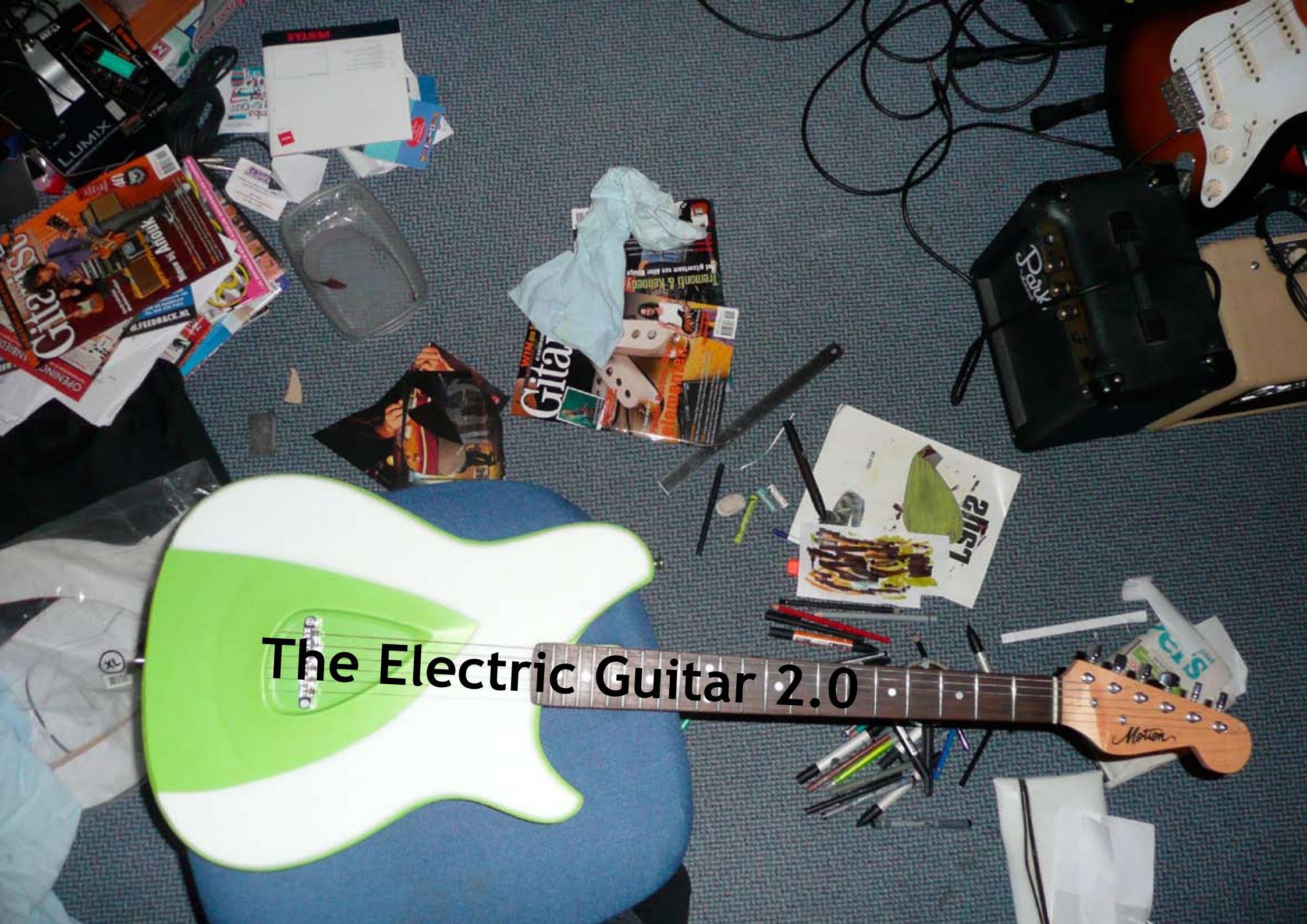

The Electric Guitar 2.0

The Electric Guitar 2.0

redesign and finite element method analysis

Content:
Redesign & FEM analysis

Course:
Evolutionary Product Development

Date:
Wednesday, April 23, 2008.

Student:
Wilco Prinsen
s0066818

Teaching Staff:
Robert Wendrich
Arthur Eger

Summary

50 years ago, the electric guitar reached both the segmentation and individualization phase. Currently, the next step should be the awareness phase. However, after closer study, it was concluded some "aware" products were not successful. Therefore, the electric guitar will remain in the segmentation and individualization phase in the near future. In the segmentation phase there are still lots of opportunities due to new technologies.

Adding wireless technologies to the already existing digital (modeling) guitar is an opportunity. For the new concept it was concluded that the electric guitar should visualize its digital revolution with sophisticated product design to differentiate from the "fifties classic"-design of the electric guitar.

Contents

1. Introduction

This report is written for the second assignment of the master course Evolutionary Product Design (EPD), part of the Master Industrial Design Engineering at the University of Twente.
The second assignment of Evolutionary Product Development is based on redesigning a chosen product, in this case the electric guitar. This redesign will be based on a study done in the previous part of Evolutionary Product Development and some knowledge and experience from myself as an user of the electric guitar.
Chapter 2 contains a short summary of the product phases evolution of the electric guitar. Conclusions of this research are the starting point for the redesign of the electric guitar. Chapter 3 will discuss the next step of the electric guitar, based on the conclusions of the product phases theory and based on the trends of the electric guitar.

Besides the product phase a product is in, it's important to know what kind of technology is used in the newest products and what might be used in the future. Therefor, new interesting technologies are discussed for the redesign.
Based on chapter 2 and 3 a new guitar concept is developed. This conceptual idea will be introduced in chapter 4. In this guitar concept several design directions were developed. These are directions of what the electric guitar might look like in the (near) future. Chapter 5 is the start of realizing the next step: a design direction is chosen. This chapter contains some redesign steps and introduces the physical model of the final concept. Chapter 6 is about production and costs of the final product. Also a part of the product is analyzed with the finite element method. This analysis is added to Appendix B.

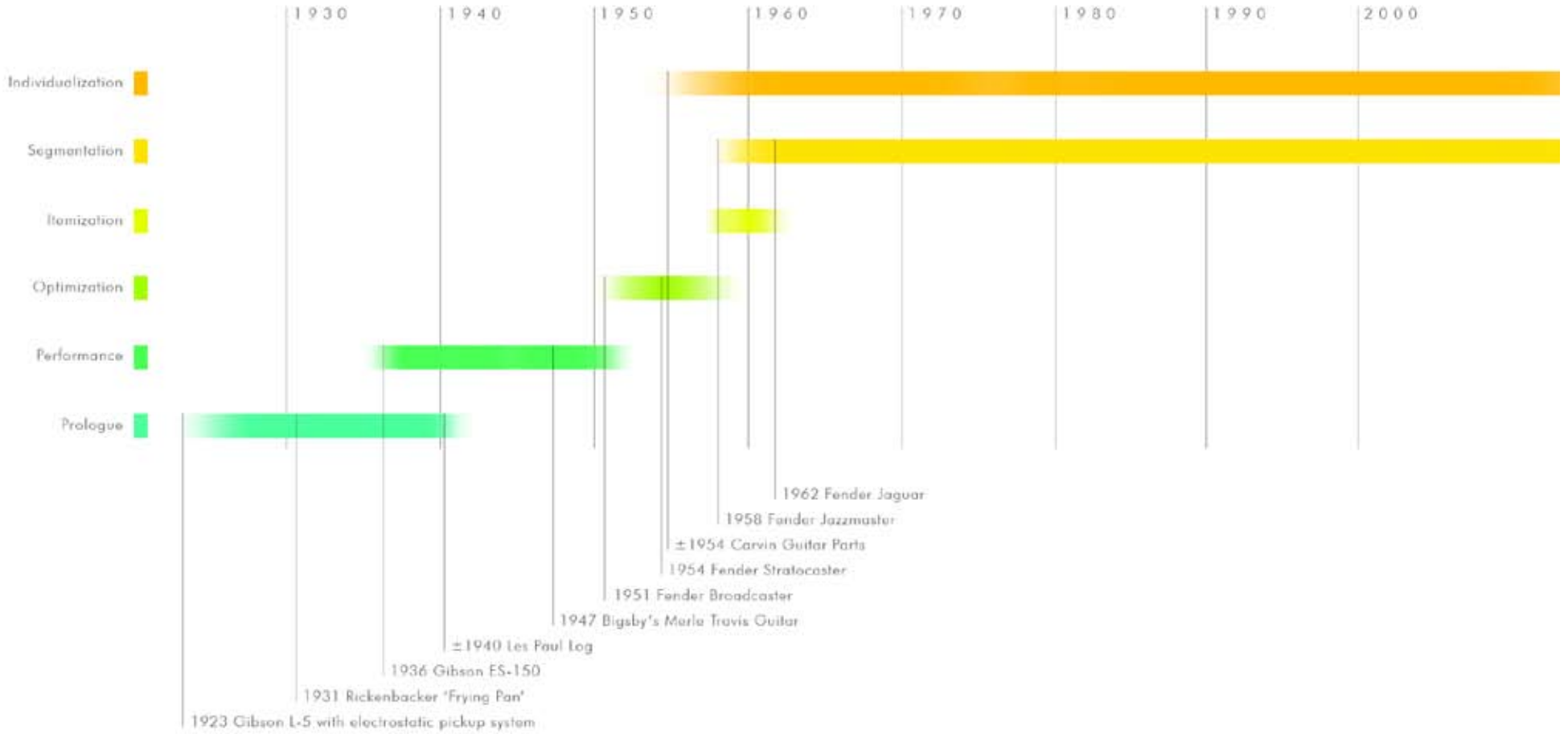


Fig.: 2.1: Product Phases and Timeline.

2. Product Phases

2.1 Introduction

For this second period of Evolutionary Product Development, the goal is to design the next step for the electric guitar. The next step is a concept for the near future and this concept will be a logical evolved version of the electric guitar which we are familiar with today. The assumption is that the electric guitar has reached the segmentation and individualization phase for fifty years now (since 1958). Hallelujah, let's celebrate that and go further with something new! The logical conclusion of this course would be that the product will reach the following phase in the future, the so called awareness phase. Question was, whether it would or would not reach this phase.

2.2 Summary of the Product Phases

Electric guitars were introduced around 1950 (figure 2.1). The technology was developed in the 1930's and its performance strongly optimized in the 1940's to become commercial successful in the 1950's. In the end of the fifties the guitar was optimized and itemized to a maximum. From the year 1958 up to now the guitar market is totally segmented and also very suitable for individuals: customization and co-creation is common. Everything is possible and everything is done. All kinds of designs, materials and techniques are used to be new and successful (again). All that segments have their own market, quality and prices. But, actually nothing is changed in fifty years. All main parts are still the same. Even some important models from the fifties are still produced!

2.3 The Awareness Phase

The market is saturated with every possible electric guitar design but strangly enough there is not an "aware" electric guitar. Only three examples are found on the internet in the strongly related market of acoustic guitars.

