

## LEVEL 4 ASSESSMENT SPECIFICATION

|                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                      |                |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|----------------|
| Student name:                   | Griff Williams                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 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:              | <p>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.)</p> <p><b>Alternative submission method (if applicable):</b></p> <p><b>Late submission of the assessment will result in a late penalty mark.</b> 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.</p> |                                                      |                |
| Academic honesty / referencing: | <p>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.</p>                                                                                                                                                                                                                                                                                              |                                                      |                |

### 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 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------|
| <b>1. Engagement with Literature Skills</b>                                                                                                                                                                                                                                                                                                                                               | 10              | 1             |
| Minimum research work, no reference list. There was evidence of data sheet being used within the assignment.                                                                                                                                                                                                                                                                              |                 |               |
| <b>2. Knowledge and Understanding Skills</b>                                                                                                                                                                                                                                                                                                                                              | 35              | 17.7          |
| Task 1 achieved 28%.<br>Task 2 achieved 62%,<br>Task 3 achieved 62%.<br><br>Knowledge of the basic underlying concepts and principles is accurate with a good understanding for Task 2 and 3. Showed very good understanding the calculated requirements and design work for Task 2 and 3. Task 1 showed a poor understanding, no design calculations for the voltage regulation circuit. |                 |               |
| <b>3. Cognitive and Intellectual Skills</b>                                                                                                                                                                                                                                                                                                                                               | 15              | 5.3           |
| Very limited attempt, with superficial evaluation of the underlying concepts and principles for most of the tasks.                                                                                                                                                                                                                                                                        |                 |               |
| <b>4. Practical Application Skills</b>                                                                                                                                                                                                                                                                                                                                                    | 30              | 18            |
| Task 1 achieved 52%.<br>Task 2 achieved 60%.<br>Task 3 achieved 68%.<br><br>A very good application of practical work for Task 2 and 3, very good use of the test equipment and Multisim to obtain the required test results.                                                                                                                                                             |                 |               |
| <b>5. Transferable Skills for Life and Professional Practice</b>                                                                                                                                                                                                                                                                                                                          | 10              | 5.5           |
| Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed.                                                                                                                                                                                                                                                                         |                 |               |

|                                                                                                                                                                                                            |                                                        |  |            |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|--|------------|
| <b>Assessment Mark</b> (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. ) | <b>Late Submission Penalties (tick if appropriate)</b> |  | <b>48%</b> |
|                                                                                                                                                                                                            | Up to 1 week late (40% Max)                            |  |            |
|                                                                                                                                                                                                            | Over 1 week late (0%)                                  |  |            |

# 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.

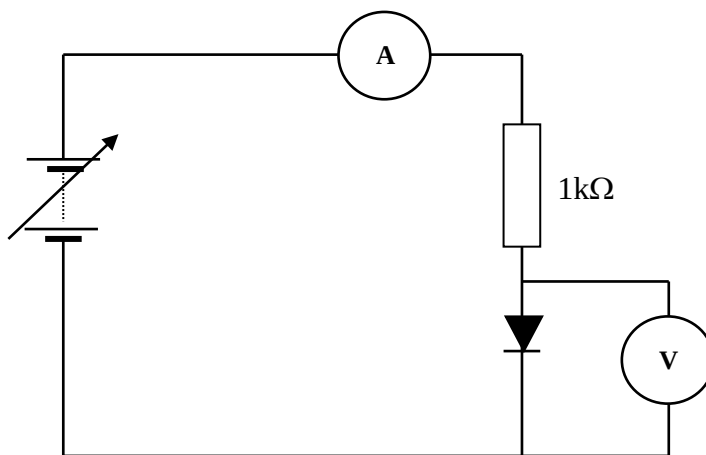
### Experimental Procedure

- 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.

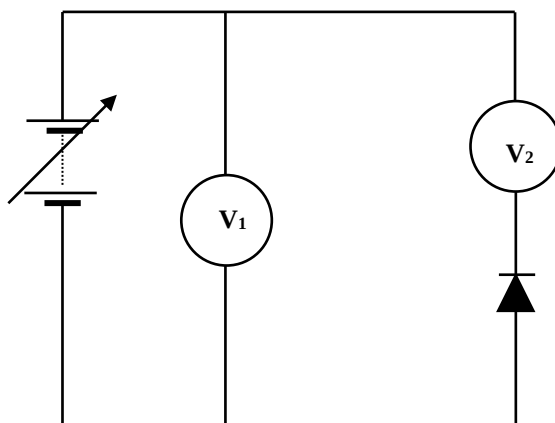
In the forward bias mode adjust the supply voltage so that the diode voltage increases from 0V in increments of 0.1 volts to a maximum of 1V.

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

### 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.

When measuring the resistor being used in the circuit it was found that when the multimeter was put across the fuse it measures 1018 Ohms. This being above what the stated resistance of the resistor is still within the +/- 10% tolerance was okay to use within the circuit. ✓

*Need to state what you are doing. You have not discussed what is a diode.*

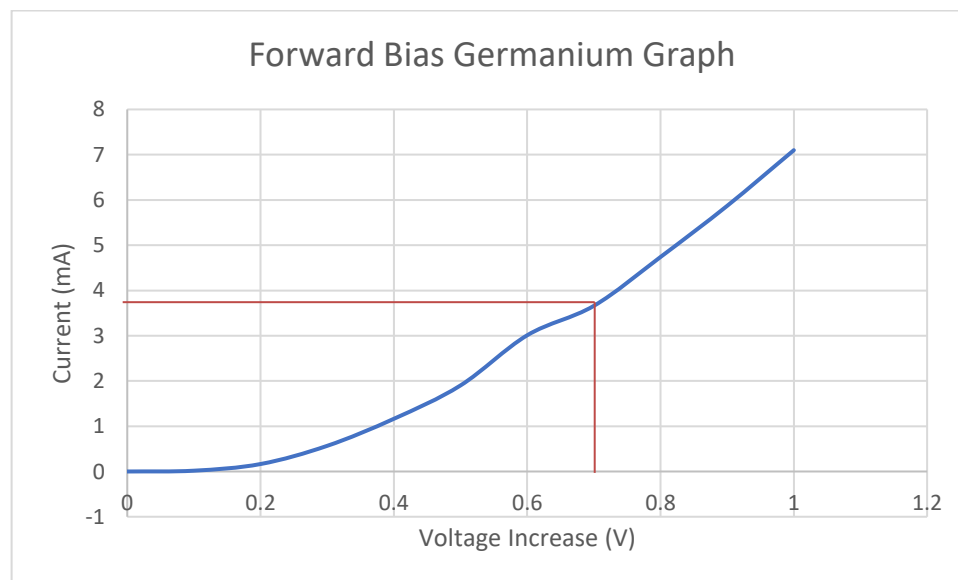
#### Forward Bias Germanium:

| Voltage Increase (V) | 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         |
| 1.0                  | 7.10         |

✓

The following is a graph displaying the progression in Voltage as the Current increases. This increase can be seen to progress slightly steeper as the current is increased. This indicates that the voltage and current aren't directly proportional to one another as towards the beginning of the graph when there is an increase in the current of around 3mA, the voltage increases to around 0.5V. However, the upper half of the graph sees that as the current goes from 3mA to 7mA the voltage increases by 0.5V. This shows that the further the graph continues the steeper the line will get.

