

Electronics. Diodes and Amplifiers.

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Course Name: HNC Electrical and Electronic Engineering Year 2

Module Code: PCEE4006

Assignment Title: Diodes and Amplifiers

Learner Name: Shay Pallas

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Task 1 – Characteristics of Diodes

A diode is a semiconductor device with a positive and negative terminal. Whilst operating with a diode the polarity is an important factor to enable the current to flow through efficiently. A diode has two sides to its molecular build up. The N-type side has an abundance of electrons and the P-type has several holes in its build up. Once the two sides are combined into the same material (The diode) the free electrons from the N-type side will begin to form with the holes on the P-type side. Minimising the number of free electrons in the centre causing what is known as the depletion region within the diode. On the N-type side of the diode positively charged cells will remain and, on the P-type side negatively charged cells will remain. The build-up of the positive and negative charged cells causes a barrier being formed in the depletion region causing the migration of free electrons and holes to stop. The polarity of the diode is important as the positive end of the battery must be connected to the P-type end and alternatively negative to the N-type end. Once applying the voltage, the current will only travel through the diode once the applied voltage is greater than the barrier potential within the depletion region. For a silicon diode the barrier potential is 0.7v and for a germanium diode the barrier potential is 0.3v. In the following statement a diodes functionality is explained "An ideal diode acts like a short circuit as long as the voltage across the anode-to-cathode junction is nonnegative. If the anode-to-cathode voltage is negative, the diode acts like an open circuit and no current flows" (Wakerly J.F.).

i) Identify different types of diode and their uses

- Zener Diode

A Zener diode is a specific diode which has been doped specifically to be able to function in a reverse biased state. When entering most diodes breakdown region, the Zener diode is capable of continuing operation within this state. Once reaching the breakdown region this is where the Zener diode will function. Once the Zener voltage has been reached (V_z) the diode will only allow this amount of voltage to pass through it even if the supply voltage is increased. To identify the positive and negative terminals on the Zener diode there is a band going around the diode on the Cathode side (negative terminal). The output voltage of the Zener diode will remain the same. The Zener diode will operate once the Zener knee current is reached ($I_{z\min}$) this is the minimum current suitable for the Zener diode to operate. $I_{z\max}$ is the maximum amount of current which the Zener diode can withstand before breaking down. The voltage regulation area is the suitable area for productive operation. Refer to image 1 for a graphical representation.

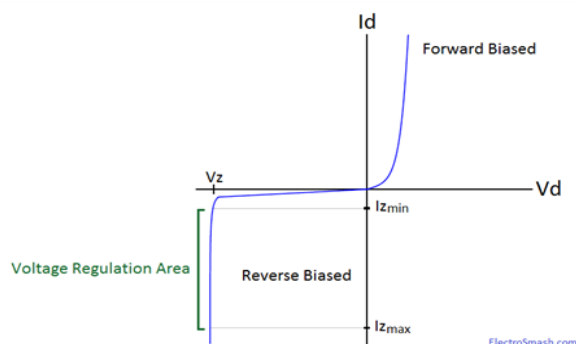


Image 1 – Zener diode operation graph. [ElectroSmash. JRC4558 Analysis]

Commented [RB1]: Detailed explanation of working of diodes.

Commented [RB2]: Citation goes as sir name with year, in your case, it should be like (Wakerly, 2005)

Commented [RB3]: Sentence structure?

Commented [RB4]: Maintain the constant voltage by increasing current flowing through it.

Commented [RB5]: Nice effort of showing it using graph.

- LED (Light-Emitting Diode)

An LED is a **D**iode which has been doped to produce a coloured light when electrical power is applied to it. To enable an LED to produce a certain colour it is dependent on the doping agent which has been applied. When applying different semi-conductor materials within the LED this will produce a range of different colours. Depending on the semi-conductor this will cause the different types of LEDs to have different operating voltages. Refer to image 2 for a table showing the different operating ranges. An LED works like a regular diode in the state that it is put into a reverse bias state the diode won't be functional, and once it passed the reverse breakdown region the diode will be permanently damaged.

