भारतीय प्रौद्योगिकी संस्थान दिल्ली
Indian Institute of Technology Delhi

3D Design and Interface for Triboeleric nanogenerators Devices

Internship report

14th July - 14th August 2022

<u>SUBMITTED BY</u>

Prashant Sharma

BSMS-4th Year

School of Mathematics

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH, THIRUVANANTHAPURAM

<u>UNDER THE GUIDANCE OF</u>

Dr. Ankur Goswami

Associate Professor Department of Material Science and Engineering

IIT Delhi, New Delhi

ACKNOWLEDGEMENT

I would like to convey my gratitude to Prof. Ankur Goswami for his patient supervision, enthusiastic encouragement, and helpful ideas in my study endeavor.

I would also like to express my gratitude to Mr. Shailendra Kumar, Mr. Suraj, Miss Shalini, Mr. Durgesh, Mr. Jaikrishna, and Mr. Chhotrai Soren for their suggestions and guidance in helping me to keep my progress on time. I also want to thank Miss Ashwani for her assistance with the tools and equipment.

Finally, I'd like to thank my parents for their inspiration and support during my academic career.

Content

1. Abstract …………………………………………………………………………3
2. Introduction……………………………………………………………………….. 4
3. Working principle of TENG in different modes………………………………………...4
    a. Contact Separation Mode…………………………………………………….5
    b. Linear Sliding Mode………………………………………………………….6
    c. Single electrode mode………………………………………………………...6
    d. Freestanding Mode In the…………………………………………………….6

4. 3D Designs…………………………………………………………………………6
    a. Contact mode-based TENG Device (Servo motor based).................................7
    b. Sliding contact mode-based TENG Device……………………………………9
    c. Contact mode-based TENG Device (Stepper Motor based).............................10

5. Load cell interfacing ………………………………………………………………11
    a. Calibration ……………………………………………………………………12
    b. Scale code…………………………………………………………………...12

6. Conclusion…………………………………………………………………………12

Abstract

The most fantastic way to deal with the energy situation is to transform the energy from our regular activities into valuable electrical energy. Energy harvesters that electrically extract energy from vibrational energy require a great deal of engineering, implementation, and upkeep. Also, batteries have complicated recycling and disposal difficulties. This project comes up with the idea that drastically cuts battery consumption. Triboelectric nanogenerators (TENGs) can replace batteries in low-power electronic devices because of their simple design, low cost of production, and excellent energy efficiency. Triboelectric nanogenerators (TENGs) can replace batteries in low-power electronic devices because of their simple design, low cost of production, and excellent energy efficiency. This project aims to design the machines and interface for harvesting triboelectric energy using vertical and horizontal sliding techniques.

TENG can operate in a number of distinct modes, including contact separation, vertical and horizontal sliding, single electrodes, and free-standing. TENG's design can also be used as a transportable and dependable power source using their separate operating modes for power generation. A total of three 3D Designs were made using SOLIDWORKS (3d- Designing Software), Arduino, Python, and Industrial Servo driver, along with a PID controller used, Light

source to enhance the emission of electrons and force provided by the oscillating primary plate can be measured by Load Cell.

Introduction

In recent decades, the boom in consumer electronics has rapidly created a need for sustainable portable and portable power sources. Too many low-power electronic devices are being deployed to improve our quality of life, such as sensors, communication devices, GPS devices, and implantable and health monitoring devices. All of these electronics require power in the range of microwatts to milliwatts. Though batteries can be used for supplying power in this range, they still have their own shortcomings, like problems in their recycling. Battery wastes contain a lot of heavy metals, contributing to soil and water pollution. The future of electronics relies on wearables and wearable sensors such as flexible electronics, e-skin-based sensor devices, and implantable biomedical electronic systems. There is a need for sustainable and reliable power sources to run electronic devices with low power consumption.

