

MARKING CRITERIA AND STUDENT FEEDBACK

This section details the assessment criteria. The *extent* to which these are demonstrated by you determines your mark. The marks available for each criterion are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Common Assessment Criteria Applied	Marks available	Marks awarded
1. Research-Informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions	15	7
References to a limited range of mostly relevant sources. Some omissions and minor errors. Need to include a range of books within your reference sources.		
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.	15	10
Knowledge is accurate with a good understanding of the field of study. Show good understanding of the calculations and have made some reference to relative theory.		
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement, analytical reflection; organisation of ideas and evidence	20	12
Have some evidence of analytical thinking. Where possible has analyse new data with minimum guidance.		
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques, application of concepts; formulation of innovative and creative solutions to solve problems.	40	32
A very good application of a range of methods, materials, tools and/or techniques when performing the practical elements of the assignment. Very good use of simulation software.		
5. Skills for Professional Practice Attributes in professional practice: individual and collaborative working, deployment of appropriate media; presentation and organisation.	10	5.5
Have communicate effectively in a suitable format, there some minor errors.		

Assignment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		66.5%
	Up to one week late	☐	
	First Attempt?	☒	



School of Applied Computing ASSIGNMENT SPECIFICATION

Student name:	Carys Williams	Student P number:	
Programme:	HND Electrical/Electronic Engineering		
Lecturer:	Jason Pointer	Internal Verifier:	Steve Roberts
Assignment Title:	Transistor & Operational Amplifier Circuits		
Hand Out Date:	02/02/18	Submission deadline:	22/03/18

Referencing:	In the main body of your submission you must give credit to authors on whose research your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have read or quoted in order to complete this assignment (e.g. for books: surname of author and initials, year of publication, <u>title of book</u> , edition, publisher: place of publication).		
Disclosure:	I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people. All references have been duly cited.		
Student's Signature:	<i>Hardcopy assignments will not be accepted without a signature here</i>	Date:	

Late submission will result in a late penalty mark, as follows:

Up to one week late, maximum mark of 40% for first attempts and 0% for resubmissions.
(Academic Quality Handbook 2015/16 7.5 (5))

Learning Outcomes tested (from module syllabus)

1. Demonstrate an understanding of semi-conductor components and characteristics and their application in **analogue** and digital electronic circuits.
2. To design, simulate, build, test and evaluate **analogue** and digital electronic circuits using information gained from datasheets.

Assignment name: Electronics 1

Module code: PDSE4004

Assignment number: 2 of 3

Student Name: Carys Williams

Student Number 110538

Tutor Name: Jason Pointer

Content Page

Page 1	Front Cover
Page 2	Content Page
Page 3	Introduction
Page 4-6	Part 1
Page 7-9	Part 2
Page 9-12	Part 3
Page 13	Conclusion
Page 14	Referencing and Bibliography
Page 15	Appendix

Introduction

During this report it will consist of different aspects of an amplifier. By covering the practical and theoretical aspects it shows understanding of the task and knowledge learnt. Here is some information about amplifiers.

Transistor
All amplifiers have different classes called A, B, AB or C. These are all due to the different transistors that are used in an amplifier combined with other components. Both A and C are both in the report, Class A is in Part 1 and Class C is in part 2. However below explains Class B and Class AB.

- ❖ Class B; this has a practical efficiency of around 50% due to the fact that no power is consumed under quiescent conditions. However due to the transistors input characteristics the current will not flow until V_{BE} has reached 0.6V, this causes distortion.
- ❖ With Class AB part of the distortion from Class B biasing is overcome, because of this it improves the quality of the output signal. However Class AB is less efficient than Class B, however this is down to the position of the Quality factor point (Q point).

An Operational Amplifier, or op-amp for short, is a voltage amplifying device designed to be used with resistors and capacitors between its output and input terminals. In the feedback from the components it helps decide the 'operation' of the amplifier. This will help it decide whether to be resistive, capacitive or both, the amplifier can perform a variety of different operations, giving rise to its name of "Operational Amplifier".

The Op-Amp is a three way terminal device which consist of one input being called the inverting input (-) and another input called a Non-inverting input (+). The third terminal represents the output of the op-amp which can both sink and source either a voltage or a current.

Would have been nice if you explained class A and C.

Part 1

Before designing the circuit the measurement across the transistor needs to be verified. As stated in the requirements a transistor needs a value between 100-600 hfe, the hfe value for ZTX300 is 190.

When designing the common emitter amplifier the transistor that is going to be used is the ZTX300. In appendix 1 is the data sheet for the transistor ZTX300, using the sheet helps a lot when make sure the calculations calculated and the measurements were correct.

While designing the amplifier R1, R2, RC and RE need to be calculated in order to construct the circuit (diagram 1).

For the calculation IC needed to be chosen and according to appendix 1 500mA is the max amount that can be used so for the calculation 1 mA will be used.

