Open-Source Wireless Universal Electrochemical Sensing System

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Abstract

We have developed an inexpensive, wireless, wearable potentiostat sensor system to expand electrochemical sensing from a controlled laboratory environment to performing analysis and continuously monitoring health in the field.

- Environmental testing for heavy metals
- Health monitoring via biomarkers in sweat
- Detection of PFAS in water
- Portable electrode development and testing

Current and future development of the sensor system on a new flexible PCB paves the way for integration of the sensor into smart bandages while the ML capabilities of the MCU allow for on-device AI-powered anomaly detection that can inform real time data driven decisions in the field and for personalized health care.

Hardware

- Texas Instruments LMP91000 potentiostat AFE ICs
- Silicon Labs EFR32MG24 microcontroller for wireless and embedded machine learning
- Lithium battery compatible connectors and voltage regulation
- Removable debug header allowing further size reduction after development phase

Software

- Onboard firmware includes Bluetooth connectivity
- Support for chronoamperometry, cyclic voltammetry, and square wave voltammetry
  - Flexible interface for defining new electrochemical experiment protocols
- Custom Android app featuring connection settings, experiment configuration, and results export
- Open sourced
  - Simplicity Studio firmware project: https://github.com/sigmondkukla/efr32mg12-lmp91000-greenpcb-cpp
  - Android app source code: https://github.com/sigmondkukla/lmp91000-app

Acknowledgements

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Hoilett, O. S., Walker, J. F., Balash, B. M., Jaras, N. J., Boppana, S., & Linnes, J. C. (2020). KickStat: A Coin-Sized Potentiostat for High-Resolution Electrochemical Analysis. Sensors, 20(8), 2407. https://doi.org/10.3390/s20082407
Alim, A., & Imtiaz, M. H. (2023). Wearable Sensors for the Monitoring of Maternal Health—A Systematic Review. Sensors, 23(5), 2411. https://doi.org/10.3390/s23052411

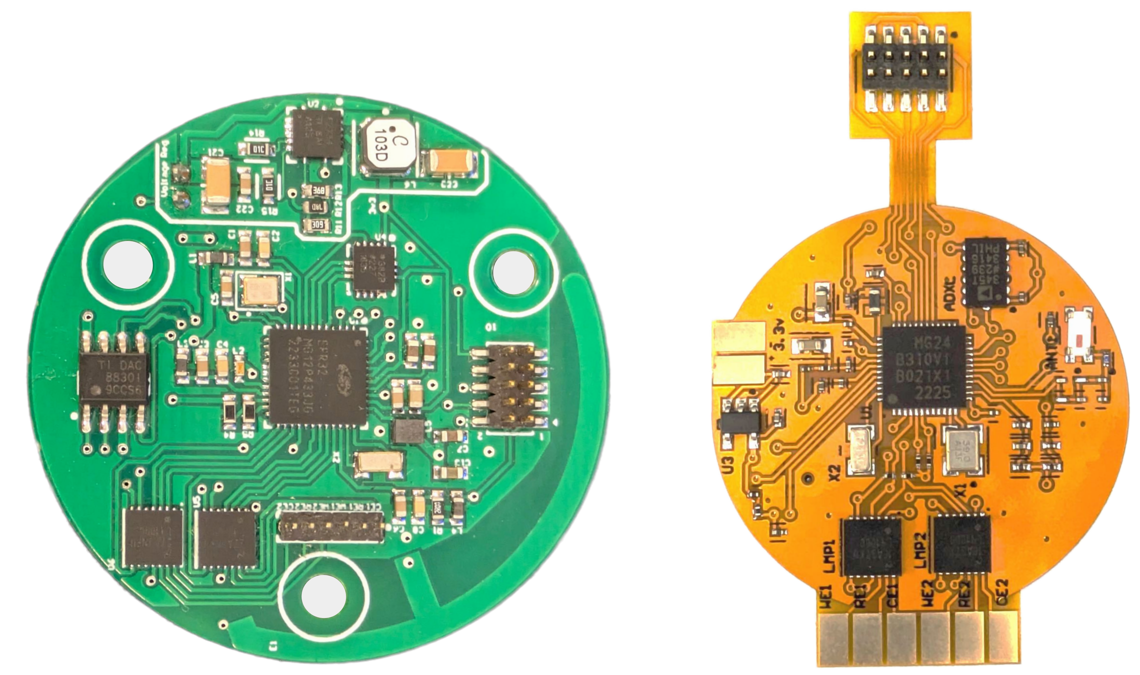

Figure 1. Miniaturization of previous potentiostat PCB, achieving 30% smaller size while being flexible for bandage application

