TECHNICAL UNIVERSITY OF CLUJ NAPOCA

FACULTY OF ELECTRONICS, TELECOMMUNICATIONS AND INFORMATION TECHNOLOGY

AUDIO AMPLIFIER

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1. Requirements

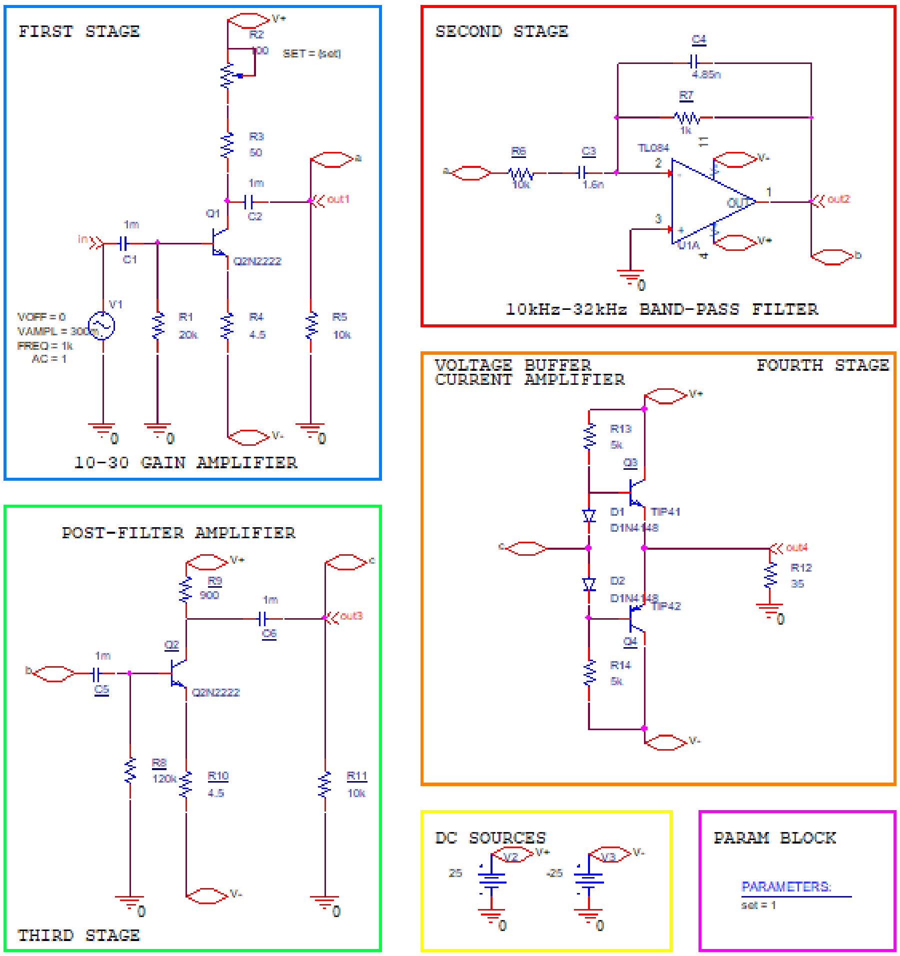
In this project I am supposed to make an audio amplifier which has as input a signal with the amplitude of 300mV, and delivers at the output a signal with the amplitude which can vary between 3V and 9V. It also must have at the output a resistance of 35Ω, and the bandwidth of the signal should be between 16,384Hz and 32,768Hz.

An amplifier is an electronic device that can increase the power of a signal (a time-varying voltage or current). It is a two-port electronic circuit that uses electric power from a power supply to increase the amplitude of a signal applied to its input terminals, producing a proportionally greater amplitude signal at its output. The amount of amplification provided by an amplifier is measured by its gain: the ratio of output voltage, current, or power to input. An amplifier is a circuit that has a power gain greater than one.

