Figure S1. The potential value of the working electrode (WE) is adjusted relative to a reference electrode (RE). Changing the potential of the WE is achieved by introducing a third electrode, known as the counter electrode (CE). In this configuration, the potentiostat allows just enough current to flow through the CE-WE path to maintain the desired potential difference between the WE and the RE.

In order to make this happen, the potentiostat sends the voltage value which we aim to set to the voltage-tracking operational amplifier. This voltage value is an analogue signal generated by a digital-to-analog (D/A) converter of a microcontroller. The potentiostat measures the actual voltage occurring between the WE and RE. Subsequently, the operational amplifier amplifies the error signal. Following this, the potentiostat precisely drives enough current between the WE and CE to nullify the voltage difference. Thus, the WE is polarized to the extent expected.

The schematic diagram, printed circuit boards and the soldered final design of the HunStat potentiostat are shown in Figure 1. The operational amplifier of choice (AD8648ARZ) is a good approximation of the ideal operational amplifier. With its low noise (<10nV/√Hz), low input current (typically 1 pA), and input and output controllability over the entire supply voltage range, it is fast enough (11 V/μs) to follow most electrochemical processes. It is designed for low-voltage single-sided power supply (2.7-5.5 V). Its output is short-circuit protected and its power consumption is small (max. 2 mA/amplifier), so it is one of the best choices for the purpose of an analog preamplifier built on a 3.3 V supply voltage digital processing unit. The programmed signal of the D/A converter from the A0 output of the Seeeduino XIAO board is sent to the input of another operational amplifier that sends it via its output 1 to the CE with reverse polarity. The potential of the working electrode is measured on an analog-to-digital (A/D) input (A2) of the microcontroller. The current of the WE is converted into a voltage by the resistor R4, and output 8 of the operational amplifier sends it to another A/D input (A1) of the microcontroller. The Seeeduino XIAO microcontroller's 10-bit D/A converter produces a "real" voltage signal (as opposed to the PWM signal of most Arduinos). Another big advantage of the used microcontroller is the 12-bit A/D converters. The printed circuit board was ordered using a self-designed Gerber file. This Gerber file can be downloaded from: https://github.com/stella209/SeeedSTAT-Potentiostat-Project (an earlier version of HunStat system was called SeeedSTAT, but the PCB board is the same). The process of soldering the 1206-size SMD components to the PCB board is shown in Figure S2. Soldering SMD (Surface Mount Device) components in 1206 size requires a certain level of skill, but it is not a daunting task.[2]

Setup Seeeduino XIAO in the Arduino IDE. In the Arduino IDE [3], select *File/Preference* menu and put https://files.seeedstudio.com/arduino/package_seeeduino_boards_index.json in the *Additional Boards Manager URLs* field (Figure S3). In order for the Arduino IDE to handle the Seeeduino XIAO, go to the Mainboard management function and find the "Seeeds SAMD Boards" window. Download the 1.8.1 version from there. Then the Arduino IDE offers Seeeduino XIAO among the motherboards. For more details see: https://wiki.seeedstudio.com/Seeeduino-XIAO/ The sketch program for the Seeeduino can be acquired from https://u.pcloud.link/publink/show?code=kZWi9Q0ZDKDqVdhYM6LeM8N1iLdgRSNH0pzy or from the authors directly.

The HunStat Graphical User Interface Software. After installing, connecting the potentiostat, and launching the GUI, the initial screen will appear (Figure S4). The icons shown in the top row, from left to right: **Open file, Save file, Start measurement, Abort measurement, Clear zoom, Save diagram (into a PNG file), Redraw current measurement, Settings, Information**. The software can handle three electroanalytical techniques: cyclic voltammetry (CV), differential pulse voltammetry (DPV), and chronoamperometry (CA). Parameters for these techniques can be adjusted in the **General**, **CV**, **DPV** and **Chronoamperometry** tabs. Additionally, the **Signal processing** tab allows smoothing of the resulting voltammogram in two different ways (Savitzky-Golay or moving average smoothing). Communication between the GUI and the potentiostat can be monitored in the **Log** tab.

