EEE109 Lab 1 – Diodes

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Abstract

The semiconductor diode is an important electronic device which can be used in a wide variety of applications. This experiment aims to make students understand the basic feature of diodes and apply them as retifiers, clippers, clampers and logic operations. Also, the purpose of the experiment is let students to use Zener diode and light emiting diode as voltage regulators and light emiting devices. The procedures of the experiment are usually devided into three steps; first, set up the circuit; next, regulate the values of electronic devices; finally, measure the value of input and output voltage. In conclusion, diodes have various applications such as retifiers, clippers, clampers, voltage regulars and light emiting devices, and logic operation can be achieved by using diodes. In short, diode is one of the most important device which helps student learn more about electricity.

1. Introduction

The semiconductor diode is an electronic device made of semiconductor materials (silicon, selenium, germanium etc.) which has unidirectional conductive properties. Diodes are used in a wide variety of applications. Particularly in electronic circuits, diodes can be connected to resistors, capacitors, inductors and other components to form circuits with different functions, such as rectifying alternating current, detecting modulated signals, limiting and clamping, and regulating supply voltage.

The objectives of the experiment are as follows. First, understand the basic feature of diodes and use them as retifiers, clippers and clampers. Second, take use of diodes to achieve logic operations. Third, use light emiting diodes and Zener diodes as light emitting devices and voltage regulators. This experiment will focus on the application of diodes as retifiers, clippers, clampers, logic operations and voltage regulators and light emitting devices for Zener diodes and light emitting diodes.

This report will firstly provide an introduction part and then experimental procedure will follow up. The experimental results and references will be given at the end of the report.

2. Experimental Procedure

a) Rectification

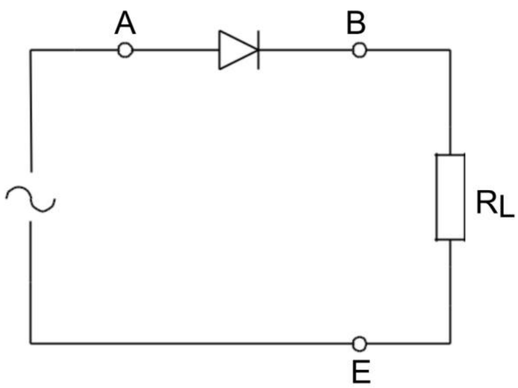
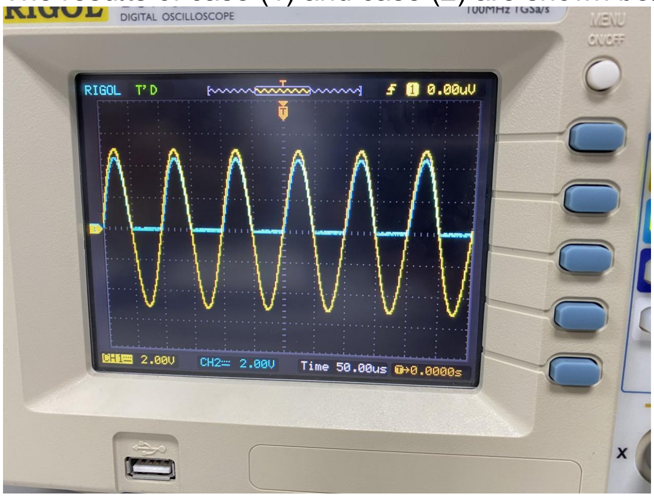


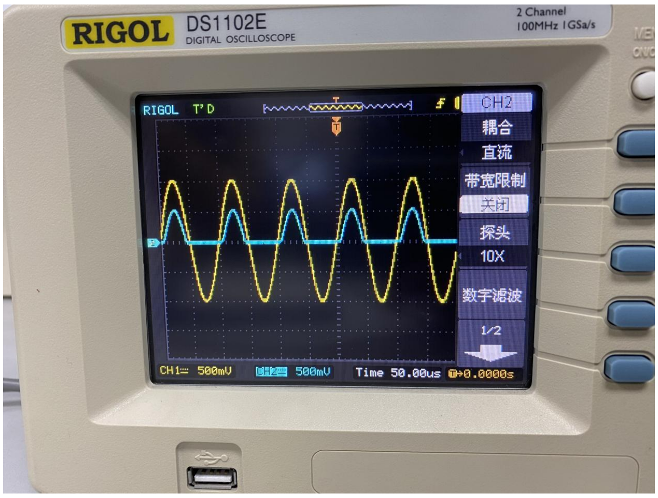
Figure 1: Basic Rectifier Circuit

First, a circuit shown as figure 1 should be set up on the breadboard. And then

1) regulate the value of V_{AE} to 10 volt p-p, frequency f to 10 kHz and R_L to 10 kΩ.
2) regulate the value of V_{AE} to 2 volt p-p, frequency f to 10 kHz and R_L to 10 kΩ.
Finally the signals of V_{AE} and V_{BE} should be sketched by Oscilloscope.

