

Unit 3: Diode circuits and DC Power

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INTRODUCTION

Semiconductor

Simiconductor is usually made by doping silicon with impurities so that to form n-type semiconductor, which have carriers as electrons, and p-type semiconductor, which have carriers as carriers as hole.

pn Junction

In the interface between two tpyes of semiconductor, a p-n junction is formed. In such interface, the carriers of two type of semiconductor are attract and form a electric field in the interface, which prevent more carriers been attract. When an external electric field been apply, if the external electric field is in the same direction of the interface electric field, it strengthen the interface electric field so that no charge can flow through the interface. On the other hand, if the external electric field is the opposite direction of interface electric field, it weak the interface electric field so that charge can flow freely along the electric field. However, in such casem a voltage drop of around 0.65V is happened in the p-n junction.

Diode

A diode can be form by a p-n junction with two types of semiconductor. The principle of a diode is the p-n junction. Thus, when voltage is larger than 0.65V, the diode is same as wire (with 0.65V voltage drop), and when voltage is smaller than 0.65V, it is a open circuit. In a very low voltage, it will allow charge to flow again, which is not discussed here.

Clipping Circuit

A clipping circuit can cut off the higher voltage or lower voltage. An example is as Figure 1. This circuit will cut off higher voltage. If the battery have voltage V_{cc} , than in the positive end of battery the we have voltage V_{cc} . If the diode allow current pass, than voltage on output would be $V_{cc} + V_d$, where V_d is the voltage drop on diode. We can find the current go through the resistor as

$$I = \frac{V_{in} - V_{cc} - V_d}{R}$$

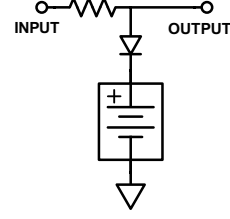


FIG. 1: Clipping circuit cut off higher voltage

On the other hand, if the diode does not allow current pass, that imply the voltage between the diode is smaller than V_d . Thus the Output have to smaller than $V_{cc} + V_d$. Thus, we have following equation:

$$V_{out} = \begin{cases} V_{in}, & \text{if } V_{in} < V_{cc} + V_d; \\ V_{cc} + V_d, & \text{if } V_{in} \geq V_{cc} + V_d \end{cases} \quad (1)$$

which cut off any voltage higher than $V_{cc} + V_d$. For example, if one wants to cut off the any voltage higher than 5.6V, we can use a 5V battery.

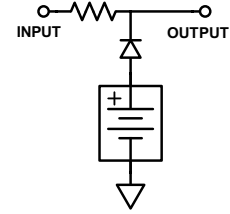


FIG. 2: Clipping circuit cut off lower voltage

In the other hand, we can reverse the diode to form a circuit such as Figure 2. This circuit will cut off lower voltage. The voltage in the positive end of battery again have to be V_{cc} . This means the voltage in the output is $V_{cc} - V_d$ when diode can go through current. If the diode cannot go through current, the output voltage have to higher than $V_{cc} - V_d$. Which suggest

$$V_{out} = \begin{cases} V_{in}, & \text{if } V_{in} > V_{cc} - V_d; \\ V_{cc} - V_d, & \text{if } V_{in} \leq V_{cc} - V_d \end{cases} \quad (2)$$

We can also use above two type of clipping circuit to form a circuit such as Figure 3. Such circuit will cut off higher and lower voltage. We can using Equation 1 and

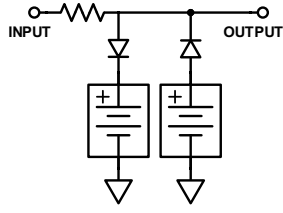


FIG. 3: Clipping circuit cut off higher and lower voltage

Equation 2 to find following

$$V_{\text{out}} = \begin{cases} V_{\text{cch}} + V_d, & \text{if } V_{\text{in}} \geq V_{\text{cch}} + V_d; \\ V_{\text{in}}, & \text{if } V_{\text{cch}} + V_d > V_{\text{in}} > V_{\text{ccl}} - V_d; \\ V_{\text{ccl}} - V_d, & \text{if } V_{\text{in}} \leq V_{\text{ccl}} - V_d \end{cases} \quad (3)$$

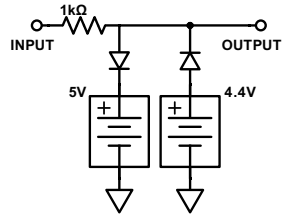


FIG. 4: An example of clipping circuit cut off higher and lower voltage

For example, if one wants to cut off any voltage higher than 5.6V, and any voltage lower than -5V, a 5V battery (for cut off high voltage) and a 4.4V battery (for cut off low voltage). Such as Figure 4.

