Vintage Vibe guitar pickups

March 2008

Howdy!

Based on many inquiries I receive on the subject of matching pickups for the best tone, this month's Tech Tips contains three related topics:

1. **An overview of the electrical signal generated by a magnetic guitar pickup**
2. **How these electrical signals from multiple pickups come together and the resulting tones**
3. **Bringing it all together: how to make sure pickups are going to play well with each other**

Before we dive into these topics, it is fair to ask, why would I care? The answer to this is relatively straight-forward: if you are considering making changes to one or more of the pickups in an instrument with more than one pickup, it is possible to buy quality pickups, make good solder connections and end up with an instrument that has good tone when each pickup is operated by itself, but a low-output, thin-sounding tone when more than one pickup is played at once. This low-output tone from two pickups is usually considered undesirable and is the result of the signals from two pickups being "out of phase" with each other.

Here we go!

1. **An overview of the electrical signal generated by a magnetic guitar pickup**
By the end of this newsletter it is my hope to communicate clearly the difference in tone which results when pickups are connected together electrically in two different ways: in parallel and in series. To illustrate the differences between parallel and series electrical connections we can use simple C-size batteries, like those in a handheld flashlight. Each battery has a positive (+) terminal and a negative (-) terminal; C-size batteries, when new such a battery generates ~ 1.5 volts of electromotive force (EMF) and the electric current flowing between the (-) pole and the (+) pole is direct current (DC). If three C-size batteries are installed in a single row in a flashlight the (+) pole of the first battery is in contact with the (-) pole of neighboring battery and so on; these batteries are said to be connected in series. The result is that the voltages of these batteries add to deliver a voltage of ~ 4.5 volts (1.5 volts x 3). It is also possible to connect batteries in parallel, which has a different result. Imagine three batteries arranged side by side in one row such that the (-) poles are next to each other and the (+) poles are next to each other. If an electrical conductor were added to the three batteries such that all of the (-) poles of the batteries were connected together, and another separate electrical conductor were added to the batteries connecting all three (+) terminals to each other these three batteries would be connected together in a parallel electrical circuit. If we measured the voltage between the (-) poles of these three batteries connected in parallel and the (+) poles we would see a voltage of ~ 1.5 volts, not 4.5 volts, as was the case in the previous series connection example. This parallel assembly of batteries would provide the ability to generate the current of three single batteries. Keep these examples in mind as we turn to another form of electrical signal generator: the magnetic guitar pickup. The electrical signal generated by a single coil passive magnetic pickup in an electric guitar, bass guitar or other similar instrument is an alternating current (AC) waveform. If you could see this AC signal it would look like a repeating wave with peaks and valleys. This AC signal is generated in a pickup when the guitar strings vibrate within the magnetic field of the permanent magnets in a pickup. Magnetic material in the vibrating guitar strings (iron and nickel) cause the magnetic field of the permanent magnets in the pickup to fluctuate at the same frequency as the strings are vibrating. This fluctuating magnetic field causes electrons in the copper coil windings of the pickup to oscillate which generates the AC electrical signal in the

pickup. This AC signal is weak (low voltage) by most standards, usually only a few hundred millivolts in passive magnetic pickups. The height of this AC waveform (measured from the extreme top of the peak of the wave to the extreme bottom of the valley of the wave) is the peak-to-peak voltage; this voltage is a good way to express the output of a pickup. In general, pickups wound with many turns of wire on the coil tend to have higher output than pickups with fewer turns. If an instrument has only one single-coil pickup, the AC signal generated in the magnetic pickup is conducted through volume and tone controls to the output jack, through a guitar cable and into am amplifier where the weak signal is boosted usually in several stages to a much higher level and finally transferred to a speaker and *voila! Y*ou're a rock star!

