

2017198

by Ryan James

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65-70

- ① RESEARCH + REFERENCE LIST WERE OK, COULD DO WITH SOME RESEARCHED DIAGRAMS THOUGH.
- ② DESIGN METHOD HAD SOME CALCULATION ERRORS.
- ③ READING THE DESIGN WASN'T EXPLAINED CLEARLY AND OMITTED A LOT OF DETAIL.
- ④ TESTING WAS OK.
- ⑤ CONCLUSIONS WERE MAINLY A CRITICISM OF MULTISIM.

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PAST TENSE

1. Executive Summary

The assignment below will be about an analogue circuit design. It will require a class A amplifier and a Colpitts oscillator in order to complete the required tasks. Research will be undertaken into the different classes of amplifiers and also oscillators before making a comparison with the built analogue circuit.

Appropriate calculations will be required to achieve the values for the amplifier circuit and also a computer software program called multisim to actually build the program on. The amplifier must contain both DC and AC components in order to be built and must show testing results in comparison to the worked calculations using appropriate equations.

Once the Colpitts oscillator and amplifier are built and tested separately they must be combined and tested in order to meet the required specification. Appropriate and accurate conclusions with possible recommendations are to be drawn from this in comparison to results and theory-based knowledge.

The required specification for that is to be achieved is as follows:

- Centre frequency 200kHz
- Bandwidth 60kHz
- Gain 50
- Input signal 50v (pk-pk)

2. Research into amplifier design techniques

An amplifier is an electrical device which uses an input signal to control a power source, which as a result an output signal is produced. Amplifiers are classified by what is known as a Duty Cycle. The Duty Cycle of amplifiers classifies the amplifiers into the following types: Class A, Class AB, Class B, and Class C.

Class A

These amplifiers are thought to be the most common type of amplifiers as they are designed to only use one transistor within their circuit. As a result of only having one transistor within its circuit it is considered to be biased. This means that it has a low distortion level, so it is able to conduct high levels of current over one full 360° output cycle.

As it is considered to be biased it is able to be kept on all the time which does come with a disadvantage. The disadvantage is its energy efficiency level, as it is extremely poor. It is thought to have an efficiency level of around 30%, which makes it an unviable piece of equipment which would use a high-power application. Therefore, an ideal source or use for this type of amplifier due to the disadvantage stated above would be for use in loudspeakers.

(ET, 2020)

Since the Class A amplifier is considered to be biased its current, also known as the collector current will operate even when there is no signal present. This means that the current will flow throughout one full cycle where conduction will take place, and at no point during this cycle should the transistor within the circuit be saturated. To prevent this from happening a small current value will flow in the base of the transistor.

(Bird, 2017)

Class B

A class B amplifier is slightly different to the Class A amplifier as the transistor only conducts for half of the input signal which is 180°. Therefore, the power efficiency is improved as the amplifier is off for half the time of the Class A amplifier as there is less power.

However due to the amplifier only conducting half the input signal, there is a limitation in which distortion now takes place. To rectify this Class B amplifiers, have two transistors within their circuit, a P-N-P transistor, and a N-P-N transistor, or also known as a BJT transistor.

(CT, 2020)

A BJT transistor is made up of two transistors P-N-P and N-P-N. The N-P-N transistor consists of two semiconductor materials and is separated by a much finer semiconductor material. Within this transistor the majority carriers are the electrons, and they flow from the emitter to the collector to generate the current flow, resulting in it being biased. It is mostly used for switching or amplifying signals. However, the P-N-P transistor is reversed biased meaning that the holes are the majority carriers, and the electrons are the minority carriers, making it ideal for controlling the current.

(EH, 2020)

Class AB

GRAPHS WOULD
HAVE HELPED ILLUSTRATE
THIS.

The Class AB amplifier is a combination of both Class A and Class B amplifiers. The purpose of combining both of these amplifiers is to eliminate the disadvantages they both have being distortion from Class B and power efficiency from Class A. Due to the combination of these two amplifiers, it has made this type, the most selected type of amplifier used for audio equipment like radios because of its excellent energy efficiency and the quality of the output, due to the lowering of distortion.

This type of amplifier works similarly to the Class B amplifier, in that it combines 2 transistors together. By having this within the circuit each transistor conducts its different cycles at different parts within the same circuit before combining at the output, which can also be known as pre-biasing. This allows the distortion value to fall of Class B but also improve the energy efficiency of Class A. As a result of this the conduction angles are within the region of 180° and 360° cycles.

There are different methods in which biasing can happen for this type of amplifier. The different biasing methods are as follows, the voltage across both transistors in order to balance the voltage difference, thus improving the load current.

Another method is by biasing the resistors. If the resistors within the circuit are put in series, when a voltage drop occurs across them, a voltage divider can be created. This allows the voltage across the transistors to be controlled and again improving the load current.

A final method is by using diodes. If a pair of diodes are put in a circuit then this will produce voltages of the same value. By controlling this a voltage of 0.7v can be applied which then results in the transistors switching.

(ET, 2020)

Class C

The Class C amplifier is a much more efficient amplifier than those above because it conducts at an angle less than 180° , typically within the region of 80° to 120° . As a result of this its efficiency level can be given at around 90%, however, it does suffer heavily with distortion.

Furthermore, with this type of amplifier, because of the high distortion levels it is unable to be used as an audio amplifier like the other classes, but it can be used with oscillators of a certain wave frequency and also in some radio frequency amplifiers.

(EPC, 2020)

Oscillators

An oscillator is a device that converts a D.C power supply into and A.C supply to produce different types of sine waveforms. These waveforms are commonly used for devices such as digital clocks, radios, TV and in computers for gaming.

An example of an oscillator in use is the Colpitts Oscillator. This type of oscillator is considered to be active and is built up of both capacitors and inductors. As the device is active it is also considered to provide positive feedback; this means that the output signal is in phase with the input signal. It usually operates between the frequencies of 10KHz and 300MHz.

