International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 04 Issue: 06 | June – 2025 DOI: 10.55041/ISJEM04517
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Prototype Design for Suspension Power Generation

Mr. V. P. Mule[1], Chetan Koli[2], Suraj Panad[3], Abhishek Waghmare[4]

[1]*Assistant Professor, Department of Electrical Engineering, Sinhgad Institute of Technology*
[2]*Student, Department of Electrical Engineering, Sinhgad Institute of Technology*
[3]*student, Department of Electrical Engineering, Sinhgad Institute of Technology*
[4]*student, Department of Electrical Engineering, Sinhgad Institute of Technology*

---***---

Abstract - The project "Generating Electricity from Vehicle Suspension Using an Alternator" introduces an innovative system for capturing energy from the vertical motion of a vehicle's suspension. Conventional shock absorbers dissipate energy generated by road-induced vibrations as heat, resulting in energy loss. This project aims to recover this wasted energy by converting it into electrical power that can support on-board vehicle systems, such as battery charging, lighting, and auxiliary electronics.

Our design canters around a specialized mechanical setup that converts two-way linear motion from the vehicle suspension into one-way rotary motion. This is achieved using a crank and one-way bearing mechanism that transmits rotational energy in a single direction, regardless of the suspension's bidirectional movement. The rotary output is then directed into a 1:50 planetary gearbox to increase the rotation speed, enabling the alternator to operate efficiently within its optimal RPM range. The car alternator, rated at 14V and 90A, utilizes this stepped-up rotational speed to generate electrical power, which can be used to charge the battery and power auxiliary systems.

By converting mechanical suspension motion into a continuous, usable power source, this project demonstrates a practical and sustainable approach to energy recovery in automotive applications. The energy harvested can reduce vehicle reliance on external charging and improve overall energy efficiency, especially in electric and hybrid vehicles

Key Words: regenerative suspension, energy harvesting, vehicle suspension system, car alternator, planetary gearbox, bidirectional to unidirectional conversion, automotive energy recovery, sustainable power generation, auxiliary system charging, crank mechanism

1.INTRODUCTION

The quest for more sustainable energy solutions has led to a surge in research and development focused on energy harvesting technologies, especially in the transportation sector. One emerging area of interest is the conversion of mechanical motion from vehicle dynamics into usable electrical energy. This project explores such a system, aiming to harness energy from the vertical motion generated by a vehicle's suspension as it moves over uneven terrain. The goal is to transform this mechanical energy, which would otherwise be wasted, into electrical energy that can be used to power on-board systems or reduce the energy consumption of the vehicle.

The core of this energy-harvesting system is a 14V, 90A car alternator, which is traditionally used to convert engine power into electricity for various automotive systems. However, in this project, the alternator is repurposed to generate electricity from the mechanical motion of the suspension. To achieve the required rotational speed for the alternator to function efficiently, a 1:50 speed-increasing planetary gearbox is incorporated. This gearbox amplifies the low-speed input from the suspension system, allowing the alternator to reach its optimal operating speed.

The key challenge in this project lies in converting the two-way linear motion of the suspension (up and down movements caused by road irregularities) into one-way rotary motion. This is achieved through a specialized mechanical mechanism that ensures consistent directional rotation, even though the input motion is bidirectional. The use of one-way bearings and a crank mechanism allows for smooth and efficient transfer of energy from the suspension to the gearbox.

Energy harvesting from vehicle suspension is a relatively underexplored area but holds significant potential for increasing the overall efficiency of vehicles. By capturing and converting otherwise wasted mechanical energy, this system could reduce the load on a vehicle's primary battery and extend its operational range. The development of such systems is particularly relevant in light of the global push toward electric and hybrid vehicles, where every bit of recovered energy can contribute to reducing reliance on external charging and improving vehicle efficiency.

