

EXPERIMENT 1

SEMICONDUCTOR DIODES IN BASIC APPLICATIONS

I. OBJECTIVES

-To construct rectifier and wave-shaping circuits based on diodes.

Laboratory dressing requirements: shoes must hold the ankle. It means no flip flops

II. THEORY

2.1 Introduction

A semiconductor diode is a non-linear device, which behaves as a small resistance in its forward direction and acts as a large resistance in its reverse direction. This is displayed in the Volt-Ampere (V-I) characteristic which is a graph of current vs. voltage for a diode. By linearizing the V-I characteristic, a diode circuit model is obtained known as a *piecewise linear model*. Diodes are used in a number of rectifier and wave-shaping circuits.

2.2 Circuit applications of conventional diodes

Conventional diodes can be divided into two groups as follows:

1) Signal diodes; and 2) Power diodes.

Signal diodes are generally used in low-voltage and low-current applications where speed and a large backward-to-forward resistance ratio are of significant importance (i.e., wave-shaping circuits). Their packages are generally the size of a quarter-watt resistor and are made of glass, ceramic, or plastic. Surface mount components are commonly used in modern circuits.

On the other hand, power diode applications are generally limited to the various rectifier circuits. Their function is to convert AC power to DC power. The more important characteristics of the power diodes are their ability to withstand large currents, dissipate power, and withstand large peak inverse voltages. Power diodes are generally made of plastic or metal, and package size varies dramatically with the current carrying and power dissipation capability of the diode.

2.3 Diode rectifier circuits

Making use of the diodes conduction in only one direction, a rectifier circuit can be designed. In electronic designs, rectifier circuits are very important since most equipment work on DC voltage, thus it is necessary to convert AC voltage to DC voltage.

The basic half-wave rectifier circuit is shown in Figure 1. The input signal V_{in} to the rectifier is assumed to be a purely AC signal with a time-average value of zero. Since current passes through an ideal diode only when the input signal is positive, the output signal V_{out} across the load resistor will be as shown below. In the case of an ideal diode, this signal does not depend at

all on the size of the load resistor and obviously it is exactly the top half of the input voltage signal V_{in} . The rectified output signal is now a combination of an AC signal and a DC component. Generally, it is the DC part of the rectified signal that is of interest, and the undesired AC component is described as ripple. Furthermore, the pulsating DC output signal can be made steady by means of a smoothing circuit. The quality of a rectifier circuit is measured by its ripple-factor which is defined as,

$$ripple\ factor = \frac{RMS\ value\ of\ output\ ac\ component}{dc\ output\ voltage}$$

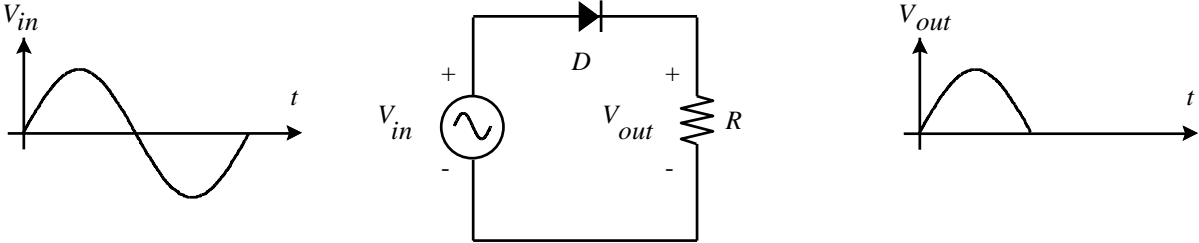


Figure 1: Half-wave rectifier circuit and respective waveforms

In power supply applications, it is common to use a transformer to isolate the power supply from the high voltage (typically 110V) AC line. A half-wave rectifier can be connected to the transformer secondary as shown in Figure 2 to generate the typical half-wave output signal as discussed before. The half-wave rectifier circuit produces an output signal whose fundamental frequency is the same as the input AC signal.

By employing a transformer with a center tap in combination with a second diode, it is possible to produce a full-wave rectifier as shown in Figure 3. This circuit produces the signal shown; both the positive and negative halves of the AC waveform now appear across the load resistor. This rectifier waveform has a fundamental frequency that is twice that of the corresponding half-wave rectifier, moving the ripple to a higher frequency where it is easier to remove by a low-pass filtering process. When a center-tapped transformer is not available, the bridge circuit of Figure 4 will also act as a full wave rectifier. The diode bridge is a commonly used circuit and is available as a four-terminal component in a number of different power and voltage ratings.

