جامعة بيرزيت

BIRZEIT UNIVERSITY

Faculty of Engineering & Technology

Department of Electrical & Computer Engineering

ENEE2103-CIRCUITS AND ELECTRONICS LABORATORY

Report#2

Experiment#6: Diode Characteristic and Applications.

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Abstract

We'll study the PN junction in this experiment to understand how it functions and how voltage and current interact in a silicon diode. We'll use a DC power supply, resistors, diodes, a multimeter, a function generator, capacitors, and a Bridge Full Wave Rectifier IC. Our main objectives are to investigate the voltage-current characteristics and functioning of the PN junction, and to explore practical applications of these components in circuits for voltage multipliers, clamping and clipping circuits, and AC to DC conversion.

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Theory

Diode Characteristics

In addition to displaying non-linear behavior, the diode is a two terminal nonlinear device whose I-V characteristic depends on polarity. The diode is an extremely intriguing and helpful device, but its polarity and non-linear characteristics can complicate circuit design and analysis.

Figure 1 shows the basic circuit symbol for the diode. Unlike a resistor, which has two equivalent terminal leads, the diode's behavior is determined by the relative polarity of its terminals.[1]

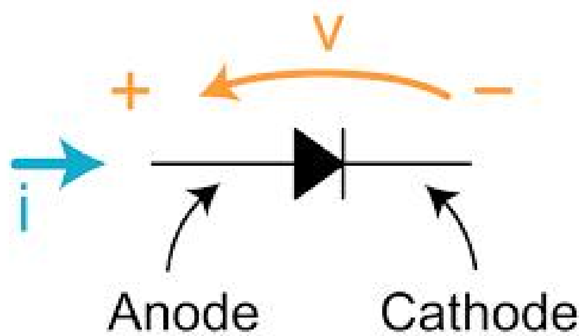

Figure 1:Diode circuit model[1]

Figure 1 shows how the voltage and current behave across the diode terminals.

Depending on the voltage Vd , the diode can be in one of two states:

- **Forward Biased** (Vd > 0): When the anode (positive side) is at a higher voltage than the cathode (negative side), current flows from the anode to the cathode. This is like a closed switch, allowing current to flow, and the relationship between current and voltage is nonlinear.[1]
- **Reverse Biased** (Vd < 0): When the anode is at a lower voltage than the cathode, the diode blocks the current, acting like an open switch. Only a tiny reverse current flows until the voltage hits a certain threshold (the breakdown voltage), at which point the current increases rapidly.[1]

Figure 2 shows the typical I-V characteristics of a diode, demonstrating these two regions. Diodes have two terminals, an anode and a cathode, and they allow current to flow in only one direction based on the applied voltage.[1]

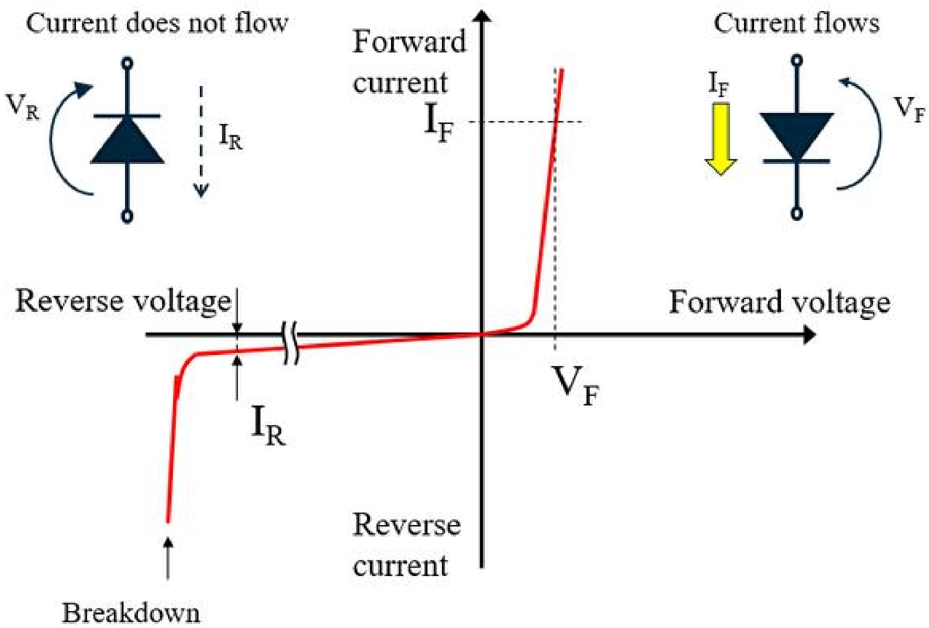

Figure 2: I-V characteristics of a silicon diode[1]

Reflection

Altering alternating current (AC) to direct current (DC) is the process of rectifying. This is required to power electronics, batteries, and motors—all of which need a steady, one-way flow of electricity. Diodes are used for this activity since they are one-way current valves. There are two main methods for rectification: half-wave and full-wave. In this post, we'll look closely at each strategy, weighing the advantages and disadvantages so you can see how they stack up.[2]

Half wave rectification

Half-wave rectification: This method allows only one half of the AC cycle—either the positive or negative part—to pass through using a single diode, while blocking the other half. This results in a pulsing DC signal with a low average value and noticeable ripples. These voltage fluctuations, or ripples, can affect the stability and performance of your device. To smooth out these ripples, you can add a capacitor to the circuit. The capacitor acts as a filter, charging and discharging with the changes in input voltage. Figure 3 shows how the half-wave rectification circuit is set up.[2]

