# Low Cost Compact Devices for Binaural Pulse Reproduction

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***Abstract*—Binaural Pulses are a interpration that the Brain has on the brain when two sources at different frequencies are placed on a different ear, in this case this is achieved using headphones. In order to reproduce this Binaural Pulses in a Low cost and compact device the Raspberry Pi was taken into account and used or this project. Along with the Raspberry Pi the developer used Python to create a Graphic User interface (GUI), that could enable users to reproduce and generate Binaural Pulses in the easiest way possible. Several windows make up the GUI, that has a simple and easy navigation though it. Finally it was developed 2 ways of connection, utilizing a 7” Raspberry Pi compatible Touchscreen and a connection via VNC viewer, both ways the user can interact with the GUI, from either the 7” display, a computer, or even a cellphone, creating a Binaural Pulse Generator and Player that is easy to use and compatible with multiple user platforms.**

***Index Terms*—Binaural Pulse, Central Frequency, GUI, Raspberry Pi**

## I. Introduction

The work evaluated in this paper it’s about using low cost and efficient devices for reproduction of binaural pulses. In order to do this, the selection of the device was very important, in this case the device that was used is the Raspberry Pi 3, this is because in comparison with other devices like laptops, the Raspberry Pi is very cheap, it’s price is about 45 dollars. Even though the development in the Raspberry Pi is much more difficult than in other devices, we have to take in account that we need a device that is the easiest to use by the user that will eventually hear.

The development consisted in two main phases, the first being the development of a Graphic User Interface (GUI) that can effectively reproduce binaural pulses, with different central frequency and a different binaural pulse frequency.

After the succesful development of the Graphic User Interface, 2 types of connections to the Raspberry Pi were considered, them being:

- 7” LCD Display
- Cellphone Connection via VNC Viewer

Considering the previous two connections to controll the Rasberry Pi for the reproduction of binaural pulses, a user and a developer can both use the GUI that was developed for either, investigating about the effects that binaural pulses have on the sleep of people or the usage of the system to address those sleep involved problems.

## II. Background

### A. Binaural Pulse

A binaural pulse it’s the understanding that the brain has when 2 different frequencies, are placed on a different ear, that causes this phenomenom wich affects the brain in certain ways,binaural pulse, that could benefit our sleep [1], [2]. This pulses could cause the following reactions:

- Memory Improvement
- Neuronal Plasticity
- Neuronal communication

The following diagram represents how a binaural beat is stimulated on a person:

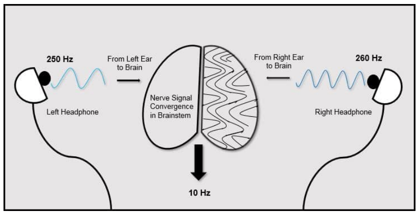

Figure 1. Binaural Beats using headphones [4]

### B. Raspberry Pi

The Raspberry Pi (RPi) is a device launched in 2012, which seeks to be a low-cost computer. By simply adding input peripherals like keyboard, mouse, and output peripherals like monitor, it can be used just like a regular computer. The RPi uses Linux-based operating systems, for example Raspbian.

One of the advantages of these devices is their price because it is quite low compared to laptops or desktops. In the development of this project, the Raspberry Pi 3 was used, which has an approximate price of 45 dollars [3].

### C. Python

Python is a high-level object-oriented programming language. This programming language is especially attractive, due to the fact that a quick application development can be carried out. The comparison of other programming languages, Python is simple both in its syntax and in how to interpret it. Another important feature of Python is that it supports modules and packages, so there is quite a lot of code recycling [5].

The Raspberry Pi has 2 modules incorporated that are able to run and develop programs on Python:

- Python (IDLE)
- Thonny Python IDE

## III. Prototype

Due to the nature of the Binaural Pulse Generator that was developed, the specification of some of the features that the prototype has and also the different components that makes it work it's needed.

### A. Binaural Pulse Generation with Python

The used software for the genaration of the Binaural Pulses was Python, this was because developing a GUI on this programming language is very attainable in comparison with other programming languages. Nevertheless the Binaural Pulses had to be generated by Python also, this was acchieved using an algorithm that consist in various variables, but first the main thng is that the Binaural Pulses are simply considered as two sine waves that have different frequencies, due to that it's needed to define a sine wave in a way that it's computable. This is achieved utilizing the Fourier Sine Series:

$$y = \sum_{i=0}^{N} \frac{4}{\pi} \frac{2\pi * n}{N} \tag{1}$$

An algorithm that was developed on a previous graduation project was recycled and adapted into a Raspberry Pi, in order to generate the Binaural Pulses. But some of the code had to be change this is because the previous program was developed on Python but utilizing Windows libraries, and the Raspberry Pi Raspbian's has some different libraries than Windows.

