

## EXPERIMENT 2

### ZENER DIODE IN BASIC APPLICATIONS AND BRIDGE RECTIFIER

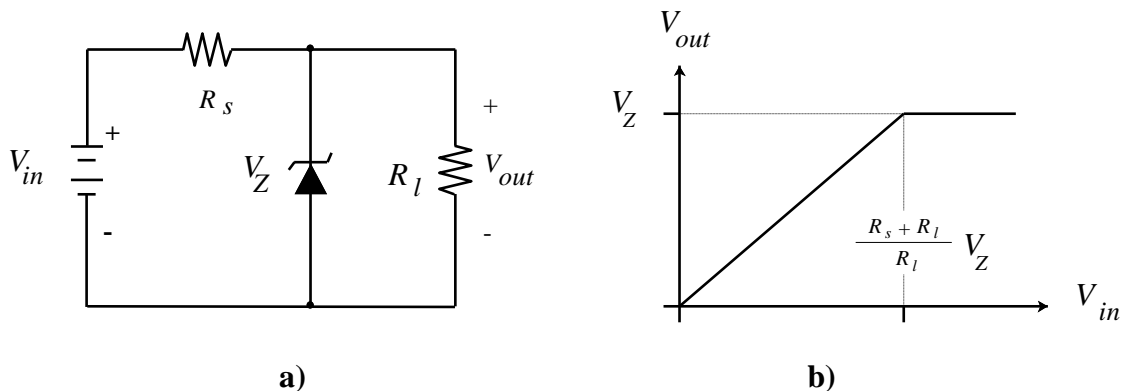
#### I. OBJECTIVES

- To analyze Zener diode circuits
- To study a bridge rectifier and its use with filter capacitor (Reference: Sedra and Smith; chapter 4)

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

#### II (a) Zener diode

A diode which is different from the conventional semiconductor diode is the *Zener diode*. The Zener diode's forward-biased characteristic is the same as that of a conventional diode. But, the reverse bias characteristic is the same as an ordinary diode up to a specific value known as the *Zener voltage*. An attempt to increase the reverse bias voltage beyond the Zener voltage results only in an increase in the reverse current and the diode voltage tends to remain constant ( see Fig.1).



**Fig. 1:** Zener diode application. **a)** Circuit. **b)** Ideal transfer characteristic.

The I-V characteristic of a Zener Diode is shown in Fig. 2. In the forward bias region, it is very similar to an ordinary diode (p-n junction). In the reverse bias region, there is Zener breakdown which limits the voltage to  $V_Z$ . The operating region shown in Fig. 2 is where voltage regulation is effective. In other words, the output would be limited to  $V_Z$  even if input exceeds it. At any point in the operating range, an incremental resistance  $r_z$  can be defined as follows.

$$r_z = \Delta V / \Delta I \quad (1)$$

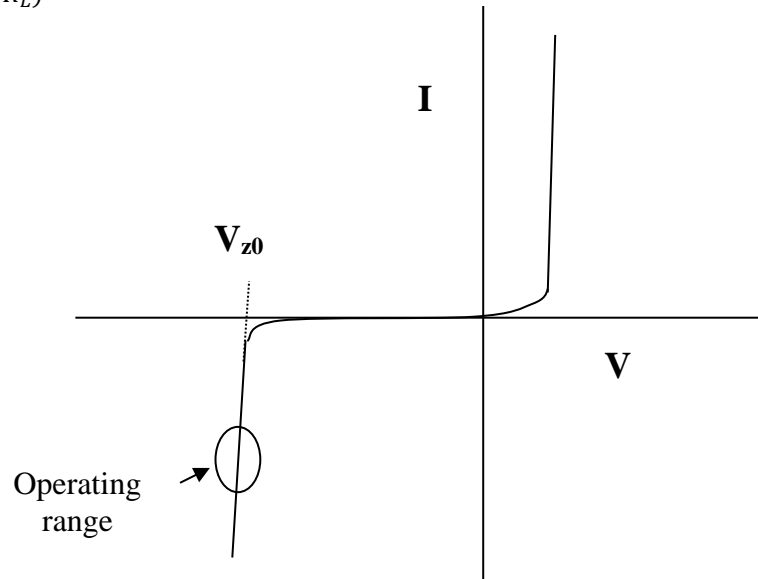
Here  $\Delta V$  and  $\Delta I$  are voltage and current change in the operating region respectively. The value of  $r_z$  can readily be obtained from the slope in the operating region. Another quantity of interest is line regulation which essentially tells us as to how effective the regulator is, in limiting the output voltage to  $V_Z$  and eliminating the ripple or noise. It is defined as follows.

$$\text{Line Regulation} = \Delta V_o / \Delta V_{in} \quad (2)$$

Here,  $\Delta V_o$  and  $\Delta V_{in}$  are fluctuation in output and input voltage respectively. See figure 4. One can measure these two quantities and then determine line regulation. A theoretical analysis gives the following expression for line regulation.

$$\text{Line Regulation} = \frac{r_z}{r_z + R_S} \quad (3)$$

Here  $r_z$  is defined in equation (1) and  $R_S$  is shown in Fig.1. If there is load attached to the output then  $r_z$  should be replaced by  $\frac{r_z \times R_L}{(r_z + R_L)}$ . Here  $R_L$  is the load.



