LAB Experiment 5
Voltage Regulator

S.V.Harshith EE19BTECH11018

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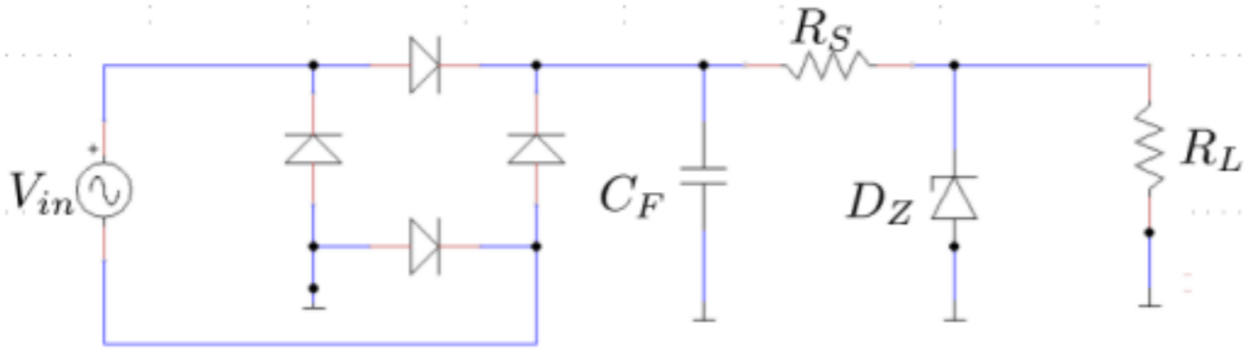
1 Aim

- Write a NgSPICE script to simulate bridge rectifier with an Low pass filter and zener voltage regulator.
- Select the values of R_S and C_F appropriately such that the zener diode, D_Z , always remains in the break down regime. Justify your choice.
- Perform a transient analysis for the above circuit.
- Run the circuit with and without Zener diode and clearly show the impact on the output voltage.
- Briefly explain the working of the circuit by plotting input, filtered and regulated voltage.

2 Procedure

Write a NgSpice script for the circuit of the voltage regulator shown below



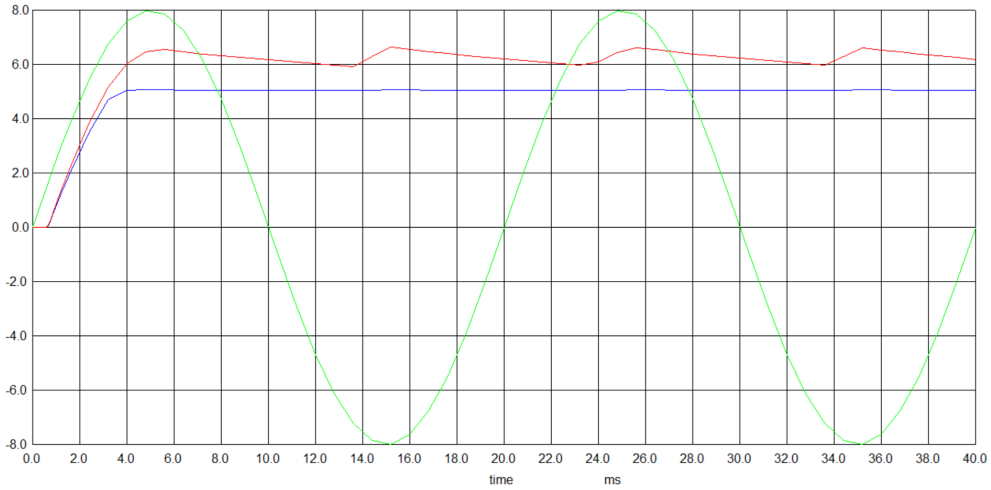
Let the values of components be as follows
Peak input voltage = 8V
Input frequency = 50Hz
Capacitance, $C_F = 150\mu$F
Series resistance, $R_S = 100\Omega$
Breakdown voltage of zener diode = 8V
Load resistance $R_L = 1k\Omega$

Plot the input , filtered and regulated voltage in the NgSpice with and without zener diode.

