Precise Onset Cell Phone Vibration Detection

Technical Deep Dive Presentation

National Center for Adaptive Neurotechnologies (NCAN)

Muhammed Shuaib, Md. Sadman Kabir, Daniel Brown, Nasser AL-Maskari

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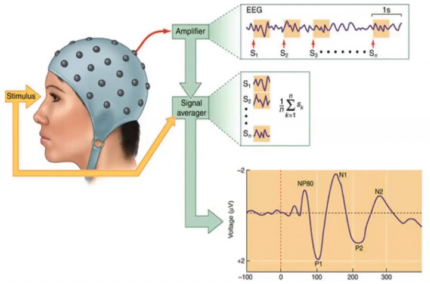
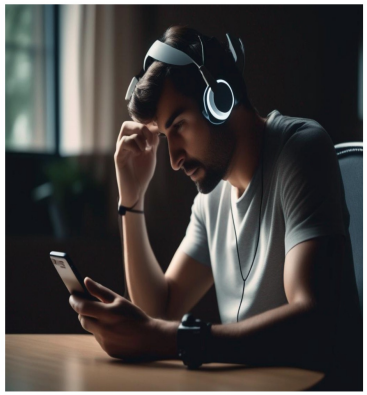
COLLEGE OF
NANOTECHNOLOGY,
SCIENCE, AND ENGINEERING
UNIVERSITY AT ALBANY | STATE UNIVERSITY OF NEW YORK

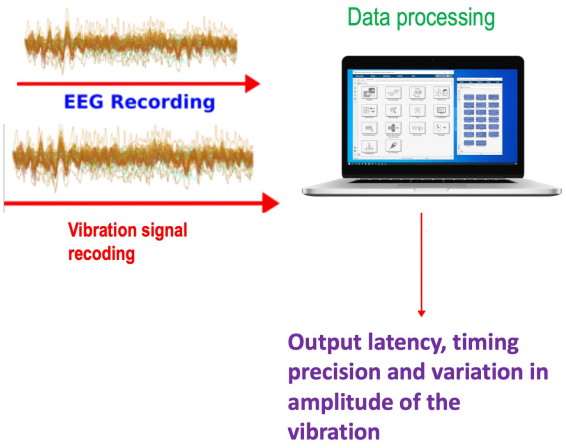
Introduction

- Brain and spinal cord injury lead to somatosensory impairments such as loss of sense of touch, there are limited methods available to improve and test during the rehabilitation of these impairments.

- There is a need for a portable device for precise detection of stimulus onset on a large group.







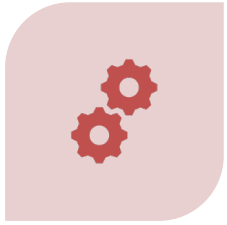
Background and Context

NCAN's senior scientists, Dr. Hill and Dr. Gupta, require us to build a high-precision, low-latency, affordable device for detecting Vibration Onset with 5ms accuracy

Image Source: NCAN website
(https://www.neurotechcenter.org/)

Agenda

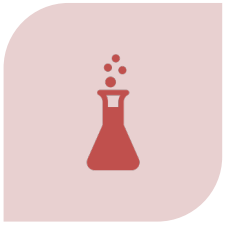
PROBLEM STATEMENT & REQUIREMENTS



DESIGN METHODOLOGY

PHYSICAL DESIGN & LOGICAL DESIGN

SYSTEM DEMONSTRATION



EXPERIMENT DESIGN

EXPERIMENT RESULTS

DATA & ANALYSIS

Problem Statement

To build a System That Detects Cell Phone Vibration within a 5ms Latency Using Hardware

*Software Solutions are **unreliable**.*

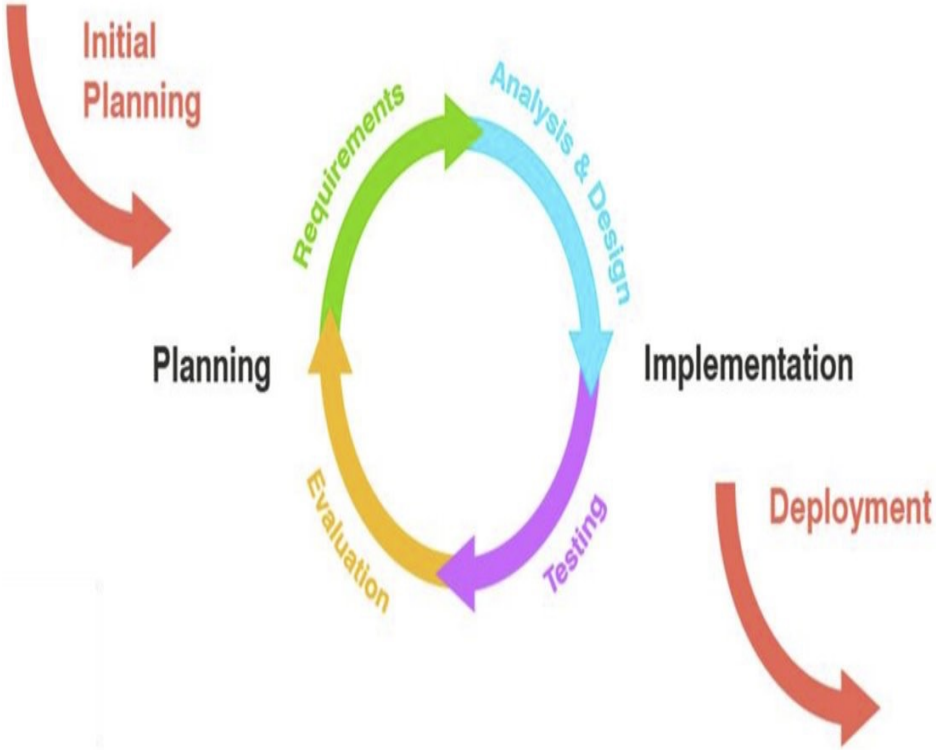
Key System Requirements

Functional Requirements	Non-functional Requirements.
• Vibration Detection • Latency of less than 5ms • TTL output: The System must output a TTL high Signal	• Under 100$ • Hardware Based • Require NO alterations to the phone • Detector must be easy to hold.

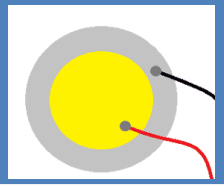
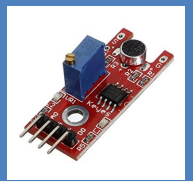
- Our System Requirements were chosen to ensure a balance between performance, Budget, and Usability.