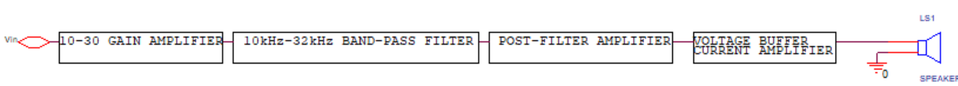
An amplifier can either be a separate piece of equipment or an electrical circuit contained within another device. Amplification is fundamental to modern electronics, and amplifiers are widely used in almost all electronic equipment. Amplifiers can be categorized in different ways. One is by the frequency of the electronic signal being amplified. For example, audio amplifiers amplify signals in the audio (sound) range of less than 20 kHz, RF amplifiers amplify frequencies in the radio frequency range between 20 kHz and 300 GHz, and servo amplifiers and instrumentation amplifiers may work with very low frequencies down to direct current. Amplifiers can also be categorized by their physical placement in the signal chain; a preamplifier may precede other signal processing stages, for example. The first practical electrical device which could amplify was the triode vacuum tube, invented in 1906 by Lee De Forest, which led to the first amplifiers around 1912. Today most amplifiers use transistors. [4]

2. Circuit and Simulations

In the next circuit it can be seen the circuit. It's composed of four stages, and it also has to additional blocks which represents the DC sources and the so called (I called it like this) the “PARAM block”, which contains the param component that helps at the variation of the potentiometer, which is used for the adjustment of the output voltage.

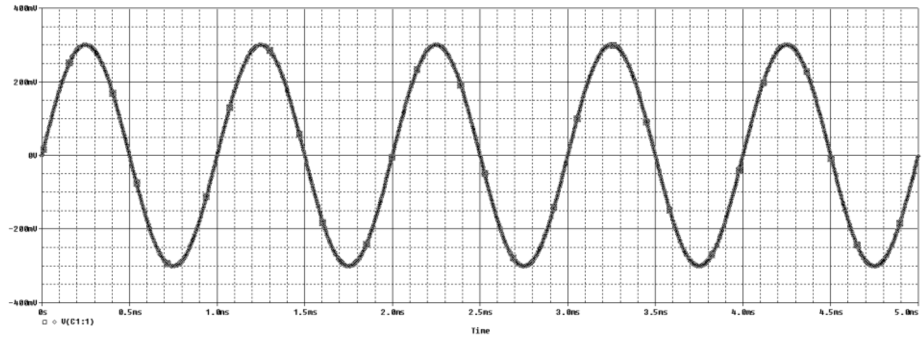


It is also presented the block diagram of the circuit.

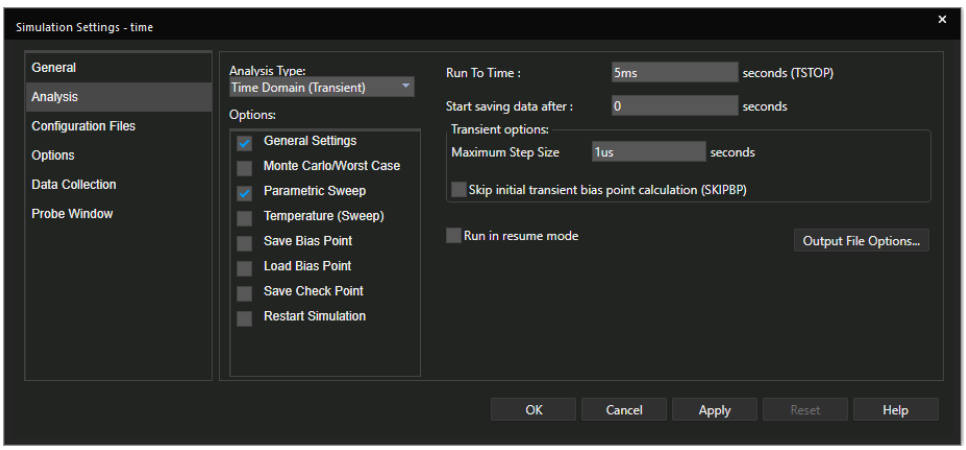


In continuation I will attach the photos corresponding to the simulation profiles and the input signal. To demonstrate the functionality of the circuit I choose a time domain simulation as well as a frequency one. When the time domain runs, it is defined also a parametric sweep simulation, which is used to verify if the output signal is adjustable between 3V and 9V, by taking into account the {set} parameter.

