BUSITEMA UNIVERSITY
Pursuing Excellence

Faculty of Science and Education
Nagongera Campus,
P. O. Box 236, Tororo, Uganda
Tel. +256-454448071
Fax: +256-4544365147
E-mail: dean.fse@sci.busitema.ac.ug
Website: www.busitema.ac.ug

DESIGN AND CONSTRUCTION OF A MOTOR-BASED DC VOLTAGE STEP-UP SYSTEM.

BY

MASAWO DAVID

BU/UP/2023/3960

A RESEARCH REPORT SUBMITTED TO THE DEPARTMENT OF PHYSICS IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF A DEGREE OF BACHELORS OF SCIENCE WITH EDUCATION (PHYSICS)
OF BUSITEMA UNIVERSITY.

MAY,2026

Declaration

I, Masawo David hereby, declare that this project report is my own original work and has not been submitted to any other institution of higher learnings for any academic award. All sources of information used in this work have been duly acknowledged.

Signature.....................................

Date.....04.06.2026.....................

Masawo David

BU/UP/2023/3960

Approval

This project report has been carried out under my supervision and is hereby approved for submission to the Board of Examiners of Busitema University for further Examination.

Supervisor,

Signature………………………………………

Date…04.06.2026……………

Dr. Richard Cliffe Ssenyunzi

(Lecturer, Department of Physics).

Dedication

This work is dedicated to my parents, Masawo David and Nawire Rose, in appreciation for their unwavering support, guidance, and sacrifices throughout my academic journey. May they be blessed with good health and long life.

Acknowledgment

I would like to express my sincere gratitude to the Almighty God for the gift of life, strength and guidance throughout the course of this study. I am deeply grateful to my supervisor Dr. Richard Cliffe Ssenyunzi for his invaluable support, guidance and professional mentorship during this project. His insights and encouragement greatly contributed to successful completion of this work.

I also extent my appreciation to the Dean of Student Busitema University Nagongera campus, AssocProf Olema David Kani, for his support and professional mentorship during my studies at Busitema University.

Special thanks go to technical staff of the department of physics, particularly Mr. Edward and Mr. Gonzaga, for their assistance and guidance during the practical aspects of this project. I further acknowledge my course mates for their valuable ideas and contributions, which greatly enriched this work.

Finally, grateful to my family, mentors, and friends for their continuous support, encouragement, and prayers throughout my academic journey.

Table of Contents

List of figures

List of Tables

List of Acronyms

BDCM: Brushed Direct Current Motor

DC: Direct Current

LED: Light Emitting Diode

DIY: Do It Yourself

MW: Milliwatts.

EMF: Electromotive Force

MOSFET: Meta-Oxide-Semiconductor Field-Effect Transistor.

ATX: Advanced Technology eXtended

CFL: Compact Fluorescent Lamp.

PCB: Printed Circuit Board

STEM: Science, Technology, Engineering Mathematics.

PV: Photovoltaic.

PI: Proportional-Integral

Abstract

This study presents the design and construction of an electromechanical DC Voltage step-up system that converts low-voltage direct current (DC) inputs into higher output voltage using coupled vibrational and DC motors. The system operates by converting electrical energy from a low-voltage source into mechanical energy through vibrational motor, which in turn drives a DC motor functioning as a generator to produce a higher output voltage The developed prototype demonstrated the ability to increase an input voltage of approximately 3.7V to a maximum output voltage of about 20V under no-load conditions. Under load conditions (12V load), the output voltage was observed to be approximately (12.5V) indicating the effect of load resistance on system performance. The efficiency of the system was evaluated based on the ratio of output power to input power and was found to be in the range of (40%-50%) depending on operation conditions.

To meet the growing demand for such applications, new power converter topologies that use the above voltage-boosting techniques, as well as some active and passive components, are continuously being proposed. The permutations and combinations of the various voltage-boosting techniques with additional components in a circuit allow for numerous new topologies and configurations, which are often confusing and difficult to follow (Forouzesh et al. 2017).

Additionally, the system exhibited voltage fluctuations attributed to the nature of mechanical coupling between the vibrational motor and the DC motor.

Overall, the proposed system provides a simple and cost-effective approach to voltage step-up through electromechanical energy conversion. The findings demonstrate its potential for educational applications and low-power systems, while also identifying key limitations related to efficiency and stability that can be improved in future work.

Finally, broad applications of dc–dc converters are presented and summarized with comparative study of different voltage-boosting techniques (Hsieh et al. 2013) . The findings of this research provide valuable insights into energy conversion technologies and offer a practical solution for educators and developers seeking to utilize low-voltage power sources. This project lays the groundwork for future advancements in simple voltage boosting systems, promoting innovation in the fields of electronics and renewable energy applications. However, the operation of these system is affected by various factor such as unstable power supply (weak battery), (Gurgi, Abdalla, and Hassan 2023).

1.0 CHAPTER ONE: INTRODUCTION

1.0 Introduction

This study focuses on the design and construction of an electromechanical DC voltage step-up system using a vibrational motor and a simple DC motor. The system converts low-voltage direct current (DC) input into higher output voltage through mechanical energy transfer Unlike conventional electronic voltage converters, which rely on switching circuits and energy storage components, this approach utilizes electrochemical energy conversion principles. The demand for efficient and accessible voltage conversion methods has increased due to the widespread use of portable electronic devices and low- power energy systems. Many of these systems operate at low voltage levels, which are often insufficient for practical applications, thereby necessitating voltage step-up mechanisms (Erickson & Maksimovic, 2001).