Full Wave Rectifier

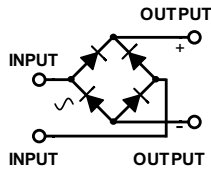


FIG. 5: Full Wave Rectifier

A full wave rectifier can transform a AC input voltage into a changing positive sign voltage. An example is as Figure 5. The incoming current can only go from positive to negative as labeled in the output port. When the current go through the full wave rectifier, we can see it will go through a diode. This means the output voltage dropped V_d .

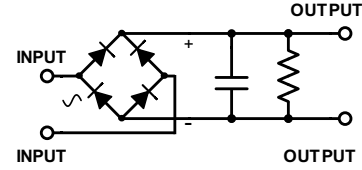


FIG. 6: Transform AC to DC

However, such full wave rectifier cannot provide a constant DC output. Thus, we want to smooth the output. A circuit such as Figure 6 can be used to do so. In such circuit, a RC circuit is connect to the output of rectifier. Once the capacitor is charged, it follows the voltage drop of a RC circuit:

$$V(t) = V_0 e^{-\frac{t}{RC}} \quad (4)$$

to drop voltage until it been charged again. This form a ripple around the peak of output of full wave rectifier. One can use the Equation 4 to find the ΔV of ripple. If the voltage dropped slow enough, that is to say, the recharge moment happened almost at the peak, the time that voltage can drop is $\frac{T}{2}$. Thus, using Equation 4, we find:

$$V\left(\frac{T}{2}\right) = V_0 e^{-\frac{T}{2RC}} \approx V_0 \left(1 - \frac{T}{2RC}\right)$$

This give us the ΔV as $V(0) - V\left(\frac{T}{2}\right)$:

$$\Delta V = \frac{V_0 T}{2RC} = \frac{V_0}{2RCf} \quad (5)$$

DATA AND CALCULATION

Diode

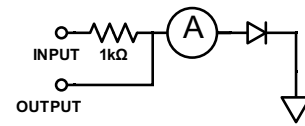
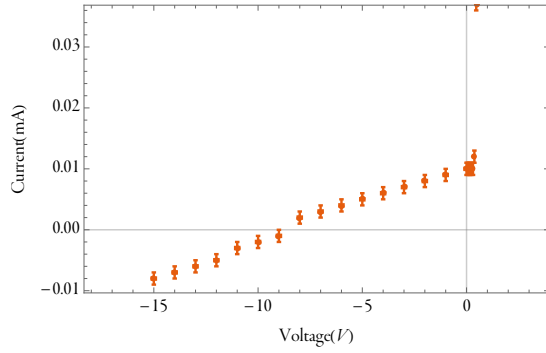


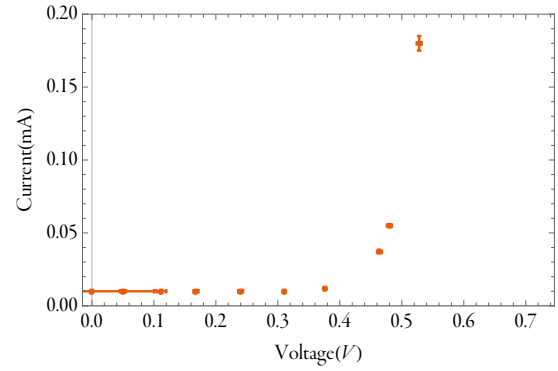
FIG. 7: Measure the I-V curve of a diode

To measure the I-V curve of a diode, we use a circuit as Figure 7. This resistor is used to protect the circuit. The data we obtained as appendix, error are from the minimum scale of the meter and the changing digit.

From the data, one can form a plot as Figure 8a. One may interested on the voltage is larger than 0 smaller than V_d , such as Figure 8b.