Input signal:



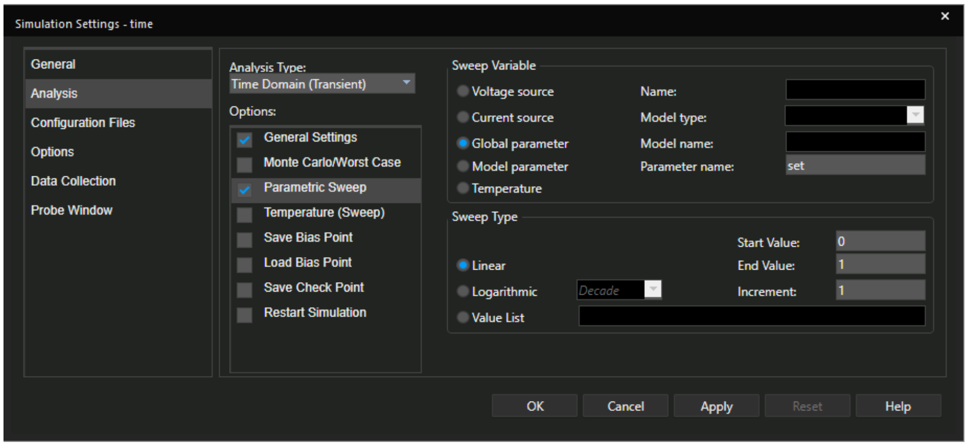
Time domain simulation profile:



The length of Y axis is of 5ms. I choose this value because the input signal has a frequency of 1kHz, and the corresponding Y axis is long enough to visualize 5 periods of the signal. The period of the signal is 1ms, and it can be computed with the next formula:

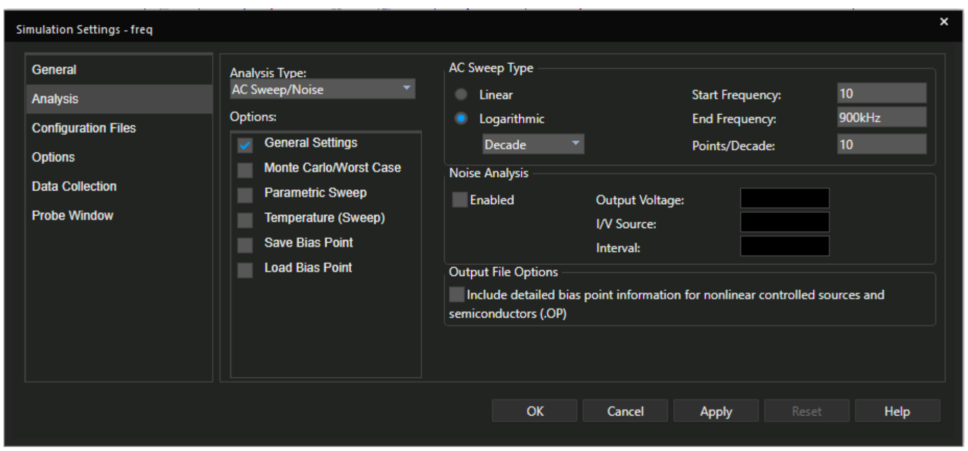
$$T=1/f \quad (1) \ [1]$$

Parametric sweep simulation profile:



As it can be seen, at the parameter name it is written ‘set’, which is the name of the potentiometer’s ‘knob’, responsible for the adjustment of its value. The simulation is made to visualize the output signal for the smallest and biggest values of the potentiometer only. This is why the simulation starts at 0 and goes up to 1 with an increment of 1.

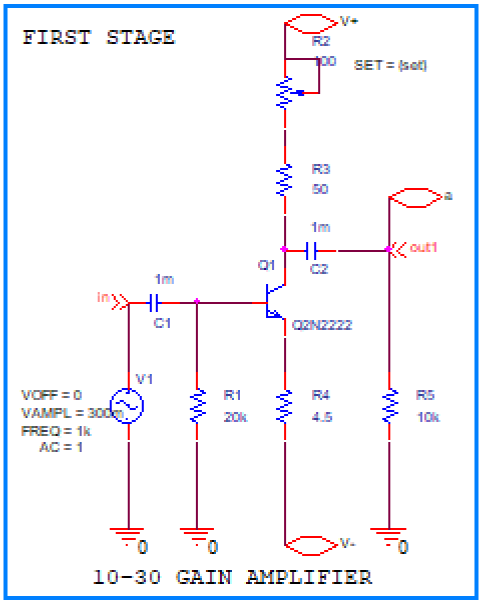
Frequency simulation profile:



3. Stages

3.1 First Amplifier

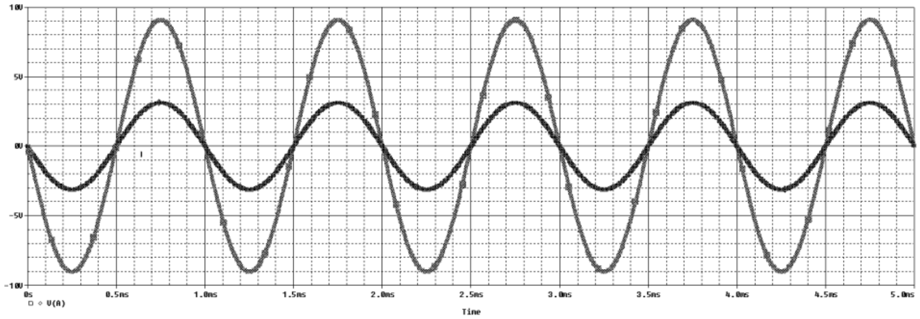
The first stage of my amplifier is a common emitter amplifier with BJT transistor. The reason why I choose this circuit I because it has a big voltage amplification (it can go up to over 100). In this case, it generates a gain between 10 and 30, to bring our input signal at the desired amplitude. The stage is presented in the picture below. [2]



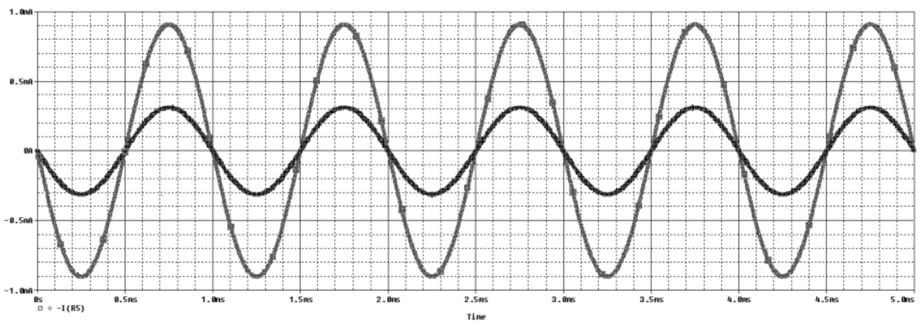
The gain is adjusted using the potentiometer ‘R_2‘. Its value is expressed by the ratio between the resistance in the collector of the transistor and the resistance in the emitter of the transistor.

$$A_v = R_c / R_e \quad (2) \; [1]$$

In the emitter the resistance is constant set at 4.5Ω, while in the collector the potentiometer makes it vary between 50Ω and 150Ω. If we make the ration between those values, we obtain the desired amplification. The output signal after this stage looks something like this:



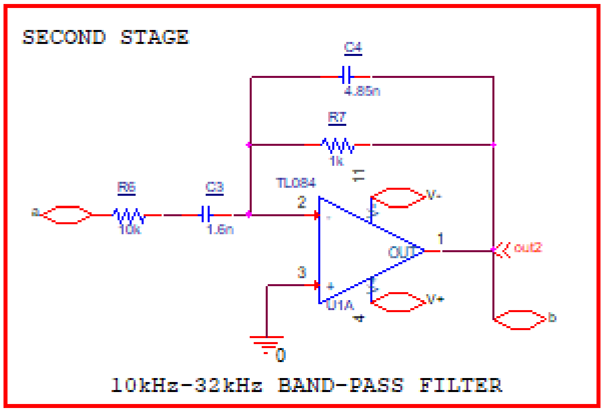
As it can be seen, the desired range for the voltage is obtained. The output voltage for this stage is measured on a 10kΩ resistor. So, by obeying the Ohm's law, the output current should be between 0.3mA and 0.9mA. As expected, this result is obtained. Below it is shown the output current of this stage, as well as the Ohm's law.



$$I=V/R \quad (3)\ [5]$$

3.2 Band-Pass Filter

The second stage of my amplifier is represented by a band-pass filter. It is used to adjust the frequency of the signal between 16kHz and 32kHz. My second stage is shown in the next image.



This stage uses a TL084 operational amplifier. The passive components situated on the negative feedback are responsible for high cut-off frequency, while the ones on the inverting input for the low cut-off frequency. The formula for computing the cut-off frequencies is the next:

$$f_c=1/(2\pi RC) \quad (4) \quad [1]$$

Using the above formula, we find the corresponding values for the passive components of our circuit.

$$1/(2\pi RC) = 32{,}768$$

$$RC=0.00000485$$

$$RC=4.85*10\text{^}(-6)$$

Following the calculation that we've just made, I choose the next values for the components on the negative feedback. Those are $R_7=1k\Omega$ and $C_4=4.85nF$.

