BIDIRECTIONAL NEURAL TESTING INTERFACE

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Introduction

Background:

- Bidirectional neuromodulation is currently developed as an effective method of therapy for neurological disorders such as Parkinson's disease and epilepsy. These systems are flexible and adaptable to patient and clinical needs.
- Most newly existing bidirectional neural interface systems are proprietary, application-specific, and difficult to modify for testing novel integrated circuits (ICs).
- Applications of this closed-loop model include:
  - The Medtronic Percept™ PC neurostimulator incorporates BrainSense™ technology, enabling simultaneous neural sensing and therapeutic stimulation. Through Adaptive Deep Brain Stimulation (aDBS), the dual-threshold control algorithms allow automatic stimulation in response to recorded neural biomarkers.
  - NeuroPace Responsive Neurostimulation (RNS), FDA-approved epilepsy device that detects seizures and intervenes.

Objective:

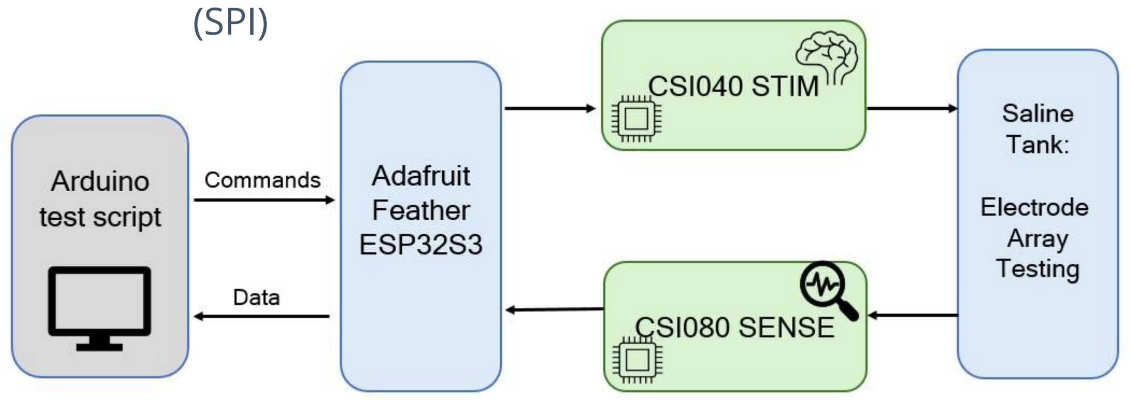
- UW Medicine is conducting clinical studies, and is in need for a modular, low-cost bidirectional neural testing platform to evaluate neural sensing and stimulation ICs from Cirtec. Such a platform can accelerate development of UW neural engineering research on closed-loop neural devices.

Contribution:

- By testing the bidirectional interface of Cirtec's neural ICs, it offers an introspective analysis for comparison of technologies with the current NIH-funded UW Medicine clinical trial led by neurosurgeon Dr. Jeffrey Ojemann and neural engineer Dr. Jeffrey Herron. The study explores the cutting-edge Cortec's Brain Interchange™ implant to safely reawaken patient's damaged pathways in the brain through the brain-computer interface (BCI) system [1].

PROJECT SCOPE

- Limitations: Without pre-existing testbenches, the complex circuitry address challenges related to signal quality and electrode functionality. In other words, test performance can be uncertain as firmware/pseudocode and control logic are still being developed, affecting accuracy in early prototypes of the neural ICs.
- Soldering Surface Mount Device (SMD)
- Standard data transfer: Serial Peripheral Interface. (SPI)



Phase 1

- Draft schematics
- Design Review and Printing
- Software Integration
- Testing Interface Individually

Phase 2 & 3

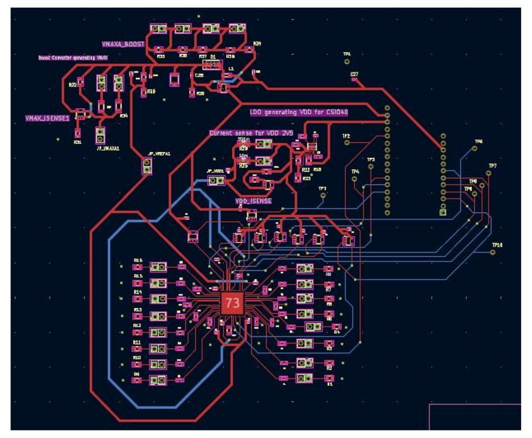
- Combine Both Chips
- Improving User Experience