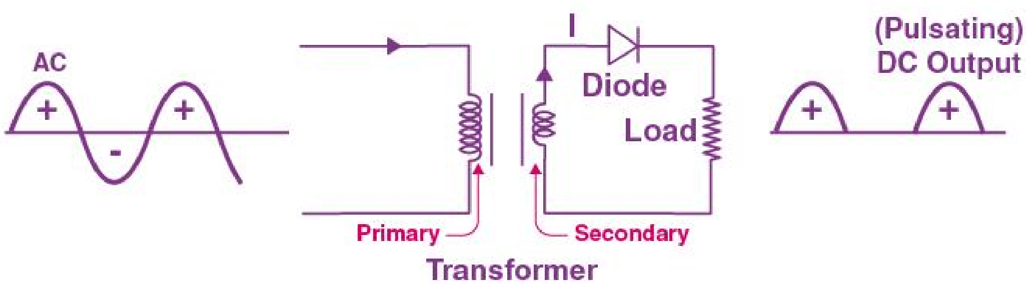

Figure 3:Half-wave rectification[2]

Full wave rectification

Full-wave rectification: In this technique, one of the positive and negative sides of the AC cycle is reversed by using four diodes to catch both of them. Consequently, as comparison to a half-wave rectifier, it generates a significantly smoother DC signal with fewer and smaller ripples. Although there are still some ripples, they are less noticeable and infrequent. Even more compensation for these waves can be obtained by including a capacitor in the circuit. Using the input voltage to charge and discharge, the capacitor functions as a filter. Figure 4 shows the full-wave rectification circuit.[2]

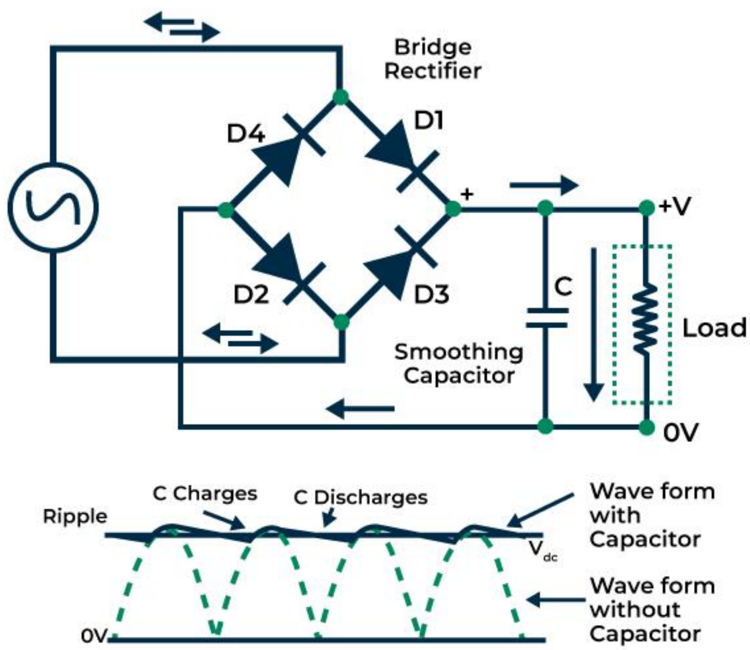

Figure 4:Full-wave rectification[2]

Other Applications

Clipping

A clipping circuit can trim part of an AC signal without altering the rest of the waveform. It's handy for shaping signals, protecting circuits from overvoltage, limiting voltage, and isolating specific parts of a signal for transmission.[3]

Figure 5 illustrates a positive series clipper, which removes the positive half-cycles of the input voltage. This circuit includes a diode and a resistor connected in series. When the input voltage is positive, the diode is reverse biased and acts like an open switch, cutting off the current and making the output voltage zero. When the input voltage is negative, the diode is forward biased, allowing current to flow and raising the output voltage.[3]

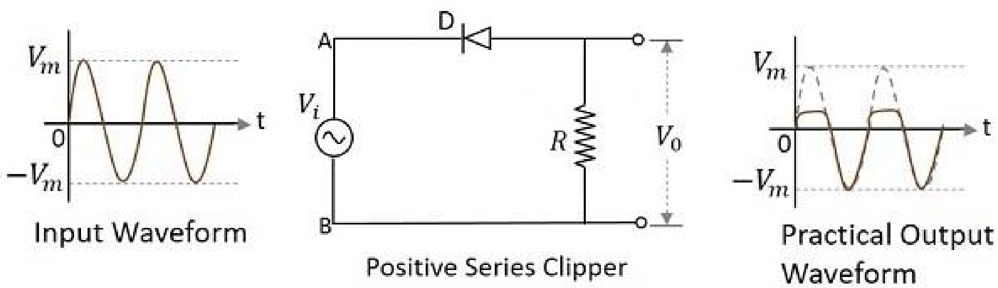

Figure 5:Series Positive Clipper[3]

A series negative clipper, which eliminates the negative portion of the AC signal, is depicted in Figure 6. It has a reverse-direction diode that, in the event that the input is negative, blocks current and sets the output to zero. The diode allows electricity to flow through it and sets the output equal to the input when the input is positive.[3]

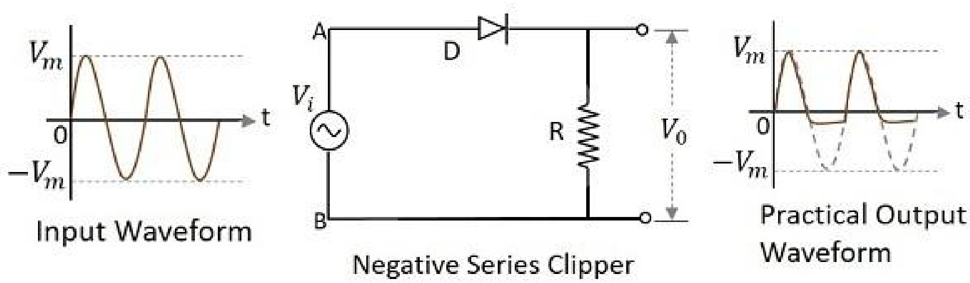

Figure 6: Series Negative Clipper[3]

Clamping

A clamping circuit shifts the DC level of a signal without altering its shape. It’s great for tasks like restoring, biasing, or modulating signals.[4]

