EEE109 Lab 1 – Diodes

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Abstract

① Purpose of this experiment: This experiment intends to help student understand the working principle of the rectification, smoothed rectifier, limiter/clipper, voltage clamper, diode logic, Zener stabilizer and Light-emitting diodes. ② Experimental procedures: Firstly, construct the indicated circuit. Secondly, choose the right experimental equipment. Thirdly, record the results and do certain analyses. ③ Conclusions: The applications of diodes can realize the functions: rectify (smoothly), limit/clip the voltage, realize logic judgement, fix the voltage, LED on (lighting)/off(not lighting).

Introduction

The diode is wildly applied in the industry, this experiment intends to help students to understand the basic usage of diode in certain application. This experiment requires students to acquire how to construct the appointed circuit and use figures or tables to test the result of the circuit. This experiment contains 7 applications of the diodes, they are rectification, smoothed rectifier, limiter/clipper, voltage clamper, diode logic, Zener stabilizer and Light-emitting diodes. In each part of the application, the function of the applications of diodes will be introduced firstly, then certain steps of construction will be described. After obtaining the outcome of test which is closed to the exception, the graph of the outcome will be provided. Lastly, certain analyses will be also provided. In addition, corresponding conclusions will be drawn subsequently. This report below will be constructed by sections of Experimental Procedure and Conclusions.

Experimental Procedure

a) Rectification

The rectifier circuit is one of the applications of diodes. Due to diodes have the function that it can only allow the current to go through in one direction, this application of the diode can be used as the rectification.

For this task, the first step was to construct the figure shown in Figure 1. Then we set the input signal V_{AE} which is sine-wave equals to 10 volt p-p and frequency f equals to 10 KHz. In addition, we chose R_L which was 10 KΩ as the load resistor. We used the oscilloscope to connect AE to CH1 and BE to CH2. Consequently, we took the picture of the graphs on the oscilloscope and the results are shown in Figure 2 Figure 3. The next step was to set the input signal V_{AE} to 2 volts p-p, then repeated the steps above. Similarly, we obtained another group of graphs and they are shown in Figure 3 and Figure 4. For this task, the yellow line represents the input voltage and the blue line represents the voltage on the R_L.

