

LEVEL 4 ASSESSMENT SPECIFICATION

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Programme:	HNC Electrical/Electronic Engineering		
Module:	Electronics		
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Lecturer:	Jason Pointer	Internal Verifier:	Nigel Richards
Assignment Title:	Diodes and Amplifiers	Word count (or equivalent):	2000
Submission deadline:	19/01/23	Return date of provisional marks & written feedback:	02/02/23
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (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.

STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill 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.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	10	4.4
Engagement with a limited range of mostly relevant and credible sources. Generally sound referencing technique but should include text books within your references.		
2. Knowledge and Understanding Skills	35	20.1
Task 1 achieved 52%. Task 2 achieved 62%, Task 3 achieved 58%. Knowledge of the basic underlying concepts and principles is accurate with a good understanding in most areas but have included some information that does not relate directly to the circuits. Generally the calculation work is very good.		
3. Cognitive and Intellectual Skills	15	6.3
Limited attempt at evaluation of the underlying concepts and principles for most of the tasks.		
4. Practical Application Skills	30	19.4
Task 1 achieved 58%. Task 2 achieved 68%. Task 3 achieved 68%. A very good application of practical work for Task 2 and 3, very good use of the test equipment and Multisim to obtain the required test results. Did not include all simulation results for Task 1.		
5. Transferable Skills for Life and Professional Practice	10	7.5
Work is coherent, very fluent and is presented professionally. Excellent layout making the assignment easy to read.		

Assessment 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)		58%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		



Diodes and Amplifiers

HNC ELECTRICAL AND ELECTRONIC ENGINEERING -
ELECTRONICS
CHLOE PRICE

JASON POINTER

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Introduction

Within this assignment I will demonstrate an understanding of semi-conductor components and characteristics and their application in analogue and digital electronic circuits. Furthermore, I will design, simulate, build, test, and evaluate analogue and digital electronic circuits using information gained from datasheets. ✓

Task 1 – Characteristics of Diodes

A **Diode** is known as a semiconductor device that allows the flow of current through one direction but restricts any current through the reverse direction. Diodes have polarity, which are determined by a positive (anode) lead and a negative (cathode) lead. When a diode allows current through, this is known as forward biased.

Whereas when a diode is reverse-biased, this does not allow current to flow and acts as an insulator. ✓

A diode is also known as a **pn junction**, this is made up of two terminals that have polarity, P-Type (anode) and N-Type (cathode) material. Bias within an electrical circuit allows current to flow only in one direction. Forward biased is where the positive terminal is connected to the anode and the negative terminal is connected to the cathode, this results in the depletion region narrowing, low resistance and maximum current flow through the diode when connected in forward bias. Reverse biased is the opposite of forward biased, where the cathode is connected to the positive terminal, the anode is connected to the negative terminal, the results in the depletion region widening, high resistance, no flow of current; there may be extreme small amounts of current through the diode, this is known as leakage. Breakdown will arise in the circuit if high voltage and will cause damage to the diode. ✓

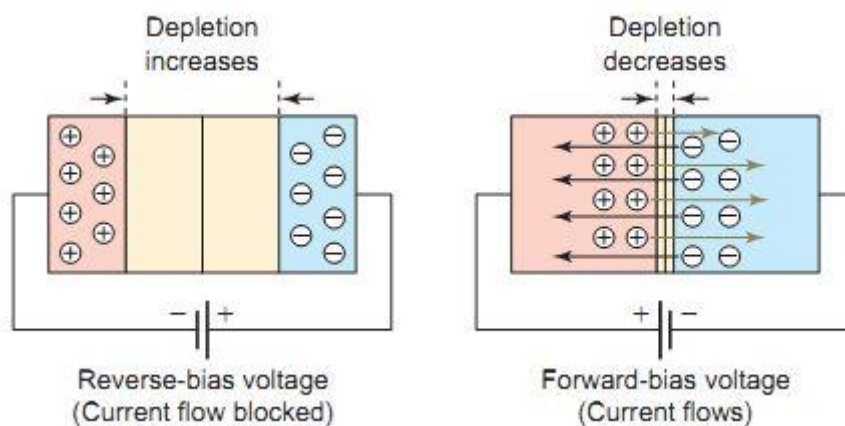


Image 1 – Reverse / Forward Bias Voltage (Motor Control Electronics (part a), n.d.)

State what you are doing

Germanium Diode Results

Forward Bias	
<u>Voltage Increase</u>	<u>Current (A)</u>
0	0
0.1	0.018mA
0.2	0.165mA
0.3	0.567mA
0.4	1.165mA
0.5	1.902mA
0.6	3.01mA
0.7	3.66mA
0.8	4.74mA
0.9	5.87mA
1	7.1mA

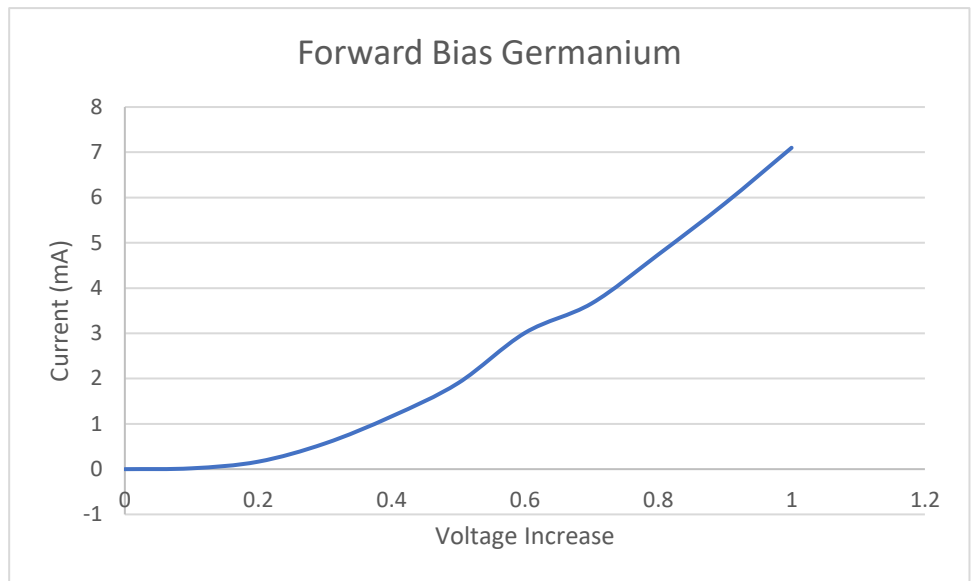


Image 2 – Germanium Forward Bias Graph

Reverse Bias			
<u>V1 (V)</u>	<u>V2 (V)</u>	Diode Voltage (V)	Current(μA)
0	0	0	0
-1.5	-0.033	-1.467	-3.3
-3	-0.052	-2.948	-5.2
-4.5	-0.07	-4.43	-7
-6	-0.097	-5.903	-9.7
-7.5	-0.132	-7.368	-13.2
-9	-0.178	-8.822	-17.8
-10.5	-0.231	-10.269	-23.1
-12	-0.291	-11.709	-29.1
-13.5	-0.358	-13.142	-35.8
-15	-0.426	-14.574	-42.6

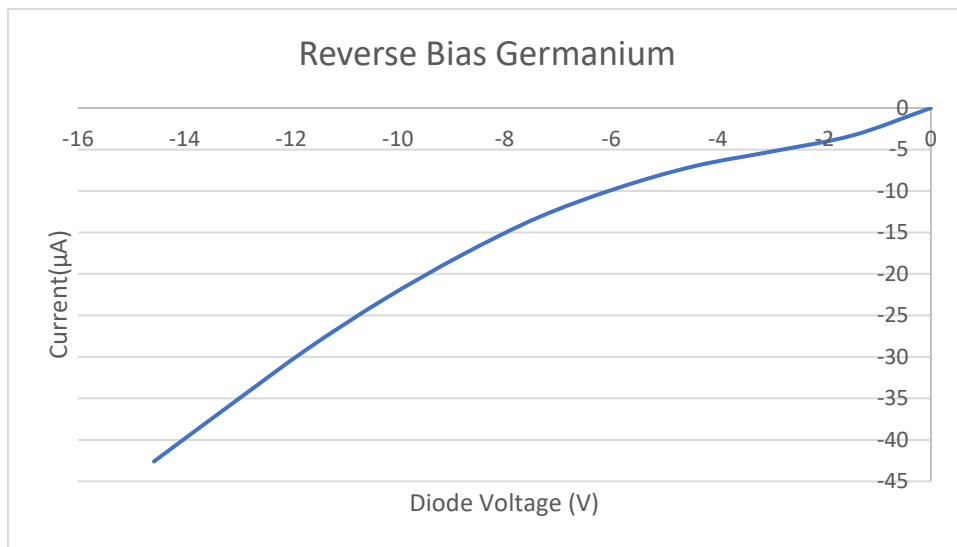


Image 3 – Germanium Reverse Bias Graph

Silicon Diode Results

Forward Bias	
<u>Voltage Increase</u>	<u>Current (mA)</u>
0	0
0.1	0.00004
0.2	0.00025
0.3	0.00177
0.4	0.01287
0.5	0.1
0.6	0.781
0.7	6.06
0.8	32.7

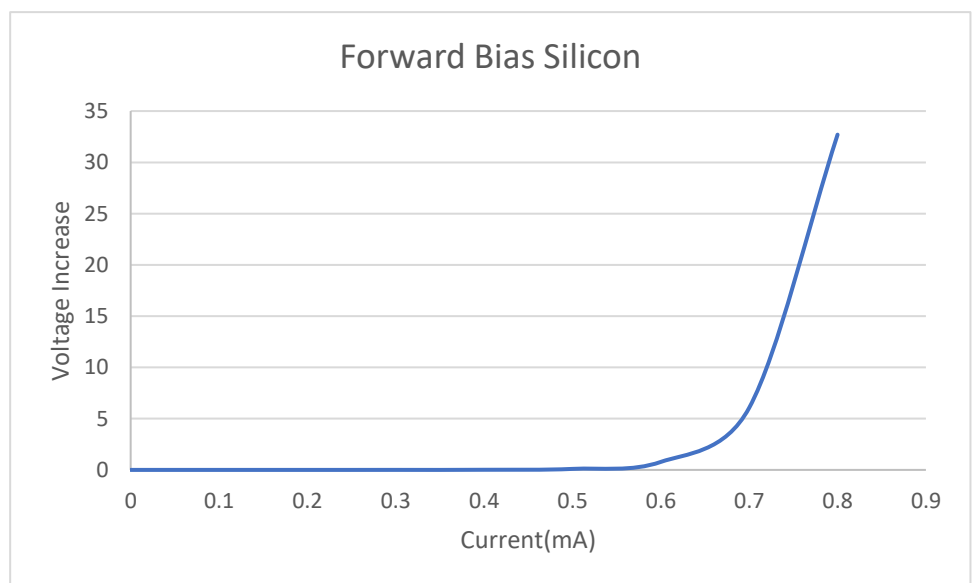


Image 4 – Silicon Forward Bias Graph

Reverse Bias			
<u>V1 (V)</u>	<u>V2 (mV)</u>	Diode Voltage (V)	Current(nA)
0	0	0	0
-1.5	-77	-1.423	-7.7

Place on new page.