A positive clamping circuit, which raises the signal from zero, is shown in Figure 7. A resistor, a capacitor, and a diode are parts of this circuit. The diode prevents current flow when the input is positive, mirroring the input and keeping the capacitor uncharged. The capacitor charges to the lowest input voltage when the input flips to negative, and the diode permits current to flow, setting the output to zero. The output is equal to the input voltage plus the charge held in the capacitor when the diode stops current once more during the subsequent positive cycle. The lowest input voltage raises the output as the capacitor gradually discharges through the resistor.[4]

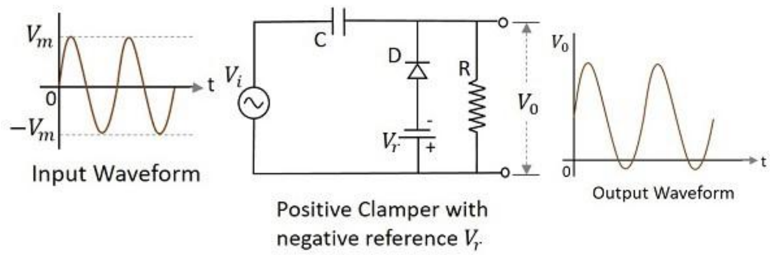

Figure 7:Positive Clamper[4]

A negative clamping circuit, as seen in Figure 8, shifts the signal below zero. With the diode switched, it functions similarly to the positive clamping circuit. The diode prevents current flow when the input is negative, mirroring the input and keeping the capacitor uncharged. The diode permits current to flow when the input becomes positive, which sets the output to zero and causes the capacitor to charge to the maximum input voltage. The output is the input voltage less the charge held in the capacitor during the subsequent negative cycle, which is caused by the diode blocking the current once more. As the capacitor gradually discharges through the resistor, the output shifts downward by the input voltage that is highest. [4]

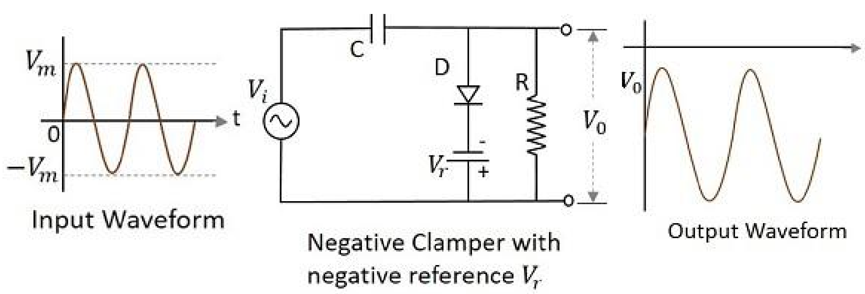

Figure 8:Negative Clamper[4]

Procedure & Calculations

Diode Characteristics

The connection of the circuit is shown below.

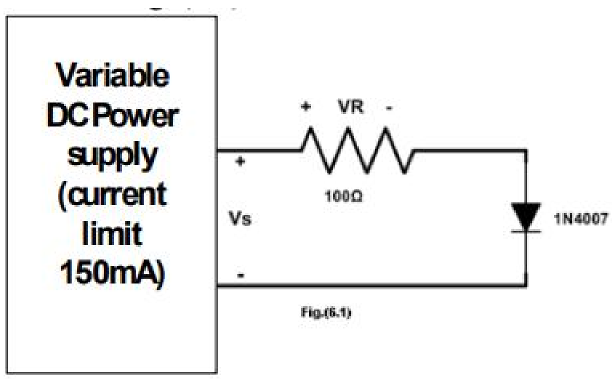

Figure 9:Diode Characteristic Lab Circuit

The DC power supply's current limit was established at 150mA. After turning on, the power supply was changed in 0.1V steps from zero to one volt, then in 0.5V steps from one volt to three volts. The following equations were used to measure the value of VR and compute the values of VD and ID:

$$V_D = V_S - V_R$$

$$I_D = \frac{V_R}{R}, \mathrm{R} = 100\Omega$$

SET		Measure	Calculate	
V_s (desired)	V_s (actual)	V_R	V_D	I_D
0	0.08	0	0.08	0
0.1	0.15	0	0.15	0
0.2	0.18	0	0.18	0
0.3	0.3	0	0.3	0
0.4	0.44	5.7m	0.4343	0.057m
0.5	0.523	37m	0.486	0.37m
0.6	0.604	60m	0.544	.6m
0.7	0.742	153m	0.589	1.53m
0.8	0.821	0.2	0.621	2m
0.9	0.9	0.26	0.64	2.6m
1.0	1.0	0.4	0.6	4m
1.5	1.5	0.8	0.7	8m
2	2	1.3	0.7	0.013
2.5	2.5	1.8	0.7	0.018
3	3.1	2.3	0.8	0.023

Table 1: Diode Characteristic

VD and ID were calculated using equations, and an Excel graph showing the diode's forward behavior was made. The experimental curve is shown in red on the graph.

