"Wide-Range"!?

A discussion of the

Fender Humbucking Pickup

Original, Clones & Competition

Tilmann Zwicker
GITEC (https://www.gitec-forum-eng.de)

Part 1

History, Build and Measurements: Original CuNiFe & Reissues

Preface by the author:

For quite a while, the Fender Humbucking pickup was kind of a mystery to me. I was aware that Fender made some guitars sporting that device (Starcaster, Telecaster Deluxe, Telecaster Custom, and the 2nd version of the Telecaster Thinline - and the 2nd version of the Telecaster Bass) but no one in my circles played anything like that. I remember playing a jam session (maybe 1975) where the other two guitarists incidentally both played Telecaster Customs (one of them heavily modded with a third Fender Humbucker - quite a feat for the time), but since I was totally nervous (being the junior amongst what I considered much more serious and accomplished musicians) I never paid much attention to whether they got a particular sound. I think I did asked one of the guys and got a response along the lines of "yeah we play these pickups 'cause the give more output but retain more of that Fender sound". Anyway, that was my one and only encounter with the Fender Humbucker for a long time. In the mid 1980's I could finally afford to keep more than just that one main guitar, and with a Les Paul and an ES-335 already at home, I decided that I should finally branch out into the world of Fenders, as well. In a strange coincidence, I found 2 Telecasters within a few days in the want ads in Munich (not a regular occurrence back then): a Vintage Reissue Tele (the first kind they made in the 1980's), and a 1973 Thinline ... with the Fender Humbuckers. Both were great guitars, the former almost brand new and the latter well used by someone who apparently had played rhythm guitar for a rather traditional band: the 1st-position C-chord could actually be seen as notches in the frets, rendering the guitar almost unplayable there. After a refret, however, that Thinline sounded absolutely great, with a particular "ring" when using both pickups together, a sharp/meaty/nasty bite in the bridge pickup (way ahead of the somewhat anemic Strats and the thin-ish Teles of those days), and the most gorgeous, warm but clear blues tone from the neck pickup. I had that Thinline for many years until at some point I felt I had too many guitars and associated mostly with Gibsons, after all ... so the Thinline got sold – to a good friend, though, who insisted that the guitar "stay in the family". I don't think he played the guitar often, but it did remain in reach. Very unfortunately, that friend passed away a couple of years ago. His wonderful family is still very much part of my social circle, so when the issue of the Fender Humbucking pickup came up in the framework of GITEC (see below), I could ask for the Thinline as a loan for investigation and measurements. After all, it is still the only guitar available in my musical environment that has the original Fender Humbucking pickups. Therefore, in a way, this article is also honoring my good friend Mike, without whom that guitar would have been lost to us here.

Mike's **1973 Fender Telecaster Thinline**. The pickguard (made from airplane plywood by another friend) is not original. Tone pot and output jack needed replacement, and the guitar had a fret-job. Everything else is original.

A1. Introduction

At the GITEC association (https://www.gitec-forum-eng.de), we try to stay on track with regard to practical added value for musicians. Helping with this objective are professional guitarists (scroll down on the web-page https://www.gitec-forum-eng.de/landing-page-news/vorstand/), and one of those is Kurt Härtl. Some years ago, Kurt has started to associate himself with a particular guitar: the Fender Telecaster Deluxe – triggered by an encounter with two made-in-Mexico Reissue Deluxe Telecasters that he liked very much - they have become his go-to axes. Kurt has since had made several Deluxe-Telecaster-clones built for him by local luthiers. He is now constantly in the process of modifying the electrics of these guitars, putting the knowledge acquired from GITEC to good use. Of course, guitar players encountering Kurt and his axes notice the peculiar pickups on these guitars, and consequently we have recently seen quite some interest in the Fender Humbucking pickup. Wolfgang Hönlein, member of the GITEC board, has also recently taken a shine to the Telecaster Deluxe and, cautiously moving into that terrain, has opted for a Squier version of the model. Without say, he is also very curious about its pickups.

As luck would have it, we could get access to a 1973 Fender Telecaster Thinline with two of the original Fender Humbuckers – this sparking further curiosity.

Therefore, it seemed the right time to investigate the Fender Humbucker a bit more, to make comparisons between original and reissue pickups, and also to compare to clones of this type of pickup.

N.B.: For support and advice, special thanks go to Prof. Manfred Zollner and to Helmuth Lemme, both of whom provided data, pictures, insights, and many years of experience in and contributing to the field of electric guitars.

Please note that this article does not only seek to give information, but is also meant to open a discussion. There are several questions that we raise but cannot answer right away - any input readers might have is therefore highly welcome. Also, due to the complexity of the matter and the not-always-fully-available historic information, we may have gotten some details wrong. If any reader finds corresponding issues, we would be most grateful if we were informed about this via dr.t@gitec-forum-eng.de. Thanks a lot in advance for any support!

This following article seeks to document our findings in three parts:
- In this **first part** we will look at the **construction** of the original 70's pickup, compare it to the Fender and Squier/Fender reissues, and give **data** for both.
- The **second part** will look at some **clones** of the original pickup by other manufacturers, and will also introduce some comparisons to the typical **Gibson humbucker,** and **Fender single coil pickups**.
- Finally, the **third part** will try to highlight the actual **sonic differences** between the various versions of the pickup (or similarities, as it were), including some sound samples.

A2. History of the Fender Humbucking pickup

The origin of the Fender Humbucker is well documented: Seth Lover /1/, the engineer who had in 1955 designed Gibson's legendary humbucking pickup, went to work for the Fender company (fresh under CBS-ownership) around 1967. In the late 1960's, much of the emerging (characteristically distorted) rock-guitar sound owed to certain aspects of the Gibson Humbucker as it was mounted on the company's Les Pauls, ES-335's, SG's, etc. These guitars enjoyed significant public presence and were used to great effect by Eric Clapton, Mike Bloomfield, Jimmy Page, Jeff Beck, Paul Kossoff, and others. In many cases, players even fitted Fender guitars with Gibson humbuckers. Given this scenario it is no wonder that the Fender company sought to step up /3/. Having Seth Lover on the payroll would have certainly helped – and he now designed Fender's own humbucker, termed Wide Range Humbucking Pickup /2/. It was released probably in late 1971 and remained available until about 1981 when a big overhaul of the production line swept through Fender.

Around 1983, a pickup that looked similar to the original reappeared on Fender guitars manufactured in Japan. Later (around 1998) another reissue was featured on Mexico-made Fenders. Compared to the original, both these reissues are of a quite different construction. The reason is probably that materials used in the original pickup had become difficult to come by , and using would have driven up cost.

With the ongoing trend that, in guitarist circles, everything (more or less) old is seen as attractive (or even superior), the Fender Humbucking Pickup has seen renewed interest in recent years. Several pickup manufacturers have issued clones, claiming that their products match the original in sound.

