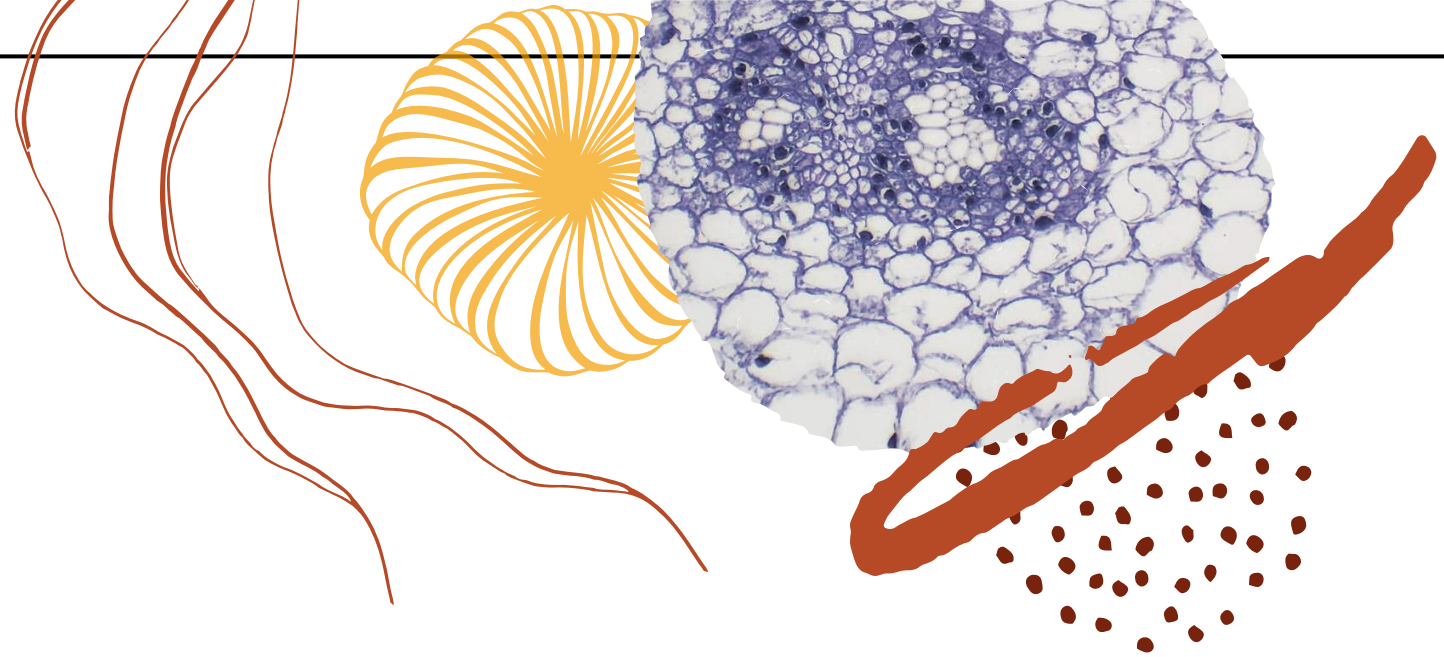
Kate Endersby, Claire Haas, Reza Choudhury, Max Tanruther

Agenda

- Design Problem and Context
- Requirements
- Overview of Collaboration Process
- Software Design
- Hardware Design
- Software Prototyping & Testing
- Hardware Prototyping & Testing



Problem & Context

Problem

Design a system to read biomedical signals for use in BME 3500 - Bioinstrumentation class

