Triboelectric Energy-Harvesting Face Mask

THE 12TH INTERNATIONAL CONFERENCE ON SENSOR DEVICE TECHNOLOGIES AND APPLICATIONS

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Biography of the Presenter

Dr. Reza Rashidi is an Associate Professor and the chair of the Department of Mechanical and Electrical Engineering Technology at SUNY Alfred State College. He received his Ph.D degree in Mechanical Engineering (MEMS development) from the University of British Columbia in 2010 and completed his Postdoctoral Fellowship in Development of Biomedical Sensing Devices in the Department of Electrical and Computer Engineering at the University of British Columbia in 2011. He also received a minor degree in Engineering Management and Entrepreneurship from the University of British Columbia in 2009. He has over 16 years of industrial experience. Before joining Alfred State, Dr. Rashidi was a Senior Engineer at Siemens, where he worked on research projects from 2011 to 2016. His expertise is in the development of nano, micro and mini sensors and actuators in Biomedical Engineering and Energy applications. Dr. Rashidi was a recipient of several awards including the 2008 British Columbia Innovation award, administered by BC province, Canada. He has written over 30 research articles and is currently a reviewer and technical committee member of several journals and conferences worldwide.

The Motivation

COVID-19 Business Regulations
- Mandatory mask wearing laws

Expensive temperature taking machines

Feverish temperatures used as an early detection

Environmentally friendly

Drive towards micro/nanogenerators

Using easily-accessible materials

Problem Statement

Need for temperature sensing

Face mask requirement- need for small components and nanogenerators

Limit the spread and exposure to infected particles

Overall Solution

Triboelectric nanogenerator face mask:

- Nanogenerator created with recyclable, low cost, common materials
- Thermistor temperature sensor
- Arduino coding
- Battery charger

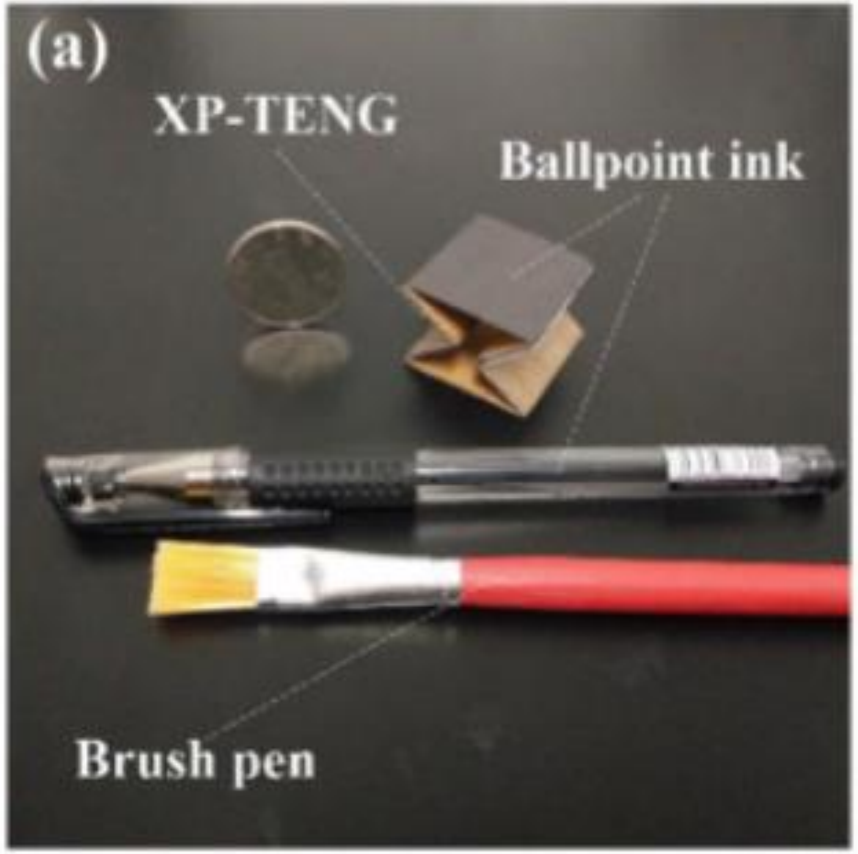
Objectives

Create a self-powered face mask equipped with a triboelectric nanogenerator

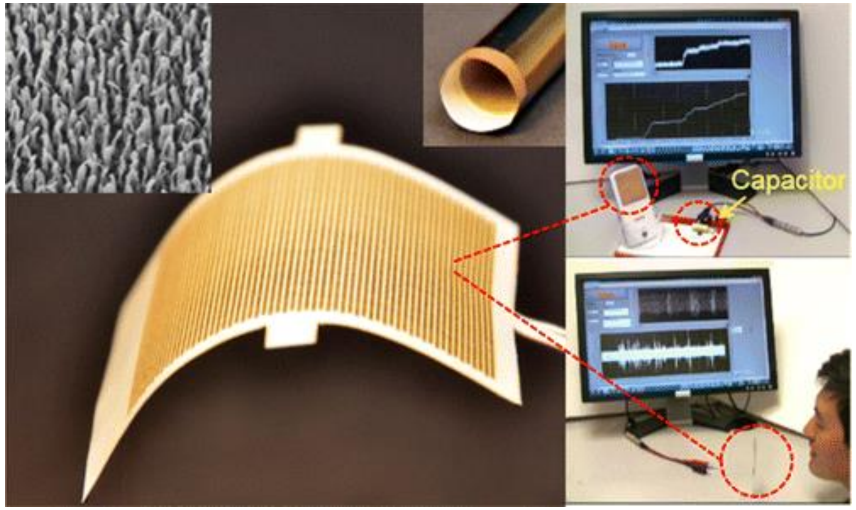
Use low-cost, common materials for the nanogenerator

Use Arduino coding to activate an LED at a set temperature read by the thermistor

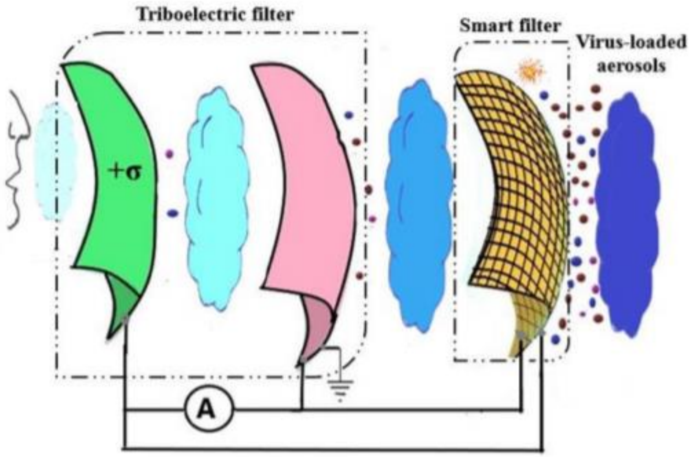
The Background



Fabricated TENG using pen ink (Xia et al., 2018)

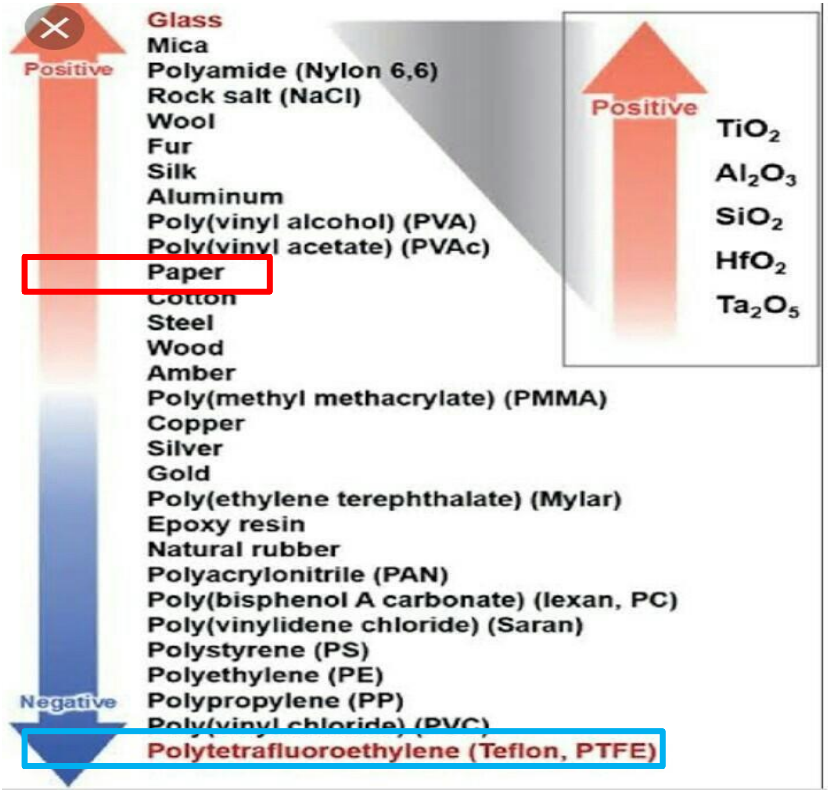


Rollable TENG for harvesting acoustic energy (Fan et al., 2015)

