

PSDE 4004 Assignmnt 1 Adam Bedner

by Adam Bedner

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PSDE 4004 Electronics I

Assignment 1

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1. Introduction, aims and objectives.

The main objective of this assignment is to design an oscillator that will produce 150KHz output at 1Vrms and an A class amplifier rated for 150KHz as centre frequency with a bandwidth of 80KHz, gain of 20 and a ratted input signal of 50mVpk.

The assignment will as well require a research to be carried out about amplifier and oscillator types, different active components and their biasing according to the intended purpose and different feedback types and common uses for those.

2. Research

2.1 Amplifier types

Amplifiers are one of the most common circuit used in almost every device we use daily therefore there is a lot of different types of amplifiers. Those amplifiers, depending on different properties, can be separated in different types:

- Power output, gain and function:
 - ❖ Voltage Amplifiers
 - ❖ Power Amplifiers

Voltage amplifier, as the name states, mainly amplifies Voltage, meaning that output voltage will be much greater than input but not the power. Voltage amplifiers usually have high gain. (Publishing, ND)

Power amplifier, as the name states, is responsible to amplify the power. Those amplifiers have very small gain, therefore the voltage is not greatly amplified and can remain the same or even be smaller than the input but big amounts of current and therefore, power to drive speakers, motors, antennas, ext. (Publishing, ND)

- The build:
 - ❖ Single stage:
 - Common emitter
 - Common collector
 - Common Base

Common emitter, as shown in Figure 1, is a set up where the transistor's emitter is common to input and output. It is well-suited for voltage amplification but it amplifies both, voltage and current as well as it inverts the signal (180° faze swift). Therefore it has both, voltage and current gain.

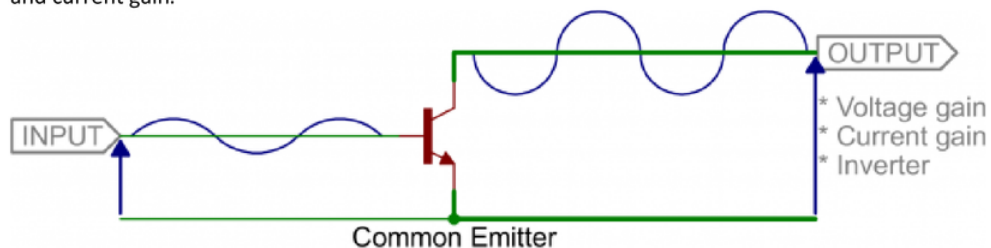


Figure 1 example model of a common emitter

In **Common collector**, as shown in Figure 2, the collector is common to the input and output. This set up does not amplify the voltage (note: the voltage will be 0.6V lower due to transistor's internal voltage drop) but it has great current amplification capabilities. Therefore, it has high current gain but no voltage gain and it can be used as Voltage buffer. (jimb0, ND)

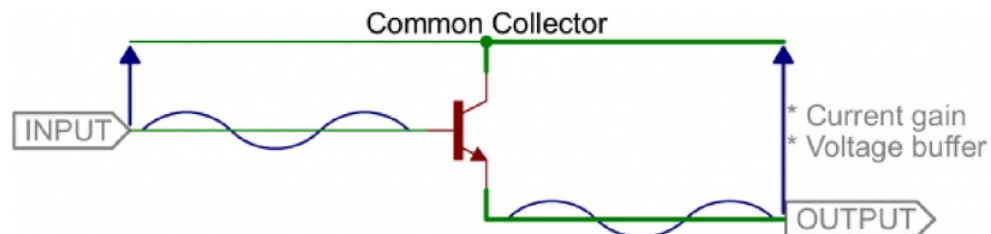


Figure 2 example model of a common collector (jimb0, ND)

Common Base configuration has the base common to the input and output as shown in Figure 3. It work great as a voltage amplifier, meaning that is has a high voltage gain but no current gain and it can be used as a current buffer. Note: this is not a very common configuration. (jimb0, ND)

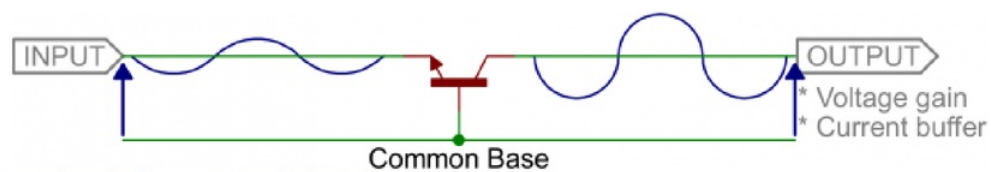


Figure 3 Example model of a common base (jimb0, ND)

❖ Multistage amplifiers (combination of single stage):

- Darlington
- Differential amplifier
- Push-pull amplifier

Darlington Pair configuration is a use of two paired transistor (both PNP or NPN) and both works in common emitter configuration but the emitter (output) of the first runs into the base (input) of the second one as shown in Figure 4. Darlington pairs are used to achieve high current gain for driving heavy loads with small current inputs. (jimb0, ND)

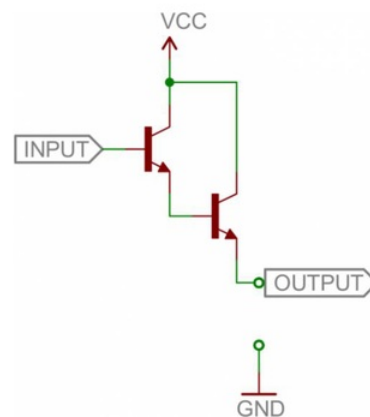
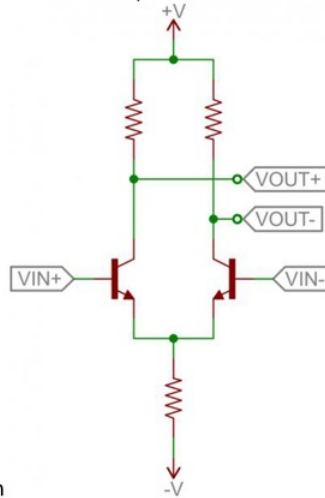


Figure 4 Example model of a Darlington Pair (jimb0, ND)

Differential Amplifier is a configuration of two paired transistors of same type which work



as a common emitter as shown in . This configuration subtracts two voltages and amplifies the difference between the two. Is a critical part of most feedback circuits. (jimb0, ND)

