A Functional Near-Infrared Spectroscopy (fNIRS) System for Monitoring Cerebral Blood Flow in Response to Cranial Nerve Stimulation

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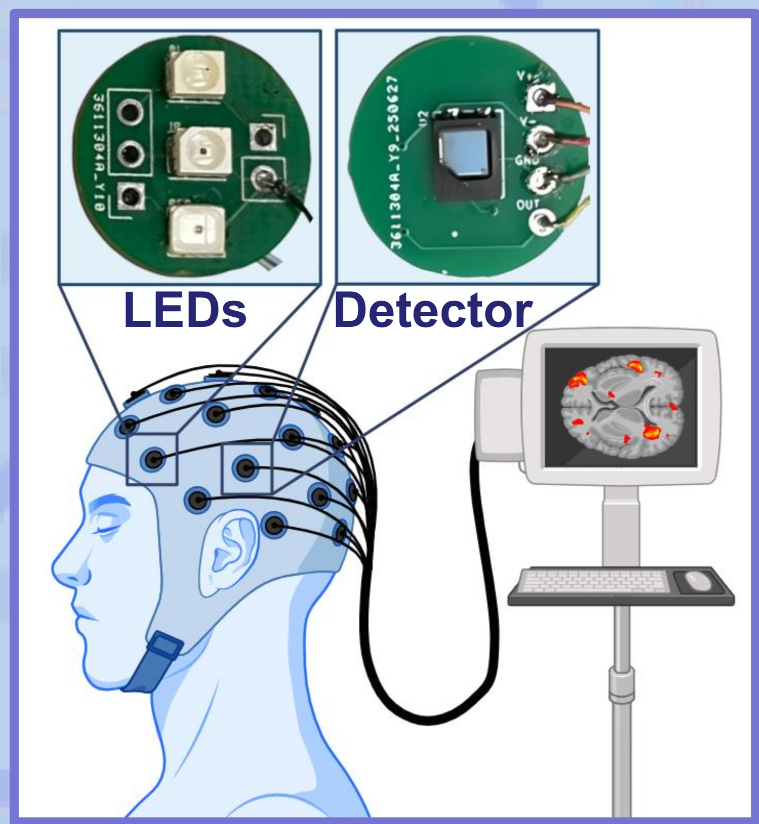
Background

Functional near-infrared spectroscopy (fNIRS)
- Non-invasive
- Monitors hemodynamics
- Utilizes optical absorption properties of hemoglobin in the blood

Cranial Nerve Stimulation
- Cranial nerve stimulation causes changes to cerebral blood flow



Project Goal

This project details the design of an fNIRS device that interfaces with an electrophysiological system, allowing for synchronized stimulation and hemodynamic recordings

Device Design

Design specifications for the fNIRS were set based Tucker-Davison Technologies (TDT) system requirements

Design Specification	Value
Voltage Output (Max)	500 mV
Sampling Frequency	20 kHz
Voltage Input (Max)	± 2.5 V

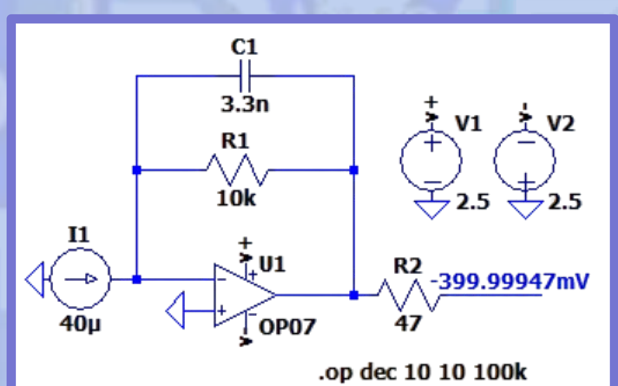
Detector Design
- A photodiode emits current in response to light
- A Transimpedance Amplifier (TIA) converts that current to voltage
- TIA component values were calculated and simulated

$$R_f \le \frac{V_{max}}{I_{max}} = \frac{500mV}{40uA} = 12.5\,k\Omega$$

$$f_{BW} \le \frac{f_s}{4} = \frac{20kHz}{4} = 5kHz$$

$$f_{BW} = \frac{1}{2\pi R_f C_f}$$

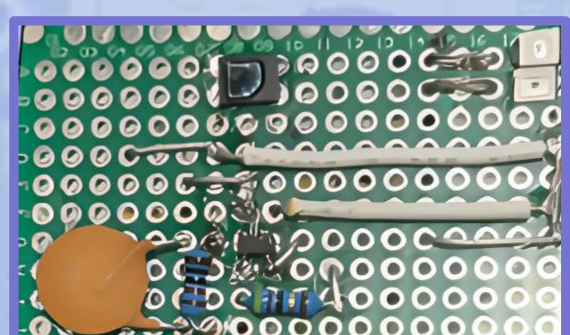
$$C_f \ge \frac{1}{2\pi * 10k\Omega * 5kHz} = 3.18nF$$



