BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Electrical and Computer Engineering Department

CIRCUITS AND ELECTRONICS LABORATORY– ENEE2103

Experiment No. 6 Report

Diode Characteristic and Applications

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Abstract

This experiment aims to study the operation of the P-N junction and the VI characteristics of silicon diodes as well as examine some applications of the P-N junction such as rectification, clamping and clipping, using an oscilloscope, a digital voltmeter (DVM), and a DC power source in the laboratory.

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Theory

1.Diode characteristics:

1.1: How Diode work:

The diode is a semiconductor device with a PN junction or a metal-semiconductor junction. It has two terminals called anode and cathode, the property of the diode is a switch that allows current to flow or not; depending on the direction of the voltage applied between the anode and cathode, and this action is called rectification. [1]

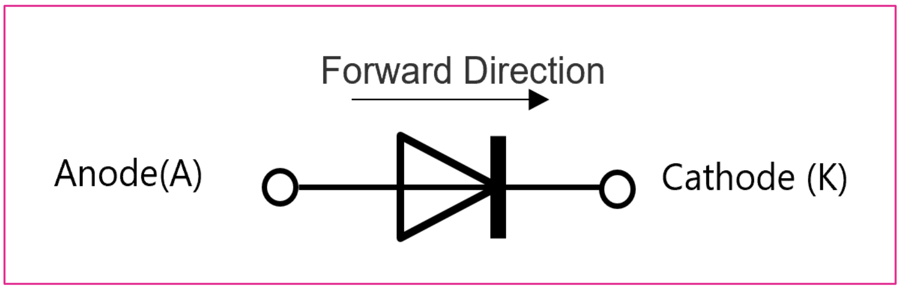

Figure 1 Symbol of diode and names of its electrodes

The diode symbol looks like an arrow pointing to a straight line as this mark represents the cathode side, just like the marking on the diode component itself, the marking is on the left side so it is the cathode side. [2]

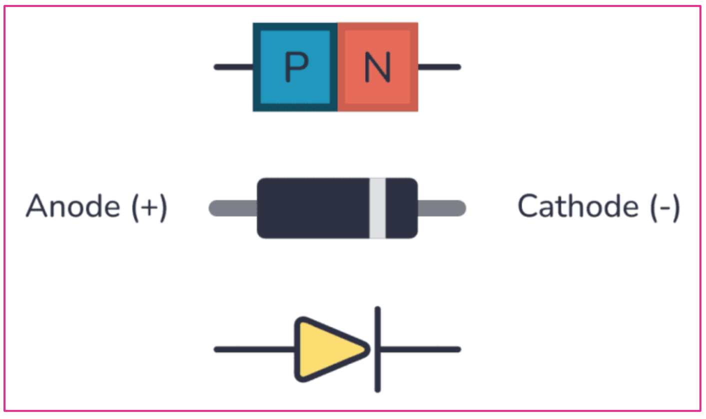

Figure 2 Diode figure

Semiconductors doped with boron (B) or other electron-accepting atoms are called p-type semiconductors because most of their charge carriers are positive holes. And semiconductors doped with arsenic or other electron donor atoms are called n-type semiconductors because most of their charge carriers are negative electrons.[1]

A p-n junction diode is formed by combining p-type and n-type semiconductors.as the diode conducts current only when it is forward biased because at the intersection of these two materials a depletion region appears. This depletion region acts as an insulator and refuses to let any current pass through depend on the voltage stream.[1]

When you apply a positive voltage from the anode to the cathode, the depletion layer between the two materials disappears and current can flow from the anode to the cathode, so it works as closed switch like in figure 3, and the LED will light up.[3]

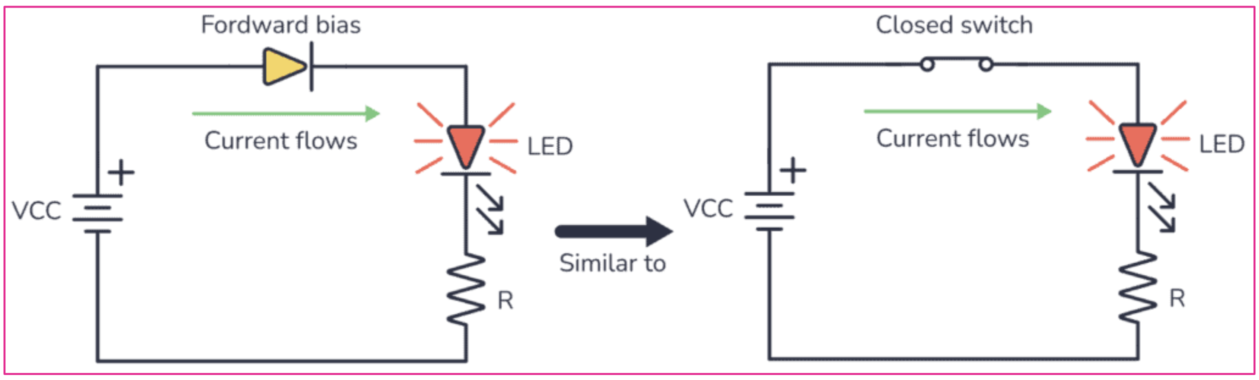

Figure 3 Diode forward bias

When you apply voltage in the other direction, from cathode to anode, the depletion region expands and prevents any current from flowing as the resistance from depletion region is high, so it works as open switch like figure 4, and the LED won't light up.[3]

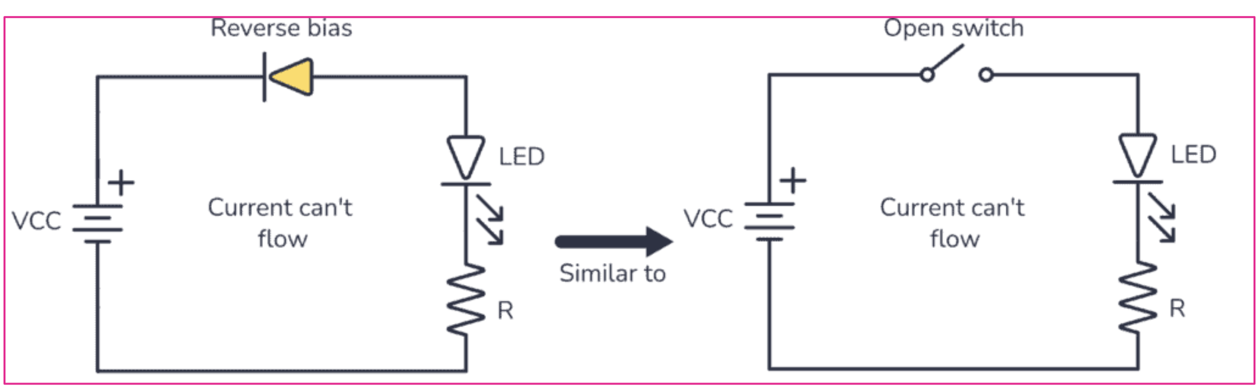

Figure 4 Diode reverse bias

1.2: Diode Biasing:

The curve between voltage and current on the circuit determines the VI characteristic of the p-n junction diode. The x-axis represents voltage, while the y-axis represents current, the VI characteristic curve of the p-n junction diode is shown in the graph below figure 5. Using the curve, we can see the diode operates in three different regions [4]

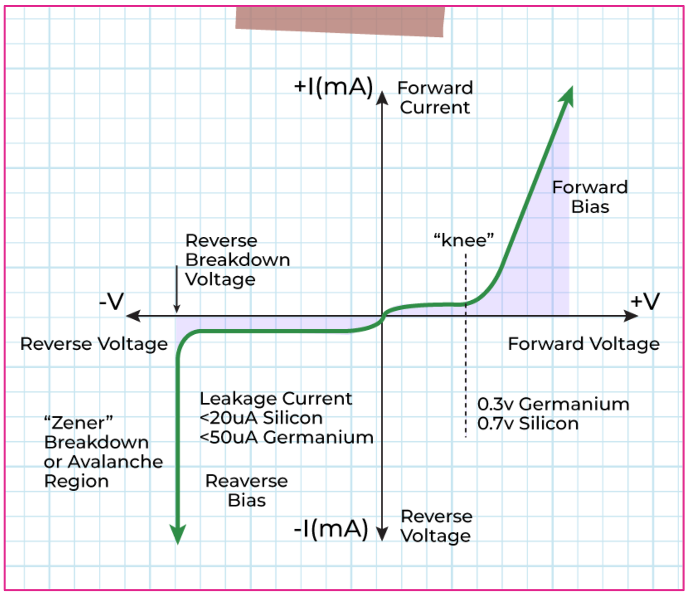

Figure 5 V-I Characteristics of P-N Junction Diode

1.2.1: Zero Bias:

No external voltage is supplied to the p-n junction diode when it has zero bias, implying that the depletion barrier at the junction prevents current from flowing.[4]

1.2.2: Forward bias:

When the p-n junction diode is forward biased, the p-type is connected to the positive terminal of the voltage 0.69 V for silicon diodes and 0.3 V for germanium diodes, while the n-type is connected to the negative terminal, as the depletion layer barrier is reduced and allow the current slowly flows.

Once the diode has overcome the depletion layer barrier the current increases slowly until it operates normally, and the curve is forming a linear curve. [4]

1.2.3: reverse bias:

When the P-N junction diode is negatively biased, the p-type is connected to the negative pole of the voltage, while the n-type is connected to the positive pole. As a result, the depletion layer barrier becomes higher; due to minority carriers are present at the junction.

When the applied voltage is raised, the kinetic energy of the minority charges increases, affecting the majority charges. At that point which the diode fails, and may be destroyed as a result. [4]

2. Rectification:

Rectifier used to convert the ac voltage (zero- average value) into either positive or negative pulsating dc.

2.1: Half Wave Rectifier

The diode in a half-wave rectifier circuit transmits only half of each full sine wave of AC supply to convert it to DC supply, this type of circuit is then called a "half-wave" rectifier because it only passes half of the incoming AC power, as shown below.[5]

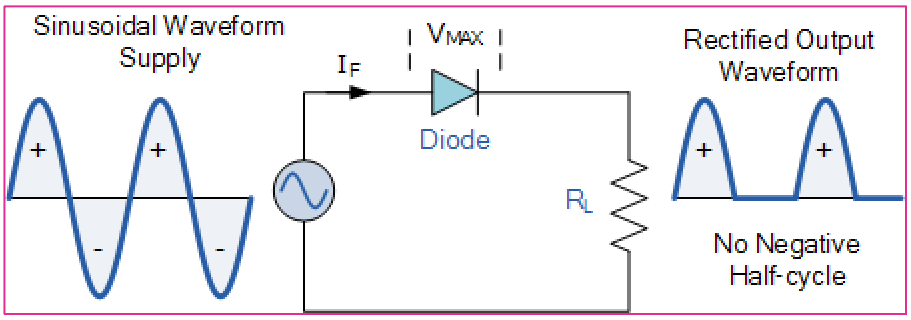

Figure 6 Half-Wave rectifier

During each “positive” half cycle of the AC sine wave, the diode is forward biased as the anode is positive with respect to the cathode resulting in current flowing through the diode so Vout = Vs. [5]

During each “negative” half cycle of the AC sinusoidal input waveform, the diode is reverse biased as the anode is negative with respect to the cathode. Therefore, NO current flows through the diode or circuit. as no voltage appears across the diode so therefore, Vout = 0. [5]

In summary:

When $V_{in} > 0$: $V_D = V_{in}$. When $V_{in} < 0$: $V_D = 0$.

2.1.1: Half-wave Rectifier with Smoothing Capacitor:

When a rectifier is used to provide a direct current (DC) voltage source from an alternating current (AC) source, the amount of voltage ripple can be further reduced by using a higher value capacitor, but there is a There are limitations in both cost and size for smoothing types capacitor is used.

For a given capacitor value, larger load current (lower load resistance) will discharge the capacitor faster (RC time constant) and thus increase the resulting ripple.[5]

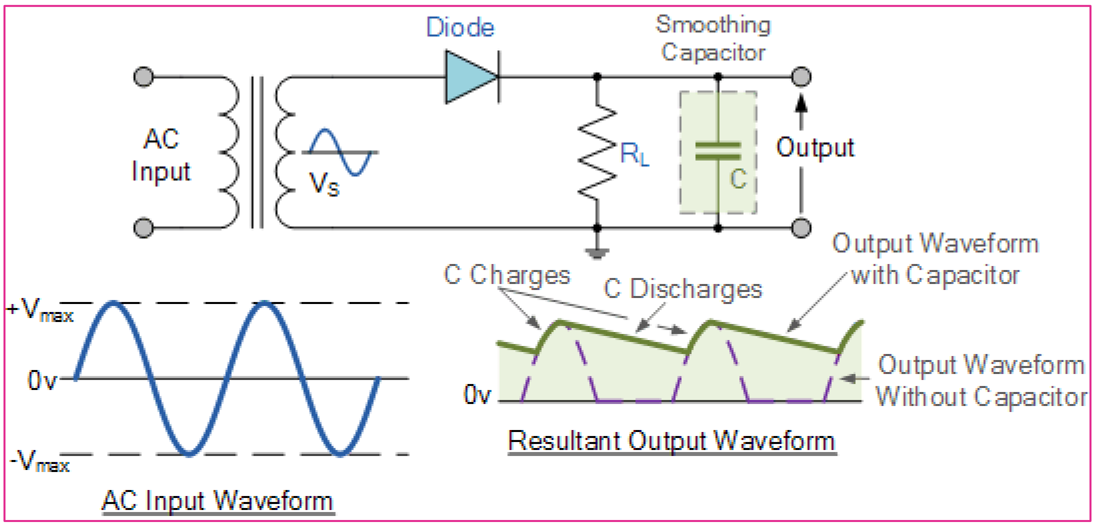

Figure 7 Half- wave rectifier with smoothing capacitor

2.2: Full wave rectifier:

The full wave rectifier converts both halves of each waveform cycle into pulsating DC signal using four rectification diodes. it is unsuitable to application to use half-wave rectifier; because it needs a "steady and smooth" DC supply voltage. One method to improve on this is to use every half-cycle of the input voltage instead of every other half-cycle. The circuit allows to do this is called a Full Wave Rectifier.