This project focuses on designing and testing a prototype that can demonstrate the feasibility of using a car alternator in conjunction with a speed-increasing gearbox and a linear-to-rotary motion converter. The design considerations include optimizing the system for efficiency, ensuring mechanical durability, and achieving the necessary output to supplement the vehicle's electrical systems. If successfully implemented, this approach could open up new possibilities for energy recovery in automotive applications, contributing to a more sustainable and energy-efficient future.

2. OBJECTIVE

The main objectives of this project are as follows:

1. **To design and develop a mechanical system** that captures vertical motion from a vehicle's suspension and converts it into rotary motion.
2. **To implement a mechanical motion rectifier (MMR)** using a crank and one-way bearing mechanism for converting bidirectional linear motion into unidirectional rotary motion.
3. **To integrate a planetary gearbox (1:50 ratio)** to increase the rotational speed for efficient operation of the car alternator.
4. **To generate electrical energy** using a 14V, 90A car alternator driven by the speed-increased rotary motion.
5. **To simulate and analyze the system's performance** under various loading and vibration conditions using software tools.
6. **To evaluate the feasibility and efficiency** of harvesting energy from vehicle suspension movements and utilizing it to power auxiliary systems or charge the vehicle battery.
7. **To explore the potential of regenerative suspension systems** in improving overall vehicle energy efficiency and reducing reliance on external power sources.

3. WORKING PRINCIPLE

The process begins with the vehicle's suspension, which moves in response to road surface variations. This motion is primarily up and down, causing the suspension components to oscillate. Attached to the suspension system is a connecting rod that moves in a back-and-forth, or reciprocating, motion with the suspension. This rod transfers the linear motion to a crankshaft and one-way clutch system designed to convert the reciprocating movement into continuous rotation in a single direction. The crankshaft translates the up-and-down motion of the rod into rotational energy. The one-way clutch, a critical part of this mechanism, locks the rotation in one direction during the forward stroke while disengaging during the reverse stroke. This setup ensures that the output shaft rotates consistently in one direction, even though the input from the suspension is alternating. This conversion is essential, as it creates a unidirectional rotation that can then be used to drive additional components effectively.

After achieving one-way rotation, the next step is to amplify the speed of the rotational output. Here, a planetary gearbox with a 1:50 speed-increase ratio is utilized. Planetary gearboxes are known for their compact design and high torque transmission, making them ideal for applications that require a significant increase in output speed while maintaining the compact structure of the system. In this setup, the sun gear (connected to the input shaft) drives several smaller planet gears, which revolve around it. The ring gear, which encircles the planet gears, remains fixed, and the planet gears rotate around the sun gear while also spinning on their own axes. This movement forces the planet carrier, which acts as the output, to rotate at a much higher speed than the input. The result is a substantial increase in rotational speed—about 50 times the original input speed. For example, if the input from the crankshaft is around 100 RPM, the output from the planetary gearbox would be approximately 5000 RPM, a speed suitable for driving the alternator effectively.

The amplified rotational speed is then transferred to the alternator, a 14V, 90A automotive model designed to operate efficiently at high RPMs. Alternators are essential for converting mechanical energy into electrical energy, and they perform best within a specific RPM range. At the 5000 RPM output speed achieved through the gearbox, the alternator operates within its optimal range, allowing it to generate a stable voltage and current. The alternator's electrical output can then be directed into the vehicle's battery for storage or used to power auxiliary systems. By continuously capturing and converting suspension motion into electrical energy, this system provides a means of generating supplemental power for the vehicle, potentially extending its range or reducing the load on its primary power systems. In practical application, this energy-harvesting mechanism could be highly beneficial for electric or hybrid vehicles, where every bit of additional energy contributes to improving overall efficiency. Since vehicle suspension movement is a consistent source of energy, especially on uneven roads, the system takes advantage of this typically wasted kinetic energy to provide additional power. Moreover, the use of compact and durable components, such as the planetary gearbox and one-way clutch, ensures that the system is both efficient and resilient in the long term. The modular design also allows for easy integration with various vehicle types and suspension configurations.