To determine RC the formula is $RC = \frac{V_{CC}}{2 \times I_C} = \frac{12}{2 \times 1} = 6K\Omega$. The nearest value is 5.6K Ω

RE formula is as followed however, to do this IC=IE is assumed also VE is 10%-15% of VCC = 0.1 x 12V = 1.2V. So, $RE = \frac{V_E}{I_E} = \frac{1.2}{1 \times 10^{-3}} = 1.2K\Omega$. To determine R2 the base voltage needs to be calculated and to do that VB = VBE + VE. To get VBE it is in the data sheet that shows the value 0.65. $VB = 1.2 + 0.65 = 1.85V$, after calculating VB next is the calculation for IB. To

calculate $IB = \frac{I_C}{h_{fe}} = 5.26\mu$. So to get the value for R2 the formula goes as followed $\frac{V_B}{10 \times IB} = \frac{1.85}{10 \times (5.26 \times 10^{-6})} = 35.17^3$ and the closest value of a resistor is 33K Ω .

And the final step to calculate R1 is as follows, $R1 = \frac{V_{CC} - V_B}{IB \times VB} = \frac{12 - 1.85}{11 \times 5.26 \times 10^{-6}} = 175.42K\Omega$. The nearest resistance to that value is 180K Ω .

After all the following calculations have been calculated the resistors are placed in the

<u>Vc</u>	6.9
<u>VE</u>	1.05
<u>VB</u>	1.68
<u>VBE</u>	0.63
<u>VRC</u>	5V
<u>IC</u>	0.96mA

corresponding place to complete the circuit.

When the circuit has been fully assembled many measurement are taken place and have been produced in a table to show the results. As seen in table 1 this shows the values that have been measured across the circuit and the values are very similar to the calculation produced. However, there is a variation in the values due to human error and not having the correct value resistors and also the resistance the multimeter provides.

Table 1

Must state all units

Table 2

<u>Frequency</u> <u>(Hz)</u>	<u>Vout (V)</u>	<u>Gain</u>	<u>Gain in dB</u>
10	1.2	30	29.54
18	2	50	33.98
26	3	75	37.50
36	4	100	40.00
56	5	125	41.94
100	6	150	43.52
150	6.5	162.5	44.22
300	7	175	44.86
2000	7	175	44.86
10000	7	175	44.86
20000	7	175	44.86
32000	7	175	44.86
73000	6.5	162.5	44.22
100000	6	150	43.52
170000	5	125	41.94
250000	4	100	40.00
350000	3	75	37.50
600000	2	50	33.98

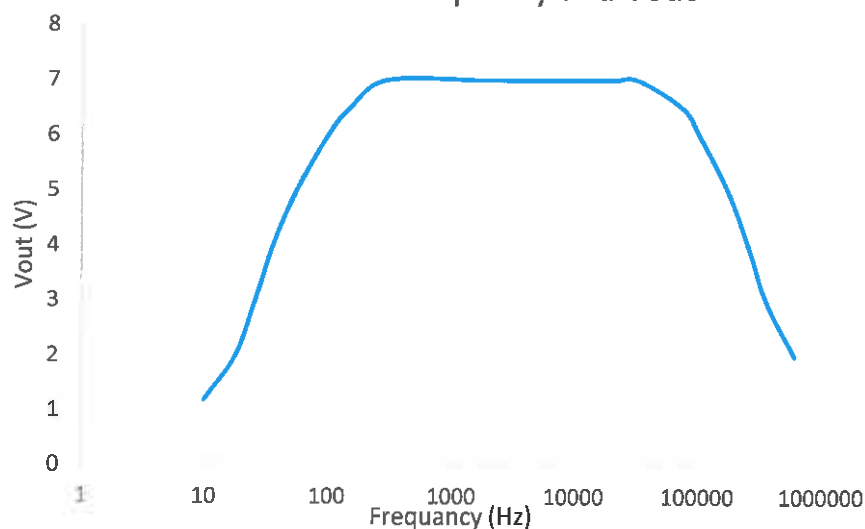
Part of the report want the AC and DC results obtained from the circuit that was produced. There are two tables, table 1 shows the DC result and table 2 shows the AC results that were recorded.

Table 2 shows the frequency that needed to be selected and then record the voltage output. However, it also shows the gain and the gain in dB (decibels). These were calculated different, Gain was calculated by dividing the Voltage Output with the value of 0.04 which is the voltage input (40mA). Gain in dB was calculated by 20 times LOG of gain. With this calculation it was possible to create 2 graphs to show how the frequency gets effect.

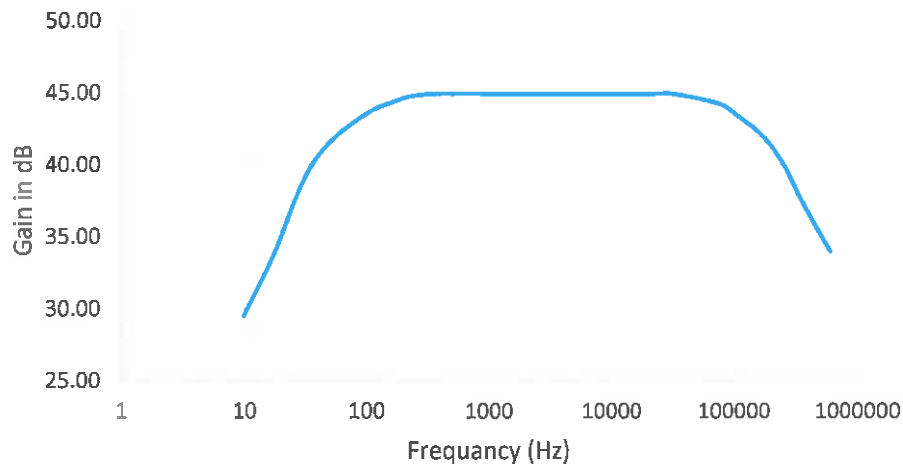
Graph 1 shows the relation between the voltage and frequency. And as seen the frequency reaches the maximum at 7V and due to the value it 'cuts off at its half power point'.