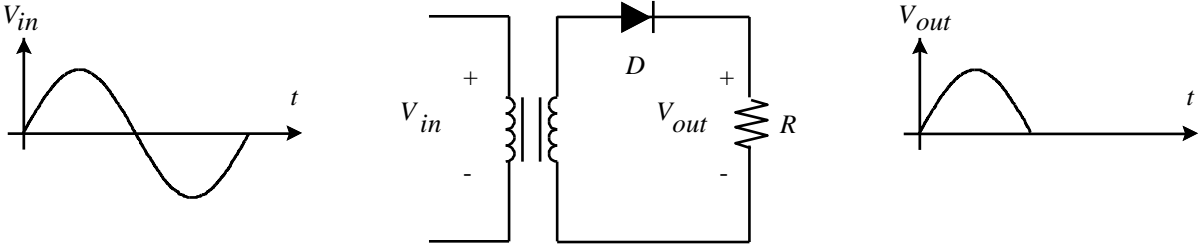


Figure 2: Half-wave rectifier circuit using a transformer

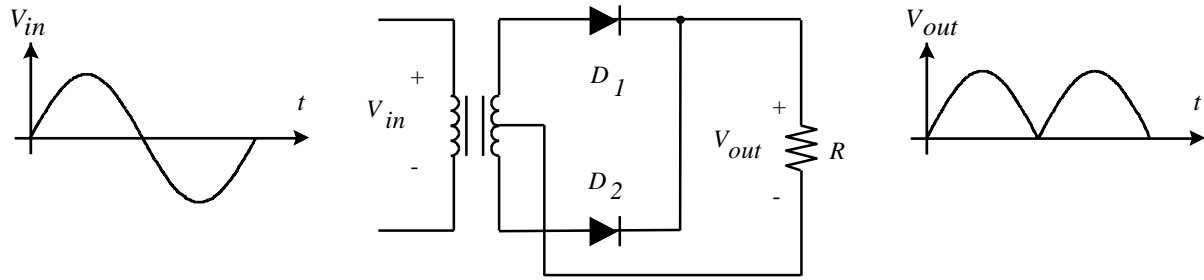


Figure 3: Full-wave rectifier circuit using a center-tapped transformer

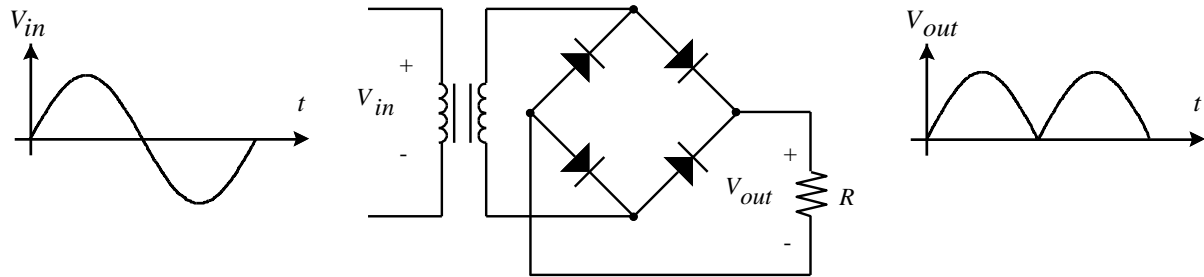


Figure 4: Full-wave rectifier using the bridge circuit

2.4 Inductive surge suppression

One important use of diodes is to suppress the voltage surge present when an inductive load is switched out of a circuit. Figure 5 shows the respective circuit arrangement. In the absence of the diode shown, the current in the inductor would generate a large transient voltage across the switch whenever it is turned off. The voltage spike can be large enough to destroy a solid state transistor switch. When the switch is turned on, the diode does not conduct since it would be reverse biased. However, when the switch is turned off, the diode provides an alternative path for the inductor current, and the inductor will not develop a voltage higher than the forward voltage drop across the diode.

