The Study of Guitar Pickups

Douglas Brown

Prof. Steve Errede
Physics 199POM
Fall 2002

The Study of Guitar Pickups

The purpose of this experiment was to compare a pickup from a 2002 Fender Mexican 60's Stratocaster with pickups from other American made Fender Stratocaster guitars. To make such comparisons, pickup data was collected using an experimental set up, created and developed by Professor Steve Errede. In following the procedures of this existing experiment, the data collected for this guitar could be quantitatively compared with other pickup data collected using this same equipment.

The guitar used in this experiment was a 2002 Fender 60's Stratocaster, made in Mexico. This guitar was compared to various Vintage Stratocasters. The specifications for these guitars were very similar. They shared the same type of body (alder), fingerboard (rosewood), lengths, and hardware. Cosmetically these guitars are almost identical. The only differences were the tremolo system, the color, and in the pickups. In my test comparison I will be comparing four different guitars. They are my 2002 Fender 60's Stratocaster, a 1994 40th Anniversary Stratocaster, a 1996 Fender Vintage Original '57/'62, and a 2002 Fender Vintage Original '57/'62.

Before testing the guitar pickups, it is important to understand what a pickup really is. The pickup in this experiment behaves as an inductor at low frequencies and as a capacitor at high frequencies. The impedance of the pickups is frequency dependent, both when it behaves as an inductor and when it behaves as a capacitor. The simple model and more complex model of the Pickup are in Appendix A. Displayed in Appendix B are the graphical representations of the response of a pickup as frequency dependent. The first graph is a pickup as an inductor which graphically is linear and increasing with frequency. The second graph is a pickup as a capacitor which decreases to zero as frequency increases without bound. In Appendix C is a graph of how the pickup acts. It is a combination of the inductor and the capacitor.

Initial Measurements

The first step in following with the experiments procedures was the take measurements of the actual pickup. First, we determined that the pickups were encased in a plastic bobbin. This was a clear indication of the lack of quality of the pickup, because using a plastic bobbin to wind the coil does not allow for good magnetic coupling between the permanent magnets and the pickup coil. Next, we determined the polarity of the magnets of each pickup. Many guitars will feature pickups that have different polarity in the middle pickup position. My guitar however, had north polarity an the top of the magnets for all three pickups. A modern Stratocaster-style theee pickup guitar will have North, South, North polarity, or the exact opposite. This is done in order to create noise cancellation in the in-between pickups position where two pickups are selected. Since this was a reissue and they actually only had three pickup selections in 1962, it makes sense that this guitar has a consistency in the polarities of its pickups, as early Stratocasters all had same polarity pickups. Many reissues come with only a three pickup selector even if they have the polarity of the pickups staggered.

The first measurement we made was to measure the DC resistance of the pickup coil. The DC resistance is a measure of how many turns of copper wire are wound around the pickup. This value, typically about 6 K-Ohms, was pretty consistent across all three pickups.

Next, we measured the strength of the magnetic field at the poles of each individual permanent rod magnet in the pickup. To do this we used a Walker Scientific Gauss Meter to measure the strength of the magnets. The measurements for the magnets were consistent with measurements for other Alnico V magnets. Also, these measurements were consistent with the pickups of the 1994 Fender 40th Anniversary Stratocaster, typical magnetic field strength at magnet poles were ~ 1000 Gauss.

Next we measured the Inductance and the Dissipation of the pickup at different frequencies using an HP 4262A LCR Meter. Both the Inductance and the Dissipation were measured at 120Hz, 1 KHz, and 10 KHz. These measurements give a preliminary idea of the impedance of the guitar as a function of frequency.

The measured DC resistance, coupled with the fact that all three pickups shared the same polarity and similar magnetic field strength and inductances, led us to the conclusion that the performances of all three pickups were essentially the same.

