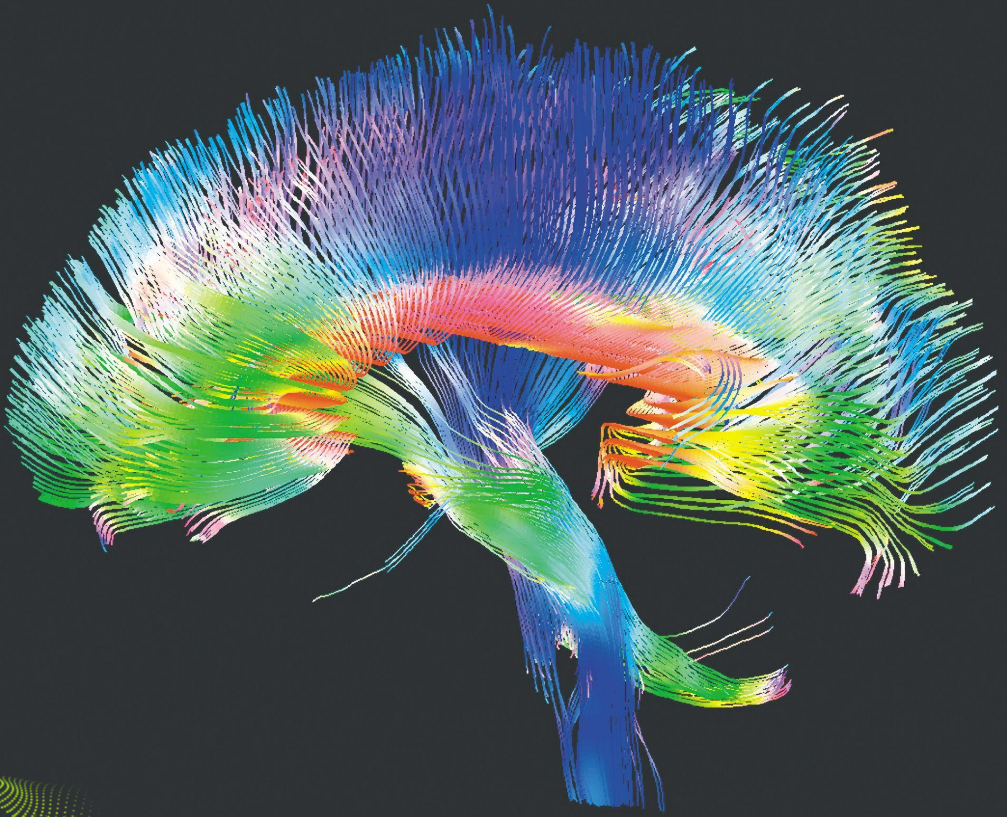
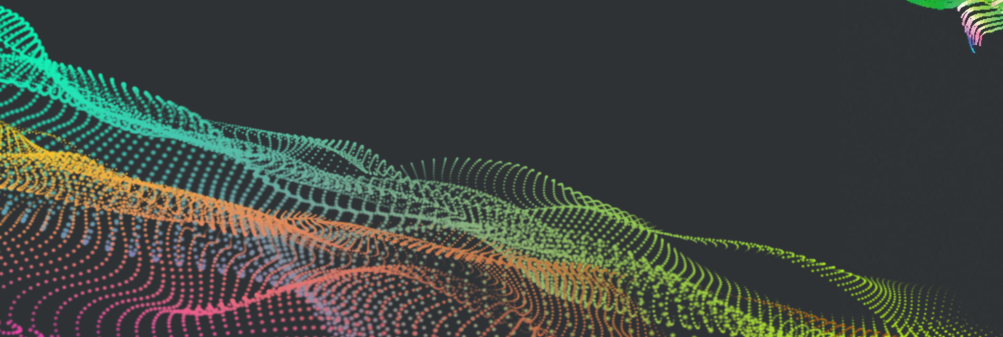
Functional Near Infrared Spectroscopy

(fNIRS)





Members

Hardware

Shovan Shakya

Tristan Valenzuela

Software

Thang Pham

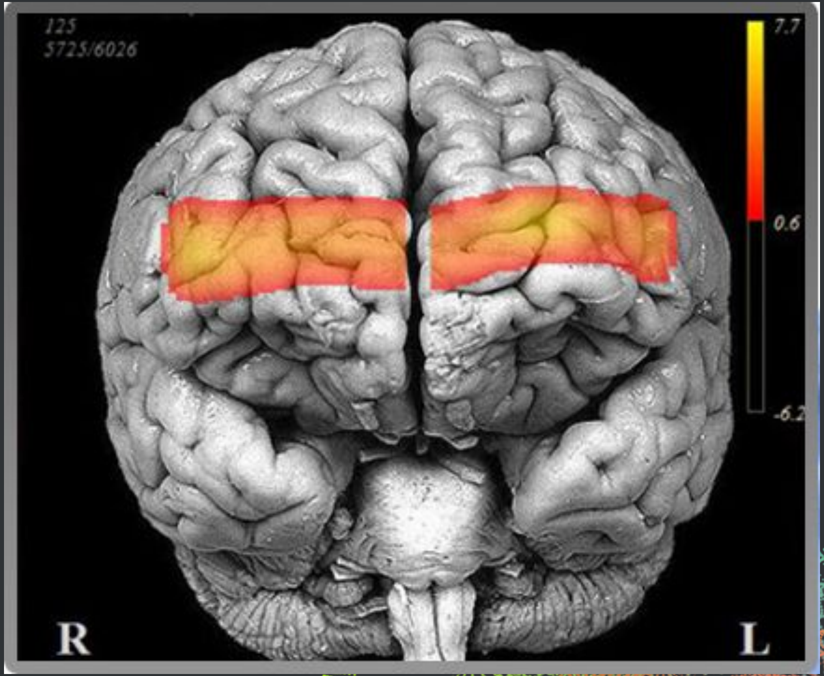
Advisor & Sponsor

Dr. Ashwin Parthasarathy (Translational Optics Imaging and Spectroscopy lab)