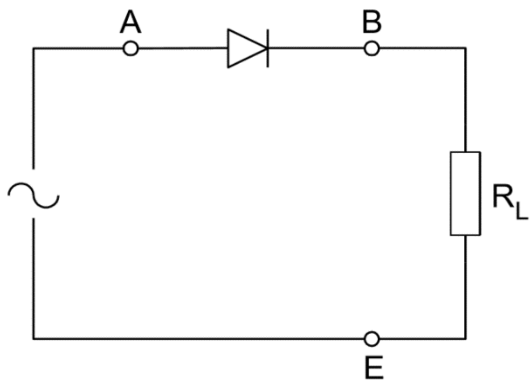


Figure 1: The circuit of the rectification

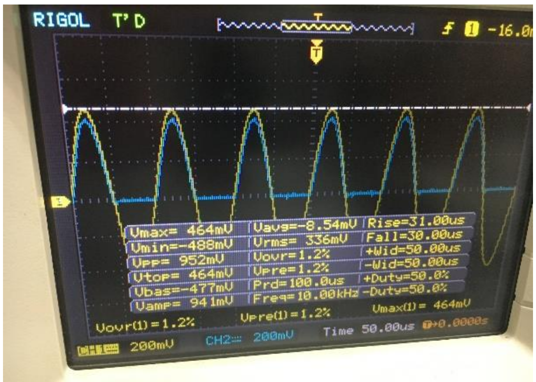


Figure 2: When V_{AE} = 10 volt p-p

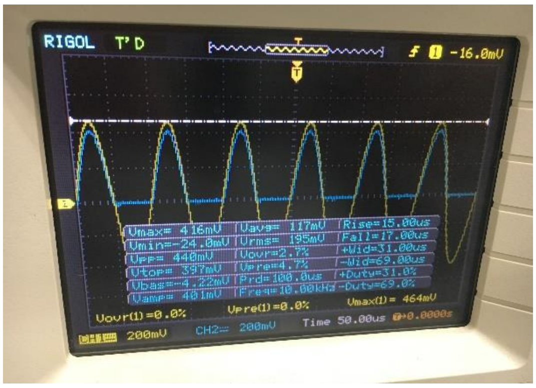


Figure 3: When V_{AE} = 10 volt p-p

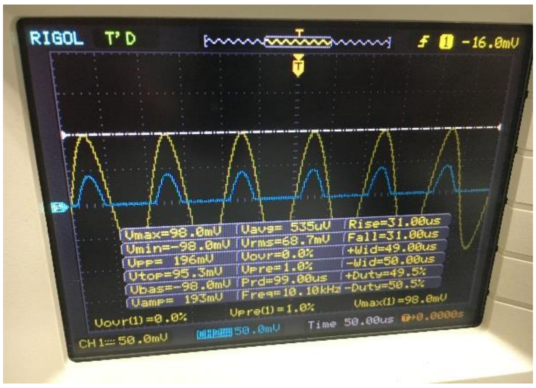


Figure 4: When V_{AE} = 2 volt p-p

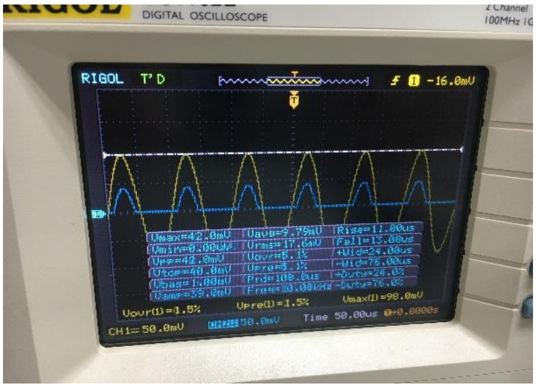


Figure 5: When V_{AE} = 2 volt p-p

Input voltage	V_{AE}		V_{BE}	
	Max	Min	Max	Min
10 volt p-p	5.03V	-5.03V	4.60V	-71.0mV
2 volt p-p	1.18V	-1.18V	0.47V	-71.0mV

Table 1

After the experiment, we needed to analyze why these two figures were different and the characteristic of these two figures. As for the Table 1, we can observe that the maximum of V_{BE} is 4.60 V and the maximum of V_{AE} is 5.03 V. Then, the minimum of V_{BE} is -71.0 mV and the minimum of V_{AE} is -5.03 V. The reason for why V_{BE} is less than V_{AE} is because the diode has turn-on voltage, which means some voltages will be distributed on the diode. To obtain more accurate conclusion, we need to study another group of the data. From Table 1, we can find that the maximum of V_{BE} is 0.47 mV and the maximum of V_{AE} is 1.18 V. Furthermore, the minimum of V_{BE} is -71.0 mV and the minimum of V_{AE} is -1.18 V. Due to the two different input signals for the circuit, Figure 3 and Figure 4 is different. Similarly, it is can be seen that V_{BE} is 0.47 V which is approximately 0.5 V less than the maximum of V_{AE}. However, the basic principle did not change, because the difference between V_{BE} and V_{AE} is 0.5 V which can be regarded as the turn-on voltage of the diode. In conclusion, this task validated that diodes have characteristic of unilateral conductivity and turn-on voltage, which is suitable to be used to convert AC signals into DC.

b) Smoothed rectifier

The next experiment is about smoothed rectifier. Although the circuit of Figure 1 could limit the direction of the current, output could not be as steady as DC. Therefore, the circuit of smoothed rectifier aims to output steady DC.

To complete this task, firstly we needed to choose the capacitor which was 100 nF and the selected diode to construct the circuit as shown in Figure 6. The next step was to set the input signal V_{AE} to 10 volts p-p and frequency f equals to 10 KHz. As for the first-time test, we chose 10 KΩ R_L as the load resistor. After conducting the circuit, we recorded the results, which are shown in Figure 7 and Figure 8. Subsequently, we chose 1 KΩ R_L as the load resistor and repeated the steps above, whose results can be seen in Figure 9 and Figure 10. For this task, the yellow line represents the input voltage and the blue line represents the voltage on the R_L.