2.3.1 The Bamboo Guitar

Yamaha has introduced the first (acoustic) bamboo guitar in 2000[1]. "*The top, back, sides, neck and braces of this attractive guitar are all crafted from easily replenishable Bamboo, resulting in a totally new sound that is remarkably bright and clear*". Although the marketing managers are very happy with this innovative guitar, the product is not a huge success (yet?). It is not findable on the Yamaha website anymore and hard to find retailers who sell this specific guitar. There are no other laminated bamboo (acoustic) guitar models introduced[2]. The reason why is not clear. In figure 2.2 this acoustic bamboo guitar from Yamaha is shown.

Fig.: 2.2: Yamaha FGB1 Bamboo Guitar.

Fig.: 2.3: The Gibson Live Earth Guitar.

2.3.2 The Live Earth Guitar

Gibson and Live Earth together fight against global warming with a special guitar and eight concerts all around the world[3]. The body and neck of the guitar are constructed using rainforest friendly, FSC-certified mahogany. "*The Gibson custom designed acoustic guitars represent the ultimate combination of music and environmentally conscious practice that is in line with our Live Earth messaging,*" said Kevin Wall, Founder and Producer of Live Earth. "*Music has the universal power to unite cultures, and we will focus that energy on July 7 to motivate people all over the world to take action to combat global warming.*" It is a powerful marketing tool for Gibson Guitar, and its philanthropic arm, Gibson Foundation. According to their website, they are dedicated to supporting the cause for climate protection and the creation of these environmentally friendly guitars.

Fig.: 2.4: The Whole Team of "Found Object"-guitars.

Fig.: 2.5: The Cigar Box Guitar.

2.3.3 Cigar Box Guitar

In figure 2.4 two hand-crafted guitars and a banjo are shown, made from found object containers, as seen on www.flickr.com[4]. So far, there's a lunch box guitar, a cigar box guitar, and cookie tin banjo. This is the most "aware" guitar that is found on the internet. It is a nice "out of the (cigar) box" statement but not a commercial product that guitarists are waiting for.

2.4 Everything is possible

If everything is possible, why not trying everything? That was a main conclusion of the first part of the course EPD. An aware guitar is a possibility for a very specific market segment. A laminated bamboo electric guitar, a FSC-certified electric guitar with lots of marketing stories or a cigar box electric guitar. But these concepts are not the "logical next step" for the electric guitar. Not in the way as the Fender Stratocaster was "the next step" for this instrument. A next step should be more state-of-the-art in my opinion.

As said, the Fender Stratocaster was a huge "next step" and state-of-the-art in 1954. Also the other electric guitar models mentioned in figure 2.1 are very important next steps in guitar evolution. To create a new state-of-the-art electric guitar, the concept should be unique.

Nowadays, unique guitars are created in new segments of the electric guitar market, based on wishes, concerns and functionalities of specific target groups, based on new technologies, or based on higher quality products for a specific price segment. Individual wishes are also available: the electric guitar customization market is huge. As said in the first assignment of EPD, this market started already in 1954 and is not a next step for the electric guitar in 2008.

Fig.: 2.6: Carvin Products and Parts Brochure, 1997.

3. What is Now

3.1 Introduction

What I am looking for is something that makes the the next electric guitar really unique. What are new technologies that can be applied? What is a new functionality or concern that is valuable for guitarists? Therefore, a market analysis is done. At first a paragraph about existing new and unique products of the electric guitar market. After that research paragraph 3.3 discusses the wishes of the guitarists and paragraph 3.4 discusses new technologies that can be applied to fullfill that wishes.

3.2 New Electric Guitars

Due to adaptation of digital technologies the guitar market rapedly created new segments in electric guitar models, guitar effects and guitar amplifiers. The most unique guitars are discussed in this paragraph.

3.2.1 Line 6 Variax

Digital modeling guitars are a new market segment since Line 6 released their Variax 600 in 2002. Thanks to digital modeling technics almost all guitar sounds are possible with only one guitar. Manipulation of the sounds is possible with both the computer and traditional guitar effects. Amplification is possible with standard hi-fi equipment or with a traditional guitar amplifier. The guitar contains a lot of electronics and there is also a need for electricity in the guitar itself, due to active electronic components. That is not the case in the passive electronics of traditional fifties guitars' design. The solution of Line 6 is a special cable which connects the digital guitar to a digital Line 6 device (for example their special "Line 6 Pod" effect box) which is also the power supply[5]. Another option is the use of some 9V batteries. The electronics in the guitar are completely hidden in the guitar body. There are no traditional electromagnetic pickup anymore. Instead of that old technology, the Line 6 Variax uses a piezo pickup which is mounted into the guitar bridge (the place where the strings hit the guitar body). This technology is adopted from the electronics found in acoustic guitar models. With this signal and the digital effects build outside the guitar, almost all sounds are possible. The retail price for the Variax 600 is €749,-. The cheaper Variax 300 costs €449,- and the topmodel is the Variax 700 (€1299,-).

Fig.: 3.1: Line 6 Variax 600 in 2-tone sunburst.

Fig.: 3.2: Line 6 Variax 700 in translucent amber.

3.2.2 Behringer USB Guitar

Another innovative product is the Behringer USB Guitar[6]. This stratocaster copy has three traditional single coil pickups but is a hybrid digital guitar. There are a headphone and an USB output added to this guitar. This simplifies recording with a computer or silent playing with a headphone. At the same time, the USB port acts as a power supply for the USB Guitar. The iAXE393 USB-Guitar comes with a software pack which allows the user to plug into virtual guitar amplifiers and effects. Digital processing of the guitar signal is done with a 16-bit converter at a sample rate of 44.1 kHz. Advantage of converting the signal in the guitar itself is the lack of signal loss through cables or effect pedals. Strange thing about this guitar is its retail price: €139,-. The quality of the guitar is probably less than a standard stratocaster.

Fig.: 3.3: Behringer iAXE393 USB analyse.

Fig.: 3.4: Behringer iAXE USB audio module.

3.2.3 Fender VG Stratocaster

Another digital guitar is the Fender VG Stratocaster. First released in 2007 this Fender "Virtual Guitar" is a modeling guitar for professionals with a retail price of €1849,-. The virtual part is developed by Roland and is a hight quality digital modeling pickup system. The guitar has 4 virtual guitar modes: Stratocaster, Telecaster, Humbucking and Acoustic. Apart from the virtual part, the standard analogue and passive stratocaster is still available. In fact, this guitar is an answer to the Line 6 Variax models. The unique selling point for Fender is the combination with a "normal" electric guitar circuit. The user still has a normal Fender Stratocaster in his hands. This is also the story for the visible part of the story: what you see is just a normal electric guitar. There are a few minimal details visible which tells a guitarists that this is a special guitar: four knobs instead of three, a small blue led light and a special Roland pickup between the bridge and the normal electromagnetic bridge pickup. So, Fender does not show their new technology but hides it in a known package. Guitar Player magazine called this VG Stratocaster "*...the most significant advancement in Stratocaster technology in 53 years*" as mentioned on the website of Fender[7].

Fig.: 3.5: Fender VG Stratocaster.

3.2.4 Gibson Robot Guitar

In december 2007, Gibson changed the world with the first robotic guitar ever made[8]. The guitar can keep the strings in tune itself with simply turning a single knob! A limited run is produced and sold for €1.899,- each. The guitars have a custom color, the special robotic guitar tuners and a special magic knob for the tuning settings (see figures 3.6 & 3.7).

Fig.: 3.6: Gibson Robot Tuners.

Fig.: 3.7: Gibson Robot Guitar.

3.2.5 Matt Bellamy's Manson Guitars

Matt Bellamy, the frontman of rockband Muse, is besides his lead vocals known for his innovative guitar playing. His skills are supported by custom made guitars from the company Manson Guitars. They created combinations of existing, but highly complex electronics, and fitted these in several guitars. Probably the most eye-catching feature was the implementation of the Korg Kaoss Pad into a guitar body, as shown in figure 3.8. With this touchpad, the guitar signal can be real-time modulated with a finger tip. For examples of the use of this guitar, watch the Manson Guitar demo on Youtube[9].

Fig.: 3.8: Manson M-one-D-one.

Fig.: 3.9: Intel/Fender Telecaster Concept Guitar.

3.2.6 Intel/Fender Concept Guitar

In 2005, Intel, in partnership with Fender, has designed and produced an one-off instrument, known as the Intel/Fender Telecaster Concept Guitar[10]. This internet-enabled electric guitar lets musician surf on the web for inspiration, send a quick e-mail in-between songs onstage or practice guitar solo via a built-in webcam. The guitar incorporates Intel mobile technology and was developed to provide the ultimate in music-on-the-move technology. It can be played anytime, anywhere, and its many innovative features let guitarists use headphones, record demo songs and e-mail them directly to friends, go online to find the chords to that song someone just requested, download your favourite tunes and listen or play along, etcetera.
This unique Telecaster contains a tablet laptop with soundcard. It uses the Intel mobile technology to access a wireless network. The guitar's pickups are routed straight into the tablet PC for direct recording. Two ¼-inch jacks lets the guitarist play the guitar like a normal Telecaster or listen to songs downloaded directly from the guitar.

Fig.: 3.10: Intel/Fender Telecaster Concept Guitar with Tablet PC.

3.2.7 Wii Guitar Hero III Les Paul

The newest Nintendo game console called "Wii" introduced a new way of interacting with the game computer. The secret of this innovation is the unconventional controller as announced in september 2005. This controller is actually a remote control with motion sensing capabilities[11]. This allows the gamer to interact with elements of the game on the screen. The momements are tracked through use of an accelerometer and optical sensor technology. The Wii version of the game "Guitar Hero III: Legends of Rock" comes with a very special add-on for the Wii remote: a white Gibson Les Paul style guitar controller. The Wii remote fits into a slot in the guitar body[12]. Thanks to the motion sense and the wireless capabilities of the Wii remote, the guitar controller is a state-of-the-art product. It interacts in many different ways with both the user and the played music. The design of the guitar is not very innovative but on the other hand it is very recognizable. It looks like a guitar and a toy at the same time. Although it is a game controller and not a real guitar, this concept is very interesting for serious guitarists. Features could be adopted in "real" guitar concepts.

3.3 New Ideas

This paragraph will discuss some new ideas based on the new guitars and guitar concepts which are introduced in paragraph 3.2. Besides these guitars an important question should be asked: "What do guitarists want?" A next step of a product should always be an useful product, no matter what specific target group is chosen. Either it is a total new product or a new small detail. the unique selling point (USP) should be clear to the customer. For electric guitars it is very difficult to find new USPs. Due to fifty years of segmentation and individualization, the market is totally saturated. In 2004 Paul Reed Smith, founder of Paul Reed Smith Guitars, says very striking to Music Trades: "*Guitarists feel that there isn't much room to make the instrument look better or play better...*"[13]. Therefore, new concepts should be more revolutionary to distinguish from existing products. This can be a conflict with the assignment of this course: design the next logical step for a product which is most of the time a very small step. Some of these small and bigger steps are introduced here.

