MUSC 258* Fall 2008 Instrument Building Project
Part 4: Final Report

Abstract

This report will document the results of a musical instrument building project, in which I have built a guitar-mounted kalimba, or thumb piano, as shown in fig. 1. I will also discuss the construction of a second instrument, a regular wood-mounted kalimba (see fig. 2), which in many ways improves upon its guitar-mounted counterpart.

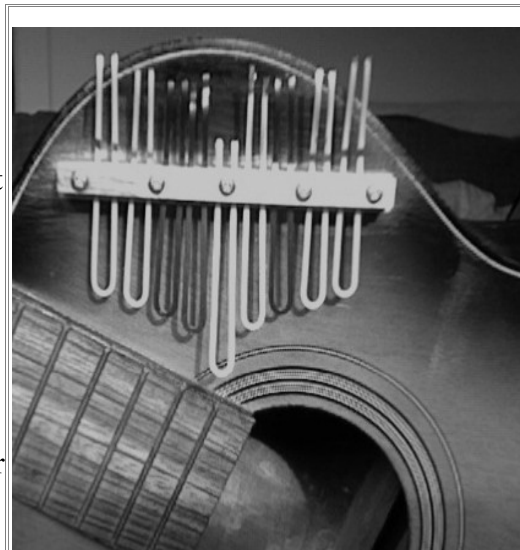
fig 1: completed guitar-mounted kalimba

Concept - *conception of the instrument; its classification; comparison with other instruments; sources of inspiration*

A kalimba can be classified as an idiophone with rods fixed at one end. In both kalimbas, the rods of the kalimbas, or tines, are held down using a bridge of two small pieces of hardwood, with the tines held tightly in between. There are many documented approaches to mounting kalimba tines , many of which are indicated in Bart Hopkin's *Musical Instrument Design* (p. 42). A common approach is to use two bridges, with a crossbar between the bridges, used to tightly hold down the tines. The approach I took is apparently similar to variations of kalimbas found in the Caribbean, on rumba boxes and marimbulas, however instead of using a steel bar for the lower half of the bridge, both parts of the bridge are made of hardwood.

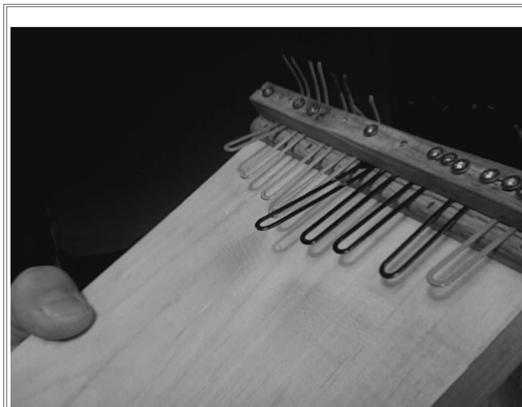
fig 2: completed wood-mounted kalimba

A major inspiration for choosing to build a kalimba actually came from my love of electronic music. This may seem strange considering a kalimba is an acoustic instrument, and this may be because the connection is not immediately apparent. One of the concepts I enjoy from electronic music is looping of phrases, which is also evident in African music using kalimbas and other traditional instruments. My hope was to build a simple instrument which I could use for looping phrases to add to musical compositions. Since I was in possession of an old lifeless guitar body, I figured if I were to build an instrument such as a kalimba, I could use the body of a guitar as a sound chamber to amplify the sound. Initially, I imagined building such an instrument would destroy the guitar's innate capabilities, however later I was motivated to build an instrument which I could control and create loops with while simultaneously playing guitar and operating a looping effects pedal (or computer looping software), should the guitar be properly restored.

I was curious to see if anyone had previously mounted a kalimba onto a guitar body. Of course, a simple search on YouTube yielded a such a result. What was amazing about this particular instance of a kalimba-guitar was that the creator affixed the kalimbas while maintaining the guitar functionality, so he could play both at the same time. An image of this invention is shown in fig. 3. I'm sure this would require a great deal of practice, so in the meantime with my instrument I plan to loop kalimba phrases while playing guitar, or vice versa. Learning to play both simultaneously will hopefully come in due time.

fig 3: from Kalimba Guitar demo – youtube.com/watch?v=oWWT3ZZlOa4

My initial construction plan involved bolting a crossbar and affixing a dual bridge to the guitar body, which may have damaged the thin body of the guitar's soundboard. I opted instead for a simpler bridge structure, which is mentioned above. In my research, I located some simple construction guidelines for building a bobby-pin kalimba, which uses a bridge structure of two pieces of hardwood, and does not damage the body (bridge is glued to the body instead of bolted). A picture of a bobby pin kalimba is shown in fig. 4.

