Non-Invasive Monitoring Device for Early Detection of BCRL

Amy Prendergast[1], MD Shaad Mahmud[1,2]
[1]Department of Electrical and Computer Engineering, University of New Hampshire [2]Remote Sensing Laboratory

University of New Hampshire

ABSTRACT

Breast Cancer Related Lymphedema (BCRL) is a common co-morbidity in cancer survivors following neoadjuvant therapies such as chemotherapy, radiation, and/or surgery. It is brought about by the disruption in the lymphatic system (think lymph node biopsy) that leads to a buildup of lymphatic fluid in the arm. Current diagnostic strategies for this condition are merely retroactive, and fairly limited in the parameters that are examined to ensure patient well-being long term. **We hypothesize that with an approach that mimics bioimpedance spectroscopy analysis, we will be able to provide a clinical support tool that would better determine early stages of lymphedema and aid physicians and patients alike in remedying this condition.**

BACKGROUND

LYMPHEDEMA

- Lymphatic fluid buildup
- Heaviness, numbness, limits of mobility, blister/sores (extreme)
- 23.8% of breast cancer survivors will experience this by the 2-year mark of remission[1]

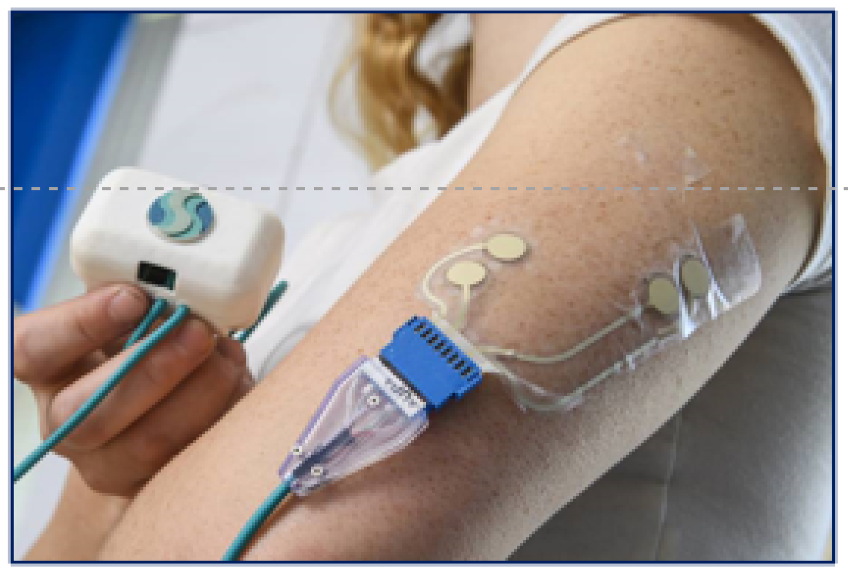

Figure 1. Johns Hopkins Lymphedema Detection Sensor

CURRENT DIAGNOSTIC TOOLS

- Arm circumference
- Patient report of symptoms
- Bioimpedance analysis

EXAMPLE

Device shown in **Figure 1** was developed by a team of researchers at Johns Hopkins[2]

CHALLENGES

- **Measuring small currents**
- **Real-Time Continuous monitoring**
- **Differentiating lymphatic fluid buildup from other activities**

