

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	6.5
References to a limited range of mostly relevant sources. Some omissions and minor errors.			
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		15	8.5
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	8
Some relevant conclusions and recommendations, where relevant.			
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	30
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
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)

Up to one week late

First Attempt?

58%

✓



School of Applied Computing ASSIGNMENT SPECIFICATION

Student name:	Harley Holmes	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:	Hardcopy assignments will not be accepted without a signature here	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.

Harley Holmes, 140243

PSDE 4004 - Electronics 1

Transistor & Operational Amplifier Circuits

Jason Pointer

Contents

Background Theory	3
Classes of amplifiers	3
Operational amplifier	4
Part 1 - Transistor Amplifier Design and Performance Measurement.....	4
.....	4
Part 2 - Tuned Amplifier	8
Task 1 – Calculations	8
Task 2 – Simulation.....	8
Part 3 - Operational Amplifier Circuits	9
Task 1: Simulation using Multisim.....	9
Task 2: Experimental measurement.....	10
.....	12
.....	12
Task 3: Comparison of simulation and experimental results.....	13
Task 4 - Negative Feedback.....	13
References.....	14
Harvard Referencing.....	14
Appendix	15

Background Theory

Classes of amplifiers

Amplifiers in electronics come in many different types, there are class A amplifiers, class B amplifiers and also a class C amplifiers. Each type of amplifier has its own different characteristic from any other type of amplifier, these characteristics can change between every amplifier, but each amplifier is produced with the same characteristics in mind, these characteristics are linearity, signal gain, efficiency and power output. In electronics class A amplifiers are the most commonly used type of amplifier, this is because they are the simplest type of amplifier, this can be shown by its name "class A" this means that it's the best type of class. The class A amplifier out of all the amplifiers has the best sound as well as it has a low signal distortion. Class A amplifiers use a single transistor that is connected in a way that allows a configuration that allows both halves of a waveform of the transistor always having a current flowing through it.

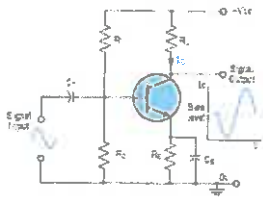


Figure 1.

The class B amplifier was created to solve heating and efficiency issues that come with the class A amplifier. Within the class B amplifier there are two types of transistor present in the amplifier, these transistors are either a bipolar or a FET, each for a half of a waveform with an output situated as a push pull arrangement, this is because each transistor amplifies only half of the waveform.

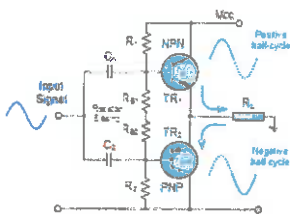


Figure 2.

The class C amplifiers design allows it to have the best efficiency of all the types of amplifiers but by having the best efficiency it also has the worst linearity of all amplifiers. The class A and B amplifiers are both linear amplifiers as the output signals amplitude and phase are both related to the input signals. However the class C amplifier is massively biased to the point that the output current is at 0 for the majority of the time of a signal cycle.

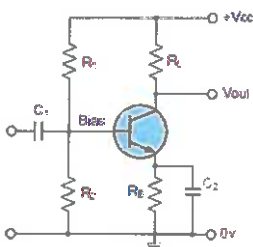


Figure 3.

Not needed for the assignment

Operational amplifier

Operational amplifiers are high-gain, DC coupled amplifiers with a differential input with a single output. In specific configurations, op amps produce an output that can sometime have a potential to output a signal that is significantly greater than what the input signal is. Op amps were first used to perform mathematical operations in either linear, non-linear and frequency dependant circuits.

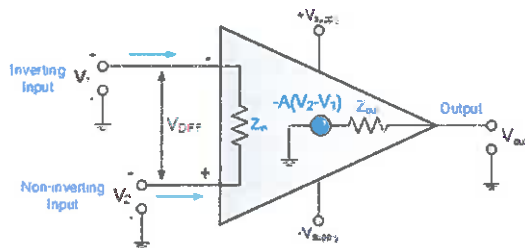


Figure 4.

