EE230: Lab 2
DC Power Supply
Unregulated DC Power Supply learning

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1 Overview of the experiment

1.1 Aim of the experiment

1. Understanding the limits of performance of a Zener regulator.
2. Understanding a BJT based series voltage regulator to appreciate the basic blocks of an IC voltage regulator.

1.2 Methods

To understand the limits of the performance of a Zener regulator, we analyzed a Zener diode regulator circuit. By varying the parameters in the circuit such as V_{in}, R_L and R_s we observed the output voltage V_{out} and the various currents (I_s, I_z and I_L) in the circuit. We futher simulated a BJT based series voltage regulator to understand it's workings.

2 Design

In this section, explain your design strategy for the experiment.Mention all the design steps you follow for each part of the experiment.An equation based analysis, with supporting circuit diagrams is expected. Circuit diagrams must be made in Xcircuit.

2.1 DC Power Supply with Zener Diode Regulator

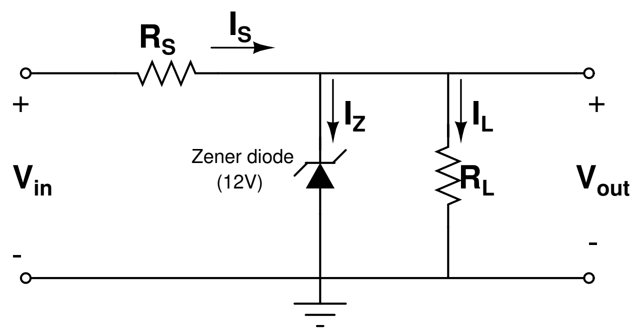

Figure 1: Zener Regulator

A Zener diode regulator is constructed by connecting a Zener diode (12V) in parallel with the load resistance R_L across which the output voltage V_{out} is measured. A resistor R_s is connected in series to limit the maximum current flowing in the circuit as shown in the figure above.

The Zener subcircuit used here is as described in the figure as follows :

