Head Phone Amplifier with Equaliser

Course	ENGN3227: Analogue Electronics	
Task	Group Project Report	
Group	TA6	
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Abstract
Project investigates equalisation using an array of second degree filters by implementation of multiple feedback band pass. Individually pass bands are mixed through (low quality) multi-channel mixer with logarithmic attenuation into high quality two-channel mixer.

1. Introduction

The original project idea was a noise cancelling circuit for use in a pair of headphones along with an onboard microphone; regrettably, this needed to be abandoned when the full complexity of such a concept came to light. Unfortunately, the combined transfer characteristics of the microphone and speaker showed bizarre spectral humps over seemingly random bands and phase shifts exceeding 180 degrees. To give a better idea of the difficulty, we found it impossible to judge the polarity of the drivers, which ought to have been simple if the drivers had some semblance of good behaviour.

A dynamic equaliser is used to adjust the frequency response characteristics about a series of logarithmically separated frequencies. This involves producing a series of band pass filters, with cut off frequencies also at logarithmic points.

For example, if you wished to cover the audible frequency band from 20Hz to 20kHz using 10 channels, you would have 20Hz–40Hz, 40Hz–80Hz, 80Hz–160Hz etc. The cut off points should have a response of -3dB.

A dynamic equaliser is generally attended by a graphic equaliser (this was not implemented in our design), this can be accomplished by buffering the output from each channel into a rectifier and then into an RC network with a decay period of about a tenth of a second.

The output from each filter will need to be mixed through a variable potentiometer with about 10 times gain sent through a log-pot and added to the inverse of the signal. The mixed output produced by summing all the outputs from all the filters can then be summed along with the original un-attenuated signal from an auxiliary device such as a CD-player or other line level source. The input channel from the source device will need a volume control and this can be accomplished using a buffer amp and a potentiometer.

Any OP-AMP intended for use in an audio application needs to have low noise and high linearity. The NE5534 op-amp (available at Dick Smith for $3.95) suits the task nicely. Typical noise levels should be around -90dB and distortion should be around 0.01% THD 20Hz to 20kHz.

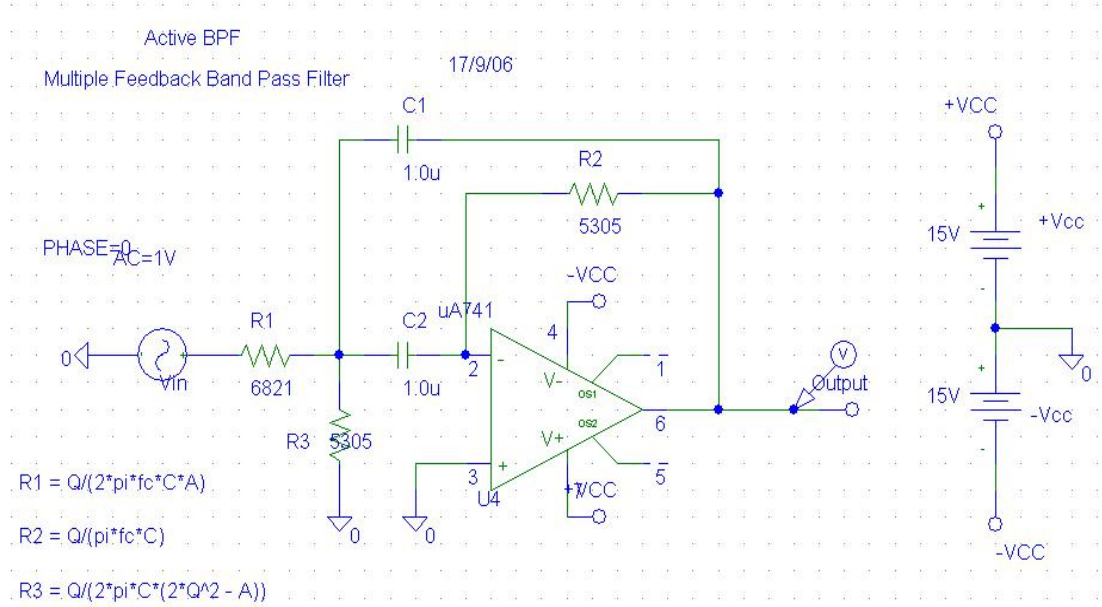
2. Background

There are number of different ways to produce a second degree band pass filter;

(1) Passive into voltage buffer using Bessel, Butterworth or Chebychev.
(2) Cascaded low pass to high pass.
(3) Multiple feedback band pass filter.

