

PSDE4004 Assignment 1

by Jonathon Williams

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HNC Electrical & Electronic Engineering

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2017-2018

Analogue Circuit Design

Assignment No. 1

Jonathon Williams

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Jonathon Williams | Reliability Maintenance Engineering Apprentice | CWL1 Swansea

E: jnathon@amazon.com | P: +44 (0) 1792 481 736 |



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1. Introduction

This report will detail research, construct and develop analogue circuit design, more specifically, amplifiers and oscillators. It will cover the different types of amplifiers and oscillators with references to their frequencies and other characteristics, including biasing. This report will then go onto the design of a sine-wave oscillator and amplifier with DC conditions, feedback and bandwidth to meet a specification. The corresponding calculations will also be included.

The circuits will then be tested individually using Multisim and then joined together using a buffer amplifier in-between to stop the voltages transferring. This integrated circuit will also be simulated on Multisim. The circuit will be tested on Multisim and recommendation for improvements will be given.

2. Research into amplifiers and oscillators

Amplifiers

“Amplifiers are devices which take a relatively weak signal as an input and produce a much stronger signal as an output.” (BBC, 2014). Amplifier performance is related to its input and output and impedance. For a voltage amplifier, input impedance is high, then your output impedance is low. Current amplifiers is the other way round.

Amplifiers have different frequency ranges. Amplifiers that amplify in the KHz range are used for audio amplifiers whereas amplifiers that are used in the GHz range are used in radar, this shows that amplifiers have a range of application.

There are two main types of amplifiers, amplifier circuits and powered amplifiers. Amplifier circuits tend to use analogue components whereas powered amplifiers start to use digital components especially when they are in Bias's D to T.

Oscillators

Oscillators are amplifiers with positive feedback. Oscillators are used in circuits to provide the central 'clock' signal that controls the sequential operation of the entire system. (Electronics Tutorial, 2016)

There are different types of oscillators, with the main ones being RC, LC, crystal, magnetron and klystron. Depending the type of oscillator used, the frequency it oscillates varies with RC oscillators oscillate in the KHz range, where LC and crystals are in the MHz range compared to magnetron and klystron which oscillate in the GHz range. The cost for each oscillator will vary depending on your specification. From RS online, crystal oscillators can vary from a couple of pounds to hundreds of pounds.

There are different types of oscillators have different constructions. An LC oscillator is where a inductor and capacitor are used in parallel. Whereas a Crystal oscillator replaces the circuit with a crystal and uses its resonance from when the crystal is vibrating.

According to the Jim Stiles of the University of Kansas. Oscillators are not usually stable due to the fact that the positive feedback is fed through a resonator, and that there are no perfect resonators. (2007)

Active Devices

Both amplifier and oscillator circuits are made up using active devices. Bi-polar transistors are made up of two signal diodes that when together, form a P-N junction. The combination of these will then create PNP junctions or NPN junction, both have different uses. Figure 1 below shows the construction of these bi-polar transistors.

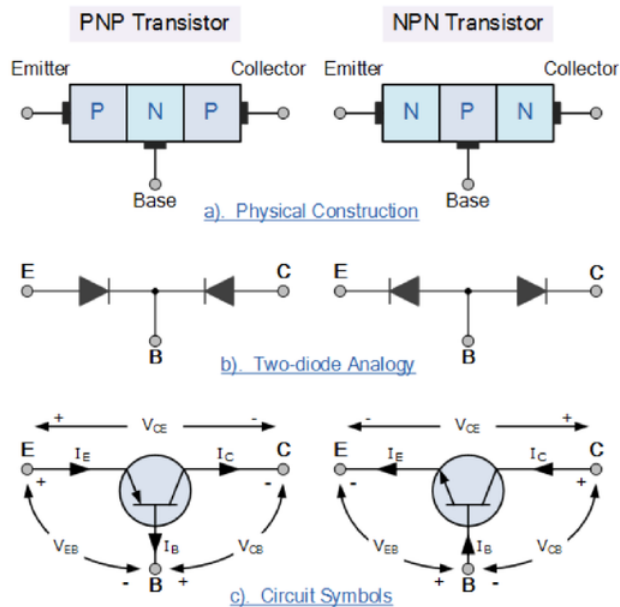


Figure 1: Bi-polar transistor construction

These transistors are then used in conjunction with resistors and capacitors in different configurations and value to create an amplifier circuit.

Valves or vacuum tubes are not that commonly used now as they tend to have been replaced with a transistor. Valves or a vacuum tube is where current between two electrodes takes place in a vacuum. A valve requires a high voltage for the anodes inside the valves and due to the heater needed to heat the tube, a lot of energy is lost.

However, valves are still used in audio amplifiers for guitars. This is due to them having a warmer sound so are the choice of most artists and audio engineers.

Class of bias

There are four main class of bias. Class A, B, AB, and C. These classes are defined by the length of their conduction state over a portion of the output waveform, such that the output stage transistor operation lies somewhere between being "fully-ON" and "fully-OFF". Figure 2 shows the wave form the bias's conduct over against their efficiency.

