

LEVEL 4 ASSESSMENT SPECIFICATION

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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
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	18
Task 1 achieved 56%. Task 2 achieved 40%, Task 3 achieved 58%. Knowledge of the basic underlying concepts and principles is accurate with a good understanding in most areas. Showed excellent understanding the calculated requirements. Have not included the design calculation for the different circuits.		
3. Cognitive and Intellectual Skills	15	9
Sound evaluation of the underlying concepts and principles for all tasks.		
4. Practical Application Skills	30	20.7
Task 1 achieved 67%. Task 2 achieved 68%. Task 3 achieved 72%. 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)		61%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

HNC Electronic and Electrical
Engineering:
Electronics Assignment PCEE4006
By Rhys Stevenson

Summary

The Assignment consists of 4 tasks that will test the knowledge and understanding of 4 different electrical components. These devices are a diode, full wave bridge rectifier, transistor and operational amplifier. In each section there is an overview of what the component is and its function along with an experiment to test its characteristics.

The diode was tested by comparing the forward and reverse bias resistance between a silicon and a germanium diode, the results of the task showed that silicon had a higher reverse resistance and lower forward resistance. Along with that it was concluded the germanium had a larger current leakage.

For the full wave bridge rectifier, a simulation was run to view its ability to convert AC voltage to a stable DC voltage. The tests showed that the addition of a large smoothing capacitor was necessary to produce a consistent DC voltage with few ripples.

The transistor experiment consisted of comparing the DC and AC characteristics of the component between simulated and real-world activity. It showed how the effect of temperature in real world and running under perfect conditions in simulation gave rise to variations between the results gathered from each.

The final task was to use an operation amplifier to produce a gain in an AC waveform for audio equipment. The experiment demonstrated the selected op-amp gave the necessary bandwidth to function as an audio amplifier with little distortion. ✓

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Task 1 – Characteristics of Diodes

Introduction

This task focuses on the differences between silicon and germanium diodes. A diode is a semiconductor (a material that conducts electricity under specific conditions) which only allows current to travel in one direction, known as forward bias whilst blocking current in the other direction (reverse bias) (McCormick, 2014). Diodes create these biases via a mechanism known as a positive – negative junction (p – n junction). The p – n junction is created by having the semiconductive material within the diode form regions of high electron density (the n – type semiconductor) and opposing this is an area of low electron density (p – type semiconductor). The p – n junction is located between the p and n type semiconductor, the material makeup of this is what allows current to only travel from the positive to negative end (McCormick, 2014). Figure 1 shows the composition of a P-N junction diode. ✓

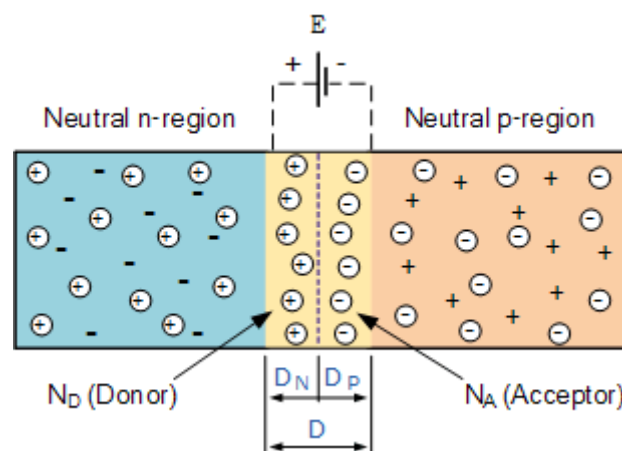


Figure 1 – Diagram of a P – N junction (Anon., n.d.)

Group IV elements are commonly used in the manufacturing of these semiconductors, as their electron shell configuration allows for efficient transfer of free electrons throughout the material, provided that they are the correct allotrope (elements that have multiple atomic structures it can arrange into) (Ware, 2014). For this reason, Silicon, Germanium and alloys of these are most commonly used, as they are metalloids (an intermediate between metals and non-metal elements) and are ideal for this purpose. ✓

Experimental procedure -

The aim of the task was to test and record the forward and reverse bias of both silicon and germanium diodes using the circuit shown in figure 2.

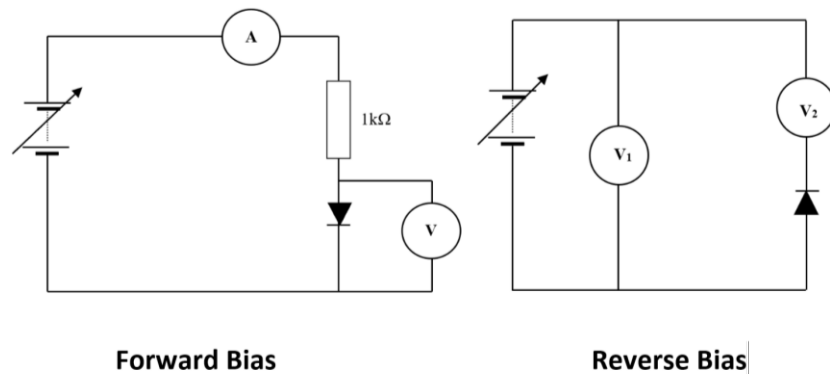


Figure 2 – Circuit diagram of forward and reverse bias diode experiment

Results -

For the forward bias experiment the voltage was increased in 0.1V increments, while the reverse test was increased in – 1.5V increments. The results from the silicon diode were recorded and placed in the following table.

Silicon Forward		Silicon Reverse			
Voltage (V)	Current (mA)	Voltage 1 (V)	Voltage 2 (mV)	Diode Voltage (V)	Current (nA)
0	0	0	0	0	-0.0003
0.1	0.00004	-1.5	-72.5	-1.5725	-7.25
0.2	0.00026	-3	-80	-3.08	-8
0.3	0.00166	-4.5	-84.3	-4.5843	-8.43
0.4	0.01305	-6	-94.1	-6.0941	-9.41
0.5	0.108	-7.5	-102.5	-7.6025	-10.25
0.6	0.928	-9	-105	-9.105	-10.5
0.7	7.41	-10.5	-108.7	-10.6087	-10.87
0.8	32.7	-12	-114	-12.114	-11.4
0.9		-13.5	-114.3	-13.6143	-11.43
1		-15	-116.8	-15.1168	-11.68

Figure 3 – Silicon Diode table of results.

The results show that the forward bias voltage show that the current flow does not increase significantly until the threshold voltage of 0.7V is reached. This is due to the makeup of the diode, with 0.7 being standard for these silicon-based devices.

For the reverse bias a number of calculations were used to obtain the current as it could not be measured directly, thus the following equations were used.

Voltage 1 (V1) was the input voltage

Voltage 2 (V2) was measured from the circuit

$$\text{Diode voltage} = V1 + \left(\frac{V2}{1000} \right)$$

$$\text{Current (nA)} = \left(\frac{V_2 \times 10^{-3}}{10 \times 10^6} \right) \times 10^9 \quad \checkmark$$

With the current determined in the reverse operation, the data shows a small amount of current which is leaking through the diode. Within normal operating parameters this current can be ignored as it is considered insignificant. The reverse voltage within this experiment never reaches the breakdown voltage for the diode so there is no avalanche. ✓

The same test was conducted on a germanium diode, with the addition of a 10kΩ resistor in parallel with V2 for the reverse experiment, the results table shown below.

Germanium Forward		Germanium Reverse			
Voltage (V)	Current (mA)	Voltage (V)	Voltage (mV)	Diode Voltage (V)	Current (μA)
0	0	0	0	0	0
0.1	0.015	-1.5	-0.013	-1.500013	-0.0013
0.2	0.171	-3	-0.027	-3.000027	-0.0027
0.3	0.658	-4.5	-0.05	-4.50005	-0.005
0.4	1.471	-6	-0.081	-6.000081	-0.0081
0.5	2.5	-7.5	-0.118	-7.500118	-0.0118
0.6	3.68	-9	-0.162	-9.000162	-0.0162
0.7	5.15	-10.5	-0.213	-10.500213	-0.0213
0.8	6.6	-12	-0.27	-12.00027	-0.027
0.9	8.31	-13.5	-0.333	-13.500333	-0.0333
1	10.28	-15	-0.401	-15.000401	-0.0401

✓

Figure 4 – Germanium diode table of results

The results from this diode show a difference in the threshold voltage being 0.3V before current depletion layer of the diode begins allowing significant current to cross the component. This is conclusive with the datasheets found in appendix A and B that corroborate these findings. ✓

Using the tables data for both diode types, 4 graphs were plotted for both silicon and germanium, forward (current against voltage) and reverse (diode voltage against current). These graphs are shown below and could be used to determine both the static and dynamic resistance values of both diode types. The points that are being measured are diode voltage of 0.7 volts for forward bias and -9 volts for the reverse.

