Electronic Devices and Circuits Lab : Report-4

Sahukari Chaitanya Varun
EE19BTECH11040
Group-4

Saturday 17^{th} October, 2020

Contents

1 Aim :

The aim of the experiment was to understand the process of voltage regulation using Zener diode and study its details.

2 Procedure :

The voltage regulator is used extract a constant DC voltage across a load from an AC voltage source. The process is done 3 major steps

- Rectification
- Low Pass Filtering
- Regulation of the ripples

2.1 Rectification

We pass the input AC signal into a full wave rectifier circuit, hence we obtain a non-zero average voltage. The amplitude of the output voltage is less than the input, due to the drop across diodes.

2.2 Low Pass Filtering

The rectified input is now passed through a capacitor which extracts the low frequency components of the voltage. Initially when the voltage across the capacitor increases, the capacitor charges to a maximum value, and when the rectified input voltage starts dropping, the capacitor starts discharging, maintaining voltage from dropping. Hence we observe ripples across the voltage of the capacitor. For lower value of capacitors, discharge rate would be large, hence the drop in ripples is large. Hence we try to use maximum capacitance possible.

2.3 Regulation

The rippled voltage signal has to be regulated so that the ripples are eliminated. This is achieved using zener diode. Zener diode is pn-junction diode which has very high doping. When such kind of diodes are applied reverse bias, after sufficient voltage, the energy bands of p and n overlap, resulting in tunneling of large amount of electrons and holes. So, at a particular breakdown voltage we get very large amount of current as can be seen in the voltage characteristics.

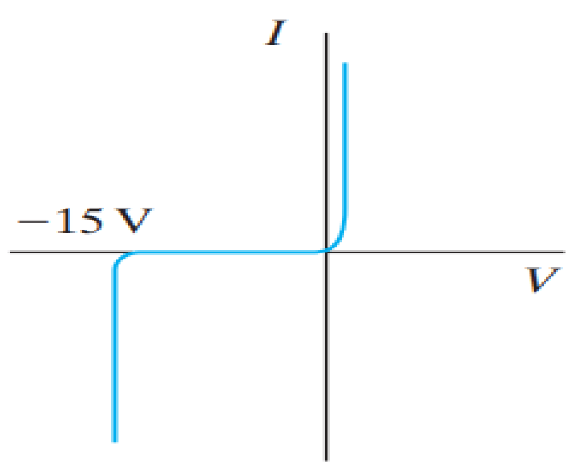


Figure 1: IV Characteristics of Zener diode with breakdown voltage 15V

Varying the doping concentration, the breakdown voltage can be varied.For higher doping concentrations, the breakdown voltages are higher. In simulation we take the breakdown value to be 9V.

As it can be observed that there is large amount of current that can pass through the diode at breakdown, it is important to limit this current as large current flow through the diode damages it. So we connect a series resistance R_s, limiting the current through the diode. Now when we connect the rippled voltage signal to the series resistance and diode, then extract the voltage across the diode to the load, we can observe that until the rippled voltage drops less than the amount that is required for making the diode work in breakdown, the voltage across load is always constant which is equal to the breakdown voltage of zener diode, eliminating ripples. Hence we can obtain the circuit for the voltage regulator as shown. Here we observe that the se-