-3	-89	-2.911	-8.9
-4.5	-90.5	-4.4095	-9.05
-6	-95	-5.905	-9.5
-7.5	-99	-7.401	-9.9
-9	-101.2	-8.8988	-10.12
-10.5	-104.8	-10.3952	-10.48
-12	-107.9	-11.8921	-10.79
-13.5	-109.8	-13.3902	-10.98
-15	-110.1	-14.8899	-11.01

In the results above we can see that in the germanium diode measured results.

There is more resistance in the diode compared to the silicon diode. This is because the silicon diode is less sensitive than the germanium diode, hence the operation of silicon diodes is stable with changes in temperature. The silicon diode has low reverse current compared to germanium and the silicon diode has a large reverse breakdown

voltage about 70-100V compared to germanium which has the reverse breakdown voltage around 50V. ✓

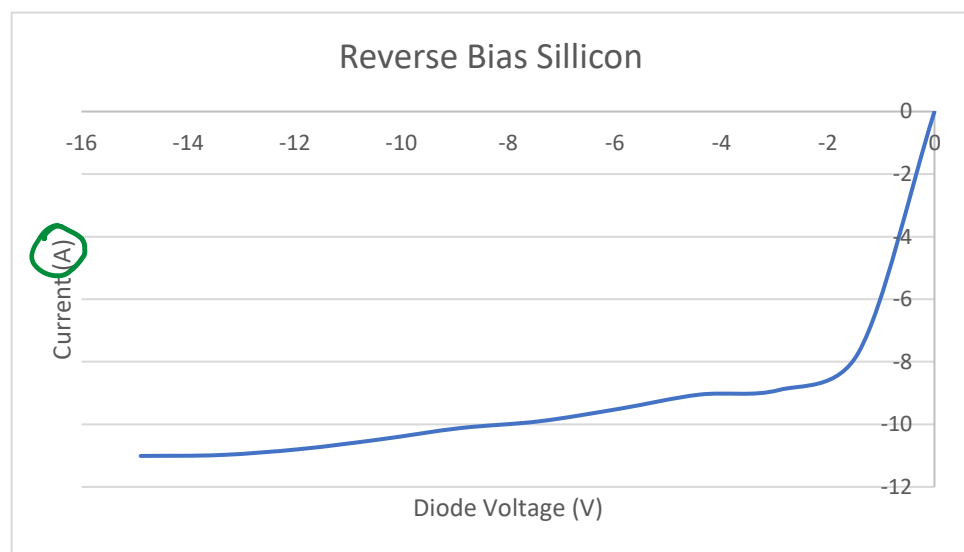


Image 5 – Silicon Forward Bias Graph

I would not put the text around the image

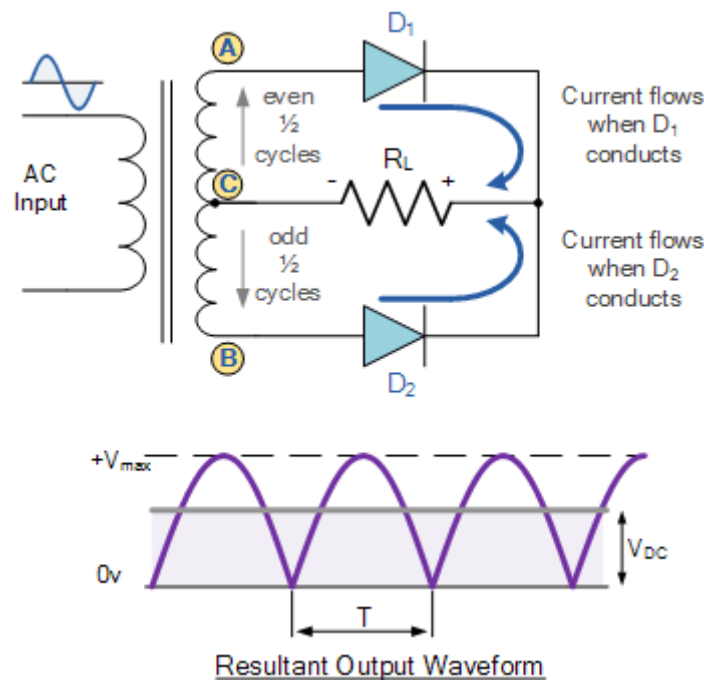
Have not not found the static and dynamic resistance which would have aided your comments.

Task 2 – Voltage Regulator Design

A **Rectifier** is a device that converts alternating current into direct current. There are three various types of rectifiers: half wave rectifier, full wave rectifier and bridge rectifier. ✓

Full wave rectifier

A full wave rectifier requires more than one diode for the full wave rectifier to convert each half of an alternating current wave into a direct current signal. When a rectifier uses both positive and negative halves of a cycle from the AC wave, this type of rectifier is a full wave. By using more than one diode, this allows current through one direction and blocks the current in the reverse direction. A full wave rectifier has less ripple than a half wave rectifier therefore generates a smoother output. ✓



The assignment used a bridge rectifier.

Image 6- Full Wave Rectifier (Full Wave Rectifier, n.d.)

Illustrated in image 6, shows a full waves rectifier that consists of two diodes connected to a single resistor, where one diode at a time will supply the current to the load. At point A labelled in image 6, when that point is positive, diode D₁ operates in the forward direction. As well as at point B, when positive (within the negative half of the cycle), diode D₂ operates in the forward direction allowing the current to flow through the resistor in the same direction in both halves of the cycle,

the direction of flow is illustrated with the blue arrows. When these two waveforms are combined from each half of the cycle, this is what creates the full wave rectifier. ✓

For this element of this task, we are developing a circuit schematic of a power supply and using a full wave rectifier to use within the circuit.

The specifications that will be used within the circuit schematic are as follows:

$$I_2(\min) = 5mA$$

$$P = 300\text{ mW} \quad ✓$$

$$I_2(\max) = \frac{P}{V_2} = \frac{300 \times 10^{-3}}{5.1} = 58.82mA$$

$$V_{in} = 14.5V \quad ✓$$

$$V_2 = 5.1V \quad ✓$$

$$I_R = I_2 + I_L$$

$$V_R = V_{in} - V_2 \quad ✓$$

$$V_R = 14.5 - 5.1 = 9.4V \quad ✓$$

$$R = \frac{V_R}{I_R}$$

$$\text{Let } R_L = 1K\Omega$$

small k

$$I_L = \frac{V_2}{R_L} = \frac{5.1}{1000} = 5.1mA \quad ✓$$

$$I_R(\min) = I_2(\min) + I_L$$

$$= 5 + 5.1 = 10.1mA \quad ✓$$

$$I_R(\max) = I_2(\max) + I_L$$

$$= 58.82 + 5.1 = 63.92mA \quad ✓$$

$$R_{min} = \frac{V_R}{I_R(\max)} \quad ✓$$

$$= \frac{9.4}{63.92 \times 10^{-3}} = 147.06\Omega \quad ✓$$

$$R_{max} = \frac{V_R}{I_R(min)}$$

$$= \frac{9.4}{10.1 \times 10^{-3}} = 930.7\Omega$$

Selected a value between 330, 390, 470, 560, 680

R1 = 470Ω

The following shows a full wave rectifier circuit that has been developed in Multisim to simulate the circuit.

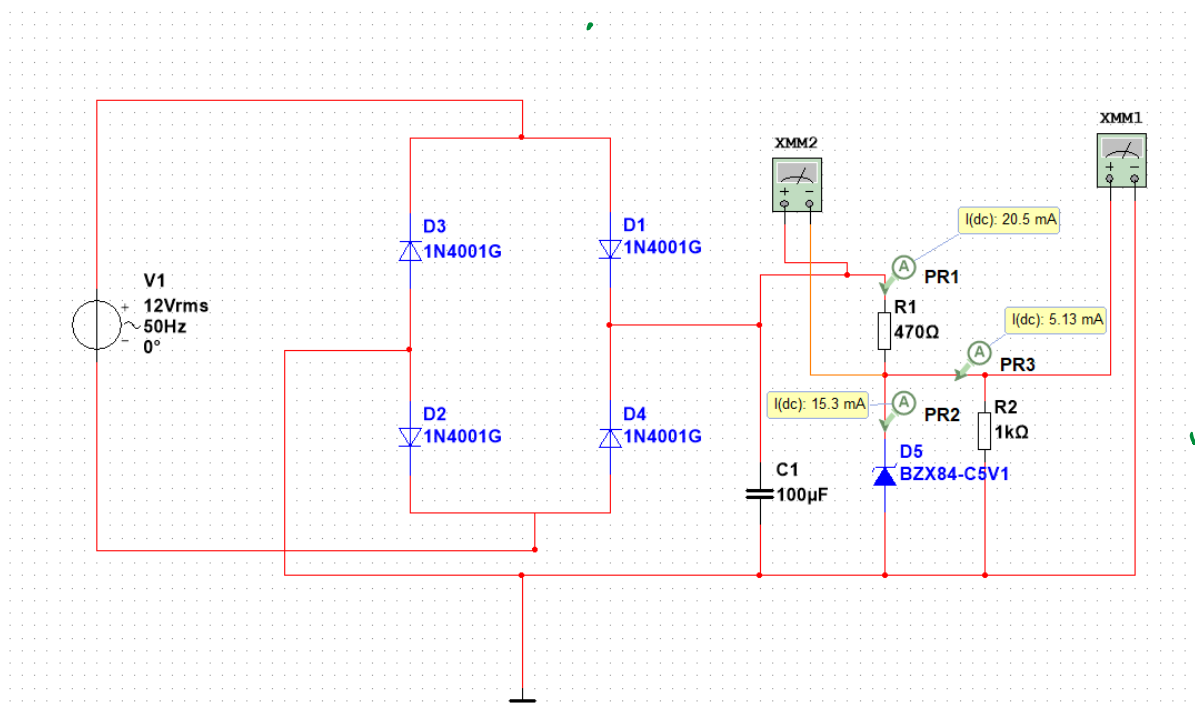


Image 7 – Full wave rectifier simulation

You have not included all the simulation results.

