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How To Build The Electric Balalaika

A Complementary Report to www.balalajka.com
and the Theory of Music behind it.

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Abstract

This short essay is only to be seen as a complementary report to the information available at *www.balalajka.com*, where you will be able to find a detailed working log along with more informative pictures of the instrument build itself.

The aim of this project was to build an electric balalaika, and the ambition was that the instrument would be completely functional and playable. The method used is primarily straightforward; the project started with researching about the building of musical instruments and then the knowledge gained was applied to build an electric balalaika.

The result of this project was, as hoped, a functioning electric balalaika. I can contently conclude that it is fully possible to build a good and working instrument, even if the instrument in question is a very unusual one. The costs were also lower than expected in the beginning of the project. Pictures and sound examples may be found at *www.balalajka.com*.

Foreword

I want to begin with thanking everyone who has contributed to this project; the support and help have been invaluable. This project itself has been worthwhile and enjoyable to execute. I sincerely hope that you will find this essay both interesting to read and also informative, if you choose to execute a similar project in a near future.

Notice: Henceforward, I will refer to the balalaika when writing “balalajka”. This is due to the fact that I want to promote the Swedish spelling of this word, as well as the address to my homepage.

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Introduction

This essay is to be seen as a short complementary report to the information available at *www.balalajka.com*. The main part of this essay will be a brief description about what I have done. I am also going to inform you about some of the basic theoretical aspects that is good to know, i.e. it will tell you for instance how to calculate the fret distances. Preferably, it is recommendable to bear in mind that the essay will only treat some of the choices and aspects of the build, for more detailed and accurate information I would refer you to *www.balalajka.com*.

The question that will be answered in this essay is how to build an electric balalajka.

Objective

The objective of the project is to build an electric balalajka, although the purpose of this essay is also to inform you about some of the more basic theoretical aspects.

Limitation

This project is limiting itself quite well; I shall build an electric balalajka, no more and no less. If any part of the project takes more time than expected, I have the possibility to cut down the final part, the electrics and/or this essay. Likewise if I get more time left over, then it will be possible to either prolong this essay or continue experimenting with the electronics.

I am not going to restrict my sources to only literature or similar; the only sense in which I will limit the essay is that I do not want it to be too long. The single purpose it should serve is as a complementary report to *www.balaljaka.com* and nothing else.

Description of the process

Even before I began this project I started researching it on the Internet, mostly to get an idea if it would be possible to build an electric balalajka. The result of this research is as you can guess; otherwise I would not have bothered with writing an essay about this subject.

As I realized that this project is fully possible to fulfil, I started to inspect the subject even more closely. I realized from the start that this project was going to take more time than what a “normal” school project would take. When researching the subject of building a musical instrument, I did not restrict myself to only balalajkas; instead I read about everything from mandolin building to building an electric guitar. I noted down all the ideas that came to me during my research and used them during the build itself. I also made sure so that I had everything fresh in my mind before commencing every new step of the build.

The theoretical part of the essay has been written and researched when I wanted to get inspiration for my work on the balalajka. The only difficulty that I have had with the process of writing this essay was to write a comprehensive and simplified version of the musical theory; this since it is a very complex subject, if you want to understand it fully.

Theoretical walk-through

Here I will tell you some things about the musical theory.

What is sound and how is it created?

To understand this subject you have to begin with understanding what sound really is. If you ever have attended a physics/biology or psychology class you probably have a pretty good idea, but depending on which of these classes you have attended you would have learned a different answer. Every one of these scientific areas has an own perspective on the subject.

It is the definition of sound that is debated, you have surely heard the philosophical question: “If a tree falls in the forest and no one is around to hear it, does it make a sound?” There are many approaches to this. A physicist would say that sound is the vibration of the molecules in the air; others would say that the definition of sound is our interpretation of the vibrations in the air.

Anyway, it does not really matter, whether the vibrations in the air or if our interpretation should be defined as sound. Let us go with the physicists and say that sound is the quickly varying pressure wave within a medium, with this I mean that sound may be transferred through all forms of matter, gases, liquids etc. The stiffness and the density of the medium will determine the ease, the distance and the speed of the sound transmission. (A lower stiffness and a higher density will make the sound waves travel slower through it.)

Sound may be transferred both as longitudinal waves and as transverse waves. These sound waves are the transmission of sound, and different sound produce different sound waves; these vary in timbre, frequency (number of oscillations per second, measured in Hertz, Hz) and amplitude (the size of the pressure differences / loudness). Other important factors to look at may be the direction and the speed. When talking about sound it is also good to remember that our ears can not pick up every frequency, our area of hearing lies between 20 and 20 000 Hz. This area of hearing is reduced by age.

The basics of a string instrument:

String instruments are made out of two parts, a vibrating string/strings and some kind of resonator, a sound box, which amplifies the sound; it also improves the sound itself. It is also this, which gives many instruments their individual characteristics. Technically a sound box does not amplify the sound of the instrument, even if this is the general explanation; the reason to this is that all the energy, which is used to vibrate the strings, has already been added. (You are not adding any extra energy to produce the louder sound.) The way in which the sound box works is that it provides a larger surface area, which vibrates. These vibrations are then transferred to the air; this gives us a larger volume of air that vibrates and the result of this is a much higher sound/volume.

The sound is produced by the vibrating strings, a string under tension will vibrate with a specific frequency. This frequency depends on several factors, the length of the string, the amount of tension on the string and the strings specifics, i.e. the density of the string along with the properties of the string material.

The string vibrates between two points/nodes, one of them is the bridge and the other one may vary. When you play on an open string the other node will be the nut, but when you are playing a chord the strings will vibrate between the bridge and one of the frets. By this method the string will get another frequency when playing a chord.

The thing that is characteristic for the sound of the balalajka is the resonance along with its special tuning (the two E-strings). The playing techniques also do a part for the sound characteristics. The frequency of the first A-strings is 440 Hz and the frequencies of the two E-strings are 329,6 Hz.

How do I build the perfect instrument?
You might ask yourself what you need to do to build the perfect instrument; luthiers have spent their lives trying to answer this question. I can tell you right away that there is no such thing as the perfect instrument. It is nearly impossible to predict the properties of an instrument; there are thousands of variables that will affect the sound. Worth mentioning concerning this subject is also the famous saying which is relevant: "beauty is in the ears of the beholder", with this phrase I mean that something that sounds great in my ears may be the worst thing that you ever have heard, an example of this is perhaps my singing voice.

If we continue this speculation; there is the fact that two different people may play the same instrument and still you might hear a difference in tune. All this ruins all kind of speculation about building the "perfect" instrument. The variables that affect the sound do this to both electrical and acoustic instruments, even though some aspects of them differ; as for example electrical instruments are affected by the pickups meanwhile the resonant is the affecting component of an acoustic instrument. If you want a short answer, every single thing that you change on an instrument may have an effect on its tone.

There is no long answer to this as all the different factors may influence the sound a great deal; surely some of them are easier to change, the pickups, the tuners, the bridge, the strings, the shielding etc. The choices of material for the body and the neck, the fretboard, the thickness of the neck etc, even how the tree has grown may influence the sound; you soon realize that the list is a never-ending one.

It is impossible to predict how the result will differ, but it might be good to keep all of this in your mind during the build, but it is no use to spend any time speculating on it.

How does an electric instrument work?
Electrical instruments work without a sound box, which amplifies the sound; instead the amplification is done with electronics. The electronics, which pick up the sound are called pickups and there are many several different types of them. The function of the pickup is to convert the vibrations that the strings make into electronic signals.

The two most usual types of pickups are magnetic pickups and piezoelectric pickups; the magnetic pickups can be divided into single coil pickups and humbuckers. Since the single-coil pickup is the most common one it might be good to understand how it works. The principle is the same with humbuckers although they are a bit more

advanced; the technique in other pickups types, as for example the piezoelectric, is much different, you might find more information about this on the Internet.

The components of a single-coil pickup are simply copper wire and magnets; usually the number of magnets corresponds to the number of strings on the instrument. The magnets are usually fastened on a piece of plastic or wood which then are screwed to the instrument, the copper wire is simply winded around the magnets.

The principle of the pickup is pretty simple; you could easily compare it to a bicycle lamp or any form of a generator. If you ever have studied physics you should have heard the basics before, it can be explained magnetic induction or, as it is more commonly known Faraday's law of induction. Faraday's law states that an electrical current will be induced in a closed circuit within a magnetic field, if a change in the magnetic flux happens.

The strings on the instrument, which vibrate, disturb the magnetic field that originates from the pickup. When this happens an electrical current is created by the induction phenomenal. This signal is by itself too weak to drive a speaker by its own; therefore the instrument is connected to an amplifier by a cable. The job of the amplifier is simply to boost the signal so that it gets powerful enough to drive a speaker. (Speakers are usually built into amplifiers designed for instruments.)

When winding a pickup there are some factors, which affect the sound, for example the thickness of the copper wire and the size of the magnets etc. To get the sound that you want, you will need to experiment with the winding. If you do not want to wind them by hand you could take help of a simple sewing machine or similar.

Some people claim that the positioning of a magnetic pickup is essential on a guitar, but this will most likely not affect you. This has to do with nodes and antinodes, but if you are using an ordinary playing style this will not affect you. You could instead of altering the positioning also change the pickup winding, but this would demand a great deal of experimentation. My personal recommendation is in short that you do not bother with it, choose the positioning by the appearance.

If you are using the correct balalajka string setup, then you will have different distances between the strings. The result of this will be that the sound will differ a bit if you are using commercially bought pickups, this is because the strings would not vibrate in the middle of the magnetic field. As you surely understand after having learned the basics of a single-coil pickup this may differ the sound very much, but this also depends much on the individual pickup. If we think about this in theory you might get a better sound if you position the pickup according to the A-string instead of the E-strings. This is because the double E-strings are wider, if you are using bass-strings on them they are with no doubt much wider. The reason to this is because a single coil pickup only captures a very small portion of the vibration, the wider E-strings would therefore give you a bigger amplitude. This is of course also something that may vary between different pickups, but it might be worth thinking of.

The faculties that I was looking for on my balalajka were a bright sound, similar to that one of an acoustic balalajka; there is not so much more that could be said about it. You can visit *www.balalajka.com* to hear sound examples of my balalajka.

How do you calculate notes?
Music is a combination of sound waves followed by each other; the difference between them is the frequency in which they vibrate. Music is usually classified as pleasant, therefore you could divide sound into two categories: noise and music. The border between music and noise is subjective, many newer composers use “noise” in their compositions.

Anyway, when talking about music there are some key objects that you should know. To begin with you have the word pitch, this simply refers to the highness or lowness of the sound, the pitch is tightly connected to the frequency. The difference between the two is that the frequency is objective and always the same, while the pitch is subjective and may therefore vary a bit. To simplify things you could say that they are the same, as both of the words refer to the way in which the sound waves vibrate.

We repeat a little of the basics of string instruments. A string under tension will vibrate in a specific frequency, a specific number of complete vibrations each second; this is measured in hertz, Hz. We humans can hear sound in the range between 20 --> 20 000 Hz, but our area of hearing is reduced by age.

The fundament of music is harmony, the way in which different pitches are connected to each other. This is what makes melodies sound pleasant and good-sounding in our ears; it is from this we have divided the frequencies into notes and tunes. A note is simply a fixed pitch or a specific frequency.

Harmonics is as said the key component in music and music theory, it has to do with the interval between the pitches; the interval between the frequencies. (It is all connected to how our ears interpret the sound waves). If the interval between two notes is small they will sound good together, which is also the reason to the system with different octaves. If you were to double the frequency of a note you would go up an octave, and if you were to divide it by two you would go down an octave.