Critical quantitative information can be obtained from the peak heights of recorded curves. To do this, you need to draw a baseline. This can be done by holding down *Shift* button and clicking the left mouse button. When placing the cursor over the desired peak, the peak height relative to the baseline (I_{peak}) can be read in the upper right corner. A more detailed manual can be downloaded from two online links [4,5] or directly asked from the authors.

Before making a real analytical measurement, it is advisable to perform the following two simple checks using cyclic voltammetry:

1. Connect a 10 kΩ resistor between the CE-RE shorted point and the WE. If our circuit is functioning properly an increasing current with increasing voltage depicted in Figure S5a should be observed.

2. Insert a 1 kΩ resistor in series with a 1000 μF capacitor between shorted CE-RE and WE. In this case the resulting current during charge-discharge cycles should be like the one shown in Figure S5b.

Please contact the authors directly if you have any questions, comments or development ideas.

SUPPORTING FIGURES

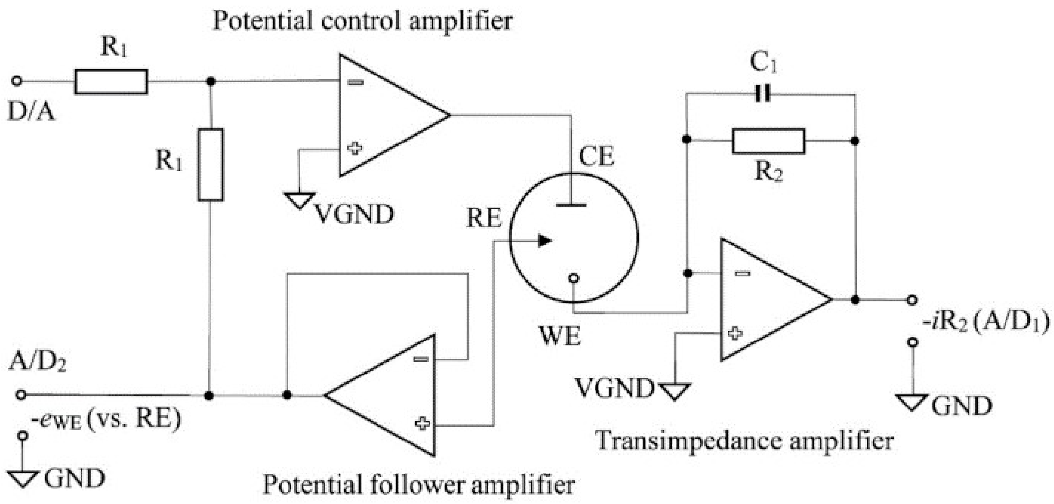

Figure S1 The basic circuit for any potentiostat (after A.J. Bard and L.R. Faulkner [1]).