Graph 1

AC Condition Frequency and Vout



Graph 2 AC Condition Gain in db and Frequency

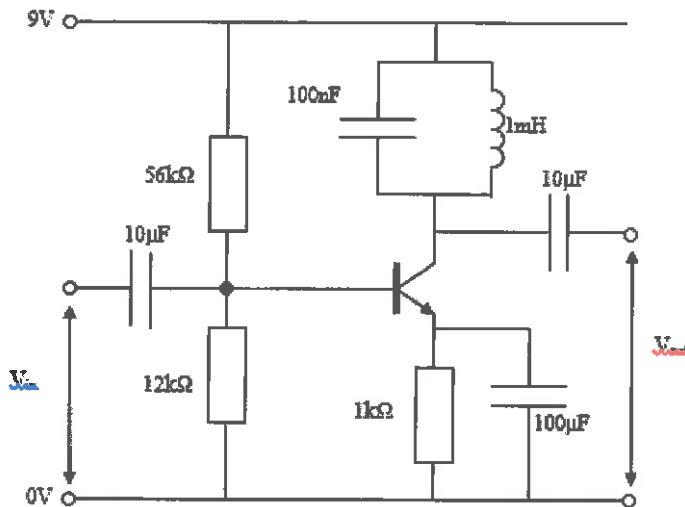


As seen on both graphs there is a 'straight' line on the top where the half power point is cuts off. This is due to the amplifier being able to amplify which means 'it works'. However, when the graph slopes on both sides it shows that the amplifier isn't good enough to amplify so it 'fails'.

Class A offers the advantage of allowing a very good quality undistorted output signal, however, current flows in the load even when there is no input. This only allows the class A to be around 25% efficient in practice.

The top is not the half power point, this will occur when the max gain (dB) falls by 3dBs.

Part 2



By using the values in the diagram it is possible to calculate the following;

- ❖ The resonant Frequency
- ❖ The Quality (Q) Factor
- ❖ The Bandwidth

Here is the formula for the resonant

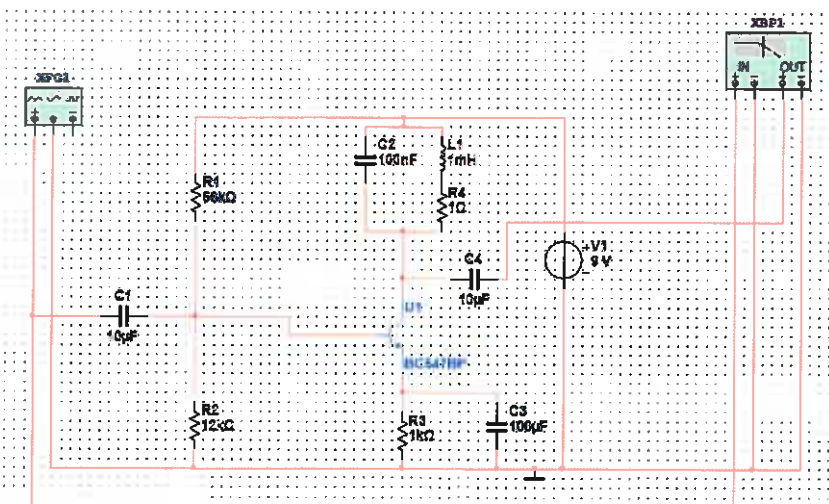
$$\text{frequency } (F_r) = \frac{1}{2\pi\sqrt{LC}} =$$

$$\frac{1}{2\pi\sqrt{1 \times 10^{-3} \times 100 \times 10^{-9}}} = 15.92 \text{ KHz.}$$

To calculate the Q factor the formula is as

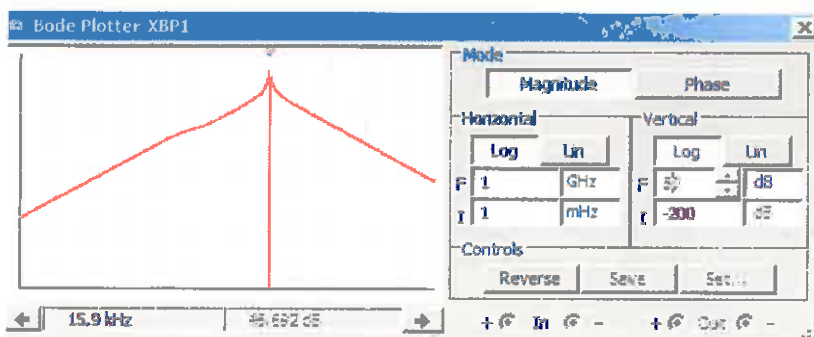
followed $Q = \frac{X_L}{R_L}$ or as followed $\frac{2\pi \times F_r \times L}{R_L} = \frac{2\pi \times 15.92 \times 10^3 \times 1 \times 10^{-3}}{1} = 100.02$. Both formulas are the same however, the second formal is a long hand version and it also shows where the values come from. *This does not relate to your formulas.*

