EEE109 Lab 1 – Diodes

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Abstract

This experiment is divided by there main parts, the first is introduction of semiconductor diode. However, this report will focus on 1N4148, Zenner diodes and LED. The second part is the experiment by using these diodes to build circuit such as Basic Rectifier Circuit, the Smoothed Rectifier Circuit, Voltage Limiter Circuit, the Voltage Clamper Circuit and the Diode Logic Gate Circuit. However, some special diode such as Zenner diodes and LED will test later. The experiment analysis is also included in the second parts. At the last part, the conclusion of all experiment will be covered.

1.Introduction

A semiconductor diode which has two terminals is an electronic component[1]. Its main characteristic is different direction's current through semiconductor diode has different effect. Specifically, different directions of resistance from semiconductor diode is different, the reason is semiconductor diode has a crystalline piece of p–n junction, it is shown in Figure 2[2].

In this experiment, semiconductor diode's characteristics will be tested and verified, and application of semiconductor diode including rectification, smoothed rectifier, limiter, voltage clamper and diode logic will be verified. In addition, special diodes which are Zenner Diode and LED will be used in this experiment.

This report is divided into four main parties which are introduction, experimental procedure, conclusion and reference list. For introduction parts, semiconductor diode and special diodes will be place in 1.1 and 1.2. For experimental procedure parts, rectification, smoothed rectifier, limiter, voltage clamper and diode logic will be placed separately in second quarter. The conclusion parts which include experimental summary and reliability assessment will be shown in third quarter. At last, reference list is placed in final quarter.

1.1 Semiconductor Diodes

This experiment used 1N4148 diodes, which is most widely used semiconductor diodes[3]. 1N4148 diode is shown in Figure 1 and model diagram is shown in Figure 2. The resistance of diode almost equal to 0 Ω from P to N, it is called forward bias. It is worth noting that two terminals need to open voltage V_γ to turn on the diode. However, resistance equivalent to infinity from N to P, it is called reverse bias.

Figure 1: 1N4148

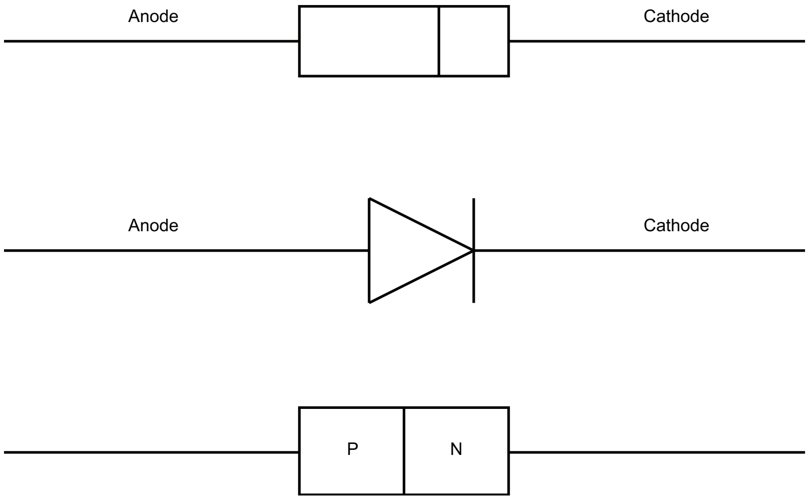


Figure 2: Semiconductor diode and its model diagram

1.2 Special Diodes

For Zenner Diodes, model diagram is shown in Figure 3, it usually be used in stabilizer which is a voltage regulator. Due to its reverse breakdown characteristics, this experiment will construct a voltage regulator circuit.

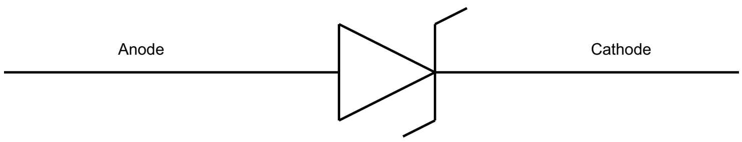


Figure 3: Zenner Diode's model diagram

For LED, when it forward bias and electrons and holes recombine, it can emit visible light. For experiment LED, the open voltage V_γ is nearly 2 V.

2.Experimental Procedure

a.Rectification

2.1a Introduction

By using a semiconductor diode in AC signal circuit, it can transform to DC signal. This is because of unidirectional conductivity of the semiconductor diode. However, there exists an opening voltage V_γ , the peak of AC signal would be reduced a value of V_γ. This experiment needs to attention is reverse current cannot be too large, it aims will protect semiconductor diode not to be breakdown.

2.2a Experiment Setup and Procedure

I. Calibration Oscilloscope

Use signal generator to produce sine wave, then use oscilloscope to connect both side of signal generator(Positive and negative). Check the sine wave in oscilloscope is symmetrical about 0 V, then check signal generator's waveform is the same as oscilloscope. If waveform is different, adjust oscilloscope.

II. Circuit Setup

Set up circuit in Figure 4. Firstly, set R_L to 10 $k\Omega$ and input 10 V_{pp} voltage and 10KHz's frequency sine wave from signal generator, then use channel 1 to measure A point to E point, channel 2 to measure B point to E point. Record oscilloscope's image and voltage value. Secondly, change V_{pp} to 2 V, and repeat the first step.

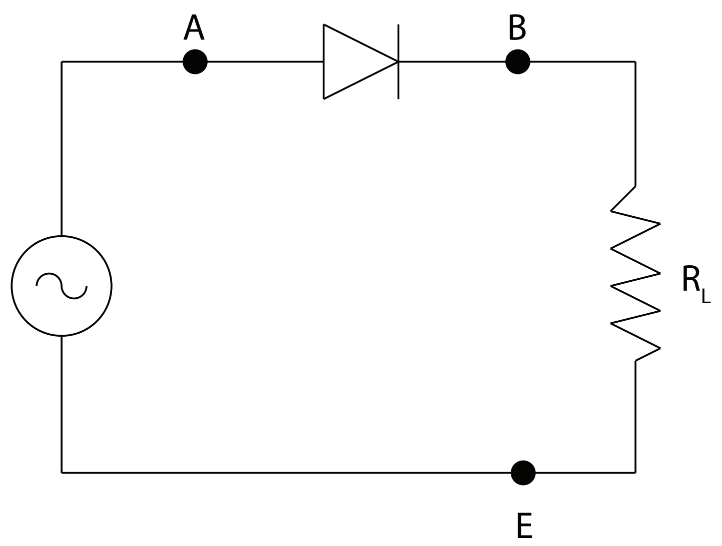


Figure 4: Rectification circuit

2.3a Experimental Data

i. V_{AE} to 10 volt's graph is shown in Figure 5, experimental raw data is shown in Figure 6. This graph shows that the sign is cut from a half, it is called a half-wave rectifier. The total voltage CH1 which measured by oscilloscope is 10.4 V (minimum value is -5.2 V, maximum value is 5.2 V), the value of CH2 is 4.6 V (minimum value is almost 0 V, maximum value is 4.6 V).From Figure 5 and Figure 6, the pack of signal which is cut from semiconductor diodes is not the same value as CH1. Specifically, it has almost 0.6 V difference.

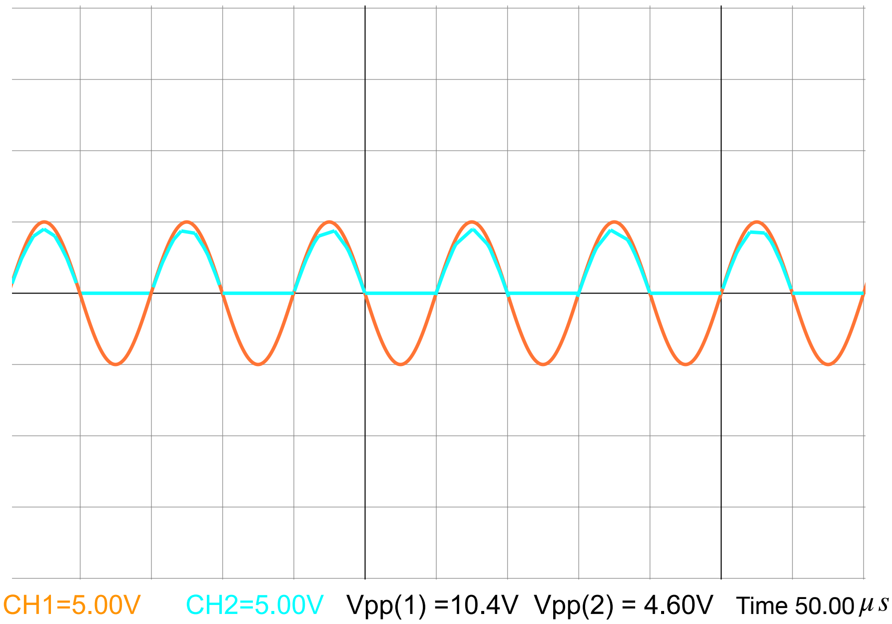


Figure 5: V_{AE} to 10 Volt P-P

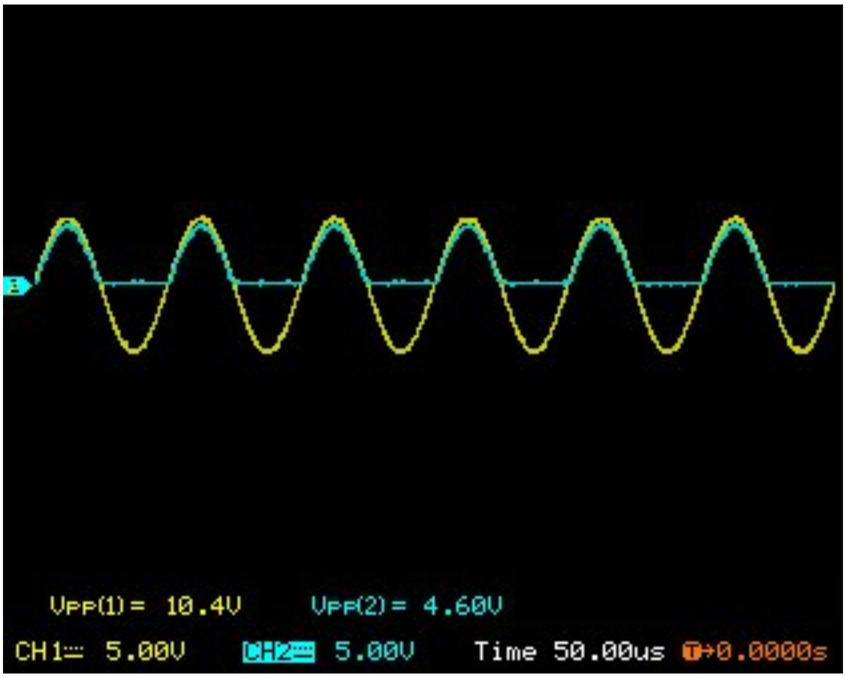


Figure 6: Experimental raw data for 10 Volt P-P

ii. V_{AE} to 2 volt's graph is shown in Figure 7, experimental raw data is shown in Figure 8. The total voltage CH1 which measured by oscilloscope is 2.08 V (minimum value is -1.04 V, maximum value is 1.04 V), the value of CH2 is 560 mV (minimum value is almost 0 V, maximum value is 560 mV).From Figure 7 and Figure 8, the pack of signal which is cut from semiconductor diodes is not the same value as CH1. Specifically, it has almost 0.6 V difference.

