a haptic device for mindful breathing

Final Presentation

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THE PROBLEM | background

- Sponsor: **Dr. Negar Fani**
  - Emory University Neuroscience Lab
- Trauma victims may suffer from **dissociative disorders** – loss in interoception
- **Existing research shows** providing vibration response to the sternum synched to patients' breath yields better outcomes than "unassisted" mindfulness breathing

Existing Device used by Dr. Fani

THE PROBLEM | mindfulness

Problem

Dr. Fani's PTSD research into non-triggered stress responses & dissociation **requires a more effective and practical device**

Goal

Amplify breath sensation to improve effectiveness of mindfulness practice

User Contexts

- **Research** - dissociation recovery
- Independently - preferred **meditation** setting

KEY CRITERIA | product

Project Objective: To design and develop a **meditation aid device** for inexperienced or intermediate meditators to **use in a clinical setting** and their preferred meditation setting. This device will track the user's **exhale** and output a **synchronized vibration response on the sternum** to amplify the subtle signal of the breath to support a mind-body connection.

- Delivers breath-synced vibrations on the sternum during the user's exhale to assist with breath mindfulness
- Designed for a general audience, with inexperienced mindful meditators as first adopter audience
- Accommodate 5th to 95th anthropometrics for adults (age 18 and above)
- Minimalistic design for ease of use in public spaces
- Works consistently without need for tuning or careful positioning
- Can be used independently
- Comfortable to use when sitting, standing, or laying down
- Can connect in some way to externally monitor respiration sensor and vibration output in the context of clinical trials
- Operates without any external connection
- Offers control of vibration strength and feel
- 5-year lifespan when used in design conditions
- COGS: <$150

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ENGINEERING SPECS | overview

OPERATION

- ✓ Worn without assistance
- ✓ No training necessary
- ✓ No external wiring
- ✓ Vibration delay <250ms
- ✓ Sample every 5ms

INPUTS & OUTPUTS

- ✓ Receives breath signal
- ✓ Delivers synced vibrations
- ✓ Vibration strength 0-100%
- ✓ Control over vibration feel
- ✓ Output breath waveform
- ✓ Vibration waveform
- ✓ Power on/off & monitoring

ENERGY

- ✓ Continuous use >180 mins
- ✓ Rechargeable with USB-C
- ✓ Battery charged >85% in <2hrs
- ✓ Battery of 1200mAh
- ✓ Replaceable battery
- ✓ Temperature < 60ºC

QUALITY CONTROL

- ✓ Calibration capability
- ✓ 5+ year lifespan with battery maintenance

COSTS

- ✓ Less than $150

ERGONOMICS

- ✓ Force of vibration >5N
- ✓ 0mm separation between vibration and chest
- ✓ >9.5cm of strap stretch for expansion
- ✓ No perceivable pinch points/rubbing
- ✓ Comfortable wearing for >30 mins
- ✓ 5^{th}-95^{th} percentile anthropometrics
- ✓ Weight target 350-500g
- ✓ Vibration strength >1.6Grms