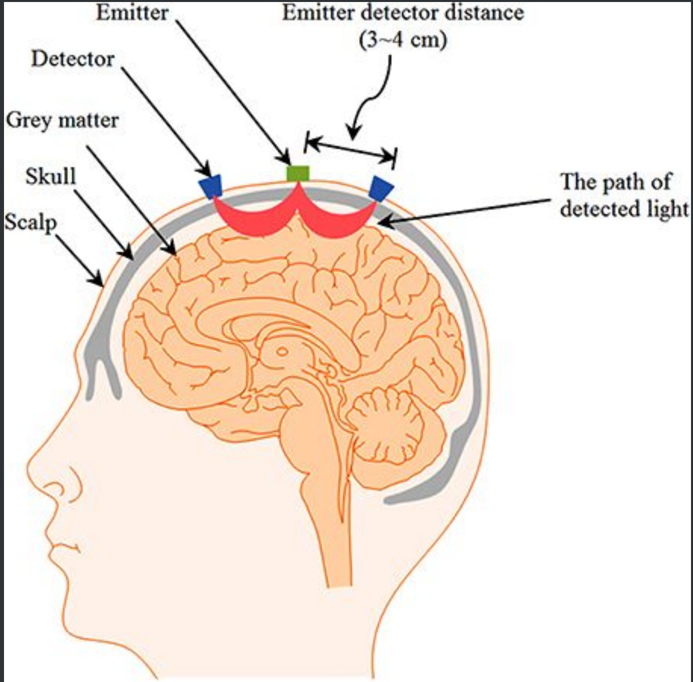
Overview

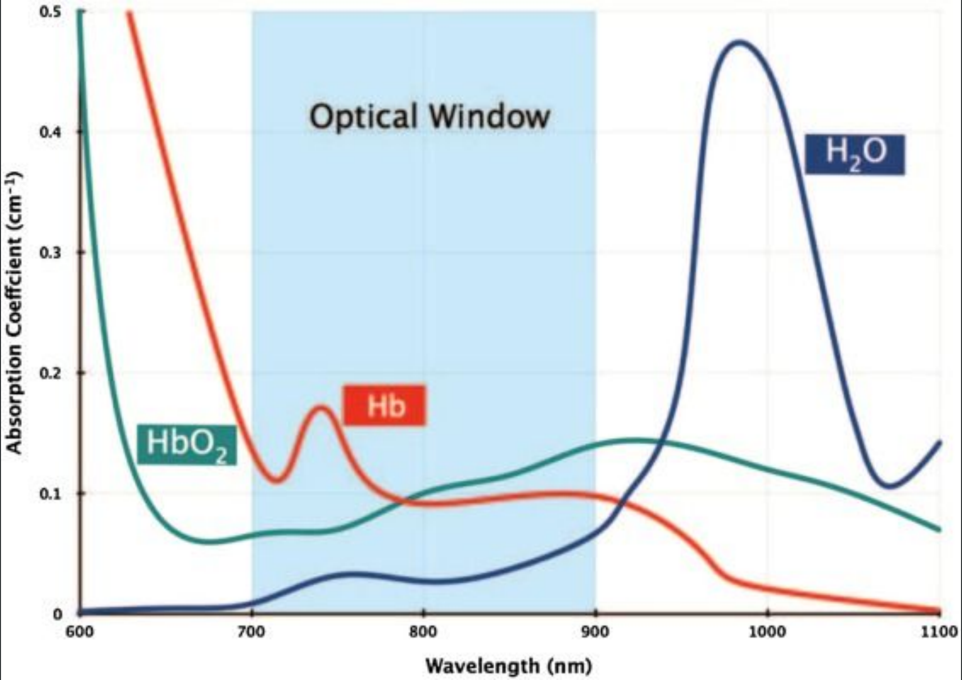
- A Brain-Computer Interface (BCI) is a computer interface which translates signals from the brain to control an external device such as a computer.
- Brain signals can be detected in several ways, one of which is Functional Near-Infrared Spectroscopy (fNIRS).
- fNIRS uses near IR light to detect changes in blood oxygen concentration due to brain activity.
- The purpose of this project is to implement a Brain-Computer Interface utilizing fNIRS for a multi-purpose system which can be used to analyze brain behavior or control external systems.
- This project is in partnership with the USF Translational Optics Imaging and Spectroscopy Lab.

fNIRS Example



fNIRS Example





Top Level Requirements

- fNIRS headset must have a temporal resolution of approximately 100 Hz.
- The system must display measured data in real time using an external PC interface.
- Headset must fit a broad range of head sizes.
- Cost effective (< $500)
- Total headset must be lightweight <0.25 lbs.