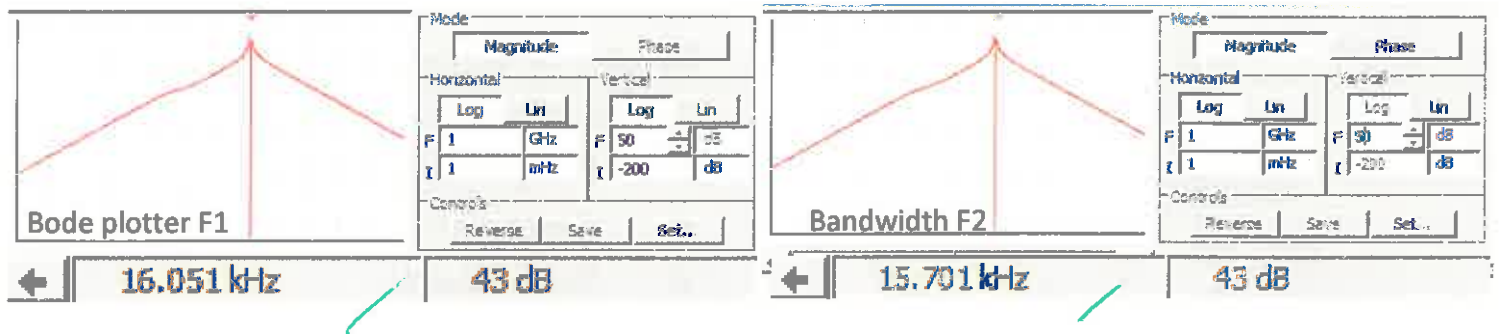
And for the Bandwidth (BW) this is the formula $BW = \frac{F_r}{Q} = \frac{15.92 \times 10^3}{100.02} = 159.17 \text{ Hz}$. To be able to calculate both the Q factor and the bandwidth it is vital that the resonant frequency has been calculated due to both formulas use the value.



A Bode plotter as shown on the left and below, are generally used in electrical engineering and is represented by a graph (as shows) depicting the frequency responses. It is important due to the fact that it shows its gain or the magnitude and the phase response with respect to different operating frequencies.

The values for the resonant frequency and gain at resonant can both be seen on the bode plotter to the left. The resonant frequency shows 15.9 KHz and the gain at resonant states 46.692 dB.





Above shows two bode plotters that gives two different values to allow the calculation of bandwidth to be calculated. The formula is as follows $Bw = F1 - F2$, and with closer expectation on the two graphs there is a slight variation in the value presented. So, for bandwidth 1 the value shows 15.701 and bandwidth 2 shows the value 16.051. When doing the formula the value is 0.35 when converting to frequency the value is in fact 350Hz.

With both the calculations and the results obtained in multisim the values are very close together especially the resonant frequency, With the bandwidth it's very difficult to get an accurate value with the multisim due to the graph being so narrow, however, being able to get a value so close to the is very difficult due to human error.

Overall this section is based on a Class C, this is the most efficient with a possible present of around 75%; however it creates a lot of distortion.

Part 3

In this part there are many different circuits that show all types of amplifiers. Amplifiers is a device which takes a weak signal as an input and produce a much stronger signal as an output. A operational amplifier (op-amp) is a special kind of amplifier used in equipment such as stereo equipment and medical cardiographs. Op-amps have a voltage gain of 100,000. This makes them very sensitive to small changes. Sometimes it is necessary to make them less sensitive, so that larger changes can be reliably detected.

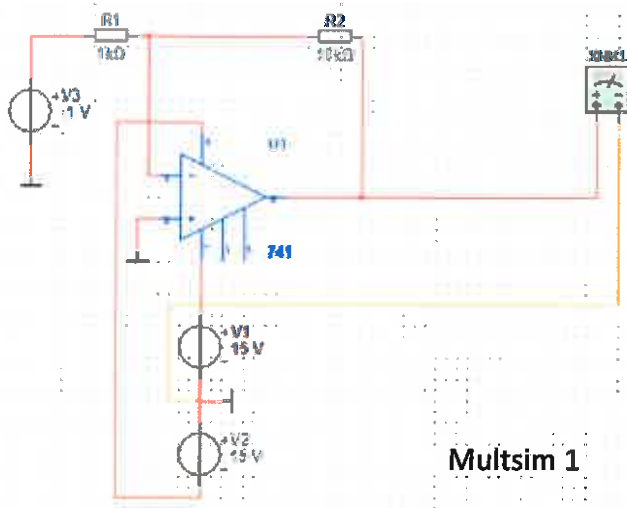
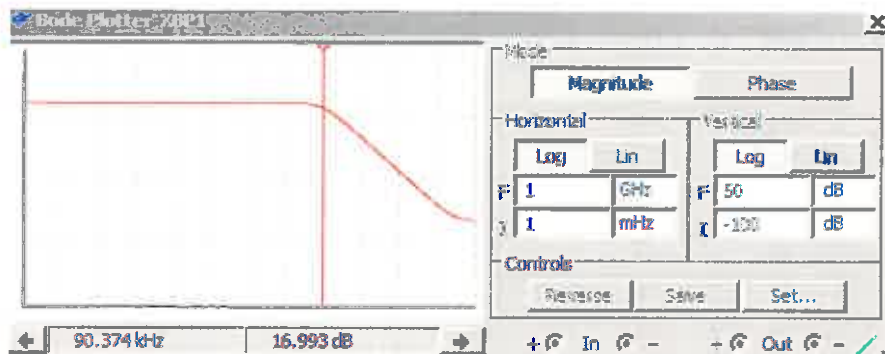


Table 1

Units

Vin	calculated	measurement	multisim
0	0	0.57	0.012
0.5	5	-5.07	-4.98
1	10	-10.08	-9.98
1.5	15	-10.41	-14.12
2	20	-10.42	-14.12
-1.5	-15	12.49	14.12
-1	-10	11	10.01
-0.5	-5	5.47	5.01

Could have shown the formulas.