Part 1 – Transistor Amplifier Design and Performance Measurement

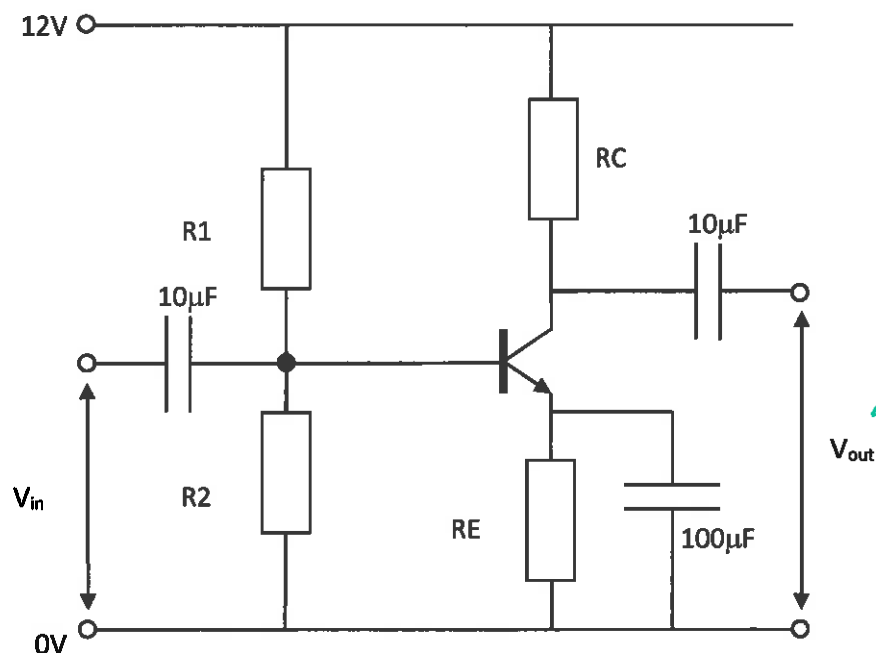


Figure 5.

The BC183 transistor was chosen for the following task, the measured current gain or the h_{fe} for the transistor was 263, from the datasheet of the BC183 transistor the max I_C value was 100mA, whereas the let I_C value for the transistor is 4mA. The calculations below correspond with figure 5.

A)

- 1) Determine RC

$$RC = \frac{V_{CC}}{2 \times I_C} = \frac{12}{2 \times 4} = \frac{12}{8} = 1.5k\Omega$$

$$RC = 1.5k\Omega$$

- 2) Determine RE

Assume $I_C = I_E$

Also V_E to 10% to 15% of V_{CC}

$$V_E = 14\% \text{ of } V_{CC} = 0.14 \times 12 = 1.68V$$

$$\text{So } R_E = \frac{V_E}{I_E} = \frac{1.68}{4 \times 10^{-3}} = 420\Omega$$

$R_E = 420\Omega$ nearest value is 390Ω

3) Determine R_2

Find the base voltage $V_B = V_{BE} + V_E$

V_{BE} from the datasheet

$$V_{BE} = 0.55$$

$$\text{So } V_B = 1.68 + 0.55 = 2.23V$$

I_2 is 10 times greater than I_B

$$h_{fe} = \frac{V_B}{10 \times I_B} = \frac{2.23}{10 \times 1.52 \times 10^{-5}} = 14.67k\Omega \text{ nearest value} = 15k\Omega$$

need to show where this came from

4) Determine R_1

$$I_1 = I_2 + I_B = 10I_B + I_B = 11I_B$$

$$\text{And } V_1 = V_{CC} - V_B$$

$$\text{So } R_1 = \frac{V_{CC} - V_B}{11I_B} = \frac{12 - 2.23}{11 \times 1.52 \times 10^{-5}} = 58.43 \times 10^{-3}$$

The nearest value to $58.43k\Omega$ is $56k\Omega$

B) DC Conditions

$$V_{RC} = 6.53V$$

$$V_C = 5.51V$$

$$V_E = 1.72V$$

$$V_{BE} = 0.67V$$

$$V_B = 2.39V$$

$$I_C = 4.58V$$

AC test results

$$V_{in} = ?$$

Frequency (Hz)	Voltage (V)	Gain	Gain (dB)
40	1.1	36.667	31.29
76	2	66.667	36.48
101	2.5	83.333	38.42
130	3	100.000	40.00
166	3.5	116.667	41.34
217	4	133.333	42.50
286	4.5	150.000	43.52
440	5	166.667	44.44
788	5.5	183.333	45.26
2000	5.8	193.333	45.73
10000	5.8	193.333	45.73
30000	5.8	193.333	45.73
50000	5.8	193.333	45.73
80000	5.8	193.333	45.73
110000	5.8	193.333	45.73
166000	5.5	183.333	45.26