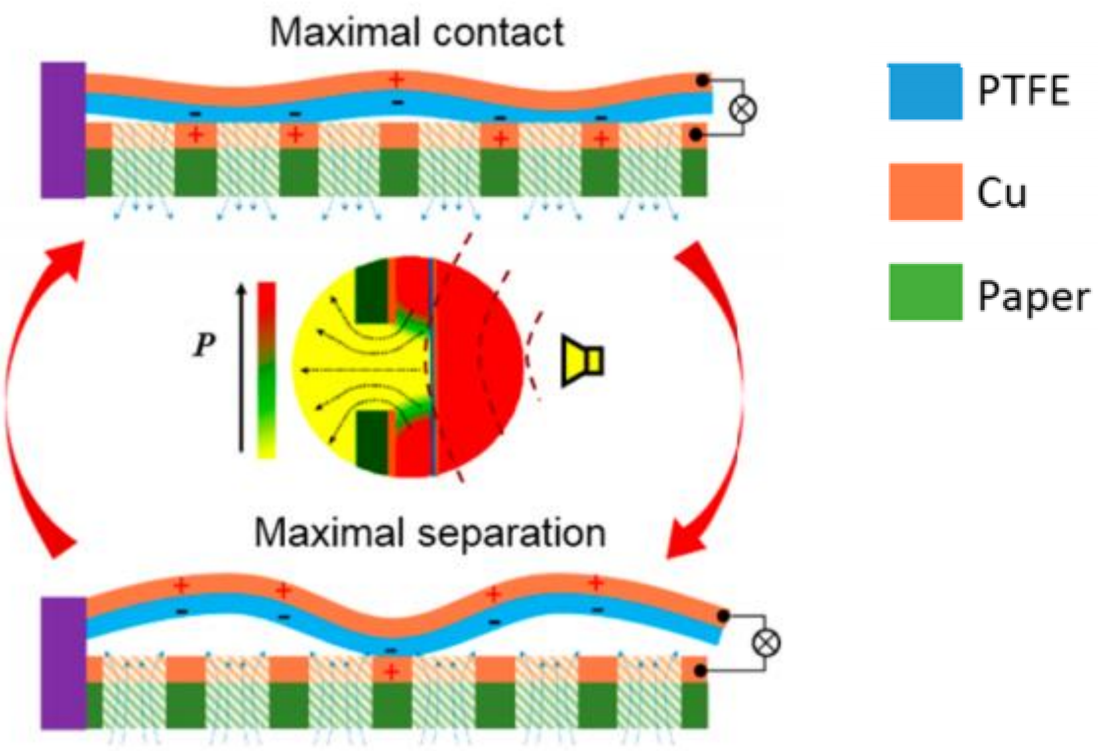


Design of a TENG face mask (Ghatak et al., 2020)

A Look at the Triboelectric Effect

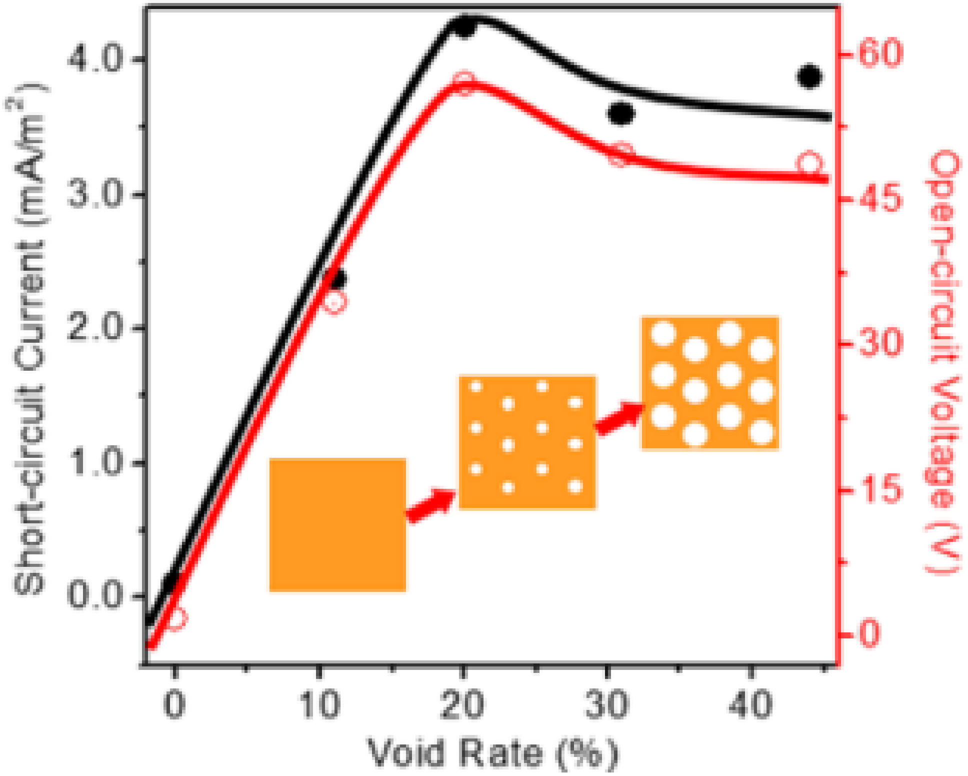


Scale of positively and negatively charged materials (Kim et al., 2017)

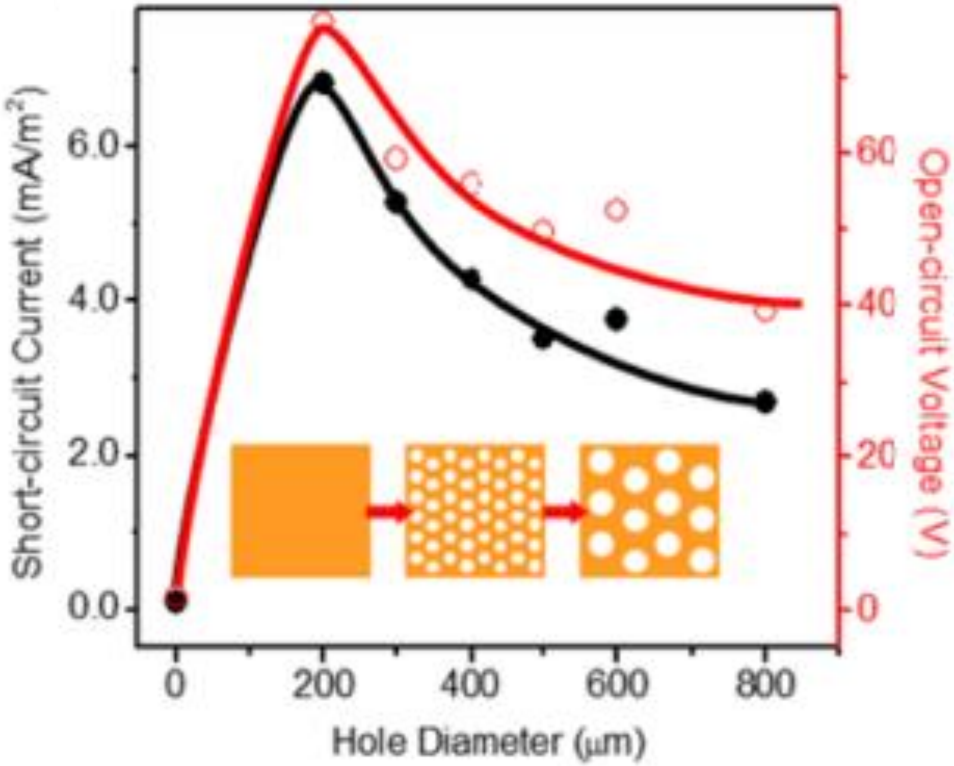


Transfer of charges using sound energy motion and vibration (Fan et al., 2015)