**Figure 2**

### **III Pre-lab Exercises:**

1. Draw the model for Zener diode.
2. Why is it necessary to put resistor R in Fig. 4?
3. From the datasheet of Zener diode 1N4732A, obtain the typical breakdown voltage.
4. Explain how the bridge-rectifier circuit works.
5. Obtain the maximum RMS voltage that can be applied to DF01M chip at  $T=25$  C. Find this information from the datasheet of this chip.

### **IV Experimental work using Zener Diode (diode characteristics)**

In this experiment we would use the following 3 components,  $1K\Omega$ ,  $100\Omega$ , and a Zener Diode (1N4732A). Assemble the circuit as shown below.

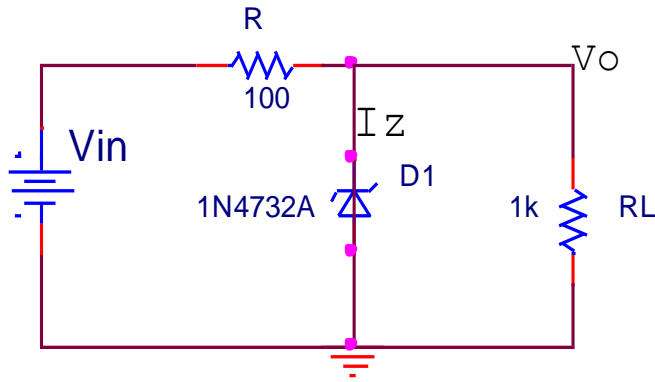


Fig.3- Reverse Bias Configuration

Change  $V_{in}$  and measure  $I_z$  and  $V_o$ . Please make **sure that  $I_z$  doesn't exceed 50 mA**. You may fill in the table below. For theoretical calculation use the information from the datasheet for the breakdown voltage. Also you may ignore  $R_L$  for  $V_{in} > 4.5V$ .

$V_{in}(V)$	2	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
Theoretical $V_o(V)$																
Theoretical $I_z(mA)$																
Experimental $V_o(V)$																
Experimental $I_z(mA)$																

From the experimental values in the table determine breakdown voltage  $V_{z0}$ . See figure 2. Draw  $I - V$  curve in the reverse-bias condition. From this curve determine  $V_{z0}$  and  $r_z$ .

### V Voltage Regulation using Zener Diode-

The purpose of this exercise is to see how effective a Zener diode as a regulator is. Please assemble the circuit as below.

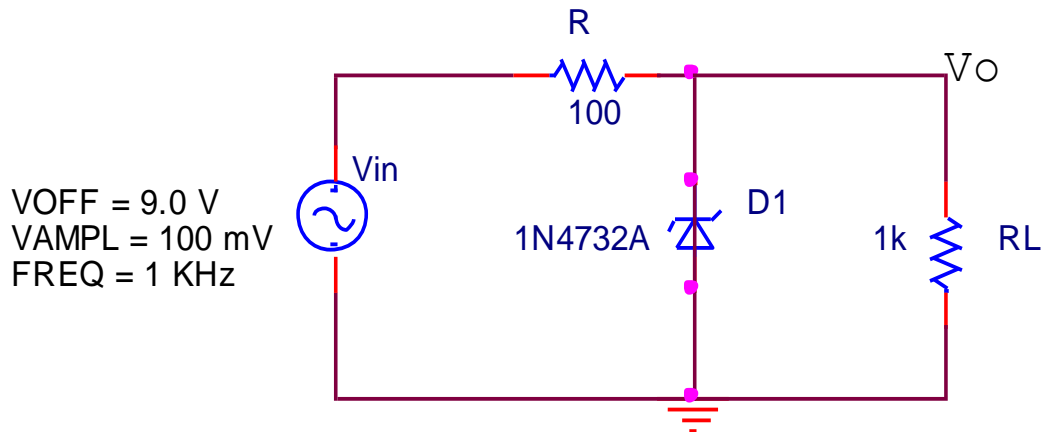


Fig. 4-Voltage Regulation

For voltage supply, use the function generator. You need to provide VOFF so that the diode is in the operating region as shown in Fig.2. You can use the option Voffset in the function generator (FG) to get this value. In figure 4, VOFF is shown to be 9V which may be good for your purpose. The sinusoidal part in  $V_{in}$  (100 mV) is supposed to be the noise that needs to be eliminated. It is same as  $\Delta V_{in}$  in Eqn. (2). Using the suitable tools measure  $V_Z$ ,  $\Delta V_{in}$ , and  $\Delta V_o$ . Fill out the table below.