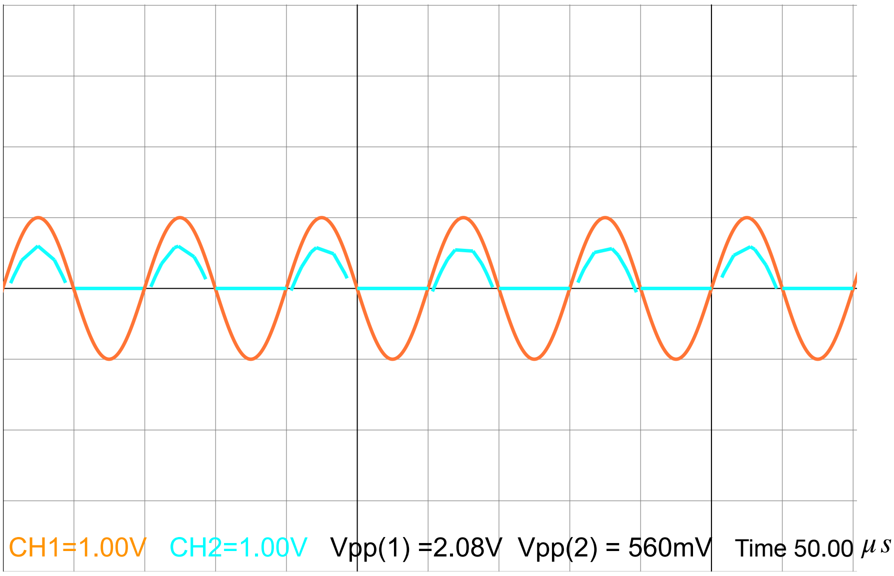


Figure 7: V_{AE} to 2 Volt P-P

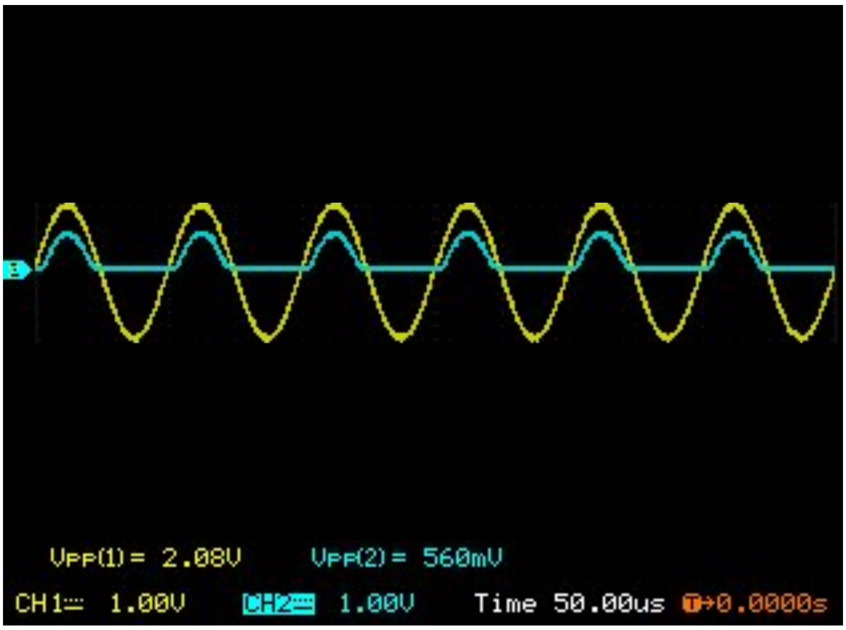


Figure 8: Experimental raw data for 2 Volt P-P

2.4a Experiment Analysis

i. For Pspice simulation, two results have shown in Figure 9 and Figure 10. By scanning analog data, when V_{AE} equals to 10 volt, the voltage in semiconductor diode 1N4148 is 0.67 volt. When V_{AE} equals to 2 volt, the voltage in semiconductor diode 1N4148 is 0.46 volt.

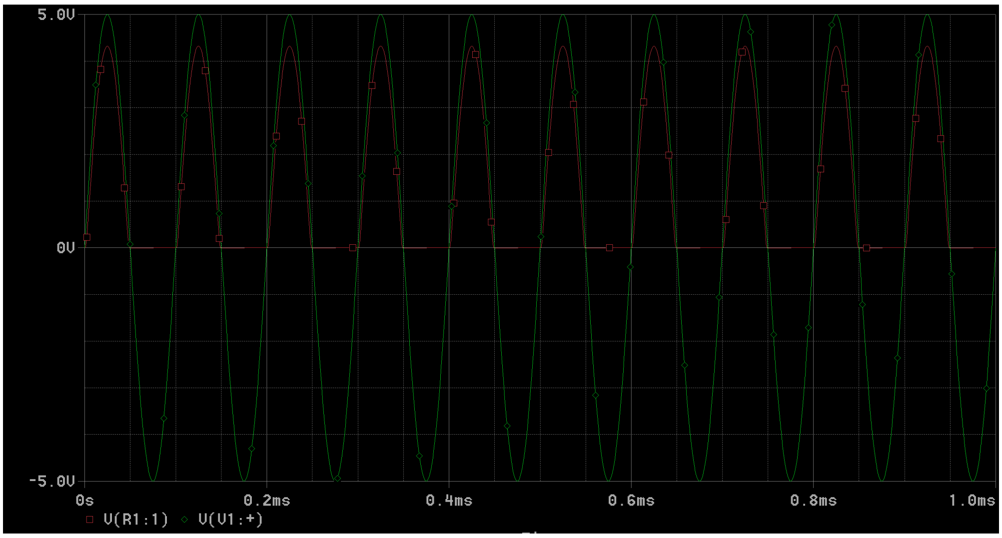


Figure 9: V_{AE} to 10 Volt P-P by Pspice

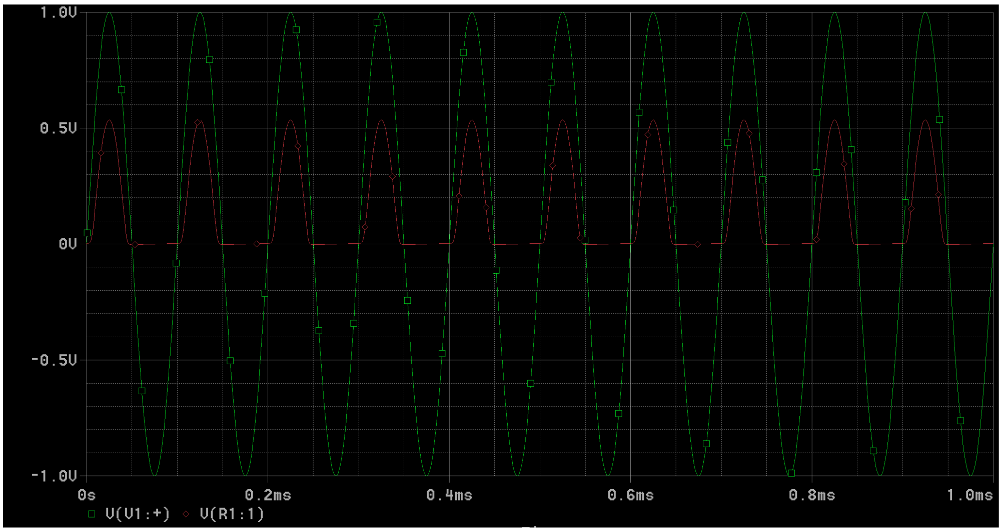


Figure 10: V_{AE} to 2 Volt P-P by Pspice

ii. In order to compare the relationship between simulation and reality, a table is shown in Table 1 and Table 2.

V_{AE} = 10	Reality Experiment	Pspice simulation
V_{AE}	10.4 V	10 V
V_{BE} Peak	4.6 V	4.33 V
V_{AB} Peak	0.6 V	0.67 V

Table 1: Rectification's result 1

V_{AE} = 2	Reality Experiment	Pspice simulation
V_{AE}	2.08 V	2 V
V_{BE} Peak	0.56 V	0.52 V
V_{AB} Peak	0.48 V	0.48 V

Table 2: Rectification's result 2

The results of this experiment are in line with expectations, by checking handbook of 1N4148 diodes which is shown in Figure 11, the opening voltage is almost 0.4 volts in 298.15 K. It is worth noting that the reason that semiconductor diode is divide different voltage it is because semiconductor diode exist a tiny resistance, when drawing Q point of whole circuit, the current is increased by different voltage, this is the reason for as the voltage increases, the diode voltage increases.

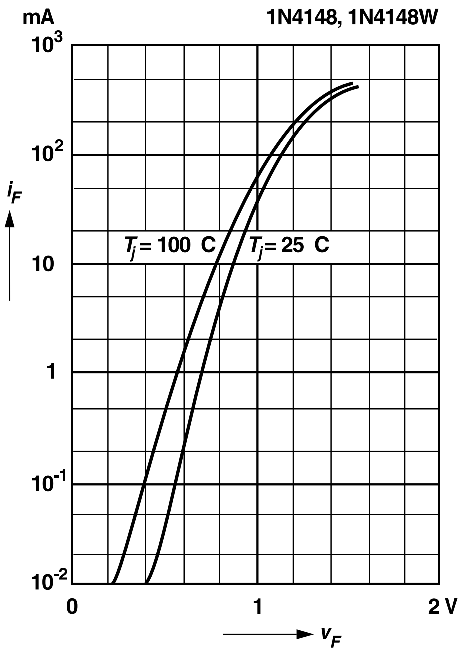


Figure 11: 1N4148[3]

b. Smoothed rectifier
2.1b Introduction

It is not enough to convert AC power to DC power through only one diode. By using capacitance and diode could let voltage more smoothly. A simply smoothed rectifier could be set up in Figure 12. Among them, capacitance will charge and discharge during the changing of V_{AE}.