The Experiment Set up

The function generator is connected to the computer by a General Purpose Interface Bus (GPIB) cable. The function generator sends a sine-wave signal through the actual pickup via a 1.5 MegOhm resistor and the signal from the pickup is then interpreted by the two lock in amplifiers. The function generator also sends a direct signal to both lock-in amplifiers that allows them to stay synchronized with the driving signal. The range of frequencies that the function generator sends is from 10 Hz to 20 KHz. The lowest note on a standard tuned guitar is usually about 82 Hz and the highest note on the guitar is less than a KHz. However, many of the higher frequencies are harmonics that give shape to the note. The first lock-in amplifier is then able to determine the Complex Voltage, which the sum of the Real voltage and the Imaginary voltage. The real voltage is in phase with the driving signal and the imaginary voltage is 90 degrees out of phase relative to the driving signal. The second lock-in amplifier interprets the complex current of the signal. It then outputs both real and imaginary current. The four output signals from the lock-ins are then converted to digital signals and sent to the computer. The complex impedance, Z, is then computed on-line. This experimental set-up is drawn out in Appendix D.

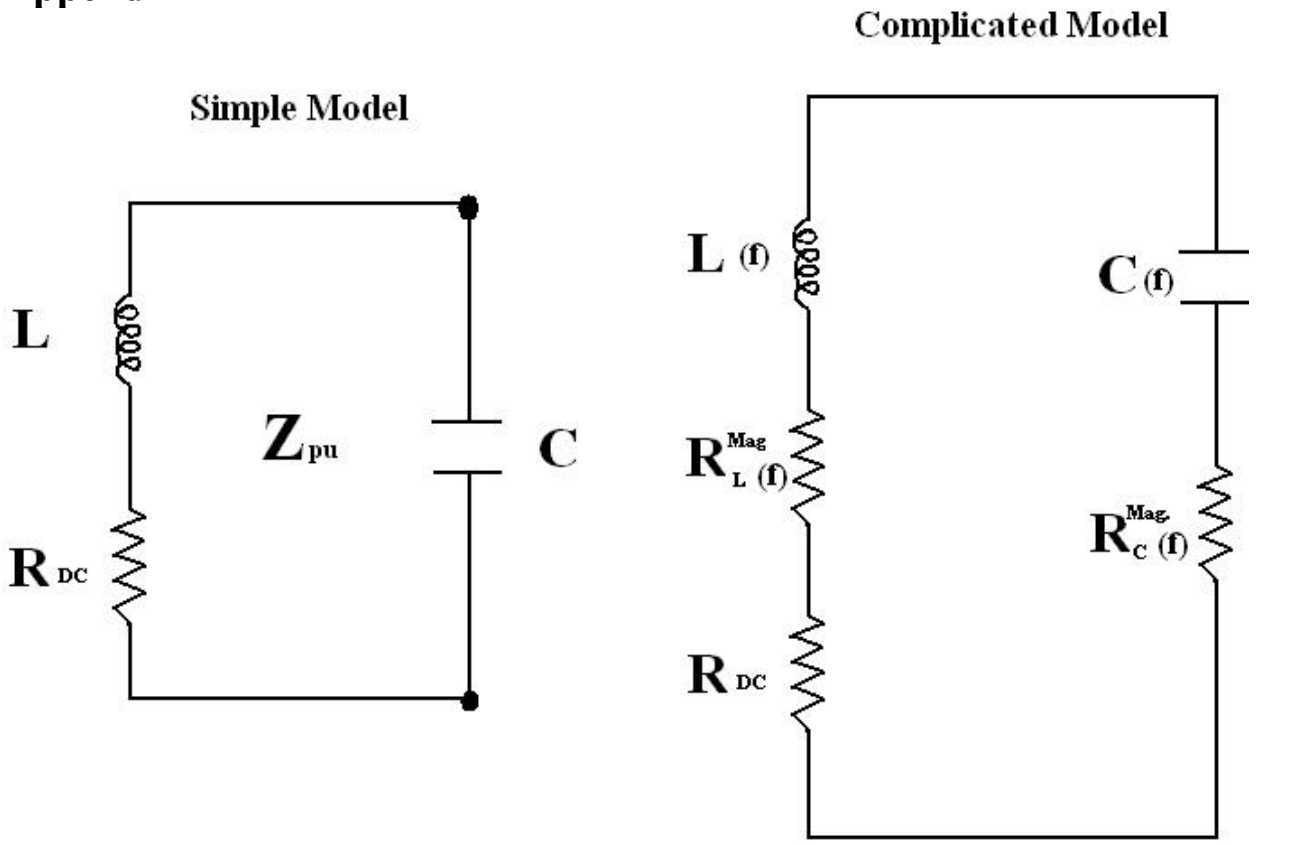
Results

All four of these guitars, 1994 40th Anniversary, the 2002 60's Stratocaster, and the 1996 and 2002 Vintage Originals, have different properties. While all four of these instruments were designed to sound like the same guitar, they do not. In the case of the 1996 Fender 40th Anniversary Stratocaster and in the 2002 Fender 60's Stratocaster, the plastic