EE236: Experiment No. 2
I-V characteristics of Schottky and Zener Diodes

Mayur Ware, 19D070070

January 23, 2022

1 Overview of the experiment

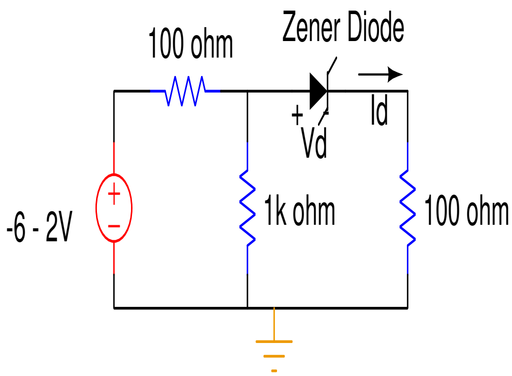
1.1 Aim of the experiment

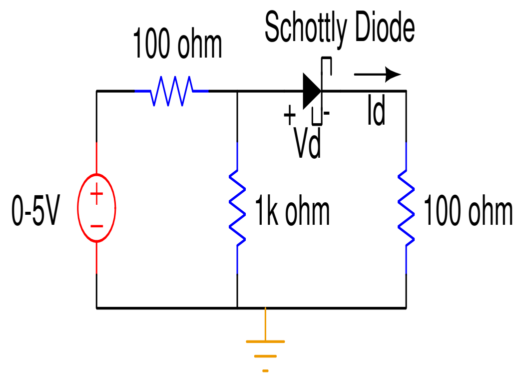
Aim of this experiment is to analyze the forward bias I-V characteristics of Schottky and Zener Diodes.
To analyze working and characteristics of Zener Regulator and 'Voltage Doubler' circuits.

1.2 Methods

Firstly, I read and understood the background theory of Zener diode and Schottky diode. Then, I wrote the netlist for simulation model and simulated both diodes one by one and plotted I_d vs V_d graphs using dc analysis. Then, I replaced Si diodes in bridge rectifier with schottky diodes to note the change in it's behaviour. Calculated recovery times of diodes. Finally, I simulated Zener Regulator and 'Voltage Doubler' circuits to analyze them.

2 Design





I-V Characteristics of

Fig. 1 : Zener Diode   Fig. 2 : Schottky Diode

These are the circuits for the I-V characteristics simulation of Zener Diode and Schottky Diode respectively. DC analysis is done for negative voltages considering the breakdown in zener. Then, I noted the check-in voltages of both diodes to compare with Si diode.

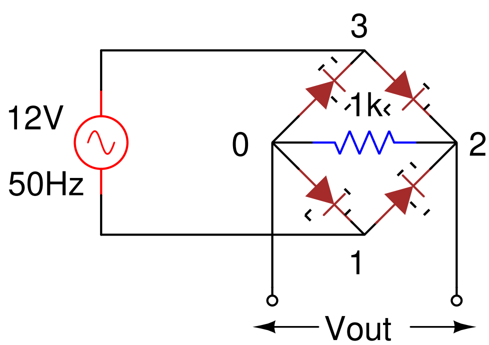


Fig 3. : Bridge rectifier using schottky diodes

Then, I replaced the Si diodes in bridge rectifier circuit with schottky diodes as shown in Fig. 3. Also, I calculated the recovery times for all diodes.

$$t_{rr} = t_s + t_t \tag{1}$$

[where, t_{rr} is reverse recovery time, t_s is storage time and t_t is transition time]
After that, I simulated the Voltage Regulator using Zener Diode (Fig. 4)

which takes a 15V unregulated power supply as input and gives 9V DC Voltage as output.

