

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Camron Thomas	Student ID number:	
Programme:	HNC Electrical/Electronic Engineering		
Module:	Electronics		
Module code:	PCEE4006	Contribution to Overall Module Assessment (%):	50%
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	6.4
Engagement with a wide range of literature sources, including sources retrieved independently. Generally sound referencing, with very few inaccuracies or inconsistencies.		
2. Knowledge and Understanding Skills	35	25.2
Task 1 achieved 68%. Task 2 achieved 75%, Task 3 achieved 73%. Excellent knowledge and understanding of the basic underlying concepts and principles of the subject. Showed excellent understanding the calculated requirements and design work.		
3. Cognitive and Intellectual Skills	15	7.8
Good evaluation of the underlying concepts and principles for most of the tasks.		
4. Practical Application Skills	30	23.4
Task 1 achieved 75%. Task 2 achieved 82%. Task 3 achieved 77%. An excellent application of practical work for all tasks, very good use of the test equipment and Multisim to obtain the required test results.		
5. Transferable Skills for Life and Professional Practice	10	7
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)		70%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		



Camron Thomas

January 2023

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TASK DESCRIPTION

Task 1 – Characteristics of Diodes

This task will investigate the characteristics of **germanium and silicon** diodes.

Before starting the experiment produce a description a diode and explain the functionality of a p-n junction in the forward and reverse biased mode.

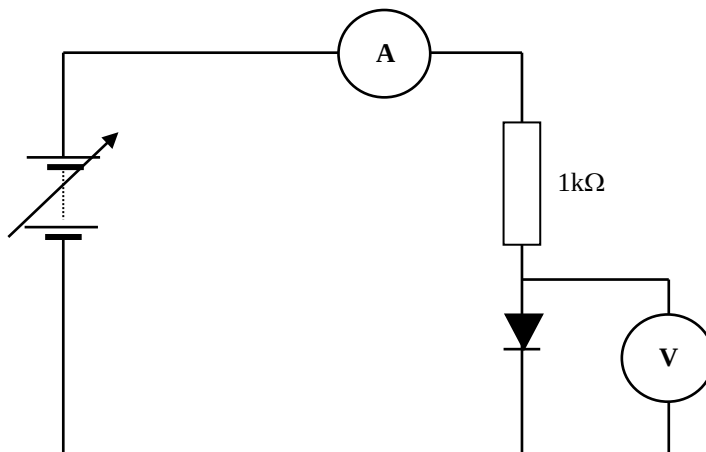
Experimental Procedure

- Using a DVM, check the two diodes.
- Measure and record the value of the resistors.
- Using the following circuits, plot the forward and reverse bias characteristics of both the germanium and silicon diodes.

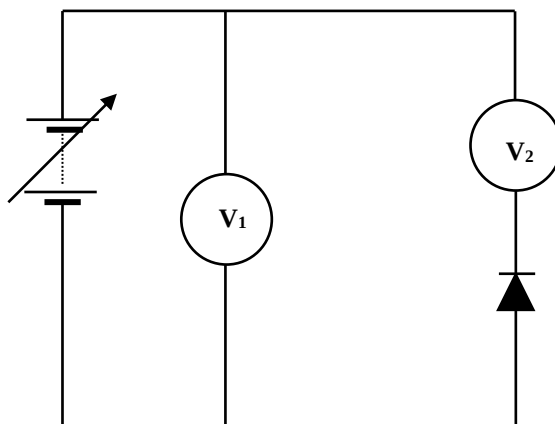
In the forward bias mode adjust the supply voltage so that the diode voltage increases from 0V in increments of 0.1 volts to a maximum of 1V.

In the reverse bias mode adjust the voltage in increments of –1.5 volts to a maximum of –15V.

Forward Bias



Reverse Bias



In the reverse direction the leakage current is very small which can be determined using the resistance of the multimeter ($10\text{M}\Omega$).
where:

$$I = \frac{V_2}{10 \times 10^6}$$

and $V_D = V_1 - V_2$

Note to get a measurable voltage for the germanium diode place a $10\text{k}\Omega$ in parallel with V_2 .

Results

- Plot the forward and reverse characteristics for the diodes.
- Determine the static and dynamic resistance (in the forward bias mode) for each diode at about $V_D = 0.7$ volts.
- Determine the static and dynamic resistance (in the reverse bias mode) at about -9 volts.

Comment on your results discussing the characteristics of each diode and how they compare.

Should not include the assignment brief as part of the write up.

What is a diode?

A diode is a semiconductive device that acts as a one-way switch to allow current flow. The current is allowed to flow freely in one direction; however, it severely stops current from flowing in the opposite direction.

‘The PN junction diode consists of a p-region and n-region separated by a depletion region where charge is stored. The behaviour of the PN junction with regards to the potential barrier’s width produces an asymmetrical conducting two terminal devices, better known as the PN Junction Diode.’ (Tutorials, 2018) ✓

In the reverse bias condition, the positive voltage is applied to the N type material and a negative voltage is applied to the P type material. At the N type material, the positive voltage attracts electrons towards and away the positive electrodes. And at the P type the opposite happens. ✓

In the forward bias condition, the positive voltage is applied to the P type material and the negative voltage is given to the N type material. When the external voltage is greater than the value of the potential barrier, for a silicon diode 0.7 volts and for germanium 0.3 volts, then the potential barriers opposition will be overdone and current will begin to flow. ✓

Could have included some diagrams.

Task 1 (Answers)

Using a DVM the two diodes being used to carry out the tests were measured and both give healthy readings.

The $1k\Omega$ resistor used in the forward bias circuit above was also measured, resistor reading = 997Ω which is within tolerance. ✓

Task 1 Results

The tables and graphs below show the forward and reverse bias characteristics of both silicon and germanium diodes. The supply voltage in the forward bias direction started at 0v and ranged up to 1v. In the reverse bias mode, the voltage ranged from -1.5v to -15 as seen in the tables below.

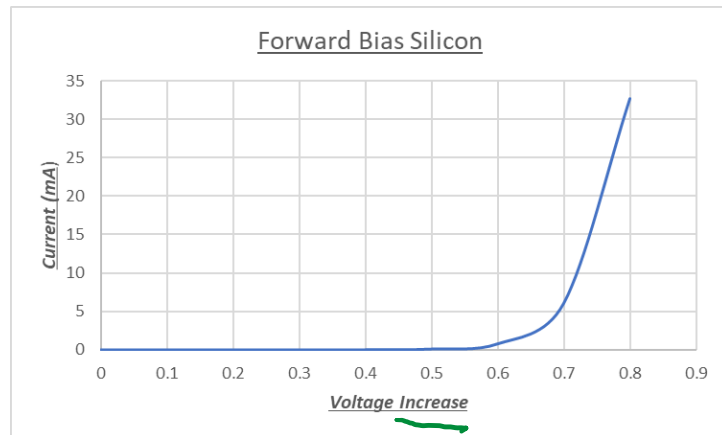
Below is the table & graphs for the Silicon Diode:

Forward Bias

(v)

<u>Voltage</u>	
<u>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

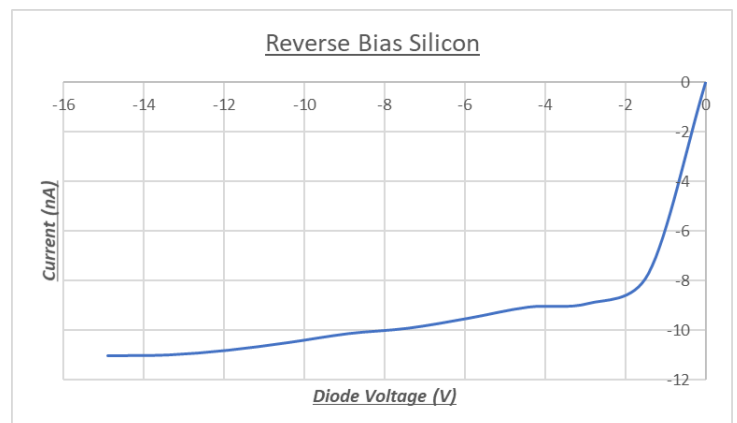
✓



Reverse Bias

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

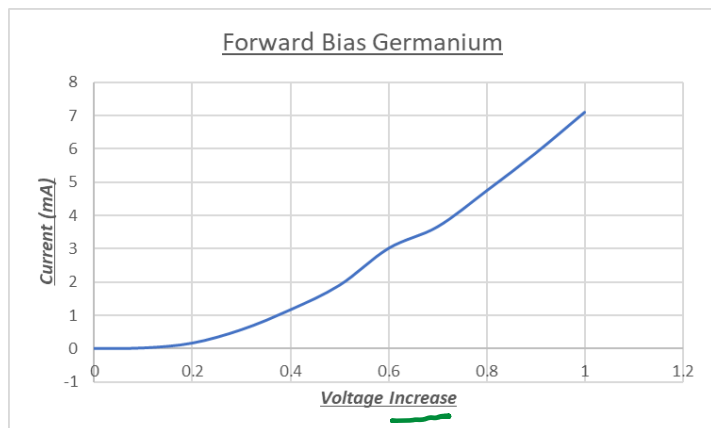
✓



Below is the table & graphs for the Germanium Diode:

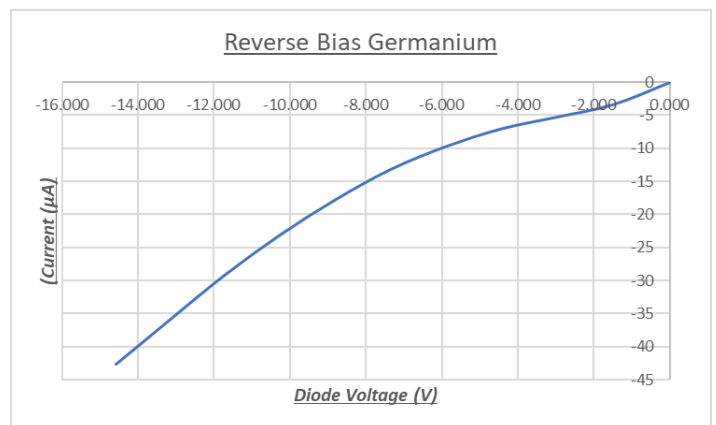
Forward Bias

Voltage	Current (mA)
0	0
0.1	0.018
0.2	0.165
0.3	0.567
0.4	1.165
0.5	1.902
0.6	3.01
0.7	3.66
0.8	4.74
0.9	5.87
1	7.1



Reverse Bias

V1 (V)	V2 (mV)	Diode Voltage (V)	Current (μ A)
0	0	0.000	0
-1.5	33	-1.467	-3.3
-3	52	-2.948	-5.2
-4.5	70	-4.430	-7
-6	97	-5.903	-9.7
-7.5	132	-7.368	-13.2
-9	178	-8.822	-17.8
-10.5	231	-10.269	-23.1
-12	291	-11.709	-29.1
-13.5	358	-13.142	-35.8
-15	426	-14.574	-42.6

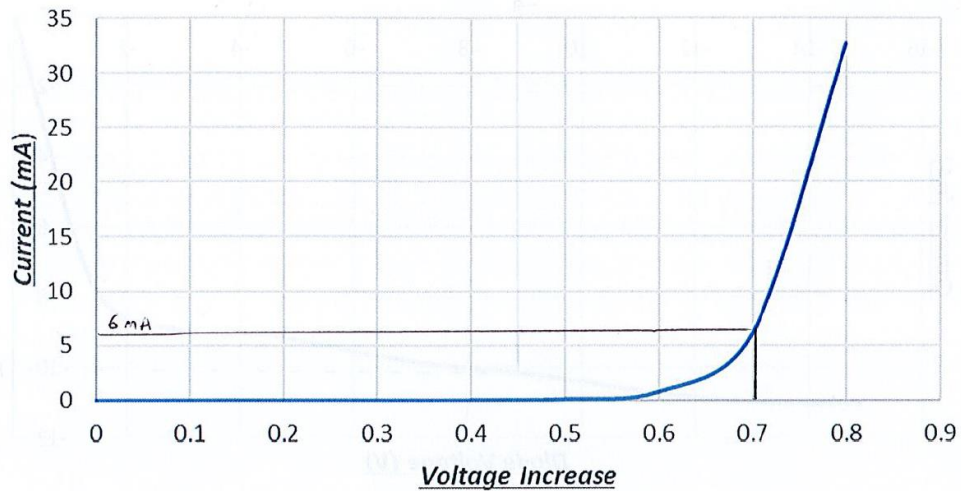


Below are the calculations for the static and dynamic characteristics.