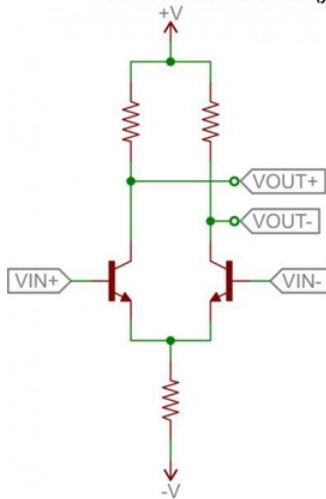


Figure 5 Example model of a differential amplifier (jimb0, ND)

Push-Pull Amplifier, as shown in Figure 6, is a configuration of two paired transistors of opposite type (ex. One PNP and one NPN) where both of them works in common collector configuration. It is an energy efficient power amplifier with high current gain but with no voltage gain. It is very useful as a final stage in multi-stage amplifiers and is mostly used as a final stage in audio amplifiers to drive loudspeakers. (jimb0, ND)

➤ Frequency

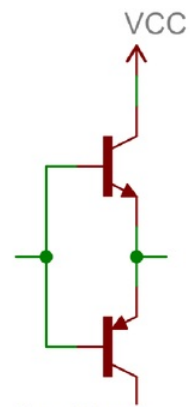


Figure 6 Example model of a push-pull amplifier (jimb0, ND)

❖ Frequency Range (general):

- Wide-band
- Narrow-band
- Tuned amplifiers
-

Wide-Band amplifiers are those that can work in a very wide bandwidths (Bandwidths of hundreds of KHz or MHz). Those amplifiers tend to have low gain.

Narrow-Band amplifiers have their bandwidths much narrower than wide-band which help them to boost the gain.

Tuned amplifiers are designed to work with one frequency only and the bandwidth is very small or nearly non-existent.

❖ Frequency Range (specific, application-related):

- Audio amplifiers
- RF Amplifiers
- video amplifiers
- GPS amplifiers, ext.

Audio Amplifiers are specially designed narrow-band amplifiers to work with frequencies that can be heard by humans, typically their bandwidth is from 10Hz up to 20kHz. (Publishing, ND)

RF (Radio Frequency) Amplifiers are mostly used in audio radio transmission and are designed to amplify frequencies between 10kHz and 100,000MHz. As one single amplifier will not be able to work with such a big frequency range, any amplifier that works in this frequency range is an RF amplifier. (Publishing, ND)

Video Amplifiers are designed to work with frequencies from 10Hz up to 6MHz. As these are wide-band amplifiers, their gain will be much lower than of other amplifiers and these will require much more components to work with such a wide bandwidth. (Publishing, ND)

2.2 Oscillator types

LC Oscillators are circuits using inductors and capacitors to define the frequency of oscillation as well as active components to sustain the oscillation. The Inductor's and capacitor's values are selected to make them resonate at certain frequency and the use of active components as an amplifier to sustain that resonance. Those circuits can work in high frequencies, usually radio frequencies. The accuracy of these depends on the tolerances of the capacitor and inductor as well as the frequency of oscillation can vary with the ambient temperature. This type of oscillators can be expensive due to the cost of inductors.

RC Oscillators are circuits composed by resistors and capacitors and an active component for the amplifier to sustain the oscillation. These oscillators operate at low frequencies, audio frequencies, and are hard to start the oscillation as well as normally are unstable but are really cheap to build.

Crystal Oscillators are circuits similar to LC oscillators but here instead of capacitors and inductors a crystal is used which gives much more stability and reliability. Crystal oscillators are able to produce very precise frequencies that doesn't vary much with change of environment temperature. Crystal

oscillators are limited in high frequencies (GHz range) as low frequency oscillating crystals are not easily accessible and very expensive.

2.3 Active components

➤ Active components in oscillators

- ❖ **Triode vacuum tubes** which is an old technology, mainly not used now a days, requires large voltages and is very power consuming. Valves, due to their construction, are very delicate and they can catch interferences (electromagnetic and mechanical such as vibrations of environment) very easily and add harmonic frequencies to the circuit. Most ordinary valves are as well frequency limited up to around few GHz. (Edson, 1953)
- ❖ **Transistors and IC's** are the most commonly used active devices and are constantly in developing. Those are usually power efficient, compact and require small voltages but most of them are limited to around 20GHz.
- ❖ **Magnetrons** are a type of high-power vacuum tube self-oscillating device which can work at up to 100GHz. It is usually used in microwaves, radio transmission and radars.

➤ Active devices in Amplifiers.

- ❖ **Vacuum Valves** is an old, power eating technology that is used only by audio lovers due to their difference in the sound.



Figure 7 Example of different Vacuum valves (trinkaus, 2006)

- ❖ **Transistors** are normally used in HI-FI (High Fidelity) audio equipment in the end stage power amp (usually a push-pull) as well as in amplifiers where large amount

are required in the output such as motor drives.



Figure 8 Example of a transistor audio amp (320Volt, ND)

- ❖ **IC's** Are small and compact components that substitute the individual transistors and part of circuitry in amplifiers in order to save space. Those can be very power efficient, can pull out quite large amounts of power as well as it is much easier to design circuits using IC's. IC's are used as well in op-amps for voltage amps, filters, signal busters, ext.



Figure 9 Example of an IC amp (Electronics, ND)

- ❖ **Hybrids** are a try of combining advantages of IC's and individual transistors. Those were usually used in audio amplifiers.

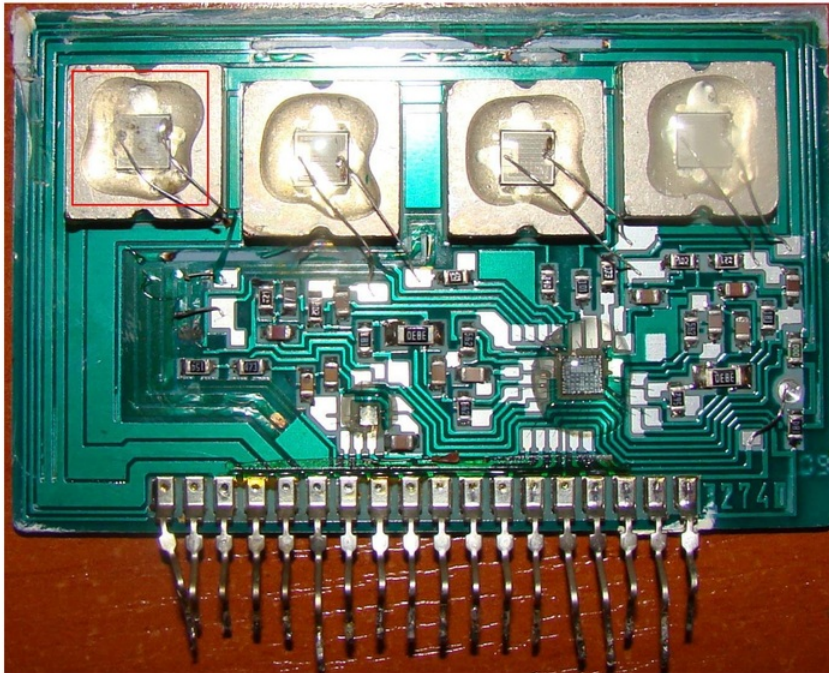


Figure 10 Example of a inside circuitry of a Hybrid (No case) (Edek_22, 2010)

