The Electric Guitar

product phases analysis & industrial design evaluation analysis

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Content:
Product Phases & IDEA

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Contents

1. Introduction

This report is written for the master course Evolutionary Product Design, part of the Master Industrial Design Engineering at the University of Twente.
The first target of this course is to analyse the history of a consumer product, in this case an electric guitar. In chapter 2, a historical overview will be combined with the product phases theory which can help a designer in creating the next generation of a product (Eger 2007).

In chapter 3 an industrial design evaluation analysis is performed of the Motion ST 250 SB electric guitar. For this analysis the electric guitar is completely disassembled and analyzed on the technical functionality, the materials, the production processes, the production costs and the assembly. The guitar is completely modeled in SolidWorks (figure 1.1) to analyse and visualise the assembly as good as possible.

Fig. 1.1: Motion ST 250 SB as modeled in SolidWorks.

2. Product Phases Analysis

2.1 Introduction

Before starting with the introduction of the product phases model, an electric guitar history will be discussed. After that the product pases will be discussed and attached to the chronological historal facts of the first part. This history starts in the 1920's.

2.2 The Prologue

In the 1920s, dancing to the music of large bands was a popular form of entertainment in America. This popularity for dance music was one of the most important factors in creating the demand for the electric guitar, which was loud enough to be heard in crowded, noisy city jazz and blues clubs and bars and in dance halls.

The introduction of steel strings in the 19th century was the first step to a greater volume, but created also a greater tension on instruments. The traditional flattop guitar evolved to an entirely different design: the stronger and louder "archtop"-guitar, which means nothing more than arched top.

2.2.1 Gibson L-5

One of the acoustic engineers at the Gibson Mandolin-Guitar Manufacturing Company was musician Lloyd Loar. He designed improvements as well as new models of Gibson instruments. He also designed the Gibson L-5 guitar (figure 2.1 & 2.2), first introduced in 1922. The L-5 was Gibson's first archtop guitar with f-holes instead of a round sound hole.

Fig. 2.1: Gibson L-5:The first arch-top guitar with f-holes.

Fig. 2.2: Gibson L-5.

Fig. 2.3: Adolph Rickenbacker with the "Frying Pan".

In 1923 Loar also developed an electrostatic pickup system for amplifying instruments. This early experimental system for electric guitar can be mounted beneath the bridge of the Gibson L-5 and with an output jack concealed in the tailpiece it is not visible for an ignorant person. Unfortunately, the guitars incorporating these unconventional pickups were not successful in the marketplace.

2.2.2 Rickenbacker 'Frying Pan'

Around 1931 George Beauchamp, working with Adolph Rickenbacker, produced an electromagnetic pickup in which a current passed through a coil of wire wrapped around a magnet, creating a field which amplified the strings' vibrations. This electromagnetic pickup invention is essentially for the technology used on all electric guitars today.
The pickup was introduced on a lapsteel crafted from a single piece of wood, which was the prototype for a Rickenbacker cast-aluminum model nicknamed the Frying Pan (figure 2.3 & 2.4). It was the first commercially successful electric guitar thanks to the innovative electromagnetic pickup.

2.2.3 Gibson ES-150

Introduced in 1936, the Gibson ES-150 was the first Spanish-style electric guitar to achieve commercial significance. This with special thanks to the inventive

Fig. 2.4: The Rickenbacker "Frying Pan", 1931.

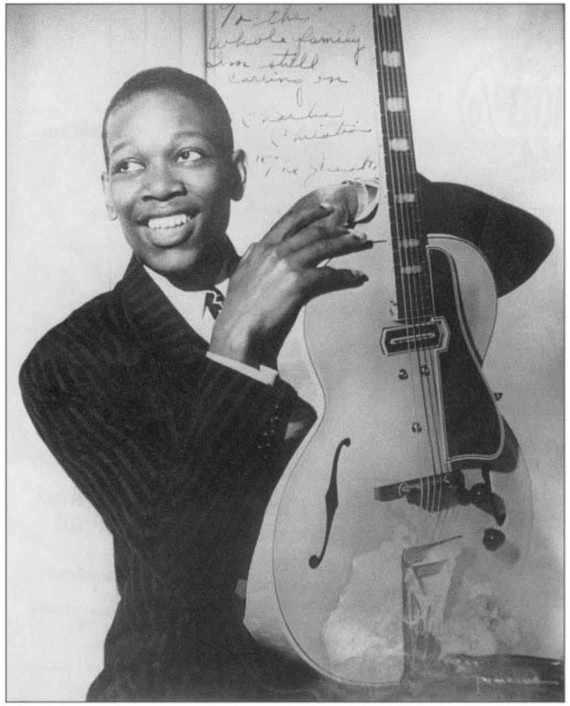


Fig. 2.5: Charlie Christiansen with a Gibson ES-150 model.

jazz musician Charlie Christian who "invented" electric guitar playing. Christian took the Gibson ES-150 (figure 2.5) and brought the guitar the forefront as a lead instrument. The design featured a one-piece steel bar surrounded by the pickup coil and two magnets below the strings. This new pickup was nicknamed the "Christian" in honor of the great guitarist with whom it is associated.


Fig. 2.6: Gibson ES-150 with amplifier and gigbag, 1936.

Fig. 2.7: Les Paul and his wife Mary Ford.

Fig. 2.8: The Les Paul Log, ±1940.

2.2.4 Les Paul Log

By the late 1930s other makers and players adapted the new electromagnetic technology to the hollow-body guitars, but were troubled with distortions, overtones, and feedback. Guitarist and inventor Les Paul (figure 2.7) was one of the first to address these sound difficulties. Around 1940 he mounted strings and two homemade electromagnetic pickups on a solid block of pine to minimize body vibrations. To make it look more conventinal, Les Paul glued the halves of a hollowbody at the sides of the log. Around 1946, Paul took his “log” idea to Gibson. The company did not use his design as a prototype, but used his name to promote its first line of solid-body guitars in the 1950s.

2.3 A New Instrument

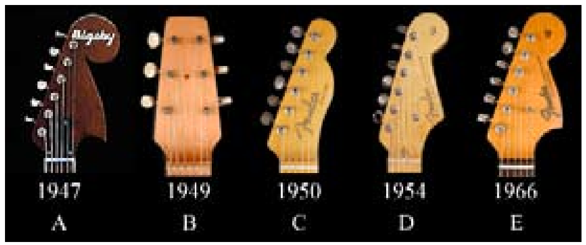
During the 1930s and 1940s some artists such as jazzmen Eddie Durham and Oscar Moore, country pickers Noel Boggs and Merle Travis, and blues masters T-Bone Walker and Muddy Waters were experimenting with the electric guitar’s tonal and harmonic possibilities. In this process, other musicians, makers, and audiences started to pay attention to the new electric sound. During the 1940s, Paul Bigsby and Leo Fender also began experimenting. Not with music, but with solidbody guitar design. They changed the design of the guitar radically.

Fig. 2.9: The Bigsby Tremolo, a design from the 40’s.

Fig.: 2.10: Merle Travis’ Guitar, build by Paul Bigsby, 1947.

2.3.1 Paul Bigsby & Merle Travis’ Guitar

In the 1940s, Paul Bigsby created the guitar pictured in figure 2.10 for Merle Travis. It doesn’t have the famous Bigsby Vibrato, also a design from Bigsby, but it does have something that would be very remarkable in the development of solidbody electric guitars: all six tuners on one side of the headstock. On the website of Bigsby Guitars the following story is told: *“The story goes that Bigsby and Travis had lunch together sometime in 1946 and during the course of that meeting Travis made a sketch for Bigsby of a new guitar design that Travis was interested in having built. Travis handed the sketch to Bigsby and asked, “Can you make this P.A.?” Bigsby is said to have answered, “I can make anything.” Bigsby made the guitar, as pictured, and thanks to its use by Travis in public appearances it became so popular that Bigsby set up shop next to his house in Downey, California, to fill orders.”*



A = 1947 Bigsby Merle Travis
B = 1949 Fender “Snakehead” Esquire Prototype
C = 1950 Fender Esquire
D = 1954 Fender Stratocaster
E = 1966 Fender Stratocaster

Fig.: 2.11: The evolution of the Fender Headstock.

Fig.: 2.12: Fender Telecaster as produced in 1952.

The headstock as designed by Paul Bigsby is clearly corresponding with the seven years later introduced Fender Stratocaster, the most famous electric solid-body guitar ever designed.

Fig.: 2.13: The Fender Esquire Snakehead prototype, 1949.

2.3.2 Fender Esquire, Broad- & Telecaster

The Fender Esquire is a solid body electric guitar manufactured by Fender, and was the first guitar sold by Fender in 1950. Shortly after its introduction, the two-pickup version of the Esquire was renamed Broadcaster, while the one-pickup version retained the Esquire name. Although the one-pickup Esquire was manufactured first, it is now generally regarded as a variant of the more popular Telecaster.

The Broadcaster, Fender's first mass-produced solid-body electric guitar, initially was derided by competitors as too simple and lacking in craftsmanship. But, everything about its patented practical design, such as the bolt-on neck, was optimal for production in large quantities. In 1951, due to a trademark infringement claim, the model's name was changed to Telecaster in honor of another popular invention—television. The many famous artists who have played the Telecaster propelled it to the status of a classic.

Fig.: 2.14: Gibson Les Paul Gold Top, 1952.

Fig.: 2.15: The Gibson ES-125 with one p-90 pickup, 1951.

2.3.3 Gibson Les Paul Gold Top

The Les Paul model was Gibson's first entry into the solid-body electric guitar market, developed in response to the success of Fender's Broadcaster/Telecaster model. Primarily designed by Gibson president Ted McCarty, guitarist and innovator Les Paul's input included the "rich-looking" gold finish and the original combination bridge-tailpiece.

In many variations, the Les Paul model has been the mainstay in the Gibson catalog since its introduction in 1952. Paul's close association with Gibson helped make its line tremendously popular.

The Les Paul model is equipped with two P-90 single-coil pickups. P-90 pickups were introduced in 1946 when Gibson resumed guitar production after World War II. They were originally used to replace the "bar" pickup on the ES-150, and by the end of the 1940s it was the standard pickup on all models.

2.3.4 Fender Stratocaster

In 1954, Fender created the ultimate combination of aesthetics and functionality in electric guitar design with the Stratocaster. The Fender Stratocaster, (often referred to as a Strat), is designed by George Fullerton, Leo Fender and Freddie Tavares in 1954, and manufactured continuously to the present. The Strat is arguably the most successful and influential electric guitar ever produced. It is easily identified by its double cutaways, contoured body, and three pickups. It also features Fender's vibrato or tremolo system that allows players to raise or lower the pitch of the strings. This system is patented in 1956, just as the headstock's contour.

The Stratocaster has been used by many leading guitarists, and thus can be heard on many historic recordings. In the hands of Buddy Holly, Jimi Hendrix, Buddy Guy, Eric Clapton, and many others, the "Strat" has become an icon of rock and pop music.

Fig.: 2.16: The Strat & Jimi: not as Leo Fender intended it.

Fig.: 2.17: The Fender Stratocaster as produced in 1954.

The Stratocaster has been widely copied since its introduction in 1954. As a result, "Stratocaster" or "Strat" is often used when referring to any guitar that has the same general features as the original, regardless of manufacturer. In chapter 3, the industrial design evaluation analysis will be projected to such a Stratocaster copy, in this case a Chinese "Mo-tion ST 250 SB", an €80,- guitar which is sold also in The Netherlands.

Fig.: 2.18: Fender Jazzmaster prototype, 1957.

2.3.5 Fender Jazzmaster

In figure 2.20 a prototype of Fender's Jazzmaster model is shown. The Jazzmaster was introduced as the new top-of-the-line guitar in 1958. It was the first guitar to have an asymmetrical waist and to feature a switch allowing quick changes between rhythm and lead tones. Fender was attempting to market the instrument to jazz musicians, thus the name. Instead, it became the guitar of surf bands such as "The Ventures". A result of that phenomenon, Fender adapted the wishes of surf guitarist to the Jazzmaster: the 1962 Fender Jaguar was born.

Fig.: 2.19: Gibson Les Paul Standard, 1958.

2.3.6 Gibson Les Paul Standard

After its introduction in 1952, Gibson's Les Paul model went through a variety of modifications that culminated in the classic Standard, or Sunburst, in 1958. Its maple cap on a solid mahogany body and the newly perfected twin-coil humbucking pickups produce a sound that is highly suitable for rock music. Famous players like Jimmy Page, Jeff Beck, and Duane Allman helped this guitar become one of the most popular ever. Les Paul Standards dating from 1958-1960 are among the most sought-after guitars on the vintage market.

Fig.: 2.20: Chet Atkins' Gretsch 6120, 1959.

2.3.7 Gretsch 6120 Chet Atkins

Introduced in 1955, the 6120 was co-designed by, and made for, Chet Atkins to feature his signature style of fingerpicking. The model was also popularized by Eddie Cochran and Duane Eddy. Like other Gretsch guitar models, the 6120 changed constantly; by 1959 the Bigsby vibrato was added as a standard feature. This hollow-body electric guitar was Atkins's personal instrument and appeared on the 1961 Chet Atkins' Workshop album cover.

Fig.: 2.21: Gibson ES-355 with Bigsby and Vari-tone circuit, 1958.

2.3.8 Gibson ES-355

In 1958 Gibson introduced the ES-355, a semi-acoustic electric guitar with pickups mounted on the solid section of the body. This model, played by Chuck Berry, jazz guitarist Grant Green, and a number of 1960s rock and roll groups, is most closely identified with B.B. King. A special feature of this guitar is the Vari-tone circuit which, in the highest position, gives the instrument its distinct nasal sound. The ES-355's standard vibrato system, made by Bigsby, allows for the rapid raising and lowering of the pitch of the strings, known as the tremolo effect.

Fig.: 2.22: Gibson Flying V, 1958.