305000	5	166.667	44.44
417000	4.5	150.000	43.52
525000	4	133.333	42.50
670000	3.5	116.667	41.34
808000	3	100.000	40.00
1035000	2.5	83.333	38.42
1368000	2	66.667	36.48
2523000	1.1	36.667	31.29

Figure 6.

$$F1 = 286, F2 = 525,000$$

$$\text{Bandwidth} = F2 - F1 = 525,000 - 286 = 524,714\text{Hz}$$

The DC test results for the amplifier are very unbalanced whereas a class A amplifier shouldn't be unbalanced it should be balanced, there are many different factors that the amplifier is unbalanced. There are many different reasons that the amplifier is unbalanced the first is the reference to the datasheet. The amplifier that was used is sensitive to the temperature, which effects the measurements, if the lab was the right temperature the results would have been the same as it states on the datasheet, therefore these results are not realistic. When the amplifier was designed some of the values for the resisters were not available for use, that meant that the nearest suitable value has to be used. By selecting a resistor that is valued close to the calculated resistor, this can cause the amplifier to become unbalanced, which this can be seen within the DC test results. As seen from the graph below and the results in the table above the AC's gain for the operational bandwidth is 524,714Hz whereas the dB is around 45.73dB, this is expected from the measurements and the calculations.

Transistor Amplifier Frequency response range

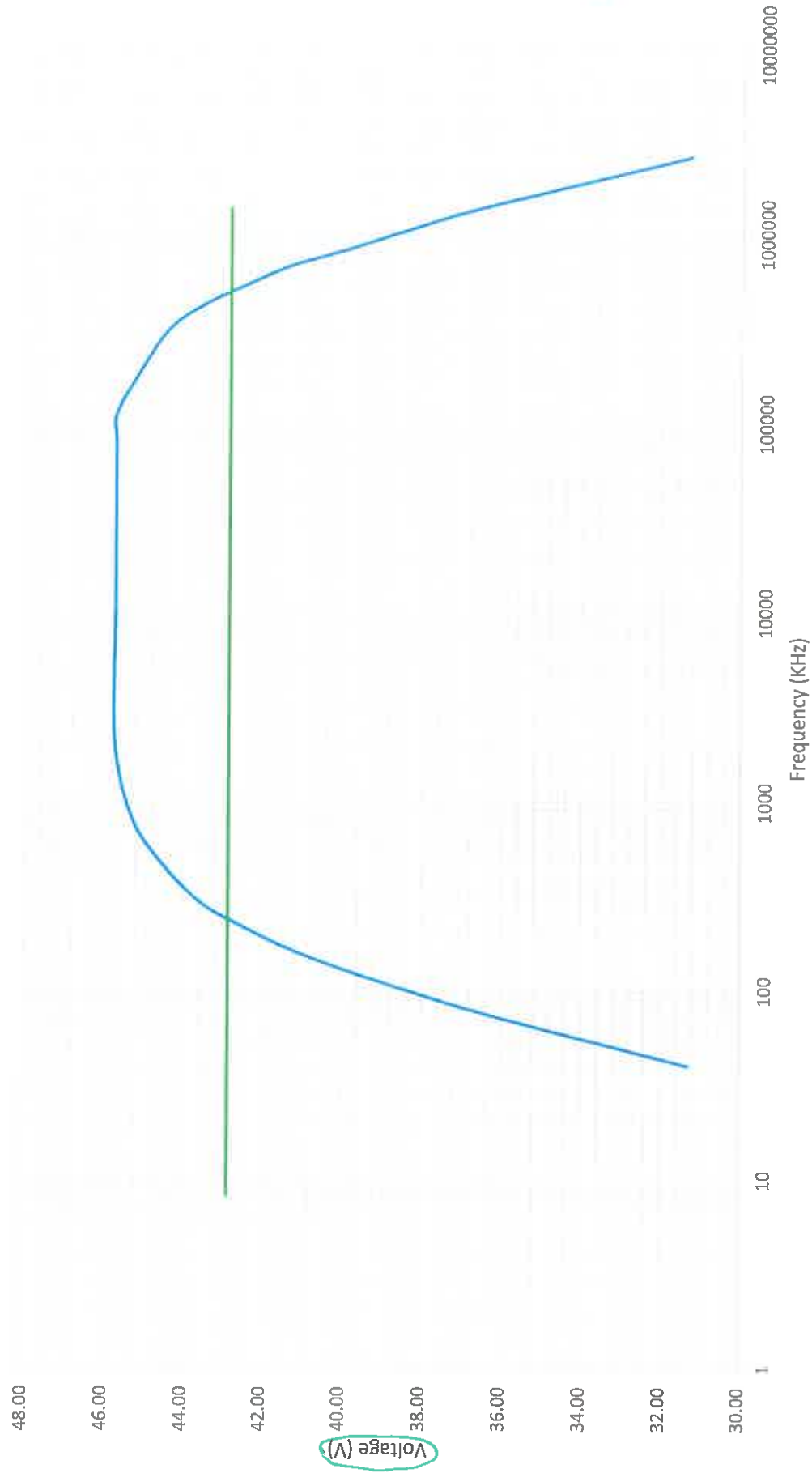


Figure 7.

Part 2 - Tuned Amplifier