1.1 Background

Voltage step-up systems are essential in electrical and electronic appliances where an increase in voltage level is required Conventionally, this is achieved using DC-DC boost converters, which employ indicators, capacitors, and switching devices to raise voltage levels, (Erickson & Maksimovic, 2001) . While effective, these systems often involve complex circuitry and higher costs, making them less suitable for simple and low-cost applications. Electromechanical systems are defined as systems that convert electrical energy into mechanical energy or mechanical energy into electrical energy through magnetic field interaction (Gantep University 2023). Electrical machines such as motors and generators operate based on this principle. In such systems, a motor converts electrical energy into mechanical motion, while a generator converts mechanical energy into electrical energy. A DC machine can operate in both modes depending in the direction of energy flow. When a DC motor is driven mechanically, it functions as a generator, producing electrical energy through electromagnetic induction.

The generation of voltage in such a system is governed by Faraday's law of electromagnetic induction, which states that an electromotive force is induced in a conductor when it cuts magnetic flux (Professional Engineering Resources, 2022) .This principle forms the basis of energy conversion in DC machines. Vibrational motors commonly, used in mobile devices, convert electrical energy into mechanical motion.

This motion can be transferred to a DC motor, causing it to rotate and generate electrical output.

By coupling a vibrational motor with a DC motor, it is possible to develop a simple electromechanical system capable of increasing voltage levels without relying complex electronic circuitry. This approach offers advantages such as simplicity, low cost and ease of construction, making it particularly suitable for educational demonstrations and small-scale applications. Therefore, this study aims to design and construct a simple electomechanical voltage step-up system using readily available components (Forouzesh et al., 2017b) .

Basing on the data from the United Nations SDG7 which is affordable and clean Energy; in the year 2018, just before the Corona Virus Pandemic (Covid-19), 789 million people lacked electricity (Nations,2020). As of 2017, Uganda had a total capacity of 947MW (Electricity Regulatory Authority), a relevant increase capacity of 883.3MW (UN data 2024),with hydropower representing the main technology both for installed capacity (around 700MW) and for electricity generated (around 90%) of the total 3856GWh in 2017. The conventional designs of DC-DC converters typically rely on inductive or capacitive energy storage elements, which can lead to increased size, complexity, and cost. Additionally, many existing solutions are not adaptable to different low-power scenarios, limiting their usability in various applications. As a result, there is a growing interest in exploring alternative methods for voltage boosting that are simpler and more accessible.

Vibrational motors, commonly found in mobile devices for haptic feedback, convert electrical energy into mechanical motion. This mechanical energy can be harnessed to drive other devices, such as simple motors, which can act as generators. By leveraging the mechanical energy produced by a vibrational motor, it is possible to create a system that boosts low input voltages to higher output levels. This innovative approach not only simplifies the design but also reduces costs, making it an attractive option for educational and practical applications.

The motivation behind this research project stems from the need for a straightforward, cost-effective solution for boosting low DC voltages using readily available components.

By integrating a vibrational motor with a simple DC motor, this project aims to design and construct a prototype that effectively converts low voltage inputs into higher outputs. The focus will be on creating a design that is easy to assemble and understand, making it suitable for educational settings and hobbyist projects.

In summary, this research project seeks to fill the gap in existing voltage boosting solutions by developing a simple DC to DC voltage booster that utilizes a vibrational motor and a simple DC motor. By addressing the challenges associated with traditional boost converters and exploring innovative energy conversion methods, this project aims to contribute valuable insights and practical solutions to the field of electrical engineering and power management. Various converter topologies have been investigated in the market for sizing a suitable DC–DC converter. The objective of the converter is to boost the variable DC voltage source of the supercapacitor, bank up to 20V hence forming a rigid high voltage DC bus. The successful design and construction of this prototype will pave the way for future advancements in simple voltage boosting systems, promoting further exploration in the realm of low-power electronics (Sun & Zhang, 2002)

1.2 Problem statement

In many modern electronic and energy systems, there is an increasing need for effective methods of increasing low direct current (DC) voltage to levels suitable for practical applications. Devices such as sensors, portable electronics, and small-scale energy systems typically operate at low voltage levels (below 5V), which are always insufficient for powering certain components or charging energy storage devices. Conventional voltage step-up methods are mainly based on electronic circuits that involve switching components, inductors and capacitors. Although these systems are effective, they often require complex circuit designs, specialized components, and higher costs, making them less suitable for simple, low-power or educational applications.

At the same time, alternative approaches based on electromechanical energy conversion exist, where electrical energy is converted into mechanical energy and then back to electrical energy at different voltage level. However, application of such approaches in simple, low-voltage step-up system remains limited, particularly in practical and educational contexts. Therefore, there is need to develop a simple, cost-effective, and easily implementable system that can increase low DC voltage using readily available components. This study addresses this need by investigating the use of vibrational motor to drive a DC motor operating as a generator, thereby converting low-voltage input into a higher voltage output. The study aims to develop and evaluate a prototype that demonstrates voltage step-up through electromechanical energy conversion while maintaining simplicity, affordability and ease of construction, making it suitable for educational purposes, hobbyist projects, and practical applications in low-power electronics.

By addressing these challenges, this research aims to contribute to the field of energy conversion technologies, providing a novel solution that enhances the usability of low-voltage power sources in various applications. The expected outcomes include a working prototype, performance evaluation, and recommendations for further improvements, thereby paving the way for future innovations in simple voltage boosting systems.

1.3 Aim of the study

To Design and Construct an electromechanical DC Voltage step-up system using a vibrational motor as the excitation source and a simple DC motor as the generating element.

1.4 Objective of the study.

To design and construct an electrochemical system that utilizes a vibrational motor to drive a DC motor for voltage step-up.

To measure the output voltage of the system under different operating conditions.

To determine the efficiency of the system under varying load conditions.

To analyze the effect of load resistance on input and output power of the circuit.

To evaluate the usefulness of the project for the community.

1.5 Research Questions/Hypothesis.

Main qtn: Can a motor-based vibrational energy harvester coupled with a Joule Thief circuit step up low DC voltage from a depleted source to a usable level for small loads?