Be able to hook up sensors and see a live graph

Used by biomedical students, professors, and TAs

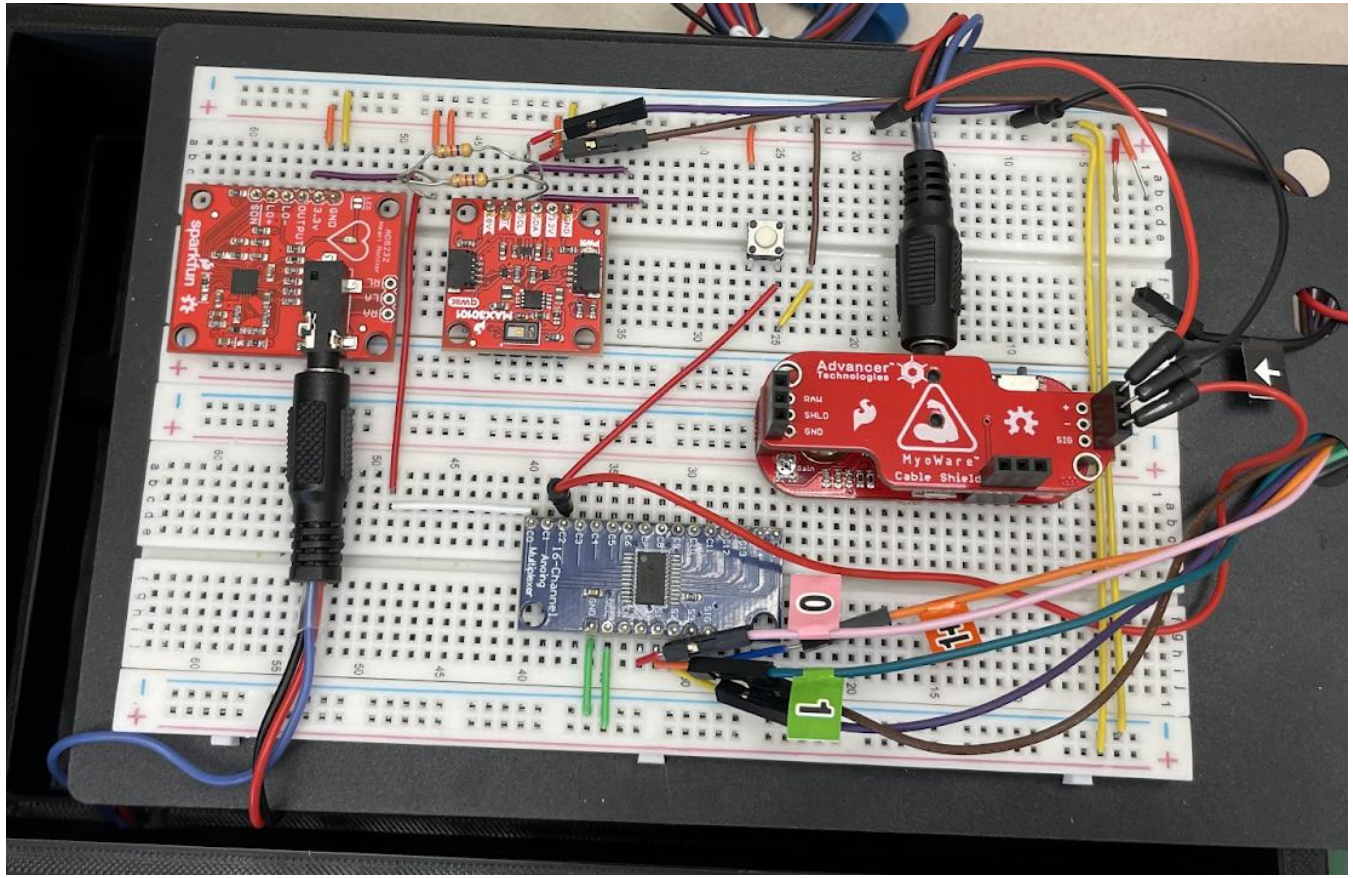
BIOPAC

- Expensive
- Cannot see hardware components
- Already been used by BME students

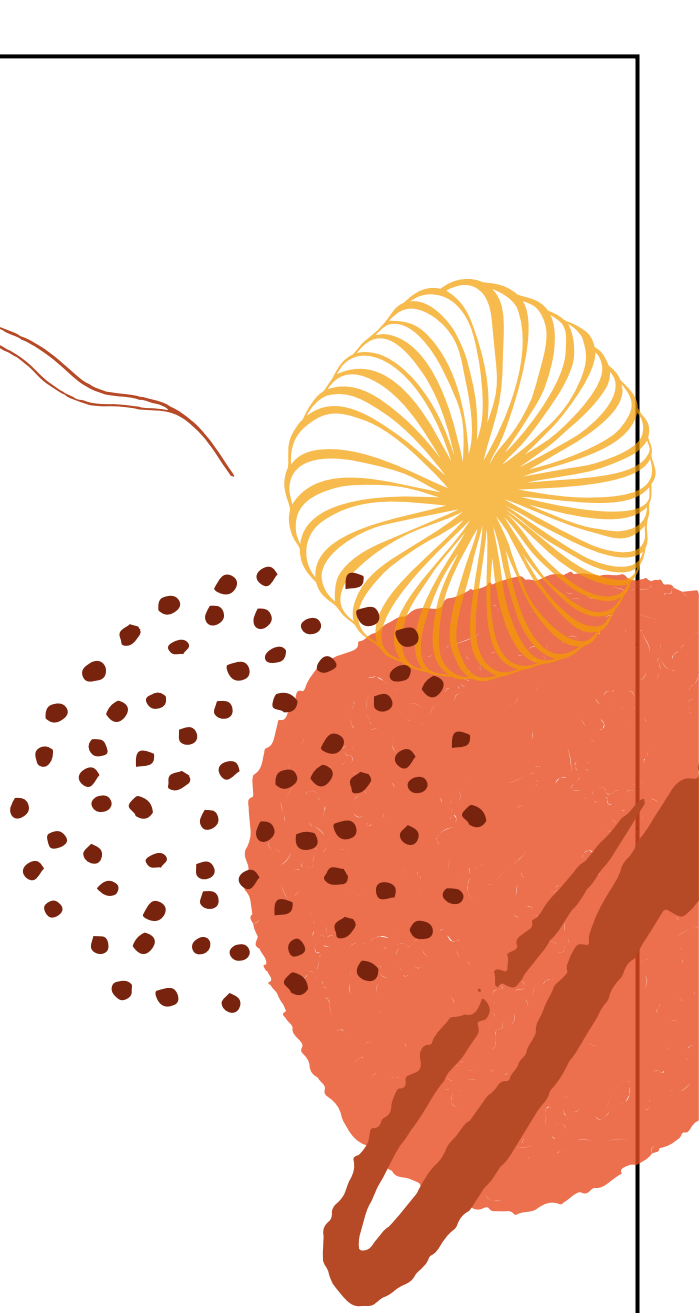
BIOPAC Module [1]

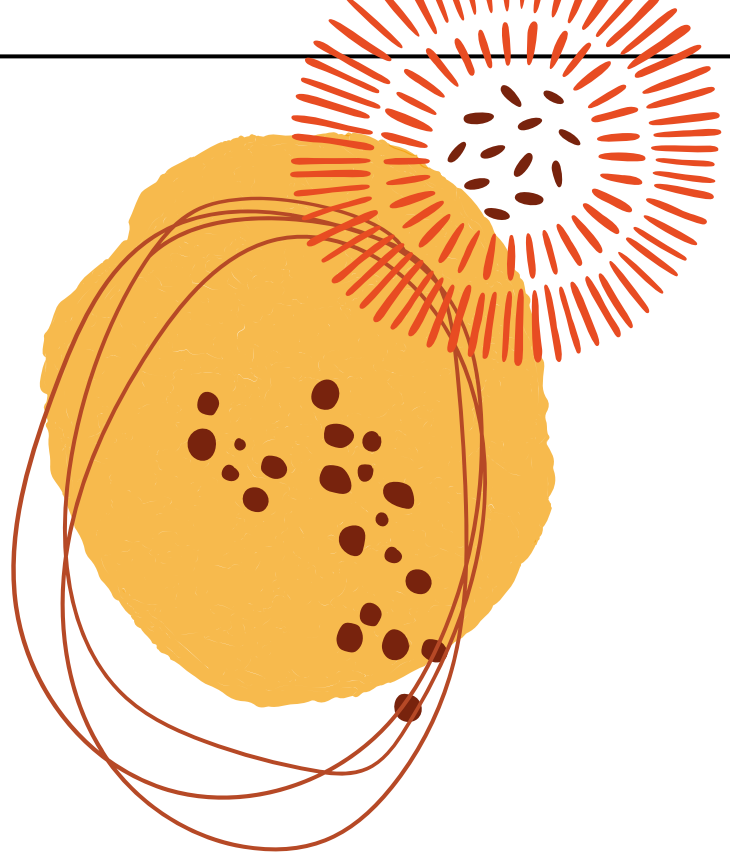
Previous Senior Design

- 4/6 sensors
- Breadboard
- Basic GUI



Requirements





Requirements

Project Goal

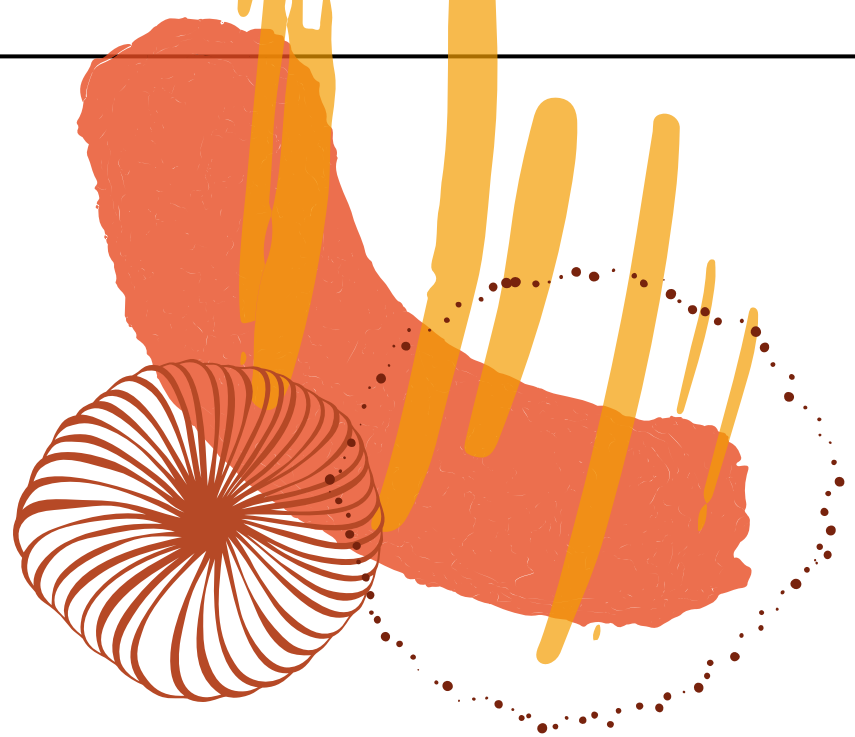
- Classroom-ready kit for BME 3500
- Real-time data collection
- Hands-on learning