Task 3 – Transistor Amplifier Design and Performance Measurement

A Class B amplifier is an active device where it only conducts for one half of the wave cycle from the input signal, therefore meaning that the conduction angle of the amplifier is 180 degrees. Subsequently the device is switched off for half of the input wave cycle, from this less power is produced but it does improve the efficiency of the amplifier. When a class B amplifier has zero input, there is zero output, meaning that there is no power being used. This is due there being no DC bias because of the transistors are biased at the cut-off, so when there is no input signal there is no power dissipation of the transistor. The class B amplifier uses two types of transistors (PNP and NPN) to be able to create a full waveform cycle. When one of the transistors is positively biased, the other is switched off, this will conduct a positive signal. Whereas, when the other transistor is negative biased then this will produce a negative signal, and the positive transistor will be switched off. Furthermore, the two transistors will create a crossover distortion as an output signal, which means it create low heat and increases efficiency.

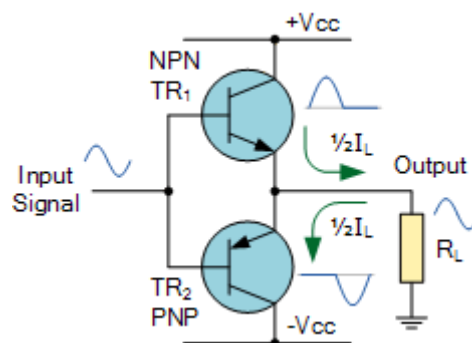


Image 8 – Class B Amplifier (Class AB Amplifier Design and Construction, n.d.)

A Class A amplifier is a device where it allows the transistor to conduct a full 360-degree wave cycle. The “operation the switching transistors Q-point is located near to the centre of the output characteristic load line of the transistor and within the linear region.” (Class AB Amplifier Design and Construction, n.d.). An advantage of a Class A amplifier is the reduction in distortion this is due to the signal always being able to reproduce an input signal. Though a Class A amplifier suffers from poor efficiency due to the transistor at the centre of the load line, therefore even if there is

no input signal to amplifier, there must always be a DC current flowing through the switching transistor. ✓

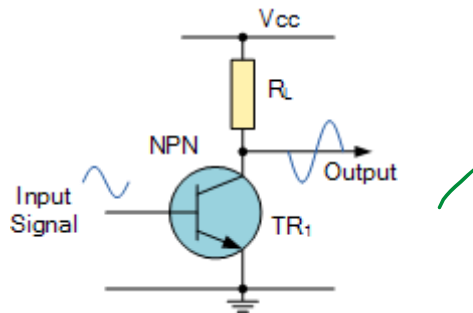


Image 9 – Class A Amplifier (Class AB Amplifier Design and Construction, n.d.)

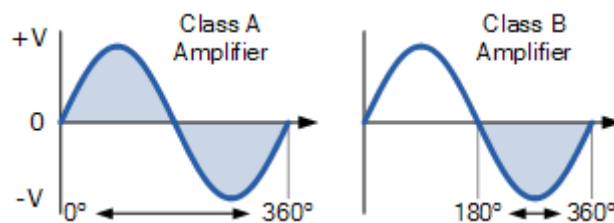


Image 10 - (Class AB Amplifier Design and Construction, n.d.)

As illustrate in image 9 a Class A amplifier produces a full 360-degree waveform from a single output transistor. Whereas a Class B amplifier conducts a 180-degree waveform from two output transistors. ✓

A Class A common emitter amplifier has been designed and calculated from the following figures.

Appendix 1 is attached for reference.

Volts (V_{cc}) = 9 Volts

Transistor Value = BC109 ✓

HfE Value = 311

Collector Current (I_Q) = 10% of 10mA = 1mA = 0.001A ✓

$$I_c = I_Q$$

$$R_C = \frac{V_{CC}}{2 \times I_C} = \frac{9}{2 \times (5 \times 10^{-3})} = 900 k\Omega$$

$$= 820 \Omega$$

$$I_E = I_C$$

$$I_E = 5 \times 10^{-3}$$

$$V_E = 1.08$$

$$R_E = \frac{V_E}{I_E} = \frac{1.08}{5 \times 10^{-3}} = 216$$

$$= 220 \Omega$$

Base Current (I_B)

$$I_B = \frac{I_C}{H_{fE}} = \frac{15 \times 10^{-3}}{311} = 16.08 \times 10^{-6} \mu A$$

$$V_{BE} = 0.7V$$

$$V_B = V_E - V_{BE} = 1.08 + 0.7 = 1.78V$$

DC bias network current

$$10 \times I_B = 10 \times (16.08 \times 10^{-6}) = 160.8 \times 10^{-5} \mu A$$

Resistance for R_2

$$R_2 = \frac{V_B}{10 \times I_B} = \frac{1.9}{160.8 \times 10^{-5}} = 11.07 \times 10^3 \Omega$$

$$11.07 k \Omega$$

Nearest value.

Resistance for R1

$$R_1 = \frac{V_{CC} - V_B}{11 \times I_B} = \frac{9 - 1.78}{11 \times 16.08 \times 10^{-6}} = 40.82 \times 10^3 \Omega$$

$$= 40.82 k\Omega$$

Nearest value.

Input capacitors = $10\mu F$

From the defined and calculated values, the circuit has been simulated using Multisim to simulate and test the designed circuit under DC and AC conditions, the results are as follows.

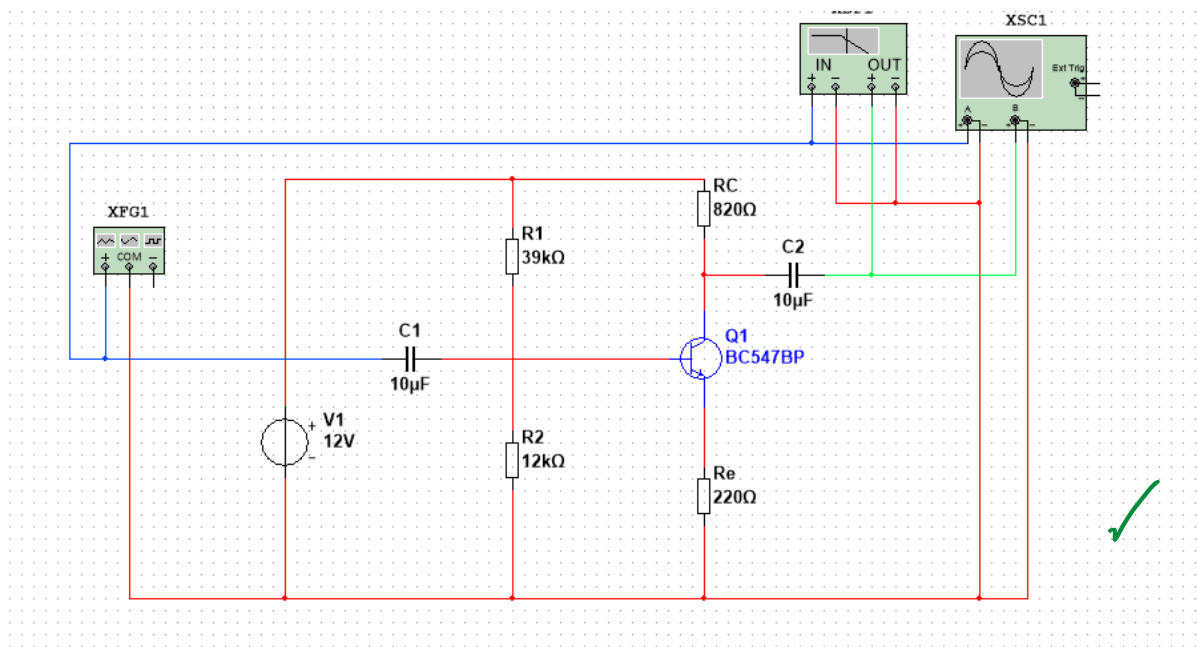


Image 11 – Multisim Class A common emitter amplifier

$$Gain = \frac{V_{Out}}{V_{in}} = \frac{-5.026}{39.799 \times 10^{-3}} = -126.284 dB$$

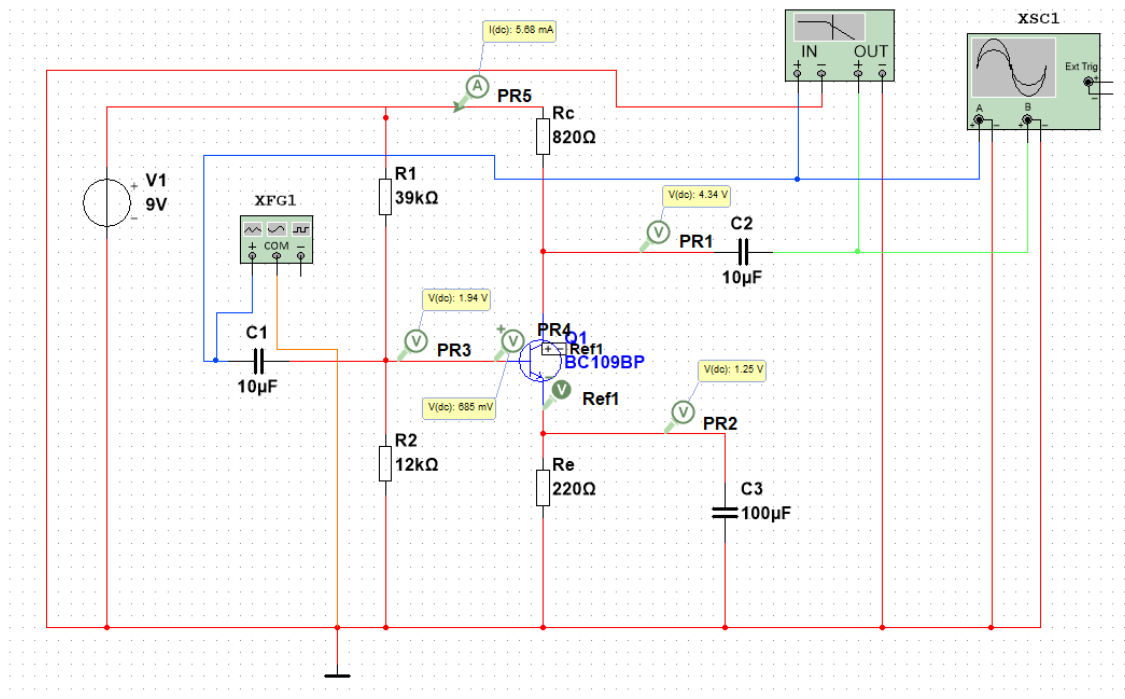


Image 12 – Multisim Circuit showing emitter/base/collector results with probes inserted into the circuit

