EE 331 Lab Experiment 2

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1.Introduction

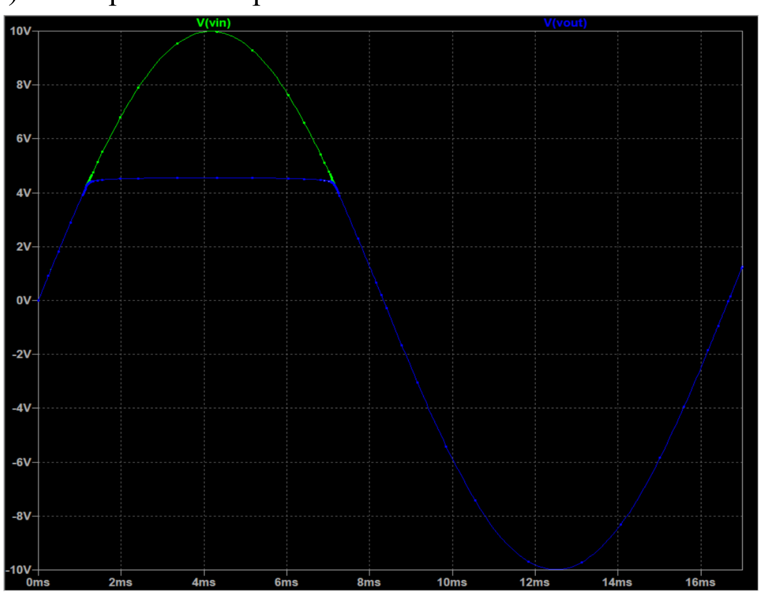
This document is a report on the behavior of complex diode currents. The information is provided in the following format. In section 2, five procedures are explained in detail and the resulting data is presented. Procedure 1 simulates a variety of voltage clippers. Procedure 2 simulates a variety of voltage limiters. Procedure 3 simulates the half-wave rectifier. Procedure 4 simulates full-wave rectifier. Procedure 5 simulates full-wave rectifier with a voltage regulator. In section 3, results are analyzed and questions regarding the procedures are addressed. Finally, in section 4, overall results are discussed and conclusions are made.

2. Data

Procedure 1

The following screenshots below show circuits that tests the voltage output and VTC of diode 1N4148 with 10V 60Hz AC source and 10k resistor, and a 4/-4V DC source connected in series for cases of positive-peak positive-level clipper, negative-peak positive-level clipper, positive-peak negative-level clipper, and negative-peak negative-level clipper. We use the transient simulation to plot the relationship between voltage output and voltage input, and use the DC sweep to plot the VTC of the diode for each case. The results are as shown in the plot.

i) The input and output waveforms as a function of time for VS = 10.0 V peak sine wave (60 Hz)



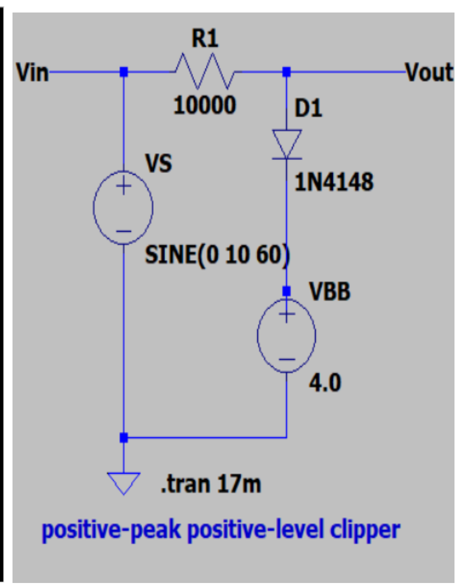


Fig. 1 Procedure 1 Setup

ii) The voltage transfer characteristics (VTC), where the x-axis is Vin and the y-axis is Vout.

