

**Guitars
Design, Production and Repair**

Jim Donahue

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My experience in the guitar business is extensive and other then-washing dishes at a Chinese restaurant, and playing in bands working with guitars is the only job I have ever had.

I studied graphic arts in high school, after high school I spent three years in Bucks County College studying music and music theory. I studied Jazz guitar but after the third year my teacher told me that I should just play rock because I really had no interest in Jazz, basically I would only practice the scales and learn chords that I liked.

In 1984 I left college and was employed by Ibanez guitars. Since I started in the guitar business I began learning how-to setup instruments, my job was to check and setup 50 guitars a day. After one year I was promoted to the guitar repair department for five years until I became the manager of repair, teaching new employees repair and restoration.

Though the late 1980's into the early 1990's I had my own repair business out of my house and I became known for working on vintage guitars. Many local people from the east coast of the United States would only let me work on their guitars.

I have built, repaired or customized guitars for many people including Steve Vai, Joe Satriani, Larry Mitchell, Andy Timmons, John Petrucci, Paul Gilbert, Frank Gambali, George Benson, Pat Metheny, John Schofield, Paul Stanley, Gerald Veasley, Gary Willis and at least 50 more people worldwide.

From 1991 I was put in charge of Ibanez worldwide quality control from our Hoshino USA office in Bensalem Pennsylvania. I have visited Japan, Korea and China over thirty times, visiting over thirty-five guitar factories through out the world working with these factories to help them understand basic guitars from a market and playing point. Each factory has their own production style so I would only try to help them improve the product, how the improvements were done was up to the factory. Now in my career I am now working designing and building prototypes for Ibanez. I also have my personal Ibanez Vintage Web site at <http://www.ibanezvintage.com>.

Since the late 1980's I have been involved with designing somehow almost all the Ibanez guitar models. I really love guitars and other then my family, my life's passion is building and designing guitars. Because of my busy lifestyle it is impossible for me to play in a band because I could never devote the time involved to learn and practice songs. I still practice playing guitar everyday, and both my office at work and home are both filled with guitars hanging on the walls. Since I am always making something I still get to practice and try new things almost daily.

I own somewhere around 35 guitars I have a hard time counting them because so many are throughout the place, under beds, in closets or even out on loan to my friends. Of these 35 I made about 25 of them for myself and I have never sold a guitar, I still own my first Harmony Rocket that I bought for \$35.00 from a friend.

Tools, Jigs
and
Templates



This chapter is maybe the most essential in this book. My father taught me about tools when I was very young, I couldn't understand why he would get so mad when I would take a hammer and not put it back or leave it in the woods. Now I understand there is nothing more important than a persons tools. I keep mine under lock and key; I never try to let them out of my site. I have actually spent hours looking for tools that fell behind the bench. I learned don't blame anyone until you check every option.

My father used only craftsman tools that he bought at Sears but almost all my specialty tools I have made or modified from something else. Today thanks to companies like Stewart Macdonald and Luthiers Mercantile, these types of specialty tools are more easily available, however, I tried many new tools but they don't have the same feel as the ones I made.



I tried to count my tools, but it is impossible. I have hundreds that I have made, bought or been given over the years. Throughout this book you will see many tools, jigs and templates that I or someone close to me have made. I can only hope that these will help you to have some ideas for tools to make building easier. If you have any good ideas, you can always let me know I am always looking for good tools.

Where do I get my tools? Many of my tools are Japanese because they have a much better selection of tools than we do in the United States. They seem to have special tools for everything. I started working on guitars using Japanese tools back in 1984, and when I went to Japan someone took me to a department store called Tokyu Hands.

They have everything not just tools, but there is nothing that they don't have from pens to toilet paper holders. I was amazed they had so many files and bits. For example in the US you need to buy nut files from a specialty store, but in Japan you can purchase the sizes individually.

Dremel bits, they have things we only dream of like actual sanding drums that are 1/8"/1/4." These are great for cleaning out neck pockets without changing the shape.

I travel to Japan at least twice a year on business, and I always make a trip to Tokyu Hands to get new tools. For example, they have Magic Markers that are great for doing touch ups in every color. I bought my fret saws right over the counter and that is all I will use. They have many size hole reamers that you could never find here as well as different sizes of end nippers that can be modified to pull frets.

In the USA I do purchase tools from Sears, Home Depot and True value hardware. Luthier supply houses like Stewart Macdonald and Luthier's Merchantile are great places to find specialty tools in the States.

But, even still most of my tools have been modified somehow even if it is just making all my screwdrivers magnetic or modifying my files by putting handles on them.

This is a collection of fretting tools all hand made, The blocks are made from mahogany scrap. The upper block on the left is a broomstick handle with first felt then rubber around it, I use it for rounding the frets after leveling the tops. Next is my fret-cut back file for putting the angle on the fret ends. To the front is hand made fretting press cauls that I made years ago. These have the fret radius in them, and I use a drill press to push the frets in. In the center with the holes is a fret holder. Before the days of fret benders we used to bend and cut each fret to the size and shape of the fretboard, this holder holds 24 frets that I shape to the exact radius of the fretboard.



This is a collection of tools I made for set up. Just Allen wrenches set in dowel rods. First, they are much easier to use than a standard angled wrenches, second they are easier to find on a crowded desk and best of all then can be setup on a work bench for easy access. To do this I just use a grinder to make the wrenches straight and drill into the dowel the correct size and super glue the wrench in. The upper left tools are hand made scrappers that I make from old hack saw blades. Next is my custom nut cutting template that



someone before me made, it also works great for removing Gibson or acoustic nuts. I hold it against the nut and give it a quick tap with a hammer. The far right is one of my fret saws modified with a depth cutting control I made by gluing paint sticks on it , this helps keep the fret slot even on both sides.



This was designed by Fritz Katoh and is used for checking the neck set angle on acoustic guitars. This is basically a straight edge with a handmade gauge on the end. When laid across the frets the guage tells what the neck angle is set at. Many people use the same type of jig but with a fixed shim of say 14mm and use this when they are actually setting the neck before gluing.

These are fretboard protection jigs for leveling frets on painted fretboard's like a Strat with a maple fretboard. The template lies over the fingerboard, and the frets come up through. This allows you to level and crown the frets without causing damage to the fretboard finish.



Here is a collection of small tools, The top two on the left were actually made by a Japanese person before me that had my work bench I don't know who it was but thanks. They are used for raising the bridge on an Ibanez Gibraltar II bridge, and the second on is for tightening a 3-way toggle switch to the body without a pair of pliers that can scratch or deform the nut. The next jig is for marking the bridge stud location for a Floyd Rose that is counter sunk in the body. The others are my modified hacksaw blades that I ground down into scrapers.

This is a Fritz Ruler designed by Fritz Katoh. This tool has a nut cutting templates on one side; the other side has a metric ruler and string height adjustment. The tip is 0.5 mm for checking the nut height of the strings off the first fret. The purpose of this tool was to control factory setups at all of our manufacturers and distributors.

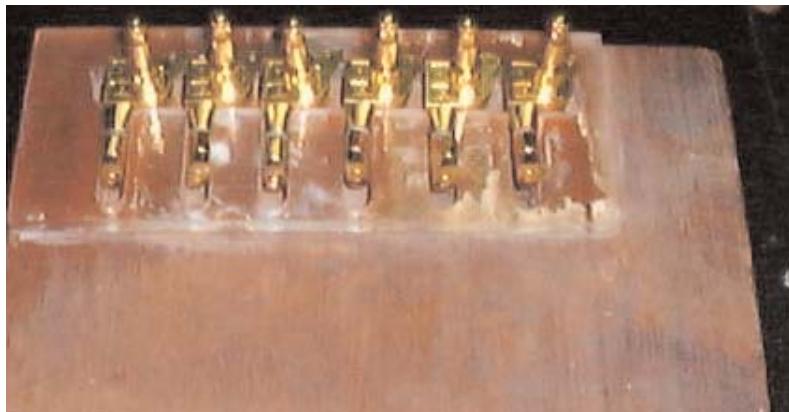


JIGS

If you will do anything more than once from drilling a side jack to presetting intonation, make a jig. I have jigs for everything. I started making jigs because I realized that if I measure something there is always a chance of making a mistake, like measuring a Lespaul bridge and then realizing you drilled the holes at 25.5" from the nut. For these reasons, I make a jig for almost every possible process.

Some jigs I made include a center jig for side jacks that marks a center hole inside for drilling, bridge and stud location templates, machine head installation, string retainer, intonation, neck set, top arch, mounting ring holes. For shaping necks on the pin router I have a jig that shapes as well as has the truss rod channel template in it.

To make a jig first figure out what you need to do, for example install a standard tremolo. Make a jig from Plexiglas that starts at the nut and has the location of the six bridge screws in it. A center line runs down the middle of the jig that you line up with the fretboard dots at the center of the guitar. Put six screws in the exact location on the template and press down this will give you the position of the bridge screws. Basically, you measure the jig once and from that point on, all your bridges will be in the exact same location.



I made this jig for machine heads, because when I replaced necks sometimes I had a hard time getting the tuners straight. This was a pain so I milled out a piece of wood to the exact location of the six tuners. I put the tuners in the jig and set the neck on it, put the nuts and washer's on the posts and tighten. This places all the tuners in a perfect line. Next I just drill the screw holes and add the screws.

Another thing that I had a problem installing off set was the Floyd Rose string retainer bar on the headstock. It seemed that no matter how hard I tried to drill the holes the retainer would be uneven. I made a small piece of Plexiglas with the two screw hole locations that I hold against the fretboard before I put the top lock on, so the holes are marked perfect every time.

The little things on guitars are what can really drive you crazy. If you make a mistake such as installing a mounting ring off a center sometimes you can see the pickup rout, or even the ring maybe crooked. I actually milled a 1/2" piece of Plexiglas to the shape of the pickup rout and then added the location for the mounting ring holes, this allows me to drop the template in the rout, push down and the screw hole position is perfect every time.

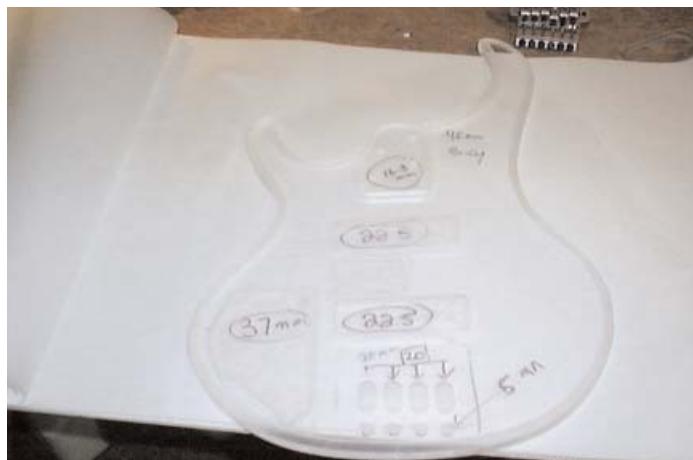


Trussrod channels can be either milled or routed. I have a few ways of doing it but for a hand router. I made truss rod channel jig for routing the channel slot.

This is a piece of Plexiglas with a milled out slot in the center. I use this for rods that are installed from the top or under the fretboard. For a rear channel trussrod that has a radius to it I have a router template that has a slight radius built in that the router travels on.

Templates

In making guitars or even modifying them, templates are not replaceable. I make templates for everything, and actually I make templates of complete guitars on the pin router just by copying them. I do this with almost every new production model just in case I need to make one.



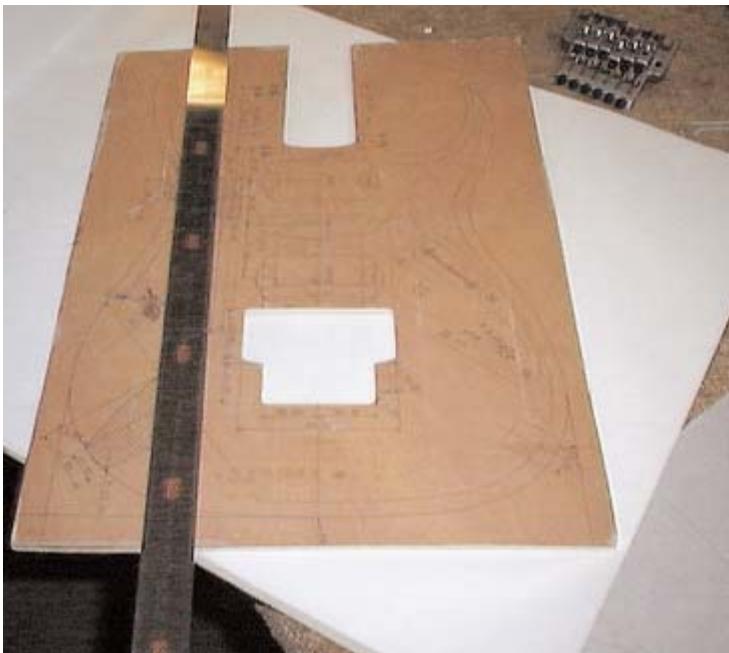
When I first started making bodies I would make the comfort cuts on the front and back by hand with a rasp. This worked fine, but everyone was different; I once saw this jig in a factory so I made one myself.

This Jig holds the body at a 15-degree angle for cutting a perfect comfort cut each time. The clamp holds the body in place, but you need a large band saw with at least 18" of headroom between the table and the head.



With the pin router it makes a perfect copy of the body, I can have one template to make the entire guitar instead of using many different ones. I found that every time I change the templates there's a possibility of making a mistake but if I use one template then I couldn't make any mistakes.

I can talk about templates all day but where do you get them. Well you can buy some of them like a pickup or tremolo rout but what fun is that. Some of my best templates are handmade.



First, you need to do something, maybe install a tremolo, add a humbucker to a Strat or something that needs routing. Most tremolo systems that you purchase come with a drawing of a template that you can make. Even the sink I installed in my bathroom had a template drawing on the box for the hole size to cut in the counter top.

What material you usually make the template out of depends on the purpose and essentially how often you will use it. Also the cost and availability of materials are also a factor.

Here's a list of materials that I use and my personal opinion as to their pro's and con's.

Plywood Templates:

These can be made out of any building grade plywood. They are really easy to make and the fastest material to work with. However, they don't last that long. If you are only going to use the template sometimes than this is great but if you will use it allot maybe you should consider a different material.

Hardwood Templates:

This is like a solid maple template. I sometimes use scraps of wood left over from cutting bodies. The cost to purchase new woods to make these is very high, and I have had a few solid wood templates warp so I don't use these.

Phenolic Templates:

These are great, but the cost is so high it just does not make sense to use.

Plexiglas:

My favorite material. It's really cheap if you get it the way I do. There is a Plexiglas distributor in Northeast Philadelphia that makes and sells Plexiglas. They have a small store that sells the scraps left over from custom orders. I buy almost all my Plexiglas here. Building stores like Home Depot also have Plexiglas. The best thing about Plexiglas is its see though so it's easy to lineup.



To make a template, if you have a milling machine this is the best (Yeah right) Ok you don't have a milling machine now what.

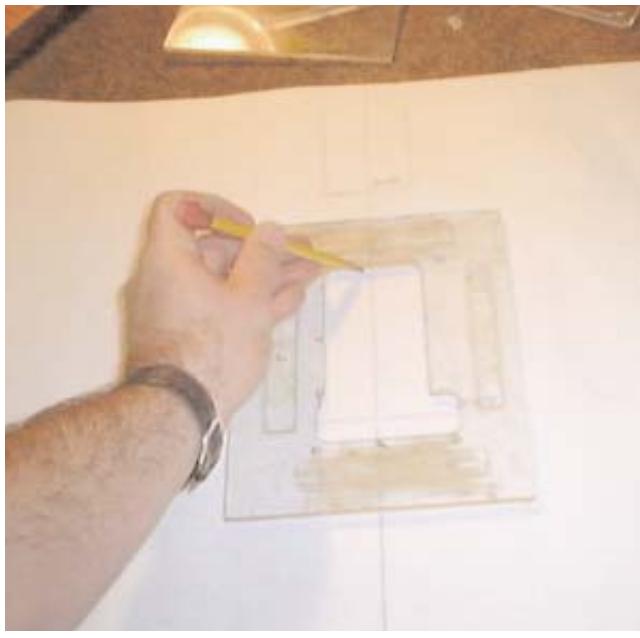
The minimum tools I suggest for this are a ruler, a circle template, drill press (Hand drill or Dremel tool) band saw or scroll saw is great, a scribe (An Exacto blade works good) and small round file, a flat file and some course and fine sand paper (#80, #120, #280, #500)

First, if you have instructions for a template, follow them and make a drawing on the material. If the material does not have a paper surface like new Plexiglas to draw on, cover the material with masking tape. Use new tape old tape will be difficult to remove after the template is finished.

If there are no instructions, measure the width, length and depth of the part that will be installed and figure out what size template you need to make. Use the circle template to figure out the corner radius. If you don't have this tool, drill bits actually have the exact size for a radius on the but end.



Always start from center, so make a centerline down the middle using a straight edge. This is the most important part. Use the scribe to mark a centerline into the material, you will need this when aligning the template to the surface for routing.

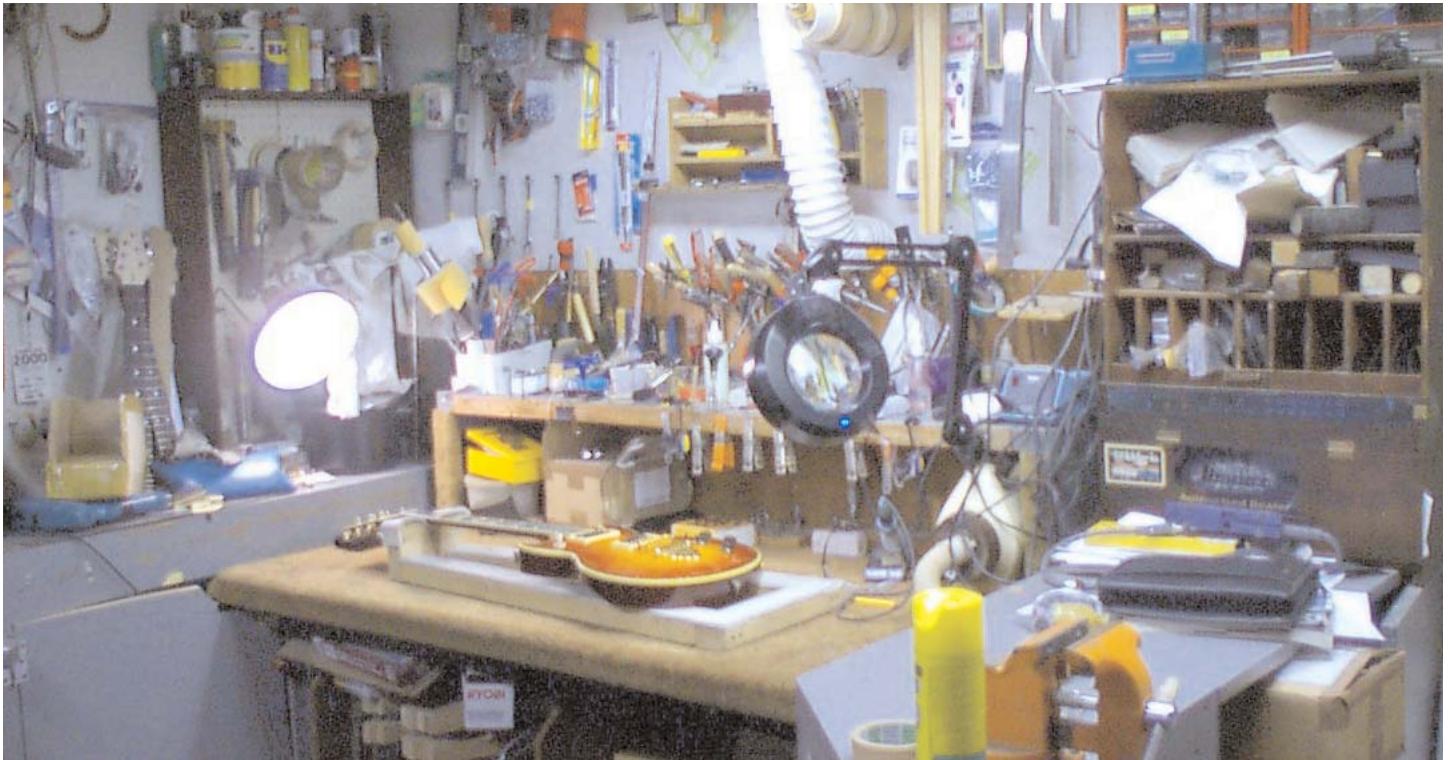


Take the part that you will be installing and find the center point using a ruler. Not all parts are perfect to center, an example is a Strat bridge that has a longer section for the tremolo arm socket so be careful. On bridges I always start from the center of the string saddles. Measure from center out. For example, if the part is 50mm wide start from center and go out in either direction 25mm from center and make the lines. Do this also with the length. For the corners if you want them to be round figure the corner radius and draw it. (Note: If you leave the corner square and use a router bit the corner will be round after routing because the router bit is round)

Next if you have a milling table just lock it down and mill away. If not use a drill press and the proper size drill bit to drill out the corners of the template. If you have a scroll saw cut out the shape of the template. You can also use a small hacksaw blade to hand cut the template's shape. I have actually drilled a bunch of holes in the template to start the shape and then filed out the remaining area with a coarse file.

Once the template is roughed out you will need to clean up the inside of the template using flat and round files. Then if you're like me, use the sandpaper to make the template look good. (You never know who will borrow it.) That's it. It's also a great idea to mark the template with the purpose, date made and your name.

For attaching the templates to the wood, you can use either double stick tape or screws. If you prefer screws try to find a location on the template that there will be a screw in the body. For humbucking pickup templates I sometimes use the pickup mounting ring screw holes to hold it down. I prefer good double stick tape though.



This is my workbench at work; it took me eighteen years to make this. Every tool is within my reach, and I get most without thinking where they are.

The guitar cradle is made from 2X3" studs covered with felt I have two vacuums one on the desk for quick clean up like fret filings and the second under the desk for major cleanup. The dryer hose is connected to an exhaust fan and when I solder it removes the fumes.

This is my workbench at my house. I also have a wood working shop in my garage for routing, cutting and some spraying. My wife also does the laundry down here so that is why you see the hangers.



Guitar Maintenance

There is nothing more important than basic maintenance, and in this chapter I would like to explain the details on the general up-keep of your guitars, how to make adjustments and the how to do the minor repairs needed to keep your guitar in great playing condition.

On my desk here are the basic tools and supplies that I use, You don't need all of them but if you have them around they are good to use.



Weather Conditions.

First, I must get into this subject. Your guitar is now part of the family, treat it like a family member and it will reward you with many years of satisfaction.

Winter, Spring, Summer and Fall

Winter

This is the worst time of the year for many instruments. Guitars are made of woods and just as a window swells in the summer, and can't be opened, or shrinks in the winter to let all the cold air in. Guitars are woods and will do the same. The problem in the winter months is the dry heat. Most heaters use some form of dry hot air to heat a room. While this makes it comfortable for people, woods need moisture. People drink water to keep themselves alive, but no one gives their guitar a drink of water? Of course, if your family member is thirsty than you give them a drink but what about your guitar? Some examples of a thirsty guitar would be one that the neck shrinks, and the fret ends stick out. The cells in the wood loosing moisture cause this. When the water leaves the wood, the cells shrink causing the wood to compress.

The best solution for this is to keep your guitar away from direct heat; a humidifier is one of the best ways to help by adding moisture to the air. Although this is not always an option never keep your guitar too close to direct heat, don't keep it on a stand next to a heater.

Spring

Spring is a great time of year and your guitar will also enjoy it. The weather is getting warmer so the heaters are off, and the air outside is getting moist. Just like your children your guitar will want to get out and play.

Summer

This is the second worst time of year for you baby. Especially in certain areas where the humidity is so high that you can actually feel it. Guitars do not like the extra moisture, and this can cause the opposite effect then winter. The neck will get too much moisture and start to swell. This can cause a neck to twist. Believe it or not, just because wood swells or shrinks does not mean it was not dried properly. If we took all the moisture out of the wood it would crack and crumble to nothing, most maple necks have a moisture content between 8% and 12% when they are dried.

Too much moisture will also cause the metal parts on the guitar like the bridge screws and frets to oxidize or rust. I recommend that after each playing you thoroughly wipe any moisture off the guitar. Also try to keep it in an air conditioned or cool environment as much as possible.

From my experience basements can cause your guitars to become covered in mold so unless the basement has climate control keep the guitars out of them. If your guitar starts to rust what I suggest is to wipe off the moisture with a dry cloth. On the fret's use #0000 steel wool in a motion with the grain of the wood (back and forth from the first fret to the last fret.) After the rust is off the frets, any exposed wood should be oiled. I use Old English lemon oil on the fretboard to add moisture and protect the wood from cracking.

If your bridge screws or any non-plated metal parts start to rust here is a good solution. Take an old toothbrush and some oil. (WD40 or Motor oil) and scrub the rusty parts with oil on the brush, this will remove the rust and keep a nice protective coat of oil on the non-plated parts.

Fall

This is another great time of year for your guitar. It will enjoy the nice weather and love to be outside its case playing.

Do's and Don't for guitars

Don't leave your guitar in the trunk of your car! Would you leave your kids in the trunk? The sun beats on a car, and the trunk can get too hot in the summer and too cold in the winter. I only sometimes travel with my guitar in the trunk for short distances but only in a hard-shell case never in a gig bag.

Don't put your guitar through checked baggage on an airplane; take it on board with you. There is nothing worse than watching a guitar come down the baggage shoot with the rest of the bags.

Don't leave your guitar unattended anywhere. Just like your children they can wonder off never to be seen again.

Don't lean your guitar against the wall, this will put too much stress on the neck and can easily slide and fall over breaking the neck off, use a guitar stand.

Do play your guitar as much as possible it likes this, the more you play with it the happier it will be. Don't let it sit on a stand and get dusty, keep it clean and polished to protect the finish.

If your guitars are not playing as well as you feel they should be, it may be time for a basic setup. If the guitar is in really bad shape and you are afraid to then maybe you should take it to a guitar shop for service, however, most basic guitar setup is fairly easy and can be handled at home with the proper tools.

Basic tools needed for guitar setups are.

New strings, WD40 oil, Allan wrench sets (Metric or SAE depending on the country or origin), A tuner, guitar polish and soft cloth, steel wool, a steel rule, string cutters, Phillips screw driver, flat head screwdriver, adjustable wrench, and the proper truss rod wrench for your guitar. Optional for truss rod adjustment. Capo, metric feeler gauges.

For FloydRose® tremolo systems I recommend propping the bridge up with a Fuzzy Stick, basically this is a piece of wood that is 5mm thick, 30mm wide with a length of 100mm, covered with either cloth, felt or rubber. I use this to hold the bridge up during string changes.



First lets start by removing the strings and cleaning all the parts. If you have a FloydRose® tremolo try this. Take the tremolo arm and press it down so that the strings are slack. Then insert the Fuzzy Stick between the bridge and the body to hold the bridge up while you remove the strings. This will help in a few ways. 1) It will hold the bridge up so that string change is easier. 2) It will keep the springs in the bridge so they don't shoot off. 3) It will make it much easier to re-string the guitar.

Note: (9 Volt Batteries also works well to hold up the bridge)



Now that the strings are off the guitar clean it up. Use the polish and a cloth for all the painted surfaces. It's good to clean around the pickups, bridge and headstock while you have the strings off.

Loose Parts.

It's best to tighten all the screws periodically on the guitar, at each string change I tighten the following parts, neck bolts, bridge lock screws, top lock mounting hardware, tuning machine heads top and back, remember "Loose Parts Break Guitars"

Always check that the strap pins are tight in the wood so they don't pull out. If the strap pin does not tighten then remove it and put a dowel in the hole and re-drill it. If this is a problem just put some toothpicks in the hole than reattach the strap pin, this will easily tighten it. Use WD40 or motor oil on all open metal parts, these are the screws that are not plated, for example, Allan screws in the bridge or some adjustable pole pieces on the pickups.

Fretboard Maintenance

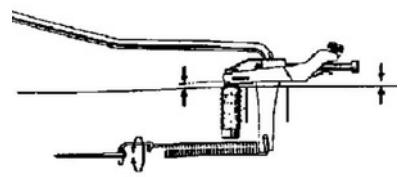
At each string change I clean the fretboard and the frets, I like the frets to be very smooth with no rough spots so I use #0000 steel wool with the grain of the neck on rosewood and ebony fretboard's and then Lemon oil on the wood. On finished maple boards I use the steel wool only on the tops of the frets, and then I use guitar polish on the fingerboard finish to clean it up. After the frets are cleaned I polish them on a metal buffering wheel; the one I have is mounted but a small buffering wheel in a drill works well also.

Now re-string the guitar with the proper gauge of strings. If you will change string gauges (say from .009's to .010s) then this is the time to do it. Depending on the type of bridge you have the strings will either go through a block, lock in at the saddles or go through the back of the bridge.

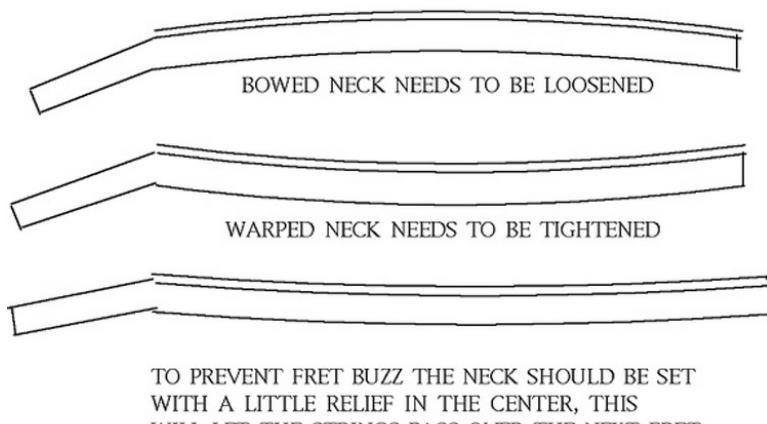
On a FloydRose® tremolo cut off the ball ends and lock them in the bridge. Tighten the strings and remove the stick that is holding the bridge up, then re-tune the guitar, remember FloydRose® tremolos take some time to tune because they float. (What I do is actually over tune the low strings in the beginning and as you tune up the higher strings, the lower strings will go flat and come back down in tune.)

After you have replaced the strings tune the guitar to A=440 or whatever tuning you might use. After tuning, stretch them by pulling up on each one around where the neck meets the body, this is good for pulling everything tight so that the guitar stays in tune.

First, if you have a FloydRose® style tremolo make sure that the bridge is sitting parallel to the surface of the guitar. Remember that the fulcrum point on a locking tremolo is well in front of the actual saddles. If you depress the tremolo arm the strings will raise, what this means is that if the bridge is sitting high in the back, the action is higher than it could be. To remedy this, adjust the screws in the back of the tremolo cavity to tighten or loosen the spring tension.



At this point there are a few things that can make a guitar play great or make it really hard to play. I will explain them in detail.



The Truss Rod.

Most guitar necks are made from wood (not all but that is another subject). Wood does tend to move over time and may need to be adjusted.

To adjust the neck they designed the truss rod. The truss rod is a steel bar with a threaded shaft used for tightening or relieving the neck. (There are many styles of truss rods out there and I will get into detail about each one and what the advantages are of each in another chapter, for now lets concentrate on the adjustments.)

The neck should be set as straight as possible and then set with a small amount of relief, relief is described as a small concave warp that allows the strings to pass over the next fret without the string touching the next fret.

There are three types of neck conditions, and you should understand each one. The way that I sight the neck is to stand up and place the guitars strap pin on my foot. Hold the guitar upright with your left hand on the horn of the body. Do not touch the neck because the headstock needs to be free floating if you hold the headstock then it will give you a false reading.

A warped neck will cause the action in the middle of the neck to be higher and cause the middle notes to play sharp. This should be tightened. If the neck is over bowed the notes will not be able to pass over the next fret causing fret buzz this should be loosened.

RELIEF: means that the neck is almost straight but has just a little warp in the middle, so the strings can pass over the next fret without buzzing. The proper amount of relief can vary from guitar to guitar depending on the actual straightness of the neck. There are three conditions that normally occur, Warp, Over-bow and Twist. The first two can usually be adjusted with the truss rod. However, a twisted neck is difficult to adjust and may need further attention.

WARP: A warped neck means that the tension on the truss rod is not enough to counteract the string tension resulting in the middle of the neck to dip. The result is higher action in the middle of the neck and false intonation on the middle frets. This type of problem can be corrected by tightening the truss rod.

OVERBOW: An over-bowed neck means that the tension of the truss rod is too great, causing the middle of the neck to raise. This will cause fret buzz usually on the first 5 frets. This problem can be corrected by loosening the Truss rod.

TWIST: A twisted neck is a neck that has a combination of warp and overbow. The condition of the neck can usually not be corrected by adjusting the truss rod. How to check neck straightness. This Procedure of checking the neck for straightness is called "sighting the neck" Follow these steps to check the neck.



Fender® Guitar Company uses a feeler gauge at the 7th fret, while a Capo is placed on the neck at the first fret. Your right hand is fretting the low and high strings where the neck joins the body. (Usually around the 17th fret). They use between a 0.20mm and a 0.25mm gauge and adjust the truss rod until the gauge just fits between the top of the fret and the bottom of the string. This is a good reference, but I still prefer to set the necks by eye, mainly because not all necks are perfectly straight on both sides. My eyes can see the difference, and then I can adjust accordingly.

Neck Straightness:

This adjustment is critical to the playability of the instrument. It involves adjusting the truss rod inside the neck to assure that the neck has the proper amount of relief.

Nut Height

This to me is the essential way to make a guitar play well. The nut height should be low (on my guitars it just passes over the first fret) most factories set the nut at the first fret low string 0.5mm and the high side 0.4mm. To measure the distance place a gauge between the first fret and the bottom of the string. This is OK, but I prefer it set lower, around 0.3mm over the first fret on all strings.

This is my personal preference for my playing style and if you are a hard player I would suggest you stay around 0.5mm. Any higher and the action on the guitar will be higher and cause the notes to play sharp when they are fretted.



For an example while holding the guitar in playing position, use your left hand to raise the string at the nut then look at the action at the 12th fret you will see it change. On a Locking nut you can add or remove shims under the nut to get the proper nut height. If the nut is as low as it can be set and is still not low enough it needs to be worked on by a repair person that will either mill the nut or file the wood area. (Note this is a very delicate operation and should be done only by guitar repair people)

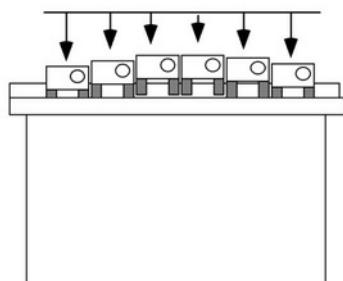
If the nut is cut from bone, plastic, graphite or brass, you will need to file the nut using special files for each size string. I will explain how to do this, but it's not that easy, I would not recommend everyone to do it. One slip of the file and the nut will need to be replaced.

The easiest way to avoid a mistake is to use a feeler gauge at the nut. First measure the height of the fret, say it is 1mm then you want the nut to be 0.5mm over the fret so use a 1.5mm gauge at the nut and file the slot to the top of the metal. This will make the nut exactly 0.5mm over the first fret.



Again, different bridges have different ways of setting the action. A locking tremolo and a Gibson® style bridge will have two studs at either side that raise or lower the bridge. Strat style tremolos have the individual height adjustment for each string, and some modern tremolos will have both.

To give you a standard is not a good idea because everyone plays his or her own way. I like really low action, but this will give a heavy player too many buzzes. I will only say one thing, set it where you want it to be. If you bend allot than you will probably like a little higher action, if you are a fast note player, lower action will probably be what you want. Remember this is your guitar so set it as you like.



If you are adjusting the individual string saddles you will need to pay attention to the fretboard radius. This means the middle strings will need to be set higher. A good way to do this is to set the high and low strings to where you like them. Using a ruler measure the distance between the top of the fret and the bottom of the string on both the high and low strings at the 12 fret.

Adjust the middle strings at the same setting as the low and high strings (The low strings for the low string setting and the high strings for the higher string setting) Play the guitar and adjust the action on each string so it feels correct.

Intonation.

Proper intonation is very important. Adjusting the length of the string at the saddle either longer or shorter sets intonation. Guitar scales are divided in the middle at the 12th fret. This is halfway to the bridge (On a 25.5" scale the 12 fret will fall at 12.75") Because of the difference in string tension and fret distance there needs to be a saddle adjustment to get the proper intonation.

Setting intonation.

First tune your guitar on a tuner; make sure that all the open notes are in perfect tune with the tuner. Start with the low string and fret the note at the twelfth fret, compare it to the open note. If the fretted note is sharp the saddle must be adjusted back. If the fretted note is flat the saddle needs to be moved forward. Both the open note and the fretted note should be the same on the tuner. Follow this method for all strings. Now its time to Jam. Play the guitar all over and make sure that there is no buzzing and that it's comfortable for you. If necessary make any adjustments to the guitar now to make it play the way you want.