2. **How electrical signals from multiple pickups come together and the resulting tone**
Instruments with multiple pickups add another level of complexity to the process of signal generation described above. In the following discussion I will assume that the electric guitar or bass we are considering has only a single monaural (mono) output jack and that the AC electrical signals from two or more pickups can be joined together in one of several ways and conducted to this single mono output jack. This assumption is true for the vast majority of electric instruments people use; notable exceptions include custom instruments wired for stereo output as used by Les Paul and Grateful Dead guitarist Jerry Garcia. In an instrument with two single-coil pickups (one bridge position pickup and one neck position pickup) and a three-way pickup selector, such as a telecaster-style instrument, the pickup selector switch typically allows one to use the bridge and neck pickups one at a time (pickup selector switch positions 1 and 3) or to utilize two pickups at once (pickup selector switch position 2, the middle position). There are potentially four ways the AC signals from two pickups can be joined in position 2:
    a. Parallel in phase
    b. Parallel out of phase
    c. Series in phase
    d. Series out of phase

For a more detailed discussion of series and parallel electrical DC circuits including drawings and examples, please see: http://www.allaboutcircuits.com/vol_1/chpt_5/1.html

a. Parallel in-phase connection of two single coil pickups:

In most instruments with two pickups and a three-way pickup selector switch, the middle position of the pickup selector switch joins the two pickup circuits in parallel. The AC waveforms from these two pickups are blended together in a very interesting way. Remember that the AC waveforms each have a "sine wave" shape with "peaks" and valleys". These two electrical signals will add in parallel to form a new waveform with higher current but not higher voltage (as was the case described above with batteries connected in parallel); this results in a good clear signal, but not higher output like that produced by a humbucker. If the AC waveforms of both pickups have the same shape and frequency, the peaks and valleys of the waveform from the neck position pickup are lined up with the peaks and valleys of the bridge position pickup) the two waveforms are said to be "in phase"; the sum of the two waveforms and will generate a clear, good-sounding signal. Most modern instruments which contain two single coil pickups and a three position pickup selector switch are configured such that the signals from these two pickups are joined in the middle switch position to form a strong, clear signal. Pickups in such instruments are often manufactured such that the pickups are reverse-wound and reverse polarity (RWRP) with respect to each other. For example, if the bridge position pickup has a north up magnetic orientation and is wound clockwise the neck position pickup will have a south up magnetic orientation and will be wound counter-clockwise. The phase orientation of the AC signal in the neck pickup is reversed 180 degrees with respect to the phase orientation of the bridge position pickup by the opposite winding direction with respect to the bridge position pickup and another 180 degrees by the opposite magnetic field direction with respect to the bridge position pickup. These two 180 degree phase changes combine to a 360 degree phase change which is the same as a zero degree phase change. The result is that when the signals from pickups are combined in parallel and the pickups are RWRP the two signals are in phase and a good tone usually results.

b. Parallel out of phase connection of two single coil pickups:
If the waveforms from the two pickups are out of phase (the peaks from the neck position pickup waveform are not lined up with the peaks of the bridge position pickup waveform) the two AC signals will oppose each other resulting in a signal that is low in volume and often has a thin-sounding tone. This situation exists when pickups connected in parallel are not reverse wound reverse polarity with respect to each other. An example of a non-RWRP set of pickups would be a bridge position pickup which is wound clockwise and has a north up magnetic polarity and a neck position pickup which is also wound clockwise and has a south up magnetic polarity.

c. Series connection in phase:
If you recall the example of batteries connected in series, the voltages of the batteries connected in series were observed to add; this is also the case with signals from guitar pickups. When two single-coil pickups are connected in series and the AC waveform signals from these pickups are in-phase a powerful signal is generated which is conveyed to the amplifier. Humbucking pickups are often wired such that the two coils in the pickup are connected in series and in the AC waveform from each of the two coils are in phase; the result is a powerful signal. Two single coil pickups in an instrument such as a Telecaster can also be connected in series, and if the pickups are manufactured such that the neck position pickup is RWRP with respect to the bridge position pickup the signals will add in the same way as signals add together in-phase as in a humbucker. The standard three position blade style pickups selector switch in a Tele style instrument and the usual three position toggle switch in a Les Paul style instrument connect two pickups in parallel as described previously, so true humbucking performance (with the waveforms from both coils of the humbucker in series and in phase) is not possible with this type of pickup selector switch. There are four and five position blade style switches available for instruments with two single coil pickups which offer series combinations of pickups. Details of blade style switches which provide series connections are provided on the following websites:

http://www.deaf-eddie.net/guitars/5-tone.html

and

http://www.musiciansfriend.com/product/Fender-4Way-Telecaster-Pickup-Selector-Mod-Switch?sku=361330&src=3SOSWXXA