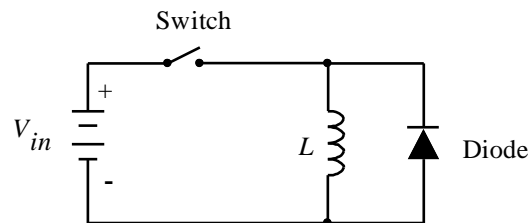


Figure 5: Diode inductive surge suppression in switching circuit

2.5 Diode clipper circuits

A clipper is a circuit in which the output of an input sinusoidal (or any time-dependent signal) waveform can be clipped at different levels. A clipping circuit requires at least two fundamental

components, a diode and a resistor. A DC battery, however, is also frequently used. The output waveform can be clipped at different levels simply by interchanging the position of the various elements and changing the magnitude of the DC battery. Generally, ideal diodes are considered and the complete analysis can be based on non-ideal diodes with specific V-I characteristic.

For networks of this type, it is often helpful to consider particular instants of the time-varying input signal to determine the state of the diode (ON or OFF). Keep in mind that even though the input varies, at a specific time instant this time varying signal can be replaced by a DC source of the same value. Figure 6 shows examples of various clipping circuits. Please note that the input to all circuits is a sinusoidal waveform.

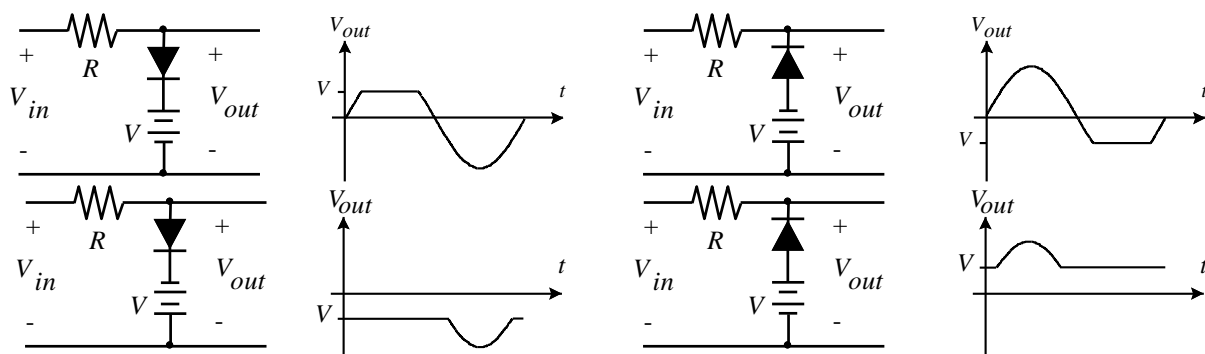


Figure 6: Clipping circuits

For two circuits on the left, the maximum output voltage is clipped at $V_{out} = V$. (Ideal diode)
 For two circuits on the right the minimum output voltage is clipped at $V_{out} = -V$. (Ideal diode)
 For a non-ideal diode, maximum or minimum output voltage is $V_{out} = V + V_d$, or $-V - V_d$ where V_d is the voltage drop across the diode.

2.6 Diode clamper circuits

A clamper is a circuit which will add or subtract a DC component from any input voltage. The clamping circuit has a minimum requirement of three elements: a diode, a capacitor, and a resistor. The clamping circuit may also include a DC battery. The magnitude of R and C must be chosen such that the time constant $\tau = R \cdot C$ is large enough to ensure that the voltage across the capacitor does not change significantly during the interval of time, determined by the input, that both R and C affect the output waveform. It is usually advantageous when examining clamping circuits to first consider the conditions that exist when the input is such that the diode is forward-biased. Figure 7 shows examples of various clamping circuits and their output waveforms. Note that the input is a square wave with peak-to-peak value of 2V. The peak-to-peak value of all the output waveforms is always 2V but the waveforms are shifted depending on the dc-biasing of the circuits.