Void-to-Surface Area Ratio

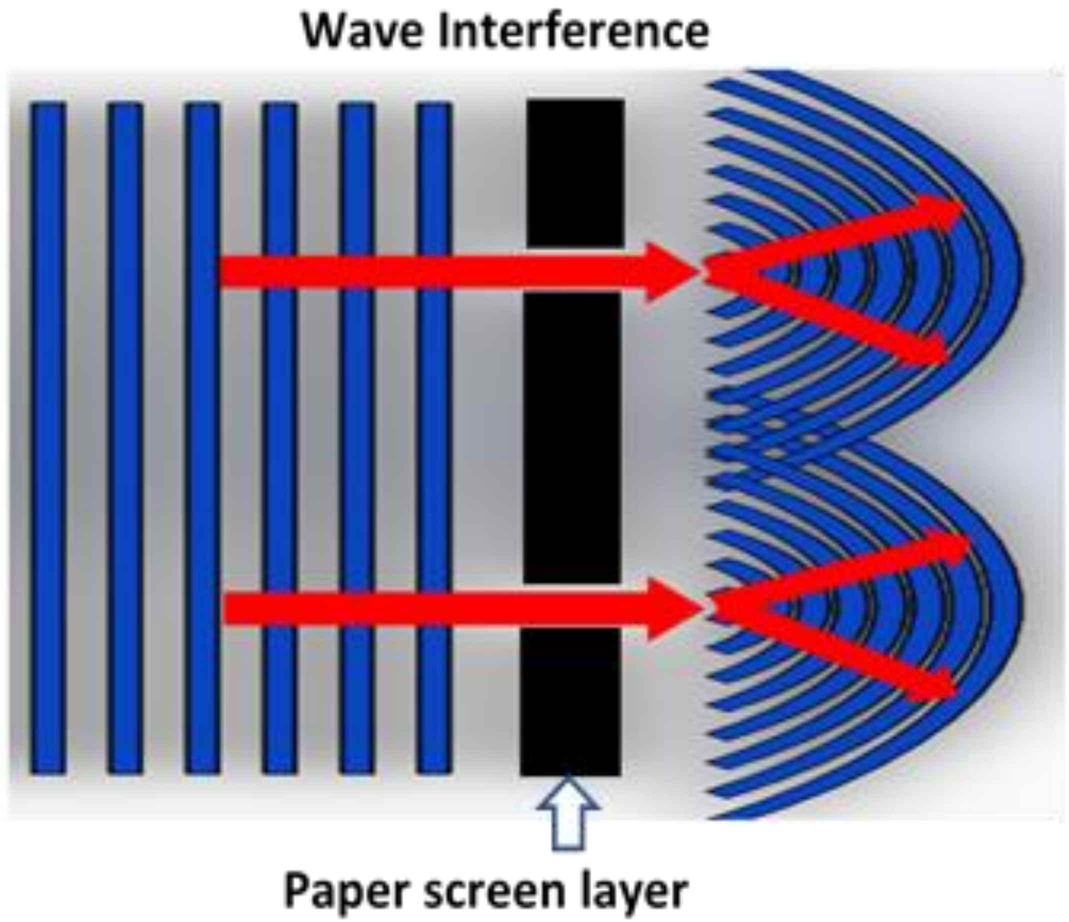


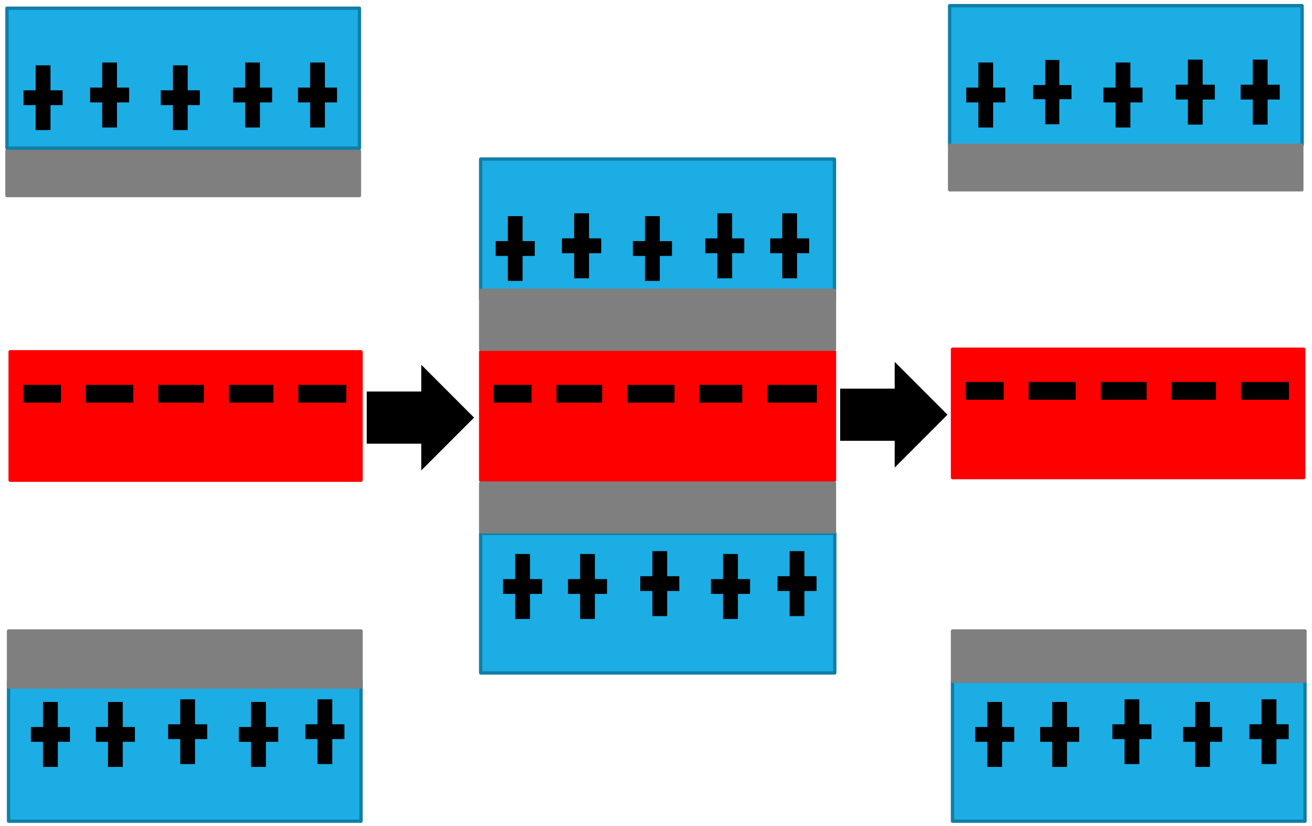
Relationship between Current/Voltage outputs and Void-to-Surface Area Ratio (Fan et al., 2015)



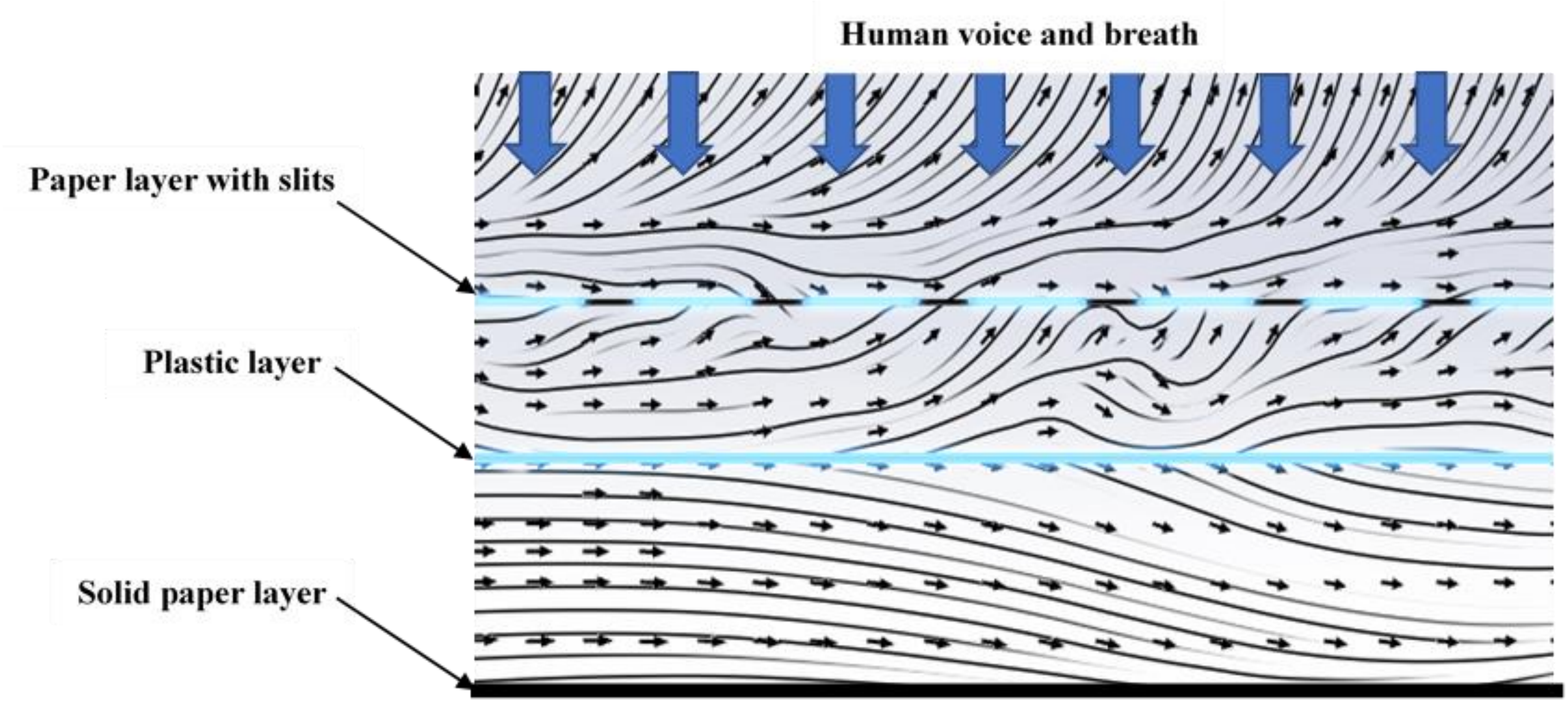
Relationship between Current/Voltage outputs and Hole Diameter (Fan et al., 2015)