In summary, this project harnesses vehicle suspension motion as a source of renewable energy through a carefully engineered sequence of conversions. Starting with a two-way to one-way motion converter, then passing through a high-ratio planetary gearbox, and finally driving a high-output alternator, this system provides a practical and sustainable solution for auxiliary energy generation in modern vehicles. By capturing and reusing energy that would otherwise be lost, the project contributes to the development of greener and more efficient automotive technologies.

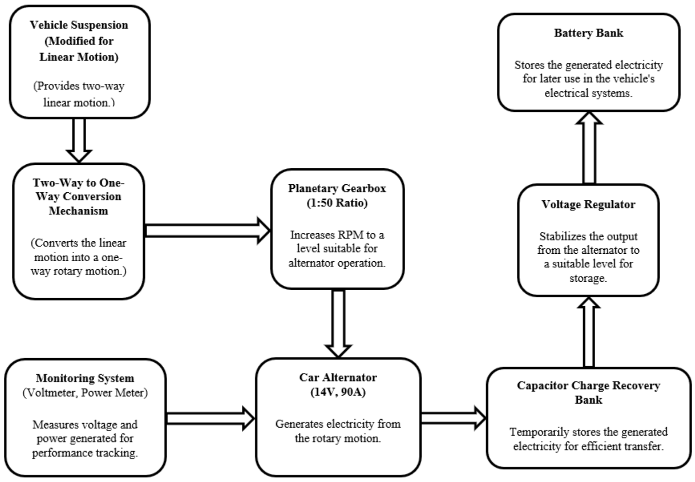
International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 04 Issue: 06 | June – 2025 DOI: 10.55041/ISJEM04517
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

4. METHADOLOGY

1. Conceptual Design and Requirement Analysis

The first step involves a **requirement analysis** of the system based on the objectives of capturing energy from the vehicle's suspension and converting it into useful electrical power. The key requirements are:

- **Two-way linear to one-way rotary motion conversion**: A crank and one-way bearing mechanism is selected to convert the vertical motion of the vehicle's suspension into unidirectional rotational motion.
- **Speed-increasing gearbox**: A planetary gearbox with a ratio of 1:50 is required to step up the low-speed motion from the suspension to the high-speed input needed for the alternator to generate electricity efficiently.
- **Car alternator selection**: A 14V, 90A alternator is chosen based on its availability and capability to generate significant electrical power at the desired rotational speeds.



A. Car Alternator

Fig.1 - Bosch 1402AAA10291N Alternator

Specifications

1. Electrical Characteristics
   - Rated Voltage: 14V DC
   - Rated Current: 90A
   - Maximum Power Output: Approximately 1260W
   - Regulation Type: Internal voltage regulator to maintain a stable 14V output
   - Operating RPM Range: Operates effectively between 1,500 to 6,000 RPM
   - Cut-In RPM: Approximately 1,500 RPM