Methodology

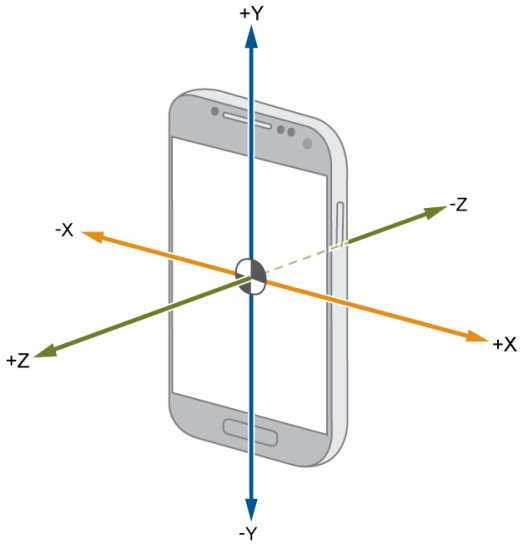
- We used an iterative process. We are currently on the third loop.
- Tested a Piezo sensor, an Accelerometer, and a Microphone
- After evaluation, we chose to use a Piezo Sensor.
- We used BCI2000, a software library developed by Dr. Hill for real time signal viewing and used Matlab for signal processing to find our final experimental results.



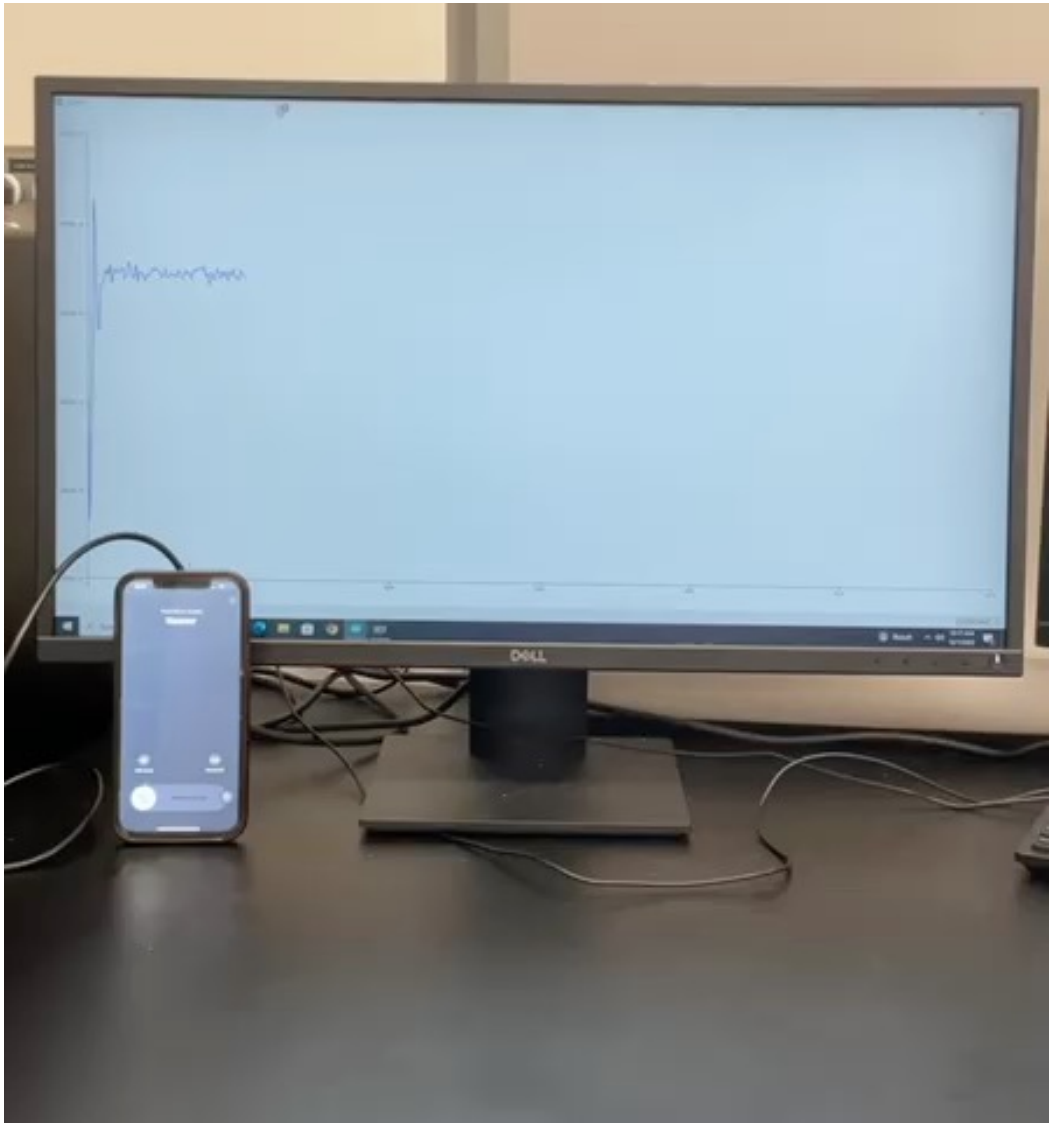
Decision matrix PIEZO vs Accelerometer vs Microphone

Criteria	Piezo 	Accelerometer 	Microphone 
Accuracy	Excellent	Good	Poor
Sensitivity	Excellent	Excellent	Poor
cost	Excellent	Good	Excellent
Durability	Good	Excellent	Good
Size	Good	Good	Good