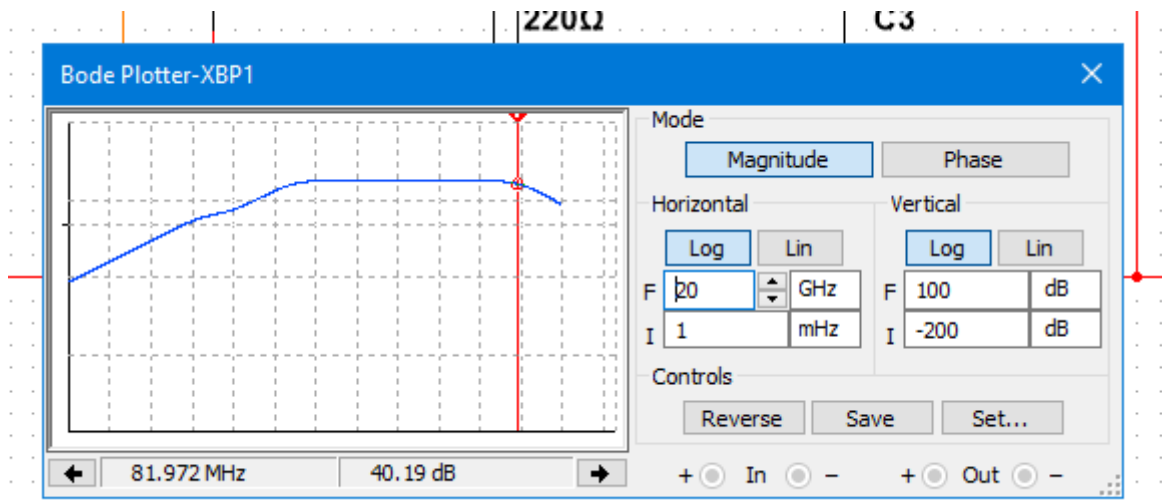


Image 13 – Upper cut of frequency

High cut off frequency = 81.972 MHz

$$81.972 \times 10^6 = 81972000 \text{ Hz}$$

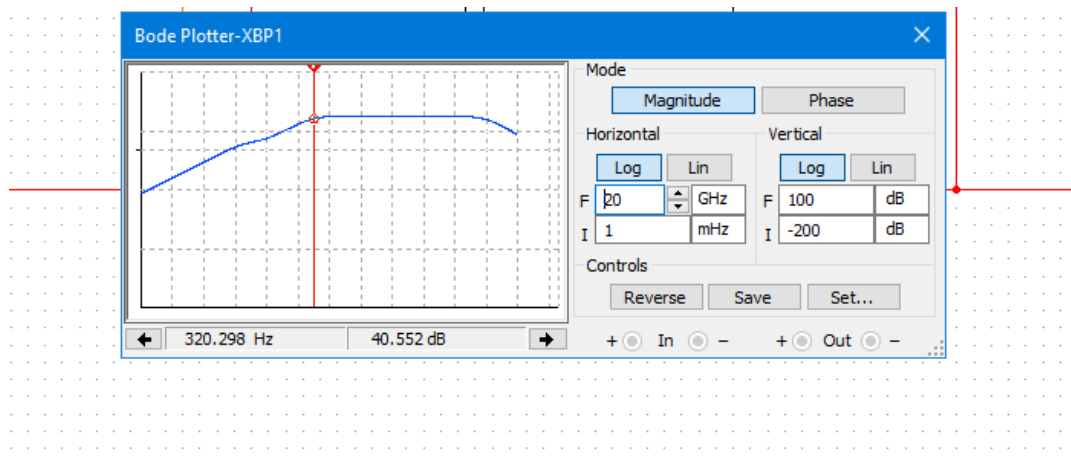


Image 14 – Lower cut of frequency

Low cut off Frequency = 320.298 Hz

Band width = High cut off frequency – Low cut off frequency

$$\text{Band Width} = 81.972 \times 10^6 - 320.298 = 81.971 \text{ MHz}$$

An amplifier circuit has been constructed and measurements of the circuit have been taken. The results taken are to see the functionality of the circuit constructed. After taking the results from the constructed circuit they will then be compared to the simulated and calculated results previously produced in this assignment. There will be slight variations from the constructed circuit in comparison to simulated and calculated results due to the slight variations in resistor values used, this is due to only being able to use what is made available to us, therefore we use the closest values there is available to the desired values used previously. The actual values used in the practical are as follows:

Desired	Actually used
900kΩ	820kΩ
216kΩ	220kΩ
40.82kΩ	39kΩ
11.07kΩ	12kΩ

The following images show the AC amplification of the transistor amplifier circuit constructed. This provides evidence of the practical being carried out, as well as the transistor successfully amplifying the AC waveform. From the images we can see

that the inverted wave signal has been produced, the phase different of the sine wave is 180 degree. The amplification of the circuit can be defined by the resistors used within the circuit.

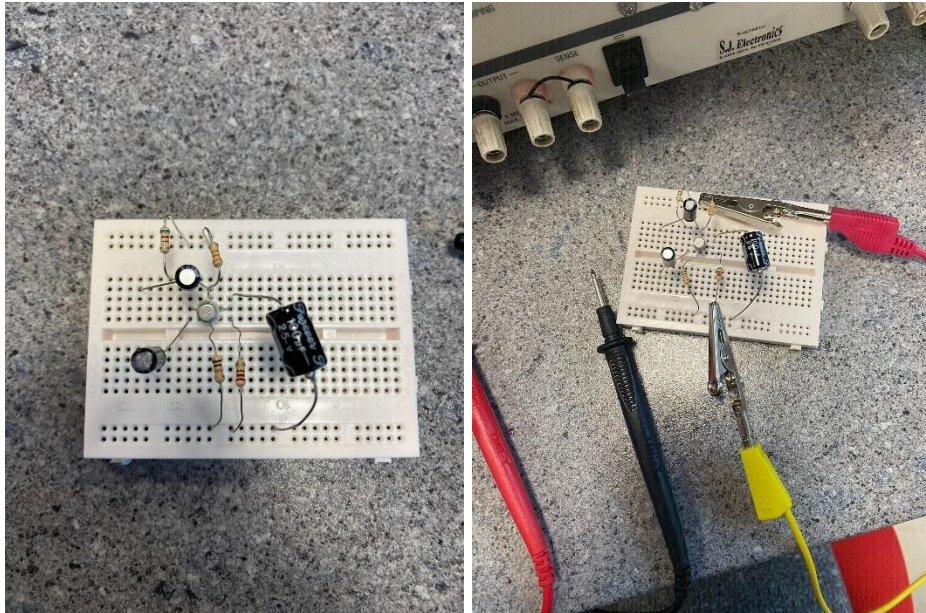


Image 15 & 16 – Breadboard set up

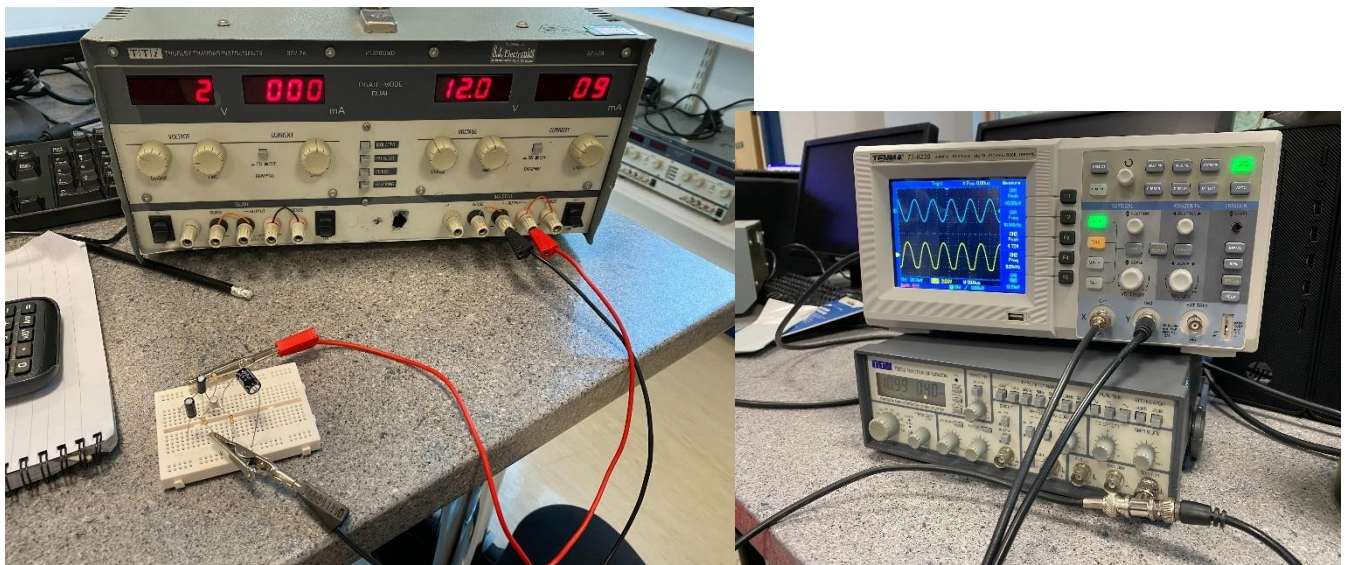


Image 17 & 18 – Amplification waveform

DC Results Compared

	Simulated	Measured	Theoretical
V _C	4.33 V	3.98 V	9 V
V _E	1.26 V	1.32 V	1.08 V
V _B	1.94 V	1.98 V	1.78 V
V _{BE}	687 mV	660 mV	0.7 V
I _C	5.7 mA	6.1 mA	0.005A

4.5V

There are variations between the simulated, theoretical and measured results. The main variations are with the measured results, this is because of the variation between the resistor values calculated and the resistor values that were physically available to use for this practical.

There are variations between the simulated / measured / theoretical results this could be down to human error with either of the types of result, human error is where a result or set of results have occurred where the outcome is outside of its acceptable limits. The fluctuation in results can also be due to tolerances within the various components used in the circuits. Also, as previously stated the resistors used in the practical element of the task had slightly different values to the ones used for the theoretical and simulated elements of this task, this will cause a variation in results.