The traditional approach to generating electrical energy involves using an electromagnetic generator (EMG) that harvests energy effectively under high-frequency mechanical energy input. Low-frequency mechanical energy is abundant worldwide and originates from sources like vibration, wind, water waves, human motion, and vehicle motion. These low-frequency movements cannot be detected effectively by EMG. A solution to this problem was solved with the invention of nanogenerators (NGs) in 2006. Piezoelectric Nanogenerator (PNG), Triboelectric Nanogenerator (TENG), Thermoelectric Generator (TEG), Pyroelectric Generator (PYG), etc., with different classifications and effects, have been deployed in a variety of energy harvesting and self-sufficiency applications over the past decades.

Energy harvesters also run several real-time applications by integrating batteries and other storage devices. Apart from energy harvesting, these NGs are self-powered sensors such as pH, glucose, chemical, humidity, temperature, barometric pressure, motion, optical, and strain sensors.

Forming TENG-PENG hybrids is a way to increase the output of TENG devices by improving their high instantaneous power density.

The project revolves around the idea of water wave energy captured by TENG-EMG hybrid configurations. The output produced is much higher in this case and can be used for GPS tracking and positioning systems.

Working principle

TENG works on the principle of triboelectric charging and electrostatic induction effects. TENG has four basic operating modes: vertical contact isolation mode, linear slide mode, single electrode mode, and free-standing mode. These modes require two different triboelectric materials with good electrode connections with good insulation between each layer. The combinations are either dielectric-dielectric assemblies or metal-dielectric assemblies. The rationale behind all four modes is that whenever there is a displacement in one of the triboelectric layers, the electrostatic charge motion breaks the existing electrostatic state, creating a potential difference between the electrodes. Upon repeated mechanical actuation of the forward and reverse layers, the triboelectric layers generate forward and reverse potentials between the electrodes, causing positive and negative spikes in the TENG output to produce an AC signal.

Four different modes of operation are shown schematically in Figure 1.

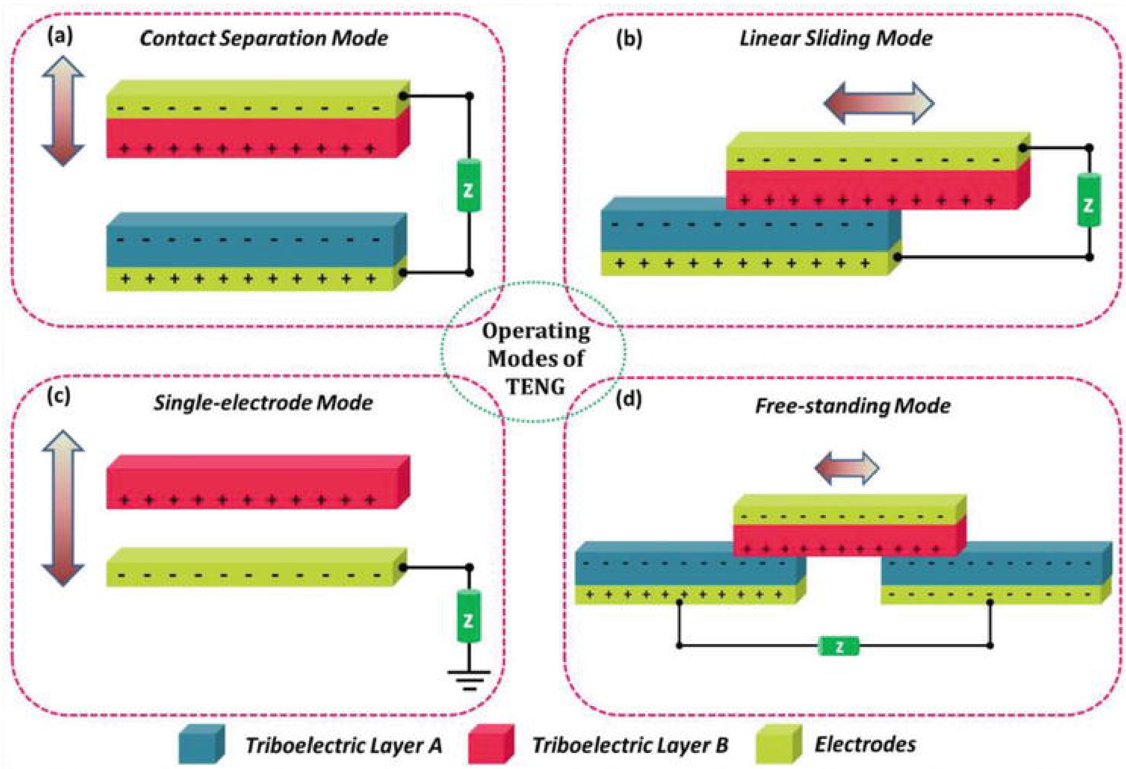

Fig-1: representation of the four fundamental operating modes of TENG.