A. Two-Way to One-Way Conversion Mechanism

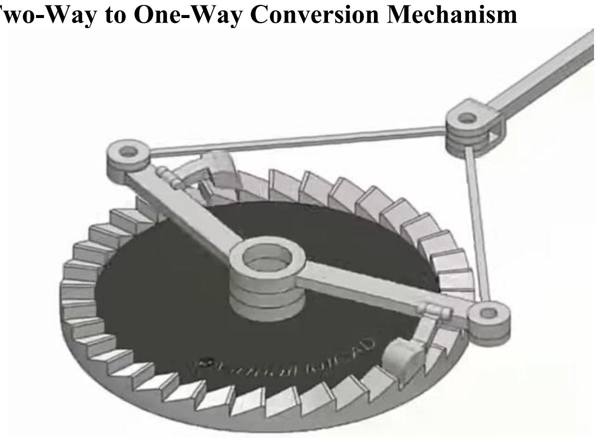


Fig. 2- Two-Way to One-Way Conversion Mechanism

A two-way to one-way conversion mechanism is designed to take a reciprocating (back-and-forth) motion and convert it into continuous rotational movement in a single direction. This conversion is typically achieved by using a crankshaft connected to a moving rod, along with a one-way clutch or bearing. When the rod moves forward, it rotates the crankshaft in one direction, which is then transferred to the output shaft. The one-way clutch engages during this forward stroke, allowing the shaft to transmit rotational energy. On the return stroke, the clutch disengages, effectively allowing the crank to reset without reversing the rotation of the output shaft. This design ensures that even though the input motion oscillates back and forth, the output shaft rotates consistently in one direction. Such a mechanism is ideal for applications like energy harvesting from vehicle suspensions, where the oscillating motion of the suspension can be transformed into a continuous rotation suitable for driving devices like an alternator. By capturing this otherwise wasted energy, the mechanism contributes to efficient energy generation in compact and reliable systems.

Advantages of the Mechanism:

Converts Bidirectional Input to Unidirectional Output
It efficiently utilizes both directions of the linear stroke, making it ideal for energy recovery systems

Simple Construction
The mechanism uses relatively few moving parts, making it easier to manufacture, assemble, and maintain.

Unidirectional Output
Ensures that the output shaft (ratchet wheel) always rotates in the same direction, regardless of the direction of the input.

Compact and Lightweight
Suitable for systems where space is limited or weight must be minimized, like portable devices or automotive systems.

Low-Cost Implementation
Most components can be made from low-cost metals or even polymers for lightweight applications.

Reliable and Robust
Time-tested in various applications and can operate in rugged environments with minimal lubrication.

Mechanical Advantage
Can be optimized to offer torque multiplication using lever lengths and gear ratios.

Core Components Used in This Mechanism:

Ratchet Wheel
A circular gear with asymmetrical teeth (angled in one direction) that allows rotation in one direction only. It is the main rotating output of the mechanism.

Pawls (Two)
Small hinged arms that engage with the teeth of the ratchet wheel. One pawl pushes the wheel during the forward stroke, the other during the backward stroke. Typically, spring-loaded to ensure engagement.

Crank Arm / Actuating Linkage
Connected to the source of reciprocating motion. Converts the linear motion into an arc-like push to the pawls.

Lever or Oscillating Arm
Transfers the motion from the input linkage to the pawls. Attached centrally to allow oscillation.

Frame/Base
Provides the structural support to hold all the components together and maintain alignment.

Bearings/Bushings
Reduce friction on rotating or oscillating parts to improve efficiency and reduce wear.

Return Spring (optional)
Helps reset the pawls or arm if natural oscillation isn’t sufficient.

B. Planetary Gearbox

A planetary gearbox is a compact and efficient mechanism used to transmit torque and adjust speed. It consists of three main parts: the sun gear (central gear), the planet gears (small gears that revolve around the sun gear), and the ring gear (outer gear with internal teeth that mesh with the planet gears). The planet gears are held in place by a planet carrier, which can act as an output or input depending on the configuration.

Working Principle

When power is applied to one component (usually the sun gear), it drives the planet gears, which rotate both on their axes and around the sun gear. The arrangement of fixed and rotating components determines whether the gearbox acts as a speed increaser or reducer. Typically, if the ring gear is fixed and the sun gear is the input, the planet carrier becomes the output and rotates faster than the input, resulting in a speed increase. This setup is commonly used for speed multiplication, making it suitable for applications where high output RPM is required from a low input RPM.