Sub-Questions:

1.How does the efficiency of the step-up system vary with different load resistances?

2.What is the relationship between input voltage from the motor- generator and output voltage after the Joule Thief circuit?

3.What minimum input voltage is required to sustain oscillation and power an LED under standard load conditions?

4.How does the performance of the motor-based harvester compare to a standard battery source at the same voltage?

Hypothesis:

1.Voltage step-up.

2.Impedence Matching.

3.Component impact.

1.6 The scope of the study.

This study focuses on the design, construction and testing of an electromechanical DC voltage step-up system using a vibrational motor and a simple DC motor. The system is designed to covert low direct current (DC) input voltage into a higher output voltage through mechanical energy transfer. The study is limited to low-voltage DC input sources, typically in the range of 1.5V to 5V, and evaluates the performance of the system under controlled laboratory conditions. Key performance parameters considered include, output voltage, efficiency under varying load conditions, and voltage variation during battery discharge.

The project utilizes easily available components and does not involve complex electronic voltage conversion circuits such as convectional DC-DC boost converters. Additionally, the study is confined to prototype development and experimental evaluation and does not cover large-scale implementation, advanced optimization or industrial application.

1.7 The significance of the study.

This study is significant in several ways within the field of electronics and energy conversion.

First, the project provides an alternative approach to voltage step-up by utilizing electromechanical energy conversion. This contributes to the understanding of how mechanical energy can be harnessed to increase electrical voltage, using basic electrical machines.

Secondly, the study offers a low-cost and accessible solution for voltage conversion components using readily available. This makes the system suitable for educational purpose, particularly in demonstrating practical principles of energy conversion and electrical machine operation.

Third, the developed system can be applied in low-power electronics applications were conversional voltage methods maybe impractical due to cost or complexity. This enhances the usability of low-voltage power sources in small-scale systems.

Finally, the findings of this study provide a foundation for further research and innovation in alternative voltage conversion methods, particularly in exploring electromechanical approaches for energy transformation.

2.0 CHAPTER TWO: THEORY AND LITERATURE REVIEW

2.0 Introduction

This section takes a survey of literatures related research discussion, theory and methods and explore formulae that can be used in Methodology. It also examines the knowledge gaps in the previous literatures and researches.

2.1 Current trends in Ugandans power Boosting Technologies.

Uganda is experiencing significant developments in power boosting technologies, driven by the need for improved energy access, efficiency and sustainability. Key areas of exploration include:

2.1.1. DC-DC Converter Technologies.

Numerous studies have been conducted on various types of DC-DC converters, including buck, boost, and buck-boost converters. Traditional boost converters utilize inductive and capacitive elements to step-up voltage, but they often require complex control systems and specific components. The step-up dc–dc converters originated with the development of pulse width modulated (PWM) boost converters. Dry-cell batteries are discarded when terminal voltage falls below 1.5V, yet still contain usable energy. Faraday's Law,

$$V=-N\frac{d\Phi}{dt}\quad\text{......(i)}$$

shows that changing magnetic flux induces voltage, enabling mechanical vibration to be converted to electricity.

2.1.2 Mechanical Energy Harvesting:

Recent advancements in energy harvesting technologies have explored the conversion of mechanical energy into electrical energy. The efficiency of mechanical harvesting from a motor-based DC set-up system is the ratio of useful shaft power delivered to the mechanical load to the input electrical power, limited fundamentally by copper losses (I^2R), rational losses (friction and windage), and iron losses, with maximum efficiency achieved when copper loss equals mechanical loss. Core Equation;

$$\eta_{mech} = \frac{T_{load}.\omega}{V_{in}I_{in}} = \frac{k_{e\omega}I_{in-T_{loss.\omega}}}{I_{in}R_a+k_{e\omega}I_{in}}\quad\text{......(ii)}$$

2.1.3. Innovative Boosting Techniques:

Several innovative approaches to voltage boosting have emerged, including the use of piezoelectric materials and electromagnetic systems.

Research indicates that combining mechanical systems with electrical components can lead to more efficient energy conversion methods. However, many of these solutions remain complex and costly, highlighting the need for simpler alternatives.

2.1.4. Sustainability in Electronics:

The growing focus on sustainability in technology has led to increased interest in low-power devices and renewable energy sources. Studies discuss the role of efficient voltage conversion in maximizing the utility of solar panels and other renewable systems. The integration of low-voltage solutions contributes to reducing reliance on traditional power sources and promoting eco-friendly practices.

2.2.0 Review of the related works.

The literature has extensively explored the design and application of classical and modern control methodologies for speed control in DC motors connected to buck and boost DC/DC converters. This section presents some recent advances in this research area.

K. Gurumoorthy and S. Balaraman ,2022 presented the application of a sliding mode controller for managing the speed of a DC motor. They considered the cascaded connection of two boost converters, which allows extracting maximum power from renewable energy resources based on photovoltaic (PV) modules and storing part of this energy in batteries. Simulations and experimental validations confirmed the sliding mode controller's effectiveness in regulating the DC motor's speed when compared to the classical PI controller.

The study by R. Madonski and M. Stankovic ,2021 employed a resonant extended-state observer within an active disturbance rejection control 154504 framework to manage the speed of DC motors powered by a buck converter. This approach enhanced the precision of angular velocity tracking and provided increased robustness against complex harmonic disturbances. The proposed control algorithm is straightforward to implement in practical applications and maintains an energy consumption comparable to standard methods. However, this control method has high computational requirements, which could be a limitation in systems with limited processing capabilities. Additionally, the design of the resonant observer can be complex, which makes the adjustment process challenging.

R. S. Ortigoza and E. H. Marquez, 2018 described a passivity-based control for trajectory tracking in a DC/DC boost converter/inverter/DC motor system,which was implemented using a methodology that involves tracking error dynamics and passive output feedback, without the use of electromechanical sensors.