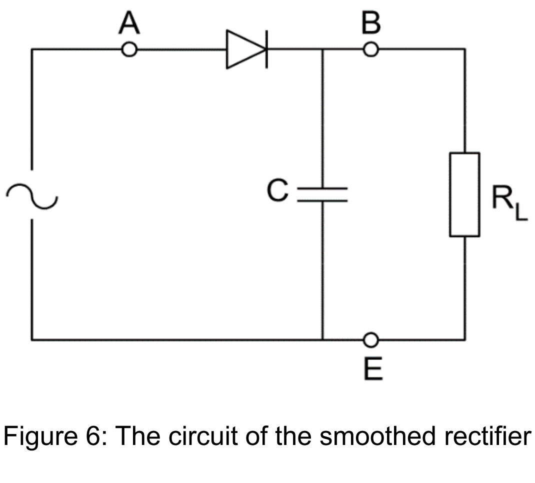


Figure 6: The circuit of the smoothed rectifier

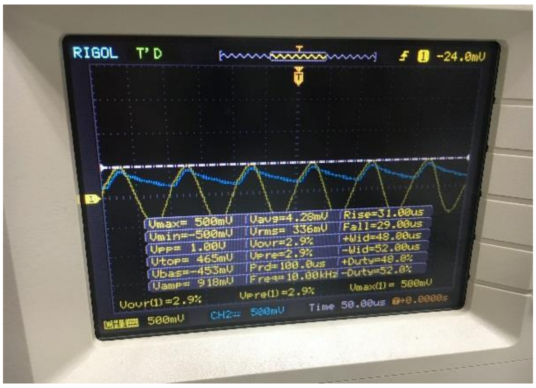


Figure 7: When R_L = 1kΩ

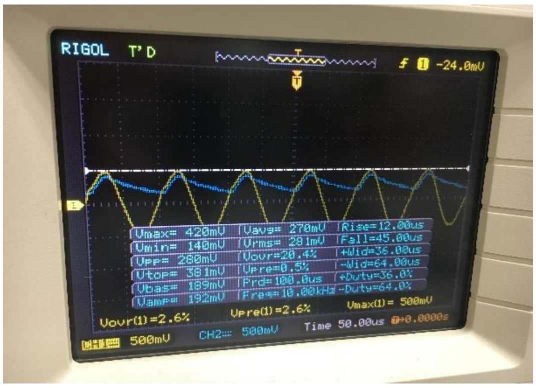


Figure 8: When R_L = 1kΩ

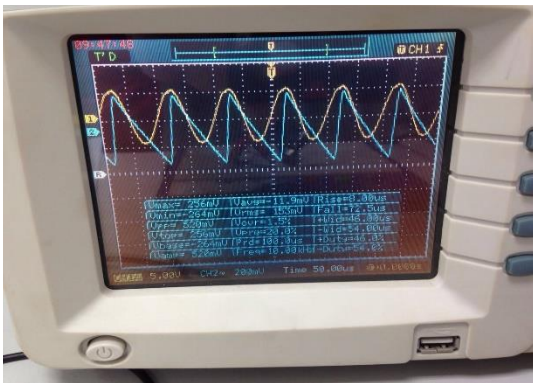


Figure 9: When R_L =10kΩ

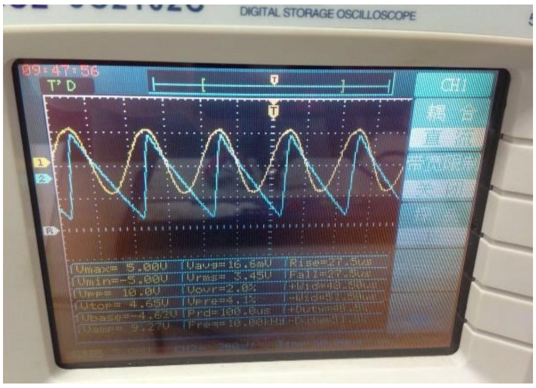


Figure 10: When R_L =10kΩ

From two groups of pictures, we could observe that they are quite similar. However, the main difference is the individual shape of the figure for V_{BE}. The only variable in this task was R_L, thus it could be concluded that the value of R_L might change the result. More specifically, the rate of discharge varies with the change of the value of R_L. At the period of the first quarter of the input signal, the capacitor was changed because the diode allowed current through it. Then the input voltage started to decrease to zero when it reached to the period of the second quarter of the input signal. The input voltage was less than the voltage of the capacitor. Consequently, the capacitor began to provide charge for the circuit. Therefore, the basic shape of the V_{BE} was drawn.

c) Limiter/Clipper

A limiter can slash the output waveform of the top or bottom of the interference. This application could be used to protect specific components in the circuit from the overcurrent. This task intends to imitate and validate the function of this circuit.

This task is mainly divided into three parts. Firstly, we set the input voltage to 10 volts p-p and frequency f equals to 10 KHz. In addition, we chose 1 KΩ R_L as the resistor. For the first part, we set V_{DC} to 0 V. Then we construct the circuit as shown in Figure 11. After operating on the circuit, we recoded the results and they are indicated in Figure 12 and Figure 13. The next part was to set V_{DC} to +3 V. To add 3 V V_{DC}, we needed to connect positive pole of the V_{DC} input to the cathode of the diode and connect the cathode of the V_{DC} input to the AC input. Similarly, we next need to repeat the steps above. The results of the second part can be seen in Figure 14 and Figure 15. As for the third part, we needed to reverse the diode connection. Then we recorded down the results of the third part and they are shown in Figure 16.