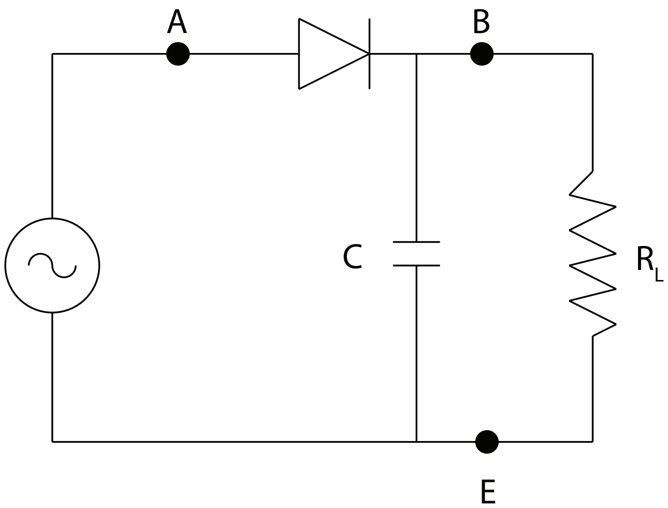


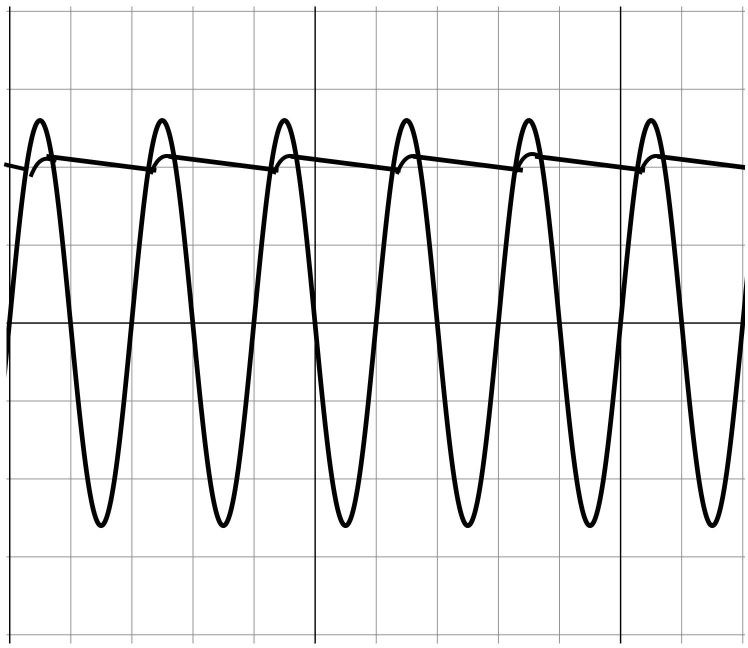
Figure 12: Smoothed rectifier circuit

2.2b Experiment Setup and Procedure

Set up circuit as Figure 12, in this experiment, set 10 volts of sine V_{AE} that frequency is 10KHz and 100nF's capacitance, the resistance was changed from 10 kΩ to 1 kΩ. Then use channel 1 to measure A point to E point, channel 2 to measure B point to E point. Record oscilloscope's image and voltage value.

2.3b Experimental Data

i. The experiment results have shown in Figure 13 for 100 KΩ resistance, experimental raw data is shown in Figure 14 and comparing data of CH1 and CH2 is shown in Table 3.



CH1=2.00V CH2=2.00V Vpp(1) =10.4V Vpp(2) = 4.60V Time 50.00 μs

Figure 13: 100 KΩ resistance of smoothed rectifier

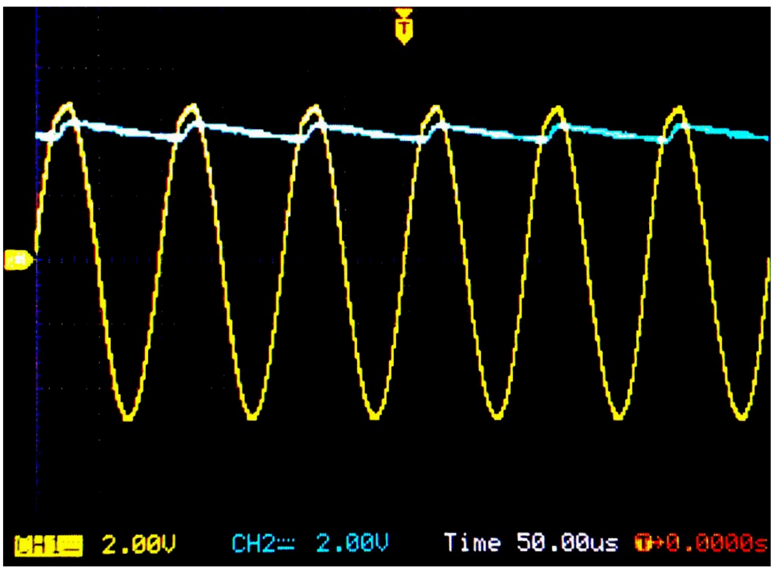


Figure 14: Raw data for 100 KΩ resistance of smoothed rectifier

CH1	Vmin = -4.96V	Vmax = 4.92V
CH2	Vmin = 3.70V	Vmax = 4.33V

Table 3: Data comparison between CH1 and CH2 in 100 KΩ resistance

ii. The experiment results have shown in Figure 15 for 10 KΩ resistance, experimental raw data is shown in Figure 16 and comparing data of CH1 and CH2 is shown in Table 4.

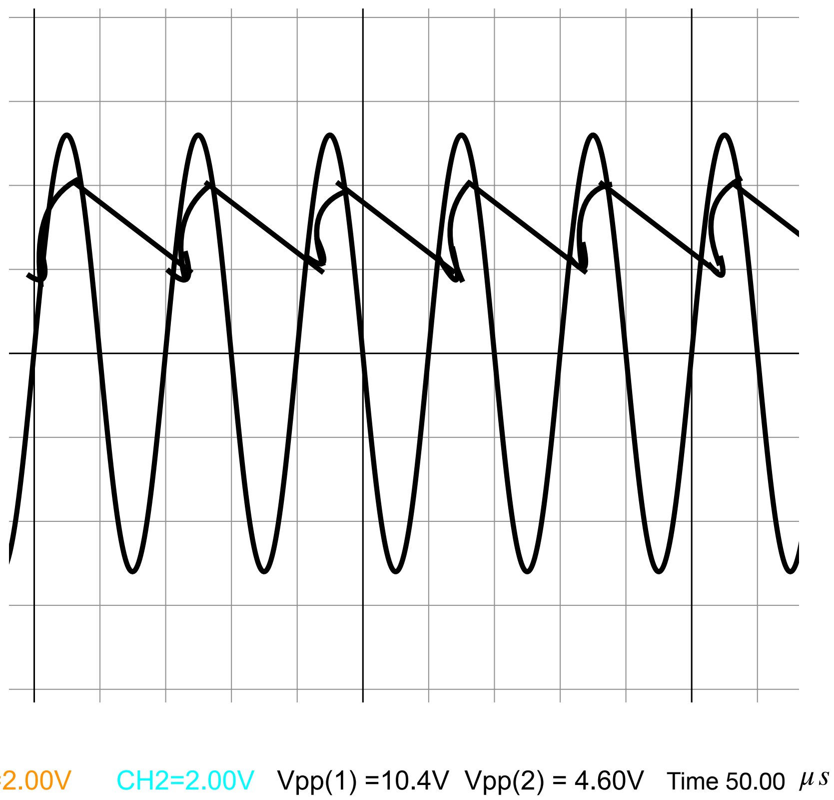


Figure 15: 10 KΩ resistance of smoothed rectifier

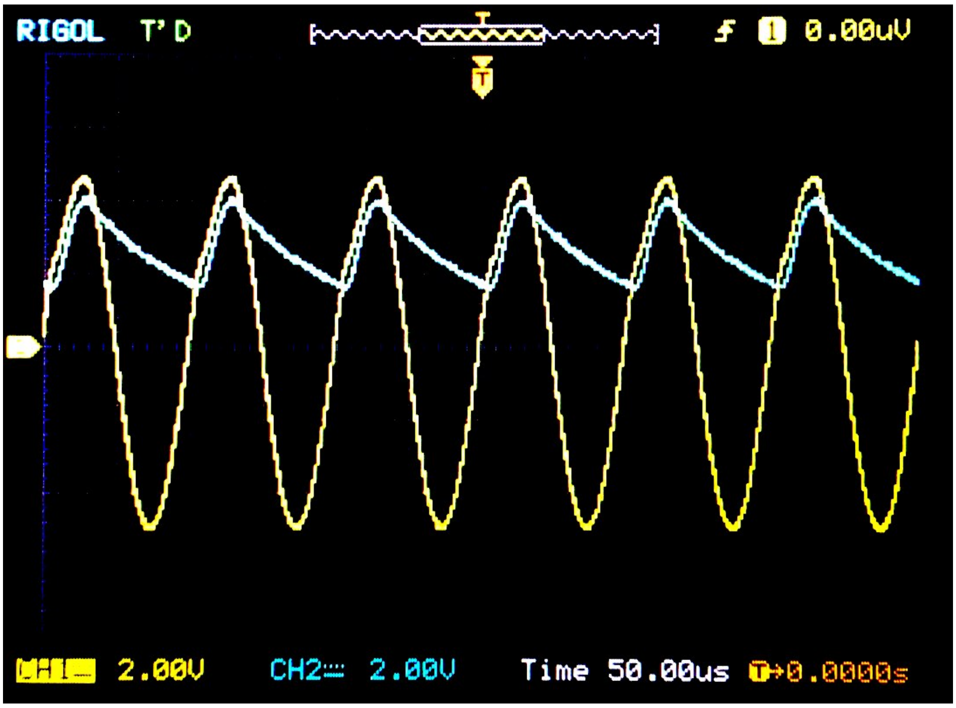


Figure 16: Raw data for 10 KΩ resistance of smoothed rectifier

CH1	Vmin = -4.99V	Vmax = 4.72V
CH2	Vmin = 1.52V	Vmax = 4.00V

Table 4: Data comparison between CH1 and CH2 in 10 KΩ resistance

2.4b Experiment Analysis

The result is in line with expectations for Pspice simulation, the simulation result is shown in Figure 17 and Figure 18. Image trend is the same as the experiment, which is for 10 kΩ's resistance, it exists small fluctuations, however when resistance is replaced by 1 kΩ, the fluctuation range has increased. The reason for this phenomena is that capacitive capacitance is fixed, so the voltage is depends on both capacitive capacitance and R. The power from the captive will using current multiple resistance , when the resistance more large, the current through resistance become less, so capacitor recovery time is relatively long.

