ESC201 Introduction to Electronics Lab 5 Handout for Lab Experiments
Normal Diode and Zener Diode: I-V Characteristics and Applications

Experiment 1: I-V Characteristics of Diodes (*2 × 5 = 10 marks*)

I-V Characteristics of Normal Diode:

Wire the circuit of Fig. E1 shown below to measure the I-V characteristic of a normal diode. Apply a ± 8V peak triangular wave of 200 Hz frequency from the FG as the input V_{in} to the circuit. Connect the diode voltage to CH-1 and the DA output to CH-2. Make sure that you are getting waveforms on both the channels of DSO. Put the DSO in the XY mode and see the XY plot on the DSO. Verify that you are getting the correct I-V characteristic of a normal diode. You may have to adjust/choose the voltage setting of the channels as required. Also, change the offset and amplitude of the input voltage using the offset and the amplitude knob of the FG, respectively. See whether you can observe a desired part (zoom in) of the I-V characteristic on the DSO by interplaying these two knobs on the FG.

Be sure to connect the +12 V, –12 V, and the Ground connections to the PCB for the DA to work properly.

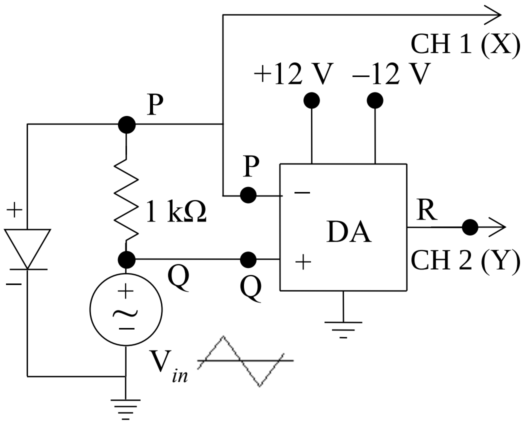

Figure E1

1. Choose two points in the conducting region (choose a nearly linear region in the forward bias) and measure accurately the diode voltages and currents at those two points on the displayed I-V characteristic using the 'Cursor' function of the DSO. You may need to zoom in and adjust the scale. From the two points, calculate the slope of the characteristic in the conducting region and the intercept of the extrapolated line having that slope. Estimate the diode forward resistance and the cut-in voltage. Write down your observation and results.
2. Plot the I-V characteristic of the diode along with the piece-wise linear approximation, and mark salient points on the plot.

I-V Characteristics of Zener Diode:

Wire the circuit of Fig. E1 shown above with the diode replaced by the Zener diode ***keeping the polarity the same as it was in the diode case*** (see last page). Follow the steps of the above experiment to:

3. Estimate the resistances in the forward bias and the forward bias cut-in voltage, write down your results.
4. Estimate the resistances in the reverse bias and the reversed bias Zener voltage, write down your results.
5. Plot the entire I-V characteristic of the Zener diode along with the piece-wise linear approximation and mark the salient points on the plot.

Experiment 2: Simple Clipper Circuit using Diode and Zener Diode (*2 × 2 = 4 marks*)

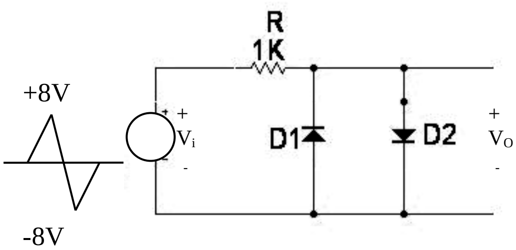

Figure E2a

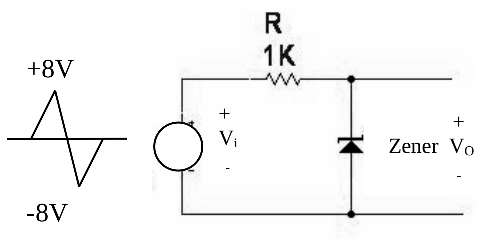

Figure E2b

1. Wire the diode Clipper circuit of Fig. E2a. Apply an 8V peak triangular wave of 200 Hz frequency as input to the circuit. Observe both the input and output waveforms on the DSO and plot the results obtained. Explain why the actual output is different from the expected one in case of ideal diode.
2. Wire the Clipper circuit of Fig. E2b, using the Zener diode. Apply an 8V peak triangular wave of 200 Hz frequency as input to the circuit. Observe both the input and output waveforms on the DSO and plot the results. Explain why the actual output is different from the expected one in case of ideal Zener diode.

