

AN ANALYSIS OF ELECTRIC GUITAR PICKUPS

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ABSTRACT

This physics research paper delves into the comprehensive study of electric guitar pickups, a vital component influencing the instrument's sonic character. The research encompasses a thorough investigation into various pickup types, delving into both the theoretical underpinnings and intricate anatomical structures that underlie their operation. The paper rigorously identifies prevalent problems associated with these pickups, offering a detailed exploration of issues such as interference, tonal inconsistencies, and sensitivity to electromagnetic noise. To address these challenges, a range of innovative solutions and design modifications are proposed, seeking to optimize the performance and versatility of electric guitar pickups. Through this research, the multifaceted world of electric guitar pickups is illuminated, unveiling not only their complex theory and structure but also strategies to enhance their functionality and overall contribution to the realm of music and technology.

KEYWORDS: Analysis, Electric, Guitar, Pickups

INTRODUCTION:

Electric guitars stand as paramount in shaping the modern musical landscape. They have been a cornerstone of rock 'n' roll, blues, jazz, country, and more, shaping the sonic landscapes of countless songs and defining the essence of iconic artists and bands. They embody innovation, craftsmanship, and artistry, combining cutting-edge technology with intricate handwork to produce the mesmerizing tones that have become the backbone of countless songs across various genres.

The electric guitar's distinctive sound is born from the manipulation of electromagnetic pickups and amplification. This design grants the electric guitar unparalleled versatility, allowing it to traverse the spectrum of musical genres with ease.

For dedicated guitarists, the pursuit of the perfect "tone" is a never-ending journey. They endlessly experiment with a myriad of effects, settings, and, of course, guitars. Frequently, outsiders may dismissively declare that "all electric

guitars sound the same," but this assertion couldn't be further from reality. Each guitar and its pickups possess distinct characteristics and nuances that set them apart from their counterparts.

In today's market, a vast array of guitars, each equipped with an even greater diversity of pickups, awaits musicians. To appreciate why these pickups differ fundamentally, it is imperative to delve into the physics involved in their operation. By understanding the intricate science behind pickups, guitarists can navigate the sonic landscape and make informed choices to achieve the precise tone they seek.

FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION:

Electric guitar pickups work on Faraday's laws of electromagnetic induction. The laws state that:

- Whenever a conductor is placed in a varying magnetic field, EMF is induced, which is called an induced EMF. If the conductor is a closed circuit then the induced current flows through it.
- The induced emf in a coil is equal to the rate of change of flux linkage.

WHAT ARE ELECTRIC GUITAR PICKUPS?

Each electric guitar employs a pickup system to generate sound, and this system typically includes one or more small bar magnets to create a magnetic field.

Electric guitar pickups feature pole pieces on top, and their quantity matches the number of strings on the guitar. These pole pieces are designed to guide the magnetic field towards the strings. They can either be magnets themselves or simply metal components used alongside magnets. Their primary role is to magnetize the guitar strings.

The bar magnets are surrounded by thousands of turns of very fine copper wire, forming a coil that plays a crucial role in the pickup's operation called a bobbin. When a string is played, it starts to vibrate in a wave-like manner. This vibration affects the magnetic field surrounding the pickup, causing fluctuations in the magnetic field. These changes are then carried through the wires that connect the pickups to the output jack, ultimately reaching the amplifier.

The guitar strings are primarily composed of steel, with the heavier strings being nickel-wound. On a standard 6-string electric guitar, the heaviest three strings are wound, while the lightest three are single strands. When these ferromagnetic materials (the guitar strings) move within the magnetic field of the permanent magnet, it leads to changes in the flux passing through the coil. The coil, being an excellent conductor, resists these changes in magnetic flux by inducing an alternating current.

This alternating current opposes the change in the magnetic field within the coil, following a principle known as Lenz's law. The result is an alternating current, as opposed to a direct current, circulating within the coil due to the motion of the string. The string moves towards and away from the pickup's pole piece, much like the way the voltage of an alternating current rises and falls. This continuous string movement is of paramount importance. The

string oscillates back and forth, effectively causing the magnetic flux to alternate in direction twice, leading to an increase and decrease in the induced current.

TYPES OF PICKUPS:

Single-Coil Pickups:

Single-coil pickups are the most common type and are known for their bright and clear tone. They are constructed with a single coil of wire wrapped around magnets and have a distinct, snappy sound.