All of those components can have different biasing which will affect the time of conductivity, efficiency and quality of the amplifier which is shown in Figure 11

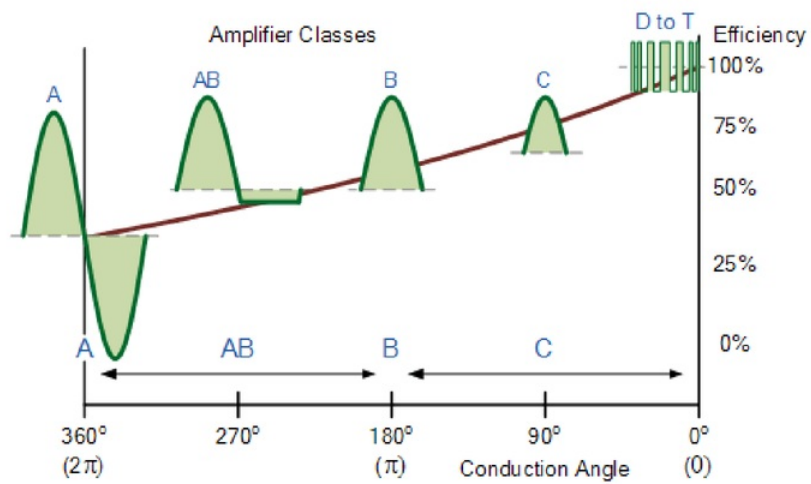


Figure 11 Figure showing the difference between the amplifier classes A, AB, B, C, D-T

3. Designing an oscillator

The task given was to design an RC oscillator that will operate at 150kHz and giving an output of 1Vrms.

To start the design I have chosen the multisim's virtual op amp. Then arranging the formulae $\omega = 1/\sqrt{6CR}$ to make R the subject and decided to use 1nF capacitor I got that $R = \frac{1}{\sqrt{6} \cdot 1 \cdot 10^{-9} \cdot 150 \cdot 10^3}$ it gave me $R = 2.7k\Omega$. multiplying that value by 29 it gave me a value of 79k Ω .

This set up did not work so I have decided to go lower the resistors (R_1 and the RC resistors) in place of the R_f I did put a variable resistor of 330k Ω . I have done to changes to the resistors, lowering them 200 Ω each time and on every change changing the value of R_f step by step from 0% to 100%. It didn't worked

I have change the resistors values to 200 Ω (except R_f) and at about 35% of R_f I started getting something but it was unstable, so I kept lowering the resistor values 10 Ω every change.

With the value of R_1 an RC resistor at 130 Ω and R_f at 70% of 330k Ω I finally got a stable signal of exactly 150kHz and 1.12Vrms

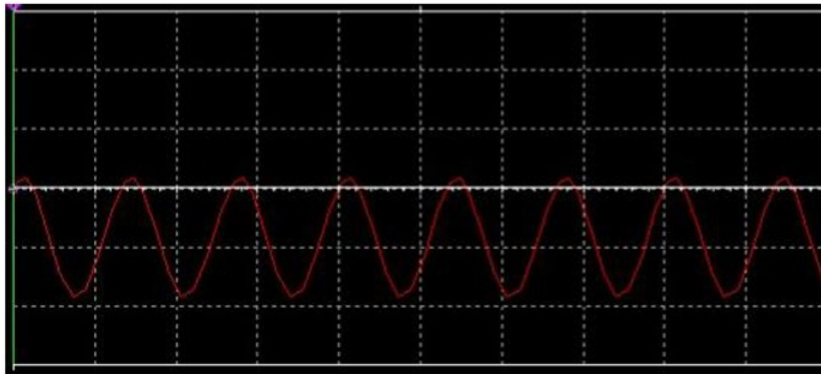


Figure 12 Output from the oscillator

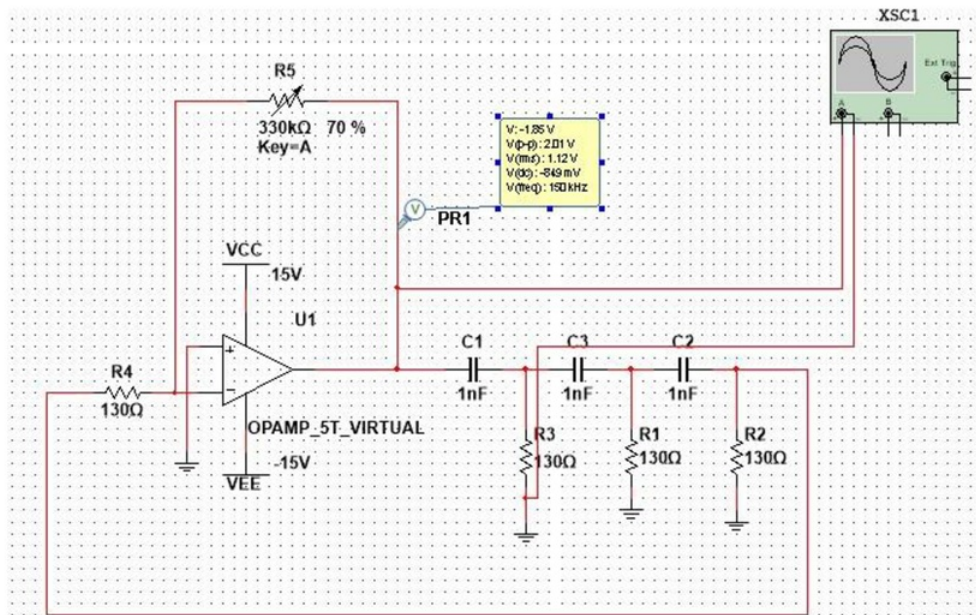


Figure 13 The finished oscilloscope circuit

4. Designing an amplifier

As a power supply I have chosen a 9V battery, the transistor used is BC107 and I_q being 20% of max is 40mA.