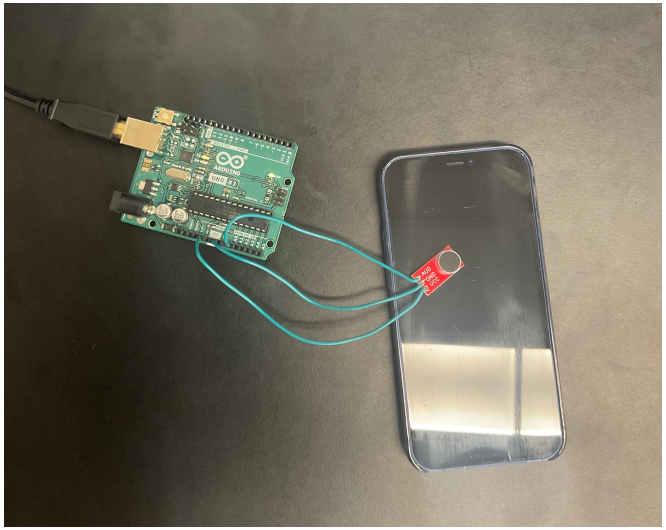
Accelerometer

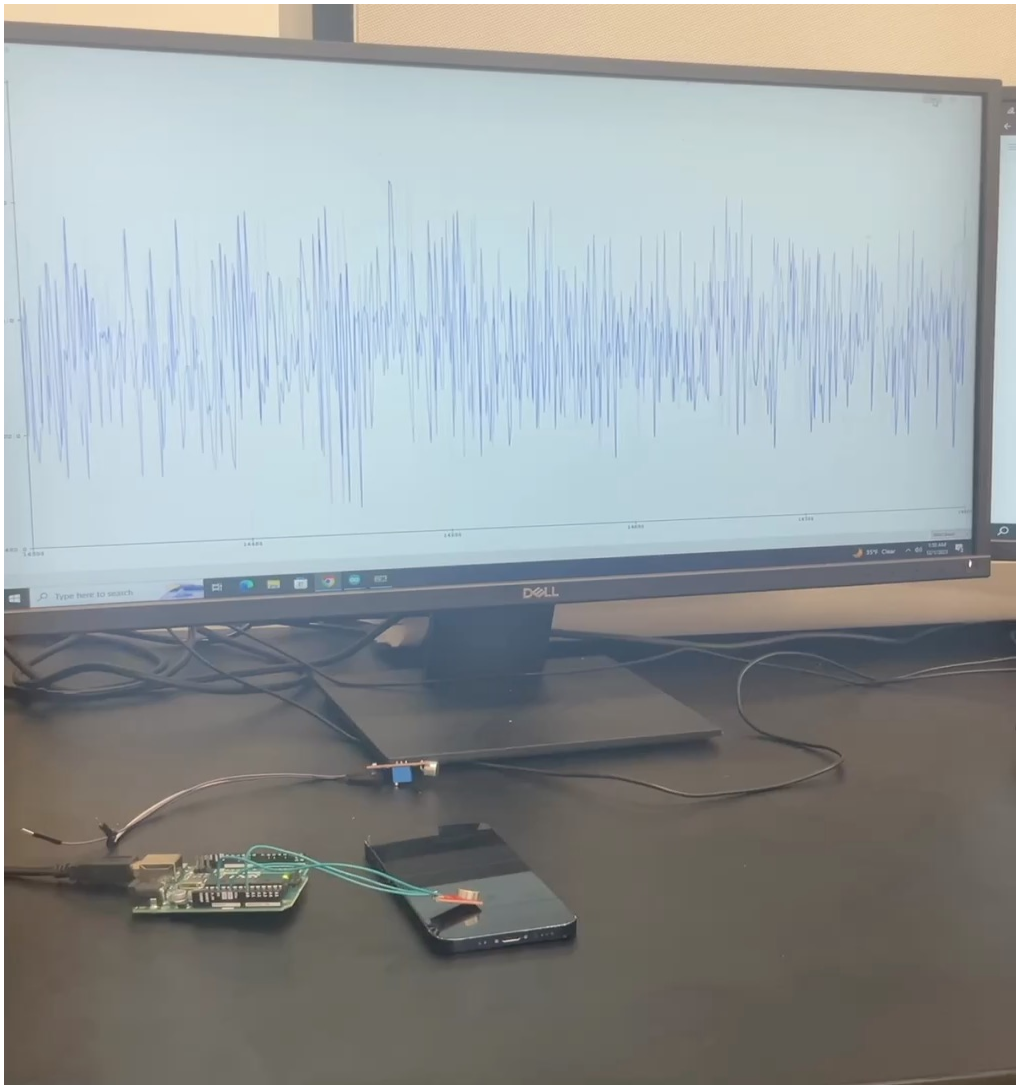


Accelerometers are positioned to detect motion and vibrations along different axes (typically x, y, and z). It measures the acceleration of forces