1 Contact Separation Mode

In the Contact Separation Mode, TENG triboelectric charging occurs through the contact and separation process of two triboelectric materials or layers, as shown in Figure 1a. The process can be between two different dielectric materials, or it can consist of a dielectric layer and a metal layer. This model has significant advantages of simple design, ease of manufacture, and low cost. This mode of TENG was also first developed and proven to power low-power electronics. This TENG mode can also be used as multi-unit stacking for better output performance.

2 Linear Sliding Mode
In the linear sliding mode, charge generation occurs by relatively sliding back and forth between the TENG layers. The setup is almost identical to the contact separation mode with electrodes attached to the back of the triboelectric layer. Still, the displacement is lateral, as shown in Fig. 1b. Sliding mode has a lower figure of merit than vertical contact separation mode due to the more protracted displacements in the sliding process. The advantage of this mode is that the contact area is large, so it can generate more charge density with very effective charge generation. Also, the output power can be improved by introducing more grating structures. Sliding mode TENG can also rotate on a cylindrical grating structure.

3 Single electrode mode
The simplest structure of TENG is a single electrode mode TENG. Still, the output power is too low due to small charge transfer, resulting in low voltage and current generated, but very suitable for self I'm here. - enough applications
The advantage of this device is to overcome the application limitations due to contact wires on both sides of the contact separation mode and sliding mode TENG devices. The basic layout of single-electrode mode TENG is shown in Figure 1c.

4 Freestanding Mode In the
freestanding model, one electrode moves freely between two electrodes or triboelectric layers. The electrodes are in a stationary position, and the triboelectric layer without electrodes can move across them. This type of TENG device has a high figure of merit, showing high output efficiency and output power. Additionally, this type of device can be easily manufactured and embedded in a variety of real-time applications. The required configuration for single-electrode mode TENG is shown in Figure 1d.

3D Designs
Here, we have three different devices that were illustrated using 3D designs that help in getting the schematics of the devices so the working can be understood easily.
There is much software that is used for CAD(Computer-aided Design) for 3D designing. CAD programs not only create models but to test and visualize those models to see what structures would look like photo realistically before they are actually created. SOLIDWORKS is one of the CAD Software we used to design the Schematics and Sketch.
The First Design That We rendered was the LOAD CELL Fig-2; the load cell is used to measure the force applied to it.

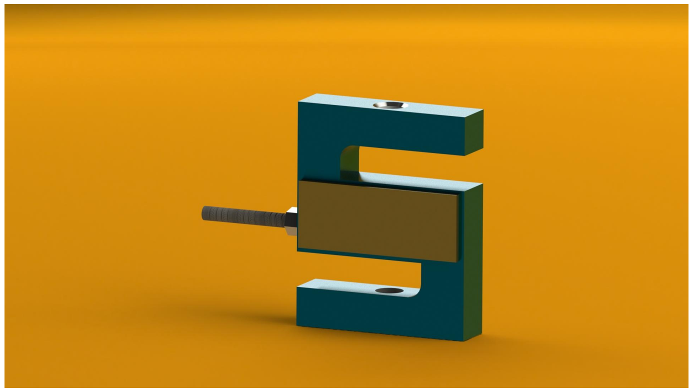

Fig-2: Load Cell

Flowing are some schematics and Sketch for the Three designs generated by Solidworks Software:-