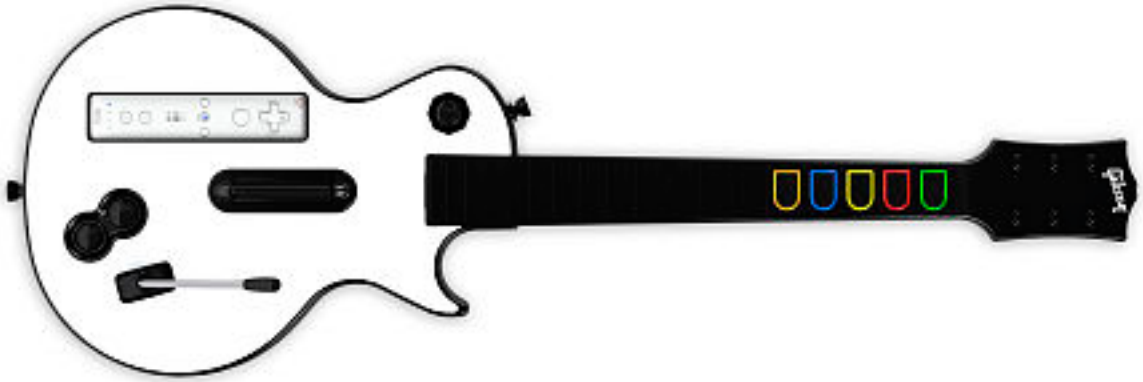


Fig.: 3.11: Wii version of the Guitar Hero III Les Paul Controller.

3.3.1 Cheap, Cheaper, Cheapest

For guitar manufacturers, a solution for more profit is efficiency. Therefore, a logical next step of a product could be a more efficient produced product. Produce the same quality products for a lower price as the competitors. This explains the enormous explosion of guitars produced in East Asia. Almost all new guitars introduced are build in China or Korea. The guitar analyzed in the first assignment of EPD was the cheapest example of that trend. Although it is a realistic next step of many guitar models, it is not interesting for designers. The look and feel should not be influenced to make cheaper guitars a realistic option for self respecting guitarists. Production methods and cheap employees are the factors that determine the efficiency. Cost reductions are most of the time very small steps for the evolution of the guitar, but make a huge step for the profit of the company. For me as a designer, the cheap guitar trend feels like a step backwards. Designing a next cheaper digital guitar like the Behringer iAXE393 is a logical next step, but not a step for the guitar evolution. Therefore, this assignment is not about the next cheap guitar.

3.3.2 Active Tuners

Paragraph 3.2 shows that automatic tuners are a new added value. False sounding guitars are a huge irritation for guitarists. Concepts that were generated for the EPD course included the active tuning system (which now exists with the Gibson Robot guitar).
In October 2007 some sketches were made of a feedback control tuning system for the electric guitar. Two months later Gibson introduced their solution. This concept combined robot tuners with an active tremolo system (fig 3.12). Because of the introduction of the Gibson Robot Guitar, this concept is not chosen.

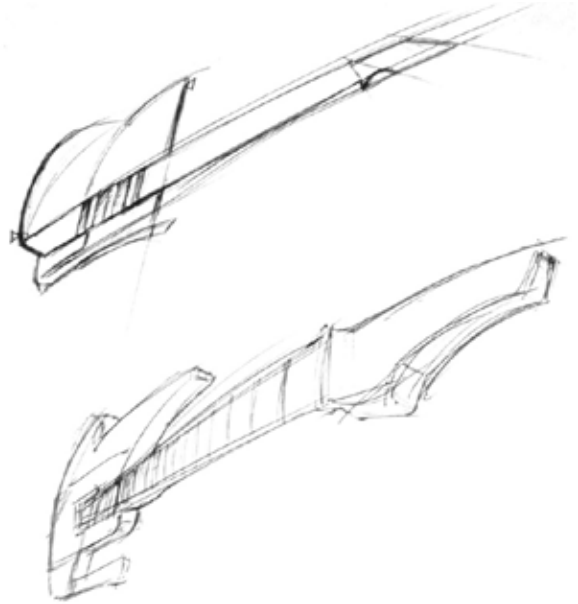


Fig.: 3.12: Active Tuner Guitar.

3.3.3 Interactive Sound Modulation

A guitar which senses the position relative to your body. This allows the guitarist to interact in more different ways with the guitar to influence the guitar's sound signal. The concept could be compared to the motion sensing of a Nintendo Wii controller. The guitarist's movements are controlling the chosen modulation effects of the guitar sound. This could be the next step for the guitars of Matt Bellamy (paragraph 3.2.5). But it is a very revolutionary and big step. Motion sensing is expensive and not a widely used technology. Therefore, also this concept is not chosen, but it is a good concept for future guitars.

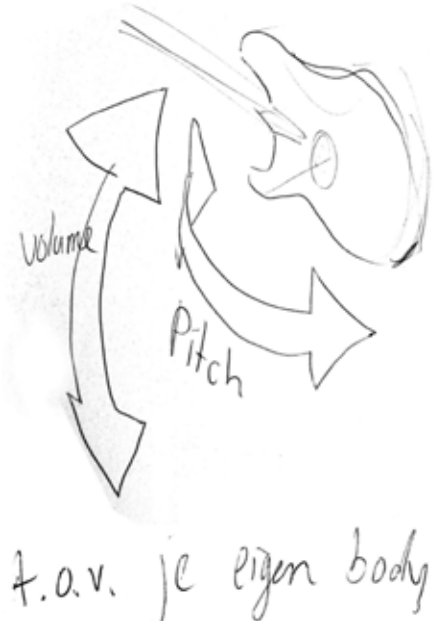


Fig.: 3.13: Interactive Sound Modulation Guitar.

3.3.4 Wireless Signal Transmission

The fourth concept is a wireless guitar. This is not a new concept. The first wireless microphones were introduced in 1976 by Nady Systems[14]. This technology, based on radio frequent signal transmission, was adopted very quickly to electric guitars. Nowadays, more wireless technologies are available, especially for digital signals. For digital guitars, like the Line 6 Variax models, this can be a huge added value. The advantage of converting the guitar's string vibration at the source to a digital signal is emerging. This advantage is even bigger when the signal can be transmitted wireless without information loss or

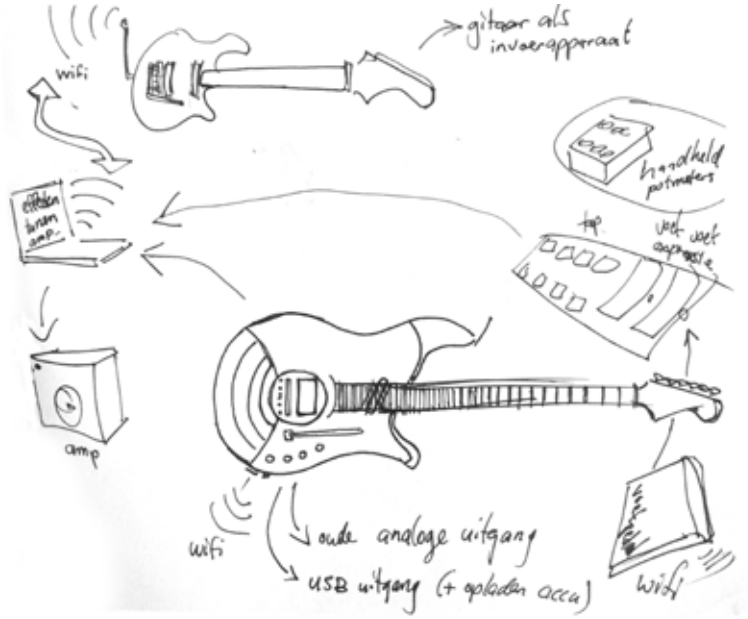


Fig.: 3.14: Wireless Digital Guitar.

interference problems. To achieve this, the wireless system should be accurate, fast and secure. Besides that, energy consumption and bandwidth are important factors for succes. To deside if this concept is viable, research on new wireless technologies should be done. If new technologies are good enough to compete with traditional wireless (RF) systems, the concept is a logical next step of the electric guitar.

3.4 New Wireless Technologies

To make a next step, an electric guitar could contain the newest technologies to impress guitarists and the rest of the world. In this paragraph, the newest wireless technologies are discussed. These technologies take care of the guitar's signal transmission to an effect processor or amplifier. Factors that are important, such as bandwidth, ranch and energy consumption, are discussed here.

3.4.1 Wi-Fi

Wi-Fi is the common name for a popular wireless technology used in home networks, mobile phones, video games and more[15]. These data network products connect through the internation standard IEEE 802.11 of wireless Ethernet. Wi-Fi has a range of about 30 meters and a maximum bandwidth of 54Mbit per second. Disadvantage of this widely used system for mobile devices, with a limited power supply, is its high energy consumption.

Fig.: 3.15: Wireless Digital Signal.

3.4.2 Bluetooth

Bluetooth is an industrial specification for wireless personal area networks (PANs). Bluetooth provides a way to connect and exchange information between devices over a secure, globally unlicensed short-range radio frequency[16]. Bluetooth is primarily designed for low power consumption, with a short range based on low-cost transceiver microchips in each device. Disadvantage is its small data bandwidth. For the first version of Bluetooth the data rate is 1Mbit per second and for the second version it is 3Mbit per second.

3.4.3 WUSB

Wireless USB is the first high-speed wireless personal interconnect technology combining the speed and security of wired High-Speed USB with the ease-of-use of wireless technology. It is backward compatible with wired USB, allows users to connect up to 127 devices and currently delivers a bandwidth of up to 480Mbit per second at 3 meters and 110Mbit per second at 10 meters. Wireless USB is based on the WiMedia Alliance Ultra-wideband Common Radio Platform[17].

3.4.4 Conclusion

With the extremely new and state-of-the-art Wireless USB (WUSB) technology the wireless digital guitar concept should be viable. The advantages are the high data rate and low energy consumption. Because it is an USB connection, the technology of the Behringer iAXE393 can also be used, in combination with the Line6 Modeling technique. More about this concept is discussed in the next chapter.

4. The Next Step

4.1 Introduction

Traditional electric guitars are strongly related to a thick audio cable. This cable connects the guitar to an amplifier. Most guitarists use effect pedals to modulate their guitar sound. The amount of effects that can be used is almost infinite and therefore even more combinations of sounds are possible. However, the order of the effects is locked in live situations, due to the cables that connect the guitar, the effect pedals and the amplifier. Rewiring the lineair structure of pedals is an opportunity, but not ideal while playing on stage in front of a crowd. There are some very expensive combinator pedals to solve this problem, or a total digital effect rack can be used. This is not suitable for non-professional guitarists. The problem can be solved with more interactive software for PC or Mac, where all digital effects are available with just one central processor. That software based system is much cheaper and more interactive than any other solution. Nowadays, the only problem is intuitive interaction with the software in a live situation. This problem can be solved with the invention of wireless USB. A guitar network is born!

