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A Historical and Technical Analysis of the Guitar Pickup

The evolution of instruments mirrors changes in technology, culture, and society. In the early twentieth century; engineers, inventors, and tinkerers started to experiment with ways of using advances in mechanics and electronics to record, enhance, and produce sound. Concrete examples of this phenomenon can observed in devices such as: the Telharmonium, a device which transmitted sequences of tones over the phone lines; the phonograph and gramophone, devices which mechanically transduced sounds onto cylinders and later onto discs; and the radio, a device which transmits and receives modulated sound waveforms as electromagnetic radiation. Often, these new technologies emerge as means to overcome technological limitations; however, with these innovations come even more problems to overcome. With the introduction of electrical amplification and its application to the guitar, many interesting design issues emerged, whose solutions led to the robustness of modern-day guitar technology.

The guitar is one of the oldest known instruments, tracing its roots back to the Oud of Ancient Mesopotamia. How the guitar works is relatively simple: a set of strings is stretched and tensed over the body of the guitar. The body of the guitar consists of a hollow cavity. When one of these strings is plucked, the string vibrates at a certain frequency, producing sound. The cavity resonates and amplifies certain frequencies, producing the signature guitar sound. Other stringed instruments work in a similar fashion. The cavity of the instrument and where the strings of the instrument are generally plucked determines the harmonics and identifiable sound of stringed instruments. Over the centuries, many models of the guitar have been created: materials used for the base and strings have changed and there exist many variations in the number of strings among guitar models.

For most of its history, the guitar had been regarded mainly as a non-orchestral instrument and had found use mainly as a solo instrument due to its low volume compared to other instruments. However, in the 1920s and 1930s, a paradigm shift in the purpose of the guitar took place: The lap steel, a guitar-like instrument placed on the performer's lap, was used increasingly in noisy clubs, where the need for amplification became evident. Additionally, Spanish guitarists, such as Eddie Lang and Lonnie Johnson, introduced the notion that the guitar be used in orchestral performances.[1] However, the guitar's potency paled in comparison to that of brass or other instruments. The electrically amplified guitar emerged as a response to the need for amplification.

The aim of this case study is to trace the emergence and development of the electric pickup, a device which transduces vibrations in strings into electrical impulses and which is a pivotal component of the electric guitar. In particular, this study will analyze and study the progressive changes that occurred in pickup design over the decades; why certain approaches to designing pickups prevailed and others failed; what problems emerged as the designs of pickups increased in sophistication; and how problems in design that were seen as hindering aspects of the electric guitar, reverse salients, were transformed into positive aspects. In order to carry out this analysis, however, the principles behind the operation of the pickup must first be discussed, in order to assess the effectiveness of each design. Therefore, this case study will be divided into several major parts: (1) a brief explanation of the physical principles behind the operation of the pickup, (2) a summarization of how the iterations of the guitar pickup were implemented, and (3)

1 McSwain (Braun), "The Social Reconstruction of a Reverse Salient in Electronic Guitar Technology," 186-198

a contrast between these different designs,.

***The Physical Principles Behind The Pickup*[2]**

Magnetism is one of the four fundamental force of nature. Its origin lies in the fact that information cannot travel faster than the speed of light and in the fields of accelerating charges. The electromagnetic fields of charges suffer “jumps” in the regions before and after it is known that the charges accelerated. Oscillating electric charges produce sinusoidally varying electromagnetic waves that propagate through space and matter.

Magnets are the components that drive all of the major pickup designs. There are several types of magnets that are used: the permanent magnet, the ferromagnet, and the coil magnet. Permanent magnets produce a magnetic field because the charges in the magnet are set into a nearly-permanent, complementary oscillatory motion. The permanent magnet can be modeled as dipole. The ferromagnet is a temporary magnet that produces a magnetic field. Ordinarily, this magnet does not exhibit a magnetic field, but is induced by a permanent magnet. Its magnetic field can also be modeled as a dipole. The coil magnet is merely a coil through which alternating current flows, which induces a magnetic field according orientation of the winding of the coil, among several other factors.

