3-Stage PLL Frequency Synthesizer User Guide

*Mildred Lizette Rodriguez Puc (*lizette.rodriguez.p@gmail.com*)*

April 22, 2021

Introduction

The 3-Stage PLL Frequency Synthesizer requires for an N division factor to be programmed into the CS2300 Cirrus board that is the main stage of the system. This N value holds a strict relation to the base frequency thus this base frequency is all that the user needs to input for the programming to have place. This interface allows the user to know beforehand the value to be expected at the output of the frequency synthesizer thanks to previous computing of the microcontroller (MCU) implemented.

Contents

Quick Block Diagram of the System

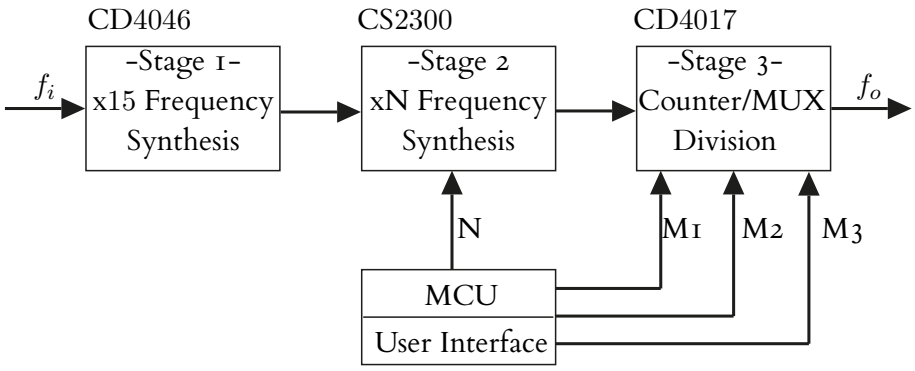


Figure 1: Block diagram of parameters to handle

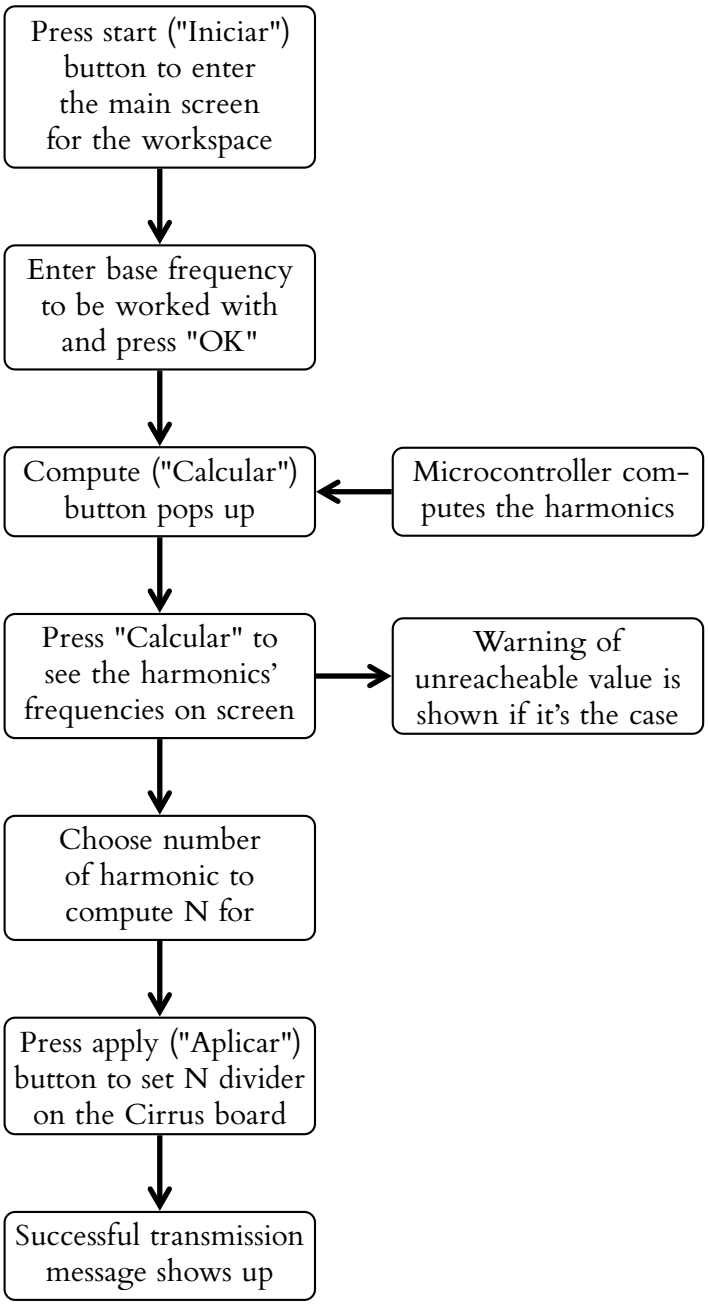
The 3 stages of the PLL Frequency Synthesizer are depicted in Fig. 1. The input of this system is a signal of 299 Hz that comes from an induction motor, while the output is the frequency to be generated proportional to the input. The Stage 1 is a first PLL frequency synthesizer that multiplies the input frequency by a constant value of 15 using the CD4046 CMOS Micropower IC and the CD4017 CMOS counter IC.