4.2 Guitar Network Concept

In this new guitar network concept, the guitar is evolved into an input device of the guitar network system. The heart of the concept is freedom in playing guitar and creating sounds. Important other factors of this concept are space, network, sounds and interaction.
The laptop (or desktop) will act as a source of possible sounds, while the foot controller acts as an

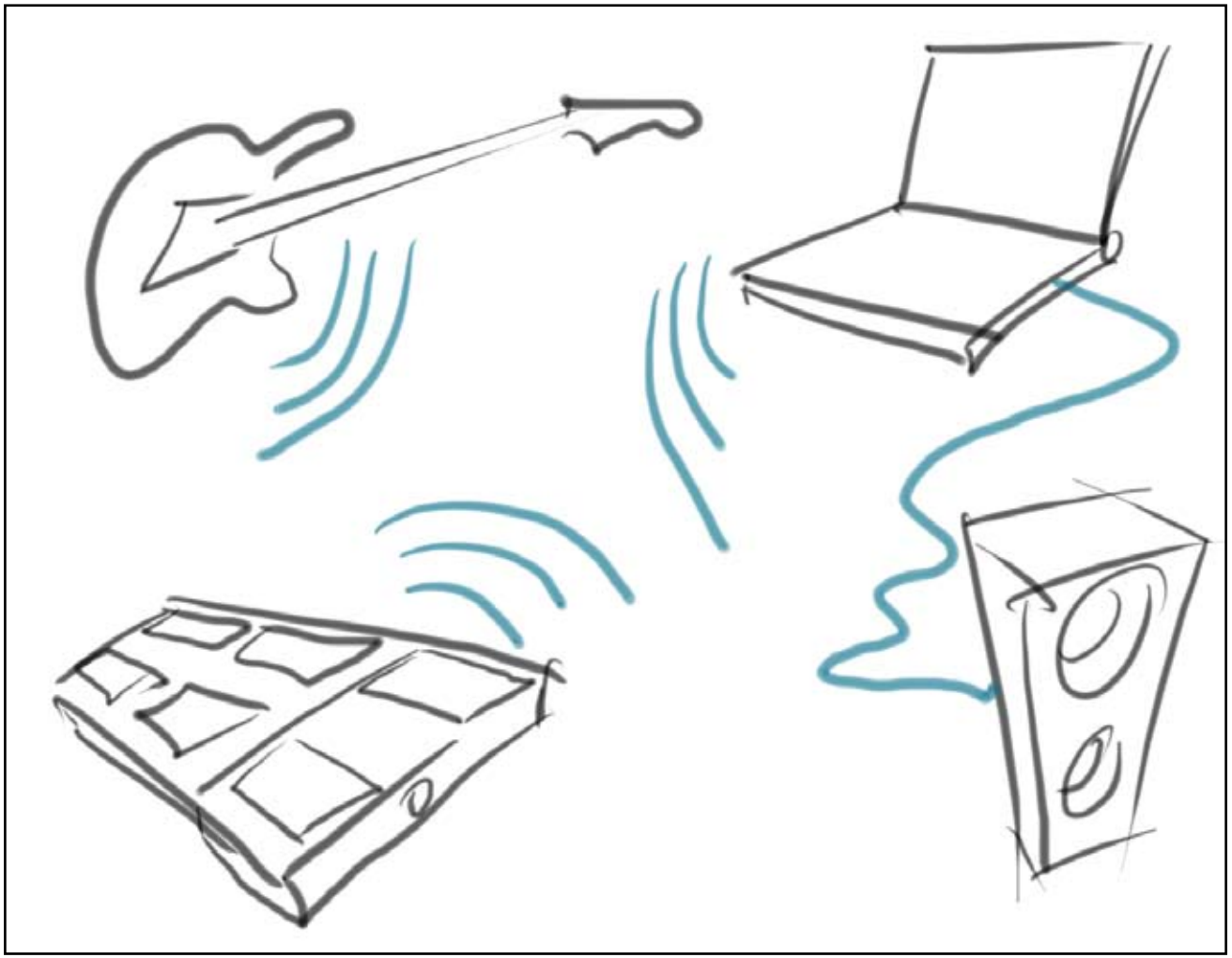


Fig.: 4.1: Guitar Network Concept.

interaction device for sound switching. The laptop could be connected to a guitar amplifier, a hi-fi system, a headphone or an enormous PA system (see figure 4.1 for a total overview of the guitar network concept).

4.3 The Technology

The technology used is the piezo guitar pickup system as used in Line 6 guitars (figure 4.2). This system is hidden in the guitar's bridge, so no pickup system is visible anymore on the guitar (see also figure 3.1 and figure 3.2). More about this visible aspect is discussed in the next paragraph. The piezo signal is converted from an analog to a digital signal in the guitar itself. This active system is in the Line 6 configuration mounted on the back of the guitar (see figure 4.3 and figure 4.4) and powered with three AA alkaline batteries. For the guitar network concept the system will be equipped with a lithium-ion battery for more energy capacity for the wireless USB component. Through that wireless USB device, the digital signal is send to the computer. When the guitar is in a ranch of 3 meter of the computer, the data rate is 480 Mbit per second. This data rate is equal to the wired USB 2.0 connections used on the computers nowadays. It is even more than the data rate of the Behringer iAXE 393, which uses the old USB 1.1 connection. The components that are not used of the Line 6 system are the traditional potentiometers and pickup switch, which acts as a guitar model switch. This components are removed because of the interactive and wireless foot controller which can act as the virtual controller of everything. For future guitars, the foot controller can be extended with controls on the guitar again with the use of a highly interactive touchpad on the whole front of the guitar. This is not the case yet, because it is still very expensive. The wireless USB system should be integrated on the PCB of the Line 6 system. The guitar network concept is also equipped with the conventional USB 2.0 connector for power supply or for wired connection with the computer while the battery is low. Detailed descriptions of the Line 6 electronics and the wireless USB system are not added to this report, because of their complexity.

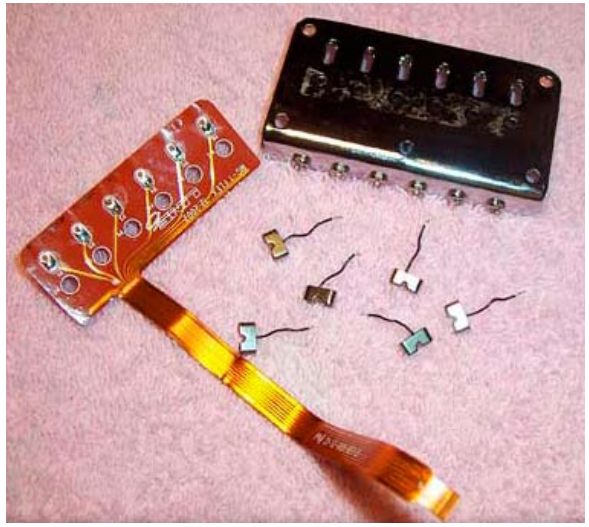


Fig.: 4.2: Line 6 bridge with integrated piezo pickup system.

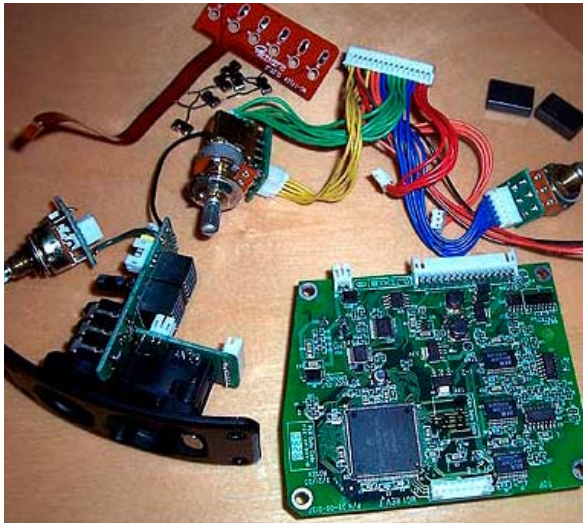


Fig.: 4.3: Line 6 electronics disassambled.

Fig.: 4.4: Line 6 electronics as mounted on the back of the guitar.

4.4 The Design

The styling of the guitar is discussed in this paragraph. A key value of this assignment is the stylling of the guitar network concept. The new technologies are more and more invisible. Therefore, most new (home) electronics products are black boxes. To reassure consumers most new technologies are packaged in copies of the design of the older product. This is also the case for the Line 6 guitar. Although it is a styled guitar and it is a guitar with its own character, something is not right. It looks like a conventional electric guitar from the fifties. Most guitarists are pretty conservative, so in that case this styling is a right decision. But for more progressive guitarists, this product is not styled right. New technologies ask for new appearances, without denying their roots. The guitar network concept should be styled in a more progressive way. It is a new technology with even more new possibilities. So, that should be translated to the external design of the guitar. The styling of the foot controller and the software interface are not shown in this report because of a lack of time.

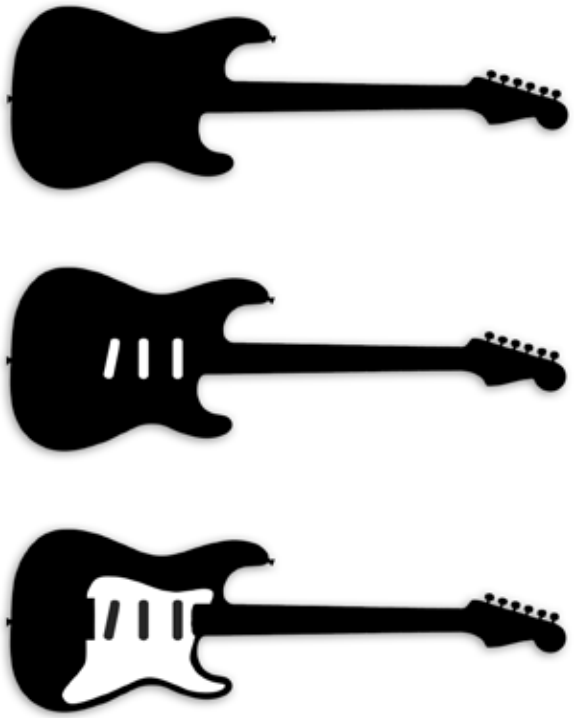


Fig.: 4.5: Fender Stratocaster outer form, pickups and pickguard.

4.4.1 First styling directions

The styling of the new technology is focused on adding an element to the guitar's body that is synonym for the amount of new technology. In the electric guitar design of the fifties, the pickups and the pickguard were a main element of the character and the "face" of a guitar (figure 4.5). Due to the introduction of the new technology of Line 6, the guitar losses its face. This is visible in figure 3.1 and figure 3.2. Therefore, this paragraph shows a study to a new 'face" for the guitar of the network concept. This styling is integrated with the archetype-like outer form of the Fender Stratocaster. The sketches of the form study for the face of the guitar of the wireless guitar concept are shown in figure 4.6. The elements added should also be a metaphore for the high tech wireless digital technology which is inside the guitar.