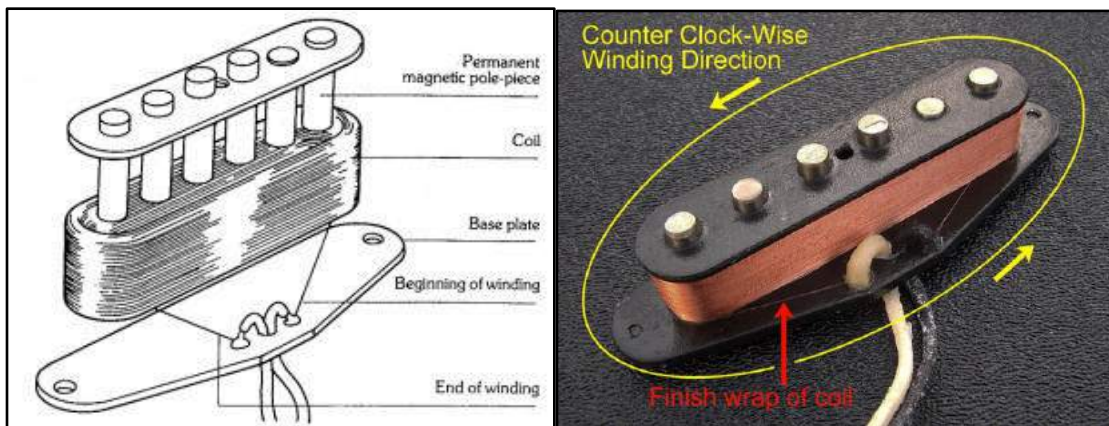
Notable examples include Fender Stratocaster pickups.

Advantages:

- Crisp and clean tone.
- Excellent for clean and jangly tones.
- Good note definition.

Drawbacks:

- Susceptible to interference (hum and noise).
- Lack of warmth and high output.
- Improvement Ideas:



Single coil pickup anatomy

Single coil pickup

Humbucking Pickups:

Humbuckers are known for their warm and thick tone. They consist of two coils wired in opposite polarity, which cancels out noise and interference.

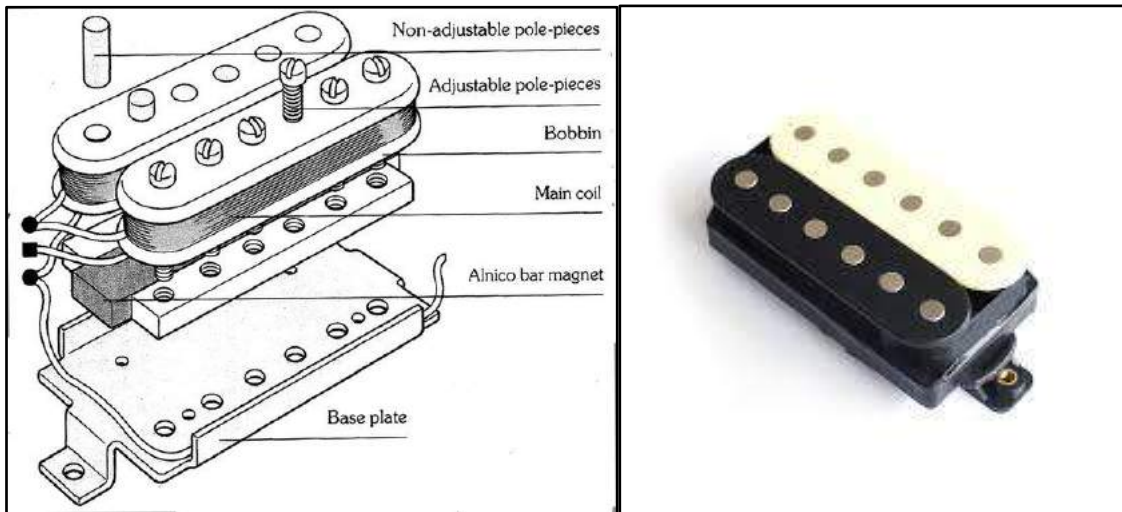
These pickups are often found in Gibson Les Paul guitars.

Advantages:

- Reduced noise and hum.
- High output and sustain.
- Warm and fat sound.

Drawbacks:

- Can lack clarity and sparkle.
- Reduced single-coil-like brightness.



Humbucker anatomy

Humbucker pickup

P-90 Pickups:

P-90 pickups are a unique type, offering a balance between the brightness of single-coils and the warmth of hum buckers. They have a single coil but are larger and produce a distinctive tone.