Wave Interference Inducing the Working Principle

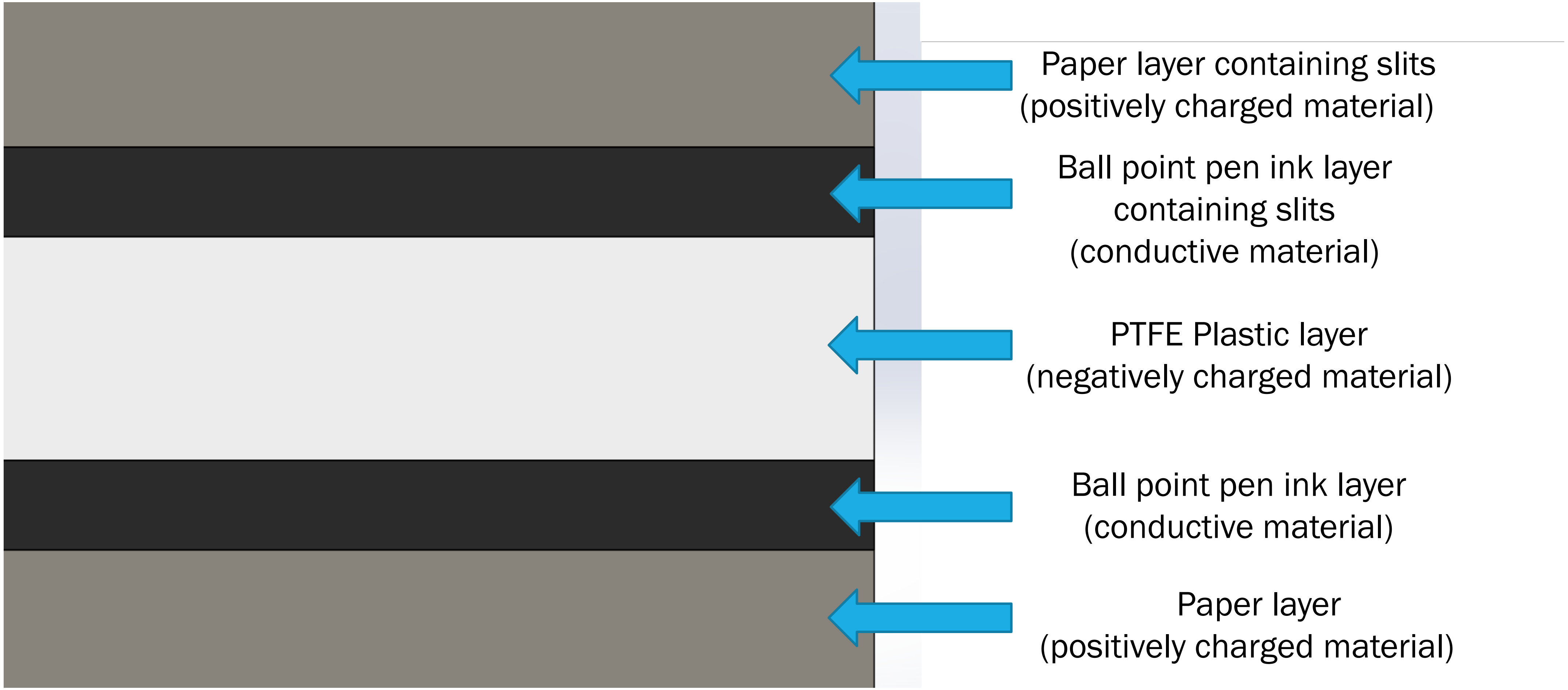




SolidWorks Flow Simulation of the Design



Triboelectric Nanogenerator Constructed View

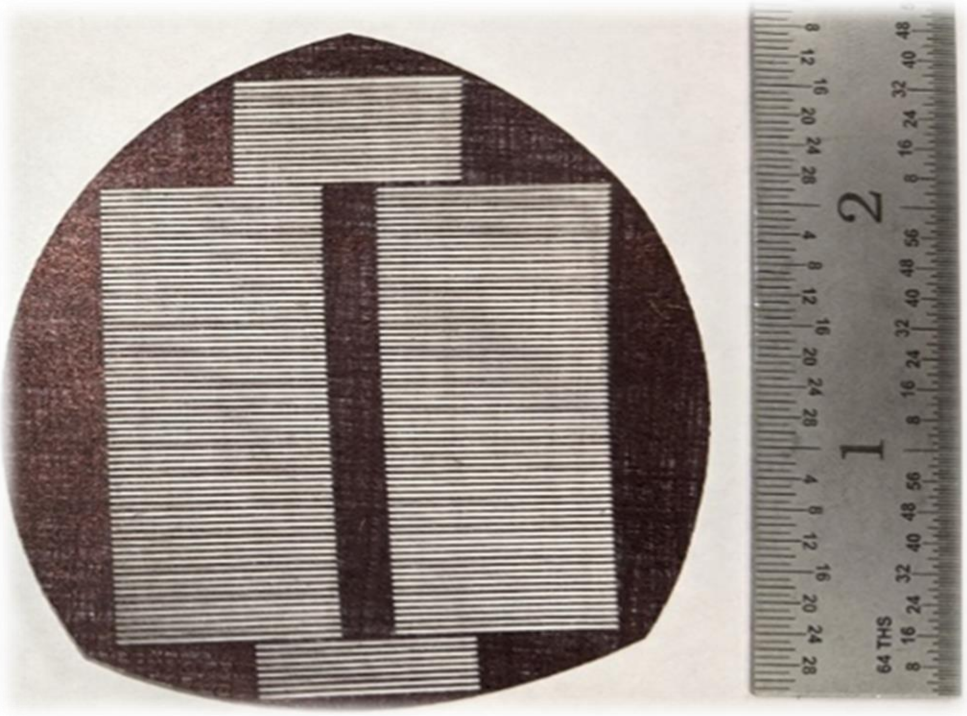


(Not to scale)

Design Progression

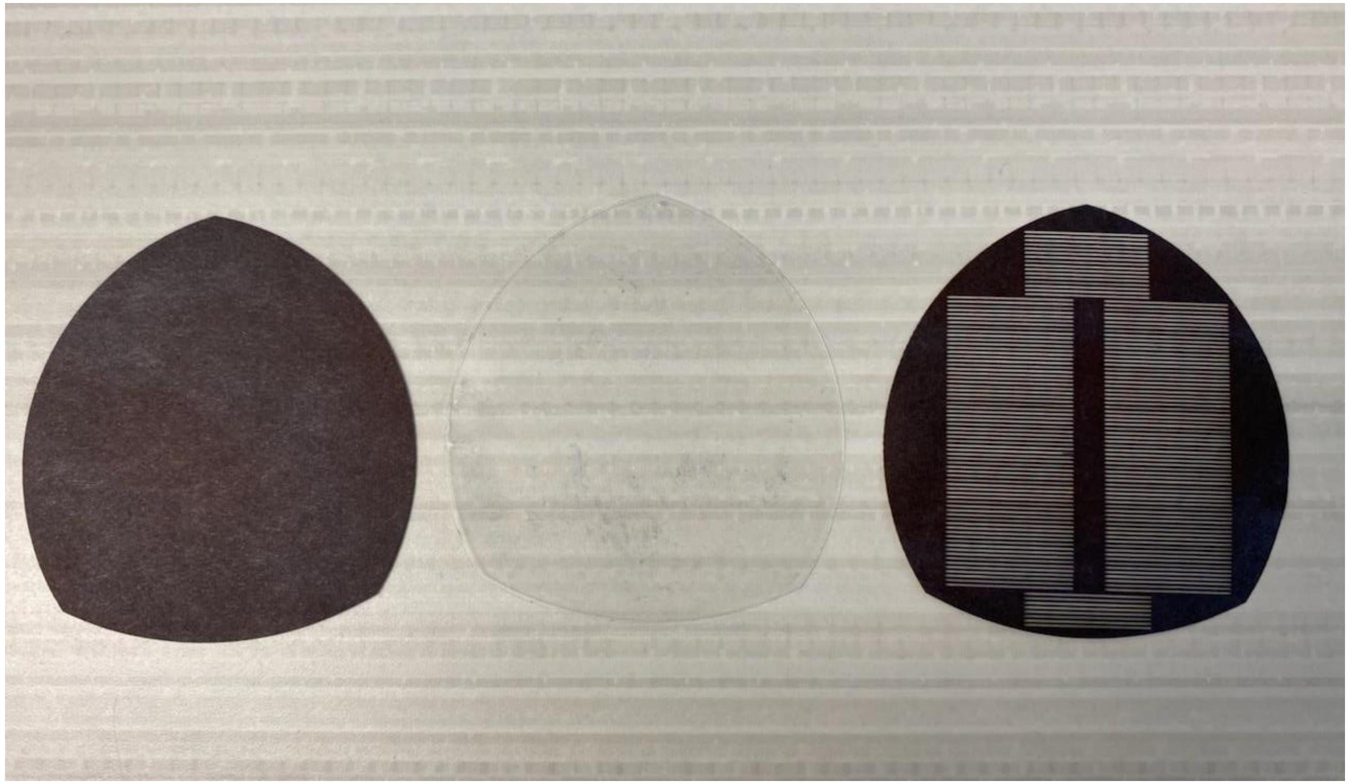
Paper-screen design using 200 µm holes (Credit: Barker, S.)

