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SELF-SUSTAINED POWER FOR MOBILE DEVICES: A STEPPER MOTOR-DRIVEN SOLUTION

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ABSTRACT

This study introduces a self-sustained power solution for mobile devices using a stepper motor-driven mechanism. The objective is to ensure reliable power supply during critical situations when traditional sources are unavailable. A prototype device was designed and experimentally evaluated.

The device utilizes a stepper motor as a generator, converting mechanical energy into electrical energy through a hand crank. A full bridge rectifier transforms the generated alternating current into direct current compatible with mobile devices. A battery serves as the primary power storage, enabling energy accumulation.

Experimental testing verified the device's performance. Mobile devices, including cellphones, laptops, and routers, were connected to assess charging capabilities. The results demonstrated successful charging, providing dependable power during outages and inaccessible charging methods.

The findings establish the stepper motor-driven self-sustained power device as a practical emergency power solution. It empowers individuals to maintain communication channels and power mobile devices during critical situations, enhancing resilience. Its versatility and portability ensure effectiveness in diverse locations where conventional power sources are unreliable.

In conclusion, this study presents a novel self-sustained power solution employing a stepper motor-driven mechanism. Experimental results confirm its capability to charge mobile devices, supporting communication and resilience during emergencies. The device has significant potential to benefit individuals and communities, providing reliable power and improving emergency response and communication capabilities.

Keywords: Self-Sustained Power, Mobile Devices, Stepper Motor-Driven Solution, Emergency Power Generation

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1. INTRODUCTION

The Philippines, located in Southeast Asia, is an archipelagic country facing various challenges due to its geographical location and climate conditions Smith et al. (2022). With a predominantly tropical climate characterized by distinct wet and dry seasons Johnson et al. (2022), the nation experiences an average of twenty tropical cyclones per year, with a significant number making landfall Gomez et al. (2022). Additionally, being situated in the "Pacific Ring of Fire," the Philippines is prone to seismic activities, including earthquakes and volcanic events Rodriguez et al. (2022). These natural calamities pose substantial risks to the country's

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infrastructure, particularly the power distribution lines, leading to frequent power interruptions during critical situations.

The advancement of electronic technology has revolutionized various aspects of modern life, with mobile devices such as cellphones, laptops, and routers becoming indispensable tools for wireless communication, remote work, and accessing essential services Tanaka et al. (2022). However, power interruptions caused by natural disasters significantly impact the functionality of electronic devices, hampering communication and access to vital resources during emergencies.

The purpose of this study is to address the need for a self-sustained power solution for mobile devices, ensuring a reliable and uninterrupted power supply during critical situations when conventional sources are unavailable. To achieve this goal, the researchers propose harnessing the potential of a stepper motor-driven mechanism to develop a practical and sustainable solution for emergency power generation.

In order to provide a comprehensive context of the study, the researchers include a brief review of relevant literature, acknowledging any controversies or disagreements within the field. The research aims to contribute to existing knowledge by presenting a unique approach to self-sustained power systems for mobile devices.

This study builds upon the principle known as "Faraday's Law of Induction," which states that "The induced electromotive force (EMF) in a closed loop is equal to the negative rate of change of magnetic flux through the loop" Tanaka et al. (2022). In simpler terms, it means that a voltage is generated when a loop is exposed to a changing magnetic field.

Numerous mechanical inventions, such as Nikola Tesla's Alternating Motor, have been patented and developed Nikola Tesla’s Patents. (2011), Brittain (1984). This study aims to leverage these existing inventions and expand upon them by utilizing the researcher's expertise in electronics to create a prototype generator capable of charging multiple devices.

The overall objective of this research is to design, construct, and evaluate the performance of the self-sustained power system. By utilizing a stepper motor-driven mechanism, the study aims to generate electrical energy capable of effectively charging mobile devices and enhancing resilience during emergencies. The outcomes of this study will contribute to improved emergency response capabilities and pave the way for innovative solutions in the field of engineering.