The term "Fender Humbucking Pickup" is often coupled with the moniker "Wide Range" (as in "Fender Wide Range Humbucking Pickup"). It seems this terminology has its source in Fender promo-speak. In their sales brochures and catalogues (the 1969 and 1976 catalogs being prominent examples), Fender almost never use the term pickup per se – it always shows up with an additional qualifier. "Wide range", "extended range", or "full range" is often seen in the description of the more expensive guitars (Strat, Tele, Jazzmaster, Jaguar, Coronado), while "high output" or "high fidelity" turns up with the student models (Mustang, Duo-Sonic, Musicmaster). Of course, all these designations are meant to aid sales and have very little scientific relevance other than maybe that Fender pickups typically have a higher resonance frequency compared to Gibson pickups and thus give a brighter tone that could be associated with a "wider frequency range". In any case, we will see that the Fender humbucker does not have a particularly wide range in terms of frequency response. The term "wide range" therefore may serve merely to distinguish the Fender pickup from the Gibson humbucker, but not to qualify its operational frequency range.

Today, the Fender Humbucking Pickup (in the "reissue" version) is found on a number of guitars (including Telecasters and Starcasters) of the Fender and Squier brands, manufactured in Mexico and Asia.

N.B.: Other kinds of "humbucking" approaches that Fender used/uses (such as the Precision Bass split pickup, or reverse-wound pickups) are <u>not</u> subject of this article.

A3. Construction

Seth Lover cleverly designed the pickup using an approach that, while based on the same principle that the Gibson humbucker employed, kept certain idiosyncrasies of the well-known Fender (single-coil) pickups. Indeed, it is very likely that the express objective of the Fender humbucker was to provide higher output (for increased overdrive) and hum-free operation while keeping some of that "Fender-sound".

A3.1 Relatives: Stratocaster pickup and Gibson humbucker pickup

In fact, and for all intents and purposes, the Fender Humbucking pickup can – in a nutshell – be seen a combination of two typical Stratocaster pickups (Fig. 1) that are reverse-wound and fitted with their magnets in opposite directions, and mounted directly side by side under a metal cover /4/.

Fig.1.1: Stratocaster-type pickup, cover removed. The cylindrical magnets protrude from the bobbin; the coil (dark brown) is wound around the latter.

Seth Lover applied the twin-coil arrangement he had used in the Gibson humbucker, but dispensed with the bar magnet underneath the coils, replacing it functionally with 12 cylindrical magnets that he located in the coils directly underneath the strings. The magnets take the place of the pole pieces of the Gibson pickup.

Let's look into this arrangement in more detail and make some comparisons (the following figures are taken from /5/, courtesy of Prof. Manfred Zollner.

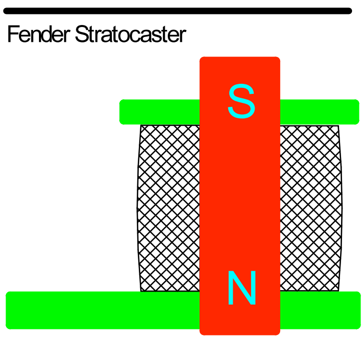


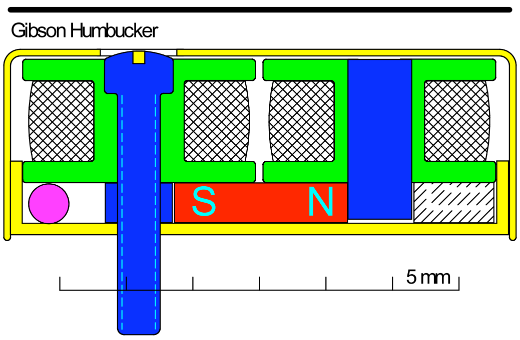
Fig. 1.2 shows a cross section through a Stratocaster pickup (see Fig. 1.1) with the bobbin (coil former) in green, the coil winding cross-hatched in black, and the magnets in red. The latter are of cylindrical shape. The magnetic field traveling from the north pole of the magnet "N" to the south pole "S" is affected by the vibrating string; the correspondingly changing magnet flux induces a voltage into the coil[1].

Fig. 1.2: Cross-section through a Fender Stratocaster pickup (/5/)

In Fig. 1.3, we see the cross-section through a Gibson Humbucker. The two bobbins (green) with their associated reverse-wound coil (cross-hatched in black) are positioned side by side. The magnet (red) is not in the coils but located underneath them such that the direction of the magnetic field (from north "N" to south "S") is opposite in one coil with respect to the other. Because of the opposite direction of the magnetic flow, the voltage induced by the moving string is opposite in the two coils.

[1] For some additional insights into the workings of pickups, see the animations offered by GITEC; e.g. Nos. 22ff on the webpage:https://www.gitec-forum-eng.de/knowledge-base-2/collection-of-animations/

By winding the coils in reverse, one of the voltages is "turned around", with the effect that when the coils are connected in series, the string-induced voltages are in-phase again and fully add up to double the value given by one coil.



For any hum and electro-magnetic interference coming from the outside and having no connection to the magnetic field of the pickup, the situation is different: it is induced in both coils the same way. The reverse winding has the resulting voltages being out-of-phase: they cancel each other out via the connection of the two coils.

Fig. 1.3: Cross-section: a Gibson humbucking pickup (/5/)

In other words, the signal given by the string is made stronger by the connection of the two coils, while the interference is (ideally) removed. (N.B.: this is exactly the same principle used for the "symmetric" 3-wire connection of microphones to mixing desks - it keeps the small microphone signals clean).

This "humbucking" approach (in fact it is the differential principle well known not only in communication engineering and instrumentation) works really well, but there are issues at higher frequencies. One of these is due to the so caller humbucker aperture: the fact that the two coils are space a given distance apart. The string will vibrate in its fundamental frequency (that determines the pitch) with the two nodes at the bridge and the fret (or nut), respectively, and the maximum displacement in the middle between the nodes. However, there will be many harmonics[2] that cause, superimposed on top of this fundamental, vibrations of many harmonic frequencies that feature multiple nodes and points of maximum displacement all along the string. The higher these harmonics, the shorter the distance between the nodes and maximum-displacement points. At some harmonic (at relatively high frequency), the vibrations of the string above the pickup will be such that one coil will sense (sample) a phase of this vibration that is the opposite of the phase that the other coil samples. Here, the humbucking effect will not cancel out merely the hum from the outside, but also this particular harmonic. This is why humbucking pickups have an inherent attenuation for certain high frequencies (in fact harmonics) at certain fretting positions on certain strings (see /5/, Chapter 5.4.4). In practice, this implies that there is a treble-loss that every side-by-side-coil humbucker incurs due to its very principle of operation. However, the treble loss is not always dramatic and occurs mostly on the low E- and A-strings, on the lower frets - and it is not necessarily a bad thing, depending on the taste of the guitarist. We will get back to this effect a bit later.