Another pivotal component of most pickup designs is the use of coils in order to “pickup” changes in the magnetic field. Utilizing induction is the most common way of picking up vibrations of the strings and transducing them, because it is passive and fairly accurate. Induction operates on the following physical principles: A varying magnetic field induces an electromotive force in a loop of wire that counters that change. This electromotive force manifests itself as a

2 Purcell, E. M. (1985). “Electricity and Magnetism: Berkeley Physics Course, Volume 2”. Published by McGraw-Hill.

voltage difference. This voltage difference is equal to the change in flux times a constant of induction, which is linearly proportional to the number of windings that compose the loop. Thus, a sinusoidally varying magnetic field induces an electromotive force in the coil that is nearly perfectly sinusoidal, and by the principle of superposition, any varying signal or repeating waveform induces an equivalent electromotive force in the coil. This voltage can then be amplified and modulated as desired.

A Survey of Different Pickup Designs

The first American, patented attempt at producing a pickup was performed by W. D. Smith in 1927.[3] This pickup was intended to be used to transduce any sound; it is a precursor of the microphone. The device operates as follows: A "magnetic member" is gently held between the two ends of a horseshoe magnet. A coil is wound at the base of the horseshoe, with many turnings. The magnetic member is held in such a way that any fluctuations in the pressure of the air cause the member to move, inducing changes in the magnetic field which are then translated into electromotive forces in the coil. This approach represents an important milestone because it forms the basis for many of the later iterations of the guitar pickup. Its design, however, was flawed in what it was intended to do because it registered sounds from any direction, except those parallel to the member, and interference from unwanted sources would be nearly impossible to prevent. It lacked portability and always needed to be held upright and stationary, functions which musicians take for granted with today's microphones.

The first patented pickup for the guitar, used in the famous “Frying Pan” guitar, was that of George Beauchamp, who attempted to patent his design in 1932 but was issued the patent in

3 Smith, W.D. (Issued: 1930.) Electrical Pickup. Obtained at http://www.google.com/patents?id=x4xWAAAAEBAJ.

1937.[4] His design, also known as the “horseshoe pickup,” is recognized as the unofficial first guitar pickup and was used as the basis for successive iterations of pickup design. His design consists of a pair of U-shaped magnets, which are attached to a supporting plate and encompassed the strings. The poles of the magnets face each other and are sandwiched in the cavity form by the magnets. A single coil picks up the electromagnetic variations induced by the strings.

A few years later, A. J. Stimson filed a patent in 1934 for another pickup design. This design uses less materials than Beauchamp's. The pickup operates as follows: Below the strings lies a horseshoe magnet and above it are attached windings. When the guitar strings are agitated, the change in the magnetic field caused by the movement of the string induces an electromotive force in the coils, which translates to a voltage waveform in direct correlation to the movement of the string.[5]

Only a year later, Arnold Lesti filed for a patent for similar design to that of Stimson's. His implementation sought to provide amplification for "instruments which are not sufficiently loud when played in the normal manner", by translating string vibrations into electrical impulses; to reproduce faithfully the tones of the instrument, without the interference of the acoustics of the instrument; to provide a means by which to adjust the intensity of treble and bass, by adjusting the intensity of the DC current used to magnetize each string and by adjusting the relative distance of each solenoid to its corresponding string; and to magnetize the strings in the most efficient manner. The design operates as follows: Several coils are placed below the steel strings. A DC voltage is applied for a short amount of time prior to performance in order to magnetize the strings. The coils are powered off and during the playing of the instrument, changes in

4 Beauchamp, G. D. (Filed 1932). “Electrical Stringed Musical Instrument”. Obtained from http://www.google.com/patents?id=xIJMAAAAEBAJ

5 Stimson, A. J. (Issued: 1937.) Electrophonic Stringed Instrument. Obtained at http://www.google.com/patents?id=7SRdAAAAEBAJ&printsec=abstract&zoom=4&source=gbs_overview_r&cad=0#v=onepage&q=&f=false

magnetic flux due to the vibrations of the strings induce an electromotive force in the coils, which translates into an electric waveform, suitable for later amplification.[6] This design is more efficient and versatile because it allows for the selection of certain tones to predominate the sound spectrum. However, DC voltage was regarded as highly dangerous and this design was never widely adopted.