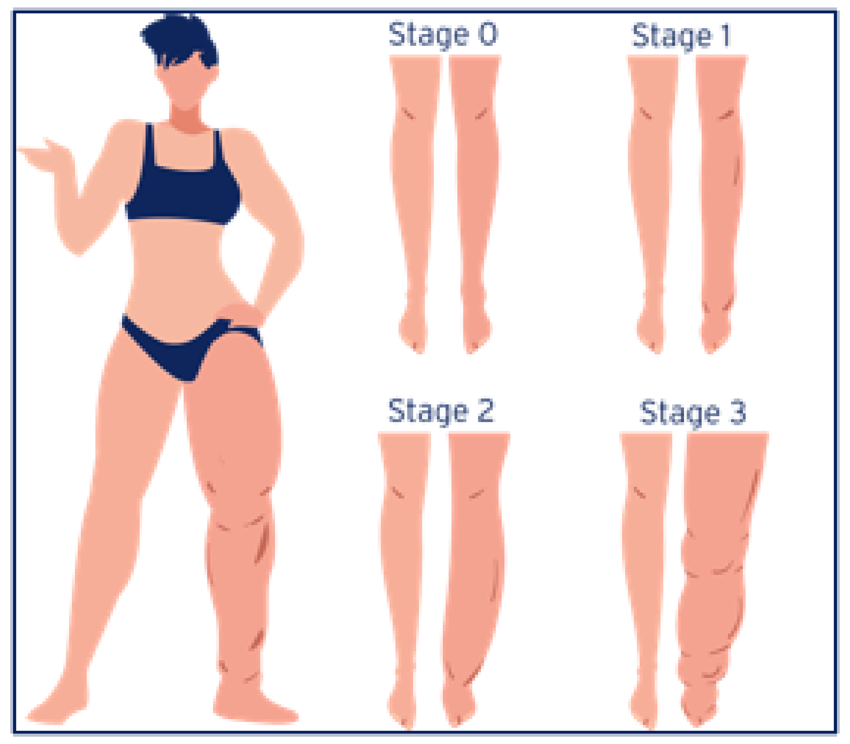

Figure 2. Lymphedema Stages

MATERIALS AND METHODOLOGY

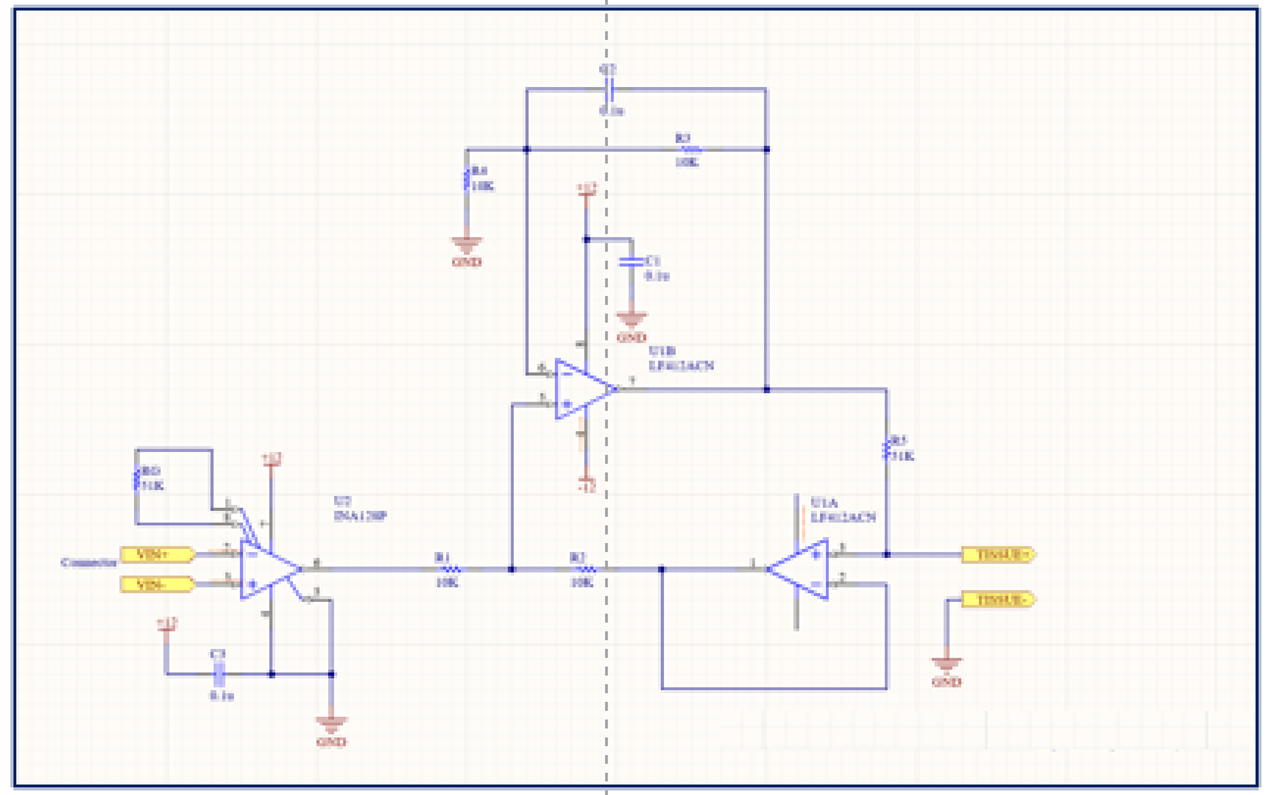

Figure 3. Howland Voltage-Controlled Current Source

MATERIALS

- INA128 Instrumentation Amplifier
- LF412 Operational Amplifier
- Arduino UNO R3
- Arduino Nano 33 BLE Sense
- Snap Electrode Pads & Lead Wires

