

2018156

by Jonathan Davies

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TIME SUBMITTED	01-FEB-2021 09:47PM (UTC+0000)	WORD COUNT	2912
SUBMISSION ID	143969731	CHARACTER COUNT	15142

50-55

Course: HNC Electrical and Electronic Engineering
Module: SGEE4003 - Electronics I
Assignment Title: Analogue Circuit Design
Name: Jonathan Daffydd Lee Davies
University number: 2018156
Date Submitted: DD/MM/YYYY
Word Count: 1943 words

WORD COUNT IS LOW

- ① RESEARCH COULD DO WITH SOME DIAGRAMS. REFERENCE LIST IS SHORT. WRONG FORMAT USED.
- ② BASIC DC CIRCUIT WAS EXPLAINED BUT NOT TESTED.
- ③ REFINEMENT OF BANDWIDTH & GAIN WASN'T EXPLAINED CLEARLY.
- ④ RESULTS WERE OK.
- ⑤ CONCLUSIONS WERE BRIEF.

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Task1

An amplifier is part of an analogue circuit and is a device that the input signal is taken and used to control a local source of power which produces a greater output signal. Active devices within a circuit provide the amplifier with the power requirement for the amplification, with modern active devices being transistors. Devices such as capacitors and resistors are known as passive devices and do not allow the circuit to alter the power gain. An example of this is a transformer, although the transformer provides a higher voltage output than its input voltage the current is sacrificed and therefore the output power cannot be greater than the input power. This means that the transformer is a passive device.

There are different types of amplifiers that are configured in different ways to amplify the signals within circuits and are typically classed by purpose because of the amplifiers output. The classification purposes of amplifiers are:

Voltage Amplifiers:

The most common amplifier used within electronic devices and work by increasing amplitude of the input voltage to produce a larger output voltage.

Current Amplifiers:

Similarly, to the voltage amplifier the current amplifier increases the amplitude of the input current to produce a larger output current.

Power Amplifiers:

Power amplifiers are used to increase the power within a circuit. For example, the output voltage and current product is greater than the input current and voltage product. The voltage or current may, at the output, be lower than the input however the overall product will be greater at the output. (Unknown, 2015)

When the amplifier is connected to an AC signal only a portion of the signal is amplified and depending on which portion of the wave that's amplified the classifications fall into 4 classes. The 4 classes are:

Class A

The class A is the most widely used because the output signal that is produced is almost exact copy of the input signal with very little distortion. A disadvantage of the class is that the efficiency is around 20%, this is very low and loses 4 watts out of 5 to heat. This means that only 1 watt is used. (Unknown, 2015)

Class B

Within the class B the current will flow through the output at half of the input cycle. This means that the efficiency is 50% with a 50% distortion.

Class AB

The current flowing through the output of the class AB is between 50% and 100% of the cycle input. This gives an efficiency of around 40%.

Class C

The current through the output of the class C is less than half of the cycle input. This gives an efficiency of around 80%

Based on the signal that is amplified the amplifiers are further classified into subclasses. These subdivisions are:

Audio Frequency Amplifiers:

These amplifiers amplify electrical signals that occupies a band of audio frequencies that range from 20Hz to 20KHz. The audio class is further subdivided into hi-fi amplifiers, speech/telephone amplifiers and tone amplifiers.

Wideband/Video Amplifiers

Like the audio amplifier but can amplify the frequencies ranging from 20Hz to around 6MHz and are used with pulse radar and television.

Narrowband/Radio Frequency Amplifiers (R.F. Amplifiers):

The amplifier uses a selective amplification of a band of frequencies and work by increasing the power of a low powered radio frequency. The radio frequency band can be in the range of 30KHz and 30GHz. As they have a low noise performance the main usage is at the earliest stages of a receiver. Low noise FET transistors are used typically in these stages. (Unknown, 2015)

Intermediate Frequency Amplifiers (I.F. Amplifiers):

A sub-class of the narrow band (R.F. amplifier) the I.F amplifiers are used in TV, radar, and radio as they provide a maximum voltage amplification before the video or audio information relayed by the signal is demodulated. (Unknown, 2015)

Direct Coupled Amplifiers (DC Amplifiers):

These amplifiers are used to amplify very low and slow changing frequencies. The output at a stage is coupled to the input of the next stage and are found within measuring instruments and electrical control systems. (Unknown, 2015)

Ultrasonic Amplifiers:

The ultrasonic waves are amplified and have a frequency range of between 20KHz and 100KHz and have specific purposes. They are used in ultrasound scanning, remote systems, and ultrasonic cleaning. Each type of purpose will operate within a narrow band of frequencies in the range. (Unknown, 2015)

Buffer Amplifiers:

The buffer amplifier is commonly found to be used for impedance transformation between two circuits. The amplifier is used to isolate circuits from each other and feature high impedance at the input and low impedance at the output. (Unknown, 2015)

Operational Amplifiers:

Operational amplifiers or commonly known as op-amps are high gain voltage amplifiers and are used to perform mathematical operations on voltages. The op amp is an inverting and none inverting amplifiers and feature two input terminals.

DIAGRAMS WOULD BE VERY USEFUL.

