VILLANOVA UNIVERSITY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ECE 3970

STEREO GRAPHIC EQUALIZER

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Executive Summary

This senior design project will consist of the design, prototyping, testing, and production of an analog electronic-based 3-4 band graphic equalizer plus 2 watt audio power amplifier suitable for use with handheld audio devices with a standard mini-stereo jack. The equalizer would plug in between the portable audio unit and stereo speakers and would allow the user to adjust the frequency response to their personal preference. The students will test their circuit both in the lab as well as in a 'real world' sense by listening to the system in action.

The device built may have a separate low-pass output for use with a subwoofer. Since it is stereo, there will be two identical halves, one for the left channel and one for the right, with the equalization of each being synchronized. The primary mechanism for filtering will be 741 Op-Amps. The unit will be powered by battery or 120 V AC @ 60 Hz.

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Introduction

Background and State of the Art

Graphic equalizers enhance the listening experience for audio enthusiasts. They allow one to fine tune multiple bands of frequencies.

The first uses of variable equalization was in the 1920s by RCA in movie cinemas.

One of the essential pieces of the design process will be to ensure smooth interfacing with both audio sources, such as portable music players, and speaker systems.

Objectives

The objective is to design, prototype, build, and finally solder the components onto a cut PCB a working package. The design should minimize any extraneous noise introduced by the circuitry.

Specifications / Constraints

The equalizer will have at least three bands of control and work with at least two channels (stereo). The power will be supplied from either a battery source or an AC adapter to the wall. It will be designed with input from a "line out" jack, which generally has a 2v peak-to-peak

It will be easy for anyone to operate, and feature either sliders or knobs to adjust the bands.

Methodology

Design Approach Analysis

This can be done using analog or digital elements. For our purpose, we are going to use all analog components to implement our graphic equalizer. To do this, we need to implement a low pass, band pass, and high pass filter, implement some way to amplify the gain of the system, and to implement a way to sum the signals together and send the summed signal to the speakers.

Proposed Approach

We will do it with operational amplifiers. They can be used for three of the purposes of the project, including filtering out the various bands of frequency, adjusting the gain for each, and summing them all back together. To obtain the signal, we will use a MP3 input/output jack such as the one shown in Figure 1, to input the audio signal to the system. From this we will split the input 6 ways, 3 for each speaker. Each wire will lead to a different filter combination.

The first filter that we will have to implement is the Low-Pass Filter. This can be implemented by a simple RC-Op Amp circuit. The circuit schematic for the Low Pass Filter is shown in Figure 2. The equations for the low pass filters are:

Low Pass Gain: $$A_{LP}(s) = \frac{\omega_0^2}{s^2 + s\frac{\omega_0}{Q} + \omega_0^2} \qquad (1)$$

Break Frequency: $\omega_0 = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$ (2)

Quality Factor: $Q = \sqrt{\frac{C_1}{C_2}} \frac{\sqrt{R_1 R_2}}{R_1 + R_2}$ (3)

These equations will give us a Bode diagram for our low pass filter. An example Bode Plot for a 2 pole low pass filter is shown in Figure 3.

The second filter that we will have to implement is the High-Pass Filter. This can be implemented by another simple RC-Op Amp circuit. The circuit schematic for the High Pass Filter is shown in Figure 4. The equations for the High pass filters are:

High Pass Gain: $A_{HP}(s) = \frac{s^2}{s^2 + s\frac{\omega_0}{Q} + \omega_0^2}$ (4)

Break Frequency: $\omega_0 = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$ (5)

Quality Factor: $Q = \left[\sqrt{\frac{R_1}{R_2}} \frac{C_1 + C_2}{\sqrt{R_1 R_2}} + \sqrt{\frac{R_2 C_2}{R_1 C_1}}\right]^{-1}$ (6)

These equations will give us a Bode diagram for our high pass filter. An example Bode Plot for a 2 pole low pass filter is shown in Figure 5.