It does this by the use of devices like a BJT, FET and Op-Amps. Within a circuit the inductor is parallel to the two capacitors, which when a voltage is applied to the circuit it becomes induced. This induced voltage that goes across a capacitor will be applied to a transistor like the BJT and create the feedback for the oscillator.

(ELP, 2020)

Another type of oscillator is the Armstrong Oscillator. This type of oscillator works similar to the Colpitts but one of the differences is that it has an additional coil and it usually oscillates around 1MHz. When the current flows through the coil a voltage drop occurs through the resistor giving negative feedback for one full cycle of oscillation. Negative feedback is when the output is fed back to the input to reduce fluctuations in the oscillation. It is when the inductor and capacitor work together to induce the voltage, does the feedback of oscillation become positive again.

(EPC, 2020)

DIAGRAMS WOULD REALLY HELP
IN YOUR RESEARCH.

3. Design method, choices, and calculations

For this section of the assignment there was a requirement to build a class A voltage amplifier that had to achieve the following specifications: Centre frequency 200kHz, Bandwidth 60kHz, a Gain of 50 and finally an input signal of 50mV pk.

Before starting the design of an amplifier there are steps that need to be taken, for example a datasheet will be needed in order to find the circuit conditions and also appropriate calculations for the biasing of components will need to be undertaken. The transistor that is being used is 2N3904.

(Semiconductor Components Industries LLC, 2019)

The first stage is to choose the supply voltage (V_{CC}), this is done by using the datasheet and finding the V_{CE0} . Once that is found decide on a value that is less than its maximum (see figure 11).

$$V_{CC} = 30V$$

Next is to find a quiescent collector current, which is the current when there is no signal generated. This is done by finding the maximum collector current and choosing a value less than that (see figure 12).

$$10\% \text{ of } I_C \quad I_C = 200mA$$

$$10\% \text{ of } 200mA = 0.02A$$

$$\therefore I_Q = 2mA$$

A large current would cause a power wastage so it must be kept low in order to prevent this hence the deduction of 10%.

The next stage would be to estimate a base current, with use of the HFE value. As the HFE value is depends on the collector current it can be calculated as a value between the lowest available value and the largest as indicated in figure 13.

$$I_B = \frac{I_Q}{HFE} = \frac{2mA}{200} = 10 \times 10^{-6} = 10\mu A$$

The value of the load resistor can be calculated by use of the following formulas.

$$R_L = \frac{V_C}{I_Q}$$

$$V_C = \frac{1}{2} \text{ of } V_{CC} \quad V_C = \frac{1}{2} \text{ of } 30V = 15V$$

$$R_L = \frac{15V}{2mA} = 7.5K\Omega$$

Next step is to calculate the emitter resistance by use of the following formulas.

$$R_E = \frac{V_B}{I_q} \quad \frac{V_E}{I_q}$$

$$V_B = V_E + 0.7V$$

$$V_E = 10\% \text{ of } V_{CC} \quad V_E = 10\% \text{ of } 30V = 3V$$

$$V_B = 3V + 0.7V = 3.7V$$

$$R_E = \frac{3.7V}{2mA} = 1850\Omega \quad 1.5k\Omega$$

Finally, the resistors R1 and R2 can be calculated as we have already worked out the necessary values for the equations (see figure 1).

$$I_{R1} = I_Q + I_B \\ = 100\mu A$$

$$R1 = \frac{V_{CC} - V_B}{I_{R1}} = \frac{30V - 3.7V}{2mA} = 13150\Omega$$

$$R2 = \frac{V_B}{I_R} = \frac{3.7V}{2mA} = 1850\Omega$$

Adding the AC components to the amplifier was the next stage of the designing. In order to do this a capacitance value for C1, C2 and C3 was needed and also a calculation for the gain, see figures 2 and 14 for the amplifier.

$$C = \frac{1}{2\pi F X_C} = \frac{1}{2 \times \pi \times 200kHz \times 1} = 795.77nF$$

$$Gain = \frac{V_{out}}{V_{in}} = \frac{26.8V}{141mV} = 190.07$$

The purpose of adding capacitors into the amplifier is to prevent the DC voltages by allowing the AC side of the circuit to act as a coupling capacitor (C1 and C2). The capacitor C3 is present to stop as much current as possible across the emitter resistor as this would affect the amplifiers gain.

The next stage of building the amplifier was to calculate the input and output impedance values (Zin & Zout). By doing this a calculation for new values of C1 and C4 could be calculated. This was needed in order to achieve a bandwidth of 200kHz (see figures 3 and 4).

The input impedance value was calculated by adding a variable resistor to the circuit. At 1kΩ 0% the voltage out was 26.8v and for the Zin value to be calculated the emitter resistance voltage had to be halved so at 3kΩ 88%, the voltage was halved to 13.4V.

$$Z_{in} = 88\% \text{ of } 3k\Omega = 2640\Omega$$

DIAGRAM TO EXPLAIN THIS?

$$C1 = \frac{1}{2\pi \times FL \times Z_{in}} = \frac{1}{2 \times \pi \times 170kHz \times 2640\Omega} = 354.623pF$$

$$C4 = \frac{1}{2\pi \times FH \times Z_{out}} = \frac{1}{2 \times \pi \times 230kHz \times 7.5k\Omega} = 92.263pF$$

As the bandwidth of 200kHz is now achieved the gain can be calculated by splitting the resistor across C3. By doing this it introduces negative feedback which as a result reduces the distortion levels. The resistor can be seen to be split in figure 5.

$$\text{Gain of } 50 = \frac{V_{out}}{V_{in}} = \frac{5.01V}{99.5mV} = 50.35$$

Due to achieving the required gain of 50, it affects the bandwidth and vice versa. In order to achieve and gain of 50, centre frequency of 200kHz and a bandwidth of 60kHz the bandwidth needed refining. In order to do this C1 and C4 needed adjustment as shown in figure 6. This enabled a gain of 49.3 to be achieved and also a centre frequency of 200kHz shown in figure 7. However, the closest bandwidth achievable was 533kHz due to the design of the amplifier as shown in figure 8.

$$\text{Refined gain} = \frac{V_{out}}{V_{in}} = \frac{4.91V}{99.6mV} = 49.3$$

After the amplifier was designed the next task required was to build a Colpitts Oscillator and add it to the amplifier circuit (see figure 16). The sign wave oscillator had to achieve 100mV (p-p) and also be able to work at 200kHz (see figure 8).