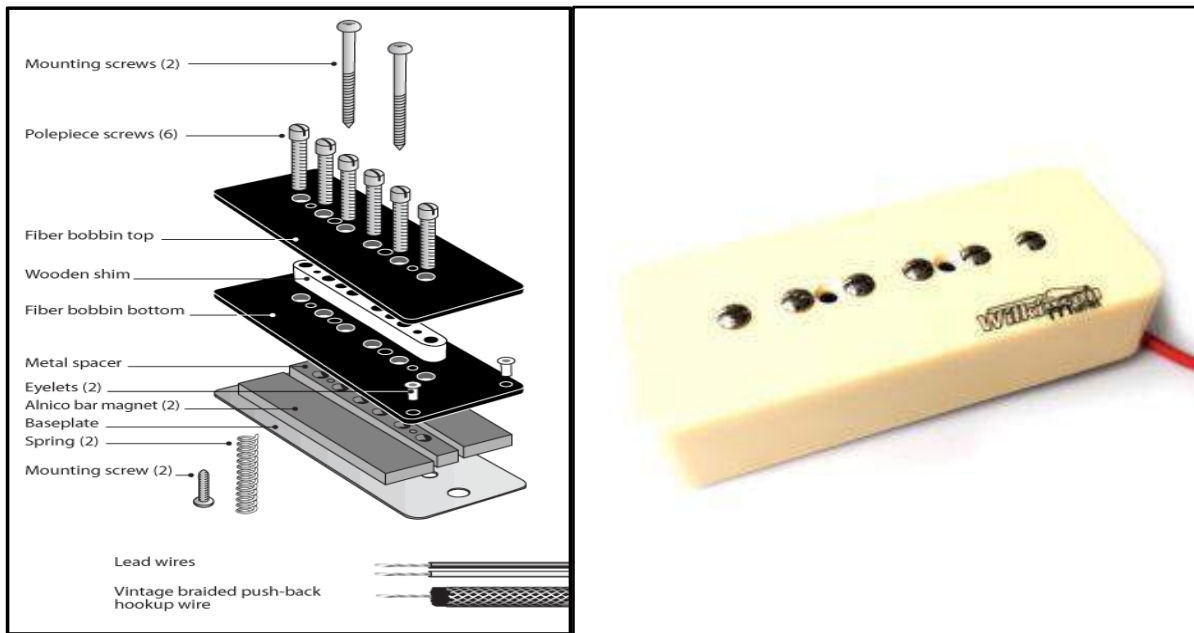
An example is the Gibson P-90 pickups, used on the earlier Les Paul guitars.

Advantages:

- A unique, gritty, and aggressive sound.
- Improved noise resistance compared to single-coils.
- Versatile for various music styles.

Drawbacks:

- Not as noise-resistant as hum buckers.
- Limited tonal options compared to humbuckers.



P-90 pickup anatomy

P-90 pickup

Active Pickups:

Active pickups are designed with an onboard preamp powered by a battery. Active pickups still use magnets and coils, but the circuit is a powered or 'active' one. The result is higher output from fewer coils, resulting in higher gain, more distortion, and less background interference.

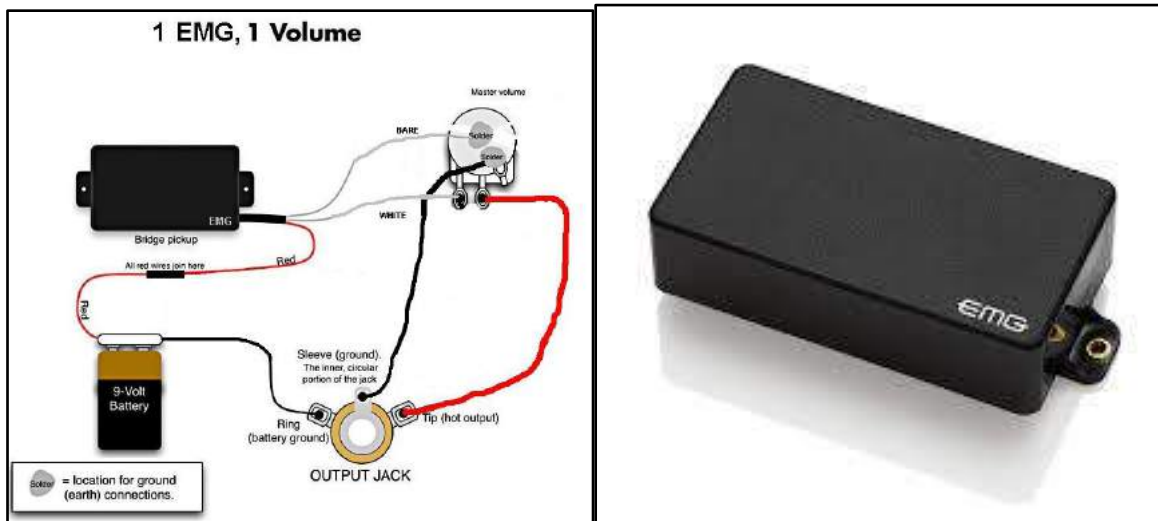
Brands like EMG popularized active pickups.