It is worth noting at this point that the Gibson Humbucker includes pole pieces (colored in blue in the figures here) guiding the magnetic filed through the coils: the pole-piece-screws in the left in the figure, and the slugs on the right. The pole pieces are made of iron - the magnetic field finds it very easy to travel through this material and much prefers it to air.

[2] For additional insights into string movements, see the animations offered by GITEC; e.g. Nos. 12ff on the webpage: https://www.gitec-forum-eng.de/knowledge-base-2/collection-of-animations/

As a consequence, the magnetic field leaving the magnet concentrates as much as possible into the pole pieces and focuses into the coils - except for the upper section of the pickup, where the field cannot but travel through air ... incidentally the space where string is placed. Here, the basic functionality of every magnetic pickup happens: the movement of the string (that contains an ample amount of steel) will cause corresponding variations in the flux of the magnetic field, and violá: the voltage induced into the coils appears.

A3.2 Fender CuNiFe Wide-Range Humbucking Pickup (original 70's version)

Now, back to the Fender Humbucker (Fig. 1.4):

as already mentioned, Seth Lover uses the same side-by-side coil arrangement of reverse-wound coils that he so successfully employed in the Gibson pickup. In Fig. 4 we see the two bobbins (shown in green) with their associated reverse winding (of about 5000 turns each of 42 AWG wire /10/; cross-hatched in black in the figure).

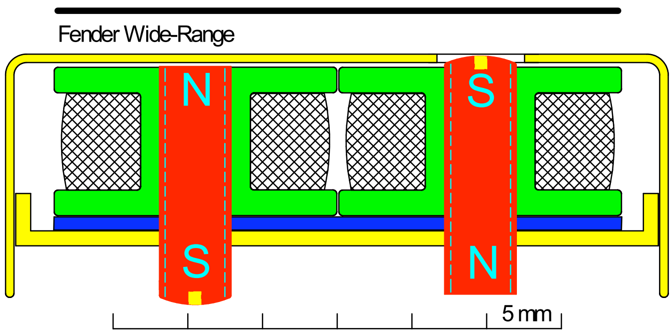


Fig. 1.4: Orig. Fender "Wide Range" Humbucker (pic. by H. Lemme), right: cross-section (/5/)

The important difference can be seen in the magnets (shown in red): as it is the case with the Stratocaster pickup (Fig. 1.2), and very differently from the Gibson pickup (compare to Fig. 1.3), the magnets are located within the coils. With this arrangement, no further guiding of the magnetic field is necessary, and pole pieces are superfluous.

Other than the difference in the build, the absence of pole pieces has another effect that may manifest itself in the sound of the pickup. The iron that the pole pieces bring to the magnetic circuit does a good job in guiding the magnetic field (if that is required), but it also introduces eddy currents into the game. The electrical conductivity of iron facilitates the flow of small currents self-induced into the system by the coil. These currents give the effect of a loss in the magnetic circuit similar to the effect a resistor connected to the pickup would have - i.e. as if an electric load would be present. It is a small load, but given the very high impedance of typical magnetic pickups (especially at their resonance frequency), it still decreases the obtainable Q-factor of the system. As such, the Fender humbuckers can be expected to deliver a more pronounced resonance peak compared to the traditional (Gibson-type) humbucker. We well look into the effect on the sound of the pickups a bit later.

The interior of the original Fender humbucker can be seen in Fig. 1.5a. Fig. 1.5b shows the pickup from underneath. The two bobbins are larger than those of a Stratocaster pickup. While they seem to be similar in size to the regular Telecaster bridge pickup at the time, the details of the bobbin are different (one-piece molded) – Fender must have tooled up specifically or outsourced a specific production run.

The "wide range" Fender Humbucking pickup is (in its physical dimensions) wider than its Gibson counterpart (although that surely was cannot have been the reason for the designation!); it will not fit into a guitar routed for the Gibson humbucker. The black parts left and right between the bobbins are sticky tape that would have facilitated the assembly process.

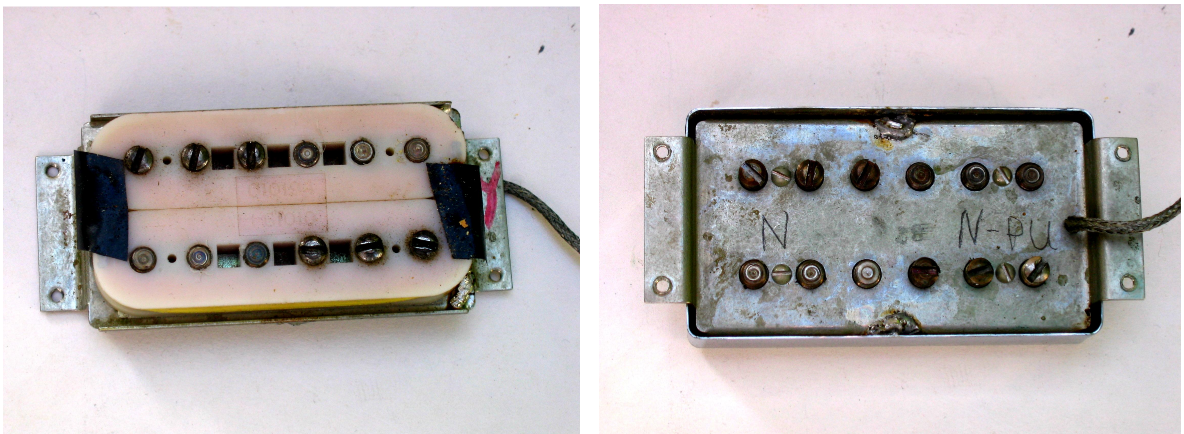


Fig. 1.5: Fender humbucker (pics. by H. Lemme),. Left: w/out cover; right: bottom view
The lettering is non-original.

It seems that while engineers debated the need and usefulness of adjustable pole pieces on pickups (in fact, some still do debate this ...), sales people were very keen to have them on the products they were given to sell /6/. Seth Lover had included the adjustable pole-piece screws at the request of the Gibson sales department although he assured them that technically they were unnecessary. Therefore Fender in all likelihood will also have requested adjustable pole pieces when their humbucker was developed. It is safe to say that this request would have put Seth Lover in a bit of a bind: while the basic material for normal pole pieces (iron) can be machined really easily to have threads or screw heads, most magnetic material completely fail to have that "machineability" quality. They are brittle and quite impervious to drills or milling machines, blunting them very quickly, or deciding right away to simply and completely break rather than have small pieces taken off.

Enter CuNiFe: a magnetic material composed of copper, nickel and iron (hence the name) that can be machined relatively easily. With it at hand, Seth Lover was able to provide cylindrical magnets that featured threads and screwheads. These magnets thus could serve as adjustable polepiece and magnet in personal union.

The leaves us to mention the remaining very explicit difference to the Gibson humbucker: the 3-by-3 offset alignement of the adjustable magnets. Again, it is highly probable that this configuration was chosen just for this one reason: to distinguish Fender against the Gibson pickup.