In this experiment the bridge full wave Rectifier is used which is more improved type of full wave rectifier. [6]

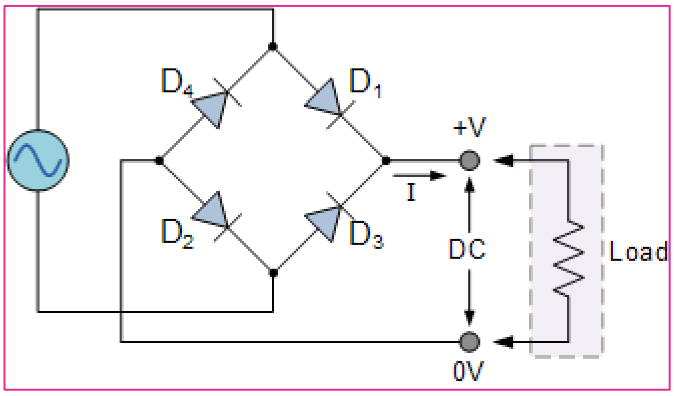

Figure 8 Diode Bridge Rectifier

2.2.1: The Positive Half-cycle:

The four diodes labeled D1 to D4 are arranged in "series pairs" with only two diodes conducting current during each half cycle.

During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and current flows through the load as shown below.[6]

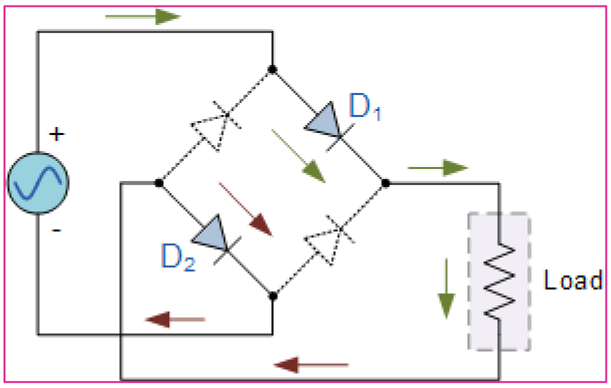

Figure 9 The Positive Half-cycle

2.2.2: The Negative Half-cycle

During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 turn off because they are now reverse biased.

The current flowing through the load has the same direction as before. [6]

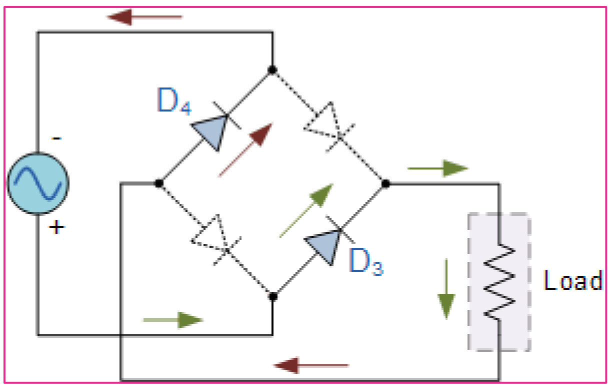

Figure 10 The Negative Half-cycle

In summary:

When $V_{in} > 0$:

$V_D = V_{in}$.

When $V_{in} < 0$:

$V_D = - Vin$.

2.2.3: Full wave rectifier negativity:

Since the current flowing through the load is unidirectional, in each half cycle the current flows through two diodes instead of just one like half-wave, so the output voltage magnitude is reduced by twice the voltage (2* 0.7 = 1, 4 V) at input V_{MAX} amplitude.

Although the ripple frequency is now twice the source frequency. [6]

2.2.4: Full wave Rectifier with Smoothing Capacitor:

Like in half-wave rectifier, to improve the average DC output of the rectifier while reducing the AC variation of the rectified output is by using smoothing capacitors to filter the output waveform.

Smoothing capacitor is connected in parallel with the load of the output of a full-wave bridge rectifier further increase the average DC output level because the capacitor acts as a storage device, as shown below. [6]

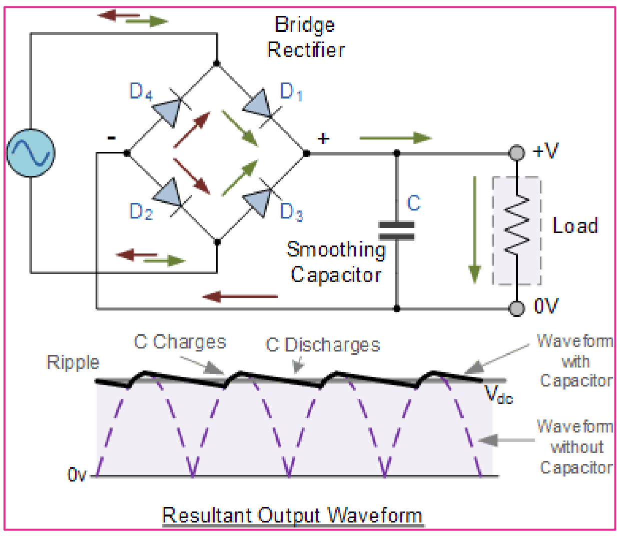

Figure 11 Full wave Rectifier with Smoothing Capacitor

3.Transformer:

A transformer is an electrical device designed to transfer electrical energy from one circuit to another at the same frequency. A single-phase voltage transformer essentially consists of two electrical coils, one called the “primary coil” and the other called the “secondary coil”. In a single-phase voltage transformer, the primary side is usually the side which has the higher voltage.

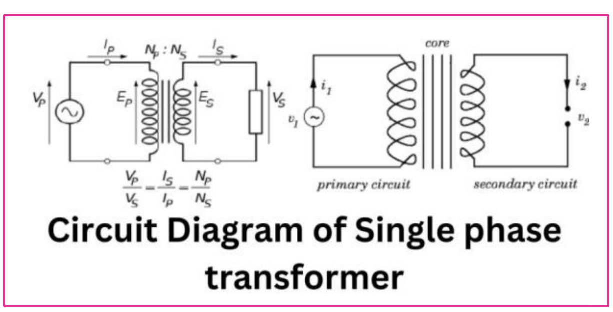

Figure 12 transformer [7]

4. Filter

4.1: Capacitors:

The filter is used to smooth the pulsed DC current generated by the rectifier by removing its ripple content and passing its direct component (average value), then the output is rectified as it passes through this filter, the AC components present in the signal are grounded through the capacitor allowing the AC components. And the remaining DC components are present in the signal captured at the output.

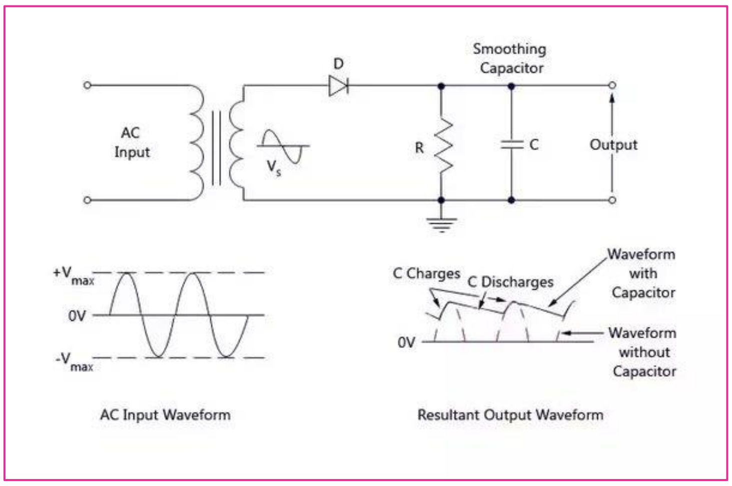

Figure 13 Filtering capacitor [8]

4.2: Ripple factor:

The ripple factor is an indicator of filter efficiency, it's determined according to the RMS value and the average value of the rectifier output, which is given as:

$$\textit{Ripple Factor } r\% = \frac{\textit{RMS (ripple of the output voltage)}}{\textbf{Average value of the output signal}} \times 100$$

Since the RMS value can be given as:

$$\text{RMS Value} = \frac{1}{\sqrt{3}}\ \textbf{Peak value}$$

$$\text{RMS Value} = \frac{1}{2\sqrt{3}}\ \text{Peak to peak value}$$

Peak to Peak Value is given as:

$$\textbf{Peak to peak value}_{\text{half-wave rectifier}} = \frac{1}{2\sqrt{3}\, fRC}\ \text{Vm}$$

$$\text{Peak to peak value}_{\text{full-wave rectifier}} = \frac{1}{4\sqrt{3}\, fRC}\ \text{Vm}$$

While the Average value of the output signal can be given as:

$$\textbf{Average value} = \text{Vm} - \frac{1}{2}\ \textbf{Peak to peak value}$$

where:

○ f is the input voltage frequency ○ R is the Load Resistance ○ C is the Filter Capacitor.

5.Other diode applications:

5.1: Clipping:

diodes can also be used to clip the high level, low level, or both of a waveform at a specific DC, diode clipping circuits are used to remove amplitude noise or voltage spikes, regulate voltages. [9].

5.1.1: positive and negative Clipping:

For the diode to be forward biased, it must have an input voltage magnitude greater than +0.7 volts during the positive half cycle, the diodes begin to conduct to keep the voltage across it constant at 0.7 V until the sine waveform drops below this value, the output voltage applied across the diode can never exceed 0.7 volts. Therefore, the diode limits the positive half of the input waveform and is called a positive clipping circuit such as shown in figure above.

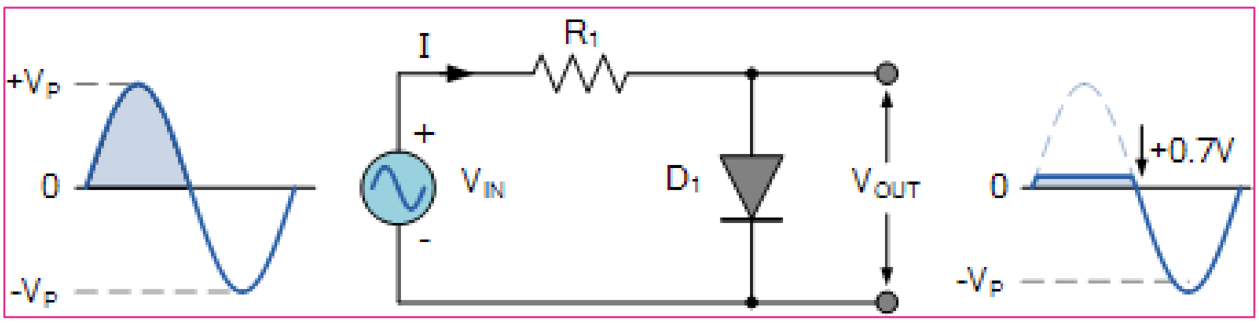

Figure 14 Positive Diode Clipping Circuit

On the other hand, when the diode is negative biased, the positive half cycle will not affect the diode current flow, but in the negative half cycle the diode will conduct until the waveform rise above 0.7v. [9].

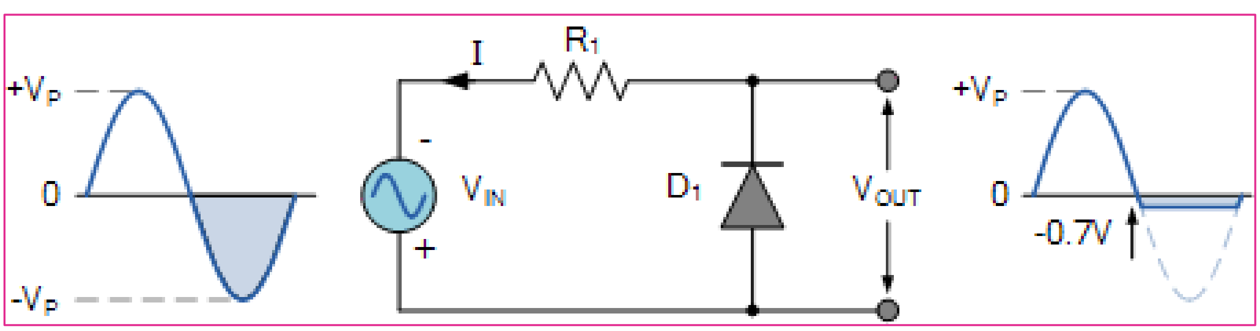

Figure 15 Negative Diode Clipping Circuit

5.1.2: clipping with positive and negative biasing:

To create diode clipping circuits for voltage waveforms at different levels, a bias voltage, VBIAS, is added in series with the diode to create a combined clipper. The voltage across the entire series combination must be greater than VBIAS + 0.7 V before the diode becomes forward biased enough to conduct.