Typical LED Characteristics			
Semiconductor Material	Wavelength	Colour	V _F @ 20mA
GaAs	850-940nm	Infra-Red	1.2v
GaAsP	630-660nm	Red	1.8v
GaAsP	605-620nm	Amber	2.0v
GaAsP:N	585-595nm	Yellow	2.2v
AlGaP	550-570nm	Green	3.5v
SiC	430-505nm	Blue	3.6v
GaN	450nm	White	4.0v

Image 2 – LED (Light Emitted Diode) Operating Table. [Electronicsguru. How LED produce different colours]

- Photodiode

A Photodiode is a diode which utilises light to help create the flow of electrical current. A photodiode works with a similar principle as other diodes with a positive and negative terminal. That will only enable the current to flow through when in a forward bias arrangement. The difference with this specific diode is that when a light element hits the diode it will cause electron holes in the molecular build up, depending on the intensity of the light the covalent bonds in the semiconductor material will be broken. This causes the overall conductivity of the diode to increase.

ii) Develop the circuit schematic of a full wave rectifier.

Whilst developing the schematic for the full wave rectifier (Bridge rectifier) the Zener diode value which is being used it a BZX85C15. Using the data sheet for the Zener diode certain values can be identified to enable the calculation for the surrounding components to be undertaken. The set value for the power supply(V) is 20V. The values for V_Z, I_Z and I_{ZK} have all been taken from the Zener diode datasheet. [Mouser Electronics. BZX85C3V3 – BZX85C56 Zener diodes datasheets].

V = 9V
 V_Z = 6.8V
 I_Z = 5mA
 I_{ZK} = 1mA
 P.d = 1W

$$I_{zmax} = \frac{P_z}{V_z} = \frac{0.5W}{9V} = 0.05 = 50mA$$

$$R_{min} = \frac{V - V_z}{I_{zm}} = \frac{9 - 6.8}{50mA} = 44\Omega$$

$$R_{max} = \frac{V - V_z}{I_{zk}} = \frac{9 - 6.8}{1mA} = 2.2k\Omega$$

$$R = 180\Omega$$

The resistor value needs to be situated in between the minimum resistor value and the maximum resistor value. To ensure the diode does not get damaged by heat dissipation the value for the resistor is substantially closer to the minimum resistor value (R_{min}).

The next part of the calculation is to develop the value for the second resistor within the circuit (R_L).

$$I_R = \frac{V - V_z}{R} = \frac{9 - 6.8}{180} = 12mA$$

$$I_L = I_R - I_z$$

$$I_{Lmax} = I_R - I_{zk}$$

$$R_{Lmin} = \frac{V_z}{I_R - I_{zk}} = \frac{6.8}{12mA - 1mA} = 0.6k\Omega$$

R_{Lmax} = will be rated at an infinite resistance. This is due to the Resistor being rated so highly there will be no current passing through it. ensuring all the current flows through the Zener diode limiting the current throughout the circuit

$$R_L = 1.2k\Omega$$

Commented [RB6]: Lower value is used to avoid loss of power due to heat dissipation.

Commented [RB7]: Sentence structure?

iii) Use multisim to simulate and test the circuit.

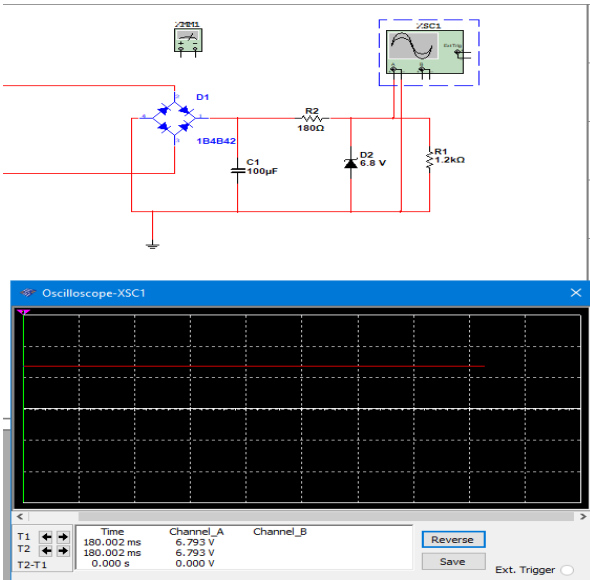


Image 3 – Output Voltage (Vout), Bridge wave rectifier simulation.

