

Investigating Shielding Strategies Based on a Nested Faraday Cage Design

Bioengineering REU

Phung, A. T., Pham, G. K., & Henderson, D.
Faculty Advisor: Dr. Alexandrakis, G., Dr. Turner, G.

Abstract

Nanopore sensors are highly sensitive to electrical, mechanical, and optical noise.

This study investigates noise mitigation and signal conditioning using controlled testing, vibration and light analysis, SPICE simulations, and physical circuit implementation to optimize analog filters.

A nested Faraday cage was implemented to reduce electromagnetic interference. Results show improved signal clarity, reduced noise coupling, and enhanced transient response.

Background

Nanopore sensors are sensitive to external electrical, mechanical, and optical noise.

A single-layer Faraday cage has been implemented, but its effectiveness is only **1.2x** compared to no cage. Additionally, there was no active mitigating methods.

Improving shielding is challenging, as these aspects must be considered:

- Post-collection signal processing
- Proper grounding
- Harmonized mechanical vibrations
- Light attenuation



Figure 1 – Previous Faraday Cage Iteration

Methodology

1. Nanopore sensor function

The nanopore sensor in our system examines the behavior of light going through a nanopore in the microamps scale. We ensured functionality of the sensor while minimizing RF leakage.

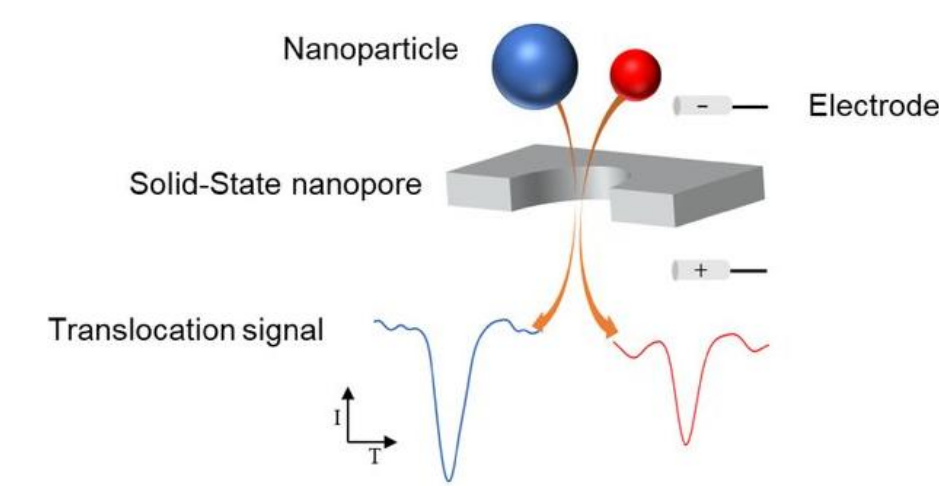


Figure 2 – Nanopore Sensor Example

2. Cage design and construction

Two nested multi-layer Faraday cages was developed, with a total of 10 layers. The system is screw on an aluminum breadboard, connected to the grounding table. The cages can protect devices from EMI signal, electrostatic charges and mechanical distortions.