Transistor Amplifiers:

Whilst the transistor is an electronic device it is also used as an amplifier by amplifying the voltage or current of the input signal. There are two types of transistor devices used for amplification which are bipolar junction transistors (BJT) and field effect transistors (FET). The BJT transistor are configured as common base, common emitter, and common collector, whilst the FET transistor are configured as common gate, common source and common drain. (Unknown, 2015)

Oscillator

The oscillator is an electronic circuit that is used to generate an AC output signal. It acts in the form of a waveform generator and incorporates active and passive elements. The circuit is powered by a DC power supply and the oscillator converts into an AC signal at very high frequency. The circuit constants determine the frequency of the voltage produced and can vary from fraction of a hertz to many giga hertz. The oscillator does not require an external input signal to produce sinusoidal, rectangular triangular or ramp output waves. (Unknown, 2015)

Negative feedback

Negative feedback within circuits have important benefits and advantages because of this most of all practical amplifiers, except for very simple circuits, use negative feedback. The feedback can be applied to only one stage or across several stages of amplification without effecting is operational principles. Regardless of the amplifier's components such as valves, transistors, or field effect transistors the feedback effects remain the same. The benefits to negative feedback are:

Increased bandwidth

The R-C coupled amplifier has a gain that falls at low and at high frequencies due to the capacitor within the circuit. The effective bandwidth of the bandwidth is increased when negative feedback has been introduced at the expense of the gain which is reduced at the same factor. By adding more feedback amplifiers, the design of wider bandwidth amplifiers is now able to be created. This type of feedback is standard practice where high-fidelity amplification is needed.

Improved Linearity

The linear amplifier's output is an almost exact replica of the input signal. Imperfections within the waves is known as distortion, this is regardless of the imperfections causes. Distortion will be introduced because the amplifier has different values for the gain when at different frequencies. Other causes of distortion are because of the non-linearity of the active device's transfer characteristic, which leads to a gain reduction when high amplitude signals are applied.

RESEARCH OK, BUT ALL CITATIONS ARE
'UNKNOWN'?

Task 2

Amplifier design

A small signal class A voltage was designed and built within the simulation software multisim. The circuit was designed to meet the required specification, which included:

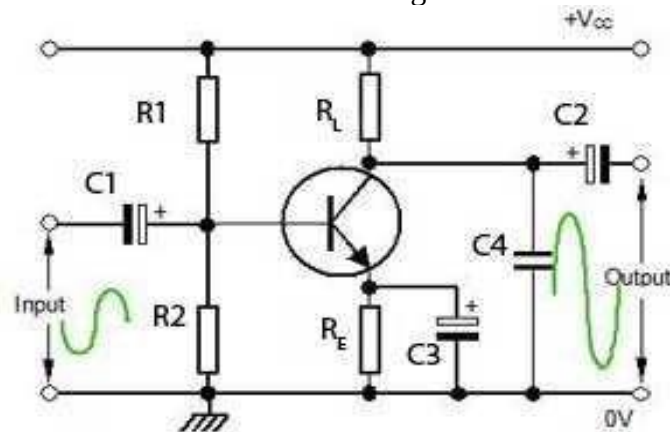
Centre frequency: 200KHz

Bandwidth: 60KHz

Gain: 50

Input signal: 50mV_{pk}

The image below shows the circuit that is to be designed within multisim.



Some of the component values are given for the circuit as above whilst others were calculated.

The first step that was taken was to select a DC power supply for the circuit this is labelled as VCC with the following step being choosing a suitable transistor for the circuit to meet the requirements.

General purpose NPN transistors were researched and the BC547BG transistor was chosen as it met and exceeded the requirements of a class A common emitter amplifier as well as having enough of a tolerance for current and voltage in order to make changes within the circuit when calculating. By selecting the BC547BG transistor the circuit parameters can be set for Ic and Iq.

Collector Current — Continuous	I _C	100	mAdc
--------------------------------	----------------	-----	------

(Futurlec, 2021)

The Ic is collected from the data sheet as above and the Iq is then calculated by being 10% of the Ic. Therefore, the $I_q = \frac{100 \times 10^{-3}}{10} = 10\text{mA}$

Below are the calculations for the circuit parameters.

$$V_{CC} = 18V$$

$$V_C = \frac{18}{2} = 9V$$

$$I_C = 100mA$$

$$I_Q = \frac{100 \times 10^{-3}}{10} = 10mA$$

$$V_E = \frac{V_{CC}}{10} = \frac{18}{10} = 1.8V$$

$$HFE \text{ from data sheet} = 290$$

$$I_B = \frac{10 \times 10^{-3}}{290} = 34.5\mu A$$

$$V_B = V_E + 0.7 = 1.8 + 0.7 = 2.5V$$

$$F_L = 170K$$

$$F_H = 230K$$

$$Z_{in} = 1.1K\Omega$$

$$Z_{out} = R_L = 900\Omega$$

DC Calculations

$$R_E = \frac{V_E}{I_Q} = \frac{1.8}{10 \times 10^{-3}} = 180\Omega$$

$$R_L (\text{Load Resistor}) = \frac{V_C}{I_Q} = \frac{9}{10 \times 10^{-3}} = 900\Omega$$

$$R_1 = \frac{V_{CC} - V_B}{I_{R1R2}} = \frac{18 - 2.5}{1 \times 10^{-3}} = 15.5K\Omega$$

$$R_2 = \frac{V_B - 0}{I_{R1R2}} = \frac{2.5}{1 \times 10^{-3}} = 2.5K\Omega$$

AC Components Calculations

$$C_2 = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 200 \times 10^3} = 850nF$$

$$C_3 = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 200 \times 10^3} = 850nF$$

$$C_1 = \frac{1}{2\pi f L Z_{in}} = \frac{1}{2\pi \times 170 \times 10^3 \times 1.1^3} = 851.1pF$$