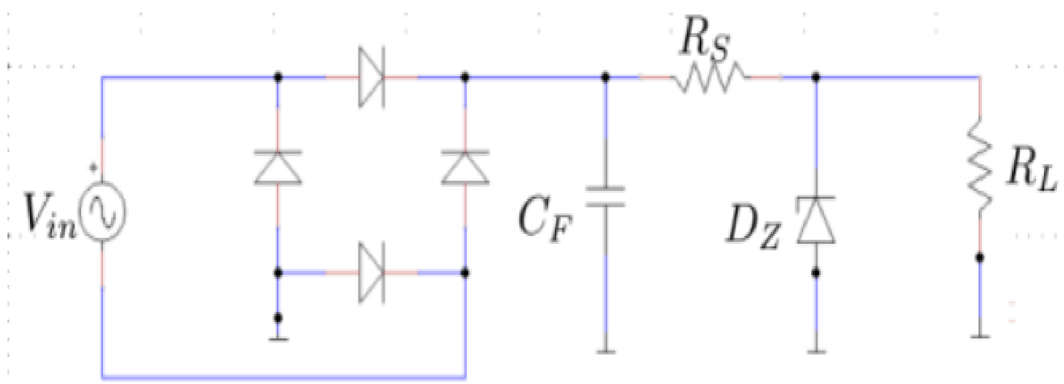


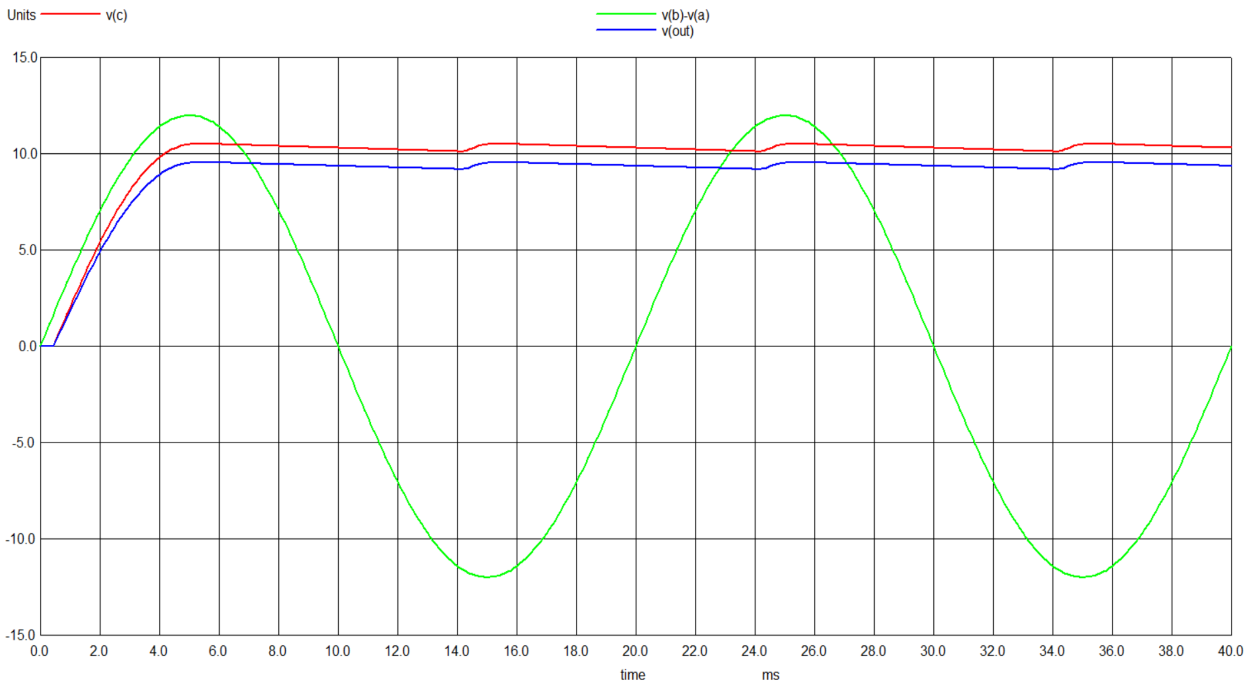
Figure 2: Circuit diagram

ries resistance should be able to create bias greater than zener voltage, at the same time also limit the amount current into diode. Calculating we get,

$$\frac{V_s - V_z}{I_{Zm} + \frac{V_Z}{R_L}} \leq R_s \leq R_L\left(\frac{V_s - V_z}{V_z}\right)$$

where V_s is the minimum voltage in ripples, V_z is the breakdown voltage, I_{Zm} is the maximum current that can be flown through the zener diode(generally 40mA), R_L is load resistance. Taking the load resistance in the given range of 1kΩ to 2kΩ, R_s can be safely taken as 100Ω. Here the input voltage sinusoidal has amplitude is taken as 12V and capacitor is taken to be 0.2mF ensuring the zener diode to be working in breakdown region.