The next stage after designing the oscillator was to combine it with the amplifier. This meant that the amplifiers signal generator had to be removed in order for the Colpitts oscillator to be the input signal. Figure 15 shows the circuits combined, however in order to prove the gain and also the sinusoidal waveforms an oscillator had to be connected to the amplifier as opposed to using the AC sweep like the other graphs in the assignment.

$$\text{Combined Gain} = \frac{V_{out}}{V_{in}} = \frac{4.75V}{100mV} = 47.5$$

3 BIG STEPS WITH VERT LITTLE EXPLANATION.

4. Testing, results, and analysis

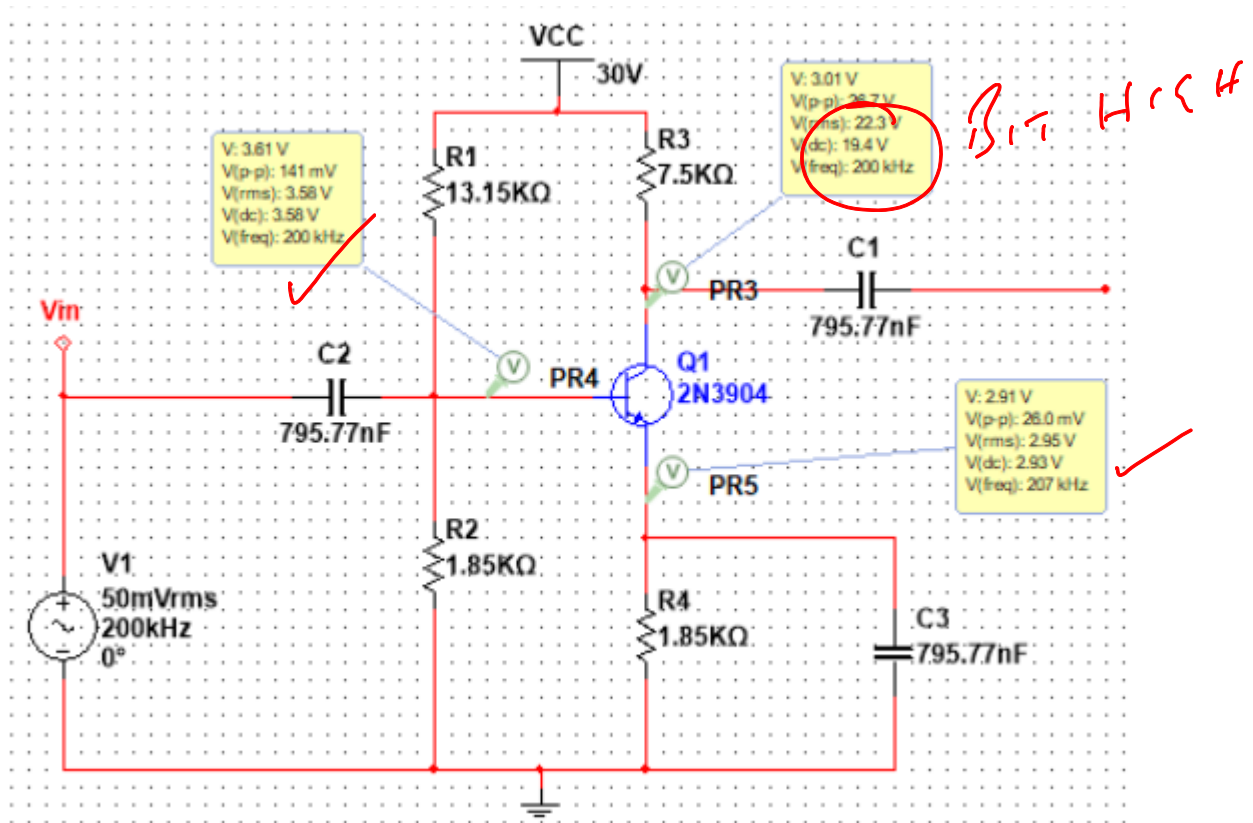


FIGURE 1: TESTING OF VOLTAGE ON BASE, COLLECTOR AND EMITTER.