A. Contact mode-based TENG Device (Servo motor based)

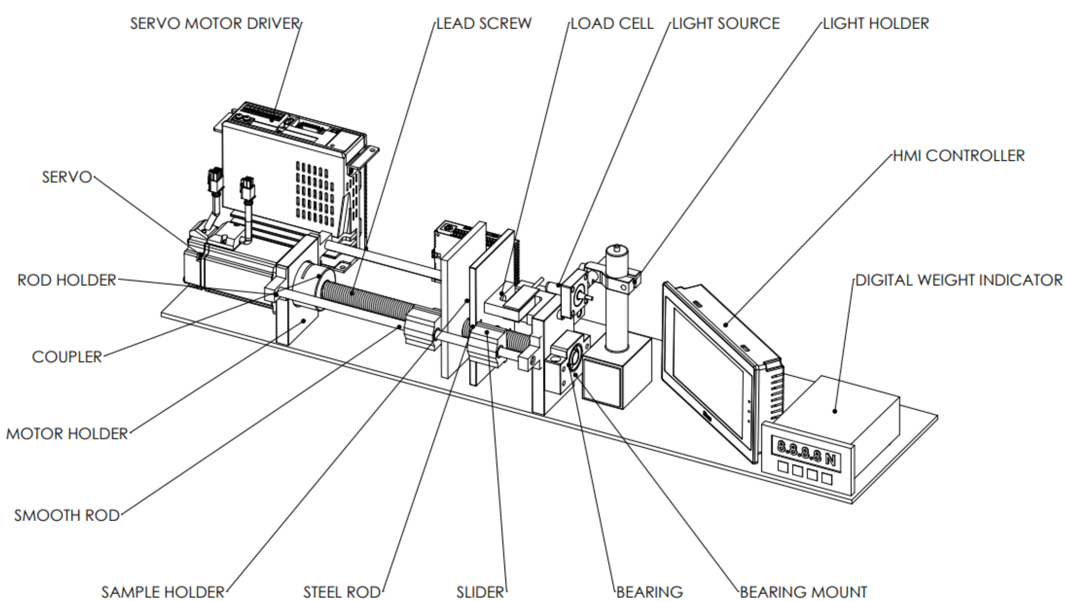

Fig-3(a): Schematic sketch of the contact mode-based TENG Device

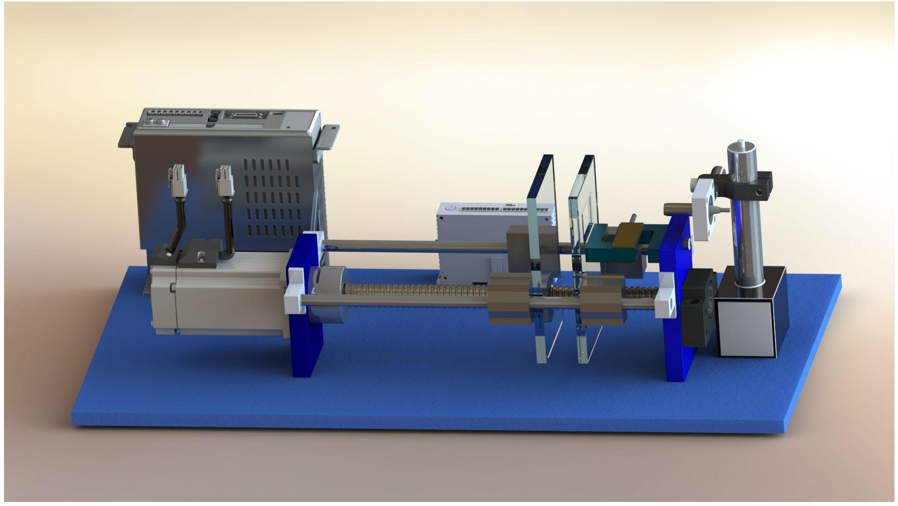

Fig-3(b): Front View

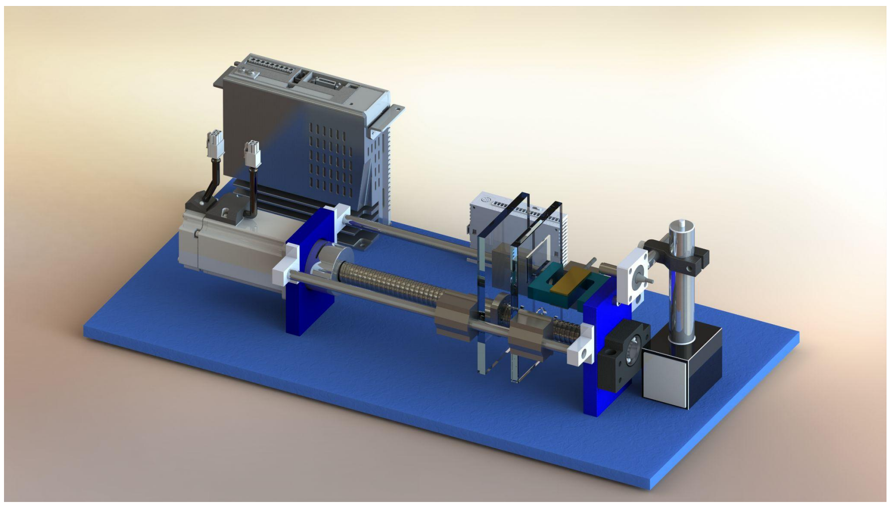