We settled on the multiple feedback band pass filter since it only required one op-amp and appeared quite simple.

Figure 2.1: multiple feedback band pass filter



3. Design

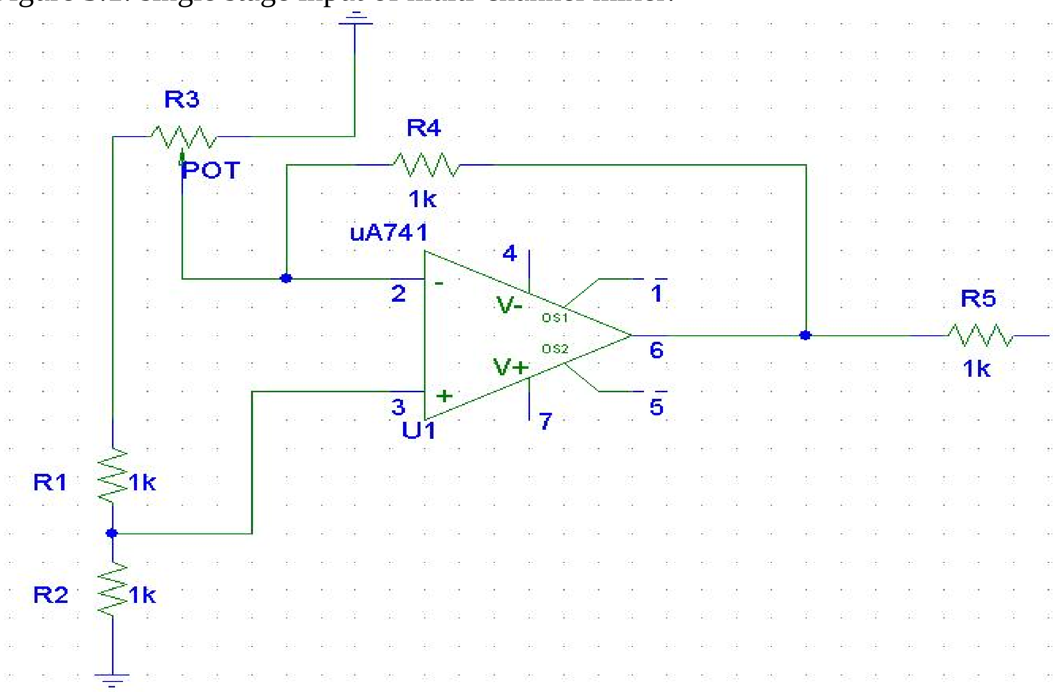
3.1 Equaliser

The equaliser is basically an array of second degree band pass filters. The output from each filter is sent through a logarithmic potentiometer divider into the non-inverting input of an op-amp. The output is also sent through a resistor divider (1/(1+9)) into the inverting input of the same op-amp. The reason for this is that the potentiometer is only capable of reducing voltage amplitude it is not capable of making it negative.
A single buffer is used for each channel to avoid cross talk between equaliser channels.

3.2 Multi-channel mixer

The multi-channel mixer combines the voltage output from the logarithmic potentiometer and straight unitary output from each equalisation channel by inputting the logpots output into the inverting input of the buffer op-amp and mixing this with the (already inverted) output of the filter.
The reason for this is to allow the filters output to be subtracted from the source signal and to also to allow positive filtered signal to be added to the input source signal. This is done for each independent channel and finally mixed via division.