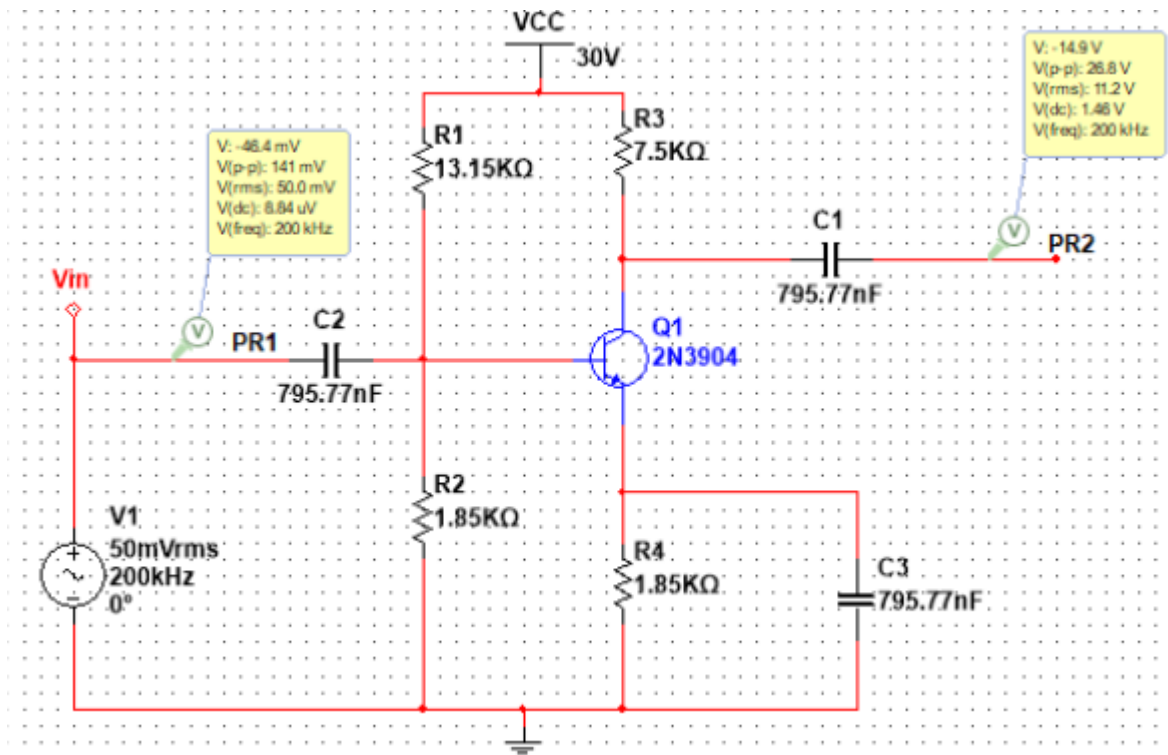


FIGURE 2: TESTING OF GAIN

NOT ENTIRELY SURE HOW THIS WORKED
AS YOUR CALCULATIONS WERE WRONG.