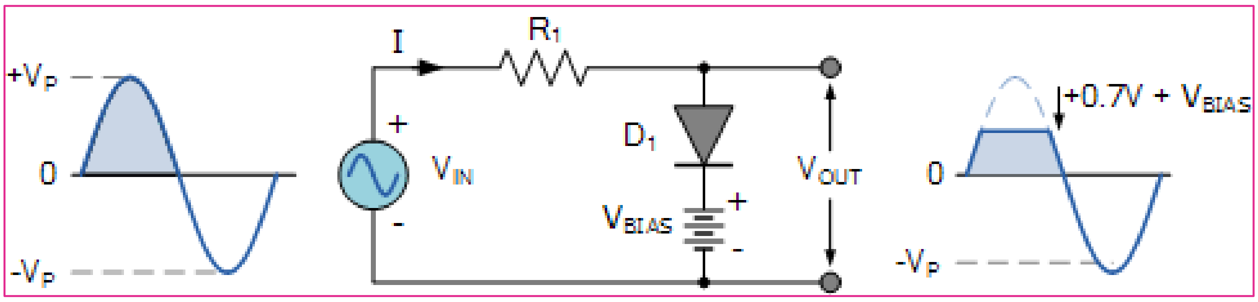

Figure 16 Positive Bias Diode

Likewise, by reversing the diode and the battery bias voltage, when a diode conducts the negative half cycle of the output waveform is held to a level –VBIAS – 0.7V as shown.

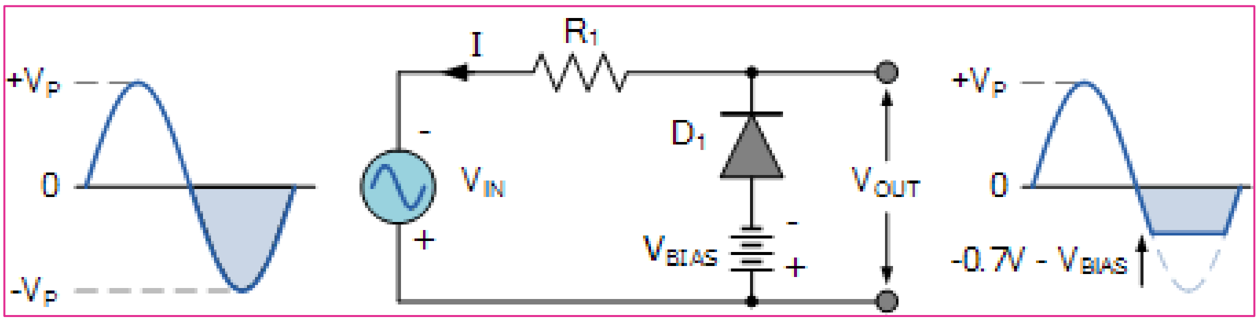

Figure 17 Negative Bias Diode

5.2: Clamping:

Clamper circuits are constructed in a similar manner as that of clipper circuits. However, clamper includes an extra charging element that is the capacitor in its circuitry. The combination of diode and capacitor in the clamper circuit is used to maintain different dc level at the output of the clamper. [10]

5.2.1: positive Clamping with biasing:

Initially, the positive half of the input signal will reverse bias the diode but the capacitor remains unchanged. For the negative half of the AC signal, the capacitor is now fully charged to the peak of the AC signal but has reverse polarity, this negative half biases the diode, causing a direct current to flow through the diode, the next positive half will reverse bias the diode, causing a signal to appear at the output. [10]

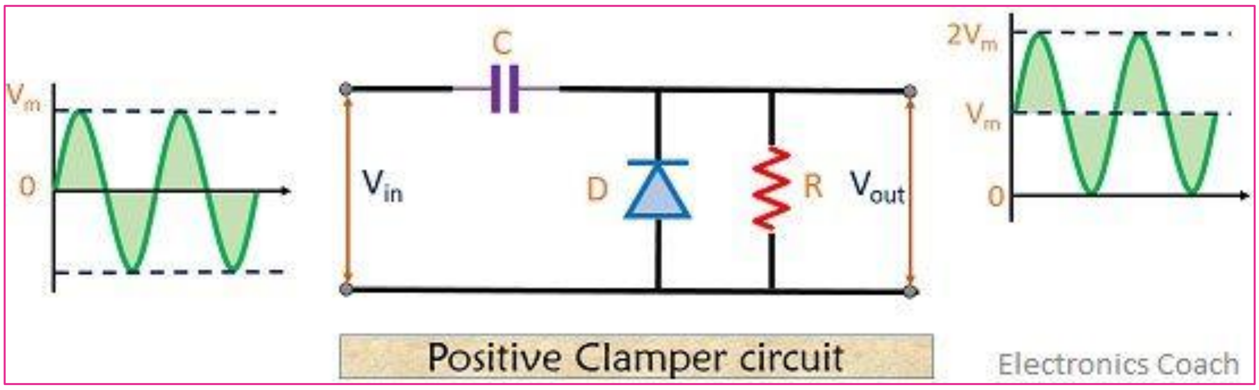

Figure 18 Positive Clamper circuit

The working is almost similar to the positive unbiased case but here an additional voltage is provided so as to have an additional shift in the level of the signal. When positive half of the input signal is applied, the diode is reverse biased due to ac input but is forward biased due to battery voltage.

On the negative half of the input signal, the diode is now forward biased due to the AC input and battery voltage and starts conducting. This will charge the capacitor using the sum of the voltage from the AC input as well as the battery voltage. Therefore, such an output voltage level will be achieved. [10]

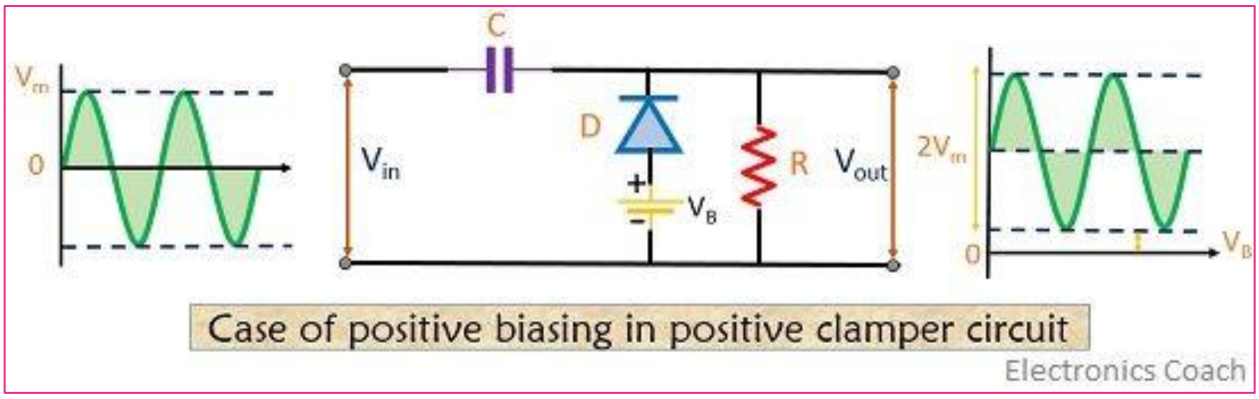

Figure 19 positive Clamping with positive biasing

For negative biasing; positive half of the AC signal, the diode gets reverse biased by both ac input and battery voltage. Due to these current flows through the load and combinedly maintain the voltage level.

At the time of the negative half, the diode is in the forward biased condition due to ac input but is in reverse biased condition due to battery voltage. So, the diode conducts only when the AC input dominates the battery voltage. This charges the capacitor hence we get a shifted signal at the output. [10]

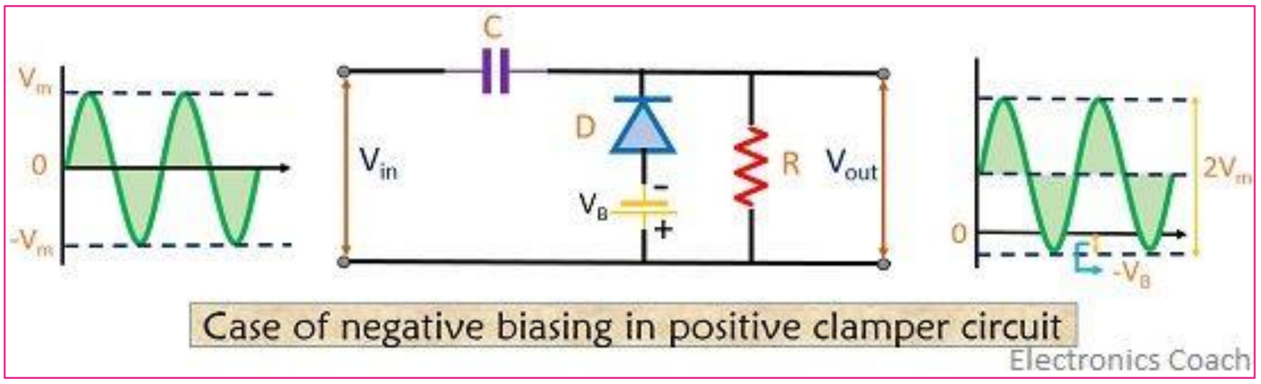

Figure 20 positive Clamping with negative biasing

5.2.1: negative Clamping with biasing:

The moment the positive half of the AC input is applied, the diode will go into forward-biased state resulting in no-load current at the output. However, a forward current flowing through the diode will charge the capacitor to the peak of the AC signal, but with reverse polarity as the capacitor is charged to the forward bias state of the diode.

When the negative half of the AC signal is applied, the diode will now be reverse biased, this allows load current to appear at the output of the circuit, the capacitor will discharge. [10]

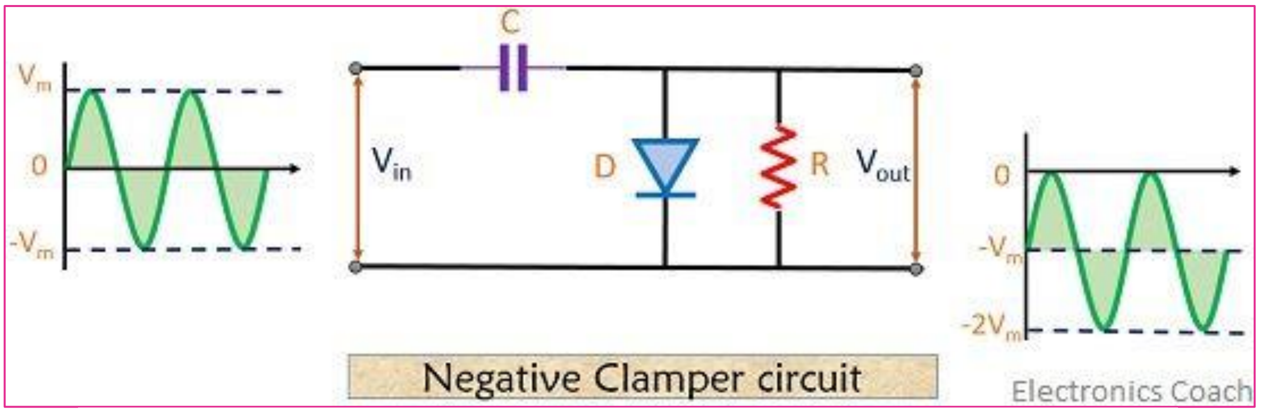

Figure 21 Negative Clamper circuit

However, in the case of positive-bias negative clamping, the signal is raised to a positive level because the battery voltage is applied, when the positive half of the AC signal is applied, the diode is in a forward-biased state due to the AC supply but is reverse-biased due to the battery voltage, so the diode conducts when the mains power exceeds the battery voltage.

Continuing forward through the negative half, the diode is now in reverse bias due to both the AC power source and the battery voltage, this non-conducting state of the diode will discharge the capacitor. [10]

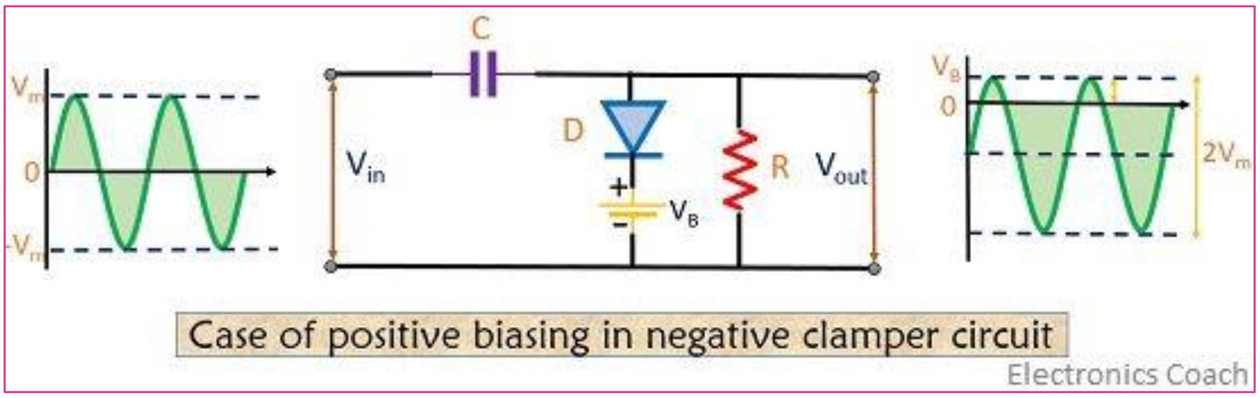

Figure 22 Negative Clamping with positive biasing

At the moment of the positive half of the AC input, the diode is forward biased due to the cause of the AC input and battery voltage, this initiates conduction through the diode and charge the corresponding capacitor.