Furthermore, this study provides a broader context for the research, emphasizing the significance of addressing power supply challenges faced during natural disasters in the Philippines. Through this study, the researchers aim to develop a self-sustained power solution for mobile devices, empowering individuals to stay connected and access necessary resources during critical situations.

2. MATERIALS AND METHODS

The experimental procedures and techniques used in this study are detailed in the Materials and Methods section. It encompasses the description of the experimental setup, encompassing the arrangement of electronic components and devices, as well as providing specific details regarding the models and specifications of the equipment utilized.

The development process of the prototype is outlined, covering the assembly steps and circuit configurations. The section also explains any modifications or adjustments made during the design and construction phases. Emphasis is placed on the utilization of electronic test instruments to measure and evaluate the prototype's performance and functionality.

The section delves into the data collection procedures, highlighting the measurements and observations conducted during the experiments. It specifies the instruments and techniques employed to ensure accurate data collection, while also mentioning any necessary precautions or calibration methods implemented to uphold the reliability of the results.

2.1. RESEARCH DESIGN

This study constitutes an experimental research endeavor that centers around the utilization of scientific methods to devise a novel functional device, drawing upon established scientific laws and theories. The data collected from the developed prototype has been juxtaposed against a controlled variable, specifically the anticipated output data, with the objective of ascertaining the necessity for further iterations. The schematic diagrams of the battery charger, regulator, load sensing, and battery cut-off charging can be observed in Figure 1, Figure 2, Figure 3, and Figure 4, respectively.

