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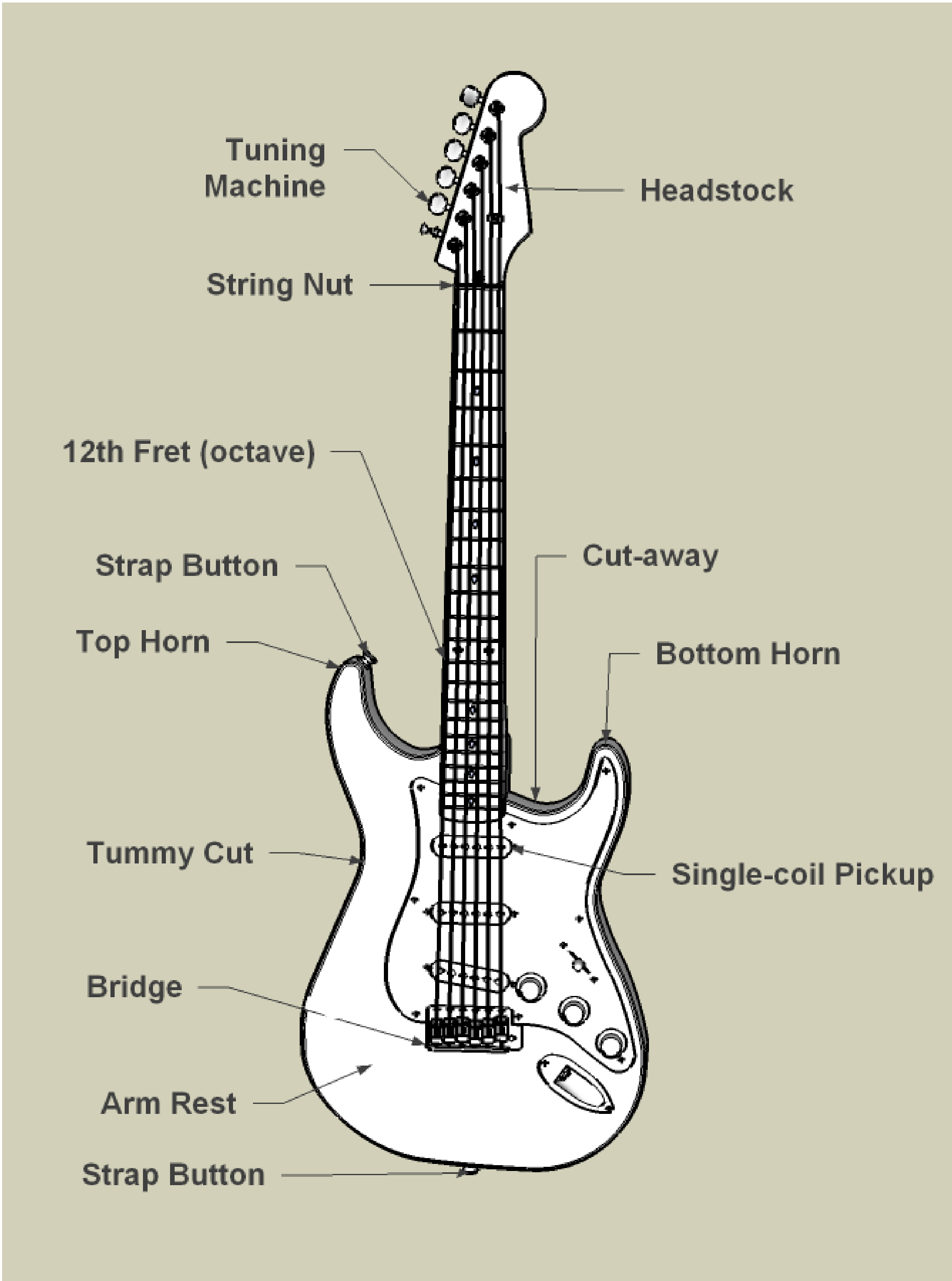
Designing an Electric Baritone Guitar

0 Anatomy of a Guitar



1 Introduction

Over the past year or so I have been in the market for a baritone guitar. I had always thought that a baritone would be a great instrument for me because I started my musical career as a bassist and then developed into a performing songwriter. The baritone's range falls in between that of a bass guitar and a standard six-string. I had the fortune to try out a number of instruments made by Danelectro, Ibanez, Schecter and Agile, but in the end none were very satisfying. Of all the instruments, the Ibanez came closest to being acceptable, but still didn't feel quite right. All of the instruments had problems in the following categories: string tension and action, instrument balance, and tone both plugged in and acoustic. Unable to find a suitable commercial instrument, I started work on a design for a new instrument that would meet my specifications and requirements.

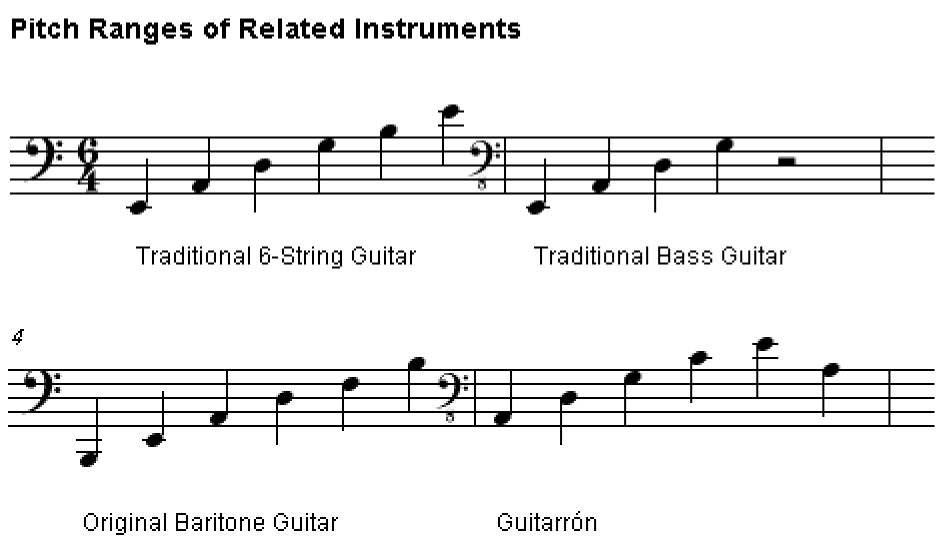
2 Baritone History

The invention of the original baritone guitar is usually credited to Danelectro during the late 1950's [1]. This instrument set the standard for tuning, choosing to go a fourth below standard guitar tuning or B E A D F# B from the lowest string to the highest (see Figure 1).

A precursor to the baritone is the guitarrón, the Mexican bass lute, which is a six string fretless instrument with a rounded back that helps to amplify the strings. The guitarrón has a rather short scale for a bass instrument and uses extremely heavy strings tuned A, D, G, C, E, A. The "high A" string is tuned a full octave below the expected A, causing the E string to be pitched the highest of the strings. Some baritone guitars take their cue from the guitarrón and start tuning with the low A and then follow traditional guitar tuning after that (i.e. 4^{th}, 4^{th}, 4^{th}, Major 3^{rd}, 4^{th} .)

Another closely related instrument is the Fender Bass VI which is a short-scale 6-string bass, one full octave below a standard guitar. The Supro Pocket Bass from 1962 was also in the same vein as the Bass VI [2]. Both of these instruments were usually used to double the bass lines, but the player played with a pick to get a more defined attack.

Figure 1 Pitches of the baritone guitar and related instruments



The baritone guitar is the least standardized instrument in the guitar family. While for standard guitars, the scale length, or the distance from the nut to the bridge, hovers around 25, the baritone guitar scale length can vary from 25 ½ to 30".

In standard guitars, the variations are minimal. The Gibson scale is 24 ¾ inches, Paul Reed Smith and National use a 25 inch scale and Fender uses the longer 25 ½ inch scale [3]. Given that the pitch of each of the strings on a guitar fixed to standard E to E tuning, scale length seriously impacts the string tension. String tension decreases when the scale length decreases allowing strings to be softer or easier to play and bend. Conversely, the longer Fender scale is stiffer, the strings are harder to bend, and can tolerate harder strumming without being knocked out of tune.

