NDnano
Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research
2026 Project Summary

1. Student name & home university: Daniel Liu, Rose-Hulman Institute of Technology

2. ND faculty name & department:
Professor Kaiyu Fu, Department of Chemistry & Biochemistry
Professor Huibin Chang, Department of Aerospace and Mechanical Engineering

3. Summer project title: High-Speed Simultaneous Sampling AFE for Customized Potentiostat

4. Briefly describe new skills you acquired during your summer research:
I learned instrument prototyping, PCB design, firmware development, and hardware validation.

5. Briefly share a practical application/end use of your research:
This instrument will be incorporated into an automated electrochemical system for drug quality control.

6. 50- to 75-word abstract of your project:
This project develops a customized potentiostat for automated quality control using cyclic voltammetry (CV) and square wave voltammetry (SWV). Each channel operates independently and simultaneously, supports high sampling rates, and drives electrochemical measurements. Five selectable current ranges enable precise measurements. It will be integrated with other scalable instruments in the system to reduce cost, labor, and quality control time.

7. References for papers, posters, or presentations of your research:

- [1] J. Ma et al., "Eprobe: A multi-technique, multi-channel wearable potentiostat," *Biosensors and Bioelectronics: X*, vol. 27, Art. no. 100686, 2025. (ScienceDirect)
- [2] T. Tichter, M. Gernhard, and P. C. K. Vesborg, "PolArStat: An Arduino-based potentiostat for low-power electrochemical applications," *Electrochimica Acta*, vol. 469, Art. no. 143119, 2023. (ScienceDirect)

One-page project summary that describes problem, project goal, and your research activities / results:

Contemporary pharmaceutical quality control is both expensive and time-consuming, as it often relies on specialized equipment, trained personnel, and strict laboratory environment. Common analytical methods such as high-performance liquid chromatography (HPLC) and nuclear magnetic resonance (NMR) spectroscopy are accurate and reliable, but they also require significant time and technical maintenance. As the demand for faster and more scalable quality-control methods grows, there is increasing interest in testing platforms that can maintain reliable measurements while reducing labor and cost.

One alternative approach is to use electrochemical techniques such as Cyclic Voltammetry (CV) and Square Wave Voltammetry (SWV). These methods study chemical and electrochemical behavior by applying controlled voltage waveforms to an electrode system and measuring the resulting current response. Compared with many conventional analytical techniques, electrochemical testing can be performed using relatively compact and lower-cost electronics. This makes it well suited for systems and applications that require many measurements to be performed efficiently. A practical approach is to develop an electrochemistry system that can run measurements with limited user input.

The driving piece of this system is called a potentiostat. Potentiostats control the voltage applied to the electrochemical cell and record the resulting sensor response. In this project, a customized potentiostat was designed and built to integrate with the existing electrochemistry platform. Each acquisition module can operate independently or simultaneously depending on the assigned task. This flexibility makes it possible to run specialized sampling on demand.

The Analog Front End (AFE) acts as the connection between the digital electronics and the electrochemical reactions taking place at the electrodes. Each AFE channel is designed for simultaneous, high-speed data collection. This allows the system to capture electrochemical signals that change rapidly over time. Each channel can also perform two electrochemical techniques: CV and SWV. These techniques give the system flexibility and allow it to support a wide range of applications.

The potentiostat supports an applied voltage range that the reactions can produce very different current responses, where each channel includes five selectable current detection ranges. The user can select the option that best matches the expected response, improving measurement sensitivity, and preventing signal saturation. Overall, the potentiostat provides a flexible and scalable platform for fast electrochemical

testing and serves as an important step toward reducing the cost, labor, and time associated with pharmaceutical quality-control analysis.