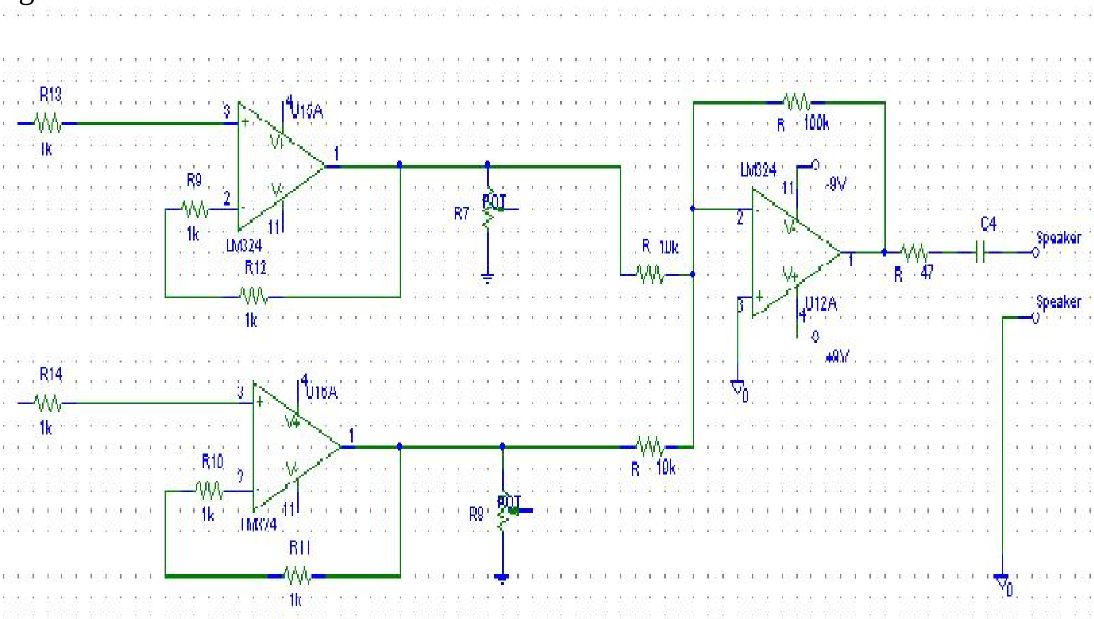
Figure 3.1: single stage input of multi-channel mixer.



3.3 Two-channel mixer

The two channel mixer is built using the most expensive of the available OP-AMPS which also produce the highest quality sound and with lowest noise and greatest linearity. Ultimately compromises must be made in any design and in this case two different op-amps were used, the lower cost LM386N units were used in the equaliser and also for the equaliser mixing circuit and higher cost NE5534 units were used in final power output stages of the two channel mixer.

Figure 3.2: Two-channel mixer.



3.2 Costing.

Table 3.2.1: Costing table, all components were purchased at Dick Smith.

COMPONENTS	NUMBER OF COMPONENTS	PRICE OF EACH COMPONENT	TOTAL COST
Resistors			
R0594 (6.8kΩ)	10	$0.06	$0.60
R0591 (5.1kΩ)	20	$0.06	$1.20
R0598 (10kΩ)	10	$0.06	$0.60
R0574 (1kΩ)	10	$0.06	$0.60
Potentiometers (logarithm scales)	4	$1.75	$7.00
OP-AMP			
NE5534	3	$3.95	$11.85
LM386N	10	$2.10	$21.00
Capacitors			
R3008 (4.7 nF)	4	$0.25	$1.00
R3014 (12 nF)	4	$0.25	$1.00
R3022 (56 nF)	4	$0.25	$1.00
R3031 (330 nF)	4	$0.45	$1.80
R3032(394 nF)	4	$0.35	$1.40
Total			$49.05

4. Method

The upper and lower frequency bands were taken as the -6dB points of the frequency response curve. Ordinarily the cut off points would be at -3dB, for example in an active loudspeaker with individually amplified drivers

The practical testing involved connecting the constructed circuit to the laboratory voltage supply with bridged voltages to produce a neutral ground at the positive part of the negative supply rail and negative part of the positive supply rail. The following voltages were used (-5.6V, 0, +5.6V).