*This is just a statement that is shown by the graph.*



✓

It can be calculated that the resistance of the Silicon Diode at 0.7Vp-p is:

$$\frac{0.7}{3.8 \times 10^{-3}} = 184.21 \text{ Ohms} \quad \checkmark$$

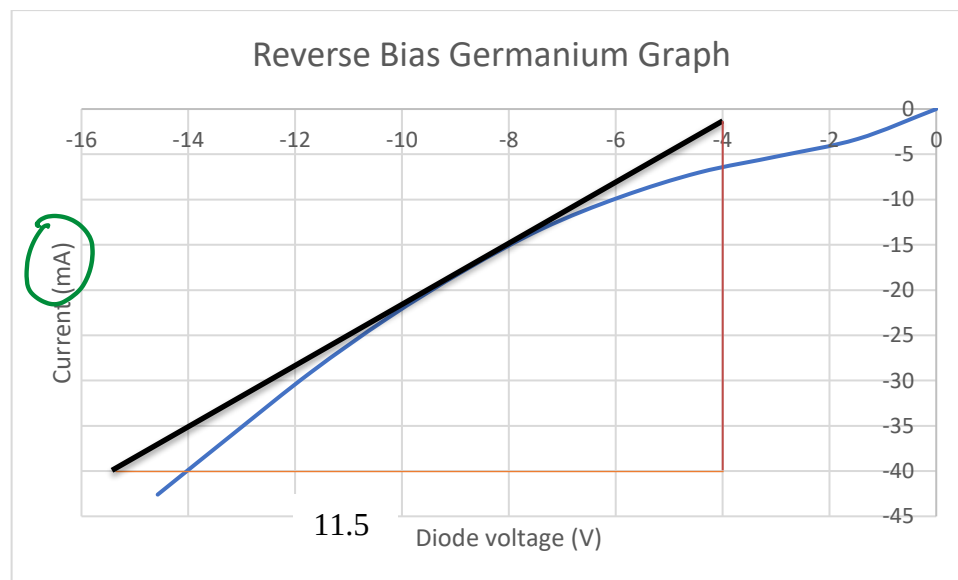
*What about dynamic resistance?*

## Reversed Bias Germanium:

| Voltage V1 (V) | Voltage V2 (mV) | Diode Voltage (V) | Current (μA) |
|----------------|-----------------|-------------------|--------------|
| 0              | 0               | 0                 | 0            |
| -1.5           | 33              | -1.467            | -3.3         |
| -3             | 52              | -2.948            | -5.2         |
| -4.5           | 70              | -4.430            | -7.0         |
| -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        |

The following is a graph displaying the reverse input current and how the voltage measured corresponds with it. As can be seen, much like the forward bias of the germanium diode, the reverse conditions are similar. Where the beginning is a slow increase. However, when the graph progresses the curve becomes steeper.

*This does not explain anything.*



$$\frac{39}{11.5} = 3.39$$

*what is this calculation ?  
The number is too small  
for resistance.*

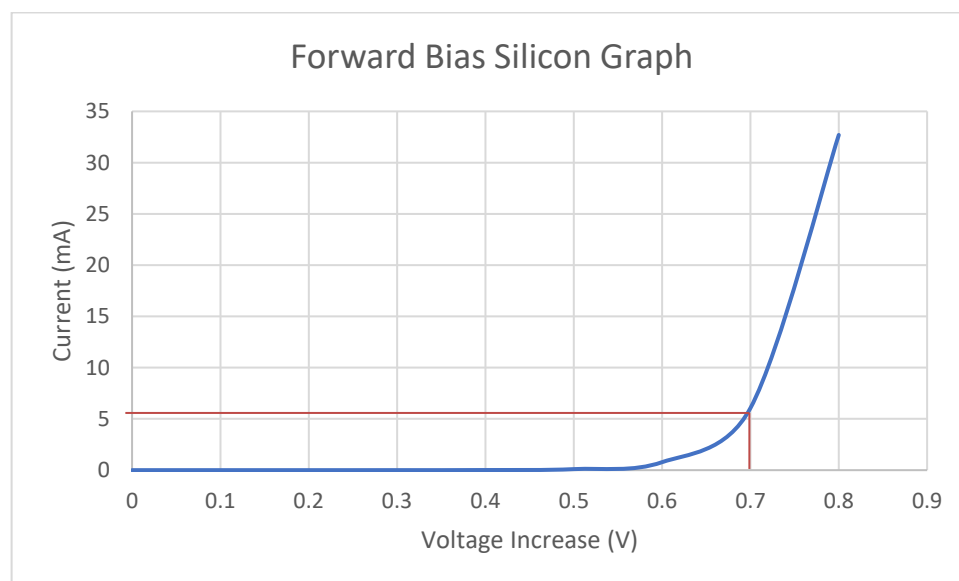
### Forward Bias Silicon:

| Voltage Increase (V) | Current (mA) |
|----------------------|--------------|
| 0                    | 0            |
| 0.1                  | 0.00004      |
| 0.2                  | 0.00025      |
| 0.3                  | 0.00177      |
| 0.4                  | 0.01287      |
| 0.5                  | 0.10000      |
| 0.6                  | 0.78100      |
| 0.7                  | 6.06000      |
| 0.8                  | 32.7000      |

When comparing the difference between the forward bias between the germanium and silicon diodes the silicon diodes progression to is seen to be much slower. The current does not increase at all until the voltage reaches between 0.5 and 0.6 Volts. When in comparison the germanium diodes current starts to increase at around 0.1 Volts.

However, the current increase of the silicon diode is much larger than the germanium diode. The graph being a lot of steeper as well. At around 0.8 Volts the silicon diode is measuring around 33mA, but the germanium diode it is only measuring around 4.8mA at 0.8 Volts in comparison. It can be determined that although the germanium diode allows for an almost instantaneous increase of current when voltage is applied, but it is only allowing for a small amount of current. When compared to the silicon diode, it takes a lot longer for the increase in current to begin, however when it does this increase is much larger than the germanium diode.

Why?