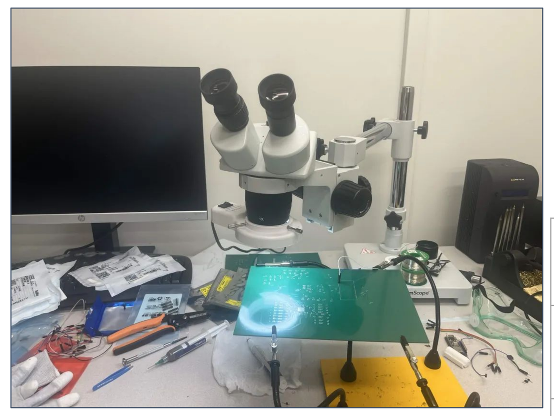
HARDWARE IMPLEMENTATION

- For the first prototype of the Printed Circuit Board (PCB) for the Cirtec stimulation chip, it follows the schematics provided by Cirtec. However, the design follows a personal as well as mentor guided process, mirroring industry standards and protocols.

Development Flow: KiCAD

Priority	Category	Why It Matters
Highest	Design Review & Architecture	Verify functionality before fabrication
High	Power Planning	Crucial use of multilayer PCB, bypass caps, vias and copper pours
High	Voltage Regulation & Logic Levels	Ensures operation at different voltages communicate safely and reliably
High	Hardware Isolation Testing	Makes debugging possible for the two ICs
Medium	PCB Layout Practices	Trace width and routing, via placements, impedance awareness
Lower	Fabrication Optimization	Important later, less critical during first prototype (DRC)


STIM PCB First Prototype KiCad Editor

Hot-Air Rework Station with Microscope


- Soldering microscopic surface mount devices required a soldering heat gun. Utilized a hot air rework station provided by Dr Herron's office at UW Medical Center.
- The PCB for the Cirtec sense chip was reworked due to its previous iteration failing SPI testing.

SOFTWARE IMPLEMENTATION

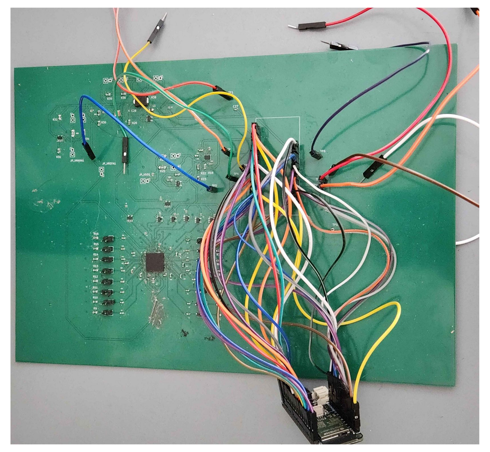
- The system software was developed in Arduino and runs on an Adafruit Feather microcontroller. Communication between the microcontroller and the Cirtec CSI080 neural sensing chip and CSI 040 stimulation chip is performed using the Serial Peripheral Interface (SPI) protocol. The software is organized in a modular architecture that allows sensing, stimulation, and data processing functions to be developed and tested independently.
- For neural sensing, the software configures chip registers, acquires recorded neural data, and transfers the data to a connected computer for visualization and analysis. Each transaction pulls CSN low, sends a command byte, register address, and data or dummy byte, then releases CSN back to high. In stimulation, the software packages stimulation parameters and transmits commands to the stimulation chip. This architecture supports future implementation of closed-loop control algorithms in which sensed neural activity can automatically trigger stimulation responses.
  - The modular design enables rapid testing of new signal-processing methods, stimulation strategies, and neural interface configurations while providing a foundation for future bidirectional neural interface development.