As part of the practical for this assignment a frequency response to determine the gain was carried out to determine the response in the voltage out by gradually increasing the frequency, the calculating the gain; the results obtained are as follows:

Frequency	output voltage	Gain	Gain (dB)
100	1.76	44	32.87
200	2.96	74	37.38
300	4.48	112	40.98
500	4.66	116.5	41.33
1000	4.72	118	41.44
10000	4.8	120	41.58

50000	4.64	116	41.29
80000	4.64	116	41.29
200000	4.56	114	41.14
500000	4.16	104	40.34
800000	4.01	100.25	40.02
1000000	2.96	74	37.38
2000000	1.8	45	33.06
3000000	1.08	27	28.63
5000000	0.56	14	22.92

From the results table a frequency response curve for the gain was created, this can be seen below:

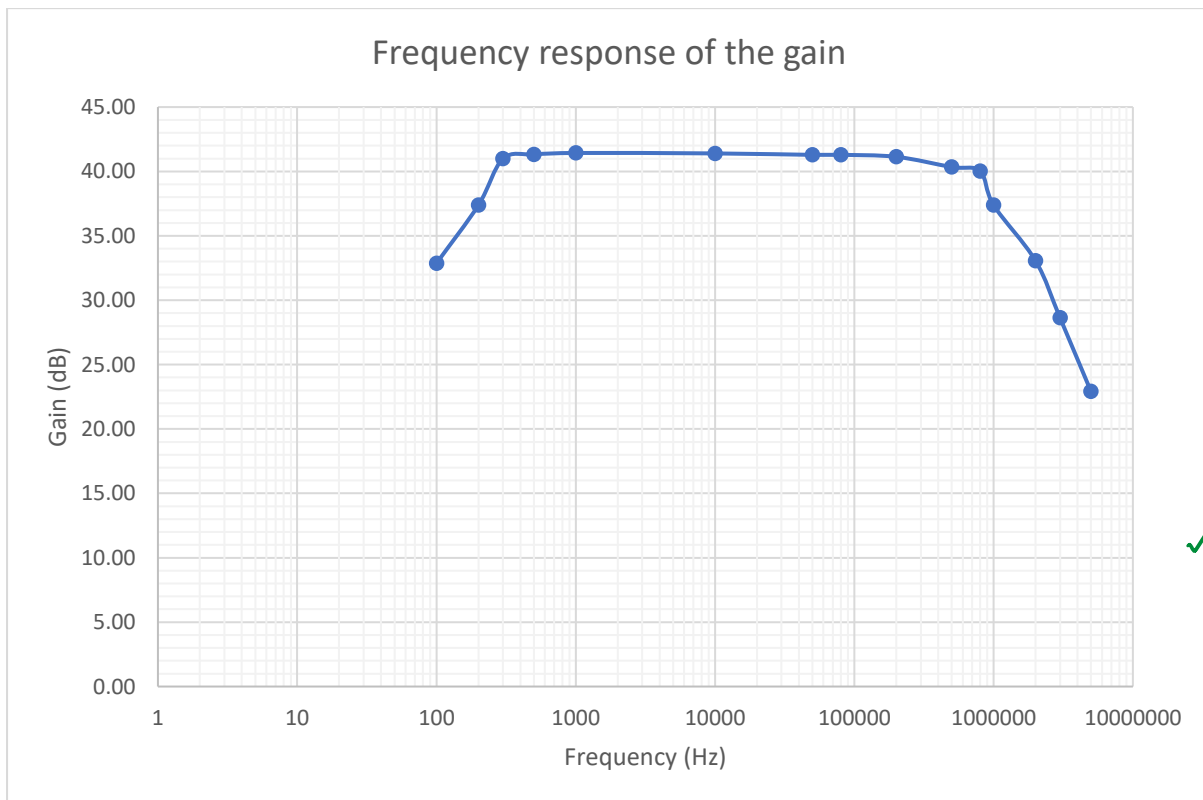


Image 19 – Frequency response of the gain

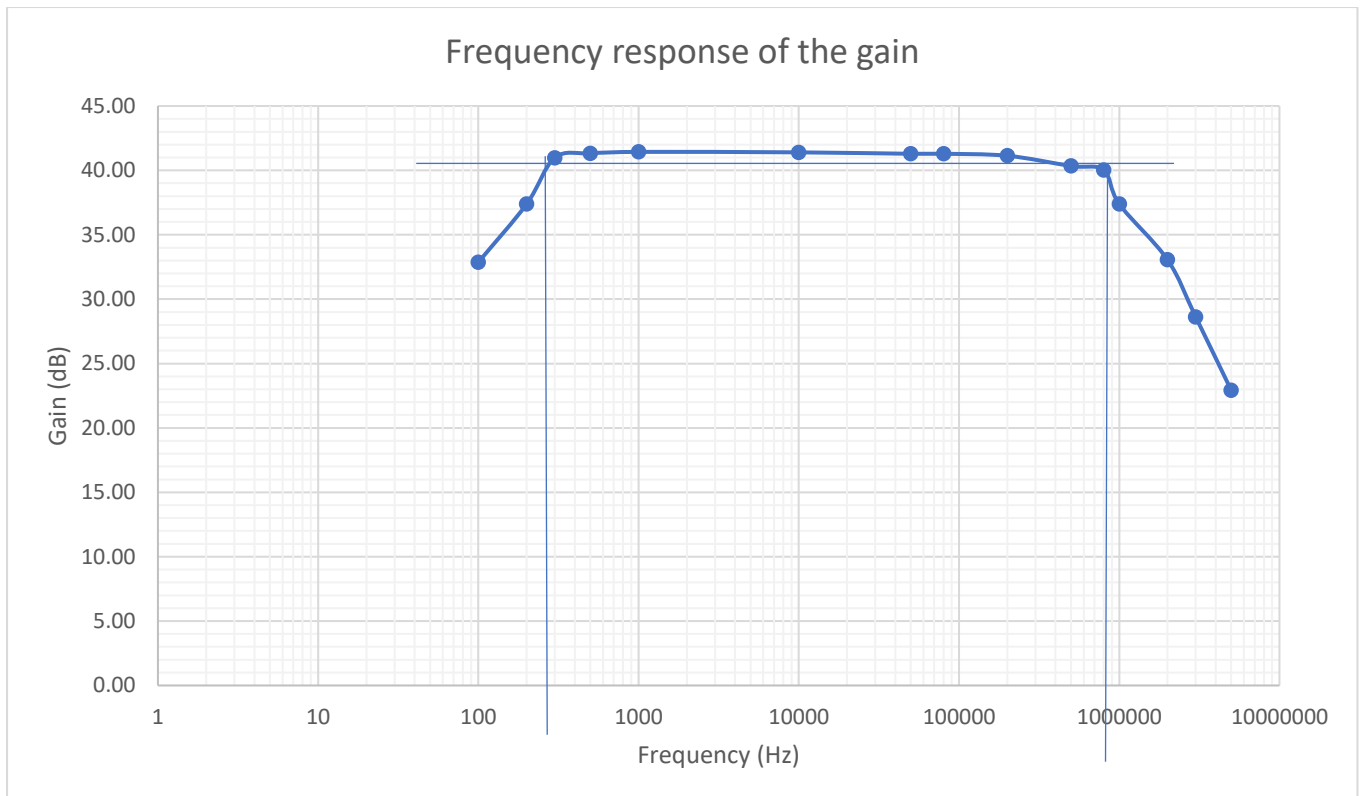


Image 20 – Frequency response of the gain, measuring high/low cut off frequency

From creating the frequency response curve of the gain (as shown in image 20), the high and low cut off frequencies could be calculated from using the curve created, this can be seen as follows:

$$\text{Maximum gain} - 3 = 41.58 - 3 = 38.58 \text{ dB}$$

$$\text{High cut off frequency} = 800 \text{ kHz}$$

$$\text{Low cut off frequency} = 0.3 \text{ kHz}$$

$$\text{Bandwidth} = \text{high cut off frequency} - \text{low cut off frequency}$$

$$\text{Bandwidth} = 800 - 0.3 = 799.7 \text{ kHz}$$

These results vary in comparison to the calculated results as the components each have various tolerances.

Task 4 – Inverting Operational Amplifier

“A inverting amplifier is an op-amp circuit configuration that produces an amplified output signal and this output signal of the inverting op-amp is in-phase with the applied input signal.” (Teja, 2021). When the input voltage is applied to the input terminal of the inverting amplifier the output gain of the amplifier becomes negative unlike a non-inverting amplifier where the output gain is positive. ✓

An inverting amplifier uses a negative feedback connection, it only uses part of the output signal voltage is fed back instead of the whole output signal. The voltage is fed back to the inverting op amp input terminal. ✓

A closed loop arrangement creates an inverting amplifier circuit which is stable, has a high impedance, the resistance in approaches infinity due to the current not flowing into the positive terminal, and has a low output impedance.

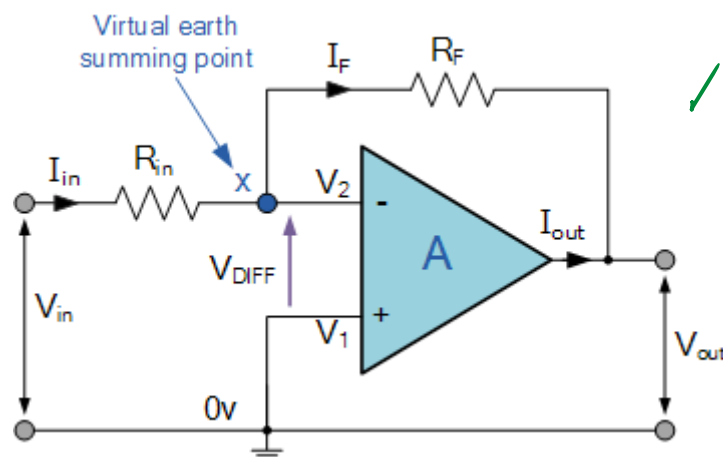


Image 21 – inverting Amplifier Diagram (Inverting Operational Amplifier, n.d.)

A inverting amplifier circuit has been simulated and constructed using a 741 op-amp and a dual power supply of 12V. ✓

Appendix 2 is attached for reference.

The following simulation shows the circuit of a non-inverting amplifier, using a 270kΩ and a 470Ω resistors from finding division factors of 9, allow us to create a voltage gain of 18. This can be seen in the calculations below:

$$\begin{aligned} R_{in} &= 18 \times 2.7k \\ &= 48.6 \end{aligned}$$
 ✓

Used $R_{in} = 470\Omega$)
 $270k\Omega$.

$$F_{max} = 20kHz$$

$$GBP = 1MHz$$

$$Bandwidth = \frac{1 \times 10^6}{18} = 55.55kHz$$

$$Gain = 18 = \frac{-R_F}{R_{in}}$$

$$R_F = 18 \times R_{in}$$

$$R_{in} = 2.7$$

$$= 18 \times 2.7$$

$$= 48.6$$
 ?

As part of the practical for this assignment a inverting operational amplifier to determine the gain was carried out to determine the response in the voltage out by gradually increasing the frequency, the calculating the gain; the results obtained are as follows:

The results below shown in a table.