Multisim 1 shows the simulation of an inverting amplifier. Table 1 shows the voltages that were used and then shows the calculated values, measurements taken

and what multisim produced. As seen in the table the measurement and multisim are very similar, however, there is a slight variation and this is down to different factors that affect the circuit. For example human error is a major factor to take into account, such as rounding decimals in calculations or not being process with the input voltage. Also another factor is tolerance; the transistor loses voltage when the current goes through and also the interference from the multimeter or the power supply.

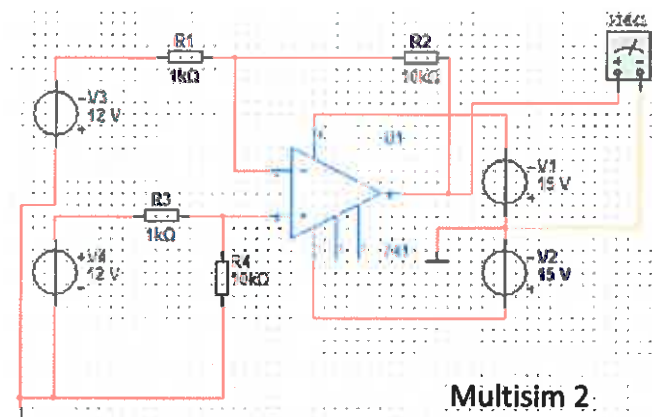
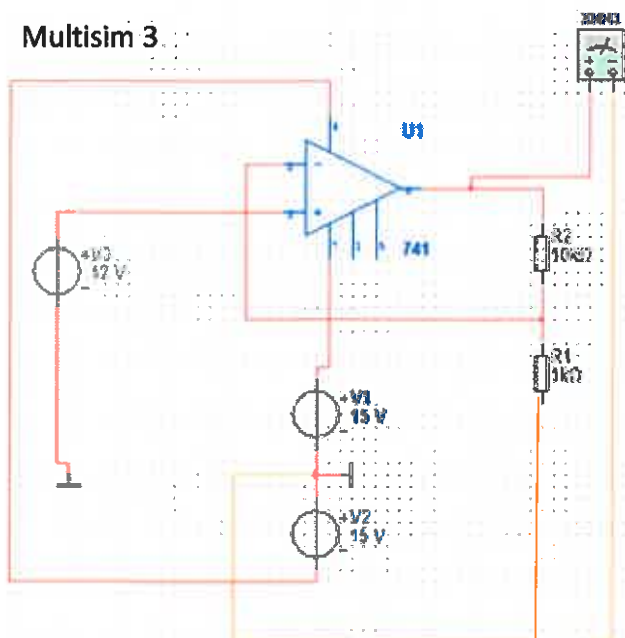


Table 2		calculated	Measured	multisim
V1	V2	Vout		
0	1	-10	-10.03	10.011
0	0.5	-5	-5.09	5.011
1	0.5	5	5.1	-4.988
1	2	-10	-9.8	10.01
3	2	10	10.06	-9.989
3	3	0	0.2	10.561m
2	4	-20	-14.06	14.117
1.5	5	-35	-14.2	14.117

Above shows multisim 2 which represent a differential amplifier. All op-amps are differential amplifiers due to the input. However, connecting one voltage signal onto one input terminal and another voltage to the other terminal the result of the output voltage should be proportional to the two inputs. Then differential amplifiers amplify the difference between two voltages making this type of operational amplifier circuit.

In table 2, all the values are very close when comparing, however, when the voltage comes close to 15V or above the values does not match. This is down to the limit the power rail gives (+/- 15V) when measuring or on multisim.

Multisim 3



These are the results for the summing amp

Table 3		calculated	Measured	multisim
V1	V2	Vout		
0	1	1	0.98	1.003
0.5	1	1.5	1.51	1.503
1	2	3	2.96	3.003
2	1	3	2.97	3.003
0	0	0	0.51	2.697m
1	1	2	2.11	2.003
3	3	6	5.93	6.003
3	5	8	8.04	8.003
5	5	10	10.01	10.003
8	8	16	16.2	16.003

'In Non inverting amplifier configuration, the input voltage signal, is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes "Positive" in value. The result of this is that the output signal is "in-phase" with the input signal' according to Electronic Tutorials.

