What's In a Pickup?

The job of a pickup is to convert the vibration of a string into an electrical signal. The basic design consists of a magnet and coil arrangement where the strings interact with the magnetic field to induce a voltage in the coil. Even with this simple concept, there are quite a few variables and trade-offs.

A common misunderstanding is that the pickups on your guitar sound different because they are made different. Maybe they are different, but there is also huge difference in sound caused by the pickup's position on the guitar. I'll explain this in more detail later.

Most electric guitars up to around the 70's (including Fenders and Gibsons) generally used the same pickups in all positions, so it was the pickup's position alone that caused different sounds. These days, it is more common to combine different pickup types, and use hotter pickups in the bridge position.

Stronger magnets (or placing pickups closer to the strings) gives a higher output but also damps string vibration by pulling the strings towards the pickup. In severe cases, this can cause "false harmonics" or "double notes".

Providing additional windings on the coil increases the output, particularly midrange. Manufacturers can only take this so far, because eventually the loss of highs gives a very muddy sound. Also the high output can overload the input of some preamps, making a "clean" sound impossible without reducing the guitar volume setting (this may be desirable by some players). Additional coil windings produce a higher impedance which pose problems with treble loss when used with long cables. There are similar options and compromises with coil wire gauge.

"Active" pickups typically have a lower number of coil windings, giving a low output, low impedance, and very clean and clear, uncoloured sound. The low output is boosted by an on-board active preamp which maintains the low impedance. Low impedance pickups (on their own, or with a preamp) can drive long cables without noticeable treble loss.

Probably the most obvious difference in pickup designs is the single pickup versus humbucking pickup. A humbucking pickup contains two single coils placed side by side, with a common magnet arrangement. The sound is typically "fatter" (more midrange) due partly to the larger number of coil windings and partly because the sound of the string is "read" over a longer portion of the string.

The shape of the magnetic field affects how much of the string is read. The pole-pieces you see on strat single coil pickups are individual magnets and give a very focused magnetic field, reading a small section of the string vibration. On the other hand, screws in a humbucking pickup are just screws, but conduct the magnetic field from a magnet placed underneath the pickup. There is another set of magnetically conductive slugs in the other coil, so the combined humbucker reads a larger length of string vibration.

I've had email from a reader who related a story of a player who has placed washers around the tops of the pole-pieces of his strat pickups (these protrude a little from the top of the coil). This was allegedly to allow him to move the pickups closer to the strings without the problem of excessive magnetic pull on the strings. I've never tried this myself, but it does illustrate how changing the magnetic field of a pickup changes the way a pickup works and sounds.

Magnetic material also affects tone. Popular opinion is that Alnico II produces a sweet, vintage sound, while Alnico V is a little stronger, and gives a brighter, more attacking tone (ideal for rock). Ceramic magnets have a slightly harder edge, and are favoured by metal players.

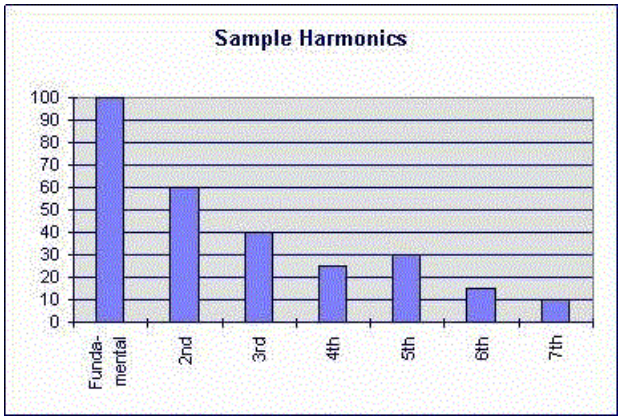
With so many variables it's easy to see why there are many different choices. There are a few established standards, notably the original Fender Stratocaster, Gibson PAF, along with some popular models from retrofit manufacturers like DiMarzio, EMG and Seymour Duncan.

Even before you plug your guitar in, its character is determined greatly by the type of guitar woods used, construction methods, string gauges, etc. It is this basic character that the pickup picks up, adding its own colouration.