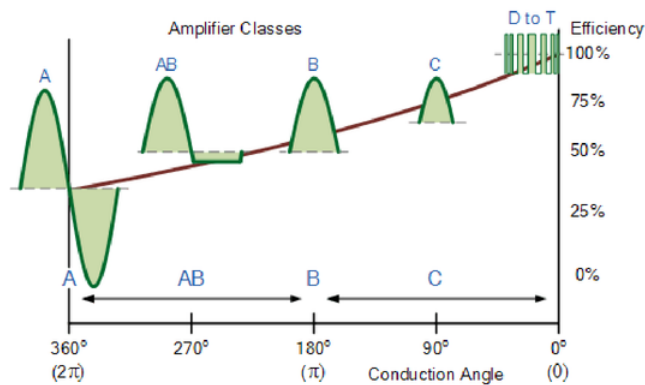
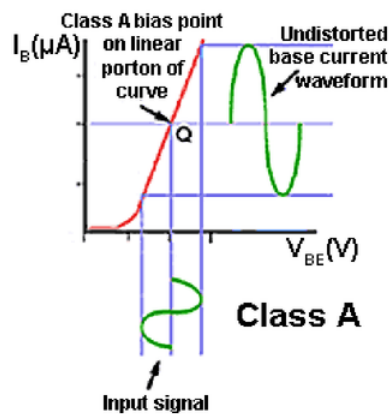


Figure 2: Bias waveforms

(Electronics Tutorial, 2016)

Class A Bias

Class A amplifiers are biased with a DC voltage across the base and emitter junction of the transistor used. Class A amplifiers conduct for the full cycle, as shown in Figure 3. Class A tend to have the least distortion which is why it is most commonly used. Class A tends to use the same single transistor, whether it be a bi-polar, FET, etc. Class A biasing is not very efficient as it only uses about 20% of its capacity, the rest is mainly dissipated as heat.



(Coates MA BSc. (Hons), 2017)

Figure 3: Class A Bias

Class B

Class B biasing will conduct only on the positive half of the cycle, as shown in Figure 4. Due to it having a quiescent current of zero, it is a lot more efficient than class A and in theory can have an efficiency of 50%. However, you do get more distortions.

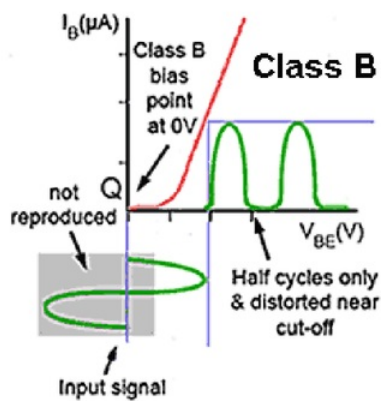


Figure 4: Class B bias

(Coates MA BSc. (Hons), 2017)

Class AB

Class AB bias, is a class which has low distortion and high efficiency as it eliminates the distortion you get from class B by using diodes or resistors in series shown in Figure 5.

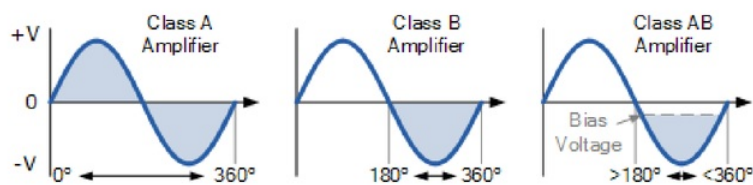


Figure 5: Class AB bias

Class C

In class c, there is only current flow through the output for less than 50% of the cycle, (as shown in Figure 6). This increases its efficiency dramatically, having efficiencies of around 75-80%. However, there is a lot of distortion.

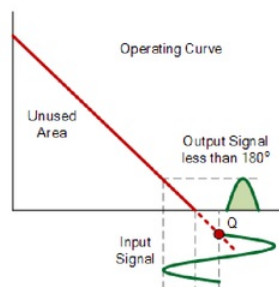


Figure 6: Class C Bias

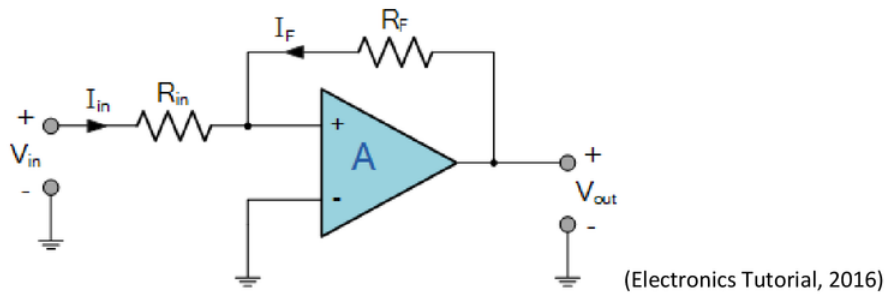
(Electronics Tutorial, 2016)

Feedback systems

There are two types of feedback used in amplifiers and oscillators. Positive and negative.