The frequency response points (resonance, lower cut off and upper cut off) were judged using the Oscilloscopes ‘Math’ capabilities to measure the voltage amplitude.

Simulation involved using Pspice and a circuit based on the design used in the lab. The simulation settings used a logarithmic frequency sweep from 1 Hz to 100 kHz and a 741 op-amp was used instead of the LM386N.

Matlab was used to generate the element values of the circuit by use of formulas found in Floyd & Buchla page 488.

All constructing involving soldering was done quickly and carefully so as to avoid damaging components, especially the expensive op-amps. All op-amps had their supply rails individually stabilised with 1µF bridged capacitors. All circuits were constructed on veroboards.

5. Results

Table 5.1: Frequency cut offs and resonance.

Capacitance	**F_{center}**			**F_{lower}**			**F_{Upper}**		
	Obs	**Calc**	**Sim**	**Obs**	**Calc**	**Sim**	**Obs**	**Calc**	**Sim**
4.7 nF	8.71 kHz	8.424 kHz	8.68 kHz	2.95 kHz	**N/A**	2.86 kHz	29.4 kHz	**N/A**	28.6 kHz
12 nF	3.46 kHz	3.45 kHz	3.32 kHz	1.12 kHz	**N/A**	1.09 kHz	11.7 kHz	**N/A**	11.4 kHz
56 nF	735 Hz	739.24 Hz	746 kHz	237 Hz	**N/A**	234.6 kHz	2.36 kHz	**N/A**	2.27 kHz
330 nF	122 Hz	124.91 Hz	121 kHz	40.4 Hz	**N/A**	38.2 Hz	404 Hz	**N/A**	399.8 Hz
394 nF	99.2 Hz	104.77 Hz	98.4 kHz	33.4 Hz	**N/A**	32.8 Hz	33.8 kHz	**N/A**	33.8 kHz

Table 5.2: Voltage input-output at resonance.

Capacitance	**V_{in}**			**V_{out}**			**A_o**		
	Obs	**Calc**	**Sim**	**Obs**	**Calc**	**Sim**	**Obs**	**Calc**	**Sim**
4.7 nF	4.15 V	**N/A**	**N/A**	1.34 V	**N/A**	1.47 V	0.322	0.357	0.362
12 nF	4.13 V	**N/A**	**N/A**	1.34 V	**N/A**	1.47 V	0.324	0.357	0.362
56 nF	4.06 V	**N/A**	**N/A**	1.34 V	**N/A**	1.47 V	0.33	0.357	0.362
330 nF	4.06 V	**N/A**	**N/A**	1.325 V	**N/A**	1.47 V	0.326	0.357	0.362
394 nF	4.06 V	**N/A**	**N/A**	1.36 V	**N/A**	1.47 V	0.33	0.357	0.362

Figure 5.1: Sample output from Pspice Simulation of the pass band feed back for c=4.7 nf (High Frequency)