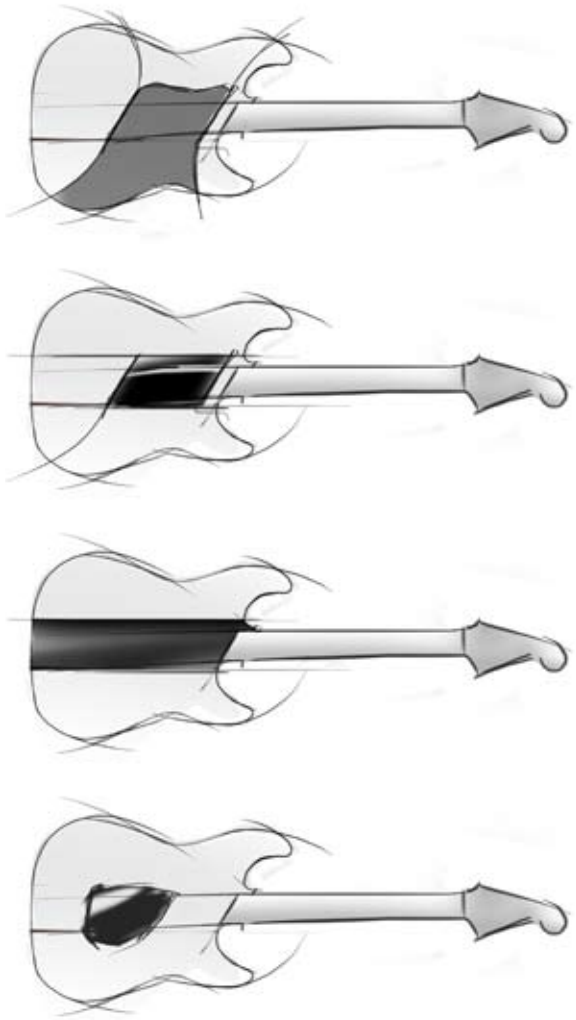


Fig.: 4.6: Sketches of Form Study.

4.4.2 Styling Concept 1

This concept as shown in figure 4.7 is based on a radical intersection of the traditional Fender Stratocaster body. The original electromagnetic technology is overwritten with a new anonymous technology. The high gloss metal and plastic parts are symbolic elements for digital electronics. This refers to the black boxes we call DVD players, laptops, mp3 players or iPODs. The archetype of the Stratocaster is preserved by not affecting the silhouette of the guitar. However, the inner styling is completely estranging this guitar from the original Fender Stratocaster guitar. It shows that this is the Stratocaster 2.0. Experiments with a kind of hybrid guitar are shown in figure 4.8. A traditional electromagnetic pickup is added at the neck position, both for the looks and the sound palette. These concepts are less interesting for the visualization of the next guitar.

Fig.: 4.8: Experiments of Styling Concept 1.

Fig.: 4.7: Styling Concept 1.

4.4.3 Styling Concept 2

This concept as shown in figure 4.9 is based on the visualization of wireless technology with dynamic light effects in the body. This dynamic part is not visible in the static pictures of this report, but should be directly related to the music played by the guitarist. To give this concept a face, the two pictures of figure 4.10 on the right show a combination with and without the intersection element of the previous concept. The chosen concept as shown in figure 4.9 is the best of both. The Body is glossy and semi transparant with the dynamic visuals in it. The "pick-guard" of high gloss metal gives a high contrast and gives the technology (and the guitar itself) a "face". This concept would even be more futuristic when the total front plane of the body is a touchscreen. In that case, the visuals should not only interact with the sound but also with the finger of the guitarist.

Fig.: 4.10: Experiments of Styling Concept 2.

Fig.: 4.9: Styling Concept 2.

4.4.4 Styling Concept 3

This concept as shown in figure 4.11 is a styling concept for integration of the visualization of wireless digital technology and the traditional guitar made of wood. The visual part of the digital technology is shrinked to the area around the guitar's bridge where the string vibration is picked up and transformed to a digital signal. The form of that area is a subtle inner form which communicates with the outer form, but is recognizable on its own. It is an archetype element for the digital component. That form is tested in different outer forms. In figure 4.11, the digital component is installed into the Fender Stratocaster model and in figure 4.12 into a Fender Telecaster and a free interpretation of the Fender Jazzmaster. This concept is more suitable for a whole guitar range and therefore more suitable for a broader market.

Fig.: 4.12: Experiments of Styling Concept 3.

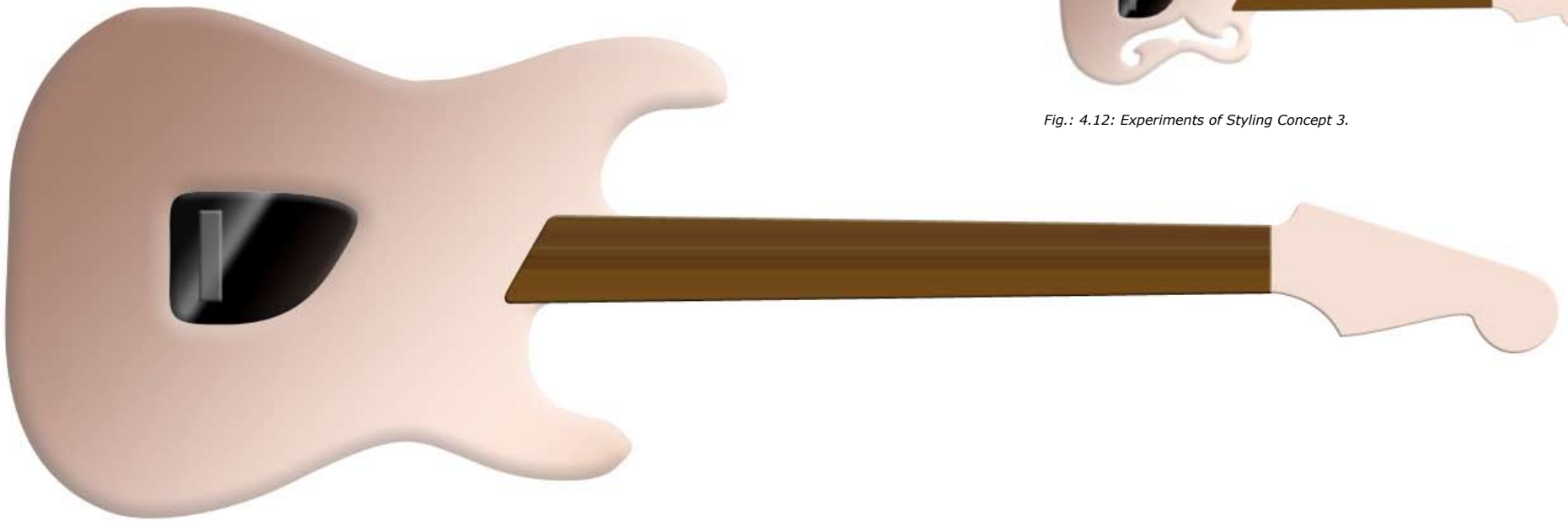


Fig.: 4.11: Styling Concept 3.

5. Concept Switch

5.1 Introduction

Although the previous three concepts have potential, the [opdrachtgever] was not enthusiast about the fact that the concept is pretty revolutionary and about the fact that the outer shapes of the concepts are based on existing guitar models. Although this was a key value of the concepts, the designer yield to the opinion of the "client".

5.2 The Design

From this moment on, the designer of this assignment focussed on the styling of the digital guitar, wireless or not. The digital aspect still needs to be visualized with the exterior styling. Therefore, a new outer form is designed and a new element within that form. This is done because of the fact that all three concepts of the previous chapter were based on the Fender-like styling and/or outer form. Evolution of the previous three concepts into a new form was not successful. Designing a new Stratocaster is not done in a few minutes. That design is a masterpiece.

5.3 Styling Direction

The new outer form is a conventional guitar form but it is unique (see figure 5.1). The shape, in combination with the inner form, should be recognizable as the digital guitar from a specific brand. The inner-form should make clear that this is a state-of-the-art guitar, but acceptable for the conservative guitarist. The last option of the four sketches shown in figure 5.1 is chosen for the final concept. This sketch shows a drop-like form, which surrounds the guitar's

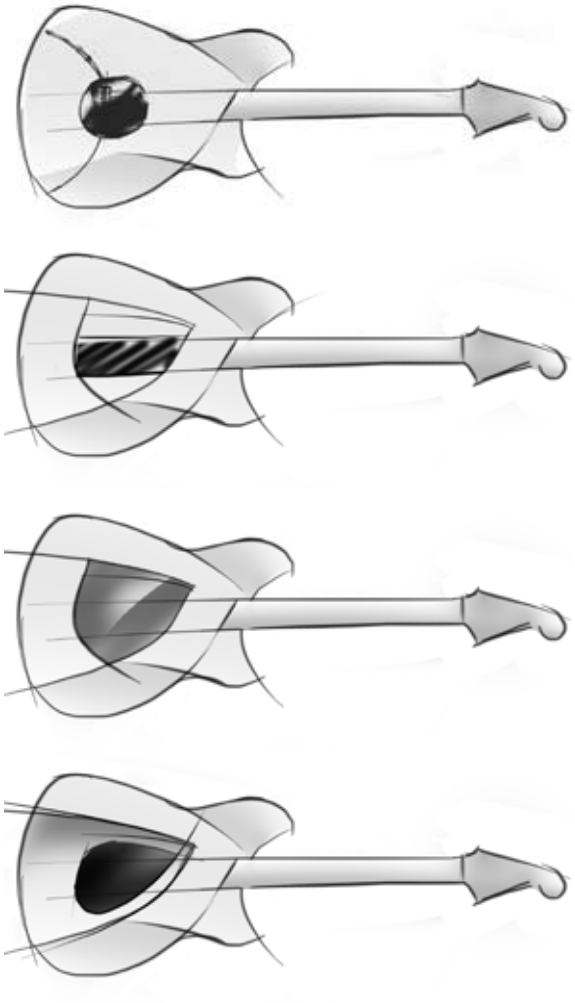


Fig.: 5.1: First Styling Concepts.

Fig.: 5.2: Variation on a Headstock Design.

bridge. This is actually the same starting-point as styling concept 3 of paragraph 4.4. The difference is that this form is round and sharp at the same time. This form language is also used in the outer contour of the guitar. Another difference is that there is a surface treatment added to the top plane of the guitar. Some 3D shapes should make the guitar more sophisticated. The headstock is also redesigned (figure 5.2). It is a variation on a known design, but balanced with the combination of round and sharp shapes, like the body contour.

5.4 Styling of the Concept

On this page some styling concepts for the digital guitar are shown. Differences are made in the use of colors, textures and 3D shapes (bevels and embosses).
In figure 5.3 the styling of the chosen concept is shown. The white panel is added as a purely aesthetic item, but refers to touch screens which might dominate the guitar in the future. The green area is the cover and the visualization for the technology of the guitar. The black area is the "heart" or "face" of the guitar and mirrors the strings. This as a metaphore for the digital technology which picks up the string vibration and "copies" it. It is a good copy of the original sound, like a mirror, but it is not the original.
The experiments of figure 5.4 show some more traditional looking styling concepts. To get the right "nowadays" / digital / web2.0 feeling, the final styling is apple green with white and high contrasts.