I've tried to compute the values of the components on the inverting input for the frequency of 16,384Hz but it did not work. I think because the bandwidth is too narrow for such big frequencies. I've tried for the frequency of 10,000Hz and it work just fine.

$$1/(2\pi RC) = 10{,}000$$

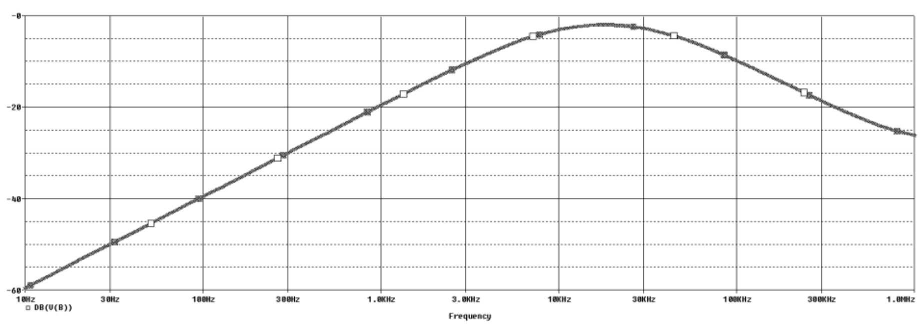
$$RC = 0.000016$$

$$RC = 16 * 10^{(-6)}$$

$$R_6 = 10k\Omega$$

$$C_3 = 1.6nF$$

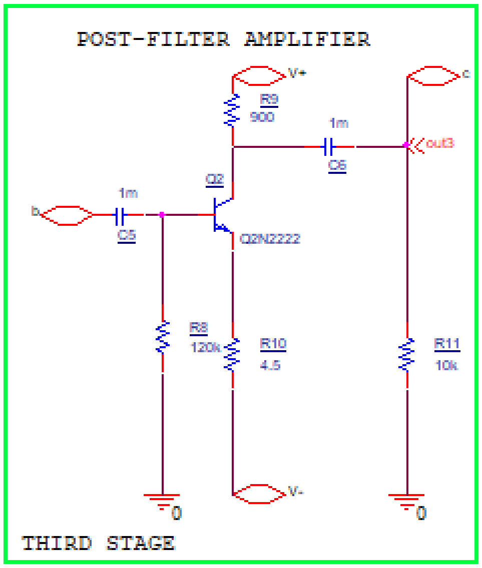
In the next picture it can be seen the results in frequency domain after the filter stage. The cut-off frequencies are computed at –3dB and they are as expected.



Trace Color	Trace Name	Y1	Y2	Y1 - Y2
	X Values	10.078K	32.868K	-22.791K
CURSOR 1,2	DB(V(B))	-3.0059	-3.0905	84.536m

3.3 Post Filter Amplifier

After going through the filter, the signal suffers an attenuation. It drops about 100 times. So, to solve this issue, I put another amplifier after the filter. The stage is illustrated in the next image.



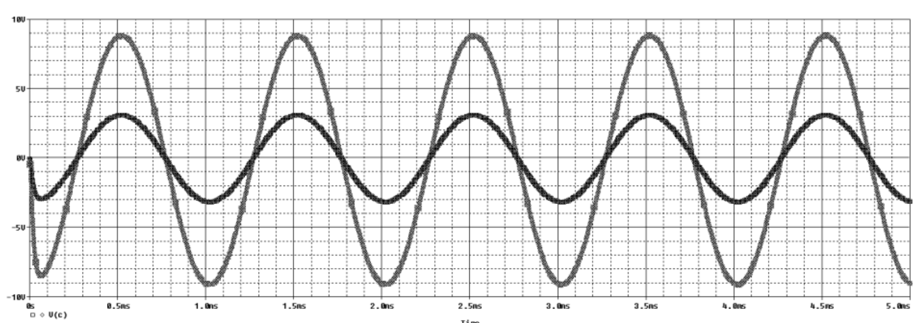
This amplifier has a gain about twice bigger than it should. A gain of 100 it should be enough. But this gain I used to be prepared for the next stage which will also drop the signal.