Unfortunately, no real standard scale length exists for baritone guitars. The scales range from 25 ½ with heavy strings all the way to 30” inch scales similar to short-scale bass guitars. . Not to be forgotten, there are quite a few models of guitars with 7 or even 8 strings which are often referred to as baritone instruments as well. These instruments tend toward the shorter 25 ½” to 26 ½” scales closer to traditional guitars and are largely manufactured mostly by Schecter, Ibanez and ESP who all cater mainly to metal guitarists.

3 Problems with Existing Designs

After trying instruments from a variety of manufacturers and finding that I was dissatisfied with all of them, I wanted to start to define what the major problems were with these instruments and what I could do to improve the designs.

3.1 String Tension

Most of the instruments that I played suffered from problems involving string tension. String gauge, instrument scale length, and desired pitch all affect the tension of the strings. Lowering the intended pitch of a string decreases the string tension, as does decreasing the scale length of the instrument. Thinner strings gauges require less tension to be tuned to specific pitches. D’Addario, a string manufacturer, provides detailed charts to help musicians choose the proper gauge strings for their playing style, scale length and instrument [4]. Gauges, length and tension are all open to adjustment with the baritone guitar because of the lack of an agreed-upon standard.

Most of the instruments that I evaluated had loose string tension causing the strings to buzz badly even with moderate playing pressure. Most of the instruments that I tried tended toward the shorter scales of the spectrum between 26 ½” and 28” and all used similar string gauges, usually in the following sizes: 1st: 013, 2nd: 017, 3rd: 026, 4th: 036, 5th: 046, 6th: 060 [5].

GHS carries a set of custom strings specifically designed for baritone in the following gauges: 1st: 014, 2nd: 018, 3rd: Wound 028, 4th: Wound 038, 5th wound 050 and 6th: wound 070. These heavier strings probably would eliminate many of the problems that I was finding on the existing production models. The manufacturers may have been using the lighter strings to attract players without the stronger fingers that are required to play this larger instrument. I concluded that a better instrument would have increased string gauge (using the GHS set), increased pitch to C, or a longer scale length to stiffen the instrument’s action.

I experimented with increasing and decreasing pitch from the typical B to B tuning and tried a C to C tuning as well as an A to A tuning. Most of the baritones were improved by tuning up from B to C and thus increasing the string tension. Unfortunately this semitone transposition proved to be extremely difficult to fully remember while playing and in the end killed my hopes of the C to C guitar. This is too bad because this tuning probably would have been very popular with the death metal bands that routinely tune down to D and then “drop” the lowest string to C creating the relationship of a major fifth in the bottom two strings. With standard lighter strings, the A tuning was completely unusable as the strings sat on the frets while playing and buzzed uncontrollably.

3.2 Balance, Ease of Playing 1st Position Chords and Bridge Position

On the production models, I found some difficulty in comfortably reaching to play chords in the lower positions, with a particular problem with 1st position bar chords. In the past I had also experienced this problem with modern style basses with 24 frets and a large cut-away to give better access to the additional frets.

Fender basses didn't share this problem because of their extended horn on the body of the instrument. The body of the instrument finds a balance on the player's body with the distance between the two strap buttons becoming a center point. If the horn is further away from the bridge and closer to the string nut, the lower playing positions will be much more comfortable. Notice in Figures 2 and 3 the difference between the location of the strap button on the Fender Stratocaster and the Telecaster. The Strat's horn balances the guitar in such a way that the player can reach closer to the string nut more easily. Notice also that the Stratocaster finds its strap button above the 12th fret of the instrument, while the Telecaster's strap button is above the 16th fret. Even though both of these instruments share the same scale of 25 ½", the Strat provides more comfortable access to the first position.

Figure 2 1957 Fender Stratocaster [6]

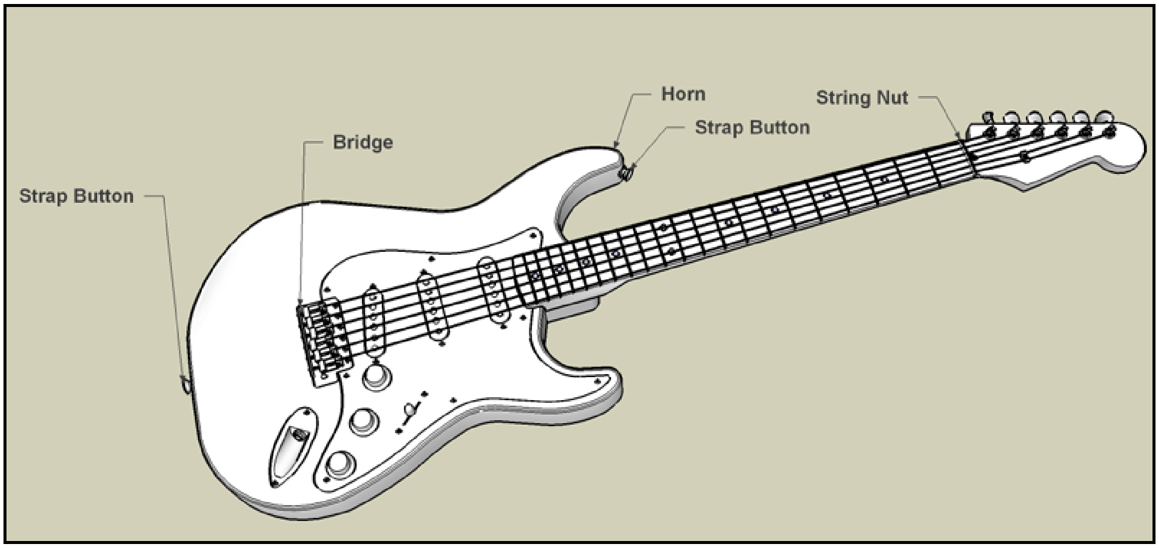
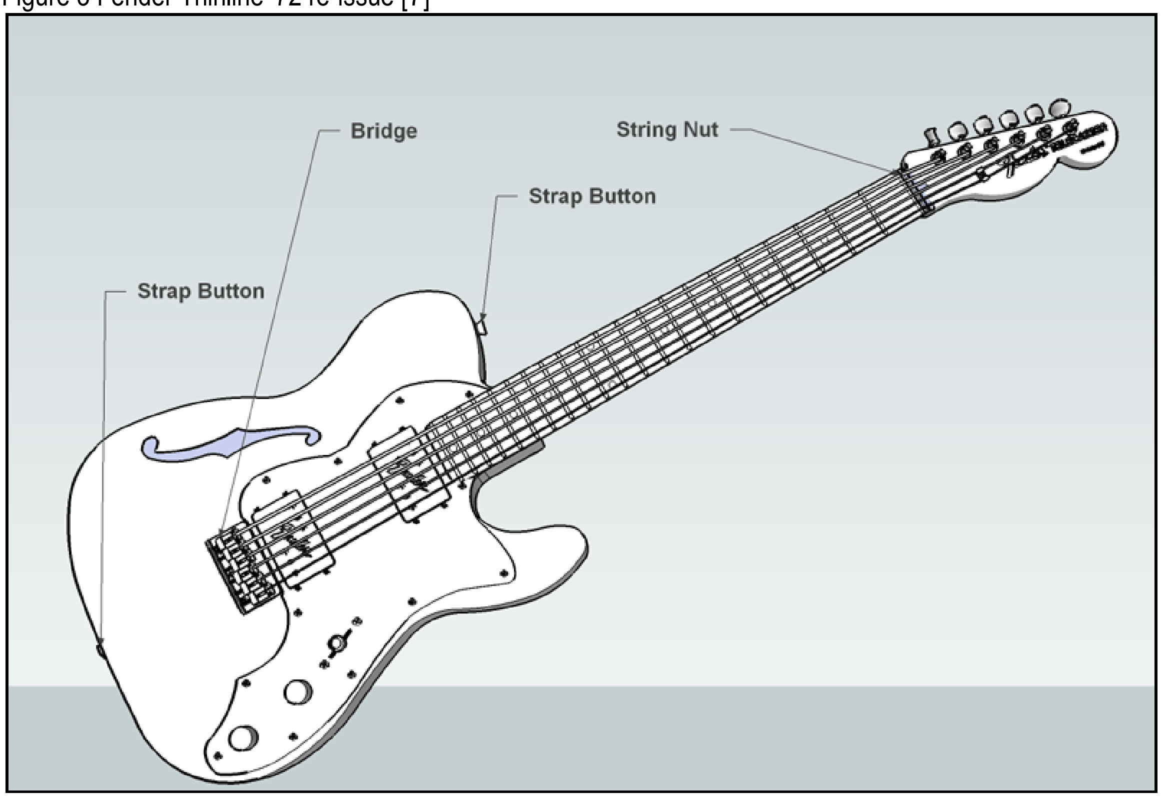