ENGINEERING SPECS | tested

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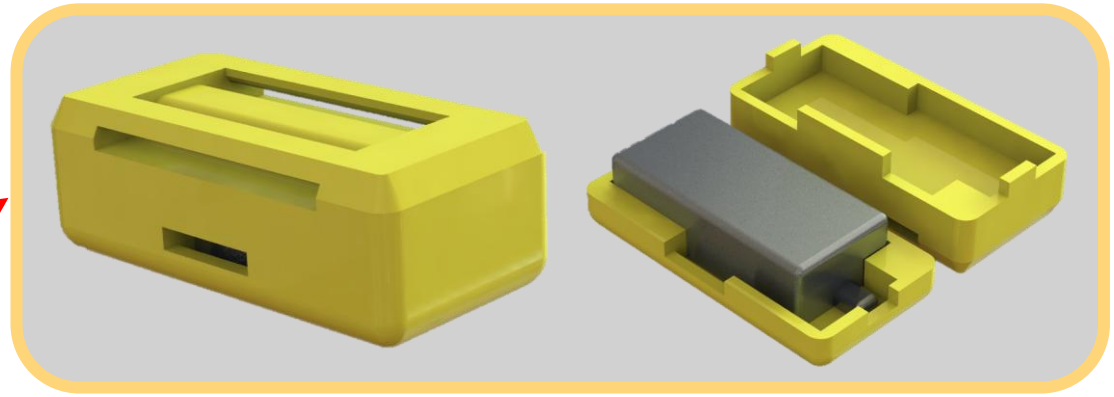
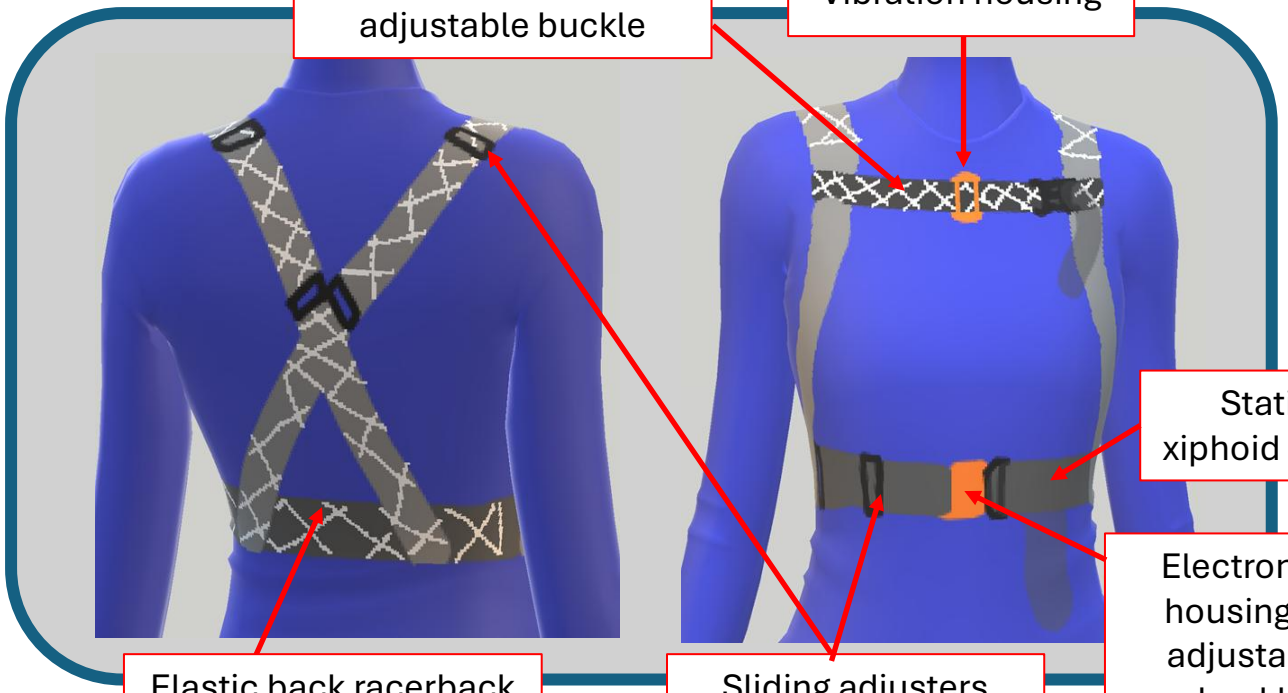
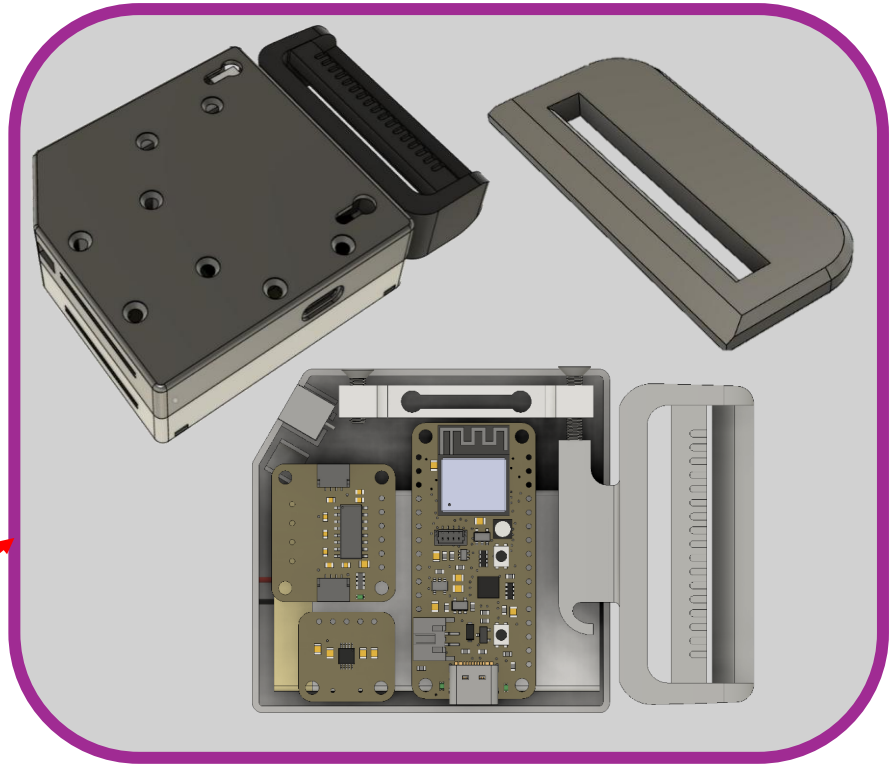
FINAL DESIGN | form factor