Guitar Pickups - Tone & Timbre

Tone and timbre are terms that are often confused and misunderstood. They are related, but are very different things. If the following explanation gets too technical, just think of tone as the type of changes you can make with the EQ knobs (bass, middle, treble, etc) on your amplifier, while timbre is the "character" of the sound you're using. Adding extra treble to the neck pickup doesn't make it sound like the bridge pickup!

A plucked guitar string produces a combination of frequencies. For example, when you pick an open E string, the note consists mainly of the E you picked (called the fundamental or 1st harmonic), but also includes quieter levels of the 2nd harmonic (an E one octave above the fundamental), and further harmonics. The 3rd harmonic is very close to a B, the 4th harmonic is another E two octaves above the fundamental, and so on. Here's a picture of the levels you might see in a plucked string. This sample has a marginally stronger 5th harmonic. True harmonics go to the limit of human hearing, or your amplifiers capabilities, whichever comes first!

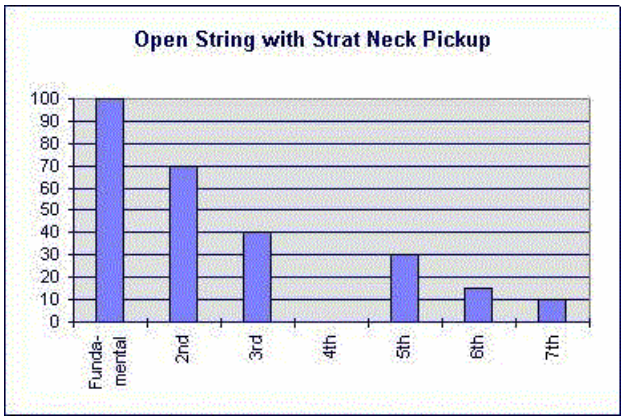


A higher level of upper harmonics compared to the lower harmonics and fundamental, produces a brighter, or sharper tone. Likewise, you can reduce the proportion of higher harmonics by using the tone control on your guitar to give a more mellow tone. This pic compares the same sound above with treble cut. Notice that there is still some "character" of the strong 5th harmonic, but the higher the harmonic, there more cut.

Timbre is determined by the relative levels of different harmonics. It is true that a sound with weak high harmonics will be perceived as having a mellow tone compared to one with strong high harmonics. Variations in timbre on your guitar are produced by an enormous number of factors from pickup design and position, the natural resonances and damping in your guitar due to the wood used (that's a different sort of timber!) and its construction and shape, the gauge and age of your strings, your playing technique, where you fret and pluck the string, and so on.

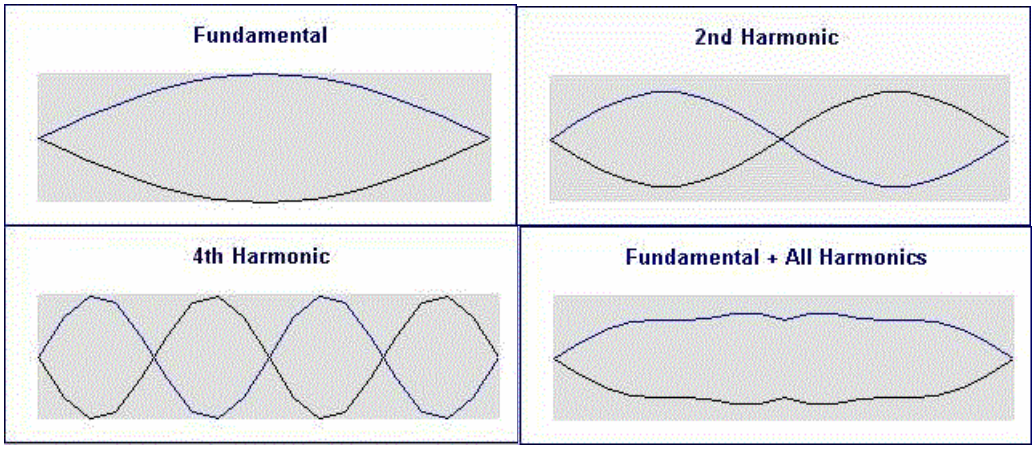
You can set a strong tone emphasis with a wah pedal (which sweeps a frequency response peak), however, different pickups still sound quite different, even through this kind of radical tone shaping. With this enormous number of variables you can see that it's hard enough to get identical guitars to sound the same, and no amount of EQ will get a strat to really sound like a Les Paul, or vice versa.