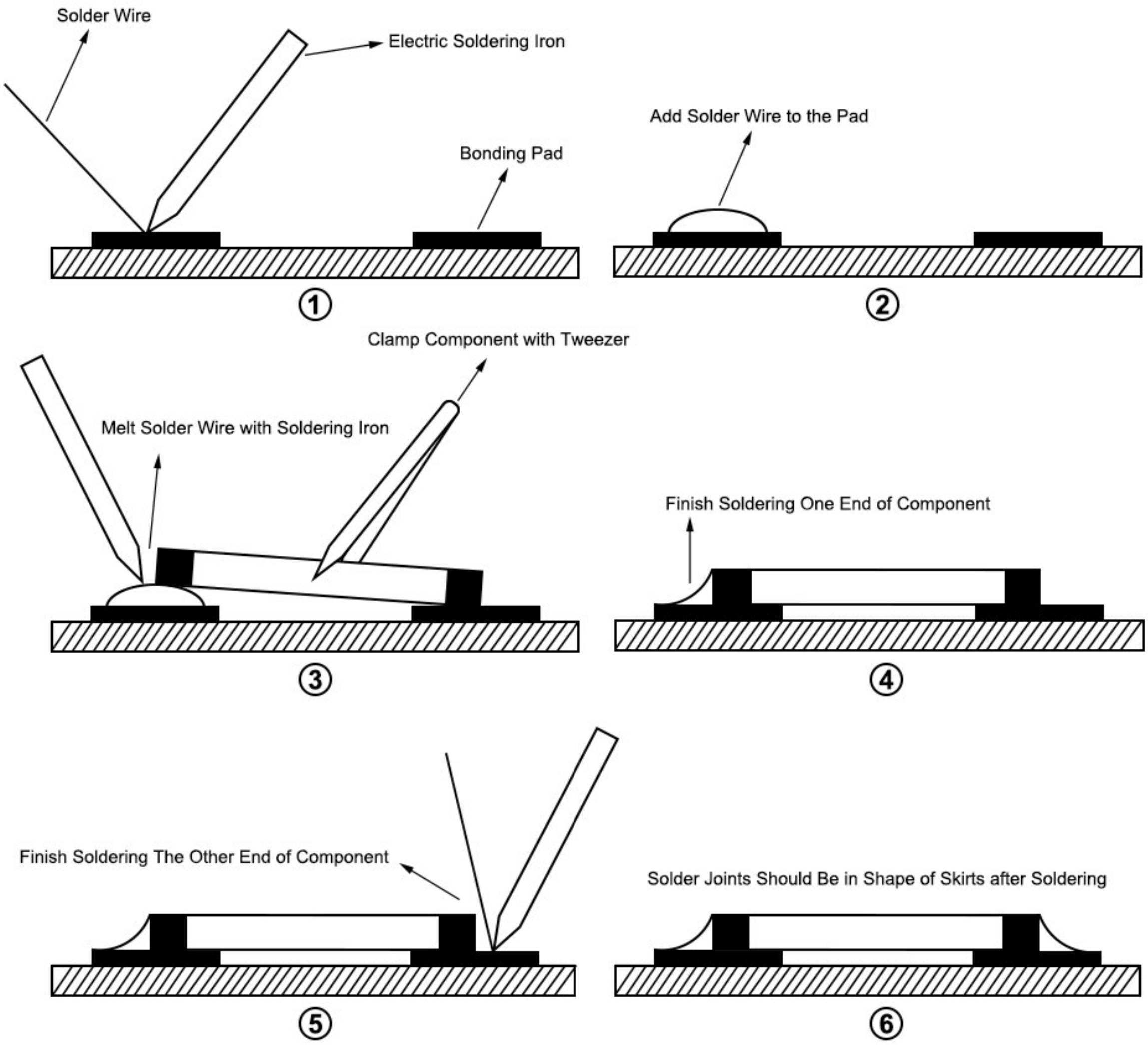

Figure S2 Soldering process of an SMD. Reproduced from reference [2].