The results of case (1) and case (2) are shown below:





The left graph is the result of case (1) and the right one is the result of case (2).

As two graphs show, for AC power $V_{AE} < 0$, the diode is reverse biased, which means the output voltage V_{BE} is zero. Therefore, the input voltage sine waves which below the x-axes are 0 in two output voltage waves. For AC power $V_{AE} > 0$, the diode is forward biased, which means the output voltage $V_{BE} = V_{AE} - V_{\gamma}$. Therefore, the maximum value for two output voltage signals are smaller than the input voltage. The reason why the maximum value of the second output voltage signal is smaller than the first one is that the input voltage in case (2) is smaller than the one in case (1).

In conclusion, the diode performs as a rectifier in this experiment.

b) Smoothed rectifier

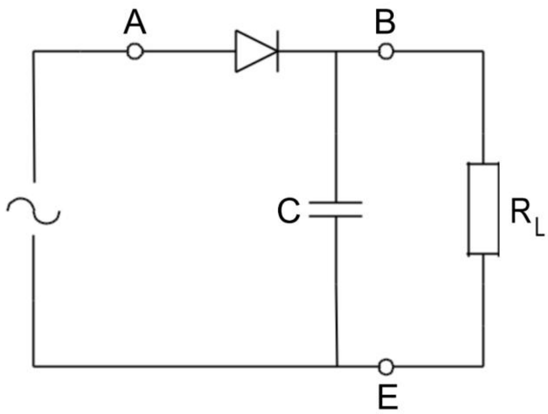


Figure 2: Smoothed Rectifier Circuit

First, a circuit shown as figure 2 should be set up on the breadboard. And then regulate the value of V_{AE} to 10 volt p-p, frequency f to 10 kHz, C to 100 nF and
1) R_L to 10 kΩ.
2) R_L to 1 kΩ.
Finally the signals of V_{AE} and V_{BE} should be sketched by Oscilloscope.

The results of case (1) and case (2) are shown below:

The left graph is the result of case (1) and the right one is the result of case (2).

As two graphs show, the ripple voltage V_r in case (2) is much bigger than the one in case (1). Since $V_r = \frac{V_M}{2fRC}$, whose V_M, f, C are all same in two cases, except R. In case (1), R_L is 10 kΩ and in case (2), R_L is 1 kΩ, which is smaller than the one in case (1). Therefore, the ripple voltage V_r in case (2) is bigger than V_r in case (1). The difference between two cases is perfectly explained.

In conclusion, the diode performs as a filter in this experiment.

c) Limiter/Clipper

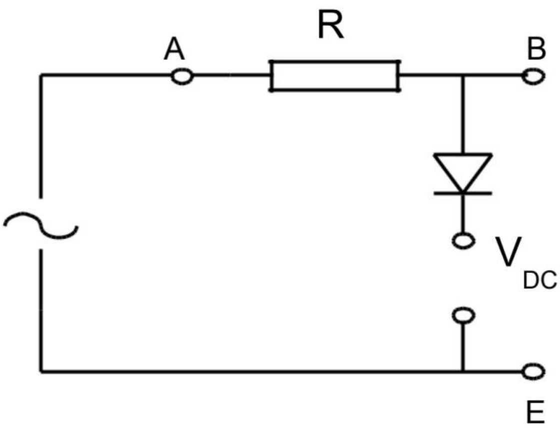


Figure 3: Voltage Limiter Circuit

First, a circuit shown as figure 3 should be set up on the breadboard. And then

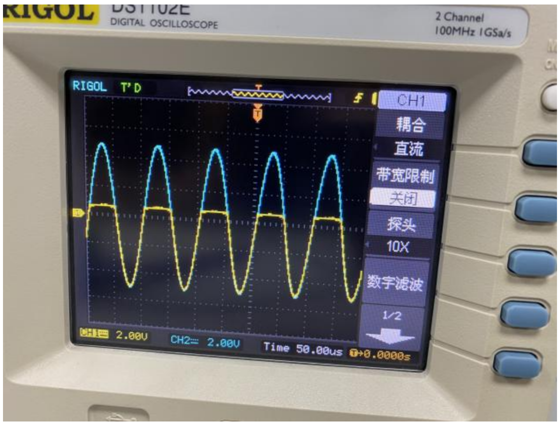
1) regulate the value of V_A to 10 volt p-p, frequency f to 10 kHz, R to 1 kΩ, and V_{DC} to 0 volt.