Forward Bias

At 0.7 silicon diode (static),

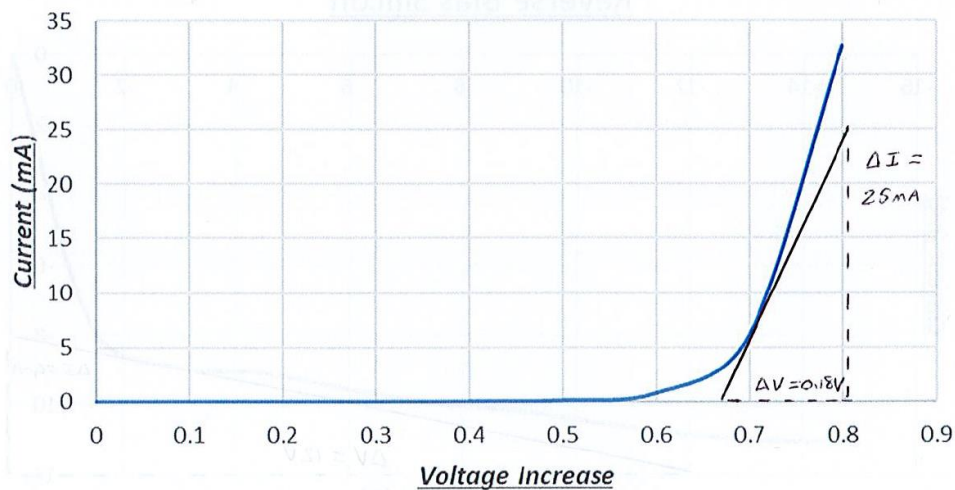
Forward Bias Silicon



$$R_s = \frac{V}{I} = \frac{0.7}{6 \times 10^{-3}} = \underline{116.6\Omega} \quad \checkmark$$

At 0.7 silicon diode (dynamic),

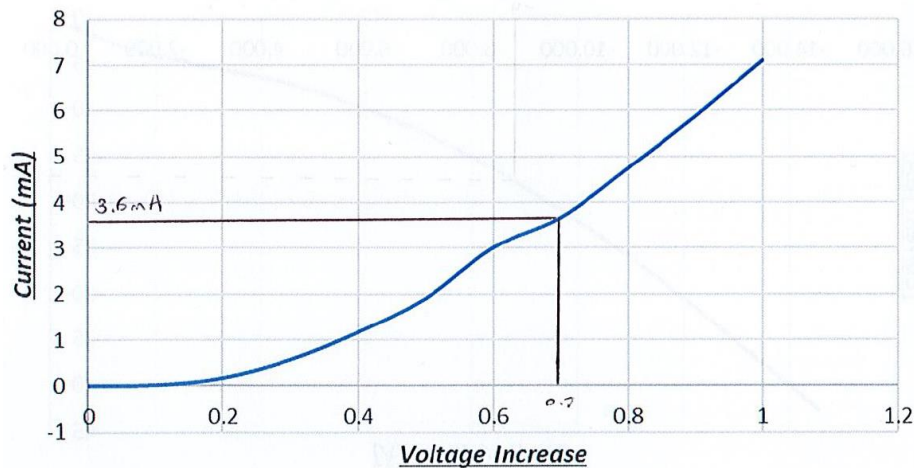
Forward Bias Silicon



$$R_D = \frac{\Delta V}{\Delta I} = \frac{0.18}{25 \times 10^{-3}} = \underline{7.2\Omega} \quad \checkmark$$

At 0.7v germanium diode (static),

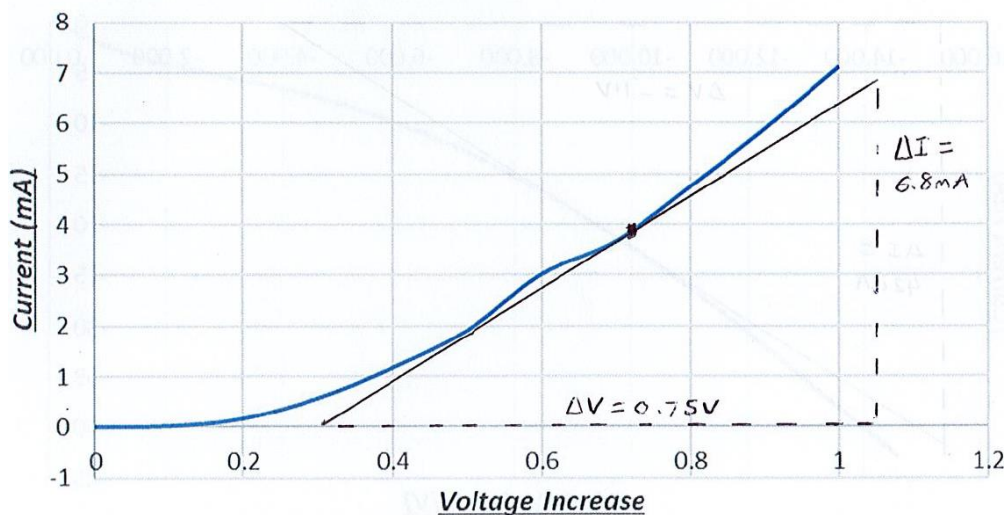
Forward Bias Germanium



$$R_S = \frac{V}{I} = \frac{0.7}{3.6 \times 10^{-3}} = \underline{\underline{194.4\Omega}}$$

At 0.7v germanium diode (dynamic),

Forward Bias Germanium



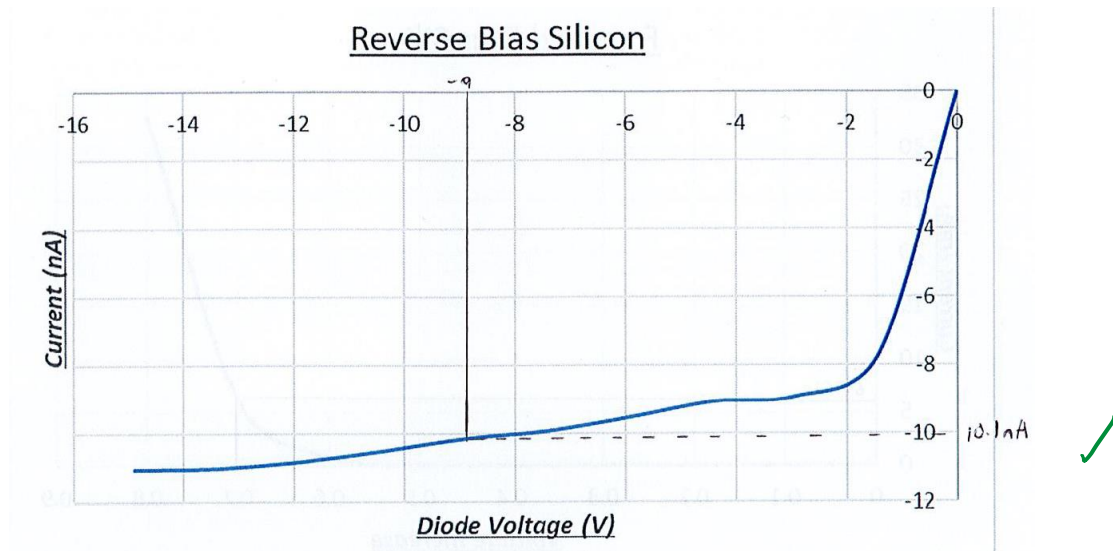
$$R_D = \frac{\Delta V}{\Delta I} = \frac{0.75}{6.8 \times 10^{-3}} = \underline{\underline{110.3\Omega}}$$

Comments on the forward bias results

At 0.7V in the forward bias volts for the static measurement it is seen that the germanium diode's resistance is approximately 70 ohms higher than the silicon diode. As seen above for the dynamic resistance the germanium diodes resistance is just above 100 ohms larger compared to the silicon diode. The germanium diode is a more efficient diode. As seen in the graphs above the germanium diode starts to conduct electricity at around 0.3 volts and the silicon diode starts to conduct at around 0.7 volts.

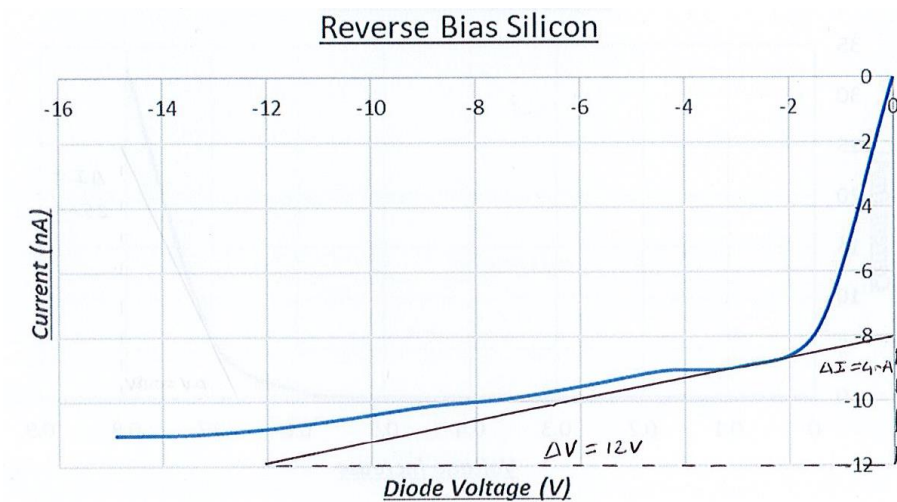
Reverse Bias

At -9v Silicon Diode (Static),



$$R_S = \frac{V}{I} = \frac{-9}{-10.1 \times 10^{-9}} = \underline{\underline{891 \text{ M}\Omega}} \quad \checkmark$$

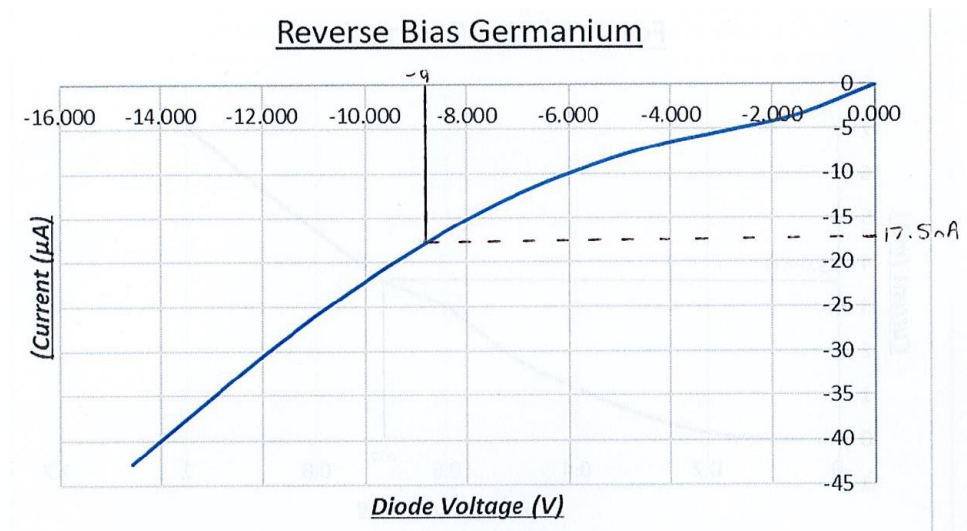
At -9v Silicon Diode (Dynamic),



Your tangent
is not at -9V.