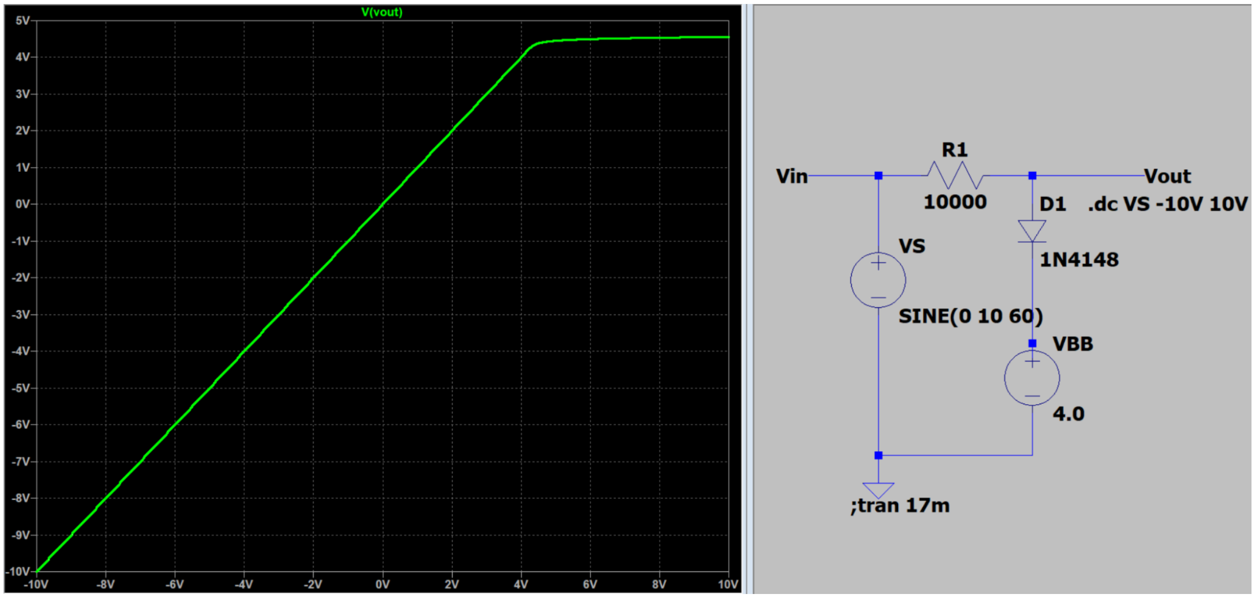


Fig. 2 DC Sweep from -10V to +10V

iii) VTC with diode D1 flipped.