2.3.9 In the year 1958

The revolution of the electric guitar ends in 1958. All icons are designed. From 1958 until 2008, the technology used further optimises, more materials are possible, production methods are more efficiënt, worldwide distribution is possible, prices drop, et cetera. From that year, everything is possible. Artists' models are available, student models, new sounding pickups, guitars from outside the USA: copies of popular models as the Stratocaster are build in many countries all over the world, even in Japan!

Fig.: 2.23: Gibson Explorer, 1958.

2.4 Everything is possible

If everything is possible, why not trying everything? On this and the following two pages are some of the most showy, flashy or jazzy guitar models shown. Some are selected for their shape, some for the material used and some for their added functionality. The collection shown here is not objective, but interesting for the product phases theory. Most pictures speak for themselves and therefore extra text is not added. More information per model can be found on the internet.

Fig.: 2.24: Fender Musicmaster, 1958.

Fig.: 2.25: Rickenbacker 325 "Capri", 1958.

Fig.: 2.26: Danelectro Dano Pro, 1959.

Fig.: 2.27: Fender Lucite Duo-Sonic, 1960.

Fig.: 2.28: Airline Guitar, 1960.

Fig.: 2.29: National Glenwood “Res-o-Glass”, 1962.

Fig.: 2.30: Mosrite Mark I, 1965.

Fig.: 2.31: Mosrite Strawberry 6, 1967.

Fig.: 2.32: Dynacord Cora, 1965.

Fig.: 2.33: VOX Mark III, 1965.

Fig.: 2.34: Yamaha SGA5 with “Samurai” headstock, 1967.

Fig.: 2.35: Ampeg Dan Armstrong, plexiglass body, 1969.

Fig.: 2.36: Fender Maverick, 1969.

Fig.: 2.37: Rickenbacker 331 with Lights in Body, 1971.

Fig.: 2.38: Ovation Deacon, 1975.

Fig.: 2.39: Ibanez Iceman, 1978.

Fig.: 2.40: Kramer Triaxe, 1986.

Fig.: 2.41: Fender Performer, 1986.

Fig.: 2.42: Stepp Digital Guitar, 1987.

Fig.: 2.43: Gittler prototype, 1987.

Fig.: 2.44: Prince's Yellow Cloud, 1989.

Fig.: 2.45: Paul Reed Smith, 1994.

Fig.: 2.46: Parker Fly, 1999.

Fig.: 2.47: Forshage, 1999.

Fig.: 2.48: Gary Kramer Delta Wing, 2005.

2.5 Product Phases

The historical overview of the electric guitar will be extended in this paragraph with the theory of product phases (Eger 2007). The theory of product phases is based on Maslow's hierarchy of needs and therefore divided in six different phases. These phases should be chronological in the products evolution, starting with "Performance" and ending with "Awareness" (figure 2.49). In this paragraph, the guitars of the historical overview will be matched with the product phases. To do that, product characteristic related statements (as formulated by Eger) are used to categorize the guitars and there historical context.

Fig.: 2.49: Product Phases Hierarchy.

2.5.1 Prologue [1923 - ±1940]

The development of the Gibson L-5 and the Rickenbacker "Frying Pan" (paragraph 2.2.1 and 2.2.2) starts the evolution of the electric guitar. This all happens in the early 1930's, but is not the real start of the product phases of the electric guitar. The Gibson L-5 with an electrostatic pickup is not a commercial success and the Rickenbacker is a success but not a real guitar. It is actually a pedal steel, which is a different instrument, with it's own market segment. The technology push is applied in / as a product, but not as a successful mass product (guitar) yet. Therefore, this period will be mentioned as the "Prologue" of the product phases in this report. The prologue ends with the realization of Les Paul's Log prototype.

2.5.2 Performance Phase [1936 - 1951]

The first phase, the performance phase, starts with the introduction of the Gibson ES-150 model as introduced in 1936 (paragraph 2.2.3). The guitar is still an acoustic archtop guitar, but with the pickup and an amplifier (figure 2.50) it becomes a total different instrument. The electric guitar is born as a product, although its performance is moderate. The Gibson is unique for its time and one of the very few electric guitars available. This won't last long, because many (guitar) engineers are inspired by this amplified guitar. The phase continues untill the Fender Broad-/ Telecaster is introduced in 1951. The Telecaster is an optimization in such a way that it is an instant classic which will be produced continuously up to now.

Product Characteristics	**True**
The product is new to the market.	+++
The performance of the product is poor.	+++
The product originates from a technology push.	+++
Comparatively the product has many parts.	+
The product development is mainly aimed at improving the performance of the product.	+++
Styling is not very important.	-
There is not much unity in the styling of the parts of the product.	++
There is only one or there are very few competitors.	+++
The price of the product (per unity) is relative high, and people find the product expensive.	+++
The product is designed for production with standard machines, such as lathes, and milling-, trimming-, bending- and welding machines.	-
Promotion is mainly based on free publicit and trade fairs.	+++
Promotion is done on a small scale: trade fairs, the internet, brochures with retailers, etc.	+++
There is no well organised service organisation.	-

Table: 2.1: Product Characteristics Performance Phase.

Fig.: 2.50: The Gibson ES-150 model in product flyer, 1937.

In table 2.1 the product characteristics of this phase (Chapter 6, Eger 2007) are tested for the applicability on the guitar history. Main differences: styling is already important in the first phase and the first electric guitar is not designed for production with standard machines. Reason for these differences is the fact that the first electric guitars a copy of the traditional archtop guitar. This product is already a cultivated design, is crafted by hand and the service is organized because of the fact that companies like Gibson already manufactured guitars for years. With that, this phase of the electric guitar evolution is comparable with the early evolution of the automobile. The first car models were actually wooden coaches with an engine added to it. They were not shaped to their new functionality, because of the unknown impact of the new technological possibilities.

2.5.3 Optimization Phase [1951 - 1957]
As said in the previous paragraph, the second phase, the optimization phase, starts in 1951 with the introduction of the Fender Broadcaster (called Telecaster after 1952, see paragraph 2.3.2). The introduction of the Fender Telecaster in 1952 and the Gibson Les Paul in 1953 started the success story of solidbody guitars and the introduction of the Fender Stratocaster in 1954 is a climax of this phase. A better example of synergy between design and functionality is not available, which is remarkable for this phase. The electric guitar is optimized very fast to a good product, but the guitar manufacturers didn't want to stop the evolution. Fender and Gibson wanted even better and luxurious model. The development of the Jazzmaster (paragraph 2.3.5) was the result of that wish. The introduction of the Jazzmaster in 1958 could be seen as the start of the next phase (a good guitar is not good enough) and the end of this phase. On the following page some advertisements are added to visualise the optimization phase. The attention is projected on the optimized functionality and the newest innovations, which asks for a lot of explanation in the advertisements.

Product Characteristics	**True**
The product is new to the market.	+++
The product is known (but not well known) within the target group	+++
The performance of the product is poor.	-
The product originates from a technology push.	+++
Comparatively the product has many parts.	-
The performance of the product is acceptable.	+++
The product development is mainly aimed at improving the performance of the product.	+++
Styling is not very important.	-
There is not much unity in the styling of the parts of the product.	-
There is only one or there are very few competitors.	+++
There are several competitors (but not many).	~
The price of the product (per unity) is relative high, and people find the product expensive.	+++
The product is designed for production with standard machines, such as lathes, and milling-, trimming-, bending- and welding machines.	+++
Promotion is mainly based on free publicit and trade fairs.	+++
Promotion is done on a small scale: trade fairs, the internet, brochures with retailers, etc.	+
There is no well organised service organisation.	~

Table: 2.2: Product Characteristics Optimization Phase.

1954 is also an important year for music history: a new music style is born when Bill Haley introduces his Rock around the Clock, Elvis Presley records his first songs and a whole new generation starts using electric guitars. This mainly thanks to a few brands. All important artists have the Fenders and Gibsons models which are mentioned before.
Elvis' lead guitarist Scotty Moore played a Gibson ES-295 model, Buddy Holly played the Fender Stratocaster and Chuck Berry, rock and roll godfather from the first hour, played on a red Gibson ES-355. Only the brand Gretsch build guitars that are important for the evolution of the (hollowbody) guitar and for music history. Eddie Cochran, Duane Eddy and Chet Atkins played Gretsch Hollowbody guitars and defined the American Electric Country and Rock 'n Roll sound. This use of those Fender and Gibson models have contributed to the iconization of the early guitar models produced by those brands. This is an interesting remark in the product evolution. According to Eger's product characteristics (shown in table 2.2), the performance of the early products should be poor, just as the styling. This is not the case for the electric guitar. Those early models are still produced by Fender and Gibson, and are the most copied models around the world. Remarkable for the Fender brand is its functional design which is completely based on production processes of the 1950's. That is a product characteristic which belongs to this and the previous phase.

2.5.4 Itemization Phase [1958 - 1960]
The year 1958, as said in paragraph 2.3.9, is an important year. The Jazzmaster is introduced by Fender, Gibson launches the ES-355, Gretsches' G6120 model comes now with a Bigsby vibrato, and the first

Fig.: 2.51: Fender Advertisement, 1953.

Fig.:2.52: Les Paul and his wife Mary Ford, 1953.

Fig.: 2.53: Fender Stratocaster Advertisement, 1954.

Fig.: 2.54: Fender Jazzmaster Advertisement, 1958.

Fig.: 2.55: Gibson Advertisement, 1959.

Fender Stratocaster reaches the European continent. Cliff Richard's lead guitarist Hank Marvin, also known as the lead guitarist of the instrumental band "The Shadows", gets this red Stratocaster which is heard on all early records of Cliff Richard and The Shadows. Therefore, the worldwide marketing and advance of electric guitars breaks out. The evolution of the guitar is now aimed at target groups (figure 2.56) and extra features (figure 2.55). The two market leaders, Gibson and Fender, are building guitars with surplus value and add extra look and feel. Meanwhile, other companies from the VS, the UK, Italy and Japan, copy their old models and create their own alternatives for every market you can imagine. Even Fender and Gibson copy this behaviour. Therefore, 1958 is actually also the direct start of the next phase: segmentation (discussed on the next page).

The product characteristics of the itemization phase are shown in table 2.3. Most of the characteristics are valid for the evolution of the electric guitar, except the evolution of the number of parts used. The most simple electric guitar ever made was the Fender Esquire, the predecessor of the Fender Telecaster. After that model, all guitars became more complex because of added features and the extra design interventions elements for a better look and feel. Also the prices stay relatively high for Fender, Gibson and Gretsch, but cheap guitars start hitting the market.

Fig.: 2.56: Gretsch Advertisement, 1966.

Product Characteristics	**True**
The product is known (but not well known) within the target group	+++
The performance and the reliability of the product are good.	+++
Product development is aimed at extra features and accessories.	+
Product development is aimed at different products for different market channels or target groups.	+++
The styling of the parts of the product (integration of form) is good.	+++
There are several competitors (but not many).	+++
There is a lot of competition, prices are under pressure and are going down.	+++
The numbers of parts of the product decreases, and automation becomes more important.	-
There is a well organised service organisation supporting the product.	+

Table: 2.3: Product Characteristics Itemization Phase.

2.5.5 Segmentation Phase [1958 - present]
As said, also the segmentation phase starts in 1958. According to the advertisements shown on the next page, a lot of extra manufacturers are added to the electric guitar market. The functionality of the product can hardly be enhanced after the models discussed in the previous paragraphs. This creates a shift from functional value to emotional value. Products are more and more designed to fit to a certain lifestyle or target group. Commercials have a different message. Instead of explaining the product they become affiliated to a lifestyle or an artist. The Jazzmaster was ment to be a top-of-the-line product for Jazz musician, but was adopted by a new youth culture: surf music! This is immediately embraced by Fender by optimising the Jazzmaster for the surf sound: in 1962 the Fender Jaguar is born (figure 2.57). The invasion of The Beatles in 1962 caused an enormous shift in popmusic, but also in the guitar market. New models that were used by The Beatles, became very popular in a short time. Rickenbacker came back on the market thanks to John Lennon, and many other (cheaper) guitar manufacturers wanted to connect their brand to artists like The Beatles.
After the guitar sounds of Jimi Hendrix (including burning a Fender Stratocaster live on stage in 1967, see front cover) the sound palette was explored. The market was ready for guitars that helped exploring the limits of electric guitar music. That exploration of the segmentation phase has never ended, according to paragraph 2.4.

Product Characteristics	True
The product is well known within the target group	+++
The market penetration of the product is high.	+++
The performance and the reliability of the product are good.	+++
The product offers much choice - there is a large assortment.	+++
Product development is aimed at extra features and accessories.	+++
Product development is aimed at different products for different market channels or target groups.	+++
The styling of the parts of the product (integration of form) is good.	+++
There are a lot of competitors and the market is highly competitive.	+++
Prices have reached their lowest possible level.	+++
The numbers of parts of the product decreases, and automation becomes more important.	~
Assembly of the product is highly automated.	~
Production is highly automated.	~
There is a well organised service organisation supporting the product.	+++

Table: 2.4: Product Characteristics Segmentation Phase.

Fig.: 2.57: Fender Jaguar Advertisement, 1962.

The shape possibilities are endless, the lowest prices are reached, the highest most valuable guitars are made, every material is tested, mass production is possible, but also custom hand-made guitars have always been there. Therefore, that 3 product characteristics in table 2.4 are variable. The customization of guitars is also discussed in the next phase of the product phases theory of Eger.

Fig.: 2.58: Epiphone Advertisement, 1967.

Fig.: 2.59: VOX Advertisement, 1966.

Fig.: 2.60: Ovation Advertisement, 1976.