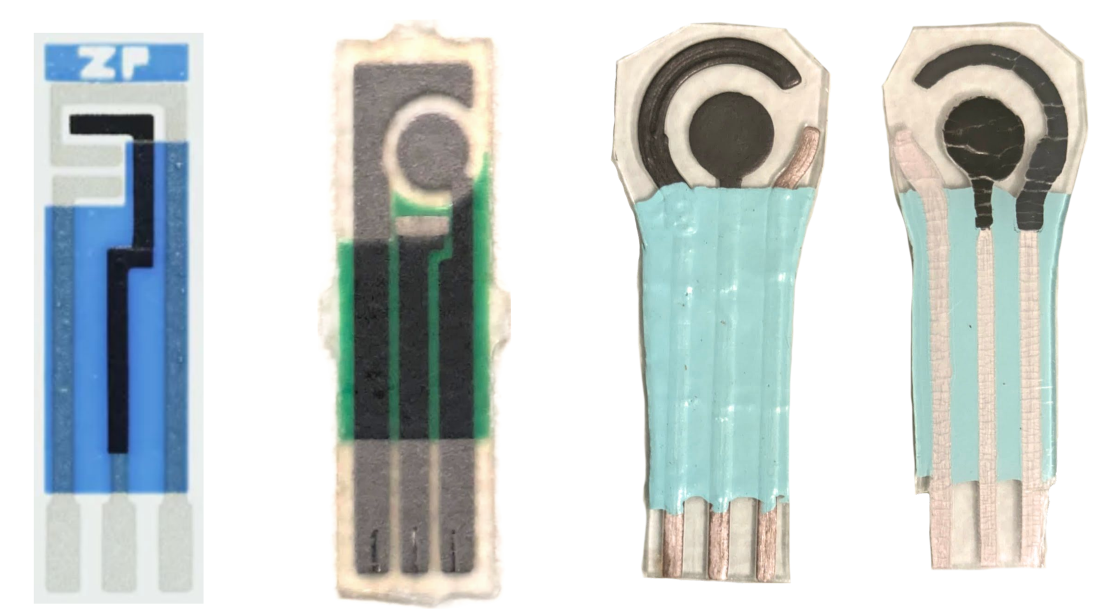

Figure 2. Universal compatibility with various commercially available as well as developed in-house sensor electrodes

Figure 3. Experimental setup demonstrating both field and lab use of sensor system