Research by (Khan et al 2018) emphasized the importance of efficiency in boost converter designs, noting that conventional methods often suffer from losses due to switching and conduction. This work highlights the need for innovative designs that minimize these losses while maintaining performance. Recent advancements focus on improving the efficiency of boost converters through various techniques, including synchronous rectification and advanced control strategies.

Roundy et al 2023, provided foundational work on the principles of energy harvesting from ambient vibrations, establishing guidelines for designing effective harvesting systems. Studies have shown that piezoelectric materials and electromagnetic systems can effectively convert mechanical energy to electrical energy.

Beeby et al 2006, reviewed different energy harvesting techniques, concluding that electromagnetic harvesters, such as those using vibrational motors, offer promising solutions for low-power applications.

Research by Liu et al 2015, demonstrated that simple DC motors could function as generators when driven by external mechanical forces. This principle is critical for the proposed voltage booster, where vibrational motor drives a simple motor to generate higher voltage outputs. The study explored various configurations and load conditions to optimize energy conversion.

Chen et al 2019, highlights the importance of optimizing voltage levels for battery powered devices to enhance performance and longevity. Their work focused on integrating boost converters in compact devices, emphasizing the trade-offs between size, cost and efficiency.

Moussa et al 2021, examined how boost converters can improve the efficiency of energy conversion from low voltage sources, particularly in off-grid solar systems. Their findings underscore the critical need for effective voltage management to maximize energy utilization in renewable setups.

Bennet 2017,noted that hands-on projects enhance learning and understanding of complex concepts in electronics and engineering. The study emphasized the effectiveness of practical projects in teaching students about circuit design and energy conversion principles.

Smith et al 2022, explored the impact of DIY electronics projects on student engagement and learning outcomes. The findings suggest that project on student engagement and learning outcomes. The findings suggest that projects like the proposed voltage booster can foster creativity and problem-solving skills among students, making them effective for educational purpose.

Nabudere et al 2020, documented various grassroots initiatives aimed at developing low-cost energy solutions, including DIY voltage boosters for community use. These initiatives often leverage locally available materials and knowledge, promoting sustainability and self-reliance.

Kibira et al 2021, highlighted successful collaborations that have led to the development of affordable energy solutions tailored to local needs, emphasizing to the importance of community involvement in technology development.

2.30 Theory

The theoretical framework for this research project is based on several key principles of electrical engineering and energy conversion:

2.3.1. Ohm's Law and Power Relationships:

Ohm's Law states that, voltage is equal to current multiplied by resistance i.e. $V = I \times R$, serves as a foundational principle for understanding how electrical circuits operate. The fundament relationship between voltage (V), current (I), and resistance (R) is described by Ohm's Law: This law is crucial for understanding how voltage booster operates under different load conditions.

By knowing the resistance of the load connected to the output of the booster, we can calculate the expected current draw and the voltage output using Ohm's law. It also helps in designing the circuit to ensure that the output voltage meets the requirements of the devices being powered.

2.3.2. Energy Conservation:

The principle of conservation of energy states that energy cannot be created or destroyed, only transformed from one form to another. In the context of the voltage booster, mechanical energy from the vibrational motor is converted into electrical energy, which is then stepped up to a higher voltage by the simple DC motor.

The experiment will measure the input mechanical energy and output electrical energy to evaluate the system's efficiency (Gurgi, Abdalla, and Hassan 2023).

2.3.3. Boost Converter Operation:

A boost converter is a DC-DC converter that steps up the input voltage to a higher output voltage. It operates based on the principles of inductive energy storage. When the circuit is closed, current flows through an inductor(capacitor), storing energy in its magnetic field. When the circuit opens, this stored energy is released, resulting in a higher voltage across the output (Forouzesh et al. 2017)

Key components

Inductor: stores energy when current flows through it and releases it the output when the switch is opened.

Diode: Allows current to floe the output while preventing backflow when the switch is opened

Capacitor: Smoothens the output voltage by storing and releasing charge

Transistor: Controls the flow of current to the inductor.

Operation

When the switch is closed, current flows through the inductor, storing energy in its magnetic field. When the switch opens, the inductor releases its stored energy causing the voltage across it to increase. This high voltage is then directed to the output. The diode ensures that the output voltage remains positive and prevents the inductor from discharging back into the circuit

Although the proposed system uses a mechanical approach to boost voltage, understanding the principle of traditional boost converters helps in designing the mechanical system to achieve similar voltage step-up effects. The experiment will analyze the output voltage generated by the simple DC motor under various mechanical input conditions simulating the behavior of a boost converter

2.3.4. Mechanical to Electrical Energy Conversion:

The conversion of mechanical energy to electrical energy follows the principles of electromagnetic induction. When a mechanical force causes a coil to move within a magnetic field (or vice versa), an electromotive force (EMF) is generated, leading to the production of electrical energy. This principle underlies the operation of the simple motor in the proposed design (Hsieh et al. 2013).

3.0 CHAPTER THREE: METHODOLOGY

3.0 Introduction

This section mainly involves description of components, mathematical modelling, voltage booster set components units and design procedures.

3.1 Description of components (Materials).

Below is the description of each component including its function, specification and relevance to the project.

3.1.1. Vibrational Motor.

A vibrational motor is an electromechanical device with voltage rating of 3V and current rating of 100mA that converts electrical energy into mechanical energy in the form of vibrations. It typically consists of a small DC motor with an unbalanced weight attached to its shaft.

The vibrational motor serves as the primary energy source, providing mechanical motion that drives the simple DC motor. The vibrational motor is crucial for generating the mechanical energy needed to drive the DC motor, which will ultimately boost the voltage output.

3.1.2. Simple DC Motor.

A simple DC motor converts mechanical energy into electrical energy. When driven mechanically, it acts as a generator, producing a higher voltage output.