The Stage 2 is conformed by the CS2300 Cirrus board and is the main PLL frequency synthesizer that allows the input frequency to be multiplied by different values of N to produce the desired outputs in the order of the MHz.

The user interface is the medium through which the user can input a base frequency that the algorithm will calculate 10 harmonics for, then the user can select a harmonic to be generated and the MCU computes and assigns the N value to the Cirrus board as well as controls the multiplexors at the Stage 3.

The Stage 3 transforms the Stage 2 output into the original desired frequency. This transformation is done through counters that divide the frequencies back to the Hz order. Various and different divisions need to take place for specific cases, thus, to activate the different divisions multiplexers (MUX) are integrated. There are 3 multiplexers involved in the Stage 3 for which 3 sets of data lines are needed (M1, M2 and M3), one line per MUX. The MCU is in charge of sending the data to each MUX. The data send by the MCU is decided upon the user's input in the interface.

Quick Guide to Workflow



1 Initial Hardware Connections

The interface is the medium of communication between the user and the hardware that builds the 3-Stage PLL Frequency Synthesizer. Therefore, in order to establish communication the hardware must be set up before attempting to enter the interface. The hardware of the system is labelled to identify all the connections needed. The connections are described bellow, alongside Fig. 2, 3 and 4.

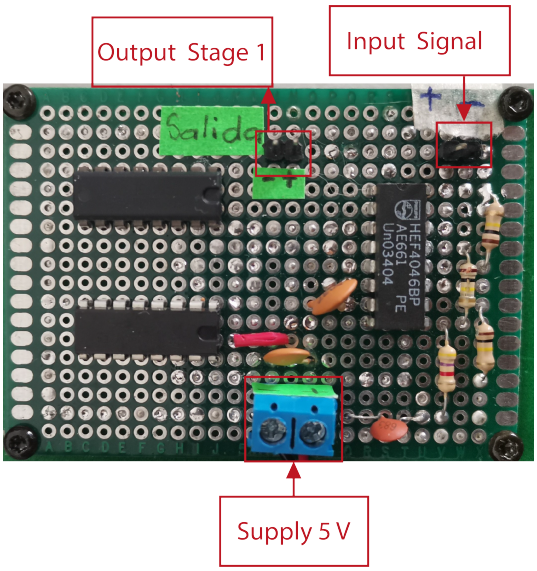


Figure 2: Connections for Stage 1 board: Input Signal, Supply Voltage and Output Signal

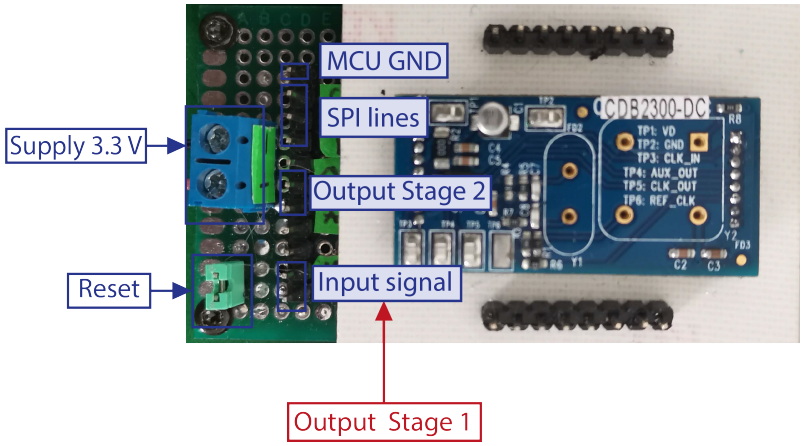


Figure 3: Connections for Stage 2 board: Input Signal, SPI Lines, MCU GND, Supply Voltage and Output Signal