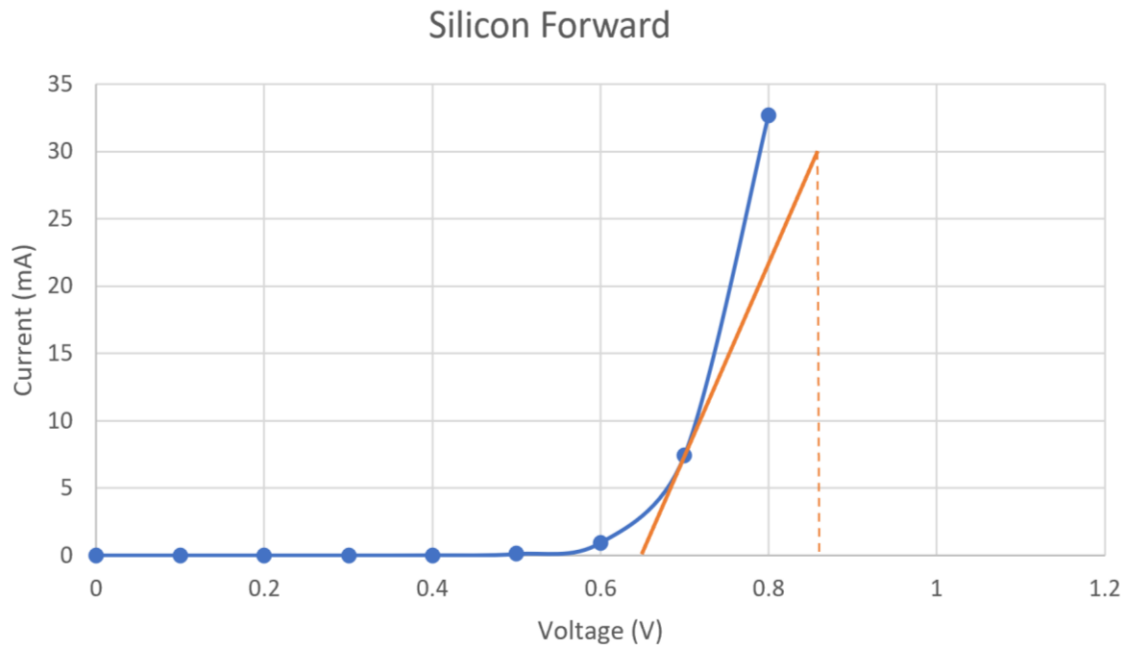


Figure 5 - Silicon Forward Bias Graph

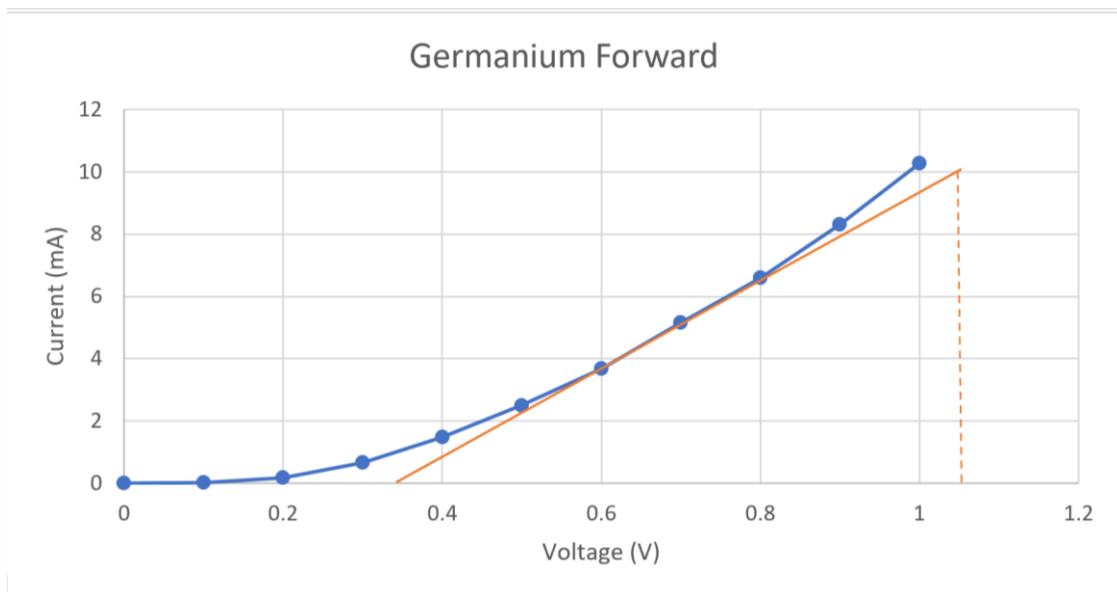


Figure 6 - Germanium Forward Bias Graph

To determine the static resistance, the calculation used is:

$$\text{Static Resistance} = \frac{\text{Voltage}(V)}{\text{Current}(A)}$$

$$\text{Silicon Static Resistance} = \frac{0.7V}{7.41 \times 10^{-3}A} = 94.467\Omega$$

$$\text{Germanium Static Resistance} = \frac{0.7V}{5.15 \times 10^{-3}A} = 135.922\Omega$$

The Dynamic resistance is calculated with the following equation, with the orange line on each graph signifying Δ :

$$\text{Dynamic Resistance} = \frac{\Delta \text{Voltage}}{\Delta \text{Current}}$$

$$\text{Silicon Dynamic Resistance} = \frac{0.85 - 0.65}{30 - 0} = \frac{0.2}{30 \times 10^{-3}} = 6.67\Omega$$

$$\text{Germanium Dynamic Resistance} = \frac{1.05 - 0.33}{10 - 0} = \frac{0.72}{10 \times 10^{-3}} = 72\Omega$$

Both the resistance results show that germanium diodes have a higher resistance value than silicon in the forward bias direction. With regards to the reverse bias, both graphs are highlighted below.