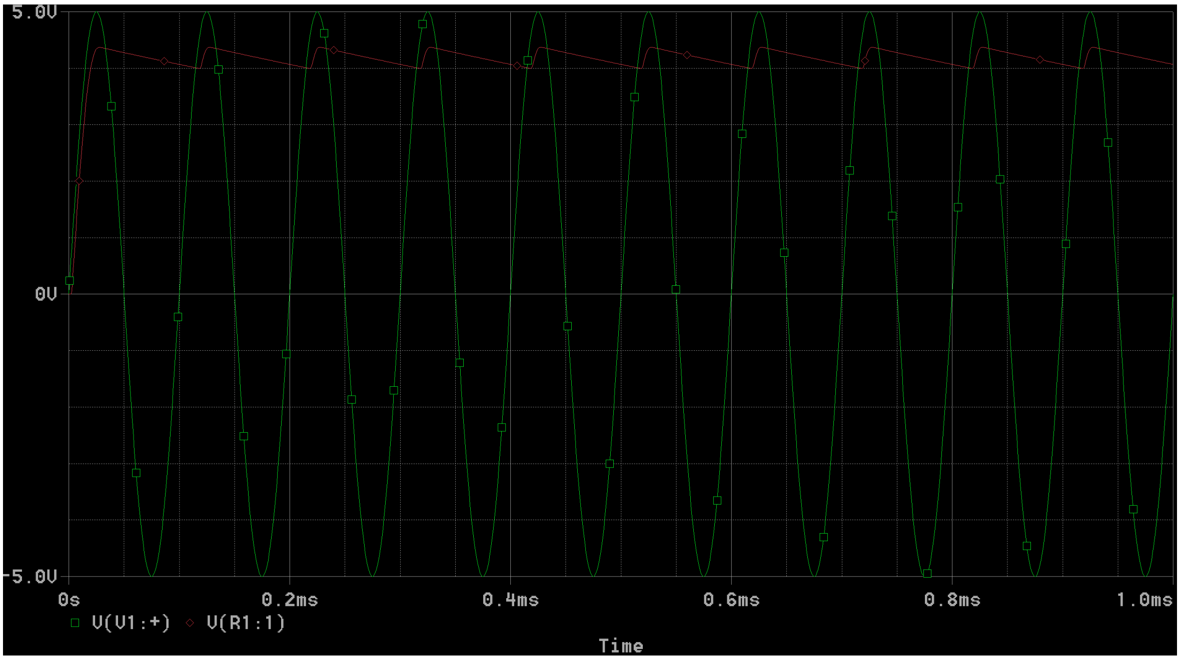


Figure 17: Pspice Simulation

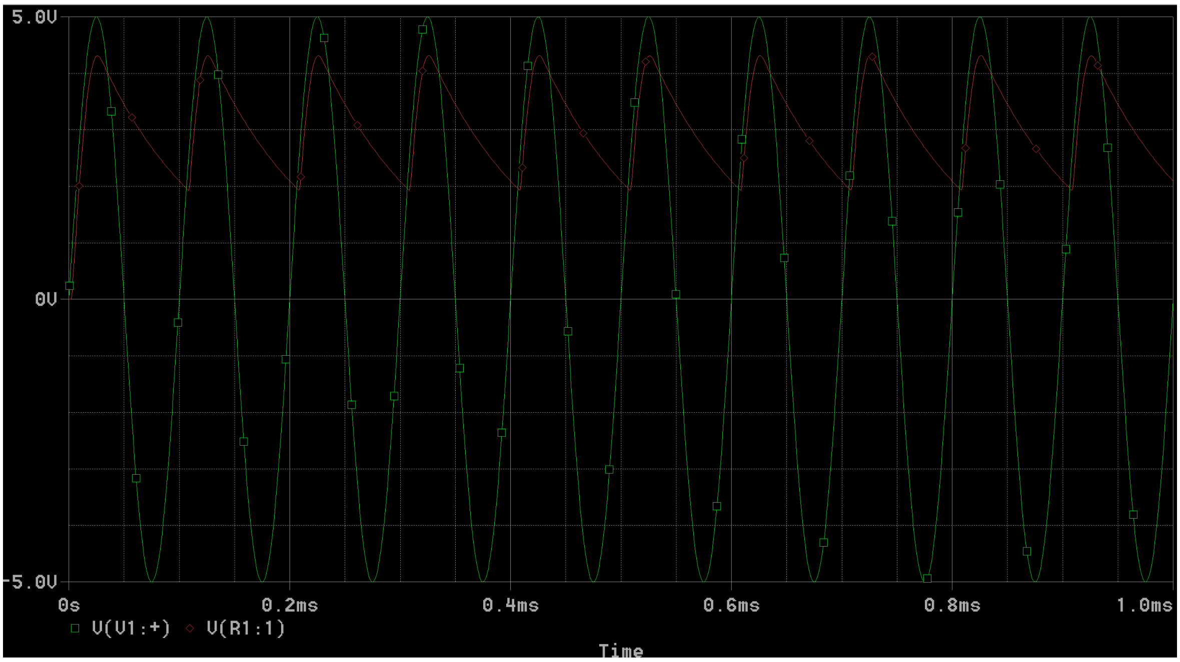


Figure 18: Pspice Simulation

C. Limiter/Clipper
2.1c Introduction

When smoothed rectifier is used make voltages stable, however when load's resistance is low, the voltage stability is lower. Limiter aims to provide a more stable voltage environment. By using limiter, the voltage could be limited in a range. In this experiment will check the limiter circuit in Figure 19.

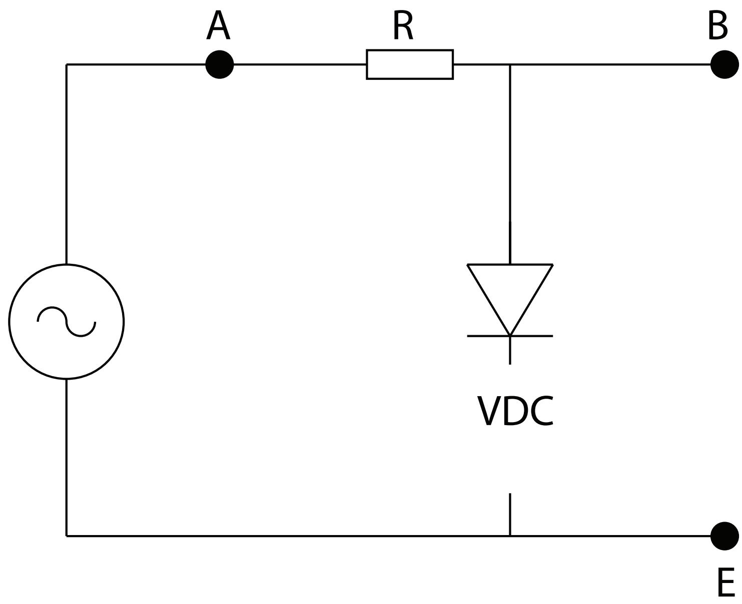


Figure 19: Limiter's circuit

2.2c Experiment Setup and Procedure

Firstly, we need to build this circuit. Then, set signal generator to 10 volt peak to peak and frequency to 10 kHz.

(a) Set R to 1 kΩ and V_{DC} to 0 volt. Then, use oscilloscope to measure A to E for CH1 and B to E for CH2.
(b) Make V_{DC} to 3 volts and measure again.
(c) Keep V_{DC} to 3 volts and make the diode connection revered.

2.3c Experimental Data

(a) The first result is shown in Figure 20 and Figure 21. As the figure shown, the voltage is cut by diode. It is worth noting that the voltage is not equal to 0, this is because of the open voltage V_γ, so the voltage is near 0.6 volt.

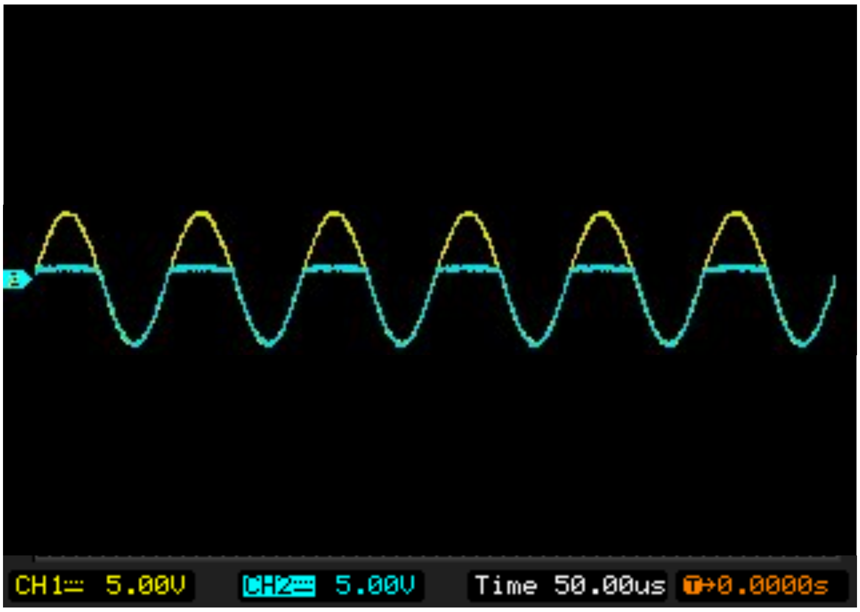


Figure 20: Limiter

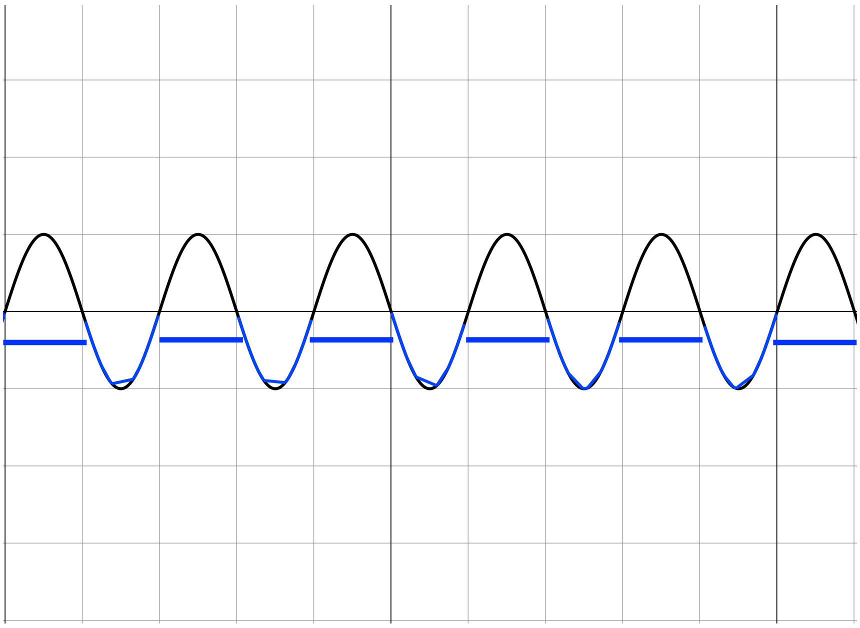


Figure 21: Limiter

(b) The second result is shown in Figure 22 and Figure 23. Because of V_{DC}, the voltage rises than (a).