First tune your guitar on a tuner; make sure that all the open notes are in perfect tune with the tuner. Start with the low string and fret the note at the twelfth fret, compare it to the open note. If the fretted note is sharp the saddle must be adjusted back. If the fretted note is flat the saddle needs to be moved forward. Both the open note and the fretted note should be the same on the tuner. Follow this method for all strings. Now its time to Jam. Play the guitar all over and make sure that there is no buzzing and that it's comfortable for you. If necessary make any adjustments to the guitar now to make it play the way you want.

Pickup Height

The higher or closer the pickup is to the strings, the more output the pickup would produce. However, this can allow a greater chance that the magnets of the pickups will affect the strings.

This type of problem can be easily noticed by the player's ears, causing a sort of in and out of tune sound.



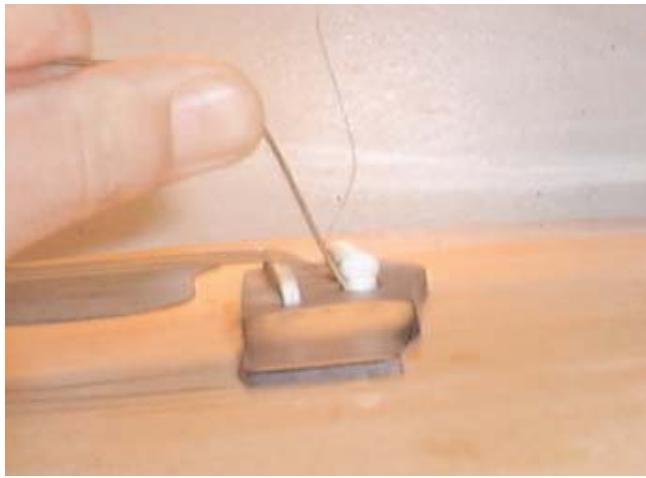
The string being pulled by the magnet causes this; you can usually see the notes going sharp on a tuner. I suggest adjusting the pickups to 2.5mm below the string when the last fret is fretted. Then adjust, as you like for the sound you desire.

Tuning

There is nothing more distracting than a guitar that won't stay in tune. So we will look at different kinds of guitars and the tuning problems that occur.

On all instruments it's good to have new strings, but new strings need to be stretched or they may continue to go flat. The reason for this is that strings are made straight without any tension on them. After the strings are installed on the guitar and tuned they begin to stretch out. The best way I have found to stretch the strings is to tune the guitar to pitch and stretch the strings, re-tune and continue this until the strings remain in tune even after pulling on them.

To stretch a string I first tune the guitar and using my right hand to hold the string at the nut (This is so I don't pull it out of the slot) I just grab the string where it meets the body and pull up.



On acoustic guitars often the strings ball end is not secure in the bridge and needs to be pulled into a secure place. This is because when you string the acoustic you put the ball end in the hole and then put the pin in. What I do for this is first put the string in the hole, put the bridge pin in and while pushing the pin in the bridge. I pull straight up on the string until it is nice and snug, frequently the hole can be too big and the pin will shoot out, in this case I pull the string towards the headstock with my left hand while holding the bridge pin in the bridge.



On nylon string guitars it seems that you can stretch and stretch the string for a long time before they hold their tune, this is of course because the nylon material has more elasticity than metal.

On the headstock always make sure that the machine heads are tight, this is done by usually tightening the nut on the top with a box wrench. They become loose because the wood will expand and contract from the weather changes, so if it is humidity is low the machine heads can easily become loose.

Once the instrument has new strings being it a bass, electric or acoustic guitar, now there are a few things that will cause a guitar to go out of tune.

The string wrap on the tuner.

The string should be wrapped even on the tuner not all over each other this can easily cause a guitar to go out of tune. How many wraps should you put on the gear? This is a question that many people argue about, and I feel that the fewer amounts are better for tuning, especially on a tremolo guitar without a top lock. The reason is each time the tremolo bar is depressed the string wrap around the tuner can become loose, and then it needs to pull back when the tremolo comes back. There are six strings and each one will need to come back exactly in tune so the more wraps on the tuner the more chance that it will not come back in tune.



Correct String Wrap



Incorrect String Wrap



Many companies make locking machine heads that has different heights for the strings at the tuner. The reason for this is that on a straight headstock the string needs to have a certain downward string tension off the nut or else the string will buzz open from the nut. This is the purpose of the tilted headstock on a Lespaul or even an acoustic, to pull the strings down from the nut. Companies such as Sperzel, Grover and Gotoh all make some type of locking gears. With a locking gear there is no string wrap, and I believe that Sperzel was the first to make this type of tuner called the Trim Lock. If you can get a set of Sperzel tuners you can easily see that these are some of the best and finest made machine heads in the world.

Now if your tuners are tight, you have new strings and they are all stretched and the guitar still does not stay in tune here are some remedies for you.

If your guitar has no locking nut such as an acoustic, Strat style or bass and when you turn the machine head you hear a creaking sound, this means that either the nut is too tight for the string or the angle of the string to the machine head is wrong.

To check if the string is too tight, loosen the string and pull it out of the nut. If it sticks at all, the nut is too tight.

To fix this just take some sand paper #400 or #500 and fold a small piece in half and sand the inside of the nut until the string is loose in the nut. Don't change the depth just work on the sides of the nut.

Usually, a quick fix for guitar nuts is to use a graphite pencil to lubricate the inside of the nut. This works well on bone or plastic nuts.



On all my guitars I use small files to change the direction of the nut for each string to aim it at the tuner. Only work on the side facing the headstock, the side towards the fretboard keeps the string spacing so don't touch that side. The main problem that you want to get rid of is the sharp edge on the tip of the nut on the headstock side.



Graphite is one of the best lubricants available and almost all pencils now a day are made from it. (The old lead ones could cause lead poisoning)

Another problem that I have found is that the directions of slots in the nut are almost always cut straight especially if the nut is molded. But if you look at the direction to the tuner, the machine head is angled away from the nut.



If the guitar has a locking tremolo make sure that the two bolts that hold the lock nut on are tight.

When the top lock pads are tight there is string tension on both sides of the nut. One is pulling towards the headstock and the other pulling towards the bridge.

If you push down on the tremolo and the top lock is loose the headstock wins the tug of war, and the guitar goes sharp. Once you pull back on the tremolo the bridge side wins, and the guitar comes back in tune

On Strat style bridges that have either six or two points these can sometimes not reset at there exact location when the bar is used. New tremolos usually work great but as they get older they can wear the knife-edges and cause the tremolo to stick. You can sand with # 800 very lightly if the bridge has the burrs but the screws that hold on the bridge is usually made of a softer material that they will wear out before the bridge plate.

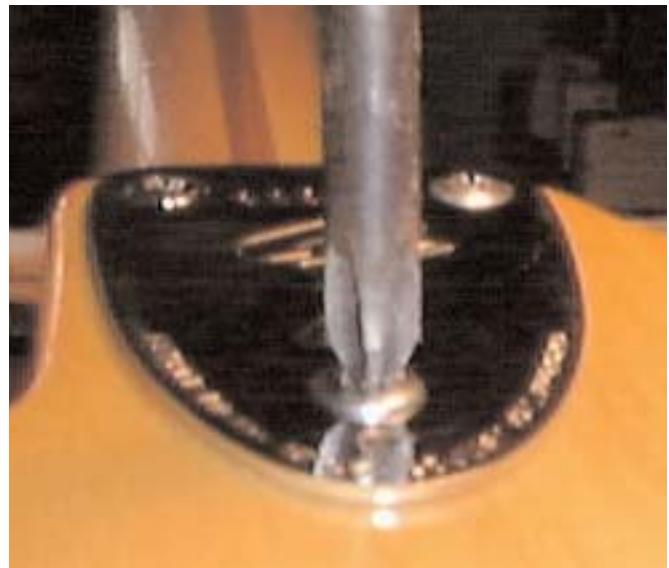
At this point it may be necessary to replace the screws or studs that hold on the bridge. You can also try a small amount of grease on the friction points to make the tremolo move better. If all else fails on this type of bridge you can always do what I do and put five springs in the back and tighten the bridge to the body or install a tremsetter. This will always assure that the tremolo returns to the exact position. Of course, you will not be able to pull up.



For locking tremolo bridges a big problem I have seen is that the inserts in the wood can become loose and move. To check this just look at the stud inserts in the wood when using the tremolo if they are moving, the guitar will not stay in tune also the action could change after using the bar. The correct way to fix this is to remove the metal insert, glue a dowel in the hole, re-drill it, and replace the insert.



But, this is not always possible at home so what I do is take the bridge off, push the insert all the way in the hole and take super glue and pour it around the outside of the insert. This is not actually gluing the metal to the wood, but the wood absorbs the super glue and when the glue hardens the wood become much stronger.



Another problem with bolt on necks is that the neck becomes loose and actually moves. This was a big problem on the old Fender three-bolt necks with the micro-tilt from the early 1980's I have changed many of these into standard four bolt neck plates because this neck system had a tendency to move. So always check the neck and body joint is tight by tightening the screws.

Parts

Parts

Guitar and bass parts are a very important subject and can easily take up an entire chapter. I have tried many different parts from bridges to machine heads and every part between. If the designer of the part is around he will try to sell you on that part no matter what. He will tell you all the best features and why it is better. Then you try the part, and it does not work, or needs allot of setup to get it to work.

Many inventors have sent me their samples of parts to try so I have a very good idea about what people are trying to improve, mainly bridges and machine heads.

Machine Heads

Ok I like Sperzel that is all I will use on my non-locking guitars. They are so well made that you don't feel any play in the gear. Again, this is my personal preference but I can talk anyone into using them.

Gear Ratio

Gear ratio is defined by how many revolutions of the button equal's one revolution of the shaft. Tighter tolerances usually mean more revolutions. When the gear ratio is say 18-1, the gear is very accurate so once the string is tight a small turn of the button is all that is needed to tune the string. because the size of the gear needed on bass tuners the ratio is usually higher. Usually between 20-1 and as high as 28-1 on large open machines.

Open Tuners

These are what you find on many acoustics also most of the vintage guitars. They are usually geared around 14-1 or 15-1. This type of tuner has a stamped plate and stamped cover.

The gear is usually visible when you take the cover off. These consist of a flat bottom plate and a gear that sits above the plate held in with a setscrew. In my mind these are the cheaper style of tuners and lend themselves to slipping, bending and breaking. This style of tuner is also what most nylon string guitars use, and on most nylon models you can easily see the construction of the tuner.



Die-Cast

With die-cast tuner construction, the tuner housing is cast and the gear is inserted in the cast. Die-casting is very accurate so there is a little margin for error on these. Once the gear is inserted and the grease is sealed in the tuner there is no further need for lubrication. Die-cast tuners on guitars are much heavier and this needs to be addressed during the design of the guitar, so as the guitar is not too headstock heavy. This is why you may not see many 12-string guitars with all Die-cast tuners.

Bridges

I have tried many bridges for both guitar and bass, and I have also repaired many a bridge. My opinion on both guitar and bass bridges is as follows. The fewer moving parts the less chance that the bridge will go out of adjustment and break.

Guitar Bridges.

I split guitar bridges down into a few different styles.

Standard Non Tremolo or Fixed.

This type of bridge is usually flat mounted on the top of the guitar and strung through the body and up over the saddles. These are good bridges for people that do allot of bends and don't want the strings going out of tune.

Standard Tremolo Bridges.

These are the bridges that a Strat uses, It normally has between two and six screws and the springs are attached in the back. It works well for basic tremolo effects but not for vigorous arm use.

Locking Tremolos.

This is a basic Floyd-Rose® or any other tremolo that locks in at the saddles as well as the nut area. These bridges generally only allow the basic height adjustment on either side of the bridge and not individual string adjustment.

Bridge and Tailpiece.

These are bridges that sit on the body and are adjusted by two studs or spinners on either side. The strings are attached to a separate tailpiece. I believe this was designed for carved top guitars because it does not need any flat surfaces to screw into. It is said that the tension on these bridges can be adjusted by raising or lowering the tailpiece. This changes the angle of the strings break-over on the saddle and increases or decreases the tension.

Tele Style Bridge.

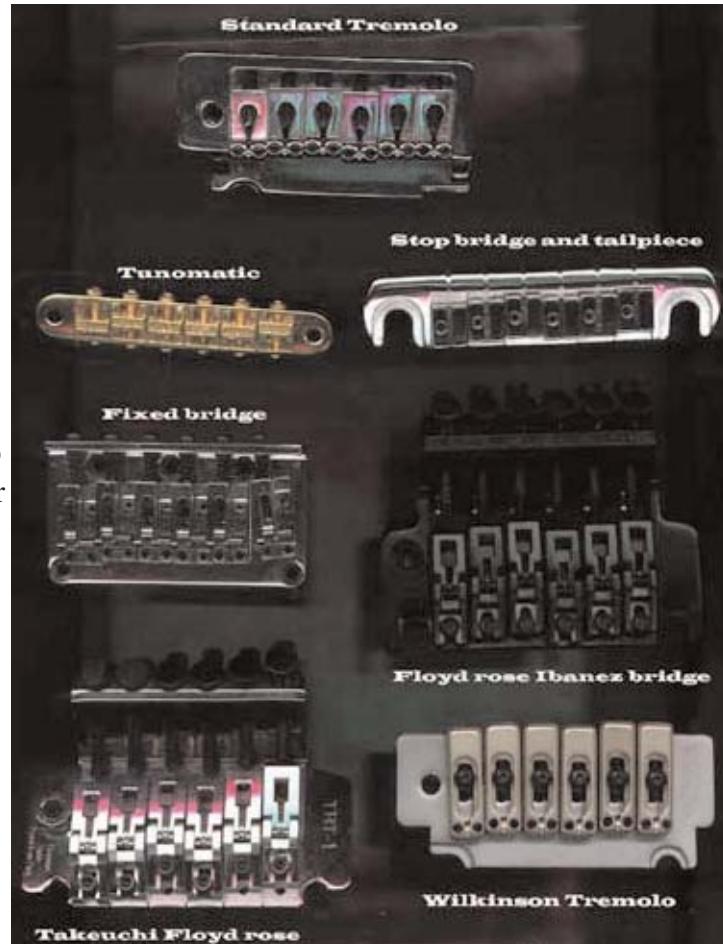
To me this is any bridge that has a pickup ring stamped into it. This could be a standard Tele pickup or even a humbucker. The strings usually go through the body.

Stop Bridge.

This is the bridge that I think of on a Lespaul Junior. It is a combination tailpiece and bridge. The strings go through the front of the bridge and wrap up and over the saddles. The older style ones usually do not have any intonation adjustment, but there have been many styles of bridges designed to over come this, such as the Baddass or the Schaller bridges.

Arch Top Bridges.

This is a bridge that has a wooden base that is sanded to match the exact arch of the top. It uses both a wooden saddle and tailpiece or a tune-o-matic bridge on the wooden base and a tailpiece. The wooden bridge is generally ebony or rosewood.



Milled Bridges.

These are usually made from brass on a machining center. They are some of the best bridges but almost impossible to find, and the price is very high.

Bridges To Avoid.

Any bridge that has adjustable string spacing either by wheel or by saddle movement. I have never seen a good one of these that stay where it is supposed to. It is also very difficult to get the string spacing exact after changing strings.

Bass Bridges.

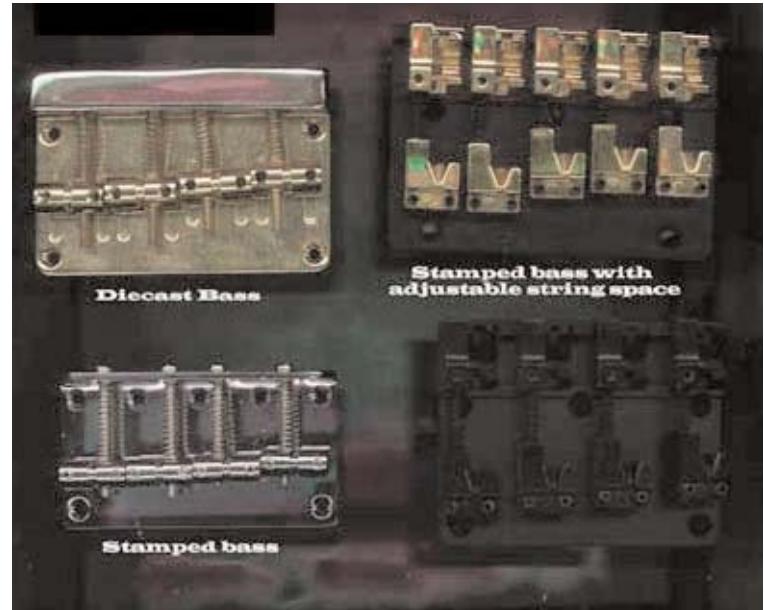
There are two kinds that I use. They are stamped and die-cast.

Stamped Bridges.

They are just as their name states made from stamped metal. The strings usually go through the back of the bridge. This is what tends to be used on cheaper basses.

Die-Cast.

This is any bridge with a cast bridge plate, these tend to be more solid than a stamped bridge and the strings usually go through the back of the bridge or through the body. I only use die-cast bridges on my basses.



Bridges to avoid.

Again, as with guitars any bridge that has too much adjustment. The best bridges for me are ones that have just height and intonation adjustment with easy string change.



Saddles.

For guitar and bass there are again mainly two types of saddles. They are cast and stamped. Many people like the sound of stamped steel saddles on their guitars (especially Strat players) for a standard tremolo bridge I prefer these stamped steel saddles but for everything else I use a cast saddle.

Electronics

As I talked about before instrument electronics are a basic principal. The sounds that are generated by the strings are picked up using magnets and amplified through the coils using copper wire. The signal is then taken to an output.

Between the pickups and the output there are certain variables that can be used such as switches, resistors or capacitors that control what pickups are on and the volume and tone control's that modify the signal before it reaches the output.

Potentiometer



The volume of a pickup is controlled by the potentiometer. A potentiometer (pot) is a variable resistor that allows you to vary signal flowing through it.

The way a pot works are that, there is an in, out and ground, as you turn the volume pot down some of the signal is sent to ground until it is completely turned off and the signal is completely sent to ground.

Potentiometers are available in various ohm ratings depending on what it will be used for. 20K, 25K, 100K, 250K, 500K are the most common we see in guitar wiring.

The actual value of the pot that you will use mainly depends on the pickups.

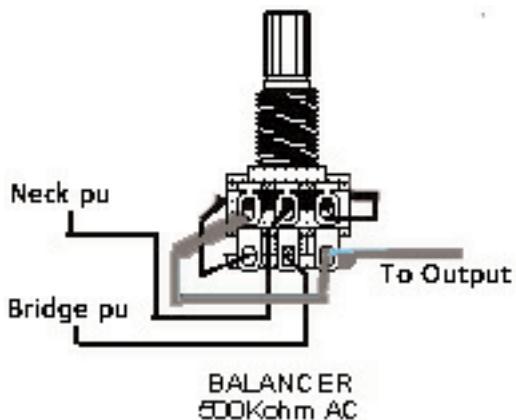
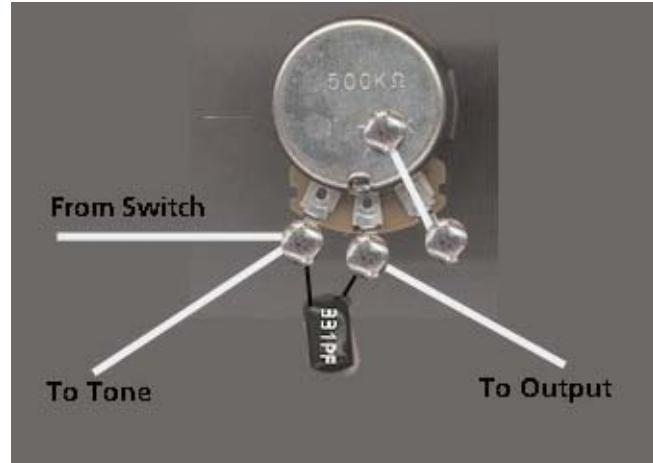
The standards used is as follows. 250k pots are used with single coil pickups. 500k pots are used with hum-buckers. 20k, 25K or 100K is used for active pickups or active circuits.

Pots are available in different tapers or curves. The basic tapers are a linear taper that works in a straight pattern to ground, or an audio taper that sends the signal to ground in a specific way so the volume is reduced much smoother when turning the volume down. Guitars usually use audio tapers.

There are many available and what one works best depends on either the person you are talking to or the person that uses the guitar. If you here someone say I use a 500KA pot for my volume this means that the taper of the pot to ground is different when the volume pot is being decreased. The basic standard depends on the manufacture. Most Japanese companies generally use a 500KG for volume and a 500KD for the tone. The reason we use two different tapers is that the curve of the tone to ground needs to be different then the volume pot. Companies like Dimarzio® make a standard 500K pot with a modified audio taper that works well for both volume and tone.

Tone controls are used with capacitors to remove some of the highs from the signal without shutting the circuit off. People use different values, but the basic ones for tone are as follows. Guitar tone capacitors are .022 and a bass tone capacitor is .047.

Capacitors can also be used to modify the volume pot. Many people use a small cap across the volume pots in and out. What this does is as the signal is sent to ground the highs remain in the circuit. The benefit of this is that you can roll the volume back to five or six, and the guitar does not lose its high end. I use a 331PF cap on all my guitars so I don't need any volume boost during solos. When I play rhythm I turn the volume down to four or five and my sound stays the same. If I will play a solo I can turn the volume on my guitar up to ten. Here is how you can modify your guitar, it's cheap and simple to do but the benefits are amazing.



Many basses use balance pots that are stacked with two pots put together. By reversing one of the pots it will blend the two pickups together. Balance pots use different tapers for each pot this assures a smooth transition between pickups. The standard tapers are A and C.

These types of pots usually have what we call a de-tent or a click in the center. This position is both pickups on full. Turning the pot in either direction sends some of the signal from a specific pickup to ground with no effect on the other pickup.

When wiring a balance pot think of it as two actual pots. Each set of lugs needs an in and out or hot and ground. Note to get the balance pot to work properly the ground for each side needs to be opposite of the other to blend only that pickup to ground while turning the pot.

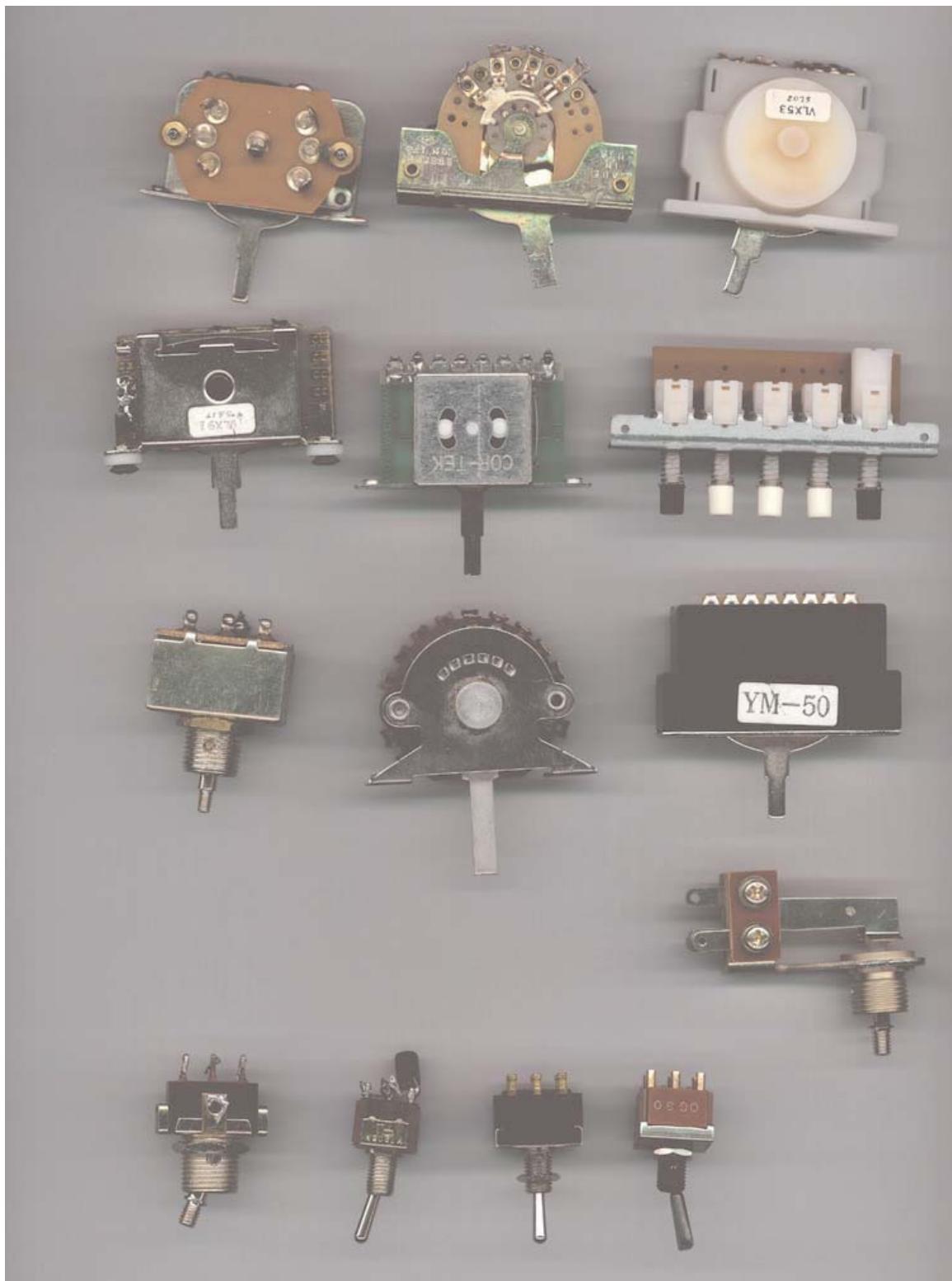
Switches.

There are so many types of switches available that to show each would take many pages. The most common used for guitars is as follows.

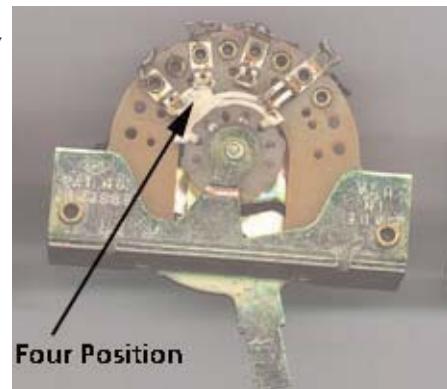
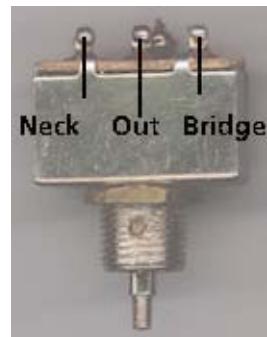
If you have an OHM meter, you can check the function of the switch by checking where the lugs allow the current to flow. By switching the lever on the switch and touching different lugs you can find the location of the connections. Usually, there is one or two constant's that is always on. On most switches there can be two constants or one on each side. Each side is independent of the other side. Fender uses the other side for the tone controls on a Strat while some other companies may use this for coil tapping or series/ parallel wiring

Five Way Switch

On most three pickup guitars is the 5-way or a 3-way slide switch. 3-way slide switches are not that popular any more. The original Stratocaster® back in the 1950's used a 3-way, however, many people found that if they removed the spring from the switch they could position the switch between the one and two or two and three positions and this would turn on two pickups at one time. This was actually the beginning of the five-way switch.

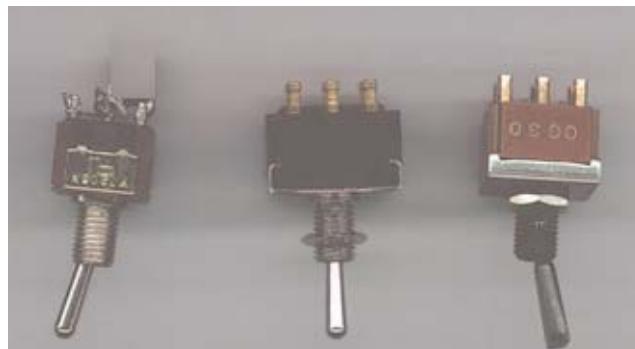


A 5-way switch works as follows. In the one, three and five position's only one pickup is one. In the two and four positions it combines both the bridge and middle or the middle and neck. When the middle pickup magnets and wires are reversed, the two pickups will work as a humbucker in Parallel Wiring.



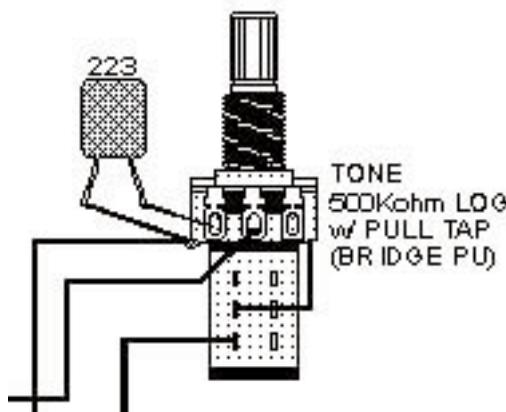
Three Way Toggle's

The three way toggle switch that is generally used on two pickup guitars, controls each pickup in the one and three position and in the two or middle position both pickups are on.



Mini Toggle Switches

If you see a small toggle switch on a guitar it is generally used as either an On/Off for a pickup, an On/Off for a coil tap or a 3-way for changing the pickups such as off / on /coil tap or even series/parallel/coil tap.



Push Pull Pots

A push pull pot can be used the same as mini toggle's for many purposes, most often they are used for coil taps. Also, they can be used to turn pickups on or series/ parallel wiring.

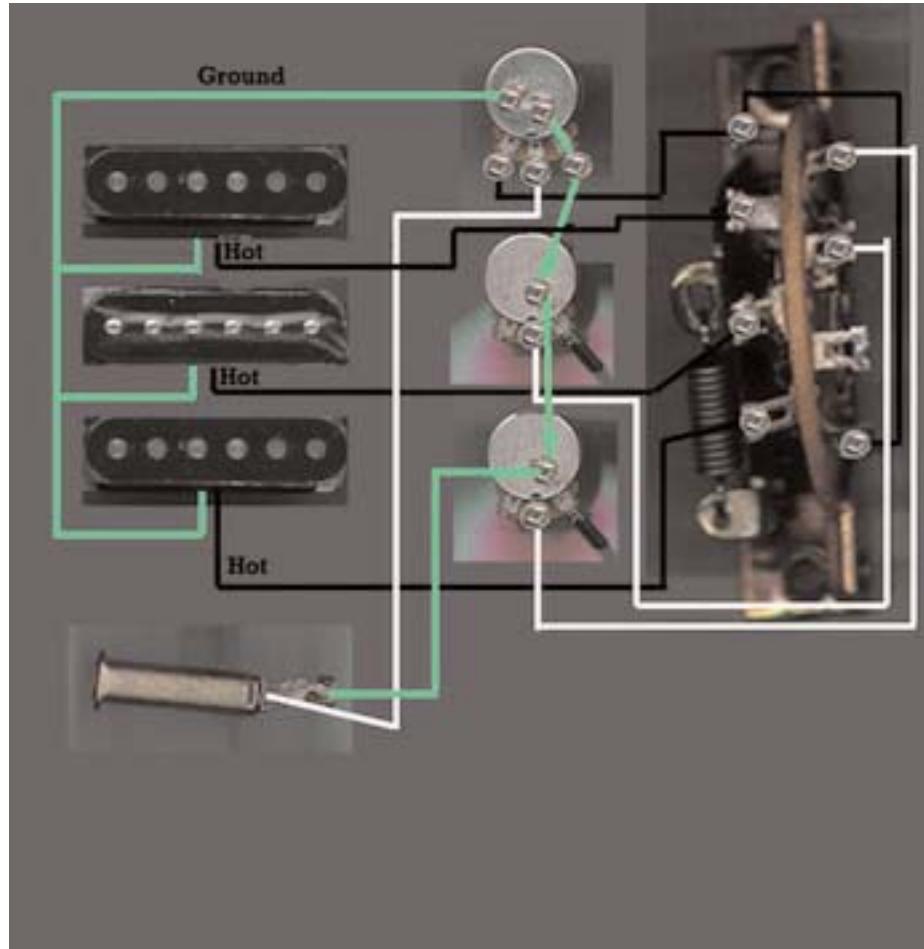
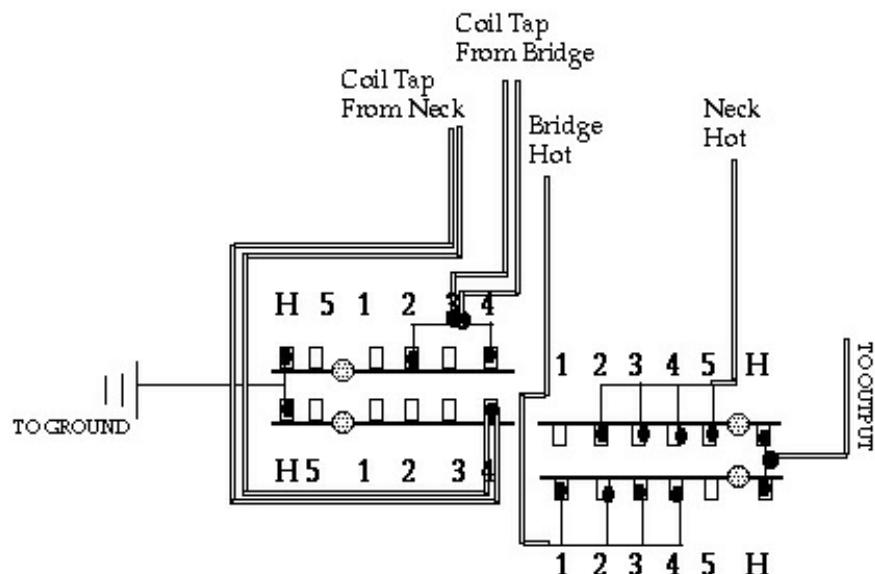
Four Pole 5 Way Switches

These are the coolest switches around. The first one that I remember was from Grover Jackson back in the late 1980's. Since then they are more popular. Dimarzio® sells the same one that Jackson used years ago. Ibanez® makes their own version that is shorter and can be used in thin guitars like the Ibanez® S model. How a 4 pole 5-way works are that there are four independent sides to the switch, on each side there are five positions. On each of the four sides there is one hot output, There is a total of 24 connections that can be made on each switch. There are no internal jumps on the switch so if you want a pickup to be on in the first second and third position you will need to wire the pickup lead to the one, two and three lug.



With a 4 Pole 5way you can wire almost anything you want. For example, if you have two humbucking pickups you can wire it many ways here is a basic example of what can be done.