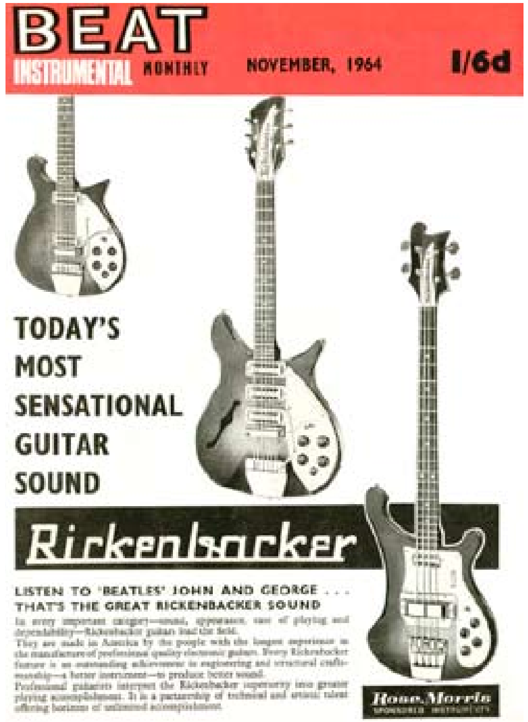


Fig.: 2.61: Rickenbacker Advertisement, 1964.

Fig.: 2.62: Carvin Advertisement, 1987.

Fig.: 2.63: Futurama Advertisement, 1964.

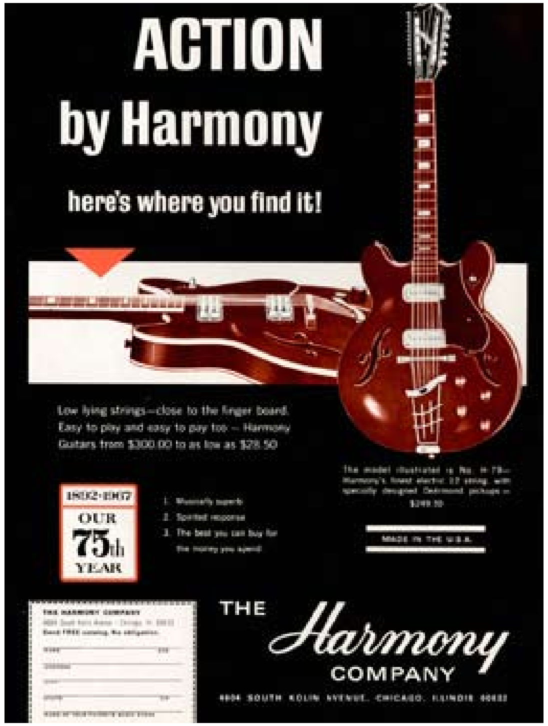


Fig.: 2.64: Harmony Advertisement, 1967.

Fig.: 2.65: Yamaha Advertisement, 1977.

Fig.: 2.66: Carvin Product and Parts Brochure, 1954.

2.5.6 Individualization [1954 - present]

According to Eger, the individualization phase follows the segmentation phase. Because of the constant segmentation, products are attuned to smaller and smaller groups. Ultimately, this leads to a product designed for a single individual. In this phase the consumer is a partial creator of the product. The individualization is not that clear for the electric guitar.

Fig.: 2.67: Carvin Products and Parts Brochure, 1997.

The guitar was an individualized product before it was optimized for mass-production. An artist needs an instrument, preferably the best one he can get. Therefore, custom made products started the innovations and made commercial success possible (for example: paragraph 2.2.4 and 2.3.1). An instrument is not just a generic product, it is always an individual property. Mass produced or not, artists create their own sound and affinity with an instrument.

Besides that, in 1954 there were already guitar parts available at Carvin's Musical Instruments shop, to customize or build your own guitar (figure 2.66). For that reason, the commercial mass-production driven customization phase is started from 1954. This customization phase is still alive nowadays.

2.5.7 Awareness [-]

According to Eger, the individualization phase is followed by the Awareness phase. From 1958 up to 2008 everything is done, and there are stills things that can be done. Unfortunately, an aware electric guitar is not found. An "aware" product could easily be introduced as a segment, but this is not done yet. Therefore, the sixt phase (Awareness) is not discussed.

2.6 Conclusion

In figure 2.68 the product phases timeline is shown. The prologue of guitar evolution is added to the overview and the awareness phase is missing. The evolution seems to stop in the segmentation phase. Individualization is a constant segment for the guitar market and the awareness phase is not a target for the big guitar manufactureres. For future developments the guitar will probably lean on a new (digital) technology push. Since the introduction of the electric guitar in the 1930's all kinds of hardware are added for extra features. Improvements have been made on these hardware parts for a greater reliability or playability. That small hardware parts make a huge difference for playability and sound. Perhaps, in future these physical parts can be improved with new production processes or be replaced with digital software solutions, just like the evolution of the guitar effects and amplifiers used nowadays. Examples of this digital revolution are there, but it's not a big market segment yet. Fact is that in spite of its out-of-date technologies, the guitar is undiminished popular and has a right to exist.

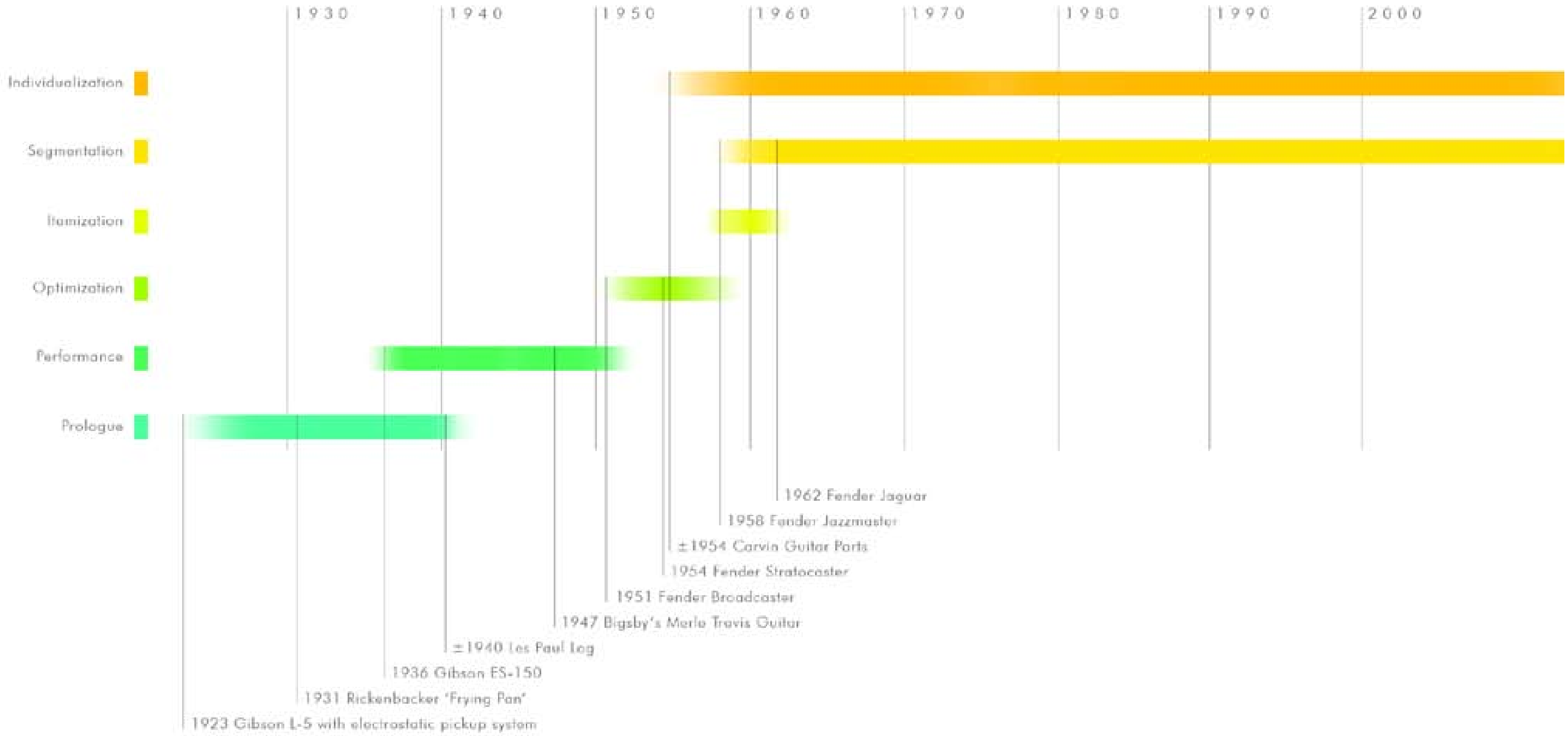


Fig.: 2.68: Product Phases and Timeline.

3. Industrial Design Evaluation Analysis

3.1 Introduction

This part of the report describes the Industrial Design Evaluation Analysis (IDEA) of the Motion ST 250 SB. The guitar is almost completely modeled in Solid-Works. In figure 3.1 the total assembly is shown with the most important parts pointed. In this chapter, the body of the guitar will be described first. After all, the different components of the guitar will be assembled on this body and the total assembly will be dis-cussed. The assembly order is determined by strip-ping down the guitar and rebuilding it. Complicated parts will be shown in exploded views. The electronic circuit in the guitar is not modeled in SolidWorks but will be discussed with photo's and an electronic circuit scheme.
Each description of a part will consist of four main points: the technical functionality, the material of the part, the production process and the production costs per part or the costs of the purchased part. Every page with an important part or assembly contains a table which describes and locates every part. The number of the part corresponds to the number in the images on the same page.
The costs of the plastic parts are calculated using the method found in Appendix B. For the metal parts the prices are estimated on the basis of the current prices of manufacturers and wholesales. The prices of the parts which are not produced but purchased are also chosen on the basis of the current prices of manufacturers and wholesales.

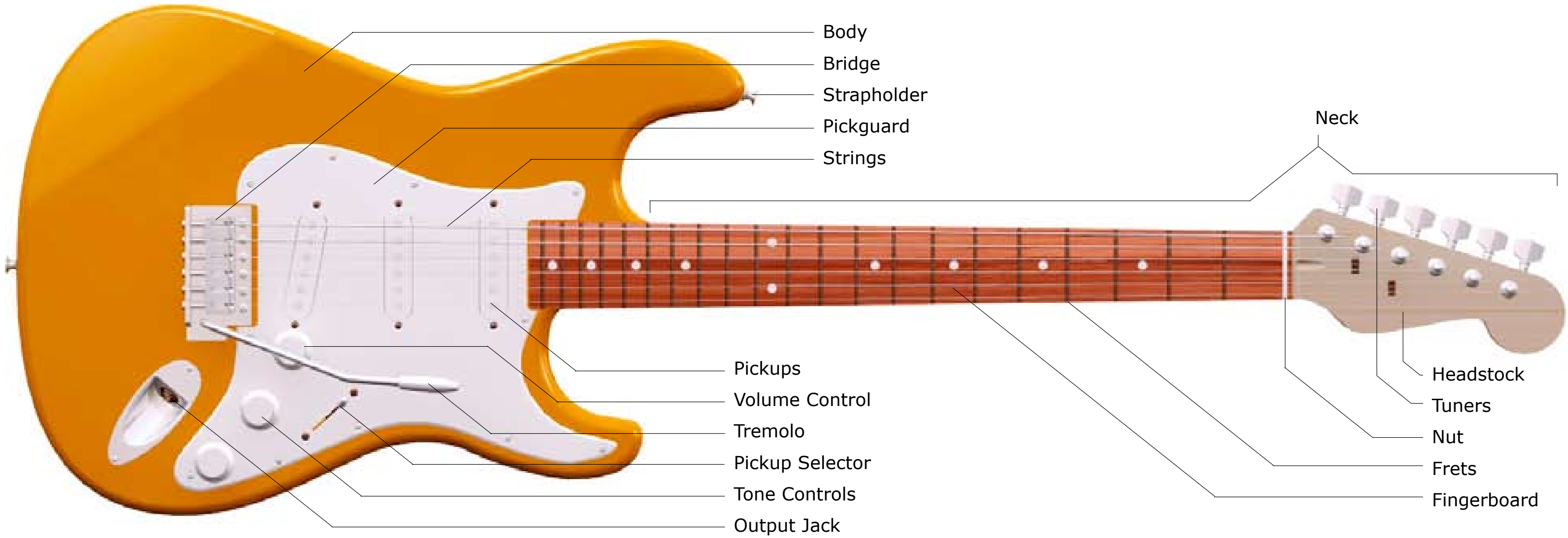


Fig. 3.1: The SolidWorks Assembly of the Motion ST 250 SB.

3.2 The Body

The body of the guitar is the basis to which all other components are attached (in paragraph 3.10 those components will be attached). Main functionality is resonating the string vibration. Other functions are keeping parts together and enabling the guitar player to hold, hang or set down the guitar.
This Stratocaster model, introduced in 1954, has an ergonomic "Contour Body" which was an important improvement compared to the Telecaster, its predecessor. The two "horns" of the body are a result of the so-called "double cut-away". This allows the guitar player to reach the highest positions on the fingerboard. The cutaways are not symmetric. This is because of two reasons. In the lower cutaway should be space for the fingers of the guitar player in contrast with the thumb in the upper cutaway. Second Reason is that the upper "horn" is also used for a strapholder (this part will be added later) on which a belt can be attached for hanging the guitar on the player's shoulder. This position is designed in such a way that the guitar is balanced while hanging.
The body is made from three glued pieces of Asian Oak and has a thick polyurethane finish, colored in so-called "two tone sunburst". The body is mechanically milled, but operated by hand. This is noticeable because of it's raw surfaces and messy cavities (see images above). Because of the use of wood and the time intensive production process, the body is the second most expensive part of the guitar.

3.3 The Neck Assembly

The neck of the guitar is the most expensive and important assembly of a guitar. The neck defines a lot of the playability and tone of the guitar. It is made from two kinds of wood with some metal parts in and on it. The base is one rounded maple piece of wood with a cavity in it and at the end of it a plane area called the headstock. The contour of this headstock is very characteristic for the Stratocaster model, and patented. This Stratocaster copy has thus a slightly different contour. In the cave of the maple base a metal trussrod is installed to care for the enormous string tension. This cavity is sealed with a rosewood fingerboard. This fingerboard highly influences the

Fig. 3.2: The Body.