Subsequent patents were very similar but differed and built on several aspects of the aforementioned designs. Delbert J. Dickerson's 1938 patent changes a few aspects of the guitar. Those of interest are the following: a horseshoe magnet is placed below the strings; a wound coil is placed sideways between two plates; and above the strings a metal plate is placed. Volume control was featured on the guitar. The plate above the strings is a radical addition: it supposedly increased volume and tone quality.[7]

Soon thereafter Gibson, Inc.'s engineers started to file patents of designs of electrical pickups. In 1936, Gibson inventor Guy Hart filed for patent of an "Electrical Musical Instrument," widely regarded as the first true electric guitar, the direct predecessor of modern electric guitars.[8] Its chassis is solid, composed of wood or metal, so as to reduce the effects of resonance. The pickup device he patented consists of the following: A pair of magnets rest on a support plate whose distance from the strings can be adjusted. "Magnetic legs" protrude a set of coils, which pickup the vibrations through induction. The pickup is embedded into the guitar and was held there by a screw, which is adjustable. Though a bit crude, Hart's design formed the basis upon which subsequent guitar designs would be built.

In 1938, Gibson inventor George R. Miller filed a patent which sought to improve many

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6 Lesti, A. (Issued: 1936.) Electric Translating Device for Musical Instruments. Obtained from http://www.google.com/patents?id=QoMWAAAAEBAJ.

7 Dickerson, D. J. (Issued: 1940.) Electric Pickup Unit for Stringed Instruments. Obtained from http://www.google.com/patents/about?id=VPxwAAAAEBAJ

8 Calore, M. (2009). "July 13, 1937: Gibson Plugs In the Electric Guitar". Obtained from: http://www.wired.com/thisdayintech/2009/07/dayintech_0713/

of the aspects of previous pickups, such as making sound be independent of the type and dimensions of the string; and to provide a pickup that is adjustable for each string, as is Lesti's; among other aspects.[9] His pickup works as follows: there is one screw for each string that is wrapped by a coil, each above a magnet which provides the necessary flux change. These six screws can be moved up and down in order to adjust the amplitudes of each string. This design is quite similar to Lesti's, but uses a permanent magnet instead of magnetizing the wires prior to performances.

In 1941, another Gibson engineer, Clarence W. Russell, filed a patent which sought to eliminate tone distortion and equalize tone volume. His invention consists of a horseshoe magnet to which is attached a plate which is screwed into the magnet. On this plate, oriented in the direction of the magnetic field between the two poles is a set of holes, which house coils, through which the strings of the guitar pass and which are affected evenly no matter the directions in which the string is oscillated. The sizes of the wholes vary depending on the diameter and make of the string.

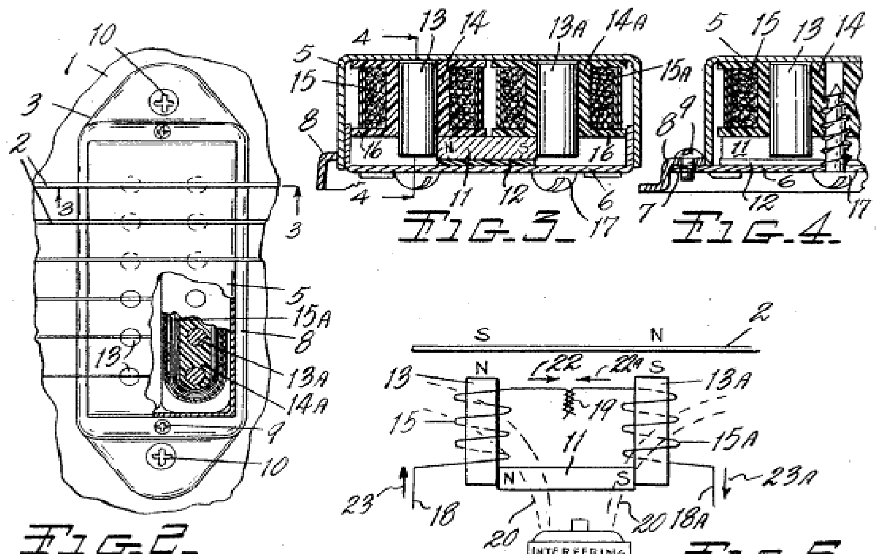
In 1946, the Gibson P90 guitar pickup was patented, which is a standard still used to this day in single-coil guitars.[10] The P90 operates as follows: One large flat coil is used as the inductor which transduces the vibrations. Below each string is an adjustable steel screw which acts as a pole piece. Two flat AlNiCo bar magnets lie under the coil. This design produced a rich treble sound and would become the pickup of choice for many musicians.

