Audio Engineering Society

Convention e-Brief 343

Presented at the 142nd Convention
2017 May 20–23 Berlin, Germany

Design of a digitally controlled graphic equalizer

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ABSTRACT

This article deals with the design of a digitally audio controller for use in general applications. The goal is to create a 10-band graphic equalizer of which the signal gain or attenuation in every octave band is controllable by a smartphone /tablet application. The application provides a user interface to enhance perceptive audio quality intuitively. Making the equalizer digitally controllable by an app eliminates the necessity of manually adjusting the equalizer faders, thus the need of the presence of a musician/engineer at the location of the equalizer is removed. Preset configurations are easily activated in the equalizer hardware with only one touch within the app. Further testing and optimization efforts are required for the validation of the system.

1 Introduction

The present project is a natural continuation of the system developed in [1]. It concerns the design of a digitally controlled audio equalizer for use in general audio applications. The main goal is to create a 10-band graphic equalizer of which the signal gain or attenuation in every octave band is controllable by a smartphone or tablet application. The application should provide a simple interface for the user to enhance perceptive audio quality in an intuitive manner.

Making the equalizer digitally controllable by an app eliminates the necessity of manually adjusting the equalizer faders, thus the need of the physical presence of the musician or sound engineer at the location of the equalizer is removed. Furthermore, the opportunity arises of programming in-app equalizer presets. These presets configurations could then easily be activated in the equalizer hardware with only one touch within the app.

The implementation of the equalizer system is divided into two main development tasks that are handled more or less separately in this project. On the one hand proper graphic equalizer circuitry needs to be designed that is accountable for the adjustment of the balance between frequency components within the electronic audio signal. On the other hand, a digital control mechanism has to be created in order to make the equalizer hardware adjustable through the tablet or smartphone application. It goes without saying that both designs should be compatible, i.e. the digital control mechanism should be able to actuate the faders used in the equalizer circuit.

At the time of writing this report, the project is still ongoing and clearly more designing, testing and optimization efforts are required.

2 Circuit design and simulation

Graphic audio equalizer circuitry generally involves a bank of linear (octave) band filters in which certain audio signal frequency components are boosted or attenuated, depending on the band. Each filter stage is provided with a potentiometer that fulfils the role of a frequency-specific volume knob. These

potentiometers are usually sliders or faders and the vertical position of each slider indicates the amount of gain or cut at that frequency band.
In this project a resonant equalizer filter stage is used like shown in figure 1. The center frequency of each octave band is determined by capacitors C_1 and C_2, while potentiometer R_6 determines the amount of gain or attenuation. 10 of these equalizer filter stages are used in order to obtain a 10 octave band frequency adjusting system.

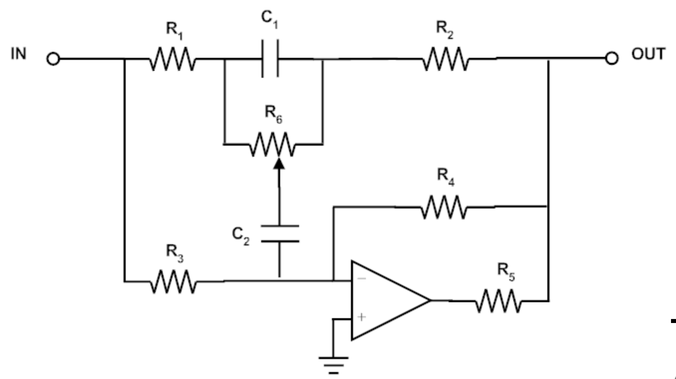

Figure 1. Electric diagram of an equalizer filter stage performing boost / attenuation in one octave band.

The values of the resistors are fixed as shown in table 1. Table 2 contains the capacitor values corresponding to the predetermined octave bands. As the capacitor values determine the center frequency of the octave bands, it is strongly suggested to use accurate components.

Table 1. Fixed resistor values in equalizer filter stage.

Resistor	*Value*
R_1	10 kΩ
R_2	10 kΩ
R_3	1 MΩ
R_4	1 MΩ
R_5	47 kΩ
R_6	10 kΩ (linear)

Simulating each resonant equalizer stage in full boost and attenuation mode with *LTspice*, we get the frequency responses shown in figure 2.

Table 2. 10 octave bands and corresponding capacitor values.