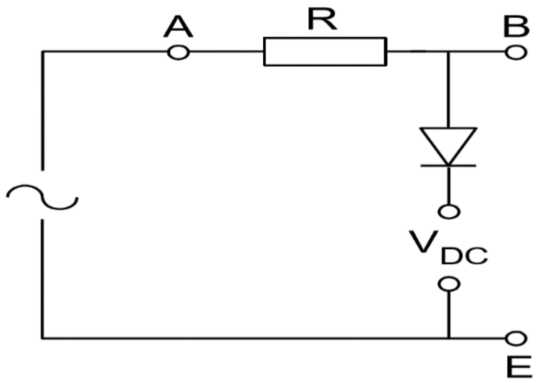


Figure 11: The circuit of the limiter

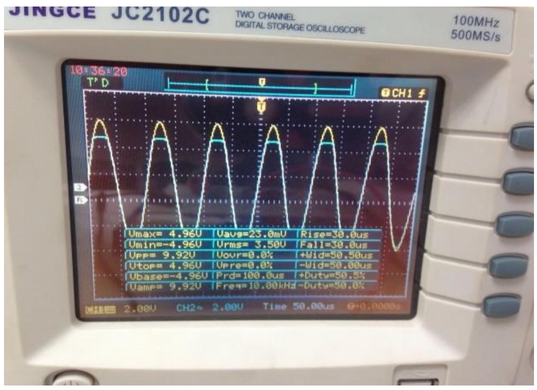


Figure 12: When V_{DC} = 0

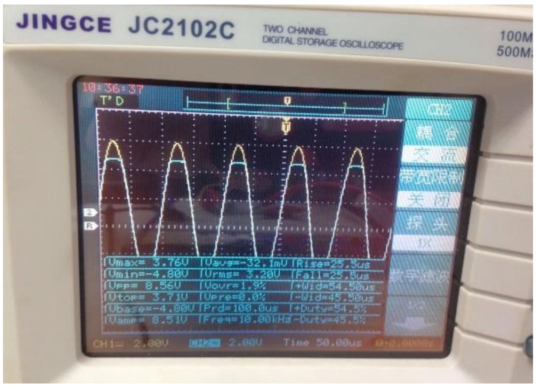


Figure 13: When V_{DC} = 0

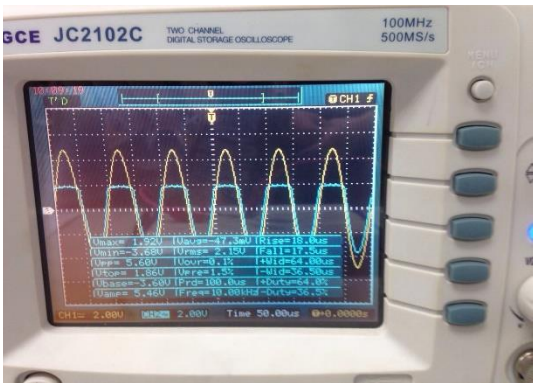


Figure 14: When V_{DC} = 3 volts

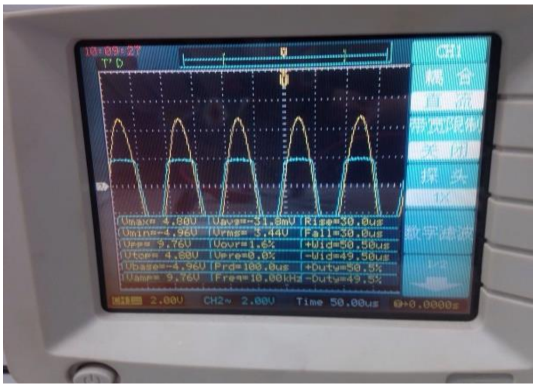


Figure 15: When V_{DC} = 3 volts

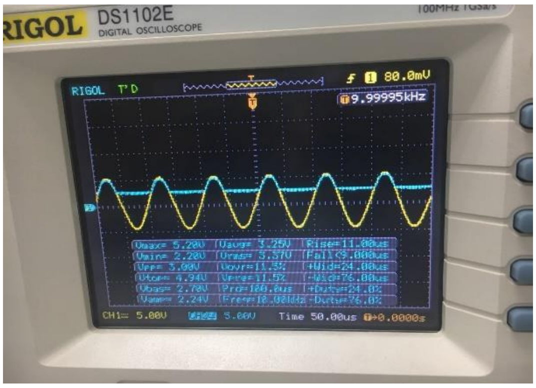


Figure 16: When the diode was reverse biasing

By three parts of this task, we could observe how did this circuit work. For the first part, V_{DC} was not added at the cathode, thus the measured value of V_{BE} was approximately 0.7 V higher than the cathode potential. Subsequently, it could be concluded that the first part of the task was a success. For the second part, there was a V_{DC} which was 3 V added at the cathode. From the Figure 13, we can find that the maximum of V_{BE} was about 3.7 V and the minimum of V_{BE} was about 1.44 V. The reason why the maximum of V_{BE} was 3.7 V was because that the turn-on voltage of the diode is about 0.7 V and V_{AE} was larger than the sum of turn-on voltage of the diode and V_{DC}, thus the diode was conductive, then V_{BE} was equal to the sum of turn-on voltage of the diode and V_{DC}. For the third part, due to the diode was reserved, the condition was totally different that the condition of previous two parts. At beginning, the diode was not conductive, and V_{DC} could supply 3 V to V_{BE}. Subsequently, the value of V_{BE} was the difference of turn-on voltage of the diode and V_{DC}. Then the direction of V_{AE} started reserving. From the Figure 12 and Figure 13, we can observe that V_{BE} began to increase and reach to the maximum of V_{AE}. Due to the outcomes of tests which were closed to the exception, we could conclude that this task is quite successfully.

d) Voltage clamper

The application of clamp circuit can make the whole signal voltage shift to a DC level. When the circuit is steady, the shape of the output waveform is totally the same as the shape of the input waveform. Therefore, the clamp circuits are widely in display devices to solve the problem of the image floating on the screen.

This task was mainly divided into two parts. For the first part, we set the input voltage signal to 10 volts p-p and the frequency f to 10 kHz. In addition, we selected the 1N4148 diode. Then we need to construct the circuit as shown in Figure 17. The next step was to record the result of and they are indicated in Figure 18 and Figure 19. For the second part, we just needed to reserve the diode and record the result and it can be seen in Figure 20 and Figure 21.