The specifications of BC107 are

$V_{CE0} \rightarrow 45V$

$V_{CBO} \rightarrow 50V$

$V_{EBO} \rightarrow 200Ma$

$H_{FE} \rightarrow 110-450$

All the calculations and adjustments are shown in figures 14-18.

Electronics Class A amplifier desing.

$f_c \Rightarrow 150 \text{ kHz}$

B/w $\Rightarrow 80 \text{ kHz}$ (40 kHz up/down)

Gain $\Rightarrow 20$

$V_{in} \Rightarrow 50 \text{ mV}$

Power supply: 9V (Battery)

Transistor: BC 107

$\beta_{FE} = 110 - 450 \approx 300$

$I_A \Rightarrow 20\% \text{ of max} = 40 \text{ mA}$

$R_L = \frac{V_C}{I_A} = \frac{4.5 \text{ V}}{40 \text{ mA}} = 112.5 \Omega$

$R_E = \frac{V_E}{I_Q} = \frac{1 \text{ V}}{40 \text{ mA}} = 25 \Omega$

$R_1 = \frac{V_{CC} - V_B}{I_1} = \frac{9 \text{ V} - 1.7 \text{ V}}{1 \text{ mA}} = 7.3 \text{ k}\Omega$

$R_2 = \frac{V_B}{I_1} = \frac{1.7}{1 \text{ mA}} = 1.7 \text{ k}\Omega$

$I_B = \frac{I_C}{\beta_{FE}} = 0.1 \text{ mA}$

In order to achieve the required specification I have adjusted the value of R_L to 120Ω .

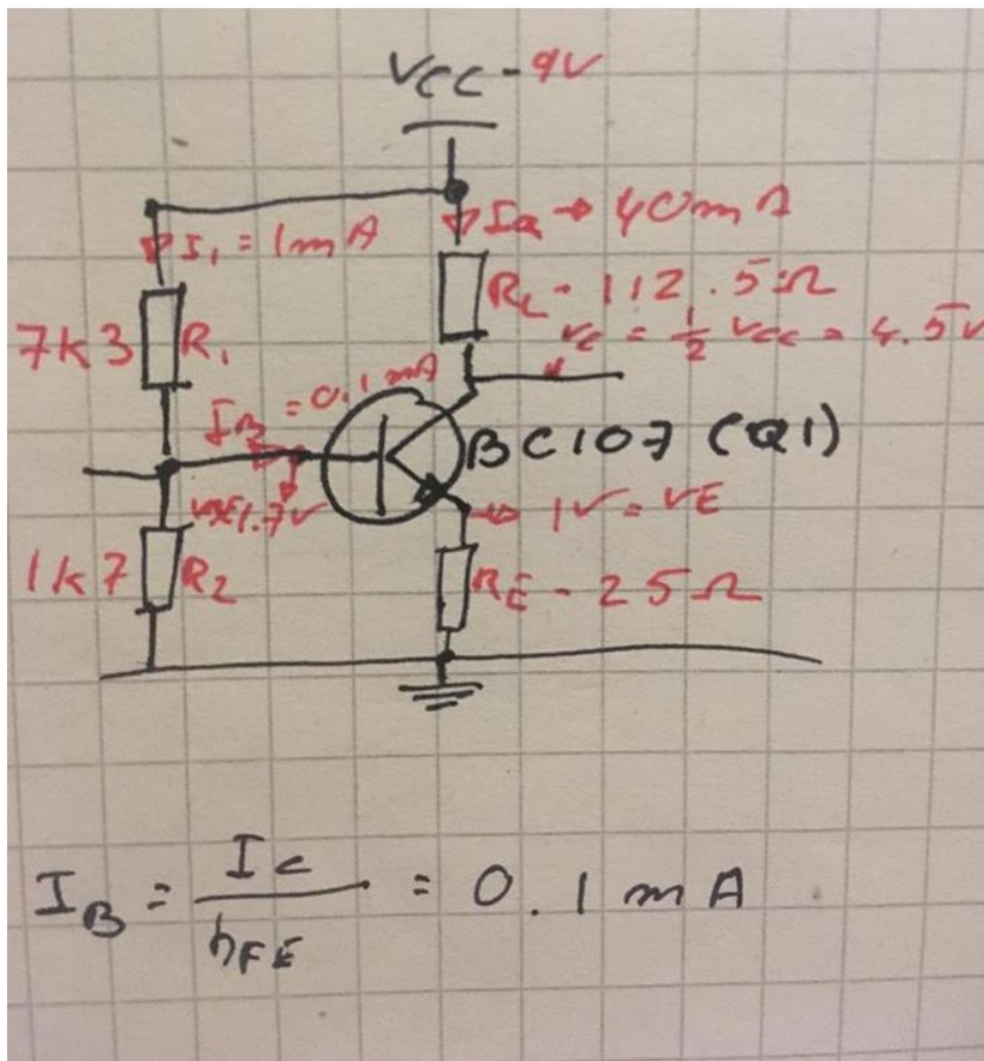


Figure 15 Close up to the drawn schematic of the design with all the values

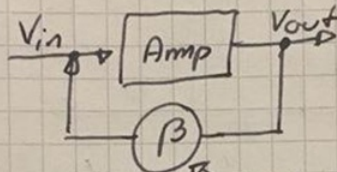
Amp designing.

Negative Feed back

$$\text{Gain} = 20$$

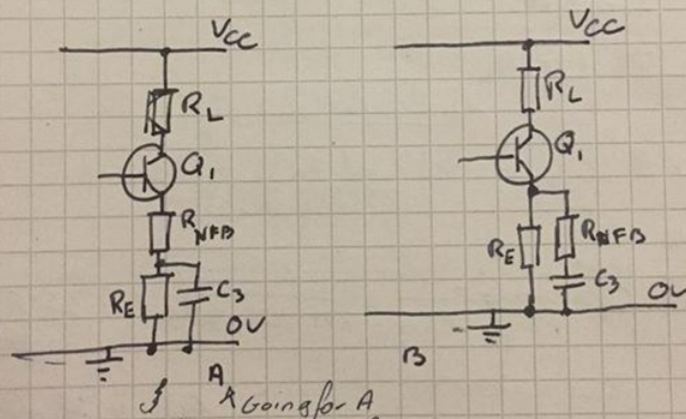
$$\text{B/W} = 150 \text{ kHz} \pm 40 \text{ kHz}$$

$$A_v = \frac{V_{out}}{V_{in}}$$



Feed back circuitry.