Experiment 3: Diode Clipper Circuit with DC Voltage Sources (*2 × 5 = 10 marks*)

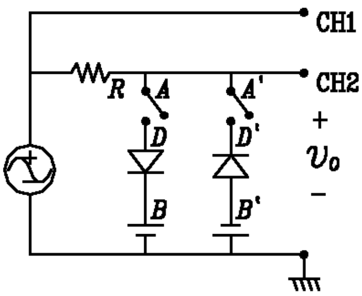

Figure E3

Construct the circuit in the diagram shown in Fig. E3. This is called clipper circuit and its primary purpose is to limit the circuit current. A and A′ are supposed to be switches, but all you need is a jumper that you can connect or disconnect at will. D1 and D2 are two normal diodes. V_B and $V_{B'}$ are values of DC voltages at node B and B′ and will determine the behavior of the circuit.

Take extreme care with the diode and dc voltage polarities, getting them wrong will burn many things including the diodes at once when you switch on.

Take R = 10 kΩ, and set the FG to a sinusoid of 15V p-p of 1 kHz frequency.

1. Close A using jumper and open A′, and set V_B to +5 V. Display both the input and output signals on the CH-1 and CH-2 of the DSO, respectively. Write down your observation along with plots.
2. Vary V_B over the range of 4.5 V to 5.5 V and see the effect on the output. Display and plot both the input and output waveforms for V_B = 4.5 V and 5.5 V. Write down your observations along with plots.
3. Now, open A and close A′ using jumper, and set $V_{B'}$ to – 5 V. Repeat the observations of part 1 for both the input and output voltages, and write down your observation along with plots.
4. Vary $V_{B'}$ over the range of –4.5 V to –5.5 V and see the effect on the output. Display and plot both the input and output waveforms for V_B = –4.5 V and –5.5 V. Write down the observations along with plots.
5. Finally, close both A and A′ using jumpers, and provide both voltages V_B = 5 V and $V_{B'}$ = –5 V as before (now both paths are available). Display both the input and output waveforms on the DSO. Write down the observations along with plots.

Experiment 4: Diode Clamper Circuit (*2 × 3 = 6 marks*)

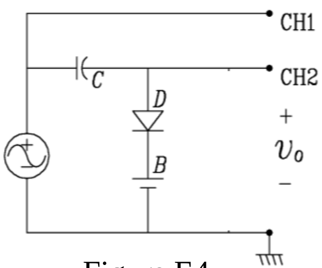

Figure E4

The circuit shown in Fig. E4 is a clamper circuit. The function of the circuit is to provide a constant vertical shift to the signal depending on the bias voltage V_B, which is the value of the voltage source at node B. To apply a negative bias V_B, you have to take the supply from the negative terminal of the power supply. You cannot apply a negative voltage by drawing power from the positive supply and switching the positive supply line and the ground line. Similarly, to put V_B = 0 V, replace the DC supply with a wire/jumper giving 0 V. Never short circuit the DC power supply at any point during the experiment.

Wire the circuit of Fig. E4, and take C = 1 µF. Using the FG, provide a supply of 15V p-p sinusoid of 1 kHz frequency. Do the following experiments, and note down your observations and results.

1. Apply V_B = 0 V (i.e., replace the DC supply with a wire), and display both the input and output signals on CH-1 and CH-2 of the DSO, respectively. Write down your observation along with plots.
2. Apply V_B = –5 V (using the negative supply line of the DC supply), and display both the input and output signals on CH-1 and CH-2 of the DSO, respectively. Write down your observation along with plots.
3. Apply V_B = +5 V (using the positive supply line of the DC supply), and display both the input and output signals on CH-1 and CH-2 of the DSO, respectively. Write down your observation along with plots.