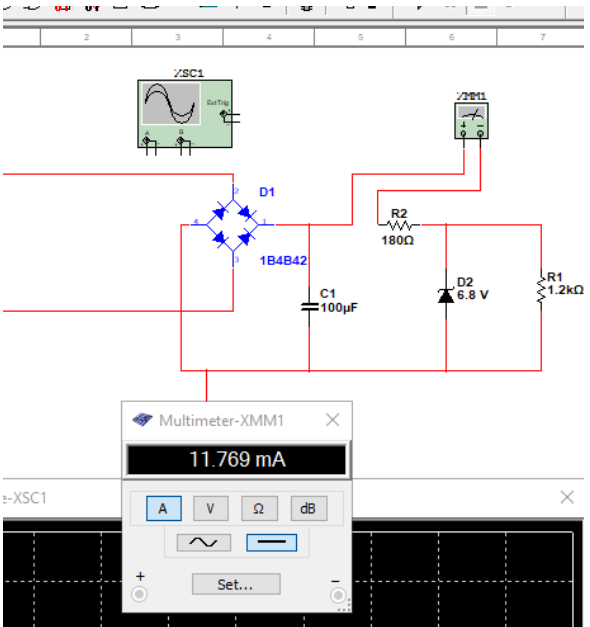
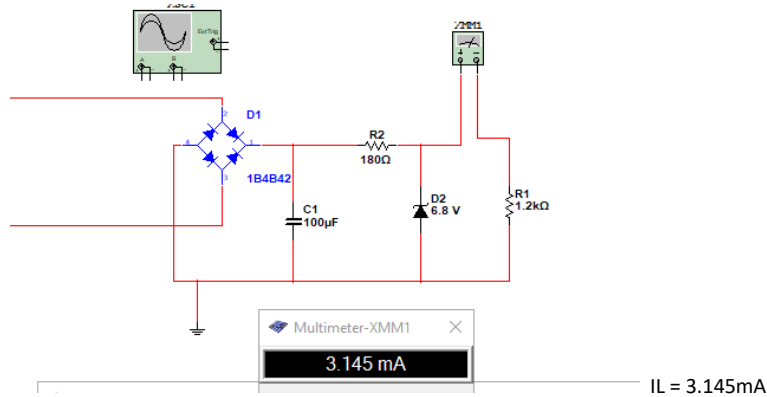


Image 4 – Current through Resistor (R), Bridge wave rectifier simulation.

Image 5 – Current through RL (I_L), Bridge wave rectifier simulation.

- iv) Build a prototype of your final circuit.

Once building the Bridge wave rectifier different results were taken determining the functionality of the circuit. With the results there are a few fluctuations due to tolerances in the components. The tolerances of the individual components must be taken into consideration whilst making comparisons to the calculations and simulations. Within the construction of this circuit there are different sections. The bridge rectifier is used to alter the sin wave to produce the beginning of the DC signal. The series resistor is used to limit the current flowing through the Zener diode. The capacitor is used as a filter for the circuit, causing the ripple in the DC voltage to be smooth and minimal. The last section of the bridge wave rectifier will regulate the output voltage causing the circuit to maintain a steady and healthy output with variations to the load current and other external factors.

- v) Record the output voltage and estimate the voltage ripple for different loads.

Name	Zener Diode	V_Z	V_i	$I = \text{Current through Resistor R}$	$I_L = \text{current through Load Resistance}$	V_{out}	Ripple in output with different load resistances
Shay	BZX556V8	6.8	9	12.1mA	3.18mA	6.56V	1.2k = 0.6v, 270 = 1.2v, 56 = 2v, 3.3k = 0.3

Table 1 – Practical Results.

Commented [RB8]: Could explain the reason behind it.

- vi) Comparison of the results

Whilst comparing the three sets of results there are a slight fluctuation between the two. These can be down to human errors and tolerances. As the multisim results are exact correct due to it being a simulation of the circuit, providing detailed answers. There can be a fluctuation due to tolerances of the equipment. Meaning their

components used are not the exact value rated. Most of the components have a tolerance of 5% - 10%. This will then vary the results slightly. Human error may also occur whilst building the circuit varying the results slightly. The results are in a suitable region of each other allowing these to be determined as correct.