The final filter that we will have to implement is the Bandpass Filter. This can be implemented by another simple RC-Op Amp circuit. The circuit schematic for the Bandpass Filter is shown in Figure 6. The equations for the Bandpass filters are:

Bandpass Gain: $A_{BP}(s) = -\sqrt{\frac{R_3}{R_1 + R_3} \frac{R_2 C_2}{R_1 C_1}} \frac{s\omega_0}{s^2 + s\frac{\omega_0}{Q} + \omega_0^2}$ (7)

Break Frequency: $\omega_0 = \frac{1}{\sqrt{R_{th} R_2 C_1 C_2}}$ (8)

(where Rth=R1 || R3)

Quality Factor: $Q = \sqrt{\frac{R_1}{R_{th}}} \frac{\sqrt{R_1 R_2}}{C_1 + C_2}$ (9)

These equations will give us a Bode diagram for our high pass filter. An example Bode Plot for a 2 pole low pass filter is shown in Figure 7.

The next thing we will need is to put the signals into a summing amplifier, so we can feed that into a power amplifier and drive the speakers. The circuit schematic for a summing amplifier is shown in Figure 8. The equation for gain is:

$$v_o = \frac{R_4}{R_1} v_1 + \frac{R_4}{R_2} v_2 + \frac{R_4}{R_3} v_3 \quad (10)$$

This summing amplifier will feed into a power amplifier that we will purchase, and from the output of the power amplifier we will drive the speakers.

Descriptions / Staffing of tasks

The first task we have is implementing a basic design. This will require the use of the equations above and specifications that we will decide to figure out the theoretical values of components we need to use. From there we will find nominal values of components.

Once we have the nominal values, the next logical step would be to put it through a PSpice simulation to figure out all the voltages and currents of the circuit, and to see if the design will work. If needed, designs will be retooled and adjusted on the fly.

After we have a working PSpice simulation, we will then try to put the components out on a breadboard. We will run tests to make sure the voltages and currents match the theoretical values closely, and then test to hear sound quality, noise, etc. Once again, if designs need to be adjusted they will be.

Next, we will use the PSpice simulation and other PC Board software tools to layout a Printed Circuit Board. Once the board is laid out and is verified that it is a correct and efficient layout, we will take it to the microwaves lab and print up a circuit board.

Subsequently, we will then take the printed circuit board and solder the discrete components onto this circuit board. We will then run tests to make sure the solder joints are correct and well connected, and we will finally be ready to run final tests on sound quality. After we do this, we will furnish the final product up and make it look presentable and professional.

Test & Evaluation Plan

The ultimate test will be the actual sound quality. We will plug in an MP3 player, and adjust the variable resistors to see if the filters do their jobs and test the capabilities of each equalizer. In addition to this final test we also will run simulations, use the theory, and test each voltage and current to make sure that everything goes exactly as planned.

Non-technical Professional and Ethical Considerations

Self-learning

Our group has thought about and come up with a couple of social, ethical, and environmental issues that could pertain to the project. The first one being that we would like to create an energy efficient equalizer, meaning that the equalizer will not take up excessive power or cause other electrical appliances to fail because of the introduction of it to the system. We also would not like to use components that would pose a health hazard to both people using it or the environment. We feel that these things should be fairly easy to do because we are keeping power consumption low and the materials we are using are not hazardous.

Core values

The core values that we hold are to try and deliver an energy efficient, working product that will minimize on power consumption while still outputting a clear, nice sounding output signal. We feel that our project will lead to a more comfortable way to listen to audio, where the user can pick out specific bandwidths that they enjoy and control them individually. As a group, we will try to assign tasks evenly and with everyone having an input on all decisions. All decisions will be run by all group members, as well as Dr. Caverly for his input and guidance.

Administration

Schedule

The bulk of the work for this project will be accomplished during the Fall semester of 2010. Here is a preliminary schedule of events.

Research on Design Types	1 week
Design Implementation/Simulation on PSpice	1 week
Ordering Necessary Parts	1 week to order, 4-6 weeks to ship
Design Implementation on Breadboard	2 weeks
Testing Circuits and Troubleshooting	4 weeks
Designing and Cutting Printed Circuit Board	2 weeks
Soldering Components on Printed Circuit Board	2 weeks
Final Testing and Furnishings	2 weeks
Total:	approx. 15 weeks

Table 1: Preliminary Schedule of Events

Budget

Qty	Part	$/Part	Total
6x	Slide potentiometers	$3.00	$18
3x	Power amplifiers	$2.00	$6
1x	Miscellaneous passive components		$5
3x	Input/output jacks	$1.00	$3
1x	Miscellaneous unforeseen expenditures		$20
	Total:		$52

Table 2: Preliminary Budget for Project

Facilities and Resources

We will utilize various facilities of the College of Engineering at Villanova. This will include mainly the circuits lab in CEER 208 and the microwaves lab in CEER for the circuit board fabrication.