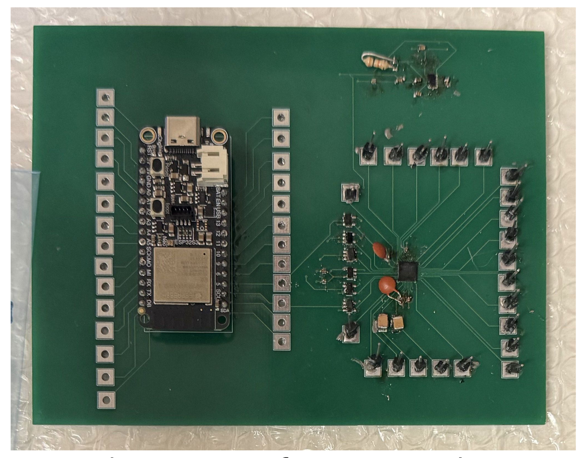
SPI Register Transaction:

CSN ↓ → CMD → ADDR → WRITE DATA / READ DUMMY → CSN ↑

MISO Readback → Computer

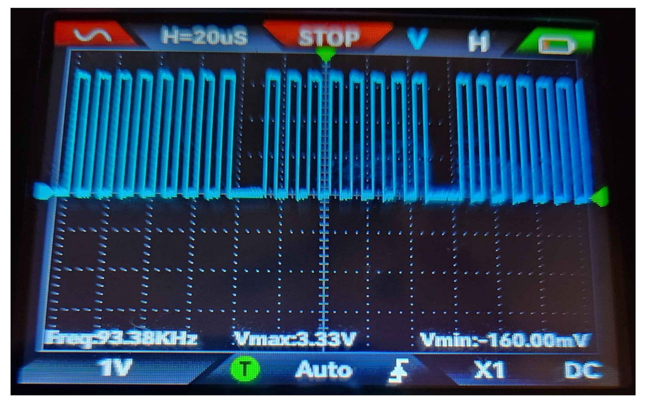
RESULTS


First Prototype of Cirtec Neural STIM PCB


Second Prototype of Cirtec Neural SENSE PCB

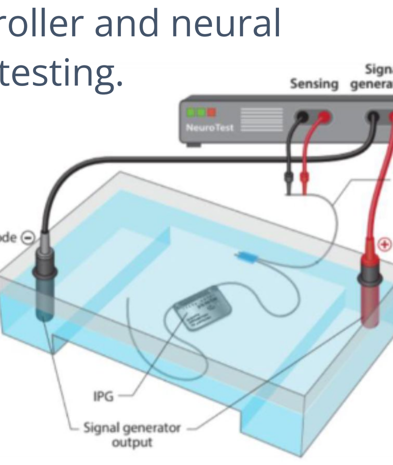
- The final schematics for the stim and sense boards were successfully printed and soldered, and using Arduino test scripts, an oscilloscope, and a function generator, the communication pins were providing feedback data.
- S-Clock, MOSI, and CSN functioned as expected when probed with oscilloscope during SPI.transfer(). Yet, when attempting to read and write registers, no MISO readback was observed in either chip. Voltage was not observed after stimulation and sensing did not pick up electrical signals to the computer.
- Despite communication challenges, the project resulted in a functional PCB platform and firmware foundation for future sensing and stimulation development

Pin	Expected Behavior	Observed Result
SCK	Clock Pulses during transfers	Confirmed
CSN	Low during transfers	Confirmed
MOSI	Command bits sent to ASIC	Confirmed
MISO	Returns register data/bits	Not Observed

SPI Clock Verification on First STIM PCB


FUTURE WORK

- Complete validation of SPI communication between the microcontroller and neural interface chips. Then confirm functionality through the saline tank testing.
- Move on to phase two with integrating neural sensing (CSI080) and stimulation (CSI040).
- Implement closed-loop control algorithms in which sensed neural activity automatically triggers adaptive stimulation.
- Move on to phase three with optimization as well as possible wireless communications.



Saline tank model

REFERENCES AND ACKNOWLEDGEMENTS

- Hanbin Cho overseeing Jamie Chang's time at Hot-Air Rework Station

[1] N. Swaby, "Experimental brain implant helps stroke survivor regain arm function," *KING 5 News*, Seattle, WA, USA, Dec. 9, 2025. [Online]. Available: KING 5 article. [Accessed: May 29, 2026].

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