Positive Feedback

Positive feedback is used in oscillators. The condition for positive feedback is that a portion of the output is combined in phase with the input. (Nave, ND)



Negative Feedback

“Negative feedback is the technique of sampling some of the output of a device or system and applying it back to the input” (Coates MA BSc. (Hons), 2017). Negative feedback is achieved by sending part of the output and inverting it through the negative input of the amplifier as shown below in Figure 7.

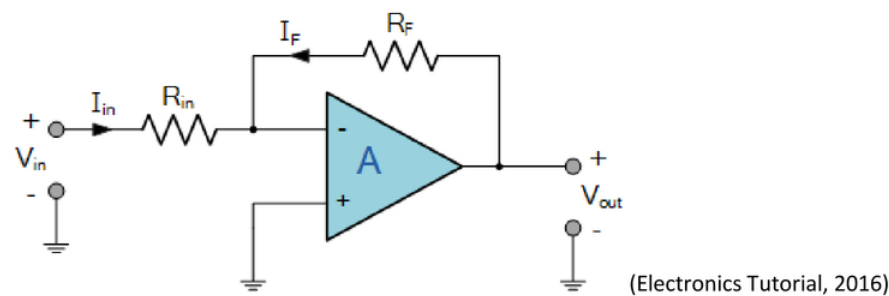


Figure 7: Negative Feedback

Storey says that the beneficial effects of negative feedback is that it can be used to increase or decrease the output resistance as well as increase the bandwidth of the amplifier. It is also used to control the gain. (Storey, 2017)

Positive and negative feedback can be configured in four different ways.

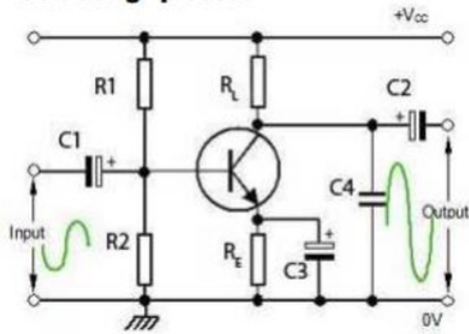
Series-Shunt Configuration – Voltage in and Voltage out.

Shunt-Shunt Configuration – Current in and Voltage out

Series-Series Configuration – Voltage in and Current out

Shunt-Series Configuration – Current in and Current out

3. Design method, choices and calculations



To design the amplifier, the following steps were undertaken:

Decide on the DC supply Voltage. I chose 10v DC.

Decide on a transistor. I decided to choose the BC548B Transistor.

The next step is to choose a quiescent current. I selected 1mA to be my quiescent current.

The next step is to calculate the value for the load resistor R_L . This can be calculated using the following equations:

$$R_L = \frac{1/2 V_{CC}}{I_q} \quad V_{CC} = 10V \therefore 1/2 V_{CC} = 5V$$

$$R_L = \frac{5}{1mA} = 5$$

The next step is to calculate R_E . This should be 10 – 15% of V_{CC}

R_E value

$$V_E = 10\% \text{ of } V_{CC} = 1V$$

$$R_E = \frac{V_E}{I_Q} = \frac{1V}{1mA} = 1K\Omega$$

The Next step is to estimate the value for I_B .

This is done by using the HFE value (taken between low and high HFE value on data sheet in appendix A), I_Q and I_B .

$$\begin{aligned} HFE &= \frac{I_Q}{I_B} \\ 100 &= \frac{1mA}{I_B} \\ I_B &= \frac{1mA}{100} = 10 \mu A. \end{aligned}$$

The next step is to calculate the base voltage (V_B). V_E should be 0.7 lower than V_B .

$$V_B = V_E + 0.7$$

$$V_B = 1 + 0.7$$

$$V_B = 1.7V$$

The next step is to calculate the DC network current for R_1 and R_2 (calculate I_{R1}). I_{R1} should be 10 times greater than the base current I_B .

$$I_{R1} = 10 \times I_B$$

$$I_{R1} = 10 \times 10$$

$$I_{R1} = 0.1\text{mA}$$

The next step is to then calculate R_1 . R_1 is the difference between V_{CC} and V_B divided by the network bias current I_{B1}

$$R_1 = \frac{V_{CC} - V_B}{I_{B1}}$$

$$R_1 = \frac{10 - 1.7}{0.1}$$

$$R_1 = 8.3\text{K}\Omega$$

After R_1 has been calculated you need to calculate R_2 by dividing V_B by I_{B1} .

$$R_2 = \frac{V_B}{I_{B1}}$$

$$R_2 = \frac{1.7\text{V}}{0.1\text{mA}}$$

$$R_2 = 1.7\text{k}\Omega$$

R_E is the resistor that configures the gain.

$$\text{Gain} = \frac{V_{\text{Out}}}{V_{\text{In}}}$$

$$\text{Gain} = \frac{8.39}{99.8 \times 10^{-3}}$$

$$\text{Gain} = 84.068 \text{ dB}$$

This can be tuned by splitting R_E into R_{E1} & R_{E2} .