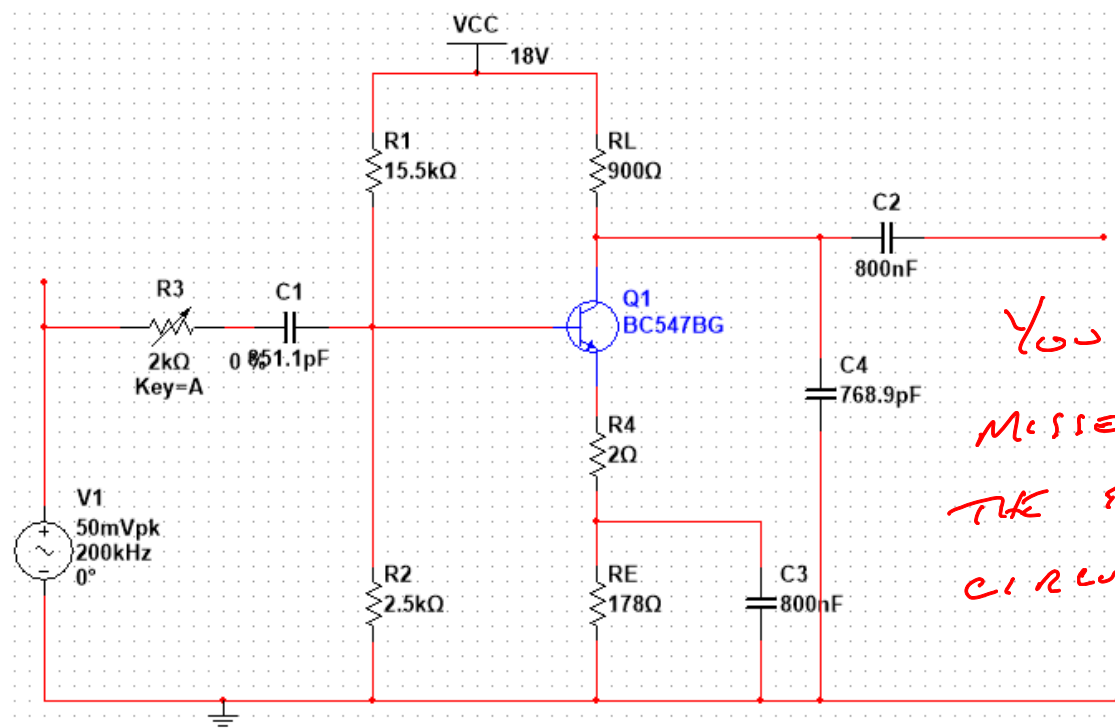
$$C_4 = \frac{1}{2\pi f L Z_{in}} = \frac{1}{2\pi \times 230 \times 10^3 \times 900} = 768.9pF$$

/ THIS COMES LATER

WHERE DID Z_{in} +

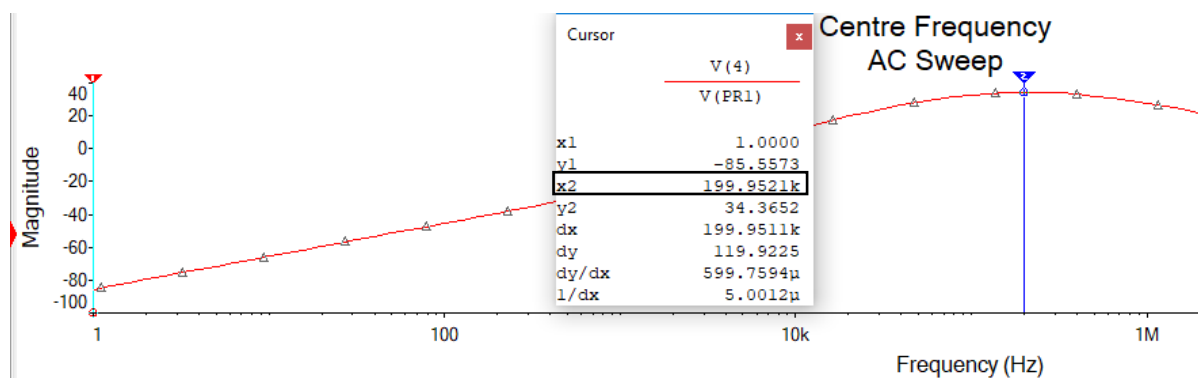
Z_{out} COME FROM?

In the circuit created shows the circuit with the completed values.



*You HAVE
MISSED ALL
THE BASIC
CIRCUIT*

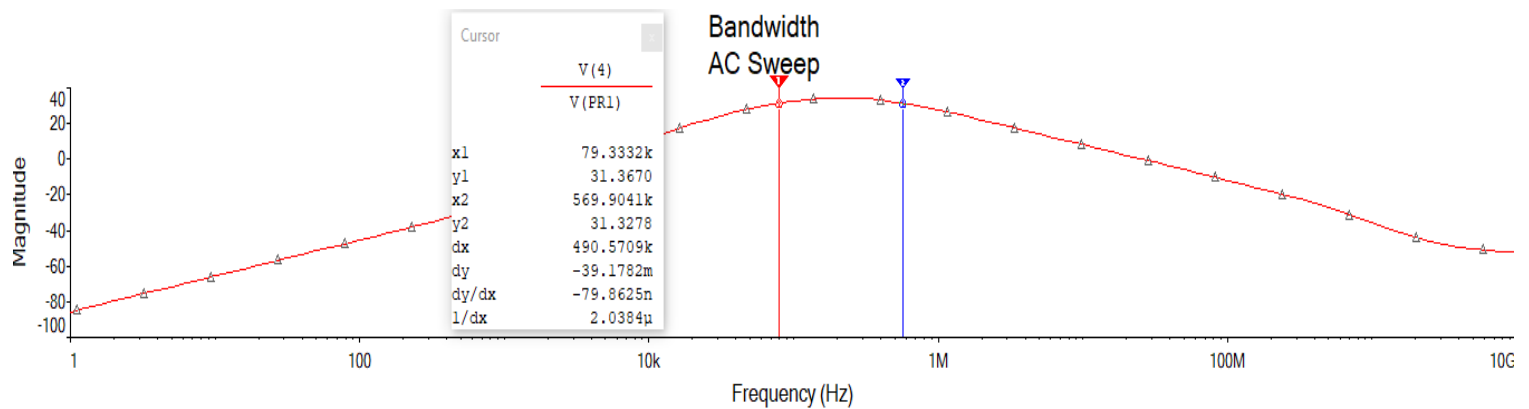
Note that the R3 variable resistor is set at 0% and was used to calculate higher and lower frequency to calculate Zin for the capacitor C1. After the C1 capacitor was calculated and placed within the circuit the centre frequency of the circuit is just under the desired 200KHz