- 1) Neck
- 2) Bridge / Outside neck coil
- 3) Both Pickups on
- 4) Outside neck coil / Outside bridge coil
- 5) Bridge Pickup

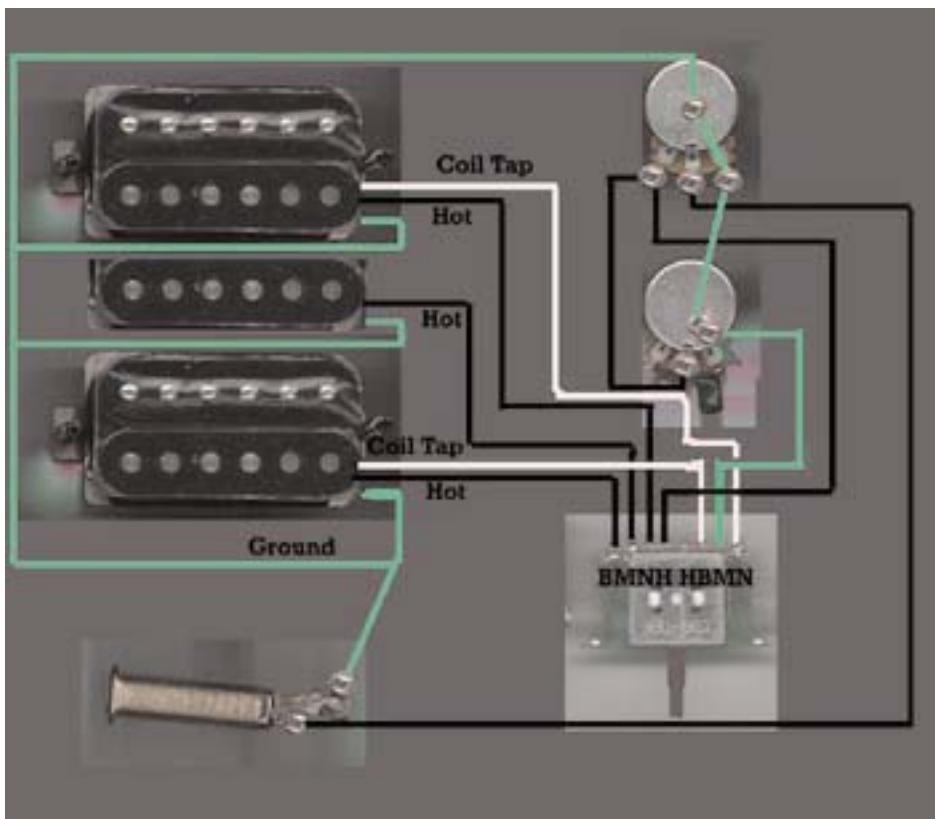
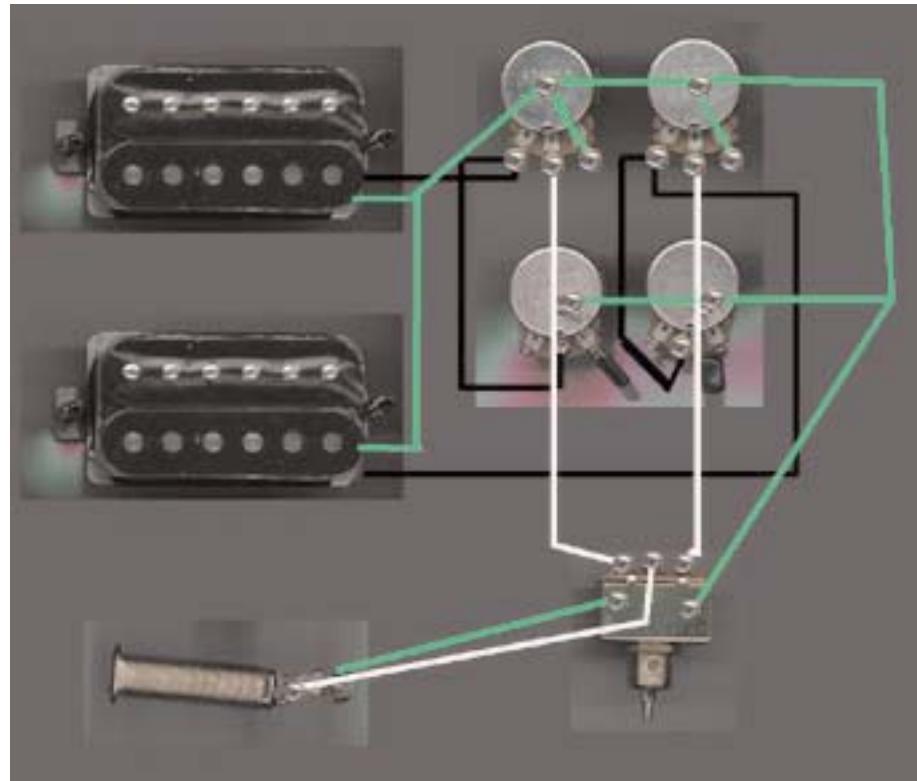


Stratocaster® Wiring.

Strat's use 5-ways with a master volume. One tone for the neck and one tone for the bridge positions. In the second and fourth positions of the switch two pickups are on.

Gibson® Lespaul® wiring

A Lespaul uses two volumes and two tones, one for each pickup. When the 3-way is in the middle both pickups share a common ground. When in the middle position, if you turn off the volume on one pickup, the other one will also turn off.



Ibanez® Split Five Wiring

On the Ibanez split five setup it uses two humbuckers and one single that are reversed in the middle position.

By putting the coil tap to the two and four positions on the other side of the switch it turns the humbuckers into single coils and humbucks with the center position. The only position that will have the 60-cycle hum is the center pickup.

For more diagrams check
<http://www.ibanez.com> They have the most diagrams on the web.

Pickups

The basic principle of a standard pickup is that a magnet picks up the metal string vibration, and the signal is amplified by copper wire that is wrapped around the coil. The wire has two ends on it, the beginning and the end or an in (Hot) and an out (Ground)

The size of the copper wire and amount of turns on the coil controls the output volume and tone of the pickup. The basic principle in pickup design is as follows the fewer winds of wire on a coil will cause the pickup to have less output and more treble or highs. The more winds on a coil will cause the output to be louder and more lows or bass response. The same holds true with the wire gauge, the thinner the wire the more treble will be produced the thicker the wire the more bass response. Too many winds will cause the pickup to distort so the designer needs to be very careful.

There are also high impedance and low impedance pickups, the difference is that to get the most output many people would put as many turns on the coil as possible. This would distort and cause the pickup to become noisy, Not only does the wire pickup the strings but it also picks up noise. This is why Low impedance pickups were invented. Low impedance pickups use less turns on the coils, and then the output of the coil is modified by a small pre-amp inside the pickup, this balances the output and removes any noise.

Low impedance pickups are used today mostly on basses because bass players like more tone control, less distortion and no noise on the bass. Often, the low impedance pickups are also used with an EQ system that can boost the treble, mid and bass usually by +15DB.

High impedance pickups have also come along way since back in the 1980's. Manufacturers understand how important it is to make good quality quiet pickups. To start with they need good materials like the wire, magnets and all the metal parts. If a pickup is made and the wires are not wrapped tight or if there is any part that is loose and vibrates this will cause the pickup to squeal or feedback at higher volumes. This makes the guitar almost impossible to play loud. Pickup manufacturers seal the wire and coils in wax after they wind them, this fills any space that is between the wire and stops the feedback.

Magnets

There are two types of magnets used in pickup construction, they are ceramic or alnico, alnico is aluminum, nickel and cobalt. Each of these magnets has their own properties and reasons that they are used. (Note there are also rare earth magnets that are starting to appear)

My feeling on this matter is as follows but some people may disagree.

Alnico is softer than ceramic and it causes the notes to have a slower attack and a longer sustain. Alnico was used for the magnetized pole pieces on single coil pickups. It is also used sometimes as a regular bar magnet on humbucking pickups. From my experience alnico is a softer sounding material.



Ceramic magnets are very hard with a quick sharp attack. What I use to describe the difference between alnico and ceramic is that if you drop both magnets from about 3 meters the ceramic magnets will shatter into pieces while the alnico will make a thud on the ground and maybe get dented. If you think about this then you will understand the difference in sound of the two materials.

Wire gauge and amount of turns.

Each pickup has its own "recipe," there are many wire gauges and amounts of turns on coils that make them louder, deeper or hotter. Fewer winds cause a pickup to have less output and more high end while more winds allow more output and deeper sounds.

Most humbucking pickups use the same amount of turns on each coil of the pickup. However, some companies have a combination of two differently wound coils they call Woofer / Tweeter pickups. These use two different winds on each bobbin in the humbucker and cause a different effect on the sound and different characters of the pickup.

Generally, if the two coils are not exactly the same the pickup will be noisier than two identical coils. For example, a humbucking pickup with two coils that are 5000 turns on each bobbin will be quiet, but a pickup that has two coils and one is 5000 and the other is 4000 will be noisier.

Wiring

Pickup wiring is not so difficult, but you do need to understand a few things that can make or break the wiring. Here they are.

Series Wiring

Most humbuckers are wired in series. Series means that there are at least two coils, and the pickup is wired with one hot and one ground and the two pickups are connected straight through. This gives the maximum output.

Parallel Wiring

If we take the same setup and wire it in parallel. Now there are still two coils, but each has a hot and ground. Some Strat's in the 2 and 4 position have the pickups humbucking but they are in parallel with each other. A basic humbucker can be wired as either. This seems to produce a less output more natural sound.

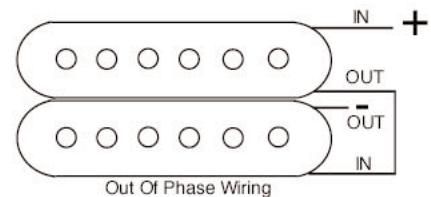
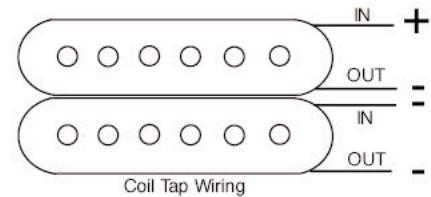
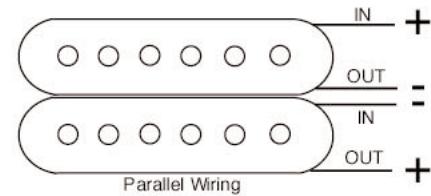
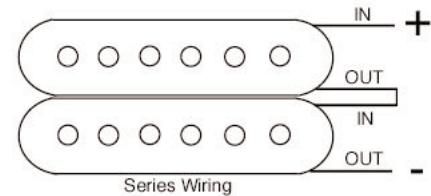
Single Coil

A humbucking pickup can be used as a single coil if one of the coils is sent to ground. Here, there is only one hot and the other three wires are grounded.

Out Of Phase

This used to be more popular in the old days, but most people don't like this sound now a day. This is when you change the pickups wiring so that the in and out wires are reversed on one of the pickups, this cause's an effect called out of phase where the actual coils are out of phase with each other.

Humbucking Wiring Combinations



What pickup is best for you?

This is an impossible question that people always ask me. It always depends on what you are looking for and what you are playing through. First, we need to figure out what you are using and what you want to decide what pickups will work for you.

Here are some examples of pickups that I have suggested to people and why. This is not a guide to what pickups are the best that is personal preferences, but I hope this can give you some idea of what type of options there are. When someone comes to me and asks me what pickups they should use I first ask what they play through. For example, the main setup is a tube head. The controls are Master Volume, Gain, Presence, Treb, Mid and Bass, a slant 4-12 cabinet with Celestion 70's in it. For settings the Bass on 10, The Treble on 4 and the Mid on about 4. The presence setting depends on the room. It is either all the way up or all the way down. The main guitar is a hot rodded Strat body. (Alder with a maple fretboard) No processors just a guitar and amp and a wah-wah in between.

This guitar has two humbuckers, and he wants a fat sound. I would suggest some hotter pickups that can drive an amp. Another guitar that needs a more mellow sound is a hollow body. If I used the same setup on this as above it would sound awful. He uses a 1965 Fender Dual

Showman Amp with a 2-10 cabinet. This guitar would feed back with pickups that are too hot because it is hollow. So I use two less output pickups that are mellow and don't feed back at high volumes.

A friend of mine once called me and complained that his pickups squeal. I checked his guitar through my setup (It was a Lespaul with two super distortion pickups) and it was fine. Then we looked at his rig and decided to change his pickups. He was using a Digitech guitar processor, and a full 100-watt Marshall Jubilee. My first thought was this must have allot of gain and too much high end. The processor takes the signal and modifies it before the amp gets it. I suggested that he change his pickups to less powerful ones, and we installed Dimarzio® PAF Pros. This fixed the problem.

The best thing I can tell you about replacement pickups is that do your research before you buy. There are many pickup companies out there and they make all kinds of pickups. The World Wide Web on the Internet is a great place to get information from pickup makers. If you go to a search guide like Yahoo or Webcrawler and search for pickup companies you will see many. Each company states that they are the best at what they do so use your best judgment and investigate each company and the pickups that they offer before deciding on what pickups will work for you.

Since the beginning of pickup replacement companies such as Dimarzio® or Duncan try to name the pickups to match what they were designed for. This is so that the name gives you a feeling of what the pickup will sound like. For example, one of the first replacement pickups from Dimarzio® was the Super Distortion pickup, by the name you know exactly what you are getting. Other ones are like Duncan® Quaterpounder; this also tells that it is powerful. Some other names of pickups that are easy to tell what they were designed for are



the Tone Zone, Humbucker from Hell, Screaming Demon, HS1-HS2 (Humbucking Stack) '59, Antiquity, Hot Rails, Pearly Gates, Dual Sound, Fast Track 2 and X2N. Can you guess why the Joe Satriani uses a Fred pickup? Here is the true story way back in the late 1980's; Dimarzio® started working with Joe to make some new pickups for him. Steve Blucher at Dimarzio® made many samples, and finally it came down to four pickups that they sent to Joe. Steve needed to call each one something so that Joe could tell him the one he liked so he named them after the cartoon Characters on the Flintstones. We received four pickup's the Dino, Wilma, Fred and Barney. Luckily Joe liked the Fred pickup, or everyone would be using a Barney, a Wilma or a Dino.

Guitar pickups also are available in two different styles, one being a single coil like a Stratocaster® uses and the other is a Humbucking pickup that has two coils. The purpose of the humbucker is so the pickup is to be quiet with more output. Single coil pickups have only one polarity north or south so they have what we call 60 cycle Hum. If you take two coils and put them next to each other and have one coil north polarity and the other coil south polarity then the pickup will humbuck and is quiet. Basically, each coil cancels the other one out.

The reason people still use single coil pickups is that they have a certain sound that a humbucker can't get. They are noisy, but the tone they produce has more treble response than a humbucker. Another reason is single coils have the pole pieces magnetized so the notes response to the pickup from the string is instant, or we say has a very sharp and quick attack. This is the Fender sound.

Other types of pickups that are used on guitars, and especially acoustics is Piezo electric pickups; these can actually either be under the bridge or part of the saddle. This work by picking up the string pressure on the saddle and then the sound is amplified. These tend to sound brighter like an acoustic sound because they are actually picking up the sound at the saddle location. This type of system can be used to make an electric solid body guitar sound like an acoustic. Many companies make these systems these days the best being Fishman®, Shadow or Mike Christian. Mike Christian makes replacement saddles for most bridges, and they can easily be installed. This is great for the electric player that only needs to do a few acoustic songs but does not want to bring an extra acoustic to every gig.

When using a Piezo pickup saddle along with regular guitar pickups it is recommended that you have two output jacks one for the standard pickups and another for the Piezo system. The reason behind this is mainly that the standard pickups will produce an electric guitar tone through an amp, and the Piezo pickups through the same amp will overdrive and sound more like an electric guitar. Most people plug the Piezo pickup system into either the PA direct or into a different amp that is set more to a true electric acoustic sound.

When looking at a guitar and seeing the pickup placement on the body there are reasons for this. The closer to the neck the pickup is the deeper tones will be produced, the closer to the bridge the pickup is located. The more treble sound is produced. This is the reason a Lespaul® can be marked as the neck pickup for rhythm or more bass and the bridge pickup for treble or more highs.

The pickups are usually located under a string harmonic. This is done to get the most character from the pickup. A string harmonic is a location on the string that has overtones or can produce another note other than the open string. The best way to find this point is to touch your finger on the top of the string in various locations over the frets or pickups. When you pick the string, you will hear other notes. The loudest and easiest harmonics to play are at the fifth, seventh and twelfth frets.

The placement of the pickup also has a lot to do with certain sounds that are produced, For an example a Stratocaster® has three pickups the bridge pickup is angled for more even output. The pole pieces on the pickup are staggered for different strings. Leo Fender designed the Strat to have a wound G string so many people

can find that when they use a standard plain steel string the note is pulled sharp from the magnetic pull of the pole piece. This is what we call "stratitis". When ever you play the G-string. The note sounds sharp. It is easy to see on a tuner because the G note will have a hard time stopping the needle. The remedy for this is easy, lower the pickups or raise the G-string at the saddle.

The placement of the neck pickup is located for a pleasant warm sound that is great to play rhythm with and to play nice slow low-end leads. The sound in this position is very smooth without too much treble. When the switch is in the second position and the neck and middle pickups are on together the pickups can actually be

humbucking, if the center pickup has a reversed polarity on the magnet. This is different from a standard humbucker in two ways first the location of the pickups is wider than a standard humbucker and second because each pickup is wired to the switch, so there are two hot and two grounds this is what we call wiring in parallel. Parallel wiring reduces the output of the pickup or actually thins out the sound of a full humbucker. This is one of my favorite selections to play rhythm even more than the neck pickup.

The center pickup is really in a bad spot, and the sound it produces is somewhat plain with no real character. I don't know many people that use this position allot. The fourth position or bridge and middle pickups on a Strat are also a great quiet twang sound with more highs then the second position because the location of the bridge pickup closer to the bridge.

Finally, the bridge pickup alone has the most harmonic response to an amp and this allows the highs to be more produced and is used for playing leads or notes that you want to stand out. The meaning is that in this position the actual strings are more noticeable through an amplifier because of the treble response. Ibanez and Dimarzio® came up with the Humbucker/Single/Humbucker Idea that Ibanez calls a Split 5 wiring. This allows the full humbucker in the bridge and neck positions but in the two, and four positions you get the Stratocaster® two and four sounds in parallel also. Somewhat the best of both worlds a Lespaul and a Strat.

On a guitar such as a Telecaster the neck pickup has a smaller bobbin that is underwound, this along with the metal cover gives it a very thin tone that is great for rhythm playing, The bridge pickup gets its added high by being mounted into a large bridge plate, This also adds highs to it.

On a bass the location of the pickups is very important, on most basses that have two pickups (such as a Fender P bass) with a Precision pickup and a Jazz pickup. Precision pickups were named because it actually has two coils one located closer to the neck and the other located closer to the bridge. And the standard straight pickup or Jazz bass pickup is placed closer to the bridge for more highs. A standard Jazz bass has two J bass pickups, and the neck pickup does have more bass response because of the location, but still the P pickup has more variety in tone because the location of the coils with the strings. This is caused by the gauges of the bass strings are much different from a guitar, or the low E string is really fat while the high G-string is much thinner. The split coils allow this to be compensated.

More basses now use more of a soap bar design pickup; this is a humbucking pickup under one big cover. Bartolini, EMG and many other companies are using these. Bigger does not always mean better but it does allow different bobbins and more options in the position of the bobbins under the strings. Often, a simple P pickup position of two coils will sit under the cover. Some of these are active, but many are actually passive designs. One easy way to figure the coils location is to take a magnet and lie it on top of the cover; it will stick or repel from wherever the magnet is. I have also (Steve Blucher will kill me for saying this) used steel wool on top of the coil to see where the magnets are. This is like how a magna doodle works.

On a Music Man bass this uses large Alnico Slugs, almost a super Strat pickup. Not only is this the Music Man sound but also the location of the pickup itself.

Many bass players prefer some type of active circuit, either the pickups and EQ or like a Bartolini® that has passive pickups and an active EQ. Active pickups I talked about above but active EQs are used to boost or cut frequency's usually the treble and bass frequency +/- maybe 15DB or so. More often these days added Mid frequency boost/ cuts are also available some with added sweeping of the mid frequency's.

Replacing a Pickup

So you finally have that new pickup and you can't wait to get it in. So you pull out the directions and you're ready to go. However after you look at the inside wiring you say maybe I should take this to someone. Or after you install it does not sound right. Here is a step by step procedure of installing or replacing a pickup. How many pickups have I installed in my lifetime? Way to many!

The first thing you want to do is plug in your guitar and get a clean tone. Check each pickup position and listen to it. Then in each position tap on the pole pieces and confirm you know exactly what the guitar does before you even start. It's good to write this down for future reference. Next take the strings off the guitar and lay it down on a soft area.

What I do just to check everything is ready to go is to take an old magnet I have lying around and check the actual magnetic pickup polarity. You will need this if you are using any type of coil tap or phase wiring. A humbucking pickup usually has a bar magnet under the bobbins attached to the plate this makes one of the coils north and one of the coils south. First, I always check the polarity of the new pickup with the one that I will be replacing.

If you are just wiring a standard three way switch on a Lespaul style two humbucking model with no coil taps then don't worry about this but if you want to having both pickups coil tap you will need to check the polarity of them in the middle position.

The terminology we use is inside coil (the bobbin toward the center) or outside coil (either closer to the neck or closer to the bridge bobbin) If you install both pickups and wire it as the directions say you will have bridge inside and neck outside during coil taps and this will humbuck but is out of phase with each other. You will need to switch the hot wire and the ground wire from one of the pickups. The guitar is now wired inside neck coil and inside bridge coil.

If the pickup has a cover or some writing on it and you can't just flip it around and change the wiring, you can take the pickup apart and flip the magnet over 180 degrees. To do this you will need to take the pickup apart. Not recommended for people with shaky hand.

The Magnet that I have has a white side that I call north and a non-painted side that I call south. For proper humbucking the coils that humbuck need to repel or be opposite of one another. This is really important if you plan on wiring a humbucker to a single coil in the center position. Just lay the magnet on the coil and see what the north and south coils are located.





1) Remove the adjustable pole pieces



2) Remove the tape



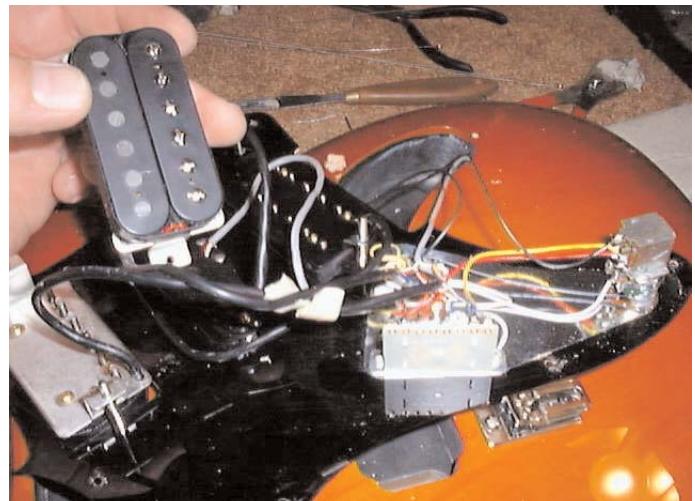
3) Remove the plate screws and plate



4) Remove the magnet, flip it over

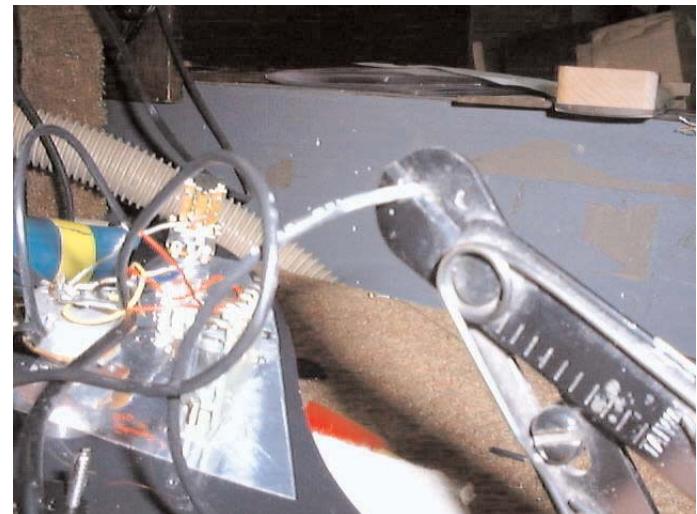


5) Put the pickup back together



Basic pickup change, what I do first is trace the wires from the old pickup if you want the new pickup to react the same than you can just follow the old pickup and wire the new pickup to the same location as the old one.

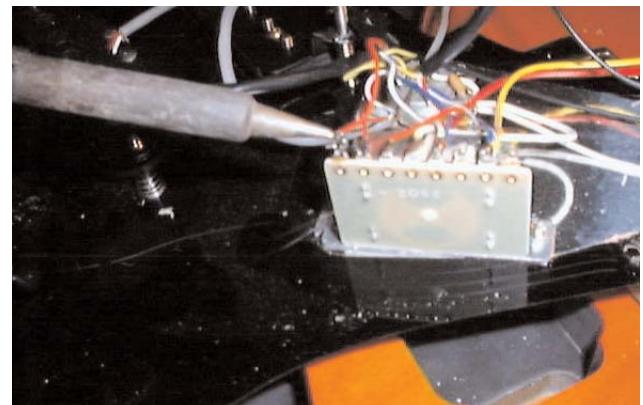
After you remove the old pickup put the new pickup in and cut the wire length to the correct size. Next to solder the wire you will first need to strip the cable to expose the wire. I usually strip about 1/4" and then twist the wires tight.



You will need to tin the wire, I use Resin Core lead electronic soldier, Don't use plumbing soldier (I know people that have done this)

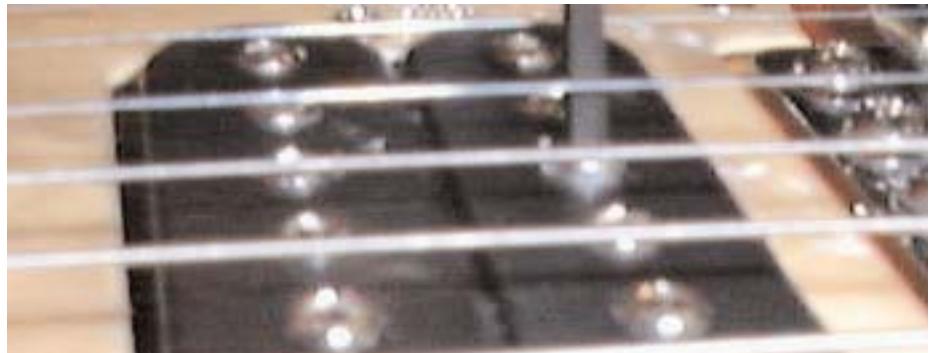
Tinning is adding solder to the wire so it will stick to the solder joint, If you don't do this the bare wires will fray throughout and make you nuts. First, heat the wire and then touch the solder to the heated wire. After you tin the wire cut the tip of the wire so that the wire will fit to the joint without hanging over.

Next just tin the lug that the wire will be soldered to and touch the wire to the lug and apply the heat. You're done. Do the same with all connections.



Before you go putting everything back together put one string on the guitar and check all the positions to check its wired correctly. If something is not right you only have to take off one string to get to the pickup.

Adjustable pole pieces can be raised or lowered to increase or decrease the output of each string.



Guitar Design

Spec Sheet Template.

Here is a list of things that you should consider and why for solid body electric guitars.

PRODUCTION GUITAR SPECIFICATION SHEET

GENERAL		DATE	11/21/97
MODEL	CUSTOM STRAT	DUE DATE	1/15/98
ITEM #		COMMENT	
FOR	CUSTOMER	COMMENT	
PHONE			
AVAIL COLOR	TRANSPARENT HONEY	FINISH	
HDWR COLOR	GOLD	HEADSTOCK	HONEY
SAMPLE NO.	1	NECK	GUN OIL
NECK MATERIAL		BODYTOP	HONEY
NO.FRETS	24	BACK & SIDES	HONEY
FRETWIRE	DUNLOP 6105	BODY MATERIAL	2PC ALDER
MATERIAL	BIRDSEYE AAA MAPLE	BODY STYLE	STRAT DEEPER CUTAWAYS
FINGERBOARD	BIRDSEYE AAAA MAPLE	TOP BACK	STANDARD
THICKNESS	19MM X 21MM	ROUND OVER	R 12 BACK ONLY
WIDTH	42MM	TREMROUT	WILKINSON VSV
SCALE	25.5	ELECT ROUT	REAR
RADIUS	430R	BINDING TOP	CREME
HEADSTOCK	STRAIGHT	BINDING BACK	NO
LOGO	NO	COMFORT CUT	BACK
HDSTK INLAY	NO	BACKPLATE	BLACK
HEAD BINDING	CREME	BRIDGE	WILKINSON VSV
MACHINE HEAD	SPERZEL	TAILPIECE	NO
STRING GUIDE	NO	NECK JOINT	STANDARD 4 BOLT
ROD TYPE	DOUBLE TOP	JOINT PLATE	BLACK
ROD COVER	NO	END PIN	DIMARZIO
NUT	GRAPHITE 42MM X 3MM	ELECTRONICS	
STRING LOCK	NO	PICKUP CONFIG	2 HUMBUCKERS
POSITION MARK	OFFSET 6MM ABALONE	NECK	PAF PRO CREME
SIDE POSTION	3MM BLACK	MIDDLE	NO
BINDING	CREME	BRIDGE	TONE ZONE
REMARKS		ESCUSION	DIRECT MOUNT
WIRING 4 POLE 5 WAY		PICKGUARD	NO
1) BRIDGE SERIES		SWITCH	4 POLE 5 WAY
2) BRIDGE PARALLEL		CONTROLS	1 VOL/ 5 WAY
3) BRIDGE AND NECK SERIES		KNOB	PLASTIC
4) NECK PARALLEL		CAVITY PLATE	STANDARD WHITE
5) NECK SERIES		JACK	SIDE JACK
CUSTOMER DOES NOT WANT THE FINISH HIGH GLOSS		MISCELLANEOUS	
NECK PICKUP AS CLOSE TO THE NECK AS POSSIBLE		STRING TYPE	DADDARIO

Just like automobiles, the type of guitar you will design has a lot to do with your style and budget. Certain guitars are designed for different playing styles and because of the construction methods and material cost the prices can vary.

To get an idea of what type of guitar you would like to design, lets take a look at some options and the purpose of the guitars.

Basic Body Woods:

Alder

Alder is a lightweight wood that has a warm even tone. Mainly grown in western North America works well with single coils and humbucking pickups.

Mahogany

Mahogany is a less consistent weight wood it can vary from really lightweight too very heavy. (Depending on the area it is grown, mainly South America, Africa and the Philippines.) The sound character of mahogany is fat, warm and much low end; it works well with humbucking pickups.

Basswood

Basswood is a very lightweight wood grown in North America; it was originally used for hand carving of decoys for duck hunting in the United States. The sound character is very even and works well with humbucking pickups in the bridge and neck positions.

Swamp Ash

Lightweight ash or swamp ash grown in the wet lands of the south eastern United States. Years ago they would throw this wood away because it was too light. If you are looking for twang this is the best wood?

Soft Maple

I like this for basses, but it does work with guitars.

Figured Maples

I use these only on the tops to bring out the highs on say mahogany or alder.

There are many other woods out there so please check the Wood Information page for more info.

Necks:

There are many neck styles out there and each has a purpose. Here is a quick guide to them.

Fretboard Material:

Maple

Maple is a very hard wood so the notes are quick and bright. Because the wood is light colored you will usually need to put a finish on it.

Rosewood

Rosewood is a softer grained wood with a slower attack and very deep properties, it tends to grab the notes and hold them.

Ebony

Ebony is a very hard wood that is mainly used on violins. The note attack is very fast and sharp with a well balanced sustain.

Fretwire:

There are many types of fretwire out there and the size you choose has a lot to do with the neck radius, and you're playing style. Fret hardness however can change from model to model; harder frets have a much quicker attack, longer sustain and last much longer than softer frets. Most inexpensive guitars use a 110-hardness fretwire that is easy to install however its life is much shorter than a harder fret. High-end guitars tend to use at least 175 to 190 hardness wire.

Small frets : Used on most guitars that have a round radius fretboard; this is good for bending without loosing the notes on the next fret. (Good Intonation)

Medium frets: More meat under them so they are easier to play then the smaller frets and good for medium radius fretboard's. (Good Intonation)

Short wide frets: Good for chords and note playing, but the actual intonation per fret can vary by where the fret crown is.

High Jumbo frets: One of the easiest for playing notes also can vary the intonation depending on the crown of the fret

Neck Shape and Construction:

Stratocaster® Necks.

This neck is a one-piece construction usually with a maple or rosewood fretboard and a 25.5" scale. It was designed for efficient production by routing a tapered channel in the back and inserting a truss rod. Strat necks have 21 or 22 frets and a 9" to 12" radius. This is good for cording and bending notes in the lower fret positions.

Telecaster® Necks.

Tele's are guitars all in themselves; they were designed also as one piece but usually with a very round 7"- 9" radius. The back of the neck is sometimes tapered like a V. Tele fretboard's are usually maple and are good for cording and pull offs. Usually the action needs to be set higher because of the radius, otherwise, when bending in the higher frets the notes sometimes choke from hitting the next fret.

Lespaul® Necks.

Lespaul's have a 24.75 scale that is shorter than a Strat. The nut is wider, and the fretboard is usually around a 12" radius and is usually rosewood with 22 frets. The Lespaul® neck is one of the easiest necks to play.

Ibanez® RG Necks

Ibanez® uses a 17" flat radius, a 43mm wide nut width and 24 jumbo frets. The necks are a hard rock maple with either a rosewood or maple fretboard and use a scarf joint to allow a tilt back headstock. This neck is good for rock playing and very fast note playing.

Tremolo or Non Tremolo:

Tremolo guitars have the advantage of moving the strings to allow a tremolo effect. They vary how well they work or what they are used for. Whenever springs are used you take the risk of the bridge raising during string bends; this makes it harder when you try to bend one note into another note.

Non Tremolo

Guitars. Very stable tuning easy to bend without the notes changing.

Standard Non Locking Tremolo

Good for subtle tremolo use, some string bending problems. Tuning is not totally stable if the tremolo is heavily used.

Double Locking Tremolo (FloydRose® bridges)

Locking tremolos have a toplock that locks the string in at the nut they also locks the strings in at the bridge, This allows the most radical tremolo use with almost perfect tuning stability, however note bending and initial tuning is not as easy as a standard or non tremolo model.

Pickups:

The type of pickups that you choose also depend on the type of sound you are looking for plus the amount of noise or 60 cycle hum that the pickups produce.

Single Coil Pickups

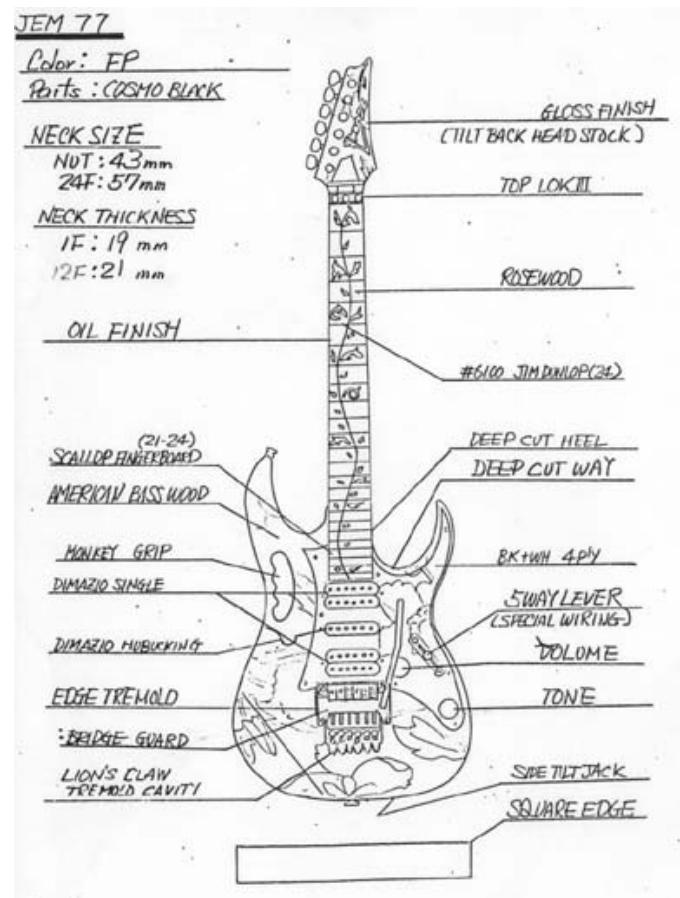
Generally, single coil pickups use Alnico slugs that are magnetized and run vertical from the top of the bobbin to the bottom this allows a very fast sharp attack with a thinner sound. However, the pickup suffers from excess noise caused by 60-cycle hum.

Humbucking Pickups

Humbucking pickups use two coils, one is reversed from the other, and this totally eliminates the hum. The magnet structure is usually mounted horizontal on the bottom of the two coils, and then slugs or screws are used to allow the strings to get picked up by the magnets.

To give a step by step detail of how a guitar is designed lets go back a few years and look at the original Jem guitar that Steve Vai and Ibanez designed back in 1986. I was actually heavily involved with the development at the time, it is not my design but I did work on the original prototypes and was there for the entire development. The information here is the best I can remember, all the guitars were actually built by Mace Bailey.

Let's take a look at Steve's style as well as what he needs to play. First, Steve prefers a 25.5" (Stratocaster®) scale, 24 Jumbo frets, A FloydRose® tremolo, no finish on the neck, the tremolo needs to be capable of allowing the G string to be pulled up a fifth, light weight body, deep cutaway's for his large hands, The ability to get a single coil or a humbucking sound all being quiet. Because of the volume he plays at, medium output pickups that don't feed back, and all the guitars need to sound the same consistently, this way he could just grab any guitar and play it.



This was the vision lets take a look at the guitars development and the birth of the first Jem.

The first proto types were made in the USA at the Ibanez Company. There were 3 models made all with the same body style and neck but three different materials. One was mahogany and hollow, one was alder and the third was basswood. They were all finished in fluorescent green that would later become Lochness Green.

Steve liked the sound the best of the American basswood (It has to be American basswood Asian Basswood is much heavier and less alive sounding) also it was much lighter than the other models. For being consistent sound and weight basswood is one of the better woods.