2) regulate the value of V_A to 10 volt p-p, frequency f to 10 kHz, R to 1 kΩ, and V_{DC} to +3 volt.

3) regulate the value of V_A to 10 volt p-p, frequency f to 10 kHz, R to 1 kΩ, and V_{DC} to +3 volt with the doide connection reversed.

Finally the signals of V_A and V_B should be sketched by Oscilloscope.

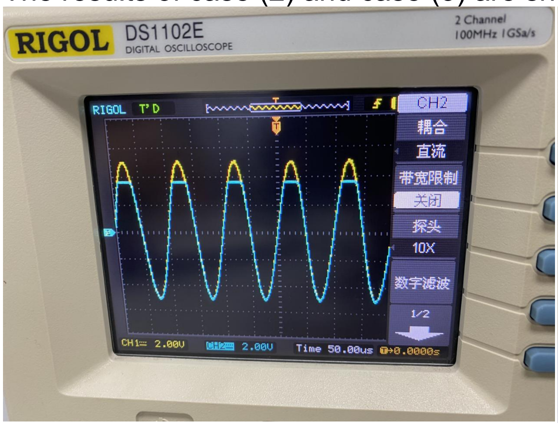
The result of case (1) is shown below:

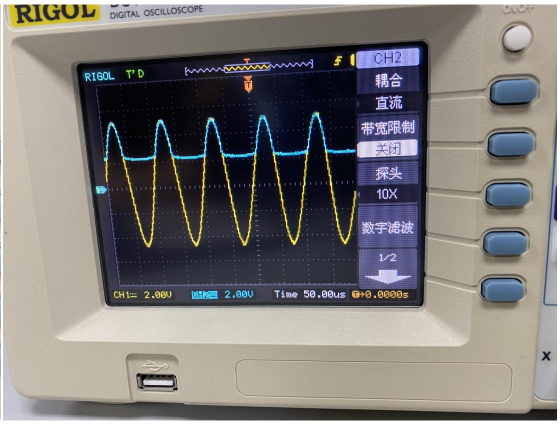


Case (1)

As the graph shows, for case (1), since $V_{DC} = 0$, the output voltage is the same as the input voltage when $V_A < V_\gamma$, for the diode is off and the current is approximately zero. Therefore, the output voltage V_B is equal to the input voltage V_A. When $V_A > V_\gamma$, the diode turns on, the output voltage is clipped to V_0 which equals to V_γ. Therefore, the gragh is plain at somewhere $V_A > V_\gamma$.

The results of case (2) and case (3) are shown below:





As two graphs show, for case (2), the output voltage is the same as the input voltage when $V_A < V_{DC} + V_\gamma$, for the diode is off and the current is approximately zero. Therefore, the output voltage V_B is equal to the input voltage V_A. When $V_A > V_{DC} + V_\gamma$, the diode turns on, the output voltage is clipped to V_0 which equals to $V_{DC} + V_\gamma$. Therefore, the gragh is plain at somewhere $V_A > V_{DC} + V_\gamma$.

For case (3), the output voltage is the same as the input voltage when $V_A > V_{DC} + V_\gamma$, for the diode is off and the current is approximately zero. Therefore, the output voltage V_B is equal to the input voltage V_A. When $V_A < V_{DC} + V_\gamma$, the diode turns on, the output voltage is clipped to V_0 which equals to $V_{DC} + V_\gamma$. Therefore, the gragh is plain at somewhere $V_A < V_{DC} + V_\gamma$.