$$R_s = \frac{V_s - V_z}{I_z} \tag{2}$$

$$R_2 = \frac{5.6}{I_{R2}} \qquad Assume R_1 = 1k\Omega \tag{3}$$

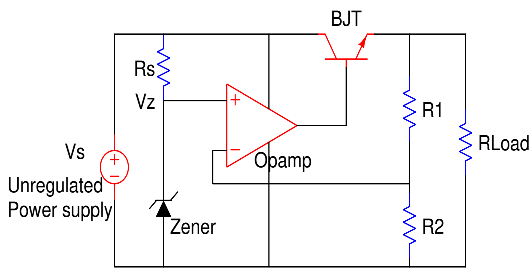


Fig. 4 : Voltage Regulator

Then, I designed following circuits (Fig. 5 and Fig. 6) by looking at the transfer characteristics given in the labsheet.

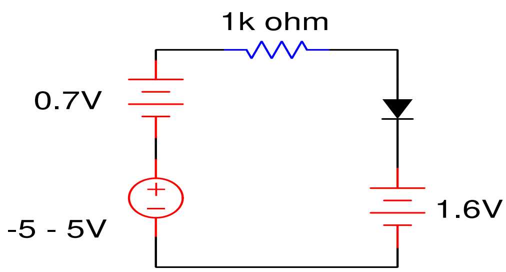


Fig. 5

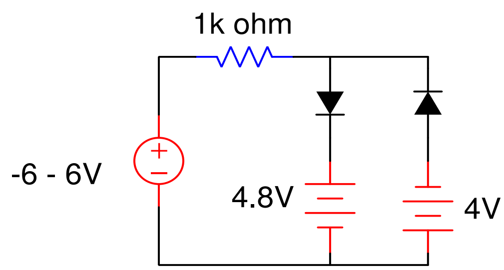


Fig. 6

Lastly, I simulated the 'Voltage Doubler' circuit (Fig. 7) to check to voltage waveform across both capacitors. And simulated the output of the circuit.

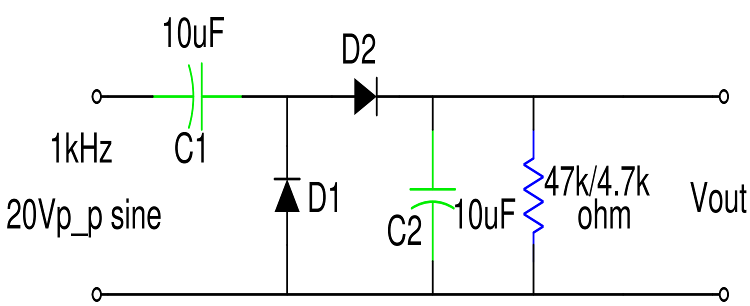


Fig. 7 : Voltage Doubler

3 Simulation results

3.1 Code snippets

Note : I-V Characteristics, Bridge Rectifier codes for Schottky diodes are the same which were used for Si diode.

3.1.1 Voltage Regulator :

```
Mayur Ware | 19D070070
*EE236 | Lab 2
*Voltage Regulator using Zener Diode
*Including BJT, Zener and Opamp model files
.include zener.txt
.include bc547.txt
.include ua741.txt
*----------------------------------------
*Bridge Rectifier using BAT85 Schottky Diode
*Including BAT85 Schottky Diode model file
.include schottky_BAT960.txt
*Bridge Rectifier
X1 1 2 BAT960
X2 0 1 BAT960
X3 3 2 BAT960
X4 0 3 BAT960
*Input Voltages
Vin 1 3 sin(0 16 50 0 0)
RL 2 0 1k
*Capacitor
C1 2 0 1000u
*------------------------------------------
Rs 2 a 52.64
Q1 2 c Out bc547a
X1 a b 2 0 c ua741
R1 Out b 1k
R2 b 0 1642
X2 0 a DI_1N4734A
*Transient Analysis
.tran 10u 100m
*Control Commands
```

```
.control
run
set color0 = white
set color1 = black
set color2 = blue
set color3 = red
set xbrushwidth = 2
plot V(Out), V(2), V(3,1)
plot V(Out) vs V(3,1)
.endc
.end
```