It is important to remark that an active input signal must be connected to the CS2300 before starting the MCU otherwise the configuration of the registers may not take effect. The connections for the SPI lines are described in Table 1 where each pin of the CS2300 involved in the SPI communication has a corresponding pin on the MCU.

CS2300 Pin	MCU Pin
CLK (Clock)	GPIO14
CS (Selecting line)	GPIO15
DIN (Data line)	GPIO13

Table 1: Connection of SPI lines

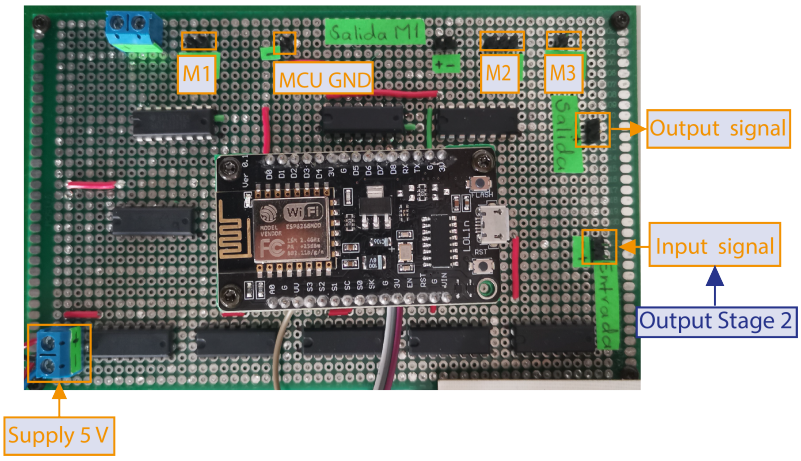


Figure 4: Connections for Stage 3 board: Input Signal, MCU GND, MUX Control Pins, Supply Voltage and Output Signal

The MUX control pins are driven by the MCU and thus have a designated set of pins for each MUX. The correlation between these pins is listed in Table 2

MUX Pin	MCU
M1	GPIO5 and GPIO16
M2	GPIO2, GPIO0 and GPIO4
M3	GPIO3

Table 2: Connection of MUX control pins

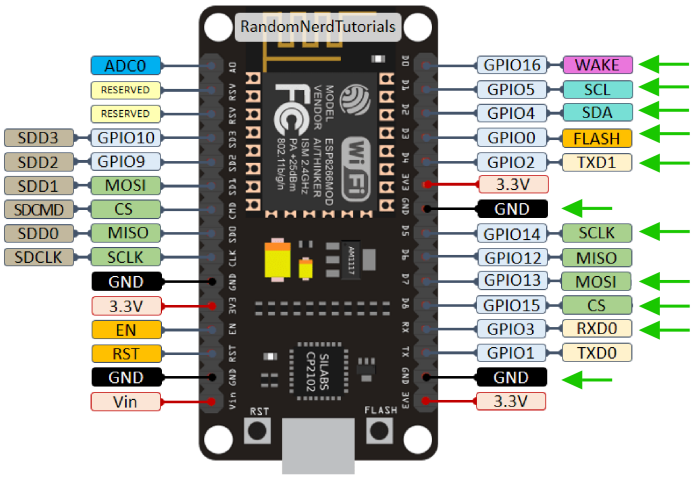


Figure 5: ESP8266, Link

The MCU used for the system is the ESP8266 and the pins to be connected are located as shown in the Fig. 5. Given that the MCU requires a WiFi connection to communicate with the interface it is recommended to ensure a stable WiFi network and to place the MCU on a firm surface and near enough to the WiFi source.

2 Start screen

The first screen of the interface, as shown in Fig. 6, shows a single start button with the name Iniciar. By clicking this button the app checks for a connection with the microcontroller, if a connection is found the app enters the main screen, shown in Fig. 7 where all functions are accessed. For this WiFi connection to be found all hardware connections must have been set up and the appropriate code for the MCU to connect to a WiFi network must have been uploaded and programmed into the MCU.