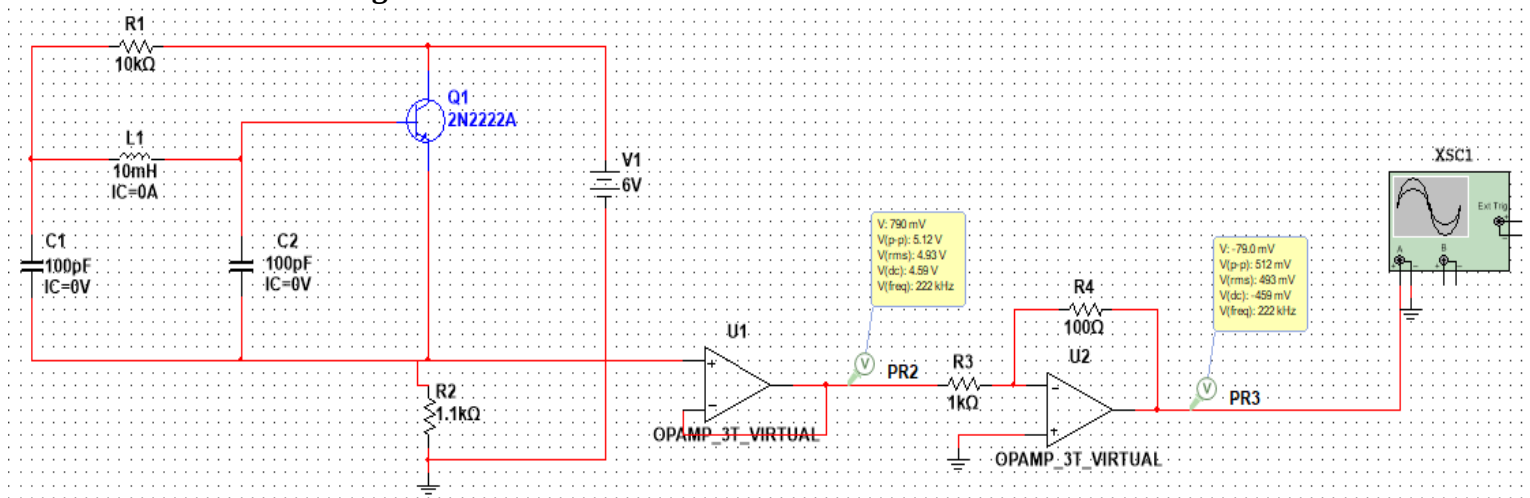
Bandwidth

The initial gain of the circuit was 200 and the initial bandwidth was 20mHz. The circuit requirements were that the gain be 50 and the bandwidth to be at 60KHz.

To achieve the required gain with the circuit R4 was added with the total value of RE (180 Ω) being split between both resistors. This introduced a negative feedback and allowed the required gain. The split began at 50/50 and the gain remeasured with split adjustments until the gain as close as 50 was achieved.



Task 3 Oscillator Design



The initial oscillator's values are above the requirements of 200KHz with an output of at least 100mVpk.

To bring down the frequency the inductor and capacitor values were altered until the frequency was reached. This was calculated using:

Initial frequency

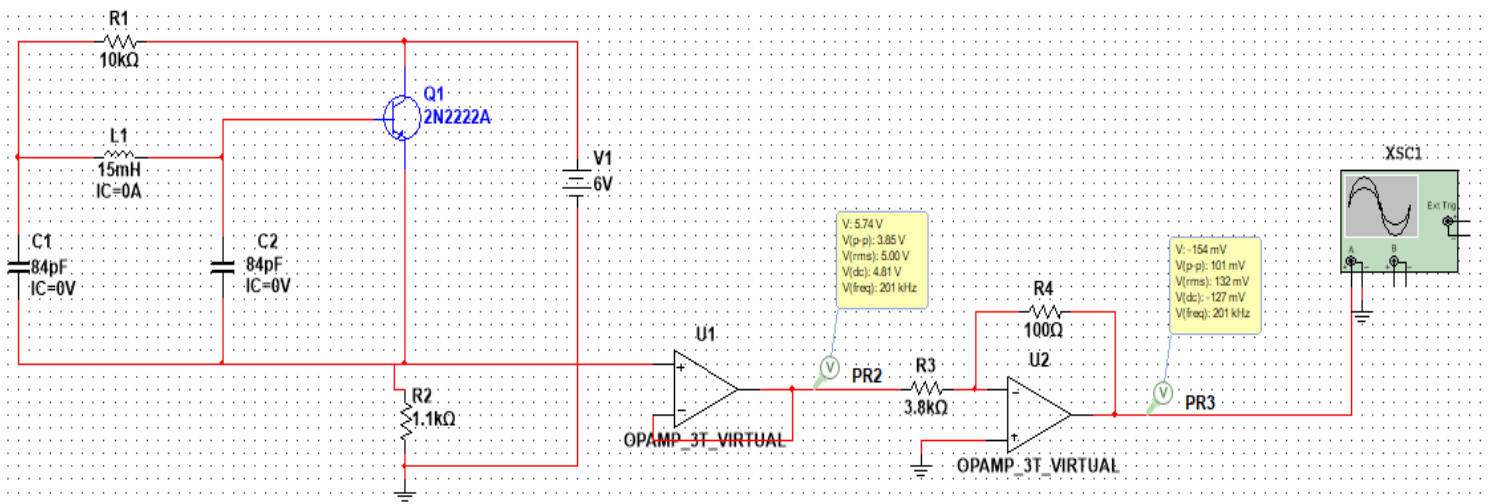
$$f = \frac{1}{2\sqrt{\frac{L_1 C_1 C_2}{C_1 + C_2}}} = \frac{1}{2\sqrt{\frac{10 \times 10^{-3} \times 100 \times 10^{-12} \times 100 \times 10^{-12}}{100 \times 10^{-12} + 100 \times 10^{-12}}}} = 225.08 \text{ KHz}$$

Final frequency

$$f = \frac{1}{2\sqrt{\frac{L_1 C_1 C_2}{C_1 + C_2}}} = \frac{1}{2\sqrt{\frac{15 \times 10^{-3} \times 84 \times 10^{-12} \times 84 \times 10^{-12}}{84 \times 10^{-12} + 84 \times 10^{-12}}}} = 200.5 \text{ KHz}$$

To change the output Vpk the R3 resistor in series with the op amp was changed to 3.8KΩ giving the Vp-p value of 101mV. To determine the value a trial and error approach was taken with readings measured until the correct measurement was obtained.