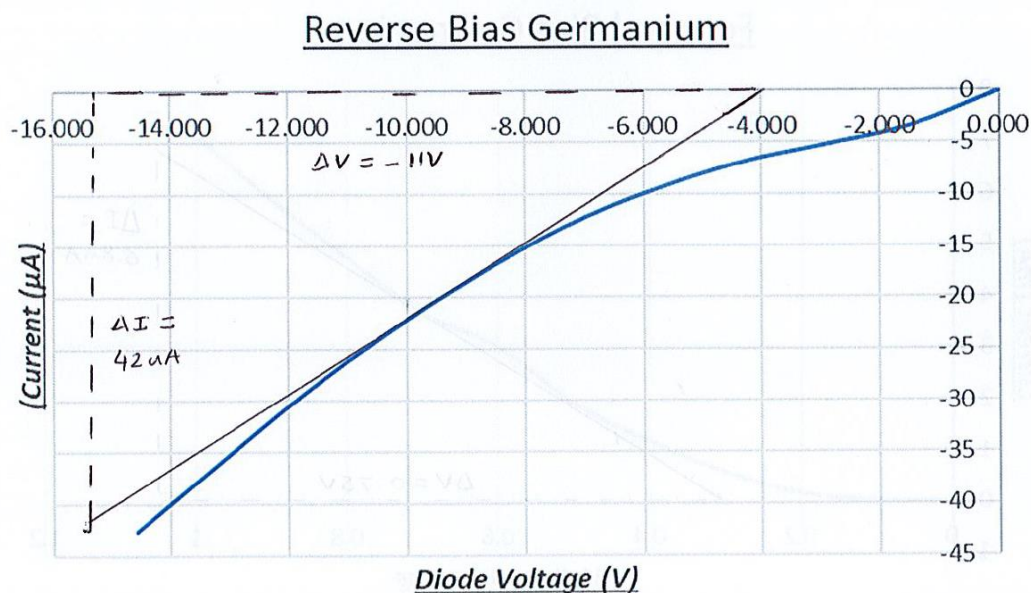
$$R_D = \frac{\Delta V}{\Delta I} = \frac{12}{4 \times 10^{-9}} = \underline{\underline{3000 \text{ M}\Omega}} \quad \checkmark$$

At -9v Germanium Diode (Static)



$$R_S = \frac{V}{I} = \frac{9}{17.5 \times 10^{-6}} = \underline{\underline{514.29K\Omega}}$$

At -9 Germanium Diode (Dynamic),



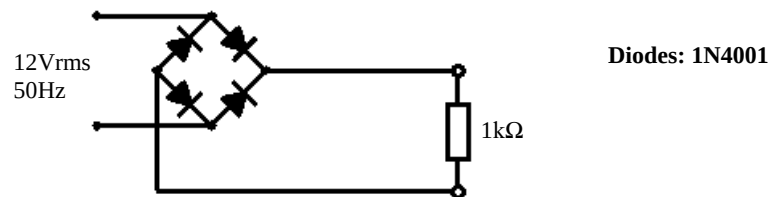
$$R_D = \frac{\Delta V}{\Delta I} = \frac{11}{42 \times 10^{-6}} = \underline{\underline{261.9K\Omega}}$$

Comments on the negative bias results

Both diodes show very high resistance, the silicon diode 1000x higher compared to the germanium. The silicon diode will allow less current to flow in the reverse direction causing the germanium diode to have more current leakage.

Task 2 – Voltage Regulator Design

The circuit below is a full-wave bridge rectifier.



The circuit above shows the construction of a full wave bridge rectifier.

- Using Multisim obtain the waveform across the load resistor and explain the operation the circuit.
- Explain how a capacitor can be used to smooth the output to produce a DC voltage, use Multisim to aid your explanation.
- Design a series voltage regulator using a BZX84c5V1 and test its performance using Multisim.

Task 2 (Answers)

- What is a full wave bridge rectifier and its operation?** ‘This type of single-phase rectifier uses four individual rectifying diodes connected in a closed loop “bridge” configuration to produce the desired output.’ (Tutorials, 2022) The four diodes are usually named D1 to D4, only two diodes conduct current each half cycle. There is a positive half cycle and a negative half cycle in the full wave bridge rectifier circuit.

Positive cycle

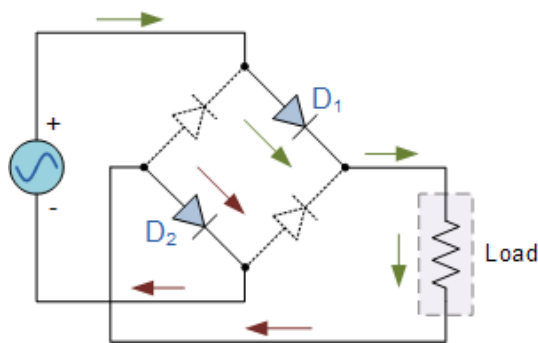


Figure 1 - (Tutorials, 2022)

Negative cycle

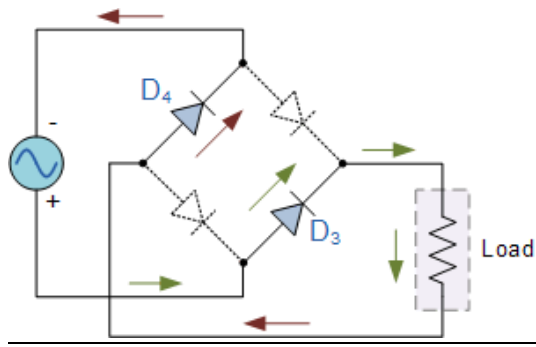
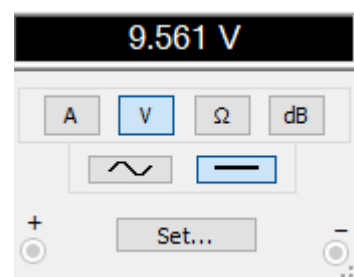
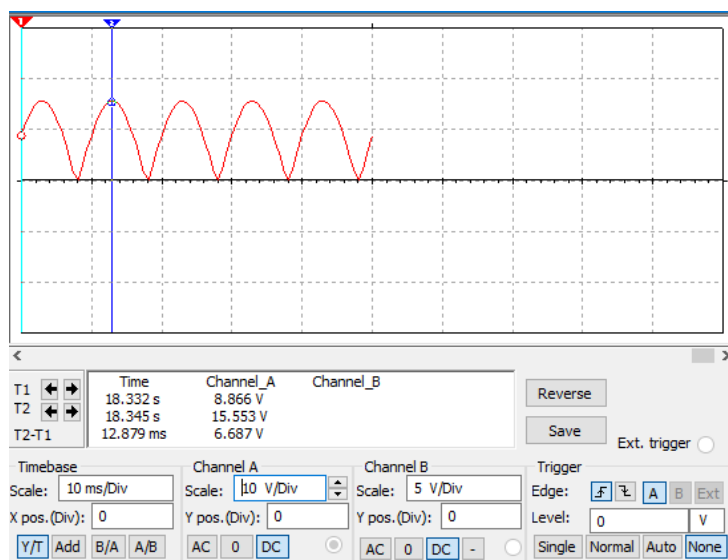
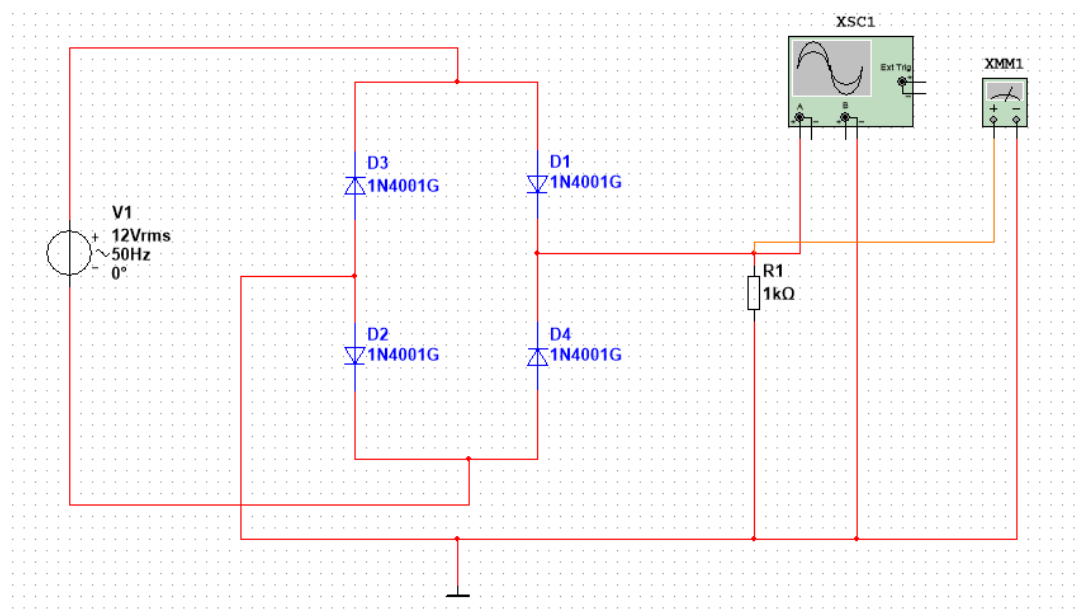


Figure 2 - (Tutorials, 2022)

In the two images above, it shows the two different cycles of the full wave bridge rectifier process. In the positive cycle D1 and D2 conduct in series, although D3 and D4 are not in use in this cycle. On the other hand, during the negative cycle D3 and D4 conduct current in series but diodes D1 and D2 are not used.



The peak voltage recorded on the oscilloscope was **15.553V**

The supply voltage x RMS (0.7071) = $12 \times \sqrt{2} = \underline{16.97V}$ ✓

Finally, 1.4V must be subtracted from the 15.57 because the current flows through 2 diodes during a half cycle.
= $16.97 - 1.4 = \underline{15.57V}$ ✓

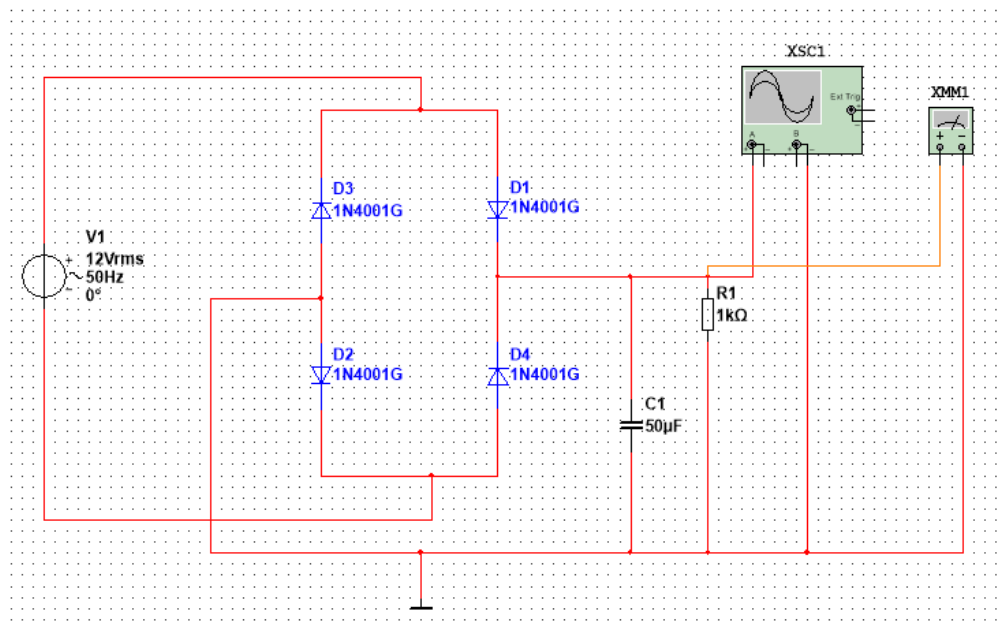
The circuit is very insufficient as it loses almost 6 volts per cycle.