References

Jaeger, Richard C. and Blalock, Travis N., *Microelectronic Circuit Design*, 3rd ed. Copyright © 2008 The McGraw-Hill Companies, Inc. ISBN 978-0-07-319163-8

Dennis Bohn, Rane Corporation, *Constant-Q Graphic Equalizers*, http://www.rane.com/note101.html

TDA8944 Datasheet, © Koninklijke Philips Electronics N.V. 2002. http://www.nxp.com/documents/data_sheet/TDA8944AJ.pdf

Hp bode plot, University of Texas at Arlington: http://www.uta.edu/ee/hw/pspice/images/pst07g.jpg

Lp bode plot, public domain: http://upload.wikimedia.org/wikipedia/commons/f/fd/Bode-pt2.png

Bp bode plot, Hindawi Publishing Corporation: http://www.hindawi.com/floats/630951/figures/30951.fig.003.jpg

Appendices

Figure 1: MP3 Input Jack

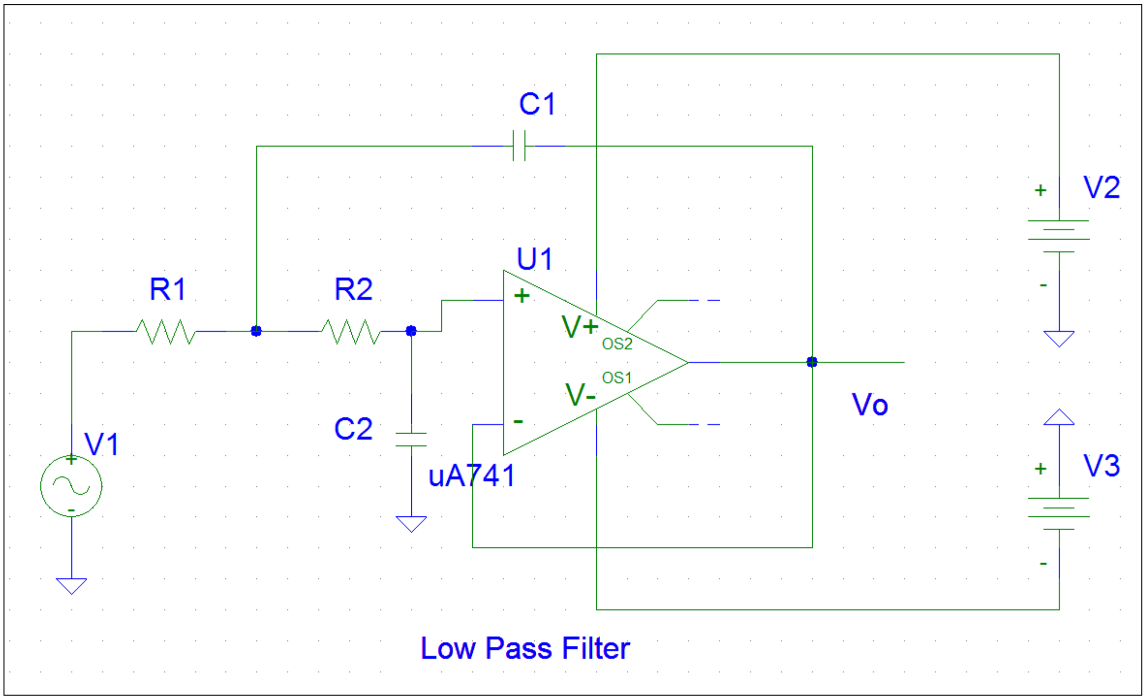