### B. Binaural Pulse Reproduction

Even though the generation of Binaural Pulses it's only adapted from a previous iteration of this project, the reproduction of the sound on the Rasberry Pi was a complete different story. This because it was challenging to find a library that could run WAV file on the Raspberry Pi, because the libraries available only could reproduce OGG files. Due to this problem a method was implemented, were a WAV file was generated to later be converter to an OGG audio file.

Having an OGG file a Python library was then used to reproduce the given Binaural Pulse. All this problems that come up are limitations, but they are limitations given by the characteristics of a low cost and compact device.

### C. Graphic User Interface

Having defined how the Bianural Pulses were generated and reproduced, the next step was to provide user and the developer with a Graphic User Interface which allowed them to generate and play the binaural pulses in a way that was easy and intuitive.

The first step of showing the GUI is to demonstrate the main features that most of the frames of interface has:

This icon enables the user to terminate the from any frame of it, it's very useful and intuitive.

Figure 2. Off Icon

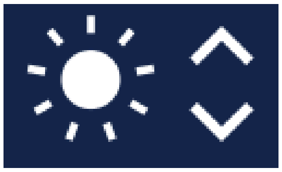

Figure 3. Brightness Icon

The brightness icon enables to change the brightness of the display of the Raspberry Pi, the arrow pointing up makes the display brighter, and the arrow pointing down makes the display less brighter.

Figure 4. Backward Icon

The backward icon enables the navigation to the previous frame of the GUI. Now knowing the general purpose icons of the GUI the different frames that the GUI has will be presented:

*1) Main Page:* Main Page is a frame that presents the GUI with a cover page with all the general icons but the backward icon. The play icon in the middle allows the user to navigate to the other frames of the GUI, as shown in Figure 5.

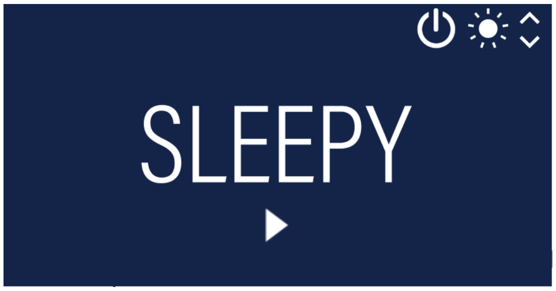

Figure 5. Main Page

*2) Sub Menu:* The Sub Menu has the ability to navigate to several pages: Main Page,Binaural Pulse Generating Page, Binaural Pulse Reproduction Page.

*3) Binaural Pulse Generation:* This frame of the GUI has several features that must be discussed. The first two features are the inputs of both Central frequency of the Binaural Pulse and the frequency of Binaural Pulse. This parameters allow the user to generate Binaural Pulse with certain frequencies.

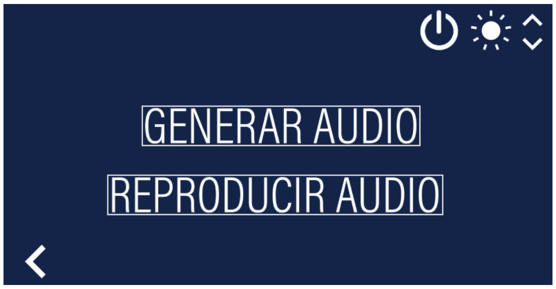

Figure 6. Sub Menu

Another feature is the Generate Audio button on the bottom of the frame.When the user has entered the Central Frequency and the Binaural Pulse Frequency and the button is pressed an Wav file is generated utilizing an algorithm that produces the binaural pulses. After the wav file is saved on a certain location, the file is located and then converted to an OGG file in order to be played on the Raspberry Pi libraries. The generated files continue are saved permanently in a folder unless they are directly deleted.

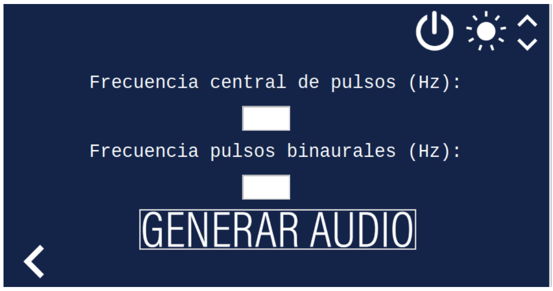
Frecuencia central de pulsos (Hz):
Frecuencia pulsos binaurales (Hz):
GENERAR AUDIO

Figure 7. Sub Menu

*4) Binaural Pulse Reproduction:* The final frame of the GUI makes possible the reproduction of Binaural Pulses, this is simply the reproduction of OGG files generated in previous stages of the program.