Frequency * 2 ^ n = Frequency in an other octave $C_0 \approx 16{,}35$ Hz $A_0 = 27{,}50$ Hz Example, A in the fourth/middle octave 27,50 * 2^4 = 27,50 * 16 = 440,00 Hz

The reason to why the forth octave is recognized as the middle octave is since it is located in the middle of a piano. A child can hear 10 octaves (15 * 2^10 = 15 360 Hz), thereby the forth octave is not the middle of our area of hearing during our whole life.

The temperament, the system of tuning that is internationally accepted today is called the twelve-tone equal temperament. You will be able to see a list of the tones on the next page; the system is built up using twelve notes in each octave, the twelve parts are logarithmically equal in size. The reason to why it is logarithmical is since a linear scale would not work as well; this is because you want the same ratio between the notes. (A linear scale would not give us the same percentage increase.) There also exist other temperaments with different number of notes in each octave, as well as systems, which are not logarithmical.

The standard for the musical pitch from which all notes are calculated is the A above the middle C, and its frequency should be 440 Hz. The standard have changed over the years, but the others are not as common nowadays.

Here is a list of our basic notes, which are located in the middle octave.

Note	Frequency
C	**261,626 Hz**
C#	277,183 Hz
D	293,665 Hz
D#	311,127 Hz
E	329,628 Hz
F	349,228 Hz
F#	369,994 Hz
G	391,995 Hz
G#	415,305 Hz
A	**440,000 Hz**
A#	466,164 Hz
B	493,883 Hz

When calculating a note, you measure the frequency of the sound wave. This is the way in which electrical tuners work; this allows a player to accurately tune an instrument.

If you study the table above you will notice that the frequency always increases with 5,9463094%, between the different notes. The exact factor is the twelfth root of two (2^(1/12)); it is also this principle that is being used when calculating fretboards. The reason to why the base is two is because of the system of octaves (overtones), when the factor is 12/12 the frequency will double... The reason to why the exponent is 1/12 is since our temperament is made up of twelve notes, other equal temperament systems that have another number of notes uses another exponent instead.

> If you look at the factor as 2 ^ (X/12), you might get a better understanding.
>
> X= 02 – 440 * 2 ^(2/12) = 493,883 Hz
> X= 12 – 440 * 2 ^ (12/12) = 880 Hz

How do you calculate a fretboard?

This is something that will be important for you, if you do not choose to make a fretless neck. If you were to do the calculations by hand, this would take a very long time, so it is recommended that you use some kind of a program. (Read more further below). The scale length, the length between the nut and the bridge will be needed before commencing the calculation.

There are two factors that often are referred to when talking about this subject; this is 17,817/17,835 and the twelfth root of two. These figures are keys to divide the fretboard into semitones, the twelfth root of two = 1,0594631. Below you may find out exactly how they are connected.

As you might have guessed if you ever have thought some more about the fretboard on a guitar, the ratio of the distance between all the different frets and the bridge are the same. This ratio is 2^(1/12) : 1 or 1,0594631 : 1. Calculating the distances by these facts is possible, but it is much simpler if we throw around the numbers a little, so that we get a simple constant instead. (This is shown below.)

This is how you get the constant:

The twelfth root of two - sqrt[12]{2} - 2^(1/12)

S = The total distance between the nut and the bridge – the scale length
X = The distance between the first fret and the nut
S - X = The distance from the first fret to the bridge
(S - X) / S = 1 / 1,0594631
(S - X) = S / 1,0594631
S = (S - X) * 1,0594631
S = S * 1,0594631 - X * 1,0594631
S * 1,0594631 - S = X * 1,0594631
S (1,0594631 - 1) = X * 1,0594631
S / X = 1,0594631 / (1,0594631 - 1)
S / X = 1,0594631 / 0,0594631
S / X = 17,81715375…

You might be wondering where the figure 17,835 comes from. 17,817 is the exact mathematical figure, but this assumes that we have a theoretically perfect string; needless to say that this is unattainable. Over the years many other factors have been tried for example 17,835 and 17,800; this has been done to try to improve the pitches of the notes, but the current standard is 17,817, it works as a good compromise. In reality it will not matter if you choose to go with 17,817 or with 17,835, since you probably will not be able to cut the slots for the frets that close anyhow. The chance is also small that you would not hear any difference, if you were to compare these two.

You start of by dividing the scale length (distance between the nut and the bridge) by 17,817, this becomes the distance between the nut and the first fret. You then subtract this distance from your scale length, and then you divide this new length by 17,817, this then becomes your distance between the first and the second fret; then you continue this way until you have reached the number of frets that you want on your balalajka (or other instrument).

Example of calculating the distances:
Scale length: 45 cm

45 / 17,817 ≈ 2,53 (distance to the first fret)
45 – 2,53 = 42,47
42,47 / 17,817 ≈ 2,38 (distance to the second fret, from the first)
42,47 – 2,38 = 40,04
. . .

Calculating in this way will place the 12th fret exactly in the middle between the nut and the bridge. If you have read the earlier text you will know that twelve frets is the same thing as an octave. From physics you remember that dividing a theoretically perfect string with two will double the frequency.

Below is a code that I used for calculating the fret distances on my TI84 calculator; it should also work on the earlier models. You should be able to translate it to other calculators or to a computer if you need; the code is not so advanced.

Code for a Texas Instrument calculator

```
Disp "17,817(1) or ", "17,835(2)"
Input A
If A=1
Then
17,817 -> k
Else
If A=2
Then
17,835 -> k
End
End
0 -> C
0 -> I
Disp "Length"
Input L
While I≠24
L/K -> X
C + X -> C
I + 1 = I
L – X -> L
C -> L1 (I)
Disp I, C
Pause
End
```

If you want more than 24 frets you only need to change I≠24 to the number of frets that you want. I would like to take the opportunity to thank Jona Hammarström for his help making this program work correctly.

If you go to lists, you will be able to see the values in a gathered form too. You might calculate this in any unit that you want, as it does not depend on it. When you have the distances there are several possible ways for you to get them to the fretboard, one is of course to use a ruler and mark them yourself. Another is that you might use a computer program and print out the lines and thereby get the correct distances.

If you need to make this program on a different calculator, then these are the important commands:

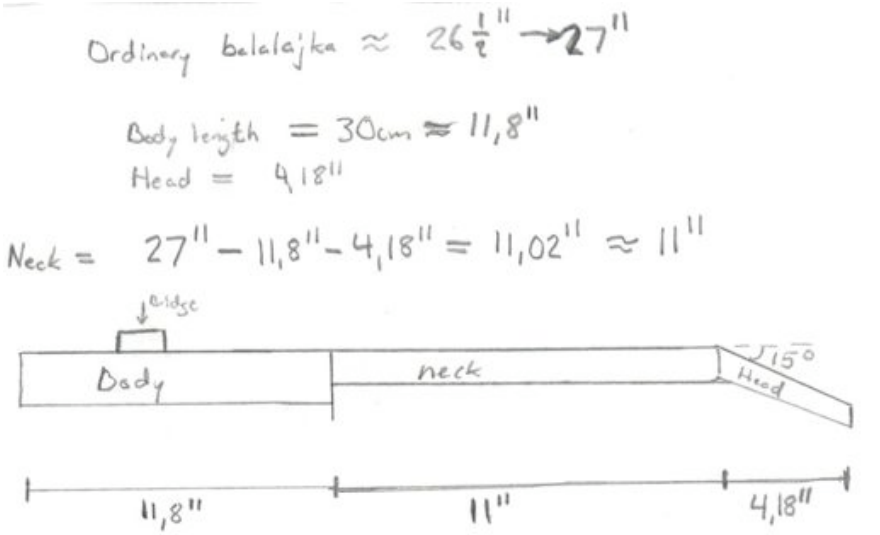
```
17,817 -> k
0 -> C
0 -> I
Input L
While I≠24
L / K -> X
C + X -> C
I + 1 = I
L – X -> L
Disp I, C
End
```

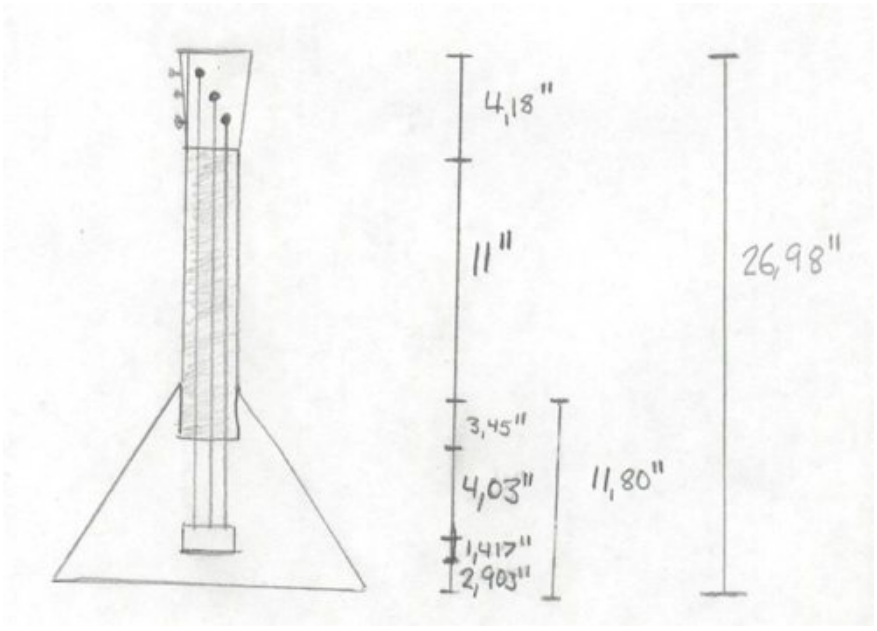
Report

This is the main point of this essay; here you will see a short description about my project and what I have done. I will begin with saying that the total material cost of the build was ≈2100 SEK or ≈330 USD or ≈235 EURO. (This excludes the tools needed etc). Afterwards I have also spent some money on improving the electronic part even further.

Intro:

I chose to use oak for the body, neck and for the head, I used ebony for the fretboard and the pickguard is made out of birch. The dimensions that I have used may be seen at the picture below, they are following the standard size of a prima balalajka.





The scale length will differ, depending on how high you want to place your bridge, and the length of the neck itself. The fretboard is calculated as I explained earlier, in the theoretical-walkthrough. Depending on the scale length and the placement of the neck the distance between the frets will differ. Needless to say, it might be easier to get clear tunes if you have longer distances between the frets.

Materials:
The properties of the wood materials used by me in the build.

Oak:
I used oak for the body, neck and the head.
The reason to why I chose this material was because it is a very strong and beautiful material. If you yourself are interested in this material remember that it is quite heavy, the body part of my balalajka had a weight of over three kilos. If you want a smooth surface on your instrument, remember that you need to use pore filling, I would also recommend you to pre-drill the holes, since I broke a couple of my screws.

Ebony:
I used ebony for the fretboard.
Ebony is a very dense material and it is also very strong, in a sense it will help me to reinforce the neck. This is one of the classical materials for fretboards; just as other fretboard materials it gives a very good tone, much of this is thanks to its density, and its ability to transfer vibrations.

Birch:
I used birch for the lowered pickguard.
The main reason to why I chose birch is that it is a pretty easy material to work with, my plan from the start was to carve out a pattern. When I was finished, I darkened the wood with lacquer, ebony coloured; the result may be seen on later pictures.