At negative half, the diode is reverse biased but will still conduct due to the forward bias condition applied by the battery, the diode current flows until the battery voltage is higher than the AC input power. the moment the AC input exceeds the battery voltage, the diode is reverse biased and the capacitor discharges. [10]

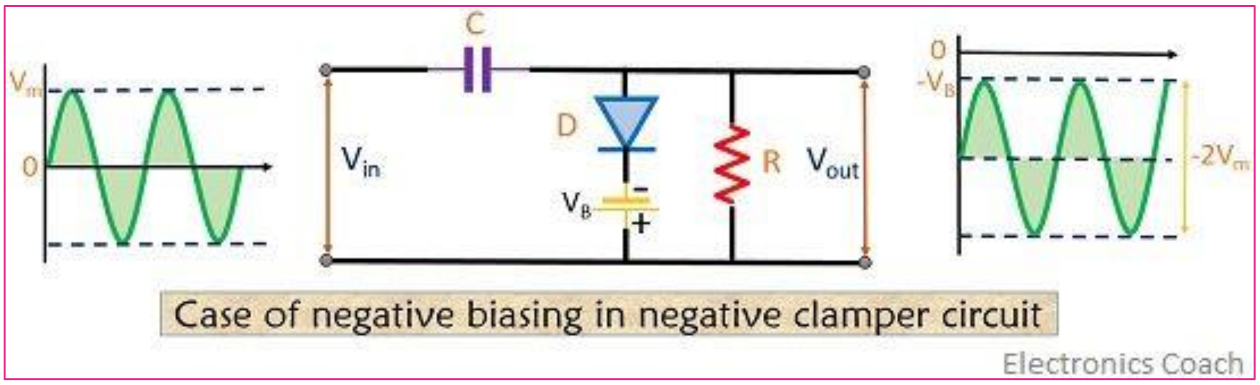

Figure 23 Negative Clamping with negative biasing

6. Electronic components:

6.1: Oscilloscope:

Oscilloscope is the device used to measure time response in the circuits, it will display the output of the circuit as a graph of either voltage or current depending on the inputs connect to its channels.[11]

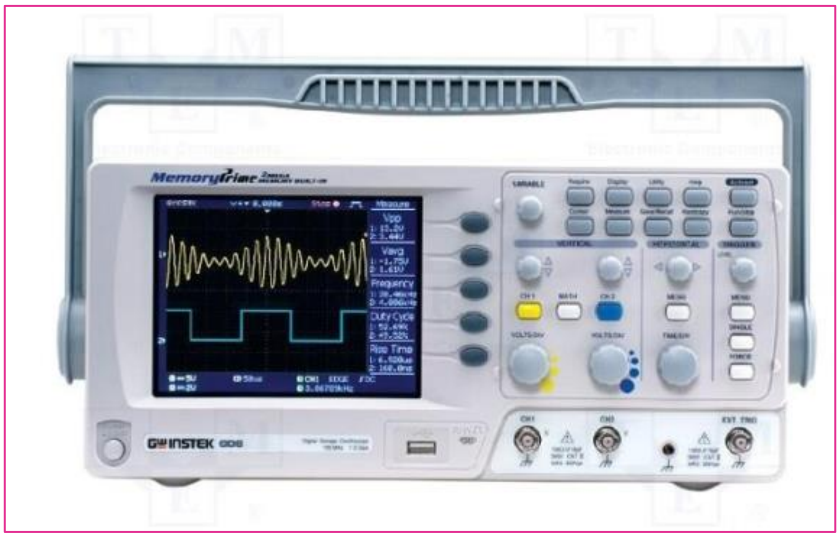

Figure 24 Oscilloscope

6.2: DVM Digital Volt Meter:

DMV is used to measure the voltage at which various appliances, the readings that a digital voltmeter offers are more accurate and fast as compared to analog meters. They are stable and hence, more reliable than earlier systems. They can measure both AC and DC voltage systems.[12]

Figure 25 Digital Volt Meter

Procedure and Data analysis

1.Diode characteristics:

After the circuit in figure 26 has been connected, and sat the current limit of the dc power supply to 150mA. Switched on the power supply and adjust it from zero to 1 volt in 0.1V steps and in 0.5 steps from 1V to 3V.

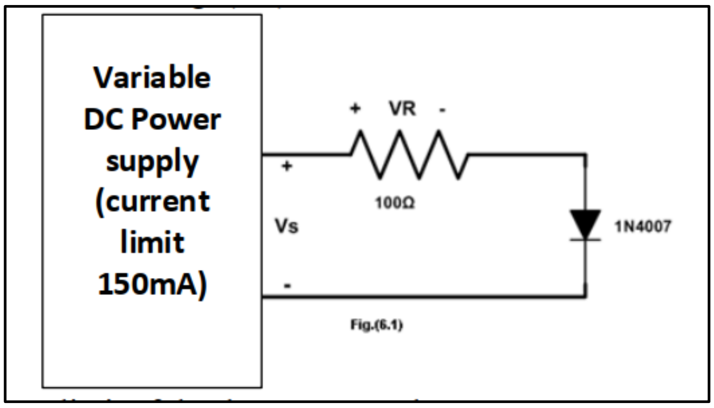

Figure 26 Diode characteristic circuit

VR values has been measured as the following:

Table 1 Measured Data of Diode Characteristcs

SET		Measure	Calculate	
V_S (desired)	V_S (actual)	V_R	V_D	I_D
0	0	0 V	0 V	0
0.1	0.109	0 V	0.109 V	0
0.2	0.237	0 V	0.237 V	0
0.3	0.374	0.001 V	0.373 V	10 µA
0.4	0.411	0.002 V	0.409 V	20 µA
0.5	0.506	0.015 V	0.491V	150µA
0.6	0.62	0.063 V	0.557V	630µA
0.7	0.73	0.138 V	0.592V	1.38mA
0.8	0.81	0.195 V	0.615 V	1.95mA
0.9	0.92	0.291 V	0.629 V	2.91mA
1.0	1.05	0.405 V	0.645 V	4.05mA
1.5	1.49	0.811 V	0.679 V	8.11mA
2	2.05	1.344 V	0.706 V	13.44mA
2.5	2.51	1.798 V	0.712 V	17.98mA
3	3.02	2.295 V	0.725 V	22.95mA

1.1: Calculating V_D:

To calculate VD, the *Kirchhoff's second law is used: "The directed sum of the potential differences (voltages) around any closed loop is zero".*

$$\sum Vi = 0$$
$$0 = VD + VR - VS$$
$$VD = VS - VR$$

1.2: Calculating I_D:

To calculate ID, *Ohm's Law is used.* Since IR equals to ID

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

1.3: I_D - V_D Chart

from table 2 Values of ID and VD has been taken as data to the chart.

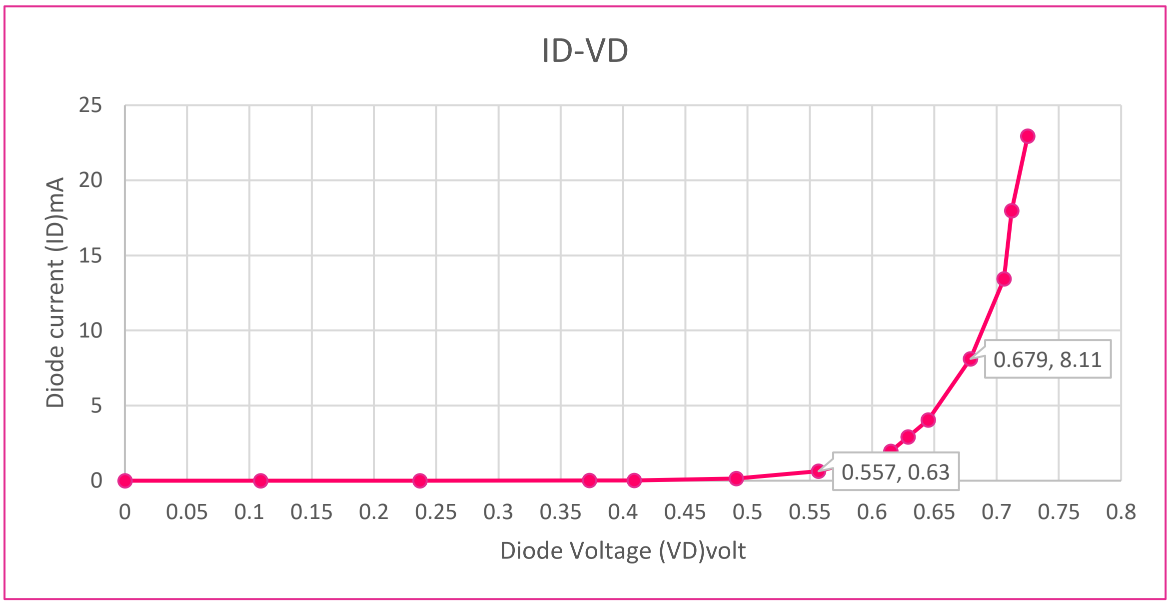

Figure 27 ID-VD chart

From figure 27, The value of ID is raised noticeably after 0.557 up to 0.679 where it stops rising noticeably, shaping something similar to knee. (aka knee value for diode).

However, when the diode has been switched to be in reverse biased, All V_D values remain 0, for all Vs values, indicating no current flew through the diode.

2.Rectification:

2.1: Half-wave rectification:

The circuit in figure 28 has been connected, the oscilloscope and the sinusoidal supply has been switched on.

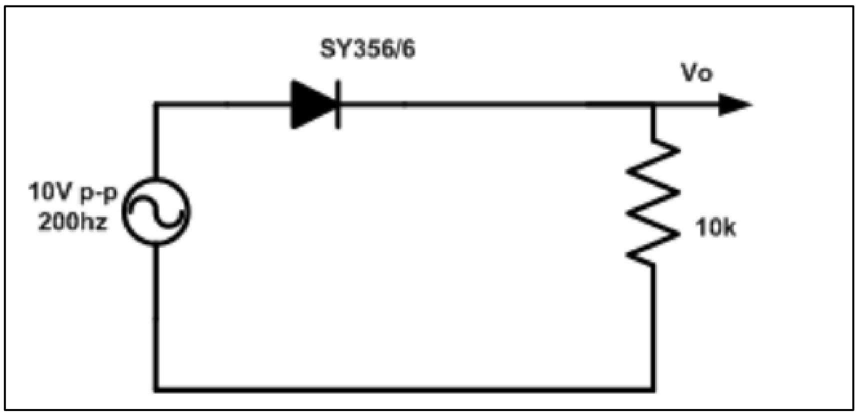

Figure 28 Half-wave rectifier circuit

2.1.1: Measurement of period and frequence:

After Oscilloscope picture of waveform has been taken as the following:

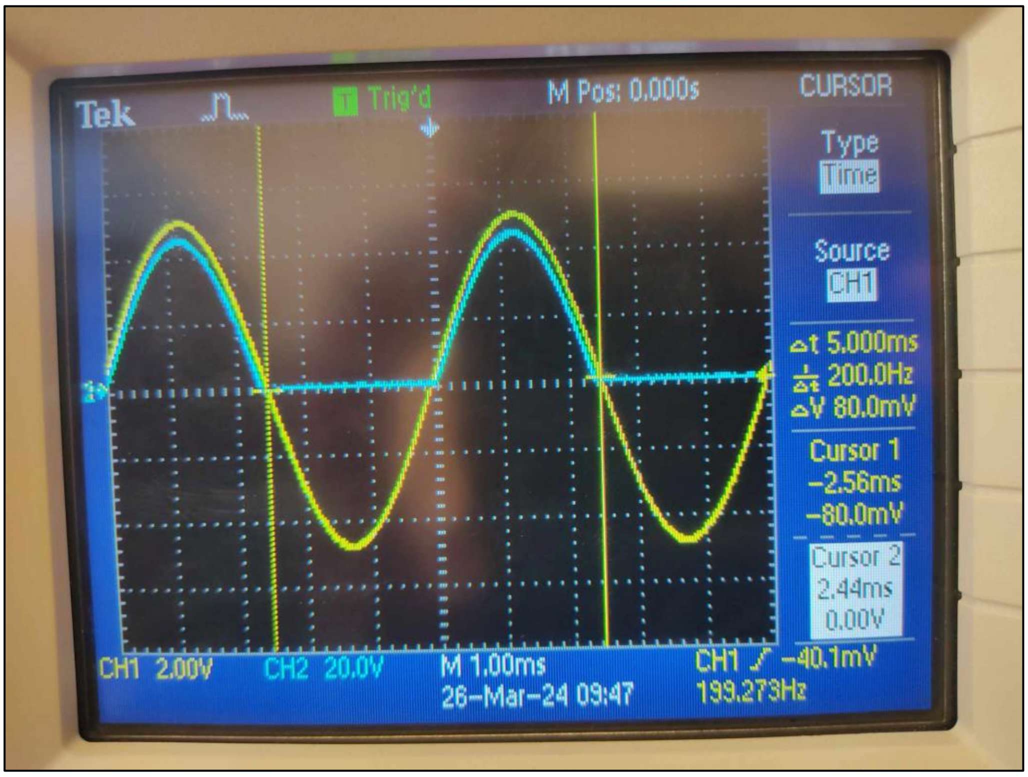

Figure 29 Half-wave rectifier T waveform measure

The space between two cursors indicated the period T of the rectifier, which is equal to 5ms, and the frequency to 200Hz as shown in figure 29.

Thus, in this picture the value of V in channel 2 was amplified to show 20V due to previous user, whom set the value to show x10, this doesn't affect the measurement of the period.

2.1.2: Measurement of V peak value:

Figure 30 show the measurements of $V_{peak\ to\ peak}$ value that indicate V peak which is 4.56V.