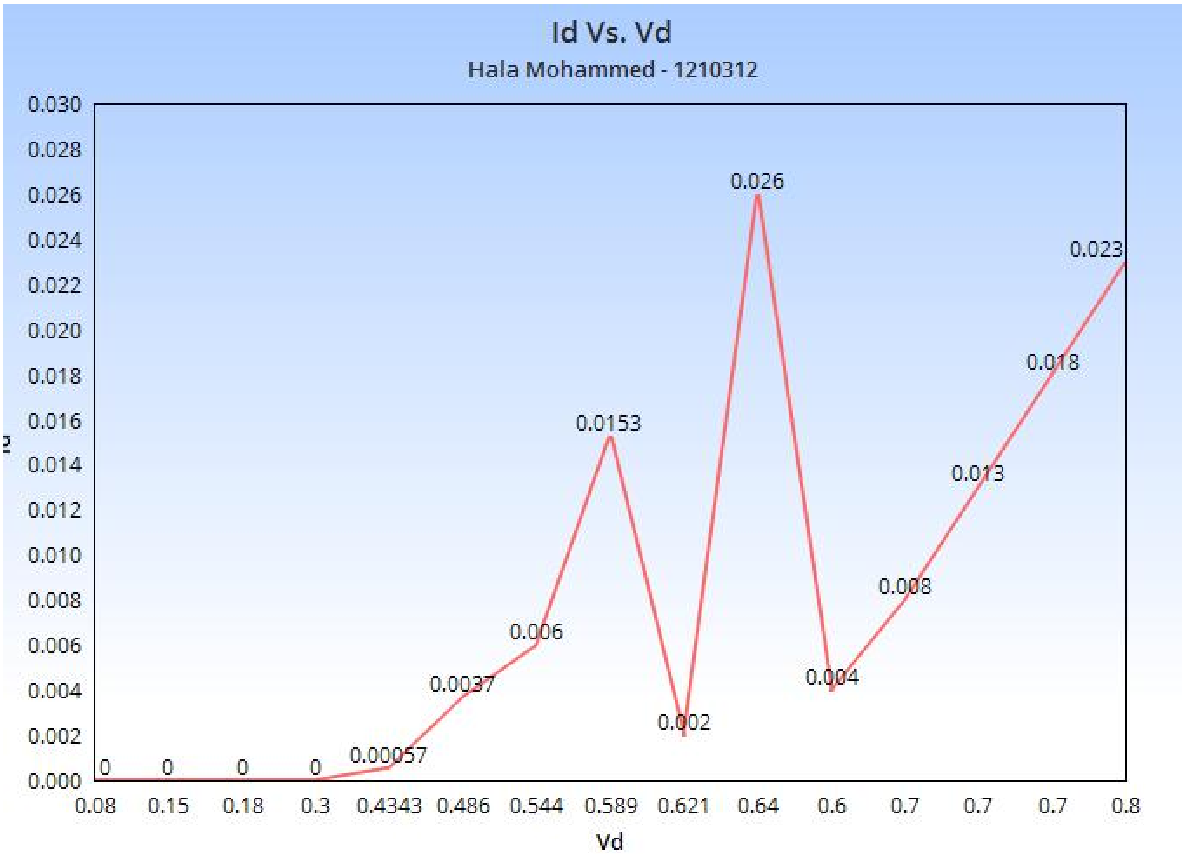

Figure 10:The forward characteristics

Some values contain an error maybe because Overloading in circuit

OR The value that I obtained from testing is definitely wrong.

Rectification

Half-Wave-Rectification

The circuit below was connected:

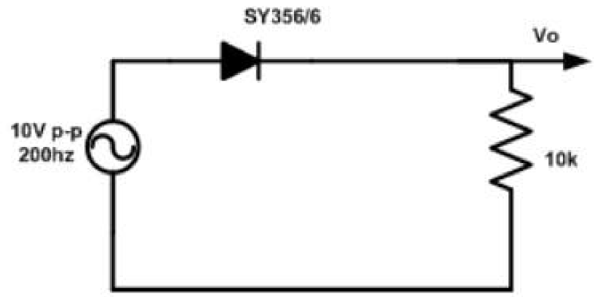

Figure 11:Half wave rectification Lab Circuit

The input and output voltages of the forward diode were measured by connecting the oscilloscope to the resistor terminals.
The waves that were produced are shown in figure 12 below. When the input voltage is positive, it is obvious that the output voltage follows it. But when the input voltage is negative, it decreases to zero. This observation reveals the behavior of the diode, which is to conduct only forward and to prevent current flowing in the opposite direction.

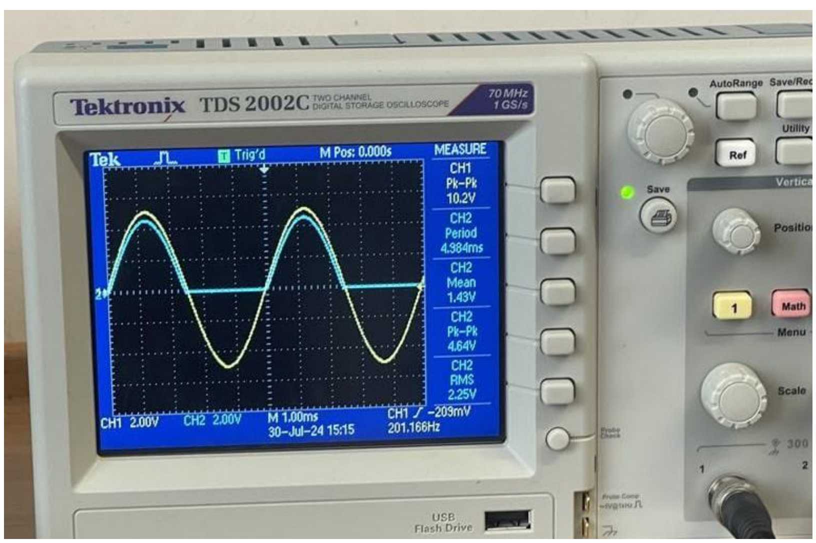

Figure 12:Forward Diode Input/Output Voltage waves

The following table displays the outcomes that were either calculated or obtained:

	T(period)	$\boldsymbol{V_p}$	$\boldsymbol{V_{dc}}$	$\boldsymbol{V_{ac}}$
Experimentally values	5ms	4.64v	1.4v	1.7v
Theoretically values	$\frac{1}{freq}$ =5ms	5v	$\frac{V_p}{\pi} = \frac{5}{\pi} = 1.59v$	not required

Table 2:the values exp and theo to Half-Wave-Rectification

Measurements of the peak voltages of the input source (Vin) and output waveform (Vp) showed a strong resemblance: Vp = 4.64V and Vin = 5 V. However, the voltage across the load (VL) is somewhat less than the input source's peak voltage because of the diode's small voltage drop when forward biased, which is = 0.7 V .

When the input voltage is negative, the output voltage follows it; when the input voltage is positive, it falls to zero. As a result, the DC component of the output voltage has a negative average value.