Task 1 – Calculations

- a) The resonant frequency

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

- b) The quality (Q) factor

$$Q = \frac{X_L}{R} = \frac{2\pi F_r}{R} = \frac{2\pi \times 15.92 \times 10^3 \times 1 \times 10^{-3}}{R}$$

$$Q = 100.03$$

- c) The bandwidth of the amplifier.

$$BW = \frac{F_r}{Q} = \frac{15920}{100} = 159.2 \text{ Hz}$$

Task 2 – Simulation

- A) The resonant Frequency

- B) The Gain At Resonant

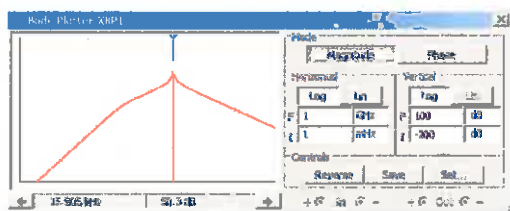


Figure 8 - Resonant Frequency and gain

- C) The bandwidth of the amplifier, which include the upper and lower frequency range

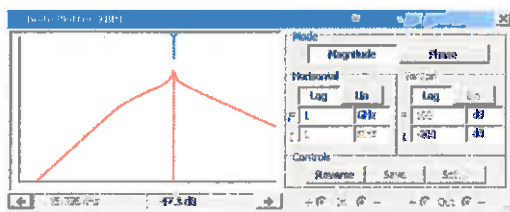


Figure 9 – Lower frequency

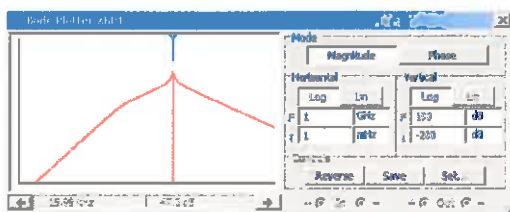


Figure 10 – Upper frequency

$$\text{Bandwidth} = F_2 - F_1 = 15.99 - 15.738 = 252 \text{ Hz}$$

When comparing the calculated results with the measured results the resonant frequency in the calculations was 15.92 kHz whereas the frequency in the measurements was 15.905 kHz, the results from both the measured and calculated is as expected with both results being very similar. The results for the bandwidth when measured and calculated is quite significant this can be seen as the calculated results are 159.2Hz whereas the measured results are 252Hz, the difference between the two results is so large because the software used (Multisim) has a narrow frequency line on the bode

plotter, in turn this make the results very hard to accurately measure which results in the results being so different.