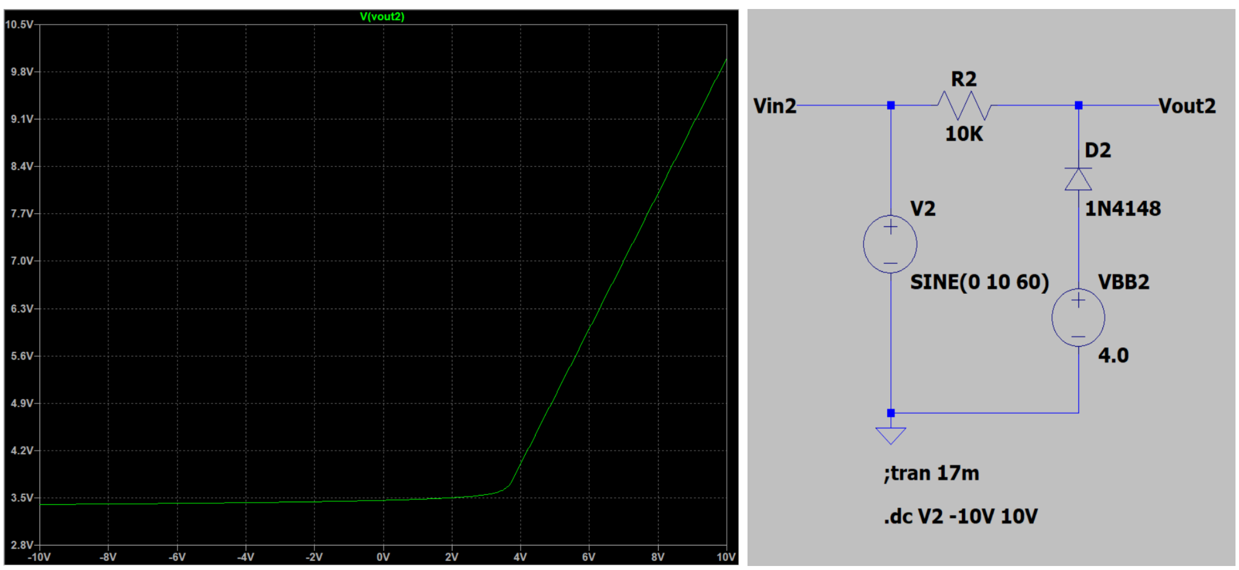


Fig. 3 Diode flipped

iv) VTC for both orientations of the diode withVBB = -4V

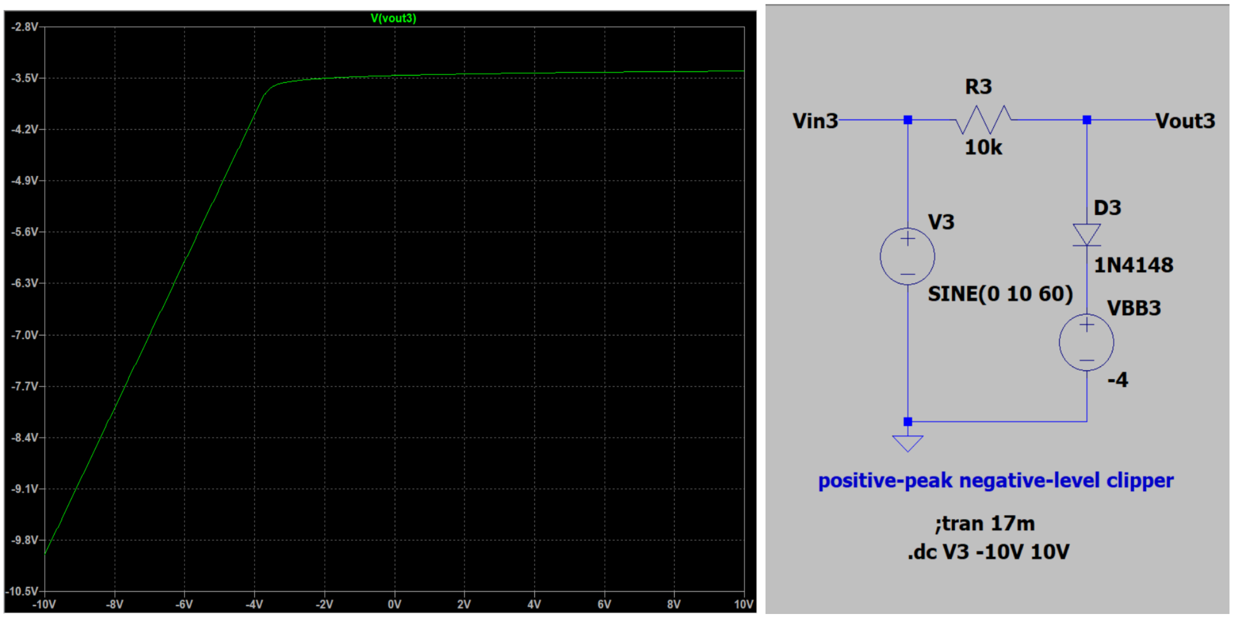


Fig. 4 VBB changes to -4V

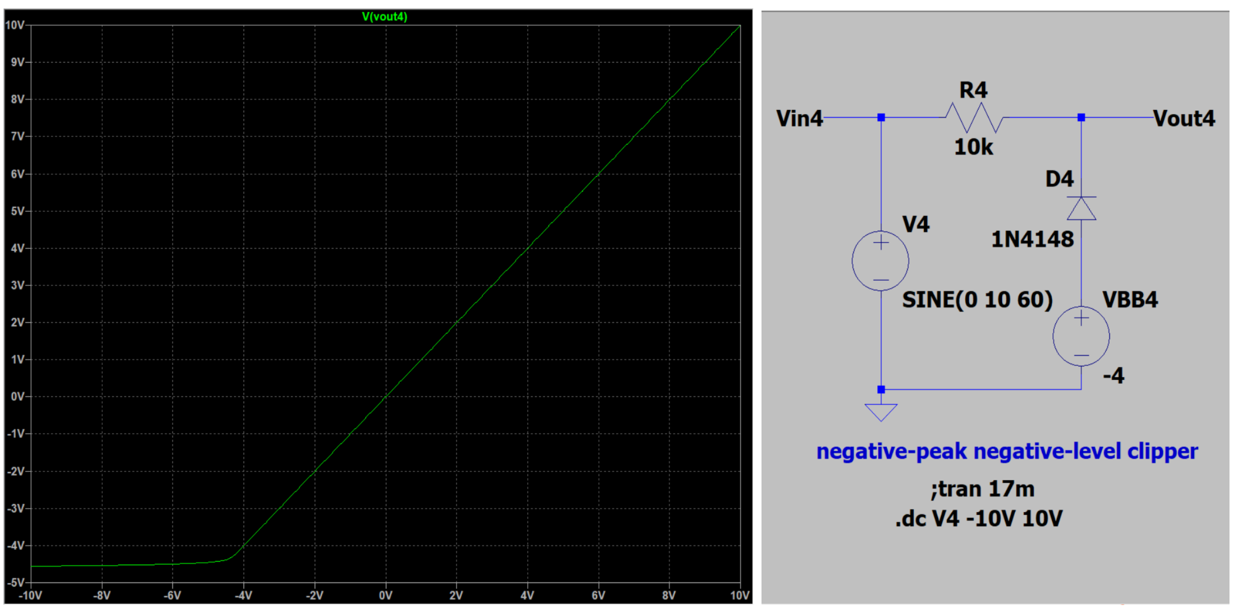


Fig. 5 VBB changes to -4V with flipped Diode

Procedure 2

In Procedure 2, we use 1N4007 diode and 1N4732 zener diode to set up 4 types of voltage limiter, namingly limiter-A, B, C, D. We connected each voltage limiter to a 100 ohm resistor, 10V DC source, and in parallel to a 1000 ohm resistor. We used DC sweep from -10V to +10V to examine the VTC for each limiter on the plot. We also tried to test limiter with two 1N4732 connected in antiparallel. Based on the observation on the output of each voltage limiter, we finally tried to design a voltage limiter that constrains the output voltage to approximately -9.4V to 2.0V, and we used two 1N4732 connected in series, as shown in Question 2.c). The VTC for each limiter are shown below.

VTC for Limiter-A:

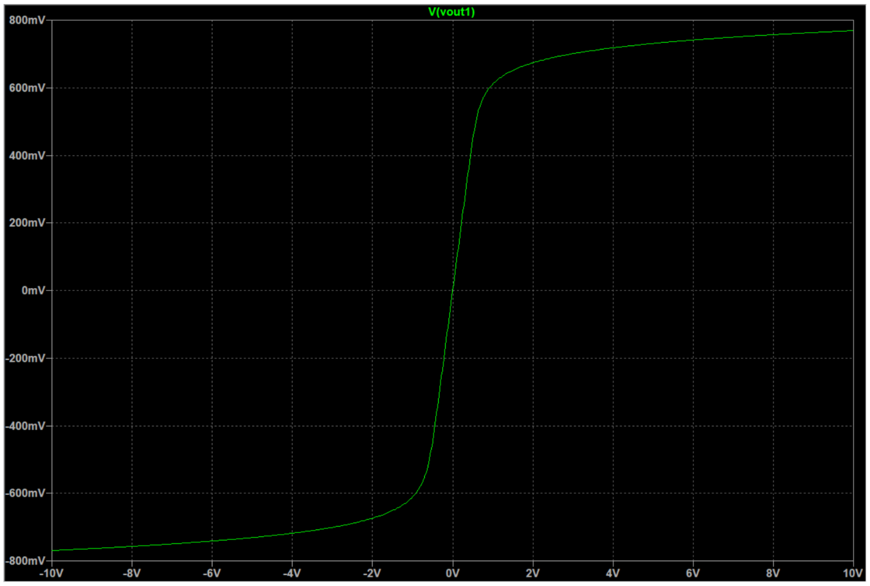


Fig. 6 Simulation of Limiter-A

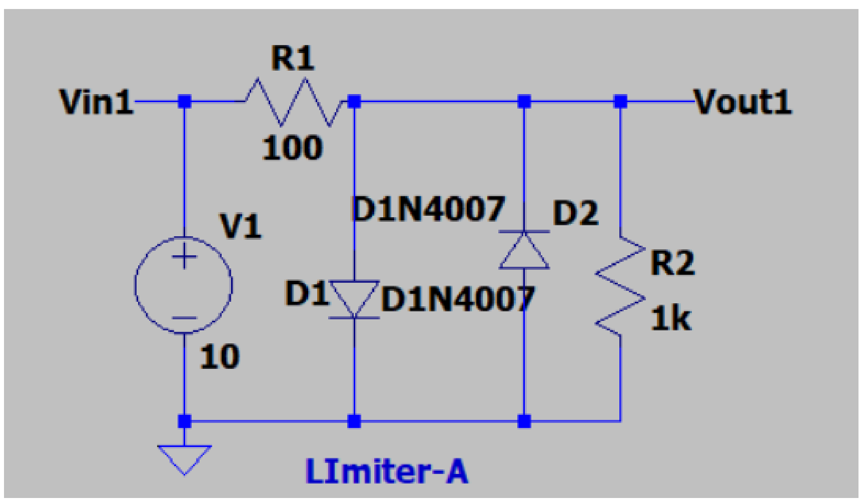


Fig. 7 Setup for Limiter-A

VTC for Limiter-B:

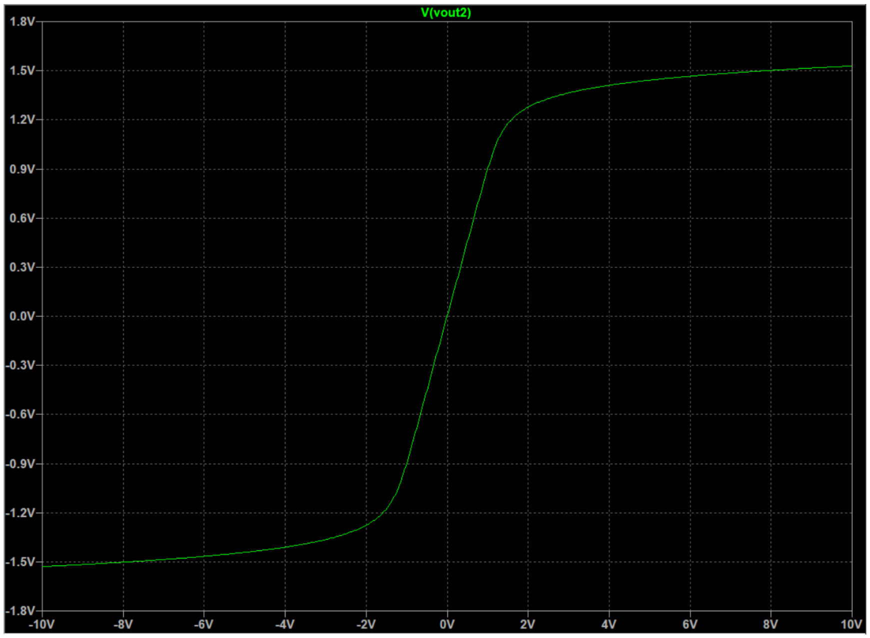


Fig. 8 Simulation of Limiter-B

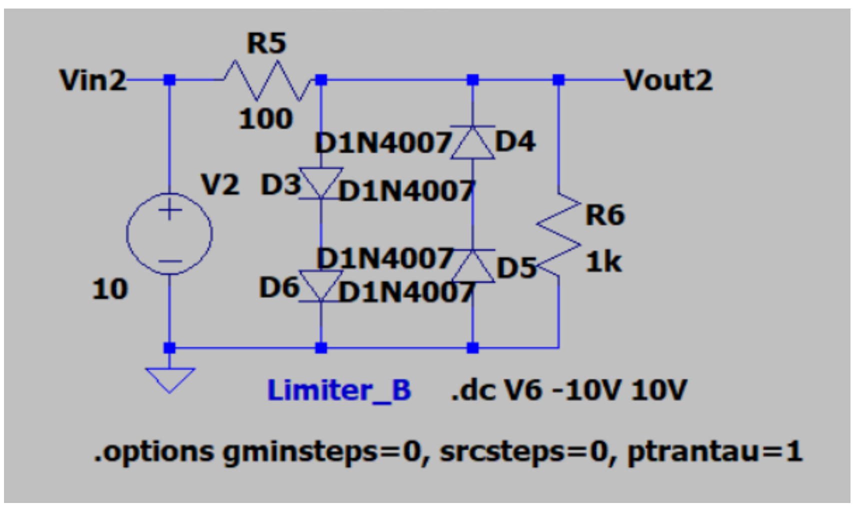


Fig. 9 Setup for Limiter-B

VTC for Limiter-C:

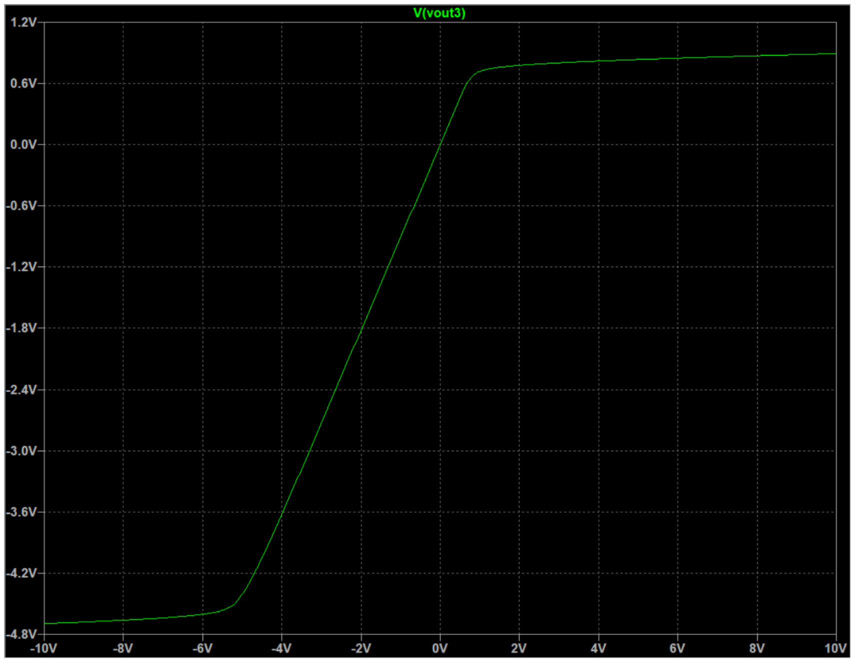


Fig. 10 Simulation of Limiter-C

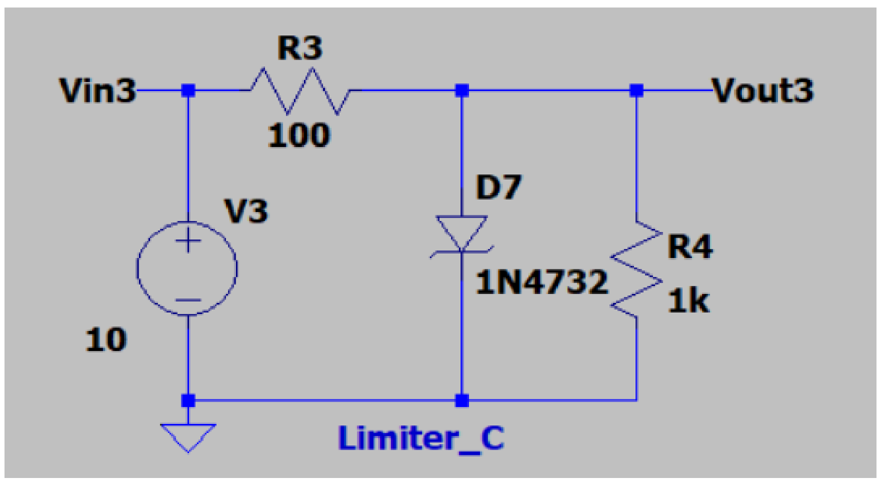


Fig. 11 Setup for Limiter-C

VTC for Limiter-D:

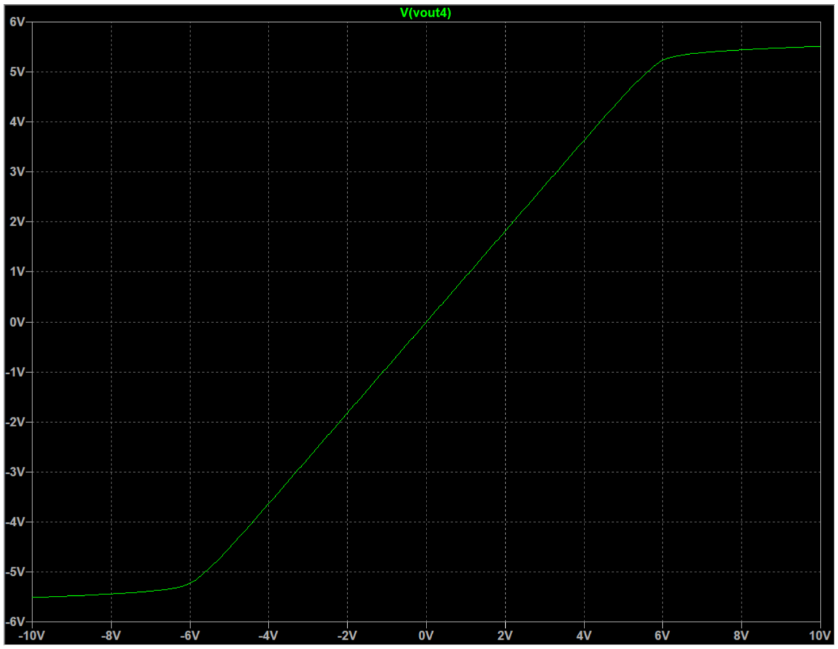


Fig. 12 Simulator of Limiter-D

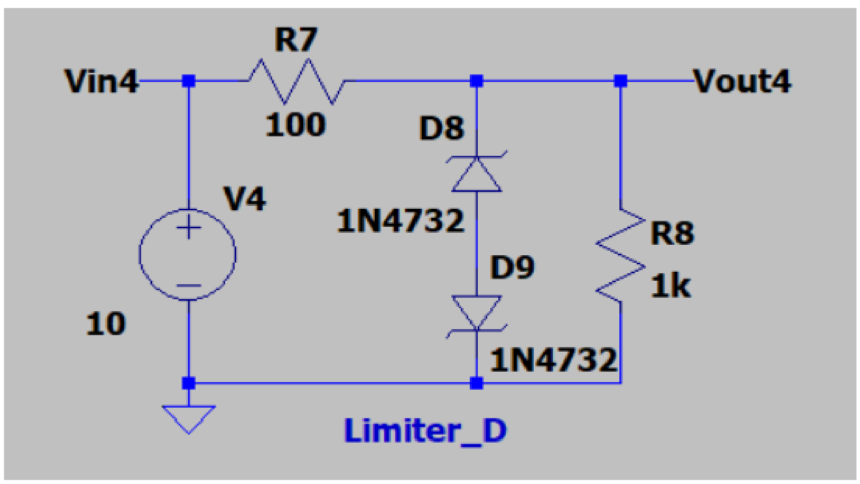


Fig. 13 Setup for Limiter-D

Procedure 3:

In procedure 3, we want to explore the capacitive filtering after the given rectification of AC power to produce DC source. We first connected a 10V 60Hz AC source, a 1N4007 diode and a 1000 ohm resistor in series for the AC rectification, then connected a 10uF capacitor in parallel to the resistor, and last added a 33uF capacitor in parallel to the resistor. We plot the voltage input and voltage output of the three cases using transient simulation, and have the following result.

Vin, Vout vs Time for no capacitor:

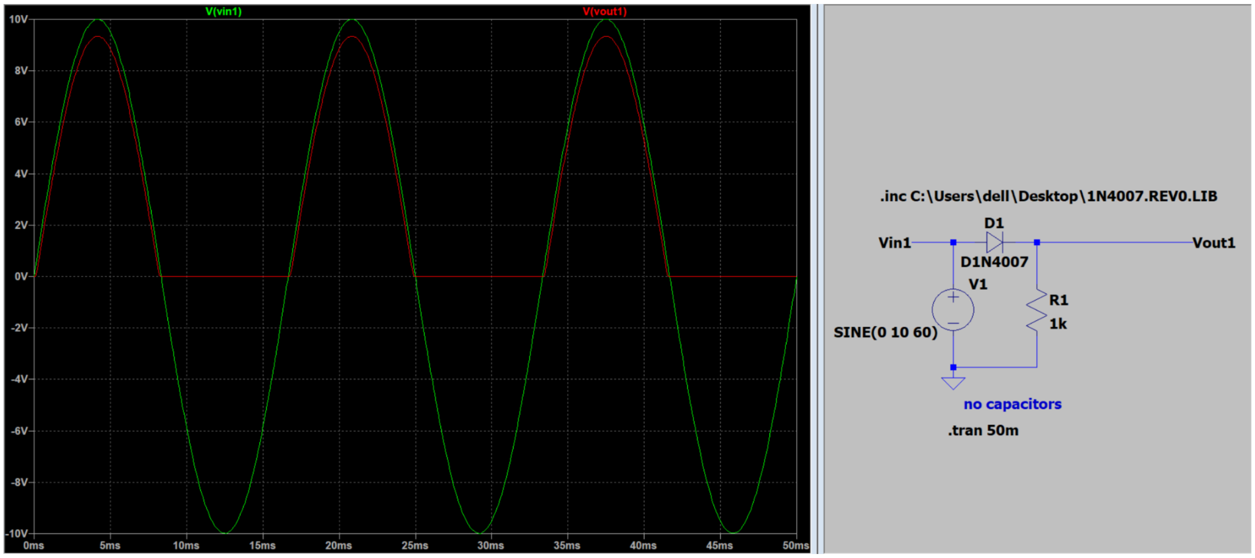


Fig. 14 Half-wave Rectifier with No Capacitor

Vin, Vout vs Time for filtering using only C1:

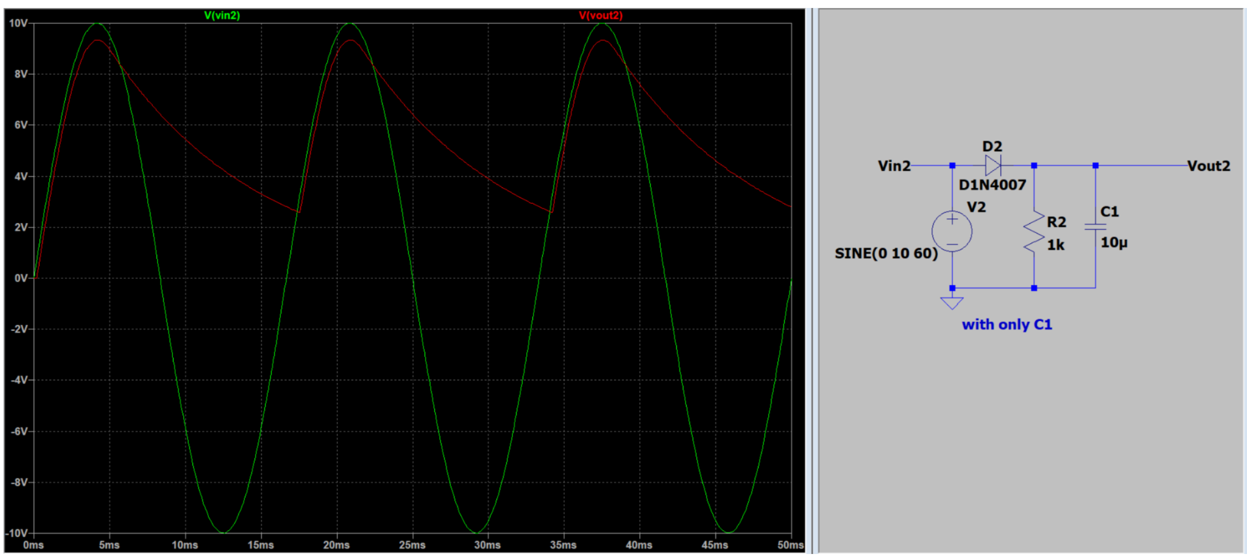


Fig. 15 Half-wave Rectifier with Capacitor C1

Vin, Vout vs Time for filtering using both C1 and C2:

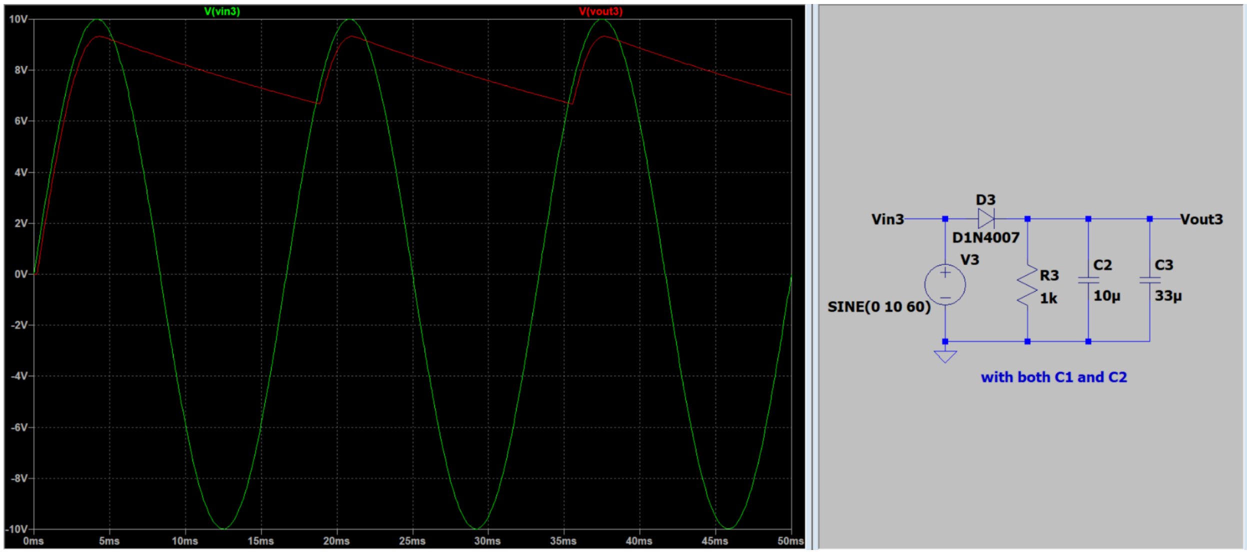


Fig. 16 Half-wave Rectifier with both Capacitor C1 and C2

Procedure 4

In procedure 4, we set up a full-wave rectifier with a resistor and two capacitors with a voltage source of amplitude of 10V, frequency of 60Hz. We first connect a 1K resistor only, and then 10microF capacitor and finally both 10 microF and 33microF capacitors.