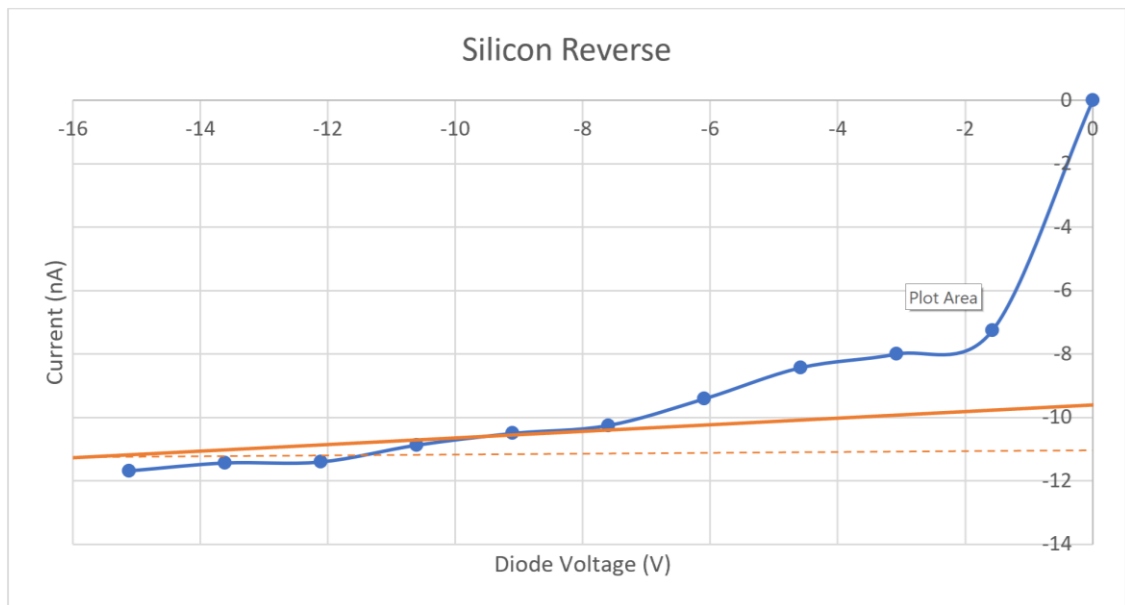


Figure 7 - Silicon Reverse Bias Graph

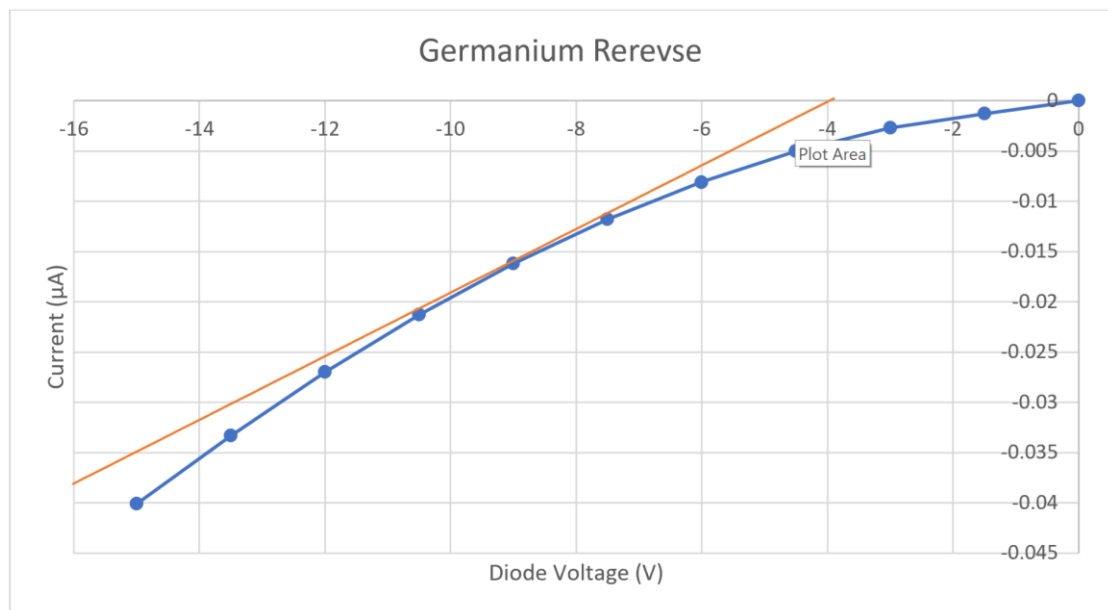


Figure 8 - Germanium Reverse Bias Graph

Both types of resistance are calculated the same for reverse as they are for forward bias, for more accurate results, the closest data point to -9 volts was used, these being -9.105V for silicon, and -9.000162V for germanium. Static resistance is shown below:

$$\text{Silicon Static Resistance} = \frac{\text{Voltage}(V)}{\text{Current}(A)} = \frac{-9.105}{-10.5 \times 10^{-9}} = 867.14 \times 10^6 \Omega \quad \checkmark$$

$$\text{Germanium Static Resistance} = \frac{\text{Voltage}(V)}{\text{Current}(A)} = \frac{-9.000162}{-0.0162 \times 10^{-6}} = 555.566 \times 10^6 \Omega \quad \checkmark$$

The final aim of the task was to calculate the reverse dynamic resistance of each diode:

$$\text{Silicon Dynamic Resistance} = \frac{-16 - 0}{-11 - -9.8} = \frac{-16}{-1.2 \times 10^{-9}} = 1.333 \times 10^{10} \Omega \quad \checkmark$$

$$\text{Germanium Dynamic Resistance} = \frac{-16 - -4}{-0.037 - 0} = \frac{-12}{-0.037 \times 10^{-6}} = 324.324 \times 10^6 \Omega \quad \checkmark$$

Conclusion -

The results of both devices show that there is a common trend in function between them. For forward function there is a relatively low resistance observed during regular operation, with silicon showing a lower resistance than germanium in both static and dynamic resistances. When considering the reverse, the opposite is true with silicon diodes recording significantly higher values than germanium. It should also be noted that silicon allows a smaller leakage current than its counterpart. ✓

Task 2 – Voltage Regulator Design

Introduction –

Voltage regulation is a fundamental aspect of electrical engineering, as not all components are created equal, manipulation of input current is needed to utilise devices at their optimum. One of the ways this can be achieved is with a configuration of diodes known as a full-wave bridge rectifier, an example of this can be seen below.

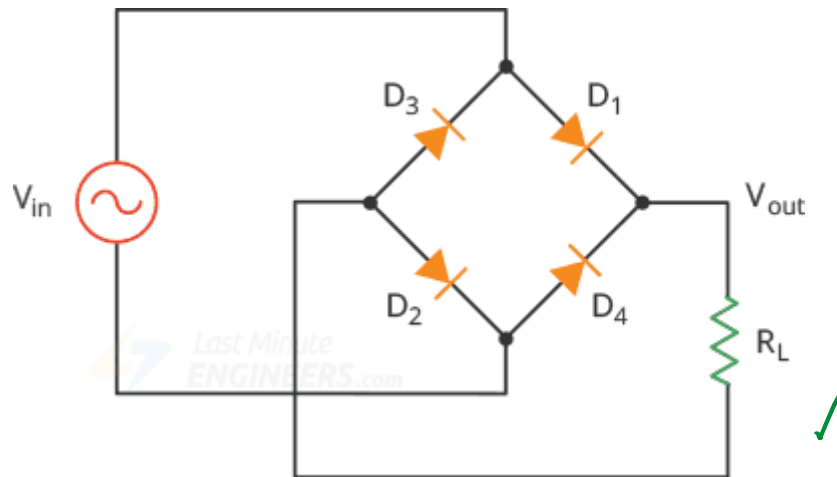


Figure 9 - Diagram of a full-wave bridge rectifier

As shown in figure 9 a full-wave bridge rectifier consists of four diodes arranged so that all of them are in series with a resistor. This device enables to conversion of AC to DC by remaining open when a positive voltage is fed though it, and inverting the signal when the voltage is less than zero (Muret, 2017). ✓

Experiment Procedure –

The aim of the experiment is to construct a full-wave bridge rectifier using multisim, recording the wave from that is produced across the resistor, along with the wave form with the presence of a smoothing capacitor. The second half of the task fill focus on testing a BZX84c5V1 voltage regulator also within multisim.

A rectifier was designed as shown in figure 10, that would be the bases for all the following experiments being conducted. The rectifier operates by D_1 and D_2 working in tandem, remaining open when a positive voltage comes from the power source, then when a negative voltage is delivered via the same route, the diodes switch and operate in a reverse bias mode. The same is true for D_3 and D_4 with the negative end of the power source. This is what allows the inverting of the sine voltage wave. Each peak is either D_1 , D_2 or D_3 , D_4 operating in a forward bias, with the other working in a reverse bias. ✓

Results -

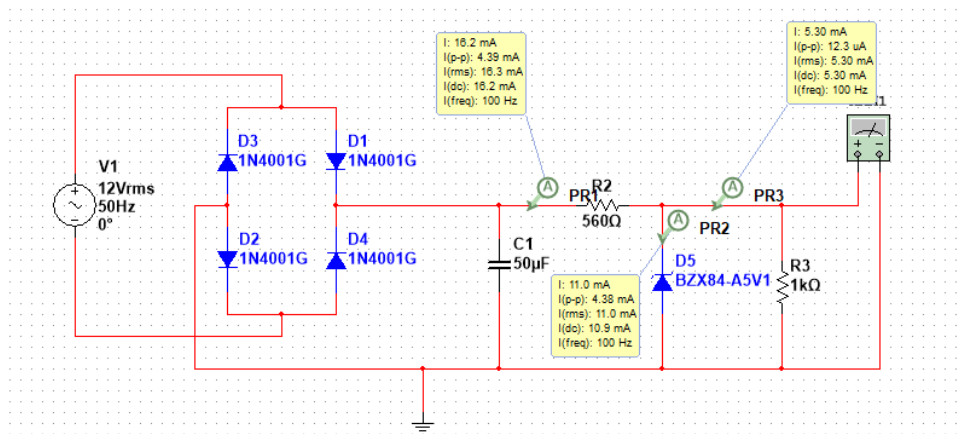


Figure 10 - full-wave bridge rectifier design

Figure 10 shows the circuit with a smoothing capacitor already integrated. The capacitors' role is intended to discharge between the peaks of the voltage waveform. Without the addition of the capacitor, the wave would resemble an inverted sin wave (with only the negative section being made positive) as shown in figure 11 below.