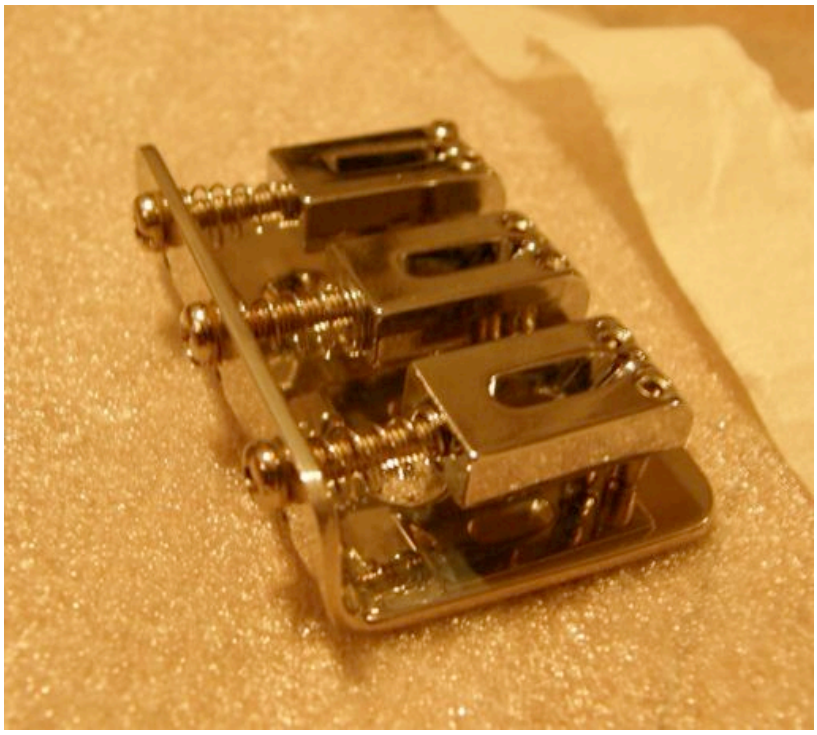
You will be able to find out how the balalajka sounds if you visit *www.balalajka.com.*

Here is a picture of the wood materials, excluding the ebony for the fretboard.

Following will be a list of the materials used in the build

The tuners:
These were ordered from the US, the price of them including shipping was 28$. They are probably made out of brass. One of the screws was damaged, so I had to get a hold of new screws for it. They are not designed to be routed down into the head; they are decorated on the other side as you might see at the later pictures.

The bridge:
The cost of it was 29.50$ plus shipping, so the total cost was 44.96. The price of these was pretty high compared to the manufacture cost and the space distance between the strings is unfortunately the same. I am not totally sure that I would make the same choice again, but the only other alternative is to make the bridge by yourself.



The frets:
I decided to go with stainless frets, since I believe that they have a higher quality. I ordered four foots, the dimensions of frets may be found at *www.balalajka.com*.

The knobs:
I made these myself by using a hole cutter attached to a pillar drill, then I used sand paper to get a smooth surface. They have been oiled just as the body.

The neck plate:
I did not use this as a neck plate, instead I engraved my name into it and placed it on the inside of the control cavity cover, I used a dremel to make the engraving. I also had to reduce it in size.

The jack holder:
This is a Fender Stratocaster style jack holder. I absolutely love the design of these, and it is the reason to why I wanted one on my electric balalajka. No matter how I am going to use and hold the balalajka the cable will never come in my way.

If you want more information about the pickups and the electronic part, please continue reading this essay and/or visit my homepage.

The other materials that I have used in my build are pretty ordinary, for example the potentiometers, capacitors etc. For more details on these materials and on the ones mentioned earlier, please visit *www.balalajka.com*. The tools needed for the build may vary depending on your design and your choice of materials. If you do not have access the tools needed for the fretting, you could choose to make a fretless neck; this may be harder to play on depending on your experience and musical talent.

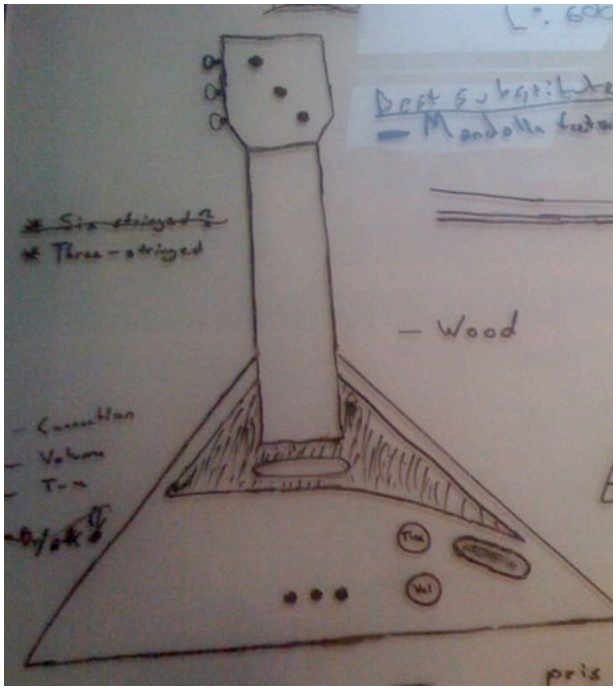
The build itself:
Here you will see a short description of the build.

The best method is if you begin with researching the subject first, and as your second step you should choose what dimensions that you want for your build. I decided the dimensions during the work, but I cannot say that I recommend it. The most important things that you need to decide are the wood materials and if you want to use a truss rod or not.

I began this project exactly as anyone else who knows nearly nothing about a subject. Since there is no literature on electric balalajkas, I started to research how electric guitars work and what things that I should keep in mind during the build. I then continued to research acoustic balalajkas, but this is a subject, where there is not much English literature and as I cannot read Russian literature, I had to be satisfied with looking at the pictures. I have been forced to do much of my work by improvisation, due to the lack of literature, I chose my design by studying guitars and balalajkas and then complementing this to my own ideas.

Both after and during the research I spent some time ordering the materials that I wanted for the build. Right before my project began I also registered a homepage for it, and during my work I have spent some time updating the information on it. Today you will have the possibility to see my whole building progress there.

I also made a couple of sketches on how I wanted the design; here is an early picture:



The first “real” step of the build was when I bought my wood material; I had decided that I wanted to use oak for the body and neck and birch for the pickguard, for the fretboard I decided to go with ebony.

Here are the dimensions of the wood

Oak
- 3,35m x 150mm x 52mm
- 0,40m x 75mm x 40mm

Birch
- 0,60m x 125mm x 26mm

Ebony
- 0,527m x 70mm x 8mm

When I was finished I still had much wood left, so you could cut the cost further. (I have 1,50m left from the long oak board.)

The first thing that I had to do was to cut the boards into smaller ones so that I could glue them together. Before glueing them they were planed, both so that I could see the pattern of the grain and so that I got a smooth surface on the sticky ends of the wood.

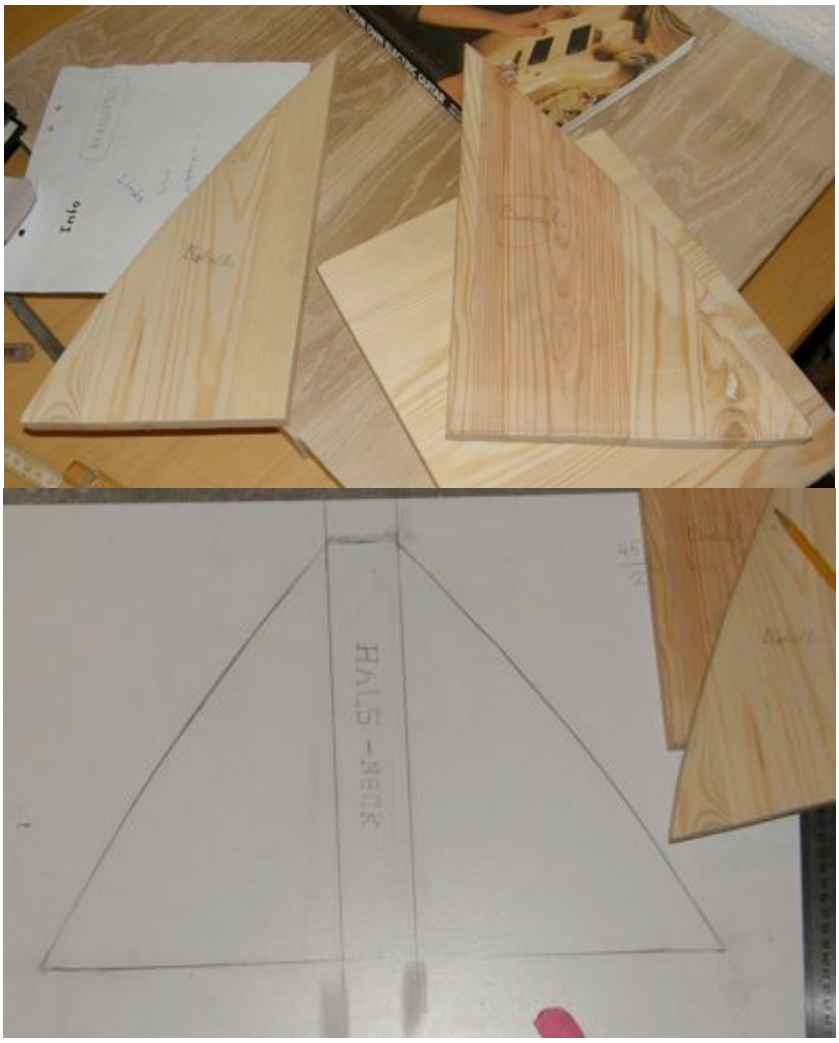
I made the glueing in two steps for the body part. I did this of two reasons; the first one was that I wanted them to really stick to each other, the second reason was that I would have had trouble planning them afterwards, since the body would have been too wide for the plane. The boards were pressured against each other and left to dry longer than they really needed.

I also got the neck and birch planed at the same time.

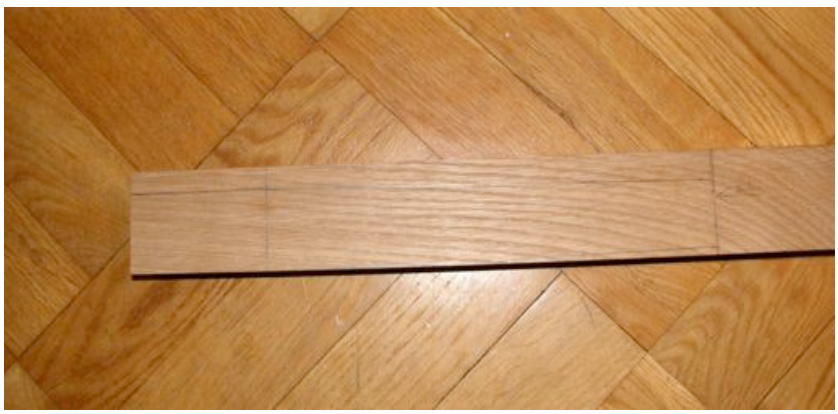
I had started to look at the design of the headstock, and I had made the first template of it. You may see it on the next picture.

This was the wood that I started with, at this stage I had a pretty good idea of how I should proceed.

My next step was sanding the body part a bit, after this I started to look at the design of the body part. I made several templates of it, this to be sure that I got the design right.

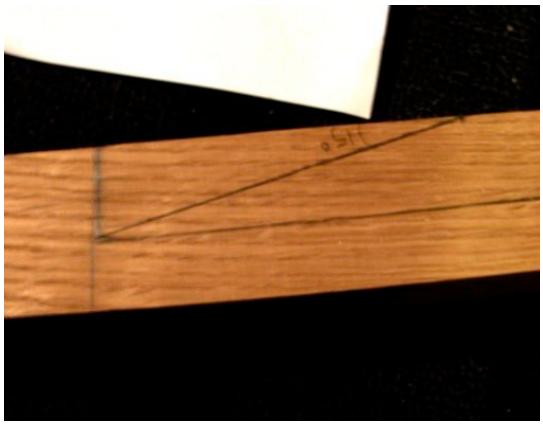


After this I started to look at the location of the pickups, pickguard, bridge and the potentiometers. My next step was to look at the dimensions of the neck.