That there is much (or any) audible effect by the location of the user-adjustable magnets on the sound is unlikely. Unfortunately, it is difficult to investigate this because fast-paced A/B-comparisons on one and the same guitar with identical playing are almost impossible. By the way, all 12 threaded magnets are identical: 6 of them are, however, inserted from the "other side" so that their screwheads do not show (i.e. they do not interfere with the pickup cover but are still adjustable (from the bottom side of the pickup).

There is one other difference between the humbuckers of Fender and those of Gibson: the Fender pickup has the two rows of pole-pieces (i.e. the magnets and the center-line of the coils) spaced 20 mm apart, while the Gibson pickup is narrower at 18 mm. The cancellation of harmonics on the lower strings mentioned above will therefore occur in a slightly lower frequency range. It is of course debatable whether this 10%-difference is actually audible or crucial in any way.

Just like the Gibson humbucker, and unlike the Stratocaster pickup, the Fender Humbucking pickup has a metal housing providing mechanical protection and also electrical shielding. However, just like metal within in the coils of a pickup, any metal around the coils can be an issue due to the already-mentioned eddy currents and resulting damping within the circuitry, and also if the material used has magnetic properties. In /6/, Seth Lover discusses this problem in relation to the Gibson humbucker, and it would appear that the nickel-silver (German silver) material he mentions there was used for the Fender pickups, as well. Helmuth Lemme found the covers of the two original Fender Humbucking pickups to be completely non-magnetic and thin enough to minimize eddy-currents. Chrome plating gives the pickups a nice shiny finish that has held up well over the decades.

Although not potted with wax, the original Fender pickups feature very low susceptibility to microphonics - probably due to the non-magnetic cover.

A3.3 The Fender Reissue Wide-Range Humbucking Pickup (mfd. in Mexico)

From the outside and above, the original 70's pickup (produced in Fullerton, CA.) and the reissue (manufactured in Ensenada, MX) look completely the same. However, turning them over (Fig. 1.6) reveals the first differences in the cables used, and in the wiring. In contrast to the original (where the shielded 2-conductor cable had penetrated to the inside of the pickup), the coil wires are fed through the base plate to the underside of the pickup (in fact facilitating single-coil switching, if that is desired!), connected there to the 3-conductor output cable (that facilitates out-of-phase switching if desired!).

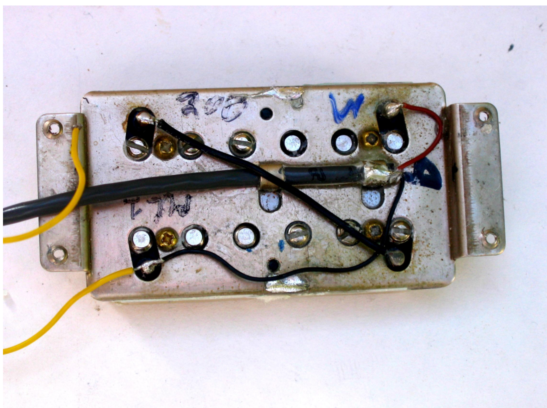


Fig. 1.6: Reissue Fender Humbucking pickup, view from the bottom (pic. by H. Lemme),. The lettering and the yellow cable (added fro single-coil-switching) are non-original.

Removing the cover and looking at the insides reveals a design that is rather removed from the original (Fig. 1.7). Clearly, the bobbins are of a different size compared to the originals: they are smaller (much like the regular Gibson humbucker bobbins), and spaced apart to compensate for the overall size in the direction of the strings. Any remaining space (also in the direction transverse to the strings) within the pickup is taken up by wax - this pickup is heavily potted. Beneath the bobbins, a bar magnet sits, and the pole pieces (screws and slugs) are of the regular iron type: what we have here is the exact same construction as in the Gibson humbucker - merely camouflaged as a Fender! The cover of the Reissue is quite magnetic, interacting with the magnet and therefore prone to microphonics. Consequently, the potting is important and highly required.

Fig. 1.7: Reissue Fender Humbucking pickup, with cover removed (pic. by H. Lemme),. Note smaller coils and wax-potting.

With the external dimensions and the positions of the center-lines of the coils just like the ones of the original 70's version, the Reissue will have the same aperture and corresponding string-to-magnetic-field transmission characteristic. However, the remainder of the build being significantly different, it would not be surprising if the data of the pickups would turn out to by different, as well.

Why did Fender change the internal construction so much? First, there is the cost issue: the reissue pickups are to be mounted on – compared to the US-made Fenders – much more budget priced "import"-instruments, and parts that are readily available on the market are preferable. Possibly even more importantly, the nicely machine-able CiNuFe had lost any significance in the world of magnets by the mid-1980's. Very difficult to come by now, using it would drive up costs considerably.

A3.4 The Squier/Fender Wide-Range Humbucking Pickup (mfd. in Indonesia)

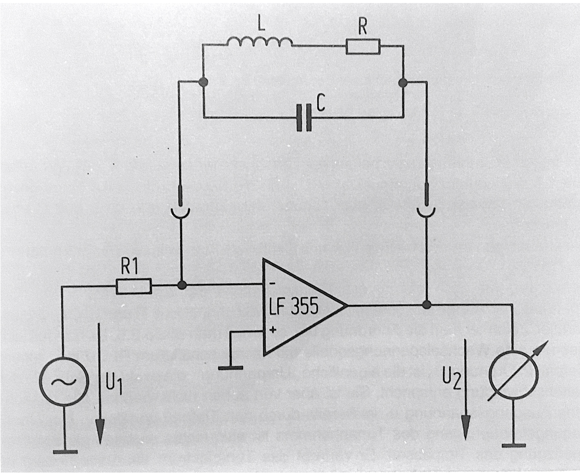
In all likelihood, the Telecaster Custom sold under the Squier name (manufactured in Indonesia) holds pickups of the exact same construction as the Mexico-made reissues. We did not verify this by opening up the available Squier pickups – but taking out one of the threaded pole-pieces revealed that these components are not magnets themselves, i.e. the pickup will hold a bar magnet.

A4. Electrical Characteristics

To get a handle on some data of the pickups investigated here, it was decided to establish the frequency response of the impedance. While this does not give the actual transmission function, it is very good indication of the sound of a pickup, especially when compared to the impedance frequency responses of other, well known pickups.

The frequency response of the impedance will help to assess the sound color of a pickup but it does not indicate the output level i.e. how loud a pickup is. However, the latter aspect is deemed less important, as more gain is always readily available in modern amps, or can be easily found via booster devices that are ubiquitous today. Back in the day of, say, Cream, or early Santana or Allman Bros., the "loudness" of a pickup was much more crucial in order to get sufficient overdrive from the amps used back then. These amplifiers had much less gain than typically available today.

A4.1 Measuring circuit



The impedance was measured using a simple setup (Fig. 1.8) as described in /7/: the pickup to be measured is connected in the feedback circuit of an operational amplifier driven from a generator via a high-impedance resistor (in the present case: 106 kΩ). The output voltage can then be easily converted into the impedance of the pickup at the given frequency.