In this experiment, diodes perform as limiter and clippers.

d) Voltage Clamper

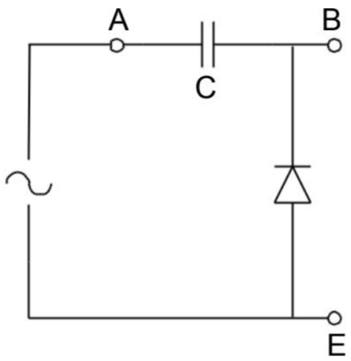
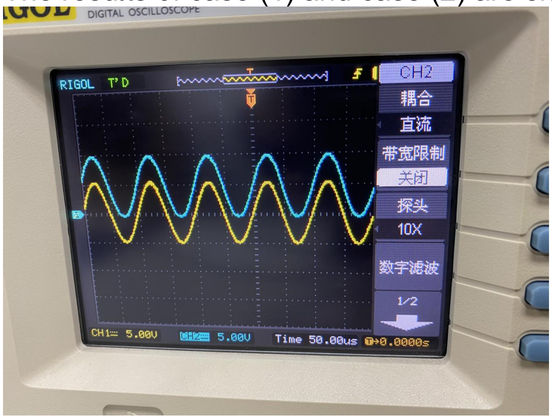
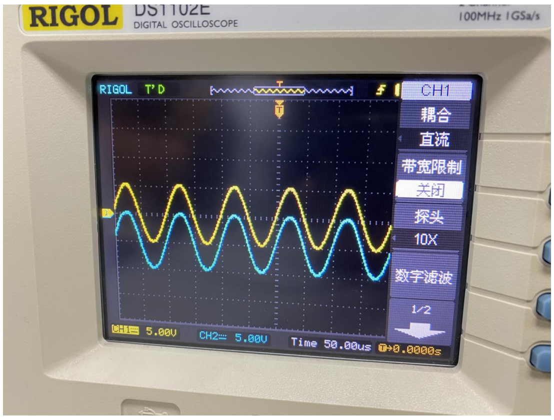


Figure 4: Voltage Clamper

First, a circuit shown as figure 4 should be set up on the breadboard. And then
1) regulate the value of V_A to 10 volt p-p, frequency f to 10 kHz, C to 10 nF.
2) regulate the value of V_A to 10 volt p-p, frequency f to 10 kHz, C to 10 nF with diode terminals reversed.
Finally the signals of V_A and V_B should be sketched by Oscilloscope.

The results of case (1) and case (2) are shown below:





The left graph is the result of case (1) and the right one is the result of case (2).

As two graphs show, During the first 90 degrees of the input waveform, the voltage across the capacitor follows the input, and V_C equals to the input voltage. After input voltage and V_C reach their peak values, the input voltage begins to decrease and the diode becomes reverse biased. And then the capacitor cannot discharge, so the voltage across the capacitor remains constant at $V_C = V_M$. By Kirchhoff's voltage law, for case (1), $V_C = V_M(\sin\omega t - 1)$. Therefore, the output is shifted in a negative voltage direction. For case (2), $V_C = V_M(\sin\omega t + 1)$. therefore, the output is shifted in a positive voltage direction.

In this experiment, diode performs as voltage clamper.

e) Diode logic

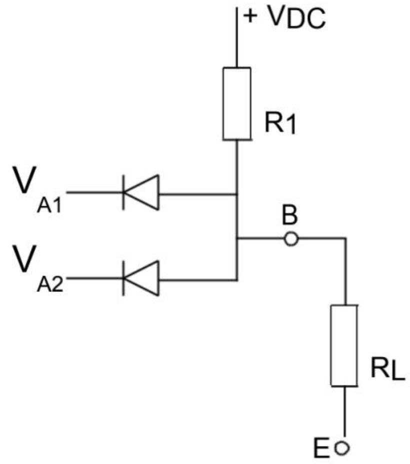


Figure 5: Diode Logic Gate Circuit

First, a circuit shown as figure 5 should be set up on the breadboard. Note that $V_{DC} = +5\ volt, R_1 = 2.2\ k\Omega, R_L = 10\ k\Omega$. And then regulate the value of

1) $V_A = V_{A2} = +5\ volt$
2) $V_A = 0\ volt, V_{A2} = +5\ volt$
3) $V_A = +5\ volt, V_{A2} = 0\ volt$
4) $V_A = V_{A2} = 0\ volt$

Finally, measure the DC output voltage and V_B .

