

Cristóvão Diniz Trevisan, Viktor Volochtchuk

# **Guitar Digitizer**

Brazil

2017, v-0.0.1

Cristóvão Diniz Trevisan, Viktor Volochtchuk

## **Guitar Digitizer**

Project presented as graduation material  
for the course of Electronic Engineering at  
UTFPR

Federal University of Technology - Paraná – UTFPR

Electronic Engineering

Graduation Program

Supervisor: Gustavo Benvenutti Borba

Brazil

2017, v-0.0.1

---

Cristóvão Diniz Trevisan, Viktor Volochtchuk

Guitar Digitizer/ Cristóvão Diniz Trevisan, Viktor Volochtchuk. – Brazil, 2017,  
v-0.0.1-

33 p. : il.

Supervisor: Gustavo Benvenutti Borba

Graduation Final Project – Federal University of Technology - Paraná – UTFPR

Electronic Engineering

Graduation Program, 2017, v-0.0.1.

1. Hexaphonic Guitar 2. Digitizer 3. MIDI 4. Pitch Detection I. Guitar Digitizer  
II. Gustavo Benvenutti Borba III. Federal University of Technology - Paraná IV.  
Electronic Engineering

CDU 02:141:005.7

---

Cristóvão Diniz Trevisan, Viktor Volochtchuk

## Guitar Digitizer

Project presented as graduation material  
for the course of Electronic Engineering at  
UTFPR

Project Approved. Brazil, October 9, 2017:

---

**Gustavo Benvenutti Borba**  
Supervisor

---

**Professor**  
Invited 1

---

**Professor**  
Invited 2

---

**Professor**  
Invited 3

---

**Professor**  
Invited 4

Brazil  
2017, v-0.0.1

*This work is dedicated to those who supported our way into through engineering course,  
even more when ourselves tried to give up.*

# Acknowledgements

We give our special thanks to Eng. Mikhail Anatholy Koslowski, who gave us both intellectual (since he once used an equipament with the same purposed) and physical support (with compenents importation and equipaments). Also to our advisor who was present even in the moment that the initial idea came to life, in a situation nobody else would have stayed.

# Abstract

Guitar are one of most popular instruments today, but there is one big disadvantage to use it: there is no good and affordable way to digitalize it's music. The biggest problem with this is the cost to annotate music, as it needs to be done by manually. This project tries to build one such system, building from passive hardware (hexaphonic pickup) to modern signal processing (pitch detection), attempting to produce a cheap and effective equipment for guitar music annotation by means of generating MIDI format data.

**Key-words:** guitar. digitizer. MIDI. pitch. detection. hexaphonic.

# Resumo

Violões e guitarras estão entre os instrumentos mais populares da atualidade, mas existe uma grande desvantagem em os utilizar: não há um meio barato e eficaz para digitalizar sua música. O grande problema com isso é o alto custo para transcrever partituras, que atualmente é um processo manual. Esse projeto tenta construir um sistema com esse propósito, criando desde sensores passivos (captador hexafônico) até processamento digital de sinais moderno (detecção de nota), visando um produto barato e eficaz para anotação musical através da geração de dados no format MIDI.

**Key-words:** guitarra. digitalizador. MIDI. nota. detecção. hexafônico.



# List of Figures

Figure 1 – React Redux Flow Diagram . . . . .	20
Figure 2 – Harmonic Series . . . . .	23

# List of Tables

Table 1 – Notes Frequencies . . . . .	22
---------------------------------------	----

# List of abbreviations and acronyms

MIDI	Musical Instrument Digital Interface
UI	User Interface
GUI	Graphical User Interface
API	Application Programming Interface
USB	Universal Serial Bus
DOM	Document Object Model
n.d.	No Date