Part 3 - Operational Amplifier Circuits

Task 1: Simulation using Multisim

A)

Simulated		circuit 2			Circuit 3		circuit 4		
Vin	Vout	Vin1	Vin2	Vout	Vin	Vout	Vin1	Vin2	Vout
0.5	-4.988	1	0.5	-4.988	0.5	5.512	0.5	0.5	1.003
1	-9.987	2	1	-9.988	1	11.012	1	1	2.003
1.5	-13.917	1.5	1.5	0.1	1.5	13.925	1.5	1.5	3.003
2	-13.917	2.5	2	-4.988	2	13.925	2	2	4.003
-0.5	5.012	-1	-0.5	5.011	-0.5	-5.488	-0.5	-0.5	-0.9
-1	10.011	-1.5	-2	-4.989	-1	-10.988	-1	-2	-2.997
-1.5	13.918	-2	-1	10.011	-1.5	-13.925	-1.5	-1	-2.497
-2	13.917	-2.5	-0.5	13.915	-2	-13.925	-2	-0.5	-2.497

Figure 11.

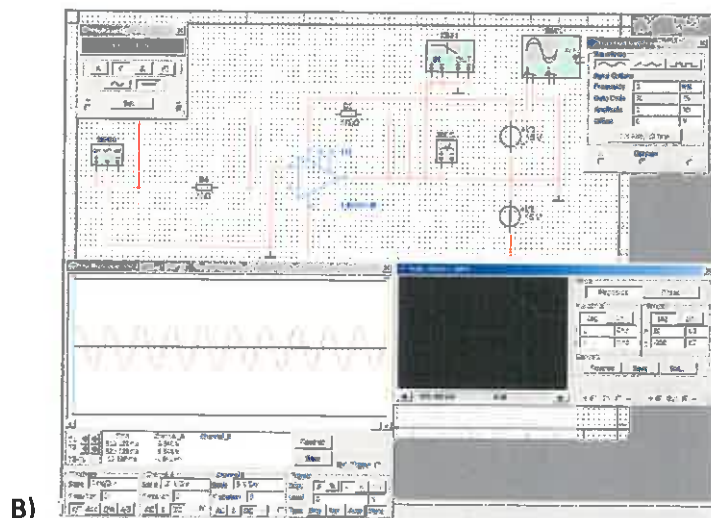
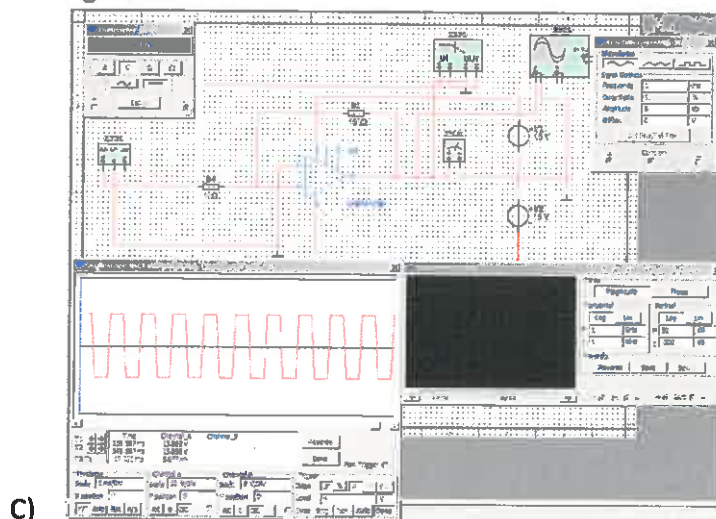


Figure 12.



Should have included calculated values.

Figure 13.

Task 2: Experimental measurement

measurements									
circuit 1		circuit 2			Circuit 3		circuit 4		
Vin	Vout	Vin1	Vin2	Vout	Vin	Vout	Vin1	Vin2	Vout
0.5	-5.04	1	0.5	5.2	0.5	5.58	0.5	0.5	0.97
1	-10.05	2	1	10.2	1	11.08	1	1	2.05
1.5	-12.65	1.5	1.5	-0.01	1.5	14.54	1.5	1.5	2.87
2	-12.67	2.5	2	4.89	2	14.54	2	2	3.98
-0.5	5.01	-1	-0.5	5.47	-0.5	-5.44	-0.5	-0.5	-1.12
-1	9.99	-1.5	-2	5.08	-1	-10.97	-1	-2	-3.03
-1.5	14.49	-2	-1	-10.07	-1.5	-12.72	-1.5	-1	-2.38
-2	14.48	-2.5	-0.5	-12.74	-2	-12.75	-2	-0.5	-2.45

Figure 14.