An explanation of the unique sound of the strat neck pickup illustrates the concept of harmonic content in different timbres. If you play an open string it contains a strong fundamental, as you would expect, a relatively strong 2nd harmonic, an average 3rd harmonic, and no 4th harmonic at all! Why such a difference between the 2nd and 4th harmonics?



The string vibration itself contains the motions of the fundamental and all of the harmonics. The fundamental vibrates between the nut (or fret) and bridge, as you would expect, with the strongest vibration half way between these points. In addition to this main vibration, there are also components identical to you playing all of the harmonics at the same time! (For non-guitarists, a harmonic is played by touching the string at a point along the string to prevent the fundamental from sounding, then plucking the sting normally).

So the 2nd harmonic has a node (the "dead spot" or point of no vibration) at the halfway point, with two points of maximum vibration 1/4 and 3/4 of the distance along the string. The 3rd harmonic has 2 nodes 1/3 and 2/3 along the string with 3 points of maximum vibration. The 4th harmonic has 3 nodes 1/4, 1/2 and 3/4 along the string, and so on. These pictures show what the string vibrations look like:



The single coil strat neck pickup reads the string at a single point exactly 1/4 the length of the string from the bridge (where the 24th fret would be), although some more recent 22-fret strats have the pickup a fraction towards the bridge.

So the 2nd harmonic component of the string vibration has its node (the "dead spot") over the 12th fret, the same as if you played a harmonic by damping the string over the 12th fret.

This 2nd harmonic has its largest string vibration at 1/4 the length of the string from both the nut and bridge - that's over the 5th fret, and the neck pickup. Hence the strong 2nd harmonic.

Now consider the 4th harmonic which has nodes at the 5th fret, the 12th fret and the neck pickup - there is no 4th harmonic vibration over the neck pickup. This strong difference in harmonic levels plays a major part in the unique character, or timbre of this pickup.

A way to prove this is to play this harmonic by damping an open string above the 5th fret (making sure not to pluck the harmonic at its nodes over the 12th fret or neck pickup). You will hear almost nothing from the neck pickup, but a strong note if you switch to the middle or bridge pickups.

Timbre Variation

Of course, as you fret different notes, the position of the nodes move, and you get a progressive change in the harmonic content of the notes. Again, because of this neck pickup position, a note fretted on the 12th fret contains no 2nd harmonic.

Humbucking pickups don't sound fatter just because of the additional coil windings involved. A typical humbucking pickup "reads" the string over about a 3 cm length, so any harmonic nodes which occur over one coil are unlikely to also occur over the other, although the level of this

harmonic will still be fairly low. These pickups have a more even and fuller sound, with a little less distinctive character.

The story doesn't quite end here either. Harmonic content usually varies over time. With a guitar string, the higher harmonics generally dissipate faster than the fundamental. On other instruments, the harmonic content can vary in different ways. For example, a sax player can blow a note, then blow harder to brighten the timbre. It is the harmonic content and the way it varies over time which is called timbre, and this is how we differentiate one instrument from another.

Guitar Pickups - Combinations

Two pickups can be combined in parallel or series, either in or out of phase (see diagram below).

With the two pickups each on their own, that's a total of 6 different sounds for the price of just 2 pickups. If you make coil taps available, or add another pickup, the combinations can very quickly become unmanageable, particularly for the performing guitarist.

The usual way to combine pickups is in parallel and in phase. In fact, this may be the only option you have for those pickups which are sealed and wired internally, providing only a shield and "hot" wire for connection.

As it happens, I actually prefer these types of combinations - a properly matched pair of humbuckers gives a great country-rock or jazz-rock sound. The strat pickup combinations give a funky sound which oozes character (after all, if it's good enough for Mark Knopfler and Robert Cray, it's good enough for me!) This sound is often mistakenly called an out of phase sound, because its slightly nasal character is typical of out of phase sounds.