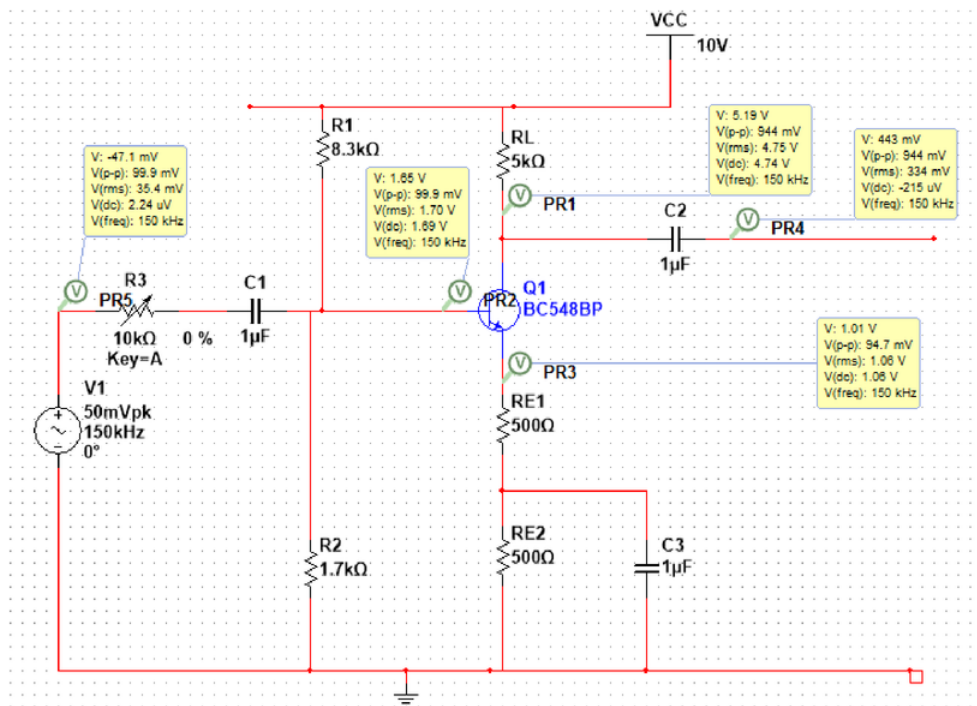


Figure 8

After adding R_E , V_{out} (p-p) dropped to 994mV, (Figure 8)

$$\text{Gain} = \frac{V_{Out}}{V_{In}}$$

$$= \frac{994mV}{99.9mV}$$

$$= 9.949 \text{ dB}$$

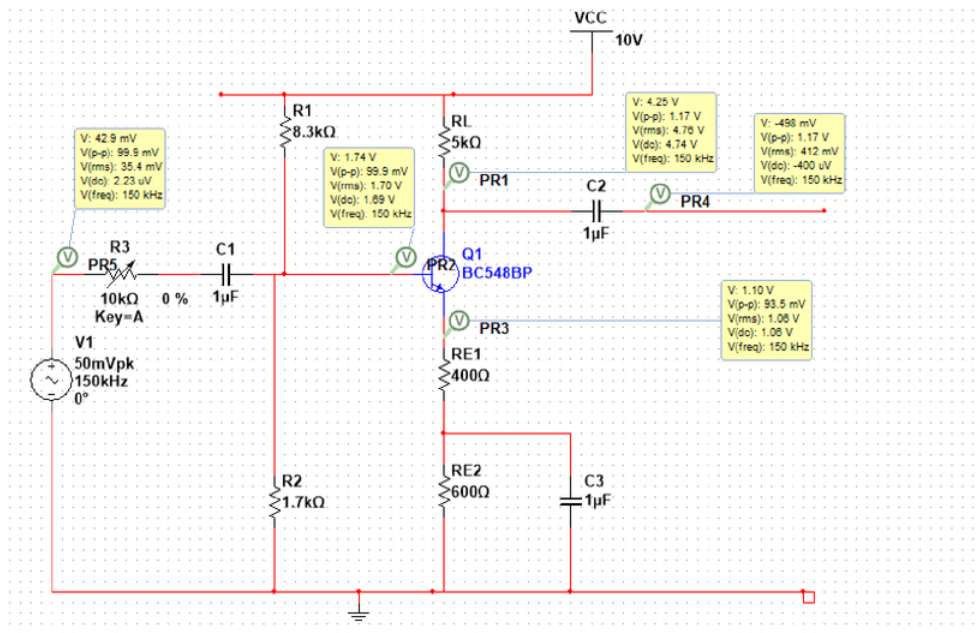


Figure 9

$$\text{Gain} = \frac{V_{\text{Out}}}{V_{\text{In}}}$$

$$= \frac{1.17V}{99.9mV}$$

$$= 11.7 \text{ dB}$$

By keep changing the ration of R_{E1} & R_{E2} , until you reach the gain required as detailed in specification.
(Figure 9)