Figure 3 Fender Thinline '72 re-issue [7]



Fender's bass designs move the bridge closer to the tail in order to compensate for the longer neck of 34" (8 ½" longer than the guitars). If you compare the basses to the guitars, the bridge on the basses is much closer to the tail of the instrument, and the strap button on the basses is located immediately above the 12th fret much like the Stratocaster.

Figure 4 Fender American Standard Jazz Bass and American Standard Precision Bass [8]

If you look carefully, you can see that the top horns of both Fender basses are identical. The repositioning of the bridge and the strap button position has the benefit of pushing the entire length of strings towards the player's right hand and bringing the 1st position closer to the player's left hand.

Fender's original basses have 20 frets, but newer designs from other manufacturers often incorporate 24 or more frets. This creates a problem of access to the higher frets, so a much deeper cut-away needs to be provided. The deep cut-away creates a somewhat unbalanced looking body like the Ibanez SR1000EFM. The top horn looks exaggerated compared to the bottom horn with the cut-away, but the strap button still needs to be at the 12th fret to remain balanced. For my taste, the visual balance of this Ibanez was disrupted by the cut-away that was needed to provide access to the higher frets.

Figure 5 Ibanez SR1000EFM Bass Guitar [9]

3.3 Rigidity for Tone and Sustain

The production models I played also had problems with neck rigidity. The amount of force generated by the string tension puts a strain on the neck and causes the wood to flex and bow. All the models I played used a standard 2-piece neck, featuring one piece of ¼" stock for the fingerboard and then a ¾" or 1" thick piece of a different wood for the majority of the neck. This technique is based on the tried-and-true method of neck construction for guitars, but it does not support the extra tension from the heavier strings very well.

Many modern bass builders solve this problem of neck flex with a technique of reinforcing the neck with rigid pieces of metal or graphite and also make use of laminated or multiple-piece necks. The laminating technique adds a tremendous amount of strength and rigidity to the instrument by varying the grain patterns and species of wood in the neck blank. Note in Figure 6 below that the Ibanez bass shows the layers of wood in the neck running through the whole body of the instrument.

Figure 6 Ibanez neck-through design showing the 5 piece laminate used in construction [10]

As Ken Parker proved with his Fly guitar [11] (See Figure 6), sustain is improved by increasing the rigidity of the instrument, not by increasing the weight of the instrument. Parker's graphite-backed mahogany instruments were extremely light, and the rigidity of the instrument resulted in much less energy being loss in transmission of vibrations [12].

Figure 7 The Parker Fly Guitar

The improved sustain offered by the Gibson Les Paul over the Fender Stratocaster was traditionally assumed to be a result of the increased density of the Les Paul's mahogany over the lighter swamp ash favored by the Fender luthiers. As it turns out, dense wood is also more rigid. The joint where the neck attaches to body is critical to tone and sustain. Running the gamut from a bolt-on neck favored by Fender to the dove tail mortise and tenon of the Les Paul, the neck pocket is the most critical construction feature of a guitar [13].

4 Designing the Baritone Guitar

Based on my experiences with the production models that I tried, I resolved to design an instrument that did not fall prey to the pitfalls mentioned above. I would optimize the scale length and string gauges to provide for a firm but comfortable amount of string tension. Learning from bass designs, I would shift the strings towards the tail of the instrument by moving the bridge away from the neck and closer to the tail.

4.1 Woods, Tone and Rigidity

Electric guitars are nearly always made of hardwoods from a small number of deciduous species from around the world. Acoustic instruments, however, use resonating tops made of coniferous species like spruce and cedar. The most popular woods for electric guitar building are rock maple (also known as hard or sugar maples), mahogany (a tropical exotic hardwood native to the West Indies, Central and South America), alder, swamp/white ash (both native to North America), or rosewood and ebony (both exotic hardwoods becoming hard to find).

Each of these woods has its own tonal characteristics as well as grain type, grain figure, hardness and rigidity. According to Warmoth Direct Guitars [14], mahogany is the warmest of the neck woods, while maple is the brightest with the most defined high frequencies. Honduran mahogany is the wood used for Gibson guitars' necks and bodies, while hard maple is the wood typically used in Fender necks. Body woods are often slightly less dense and softer to allow for a lighter instrument. Swamp ash, which is very popular with Fender bodies, is a softer, lighter variety compared to Northern hard ash which is harder and heavier. Alder, basswood and poplar are all slightly softer woods commonly used in body construction as well [15].

I opted to use swamp ash for the body because it would cut down on the weight of the instrument and would still provide a tone in between the warmth of mahogany and the brightness of maple. Ash has a natural rustic feel to it, even when sanded with 200 grit paper and it is an open-grained wood, which means the grain has deep pores that must be filled in order to get a smooth finish.

Figure 8 A close-up of swamp ash grain

For the neck, I chose rock maple, which unlike swamp ash, has a closed grain and can be sanded almost as smooth as a polished rock or buffed steel. The neck is the part of the instrument that will be touched the most, and the feel of this critical part affects the player's impression of the instrument as a whole. I also used purpleheart in the lamination of the neck blank mostly because of its striking color, but also to tone down the brightness of the maple.

The fingerboard is glued to the top of the neck over the truss rod and the frets are pressed into the fingerboard. I chose to make the fingerboard from macassar ebony which is a figured ebony with visible grain varying from black to browns and tans.

The lamination technique that I used is very similar to the style shown on the Ibanez bass above. I ripped three pieces of hard maple to ¾" by 1" and 2 pieces of purpleheart to ¾" by ¼" and then glued all five of the pieces together as shown in Figure

10. I made sure that I reversed the grain pattern for each piece to try to create the most stable neck blank possible. The notch cut down the length of the neck for the truss rod is centered on the middle piece of maple, so that the truss rod will not disrupt the various laminations.