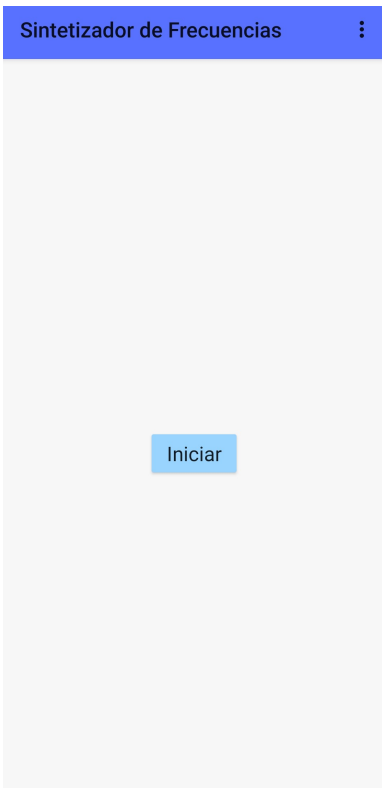


Figure 6: Start screen

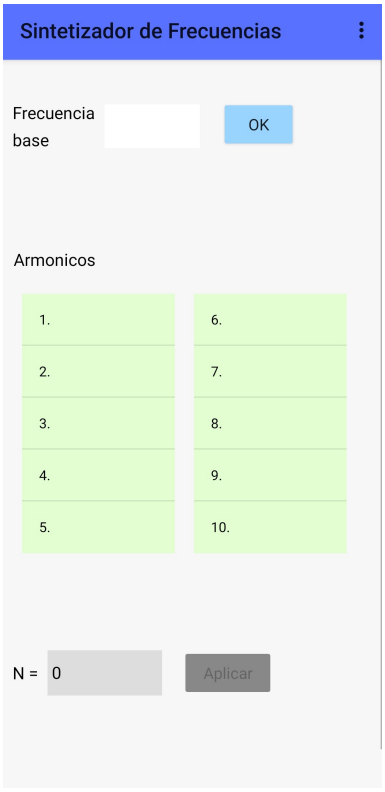


Figure 7: Main screen

The main screen initializes with only the base frequency field available to avoid malfunctioning.

3 Entering the Base Frequency

The first blank field on the main screen is where the base frequency is input (Fig. 8).

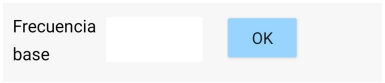


Figure 8: Base frequency blank field

- The base frequency is the frequency that represents the first harmonic.
- The range of the base frequency is 5 Hz to 100 Hz if all ten harmonics want to be reached.
- If not all harmonics want to be reached higher values than 100 Hz can be input keeping in mind that the maximum harmonic that can be reached must be equal or less than of 1000 Hz.
- The base frequency can be a fractional number.
- The number of digits after the decimal point is limited to 20 due to the resolution of the Cirrus board.
- A new base frequency value can be entered at any given point but it is recommended to wait at least 2 seconds if the Aplicar has been pressed.

1. Write on the blank field next to Frecuencia base the base frequency in Hz you want to use.
2. Press the OK button to save the value.
3. The input number shows next to the button so the user can be aware of the value sent.
4. Right after pressing OK a message of processing ("Procesando...") shows up on screen until the MCU is ready to compute the harmonics.
5. After a few seconds and the processing message has disappeared a compute button Calcular pops up to engage the next stage.

> The following example shows a base frequency of 95.92 Hz, before and after pressing the OK button

4 Computing the Harmonics

The compute (Calcular) button pops up after the base frequency is input, right next to the Armonicos title, Fig. 10. This button also represents the stage where the input base frequency is evaluated.

1. Press Calcular button.
2. The harmonics calculated (maximum 10 harmonics) are shown in Hz on screen and listed in order, Fig. 11.

> - If the value input is outside of the designated range of frequencies stated in section 2 a warning will be displayed.
> - If the value is greater than 100 Hz a warning will be displayed to inform the maximum harmonic that can be reached.