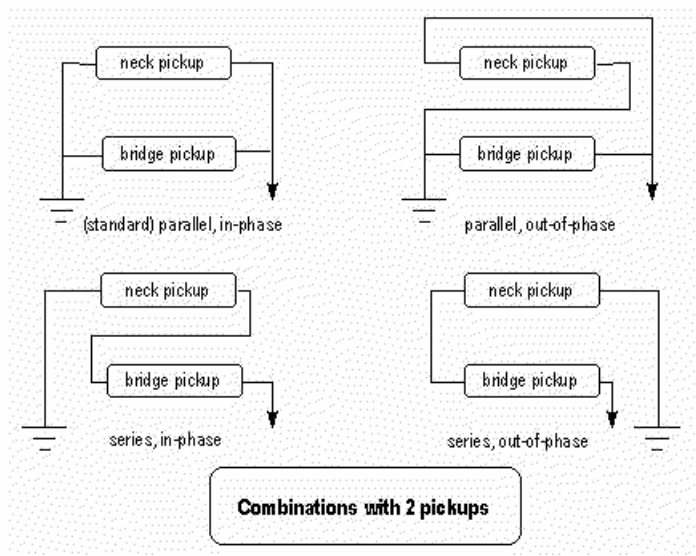
To provide a sensible number of alternatives requires a little time and experimentation. I can offer some recommendations, but the ideal way to find the good pickup combinations is to first install the pickups where you like their individual sounds, then bring all of the pickup wires outside the guitar and try different wiring arrangements.

If you're not sure how to go about this, ask a friend with some electronics knowledge for help. After you have found a realistic number of good sounds, try to come up with a practical switching arrangement. My rule of thumb is that you should never need to move more than 2 switches to get to any sound, and your main solo sound(s) should be accessible from just one master switch.

If you play live, you may find it useful to experiment by playing along to music, with the music and guitar set to similar volume levels. This is because sounds that impress you in the peace and quiet of your own practice room (or recorded) may not have enough highs or middle "punch" to cut clearly through a band. The music will help mask these "great but useless" sounds.

An easier path is to stick to a few traditional set-ups, which are guaranteed to give good results as long as you follow a few simple rules.

The different ways to wire 2 pickups:



Probably the most common trap is to go for a super hot bridge pickup with a clean neck pickup. A great idea in theory, and fine if they are the only two sounds you want, but when you combine these pickups (in the usual way - in parallel and in phase), it doesn't sound very different from the neck pickup on its own.

This happens when there is an impedance mismatch between the pickups, and the lower impedance single coil shunts (or drains) much of the sound of the higher impedance humbucking pickup. The lower impedance neck pickup, however, is hardly affected by the higher impedance bridge pickup.

You can avoid this trap my measuring the DC resistance of a pickup with a multimeter. Even though this does not measure the impedance, it is a reasonable guide - you can expect to measure values of about 5 Kohms for lower impedance single coil models, 7-8K for vintage humbuckers, up to around 15 Kohms or more for the higher impedance super-hot humbuckers. If one pickup is over double the resistance of the other, you can be fairly sure they won't mix well. Less than double will at least provide a noticeable difference, but of course identical pickups are guaranteed to combine best.

If your guitar provides a separate volume control for each pickup, you can compensate for mismatched pickups, but I find this fiddley, and not as clear as properly matched pickup combination. For this reason I prefer to have the pickups and switching come before a master volume control, and use the master volume control for level changes.

Combining pickups in parallel and in phase provides a special tone due largely to the inductive (coil) load each pickup places on the other. This sound is not the same as combining pickups electronically, such as using a separate pre-amp channel for each pickup, or combinations found in some active pre-amp guitars.

Not all pickups have the same "polarity", even similar models from the same manufacturer are not guaranteed to be the same. Polarity refers to the phase of the signal in relation to the string vibration. Most custom pickups provide (as indeed ALL pickups should) a pair of wires for each coil, and a separate shield connection which must be earthed. At the other end of the scale you will find some pickups with their connections encapsulated in epoxy resin, providing only a single wire and shield.