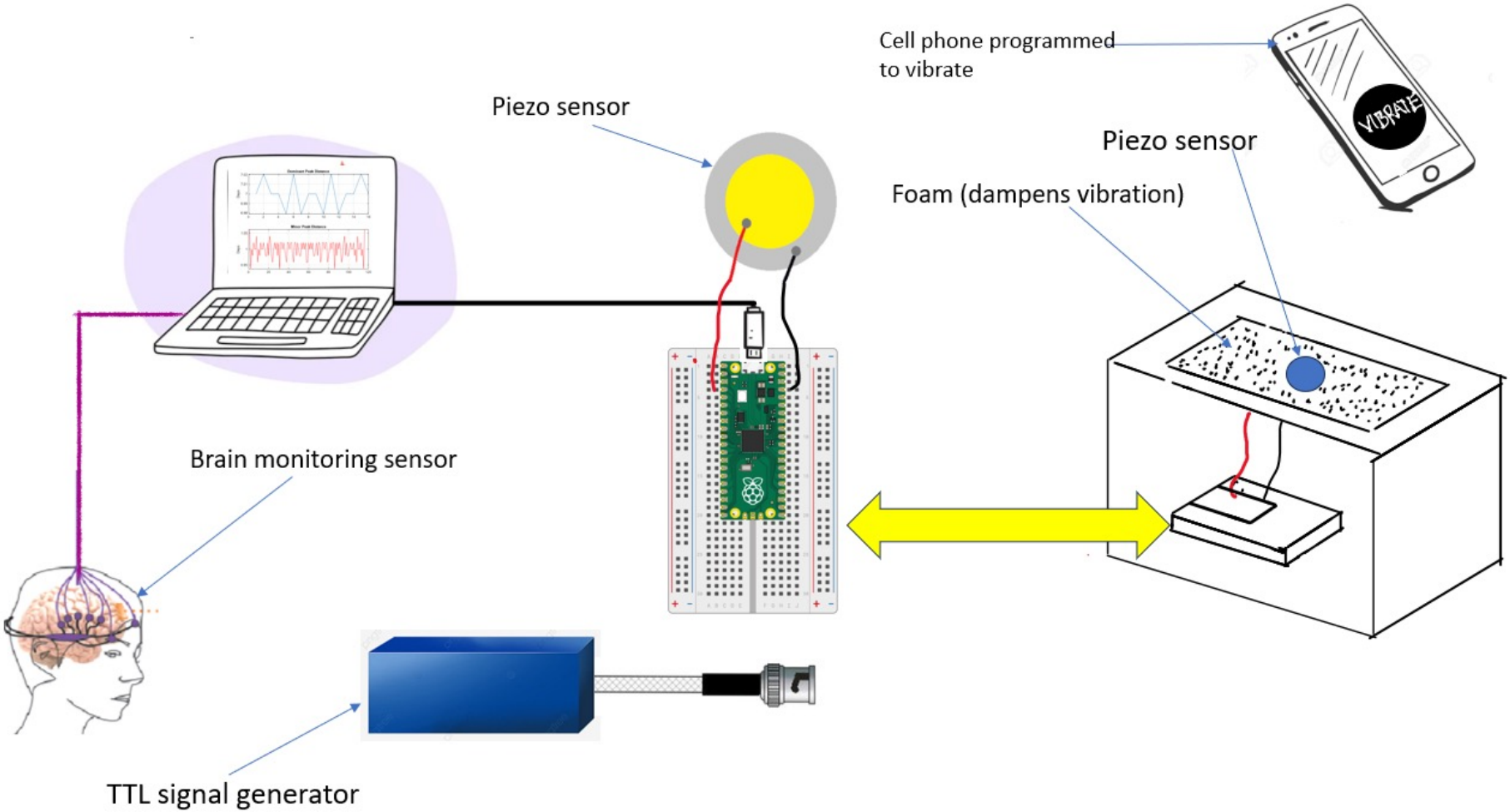


Microphone

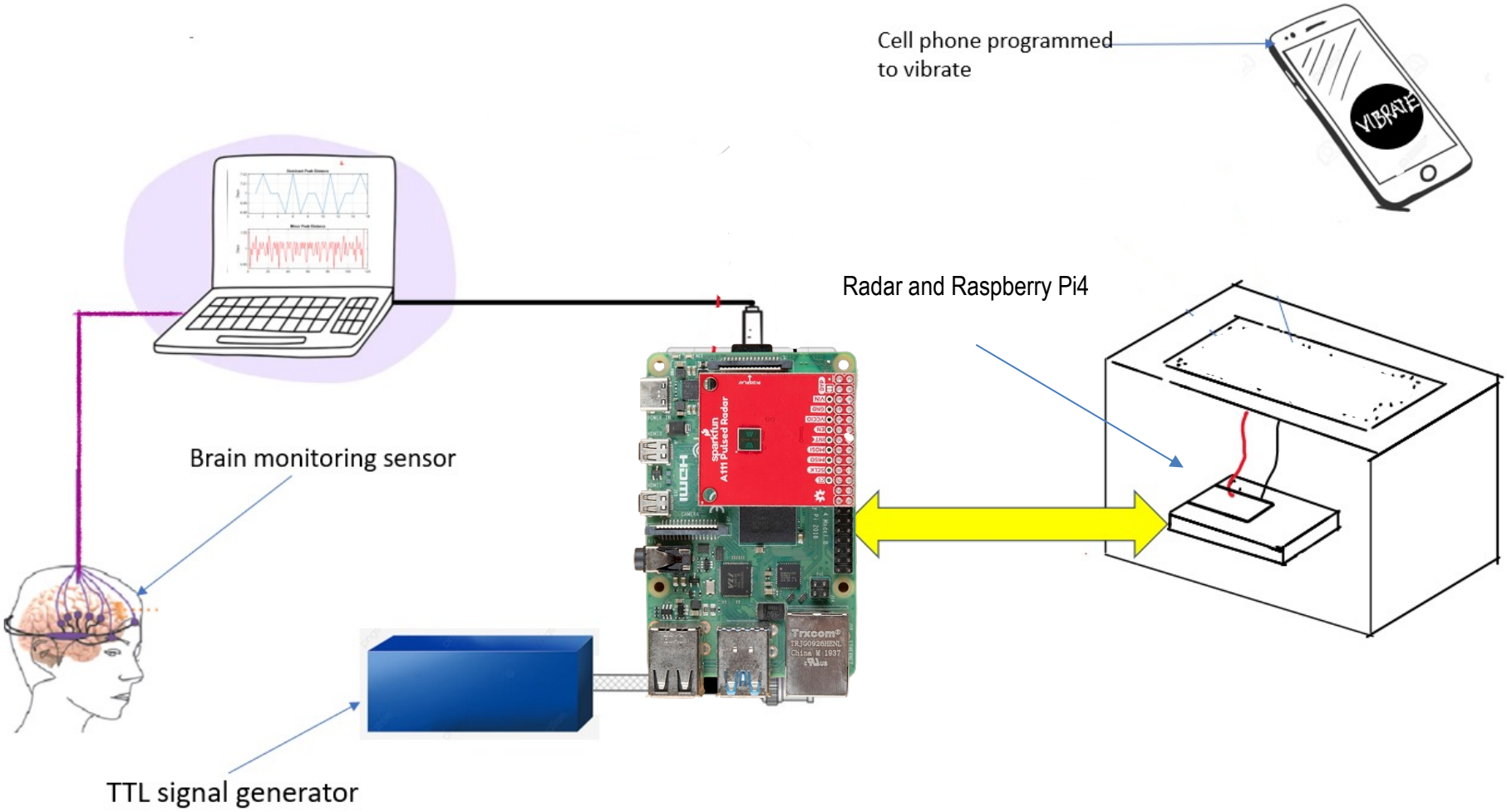


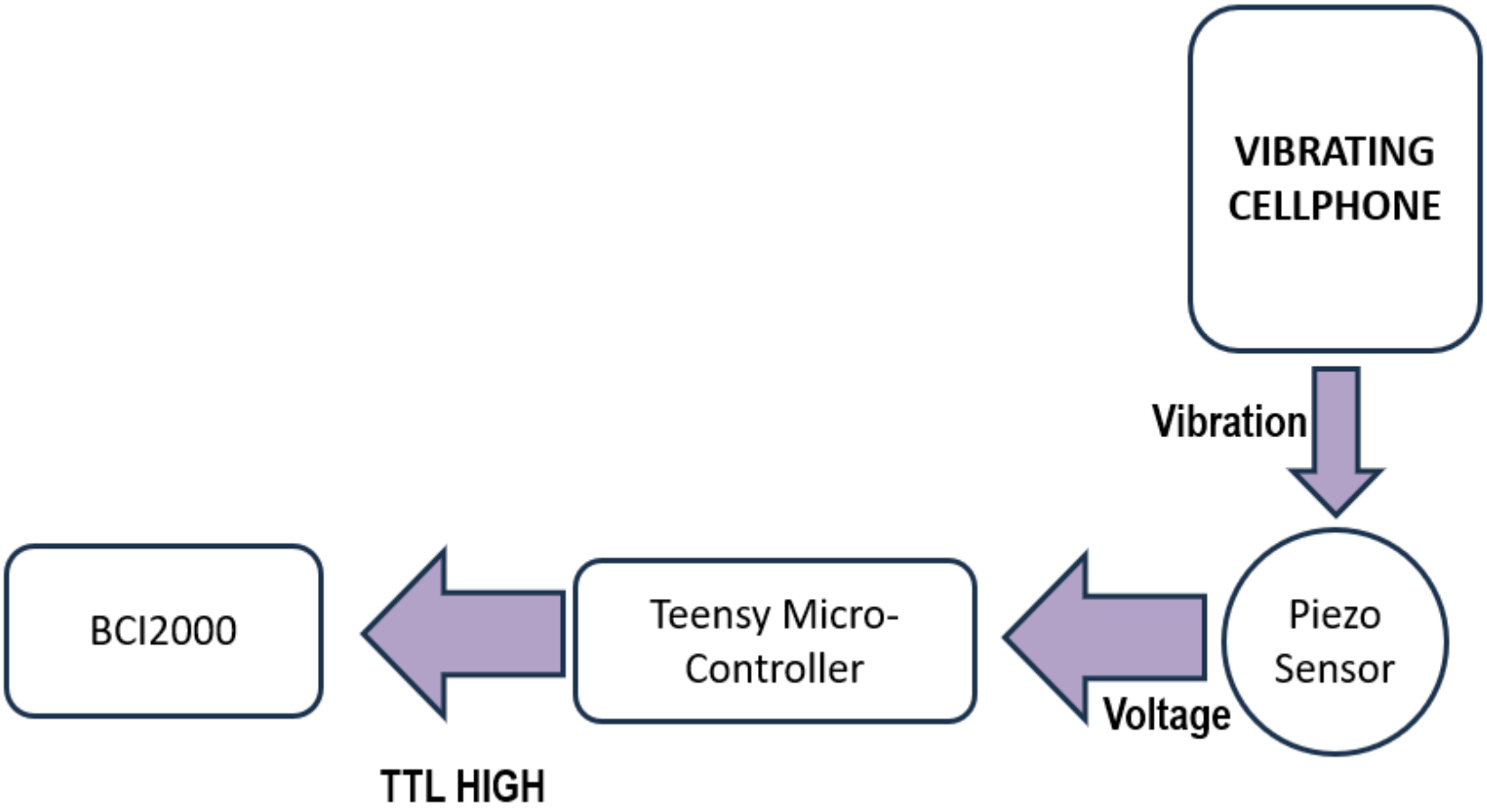


Logical Design

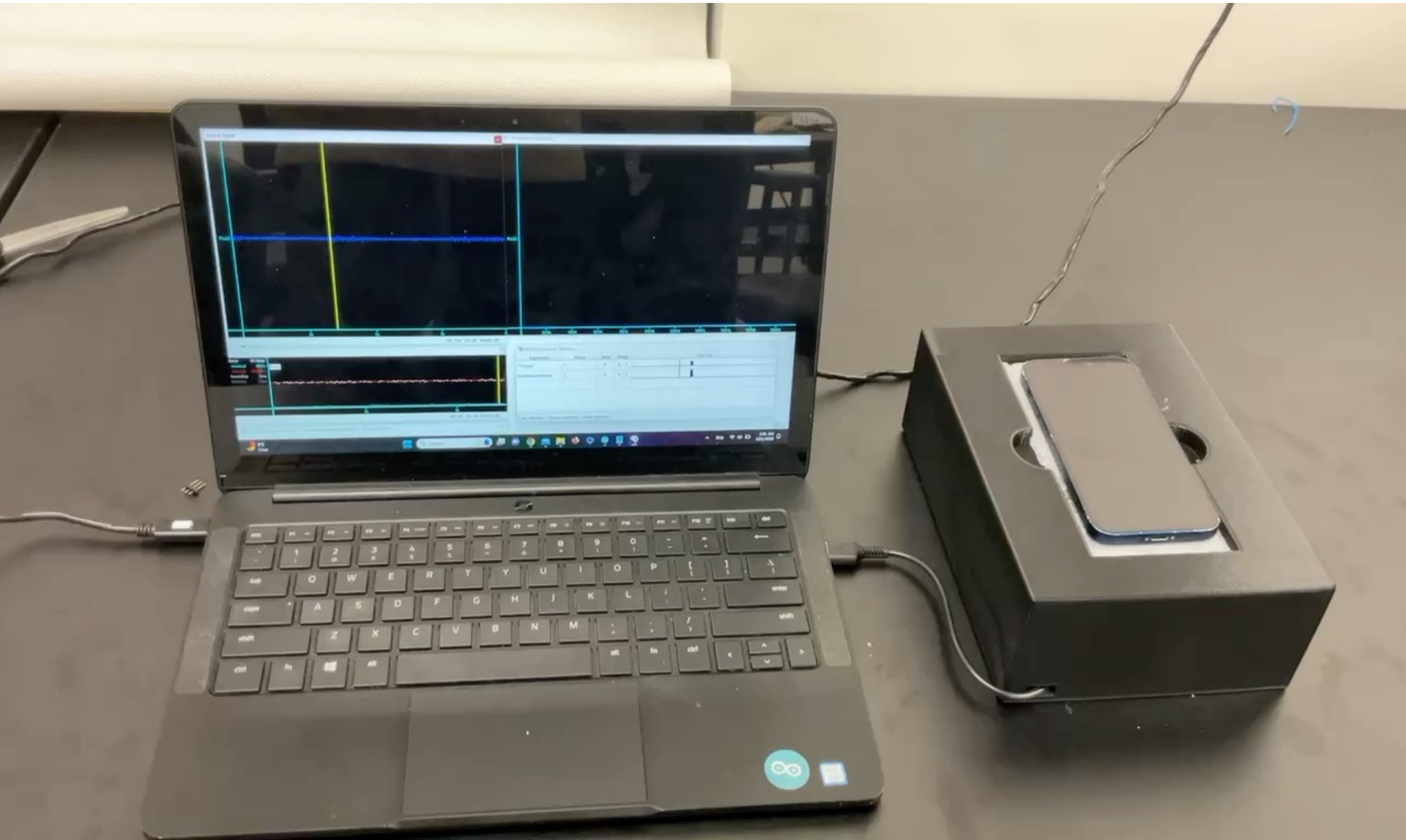