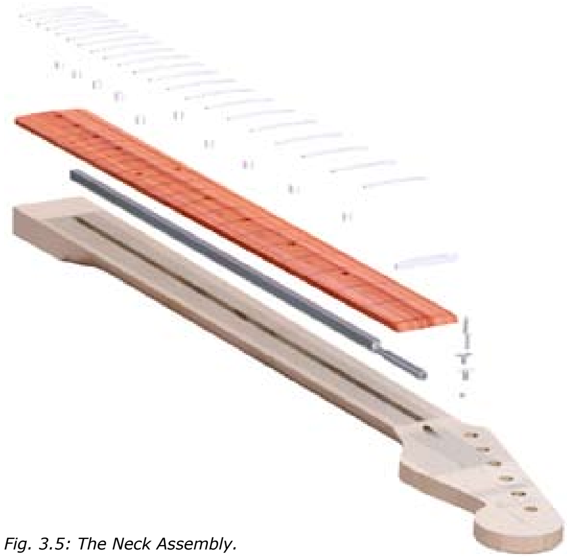
Fig. 3.3: The bottom of the body.

Fig. 3.4: Photos of the milled cavities in the body.

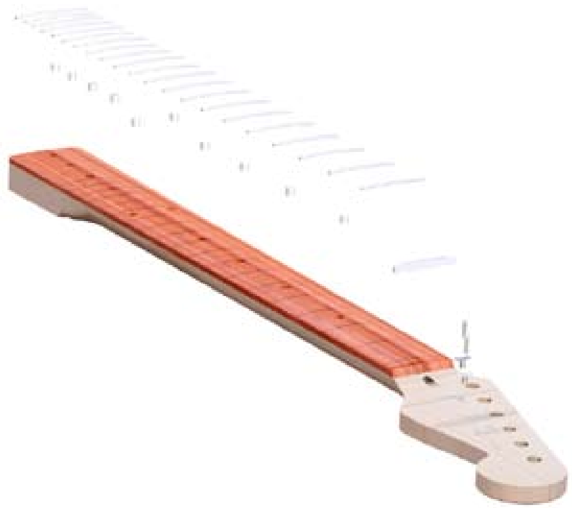
Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
0.01	Body	Asian Oak, with polyurethane lacquer finish.	1	1775 g	Sawing, Milling & Drilling, Sanding, Painting & Lacquering, Drying	€ 10,00

Table 3.1: The Body.

sound of the guitar. Its timbre is a bit more “smooth” and warm with Rosewood. On this fingerboard 21 thin metal frets are installed. The spacing of two consecutive frets is the twelfth root of two: the twelfth



fret divides the scale length in two exact halves and the 24th fret position divides the scale length in half yet again, etc. Between these frets there are some inlay dots which functionality is to mark the third, fifth, seventh, ninth, twelfth, fourteenth, sixteenth,



eighteenth and twentieth position on the fingerboard. This is an effective tool for guitarists to recognize the position of their hand rapidly. Finally, a nut and two string guides are added. The nut, along with the bridge, defines the distance between the strings and the fingerboard (this distance is called “action”) and the distance between the strings. The string guides lower four of the six strings between the nut and the tuners to keep them in the right position on the nut.

Fig. 3.5: The Neck Assembly.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
1.01	Neck Base	Maple, with polyurethane lacquer finish.	1	370 g	Sawing, Milling & Drilling, Sanding, Lacquering, Drying	€ 7,00
1.02	Truss Rod	Chromed iron	1	100 g	Rolling, Cutting, Milling & Drilling, Chroming	€ 1,40
1.03	Fingerboard	Rosewood	1	70 g	Sawing Milling & Drilling, Sanding	€ 3,00
1.04	Dot Inlay	Polycarbonate	10	<1 g	Extrusion, Sawing, Sanding	< € 0,01
1.05	Frets	Alloy of Nickel, Copper, and Zinc	21	3 g	Rolling, Cutting, Sanding	€ 0,25
1.06	Nut	Polycarbonate	1	<1 g	Injection Molding (see paragraph 3.11 for more info)	€ 0,03
1.07	String Guide	Chromed iron	2	<1 g	Rolling, Cutting, Drilling, Chroming	€ 0,03
1.08	String Guide Extend	Chromed iron	1	<1 g	Rolling, Cutting, Drilling, Chroming	€ 0,03
1.09	String Guide Screw	Nickeled iron	2	<1 g	Purchased	€ 0,01

Table 3.2: The Neck Assembly.

3.4 The Tuner Assembly

The six strings of the guitar are hold by six tuning devices (called tuners or machine heads) positioned at the end of the neck’s headstock. Their functions is to enable tuning the string in the right tension and hold this tension during playing. The assembly is made of metal parts with four polyvinyl chloride bearings. Thanks to the worm wheel the string is

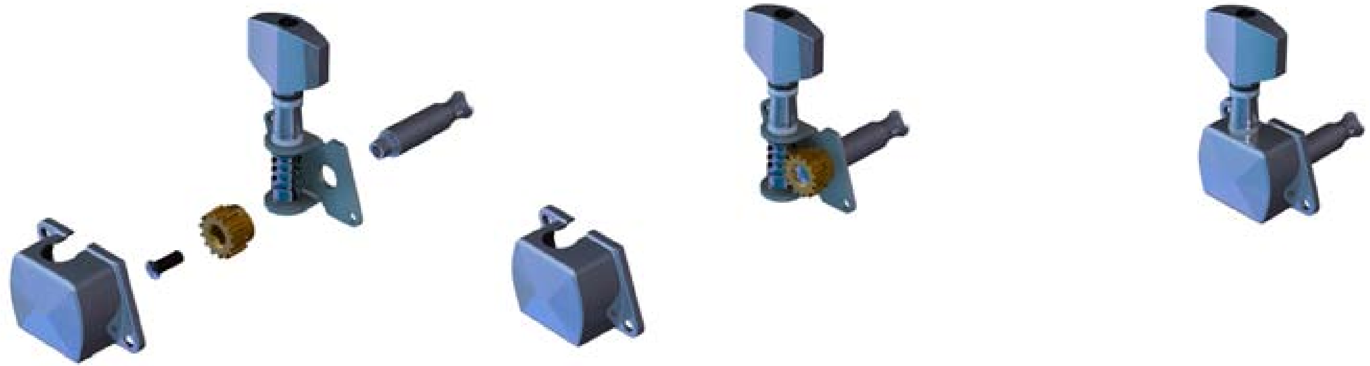


Fig. 3.6: The Tuner Assembly.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
2.01	Tuner Base	Galvanized iron	1	3 g	Rolling, Cutting, Bending, Galvanizing	€ 0,20
2.02	Worm Wheel Axis	Chromed iron	1	4 g	Rolling, Cutting, Milling & Drilling, Chroming	€ 0,20
2.03	Black Bearing	Polyvinyl chloride	1	<1 g	Injection Molding (see paragraph 3.11 for more info)	< € 0,01
2.04	White Bearing	Polyvinyl chloride	2	<1 g	Injection Molding (see paragraph 3.11 for more info)	< € 0,01
2.05	Tuner Head Extend	Chromed iron	1	<1 g	Rolling, Cutting, Milling & Drilling, Chroming	€ 0,05
2.06	Black Ring	Polyvinyl chloride	1	<1 g	Injection Molding (see paragraph 3.11 for more info)	< € 0,01
2.07	Tuner Head	Chromed iron	1	7 g	Rolling, Cutting, Milling & Drilling, Chroming	€ 0,10
2.08	Tuner Head Screw	Nickeled iron	1	<1 g	Purchased	€ 0,01
2.09	Cogwheel Axis	Chromed iron	1	5 g	Rolling, Cutting, Milling & Drilling, Chroming	€ 0,15
2.10	Cogwheel	Brass	1	2 g	Rolling, Cutting, Milling & Drilling	€ 0,10
2.11	Cogwheel Screw	Steel	1	<1 g	Purchased	€ 0,01
2.12	Tuner Cover	Chromed Copper	1	2 g	Stamping, Chroming	€ 0,20

Table 3.3: The Tuner Assembly.

locked after tuning. The tuner's assembly and production accuracy are very important for the usability of the guitar. For a cheap guitar, like this Motion Stratocaster copy, the tuners are a self produced part to reduce costs (original Fender Stratocaster use purchased expensive parts). A simplified construction and cheap materials are factors to achieve this goal. This is unfortunately the reason why cheap guitars won't stay tuned during playing. Replacing those parts with a bit more expensive tuners is a solution which satisfies most guitar players.

3.5 The Bridge Assembly

On the other end of the string there is another assembly called the "bridge". For the stratocaster, this bridge is also a floating tremolo: a device to shift or lower the string tension. For more information about this tremolo system see paragraph 2.4.5. The function of the bridge is adjusting the string length and height, and transporting the string's vibration (sustain). This last function is a contradiction with the floating tremolo system, which reduces the sustain. The solution for this problem is a heavyweight massive steel tremolo block which is added underneath the bridge plate, in a cave in the guitar's body. The adjustment possibilities are solved with six springs and two pairs of six screws, assembled on the bridge saddles (which guide and uphold the strings). The height of the string is also influenced by the floating tremolo system. The bridge plate can move upwards due to string tension or the tremolo handle (this part weill be discussed later). This tension is compensated by three strings in the bottom of the body (this part of the tremolo system will also be discussed later).

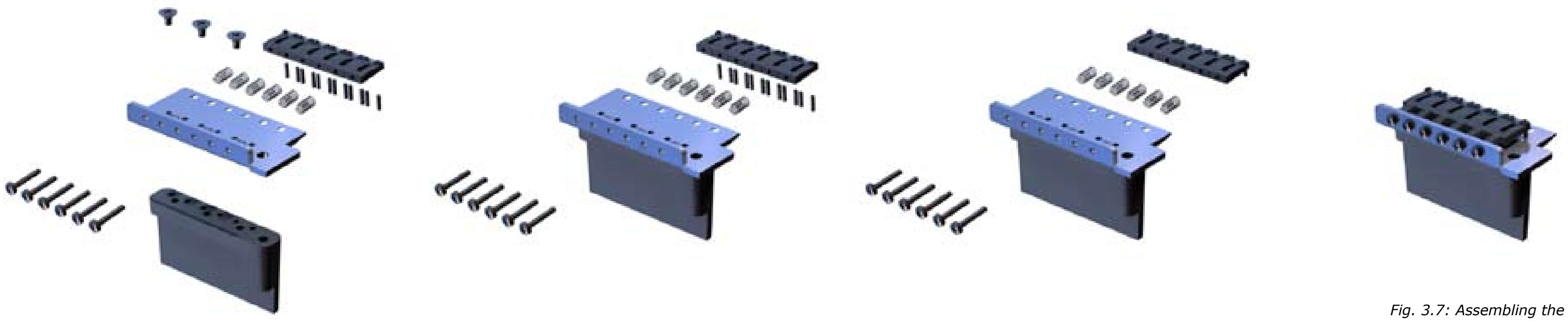


Fig. 3.7: Assembling the guitar's bridge.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
3.01	Bridge Plate	Chromed iron	1	54 g	Rolling, Cutting, Milling & Drilling, Bending, Chroming	€ 0,40
3.02	Tremolo Block	Galvanized steel	1	138 g	Molding, Drilling, Galvanzing	€ 1,00
3.03	Screw Countersunk [6 x 3 mm]	Nickeled iron	3	<1 g	Purchased	€ 0,01
3.04	Bridge Saddle	Chromed iron	6	6 g	Rolling, Sawing, Milling & Drilling, Chroming	€ 0,20
3.05	Screw Inbus [12 x 3 mm]	Nickeled iron	12	<1 g	Purchased	€ 0,01
3.06	Bridge Saddle Spring	Nickeled iron	6	<1 g	Purchased	€ 0,01
3.07	Screw Round	Nickeled iron	6	<1 g	Purchased	€ 0,01

Table 3.4: The Bridge Assembly.

3.6 The Pickguard Assembly

The fourth important assembly is the guitar's pick-guard which contains all electronic parts and the biggest part of the electronic circuit, which will be discussed in paragraph 3.7. The pickguard is not produced by injection molding. The part is stamped out of a sheet of 2 mm thick polycarbonate. On the border of the pickguard a 45 degree angle is sanded for a more fluent transition to the body.

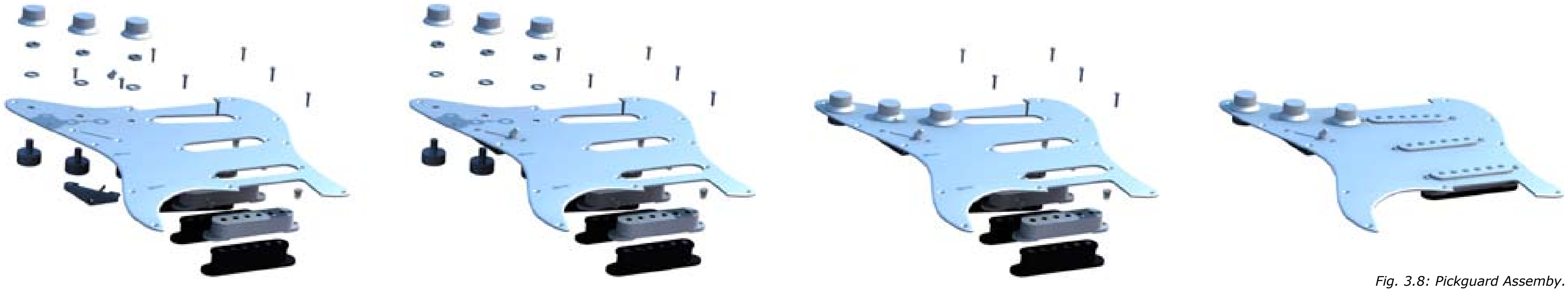


Fig. 3.8: Pickguard Assemby.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
4.01	Pickguard	Polycarbonate	1	67 g	Stamping, drilling, sanding (45 degree angle on outside)	€ 0,50
4.02	Pickup Selector Switch	Metal and Plastics	1	35 g	Purchased	€ 0,50
4.03	Screw Countersunk [12 x 3 mm]	Nickeled iron	2	<1 g	Purchased	€ 0,01
4.04	Pickup Selector Switch Knob	Polycarbonate	1	<1 g	Injection Molding (see paragraph 3.11 for more info)	€ 0,02
4.05	Volume Potentiometer	Metal and Plastics	1	16 g	Purchased	€ 0,50
4.06	Tone Potentiometer	Metal and Plastics	2	16 g	Purchased	€ 0,50
4.07	Potentiometer Ring	Nickeled iron	3	<1 g	Purchased	€ 0,01
4.08	Potentiometer Nut	Nickeled iron	6	<1 g	Purchased	€ 0,01
4.09	Volume Knob	Polycarbonate	1	2 g	Injection Molding (see paragraph 3.11 for more info)	€ 0,05
4.10	Tone Knob	Polycarbonate	2	2 g	Injection Molding (see paragraph 3.11 for more info)	€ 0,05
4.11	Pickup	Metal and Plastics	3	<1 g	Purchased	€ 1,00
4.12	Pickup Cover	Polycarbonate	3	2 g	Injection Molding (see paragraph 3.11 for more info)	€ 0,10
4.13	Pickup Cover Spring	Nickeled iron	6	<1 g	Purchased	€ 0,01
4.14	Screw Round [20 x 3 mm]	Nickeled iron	6	<1 g	Purchased	€ 0,01

Table 3.5: The Pickguard Assembly.