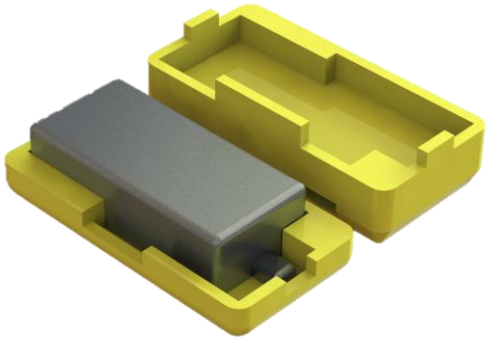
Key Considerations:
- Comfort
- Adjustability + well fit to range of users
- Ease of use/intuitive design

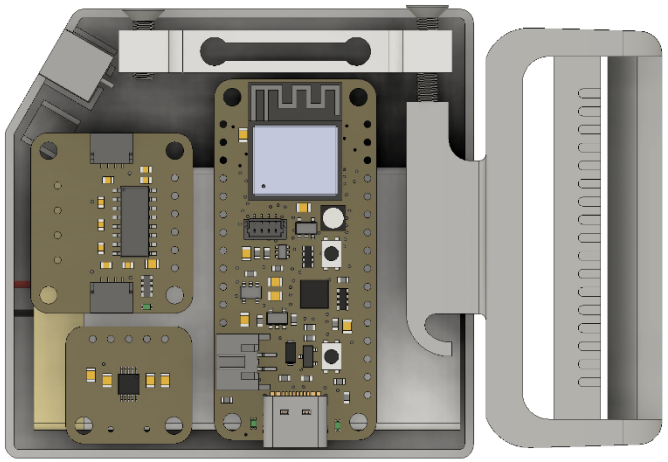


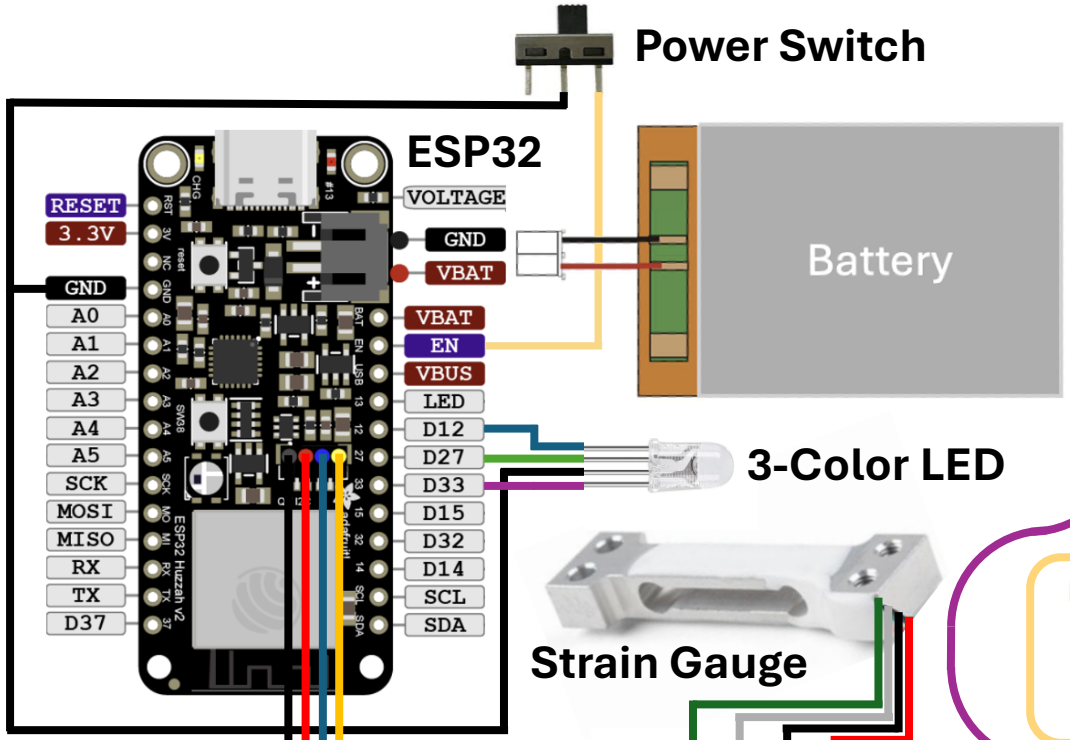


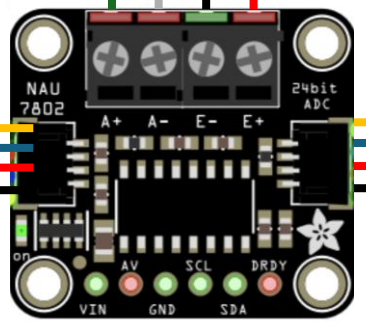


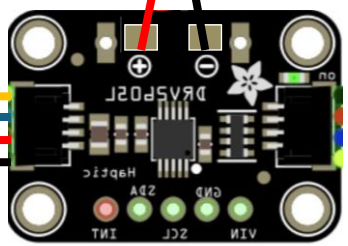