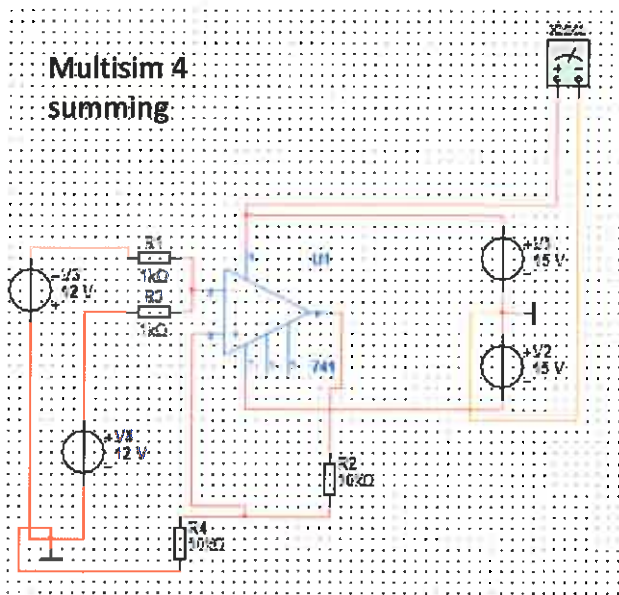


Table 4

	Calculation	Measure	Multisim
Vin	Vout		
0	0	-0.61	12.02
0.5	5.5	5.49	5.52
1	11	11.03	11.01
1.5	16.5	11.03	14.12
2	22	11.03	14.12
-1.5	-16.5	-11.2	-14.12
-1	-11	-11.02	-10.99
-0.5	-5.5	-5.51	-5.49

Non-inverting amp

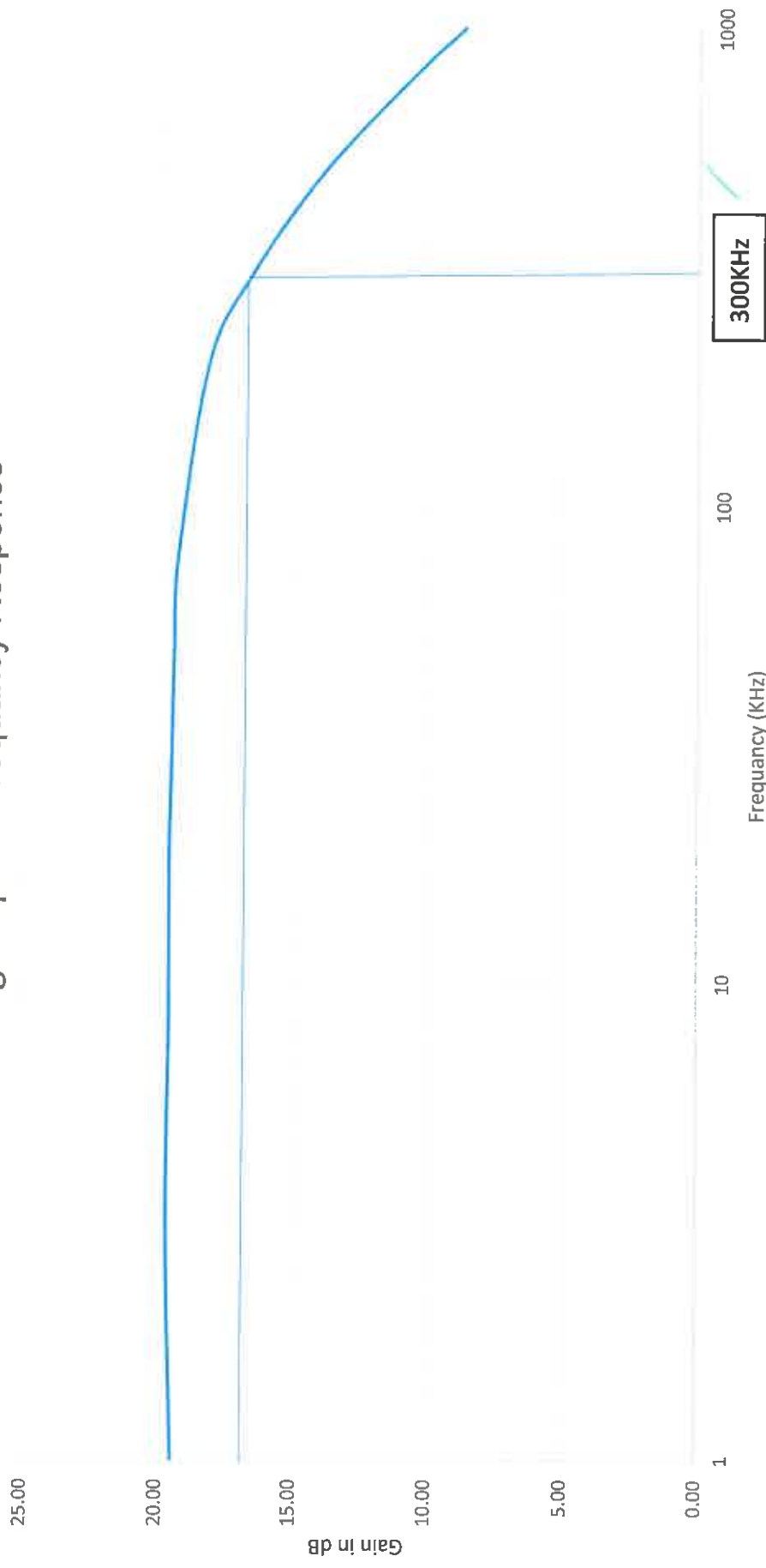
Summing amplifier is very similar to the inverting operational amplifier due to the fact that it has a single input voltage, applied to the inverting input terminal. If however, more resistors are to be added to the input, each equal in value to the original input resistor this is how the summing amplifier works.

