

Potentiostat Development Project — Prototype Toward High-Throughput Electrochemistry (Draft)

1) Project goal and context

This project develops an early potentiostat prototype as a stepping stone toward a **target platform for high-throughput electrochemical experiments**. The long-term objective is a **compact, highly parallelized architecture** that can scale to many channels while remaining robust, reproducible, and easy to operate through a modern software interface.

The current prototype is used in ongoing experiments, including measurements in sulfide-containing systems. These experiments serve as a **validation and stress test** for the prototype, helping to define requirements and guide hardware and software improvements for the high-throughput target device.

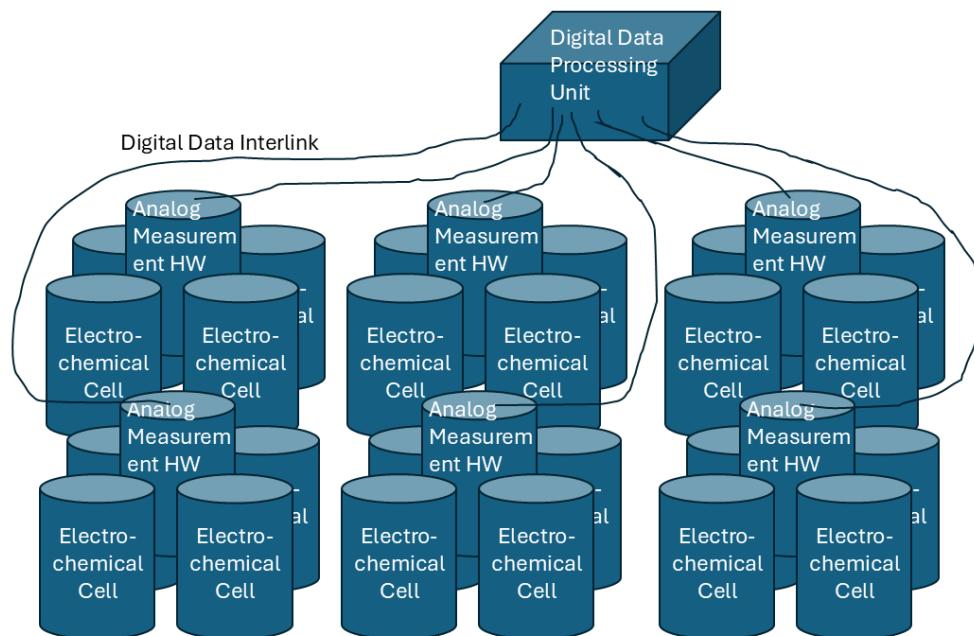


Figure 1: Concept sketch of the prototype and the envisioned parallelized multi-channel target architecture

2) Development approach: simulation → prototype validation

Development started with **SPICE simulations** to evaluate key circuit blocks and component choices before building hardware. These simulations were used to validate the basic behavior of the control and measurement chain and to reduce iteration time during early prototyping.

For the first prototype validation, **TL097 operational amplifiers** were selected as a pragmatic choice to verify core functionality. The intent at this stage was fast bring-up

and functional confirmation, with the understanding that higher-performance amplifiers will be evaluated for the next iterations in line with high-throughput requirements (noise, stability, reproducibility, and scalability).