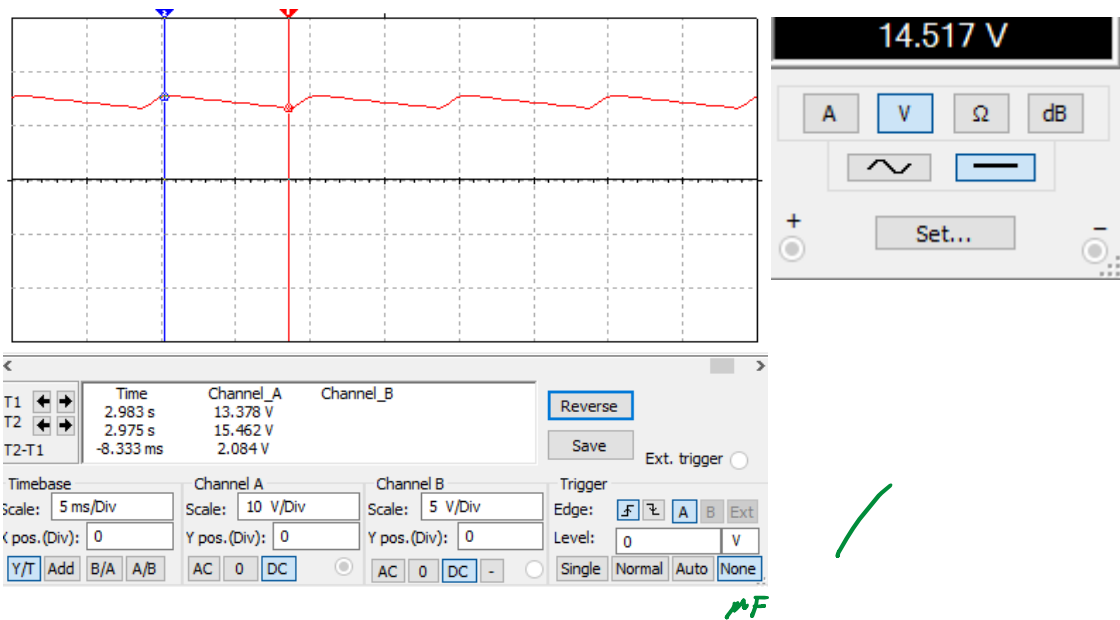
This can be calculated by:

The peak voltage – The multimeter value = $15.553 - 9.561 = \underline{5.992V}$. ✓

- b) The following quote is from the John Bird Electrical Circuit Theory and Technology book. ‘A capacitor is an electrical device that is used to store electrical energy. Capacitors are used to smooth rectified ac outputs.’ (Bird, 2007) The smoothing of the DC voltage works because the capacitor charges up at the point when the voltage from the rectifier rises above the capacitor and then when the rectifier voltage drops. This then provides the circuit with enough current from the capacitors stored charge. ✓

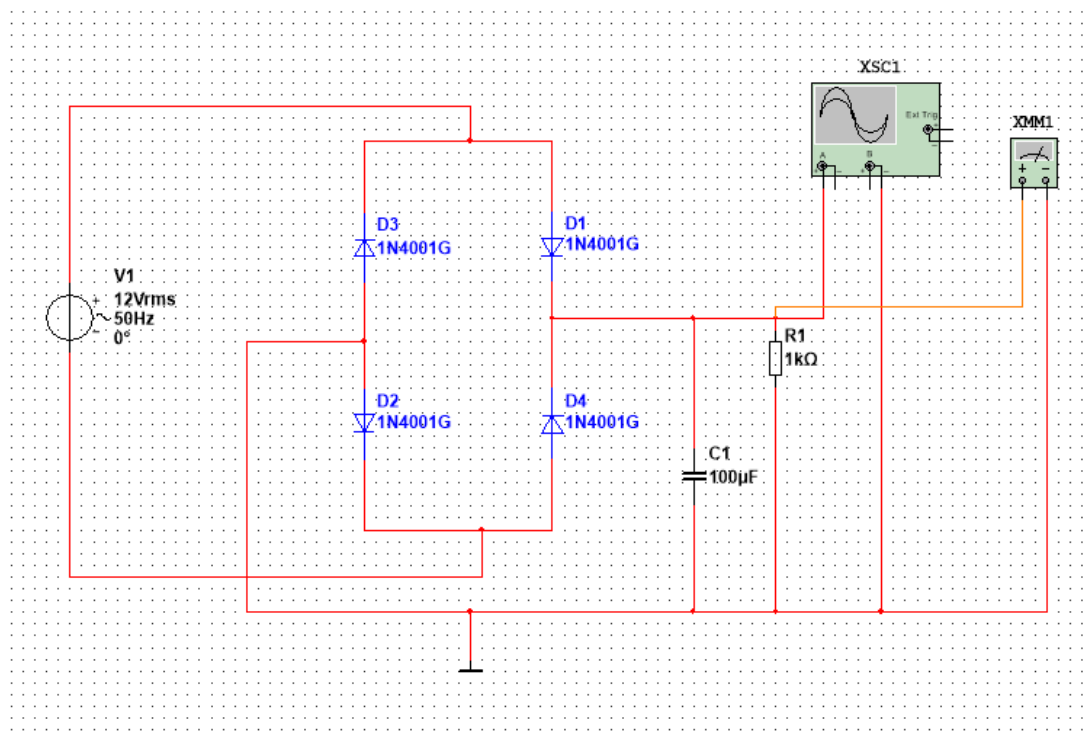
50uf Capacitor added to the circuit

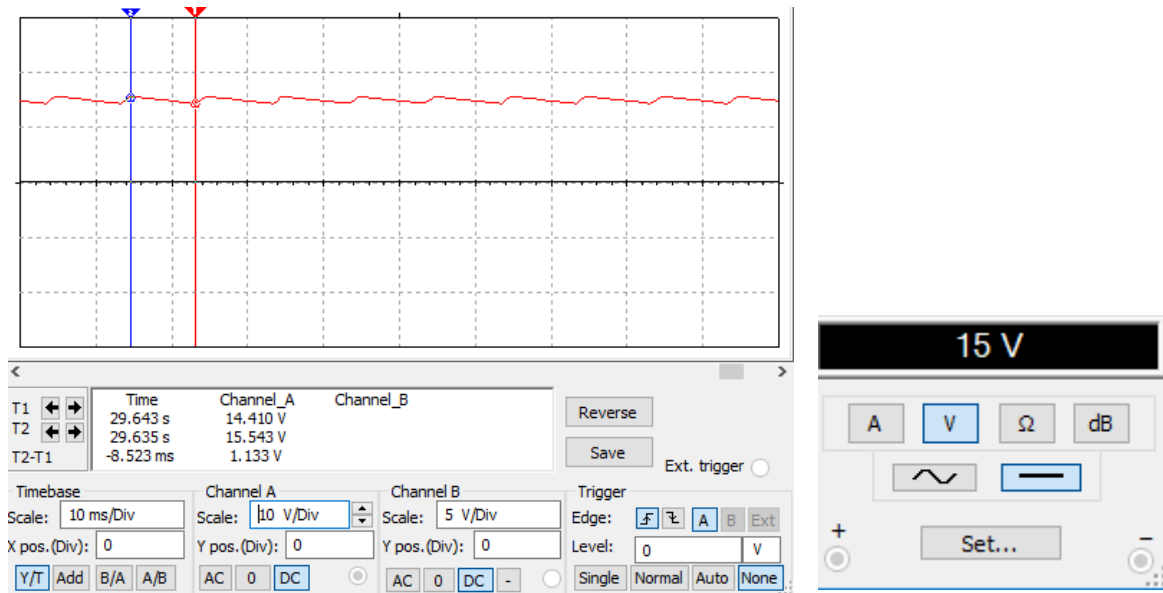




The circuit above shows a full wave bridge rectifier circuit with a 50 μ F storing capacitor included. As seen on the oscilloscope the waveform has become smoother. The capacitor also helps the circuit store charge, the voltmeter is reading 14.517V with a 50 μ F capacitor compared to 9.561V without a capacitor in the circuit. This makes the circuit more efficient as it's only losing roughly 0.8 volts per cycle.

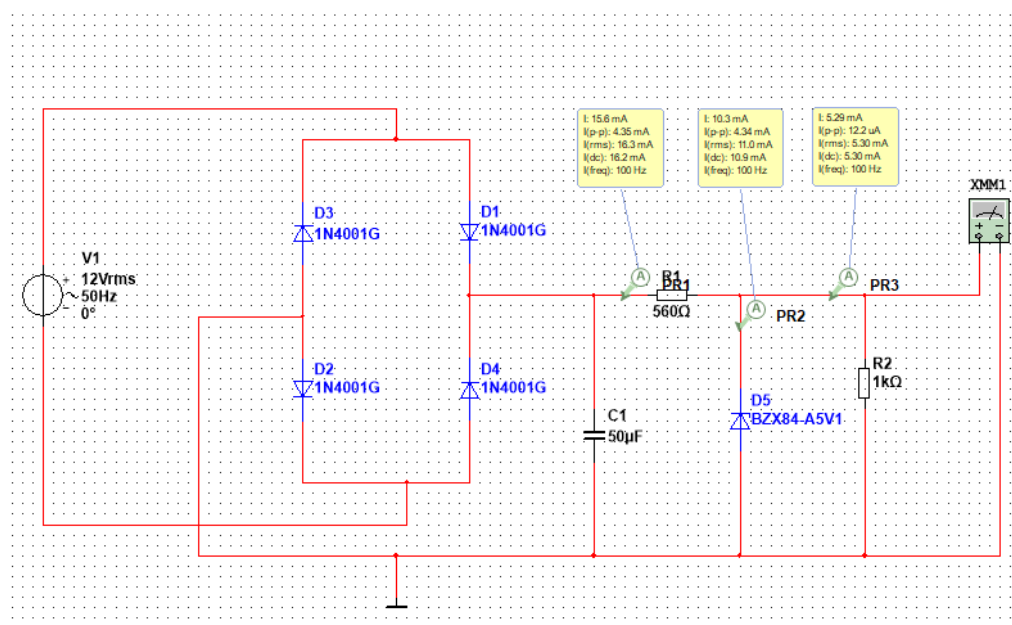
100 μ F Capacitor added to the circuit

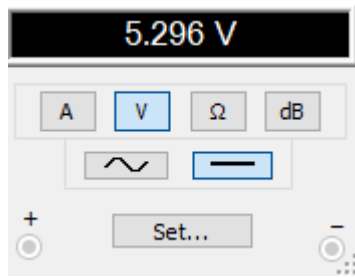




The circuit above shows a full wave bridge rectifier circuit with a 100µF storing capacitor included. Comparing the oscilloscope waveform and voltmeter to the two previous circuits it is obvious that when there is an increase in capacitor rating the circuit will not waste as much per cycle and the waveform becomes more smoother due to the capacitor being able to store more charge depending on power rating.

c) Design a series voltage regulator using a BZX84c5V1 and test its performance using Multisim.