Figure 2: Low pass filter schematic

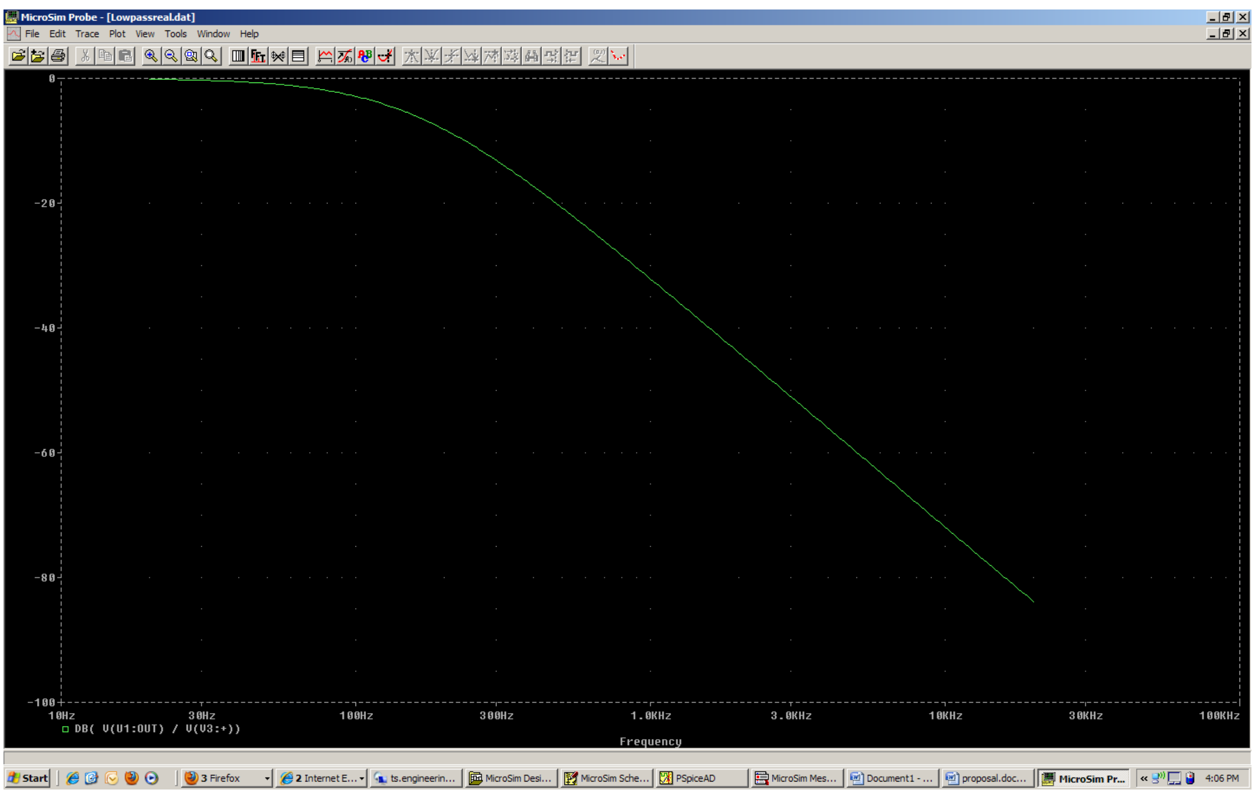

Figure 3: Example of Low Pass Bode Plot

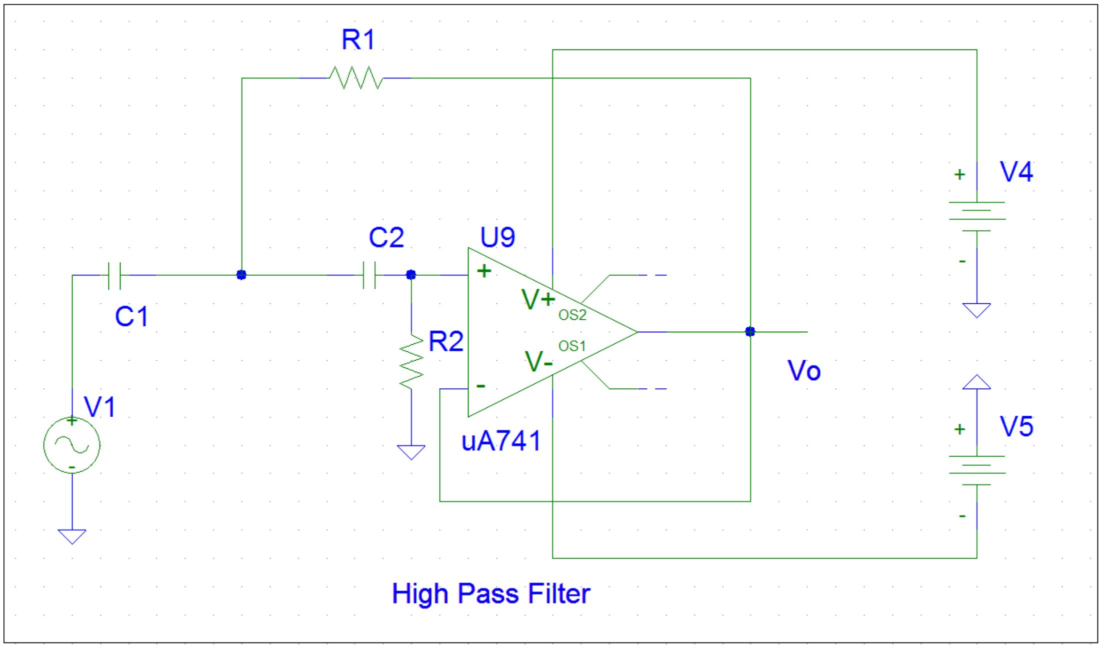

Figure 4: High pass filter schematic

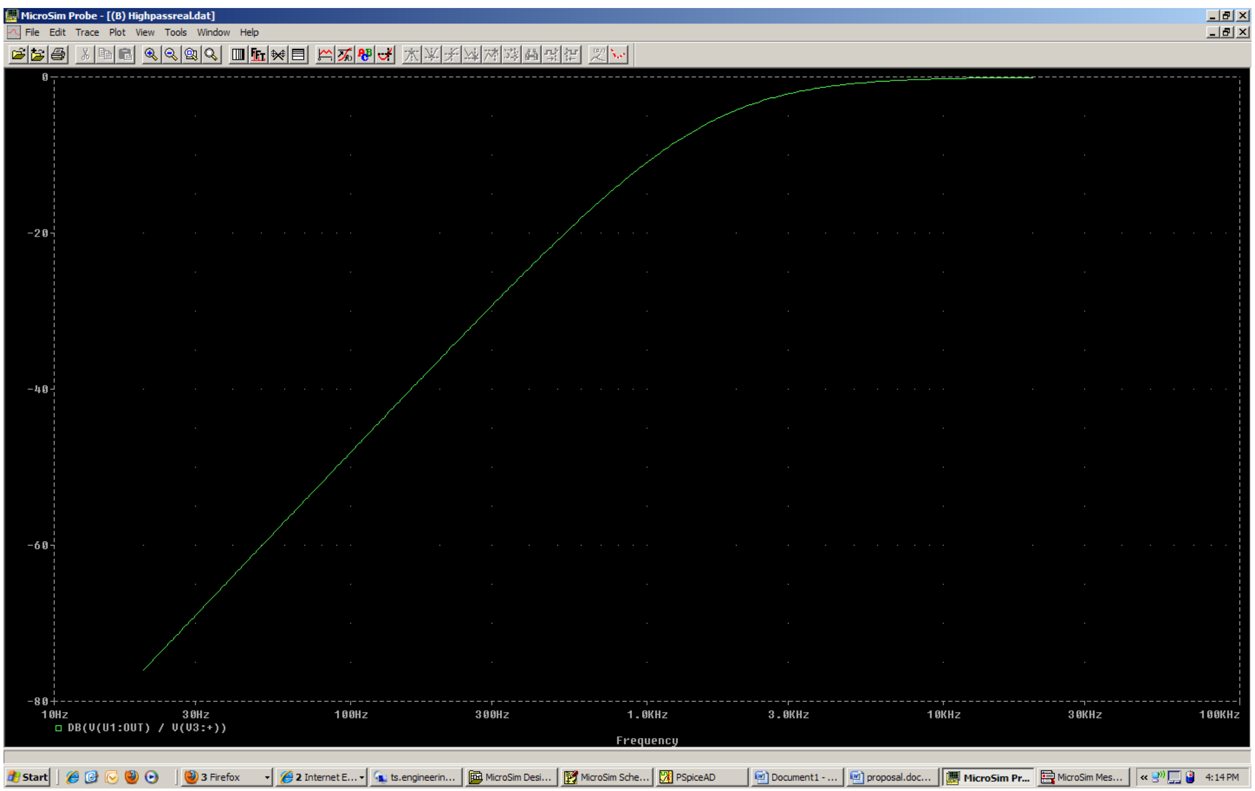