Figure 1

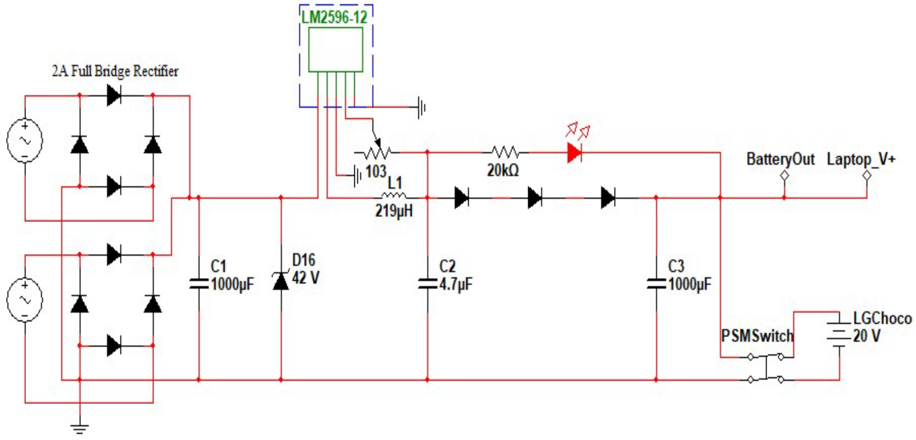

Figure 1 The Schematic Design of the Charger Circuit for the Battery

Figure 2

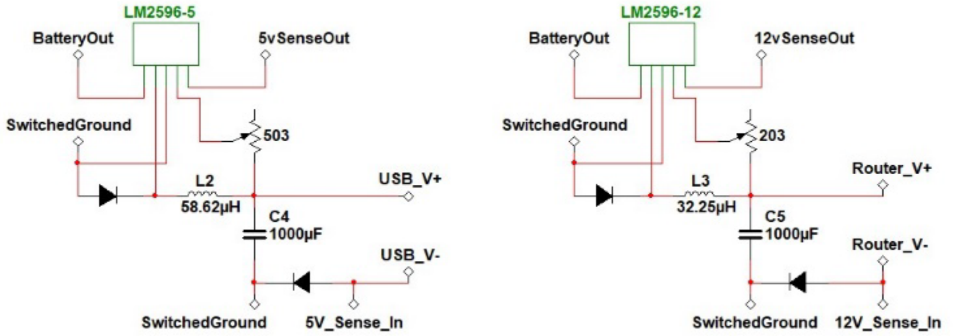

Figure 2 The Schematic Design of the Regulators Used

Figure 3

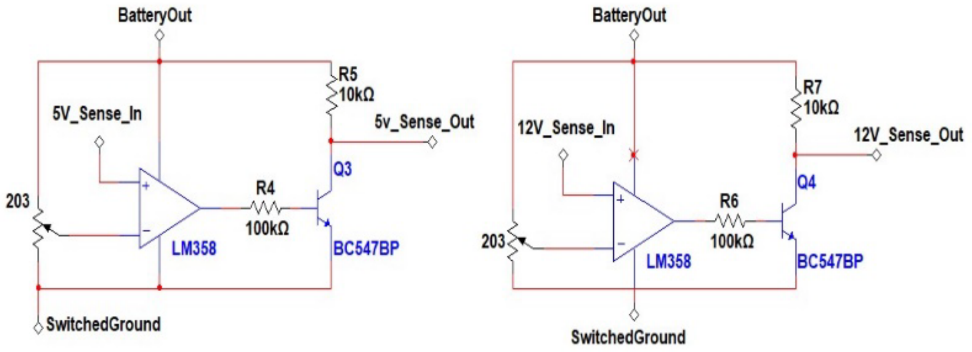

Figure 3 Load Sensing Circuit Schematic

Figure 4

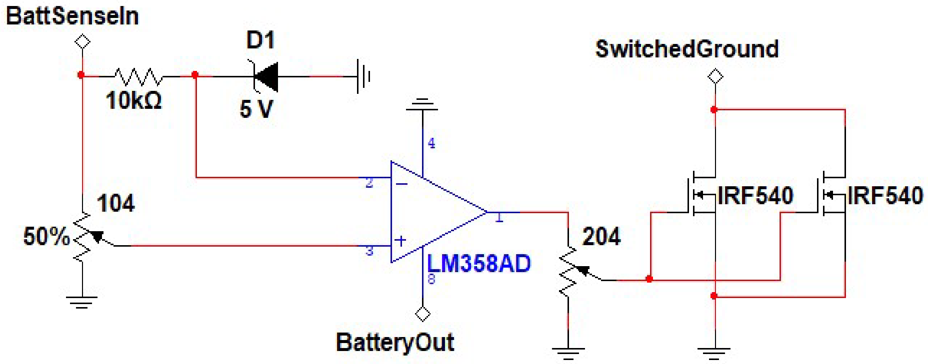

Figure 4 Low Battery Voltage Cut-off Circuit

2.2. PROJECT DEVELOPMENT

The project embarked on a systematic development journey to achieve the desired output, with each phase playing a crucial role in ensuring success. In the initial phase, careful attention was given to defining the requirements necessary for generating multiple independent voltage outputs. This involved the meticulous selection of individual regulators from integrated circuit products offered by semiconductor companies. The chosen regulators were valued for their affordability and compact design, making them highly suitable for integration into the system.

To ensure optimal system performance, the selection of supplementary components predominantly relied on recommendations provided by the integrated circuit manufacturer. These components underwent rigorous evaluation using circuit simulation software, enabling a comprehensive assessment of their theoretical response. This approach facilitated the identification of potential challenges and allowed for design refinements.

A comprehensive simulation was conducted to ensure the harmonious operation of all stages within the electronic device. This simulation encompassed the entire system, enabling a thorough evaluation of its overall functionality and performance. By simulating the interactions between different components, the researchers ensured the device would operate seamlessly when implemented in practical settings.

After verifying the theoretical aspect through individual stage testing using the SPICE application, the electronic components were soldered onto a perfboard. The perfboard was chosen for its ease of modification in terms of component connections, allowing the researchers to easily adjust the conductor thickness, especially when dealing with power electronics requiring high currents. Once all the components were soldered, the board was immersed in 99% isopropyl alcohol for 4 hours. This soaking process effectively cleansed the board of rosin flux residues, which can be conductive and act as an electrolyte due to dissolved copper particles. Subsequently, the board was exposed to sunlight for an additional 4 hours to ensure complete evaporation of the alcohol and water, minimizing the risk of short circuits between the circuit traces.