FINAL DESIGN | electronics packaging











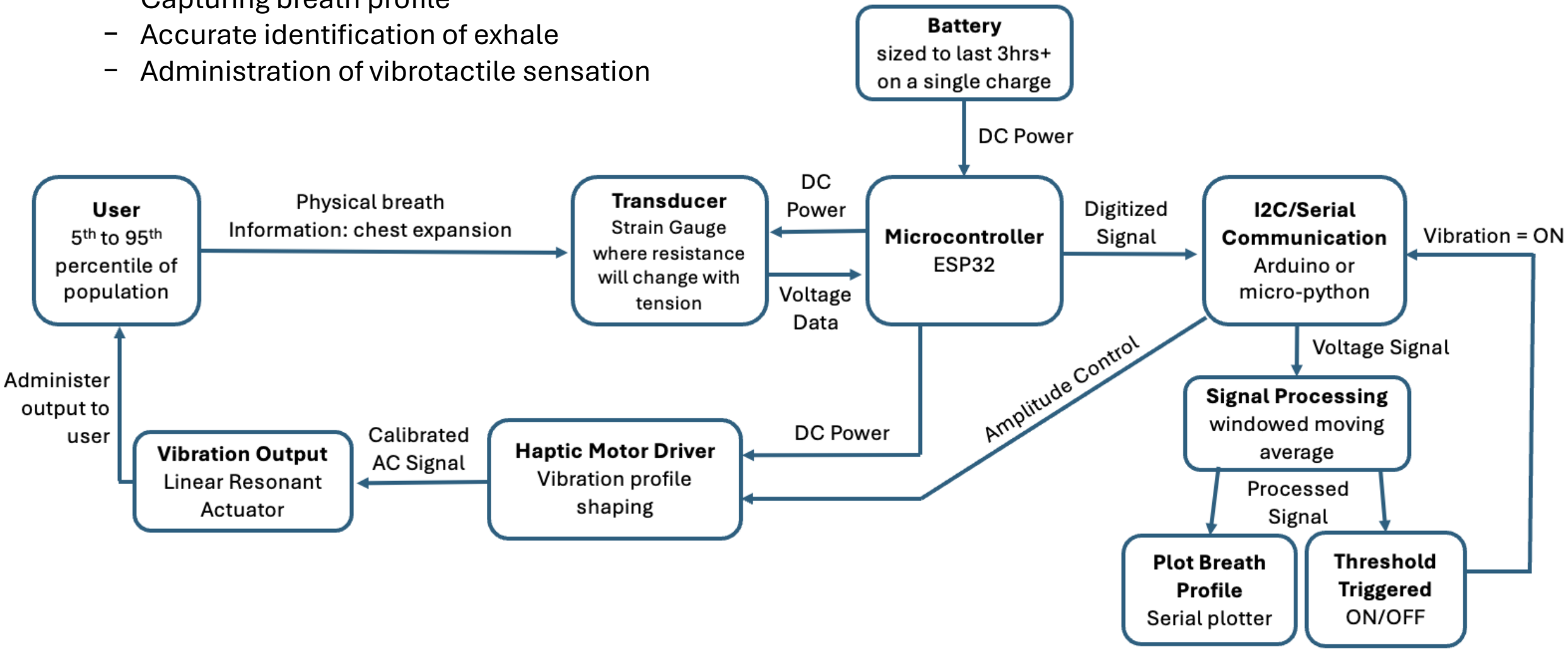
Key Considerations:

- Small package size
- Robust mounting
- Accessibility for maintenance

FINAL DESIGN | electronics & software

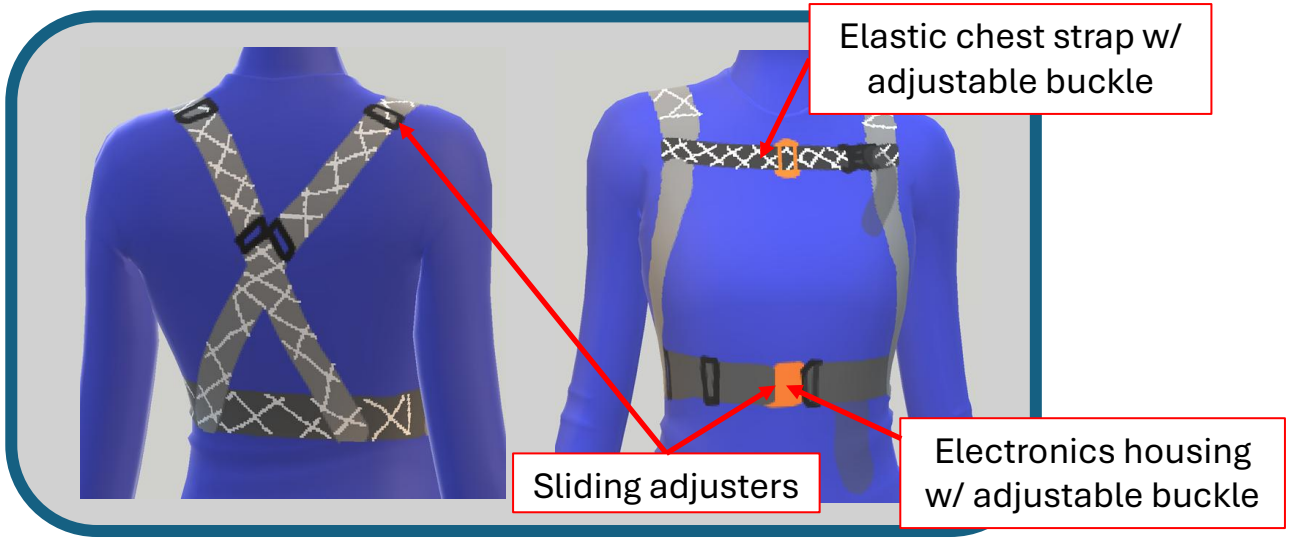
Key Considerations:

- Capturing breath profile
- Accurate identification of exhale
- Administration of vibrotactile sensation

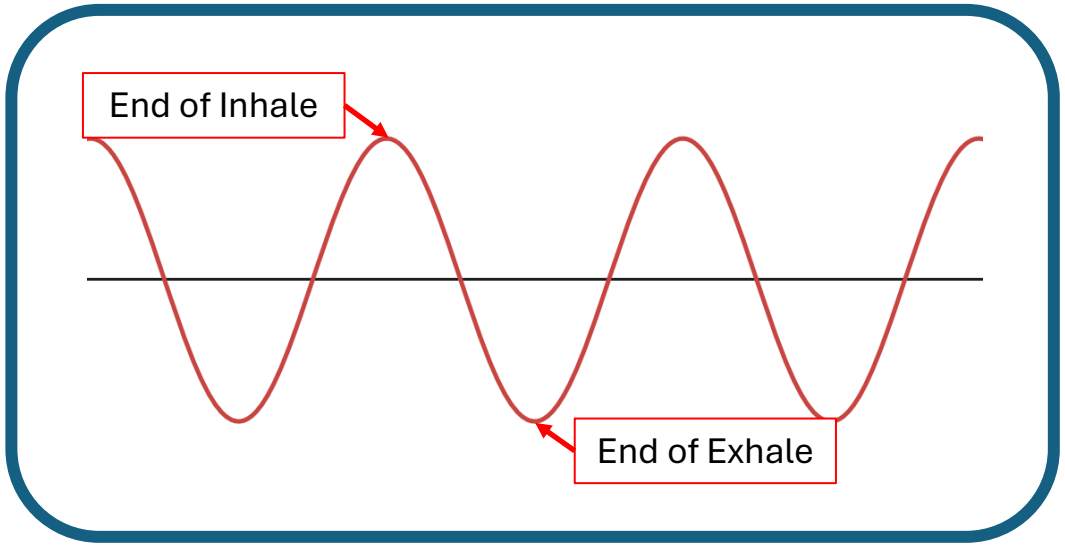


FINAL DESIGN | in practice

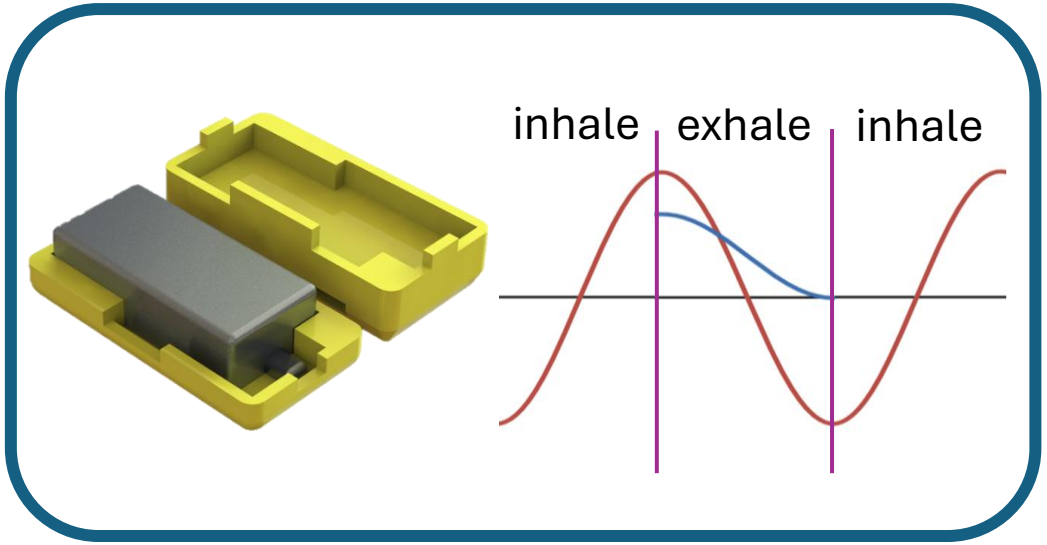
1. User dons the device and adjusts to achieve proper fit