bobbin probably had the biggest effect. Plastic bobbins do not yield good magnetic coupling between the permanent magnetic rod and the pickup coil. This causes a higher resonance frequency. At a lower resonance frequency a guitar will be more "hot." The resonance frequency for any guitar is usually at least 7 KHz and for most Fender Strarocasters pickups the resonance frequency is closer to 10 KHz. Frequencies on this order exist only as harmonics of the guitar. The fundamental frequency never goes any higher than a KHz. However, it is these harmonics that give shape to the sound of the guitar. Because of this the lower resonance frequencies will yield a "hotter" sounding guitar. Also the type of magnets in the pickups and how it is wound will affect the sound. Guitar pickups designed to be very "hot" are often overwound by five percent. Also the different magnets have their own different properties and also couple differently with different material. In comparing all four of these reissue guitar pickups to an actual 1954 Fender Stratocaster pickup, it is clear that there is a big difference. The actual 1954 pickup was clearly made of a different magnets because the B-field strength of that pickup is much smaller that that of the Alnico V in the other four pickups. Also the width of the Impedance versus frequency graph of ht e1954 pickup had a much wider peak. All of the reissues had similar resonance frequencies to the 1954 pickup, but none of them were nearly as wide of a peak as the 1954 pickup. In Appendix E is the Complex Impedance vs. Frequency graph of the pickup of the 2002 Fender 60's Stratocaster, made in Mexico. This graph follows the same shape of the other three reissues' pickups. The 60's Stratocaster pickup