After this I was ready to begin routing the area for the pickguard. I used the templates to be sure that the lines got right. I also routed the neck socket.

I also continued with the neck, and at this time I had everything about the dimensions decided, the angle for the neck is 15°. Also, I had calculated the fretboard distances.



After that I continued with the body, I drilled the holes for the potentiometers. I also routed the space for the jack holder, the bridge was also fastened for the first time.

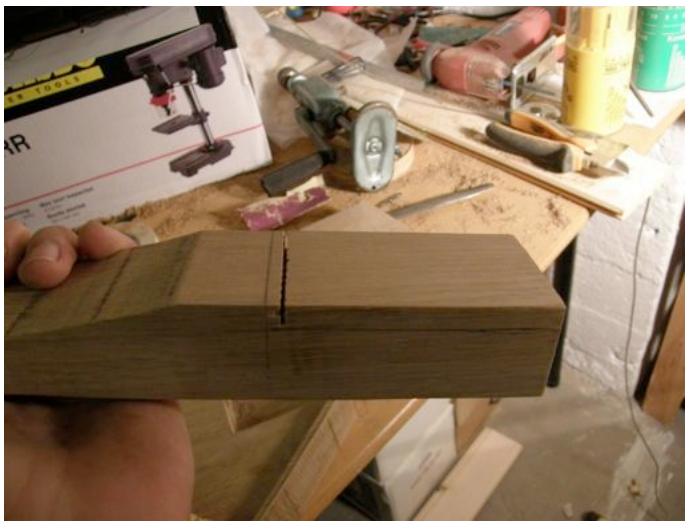
I also drilled the hole for the piezo pickup, which were placed below the bridge.

Now I was ready to have the body sawn out. From the parts left over I made the headstock. Later I also made the knobs and the inlays out of the wood.

After this I chose to improve the pickguard area, so that it is rounder.

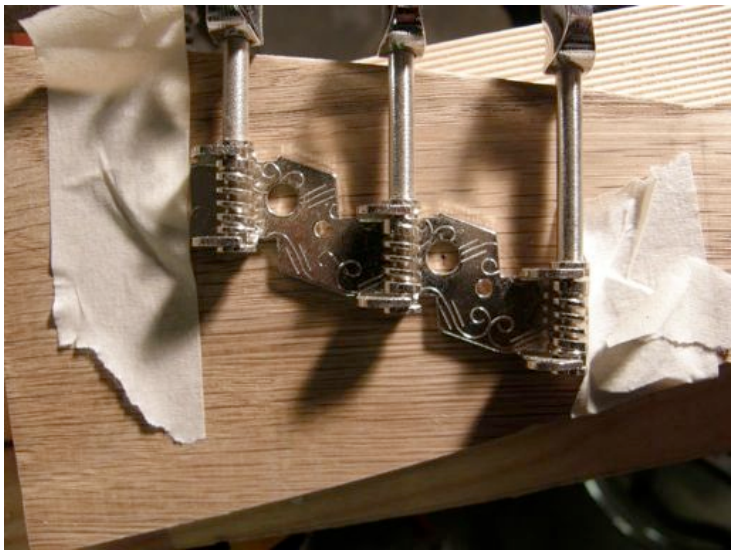
I also began to route the control cavity.

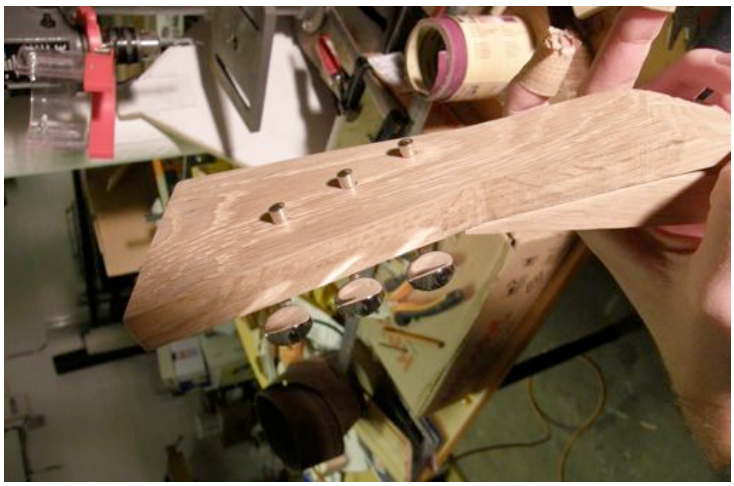
The next step was to cut the neck down so that it fitted into the body.



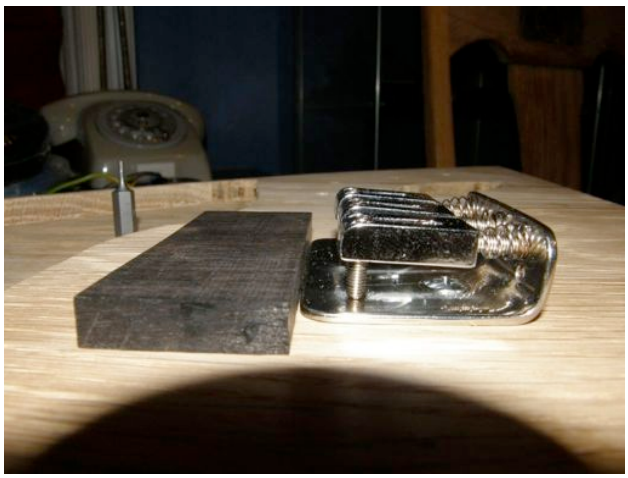
I then decided to begin the fastening of the headstock; for this I used glue and an oak plug that I made from the wood left over.

The next step was to fasten the tuning pegs.



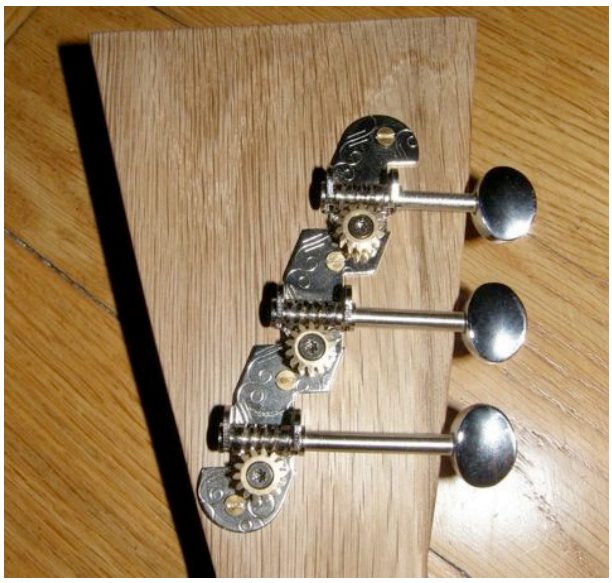


I then tested the setup. As you can see I have every possibility in the world to higher and lower the bridge so that it both sounds and feels good to play.

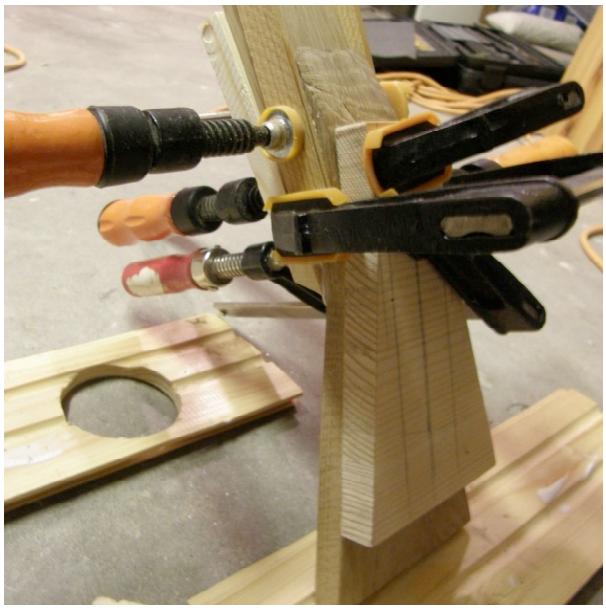


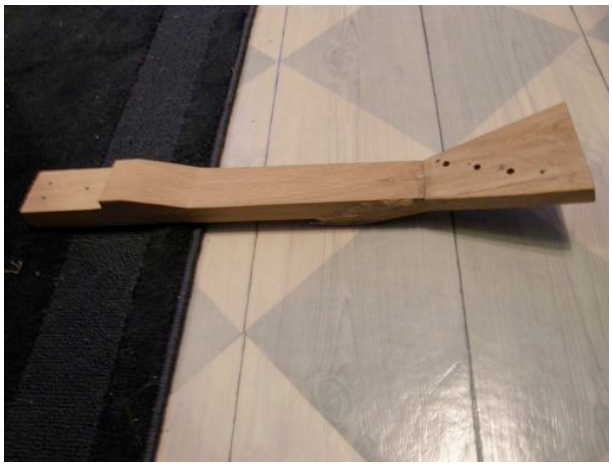
The next step was to actually fasten the neck itself. I chose to keep the neck straight since I have the possibility to both higher and lower the bridge.

Then I fastened the tuners to the headstock, I had to get a hold of really small screws to fasten it.



I then removed the tuners again and glued it together with the oak plug and the neck.

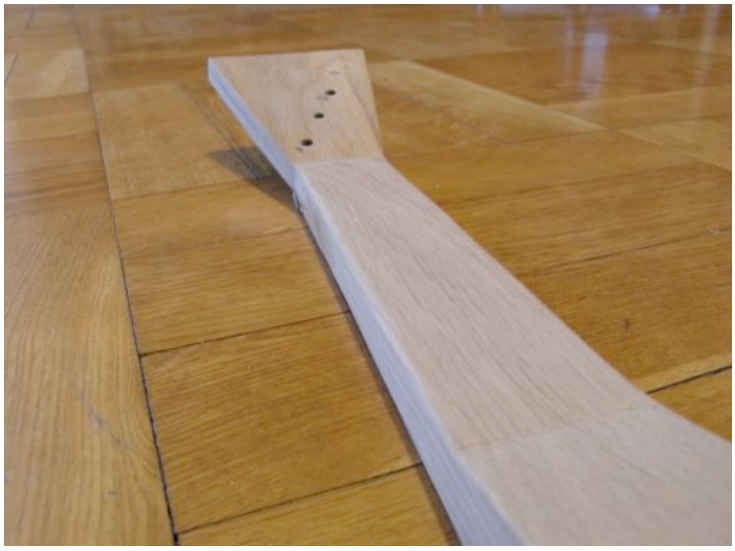




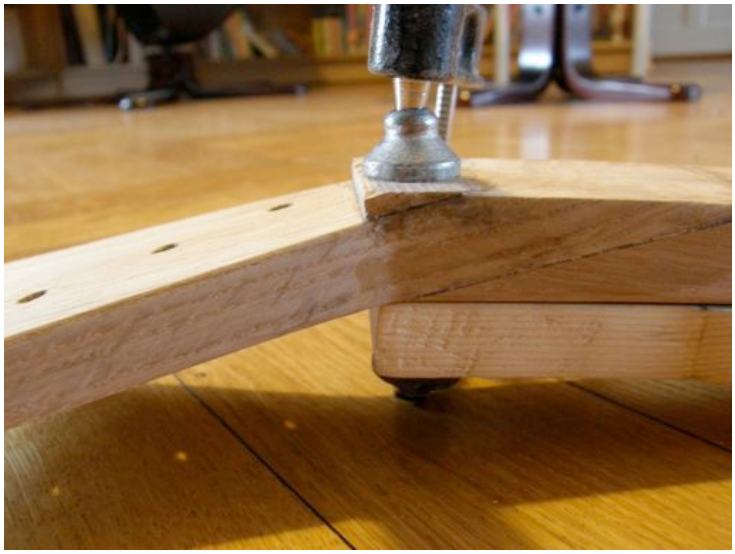
After this I chose to test and see if the neck could stand the pressure from the strings. This was the moment I had feared from the start of the build.