Fig.: 5.4: Styling Experiments of the Concept.

Fig.: 5.3: Styling of the Concept.

5.5 The last changes

The last changes made to the body are shown in this paragraph. The body is slightly smaller, the "face" is also it bit smaller and the green color is adjusted. These last changes are applied on the 3D model, as shown in the next paragraph.

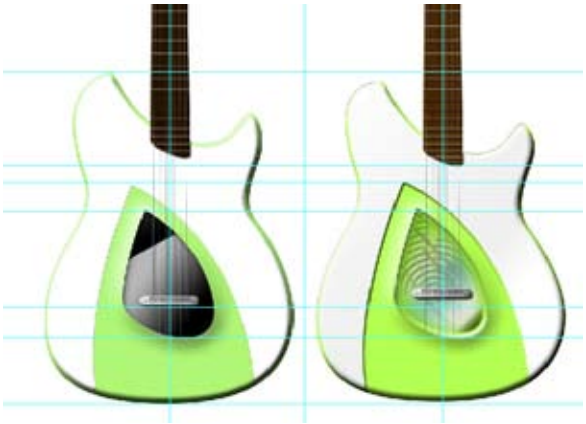


Fig.: 5.5: New Colors and Proportions of the Concept.

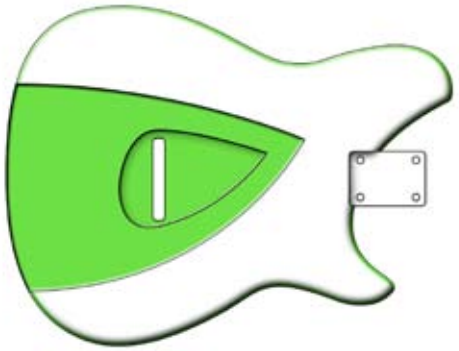


Fig.: 5.6: Final Proportions of the Concept.

Fig.: 5.7: Final Styling of the Concept.

5.6 The 3D Model

A 3D model is made as a mock-up. The guitar is real size and playable but not electric. The guitar's body is completely self made. The neck is taken from the electric guitar which is analyzed in the first assignment of EPD. Therefore a few compromises had to be made. Figure 5.8 shows the mock-up.

Fig.: 5.8: Mock-up of the Concept.

6. Production & Costs

6.1 Introduction

An intensive study is done in the first assignment of EPD. The Industrial Design Engineering Analysis of the electric guitar is descriped in the first report. The analysis was very useful to understand the production of the guitar. The guitar was completely copied in a 3D CAD model. The conversion to a proper Solidworks model was very time intensive. For this reason, the redesign is not designed in a 3D model. Therefore, a lot of the production information is based on the study of the first report.

6.2 Body

The body is a different shape as the standard stratocaster as analyzed in the first assignment of EPD. The ergonomics of the backside of the stratocaster body are copied, but the outer form is different. This is done for a unique look, but also because of a functionality: to reach the highest position on the neck of the guitar, the cutaways are slightly deeper than a Stratocaster. More important are the different places for milling. Almost all milling is done on the front side of the guitar, but all wood is kept between the bridge and the neck. The body is slightly bigger than a Stratocaster to keep enough wood around the guitar's bridge. That is good for the string vibration in the body (figure 6.1).
Apart from that milling for the electronics of the guitar, no extra cavities are necessary for potentiometers or the pickup switch. These functionalities are placed in the foot controller (see chapter 4). These changes make the production of this guitar body cheaper than the standard Stratocaster body.

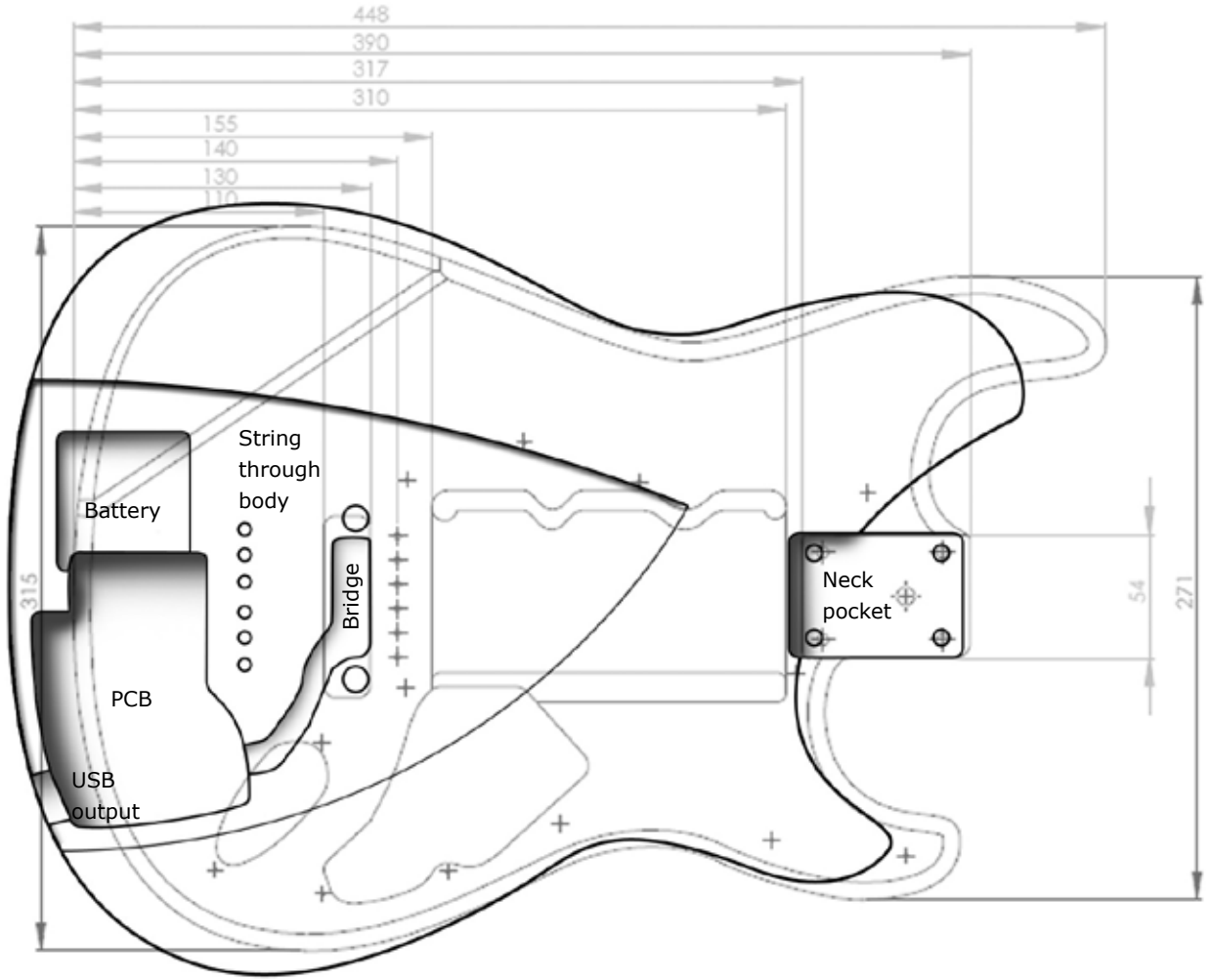


Fig.: 6.1: Body with Milled Areas (The Stratocaster body is viewed as a reference picture, also see Appendix A for more reference Technical Drawings).

6.3 Neck

The neck remaines the same as the traditional guitars and is a copy of the Fender Stratocaster neck. The dimensions of the neck are shown in Appendix A. Only the form of the headstock did change (see figure 5.2). This part is also analyzed with the Finite Element Method. Results of this analysis are shown in Appendix B. The neck is mounted with the same four screws as the Stratocaster.

6.4 Tuners

The tuners of the cheap stratocaster analyzed for the first assignment of EPD were not good enough to keep the strings in tune. Therefore, most smaller but quality guitar manufacturers buy these parts from specialists. Famous brands are Gotoh, Grover, Schaller and Kluson. Possible tuners for this guitar are the high quality chrome Grover mini rotomatics tuners (figure 6.2)[18]. These tuners are very accurate and stable.

Fig.: 6.2: Grover Mini Rotomatics Tuners.

6.5 Bridge

The bridge is also a part which should be bought. The Line 6 Variax bridge is a special stratocaster copy. This bridge has six small piezo pickups mounted under the bridge saddles (figure 4.2). The bridge of the digital guitar as designed in Chapter 5 comes with a so-called Tune-o-Matic bridge, which is a much smaller design. This looks more sophisticated in combination with the strings disappearing in the body (figure 6.3). The strings are removable via the back side of the body. The bridge that could be used for a definitive product is the L.R. Baggs T-Bridge: a Tune-o-Matic bridge with piezo pickups in it (figure 6.4).

Fig.: 6.3: Strings Disappearing in the body.

6.6 Output

The USB output, which is necessary for the power supply and / or the output of the signal (wireless or not), is positioned in the side of the guitar, connected to largest milled cavity in the body (figure 6.1). The

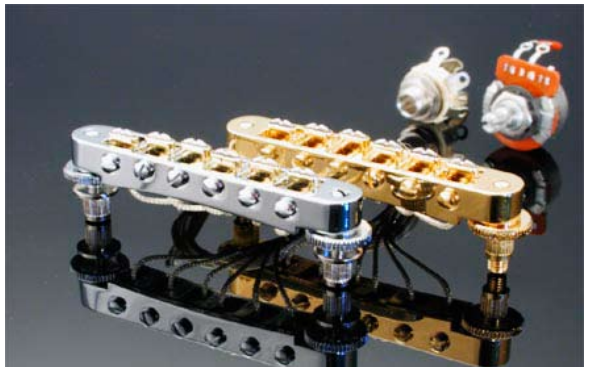


Fig.: 6.4: L.R. Baggs T-Bridge.

digital signal is processed here on the PCB as found in the Line 6 Variax guitars. The electricity is stored in the upper cavity in a 3,7 volts lithium-ion battery.

6.7 Front

The front plane of the guitar as dicussed in chapter 5 is made of two plastic panels. The white panel is made of white semi-transparent high gloss acrylic. The panel is glued on the upper surface of the wood. The green panel around the bridge covers the electronics of the guitar and gives the guitar a “face” (as mentioned in paragraph 4.4). This part is vacuum formed and should be removable. To remove this part, the bridge should be removed first. Than the part can be slided out of the guitar front. The cavity that appears under this part works as an acoustic sound chamber. While playing the guitar acoustic, the “amplified” string vibration is hearable.

6.8 Costs

All main parts are discussed now and therefore the costs per part are calculated or estimated. The calculation is shown in this paragraph.