Testing the regulator

The maximum power dissipated = 300mw

The load voltage can be seen on the Multimeter above, 5.296V

Measure the voltage across R (Series Resistor).

V_R = The voltage from the 50uf capacitor circuit above – the voltage regulator circuit above.

$$I_R \text{ Min} = I_2 \text{ Min} + I_L = 5 + 5.1 = 10.1\text{mA}$$

$$I_R \text{ Max} = I_2 \text{ Max} + I_L = 58.82 + 5.1 = 63.92\text{mA}$$

$$R \text{ Min} = V_R / I_R (\text{Max}) = 9.4 \times (63.92 \times 10^{-3}) = 147.06\Omega$$

$$R \text{ Max} = V_R / I_R (\text{Min}) = 9.4 \times (10.1 \times 10^{-3}) = 930.7\Omega$$

Measure Current - I_R , I_Z , and I_L . (All currents measured on Multisim using the probes available)

$$I_R = \underline{16.2\text{mA}}$$

$$I_Z = \underline{10.9\text{mA}}$$

$$I_L = \underline{5.3\text{mA}}$$

Appendix 1 states that I_Z should be between 5mA to 58.82mA. The I_Z value above meets the requirements of the Zener Diode.

Determine power for R, $P = I_R \times V_R$ (Voltage taken from 50uf capacitor circuit)

$P = 16.2 \times 10^{-3} \times 14.5 = \underline{0.2349\text{w}}$, due to this being such a small value it may need a bigger resistor to avoid burning out. *Good.*

Task 3 - Transistor Amplifier Design and Performance Measurement

The aim of this task is to construct a transistor amplifier configured in common emitter (CE) mode, to measure its performance, and to compare measured results against theoretical performance.

Experimental Procedure

- Design a common emitter amplifier using a suitable transistor that has a h_{fe} value between 50 to 600 (value to be checked using datasheets and multimeter). A suitable voltage supply is to be selected, the decoupling capacitor will be 100μF and coupling capacitors will be 10μF.
- Build the circuit and produce a record of test results under dc and ac conditions.
- Use Multisim to simulate the test performed in part b. and compare the results
- Analyse the performance of the circuit, commenting upon any variations in the results and the overall performance of the amplifier.

Task 3 (Answers)

a) Below are the calculated results for the BC108 Transistor:

Transistor – **BC108**.

VCC = **12V**

Multimeter – HFE = **207**

Quiescent collector current $I_Q = 2A = \mathbf{200mA}$

$I_C = \mathbf{6mA}$

$$R_C = \frac{V_{CC}}{2 \times I_C} = \frac{V_{CC}}{2 \times 6 \times 10^{-3}} = \mathbf{1.2k\Omega}$$

V_E should be about 10% to 15% of VCC. Chosen V_E value is 12%.

$$V_E = 12 \times 0.12 = \mathbf{1.44V}$$

$$R_E = \frac{V_E}{I_E} = \frac{1.44}{6 \times 10^{-3}} = \mathbf{240\Omega}$$

$$\text{As } h_{fe} = \frac{I_C}{I_B}$$

$$\text{so } I_B = \frac{6 \times 10^{-3}}{207} = \mathbf{28.99 \times 10^{-6}}$$

The base voltage should be about 0.7V (V_{BE}) higher than V_E to ensure that the input signal is biased on the linear part of the transistor input characteristic.

$$V_B = V_E + V_{BE} = 1.44 + 0.7 = \mathbf{2.14V}$$

The value of R_2 will be the base voltage V_B divided by the bias network current through R_1 and R_2 .

$$R_2 = \frac{V_B}{10 \times I_B} = \frac{2.14}{10 \times 28.99 \times 10^{-6}} = \mathbf{7.38k\Omega} \text{ (Closest resistor value is } 6.8k\Omega)$$

The value of this resistor will be the difference between V_{CC} and V_B divided by the bias network current through R_1 and R_2 .

$$R_1 = \frac{V_{CC} - V_B}{11 \times I_B} = \frac{12 - 2.14}{11 \times 28.99 \times 10^{-6}} = \mathbf{30.91k\Omega} \text{ (Closest resistor value is } 33k\Omega)$$

Well done.

b) Build the circuit and produce a record of test results under dc and ac conditions.

DC Conditions Test Results

The table below shows compares the voltmeter reading, calculated results and practical results under DC conditions.

Multisim

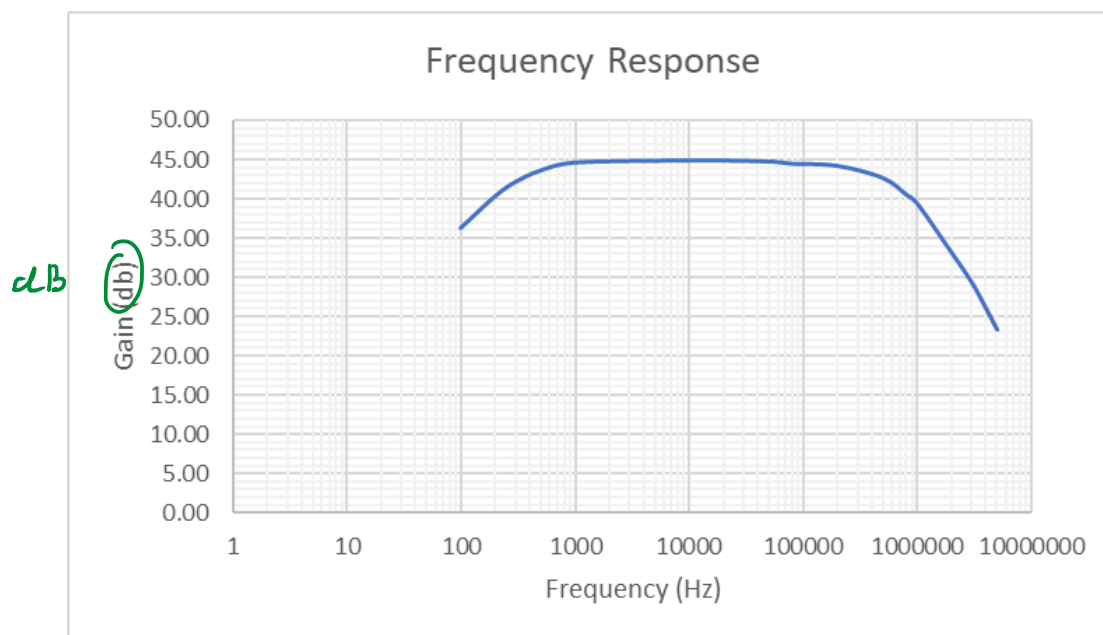
	<u>Voltmeter Reading</u>	<u>Calculated Result</u>	<u>Practical results</u>
V_C	5.16V	6V	5.54V
V_E	1.26V	1.44V	1.23V
V_B	1.95V	2.14V	1.91V
V_{BE}	687mV	700mV	695mV
I_C	5.7mA	6mA	5.48mA

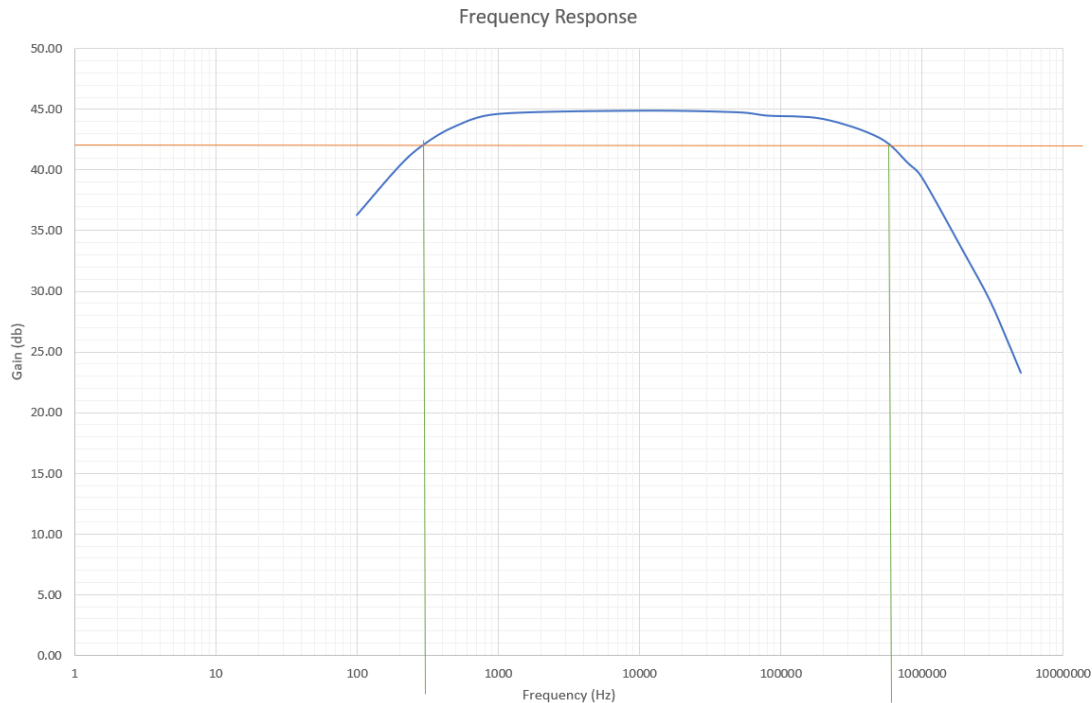
AC Conditions Test Results

The table below shows a range of frequencies that was determined using a function generator, the output voltage was identified from the oscilloscope. The gain was calculated by using the following formula, $\frac{\text{Output Voltage}}{0.03}$ and the gain (db.) was calculated using the following formula, $20 \times \log(\text{gain})$

<u>Frequency</u> <u>(Hz)</u>	<u>Output Voltage</u> <u>(V)</u>	<u>Gain</u>	<u>Gain (db.)</u>
100	1.96	65.33	36.30
200	3.12	104.00	40.34
300	3.84	128.00	42.14
500	4.56	152.00	43.64
1000	5.12	170.67	44.64
10000	5.28	176.00	44.91
50000	5.2	173.33	44.78
80000	5.04	168.00	44.51
200000	4.88	162.67	44.23
500000	4.08	136.00	42.67
800000	3.2	106.67	40.56
1000000	2.8	93.33	39.40
2000000	1.36	45.33	33.13
3000000	0.88	29.33	29.35
4000000	0.6	20.00	26.02
5000000	0.44	14.67	23.33

Below shows the frequency response graph for the table of results in the previous page, the calculations for the maximum gain and bandwidth are also below.