3.7 The Electronic Circuit

The three pickups, pickup selector switch, and the three potentiometers are connected with 14 pieces of copper wire. The electronic circuit is shown in figure 3.9. Each pickup is connected to the ground of the jack output, via the casing of the volume potential-meter. The hot wire of each pickup is connected to the pickup selector switch. This switch has five positions:

1. Only the bridge pickup
2. The bridge pickup and the middle pickup
3. Only the middle pickup
4. The middle pickup and the neck pickup
5. Only the neck pickup

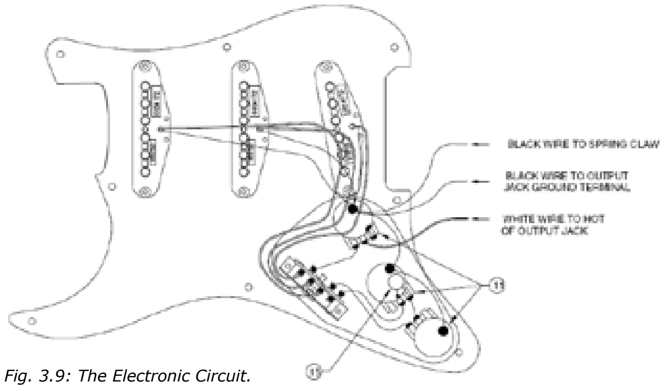


Fig. 3.9: The Electronic Circuit.

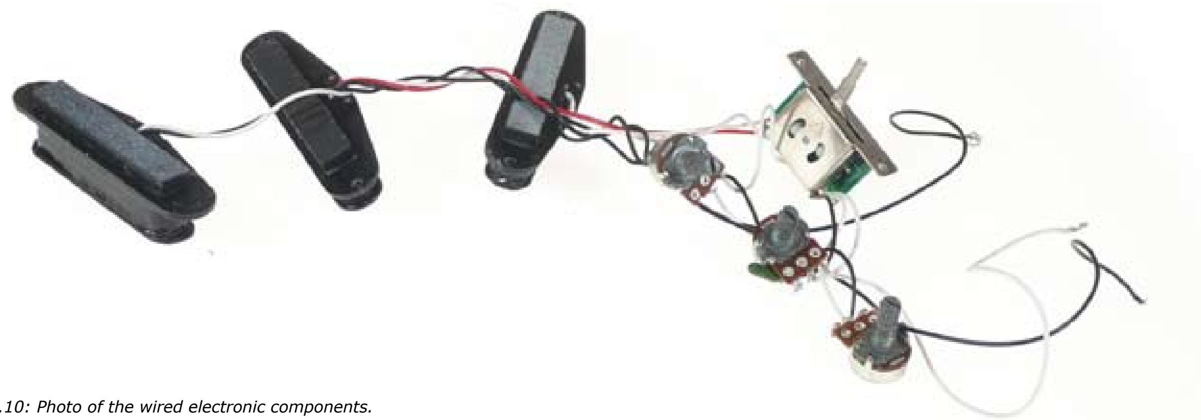


Fig. 3.10: Photo of the wired electronic components.

The ground of the pickup selector switch is connected to the casings of the potentiometers. The hot of switch position 1 is connected to the volume potentiometer. The hot of positions 4 and 5 is connected to ingoing terminal of the volume and to the ingoing terminal of the middle potentiometer. This potentiometer is a tone control (eleminating high frequencies when turned counterclockwise). The influence of the tone control is transported via a capacitor and the ground connection of the three potentiometers. The hot of the middle pickup is also connected to the volume but to the second tone control. The output terminal of the volume potentiometer is connected

Fig. 3.11: Photo of the electronics, the pickguard and the output jack.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
5.01	Black Copper Wire	Copper, Polyurethane	7	<1 g	Purchased	< € 0,01
5.02	Red Copper Wire	Copper, Polyurethane	1	<1 g	Purchased	< € 0,01
5.03	White Copper Wire	Copper, Polyurethane	6	<1 g	Purchased	< € 0,01
5.04	Capacitor [.022 mfd]	Metal & Plastic	2	<1 g	Purchased	€ 0,01

Table 3.6: The Electronic Circuit Parts.

to the hot of the output jack (see also figure 3.9 and 3.11). The casing of the volume potentiometer is connected to the ground of the output jack, and to the floating tremolo's spring claw (this part will be descriped later). The function of this connection is grounding all other metal parts of the guitar: the tremolo and bridge, the strings and the tuners.

3.8 Output Jack Assembly

The connection between the electric guitar and the amplifier is made by a cable, which can be inserted in the output jack of the guitar. This cable connects the ground and hot wire of the electronic circuit with the amplifier. The output jack is part of an assembly along with a chrome cover, two nuts, and a ring.

3.9 Tremolo Arm

The floating tremolo (as discussed in paragraph 2.4.5 and paragraph 3.5) is operated with a tremolo arm. This arm is positioned in a hole with screw-thread and is removable. This part is not assembled when the guitar is shipped because of the extra thickness it ads to the total assembly.

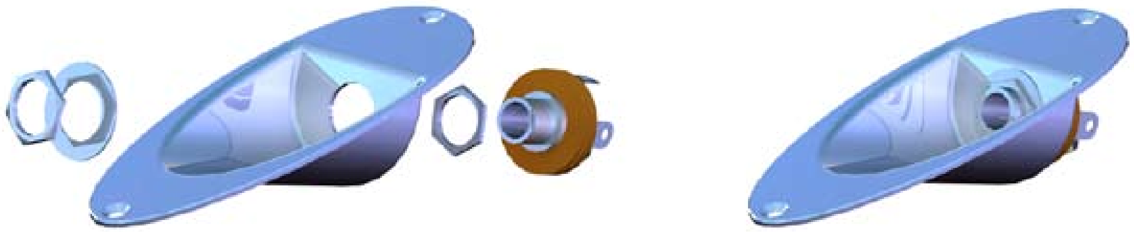


Fig. 3.12: The Output Jack Assembly.

Fig. 3.13: The Tremolo Arm Assembly.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
6.01	Output Jack	Metal and Plastic	1	8 g	Purchased	€ 0,35
6.02	Output Jack Cover	Chromed Iron	1	15 g	Stamping, Drilling, Chroming	€ 0,15
6.03	Nut	Nickeled Iron	2	<1 g	Purchased	€ 0,01
6.04	Ring	Nickeled Iron	1	<1 g	Purchased	€ 0,01

Table 3.7: The Output Jack Assembly.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
7.01	Tremolo Arm	Chromed Iron	1	30 g	Rolling, Bending, Chroming	€ 0,35
7.02	Tremolo Arm Knob	Polycarbonate	1	<1 g	Injection Molding (see paragraph 3.11 for more info)	€ 0,01

Table 3.8: The Tremolo Arm Assembly.

3.10 Total Assembly

All sub-assemblies are discussed now and therefore the guitar can be totally assembled. A few parts will be added free (not in a sub-assembly). Those parts will be discussed in the paragraph in question and included in the parts tables at the bottom of the page, along with the sub-assemblies.

3.10.1 Body and Neck

At first, the neck is attached to the body. This is done by a so-called "bolt on" construction, which is actually screwing the body and the neck together. To protect the body for the tension of the screws, a neck plate is added at the back of the guitar, with a extra polycarbonate protection plate.

3.10.2 Attaching Tuners

The tuners are placed on the bottom of the headstock, with 2 screws per tuner. The contour of the headstock is designed in such a way that the strings go straight ahead to their tuner. The tuner cramps are placed from the upper side of the headstock to remove unwanted degrees of freedom.

Fig. 3.12: Attaching Neck.

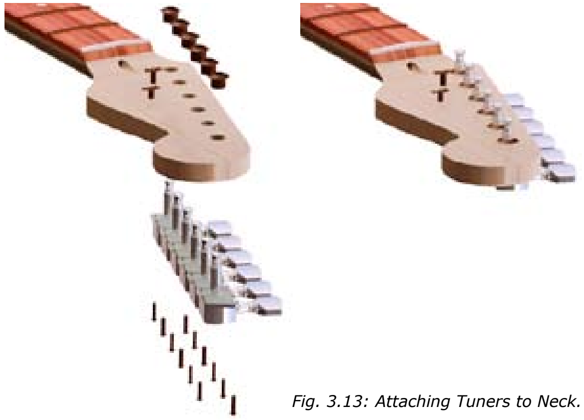


Fig. 3.13: Attaching Tuners to Neck.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
0.01	Body	(See Paragraph 3.2)	1	1775 g	(See Paragraph 3.2)	€ 10,00
1.00	Neck Assembly	(See Paragraph 3.3)	1	545 g	(See Paragraph 3.3)	€ 11,75
0.02	Neck Plate	Chromed Iron	1	46 g	Cutting, Drilling, Sanding, Chroming	€ 0,20
0.03	Neck Plate 2	Polycarbonate	1	4 g	Injection Molding (see paragraph 3.11 for more info)	€ 0,02
0.04	Wood Screw Countersunk [45 x 4 mm]	Nickeled Iron	4	4 g	Purchased	€ 0,02
2.00	Tuner Assembly	(See Paragraph 3.4)	6	25 g	(See Paragraph 3.4)	€ 1,02
0.05	Tuner Cramp	Chromed Iron	6	<1 g	Purchased	€ 0,01
0.06	Screw Round [10 x 1,5 mm]	Nickeled Iron	12	<1 g	Rolling, Stamping, Chroming	€ 0,05

Table 3.9: Creating the Total Assembly.

3.10.3 Attaching Bridge

The bridge is placed in line with the neck on the top of the body. It is positioned with 6 screws but not completely fitted. The screws stick 2 mm out of the body, with a result that the bridge can move up and down a bit (the floating system).

Fig. 3.14: Attaching Bridge to Body.

3.10.4 Attaching Pickguard

The pickguard is placed in between the bridge and the neck on the top of the body with 11 screws. The wires to the output jack and the tremolo spring claw should be positioned before fitting the pickguard.

Fig. 3.15: Attaching Pickguard to Body.

3.10.5 Attaching Output Jack

The output jack is placed in the cavity besides the pickguard. It is positioned with 2 screws (see next page, figure 3.19). The wires to the output jack should be soldered before fitting the output jack with the screws.

Fig. 3.16: Attaching Output Jack to Body.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
3.00	Bridge Assembly	(See Paragraph 3.5)	1	545 g	(See Paragraph 3.5)	€ 2,87
0.07	Screw Round [23 x 3 mm]	Chromed Iron	6	<1 g	Purchased	€ 0,01
4.00	Pickguard + Electronics Assembly	(See Paragraph 3.6 + 3.7)	1	198 g	(See Paragraph 3.6 + 3.7)	€ 6,20
0.08	Screw Countersunk [12 x 3 mm]	Nickeled Iron	13	<1 g	Rolling, Stamping, Chroming	€ 0,01
6.00	Output Jack Assembly	(See Paragraph 3.8)	1	23 g	(See Paragraph 3.8)	€ 0,52

Table 3.10: The Bridge, Pickguard, and Output Jack Attached.

3.10.6 Attaching Tremolo Springs & Cover

On the bottom of the tremolo block three strings are added. These string are connected with the spring claw in the cavity the bottom of the guitar. This spring claw is attached to the body with two wood screws. As said, there is also a wire which connects this claw with the ground of the volume potential-meter. For that purpose, an extra hole is created between the cavity in the bottom and the cavity for the electronics. This facilitates rapid assembling, but influences the resonance of the body negative. A lot of wood is lost due to excessive milling (figure 3.4).