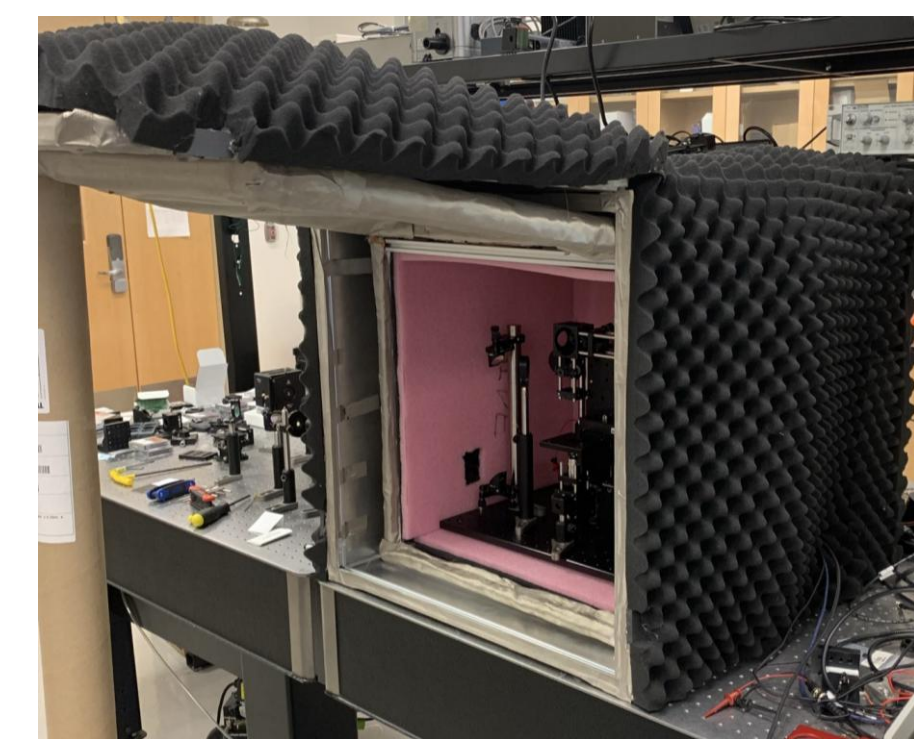


Figure 3 – Nested Faraday Cage Design

3. Analog signal processing

The purpose of implementing the RLC circuit was to effectively eliminate baseline drift in the nanopore transient events. Baseline drift can reduce the temporal resolution of events and cause overlap between successive transients, potentially leading to misrepresentation of the data. Accurate baseline stabilization is essential for precise detection of specific molecules passing through the nanopore.

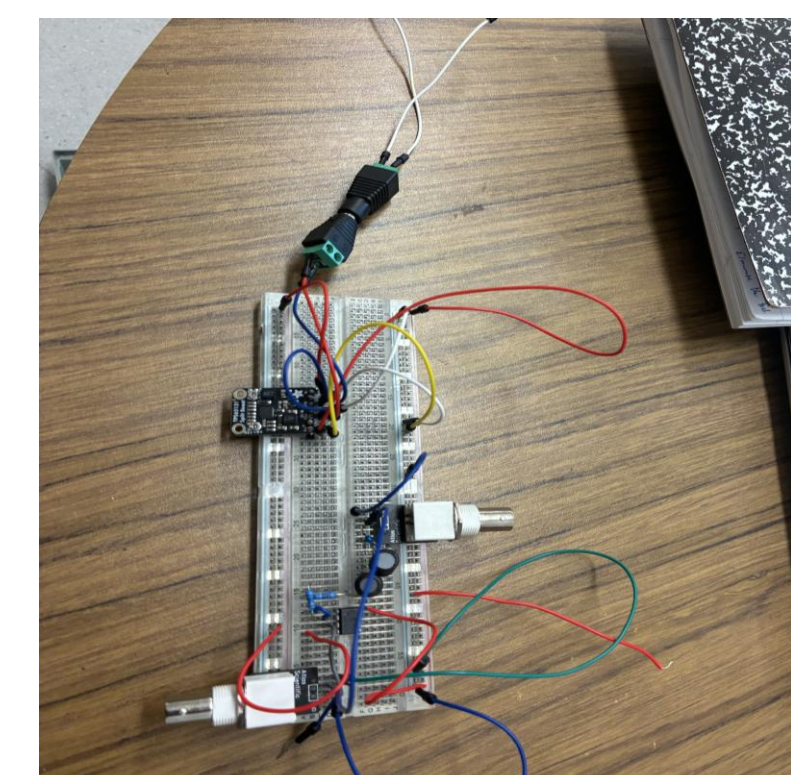


Figure 4 – Analog Signal Filtering Circuit

Testing Methods

1. Cage Signal-to-Noise Ratio

Examining the current going through a nanopore sensor at different voltages created IV Sweeps and SNR.

$$SNR = 10 \log \left(\frac{\sqrt{I_{total}^2 - I_{noise}^2}}{I_{noise}} \right)$$

2. Light Attenuation Test

Light attenuation was done through measuring the reflected light intensity from the shielding material.