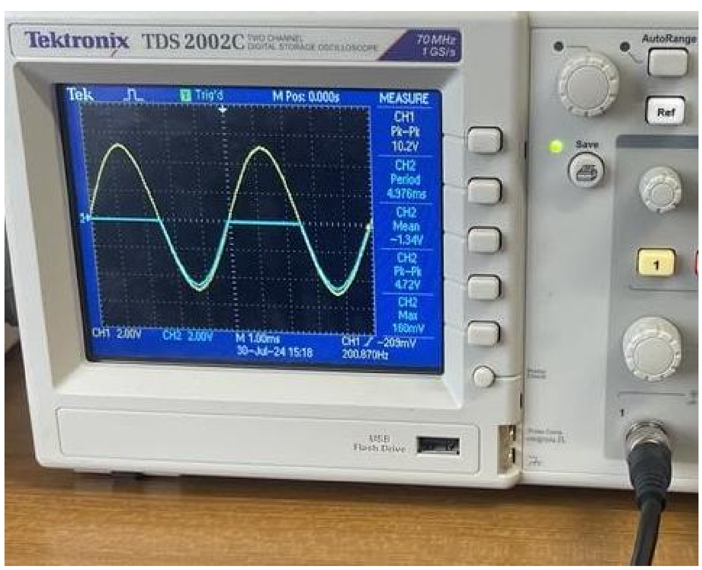

Figure 13:Half Wave Rectification with Reversed Diode

- The circuit was fitted with a 2.2uF capacitor.

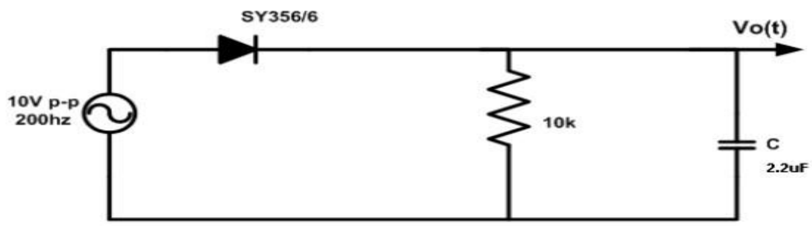

Figure 14:Half-wave rectifier with 2.2uF filter

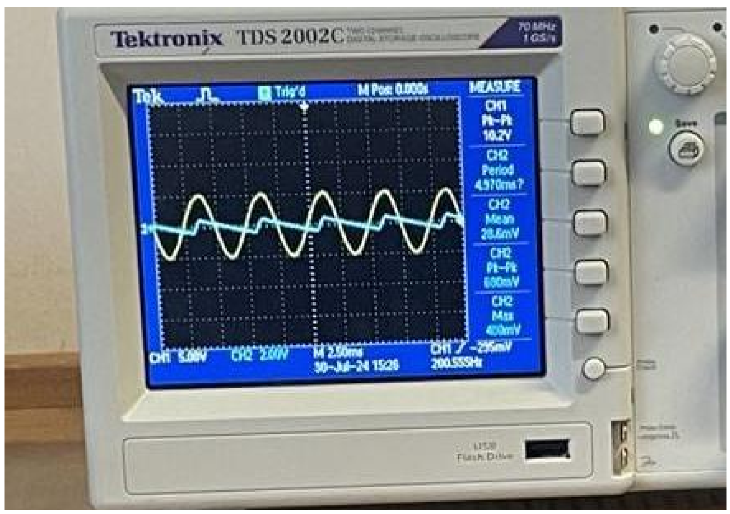

Figure 15:Half Wave Rectification Waveform with Capacitor 2.2uF

To calculate the ripple factor (r%) with the provided information, use the following formula:

$$r\% = VLr, RMS \,/\, Vdc$$

where VLr,RMS is the RMS value of the ripple voltage and Vdc is the average value of the output voltage.

Given the values:

Vm =4.3, R=10k, f=200Hz, C=2.2uF,

The expected ripple factor can be calculated using these parameters. :

	$V_{p-p}RMs$	RMS ripple	V_{dc}	r%
Experimentally values	880mv	241mv	4.04 mv	6.2%
Theoretically values	$\frac{V_m}{f*R*C} = 0.977v$	$\frac{V_{lr,p-p}}{2\sqrt{3}}$ =0.282 v	$V_m - 0.5 * V_{LR,RMS} = 4.15v$	6.8%

Table 3:The result exp and theo when we put a 2.2uF capacitor in the circuit

- The 2.2uF capacitor was replaced by a much larger value of 47uF..

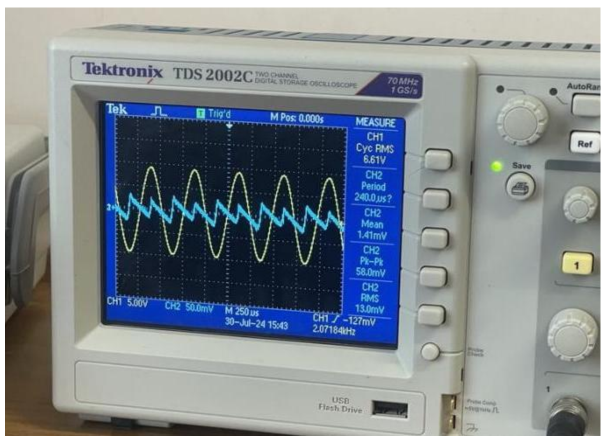

Figure 16:Half Wave Rectification Waveform with Capacitor 47uF

Using the provided data, the ripple factor (r%) can be determined as follows:

	$V_{p-p}RMs$	RMS ripple	V_{dc}	r%
Experimentally values	58.0mv	13.0mv	4.19	.399%
Theoretically values	$\frac{V_m}{f*R*C} = 0.046v$	$\frac{V_{lr,p-p}}{2\sqrt{3}} =$ 0.013v	$V_m - 0.5 * V_{LR,RMS} = 4.29v$	0.30%

Table 4:The result exp and theo when we put a 47uF capacitor in the circuit

Full-Wave-Rectification

In this section, we used a diode bridge circuit to convert the AC input into a DC output, as illustrated in figure 17.