Fortunately the neck seems to handle the pressure without any trouble, I then cut away the extra wood using a grinding machine.

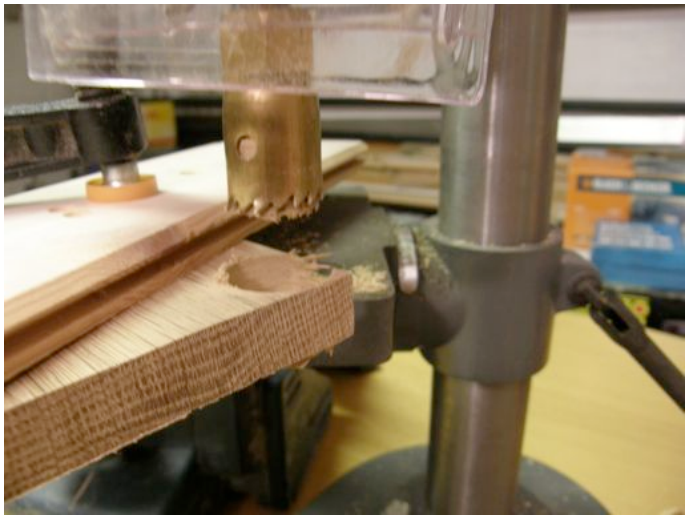
I then spent some time improving all the edges of the neck and the body.



The next step for me was to add the extra wood to the space on the neck, so that the fretboard can lie straight against the neck itself.



The next step was to make the knobs for the potentiometers, even though I had not bought them yet. The knobs were made out of oak and I oiled them later.



Then I started to cut down the size of the neck; here you can see the result, there are more pictures on the next page.

Here ends the year 2010.

Here begins the new year 2011.

The following step was to continue to trim down the neck a bit; this is the result.

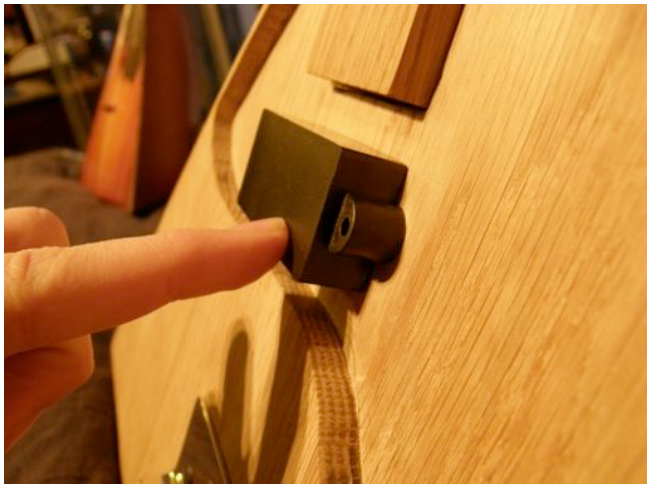
The next step on the body part was to drill the hole to the control cavity; I began with using the router and then drilling the hole with the help of a hand drill. I then successively increased the size of the hole from 4 mm to 8 mm.

This is a picture from inside the cavity.

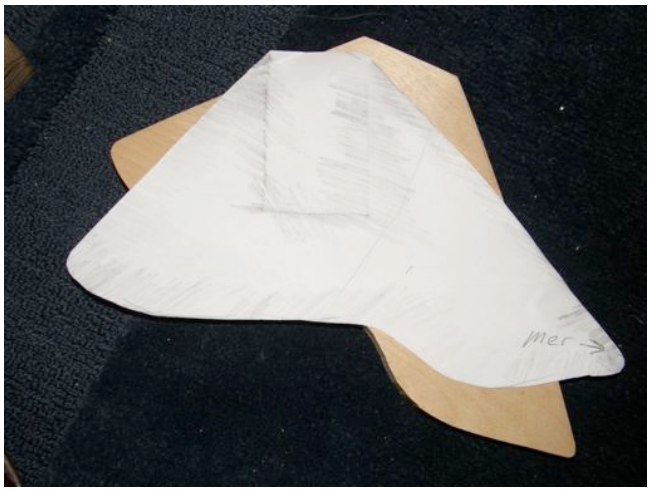
I now had to choose if I wanted to drill down the potentiometers or if I wanted to route the whole cavity down. I went with the routing.

The following step was to finish the knobs; I had to redo two of the earlier ones, but it went great. I also had to repair two of the potentiometers as they broke down.

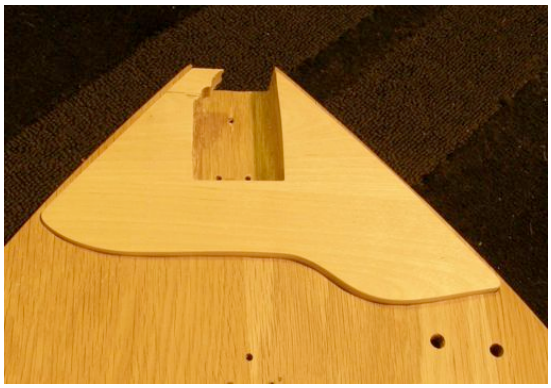
The next step was to place the pickup cover on top of body. To do this I used a ruler and a double-sided tape. It is located approximately 0,7 cm below the end of the neck.



The next step was to make the pickguard, and the control cavity cover, planning the fretboard once more, for this I had to use the woodwork. I began with making a sketch of the pickguard on the birch.



The way I made the pickguard was by the use of a grinding machine and a machine saw, I began with cutting out a rough form of the pickguard. I then worked slowly with a grinding machine; I adjusted it to the size of the routed hole in the body. The next step with the pickguard was adjusting it so that the neck also could be fitted into the body, for this I used the router. I later fastened it with four torx screws.



The control cavity cover was made by a piece of oak that was planed to the right thickness; I used the same procedure as on the pickguard. I began with using a machine saw to cut out a rough shape, I then moved on to use the grinding machine. Later on, I drilled holes for the screws that were needed for the attachment of it.

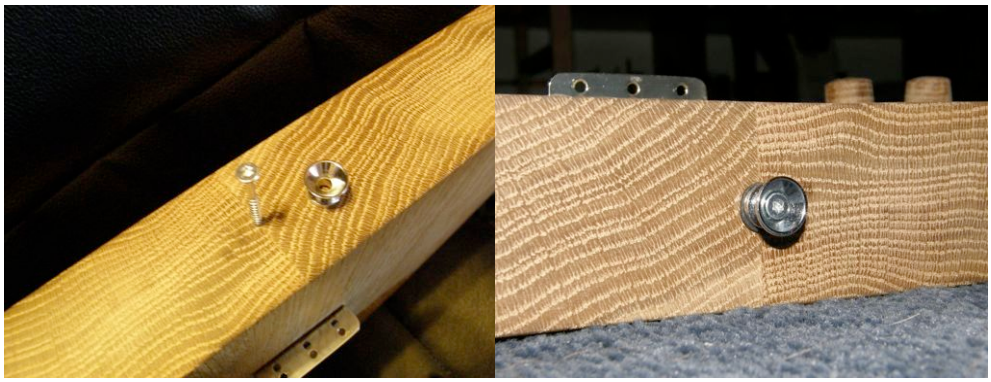
I also planed the fretboard once more to get it thinner, and the fretboard was cut in the right “angle”, for this purpose a machine saw was used after two lines had been drawn on it.

The following step was to route the channel for the cables; I did this using the router in freehand, before I drew a line where I wanted to route.

The next step was to lower the pickup into the pickguard. For this I used the router and a couple of files.

Below is a picture of how the balalajka looked at this stage,

The next step was to attach a shoulder-strap mount at the bottom of the body; I began with making a mark in the centre of the bottom, this was easily done since the middle line runs through its place. I then pre-drilled a hole and attached it.



The next step was to make the nameplate from the neck plate. The size of it was too big, so I had to reduce its size; I then chose to place it on the inside of the control cavity cover instead of under the pickguard. I made the engraving in it before I reduced its size.

I then glued the nameplate onto the cover using Karlsons Klister. (Contact adhesive).

Now I had finished with the body if you overlook the oiling part, therefore I went on with working with the neck and the fretboard.

Here is a table of my distances (from the nut to the frets):

Fret number	Inches	Centimeters
1	1,049559410	2,665880900
2	2,040211068	5,182136112
3	2,975261241	7,557163551
4	3,857830627	9,798889793
5	4,690864773	11,91479652
6	5,477143901	13,91194551
7	6,219292192	15,79700217
8	6,919786540	17,57625781
9	7,580964823	19,25565065
10	8,205033700	20,84078560
11	8,794075980	22,33695299
12	9,350057571	23,74914623
13	9,874834045	25,08207847
14	10,37015680	26,34019833
15	10,83767903	27,52770474
16	11,27896101	28,64856096
17	11,69547552	29,70650781
18	12,08861266	30,70507615
19	12,45968452	31,64759868
20	12,80992954	32,53722103
21	13,14051664	33,37691227
22	13,45254916	34,16947487
23	13,75706849	34,91755396
24	14,02505757	35,62364623

(The scale length is 18,7", with 17.817)

The first step with the fretboard was to mark the distances so that I knew where to saw. For this I used a simple ruler, I checked all the distances twice afterwards so that I knew that I got them correct.

The next step was to make the actual slots, for this I used a mitre box and a Japanese saw. I then made sure that the fretboard could not move by using a clamp. The whole slotting procedure took a couple of hours, but it went much faster when I optimise the procedure of it.

The next thing I did was to use sandpaper on the fretboard's surface, the appearance improved quite a bit since I had not done this earlier.

The next step was to glue the fretboard on to the neck; I made sure that the distance from the bridge to the fret slots was the same, so that they would be straight in comparison to the rest of the balalajka. Even if they would come a bit off it would not affect the music, since it is possible to adjust the lengths of each string with the bridge model that I chose for the build.

I began with attaching the neck to the body, and then I made sure that the whole balalajka was properly fastened on the workbench.

Then I chose to use woodblocks that were placed on the top of the bridge, this made sure that the neck became glued on straight. The last of these blocks were then fastened with a clamp, and the other blocks were then removed. I became happily surprised over the fact that the neck and the bridge are completely straight in comparison to each other. I had not expected this.

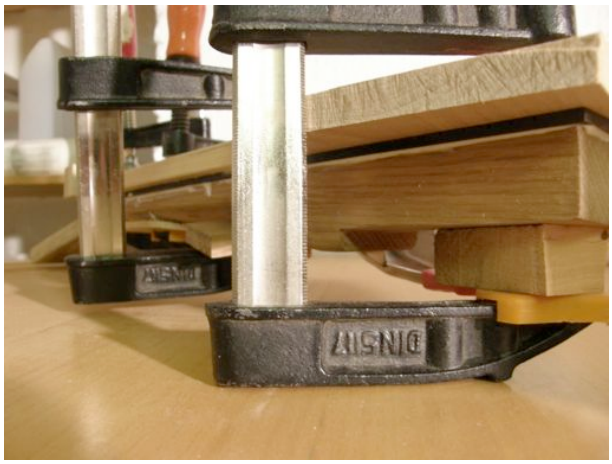
Even if the fretboard itself had become a bit wry, this would not have been a problem since the bridge is adjustable for each different string. Therefore the tunes would have been the same. Anyway the fretboard became perfectly straight.