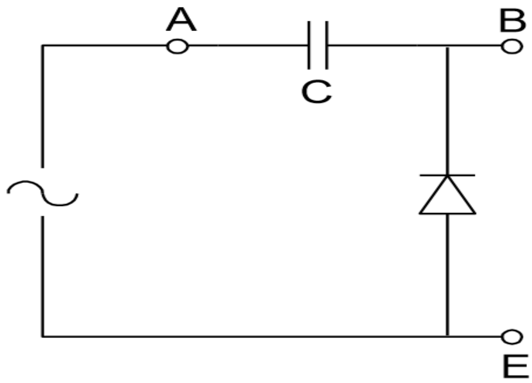


Figure 17: The circuit of the voltage clamper

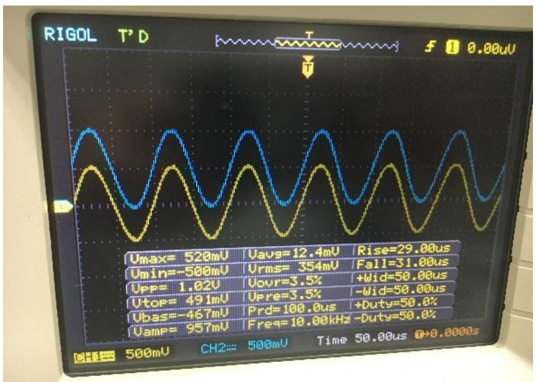


Figure 18: When the diode terminals forward bias

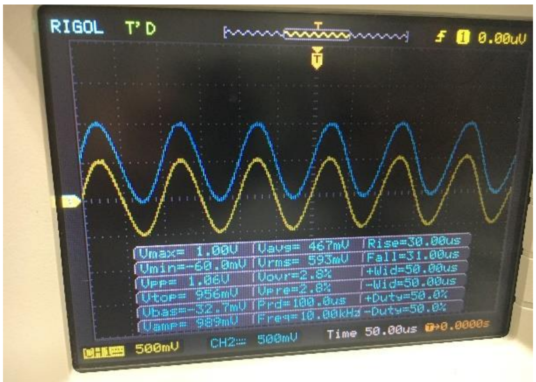


Figure 19: When the diode terminals forward bias

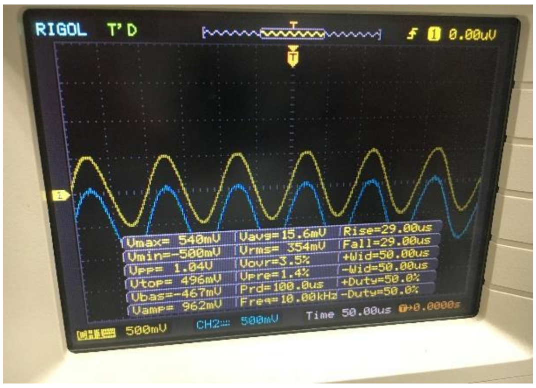


Figure 20: When the diode terminals reversed

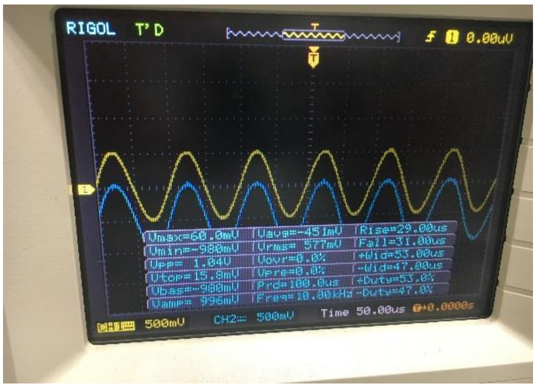


Figure 21: When the diode terminals reversed

From the two figures, we can observe that the shape of V_{AE} was totally the same as the shape of V_{BE}, which is consistent with the exception. At beginning, the voltage increased from 0 V to the maximum of the maximum of the input voltage V_{AE}, thus the first quarter of input signal represented that the input voltage was charging the capacitor. In the second quarter of the input signal, the direction of the input voltage started to reverse, and then voltage on the capacitor was still V_m, then the figure of V_{BE} would shift a maximum of V_{AE} level which could be observed in Figure 18. In the third quarter of the input signal, the capacitor still did not change, however, the direction of the input voltage reversed again, then the voltage on the capacitor and V_{AE} counteracted with each other, therefore V_{BE} was equal to 0 V. In the fourth of quarter of input signal, the input voltage increased from the minimum value to 0 V. Due to the voltage on the capacitor would not change, finally the shape of V_{BE} could be drawn. In brief, this process could be described via using a formula which is:

$$V_{BE} = V_m(1 + \sin\omega t) \qquad (1)$$

For task b, whose process was very similar to the process of task a, it could be described by this formula:

$$V_{BE} = V_m(\sin\omega t - 1) \qquad (2)$$

Through this experiment, we know how does the clamp circuit work. Furthermore, the direction of the diode might cause the position the waveform.

e) Diode logic

The next application of the diode is about the diode logic. This experiment mainly introduces the “and” gate which means if two conditions is true, then the whole condition is true; if one of the conditions is false, then the whole condition is false. In this experiment, the high voltage represented logic 1 which was true, and low voltage represented logic 0 which was false.

For completing this experiment, we should construct the circuit as shown in Figure 22. This experiment needed to use V_{DC} which was 5 V as the DC power supply. The first step was to add 5 V on the cathode of two diodes, then we used the multimeter to measure V_{BE}. The second step was to only add 5 V on the second diode, then we used the multimeter to measure V_{BE}. The next step was to only add 5 V on the first diode, then we used the multimeter to measure V_{BE} again. For the finally step, we removed the 5 V power supply from both diodes, then used the multimeter measure V_{BE}. The results of this experiment could be arranged into a table which is indicated in Table 2.