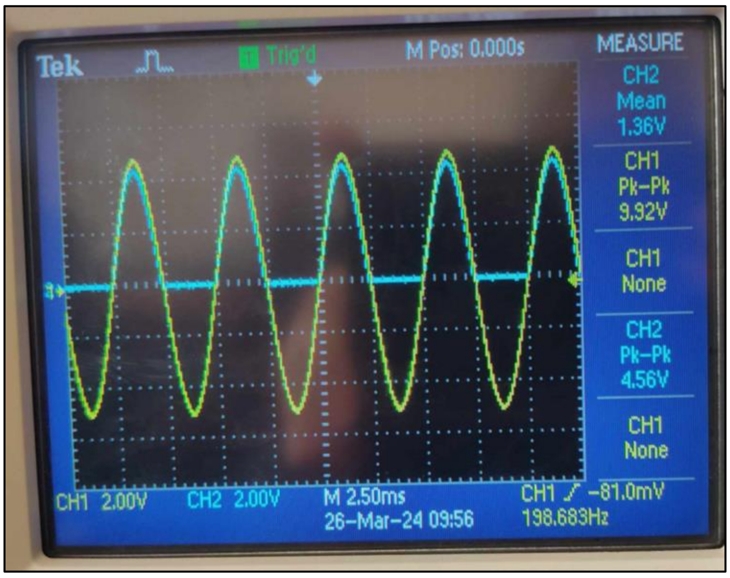

Figure 30 Half-wave rectifier Vpeak waveform measure

The input voltage peak value is 4.96V, while the output voltage peak value is 4.56V with difference of 0.4V is due to voltage drop.

2.1.3: Dc and Ac components:

The DVM device from theory has been used to indicate the values of DC and AC as the following:

Table 2 DC and AC value of half-wave rectifier

DC	AC
1.324	1.670

Theoretically:

$$\text{DC value} = \frac{V\ peak}{\pi}$$

$$= \frac{5 - 0.7}{\pi}$$

$$= 1.3687$$

The difference between the theoretical value of DC component and the resulted value, is due to the $V_{peak,\ out}$ (Theoretical = 4.3, Practical = 4.56) due to Diode voltage drop and load impedance.

To obtain nearly a perfect result is by using ideal diodes, and devices with Zero load impedances to unsure the voltage from the supply reach fully to the output.

Questions Answers:

1. The input voltage peak value is 4.96V, while the output voltage peak value is 4.56V with difference of 0.4V is due to voltage drop.

2. By reversing the diode bias.

2.1.4: incase the diode is reversed biased:

After the diode position has been switched to be reversed biased.

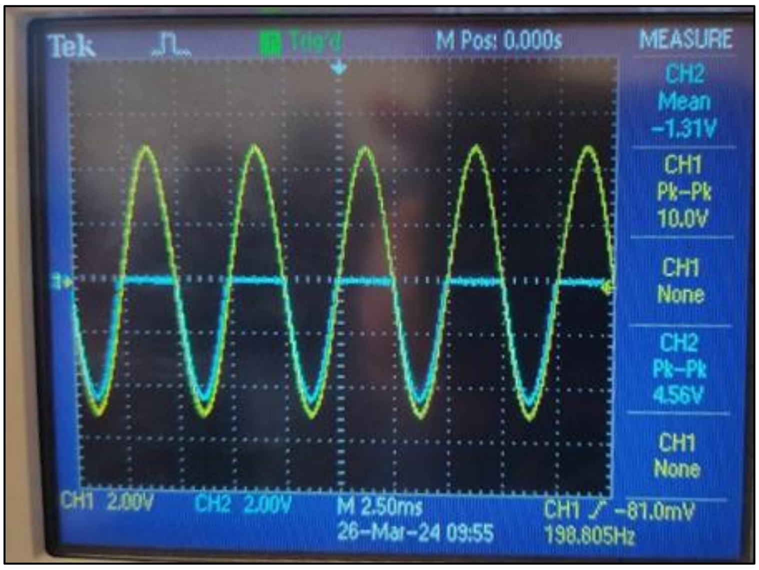

Figure 31 Half-wave rectifier with reversed diode

The output obtained rectification only on the half negative cycle of the input which is the opposite of positive half-wave rectifier, that's due the diode nature to only let the current to flew only on one direction. (unidirectional).

This is how to obtain negative voltage relative to zero.

2.1.5: After 2.2µF capacitor is added:

After connecting the capacitor, the following waveform is obtained:

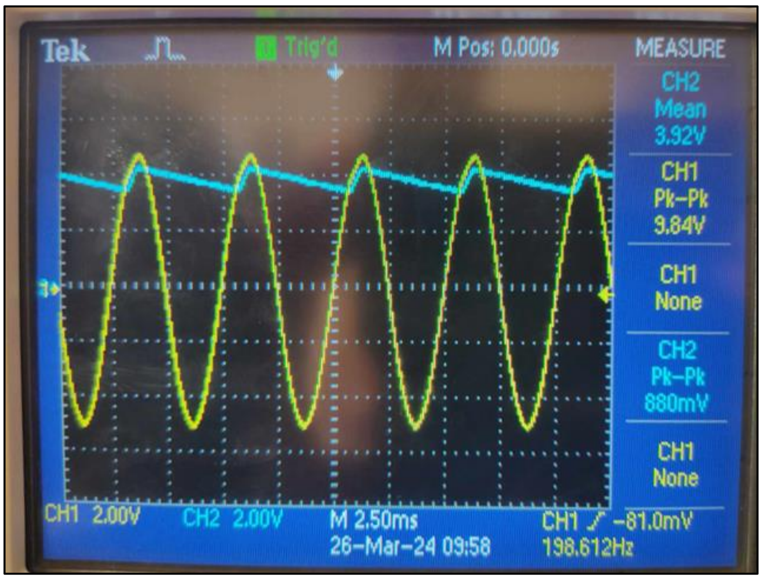

Figure 32 Half-wave rectifier with capacitor

The output of the waveform is noticed to be filtered according to the capacitor phase of charge and discharge.

The oscilloscope is used to measure the peak values and RMS, and mean values such as following:

Figure 33 Ac coupling using oscilloscope

The figure 33 shows the AC coupling of the output, as the RMS value is 234mV, Vp-p=880mV, and mean of 10.2mV.

Figure 34 Dc coupling using oscilloscope

The figure 34 shows the DC coupling of the output, as the RMS value is 3.92V, Vp-p =800mV, and mean of 3.91V

To measure the ripple factor:

$$\textbf{Ripple factor } r\% = \frac{RMS\ (ripple\ of\ output\ voltage)of\ Ac}{Mean\ value\ of\ Dc\ output} \times 100\%$$

$$= \frac{234mV}{3.91V} \times 100\%$$

5.9846%

Theoretically:

$$Ripple\ Factor\ r\% = \frac{1}{\sqrt{3}\ (2\ f\ RC\ -1\ )} \times 100\%$$

$$\frac{1}{\sqrt{3}\ (2 * 200 * 10k * 2.2u\ -1\ )} \times 100\%$$

7.4019%

Both Values, theoretically and manually is close.

2.1.6: After 47µF capacitor is added:

A capacitor of value 47µF, was not found, so 35µF Capacitor is replaced, and picture of the oscilloscope has been taken as the following:

The figure 35 shows the AC coupling of the output, as the RMS value is 37.8mV, Vp-p=160mV, and mean of 12.8mV

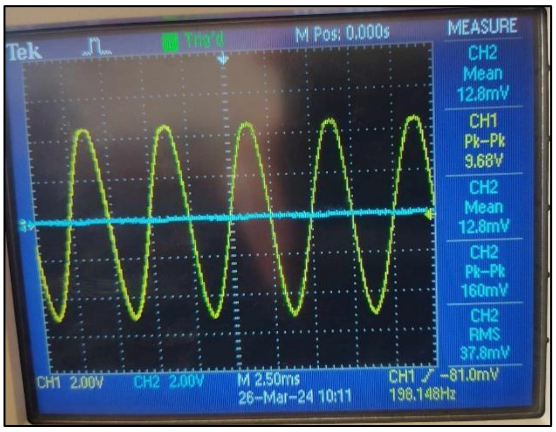

Figure 35 AC coupling for half-wave rectifier with 35uF capacitor

The figure 36 shows the DC coupling of the output, as the RMS value is 4.06V, Vp-p=160mV, and mean of 4.06V.

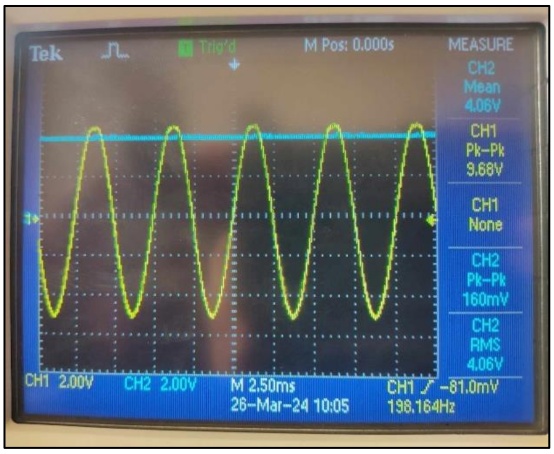

Figure 36 DC coupling for half-wave rectifier with 35uF capacitor

$$\textbf{Ripple factor } r\% = \frac{\boldsymbol{RMS\ (ripple\ of\ output\ voltage)\ of\ Ac}}{\boldsymbol{Average\ value\ of\ the\ output\ signal\ \ (mean\ in\ Dc)}} \times 100\%$$

$$= \frac{\mathbf{37.8}\boldsymbol{mV}}{\mathbf{4.06}\boldsymbol{V}*\mathbf{2}} \times 100\%$$

$$= \mathbf{0.4655\%}$$

Theoretically:

$$\boldsymbol{Ripple\ Factor\ r\%} = \frac{\mathbf{1}}{\sqrt{3}\ (\mathbf{2\ f\ RC\ -1})} \times \mathbf{100\%}$$

$$\frac{\mathbf{1}}{\sqrt{3}\ (\mathbf{2*200*10k*35u\ -1})} \times \mathbf{100\%}$$

$$\mathbf{0.4141\%}$$

Thus, the two values differ, the ripple factor decreased with better filtering such as 35uF capacitor, as RMS value decreased and mean value noticeably increased.

2.2: full-wave rectification:

Circuit of full wave rectifier has been connected as the following figure number 37:

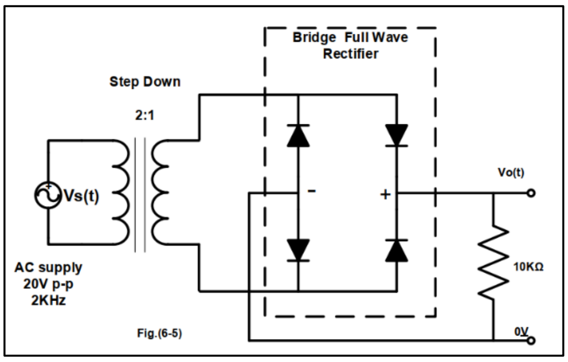

Figure 37 full-wave rectification

Connected the oscilloscope to the output and a picture has been taken of the waveform showing key quantities:

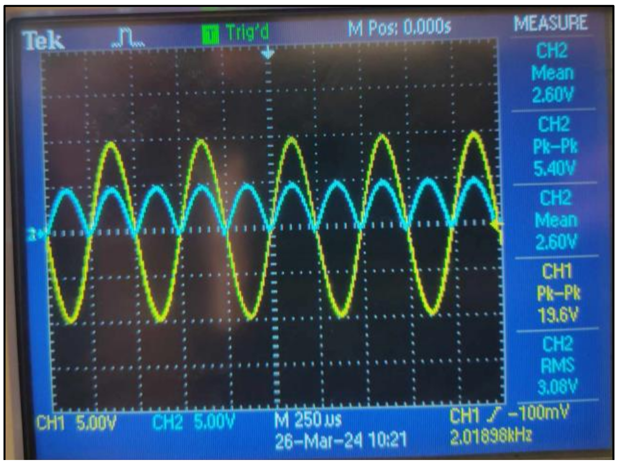

Figure 38 Full-wave rectifier waveform

After figure 38 has been observed, output Voltage peak to peak value is 5.40V while the input Voltage peak Value is 9.8Volt, the peak voltage is less than the input is due to stepdown transformer along with voltage drop that been explained in the theory.

2.2.1: Ac and Dc components:

After DVM device has been used, the values of DC and AC for full wave rectifier are:

Table 3 Full-wave rectifier Ac and Dc values

DC	AC
2.597 V	1.622 V

Theoretically:

$$\text{DC value} = \frac{V\ peak}{\pi}$$

$$= \frac{10 - 1.4}{\pi}$$

$$= 2.7374$$

Which both values are close.

2.2.2: Full-wave rectifier with 2.2μF capacitor:

After a capacitor of value 2.2μF has been added to the circuit:

Figure 39 DC coupling for full-wave rectifier

Figure 39 shows the component of DC coupling of the output after the capacitor has been added, which indicate the value of VRMS = 4.39V, Vp-p = 400mV, and Vmean = 4.39V.

Figure 40 AC coupling for full-wave rectifier

Figure 40 shows the component of AC coupling of the output after the capacitor has been added, which indicate the value of VRMS = 58.8mV, Vp-p = 400mV, and Vmean = 4.96mV.

To measure ripple factor:

$$\textbf{Ripple factor } r\% = \frac{RMS\ (ripple\ of\ output\ voltage)\ of\ Ac}{Average\ value\ of\ the\ output\ signal\ \ (mean\ in\ Dc)} \times 100\%$$

$$= \frac{58.8mV}{4.39V * 4} \times 100\%$$

$$= \mathbf{0.3348}\ \%$$

Theoretically:

$$Ripple\ Factor\ r\% = \frac{1}{\sqrt{3}\ (4\ \text{f RC} - 1\ )} \times 100\%$$

$$\frac{1}{\sqrt{3}\ (4 * 2000 * 10\text{k} * 2.2\text{u} - 1\ )} \times 100\%$$

$$0.3291\%$$

Full-wave rectifiers are more efficient and provide smoother and more stable DC output than half-wave rectifiers.