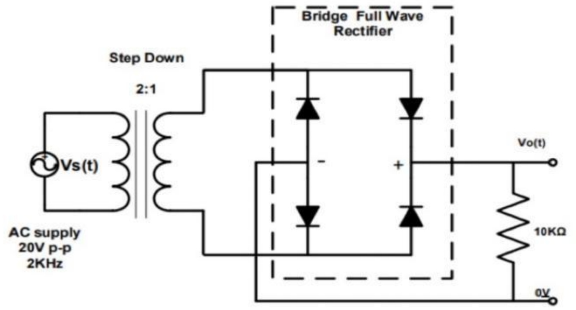

Figure 17:Full-Wave Rectifier circuit

We connected the oscilloscope to the output.

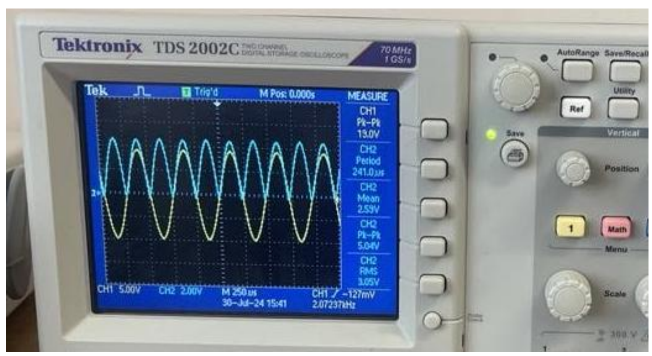

Figure 18:Full Wave Rectifier Waveform

The outcomes we were able to obtain or wish to compute are displayed in the following table:

	T(period)	V_{p-p}	RMS	V_{dc}	V_{ac}
Experimentally values	241us	19v	3.05v	2.6v	1.6v
Theoretically values	$\frac{1}{freq}$ =500us	17.2v	not required	$\frac{V_p}{\pi} = \frac{8.6}{\pi} = 2.73v$	not required

Table 5:The result value for exp and theo in the Full-Wave-Rectification

The values are close to the theoretically values.

Other Applications

Clipping

The circuit below was connected:

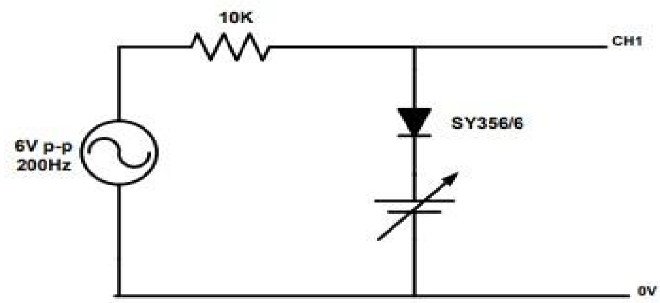

Figure 19:Clipping Circuit

Figures below show the output waveforms for each voltage and show how the waveform varies when the DC source is slightly increased while applying various voltages.

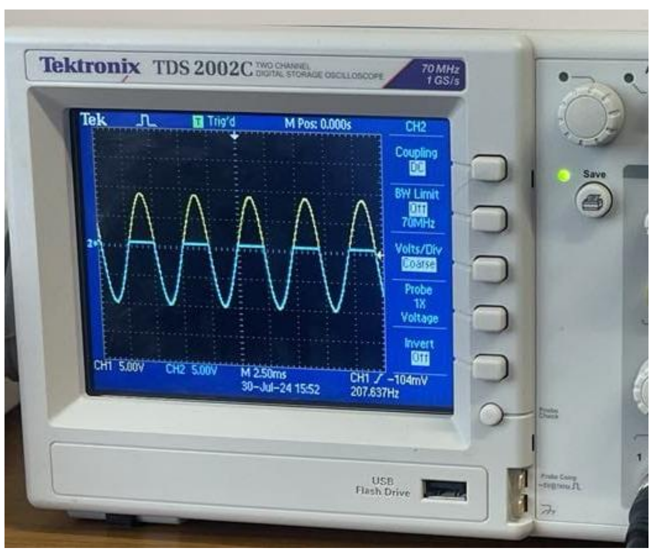

Figure 20:Clipping Circuit Waveform for 0 volt

The output voltage is equal to 0.7 when the diode is ON.

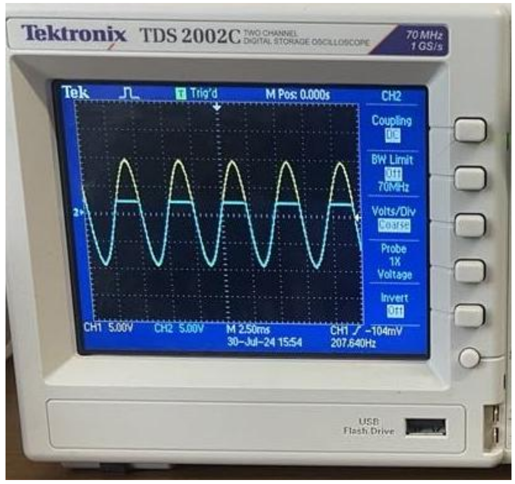

Figure 21:Clipping Circuit Waveform for 1.5 volt

The output voltage that results from adding 0.7V to the 1.5V input voltage when the diode is turned on is shown in the above figure.