Temporal Resolution at 100Hz

- The fNIRS headset must perform a complete scan within a tight 10ms window while simultaneously handling communication.
- To ensure this timing constraint:
  a. A sufficiently fast microcontroller will be chosen for the task.
  b. Real time operating system (RTOS) will be implemented in software to manage multitasking behavior and ensure timing constraint is met.

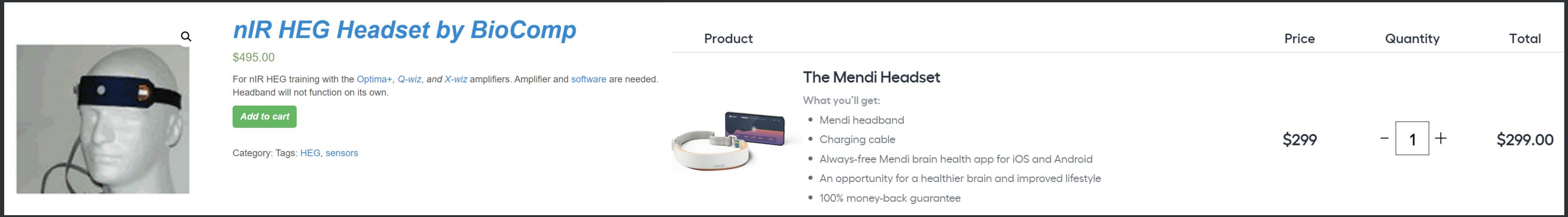
Signal Processing and Application

- The data acquired from the ADC has to be simultaneously transmitted to the main computer.
- A python application is used for graphing and visualizing the brain imaging data.
- Develop simple proof of concept application using the data (moving a virtual object on the screen).

Headset Size

- Use flexible material as the headband with strap for adjusting various head sizes.
- Design flexible PCB assembly for the Source/Detector headset.

Total Cost



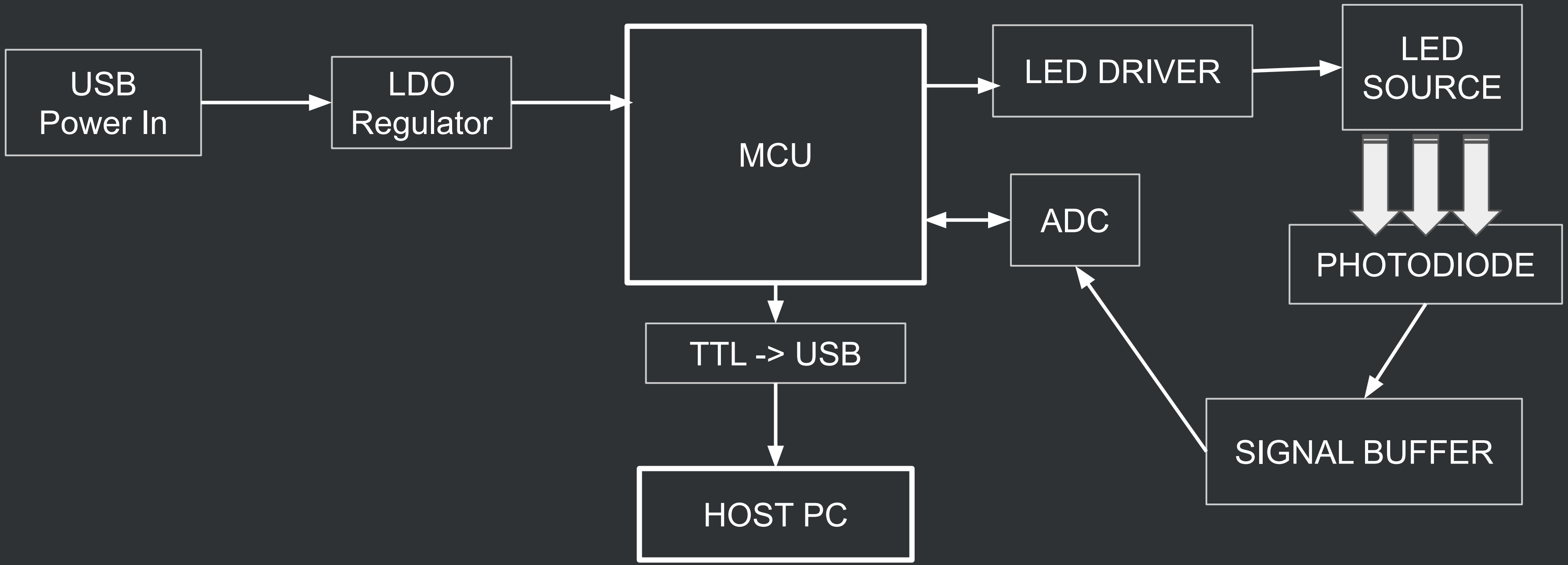
fNIRS headset are prohibitively expensive since they are usually made for medical or research purposes with headsets price being above $1000 usually.

Using common components and microcontrollers, we aim to produce a low cost headset targeting price ($100 - $300).