As it has been noticed, after the capacitor has been added, the waveform of the AC value became Similar to DC with little no noticeable pulsing.

That’s due to the nature of the capacitor in storing voltage and acts such as power supply whenever the amplitude of the input changes.

The ripple amplitude, which is the change in the DC output voltage, is increases with respect to decrease in the product of the frequency (output) and the capacitance of the filter capacitor (C).

$$f_{ripple} = 2 \text{ x } f_{input}$$

$$Vr \propto \frac{1}{C\ x\ f_{input}}$$

To achieve the same ripple amplitude at a lower frequency, typically it is needed of a larger capacitor. (increase C when decrease f, to maintain balance).

3.Other applications:

3.1: Clipping:

After the circuit in figure 41, the power supply variable control has been sat to zero, and the output waveform has been connected.

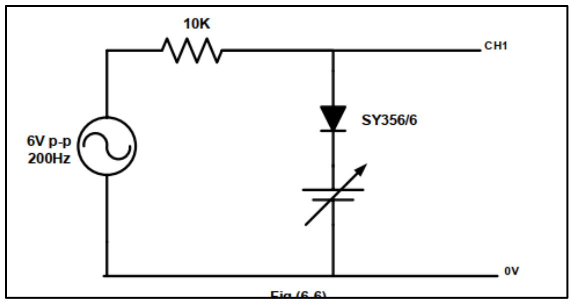

Figure 41 clipping circuit

3.1.1: Clipping at Dc value of 0 Volt.

As the oscilloscope has shown the figure 42 when the voltage was 0.

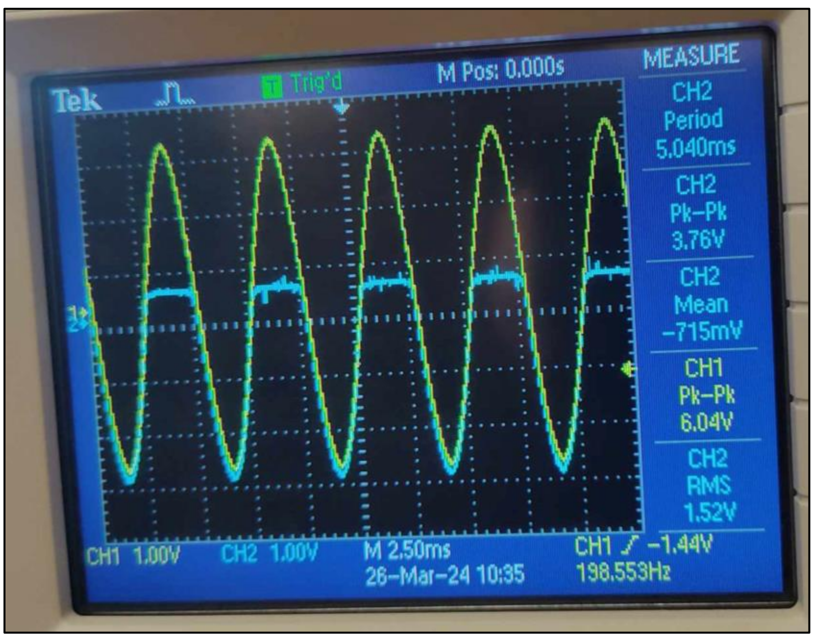

Figure 42 Clipping waveform at 0 volt

After figure 42 has been analyzed, at around 0.76 the output has been chopped off.

When $V_{in} > 0$: $V_{out} = V_D$.   When $V_{in} < 0$: $V_{out} = V_{in}$.

V_D is 0.7 volt.

3.1.2: Clipping at Dc value of 1.5 Volt:

the dc supply voltage has changed to 1.5 volt, the oscilloscope showed the following waveform:

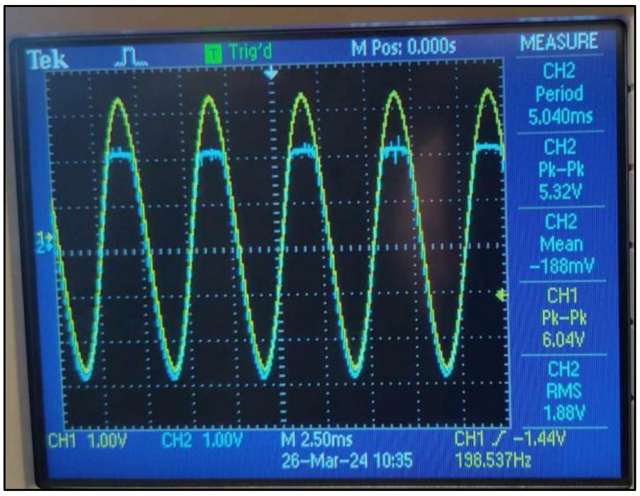

Figure 43 Clipping waveform at 1.5 volt

Manually the voltage stops at around Vpeak = 2.32V that's due voltage drop from diode and from additional voltage from the DC supplier.

Theoretically:

When $V_{in} > 0$:

$$V_{out} = V_D + 1.5.$$
$$= 2.2 \text{ V}$$

When $V_{in} < 0$:

$$V_{out} = V_{in}.$$

3.1.3: Clipping at Dc value of 4 Volt:

the dc supply voltage has sat to 4 volts, the oscilloscope showed the following waveform:

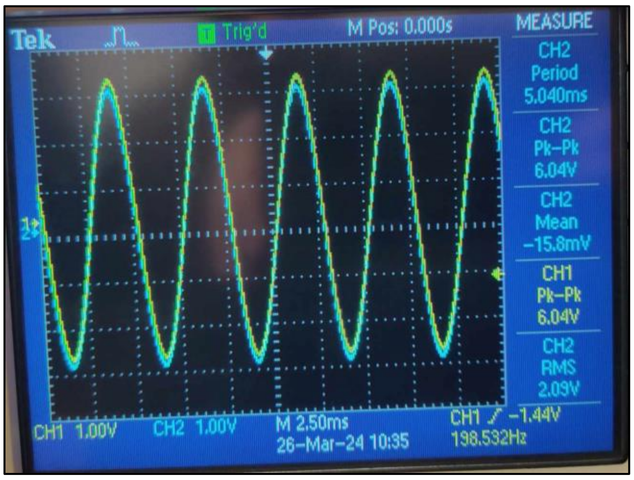

Figure 44 Clipping waveform at 4 volts

When $V_{in} > 0$:

$$(V_{DC} = 4) > (V_i = 3).$$
$$V_{out} = V_{DC}$$

When $V_{in} < 0$:

$$V_{out} = V_{in}.$$

After the figures has been observed:

The relationship between clipping level and DC voltage is a Positive Bias Diode with positive biasing:

clipping level = DC voltage + diode forward voltage

Therefore, when the DC voltage extend the input voltage, the main supply for the diode will be the DC supply, and the diode will pass the current accordingly.

But whenever the DC voltage does not extend the input voltage, it will only feed the diode to extend depending on its value, leading the diode to be forward bias for the DC voltage, and reverse for the input, clipping whenever the Input value extend the DC and diode voltage.

So, If $V_i = 5$, the output voltage will be as:

When $V_{in} > 0$:

If $V_{DC} = 0$

$V_{out} = V_D < 5V$

If $V_{DC} = 1.5$

$V_{out} = 1.5 + V_D < 5V$

$= 2.2V < 5\ V$

If $V_{DC} = 4$

$V_{out} = V_{DC} + V_D < 5V$

$= 4.7\ V < 5V$

If $V_{DC} > 5$

$V_{out} = V_{DC} > 5\ V$

When $V_{in} < 0$:

$V_{out} = V_{in}$.

3.2: Clamping:

After the circuit in figure 45 has been connected, the output is connected to the oscilloscope, and power supply variable control is sat to zero.

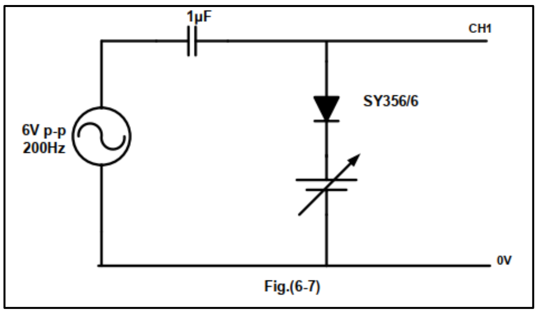

Figure 45 clamping circuit

3.2.1: clamping at Dc value of 0 Volt:

Figure 46 shows the output and input voltage after the voltage power supply is set to 0.

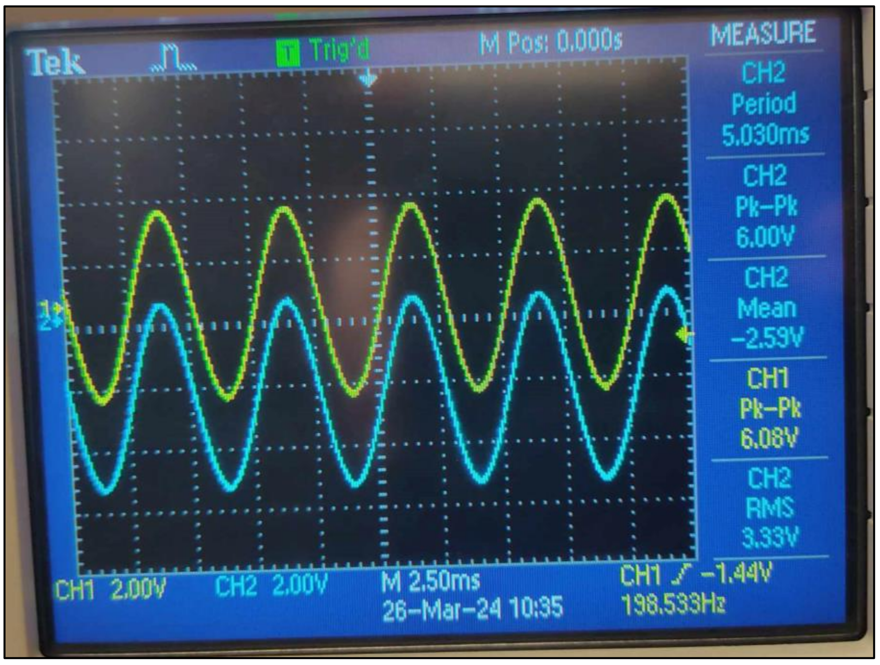

Figure 46 Clamping waveform at 0 volt

As shown in the figure:

Using ***Kirchhoff's second law***:

$$V_c = V_i - V_D$$

$$V_{out} = V_i - 2.3$$

When $V_{in} = V_{peak} = 3$:

$$V_{out} = V_D.$$

$V_D = 0.7.$

3.2.2: clamping at Dc value of 1.5 Volt:

Figure 47 shows the output and input voltage after the voltage power supply is set to 1.5V.

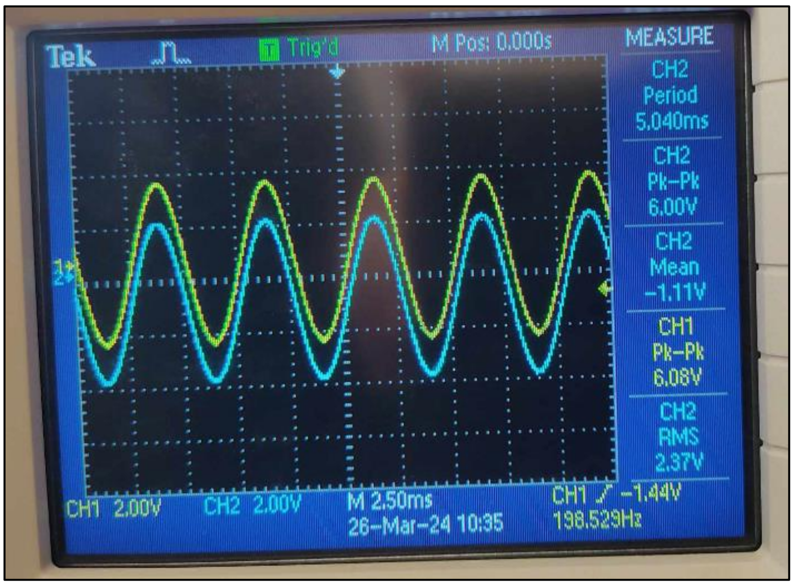

Figure 47 Clamping waveform at 1.5 volt

As shown in the figure:

Using ***Kirchhoff's second law***:

$$V_c = V_i - V_D - 1.5$$

$$V_C = V_i - 2.2$$

$$V_{out} = V_i - 0.8$$

When $V_{in} = V_{peak} = 3$:

$$V_{out} = 2.2.$$

3.2.3: clamping at Dc value of 4 Volt:

Figure 48 shows the output and input voltage after the voltage power supply is set to 4 V.

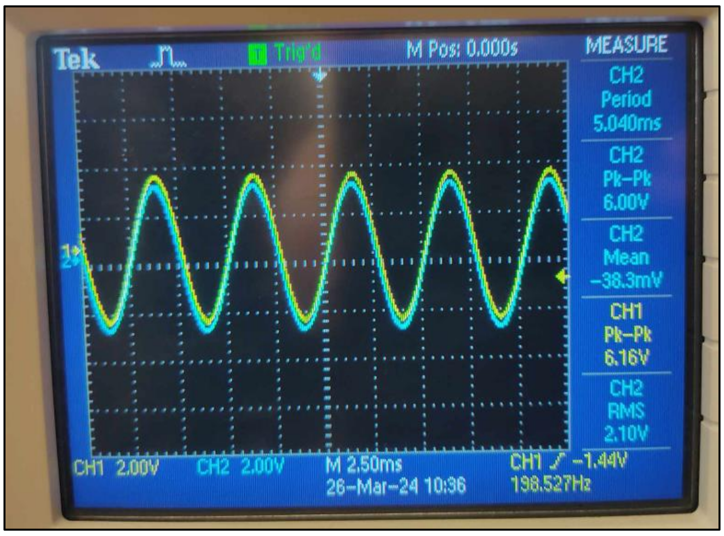

Figure 48 Clamping waveform at 4 volts

As shown in figure 48:

$$V_{out} = V_i.$$

After the figures above has been observed, the direct relationship between the references or clamping voltage and the clamping level can be given as:

Clamping Level = battery Voltage + AC Input Peak

Since V_{DC} is greater than $V_{peak,}$ when V_{in} reaches V_{peak} during the positive half cycle and V_{DC} is already greater than V_{peak}, the diode will be reverse biased and the capacitor will not charge any further, which leads to $V_{out} = V_{in}$.