$V_Z$	$\Delta V_{in}$	$\Delta V_o$	Line Regulation using Eqn. (2)	Line Regulation using Eqn. (3)

For line regulation using Eqn. (3), you would need the value of  $r_z$  obtained in the previous section.

## VI. BRIDGE RECTIFIER AND RECTIFIER WITH FILTER CAPACITOR

We want to convert ac voltage into dc using bridge rectifier circuit and measure ripple voltage. Subsequently, we would reduce the ripple voltage by putting a suitable capacitor in parallel with the resistor. The theoretical values of ripple voltage ( $V_r$ ), dc (average) value of the output ( $V_o$ ) and conduction angle ( $\Delta t$ ) would be compared to theoretical and experimental result.

**VII. Theory** – A bridge rectifier circuit, shown in Fig. 5 below rectifies ac into a dc voltage. In the positive cycle of the waveform, diodes  $D_1$  and  $D_2$  conduct. In the negative cycle of the waveform, diodes  $D_3$  and  $D_4$  conduct. The output  $V_o$  is measured across  $R$ . However there are two limitations.

- The ripple voltage is large.
- The mean value of the signal is (dc value) is reduced by almost half.

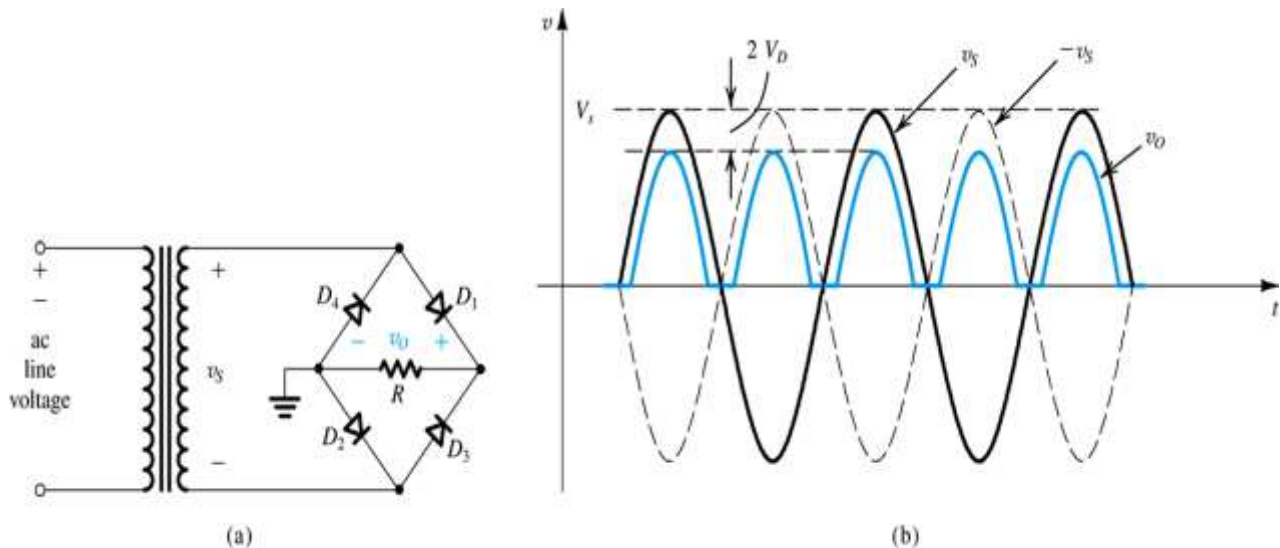


Fig. 5(a) – A bridge rectifier circuit, (b) Input and output waveform

For example if the amplitude of the AC signal is  $V_s$ , then the ripple voltage is given by the relation,

$$V_r = V_s - 2V_D \quad (4)$$

The dc component is given by the relation  $V_o = (2/\pi) V_s - 2V_D$  (5)

Here  $V_D$  is the typical diode drop of about 0.7V. In order to reduce  $V_r$  and increase  $V_o$ , usually a capacitor is attached in parallel with R. Fig. 8 shows this circuit. Assume that the time-period of the signal is T.