SAFETY CONSIDERATIONS

- Tissue impedance model (Hodgkin-Huxley)
- Followed Shannon paper on safe current limits[4]

METHODOLOGY

- Research Phase
- Prototyping stages
  - Benchtop supply
  - Arduino PWM input signal
- Spectroscopy across range of frequencies for tissue differentiation
- Howland Voltage Controlled Current Source

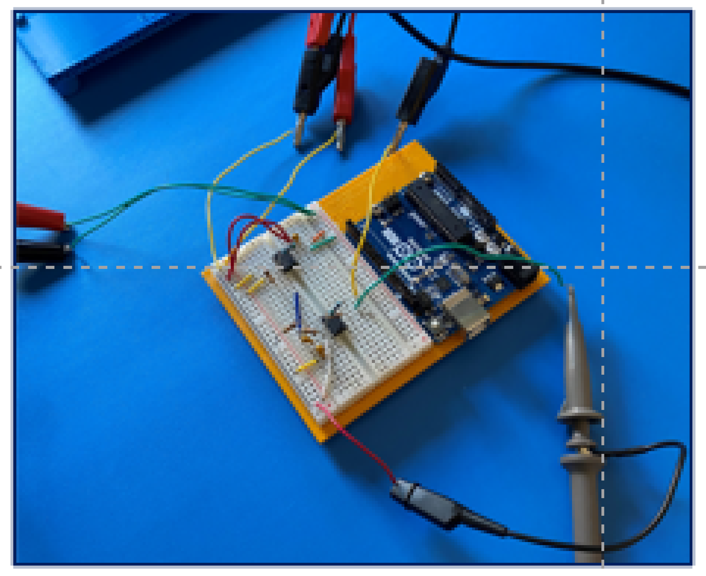