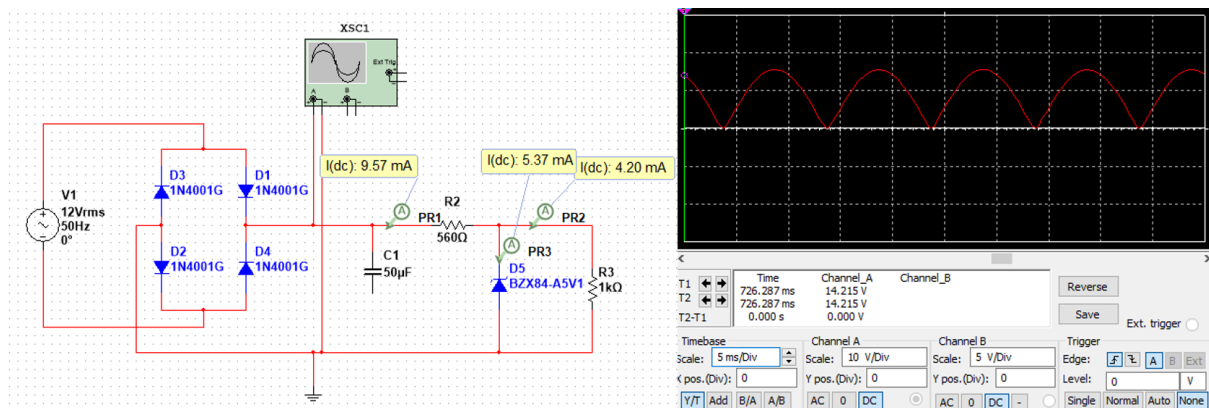


Figure 11 - Full-wave Bridge rectifier waveform (no smoothing)

Without the smoothing, the waveform is still classified as AC current, as the current alternates between positive peak and zero amps. To transform this into DC current, the capacitor must be placed in parallel with the diode and resistor for this to occur, as shown in figure 12.

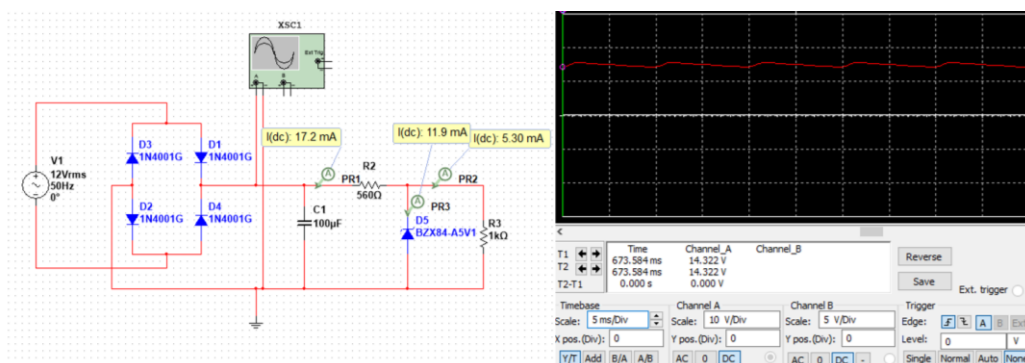


Figure 12 - Full-wave Bridge rectifier waveform (with 100 μ F smoothing)

The smoothing effect in figure 12 is apparent in the waveform as it is more in line with direct current, however there are still small ripples seen in the wave. These ripples are a result of the size of the capacitor installed. With a more power capacitor, the ripples would be less measurable. As figure 13 shows, the reverse is also true where having less capacitance would result in larger more measurable ripples.

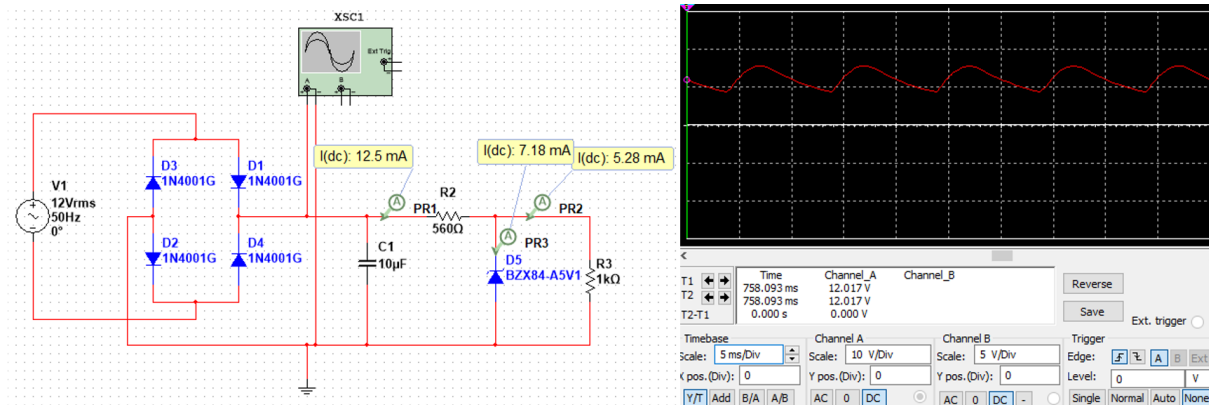


Figure 13 - Full-wave bridge rectifier waveform (with 10 μF smoothing)

Conclusion –

The simulation of the BZX84c5V1 shows that it can reliably convert an AC input into a DC output. However, it should be noted that the size of the smoothing capacitor integrated into the circuit is of vital importance to get as close to a true DC voltage. Without smoothing the result is that of an inverted sine wave, with an average voltage half of the total maximum.

Have not included your design for the regulator.

Task 3 – Transistors

Introduction –

Transistors are versatile components with a number of applications, including acting as a diode and as an amplifier. They are semiconductors which have a NPN junction, being the reverse of a diodes PNP. Common emitter configuration is used to produce gain in the current fed into the collector leg, and produces a significantly larger current in the emitter leg. This is only possible when a small current is applied to the base. This can be measured and signified by the h_{fe} (DC current gain) of the device (Dummer, 2016). The configuration of a common transistor can be seen in figure _ below.

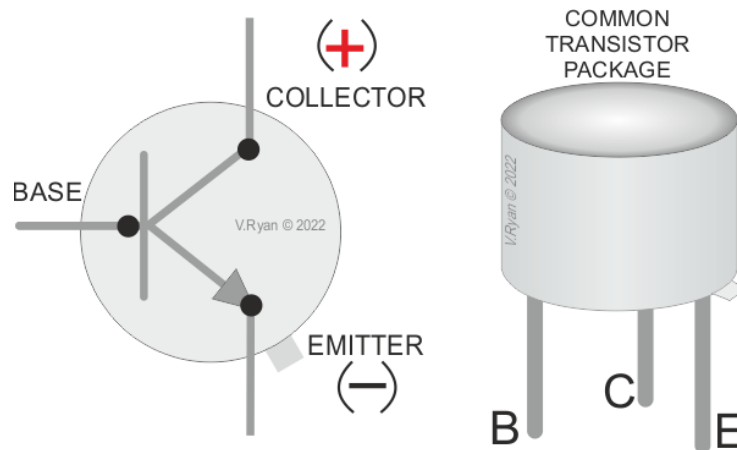


Figure 14 - Diagram of a transistor

Experiment procedure –

The aim of the experiment is to design a common emitter amplifier using a BC184BP transistor which has a h_{fe} value of between 100 and 130 as supported by the datasheet seen in App C. This is within the limits set for the task. Along with this a supply voltage of 10V was chosen. A 100uF decoupling capacitor and 10uF coupling capacitor are also integrated. With these specifications the following design was produced shown as figure 15.

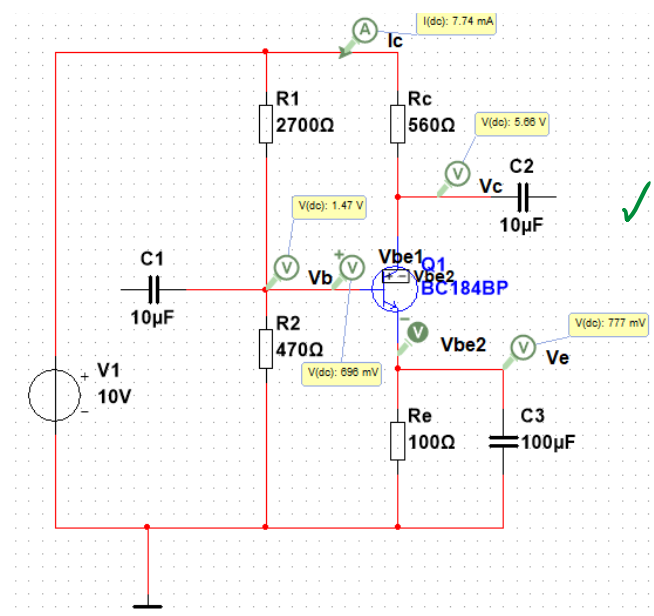


Figure 15 - Diagram of BC184BP common emitter amplifier circuit

Have not include your design calculations.