TIA LTSpice Simulation

Emitter Design
- Hemoglobin absorbs light
  - Deoxygenated <790nm
  - Oxygenated >790nm
- LEDs of 730nm and 850nm

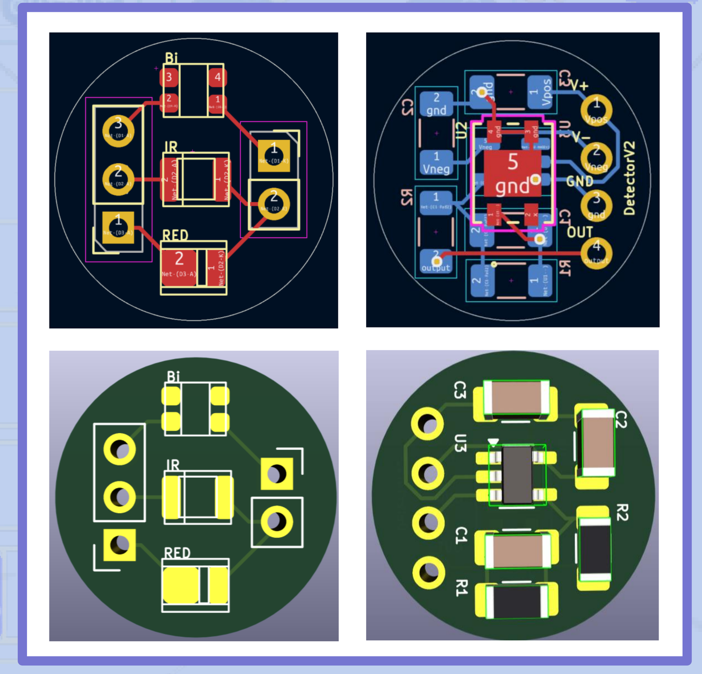
TDT Port Design
- Designed and labeled PCBs that fit over the TDT connector pins



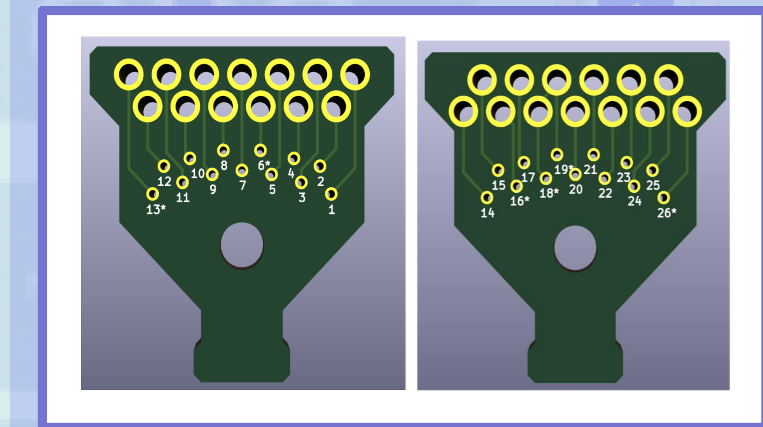
Prototype on Perfboard

Device Fabrication

PCB Design
- PCBs were designed in KiCAD
- Custom footprints
- Decoupling capacitors were placed near power sources

