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EEE109 Lab 1 Semester 1

Diodes Characteristics and Their Applications

1. Aims

- To investigate the basic properties of diodes
- Use diodes in retifiers, clippers and clampers
- Perform logic operations with diodes
- Use special diodes: Zener diodes and light emiting diodes as voltage regulators and light emitting devices
- Reinforce practical usage of lab equipments such as oscilloscope, function generators and multimeters.

2. Equipment

a) Oscilloscope
b) Function Generator
c) DC Power Supply
d) Digital Multimeter
e) Breadboard

3. Electronic Components

Diodes 1N4148 × 2
Zener diode, 10 volts
LED
Resistors: 330 Ω, 820 Ω, 1 kΩ ×2 , 1.5 kΩ, 2.2 kΩ, 3.3 kΩ, 10 kΩ
Capacitors: 10nF, 100nF

4. Introduction

The semiconductor diode is a two-terminal active component, whose main property is that the apparent resistance to current flow in one direction (the *forward* direction) is much less than its apparent resistance in the other direction (the *reverse* direction). Unlike an ideal carbon or metal resistor, the diode is a non-linear device such that voltage is not exactly proportional to current. Diodes can also be made sensitive to light, or to emit light. These properties of this deceptively simple component have been exploited by modern advanced semiconductor processing techniques to produce diodes of very high quality and enhanced characteristics at very low cost. This experiment investigates typical electronic applications of this remarkable device.

For each part of this experiment, construct the circuit on the breadboard. Most p-n junction diodes are tiny (less than 1mm across), but they are packaged in a cylindrical glass or plastic case for protection and ease of handling. The case has a stripe at one end, which marks the cathode as shown in Figure 0.

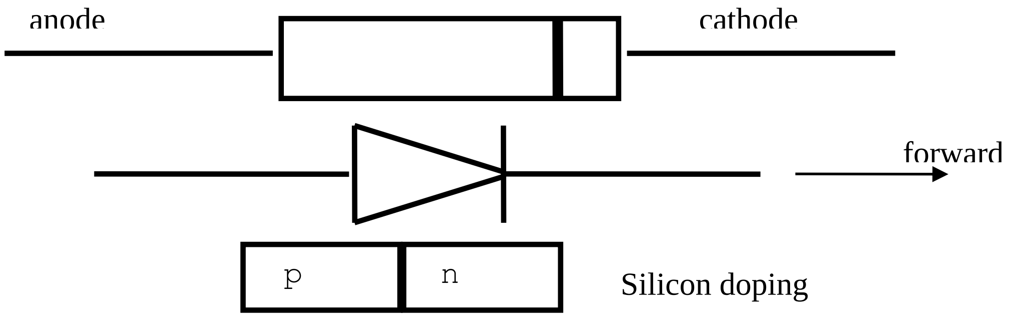

Figure 0: Diode Symbols

All AC measurements should be made using the oscilloscope set to display two channels simultaneously. Ensure that the oscilloscope is set to 'DC' mode for both channels throughout the experiment. Make sure that the earth (ground) line is connected. On the power supply, the earth terminal should be connected to the 0 V terminal; the 0 V should be connected to point **E** on the circuit diagrams; point **E** should be connected to the earth clip of the oscilloscope probe and to the earth terminal of the signal generator. Use a properly adjusted x10 oscilloscope probe for this experiment.

5. Experiments with the General Purpose Diodes

5.1. Rectification

Rectifier circuits are used to convert AC signals into DC (Dictionary: *rectify = put right, correct*). This application makes use of the fact that a diode allows current to pass in one direction only. In the circuit of Figure 1, the diode blocks the current during the negative part of the signal and allows the current through it during the positive part. Therefore, such a circuit is called a half-wave rectifier. The **~** symbol represents the signal generator, set to produce a sine-wave. Check that the sine wave is symmetrical about 0V by observing directly on the oscilloscope. If not, consult a demonstrator

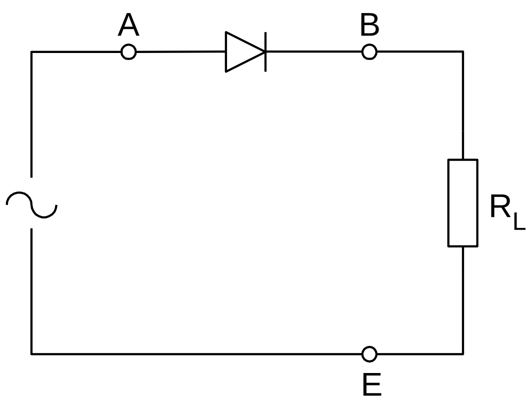

Figure 1: Basic Rectifier Circuit

Display, sketch and measure V_{AE} and V_{BE} under the following conditions:

a) Input signal V_{AE} = 10 volt p-p (peak-to-peak amplitude) and frequency f = 10 kHz
Load resistor, R_L = 10 kΩ

b) Same as for (a) but with V_{AE} = 2 volt p-p

Your report should contain:

1) *Two graphs containing the input signal V_{AE} and the output signal V_{BE} displayed in the same axes for cases (a) and (b) above. Note clearly the maximum, the minimum value for each signal.*
2) *A brief explanation of the two graphs.*

5.2. Smoothed rectifier

The circuit of Figure1 does rectify, but the output is not steady DC. A capacitor can be added to smooth the output by storing charge to supply the load during the dips in the input waveform. The circuit shown in Figure 2 is a smoothed rectifier.

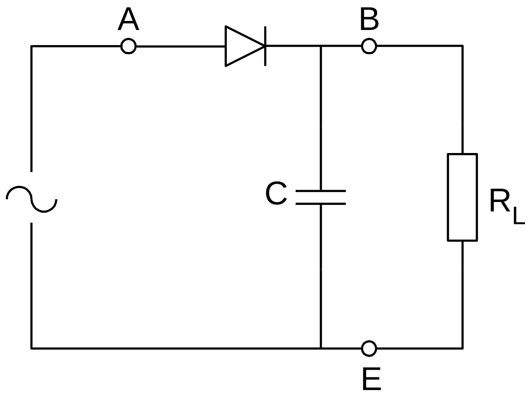

Figure 2: Smoothed Rectifier Circuit

During the 1st quarter of the input signal (positive), the diode allows current through it. As a result the capacitor starts charging. By the time the input voltage reaches its maximum value, the capacitor voltage will have reached a similar value. As the input voltage start decreasing toward zero (2nd quarter of input signal) the capacitor has a higher voltage and therefore starts supplying charge to the circuit. This results in V_{BE} being higher than the input. During the negative part of the input signal (3rd and 4th quarters), the diode cuts off the current and the output voltage is now due to the charge stored in the capacitor. In this period the capacitors discharges through R_L. The rate of discharge will depend on the value of R_L.

Display, sketch and measure V_{AE} and V_{BE} in figure 2 for:

V_{AE} = 10 volt p-p, C = 100nF and

a) R_L = 10kΩ
b) R_L = 1kΩ

Your report should contain:

1) *Two graphs displaying V_{AE} and V_{BE} in the same axes for cases (a) and (b). Indicate the maximum and minimum values of the displayed signals*
2) *Explaination on the shape of the output voltage in the two cases. Give a short explanation of the difference in output voltage when R_L is varied.*

5.3. Limiter /Clipper

A limiter or clipper circuit cuts-off a signal above, or below, a set threshold voltage. It does this by using a diode – not to block the signal but – to short it to a set DC level. The desired threshold level at which the waveform is cut off can be adjusted by adding a DC offset voltage. In fact a diode allows current through it when the anode potential is approx. 0.7 V higher than the cathode potential. Therefore, by adding a dc voltage at the cathode, the anode voltage needs to be raised at 0.7V+V_{DC}. Before current is allowed to go through the diode (i.e. the diode is like open circuit), the voltage drop across R is zero (I=0). Therefore V_A=V_B. However, when V_{BE}=V_{DC}. The circuit shown in Figure 3 works as a *limiter* or *clipper*. Adjusting the DC input voltage V_{DC} changes the desired output voltage.

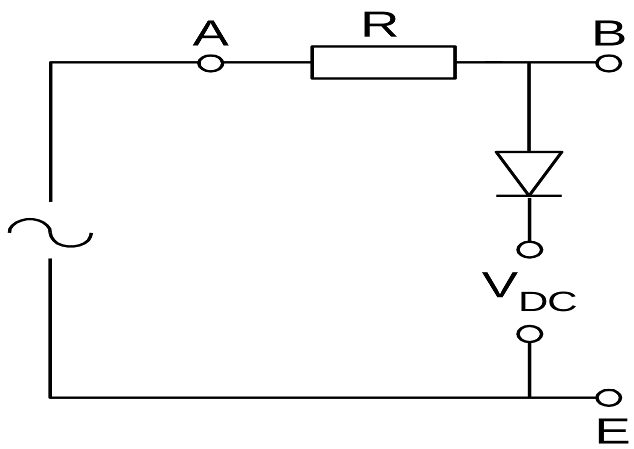

Figure 3: Voltage Limiter Circuit

Display, sketch and measure V_A and V_B for:

a) V_A = 10 volts p-p. and frequency f = 10kHz
R = 1kΩ
V_{DC} = 0 volt

b) as for (a) but with V_{DC} = +3 volt

c) as for (b) but with the diode connection reversed

Your report should contain:

1) *Three graphs displaying the input and output voltages in the same axes; one graph for each case of (a), (b) and (c).*
2) *A short explanation of the circuit's behaviour following every graph*

5.4. Voltage Clamper

The circuit shown in Figure 4 is a voltage clamper or a voltage-level shifter. The diode allows the current to flow from E to B. Therefore, during the negative part of input voltage, current is allowed to flow toward B, establishing a voltage V_B=-V_A (positive). Since the diode does not allow current to flow toward E, V_B follows the input voltage with a DC level (=Vpp/2) added to it.

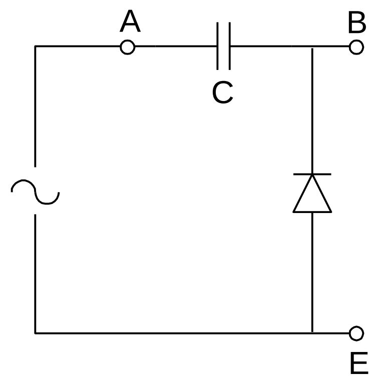

Figure 4: Voltage Clamper Circuit

Display, sketch and measure V_A and V_B for :

a) V_A = 10 volt p-p and frequency f = 10kHz
   C = 10nF

b) as for (a), but with the diode terminals reversed.

Your report should include:

1) *Two graphs displaying V_A and V_B for cases (a) and (b) above. Mark the maximum and minimum values for each voltage*

2) *Explain the evolution of V_B for a full cycle of the input voltage*

5.5. Diode Logic

The circuits investigated so far are all ‘analogue’ circuits, where the diode changes the shape or level of the input voltage. The next circuit is ‘digital’, where the main consideration is whether the voltage is high (logic 1 or TRUE) or low (logic 0 or FALSE).

The circuit shown in Figure 6 is diode logic gate. Use two of the 1N4148 diodes.

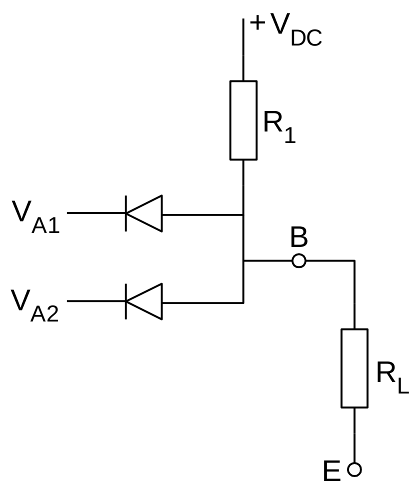

Figure 6: Diode Logic Gate Circuit

This experiment uses only a single +5 volt DC supply with:

V_{DC} = +5 volt
R_1 = 2.2kΩ
R_L = 10kΩ

Measure the DC output voltage, V_B for:

a) $V_{A1} = V_{A2}$ = +5 volt

b) V_{A1} = 0 volt, V_{A2} = +5 volt

c) V_{A1} = +5 volt, V_{A2} = 0 volt

d) $V_{A1} = V_{A2}$ = 0 volt

In your report:

1) *Show the values of the output voltage V_B that you measure with the above values of V_{A1} and V_{A2}.*
2) *Using the results in 1), prepare a truth table to show how the logic level at B is related to the logic inputs at A_1 and A_2. Write down the logic expression of B using A_1 and A_2? What logic operation does this gate do?*

6. Experiments using Special Diodes

6.1. Zener Stabiliser

Most power supplies are intended to give a steady DC output, independent of the applied load. A basic mains transformer and smoothing rectifier produce a smooth DC output, but the output voltage will drop on load because of the resistance of the components. A stabilised supply has some form of voltage regulator to keep the output voltage constant. The simplest form of voltage regulator is the Zener stabiliser.

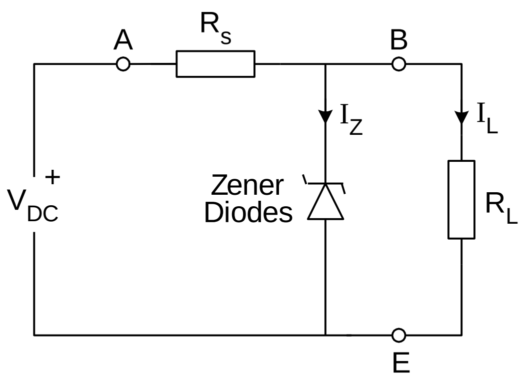

Figure 8: Zener Stabiliser Circuit

The circuit shown in Figure 8 is a Zener diode voltage stabiliser. The DC voltage source, V_{DC}, supplies a current through a series resistance, R_S, to the zener diode and load resistor, R_L. The diode is reverse biased, so should not conduct, but Zener diodes are designed to have a sharp reverse breakdown characteristic at fairly low voltage. If the supply exceeds this breakdown voltage, the diode will conduct. The combination of R_S and the Zener diode acts to keep the output voltage steady at the Zener voltage.