3 Results and Discussion



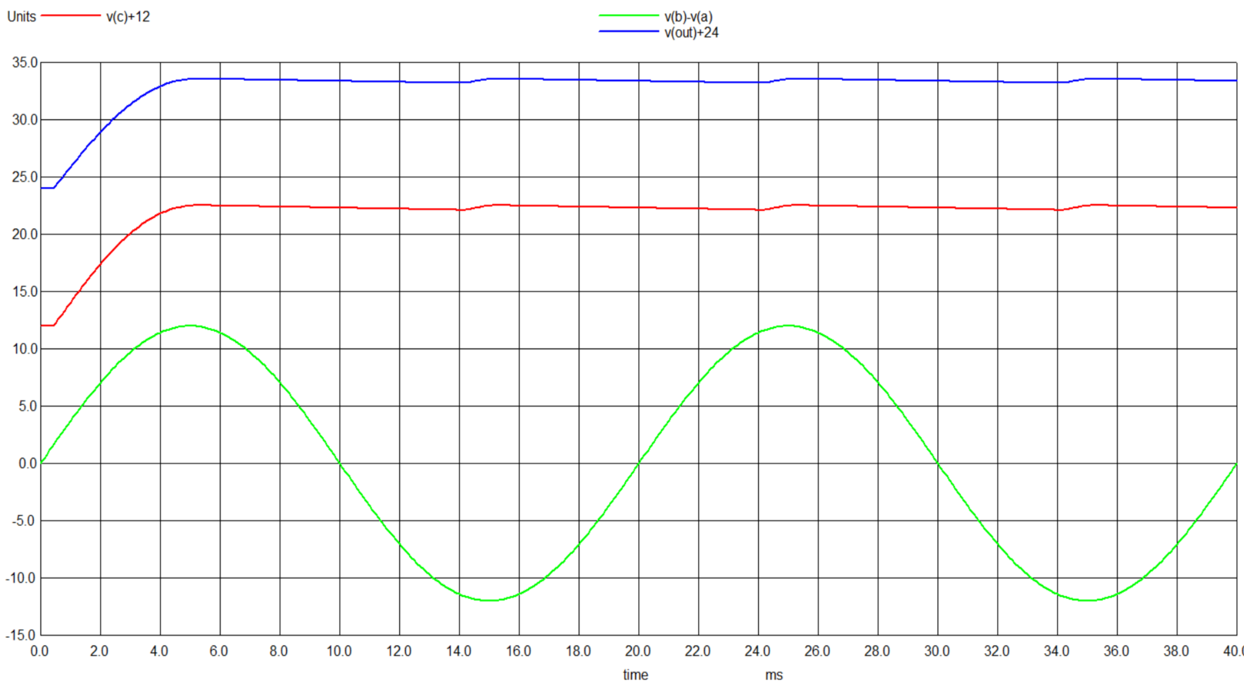
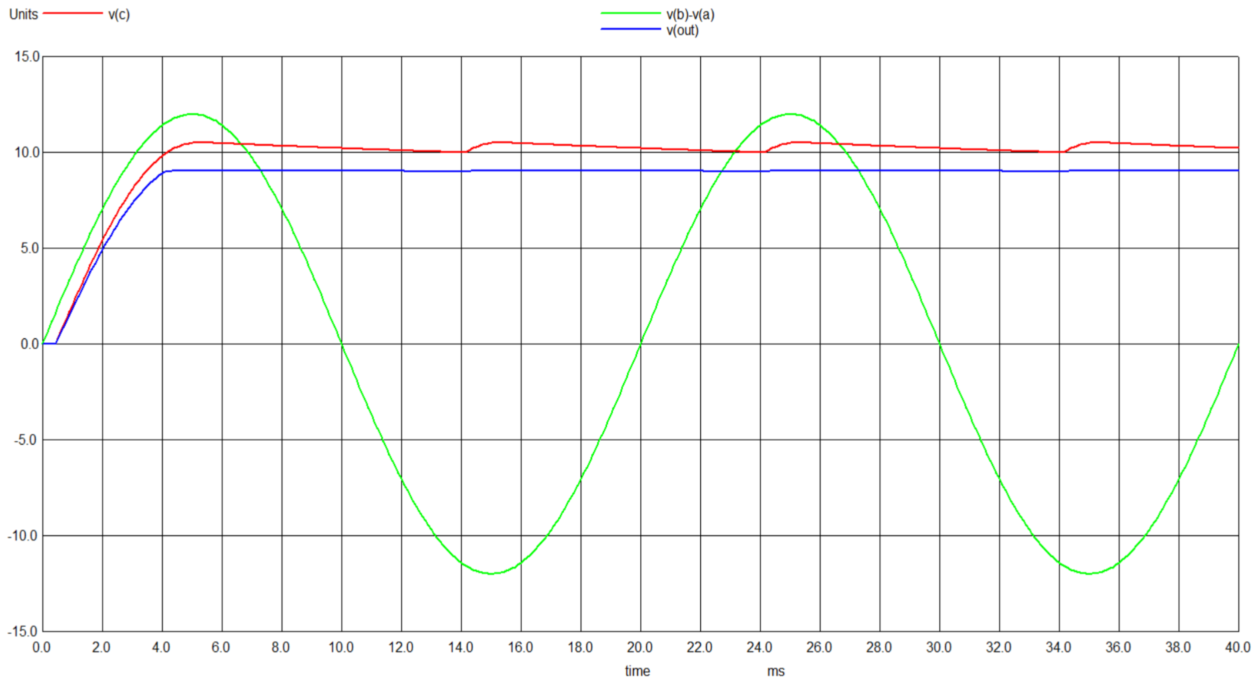


Figure 3: Simulation Outputs in the absence of Zener diode for 1kΩ load. Input voltage(green),Voltage across capacitor(red),Voltage across load(blue)

Affect of Regulation :