Reversing the coil connections reverses the polarity, and may be necessary on one pickup to allow the standard "in-phase" connections. Your ears are a good guide - if you expect an in-phase sound you should hear a full, slightly nasal sound. If you get a hollow, middley sound with a volume drop, you probably have pickups with opposite polarity, and need to reverse the connections on one pickup to restore normality.

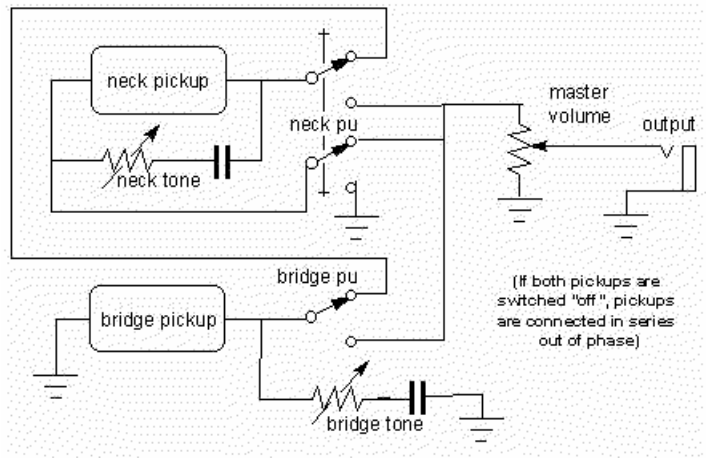
Combining pickups in parallel, but out of phase is less sensitive to impedance differences, and this may the best way of getting some useful variety if you're stuck with a guitar with mismatched pickups.

Combining pickups in series is a matter of personal taste and experimentation, but I recommend NOT using similar sounding pickups. In phase it's just louder and mushier, while out of phase you will find a dramatic loss of volume. On the other hand, wiring very different sounding pickups in series will add their sounds, and exaggerate their differences when wired out of phase.

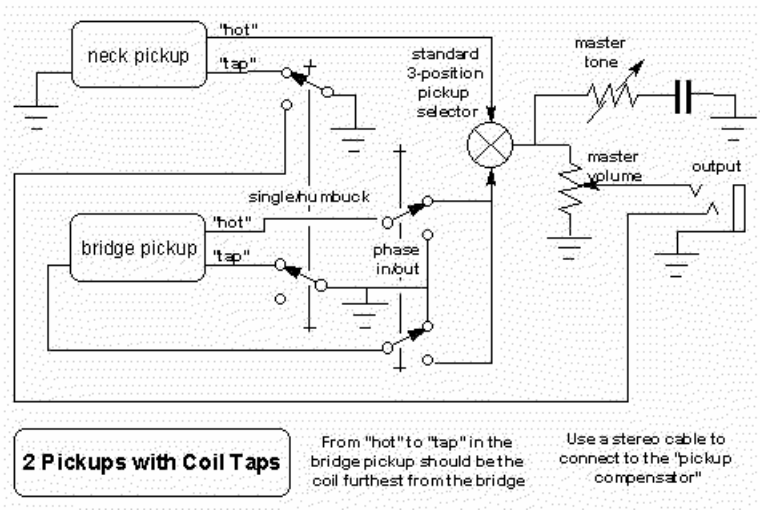
Wiring Arrangements

I have included some schematic diagrams of wiring and switching arrangements I have found useful.