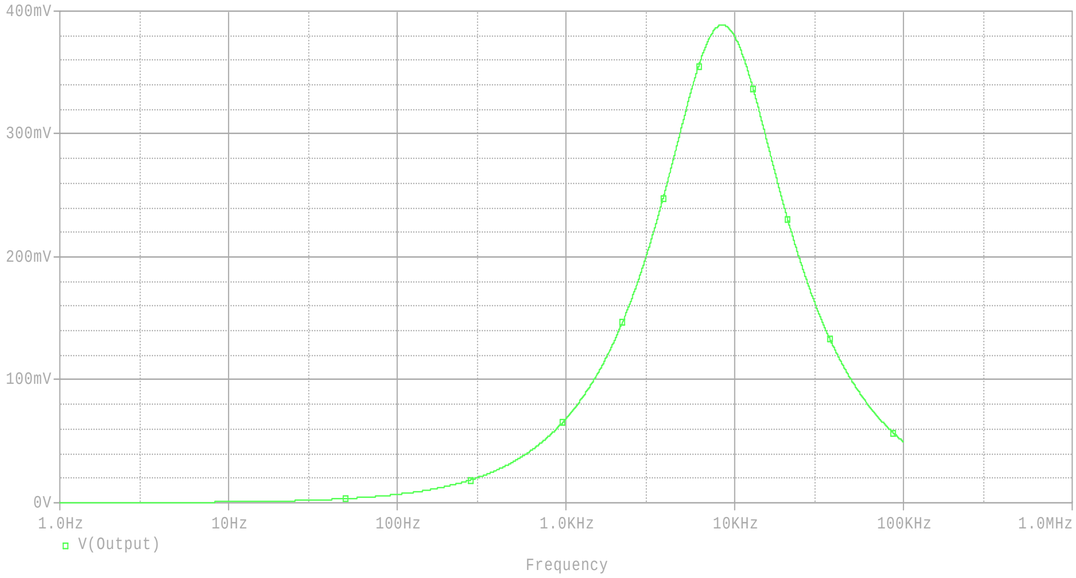
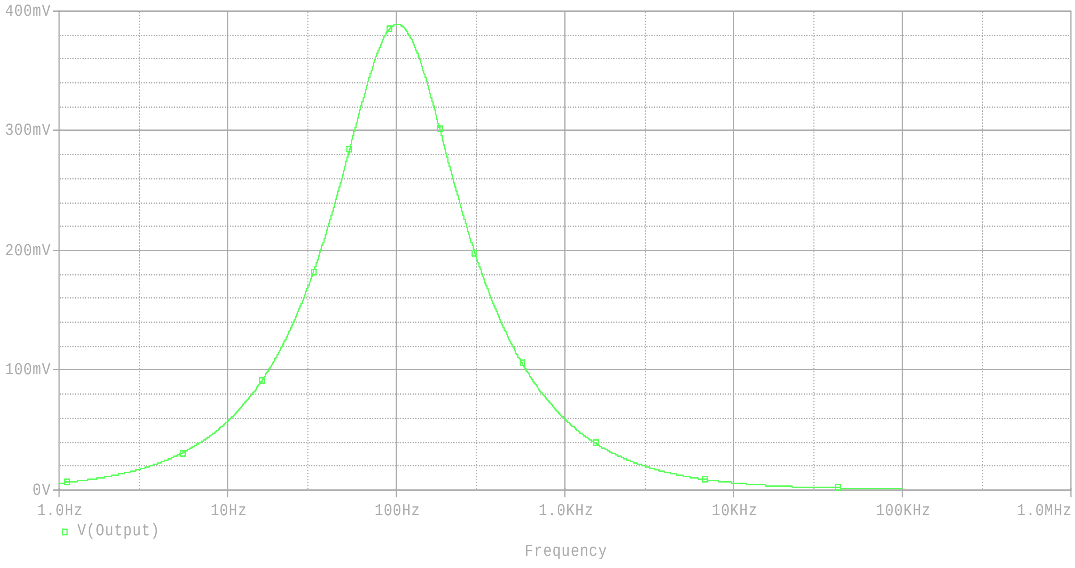


Figure 5.2: Sample output from Pspice Simulation of the pass band feed back for c=4.7 nf (Low Frequency)



6. Discussion

Table 5.1 shows various results from practice and theory along with simulation and all seem to correlate quite nicely. The only concerning factor is an absence of a nice frequency spread with the 330nF and 394nF capacitor (not surprisingly) generating very similar resonant frequencies. This is due to Dick Smith not having the exact components desired for the project, in order to suit needs of the circuit we would have needed to regenerate all the circuit values in the store and/or used multiple resistors and capacitors to produce the needed values.

It was felt that in a professional circuit, a company ought to be able to source the exact right components and that since this is only a group project intended to demonstrate comprehension, it was probably unnecessary to combine multiple elements to generate the exact right values.

7. Conclusion

Equalisation can be accomplished using filtering with multiple feedback band pass filters. The LM386N op-amps can be used quite effectively in analogue signal conditioning.