One can also use a “Push-Pull” pot or an on-on-on mini toggle switch to add series combinations of two single coil pickups; details are provided on:

http://www.deaf-eddie.net/pushpull/pushpull.html

d. Series connections out of phase:

When the AC waveforms of two single coil pickups are connected in series and the waveforms are out of phase the result is a weak low output signal.

All of the pickup configurations described above (parallel in phase, parallel out of phase, series in phase and series out of phase) also apply to instruments with three single coil pickups such as stratocaster style instruments. In most of these instruments the 2- and 4- positions of a five position blade switch combine signals from two pickups in parallel. It is usually the case in modern instruments with three pickups that the middle pickup is made such that is RWRP with respect to both the bridge and neck position pickups.

3. Bringing it all together: how to make sure pickups are going to play well with each other

If you are purchasing a complete new set of pickups it is wise to ask the pickup maker if the pickups will be made RWRP. Most pickup manufacturers will be able to provide a set of pickups in which each pickup will have the correct phase orientation and all will be good. If you are considering adding a new pickup to a guitar which already has one or more pickups it is important to make sure the signals from multiple pickups have the desired phase orientation for the tone you're after. Most often the desired tone is yielded when signals from pickups are in phase. To determine if pickups will deliver an "in phase" tone when connected in series or in parallel one must know both the magnetic field direction and magnetic polarity of the connected pickups. It is quite often difficult to determine by visual examination the winding direction of a pickup. Single coil pickups which have no grounded shielding often have a single output lead for the start of the coil and a single output lead for the end of the coil. The effective winding direction of a pickup can be reversed by switching the wiring assignments of these two leads. If the pickup was originally wired with the black lead soldered to electrical ground (such as the back of a pot) and the other lead used as the "Hot output" (soldered to one of the tabs on a pickup selector switch or one of the tabs on a volume pot) the "reversed" pickup would have the white lead soldered to ground and the black lead used as the hot output. Telecaster neck position pickups with grounded metal covers and other pickups with grounded shielding offer an added complexity to reversing the effective winding direction: one must remove the connection from the ground lead to the metal cover or grounded shielding, reverse the output lead assignments as just described, then add a new electrical connection from the new ground lead to the metal cover or grounded shielding of the pickup. Single coil pickups with a three conductor output cable (one lead for coil start, one lead for coil finish and an independent ground (the ground is often an externally-braided shield for the cable)) make the process of reversing the effective winding direction much easier. With such a three conductor cable one only needs to reverse the assignment of the coil start lead and coil finish lead in the guitar control circuit (leaving the grounded shield connected to ground). All that remains is to complete assembly of the instrument and check the tone in all positions of the pickup selector switch. If the desired tone is achieved, you're done! If the tone still not right, one must check the magnetic field direction of the pickups. I use a compass to do this. In an instrument with two pickups one pickup should have the opposite magnetic field direction from the other (one north up, the other south up). Place the compass near the pole pieces of a single coil pickup and you will notice that either the north end of the compass needle will point to the poles or the south end of the compass needle will be attracted to the poles. Check the other pickup; if the magnetic orientations of the two pickups are opposite the set of pickups if wired properly can be configured RWRP. Instruments with three pickups often have the middle pickup opposite in magnetic orientation with respect to the neck and bridge position pickups.

Many of the pickups manufactured by Vintage Vibe Guitars are designed to allow the owner to change both the effective winding direction via a three conductor output cable and the magnetic orientation of the pickup by changing the magnets. These design features will allow you to configure the pickup to match any other pickup.

My congratulations to all of you who have read all the way through this long newsletter!

I hope this information is helpful to you!