It can be calculated that the resistance of the Silicon Diode at 0.7Vp-p is:

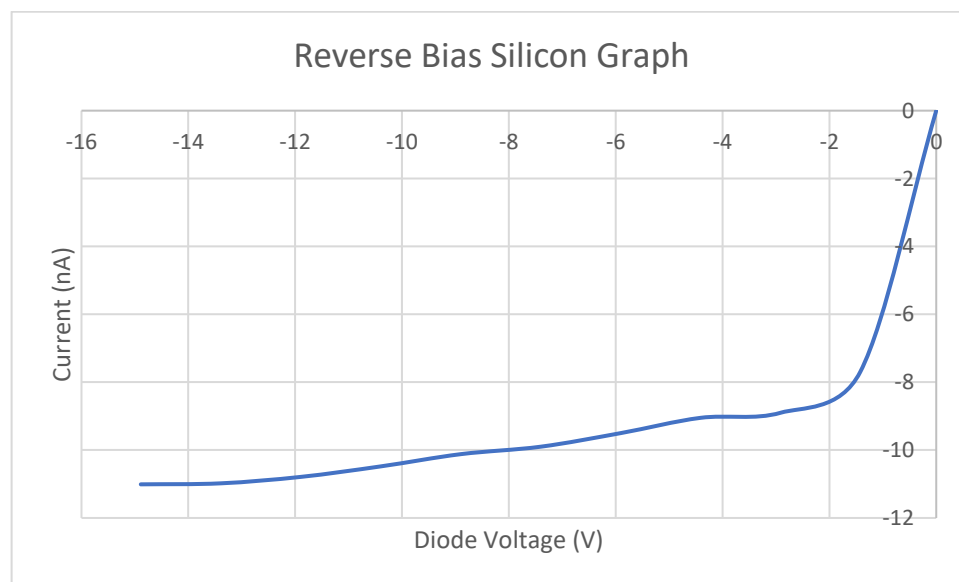
$$\frac{0.7}{5.5 \times 10^{-3}} = 127.27 \text{ Ohms}$$

## Reverse Bias Silicon:

| Voltage V1 (V) | Voltage V2 (mV) | Diode Voltage (V) | Current (mA) |
|----------------|-----------------|-------------------|--------------|
| 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       |

When comparing the graphs between the reverse bias of the germanium and silicon diodes there is quite an obvious difference again. However, unlike the germanium reverse bias where the curve decreases at a gradual rate the silicon diodes reverse bias is seen to quickly decrease a lot and then slowly taper off. When looking at this compared to its forward bias it is seen to be the opposite where the start decreases rapidly and then begins to taper off, where the forward bias does not really increase that much until it eventually starts to rapidly increase.

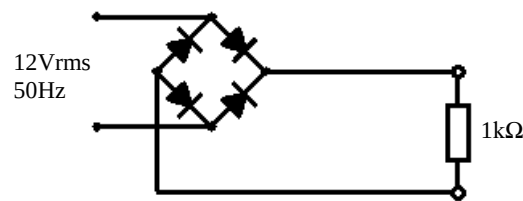
why?



what about resistance?

## Task 2 – Voltage Regulator Design

The circuit below is a full-wave bridge rectifier.



- a) Using Multisim obtain the waveform across the load resistor and explain the operation the circuit.

Using Multisim, the following circuit was created. The peak voltage which was measured was 15.598V. However, the recorded voltage was 9.561V. This is because to find the mean voltage the measured value must be times by the RMS (which has a value of 0.7071), then minus 1.4 to compensate for loss of voltage through the diodes. ✓

The following equation is below:

$$\text{Recorded Voltage} = (15.598 \times 0.7071) - 1.4 = 9.629 \text{ V} \checkmark$$

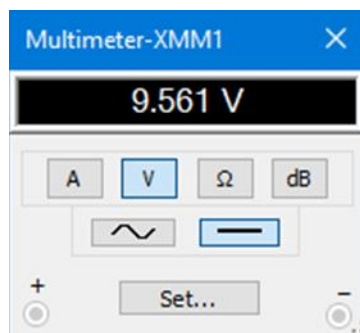
As seen the value that has been calculated is very similar to the value which the multimeter has displayed ✓

$9.629 - 9.561 = 0.068 \checkmark$  This indicates that there is an error of 0.068, which is within tolerance.

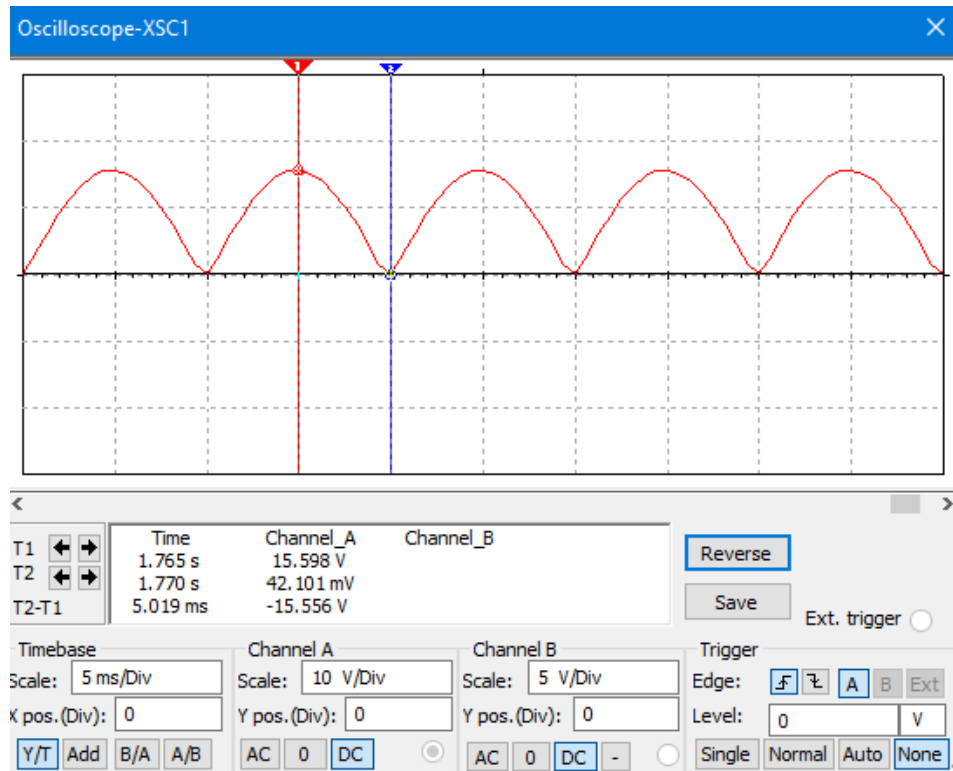
The multimeter is displaying 9.561, this indicates that the circuit is losing 6.037V indicating that the circuit is not very efficient in that regard.

Furthermore, when split between the positive and negative cycles, each cycle is reading 4.7805V? DC.