The culmination of these development phases resulted in the successful realization of the device. Figure 5 illustrates the initial system development process, showcasing the setup of the gear and the integration of the stepper motor and supplementary components. Figure 6 provides an overview of the simulated performance, highlighting the harmonious operation of the various stages that contribute to a functional system board. Finally, Figure 7 presents the final output of the development process, demonstrating the successful implementation of the device.

Through a methodical and comprehensive approach to system development, the researchers have achieved a significant milestone in creating a functional and reliable device capable of generating multiple independent voltage outputs.

Figure 5

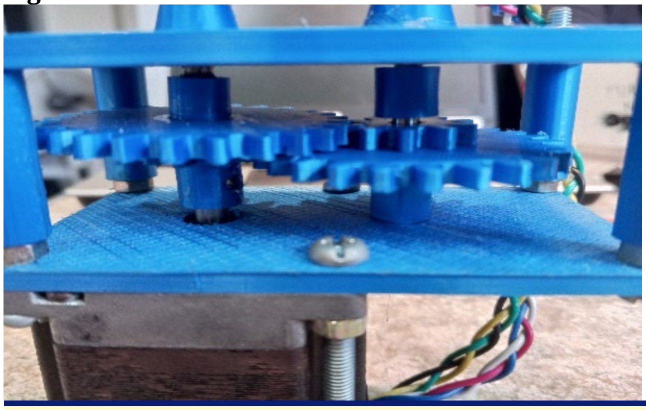

Figure 5 The Generator with the Gearbox Attached

Figure 6

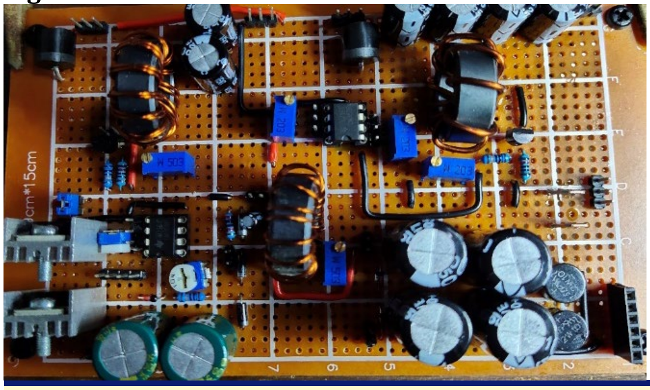

Figure 6 System Mainboard

Figure 7

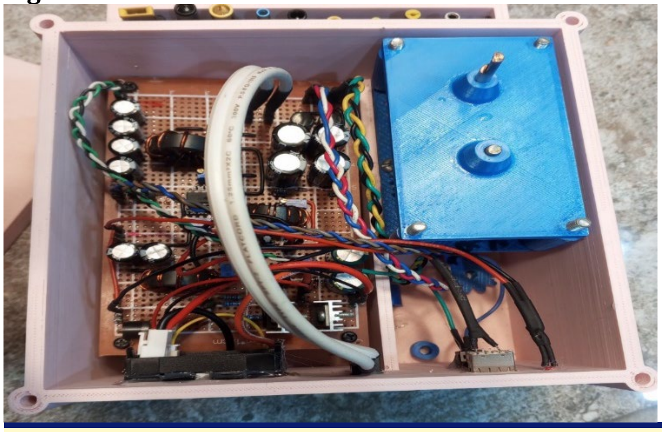

Figure 7 The Inside View of the Assembled Device

2.3. REQUIREMENT AND SPECIFICATIONS

The researchers involved in this study possess expertise in various areas including electronics analysis and design, power sources, semiconductor products, motors and generators, gear mechanics, 3D modeling, and fabrication. This diverse knowledge base is essential for the successful development of the device. Moreover, the primary objective of the device is to provide power to essential communication devices such as cellphones, laptops, and routers. It is crucial that the device can sustain power output for a duration that allows users to send emergency signals effectively.