# List of symbols

$\Omega$	Ohm resistance unit
----------	---------------------

# Contents

	<b>Introduction</b> . . . . .	<b>14</b>
<b>I</b>	<b>HARDWARE</b>	<b>15</b>
<b>II</b>	<b>FIRMWARE</b>	<b>16</b>
<b>III</b>	<b>SOFTWARE</b>	<b>17</b>
<b>1</b>	<b>TOOLS SELECTION</b> . . . . .	<b>18</b>
<b>1.1</b>	<b>Top Level Requirements</b> . . . . .	<b>18</b>
<b>1.2</b>	<b>Language Choice</b> . . . . .	<b>18</b>
1.2.1	Java . . . . .	18
1.2.2	JavaScript . . . . .	18
<b>1.3</b>	<b>Desktop Framework</b> . . . . .	<b>19</b>
1.3.1	Interpreter . . . . .	19
1.3.2	Electron . . . . .	19
1.3.3	Node Webkit . . . . .	20
<b>1.4</b>	<b>Architectural Tools</b> . . . . .	<b>20</b>
<b>1.5</b>	<b>Fast Signal Processing</b> . . . . .	<b>21</b>
<b>1.6</b>	<b>Real Time Visualization</b> . . . . .	<b>21</b>
<b>2</b>	<b>PITCH DETECTION</b> . . . . .	<b>22</b>
<b>2.1</b>	<b>YIN algorithm</b> . . . . .	<b>22</b>
<b>IV</b>	<b>RESULTS AND DICUSSIONS</b>	<b>24</b>
	<b>Conclusion</b> . . . . .	<b>25</b>
	<b>BIBLIOGRAPHY</b> . . . . .	<b>26</b>
	<b>APPENDIX</b>	<b>27</b>
	<b>APPENDIX A – QUISQUE LIBERO JUSTO</b> . . . . .	<b>28</b>

APPENDIX B – NULLAM ELEMENTUM URNA VEL IMPERDIET SODALES ELIT IPSUM PHARETRA LIGULA AC PRETIUM ANTE JUSTO A NULLA CURABITUR TRISTIQUE ARCU EU METUS . . . . .	29
ANNEX	30
ANNEX A – MORBI ULTRICES RUTRUM LOREM. . . . .	31
ANNEX B – CRAS NON URNA SED FEUGIAT CUM SOCIIS NA- TOQUE PENATIBUS ET MAGNIS DIS PARTURI- ENT MONTES NASCETUR RIDICULUS MUS . . .	32
ANNEX C – FUSCE FACILISIS LACINIA DUI . . . . .	33

# Introduction

Part I

Hardware



## Part II

### Firmware

Part III

Software

# 1 Tools Selection

## 1.1 Top Level Requirements

The exact implementation of each of the items will be discussed later, but to simply set our requirements a general list of them is:

- a) Desktop GUI
- b) Efficient signal processing (for pitch detection)
- c) Real time graph visualization of the signals (oscilloscope like)
- d) Access to *libusb* ([LIBUSB](#), n.d.) API
- e) Access to MIDI API

## 1.2 Language Choice

### 1.2.1 Java

The first choice was Java, as it meets all requirements. Desktop GUI can be done using Swing, a good library for pitch detection is also available (called TasosDSP ([SIX; CORNELIS; LEMAN, 2014](#))). There is also a binding to libusb called usb4java and native MIDI support.

Following that idea a functional prototype was built, but a few problems came to rise. The first is that usb4java high-level API had bugs and was not working correctly. The solution was to fall back to the lower level API, but that made things much more complicated as threading and synchronization problems had to be dealt with. There was no good library for real time visualization either, which made really hard to both debug and tune the frequency detection algorithm. On top of that Swing is at least non-pleasant compared to more modern UI programming, so a second approach came to be.

### 1.2.2 JavaScript

In alignment with both current work experience and world programming tendencies JavaScript was taken as a choice. We will see that requirements fit much better now, for the following reasons.

For the desktop GUI, JavaScript has a few nice and mature Desktop GUI frameworks, like Electron and NW.js.