Figure 9 A close-up of purpleheart and hard maple

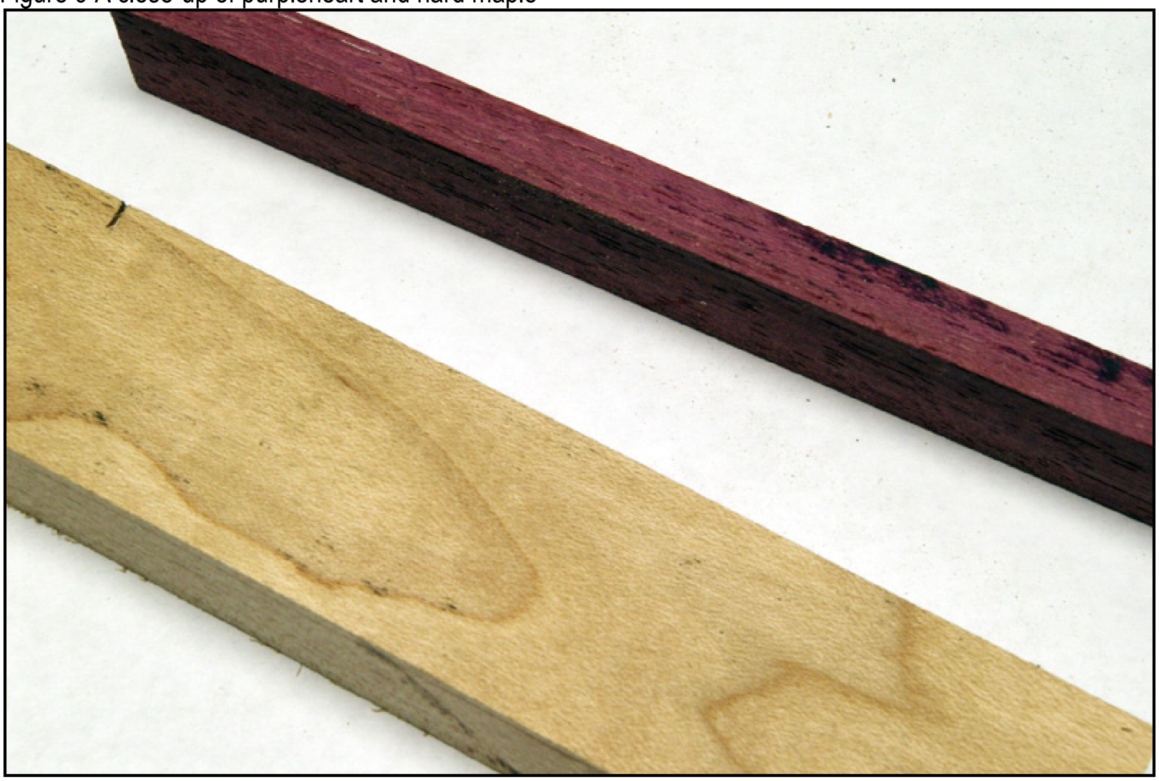
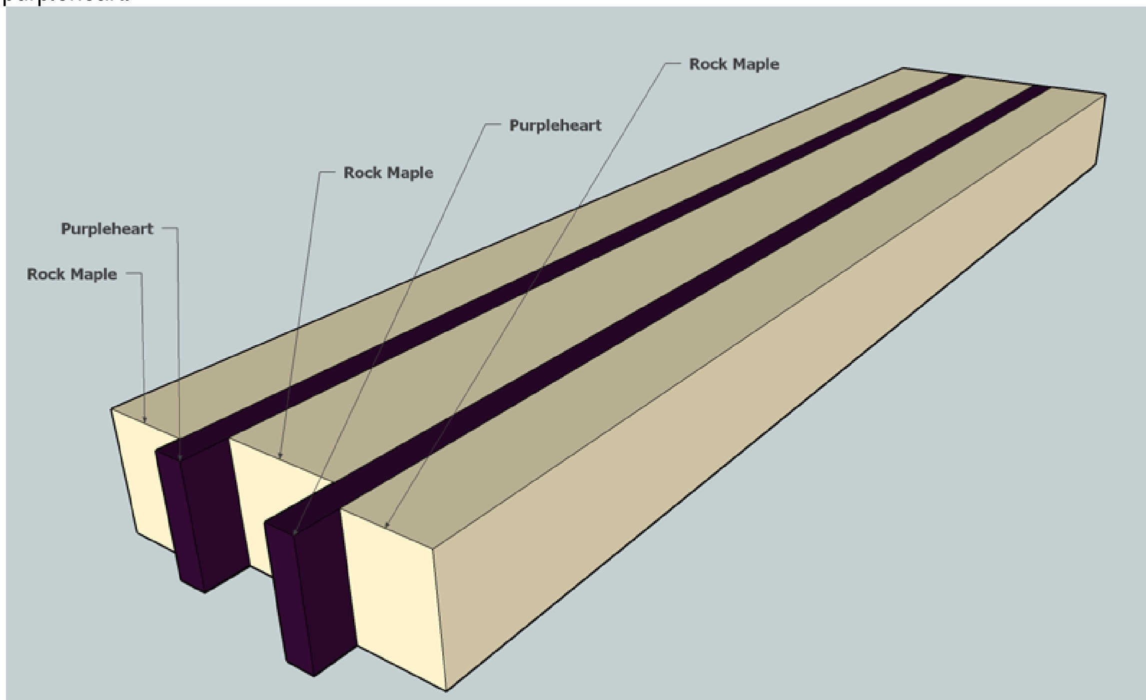


Figure 10 5-piece neck blank lamination method with 3 1" pieces of rock maple and 2 ¼" pieces of purpleheart.



4.2 Angled Headstock and 'V' Neck Contour

The shape of the neck is another critical part of the design process that affects string tension, sustain and the feel of the instrument. The traditional method of the headstock configuration is the angled back headstock used in all string instruments from lutes, violins and viols, as well as guitars. This angle increases the pressure of the strings on the string nuts and eliminates the use of a string tree to hold the string down onto the headstock as required by the Fender instruments. Angles from 10° to 15° are common and I opted for 15° as it was an easy multiple of 90°.

Figure 11 A 3D rendering of the neck blank with a 15° angled headstock and radiused fingerboard