Frequency (kHz)	Output Voltage (V)	Phase Relationship	Gain dB
1	9.8	180	19.82
3	10.2	180	20.17
8	10.2	180	20.17
10	10	180	20.00
13	10	180	20.00
16	10	180	20.00
20	10	180	20.00
30	10	180	20.00
50	9.8	175	19.82
80	9.6	170	19.65
200	8.4	154	18.49
300	7.2	146	17.15
500	5.6	121	14.96
800	3.8	110	11.60
1000	3	92	9.54

Figure 15.

Vin ?

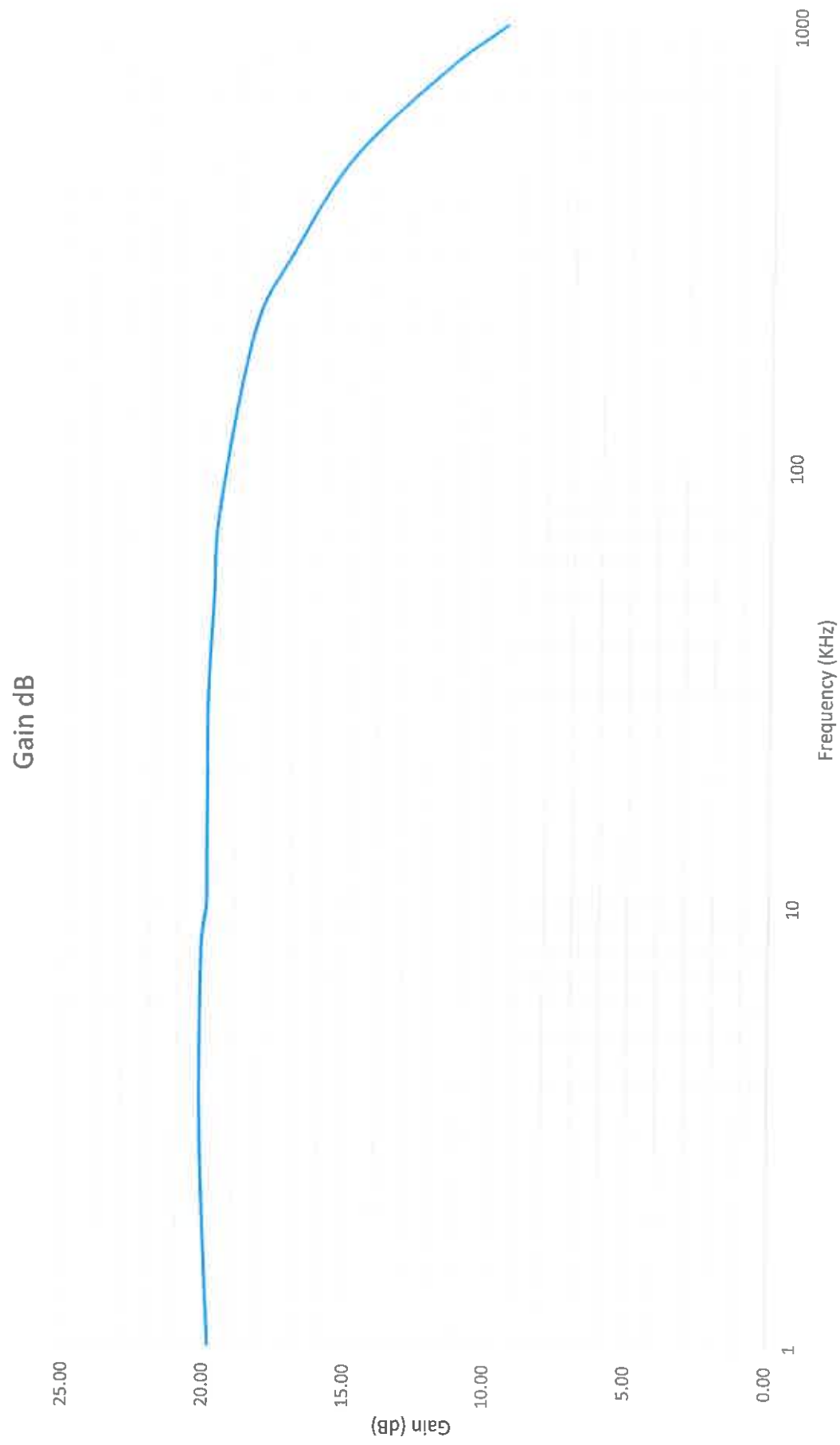


Figure 16.