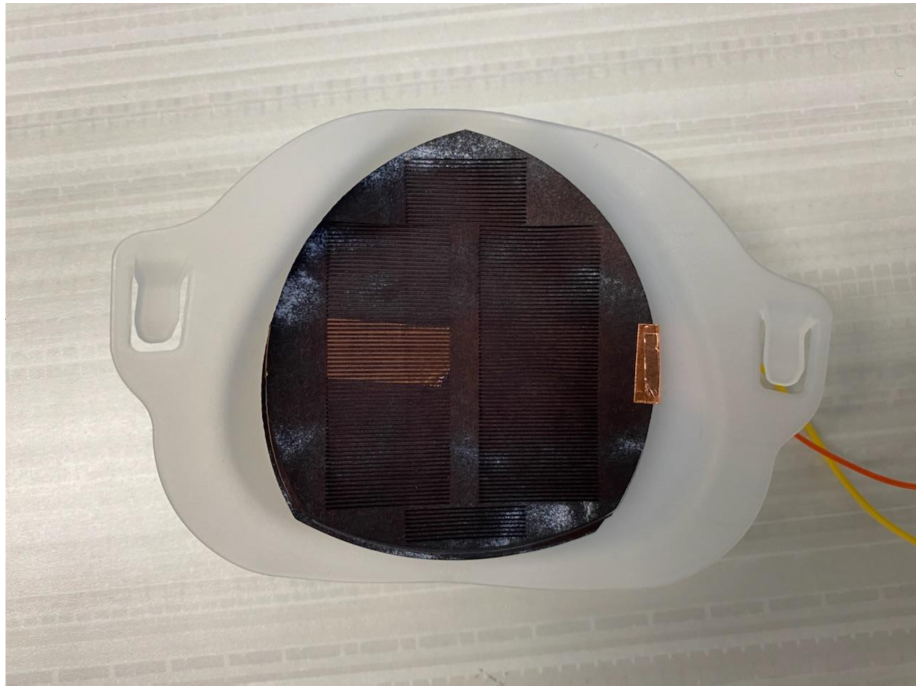
Paper-screen design using 200 µm x 20,000 µm slits (Credit: Barker, S.)

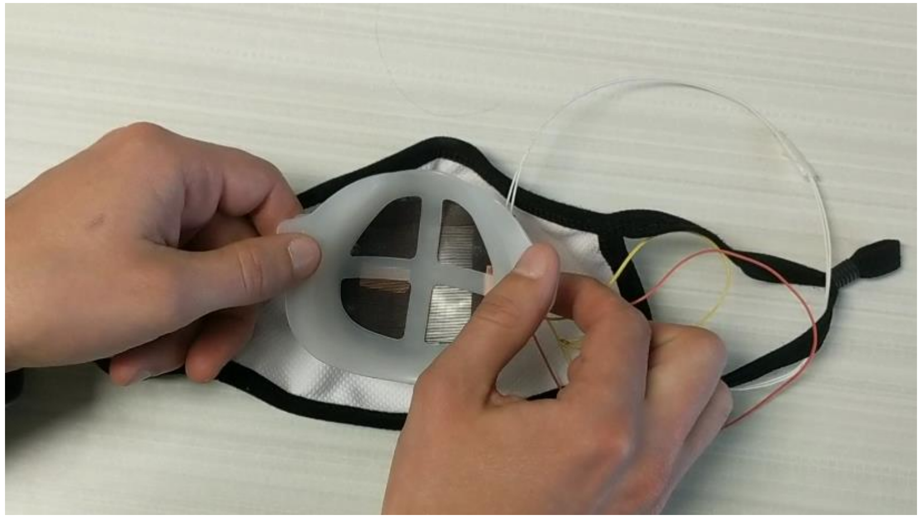


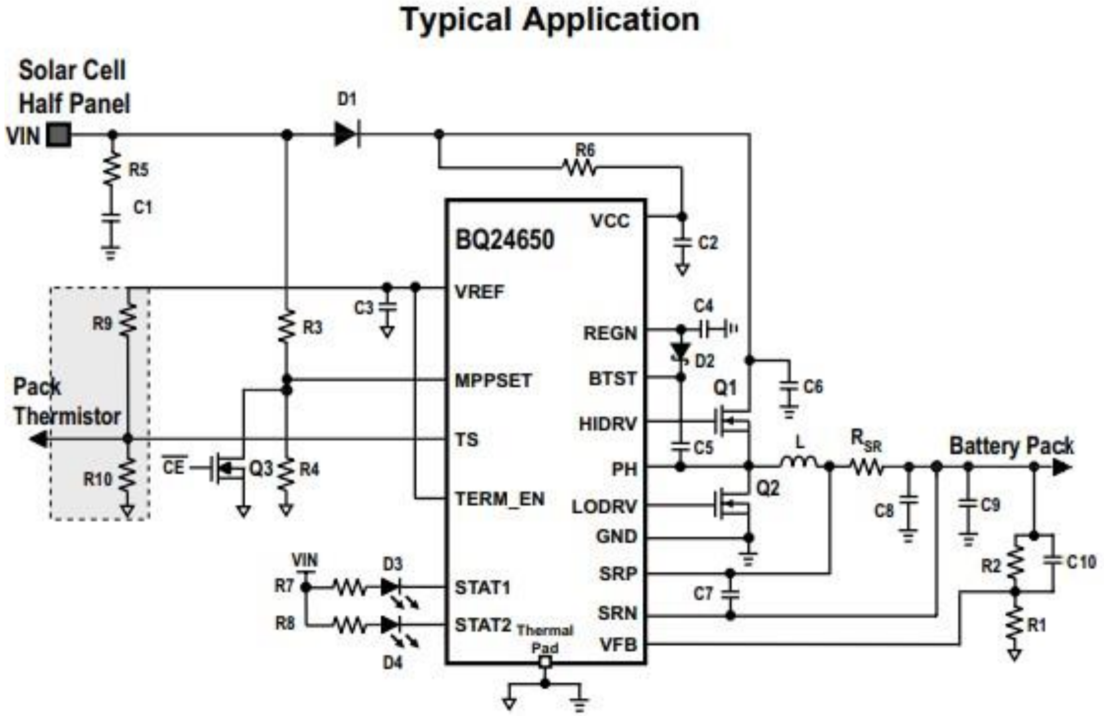
Insert-shape, paper-screen design using 200 µm slits x 20,000 µm slits (Credit: Barker, S.)