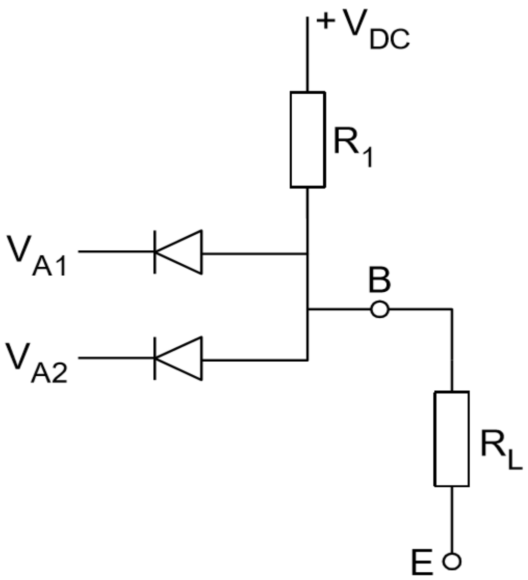


Figure 22: The circuit of the diode logic

V_{A1}	V_{A2}	V_{BE}
5 volts	5 volts	4.530 volts
0 volts	5 volts	0.627 volts

5 volts	0 volts	0.617 volts
0 volts	0 volts	0.610 volts

Table 2

V_{A1}	V_{A2}	V_{BE}
High	High	High
Low	High	Low
High	Low	Low
Low	Low	Low

Table 3

From Table 1, we can find that the result of this experiment was correspond to the expectation. Below are certain analyses for this circuit. For the first part, V_{A1}, V_{A2} and V_{DC} were all equal to 5V, thus diodes were all off and there was no current going through two diodes. Subsequently, the whole V_{DC} would be diffused on V_{BE}. Due to the experimental error, it was allowed that the measured V_{BE} could be less than V_{DC}. For the second and the third step, they had the same analysis. Due to these two diodes were parallel and only one diode was conductive, the current was allowed to go through the diode which was on, therefore there was no current going through R_L. For the final step, these two diodes were both on, similarly, the current could go through these two diodes and R_L would not have current, then V_{BE} was approximately equal to 0.7 V. For the second, third and final step, measured V_{BE} were all closed to 0.7 V, because R_L and two diodes were parallel. Therefore, the measured voltage was the turn-on voltage of the diode. In conclusion, the whole result could be also represented by Table 3.

f) Zener Stabilizer

Zener diode uses the reserving breakdown state of the PN junction to realize the function of fixing a stable voltage with the current changes in a large range, which makes the diode form the stabilizing effect. This experiment intends to modify and test the application of Zener diode.

The procedure is mainly divided into two parts. For the first part, we firstly construct the circuit as shown in Figure 23 and we open circuit R_L. Then we varied V_{DC} from 0 volt to 20 volts in 2-volt steps, in every adjustment of V_{DC}, we measured V_{BE} and V_{AE}. The final step was to arrange the result into a table which can be indicated in Table 4. For the second part, we set V_{DC} to 20 volts and measured V_{BE} on the R_L which was equal to 3.3kΩ, 1.5kΩ, 1kΩ and 820Ω successively, then we calculated I_L in each case. The formula to calculate I_L is:

$$I_L = V_B/R_L \tag{3}$$

Subsequently, we could arrange the data into the table as it could be referred in Table 5.

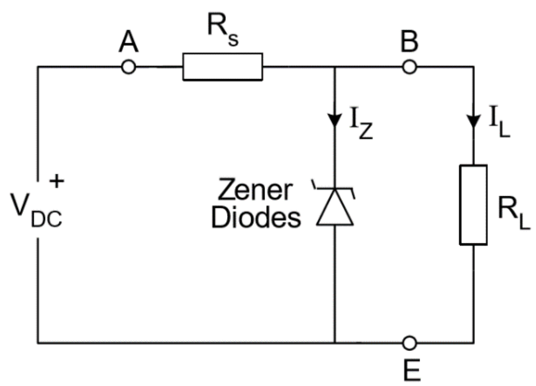


Figure 23: The circuit of the Zener stabilizer

V_{AE}	V_B	V_{DC}
0.104	0.2	0
2.101	2.021	2
4.072	4.071	4
6.03	5.997	6
8.14	8.011	8
10.03	9.737	10
12.07	9.811	12
14.11	9.875	14
16.15	9.925	16
18.34	9.964	18
20.02	10.008	20

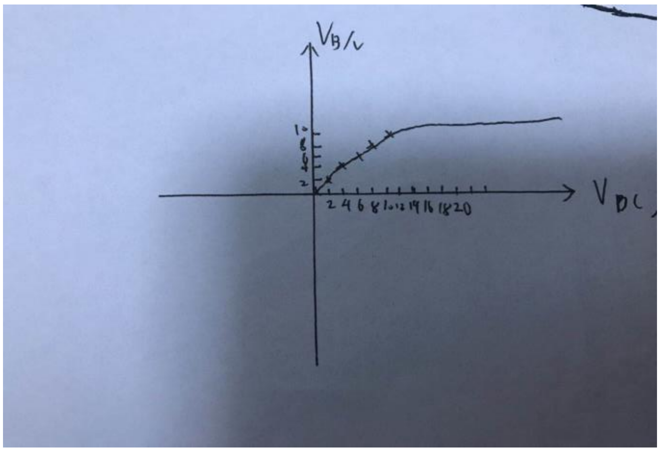
Table 4

R_L	V_{BE}	I_L
3.3kΩ	10.13 volts	3.070 mA
1.5kΩ	10.05 volts	6.7 mA
1kΩ	9.85 volts	9.85 mA
820Ω	8.97 volts	10.93 mA