Figure 17 – The screenshot above is an image of a practical task that needed the use of a oscilloscope.

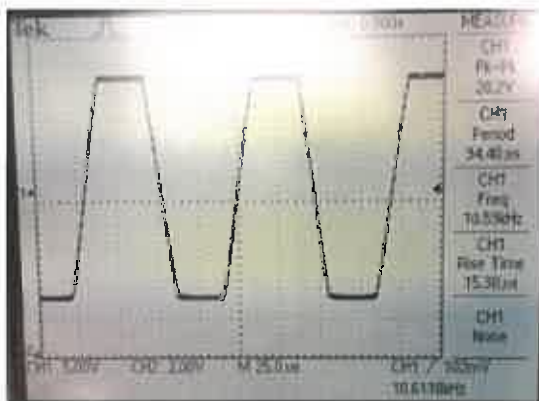


Figure 18 - The screenshot above is an image of a practical task that needed the use of a oscilloscope.

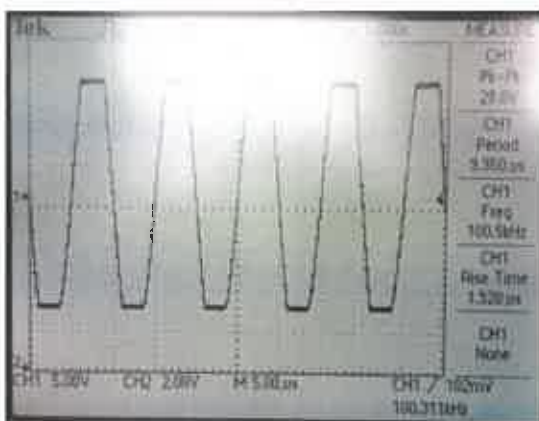
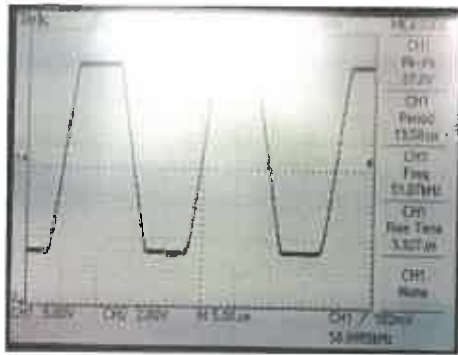


Figure 19 - The screenshot above is an image of a practical task that needed the use of a oscilloscope.



What does the shape of the waveform tell you?

Figure 20 - The screenshot above is an image of a practical task that needed the use of an oscilloscope.

Task 3: Comparison of simulation and experimental results

When getting the results from the simulation, the data that was produced was close but not exactly the same as the experimental results, this is because when using a piece of equipment such as an oscilloscope, there are many different factors that can cause the results to be different from the simulation results, this is because the components within the oscilloscope can differ slightly from every time that a result is being produced.

Task 4 – Negative Feedback

A negative feedback amplifier is designed to have a certain amount of voltage feedback to control its gain. A negative feedback amplifier has a fraction of its output feedback into the input terminals in antiphase with the input, so that the negative feedback opposes the original signal input.

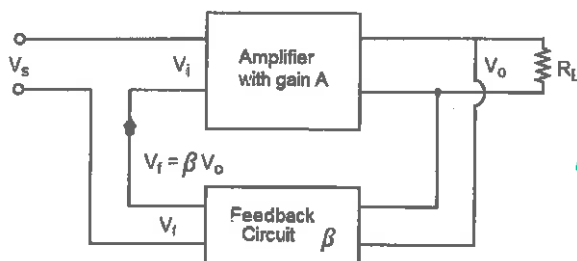


Figure 21.