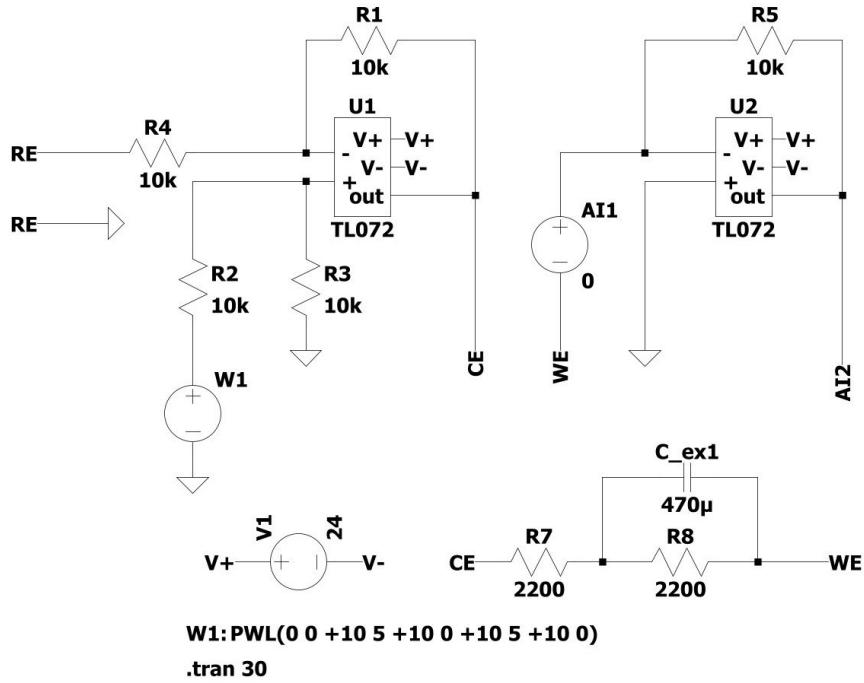


Figure 2: Circuit diagram, which was used for the SPICE simulations.

3) Current application use case: pseudo-reference electrode in sulfide systems

In the current experimental use case, sulfide is present in the electrolyte. For these measurements, a **Ni(OH)₂/NiOOH pseudo-reference electrode** is used, prepared in-house. The pseudo-reference is created by cycling the electrode in **sulfide-free KOH** against a **standard Ag/AgCl reference electrode** during conditioning.

This electrode approach is part of the **current experimental workflow** and supports reliable measurements in the present application environment. Importantly, the potentiostat development itself remains oriented toward a **general, scalable high-throughput platform**, with the sulfide system acting as one practical validation scenario.

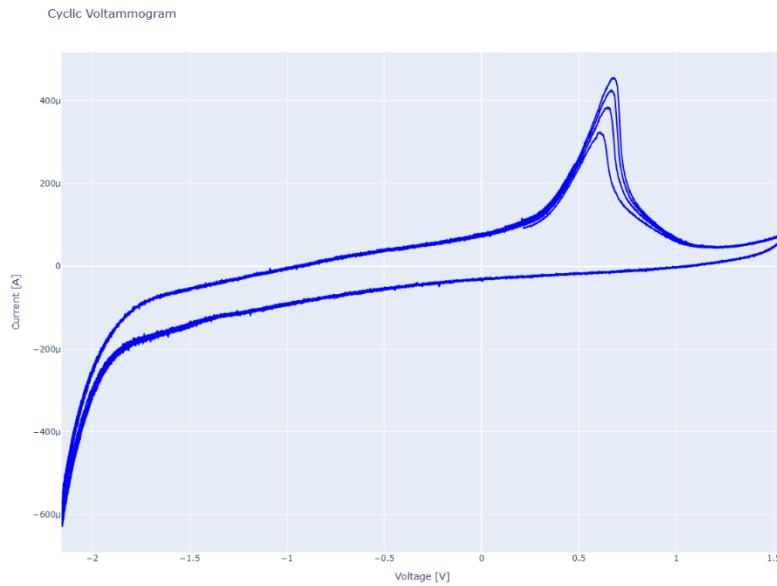


Figure 3: Cycling/conditioning data used to form the $\text{Ni}(\text{OH})_2/\text{NiOOH}$ pseudo-reference.