Figure 4. Benchtop setup

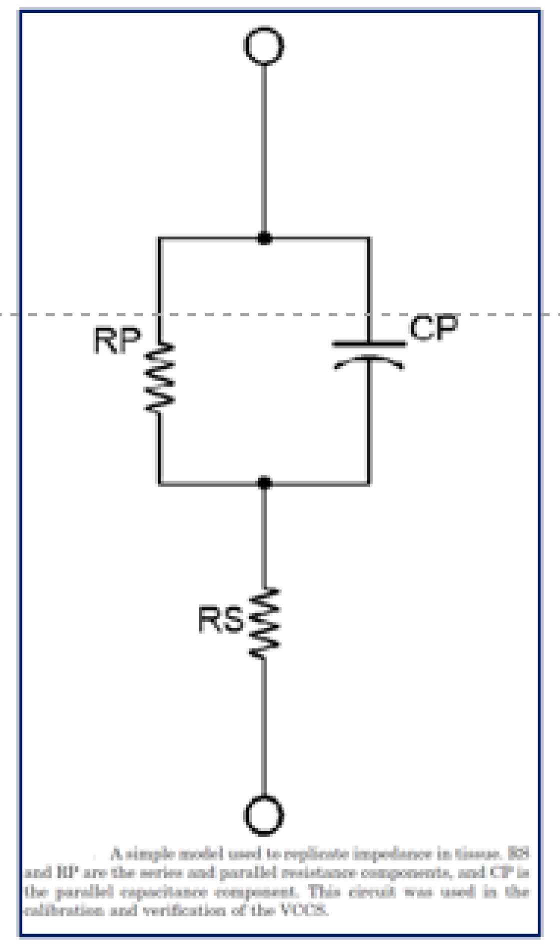

Figure 5. Tissue Impedance model

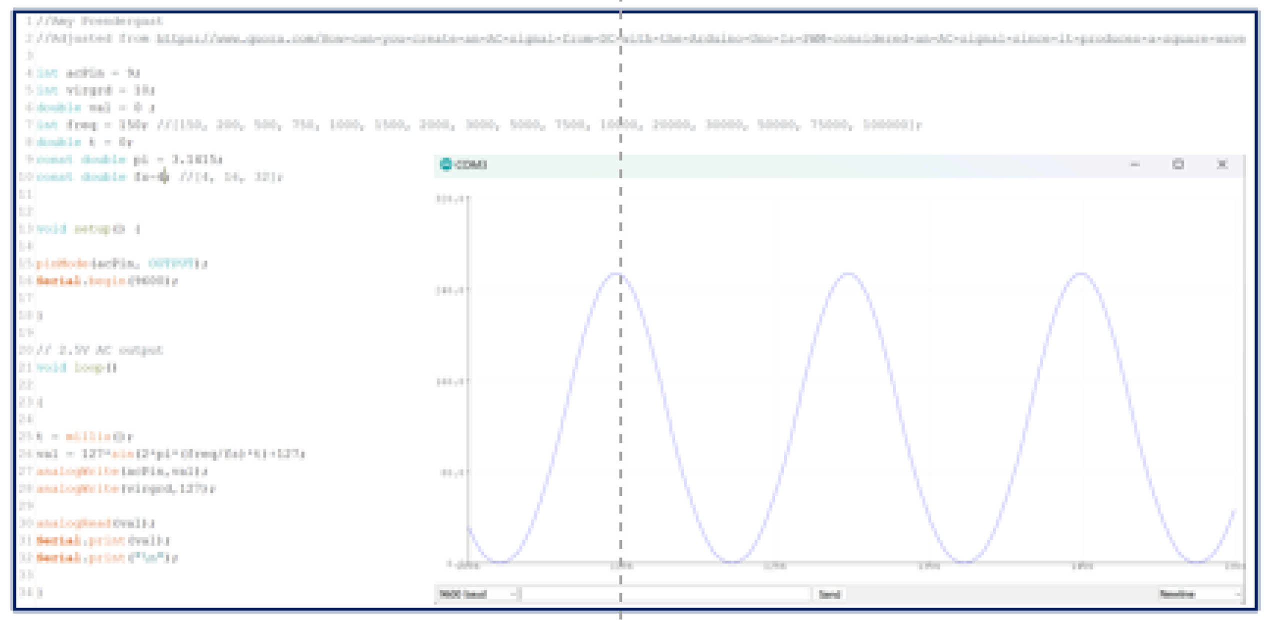

Figure 6. Input from Arduino

RESULTS & CONCLUSIONS

Hz	V
150	0.184
200	0.1600
500	0.104
750	0.088
1000	0.076
1500	0.072
2000	0.064
3000	0.062
5000	0.054
7500	0.046
10000	0.04
20000	0.038
30000	0.034
50000	0.028
75000	0.028
100000	0.028