DC Input	DC Output	Gain
0.1	-1.64	-16.4
0.3	-3.38	-11.2666667
0.4	-6.69	-16.725
0.5	-8.54	-17.08
0.6	-10.14	-16.9
0.7	-10.68	-15.2571429
0.8	-10.69	-13.3625
0.9	-10.69	-11.8777778
1	-10.69	-10.69

 ✓

AC Input Voltage	Output Voltage
0.2	3.4
0.4	7
0.6	9.6
0.8	13.4
1	17.4
1.2	20.8
1.4	22.4
1.6	22.6
1.8	22.4

 ✓

2	22.6
---	------

Frequency (Hz)	Vout (V)	Gain	Gain (DB)
100	8.08	16.16	24.16882713
500	8.08	16.16	24.16882713
1000	8.16	16.32	24.25440309
10000	7.76	15.52	23.81783434
20000	6.8	13.6	22.67077817
30000	5.68	11.36	21.10756663
60000	3.22	6.44	16.17771735
90000	2.08	4.16	12.38186661
100000	1.9	3.8	11.59567193
300000	0.708	1.416	3.021265067
500000	0.42	0.84	-1.51441428
700000	0.308	0.616	-4.20838576
900000	0.23	0.46	-6.74484337
1000000	0.198	0.396	-8.04609628

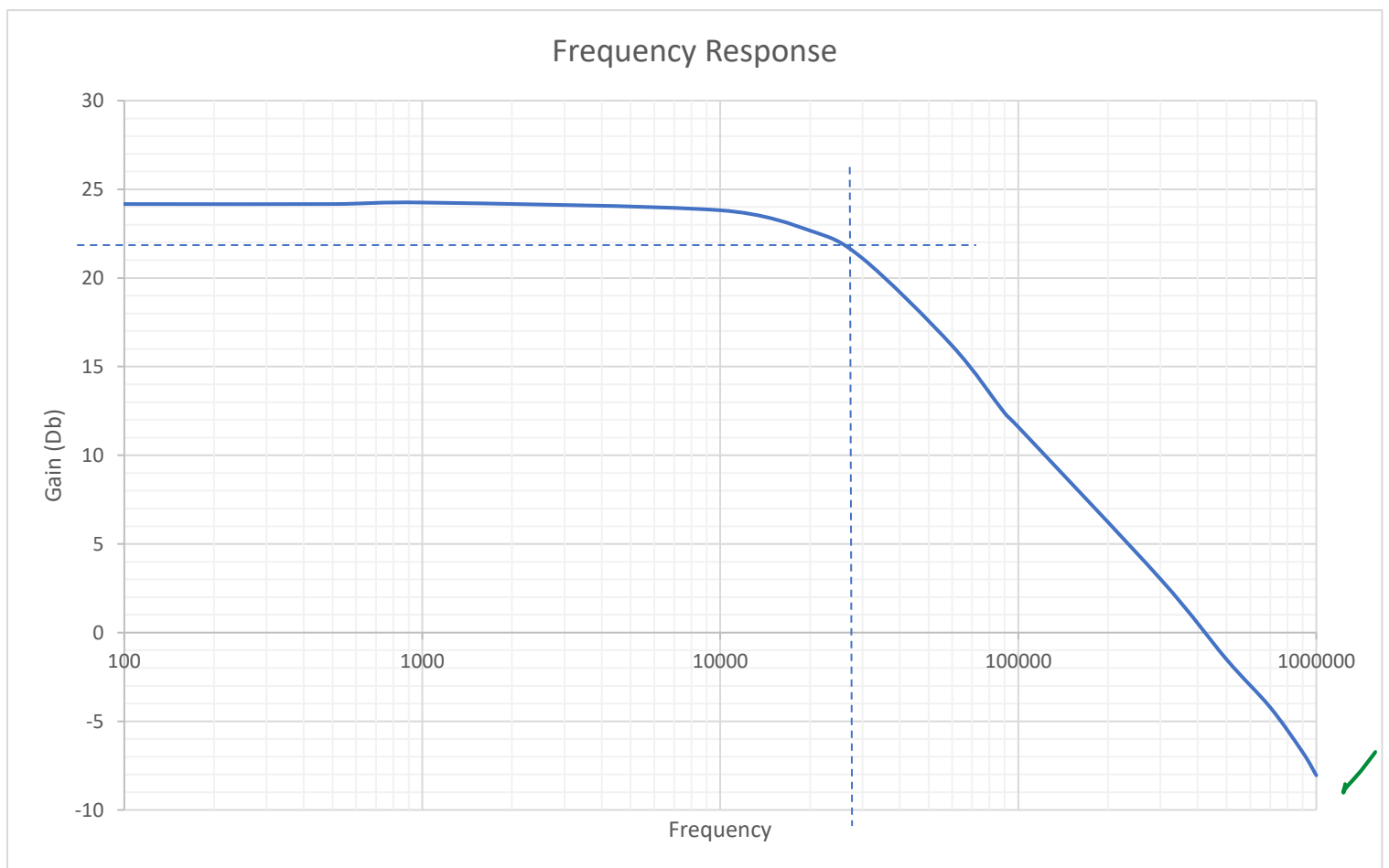


Image 22 – Frequency Response

There following images show the inverting amplifier circuit constructed. This provides evidence of the practical being carried out, as well as the inverting amplifier

successfully amplifying the AC waveform. From the images we can see that the inverted wave signal has been produced. The amplification of the circuit can be defined by the resistors used within the circuit.

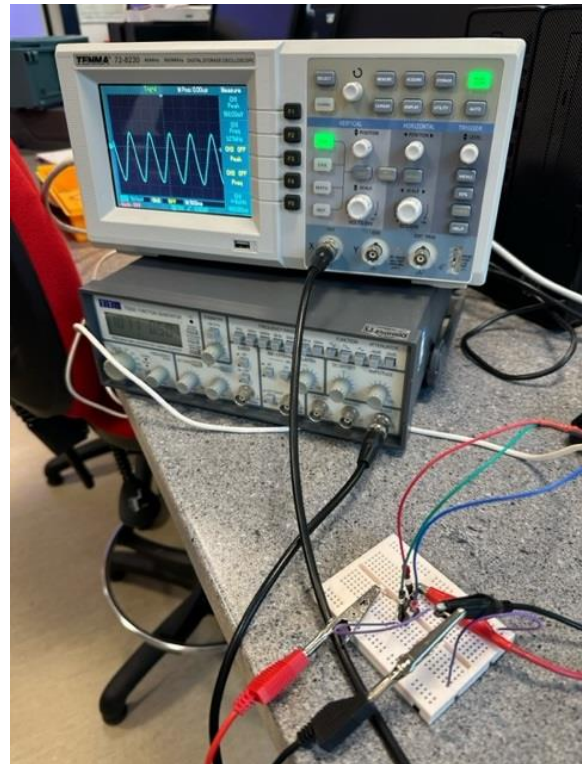
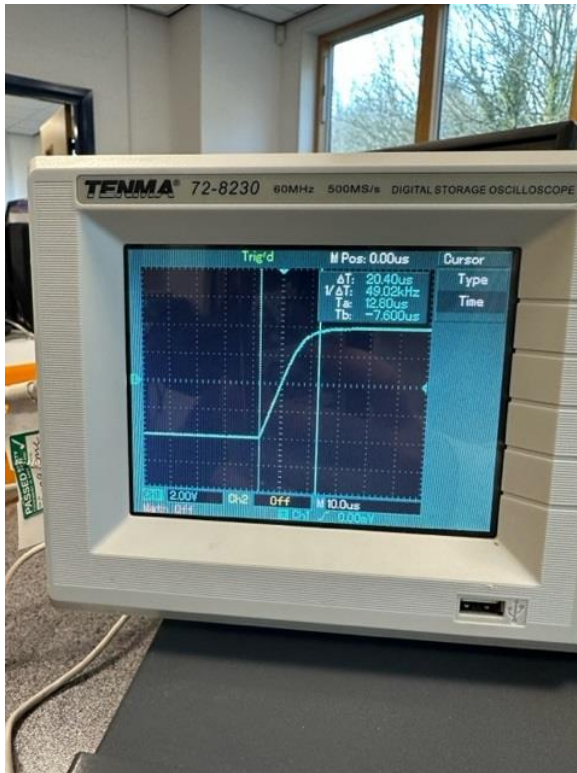


Image 23 & 24 – Amplification waveform

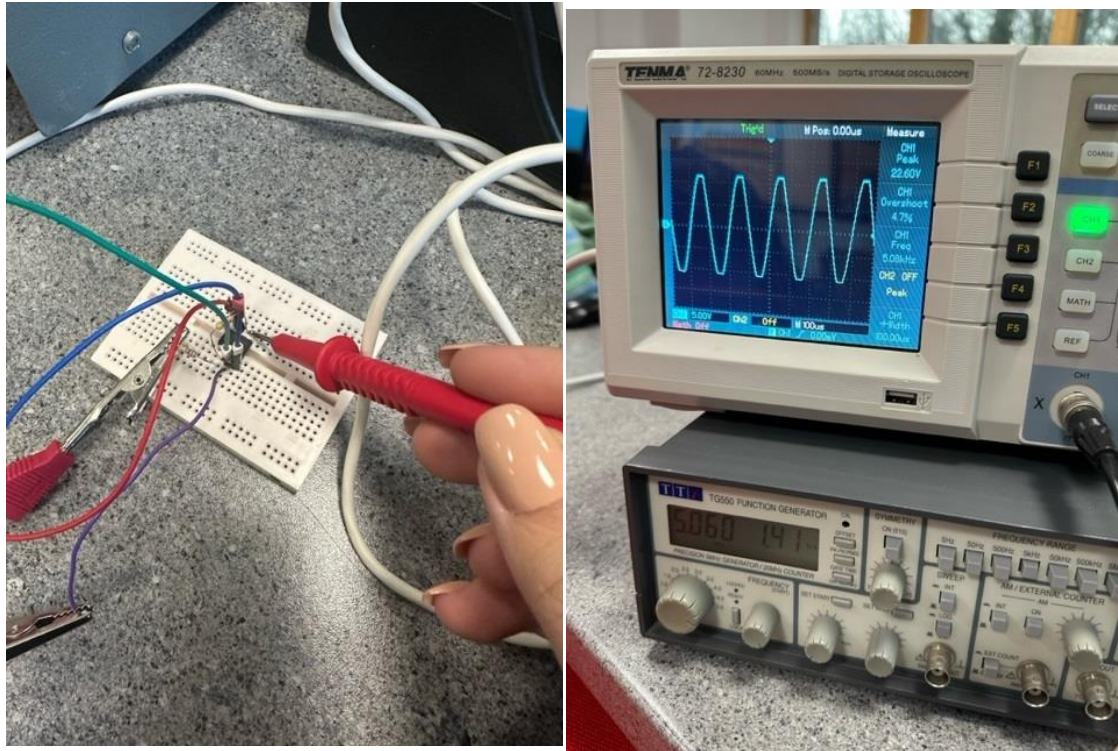


Image 25 & 26 – breadboard &
Amplification waveform

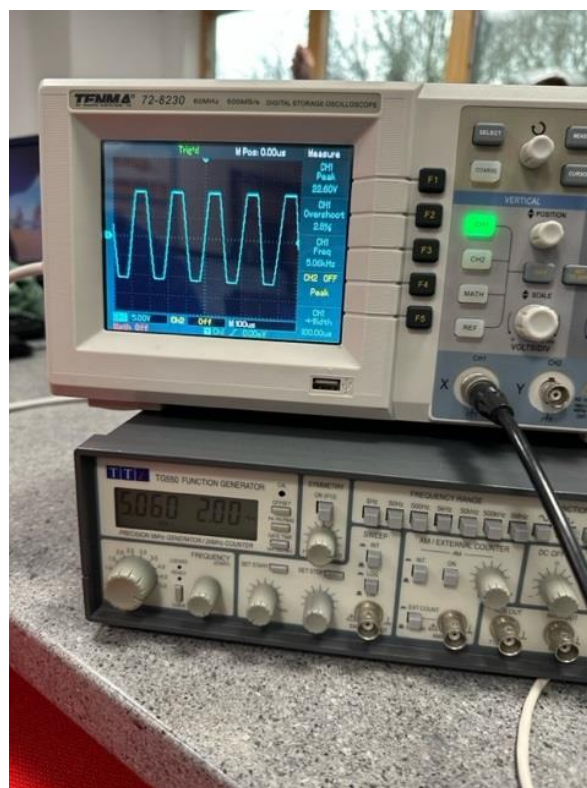


Image 27 – Amplification waveform

There are variations between the simulated, theoretical, and measured results. The main variations are with the measured results, this is because of the variation between the resistor values calculated and the resistor values that were physically available to use for this practical.