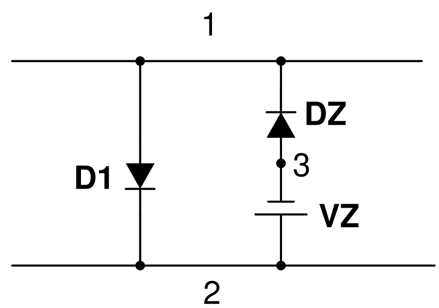

Figure 2: Zener Subcircuit

2.2 DC Power Supply with a BJT Series Regulator

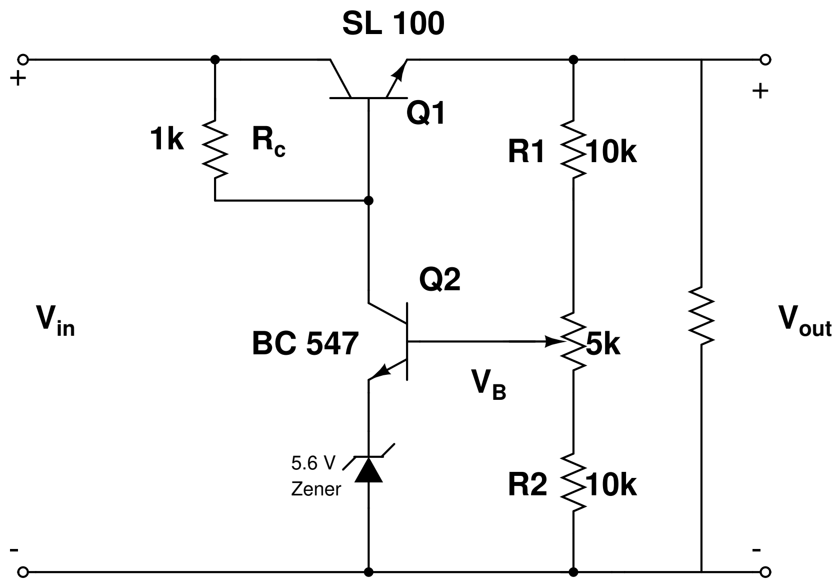

Figure 3: Zener Regulator

3 Theoretical Analysis

3.1 Zener Regulator - Analysis

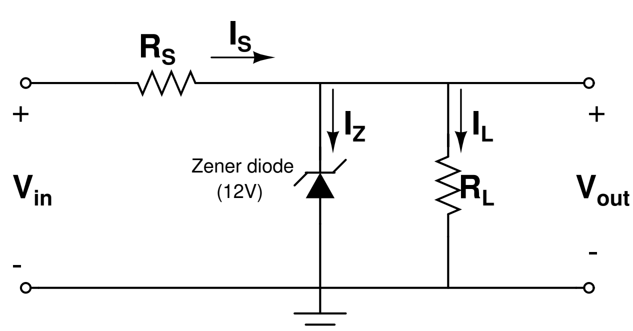

Figure 4: Zener Regulator

3.1.1 Zener Regulator - Analysis : Case (i)

By Thevenin theorem, we can calculate the voltage across the zener diode for V_{in} = 20V.
By calculations, we get that,
V_Z = 13.6V > 12V (Zener Voltage)

Output Voltage

$$V_{out} = \frac{R_L}{R_L + R_Z} \tag{1}$$

$$\therefore V_{out} = 12V \tag{2}$$

By applying KCL and KVL equations, we get,

$$I_Z = 3.61mA \tag{3}$$

$$I_L = 12.05mA \tag{4}$$

$$I_S = 16.06mA \tag{5}$$

The variation in the theoretical values and the simulated values is due to the consideration of the zener resistance.

3.1.2 Zener Regulator - Analysis : Case (ii)

V_{in} **= 15V** By Thevenin theorem, we can calculate the voltage across the zener diode for V_{in} = 15V.
V_{out} = 10.3V The zener is not reversed biased (10.3V ¡ 12V) Here, we can directly calculate the various current values.

V_{in} **= 25V** By Thevenin theorem, we can calculate the voltage across the zener diode for V_{in} = 25V.
V_{out} = 17V

4 Simulation results

4.1 Code snippet

4.1.1 Part (a)

```
Zener Regulator Analysis
* Case 1
* Include the zener_12 model
.include ZENER_12.txt
* Specifying the input voltage
vin 1 0 20
* Specifying dummy voltages
vdummyis 1 3 0
vdummyiz 4 0 0
vdummyil 5 0 0
* Specifying Rs
rs 3 2 470
* Specifying RL
rl 2 5 1k
* Specify the zener model in the circuit
x1 4 2 ZENER_12
.op
.control
run
* Print the output voltage and currents
print v(2) i(vdummyil) i(vdummyis) i(vdummyiz)
.endc
.end
```

4.1.2 Part (b)

```
Zener Regulator Analysis
* Case 1
* Include the zener_12 model
.include ZENER_12.txt
* Specifying the input voltage
vin 1 0 20
```

```
* Specifying dummy voltages
vdummyis 1 3 0
vdummyiz 4 0 0
vdummyil 5 0 0
* Specifying Rs rs 3 2 470
* Specifying RL
rl 2 5 1k
* Specify the zener model in the circuit
x1 4 2 ZENER_12
.dc vin 15 25 0.5
.control
run
* Plot the output voltage and currents
Plot v(2)
Plot i(vdummyil) i(vdummyis) i(vdummyiz)
.endc
.end
```

4.1.3 Part (c)

```
Zener Regulator Analysis
* Case 1
* Include the zener_12 model
.include ZENER_12.txt
* Specifying the input voltage
vin 1 0 20
* Specifying dummy voltages
vdummyis 1 3 0
vdummyiz 4 0 0
vdummyil 5 0 0
* Specifying Rs
rs 3 2 470
* Specifying RL
rl 2 5 1k
* Specify the zener model in the circuit
x1 4 2 ZENER_12
.dc rl 10 1k 10
```

```
.control
run
* Plot the output voltage and currents
Plot v(2)
.endc
.end
```

4.2 Simulation results

4.2.1 Zener Diode Regulator

Part (a)

Here :

- v(2) = V_{out} = 12.26V
- i(vdummyil) = I_L = Current through the load
- i(vdummyis) = I_S = Current through the series resistor
- i(vdummyiz) = I_Z = Current through the zener diode