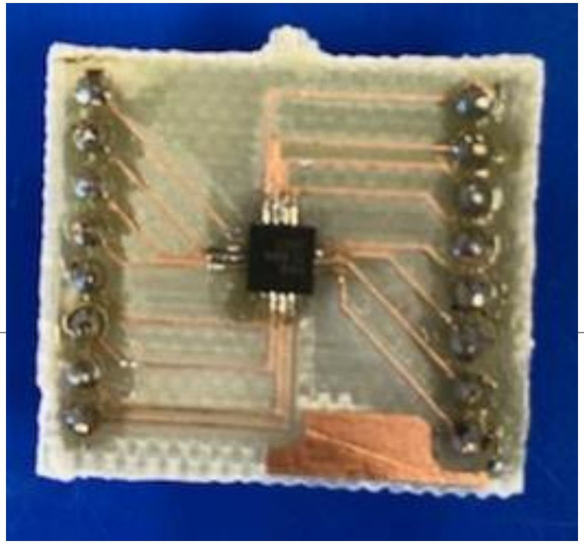
Implementation

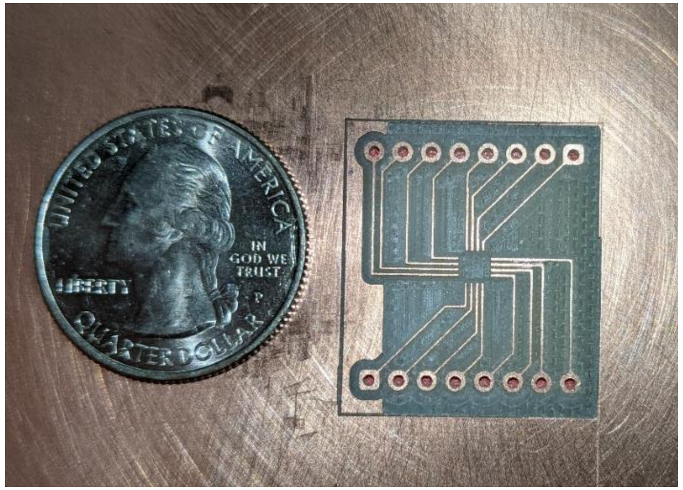












Design: Battery Charger

BQ24650 Stand-Alone Synchronous Buck Battery Charge Controller for Solar Power With Maximum Power Point Tracking

Design: The Temperature Sensor

NTC 3950 100k Thermistor

Thermistor Calculations

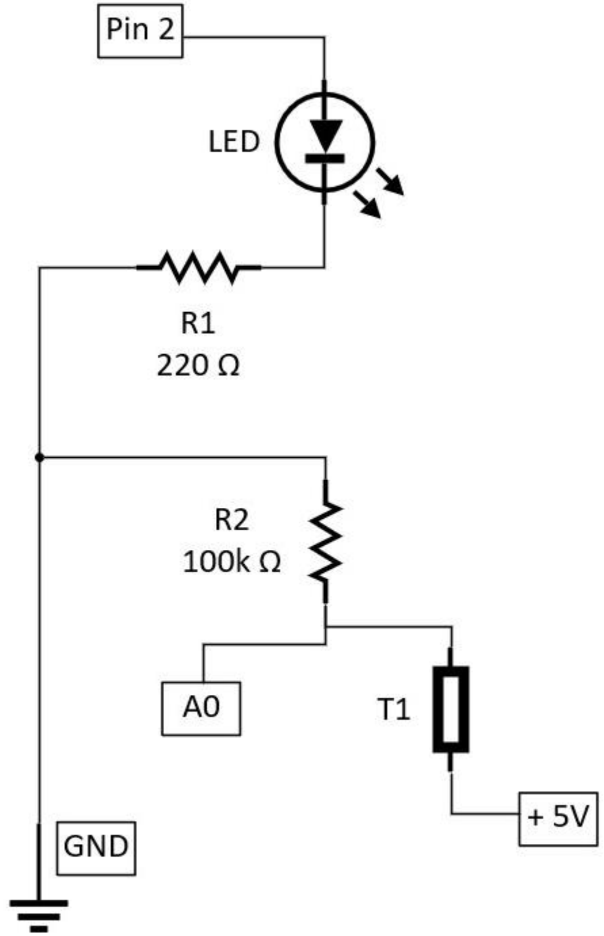
- The Steinhart-Hart Equation and Coefficients

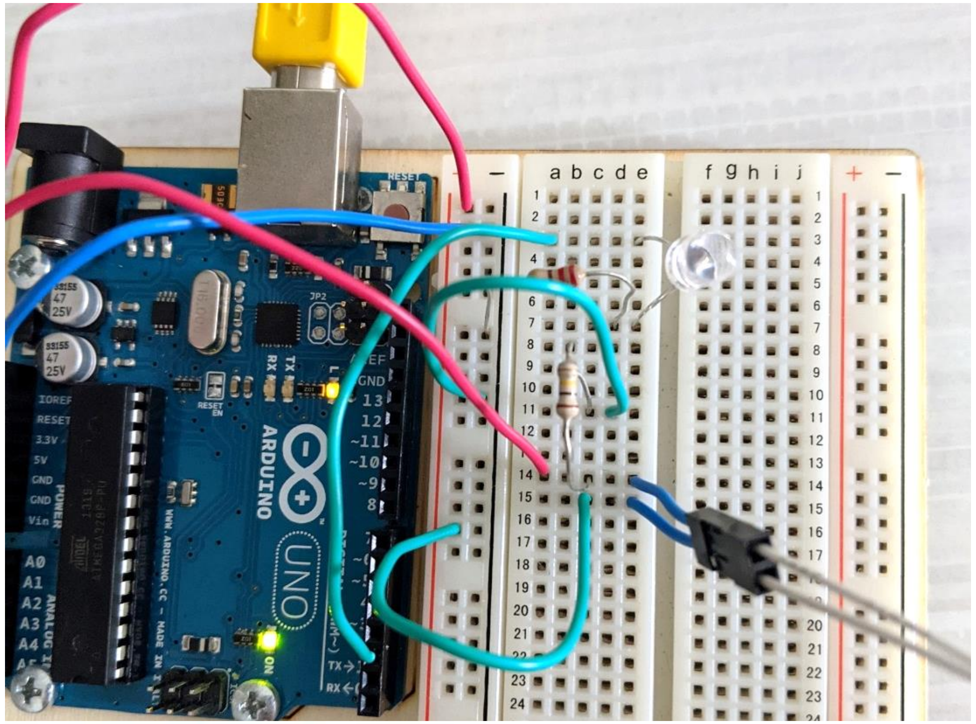
The Steinhart-Hart equation:

$$\frac{1}{T} = C1 + (C2 * \ln(R)) + (C3 * (\ln(R))^3)$$

$$\begin{bmatrix} 1 & \ln(R1) & (\ln(R1))^3 \\ 1 & \ln(R2) & (\ln(R2))^3 \\ 1 & \ln(R3) & (\ln(R3))^3 \end{bmatrix} * \begin{bmatrix} C1 \\ C2 \\ C3 \end{bmatrix} = \begin{bmatrix} \frac{1}{T1 + 273.15} \\ \frac{1}{T2 + 273.15} \\ \frac{1}{T3 + 273.15} \end{bmatrix}$$