As stated above with multisim 2 and table 2, all the values match up well in the table with a few decimals out. However, due to the power rail it is difficult to be able to have an accurate result when the voltage output comes to close to (+/-) 15V.

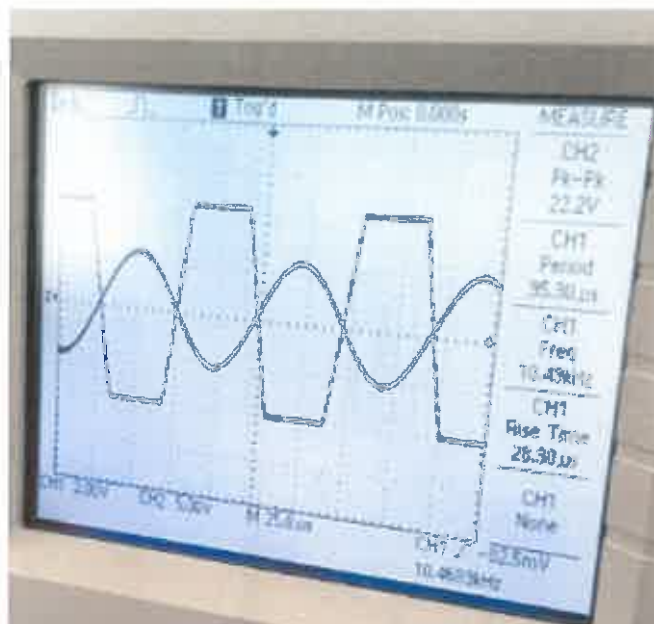
(All information used in part 3, selected from Electronic Tutorials)

Frequency (kHz)	Output Voltage (V)	Phase Relationship	Gain	Gain in dB
1	9.36	180	9.36	19.43
3	9.6	180	9.6	19.65
8	9.52	180	9.52	19.57
10	9.52	180	9.52	19.57
13	9.52	180	9.52	19.57
16	9.52	180	9.52	19.57
20	9.52	180	9.52	19.57
30	9.44	175	9.44	19.50
50	9.36	170	9.36	19.43
80	9.2	168	9.2	19.28
200	8.08	165	8.08	18.15
300	6.8	152	6.8	16.65
500	4.96	130	4.96	13.91
800	3.36	122	3.36	10.53
1000	2.72	105	2.72	8.69

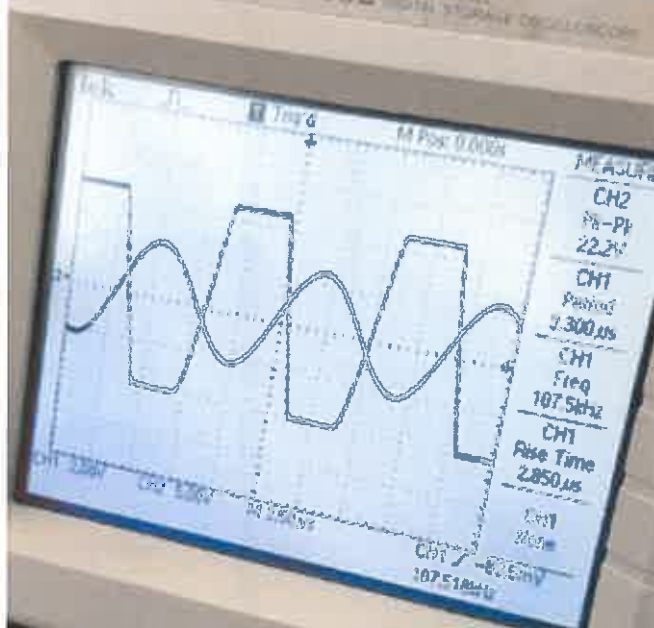
Inverting Amplifier Frequency Response



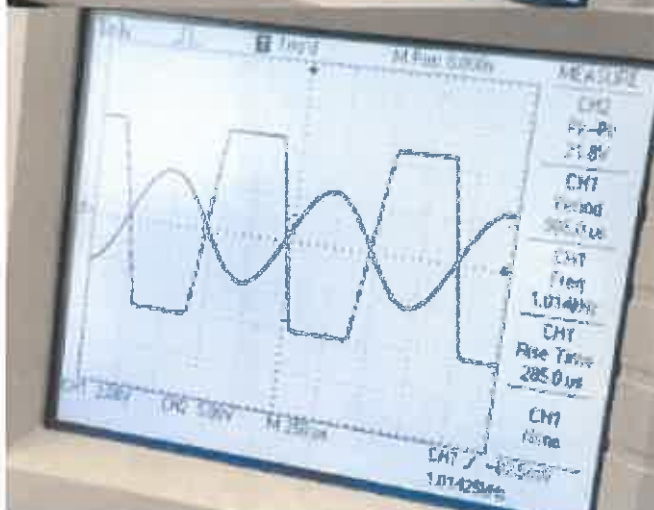
Here shows a inverting amplifier frequency response graph that shows the relationship between gain in dB and frequency.



Here shows a photograph that shows an oscilloscope with a wave form at 10KHz, But the wave form has been 'Cut Off'. The reason for this is that the input voltage has been set to 5V max. Due to the frequency still being able to continu the graph cuts off the top of the wave to show it still works.



With this Photograph it shows a similar wave form however it has moved slightly away from the centre. This is due to the frequency being at 100KHz.