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

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

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

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

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

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

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

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

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

$$V_{out}/V_{in} = \text{Voltage gain} = A_V$$

References

<https://www.electronics-tutorials.ws/amplifier/amplifier-classes.html>

https://www.electronics-tutorials.ws/amplifier/amp_5.html

https://www.electronics-tutorials.ws/amplifier/amp_6.html

https://www.electronics-tutorials.ws/opamp/opamp_1.html

<https://www.electronics-tutorials.ws/systems/negative-feedback.html>

<http://www.learnabout-electronics.org/Amplifiers/amplifiers52.php>

<http://www.circuitstoday.com/class-b-power-amplifiers>

<http://www.circuitstoday.com/class-c-power-amplifier>

https://www.electronics-notes.com/articles/analogue_circuits/operational-amplifier-op-amp/op-amp-basics.php

Harvard Referencing

Anon, (2018). [Online] Available at: https://www.electronics-tutorials.ws/amplifier/amp_5.html [Accessed 23 Mar. 2018].

Class A Power Amplifiers. 2018. Class A Power Amplifiers. [ONLINE] Available at: <http://www.learnabout-electronics.org/Amplifiers/amplifiers52.php>. [Accessed 23 March 2018].

Electronic Circuits and Diagrams-Electronic Projects and Design. 2018. Class B power amplifier. [ONLINE] Available at: <http://www.circuitstoday.com/class-b-power-amplifiers>. [Accessed 23 March 2018].

Electronic Circuits and Diagrams-Electronic Projects and Design. 2018. Class C power amplifier circuit diagram and theory. Output characteristics DC load line. [ONLINE] Available at: <http://www.circuitstoday.com/class-c-power-amplifier>. [Accessed 23 March 2018].

electronics radio. 2018. Op Amp Basics | what is an Operational Amplifier | Electronics Notes. [ONLINE] Available at: https://www.electronics-notes.com/articles/analogue_circuits/operational-amplifier-op-amp/op-amp-basics.php. [Accessed 23 March 2018].

FAIRCHILD
 SEMICONDUCTOR

June 2007

BC183

NPN General Purpose Amplifier



TO-92
 1. Collector 2. Base 3. Emitter

Absolute Maximum Ratings $T_C=25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Value	Units
V_{CE0}	Collector-Base Voltage	45	V
V_{CE0}	Collector-Emitter Voltage	30	V
V_{EB0}	Emitter-Base Voltage	5	V
I_C	Collector Current (DC)	100	mA
P_C	Collector Dissipation ($T_A=25^\circ\text{C}$)	350	mW
T_{JTB}, T_J	Storage Junction Temperature Range	-55 ~ 150	$^\circ\text{C}$

Electrical Characteristics $T_C=25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Conditions	Min.	Max	Units
BV_{CE0}	Collector-Base Voltage	$I_C = 10\mu\text{A}$	45		V
BV_{CE0}	Collector-Emitter Voltage	$I_C = 2\text{mA}$	30		V
BV_{EB0}	Emitter-Base Voltage	$I_E = 10\mu\text{A}$	5		V
I_{CE0}	Collector Cut-off Current	$V_{CE} = 30\text{V}$		15	nA
I_{EB0}	Emitter Cut-off Current	$V_{EB} = 4.0\text{V}$		15	nA
h_{FE}	DC Current Gain	$V_{CE} = 5\text{V}, I_C = 10\mu\text{A}$ $V_{CE} = 5\text{V}, I_C = 100\text{mA}$	40 80		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 10\text{mA}, I_B = 0.5\text{mA}$ $I_C = 100\text{mA}, I_B = 5.0\text{mA}$		0.25 0.6	V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	$I_C = 100\text{mA}, I_B = 5\text{mA}$		1.2	V
$V_{BE(on)}$	Base-Emitter On Voltage	$V_{CE} = 5\text{V}, I_C = 2\text{mA}$	0.55	0.7	V
C_{ob}	Output Capacitance	$V_{CE} = 10\text{V}, f = 1.0\text{MHz}$		5	pF
f_T	Current gain Bandwidth Product	$V_{CE} = 5\text{V}, I_C = 10\text{mA}$, $f = 100\text{MHz}$	150		MHz
h_{fe}	Small Signal Current Gain	$V_{CE} = 5\text{V}, I_C = 2\text{mA}$, $f = 100\text{Hz}$	125	900	
NF	Noise Figure	$V_{CE} = 5\text{V}, I_C = 200\text{mA}$ $R_G = 2\text{K}\Omega, f = 1\text{KHz}$		10	dB

BC183 NPN General Purpose Amplifier