$$A_v=R_9/R_{10}$$

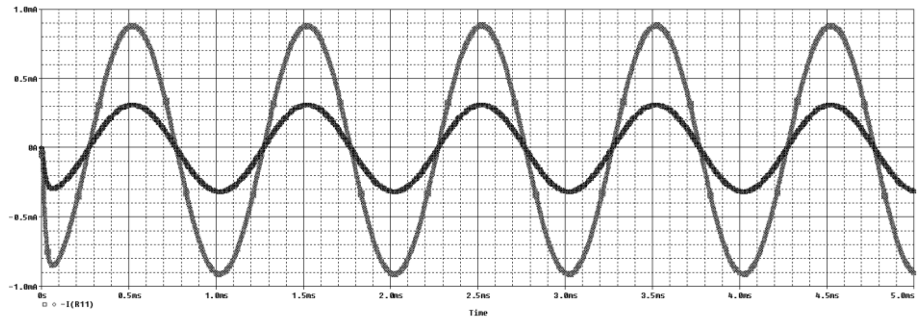
$$A_v=900/4.5$$

$$A_v=200$$

Here we have a photo of the output voltage after this stage.

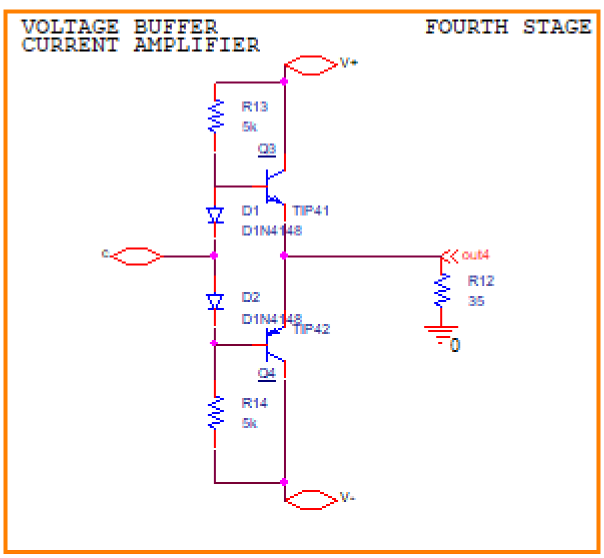


Using the formula (3), and taking into account that the signal is measured on a 10kΩ resistor, we can predict how the current will look like.



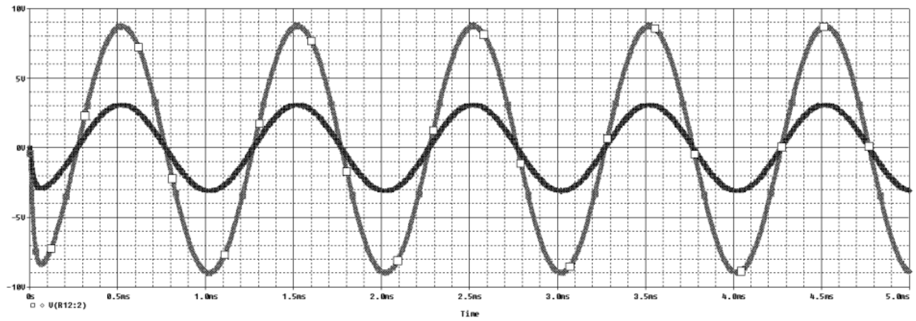
3.4 Voltage Buffer, Current Amplifier

We saw that all the requirements were fulfilled except for one, the output resistance, which for a common emitter amplifier it varies between 30kΩ and 50kΩ. So, to fulfill that task, I choose to put a class AB amplifier. This type of amplifier steals about 1.4V from the input voltage (from the diodes), but it behaves as a current amplifier, because the output resistance is small, and with a big voltage drop on it, a greater current result. The fourth stage of my amplifier is shown below.