There are variations between the simulated / measured / theoretical results this could be down to human error with either of the types of result, human error is where a result or set of results have occurred where the outcome is outside of its acceptable limits. The fluctuation in results can also be due to tolerances within the various components used in the circuits. Also, as previously stated the resistors used in the practical element of the task had slightly different values to the ones used for the theoretical and simulated elements of this task, this will cause a variation in results. ✓

Slew rate is defined as the maximum rate of change of an op amp's output voltage. It is a different specification than small-signal bandwidth, which considers differential input signals of $\pm 100\text{mV}$ or less. In the waveform we can see that the op amp is operating above its slew rate limit, therefore the signals become distorted. The op amp slewing distortion results in the creation of a square waveform. If the frequency is increased the op amp will be even less able to keep up therefore, the amplitude of the output waveform will decrease. ✓

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BC107/BC108/ BC109

Low Power Bipolar Transistors



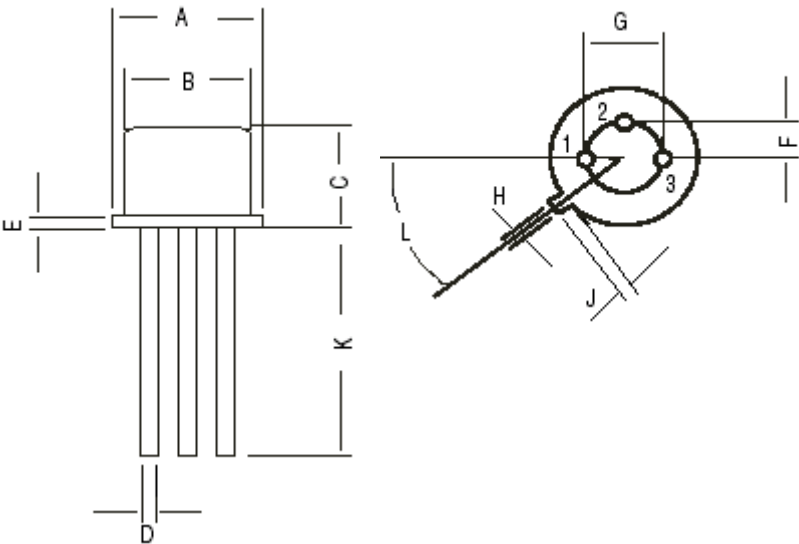
TO-18



Features:

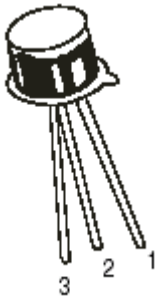
NPN Silicon Planar Epitaxial Transistors.
Suitable for applications requiring low noise and good h_{FE} linearity, eg. audio pre-amplifiers, and instrumentation.

TO-18 Metal Can Package



Dimension	Minimum	Maximum
A	5.24	5.84
B	4.52	4.97
C	4.31	5.33
D	0.40	0.53
E	-	0.76
F	-	1.27
G	-	2.97
H	0.91	1.17
J	0.71	1.21
K	12.70	-
L	45°	

Dimensions : Millimetres



Pin Configuration

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



BC107/BC108/ BC109

Low Power Bipolar Transistors



Absolute Maximum Ratings

DESCRIPTION	SYMBOL	BC107	BC108	BC109	UNIT
Collector-Emitter Voltage	V_{CEO}	45	25	25	V
Collector-Base Voltage	V_{CBO}	50	30	30	V
Emitter-Base Voltage	V_{EBO}	6.0	5.0	5.0	V
Collector Current Continuous	I_C		0.2		A
Power Dissipation at $T_a = 25^\circ\text{C}$	P_D		0.6		W
Derate Above 25°C			2.28		mW/ $^\circ\text{C}$
Power Dissipation at $T_c = 25^\circ\text{C}$	P_D		1.0		W
Derate Above 25°C			6.67		mW/ $^\circ\text{C}$
Operating And Storage Junction	T_j, T_{stg}		-65 to +200		$^\circ\text{C}$
Temperature Range					
Thermal Resistance					
Junction to Case	$R_{th(j-c)}$		175		$^\circ\text{C/W}$

Electrical Characteristics ($T_a = 25^\circ\text{C}$ Unless Otherwise Specified)

Description	Symbol	Test Condition	Minimum	Maximum	Unit
Collector-Emitter Voltage	V_{CEO}	$I_C = 2\text{mA}, I_B = 0$	BC107	45	V
			BC108/109	20	V
Emitter-Base Voltage	V_{EBO}	$I_E = 10\mu\text{A}, I_C = 0$	BC107	6.0	V
			BC108/109	5.0	V
Collector-Cut off Current	I_{CBO}	$V_{CB} = 45\text{V}, I_E = 0$	BC107	15	nA
		$V_{CB} = 25\text{V}, I_E = 0$	BC108/109	15	nA
		$T_{amb} = 125^\circ\text{C}$			
		$V_{CB} = 45\text{V}, I_E = 0$	BC107	4.0	μA
		$V_{CB} = 25\text{V}, I_E = 0$	BC108/109	4.0	μA

BC107/BC108/ BC109

Low Power Bipolar Transistors



Description	Symbol	Test Condition	Minimum	Maximum	Unit
DC Current	h_{FE}	$I_C = 10\mu A, V_{CE} = 5V$	B Group	40	
			C Group	100	
		$I_C = 2mA, V_{CE} = 5V$	BC107	110	450
			BC108	110	800
			BC109	200	800
			A Group	110	220
			B Group	200	450
			C Group	420	800
Base Emitter Saturation Voltage	$V_{BE (Sat)}$	$I_C = 10mA, I_B = 0.5mA$		0.83	V
		$I_C = 100mA, I_B = 5mA$		1.05	V
Collector Emitter Saturation Voltage	$V_{CE (Sat)}$	$I_C = 10mA, I_B = 0.5mA$		0.25	V
		$I_C = 100mA, I_B = 5mA$		0.60	V
Base Emitter on Voltage	$V_{BE (on)}$	$I_C = 2mA, V_{CE} = 5V$	0.55	0.70	V
		$I_C = 10mA, V_{CE} = 5V$		0.77	V
Collector Knee Voltage	$V_{CE (K)}$	$I_C = 10mA, I_B = \text{The Value for which } I_C = 11mA, \text{ at } V_{CE} = 1V$		0.60	V
Transition Frequency	f_t	$V_{CE} = 5V, I_C = 10mA, f = 100MHz$	150		MHz
Noise Figure	NF	$V_{CE} = 5V, I_C = 0.2mA$ $R_g = 2k\Omega$, $F = 30Hz \text{ to } 15 KHz$ $F = 1kHz, B = 200Hz$	BC109	4.0	dB
			BC109	4.0	dB
			BC107/108	10	dB
Output Capacitance	C_{obo}	$V_{CB} = 10V, f = 1MHz$		4.5	pF
Small Signal Current Gain	h_{FE}	ALL $f = 1kHz$ $I_C = 2mA, V_{CE} = 5V$	BC107	125	500
			BC108	125	900
			BC109	240	900
			A Group	125	260
			B Group	240	500
			C Group	450	900
Input Impedance	h_{ie}	ALL $f = 1kHz$ $I_C = 2mA, V_{CE} = 5V$	A Group	1.6	$K\Omega$
			B Group	3.2	$K\Omega$
			C Group	6.0	$K\Omega$
Output Admittance	h_{oe}	ALL $f = 1kHz$ $I_C = 2mA, V_{CE} = 5V$	A Group	30	umhos
			B Group	60	umhos
			C Group	110	umhos

BC107/BC108/ BC109

Low Power Bipolar Transistors



Specifications

V _{CEO} maximum (V)	V _{CBO} maximum (V)	I _C maximum (A)	h _{FE} minimum at I _C = 2 (mA)	Noise Figure maximum (dB)	Transition Frequency minimum (MHz)	P _{tot} at T _a = 25°C (mW)	Package and pin out	Part Number (NPN)			
45	50	0.2	125	10	150	600	TO-18	BC107			
								BC107A			
								BC107B			
25	30										
	240		4					BC108			
								BC108B			
								BC108C			
								BC109			
BC109B											
							BC109C				



LM741 Operational Amplifier

1 Features

- Overload Protection on the Input and Output
- No Latch-Up When the Common-Mode Range is Exceeded

2 Applications

- Comparators
- Multivibrators
- DC Amplifiers
- Summing Amplifiers
- Integrator or Differentiators
- Active Filters

3 Description

The LM741 series are general-purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439, and 748 in most applications.