Results	V _z	V _i	I = Current through Resistor R	IL = current through Load Resistance	Vout
Practical	6.8	9	12.1mA	3.18mA	6.56V
Simulation	6.8	9	11.769mA	3.145mA	6.793V

Table 2 – Table of results for comparison.

Task 2 – Transistor amplifier design and performance measurements

A transistor is a semiconductor device with three terminal connections. A transistor is used within a circuit to amplify or switch electrical power. There are predominantly two types of transistors used. These are the NPN and PNP type transistors. The following statement describes how semiconductors behave when electrical power is applied. "semiconductors will be n-type, or negative, which means that free electrons in the material drift from a negative electrode (of, say, a battery it's connected to) toward the positive. Other semiconductors will be p-type, in which case the electrons fill "holes" in the atomic electron shells, meaning that it behaves as if a positive particle is moving from the positive electrode to the negative electrode." (Andrew Z. Jones). The functionality of an NPN works from attaching a N-type region to the negative side of the supply, which enables electrons to pass to the middle (P-type) region. On the other side the other N-type region connects to the positive end of the supply. Slowing down the electrons leaving the P-type region. Using this methodology and varying the potential can significantly the flow of electrons throughout the transistor.

Commented [RB9]: Please pay attention to the use of full stops.

Commented [RB10]: ?

Commented [RB11]: Could mention about the different operating regions of transistors and their significance, DC load line and role of biasing of the transistor in amplification without any distortion.

- i) Design a common emitter amplifier.

Transistor = BC550

Transistor I_c max = 100mA

H_{fe} Value = 573

Collector Current (I_Q) = 1mA

Volts (V_{cc}) = 12V

I_c = I_Q

$$R_c = \frac{V_{cc}}{2 \times I_c} = \frac{12}{2 \times 1 \times 10^{-3}} = 6000\Omega = 6.8k\Omega \text{ used}$$

I_E = I_c

I_E = 1mA

V_E = 12% of V_{cc}

$$V_E = 12 \times 0.12 = 1.44V$$

$$R_E = \frac{1.44}{1mA} = 1440\Omega = 1.5k\Omega \text{ used}$$

Base Current (I_B)

$$I_B = \frac{I_C}{\beta_{FE}} = \frac{1mA}{573} = 1.745\mu A$$

$$V_{BE} = 0.7V$$

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

DC bias network current

$$I_B \times 10 = 1.745 \times 10^{-6} \times 10 = 17.45\mu A$$

Resistance for R_2

$$R_2 = \frac{V_B}{10 \times I_B} = \frac{2.14}{10 \times 1.745 \times 10^{-6}} = 122636 = 120k\Omega \text{ Resistor used}$$

$$R_1 = \frac{V_{CC} - V_B}{11 \times I_B} = \frac{12 - 2.14}{11 \times 1.745 \times 10^{-6}} = 527k\Omega = 560k\Omega \text{ Resistor used}$$

$$\text{Input Capacitors} = 10\mu F$$

$$\text{Input Capacitors} = 22\mu F$$

ii) Construction of design circuit

An amplifier circuit has been constructed to take measurements of the circuit. These results were ~~taken~~^{taking} to see the functionality of the circuit. Using the practical results, a comparison will be made to the simulation results to address the fluctuations. The results which have been taken from the practical element shows the circuits functionality. Image 6 is showing the AC amplification ~~for~~^{of} the transistor amplifier circuit. This is providing evidence of the transistor successfully amplifying the AC wave form. The wave form is showing an inverting wave signal being produced. The phase difference of this sine wave is 180° . Image 6 is showing the amplification factor of the two wave signals. The amplification can be determined from the resistors within the circuit.