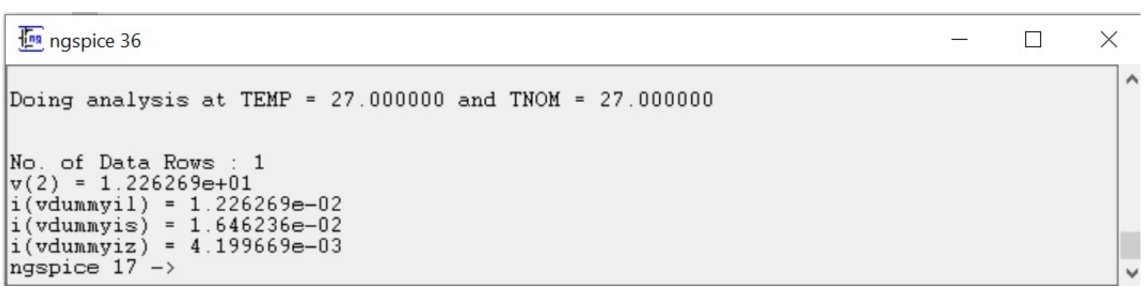

Figure 5: Zener Diode Regulator : Part A outputs

Refer to figure 1 in the section 2.1 : DC Power Supply with Zener Diode Regulator.

Part (b)

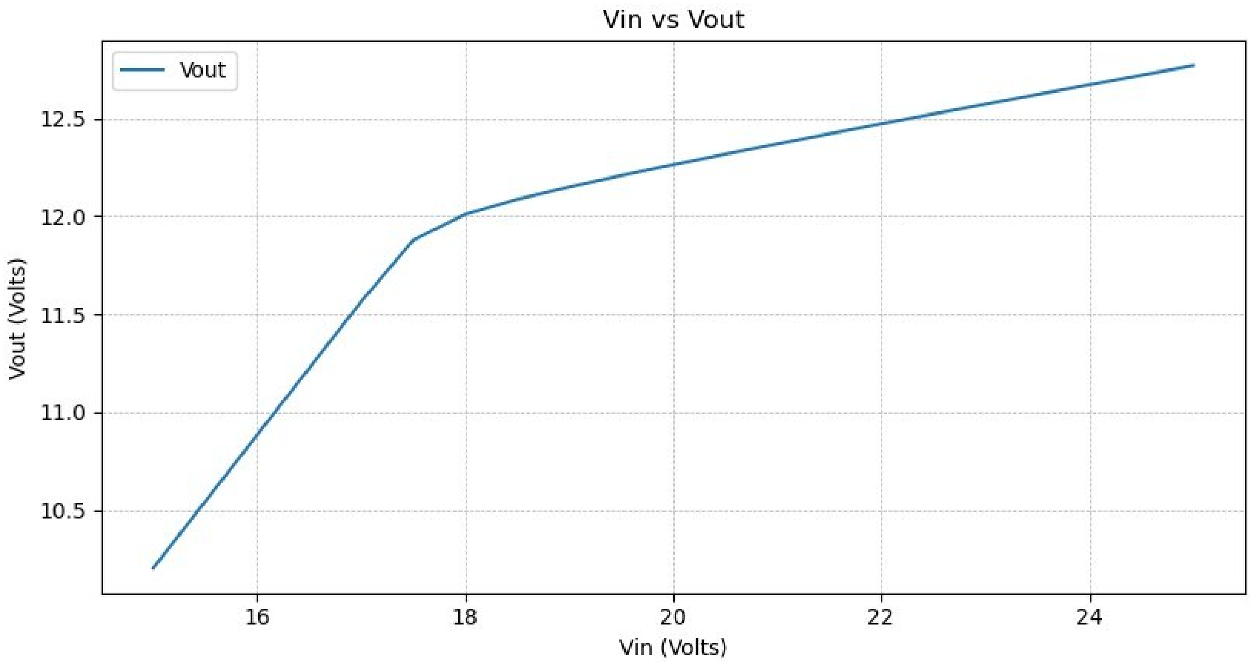

Figure 6: Zener Diode Regulator : Part B Output Voltage

Observe in the plot given above, the rate of change of Vout with respect to Vin decreases sharply at $Vin = 17.64$V
At $Vin = 17.64$ Volts, the voltage across the load resistor R_L and thus the Zener diode is given by the calculations as follows :

$$V_Z = \frac{R_L}{R_S + R_L} V_{in} \tag{6}$$

$$\therefore V_Z = \frac{1000}{1470} * 17V \tag{7}$$

$$\therefore V_Z \approx 12V \tag{8}$$

Which is the Zener Voltage of the given zener diode.