Fig-3(c): Isometric View

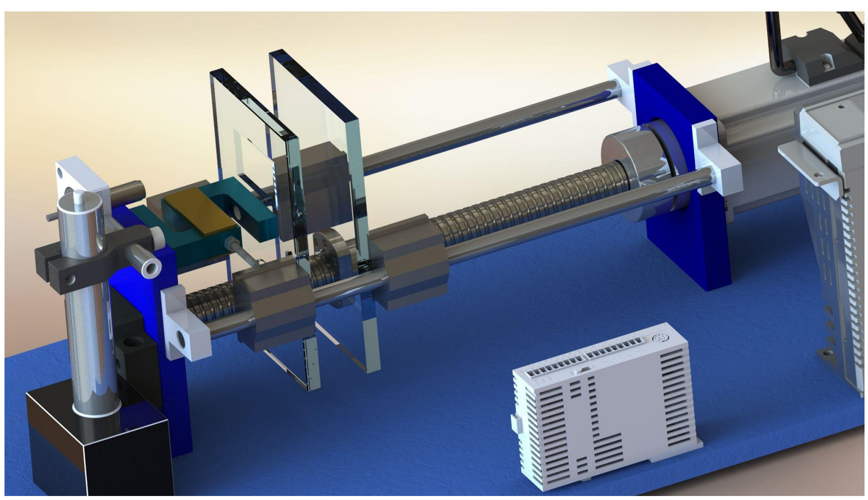

Fig-3(d): Close Isometric View

B. Sliding contact mode-based TENG Device

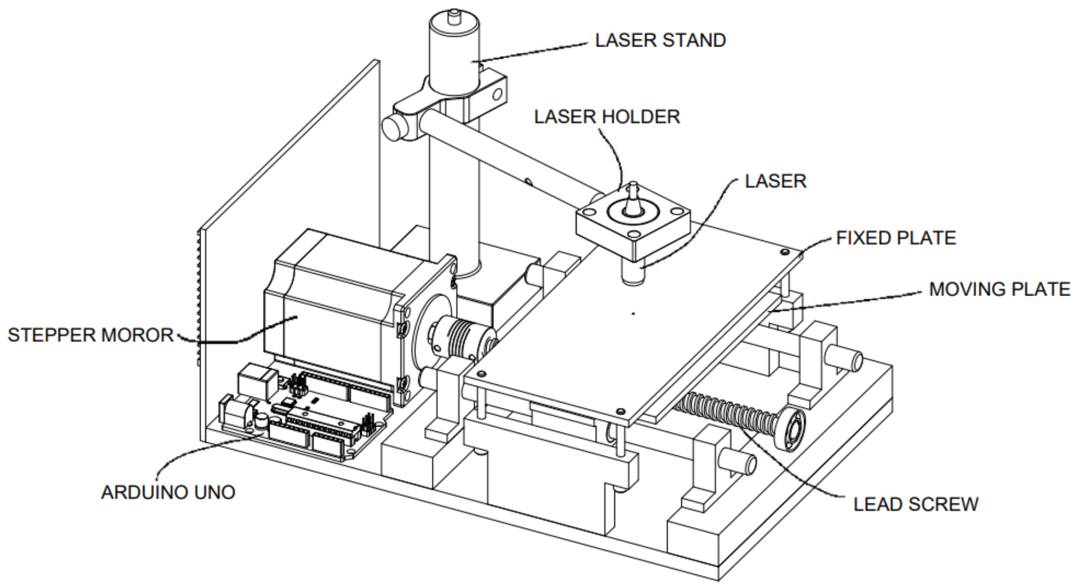

Fig-4(a): Schematic Sketch of Sliding contact mode-based TENG Device

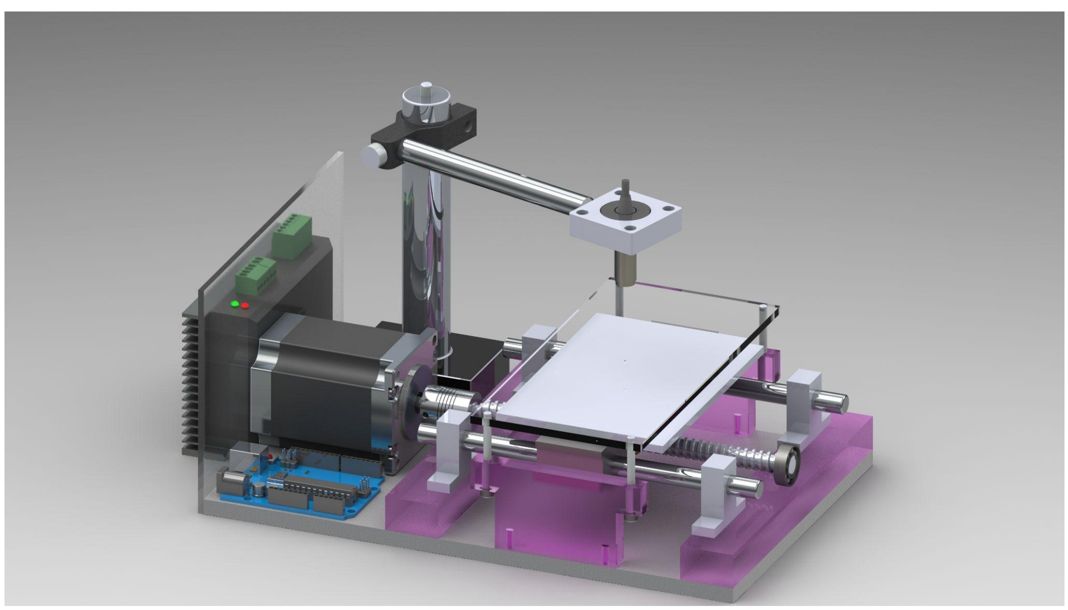