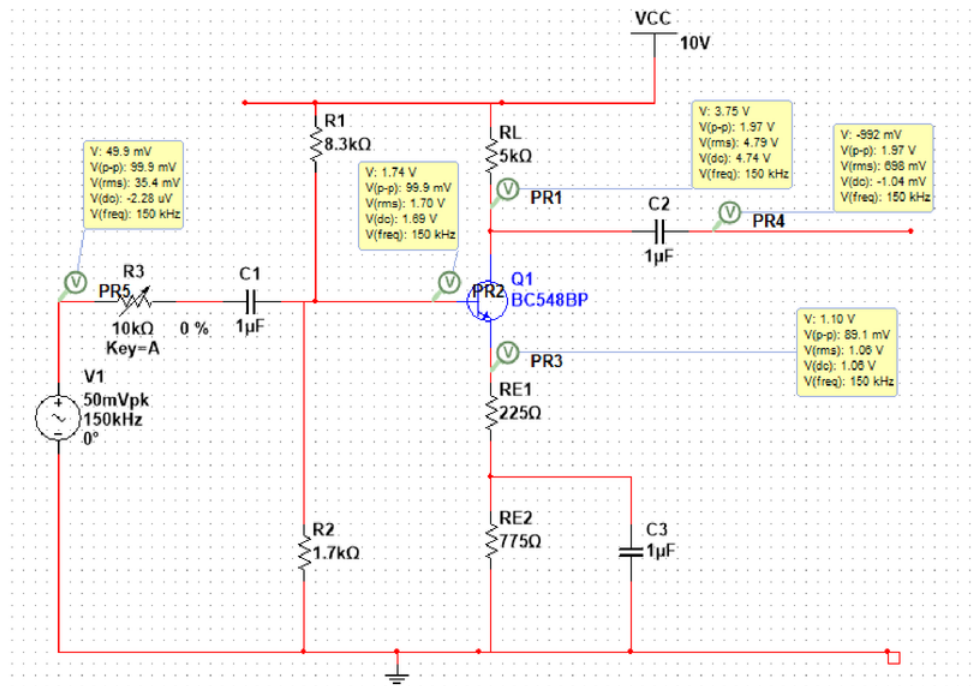


Figure 10

$R_{E1} = 225$, $R_{E2} = 775$, (Figure 10)

$$\text{Gain} = \frac{V_{\text{Out}}}{V_{\text{In}}}$$

$$= \frac{1.97V}{99.9mV}$$

$$= 19.7 \text{ dB}$$

were adjusted until the correct outputs were achieved. Below shows the finished oscillator circuit and its resultant trace from an oscilloscope. (Figure 12 and Figure 13 respectively)