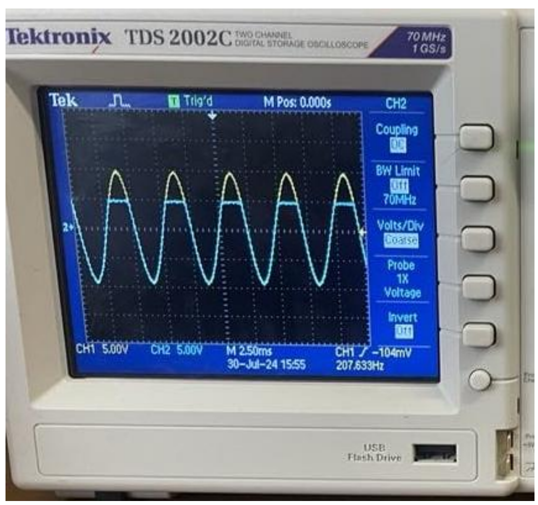

Figure 22:Clipping Circuit Waveform for 4 volt

The dc voltage of 4v is higher than the peak voltage of 3v. The clipping level, which should be 0.7 less than the dc voltage, is determined by the dc voltage.

Clamping

The circuit below was connected:

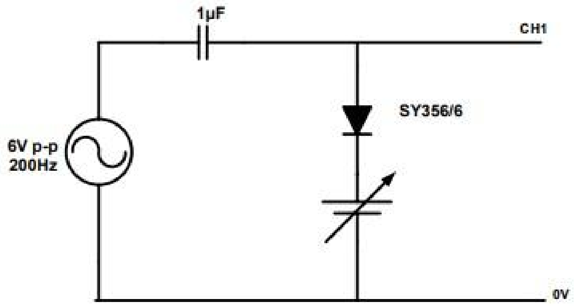

Figure 23:Clamping Circuit

The process was repeated in order to observe the output wave, and the results are shown in the figures below.

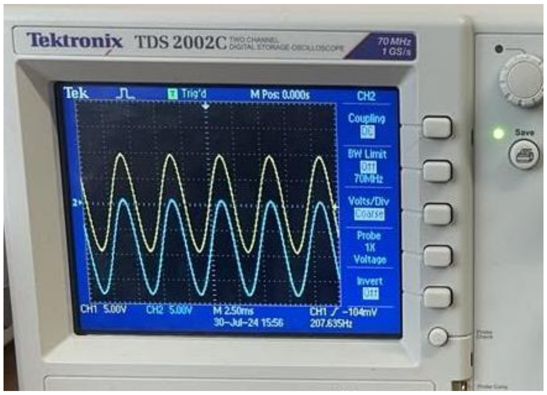

Figure 24:Clipping Circuit Waveform for 0 volt

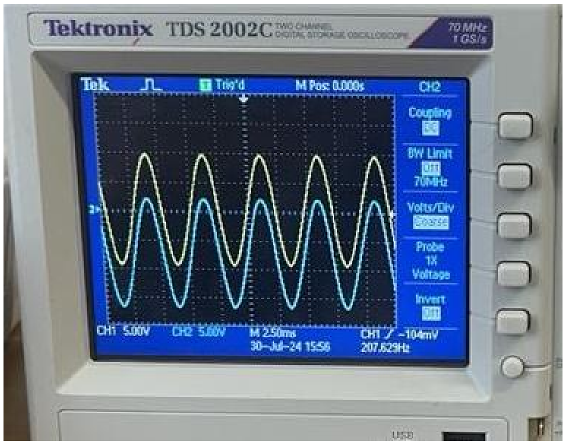

Figure 25:Clipping Circuit Waveform for 1.5 volt

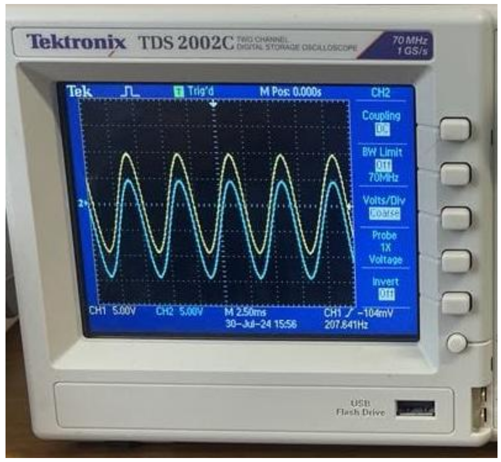

Figure 26:Clipping Circuit Waveform for 4 volt

The output waveform doesn't alternate around the same DC level as the input; it was shifted. However, the positive peak remains clamped at the same level. The clamping level is related to the reference voltage setting and can be expressed as Clamping Level = Vi ± Vc.

Conclusion

In conclusion, our study focused on the I-V characteristics and the forward and reverse bias functions of diodes. Diodes are essential for rectification, allowing current to flow in only one direction. We examined their applications in full- and half-wave rectifiers, which convert AC to DC and regulate voltage levels, as well as in clampers and clippers. The experiment demonstrated how filters, capacitors, and load resistors work to smooth waveforms, and it also illustrated the workings of clamping, clipping, and voltage multiplier circuits.

References

[1] https://ocw.mit.edu/courses/6-071j-introduction-to-electronics-signals-and-measurement-spring-2006/resources/17_diodes1/

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[2] Diode As A Rectifier - Half Wave Rectifier & Full Wave Rectifier (byjus.com)

[Accessed 2/8/2024 ,7:00PM]

[3] Diode Clipping Circuits and Diode Clipper (electronics-tutorials.ws)

[Accessed 2/8/2024 , 7:54PM]

[4] What is Clamper Circuit? Types, Working and Applications (electricaltechnology.org)

[Accessed 2/8/2024 , 8:30PM]

[5] lab manual

[Accessed 2/8/2024 , 6:15PM]

Appendix

هالا محمد
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أحمد حمر

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:

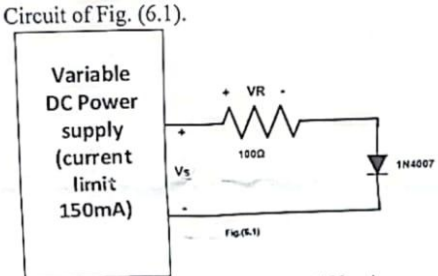
1. Simulate the circuits in the procedure section and determine the required values (set the parameters that must be assigned by the instructor in the procedure to proper values).
2. Verify if Simulation Results match the expected results

Procedure:

I. DIODE CHARACTERISTICS

30/7
11:00

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	
V_S (desired)	V_S (actual)	VR	V_D	I_D
0	0.08	~~0.02m~~ 0		
0.1	0.15	0		
0.2	0.18	~~20m~~ 0		
0.3	0.3	0		
0.4	0.44	5.7m		
0.5	0.523	37m		
0.6	0.604	60m		
0.7	0.742	153m		
0.8	0.821	0.2		
0.9	0.9	0.26		
1.0	1.0	0.4		
1.5	1.5	0.8		
2	2	1.3		

2.5	2.5	1.8		
3	3.1	2.3		

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?