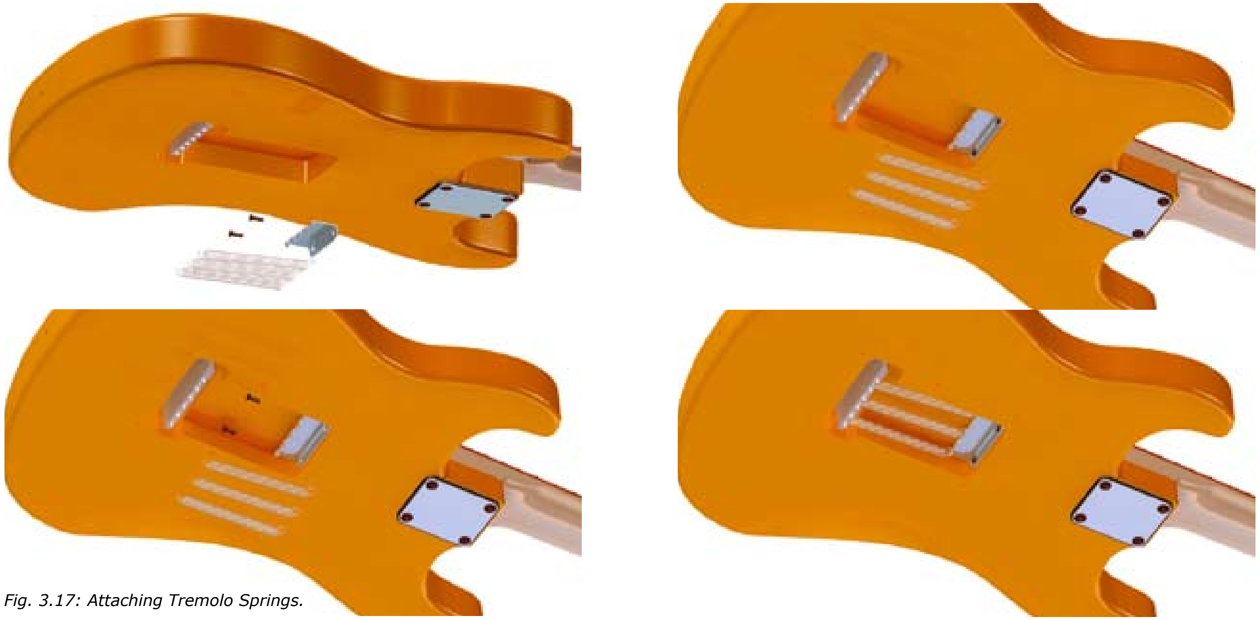


Fig. 3.17: Attaching Tremolo Springs.

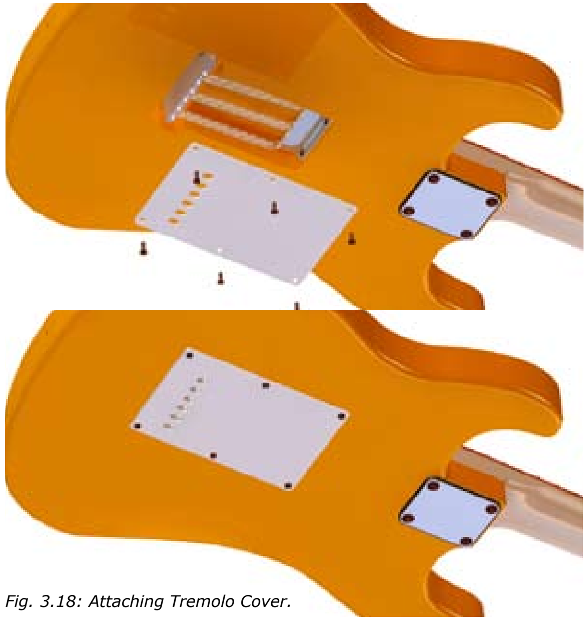


Fig. 3.18: Attaching Tremolo Cover.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
0.09	Spring Claw	Galvanized Iron	1	11 g	Cutting, Drilling, Bending, Galvanizing	€ 0,10
0.10	Spring	Chromed Iron	3	9 g	Purchased	€ 0,10
0.11	Wood Screw Countersunk [25 x 3 mm]	Nickeled Iron	2	<1 g	Purchased	€ 0,01
0.12	Tremolo Cover	Acrylonitrile Butadiene Styrene	1	25 g	Injection Molding (see paragraph 3.11 for more info)	€ 0,20
0.13	Screw Countersunk [12 x 3 mm]	Nickeled Iron	6	<1 g	Purchased	€ 0,01

Table 3.11: Tremolo Springs and Cover Attached.

3.10.7 Attaching Strapholders

On two sides of the border of the body 2 strapholders are added. These parts are installed with 2 screws and makes it possible to hang the guitar on your shoulder with a strap.

Fig. 3.19: Attaching Strapholders.

3.10.8 Attaching Strings

Fig. 3.20: Attaching Strings.

3.10.9 Attaching Tremolo Arm

The last part attached to the guitar is the tremolo arm. As said in paragraph 3.9, this part is removable and not assembled while shipping.

Fig. 3.21: Attaching Tremolo Arm.

Part No.	Part Name	Material	Amount	Weight	Production Process	Costs
0.14	Strapholder	Nickeled Iron	2	4 g	Purchased	€ 0,10
0.15	Wood Screw Round [25 x 3 mm]	Nickeled Iron	2	<1 g	Purchased	€ 0,01
0.16	Strings Set [0.10” - 0.42”]	Steel	1	12 g	Purchased	€ 0,50
7.00	Tremolo Arm Assembly	(See Paragraph 3.9)	1	25 g	(See Paragraph 3.9)	€ 0,36

Table 3.12: Strapholders, Tremolo Arm and Strings Attached.

3.11 Injection Molded Parts

The plastic parts need some special attention because of their production process. Most of the plastic parts are injection molded part. These parts are very cheap when produced in large quantities. Therefore, some special remarks are made during the for this guitar analysis.

3.11.1 Recognition of Plastics

Most of the parts are made from Polycarbonate, which is a bit flexible and therefore a non-breakable material. This is visible thanks to it's recognizable burning style. The plastic gets bubbled and black while burning (figure 3.22). The flame is yellow without noticable smoke and it stops itselfs from burning. The tremolo cover plate is made from a different material. This part is made from less flexible Acrylonitrile Butadiene Styrene (ABS) and is a bit whiter than the other parts. The burning style of this part was dominated with excessive smoke.

Fig. 3.22: Burned Polycarbonate.

3.11.2 Pickup Covers

The pickup covers are cold runner molded parts. These parts have a wall thickness of 1mm and can be produced with a simple and cheap two plate mold. The parts are not molded individually (probably with three covers at once). The cold runner injects the parts through through small sub-runners and gates into the cavity. The runner's attachment point, knockout points and parting plane are shown in figure 3.23. All 3 marks are found at the part's bottom.

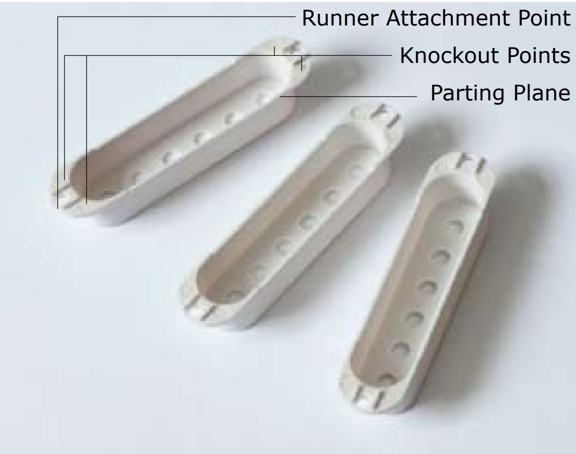


Fig. 3.23: Pickup Covers.

3.11.3 Volume & Tone Knobs

The volume and tone knobs are also cold runner molded parts. These parts have a wall thickness of 2mm and can be produced with a simple and cheap two plate mold. The parts are not molded individually (probably with the three knobs at once, two Tone knobs and one Volume knob). The cold runner injects the parts through through small sub-runners and gates into the cavity. The runner's attachment point, knockout points and parting plane are shown in figure 3.24. All three marks are found at the part's bottom.

3.11.4 Tremolo & Pickup Switch Knobs

The volume and tone knobs are also cold runner molded parts. These parts have a wall thickness of 2mm and can be produced with a simple and cheap

Fig. 3.24: Volume & Tone Knobs.

two plate mold. The parts are not molded individually (probably with the three knobs at once, two Tone knobs and one Volume knob). The cold runner injects the parts through through small sub-runners and gates into the cavity. The runner's attachment point, knockout points and parting plane are shown in figure 3.25. All three marks are found at the part's bottom.

3.11.5 Neck Plate 2

The black polycarbonate neck plate is also a cold runner molded part. This parts has a wall thickness of 1mm and can be produced with a very simple, thin and cheap two plate mold. This parts is probably molded with four pieces at once, just like the material samples as seen at BASF's Design Fabrik (figure 3.27). The cold runner injects the parts through through small sub-runners and gates into the cavity. The runner's attachment point, knockout points and parting plane are shown in figure 3.26. All 3 marks are found at the part's top, which is covered with a chromed iron part and therefore not visible.

3.11.4 Tremolo Cover Plate

The ABS made tremolo cover plate is also cold runner molded part. This part has a wall thickness of 2mm and can be produced with a simple, thin and cheap two plate mold. The part is probably molded with two parts at once, due to it's size. The cold runner injects the parts through through small sub-runners and gates into the cavity. The runner's attachment point, knockout points and parting plane are shown in figure 3.28. All three marks are found at the part's bottom.

Fig. 3.27: Four parts in one cold runner mold.

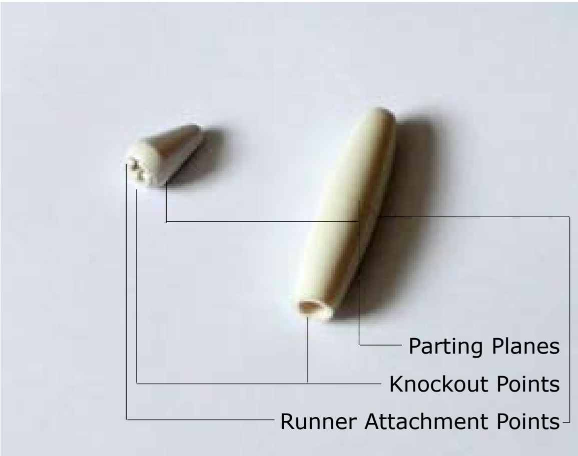


Fig. 3.25: Tremolo & Pickup Switch Knobs.

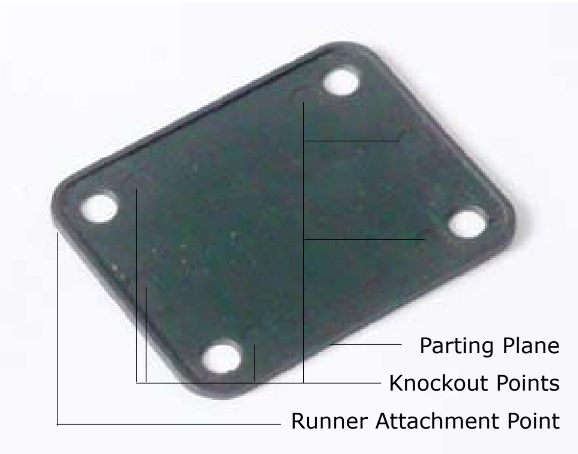


Fig. 3.26: Neck Plate 2.

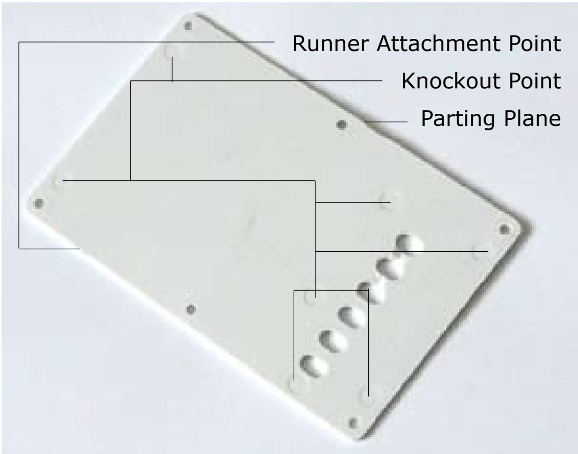


Fig. 3.28: Tremolo Cover Plate.

3.12 Total Cost Calculation

All sub-assemblies, parts and screws are discussed now and therefore the guitar is totally assembled. The costs per part are calculated or estimated. The calculation is shown in this paragraph.

3.12.1 Retail Price

The price of the Motion ST 250 SB in The Netherlands is €79,- with 19% VAT included. The Gross price is: €56,- (19% VAT and 10% retail profit excluded).

3.12.2 Shipping Costs

The price for shipping a 20 feet container from China to The Netherlands is $2700 * 0,68 = €1836 (see figure 3.22). This price is for shipping 750 guitars from China to Rotterdam. The calculation of the volume of one guitar is: 1.00m * 0,35m * 0,10m = 0,035m³. The volume of the container is 6m * 2,3m * 2,3m = 31,7m³. In one 20 feet container 31,7 / 0,035 = 907 guitars can be shipped. Therefore, the shipping price per guitar is €1836 / 907 = €2,02. The guitars should also be distributed in The Netherlands, and the transport from factory to shipping port is not included yet. The total transportation costs are estimated on €4,00 per guitar. So, the costs of the guitar before shipping is approximately €52,00.