The circuit below is the updated circuit that meets the required specifications.

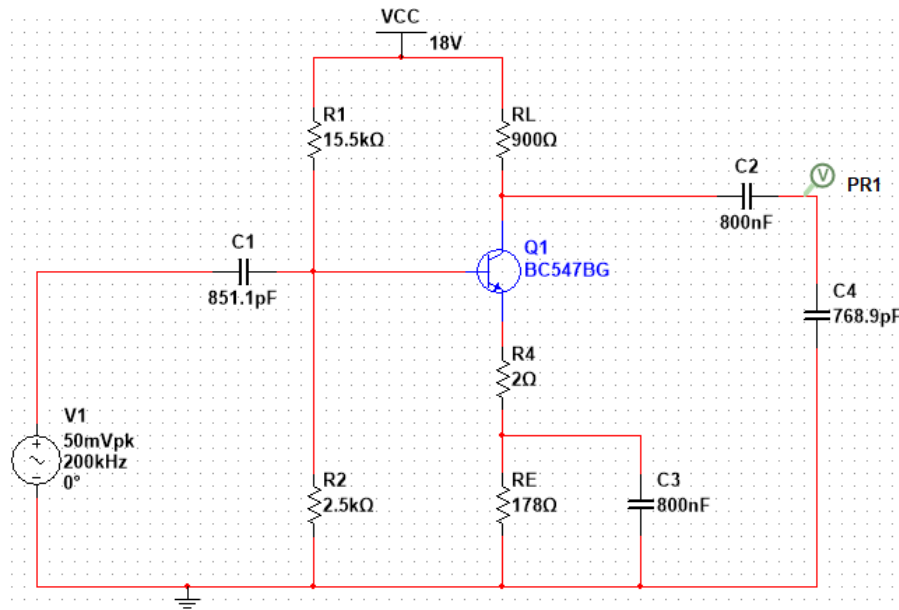


Task 4

Circuit Simulation

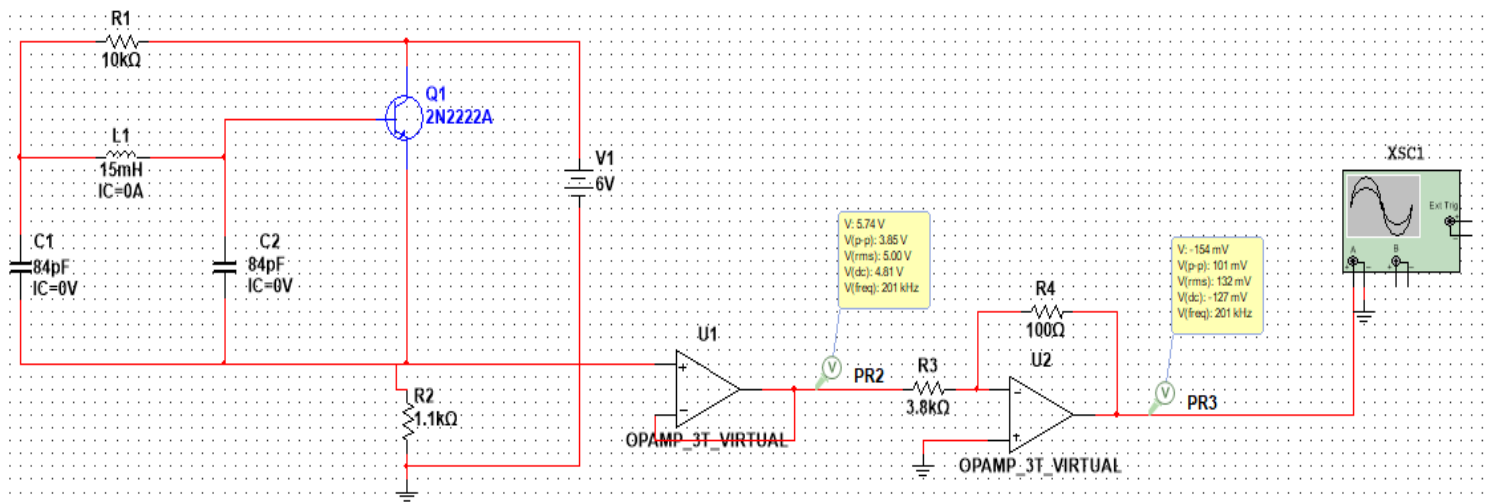
Amplifier circuit simulation

The circuit below shows the finished amplifier before testing.



Oscillator circuit simulation

The circuit below shows the finished oscillator before testing.