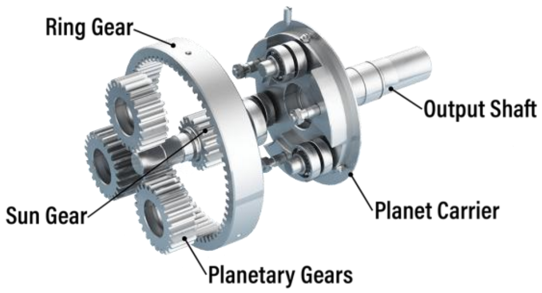


Fig. 4 - Planetary gearbox

5. PROTOTY0PE

To validate the concept of energy harvesting from suspension motion, a small-scale prototype was developed utilizing commonly available components. This prototype captures the fundamental principle of converting vertical linear motion into electrical energy through mechanical and electromechanical means. Prototype Setup: - Mechanical Assembly: A crank-ratchet mechanism is used to simulate the two-way linear motion of a vehicle suspension system. Manual vertical displacement is applied to the crank, which rotates accordingly. The ratchet mechanism allows rotation of the shaft in only one direction, converting the oscillatory motion into continuous unidirectional rotary motion. - Generator Unit: The rotary shaft is coupled directly to a 4W AC synchronous motor (TYC-50 model), functioning as an electrical generator. The motor’s internal rotor magnets induce an alternating current in the stator windings as the shaft rotates. - Load: A 9W AC LED bulb is connected directly to the generator output without intermediate energy storage or power conditioning.

Operational Characteristics: When the crank is rotated by hand simulating suspension movement, the synchronous motor generates an AC voltage ranging between 60V to 90V (no load), sufficient to power the 9W LED bulb. The torque required to sustain steady rotation is approximately 1.2 to 1.5 kg.cm, achievable through manual input. This prototype successfully demonstrates the feasibility of mechanical-to-electrical energy conversion from suspension-like motion in a simple and cost-effective manner. Although the power output is limited and manual operation is used for demonstration, the concept provides a foundation for scaling the system for real automotive applications.

6. RESULTS AND DISCUSSION

Experimental observations: -
- **Output Voltage**: 60V–90V AC (no load)
- **Load Performance**: 9W AC LED bulb glows during active motion
- **Torque Requirement**: ~1.2–1.5 kg.cm (~0.147 Nm)
- **Crank Speed**: Estimated ~40 RPM (manual)
- **Visual Feedback**: LED brightness increases with crank speed

Performance Analysis and Calculations:

1. **Prototype Mechanical Power Input:**

$$P = T \times \omega = 0.1471 \text{ Nm} \times 12.57 \text{ rad/s} \approx 1.85 \text{ W}$$

Assuming 50% system efficiency, actual mechanical power input ≈ 18W for 9W output

2. **Full-Scale Estimation (with Alternator):**

Target system: 14V, 90A alternator → $P = 14 \times 90 = 1260W$ Assuming 60% efficiency

$$\mathbf{Pin = 1260*0.6 = 756W}$$

3. **Torque Requirement (Scaled):**

From prototype: 0.1471 Nm → scaled by factor 140:

$$T = 0.1471 \times 140 = 20.6 \text{ Nm}$$

4. **Required Speed:**

To meet alternator needs (2000 RPM), with suspension motion at 2 Hz → 40 RPM crank × 50 gear ratio = 2000RPM

7.ADVANTAGES

1. **Energy Efficiency**:

This system recycles the otherwise wasted kinetic energy from the vehicle's suspension, providing a supplementary power source that enhances the overall energy efficiency of the vehicle.

2. **Extended Range for EVs**:

By generating additional power, this system can help extend the range of electric vehicles (EVs) or reduce the frequency of recharges, contributing to greater convenience and lower operating costs.

3. **Reduced Load on Primary Power Source**:

By providing supplemental energy, this system decreases the strain on the main battery (in EVs) or the fuel engine (in hybrids), potentially improving battery life and fuel efficiency.

4. **Sustainability**

The system aligns with global efforts to adopt sustainable and renewable energy sources, reducing dependency on traditional fuel and lowering emissions in hybrid vehicles.

5. **Modular Design**:

The system can be adapted for various vehicle types with different suspension configurations, making it versatile and suitable for a wide range of applications.

6. **Cost-Effectiveness**:

Since the project uses relatively simple mechanical components, it can be a cost-effective solution for improving vehicle efficiency without requiring extensive or expensive modifications.
The scaled system needs ~20.6 Nm torque and ~2000 RPM to deliver 1260W, requiring robust real suspension force. Prototype validates concept feasibility.