The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common-mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741 and LM741A except that the LM741C has their performance ensured over a 0°C to +70°C temperature range, instead of –55°C to +125°C.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM741	TO-99 (8)	9.08 mm × 9.08 mm
	CDIP (8)	10.16 mm × 6.502 mm
	PDIP (8)	9.81 mm × 6.35 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Application

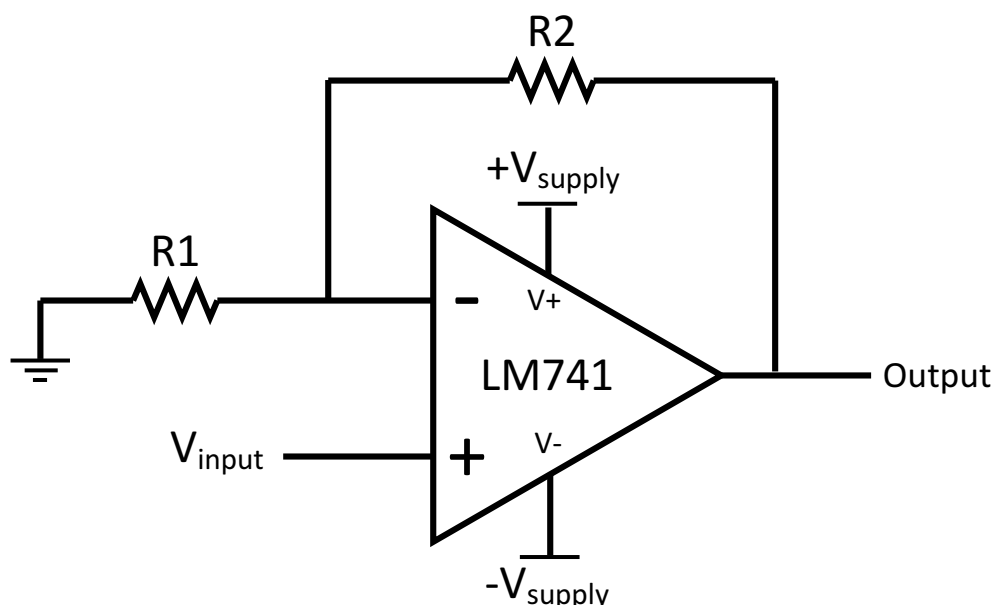


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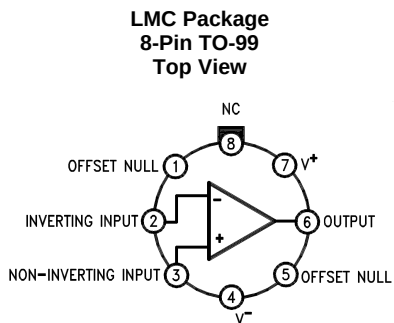
4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

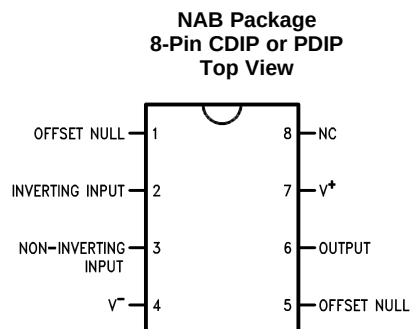
Changes from Revision C (October 2004) to Revision D	Page
• Added <i>Applications</i> section, <i>Pin Configuration and Functions</i> section, <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section	1
• Removed NAD 10-Pin CLGA pinout	3
• Removed obsolete M (S0-8) package from the data sheet	4
• Added recommended operating supply voltage spec	4
• Added recommended operating temperature spec	4

Changes from Revision C (March 2013) to Revision D	Page
• Added <i>Applications</i> section, <i>Pin Configuration and Functions</i> section, <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section	1
• Removed NAD 10-Pin CLGA pinout	3
• Removed obsolete M (S0-8) package from the data sheet	4
• Added recommended operating supply voltage spec	4
• Added recommended operating temperature spec	4

5 Pin Configuration and Functions



LM741H is available per JM38510/10101



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
INVERTING INPUT	2	I	Inverting signal input
NC	8	N/A	No Connect, should be left floating
NONINVERTING INPUT	3	I	Noninverting signal input
OFFSET NULL	1, 5	I	Offset null pin used to eliminate the offset voltage and balance the input voltages.
OFFSET NULL			
OUTPUT	6	O	Amplified signal output
V+	7	I	Positive supply voltage
V-	4	I	Negative supply voltage

6.5 Electrical Characteristics, LM741⁽¹⁾

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage		$R_S \leq 10\text{ k}\Omega$	$T_A = 25^\circ\text{C}$		1	5	mV
			$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$			6	mV
Input offset voltage adjustment range		$T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$			± 15		mV
Input offset current		$T_A = 25^\circ\text{C}$			20	200	nA
		$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$			85	500	
Input bias current		$T_A = 25^\circ\text{C}$			80	500	nA
		$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$				1.5	μA
Input resistance		$T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$		0.3	2		M Ω
Input voltage range		$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$		± 12	± 13		V
Large signal voltage gain		$V_S = \pm 15\text{ V}$, $V_O = \pm 10\text{ V}$, $R_L \geq 2\text{ k}\Omega$	$T_A = 25^\circ\text{C}$	50	200		V/mV
			$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$	25			
Output voltage swing		$V_S = \pm 15\text{ V}$	$R_L \geq 10\text{ k}\Omega$	± 12	± 14		V
			$R_L \geq 2\text{ k}\Omega$	± 10	± 13		
Output short circuit current		$T_A = 25^\circ\text{C}$			25		mA
Common-mode rejection ratio		$R_S \leq 10\text{ }\Omega$, $V_{\text{CM}} = \pm 12\text{ V}$, $T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$		80	95		dB
Supply voltage rejection ratio		$V_S = \pm 20\text{ V}$ to $V_S = \pm 5\text{ V}$, $R_S \leq 10\text{ }\Omega$, $T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$		86	96		dB
Transient response	Rise time	$T_A = 25^\circ\text{C}$, unity gain			0.3		μs
	Overshoot				5%		
Slew rate		$T_A = 25^\circ\text{C}$, unity gain			0.5		V/ μs
Supply current		$T_A = 25^\circ\text{C}$			1.7	2.8	mA
Power consumption		$V_S = \pm 15\text{ V}$	$T_A = 25^\circ\text{C}$		50	85	mW
			$T_A = T_{\text{AMIN}}$		60	100	
			$T_A = T_{\text{AMAX}}$		45	75	

(1) Unless otherwise specified, these specifications apply for $V_S = \pm 15 \text{ V}$, $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$.

6.6 Electrical Characteristics, LM741A⁽¹⁾

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input offset voltage	$R_S \leq 50 \Omega$	$T_A = 25^\circ\text{C}$		0.8	3	mV
		$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$			4	mV
Average input offset voltage drift					15	$\mu\text{V}/^\circ\text{C}$
Input offset voltage adjustment range	$T_A = 25^\circ\text{C}$, $V_S = \pm 20 \text{ V}$		± 10			mV
Input offset current	$T_A = 25^\circ\text{C}$			3	30	nA
	$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$				70	
Average input offset current drift					0.5	nA/ $^\circ\text{C}$
Input bias current	$T_A = 25^\circ\text{C}$			30	80	nA
	$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$				0.21	μA
Input resistance	$T_A = 25^\circ\text{C}$, $V_S = \pm 20 \text{ V}$		1	6		M Ω
	$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$, $V_S = \pm 20 \text{ V}$		0.5			
Large signal voltage gain	$V_S = \pm 20 \text{ V}$, $V_O = \pm 15 \text{ V}$, $R_L \geq 2 \text{ k}\Omega$	$T_A = 25^\circ\text{C}$	50			V/mV
		$T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$	32			
	$V_S = \pm 5 \text{ V}$, $V_O = \pm 2 \text{ V}$, $R_L \geq 2 \text{ k}\Omega$, $T_{\text{AMIN}} \leq T_A \leq T_{\text{AMAX}}$		10			

(1) Unless otherwise specified, these specifications apply for $V_S = \pm 15 \text{ V}$, $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$.

LM741

SNOSC25D – MAY 1998 – REVISED OCTOBER 2015

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Electrical Characteristics, LM741A⁽¹⁾ (continued)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Output voltage swing		$V_S = \pm 20\text{ V}$	$R_L \geq 10\text{ k}\Omega$	± 16			V
			$R_L \geq 2\text{ k}\Omega$	± 15			
Output short circuit current		$T_A = 25^\circ\text{C}$		10	25	35	mA
		$T_{AMIN} \leq T_A \leq T_{AMAX}$		10		40	
Common-mode rejection ratio		$R_S \leq 50\text{ }\Omega$, $V_{CM} = \pm 12\text{ V}$, $T_{AMIN} \leq T_A \leq T_{AMAX}$		80	95		dB
Supply voltage rejection ratio		$V_S = \pm 20\text{ V}$ to $V_S = \pm 5\text{ V}$, $R_S \leq 50\text{ }\Omega$, $T_{AMIN} \leq T_A \leq T_{AMAX}$		86	96		dB
Transient response	Rise time	$T_A = 25^\circ\text{C}$, unity gain			0.25	0.8	μs
	Overshoot				6%	20%	
Bandwidth ⁽²⁾		$T_A = 25^\circ\text{C}$		0.437	1.5		MHz
Slew rate		$T_A = 25^\circ\text{C}$, unity gain		0.3	0.7		V/ μs
Power consumption		$V_S = \pm 20\text{ V}$	$T_A = 25^\circ\text{C}$		80	150	mW
			$T_A = T_{AMIN}$			165	
			$T_A = T_{AMAX}$			135	

 (2) Calculated value from: BW (MHz) = 0.35/Rise Time (μs).

6.7 Electrical Characteristics, LM741C⁽¹⁾

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage		$R_S \leq 10\text{ k}\Omega$	$T_A = 25^\circ\text{C}$		2	6	mV
			$T_{AMIN} \leq T_A \leq T_{AMAX}$			7.5	mV
Input offset voltage adjustment range		$T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$			± 15		mV
Input offset current		$T_A = 25^\circ\text{C}$			20	200	nA
		$T_{AMIN} \leq T_A \leq T_{AMAX}$				300	
Input bias current		$T_A = 25^\circ\text{C}$			80	500	nA
		$T_{AMIN} \leq T_A \leq T_{AMAX}$				0.8	μA
Input resistance		$T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$		0.3	2		M Ω
Input voltage range		$T_A = 25^\circ\text{C}$		± 12	± 13		V
Large signal voltage gain		$V_S = \pm 15\text{ V}$, $V_O = \pm 10\text{ V}$, $R_L \geq 2\text{ k}\Omega$	$T_A = 25^\circ\text{C}$	20	200		V/mV
			$T_{AMIN} \leq T_A \leq T_{AMAX}$		15		
Output voltage swing		$V_S = \pm 15\text{ V}$	$R_L \geq 10\text{ k}\Omega$	± 12	± 14		V
			$R_L \geq 2\text{ k}\Omega$	± 10	± 13		
Output short circuit current		$T_A = 25^\circ\text{C}$			25		mA
Common-mode rejection ratio		$R_S \leq 10\text{ k}\Omega$, $V_{CM} = \pm 12\text{ V}$, $T_{AMIN} \leq T_A \leq T_{AMAX}$		70	90		dB
Supply voltage rejection ratio		$V_S = \pm 20\text{ V}$ to $V_S = \pm 5\text{ V}$, $R_S \leq 10\text{ }\Omega$, $T_{AMIN} \leq T_A \leq T_{AMAX}$		77	96		dB
Transient response	Rise time	$T_A = 25^\circ\text{C}$, Unity Gain			0.3		μs
	Overshoot				5%		
Slew rate		$T_A = 25^\circ\text{C}$, Unity Gain			0.5		V/ μs
Supply current		$T_A = 25^\circ\text{C}$			1.7	2.8	mA
Power consumption		$V_S = \pm 15\text{ V}$, $T_A = 25^\circ\text{C}$			50	85	mW

 (1) Unless otherwise specified, these specifications apply for $V_S = \pm 15\text{ V}$, $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$.