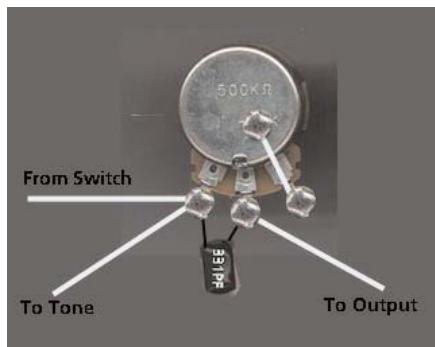
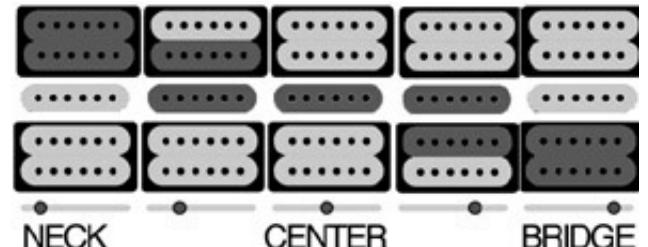
The body was designed to have two deep cutaways for his hands. Ibanez also added a cutaway heel an area that thinned out the body where the neck and body are joined, this makes it easier for your hand to reach around the body and play the upper frets. The tremolo rout was designed so the tremolo could be pulled up a full fifth. The tremolo area was routed down 14 mm from the surface. This was the easy part, the problem was first the tremolo block was too long and would stick out the back. Ibanez Japan molded a new block to be 31mm in length and this worked well until the tremolo was pulled up all the way, and then the springs would shoot off. Mace designed the block lock that locks the springs in place so you can pull up as much as you like.

For tuning stability Fritz Katoh designed the stud lock system. This is so that when the action is set exactly where you like the tremolo bridge the studs can be locked in that position so there is no movement, this increases the tuning stability of the guitar. Ibanez added the Lions Claw under the tremolo rout and the disappearing pyramids were designed by Bill Reim. Steve wanted the jack to be located so that when he put the cord around the strap, the jack would be there so we put the jack on the lower side of the body and called it the tilt jack.

Pickup wise Steve played the Dimarzio® PAF PRO® pickups and needed more sounds than just a Lespaul® or a Strat® so the Split 5 wiring was designed. This wiring came from Steve Blucher at Dimarzio® as far as I can remember and uses a standard 5-way switch with 2 Humbuckers and one single in the middle.

The guitar is wired so that as follows.

- 1 Position is the bridge humbucker.
- 2 Position is the Inside bridge coil and middle single.
- 3 Position is just the single.
- 4 Position is the Inside neck coil and middle single
- 5 Position is the neck humbucker.



They also added a 331PF capacitor across the volume pot. This is so that the highs don't roll off when the volume is lowered.

Ibanez had designed new color plating called Cosmo Black to use on the high-end models and decided to use this on the Jem series. This was somewhat black chrome plating. Many other companies are using this type of plating more now.

The neck needed to be designed like no other neck before it. Steve wanted the nut to be wider than a Strat® neck that is usually 41.5mm we made the neck 43mm X 57mm with the upper four frets scalloped over the body. The reason for this I believe was from Billy Sheenan basses. We found that the notes over the body have less sustain than the notes that are not. Scalloping the area between the frets brings the sustain back. The original Jem guitars used Dunlop® 6100 fretwire that is very large also the finish on the neck was Watko Danish oil finish. Steve didn't like the feeling of a painted neck. The headstock also needed to be set at a 14-degree angle for even string pull from the nut.

Now that the body and neck were finished it was time to add some cooler things to set these guitars apart from any guitars made before them? Steve had many of his guitars modified to have what was called a Monkey grip; this was so the guitar had a built in handle in it.

The main guitar Steve played was Fluorescent Green color, we made three colors first for the JEM777 model one was Lochness Green, Desert Sun Yellow and Shocking Pink all were from a company in California called Deglo colors. The factory however found that to get a fluorescent color the paint was actually radioactive (Just a little) We decided to try a different way of making the colors using two parts first a white base coat and then spraying over it with an almost transparent color to give the fluorescent glow.

The Making Of The PrototypeI will get into how we actually made the proto types. First I would like to say since the early days when we made the Jem guitars we have upgraded our shop and now have a facility that is capable of making anything, in those days we would improvise. This is a good way to see how to make a guitar with minimal tools.

Back in 1986 our shop consisted of the following a belt sander, hand router , drill press, band saw and a small paint booth. We also had a variety of chisels and the wood rasp, (Every one of these tools was purchased at the local Sears store in Bensalem PA) The original Jem models were made with just these tools. Hard to believe?

Here is how we did it.

The first thing that always needs to be done is to make a drawing of what you will be making. (See the next chapter for detailed drawing information) Every measurement must be drawn exact. Always start with a center line and work from center, this way when you start with a block of wood you can draw the center line on the wood and this always helps line up the templates used for routing and also any bridges or tailpieces will always be set on center.

The system that I use to do the drawing layout is as follows. First draw the basic body outline. Next the neck pocket area is drawn, this tells exactly where to put the pickups and bridge. Once the neck pocket is located and drawn, modify the area around the neck pocket in the drawing for strength and support.

Depending on the scale of the neck , figure the exact bridge location and any routing that will be needed. Finally position the pickups where you want them, this depends on how many frets and what type pickups. Generally put the pickups at the most harmonic areas of the body, to find this location use your left hand over the pickup area just touching the string to get harmonic's , move your finger all around the string to here the loudest harmonic. This will be the location of the pole piece.Use the drawings to make the templates needed for doing the routs such as the neck pocket, pickups and tremolo rout. Always make the templates from a hard material like plexiglass because it is very durable (a wooden template wears out too fast and can cause mistakes).

To make a template trace the drawing onto the plastic and first use plexiglas drill bits to drill out the round corners, also the basic shape of the template. Because these are difficult to do with a band saw always use the drill press or a mill to start and a hand file and sand paper to clean up the insides.

There are a few ways to make templates, back then we would make many templates for each part of the guitar, Today I have a pin router so I make a single template that has all the routs located in it, this way everything always lines up and there are no mistakes.

The main templates are the shape of the guitars body and the shape of the guitars neck, use double stick tape to attach the templates to the wood, (If you every notice on the old Fender® guitars they have two filled in holes on the front and back this is how they attached the templates)

After we finished making the templates, we needed the wood. In the United States guitar woods are easy to get but quite expensive if you only purchase enough for one or two bodies. Back in the late 1980's during the Jem development we would purchase the wood from a supplier already joined and sanded to the thickness we wanted, today we purchase the wood in blanks and join woods to size in our shop.

When making a body use a band saw to cut the wood to the basic shape of the template, this gives a rough guitar body. To make the body exact to the template we used the belt sander. While the body is still flat rout the tremolo rout, pickups or pickguard cavity and the neck pocket, every rout needs to be a specific depth. This has to do with the neck set angle and how the bridge will sit. The Jem guitars have a very low profile tremolo that is routed into the body, this also lets the strings sit very close to the body and pickups unlike other guitars like Lespaul's® that have a higher neck set angle that allows more space between the body and the strings.

On the Jem guitars now came some tricky parts because a Strat® body is fairly simple to make but we needed to add the monkey grip, lions claw tremolo, tilt jack, and the scooped neck joint.

For the monkey grip we first used a 1" forstner drill bit to drill four holes next to each other through the guitars body. The holes were drilled close together so they connected, and there was the monkey grip. We just used sandpaper and a small round block to clean up the inside of the monkey grip. To get the comfort cuts in the body (comfort cuts are the top and back contours that fit the body) We used a hand held rasp file and contoured the body by hand.

To get the scooped neck joint we needed to make a template the shape that we wanted and used the hand router to rout the shape. We then used a half-round chisel to clean up the edge and make it round instead of a square edge.

For the Lions Claw tremolo rout we used a ball mill round router bit on a separate piece of basswood, and made 6 grooves in it. After the routs were done we cut the piece to size and glued it in the tremolo rout (They don't do that in production they have a CNC router that make all the routs in 3 dimensions) after we glued the lions claw in the tremolo area we did the final body round over using a 2mm round over bit on the hand router.

The hardest part on the Jem was the tilt jack, it is in such a strange place we needed two people to drill it, one person held it against the side of the drill press while the other person worked the drill press. I was always the one holding. The body and it was tough because I could not let it move at all.

Now that the body is almost finished its time to make the neck. Necks are more difficult to make then bodies. The final Jem necks were made in Japan to our specifications and sent to our shop by Air.

Because the headstock needed to be tilted back we used a Scarf Joint (a scarf Joint is when you take a piece of wood and cut it on an angle, after it is cut, the piece that was cut off is turned over and glued on) The Jem neck has a 14 Degree headstock, This works very well with locking nuts but a guitar without a locking nut the 14 degrees and six tuners in a line is too much angle and will usually cause the G string to go out of tune.

The fretboard needed to be maple with disappearing pyramid inlays this was not so easy so Ibanez Japan made these necks.

To scallop the high four frets I remember and still have the Jig that Mace Bailey made; it had a 430mm-radius top. We used the same router bit that we used on the lions claw tremolo rout to scallop the upper four frets.

The neck and body were now final sanded and were getting ready for finish. The body was sprayed with a Polyester sanding sealer to seal the wood and allow an even paint coat. After the sealer dried the body was wet sanded flat by hand with # 800 sandpaper. The body was first painted white and a see through green was applied to give it a florescent color. The lion's claw was masked off, and we sprayed the inside fluorescent pink. After the paint dried we cleared the guitar with polyester and sanded to #1500 and used a buffing wheel and 3M compound to buff out all the little scratches and bring up the shine.

For the neck we used an oil finish, the original Jems used a Watco Danish oil finish that is rubbed on and let sit until it dries and then we steel wool the neck smooth and repeat this process for two days. (At least 5 heavy coat were applied) after the oil dried on the final coats, again used the #0000 steel wool to make it smooth. For fretwire Steve liked the 6100 Dunlop Jumbo frets, The hardness of this wire is 16% nickel silver very hard wire but you can hear the difference in the attack and sustain of the note.

The body and neck were complete, and we needed to make the pickguard, we used BK/WH/BK three-ply material and the band saw to cut the shape. To make the pickup routs in the pickguard we just used another pickguard on top of it as the template. On the back of the pickguard we completely shielded it using. A cooper foil this will eliminate any noise from outside the guitar, we also used a conductive shielding paint inside all the routes to shield the electronics from any noise.

Dimarzio sent us the PAF Pro pickups and the specially designed Jem single for the middle position and we wired up the first split 5 wiring at Ibanez.

The neck and body were screwed together, and the pickguard was installed, The tremolo and tuners were added and there it was history. Then we played the guitar very loud testing all the parts to make sure it would stay in tune.

That was the way we made guitars back then, Today when we look back to how we made these guitars it was pretty primitive but that is what makes a great prototype.

Today the process I use is completely different then what I talked about in the Jem design days. Now I have many machines and jigs designed just for making certain parts of the guitar. I also have a milling machine for making templates very accurate and quick. The old way was a great way to learn, but it surely is not efficient.

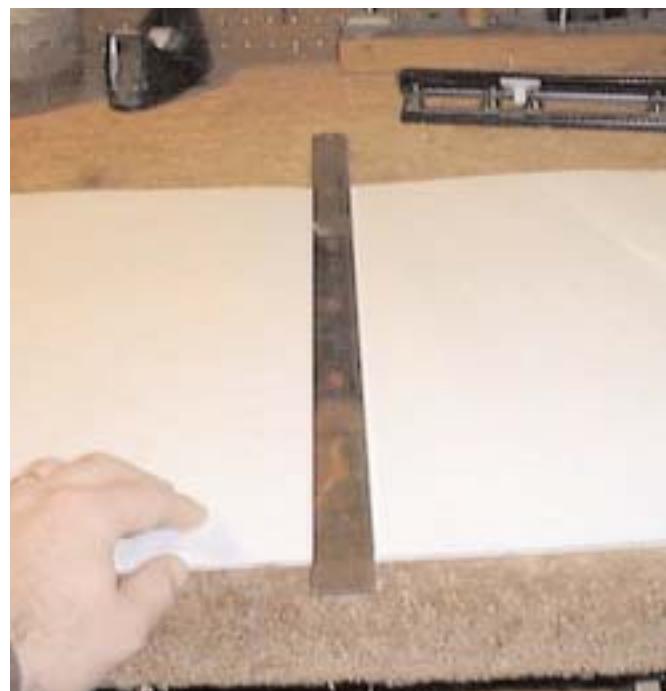
Making A Drawing

Making a Paper Drawing

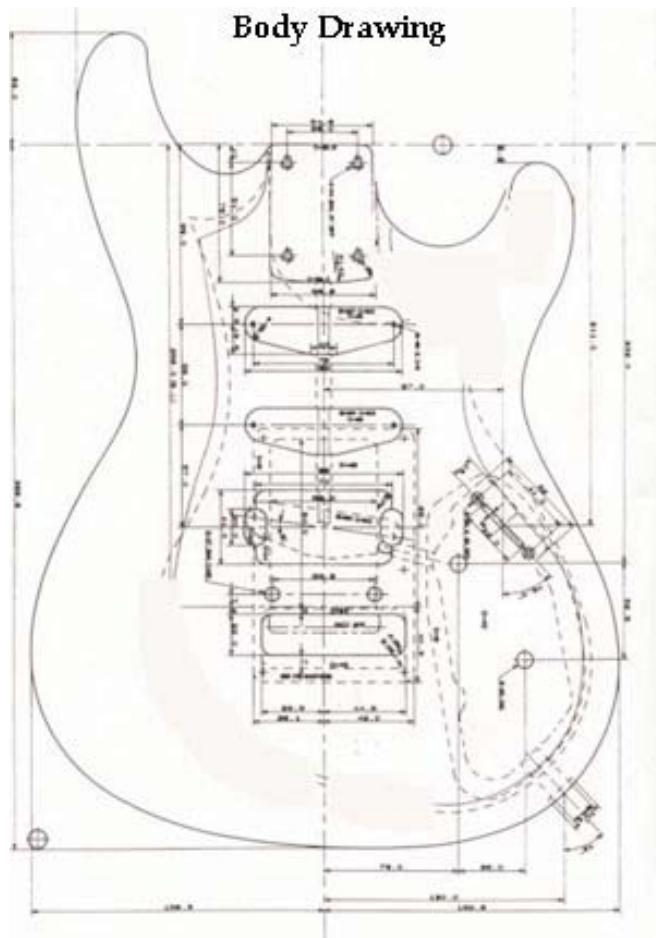
Before you even think about gluing up any wood, first you should make a detailed drawing or we can say a blueprint of all details. The purpose of this is so you know what you are in for before you start building. There are many how to make a guitar book out there and all have drawings to follow. Remember pencil can be erased but a band sawed or routed piece of wood can't.

The first thing you need to do is get a large piece of paper, I use tracing paper because you can easily lay a new piece of paper over it and trace the details that you have done and then maybe modify the body a little. This is also great because once you make one drawing and someone else wants the same pickup configuration or tremolo you already have it and can easily trace it. It's a good thing to have a finished guitar body around to check the details on for reference, but you can wing it without one, however the chances of making a big mistake are increased.

What I use to make a drawing on paper is the following. The paper, a small scale (as you might have noticed I use millimeters) A long ruler, the ones I have are 3 feet and 5 feet long. The main reason I have to carry it on plane from Japan because they measure in inches because this is the standard.

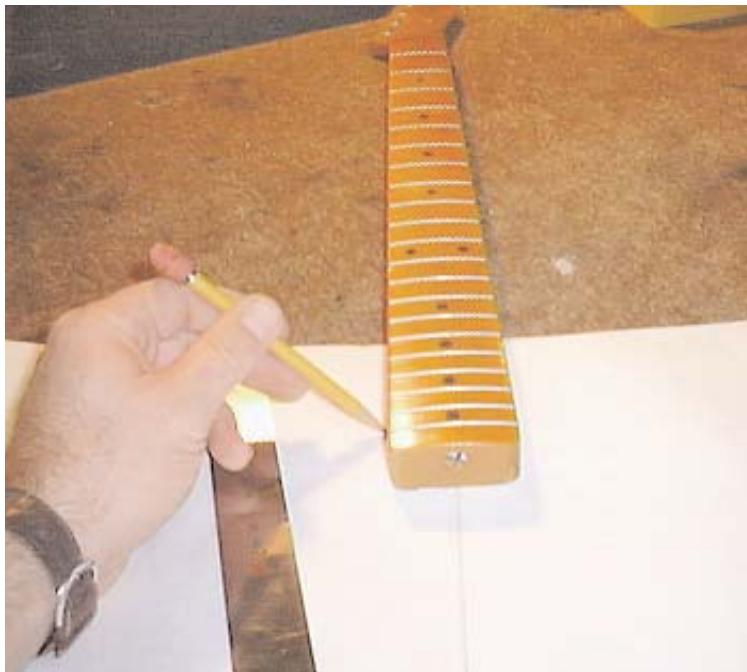


Body Drawing



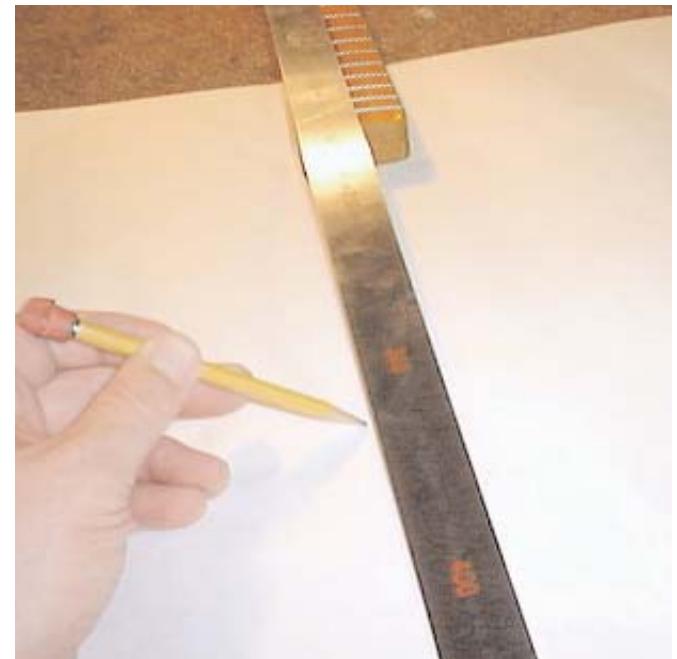
I keep templates around for humbuckers; tremolo routs and control cavities that I have made before to speed up the drawing process. If I need to make some new drawings I first do it on paper then make a template of it for next time. Other things that are important are a neck so you can get all the placement right and for an outline I use a flexible scale that can be shaped to multiple radius for the bodies shape. (See computer drawing) also I have a digital caliper and a set of radius gauges I bought in Korea these are hard to find here, but you can make them if you really want them.

The most important part of the drawing is first the centerline, without this everything will be off. Take the long ruler and make a centerline down the paper other parts will be set to this.



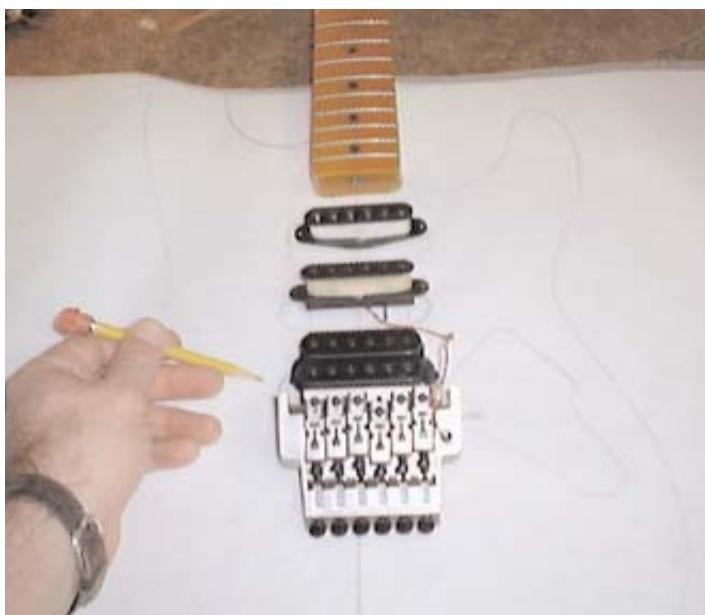
The next part is up to you, but I found the best way unless I have a body to trace is to lay a neck on the paper at center and trace the neck and body joint. To find the center of the neck just measure the width of the neck at the bottom and split it in two; this is center.

If the drawing will be a set neck or neck through you will need to make a basic drawing of the neck first so you know where to put everything.



What you need is the nut, twelfth fret and the last fret. It really helps to have a slotted fretboard or a complete neck to lay down, this is the most accurate way,. If not you will need to figure it out mathematically.

After drawing the centerline lay the neck on the drawing and mark the 12 fret and draw the neck pocket for the neck in the exact position with the 12 fret. After the neck pocket is in the drawing figure out the bridge position next and mark it, to do this take the total scale length and divide it by /2 then measure from the twelfth fret to the body, we will compensate for intonation later. (A 25.5-inch scale is 12.75" from the twelfth fret to the body scale location.)



Next figure the pickup position, This is not hard but there are some different ways to do it. The "this looks cool way" where you put them so that it looks good, usually this is as close to neck as possible and fairly close to the bridge.

Another way that I do it is to take another guitar with the same scale length and play the harmonics over the pickups and find the location of the strongest harmonic points and mark it from the twelfth fret then put lines on the drawing. (If you will use-mounting rings remember to add enough room so that the rings clear the end of the neck and the tremolo when it is used.) Sound wise the closer a pickup is to the neck the more bass response and the closer to the bridge the more treble response.

I will set the humbuckers on this guitar at center to the strongest harmonic location. Next flip over the pickups and draw the outline of the bobbins at center, If it is a single coil I trace the bottom of the pickup because of its shape.

Next lets figure the complete heel or neck pocket area and draw it in. I will use a neck plate for this guitar so I lay the neck plate on center in the neck pocket drawing and mark the four holes for the screws then trace the plate. From the plate drawing I add 5 millimeters all around and draw it; this will be the final neck area.

Next take the bridge that will be installed and find the center of it by measuring the saddles to center. Move the bridge saddles so there is room to move the intonation forward and backward, set the High E string as a reference and move the low E string saddle back 5 mm's from the high E string this will give enough movement for the intonation. Lay the bridge on center to the drawing and from the scale line that we drew lay the high E saddle 1.5-mm's back and trace the bridge.



Ok your mind is fresh, look at the drawing and first figure out what does not make sense maybe the tremolo runs into the back of the guitar or the control's do not have room or the guitar does not look balanced.

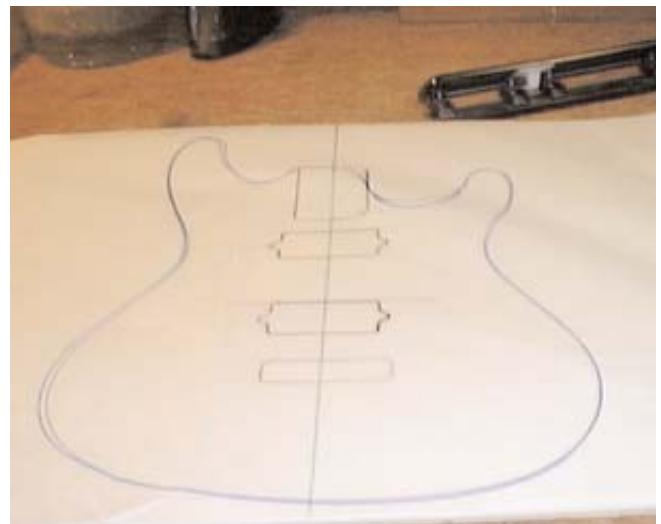
Clean up the body outline by using a flexible ruler by finding two points around the body and bend the ruler until it looks like a good shape then draw the line. This can be a large section of the guitar outline and does not need to be just a small area.

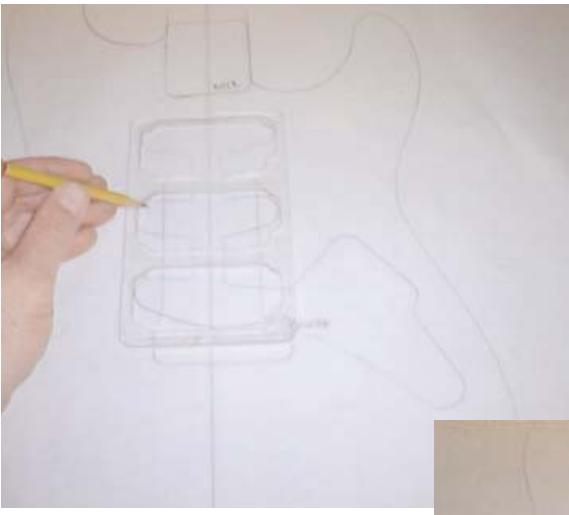
Keep doing this erasing things and adding things until the guitar 's shape is perfect, and I really mean perfect there is no second chance. If it is a customer's personal design ask them to come look at it, you can explain any changes and maybe do some modifications while they are there.

After this is finalized you will need to draw the routed areas on the paper for the pickups, tremolo and control cavity routs. My system is all routs on the front are regular lines and all routs on the back I use a dotted line. What ever the depth needed for the rout is, figure it out and write it on the drawing. Maybe the humbucker needs to be 25 mm 's deep but the screws for the humbucker need to be 32mm. Mark this and remember the less wood routed is probably better. (Some people have a different opinion on this).

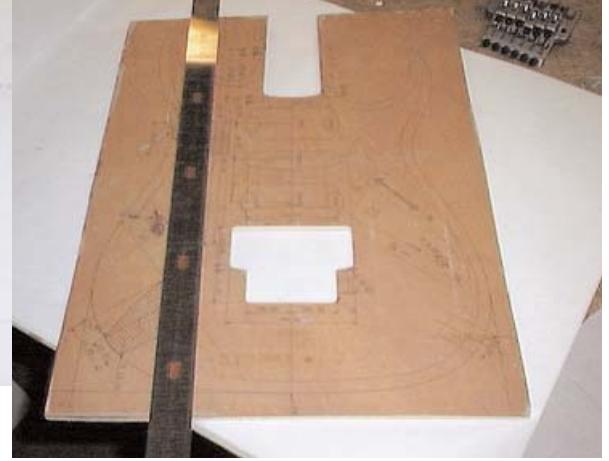
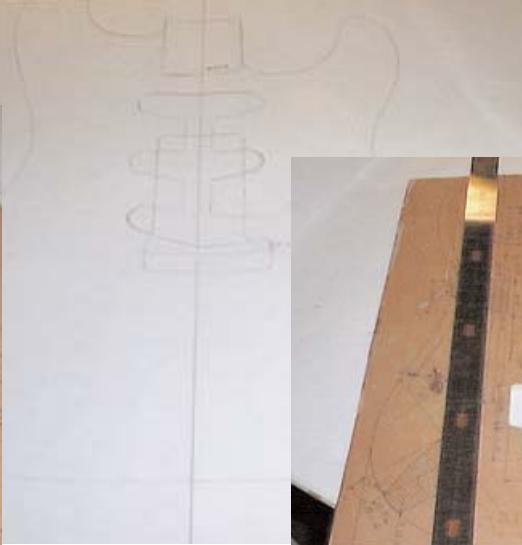
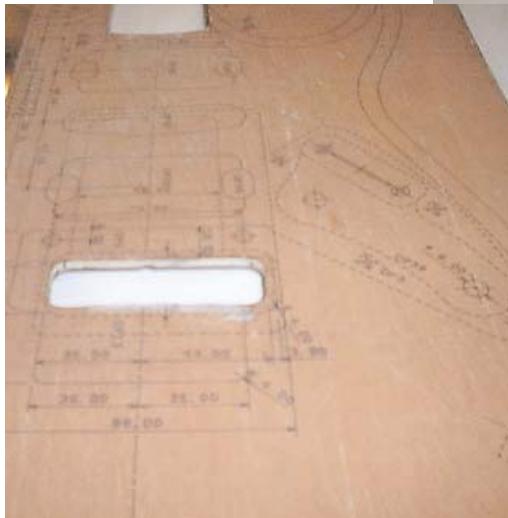
Now if the customer gave you a drawing, find the center of the drawing and make a line. If you are copying another guitar find the center and lay it on center with the neck pocket as a position guide and trace the body.

Find the knob and switch locations marked from before and draw the location. Lay a knob at the point and trace it. Get up go to lunch or get some coffee because you will need to focus now.





If the cavity plates are recessed draw this on there to. I usually measure away from the routs 7 mm's and then draw the outline of the plate. Then figure out where the screws will be and make sure there is enough room for the screw to go into the wood without breaking out the side. This is a mistake I made only once and it was a pain to fix I had to drill 12mm holes at the screw holes, epoxy dowels in and reshape them to hold the screws. That's it for drawing by hand if you want to start making a guitar you should make templates from the drawing, See Templates.



After the specs are finished it is time to do the Cad drawing; some programs like Bobcad Cam actually run the CNC after the drawing is made so this is convenient. This section is very confusing for people that are not familiar with cad drawing's but I will give an overview.

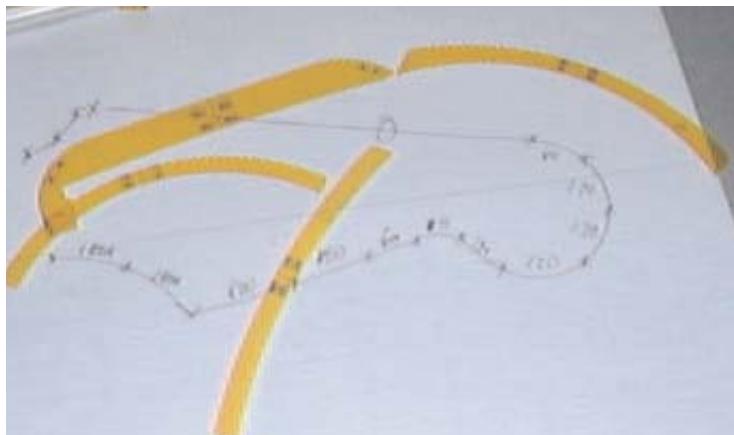
After the prototypes are finished it is time to move the guitar into production. The factories will need detailed drawings to work from; this is so that there will not be any chance of mistakes during production. What is done next is that we complete a final specification sheet. The spec sheets have all the information that you will need to start producing the guitars. The first page of this chapter has a standard form specification sheet that I use to finalize the designs.

Many people I talk to use different drawing programs for there own specific reasons. I started and still prefer AutoCad for most design work because of its simple interface, I have tried Many Cad programs but the only one that is easier than Autocad for many operations is Bobcad, I have not tried every program because they are so expensive but I still recommend from my experience one of these.

To start a Cad drawing we need to have a basic layout hand drawn, I use graph paper in millimeters, and this is impossible to find in the states so I either make it with a ruler or get it in Japan. From my book you can tell that I prefer metric.



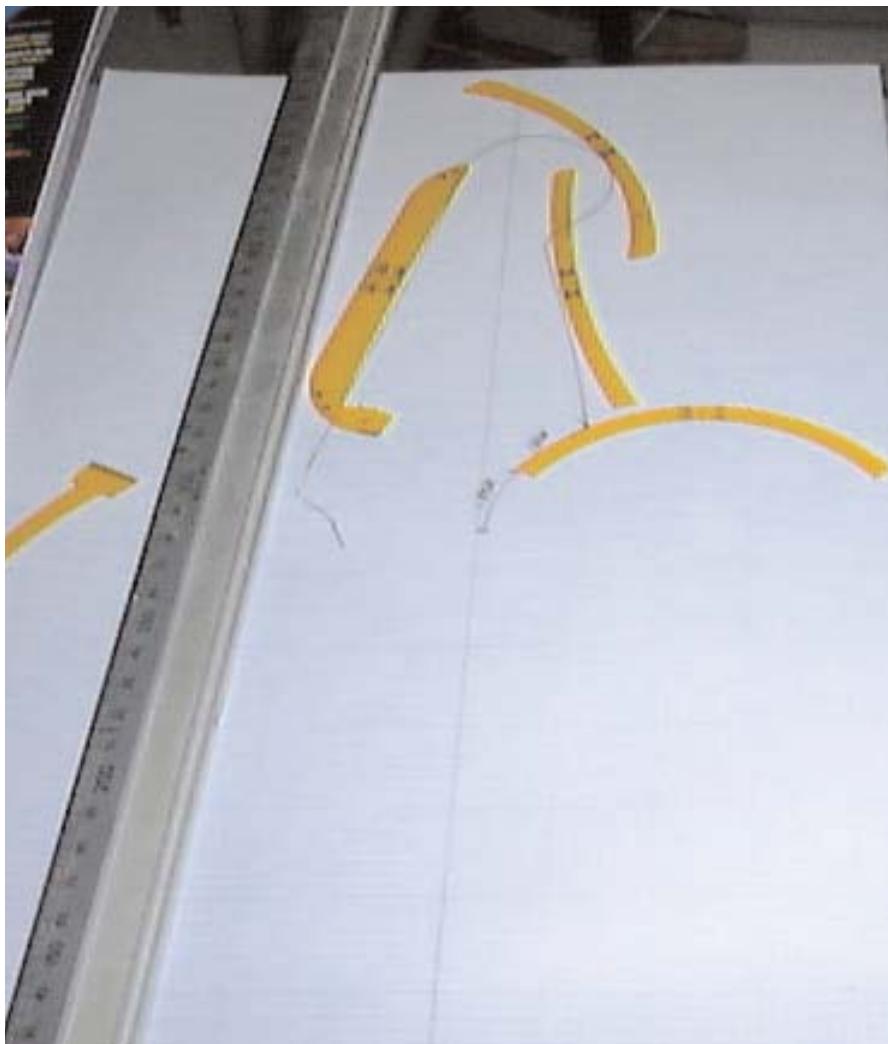
Take the graph paper and start with a centerline down the middle this will be 0 on the X-axis, Then trace the body or neck layout on center. After the body or necks are traced onto the paper we use the radius gauges all around the body to check each arcs location and radius. Mark the points of the beginning of the radius and the end of the radius as it follows the gauge.



Completely layout every radius on the drawing so that the drawing is now broken down into multiple radius.

Now we need to find the X and Y coordinates for each arcs location, to do this start at the center line anything to the left is Negative X any on the right side of the center line is Positive X. For the Y coordinates I start at the lowest point on the drawing say the lower bout and make that 0 on the Y axis.

Just to make it easier for me I write the numbers on the graphs at 5mm intervals so that I can easily see where I am on the page.



Start at a flat area like the neck pocket and work your way around the drawing, measure the distance from the center Line in Y and X and make a note; for example, X=-39.3 Y=28.71 this is the start of the Arc; the Arc ends at X=-47.09 Y=40.38 The radius between the two is 30mm. This is one line in the program.

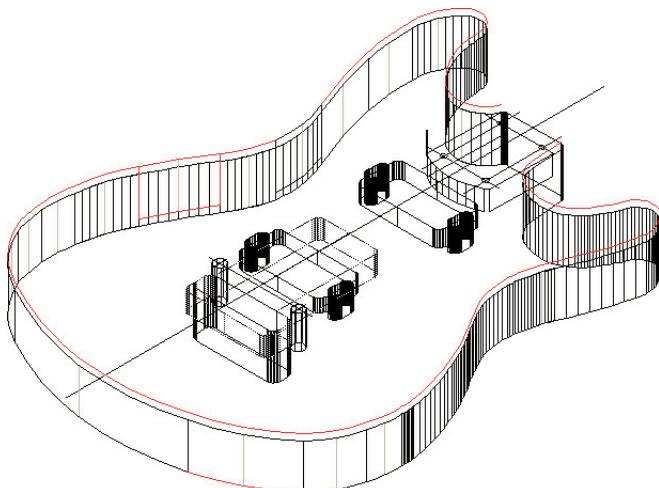
I usually do this type of drawing in Bobcad because it has a points menu that you can type in all the coordinates by points of the XY Axis and then after all the points are typed you can select two points and add the radius; this is really quick after you get all the X and Y locations.

You do the same with all the pickup or pickguard routs and enter all the information into the drawing, If you are working in 3D than you will also have a Z axis that is the depth of the routs. I start on a flat surface as 0 and anything below is Negative Z. If the pickup rout is a depth of 25mm this would be Z=-25.

Another interesting feature in the Bobcad program is the offset curves feature this will automatically offset an area by any number you want. If you are putting binding on the top and it will be 5mm thick than you can select the body outline, select offset curves, put in the distance of 5mm and it will put the binding channel on the drawing.

I also use this for designing arch tops by using 10mm offsets and continuing the curves until it reaches the center, Bobcad automatically compensates for the differences to center. For the round over on the body I also use the offsets, if the round over is R12mm than I set the offset to 6mm.

Once the drawing is finished, we use it to either make the templates or to make the actual CNC program that will cut the bodies. The drawing will always be the main reference for all production models.



Making Necks



Making Necks

The procedures I use for making necks have also changed over the years. Since I have the pin router, it's used for almost all the neck making procedures. In production there are also a few ways to produce necks. The way I describe in the large factory section is using a CNC to cut the basic shape and then do the back round over. This way still needs much handwork after the neck is cut.

Many companies use a copy machine to make necks. They have a mold of the neck shape, and the copy machine using blades makes an exact copy of the mold. This is a

very quick and efficient way to make necks, and the results are very consistent. I feel the best way to make a neck is by hand, but many companies nowadays are using a ball mill cutter and a digitizer.

Many CNC machines can have an attachment on them called a digitizer. The digitizer is a small ball attached to the CNC's main head that moves in every direction, up, down and side by side. First you need a good shaped neck. Usually the prototype will be made by hand or it could be one that was on someone's guitar that they really liked. (This is what Music Mann stated in the Eddie Van-Halen model)

The computer lowers the digitizer into the sample neck and slowly moves the sensor around the neck very slowly. At this time the computer is recording every movement that the ball rides on. After the digitizer completely records the information into the computer, the computer can rerun the program exactly the same way that the digitizer traveled.