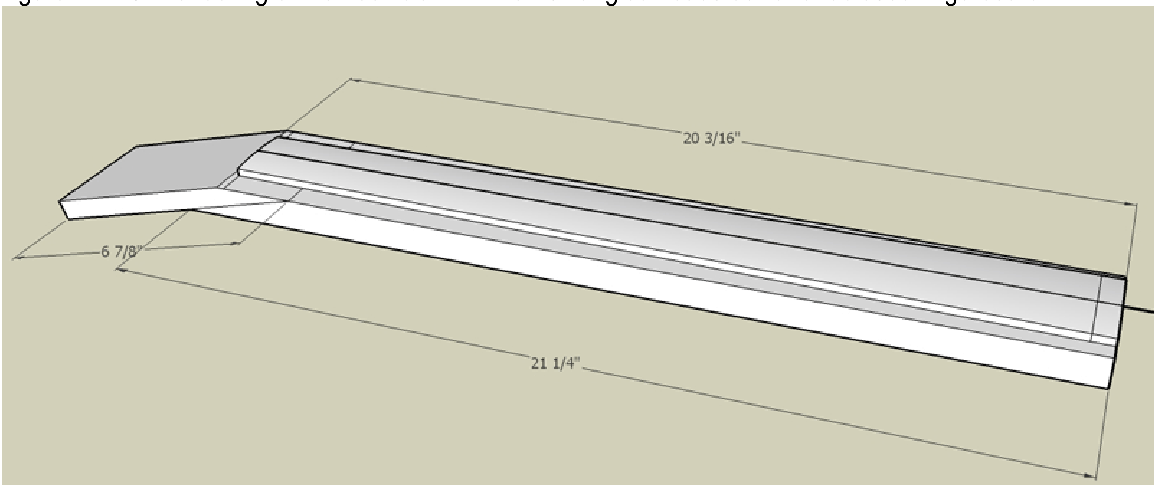
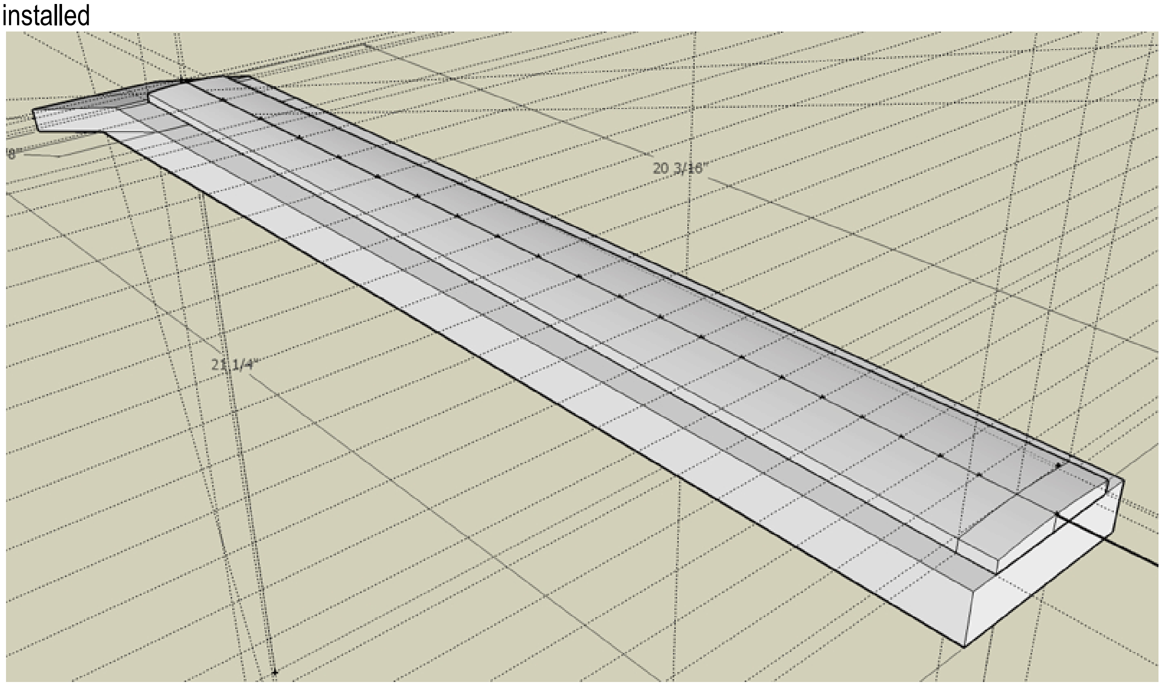
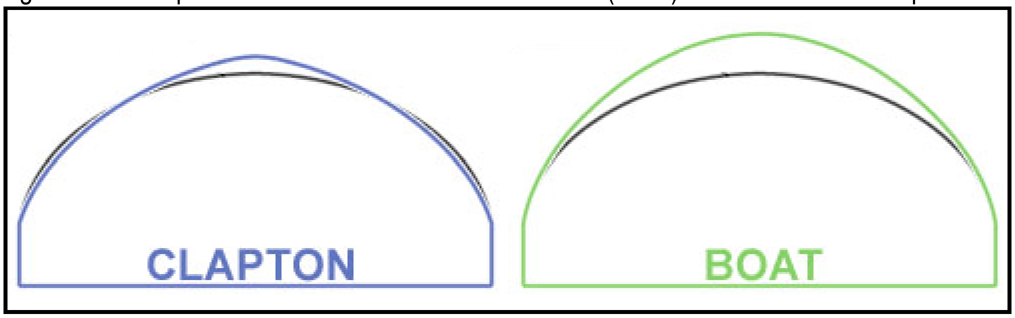


Figure 12 A different angle of the neck blank before carving with guides to show where the frets will be installed



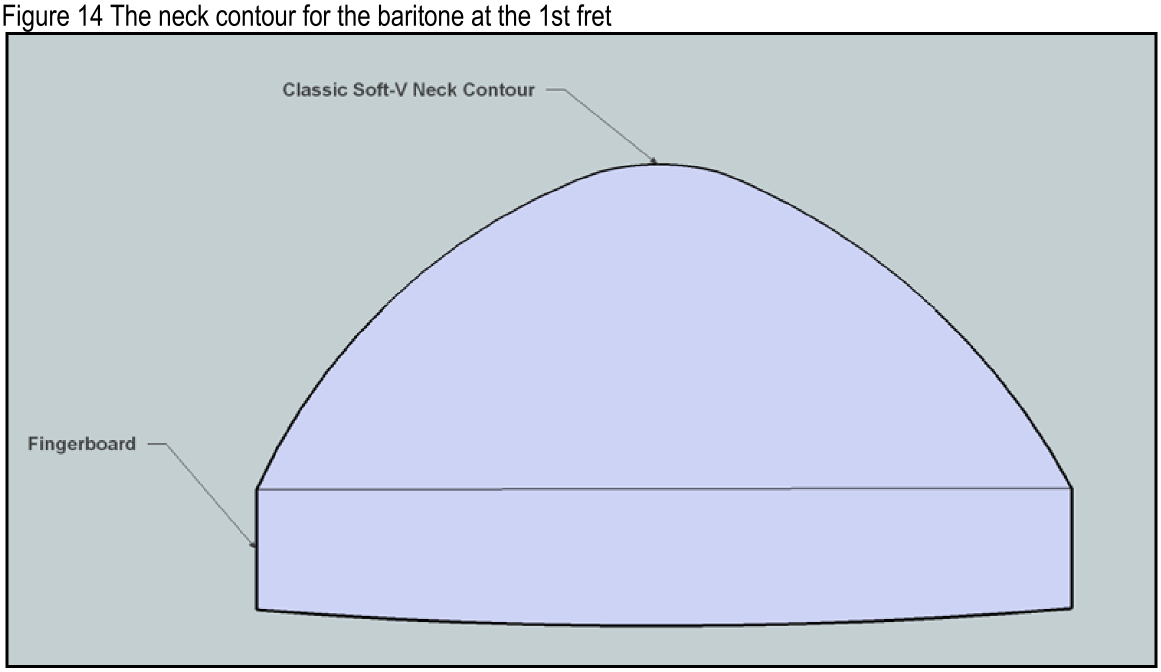
The neck back contour is the shape of the neck as cut laterally through the neck. Historically guitars have used either a 'C' or a 'U' shape, but Fender pioneered the 'V' neck shape which optimizes the player's ability to wrap his or her thumb round the neck of the instrument. The 'V' has been popular particularly with blues and country musicians. It makes playing open chords easier and more comfortable and is particularly useful for instruments with a longer scale like basses and baritones.

Figure 13 A comparison of the standard 'C' neck contour (black) with two more 'V' shaped contours [16]



I chose to use a slightly stronger 'V' shape than the two designs above because I was planning on tapering from the 'V' at the first fret to the flatter 'C' shaped neck by the 12th fret to make it easier to play single notes and bar chords. The Figure below shows the shape of the neck at the first fret.