Octave band	C_1	C_2
32 Hz	1.7 µF	170 nF
64 Hz	880 nF	88 nF
125 Hz	430 nF	43 nF
250 Hz	220 nF	22 nF
500 Hz	110 nF	11 nF
1 kHz	54 nF	5.4 nF
2 kHz	27 nF	2.7 nF
4 kHz	14 nF	1.4 nF
8 kHz	6.6 nF	660 pF
16 kHz	3.4 nF	340 pF

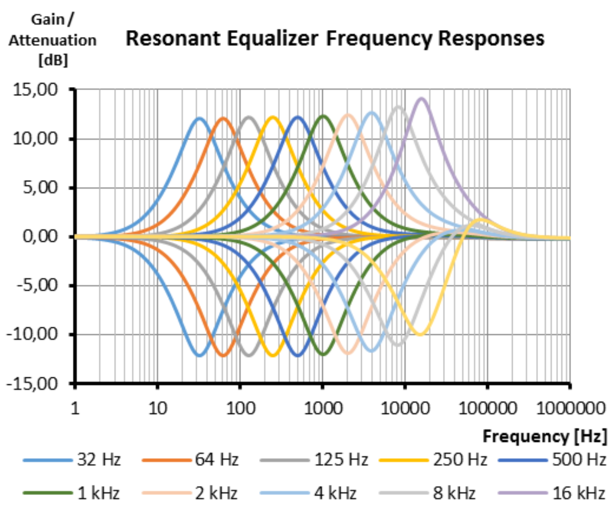

Figure 2. Frequency responses of the 10 resonant octave band filters.

The simulations show that a gain or attenuation of about $12\ dB$ can be achieved per resonant band filter. The shapes of the $8\ kHz$ and $16\ kHz$ equalizer stage frequency responses however deviate from those of the other octave band filters. A higher gain and smaller attenuation can be noticed and the attenuation responses are no longer perfectly symmetric. However, the asymmetry is located out of the audible frequency range $(20\ kHz\ +)$ and will thus not cause any audible defects. The same goes for the slightly different gain and attenuation values in these frequency bands: in the final product these imperfections will not lead to major audible deficiencies.

Furthermore, it is observed that overlap occurs between neighbouring octave band filter responses. Consequently, boosting or attenuating frequency components in one octave bands will also affect the gain or cut of frequency components in neighbouring octave bands, although to a lesser extent. The exact amount of gain or attenuation in a certain octave band will thus not only depend on the configuration of the corresponding potentiometer, but also on the configuration of the faders corresponding to adjacent octave bands.

In the final circuit an input op-amp stage is used that performs some initial filtering as well. DC currents are blocked and only frequency components within the human hearing range $(< 20\ kHz)$ are retained as shown in figure 4. The electric diagram is shown in figure 3.

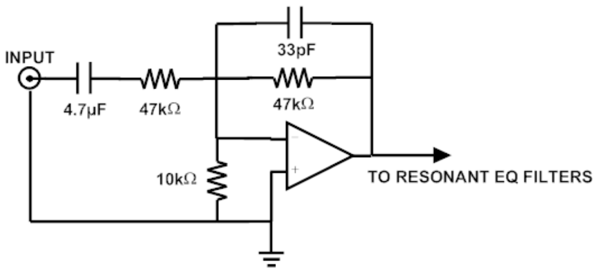

Figure 3. Circuit diagram of the input op-amp stage.

After the resonant equalizer stages, the audio signal is led through an additional output op-amp stage that performs the same filtering action as the input stage to filter out any harmonic distortion that may occur during the frequency boosting or attenuation processes. Furthermore, this final op-amp stage allows to control the output volume via a logarithmic potentiometer. The circuit diagram is shown in figure 5.

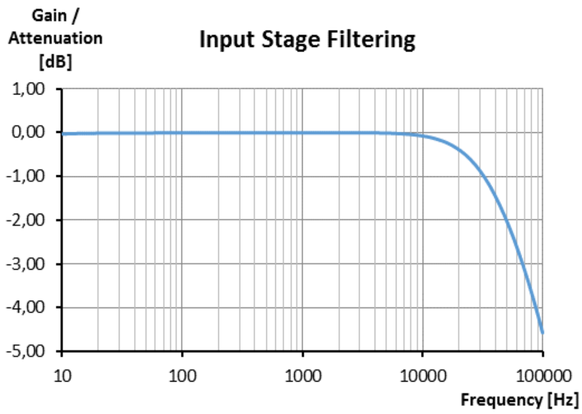

Figure 4. Filtering action of the input op-amp stage.