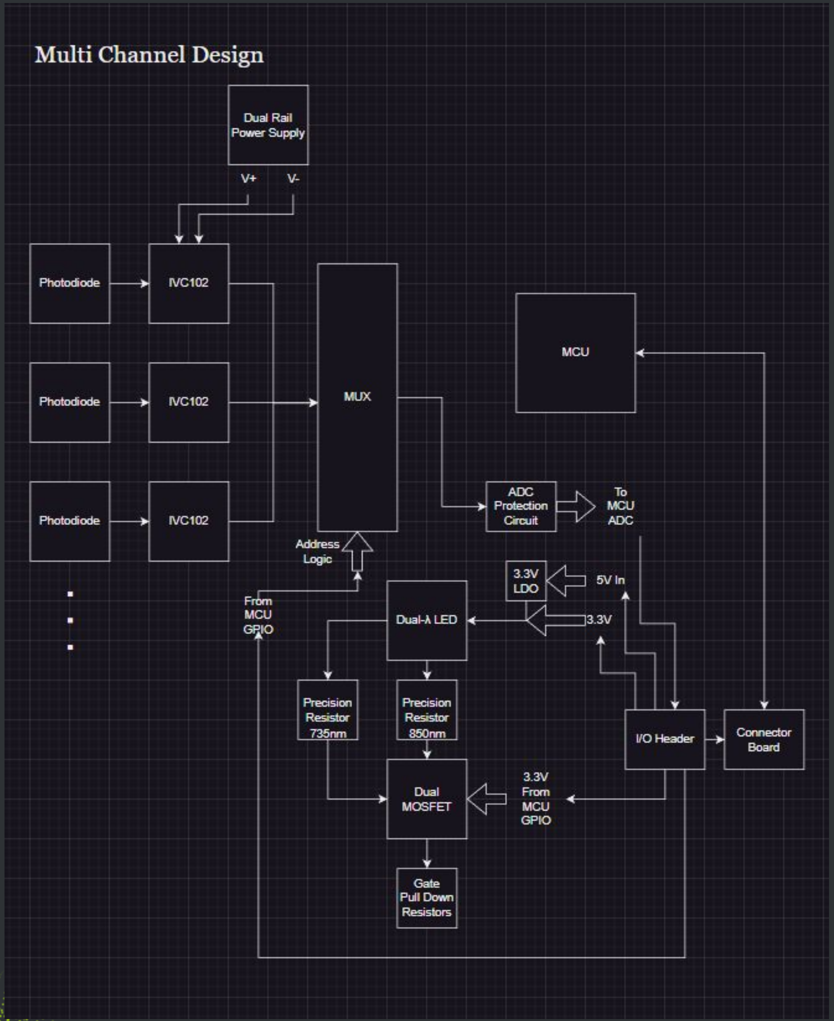
Headset Weight

- Total headset must be lightweight <0.25 lbs.

System Diagram



Low Level Circuit Block Diagram



Size, Weight, Power and System Performance

Size:

- Headset: 5.5 x 1.5 inches

Weight:

- 0.06 lbs

Power:

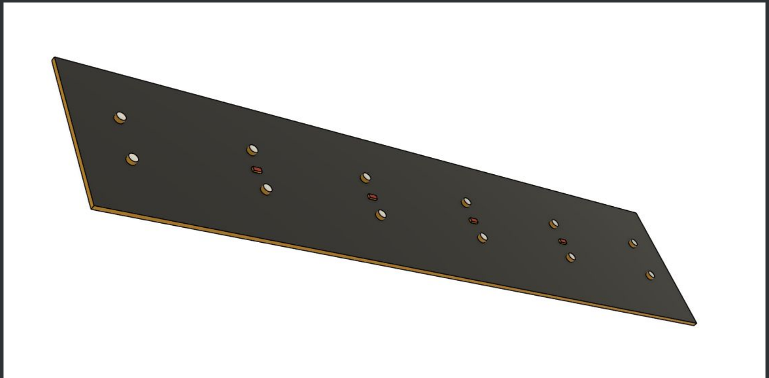
- 1.1 Watt

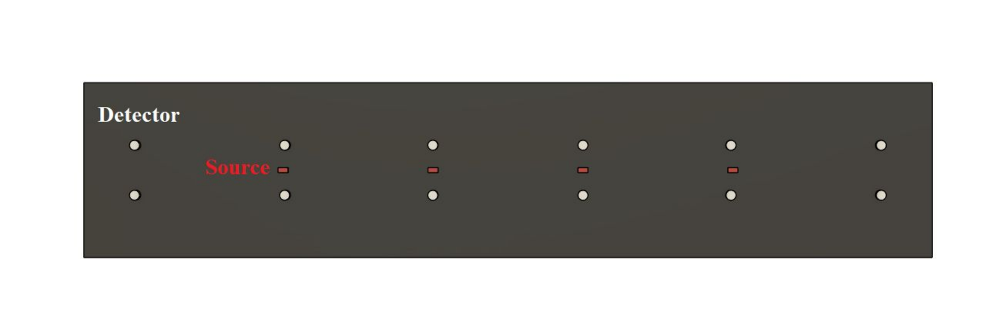
System Performance:

- 75 - 100 Samples/s
- 1 ms Latency

SWAP: Size

Created 3D model based on Source-Detector and Formfactor requirements.





SWAP: Weight

Weighed an equivalent PCB of similar size and part count and multiplied by a factor of 2.

The weight requirement is not a main concern for this project as worst-case scenarios meet the requirement by an order of magnitude.