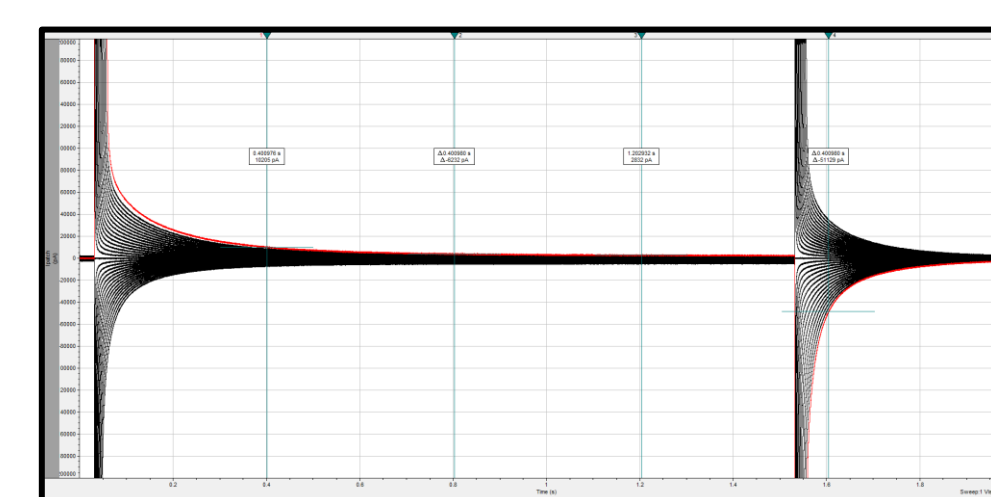


Figure 5 – I-V Sweep Graph

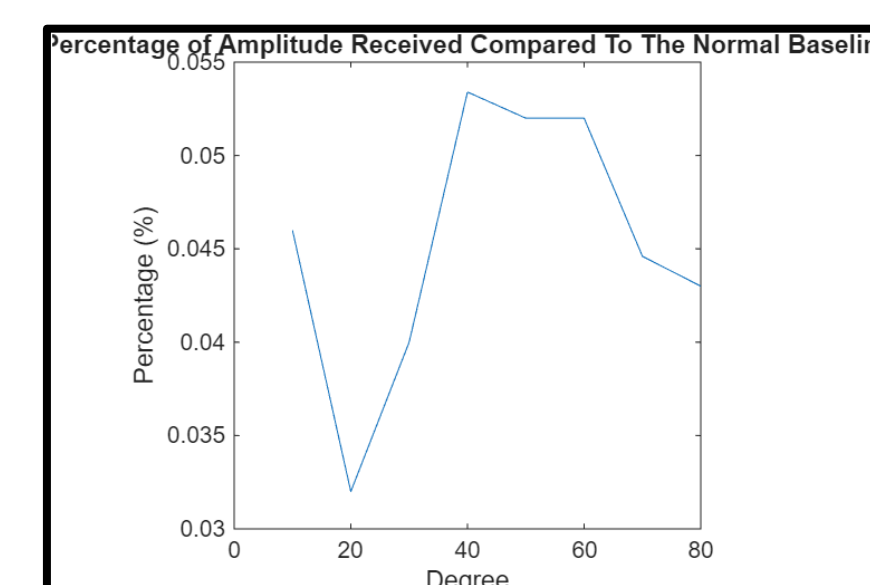


Figure 6 – Light Attenuation at Different Distances

Results and Discussions

1. Signal-to-Noise Ratio Comparisons

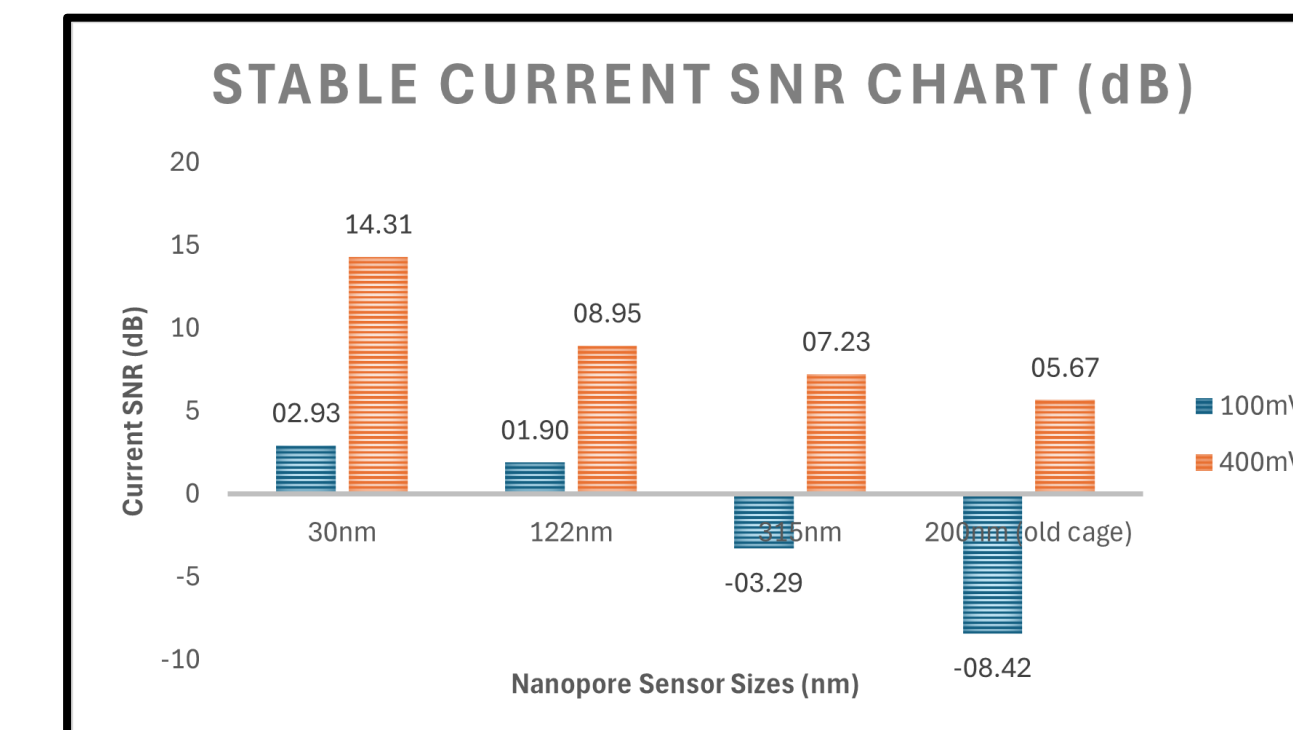


Figure 7 – Stable Current SNR with Different Nanopore Sizes