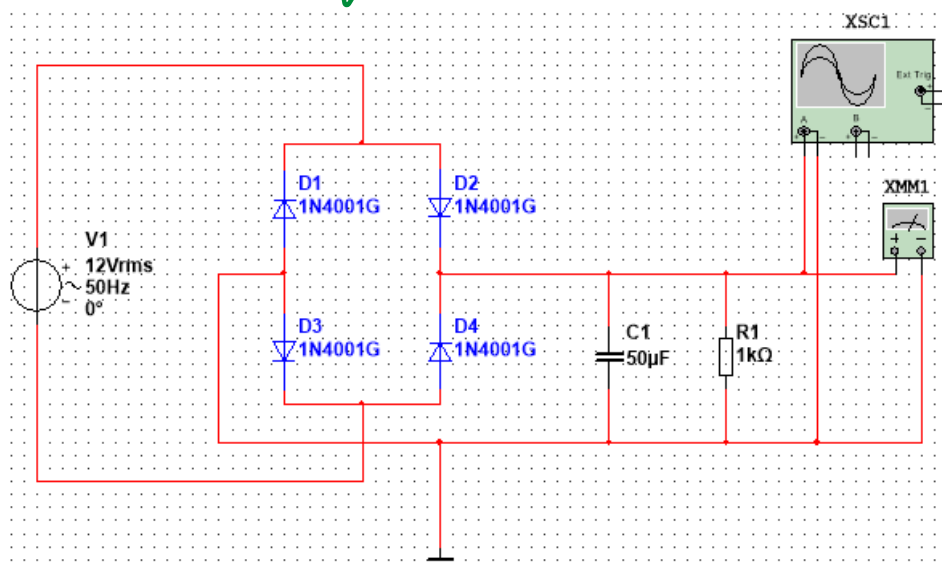
*Have not explained the operation.*

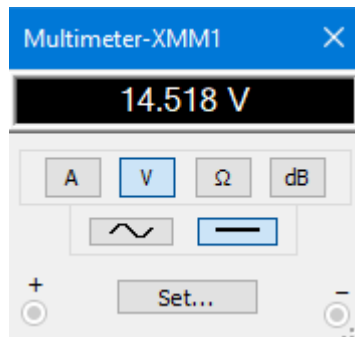


Included below are some screenshots of the multisim circuit with the resistor and capacitor in place, as well as the multimeter and oscilloscope readings.



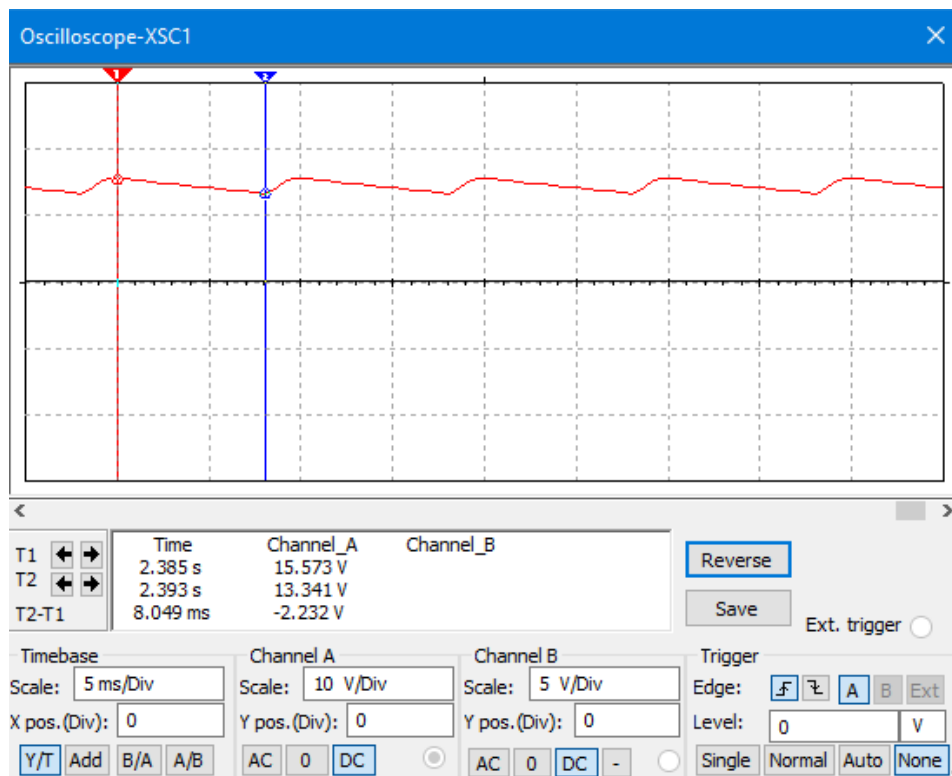
*What are you doing ?*





- b) Explain how a capacitor can be used to smooth the output to produce a DC voltage, use Multisim to aid your explanation.

The capacitor in this context smoothens out the output voltage by periodically storing and releasing energy, this creates the ripple effect in the image below. The capacitor discharges as the voltage begins to drop bringing it back up to its required output level. If this capacitor was not in place, then the wave form would look like the image in part a) which was taken from the oscilloscope reading. The ripple effect of this wave form is reduced to create the DC voltage output.



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

Below is the data sheet for BZX84C and its various types.

**Electrical Characteristics** ( $T_A = 25^\circ\text{C}$  unless otherwise noted,  $V_F < 0.9\text{V}$  at  $I_F = 10\text{mA}$ )

| Part Number | Marking | Zener Voltage Range <sup>1)</sup> |          |          |                          | Dynamic Impedance                   |                          | Maximum Reverse Leakage Current      |                        |
|-------------|---------|-----------------------------------|----------|----------|--------------------------|-------------------------------------|--------------------------|--------------------------------------|------------------------|
|             |         | V <sub>ZT</sub>                   |          |          | at I <sub>ZT</sub><br>mA | Z <sub>ZT</sub><br>Max.( $\Omega$ ) | at I <sub>ZT</sub><br>mA | I <sub>R</sub><br>Max. $\mu\text{A}$ | at V <sub>R</sub><br>V |
|             |         | V(Nom.)                           | V (Min.) | V (Max.) |                          |                                     |                          |                                      |                        |
| BZX84C10    | B9      | 10                                | 9.4      | 10.6     | 5                        | 20                                  | 5                        | 0.2                                  | 7                      |
| BZX84C11    | C9      | 11                                | 10.4     | 11.6     | 5                        | 20                                  | 5                        | 0.1                                  | 8                      |
| BZX84C12    | D9      | 12                                | 11.4     | 12.7     | 5                        | 25                                  | 5                        | 0.1                                  | 8                      |
| BZX84C13    | E9      | 13                                | 12.4     | 14.1     | 5                        | 30                                  | 5                        | 0.1                                  | 8                      |
| BZX84C15    | F9      | 15                                | 13.8     | 15.6     | 5                        | 30                                  | 5                        | 0.05                                 | 10.5                   |
| BZX84C16    | H9      | 16                                | 15.3     | 17.1     | 5                        | 40                                  | 5                        | 0.05                                 | 11.2                   |
| BZX84C18    | J9      | 18                                | 16.8     | 19.1     | 5                        | 45                                  | 5                        | 0.05                                 | 12.6                   |
| BZX84C22    | M9      | 22                                | 20.8     | 23.3     | 5                        | 55                                  | 5                        | 0.05                                 | 15.4                   |
| BZX84C24    | N9      | 24                                | 22.8     | 25.6     | 5                        | 70                                  | 5                        | 0.05                                 | 16.8                   |
| BZX84C27    | P9      | 27                                | 25.1     | 28.9     | 2                        | 80                                  | 2                        | 0.05                                 | 18.9                   |
| BZX84C30    | R9      | 30                                | 28       | 32       | 2                        | 80                                  | 2                        | 0.05                                 | 21                     |
| BZX84C33    | X9      | 33                                | 31       | 35       | 2                        | 80                                  | 2                        | 0.05                                 | 23.1                   |
| BZX84C36    | Y9      | 36                                | 34       | 38       | 2                        | 90                                  | 2                        | 0.05                                 | 25.2                   |