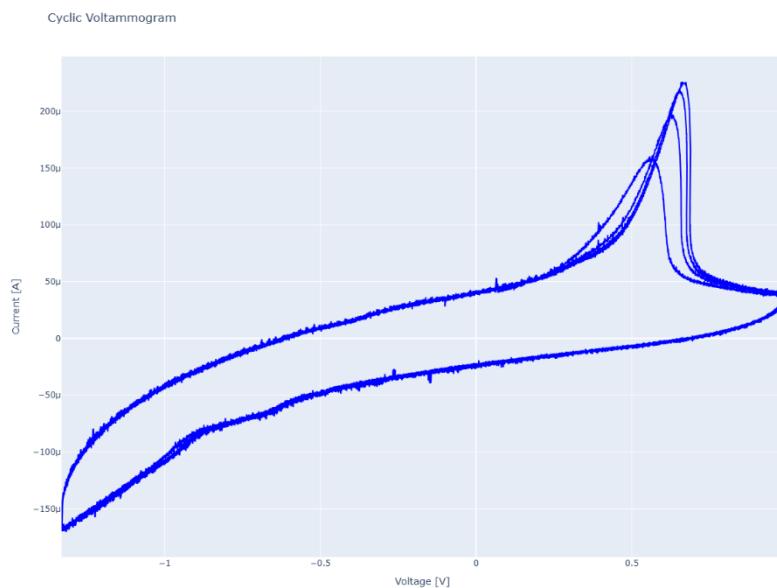


Figure 4: $\text{Ni}(\text{OH})_2/\text{NiOOH}$ pseudo-reference electrode after measurement.

4) Software stack and GUI

Operation and visualization are implemented using a **FastAPI + Dash** software stack:

- **FastAPI** provides the backend layer for instrument control, method execution, and data handling.
- **Dash** provides an interactive web-based GUI for experiment configuration and immediate visualization of results.

This setup supports rapid development iteration and is aligned with the long-term goal of running **many experiments efficiently**, which is central to high-throughput operation.

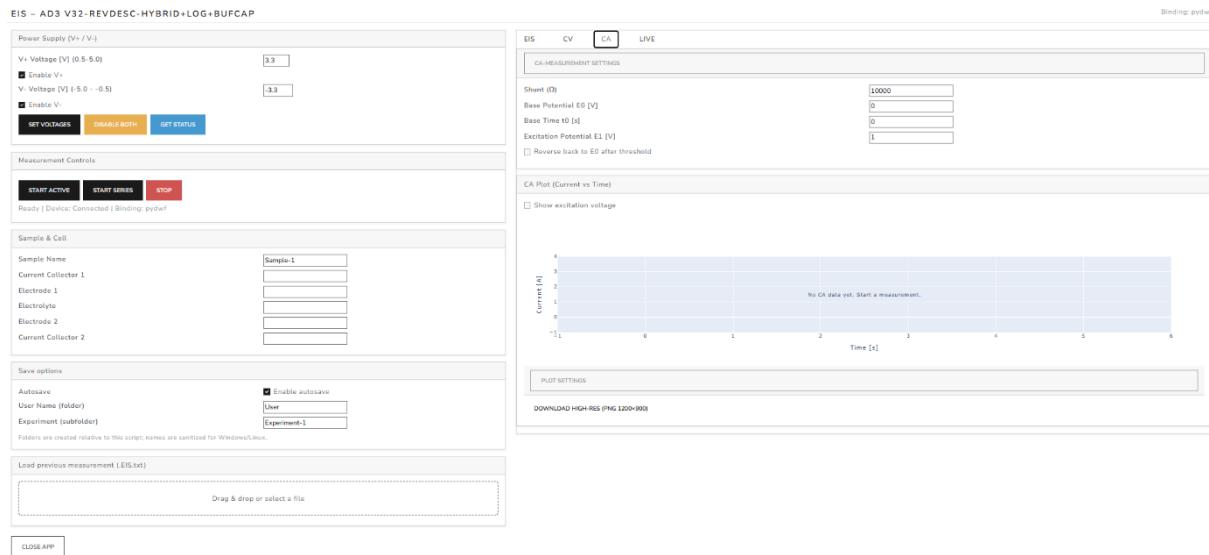


Figure 5: GUI screenshot showing method controls and fields for measurement plots.

5) Implemented electrochemical techniques

The prototype currently supports:

- **Cyclic Voltammetry (CV)**
- **Electrochemical Impedance Spectroscopy (EIS)**

Planned next is:

- **Chronoamperometry (CA)**

These techniques form a practical baseline for validating measurement integrity and for shaping the method pipeline needed in the high-throughput target system.