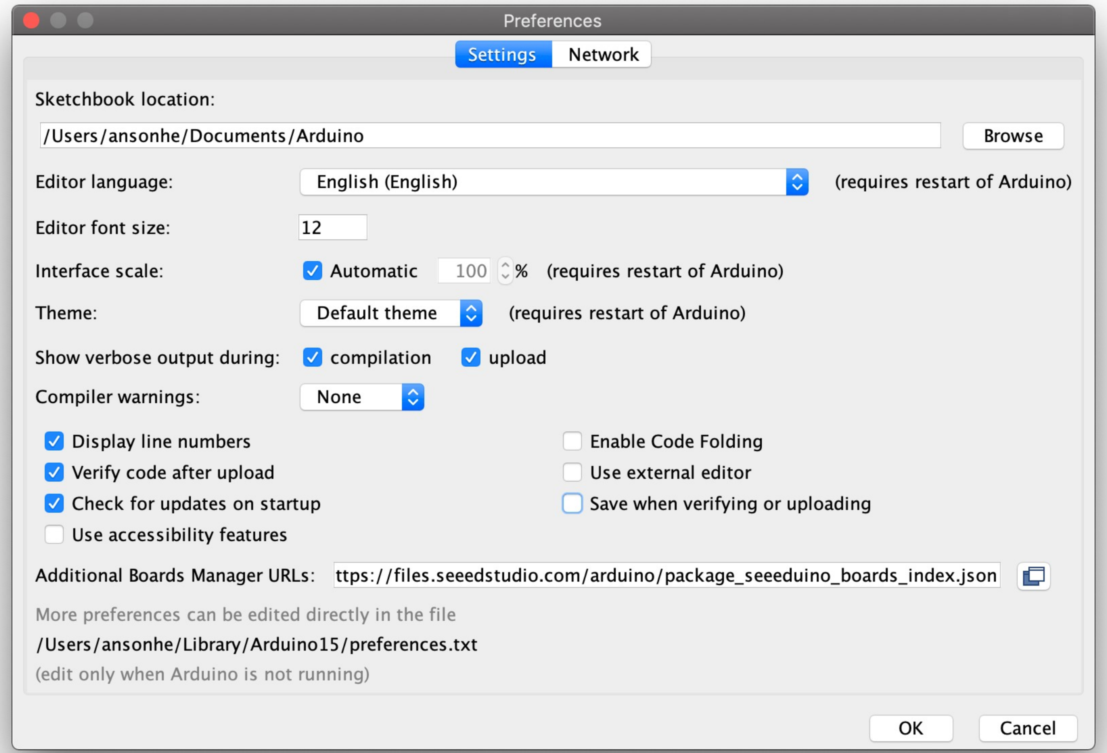

Figure S3 Setting up additional boards in the Arduino IDE.

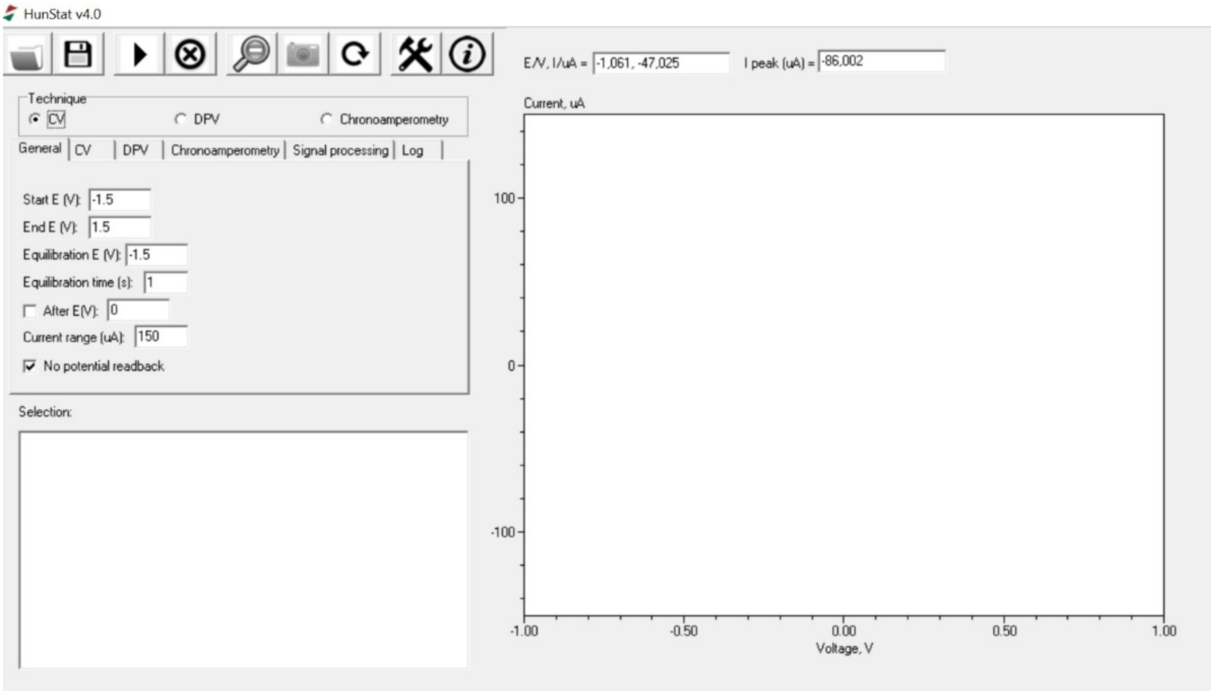

Figure S4 Start screen of the HunStat.exe software.