3.12.3 Parts Costs

The estimated prices are based on material prices and the retail prices for guitar parts (www.voxhumana.nl). A Stratocaster build from their parts costs approximately €400,-. The total costs for guitar parts and raw materials is estimated on €40. Therefore, a

Part No.	Part Name	Amount	Weight	W. x A.	Costs	C. x A.
0.01	Body	1	1775 g	1775 g	€ 10,00	€ 10,00
1.00	Neck Assembly	1 (40 sub)	545 g	545 g	€ 11,75	€ 11,75
0.02	Neck Plate	1	46 g	46 g	€ 0,20	€ 0,20
0.03	Neck Plate 2	1	4 g	4 g	€ 0,02	€ 0,02
0.04	Wood Screw Countersunk [45 x 4 mm]	4	4 g	16 g	€ 0,02	€ 0,08
2.00	Tuner Assembly	6 (13 sub)	25 g	150 g	€ 1,02	€ 6,12
0.05	Tuner Cramp	6	<1 g	1 g	€ 0,01	€ 0,06
0.06	Screw Round [10 x 1,5 mm]	12	<1 g	2 g	€ 0,05	€ 0,60
3.00	Bridge Assembly	1 (35 sub)	545 g	545 g	€ 2,87	€ 2,87
0.07	Screw Round [23 x 3 mm]	6	<1 g	1 g	€ 0,01	€ 0,06
4.00	Pickguard + Electronics Assembly	1 (54 sub)	198 g	198 g	€ 6,20	€ 6,20
0.08	Screw Countersunk [12 x 3 mm]	13	<1 g	2 g	€ 0,01	€ 0,13
6.00	Output Jack Assembly	1 (5 sub)	23 g	23 g	€ 0,52	€ 0,52
0.09	Spring Claw	1	11 g	11 g	€ 0,10	€ 0,10
0.10	Spring	3	9 g	27 g	€ 0,10	€ 0,30
0.11	Wood Screw Countersunk [25 x 3 mm]	2	<1 g	<1 g	€ 0,01	€ 0,02
0.12	Tremolo Cover	1	25 g	25 g	€ 0,20	€ 0,20
0.13	Screw Countersunk [12 x 3 mm]	6	<1 g	1 g	€ 0,01	€ 0,06
0.14	Strapholder	2	4 g	8 g	€ 0,10	€ 0,20
0.15	Wood Screw Round [25 x 3 mm]	2	<1 g	<1 g	€ 0,01	€ 0,02
0.16	Strings Set [0.10” - 0.42”]	1	12 g	12 g	€ 0,50	€ 0,50
7.00	Tremolo Arm Assembly	1 (2 sub)	25 g	25 g	€ 0,36	€ 0,36
Total:		**289 parts**		**3371 g**		**€ 40,37**

Table 3.13: Total Amount, Weight and Costs.

factor of 0,1 is used for the retail part prices (which is in according with the total parts cost shown in Table 3.13: €40,37). This means that approximately €12,00 remains for assembling the guitar and the manufacturer's profit.

3.12.4 Manufacturer's Profit

The manufacter's profit depends on the assembling costs, based on the time needed to assemble one guitar and the hourly wages for an employee in China. This profit of the manufacturer also depends on the prices of the raw materials. A few parts are very expensive in comparison to the others. Wood is expensive although not the best quality is used. The wood prices rise more and more, as well as the metal prices.
Conclusion: based on an average Chinese wage of $0.57 per hour (which is €0,39 per hour, source: www.munafacturingnews.com) and an assembling time of 1 hour for 1 guitar, the profit is approximately €11,60 per guitar for the manufacturer in China.

Calculation Results

Commodity:	**Dry Cargo : Class 1 Commodities**	Shipping Date:	**28Jan2005**	Expiration Date:	**31Mar2005**
Origin:	**JINZHOU, CHINA**	Via Port:	**BANDUNG, INDONESIA**	Mode:	**N/A**
Destination:	**ROTTERDAM, NETHERLANDS**	Via Port:	**ROTTERDAM, NETHERLANDS**	Mode:	**N/A**
Base Freight:	**2050.00USD**	Basis:	**PC**	Ctr. Size:	**20**
Tariff Code:	**MAEU-401**	TLI:	**0000-00-0003-0001**	Service:	**YY**
Currency Date:	**28Jan2005**	FF/Broker:	**Freight Forwarder**		

Bottom Line Charges As of 28Jan2005

Ocean Freight	2050.00 USD	
CARRIER SECURITY CHARGE	6.00 USD	
PORT SECURITY CHARGE	6.52 USD	(5.00 EUR)
HANDLING CHARGE - DESTINATION - NL	179.22 USD	(137.50 EUR)
HANDLING CHARGE - ORIGIN - CHINA	44.70 USD	(370.00 CNY)
BAF - ASIA TO EUROPE (BAF)	128.00 USD	
CAF - FEA to EUROPE	168.10 USD	
DOCUMENTATION FEE - DEST. - NL	26.07 USD	(20.00 EUR)
	===========	
Total Charges	2608.61 USD	

Charge Summary

Ocean Freight	2,050.00USD per Container
Destination Spreads	(0.000USD + Ocean Freight)
Rounding up of Ocean Freight	Ocean Freight
CARRIER SECURITY CHARGE	6.00USD
PORT SECURITY CHARGE	5.00EUR
HANDLING CHARGE - DESTINATION - NL	137.50EUR
HANDLING CHARGE - ORIGIN - CHINA	370.00CNY
BAF - ASIA TO EUROPE (BAF)	128.00USD
CAF - FEA to EUROPE	8.20% of Ocean Freight
DOCUMENTATION FEE - DEST. - NL	20.00EUR

The above rate quotation is valid for 30 days. All rates published in the tariff at the time of receipt of cargo will be applicable and supercede the above quoted rates.

If you have questions about rates and service please contact your local Maersk Line sales office.

Please Note that hazardous cargo is subject to acceptance by all ports involved at time of booking.

Fig. 3.22: Shipping Costs Calculation (Source: www.maerskline.com).

4. Sources

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http://en.wikipedia.org/wiki/Gibson_L5
http://en.wikipedia.org/wiki/Gibson_ES-150
http://en.wikipedia.org/wiki/Fender_Esquire
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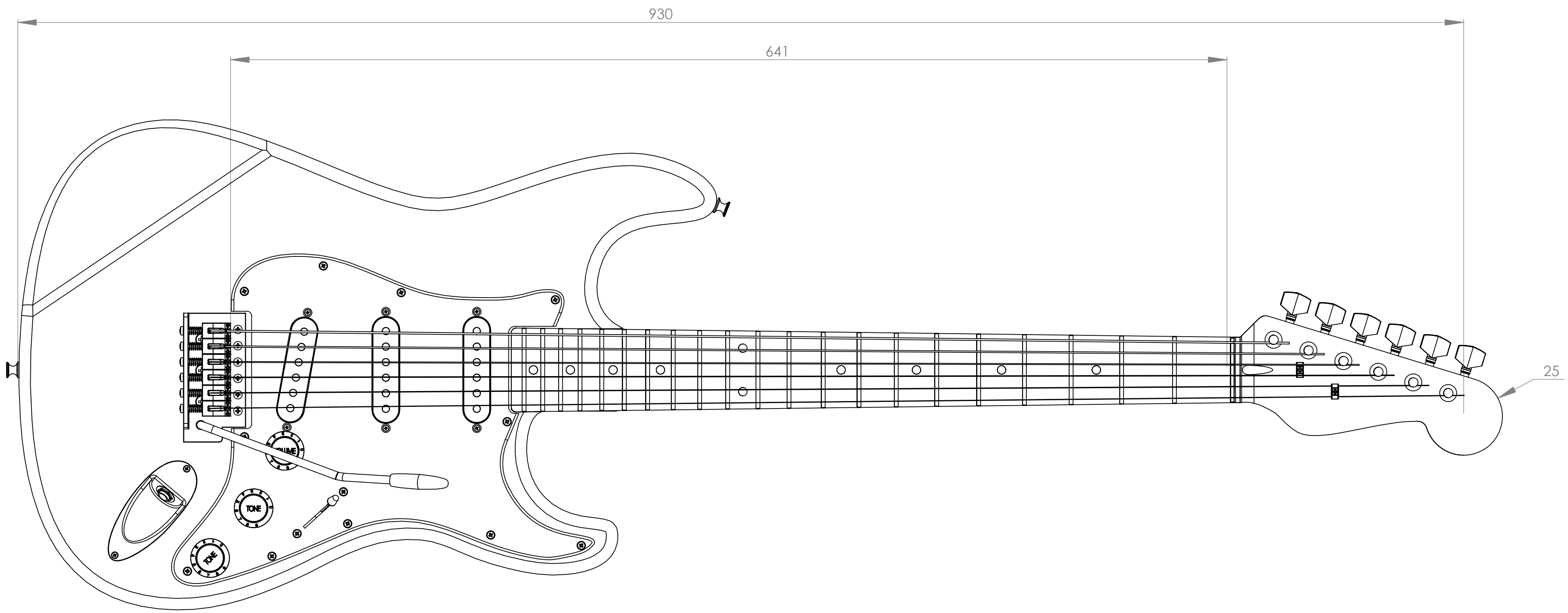
Appendix A
Technical Drawings



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DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

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DRAWN			
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MATERIAL:

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Stratocaster

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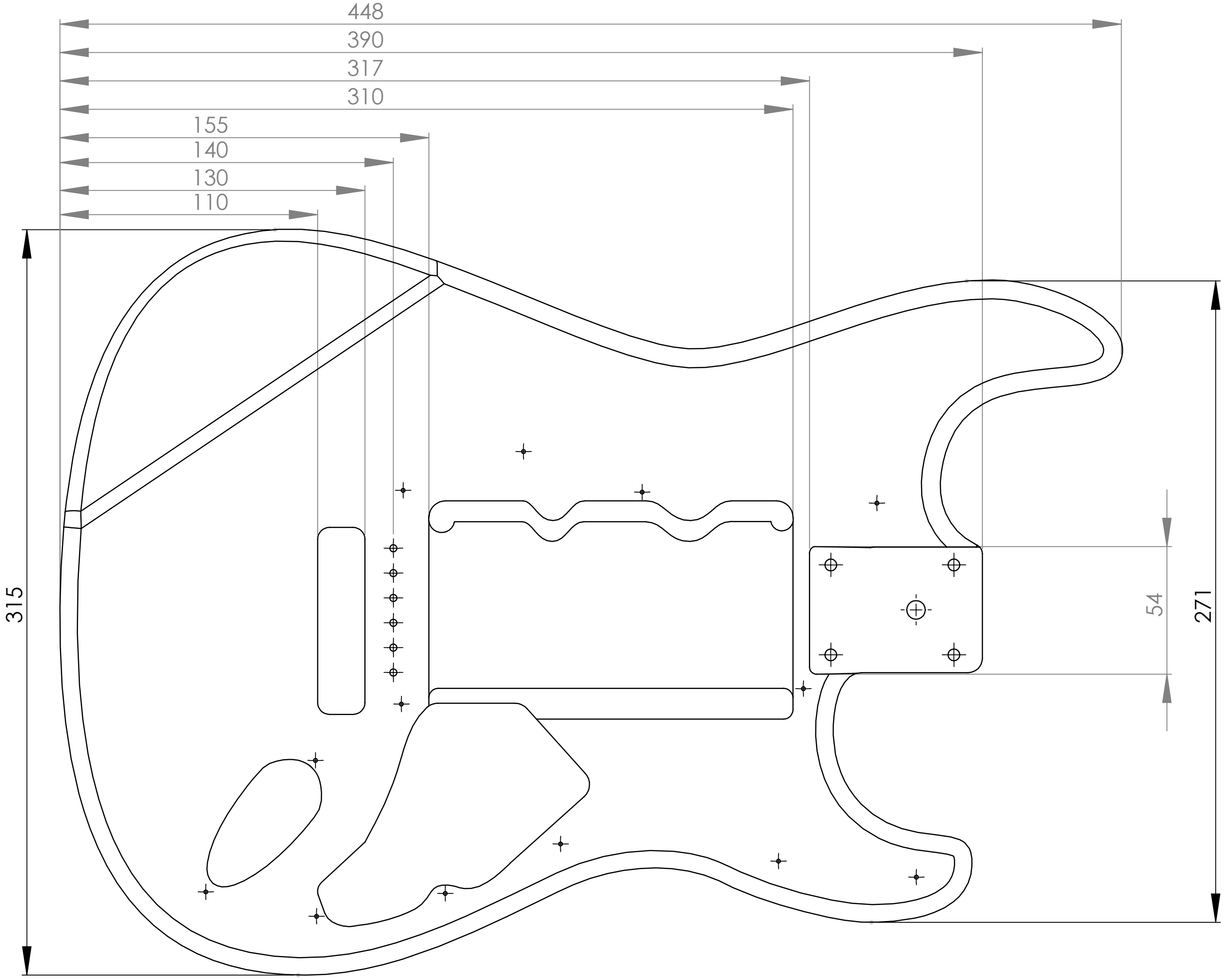

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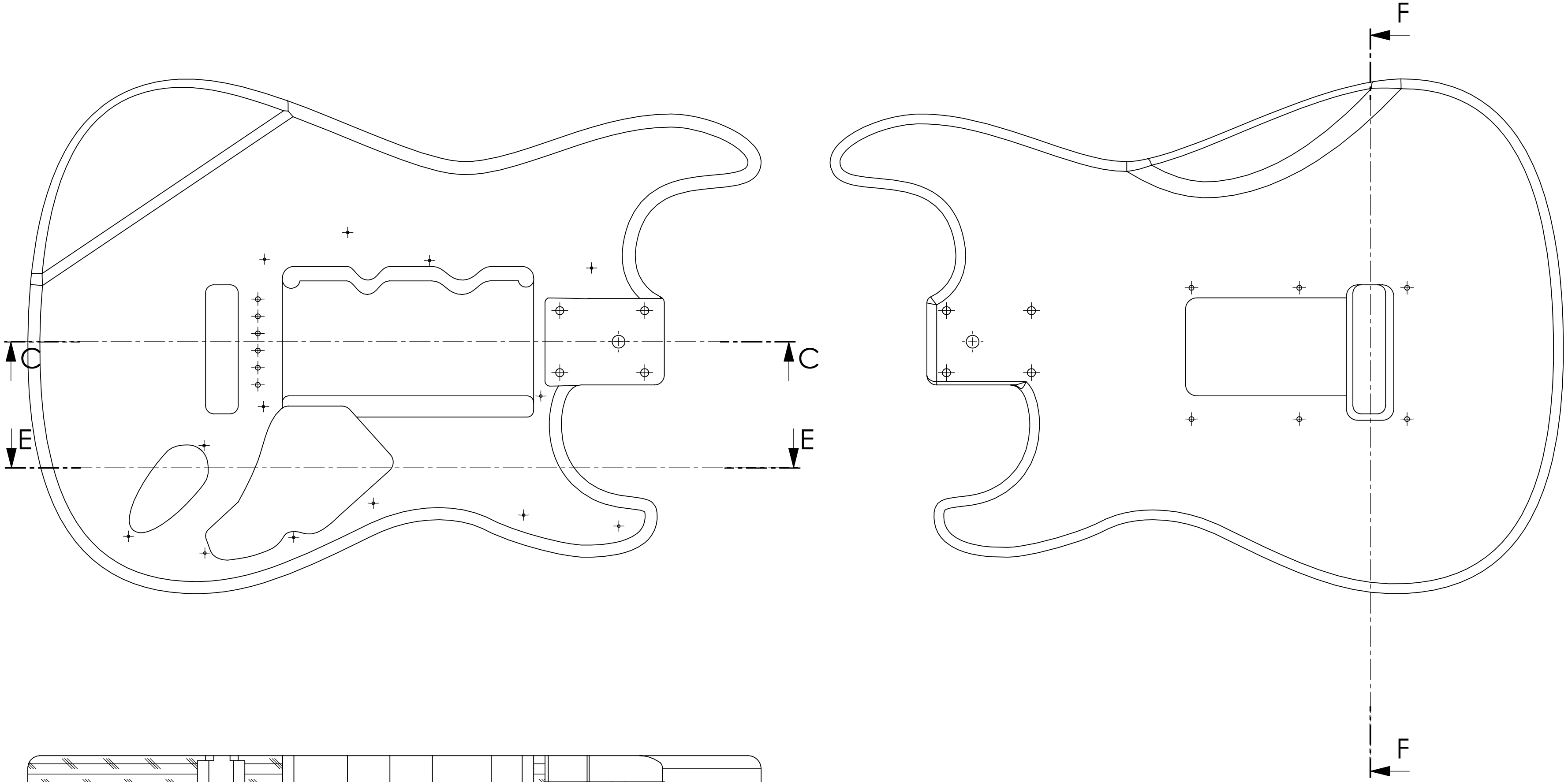