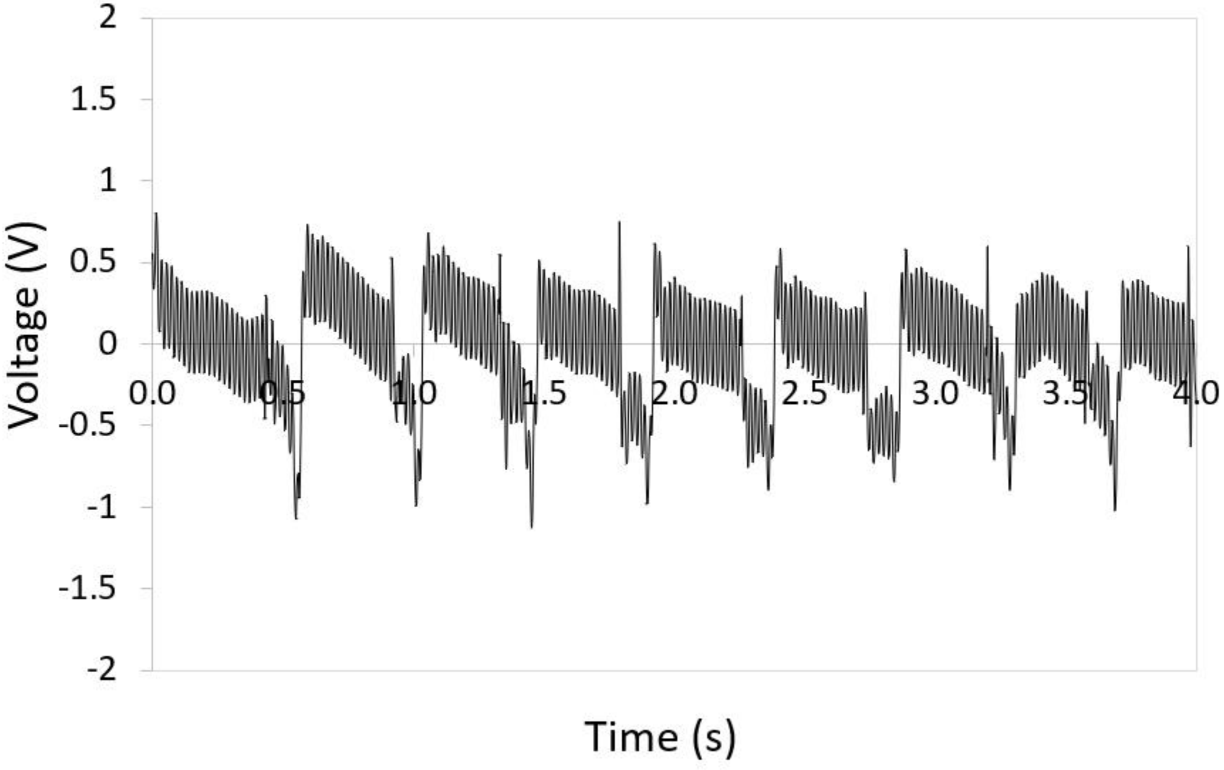
Design: The Arduino Set-up



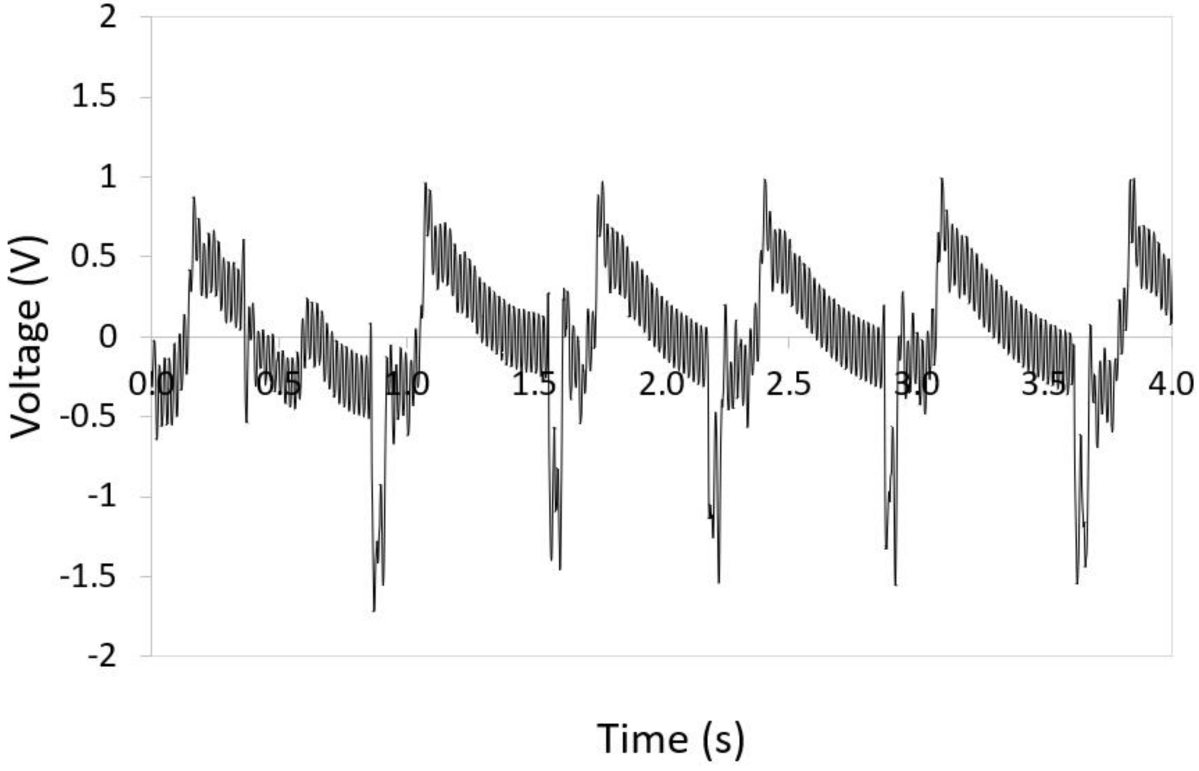



```
Vo = analogRead(ThermistorPin);
R2 = R1 * (1023.0 / (float)Vo - 1.0);
logR2 = log(R2);
T = (1.0 / (c1 + c2*logR2 + c3*logR2*logR2*logR2)); //Steinhart-Hart equation
T = T - 273.15; //Conversion from Kelvin to Celcius
T = (T * 9.0)/ 5.0 + 32.0; //Conversion from Celcius to Fahrenheit
```