JavaScript is an interpreted language, and for that has a low efficiency when compared

to C++ or Java. That is huge problem, but there is an easy overcome. As this project tries to build a desktop application, Node.js will be used ultimately, and it has support for C++ bindings. That means the JavaScript code can call a compiled C++ library to calculate the pitch, thus solving the problem.

Graph visualization should not be a problem either as there are a lot of libraries for that. The most problematic requirement in Java was *libusb* support. It is available in JavaScript using *node-usb* ([NODE-USB](#), [n.d.](#)), and a few simple tests returned good results with a much simpler API. MIDI was also tested and worked just fine.

## 1.3 Desktop Framework

Now that JavaScript is set as our final selection we need an environment to run it. There are two already listed really mature and popular choices: Electron and NW.js. At first Electron was used to build a test application, because it is the most popular of the two (in fact even the editor used to write this words is built with it), but the pitch detection call was running slowly. As a matter of fact it was running much faster using pure JS code rather than the C++ library. A deeper research was needed, and the way Electron worked was getting in our way, but first it's necessary to know what Node.js is.

### 1.3.1 Interpreter

JavaScript is a interpreted language and thus needs an interpreter. The most common one is Google V8, which happens to be the same one used in most web browsers as well as in Node. The difference between browsers and Node is simply the API that comes with them. Web needs firstly to access the UI (html) and ways to modify it, it also needs secure and limited access to hardware and internet calls. Of course that means web JavaScript code cannot use C++ libraries directly.

On the other hand Node is a more pure version of V8, it also gives the possibility to write and call C++ code (feature needed for this project), which ultimately makes it as capable as any desktop program can be. Node also comes with a hand-full set of native resources (like file system and full communication access), but it does **not** provide any kind of GUI. Knowing that it is possible to have a better understanding on how the two desktop environments work.

### 1.3.2 Electron

Electron by design has at least two processes running ([HOW...](#), 2017), one for the "web" and other for Node access. The answer for how the web process access native resources is also to why the execution of the C++ processing library was slow: it uses

inter-process communication (IPC). IPC makes things a lot slower, which ultimately makes impossible to use Electron in this project.

### 1.3.3 Node Webkit

Differently from Electron, NW.js ([NODE...](#), n.d.; [HOW...](#), 2017) takes the Node environment and combines it with Chromium into a single process, removing the use of IPC. Initial tests reported that the pitch detection library has fast execution as expected.

## 1.4 Architectural Tools

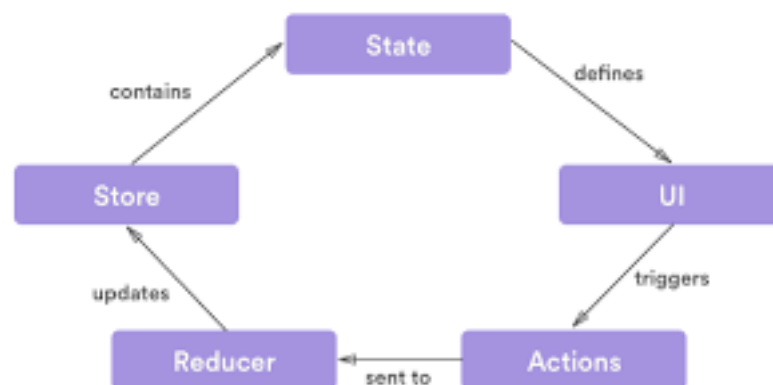
NW.js will go only as far as to give access to both Node and DOM API's. But that is too crude, and not what we wanted by given up on Java Swing. Again based on current work experience and world tendencies the setup chosen is React + Redux.

React ([REACT](#), n.d.) is a library created by Facebook and world wide used for UI applications. It uses a declarative component-based system that makes it easy to build scalable and reusable code.