Fig. 1.8: circuitry for measuring the frequency response of the pickup impedance (represented by L, R and C), from /7/.

Some considerations were made as to realistic operating conditions for the pickup:

- unless active circuitry is built into the guitar, a pickup is always connected to the amplifier input (or the input of sound processing devices) via a cable of not inconsiderable length (3 m - 10 m, typically). The cable influences the sound color a pickup provides in that the resonance frequency of the system depends on the given capacitance (C in Fig. 8). This capacitance is largely determined by the cable capacitance (usually between 300 pF and 2 nF). In fact, the sound of electric guitars that players and listeners are accustomed to is only achieved when a capacitance as given by a guitar cable is present. To reflect this, a capacitor of 470 pF was connected across the pickup, simulating a (high quality) cable of a length of 6 m to the amplifier.
- normally, a passive guitar circuit includes a volume and a tone control, with values typically ranging from 220 kΩ to 1 MΩ each. Moreover, the amplifier will have an input impedance of typically between 100 kΩ and 1 MΩ. These three (ohmic) resistances will jointly impose a load of between about 50 kΩ (worst case) and 500 kΩ (best case, if a "no-load"-type tone control is deployed) to the pickup. The effect is a damping of the resonance of the system, making the sound somewhat less distinct (for lack of a better word - it is always difficult to describe sound via the meaning of words). It was decided not to emulate these ohmic loads in the present context, because we wanted to get "maximum performance" from the pickup. It is very easy to add more loading (i.e. damping) to a pickup but very difficult to reduce damping, and thus we opted for the extreme where the pickup is pushed to its "internal extreme". We anticipated that comparison between pickups would be more distinct that way.

Measurements in the present context were not of the high precision kind - an error of about 3% was likely to occur for impedance measurements. All measurements were, however, repeated – ensuring that no large errors could occur.

A4.2 Available pickups

For investigating the Fender Humbucking pickup, 8 specimen were available: 4 reissue pickups made in Mexico and mounted in 2 Telecaster Deluxe (Mexico) guitars from about 2005 and 2009, respectively, 2 specimen mounted on a Squier/Fender Telecaster Deluxe acquired in 2019, and 2 original CuNiFe-pickups mounted in a 1973 Telecaster Thinline (neck-date 8-Dec-1972).

A4.3 Frequency responses

A4.3.1 Precursory basic considerations (see also Appendix 1)

From the below data, and given definitions from textbooks, we could calculate a "quality factor" (Q-factor) of the pickup. For example, a well-known concept for establishing a Q-factor in a resonance frequency response is to determine those points left and right of the peak of the resonance curve (i.e. on the x-axis; frequency-wise above and below the peak frequency f_{peak} that are (on the y-axis) 3 dB below the peak. To obtain the Q-factor, the distance in frequency Δf of these two points is fed into the formula:

$$Q = f_{peak}/\Delta f \,.$$

However, closer inspection of the matter (**see** corresponding article "**Factoring in the Q**" in the GITEC Knowledge-Base and Repository) shows that the simple definitions in textbooks hold for resonance system with a high Q-factor (say 5 and up), and need not apply to lower-Q systems such as guitar pickups. A unifying approach to the Q-factor is difficult to establish. In fact, it turns out that from a strictly scientific point of view, specifying a Q-factor may not be the most suitable way, and that the height of the peak in the transmission characteristic of a pickup might be a much better qualifier.

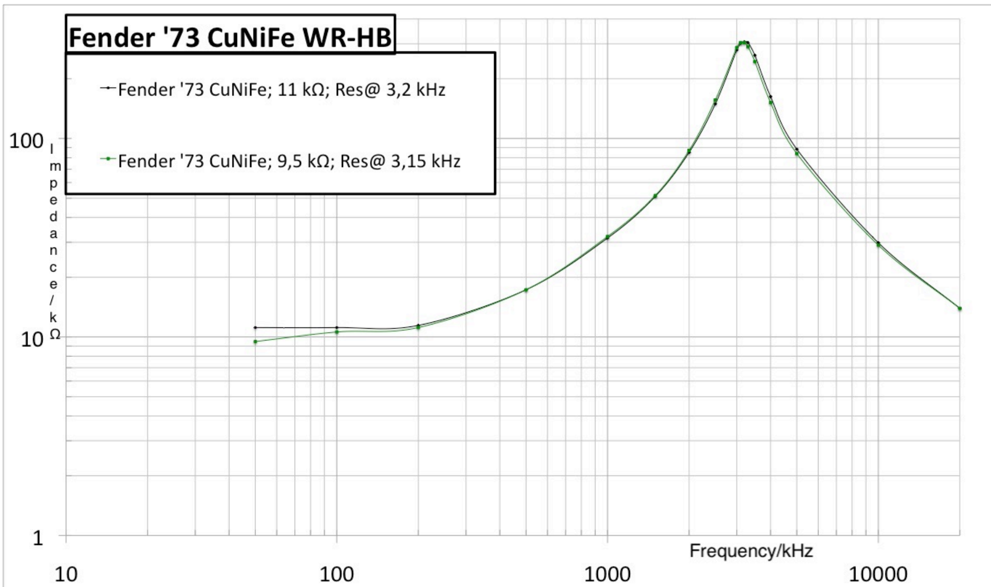
Complicating the matter further is the fact that the resonance of the guitar system is not the resonance of the pickup by itself, but one of the overall system including external components (in particular capacitive and resistive loads imposed by guitar cable, control potentiometers, and amplifier input). This needs to be considered, as well (see also 4.1 above).

In the present context, we decided to continue to work with the above "3-dB-down"-concept, and for comparison purposes use a Q_{3dB}-factor, after all - always bearing in mind that this is not a universally applicable Q-factor but one that may only be used in the present context for comparisons between measurements using the same boundary conditions (i.e. loading situation) for the investigated pickup.

A4.3.2 Original Fender Humbucking pickup

Measured frequency responses of the impedance of the original CuNiFe-pickups are given in Fig. 9. The two frequency responses line up rather well, starting from a DC-resistance of around 10 kΩ, and rising to about 300 kΩ at the peak frequencies of around 3.2 kHz. At the time of production, no distinction was made between pickups placed at bridge or neck.

At the resonance frequency, there is the expected pronounced peak in the frequency response, with a bandwidth of 600 Hz between the 3-dB-down points at about 2,9 kHz and 3.5 kHz. Our "special" Q_{3dB}-factor is calculated from dividing the peak frequency by the established bandwidth (see 4.3.1 above) and amounts to about 5.3.