Advantages:

- High output and clarity.
- Reduced susceptibility to interference.
- Extended sustain and tonal shaping options.

Drawbacks:

- Dependence on battery power.
- Limited dynamic range compared to passive pickups.



Active pickup-battery connection

EMG active pickup

Fender Noiseless Pickups:

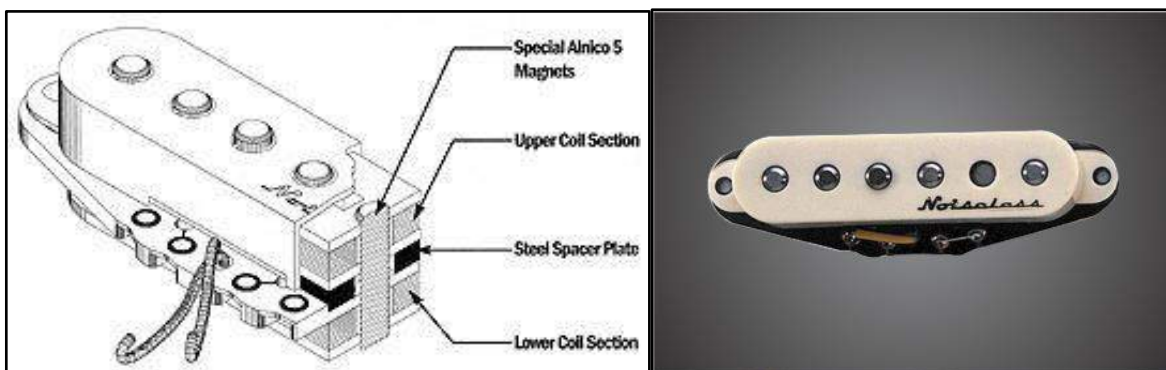
These pickups are designed to cancel 60 cycle (Hz) hum noise while retaining the characteristic sound of single coil pickups. These pickups consist of a pair of single coils stacked one on top of the other, compacted so as to match the shape and width space as a traditional Fender single coil guitar pickup, while being only slightly taller. The upper coil is actually the sound source, while the lower coil is responsible for the 60-cycle hum attenuation.

Advantages:

- Reduced hum, a cleaner and quieter signal.
- Preserve the desired sound characteristics of single-coils, unlike some noise reduction methods that may affect tone quality, noiseless pickups

Drawbacks:

- While noiseless pickups aim to retain the single-coil tone, some players argue that they may lack the exact tonal qualities and nuances of traditional single-coils.
- Noiseless pickups are more intricate in design compared to standard single-coil pickups, making them potentially more challenging to manufacture and repair, and are more expensive.



Fender Noiseless pickup anatomy

Fender Noiseless pickup

PICKUP INTERFERENCE- THE BIGGEST DRAWBACK:

Pickup interference, often referred to as hum or noise, is a common issue in electric guitars and other electronic devices that use pickups to capture audio signals. This interference can be caused by various external and internal factors, resulting in unwanted, often audible, disturbances in the signal. Below, I'll provide a detailed explanation of pickup interference, its causes, and how it can be mitigated:

1. Causes of Pickup Interference:

- a. Electromagnetic Interference (EMI): This is one of the most common causes of pickup interference. EMI is the result of electromagnetic fields produced by electronic devices or power sources. Common sources of EMI include fluorescent lights, computer monitors, power transformers, and wiring in buildings. When the guitar's pickups intercept these electromagnetic fields, it induces an unwanted hum in the signal.
- b. Radio-Frequency Interference (RFI): RFI occurs when radio frequency signals, such as those from radio stations, mobile phones, or Wi-Fi routers, interfere with the guitar's pickups. These high-frequency signals can be induced into the pickup's wiring, resulting in noise or radio interference being audible through the amplifier.
- c. Ground Loops: Ground loops happen when there is a difference in electrical potential between various grounded points in an audio system, including the guitar, amplifier, and other equipment. These potential differences can create unwanted currents, causing humming and buzzing in the signal.
- d. Shielding Issues: Poor shielding in the guitar's electronics or cables can expose the pickups to external interference. A lack of proper shielding allows electromagnetic fields to penetrate the pickup's circuitry, introducing noise into the signal path.