Despite all of the changes and variations introduced in the preceding patents, regular, single-coil pickups suffered from what many consider to be a major flaw: the coils would pick up a hum from the alternating current supplying the power to the devices. This phenomenon

9 Miller, G. R. (Issued: 1939.) Magnetic Pick-up for Musical Instruments. Obtained from http://www.google.com/patents?id=Ry0CAAAAEBAJ.

10 Hart, G. (Filed 1936). “Electrical Musical Instrument”. Obtained from: http://www.google.com/patents?id=e7hGAAAAEBAJ

happens because of another fundamental property of electromagnetism: currents induce magnetic fields; and most equipment is powered by alternating current power sources. Thus, a detectable low-frequency (about 50 to 60 Hz) hum is audible with the use of single-coil pickups. This reverse salient would remained unsolved until, in 1957, a Gibson engineer, Seth Lover, patented a novel approach, still used to this day, to eliminate the hum.



The hum-eliminating pickup (pictured above, from the original patent), later to be known as the Humbucker, is composed of two sets of windings, located next to each other and under the guitar strings. Both coils are perturbed by plucked strings; however, both have opposite polarities and winding directions. The plucking of the string is amplified by this arrangement, but background interference, from lights or from AC sources, induces canceling electromotive forces. The net result is that barely no interference affects the sound of the guitar and that the tones of the guitar get amplified, providing purer sound.[11]

11 Lover, Seth. E. (Issued: 1959). MAGNETIC PICKUP FOR STRINGED MUSICAL INSTRUMENT. Obtained from http://www.google.com/patents?vid=2896491.

A Contrast Between the Different Pickup Designs

The iterations of the pickup do not differ much from each other, for they operate using the same physical principles. Single-coil pickup design has not changed much since the 1940s. The manner in which the pickups most differ is in how they were assembled and in how they were positioned. The most popular pickup designs are the P90 and the Humbucker, which triumphed over many of the proposed alternate designs. The reasons for which these pickups were favored and other were abandoned will be discussed in detail in the following paragraphs.

Beauchamp's “horseshoe” pickup triumphed early in the 1930s due to its success on the lap steel guitar. However, it failed to gain acceptance as a pickup in standard electric guitars, particularly because the magnets which circle the strings were hard to set up, could dislodge, posed a hazard because were located above the strings and could cling to foreign objects and because its coils were exposed to other forms of radiation, including light, which produced a significant hum.

Arnold Lesti's design, which sought to correct many of the problems encountered with previous single-coil designs and which was quite advanced for its time, never gained much use. One main reason for which it was not accepted was the fact that it used DC voltage to magnetize the strings, which presents a set of serious problems: (1) Lesti's design did not use magnets and relied on DC voltage to magnetize the strings prior to every performance. This approach does not guarantee that each string will be magnetized equally, magnetizing more the inner strings. (2) The magnetized strings did not induce voltages as strongly as they would with permanent magnets, as the flux induced by permanent magnets is much greater. (3) DC voltages are considered extremely dangerous, as any short or any nearby metals greatly increased the risk of shocking those around the guitar, potentially injuring those who are around the guitar while it is charging. (4) The magnetization of the strings would dwindle over time. Mid-performance, it is extremely inconvenient to be forced to stop and remagnetize the strings. His idea of being able to adjust the intensity of the treble and bass is echoed throughout the designs of future pickups, such as the widely used P90 and Fender pickup models.

Dickerson's approach is similar to Beauchamp's in that it also covers the strings. The plate above the strings greatly limited this design's potential for adoption. Though his patent never saw much use, one idea of his guitar design is also seen in future patent designs: volume control. Modern guitars feature knobs that are used to adjust tone and volume, that are very similar to those proposed by Dickerson in the 1930s.

Hart's guitar design definitely had a lasting influence on the design of future guitar chasee. However, his approach to incorporating the pickup was not very practical: it limited the potential of the guitar by embedding it into the chassis. Removing it or replacing it would be a hassle to the guitarist and limits the choice of pickup to those that would be compatible with the dimensions of the guitar.

Clarence Russell's design suffered from many of the flaws of Beauchamp's. His threaded pickup design is flawed because it can interfere with the vibrations of the strings itself were they to be plucked to forcefully. Additionally, removing or replacing the pickup would be inconvenient, as each string would have to be threaded through each individual hole.