The digitizer is removed and the standard ball mill bit is put on the router and the program makes a perfect copy of every detail of the first neck. If there are any imperfections in the sample neck the computer will copy them but actually smooth them out. For example if there's a big dent in the sample neck the digitizer will copy it but because it can't make a puncture in the wood like a dent it will smooth out that area.



Companies like Martin and Taylor use Fadal-machining centers to make necks. These machines were originally made for milling metal parts but slight modification on them can easily make guitar necks. These are very expensive machines but they have tool changers on them that hold the tools in place with suction. This saves time from having to change the bits by hand and the machine can perform many operations one after another so that the neck could actually come off the machine and only need some final sanding.

I have seen these machines do the truss rod channel, fretboard radius, fretboard position marker, machine head holes and even in some cases cut the nut and fret slots. If you ever get a chance to go to the Martin Factory they have daily tours and you can view this process in person. Unfortunately we all don't have an extra \$100,000 or so to spend so lets make a neck with some basic hand tools and also with a pin router.

First when you are about to make a neck there are many things you need to think about. First what is this neck for? Is it a bolt on, set in or neck through? What scale, neck material, shape and construction will you do?

Neck Construction.



There are basically four types of neck construction I use and I only use Quartersawn wood for any neck. The price for Quartersawn is worth it in strength and durability. I can understand why companies that purchase log lumber wind up using flatsawn to get the best yield but I would not recommend this to anyone that is making a neck to play.

The first neck is a standard one piece with a straight headstock. This construction is used on most Fender style guitars. One draw back is the need for either a two string trees to hold the strings down so that they have enough angle and don't come out of the nut or the use of staggered machine heads such as Sperzel Trim locks. This type of neck construction is fairly simple and is the only one that the truss rod is usually inserted in the back of the neck.

The second type of construction is a one piece neck with a angled headstock. You don't see very often because depending on the angle of the headstock it is not that strong and it can be waste good wood material. This type of neck I use for making modified Strat style necks that don't need string retainers. To do this cut the headstock to a 4 to 6 degree tilt and install the truss rod on the top of the neck before the fretboard is glued on.

Laminated Three/ Four/ Five or more piece necks are very strong, these are made by taking a standard piece of wood and cutting out the side shape of the neck in three pieces, then glue the pieces together with the middle having the opposite grain for strength. These necks are fairly easy to make and I use these for all set-in neck construction.





Scarf Joint necks with angled headstock are what many acoustic, neck through and locking tremolo guitars use. This type of construction takes one piece of maple and depending on the tilt of the headstock, cut the wood on an angle between 10 degrees and 14 degrees and glue the piece back on the neck in the opposite direction. This is the type of neck I used for most of the bolt on locking nut guitars I make.

Truss Rods.

There are a few truss rods that I use and there are many truss rods out there that I would never use for one reason or another.

Rear Channel Rods.

This is a basic Fender style rod that is inserted in the back. This type of rod is just basically a long metal bar that has one end permanently locked into a position and the other end is threaded. The slot that the rod is put in is routed on a slight curve so that when the nut is tightened the rod will pull closer together and straighten the neck.



Aluminum Channel Rods.

This is what you see on many acoustic models. I never use this rod because of the amount of wood that is removed. First the wood is not that strong after that much wood is removed, and second I feel that most of the sound from the neck's wood is also removed.

Standard Single Rods.

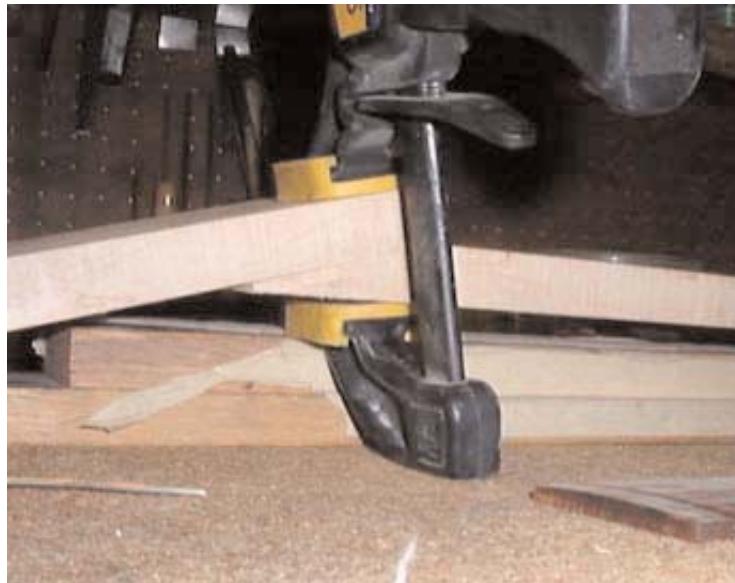
These are almost like the Fender style rods but the slot is usually straight without the curved rout. These work well but the truss rod has come along way since the days when this was popular, and installing most of the other rods uses the same procedure so I would prefer using a different rod.

Double Rods.

The word "double truss rod" does not mean two way. Basically a double rod uses two bars that are welded together at the ends. There is one nut on the front end and when it is turned clockwise the truss rod tightens together and straightens the neck.

Two Way Rods.

These truss rods are almost the same construction as the double rod using two rods but they work by contracting and expanding the rods. If you turn the nut clockwise the rod is compressed and tightens the neck and if you turn the nut counter clockwise than the rods expand and actually add relief to the neck. I would like to use two way rods but until I find one that does not have a neutral spot I will stick with the double rods. I have tried many two way rods but the problem is that there is a small area between the clockwise and counter clockwise positions. This area causes the rod to be loose and rattle. If it just happens that this is the exact position to set the neck up than the inside of the neck will rattle. I prefer and really only use double rods at this time. I also only use ones that have the round bottom bar round and a top flat bar. I feel that the ones with two round bars do not touch the fretboard correctly where as a flat double rod will.



Headstock Angle. / Machine Head Placement.

I do use straight headstocks sometimes if people ask for it, and only with Sperzel's and six machines heads on one side. If the guitar will have a standard non-locking tremolo than I would probably make a one-piece neck with a 4 to 6 degree headstock tilt and six in a line machine heads. I have found that any greater of an angle on a headstock with six in a line and a standard nut will not stay in tune without allot of work. If the guitar will have three and three tuners than I would use a 10 to 14 Degree headstock angle and if the neck is a locking tremolo with a locking nut I usually use a 14-degree scarf joint.

Scale Length

Figuring out fret placement is easy these days with programs like Excel. Just take the total scale length say 25.5 and divide it by 17.817 to figure out the distance to the first fret, Then take the scale length subtract the distance to the first fret and divide this by 17.817, continue till you get all the fret placement. This is sometimes called the 18th rule.



I pretty much stick with the standards on this if the neck is bolt on neck and uses a tremolo I will use a 25.5" scale and if the neck is a set in and uses a non tremolo bridge I always use the 24.75" scale. For basses I use standard 34" scales for almost all of them except for five and six strings that I would maybe use 35" so that the low B string does not flop around.

Fretboard Radius.

This has to do with other options on the neck, mainly the bridge style and scale. If the bridge is a tune-o-matic or FloydRose® than the saddles are preset to a certain radius and this is the one that you should use, because you can modify the nut to a different radius there is a little option even on some non adjustable bridges but this tends to be more trouble than its worth. The main purpose of fretboard radius is a personal preference. This is not a guarantee but generally people that dig in the notes like rounder boards and technical players that bend the higher notes and play fast tend to like a flatter radius. Again, this is not gold just the standard that I have come to know.



Fretwire Size.



I have talked about this in other parts of this book so I won't go into details again, but for rounder radius fretboard's I use lower thinner frets and for flatter boards I use higher frets that are sometimes wider also. Now that we have that out of the way, here is the basic way of making a neck.

The minimum tools I would suggest for these are a band saw, hand router, drill press, belt sander, drill bits, router-bits, round over bits at 20 to 25mm(3/4"-1.0") Sandpaper
80/180/220/320/400.

First, you need to make a drawing and figure out what type of neck you will make . Lets say this will be a bolt on neck that is 25.5" scale has 24 frets a 430R (17") fretboard radius and will be a thin wide neck, Say 18mm thick at the first fret and 20mm thick at the twelfth fret. The width of the neck will be 43mm at the nut and 56mm at the 24th fret. No binding, quatersawn maple neck with a rosewood fretboard, a 14 degree tilt back headstock and a locking nut.

This is the formula that I will need to make a drawing for it. Always the first thing to do is make a center line that everything will follow then layout the entire neck drawing to scale. From here I make the templates.

Because I have a pin router I will make one template for the neck and one template for the headstock, The reason for two templates is the neck will have a tilt and I will need to do some work on the headstock laying it flat. If the neck were a straight headstock I would use just one template.



Next I get the wood ready; I have found that the best way to make a neck is to start from the exact thickness wood needed. For example, if the neck at its thickest part is 25mm (At the neck pocket) and I will use a 4mm thick fretboard I will plane the wood to 21mm before I even start making the neck, once the neck is glued up I don't want to remove any extra wood just shape the back and it's done.

Once the wood is planed to 21mm, I locate the scarf joint on the neck. I want it to start at the third fret for strength. I prefer a chop saw set for 14 degrees, but a miter saw or very steady hand on a band saw will also work, (my hands are not that steady I would make a jig)



Cut the scarf joint and if you have a jointer plane the wood flat if not use the belt sander to flatten the surface. Once the wood is ready for gluing, take a small amount of water and open the cells in the area that will be joined they were crushed when they were sawed so the glue could easily come loose. Just dampen the area and wait for it to dry before gluing it up.

After the wood is glued and dried make a straight centerline down the middle of the neck and use double stick tape to attach the template. Band saw the basic shape of the neck at the fretboard, be careful around the headstock area. After the neck is sawed to the basic shape, I use the pin router with a 12mm bit and pin rout to shape the fretboard part of the neck. Without the pin router I will wait until the fretboard is on before I finish shaping the necks dimension.

Next figure out the location of the truss rod and the width and depth that will be needed. The best way for this is to put the truss rod channel in the template then just use the proper bit in the hand router and rout the slot. For routing the slot with the pin router, I have a fixture that I made just for routing this slot. It holds the neck in place and the slot is under the jig and follows the pin. -After the truss rod channel is routed install the rod and check that it is not loose it should fit tightly with no rattle if it does not fit tight I recommend covering it with a heat shrink tubing to make it snug.



For fretboard's I purchase them already slotted because the time it takes me to set up the radial arm saw and accurately slot a fretboard is not worth the headaches when people that have gang saws can do it in seconds. Many places like Exoticwoods or Stew Mac have these.

Take the fretboard and draw the centerline on it. Line it up with the neck, when you clamp it up the fretboard tends to move. Before I glue up the board I take four small finish nails and hammer them in about 4mm the neck at the first fret and the last fret and use end nippers to cut the tops off. Line up the fretboard on the neck and push down, the fretboard will have imprints of the nails in it then use a small drill bit to drill the pinholes in the fretboard. Put the fretboard back on and verify it is straight.

Remove the fretboard and apply woodworkers glue to the fretboard and neck and put them together. Wait a few minutes before clamping it just until the glue is tacky. To clamp the fretboard, I made a clamp that just touches the ends for pre radius fretboard. Be careful with these because the center needs to be exact or one side may be too thin.



Once the neck is set up, band saw the extra fretboard off and put the template back on and final shape the neck with the fretboard on. I have a jig that has the position markers already in it with small nails to mark the exact location of the fretboard markers. Other wise I would have to measure each one using the fret slots to find the center and the centerline. Drill and install the position markers and sand them flat to the fretboard.

Use the headstock jig to final shape the headstock and mark the machine head holes. On my template the holes are in the template, and I just drill through the holes to place the machine head positions, it saves time having to measure each one. Again it's better to use forstner bits for any holes that go through the wood.

Before final shaping of the neck install the side markers in the neck, again I have a jig that marks the exact location for each one. Drill and insert the side dots.

Once the headstock is shaped you will need to take the thickness of the headstock from 20mm to 14mm. To do this I use the pin router holding the neck on an angle with the headstock flat, If I did not have the pin router I would measure it, and band saw the extra off then clean it up on the belt sander.



Now I want to shape the back of the neck; for this I also made a jig for the pin router. Depending on the neck thickness I use different shims to hold the neck up higher on the nut end of the neck. This holds the neck 2mm higher so that when I shape it on the pin router the neck will be shaped 2mm thinner at the nut area. If I did not have the pin router, I would rough shape the necks back radius on the belt sander.



Now comes the fun part final shaping. First, rough out the fretboard radius so that when you hold the neck in your hand it feels natural then use round files to shape the actual necks back profile to the desired feel. Keep checking the shape with your hand and feel each area of the neck to verify it is what you want.



Once the neck is final shaped I use an 80 paper by hand to clean up the file marks and then 180/220/320 paper on an orbital sander to final sand out the neck.

The neck is basically finished now we just need to verify that the neck is straight and that the fretboard radius is correct and fret it.



Fretting and Fretwork

Fretting

I started doing fretwork back in 1984; those days seem primitive to all the tools that are available today. Since then I have changed fretting procedures repeatedly to try to improve it as well as cut some time off the process.

No matter what you do if you play your guitar your frets will become worn. The first thing you will notice is actual dents caused by the string being pushed against the fret. The most popular spot for this is the second fret G string off the A note. This seems to be the most popular area. If you notice any strange fret buzz this could also be caused by either worn frets, loose frets, uneven frets or damaged frets, here is the difference.



Worn Frets

Caused by playing and tend to concentrate in the areas that are played the most by the actual player.

Loose Frets

Caused by the fret tang becoming loose and lifting out of the slot. This is usually easy to see if you push down on the fret and it lifts back out of the slot. This is usually on the ends or in the middle of the fret.

Uneven Frets

Usually caused by either worn or loose frets. Possibly a poor fret dress from the factory, this type of problem can also cause notes to die during string bends.

Damaged Frets

Usually caused by the guitar falling and the strings put large grooves in the frets the shape of the strings, depending on how bad they are it could need to have the frets filed or even replaced.



Fret Dressing

What we call a fret dress is sanding off the tops of the frets to make them level. A fret dress is not too difficult to do and I feel that most people with the correct tools can handle this.

Before you even think about doing a fret dress check the truss rod and check it is adjusted properly. If the neck is over-bowed than you could also have a fret buzz and maybe the neck just needs an adjustment. Also play the guitar and if there is and a noticeable fret buzz check the area for loose frets or what we call spongy frets that move.

Before starting any work on the frets, sight the neck, This means look down both sides of the neck with the strings on and the guitar in tune. The purpose of this is to check the neck condition under string tension. Some necks could have uneven fretboard or even be twisted. Make mental notes of any bad area or even use a grease pencil to mark the area.

Next if the neck is detachable or bolt on remove the strings and take the neck off the guitar, this will save any damage to the guitar body. If the guitar has a set-in neck, remove the strings and lower the pickups to their lowest point. If you feel you could damage the pickups or mounting rings take the pickups off the ring and remove the mounting rings from the guitar. Just leave the pickups in the cavity and use masking tape and paper to hold the pickups in the cavity.

Check for loose frets by looking at the sides of the fret and use the back end of a hammers handle to push down on the frets, if the fret is loose it will push down and come up when the pressure is released. If you have any, the easiest solution to this is to take a small amount of super glue, two drops that's it and put it under the loose part of the fret, then quickly push the fret into place with the handle of a hammer until the glue dries. You are not gluing the fret just hardening the woods around the frets tang.

If the frets are just uneven or worn, a simple fret dress may be all that is needed. To do this first you will need a few things. 2 long wooden blocks about 8" long and 1.5" wide X 1.5" high. A round block covered with either felt or thick rubber, sandpaper #280/#500/#800/#1000/#1500, #0000 steel wool and masking tape. Attach the sandpaper to the long blocks with double stick tape.

Depending on the fretboard, I suggest the following.

If it is maple then use the masking tape between the frets so not to damage the fretboard. When you pull the tape over the sides of the neck roll up the ends so it is easy to remove after the fret dress. Darker unfinished wood such as rosewood or ebony does not need to be masked off because the scratches will be sanded out.

First, we want to adjust the neck as straight as possible. Site the neck to see whether there are any obvious spots that may cause trouble and set the neck as straight as possible by eye. Then take a long straight ruler and lay it against the top of the frets and adjust the rod until all the frets are against the ruler. On a detachable neck lay it flat on a table if it has a tilt back headstock keep the headstock over the edge of the table so that the fretboard is sitting flat.





Sand the frets back and forth until all the marker is removed and look to see whether any marker remains in the fret grooves that were caused by playing. If so continue to sand with the long blocks to remove these dents don't concentrate in just one area but sand long strokes to keep the frets even. Check the line over the top of each fret; this will show where any high spots are.

Next this is a trick I learned from the Japanese, take a black marker and draw a Take the long block with the #280 on it and slowly sand the top of the frets back and forth. Make sure you follow the radius of the fretboard or the middle may become to flat.

After a few passes of the sand paper look at top of each fret, some may be wider than the others this is ok but if the marker remains on the top of the fret then probably one of the frets next to it is too high or loose.



After the frets are even then use the long block with the #500 to sand out the #280 scratches on the frets. Next take the round block and hold #500 paper on it and sand back and forth the length of the fretboard to remove any scratches from the frets, this will also round the tops and sides. Be careful not to sand the tops too round you don't want to loose the top crown. Repeat this process with the #800/#1000 and #1500 paper and final polish the tops of the frets with the #0000 steel wool.

What we would do next is look to see whether any of the tops are too wide if so this will not cause fret buzz but it could cause poor intonation. I like the tops to have no more than a 1mm flat center.

For crowing the tops I use a triangle file that I ground down the sharp edges on the sides. Hold the file on an angle and file each fret to make the tops the exact same width. This is really important with a smaller radius neck

That is the basic fret dress, as for total fret replacement this is better left to a professional; however, if you want to try it and have an old neck around it's not that difficult to do, so here are some step by step methods.



Fret Jobs

There are three main ways to I use to replace frets, and I will talk about each individually. The first is the way we all learn is to hammer them in. The second way is to use an arbor and press them in, and the third way is to use epoxy and set the frets in. From my experience the arbor press is the fastest and most accurate way possible but if you don't have the tools for this, just a standard rubber mallet works just as well.

The start of all fret jobs is the same if you are replacing frets. If you are making a new neck, just omit the fret removal from the following. First, as in the fret dress remove the neck if possible; on a set-in neck remove the parts on the body. Remove the nut, If the nut is old, it may break when you try to remove it,

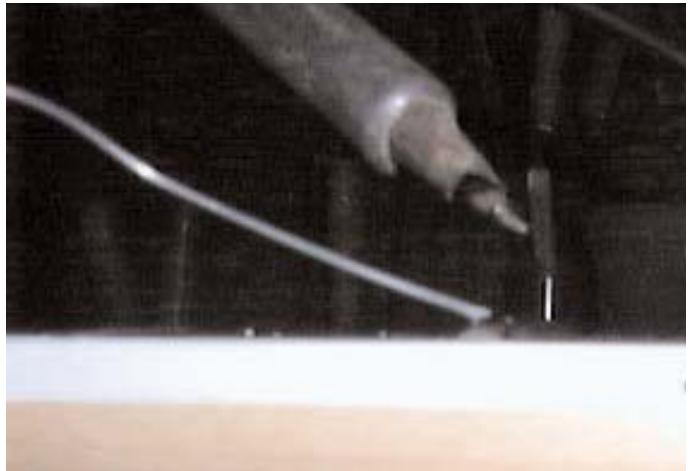
Be careful and try to save the nut for either putting it back in or as a template for a new nut. Gibson® style nuts, first check to see whether any of the nut is covered by finish. (Many Japanese guitars are like this.) You will need to remove the finish around the nut by using an Exacto blade and cut the shape of the nut in the finish.



Then use a hammer and a short metal piece to pop the nut out. Lay the flat edge of the metal bar against the nut and give it a sharp tap with the hammer. The nut should come loose then lift the nut out of the slot. For Fender® style nuts that are bone, or graphite these can be tricky. The best way I have found to remove these nuts is to use a pair of end nippers that remove the frets to wiggle the nut until it becomes loose and then remove it.

The next procedure is to remove the frets, be careful not to chip the wood around the fret tangs. The way I do this is to use a solder iron and rosin core solder used for wiring the electronics. I use the solder iron and actually melt the solder across the top of the fret.

When the entire fret is covered with liquid solder. I use the end nippers and starting from one end, get under the fret sides and carefully remove the frets, starting at one end and moving across until the fret is removed, repeat this on all the frets.



For old worn frets that are hard to get with the end nippers, I use a hacksaw blade that is ground down to a very tapered end. We call this a fret-lifting tool. It works like a small wedge that can be inserted under the frets end lifting it just enough to get the fret nippers under it.



Depending on whether the fretboard is finished and if the neck is straight we will make our next choices. If the neck has a maple fretboard and is finished with clear; hopefully, the neck would have been straight and we will just carefully sand the fretboard with #500 not breaking the finish, clean the slots with a small fret saw and replace the frets.

If a finished fretboard is uneven and needs to be sanded, we will have to refinish the fretboard. Adjust the truss rod so the neck is as straight as possible. Use a straight edge on the fretboard and look for light under the edge and adjust the truss rod till the neck is straight.

To remove the finish, first start with a grit of #180 on a long block to remove the fretboard finish and sand the fretboard level keeping the proper radius. Sand the scratches out with #220, #280/#500 sandpaper.

I always spray the finish on before fretting because the fretboard is easier to sand before the frets are in. When applying a finish after fretting, you will need to sand the finch between the frets. This is a royal pain, not impossible but the end result will not look as good. Now you need to check the slot width and depth, comparing it to the new frets that will be installed.

For some reason most Dunlop frets have a different tang and stud width. Why? I guess they are trying to make replacements for originals? With other fretwire the tangs are usually uniform in width so they are easy to replace. Fretwire like Dunlop® has so many sizes in the studs and tangs you need to check the size of the wire before installing it.

Now a very important thing to think about is the fretwire hardness. If the fretwire is very hard, you need to compensate with a larger fret slot. If the wire is softer like most production guitar frets, a tighter slot is not so much of a problem. The same exact size fret with a different hardness can cause the necks to back bow. This is caused by when you put the frets in they are compressed in the wood, this actually will push the wood between the frets together and if the wire is very hard then it can cause a back bow in the neck that string tension and the truss rod will not be able to compensate for.



The best way to check the fret slot size is to ask the manufacturer of the wire for a spec chart for the fret wire this will tell you the hardness as well as the recommended slot depth and width. To make a slot deeper I use a Japanese Saw (German saws are good too but the handles are rarely long enough and can cause mistakes.) I modified the saw with two pieces of wood glued to the sides of the blade about 2.5mm. I did this because when you are working on the fret slots. The side you are looking at is ok but sometimes the other side can become too deep. This is no problem on rosewood or ebony fretboard's but on maple it is easy to see. This way all the slots are the same depth on both sides.

If the fretboard is bound, I use a ground flat screwdriver tool to add depth to the slots. Another way I do this on a bound neck is to use a Dremel tool with a modified dental tooth bit in the collet and a special router base template that I made from Plexiglas. (So I can easily see through it.) Depending on the fret to be installed I use either a 56-57 or 58 dental bit. The 56 is the most used because it is the smallest but even still this is too big for many Dunlop® fretwire sizes such as 6100 or 6105. If I use these frets and the Dremel I will either use a 24-hr epoxy set or modify the fret tang by crimping it and making it wider.



Now that the fretboard is sanded and the slots are properly cut we need to install the new frets. I always pre shape the frets before installing just because it will take less sanding of the frets later and always gives a better fret job.

Another reason is that on hard frets it is difficult to hammer the frets in evenly without one end popping up. I use either the StewMac fret bender for straight wire, or mainly I purchase fretwire in a roll that is too round and I straighten it out a little.



First, I cut the frets to size; I have a block with the fret numbers in it from one to twenty-four. Verify that the fret is the same shape as the fretboard and if there is binding nip the ends of the tang off so it just comes in at the binding and the edge of the fret hangs over. To do this I usually use a standard pair of end nippers and a small smooth file to file the tang flush. Lately, I have become to rely more on a fret end-nipping tool that I purchased from Stew Mac. It is very good tool, but you need to be careful that it cuts them even; otherwise, the fret ends may have space under them and this can cause a string to get caught. So even when I use the Stew Mac nippers I check the ends carefully and usually file them a little.



I first use the same radius as the fretboard to press the frets, and then I use a smaller radius to check the fret ends are pressed in. For example, if the radius is 9"

Now to install the frets I first use a rubber mallet to set the frets in the slots and then a drill press with the proper radius arbor to set the frets in. I made my own wooden presses a while back on my pin router but since I purchased the brass ones from Stew Mac, I have been using them.



I first use the 9" radius on the board and then I use the 7.25" to press just the ends down. This does not touch the middle just the ends.

After the frets are pressed in I check to verify that all the frets are tight and just to be sure I use a drop of super glue in the side of the slots. If any of the frets are loose I use a fret clamp that I made to hold the ends in place while I put the glue in the sides.

The next step is to cut the frets back with the end nippers, be careful not to lift the fret. So I tend to cut the frets from the side with the nippers, then I use a flat coarse file to file the fret ends back to the wood.



I tried many of the angle fret files that companies sell, but I still prefer doing it by hand. After I get the frets filed back to the neck, I angle the file at 38 degrees and put this angle on the fret ends.

After the ends are cut and filed back its time to level the frets I use #280 and a black marker on the top of the frets to check that the frets are even. (Check the last chapter) I never use a file on them because it takes off too much meat and also make the crowns too flat. I use the #280 then #500 on the long blocks and finish the same as the fret dress above with the round block #500, #800, #1000, #1500 and then the #0000 steel wool.

To finish the fret ends I use a ground off corner file to break the sharp edges, and then I use the round block and the same #500 paper, back and forth on the frets ends until there are no sharp edges then I use the #800, #1000 and #1500 to finish them off.

To crown the tops of the frets, I use the ground down triangle file. I will not use the crowning files that they sell because they are first too coarse and second they can actually damage the frets after I spent time getting them the way I like. Generally, I tape off next to the frets with 1/8" masking tape just to prevent scratching the fretboard; I use the file to put the tops on the frets even and on center.



I have a special buffing wheel for metal that I use to bring the frets to a mirror shine and feel. I love smooth frets, and this to me is the best way. If the neck is finished maple, buffing the frets is usually always done to get the gloss on the fretboard I also buff Rosewood or Ebony to get the frets shiny. Some people complain about the fretboard being gritty feeling after buffing or getting black on their fingers so I use Lemon oil on the fretboard to remove any of the compound.

If the fretboard has binding I then scrape the binding using my scraper that was made from a ground down hack saw blade.



Another way that I use to replace frets is the epoxy method. This I learned a long time ago, and the person that showed me swore this was the best way. The way he showed me and the way I finally wound up doing it was a little different because I needed to eliminate the sanding between the frets needed for the removal of the epoxy that squeezed out. Here is the detailed epoxy fretting process.

I really don't use the epoxy fret method anymore because I feel that the frets should fit in the neck tight and not rely on the epoxy to hold them in. The only time I would think about doing an epoxy job today is if the guitar has binding and the slots are either too loose for the new frets or too high for the current slots.

To start an epoxy fret job is the same as any other, check the neck before taking it apart to see what you are in for, again if the neck is straight and you only need to replace the frets this is ideal but if the neck is not straight or has some uneven spots, sand the fretboard the same way as before.



After the frets are removed and the board is sanded to the proper radius. We are ready for fretting. First figure out the size and depth of the new fret by using a dial or digital caliper. Use the manufacturer's specs with caution, I have had many problems with Dunlop frets tang and stud width for many years. Measure the tang and stud width as well as the depth of the tang.

To open the slots I use a Dremel tool with a dental bit that I get from our local dental supplier. The sizes I use are the smallest FG56 (0.79mm) medium FG57(1.03mm) and large FG58 (1.26mm). I use a modified Dremel router base that I modified by putting a 1/4" thick clear Plexiglas base on. This one only works with my old Dremel it seems that since I started using Dremel tools back in the early 1980's it has changed a few times, and the old and new ones don't have interchangeable parts. I have rebuilt this Dremel tool about five times, but I am afraid that its time is almost up and probably when you read this I will make a new base for a new Dremel.

After the bit is in the Dremel adjust the height so that it is just below the bottom of the tang, Then rout the slots, be careful I remember when I first started doing this the slots would be all messed up but after a while you get the hang of it and just let the tool do the work, remember you are only modifying the slot.



After the slots are routed to the proper depth and width its time to start the fret process. Again, as I mentioned before

I prefer to radius the frets to size. After the frets are radiused I cut each one to the width of the fretboard you can use a caliper for this if you like but I just hold the fret on the board and cut it to size. If there is binding then I nip the fret ends back as above and gently file the hang over edge flat. The reason for this is that sometimes the nippers don't remove some of the tang.



Each fret is placed in the slot to check that it fits well, and then I carefully remove it, on some boards like ebony I will use some Lemon oil on the wood before I put the frets in so that when I pull them out the wood does not chip. If you use the lemon oil only use a little and make sure it is only on the top of the fretboard and none gets in the fret slot.

When all the frets are cut and shaped to size I put all the frets in my fret holder and sand the top of the board again with #1000 just to remove any of the wood that might have pulled up after I pulled the fret out of the slots

For epoxy I use only one kind that is Elmers 24 hr epoxy, It gives you two hours to work with it until it sets so if for some reason you need to bail out of the fret job you have time to work before the epoxy dries. A Five-minute epoxy does not give you this luxury.

Mix the epoxy well at 50/50 in a small paper Dixie cup. Next take a paper towel and wipe the fretboard down with alcohol use either denatured or I use the regular kind you get in a store.





The next step is to take the epoxy and spread it out on the fretboard. Only put the glob's in the middle of the board because we don't want to get any on the neck if possible, I tried taping off the neck with masking tape once but that turned in to a big mess so now I just don't get any epoxy on the neck's sides. Spread the epoxy evenly down the fretboard using a nylon or rubber squeegee and make sure that all the slots are filled. Wipe the excess epoxy off the fretboard and let the neck sit for a few minutes so that the epoxy sets in the slots.



I use a modified piece of wood that has half the slot depth sanded away on it. I use this to clean out the epoxy in the slots half way down; this is so that when I place the frets in, the excess epoxy only comes up to the top of the slot and none comes out and onto the fretboard.



After all the frets are placed in the neck, again wipe the board down with the alcohol.

To hold the frets in place I made a clamp that just touches the frets ends and the middles are snug because the radius matches the board. Use the clamp and wooden cam clamps to hold the frets in place while the epoxy dries overnight, don't clamp too hard remember you are just holding the ends down.



The next day remove the clamps and finish the fret job like any other one.

Basic Building

Making a guitar with the least amount of tools.

Well I don't really do this so much any more, but I did before so I can explain it easy in detail. I know people that have made a guitar with a jigsaw and some chisels. The results were not so great so I need to recommend some basic tools. If you want to make a guitar with a jigsaw and chisels. Just omit all the power stuff. (Just kidding)

The first guitar I ever made for myself, I made with the following tools. A band saw, hand router, drill press, a small belt sander, templates that I bought from WD music, a neck that I took off an old guitar, sand paper, a soldiering iron and some small hand tools (screwdrivers, chisels, the essential rasp, files, and chisels.)

First, I made a drawing of the guitar I wanted, My dream guitar then was a Telecaster body with the shaping of the Ibanez S, thick in the middle and thin on the sides. Mahogany body with two humbuckers, one volume one tone , a three way switch, and a Floyd Rose. (Don't laugh at the guitar I made in the late 1980's when I was young.)

So I made the drawing and I ordered a body blank from Exotic woods company in New Jersey a two piece mahogany blank. I don't remember the thickness from back then, but I remember I ordered the blank custom planned to around 1 3/4" The total size was around 15" wide and 24" long. This body was joined in the middle so there was my perfect centerline on both sides. No need to measure. If it had been, a one piece I would have measured in from one side 7 1/2" and made the centerline. Then flipped it over and measured from the same side again so that the center is accurate, check it three times to make sure it is correct.

I remember I had a drawing and a block of wood, and I needed to get the drawing on the wood so Mace my boss at the time told me to tape the drawing on the wood and use a push pin all around the drawing to make the body shape, neck pocket, tremolo and other routs imprinted on the wood then use a marker and a ruler to complete the dots and copy the drawing on the wood. This worked great. Another way I could have done it was to spray adhesive on the drawing and laminate it to the body. I found a few problems with this before like the spray adhesive made the ink run, and I lost the drawing anyway, I also remember once sanding the body and the paper lifted up while I was sanding away at the wood. Let's say the body shape turned out a little different. Nowadays just as I would have done then if I had made the templates, I would have used them to make the drawing on the wood.

I am doing a reenactment here with these pictures just to give you an idea of the process. Once the drawing was on the wood, take it to a band saw and carefully cut the shape of the body. If you are doing this for the first time, I need to explain a few things to help you from getting into a bad situation.

The outside body like the sides is easy to cut, but up around the neck pocket these cuts are harder to make. Nowadays I use 1/4" band saw blade because it can get into the area well, make turns and get back out. For the deep cutaways at the neck area make straight cuts in from the outside to different points in the cutaways before making the main cut, so that the blade does not get stuck in the middle and stop.



Once the body was cut, the edges were rough and I also usually stay on the outside of the bodyline when cutting because I don't like to make a mistake. I have seen many people that can cut exactly on the line, but it is too much of a chance to make a mistake.

Anyway no matter how fine a cut you do you still need to clean it up on the belt sander. So take the body to the edge of the belt sander and sand it to the line to final shape the body sides and to get out any lines or imperfections caused by the band saw. Now you have a guitar body.

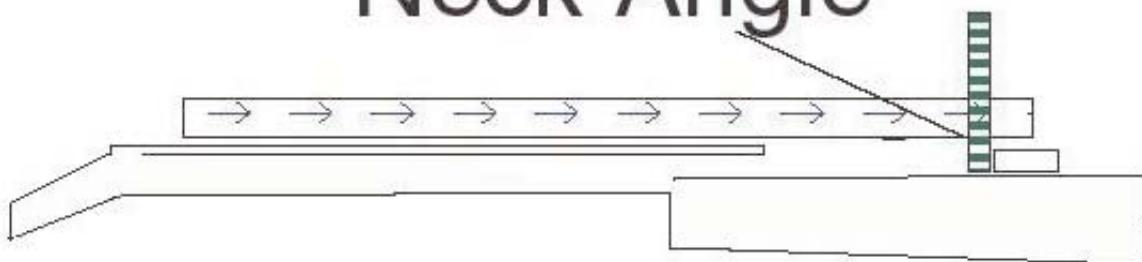


You will need a router bit with the roller bearing on top, I purchased them from WD back then but today I get them at Woodcraft. The roller bearing is the guide that follows the templates; I used a 1/4" bit that was 1/2" depth to do all the routs. I super glued shims on the bottom of each template that was 1/4" thick because it's best to keep the template above the body so that the first routs are not too deep and the wood will not burn.

First, I did the neck pocket rout from center by laying the template over the drawing on the wood, I used my favorite double stick tape (Japanese brand Nitto tape) to hold the template down, just verify it does not move.

You need to rout the neck pocket to the correct depth so that the neck sits just above the body. This is called neck angle. Neck angle is measured by laying a straight edge over the frets and checking the distance that the saddle on the bridge sits over the body.

Neck Angle



Lower the router in the wood just enough so that the bearing guide rides on the inside of the template and rout away following the template. After the first rout lower the bit and do the second depth rout. Continue until you have the proper depth, I used 18.5mm for the neck pocket on this guitar.



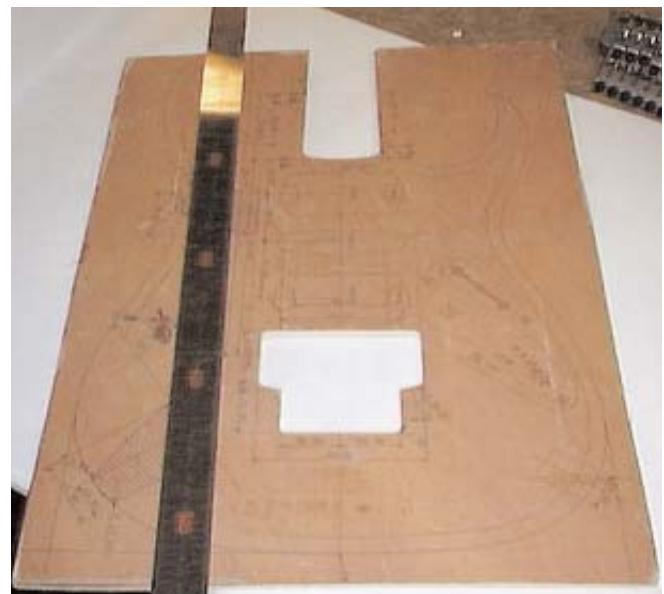
After the neck pocket is routed lay the neck in the neck pocket it should fit snug. Check the centerline to confirm it is lined up with the rest of the body routs. It's good to lay a long ruler down both sides of the neck and draw a line on the body. Hold the ruler against the sides of the neck from around the 15th fret tightly against the neck and draw the line make sure you hold both sides the same.