Figure 14 The neck contour for the baritone at the 1st fret



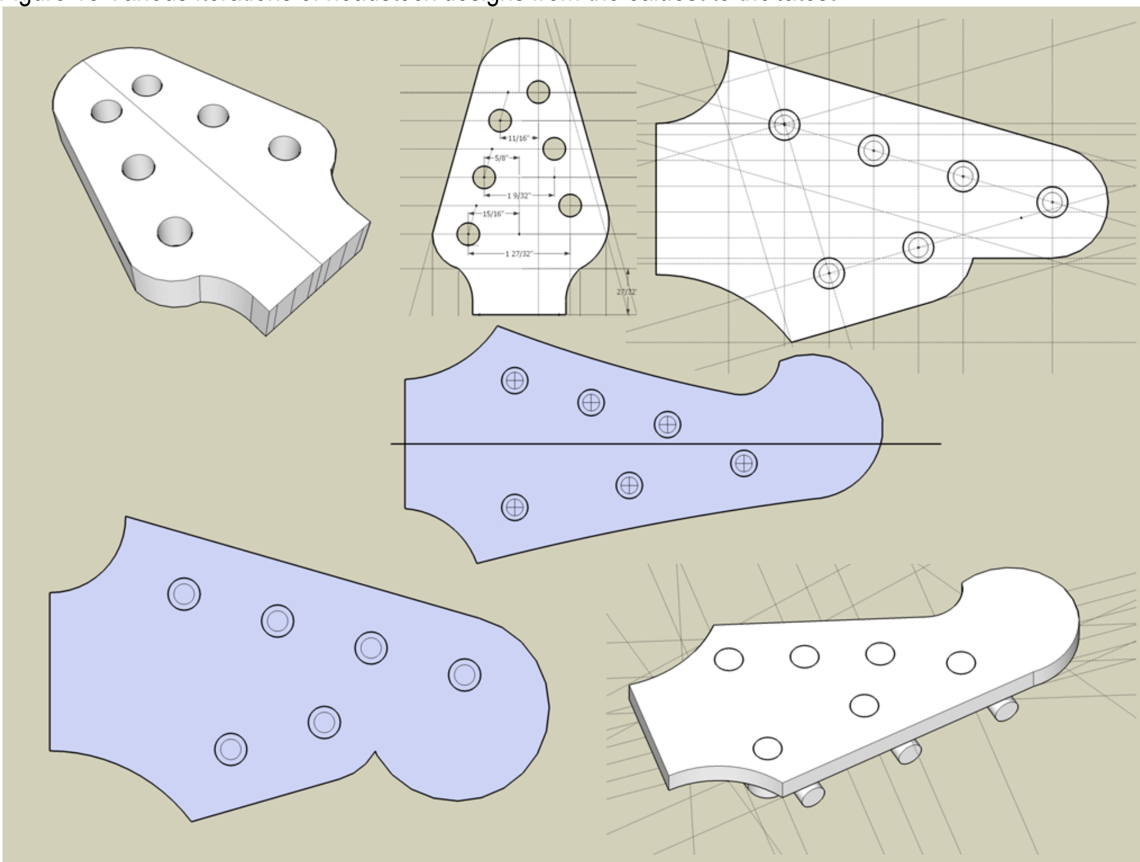
4.3 Headstock Shapes

My design goal for the headstock was to use the least amount of wood possible, but still allow the strings to remain straight as they travel from the nut to the tuning machines. A smaller headstock weighs less and does not affect the balance of the guitar as much as a larger headstock.

The three-top, three-bottom (3+3) traditional symmetrical headstock used on early acoustic instruments and later adopted by Gibson, causes the strings to bend outward from the nut to the tuning spindle on the tuning machine. This can lead to problems of the string binding at the nut and intermittently slipping, causing tuning problems and unnecessary string breakage. The 3+3 style headstock is more user-friendly however, in that it is easier to feel which machine the player is tuning on dark stages while still maintaining eye contact with the audience or the panel of a digital tuner.

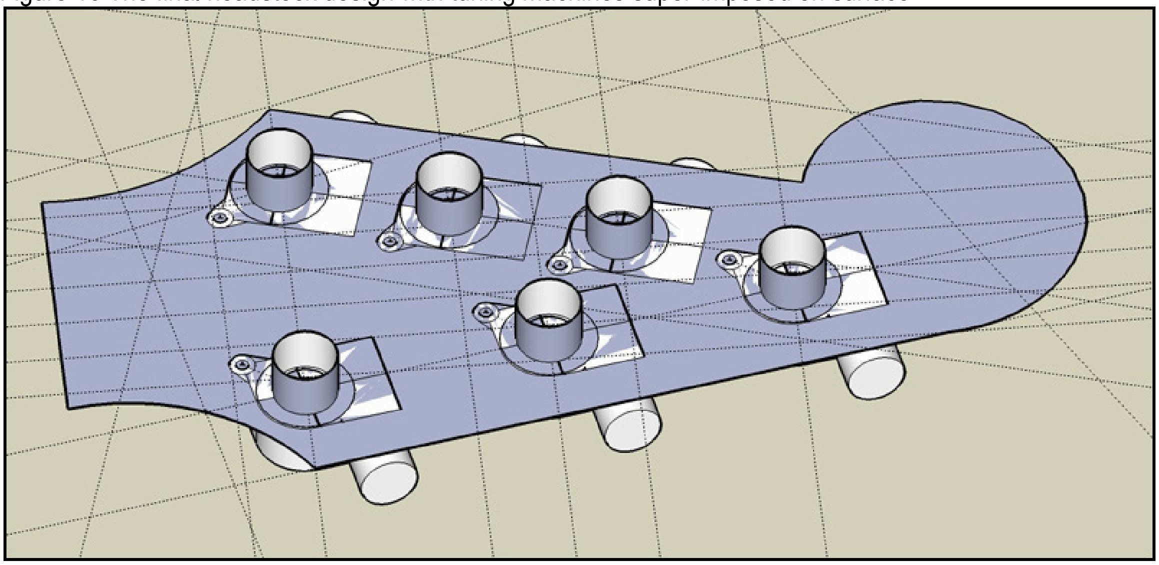
The design goal of a small headstock, in the 3+3 configuration, is difficult to achieve because the tuning machines on a symmetrical headstock bump into each other if they're not offset. This is further complicated by the desire to maintain a straight angle from the string from the nut to the winder. Figure 15 below shows the many different iterations of the headstock that I went through to find a design that was both visually appealing and effective at maintaining straight string runs while allowing for the tuning machines not to touch. The center and lower right mockups became the actual headstock in my design.

Figure 15 Various iterations of headstock designs from the earliest to the latest



The first prototype of the headstock was the upper left model. The symmetry was appealing, but the tuning machines would not fit so close together on the top holes, for strings 3 and 4. The second version to the right offset locations of the machines slightly, but the tuning machines still butted against each other. The next two designs, upper right and bottom left, solved the issue of tuning machine spacing, but they were quite unattractive. Figure 16 below shows the final contour of the tuning machines super-imposed through the surface of the headstock.

Figure 16 The final headstock design with tuning machines super-imposed on surface.



The final design offset the machines substantially and added the style of an inverted Fender shape to balance the large hips on the body of the instrument. The final touch is the purpleheart cover over the truss-rod adjustment notch. The headstock was successful both in the elimination of extra bends in the string and in providing aesthetic balance to the instrument.

Figure 17 Photo of the baritone's headstock from the front

Figure 18 Photo of the baritone's headstock from the back

4.4 Joining the Neck to the Body

The neck joint is the critical connection through which vibrations travel from the nut to the bridge of the instrument. A poor neck joint will decrease vibrations and reduce the volume and sustain of notes as well as causing an unstable playing experience. The worst example of this is a bolt-on type neck where the neck pocket is routed too largely for the neck, allowing the player to torque the screws loose while playing. Over time this could lead to the screws or even the neck breaking.

There are three joint options for the custom guitar builder: bolt-on (actually uses screws), mortise and tenon glued or set neck, and neck-through where the neck continues all the way through the body of the instrument.

The bolt-on neck is the simplest method of attachment and also the least expensive, but is rarely used for custom guitars. The advantages of the bolt-on neck include non-destructive neck replacement and faster manufacturing because gluing time is eliminated. The primary disadvantage is that the bolt-on connection is often not as rigid as a set-neck or a neck through design, which are said to have increased sustain due to the improved mechanical connection between the body and the neck. The vast majority of bolt-on necks use Fender’s original measurements for the neck pocket: 2 3/16” wide, 3” long and 5/8” deep.

The second type of neck joint is the mortise and tenon, also known as the set neck. In short, this is a glued neck joint that uses increased surface area to create a stronger connection between the neck and the body. The mortise is the neck pocket and the tenon (the end of the neck) is inserted into the mortise. Great care is taken to ensure that the joint has a high tolerance and that the joint will hold simply with pressure before the joint is glued.

This particular style of joint has been used to connect necks on string instrument bodies for hundreds of years. Instruments in the viol, violin, and classical guitar families all share the same neck join, which also includes the subset of the dove-tail neck joint. The classical guitars have a neck that is parallel to the top of the body, while the violin family has necks that tilt back from the face of the instrument. This angle increases the pressure on the bridge of the instrument and thus improves the length of the sustain of the instrument. The tilt-back angle (usually 2° To 3°) of the neck requires a taller bridge to prevent the string action from being too low.

In addition to the neck angle, often this style of guitar includes an angled headstock as well. The angle serves to increase the pressure of the strings on the nut and eliminates the need for a string tree to hold the strings down to work well with the tuning machines. A great example of this type of guitar in the Gibson Les Paul, which is a solid body guitar that borrows heavily from the look of arch-topped hollow body instruments like violins and viols.