6.8.1 Parts Costs

The estimated prices are based on the total costs calculation as made in the first assignment for EPD. The gross costs for the guitar parts and raw materials of the Motion Stratocaster copy are estimated on €40,00. Because of the fact that the new digital guitar should use better wooden and metal parts the costs of the parts are estimated on €100,-.
Apart from the normal parts, the new bridge costs $159.00 in retail [19]. A factor of 0,1 is used for the retail part prices, which means that approximately €15,00 is added for the bridge. The electronics of the Line 6 Variax models are not sold seperately. The gross costs of the Line 6 PCB are estimated on €15,-. That price includes the USB output connector. The price of wireles USB components are not available. The total costs of the parts is approximately €155,00 for the new digital guitar.

6.8.2 Manufacturing

The assembling costs are based on the time needed to assemble one guitar and the hourly wages for an employee in China. 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 costs for manufacturing a guitar is approximately €0,50 per guitar.

6.8.2 Shipping Costs

The price for shipping is also calculated in the first report of EPD. Shipping a 20 feet container from China to The Netherlands costs $2700 * 0,68 = €1836 (see first report EPD). This price is for shipping 750 guitars from China to Rotterdam. 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 including shipping is approximately €160,00.

6.8.4 Retail Price

The price of the new digital guitar in The Netherlands should be approximately €449,- with 19% VAT included. The profit for the manufacturer, distributers and retailers are estimated higher than in the first report of EPD. The profits are respectively 50%, 25% and 25%. The manufacturer gets 50% of €160,-, the distributers (and / or the government) get 25% of €240,- (gross price plus manufacturers profit) and the retailers get 25% of €300,- which is €75,-. The price in the stores is therefore (€375 * 1,19 =) €446,25.

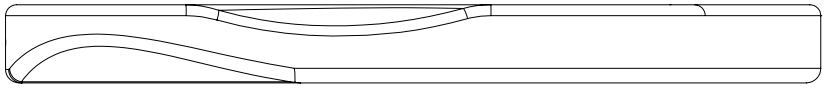
7. Conclusion

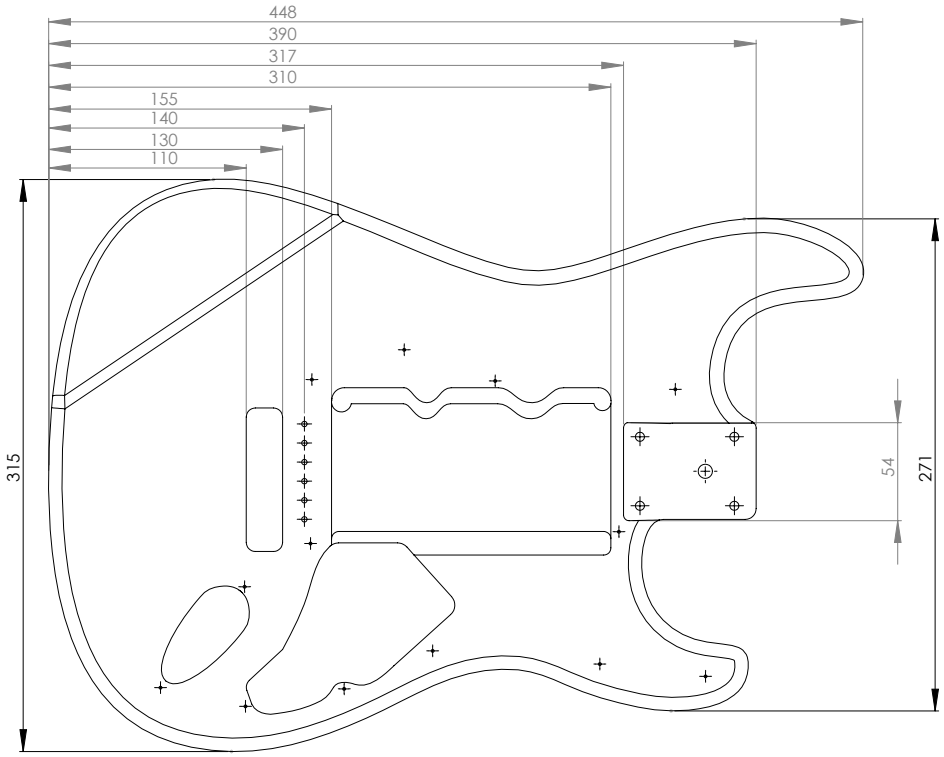
The first assignment of the course Evolutionary Prod¬uct Development was to make a complete analysis of a chosen product. Many students produced a very successful study with a complete overview of the products' history, context and inner beauty. This report, concerning the second part of the course, is not what I expected it would be. The second assign¬ment of the course started many discussions about "the next step" of a product but did not lead to any clear vision of the near future. The product phases theory did not help me in the way it helped analyz¬ing the product's history. In my opinion, the theory should not be used in the second part of the course Evolutionary Product Development, because this linear model limits creative investigation of new visions and perspectives.
The course asks for a rationalized and structured redesign of a product with these product phases in mind. I did not succeed in that way. But thanks to market and trend analysis and a concept switch, the end result is a nice concept guitar, wireless or not. More time was needed to find out if the wireless concept guitar is more than a conceptual thought: is it possible yet? Is wireless USB ready for the market? Nowadays almost everything is possible in my opinion. The digital revolution has created lots of possibilities that can be adopted in products. For the designer the task to determine which possibilities create sufficient added value. I hope that next year, students are allowed to explore these possibilities instead of argu¬ing why things are (r)evolutionary or not. Therefore, I have a recommendation for the course EPD2: why not fo¬cus on the next step of a company? Is it the product that evolves or is it the company that should try new market segments?

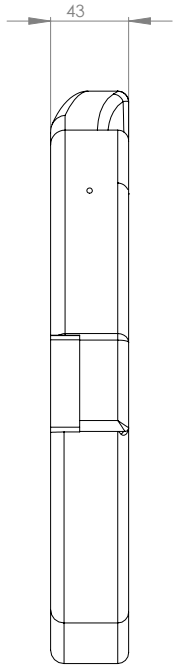
4. Sources

1. **Yamaha Announces World's First All-Bamboo Guitar,** http://www.harmony-central.com/Events/WNAMM00/Yamaha/YamahaBambooGTR.html
2. **Bamboo Guitar, where?**, http://www.ultimate-guitar.com/forum/archive/index.php/t-692253.html
3. **Gibson and Live Earth Announce Partnership in the Fight against Global Warming,** http://www.gibson.com/allaccessfeatures.aspx?aliaspath=/AllAccess/Gibson%20and%20Live%20Earth%20Announce
4. **Mctracz's Photos**, http://flickr.com/photos/mctracz/
5. **Line 6 Variax**, http://www.line6.com/
6. **Behringer iAXE393**, http:// www.behringer.com/iAXE393/
7. **Fender VG Stratocaster**, http://www.fender.com/vgstrat/
8. **Gibson Robot Guitar**, http://www.gibson.com/RobotGuitar/
9. **Manson Guitar Demo**, http://www.youtube.com/watch?v=B-4lPjRsrIA
10. **While My Guitar Gently Beeps**, http://www.intel.com/cd/corporate/pressroom/emea/eng/248418.htm
11. **Wii Controllers**, http://www.nintendo.com/wii/what/controllers#remote
12. **Guitar Hero III: Legends of Rock**, http://en.wikipedia.org/wiki/Guitar_Hero_III:_Legends_of_Rock
13. **What do guitarists want?**, http://findarticles.com/p/articles/mi_hb5264/is_/ai_n20418033
14. **Meet Your Maker: John Nady**, http://www.guitarplayer.com/article/meet-your-maker/Aug-07/30302
15. **Wi-Fi**, http://en.wikipedia.org/wiki/Wi-Fi
16. **Bluetooth**, http://en.wikipedia.org/wiki/Bluetooth
17. **New Wireless USB Products Expand Marketplace Offerings**, http://www.usb.org/press/WUSB_press/2008_04_02_usbif.pdf
18. **Grover mini rotomatics chrome 6L**, http://www.voxhumanawebstore.nl/webstore/product_info.php?cPath=81_82_87&products_id=528
19. **L.R. Baggs T-Bridge**, http://www.stewmac.com/shop/Bridges,_tailpieces/Electric_guitar,_Tune-o-matic_bridges/L_R_Baggs_T-Bridge,_Piezo_Loaded_Tune-o-matic.html

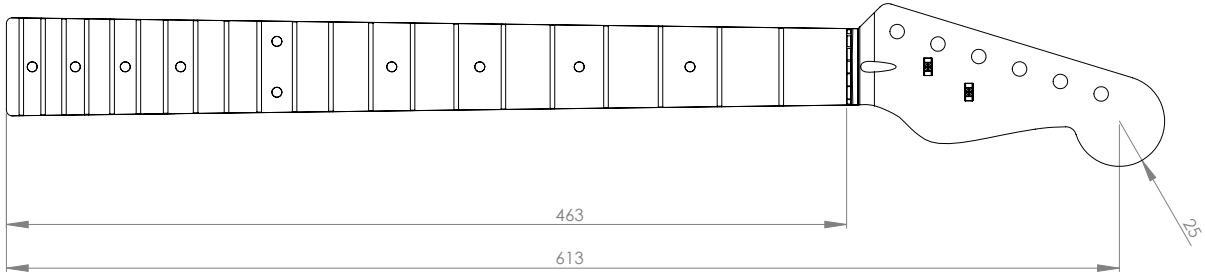
Appendix A
Technical Drawings

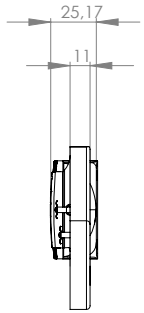






UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	TITLE:	
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A				DWG NO.	A2
			MATERIAL:	Body	
			WEIGHT:	SCALE:1:5	SHEET 1 OF 1





UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE:
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. Neck Assembly / A2
				WEIGHT:			SCALE:1:5 / SHEET 1 OF 1

Appendix B
FEM Analysis

Introduction

For this assignment the deformation of the neck of the electric guitar is analyzed, using the finite element method. The neck should resist the enormous amount of string tension. Therefore, a metal truss rod is added inside the neck. This truss rod delivers a contra moment, to compensate the string tension (see figure 1). This analysis will show what happens when the truss rod is removed.

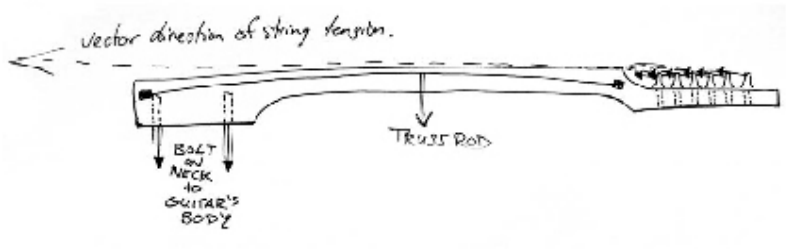


Figure 1

Goal of the analysis

Figure 2 shows us that the neck will bend in a vertical direction. The goal of the analysis is to calculate the total deformation of the neck. This is very important for the guitarist, who wants a maximum "action" (string height above the neck at the so-called "twelfth position") of 1mm.