Key User Groups

- Students
- TAs (easy troubleshooting)
- Professors

Sensors

- Electrocardiogram (ECG): For heart
- Electromyography (EMG): For muscles
- Pulse Oximeter Sensor: For blood oxygen
- Respiratory Band: For breathing
- Reaction Time Sensor: For reflexes
- Blood Pressure Cuff



CyVital

CyVital

Biomedical Monitor

- **Reaction Time**
  Response Test
- **Respiratory Effort**
  Thoracic Belt
- **ECG**
  Electrocardiogram
- **EMG**
  Electromyography
- **Pulse Oximeter**
  Blood Oxygen

Live Monitoring

Respiratory Effort Monitor

Real-time thoracic belt analysis

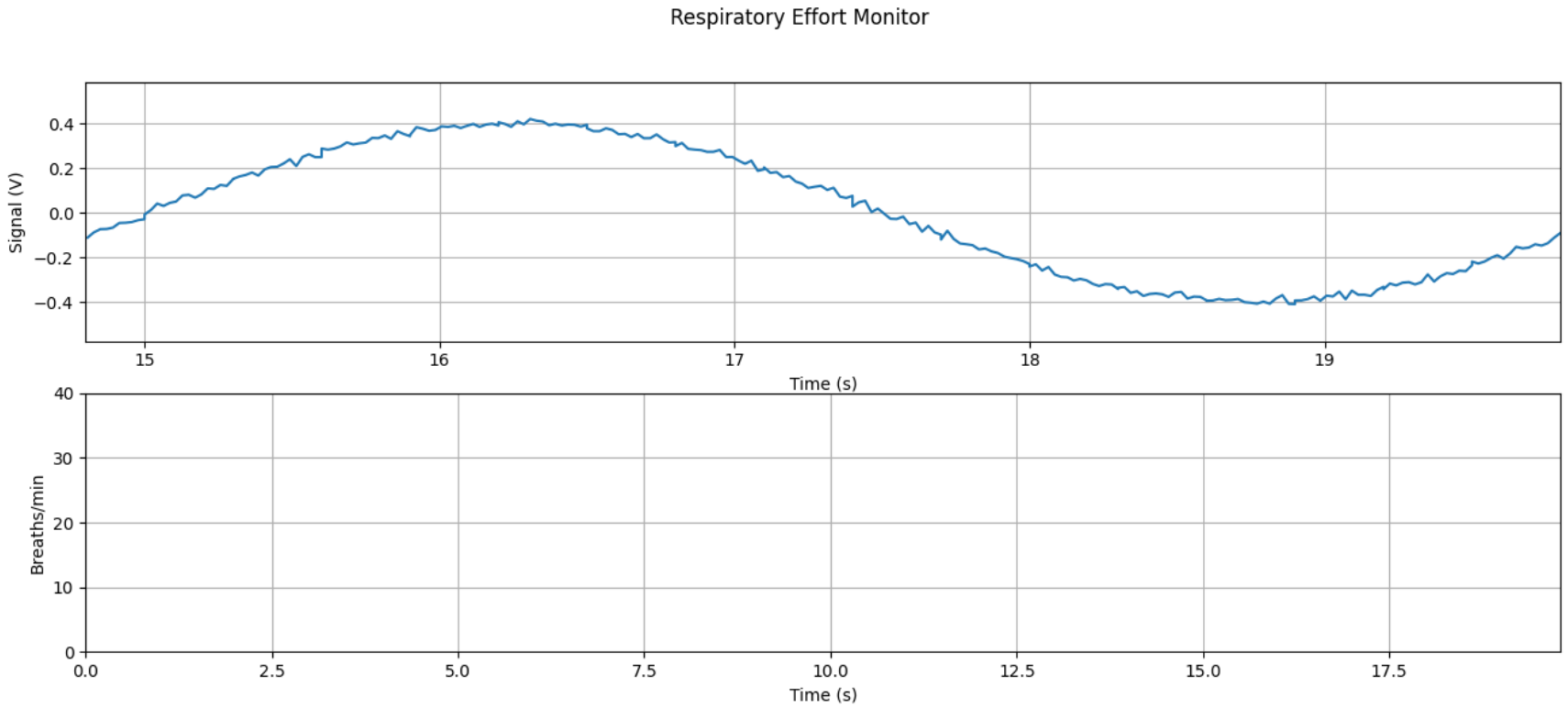
Paused | Resume | ◂ | ▸

Respirations/min

312.2 BrPM

Effort Range

0.831 V Δ



Breaths detected in last 60s: 101

Last updated 2s ago

Export CSV

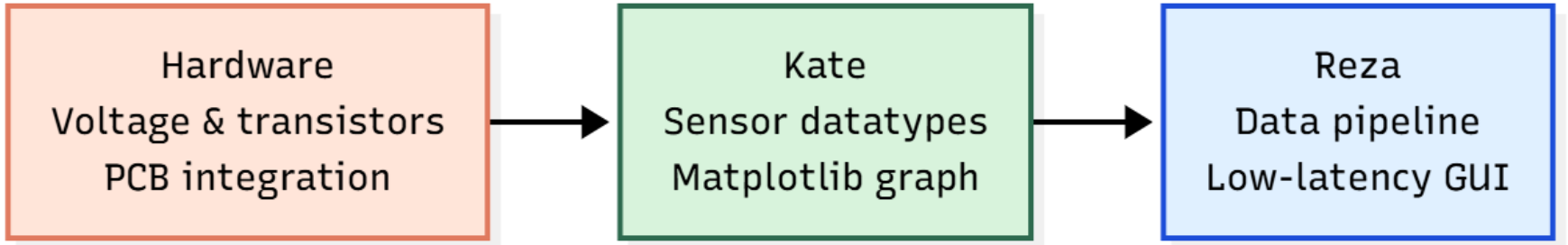
Overview of Design and Collaboration Process

Software Collab

Kate
- Kate -> Reza: sensors were shipped and ready for polishing
- Kate -> Claire: Direct sensor developing