2. Device monitors to user's breath



3. Signal processing triggers vibration on exhale



4. Deepened, more engaging meditative practice

FEASIBILITY TESTING | overview

Limit Testing

Thermal
- Max temperature (and location) during full battery cycle @ 100% vibration

Tensile
- Monkey test strain gauge mechanism

User Testing

Device detection & delay
- Comparative to real breath response
- User feedback of synchronization

Comfort & usability
- 30-minute wear
- Ease of use (don/doff)

Considerations:
- Keep positioning constant
- Note component locations

Clinical Compatibility

Read Out Info
- Test waveform tracking readout and user compatibility

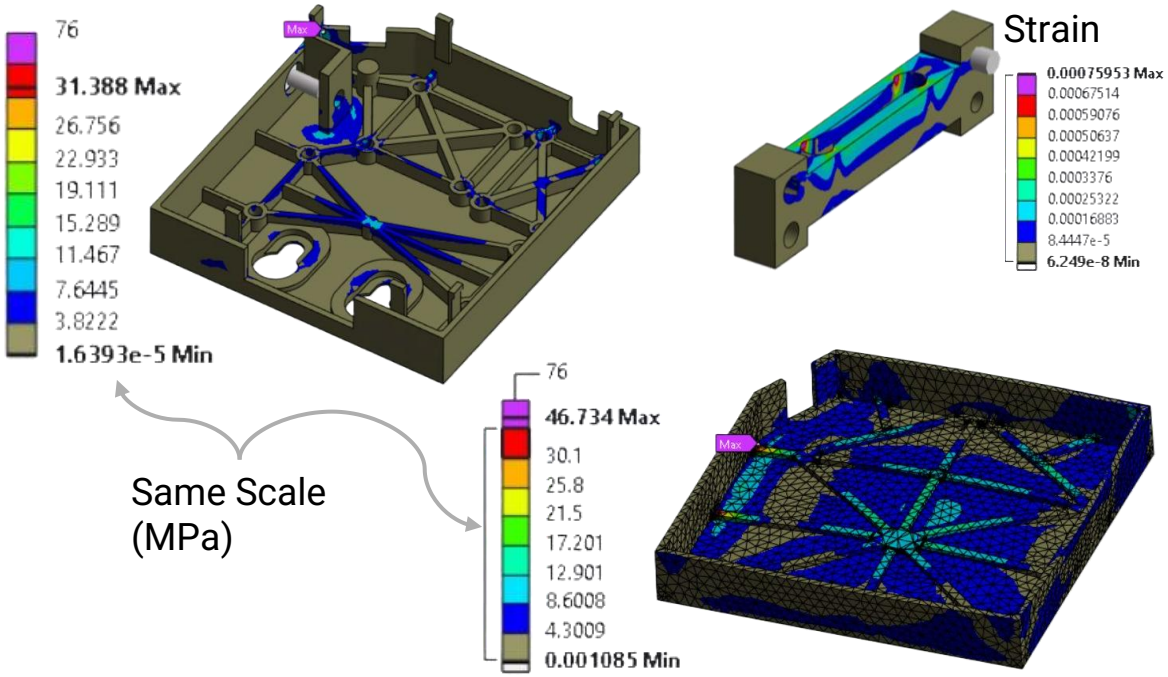
Data storage
- Test data storage mechanism and formatting