The max gain of the recorded results is 44.91dB = **45db**

Half point power = max gain – 3db

Half point power = 45– 3 = **42db**

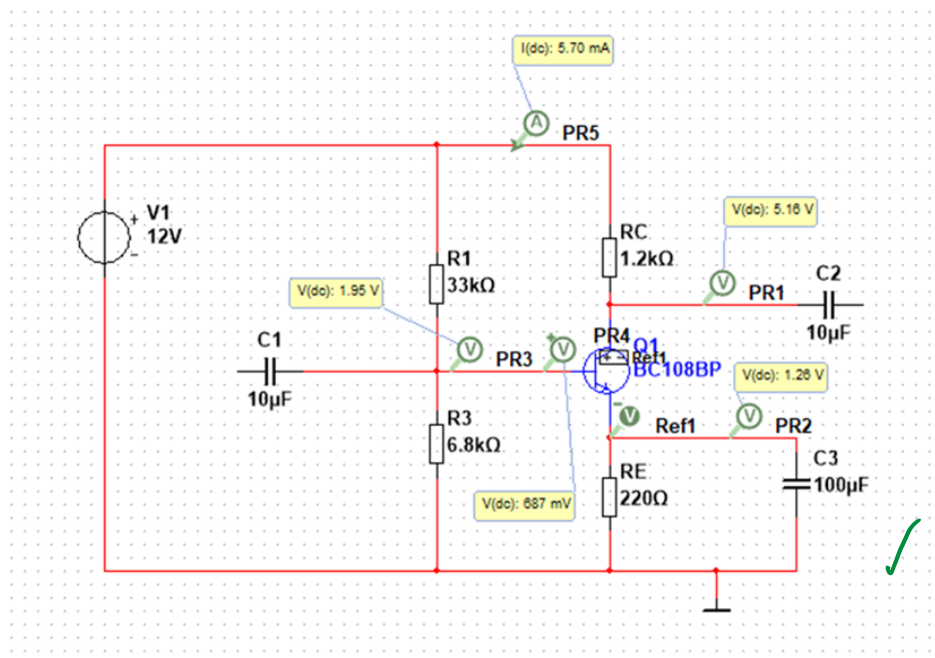
Bandwidth = $f_2 - f_1 = (5 \times 10^6) - 300 = \mathbf{4.9997\text{MHz}}$ ✓

Good.

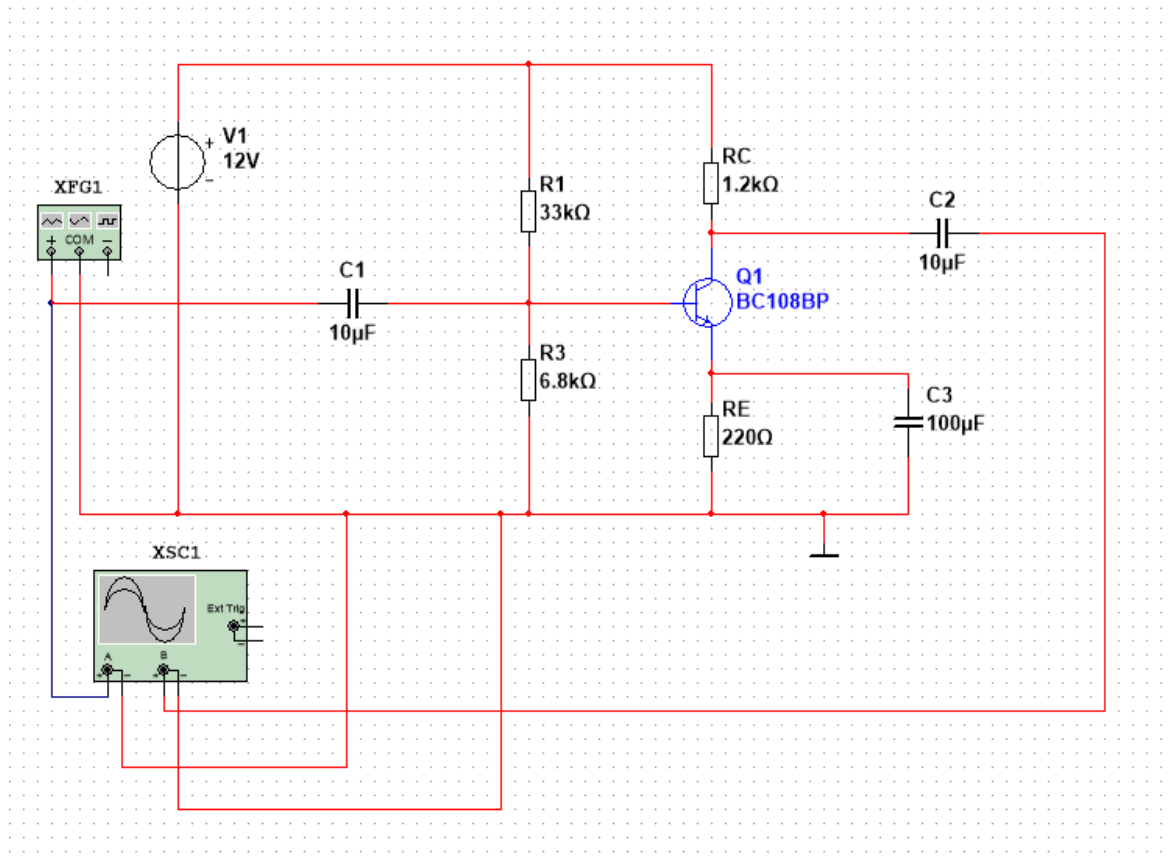
c) Use Multisim to simulate the test performed in part b. and compare the results

DC Conditions (Multisim)

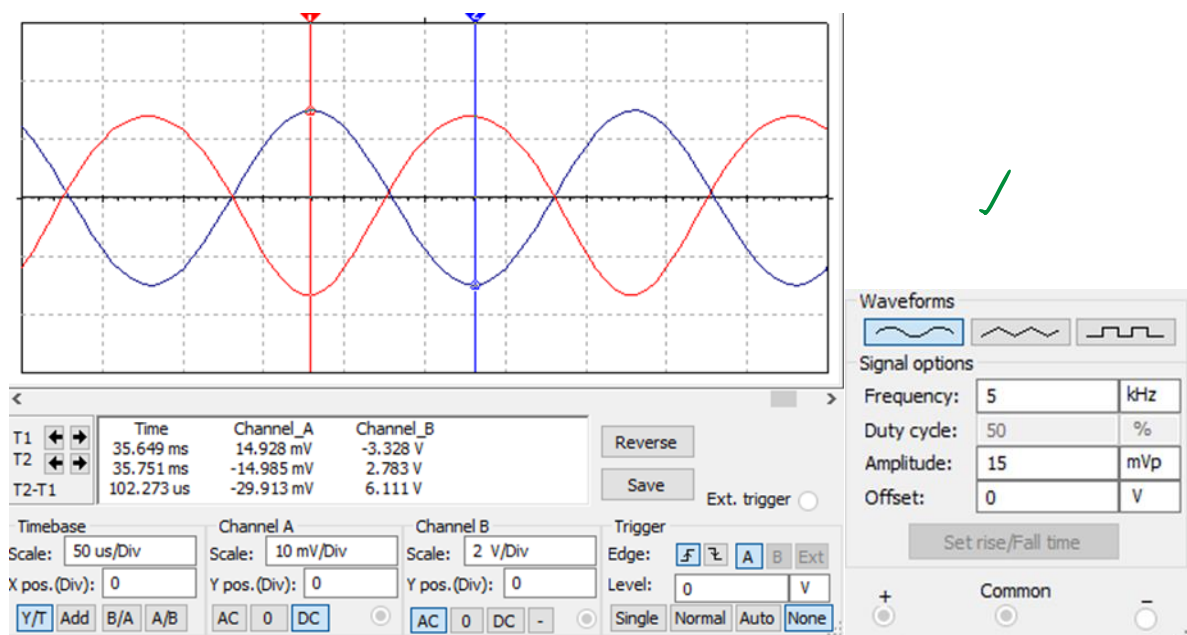
The screenshot below shows the circuit that was designed on Multisim for the BC108 common emitter amplifier. 5 voltmeter probes have been put across different parts of the amplifier legs.



AC Conditions (Multisim)



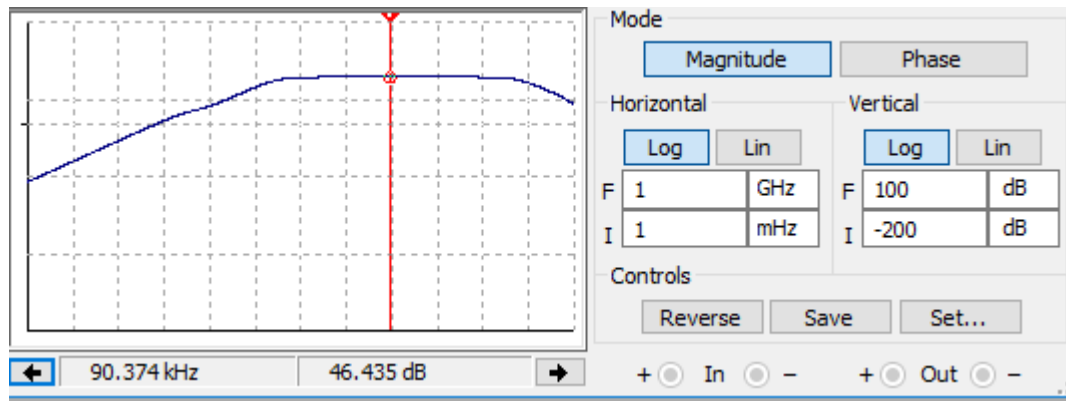
The AC condition circuit above shows the circuit that was designed on Multisim for the BC108 common emitter amplifier with a function generator and an oscilloscope connected to the circuit. The oscilloscope will be able to give a gain (db.) reading and a bandwidth measurement.



$$\text{Gain} = \frac{V_{\text{OUT}}}{V_{\text{IN}}} = \frac{6.111}{30 \times 10^{-3}} = \underline{203.7}$$

$$\text{Gain (db.)} = 20 \times \log \left(\frac{V_{\text{OUT}}}{V_{\text{IN}}} \right) = 20 \times \log \left(\frac{6.111}{30 \times 10^{-3}} \right) = \underline{46.18}$$

Measuring Bandwidth



The max gain of the circuit is **46.435dB**

Half point power = max gain – **3db**

Half point power = 46.435 – 3 = **43.435db**

Bandwidth = $f_2 - f_1 = 61.243 \times 10^6 - 294 =$ **61.2MHz**

DC conditions (Comments) – Part b and c

- After analysing the three separate results under DC conditions I have noticed one main trend in the results, the practical result is always further away from the calculated result compared to the voltmeter/current readings from the Multisim circuit. This is because the resistors used on the breadboard have a tolerance of +/- 5%. When measuring the voltage and current the tolerance will have a knock-on effect on the results recorded. Also, the connection on the breadboard with the meter probes may not have a proper contact, this will cause slight variation in results.

AC Conditions (Comments) – Part b and c

- The max gain of the practical circuit was 44.91db and the max gain of Multisim circuit was 46.435db. These two results are very accurate. Whereas the bandwidth measurements had a massive difference, the Multisim result was 61.2MHz and the practical result was near enough 5MHz.

d) Analyse the performance of the circuit, commenting upon any variations in the results and the overall performance of the amplifier.

The overall performance of the circuit met all requirements for the BC108 Transistor as seen in appendix 1. I have covered some of the variations in results above in part c. Another reason for slight variations in the results is down to the resistor values chosen from the tray compared to the calculated results. Also, the temperature of the transistor may have changed over time which will cause variations in H_{fe} .