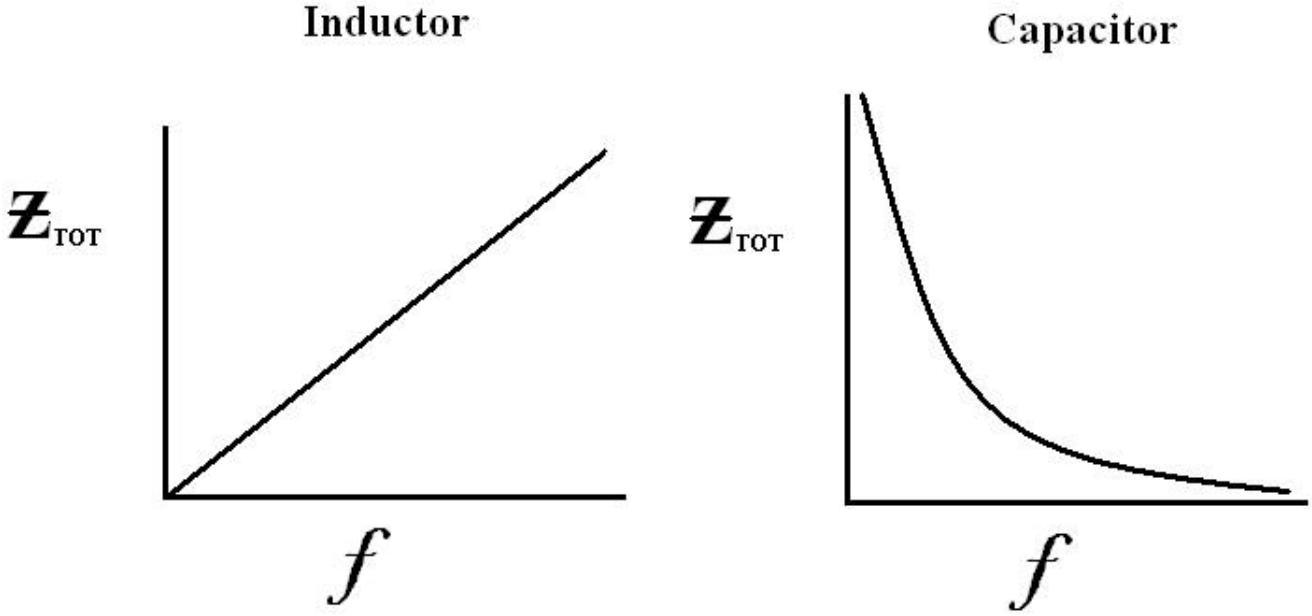
also has a similar resonance frequency as the 1954 pickup. The only difference that can be seen is the strength of the B-field and the width of the peak of the Impedance vs. frequency graph. Attached in Appendix F is the data for several pickups of Stratocasters used in this data comparison.

In conclusion, all four of these pickups out of reissue guitars are not very similar to the actual 1954 pickup. Perhaps for those who are more interested in value than top quality, it would make sense to buy the 2002 Fender 60's Stratocaster and outfit it with different pickups.