<https://www.farnell.com/datasheets/2864008.pdf>

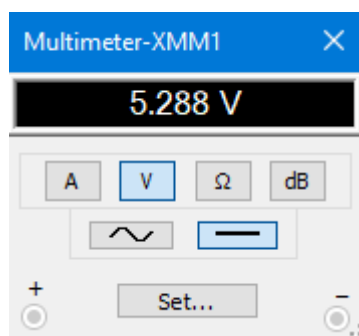
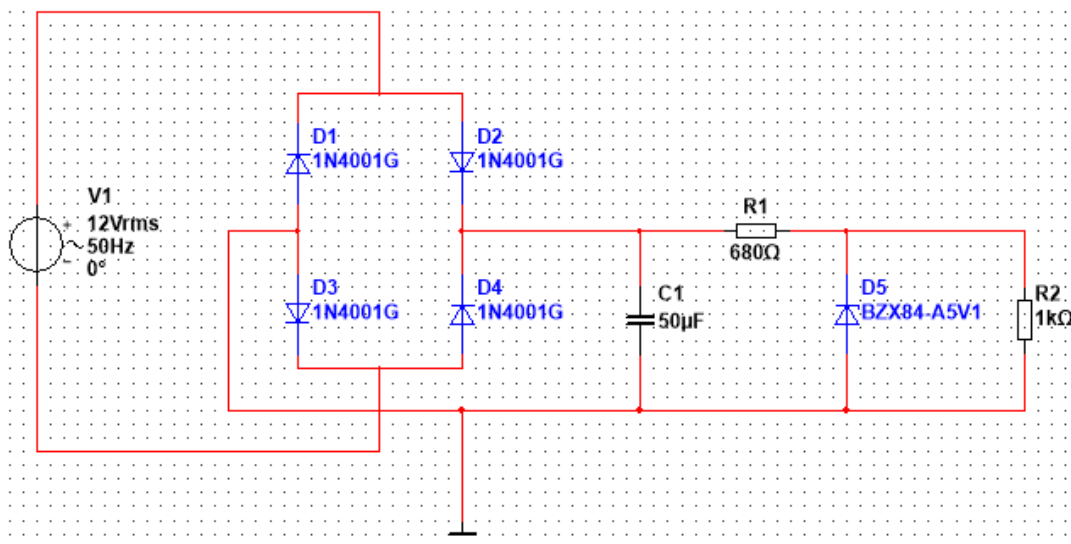
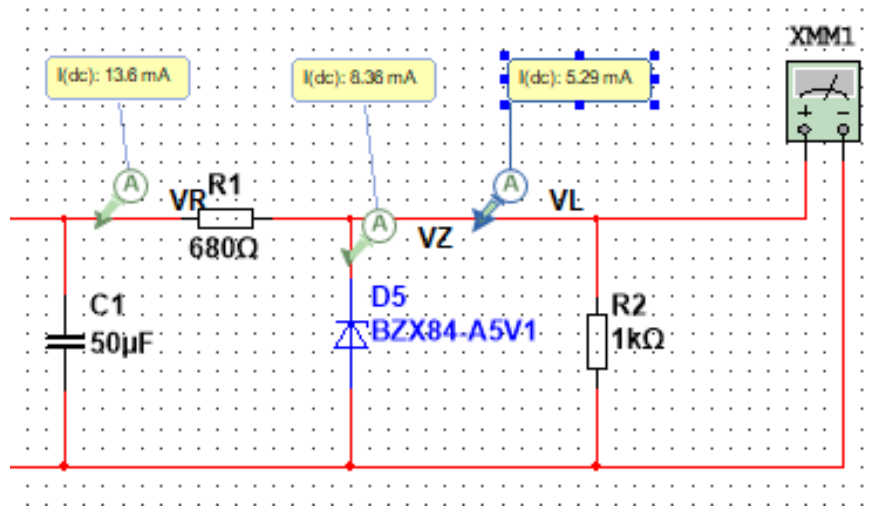
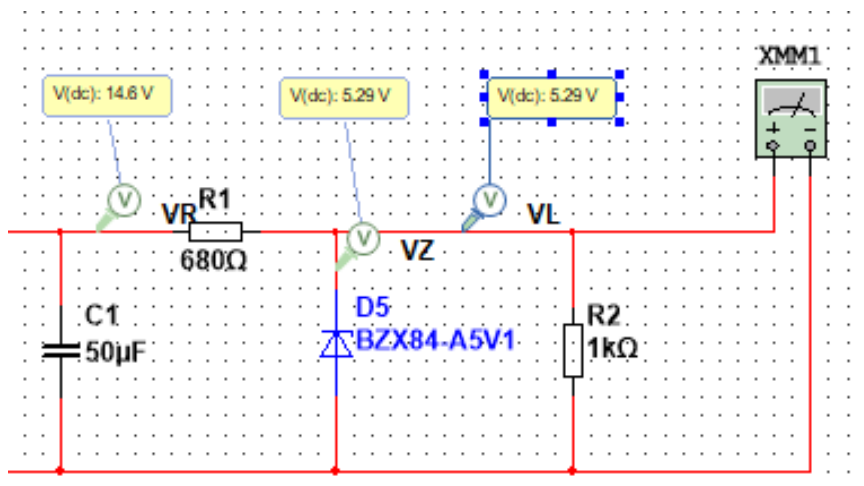


Image displays currents for IR, IZ and IL



Testing the regulator – measure the load voltage = 5.1V-5.3V, measure the voltage across R1(**series resistor**), measure current IR, IZ (**should be between 5mA and 58.82mA**) and IL (**output current**), Determine power for R1,  $P = I_R \times V_R$  ( $P = 14.2\text{mA} \times 14.5\text{V} = 0.202\text{W}$ ) – might need to use a slightly higher wattage resistor if circuit is built as the output wattage from the supply might be too high for the current resistor to handle.

Image displays Voltages across VR, VZ and VL



*Have not include the design calculations*

### 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

- a) 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  $100\mu F$  and coupling capacitors will be  $10\mu F$ .  
Transistor – NPN transistor (2N2222A).  
2N2222A used in practical has  $H_{fe}$  reading of 202.  
Has a Continuous Collector Current of ( $I_c = 800mA$ ) ✓

$I_q = I_c$  these should equal between 2 and 10mA.

$V_{cc}$  should be between 9V and 15V.