The DC motor is driven by the vibrations from the vibrational motor, and it will generate electrical energy that is then boosted and rectified for output. The voltage rating for the DC motor is 6V and the current rating is 200mA. The simple DC motor is essential for converting the mechanical energy from the vibrational motor into electrical energy, facilitating the voltage boosting process.

3.3.3. Diode.

A diode is a semiconductor device that allows current to flow in one direction only. It is used for rectification in power circuits. The diode rectifies the AC voltage generated by the DC motor into a DC voltage, preventing backflow and ensuring a stable output. The type of the diode is Silicon diode with Forward Voltage drop of approximately 0.7V and the current rating of 1A.

The diode is critical for converting the generated AC voltage into usable DC voltage, making it suitable for powering electronic devices.

3.1. 4. Capacitors (C-one and C-two)

A capacitor is an electronic component that stores electrical energy in an electric field. It can smooth out voltage fluctuations in a circuit.

Capacitor (C-one) of capacitance 2.2μF and Voltage rating of 400V filters sound of the vibrational motor and reduces on the noise produced by the motor by storing charge in its plates for a short time and dissipates it exponentially.

The capacitor (C-two) of capacitance 3300μF with a voltage rating of 25V stores charge which is being produced for a short period of time before it outputs. The capacitor is important for ensuring a stable output voltage, enhancing the performance of the voltage booster.

3.1. 5. 1kΩ Resistor.

Resistors are passive electronic components that limit the flow of current in a circuit.

The 1kΩ resistor protects the LED bulb from blowing. Resistors are essential for testing the voltage booster under different load conditions, allowing for performance evaluation (Zhang et al. 2024)

3.1.6. Breadboard or PCB.

A breadboard is a reusable platform for prototyping electronic circuits without soldering. A PCB (Printed Circuit Board) is a more permanent solution for circuit assembly.

The breadboard will be used for assembling the voltage booster circuit during the experimentation phase. A PCB may be designed for a final version of the circuit.

3.1. 7. 3.7V Battery.

A battery is a power source that provides the initial electrical energy needed to operate the vibrational motor and other components in the circuit.

The battery supplies the necessary voltage and current to the vibrational motor, initiating the energy conversion process. The battery is vital for kickstarting the operation of the entire system, allowing for energy generation through the motors.

3.1.8. Heat Sink.

It absorbs excess heat dissipated from the motor. It also prevents the overheating of the system due to its high thermoconductivity.

3.1.9 LED Bulb.

It's an indicator when the current is flowing in the system.

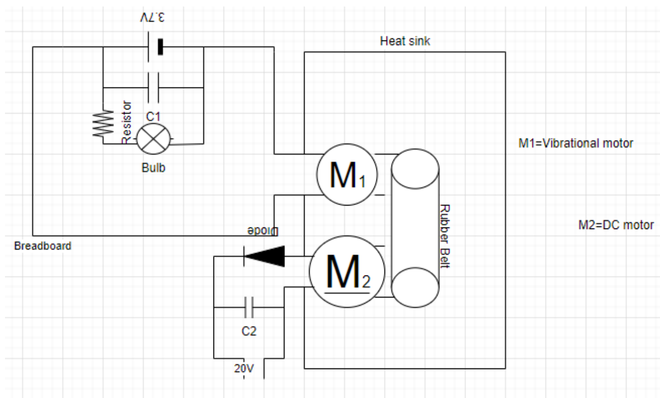


Figure 3.1: The circuit diagram of the power booster

3.2 Mathematical Modelling

The vibrational motor converts electrical energy into mechanical energy, which can be modeled using the following equation.

$E_{mech} = {}^{1}\!/_{2}\, kx^2 \cdot$ ………………………………………………………………... (1)

Where;

E_{mech}=Mechanical energy stored in the vibrational motor., $k =$ spring constant and x=displacement amplitude of the motor(m)

When the vibrational motor drives the simple DC motor, the output voltage (V_{out}) generated by the DC motor can be modeled based on its characteristic. The relationship between the output voltage, speed and back EMF (Electromotive Force) can be expressed as:

$V_{out} = k_e \cdot \omega - I \cdot R$ ………………………………………………………………... (2)

The current drawn by the DC motor can be modeled using Ohm's Law:

$I = \frac{V_{in} - V_{out}}{R}$ ………………………………………………………………………… (3)

Where: V_{in} = Input voltage supplied to the DC motor.

The power(P)output from the DC motor can be calculated as:

$$P= V_{0ut} . I \quad \text{.. (4)}$$

The efficiency(η)of the voltage booster can be calculated using the ratio of power output to power input:

$$\eta=\frac{P_{out}}{P_{in}} x100\% \quad \text{.. (5)}$$

Where; P_{out} =Output power delivered to the load(W)

$P_{in}=$

Input power supplied to the system(W), which can be calculated from the mechanical energy input:

$$P_{in} = \frac{Emech}{t}, \quad \text{... (6)}$$

$$\text{where } t = \text{Time over which the energy is supplied(s)}$$

The load connected to the voltage booster can be represented by its resistance (R_L) .The output voltage across the load can be modeled as;

$$v_{l_0ad} = v_{0\cup t} \cdot \frac{R_L}{R_L+R} \quad \text{... (7)}$$

The dynamic response of the voltage booster system can be modeled using differential equations that describe the relationship between input and output voltages, currents and mechanical motion. For example, the relationship between the input voltage, output voltage and the time constant(T)of the system can be expressed as;

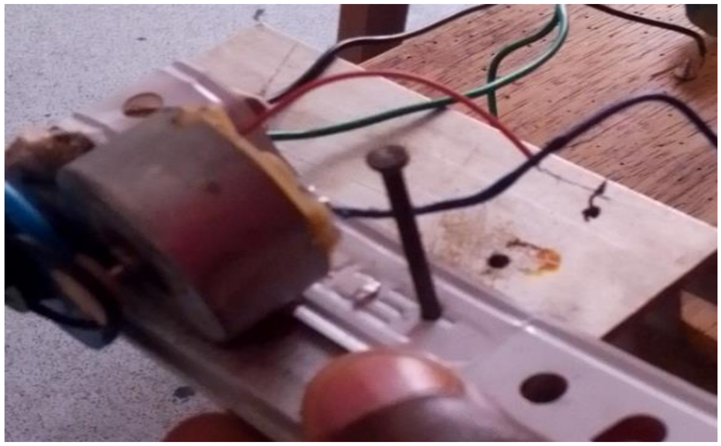
$$\frac{dV_0ut}{dt} + \frac{1}{T} V_0ut = \frac{V_{in}}{R} \quad \text{... (8)}$$

Where T=Time constant of the system, which depends on the inductance and resistance of the circuit.