8. Appendix

A1. Calculations

C= 4.7 nF

$$fo = \frac{1}{2\pi c}\sqrt{\frac{R1+R2}{R1*R2*R3}} = \frac{10^9}{2\pi*4.7}*\sqrt{\frac{11.9*10^{-6}}{176.87}} = 8.424kHz$$

$$Ao = \frac{R2}{2R1} = \frac{5.1*10^{-3}}{2*6.8*10^3} = 0.357$$

$$Q = \pi focR2 = \pi(8.424*10^3*4.7*10^{-9}*5.1*10^3) = 0.634$$

$$Bw = \frac{fo}{Q} = \frac{8.424*10^3}{0.634} = 13.28kHz$$

C = 394 nF

$$fo = \frac{1}{2\pi c}\sqrt{\frac{R1+R2}{R1*R2*R3}} = \frac{10^9}{2\pi*394}*\sqrt{\frac{11.9*10^{-6}}{176.87}} = 104.77Hz$$

$$Ao = \frac{R2}{2R1} = \frac{5.1*10^{-3}}{2*6.8*10^3} = 0.357$$

$$Q = \pi focR2 = \pi(8.424*10^3*4.7*10^{-9}*5.1*10^3) = 0.881$$

$$Bw = \frac{fo}{Q} = \frac{8.424*10^3}{0.634} = 118.92$$

C= 56 nF

$$fo = \frac{1}{2\pi c}\sqrt{\frac{R1+R2}{R1*R2*R3}} = \frac{10^9}{2\pi*56}*\sqrt{\frac{11.9*10^{-6}}{176.87}} = 739.24Hz$$

$$Ao = \frac{R2}{2R1} = \frac{5.1*10^{-3}}{2*6.8*10^3} = 0.357$$

$$Q = \pi focR2 = \pi(739.24*10^3*4.7*10^{-9}*5.1*10^3) = 0.663$$

$$Bw = \frac{fo}{Q} = \frac{739.24*10^3}{0.663} = 1.114kHz$$

C=12 nF

$$fo = \frac{1}{2\pi c}\sqrt{\frac{R1+R2}{R1*R2*R3}} = \frac{10^9}{2\pi*12}*\sqrt{\frac{11.9*10^{-6}}{176.87}} = 3.45kHz$$

$$Ao = \frac{R2}{2R1} = \frac{5.1*10^{-3}}{2*6.8*10^3} = 0.357$$

$$Q = \pi focR2 = \pi(3.45*10^3*4.7*10^{-9}*5.1*10^3) = 0.663$$

$$Bw = \frac{fo}{Q} = \frac{*10^3}{0.663} = 5.21kHz$$

C= 330 nF

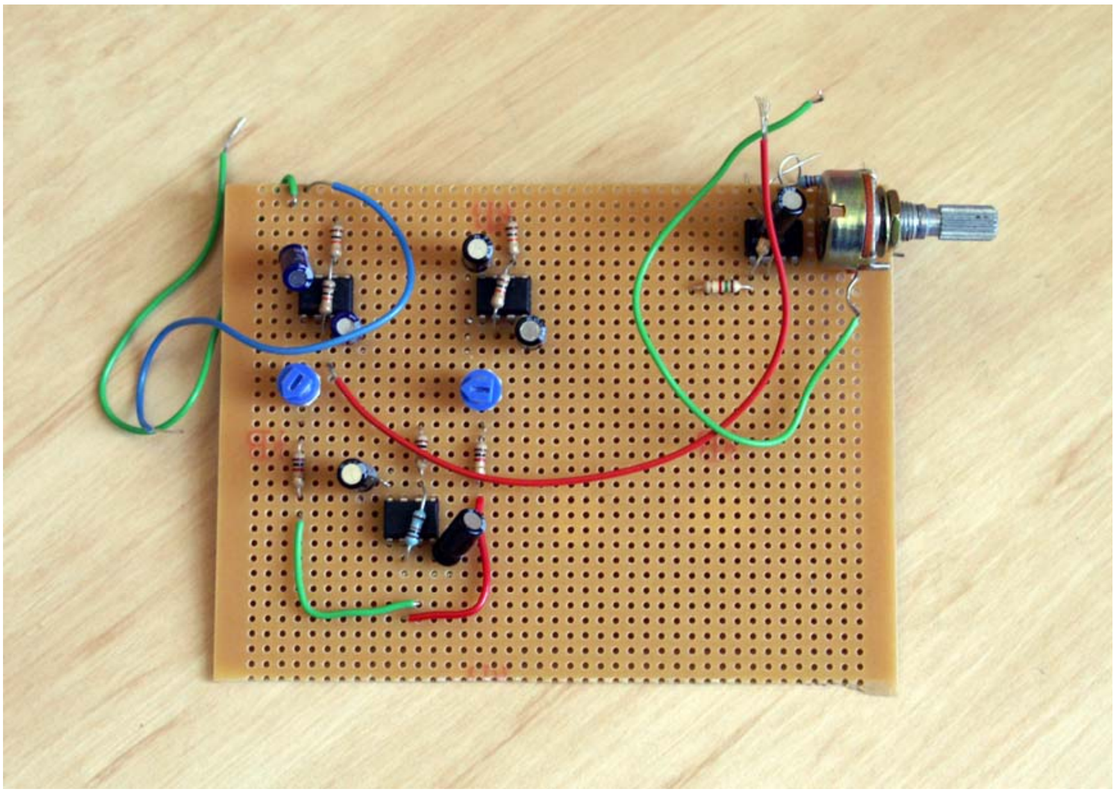
$$fo = \frac{1}{2\pi c}\sqrt{\frac{R1+R2}{R1*R2*R3}} = \frac{10^9}{2\pi*12}*\sqrt{\frac{11.9*10^{-6}}{176.87}} = 124.91Hz$$