React only go as far to help building the UI, but we also need to pass the state of the application to the UI components, and that is where Redux comes in. It keeps all the application state stored in a single place, described by transition functions. That makes the storage system easy to be tested and used, because all actions (that modify the state) must be well defined and it doesn't rely on the UI (React), making it easy to test.

[Figure 1](#) shows the flow of an application that uses React + Redux. It is obvious to see the simplicity it has, a single path must be followed. This simplicity is what makes it much easier to use against other frameworks like Java Swing.

Figure 1 – React Redux Flow Diagram



Source: [Getting...](#) (2016)

## 1.5 Fast Signal Processing

Pitch detection is a heavy problem to solve, and good implementations are time consuming, so we need efficiency to run it real-time. The library already said to be used didn't actually exist, the only one available was a pure JavaScript library ([PITCHFINDER](#), [n.d.](#)) which is not suitable for this project. The solution was to build our own library based on both the pure JavaScript one and TarsosDSP ([SIX; CORNELIS; LEMAN, 2014](#)). Implementation details discussed further on [chapter 2](#).

## 1.6 Real Time Visualization

There are lots of charting libraries available for use with web interfaces (and by extension NW.js), unfortunately none was a good fit for real time high density signals such as audio. The solution was again to build one, since all other things are looking to run smoothly in JavaScript, implementation details on [TODO-REF](#).

## 2 Pitch Detection

Pitch detection is simply frequency detection with the restriction of note quantization, [Table 1](#) shows the base frequency for each of the 12 existent notes. Multiples of the same frequency are seen as the same note on a different range, known as octave.

Table 1 – Notes Frequencies

Note Name	Frequency
A	440.00
A#	466.16
B	493.88
C	523.25
C#	554.37
D	587.33
D#	622.25
E	659.25
F	698.46
F#	739.99
G	783.99
G#	830.61

Source: made by authors

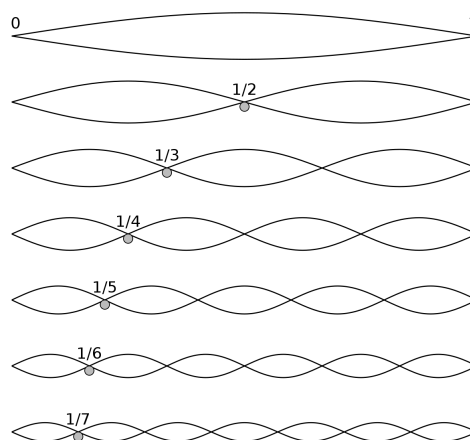
Even though the quantization makes things simpler it's still a hard task, even more for instruments whereas there is the presence of harmonic series. Harmonic series notes are multiples of the fundamental frequency (most important note) produced by integer sections of the instrument vibration. [Figure 2](#) shows an visual representation of why there exist. The existence of them as well as the presence of both inter-signal and white noise makes necessary the use of non-trivial algorithms for pitch detection, and two of them will be discussed next.

### 2.1 YIN algorithm

Autocorrelation is a well know function to calculate a signal's fundamental frequency, but it gives too much error for this project use case. YIN ([CHEVEIGNÉ; KAWAHARA, 2002](#)) is a method that uses a few improvements to the autocorrelation method, achieving a much higher precision. The algorithm can be divided in 6 steps, as follows:

1. Autocorrelation function
2. Difference function
3. Cumulative mean normalized difference function

Figure 2 – Harmonic Series



Source: [Wikipedia](#) (2017)

4. Absolute threshold
5. Parabolic interpolation
6. Best local estimate



## Part IV

### Results and Dicussions

# Conclusion

Sed consequat tellus et tortor. Ut tempor laoreet quam. Nullam id wisi a libero tristique semper. Nullam nisl massa, rutrum ut, egestas semper, mollis id, leo. Nulla ac massa eu risus blandit mattis. Mauris ut nunc. In hac habitasse platea dictumst. Aliquam eget tortor. Quisque dapibus pede in erat. Nunc enim. In dui nulla, commodo at, consectetur nec, malesuada nec, elit. Aliquam ornare tellus eu urna. Sed nec metus. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas.