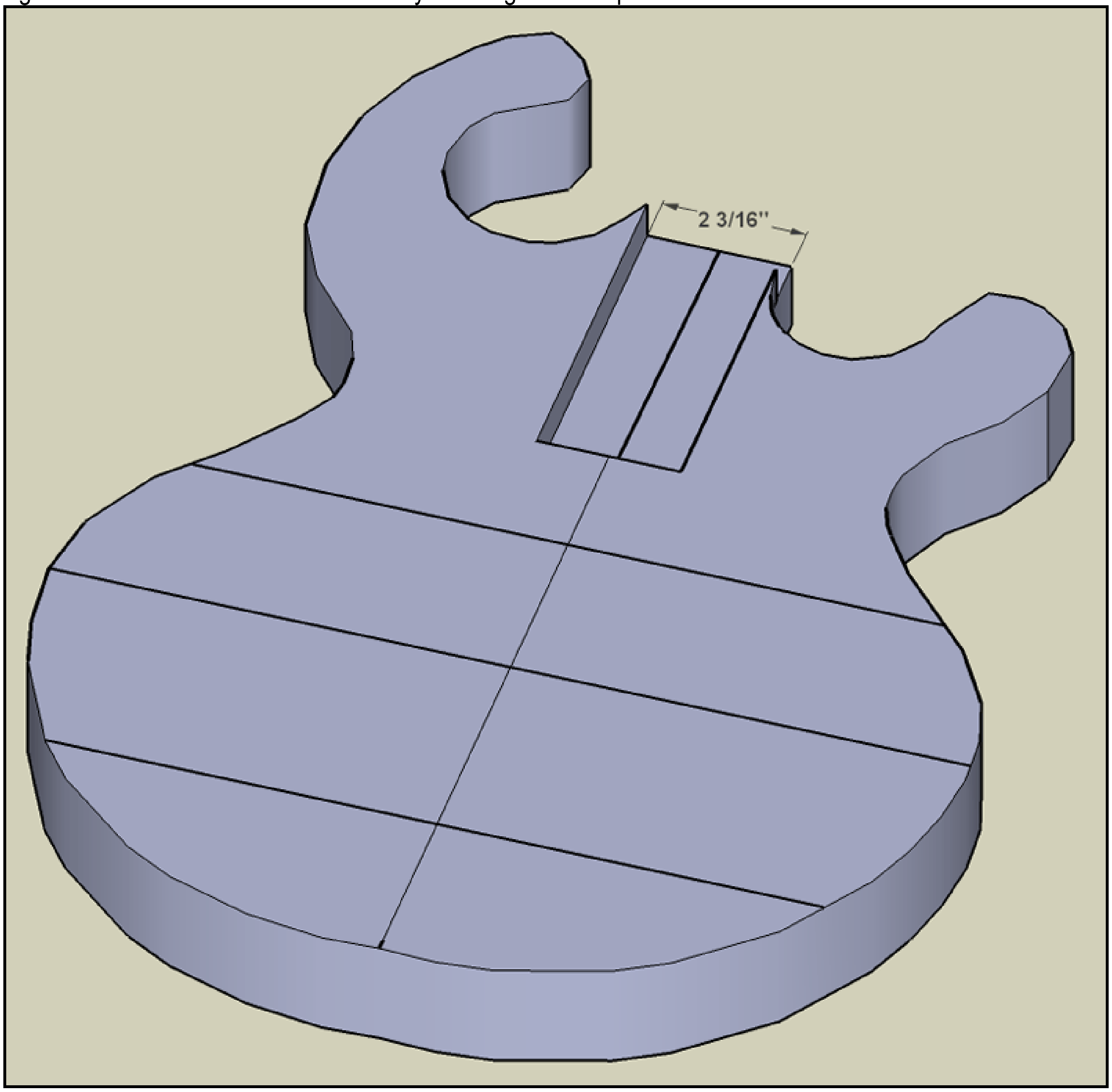
The third style of guitar neck joint is the neck-through style. This construction technique actually is not a neck joint at all. The wood of the neck continues through the body of the guitar in one continuous piece. Les Paul's "Log" guitar was probably the first neck-through instrument. This type of design was originally found more often in electric basses than in guitars, but now many models of both are available. Body wings are attached to the neck core to obtain the traditional shape of the guitar. The pickups and bridge all are mounted into the neck piece, which contributes to increased sustain.

Most neck-through instruments do not have the angled back neck that requires a higher bridge. This may counteract the improved sustain of the neck-through design by decreasing pressure on the bridge and nut of the instrument. The neck-through body design is more complicated to build and manufacture than either the bolt-on or set neck styles. As a result, most neck-through designs come from higher-end instrument manufacturers and small custom luthier shops.

I chose the mortise and tenon set-neck option because I was interested in an extremely strong rigid joint, but did not want to give up the warmth of a full swamp ash body. In my design (see Figure 19 below), I allowed for a neck width of 2 3/16," but during construction opted for a slightly wider neck at the body around 2 5/16." In the Figure below you can see both the routing for the neck to fit into the instrument and the template on the left that was used as a guide to route the pocket accurately.

Figure 19 A router template and the neck pocket routed out of the body

Figure 20 A 3-D view of the baritone body showing the neck pocket dimensions



4.5 Body Shape

The body of the guitar makes up the bulk of the size and weight of the instrument and is the part of the instrument that rests against the body and determines the balance of the instrument, both in seated and standing positions.

I designed my instrument with the traditional 20 frets to avoid the need for a large cut-away. I positioned the bridge of the instrument towards the tail to move the entire length of the strings to the right, bringing the first position closer to me. I also created a full-sized top horn to position the top strap button at the 11th fret ensuring a comfortable playing position even with a longer neck of 27 ½."

The unusual body carving has given the baritone its distinctive look. Some of the carving is merely ornamental, like the 'S' curve connecting the top horn to the bottom hip of the guitar, but other features of the carving are designed to make it easier or more comfortable to play.

The cut-away that allows access to the higher frets is a good example of a functional carving. By streamlining the edges of the instrument and thinning the body at the cut-away, I have improved access to the frets that normally would be difficult

Another functional carving technique is called the tummy cut (see Figure 18), which removes wood where the player's belly presses into the instrument. This allows the instrument to feel like it is wrapping around the performer, and removes wood to decrease the weight of the instrument. In addition, the top hip of the guitar is contoured to allow the arm to rest on the instrument without hitting a sharp corner of the instrument's body. Both the tummy cut and the arm rest cut were pioneered by Fender with the sleek modern design of the Stratocaster.

Figure 21 An example of a tummy cut on the back of a guitar body [17]

Figure 22 Front of the body of the baritone

Figure 23 Back view of the baritone's body and heel

Several guitars influenced the shape that I designed: the Parker Fly, Prince's Cloud Guitar from the end of the 1980's and the 000 Auditorium style guitars made by C.F. Martin. The shape of the Martin 000 has been a staple of American instruments for the past century. The smaller size body is very comfortable both to wear with a strap or to rest on a leg because of the depth and location of the so-called waist of the body. I used the bottom hips and the waist contour from the 000 guitar as the beginning of the shape of the baritone guitar (See Figure 24).

Figure 24 C.F. Martin's 000 14 fret Guitar Body Shape used for the "hips" of the baritone body. From the left to the right: Martin 000 [18], a 000 14-fret body mold [19], the borrowed shaped for the baritone.