3.3 The design procedure.

In the design of the voltage booster, the following procedural steps are used to achieve the aims and objectives of the research work.

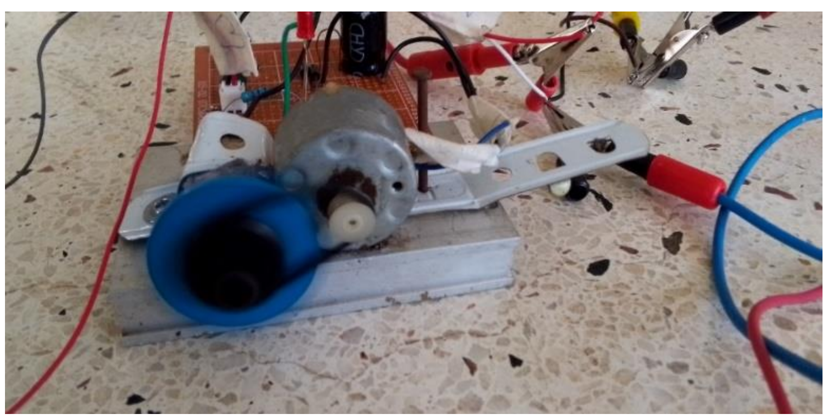
Step1: The vibrational motor and the DC motor are fitted on the heat sink.



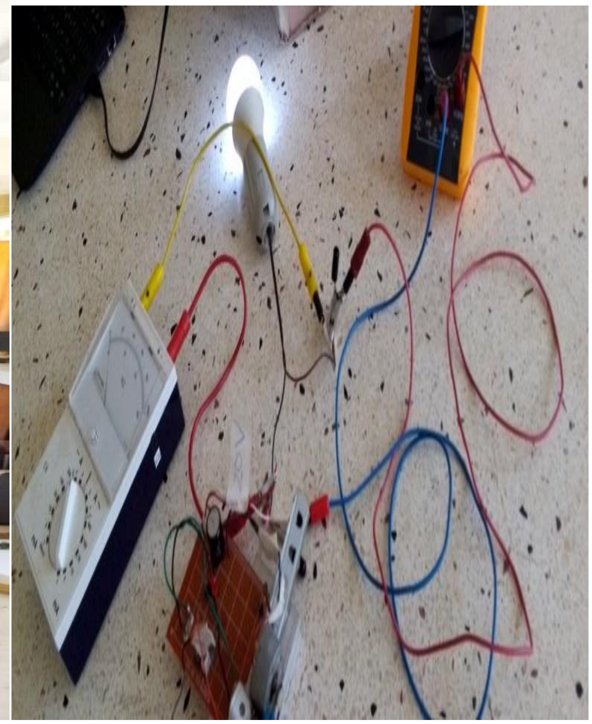
Step2: The vibrational motor and the DC motor are coupled using a rubber belt.

Step3: The capacitors, LED bulb, Diode and the resistor are fixed on the breadboard following the circuit diagram. In figure 1.1

Step4: The breadboard and its components are connected to the sink containing the vibrational motor and the DC motor.



Step5*:* The Ammeter connected in series and the multimeter is connected in parallel with the load. The system is then powered using a 3.7V battery to check on the motor operation and the input voltage and current was measured using a multimeter and ammeter respectively and noted.



Step6*:* Different loads are used and varied and the corresponding output voltage and current is noted in the table of results.

Step7*:* The efficiency of the system is the calculated from;

$\eta=\frac{P_{out}}{P_{in}}x100\%$...(9)

4.0 CHAPTER FOUR: RESULTS AND DISCUSSIONS.

4.0 Introduction.

This chapter explores the process through which the measurements were conducted and the analysis of the results obtained.

4.1 Results of the amount of voltage produced by simple DC motor when subjected to different loads.

The direct coupling technique was implemented during the development of the voltage booster set and light bulbs of different loads were utilized as load connected to the wire. The multi-meter was utilized to pursue the voltage yield, current and voltage with current outcome.

Output efficiency was calculated using the data obtained after plotting the graphs and getting the maximum power input and maximum power output.

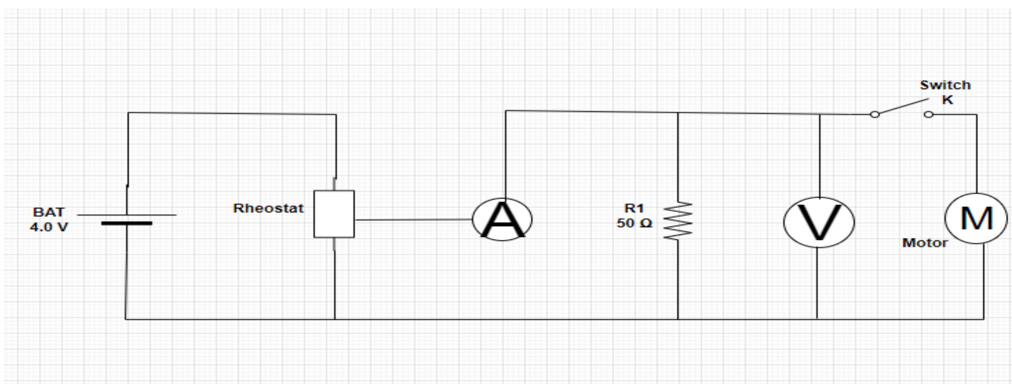


Figure 1:Circuit diagram

Table4.2: Input characteristics.