---

$$V_{cc} = 12V$$

$$I_c = 8mA$$

$$R_c = \frac{12}{2 \times (8 \times 10^{-3})}$$

$$R_c = 750\Omega \text{ (820}\Omega \text{ Resistor)}$$

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$V_E$  should be around 10-15% of  $V_{cc}$  ✓

13% of  $V_{cc}$ : ✓

$$V_E = 12 \times 0.13 = 1.56V$$

Assume  $I_E = I_C$  ✓

$$I_E = 8mA$$

$$R_E = \frac{1.56}{8 \times 10^{-3}} = 195\Omega \text{ (180}\Omega \text{ Resistor)} \quad \checkmark$$

---

$$h_{fe} = 202 \quad \checkmark$$

$$I_B = \frac{I_C}{h_{fe}} = \frac{8 \times 10^{-3}}{202} = 9.669 \times 10^{-6} \text{ (9.669}\mu A) \quad \checkmark$$

---

$$V_B = V_E + 0.7 \quad \checkmark$$

$$V_B = 1.56 + 0.7 = 2.26V \quad \checkmark$$

DC Bias for R1 and R2:

$$I_B \times 10 = 9.669 \times 10^{-6} \times 10 = 96.69 \times 10^{-6} \quad \checkmark$$

$$R_2 = \frac{V_B}{10 \times I_B} \quad \checkmark$$

$$R_2 = \frac{2.26}{10 \times (9.669 \times 10^{-6})} = 23.37k\Omega \text{ (22k}\Omega \text{ Resistor)} \quad \checkmark$$

$$R_1 = \frac{V_{CC} - V_B}{11 \times I_B} \quad \checkmark$$

$$R_1 = \frac{12 - 2.26}{11 \times (9.669 \times 10^{-6})} = 91.58k\Omega \text{ (100k}\Omega \text{ Resistor)} \quad \checkmark$$

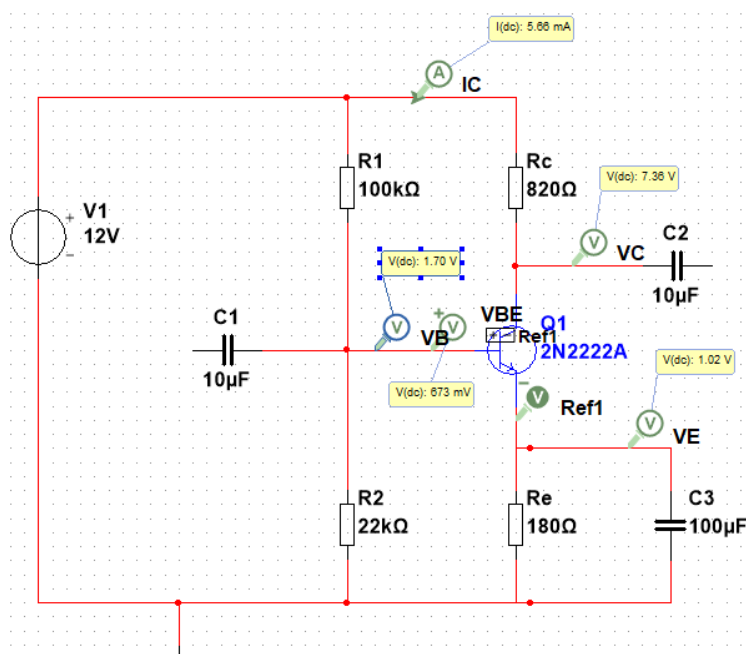
*Good.*

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

The following is covered in part c) below.

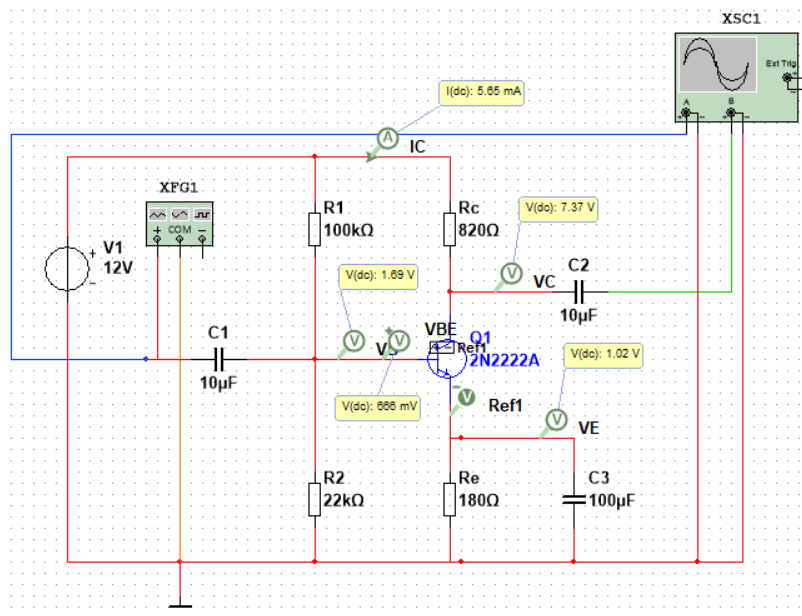
- c) Use Multisim to simulate the test performed in part b. and compare the results

DC Input:

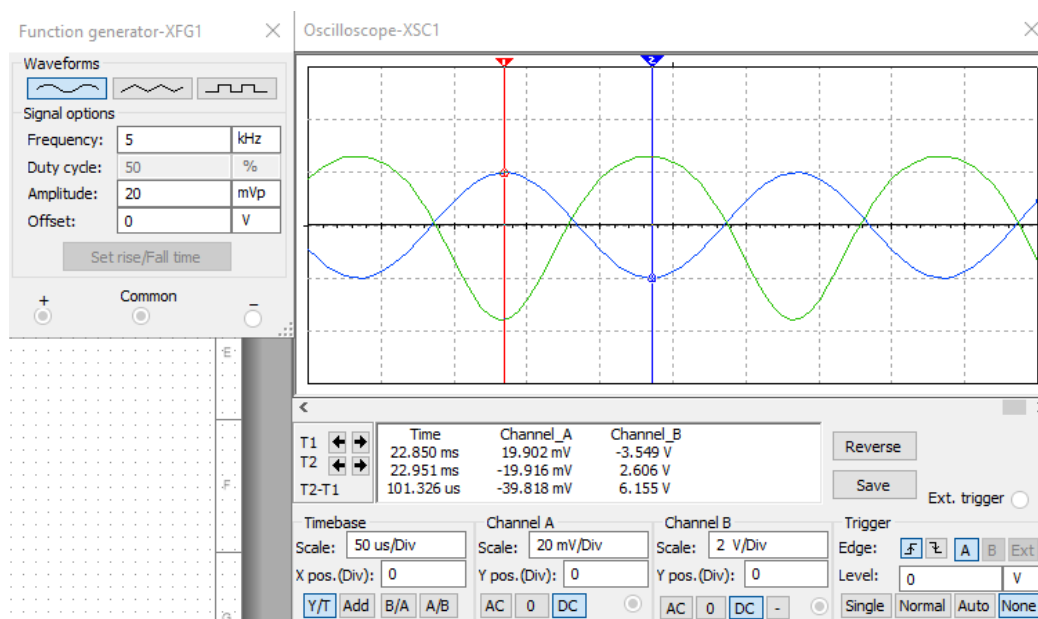


|          | Multisim Test Reading | Calculated Number | Practical Results |
|----------|-----------------------|-------------------|-------------------|
| $V_C$    | 7.36V                 | 6V                | 5.88V             |
| $V_E$    | 1.02V                 | 1.56V             | 1.46V             |
| $V_B$    | 1.70V                 | 2.26V             | 1.97V             |
| $V_{BE}$ | 673mV                 | 700mV             | 722mV             |
| $I_C$    | 5.66mA                | 8mA               | 7.43mA            |

AC Input:



Screenshot from the oscilloscope readings:



Peak to Peak value produced from the function generator = 40mVp

$$\text{Gain} = \frac{V_{out}}{V_{in}} = \frac{6.16}{0.04} = 154$$

Measuring the bandwidth is determining the gain over a range of frequencies

$$\text{Gain (dB)} = 20 \times \log\left(\frac{V_{out}}{V_{in}}\right) = 43.75\text{dB}$$

$$\text{Bandwidth} = f_2 - f_1$$

Max Gain of 44.21dB

$$\frac{1}{2} \text{ Power point} = 44.21 - 3 = 41.21\text{dB}$$

$$f_2 = 56.323\text{MHz}$$

$$f_1 = 333.647\text{Hz}$$

$$\text{B/W} = (56.323 \times 10^6) - 333.647 = 56.32\text{MHz}$$

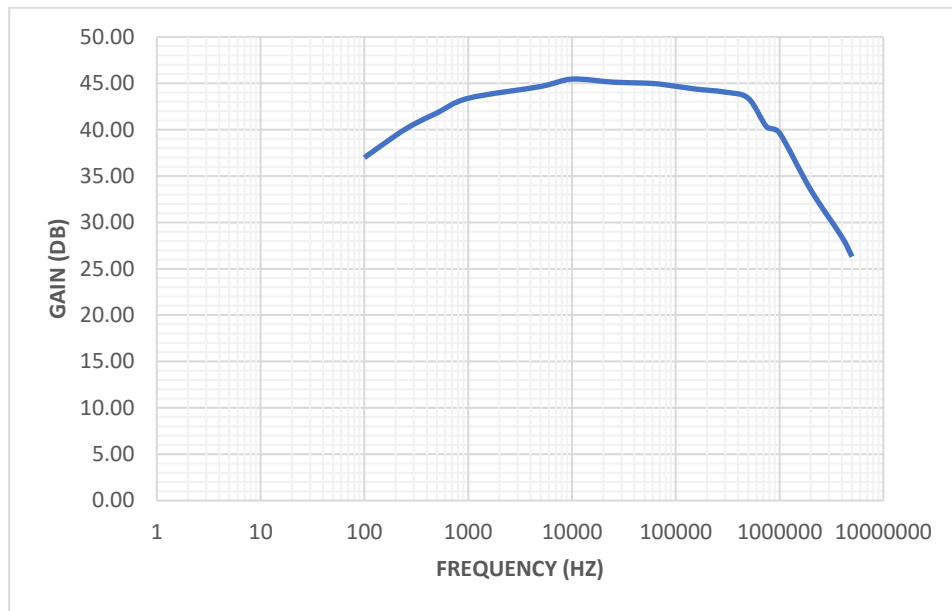
### AC Input Practical Results:

| Frequency (Hz) | Output Voltage (V) | Gain    | Gain (dB) |
|----------------|--------------------|---------|-----------|
| 100            | 2.12               | 70.667  | 36.98     |
| 200            | 2.79               | 93.000  | 39.37     |
| 300            | 3.21               | 107.000 | 40.59     |
| 500            | 3.69               | 123.000 | 41.80     |
| 1000           | 4.43               | 147.667 | 43.39     |
| 5000           | 5.13               | 171.000 | 44.66     |
| 10000          | 5.62               | 187.333 | 45.45     |
| 25000          | 5.41               | 180.333 | 45.12     |
| 50000          | 5.35               | 178.333 | 45.02     |
| 75000          | 5.26               | 175.333 | 44.88     |
| 150000         | 4.98               | 166.000 | 44.40     |
| 300000         | 4.78               | 159.333 | 44.05     |
| 500000         | 4.43               | 147.667 | 43.39     |
| 750000         | 3.11               | 103.667 | 40.31     |
| 1000000        | 2.88               | 96.000  | 39.65     |
| 2000000        | 1.42               | 47.333  | 33.50     |
| 4000000        | 0.79               | 26.333  | 28.41     |
| 5000000        | 0.62               | 20.667  | 26.31     |

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

Under DC conditions the circuit performed as expected, where there were only slight variations between the multisim results and the actual practical results. *why?*

As seen from the results, when under AC voltage, the circuits gain slowly increases until at around 1kHz the gain (dB) begins to level off. This level stays constant until around 500kHz, when the gain begins to fall off quite rapidly. This trend can be seen by looking at the graph below:



*what is the bandwidth?*

#### Task 4 – Inverting Operational Amplifier

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

‘Op-amp’ stands for Operational Amplifier. An op-amp contains an internal circuit that which is used to amplify weak electric signals.

The typical format of an op-amp consists of two input pins and one output pin; its function is to amplify and output the voltage difference between the two input pins which is usually a much weaker input voltage. ✓

An Op-amp tends to have three main characteristics which make it useful for things such as reducing electrical noise in circuits. They are typically paired with other components and can perform a large variety of other things. The following characteristics include:

- High Input Impedance
- Low Output Impedance
- High Gain ✓

- 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.

Gain = 18

Bandwidth = 20kHz (audio maximum frequency)

LM741 has a gain bandwidth product (GBP) of 1MHz

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

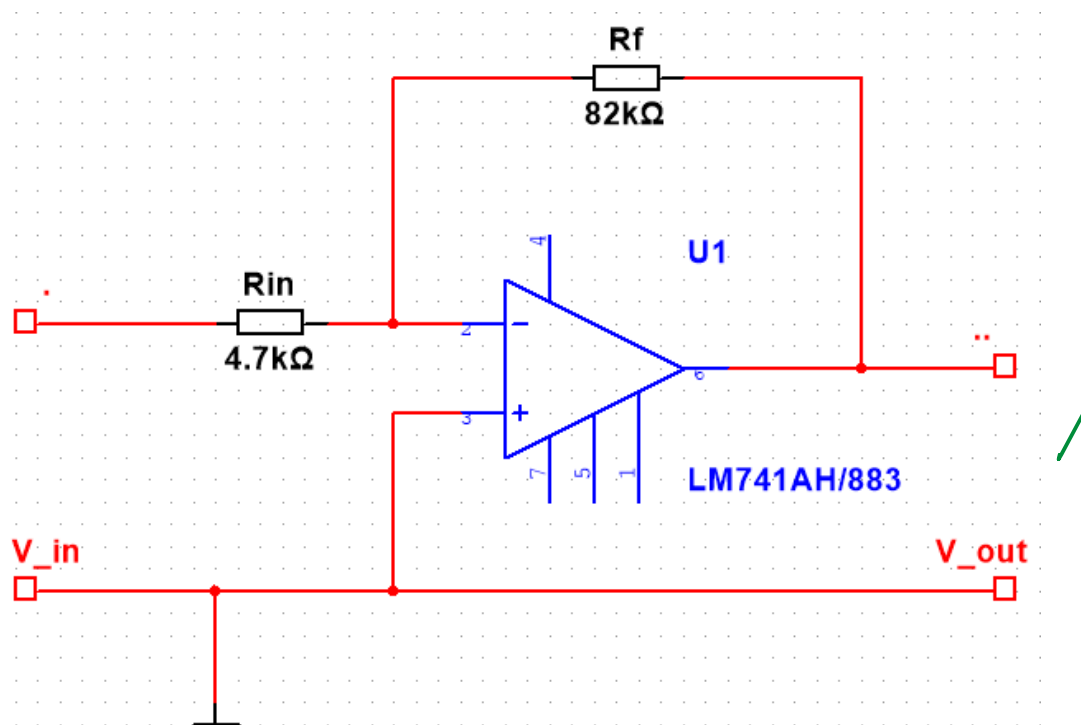
$$\text{Gain} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}} \quad \checkmark$$

$$R_{in} = 4.7 \text{ k}\Omega \quad \checkmark$$

$$R_f = 18 \times R_{in} = 18 \times (4.7 \times 10^3) = 84.6 \text{ k}\Omega$$

$$R_f = 82 \text{ k}\Omega \quad \checkmark$$

The following is a diagram showing the configuration of the Op-amp circuit.