Environment compatibility
- Test in soundproof environment

TESTING | limit testing

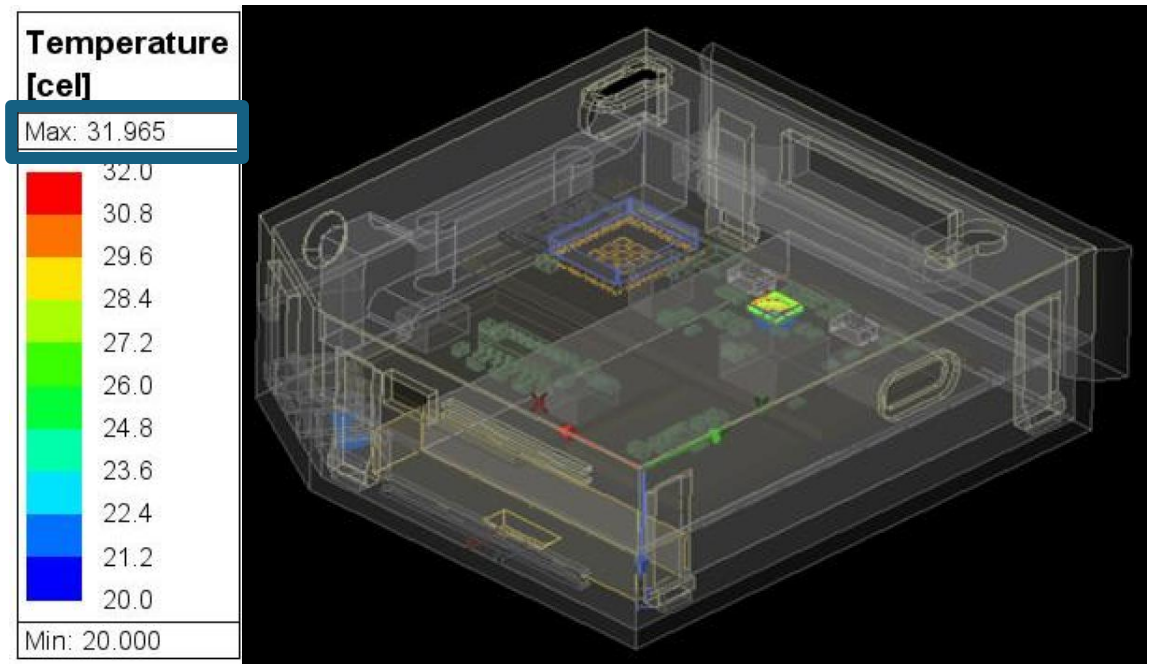
FEA

- **Setup:** Simultaneous Max Static Load @ all interface points, Von Mises
  - Material Strength: Bambu Labs PLA 76Mpa
- **Results:** Passes max load case with S.F. of at least 1.5 to Yield Strength



Thermals

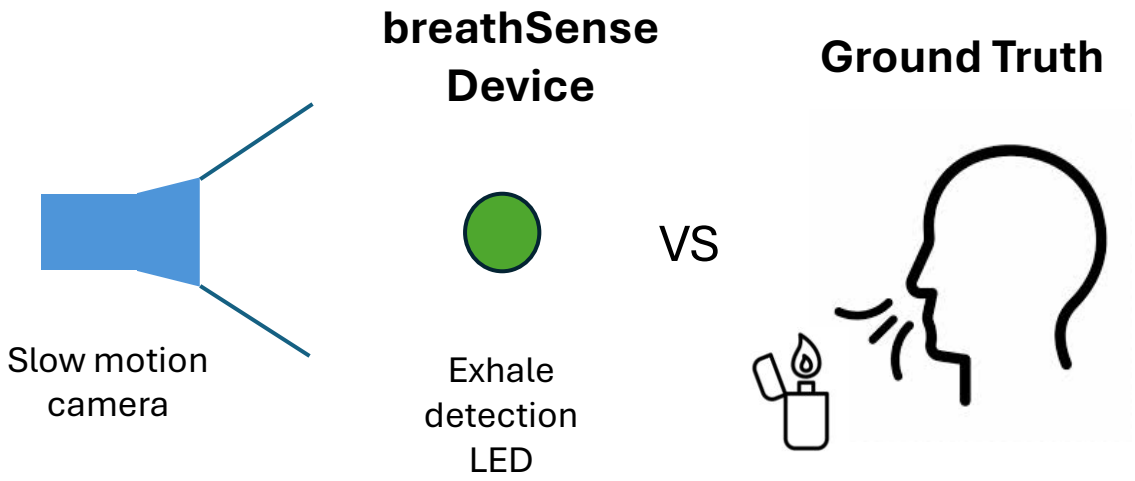
- **Setup:** heat generated from power losses of LED, ESP32, and LiPo
- **Results:** device surface stays well under 43C limit



TESTING | user testing: detection & delay

Test Set-Up

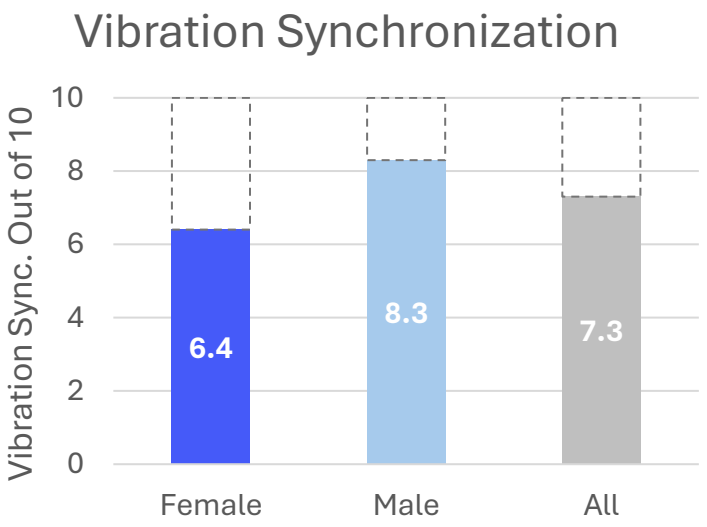
- Compared breathSense device to airflow reference of the breath with a flame
- Slow motion camera captured actual breath and device action (light indicated)
- Environment: at home or FaniLab
- Subjects: 10 (5 F, 5 M)