Phasellus id magna. Duis malesuada interdum arcu. Integer metus. Morbi pulvinar pellentesque mi. Suspendisse sed est eu magna molestie egestas. Quisque mi lorem, pulvinar eget, egestas quis, luctus at, ante. Proin auctor vehicula purus. Fusce ac nisl aliquam ante hendrerit pellentesque. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi wisi. Etiam arcu mauris, facilisis sed, eleifend non, nonummy ut, pede. Cras ut lacus tempor metus mollis placerat. Vivamus eu tortor vel metus interdum malesuada.

Sed eleifend, eros sit amet faucibus elementum, urna sapien consectetur mauris, quis egestas leo justo non risus. Morbi non felis ac libero vulputate fringilla. Mauris libero eros, lacinia non, sodales quis, dapibus porttitor, pede. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi dapibus mauris condimentum nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Etiam sit amet erat. Nulla varius. Etiam tincidunt dui vitae turpis. Donec leo. Morbi vulputate convallis est. Integer aliquet. Pellentesque aliquet sodales urna.

# Bibliography

CHEVEIGNÉ, A. de; KAWAHARA, H. YIN, a fundamental frequency estimator for speech and music. *The Journal of the Acoustical Society of America*, p. 111, jan. 2002. Available from Internet: [http://audition.ens.fr/adc/pdf/2002\\_JASA\\_YIN.pdf](http://audition.ens.fr/adc/pdf/2002_JASA_YIN.pdf). Accessed: 30 sep. 2017. Quoted in page 22.

GETTING Started with React, Redux and Immutable: a Test-Driven Tutorial (Part 2). 2016. Theodo. Available from Internet: <https://www.theodo.fr/blog/2016/03/getting-started-with-react-redux-and-immutable-a-test-driven-tutorial-part-2/>. Accessed: 8 oct. 2017. Quoted in page 20.

HOW does Node.js work with NW.js and Electron? 2017. Medium. Available from Internet: <https://medium.com/@paulbjensen/how-does-node-js-work-with-nw-js-and-electron-da9e50e2c3c1>. Accessed: 8 oct. 2017. Quoted 2 times in pages 19 and 20.

LIBUSB. n.d. Cross-platform API for generic USB access. Available from Internet: <http://libusb.info/>. Accessed: 8 oct. 2017. Quoted in page 18.

NODE-USB. n.d. Node bindings to libusb. Available from Internet: <https://github.com/tessel/node-usb>. Accessed: 8 oct. 2017. Quoted in page 19.

NODE Webkit. n.d. Available from Internet: <https://nwjs.io/>. Accessed: 8 oct. 2017. Quoted in page 20.

PITCHFINDER. n.d. A compilation of pitch detection algorithms for Javascript. Available from Internet: <https://github.com/peterkhayes/pitchfinder>. Accessed: 8 oct. 2017. Quoted in page 21.

REACT. n.d. A JavaScript library for building user interfaces. Available from Internet: <https://reactjs.org/>. Accessed: 8 oct. 2017. Quoted in page 20.

SIX, J.; CORNELIS, O.; LEMAN, M. TarsosDSP, a Real-Time Audio Processing Framework in Java. In: *Proceedings of the 53rd AES Conference (AES 53rd)*. [S.l.: s.n.], 2014. Quoted 2 times in pages 18 and 21.

WIKIPEDIA. *Harmonic series (music)*. 2017. Available from Internet: [https://en.wikipedia.org/wiki/Harmonic\\_series\\_\(music\)](https://en.wikipedia.org/wiki/Harmonic_series_(music)). Accessed: 9 oct. 2017. Quoted in page 23.