Two way of attaching the feedback.



$$R_{NFB} = 10\% \text{ of } R_E = 10\% \text{ of } 25 \Omega = 2.5 \Omega$$

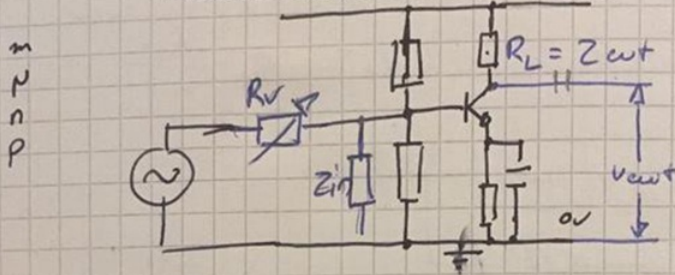
$$R_E = 25 - 2.5 \Omega = 22.5 \Omega$$

Adjusted to 15Ω

Figure 16 Calculations for the Negative Feedback

Amp Design.

Output/Input impedance.



Set R_v to 0Ω , measure V_{out}
 set R_v to $\frac{V_{out}}{2}$

$$Z_{in} = R_v$$

$$Z_{out} = R_L$$

Calculations.

$$Z_{in} = 33\% \text{ of } 1k\Omega = 330\Omega$$

$$f_L = 110kHz \quad C_1 = \text{input}$$

$$f_H = 190kHz \quad C_1 = \frac{1}{2\pi f_L Z_{in}} = \frac{1}{2\pi \cdot 110k \cdot 330} = 4.38 \times 10^{-9} F$$

$$Z_{out} = 120\Omega$$

$$C_1 = 4.38 nF$$

output

$$C_2 = \frac{1}{2\pi f_H Z_{out}} = \frac{1}{2\pi \cdot 190k \cdot 120} = 6.98 \times 10^{-9} F$$

$$C_2 = 7 nF$$

Figure 17 Calculations for the input and output impedances and bandwidth.

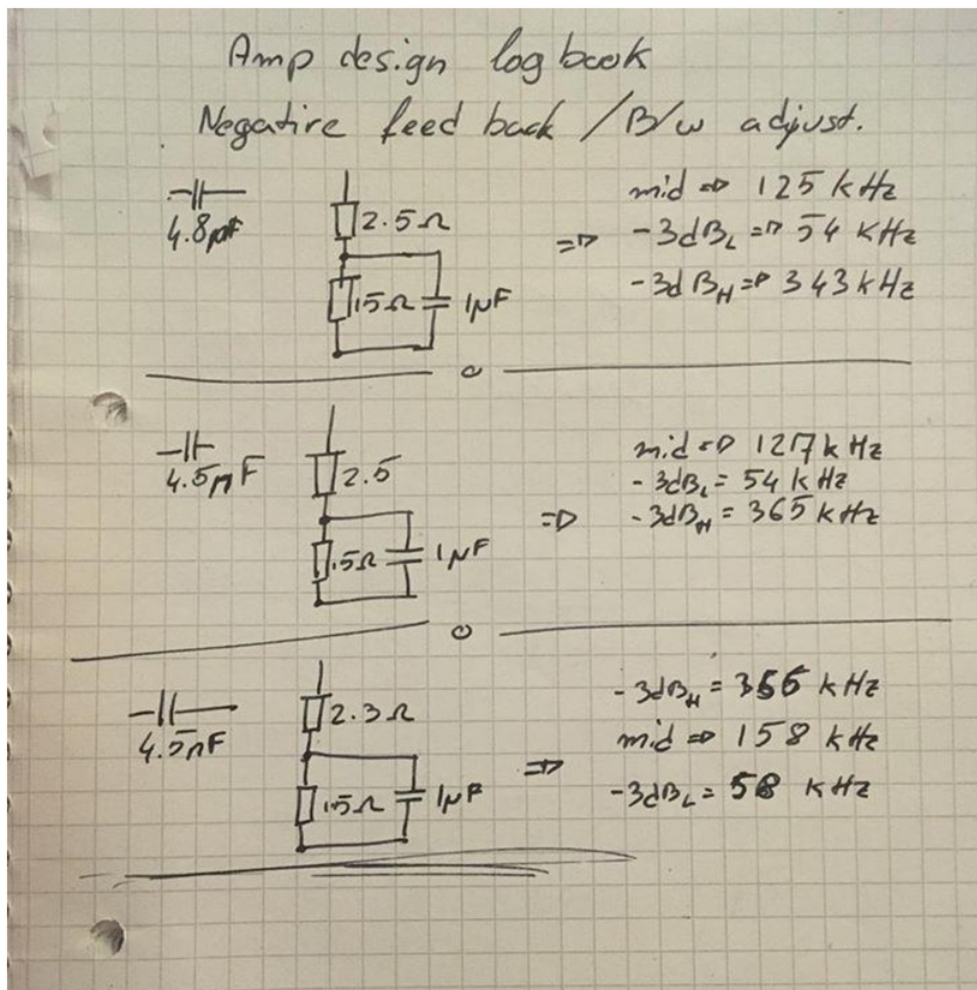


Figure 18 Logbook from the design with the adjustments of the components to achieve the required bandwidth