Reza
- Data streaming, data pts/sec (improving latency)
  Reza -> Kate: Modular GUI
  Reza -> Claire GUI x PCB scope correct

TASK TITLE	TASK OWNER	PCT OF TASK COMPLETE	PHASE ONE - Design							PHASE TWO - Development							PHASE THREE - Testing		PHASE FOUR - Iteration				
			September					October				November					December		Next Semester				
			Sept 1	Sept 7	Sept 14	Sept 21	Sept 28	Oct 5	Oct 12	Oct 19	Oct 26	Nov 2	Nov 9	Nov 16	Nov 23	Nov 30	Dec 7	Dec 14	Jan	Feb	Mar	Apr	May
Phase One - Design																							
Git Repo Created	Reza	100%																					
Software Plan	Kate	100%																					
Hardware Assembly	Claire and Max	100%																					
BOM Creation	Claire	100%																					
Lab Access	All	100%																					
Testing of Previous Version	All	100%																					
Phase Two - Development - Software																							
Base GUI	Reza	5%																					
Reaction	Kate	0%																					
EMG	Kate	0%																					
ECG	Kate	0%																					
Pulse Ox	Kate	10%																					
Respiratory	Kate	0%																					
Blood Pressure	Kate	0%																					
Phase Two - Development - Hardware																							
Sensor Testing	Max	50%																					
Schematic Design	Claire	75%																					
Component Layout	Claire	0%																					
Order PCBs	Claire	0%																					
Box Design	Max	0%																					
Cover Design	Claire and Max	0%																					
PCB Assembly	Claire and Max	0%																					
Phase Three - Testing																							
Hardware	Claire and Max	0%																					
Software	Kate and Reza	0%																					
Phase Four - Iteration																							
Documentation	All	0%																					
Gathering Information From Students	Claire and Kate	0%																					
Design Impovements	All	0%																					



Conflicts and Collaboration

Hardware: Hardware transported, lots of modifications, falling apart, previous Documentation lacked in key areas. Hardware behaved unexpectedly -> redesigning and relearning needed. Communication with previous team and Client important

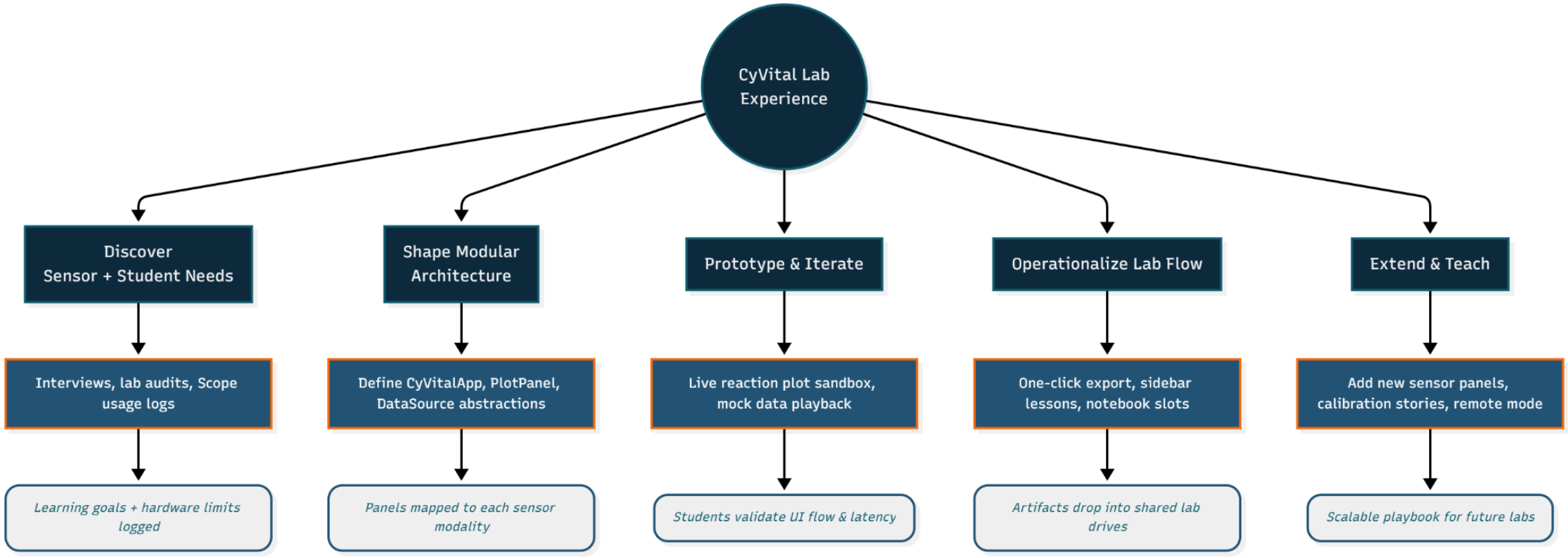
Sensor Software Challenge: Data Types and units from Hardware not lining up with real sensor behavior. Software team reorganized the problem and tailored the GUI to key differences found across sensors.

- Normalizing units
- Visually checking Matplotlib
- Help from HW about frequency range
- Help from BIOPAC documentation