$$Ao = \frac{R2}{2R1} = \frac{5.1*10^{-3}}{2*6.8*10^3} = 0.357$$

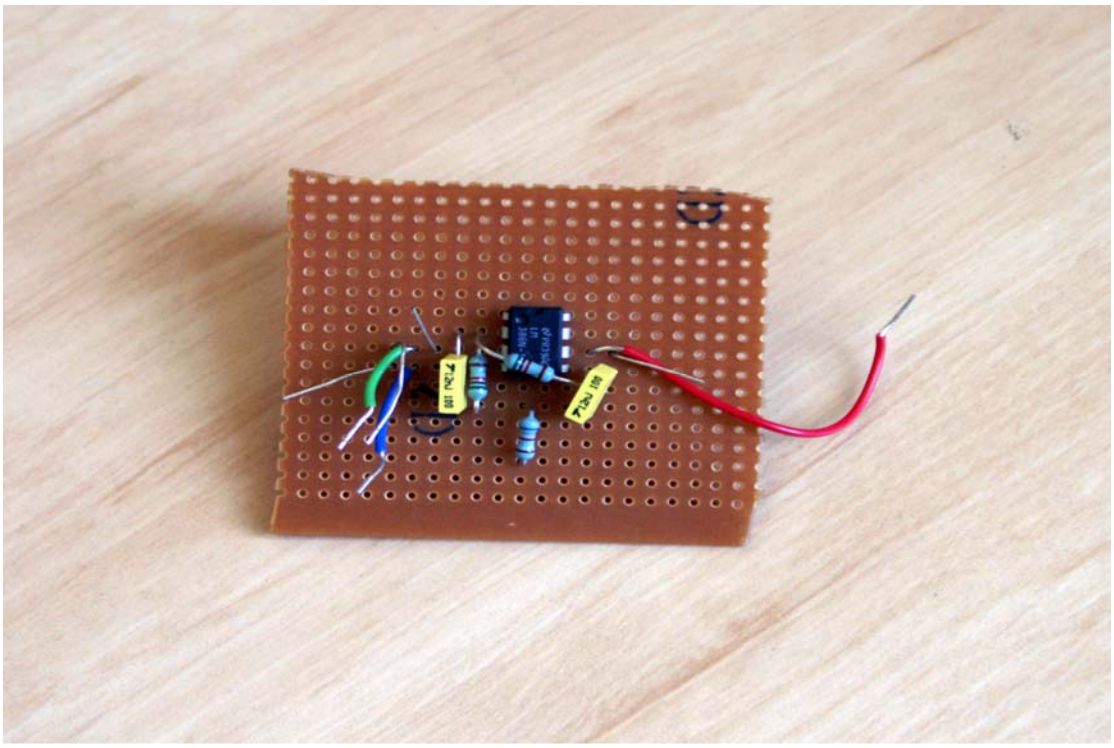
$$Q = \pi focR2 = \pi(124.91*4.7*10^{-9}*5.1*10^3) = 0.661$$