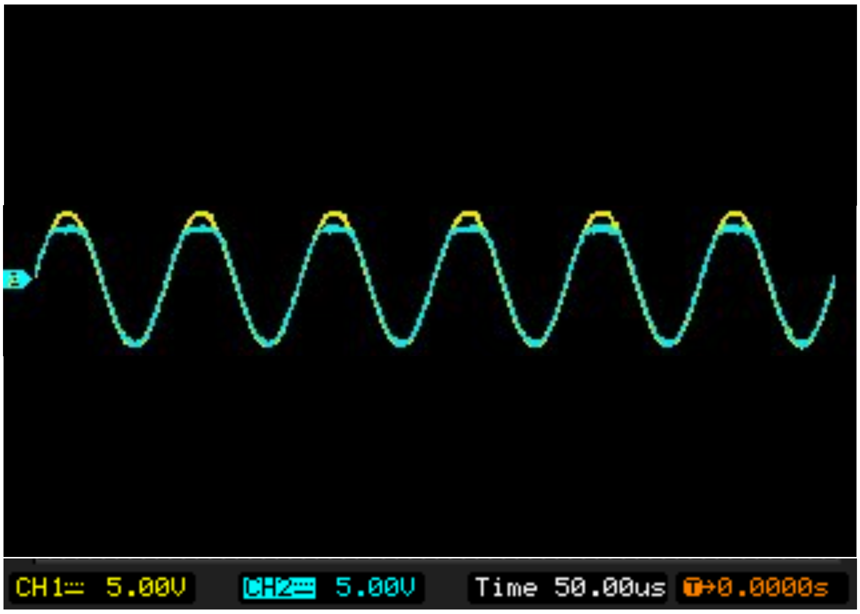


Figure 22: Second part of Limiter

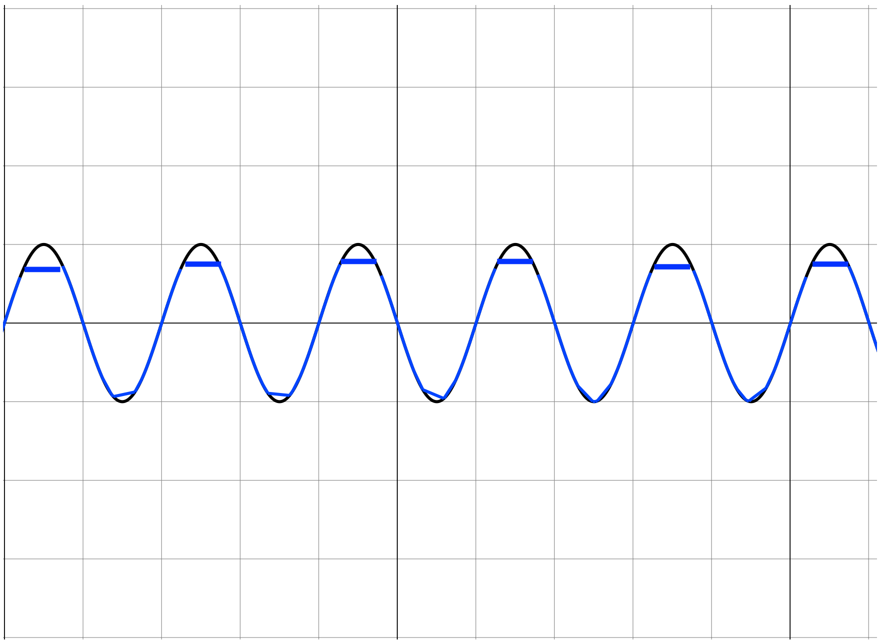


Figure 23:Second part of Limiter

(c) Reverse diode connection's Figure is shown in Figure 24 and Figure 25.

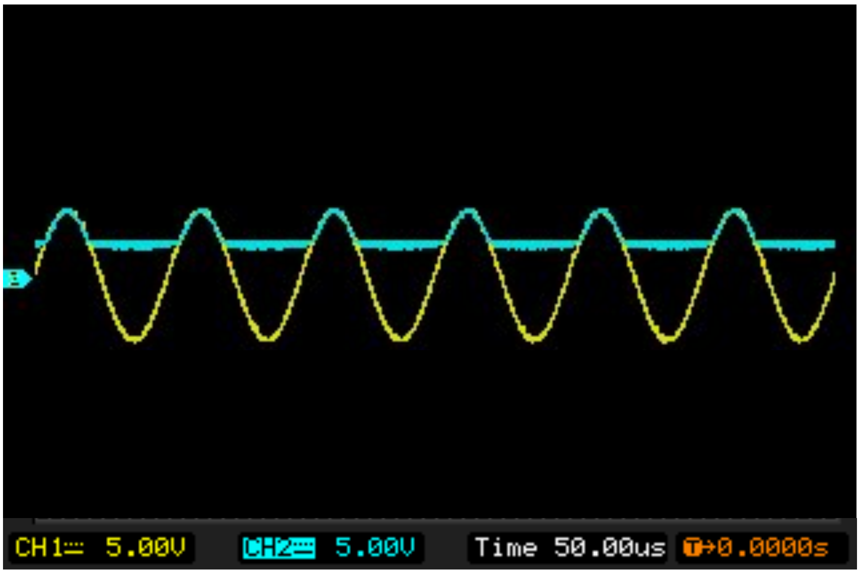


Figure 24: Reverse diode of result

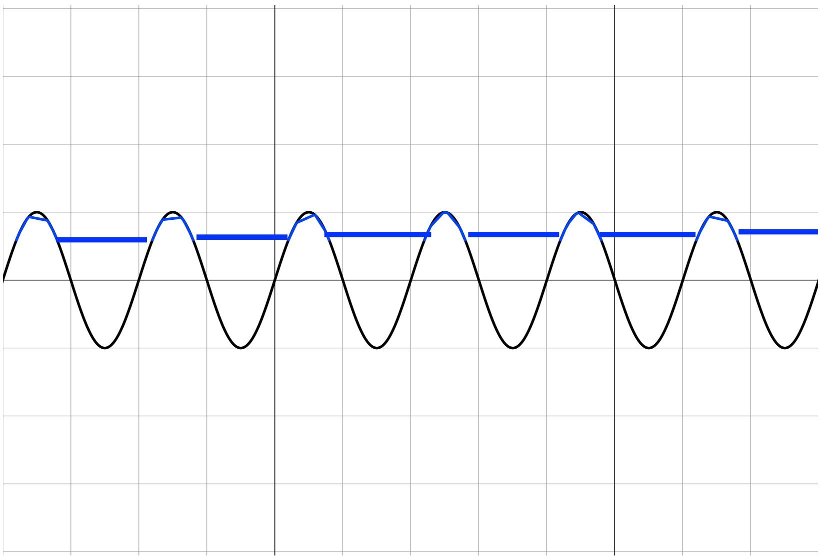


Figure 25: Reverse of diode's result

2.4c Experiment Analysis

(a) This experiment result is in line with the simulation, the reason why for result (a), it is shown in the part a, however V_{BE} is the voltage on the diode, when diode is off, that is mean that the voltage is not catch the open voltage, the whole circuit is open circuit, so the signal CH1 is followed CH2. When diode conduction, the V_{BE} is following the V_{γ}. We could read that the CH2's voltage is not 0 volt ranter than 0.6 volt.

(b) If we add a voltage source V_{DC}, it will let V_{BE} in an expected range. In this experiment, we added a 3 volt's V_{DC}. It leads V_{BE} catch almost 3.6 volts.

(c) If we reverse diode, when current through A to E, it is diode cutoff, for whole circuit is opening, so the CH2 is following CH1. When diode is open, the voltage BE is voltage source V_{DC} plus V_{γ}.

The Pspice simulation result is shown in Figure 26, Figure 27 and Figure 28.

