SOLA 2060
Introduction to Electronic Devices

Lab Project 1: Diode Characteristics

1. AIM
The aim of this assignment is to familiarise yourself with the operating characteristics of diodes. Due to restrictions on face to face activities and to make sure of fairness these activities will be done through simulations in LTSpice. We will look at forward and reverse characteristics of three different types of diodes, the impact of temperature, and some simple circuits that make use of these diodes.

2. BACKGROUND
As we covered in class, an ideal p-n junction allows electrical current to pass in one direction while blocking current in the opposite direction. In real diode devices non-zero voltage needs to be applied for the current to pass, the so called turn-on voltage. The turn-on voltage of a diode depends on many factors, including the semiconductor material used to fabricate the p-n junction and the doping levels used. For a rectifying diode in reverse bias, ideally there is no current flow at all, no matter the level of bias applied, but in Zener diodes there is a reverse breakdown voltage at which current will begin to flow. We have seen the processes that lead to this current flow in class (the process is not always Zener mechanism). Finally, there are Schottky diodes that don't use a p-n junction at all, but use a metal-semiconductor junction (more will be seen on this later in the course). Schottky diodes are characterized primarily lower turn on voltages and faster switching times in comparison with p-n junctions of the same semiconductor material.

3. THE DIODE CIRCUIT SYMBOL
All electrical devices have internationally agreed symbols representing the device. The diode's symbol is shown in Figure 1(a). A picture of a diode is shown in Figure 1(b). The diode's black plastic package has a white line marked on it that corresponds to the "cathode", which is the electrode from which holes leave the device (or that electrons enter). This white line represents the single line part of the diode symbol. It is important to keep this convention in mind as the polarity of your device is obviously important to its operation in real devices.

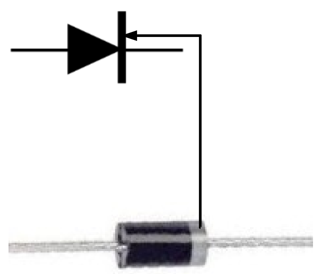

Figure 1: (a) Circuit symbol of a diode, (b) A picture of a 1N4004 silicon diode.

4. LTSPICE SOFTWARE AND DIODE MODELS

You should first go to:
https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html
and download the version of LTSpice most appropriate to your device.
There are several example files that come with the software, as well as help files and even Youtube videos to help you get familiar with building circuits in LTSpice.
You will simulate the I-V characteristics of and simple circuits using rectifying diode, a Schottky diode and a Zener diode. There are many different models in LTSpice for devices, but you will need to use particular models based on the last three digits in your student ID.

Rectifying Diode: Take the fifth digit of your student ID. The model you use is based on whether it is odd or even:
ODD – 1SR154-400 EVEN – 1SR156-400

Schottky Diode: Take the sixth digit of your student ID.
ODD – 1N5817 EVEN – 1N5818

Zener Diode: Take the seventh digit of your student ID.
ODD – 1N750 EVEN – BZX84C6V2L

5. SIMULATIONS

Simulation Task 1
For each of the three diodes connect as in Figure 2, below. You don't need to create a voltmeter or ammeter, these are more to help understand what you are to measure. Vary the voltage supply from -20 to +20 V (set the default of the DC supply to 0 to avoid error messages) and probe the current flow through the diode as a function of the voltage across the diode.

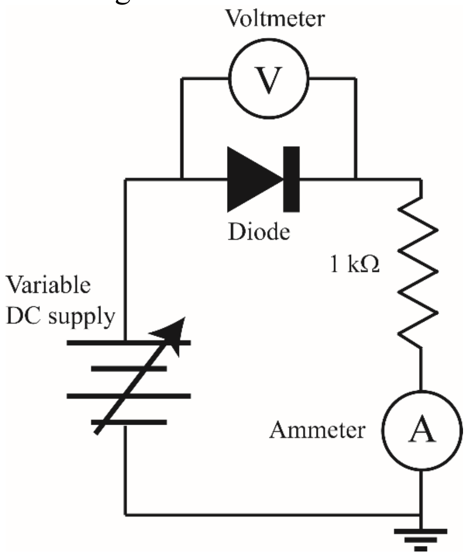

Figure 1: Test circuit for Diodes

Report Requirement: Provide plots of the current flowing through the diode and the voltage across it. You can change the range of both the current and voltage.

Analysis Tasks
ST1.1 Find the turn-on voltage for each of these diodes using the definition of the turn-on voltage being

the forward bias across the diode that allows a current flow of 1 mA.
ST1.2 At the forward bias turn-on voltage for each diode determine the dynamic resistance (this means you need to think about increments in the supply voltage to get a good fit around the ‘knee’ of the curve).
ST1.3 For the rectifying diode estimate the ideality factor (you should give an explanation for how you do this and give details on which data you are using i.e. give numbers).