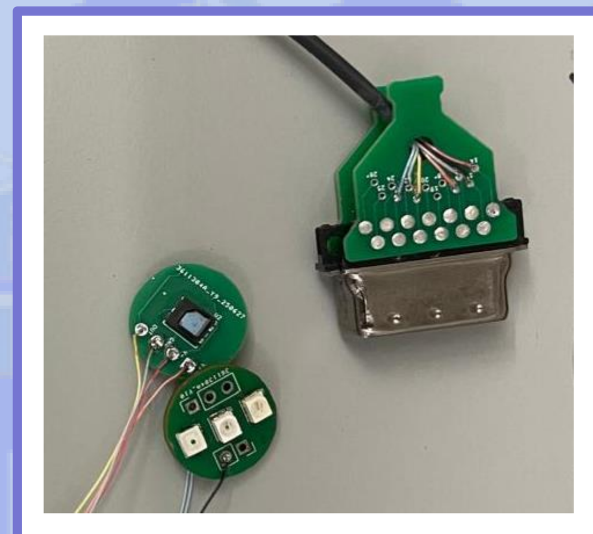


Emitter Detector



TDT Port Connectors

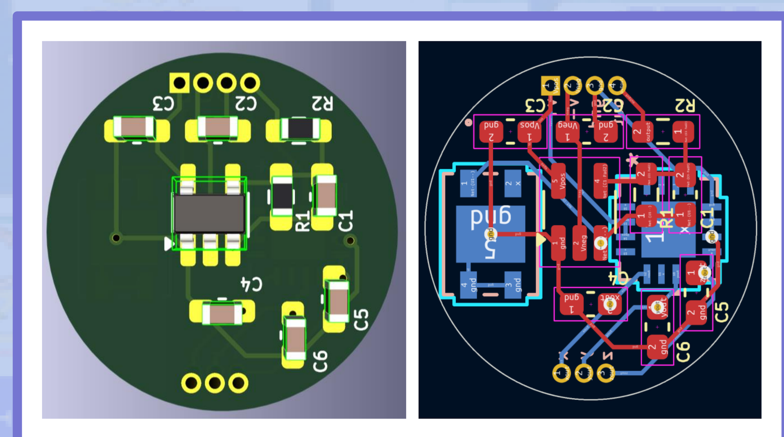
Initial Iteration Issues
- The pins did not fit the connector perfectly
- Motion artifacts could be seen while testing



Printed and Soldered Boards

Second Iteration

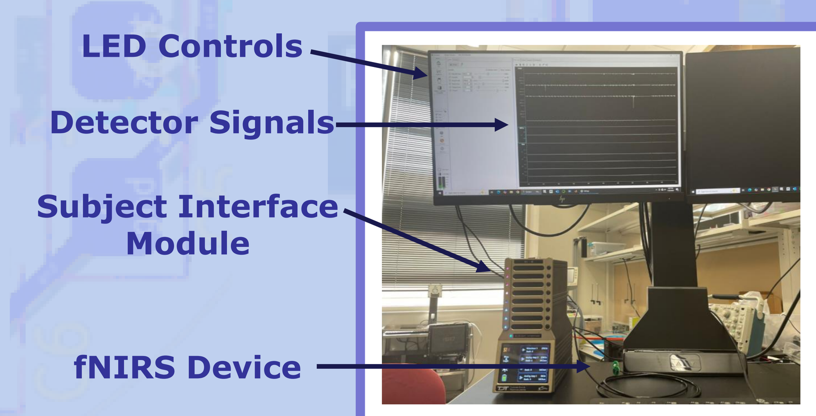
Motion Artifacts
- Movement can create voltage spikes unrelated to hemodynamics
- Stimulating nerves can cause off target muscle activation
- Participants naturally move while sitting



Accelerometer PCBs

Assembled fNIRS

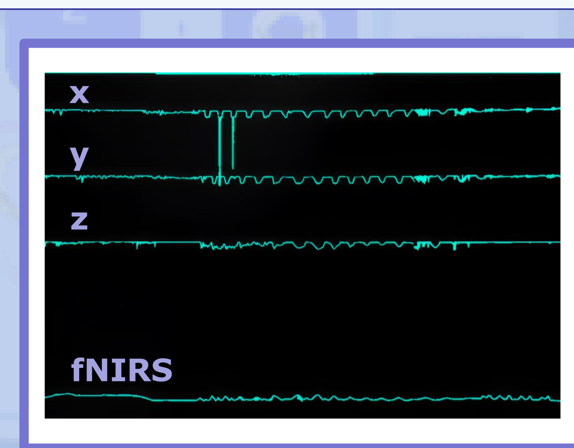
Accelerometer
- An accelerometer was added to the design to capture motion
- Acceleration in the XYZ directions can be measured and quantified



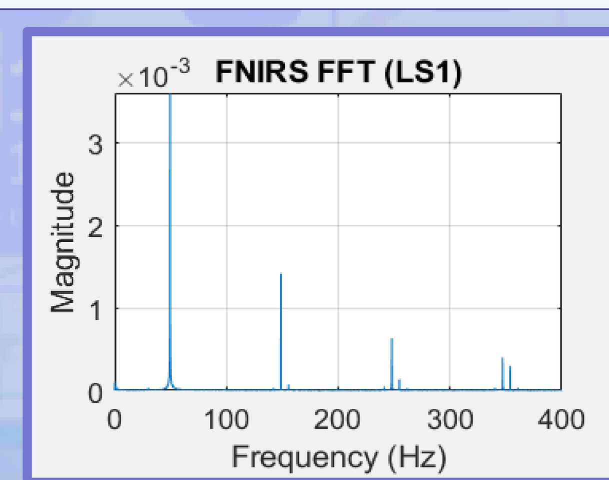
TDT Interface

Design Validation

Verification Test	Result
Preliminary PCB Testing (Multimeter)	No unwanted shorts
Maximum voltage under bright light	<400 mV
LED Functionality testing with TDT	LEDs flash
FNIRs with against skin testing	Detector can read signals from the LEDs on the TDT
Accelerometer XYZ testing	XYZ acceleration can be seen on TDT



TDT Raw Outputs while Generating Motion Artifacts Visualized



FFT of LED through Skin

Next Steps

- Design an apparatus to hold the fNIRS against the skin
- Real time analysis of blood flow changes
- Improve user interface and documentation for the TDT

Acknowledgements

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Open-Source Files

If you would like the design files or component information for this project, please visit our GitHub

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