Table 1. Benchtop Results

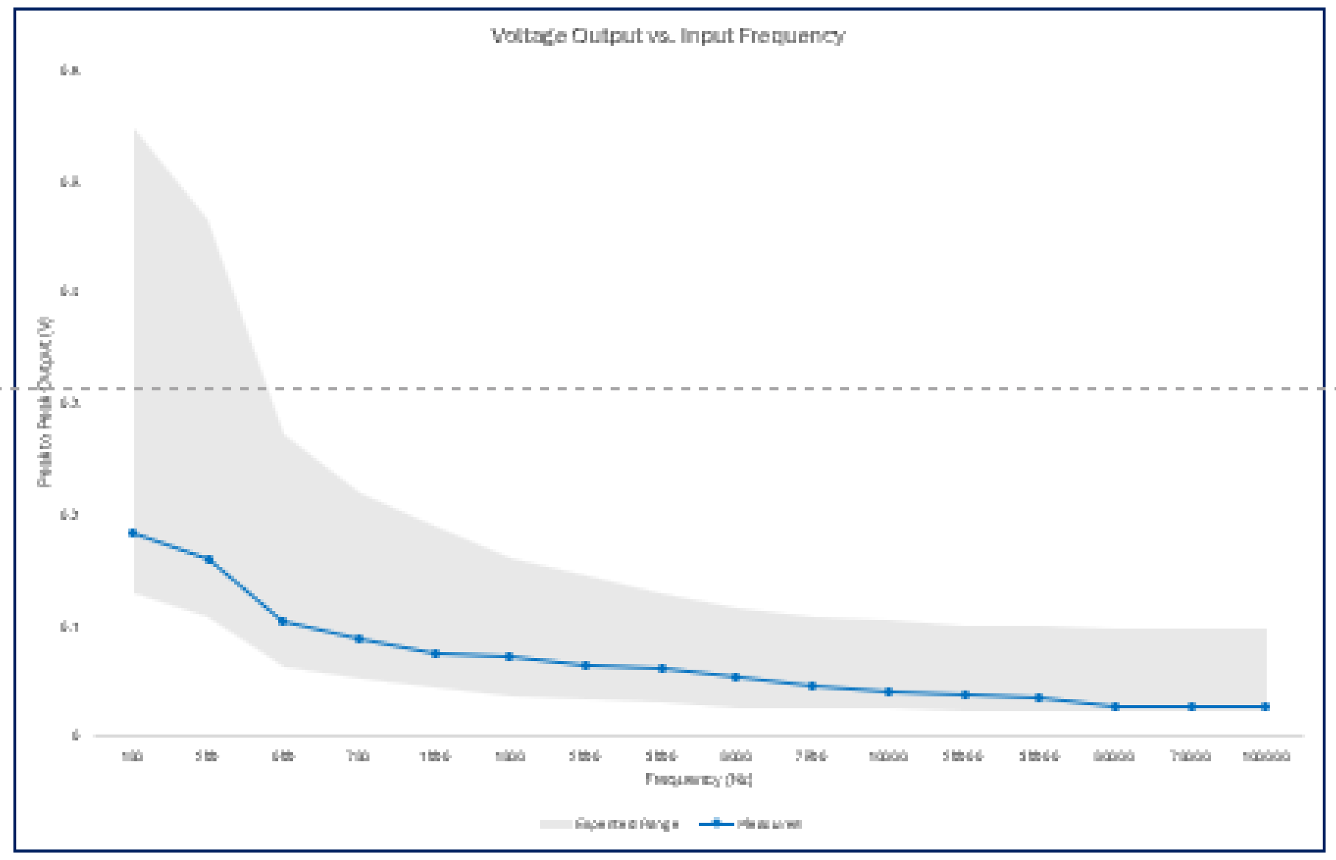

Figure 7. Benchtop Results

By examining our benchtop prototype, our design yields consistent measurements to that of the expected theoretical calculations. **This calibration of the sensor response is promising as early treatment intervention may prevent long term side-effects due to delayed lymphedema treatment.**

FUTURE STEPS

Upon completion of this project, objectives of portability and ensured patient safety should be met. Therefore, these are some logical future steps.

1. Arduino interpretation of data
2. Hydrogel testing (varied ionization levels)
3. Patient tunability

Then, this technology may be applied beyond lymphedema: sports medicine, etc.

ACKNOWLEDGEMENTS & REFERENCES

Acknowledgements: Funding from the Electrical & Computer Engineering Department at the University of New Hampshire, Guidance and material support from the Remote Sensing Laboratory at the University of New Hampshire

References: [1]American Cancer Society medical and editorial content team, "About Breast Cancer." American Cancer Society, Jan. 25, 2022. [Online]. Available: https://www.cancer.org/cancer/types/breast-cancer/about.html

[2]Jason Lucas, "Johns Hopkins graduate students create a lymphedema detection sensor." HUB at Johns Hopkins University, Apr. 28, 2022. [Online]. Available: https://hub.jhu.edu/2022/04/28/students-develop-lymphedema-detection-sensor/

3 K. R. Aroom, M. T. Harting, C. S. Cox, R. S. Radharkrishnan, C. Smith, and B. S. Gill, "Bioimpedance Analysis: A Guide to Simple Design and Implementation," *J. Surg. Res.*, vol. 153, no. 1, pp. 23–30, May 2009, doi: 10.1016/j.jss.2008.04.019

4 R. V. Shannon, "A model of safe levels for electrical stimulation," *IEEE Trans. Biomed. Eng.*, vol. 39, no. 4, pp. 424–426, Apr. 1992, doi: 10.1109/10.126616.