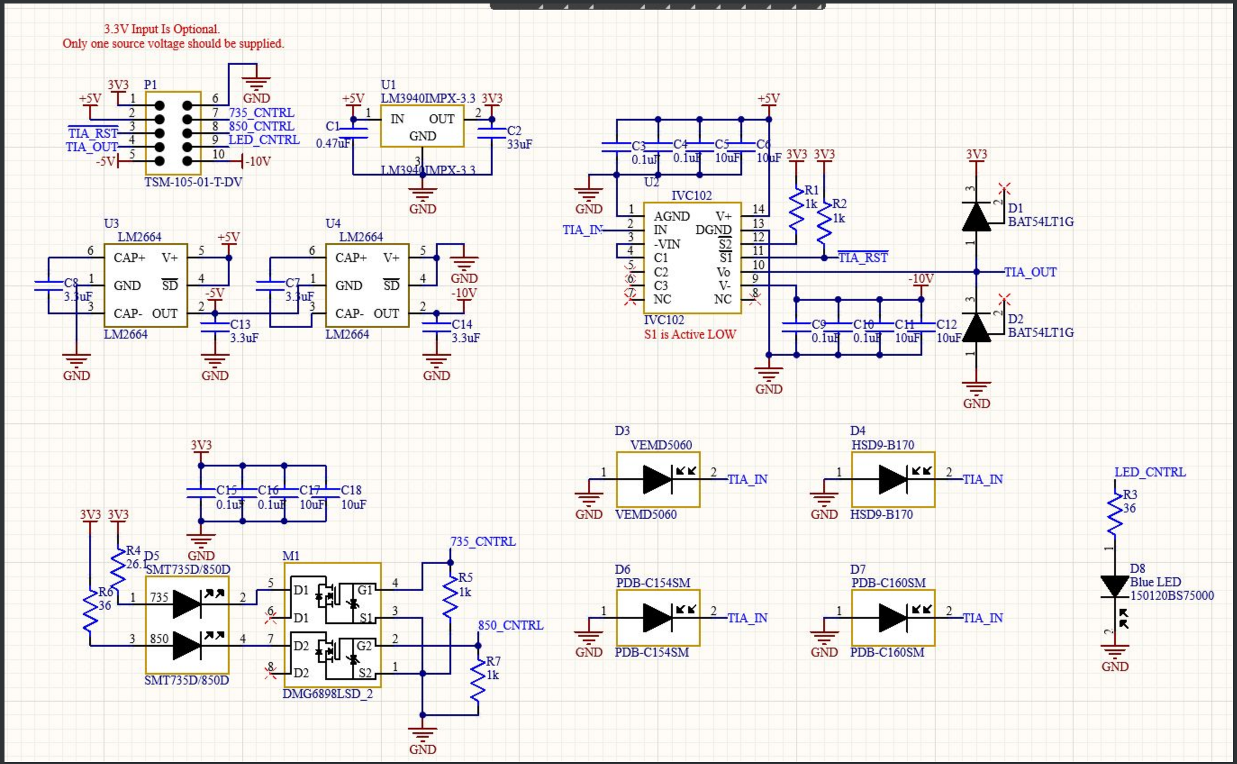
SWAP: Power

Power:

Designed a prototype and

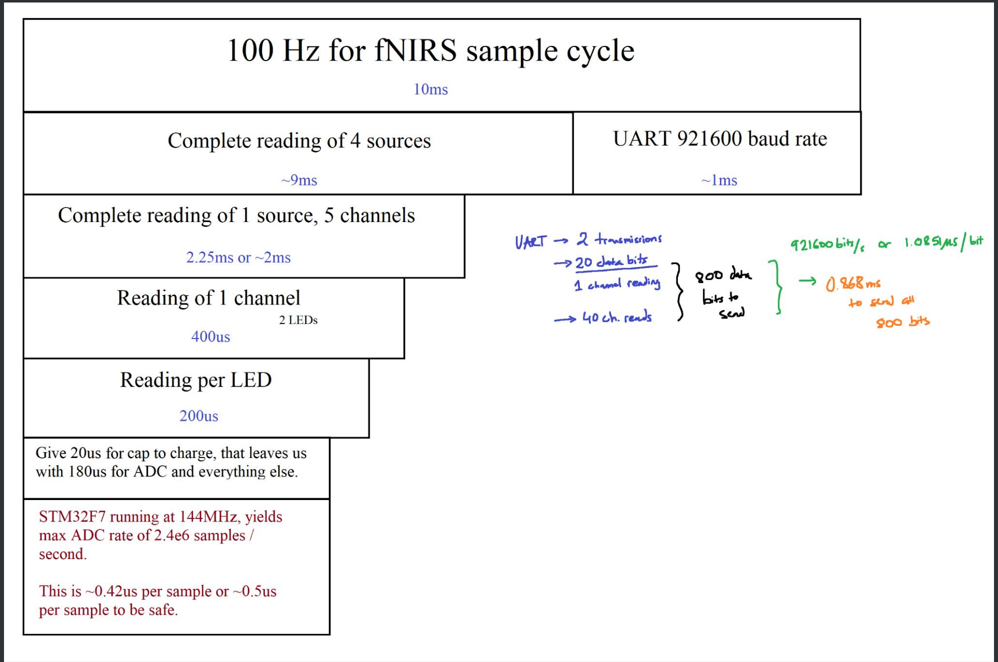
Measured the worst-case maximum power draw.

i.e. all sources on and microcontroller with all GPIOs powered.