Again this is the same wave form however this is at 1000KHz. However, the wave has moved over slightly again due to the frequency being higher.

But as stated in the first photo, all the wave forms waves have been 'cut off'. This is down to the half power point.

No

Negative Feedback

As Electronic Tutorials states 'Negative Feedback is the process of "feeding back" a fraction of the output signal back to the input, but to make the feedback negative, we must feed it back to the negative or "inverting input" terminal of the op-amp using an external Feedback Resistor called R_f . This feedback connection between the output and the inverting input terminal forces the differential input voltage towards zero'.

$$V_s = V_{in} - V_\beta$$

$$V_{out} = A_o \times V_s \Rightarrow V_s = \frac{V_{out}}{A_o}$$

$$V = V_{out} \times \beta$$

So,

$$\frac{V_{out}}{A_o} = V_{in} - V_{out} \times \beta$$

$$V_{out} = A_o (V_{in} - V_{out} \times \beta)$$

$$V_{out} = A_o V_{in} - A_o V_{out} \times \beta$$

$$V_{out} + A_o V_{out} \times \beta = A_o V_{in}$$

$$V_{out}(1 + A_o \beta) = A_o V_{in}$$

Therefore,

$$\frac{V_{out}}{V_{in}} = \frac{A_o}{1 + A_o \beta}$$

*Should have included
a block diagram.*

Conclusion

At the beginning when building the circuit to creating an amplifier was very difficult. Especially finding the data sheet, that was needed to be able to collect the data needed to proceed with the calculations. Even with the data sheets help it was difficult to understand why the measured results were different from the calculated results.

While building the tables and graphs it was interesting to see how the frequency could change drastically when the values increased on the other axis. ✓

Your conclusion needs to more detailed, discussing the theory and results and how they link together.

Referencing

Appendix 1 - [file:///pembrokeshire.ac.uk/Files/Student/110538/Downloads/ZTX300%20\(1\).pdf](file:///pembrokeshire.ac.uk/Files/Student/110538/Downloads/ZTX300%20(1).pdf)

unknown author. March 1994, issue 2.

https://www.electronics-tutorials.ws/opamp/opamp_2.html accessed on the 15th February.

Bibliography

<https://www.electronics-tutorials.ws/amplifier/frequency-response.html> accessed on 5th of February.

<http://www.learnabout-electronics.org/Amplifiers/amplifiers20.php> (accessed on 5th of February)

<https://www.allaboutcircuits.com/textbook/alternating-current/chpt-6/q-and-bandwidth-resonant-circuit/> accessed on 7th of February.

<https://www.electronics-tutorials.ws/accircuits/series-resonance.html> accessed on 8th of February.

<https://www.corrosionpedia.com/definition/6386/bode-plot> accessed on 10th of February.

Appendix

Appendix 1

NPN SILICON PLANAR SMALL SIGNAL TRANSISTOR

ISSUE 2 - MARCH 94

ZTX300



E-Line
TO92 Compatible

ABSOLUTE MAXIMUM RATINGS.

PARAMETER	SYMBOL	VALUE	UNIT
Collector-Base Voltage	V_{CBO}	25	V
Collector-Emitter Voltage	V_{CEO}	25	V
Emitter-Base Voltage	V_{EB0}	5	V
Continuous Collector Current	I_C	300	mA
Power Dissipation at $T_{amb}=25^{\circ}\text{C}$	P_{tot}	300	mW
Operating and Storage Temperature Range	$T_j; T_{stg}$	-55 to +175	$^{\circ}\text{C}$

ELECTRICAL CHARACTERISTICS (at $T_{amb} = 25^{\circ}\text{C}$ unless otherwise stated).

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITIONS.
Collector-Base Breakdown Voltage	$V_{(BR)CBO}$	25			V	$I_C = 10\mu\text{A}$, $I_E = 0$
Collector-Emitter Sustaining Voltage	$V_{CEO(sus)}$	25			V	$I_C = 3\text{mA}$, $I_B = 0$
Emitter-Base Breakdown Voltage	$V_{(BR)EBO}$	5			V	$I_E = 10\mu\text{A}$, $I_C = 0$
Collector Cut-Off Current	I_{CBO}			0.2	μA	$V_{CB} = 25\text{V}$, $I_E = 0$
Emitter Cut-Off Current	I_{EBO}			0.2	μA	$V_{EB} = 4\text{V}$, $I_C = 0$
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			0.35	V	$I_C = 50\text{mA}$, $I_B = 5\text{mA}^*$
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	0.65		1.0	V	$I_C = 10\text{mA}$, $I_B = 1\text{mA}^*$
Static Forward Current Transfer Ratio	h_{FE}	50		300		$I_C = 10\text{mA}$, $V_{CE} = 6\text{V}^*$
Transition Frequency	f_T	150			MHz	$I_C = 10\text{mA}$, $V_{CE} = 6\text{V}$ $f = 100\text{MHz}$
Output Capacitance	C_{obo}			6	pF	$V_{CB} = 6\text{V}$, $I_E = 0$ $f = 1\text{MHz}$
Noise Figure	N		7		dB	$V_{CE} = 6\text{V}$, $f = 1\text{KHz}$ $R_S = 1500\Omega$, $I_C = 100\mu\text{A}$

*Measured under pulsed conditions. Pulse width=300 μs . Duty cycle $\leq 2\%$