The output value of V_B are shown below:

V_{A1} (V)	V_{A2} (V)	V_B (V)
5	5	4.08
0	5	0.639
5	0	0.637
0	0	0.601

The truth table for the logic level at B relating to the logic inputs A_1 and A_2 is:

A_1	A_2	B
1	1	1
0	1	0
1	0	0
0	0	0

The logic expression is $B = A_1 * A_2$.
From the table, it is easy to find that the circuit is an AND gate.

f) Zener Stabiliser

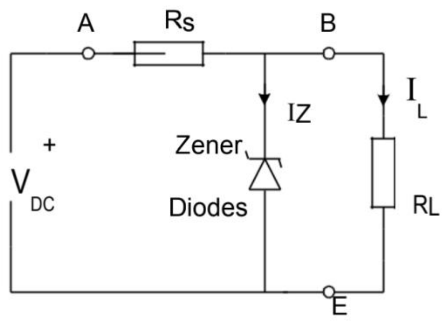


Figure 6: Zener Stabiliser Circuit

First, a circuit shown as figure 6 should be set up on the breadboard. Note that the Zener diode is 10 volt and R_s is 1 kΩ. And then

1) set R_L to open circuit. Vary V_{DC} from 0 volt to 20 volt in 2-volt steps. Finally, V_B and V_{DC} should be measured.

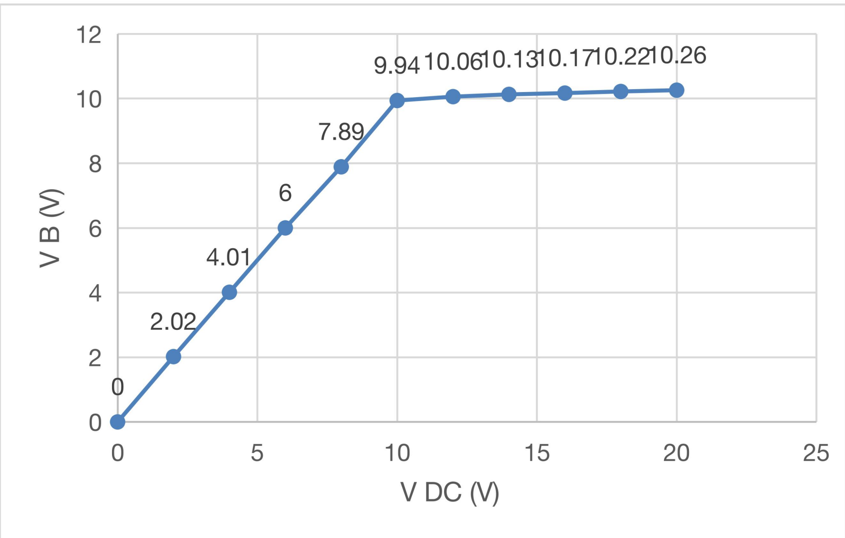
2) set V_{DC} to 20 volt. Measure V_B with R_L = *3.3* kΩ, 1.5 kΩ, 1 kΩ and 820 Ω. calculate the value of the load current by using the equation $I_L = \frac{V_B}{R_L}$.

For case (1),

The table with the values of V_B and V_{DC} is:

V_{DC} (V)	0	2	4	6	8	10	12	14	16	18	20
V_B (V)	0	2.02	4.01	6.00	7.89	9.94	10.06	10.13	10.17	10.22	10.26

The graph of V_B against V_{DC} is:

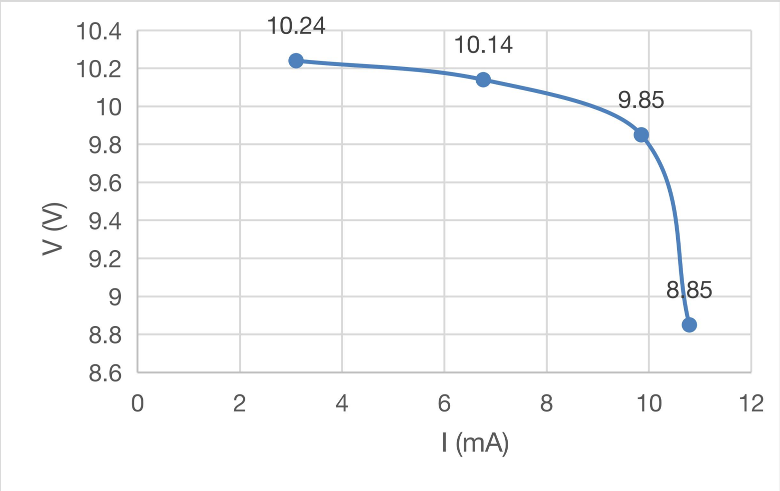


For case (2),

The table with the values of V_B and I_L is:

R_L	3.3kΩ	1.5kΩ	1kΩ	820Ω
V_B	10.24V	10.14V	9.85V	8.85V
I_L	3.10mA	6.76mA	9.85mA	10.79mA

The gragh of V_B against I_L is:



From two graghs, the circuit acts as a Zener diode voltage stabiliser. Since Zener diode has a sharp reverse breakdown characteristic at fairly low voltage, when the supply exceeds this breakdown voltage, the diode will turn on. Therefore, the output voltage changes a little regardless of and change in the supply voltage. That's the reason there is a flat fold at the end of the gragh 1 and a sharp decrease at the end of gragh 2.

g) Light-emitting diodes

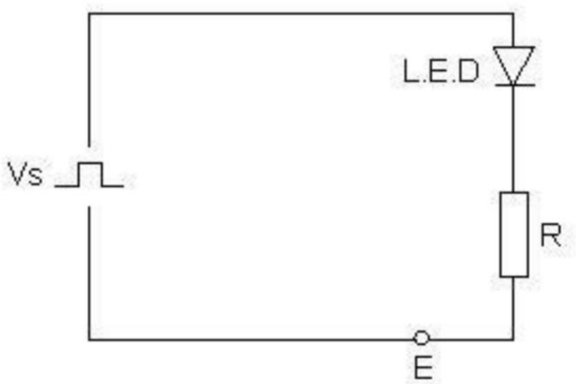
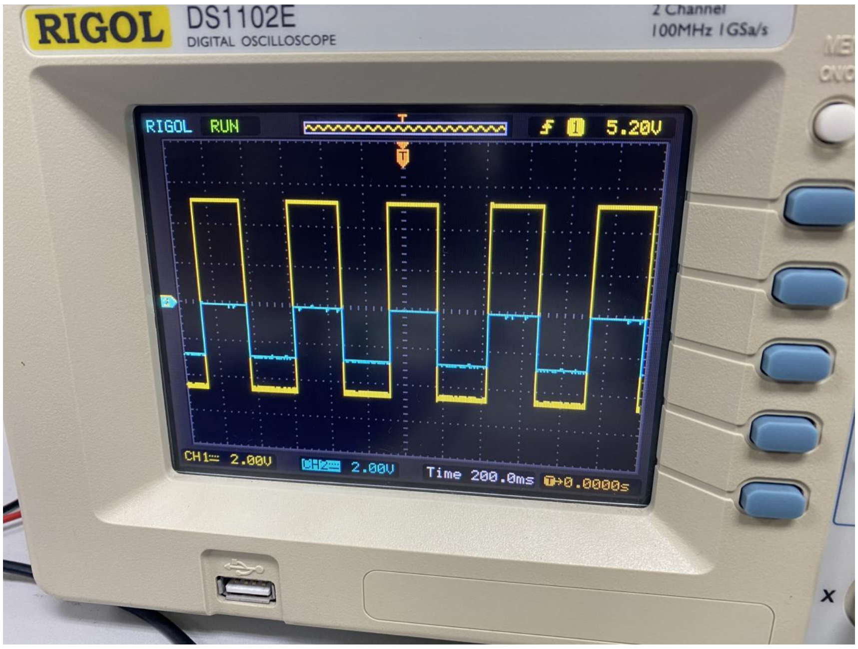


Figure 7: Optical Receiver

First, a circuit shown as figure 7 should be set up on the breadboard. And then regulate the value of V_S to 10 volt p-p square-wave, frequency f to 2 kHz, R to 330 Ω.
Finally the voltage drop across the LED when it is conducting by Oscilloscope.

The result is shown below:



From the gragh, the square wave above the x axis are all zero in the output voltage, for the diode is off and no current across the circuit. The reason why output voltage below the x axis is smaller than supply voltage is that the diode itself consumes some voltage.

In conclusion, light emitting diode can be used as light emitting devices.

3. Conclusions

In conclusion, from this experiment, we used diodes in retifiers, clippers and clampers and perform logic operation with diodes and we understood the principles of them. Moreover, we used Zener diodes and light emiting diodes as voltage regulators and light emitting devices. During the experiment, we reinforced the usage of lab equipement such as multimeters, oscilloscope and function generators.

There are some experimental errors in the experiment, the reasons we assumed are as follows:
1. Any measuring instrument has a certain accuracy level, and there will be measurement errors.
2. The actual value of any actual component will not remain unchanged, and is affected by temperature, humidity, voltage, and current. For example, the higher the carbon film resistance temperature, the lower the resistance, and the higher the metal film resistance temperature, the greater the resistance.

To improve the accuracy of the experiment, we can use more accurate electronic devices and components of the circuit. Moreover, we should measure more times to get an average value to eliminate the accidental errors.