Simulation Task 2
Using the circuit in Figure 2 with the rectifying diode repeat the forward characteristic measurement, but this time with the diode being heated. To do this you need to include the command:
.step temp 25 75 10
This will vary the temperature of the diode from 25 C to 75 C in steps of 10 C. When you simulate, you should get a series of I-V curves.

Report Requirement: Provide the plots of the current flowing through the diode and the voltage across it at the different temperatures clearly marking them.

Analysis
ST2.1 Determine from your results the change in turn-on voltage per degree of temperature change.
ST2.2 With reference to the p-n junction diode equation or any other way that you can think of, explain why the turn-on voltage decreases.
ST2.3 Solar cells work be separating the electron and holes generated in pairs by illumination and extracting with a potential difference between them before recombination can occur. Given your result here, do you think having a hot solar cell will help or hurt performance?

Simulation Task 3
Using the Zener diode assigned construct the circuit shown in Figure 2, below. Increase the supply voltage from 0 to 20 V and plot the output voltage of the circuit (across either the 1k Ω resistor or the Zener).

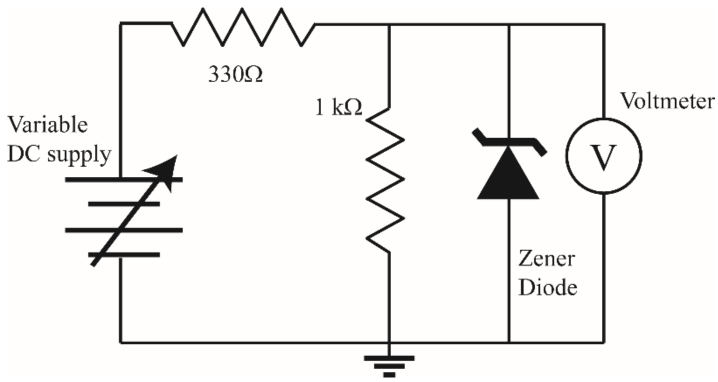

Figure 2: Zener regulated power supply

Report Requirement: Provide the plots of the output versus input voltages as well as the current flowing through the diode and 1k Ω resistor.

Analysis
ST3.1 How does the Zener diode provide voltage regulation for this circuit?
ST3.2 Based on your measurements estimate the dynamic resistance for the Zener diode in breakdown.
ST3.3 What would the dynamic resistance be if the regulation was ideal?
ST3.4 Is the breakdown mechanism Zener type (give a reason for your answer)? Can you think of a way to check your answer on the breakdown mechanism?

Simulation Task 4

You will need to create a signal generator to provide the ac input for this part. Make the input an AC supply connected in series with the rectifying diode you have been assigned and a 1 kΩ resistor as in Figure 3. The signal should be 12 V rms, with a frequency of 50 Hz.

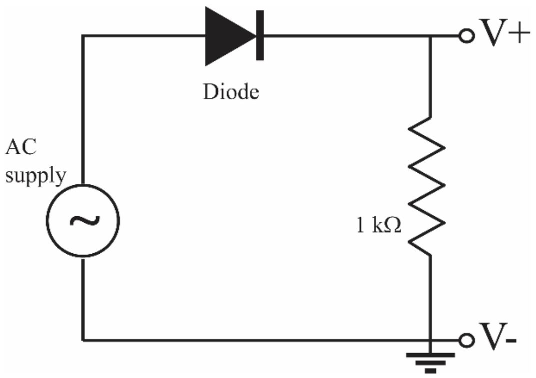

Figure 3: Diode rectifying circuit.

Report Requirement: Plot the input and output ac signals for this circuit. Have at least 6 cycles included in your plot. Include as much numerical information as possible.

Analysis

ST4.1 Having noted the waveforms for the input and output signals, briefly explain why they look like they do (explain how the circuit works).
ST4.2 Find an expression for the signal measured across the diode before turn on and explain whether it is a constant or not. Explain your answer.
ST4.3 Determine the capacitor value required to ensure a ripple of 5% on the output voltage.

Add the capacitor you have determined above to the circuit and confirm the ripple is below 5%.

Report Requirement: Plot the input and output ac signals for this circuit. Have at least 6 cycles included in your plot. Include as much numerical information as possible to prove the circuit is performing as expected.

6. SUMMARY QUESTIONS

SQ1 How do real diodes differ from the simple models you have seen (name them)?
SQ2 What process is ultimately responsible for current flow in a pn junction diode?
SQ3 Why might a Schottky diode be preferred to a pn junction diode?
SQ4 How is the breakdown of a Zener diode useful for circuits?

Report Due: 5pm, Monday 29 March 2021 via Moodle.

Submit a single pdf format file to the Moodle Assignment submission section. The filename must be of the form: "z1234567_SOLA2060_Lab1_Report.pdf".

NOTE: It is an individual report, not a team effort!