Results -

The next step was to build the aforementioned design on a breadboard and test it under AC and DC conditions. For the DC conditions the following results were obtained.

	DC conditions	
	Recorded Results (V) (breadboard)	Calculated Results (V) (multisim)
Vb	1.74	1.47
Ve	1.04	0.277
Vc	4.09	5.66
Vbe	0.69	0.696
Ic	10.56mA	7.74mA

A similar test was conducted under AC conditions with a fixed input frequency of 10Hz to find the gain the common emitter produces. This experiment involved the addition of a function generator and oscilloscope as shown in figure 16.

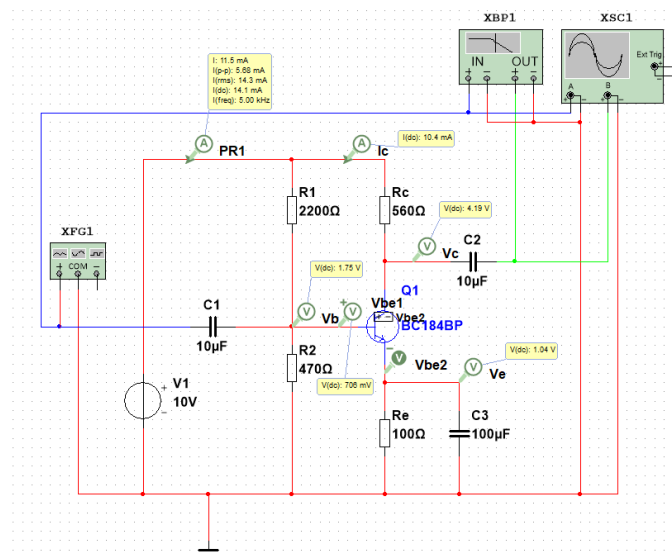


Figure 16 - Common emitter amplifier with function generator and oscilloscope

The practical results were recorded and laid out in the table below.

Frequency (Hz)	Input channel 1 (V)	Output channel 2 (V)	Gain (DB)
100	0.0424	1.12	28.43704
500	0.0416	4	39.65933
1000	0.0408	5	41.7662
5000	0.0408	5.2	42.10686
10000	0.0408	5.2	42.10686
50000	0.0408	5.2	42.10686
100000	0.0408	5.2	42.10686
500000	0.0408	4.8	41.41162
1000000	0.0408	3.8	39.38247

Figure 17 - AC practical results for transistor

From this table it was possible to calculate the half power point by reducing the maximum gain by 3. This gives a result of 39.1DB for the half power. With this it is possible

to estimate the bandwidth by subtracting the minimum frequency (F1) from the maximum (F2).

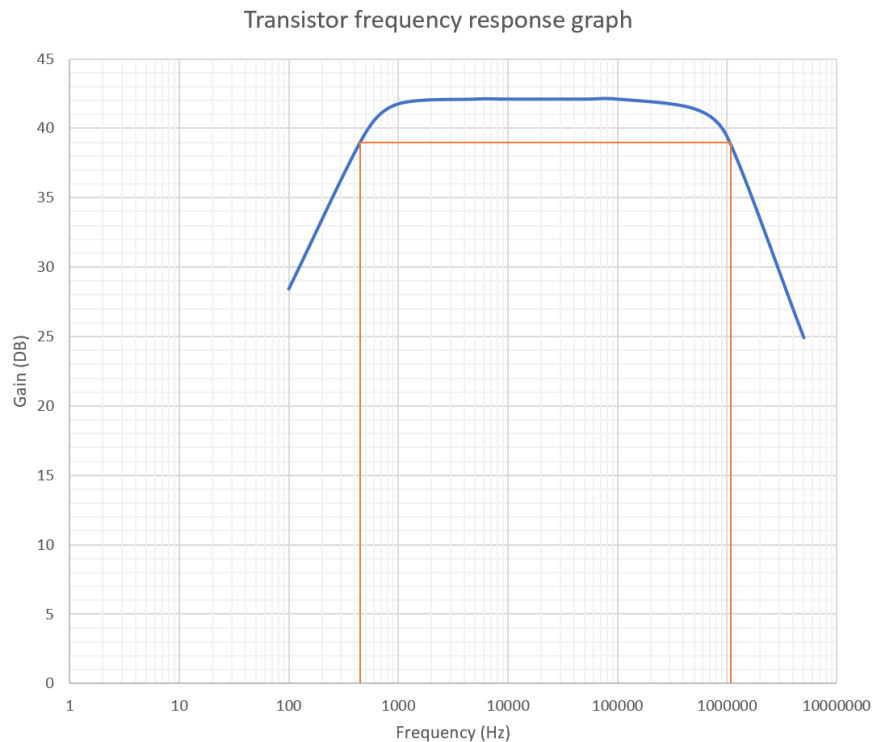


Figure 18 - Transistor frequency response graph

From the frequency response curve it can be seen that the half power point intersects at 450Hz and 1100000Hz, this allows for the following equation:

$$\text{Bandwidth} = F2 - F1 = 1100000 - 450 = 1.09955\text{MHz}$$

For the simulated results, as figure 19 shows the bode plotter and waveform output of the simulated transistor circuit.

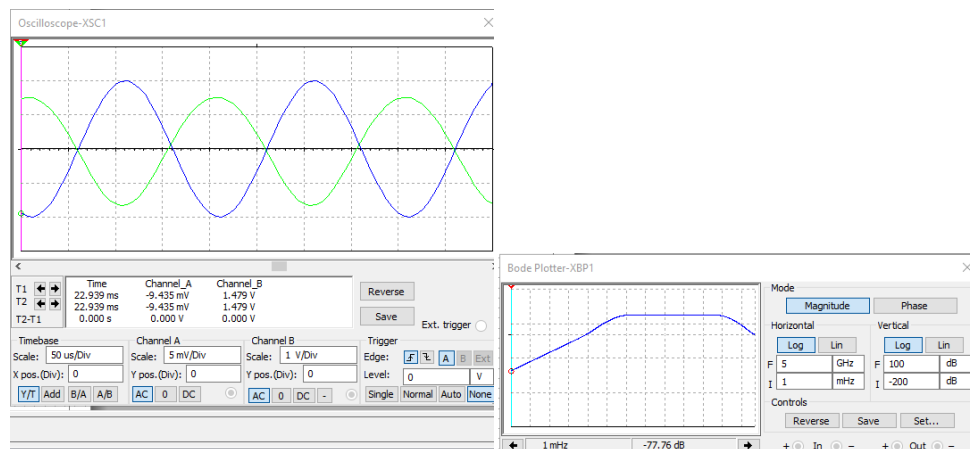


Figure 19 - Simulated transistor wave forms and frequency response

From this it was recorded the maximum gain was 42.286DB. This gives a half power point of 39.286DB, which intersects the frequency response at 404.47Hz and 128.882MHz, using this it is possible to calculate the simulated bandwidth:

$$\text{Bandwidth} = F2 - F1 = 128.882 \times 10^6 - 404.47 = 128.881\text{MHz}$$

Conclusion –

The BC184 transistor performed as intended, with minor variations between simulated results and practical tests. This can be accounted to the sensitivity of the component to variations in temperature, as the simulated results are performed under perfect conditions and therefore do not account for this factor. It should be noted that AC practical condition results have a degree of human error associated with it due to the fact that the logarithmic graph is an ineffective way to take readings.

Task 4 – operational amplifiers

Introduction –

Operational amplifiers (Op-amps) are electronic devices which are used in analogue electronics to undertake a variety of functions. They are constructed using transistors, resistors and capacitors. The op-amp can function as a amplifier, impedance converter, controller, comparator among a number of other useful operations. The component has an inverting (negative) input, a non-inverting (positive) input and an output (Hacker and Sumereder, 2020). This is shown in its symbol, figure _.