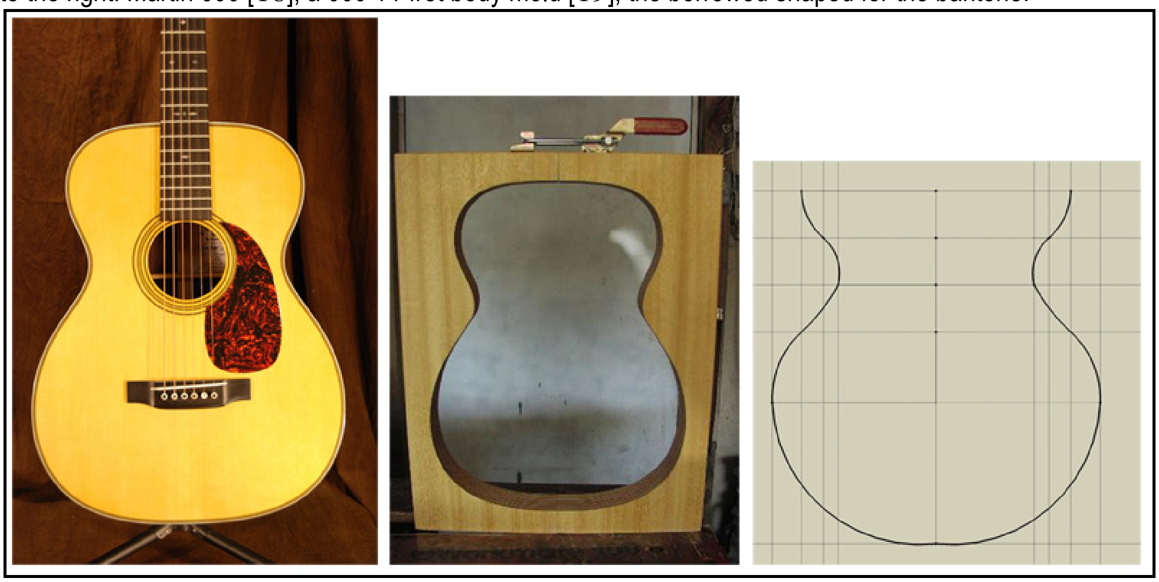


Figure 25 The Parker Fly, probably the last major innovation in commercially available guitars

The contoured shape of the Parker Fly was also an inspiration for the body of the baritone. The Fly has a dramatically rounded arm rest which effectively shaves a lot of material off to lighten the instrument in addition to making it more comfortable to play. I also spread the tapered armrest across the entire top hip of the instrument to reduce weight and make playing the instrument more comfortable (See Figure 22).

Prince's Cloud Guitar was another influence on the design of the body. This was the first guitar I had seen with an exaggerated top horn that moved the strap button towards the nut of the guitar. I suspect that this innovation would have made it easier for Prince, with his shorter arm length, to reach the lower positions on the neck. Prince was the first artist, that I was aware of, who had special guitars made for him to meet his needs both from an ergonomic and aesthetic point of view.

Figure 26 Prince's Cloud Guitar at the Rock 'n' Roll Hall of Fame

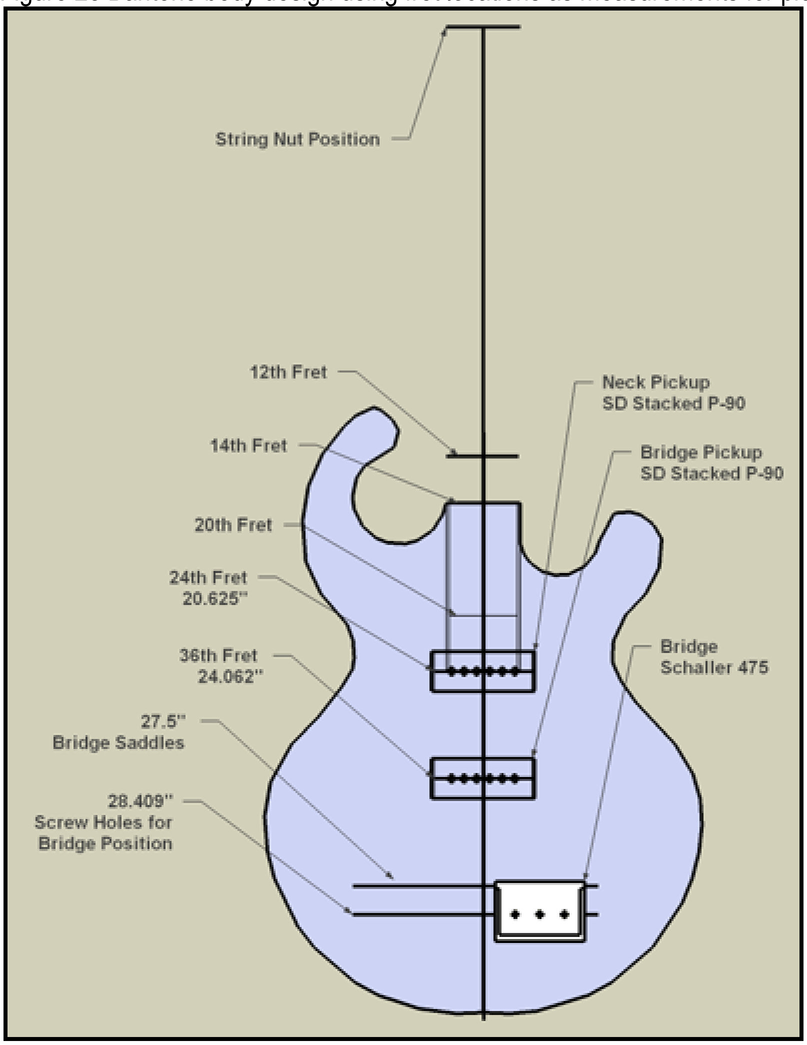
4.6 Pickup Types and Locations

There are a wide variety of pick-ups in use by manufacturers of baritones, with most instruments being targeted towards certain types of music. Instruments using single-coil lipstick pickups are targeted at the country-western and roots rock genre, while instruments with double coil pickups are targeted toward hard rock and metal. The traditional baritone sound used in spaghetti westerns, surf rock and country music comes from baritones equipped with single coil, twangy sounding pickups.

I chose to use a humbucking version of Gibson's famous P-90 soap-bar pickups because I wanted the bright and growling tone of a single coil, but without the associated hum from a single coil P-90. Seymour Duncan carries a "stacked" P-90 (Figure 28) that positions the second coil beneath the first so it is not visible and influences the sound only minimally. I placed the pickups on the body so that the pole-pieces of the neck pickup were beneath the 24th fret position and the bridge pickup was beneath the 36th fret position [20]. (See Figure 27)

Figure 27 Seymour Duncan P-90 Stack Pickups

Figure 28 Baritone body design using fret locations as measurements for pickup placement



These two locations offer a much richer viewpoint to the nodes and anti-nodes of the harmonics of the string. The string vibrates the least at the nodes and vibrates the most at the anti-nodes. In addition, the location of the nodes and anti-nodes change as the player shortens the string length by fretting notes. Generally, pickups closer to the neck have a deeper sound and pickups near the bridge have a brighter sound. Gibson named the pickups, Rhythm and Lead, to suggest that the bridge pickup would be better for solos, while the rhythm pickup would be better for chords and accompaniment.

5 Conclusion

I created a new guitar design to improve on existing production baritone guitars and to correct problems with the instruments' balance, rigidity, tone and ergonomics. The most significant innovation was to change the balance of the instrument by moving the bridge down the guitar to the tail of the instrument and ensuring that the strap button on the top horn of the body is above the 11th fret on the instrument. This change brings the first position on the instrument closer to the player and improves the ease of playing close to the nut.

The shape of the neck returns to the 'V' neck, which makes it easier to hold the instrument comfortably when playing open chords. As the neck gets closer to the body of the instrument, the back of the neck becomes flatter, making is easier to finger bar-chords.

The neck is laminated from 6 pieces of wood: a macassar ebony fingerboard, three thick layers of hard maple and two thin layers of purpleheart, in order to improve the sustain and tone of the instrument. The lamination improves the rigidity of the instrument and so it improves the length of time that the guitar vibrates after being plucked.

The pickup pole pieces fall beneath the 24th fret position and the 36th fret position, which are active harmonic locations. This improves the electric tone of the instrument. I will continue to make improvements to the guitar in hopes of creating a high-quality production instrument.

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