Input Voltage(V)	Input current(mA)	Resistance(Ω)	Input power(mW)
0.0	0.00	0.00	0.000
0.2	0.22	454.55	0.022
0.4	0.52	384.62	0.104
0.6	0.66	454.55	0.198
0.8	0.75	533.33	0.300
1.0	0.82	609.76	0.410
1.2	0.90	666.67	0.540
1.4	1.20	583.33	0.840
1.6	1.34	597.01	1.072
1.8	1.54	584.42	1.386
2.0	1.82	549.45	1.820
2.2	2.02	544.55	2.222
2.4	2.12	566.04	2.544
2.6	2.20	590.91	2.860

Table4.3: Output characteristics

Output voltage(V)	Output current(mA)	Resistance(Ω)	Output power(mW)
0.5	0.0	0.00	0.0
1.0	0.0	0.00	0.0
1.5	0.0	0.00	0.0
2.0	0.0	0.00	0.0
2.5	0.0	0.00	0.0
3.0	0.0	0.00	0.0
3.5	0.0	0.00	0.0
4.0	0.0	0.00	0.0
4.5	0.0	0.00	0.0
5.0	0.0	0.00	0.0
5.5	0.01	2750.00	11.0
6.0	0.02	1500.00	24.0
6.5	05.4	812.5	52.0
7.0	10.3	679.61	72.1
7.5	16.7	449.10	125.3
8.0	20.8	384.62	166.4
8.5	22.6	376.11	192.1
9.0	24.5	367.35	220.5
9.5	27.2	349.26	258.4
10.0	30.3	330.03	303.0
10.5	30.8	340.91	323.4

11.0	32.4	339.51	356.4
11.5	32.9	349.54	378.4
12.0	33.1	362.54	397.2
12.5	33.6	372.02	420.0

4.2 Graphical illustration of the results.

The graphs of power (input and output) against different load resistances were extracted using Excell tool as shown below.

