Astronics - Energy Harvesting to Support Remote IoT Sensors

J. Nielan, R. Chatterjee, B. Patel
Northern Illinois University
1425 Lincoln Highway
Dekalb, Illinois 60115
USA

***Abstract*— Internet of Things (IoT) is a growing industry that is emerging to connect wireless protocols such as sensors, gadgets, and Bluetooth technology into an all-inclusive infrastructure network. Billions of devices will be connected that require some form of small, wireless power source, usually a battery. Within the IoT infrastructure inside an aircraft are remote sensors, often in inaccessible, isolated locations around the physical structure. Technological advances have hit a point where the efficiency and power consumption statistics are favorable allowing energy harvesting techniques to be used to provide constant charging to a battery. Both academic and industrial stakeholders are aiming to develop state-of-the-art technological design solutions by evolving existing energy harvesting technology to a point where the potential output exceeds the power demands of the system and negates the function of using a battery as an energy storage device. This paper outlines the specifications for harvesting unexploited energy sources such as vibrational kinetic energy at the resonant frequencies from an aircraft's engines.**

Keywords-component; Internet of Things; IoT; energy harvesting; vibration ; magnetic induction

I. INTRODUCTION

A. Internet of Things (IoT)

The IoT is used to perform data acquisition activities, exchanging information and data within internet enabled systems. It entails a wirelessly interconnected network of physical devices exchanging data to facilitate enhanced ease of living [1]. Much of the IoT network is powered by batteries which exist as a finite resource and limits the practicality of such devices.

B. Wireless Protocals

Wireless infrastructure systems are becoming commonplace in applications requiring condition-based monitoring (CBM) replacing traditional, existing wired infrastructure. Application placement can be facilitated in previously inaccessible locations allowing the innovation of remote systems within an existing infrastructure network.

C. Magnetic Induction

Magnetic induction can be used to efficiently generate power using a combination of permanent magnets and enamel-plated motor wire. In accordance to Faraday's Law of Induction, a potential difference is induced when an electrical conductor is passed through a magnetic field. The characteristics of a magnetic generator are determined by the properties of the electrical coil surrounding the oscillating magnet(s). Properties and geometry of the coil dictate the voltage output and the amount of power development by the system. [2].

II. DESIGN FEATURES AND MECHANISMS

Eight Total Components

1. 2 Neodymium Grade N52 Endcap Magnets
2. 2 Neodymium Grade N52 Oscillating Magnets
3. Enamel-plated motor wire
4. Housing (3D Printed)
5. Housing covers (3D Printed)
6. Delrin Tube (3D Printed)

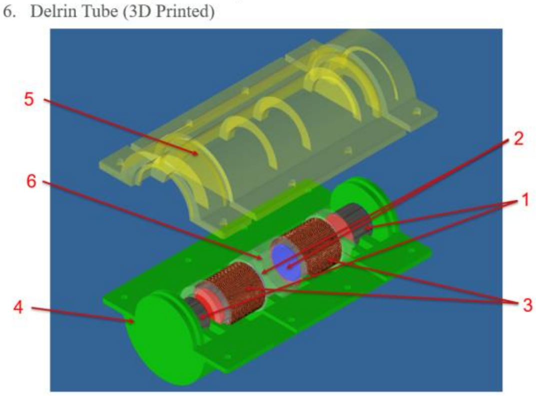

Figure 1: Assembled Device Model & Part Inventory

A. Materials

1) Delrin

The design of the energy harvester warranted a low-friction, high-wear material. To achieve this, the engineering thermoplastic Polyoxymethylene POM (brand name of Delrin from Dupont plastics) was selected as the inner housing to contain the oscillating magnets in *Figure I*.

2) Polycarbonate

The outer housing as seen in *Figure 1* is constructed from the thermoplastic polymer polycarbonate which exhibits excellent manufacturing properties (molding, forming) while still possessing the necessary mechanical strength to hold the device together.

B. Neodymium Permanent Magnets

Neodymium-iron-boron magnets are widely used in the fabrication of permanent rare earth magnet applications. Given the high magnetic field intensity, producing push-pull forces, they can be used in a kinetic energy harvesting device along with an enamel-plated coil of motor wire to generate a usable voltage. This produced voltage can be used in conjunction with an existing battery to power a subsystem within the infrastructure network.