3.1.2 Designing using Transfer Characteristics :

```
Mayur Ware | 19D070070
**EE236 | lab 2
*Writing Netlist for given Transfer Characteristics - 1
*Including 1N914 Diode model file
.include Diode_1N914.txt
*Netlist
Vin In GND dc 2
V1 2 In dc 0.7
V2 4 GND dc 1.6
R1 2 3 1k
D1 3 4 1N914
*DC Analysis
.dc Vin -5 5 0.1
*Control Commands
.control
run
set color0 = white
set color1 = black
set color2 = blue
set color3 = red
set xbrushwidth = 2
plot V(3) vs V(In)
.endc
.end
```

```
Mayur Ware | 19D070070
*EE236 | Lab 2
*Writing Netlist for given Transfer Characteristics - 2
*Including 1N914 Diode model file
.include Diode_1N914.txt
*Netlist
Vin In GND dc 2
V1 1 GND dc 4.8
V2 GND 2 dc 4
R1 In Out 1k
D1 Out 1 1N914
D2 2 Out 1N914
*DC Analysis
.dc Vin -6 6 0.1
*Control Commands
.control
run
set color0 = white
set color1 = black
set color2 = blue
set color3 = red
set xbrushwidth = 2
plot V(Out) vs V(In)
.endc
.end
```

3.1.3 Voltage Doubler :

```
Mayur Ware | 19D070070
*EE236 | Lab 2
*Voltage Doubler
*Including 1N914 Diode model file
.include Diode_1N914.txt
*Input Voltage
Vin In GND sin(0 10 1k 0 0)
*Capacitors
C1 1 In 10u
C2 Out GND 10u
*Diodes
D1 GND 1 1N914
```

```
D2 1 Out 1N914
*Resistor
R Out GND 4.7k
*Transient Analysis
.tran 10u 10m
*Control Commands
.control
run
set color0 = white
set color1 = black
set color2 = blue
set color3 = red
set xbrushwidth = 2
plot V(1) - V(In)
plot V(Out) - V(1)
plot V(Out)
.endc
.end
```

3.2 Simulation results

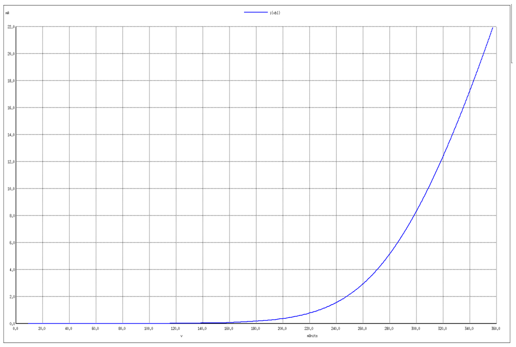


Fig. 8 : Schottky BAT85 Diode

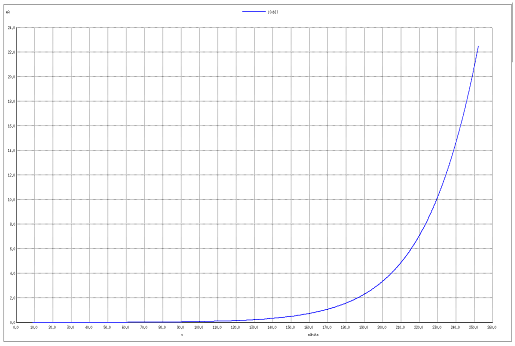


Fig. 9 : Schottky BAT960 Diode

From Fig. 8 and Fig. 9, we can notice that the cut-in voltages for BAT85 and BAT960 are approximately 240mV and 180mV respectively.
They are considerably low as compared to Si diode.