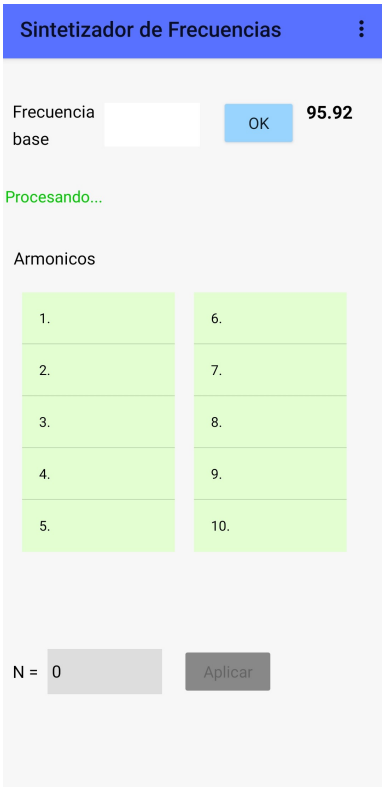


Figure 9: 95.92 Hz input base frequency

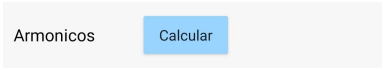


Figure 10: Compute button

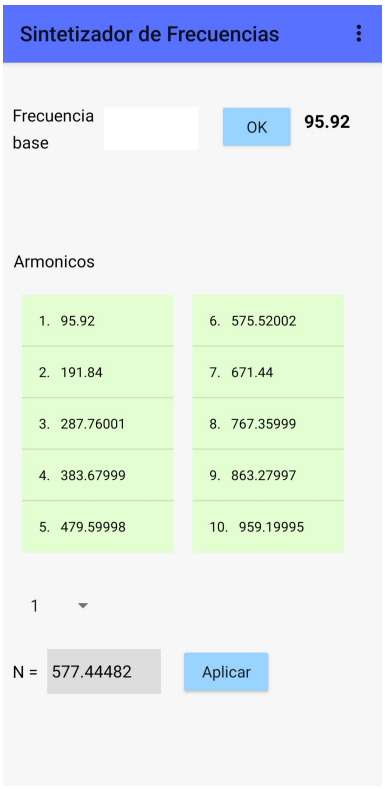


Figure 11: 95.92 harmonics list

4.1 Warnings

There are two different warnings that could be displayed if necessary after pressing the Calcular button.

1. If the base frequency input is below 5 Hz or above 1000 Hz, and the Calcular button has been pressed, the warning shown will let the user know that the value is unreachable as shown in Fig. 12. If this is the case the values on the list field will all be set to 0.
2. If the base frequency input is greater than 100 Hz, and the Calcular button has been pressed, a warning telling the user that only a certain amount of harmonics can be computed given that the final output of the frequency synthesizer is limited to 1000 Hz, Fig. 13. In the harmonics list all available harmonics will be shown and the rest will be put to 0.