Generated Voltages of the Developed TENG

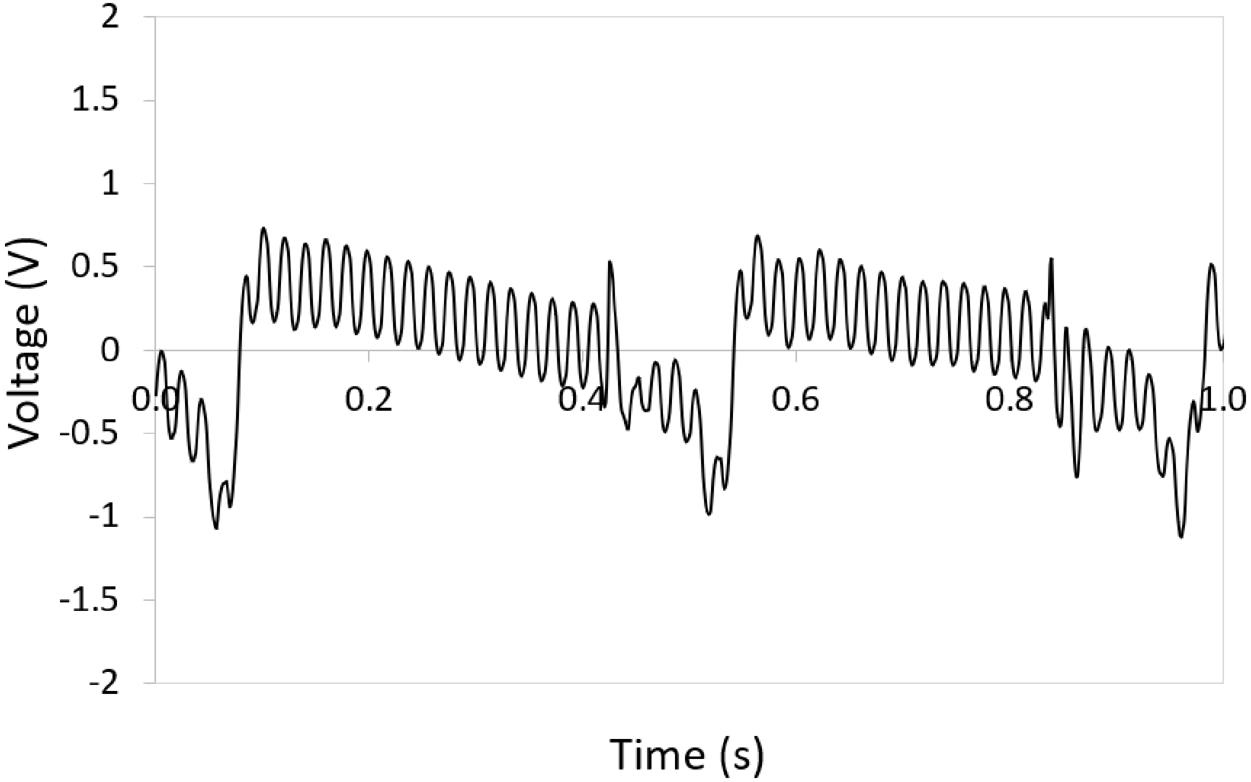


70 dB

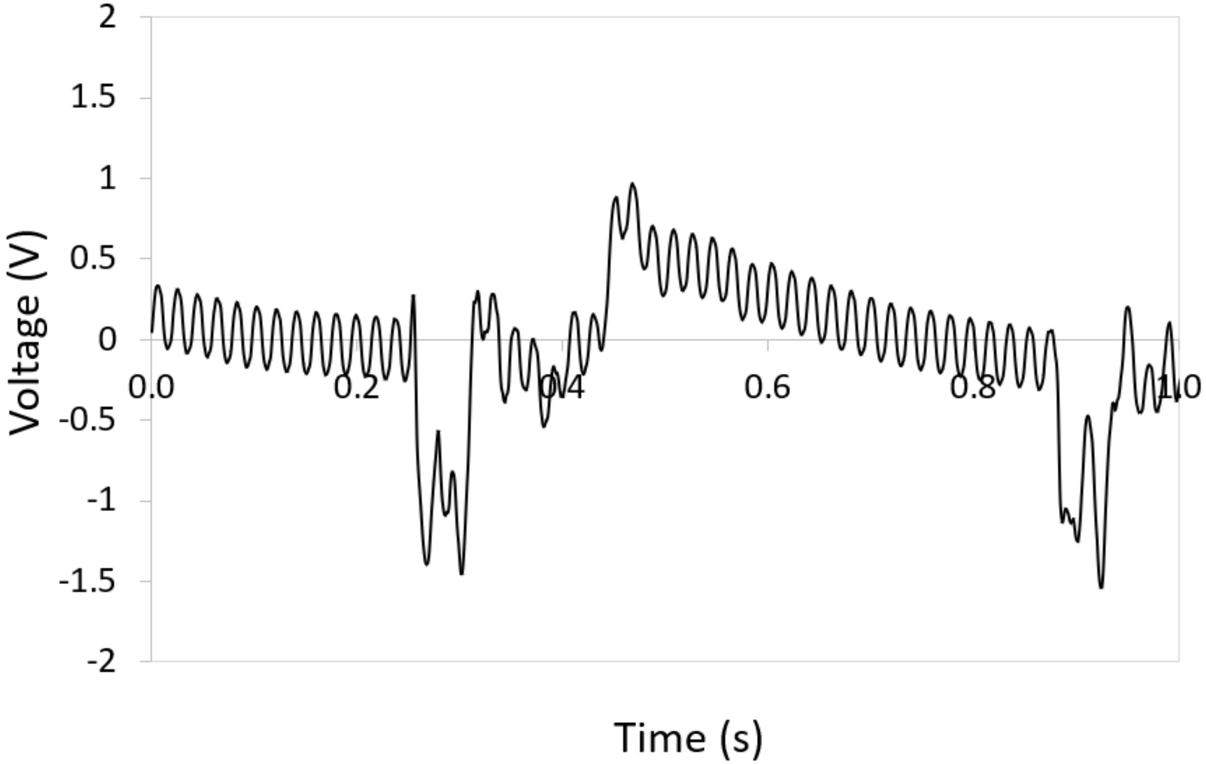


80 dB

Zoomed Generated Voltages of the TENG

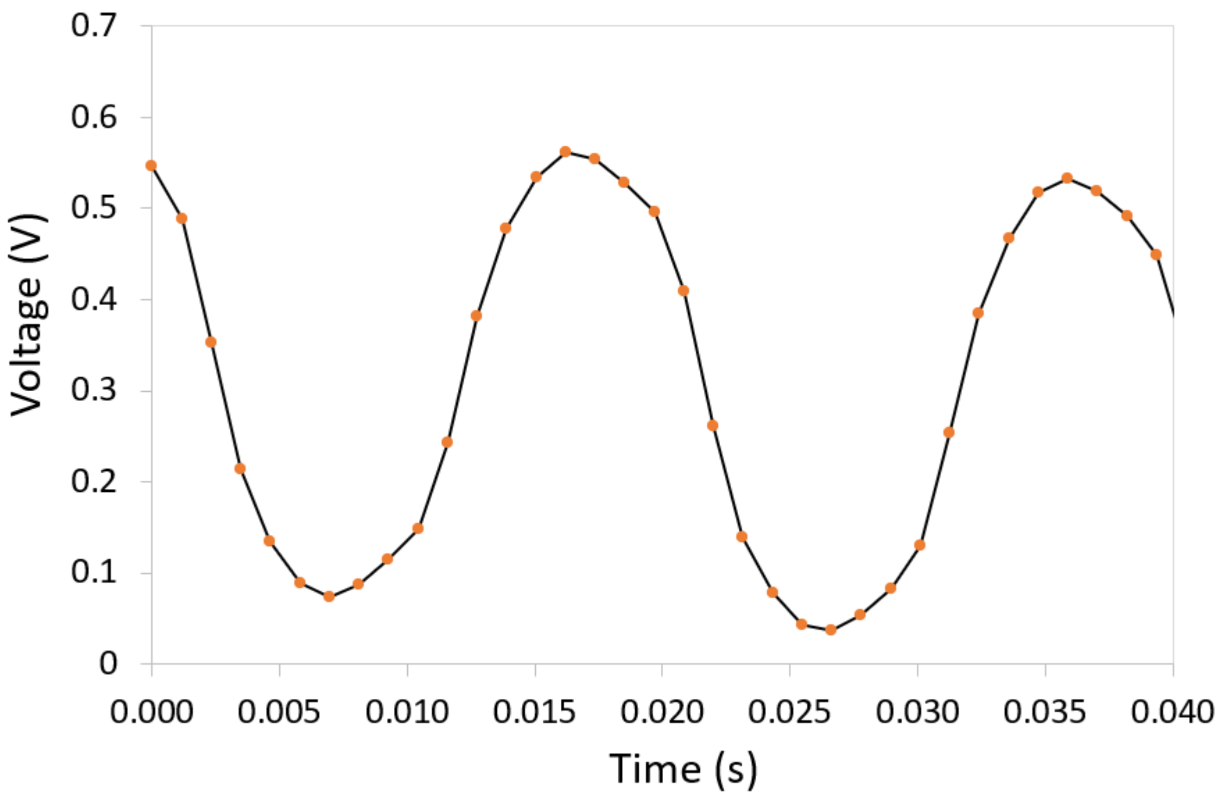


70 dB

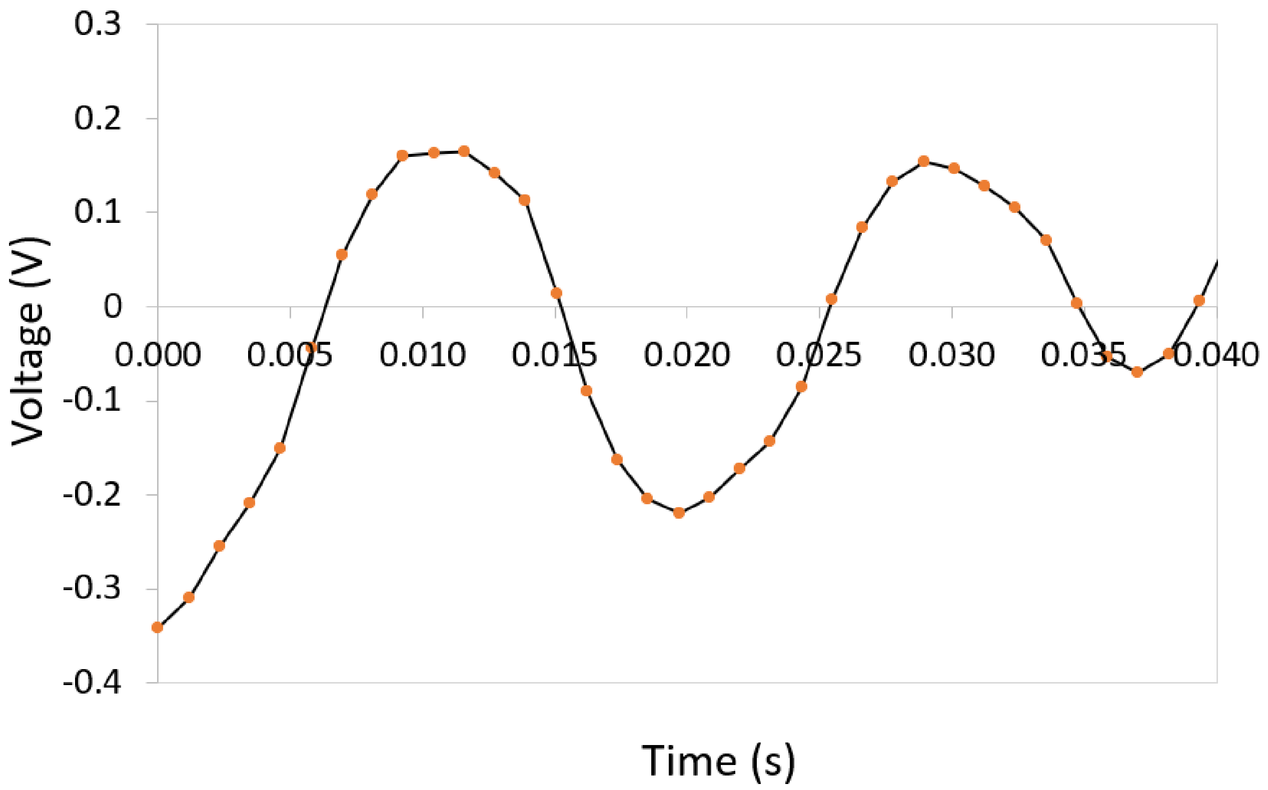


80 dB

Individual Minor Cycles in Generated Voltages



70 dB



80 dB

Summary of Voltage and Frequency Values

Cycle Type	Parameter	Sound Pressure Level (SPL)	
		70 dB	80 dB
Major Cycles	Peak-to-Peak Voltage (V)	1.72	2.48
	Frequency (Hz)	2.27	1.61
Minor Cycles	Peak-to-Peak Voltage (V)	0.60	0.38
	Frequency (Hz)	51.3	52.2

Summary

- Development of the TENG
- Implementation into the face mask
- Finalization of Arduino code and set-up
- Power output of nanogenerator is not sufficient to continuously feeding thermistor, thus requiring a battery charger

Future Work

- Moving from an LED to a transmitting device
- Radio Frequency Identification (RFID) tracking for businesses
- Bluetooth development of code
- Carbon dioxide detector to show when mask insert is expended