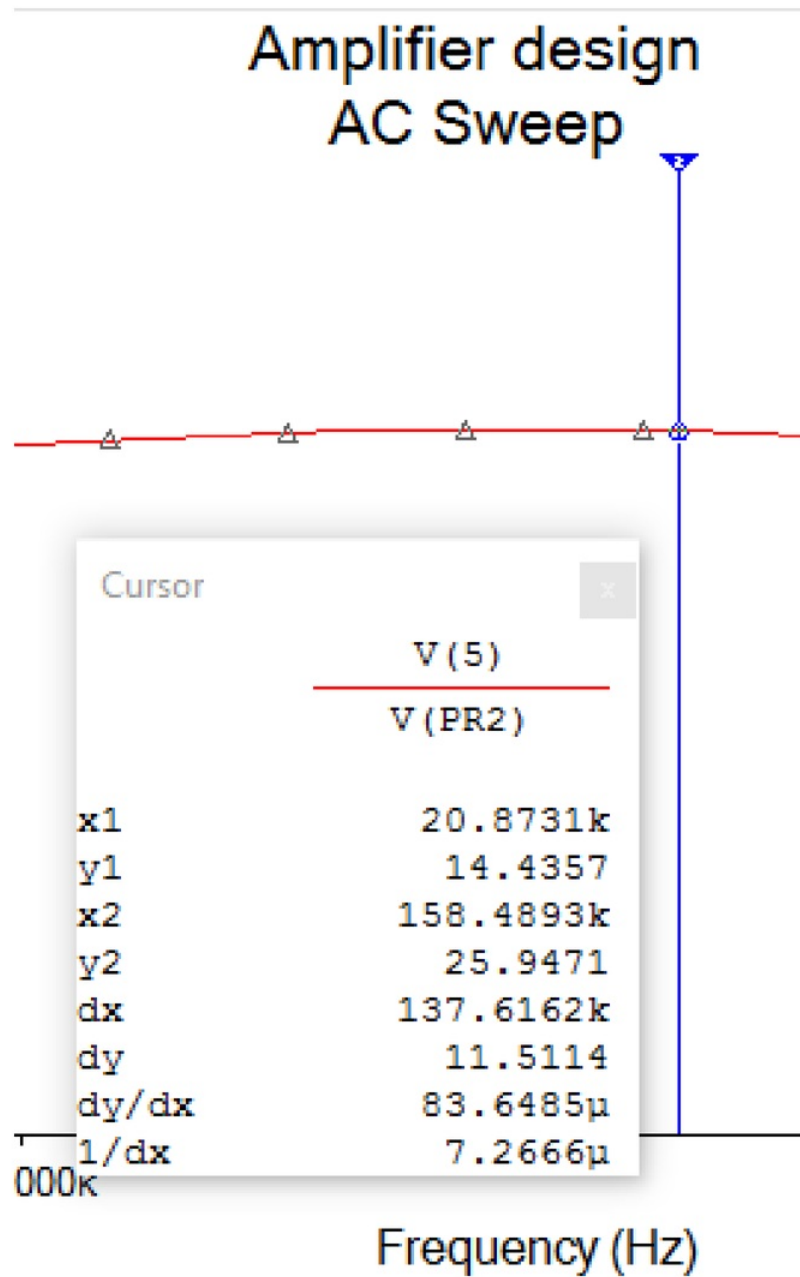


Figure 19 Graph showing the middle point of the amplifier's bandwidth where x2 is the middle point measured in Hz

Amplifier design AC Sweep

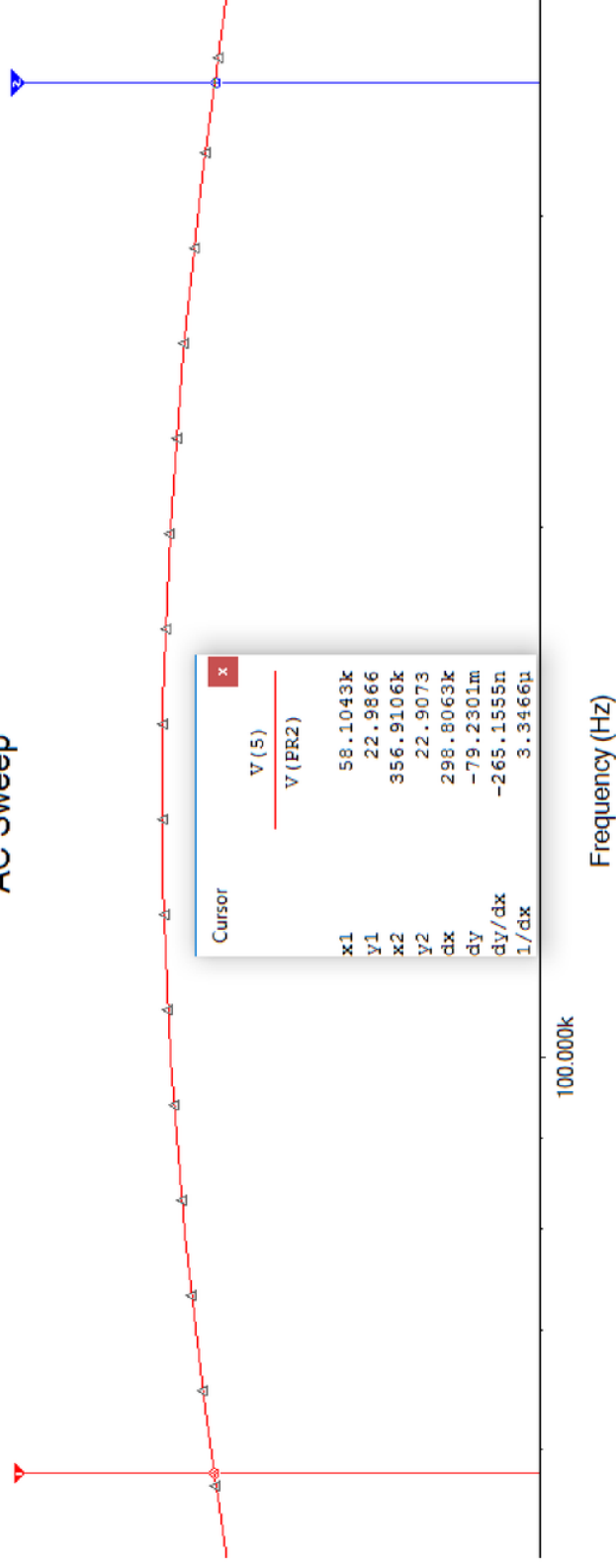


Figure 20 AC sweep showing the points at - 3dB where x1 is the low pass frequency and x2 is the high pass frequency; both are measured in H