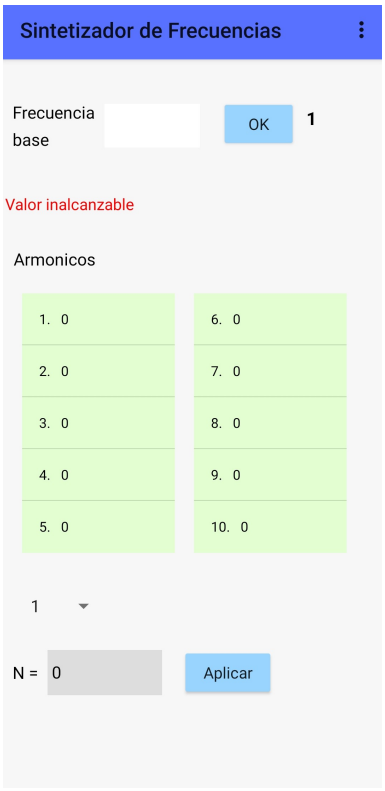


Figure 12: Warning of unreachable value

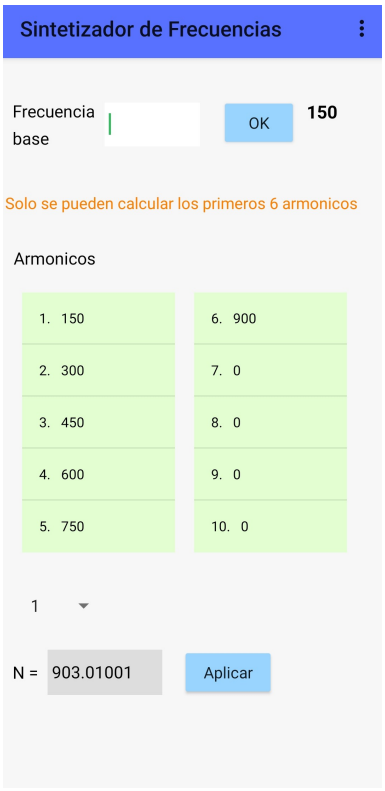


Figure 13: Warning of limited harmonics

5 Choosing the Number of Harmonic to Compute N For

The interface allows the user to select any harmonic from 1 to 10 (or to the highest available below 10). This selection is done with the drop down menu under the harmonics list, Fig. 14 and 15.

The N value field will initially, after a few seconds of having pressed Calcular, shows the value for the first harmonic. Once another number

is selected a message of computing ("Calculando...") shows on screen and when the N value is ready the N field will change its value to the current corresponding N value. The apply (Aplicar) button is not available until the N field has been uptaded.

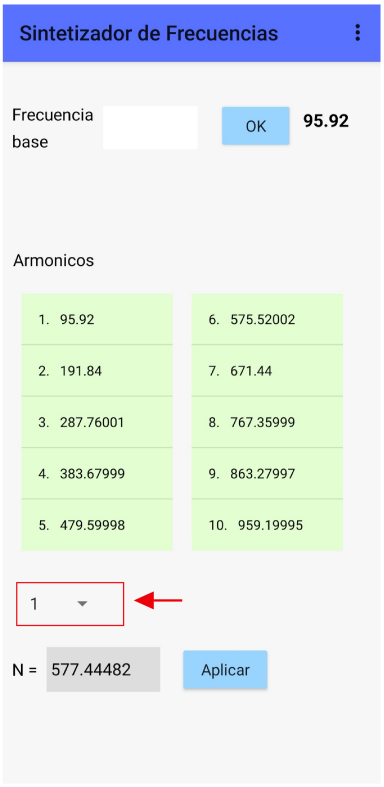


Figure 14: Drop down menu location on main screen

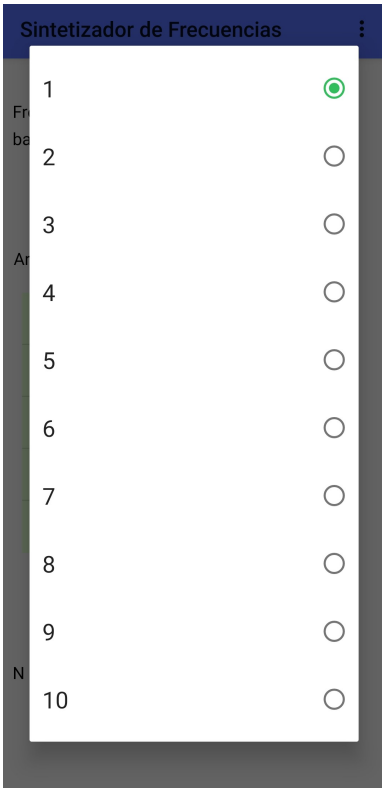


Figure 15: Drop down menu for selecting number of harmonic

1. Click the drop down menu.
2. Select the desired number of harmonic.
3. The computing messages is displayed.
4. Wait for the N value to change, around 2 seconds.

> The example in Fig. 16 shows the selection of the fourth harmonic of a base frequency of 95.92 Hz and the computing message displayed.

Figure 16: Selecting a number of harmonic and display of the computing message

6 Setting N into the CS2300 Board

After selecting the desired number of harmonic and getting the corresponding N value the process is ready to enter the next stage. The apply (aplicar) button sends the N value to the CS2300 Cirrus board for programming it.

1. Click on aplicar button.
2. Wait for the successful transmission ("transmisión exitosa") message to pop up.

> The following example, Fig. 17 shows the result for the N for the fourth harmonic of a base frequency of 95.92 Hz, as well as the message after pressing the aplicar button.

Figure 17: Setting an specific N value for a selected number of harmonic into the CS2300 board

If another number of harmonic of the already input base frequency wants to be selected the user must repeat all steps stated in this section (Section 5).