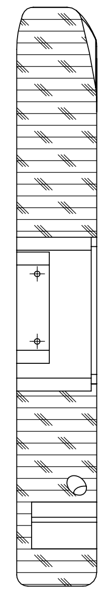

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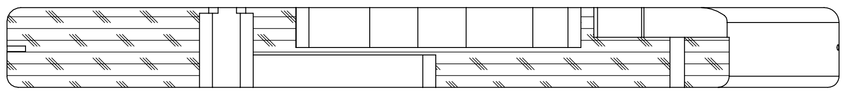

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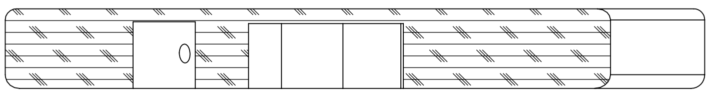

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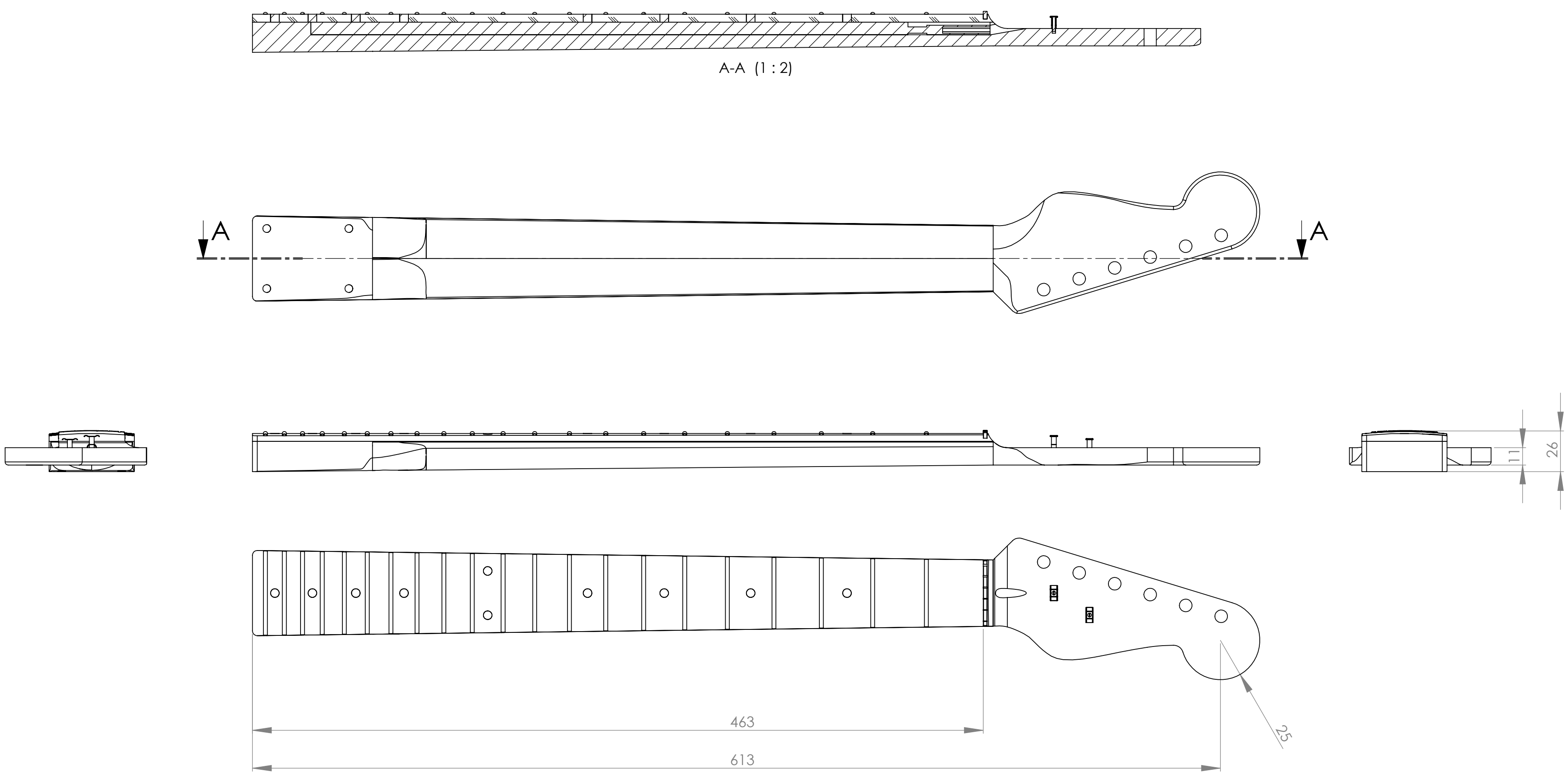

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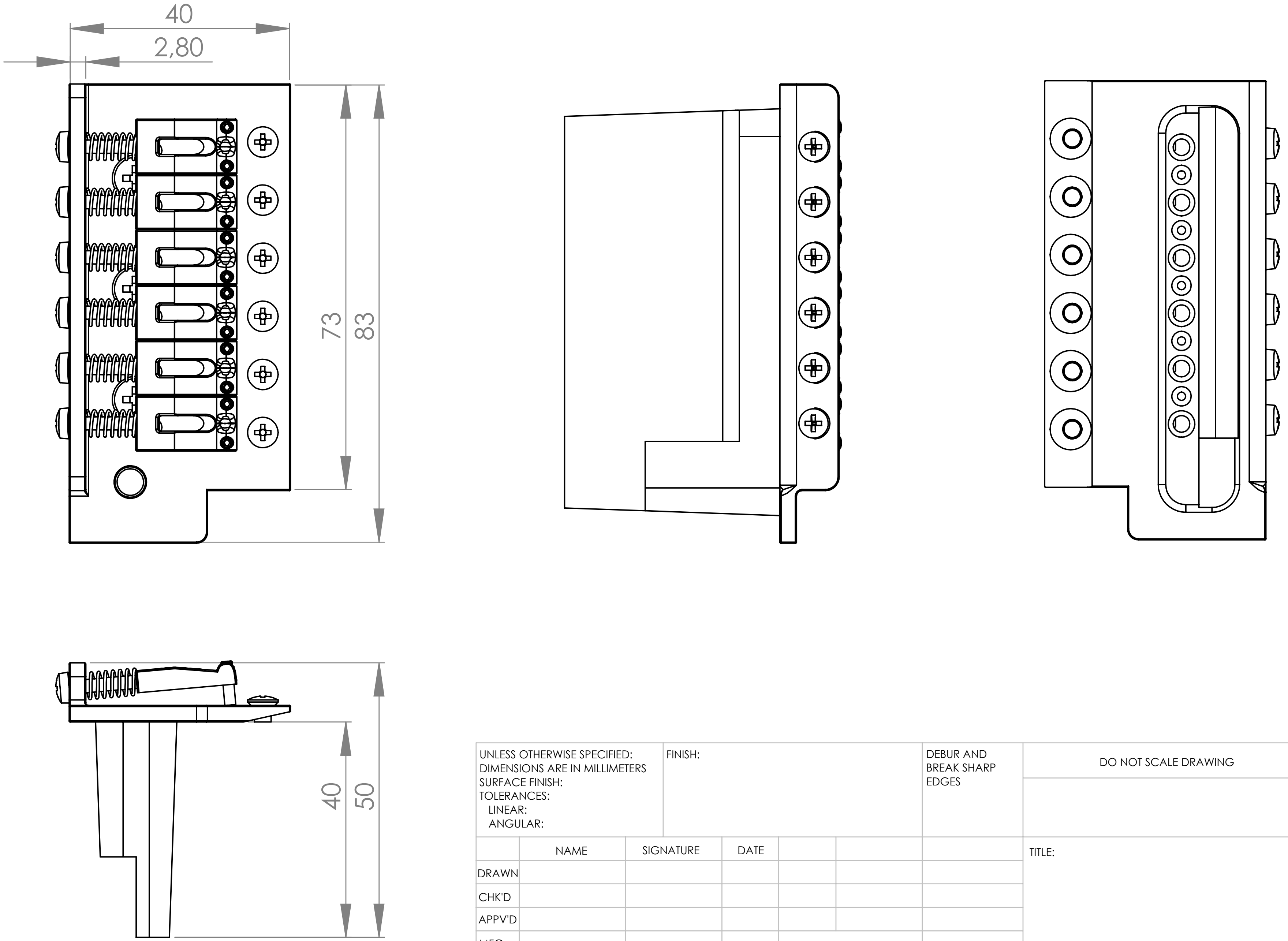

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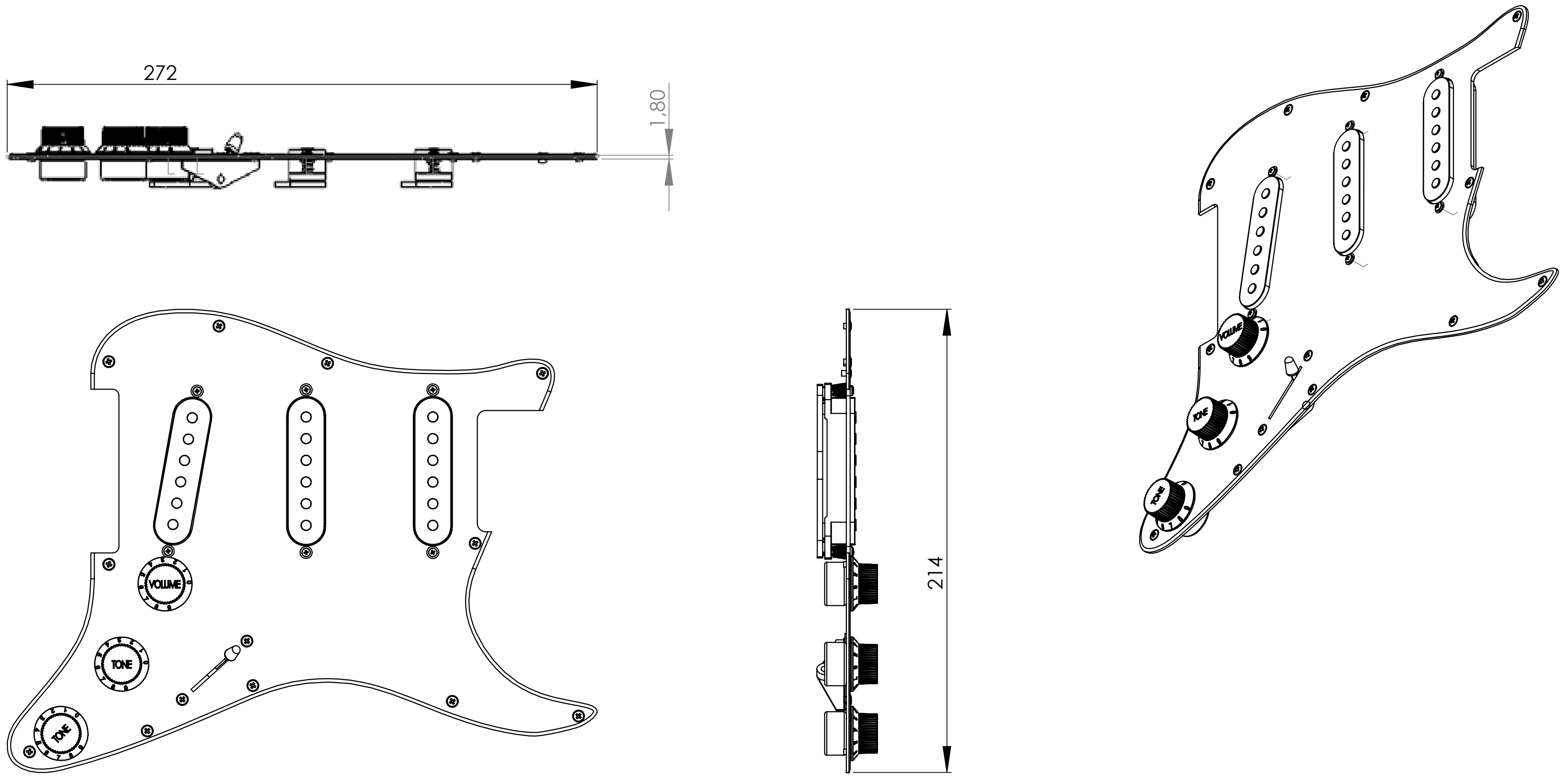

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MFG			
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TITLE:

DWG NO.

Pickguard Assembly

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