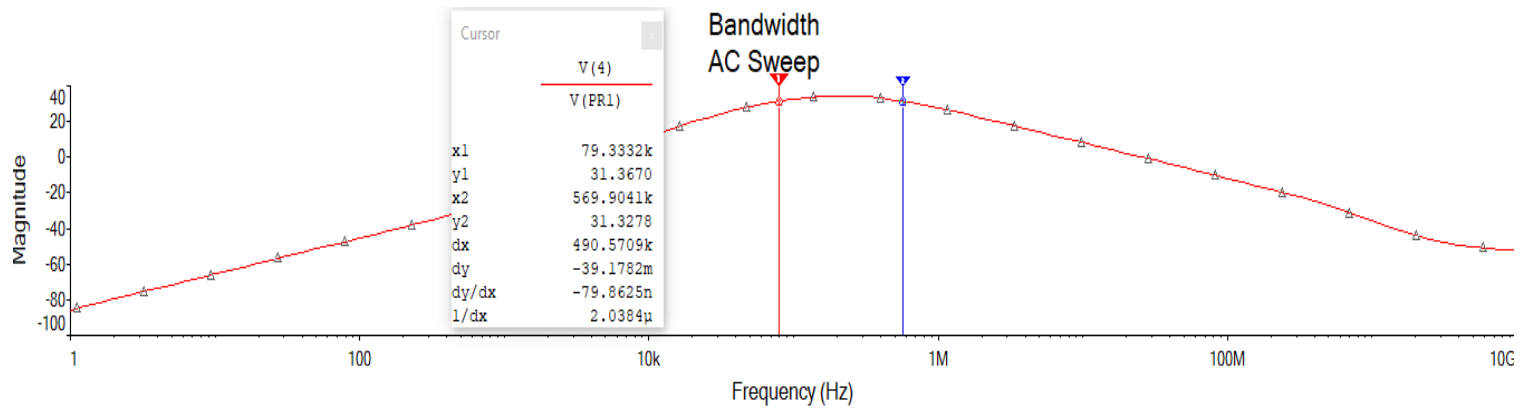
Below is the amplified and the oscillator circuits combined.

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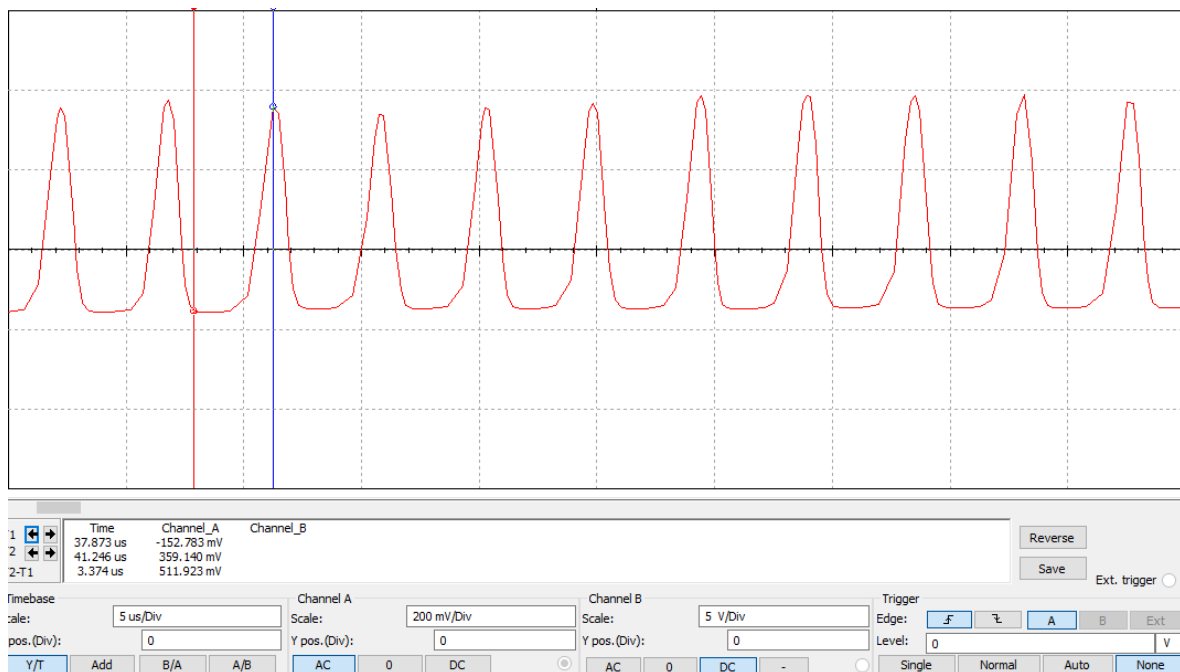
Testing and evaluation

