

# ***Application of Active Components such as DC Generators and Operational Amplifiers in Mechanical Design***

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**Abstract:** DC generators and operational amplifiers have become increasingly important as the need for automation and precise control in mechanical engineering continues to grow. Since their invention in the 19th century, DC generators have played an important role in power systems, especially in applications that require a stable DC power supply. Meanwhile, since the 1960s, operational amplifiers have played an important role in analog circuits, and their applications cover a wide range of fields such as audio processing, signal conditioning, data acquisition and control systems. This paper explores the multiple applications of DC motors and operational amplifiers in mechanical systems and their integration through a literature review approach. It is found that these components not only improve the efficiency and performance of mechanical systems, but also provide higher control accuracy in areas such as robotics and industrial automation. In addition, with the continuous advancement of technology, the combination of the two is expected to realize innovations and breakthroughs in more fields. The research in this paper provides an important reference for the future innovation and development of mechanical engineering.

**Keywords:** DC Motors, Operational Amplifiers, Mechanical Engineering, Control Systems

## **1. Introduction**

In today's mechanical engineering, the rising demand for automation and precise control has driven intensive research into active components, especially DC motors and operational amplifiers. DC motors, with their superior speed and torque control, are widely used in a variety of applications such as robotics and conveyor belts. Operational amplifiers, on the other hand, play a key role in signal processing and control systems, enabling highly accurate feedback and control mechanisms.

In recent years, related research has been intensified and many scholars have explored the application of DC motors and operational amplifiers, emphasizing the importance of these components in modern mechanical engineering. For example, according to Mostafa Jabari and others, DC generators have a kind of application in mechanical engineering, and this literature emphasizes their application and improvement in robot control, and the authors propose a novel DC generator speed controller optimized by POA with FOPD(1 + PI) controller significantly improves the dynamic response and stability of the DC motor in terms of performance metrics [1]. Similarly, Carter and Brown in Texas Instruments mention the importance of internal compensation to ensure the stability of circuits using operational amplifiers, and that the stability of closed-loop amplifiers

can be improved through proper phase compensation, leading to a wider range of applications and improved performance [2]. These advances highlight the growing synergy between mechanical engineering and electrical components.

This paper uses a literature review to analyze the current state of research regarding the use of DC motors and operational amplifiers in mechanical engineering. An examination of various case studies and theoretical frameworks provides insight into the effectiveness and importance of these components in the control of mechanical systems. These findings contribute to a broader understanding of how these technologies can be better utilized to improve effectiveness in mechanical engineering applications.

## 2. Literature review

In the field of mechanical engineering, DC generators and operational amplifiers are widely used as important electrical components in various devices and systems. With their stable voltage output and good control characteristics, DC generators play an important role in the fields of electric power drive, automation control and electric vehicles. Operational amplifiers, on the other hand, play a key role in signal processing, control systems and sensor interfaces. This paper will review the applications of these two components in mechanical engineering and their related research progress.

DC generator is a device that converts mechanical energy into electrical energy, which is widely used in the fields of motor drive, power generation and power supply systems. According to different excitation methods, DC generators can be categorized into series excitation, parallel excitation and compound excitation. DC generators are also used in the field of renewable energy sources such as wind power and hydroelectricity, becoming an important part of realizing the green energy transition. The importance of DC generators in the transition to green energy and their role in ensuring a stable and sustainable energy supply in automated and renewable energy systems is emphasized in the study by Shafiul Alam et al. [3].

Operational amplifiers are high-gain voltage amplifiers that are widely used in signal processing, control systems and sensor interfaces. The design and optimization of operational amplifiers are discussed in a study by Zihao Chen and others, which highlights the importance of operational amplifiers in achieving precise control and signal conditioning in a variety of applications, including automation and sensor interfaces [4]. There are also studies that discuss the role of operational amplifiers in signal conditioning and data acquisition. Preventing broadband noise and achieving the required signal processing accuracy with operational amplifiers is essential for the reliability and accuracy of sensor signals in automation systems [5]. In addition, there are broader ways in which operational amplifiers can be used, such as characterizing them in terms of gain and bandwidth, and how auxiliary operational amplifiers can increase gain and output impedance by reducing the poles of the main operational amplifier to achieve high gain and bandwidth [6].

In recent years, the application of DC generators in conjunction with operational amplifiers has been gaining attention. Operational amplifiers are used to monitor and regulate the output voltages and currents of DC generators in many power drive and control systems. For example, operational amplifiers can be used to construct a feedback control system that regulates the excitation current to achieve a stable output voltage by monitoring the generator output in real time. This combination not only improves the stability of the system, but also enhances the ability to adapt to load changes. With the continuous development of technology, the combined application of the two will provide new opportunities for the innovation and development of mechanical engineering. Future research will further promote the application of these two components in a wider range of fields and enhance the intelligence and automation of mechanical engineering.

### 3. Case Studies

#### 3.1. DC motors in electric vehicles

In electric vehicles (EVs), DC generators are mainly used in EVs to provide power and charging functions. They can effectively convert mechanical energy into electrical energy to charge the battery or power the electric motor. The types of DC motors commonly used in EVs include two types - brushed DC motors, which have a simple structure and lower cost and are suitable for small EVs and low-power applications, but have the disadvantage of wearing out faster and needing to replace carbon brushes on a regular basis, and brushless motors, which use electronic controllers instead of mechanical brushes, and have higher efficiency and longer service life, making it suitable for high-performance electric vehicles. Control systems for brushless motors typically use pulse width modulation (PWM) technology for precise speed and torque control [7].