8.CONCLUSION:

This project presents an innovative, practical, and scalable approach to energy harvesting from the otherwise wasted mechanical vibrations in vehicle suspension systems. Through detailed theoretical groundwork, component-level selection, and physical prototyping, the study successfully demonstrates that vertical motion in suspension systems can be harnessed and converted into usable electrical energy. By integrating a crank and ratchet-based motion conversion mechanism with a conventional automotive alternator (14V, 90A), and validating the idea with a small-scale prototype using a TYC-50 synchronous motor, the core concept has been substantiated effectively.

The small-scale prototype was able to generate enough energy to light a 9W LED bulb, which, although limited in capacity, reinforces the functional feasibility of the concept. The mechanical design involved clever utilization of one-way bearing, crankshaft, and gear mechanisms to allow bidirectional vertical motion to be transformed into unidirectional rotary motion, which was then used to generate electricity.

Key mechanical and electrical calculations suggest that, when scaled appropriately, the system could contribute significantly to auxiliary power demands in vehicles, particularly electric and hybrid electric vehicles (EVs and HEVs), where battery conservation is vital. Considering that vehicular suspensions experience constant and repetitive oscillations due to road conditions, speed, and payload, this system can function continuously during vehicle operation, making it a renewable and regenerative power source.

Furthermore, the proposed system aligns well with global efforts in reducing fossil fuel dependency, improving fuel efficiency, and promoting energy sustainability in transport infrastructure. The design is cost-effective and uses widely available components, making it suitable for implementation even in mid-range or budget automobiles with minimal structural changes.

Despite the prototype's limitations—such as small output power, limited load testing, and lack of integration with a real vehicle system—it sets the stage for more advanced research in this domain. Future work can involve optimizing the conversion mechanism, improving power electronics for energy management, and integrating data logging and IoT monitoring systems for real-time energy analytics.

In conclusion, this research not only proves the technical feasibility of energy harvesting from vehicle suspension systems but also opens avenues for practical implementations in the automotive industry. It encourages a paradigm shift in how we view vehicle dynamics—not just as a means of motion control and comfort but also as an untapped source of renewable energy.

8.REFERENCES

- Zuo, L., & Zhang, P. S. (2013). Energy harvesting, ride comfort, and road handling of regenerative vehicle suspensions. *Journal of Vibration and Acoustics*, 135(1), 011002. https://doi.org/10.1115/1.4007680
- Gupta, S., Kumar, N., & Tiwari, R. (2017). A review on regenerative suspension systems for energy harvesting in automobiles. *International Journal of Vehicle Structures & Systems*, 9(2), 100–106.
- Lin, T., Liao, W. H. (2011). A magnetorheological damper with self-powered capability. *Smart Materials and Structures*, 20(7), 075015.
- Tzanov, T., Georgiev, S., & Dobrev, D. (2019). Energy harvesting from vibrations in vehicle suspension systems. *IOP Conference Series: Materials Science and Engineering*, 618(1), 012014. https://doi.org/10.1088/1757-899X/618/1/012014
- Zhang, H., & Zhang, J. (2016). Design and analysis of a rack and pinion-based regenerative shock absorber. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 230(6), 768–778.
- Bao, Y., & Yu, Y. (2014). Energy harvesting from vehicle suspensions using an electromagnetic damper. *Journal of Intelligent Material Systems and Structures*, 25(11), 1346–1356.
- Bosch Automotive Handbook (10th Edition). Robert Bosch GmbH, Germany. ISBN: 9783658344994
- National Instruments. (2020). Data Acquisition Handbook. Retrieved from: https://www.ni.com
- Valeo Alternator Product Specifications – 14V 90A. Available from: https://www.valeo.com
- TYC Electric Motor (TYC-50) Technical Datasheet. Manufacturer: Ningbo Shengye Electric Co. Ltd. Retrieved from: https://www.tycmotor.com