Logical Design

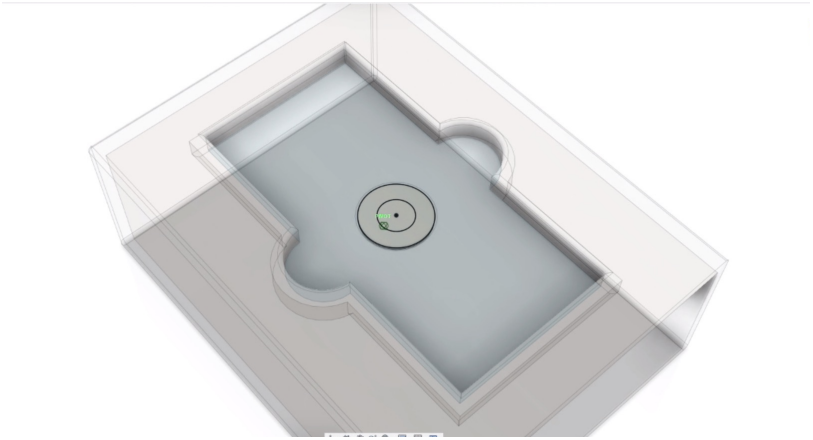


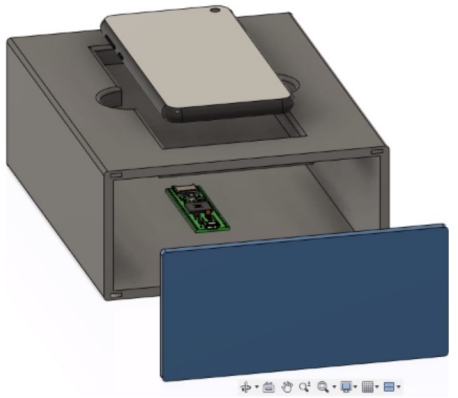

VIBRATING CELLPHONE
Vibration
Piezo Sensor
Voltage
Teensy Micro-Controller
TTL HIGH
BCI2000