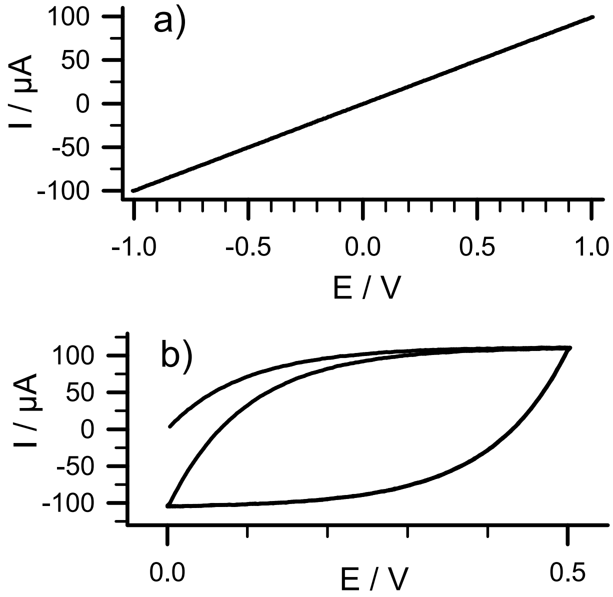

Figure S5 Linear sweep and cyclic voltammograms of circuits when (a) a 10 kΩ resistor and (b) a 1 kΩ resistor is connected in series with a 1000 µF capacitor, respectively, were inserted between the short-circuited CE-RE and the WE. (a): Start and end potentials were -1 V and 1 V, respectively. The WE was equilibrated at -1 V for 1 s. Scan rate was 0.1 V/s. (b): Start and end potentials were 0 V and 0.5 V, respectively. The WE was equilibrated at 0 V for 1 s before the first cycle. Scan rate was 0.1 V/s and two potential cycles were recorded.