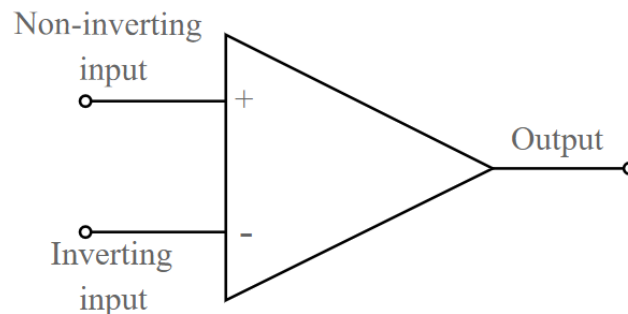


Figure 20 - Circuit diagram of an operational amplifier

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

The input impedance of an op-amp is theoretically infinite, in reality the impedance is 100MΩ or higher, the output voltage is the difference of the 2 input voltages, which gives the equation:

$$v_o = A(V_1 - V_2)$$

The equation states that if the open-loop gain (A) is infinite (in an ideal op-amp) then the output voltage (v_o) is finite, indicating $V_1 - V_2 = 0$. For this reason, it is common for a feedback loop to be integrated. This involves a resistor or capacitor bridging an input and the output of the op-amp (Warnes, 2017). This gives rise to the two golden rules:

The current drawn by the op amp at the input terminals is zero

The output voltage is whatever makes the input terminals voltages equal

(Warnes, 2017, pg 81)

Experiment procedure –

For the experiment the aim was to design an inverting amplifier that was to be used as a pre-amp for audio equipment, producing a gain of 18. The circuit was then to be built and tested under DC and AC amplification. Finally, a frequency response curve for AC amplification was plotted, and the slew rate recorded.

Figure 21 shows the design of the amplifying circuit, using an inverting loop to produce a positive feedback system that would produce the necessary gain. A LM741 op amp was used, with its data sheet shown in App D, along with a standard 12V power supply.

A minimum input resistance of 1K Ω is needed to protect the transistor from damage, so a 2.2K Ω resistor was selected for R1. The equation for R2 can be found in App E.

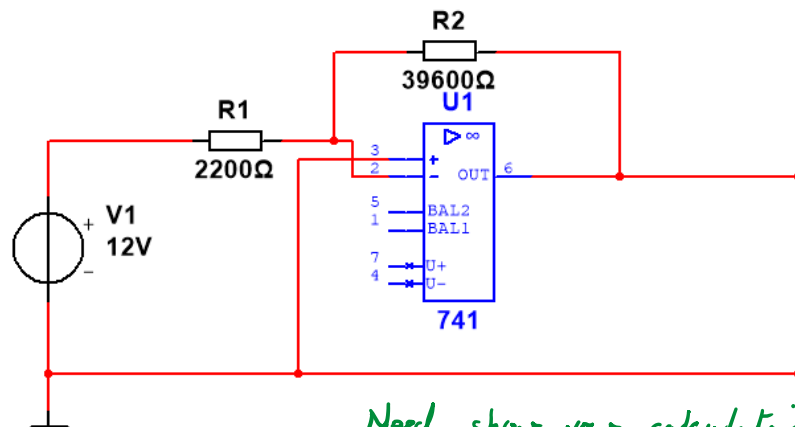


Figure 21 - Diagram of the op amp circuit

This op-amp was selected as it has a gain bandwidth product (GBP) of 1MHz, therefore using the equation:

$$Bandwidth = \frac{GBP}{Gain} = \frac{1 \times 10^6}{18} = 55.5KHz \quad \checkmark$$

55.5KHz makes it ideal for audio equipment as it is within the range of human hearing.

Results -

The circuits were then constructed on a breadboard for the DC and AC results to be recorded from. Shown below are the DC voltage gain results obtained:

DC Input (V)	DC output (V)
0.1	1.67
0.2	3.5
0.3	5.2
0.4	7.06
0.5	8.78
0.6	10.43
0.7	10.6
0.8	10.6
0.9	10.6
1	10.6

Figure 22 - Table of DC voltage gain

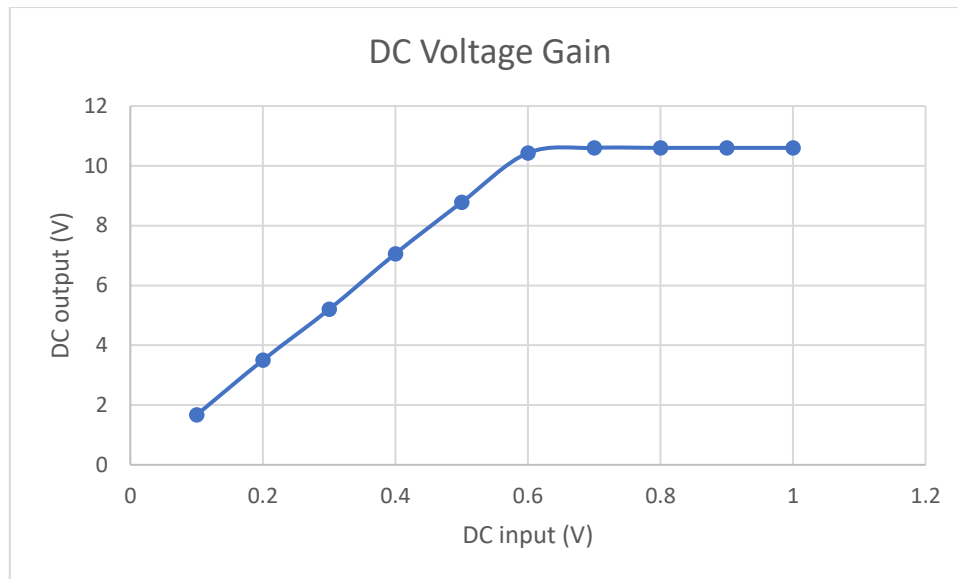


Figure 23- Graph of DC voltage gain

As Figure 23 and its table show, the output voltage is around 18 times the input. It is consistently slightly lower than the expected value as it was done under perfect conditions, any temperature fluctuations can affect the efficiency of the op-amp. The levelling off at 10.6V output is due to the output not being able to exceed the input voltage of 12V, as well as the op-amp typically loosing 2V over the component.

For testing under AC conditions, a function generator was added to produce a waveform of 500Hz, the output voltage was then measured with a known input.

AC Input (V)	AC Output (V)
0.15	2
0.3	4.24
0.45	6.14
0.6	8.08
0.75	10.15
0.9	12.65
1.05	14.4
1.2	16.8
1.35	19
1.5	21
1.65	22.2
1.8	22.4

Figure 24 - Table of AC voltage gain

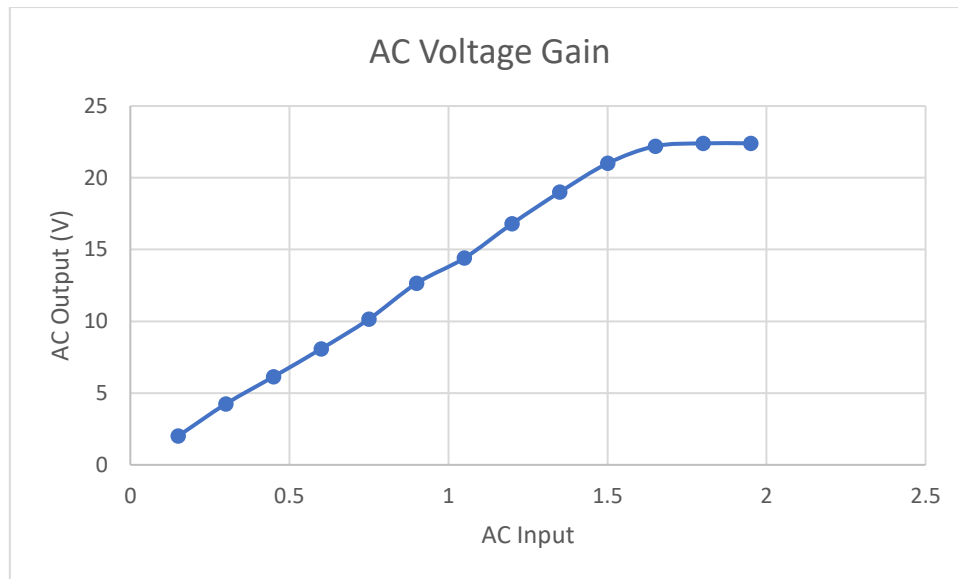


Figure 25 - Graph of AC voltage gain

As with the DC gain, the figure 25 shows a similar distribution with consistent gain of just below 18 until reaching a ceiling of 22.4V. The maximum output voltage is almost twice the DC voltage due to the sine wave, meaning that both the positive and negative oscillations are measured, resulting in double the voltage reading. ✓

For frequency gain, the input voltage was a consistent 0.5V and the frequency of the wave was increased logarithmically for meaningful measurements to be taken. The gain was calculated using the equation:

$$Gain = 20 \times \text{Log}\left(\frac{V_{out}}{0.5}\right)$$

The table below shows the results obtained.