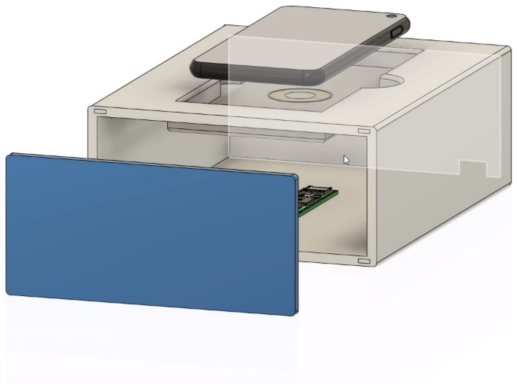
System demo

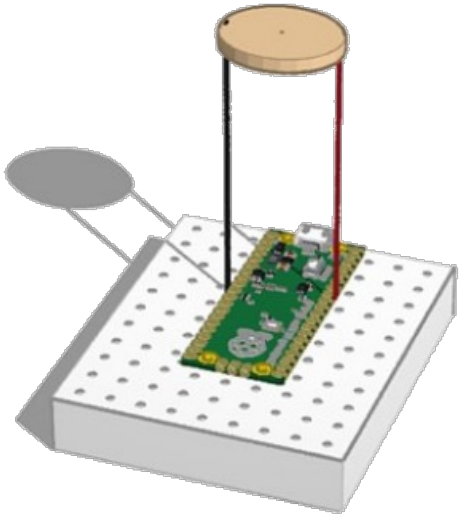


Physical Design









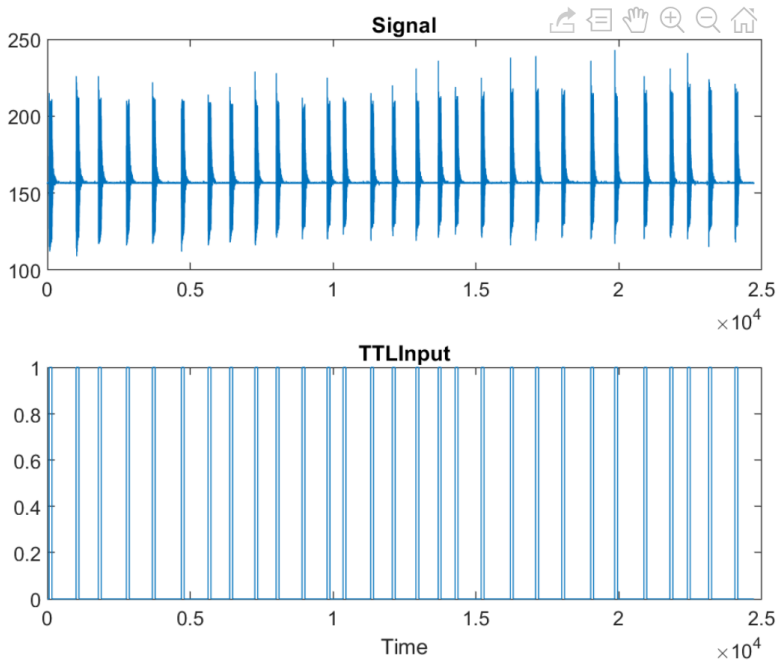
Decision matrix: Teensy vs Raspberry Pi Pico

Criteria	Teensy	Raspberry Pi Pico
Processing Power	High processing power with powerful cores.	Dual-core processor, suitable for many projects.
Speed and Performance	Offers high-speed processing.	Good performance for general embedded applications.
Community Support	Good community support and compatibility with Arduino.	Growing community support with official MicroPython support.
Ease of Use	Compatible with Arduino IDE, but may have a steeper learning curve.	Beginner-friendly with MicroPython support.
Cost	Higher cost compared to Raspberry Pi Pico.	Generally cost-effective, suitable for budgets.

We chose Teensy for our project because we require high-speed processing and extensive capabilities. And, based on our experiment results with the Piezo in different orientations with the both of them, Teensy is a far better option for us.

Data and Results

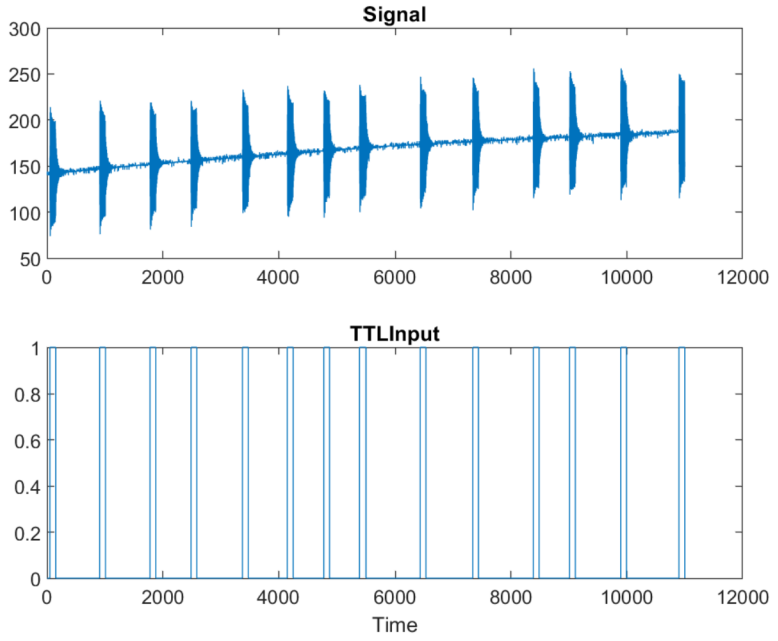
sensor down




```
Mean Latency: 6.137931, Jitter (standard deviation): 1.216674
```

Latency: 6.138 Jitter: 1.2166

sensor taped

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Mean Latency: 4.642857, Jitter (standard deviation): 1.691933
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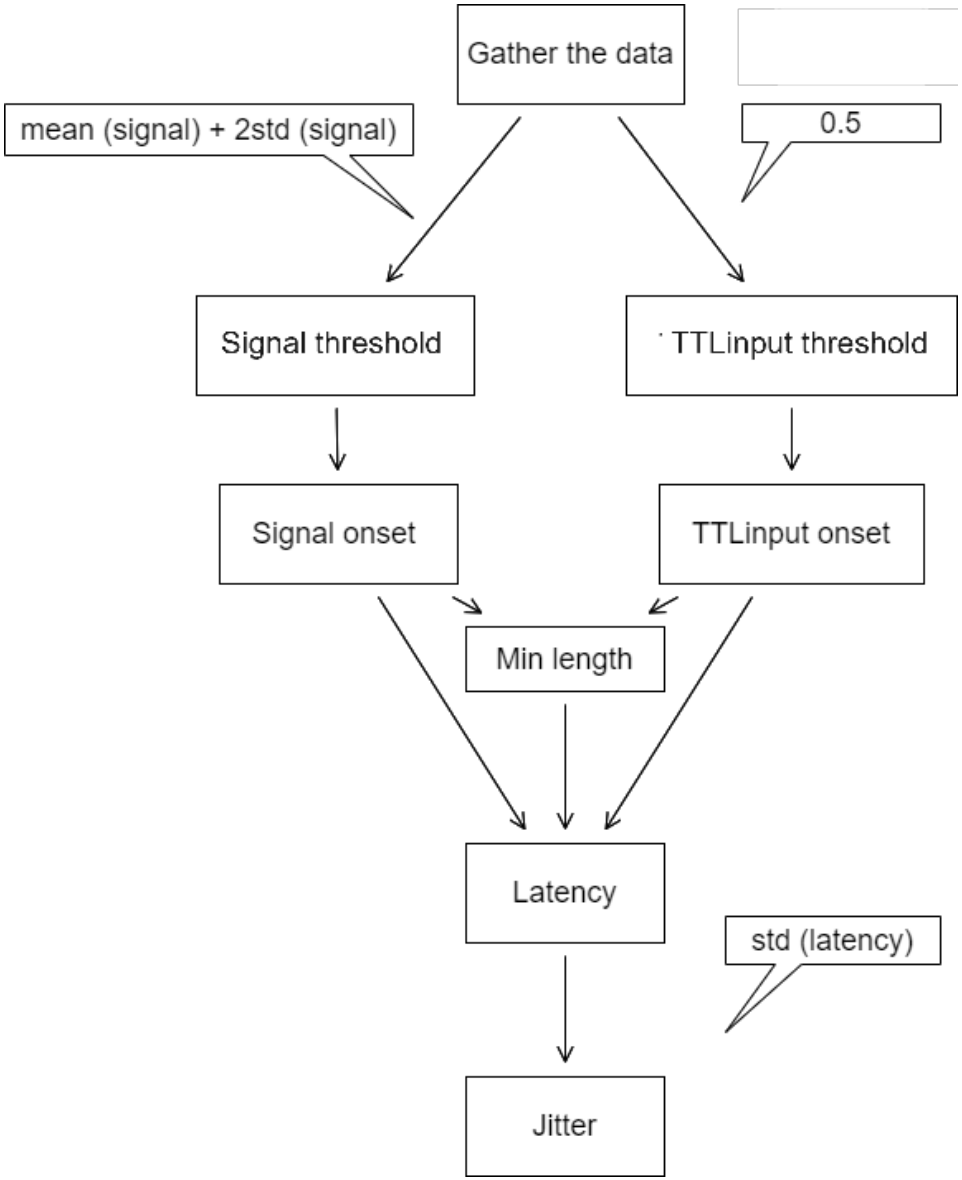
Latency: 4.648 Jitter: 1.6919