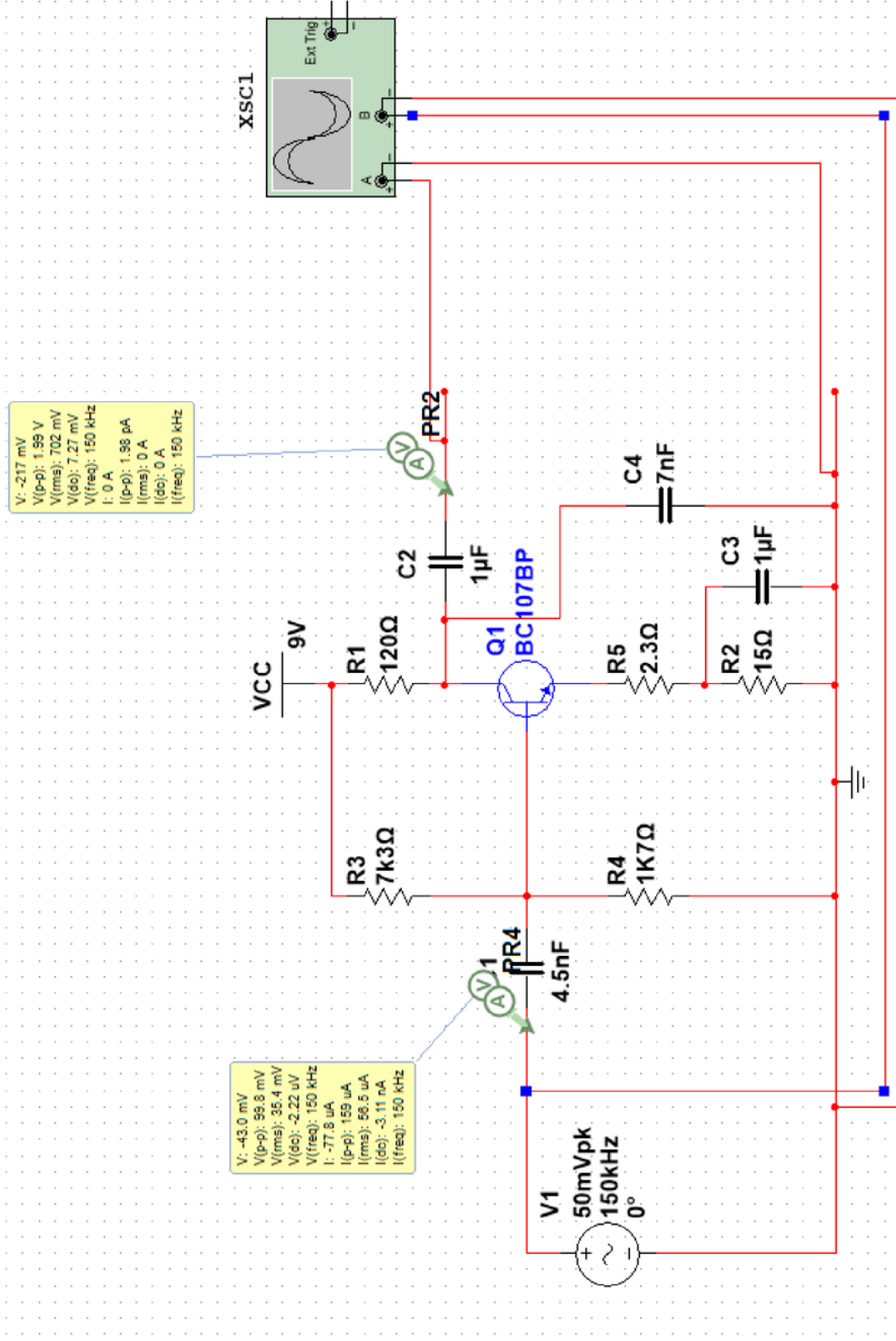


Figure 21 The finished amplifier circuit with all the probes

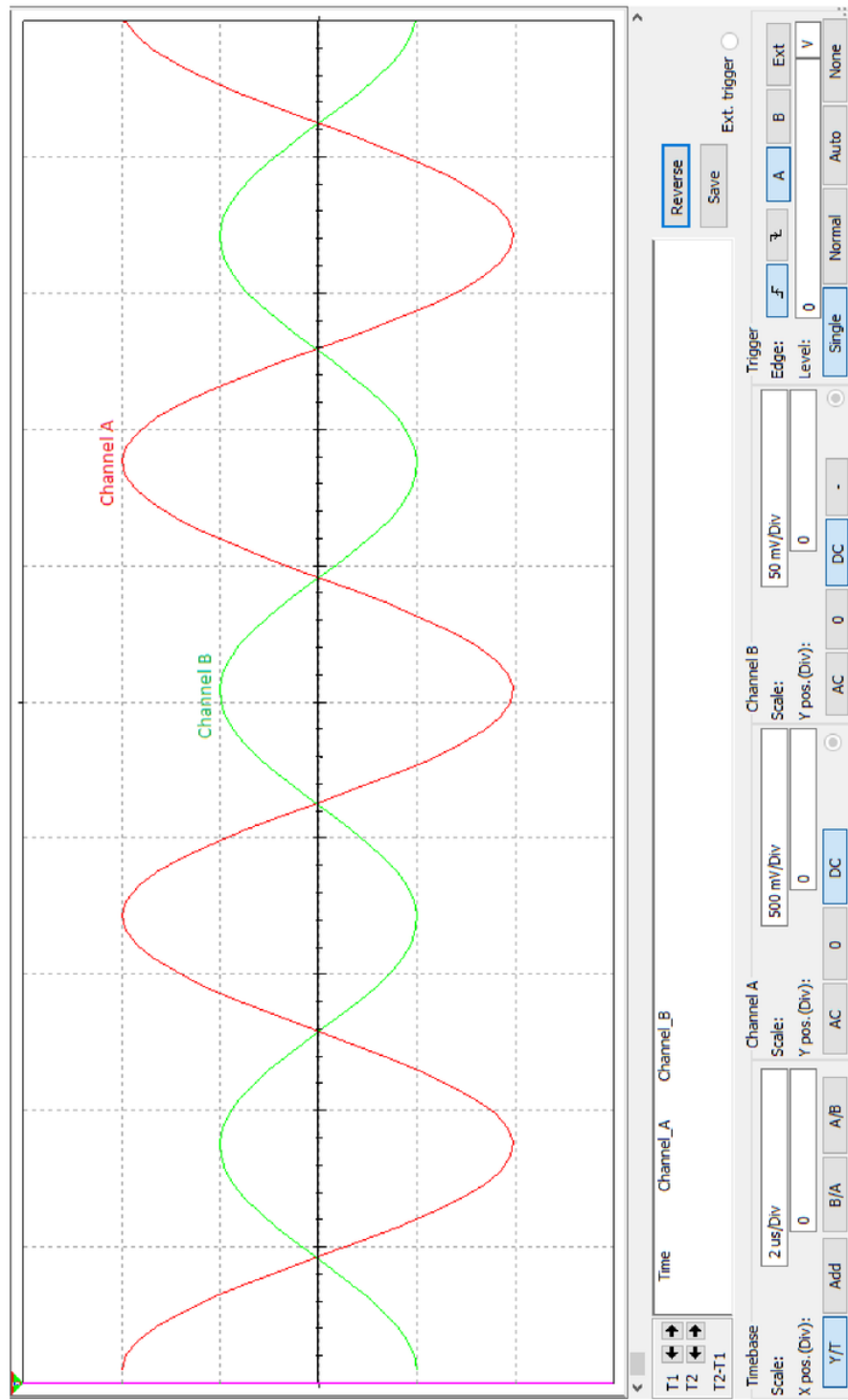


Figure 22 The scope reading of the finished amplifier circuit where channel A is the output and channel B is the input