Design Elements

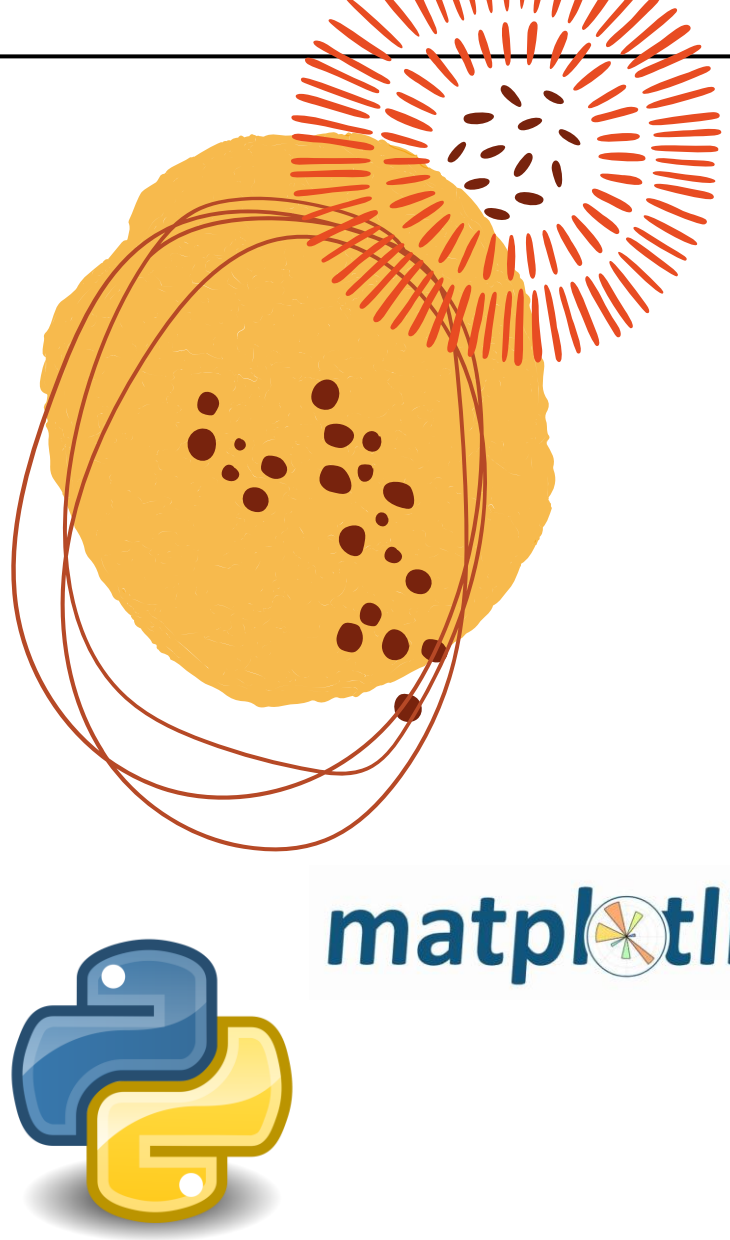
Software Design Elements

- UI Overview
- Panels for each sensor – Plug and Play Design
- Embedded plots (Matplotlib) into canvas (Live Data)
- DataSource abstraction -> switch between live Scope feeds and simulations



Software Development

- Simplistic UI for student use
- Easy to navigate for the first time - clean, modular, sectioned (Tkinter and Python)
- Simple exporting of data - "one click", data goes where expected (wired into PlotPanel, linked to a DataSource-aware exporter)
- Easily Updated - New sensors easily added or removed from software (PlotPanel - each sensor inherits layout hooks and global methods)
- Live Data Mapping Fluidity
  - Sensors produce Live data - Live data can have unwanted stutters and high latency when integrated with custom built PCBs
  - Adjust for Student Lab Machines - Depending on connection strength and computer used, results may vary slightly
  - High traffic graphs with large volumes of data forced us to balance volume of data points with Refresh rate; ensuring a smooth viewing experience and exporting



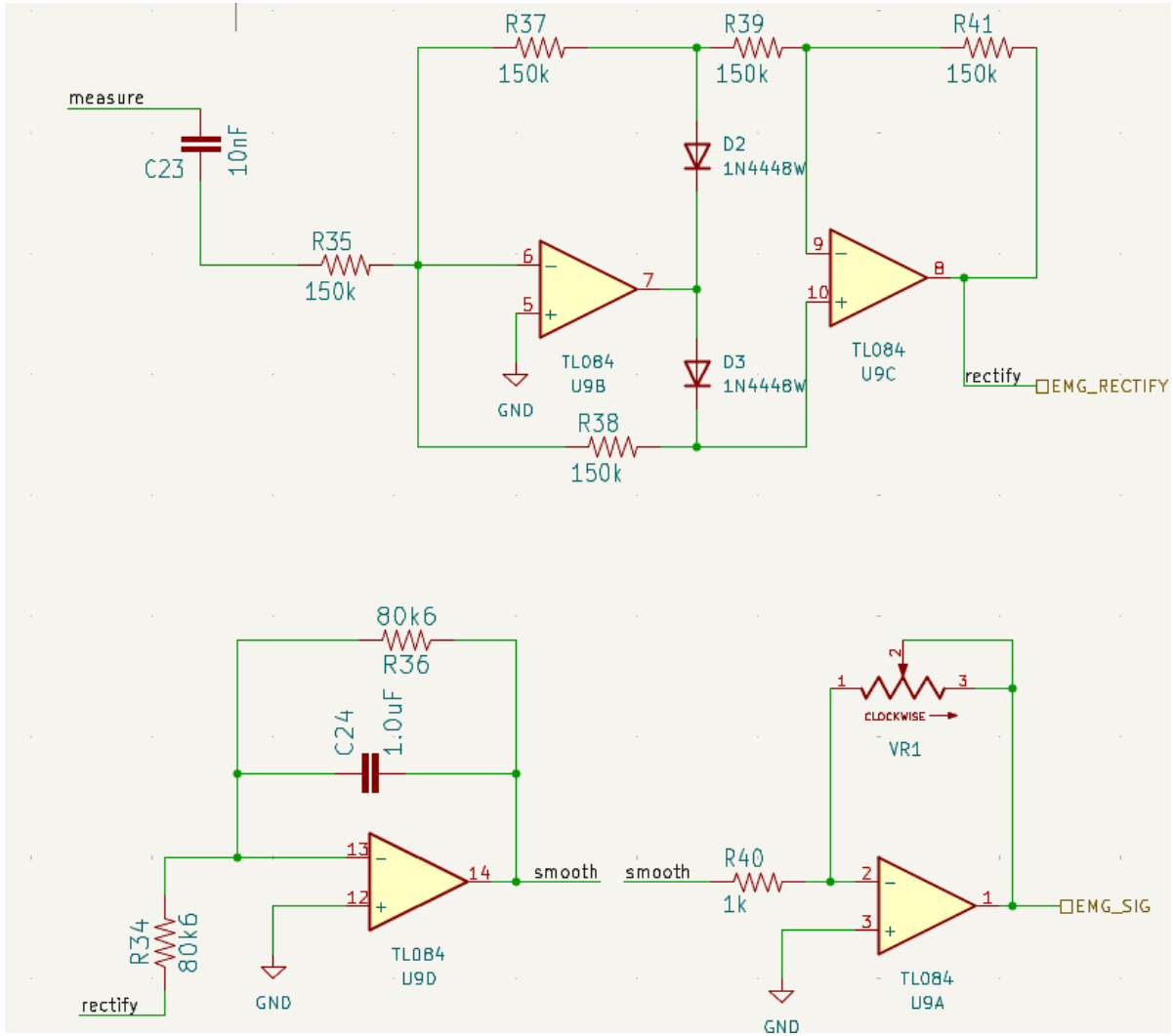
Python [2]and MatplotLib Logos [3]