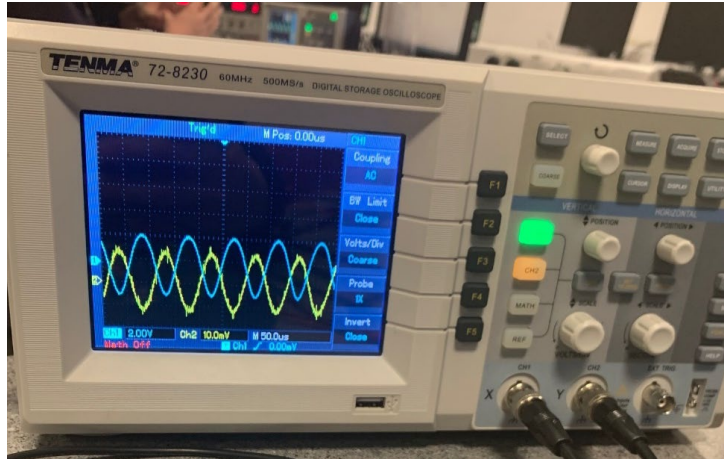


Image 6 – Amplification Waveforms.

iii) Creation of multisim circuit and testing results.

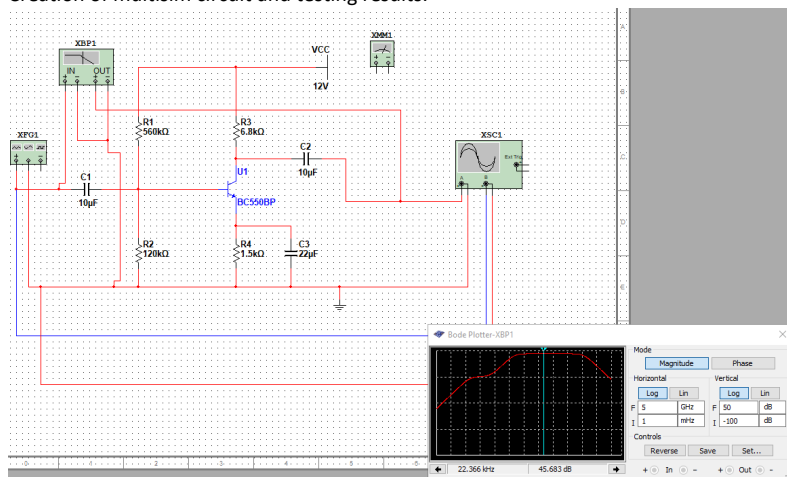


Image 7 – dB Value.

dB Value = 45.683dB
Frequency = 22.366 kHz

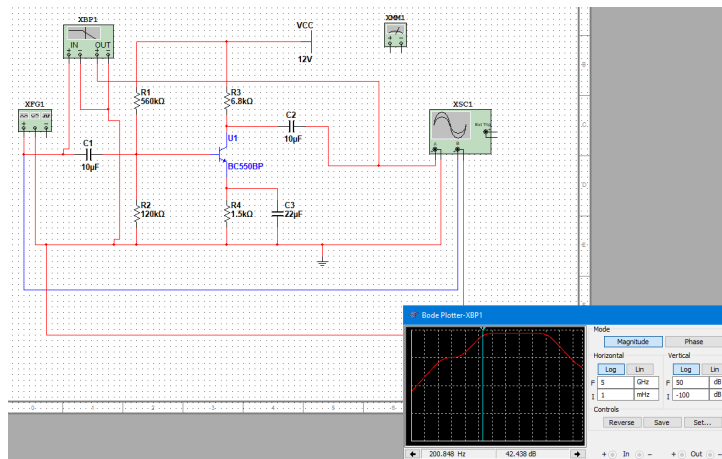


Image 8 – Lower cut off frequency.