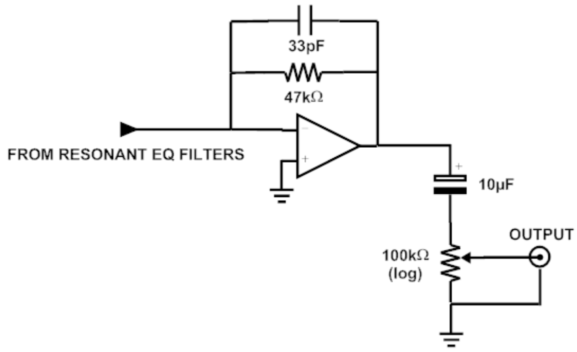

Figure 5. Circuit diagram of the output op-amp stage.

Connecting the input, 10 resonant equalizers and output stages together, a full equalizing system for 1 audio channel is obtained. If one wants to build an equalizer for stereo audio, this whole circuit can simply be copied for the second audio channel. A breadboard circuit is shown that was used to test and measure the circuit. As 2 slide potentiometers were lacking, the breadboard equalizer only contains 8 faders and thus only 8 resonant equalizer bands. Only the working principle was tested, which may be considered to be independent of the exact amount of octave bands used.

The full circuit diagram includes decoupling capacitors. Furthermore, some *LTspice* files that were used to simulate several circuit blocks were obtained in this investigation.

3 Digital Control Mechanism

As the Arduino module would be inherent to the equalizer hardware, and the aim is to develop a smartphone or tablet application to control the equalizer, a mechanism is needed to wirelessly connect the smartphone or tablet to the Arduino such that instructions can be sent to adjust fader positions. Again, the use of an Arduino [2] facilitates the creation of this wireless control mechanism: Arduinos can easily be extended with a *Bluetooth* module for wireless serial communication. The schematic in figure 6 clarifies this control mechanism.

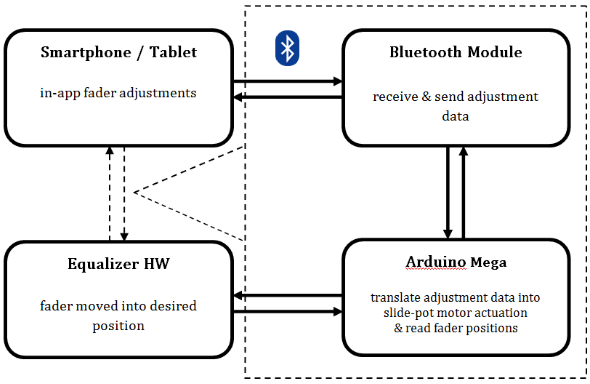

Figure 6. Schematic representation of the digital control mechanism.

The Arduino has to make sure that the in-app fader position adjustments result into actual slide potentiometer adjustments that accurately correspond to the desired positions. To obtain sufficient accuracy, a feedback control mechanism might be needed. In that case it should be possible for the Arduino to read the slider position and to adjust it accordingly. This can be done by reading the slide-pot resistance value as it correlates to the fader position.
Furthermore, the slider positions might be adjusted manually in the equalizer hardware. If that happens, the GUI in the smartphone or tablet application should be updated in order to keep the whole system synchronized. Thus, both the serial communication between the Arduino and the *Bluetooth* module and the wireless *Bluetooth* communication between the *Bluetooth* module and the smartphone or tablet app should be two-way: one way to push instructions from the app to the equalizer and the opposite way to alert the app if manual configurations are made to the equalizer sliders. Figure 6 illustrates how the interfacing between the smartphone or tablet app and the actual equalizer hardware is done by the Arduino combined with the *Bluetooth* module. Together they constitute an underlying mechanism that is responsible for three main functions:

1)-Communication with the smartphone or tablet app through the *Bluetooth* module:

a)-to receive in-app slider position adjustments.

b)-to send manual slider position adjustments to the app.

2)-Translation of the in-app fader adjustment data into actuation of the slide potentiometer motors.

3)-Reading of the eventually altered hardware fader positions.

4 Conclusions

This paper has described how better harmony has not only been achieved by bringing together many different types of bear in a musical context, but also how the outlined technology can be used to cross borders of species.

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