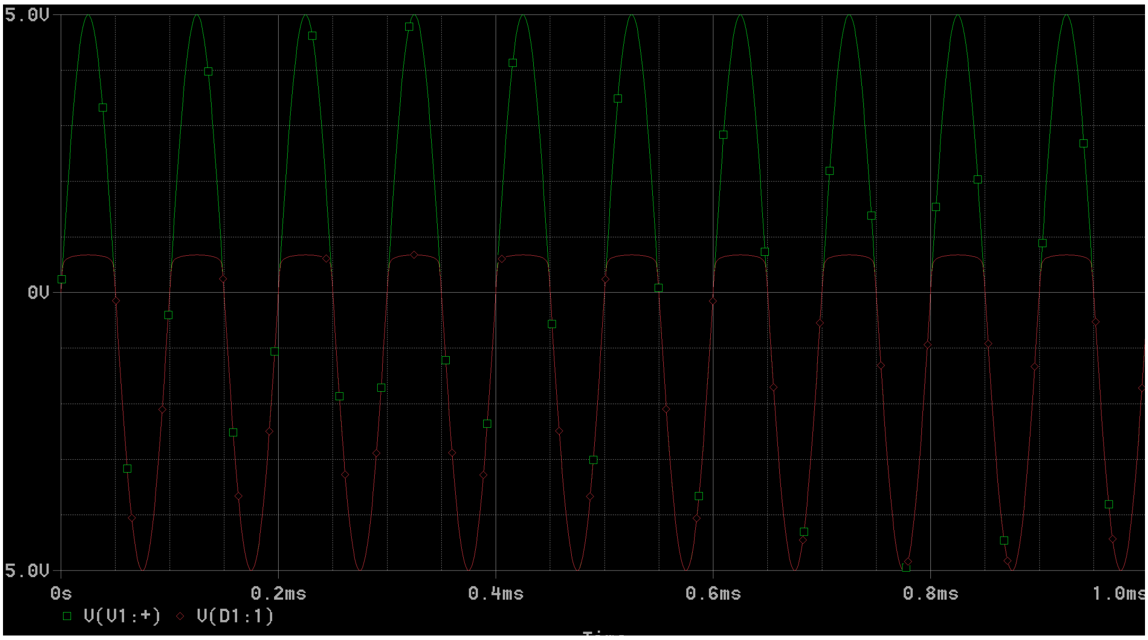


Figure 26: Pspice Simulation

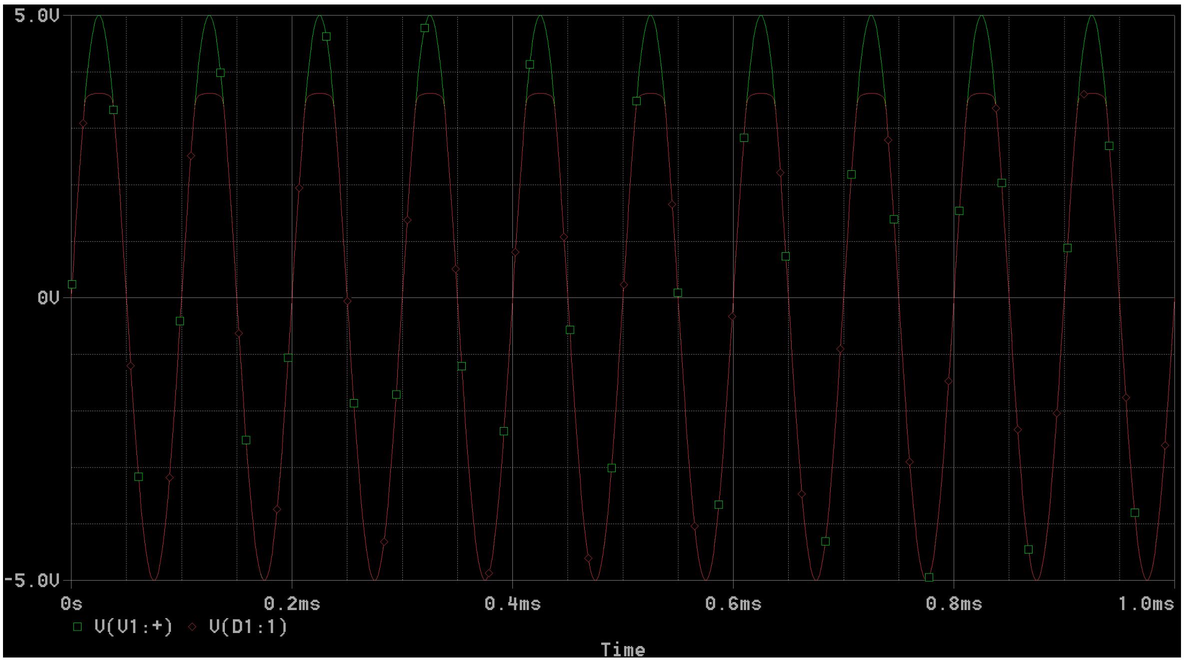


Figure 27: Pspice Simulation

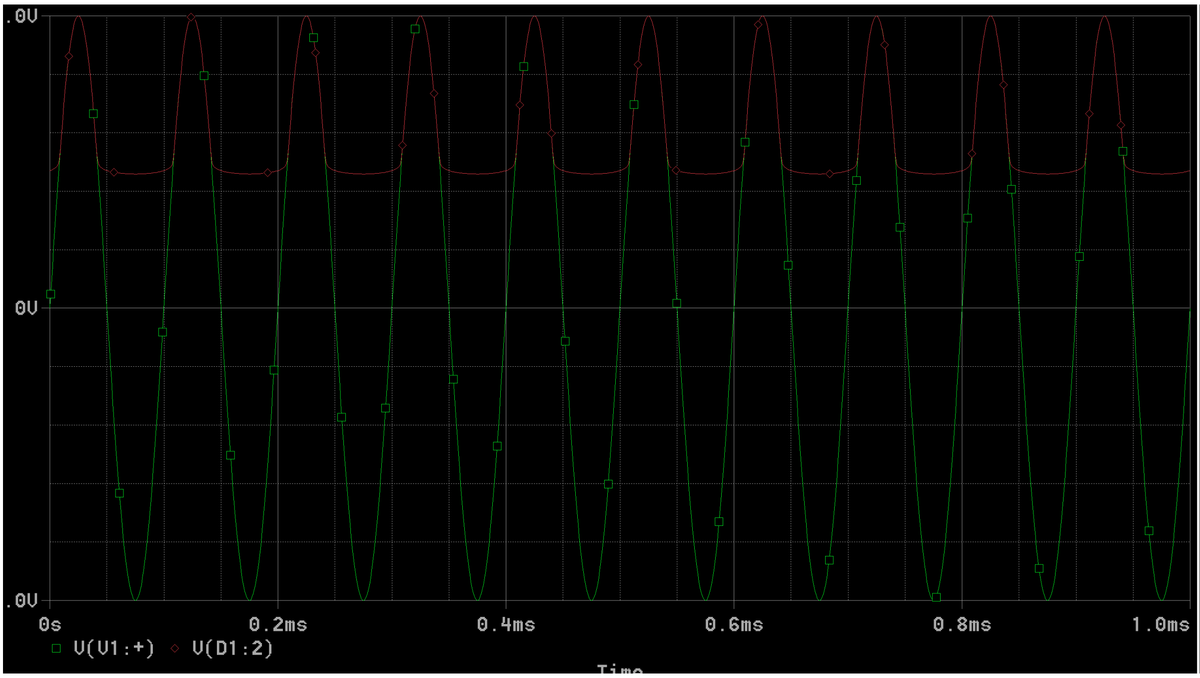


Figure 28: Pspice Simulation

D. Voltage Clamper

2.1d Introduction

By using diode and capacitor, voltage clamper is a way to let the output voltage rise or fall. The reason for it, it is because that it uses capacitor charging properties. The circuit is shown in Figure 29.

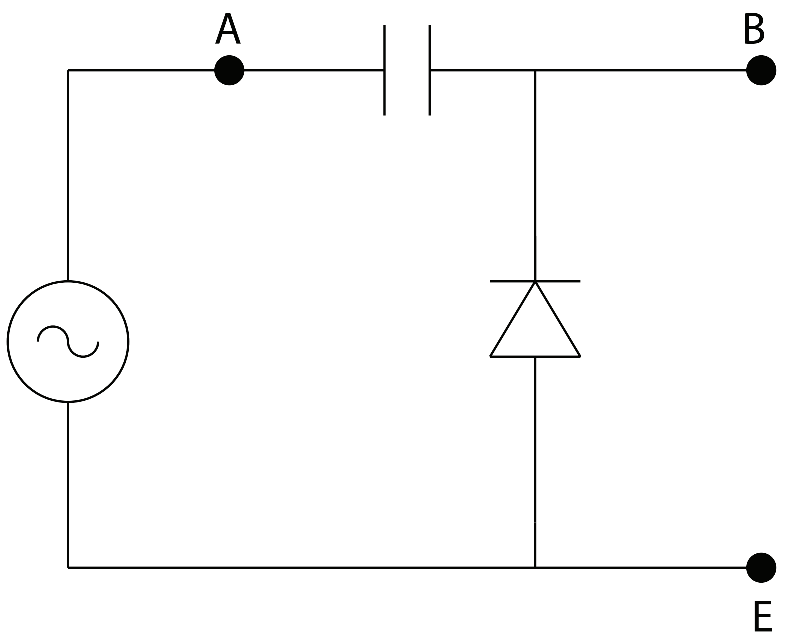


Figure 29: Voltage Clamper Circuit

2.2d Experiment Setup and Procedure

(a) Set signal generator to 10 volt peak to peak voltage firstly, and set the frequency to 10 kHz.

(b) Use 10nF's capacitor and build the circuit as shown in Figure 29.

(c) Measure V_{AE} for CH1, and V_{BE} for CH2.

(d) Reverse diode and measure again.

2.3d Experimental Data

(a) The experiment data is shown in the Figure 30 and Figure 31. The voltage is raised in 4.6 volt.

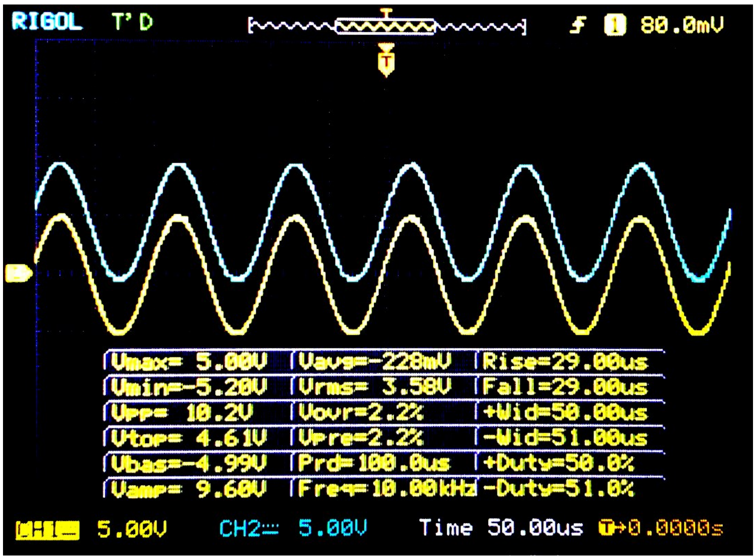


Figure 30: Result for Voltage Clamper (a) in CH1

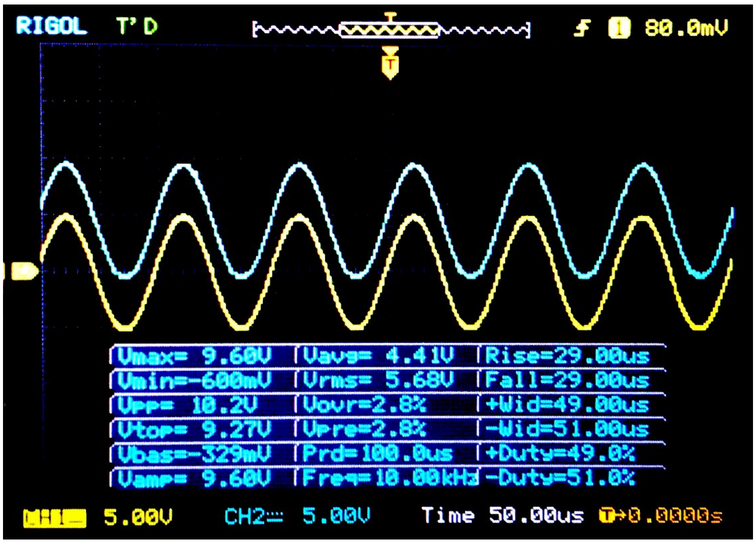


Figure 31: Result for Voltage Clamper (a) in CH2

(b) The experiment data is shown in the Figure 32 and Figure 33. The voltage declines in 4.6 volt.