# Appendix

## APPENDIX A – Quisque libero justo

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

## APPENDIX B – Nullam elementum urna vel imperdiet sodales elit ipsum pharetra ligula ac pretium ante justo a nulla curabitur tristique arcu eu metus

Nunc velit. Nullam elit sapien, eleifend eu, commodo nec, semper sit amet, elit. Nulla lectus risus, condimentum ut, laoreet eget, viverra nec, odio. Proin lobortis. Curabitur dictum arcu vel wisi. Cras id nulla venenatis tortor congue ultrices. Pellentesque eget pede. Sed eleifend sagittis elit. Nam sed tellus sit amet lectus ullamcorper tristique. Mauris enim sem, tristique eu, accumsan at, scelerisque vulputate, neque. Quisque lacus. Donec et ipsum sit amet elit nonummy aliquet. Sed viverra nisl at sem. Nam diam. Mauris ut dolor. Curabitur ornare tortor cursus velit.

Morbi tincidunt posuere arcu. Cras venenatis est vitae dolor. Vivamus scelerisque semper mi. Donec ipsum arcu, consequat scelerisque, viverra id, dictum at, metus. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut pede sem, tempus ut, porttitor bibendum, molestie eu, elit. Suspendisse potenti. Sed id lectus sit amet purus faucibus vehicula. Praesent sed sem non dui pharetra interdum. Nam viverra ultrices magna.

Aenean laoreet aliquam orci. Nunc interdum elementum urna. Quisque erat. Nullam tempor neque. Maecenas velit nibh, scelerisque a, consequat ut, viverra in, enim. Duis magna. Donec odio neque, tristique et, tincidunt eu, rhoncus ac, nunc. Mauris malesuada malesuada elit. Etiam lacus mauris, pretium vel, blandit in, ultricies id, libero. Phasellus bibendum erat ut diam. In congue imperdiet lectus.

## Annex

## ANNEX A – Morbi ultrices rutrum lorem.

Sed mattis, erat sit amet gravida malesuada, elit augue egestas diam, tempus scelerisque nunc nisl vitae libero. Sed consequat feugiat massa. Nunc porta, eros in eleifend varius, erat leo rutrum dui, non convallis lectus orci ut nibh. Sed lorem massa, nonummy quis, egestas id, condimentum at, nisl. Maecenas at nibh. Aliquam et augue at nunc pellentesque ullamcorper. Duis nisl nibh, laoreet suscipit, convallis ut, rutrum id, enim. Phasellus odio. Nulla nulla elit, molestie non, scelerisque at, vestibulum eu, nulla. Ut odio nisl, facilisis id, mollis et, scelerisque nec, enim. Aenean sem leo, pellentesque sit amet, scelerisque sit amet, vehicula pellentesque, sapien.



## ANNEX B – Cras non urna sed feugiat cum sociis natoque penatibus et magnis dis parturient montes nascetur ridiculus mus

Sed consequat tellus et tortor. Ut tempor laoreet quam. Nullam id wisi a libero tristique semper. Nullam nisl massa, rutrum ut, egestas semper, mollis id, leo. Nulla ac massa eu risus blandit mattis. Mauris ut nunc. In hac habitasse platea dictumst. Aliquam eget tortor. Quisque dapibus pede in erat. Nunc enim. In dui nulla, commodo at, consectetur nec, malesuada nec, elit. Aliquam ornare tellus eu urna. Sed nec metus. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas.

## ANNEX C – Fusce facilisis lacinia dui

Phasellus id magna. Duis malesuada interdum arcu. Integer metus. Morbi pulvinar pellentesque mi. Suspendisse sed est eu magna molestie egestas. Quisque mi lorem, pulvinar eget, egestas quis, luctus at, ante. Proin auctor vehicula purus. Fusce ac nisl aliquam ante hendrerit pellentesque. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi wisi. Etiam arcu mauris, facilisis sed, eleifend non, nonummy ut, pede. Cras ut lacus tempor metus mollis placerat. Vivamus eu tortor vel metus interdum malesuada.