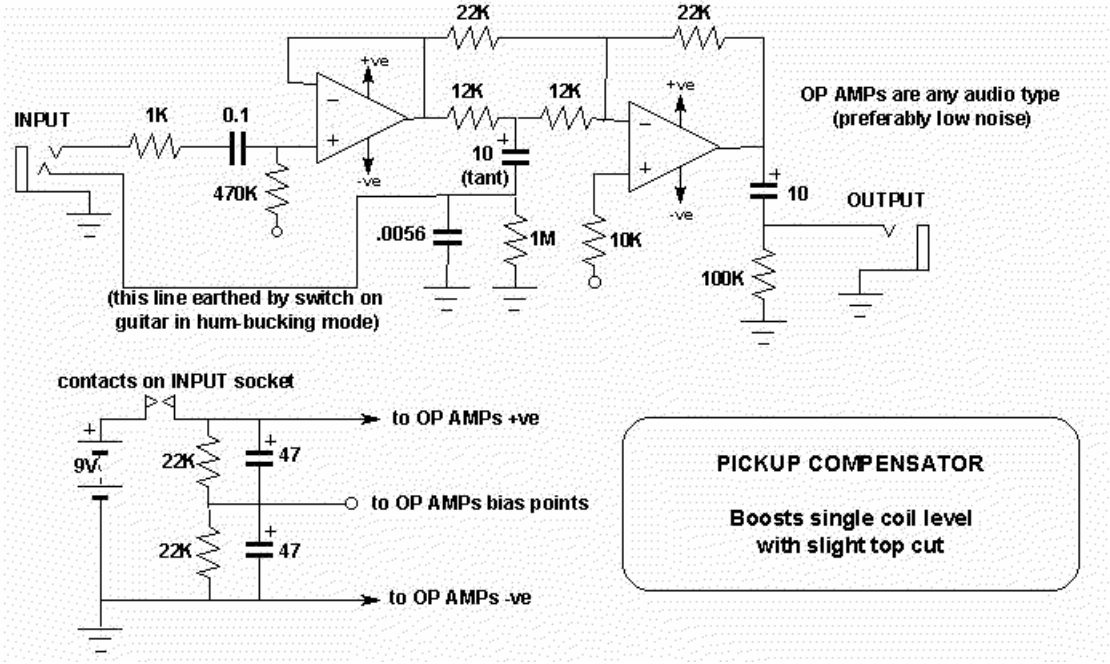
The first is very easy to use - there is a separate toggle switch for each pickup. You can turn either or both "on" for the standard sounds, but with both in the "off" position, the pickups are actually connected in series and out of phase. With pickups of similar impedance but different timbres, you will have 4 very different and usable sounds.



The next schematic gives a useful arrangement for 2 humbucking pickups incorporating coil taps and phase switching. There are a couple of special features in this circuit. Changing to "out of phase" while in the single coil mode changes the coil used in the bridge pickup, offering another sound while using just the bridge pickup.



Also, you can use the preamp shown below to automatically compensate for the difference in volume and tone between single coil and humbucking sounds. When you select a single coil sound, the preamp boosts the volume and marginally cuts some highs to give the single coil sounds the same volume and similar tones to your humbucking sounds. It can be placed as the first effect on your pedal board, powered by either a battery or adapter, and connected to the guitar with a stereo cable.



And for the dual humbucker guitar ...

I use a Gibson Alnico V pickups: 490R in the neck position and a 498T in the bridge position. This combination is common on many of Gibson's Les Paul models.

I have replaced 2 of the controls with 2-position mini toggles to give effectively 11 different & useful sounds. The mini-toggle switches change the sounds available on the standard 3-position pickup selector, and the remaining 2 controls are master volume and master tone ('cause that's the way I like it, uh huh uh huh ...).

•Mini-toggle #1 selects humbucking / single-coil sounds •Mini-toggle #2 is 'normal' / 'variation'

With toggle #2 set to 'normal', toggle #1 selects:

•Standard humbucking sound (the pickup coils connected in series) •Single coil sound (the pickup coils connected in parallel)

Both of these are actually humbucking (in the sense that they don't pickup interference), but I've labelled them humbucking and single-coil because players recognise these sounds.

With toggle #2 set to 'variation', toggle #1 gives:

•Humbucking sounds with the pickup centre taps connected to each other. This is unusual (I've never seen it done before so I'll call it the GM Arts sound), and gives a sound halfway between the normal sound of the pickup, and the sound of both together. It's useful because it retains the normal humbucking volume, and brings the sounds of the two pickups closer to each other.

•True single coil sound - just a single coil in each pickup, which of course, is not humbucking. This is similar to the 'normal' single-coil sound above; just a little less 'strat quack'. I've designed it to use the bridge coil furthest from the bridge to give the fullest possible bridge sound; the neck pickup coil is arbitrary.

Even though there are technically 12 different sounds, normal/variation has no effect in one case (both pickups together in humbucking mode). Many other sounds are similar, but there's a lot more useable variety here than the standard 3 sounds.

Here's the wiring diagram: