

PURDUE
UNIVERSITY



COLLEGE OF TECHNOLOGY

Manufacturing Summer Camp

MET – KITTING GUIDE

Assembling an Electric Guitar

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Introduction

This set of instructions was written to accompany guitar making workshops held at Purdue University. We assume you have never made a guitar before and that you may not even have worked with wood before. If you follow these directions, take your time and enjoy the process, you'll make great sounding guitar.

It's easy to get enthused about making a guitar and want to add custom touches. A little bit of customization is OK, but too much means you won't get finished. It's way better to finish the week with a nice, completed guitar in your hand than to be still looking at an unassembled pile of customized parts. We want you to make the guitar your own, but we'll steer you away from trying to make changes that will take too much time.

Don't be discouraged if you make mistakes. If you can't bear to fix mistakes, you probably shouldn't be making guitars. Seriously, most mistakes can be fixed, usually without leaving much of a trace. The most important thing is to let somebody know as soon as you find an error so it can be fixed before it gets bigger.

Parts

At the beginning of the process, you should have a kit of parts. This kit will include everything you need to make a guitar. Be careful not to lose anything. The list of parts depends on what guitar you are making. These instructions cover both a single pickup guitar and one with two pickups and a switch.



Figure 1 – Rough Milled Necks and Bodies

Parts List

Number	Description	Qty	Notes
1	Neck Blank	1	Paddle headstock, slotted for truss rod
2	Body Blank	1	
3	Fretboard	1	Slotted and radiused, but no dots or inlays
4	Truss Rod	1	
5	Tuners	6	May include bushings, washers and nuts
6	Tuner screws	6	3/8" #2 stainless steel pan head Phillips sheet metal screws. Not needed for all types of tuner
7	Nut Blank	1	
8	Neck plate	1	
9	Neck Screws	4	1-3/4" #8 stainless oval head Phillips sheet metal screws
10	Fret Wire	3	Medium-Medium fret wire bent to an 8-10 inch radius. Best to start with this and experiment with other styles on your next instrument.
11	Neck Dots	12	Wood or mother of pearl. You don't need to install these if you don't want to
12	Side Dot Rod	1	Black or white 1/16" Delrin plastic. Don't need this either if you don't want side dots.
13	Potentiometers	2	Either 250kΩ or 500kΩ depending on your wiring. Includes hex nuts and flat washers
14	Knobs	2	One for each potentiometer
15	Capacitor	1	Either 22pF or 47pF depending on your wiring
16	Hookup Wire	2ft	Different colors of stranded 22 gauge wire
17	Pickup	1	Either single or double size humbucker
18	Mounting Screws	2	1" #4 stainless Phillips sheet metal screws for single size 1" #3-48 machine screws for double size humbuckers
19	Pickup Ring	1	Only needed for double sized humbuckers
20	Ring Screws	4	3/4" #4 oval head Phillips stainless steel sheet metal screws. Only needed for double sized humbucker
21	Pickup Springs	2	Coil springs or sections of 1/4 inch silicone tubing
22	Bridge	1	There are three different bridges currently being used. Two use screws to attach to the body and one uses threaded studs.
23	Bridge Screws	3 or 4	Four 1" #4 flat head stainless steel Phillips sheet metal screws Three 1" #8 flat head stainless steel Phillips sheet metal screws
24	Body Ferrules	6	Only needed for one type of bridge
25	Strap Buttons	2	
26	Strap Button Screws	2	1" #8 oval head stainless steel Phillips sheet metal screws
27	Electronics Pocket Cover	1	Either white or black
28	Pocket cover screws	4	3/4" #4 stainless steel Phillips sheet metal screws
29	Output Jack	1	1/4 inch phono jack with hex nut and lock washer
30	Jack Plate	1	
31	Jack Plate Screws	2 or 4	3/4" #4 oval head stainless steel Phillips sheet metal screws
Two Pickup Guitars Only			
29	2 nd Pickup	1	Double size
30	2 nd Pickup Ring	1	Double size, might be higher than first one
31	Pickup Ring Screws	4	3/4" #4 oval head Phillips stainless steel sheet metal screws. Only needed for double sized humbucker
32	Mounting Screws	2	1" #4 stainless Phillips sheet metal screws for single size 1" #3-48 machine screws for double size humbuckers
33	Ring Screws	4	3/4" #4 oval head Phillips stainless steel sheet metal screws. Only needed for double sized humbucker
34	Pickup Springs	2	Coil springs or sections of 1/4 inch silicone tubing
35	3-way Switch	1	Includes knurled ring and flat washer if Gibson type switch. Includes oval head machine screws if blade switch
36	Switch Knob	1	Threaded for Gibson type switch or slotted for blade switch

Preparing the Body for Finishing

The body has been milled from a block of wood 1.75 inches thick. All the necessary pockets have been milled out and all the holes have been drilled. This was done on a computer controlled milling machine and all the dimensions should be correct to a few thousandths of an inch.

Figure 2 shows a body with the back radiused and holes drilled. The large hole (7/8 inch diameter) in the edge is for the output jack. The larger of the two holes inside the electronics pocket is to run the pickup wire(s) into the electronics pocket. The smaller of the two holes is for the bridge ground.



Figure 2 – Guitar Body with Body Radius and Holes Drilled

Before the body can be finished, you will need to do the final shaping and sand it smooth. The final shaping is up to you. Some people like a simple slab body like that on a Fender Telecaster. Figure 3 shows a Telecaster with wear on the paint. This wear may be real (due to extended use) or simulated (done at the factory) so that the guitar appears to be a vintage instrument.



Figure 3 – A Telecaster Showing either Real or Simulated Wear

The Telecaster is a very early design and the slab body was probably adopted to make the guitar easy to make. Some players found it uncomfortable and Fender's response to this problem was the Stratocaster, a more refined design with a deeply contoured body.



Figure 4 – Body Contouring on a Fender Stratocaster

Contouring is strictly for comfort and appearance; it doesn't affect the sound, so contour or not as you wish. Rough contouring should be done with a rasp and a pneumatic sanding drum. Figure 5 shows a pneumatic drum being used to contour a body. Note that the body is securely clamped down.



Figure 5 – Contouring a Body Using a Pneumatic Sanding Drum

Figure 6 shows a body being contoured by hand with a rasp. A sharp rasp can remove a lot of material quickly and accurately. It is a more precise tool than the pneumatic sander, but leaves a rougher surface. Unless you have previous experience with a pneumatic sander, it's generally a good idea to do the rough shaping with a rasp and refine the surface with the sander. Figure 6 shows a machine cut rasp with very heavy teeth. In general, you will have better results using a hand-cut rasp with slightly finer teeth.



Figure 6 – Shaping a Body with a Rasp

Once you have done the rough shaping with a rasp and pneumatic sander, you can do the final shaping and smooth the body using sandpaper. Sandpaper should be used only when the contouring is close to the desired final shape. Start with 120 grit sandpaper. You should try to smooth any rough areas and relieve hard edges that might make the guitar uncomfortable to hold or to play.

A quick note about sandpaper: Sandpaper is designated by its grit. Grit is the number of abrasive elements per square inch. Coarse sandpaper is 80-100 grit. You'll do much of your shaping with 120 grit sandpaper. Fine sandpaper is about 220 grit. You'll use this for the final sanding before applying the first coat of sealer. Very fine sandpaper is 320 grit. This is for smoothing the sealer coat before applying the top coats.

Always sand wood parallel to the grain. If you sand across the grain, you will make scratches that you'll then have to sand out. Also, don't use fine sandpaper too soon. Coarse sandpaper is for shaping and leveling. Only when the shape is correct should you go to finer sandpaper. If you try to level a rough surface with smooth sandpaper, all you will do is make the tops of the bumps smooth.

After the body is contoured, it should be sanded smooth. You can smooth the body with 180-240 grit sandpaper. Take your time to remove any machining marks and make sure the entire body is smooth. **You can't do a good finish over a badly prepared surface!**

Finishing the Body

The finish on your guitar will be applied in either two or three layers.

- If you want a natural finish, you'll apply a sealing layer and then a clear top coat.
- If you want a tinted finish, you'll apply a sealing layer, a tinted layer and a clear top coat.

The first layer seals the wood grain and forms a smooth surface for the next layers. Typically, you'll want to apply two coats of sealer and sand in between them. Apply the first coat of sealer and let it dry completely. Then sand with 220 grit sandpaper. If the sealer is dry, the sandpaper should make dust. If it isn't dry, the sandpaper will get gummy with partially cured sealer. After the first coat of sealer has been sanded smooth, apply a second coat. Just like before, let it dry and sand it.

Sealer is formulated to dry quickly, sometimes as little as 60 minutes. If you plan your work, you can avoid delays. For example, apply a coat of sealer right before lunch or at the end of the work day so it can dry while you are away. At the very least, you can let the sealer dry while you work on something else.

A word about finishes:

One way to organize finishes is by whether there is any chemistry when they dry. Shellac and lacquer dry by evaporation. They are made of solids dissolved in a volatile solvent. When the solvent completely evaporates, the solid is left. Shellac is made from refined secretions from the Lac bug dissolved in alcohol. Lacquer is made from nitrocellulose dissolved in a solvent made from a mixture of volatile organic compounds (VOCs). It's nasty stuff so always wear a cartridge breather.

Other finishes undergo a chemical reaction. This means that the chemical makeup of the cured finish is different than that of the wet finish. This class includes oils, polyurethane, epoxies, catalyzed finishes and light cured finishes.

There are many different combinations of materials that can be used to do a nice finish on a guitar. It's probably more important to be familiar with the properties of the type you are using than to select any particular finish. It is also very important to select a sealer and top coat that are compatible with one another; otherwise the finish may peel off. It's happened to us and, trust us, it's a bad feeling.

It can be really tempting to plan a complicated finish. Especially if this is your first guitar, though, you should keep it simple. The simplest choice is a clear finish that is even and shows off the grain of the wood underneath. The nice part of a clear finish is that it is easy to touch up or repair.

Slightly more involved is a single color – either solid paint or translucent stain. Well done, this can be very attractive. A nice variation of the single color finish is to concentrate the color around the edge of the instrument in something like a sunburst pattern. Figure 7 shows several guitars with single color finishes and two with clear finish.



Figure 7 – Guitar Bodies Drying After Finishing

If you are willing to do two colors and tape off some interesting pattern, another dimension of creativity is possible. Figure 8 shows a guitar painted simply with white and black. The first color was black. The builder then taped off an angular spiral pattern so that a white layer could be applied. After the white dried, he removed the tape, leaving the taped off pattern in black. Finally, a protective clear coat was applied over the color coats.



Figure 8 – A Two Color Instrument before the Clear Coat

A nice, but slightly more involved finish is a sunburst. Sunbursts usually have either two or three colors and can have several different themes. Figure 9 shows a three color antique cherry sunburst. It's perhaps not a good idea to try a sunburst yourself on your first guitar, but a workshop instructor can spray one for you if you like.



Figure 9 – A Three Tone Sunburst on a Double Cutaway Guitar

Designing the Headstock

You'll be able to design your own headstock using computer aided design (CAD) software. The shape of the headstock is up to you – it's a chance to make the guitar uniquely yours. However, the tuners must fit on it and it must be strong enough to withstand the tension of the strings.



Figure 10 – Designing Headstocks in the Computer Aided Design Lab

After you design your headstock, your design will be loaded into a computer controlled milling machine that will cut out the headstock for you. After the headstock is milled, you will sand and finish it.



Figure 11 – Headstock Being Milled

Preparing Fretboard

The fretboard is where the player interacts most with the instrument, so it is important to get it right. The fretboard you get has the fret slots already cut in it and has been sanded to the correct radius (usually 12 inches or 305mm). It has also been cut to the right shape; the nut end is about 1.69 inches (42.9 mm) wide and the heel end is 2 3/16 inches (2.12 inches or 53.8 mm).

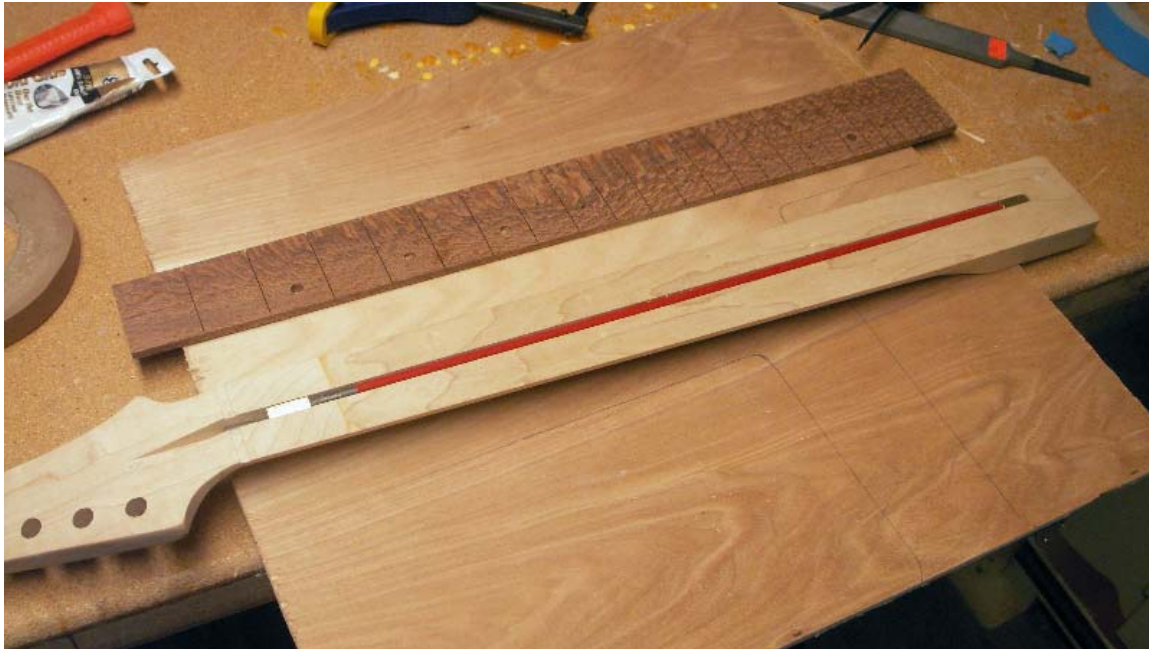


Figure 12 – Neck with Truss Rod and Fretboard

You will need to sand both the flat and curved sides of the fretboard before you do anything else. First, you can level the flat side by putting a piece of fine sticky-back sandpaper on a very flat surface and moving the fret board back and forth. A granite surface plate is ideal, but a table saw is also flat enough. It helps to make chalk marks on the back surface of the fretboard before sanding. When all the chalk is sanded off, the surface is flat.

The rounded surface needs to be sanded as well. It has been sanded to a 12 inch radius using coarse sandpaper and needs to be smoothed before finishing. It is best to use a radius block and 220 grit sandpaper. It helps to use a strip of double sided tape to fix the fretboard to a flat surface before sanding it with the radius block. When the radiused side is smooth, seal it with at least one coat of Tru-Oil sealer. This keeps dirt and sawdust from being rubbed into the fretboard as the dots are installed and the fretboard is fixed to the neck. Make sure not to get oil on the back (flat side) of the fretboard. This is the surface that will be glued to the neck and the glue only sticks to bare wood.

After the fretboard has been finish sanded and sealed, you can install fret dots. Typically, the dots are either mother of pearl (MOP) or wood. Mother of pearl is made from the inside of oyster shells and the dots are thin – about 0.040 in. You can cut wood dots from any wood you like using a tapered plug cutter.

Mark the locations of the dots on the fretboard and drill $\frac{1}{4}$ inch holes using either a brad point or Forstner bit. Holes for MOP dots are shallow so that the dots stick up above the surface of the fretboard. After the holes are drilled, the dots can be glued in place with superglue. When the glue is dry, the dots are sanded flush with a radius block and fine sandpaper. 320 grit sandpaper is ideal.

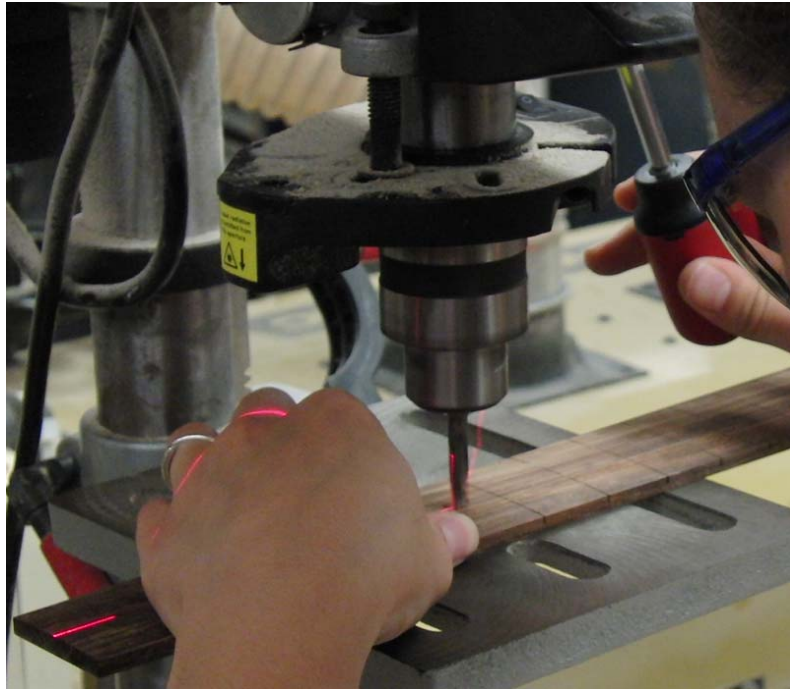


Figure 13 – Drilling Holes for Fretboard Dots

For wood dots, drill $\frac{1}{4}$ inch holes at least $\frac{1}{8}$ inch deep. While it is not preferred, don't worry if you drill completely through the fretboard. Cut the wood plugs from a hard, contrasting wood using a plug cutter. Pop the plugs free from the larger board using a small screwdriver. The plugs will have a smooth side - what had been the smooth surface of the board - and a rough side where it was broken free.

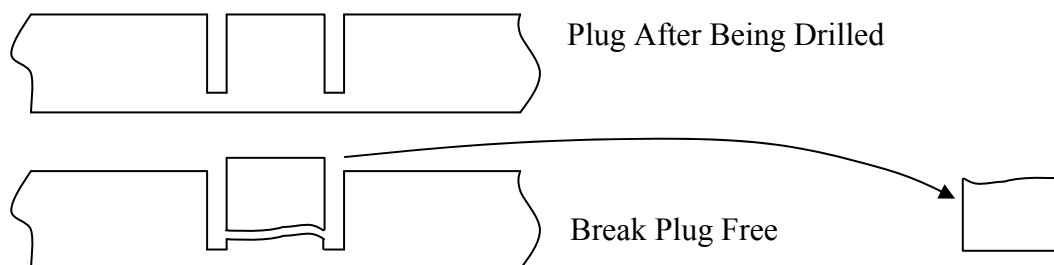


Figure 14 – Cutting Wood Plugs from a Board



Figure 15 – Fretboard with Dot Holes Drilled

To install a plug, put a drop of wood glue in the hole, making sure it coats the sides of the hole. Then tap a plug in, smooth side down. It is OK to use a small hammer to lightly seat the plug. Also, make sure the grain of the plug is lined up with the grain of the fretboard.

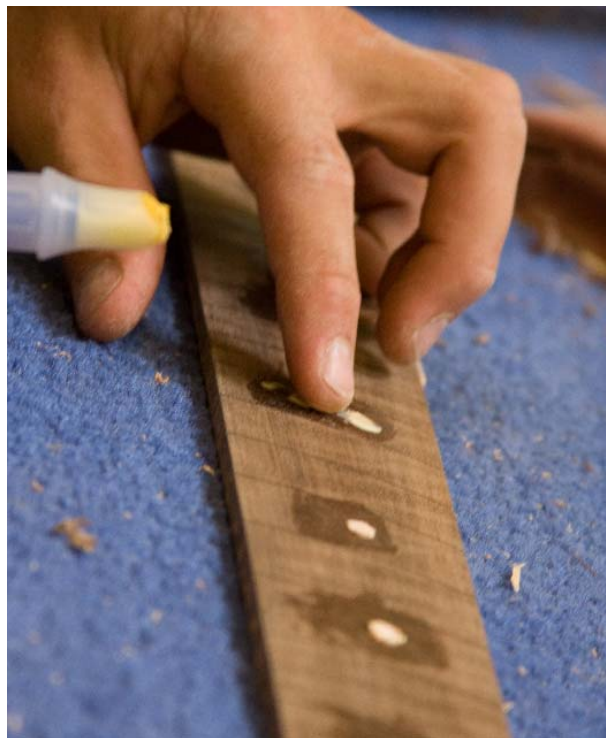


Figure 16 – Gluing Wood Dots into the Fretboard

After the glue dries, carefully level the plug with the fretboard. If there isn't much material to remove, use sandpaper and a radius block. If the plug sticks up more than 1/8 inch, you can

carefully saw some of the excess off with a small hand saw. Use masking tape to protect the fretboard from being scratched by the saw teeth. Then, finish up with sandpaper. When the dots are flush with the rest of the fretboard, apply another coat of Tru-Oil sealer to the fretboard.

Preparing Neck for Assembly

Before the fretboard is glued to the neck, you need to flatten the flat surface of the neck (the one with the slot in it). This is basically the same thing you did with the flat side of the fretboard. Mark the flat parts of the neck with some chalk and sand it on the same flat surface you used for the fretboard. When all the chalk is removed, the neck is flat.



Figure 17 – Flattening Neck Before Gluing on Fretboard

The next step is to make sure the truss rod fits into the slot correctly. It goes in the slot with the nut at the headstock end of the neck. Also, the nut should be toward the bottom of the slot. The brass blocks should be flush with the flat side of the neck. If they are not, make sure the slot is free of any wood chips. If either of the blocks still protrudes from the slot, talk to one of the instructors. When you are done with this step, the neck is ready to be assembled.



Figure 18 – Correct Truss Rod Orientation with Nut at Bottom of the Slot

Assembling Neck

The first step is to make sure the fretboard will be at the right location on the neck. The 24th fret slot should be even with the heel of the neck. Also, the nut end of the neck should line up exactly with the nut slot in the neck as shown in Figure 19. The next step is to make sure that the fretboard is pinned to the neck so that it won't slip when being glued on. Wet wood glue is extremely slippery and you can't count on the fretboard staying in place while the glue dries.

Align the fretboard on the neck **without** any glue and clamp it in place. Then drill a small hole through the bottom of the first fret slot about ½" off center. Then put a push pin through the hole, pinning the fretboard to the neck. Do the same thing at the 20th fret slot. Now you can remove the clamps and prepare to glue the fretboard to the neck.



Figure 19 – Fretboard Correctly Aligned on Neck

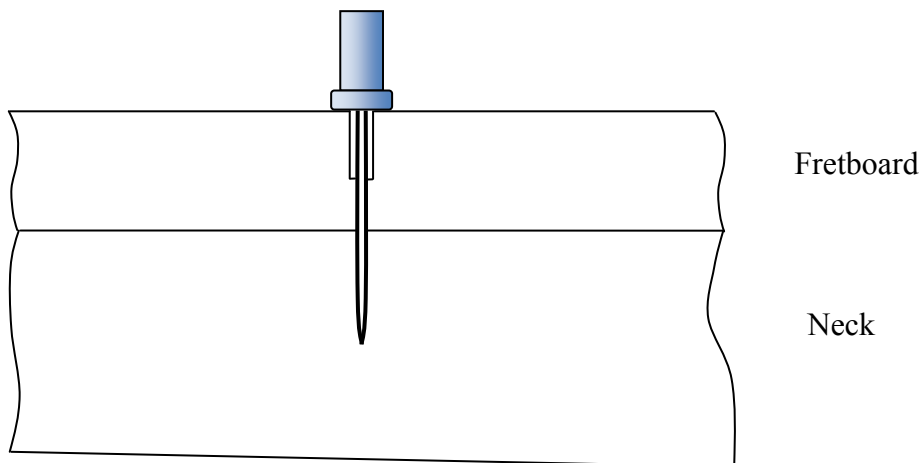


Figure 20 – Using a Push Pin to Fix Fretboard before Gluing

Before applying glue to the neck, do one last check to make sure there is no debris in the truss rod slot and make sure the truss rod is seated correctly. Then cover the truss rod slot with a piece of $\frac{3}{4}$ " wide masking tape; this will keep glue off the truss rod. Then, apply a thin, even layer of wood glue to the neck where the fretboard will join it. Before placing the fretboard on the neck, remove the tape to leave a clean wood surface.

Now, place the fretboard on the neck and insert your two push pins to make sure it is aligned. The most effective way to apply a uniform pressure while the glue dries is to use heavy rubber bands. Two or even three of them wrapped tightly around the neck creates a heavy, even pressure between the fretboard and the neck. Be sure to distribute the windings evenly so that there is pressure distributed all along the neck.



Figure 21 – Heavy Rubber Bands Being used to Clamp a Fretboard to a Neck (picture courtesy of Stewart MacDonald, www.stewmac.com)

Sanding and Finishing Neck

Once the neck and fretboard have dried, finish sanding the neck and make sure the curved surface of the fretboard is straight (as measured down the centerline of the neck). Use a straight edge at the center line of the fretboard to look for high or low spots. If the neck is not perfectly straight – and it probably won't be – start by adjusting the truss rod. If you are unsure of how to do this, ask one of the instructors to help you.

Once the neck is as straight as you can get it by adjusting the truss rod, use a radius bar to carefully level the fretboard. The radius bar (see Figure 21) has a concave surface with a 12" radius that matches the convex surface of your fretboard. Put a piece of 180 grit or 220 grit sticky back sandpaper the full length of the radius bar and then clamp the radius bar, sandpaper side up, into a guitar vise.

Carefully sand any high spots off the fretboard. It can be helpful to mark a couple lines down the fretboard using chalk. The chalk will be sanded away wherever the fretboard contacts the sanding bar. The chalk will stay in low spots that don't contact the sanding bar. When all the chalk marks have been sanded off, the neck should be level.

If the fretboard is close to level and only needs work over a small area, you can use a smaller, wood radius sanding block as shown in Figure 23. Be careful with the shorter blocks, since it's possible to sand a low spot into the fretboard with them.



Figure 22 – A Radius Sanding Bar used for Leveling the Fretboard (image courtesy of Stewart MacDonald, www.stewmac.com)



Figure 23 – A Short Radius Being Used to Level a Fretboard

Now that your neck has been finish sanded and the fret board is level, you can apply finish to the neck. Wipe a coat of Tru-Oil sealer on both the fretboard and the neck and let it dry thoroughly. Depending on the humidity, this may take less than an hour. If you notice any bumps or other flaws that need to be sanded out, do this now with fine (about 220 grit) sandpaper and apply another coat of sealer.

When you are satisfied with the seal coat, sand it lightly with very fine sandpaper – 320 grit or 400 grit. If you like, you can apply another coat of sealer and smooth it again, but this is not required.



Figure 24 – Tru-Oil Sealer and Finish

When you are done with the sealer coat, you should apply two coats of Tru-Oil finish. This is a similar formulation to the sealer, but dries to more of a shine and takes a little longer to dry. It is often a good idea to apply a coat of finish right before lunch or at the end of the day so you can do other things while it dries. Most players prefer a matte or satin finish on the fretboard. If you don't want a shiny finish on the fretboard, don't apply finish on it after the sealer coats.

It is very important for the neck to feel smooth under the player's hand. Smooth the finish between coats using either very fine sandpaper or #0000 steel wool. Tru-Oil is durable and easy to touch up; if you ever scratch the finish, you can just sand lightly, if necessary, and just apply some more finish.

When you are done with the finish on the neck, it is time to install the frets.

Fretting

Fret wire has a rounded section called a crown and a straight section called a tang. When fret wire is installed, the tang is tapped into the fret slots and the crown stands out from the fret board. The tang has small teeth protruding from it so the fret won't pull out.



Figure 25 – Fret Wire

Fret wire is usually supplied either in rolls or in straight pieces. Either way, it needs to be bent to the correct radius before being installed. The radius of the fret wire needs to be a little smaller than the radius of the fret board. Since the fret board radius is 12", the wire should be bent to around a 9" radius. The easiest way to bend the wire is with a tool designed specifically for the job (Figure 26). However the wire can also be bent with a simple wooden form or even by hand with a little practice.



Figure 26 – Fret Wire Bender (image courtesy Stewart MacDonald, www.stewmac.com)

There are two common ways to install fret wire. The first one is to tap it in with a small hammer and the second is to use a small arbor press. If you are using a hammer, tap the ends of the fret in first and then tap the center into place. Remember that you are only trying to seat the fret, not drive nails. You only need to tap the wire in.



Figure 27 – Arbor Press for Installing Frets (image courtesy Stewart MacDonald, www.stewmac.com)



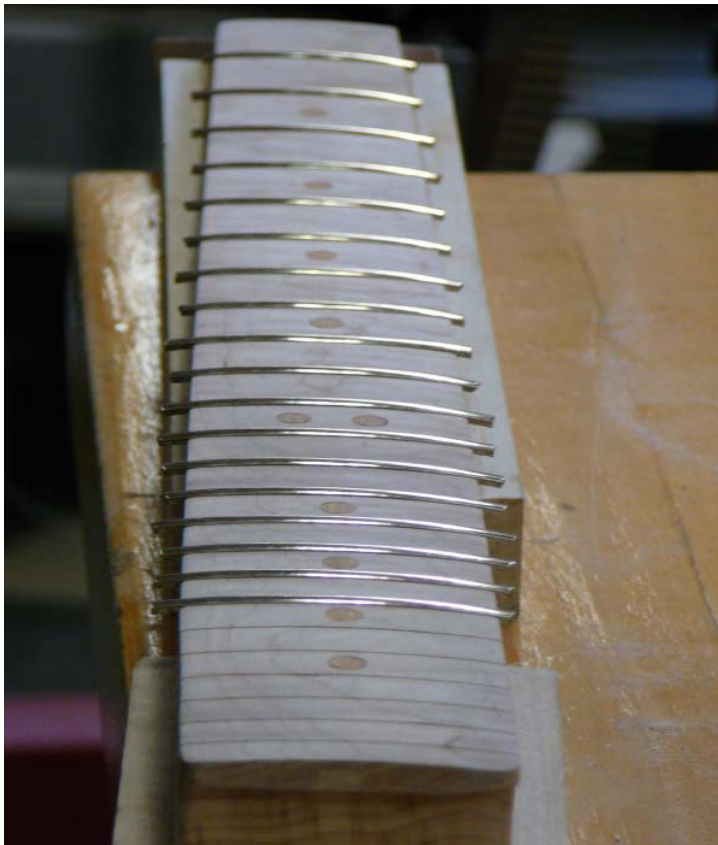
Figure 28 – Seating the Center of a Fret with a Fretting Hammer (image courtesy of Stewart MacDonald, www.stewmac.com)



The arbor press applies an even force across the fret and works quickly with only a bit of practice. Again, only use enough force to seat the fret. The gearing gives you quite a bit of leverage, so make sure you don't apply too much force. It is possible to crush the crown right into the fretboard if you pull hard enough. Also, make sure to support the neck on a convex block (called a caul) when using the arbor press.

Figure 29 – Neck Caul (image courtesy Stewart MacDonald, www.stewmac.com)

Cut the fret wire into approximately 3in lengths so that when the frets are installed, each one sticks out about $\frac{1}{4}$ in. Figure 30 shows a neck with most of the frets installed



Once the frets are put in place, put a drop of thin super glue on each end of each fret so that it will be drawn into the fret slots. This reinforces the wood around the frets and helps hold them in place. It also makes the wood a little more durable in case frets need to be replaced later.

The next step is to trim the frets to the correct length and to dress the ends. Cut the frets flush with the end of the fretboard using fret end nippers (see Figure 31)

Figure 30 – Neck with Most Frets in Place



Figure 31 – Trimming the Fret Ends Flush (image courtesy of Stewart MacDonald, www.stewmac.com)

When the frets have been trimmed, the next step is to dress the ends. Clamp the neck in a guitar vise with one edge of the fretboard up so that you have clear access to the entire edge of the neck. Then, file the ends of the frets so that they are flush with the edge of the fretboard. Use a 6" fine tooth file – the middle one in Figure 32.

Once the frets have been filed flush with the edge of the fretboard, the next step is to bevel the edges at a 35° angle to the edge of the fretboard (or 55° from the plane of the fretboard). This can be done freehand with the same file used to file the fret ends, but there is a dedicated tool with the file set at the correct angle (Figure 33).



Figure 32 – Files Used for Leveling Frets and Fretboards (image courtesy Stewart MacDonald, www.stewmac.com)

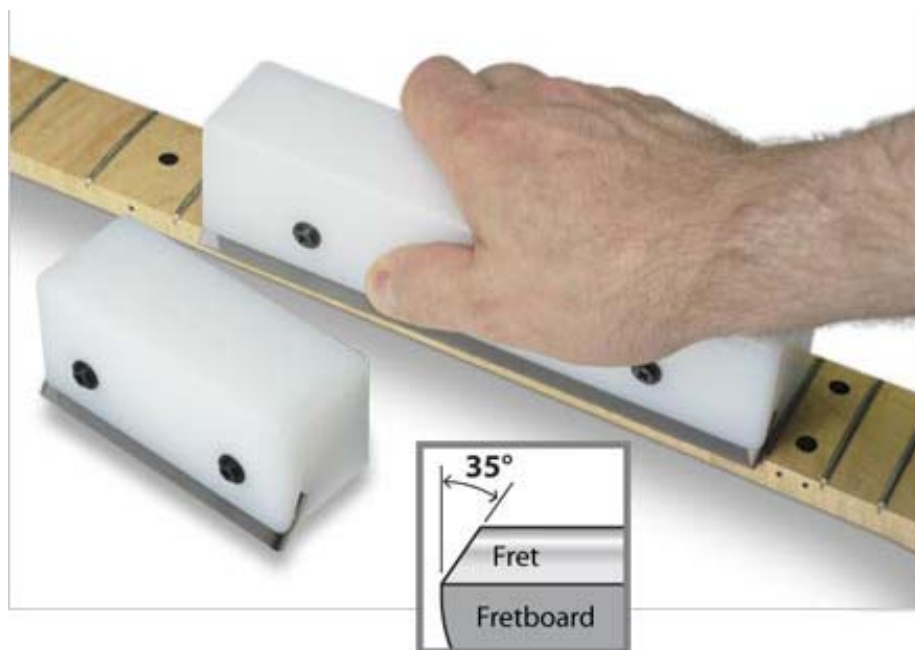


Figure 33 – Fret Beveling File (image courtesy Stewart MacDonald, www.stewmac.com)

The last step in dressing the fret ends is to debur the ends. The most convenient tool is a diamond fret file. Lightly file the ends of the frets to remove any burs. You aren't trying to round off the ends of the frets, just to remove any sharp edges that would be uncomfortable for the player's hands.

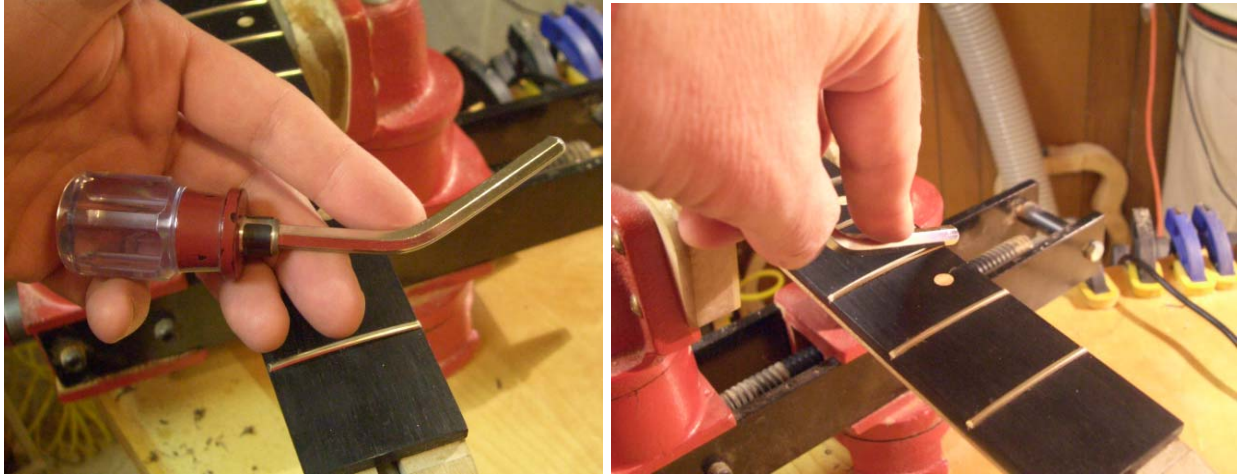


Figure 34 – Diamond Fret File



Figure 35 – A Correctly Dressed Fret End

Making Wiring Harness

Before you can assemble the guitar, you will need to make a wiring harness. It is easier to make most of the connections before the wiring goes into the guitar. The only connections you will make after installing the wiring harness are the bridge ground and the pickup connection(s). Your parts kit will include all the components needed to make the wiring harness.

It is easier to make the solder connections if you temporarily mount the potentiometers and the output jack in a piece of cardboard. This holds them steady while you work.



Figure 36 – Making a Wiring Harness

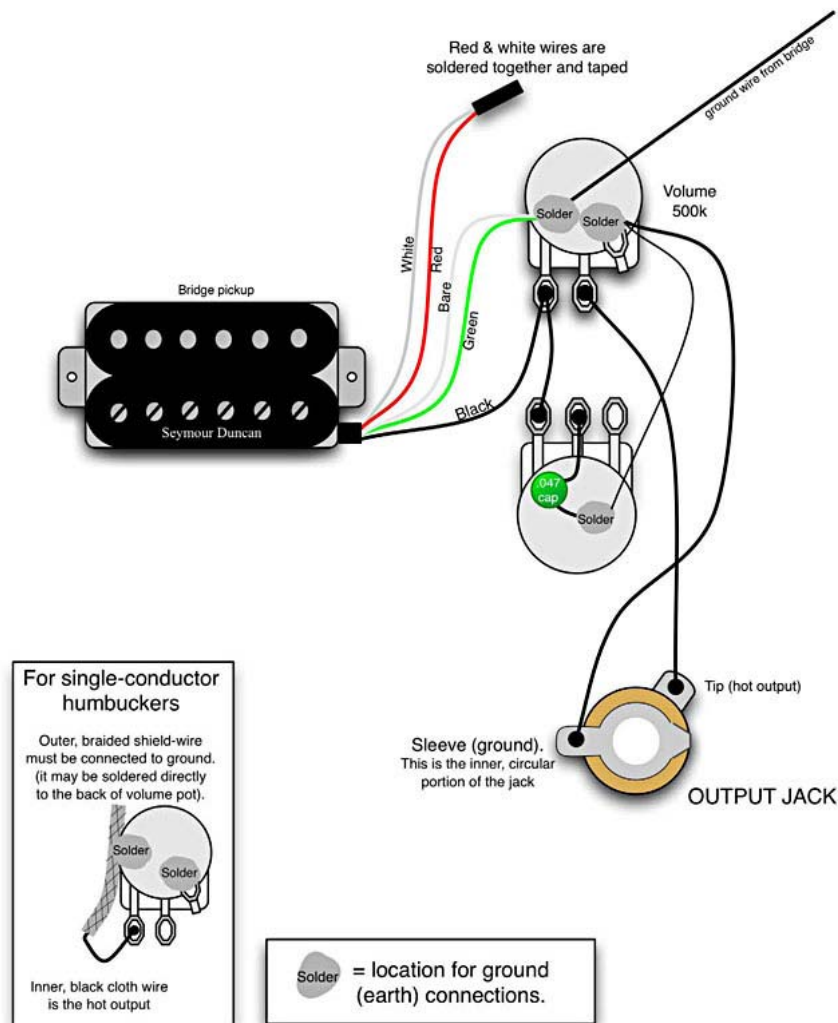
If your guitar has one pickup, there is no switch in the wiring harness. If your guitar has two pickups, there will be a three way switch. There are several styles of switches commonly used, but they all do the same thing. Figure 37 shows a common type of three way switch. This one mounts using a round hole in the front of the guitar.



Figure 37 – A Typical Three Way Switch

There are many different wiring arrangements used in electric guitars. For this workshop, you will use one of the most simple and common of these. If your guitar has one pickup, use the wiring diagram below in Figure 38. If your guitar has two pickups, use the wiring diagram in Figure 39. You can find a very complete selection of wiring diagrams at the Seymour Duncan web site (www.seymourduncan.com).

1 Humbucker, 1 Volume, 1 Tone



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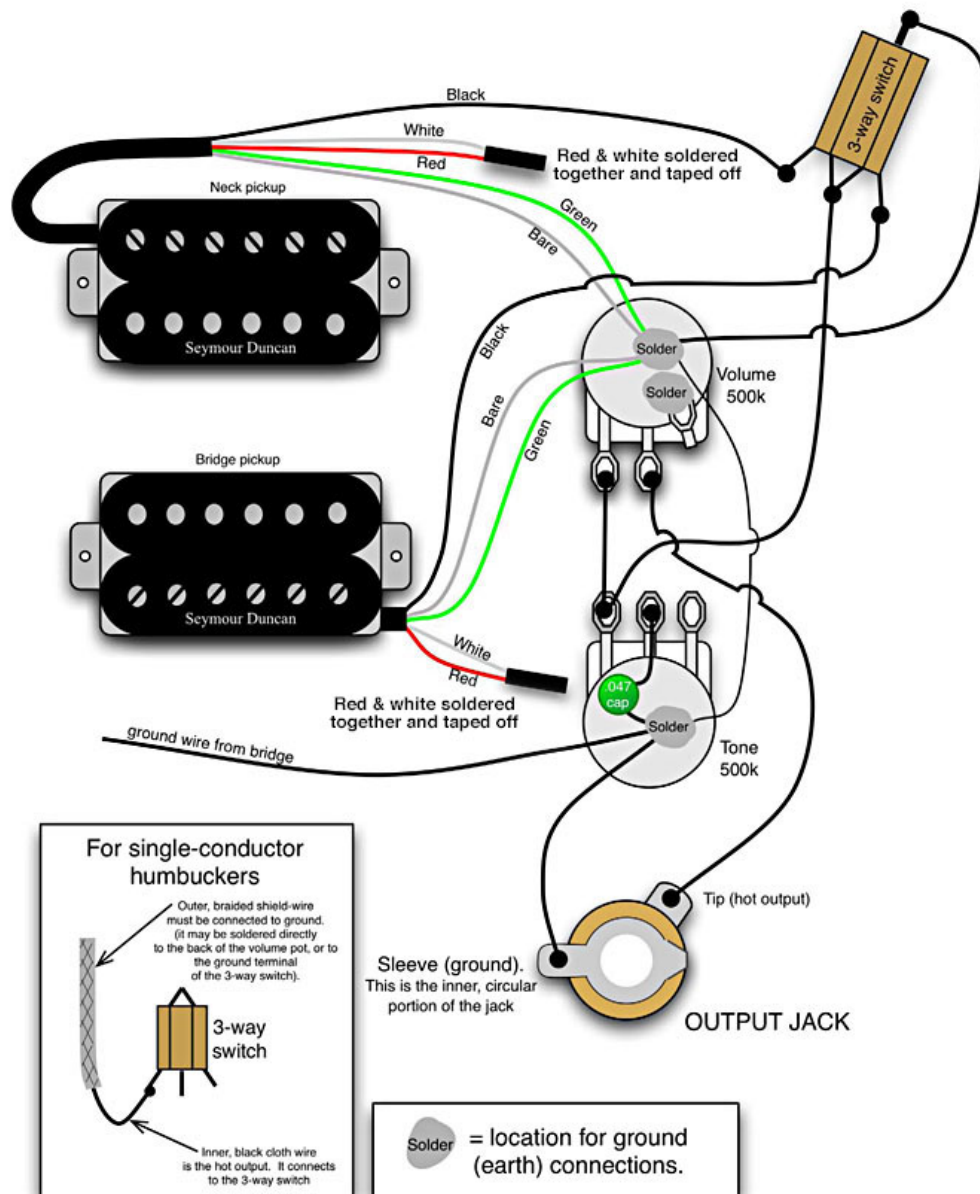


Seymour Duncan

5427 Hollister Ave. • Santa Barbara, CA. 93111
Phone: 805.964.9610 • Fax: 805.964.9749 • Email: wiring@seymourduncan.com

Figure 38 – Wiring Diagram for Single Pickup Guitar (image courtesy of Seymour Duncan, www.seymourduncan.com)

2 Humbuckers, 1 Volume, 1 Tone, 3 Way Switch



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**Seymour
Duncan®**

5427 Hollister Ave. • Santa Barbara, CA. 93111

Phone: 805.964.9610 • Fax: 805.964.9749 • Email: wiring@seymourduncan.com

Figure 39 – Wiring Diagram for Two Pickup Guitar (image courtesy of Seymour Duncan, www.seymourduncan.com)

Assembling Guitar

Now, you are ready to assemble your guitar. Install the bridge, making sure that the bridge ground wire is in place. To make sure that the bridge ground works, check the electrical resistance between the top of the bridge and the free end of the ground wire; there should be no resistance.

Now, install the wiring harness in the electronics pocket and make the final connections with the pickup and the bridge ground. Secure the potentiometers with nuts and lock washers. Also, secure the output jack to the jack plate, then screw the jack plate to the body using #4 sheet metal screws.



Figure 40 – Jack Plate Secured to the Body

It is usually convenient to install the tuners before the neck is attached to the body. There are several different type of tuner, but most of them have a nut surrounding the string post that must be tightened in order to hold the tuner in place. Also, most tuners have a small screw on the back that keeps the tuner from rotating. Figure 41 shows typical tuners from the front. There is a heavy washer between the retaining nut and the wood headstock. Figure 42 shows the same tuners from the back - note the small (#2) screws. Be sure to install the tuning machines so that the gearbox is toward the body.



Figure 41 – Tuning Machines Mounted on a Headstock



Figure 42 – The Back of a Headstock Showing the Small Set Screws

The next step is to screw the neck to the body. Be sure that the neck is completely seated in the neck pocket before tightening the neck screws. If the neck is seated well, there will be no gap between the bottom of the neck and the top surface of the neck pocket. Figure 43 shows the neck plate with the screws installed. The screws are 1 3/4" #8 sheet metal screws. Figure 44 shows the same instrument from the side. Note there is no gap at the joint between the bottom of the neck and the top surface of the neck pocket.



Figure 43 – Neck Fixed to Body with a Neck Plate and Screws



Figure 44 – Neck Properly Seated In Pocket

This is a good time to install the strap buttons. One should go at the back of the body and the other one should go at the top of the upper bout. If there is a horn at the top of the body, the strap button should be placed at the end. It is important that the balance point (center of gravity) of the instrument be behind the front strap button. If it isn't you will likely have balance

problems with the instrument when playing while standing up. The strap button is just held in place with a #8 sheet metal screw.



Figure 45 – Rear Strap Button

Making the String Nut

The last part to be installed on the guitar is the string nut. The nut can be made of many different materials including plastics, wood, brass and bone. You will likely be made of Corian, a durable plastic sold for counter tops. It is inexpensive, effective, easy to shape and comes in many different colors.

Start by sanding the nut blank so that it fits snugly in the nut slot. You should be able to seat it with finger pressure, but it shouldn't be loose enough to wiggle. Also trim the sides so that it is exactly as wide as the fretboard. The next step is to radius the top so that it matches the radius of the neck. Use a wood pencil that has been cut in half the long way to mark the nut as shown in Figure 46. Figure 47 shows the result.

Now sand the nut to the top of the radius line you just marked. If you are worried about sanding too far down, it's fine to leave a little material (1/32" or so) above the pencil mark. Also, make sure the top of the radiused nut is sloped toward the headstock by about 15° as shown in Figure 48.



Figure 46 – Marking the Neck Radius on the Nut



Figure 47 – String Nut with the Radius Marked Correctly

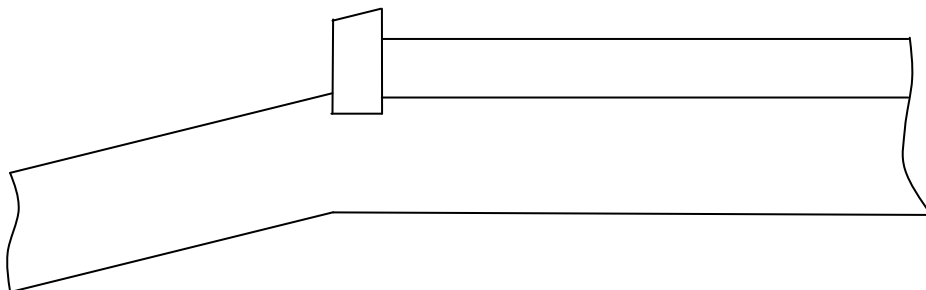


Figure 48 – Taper the String Nut towards the Headstock

Once you have sanded the nut to the correct radius, you can mark the locations of the strings. Using a sharp pencil, first mark the locations of the 1st and 6th strings. String 1 is the lightest treble string and string 6 is the heaviest bass string.

The 1st and 6th strings should be $\frac{1}{8}$ " from the edge of the nut. Some players like the 6th string to be a little closer to the edge of the nut. When you are locating strings, even tiny distances are important – moving a string even $\frac{1}{64}$ " is enough to be noticeable to a skilled player. Figure 49 shows the first two strings locations marked on a string nut.

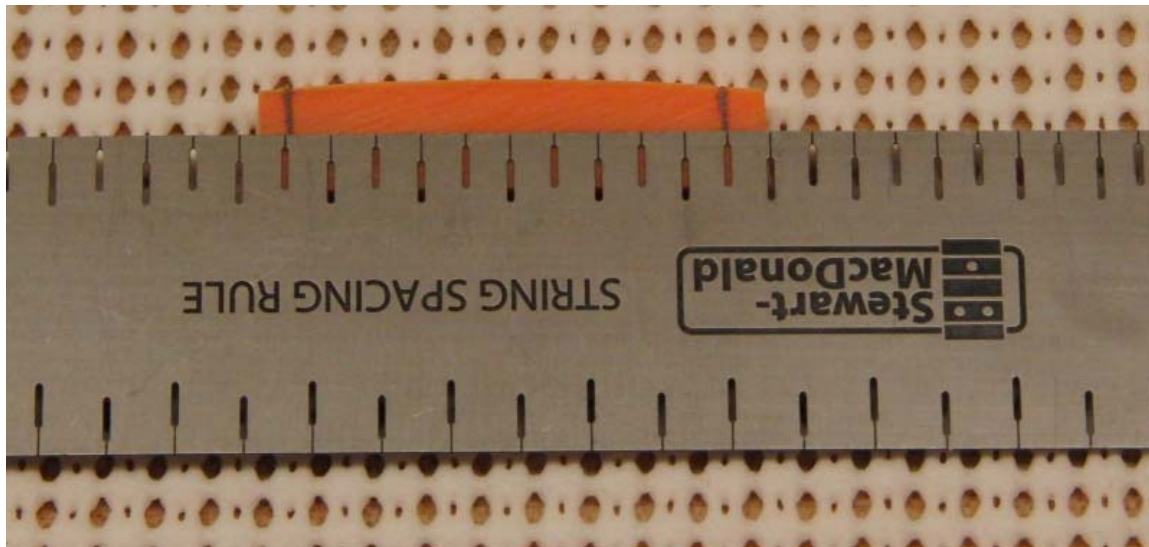


Figure 49 – Locations of 1st and 6th Strings

Strings are not evenly spaced on center. Rather, the distance between the strings is the same across the neck. To get this spacing correct, use a string spacing rule as shown in Figure 50.

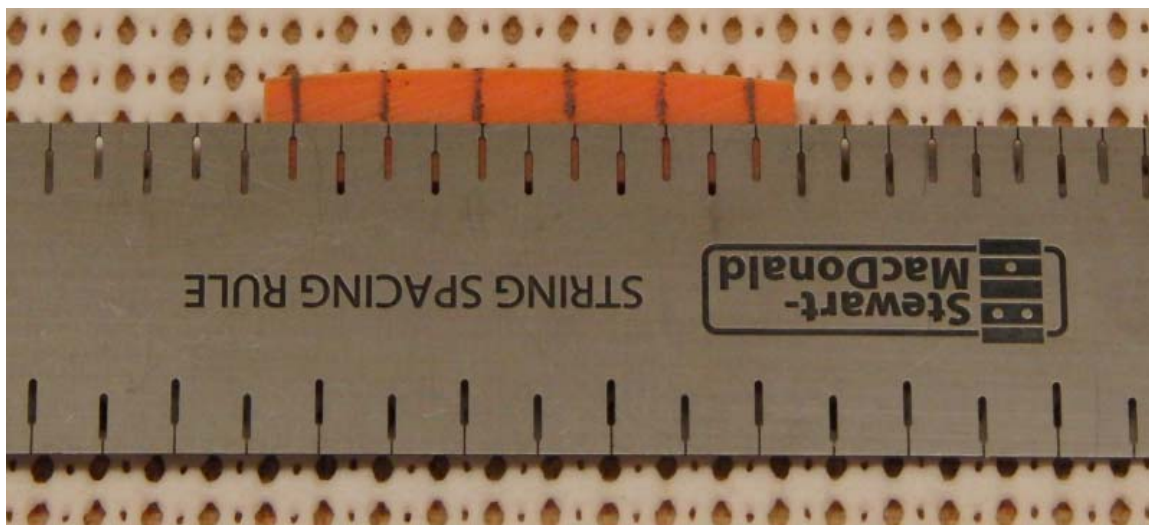


Figure 50 – Laying Out String Locations with a String Spacing Rule

There are slots along both sides of the string space rule and you just select the side you need; you'll need the side with the slots closest together. Make sure you have it placed so the larger spacing is on the bass side of the nut and then move the rule until you find a group of six slots where the outer two line up with your first two pencil marks. Also, the slots are staggered so they are alternately closer and farther from the edge. You can't mix and match – you have to use one or the other. In Figure 50, the slots closer to the edge of the rule are being used.

The last step in making the string nut is to file the string slots. You'll need three nut slotting files as shown in Figure 51. They have a total of six different edge radii. Start with the sharpest one (the one marked .012"/.016") and find the sharpest edge. You'll have to do this by feel and appearance since the blades aren't marked directly.



Figure 51 – Nut Slotting Files

File a shallow slot across top of the nut, splitting each of your pencil marks. Accuracy is very important, so take your time and get it right. Make sure the file is perpendicular to the face of the nut (parallel to the centerline of the guitar). Once the thin notches are made, widen the bass ones using a larger radius file. At this point, you are just making a notch big enough to hold the strings in place; you'll deepen the slots later to set the correct string height. Now, it's time to install the strings.

Stringing Your Guitar

Insert the strings through the bridge or the back of the body, depending on the type of bridge on your guitar. The ball ends of the strings prevent the strings from pulling through. Also make sure you put the strings in the proper order – treble on the right and bass on the left as you look at the front of the guitar. Figure 52 shows color coded D'Addario strings installed on a top-loading bridge. When winding the strings around the tuner post, make sure that the strings leave the post on the side of the post towards the center of the headstock. Figure 41 shows strings on a 3/3 headstock and Figure 53 shows strings on a 6 inline headstock.

Now that your guitar has a nice finish on it, make sure to put a soft pad between it and the bench top. Note that some finishes react with some soft plastics. The type of pad shown Figure 54 is often sold for drawer liners. It is inexpensive and effective, but reacts with lacquer finishes. The guitar in this picture has a Tru-Oil finish over tinted shellac, so there was no problem.



Figure 52 – Color-coded Strings Made by D’Addario (www.daddario.com)



Figure 53 – Strings on an Inline Head



Figure 54 – A Guitar on a Protective Pad

The wound strings don't generally need to be twisted after going through the hole in the tuner post since the windings create friction. However the plain strings need some additional locking. There are several different ways to secure the strings around the tuner posts. Here is one that works pretty well. Start by putting the plain string through the hole in the tuner as shown in Figure 55. Be sure to leave enough slack in the string to allow it to wind around the tuner post several times.



Figure 55 – Inserting Plain String through Hole in Tuner Post

Next, bend the free end of the string forward as shown in Figure 56 and then wrap the free end around as shown in Figure 57.

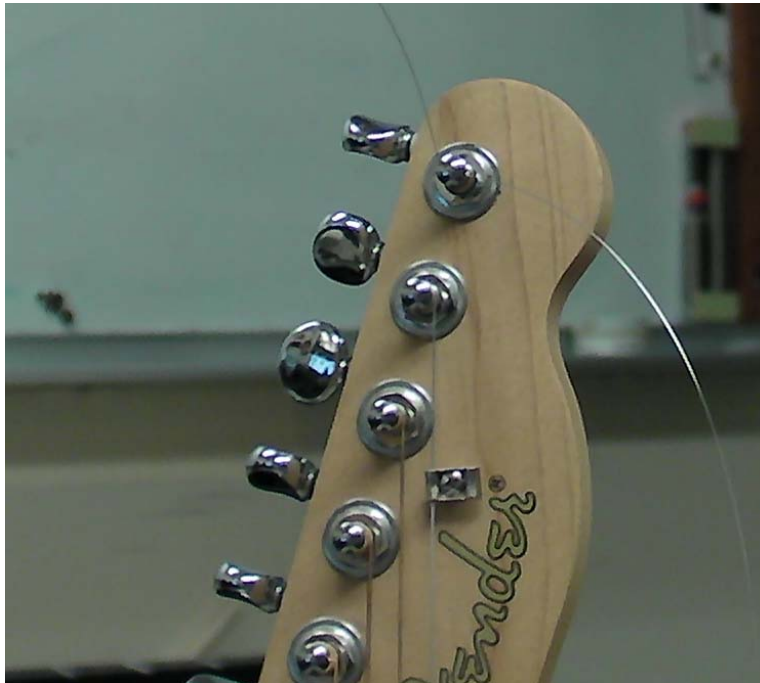


Figure 56 – Bending String Forward

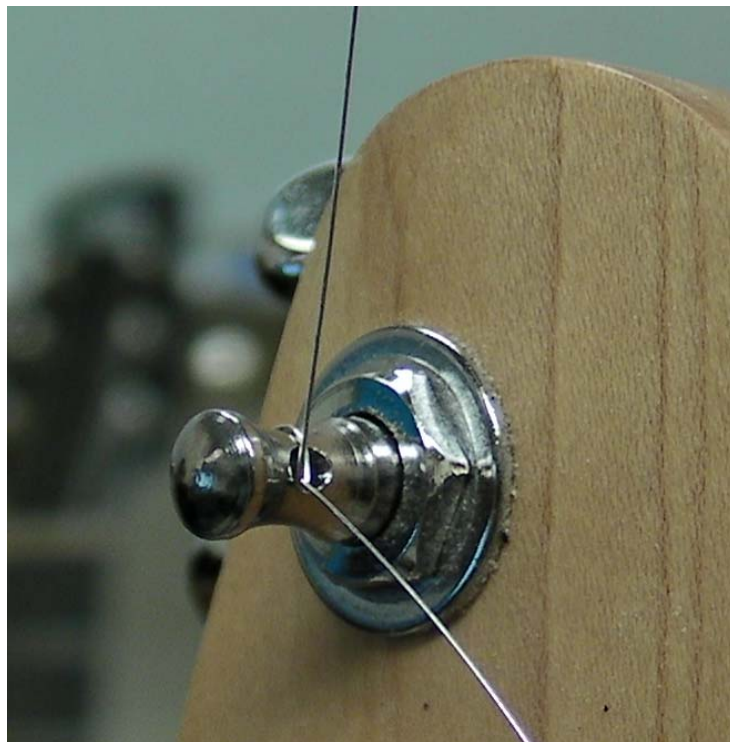


Figure 57 – Free End Wrapped Around

Finally, turn the tuner knob with a tuner wrench so that the string winds up neatly around the tuner post as shown in Figure 58. Use a pair of wire cutters to trim the excess string. Be careful, though, the short trimmed end is really sharp – think hypodermic needle.

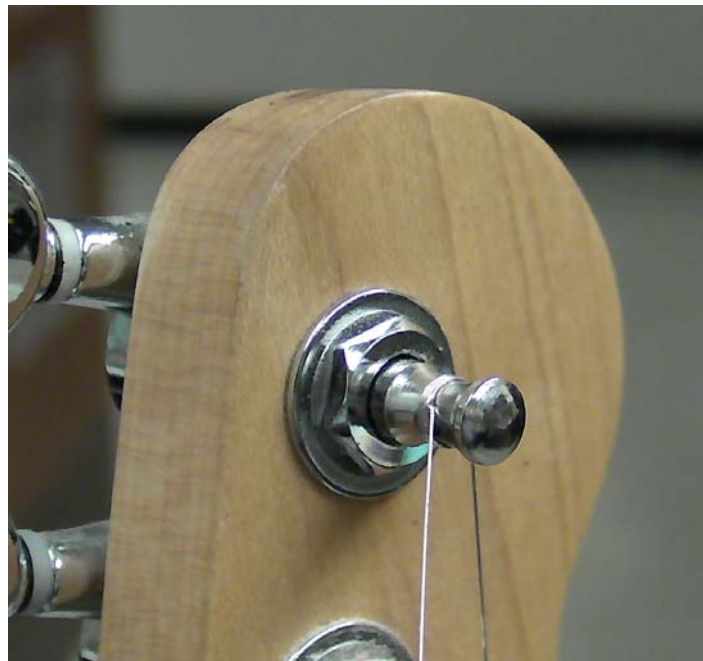


Figure 58 – String Wound onto Tuner Post



Figure 59 – Trimmed End of String (Sharp!)

Setting String Action

Your guitar is now completely assembled. However, before you can play it, you will need to set the string height, the saddle position and tune it. Start by setting the string height. Players often call the string height the action. Different players prefer different string heights and you may well want to change the string height later. Since it's easier to lower than to raise the strings, it makes sense to set them a little high at first. The height is defined as the distance from the bottom of the string to the top of the fret. Use these heights for now:

- 0.030" at the 1st fret (0.76 mm)
- 0.090" at the 12th fret (2.3 mm)

Figure 60 shows how to use a string action gauge to check the height of the string above the fret.



Figure 60 – Using String Action Gauge

The strings are likely to be way too high since you haven't finished slotting the string nut. Lower the strings at the first fret by filing the nut slots deeper. Simply pop the string out of the slot, file as needed and replace the string to check the height. The strings don't have to be at

concert pitch, but they should be tight enough that they are straight. Heavy strings will bend slightly between the nut and 1st fret if the tension is very low and this could give you an incorrect height measurement.

Height at the 12th fret is changed by raising or lowering the bridge saddles using an Allen wrench. Each saddle has two small set screws that adjusted in unison keep the saddle level. In addition setting the action, the saddles should be adjusted so that they maintain the 12" radius of the fretboard. Figure 61 shows a typical bridge with adjustable saddles.