II. RECTIFICATION.

A. *HALF - WAVE RECTIFICATION.*

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

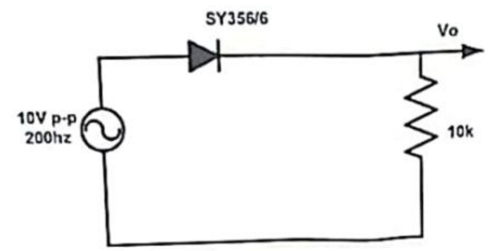


Fig.(6-3)

2. Switch on the oscilloscope and the sinusoidal supply. T= 5ms Vpk=4.64v
3. Measure and record time T (the period) and peak voltage V_{pk} for the output voltage *(also take pictures of the waveforms from scope screen)*
4. Measure the dc and ac components of the output voltage using DVM (fill the results in Table 6.2)
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).

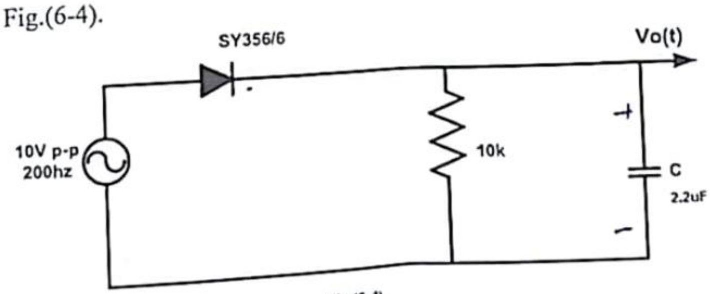


Fig.(6-4)

7. Observe the output waveform on the **oscilloscope** and measure peak-to-peak ripple and rms ripple voltage **using ac coupling on the oscillocope**.(take pictures from oscilloscope screen) 880 mv rms ≈ 241 mv

8. Use the oscilloscope **(with channel dc coupling)** to measure the mean value of Vo(t). 4.89v

9. Measure the dc and ac components of the output voltage using DVM (fill in results in Table 6.2)

10. 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).

11. Repeat step 9

Table 6.2

Quantity	Without capacitor	With capacitor 2.2uF	With capacitor 47uF
Vo –dc	1.4	4.04	4.19
Vo -ac	1.7	0.23	0.012
Calculate ripple factor r%	Not required		

12. Compare results obtained from theoretical calculations with practical results.

Questions:

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

B. FULL-WAVE RECTIFICATION

Diode bridge circuit as a full wave rectifier:

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

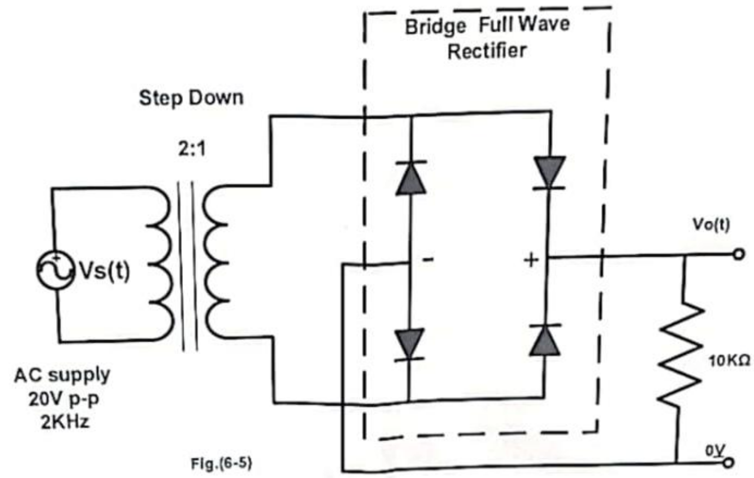


Fig.(6-5)

2. Connect the oscilloscope to the output.
3. Draw the output waveform as seen on the oscilloscope and take a picture showing key quantities. 3.
4. Measure the **dc** (average) and **ac** (rms ripple) components of the voltage across the load using DMM. *fill in the results in table 6.3
5. Now add a capacitor of 2.2μF to your circuit, and observe the output on the oscilloscope and repeat step 4 above

Table 6.3

Quantity	Without capacitor	With 2.2uF Capacitor
Vo – dc	2.6	4.3
Vo - ac	1.6	13u
Calculate r%	Not required	

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?

III. Other applications:

A. clipping:

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

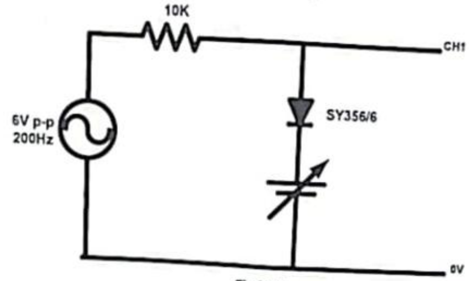


Fig.(6-6)

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

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).

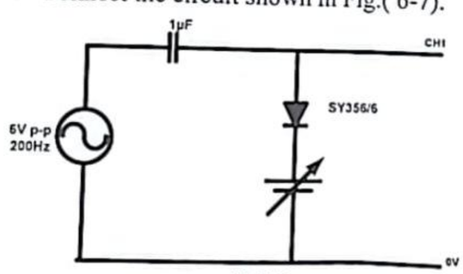


Fig.(6-7)

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

Note: make sure to have dc coupling for oscilloscope channels