5. Combining the circuits

To combine both circuits an op amp will be required between the oscillator and amplifier of a gain of

$$1/32 \text{ because, using the opamp formulae } Gain = \frac{V_{out}}{V_{in}} = \frac{\left(\frac{50mV_{pk}}{\sqrt{2}}\right)}{1.12V_{rms}} = \text{aprox. } \frac{1}{32}$$

Therefore, supposing that R1 is 10kΩ, Rf will be 312.5Ω

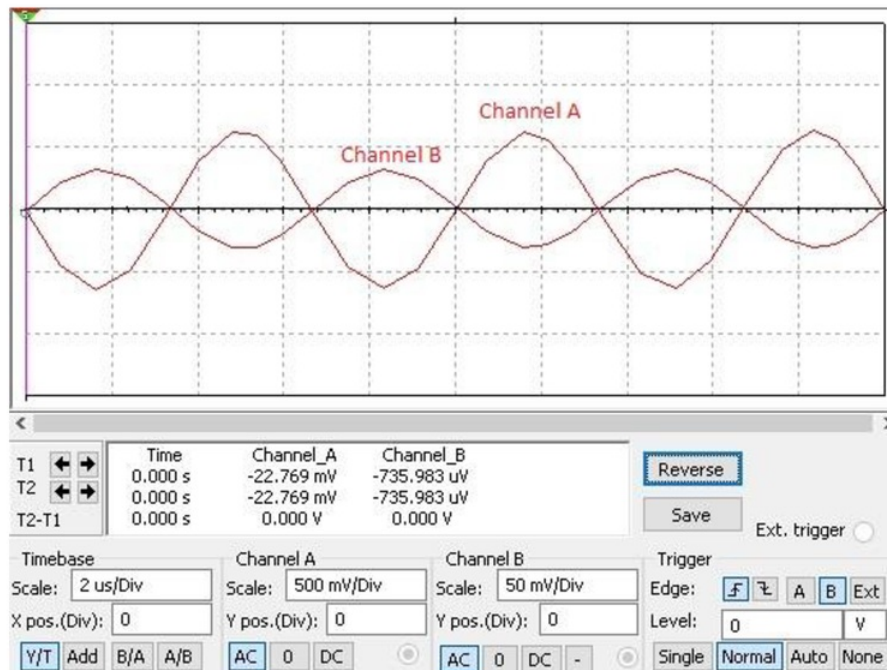
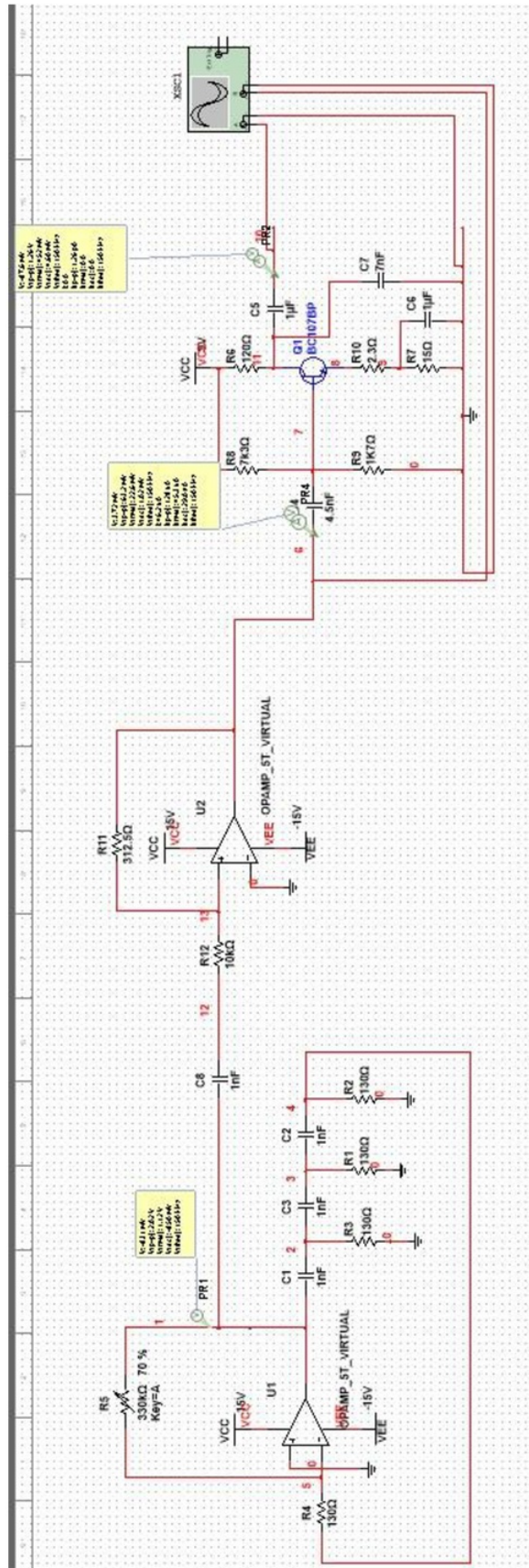


Figure 23 Scope reading of the final circuit where the channel B is the input to the final stage amp and channel A is the final output



6. Test and evaluation of the final circuit

The scope readings from the testing of the oscillator, class A amplifier and final circuit can be seen in Figure 12, Figure 22 and Figure 23 respectively.

In order to improve the circuit I would have designed the final stage amp to take an input of 1Vrms and instead of the op amp between the oscilloscope and amplifier I would have used nothing or maybe just a voltage buffer.

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PSDE 4004 Assignmmt 1 Adam Bedner

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: CSG-RUBIC

ADAM BEDNER**72****RESEARCH-INFORMED LITERATURE**

There was evidence of extensive further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was very good and demonstrated a deep underlying appreciation of the subject. Your references were appropriate to the task and your reference list was of an appropriate length for this assignment.

7**KNOWLEDGE AND UNDERSTANDING**

The knowledge and understanding of the subject demonstrated by this assignment was generally very good. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was very good. Your research and explanation was particularly good and extended your knowledge well beyond that contained in the course notes.

25

ANALYSIS



Your analysis of the task was generally satisfactory, both in class and as shown in this assignment. You have demonstrated some analytical skills and your approach to the task was logical. You carried out a short analysis and a short conclusion. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory.

12

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally very good. You used the resources available in MultiSim appropriately when designing the circuit and you used appropriate options for testing and evaluating the circuit performance. You managed to design an efficient circuit that functioned within the specification and achieved this by only asking for assistance when appropriate. Your results were comprehensive and allowed for a good conclusion to be attempted.

23

SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was generally good and contained most of the required detail, it was also written in a coherent and logical way. Try not to get too reliant on handwritten annexes though.

5