The following are the data sheets which are for the Op-amp being used in the circuit above (LM741AH/822):

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

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)(2)(3)</sup>

|                                       |                                    | MIN        | MAX | UNIT |
|---------------------------------------|------------------------------------|------------|-----|------|
| Supply voltage                        | LM741, LM741A                      |            | ±22 | V    |
|                                       | LM741C                             |            | ±18 |      |
| Power dissipation <sup>(4)</sup>      |                                    |            | 500 | mW   |
| Differential input voltage            |                                    |            | ±30 | V    |
| Input voltage <sup>(5)</sup>          |                                    |            | ±15 | V    |
| Output short circuit duration         |                                    | Continuous |     |      |
| Operating temperature                 | LM741, LM741A                      | -50        | 125 | °C   |
|                                       | LM741C                             | 0          | 70  |      |
| Junction temperature                  | LM741, LM741A                      |            | 150 | °C   |
|                                       | LM741C                             |            | 100 |      |
| Soldering information                 | PDIP package (10 seconds)          |            | 260 | °C   |
|                                       | CDIP or TO-99 package (10 seconds) |            | 300 | °C   |
| Storage temperature, T <sub>stg</sub> |                                    | -65        | 150 | °C   |

[LM741 Operational Amplifier datasheet \(Rev. D\)](#) – Link to datasheet.

- 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:

| Input (V) | Output (V) | Gain   |
|-----------|------------|--------|
| 0.1       | -1.60      | -16.00 |
| 0.2       | -3.45      | -17.25 |
| 0.3       | -5.22      | -17.40 |
| 0.4       | -7.03      | -17.58 |
| 0.5       | -8.78      | -17.56 |
| 0.6       | -9.54      | -15.90 |
| 0.7       | -9.56      | -13.66 |
| 0.8       | -9.57      | -11.96 |
| 0.9       | -9.57      | -10.63 |
| 1.0       | -9.57      | -9.57  |

AC Input:

| Input (V) | Output (V) | Gain  |
|-----------|------------|-------|
| 0.15      | 2.52       | 16.80 |
| 0.30      | 5.04       | 16.80 |
| 0.45      | 7.44       | 16.53 |
| 0.60      | 10.20      | 17.00 |
| 0.75      | 12.65      | 16.87 |
| 0.90      | 15.35      | 17.06 |
| 1.05      | 18.39      | 17.51 |
| 1.20      | 20.48      | 17.07 |
| 1.35      | 21.20      | 15.70 |
| 1.50      | 21.20      | 14.13 |



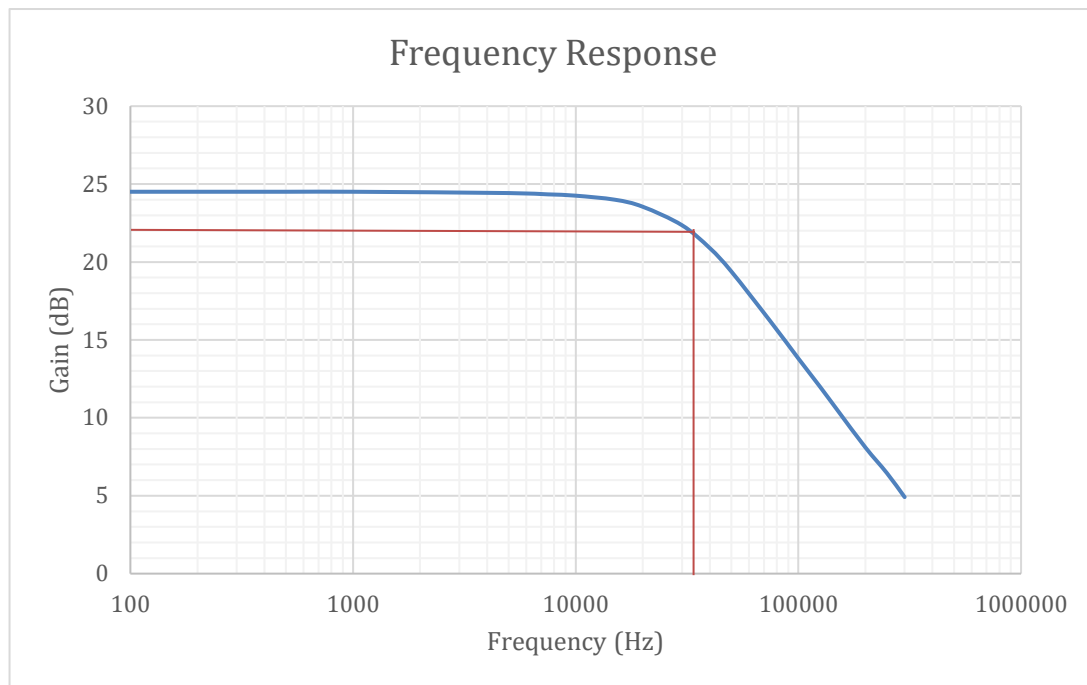
- d) Produce the frequency response curve for AC amplification. Also analyse the effect of slew rate and input signal frequency on signal distortion and AC amplification.

$V_{in}$  stays constant (0.5Vp-p)

| Frequency (Hz) | Voltage Out (V) | Gain (dB) |
|----------------|-----------------|-----------|
| 100            | 8.40            | 24.51     |
| 500            | 8.40            | 24.51     |
| 1000           | 8.40            | 24.51     |
| 5000           | 8.32            | 24.42     |
| 7500           | 8.24            | 24.34     |
| 10000          | 8.16            | 24.25     |
| 15000          | 7.92            | 24.00     |
| 20000          | 7.52            | 23.55     |
| 30000          | 6.56            | 22.36     |
| 40000          | 5.54            | 20.89     |
| 50000          | 4.66            | 19.39     |
| 75000          | 3.22            | 16.18     |
| 100000         | 2.45            | 13.80     |
| 125000         | 1.99            | 12.00     |
| 150000         | 1.67            | 10.47     |
| 200000         | 1.27            | 8.10      |
| 250000         | 1.05            | 6.44      |
| 300000         | 0.88            | 4.91      |



*Have not comment upon results.*



Bandwidth = 33.5kHz > 20kHz, within design specification of op-amp. ✓

Slew rate = 17.20μs

Slew rate can be described as the maximum rate which an amplifier can respond to a sudden change in input. With regards to this frequency response graph, there isn't much response at all until the frequency around 10kHz. However, once it reaches this frequency, this is when the amplifier responds and begins to decrease in gain (dB). Therefore, it can be determined that for this op-amp it takes around 10kHz in frequency to prompt a change in the gain. ✓