Task 4 – Inverting Operational Amplifier

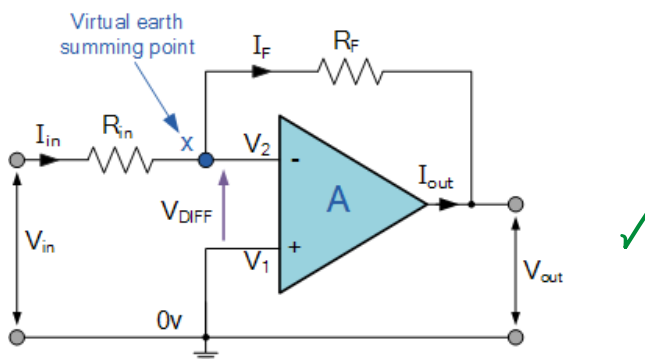
- Describe the configuration of Op-amp as an inverting amplifier and explain the importance of negative feedback in the configuration.
- Design an inverting amplifier to be used in a pre-amplifier in an audio system that will produce a gain of **18**. Suitable operational amplifier and power supply must be selected, use a data sheet to confirm the suitability of the operational amplifier.
- Build the circuit and produce the record of test results for analysis of DC and AC amplification in relation to the developed circuit.
- Produce the frequency response curve for AC amplification. Also analyse the effect of slew rate and input signal frequency on signal distortion and AC amplification.

Task 4 (Answers)

- Describe the configuration of Op-amp as an inverting amplifier and explain the importance of negative feedback in the configuration.

Operational Amp (Inverting)

The image below is from the Electronics Tutorials webpage, it shows the construction of an Inverting Op Amp.

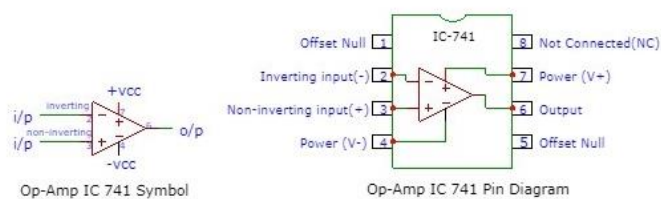


https://www.electronics-tutorials.ws/opamp/opamp_2.html

‘The inverting operational amplifier is basically a constant or fixed-gain amplifier producing a negative output voltage as its gain is always negative.’ (Tutorials, 2022)

The Op Amp gain can give very large readings, such as 1,000,000 and more.

IC – 741 Configuration



<https://how2electronics.com/op-amp-ic-lm741-basics-characteristics-pins-applications/#:~:text=Op%20Amp%20IC%20741%20Pin%20Configuration,-The%20symbol%20and&text=The%20diagram%20comprises%20eight%20pins,is%20inactive%20in%20the%20circuit.>

The screenshot above shows the IC 741 configuration, it is an 8-pin device.

Pins 4 and 7 are the power supply pins, 4 is the negative supply and 7 is the positive supply. These pins have a voltage range from 5v to 18v.

The following quote explains how Pin 2 and Pin 3 are used in the IC 741 configuration, 'Pin 2 is considered as inverting input and pin 3 is considered as non-inverting input. When the voltage at pin 2 is greater than the voltage at pin 3, i.e., the voltage at inverting input is higher, then the output signal is low. Similarly, when the voltage at pin 3 is greater than the voltage at pin 2, i.e., the voltage at the non-inverting input is higher, then the output signal is high.' (Subedi, 2022)

Pin 1 and pin 5 are used for offset voltage in op-amp IC 741. Due to this Op Amp, there is a higher voltage gain, little variation of volts at the inverting and non-inverting inputs causes further disruptions to the output voltage. A potentiometer can be used to overcome this issue.

Finally pin 6 is the output pin in the IC741 amplifier. If the voltage at pins 2 and 3 are high the voltage at pin 6 is near to the positive supply voltage (pin 7).

Negative feedback importance

'For an ideal op amp, the open-loop differential gain is assumed to approach infinity, and even a very tiny input voltage results in a very large output voltage. In a negative feedback circuit, a fraction of the output is returned to the inverting input terminal'. (Hambley, 2013)

The importance of negative feedback is because it reduces the overall gain of the circuit, meaning the stability of the circuit is better. Also the use of negative feedback allows the gain to be more constant over a wide range of frequencies and voltages.

b) Design an inverting amplifier to be used in a pre-amplifier in an audio system that will produce a gain of **18**. Suitable operational amplifier and power supply must be selected, use a data sheet to confirm the suitability of the operational amplifier.

Below is the design and calculations for part B above:

Bandwidth = 20KHz (Audio max frequency).

Select a LM741 Op Amp, gain bandwidth product (GBP) of 1MHz.

$$\text{Bandwidth} = \frac{GBP}{\text{Gain}} = \frac{1 \times 10^6}{18} = \underline{\underline{55.55\text{KHz}}}$$

$$\text{Gain} = \frac{V_{OUT}}{V_{IN}} = -\frac{R_F}{R_{IN}}$$

$$R_F = \text{Gain} \times R_{IN}$$

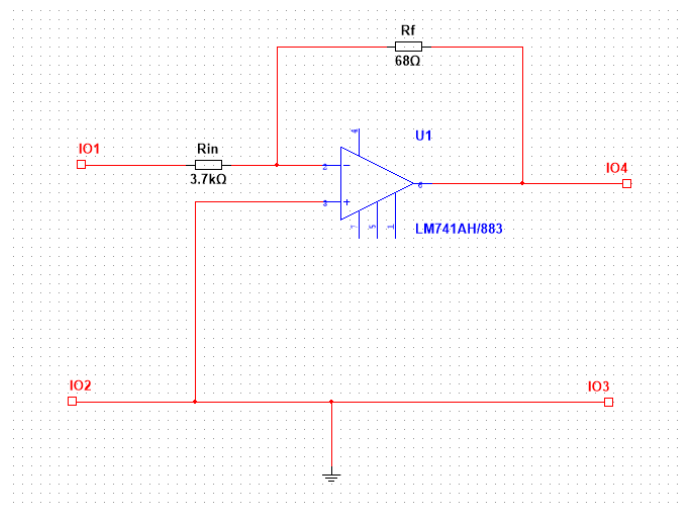
$$R_F = 18 \times R_{IN}$$

$$R_{IN} = \underline{\underline{3.9\text{k}\Omega}}$$

$$R_F = 18 \times (3.9 \times 10^3) = \underline{\underline{70200\Omega}} \text{ (Closest resistor value} = 68\text{k}\Omega)$$

Good.

Multisim Design for circuit



The screenshot above shows the design for the inverting amplifier, the resistor used for the inverting signal input is 3.7Ω . Pin 3 is the non-inverting signal input which is connected to ground. Pin 6 is the amplified signal output pin. The R_f resistor is put across the inverting signal and the output signal pins.

- c) Build the circuit and produce the record of test results for analysis of DC and AC amplification in relation to the developed circuit.

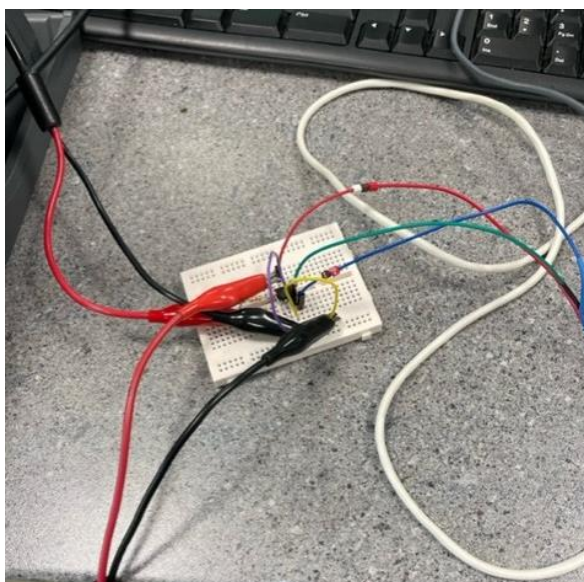
DC Input

Red to pin 7

Blue to pin 4

Earth to pin 3

<u>DC Input</u>	<u>Output</u>	<u>Gain</u>
0.1	-2.08	-20.8
0.2	-4.25	-21.25
0.3	-6.06	-20.2
0.4	-8.25	-20.625
0.5	-10.46	-20.92
0.6	-10.75	-17.916667
0.7	-10.75	-15.357143
0.8	-10.75	-13.4375
0.9	-10.75	-11.944444
1	-10.75	-10.75



AC Input

Input Voltage	Output	Gain
0.2	3.8	19.00
0.4	7.2	18.00
0.6	10	16.67
0.8	13.2	16.50
1	17.6	17.60
1.2	20.8	17.33
1.4	22.2	15.86
1.6	22.4	14.00

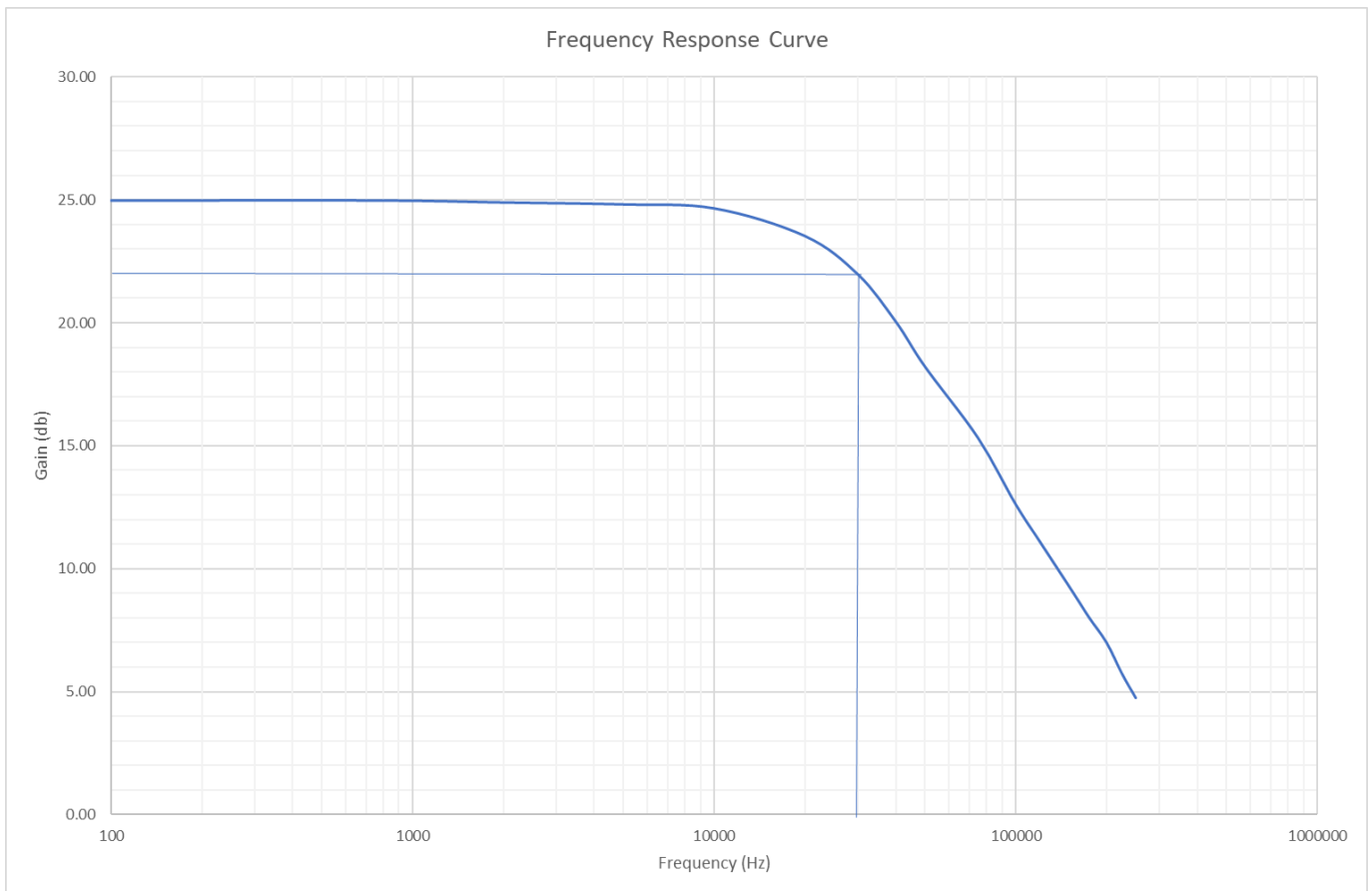


d) Produce the frequency response curve for AC amplification. Also analyse the effect of slew rate and input signal frequency on signal distortion and AC amplification.