Experiment 5: Half-wave Rectifier Circuit (*2 × 5 = 10 marks*)

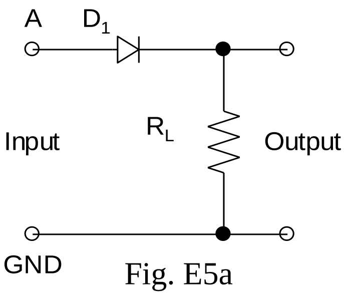

Fig. E5a

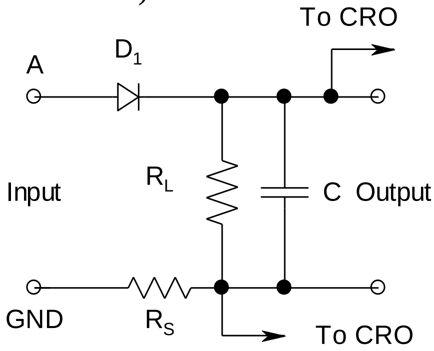

Fig. E5b

Figure E5a is to study the characteristic of half-wave rectifier without capacitive filtering. Take R_L = 10 kΩ. Figure E5b is to study the effect of capacitive filters on ripple voltage and peak diode current. The resistor R_S in the circuit is used to observe the diode current waveforms. Take R_L = 10 kΩ, R_S = 100 Ω. Also, you will see the effect for C = 1 μF and 10 μF. Using the two channels of the DSO, you can observe any two waveforms, e.g., the input and output voltages simultaneously, or the output voltage and the diode current (in the form of voltage) simultaneously, or the input voltage and the diode current (in the form of voltage) simultaneously.

Using the FG, provide a supply of 10 V p-p sinusoid of 50 Hz frequency. Do the following experiments, and note down your observations and results.

1. Wire the half-wave rectifier circuit of Fig. E5a. Observe and plot the input and the output waveforms.
2. Wire the half-wave rectifier circuit of Fig. E5b without the resistor R_S, and take C = 1 μF. Observe and plot the input and the output waveforms.
3. Now, wire the half-wave rectifier circuit of Fig. E5b with the resistor R_S = 100 Ω, and take C = 1 μF. Observe if there is any change in the output waveform because of R_S. Now, observe the output voltage and the diode current (in voltage form) simultaneously, and plot the results.
4. Wire the half-wave rectifier circuit of Fig. E5b without the resistor R_S, and take C = 10 μF. Observe and plot the input and the output waveforms. Increase the amplitude of the input beyond 10 V p-p and observe if there is any distortion in the input or not. (The distortion may arise due to current limitation of the FG.)
5. Now, wire the half-wave rectifier circuit of Fig. E5b with the resistor R_S = 100 Ω, and take C = 10 μF. Keep the input voltage to be 10 V p-p sinusoid, and observe if there is any change in the output waveform because of R_S. Observe the output voltage and the diode current (in voltage form) simultaneously, and plot the results. Also, observe the input voltage and the diode current (in voltage form) simultaneously, and plot the results. Increase the amplitude of the input beyond 10 V p-p and observe the relation between the distortion of the input voltage and the diode current waveforms. Comment on what you observe.

Supplementary Notes on Normal Diode and Zener Diode

The picture of a normal diode along with the circuit symbol of a diode are shown in Fig. 1a. Note that the grey band in the real diode represents the solid line in the diode symbol, which is the n-side of a PN junction diode.

The diode current I_D as a function of the voltage V_D across it (with its polarity given by that of the p-region with respect to the n-region of the diode) is given by: $I_D = I_S[\exp\{V_D/(nV_T)\} - 1]$, where I_S is called the ***reverse saturation current*** of the diode (typically ranging from pA to μA), V_T is the ***thermal voltage*** (V_T = 26 mV at 300 K), and n is called the ***ideality factor*** (typically ranging between 1 and 2).