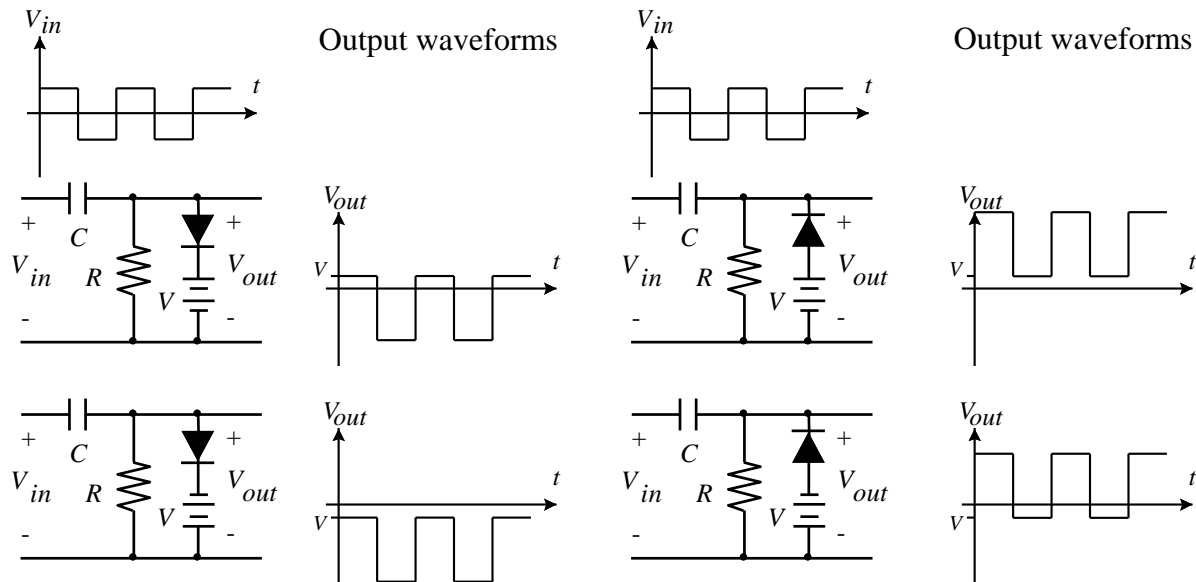


Figure 7: Clamping circuits

III. Pre-Lab Exercise

1. Familiarisation with datasheets

- Obtain a datasheet for 1N4004 diode. You can use a simple search for “1N4004 datasheet” or, better, go to www.digikey.ca and run a search by the part number. The latter will yield a few different datasheets – there are a few manufacturers that make 1N4004.
- Insert Table 3 from Appendix 1 to your lab report and fill it in.
- Compare the characteristics of the same part produced by different companies. What conclusion can you make?
- Compare the information available in the datasheets from different companies. Share your observation on quality of datasheets.

2. Sketch a half-wave rectifier circuit and then draw the output for an input that is sinusoidal.

3. Design and draw a circuit that clamps at $+2V$ a signal with the following parameters:

- $F = 1 \text{ KHz}$
- Square wave
- $V_{p-p} = 10 \text{ V}$
- $V_{off} = 0 \text{ V}$

The circuit must comply with IEEE315 or IEC60617 standard. In other words, the minimum of the output should be at $2V$.

4. Fill in theoretical values in the Table 1.

IV. EXPERIMENTAL PROCEDURE

1. Rectifier circuits

a) Connect the half-wave rectifier of Fig. 8(a) with a suitable R_L and the diode 1N4004. Determine R_L so that you get a peak-to-peak current of 10 mA for a sinusoidal input signal (V_{in}) of 10 V peak to peak with a frequency of 1 kHz. Sketch the output V_{out} and input V_{in} for one complete cycle.

b) Repeat (a) using the circuit of Fig. 8(b).

Fill out the following data-table. Assume a voltage drop across the diode of 0.7V for theoretical calculations.

Table 1: Diode experiment

	DC value of V_{out}	RMS value of V_{out}	Ripple Factor
Theoretical values for Fig. 8(a)			
Experimental values for Fig. 8(a)			
Theoretical values for Fig. 8(b)			
Experimental values for Fig. 8(b)			