After that, find the center of the two lines, this should be the same as the centerline you already have. If not try to move the neck in the pocket a little to make the center line up, If the center is off that bad replace the center line with the new center line off the neck.



Lay the humbucking templates over the pickups and rout them as above to the correct depth needed for the pickup you are putting in. usually around 18mm's deep for the main part of the pickup.

For the area that the humbucking screws go in it needs to be deeper so after you make the total rout 18mm. Take the router out and lower the bit you will need around 25mm's depth for the screws so just rout the area for the screws to that depth



Next the tremolo, you will need a template for this. The tremolo I did was recessed in the body so first I drilled the stud insert holes where the bridge posts are located. It's just easier to drill on a flat surface then to try to hit center in side a rout. I measure the exact distance from the nut that the instruction stated. Then the width of the studs from center. I use a small center punch to mark the center and use a drill press with the correct drill bit and a piece of masking tape with the exact depth of the hole marked on it.

If I did not have a drill press I would first try to find one or if all else fails use a thick piece of scrap wood, Drill through it nice and straight and then put the drill bit through that piece of wood, line up the drill bit to the punched hole in the wood and use the scrap block as a straight guide to drill the hole.

Like I said try to find a drill press. Don't put the studs in yet and if for some reason you want to, verify the bridge lines up, remember that on a fixed bridge you need to install the ground wire from the stud insert before installing the studs. On a tremolo there is no need because you have the claw hook.

After the stud insert holes are in, follow your pre drawn rout information and do all the front routs for the tremolo using the template. Flip the guitar over and do the back tremolo routs the same way. Just verify they line up by always double or triple checking your measurements for the templates off the centerline.

Nowadays I rout through the body from the front. This is dangerous and you need a long bit, but it does help me line everything up on the back.

To rout the control cavity plate check where you want your controls to be also where your jack is located to make sure you have room. If you have a pre made template that fits use that. If not it is good to make one. I have actually figured out the location of all the pots and switches and drilled the holes through the body so that the templates would line up with enough room for all the components. This is also great for rear mount electronics because the depth that you need to make the control cavity on the back needs to be measured exactly to the correct depth. You don't want to rout through the body, and it needs to be deep enough so that the pots fit up through the holes and the shafts have enough room for the nuts and washers. Remember long shaft pots are what you need for rear mount. Pickguard's can use either long shaft pots or short shaft pots.

If you are going to counter sink the plates so that they don't stick above the surface you will also need templates for that. The depth of the plate rout should be measured by the thickness of the plate routed just that much. Nowadays because of the thickness of paint I do the cavity plate cover routs after finish it makes it clean.

Next drill the holes for all the wires from rout to rout. Go to a hardware store and get the 12" long drill bits I use a Big Half Inch" one for the main wire for the humbuckers, drill this one from the neck pocket through the neck pickup to the bridge pickup. Then use a 1/4" to drill from the bridge pickup rout to the control cavity area. I drill two holes one for each pickup wire. Then drill the ground wire from the control cavity to the tremolo cavity, it will be soldered to the claw hook. If there is no tremolo you will need a long 1/8" bit and tape off the top of the guitar at the bridge stud hole closest to the cavity so that the side of the drill bit does not damage the surface of the guitar and drill slowly on an angle around 15 degrees to get to the control cavity.

Careful this is the easiest one to drill through the back of the guitar. My Tele thing has a filled hole in the back from a miss drill.

To do the body round over on the edge I used a hand router and a basic round over bit that I bought at a local hardware store. A 1/2" round over bit, These are easily available from any good hardware store. Make sure it has the roller bearing on the bottom.



We also used a router table, but I never liked using these because you hold the work, with the hand router I can clamp the body down and use my hands to hold the router, just feels safer. If you are using a 1/2" or 3/4" inch round over bit be careful around the back at the neck pocket because this area should not be too far in or the edge of the neck plate may stick out over the edge. Check this and if necessary use the 1/4" bit around the location of the neck plate and sand by hand the two round overs smooth together. Now you have a guitar body plain and simple



Finally, you need to drill the jack hole, use a forstner bit unless you plan on using some type of big washer to cover the damage by the regular drill bits tear out. If you don't have a forstner bit run the drill backward to start the hole.



Now that this is done you will want comfort cuts on the front and back. Put the neck in the body and hold the guitar as if you will play it, feel where the sharp edge is for your elbow and the back of the guitar that rests against your body.

On the front draw a straight line on an angle and on the back draw a modified radius shape, Use a rasp or a round coarse file to shape it out. I sometimes use a pneumatic drum sander to do this.

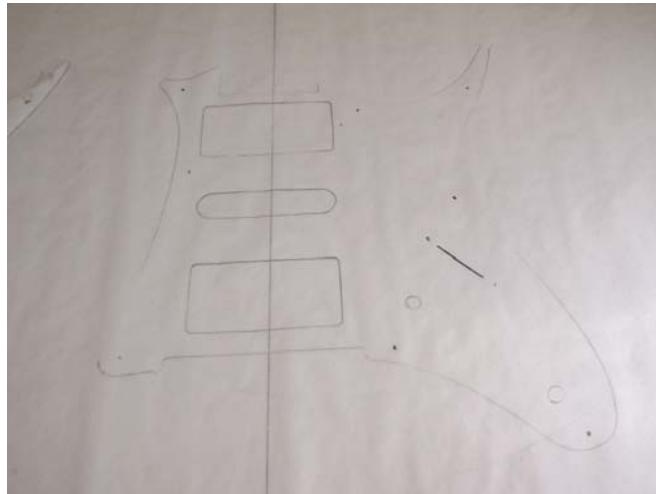


You're nearly done. Use a round block and #120 sand paper to clean up the rasp marks and hand shape the edge to match the rest of the guitar edge round over. You can try to use the hand router with the round over bit, but it's really hard to hold the router. Sand out the body with #120, #180, and #220 and get ready for Paint and Finish

Making Pickguard's

Making a Pickguard

If the guitar or bass will have a pickguard and you can't buy one, they are not that hard to make. What I always do is first find another pickguard that has the same holes or routs in it, like a humbucker or a single coil. I use the other pickguard as a template to do the routs in the new pickguard.



If you made a drawing on paper draw the pickguard on the drawing. I use the other pickguard to layout the pickups. With the knobs and switches you need to check their location in the cavity.

Remember that most guitars will have a round over on the top and if you will do this you will need to compensate on the drawing. If it is a 1/2" round over measure in from the edge at least 1/4" or half the total radius to verify there is enough room.

When the pickguard looks good lay another piece of tracing paper over the drawing and make a trace of it to make the pickguard. If you will make more than one pickguard make a template, Other wise you can just make it by hand. Band saw the basic shape and use a hand router and a really small bit 1/8" to copy the routs.



Make sure you raise the old pickguard above the new piece other wise there is no room for the bearing. Just drill out the other holes for the pots and if you have a 5way switch drill some small pilot holes where the lever will be and clean it up with a small file. I use the mill to do this for a one of a kind.

To do the pickguard edge bevel (it should be at 45 degrees). We used to do the edge on the belt sander by holding the pickguard on a 45-degree angle.

Then I bought a bit and used the router table, very



dangerous. Now I just use the pin router with a 45 bit and a pin. It looks dangerous, but it's not so bad.

Small Shop Building

Building in a small shop

Today I start to make guitars the same way as before from a drawing. After the drawing I make a full body Template with all the routs in it. Obviously, I have a very good amount of equipment and I recommend using the best tools available. Below I will go into a step by step process of how I make a body from scratch.

First, layout the wood and trace a copy of the body outline on it, so that you can verify the block is big enough for the body.



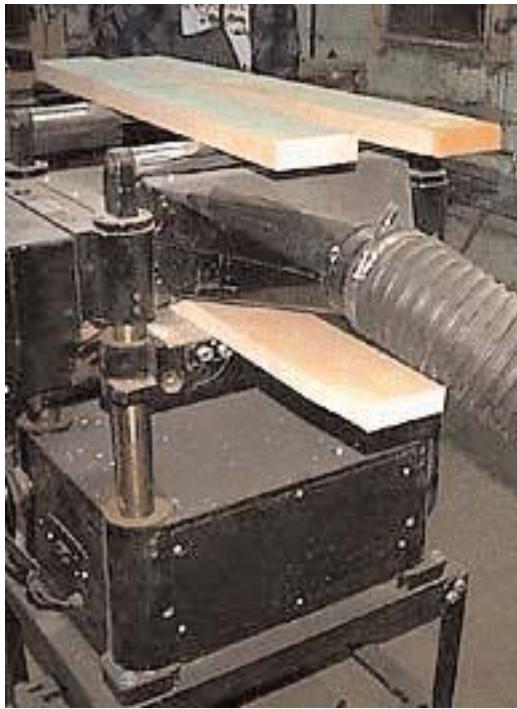
Next open the wood flipping up the two sides that will be joined. Glue is applied to both sides and then use a rubber, nylon or wooden squeegee to smooth out the glue.

Next lift one of the sides up and put it on top of the other and use two clamps in the middle of the two pieces to keep the wood even. Then use long clamps to clamp the wood together nice and tight, wipe off the excess glue with a damp sponge.

After the tracing use the jointer to get the sides of the wood ready for joining.

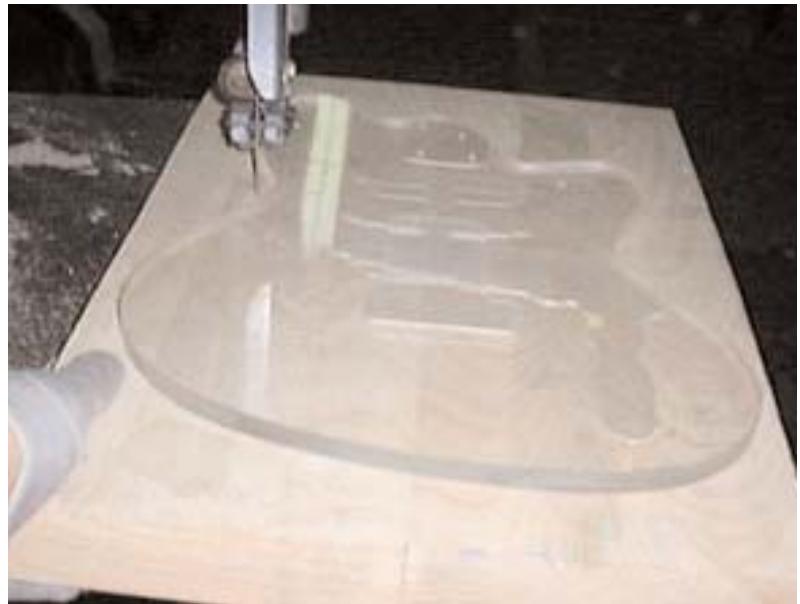
When you join wood you need to check that the end grain is running the same way on both pieces otherwise the body could twist. If you do not have a good eye for this, look at the ends of the blocks and you can see the direction of the grain pattern. Both grains should run as if the wood were book matched. I use Titebond glue to join the woods. First lay the woods out and check the body joint to make sure everything lines up tight and that the grain looks good in case you will do a transparent color.





After the wood is glued up and dried run the wood through a planer to get the exact thickness needed for the body, always start from wood that is the correct thickness this will save allot of work later.

For hard wood like maples I recommend if you can use a thickness sander that uses a wide belt to thickness sand the wood. My planner rips chunks of maple out so I either use a thickness sander or pin rout the top thickness down.



Once the drawing is on the wood, take it to a band saw and carefully cut the shape of the body. If you are doing this for the first time, I need to explain a few things to help you from getting into a bad situation.

The outside body like the sides is easy to cut, but up around the neck pocket these cuts are harder to make. Nowadays I use 1/4" band saw blade because it can get into the area well, make turns and get back out. For the deep cutaways at the neck area make straight cuts in from the outside to different points in the cutaways before making the main cut, so that the blade does not get stuck in the middle and stop.



The next step for me is to take the body to the pin router and rout the bodies shape and all the front and back routs for the pickups, tremolo and electronics.

The way a pin router works is simple. The router head is attached to the top of the machine. Directly under the head is a table that has a socket for different pin sizes. This pin is on center with the router collet so if a template is under the work, the pin will follow the template and copy the template with the router bit.

To make a perfect one to one copy use the same size bit and pin. If you want to reduce the body size you can do this by increasing the size of the pin while using a smaller router bit. The table or the head will have a depth control on it for controlling the depth of the rout.

To do the body round over use the pin router and the proper round over bit between 2mm up to 20mm depending on the body. If there is binding on the top, figure out the thickness of the binding and reduce the pin size to bring the router bit in.



For example, if the binding is 2mm I use an 8mm pin with a 12mm bit this will rout a perfect 2mm channel for binding.

To cut the comfort cuts in the front and back I made a jig that sits at 15 degrees. Two clamps hold in the body a band saw is used to cut the front and back comfort cuts.

Now all the routing is finished. final sand out the body with a pneumatic palm sander and 80/180/220 paper and get ready for finish.

The finish process depends on the type of wood. If the body will be stained or sunburst, use alcohol or water dyes to stain the wood and then either spray the burst in or start clearing the body. (See Paint and Finish chapter for more info)



On woods like mahogany or solid colors I use a polyester sanding sealer on the wood to seal it before finishing. I have used a pore filler on mahogany before, but it's a pain to sand and clogs the paper so I prefer the polyester to seal the wood.

The next step is to spray the color on the guitar I use House of Color urethanes (800-328-5139) for most of my custom work because it is fool proof and they have every color you could need.



I let the paint dry at least 24 hours, and then the type of clear used depends on the guitar. I use Polyester clear over all electric solid body guitars except for white because the poly yellows, for white I use urethane clear.

For jazz guitars and vintage necks I use Lawrence Macfayden (215-624-6333) nitro lacquer straight out of the can. I have tried many lacquers and most crack to early. I used a product called Star Lacquer for a while, but it was so hard that the body would get finish cracks if the finish was not applied exactly the way the directions said. The Lawrence Macfayden lacquer is also fool proof.

For Polyester I use at least two heavy coats of clear. For urethane or lacquer it depends on the temperature and the wood. If it is really humid outside I only spray early in the morning so it does not fog up ,I also use thinner coats.

In the winter I spray the coats a little thicker so that it looks as if it will run, most of the lacquer evaporates anyway so I just keep dumping coats on. Drying of Polyester and urethane is at least one week people say they need only 24 hours but that's bull, The harder the finish the easy it is to get a good shine. For Lacquer I let it dry for as long as possible this could be three weeks to three months depending on how much time I have.

The finish sanding process I use is first #400 on an orbital sander for the polyester clear some people might cringe when they hear #400 but it cuts well, and I can get the body level in a few minutes.

Then I use the orbital sander with #600/#800/#1000.



Wet sand the body in a back and forth motion with #1000 and #1500 to get the circle scratches out. The next step is I hand rub certain areas with a 3M Buffing Compound, but a car compound also works well. I do this to areas that are hard to get the buffer in on like some cutaway's or edges.

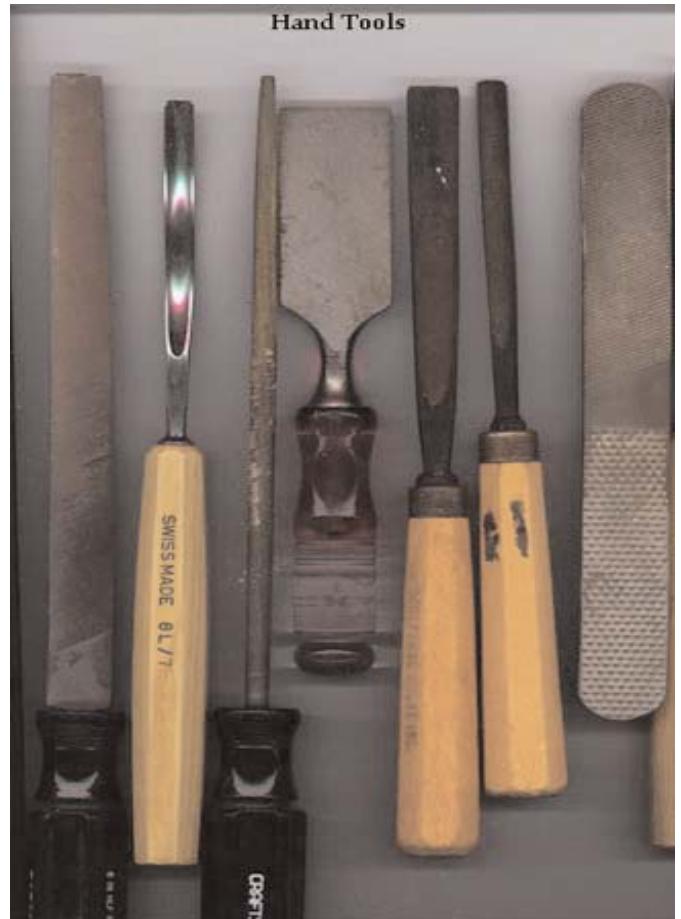
The Next step is the buffing machine and Menzerna polishing compound (From Germany) on the wheel, the first wheel cuts the scratches and the second wheel will bring out the shine.



Carving Top's

Carving a top by hand with chisels and planes is a long process, it's fun but a time consuming project. To cut this time down I have a few ways of doing this. One way is by use a milling table, some math and a router bit. The top can be carved in about one hour.

In factories most carving is done on a pantograph router (or copy machine) this is great if you want to make many bodies with the same arch. However, each guitar I make is different so I need to carve each body separately.



Many guitars are not carved but actually pressed plywood tops that are pressed into shape using large presses. This is like an ES335.

First, the wood needs to be glued up. Depending on how much of an arch from the center and the total thickness of the body you will need to plane the wood to the proper thickness.



What I use to figure out the total blank thickness is to decide what the depth of the arch from center to the side of the body will be. If the top will be carved say 12mm (1/2") then figure the body thickness plus 12mm for the top. On many models I also carve the back so I usually start with some very thick wood. (As you can see from the photos) On a body that I will carve the top and back I have to figure out what the total thickness will be when it is finished. If the body will be 40mm thick and I want to carve a 12mm back and a 12mm top I need to start with a 64mm piece of wood. If just the top will be carved, I figure the thickness of the edge of the body plus the amount that will be carved away.

After the wood is glued and planed you will need to do some math to figure out the carve. Depending on what type of arch you want you can figure out the depth of each area.

After the wood is glued-up start by cutting the bodies' shape and do as many routs as possible while the wood is flat. After the top is carved routing many areas of the guitar can be difficult. I basically will rout the neck pocket, pickups and if there is any, all the tremolo routs.



on the top. I usually like to keep the pickup area as well as the bridge location on a flat surface. I will start carving after these routs. For this example I will make a 12mm arched top from the center. I want the arch to be fairly steep so I will step rout 2mm at a time.

Starting 55mm's from the center draw the first line.



Once the basic body is shaped we need to find the center of the guitar. If the neck pocket is routed use this for the most accuracy. The reason for this is that the bodies center may be slightly different from the necks center. Put the neck on the guitar and run a straight edge down either side of the neck and draw a line. After both sides have this line, find the center of the body with these lines.

On the body you will need to layout the basic idea in lines



I will use a 12mm bit to rout so I measure every 12mm's and make another line. For the back by the bridge I want the arch to be less until after the bridge and then carve down, for this I will step rout 1mm depth every 12mm's until I reach the 6 mm depth than I will increase it 2mm every 12mm's.

Place the body on the mill and lock it down with clamps. Verify that the centerline on the body is center with the mill's centerline. To do this start at one end of the body and move the table following the line, it should follow the line exact, if not adjust the body so the line is straight.

Next I bring the table up so that when the bit touches the wood it is set at 0. Move the table to the first step line and lower the bit 2mm into the body and mill a straight line.



Continue milling each line to the proper depth.



Once the step routing is finished you will see the basic shape of the arched top. From this point I use a round chisel to carve off the sharp edges.

After all the sharp edges are removed I use an orbital palm sander and #80 grit paper to smooth the layers out. After all the lines are sanded out I use #180 and #240 and #320 to final sand the top.



Now that the first guitar or prototype is finished I want to make a few more. Well I use to need to repeat this process until I stumbled onto the Dupli carver at a local wood show. I saw this and went nuts. I bought a new one the next day. The price for the basic machine was around \$750.00, I bought the Porta Cable router and the needed pins, made the table and the total cost was around \$1000.00. That's cheap when you consider what it can do. I make dead on neck copies with it also. The company I purchased it from is Terrco and their phone number is (605) 882-3888

The left side is the copy area, and this is where the template goes. There are different size pins available that match the size and radius of the router bits.

Normally I cut the basic shape of the guitar out on the pin router first to save time. But actually I found that you can easily make the entire guitar with this machine, I found out the hard way that things don't always line up so you need to be very carefull setting up the body that will be carved if you already have the routs in it. In this picture I am lining up the pins.



Then similar to with the prototype I use a palm sander to clean it up and presto a carved top.



Once everything is lined up and depending on the wood I set the depth of the router bit higher then the actual final cuts. (The depth I go on each pass depends on the wood. harder wood not so deep passes but a softer wood like spruce you can go fairly deep. This is actually gutting the wood. The pin is easily adjustable. Once it is set I go back and forth until the basic arch is carved.



Paint and Finish

I remember back in the early 1980's when I was in college studying music. Everyone was playing plain guitars, no fancy colors just black and sunbursts. I played my 1977 BC Rich Eagle, this was the first real guitar I ever owned. I remember this was the first time someone showed me a FloydRose® (on a Lespaul.) Most people were playing Gibson's, Fender Lead II's and Ovation's. Then I remember putting the first sticker on my case for a new football team in Philadelphia called the Stars. They won that year.

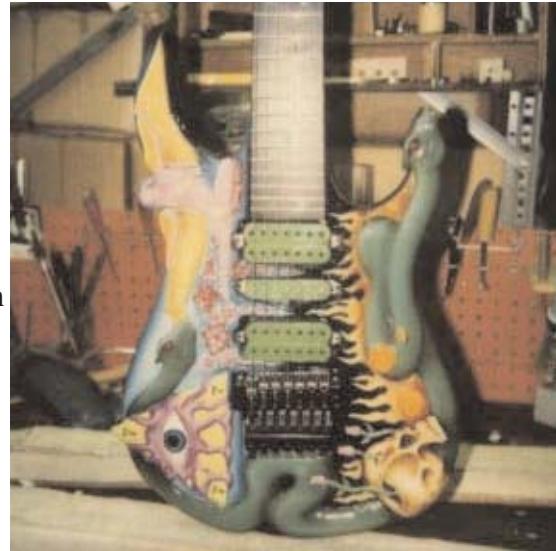
The reason I told that story was because when I started working at Ibanez I remember this was when people started adding graphics to their guitars, basically they were putting stickers all over them. The stickers were anything that they could find from a car bumper sticker to whatever they felt was cool. Painting a guitar is not difficult if you have the correct equipment, however, it is time consuming. Painting a guitar without the correct equipment is not impossible, but it is more time consuming. To do some special graphics on a guitar you first need to figure out what you want to do.

Sitting in front of you is a guitar body and neck unfinished. Its time to do some finish work so where do you start? It depends on what type of finish you want and what type of wood you have. The easiest and quickest finish is a standard oil finish. It is not a law, but I sometimes tend to like oil on any type of grainy wood like mahogany or ash. Any bass I make with an exotic top or an exotic wood construction other than transparent colors I like oil. Oil finish gives you a more true to life wood feel, but it has its drawbacks. It's hard to keep clean, it wears uneven in the areas that your hand rests and the wood sometimes gets darker after time. I made a bubinga top bass with a solid mahogany back years ago, and it was beautiful when I finished it, but it came back six months later and it was completely black in color from the air. So be careful when using oil.

What type of oil to use. Every one has some idea about this and I only talk from experience. I first started with Watco Danish oil; many other companies like formby's make Danish oil also. This is a great finish, but it is

almost dull. I wipe it on with a rag and I have heard stories of the rags catching fire or exploding so be careful. I still use Danish oil on necks but that's about it. Then there is tung oil; it is really almost the same to me as the Danish oil finish so the method for doing this is the same.

Recently, I heard that Musicman was using gun oil to finish their necks. I went to my local gun shop and bought Hoppes machine oil and I used this on allot of samples. I thought it was great but when I went back to the gun shop and asked for more they looked at me strange and pointed me at the gun stock oil in a can. So I bought this and now that's all I will use. It sprays on easy, dries fast and has a slight shine to it. I figure if it protects gunstocks from sweaty armpits then it must be able to handle any musician. The brand I use is Tru-Oil.



To do an oil finish first you need to sand the body well. Make sure every scratch from the sandpaper is gone. I never start sanding wood with anything less than 180 grit sandpaper. I feel that even #120 leaves deep scratches that are hard to get out. Sandpaper is used in grades starting with lower aggressive grit and moving up to a smooth grit to get the previous scratches out.



I generally use power tools to sand the body, if I try to sand by hand there is always some small spot that I sanded too deep and it shows when the instrument is finished. I use an orbital sander that is air powered that I purchased at our local auto body store Bill Flannery's automotive (They send me a great basket of snacks every Christmas too), The orbital sander works quickly but leaves some circle scratches in the wood that can appear after finishing. To eliminate these you need to sand back and forth with the grain before finishing. For this I use a regular back and forth Black and Decker palm sander. Some people I have worked with use this for the entire process and it seems to work well, but the orbital cuts faster and keeps the paper cleaner longer.



My process on wood is to start with #180 (Some other builder's start with more aggressive paper.) sand with the grain that means back and forth from top to bottom, this way any scratches match the grain. (Cross grain scratches are hard to remove.) On the top/back, and sides I use the palm sander but on other areas like cutaways or areas that the sander does not fit, I made special blocks that fit in the cutaways. (I just use large dowels or broomstick handles, cut to size and covered with rubber or felt.)

Sealing the wood.

Depending on the type of wood and the grain different ways are used. If the wood is very porous like mahogany sometimes I use an actual pore filler. This is a paste that is brushed on the body in the direction of the grain. Let it sit for about twenty minutes and then wipe it off against the grain so that any of the filler in the grain pattern does not come out. If you wait any longer than twenty minutes it will harden and become almost impossible to get off, sanding this does not work because the pore filler clogs the pores.

After the wood is pore filled or if I am using a body material that is not so grainy like alder, maple or basswood, I use a Polyester sanding sealer sprayed on in my paint booth. The difference between polyester and other finish like lacquer is as follows. When you spray lacquer finish on a body it is sprayed at around 28PSI (Pounds per square inch) over 80% of the paint evaporates into the air. This is why it is almost illegal to spray in many places in the United States. All the finish that evaporates goes into the air and causes pollution.

Polyester however is sprayed at a much higher PSI around 40-42 PSI and almost all the finish that goes on just stays there. It is almost like spraying honey or maple syrup it just goes on really thick. The advantage of this is that fewer coats are needed to seal the body. Most woods can be sealed with two coats of Polyester compared to maybe six to eight coats of lacquer and a two-week drying time. The polyester being so thick seals and levels the wood. After it is dried polyester is easy to sand. I use an orbital palm sander with 400 grit paper to level it out then I hand sand the scratches out with a wet sand paper of #500 to remove any scratches and get the body ready for paint.

If there is any graphic to be painted on the body the guitar still needs a base coat usually black or white depending on the graphic. A base coat will cover the wood so that any graphic painted on will stand out. For a base coat I use urethane base, or lacquer base paints, depending on the application. I actually prefer using the urethanes more than the lacquers for any graphics. I use mostly House of Color paints they are great or sometimes PPG paints (because they have every color in the world.) To spray a base coat follow the mixing and spraying instructions exactly as the manufacturer states.

Base coats can also be metallic or pearl I use mostly House of Color or PPG for these also. I have a special gun and a separate area for mixing so as not to contaminate the rest of my paints and spray guns. After the base coat is applied over the sanding sealer let it dry at least 24 hours before any graphic is painted on. If the body is already finished (maybe you have a complete guitar that you bought and want to add a graphic.) First you will need to take the guitar completely apart, this is all the parts and neck. For a graphic to stick to the finish you will need to rough up or scratch the surface of the guitar. To do this you can use a Scotchbrite course pad or use #500 wet sandpaper. Completely rough up the area that the graphic will be located. It will look dull but don't worry this will disappear when the clear is applied. There are many types of graphics that can be done, and many ways it can be applied; here are some examples.



Airbrush:

An Airbrush is a small spray gun that sprays a very fine line. This takes a really good hand to do and many artists are good with this, personally I have no luck trying to paint this way.



Next is a standard paintbrush, similar to the way a painting is done. It's best to use urethane, or lacquer base paints. This system is also best left to people with good artistic ability unlike myself. There are many great artists out there that can do this for you.



To get a finish like Eddie VanHalen just start with a base coat say red and then use masking tape on the body in lines and spay different colors over it. When you remove the tape, the guitar will have lines on it. You can remove a different layer of tape one at a time and add new colors until finally you have what you want.

I made a guitar years ago (THIS PICTURE IS OF ME WHEN I FIRST STARTED AT IBANEZ IN 1984) for myself that had gears on it. I was in a band called Moving Parts and we thought it would be cool to have a guitar with gears. To do this I first painted the body red, after this I used what we call Frisk-it paper. This is a large piece of low tack tape that is easy to cut. The thing about Frisk-it paper is that the edges are strong so the paints do not run or blur under the tapeline. Normal masking tape can do this and leave the edge lines blurry.

After I put the frisk-it paper on the body I used a small Exacto knife to cut the shapes of the gears and then I sprayed the guitar black. When I removed the Frisk-it paper the gears where there in red, Next I masked off the edges of the gears and painted them white to give the gears three dimensions.

One other way to put a graphic on is to find a drawing or a picture that you like and shellac it on the top of the finish and clear coat over it.

Whatever graphic is done the guitar needs to be cleared or finished. The body needs to have some clear coat applied over the graphic to protect it. For almost all graphics I prefer polyester because it is thick and it dries quickly, It also sticks to almost anything. I had a problem with urethane not sticking to the graphic and when I buffed the body the finish just peeled off.



Clearing the instrument:

The type of clear depends on the application, and the amount of coats needed. For polyester I use two coats, urethane I use three or four and lacquer I use at least six. Again follow the paint manufacturers directions. I spray the instrument hanging up with a holder attached to the neck pocket. If the guitar is a set neck or neck through I attach a hook at the strap pin. I also make a holder out of a dowel that fits in the machine head holes; this stabilizes the guitar when spraying; otherwise, the body will be blown around by the air pressure of the spray gun.

Sanding and Buffing:

After the finish has dried it needs to be sanded and buffed to a high gloss. To do this I start with a palm sander and #400 paper to level out the surface and then I use wet sand paper #500-#800-#1000 and then #1500 to remove the scratches to get it ready for buffing. The more and finer sanding you do the less buffing and more shine you will have. Also, wet sand in one direction back and forth never go in circles.



Once the body is sanded I use an up-right buffing wheel with a German Menza compound. First I use an abrasive wheel with the compound on it to get the fine sanding scratches out and than a second wheel that is just soft cotton to bring out the shine.



I use the buffing wheels because I have them, but you can get the same shine using a buffing compound that would be used on a car and just rubbing the scratches out. In the states I use a 3m compound and then I use a car polish called Macquires to bring the body to a high gloss.

Lacquer finish models:

I use Lacquer on all arch top hollow bodies, vintage guitar refinishes and acoustic models. The process for this is the same as above, but I use mineral spirits instead of water to wet sand the lacquer because it does not clog the paper. Generally with Lacquer the drying time needs to be at least two or three weeks before sanding and buffing.

Removing a finish:

If you are refinishing a guitar, you will usually need to remove the finish. For lacquered instruments I use Zip-Strip, brush it on watch it bubble and scrap it off. No problem, For urethane or polyester finish I use a Wagner power stripper and a dull scraper blade held in place with a pair of vise grips so I don't burn my hands. Use the power stripper on low so the wood does not burn and the old finish does not bubble. When an area gets hot, scrape the finish off but be patient or you will put deep gouges in the wood. After the finish is removed follow the above procedure to refinish the body.

Finishing a neck:

I use the same process for finishing a neck as above but if the fretboard is rosewood or an exposed wood I mask the fretboard off during the entire painting process. If there is an inlaid logo and you don't want to paint over it, I use a 3M plastic tape over the logo and carefully cut it around it with a new Exacto blade, paint the color and remove the tape and clear it. To get a vintage tint on the neck I prefer using an alcohol base stain (amber vintage yellow) that I mix myself and hand rub it in the wood before spraying the clear.



Factory Repair

Factory Guitar Repair:

I have spent almost 15 years repairing guitars, one thing that I always felt lucky about was that if I made a mistake I could always replace the guitar that is one advantage that most people don't have. The good thing about this was that I had a chance to try some crazy things to do repairs, sometimes dangerous but I have never been one to worry about trying something new.

In this chapter I will go into how we repair guitars from a factory standpoint, I am not recommending all these ways for everyone but you may get some ideas. The reason I call this factory guitar repair is that this is the way that the factory would or may repair the guitar, It's like taking your car back Detroit to have it fixed.

Chips Dents, Dings and Scratches.

Here's a tough one; your guitar has a chip in it from bumping into something. You have a small chip in the finish. If it is a vintage guitar or may become a vintage guitar people usually like to leave these alone because any modification to the finish will decrease the value. Unless it's really big I leave it alone, most amateur repairs look much worse than the small chips in my guitar.

If it's a big chip try to find the piece that fell off, in a club this is hard, but at home you can usually find the chip. Here is an easy repair for that. You will need #1500 grit sand paper. Super glue, two wooden tooth picks and some polishing compound.



First place the chip back into the body and hopefully, it will match exactly to where it came out.



Take one drop! No more on a toothpick and place it in the edge of the crack so the glue runs under and in the chip. Don't use your fingers on this because super glue adheres to skin better than anything, Use the second tooth pickup with no glue on it to hold the chip in place while the glue dries.

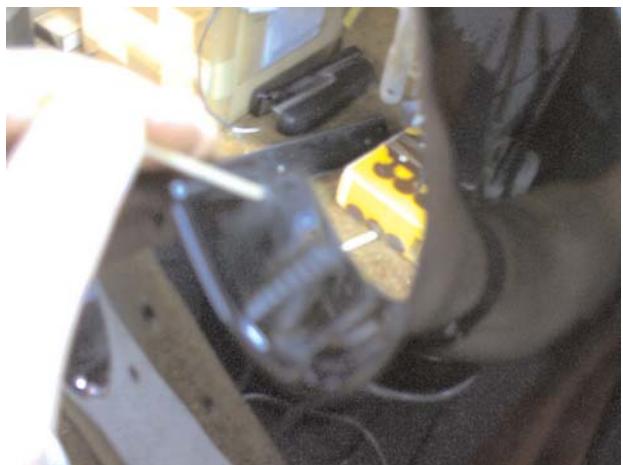
After it is dry take a few more drops of glue and cover the chip and the line will disappear. Use the 1500 paper to wet sand the area even. A car finish compound should be used to rub the finish and bring the shine back. If you don't have the chip and want to touch up the guitar take the guitar to an auto part store that sells touch up paint for cars. Try to match the color with a car touch up paint. Usually, this paint has the clear coating mixed in, if you can't find this than maybe try to match it with nail polish from a department store. They usually don't have metallic though.



Heel Cracks (Cracks around the neck joint)

Heel cracks are caused usually by some type of impact on the guitar, even if the guitar case is dropped; this can cause heel cracks. The problem seems to be that bolt on necks move separate from the body. Most heel cracks tend to be just in the finish so they are not actually effecting the guitar structure, but sometimes the cracks can go right through the wood.

To repair a heel crack first we need to take the neck off and check the cracked area. On small finish cracks this repair is fairly simple just verify the crack can close back up and take a tooth pick and super glue and cover the crack with a small amount of glue. You will see the glue run in the cracked area, never use any type of setter because this dries the glue too fast and causes the glue to break down and turn white. After the glue dries wet sand the area with #800, #1000 and #1500 than buff the area with a compound or buffing wheel if one is available. On most guitars the crack will be totally invisible and don't worry the glue is stronger than the finish was.



On more complicated cracks you will need to repair the crack as well as refinish the area of the crack. For this type of repair remove all the parts off the body. Close the crack the same way as before using super glue until the cracks are completely closed up. Next you will need to break the finish area that will be repainted because paint does not stick to a buffed finish. I recommend using Scotch Bright® pads to rough up the finish in the area that will be repainted.