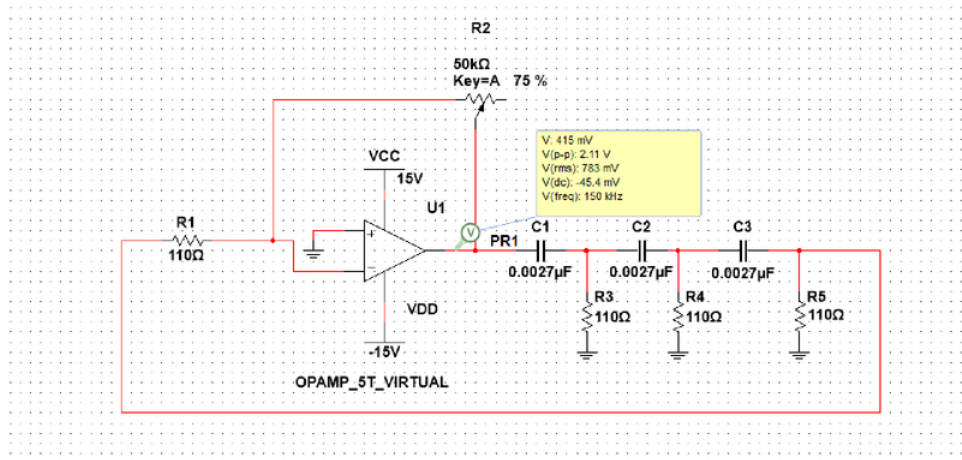


Figure 12

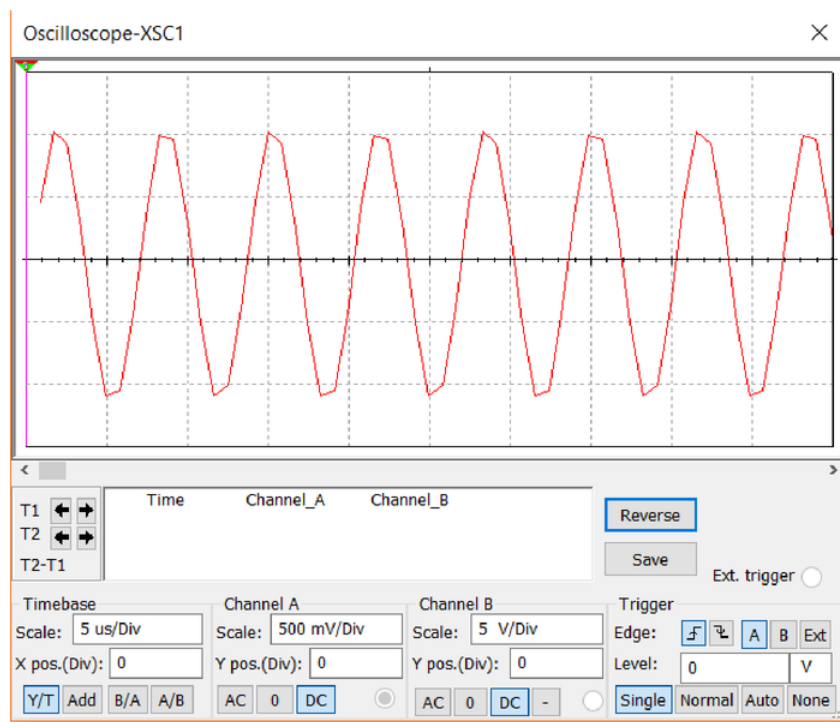


Figure 13

The trace shows that it is not a perfect sine wave. To achieve this you would need to change the resistors and capacitors with accurate values and components must have tight tolerances.

To join these circuits together, you needed to use a buffer amplifier. A buffer amplifier is used to stop voltages transferring. You can use a 741 op amp to create this. Figure 14 shows the buffer amplifier.

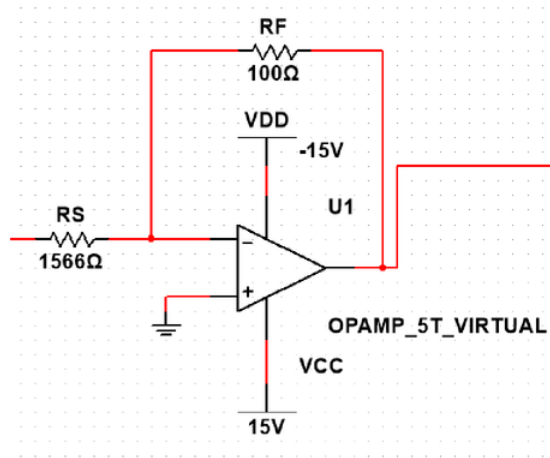


Figure 14: buffer amplifier

To calculate the value of R_F and R_S , you need to divide the required input for the amplifier by the output of the oscilloscope.

$$\text{Output of oscilloscope} = 783\text{mV}, \frac{\text{output}}{\text{input}} = \frac{50\text{mV}}{783\text{mV}} = \frac{1}{15.6}$$

$$R_S = 15.6 \times 100 = 1556\Omega$$

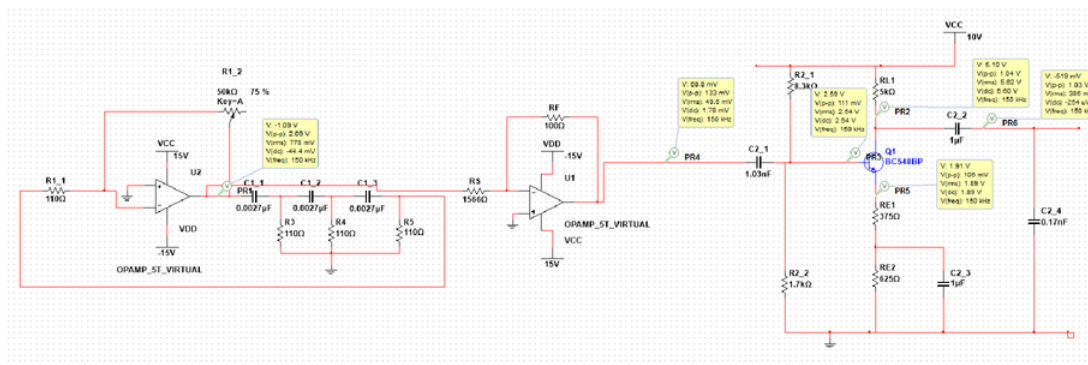
$$\text{Gain} = \frac{50}{15.6} = \frac{1}{15.6}$$

$$\therefore \frac{1}{15.6} = \frac{R_F}{R_S}$$

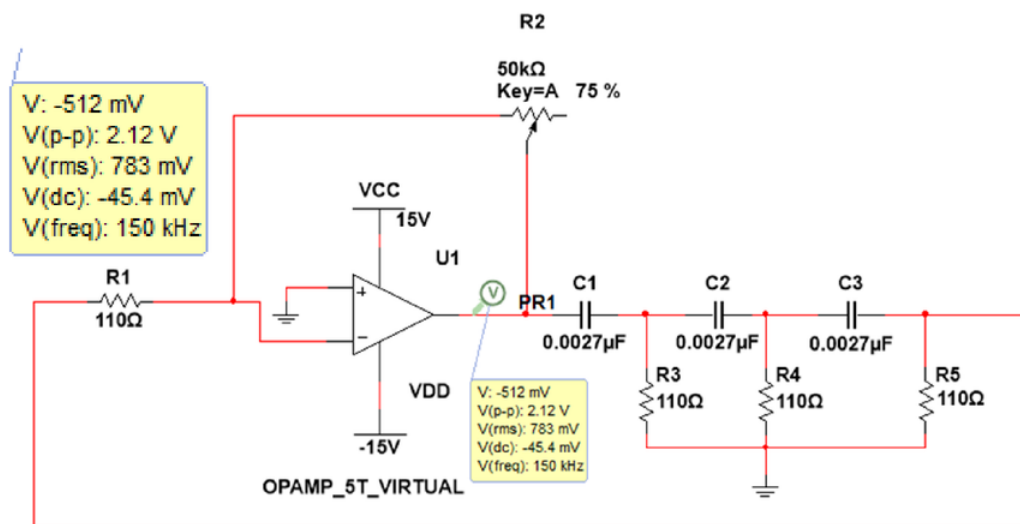
$$\therefore R_S = 15 \times R_F$$

$$R_S = 1556\Omega \text{ if } R_F 100 = \Omega$$

Figure 15 shows the circuits joined together.