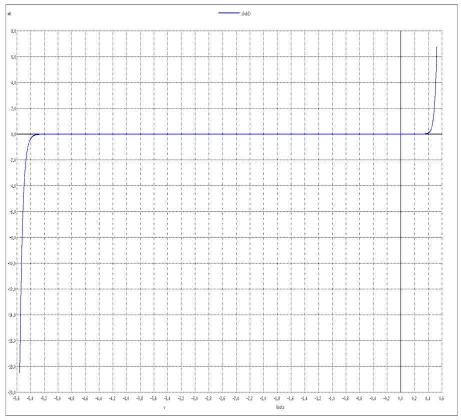
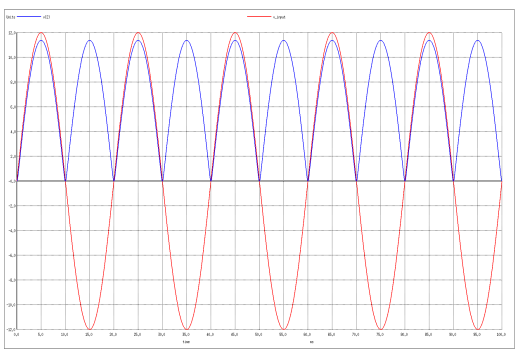
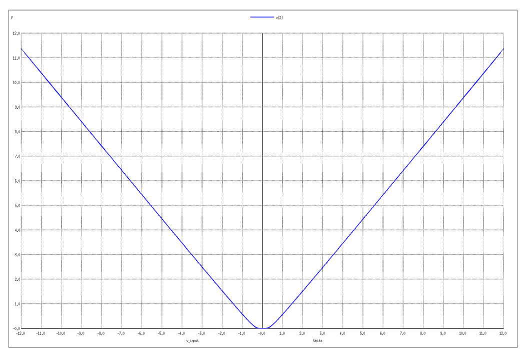


Fig. 10 : I-V Characteristics of Zener Diode

Forward Bias behaviour of Zener diode is similar to other diodes, this can be seen in Fig. 10. But, a sharp breakdown can be observed around -5.5V.