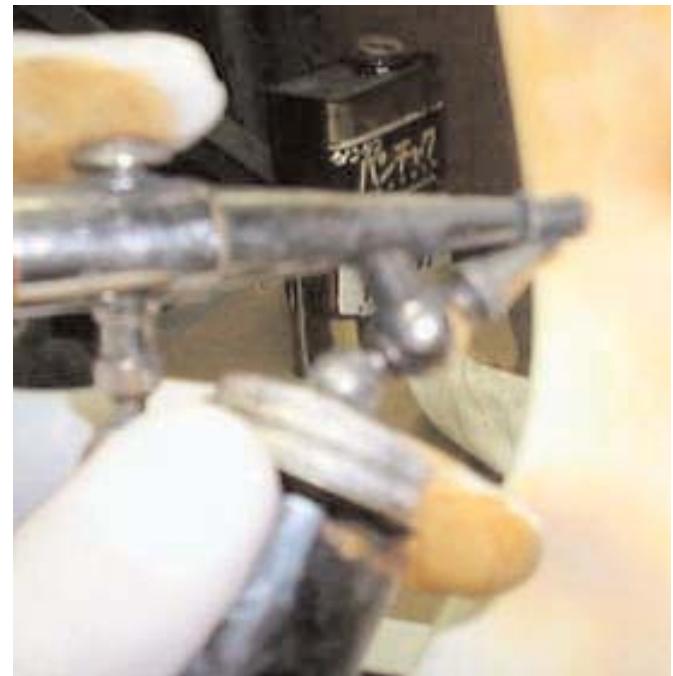
We have what we call polylines, this is the same as in the auto body business and you always want to refinish an area not just a spot. Always try to find a line to finish up to. On a heel we will usually refinish the entire cutaway area. This will hide the topcoat lines from being visible. To do this type of repair you need to tape off the rest of the guitar that you don't want to refinish. Once the crack is repaired use the correct color in an airbrush to repaint the repaired area and then clear the whole section. Once the paint and clear dries wet sand with #800/#1000 and #1500 and buff. See Paint and Finish

Nut Replacement

If a nut is too low sometimes you can put a little drop of super glue in the slot and wait till it dries so the string does not buzz open. However, you will need to replace the nut eventually. So the hardest part is getting the old one out. On some guitars the nut is under some clear so you will need to use an Exacto blade to slice the finish that around the nut.



On a blank style nut I use a small metal bar to pop off the nut. With a Fender® style nut I try to wiggle it out with a pair of dull fret nippers, be careful you can easily take the wood with it. I read somewhere to saw the nut in half-long ways down the center. I tried this and it worked however, I always like to keep the original nut intact for at least marking the nut slots for the new nut.



To install a new nut measure the nut slot and nut material. Cut and shape the nut material to the exact size of the nut slot before gluing it in. I use super glue to mount the nut, but you can use white glue if you want.

If you have the old nut use it to mark the slots. If you need to cut a new nut from scratch, you need to think about the string spacing.



For a six string divide the total width by 5, on a four-string divide the total width by 3. Mark the nut and cut the slots.

Make sure you hold the file straight and don't go too deep, You can put a metal thickness gauge under the file that is higher than the fret to verify you don't go to deep. (Say is the fret is 1.0mm use a 1.5 mm thickness gauge)



Start by figuring out how far from the edge the outside strings will be. On most nuts it is usually around 3-4mm. Mark these on the nut and measure the inside distance of the two. Then depending on how many strings you have figure out the distance



Loose Tremolo Studs:

Since the invention of the Floyd Rose® loose tremolo studs have been a problem. This is caused by the tremolo being used, and the actual area of the stud inserts can't always handle heavy use of the tremolo, the weaker always loosens so the studs come loose or even crack the wood around the tremolo.

If the studs are just spinning but there is no structure damage around the studs you can use super glue or epoxy to set the insert in the wood.

Guitars that are either damaged in that area because the stud inserts have cracked the wood, or on a standard Floyd Rose® the screws are directly in the wood and the wood just can't handle the pressure; we will need to replace the wood area.



First, if there are inserts in the wood remove them. To do this I use a stud extractor that is similar to a wheel extractor. First, I use a threaded bolt that fits the studs, a nut and a washer. I use a bass machine head grommet as a spacer.



Place the grommet over the stud, insert the bolt through the insert with the washer and nut in place, tighten the nut into the grommet and the stud insert will be pulled out of the wood. (Stew Mac sells one of these but they are easy to make)

Next you will need a wooden dowel that is larger than the hole. If the hole is 10mm I use at least a 12mm dowel. Use the correct drill size for the new dowel and drill the insert area with the drill bit. Measure the depth that you drill and mark it on the dowel and cut the dowel to the exact length that you need. Remember most drill bits drill the center of the hole deeper than the sides so measure the depth at the side of the hole not the center.



Take the dowel and place it in the holes and don't hammer it in because this can cause a crack. Take it to the drill press and put a bolt in the drill press and press the wood in like an arbor. This will give you a perfect fit. If you choose to use wood glue on this it won't work, because the dowel fits so tightly in the hole that the glue would just be pushed out after the dowel is in, use super glue or 5 minute epoxy around the sides of the dowel to make sure it is sealed.

Now re-drill the bridge stud inserts and that's it you can touch up the area with either touch up paint or magic markers that are the correct color.

Body Seam lines:

Body seams mostly appear where the wood is joined. Most bodies are two or three pieces. It is standard that on guitars with natural or sunburst this type of problem is not totally visible but on solid colors it is a big problem.

From a production point we use a veneer on the top and back of all solid color alder bodies. The veneer will not show any seams after finishing.

When body seams appear on a guitar it is a fairly easy repair you just need to be careful not to sand through the finish. First take all the parts off the guitar so you have a flat area to work on. Next if there is any area that is open wood, you should seal it so it does not swell if it gets wet.

This area is usually anywhere a screw is like the pickguard, mounting rings or five -way. I just seal the holes with super glue. If bare wood gets wet and swells under the finish there is nothing you can do about this.



I use a palm sander with #800 dry on it and sand the area flat until all the shiny spots are gone, and the seam lines disappears. Then I use #1000 and #1500 wet, then buff the area. If you don't have a palm sander just use the #800 wet with a flat block to sand out the seams then follow the #1000 and #1500 paper and buff.

Sharp Fret Ends (Fret ends that stick out)

The wood shrinking when moisture leaves the wood causes sharp frets. If there is no finish on the ends of the fretboard just use a fret file to file the frets back, then a long block with #280/#500 to finish the sides and use a triangle file to remove the sharp edges from the fret ends. Use the #800 and #1000 with a short block and finish with #0000 steel wool.

If the fretboard has a finish on it, and the frets finish is bubbled out. Use an Exacto blade on the side of fretboard at the top to make sure the air bubble is open and use a new bottle of the thinnest super glue you can find. In the states the Hot Stuff is good, but I prefer the Japanese thin glue from Arron Alpha. You can not get this in the states.



Take the glue and put it on a piece of wet sandpaper and use a toothpick. Take the glue and touch it on the top of the fretboard below the fret and watch in amazement as the air bubble disappears. Then use the #280 long block to sand the fret end back, Follow the same procedure as above to finish the frets.

Sometimes the glue does not work and if the fretboard is Rosewood or Ebony than I first use a file to file the frets back than I use a scraper to scrape off the finish on the fretboard down below the fret line or the air bubble and use the same finishing procedure described above.

Shielding Noisy Electronics:

Shielding the cavity and all the electronic areas are the only thing to do. The shielding paints that they sell are OK, but this hardens up if it is not used and can be a waste of money. I use these paints to seal the wood area after the body is routed then go to an auto part store and get the silver or gold tape they sell for doing repair work on cars. This is a great shielding tape that is cheap and easy to use. Be careful not to cut your fingers on the sharp edges this hurts like hell. Use an Exacto knife to cut the shape of the cavity in the tape and install it in the cavity. On my guitars I prefer the copper tape, but it is really expensive I get rolls from Dimarzio® and one advantage of this is you can solder to it and run a ground line from the pots to the shielding area. I found that on bodies without pickguards that a single coil pickup with two wires, and no shield could pickup allot of noise through the drilled area that the wire runs through. This is next to impossible to use tape in so I pour the shielding paint in the hole to seal it. If I really want the guitar to be quiet, I replace the two wires with a shielded two-conductor wire.



Cleaning Electronics:

Sometimes all that sweat, dirt and bar smoke get in the electronics and cause noise when you change pickups or turn the pots. You can use the compressed air in a can for cleaning computers first, I have used some contact cleaners but some tend to cause goo that locks up the pots. What I have been using as lately is CRC with a red label, this works well. I don't like the blue stuff. If something is giving you allot of problems it may be a good idea just to replace it so it does not go down again. If you are a vintage person save the old parts in case you want to sell it, but just because it's a vintage pot does not mean it is good, although it may add to the value.



Electronic Problems:

Some time in your life you will encounter some type of electronic problems from noisy pots, bad pickups, distorting electronics to jacks that crackle when the cord is moved and everything between. First before you read this remember as we say in the repair world. (Keen Eye for the Obvious!) What this means is first try to figure out what happened and usually the answer is right there under your nose. A simple example is maybe a dead battery, or the pot turned and is touching the side of the cavity that is shielded and intern is sending the signal to ground.

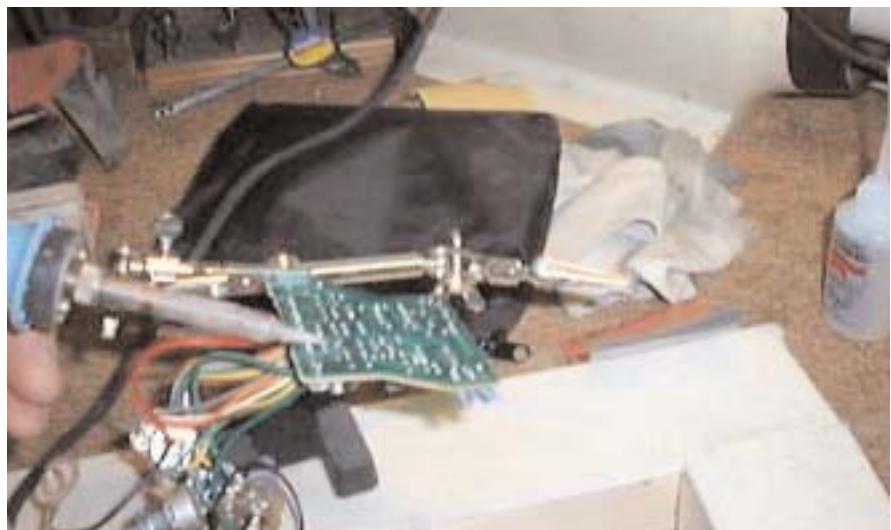
No Sound from the electronics passive instrument (No Batteries)

First, things first check that the amp and cords are good. Then ask yourself or whoever's guitar it is when did this happen and what where you doing.

Did the knob turn all the way around, This may be a loose nut and when knob turned it took the pot with it and the wire snapped off, or even the lugs for the wires could be touching ground somewhere. Look all around for things loose or touching or broke off. Try to figure out where they came from and return the wires to that location.

Cold Soldier Joints

This is a soldier joint that has lost its conductivity, usually they are not shinny. A quick touch with a hot soldier iron and a new piece of solder usually fixes this up quick.



Bad pickup?

A pickup that has an internal ground problem will send the signal to ground. You can use a multi meter to check the pickup's output using DC resistance ohms, it should read between 5.0K to 18.0K Ohms, depending on the pickup style or output. If it reads 0, it is open or if it reads more than 100000 or something it is also bad. Your best chance on fixing the pickup is to hope that the only problem is that the wire leads that are attached to the beginning and end of the coil are somehow not connected. Anything else is almost impossible to fix because it is inside the coil winds.

The wiggle test:

Grab the wires when the instrument is plugged in and tug on each one just a little and wiggle them, any sound come out? Trace the wire back to the problem.

The by pass:

What I do sometimes is by pass different parts of the circuit to see whether I can find the problem. First, wire a pickup straight to the jack, the hot wire from the pickup goes to the hot lug on the jack and the ground goes to the ground on the jack. Is there any output? If yes the problem is in the other part of the circuit if no sound comes out it is either the pickup or the jack. This works really well with active electronics because sometimes you have no idea where the problem is coming from.

Volume pots that don't turn off:

This is usually caused by the lug not being grounded (See Wiring)

Pots that keep turning:

Well this could be a loose nut but sometimes if you look at the top of some pots there is a bent piece of metal that goes into the pot, this is the piece that stops the pot from turning verify it is all the way down. The guitar is noisy even when your hands are not on the strings? Check the bridge ground at the claw hook, studs or pot.

Active Electronics:

First check the battery, then perform the wiggle test as above. If there is, a PC board also do the by pass test as above. Check the PC board for broken traces, This is where a small trace may have lifted off the board and broken contact, if you find one of these you can hardwire the connection. Just find the beginning and end of the trace and put a jumper on. If the electronics are distorting this is often a loose trace, bad op amp or a low battery under 9 volts. (Some electronics are very sensitive to voltage and as a battery loses its power the output will distort.)

Batteries that die too fast:

Usually, electronics today are optimized for at least 20 hours or so of usage, However remember that whenever the instrument is plugged in the circuit may be on so keep the instrument unplugged when not in use. If the problem occurs check the circuit with a meter to see whether the battery shuts off when the instrument is unplugged. Do this by touching the red to the battery red and the black to the jack ground, when you remove the cord it should have no DC volts when it is plugged in it should read the value of the battery (9 volts or so)

Cracked Fretboard or Bridges.

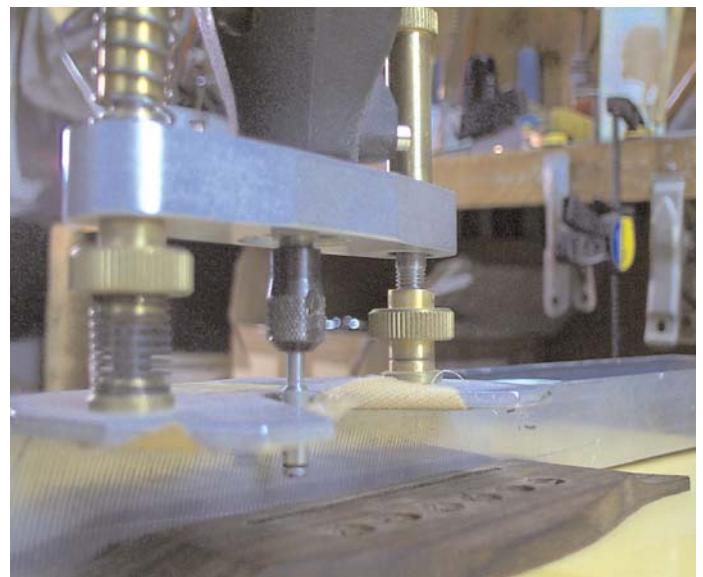
On acoustic bridges, arch top bridges or even ebony fretboard's that are not properly kept moisturized with oil can crack. These types of cracks are usually structure cracks and need to be repaired well. For a bridge crack I use wood glue in the crack and a clamp to hold the crack closed. After the glue dries I use #280 sand paper to sand the area and get some wood powder, then I seal the top of the crack with super glue and while the glue is wet, sand the area with #280. This mixes the glue and wood powder together and seals the crack to an invisible repair. On a cracked fretboard I do the same as above however, I use a thin sanding block and a scraper to sand between the frets. This is a pain and if the fretboard is cracked allot or the length of the board I pull the frets repair the cracks as above and then re-fret it. I also tell the person that owns it how to moisture the fretboard from cracking.

Acoustic Guitar Bridges.

Since the invention of the acoustic there has been lifting bridges. On most American guitars the bridge is glued to the wood. But on almost all-foreign guitars the bridge is glued on the top over the finish with super glue using Arron Alpha the strongest super glue in the world. If the bridge is just lifting in the back you can sometimes just put glue under the bridge and clamp it back on. On foreign guitars use super glue on American guitars use wood glue.

To remove a bridge it depends on if I will replace the bridge with a new one or not. Usually, if I am going to take the bridge off I will always replace it with a new bridge or make a new bridge if I can't find one.

Sometimes the bridge is almost falling off here you can usually work the bridge loose using a pallet knife and heat. For super glued on bridges I use the Super Solvent that I get from Stewart MacDonald and squirt it under the bridge and wait for the glue to break down and remove the bridge. Before you try this make sure the super solvent won't melt the finish. On lacquer finishes and some urethanes this can happen. Here is the factory way to replace a bridge. We always put a new bridge on so I use a hand router and a jig that sits on the top of the guitar that has a hole in it around the bridge shape, I use a router to rout the bridge off the guitar until it is flush with the top. Simples than I re-glue a new bridge on and that's it.



Acoustic Guitar High Action.

This is usually simple, just remove the saddle and sand the bottom of the saddle down to lower the action. Use a belt sander to do this and I just hold it in my fingers. (What's left of my fingertips)? I found that holding it any other way would cause the saddle to sand unevenly. This is caused by one side of the saddle will need to be sanded more than the other most jigs will cause the saddle to be sanded even; thus, defeating the purpose. If you don't have a belt sander, you can tape a piece of 220 paper to a flat surface and move the saddle back and forth until the saddle it's the correct height.

John Lomas at Ibanez showed me a way where you take a flat block and lay it against the side of the belt sander. This keeps the saddle bottom flat, use your finger to push the saddle against the belt and sand it. Of course until you get good at it the saddles tend to fly off the belt.

Always make sure the saddle bottom is flat and not on any angle this will cause less string transfer from the saddle to the bridge and will also cause many problems with the output on Piezo pickups. To fix this use a piece of sand paper on a flat service and hold the saddle evenly and move it back and forth until the bottom is flat. Sometimes no matter how low you sand the saddle the bridge is too high and needs to come down. This is what has become known as a bad neck angle. Usually the guitars neck angle is fine when it was made but because wood moves and settles the angle can change a little. To fix this remove the strings, lay a piece of thick cardboard over the top with the shape of the bridge cut out of it and use #80 paper on a long block to sand down the top of the bridge. Use the #180/#280 and #500 to reshape the look of the bridge. In a production setting I designed a crazy way of fixing these in a few seconds. I don't recommend this unless you can replace the guitar but here it is. Once I needed to fix over 500 guitars because the bridges were too high and we could not get the action down.

I first put thick masking tape on the top of the body to protect it then I put on a respirator and goggles, get on my knees and hold guitar over the belt sander and touch just the bridge on a belt. Sounds crazy but it works in seconds the only chance I have of messing up the guitar is on the outside front of the body so this is taped off. After sanding the bridge top down I use #320 on the palm sander to reshape the bridge. This process is less than five minutes to repair one guitar.

Loose Braces

On acoustic guitars that have a distinct rattle when played usually this can be caused by loose braces. Basically the brace is vibrating different from the top because the glue may have broken down. First tap around the top of the guitar and listen you can usually find the loose braces this way. After the loose braces are discovered reach in the sound hole and grab the braces, you can usually feel them move. If the brace pulls off then remove it and re-glue it back. If the brace does not pull off then just re-glue it. I have tried many of the clamps that they make for this but I prefer to take paint sticks and cut them to the correct size to fit up under the brace. Then I use a tooth pick to get the wood glue between the brace and the top or back and wedge the paint sticks in there on an angle this works great and does not dent the bracing like some of the metal clamps can.

Replacing Acoustic Bridges

I have read many peoples ideas for this and I have tried all of them. The results are good, but it takes time, and the chance of putting a putty knife through the top is increased. In the old days I used heat and a putty knife. I heated the bridge with my neck-heating block and use a Wagner power stripper to heat the putty knife and work the bridge off, slowly. If you are not careful and patient a little more than the bridge comes off. I also found all kinds of ways that bridges are attached, some are glued to the wood under the finish like a Martin, and most Asian guitars are glued directly on top of the finish with super glue. Some bridges have hidden dowel set pins to line up the bridge, if you do not know that they are there this is a real pain.

So what do I do today? Well if I will completely replace the bridge with a new one then I rout it off with a hand router. I made a simple bridge template that I double stick tape on the top, and I just use a standard hand router and slowly rout down the bridge until it is just a micro thin piece over the top and the last piece just peels off leaving the top perfect for the new bridge.



To install a new bridge, I like to have an exact one made before I rout the old one off, you can sometimes buy them or just simply make it out of Rosewood or Ebony. If I am making a new bridge I usually increase the outside diameter by a 1mm or so just to cover up any bad area from the old bridge. Once you have a new bridge, place it on the guitar and put the bridge pins in through the top. This will line up the bridge, Next place the saddle in the slot and measure from the nut to the high E string saddle it should sit at the scale length plus 1-1.5 mm back from scale for intonation. Most bridges have the slot already compensated for the low E string. If the measurement is off the intonation will be off. Your best bet is to make a new bridge that has the correct saddle placement. Mainly because the saddle needs to sit correctly over the bridge plate under the top. If it does not the top can buckle.

Once the bridge is positioned correctly think about how to glue it on. If the finish is there and you will glue it on top of the finish with super glue like the factories do, you need really strong super glue not just Hot stuff thin. I use a special super glue that I get from Japan Arron Alpha you can find an equivalent here in the states under 3M. This glue is thick, but it sets in seconds so you only have one shot. You can also lay the bridge on the top with the pins and carefully trace the out line of the bridge on the top and scribe it with an Exacto knife. Then take the bridge off and use the Exacto knife to cut through the finish to the wood and use a sharp chisel to remove the finish. Then use wood glue to glue the bridge to the top. Good luck the chances of screwing up are good.

Put a good amount of wood glue on the bottom of the bridge and if you use the super glue put it on about 3mm back for all edges for the squeeze out when clamping. For wood glue this cleans up easy with a towel and water. To clamp it on I have tried a hundred ways. I lay the bridge on the guitar with the two out side bridge pins to line it up. Then you can use Cam clamps. These are the wooden cam clamps, They need to be the correct size Stew Macs are either too long or too short at least they seem, The best ones are hand made ones from Bucks County Music (215-345-0616) I have seen these everywhere the world in wood working stores or you can buy them directly or just look for the Buck Musical stamp. To get the clamps over the X bracing you should use a piece of wood in the sound hole to bring the clamp just over the X brace and them clamp. Be careful the glue that comes through the bridge pinholes will glue this block on so lay wax paper between the thickness block and the bridge plate inside the guitar. Then clamp and wait for the glue to dry.

Ok this is a pain in the butt so I had custom vise-grip clamps made so I can vise-grip clamp the bridge on in one shot. Here are the clamps I had made. I am sure some one will make these after they see it. Just remember where you saw it first.





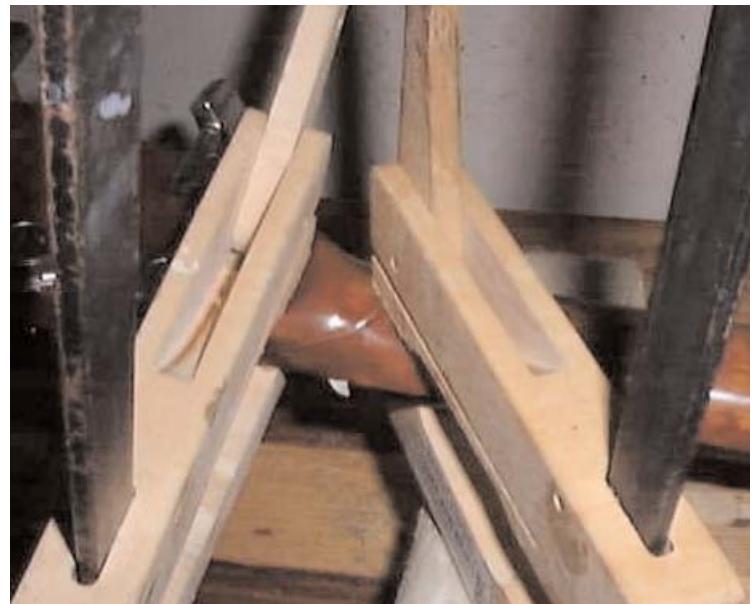
If you remove the bridge pins too early, the bridge can move, and then you need to start again. I leave them in and drill them out after the glue is dry because they usually wind up glued in.

Cracked Necks or Headstock's.

If the guitar has a detachable neck and a new neck is available I always replace them. No questions asked. However on many guitars that you run into the necks just are not available so here we will glue it back together.

Hopefully, the crack will be clean and when you close the crack up all the pieces fall back in place, here use wood glue and clamps to glue the cracks. On some guitars that the crack is on say the headstock or a scarf joint I use either wooden dowels or wooden splints depending on the crack. To strengthen the area just for safety after the cracks are glued I drill the 1/4" holes at the weakest part of the crack and insert dowels in the hole. I use the same material as the neck for this. If the neck is Mahogany, I make the dowels from mahogany. If you are making, a dowel verify the grain of the wood is the same as the area the dowel will go in, or you will wind up with a different grain that will stain differently.

For really bad cracks that are in areas that are weak I use what they call splints. This is a small piece of the same wood as the neck cut to run about 3/4" above the crack. I use a mill and a 1/4" router bit at the cracked area. The wooden splints should be shaped the same as the rout with a rounded top like a Popsicle stick has. The depth on the splints depends on the headstock but usually around 5mm or so. Glue this in with wood glue and clamps.



Don't worry about the height yet we will file and sand them after the glue dries. If the neck has a finish; hopefully, it has a sunburst right at the area of the repair. Then I will blow the burst in and refinish the whole neck.

I tried using a Dremel to rout through the finish, this worked but I remember the result was not great because still the ends of the bridge did not line up exact with the old finish lines. Most repairs I do need to look as though they just left the factory.

Small Factory Production

Small Factory Guitar Production

Over the last ten years or so I have been lucky enough to visit over 30 factories throughout the world. Each factory has different procedures from one to the next. I would never give any of the factory secrets, but I can go into detail about basic production techniques.

From the word guitar production this could mean anything, there are different levels of quality from different countries, mainly because of the experience of the factory. Years ago, before my time Japan was making most of the guitars in the world. But, as the Yen and dollar changed it became more expensive to manufacture guitars in Japan and most companies left Japan for Korea or later China or Indonesia. The Koreans moved fast in the early 1990s trying to catch up to the Japanese quality, however, they did not have the same experience as the Japanese, plus the orders at the Korean factories were strong and most factories were booked solid. So they were busy producing guitars and did not have time to advance in guitar making, they were just too busy making guitars.

Then in the mid 1990's Korea became too expensive to make low price range guitars and Japan again was trying to be competitive in the market, most companies in Korea started losing orders to China or Indonesia, during 1995 and 1996 I watched many Korean factories close or relocate to China.

To explain guitar production as a whole I need to split it up from large factories and smaller factories. The difference is that the larger factories have more orders and more money to invest in new machines like CNC routers or static paint systems that save time and money in the long run. The smaller factories use more manpower and handwork.

A smaller factory production starts in the months before the guitars are made usually two or three months' lead-time. They need this to purchase the materials needed for production. In Korea they have one of the largest construction of buildings and roads in the world so the material for building guitars such as maple is easy to get, and the price is good as long as the exchange rate does not change drastically. For bridges, pickups and all guitar parts many small companies throughout Korea made these parts. The truth is that many manufacturers families were in some type of the guitar business if one person made the guitars. His brother supplied the pickups, and pickguard's and his cousin made guitar cases. This was efficient, but the quality of the parts lacked the competitive edge that we are used to here in the US. We purchase the best quality for the best price, but they would just get the best price, and the quality could be marginal. After the parts are ordered and the production begins; here is the basic process of a smaller factory.



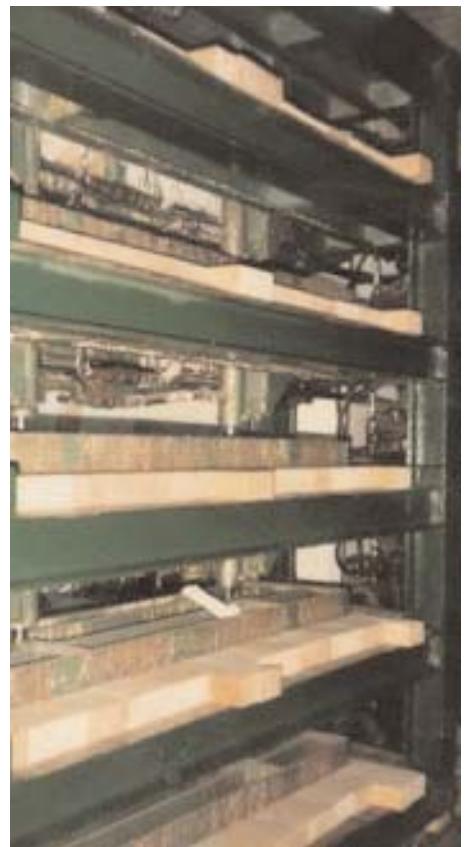
The woods are delivered and stacked up in the building to be cut, planed and joined; some of the smallest factories purchase the wood already joined to size.

Many factories I visited had drying rooms that they could control the moisture of the wood before production and many didn't have this and claimed that the company they purchase the wood from controls the drying and moisture content.

Before the woods go into production, they are placed in a drying room for between 24 to 72 hours depending on the factory and the type of wood. The wood is already dried from the supplier but they like to bring the moisture level down before production.

After the wood is dried it is planed and ready to be joined, smaller factories that use plywoods usually purchase the wood already in body blanks.

In mass production they glue up large quantities of wood simultaneously using presses. This is why sometimes guitars are three or four piece bodies



Depending on the type of necks the blanks are also glued up at this time, a three-piece neck or a scarf joint would be cut and glued.

The bodies and necks are moved to the shaping section where they are rough cut on a band saw and shaped on pin routers with templates.



The fretboard's are cut to size, slotted for the frets and the position markers or inlays are added before the neck is assembled. For the fret slots they use gang saws that have each frets location preset. One pass and all the slots are cut perfectly.

The trussrod channel is routed and the rod is inserted in the neck, then the fingerboard is glued and clamped using pot glue

The body is rough routed for the tremolo and pickups but the final routs will be done after finishing, for arched top guitars the arch is shaped using a pantograph and a large saw blade. The roller follows the metal mold as the cutters shape the arch

If the body is bound the binding is done on a router table, otherwise, the top and back round over is done with round over bits on a pin router and the comfort cuts are cut using a hand jig and a band saw.



The back of the necks are shaped on a shaper table with a jig and the final shaping is done manually on a belt sander.



The bodies are moved to the final sanding section, and they are first sanded with a stroke sander then the bodies move down a sanding line and are sanded with either a palm sander or manually, each person sands a certain area and the guitar moves on.

The bodies are cleared by hand spraying to keep the top coat even and thin.



Frets are precut and hammered in the slots; they are pressed in with a pneumatic fret press that operates with a foot pedal.

The frets are leveled and dressed by hand



After the neck is cleared and dry they are sanded out and sent to the fretting section where the necks are radiused.

An arbor is used that is adjusted to swing at the proper radius while the neck is slowly raised into the belt sander. The back of the necks are sealed with polyester so the wood will not get dirty from any rosewood powder.



After the bodies are finished and the clear is dry they are sent to the final sanding section where they are first sanded with a stroke sander to level out the finish, and then they are wet sanded to #1000 in a sanding line.

The bodies are buffed, and the final control cavity, tremolo routs and pickup routs are done they do this after the wet sanding so the wood does not swell.

After routing the open wood is sealed with shielding paint to protect the wood and control the noise.

The bodies and necks are assembled in a line moving from one person to another. All the parts that are used are in bins around the assembly area. For all bridge, pickup and tuner placements they have jigs that are preset so that the location of all the parts is exact.



The tools for assembly such as drills or screwdrivers are attached to springs hanging from above; this is very easy for them to grab and use. When they are finished, they can just release the tool, and it is pulled back up by the spring.

After the guitars are assembled they are checked for any flaws that might have happened during the assembly, cleaned and buffed and sent to the final setup and inspection area.

Guitars are setup to the factory or customers specifications, checked for fret-buzz, electronic problems then polished, plates and covers are installed and packed for shipping.



Large Factory Production



Larger factories can usually produce between 8000 to 15000 guitars per month and usually have more automation in the line. This saves costs in hand work as well as keeping the production very consistent. One problem with this, one mistake with a machine and chances are many guitars could have the same problems.

The production starts the same way as any factory, they need to have orders so they can prepare the materials that will need to be ordered for production. This is everything from woods to electronics.

After the supplies are in stock, the guitars are ready to be produced; here is a basic production process.

The woods are stocked and dried to the proper moisture content depending on the type of wood and the time of year that the guitar will be produced.

Before production begins, large factories buy the woods usually in either logs or board feet by the container. To get the best yield the logs are used for any number of parts on the body or neck. An example would be a guitar that has a mahogany body as well as a mahogany neck.



The woods are first sorted, cut to size, planed to the correct thickness and placed in a drying room to sit for a few days until the moisture content is stable.

After the woods are joined and planed to the correct size, massive CNC machines that usually have between eighth to twelve heads are used for rough shaping the bodies and necks. The CNC usually uses two heads per piece, this way they don't need to change the tools during the machining.

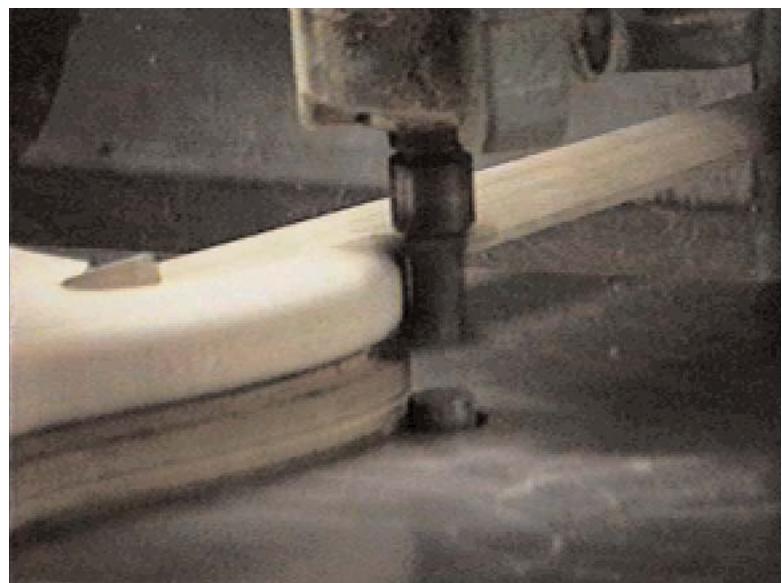
A ten-head machine can make five bodies or necks simultaneously. One head will cut the bodies' shape, neck pocket, tremolo routs and pickup routs and the other head will come down and do the round over.

The same with a neck, the first head will shape the neck and the second head does the round over on the back. Run time on these machines is generally between two to five minutes per side. You can figure that a CNC with ten heads is capable of making five bodies every eight minutes. If you do the math this is roughly 300 bodies per day or 7200 bodies per month in just 24 eight-hour days.

One person can usually operate these machines, each machine has two large tables so while the CNC is working on one table they are unloading and loading the other table.

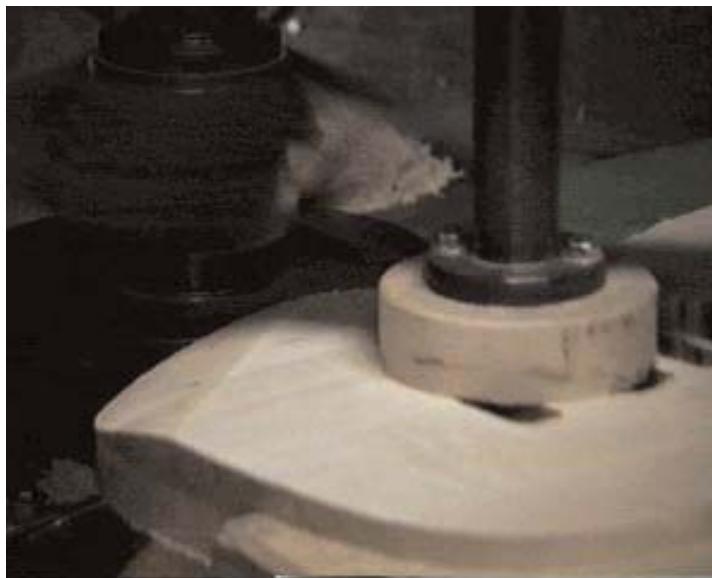
To attach the wood to the table, location holes are drilled for use with set pins mounted on the tables. This is used for lining up the wood when it is flipped over so the CNC can rout and shape both sides. The basic profile of the part is outlined on the table so the wood blanks can be lined up and locked in place using vacuum.

On models that are through necks. The production is still mainly manually because of the construction techniques. For these models, they are roughed out on a band saw and than a pin router will do the final body shape. For a round over on this type of body they sometimes use special round over cutters on pin routers that shape the entire round over at one time

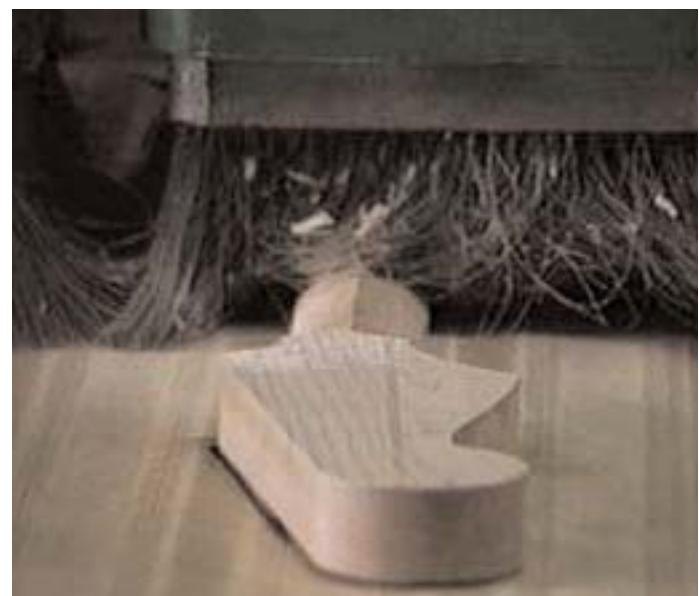


After the bodies are rough, cut on the CNC they are moved to the sanding section where the comfort cut is added and any imperfection or tear out is removed.