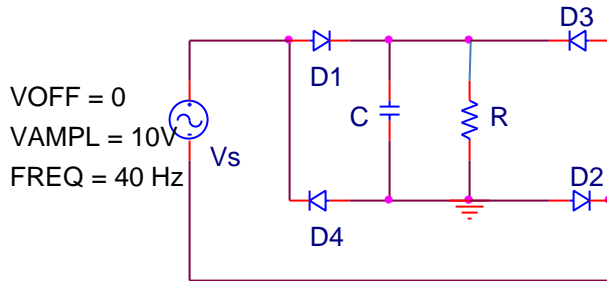


Fig. 6 - Bridge rectifier with filter capacitor  
For  $CR \gg T/2$ , Equations (4) and (5) change to the following.

$$V_r = \frac{V_s}{2fCR} \tag{6}$$

$$V_o = V_s - \frac{V_r}{2} \tag{7}$$

Furthermore, the conduction angle is given by  $\Delta t = \frac{\sqrt{2V_r/V_s}}{2\pi f}$  (8)

The circuit below is a bridge rectifier which you will assemble and test in this lab.

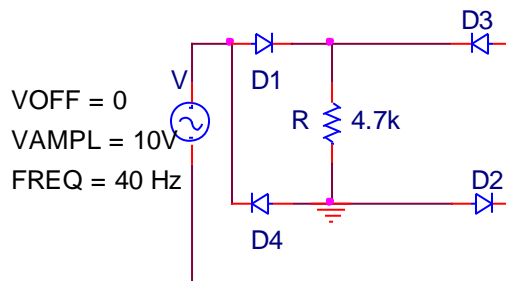


Fig. 7 Bridge rectifier circuit

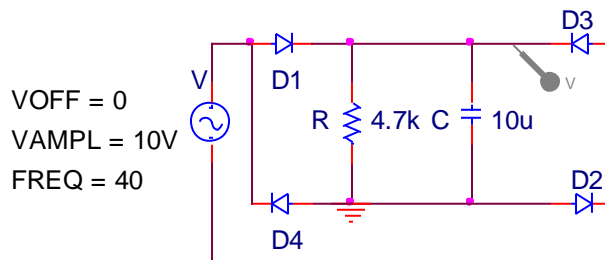


Fig. 8 Bridge rectifier circuit with filter capacitor

**VIII Experimental Work** – The chip DF01M is shown below. It consists of 4 diodes arranged in such a manner that it is a bridge-rectifier. This chip is shown in Fig. 9. The two points denoted by

tilde (~) are meant for applying ac signal. The other two points shown as ‘+’ and ‘-‘ are meant for load (R<sub>L</sub> and C).

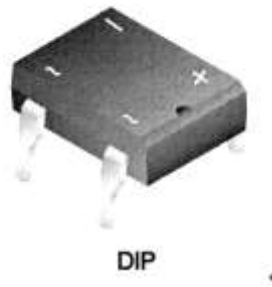


Fig. 9 Bridge-rectifier chip

Follow the procedure given below.

1. Assemble the circuit in Fig 7 using chip shown above. The Function generator (FG) should have an amplitude and frequency shown in Fig. 7 and applied to the two terminals denoted by tilde (~). Observe the output and verify that the output has a peak  $V_p - 2V_D$ . Don't try to observe input and output simultaneously on the oscilloscope as this creates a grounding loop and thus introduces error.
2. Attach a 10 $\mu$ F capacitor in parallel to R<sub>L</sub> (as in Fig. 8) and observe the output. Now measure ripple voltage ( $V_r$ ) and the conduction time ( $\Delta t$ ) using the cursers. There are two cursers, voltage and time. Measure the mean-value of the output in DC-coupling mode.
3. Replace 10  $\mu$ F capacitor with 47 $\mu$ F capacitor and attach it in parallel to R<sub>L</sub> and observe the output. Now measure ripple voltage ( $V_r$ ) and the conduction time ( $\Delta t$ ) using the cursers. Measure the mean-value of the output in DC-coupling mode.

Present your experimental results in the table below.

C	$V_r$ (Theoretical)	$V_r$ (Experimental)	$\Delta t$ (Theoretical)	$\Delta t$ Experimental)
10 $\mu$ F				
47 $\mu$ F				

Compare the theoretical and experimental value.

### IX Questions

1. Do you expect  $V_{z0}$  to depend on the temperature of the surrounding?

2. Assume that the Zener diode in Fig. 4 has  $r_z = 20\Omega$ . Find the numerical value of load regulation. For simplicity, ignore  $R_L$  since it is much larger than  $r_z$ .
3. Which capacitor give smallest amount of ripple and why?
4. Which capacitor gives the largest mean value in the output? Explain your answer.