$$Bw = \frac{fo}{Q} = \frac{124.91}{0.661} = 188.97$$

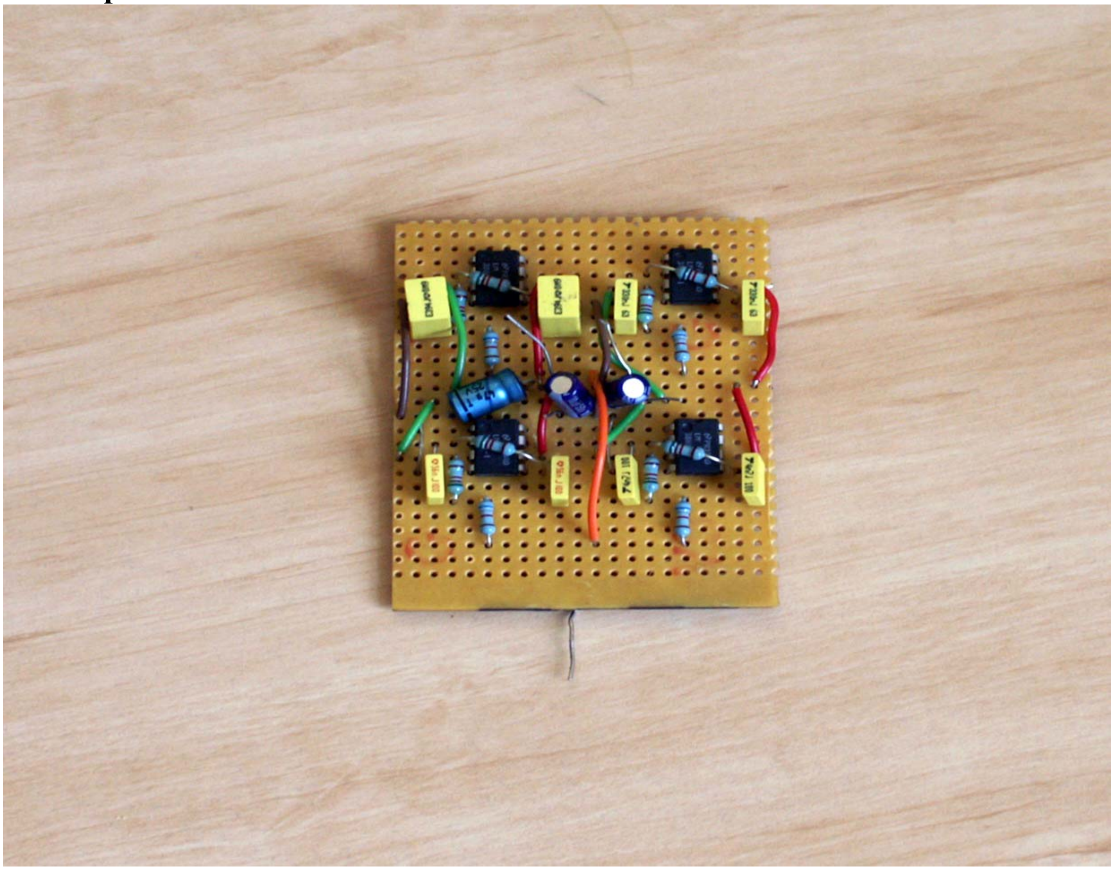
Two Channel-Mixer:



Band Pass Filter



4 band pass filters



9. References

[1] Floyd & Buchla, Fundamentals of Analog Circuits Second Edition, Thomas L. Floyd and David Buchla, Copyright © 2002, 1999 by Pearson Education, Inc.