Amplifier testing

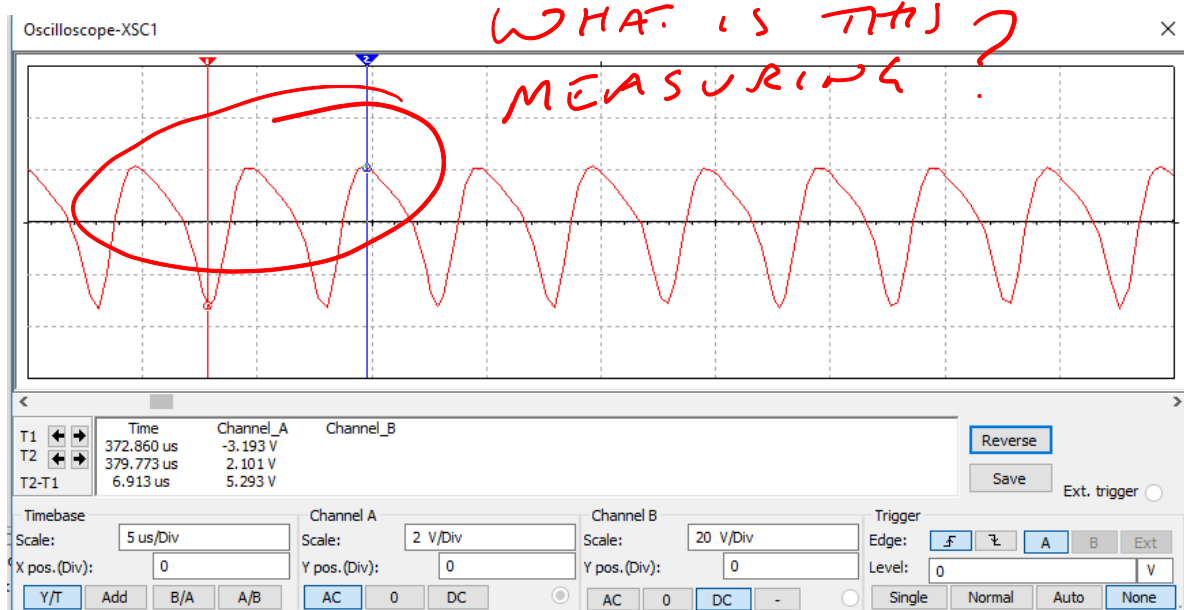
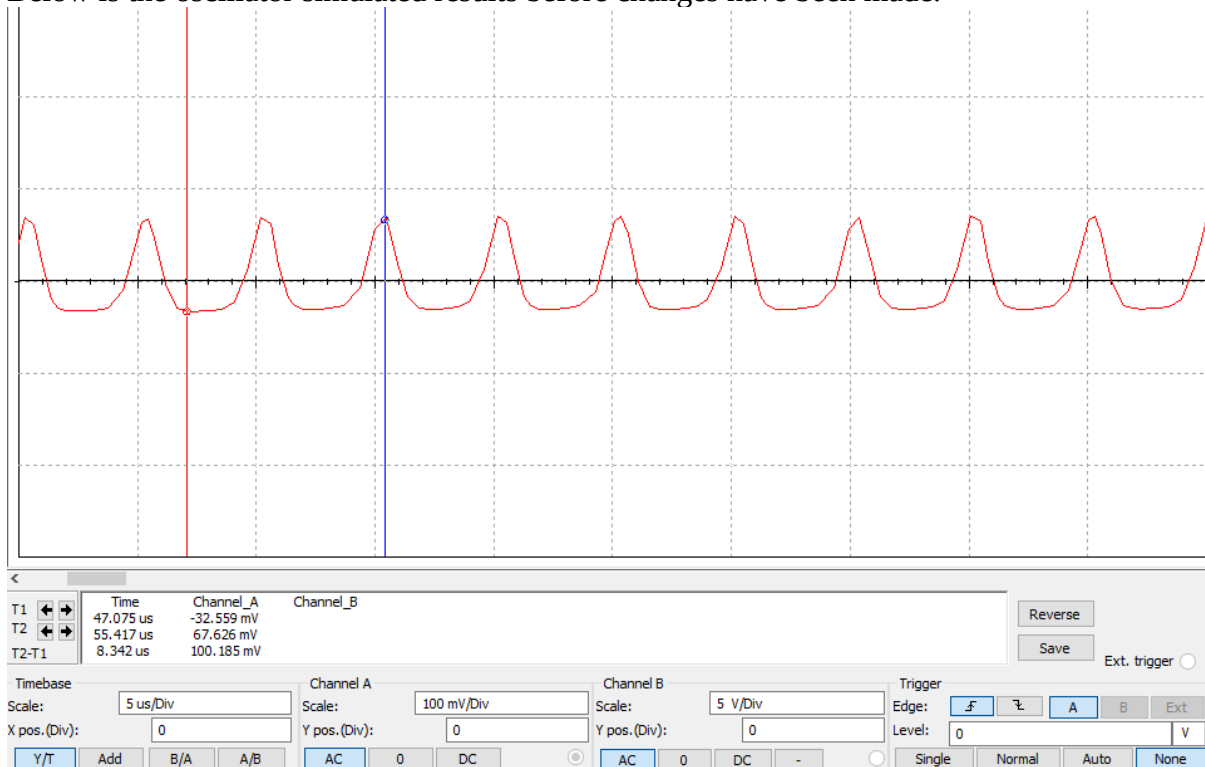


Oscillator testing

Below is the oscillator simulated results before changes have been made.



Below is the oscillator simulated results before changes have been made.



The image above shows the results from the completed circuit of the amplifier and oscillator and shows that the gain of 5.293V has been achieved.

From the testing most of the parameters that was set out had been met however the bandwidth had been recorded at an extremely high number and could not be met with the required 60KHz. The wave form in the oscillator shows the voltage drop from 510mV to the required 100mV whilst the wave form remained in the same shape but smaller. The final readings of the combined circuit show the gain at 5.0 which meets the specification.

Conclusion

When the components within the circuit were updated and changed elements required recalculation and several tests this is because as certain components such as resistors and capacitors change the previous test results will change also. Negative feedback was introduced to make the gain dependant on fixed components values rather than variable values of the h_{fe} of the transistor. This is however done at the expense of some lost gain. Another benefit of negative feedback is to reduce distortion of the circuit and balance out the gain over the amplifier's bandwidth. If the gain is not constant, then there are inconsistencies in the amplified frequencies, some higher and some lower.

In the circuit it was not possible to reach the required bandwidth of 60KHz due to the equipment that was used and the circuit design. When gain is achieved the bandwidth is at a set value. When the bandwidth is reduced or widened this has an impact on the gain forcing recalculation and tweaking. Another reason that the frequency could not be reached is due to the circuit could be unbiased. The buffer amp was added to bring down the output to 50mV peak. The buffer amp works by providing an electrical impedance from the oscillator circuit to the amplifier circuit.

References

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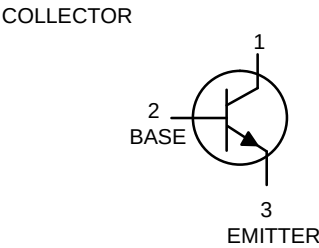
Available at: <https://www.electronicshub.org/oscillator-basics/>

[Accessed 1 February 2021].