Materials - *what is it made of? how are the parts connected together?*

My guitar-mounted kalimba (fig. 1) is made of two pieces of hardwood, bolted together using 5 3/4” wood screws. The top piece is 4” long, and 1/4” square. The bottom is also 4” long, and 3/8” square. These specifications were adapted from instrument builder Dennis Havlena's website (dennishavlena.com/bobbypin.htm), in which he documents his construction of a bobby-pin kalimba (fig. 4). I also use bobby pins in the construction of my kalimbas, however of a different type used by Havlena (the largest flat bobby pins I found at the drug store). Holes are pre-drilled through the two pieces of wood (which ensures the wood does not split when the screws are added). Once the bridge was competed and 8 tines were held roughly in place (not yet in tune) between the two pieces of wood, the structure was glued to the guitar body below the soundhole. Clamps were used while the glue was drying.

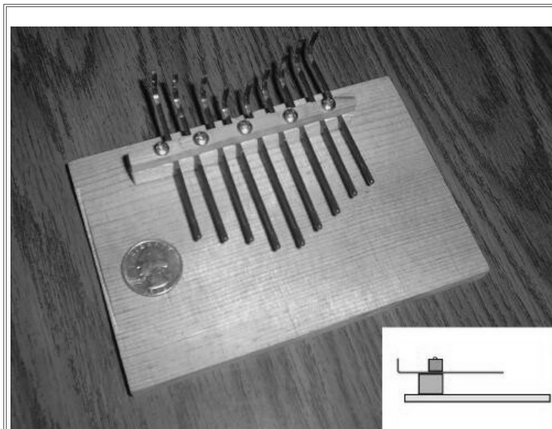

fig 4: bobby pin kalimba - dennishavlena.com/bobbypin.htm

My second kalimba (fig. 2) was built in a single afternoon using materials available on hand while visiting my parent's house. The concept of the bridge is similar to that of the guitar kalimba, however the bridge is longer (roughly 5½”). The top piece of hardwood is 3/8” square, while the bottom piece is a flatter piece of hardwood trim. Once the pieces were assembled and screw holes drilled, the entire unit was screwed (not glued) onto a 5½” by 7½” piece of pine, which serves as the body of the instrument.

Construction Process - *comparison with original concept; testing procedures; pitfalls and changes in plans;*

As previously mentioned, my initial plans included the construction of another form of kalimba bridge than which was later implemented. This was due to the availability of materials and the ease of construction. After settling on this new bridge structure, the construction process went fairly smoothly for the guitar-mounted kalimba. Before the holes for the screws were drilled in the bridge, the functionality of the bridge was tested using clamps held to a table to hold the tines in place.

One pitfall was that the bridge was not being held well to the guitar body with wood glue. This problem was solved after sanding down the finish of the guitar body, and by using a stronger glue. Another small problem was that the bobby pins were fairly brittle and snapped easily. For this reason some were discarded.

More problems were encountered during the construction of the second kalimba. This was largely due to the availability of materials at the time of construction. The choice of screws was the main issue; as they were made of a softer metal, screwing them into hardwood broke many of the screws, or cross-threaded them. For this reason more screws were required, rendering the bridge of the second kalimba somewhat unsightly, and is split in one area. The construction of this second kalimba was largely experimental, and in the process of construction I discovered that with an extra 1½" in width (compared to the guitar kalimba), at least 4 additional screws were required to hold the tines in place. This would have been ideal, but due to the poor choice of screws, 14 screws were used in the final construction. Despite these problems, the second kalimba has a significantly more pleasant sound, and does not dampen the sound as much as the guitar kalimba.