Frequency (Hz)	Output (V)	Gain (DB)
100	6.64	22.4639615
500	6.64	22.4639615
1000	6.64	22.4639615
5000	6.64	22.4639615
10000	6.52	22.30555183
20000	6.08	21.6986715
30000	5.32	20.53883256
40000	4.48	19.04616019
50000	3.72	17.43145871
60000	3.2	16.12359948
70000	2.78	14.90149583
80000	2.44	13.76839644
90000	2.24	13.02556028
100000	2.04	12.21320326

Figure 26 - Table of AC frequency gain

The results were then used to form the graph to calculate the slew rate as seen below.

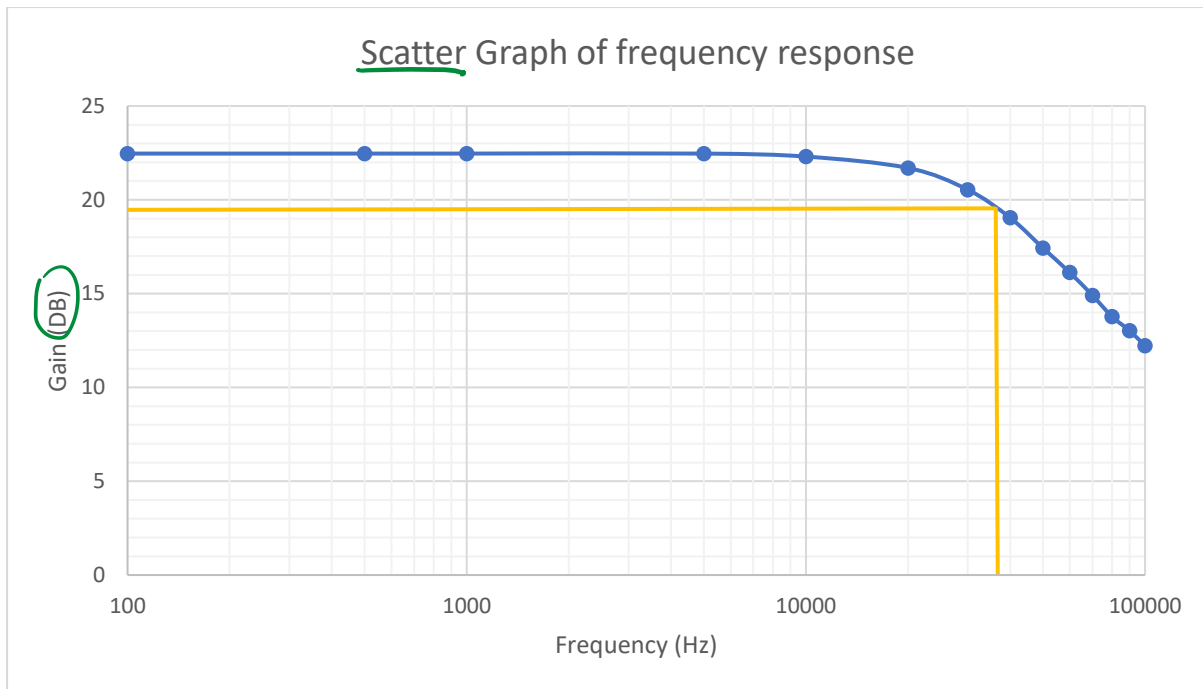


Figure 27 - AC amplification frequency response curve

The bandwidth of these results is 3 less than the total gain. For this the bandwidth would be equal to 19.46DB. As figure 27 shows with a bandwidth of 19.46DB the frequency (f_0) is 38KHz. This exceeds the 20KHz minimum needed to be used as an audio amplifier.

The slew rate was recorded by using an oscilloscope, figure _ below shows a picture of the output reading.

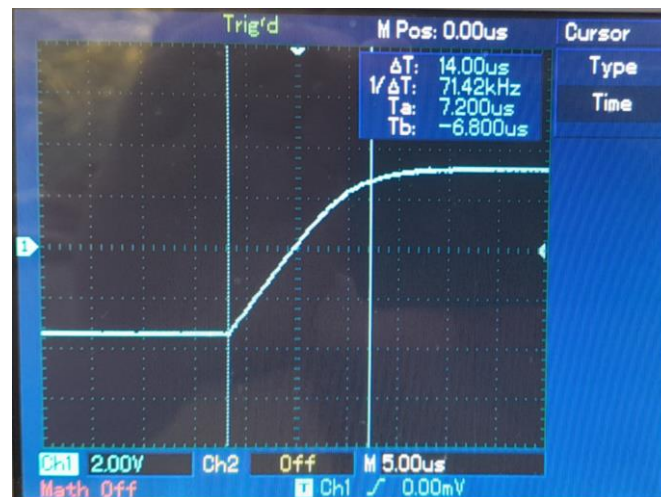


Figure 28 - Photograph of recorded slew rate

Using the graph indicated in figure 28, and the known output voltage of 22.4V the slew rate can be calculated using the following equation:

$$\text{Slew rate} = \frac{\Delta V_{out}}{\Delta T} = \frac{22.4}{14} = 1.6 \text{ V}/\mu\text{s}$$

The slew rate has an effect on distortion, which is the alteration of the waveform, having too low a slew rate can cause the output signal to lag behind. This can cause a sine waveform to form a sawtooth wave. ✓

Another form of distortion as shown in figure 29 below is peak clipping, once the peak output voltage reaches 22.4V, the waveform is compressed creating the distortion. ✓

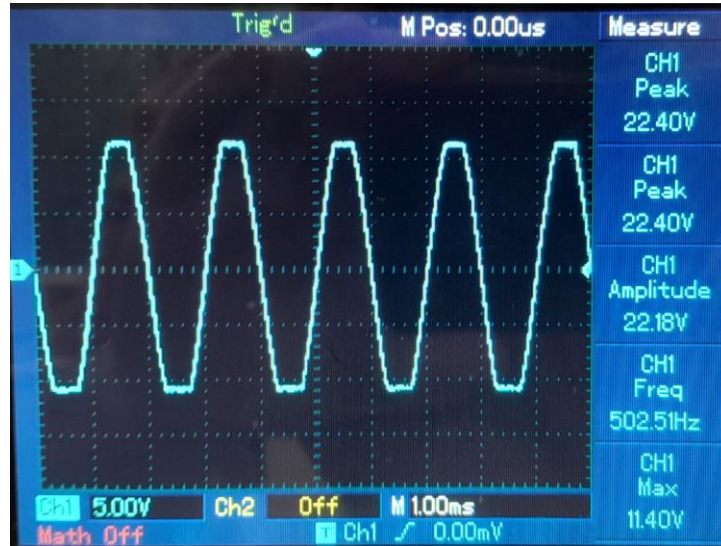


Figure 29 - Sine wave distortion from op-amp

From this it can be shown that AC amplification like that of DC can not exceed the maximum input voltage. In the case of an audio system this would result in unwanted noise being generated in the unit. ✓

Conclusion –

The results have shown that the LM741 op-amp is ideal for use in audio equipment as it generates an f_0 of 38kHz, well within the audible range for humans, and sufficient gain to meet the requirements. A slew rate of $1.6 \text{ V}/\mu\text{s}$ is acceptable for this kind of op-amp. ✓

References –

Task 1 –

Mccormick, S. a. M. J., 2014. *Diodes (Important Electrical Components)*. Delhi: College House Publishing.

Ware, V., 2014. *Handbook of Chemical Elements*. Revised Edition ed. Dehli: Research World.