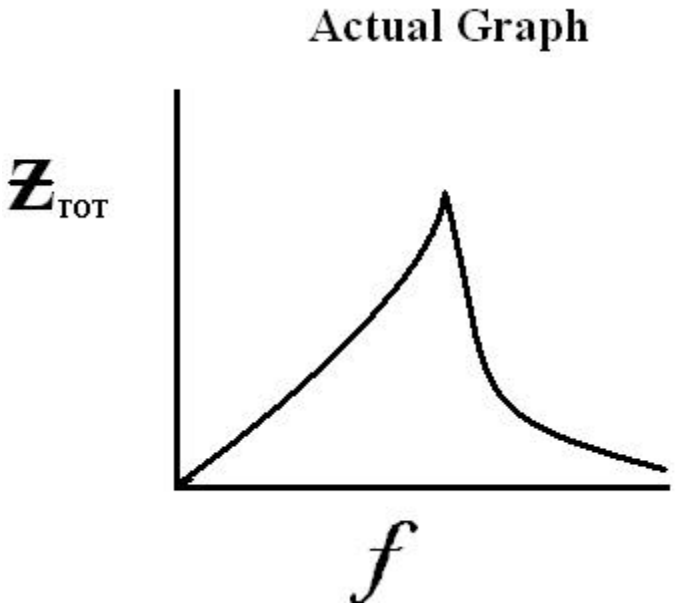
Appendix A



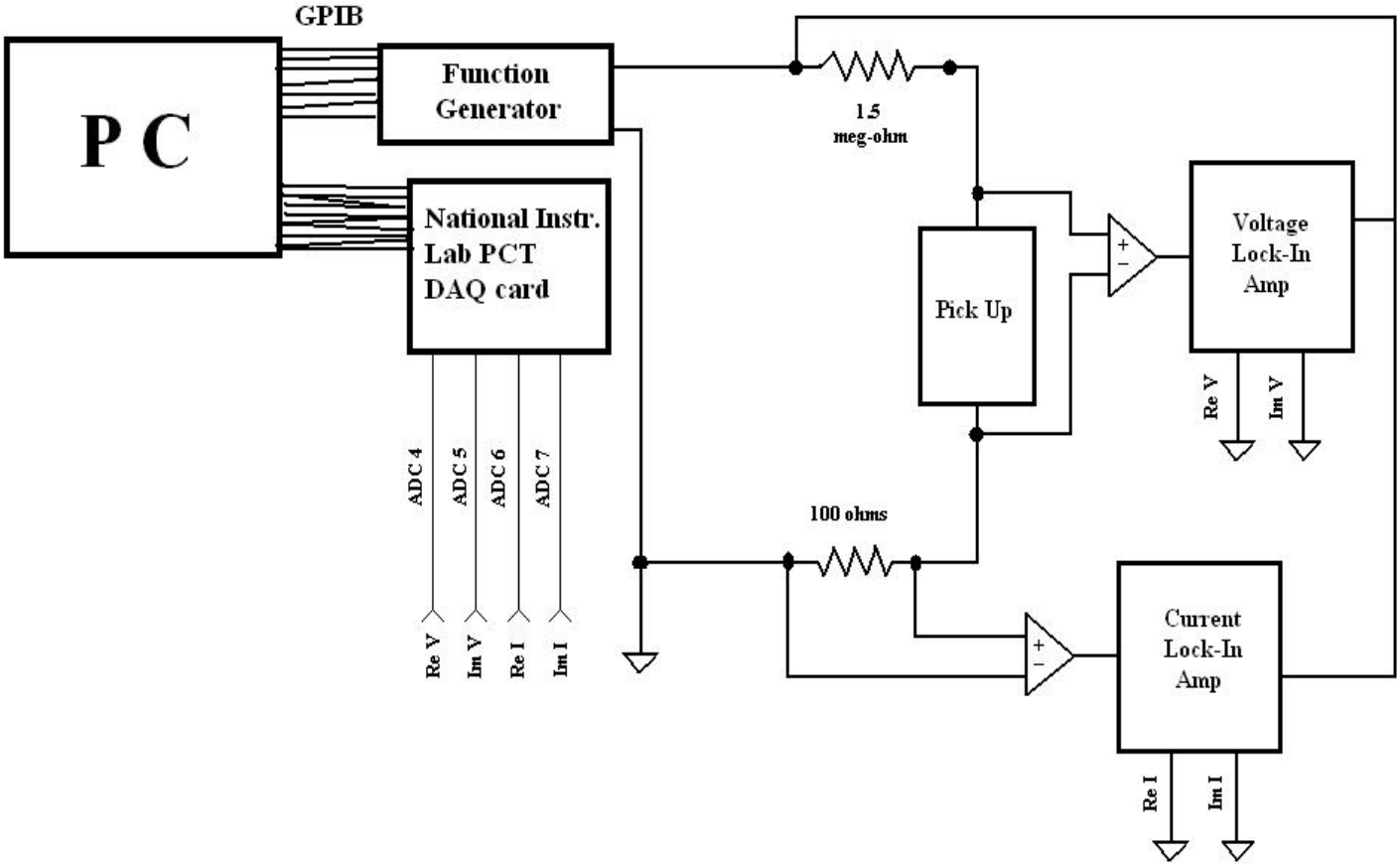
Appendix B



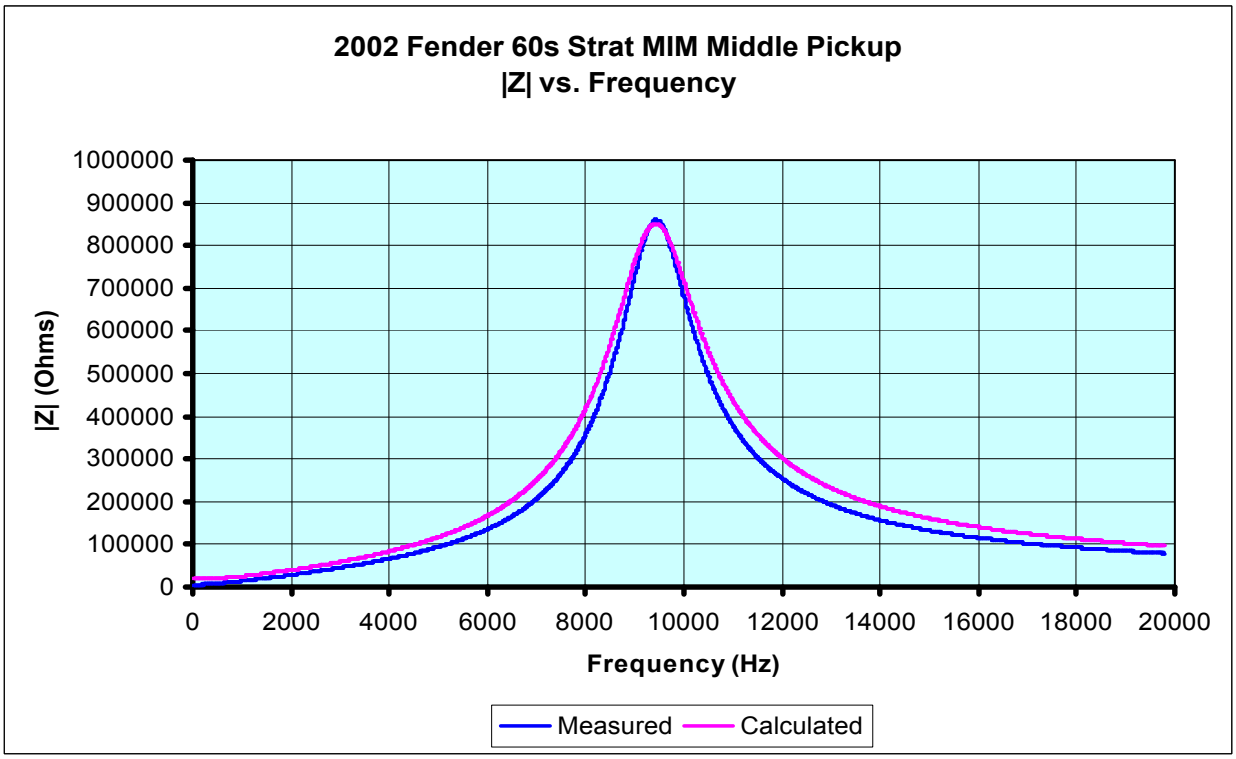
Appendix C



Appendix D



Appendix E



Appendix F

2002 Fender 60's Stratocaster, made in Mexico

	Magnetic	Field	at Poles	(@ Top	of Pickup)	
Magnet	Lo_E	A	D	G	B	Hi_E
Polarity	(Gauss)	(Gauss)	(Gauss)	(Gauss)	(Gauss)	(Gauss)
Neck: N	1055	940	940	930	925	1135
Middle: N	1010	870	810	960	830	1140
Bridge: N	1030	900	1010	900	890	1130

R_dc	L_120Hz	L_1KHz	L_10KHz	D_120Hz	D_1KHz	D_10KHz
(KOhms)	(H)	(H)	(H)			
5.81	2.20	2.66	-	3.530	0.446	-
5.91	2.18	2.64	-	3.570	0.454	-
5.93	2.20	2.66	-	3.640	0.451	-

Rm_120Hz	Rm_1KHz	Rm_10KHz	f_res	FWHM_res	|V_res|	|Z_res|
(KOhms)	(KOhms)	(KOhms)	(KHz)	(KHz)	(mV)	(MegOhm)
0.05	31.66	-	-	-	-	-
-0.04	30.63	-	9.380	2.740	262.8	0.860
0.11	31.13	-	-	-	-	-

C_10KHz	Dc_10KHz	Rm_10KHz
(pf)		(KOhms)
43.0	0.453	811.25
1.3	14.500	872.19
-	-	-