A typical diode characteristic is shown in Fig. 1b. When a silicon diode is forward biased (i.e., V_D is positive), very little diode current I_D will flow till V_D reaches a certain voltage. However, beyond this point, known as the ***knee voltage*** or the ***cut-in voltage*** (V_γ) of the diode as shown in Fig. 4b, the diode current I_D starts to increase rapidly with the forward bias voltage V_D with further increase in the forward bias V_D. The value of the forward bias cut-in voltage V_γ of a diode actually depends on the circuit that one is interested in studying. Typically, the value of the forward bias cut-in voltage V_γ will be around about 0.5 V to 0.7 V.

When the diode is reverse-biased (i.e., V_D is negative), the diode current reverses its direction and maintains a nearly constant value of I_S, which is much smaller than the typical forward bias current through the diode. Hence, to clearly depict the entire I-V characteristic of a diode, one needs to use different linear scale for the current axis when the diode is forward biased and when the diode is reversed bias. In Fig. 1b, you can see the break in the I-axis (denoted by '≈') and different scales for positive and negative currents (mA and μA, respectively). In reality, the entire diode characteristic is a continuous function as you will observe in lab.

The magnitude of the reverse bias voltage across the diode should not exceed its reverse breakdown voltage, also known as the ***Breakdown Voltage*** (V_{BR}) as shown in Fig. 1b, otherwise it would result in a destructive breakdown of the diode. The PIV of diodes in the series 1N 4001 to 1N 4007 ranges from 50 V to 1000 V.

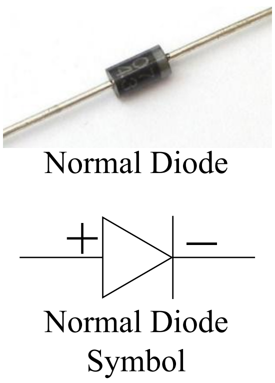

Figure 1a

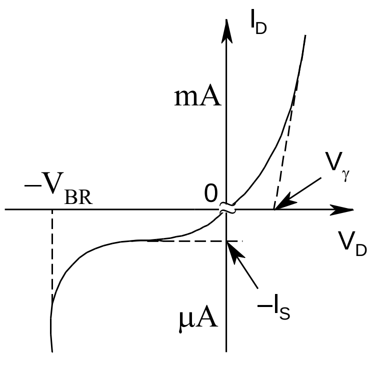

Figure 1b

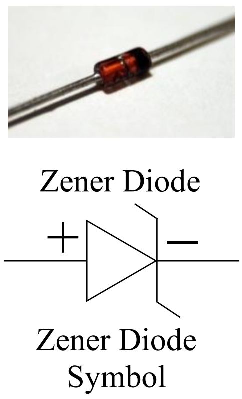

Figure 2a

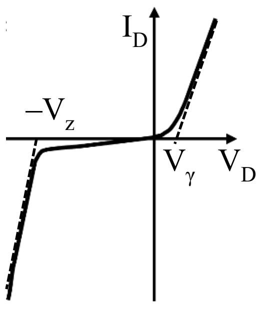

Figure 2b

Zener diode is a special diode with lower reverse breakdown voltage. For a Zener diode, the magnitude of reversed bias breakdown voltage is also called the ***Zener Voltage*** (V_z). The picture of a Zener diode along with the circuit symbol of a Zener diode are shown in Fig. 2a. Note that the dark band in the actual Zener diode represents the solid line in 'Z'-shape in the Zener diode symbol, which is the n-side of the Zener diode.

A typical Zener diode characteristic is shown in Fig. 2b, which is similar to that shown in Fig. 1b having three different regions of operation: forward bias, reverse-bias and the breakdown region. For the circuit with the Zener diode that you will use in lab, the forward bias cut-in voltage (V_γ) will be around 0.5 V to 0.7 V and the reverse bias Zener voltage (V_z) will be around 4 V to 5 V.