dB Value = 42.438 dB

Lower cut off frequency = 200.848 Hz

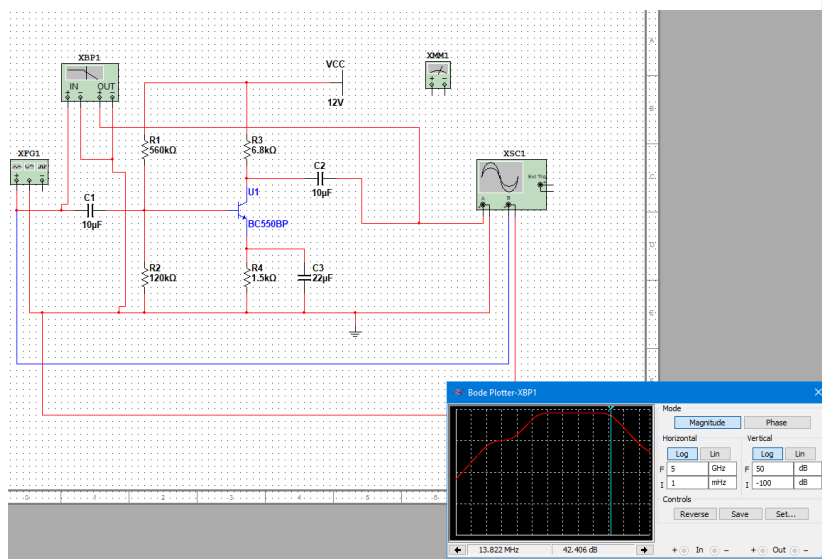


Image 9 – Upper cut off frequency.

dB Value = 42.406 dB

Upper cut off frequency = 13.822MHz

$$\text{Gain} = \frac{V_{\text{out}}}{V_{\text{in}}}$$

$$dB = 20 \log \left(\frac{V_{out}}{V_{in}} \right)$$

$$dB = 20 \log \left(\frac{1.9}{9.95 \times 10^{-3}} \right) = 45.6 \text{ dB}$$

These simulation screenshots are showing the dB values of the circuit and the difference between the lower and upper cut of points for the frequency. Also providing the frequency where the circuit maintains a consistent value. The calculation results are the same as the practical results for the frequency of the circuit, showing the functionality of both products.

Commented [RB12]: Could explain bandwidth and its significance.

Due to current circumstances, I was unable to retrieve all screenshots for this task.

iv) Analysis of results

These variation in results can be seen within the table 3. The fluctuation in results can be a cause of various factors. One of the main factors for the variations is the tolerances of the equipment used within the practical element. Due to the tolerances of most the equipment and components being used to be $\pm 5\%$ - 10% this can cause a noticeable difference. The other factor of the practical which can cause a variation within the results is human error. Not connecting equipment correct or a slight loose connection can cause the results to vary slightly. Taking into consideration the external factors which are causing the variation in results the practical results are in a suitable region to be determined correct. The simulation of the results are exact numbers with no human error or tolerances being implicated. These measured results can be deemed as correct. With the screenshots which were retrievable this can highlight that all circuits were functional. As image 6 is showing an amplified sine wave with an 180° phase difference. Image 7 through 9 are providing evidence of the simulated circuit functioning.

Commented [RB13]: Good explanation of variation in calculated, simulated and practical results.

Values	Practical (V)	Simulation (V)
VC	5.96	6.5
VE	1.32	1.2
VB	1.92	1.832

Table 3 – Comparison of Results.

Due to the current circumstance, I was unable to obtain all the relevant results to complete table 3.

Task 3 – Inverting Amplifier

Within task 3 the criteria being covered is looking at the functionality of an inverting amplifier. Within this circuit an op-amp is being used to construct the circuit. An op-amp is a voltage amplifier which produces a high gain factor within the circuit. An op-amp is a linear integrated chip which has multiple terminals. The design of an op-amp is to use feedback components such as resistors in this case of the assignment. There are various legs on an op-amp which have different functions. The main legs are the non-inverting input which is used to amplify the existing signal. Inverting input which will invert the sine wave inputted whilst amplifying it. There are positive and negative input

connections. Depending on the value of the supply input it will cause a variation in the gain factor. Gain factor will be decided by the feedback value and input resistor. The voltage gain will be dependent of the open-loop gain of the op-amp. There is also an output pin. Refer to image 10 for a simplistic schematic of an op-amp. Due to current circumstances, we were unable to undertake the practical element of this task.

Commented [RB14]: Good point to be considered.

Commented [RB15]: Not the case when feedback resistors are used.