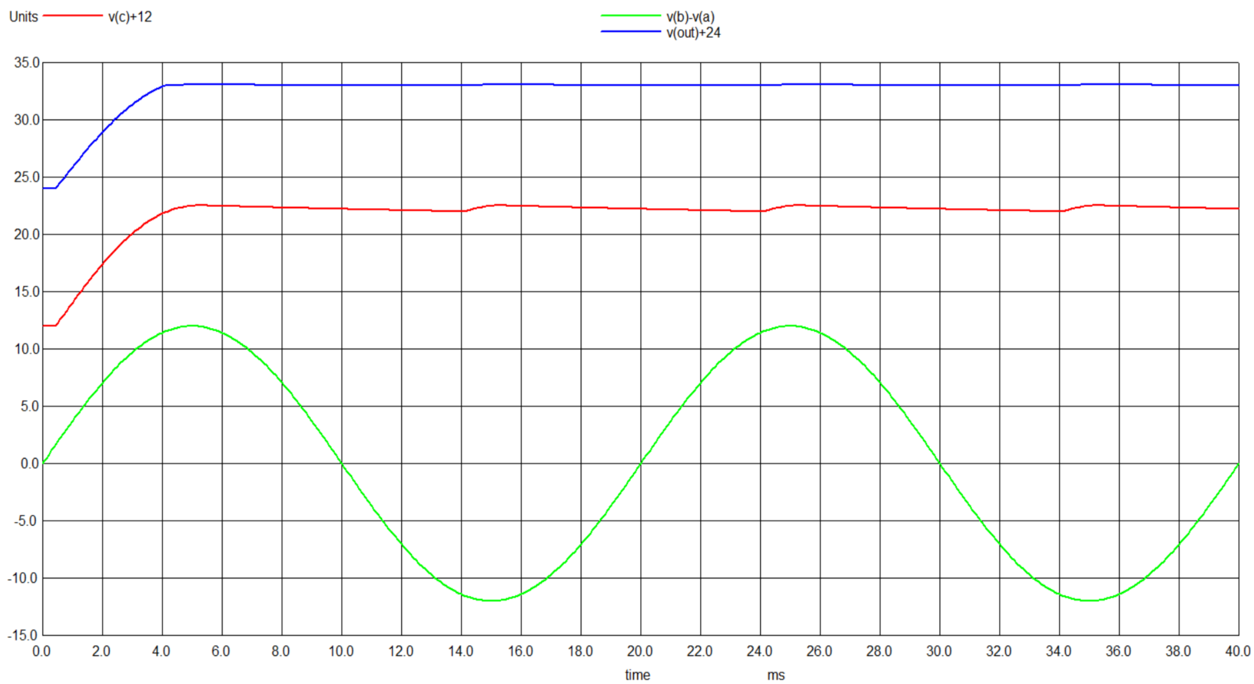


Figure 4: Simulation Outputs in the presence of Zener diode for 1kΩ load. Input voltage(green),Voltage across capacitor(red),Voltage across load(blue)

Observations :

- The rectified voltage has less amplitude than that of input, suggesting the drop across the diodes and the difference is approximately 1.4V.
- In the absence of the regulator(zener diode), the voltage across load is scaled output of the voltage across capacitor and hence retains the ripples. The scaling depends on the ratio of load resistance(R_L) and series resistance(R_s), higher the ratio, more similar is the voltage across load.
- In the presence of the regulator(zener diode), the voltage across the load initially ramps up and then settles at constant value, without any ripples. And the constant value is the zener voltage(9V).
- The least value of voltage in ripple is greater than the breakdown voltage and hence the zener diode is always working in breakdown voltage.
- Increasing the resistance of the load has almost no affect on the output, suggesting that the series resistance allows permissible current for all range of resistances in 1kΩ to 2kΩ.
- Increasing the value of capacitance the length of the ripple can be minimised because of the slower discharge rate.
- The process of low pass filtering is done by the capacitor itself, making maximum voltage drop available for the zener diode.
- Increasing series resistance R_s, results in zero in the output, suggesting the insufficient reverse bias across the diode shorts the load. Where as decreasing results in large current pass through the diode, which actually does not reflect in simulation.

4 Conclusions

1. An a.c. voltage can be converted to a constant d.c. voltage using a voltage regulator.

2. The process involved has three steps namely, rectification done with help of full wave rectifier, low pass filtering which is done with the help of capacitor, and regulation which done with the help of zener diode.

3. Zener diode is a heavily doped pn junction diode, which when happens to be at reverse bias, after sufficient bias has almost constant voltage for wide range of current.

4. The breakdown voltage of the zener diode depends on the doping concentrations, for higher doping, larger is the breakdown voltage.

5. The value of the capacitor changes the size of the ripple, higher the capacitance smaller is the ripple and vice-versa.

6. The series resistance R_s is used to limit the large amount of current entering into the diode damaging it. But it also has to ensure the sufficient bias required for the breakdown of diode.

7. The zener diode removes the ripples from the voltage from the capacitor and supplies a constant voltage across diode assuming it to be in breakdown region.

8. The load resistance always extracts constant current and the remaining current enters into the diode.