There are many advantages of using DC generators, such as DC motors can still maintain high efficiency at low speeds and high load conditions, which is suitable for the needs of electric vehicles; and the rotational speed and torque of DC motors can be accurately controlled by adjusting the current and voltage, which is suitable for the dynamic response characteristics needed by electric vehicles, with good controllability; in addition, DC motors have a simple structure, especially brushed DC motors, which are relatively simple and easy to maintain and replace [8]. Finally, the DC generator has a fast start and reverse capability, which can start and reverse quickly and provide good acceleration performance, which is suitable for city driving and high-speed driving.

These benefits are due to the fact that DC motors in electric vehicles are often equipped with advanced control systems for high performance and precise control. Speed control in the control system can control the speed of the motor by adjusting the input voltage and current for smooth acceleration and deceleration. Torque control can adjust the motor output torque in real-time to provide the required power according to the driver's needs. Regenerative braking allows the motor to work in reverse when decelerating or going downhill, converting kinetic energy into electrical energy to be fed back into the battery to extend the range; fault monitoring and protection. Its fault and monitoring protection can monitor the working status of the electric motor in real time, detect faults in time and take protective measures to ensure the safety and reliability of electric vehicles.

Although DC motors have many advantages in electric vehicles, they also face some challenges, such as the cost issue they have, and the relatively high cost of brushless DC motors limiting their application in the low-end market. The heat dissipation problem cannot be ignored, as high-power motors may overheat when working for a long time, so an effective heat dissipation system is extraordinarily needed. In addition, DC generators need higher energy density and longer service life to meet the growing performance requirements of electric vehicles. Of course, as battery and motor control technologies continue to advance, more efficient and lower-cost motor solutions are likely to emerge in the future.

In fact, not only are DC generators fully utilized in electric vehicles, but also in hybrid electric vehicles, DC generators play an important role in converting the mechanical energy of the engine into electrical energy to charge the batteries and power the drive motors, and this energy conversion is the key to achieve electric drive in hybrid electric vehicles, ensuring that the vehicle has sufficient power supply under different driving conditions [9]. As with the advantages of this structure in electric vehicles, the DC generator is able to provide high efficiency to hybrid electric vehicles in a wide range of operating conditions, especially at low and medium speeds. Its flexible speed regulation characteristics enable the vehicle to achieve better energy management under different driving conditions.

### 3.2. Operational Amplifiers in Automated Production Lines

Operational amplifiers (Op-Amp) play an important role in automated production lines and are widely used in a variety of applications such as signal processing, control systems and monitoring. For example, in a food packaging line, Op-Amps are used to amplify signals from temperature sensors to ensure that the temperature in the packaging process remains within safe limits. With feedback control from the operational amplifier, the system is able to adjust the power of the heating elements in real-time to ensure product quality [10]. Then again, in automated production lines, it is often necessary to convert analog signals to digital signals through a data acquisition system for calculation and analysis. This conversion often relies on the use of operational amplifiers in conjunction with analog-to-digital converters (ADCs), which provide the appropriate analog signal for conversion. Operational amplifiers can be used as buffers in this process, providing high input impedance and low output impedance to ensure signal stability during the conversion process, or they can be used as comparators to monitor whether a signal exceeds a set threshold, thereby triggering the appropriate control action.

## 4. Discussion

Research on DC motors and operational amplifiers has provided the basis for automation and intelligence in the field of mechanical engineering. Advances in these technologies have enabled mechanical systems to achieve higher levels of autonomy and intelligent decision-making capabilities, promoting the rapid development of intelligent manufacturing. The research promotes the cross-fertilization of several disciplines, including mechanical engineering, electrical engineering, and control engineering. By combining motor drive and signal processing technologies, more complex and efficient mechanical systems can be designed, which promotes the progress of overall engineering technology. At the same time, by optimizing the performance of DC motors and operational amplifiers, companies are able to improve productivity and reduce energy consumption, thereby significantly lowering production costs. Such economic benefits are crucial to the sustainable development and market competitiveness of enterprises. High-precision control and signal processing capabilities can improve the production accuracy and stability of mechanical equipment, which in turn improves the quality of the final product. This has a direct positive impact on the enterprise's reputation and customer satisfaction in the market; in addition, with the rapid development of electric vehicles, aerospace, smart home and other fields, the application of DC motors and operational amplifiers has great potential. The in-depth research will provide more innovative solutions for these emerging fields and drive the further evolution of the technology. In the context of globalization, mastering advanced motor and signal processing technologies will make countries and enterprises more competitive in the international market. Through continuous research and innovation, it is possible to occupy a favorable position in the global technological competition.

## 5. Conclusion

This paper summarizes the applications and importance of DC generators and operational amplifiers in mechanical engineering. DC generators are widely used in many fields such as drive systems, electric vehicles, automation control, and adjustable speed drives, while operational amplifiers play an important role in mechanical engineering systems such as signal processing, data acquisition systems, control systems, and detection and alarms. The combination of DC motors and operational amplifiers makes the control of mechanical systems more accurate and efficient, improves production efficiency and product quality, and makes the mechanical system adaptable to different operational needs and environmental changes; at the same time, their application enhances the

stability and reliability of the system, reduces the failure rate, and extends the service life of the equipment. And in modern mechanical engineering, the application of DC motors and operational amplifiers promotes the development of automation and intelligence, and lays the foundation for Industry 4.0 and intelligent manufacturing. However, this study has some limitations, such as the lack of field investigations and case studies in some areas, and future research could explore these aspects in greater depth. Looking ahead, as technology continues to advance, the applications of DC motors and operational amplifiers will continue to expand, bringing more opportunities for innovation and development in the field of mechanical engineering.

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