Flow Chart of MATLAB Functions



Project Limitations

Research Vacuum

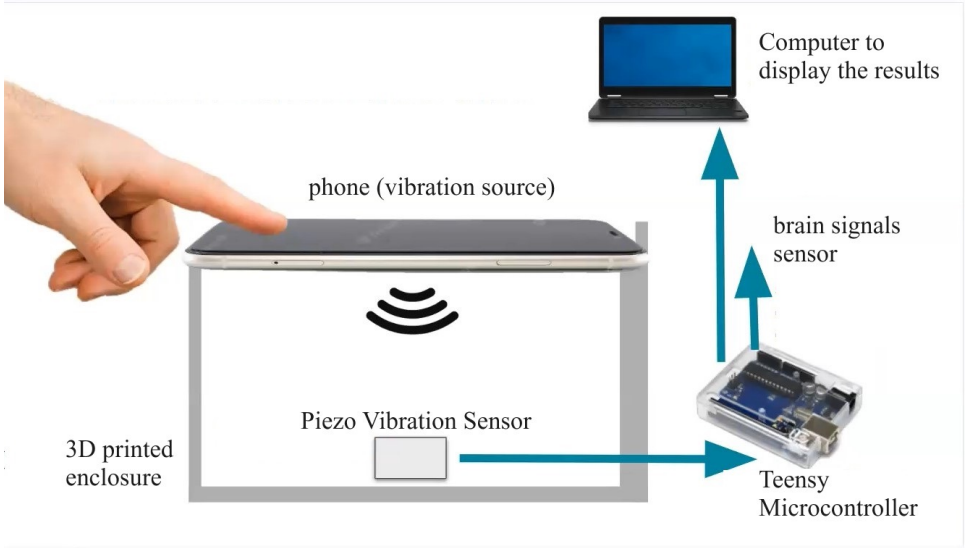
Lack of pre-established frameworks and detailed project specifications necessitated extensive research. Initial project progress was delayed as the team invested significant time understanding the problem domain, relevant technologies, potential solutions and experimentation.

Time Crunch

Strict deadlines necessitated a rapid pace for research, development, and implementation. Due to that we had limited time for in-depth exploration, potentially compromising the thoroughness of research and the depth of project outcomes.

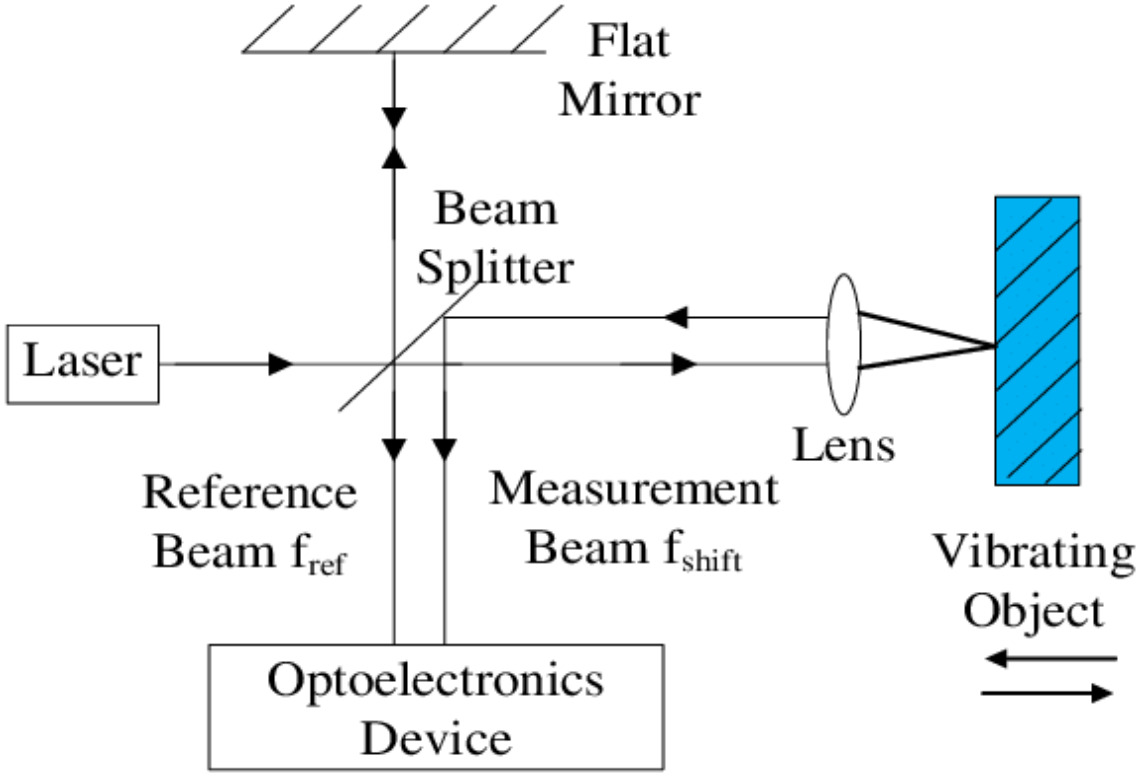
Recommendations for Future Work

- Research how Finger pressure can dampen the signal given by the piezo.