For the comfort cuts on the top and back they usually use a slanted jig on a band saw, but recently I have seen a machine that is similar to a "merry go round" that slices the top and back as it passes the saw blades. This machine is quite expensive but a big time and labor saver.



For a standard skunk stripe neck, the channel would be routed from the back and a vertical drill press will drill the truss rod bullet under the nut area. With standard truss rods the neck is routed before the fretboard is installed.



After the CNC rough shapes the necks, they still need allot of handwork. First, they are moved to an area where the headstock and heel areas are shaped and the truss rod slots are cut.



After the truss rod channel is routed the fretboard's are installed, if there is any inlay work or position markers this is done in the fretboard before it is glued on. Position markers are drilled with a multiple press; they have a different press for each scale length as well as ones for basses

The necks are now final shaped and sanded to their specific shapes and prepared for stain and sanding sealer before finish.

If there is any binding, the channels are routed on a router table and the binding is installed using a ducco cement and masking tape.

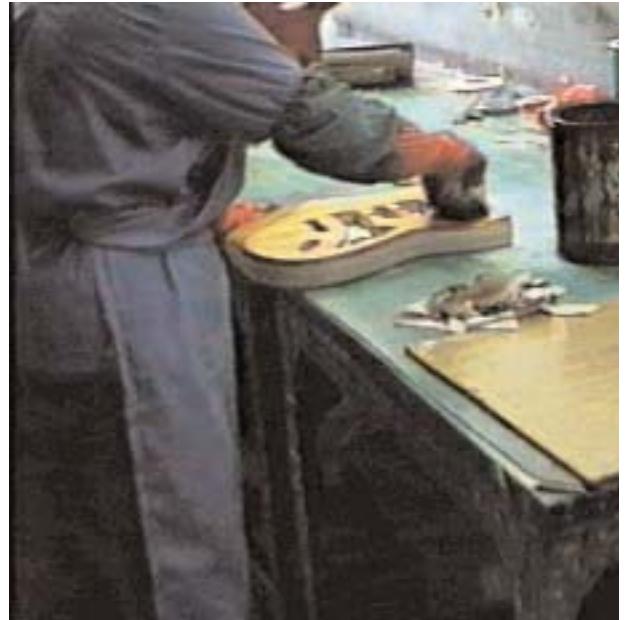


On areas that are bound such as the headstock, the binding is pre shaped in small presses that are the shape of the headstock and then the binding is installed, this saves the time of bending the exact shape for each headstock

For bodies or necks that are stained, the parts are moved to a separate area and a urethane based wood stain is applied to the bare wood. If there is any bursting to be done it is done after the first stain coats are applied, and the sanding sealer is cleared over the stain.

Sanding sealer will seal the grain so that a finish can be applied evenly without sinking. Sanding sealer formulas throughout the world are different. Most Japanese companies use straight polyester while most of the Korean or Chinese factories use a 50/50 mixture of Polyester and Polyurethane.

The reason is that the Japanese factories have better climate control in the factories and Polyester should be sprayed at approx. 70 degrees, or the formula needs to be modified so that it will dry. In Korea the factories are less climate controlled so the Polyurethane insures that the polyester will dry.

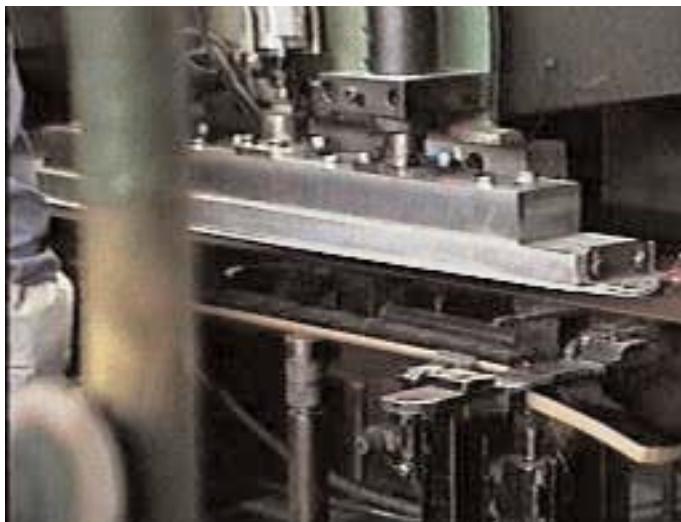


The larger factories use static paint systems for this process. Static paint works this way; it uses a positive and a negative charge. The body moves around slowly on a chain and as it passes the paint head, finish is sprayed in the air and it is pulled to the body like a magnet. The line constantly moves, and the bodies and necks are added or removed from the line.



From there the necks are sent to the fretting department, and the bodies are moved to a sanding area to prepare them for paint.

On the necks, the fretboard radius is cut using either on a shaper table or a special machine that is designed to use a radiused cutter that passes over the fretboard radiusing it. Most factories still use a standard shaper table and a radiused cutter.



After the sanding sealer is applied, the bodies and necks are sent to a heated drying room where they will sit for three days until the sealer is dry.



Final sanding of the fretboard before fretting they use a 3 belt multiple press, the fretboard radius is milled into the stainless steel block along with a small amount of relief in the center of the mold.

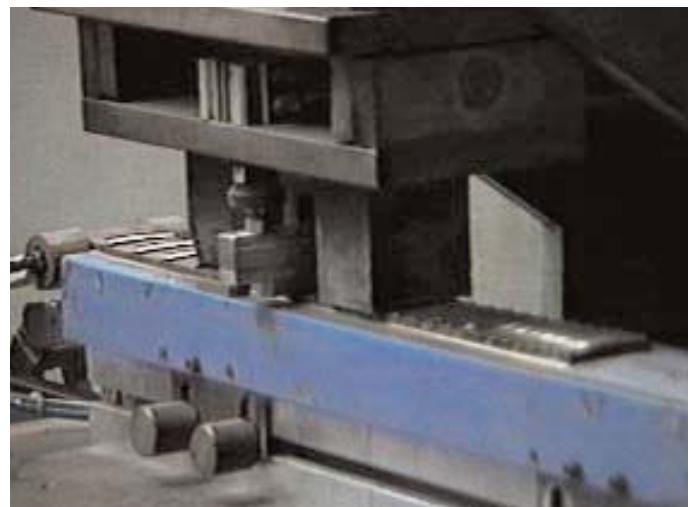
The neck moves automatically from one belt to the other starting at 80 and ending at 400. The amount of times that the belt is lowered to the fretboard can be changed to any number of passes; also if the radius is different the stainless mold can be changed

For fretting, the wire comes in large rolls and they have a machine that first straightens the wire and then cuts it to the exact length for each fret. If there is binding the frets ends are cut back on this machine.



The frets are first hammered in manually, just to set them and then the frets are pressed in using an arbor press.

The next step is the sides are sanded back to a 45-degree angle using a belt sander and an angled table. The frets are then leveled and dressed by hand



When the finish is dry, the bodies are moved on carts to the sanding area where they are prepared for the final finish. The top and backs are sanded on a stroke sander with between 320 and 400, and the sides are sanded on the end drum of a belt sander.

Before finishing, the bodies are roughed up with Scotch pads to check that the surface is ready for finish.

After the bodies are sanded and prepared for finish they are sent to the paint area for color spraying.

Depending on the factory the color spraying system is different. Most factories still use standard spray guns to apply the color coats and all metallic colors are also sprayed through standard paint guns.

In Japan many solid colors like red, black and white can be added directly to the Polyester and used as a static paint that can be applied using the static paint system. This system applies the color and the finish simultaneously.



Certain colors in the factory require different spraying techniques, on many colors the bodies are first painted a base coat and when a second or third color is applied. The final color is made. Usually, to brighten up a color they would use a white base coat and on some darker colors a black base coat may be used.

Metallic colors usually have the flake added into the paint at the factory before spraying so that when the paint is applied. The metallic is applied simultaneously. Larger colored flakes and certain pearl finishes are added to a clear and applied over the color; this adds more dimensions to the finish.

After the finish is applied, the bodies are hung on racks and again moved to a heated drying area for 24 hours before they are cleared with a topcoat. Most topcoats are either polyester or the 50/50-polyester/ polyurethane mixture and applied with the static paint system.

The drying time for each factory is different depending on the formula of finish and the factory production, but drying of the final finish is usually in the drying room for between one to three days. The longer the drying time the harder the finish is, and this allows a better shine because the sanding scratches are not as deep on a harder finish.

Once the finish is dry, it is moved to the sanding and buffing section where the clear is first sanded on a stroke sander with #400 paper, and then the body moves through a wet sanding area where the body is completely wet sanded to 1000 manually before buffing.



When the bodies are completely wet sanded to #1000 they are first buffed on a buffing machine, using a liquid compound that is brushed on the top and back. The table moves back and forth and side by side. This machine buffs the top and back and the final buffing of the sides is finished on a buffing wheel by hand.

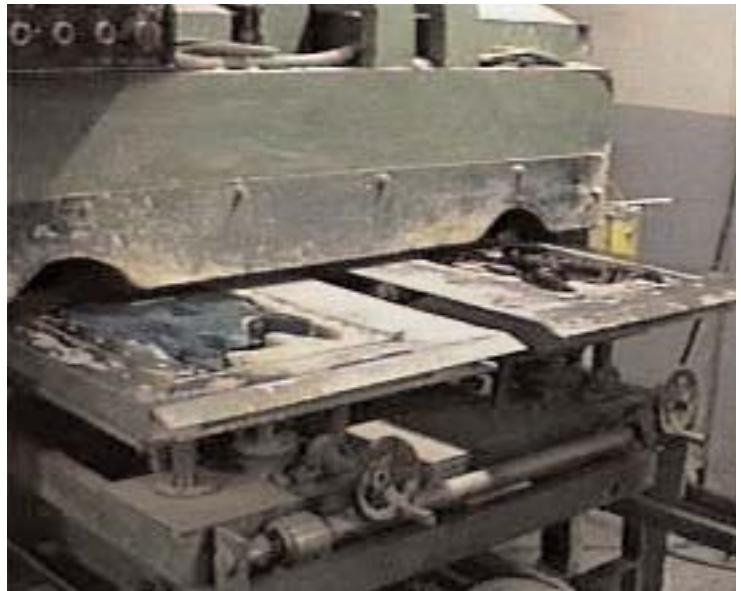
The guitar bodies are final polished by hand, and depending on the factory they could have the pickup and back plates routed.

The purpose of routing after the finish is so that the plates and pickups fit perfectly without having extra paint and finish in the cavities.



Once the bodies and necks are completed, they are matched up for a perfect fit. If the neck is too tight, the neck pocket can be sanded inside with a Dremel tool and a small sanding drum to check that there is a tight fit.

To install the bridge location they have jigs that start at the nut and follow the center line of the fretboard. The exact location of the studs or screws is marked in the body and the bridge is installed at that location. This is so exact that the intonation on the bridge can be pre-set at the manufacture and when the bridge is installed only a slight intonation adjustment may be needed.



All open routs are sealed with a shielding paint that first seals the open wood and then shields the electronics.

In the assembly area the parts are installed on the bodies, and the electronics are wired up. The necks are also assembled, and the tuning machines and any other hardware such as a top lock are installed.



After the guitars are assembled they sit for a day, so that the finish can settle. Then they are sent to the setup area where they are setup to the factories or customers specifications.

Each guitar is checked to verify all the electronics, pickups, and parts are ok and that the guitar plays without fret-buzz. If there are any problems, the guitar is rejected and sent to a repair area.



Acoustic Guitars

Acoustic Guitar Info

If you are looking to design or buy an acoustic guitar this is for you. It always depends on the sound that you want and how much money you have to spend.

Over the years I have visited many factories that produce acoustic guitars and each have its own way of production. This is where much of the cost involved happens. Why are some guitars so expensive while others are inexpensive?

This has to do with two main subjects. The first is labor costs. You can purchase a Chinese made guitar much less than a Japanese or American guitar. Korean guitars usually fall in between in the US market.

The second cost is the materials used more expensive guitars such as Martin and Taylor's use only solid woods. Solid wood guitars are more expensive; not only because of the cost of materials but the production itself is more critical than a laminated guitar. Laminated guitars are easier to produce and are much less prone to cracking.

Most inexpensive guitars use laminated woods for their construction. Laminated woods are thin ply's of wood material that is glued together, they can easily be pressed into shape without cracking, solid woods need to be heated and slowly bent. Laminated woods don't shrink and expand the same way a solid wood does mainly because the plies are individual and the grain patterns are staggered. Solid woods have the grains going in one direction, so if the temperature is very dry the moisture will leave the cells of the wood and cause the wood to shrink, this is what can cause stress cracks.

Many companies use a combination of laminated woods and solid woods on models to achieve different results for example. A Guild generally can have a solid top, and sides with a laminated pressed back. Many companies produce guitars that have a solid spruce tops and laminated back and sides or just laminated sides. It's good to know what you are getting up front. The top is easy to see because of the sound hole, but the back and sides may be very difficult to tell because there is no opening to see inside the wood. I can almost say that with any guitar you purchase, if it is not stated that it uses solid woods; it is probably laminated. Any guitar that says Solid Spruce Top will have a solid spruce top but laminated backs and sides.

Now that we understand about the woods we should also talk about the Ovation style round back guitars. Ovation style guitars are copied by many Asian companies so you can find allot of these models in Asia however in the US this type of guitar is almost exclusive to Ovation company. Ovation guitars are designed and owned by Kaman Corporation in the United States. Kaman Corporations main business in aerospace technologies (they make helicopter parts and such.) They use the same type of technology to make their guitars, The backs are molded from a synthetic material and the tops are then installed over the backs. There is no bracing on the backs but the tops are braced.

I have visited many factories over the years and each has its goods sides and many have bad sides. Each factory has its own way of production, and they swear by it. Every factory is different, and the results are different as well. Let's take a look at some of them. (I have never visited Ovation so I can't comment on their production)

Martin Guitars in Nazareth Pa.

I love this place it is actually 1hr from my house. I go at least once a year. Each time I learn something new about acoustic guitar production. They make guitars mostly by hand, however, they are changing and you can see many computer-controlled machines to make parts like the necks. They have a daily tour of the plant at 1:15pm for anyone that is interested. Martin guitar factory is very clean, the floors are painted so that you can't go over the yellow lines (This is a regulation for safety in the US) The factory is totally climate controlled so the humidity and temperature of the factor never change. This is so important when you are dealing with solid woods. Up until a few years back they used only solid woods, but recently they started making some laminated back and side models. All high end Martins use dovetail neck joints. A Dovetail joint is the strongest type of joint but also the most difficult to make. A rout is made in the body shaped similar like a doves tail and the neck it self is shaped and glued in a routed slot in the body. This is the strongest and hardest style of neck joint. Recently, I found that Martin started making some inexpensive models that use another type of neck joint they called a neck to body joint. This consists of a tenion and a long screw to set the angle of the neck while the glue dries.

They also use lacquer finish on the guitars and this is a much thinner finish that takes much longer to apply, they use many very thin coats of clear and a long drying time. But you can see, feel and hear the difference in their guitars. I must say that Martin's get better with age, most new ones need some time to age before there true sound comes out.

Taylor Guitars in California has become an almost legend in guitar making. They use a combination of hand making and the most modern techniques I have every seen. Their production consists mainly of all solid woods on their main guitars. Many guitar parts are totally machined by computer routers. They even use lasers to cut the rosette in the top.

They have a special paint system they use called UV to dry the finish. The clear is sprayed and then Ultra Violet rays are used to dry the finish in two minutes. This saves allot to produce the guitar. Generally, the drying of the finish is what can take weeks or months depending on the types of paints used.

Taylor actually makes the cases for each guitar in the same building. They have a wing of the factory that makes each case individually so you can always be sure to have only the best fit for each guitar.

Taylor guitars use a special bolt on neck system. After the neck is bolted on and the angle is set they use a small amount of glue to close up the joint and add strength. The inside of the neck block is covered with a label so the bolts are not visible. I must say from my opinion that the Taylor guitars sound the best when new, however, I have never heard a really old one yet so I still think that the old Martin's sound the best.

Asian Factories

I actually visit these factories more than Martin, (Martin is one hour from my house and Korea is exactly 22 hours from my house)

I must say I have watched the Korean factories improve over the past 10 years since I first visited. Nowadays Korea is producing much better production guitars then five years ago. Many Korean factories use a Dowel pin system to attach the neck. The body and neck are both drilled in the exact location and the neck and body are pressed together with the dowels in the between.

All guitars bodies have many things in common mainly they have a back, sides, top and bracing inside to strengthen the tops and backs (If they are wood) Basic bracing is usually copied from Martin X bracing pattern that has been around for over 50 years that I know of. The location of the center X brace has been changed over the years to add strength to the top and allow better projection from the sound hole.

X Bracing is the system used to strengthen the guitars top from the extreme string tension that the strings will cause. Braces are made from spruce, and each brace should have a specific radius to keep the top slightly arched for strength. Under the bridge is a bridge plate that supports directly under the strings, this is usually a harder wood like mahogany, rosewood, maple or even plywood.



Scalloped
braces are
more com-



mon nowadays than they used to be. In the old days and still at Martin all scalloping is done by hand. Scalloping is when you shave the braces thinner to give the top better vibration with less stiffness caused by the braces. Asian factories have designed a machine that scallops all the braces simultaneously that they are cut to size and shape. Almost all factories now use some type of scalloped bracing.

Shapes and Sizes.

Dreadnought

This is the most popular style of guitar. It is copied from the standard Martin size guitars. This style is the easiest to manufacture so tend to be the cheapest to make.

Jumbo

Jumbo bodies are larger than dreadnought's and have a wider bout. These guitars have a louder sound.

Grand Concert

Grand Concert bodies are smaller bodies with less volume.

Grand Auditorium

Grand Auditorium models have wider bottoms for increased low end. Materials.

Similar to electric guitars, acoustics come in many shapes and sizes. Also, different woods are used to produce a variety of tones.

Wood Types

Spruce.

Spruce is generally what the tops are made of however, other woods used are cedar, maple or even exotic woods like Koa from Hawaii. Generally, I would say 95% of steel string guitars have spruce tops. Nylon string guitars use cedar more often than steel string models.

Many grades of Spruce are used in guitar production, the yield from a tree depends on the conditions that the tree was under during its life. The best spruce is usually taken by smaller custom builders that can afford to purchase the best woods. This type of wood is only used for generally the finest hand made instruments. This type of wood is called master grade spruce and it is said that only one in 200 tops may be a master grade. Master grade are selected by the grain pattern running straight with no color variations.

Different types of spruce used in production.

German Spruce

Up until a few years ago this was the most popular type of spruce used by many builders, However because of price and availability over the years it is less popular nowadays for any type of production. German spruce is less dense than North American spruce with a very white color and almost a silky shine after finished.

Sitka Spruce

Sitka spruce is grown from Northern California all the way up to Alaska. Most of the Sitka nowadays is second growth so it tends to be less than perfect. This is generally what is used on most Asian solid top guitars because it is very dense in weight, but the color is less white, and it tends to have red colored streaks.

Engleman Spruce

Engleman spruce generally comes from North America in the rocky mountain range of the United States. This wood is very light in color with a strong grain structure. It is more expensive than the Sitka, but many companies will pay the extra for the better yield.

Other Woods Used

Cedar

Western Red Cedar has been used on many acoustic for years, it was preferred for classical guitar tops but because of its mellowness and moisture content. Nowadays it is becoming more popular with standard steel string builders as well.

Mahogany

Mahogany is used for many backs and sides, It is very warm sounding and easy to work with. Mahogany is generally used for the necks also because of its warm sound and ease of manufacturing.

Rosewood

Rosewood is used for backs, sides and fretboard's. Rosewood back and side guitars are much brighter than mahogany because it is a much harder wood. Rosewood also tends to look better because of its darker color and grain pattern.

Electronics and Pickups

Many guitars come with electronics. The most popular is called a Piezo electric pickup, This type of pickup senses the pressure through the saddle of the strings and the sound is picked up. Piezo pickups are much different than a standard Electro magnetic pickup. Fishman® makes the most popular piezo pickups on the mar-

ket, however many companies produce Piezo pickups for their guitars. Lets just say Fishman® makes the best today and if your guitar has a Fishman® in it you can usually say it will sound good out of the box while plugged in. Other companies like Dimarzio, Benedetto® or Duncan® make pickups that fit in the sound hole for after market use. These work well but still the piezo system seems to be the best available. If you have a guitar and don't want to drill or modify it, the sound hole pickup may be for you.

EQ Systems.

Many acoustics come with either a standard passive volume and tone system or a more elaborate battery powered EQ usually 3 bands with a presence or added mid control. These systems are more popular these days than in the past. It's hard to say what ones are the best I prefer the Fishman® again. There are lots of factories making the EQs for different customers so just because there is a brand name on the EQ doesn't mean that it is a great system. If you are going to buy a guitar with an EQ don't just think it will sound good, check the sound through a powered amp to see if its really for you. Many systems will feed back and be almost useless at a stage volume.

So what should you buy?

Let your fingers, your ears and your budget decide. I suggest only looking at guitars that have names you can trust to be around for sometime to come.

Acoustic Guitar Mass Production

Many people purchase acoustics guitars but do they really know where they come from? I have read many books on building acoustics one at a time, but to understand them in mass production is a completely different story. Here is a factory tour of a Korean acoustic guitar factory.

It all starts on the drawing board. Every detail of the guitar construction needs to be drawn out.

The drawing usually starts with a hand drawing and after the layout is finished the final drawings are done on a Cad program and printed out on a plotter.

Acoustic guitars are not easy to mass produce you may look at one and feel it is not so difficult, however, if every detail is not exact than the guitar will not play and sound good and may also be not durable.



For example, the top on an acoustic is not flat.

They call them flat tops but really a properly constructed acoustic has a top and back radius to strengthen the guitar. Shaping each brace to a certain radius does this. When the top or back is glued on the woods shape is controlled by the bracing. It is similar to a bridge over a river; they never construct them flat because the bow makes it stronger. After the drawing is laid out, it is time to produce a proto type. This allows them to understand what jigs will need to be made, what materials will need to be ordered, and if they will need to make any special equipment to manufacture the model.

All the proto types are hand constructed so that they can understand all the processes that are involved. Certain models in the factory will always need to be custom made even after the proto types are finished, this is that many high end models that are produced need more care and time to be spent producing the guitars detailed work such as inlays or hand scalloped bracing. Most guitars production designs are the standard dreadnought

shapes, however, it has been found that they can also adjust the sound that will be produced by changing the size, dimension, bracing pattern or the materials that is used. Certain woods retain different sound characters and this needs to be addressed during the initial design.

After the basic layout and proto types are made, it is time to order materials needed for production. They purchase woods from throughout the world so they need to think ahead in ordering materials. The solid spruce nowadays usually comes from North America and is either Sitka or Engleman. Other materials like the rosewood backs and fretboard's come from India, most mahogany is from Africa or Indonesia (Natoch) Most of the other materials are either produced in house or purchased from local suppliers. All the woods used must be properly dried before any production can begin. To check the moisture they have meters throughout the factory to monitor the moisture content of the woods before and during production.

In the start of production, after they have all the materials they start by gluing up the wood. Here is a picture of them joining a set of solid rosewood backs. They join the tops, and backs the same way, using side presses to hold the joint together and weights on the joint to keep the wood from buckling up during the drying process.

First, the wood is book-matched. Book matching is taking a piece of wood and splitting it down the center, then you open it up like a book and join the wood. The wood is laid flat on a table and two side clamps are closed on the wood, weights are laid on the joint to remove any flexing. The glue sets in about 30 minutes and takes 24 hours too completely dry before any production can begin.



After the woods are glued and dried its time to start production. The tops and backs are rough cut to shape and size. Next the sound hole is cut in the guitar as well as any fancy rosette routing. This is easier before the tops and backs get braced.

The sound hole is cut in the body using a large custom bit that has the exact shape and size of the sound hole. The placement of the sound hole is important to the construction of the guitar so they designed a special machine that holds the top in the exact position so that the hole is set to center.

The size of the sound hole is also important in the strength of the top. If the hole is too big, you will get a louder guitar but a less stable top.

Before the back is braced, they also inlay any materials like the backs center strip. The bodies will have a contoured shape after they are braced and glued. So they do all the routs on a flat service.



Before they can start the bracing process the spruce braces need to be sanded and shaped to an exact radius. This process is started by machine, but any fine adjustments must be made by hand.



After the braces are finished, it is time to glue them in place. They use polyvinyl glue and a glue wheel. The wheel spins and keeps a constant amount of glue on the wheel always. The braces are passed over the wheel, and the exact amount of glued needed is applied evenly over the braces



For placing of the actual braces on the tops and backs, they have a jig that has the exact placement laid out on it. Each brace is a different size so they are pieced together on the top using the jig. They are then placed in a heated press until the glue sets. The press is designed to allow even pressure throughout the tops and backs so all the braces are glued tightly.

While the tops and back are drying it is time to start on the sides. They bend the sides in heated presses that have the side shapes molded in the press. The pieces of wood for the sides are thickness sanded and cut to size, then pressed to their shape.

The sides are then placed in molded side templates to control their exact shape while they prepare to glue the top and back on. The kerfed lining that holds the top and back on is installed using modified clips that work like cloth pins.



Before gluing the top on they cut the ends of the bracing. This could be done before they installed the braces but because it is much easier to keep accurate the length of the braces so they are flush with the sides of the body; this is important for the sound transfer to the top.

After the body sides are placed in the jig, they use a contoured belt-sanding machine that has the exact shape of the body molded in it.

The body top and back are sanded on this machine. Acoustic guitars are thicker in the back and get thinner up in the neck area. The contouring machine controls this while also placing an arch in the bodies tops and backs.

Once the bodies' sides are shaped, the tops and backs are installed on the side jigs and put in a press till the glue sets.

The neck is rough shaped out on a band saw before it is final shaped using cutters. The main reason for roughing it is that to keep the cutters sharp and accurate it is better to cut the least amount of wood possible. By roughing the neck they are actually saving the cutters from becoming dull too early.



They have many different cutters and jigs for shaping all the parts of the neck. To keep the neck production consistent they have specially made cutters that have the shapes for the back of the neck and heel area, these machines are very high speed so they make large jigs to hold the material without standing too close to the blades.

After shaping the neck they laminate and trim and headstock veneers and cut the binding channel on the necks using a modified shaper table and bit. The neck is then bound manually using Ducco cement and ABS materials.



bonds the binding strips together as it bonds it to the body. They use a low tack masking tape to hold the bindings in place while they dry.

After the body and neck are final sanded they will be matched and joined. A machine was designed that actually sets the neck and body to the perfect neck angle using a belt sander. After the body and neck are shaped to each other, a multiple drill press drill the exact joint location on the body and neck so that a perfect match is made. This body and neck are now joined as one.



The preparation for finishing is started and scratches, or dents from production are sanded out. The binding is final scraped to bring out its true color.



After the body is dry and removed from the side presses the binding channel is cut around the body using a modified router table; The body is then bound.

Multiple bindings are made during the installation, If the binding is 5 ply they use 5 different pieces of binding and install all five at once, The Ducco cement



Once the neck and body are joined and dried a truss rod is installed and the fretboard is glued on. The guitar is starting to take its final shape, and the craftsman makes the final neck shaping contours manually. They do this so that the necks heel shape and body are smooth with no high or low spots.

This area is very critical because after the guitar is finished any defects in the woods or bindings can be seen.

Before the finish is applied, the body is stained to the color by hand and then the decals are installed. If there is any color or sunburst on the model, it is sprayed before the logo is installed.



The guitar is moved to a dust free paint area where it is



cleaned again, and the final finish coat is applied. The thickness of the finish is controlled by hand. The painters are very experienced in spraying and each coat is applied in the same amount to control the sound after the guitar will be finished.

From the spray room the guitars are moved into the heated drying area where they will sit for a few days until the finish is hard enough to sand and buff. This is the longest amount of time in production they can't stress enough how important drying is.

After the finish is dry, it is time to start the fretting. The fretboard is shaped and sanded to the proper radius. First using a cutter that controls the neck set angle, and then on a sander to final sand the radius and get any imperfections out of the wood.

Once the fretboard is ready the frets are first hammered in, They use a fret press to establish the frets are seated properly and final adjusts the frets by hand.

After the frets are seated, they level the frets using a straight block. This assures that all the frets are the same height, and no fret buzz will occur. The frets are final sanded and polished to remove any scratches in the fret finish that can cause the strings to feel scratchy on the frets.



Time for the final finish sanding and getting the guitar ready for final assembly. Depending on the finish of the guitar they take different steps if the guitar will have a gloss finish it will need to be sanded and buffed. Matte finish guitars are sanded, and a thin clear matte finish is applied. Sanding is not recommended after this is applied because they don't want the finish to have any shiny spots.

Gloss guitars are sanded to #1000 before they use a polishing compound and buffing wheels to remove any finish scratches and bring a high gloss finish to the guitar. The tops and backs are first buffed by an automatic buffing machine, and then hand buffed to their final finish.

Once the guitar is final buffed it is time to place the bridge on the guitar. They use a jig that centers the bridge and places the exact intonation points for each string. The area is roughed and then they use an air-press to glue the bridge down. The bar going in the sound hole is support for under the bridge at the bridge plate so that the pressure does not crush the top of the guitar.

Now the hardware and any electronics are installed. The slot is final adjusted, and the nut is seated into the slot. Machine heads are installed using a pneumatic socket to control the torque of the nuts.

Finally, it is time to string the guitar. Before stringing the guitar is checked again for any defects. After the guitar is inspected, the strings are installed and its time for the guitar to move to the final setup area.

The guitar is setup by their final inspectors manually using jigs and templates to assure the exact specification for each model. The nut is cut to its height, and the action is set at the bridge.



After the inspection and setup the guitar is polished and packed for shipping.



The guitar is tuned to 440 pitch, and then the necks truss rod is set and the guitar is played by the inspector to verify there is no fret buzz or other problems. If there is, electronics such as an EQ or Piezo it is tested now to check that there is even string response for all six strings.



Wood Information

Wood Specifications

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1. Grade 'A' Ebony has at least one face black and the other face may or may not have a few brown streaks.
2. The following items may or may not be quartersawn;
 - a. Birdseye Maple and Curly Mapleb. Honduras Mahoganyc. Madagascar Rosewood
 3. A. Rosewood fingerboards, peghead overlays, bridgeblanks, and backs and sides sets are quartersawn.
 - B. German Maple and Koa backs sides are quartersawn.
 - C. Sitka Spruce, Cedar and German Spruce tops are quartersawn.
4. The Difference Between Rosewood '3A' and '2A' for guitar backs and sides sets is with the straightness of the grain. '3A' grain is quite straight, while '2A' may be slightly curved or may go off a little. '2A' sets may also have some solid pin knots and waviness in grain.

Alder: We get it from the Pacific Northwest. The prices are a little high and the quality is lower today.

Ash Lightweight: It can be used with a clear finish and has good texture. It is used in a lot of expensive guitars. It grows mostly Southeastern USA.

Basswood: For a solid color guitar it is one of the better woods. It is used by many well known large manufacturers. It comes from Northern U.S.A. and Canada.

Bois de Rose: It is the Prettiest Rosewood we have ever seen. It is a little more expensive than East Indian, but a lot more rare; we are trying to introduce it to provide more variety of Rosewoods. It grows only in Madagascar. **Bubinga:** This African Import is a very heavy Rosewood, but some customers like it for solid body guitars.

Cedar; Red: Guitar tops of Red Cedar are the Best Buy today. Material is very fine with good prices in the market.

Cherry: We use mostly Curly Cherry from upstate New York. Curly Cherry is not as curly as Curly Maple.

Cocobolo: We get it from Mexico and have sold it mostly for Laminate Body Tops.

Koa: It comes from Hawaii. The good Curly Koa is very hard to get.

Lacewood: It is a nice wood for Laminate Bodies, with good figure.

Mahogany; Honduras: Nice and Lightweight, this wood is good for bodies, laminates and necks.

Maple; Curly: Most of our Curly Maple comes from upstate New York, Michigan and Canada.

Maple; German: Not much Maple is left in Germany. The prices for what is available have been going up with every shipment; we have tried to keep the quality up as much as possible.

Maple; Soft: A little more expensive than Basswood and Poplar, and also a little heavier.

Oak; Fishtail: This dark brown wood is heavy, so it is only good for Laminate Tops.

Poplar: Same as Basswood, as far as its application is concerned, and in the same price range.

Pau Ferro: Also known as Bolivian Rosewood or Morado. It is a heavy, brownish-orange wood with dark black stripes.

Rosewood; Brazilian: The quality of this wood has gone down over many years and prices have gone up. Very few pieces are instrument grade. Our Brazilian Backs and Sides Sets, even though not up to par with East Indian Sets, are the best available at this time. The quality of bridge blanks and the few fingerboards is good.

Rosewood; East Indian: It is preferred for musical instruments. It is not the Indonesian Plantation Rosewood, which happens to be the same species, but with different color and much wider grain.

Rosewood; Madagascar: It appears to be similar to East Indian Rosewood in texture, and color. It is a wood which has not been imported earlier.

Satinwood: Our Genuine Satinwood is from Sri- Lanka. We do not believe that there is any other kind to compete with it. It is of golden color and shiny texture.

Spruce; German: The problem is the same as with German Maple.

Spruce; Sitka: It used to be very easily available, at reasonable prices. This is not the case anymore.

Zebrawood: Same as Bubinga in application. It also comes from West and Central Africa

Supplies

FINISH SUPPLIES

Mohawk Finishing Supplies
Finishing supplies Rt 30 North
Amsterdam, NY 12010
800-545-0047

Metal Flake
Global metal flake
508-388-6670

Lawerence Mcfadden
Paint, Polyester, lacquer
7130 State Road
Philadelphia, PA 19136
215-624-6333

Jescar-Menzerna
Polishing Compound
200 Airport Executive
Manuet, NY 10954
914-352 5850

Reranch stains
Stains and custom color small amounts
605 Pebble Creek
Garland ,TX 75040
972-495-2074

House of Color
Paint and Finish supplies
(800) 328-5139

PARTS AND ACCESSORIES

Guitar makers Connection
(Martin Guitar Parts)
PO Box 329
Nazareth, PA 18064
800-247-6931

Musikraft
Bodies, necks custom made
PO Box 532
Sicklerville, NJ 08081
856-728-5555

Jim Dunlop
Fretwire/ Supplies
PO Box 821
Benicia, CA 94510
800-722-3434

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Guitar Cables
3581 Larch Lane
Jackson, MO 63755
800-GO-RAPCO

String Swing
Guitar Hooks
PO Box 132
Ontario, WI 54651
608-435-6628

Allparts
Guitars Parts
PO Box 1318
Katy, TX 77492
800-327-8942

Buck Musical
Inlays, Pearl, Lutherie supplies cam
clamps
New Britan, PA
215-345-9442

Sperzel Tuners
Machine heads (The good ones)
7810 Lake Ave
Cleveland, OH 44102
216-281-6868

Duke Of Pearl
Mother of Pearl Abalone
18072 Greenhorn Road
Grass valley, CA 95945
916-273-4116

Custom Pearl Inlay
Mother of Pearl Abalone
RT 1 Box 240
Malone , NY 12953
518-483-7685

Switchcraft
Output Jacks bulk
5555 N Elston Ave
Chicago, IL 60630
773-792-2700

WD Music Products
Pickguards, Lutherie supplies
4070 Mayflower Road
Ft Meyers, FL 33916
813-337-7575

MACHINES AND TOOLS

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Buffing machine and hand made tools
1477 E Michigan Ave
Battle Creek , MI 49014
800-253-2261

Terrco Inc
Carving machine
222 First Ave
Waterson, SD 57201
605-882-3888

Mouser Electronics
Electronic parts,
Soldier PO Box 699
Mansfield, TX 76063
800-346-6873

Stewart Macdonald
Lutherie supplies

21 N Shafer St Box 900

Athens, Oh 45701

800-848-2273

Luthiers Mercantile

Lutherie supplies

412 Moore lane

Healdsburg , CA 95448

800-477-8802

Grizzly Imports
Machines and supplies
PO Box 069
Bellingham, WA 98227
800-541-5537

Norfield Tool and Supply
Sanding machine and belts
PO Box 459
Chico, CA 95927
916-342-2383

Wood Workers supply
Tools and supplies
1125 Jay Lane
Graham, NC 27253
800-645-9292

WoodCraft, Tools supplies and hardwoods
PO Box 1686
Parkersburg , WV 26102
800-223-8087

Exotic Woods Company
All kinds of wood
444 Chews Landing Road
Sicklerville, NJ, 08081
800-GIDWANI

The End