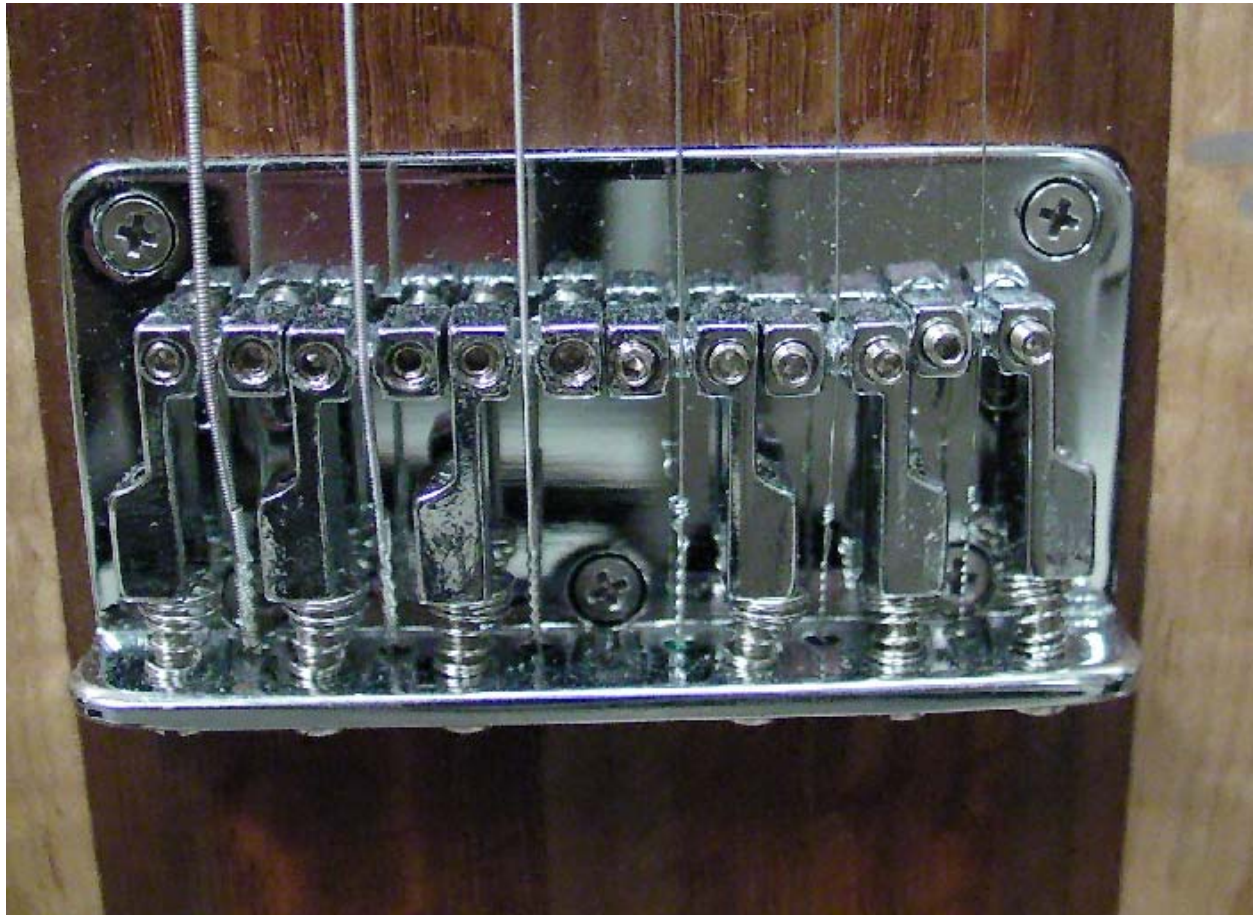


Figure 61 – Adjustable Saddles on an Electric Guitar Bridge

Setting Intonation

The last adjustment to be made is intonation. Adjusting the saddle requires moving the saddle forwards or back using screws at the back of the bridge (Figure 62). Intonation adjustments are required because real strings do not behave exactly like the mathematical ideal used to calculate the fret locations. Rather, the pitch of the strings is increasingly too high as you fret notes high up the neck. To correct for this effect (called inharmonicity), the saddles are moved back slightly from their theoretically correct position.



Figure 62 – Intonation Adjustment Screws

To set intonation, bring the instrument to concert pitch using an electronic tuner. Then, one by one, compare the open string pitch to the pitch at the 12th fret. These notes should be exactly an octave apart, but the 12th fret is likely to be sharp. If this is the case, move the saddle back slightly (about 1/16" is enough to start with). Re-tune the open string and repeat the process until the open string and the 12th fret are exactly an octave apart – a chromatic tuner will show the same note for both of them.

After you've set the intonation, you are done. You've made your own electric guitar! Now go play it.

Additional Reading

- Technical Books
 - Engineering the Guitar: Theory and Practice by Mark French, Springer, 2008.
 - The Physics of Musical Instruments by Neville Fletcher and Thomas Rossing, Springer 2008
- Electric Guitar Construction - General
 - Build Your Own Electric Guitar: Complete Instructions and Full-Size Plans by Martin Oakam, Trafalgar Square Books, 2006
 - Building Electric Guitars: How to Make Solid-Body, Hollow-Body and Semi-Acoustic Electric Guitars and Bass Guitars by Martin Koch, Koch Verlag, 2001
 - Electric Guitar Construction: A Guide for the First Time Builder by Tom Hirst, Centerstream Publications, 2002
 - Make Your Own Electric Guitar, 2nd ed. by Melvyn Hiscock, NBS Publications 2003
- Electric Guitar Construction - Specialized
 - How to Make Your Electric Guitar Play Great by Dan Erlewine, Backbeat Books, 2001
 - Fret Work Step by Step by Dan Erlewine, Stewart MacDonald, 1994
 - Complete Illustrated Guide to Finishing by Jeff Jewitt and Susan Jewitt, Taunton Press, 2004
- Electronics
 - The Guitar Pickup Handbook by Dave Hunter, Backbeat Books, 2009
 - Guitar Electronics for Musicians by Donald Brosnac, Omnibus Press, 2009

Suppliers

- Irwin Industrial Tools, www.irwin.com
 - Their Quick Grip clamps are where it's at. You'll never use a C-clamp again. Also, their little dovetail pull saw is perfect for cleaning out fret slots.
- Stewart MacDonald, www.stewmac.com
 - If they don't have it, you don't need it. They have a staff of experts who also develop new tools and write instructional books. Prices are competitive, but you can occasionally find better deals elsewhere. They offer at 10% educational discount and quantity discounts that usually make up the difference.
- Seymour Duncan, www.seymourduncan.com
 - Lots and lots of high quality pickups. Hard to imagine a need they can't fill. Their web site has zillions of wiring diagrams and other useful information
- Woodcraft, www.woodcraft.com
 - Tools and other supplies for hardcore woodworkers. Tools are generally of high quality. One of the few places to buy center finding rules.

Electromagnetic Pickups

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The first electromagnetic pickups were developed in the 1930's. Perhaps the best known among the early pickups was that used by Charlie Christian in the Gibson ES-150. It was very large by current standards, being about 6 inches long and weighing almost two pounds. The ES-150 was first sold in 1936.



Figure 1 – Gibson ES-150 with a Charlie Christian Pickup. (Wikipedia Commons, image is in the public domain)

Pickups with single coils are usually sensitive to the electromagnetic field produced by the AC power supplied to essentially all buildings (mains power). The frequency of mains power in the US and a few other countries is 60 Hz. It is 50 Hz elsewhere. Thus, single coil pickups tend to produce a 60 Hz or 50 Hz hum superimposed over the signal from the vibrating strings.

The electromagnetic pickup was further developed in 1955 when Seth Lover, a Gibson employee, developed the humbucker, a dual coil, hum cancelling pickup. Since then, other designers have introduced new magnet and coil geometries along with other innovations that have kept the magnetic pickup as the universal string sensor for solid body electric guitars.

Let's start by looking at the basic operation of a magnetic pickup. The principle that makes electromagnetic pickups work is Faraday's law of electromagnetic induction. This law states that when an electromagnetic field moves with respect to a wire, then an electromotive force is induced in the wire. Electromotive force is the force that causes electrons to move through a wire and is measured in volts, after Alessandro Volta who invented the battery.

We all are dependent on Faraday's law in our daily lives as it is the principle that makes electric motors and generators work. Figure 2 shows a bar magnet rotating next to a coil of wire. As the poles of the magnet pass the coil, they induce a voltage. The different poles will induce voltages of opposite signs, so the result will be a wave with both positive and negative peaks – alternating current or AC for short.

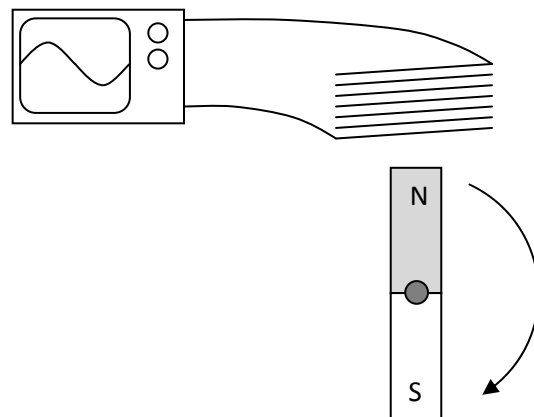


Figure 2 – A Simple Generator Making a Time-Varying Signal

Using the same principle, applied in a different way, the magnetic pickup generates a time-varying voltage in response to a moving string. There is an elegant difference in pickups in that the coil is wrapped around a stationary magnet or a group of several stationary magnets. Without relative motion between the coil and the electromagnet field, there is no signal, so this would seem to be a problem. However, the interaction between the magnet and the moving wire is reversible; not only does the field affect the wire, the wire also affects the field, making it vibrate slightly. Since the field vibrates and the coil doesn't, a voltage is induced in the coil. That's the signal that is sent to the amplifier to make sound.

Figure 3 shows a single magnet and single coil in the presence of a vibrating string. However, the most common type of single coil guitar pickup uses six magnets with the poles all aligned in the same direction. The coil of wire is typically wound around the magnets directly or around a bobbin which holds the magnets.

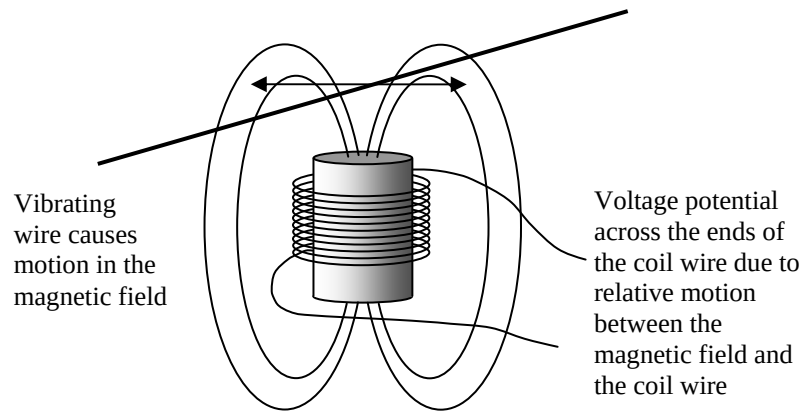


Figure 3 – Vibrating Wire Inducing a Voltage

Figure 4 shows the magnets for a traditional single coil pickup and the flat fiber plates in which they are mounted. Very fine wire is wound around the magnets to form the coil that senses the vibrating magnetic field.



Figure 4 – The Magnets and Flatwork of a Single Coil Pickup (image courtesy Stewart MacDonald, www.stewmac.com)

Figure 5 shows two single coil pickups in a solid body electric guitar. The ends of the magnets are clearly visible in both pickups. The upper pickup has a plastic cover hiding the coil while the lower pickup doesn't.



Figure 5 – Two Single Coil Pickups



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