Tuning - *tuning schema in detail, how are the frequencies in the tuning achieved in terms of the mechanics of the instrument? frequency range;*

The tuning of the guitar kalimba and regular kalimba are both tuned in an equal temperament tuning schema. The tuning schema of the guitar kalimba and second kalimba are as follows:

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====E4                ====D4
======C3              ======B3
========A3            ========G3
==========F#3         ==========E3
============G#2       ============A2
==========E3          ==========D3
========G#3           ========F#3
======B3              ======A3
====D#4               ====C#4

1. guitar kalimba    2. regular kalimba
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The exact tuning of the instrument was determined using Sonic Visualizer. These are not the tunings which were initially planned, however the length of the bobby-pins was a limiting factor when determining a key. When assembling the instruments, I used a chromatic guitar tuner to approximate the note generated by the middle tine, which in these cases are G#2 and A2. The other tines were tuned by ear. Based on construction guidelines, with this tine formation, a popular tuning pattern alternates on either side of the middle tine: do-re-mi-fa-so-la-ti-do. The 'do' note was initially planned to be a full octave above the middle tine, however the length of the tines was again a limiting factor for accomplishing this. Thus the keys of the two instruments are E and D, respectively, and not G and A, which was originally planned.

As kalimbas are of the class of idiophones which use rods fixed at one end to generate a pitch, the frequencies in the two aforementioned tunings are attained by holding down the bobby pin tines at a single point. The tuning of an individual tine can be altered by sliding the tine out farther from the bridge (lowering the pitch), or sliding the tine back through the bridge (raising the pitch). The bobby pins are short enough to only emanate an audible pitch on one side of the bridge. The length of the bobby-pins used were a limitation in attaining certain pitches, so the final tuning was attained when the tines were tuned in such a way which generated a major scale when played in order.

Using Sonic Visualizer, the frequency range of the guitar kalimba from lowest playable note to highest playable note is from G/G#2 (~200Hz) to E4 (~660Hz). Some of the notes have observable harmonic content with higher frequencies, although hardly audible. The C#4 note, for instance has overtone content as high as G#6 (~3400Hz) (see fig. 5). The regular kalimba has a playable range from from A2 (~220Hz) to D4 (~590Hz). The harmonic content for this kalimba for may of the notes is richer, however the highest detectable overtone (for D4) is its octave (D5, ~1200Hz).

Resonant Characteristics - *examination of resonant characteristics in detail: how the instrument is expected to behave given textbook definitions applying to this type of instrument; how it actually behaves;*

My decision to mount a kalimba onto a guitar body was reinforced with the fact that many kalimbas use a sound chamber, which is already analogous to guitar body in the sense that the resonance in the sound chamber enriches the tone, especially for low frequencies. Larger soundboards such as one the size of a guitar body should also be able to project lower pitches. Unfortunately, the volume of my kalimba is not substantial. The reason for this may be that the tines of my kalimba are too light relative to their mountings. The tines are a type of bobby pin which are hollow in the centre, hence having less mass than similarly sized bobby pins with no hollow centre. The same is true of my second kalimba, which uses the same type of bobby pins as tines. The second kalimba in particular produces very pleasant tones, but like the guitar-mounted kalimba, it fails to drive the soundboard enough to produce a louder sound. Should I build another kalimba, I will make sure to use tines of a heavier material (relative to its mounting). Furthermore, the soundboard itself may need to be of a heavier, denser material than a guitar body, and the mounting to the soundboard may need to be stronger in order to produce a louder sound. In the case of my guitar kalimba, I did not want to seriously risk damaging the guitar body beyond repair, so a heavier mounting of the bridge to the thin wood of the guitar's soundboard was not attempted.

In terms of the tines themselves (other than being hollow in the middle), they are uniform in thickness and width, and the plucked ends of the kalimba are all rounded. Thus the only parameter I can control is the length of the tine from the plucked end to the bridge. Should the tines have initially been thicker and uniformly shaped, I could have experimented with different thicknesses for the tines, affecting the overtones generated. Experimenting with different widths may have also yielded a wider range in pitch (wider tines could have been used for lower notes). Some documented variations of kalimbas have reached lower ranges as low as A1 and as high as D6 – which take advantage of other parameters of the tines, such as thickness, width, and shape of the plucked end. As previously mentioned, the arrangement tines on my kalimbas yielded a range of base frequencies from G#2 to E4 for the guitar kalimba, and from A#2 to D4 for the second kalimba, which could have been improved with the use of a more versatile material for the tines.