C. Resonance and Vibration

All mechanical mechanisms produce vibrations due to design or deficiencies within the system. Available energy sources are present in the surrounding environment which can be harnessed and transformed into practical electrical power. These mechanical vibration frequencies assuming proper inductance of the coil will also determine the frequency of the circuit. This property conjoins the mechanical and electrical properties of the device and ensures proper conversion.

D. Faraday's Law of Induction

The electrical and magnetic portions of this device are key to its operation.

$$V = -N \cdot \frac{\Delta(B \cdot A)}{\Delta t} \qquad \text{(Eq. 1)}$$

Faraday's Law of Induction (Eq. 1) is the deciding law of science that drives this devices operation. This ensures that when the magnets oscillate within the confines of the coiled wire, there will be an induced electromotive force (EMF, also known as Voltage) across the coil. If the equation is to be holistically examined in detail, then it can be observed that the Voltage will increase along with how fast the magnetic field changes within a certain time frame. Therefore, frequency of oscillation, number of coils turns, and magnetic field strength across the area of the coil will determine the voltage induced in the coil.

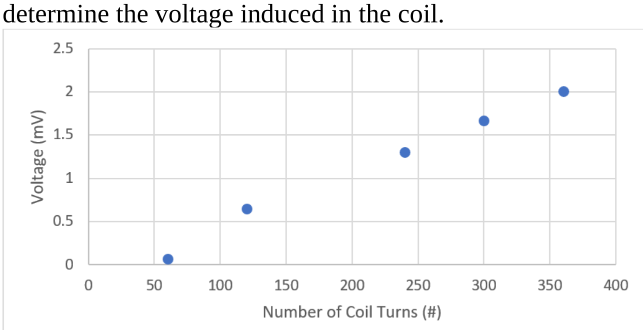

Figure 2: Average RMS value of AC Voltage vs Number of Coils

Given the data set collected in *Figure 2*, it is obvious that the voltage needs to be increased prior to diodes even entering the equation. By Faraday's Law of Induction (Eq.1), this can either be done by changing the strength of the magnetic field, increasing the oscillation frequency, and thereby reducing Δt, or positioning the coil in a more efficient manner to ensure that the ΔB is maximized. A 100KΩ was used as the load for measurements.

E. Waveform

The visual representation of this voltage waveform will be sinusoidal, seen in *Figure 3*, as it is a continuous, time-variant system. Given that this is a two-phase power input as there are two separate magnets oscillating, the net power harvested will double, given that it is rectified properly. As such, given a 2.00 mV_{max}, this can be rectified with a properly rated circuit. As to what that circuit will be depending on different iterations of the device remains yet to be seen and will occur with optimization of the device to provide a constant, DC trickle-charge value; however, the circuit will need basic full-wave rectification, and rated for micro-level power. Particularly, the diodes need to be able to bias properly to prevent the battery's charge from flowing in reverse and inducing a movement in the magnets. However, the power generated by the magnets still needs to be able to trickle charge the battery.

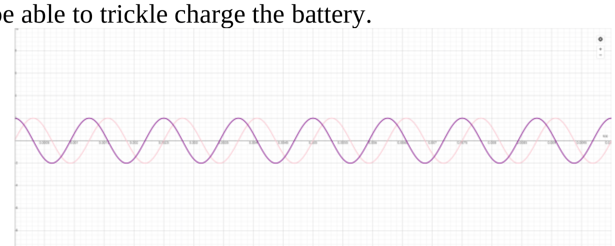

Figure 3: Waveform of voltage during magnetic oscillation

III. Conclusions and Optimization

This device provides proof-of-concept for harvesting otherwise wasted vibration. The iteration of design ideas has led to an operational, functioning prototype exhibiting a change in voltage when the device is placed on a vibrating surface under testing conditions.

The next phase of the project is to optimize the power harvested. Unfortunately, due to the outbreak of COVID-19 during the testing phase of this project, the device is not properly optimized for stable power rectification. Furthermore, lacking access to a lab meant that the group was unable to produce the proper AC-to-DC power converter and implement it on a PCB within the device.

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