The output waveform in clamping circuit is almost about the same DC value as the input in the waveform.

Therefor if the $V_{in,\ peak} = 5$ V.

Using Kirchhoff's second law:

If $V_{DC} = 0$

$V_c = V_i - 0.7$

$V_{out} = V_i - 4.3$

If $V_{DC} = 1.5$

$V_c = V_i - V_D - 1.5$

$V_C = V_i - 2.2$

$V_{out} = V_i - 2.8$

If $V_{DC} = 4$

$V_c = V_i - V_D - 4$

$V_C = V_i - 4.7$

$V_{out} = V_i - 0.3$

If $V_{DC} > 5$

$V_{out} = V_i$

Conclusion

In summary, the experiment studied diode rectification and the built the half-wave and full-wave rectifier circuit. And the influence of the load resistor and capacitor on the output voltage. As well the use of filters has been shown to obtain specific output waveforms. And the experiment also explores the difference between the clipping circuit and the clamping circuit.

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[2] https://www.build-electronic-circuits.com/what-is-a-diode/ (12:45 Sunday, March 31, 2024)

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[7]https://vidhutinfo.com/single-phase-transformer-define-working-types-advantages-disadvantages/ (16:00 Sunday, March 31, 2024)

[8]https://www.quora.com/A-capacitor-can-pass-an-AC-component-but-when-we-use-a-capacitor-as-a-filter-for-the-rectifier-output-how-do-we-get-DC-through-the-load-resistance (16:15 Sunday, March 31, 2024)

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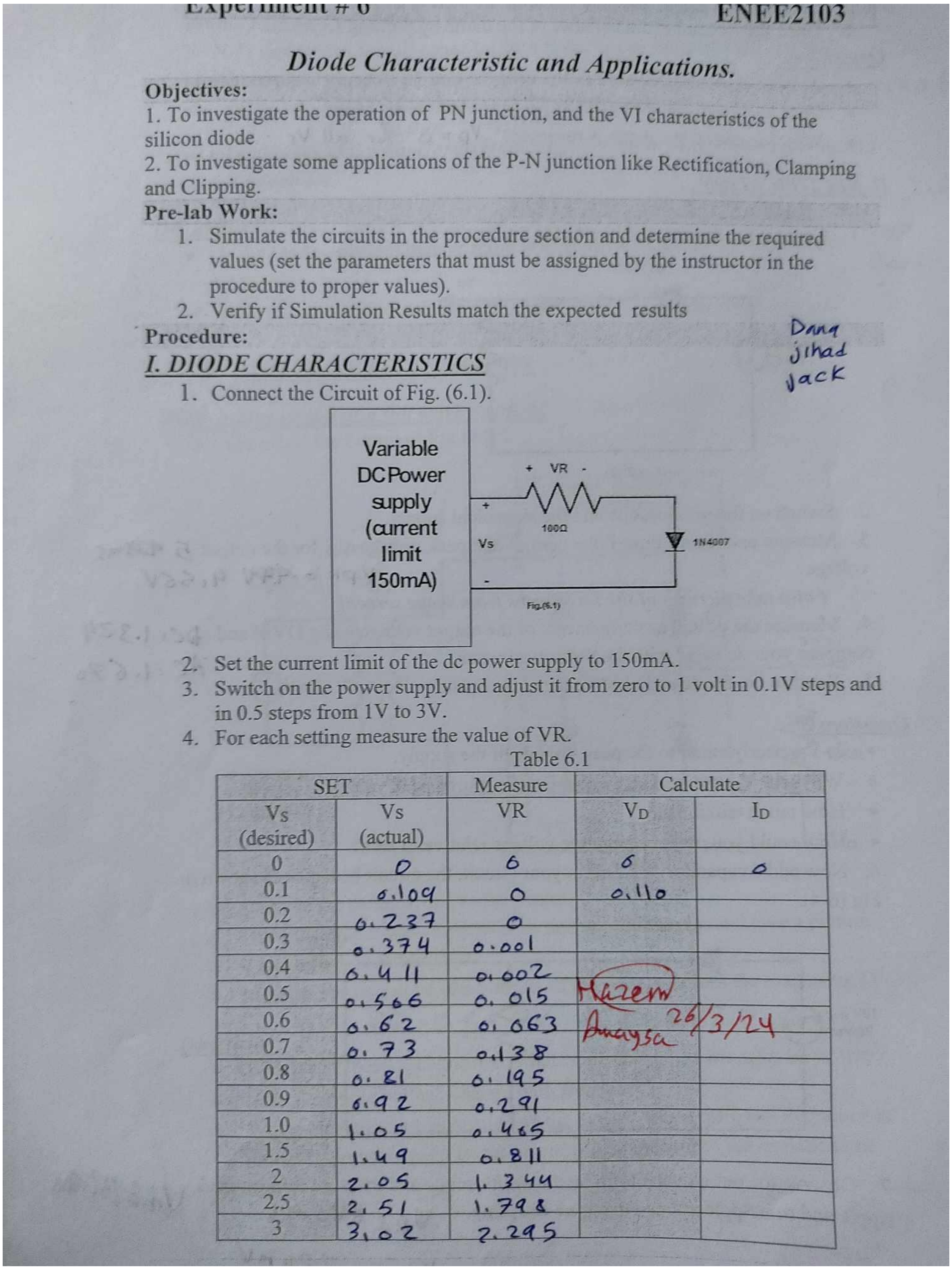
Appendix

1.


Experiment # 6 ENEE2103

Diode Characteristic and Applications.

Objectives:

1. To investigate the operation of PN junction, and the VI characteristics of the silicon diode
2. To investigate some applications of the P-N junction like Rectification, Clamping and Clipping.

Pre-lab Work:

1. Simulate the circuits in the procedure section and determine the required values (set the parameters that must be assigned by the instructor in the procedure to proper values).
2. Verify if Simulation Results match the expected results

Dana
jihad
jack

Procedure:

I. DIODE CHARACTERISTICS

1. Connect the Circuit of Fig. (6.1).

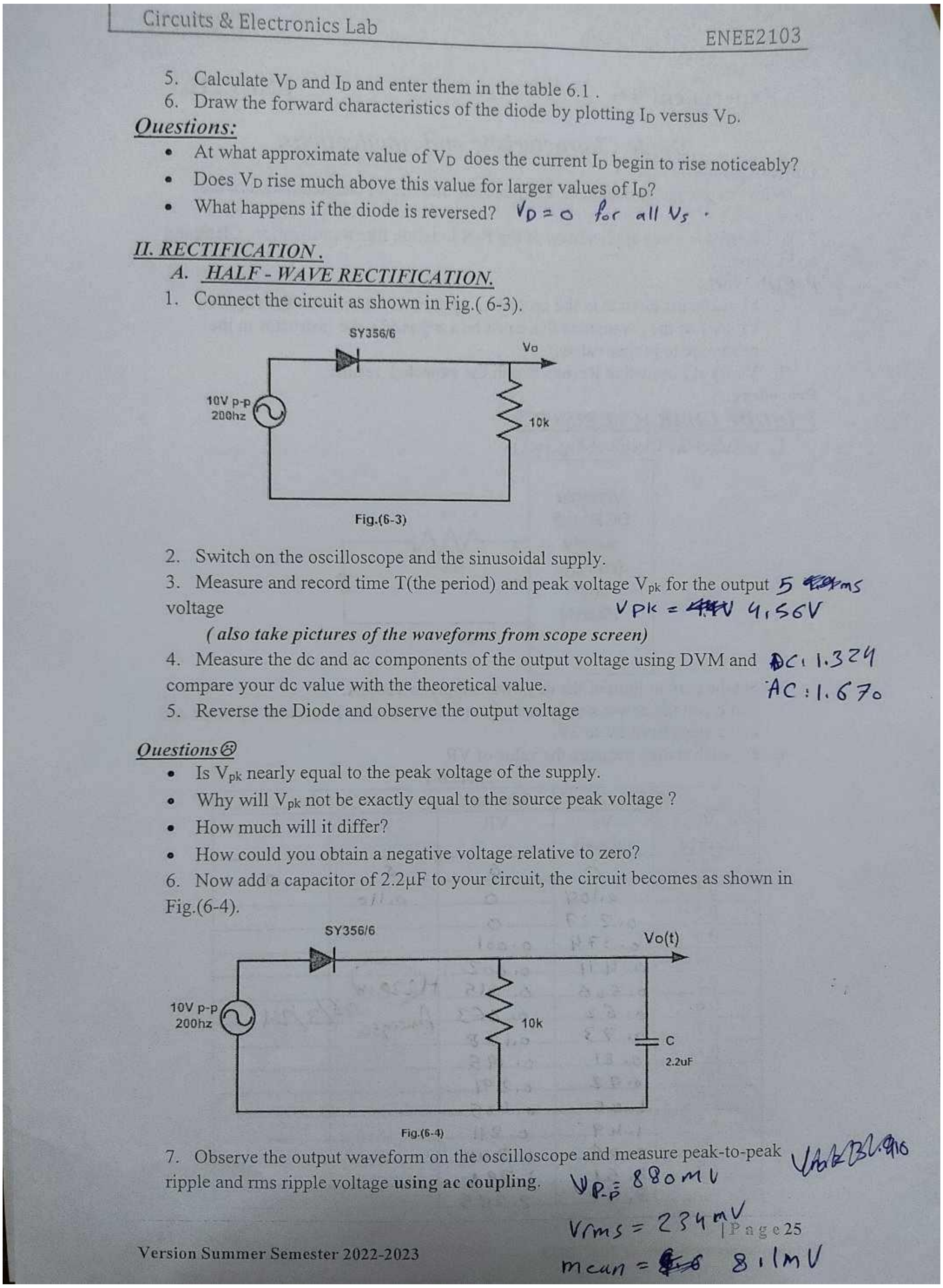
2. Set the current limit of the dc power supply to 150mA.
3. Switch on the power supply and adjust it from zero to 1 volt in 0.1V steps and in 0.5 steps from 1V to 3V.
4. For each setting measure the value of VR.

Table 6.1

SET		Measure	Calculate	
Vs (desired)	Vs (actual)	VR	V_D	I_D
0	0	0	0	0
0.1	0.109	0	0.110	
0.2	0.237	0		
0.3	0.374	0.001		
0.4	0.411	0.002		
0.5	0.566	0.015	Hazem	
0.6	0.62	0.063	Amaysa 26/3/24	
0.7	0.73	0.138		
0.8	0.81	0.195		
0.9	0.92	0.291		
1.0	1.05	0.465		
1.5	1.49	0.811		
2	2.05	1.344		
2.5	2.51	1.798		
3	3.02	2.295		

Figure 49 Lab paper 1

2.



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5. Calculate V_D and I_D and enter them in the table 6.1 .
6. Draw the forward characteristics of the diode by plotting I_D versus V_D.

Questions:

- At what approximate value of V_D does the current I_D begin to rise noticeably?
- Does V_D rise much above this value for larger values of I_D?
- What happens if the diode is reversed? $V_D = 0$ for all V_s .

II. RECTIFICATION .

A. HALF - WAVE RECTIFICATION.

1. Connect the circuit as shown in Fig.(6-3).

Fig.(6-3)

2. Switch on the oscilloscope and the sinusoidal supply.
3. Measure and record time T(the period) and peak voltage V_{pk} for the output voltage 5 ms

V_{pk} = ~~4.4V~~ 4,56V

(also take pictures of the waveforms from scope screen)

4. Measure the dc and ac components of the output voltage using DVM and compare your dc value with the theoretical value. DC: 1.324 AC: 1.670
5. Reverse the Diode and observe the output voltage

Questions:

- Is V_{pk} nearly equal to the peak voltage of the supply.
- Why will V_{pk} not be exactly equal to the source peak voltage ?
- How much will it differ?
- How could you obtain a negative voltage relative to zero?