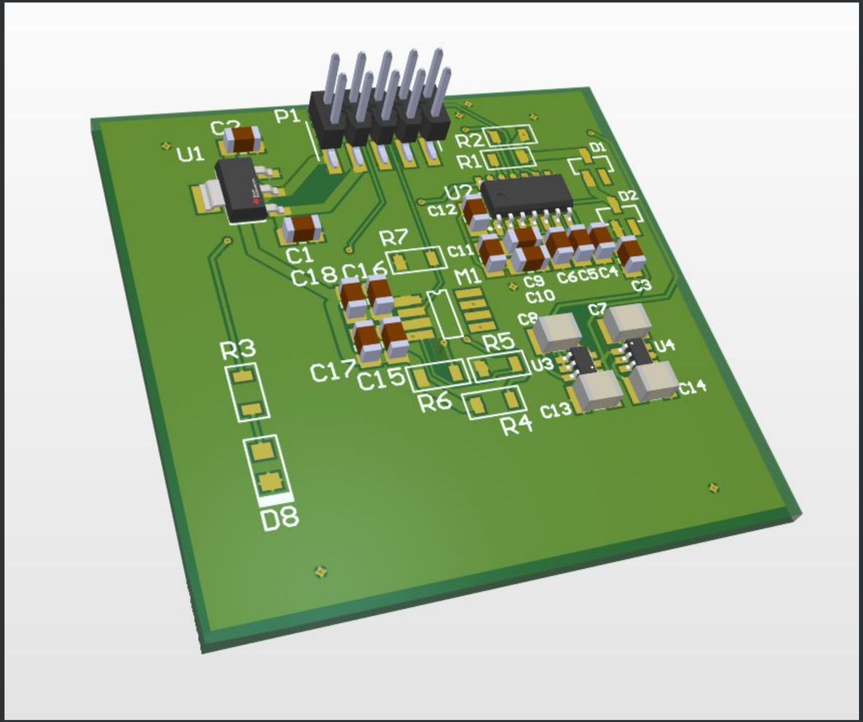
SWAP: System Performance

Performed timing analysis of system using worst-case scenario values.



Prototype Initialize/Setup Function

Designed a PCB, which will interface with a development board. Will be utilized to test proof of concept for fNIRS as well as to analyze issues in meeting timing constraints.



Technical Trade Study

Electroencephalogram vs functional Near Infrared Spectroscopy

- fNIRS has higher spatial resolution, less overhead, more lightweight and portable.

Microcontroller: STM32 vs ESP32 vs Arduino

- STM32 has higher resolution ADC, and documentation than ESP32 and Arduino.
- While inherently available in ESP32, Wireless / Bluetooth capabilities can also be integrated into the STM32 board.
- STM32FR has higher clock speed than ESP32 and Arduino.
- Arduino is made for toddlers.

Test and Integration Plans

Req#	Function	Requirement	Test Method
1.	SW	Data loss and error must be under 5% of overall data transmission.	Create test software to measure data/error rate
2.	SW	Check if the data is transmitted from the MCU to the PC at 100 Hz.	Create test software using timers to ensure sample rate is met.
3.	HW	Voltage supply ripple voltage test.	Observe supply voltage with oscilloscope to ensure low ripple.
4.	HW	Circuit must be powered by USB bus.	Connect the circuit to USB and ensure proper behavior.

Risk Analysis

The following is a list of risks and solutions if encountered.

- Critical components have long lead times or have become obsolete (eg. Dual-Wavelength IR LED)
  - Find possible drop-in replacements or re-design while ensuring equivalent performance.

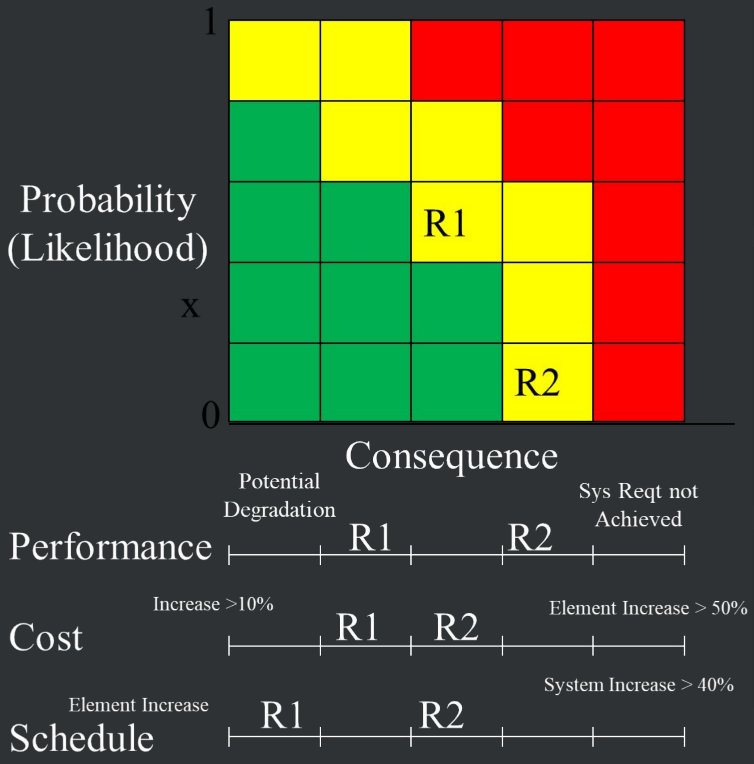
- Data sent to host PC shows significant noise
  - Readjust and tighten headset to ensure sources and detectors are contacting the skin.