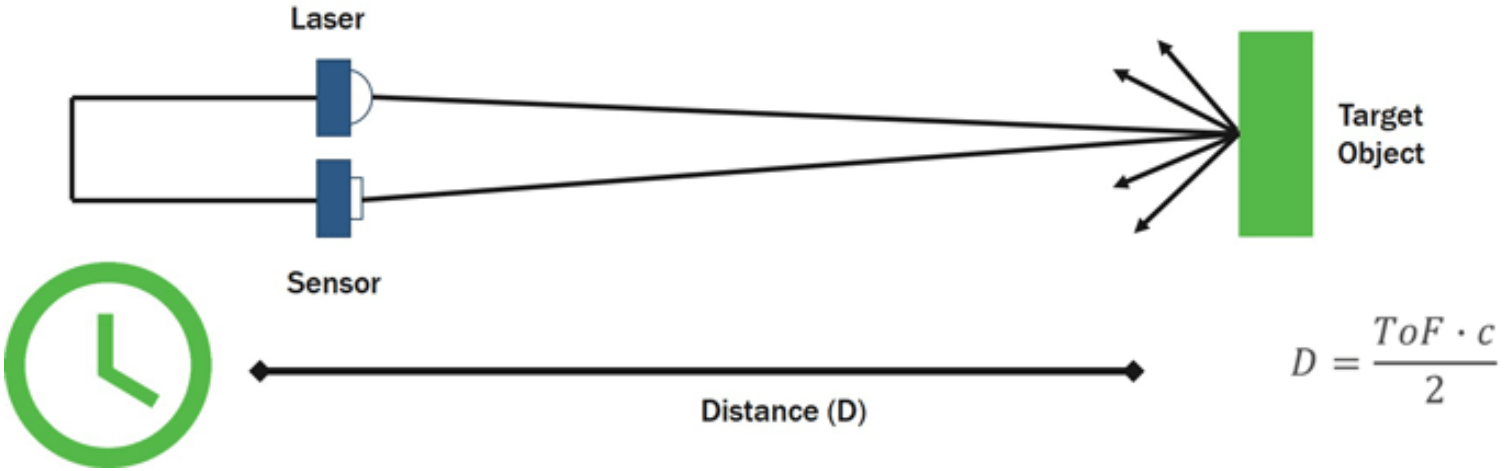
Recommendations for Future Work

- Transition to a contactless solution using **Laser Doppler Detection**



Recommendations for Future Work

- Transitioning to a contactless solution using **RADAR**
- Implement current System with **RADAR replacing Piezo**



Conclusions

- Piezo detection: **1.6ms Jitter**, **4.6ms Latency**
- Goal: <5ms Latency.

As defined earlier, a sub 5ms Latency is considered **Instantaneous to the human perception.**

- We have Shown that the Piezo can be considered both **Precise and Accurate.**
- We have Printed and mounted the Box unto the cell phone and Piezo Sensor.

Individual Contributions

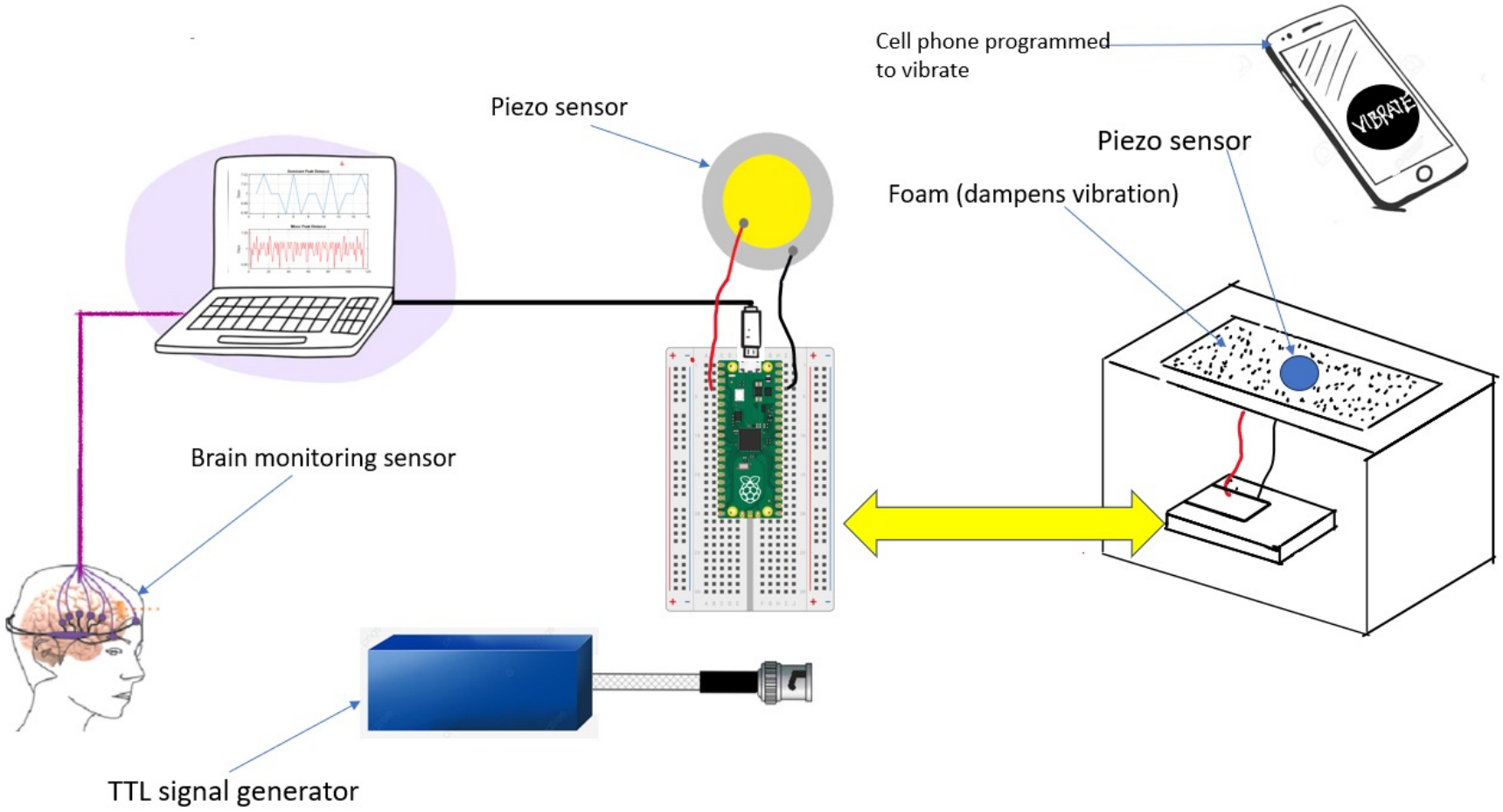
- **Muhammed Shuaib**
  - Support Roles: Point of contact, Scheduler
  - Most Significant Contributions: Designing logical design diagram, Accelerometer research and implementation. Experimentation.

- **Md. Sadman Kabir**
  - Support Roles: Editor
  - Most Significant Contributions: 3D Design of the prototype and printing, Research, Teensy experiments with the Piezo.

- **Daniel Brown**
  - Support Roles: Archivist
  - Most Significant Contributions: Piezo and future implementation research. Raspberry Pi Pico experiments with the Piezo.

- **Nasser AL-Maskari**
  - Support Roles: Treasurer
  - Most Significant Contributions: Data and result implementation, MATLAB signal acquisition, Experimentation.

Questions


Cell phone programmed to vibrate
Piezo sensor
Piezo sensor
Foam (dampens vibration)
Brain monitoring sensor
TTL signal generator