Fig-4(b) 3D Isometric View of Sliding Contact mode-based TENG Device

C. Contact mode-based TENG Device (Stepper Motor based)

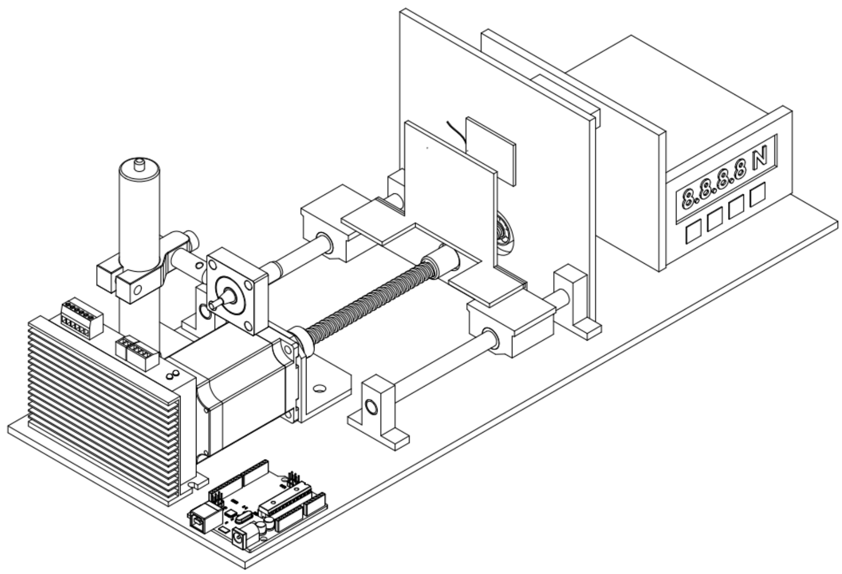

Fig-5(a): Schematic Sketch of Contact mode-based TENG Device (Stepper Motor based)