- Electrical discharge to the wearer.
  - Design a quick-disconnect and fault detection to eliminate harm to the user.

Top Two Risks

R1
Critical Components Long Lead Time

R2
Electrical Discharge to the User

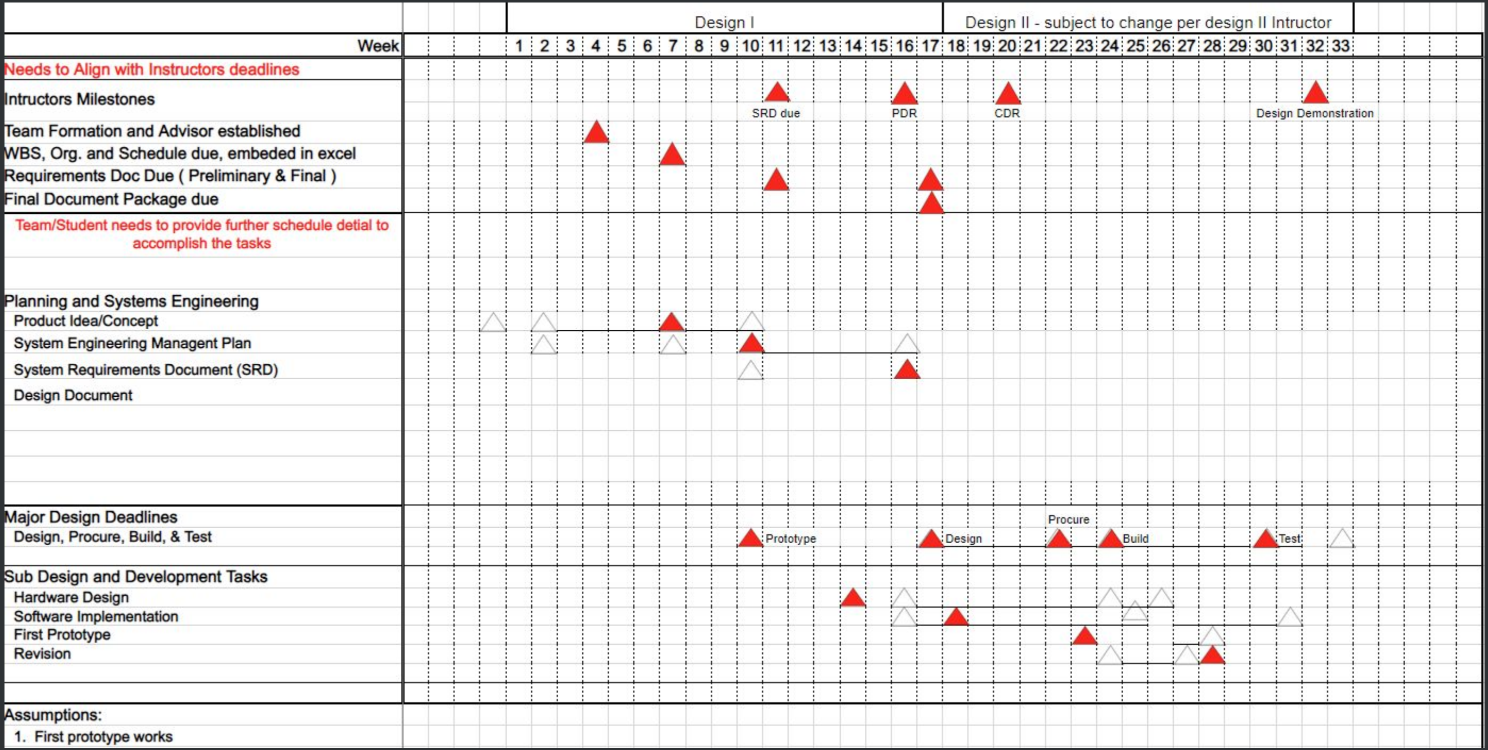


High Risk – Severe disruption expected to performance, cost, and / or schedule even with risk mitigation plans in place.

Moderate Risk –Expected disruption to performance, cost, and / or schedule can be overcome by implementing risk mitigation plans.

Low Risk – Little disruption expected to performance, cost, and / or schedule.