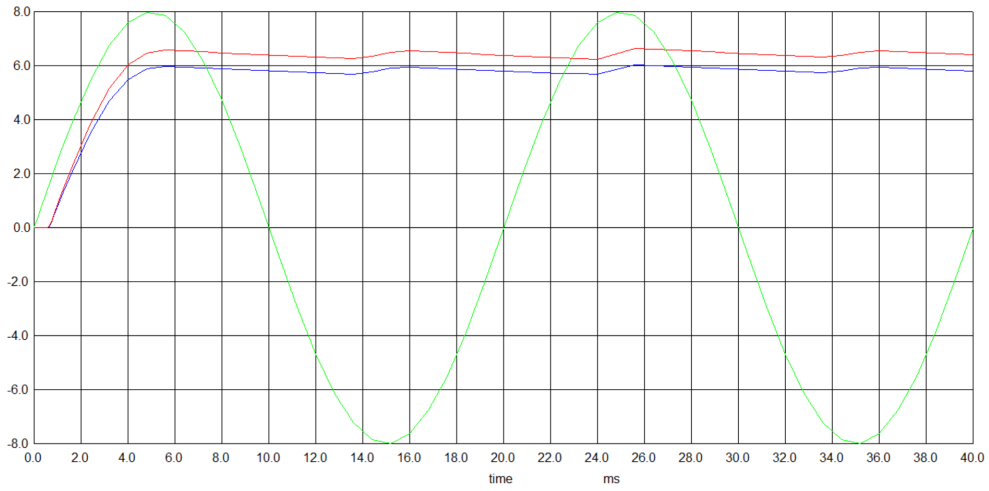
3 Results

Green - Input voltage , Red - Filtered Voltage($V_{Capacitor}$) and Blue - Regulated voltage(V_{Load})

3.1 With Zener diode



3.2 Without Zener diode



4 Understanding

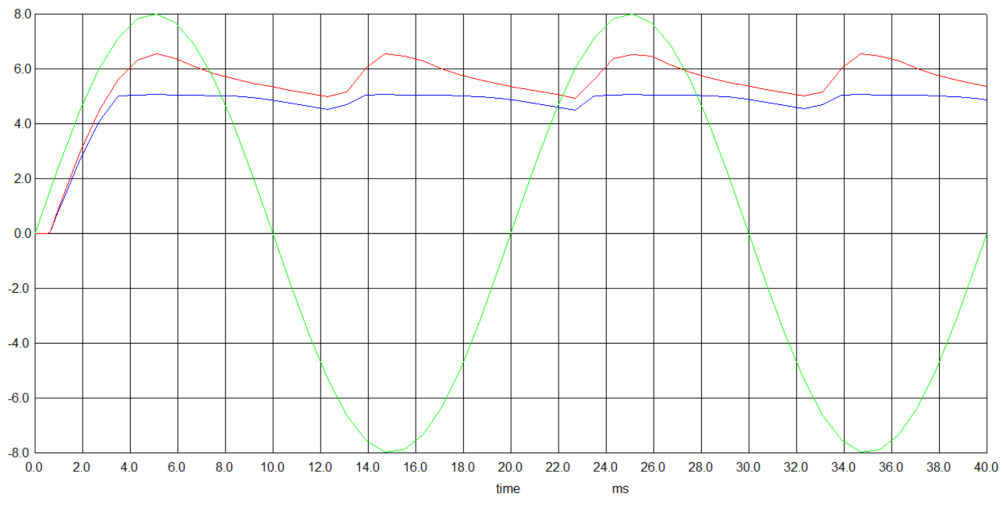
4.1 Choosing the values of R_S and C_F

The breakdown voltage of the zener diode is 5V.For the zener diode to stay in the breakdown region we don't want the voltage in the zener diode to go far below 5V.
So if we choose the resistance and capacitance values such that the time constant of the circuit(RC) is much greater than the time taken by the voltage from full wave rectifier to go till 5V.That is