Hardware Design Elements

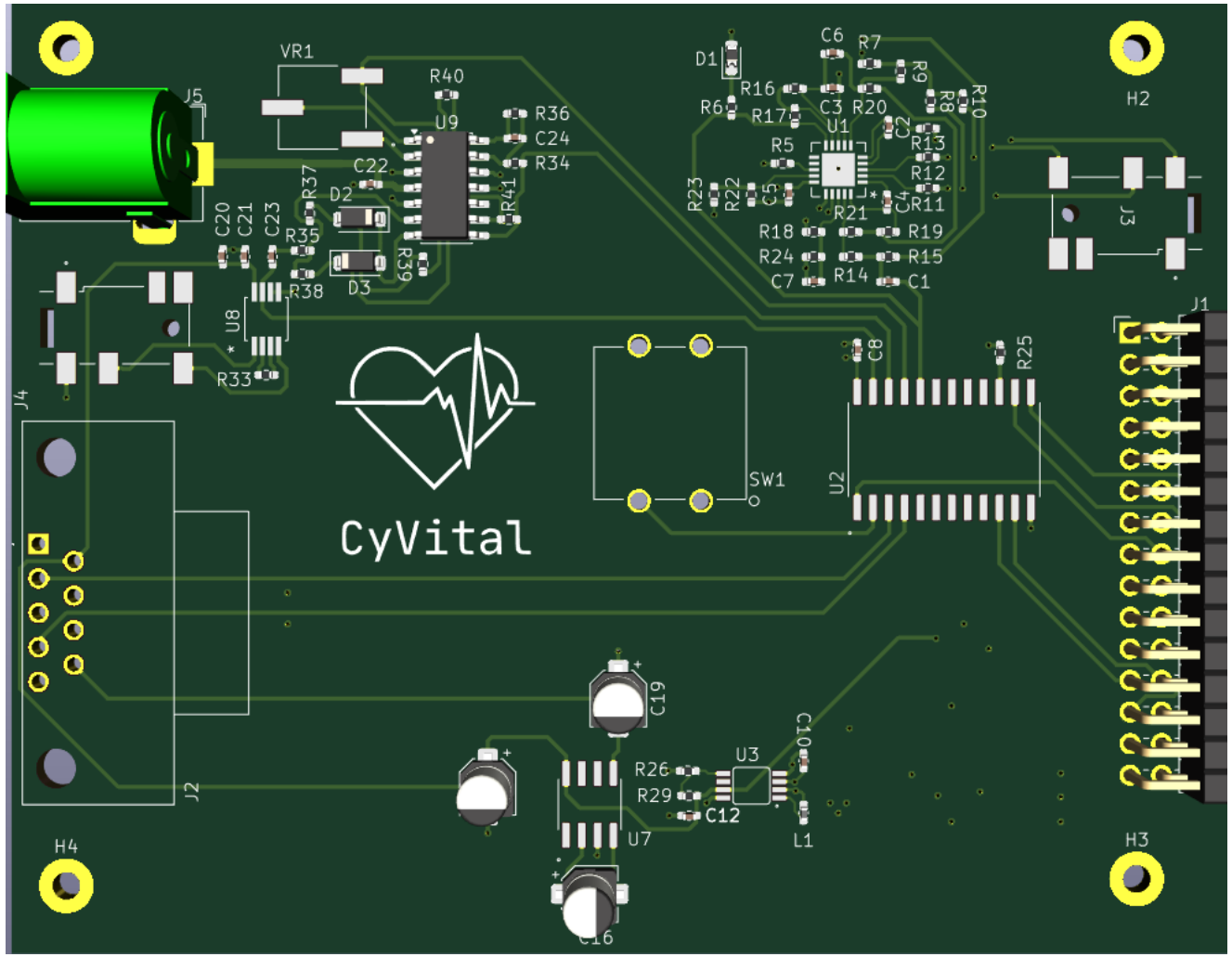
Digilent Analog Discovery [4]

- Oscilloscope from Digilent
- I2C and analog signals
- Around $100 without the oscilloscope

Hardware Design Elements



Hardware Design Elements



Testing & Prototyping

Software Prototyping & Testing

- Unit tested each sensor before adding it to prototype
- Tested using the sensors on the breadboard CyVital Phase I while PCB in development

CyVital

CyVital

Biomedical Monitor

- **Reaction Time** — Response Test
- **ECG** — Electrocardiogram
- **EMG** — Electromyography
- **Pulse Oximeter** — Blood Oxygen