7 Resetting

Every time the interface is re-opened it will initialize at the start screen. In order to ensure a great connection with the microcontroller it is recommended to reset it using the on-board RST button, which is found on the bottom left part of the board as can be seen in Fig. 5 . It is also recommended to press the RST on the Cirrus board, which is labeled in Fig. 3 to ensure a proper functioning and accurate output of the system. Then the user can confidently press the start (Iniciar) button on the interface and access the main screen.

8 Exiting

The interface can be close similarly to other mobile apps by pressing the home button of the phone. Yet, it also offers the option to press a stop button located at the top right corner where the 3 dots menu is located. The button and its message are shown in Fig. 18 and Fig. 19. Pressing this option will instantly shut down the mobile interface.

Figure 18: Stop button menu location

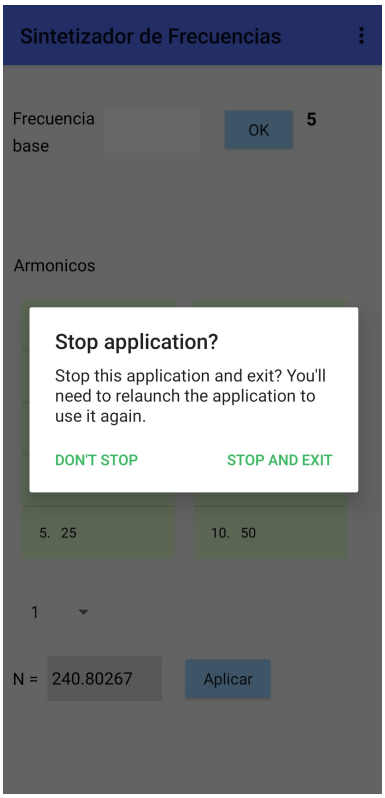


Figure 19: Stop button confirmation message

9 Troubleshooting

9.1 WiFi Connection

The interface will not enter the main screen if the MCU is unable to connect. If after 5 seconds the interface does not enter the main screen the main recommendations are:

- Move the ESP8266 closer to your WiFi source and wait 2 more seconds.
- Reset all components in the system, (MCU and Cirrus board), close and re-open the interface and press the Iniciar button again.

Once the Iniciar button has been pressed the interface will not stop looking for a connection unless the interface is closed. Therefore, the most recommended solution is to ensure that the MCU is in a position close enough to the WiFi source and to have an stable WiFi network.

9.2 Pressing "OK" or Sending Empty Base Frequency Value

If an empty value is sent as the base frequency the actual value that will be received is zero "0" making the computing of the harmonics and of the N both equal to "0".

9.3 Entering Wrong Characters

The base frequency field is designed to only accept numerical characters (including "."), thus the keyboard that pops up is a numerical-only one. Yet, if another character were to be entered the interface is only able to read the numerical part of the input. For example, if "20F" were to be entered the value treated would be the "20 only.

9.4 Inaccurate Harmonic Values

If after pressing the compute (Calcular) button the values of the harmonics seem to be erroneous, these must be calculated using an external calculator to compare results. In case this values turn out to be wrong it is recommended to re-enter the base frequency and press the Calcular button again.

9.5 No Successful Transmission Message

The successful transmission message should appear after just a few seconds of pressing the Aplicar button. If no message appears after 5 seconds or more the recommended solutions are:

- Press the Aplicar button again to resend the data.
- Check the connection of the SPI lines between the MCU and the Cirrus board, then press the RST button on the Cirrus board, and finally press the Aplicar button on the interface again to send the data.

9.6 Inaccurate Output

If the output of the whole system (Stage 3 output) turns out to be inaccurate the recommendations are the following:

- Reset the Cirrus board with its RST button and re-check the output signal.
- Reset the Cirrus board using the RST button on board, Fig. 3, and press the Aplicar button on the interface again.
- Check the connection of the SPI lines between the MCU and the Cirrus board, then press the RST button on the Cirrus board, and finally press the Aplicar button on the interface again to send the data.
- Check the connections of the inputs and outputs of the system (including supply connections) to identify any possible problems.
- The functioning of the system is affected by the temperature of the environment, therefore, if the output signal seems unstable one should try to lower the temperature and analyze if the signal stabilizes.

9.7 Lost Output

In case of the output to have been generated but then lost the user must press the apply (Aplicar) button to send again the data. This pressing of the button is recommended to be repeated a maximum of 3 times if the output is still no generated. If the output is not generated after three trials it is recommended to reset the whole system following the section 7 Resetting.