WAYS TO IMPROVE PICKUPS:

1. Reducing Interference:

To mitigate interference, the following improvements can be made:

Advanced Shielding: Employing superior shielding materials and techniques, manufacturers can better protect the single-coil pickup from external interference. This might involve using materials with higher magnetic permeability to create a more effective shield.

Noise-Canceling Technology: Implementing noise-canceling technology, similar to that found in noise-canceling headphones, within the pickup design can actively negate the hum and noise while preserving the desirable single-coil clarity. This technology could involve additional coils or circuitry to cancel out unwanted signals.

Humbucking Pickups: Humbucking pickups are designed to reduce interference significantly. They consist of two coils wired in opposite polarity, which effectively cancel out noise and hum. Many guitarists prefer humbuckers when playing in environments with high interference potential.

2. Versatile Humbuckers:

Humbuckers are popular for their noise resistance and warm sound, but some players desire more tonal flexibility. Potential improvements for humbuckers include:

Coil-Splitting: Adding a coil-splitting feature would allow players to convert a humbucker into a single-coil pickup with the flip of a switch. This provides access to brighter, cleaner tones without the need for additional guitars.

Parallel/Series Switching: By incorporating switches to change the wiring configuration between parallel and series, players can access different tonal options, from the clarity of parallel wiring to the thicker, hotter sound of series wiring.

Additional Coil-Tap Features: Manufacturers could explore options that tap only a portion of one coil, creating tonal variations without switching to a single coil. This technique would preserve some of the humbucker's characteristics while adding tonal diversity.

3. Noise-Canceling Technologies:

Single coil pickups offer a unique and gritty sound but are still susceptible to interference. Enhancements in noise reduction can make them more attractive to players looking for vintage tones without unwanted noise:

Noise-Canceling Coils: Introducing noise-cancelling coils within single coil pickups would provide a way to actively cancel out the hum and noise while maintaining the aggressive sound. This technology could be adapted from advancements in single-coil pickup noise cancellation.

Improved Shielding: Implementing advanced shielding techniques in single coil pickups can help reduce interference from external sources, improving their noise resistance without altering their distinctive tone.

4. Battery Efficiency:

Active pickups depend on batteries to operate their onboard preamps. To make them more reliable and convenient, manufacturers can focus on battery efficiency:

Longer-Lasting Batteries: Research and development in battery technology could yield longer-lasting power sources, reducing the frequency of battery changes or recharges. This would benefit players during live performances and studio sessions.

Rechargeable Options: Designing active pickups with built-in rechargeable batteries could eliminate the need for disposable batteries altogether. This eco-friendly solution would also be more cost-effective in the long run.

5. Enhanced Dynamics:

Active pickups are known for their high output and clarity but are sometimes criticized for their limited dynamic range. Potential improvements to address this issue include:

Advanced Materials: Research into innovative materials, such as magnetic materials with unique properties, could result in active pickups that offer a wider dynamic response. These materials might better capture the nuances of a player's touch.

Improved Coil Design: Advancements in coil design, including different shapes and winding patterns, could lead to active pickups that respond more dynamically to a player's playing style. This could make them more versatile and appealing to a broader range of guitarists.

LIMITATIONS:

Availability of Sources: Some specific technical information and detailed specifications for certain pickups were challenging to obtain, as manufacturers do not always disclose proprietary details. This limited the depth of analysis in some areas.

Scope and Depth of Analysis: The research project aimed to provide a comprehensive overview of electric guitar pickups and their features. However, the sheer breadth of this topic made it impossible to delve into every type and design of pickups available, which, in turn, limited the scope and depth of the research.

CONCLUSION:

The journey into the anatomy of electric guitar pickups reveals that these unassuming components are, in fact, at the heart of the guitar's voice. Their influence on the instrument's sound, responsiveness, and versatility cannot be overstated. As musicians and luthiers continue to explore new materials, designs, and technologies, the future of electric guitar pickups promises to be as dynamic and inspiring as the music they help create. With this, we conclude our exploration into the fascinating world of electric guitar pickups and their remarkable features.

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