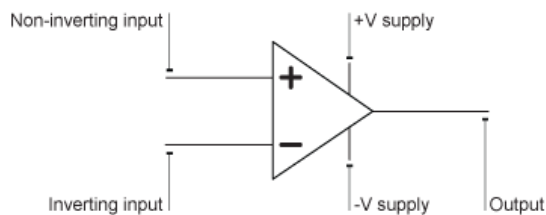


Image 10 – Op-Amp Schematic.

i) A) Construction of an inverting amplifier

Whilst looking at the theoretical aspect of the inverting amplifier the different types of feedback must be looked at. Positive and negative feedback is the two different types within this circuit, the feedback will vary the input voltage. Negative feedback will cause the input voltage to reduce. The positive feedback will cause the input voltage to increase. In the application the negative feedback is the most suitable option as it stabilizes the gain within the circuit which is desirable. This minimises the risk of damage to the circuit with a fluctuation of the supply voltage. There are two different types of amplifiers which need to be discussed. The inverting amplifier and the non-inverting amplifier. An inverting amplifier a type of op-amp which is 180° out of phase. Due to this signal being out of phase this is implying when the input signal is positive and the amplified signal will be negative. This circuit needs to be a closed loop method. This will cause the amplifier to be in a negative feedback state, the input as well as the feedback signal shall be provided to the inverting terminal of the chip. A non-inverting amplifier is a device which produces and amplified signal of the input signal. With the same or relatively similar phase angle. Weather the input is positive or negative. The non-inverting amplifier will replicate the phase angle with an amplified signal. Whilst working with amplifiers gain is a large factor of the functionality of the circuit. The formula for gain is as followed.

$$\text{Gain} = \frac{\text{Negative Resistor}}{\text{Resistor}} = \frac{10k\Omega}{1k\Omega} = 10$$

Commented [RB16]: Could say how input and feedback connection need to be done in case of non-inverting amplifier.

B) Construction of a non-inverting amplifier

A non-inverting amplifier is an op-amp circuit with a specific configuration which will produce an amplified output signal with a 0° phase shift. With a non-inverting amplifier, the non-inverting terminal is connected to ground. Due to this the inverting terminal needs to be brought back to ground level. This is to avoid any voltage difference in between the two input terminals. This is achieved through the virtual earth. The virtual earth causes the resistors to form a potential divider. As the inverting terminal is at ground this means the two resistors in the circuit need to also be at ground level. The gain of a non-inverting amplifier can be determined through the following.

Commented [RB17]: Why to mention non-inverting amplifier bits in upper paragraph then.

Commented [RB18]: ?

$$\text{Gain} = 1 + \frac{\text{Resistor connected to feedback}}{\text{Resistor connected to ground}}$$

Commented [RB19]: Circuit diagrams showing the connection of inverting and non-inverting amplifier could have helped.

ii) DC Amplification

With a DC input the circuit will be amplified. The amplification will depend on the two resistors and the gain which is caused within the circuit. as explained in the previous section the gain is equal to 10. An output voltage is determined by $V_{in} \times \text{Gain}$. Due to the input voltage (15v) the output voltage will be capped at this specific amount (15v). The 741-transistor given in the assignment has a $\pm 15\text{v}$ range. This causes the output voltage to be capped at 15v. For example, if 2v is inputted in theory $V_{out} = 2 \times 10 = 20$ but due to the supply voltage value it will be limited to a 15v output. From 0.1v to 1.5v input voltage the amplification will cause a gain of 10. Once 1.5 has been exceeded the value will be capped and the gain will be less.

Commented [RB20]: Could rather say signal

Commented [RB21]: Could say supply voltage to avoid any confusion.

Commented [RB22]: Good point

iii) AC Amplification.

With the AC amplification the gain in the circuit will remain the same as the DC amplification. As the gain is acquired using the same equation of the two resistors. This circuit has the same functionality of a common emitter amplifier. This will cause the sine wave of the input signal and the output signal to have a 180° -phase difference. The gain-bandwidth product within this amplification circuit is the bandwidth and the gain when the bandwidth is measured. "The bandwidth of the operational amplifier is defined as the frequency range over which the voltage gain of the amplifier is above -3dB (maximum is 0dB) of its maximum output value." [ElectronicsHub]. In image 11 the -3dB of the max A_v value is 37dB. The dB line is showing the frequency over 10kHz. This method of retrieving the frequency value can be applied to all bandwidth curves.

Commented [RB23]: Not clear?

Commented [RB24]: Good definition.

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Commented [RB25]: Could explain how gain and bandwidth are interrelated.