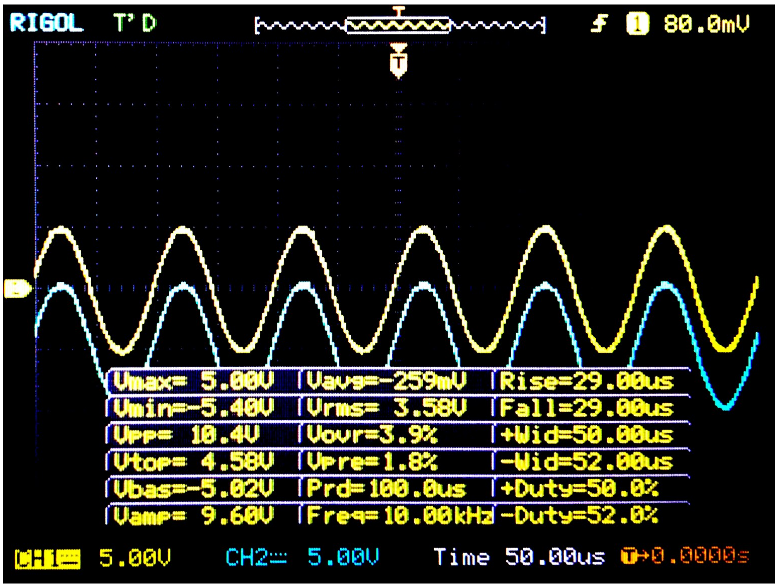


Figure 32: Result for Voltage Clamper (b) in CH1

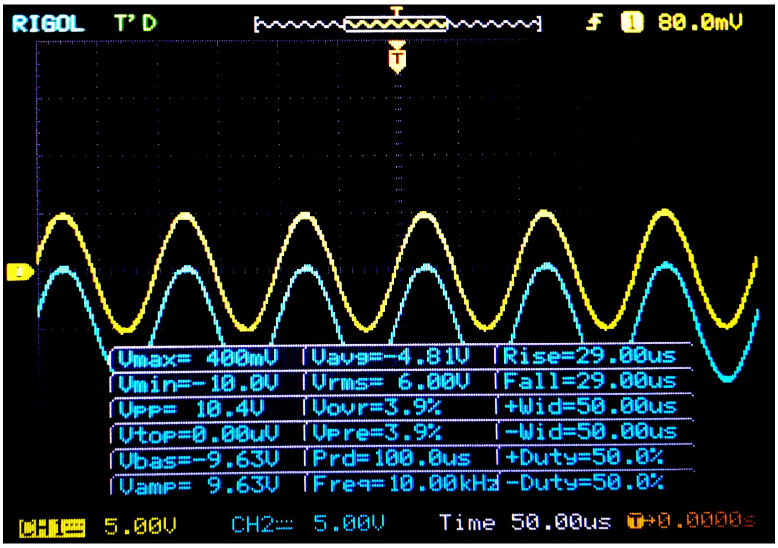


Figure 33: Result for Voltage Clamper (b) in CH2

2.4d Experiment Analysis

The reason for voltage clamper is both diode and capacitor. Under theoretical conditions, when the capacitor is over charging, the current is not flow out from the capacitor. We make an example for diode terminal reversed situation. We can use KVL for the circuit. For V_M is the maximum value power could supply or the maximum voltage of capacitor and V_0 is the voltage of diode. By using this way, we could find that the V_0 which is the CH2. The CH2 is cut off 1 for CH1.

$$V_s = V_c + V_0$$

$$V_0 = V_s - V_c$$

$$V_0 = V_M sin\omega t - V_M$$

$$V_0 = V_M(sin\omega t - 1)$$

If the diode terminal forward's like (a), the calculation formula is as follows.

$$V_0 = V_s + V_c$$

$$V_0 = V_M sin\omega t + V_M$$

$$V_0 = V_M(sin\omega t + 1)$$

E. Diode Logic

2.1e Introduction

Using the nature of diode on and off, we could build a circuit which give the input and give output logic 0 or logic 1. The AND circuit is shown in Figure 34.

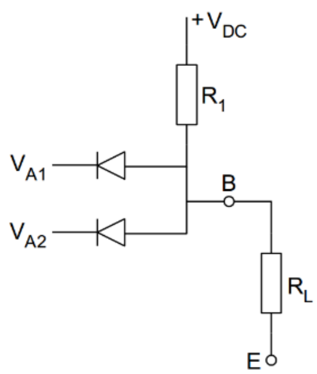


Figure 34: AND Logic Circuit

2.2e Experiment Setup and Procedure

(1) Set up circuit as Figure 34

(2) Give the V_{DC} to 5 volts

(3) Firstly, give V_{A1} and V_{A2} to 5 volts, then measure the output voltage V_{BE}

(4) Secondly, give V_{A1} 0 volt and V_{A2} to 5 volts, then measure the output voltage V_{BE}

(5) Thirdly, give V_{A1} 5 volt and V_{A2} to 0 volts, then measure the output voltage V_{BE}

(6) Fourthly, give both V_{A1} and V_{A2} to 0 volt, then measure the output voltage V_{BE}

2.3e Experimental Data

(1) The values of the output V_B which above value of V_{A1} and V_{A2} is shown in Table 3.

V_{A1}	V_{A2}	V_{BE}
5 V	5 V	4.10 V
0 V	5 V	0.64 V
5 V	0 V	0.63 V
0 V	0 V	0.64 V

Table 3: Output Result

(2) True table of logic is shown in Table 4.

V_{A1}	V_{A2}	V_{BE}
1	1	1
0	1	0
1	0	0
0	0	0

Table 4: Real Logic Output Result

2.4e Experiment Analysis

This experiment shows that this circuit is AND circuit. If we give the high voltage to both V_{A1} and V_{A2}, than we will get high voltage of output. If one of the two is low, then the output is low voltage.

F. Zener stabiliser
2.1f Introduction

Zener diode has a good reverse breakdown recovery characteristic. So the circuit which is called zenner stabiliser circuit. The circuit is shown in Figure 35. When zenner diode is reverse breakdown, the voltage of V_{BE} is constant.

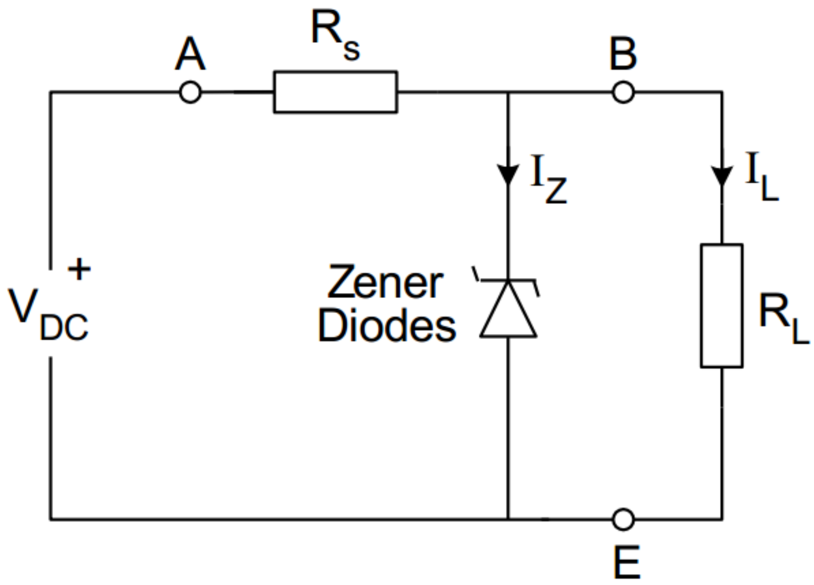


Figure 35: Zener stabiliser

2.2f Experiment Setup and Procedure

(1) Set R_L for an open circuit and vary V_{DC} from 0 to 20 volts in each 2 volts step, then measure V_B and V_{DC}.

(2) Set V_{DC} to 20 volts, and take four measurement of V_{BE} with R_L to 3.3 kΩ, 1.5 kΩ, 1 kΩ and 820 Ω, then calculate load current.

2.3f Experimental Data

The first result is shown in Table 4 and Figure 36.