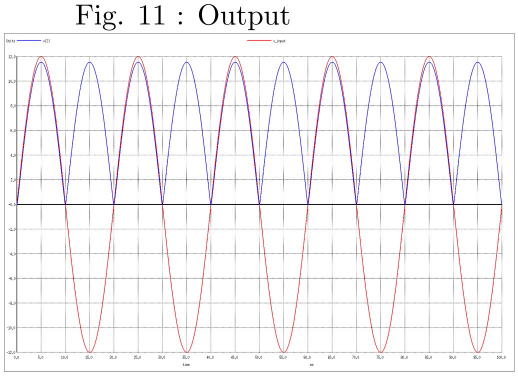


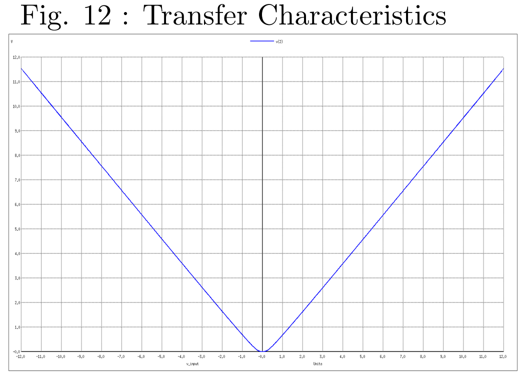


Bridge Rectifier using Schottky BAT85 Diode

Fig. 11 : Output

Fig. 12 : Transfer Characteristics



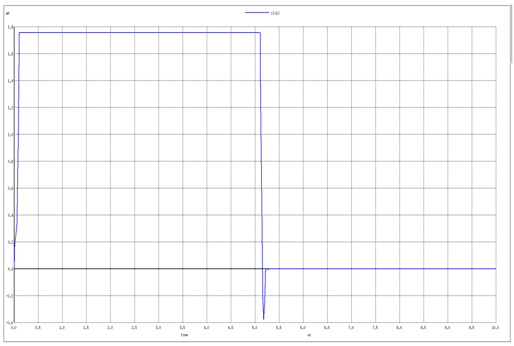


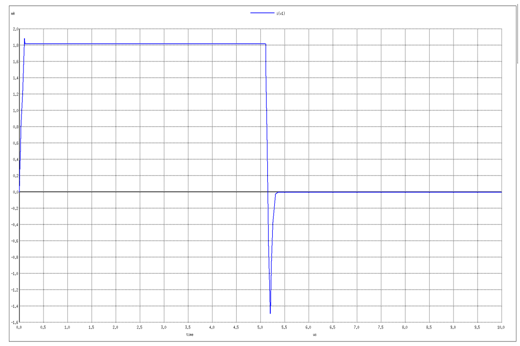
Bridge Rectifier using Schottky BAT960 Diode

Fig. 13 : Output

Fig. 14 : Transfer Characteristics

From Fig. 11, 12, 13 and 14, it can be observed that the behaviour of Schottky based bridge rectifiers is similar to Si based bridge rectifier. Non-ideadlities are less than Si diode due to lower cut-in voltages.





Reverse Recovery time (t_{rr}) for

Fig. 15 : Schottky BAT85 Diode

Fig. 16 : Schottky BAT960 Diode

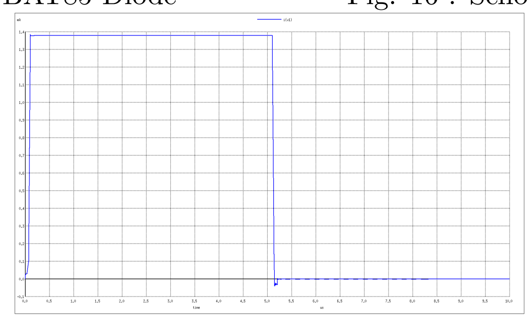
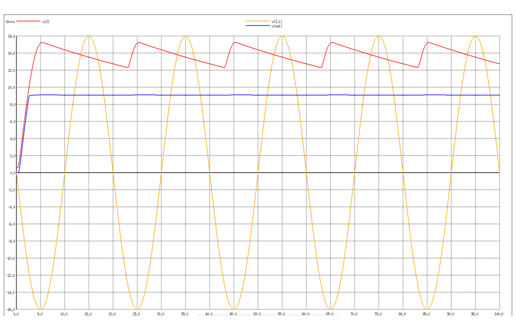
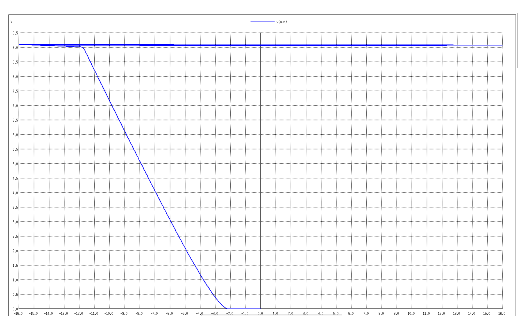


Fig. 17 : Reverse Recovery time (t_{rr}) for Si diode

Calculated Reverse Recovery times (t_{rr}) are : BAT85 - 4.5e-9 sec, BAT960 - 22e-9 sec and Si - 2e-7 sec. Schottky diodes have significant low t_{rr} as compared to Si diode.