Preliminary Schedule



Material Cost estimate

Comment	Description	Designator	Footprint	LibRef	Quantity	Per 1	Per 10	Per 50	
0.47uF	1206	C1	CAPC3216X180N	C3216X7R2A474K160AA	1	0.48	3.18	11.72	0.48
33uF	1206	C2	CAPC3216X180N	C3216X5R1E336M160AC	1	0.98	0.73	0.669	0.98
0.1uF	1206	C3, C4, C9, C10, C15, C16	CAPC3216X180N	C1206C104K5RAC7210	6	0.1	0.067	0.0398	0.6
10uF	1206	C5, C6, C11, C12, C17, C18	CAPC3216X180N	CL31B106KOHNNWE	6	0.17	0.108	0.0756	1.02
3.3uF	1210	C7, C8, C13, C14	CAPC1210(3225)190_	C1210C335K5RAC7800	4	0.76	0.531	0.4474	3.04
BAT54LT1G	Schottky Barrier Diode,	D1, D2	BAT54LT1	BAT54L	2	0.13	0.095	0.0511	0.26
VEMD5060		D3	VEMD5060	VEMD5060	1	1.86	1.177	0.8707	1.86
HSD9-B170		D4	HSD9-B170	HSD9-B170	1	1.31	0.828	0.6129	1.31
SMT735D/850D		D5	SMT735D_850D	SMT735D/850D	1	5.45	x	x	5.45
PDB-C154SM		D6	PDB-C154SM	PDB-C154SM	1	1.81	1.208	0.9296	1.81
PDB-C160SM		D7	DS-PDB-C160SM	PDB-C160SM	1	6.24	4.412	3.6134	6.24
Blue LED	Single Color LED, Blue,	D8	150120BS75000	150120BS75000	1	0.23	0.211	0.182	0.23
DMG6898LSD_2		M1	SO-8-DMG6898LSD	DMG6898LSD_2	1	0.6	0.517	x	0.6
TSM-105-01-T-DV	0.025" SQ Post Header	P1	SAMTEC_TSM-105-01-	TSM-105-01-T-DV	1	1.11	x	0.86	1.11
1k	1206 1kOhm	R1, R2, R5, R7	R1206	RT1206BRD071KL	4	0.33	0.241	0.1868	1.32
36	1206 36 Ohm	R3, R6	R1206	RT1206BRD0736RL	2	0.33	0.241	0.1868	0.66
26.1	1206 26.1 Ohm	R4	R1206	RQ73C2B26R1BTD	1	0.93	0.653	0.4964	0.93
LM3940IMPX-3.3		U1	LM3940	LM3940IMPX-3.3	1	1.74	1.566	x	1.74
IVC102		U2	D0014A_M	IVC102	1	10.59	9.563	x	10.59
LM2664	Switched Capacitor Vo	U3, U4	LM2664	LM2664	2	0.88	0.787	x	1.76
PCB					5	$4			20
						Total:	61.99		

Review Action Items

Date Created	Originator	Description	Assignee	Original Due Date	Status	Updated Due Date	Status and Closure Comments
		SRD documents					
1/27/24	Tristan	Meet Faculty advisor	Tristan	2/6/24	**Closed**		Met with Faculty advisor and established a task.
		PDR preperation					
		Meeting to prep for PDR					
2/18/24	Tristan	WBS development	Shovan	2/18/24	**Closed**		Held a meeting and discussed roles.
		Schedule development					
		Establish Bill of material					
2/1/24	Shovan	Arrange Meeting with faculty advisor	Thang	2/6/24	**Closed**		Met with faculty advisor and established a weekly meeting schedule.
2/1/24	Shovan	Establish weekly teleconference/meeting	Thang	2/6/24	**Closed**		Met with faculty advisor and established a weekly meeting schedule.
Additional							
1/27/24	Tristan	Reach out to Dr. Ashwin and schedule a periodic meeting.	Tristan	1/27/24	**Closed**	1/27/24	Successfully reached out to Dr. Ashwin. Scheduled meeting time is every Monday at 3 PM.
1/27/24	Shovan	Research DSP techniques for FNIRS.	Shovan	1/27/24	**Closed**	1/27/24	Looked into research papers and other documentation. Wrote into Github.
1/27/24	Thang	Finish documenting the created UART system for the project.	Thang	1/27/24	**Closed**	1/27/24	Documentation of the UART system is on Github.
1/28/24	Tristan	Research LED Driving system for fNIRS systems.	Tristan	1/28/24	**Closed**	2/30/2024	Gathered sufficient information regarding LED Sensor system to begin project.
2/18/24	Tristan	Research LED sensor system (Transconductance Amplifier etc.)	Tristan	2/30/2024	**Closed**	2/30/2024	Gathered sufficient information regarding LED Sensor system to begin project.
2/18/24	Thang	Research STM32 MCU.	Thang	2/30/24	**Open**	5/1/24	There is still a lot to learn about the STM32. What is needed to know increases due to new requirements for the project being made.
3/18/24	Tristan	Research Hardware Design for STM32F7	Tristan	3/22/24	**Open**	5/2/24	
3/18/24	Tristan	Create schematic block diagram for both MCU and Source-Detector systems.	Tristan	3/22/24	**Closed**	3/22/24	Completed block diagram.
3/18/24	Thang	Research the ADC on the STM32F7 board.	Thang, Tristan, Shovan	4/18/24	**Open**	4/18/24	Have yet to start.
3/18/24	Thang	Research how to implement RTOS.	Thang, Shovan, Tristan	5/2/24	**Open**	5/2/24	Currently in progress.
3/18/24	Shovan	Research flexible PCB	Shovan, Tristan	3/22/24	**Open**	5/2/24	In progress
3/18/24	Shovan	Research flexible material for headband	Shovan, Tristan	4/8/24	**Open**	5/2/24	In progress
4/1/24	Tristan	Create Prototype PCB with a single channel	Tristan	4/8/24	**Open**	4/8/24	In progress
4/14/24	Thang	Start setting up skeleton structure for RTOS on STM32F7 board.	Thang	6/2/24	**Open**		In progress
4/14/24	Thang	Start developing the firmware for the MCU on the headset.	Thang	8/1/24	**Open**		In progress