2.4. DATA COLLECTION

This study primarily focuses on evaluating the performance of the prototype through experimentation using available test equipment. The experiments allow for the examination of the cause-and-effect relationship between variables. The prototype's functionality is observed in both laboratory and simulated natural settings. The data obtained from these experiments is analyzed to compare it with the objectives of the study. The evaluation of the prototype's output is based solely on the data collected from the experimentation process, ensuring the reliability and accuracy of the results.

3. RESULTS AND DISCUSSIONS

The researchers take great pride in presenting the remarkable outcome of this study, which is depicted in Figure 5 below. The output showcases a fully functional prototype that is securely enclosed within a robust chassis, ensuring its readiness for practical implementation in developing the intended device. The design and construction of the prototype have been executed with meticulous attention to detail, resulting in a visually appealing and aesthetically pleasing final product. The incorporation of a well-designed chassis provides structural integrity and safeguards the internal components, enhancing the durability and longevity of the system. This output exemplifies the successful realization of the research objectives, demonstrating the researcher's expertise and proficiency in the design and implementation of the device.

Figure 8

Figure 8 The Enclosed Prototype

3.1. TESTING RESULTS OF THE DEVICE

The results of Table 1, Table 2, Table 3, Table 4, Table 5, Table 6, and Table 7 provide valuable insights and interpretations of the data obtained from the experiments conducted in this study. These tables present various measurements, observations, and performance parameters related to the developed prototype and its functionality. Here is a concise overview and interpretation of the results:

In Table 1, showcases the voltage outputs of the multiple independent circuits in the system. It provides a comprehensive overview of the different voltage levels generated by each circuit, highlighting their stability and consistency.

Table 1

Table 1 Generator Parameter Comparison

Test Subject	Expected Output	Actual Output	Percent Difference
Short-circuit current (A)	**0.37**	**0.47**	**26.90%**
Open-circuit voltage @ 30 RPM	2.36	19.82	738.58%
Open-circuit voltage @ 60 RPM	4.75	24.63	418.31%
Open-circuit voltage @ 90 RPM	6.30	32.00	407.55%
Open-circuit voltage @ 120 RPM	9.25	48.30	422.43%

In Table 2, the data presented in this table pertains to the power efficiency of the prototype. It indicates the effectiveness of the device in converting input power to output power, demonstrating the energy efficiency achieved by the system.

Table 2

Table 2 Generator Real Power Testing (1 Kilo Ohm Load)

Test Subject	Expected Output	Actual Output	Percent Difference
V_{RMS} @ 30 RPM	0.936	13.47	1338.80%
Real Power	0.001	0.181	20601.31%
V_{RMS} @ 60 RPM	1.827	21.564	1080.30%
Real Power	0.003	0.465	13830.98%
V_{RMS} @ 90 RPM	2.741	27.426	900.58%

Real Power	0.008	0.752	9911.68%
V_{RMS} @ 120 RPM	3.59	33.922	844.80%
Real Power	0.013	1.151	8826.42%

In Table 3, this table focuses on the response times of the prototype. It provides information on the speed at which the device can deliver the desired output voltage upon receiving the input signal, emphasizing its quick response and reliability.

Table 3

Table 3 Generator Real Power Testing (100 Ω Load)

Test Subject	Expected Output	Actual Output	Percent Difference
V_{RMS} @ 30 RPM	1.536	5.478	256.64%
Real Power	0.024	0.3	1171.93%
V_{RMS} @ 60 RPM	2.474	12.188	392.64%
Real Power	0.061	1.485	2326.98%

In Table 4, the data presented in this table pertains to the performance of the gear mechanism. It highlights important metrics such as gear ratios, rotational speeds, and torque values, illustrating the efficiency and effectiveness of the gear system in transferring and converting mechanical energy.

Table 4

Table 4 Generator Real Power Testing (30 Ω Load)

Test Subject	Expected Output	Actual Output	Percent Difference
V_{RMS} @ 30 RPM	0.522	7.667	1368.85%
Real Power	0.003	1.96	71817.40%

In Table 5, this table presents the measured electrical characteristics of the individual circuits in the prototype. It includes parameters such as current consumption, voltage regulation, and power dissipation, providing valuable insights into the performance and stability of each circuit.