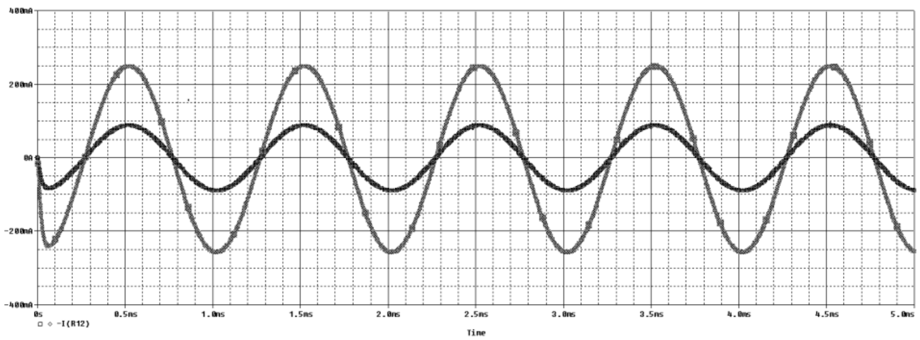


It can be seen that the output resistance has the value of 35Ω. The input voltage is the output one from the previous stage, which was a sine with the amplitude that could vary between 3V and 9V. Using the Ohm's law (relation (3)), at the output results a current that varies between 90mA and 250mA.

Output voltage:



Output current:



The class AB amplifier combines the advantages of the class A amplifier and class B amplifier. The class B amplifier has pretty much the class AB one, but it meets cross-over distortions. The diodes resolve this issue. Each transistor is responsible for a part of the sine. Q_3 (the one connected at the positive voltage supply) work when the voltage is bigger than 0.7V (the thresh hold voltage in the base of the transistor), while Q_4 works on the negative half-wave. [1]

4. Standardization

Next, I will make a table in which I will put the components and other more specifications.

Component	Shop	Link	Price	Tolerance	Manufacturer
3x10kΩ resistors	Jameco Electronics	https://www.jameco.com/webapp/wcs/stores/servlet/StoreCatalogDisplay?langId=-1&storeId=10001&catalogId=10001&CID=BING&msclkid=529de58e7549146cca8cbb34c81327c7	0.0092€	5%	NIC Components
1x1kΩ resistor	-//-	-//-	0.0046€	1%	NIC Components
1x20kΩ resistor	Allied Electronics	https://www.alliedelec.com/product/nippon-chemi-con/emza350ada331mja0g/R1029735/?mkwid=YQaPNumu&pcrid=817762208435 47&pkw=EMZA350ADA331MJA0G&pmt=bb&utm_source=bing&utm_medium=cpc&utm_campaign=ERFeed%20-%20Nippon%20Chemi-Con&utm_term=EMZA350ADA331MJA	0.097Ω	1%	RN55D2002FB14

		0G&msclkid=f404662c141113cf545c3896c3b42281&gclid=CPb25cLorukCFQuChQodp4cCFg&gclsrc=ds			
1x120kΩ resistor	-//-	-//-	0.015€	1%	LR1F120K
2x5k€ resistor	-//-	-//-	0.14€	1%	RN60D5001FB14
1x900Ω resistor	-//-	-//-	0.78€	5%	CW02B900R0JE12
1x50Ω resistor	-//-	-//-	0.89€	5%	CW00550R00JE12
1x100Ω resistor	-//-	-//-	0.0092€	5%	OK1015E
1x4.5€ resistor	-//-	-//-	0.009€	10%	PFE5K4R50E
4x1mF capacitor	-//-	-//-	0.22€	20%	UPW1A102MPD6
1x1.6nF capacitor	-//-	-//-	0.072€	2%	C0402C162G3JACAUTO
1x4.85nF capacitor	-//-	-//-	1.20€	20%	564R30GAD47

As it can be seen, I've found all the components that I used for the design of the circuit. So, there is no need to redone the computations.

5. Conclusion

Doing this project, I've learned the internal structure of an audio amplifier. The circuit wasn't made with the thought of economy or optimization in mind, so, the values that I've choose for the components could not be the best ones, and the components that I've choose in the standardization part could not be the cheapest ones. But, taking all of this into account, the circuit is doing its job and fulfills the requirements.

I've also had the opportunity to apply everything that I've learned at other disciplines, and also to explore on the internet after new knowledges that I can use from now on in the future projects.

All in all, I am glad I had the opportunity to do this project and I hope that the time that I will spend in the university to be full of that kind of experiences.

6. Bibliography

[1]http://www.bel.utcluj.ro/dce/didactic/fec/

[2]https://eprofu.ro/docs/electronica/carti/auxiliar-circuite-electronice.pdf

[3] Ovidiu Pop, Raul Fizeșan, “Computed aided Design”

[4]https://en.wikipedia.org/wiki/Amplifier

[5]https://en.wikipedia.org/wiki/Ohm%27s_law

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