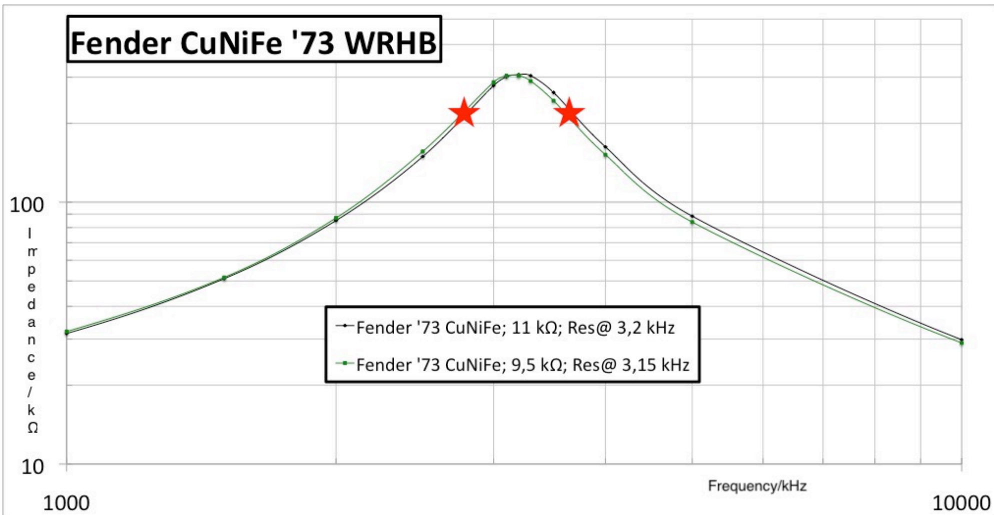
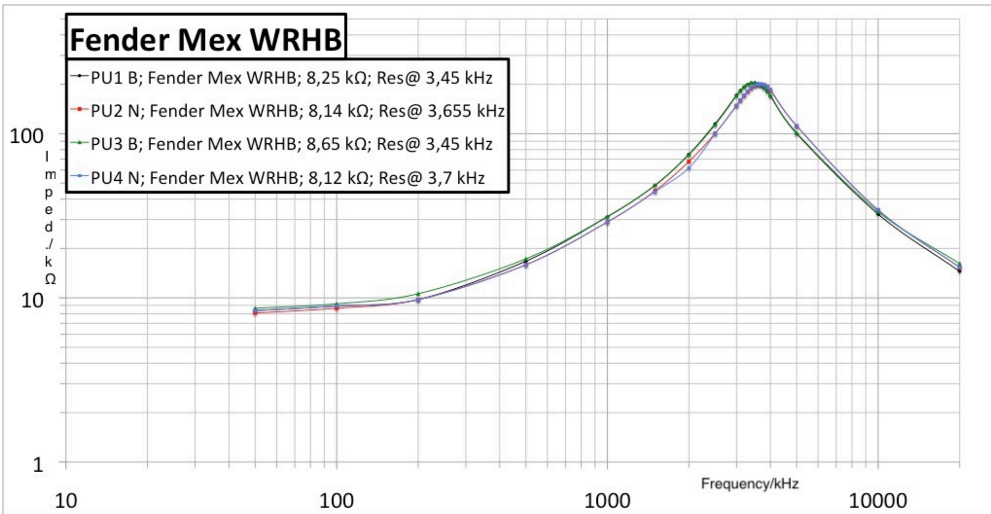


Fig. 1.9: Original 70's Fender Humbucking Pickup - frequency resp. of impedance of 2 pickups. Top: complete frequency range. Bottom: smaller range around the peak frequency with red stars indicating the 3dB-down frequencies.

A4.3.3 Reissue Fender Humbucking pickup

The 4 reissue pickups had to be categorized into "bridge"- and "neck"-versions, as it is customary today to mount slightly different pickups in these positions on the guitar. The impedance responses of the resulting two pairs of specimen line up very well (Fig. 1.9), respectively - a testimony to the tight control of production at Fender Mexico. The "neck"-position units had a resonance frequency at about 3.7 kHz, and a slightly lower DC-impedance of a little more than 8 kΩ, while the "bridge"-position units had just a bit more resistance around 8,5 kΩ, topping out impedance-wise at just about 200 kΩ at the resonance frequency of 3.4 kHz.

With a 3-dB-down bandwidth of about 1200 Hz for both "bridge" and "neck" versions, the Q_{3dB}-factor calculates to about 2.9.



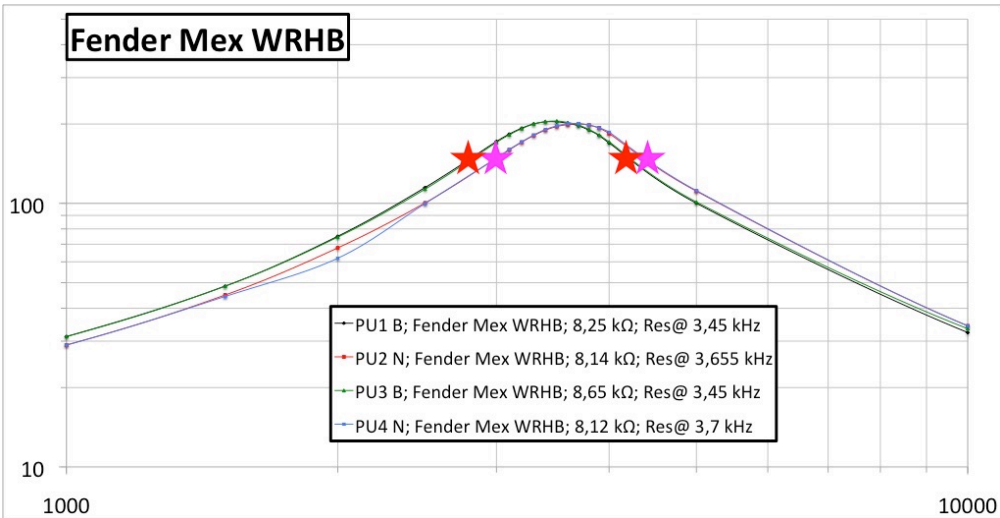


Fig 1.10: Reissue Fender Humbucking Pickup - frequency response of impedance of 4 pickups (two each bridge- and neck-position).
Top: complete frequency range. Bottom: smaller range around the peak frequency with red (bridge pickup) and violet (neck pickup) stars indicating the 3-dB-down frequencies.

A4.3.4 Squire/Fender Humbucking Pickup

The "neck"-position unit had a resonance frequency at about 3.4 kHz (with the impedance peaking at about 160 kΩ, and a slightly lower DC-impedance of 7.7 kΩ, while the "bridge"-position units had just a bit more resistance around 8.4 kΩ, topping out impedance-wise at just about 185 kΩ at the resonance frequency of 3.2 kHz.

With a 3-dB-down bandwidth of about 1300 Hz for the "bridge" version, and 1700 Hz for the "neck" version, the Q_{3dB}-factor calculates to about 2.4 and 2, respectively.