$$R_S \times C_F > \frac{T}{2} = \frac{1}{50 \times 2} = 10ms$$

The exact value lies between $\frac{T}{4}$ and $\frac{T}{2}$ but the above case is sufficient for the zener diode to stay in breakdown region.
By doing this we filter out the voltage below 5V approximately(Since the decaying time is much larger) and the zener diode stays in the breakdown region as shown in the above plot.
Also the value of R_S should be much less than R_L so that the current flowing through the zener diode is high enough(greater than breakdown current) for it to stay in breakdown region.
Considering the above observations we took the values of the components as $C_F = 150\mu F$, $R_S = 100\Omega$ and $R_L = 1k\Omega$.($R_S \times C_F = 15ms$)

We can see in the below plot that if we take a low value of capacitance like $10\mu F$, the zener diode can't stay in the breakdown region as the filtered voltage goes below 5V at some point and the voltage is not regulated.



4.2 Impact of zener diode

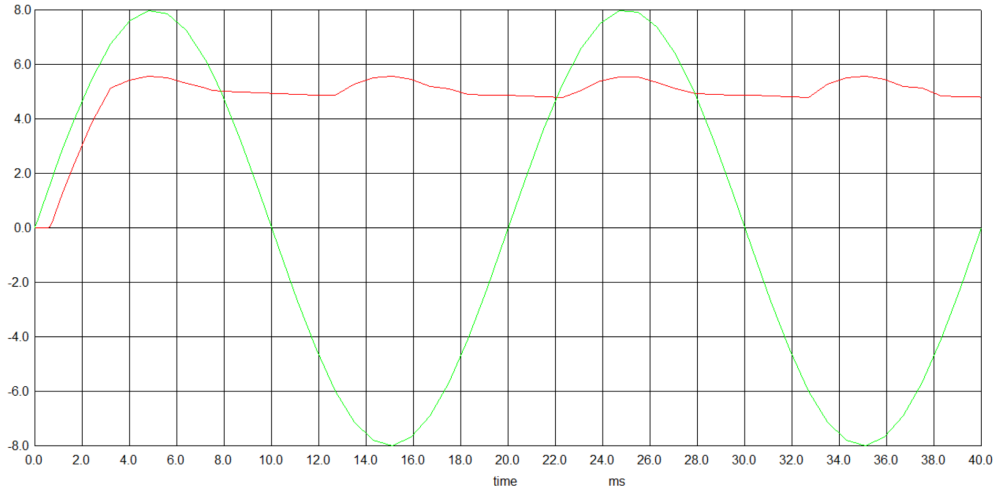
We can clearly see from the plots shown in results that the voltage is not exactly regulated(i.e perfect constant DC) without a zener diode.
This is because when the reverse voltage applied across the zener diode exceeds the rated voltage of the diode a process called Avalanche Breakdown occurs in the semiconductor depletion layer and a current starts to flow through the diode to limit this increase in voltage and the voltage stays almost constant from there even if there are some large changes in the current as long as the diode is in breakdown region.

4.3 Working of the circuit

First after the input voltage is passed through the rectifier circuit we get the output of a $\mid Sin \mid$ wave as discussed in the previous lab experiment. As explained in the observations above, when this output from the full wave rectifier passes through the capacitor it is filtered so that the zener diode is maintained in the breakdown region(i.e $V_C > 5V$).And since the zener diode undergoes avalanche breakdown the voltage is regulated and maintained at a constant voltage of 5V.

5 Additional Result

If the series resistance is removed then we get the load voltage as shown in the below plot



6 Conclusion

The voltage regulators are used in all power supplies and electronic gadgets to regulate voltage and save the device from damage.