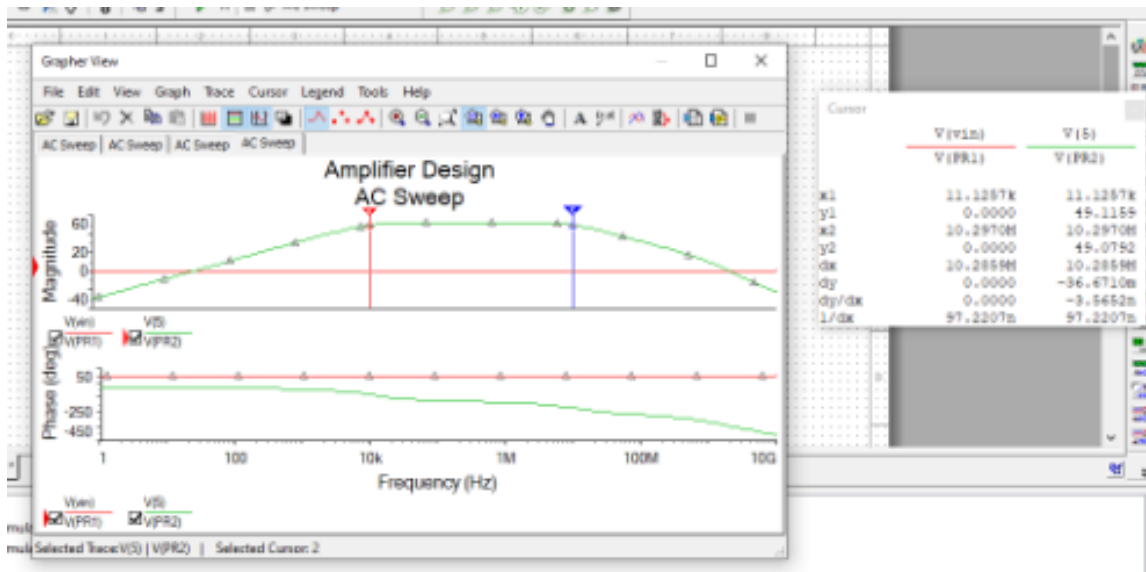


FIGURE 3: TESTING THE BANDWIDTH OF THE AMPLIFIER

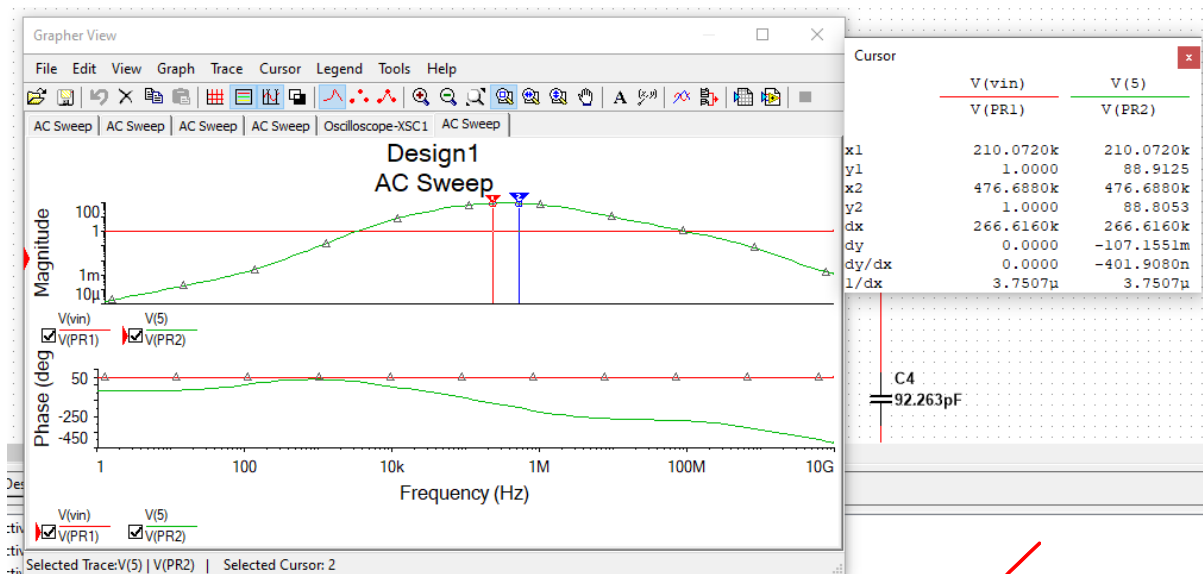


FIGURE 4: BANDWIDTH AFTER C1 AND C4 RECALCULATION

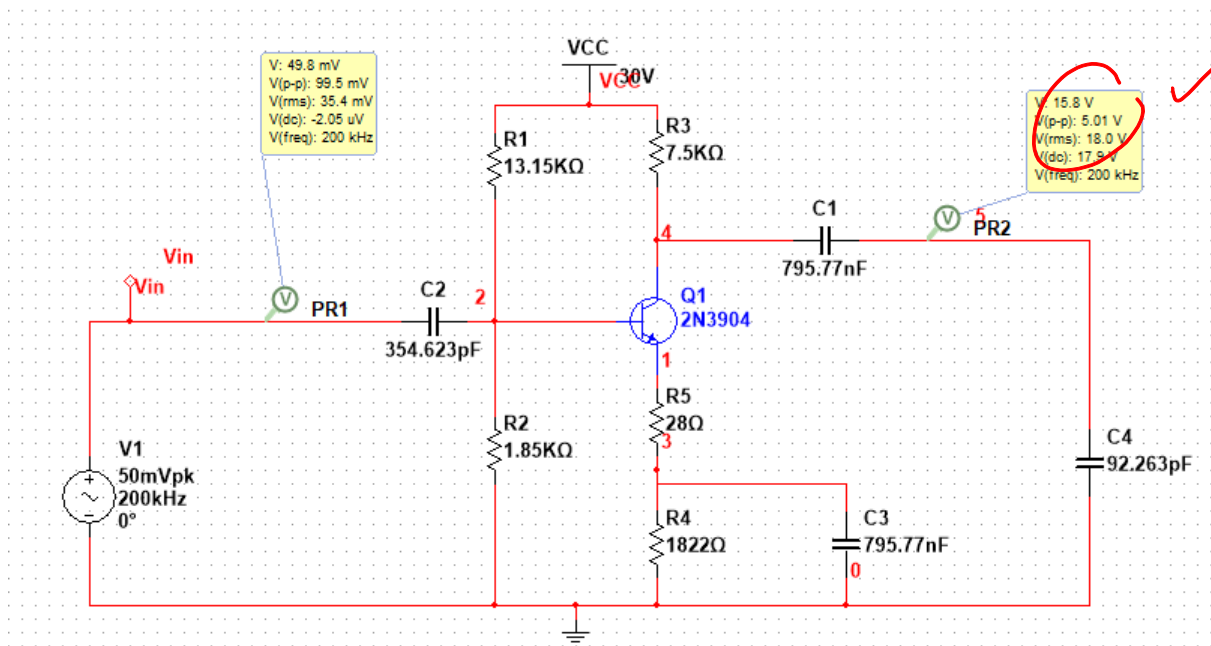


FIGURE 5: ACHIEVING GAIN OF 50

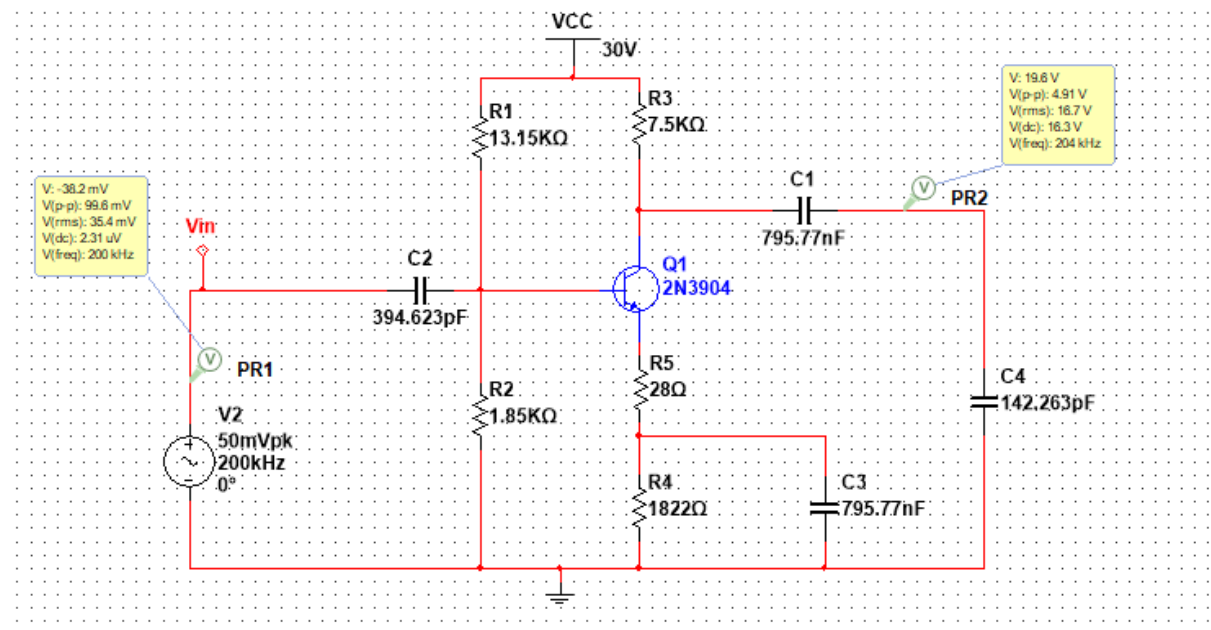


FIGURE 6: ADJUSTED C1 AND C4 VALUES

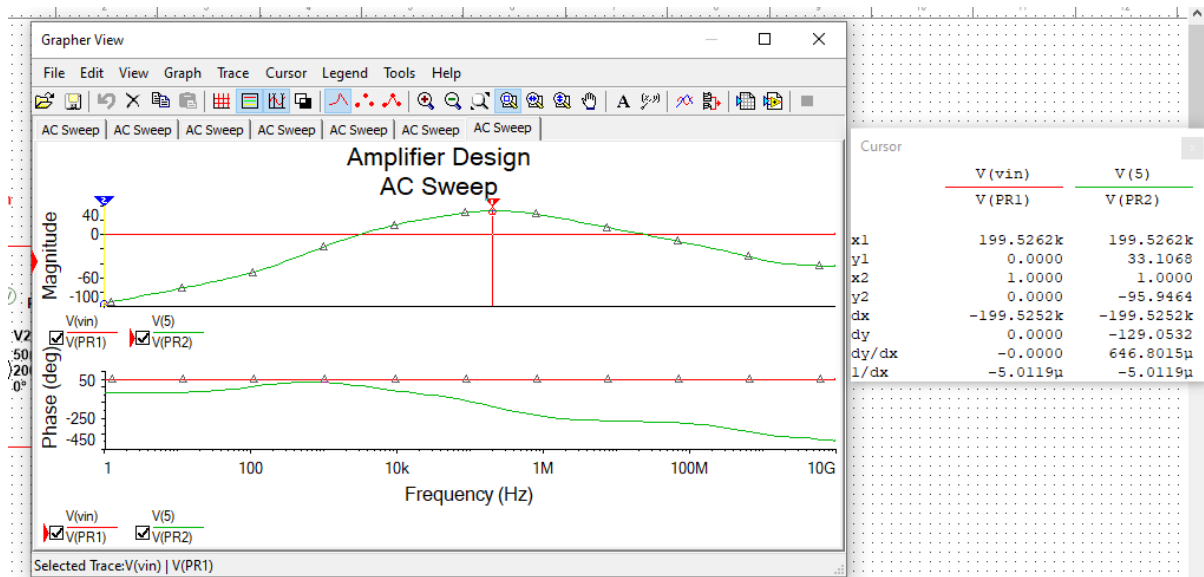


FIGURE 7: CENTRE FREQUENCY

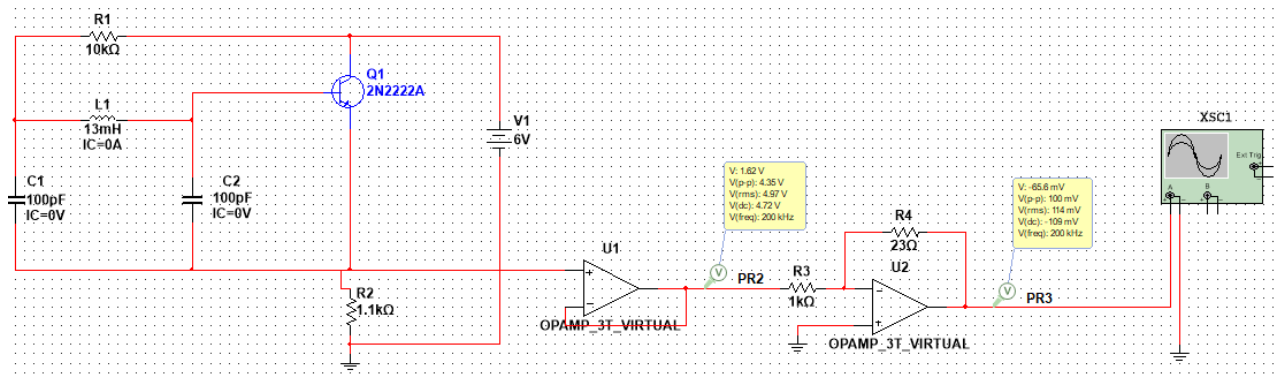


FIGURE 8: COLPITTS OSCILLATOR WITH TESTING

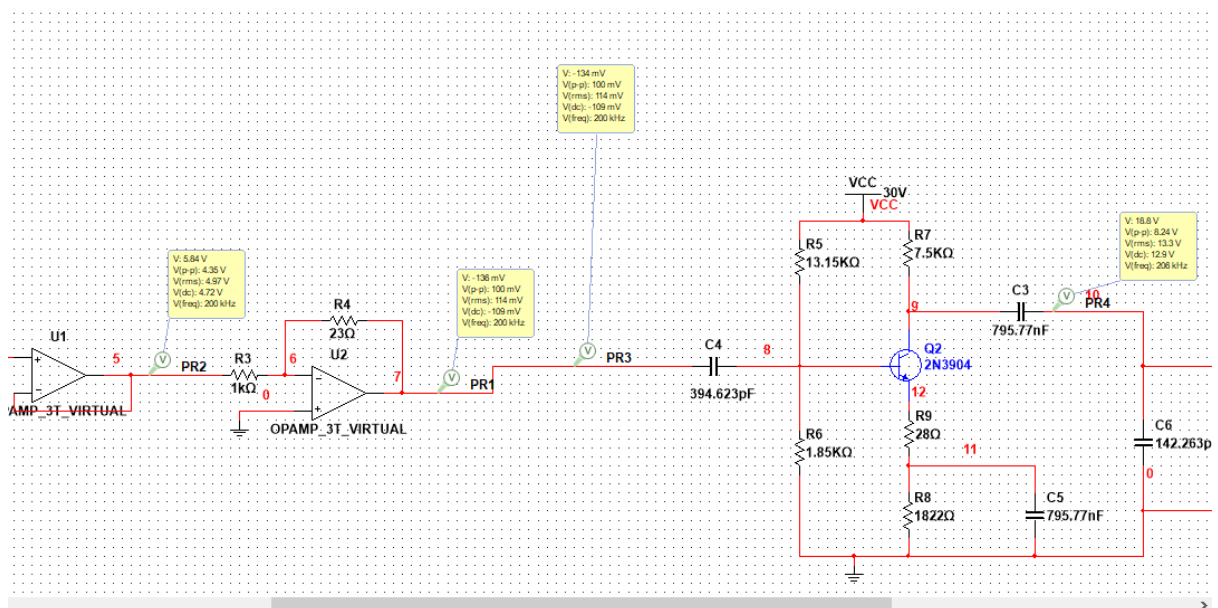


FIGURE 9: COLPITTS OSCILLATOR AND AMPLIFIER TESTING

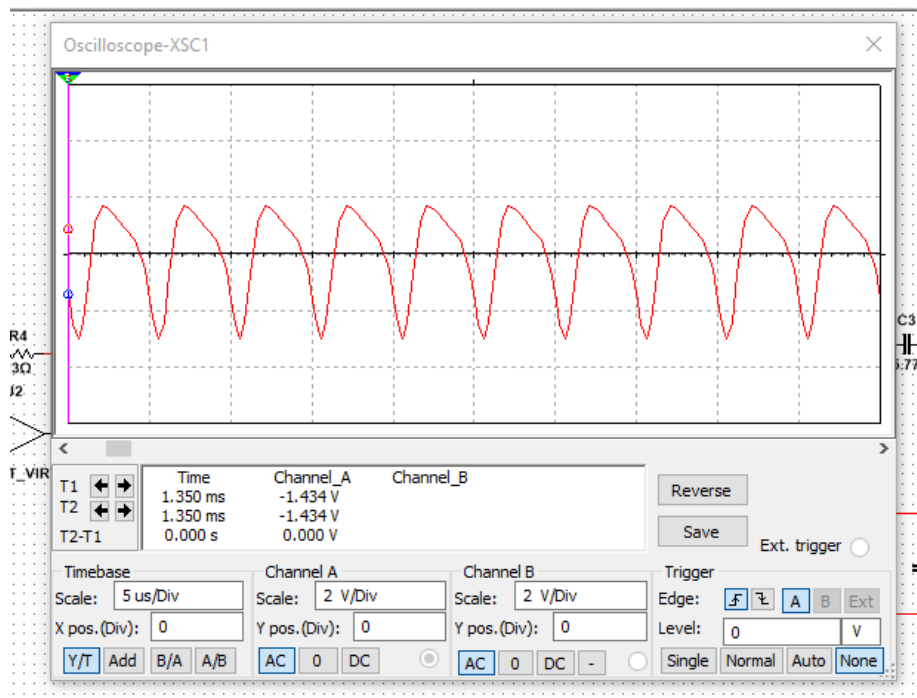


FIGURE 10: OSCILLATOR GRAPH OF COMBINED CIRCUITS

The results obtained throughout the assignment in comparison to what the calculations are worked out at are relatively accurate however, rounding issues and the actual accuracy of the multisim software could be the reasoning for minor discrepancies.

In order to get the figure for bandwidth there is a feature on multisim called AC sweep which allows this. On the interactive menu there is an option of AC sweep and once selected with the variables that are required to be measured (VPR2) select run and it will create a graph as shown in figure 3 and 4. Using the cursors select R1 and right click it to select “Ymax value” then right click it again after its moved to the centre and select “y-value”. From that take off -3db and repeat for the second cursor. The value given by dx is the bandwidth value.