There are 3 main steps to get the Binaural Pulse Reproduction to work, the first is determining the time that the binaural pulse will be played, that is achieved when the user enters a value in both of the Text Boxes. After having selected a time of reproduction, the user must select the Binaural Pulse that is needed, this happens when the Select Binaural Pulse button is pressed, opening the following window:

After the selection of the Binaural pulse OGG file and the time that it will be played, the next step is to press the play button. The user is able to pause the pulse or to stop it, the difference is that when you stop the audio, the time that the binaural beat will be played is the same that the user entered when the playing started.

Having described all the frames of the GUI that was developed, the following diagram describes how it works:

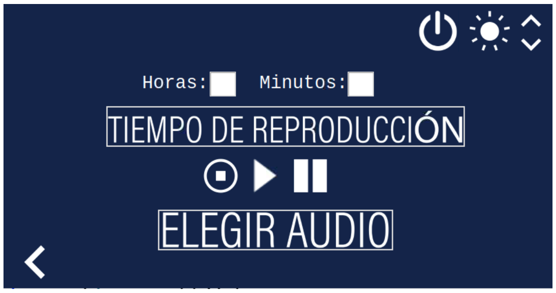

Figure 8. Play Binaural Pulse

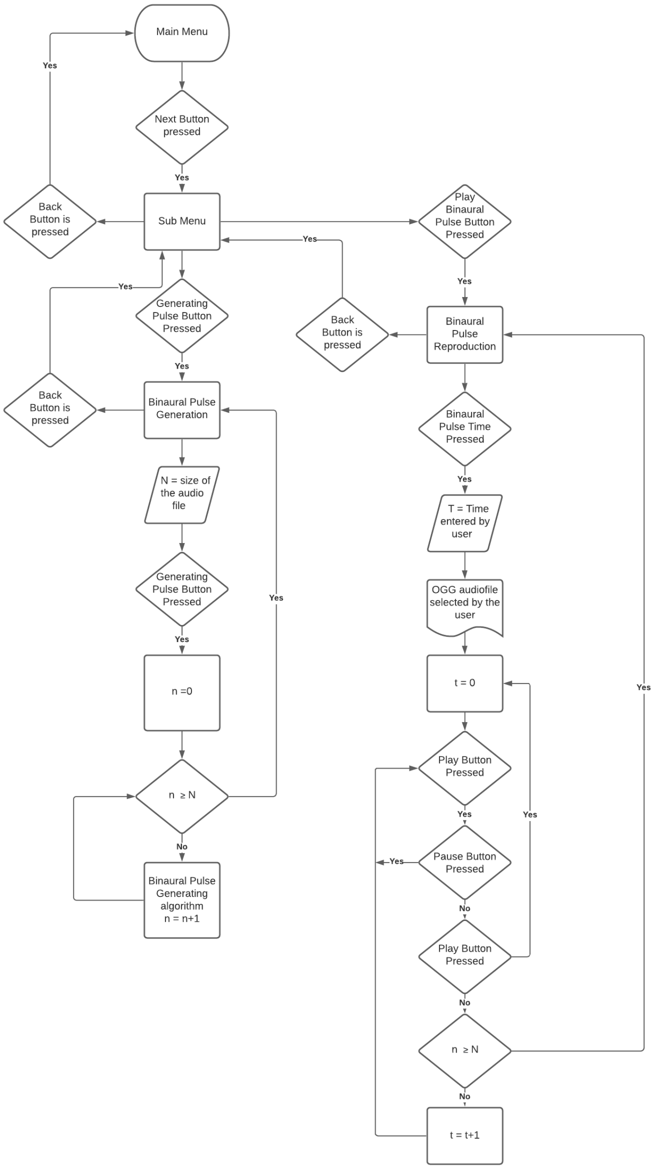
Main Menu
Yes
Next Button pressed
Yes
Back Button is pressed
Sub Menu
Yes
Play Binaural Pulse Button Pressed
Yes
Generating Pulse Button Pressed
Yes
Back Button is pressed
Binaural Pulse Reproduction
Yes
Back Button is pressed
Binaural Pulse Generation
Binaural Pulse Time Pressed
Yes
N = size of the audio file
T = Time entered by user
OGG audiofile selected by the user
Generating Pulse Button Pressed
Yes
Yes
n =0
t = 0
Yes
Play Button Pressed
Yes
Yes
n ≥ N
No
Yes
Pause Button Pressed
No
Binaural Pulse Generating algorithm n = n+1
Play Button Pressed
No
n ≥ N
No
t = t+1

Figure 9. Play Binaural Pulse

All this components, frames or windows are a part of the GUI that is able to generate and reproduce Binaural Pulses. In order to achieve a paralell run of several modules at the same time when the GUI was coded on Python it was developed taking much consideration of object oriented programming managing to get this goal done.