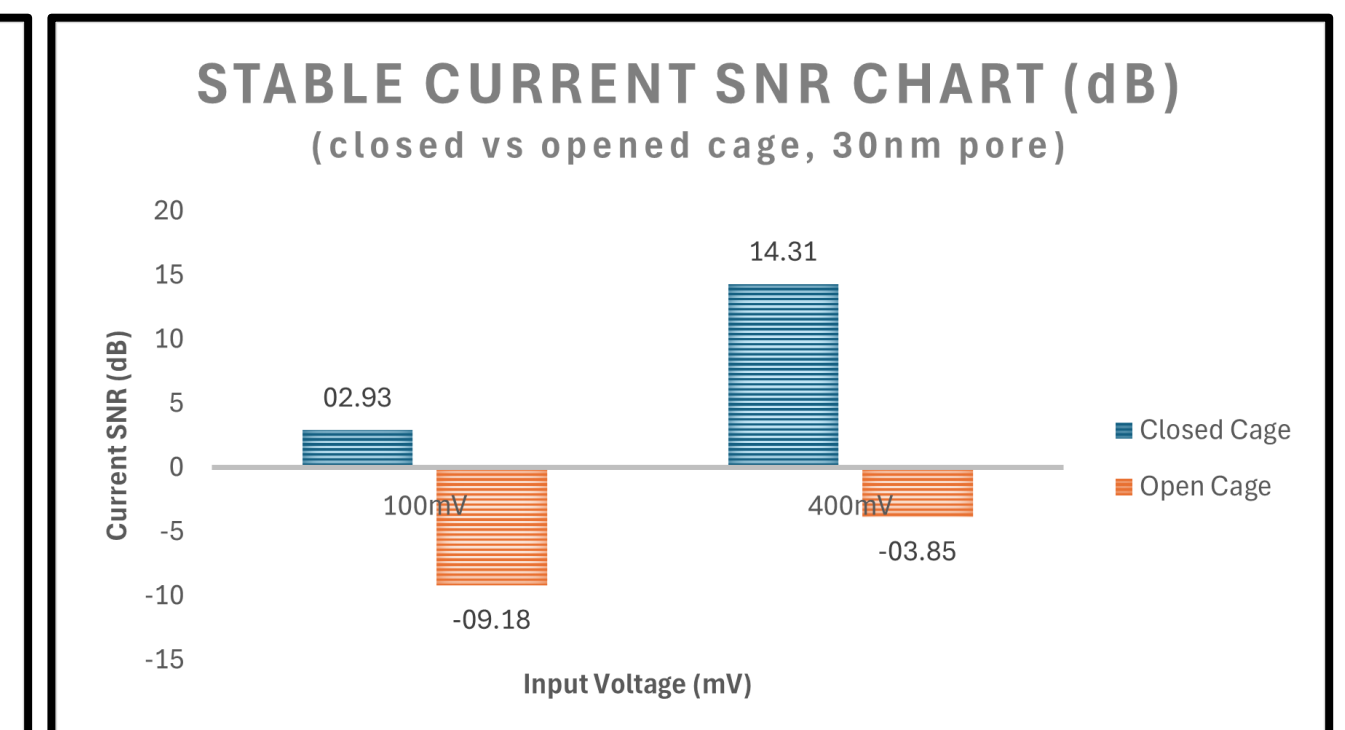


Figure 8 – Stable Current SNR Comparison

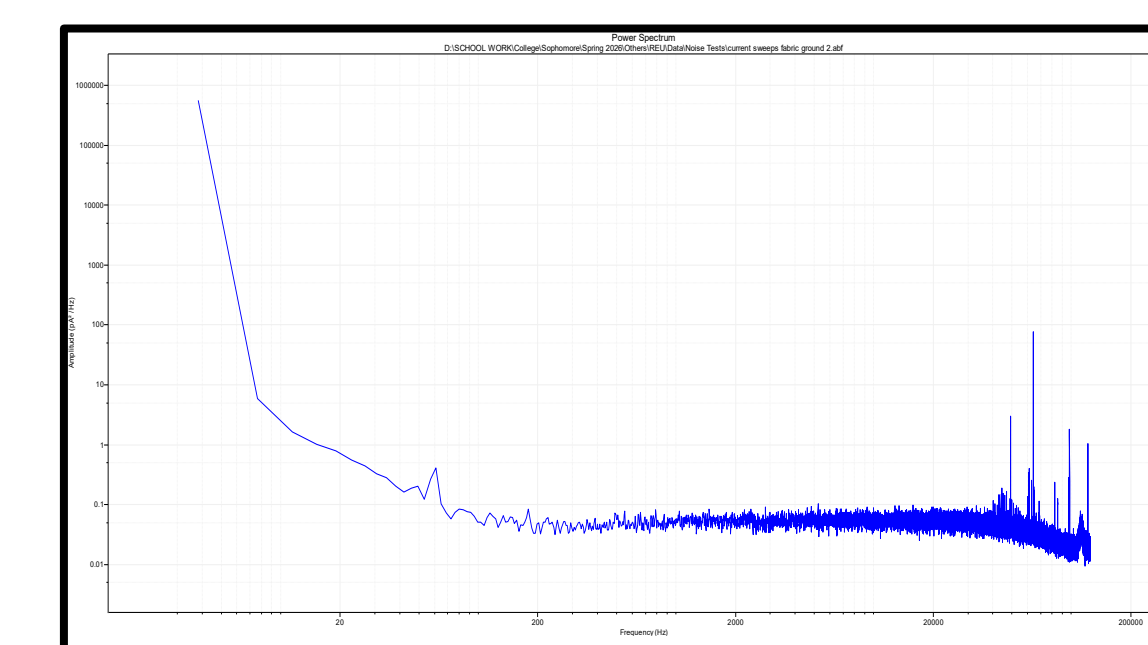


Figure 9 – Power Spectrum of I-V Sweeps

2. Analog Filtering

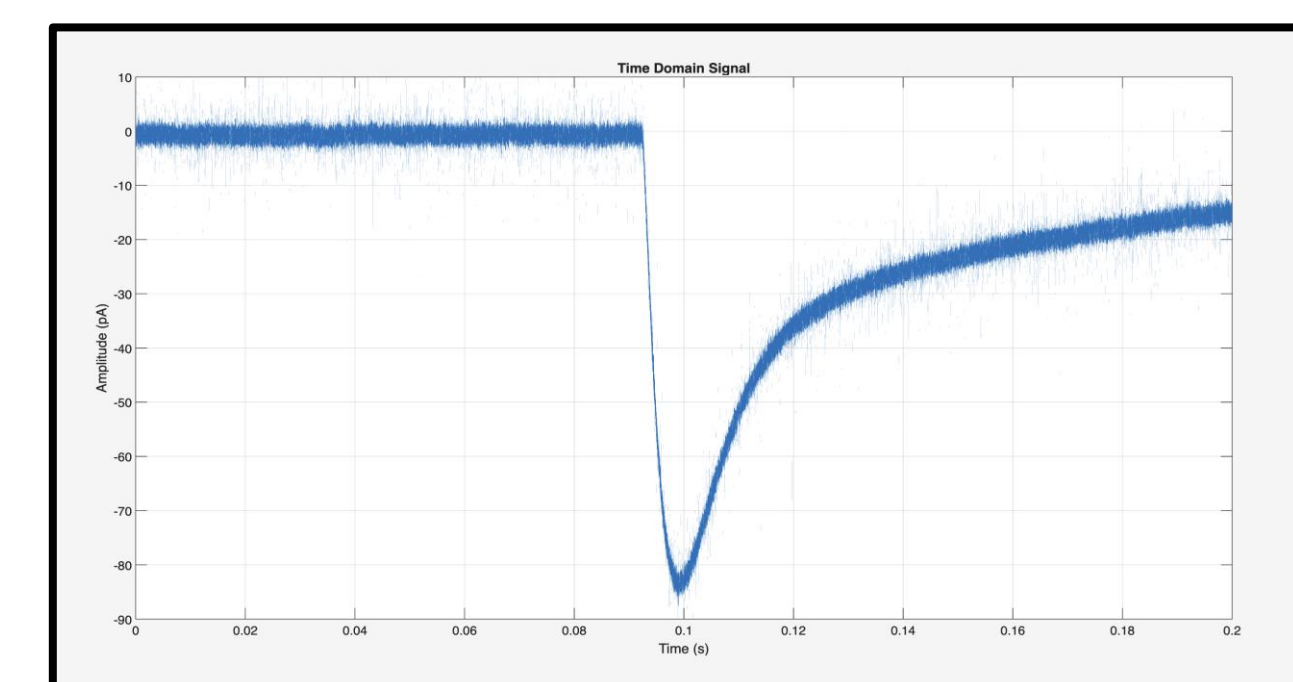


Figure 10 – Nanopore curve before analog filter