The P90, along with the Fender single-coil pickups, is the most widely used single-coil pickup to date. Its success can be attributed to the following factors: (1) a robust design which captures the vibrations effectively; (2) a simple compartmental design that makes replacement and installation an easy task; (3) amplitude adjustment for each individual string; (4) effective marketing strategies carried out by Gibson; (5) widespread celebrity use by famous guitarists; (6)

a distinct sound only attainable with this pickup; and (7) increased durability and ease of transportation, as its casing made the pickup much more robust than its earlier counterparts; among many other factors.

There is no doubt as to why the Humbucker has been so successful since its inception: the hum produced by single-coil pickups was widely regarded as a reverse salient in electric guitar technology. Borrowing many of its aesthetic and functional aspects from the P90, the Humbucker resolved the problem of the hum and produced a unique, terser sound, as well. Produced by Gibson and marketed extremely well, use of the Humbucker caught like wildfire and quickly and nearly completely replaced the use of single-coil pickup models. The single-coil pickup still saw use because the humbucker produced a unique sound called the “humbucker tone” and because the guitar had different resonance frequencies, which produced a less treble tone. In fact, several musicians, such as Jimi Hendrix, embraced the single-coil pickup's faults in order to experiment and produce unique music.[12]

Conclusion

In the development of the guitar pickup, a tendency towards exploiting new developments in technology is observable. The pickup developed from Smith's humble, fragile, ineffective omnidirectional pickup to a robust, compact element that easily amplifis a guitar's sound. The development of the pickup mirrored other changes in electric guitar design: namely, a desires for increased amplification, the possibility of signal processing before outputting signals, and a desire to decrease the influence of body resonance on the output of sound. The reasons as to why the P90 and the Humbucker trumped other pickup can be summarized as follows: better marketing, compactness, effectiveness, and convenience. The simplicity of both models allowed

12 McSwain (Braun), “The Social Reconstruction of a Reverse Salient in Electronic Guitar Technology,” 186-198

musicians to experiment and create their own unique sounds. The concurrent development of these electrical guitar technologies converged to what we know as the electric guitar, ushering in an era of experimental music that is still progressing to this day.

Bibliography

Purcell, E. M. (1985). “Electricity and Magnetism: Berkeley Physics Course, Volume 2”. Published by McGraw-Hill.

Smith, W. D. (Filed 1927). “Electrical Pick-up”. Obtained from http://www.google.com/patents?id=x4xWAAAAEBAJ

Beauchamp, G. D. (Filed 1932). “Electrical Stringed Musical Instrument”. Obtained from http://www.google.com/patents?id=xIJMAAAAEBAJ

Stimson, A. J. (Filed 1934). “Electrophonic Stringed Instrument”. Obtained from: http://www.google.com/patents?id=7SRdAAAAEBAJ

Lesti, A. (Filed 1935). “Electric Translating Device for Musical Instruments”. Obtained from: http://www.google.com/patents?id=QoMWAAAAEBAJ

Dopyera, R. (Filed 1938). “Stringed Musical Instrument”. Obtained from: http://www.google.com/patents?id=YK4BAAAAEBAJ

Hart, G. (Filed 1936). “Electrical Musical Instrument”. Obtained from: http://www.google.com/patents?id=e7hGAAAAEBAJ

Dickerson, D. J. (Filed 1938). “Electric Pickup Unit for Stringed Instruments”. Obtained from: http://www.google.com/patents?id=VPxwAAAAEBAJ

Miller, G. R. (Filed 1938). “Magnetic Pick-up for Musical Instruments”. Obtained from: http://www.google.com/patents?id=Ry0CAAAAEBAJ

Russell, C. W. (Filed 1939). “Musical Instrument”. Obtained from: http://www.google.com/patents?id=gM1OAAAAEBAJ

Fuller, W. L. (Filed 1940). “Pickup for Electrical Stringed Musical Instruments”. Obtained from: http://www.google.com/patents?id=rBZMAAAAEBAJ

Lover, S. E. (Filed 1955). “Magnetic Pickup for Stringed Musical Instruments”. Obtained from: http://www.google.com/patents?vid=2896491

McSwain “The Social Reconstruction of a Reverse Salient in Electronic Guitar Technology,” 186-198 of Braun, “Music and Technology in the Twentieth Century”.

Calore, M. (2009). “July 13, 1937: Gibson Plugs In the Electric Guitar”. Obtained from: http://www.wired.com/thisdayintech/2009/07/dayintech_0713/