Pulse Oximeter Monitor

Real-time blood oxygen analysis

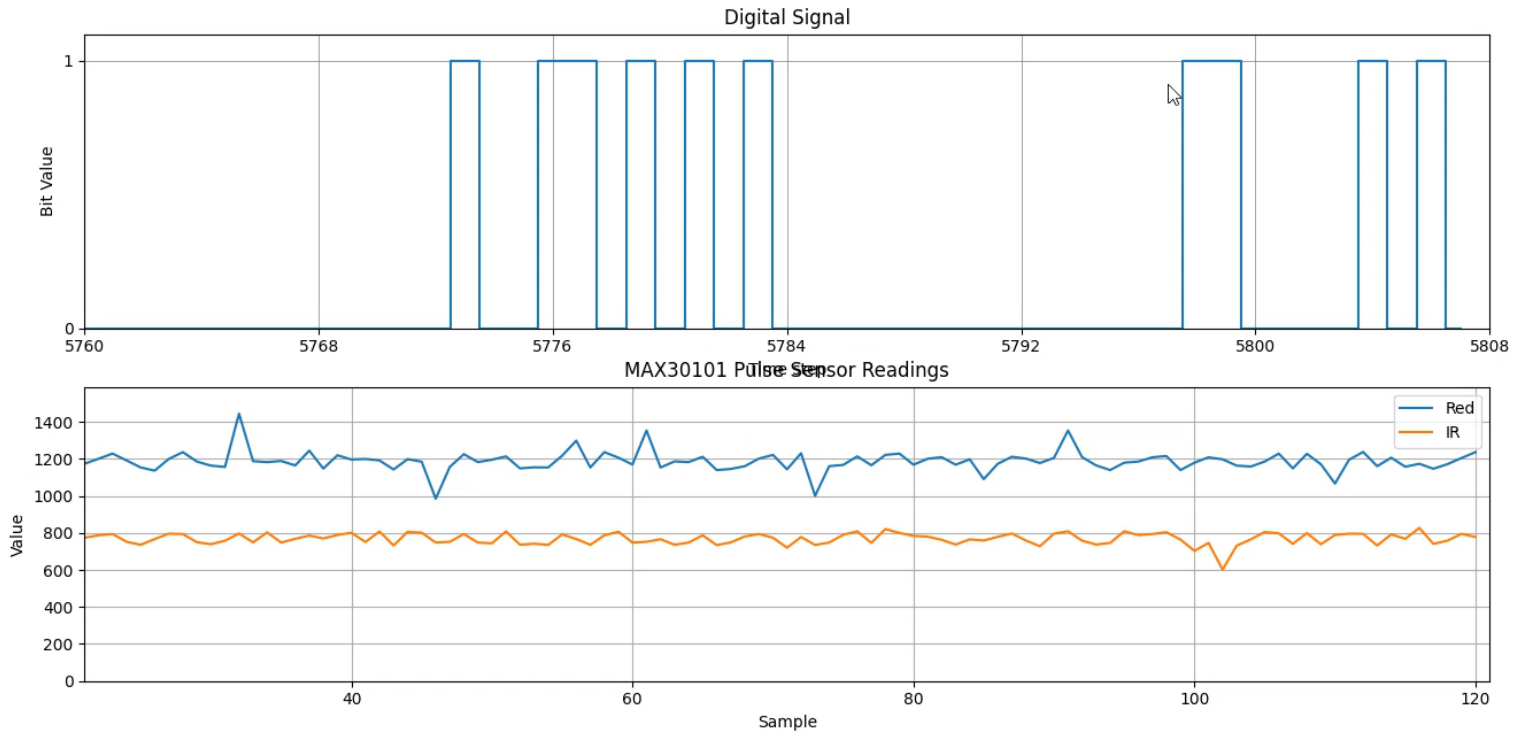
Live | Pause

SpO_2

76.9 %

Pulse

96 bpm

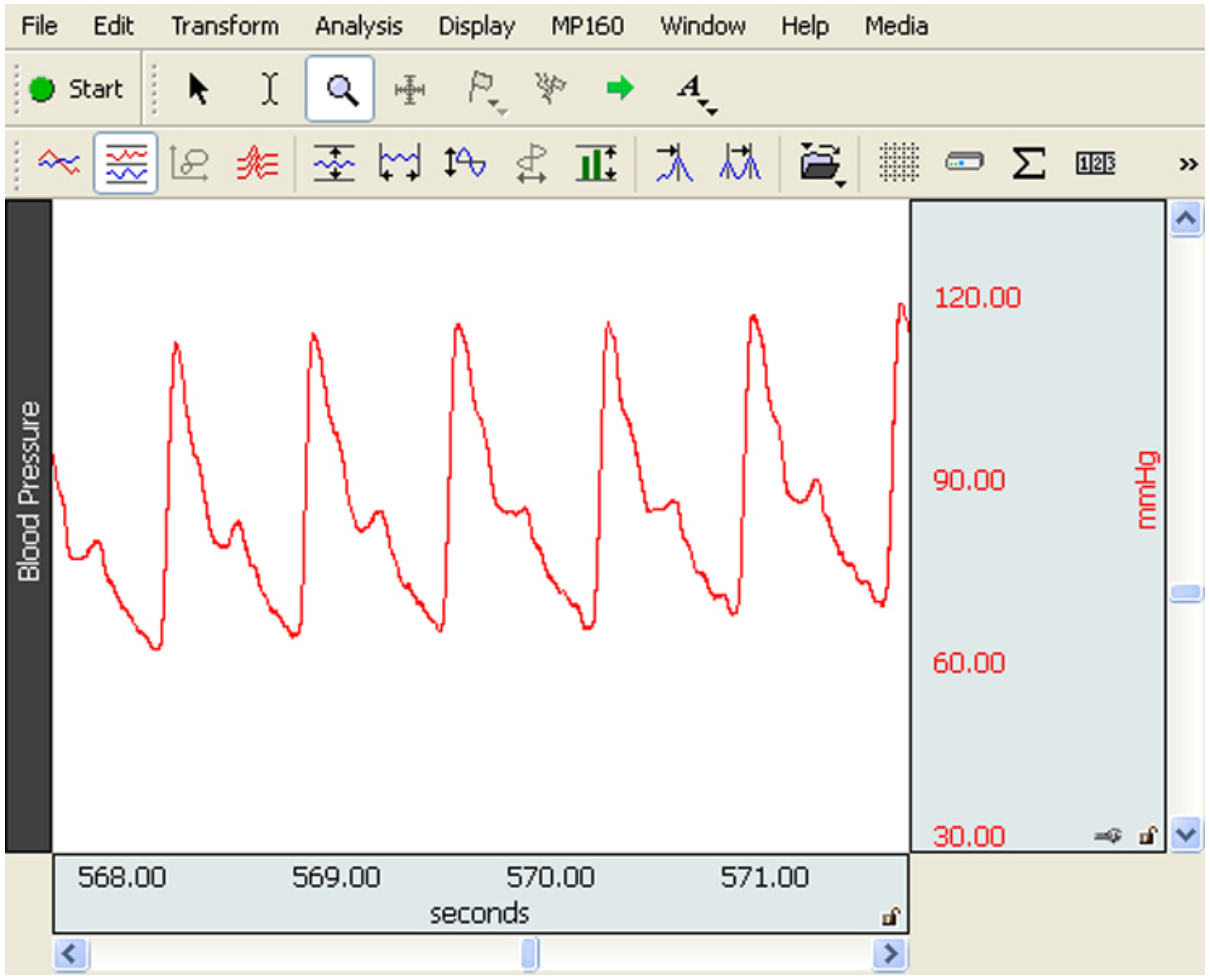


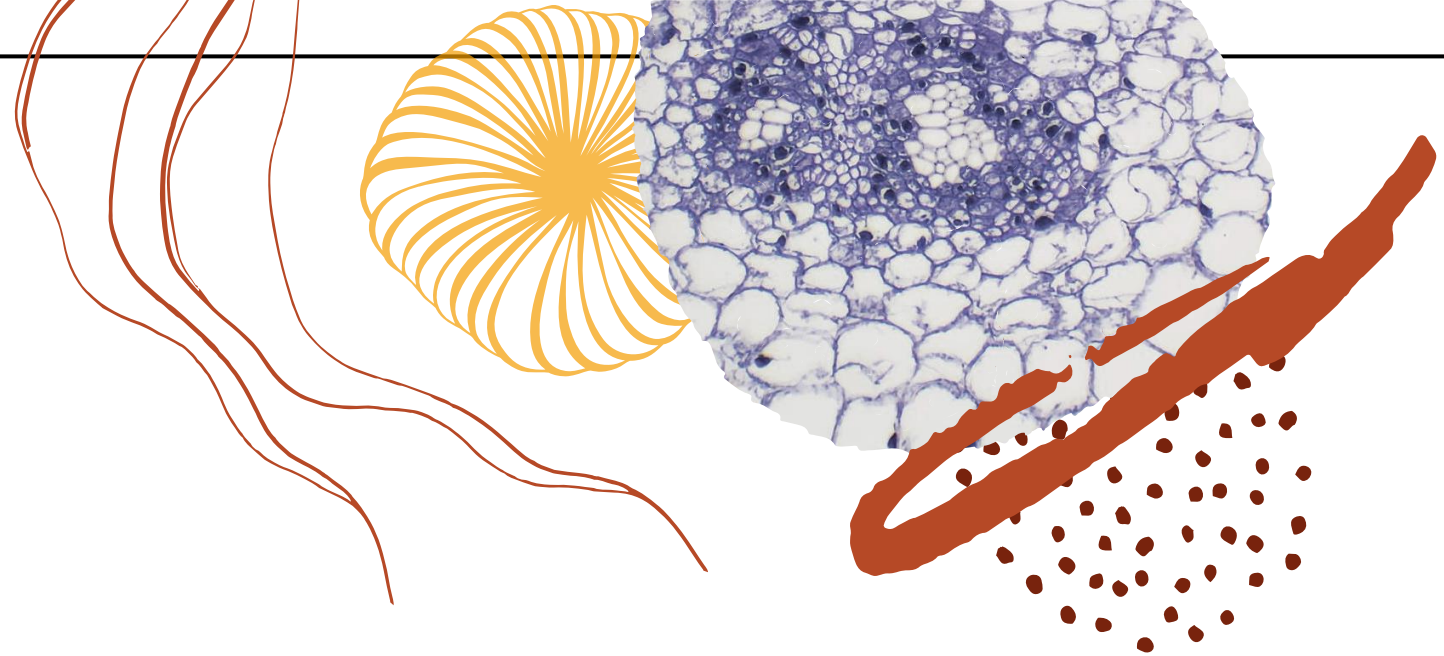
Live Monitoring

bpm and spo2

Export CSV

Hardware Prototyping & Testing



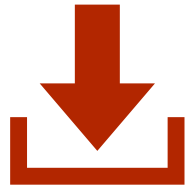


Conclusion

Project Progress

PCB will be assembled over break

Parts on the way



Software is available for students to download

Lessons Learned

Modular Software

Latency Matters

Simplicity is Key

Future Initiatives

Student Feedback

Create Lab Manuals

Software Updates

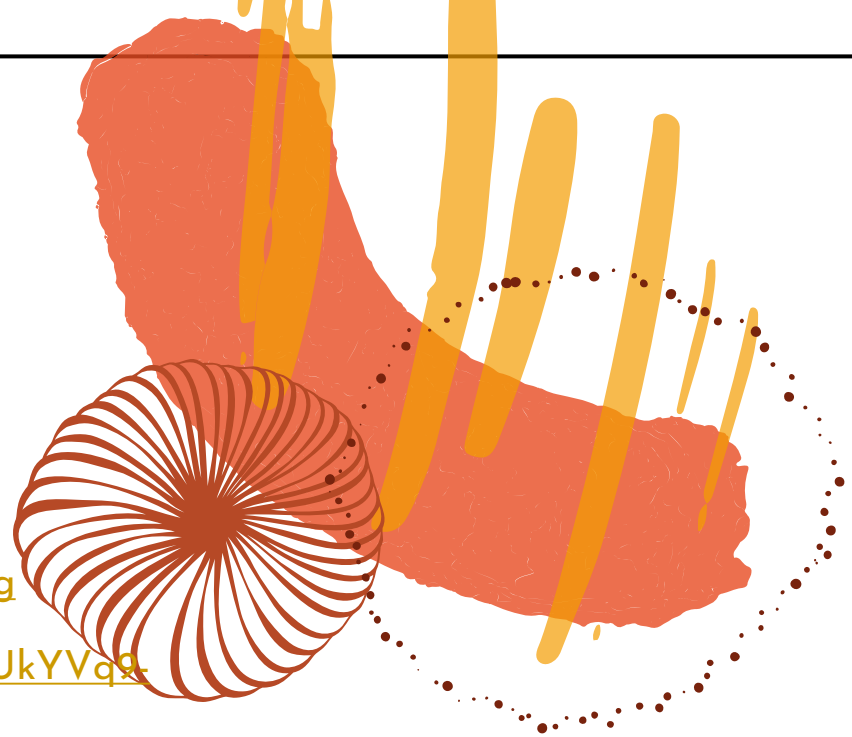
Thank You!

The CyVital Team

Senior Design 006

sdmay26-06.sd.ece.iastate.edu

External Figures



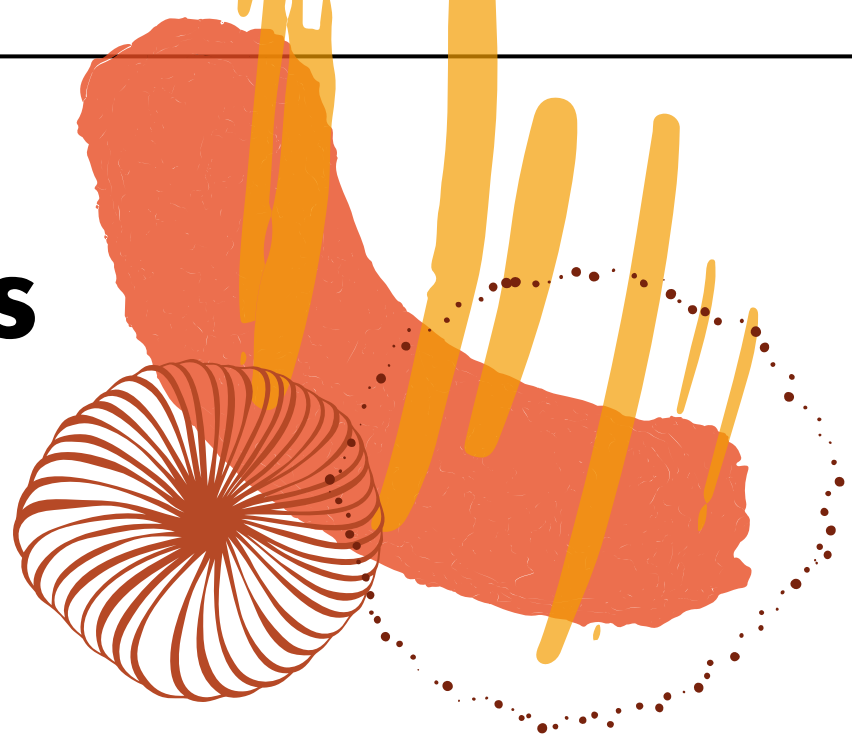
[1] BIOPAC - https://www.biopac.com/wp-content/uploads/MP36-back-ports.jpg

[2] Python – https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQkdgUkYVq9-UPHtkrQyNzA1t-hCdSG65-XYw&s

[3] Matplot Lib - https://matplotlib.org/stable/_static/logo_light.svg

[4] Digilent - https://digilent.com/shop/analog-discovery-3/?srsltid=AfmBOoqgUqTjCw_Sx-oZy8pLxHcZ-t_XezEgb_LapbcTe7b0V547_Vxb

Technical Requirements



Functional Requirements

- Real-time display of ECG, EMG, SpO_2, and reaction signals
- Basic signal processing (ECG filtering + R-peaks, EMG RMS, SpO_2 calc)
- Record → replay → export (CSV)
- Plug-and-play sensor interface

Performance Requirements

- ECG ≥ 250 Hz, EMG ≥ 1 kHz
- Latency < 200 ms
- Missed samples < 0.1%
- Runs on typical student laptops (Windows)

Hardware Requirements

PCB Requirements

- Custom surface-mount PCB integrating ECG, EMG, SpO_2, and reaction circuits
- Proper filtering, grounding, and ADC paths
- Silkscreened sensor connectors for ease of use
- 10 fully assembled boards for pilot testing

Integration Requirements

- Clean digital interface to oscilloscope/data acquisition
- Modular sensor testing and replacement
- Hardware + software must operate with <200 ms end-to-end latency

Hardware Requirements Cont.

Electrical Requirements

- Stable, low-noise analog front-ends
- Safe, isolated design—no exposed high-voltage circuits
- Consistent signals within ~5% of BIOPAC benchmarks

Safety & Durability

- Plastic enclosure
- Must survive a 3 ft drop
- Test points for oscilloscope verification