For the figure given below :

- i(vdummyil) = I_L = Current through the load
- i(vdummyis) = I_S = Current through the series resistor
- i(vdummyiz) = I_Z = Current through the zener diode

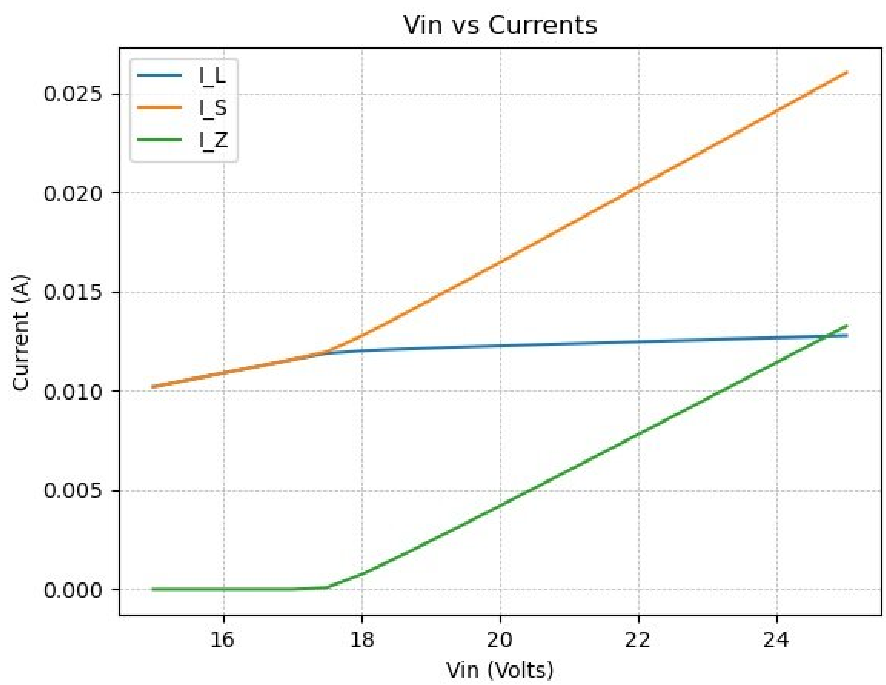

Figure 7: Zener Diode Regulator : Part B Currents

As explained above, for $V_{in} < 17.64V$, the Zener diode is not reversed biased (12V).
Thus for $V_{in} < 17.64V$ the current in the Zener diode given by I_Z **can be observed to be 0.**

Part (c)