(a) All data point



(b) A close look

^a Some error bar on voltage and current are too small to see

^b Notice the error bar in this range are smaller than others. Some error bar on voltage and current are too small to see

FIG. 8: I-V curve of a diode

Clipping Circuit

One can make a clipping circuit so that the voltage higher than 5.6V are limited, such as Figure 9. To do so, one must follow Equation 1 to find the battery voltage.

$$\begin{aligned} V_{cc} &= V_{cut} - V_d \\ &= 5.6V - 0.6V \\ &= 5V \end{aligned}$$

We assume the voltage drop on the diode is 0.6V. Therefore, to cut off voltage higher than 5.6V, one has to use a 5V battery.

The output of the circuit is as Figure 10.

Full-Wave Rectifier

A 9.800(5)V and 60.00(5)Hz AC input voltage are given, to make a full-wave rectifier such that the ripple

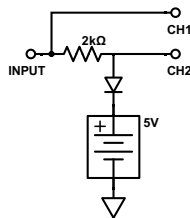


FIG. 9: Clipping circuit used in lab

is around 0.5V, one must use the Equation 5.

$$\begin{aligned} \Delta V &= \frac{V_0}{2RCf} \\ RC &= \frac{V_0}{2f\Delta V} \\ &= \frac{9.8V}{2 \times 60\text{Hz} \times 0.5V} \\ &= 0.1633 \end{aligned}$$

Thus, the value of RC could be 0.1633ΩF. In this lab, a 103(1)μF capacitor and a 1.50(5)kΩ resistor are used.

Thus, one can form a circuit as Figure 11. The output of the circuit is as Figure 12. Notice that the output zero voltage line is below the screen.

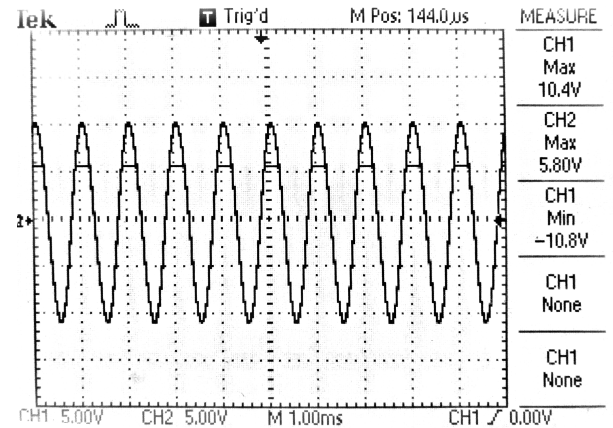


FIG. 10: Output of clipping circuit

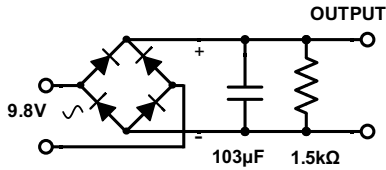


FIG. 11: Full-Wave Rectifier used in lab

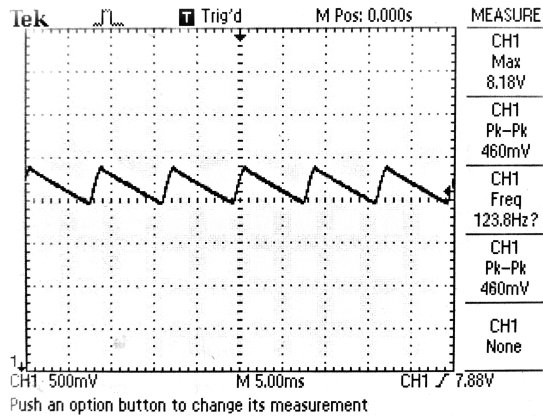


FIG. 12: Ouput of Full-Wave Rectifier

ANALYSIS

Diode

The result is reasonable. The curve blow up after around 0.6V, which is reasonable for a diode. when voltage is smaller and negtive, the current is small and almost zero.

When voltage is negative, at some point, the current is larger than zero, which is not very reasonable. That might due to the background noisy voltage.

Clipping Circuit

The output of the circuit is reasonable. It is indeed a clipping circuit that cut off higher voltage.

We see the output have maxumum voltage 5.8, which is higher than 5.6V. The diode used in this circuit could have a higher V_d . One can use a better diode to achive a better result.

Full-Wave Rectifier

The result is reasonable. We obtained a circuit such taht the ripple is around 0.5V. It is almost a DC output.

CONCLUSION

The reusult of this lab is reasonable. The only part interesting is when measure the I-V curve of a diode, it gives a positive current when voltage are negative, which might due to the background noisy voltage.

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