6. Now add a capacitor of 2.2µF to your circuit, the circuit becomes as shown in Fig.(6-4).

Fig.(6-4)

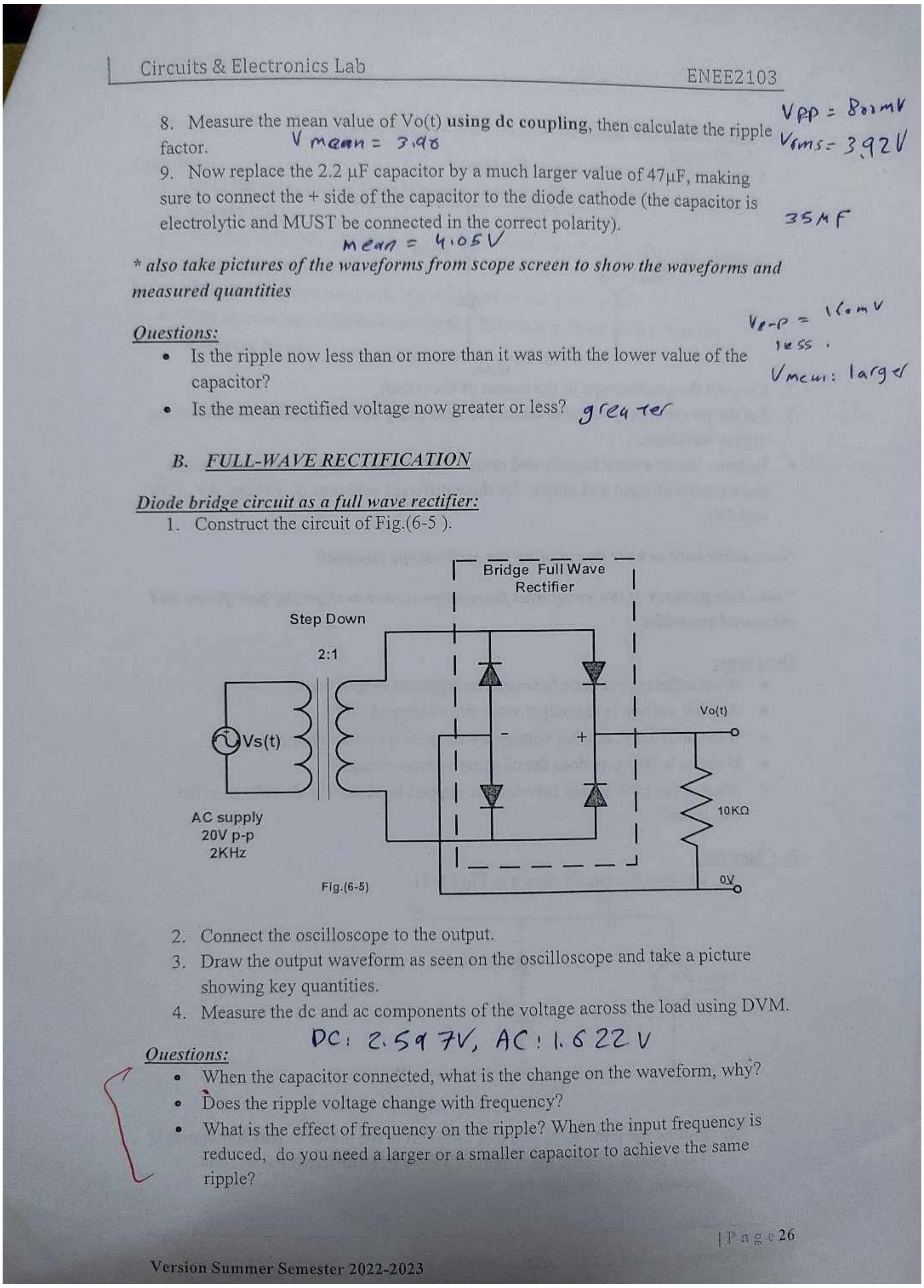
7. Observe the output waveform on the oscilloscope and measure peak-to-peak ripple and rms ripple voltage using ac coupling. V_{P-P} = 880 mV

Vrms = 234 mV

mean = 8.1 mV

Figure 50 Lab paper 2

3.



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8. Measure the mean value of Vo(t) **using dc coupling**, then calculate the ripple factor. V mean = 3.98 Vpp = 802mV Vrms = 3.92V

9. Now replace the 2.2 μF capacitor by a much larger value of 47μF, making sure to connect the + side of the capacitor to the diode cathode (the capacitor is electrolytic and MUST be connected in the correct polarity). 35μF

mean = 4.05V

** also take pictures of the waveforms from scope screen to show the waveforms and measured quantities*

Questions: Vp-p = 160mV

- Is the ripple now less than or more than it was with the lower value of the capacitor? less.
- Is the mean rectified voltage now greater or less? greater Vmean: larger

B. FULL-WAVE RECTIFICATION

Diode bridge circuit as a full wave rectifier:

1. Construct the circuit of Fig.(6-5).

Fig.(6-5)

2. Connect the oscilloscope to the output.
3. Draw the output waveform as seen on the oscilloscope and take a picture showing key quantities.
4. Measure the dc and ac components of the voltage across the load using DVM.

DC: 2.597V, AC: 1.622V

Questions:

- When the capacitor connected, what is the change on the waveform, why?
- Does the ripple voltage change with frequency?
- What is the effect of frequency on the ripple? When the input frequency is reduced, do you need a larger or a smaller capacitor to achieve the same ripple?

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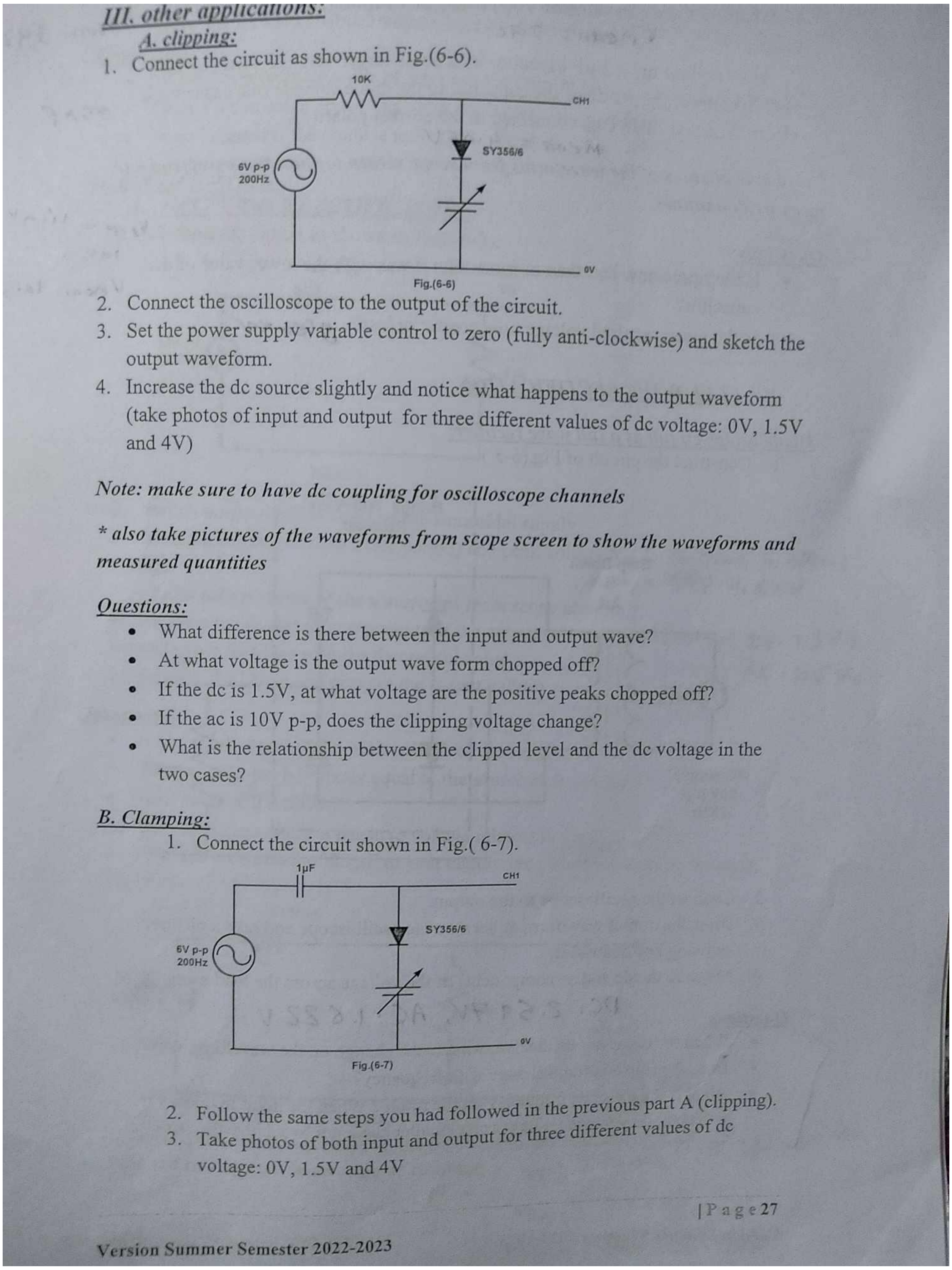
Figure 51 Lab paper 3

4.



III. other applications:

A. clipping:

1. Connect the circuit as shown in Fig.(6-6).

10K CH1 SY356/6 6V p-p 200Hz 0V

Fig.(6-6)

2. Connect the oscilloscope to the output of the circuit.
3. Set the power supply variable control to zero (fully anti-clockwise) and sketch the output waveform.
4. Increase the dc source slightly and notice what happens to the output waveform (take photos of input and output for three different values of dc voltage: 0V, 1.5V and 4V)

Note: make sure to have dc coupling for oscilloscope channels

** also take pictures of the waveforms from scope screen to show the waveforms and measured quantities*

Questions:

- What difference is there between the input and output wave?
- At what voltage is the output wave form chopped off?
- If the dc is 1.5V, at what voltage are the positive peaks chopped off?
- If the ac is 10V p-p, does the clipping voltage change?
- What is the relationship between the clipped level and the dc voltage in the two cases?

B. Clamping:

1. Connect the circuit shown in Fig.(6-7).

1µF CH1 SY356/6 6V p-p 200Hz 0V

Fig.(6-7)

2. Follow the same steps you had followed in the previous part A (clipping).
3. Take photos of both input and output for three different values of dc voltage: 0V, 1.5V and 4V

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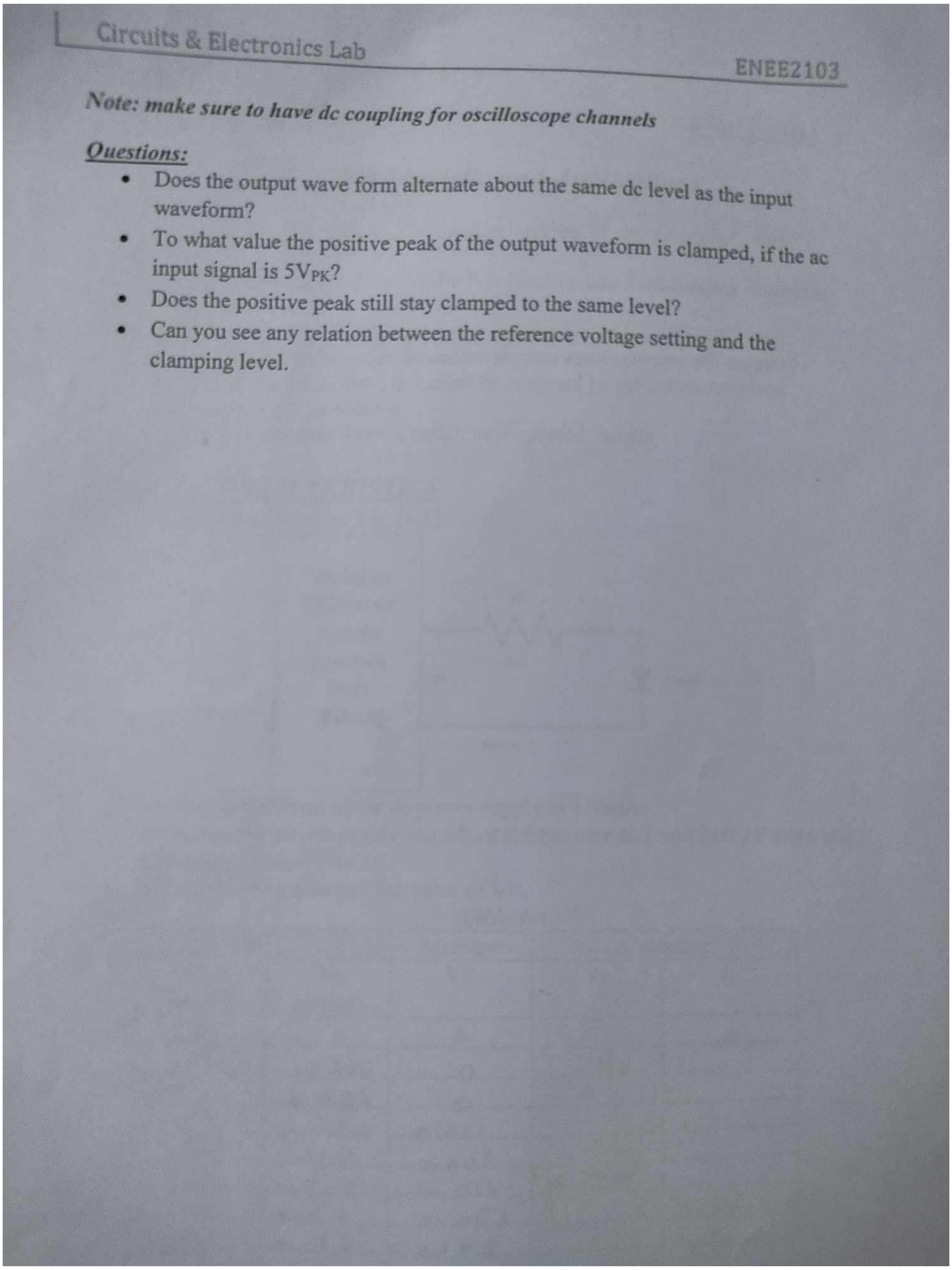
Figure 52 Lab paper 4

5.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Note: make sure to have dc coupling for oscilloscope channels

Questions:

- Does the output wave form alternate about the same dc level as the input waveform?
- To what value the positive peak of the output waveform is clamped, if the ac input signal is $5V_{PK}$?
- Does the positive peak still stay clamped to the same level?
- Can you see any relation between the reference voltage setting and the clamping level.

Figure 53 Lab paper 5