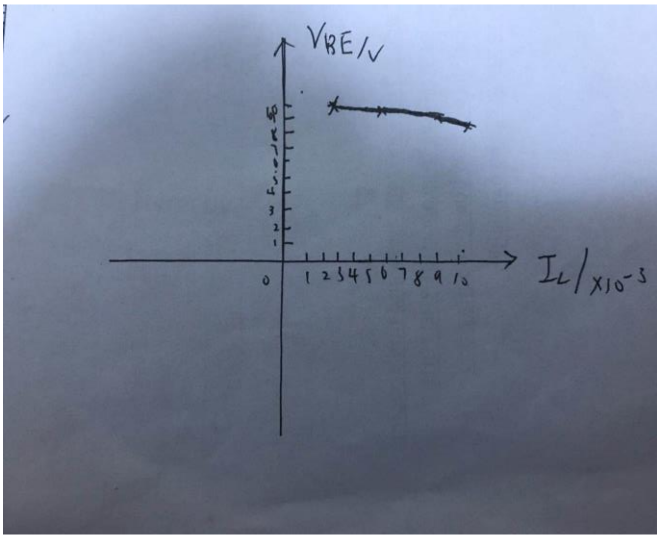
Table 5

After this experiment, we could find certain results and analyses. Due to the diode was reverse biasing, V_{DC} was equal to V_{BE} which was the voltage on the diode. In consideration of the existence of the experimental errors, from Table 4, V_{DC}

could be equal to V_{AE}. In addition, we could find that if V_{DC} reached to 12 volts, no matter how much V_{DC} increased, V_B was always around 10 volts. This condition shows the characteristic of the Zener diode. From the second part, we could observe that V_{DC} was 20 volts and V_B was still around 10 volts, the only thing changed was R_L, subsequently, I_L would be different. From this experiment, we could conclude that the function of the Zener diode could be used as the voltage regulator. In brief, the characteristic of Zener diode could be expressed by Graph 1 and Graph 2.



Graph 1



Graph 2

g) Light-emitting diodes

If the diode is doped by suitable materials, it can be applied to transform electrical energy into light energy. This diode is called LED (Light-emitting diodes). This experiment aims to introduce this application of this diode.

Following is certain procedures for this experiment. The first step was to construct the circuit as shown in Figure 24. For V_S, we set it to 10 V p-p square-wave from signal generator and frequency f = 2 Hz. When LED was flashing, we used the oscilloscope to measure the voltage drop across LED. Figure 25 is the waveform of the voltage drop across the LED.

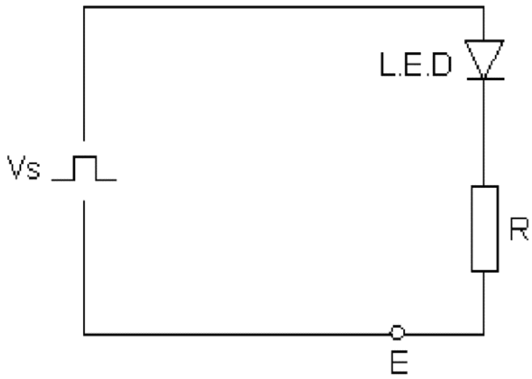


Figure 24: The circuit of the LED

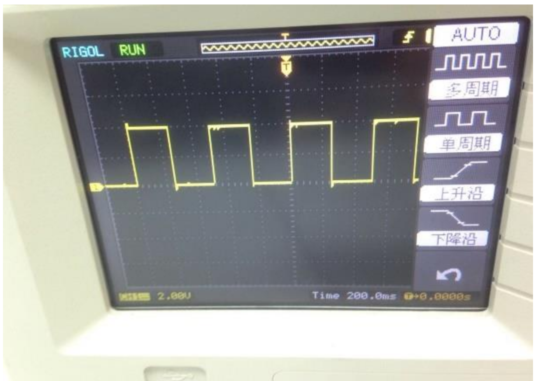


Figure 25: Out put waveform

From the process of this experiment, we could observe that when the voltage was negative, the diode was off and it was not lighting; when the voltage was positive, the diode was on and it was lighting.

Conclusion

From this experiment, we know how to construct circuit with diodes. Furthermore, we understand the functions of applications of the diode. They are rectification, smoothed rectifier, limiter/clipper, voltage clamper, diode logic, Zener stabilizer and Light-emitting diodes. In addition, we know the operation of the oscilloscope, function generator and the multimeter. During this whole experiment, there existed certain experimental errors. If the results were far from the expectation, we should redo the experiment until the results were very closed to the outcome we expected. The workable proposition to reduce experimental error might be replacing new experimental equipment and experimenting more. In addition, the way to measure voltage, current or resistance, it is better to use the digital multimeter rather than common one. In brief, the whole experiment is very successful, and the results are quite accurate.