It is possible to make some comparisons with the amplifier and the oscillator with the research given at the start. A comparison that can be made is shown in figure 10, with the distortion level as stated above in the research it is thought that class A amplifiers have “a low distortion level”. This is shown as the waveform produced is not as clean of a waveform which indicates distortion is present.

Another comparison between results and theory is the use of the Colpitts oscillator that was created as the signal source in the combined circuit. The oscillator is working at 200kHz which is between the values stated in the research and also the way it works is identical to the research in that it uses op-amps to control the frequencies and also indicates induced voltage on the oscillator as shown in figure 10. The op-amps induce the voltage by not allowing the impedance produced by the amplifier affect the readings of the output impedance from the oscillator.

5. Conclusions and recommendations

From building the circuits on multisim it is possible to say that due to the values chosen it would be highly unlikely that the required bandwidth as stated in the specification could be achieved. This is because of the transistor selected had to be on the multisim software which was why the 2N3904 was chosen as there are limited options. If the multisim software was capable of storing more transistors, then it is possible that all the values including the bandwidth could be accurately shown.

As already stated, there are some inaccuracies which could be down to the type of equipment used. For example, when the calculations were done there could be a slight human error in the rounding of figures or not being as accurate as possible by giving calculated values to 3dp. Whereas, with the multisim values calculated they will never suffer with this as they are generated by a computer software.

Another factor to consider could be that multisim will not face any sort of real-life problems like a practical task would as again it is a computer software program which its values will always be accurate and do what they are set to as they do not have a tolerance like a real component would.

A possible recommendation that would further improve the accuracies and provide evidence as to how this amplifier works is by building a practical circuit with real life components. This would further the evidence and produce a better comparison of results to look at. However, it will bring some minor issues like not knowing the real values of the resistors as they all will have a different tolerance.

Another possible recommendation could be to improve the accuracy of calculated results, make all working to 3dp as this will be more alike to the generated values of the multisim software program.

IT IS UNLIKELY MULTISIM WAS THE
CAUSE OF ANY ERRORS.