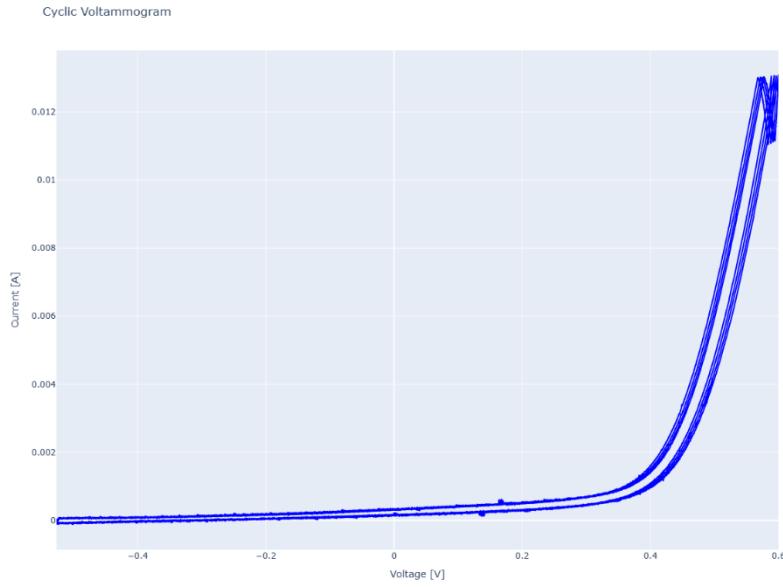


Figure 6: Representative CV measurement of an iron-air-battery, current setup went into clipping towards the end, due to overamplification. An auto-ranging is under development.

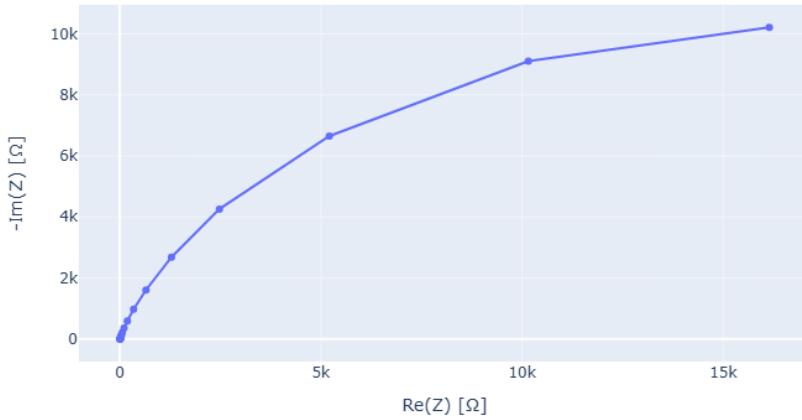


Figure 7: Test measurement of EIS of a 6 M KOH solution.

6) Conversion chain and planned hardware upgrades

At present, digital-to-analog conversion is performed using an **Analog Devices AD3**, enabling functional closed-loop control and measurement in the prototype stage.

For the next iteration—especially with high-throughput scalability in mind—hardware upgrades are already planned:

- Integration of a **dedicated 16-bit ADC/DAC** stage to improve resolution and measurement quality
- Evaluation and replacement of the current op-amps with **higher-performance amplifiers** better suited for low-noise and stable electrochemical control loops

These changes are expected to improve precision, reduce noise sensitivity (particularly relevant for EIS), and provide a stronger foundation for a compact multi-channel design.

7) Status and next steps toward the high-throughput target platform

Current status: working prototype with GUI and validated operation for CV and EIS, plus ongoing experimental use in real measurement scenarios.

Next steps:

1. Add **CA** to the measurement and GUI pipeline
2. Implement the planned **16-bit ADC/DAC**
3. Upgrade to **better op-amps** and re-validate core performance (noise, stability, repeatability)
4. Translate lessons learned into the **compact, parallelized architecture** required for high-throughput experiments