The next step was to attach the fretboard; I began by pouring out very much glue on the middle of the neck, then I used a piece of wood to spread it out on the whole surface.

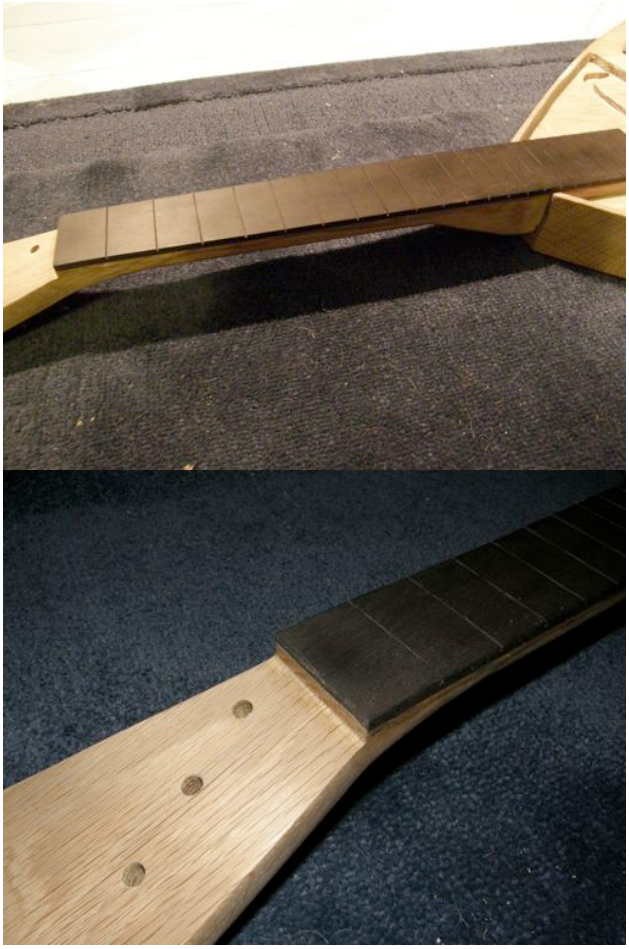
After this I simply placed the fretboard on the neck and pressed it against the woodblock that I fastened on the body earlier on. I fastened the fretboard on the neck by the use of two clamps. (I also had pieces of wood in-between, so that I would not damage the neck). After this I removed the three screws that I had used to fasten the neck, and removed it from the body.

When the neck now was loose I attached yet more clamps.

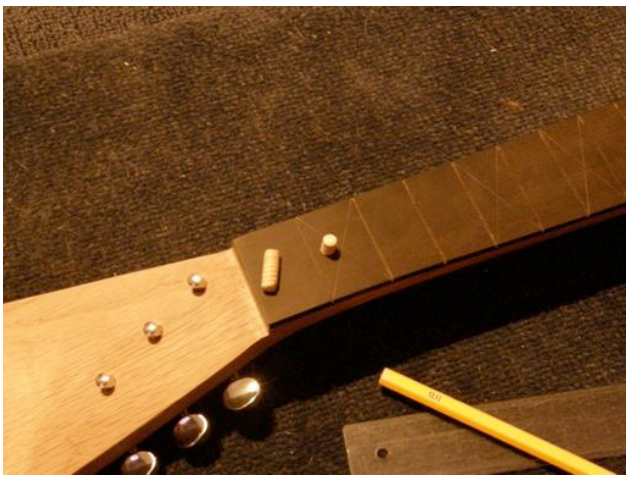
As you can see the glue is seeping out at the edges, this is a good sign that the fretboard will be fastened properly; enough glue had been used… At this stage I used paper to mop up the extra glue.



After this I left the neck to dry for a couple of days. The next step was to remove the extra wood on the fretboard so that it would get the same dimension as the neck. I also took the time to use sandpaper on the neck as well as on the fretboard; this removed the extra glue and the small damages that had been made by the clamps.



The next step was to make the inlays on the fretboard. I wanted to make these out of oak, which would fit nicely together with rest of the balalajka; the method that I used for this was first by marking the place where they should be placed. I placed them at the 2nd, 5th, 7th, 10th, 12th and then some smaller inlays at 17th, 19th, 22nd and 24 fret. I marked their place by using a ruler and a pen; see the pictures below.



The next step was to use a drill to make the holes for the inlays, I began with the five first, for them I used a 6 mm drill. I drilled through the ebony so that I just could see the oak.

When the holes were finished I choose to make the actual inlays, for the first five it was really easy; I chose to use a 6 mm plug cutter. When all the oak inlays then had been made, all I had to do was to glue them into the holes.

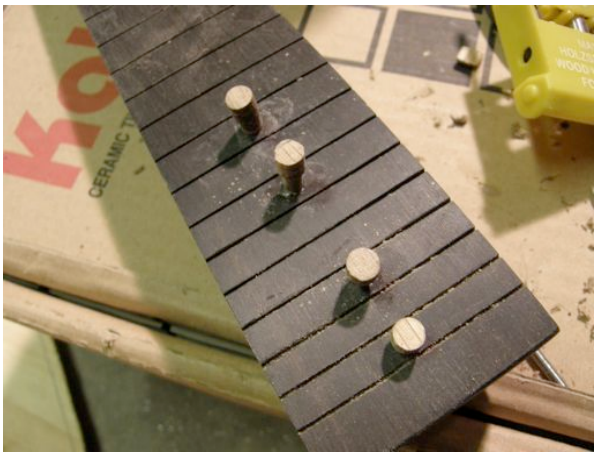
When the inlays had dried I had to reduce the height of them, for this I used a knife and peeled of layer after layer of oak. When they were a few millimetres above the fretboard I used regular sand paper to get them to the exact height; this also removed the pen marks on the board.

Below is a picture of how it looked after the sanding procedure.

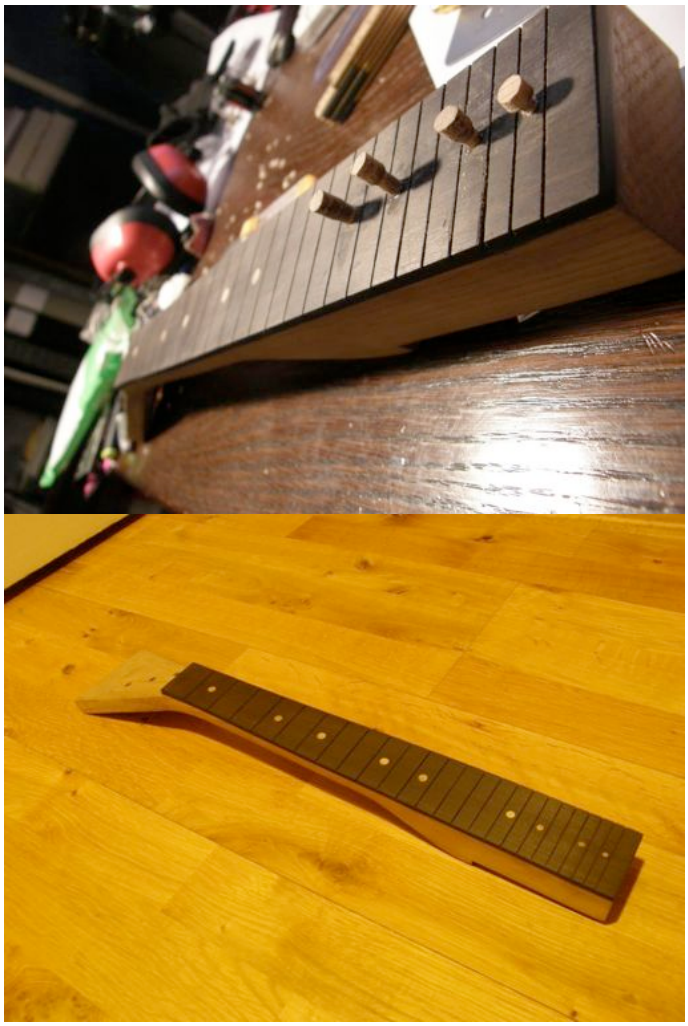
Now when the first inlays were finished I continued with the rest; I used a 5 mm drill for the 17th inlay, a 4 mm drill for the 19th inlay and lastly I used a 3 mm drill for the 22nd and the 24th inlay.

Unfortunately I doubt that there exist plug cutters smaller than 6 mm (≈1/4 inch), therefore I had to make the inlay in another way than the earlier. I began by making a couple of 6 mm plugs. I fastened these plugs in the chuck of my pillar drill; I then held sand paper against the plug till it got the right dimension. This process was quite time consuming. When I only had one plug left I realized that it would go much faster to use a file instead of sand paper.

The following step was to glue the inlays into their holes just like the first ones.

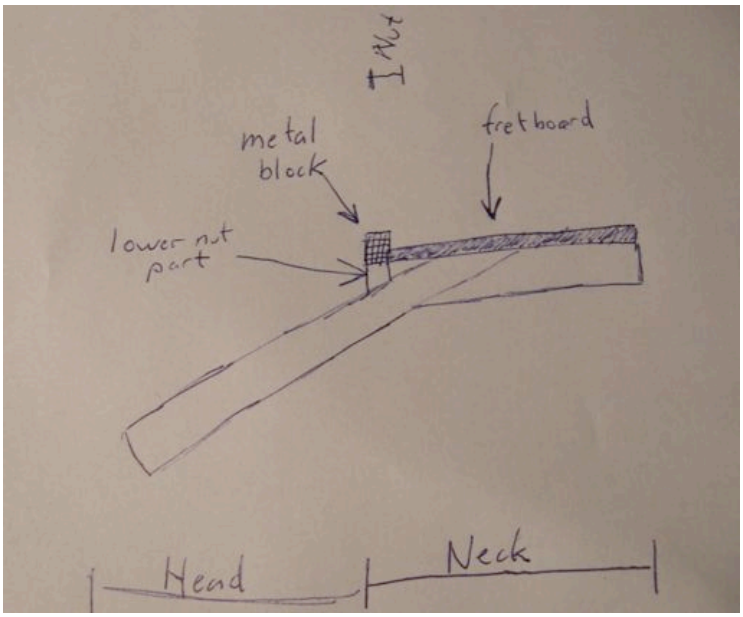


I then used the same procedure on these inlays, though I used a saw instead of a knife, since they had a much shorter diameter. If I had used a knife they would have broken down by the force and left a mark in the inlay itself. After this I used a sand paper just as on the first couple of inlays.



Now the inlays themselves were complete, the next step that I performed was to oil them. I used normal paraffin oil; this made the inlays a bit darker. You can see the result below; the picture is far from perfect, but you get the idea.

Now that the inlays were finished, the next step was to make the nut of the instrument. The solution that I had for this was to make a lower part of the nut and then to place a metal block on top of it, which will work as the real nut.



This will give the similarity of a zero fret in the sense that the material that the open-string vibrate against will be more similar to the frets of the instrument. I believe like many others that this will improve the tone of the instrument; of course none of this can be proven, so there is no absolute truth to it. In theory this design will reduce the difference between the open tones and the “normal” closed frets, thereby the result will be a better sounding instrument. It is good to keep in mind that there also exist many other factors that will influence the tone, as for example the way that your fingers “dampen” the tone when holding the string against the frets, but this is also a diffuse example, which people may debate.