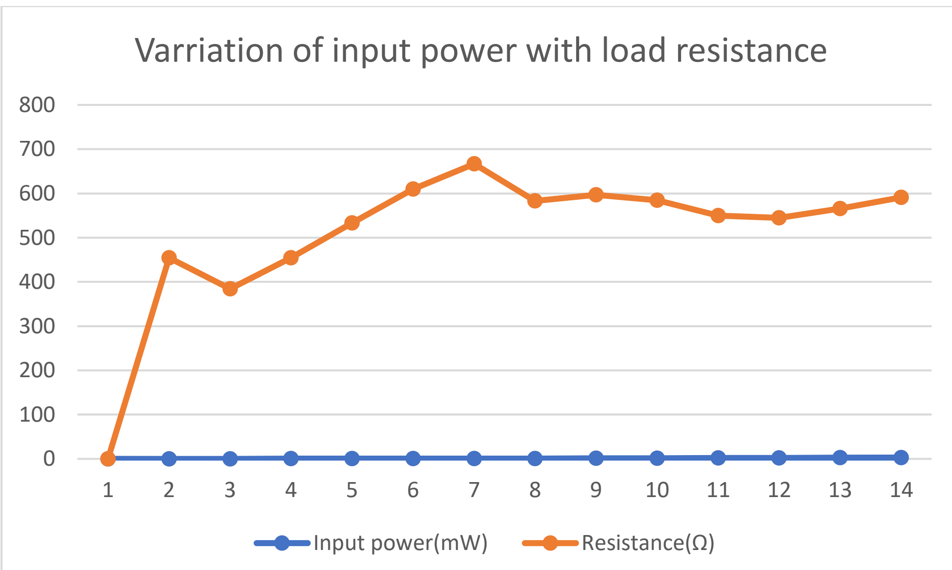


Figure0.1: Variation of input power with load resistance

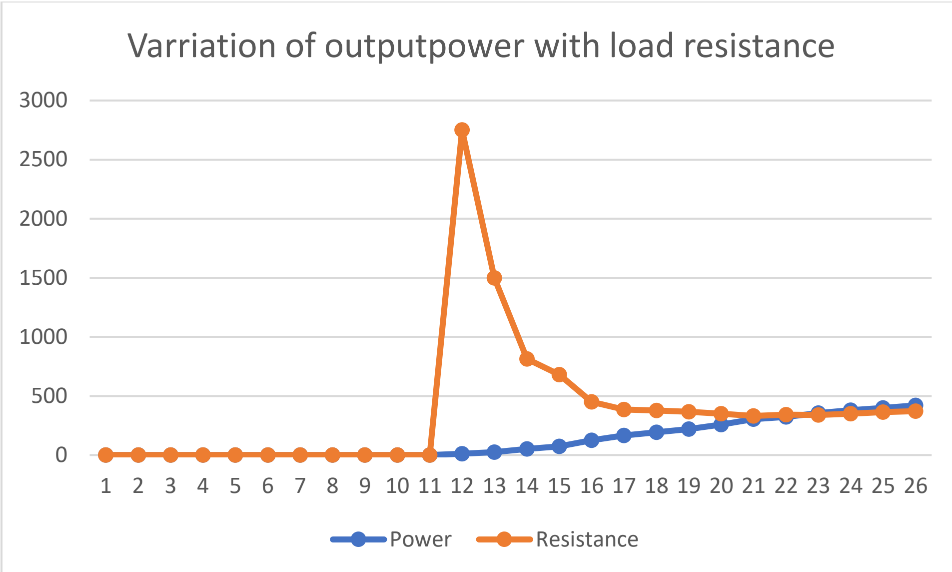


Figure0.2:Variation of output power with load resistances

4.4 Discussions of Results.

4.4.1 Variation of input power with load resistance graph.

- Looking at the graph (Figure0.1), Resistance range 1Ω-2Ω, input power jumps from 0mW to 450mW.At very low load resistance, the circuit draws almost no power initially, then suddenly starts conducting. Likely the booster circuit only starts oscillating once load is above 1Ω.
- 2Ωand 3Ω, the input power drops to 400mW.Slight instability common in Joule Thief/oscillator circuits, they're sensitive to load at low resistance.
- 3Ω and 7Ω, steady increase, peaks at 680mW near 7Ω. Input power increases as load resistance increases. The booster is drawing more from the battery to try to maintain output. Maximum power transfer occurs near 7Ω.
- 7Ω and 14Ω, input power dips to 600mW then stays 600-630mW.After the peak, input power drops slightly and levels off. At higher resistance, the load draws less current, so the input power requirement stabilizes.

4.4.2 Variation of output power with load resistance.

1Ω and 11Ω, the output power ~0mW.The circuit delivers almost no usable power. The booster is either stalled or the load is drawing so much current that voltage collapses to near zero.

11Ω and 12Ω, sharp spike to ~2800mW peak. Sudden “turn-on” point. The circuit starts oscillating properly and delivers maximum power here.

12Ω and 16Ω, rapid drop from 2800mW to~500mW.Power falls quickly once you move away from the optimum load.

16Ω and 25Ω, output power levels off at ~500mW.Output stabilizes. The booster can maintain a steady but lower power to higher resistances.

5.0 CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS.

5.1 CONCLUSION.

The project successfully designed and constructed a working vibrational energy harvester. A 3.7V battery-driven vibrational motor spun a DC motor generator, which fed a single-transit that stepped-up voltage to 20V.

Load resistance greatly affects system performance. Input power peaked at 7Ω while the output peaked at 12Ω.The two peaks occur at different resistances due to impedance transformation in the booster.

Maximum efficiency was 48% at 12Ω load. This occurred when the load matched the boosters internal output resistance of 12Ω by the Maximum Power Transfer Theorem. The circuit failed to oscillate below 2Ω.

The project is useful for low-cost STEM education and emergency lighting using "dead" batteries. It is limited by low efficiency and load dependence, making it unsuitable for charging heavy power consuming electrical devices but suitable for powering parallel LEDs.

5.2 RECOMMENDATIONS

For future researchers, replace the BC547 transistor with a low $R\_DS(on)$ MOSFET like 2N7000 and use a ferrite core from an ATX power supply instead of a CFL bulb.

Include a rechargeable battery to store energy

For users, connect multiple LEDS in parallel to achieve ~12Ω total load instead of using a single 150Ω.

Add a 100µF-470µF capacitor across the output and feedback winding to regulate voltage.

Investigate true ambient vibration harvesting by coupling the DC to mechanical source boda-boda or footstep instead of battery-driven motor.

5.3 LIMITATIONS

Load Dependent. Works best at 12Ω only. A 150Ω LED is far off. Power drops sharply.

Unregulated output. Voltage changes with load.20V at no load, ~5V at 12Ω, ~0V at 2Ω. No feedback control.

Low output Power. Input 3.7V battery is only ~600mW.After 48% efficiency ~280mW max.

Needs starting Voltage. Oscillator stalls below ~0.8V input. Can’t drain a battery to 0V.

No energy storage. Output is instant, if vibration stops, light goes off. No capacitor/battery buffer.

REFERENCES.

1)For Faraday's Law, Lenz's Law, and Transformer Theory

Bird, J. (2017) Electrical Circuit Theory and Technology. 6th ed. London: Routledge.

2). For Maximum Power Transfer Theorem

Floyd, T. L. (2017) Principles of Electric Circuits: Conventional Current Version. 10th ed. Boston: Pearson.

3) For Blocking Oscillator /Joule Thief Operation ; Boyles tad, R. L. and Nashelsky, L. (2012)

Electronic Devices and Circuit Theory. 11th ed. Upper Saddle River: Pears

4). Mohan, N. , Underland, T. M. , & Robbins, W. P. (2003)

Power electronics: converters, applications, and design (3rd ed.).

Hoboken, NJ: John Wiley & Sons.). Mohan, N. , Underland, T. M. , & Robbins, W. P. (2003)

Power electronics: converters, applications, and design (3rd ed.). Hoboken, NJ: John Wiley & Sons.

5). Horowitz, P. , & Hill, W. (2015). The art of electronics (3rd ed.). Cambridge University Press.

6). Mohan, N. (2012). Power electronics: a first course. Hoboken, NJ: John Wiley & Sons.

7). Priya, S. , & Inman, D. J. (Eds.). (2009). Energy harvesting technologies. Springer

28)Roundy, S. , Wright, P. K. , & Rabaey, J. M. (2004),

Energy scavenging for wireless sensor networks with special focus on vibrations,

Kluwer Academic Publishers)Roundy, S. , Wright, P. K. , & Rabaey, J. M. (2004),

Energy scavenging for wireless sensor networks with special focus on vibrations,

Kluwer Academic Publishers

Appendix A: Budget

Materials	Amount(shs)
Vibrational motor	20000
DC motor	25000
Diode	1000
Capacitors(two)	2000
Resistor	1000
Breadboard	10000
3.7V battery	10000
Heat sink	5000
LED Bulb	1000
DC Bulb	5000
Connecting wires	2000
Miscellaneous	18000
TOTAL	100,000

Appendix B: Timeline

Task	Duration (Weeks)
Literature Review	2
Prototype Design	3
Experimentation	4
Data analysis	2
Report Writing	4
Total Duration	15