Any increase in the load current, I_L, is matched by an equal decrease in the Zener current, I_Z.

Any change in the supply voltage, V_{DC}, has little effect on the output voltage. If the effective internal Zener resistance of the diode is r_Z: the change in output voltage is only a fraction $r_Z/(r_S+r_Z) \approx \frac{r_z}{R_s}$ of the change in the input voltage.

Using a **<u>10 volt Zener diode</u>** and series resistance $R_S = 1k\Omega$, **measure the voltage, V_B, with a digital voltmeter for :**

a) R_L = open circuit
Vary V_{DC} from 0 volt to 20 volts in 2-volt steps (eleven readings), and measure V_B and V_{DC}.

b) Set V_{DC} = 20 volts. Take four measurements of V_B with $R_L = 3.3k\Omega$, $1.5k\Omega$, $1k\Omega$ and 820Ω. Calculate in each case the value of the load current, $I_L = V_B/R_L$.

In your report, you should:

1) *Show a table with the values of V_B and V_{DC} for a). Plot a graph of V_B against V_{DC}.*
2) *Show a table with the values of V_B and I_L for b). Plot a graph of V_B against I_L.*

6.2 Light-emitting diodes

With suitable materials and doping, the junction of a semiconductor diode can be used to transform electrical energy into light energy and vice versa. Devices designed to convert electricity to light are *light emitting diodes* (LED).

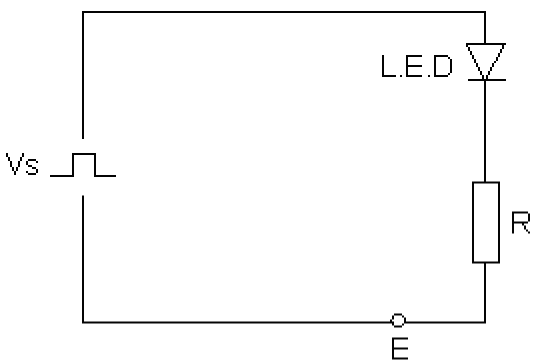

Figure 9: Optical Receiver

The circuit shown in Figure 9 is designed to put pulses of forward current through an LED, causing it to emit pulses of light. The resistor R limits the forward current.

Construct this part of the circuit with

V_S = 10 V p-p square-wave from signal generator and frequency f = 2 Hz
R = 330 Ω

check that the LED is flashing. Use the oscilloscope to **measure the voltage drop across the LED when it is conducting.**

In your report:

For the above experiments, plot the waveform of the voltage drop across the LED with all the details shown.

7. Lab 1 Report Guideline

The experimental report for Lab 1 will cover the following parts:

1) Cover Page

The cover page contains experimental title, student name and ID numer.

2) Abstract (5%)

The abstract is a short section of 50 to 300 words which must be capable of being read and understood independently of the rest of the report. This section should briefly summarise

(a) purpose and scope of the experiment,
(b) experimental procedures that were carried out, and
(c) main conclusions.

This section is possibly the most difficult to write and you are advised to write it last.

3) **Introduction (10%)**

The introduction session is a brief section, which describes, in general terms, the scope of the experiment and its relevance to the field of study you are engaged in. A statement of objectives should be given along with general comments about how the experiment will be carried out. The organization of the report should be provided at the end of the introduction session.

4) **Experiment procedure (70%)**

The section gives details of how experiments/measurement are carried out. Experiment results are recorded and analyised properly via tables and graphs. The procedure and the report subsections should follow the requirements as shown in the lab script for each of the 7 experiments.

a) Rectification **(10%)**

b) Smoothed rectifier **(10%)**
c) Limiter/Clipper **(10%)**
d) Voltage Clamper **(10%)**
e) Diode logic **(10%)**
f) Zener Stabiliser **(10%)**
g) Light-emitting diodes **(10%)**

5) **Conclusion (15%)**

The section provides a concise statement of what has been learnt or confirmed by the experiment. It might include an assessment of the significance and reliability of the results, implications of experimental errors and possible alternative experimental approaches. It must be consistent with earlier sections.