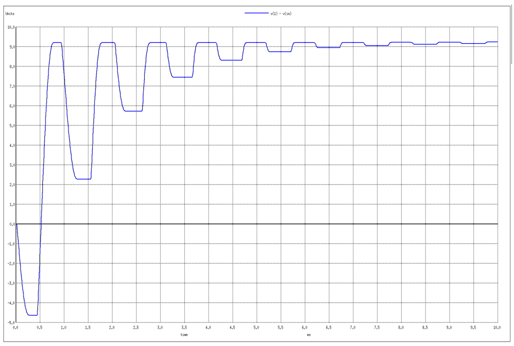


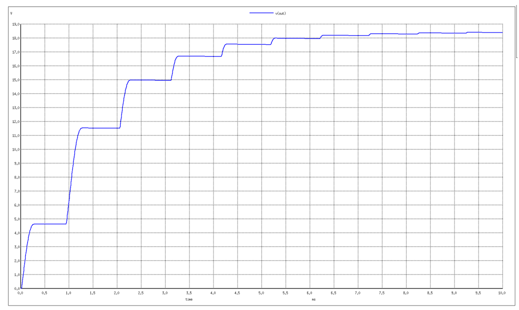
Voltage Regulator using Zener Diode

Fig. 18 : Transient Response

Fig. 19 : Transfer Characteristics

I used the Schottky diode based bridge rectifier as the unregulated 15V supply. The output is a DC voltage around 9V. Transfer characteristics start from 0 and oscillate around 9V. We use BJT here as it provides feedback to the circuit. Also, it amplifies the current.

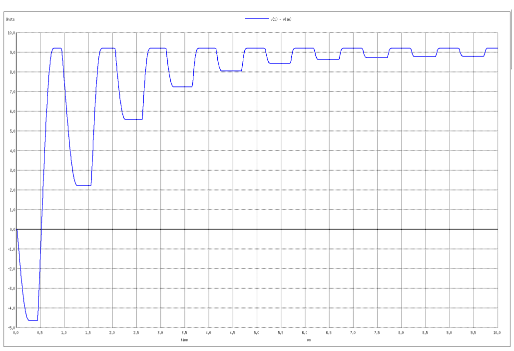


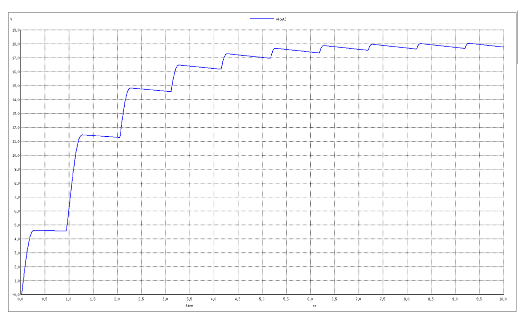


Voltage Doubler circuit with 47kΩ resistor

Fig. 20 : Voltage across C1 Fig. 21 : Output

Voltage across capacitor C1 initially oscillates and then settles around 9.2V. Whereas, Output waveform increases in some steps and finally settles around 18.4V. So, C2 will have a maximum charge of 18.4V. Note that voltage is not exactly doubled here because of diode non-idealities.





Voltage Doubler circuit with 4.7kΩ resistor

Fig. 20 : Voltage across C1 Fig. 21 : Output

Voltage across capacitor C1 initially oscillates and then settles around 9.2V. Whereas, Output waveform increases in some steps and finally settles around 17.8V. So, C2 will have a maximum charge of 17.8V.
All waveforms are similar to 47kΩ ones but aren't very smooth like it because of capacitor discharging due to low resistance.

4 Experimental results

This section is not applicable for this experiment.

5 Experiment completion status

I have completed all sections as well as exercises in this lab.

6 Questions for reflection

Q1) From the above measured reverse recovery time, comment about few applications where schottky diode can be used.
Answer : Schottky diodes are used in power electronics circuits where fast switching is required due to fast recovery time.
Q2) Why the BJT is required in the circuit?
Answer : BJT is used in the Voltage Regulator circuit to amplify current. The current flowing through Zener is limited, so amplifying current is required to regulate the output.
Q3) What are the limiting factors those will affect the limit of the load? How will you overcome those?
Answer : Limiting factor of given Voltage Regulator is it's efficiency is low in high current aplications. We can use better voltage ICs to correct this issue.
Q4) What will be the change in output if the resistor is replaced by a 4.7 kOhms resistor?
Answer : In Voltage Doubler, when 4.7k resistance is used there is more ripple in the output voltage. Also, the capacitor is discharging fast due to low time constant.

■