4. Test and improving the design



As displayed in Figure 16 the oscillator circuit is producing a frequency f 150 KHz which is matching the specification give. However, it is only giving a output of 783 mV (rms) whereas the specification asked for 1V (rms). To achieve this, you would need to fine tune by altering the values of $C_1 - C_3$ and $R_3 - R_5$. However, this discrepancy can be compensated by the buffer amplifier.

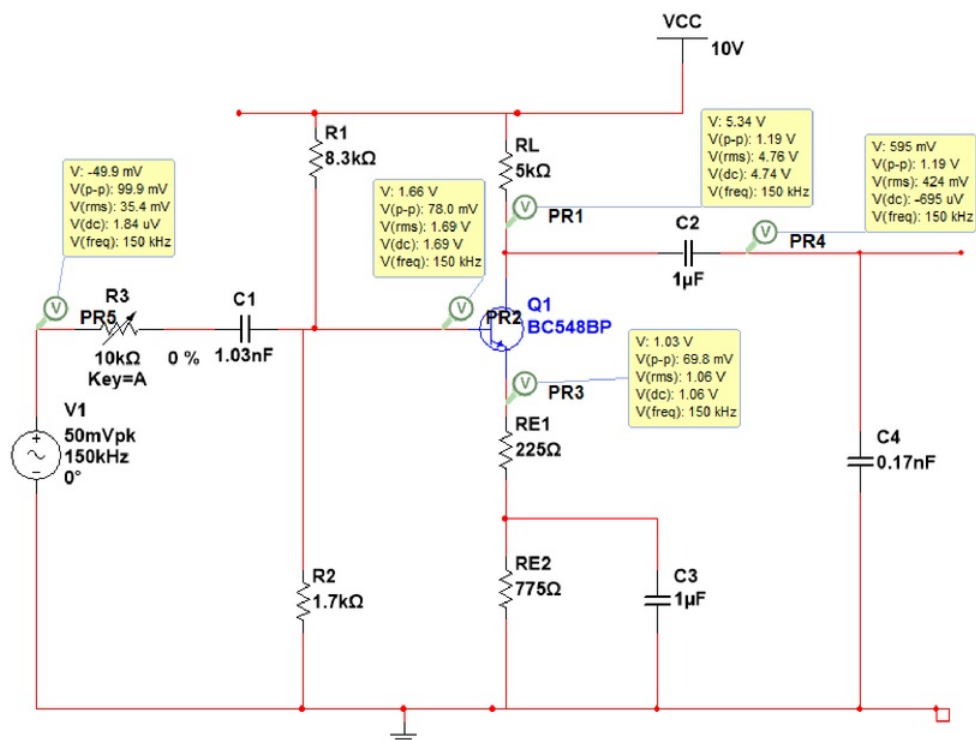


Figure 17

As shown in PR5 and PR4, the voltage has increased by the gain of 20 which matches specification. However, before the specification was met, the ratio of the components needed to be altered.

When the final circuit is constructed, you can tell if the specification has been met by comparing the input and outputs.