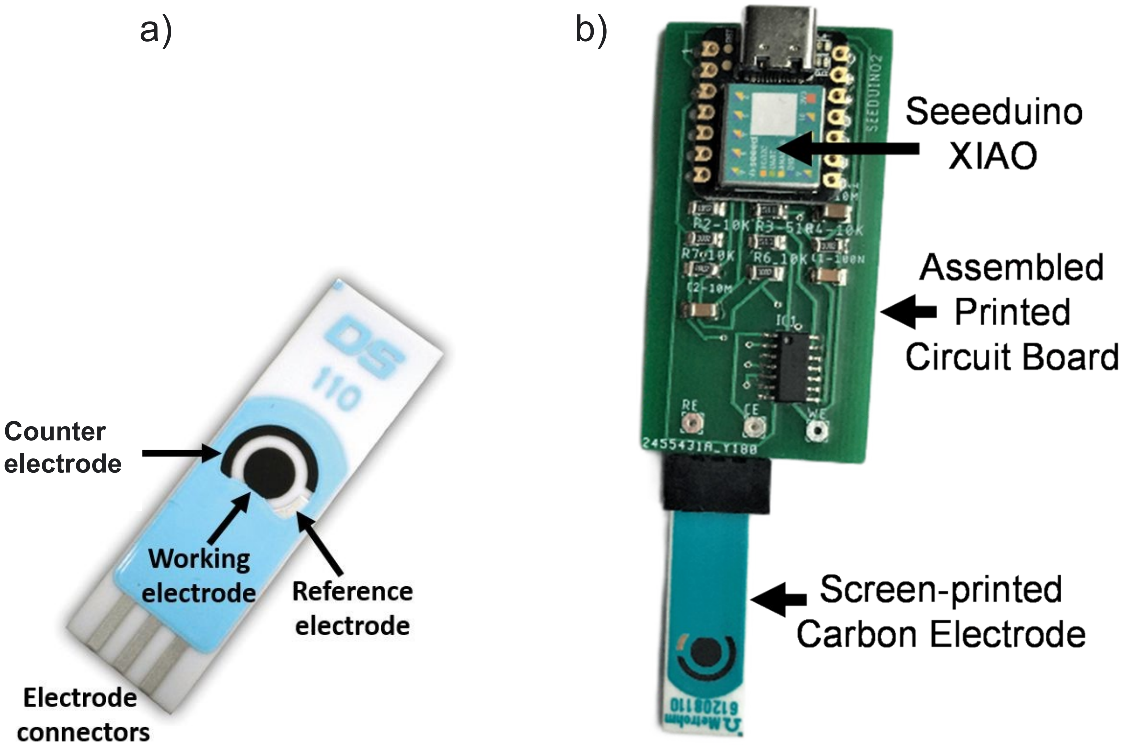

Figure S6 Photo of the (a) DS110 3-electrode board and (b) the board connected to the HunStat potentiostat.

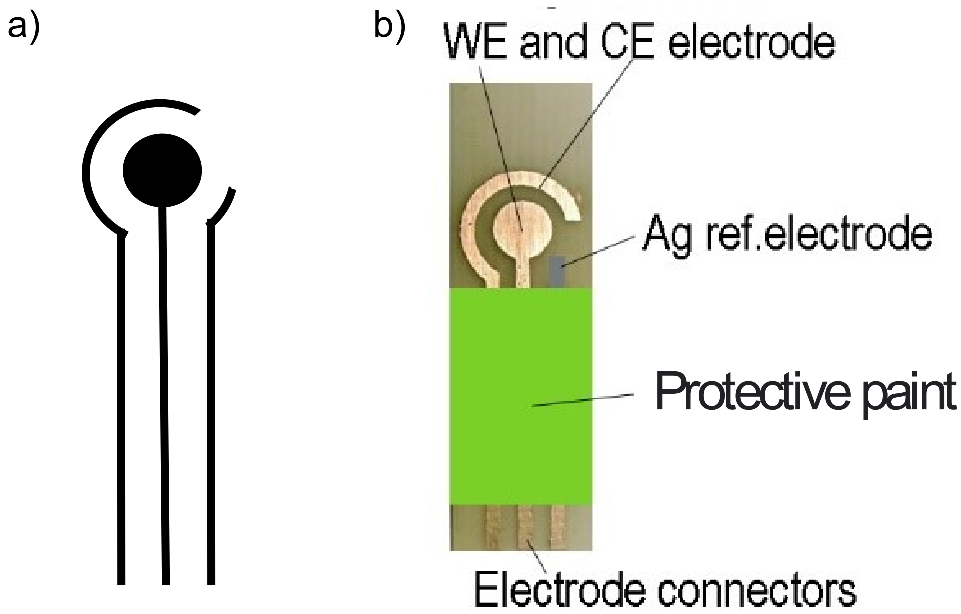

Figure S7. (a) Layout and (b) photo of the home-made 3-electrode board.

REFERENCES

[1] A. J. Bard, L. R. Faulkner, Electrochemical methods: fundamentals and applications, Wiley, New York, USA, 2001.

[2] SMD components soldering practice board DIY kit; https://images-na.ssl-images-amazon.com/images/I/A1cxOnoVBsL.pdf Last accessed on April 24, 2024.

[3] https://www.arduino.cc

[4]

https://u.pcloud.link/publink/show?code=kZWi9Q0ZDKDqVdhYM6LeM8N1iLdgRSNH

0pzy Last accessed on April 22, 2024.

[5] https://www.osti.gov/doecode/biblio/105058 Last accessed on April 22, 2024.