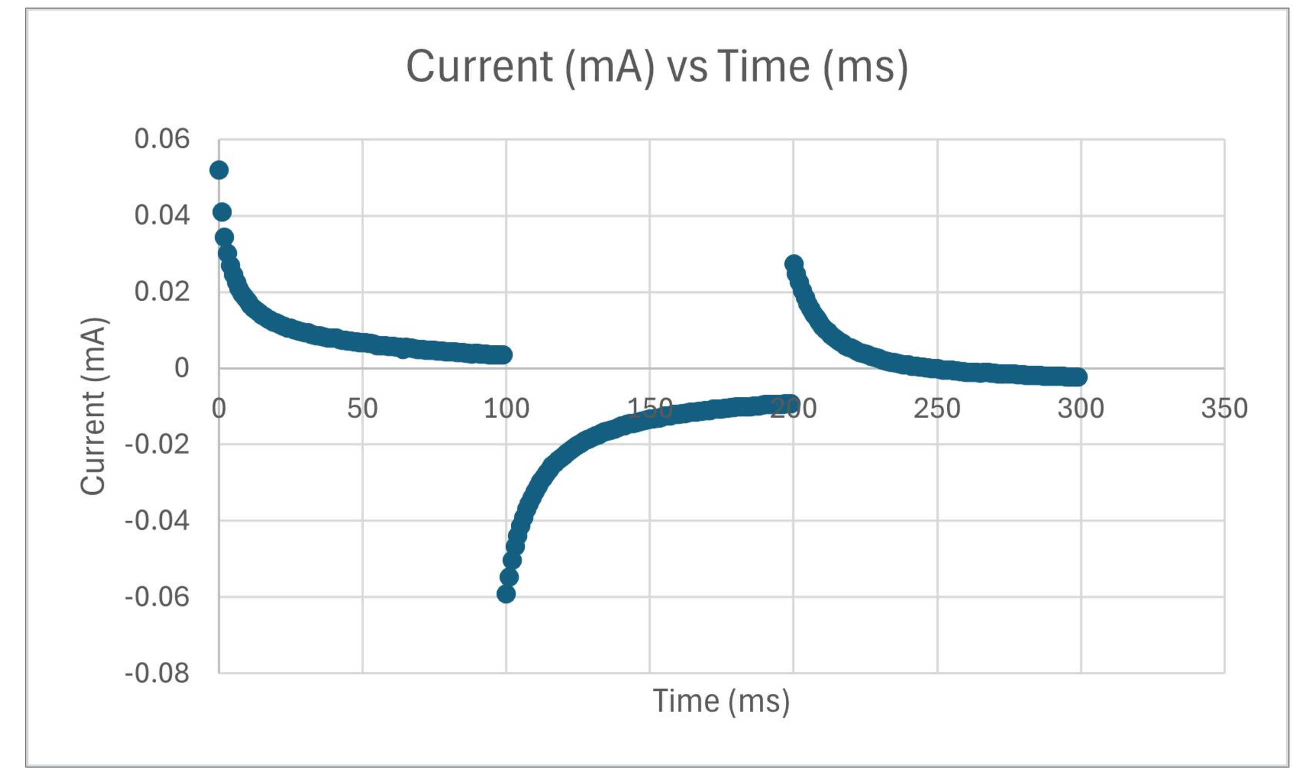

Figure 4. 3-cycle chronoamperometry experiment results on 0.1M Phosphate Buffered Saline (PBS) buffer solution