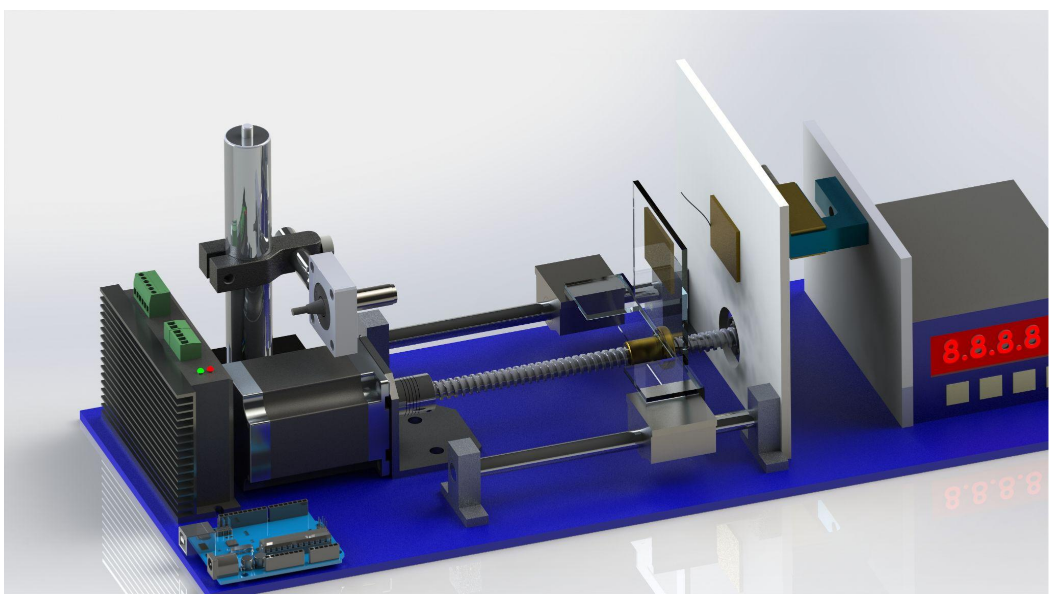

Fig-5(b): view-1

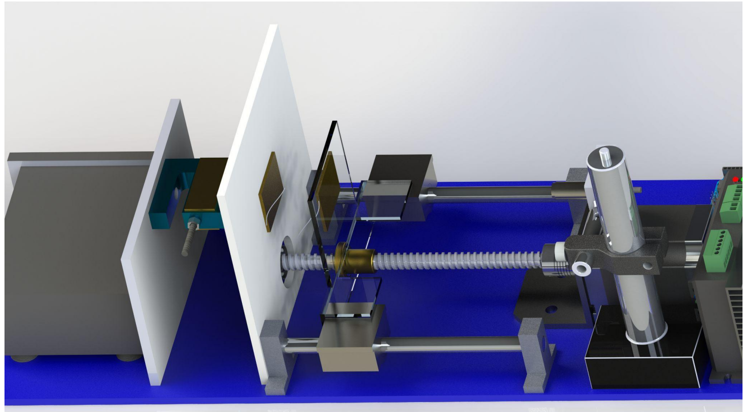

Fig-5(c): view-2

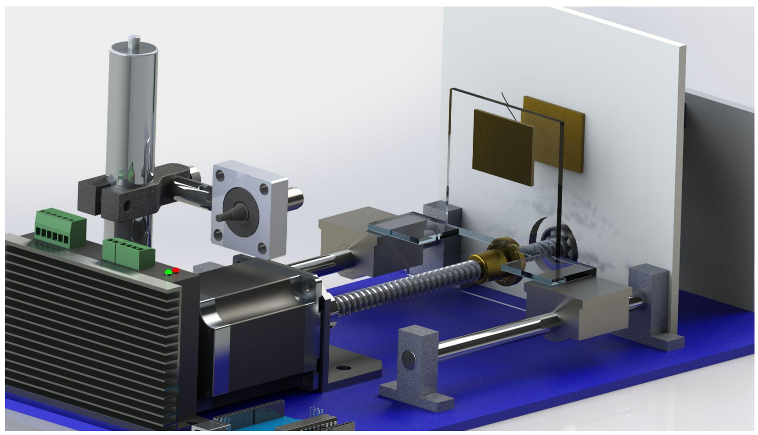

Fig-5(d): isometric view-3

Interfacing LOAD Cell

A load Cell is a device that gives analog values relative to the force applied to it. The analog values cant be used directly to measure the force. We need to read the analog values and convert them into the amplified desired range for that a Driver IC(HX711) for Load Cell can be used. HX711 on breakout board microchip is specially made for amplifying the signals from load cells and reporting them to another microcontroller. The load cells plug into this board, and this board tells the Arduino what the load cells measure(see Figure-6). The Library for the HX711 IC is already providing the amplification of the load cell, so the only task left is to calibrate the load cell.

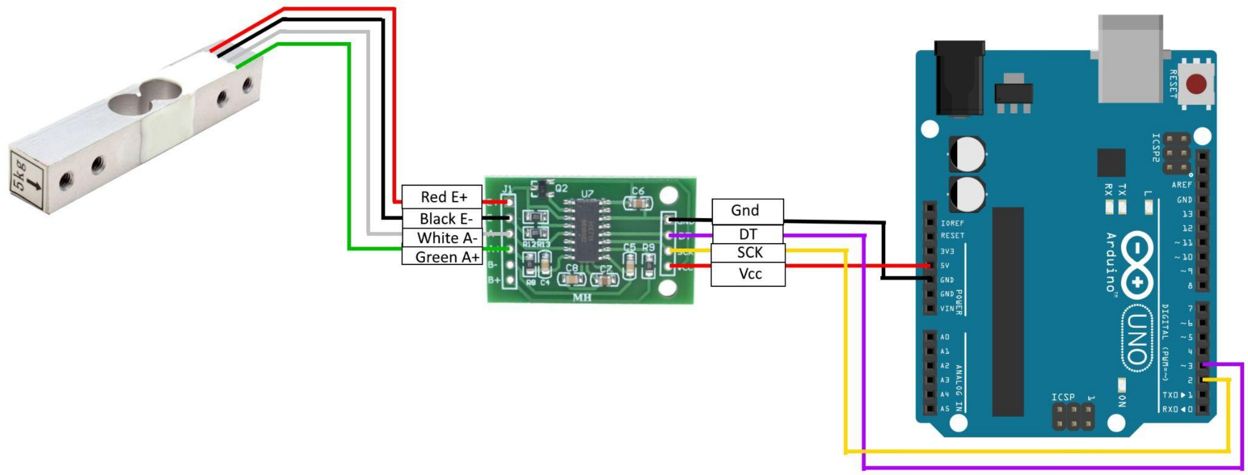

Fig-6: Schematic of the Arduino, HX711, and Load cell

1. Calibration
   The first software step is to determine calibration factors for the scale. Without calibration, measured values from the load cell don't give the unit values correct.
   Zero Balance (No Load): Shifts in the zero balance are usually caused by residual stress in the sensing area. Residual stresses result from overloading the cell or from repeated operation cycles. With a voltmeter, measure the load cell's output when there is no weight on the cell. It should be within 0.1% of the specified zero output signal. If the output is outside the zero balance tolerance band, the cell is damaged but perhaps correctable.
2. Main code
   After getting the calibration value, the calibration factor from the previous code twicks can be used for the final measurement.

Conclusion

In this report, we present in-depth 3D-Schematics and sketches that we rendered from SolidWorks. Our primary focus is to design devices to harvest energy using Triboelectric generators.

Adding to this, I have also reported the code which I had developed for the interfacing in Arduino.