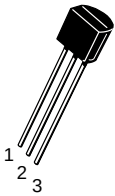
SHORT AND WROTE FORMAT.
THE 'AUTHOR' CAN BE THE COMPANY,
DOESN'T HAVE TO BE A PERSON.
YOU ARE JUST ACKNOWLEDGING THE SOURCE.

NPN Silicon

MAXIMUM RATINGS



Rating	Symbol	BC 546	BC 547	BC 548	Unit
Collector–Emitter Voltage	VCEO	65	45	30	Vdc
Collector–Base Voltage	VCBO	80	50	30	Vdc
Emitter–Base Voltage	VEBO	6.0			Vdc
Collector Current — Continuous	IC	100			mAdc
Total Device Dissipation @ TA = 25°C Derate above 25°C	PD	625 5.0			mW mW/°C
Total Device Dissipation @ TC = 25°C Derate above 25°C	PD	1.5 12			Watt mW/°C
Operating and Storage Junction Temperature Range	TJ, Tstg	–55 to +150			°C



CASE 29–04, STYLE 17
TO–92 (TO–226AA)

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	R JA	200	°C/W
Thermal Resistance, Junction to Case	R JC	83.3	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
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OFF CHARACTERISTICS

Collector–Emitter Breakdown Voltage (I _C = 1.0 mA, I _B = 0)	BC546 BC547 BC548	V(BR)CEO	65 45 30	— — —	— — —	V
Collector–Base Breakdown Voltage (I _C = 100 µA _{dc})	BC546 BC547 BC548	V(BR)CBO	80 50 30	— — —	— — —	V
Emitter–Base Breakdown Voltage (I _E = 10 A, I _C = 0)	BC546 BC547 BC548	V(BR)EBO	6.0 6.0 6.0	— — —	— — —	V
Collector Cutoff Current (V _{CE} = 70 V, V _{BE} = 0) (V _{CE} = 50 V, V _{BE} = 0) (V _{CE} = 35 V, V _{BE} = 0) (V _{CE} = 30 V, T _A = 125°C)	BC546 BC547 BC548 BC546/547/548	ICES	— — — —	0.2 0.2 0.2 —	15 15 15 4.0	nA µA

REV 1

Motorola Small-Signal Transistors, FETs and Diodes Device Data

□ Motorola, Inc. 1996

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

(Continued)



Characteristic	Symbol	Min	Typ	Max	Unit
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ON CHARACTERISTICS

DC Current Gain (I _C = 10 µA, V _{CE} = 5.0 V)	BC547A/548A BC546B/547B/548B BC548C	hFE	— — —	90 150 270	— — —	—
(I _C = 2.0 mA, V _{CE} = 5.0 V)	BC546 BC547 BC548 BC547A/548A BC546B/547B/548B BC547C/BC548C		110 110 110 110 200 420	— — — 180 290 520	450 800 800 220 450 800	
(I _C = 100 mA, V _{CE} = 5.0 V)	BC547A/548A BC546B/547B/548B BC548C		— — —	120 180 300	— — —	
Collector–Emitter Saturation Voltage (I _C = 10 mA, I _B = 0.5 mA) (I _C = 100 mA, I _B = 5.0 mA) (I _C = 10 mA, I _B = See Note 1)		VCE(sat)	— — —	0.09 0.2 0.3	0.25 0.6 0.6	V

Base-Emitter Saturation Voltage ($I_C = 10\text{ mA}$, $I_B = 0.5\text{ mA}$)	$V_{BE(sat)}$	—	0.7	—	V
Base-Emitter On Voltage ($I_C = 2.0\text{ mA}$, $V_{CE} = 5.0\text{ V}$) ($I_C = 10\text{ mA}$, $V_{CE} = 5.0\text{ V}$)	$V_{BE(on)}$	0.55 —	— —	0.7 0.77	V

SMALL-SIGNAL CHARACTERISTICS

Current-Gain — Bandwidth Product ($I_C = 10\text{ mA}$, $V_{CE} = 5.0\text{ V}$, $f = 100\text{ MHz}$) BC546 BC547 BC548	f_T	150 150 150	300 300 300	— — —	MHz
Output Capacitance ($V_{CB} = 10\text{ V}$, $I_C = 0$, $f = 1.0\text{ MHz}$)	C_{ob}	—	1.7	4.5	pF
Input Capacitance ($V_{EB} = 0.5\text{ V}$, $I_C = 0$, $f = 1.0\text{ MHz}$)	C_{ib}	—	10	—	pF
Small-Signal Current Gain ($I_C = 2.0\text{ mA}$, $V_{CE} = 5.0\text{ V}$, $f = 1.0\text{ kHz}$) BC546 BC547/548 BC547A/548A BC546B/547B/548B BC547C/548C	h_{fe}	125 125 125 240 450	— — 220 330 600	500 900 260 500 900	—
Noise Figure ($I_C = 0.2\text{ mA}$, $V_{CE} = 5.0\text{ V}$, $R_S = 2\text{ k}$, $f = 1.0\text{ kHz}$, $\Delta f = 200\text{ Hz}$) BC546 BC547 BC548	NF	— — —	2.0 2.0 2.0	10 10 10	dB

(Futurlec, 2021)

FINAL GRADE

GENERAL COMMENTS

Instructor

56/100

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JONATHAN DAVIES

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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 OK. The sources referenced were insufficient at this level given the amount of potential research areas for this assignment and relied on a small selection of mainly inappropriate and non-authoritative sources. You also need to include more in-text citations using the Harvard reference system.

3/10

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was reasonably detailed and mainly accurate. There a few gaps in your knowledge of the basic concepts and your understanding of the higher level concepts was demonstrated to a limited degree - you could have explained in more detail how the circuit evolved. Further work – Your explanations need to be more detailed and written with a greater emphasis on critical evaluation rather than description.

17/30

ANALYSIS



Your analysis of the task was generally satisfactory, both in class and as shown in this assignment, 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. 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.

13/30

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.

15/20

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

8/10