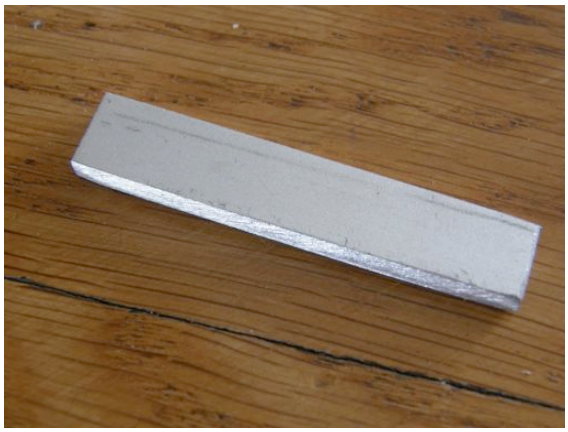
The reason to why I wanted to make the nut out of two parts has mainly to do with the appearance, but also with practical reasons. I began making the lower nut part by getting the right angle of a smaller oak block that I had cut out using a bandsaw.

After attaching it I began to file it to the right size and I also used sandpaper to improve its surface. (Against the tuning pegs.)

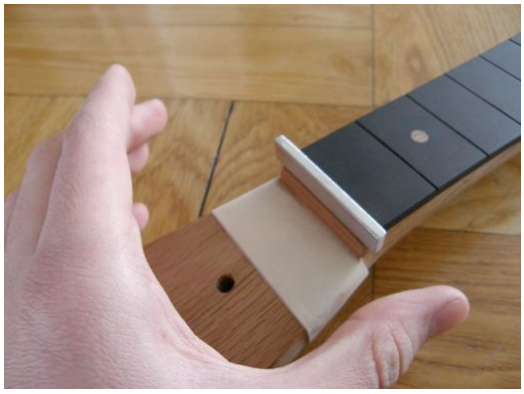
I wanted the appearance to be good, and it would look weird if the whole nut was made out of either metal or oak. The second reason is that I wanted the nut to be fastened properly, and I believe that I will get it to fit tighter by this design. On the whole my solution was naturally by the qualifications that I had, I did not have much choice when I noticed that my first design did not work as I had hoped.

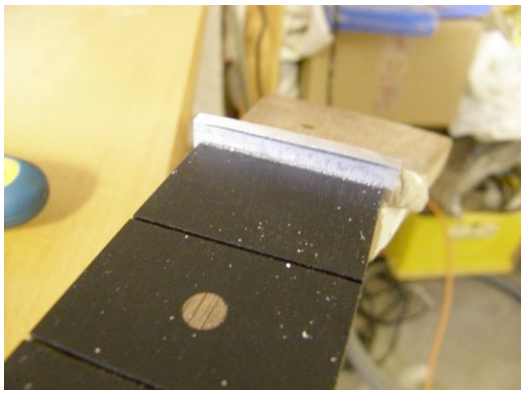
When this had been done, the next step of the process was the top of the nut; I had chosen to use aluminium for this. The height of the nut can be adjusted afterwards, so I did not have to consider this when adjusting the aluminium part. (I also chose to wait with making the string slots…)

First off, I began with trying to find a suitable piece of aluminium; I succeeded to find half a door hinge. I do not know why we only had one part of it, but it made it perfect for my purpose. I simply cut out a suitable piece and grinded it.

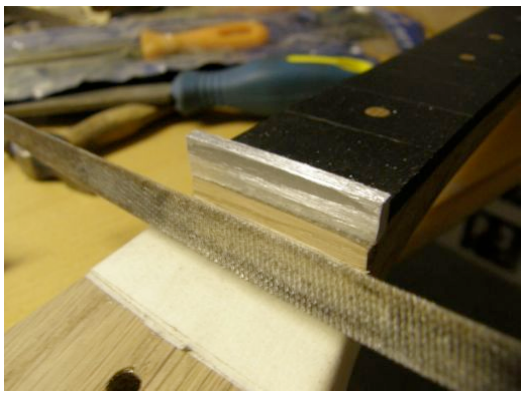


The next thing that I did was to glue it on to the lower nut, and I also used a pen to mark which heights that I wanted on the bridge.



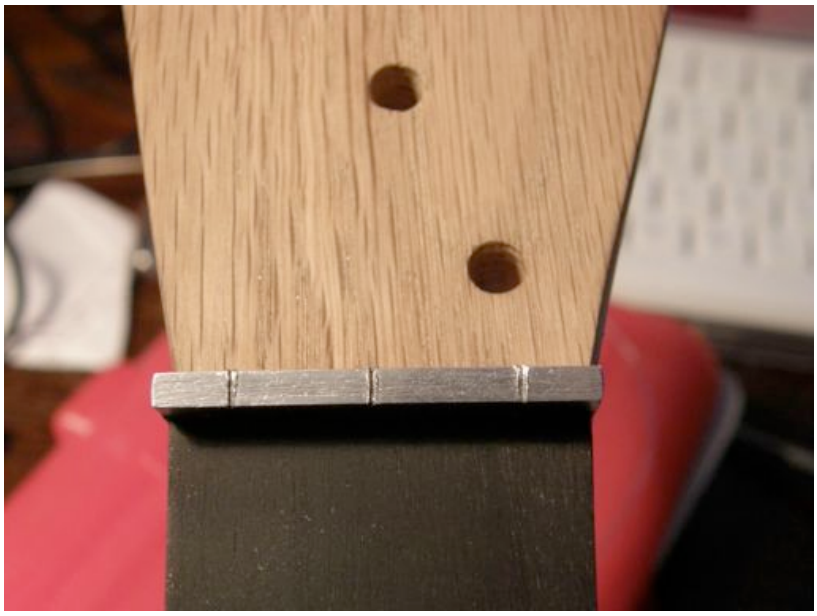


After this I simply used a file to adjust its dimensions. Be sure to use a small file on when doing this, otherwise you will risk damaging the head or the fretboard. I also suggest the use of masking tape to protect it.



When the dimensions were right, I used sandpaper to improve its appearance. This was the result.

Now the nut was almost finished, the only thing left to do were the string slots. I began by marking the right place using a ruler and a pen, and then I used a knife to make the slots themselves. I did not make the string slots so deep yet since I wanted to get the perfect height of the strings, and for this I must know how high the frets will be.



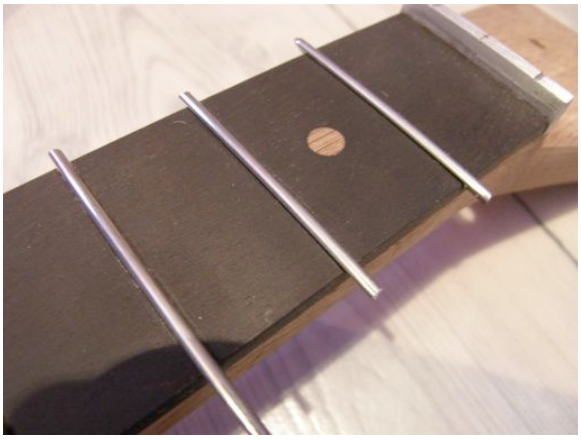
The whole nut is 4 cm wide, so I placed the middle string slot 2 cm in from each side. The other two string slots were placed 0,7 cm from the side, this makes the distance between each string 1,3 cm.

It was easy to work with the aluminium; the whole process was much easier than what I believed that it would be.

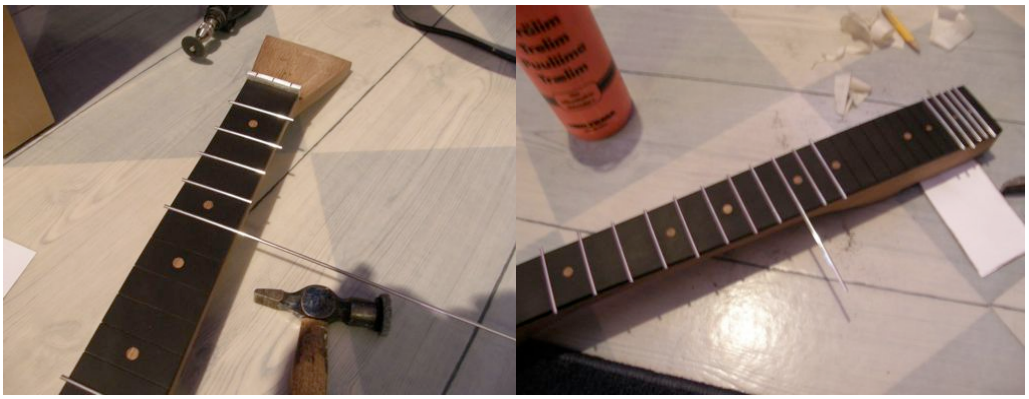
Now when both the inlays and the nut were finished I could fret the neck, if I had done it earlier I would have had trouble with making the inlays, as you can imagine. I could of course have done it before the nut, but at the moment I believed that I would go with another nut design.

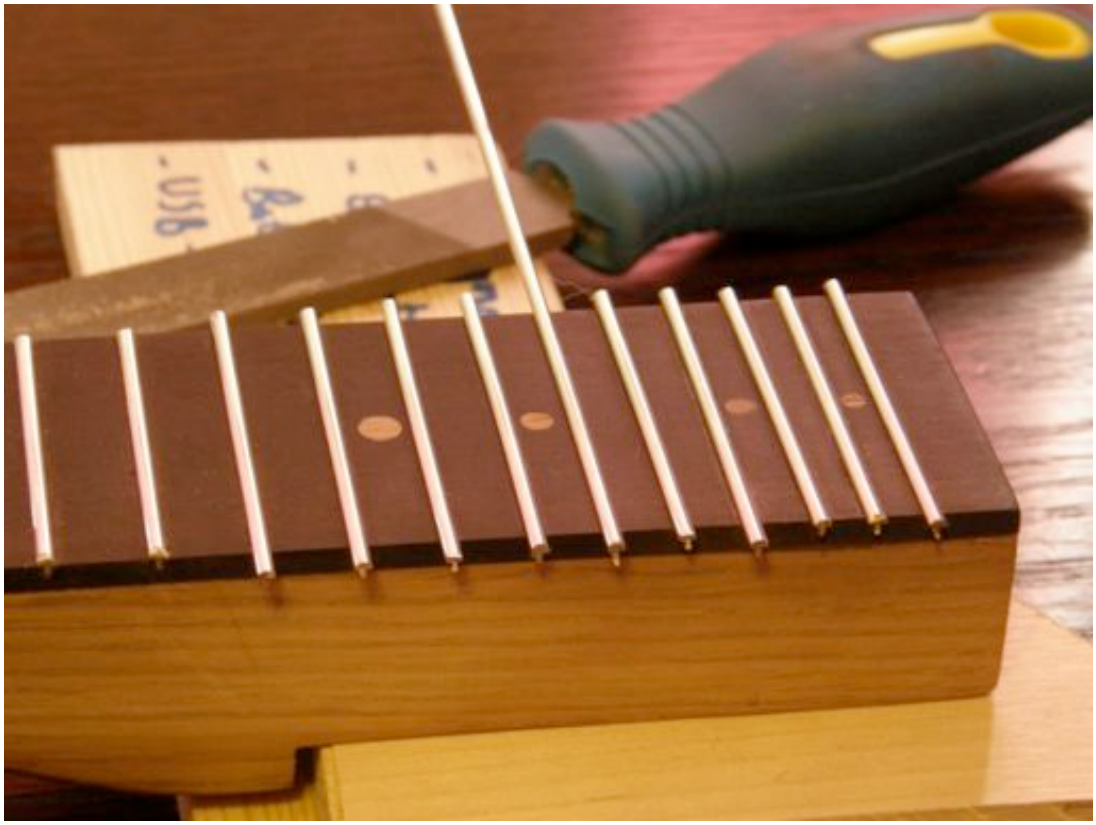
For this process I wanted to find and use rubber hammer, but in the lack of this I used furniture feet, which were attach on a small hammer. This worked excellent and I did not damage the frets or the fretboard or anything else for that matter.