Overtones of tuned tongues of uniform dimension over their length (width, density, and rigidity), such as those used in my kalimbas, are non-harmonic. Since kalimbas tines are often metal, overtones structure is usually very rich. For the second mode of vibration for a rod fixed at one end, the overtone is somewhere around 2 octaves and a flat sixth above the fundamental. The third partial is about 4 octaves and a flat major 2nd above the fundamental, which is high enough to ignore for analysis purposes. The second partial is apparently quite a nuisance in kalimba-building, as this interval is non-harmonic and dissonant. Overtone tuning and adding mass to the end of a tine (enhancing the fundamental) can alleviate this problem, altering the overtones to be harmonic. As for my kalimbas, it is apparent that my tines are not dense enough to elicit such a rich overtone structure, so the troublesome second overtone does not seem to make much of an appearance, both when listening to the kalimbas and when visualizing the melodic range spectrogram of the kalimbas in Sonic Visualizer, although in some cases traces of it are observable (see fig. 5, fig. 7).

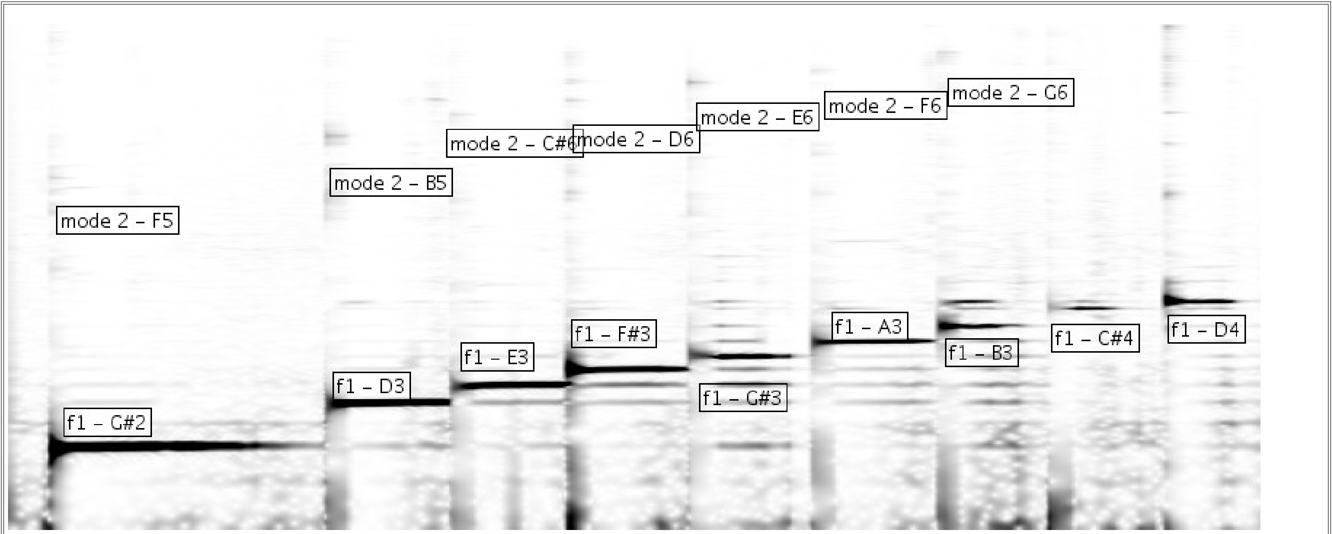

fig 5: melodic spectrogram of a scale played on the guitar-mounted kalimba

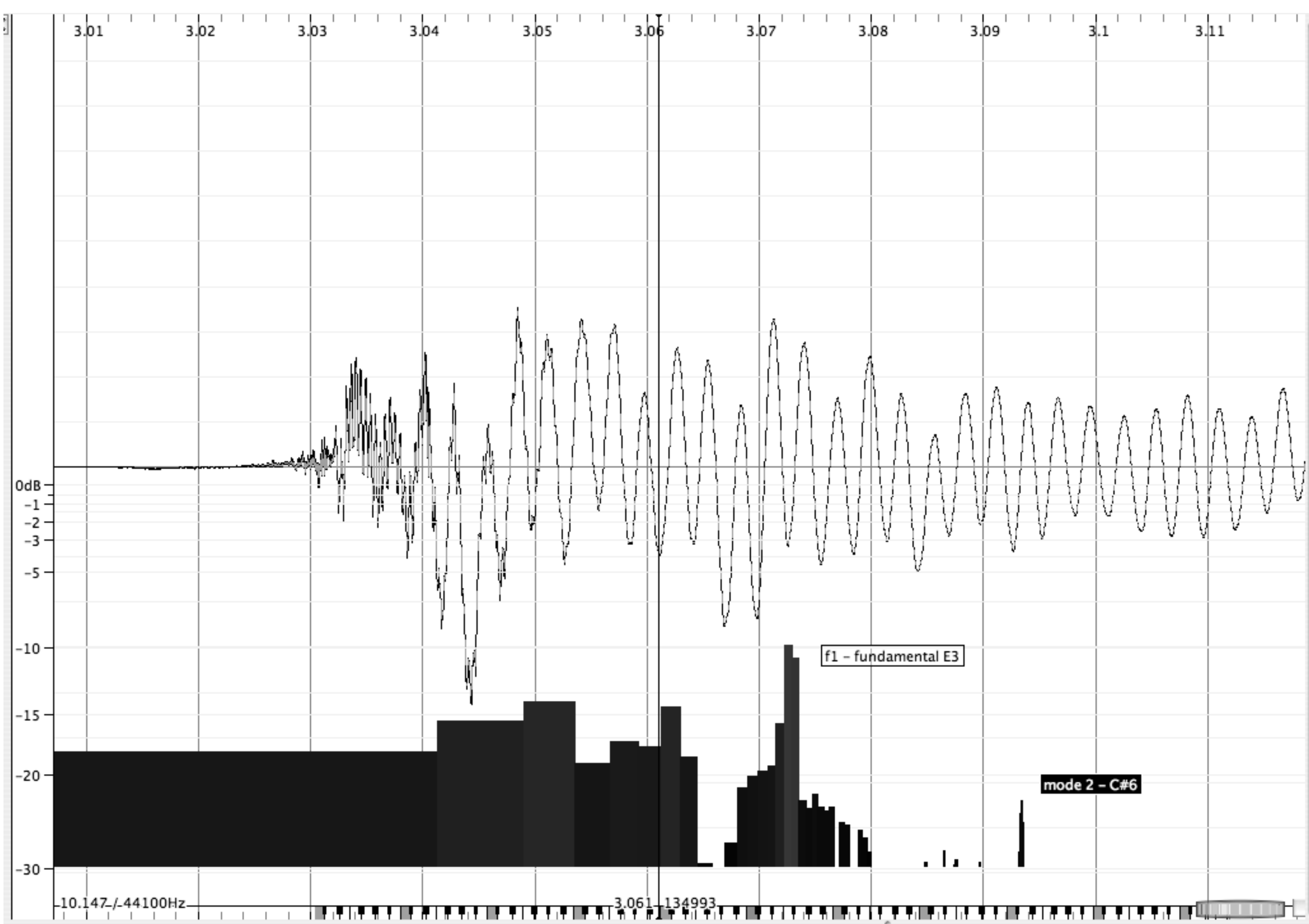

fig 6: waveform and freq. spectrum of E3 tine played on guitar-mounted kalimba

For both kalimbas, there seems to be a lot of content in the range below the fundamental frequency of the tine, however it appears to be non-harmonic, small (and some) inaudible low-end vibrations[1]. Above the fundamental, there does not appear to be any consistently strong harmonic content among the tines. The resulting waveform generated by plucking each tine is relatively simple in shape immediately after the decay of the note, indicating that overtones are not having a substantial effect on the sound (see fig. 6).

With the second, wood-mounted kalimba, this second overtone is less apparent; and as a result the shape of the waveform is simpler than that of the guitar-mounted kalimba for most notes after the decay of the note (see fig. 8). Some inconsistent melodic spectrogram content in the few intervals immediately above the harmonic also appears for some tines, but not others.