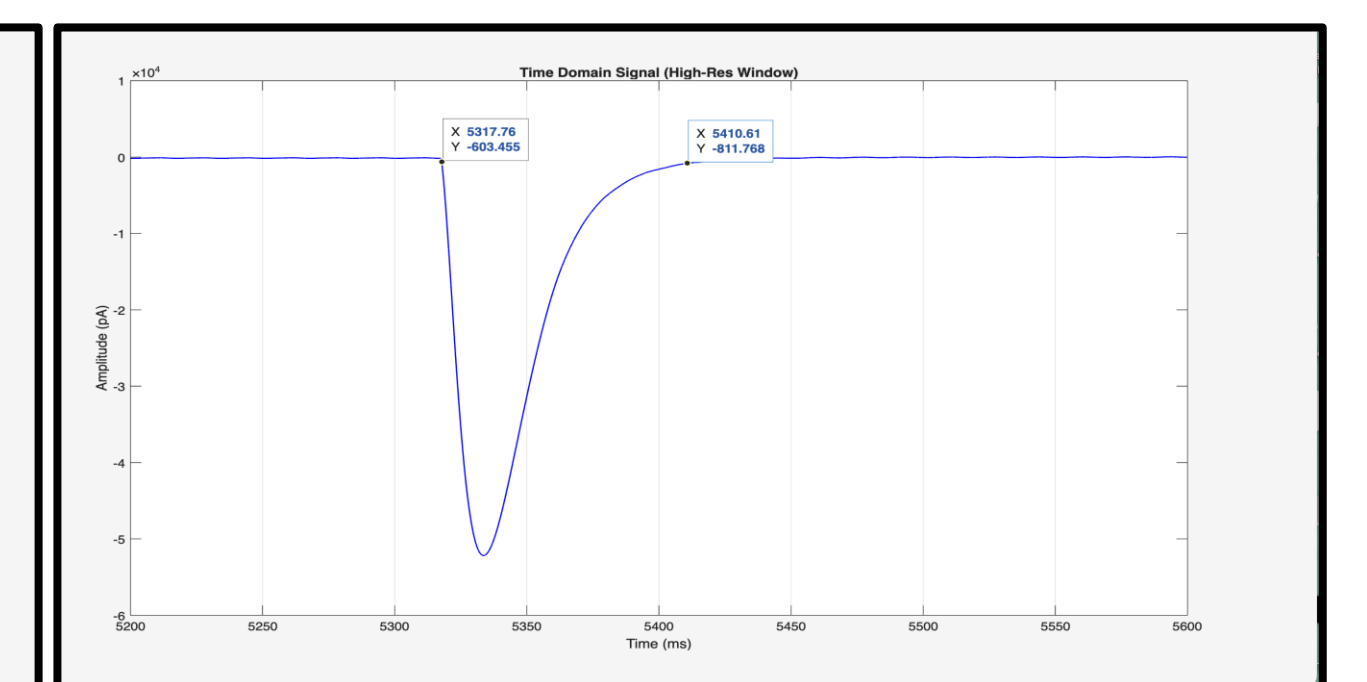


Figure 11- Nanopore curve after analog filter

Conclusions

This study demonstrated that a multi-layer Faraday cage design significantly improves signal quality in nanopore sensor recordings, by up to 900% compared to an opened cage configuration. Combined with RLC analog filtering to eliminate baseline drift, these shielding strategies effectively reduce electromagnetic and other interferences.

References

- Yiheng Che "Design of solid-state nanopores for nanoparticle identification", Proc. SPIE 12600, International Conference on Optoelectronic Materials and Devices (ICOMD 2022), 126000R (9 March 2023); <https://doi.org/10.1117/12.2674046>
- Katherine Gussenhoven, Dhanush L. Amarasekara, Jack Canfield, and Y. M. Nuwan D. Y. Bandara, "Investigation of Shielding Strategies to Mitigate Noise in Nanopore Recordings," ChemRxiv (2025); <https://doi.org/10.26434/chemrxiv-2025-qrtx1>