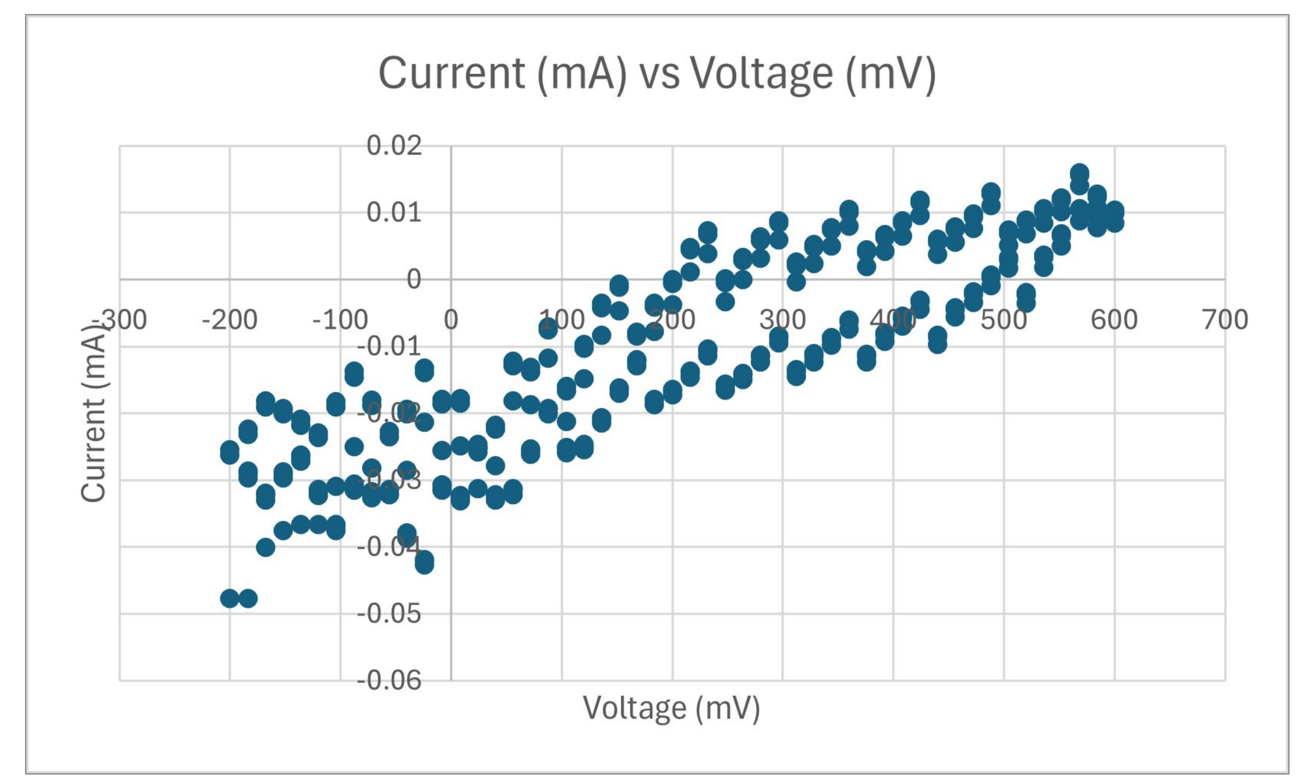

Figure 5. 3-cycle cyclic voltammetry experiment results on 0.1M PBS solution

Figure 6. Android app interface highlighting potentiostat control and data export features

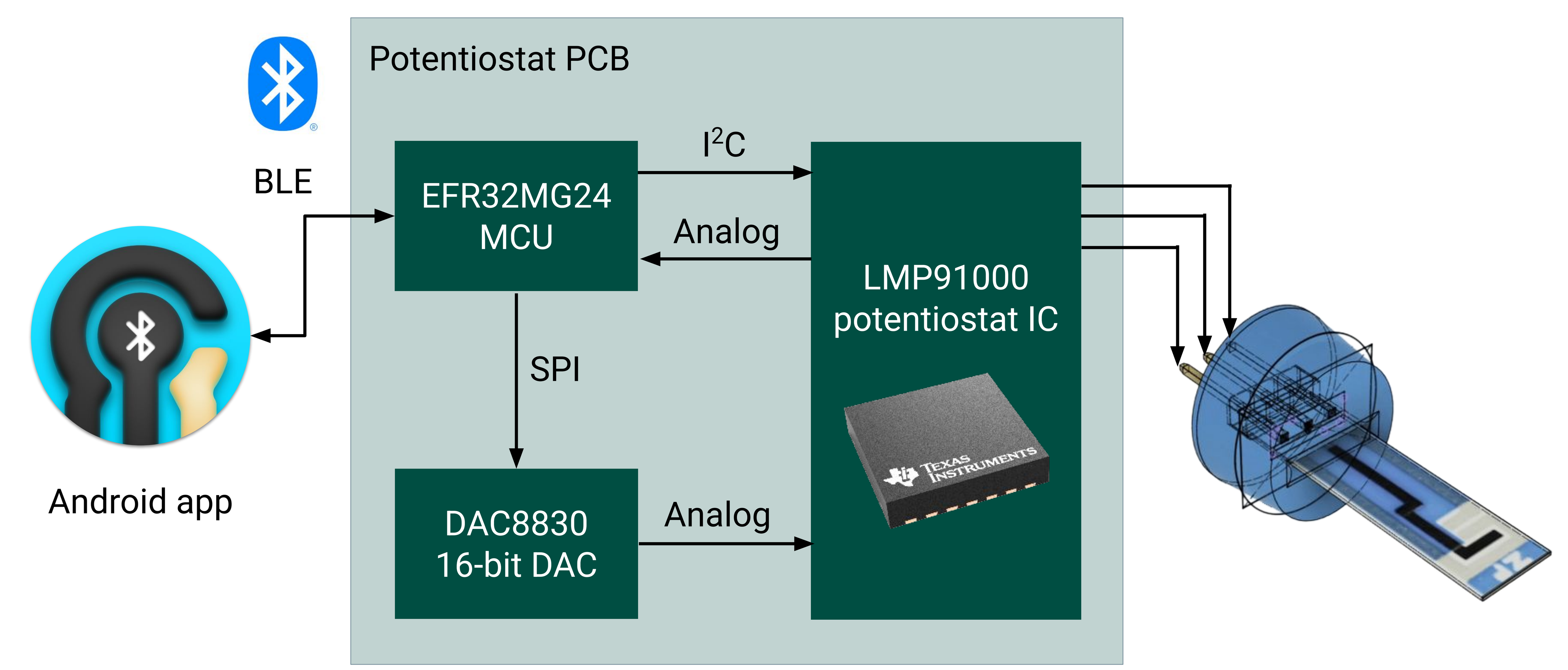

Figure 7. Concept of operations for wireless experimentation