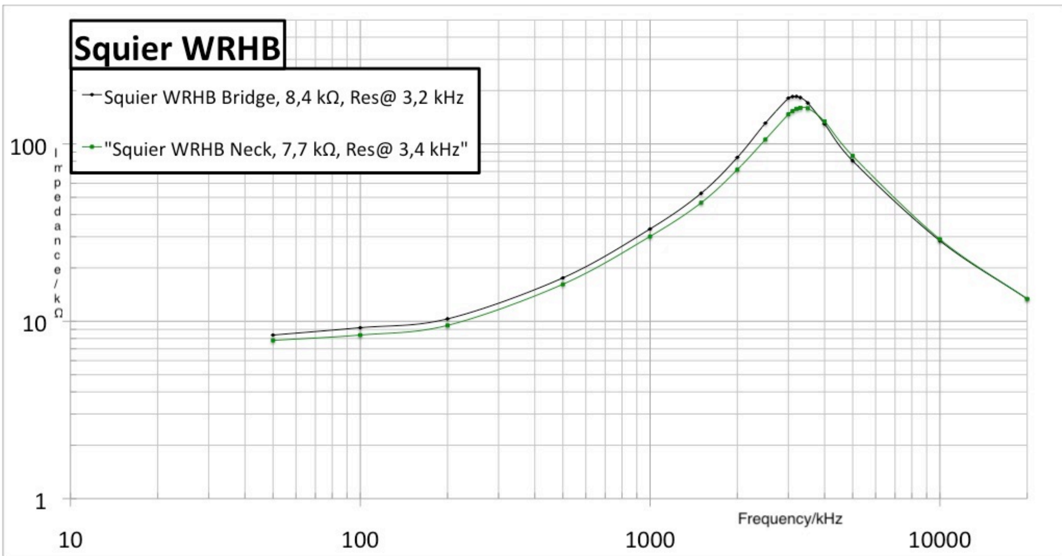


Fig 1.11: Squire/Fender Humbucking Pickup - frequency resp. of impedance of 2 pickups (bridge- and neck-position).
Top: complete frequency range. Bottom: smaller range around the peak frequency with black (bridge pickup) and green (neck pickup) stars indicating the 3-dB-down frequencies.

A4.3.5 Comparison to literature data

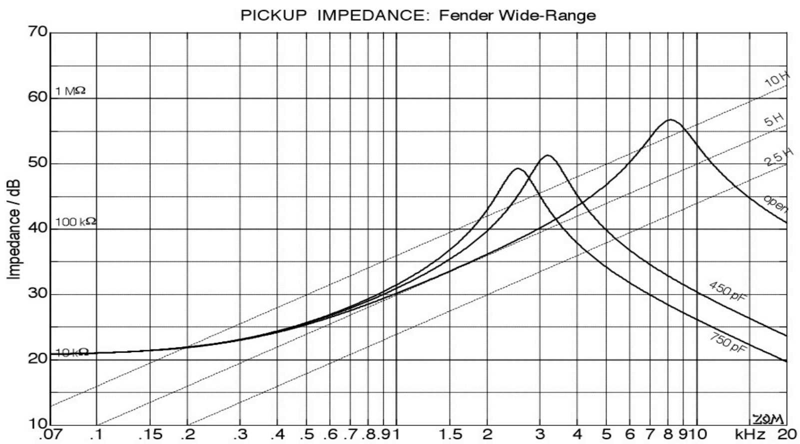
A4.3.5.1 Manfred Zollner's data from "Physics of the Electric Guitar" /5/

In /5/, a very large selection of pickups have been investigated using precision instrumentation - among the both the original and the reissue Fender Humbucking pickups so that data are available for comparison Fig. 1.12.

In comparison to the above results from the present investigation, the data from /5/ do not find a significant difference between the resonance frequencies of the two pickup types. The impedance of both tops out at around 3.2 kHz when connected to a load capacitor of 450 pF. There is, however, a distinct difference in the Q_{3dB}-factor with the original CuNiFe-pickup showing about double the Q_{3dB}-value.

Fender Wide-Range Humbucker

Humbucking pickup, 12 CuNiFe magnets.



Fender Thinline-Reissue Humbucker

Humbucking pickup, alnico bar-magnet.

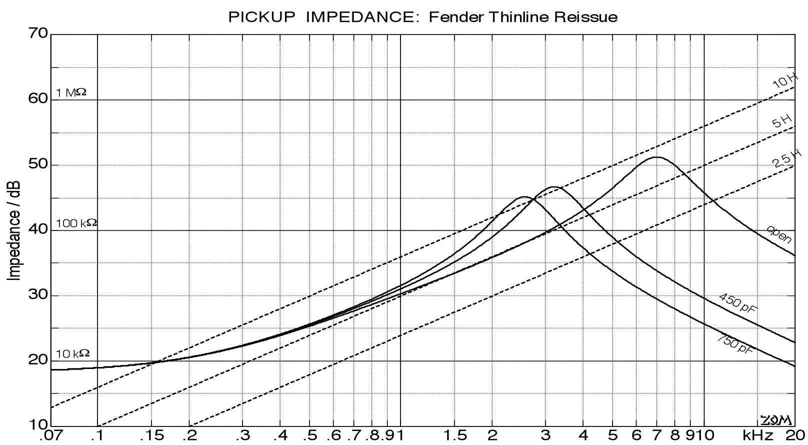


Fig. 1.12: Frequency responses of Fender Humbucking pickups according to /5/.
Top: original CuNiFe pickup. Bottom: reissue pickup.

A4.3.5.2 Helmuth Lemme's data from several of his books

Over the years, Helmuth Lemme has put together a significant collection of pickup data. Except for /4/, his publications are all in German language. As early as 1977, he already dicusses the Fender Humbucking Pickup /8/ and shows the insides (of the then exclusively available original version) but gives no measurement data. In 1993, Lemme publishes specific data /9/ for presumably the same original CuNiFe-pickup: given a 470-pF-load, the resonance is found to be at 3 kHz, with a Q-factor of 3.1 with cover and 3.7 without cover. The same numbers are found in Lemme's subsequent publications incl. /4/. In view of the various possible definitions of the Q-factors, and many possible load situations, caution is advised when comparing these numbers with the ones presented above.

Recently, Helmuth Lemme has done some more measurements on the original and the reissue Fender humbuckers /11/. As in /5/, no clear difference between the two types is found in the resonance frequency which is located at about 3.3 kHz. The measurements do however again establish a significant difference in the Q_{3dB}-factor, the latter being about 80% higher in the original pickup.

Also of interest: Lemme has investigated the effect of the pickup covers. It turns out that for the original pickups, the respective covers degrade the Q-factor much less than for the reissue pickups.

A4.4 Discussion of the measurement results

Often, cursory discussions – in particular those on Internet fora but also quite frequently in guitar magazines – about pickups seek to characterize and describe the "sound" of a pickup simply via its resistance, i.e. the ohmic impedance. The original Fender Humbucking pickup is a good example that this approach is far from conducive: with a DC-resistance of around 10 kΩ, it has a relatively high impedance (compared to e.g. regular Stratocaster pickups or Gibson humbuckers weighing in at around 6 and 8 kΩ, respectively), and would therefore fall in the category of "powerful, mid-rangy, distortion oriented" for those looking at the DC-resistance alone. However, the pickup has quite a different characteristic, with a relatively high resonance frequency, with creating a rather "normal" loudness perception. But we are getting ahead of ourselves: such "sonic" evaluations are reserved for the third part of this article.