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Figure 1 – Found at https://www.electronics-tutorials.ws/diode/diode_2.html (07/12/2022)

Figure 2 – Reused from the Assignment brief Task 1

Figure 9 – Found at: <https://lastminuteengineers.com/the-full-wave-bridge-rectifier/> (16/01/2023)

Figure 14 - Diagram of a transistor found at: <https://technologystudent.com/elec1/transis1.htm> (19/01/2023)

Figure 20 - Circuit diagram of an operational amplifier found at: https://www.electronics-notes.com/articles/analogue_circuits/operational-amplifier-op-amp/op-amp-basics.php (19/01/2023)

Figure 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26, 27, 28, 29 –
Produced from practical results

Bibliography –

Mccormick, S. a. M. J., 2014. *Diodes (Important Electrical Components)*. Delhi: College House Publishing.

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Appendix

Appendix A – Silicon Diode (1N4001 – 1N4007) Datasheet Found at:
<https://www.digchip.com/datasheets/parts/datasheet/139/1N4001-pdf.php>

MAXIMUM RATINGS AND ELECTRICAL CHARACTERISTICS

Rating at 25 °C ambient temperature unless otherwise specified.
 Single phase, half wave, 60 Hz, resistive or inductive load.
 For capacitive load, derate current by 20%.

RATING	SYMBOL	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	BY133	UNIT
Maximum Repetitive Peak Reverse Voltage	V_{RRM}	50	100	200	400	600	800	1000	1300	V
Maximum RMS Voltage	V_{RMS}	35	70	140	280	420	560	700	1000	V
Maximum DC Blocking Voltage	V_{DC}	50	100	200	400	600	800	1000	1300	V
Maximum Average Forward Current 0.375"(9.5mm) Lead Length $T_a = 75^\circ\text{C}$	$I_{F(AV)}$	1.0								A
Peak Forward Surge Current 8.3ms Single half sine wave Superimposed on rated load (JEDEC Method)	I_{FSM}	50								A
Maximum Forward Voltage at $I_F = 1.0$ Amp.	V_F	0.95								V
Maximum DC Reverse Current $T_a = 25^\circ\text{C}$ at rated DC Blocking Voltage $T_a = 100^\circ\text{C}$	I_R	2.0								μA
	$I_{R(H)}$	50								μA
Typical Junction Capacitance (Note1)	C_J	15								pF
Typical Thermal Resistance (Note2)	$R_{\theta JA}$	26								$^\circ\text{C/W}$
Junction Temperature Range	T_J	- 65 to + 175								$^\circ\text{C}$
Storage Temperature Range	T_{STG}	- 65 to + 175								$^\circ\text{C}$

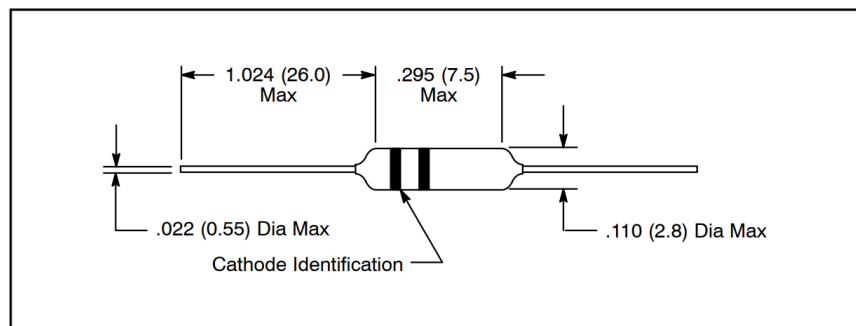
Appendix B – Germanium diode (1N34A) Datasheet, found at: <https://www.silicon-ark.co.uk/datasheets/1N34A.pdf>

Absolute Maximum Ratings: ($T_A = +25^\circ\text{C}$ unless otherwise specified)

Peak Reverse Voltage, V_{RM} 45V
 Reverse Voltage DC, V_R 20V
 Peak Forward Current, I_{FM} 150mA
 Average Rectified Output Current, I_O 50mA
 Surge Forward Current, I_{surge} 500mA
 Operating Junction Temperature, T_J +75°C
 Storage Temperature Range, T_{stg} -55° to +75°C

Electrical Characteristics: ($T_A = +25^\circ\text{C}$ unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Forward Current	I_F	$V_F = 1\text{V}$	4	–	–	mA
Reverse Current	I_R	$V_R = 10\text{V}$	–	–	50	μA
Junction Capacitance	C_j	$F = 1\text{MHz}, V = -1\text{V}$	–	–	1	pF
Rectification Efficiency	η	$V_i = 2V_{rms}, = 5K\Omega, C = 20\text{pF}, f = 40\text{MHz}$	55	–	–	%

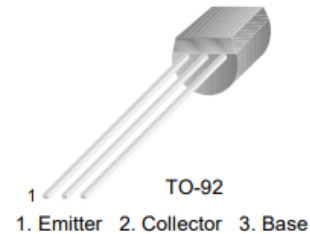




BC184L

Silicon NPN Small Signal Transistor (Note 1)

- $BV_{CEO} = 30V$ (Min.)
- $h_{FE} = 130$ (Min.) @ $V_{CE} = 5.0V$, $I_C = 100mA$



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

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage	45	V
V_{CEO}	Collector-Emitter Voltage	30	V
V_{EBO}	Emitter-Base Voltage	5	V
I_C	Collector Current (DC)	500	mA
P_C	Collector Dissipation ($T_a = 25^\circ C$) (Note 2, 3)	350	mW
T_J	Junction Temperature	150	$^\circ C$
T_{STG}	Storage Temperature	- 55 ~ 150	$^\circ C$

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

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
BV_{CBO}	Collector-Base Voltage	$I_C = 10\mu A$	45			V
BV_{CEO}	Collector-Emitter Voltage	$I_C = 2mA$	30			V
BV_{EBO}	Emitter-Base Voltage	$I_E = 10\mu A$	5			V
I_{CBO}	Collector Cut-off Current	$V_{CB} = 30V$			15	nA
I_{EBO}	Emitter Cut-off Current	$V_{EB} = 3V$			15	nA
h_{FE}	DC Current Gain	$V_{CE} = 5V$, $I_C = 10\mu A$ $V_{CE} = 5V$, $I_C = 100mA$	100 130			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 10mA$, $I_B = 0.5mA$ $I_C = 100mA$, $I_B = 5mA$			0.6 0.25	V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	$I_C = 100mA$, $I_B = 5mA$			1.2	V
$V_{BE(on)}$	Base-Emitter On Voltage	$V_{CE} = 5V$, $I_C = 2mA$	0.55		0.7	V
C_{OB}	Output Capacitance	$V_{CE} = 10V$, $f = 1MHz$			5	pF
f_T	Current gain Bandwidth Product	$V_{CE} = 5V$, $I_C = 10mA$ $f = 100MHz$	150			MHz
h_{FE}	Small Signal Current Gain	$V_{CE} = 5V$, $I_C = 2mA$ $f = 1KHz$	450		900	
NF	Noise Figure	$V_{CE} = 5V$, $I_C = 200mA$ $R_G = 2K\Omega$, $f = 1KHz$			4	dB

Notes:

1. These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.
2. These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.
3. These ratings are based on a maximum junction temperature of 150degrees C.

App D – IC741 datasheet as found at: <https://www.ti.com/lit/ds/symlink/lm741.pdf>

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
		$T_{AMIN} \leq T_A \leq T_{AMAX}$		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
	$T_{AMIN} \leq T_A \leq T_{AMAX}$		85	500	nA
Input bias current	$T_A = 25^\circ\text{C}$		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			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	$T_{AMIN} \leq T_A \leq T_{AMAX}$	± 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
		$T_{AMIN} \leq T_A \leq T_{AMAX}$	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	$R_S \leq 10\text{ }\Omega$, $V_{CM} = \pm 12\text{ V}$, $T_{AMIN} \leq T_A \leq T_{AMAX}$	80	95		dB
Supply voltage rejection ratio	$V_S = \pm 20\text{ V}$ to $V_S = \pm 5\text{ V}$, $R_S \leq 10\text{ }\Omega$, $T_{AMIN} \leq T_A \leq T_{AMAX}$	86	96		dB
Transient response	Rise time	$T_A = 25^\circ\text{C}$, unity gain	0.3		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
		$T_A = T_{AMIN}$	60	100	
		$T_A = T_{AMAX}$	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 $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$.

Appendix E – Transistor R2 resistance calculation

$$\text{Gain} = \frac{V_{out}}{V_{in}} = -\frac{R2}{R1}$$

$$R2 = \text{gain} \times R1$$

$$R2 = 18 \times 2.2 \times 10^3$$

$$R2 = 39.6\text{K}\Omega$$

The negative at the start of the equation shows that this is inverted feedback