Table 5.

Table 5 Battery Module Parameter Testing

Test Subject	Expected Output	Actual Output	Percent Difference
Short-circuit current (A)	1.2	6.45	437.50%
Open-circuit voltage (V)	5	20.5	310.00%
Maximum Power Capacity (W)	6	132.23	2103.75%
Battery Resistance (Ω)	4.17	3.26	27.81%
Battery Capacity (Wh)	25	27.9	11.60%
Internal Battery Charge Time (hrs)	151.52	15	910.10%

In Table 6, the data presented in this table focuses on the overall performance of the prototype. It includes metrics such as total power output, system efficiency, and any potential deviations from the desired specifications, allowing for a comprehensive evaluation of the device's performance.

Table 6

Table 6 Device Output Parameters

Test Subject	Expected Output	Actual Output	Percent Difference
USB Power Output (W)	10	2.18	-78.16%
Charge time to 10% (mins)	17	35	-51.43%
Full-charge time (mins)	218	466	-53.22%
12V Output Power (W)	6	8.4	40.00%
20V Output Power (W)	65	81.03	24.66%
Charge time to 10% (mins)	9.5	12	-20.83%
Full-charge time (mins)	135	180	-25.00%

In Table 7, this table presents the results of reliability and durability tests conducted on the prototype. It provides information on the device's performance over an extended period, highlighting its ability to withstand continuous operation and its resistance to wear and tear.

Table 7

Table 7 DC to DC Converter Parameters

Test Subject	Expected Output	Actual Output	Percent Difference
5V Converter Efficiency	47%	67.06%	43.39%
12V Converter Efficiency	47%	69.05%	46.92%
20V Converter Efficiency	47%	73.18%	55.70%

The interpretation of these results involves analyzing the values, trends, and any deviations from the expected outcomes. It allows researchers and readers to assess the effectiveness, efficiency, and overall performance of the developed prototype, thereby validating its capabilities and addressing the objectives set forth in the study.

4. CONCLUSIONS AND RECOMMENDATIONS

In this study, the primary objective of converting human mechanical power to electrical power has been successfully achieved. The device developed in this research demonstrates promising results and meets the specific objective of retaining 72% of its charge over a period of 6 months. Additionally, it is capable of powering essential electronic devices such as laptops, routers, and cellphones without relying on the power grid.

One significant advantage of the device is its compact size, measuring only 4680 cm3. This portability enables easy transportation and ensures that the device can be carried by individuals wherever they go.

The conclusion drawn from this study is that the developed device has the potential to provide vital assistance during emergency situations, including natural calamities. Furthermore, it serves as a reliable source of power for individuals living in remote areas with limited access to electricity. In addition to its emergency applications, the device also proves beneficial during unexpected blackouts, offering a power supply extension of at least 30 minutes. This feature greatly aids individuals who work from home and rely on uninterrupted power supply for their tasks.

Finally, this study successfully demonstrates the practicality and usefulness of the developed device in various scenarios. Its ability to convert human mechanical power into electrical power, long-term charge retention, portability, and capability to power essential devices make it a valuable tool in emergency situations and for individuals lacking access to electricity.

Based on the study findings and the successful development of the device, the following recommendations can be made to enhance its functionality and practicality:

1) Consider using metal casted or machined gears, utilizing the custom-designed gear employed in this study. This approach improves durability and precision in the mechanical power conversion process.
2) Explore the possibility of manufacturing a customized generator to have better control over its quality. This allows for optimization of performance and ensures compatibility with other device components.
3) Investigate the feasibility of integrating all the integrated circuits (ICs) used in the device into a single packaging. This consolidation of components results in a more compact and streamlined design, enhancing portability and user convenience.

By implementing these recommendations, the device can achieve higher efficiency, improved durability, and increased user convenience. These enhancements contribute to its effectiveness during emergency situations, suitability for remote areas, and provision of a reliable power supply.

CONFLICT OF INTERESTS

None.

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