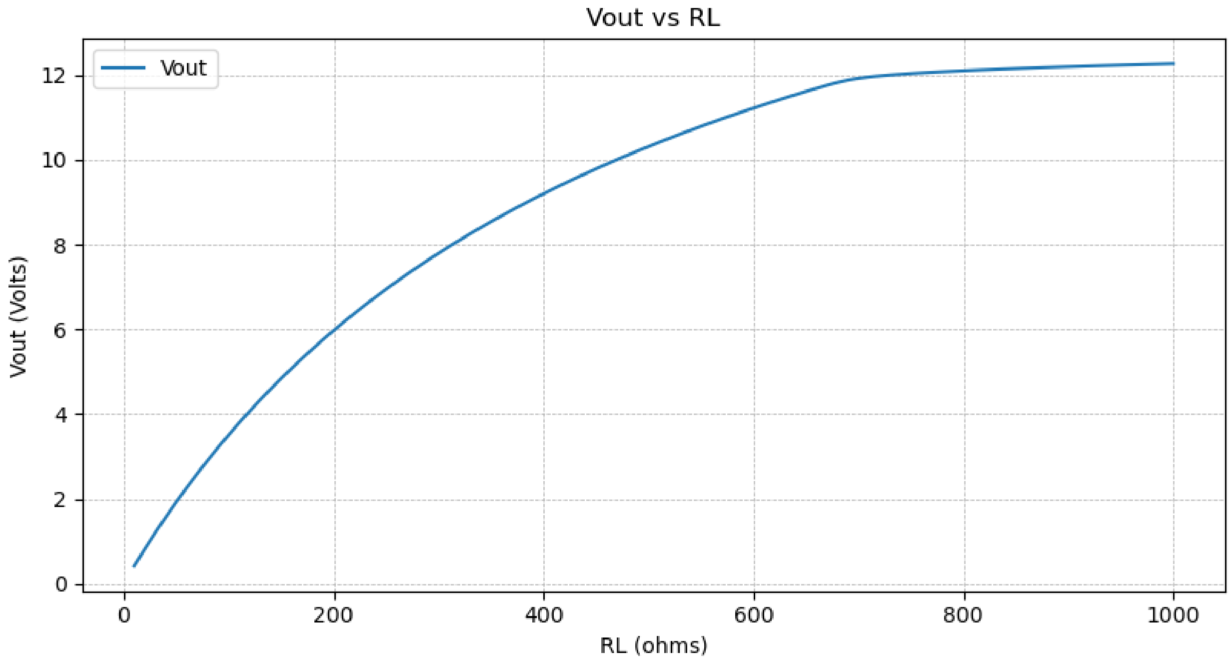

Figure 8: Zener Diode Regulator : Part C

4.2.2 BJT Series Regulator

Case (i)

```
No. of Data Rows : 1
Error: no such vector 5
  in term: v(5)

v(2) = 1.304369e+01
v(3) = 1.374712e+01
v(4) = 6.235345e+00
v(6) = 5.512430e+00
ngspice 3 ->
```

Figure 9: BJT Series Regulator : Case (i)

Here, V2 is the output voltage.
Refer to figure 1 given in the section 2.1.
Refer to the theoretical analysis in the section 3.1.
The simulated values are in accordance with the calculated theoretical values.

Case (ii)

```
No. of Data Rows : 1
Error: no such vector 5
  in term: v(5)

v(2) = 1.202664e+01
v(3) = 1.272388e+01
v(4) = 6.250379e+00
v(6) = 5.518861e+00
ngspice 3 ->
```

Figure 10: BJT Series Regulator : Case (ii)

Here,
R1 = 11.3 kΩ
R2 = 13.7 kΩ
From these values of R1 and R2, we get V_{out} = 12.02V.

Case (iii)

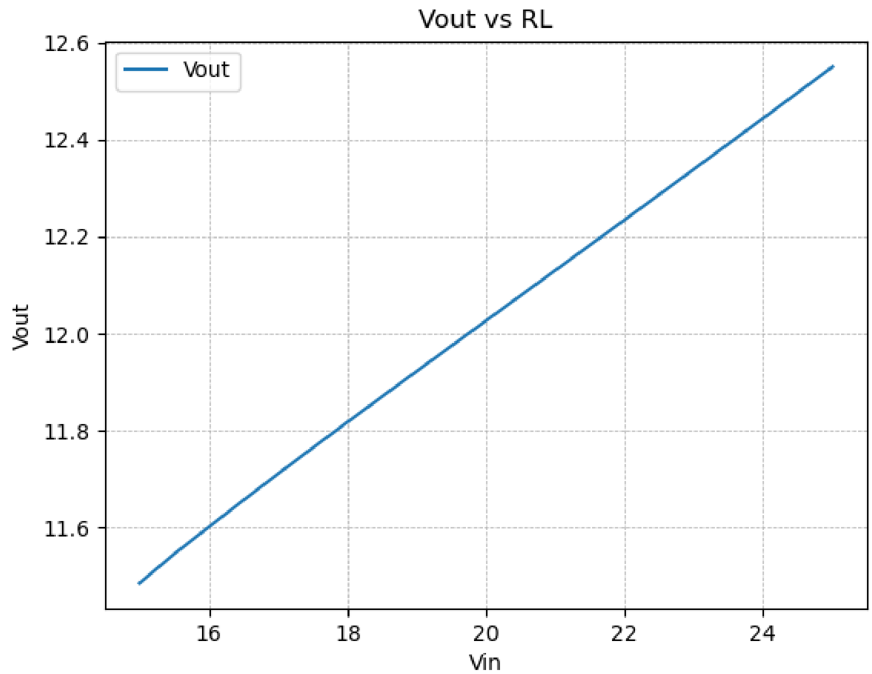

Figure 11: BJT Series Regulator : Case (iii)

Here,
R1 = 11.3 kΩ
R2 = 13.7 kΩ
We are varying the value of Vin from 15V to 25V in steps of 0.5V.

5 Experimental conclusions

5.1 Zener Diode Regulator

By simulating circuits with varying parameters in NGSPice, we observed and analysed DC Power supply using a Zener diode. From this, we also understood the limitations of the zener diode in the Zener regulator circuit and how different input voltages and load resistances affect the various parameters of the circuit.

5.2 BJT Series Regulator

By simulating the BJT Series Regulator with varying input voltages and resistances in NGSPice, we observed and analysed the output voltage provided by the circuit.

5.3 Zener Diode vs BJT Series Regulator

By comparing the output voltages of Zener Diode regulator and BJT Series regulator, we observe that BJT series regulator is more suitable and viable over a wider voltage range from 15V to 25V. On the other hand, the Zener diode regulator is not suitable for the input voltage $V_{in} < 17$V.