I simply placed the fret above the fret slot and then hammered it in; between each step I used the dremel so that I could continue the process. The end of the process was delayed since I had to order extra fretwire.



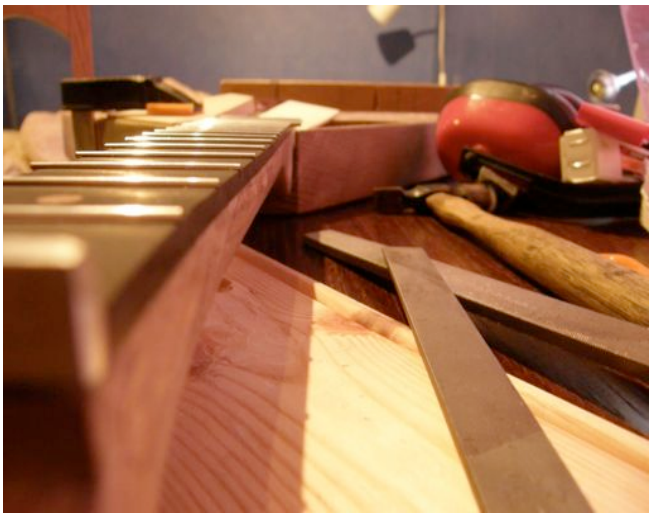
The process was painless and went very smoothly, but still it took a couple of hours.

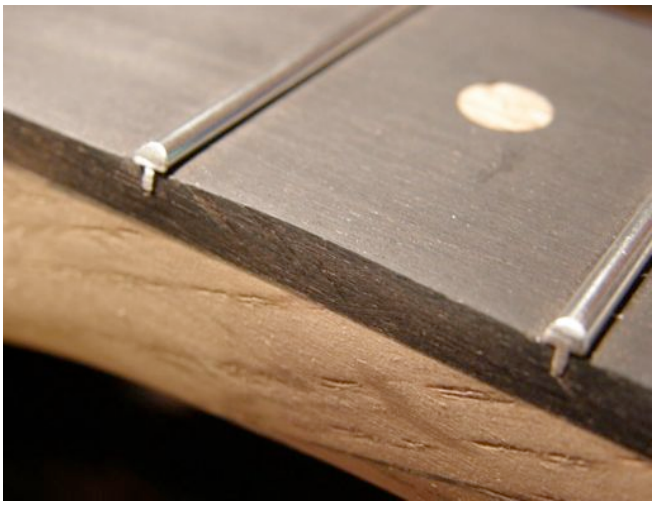




The next step was to adjust the size of the frets, for this I began with using an ordinary file. Then I continued with two “special” files that I had borrowed. There is not much that can be said about the process, if you find any problems when doing this take a look at YouTube; you can with ease find some good videos about the subject.

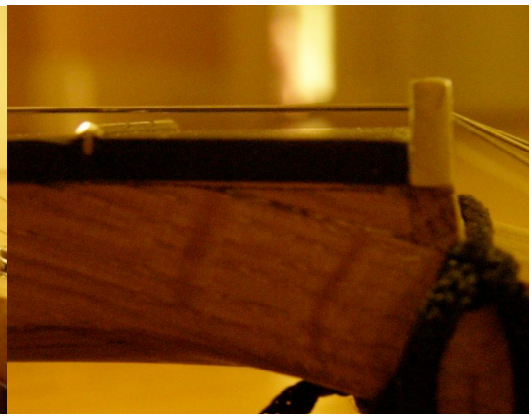
Remember that this will be much easier if you use regular fretwire instead of stainless frets.





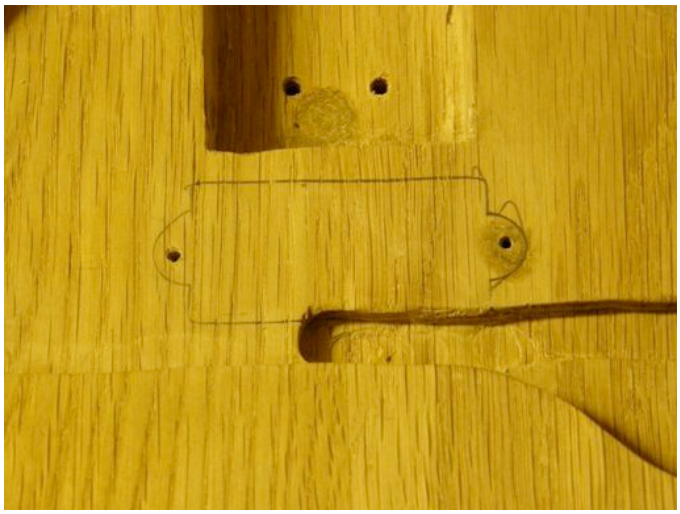
Below are two pictures of the result.

The next step was to fix the intonation of the balalajka, I had some trouble getting it right. Pythagoras Theorem can explain most of the troubles that I had, the solution was to lower the nut slots; this also makes it more comfortable to play on the balalajka. Below are two pictures of the result:

Now that the balalajka was not far from the finish line, the next thing I did was to disassembly it. I removed the different parts from each other, for example the strings, bridge, the knobs, the tuners, the potentiometers etc. I did this so that I could continue with the last steps.


When this was done I could begin lowering the pickup cover a bit. I chose to route it deeper than necessary, this so that I could add springs between the body and the pickup cover. The middle part of the lowered area is extra deep; this is so that I can add a bigger magnet to the pickup.



Now when I only had one real procedure left it was time to use sand paper and remove any possible damages on it before the to oiling could begin. I also chose to use finer sand paper than I had used before, grade 600.

The pictures below were taken just after the process was finished.

When this was finished the last step was to oil it, I chose to use regular paraffin oil for all the parts: the pickguard, knobs, neck, body and cover for the control cavity.

Below are a couple of pictures from the oiling procedure and of the oil bottle that I used. The knobs were left in a bowl so that they could absorb as much oil as possible.

When the parts had been oiled and dried they looked as the pictures below show:

When this was done I simply reassembled the whole balalajka and suddenly the whole balalajka project was finished!

On the following pages you will be able to see the result of my school project. (The only thing left to do now was the electronic part, which you can read about further below.)

Notice: The following pictures have been taken by the photographer Johannes Erixon, and he has released them under a different CC-license. (CC BY-NC-ND). For more details on this, please read the copyright information on the last page.

More pictures are available if you visit my homepage, at *www.balalajka.com*.

The electronics:
This section is kept very short, due to time issues, but you will find more information if you visit me at *www.balalajka.com*; Afterwards I have also improved the electronics a bit, this is something that easily can change the sound of an instrument.

I decided early on to use four potentiometers, two of these will be for volume control, and the last two will be for tone control. The setup will be a very simple, one volume potentiometer and one tone potentiometer will be connected to the piezo pickup, which will be located under the bridge. The last two potentiometers will be connected to a single-coil pickup. Since the pickup cover is pretty big I will have the possibility to later change the electronics to a humbucker or two single-coil pickups instead, I also have the possibility to add extra piezoelectric elements under the pickguard for example.

The knobs, which I use, may be seen in the earlier section, they are made out of oak. First I used a simple hole cutter, to make them fit the potentiometers I used a 6 mm drill to make a hole in them. I then used a screwdriver to expand the top of the potentiometer, this made them fit perfectly.

Since the electronics to the pickups will not interfere on any other place than at the socket, the scheme will therefore be similar to a basic electric guitar scheme. (With the difference that the balalajka will consist of two similar circuits.)

I used basic potentiometers, the piezo pickup was easily made from a piezoelectric element. You might find more information about how on the Internet. The single-coil pickup was made from an old jazz-bass pickup, for more information please visit *www.balalajka.com.*

To end this section I want to tell you something that I started to think on. Many people say that older guitar pickups sound better than newer. Some argue that this is because they are older and of better quality or that they have aged and thereby sound better, but I doubt these explanations. I do not have a straight answer that I can guarantee is correct, but I have received a theory that is believable, and if you are winding your own pickups this could be good to at least have heard. The easiest and best way to explain this is by quoting my source, who prefers to remain anonymous: “The reason to why people tend to think that older pickups sound better is because they are hand made. Nowadays, the pickups are made by machines, which makes them perfect: the wiring is exactly the same everywhere. Older pickups that are man made have their faults and they are therefore not perfect. This gives us similarities to real life, since the sounds that we hear in everyday life are not perfect; the objects around us do not create perfect sound waves. In conclusion the sounds from older pickups sound more realistic.”

The value of the instrument:
Now that the instrument was finished I wanted to know how high the value of it is, even though I want to keep this beautiful instrument. I got two reasons for the fact that I want to get it valued. For the first, it is the question of insurance: without getting the instrument valued it would be hard for me to get compensation if anything should happen to it. Of course I can prove the material cost, but it would be hard to get anything for the work hours or for the sentimental value of the balalajka. Secondly,

another reason for this is that this can be seen as a measurement if my project has been a success or not.

Unfortunately, I could not find any place that could value the balalajka in time for the submission of this essay. If I someday get the balalajka valued, you can find the information on my homepage, *www.balalajka.com*.

Result and discussion

There is not much that can be concluded from the information given to you in the report, since this project is a bit special. It is more of a guide, what I can do is to mention some parts that might be done differently if I ever were to build another balalajka.

What I can conclude directly is that it was not necessary to use a truss rod, at least if you are using a harder material as oak. Remember to make sure that the wood is dry so that it does not bend. This would not be good for it even if you have a truss rod.

One thing that I had in mind before the build, but which still could be interesting if you build a balalaika, is to insert diodes into the neck. When I made the neck it did not feel like the end would justify the means, especially since I did not use a truss rod. If you use a truss rod, then you have got a ready channel in which you can lay the cables.

There are some points that you still should remember, you would have to insert a battery to light them up, also you would need an on/off button. One solution to the last problem is of course to use a stereo contact instead and thereby it would light them up as soon as you insert the cable into the balalajka. Remember that it might damage other electrical equipment if you do this the wrong way. I take no responsibility for your actions…

There are also some ways in which it is possible to evolve the build and make it better. The first thing that springs to my mind is the bridge itself, the distances between the strings. The bridge that I used has its sides, the intonation can be improved as well as the height of the strings; nevertheless it is worth thinking of. You could with a little bit of effort make yourself a bridge with the right distances, which have the same qualities.

If I had done this project over again I would have considered choosing another design of the headstock. This has to do with the angle of the strings; if you look at the nut pictures you will see that the string angle is pretty high. It would be impossible to use the same design and reduce it, what could be done is to reduce the thickness of the fretboard even more, but I would not recommend this. You would also get a better result with a non-symmetrical design, since it would be easier to get it good; it is very hard to get my design perfect and as you can see I did not succeed on it. As a last point it would also be cheaper since you can use regular guitar tuners instead.

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Notice: These sources do not include the ones that have been used for the creation of www.balalajka.com nor the research of the build itself. Those may be found at www.balalajka.com/sources.html.

Source critics

There is not much that can be said about the sources that I have used for this essay. The most obvious reason to this is of course that the essay itself is very short and the main article is how you build an electric balalajka. Therefore, not so many sources have been used.

The sources that I have used are pretty trustworthy, as an example the book Heureka! by Lars Bergström, Erik Johansson, Roy Nilsson, Rune Alphonce and Per Gunnvald is being used as my physics book in school. Other sources may not be as trustworthy, but the information that I have used, has been confirmed both by other sources and by earlier knowledge that I have.

The source www.balalajka.com is totally trustworthy about the process of the instrument building; this is also the only aspect that I have used this source in this essay. I reserve myself from any possible errors on the homepage.

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