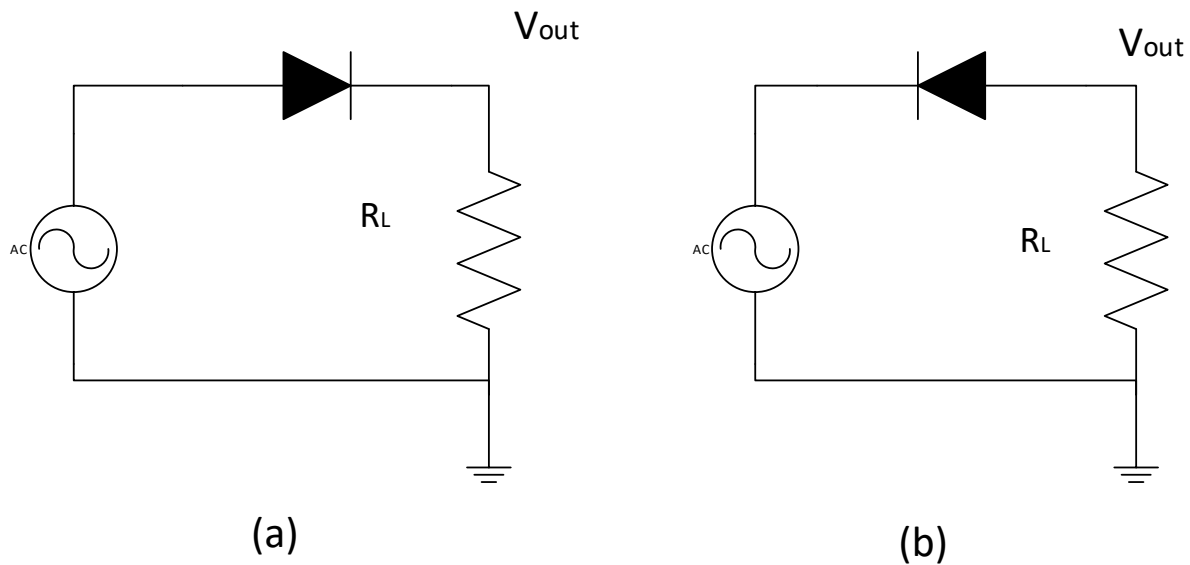


Fig. 8

2. Limiting Circuits

a) You have a sinusoidal input which is 1 KHz and 16V peak-to-peak. Design a circuit that would limit the output to a maximum of 5V on the positive cycle and a minimum of 3V on the negative cycle. Test your circuit. Sketch the output.

b) Assemble the circuit in Fig. 9 with V_{in} as a DC source. You need to vary V_{in} from -8 to 8V in the steps of 2V. Using “5V-fixed” terminals of the other power supply (the black one) make $V_1=5V$. Use the other variable DC terminal to make $V_2=4V$. Measure the output (V_{out}). Fill out the table below and draw the relationship between V_{in} and V_{out} .

Table 2: Voltage limiting circuit result

V_{in} (V)	-8	-6	-4	-2	0	2	4	6	8
V_{out} (V)									

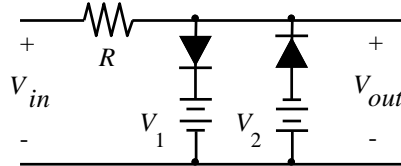


Fig. 9

3. CLAMPING CIRCUITS

- Connect the circuit of fig. 10 with $C=22\ \mu\text{F}$, $R=300\text{K}\Omega$, and voltage $V=0$.
- Apply a square wave input signal of 14 V peak to peak at a frequency of 1 kHz.
- Use the DC-Coupling on the oscilloscope and sketch the output V_{out} and input V_{in} .
- Set the value of V to 7 volts and repeat steps a-c. Compare the results of steps c), and d).

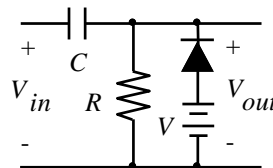


Fig. 10

- e) If the diode was considered an ideal diode, what would be the clamping voltages for $V=0$ and $V=7V$.

V. QUESTIONS AND DISCUSSION

1. How would you identify the anode of an unmarked diode using a DMM?
2. Under what conditions will a diode turn-on? Explain.
3. Why is the output peak voltage (Fig.8a) lower than the input peak voltage?
4. How much power is dissipated in R_L (Fig.8a)?
5. Explain how the clamping circuit adds or subtracts a DC component to an input voltage.
6. What will happen to the diode if you apply a forward voltage of $V_F=1.2V$. Explain your answer.

Appendix 1

Table 3: 1N4004 Absolute maximum parameters vs. manufacturer

SYMBOL	Parameter	Test conditions	Value				Unit
			Vishay	Fairchild	Diodes incorporated	ON Semiconductor	
V_{RRM}							
V_{RMS}							
V_{DC}							
$I_{F(AV)}$							
I_{FSM}							
$I_{R(AV)}$							
$I^2t^{(1)}$							
T_J, T_{STG}							
P_D							