V_{dc}	0	2	4	6	8	10	12	14	16	18	20
V_B	0.00	2.12	4.13	6.07	7.99	9.81	9.94	9.97	10.01	10.03	10.05

Table 4: Zener stabiliser's result

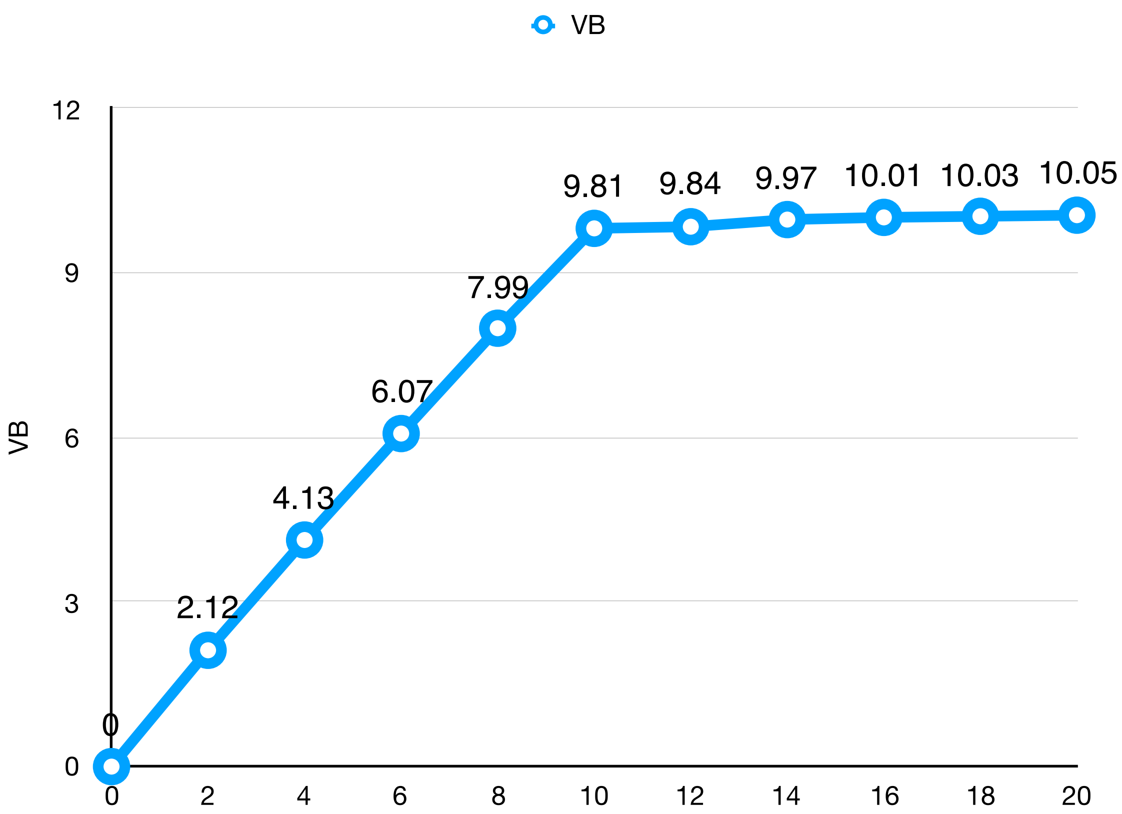


Figure 36: Zener stabiliser's result

V_{DC}

The second result is shown in Table 5 and Figure 37.

RL(Ohm)	3300	1500	1000	820
VB(V)	10.2V	10.14V	9.92V	8.89V
IL=VB/RL	3.09mA	6.75mA	9.86mA	11.1mA

Table 5: Zener stabiliser’s result part two

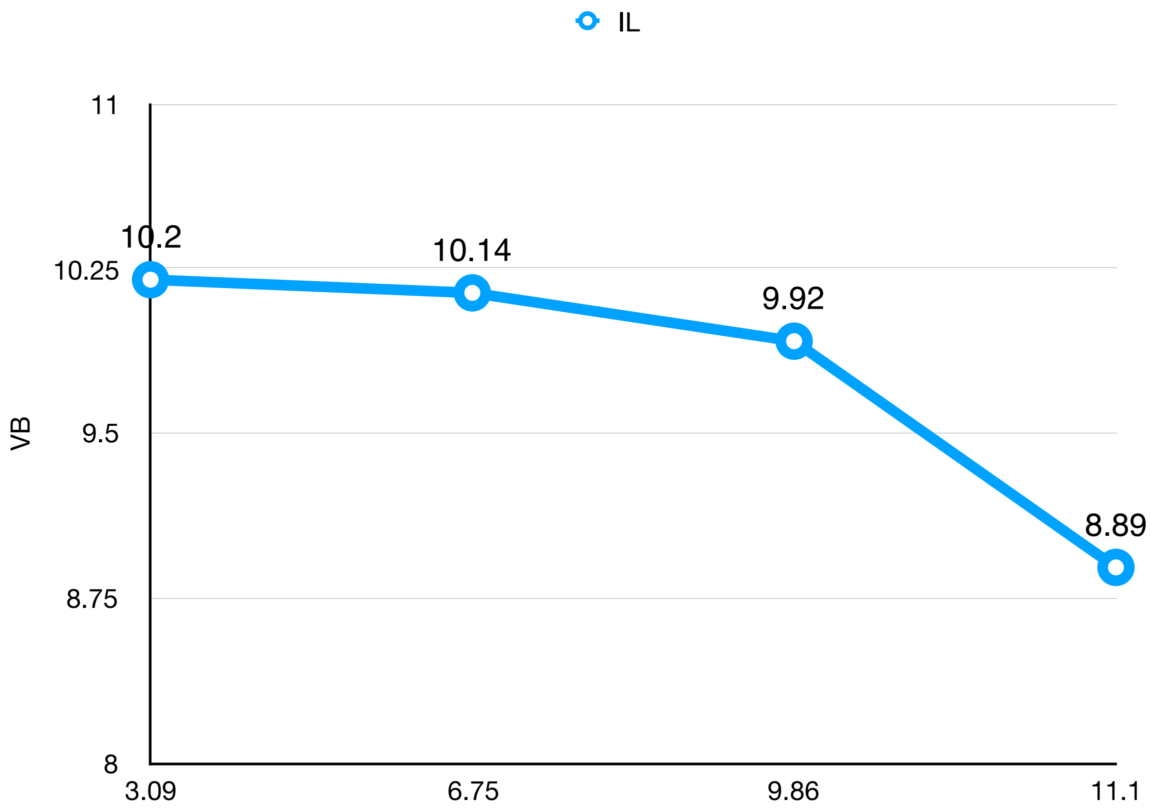


Figure 37: Zener stabiliser’s result part two

2.4f Experiment Analysis

By analysing experiments data, firstly, it is V_{DC} and V_B, when V_{DC} almost equals to 10 volts, the V_B is almost 10 volts. This is because the zenner diode's breakout voltages is almost 10 volts. For second part of result, more I_L lead V_B less.

G.Light-emitting diodes

2.1g Introduction

LED is a special diodes which could supply energy into light. The experiment circuit is shown in Figure 38.

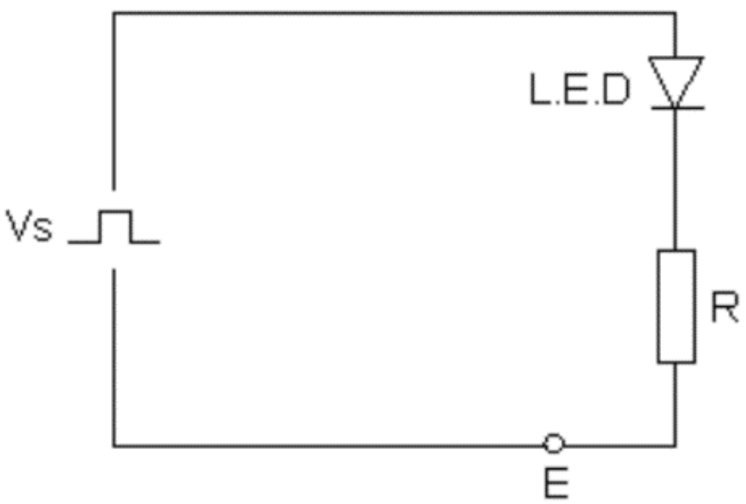


Figure 38: Optical Receiver

2.2g Experiment Setup and Procedure

Use signal generator to input 10 volt peak to peak square-wave and set it frequency to 2 Hz. Measure the voltage drop across the LED.

2.3g Experimental Data

The voltage of LED is shown in Figure 39.

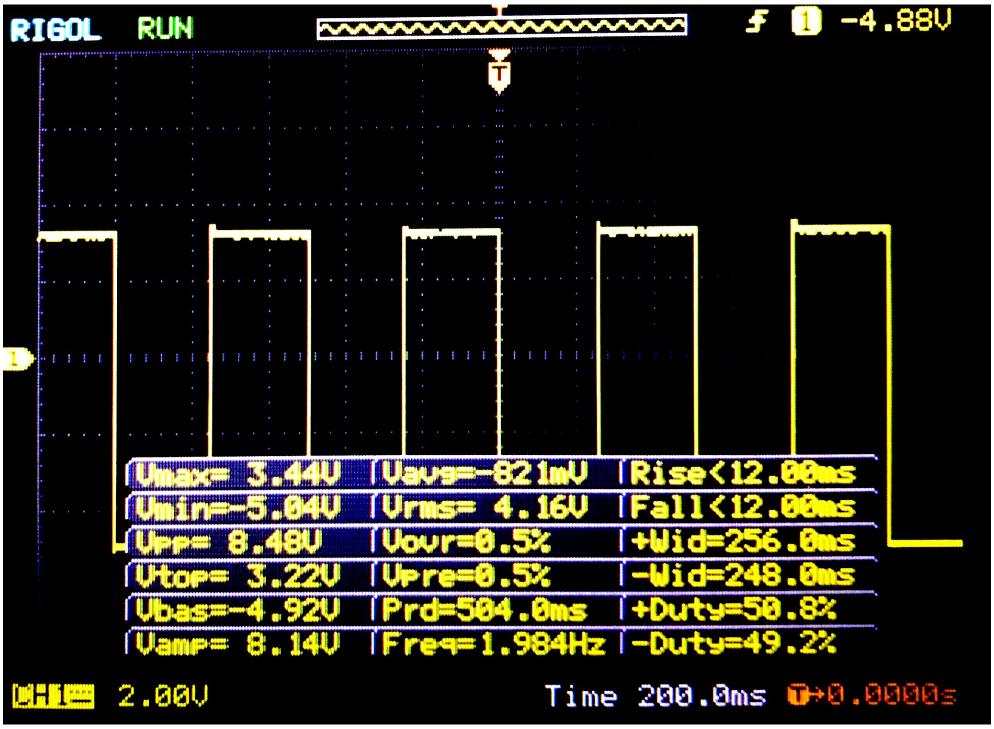


Figure 39: LED

2.4g Experiment Analysis

The LED's voltage when Square get to the maximum 5 volts is 1.52 volts. Compared with other diodes, LED's opening voltage is bigger than others.

3.Conclusions

3.1 Error Conclusion

For this experiment, error is a biggest problem needs to solve. For example, some errors had happened such as oscilloscope. My group forgot to calibrate oscilloscope before experiment. This things lead that all the value which measure from the oscilloscope is different from the theoretical value. So we test the device and eliminated the error. However, some system error such as multimeter happened in the experiment. Some problems such as contact is not tight, by measuring more times could reduce it happed.

3.2 Conclusion of the circuit

Because all if circuits is built up in the breadboard, some mistakes of building circuits happened in my experiment. For example, in the logic circuit, if we do not use public ground wire, the lines will let the circuits more complex. However, try to reduce the connection point could let the percentages of experiments higher.

3.3 Experimental summary

This experiment let me learn the application of diode， in summary, the vast majority of the nature for applications is using diode's power-off nature. Such as limiter, by leaning this, we could learned how to convert AC power to DC power.

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