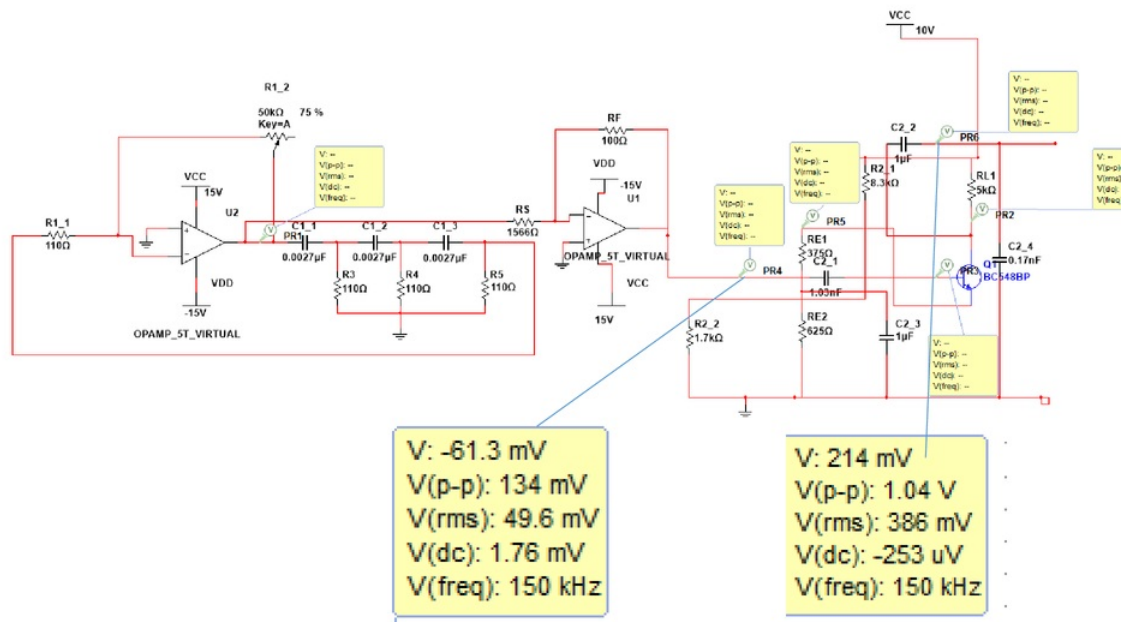


Figure 18

Figure 18 shows the final circuit with the probe readings PR4 and PR6. PR4 shows the output signal voltages.

As show, V (rms) has increased by a gain of twenty. The bandwidth can be checked by doing an AC sweep. When the cursors are positioned correctly, there is 80KHz between the cursors. (Figure 19)

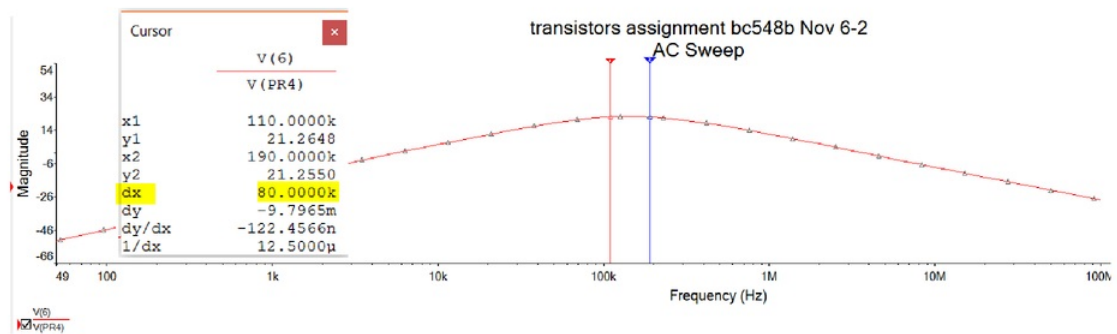


Figure 19

5. Conclusion

The circuit that was made up of a Sine wave oscillator and two amplifier. The oscillator was almost made to specification but the frequency was out ever so slightly, but backed up by the research this is because there are no perfect resonators, there for to get the output spot on, you would need to fine tune the values of the components which would need to be precision with tight tolerances. This was compensated by use of the buffer amplifier and increased the input circuit to 150 KHz. As I was able to build all the circuits and get them working, I managed to stop amplifiers from oscillating while trying to get oscillators to oscillate which is one of the biggest problems that occur.

The amplifier was built to specification, with having a gain of 20, bandwidth of 80KHZ and centre frequency of 150 KHz. This was tested on Multisim to prove its correct operation. Again, if you wanted to get really accurate results, you would need to use precision components compared to the general use components.

6. Works Cited

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6. Annexe

Appendix A

Data sheet for transistor

Common parameters

Thermal resistance junction:	200.00	°C/W
Thermal resistance case:	83.30	°C/W
Power dissipation:	1.50	W
Derating knee point:	25.00	°C
Minimum operating temperature:	-55.00	°C
Maximum operating temperature:	150.00	°C
ESD rating:	0.00	

Device specific parameters

Label	Value	
Vceo	30	
Vcbo	30	
Ic(max)	0.1	
hFE(min)	90	
hFE(max)	150	
Ft	150	
Pd	1.5	
Package	TO-92	

PSDE4004 Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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JONATHON WILLIAMS

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RESEARCH-INFORMED LITERATURE



There was evidence of further reading and research and appropriate in text referencing. Your interpretation and understanding of the additional research was good. Your references were appropriate to the task, but the reference list was very short and limited to a small range of sources.

5

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was generally satisfactory. However the report lacked a lot of the required detail and there were many gaps in your knowledge of the basic principles. Additionally, your understanding of the higher level concepts was not shown. Further work - There were a few omissions and misunderstandings throughout the task, which could be read up on for future reference. Explanations need to be written in much more detail and written in a more logical and clearer way.

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ANALYSIS



Your analysis of the task was brief and lacked a lot of the required detail. You have demonstrated

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reasonable analytical skills and your approach to the task was logical. You carried out a reasonable evaluation of the results, but the conclusions were very brief.

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task were generally OK, you used the resources appropriately when carrying out the experiment and you used appropriate options for testing and evaluating the circuit performance - albeit to a limited fashion. Testing generally lacked a lot of the required detail however and you should have included a comprehensive set of results for each stage.

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SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was of an appropriate length, you could however be more efficient with your word count. The report was well presented, with good diagrams in appropriate places, good sentence/paragraph structure and clear calculations.

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