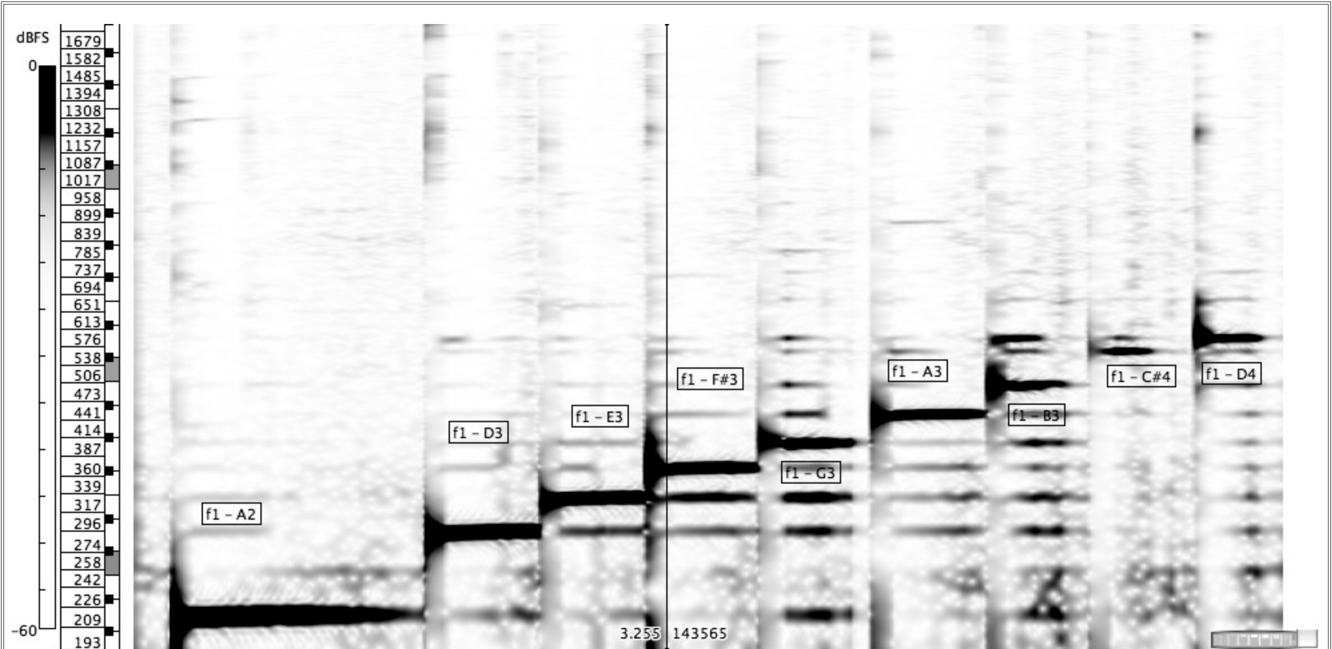

fig 7: melodic spectrogram of scale played on wood-mounted kalimba

1 When recording the series of kalimba notes (a complete scale), I forgot to dampen the tine before plucking the next tine; as such, some of the sustained preceding notes remain in the spectrogram under the new notes.

