Guitar Pickups - Some Basic Physical Measurements

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Introduction

In starting a brief analysis of electromagnetic pickups, the first stage of testing was to use a vernier calliper and measure these pickups.

This chapter gives an insight into some dimensions of physical construction of some magnetic pickups, starting off with single coil designs and this in turn provides a basis of understanding for more complex designs using more than one coil.

For consistency, Cartesian (x, y, z) axes were chosen, and it is assumed that the pickup is placed normal (90 deg) to the strings. The x ordinate passes through the nominal centres of the magnetic pole pieces and cuts midway through the ends of the of the pickup coil.

The y ordinate is parallel to the strings and passes through the sides of the pickup coil and the z ordinate passes through the centre of the pickup coil. The origin is therefore at mid-height of the coil, in the middle of the coil – and this may not agree with the pole faces or balance of the magnetic structure.

Pole Pieces

In the case of the ‘Strat” pickups, these are basically 6 Alnico bar magnets (different lengths for some as yet undefined purpose) with a single coil.

Both the White and Black covered pickups have soft iron pole pieces with a flat Ferrite bar magnet as the magnetic energiser source beneath the bobbin assembly. These pole pieces are all the same length.

The Kinman Strat pickup is a vertical hum buckers and it is a very complex composite design. Externally it looks like it has six Alnico 5 bar magnets of differing length.
The Kinman Tele pickup is a vertical hum buckers and it is a very complex composite design. Externally it looks like it has six Alnico 5 bar magnets of same lengths.

Hum Buck 01 has two laterally positioned coils. The main coil has even length Alnico 5 bar magnets and the buck coil has soft iron pole pieces.

Hum Buck 02 has two laterally positioned coils. The main coil has even length Alnico 5 bar magnets and the buck coil has nickel-plated iron metal thread screws as pole pieces.

Pole Spacing

This is the first set of measurements that were done and these showed significant differences. The Rod Diameter is the pole piece structure which seems to consist of sets of 6 rod magnets - or pole pieces, and there was a marginal difference here.

The Total Span was the measurement from outer edge to outer edge along the six pole pieces. By subtracting the Rod Diameter from the Total Span, this leaves the Span Centres along the x axis, and by dividing this figure by five, this gives the nominal Span Centres of the pole pieces. Really simple high school maths stuff!

	Rod Diameter	Total Span	Rod Centres	Span (x) Centres	Lateral (y) Span Centres
Strat 01	4.85 mm	52.1 mm	9.42 mm	47.3 mm	
Strat 02	4.85 mm	55.8 mm	10.2 mm	51.0 mm	
White	5.00 mm	57.3 mm	10.5 mm	52.3 mm	
Black	5.00 mm	54.9 mm	9.98 mm	49.9 mm	
K Tele	4.80 mm	60.0 mm	11.0 mm	55.2 mm	
K Strat	4.80 mm	54.4 mm	9.92 mm	49.6 mm	
H B 01	4.85 mm	54.6 mm	9.95 mm	49.8 mm	18.75 mm
	5.00 mm	54.8 mm	9.96 mm	49.8 mm	
H B 02	5.00 mm	54.6 mm	9.92 mm	49.6 mm	18.75 mm
	5.00 mm	54.8 mm	9.96 mm	49.8 mm	

This little table shows that there is a variation in the total span centres, and this probably aligns with string spacing, depending on where the pickup is located on the body of the guitar in relation to the total string span.

String Spans

To get some idea of this the string spacing/span on some guitars was measured at the bridge, mid and neck positions:

	Bridge	Mid	Neck
Stratocaster	52.5 mm	50.7 mm	49.0 mm
Telecaster			

These figures give a hint that the total span (centre - centre) for pole pieces on various pickups may aesthetically align with string spans for various guitars.

Pole Piece Lengths

There seems to be so much said about the pole piece lengths and in some cases they are different on the same pickups. The table below gives some typical measurements for the sample pickups for each pole piece. In all cases the base side of the pickups is consistent, so it appears that for some pickups, the length of the magnet/pole piece is different.

	1	2	3	4	5	6	Comment
Strat 01	18.0 mm	18.0 mm	18.5 mm	18.5 mm	16.0 mm	16.9 mm	Staggered
Strat 02	18.0 mm	18.0 mm	18.5 mm	18.5 mm	16.0 mm	16.9 mm	Staggered
White	17.3 mm	17.3 mm	17.3 mm	17.3 mm	17.3 mm	17.3 mm	Level
Black	15.7 mm	15.7 mm	15.7 mm	15.7 mm	15.7 mm	15.7 mm	Level
K Tele	18.2 mm	18.2 mm	18.2 mm	18.2 mm	18.2 mm	18.2 mm	Level
K Strat	22.1 mm	22.7 mm	23.3 mm	22.3 mm	22.1 mm	22.2 mm	Staggered - apparent lengths
H B 01	12.6 mm	12.6 mm	12.6 mm	12.6 mm	12.6 mm	12.6 mm	Level
	14.9 mm	14.9 mm	14.9 mm	14.9 mm	14.9 mm	14.9 mm	Level
H B 02	17.9 mm	17.9 mm	17.9 mm	17.9 mm	17.9 mm	17.9 mm	Level
	16.8 mm	16.8 mm	16.8 mm	16.8 mm	16.8 mm	16.8 mm	Level

It seems to be important that the quasi-distance from an actioned string and the pole-piece end is a well defined distance, (even though this distance will vary, depending on the fret being used, and the string being 'bent') and therefore the variation in magnetic field intensity may be attributed to the string being closer or further from the pole-piece. Whether or not this actually makes a difference in comparative level from a string is not covered in this area.

Strat 01: Magnet pole pieces sit flush with the base of the in the non-magnetic mounting base which is 2.55 mm thick. (This mounting forms the bottom side bobbin face.)

Strat 02: Magnet pole pieces sit flush with the base of the in the non-magnetic mounting base which is 2.55 mm thick. (This mounting forms the bottom side bobbin face.)

White: Soft iron pole pieces sit flush with the base of the in the non-magnetic mounting base which is 2.55 mm thick and this mounting forms the bottom side bobbin face. A ferrite magnet sits under these pole pieces to energise the field. The ferrite magnet is 60.2 mm long, 10.0 mm wide and 4.2 mm thick (between the North and South poles), so the magnet overlaps the pole pieces with about 1.5 mm spare at each end.

Black: Soft iron pole pieces sit flush with the base of the in the non-magnetic mounting base which is 2.20 mm thick and this mounting forms the bottom side bobbin face. A ferrite magnet sits under these pole pieces to energise the field. The ferrite magnet is 60.2 mm long, 14.1 mm wide and 5.1 mm thick (between the North and South poles), so the magnet overlaps the pole pieces with about 5.65 mm spare at each end.

Kinman Tele: This is a composite design of both magnets and soft iron pole pieces. Externally it looks like the rod magnets extend through to the top of the mounting plate.

Kinman Strat: This is a composite design of both magnets and soft iron pole pieces. Externally it looks like the soft iron pole pieces under the rod magnets extend through the mounting plate by about 2.00 mm.

Hum Bucker 01: The pickup coil has six Alnico 5 magnets that are embedded on the bottom side through a 2.5 mm thick soft iron plate common to both coils, and the magnets are flush to a 1 mm galvanised iron base plate – that has 4 mm diameter holes punched in it aligning with the rod magnet centres – probably to 'entice' the magnetic field into the iron plate.

The buck coil has six 1/8 inch Whitworth soft iron metal thread screws (Allan key heads) feeding into the common iron block and through larger holes in the base plate. The common iron block is about 24.3 mm by 57.3 mm by 2.5 mm thick.

Hum Bucker 02: The pickup coil has six Alnico 5 magnets that are embedded on the bottom side through a 2.5 mm thick soft iron plate common to both coils, and the magnets are flush to a 1 mm galvanised iron base plate.

The buck coil has six 4 BA soft iron metal thread screws (Raised heads) feeding into the common iron block and through larger holes in the base plate. The common iron block is about 24.3 mm by 57.3 mm by 2.5 mm thick. (Interesting to see that the metal thread screws have been cut off with pliers.)

Bobbin Dimensions

This is another aspect of the pickup and it reflects on the available winding space – which in turn associates with the internal resistance, and the inherent inductance, as both of these electronic parameters define some aspects of the pickup spectral response. There are a large amount of interactive relationships here!

As the coils are flattened, the x dimension refers to the long side, y refers to the short side ands z refers to the height.

X External	X Internal	Y External	Y Internal	Z Internal	
Strat 01	62 mm	52.2 mm	15 mm	5.0 mm	11.4 mm
Strat 02	64.5 mm	55.9 mm	14 mm	5.0 mm	11.4 mm
White	65 mm	57.4 mm	12.2 mm	5.1 mm	11.8 mm
Black	61 mm	55.0 mm	12.2 mm	5.1 mm	10.3 mm
K Tele				4.9 mm	
K Strat				4.9 mm	
H B 01	65 mm	54.8 mm	14.8 mm	5.0 mm	6.8 mm
	65 mm	55.0 mm	14.8 mm	5.1 mm	6.8 mm
H B 02	68 mm	54.8 mm	16 mm	5.1 mm	6.8 mm
	68 mm	55.0 mm	16 mm	5.1 mm	6.8 mm

These figures give secondary information about the bobbins. The cross section area can be approximated by the differences between the associated internal and external dimensions as follows:

	X Ext – Int	Y Ext – Int	Int-Ext	Z Internal	Approx Area mm^2
Strat 01	4.9 mm	5.0 mm	4.95 mm	11.4 mm	56.4
Strat 02	4.3 mm	4.5 mm	4.40 mm	11.4 mm	50.2
White	3.8 mm	3.55 mm	3.68 mm	11.8 mm	43.4
Black	3.0 mm	3.55 mm	3.28 mm	10.3 mm	33.8
K Tele					
K Strat					
H B 01	5.1 mm	4.9 mm	5.0 mm	6.8 mm	34.0
	5.0 mm	4.9 mm	4.93 mm	6.8 mm	33.5
H B 02	6.6 mm	5.45 mm	6.03 mm	6.8 mm	41.0
	6.5 mm	5.45 mm	5.98 mm	6.8 mm	40.7

A couple of other derived measurements can provide the mean length of the turns in the coils. Just like a cake mix! First identify the internal and external coil measurements along the ‘y’ axis, multiple these and then take the square root – this gives the mean radius.

Now convert this radius measurement into a circumference by multiplying by 2*PI (as there are two half-circle components – one at each end of the ‘x axis). The two semi-circular winding components are separated by the long span that is effectively the ‘x’ axis span centres that were recorded much earlier.

Adding the circle component (two half circles) to two span centres comes out with the total mean length for the turns on the coils. This is just a practical application of lower high-school maths, and unfortunately my teachers never showed me practical examples like this or I would have really aced maths in school!

The table below shows the workings – and it is much faster using a spreadsheet program than with a hand calculator!

	Y External	Y Internal	Mean Radius	Circle Component	Span Centres	Mean Length
Strat 01	15.0 mm	5.0 mm	8.66 mm	54.4 mm	47.3 mm	149.0 mm
Strat 02	14.0 mm	5.0 mm	8.37 mm	52.6 mm	51.0 mm	154.6 mm
White	12.2 mm	5.1 mm	7.89 mm	49.6 mm	52.3 mm	154.2 mm
Black	12.2 mm	5.1 mm	7.89 mm	49.6 mm	49.9 mm	149.4 mm
K Tele		4.9 mm			55.2 mm	
K Strat		4.9 mm			49.6 mm	
H B 01	14.8 mm	5.0 mm	8.60 mm	54.1 mm	49.8 mm	153.4 mm
	14.8 mm	5.1 mm	8.69 mm	54.6 mm	49.8 mm	154.2 mm
H B 02	16.0 mm	5.1 mm	9.03 mm	56.8 mm	49.6 mm	156.0 mm
	16.0 mm	5.1 mm	9.03 mm	56.8 mm	49.8 mm	156.4 mm

Conclusions

Pole Piece Spacing

It seems to be (aesthetically) important that the pole pieces are directly under the strings being played, and for that reason alone there seems to be a spread in the pole spacings and therefore total span. With this in mind, with the pickups used in these tests, the measurements seem to indicate the following:

	Span Centres	Probable Position	String Span
Strat 01	47.3 mm	Neck	49.0 mm
Strat 02	51.0 mm	Mid/Bridge	50.7 mm
White	52.3 mm	Bridge	52.5 mm
Black	49.9 mm	Mid/Neck	49.6 mm
K Tele	55.2 mm	Bridge?	
K Strat	49.6 mm	Mid/Neck	49.6 mm
H B 01	49.8 mm	Mid/Neck	49.6 mm
	49.8 mm	Mid/Neck	49.6 mm
H B 02	49.6 mm	Mid/Neck	49.6 mm
	49.8 mm	Mid/Neck	49.6 mm

The reference for the string span was taken from the earlier string span table, and the approximation for the Mid/Neck is a simple average of the two values for the Mid and Neck string spans. This table shows that aesthetically the pickups could sit so that the pole pieces roughly aligned with the strings.

Pole Piece Lengths

The table showing the pole piece lengths shows that for the Strat 01, Strat 02 and Kinman Strat, the pole pieces are of differing lengths, but otherwise all pole pieces for each magnetic assembly, the pole pieces are very consistent. At this stage there is no relation to other results to criticise or justify this form of structure.

Magnetic Structure

This was extremely interesting because externally the Strat style pickups all looked the same but there were radical differences in assembly with the White and Black covered pickups both having ferrite permanent magnets and soft iron pole pieces, while the Kinman Strat and Kinman Tele had both Alnico permanent magnets and soft iron pole pieces – vertically assembled as Hum Buckers.

The lateral Hum Buckers both had Alnico permanent magnets as rods similar to the Strats, but the second Hum Bucker coil had soft iron rods/metal thread screws as the magnetic cores. Both of these assemblies had a thick iron linking plate between the coils and this directly impacted on the available size of the coils.

From first inspection it appears that the magnetic fields of the Strat style pickups are very loose and a return path has apparently not been considered. Conversely the lateral Hum Bucker assemblies actually have a return path for the magnetic field via the strings.

Bobbin Structures

The Strat 01, Strat 02, Black Strat, White Strat, Kinman strat and Kinman Tele all appear to use the magnetic rods (and/or soft iron pole pieces) together with mounting material/board as the bobbin or former for the wire to be wound on. This maximises the area and therefore maximises the number of turns available – considering that the wire is very thin.

The lateral Hum Buckers appear to have bobbins constructed by injected plastic/nylon so that the coils could be manufactured and the unit later assembled to include the (thick) common iron plate, mounting plate and then wired together.

Measurements gave both the approximate winding area and mean length and this might have use in identifying other winding and inductance parameters when electrical measurements are included. In terms of resistance, resistivity is a function of cross sectional area and mean length, so combining these two we can get the following:

	Mean Length	**Approx Area mm^2**	**Area/Length mm**
Strat 01	149.0 mm	56.4	0.3785 mm
Strat 02	154.6 mm	50.2	0.3247 mm
White	154.2 mm	43.4	0.2815 mm
Black	149.4 mm	33.8	0.2262 mm
K Tele			
K Strat			
H B 01	153.4 mm	34.0	0.2216 mm
	154.2 mm	33.5	0.2173 mm
H B 02	156.0 mm	41.0	0.2628 mm
	156.4 mm	40.7	0.2602 mm

This is quite a big range and the spread is in the order of 74%. Ideally the cross sectional area of the bobbins should be large and the mean length of the windings should be small – so the wire can be thick and of few turns! But that is another story.

Overall Conclusions

Even though the general structures of these guitar pickups is relatively consistent, ***there are structural variations that seem to be more for cosmetic reasons than actual functionality***. These structural variations will lead to significant electrical differences that may (or may not) cause differing tonal qualities.

At least we now know that there are structural differences and that the main one is the spacing between the magnet/pole-piece centres - apparently so that the magnetic field is positioned directly below the string of interest - provided that the strings are not 'bent' during playing!

We also know that the height of the magnets/pole-pieces seems to be consistent on the 'bottom side of the pickups (further away from the strings), but nearer the strings, the heights on some pickups pole-pieces are specifically set so that apparently the magnetic field strength will be comparatively less or greater and this apparently will cause a significant change in the level from the associated vibrating string!

Comments and Corrections are welcome