6. Works Cited

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Good list

Annexe

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector – Emitter Voltage	V_{CEO}	40	Vdc

FIGURE 11: SNIPPING OF V_{CEO} OFF THE DATASHEET

Collector Current – Continuous	I_C	200	mA dc
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FIGURE 12: SNIPPING OF I_C OFF THE DATASHEET

DC Current Gain (Note 2) ($I_C = 0.1$ mA dc, $V_{CE} = 1.0$ V dc)	2N3903	h_{FE}	20	–
($I_C = 1.0$ mA dc, $V_{CE} = 1.0$ V dc)	2N3904		40	–
($I_C = 10$ mA dc, $V_{CE} = 1.0$ V dc)	2N3903		35	–
($I_C = 50$ mA dc, $V_{CE} = 1.0$ V dc)	2N3904		70	–
($I_C = 100$ mA dc, $V_{CE} = 1.0$ V dc)	2N3903		50	150
	2N3904		100	300
	2N3903		30	–
	2N3904		60	–
	2N3903		15	–
	2N3904		30	–

FIGURE 13: SNIPPING OF h_{FE} OFF THE DATASHEET

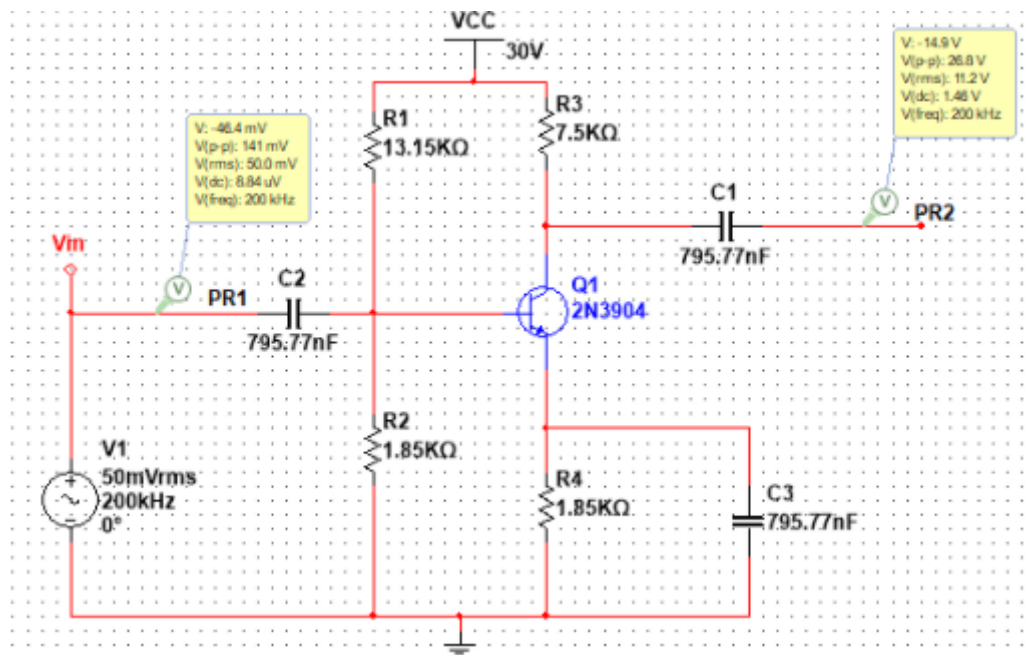


FIGURE 14: IMAGE OF THE AMPLIFIER

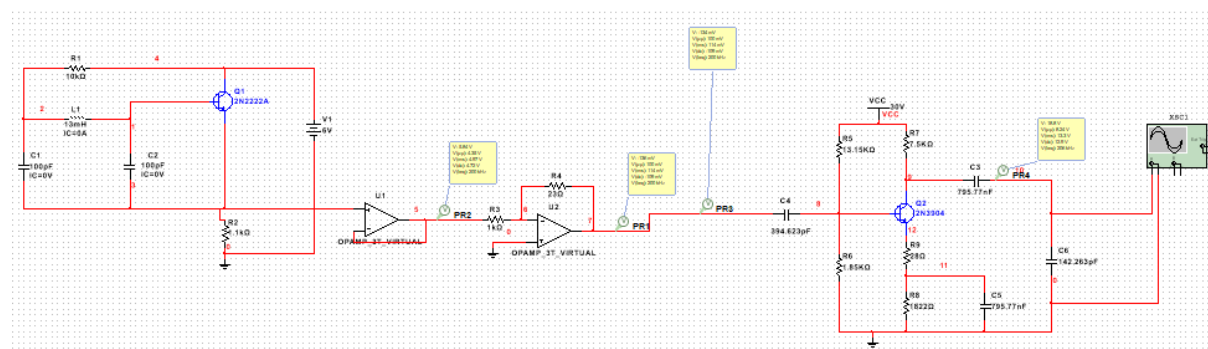


FIGURE 15: COMBINED COLPITTS OSCILLATOR AND AMPLIFIER CIRCUITS

FINAL GRADE

GENERAL COMMENTS

Instructor

66/100

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RESEARCH-INFORMED LITERATURE



There was some evidence of further reading and research and your interpretation and understanding of the additional research was satisfactory and demonstrated an underlying appreciation of the subject. Your references still rely on a small selection of mostly credible sources and you need to be more consistent with your referencing conventions e.g. citing diagrams as well as text.

6/10

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was reasonably extensive. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was demonstrated to a limited degree. You have demonstrated some critical understanding of the main concepts and expanded your knowledge beyond that contained in the course notes, however your explanations need to be more detailed and written with a greater emphasis on critical evaluation rather than description.

19/30

ANALYSIS



Your analysis of the task was generally satisfactory, , however it did tend more towards descriptive rather than analytical. You have demonstrated some analytical skills and your approach to the task was logical. You wrote a short conclusion that demonstrated some skills in analysing quantitative and qualitative data, however this was generally basic in nature and mainly criticised the course software. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory and provide a detailed critical analysis of this.

17/30

PRACTICAL APPLICATION AND DEP.



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

16/20

SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was written in a professional and confident style, however you still need to be more

8/10

efficient with your word count. The report was very well presented, with excellent diagrams in appropriate places, good sentence/paragraph structure and clear calculations.