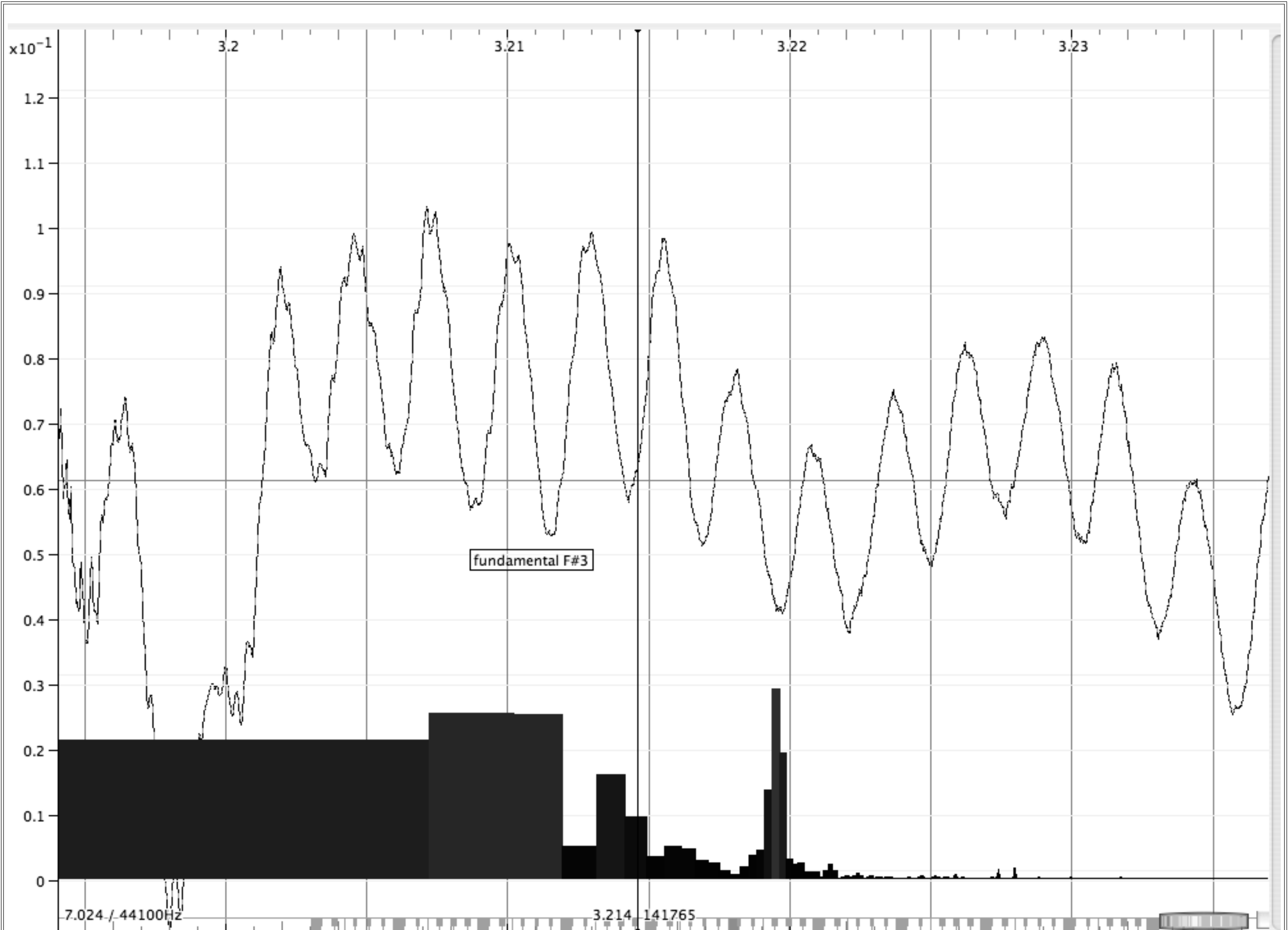

fig 8: waveform and freq. spectrum of F#3 tine played on wood-mounted kalimba

Evaluation - *evaluation of the instrument in terms of its viability for live performance: dynamic range and spectral variation produced; would it work well as an ensemble or solo instrument?*

As previously mentioned, the sound is not projected well from the guitar body, probably due to a combination of the tines not having enough density, and the mounting of the bridge to the soundboard not being heavy enough. The lack of density in the tines may also be the reason for is the lack of spectral content – notably the weakness of the second overtone. In some ways this is a blessing because the second overtone for rods fixed at one end is non-harmonic. Furthermore, the soundboard of the guitar is not heavy enough to project the sound. As such, the sound does not audibly sustain for very long (although it is still detectable in the melodic spectrogram – see fig. 5 and 7 above).

With these drawbacks in mind, the kalimbas are viable for use in live performances only is amplified with a contact pickup or microphone – otherwise they are hobby instruments or toys. Their dynamic ranges are fairly disappointing, as the mountings are not rigid enough (stronger plucks vibrate the mounting and distort the sound).

Provided it is amplified, the kalimbas may work well in an ensemble provided the key of the

composition matches the key of the kalimbas (E major for the guitar-mounted kalimba, D for the wood-mounted kalimba).
As a solo instrument (or combined with a guitar, which may also be amplified), the kalimbas would be ideal for creating simple loop phrases in their respective keys. For at least this purpose, the kalimbas are somewhat successful in accomplishing their purpose.

Suggested Improvements

Several suggested improvements have been mentioned throughout this report, however I will summarize them here:

- A more rigid and heavier mounting to a soundboard would drive the sound with more volume; a denser soundboard (than a guitar body soundboard) would also be required to withstand this heavier mounting.

- Tines of varying thickness, width, and shape/mass at the plucked end could be used to expand the range of the kalimba, and exploit/manipulate the overtones. Most importantly, the tines should be of a denser material than the hollow bobby-pins used here.

- Experimenting with different bridge structures, such as those mentioned on p.42 (fig. 4-9) of Bart Hopkin's *Musical Instrument Design*, may yield differences in dynamic and spectral range.

References

1. Hopkin, B. *Musical Instrument Design,* 1996, See Sharp Press, Tucson AZ., p. 40 – 43 (Rods fixed at one end: kalimbas, tongue drums, and others);

2. Instructables (website), “Thumb Piano”, instructables.com/id/Thumb-Piano/

3. Havlena, Dennis (website), “Bobby Pin Kalimba”, - dennishavlena.com/bobbypin.htm

4. (Kalimba Guitar demo), - youtube.com/watch?v=oWWT3ZZlOa4