## IV. Connection

After the development of the GUI, that was developed on a Rasberry Pi, that was connected to an HDMI connector to a monitor, there had to be developed a way to connect the Raspbery Pi in a way that could still be compact, coming up with the following connections:

- Connection with 7” display
- Connection with VNC Viewer from cellphone

The first connection that is mentioned is the one utilizing 7” Display that connects directly to the raspberry Pi through 4 jumper cables, a ribbon cable, headphones and a numeric keyboard as shown in the figure 10.

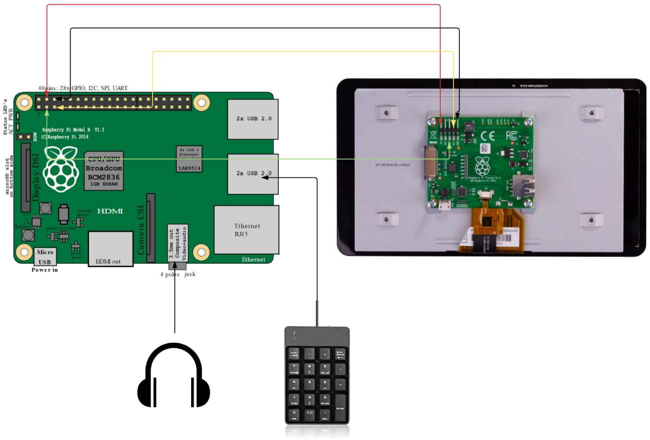

Figure 10. Connection Diagram with the 7” Display

This connection it’s more about the final user this because it has certain features like adjusting the brightness of the screen among other that enable an easy and good interaction between the user and the interface. The 7” screen is very useful because it is a touch screen too, because of that a peripheral device to move the mouse around the screen is not necessary.

A peripheral device that is suggested in this connection is a numerical key boar, this because even though the Raspbery Pi has a built in keyboard that can be used to type down numbers or words it is a little bit difficult to work with, because it takes screen space that is being used to display the GUI, to avoid this is fairly easy to connect a numerical keyboard that does not take a lot of space and it makes the utilization of the application easier.

It is important to know that the Raspbery Pi has to be connected to a power source directly, it could be a very or directly connected to an electric outlet.

Some tests took place in order to get the values of the Binaural Pulse Frequency, and the Central Frequency of the binaural pulse, being that the best ranges that allow a user to sleep are from 170 Hz- 300 Hz and 1 Hz - 50 Hz, respectively.

This type of connection has a case which make the look of it more aesthetic, the Raspbery Pi gets attached to the touchscreen with screws and later a plastic cover is attached to make it like an embedded system.

The second connection involves an external app called VNC Viewer, allows the user to connect to a Raspbery Pi through another devices that also have the same application, the only specification needed to connect the 2 devices is that both of them are connected to the same network. The following diagram represent the connection described before:

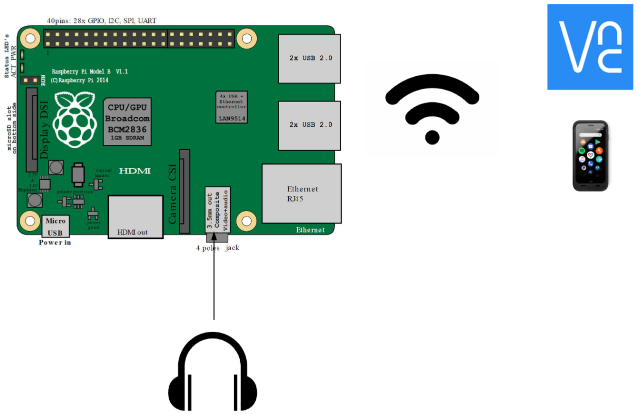

Figure 11. Connection Diagram with VNC Player

This is a fairly easy system that does not takes much space, this because the connection is done via Wi-Fi. The GUI is very similar if not the same in some aspects as of the previous connection, but the brightness is not adjustable in this GUI because the physical screen is not the one being controlled.

This connection is thought more to be usded by the developer, because the user can change the Binaural Pulse remotely, so this is a prototype that could be used to evaluate the effects of Binaural Pulses on sleep or similar studies.

The steps to connecting the device that has VNC Viewer and the Raspberry Pi are very simple. First the user has to verify what’s the IP address that the Raspberry Pi has, after that in the VNC viewer app in the device the user enter the IP address and the connection has been set. If the devices are on different Wi-Fi networks the connection will not work.

## Acknowledgment

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## References

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