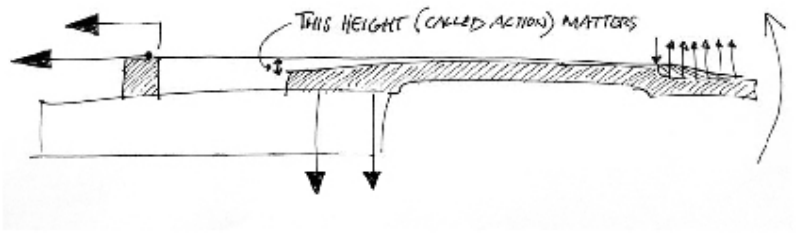


Figure 2

Validation of the model

To validate the used Ansys model an estimation of the phisycal behaviour of the neck should be calculated. If the results of this calculation correspond with the results found in Ansys, the simplified model should be viable.

At first, a VLS is made (figure 3). Force P is the string tension, with angle α. The neck is simplified as a beam with length L, height h and width b. The bending of the beam is calculated with the formula $\delta = \frac{PL^3}{3EI_z}$. The profile of the simplified neck is a rectangular beam. Therefore, the moment of inertia is $I_z = \frac{bh^3}{12}$.

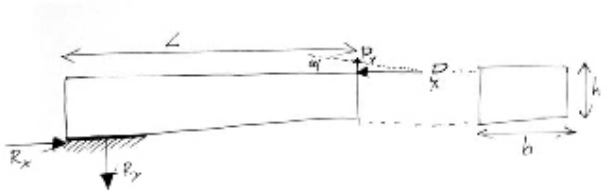


Figure 3

Data:

$P = 460N$

$L = 550 \cdot 10^{-3} m$

$b = 50 \cdot 10^{-3} m$

$h = 25 \cdot 10^{-3} m$

$\alpha = 7°$

$E = 12 \cdot 10^9 \, N/m$

$$\delta = \frac{P \cdot L^3}{3 \cdot E \cdot \left(\frac{b \cdot h^3}{12} \right)}$$

$$\Rightarrow \delta = \frac{460 \cdot \left(550 \cdot 10^{-3}\right)^3}{3 \cdot 12 \cdot 10^9 \cdot \left(\frac{50 \cdot 10^{-3} \cdot \left(25 \cdot 10^{-3}\right)^3}{12} \right)} = \frac{76{,}5}{2{,}3 \cdot 10^3} = 33 \cdot 10^{-3} m$$

The total deformation in the Ansys model with vector force $P = 461N$ is 33 mm. This should prove that the model is viable.

Analysis

The Ansys model is also a simplified version of the guitar's neck. The headstock is removed and the curve of the neck intersection is simplified. This is done because the student edition of Ansys Workbench 9.0 has lots of limitations.

First, the mechanical properties of the material are added, in this case maple wood.
Properties:
Young's Modulus: 1.2*10^10 Pa
Poisson's Ratio: 0,434
Density: 700 kg/m3

The mesh that is added by Ansys is shown in figure 4 and 5.

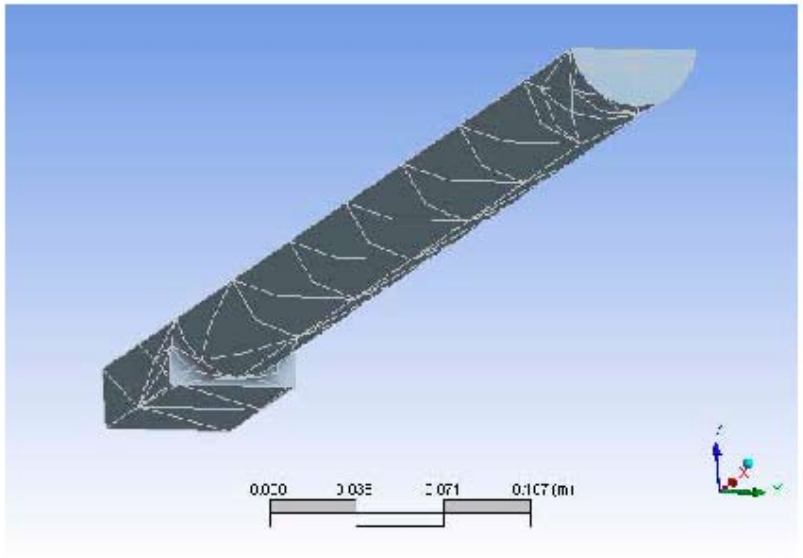


Figure 4

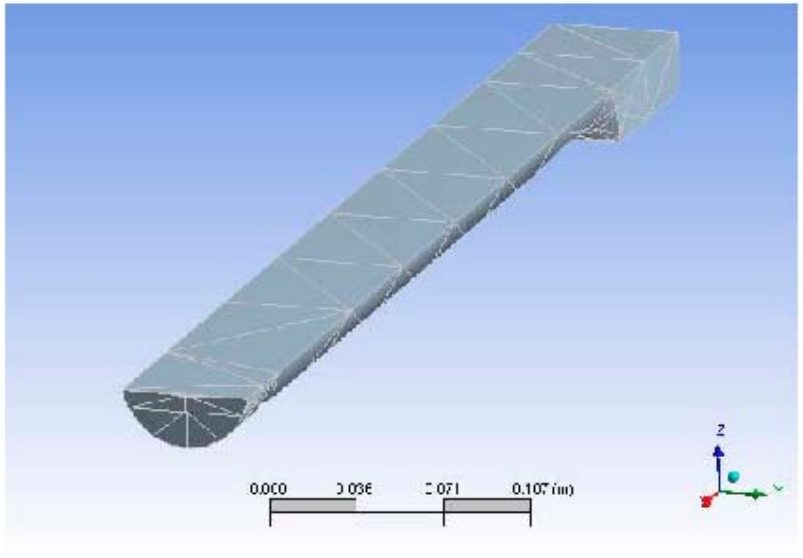


Figure 5

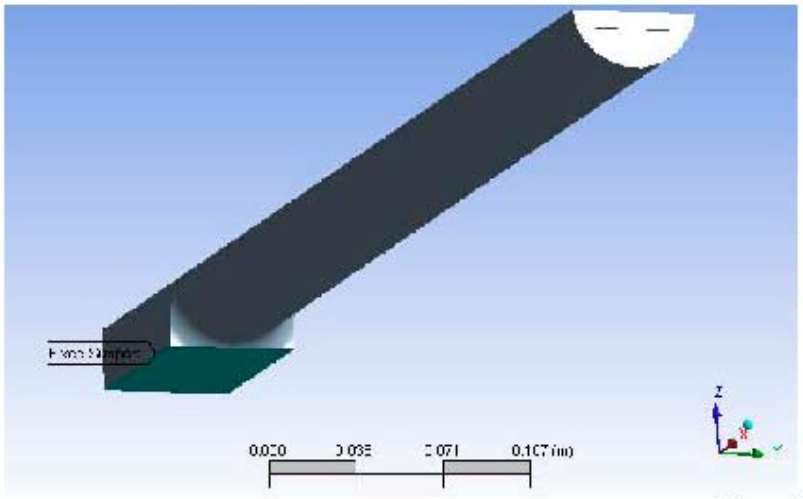


Figure 6

The neck is fixed on the surface that is mounted to the body (see figure 6).

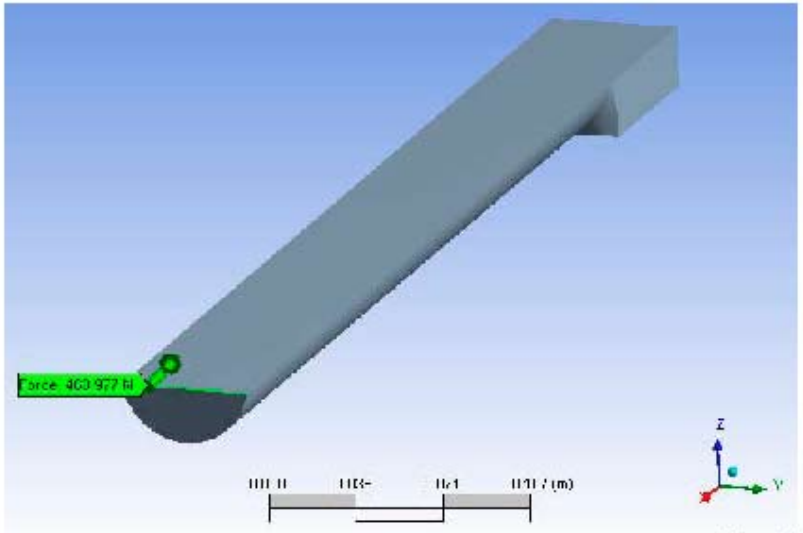


Figure 7

The Force added to the model is the total amount of string tension, which is 461N (see figure 7). The x-component is 460N and the z-component is 30N (based on the angle of the strings).

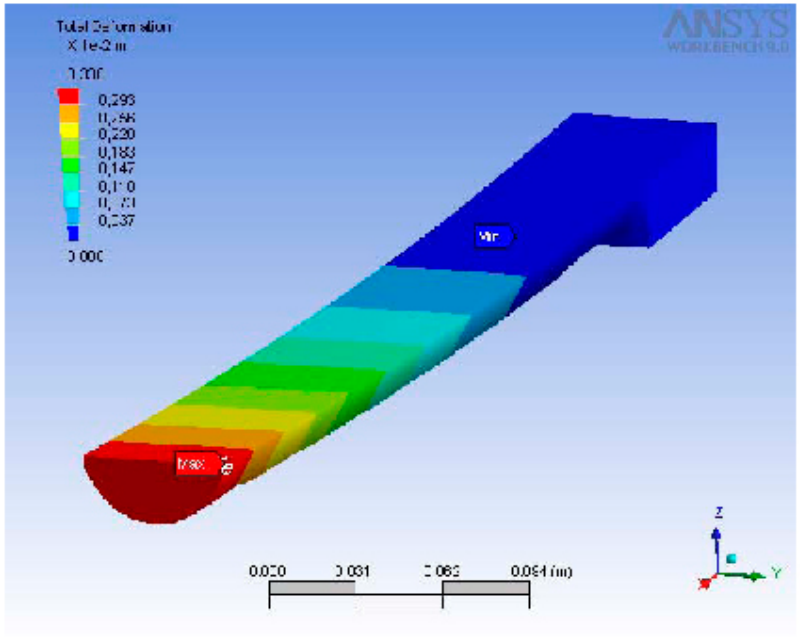


Figure 8

The maximum total deformation is 3,2963*10^-3m (figure 7), which shows that the model is viable. This also shows the need for a truss rod in the guitar's neck.

Sources

String tension: http://www.noyceguitars.com/Technotes/Articles/T3.html
Poisson ratio & E-modulus: http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/ch04.pdf
Density of maple wood: http://hypertextbook.com/facts/2000/ShirleyLam.shtml
More Information about woods:
http://docserver.ingentaconnect.com/deliver/connect/dav/16101928/v88n6/s18.pdf?expires=1208808521&id=43761658&titleid=75000347&accname=TWENTE+UNIVERSITY&checksum=91CF66636059D686A07ECF1CB342427F