Results

- Device recognition delay: **150-350ms**
- Average human reaction time: **250ms**

- Users rated the device's synchronization performance on average as **7.3/10** (10 being completely in sync)



**Note: 2 outliers present in data set (female)*

TESTING | user testing: comfort & usability

Test Set-Up

- **Don/doff** demonstration and trial
  - Time to don was recorded
- **Questionnaire**
  - Comfortability, ease of use, and performance of the device
- Environment: at home or in FaniLab
- Subjects: 15 (8 F, 6 M)

Results

- **Don Time:** Average ~ 60 seconds

- **Comfort:** Users rated the device's comfort on average as **8.4/10** (10 being able to sleep with the device on)
- Little change was seen between initial comfort level and after 30 minutes of use

Feedback

VIBRATION

smoother | lighter | quieter

OTHER CONSIDERATIONS

Wire & Strap Management | Panic Breathing | Size Accessibility

TESTING | clinical compatibility testing

Test Set-Up

- Clinical **compatibility** testing and user feedback
- Environment: FaniLab
- Subjects: 5 (3F, 2 M)

Results

- No expected complications

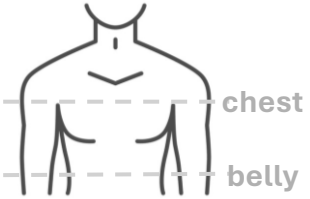
Feedback

Increase mid-section size range

Increase vibration puck size + smoother feeling

Data collection warning

Panic breathing



Chest vs belly breathing

CONCLUSION | product outcomes

- Lightweight, portable product
- Delay is less than average human perception time
- Controllable vibrotactile output
- Breath-synced system with plotting capability for lab application
- Under $150

NEXT STEPS | production and feasibility

Cost

- **$66.29**
  - Per unit cost for a 500-unit build.
  - Tooling and equipment not included.
  - Initial target <$150 ✓

Feasibility

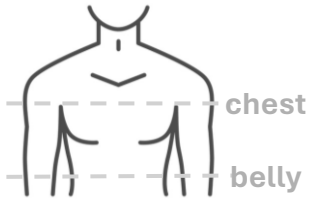
- Easy assembly using off the shelf parts, ABS 3D printed housings, and simple sewn strap sections.
- Potential for much greater cost reduction past the 500-unit mark with a custom PCB, injection molding, and different size offerings.

Application	Part Name	500 units	/unit	Vendor	Part number
Sensors + Electronics	Strain gauge	$ 4,930.00	$ 9.86	Sparkfun	14728
	Breakout board	$ 2,380.00	$ 4.76	Adafruit	4538
	ESP32	$ 8,380.00	$ 16.76	Adafruit	5900
	Lithium ion battery	$ 3,980.00	$ 7.96	Adafruit	258
	LRA	$ 2,472.55	$ 4.95	Digikey	16719293
	Haptic motor controller	$ 3,180.00	$ 6.36	Adafruit	2305
	Power Switch	$ 380.00	$ 0.76	Adafruit	805
	Power LED	$ 64.00	$ 0.13	Adafruit	298
	Cable (3m)	$ 2,240.00	$ 4.48	Digikey	4496906
	Heat Shrink (4in)	$ 205.00	$ 0.41	Mouser	538-19269-0010
	Wire sheathing (1m)	$ 265.00	$ 0.53	Grainger	PTN0.13BK500
	I2C JST4 Female 4x	$ 200.00	$ 0.40	Dfrobot	525
Form Factor / Wearable Device	ABS Filament (60g)	$ 478.18	$ 0.96	Bambu Lab	40101
	Screw	$ 384.00	$ 0.77	Mouser	50M025045M008
	1in elastic strap (70in/u)	$ 485.30	$ 0.97	Airisoer	B0869KZ9CT
	1in static strap (48in/u)	$ 395.72	$ 0.79	TKYPZY	ZHJ_205061
	2in elastic strap (9in/u)	$ 75.94	$ 0.15	Airisoer	B0CBYSMRCP
	2in static strap (50in/u)	$ 600.00	$ 1.20	Strapworks	8.48862E+11
	1in linear slide adjusters 4x	$ 948.32	$ 1.90	CooBigo	FLC129-B2
	2in strap retaining loops 2x	$ 1,000.00	$ 2.00	Uxcell	B0DG2WPCRN
	1in strap retaining loop 1x	$ 99.83	$ 0.20	Uxcell	B0DG2XHRY7
Total	21 distinct parts	$ 33,143.83	$ 66.29		

NEXT STEPS | timeline

Continue with PMW

Vibration waveform testing



Chest vs belly breathing testing

Continue with patenting

FaniLab implementation

Sensor Evaluation → Signal Processing → Sensor Selection → Packaging → MVP → Prototype Testing → Mass Production Optimization

QUESTIONS?