Frequency (Hz)	V (Out)	Gain (db)
100	8.88	24.99
800	8.88	24.99
2000	8.8	24.91
5000	8.72	24.83
10000	8.56	24.67
20000	7.52	23.54
30000	6.28	21.98
40000	5.04	20.07
50000	4.08	18.23
75000	2.92	15.33
100000	2.14	12.63
120000	1.8	11.13
150000	1.46	9.31
175000	1.26	8.03
200000	1.12	7.00
225000	0.968	5.74
250000	0.864	4.75

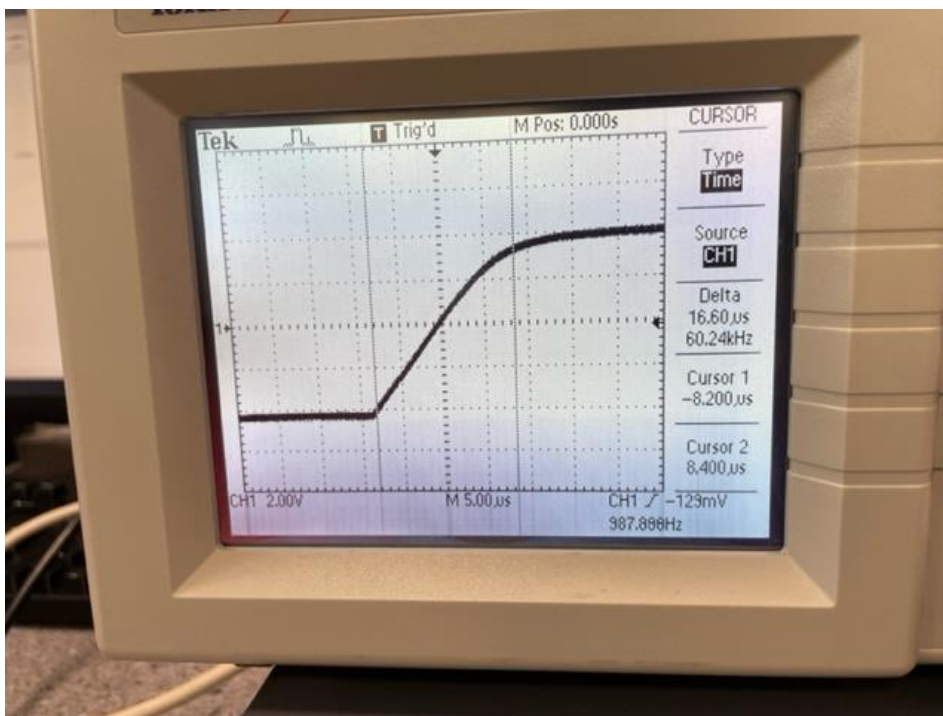


$$\text{Gain in d.b} = 20 \times \log \left(\frac{V(OUT)}{V(IN)} \right)$$



The Bandwidth of the curve above = 30,000Hz, this value meets the design specification.

Slew rate is the rate of change on the 741 Op Amp, = 16.6us



Input signal Frequency on signal distortion

In Appendix 3 it can be seen that the 741 Op Amp has a slew rate rating of 0.5V/micro seconds, this is quite slow, due to this being slow it will cause distortion.

If the input frequency is too high the gain becomes smaller.

Conclusion

Overall throughout the assignment the results that were gained in the practical element of each task shown the same common reasons for differences in results. This was mainly down to tolerances with components used and human error in measurements. In task 1 diodes were discussed and explained how the characteristics of the silicon and germanium diodes are different. In task 2 Multisim was used to build a full wave bridge rectifier circuit as well as a voltage regulator circuit, a capacitor was used to smooth the output, the higher capacitor value the smoother the ripple. In task 3 I designed a common emitter amplifier that had a suitable H_{fe} value with other calculations completed, the circuit was then built using Multisim under AC and DC conditions. Finally, for Task 3 I analysed the overall performance of the circuit. To complete Task 4 I gave a brief description of the configuration of an Op Amp as an inverting amplifier and how the importance of the negative feedback is needed, for part B calculations were done to meet the specifications, then the circuit was built and tested on a breadboard under DC and AC amplification, to finish Task 4 a frequency response curve was created for AC amplification. ✓

References

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Hambley, A. R., 2013. *Electrical engineering: principles and applications*. International edition ed. s.l.:Pearson Education.

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[The%20symbol%20and&text=The%20diagram%20comprises%20eight%20pins,is%20inactive%20in%20the%20circuit.](https://how2electronics.com/op-amp-ic-lm741-basics-characteristics-pins-applications/#:~:text=Op%20Amp%20IC%20741%20Pin%20Configuration,-The%20symbol%20and&text=The%20diagram%20comprises%20eight%20pins,is%20inactive%20in%20the%20circuit.)

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[Accessed 19 December 2022].

Appendix 1 - <https://html.alldatasheet.com/html-pdf/26333/VISHAY/BZX84C5V1/371/2/BZX84C5V1.html>

Appendix 2 - <https://www.farnell.com/datasheets/296633.pdf>

Appendix 3 - <https://www.mit.edu/~6.301/LM741.pdf>

Could have include a few more text books.

Bibliography

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Maddock R J, Calcutt D M. *Electronics for Engineering*. Prentice Hall. ISBN: 9780582215832 (1994)

Appendix

Appendix 1 – (Vishay – BZX84C5V1 – Datasheet)

Type	Marking	V _Z	Z _{KT}	@ I _{ZT}	Z _{ZK}	@ I _{ZK}	T _C	I _R	@ V _R
BZX84C...		V	W	mA	W	mA	%/°C	mA	V
		@ I _{ZT}							
2V7	KZC	2.5 to 2.9	100	5.0	600	1.0	-0.065	20	1.0
3V0	KZD	2.8 to 3.2	100	5.0	600	1.0	-0.060	10	1.0
3V3	KZE	3.1 to 3.5	95	5.0	600	1.0	-0.055	5.0	1.0
3V6	KZF	3.4 to 3.8	95	5.0	600	1.0	-0.055	5.0	1.0
3V9	KZG	3.7 to 4.1	90	5.0	600	1.0	-0.050	3.0	1.0
4V3	KZH	4.0 to 4.6	90	5.0	600	1.0	-0.035	3.0	1.0
4V7	KZ1	4.4 to 5.0	80	5.0	500	1.0	-0.015	4.0	2.0
5V1	KZ2	4.8 to 5.4	60	5.0	480	1.0	+0.005	2.0	2.0

Appendix 2 – Farnell – BC108 – Datasheet)

BC107/BC108 Series

Low Power Bipolar Transistors

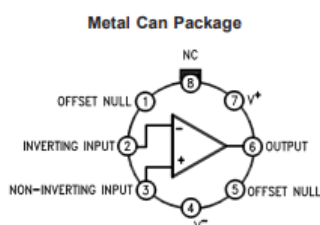
multicomp

Absolute Maximum Ratings

Description	Symbol	BC107	BC108	Unit
Collector-Emitter Voltage	V _{CEO}	45	25	V
Collector-Base Voltage	V _{CBO}	50	30	
Emitter-Base Voltage	V _{EBO}	6.0	5.0	
Collector Current Continuous	I _C	0.2		A
Power Dissipation at T _a = 25°C Derate above 25°C	P _D	0.6 2.28		W mW/°C
Power Dissipation at T _C = 25°C Derate above 25°C		1.0 6.67		
Operating and Storage Junction Temperature Range	T _J , T _{stg}	-65 to +200		°C
Thermal Resistance				
Junction to Case	R _{th (j-c)}	175		°C/W

Appendix 3 – National Semiconductors – 741 Op Amp – Datasheet)

Connection Diagrams

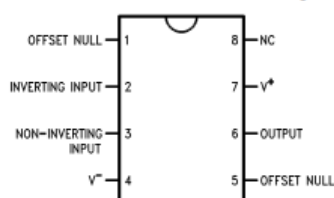


DS009341-2

Note 1: LM741H is available per JM38510/10101

Order Number LM741H, LM741H/883 (Note 1),
LM741AH/883 or LM741CH
See NS Package Number H08C

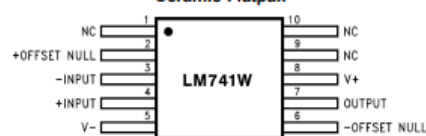
Dual-In-Line or S.O. Package



DS009341-3

Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

Ceramic Flatpak



DS009341-6

Order Number LM741W/883
See NS Package Number W10A

Electrical Characteristics (Note 5) (Continued)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	$T_A = 25^\circ\text{C}$, $R_L \geq 2\text{ k}\Omega$ $V_S = \pm 20\text{V}$, $V_O = \pm 15\text{V}$ $V_S = \pm 15\text{V}$, $V_O = \pm 10\text{V}$	50			50	200		20	200		V/mV V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $R_L \geq 2\text{ k}\Omega$, $V_S = \pm 20\text{V}$, $V_O = \pm 15\text{V}$ $V_S = \pm 15\text{V}$, $V_O = \pm 10\text{V}$	32			25			15			V/mV V/mV V/mV
	$V_S = \pm 5\text{V}$, $V_O = \pm 2\text{V}$	10									
Output Voltage Swing	$V_S = \pm 20\text{V}$ $R_L \geq 10\text{ k}\Omega$ $R_L \geq 2\text{ k}\Omega$	± 16 ± 15									V V
	$V_S = \pm 15\text{V}$ $R_L \geq 10\text{ k}\Omega$ $R_L \geq 2\text{ k}\Omega$				± 12 ± 10	± 14 ± 13		± 12 ± 10	± 14 ± 13		V V
	$T_A = 25^\circ\text{C}$	10	25	35		25			25		mA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
Common-Mode Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$ $R_S \leq 10\text{ k}\Omega$, $V_{CM} = \pm 12\text{V}$				70	90		70	90		dB
	$R_S \leq 50\Omega$, $V_{CM} = \pm 12\text{V}$	80	95								dB
Supply Voltage Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$ $V_S = \pm 20\text{V}$ to $V_S = \pm 5\text{V}$ $R_S \leq 50\Omega$	86	96								dB
	$R_S \leq 10\text{ k}\Omega$				77	96		77	96		dB
Transient Response	$T_A = 25^\circ\text{C}$, Unity Gain										
	Rise Time		0.25	0.8		0.3			0.3		μs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 6)	$T_A = 25^\circ\text{C}$	0.437	1.5								MHz
Slew Rate	$T_A = 25^\circ\text{C}$, Unity Gain	0.3	0.7			0.5			0.5		V/ μs

Report Guidance

Your write up should be produced as an engineering report containing the following:

- Front Page
- Summary
- Table of Content
- Introduction & Theory
- Experimental Apparatus and Procedure
- Results and Discussion
- Conclusions - conclude what was discussed in the Results and Discussion section. Think of the conclusion as a short restatement of important points being presented in the report. The conclusion should also make links to the theory discussed earlier in the report.
- References - any direct quotes or images taken from a source material must be referenced using the **Harvard System** in the main body of the report but they should also be listed in a reference section at the end of the report.
- Bibliography - a list of the books or other sources of information that you consulted when writing the report.