In any case, the available measurements show that the reissue version of the Wide-Range humbucker has a slightly lower impedance of around 8 - 8.5 kΩ compared to the impedance of the original of about 10 kΩ. The resonance frequency of the original is, at about 3.2 kHz, the lowest of all the Fender humbuckers available for the present measurements: the reissues sport slightly more than 3.4 kHz for the bridge-position pickup, and slightly less than 3.7 kHz for the neck-position pickup. The consistency within the pairs of the 3 types (original, reissue-bridge, reissue-neck) is quite good.

The measurements from literature (derived each from one single specimen of the respective pickup that differed from author to author) do not show any clear difference between the resonance frequencies of the original and the reissue pickups. However, this may be due to scatter amongst the pickups, and also to aspects of the instrumentation used, which was different for each author. Also, the present investigations could take advantage of the availability of several specimen of the pickup types. Given the consistency mentioned above, it is likely that the differences established via the present measurements would hold in general, and would show up for a larger population of pickups, as well.

It is nice to see that the theory derived from the different build of the originals and the reissues hold well in practice: in the reissue, the bar magnet, the iron pole-screws and slugs, and the magnetic cover all make for additional (eddy-current) losses that will reduce the Q_{3dB}-factor of the resonance. Measurements completely confirm this: the original pickup with its magnets placed within the coils (and thus not requiring any pole-pieces) and the non-magnetic cover has a markedly higher resonance peak than the reissue.

The difference in the Q_{3dB}-factor appears to be the major characteristic distinguishing the original 70's CuNiFe-pickup from the reissue humbucker. The measurements done by other authors confirm this.

A5: Outlook

It will be the objective of the **third part** of this article to try and establish if (and how) this difference manifests itself audibly in the perceived sound of the pickup.

First, however, a number of clones of the Fender Humbucking Pickup will be investigated in the **second part** of the article. 4 "Wide-Range" humbuckers from Creamery and 2 from Lollar were available for measurements. To be able make additional comparisons, measurements of regular Fender single-coil pickups and typical Gibson 490 humbuckers will also be included in the assessment.

So: to be continued ... stay tuned!

Appendix 1:
The present series of articles is geared towards a rather practical approach to comparing pickups. For a more in-depth consideration of how the elements of a pickup (and in addition the connected circuitry) interact, and how pickups can theoretically be modeled and explained, Chapter 5 in /5/ (https://www.gitec-forum-eng.de/the-book/) offers exhaustive information. Diving into this material is highly recommended: it includes how inductance and capacitance within the pickup coil form and influence, together with connected components, the frequency response of impedance and transmission factor.

Appendix 2:
add'l remark ... an impossible magnet ... found in a 70's Fender humbucker

Here's an excerpt from /5/ (courtesy of author M. Zollner, see data collection in Chapter 5, page 5-183), relating to magnets found in a Wide-Range Humbucker that had south poles on either end!

Did we just pass into another dimension or different reality? Read on:

Two different Fender humbuckers could be examined: one original Wide-Range from the 1970's and a reissue pickup from a 2012-Thinline. The original has surprisingly special magnets. The reversible permeability of the CuNiFe-magnets is very small (compare to Fig. 4.42), and their static magnetization is decidedly peculiar. That may be a special characteristic of this individual pickup – we could not establish an assembly-line-production standard with just one representative. In any case: two of the **magnets** feature south poles on both facing surfaces! Yes, this is indeed physically permissible if a north pole is located in between the two south-poles. Also, the pickup does not become totally unusable, either, because the large differences occur on the lower side of the pickup. This still is rather peculiar …vintage, in any case and after all….

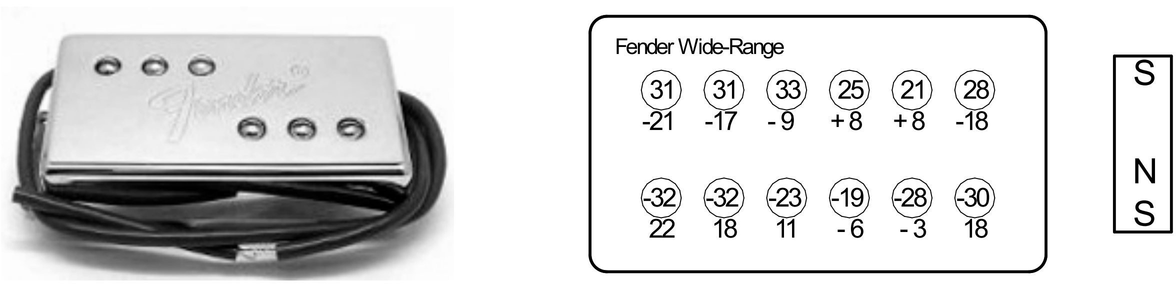


Fig. 5.15.4d: Fender Wide-Range humbucker [www.fender.com]. In the right-hand diagram the magnetic flux density measured at a distance of 2 mm is given; within the circle = top, numbers below: bottom of pickup

Appendix 3: Literature

- /1/ https://www.latimes.com/archives/la-xpm-1993-03-10-vw-1323-story.html
- /2/ https://www.fender.com/articles/gear/a-classic-evolved-the-telecaster-custom-story
- /3/ The Fender Book; Tony Bacon and Paul Day, Miller Freeman 1992, (esp. p. 41)
- /4/ Electric Guitar - Sound Secrets & Technology; Helmut Lemme, Elektor, 2012, (esp. p. 89 - 91)
- /5/ Physik der Elektrogitarre Manfred Zollner,
  https://gitec-forum.de/wp/gitec-community/buch/;
  Translation:
  Physics of the Electric Guitar:
  https://www.gitec-forum-eng.de/the-book/ (esp. p. 5-176, 5-182)
- /6/ Gibson Electrics - The classic years; André Duchossoir, Hal Leonard, 1994, (esp. p. 64)
- /7/ Elektro-Gitarren Teil 1; Helmut Lemme; Frech Verlag, 1982
- /8/ Elektro-Gitarren Teil 1; Helmut Lemme, Frech Verlag, 1977
- /9/ Elektro-Gitarren; Helmut Lemme, Pflaum Verlag, 1994

-/10/ The Fender Telecaster; André Duchossoir, Hal Leonard, 1991

-/11/ https://gitec-forum.de/wp/?ddownload=8419
(https://gitec-forum.de/wp/mitgliedsbereich/downloads-fuer-mitglieder-2/;
download possible only for members)

-/12/ The Gibson; Rittor Music Inc., IMP,1996, (esp. the interview with Seth Lover)