Figure 5: Example of High Pass Bode Plot

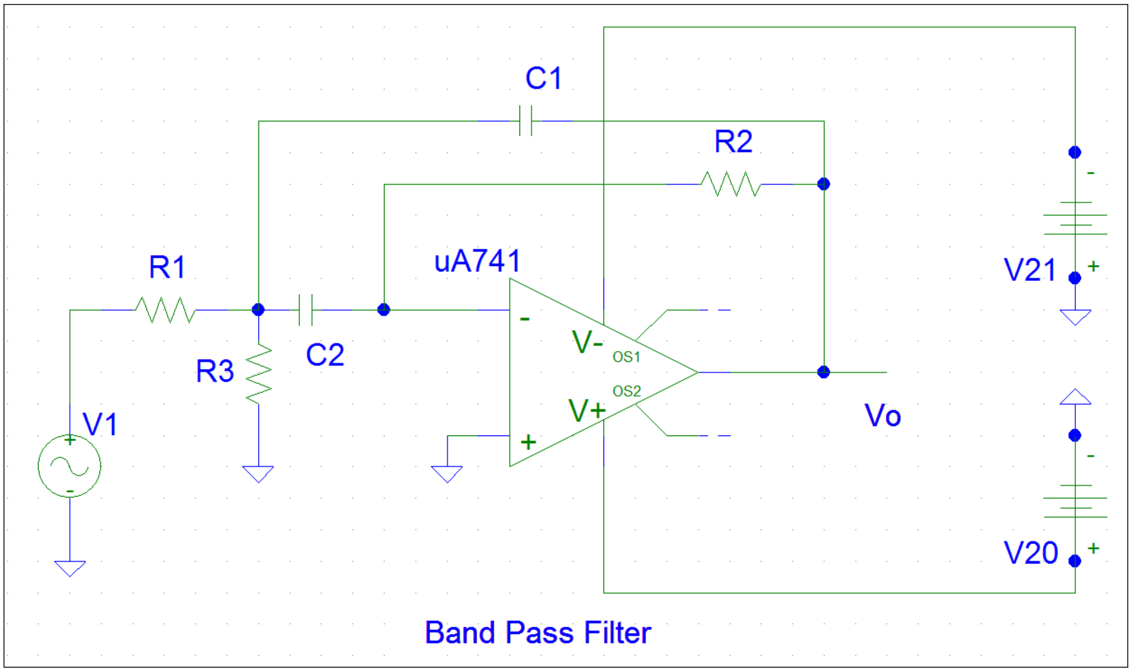

Figure 6: Band pass filter

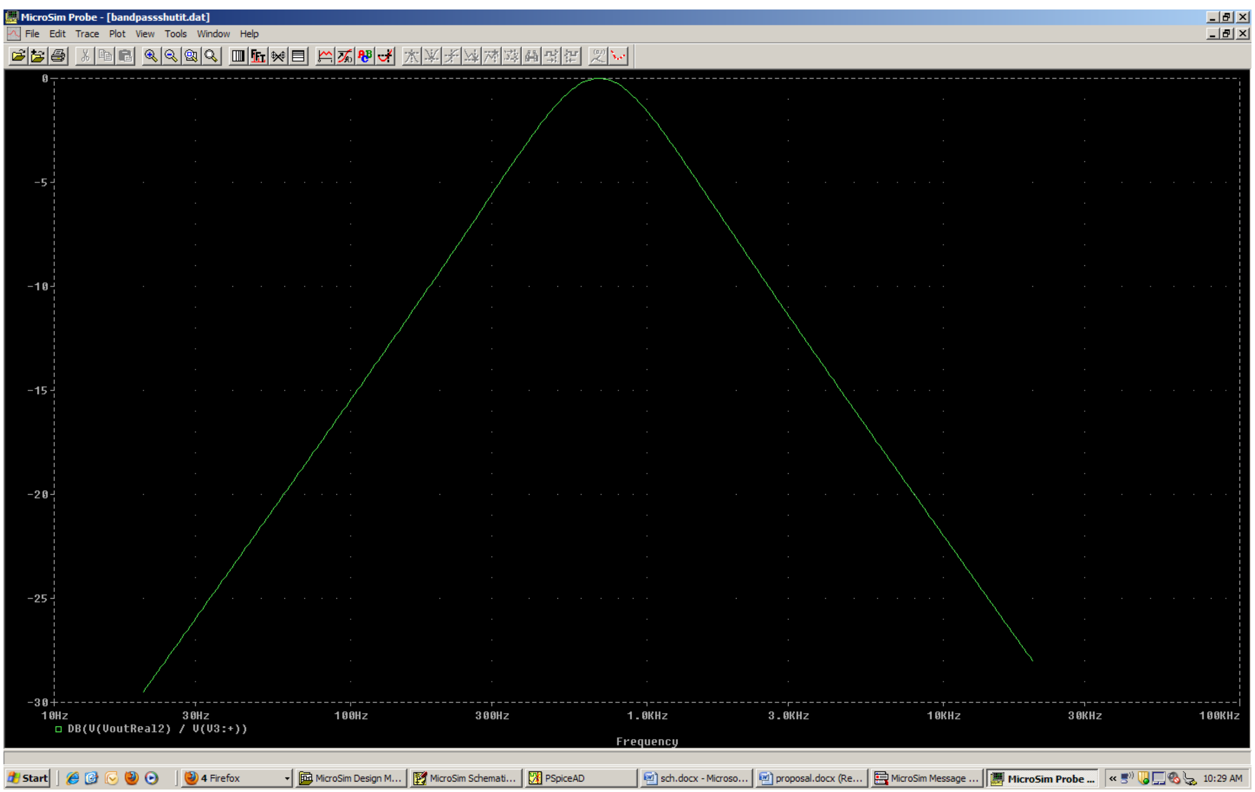

Figure 7: Example of Bandpass Bode Plot

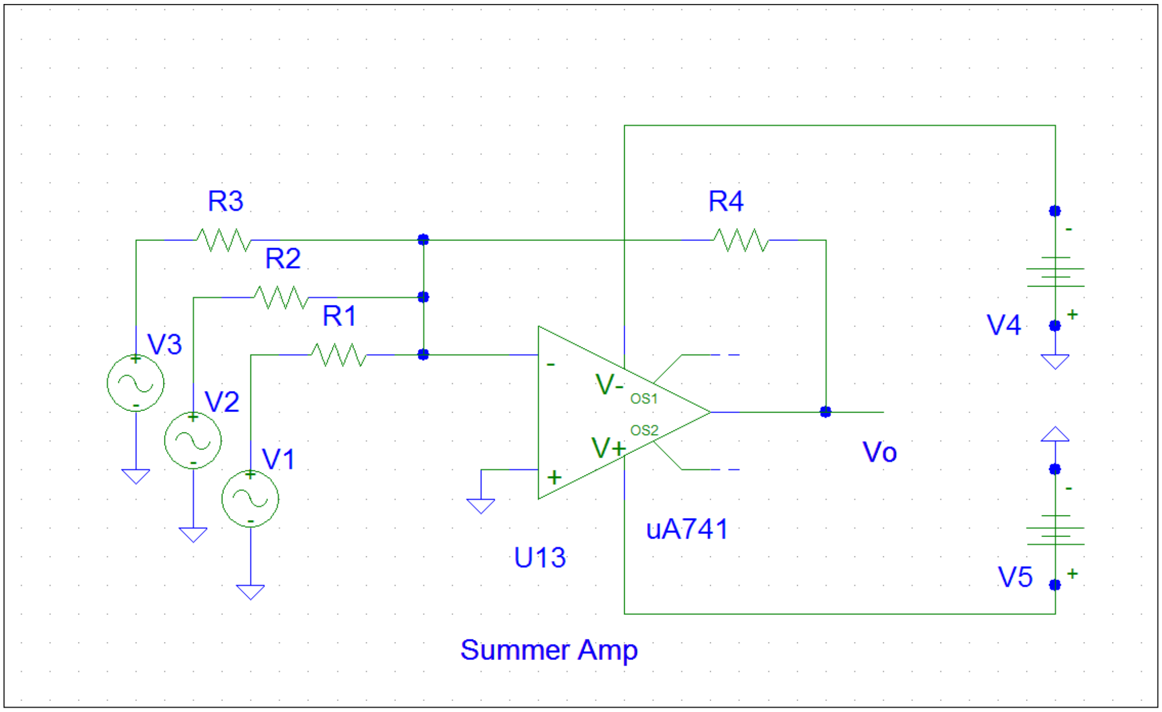

Figure 8: Summer