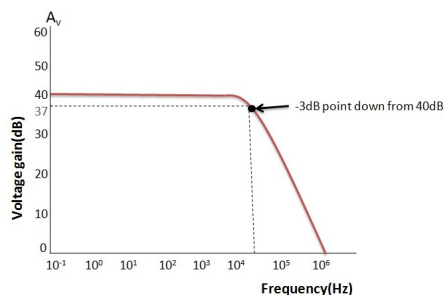


Image 11 – Gain Bandwidth Product.

$$\text{Phase angle} = 360 \times \Delta t \times F$$

iv) Slew Rate Detailing and Effects to circuit

Slew rate is a measurement of the amplifiers reaction to the change in input. The slew rate occurs due to the amplifier being unable to respond instantaneously to the change in input. A good slew rate is necessary for a functioning amplifier with a quick response

time. The unit value slew rate is measured in $V/\mu s$. Slew rate of a circuit can be calculated from the following equation.

$$\text{Slew Rate} = 2 \times \pi \times \text{Frequency} \times \text{peak output Voltage}$$

Commented [RB26]: Good understanding of the slew rate

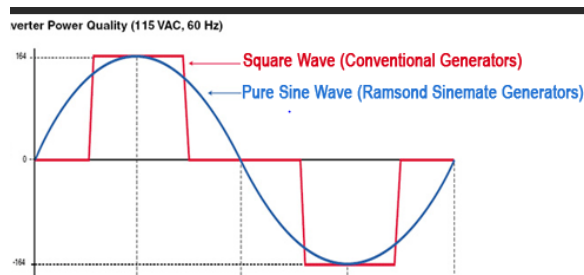


Image 12 – Sin wave with Slew rate effect.

When the frequency of the inputted is changed to 100kHz this will cause the slew rate to have a greater effect on the graph. Responding slower to the change in frequency will cause the graph to be affected even more so. The change in frequency will cause the output sign wave to be much more rapid causing the graph to change even further. Refer to image 13 for an example of the graph. "The slew rate of an op amp is the maximum rate of change of output voltage following a step input voltage. It causes the output voltage to change at a slower rate than the input. Such that the output waveform is a distortion of the input waveform." 0.5V/ μs is a typical value for the slew rate" [John Bird, 2007].

Commented [RB27]: Could say make it difficult for output signal to follow the input signal, leading to the distortion of the signal.

Commented [RB28]: ?

Commented [RB29]: A concluding statement could be provided.



Image 13 – Sin wave high frequency effect.

Word count - 2719

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Commented [RB30]: Only year needs to be mentioned.

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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	15	
You have used a wide range of the literature including books and relevant website and have followed Harvard referencing style with few inaccuracies. For next time, please pay attention to text-citation to score more in this section. Otherwise, you have done a good job in providing the supporting evidence for your explanations throughout the assignment.	68% 15	10.2
2. Knowledge and Understanding Skills	30	
You have demonstrated the sound and detailed knowledge and understanding of the basic underlying concepts of diodes and transistors and Op Amps. However, at times your explanation could be expanded. For details please see the comments given in the assignment.	65% of 30	19.5
3. Cognitive and Intellectual Skills	15	
You have exhibited excellent cognitive and intellectual skills by verifying simulated and measured results against the calculated values and providing the explanation for any variation in the measured and simulated results. All the calculations are also accurate and well presented by stating the formulas at first place. However, at times, you missed the opportunities to explain the measured results like, in task 1, you could explain the reason behind the change in ripple voltage with load variation.	75% of 15	11.2 5

4. Practical Application Skills	25	
While performing simulation and practical work in classroom, you have demonstrated your exceptional ability to use different approaches to find solution for the encountered problem. I acknowledge that you could not provide the evidence for all your simulation and practical activities due to unforeseen closure of the college.	85% 25	21.2 5
5. Transferable Skills for Life and Professional Practice	15	
You have presented your work well with good usage of equation editor. However, you need to pay attention on the usage of full stops and having a capital letter after full stop. At times, your sentences are not clear and having missing words. Proof reading your work before submission could help to avoid these mistakes in future. Moreover, more pictures could be used at times, like in task 2 and 3 to explain the concept in depth. Beside this, your work was structured and well presented, showing your ability to work effectively independently and/or as part of a team.	64% 15	9.6

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)		71.8%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		