(a) no capacitors

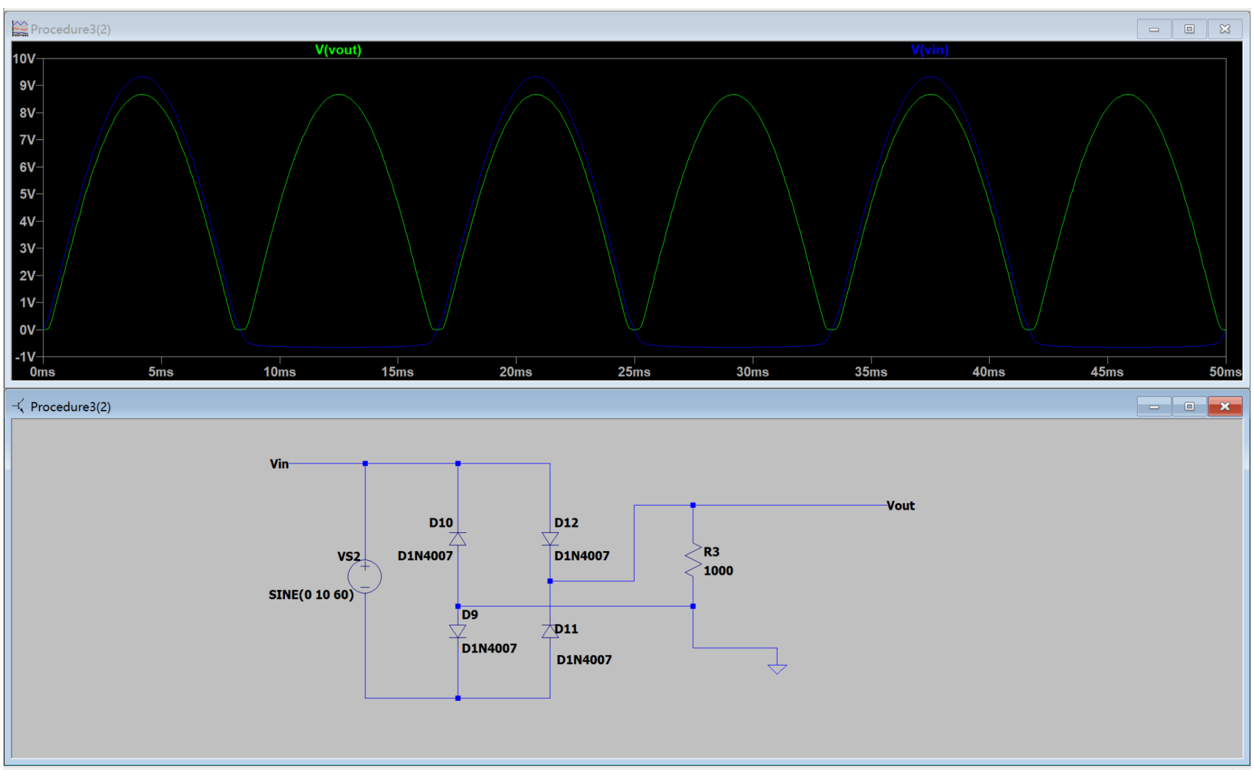


Fig. 17 Full-wave Rectifier with No Capacitor

(b) only C1

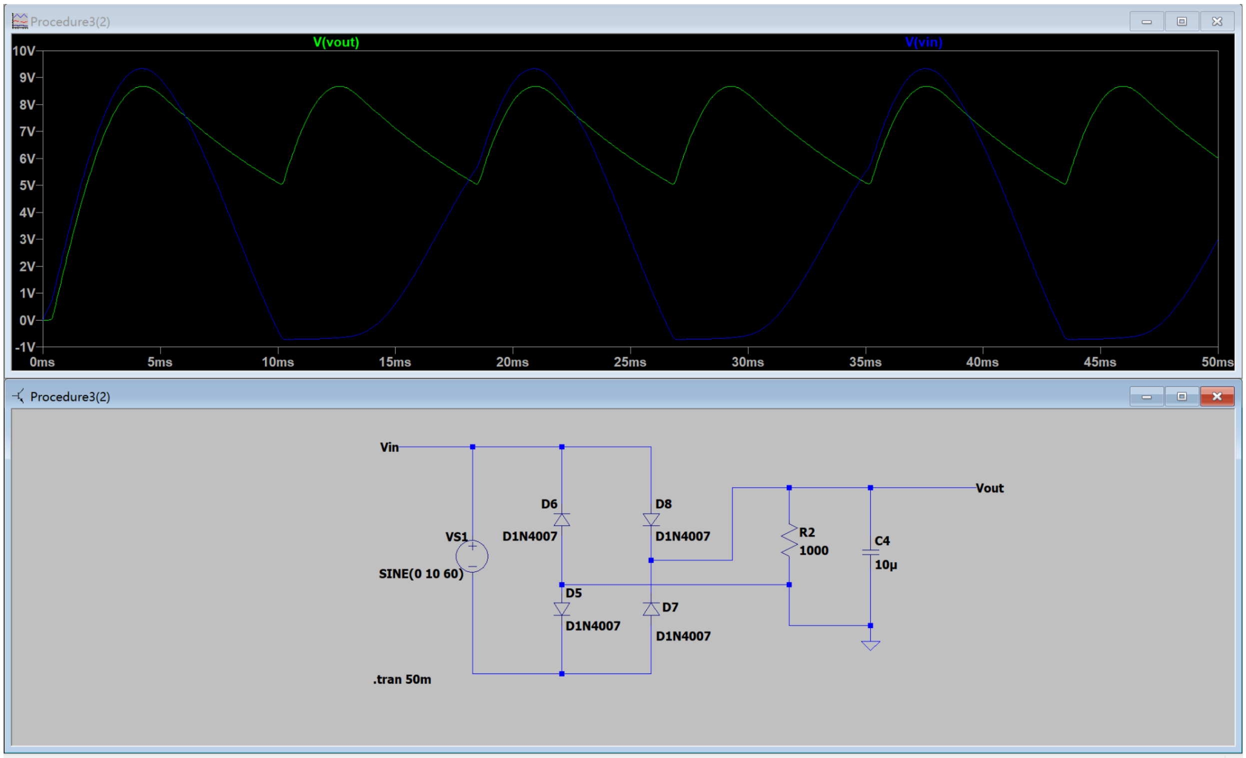


Fig. 18 Full-wave Rectifier with Capacitor C1

(c) with both C1 and C2

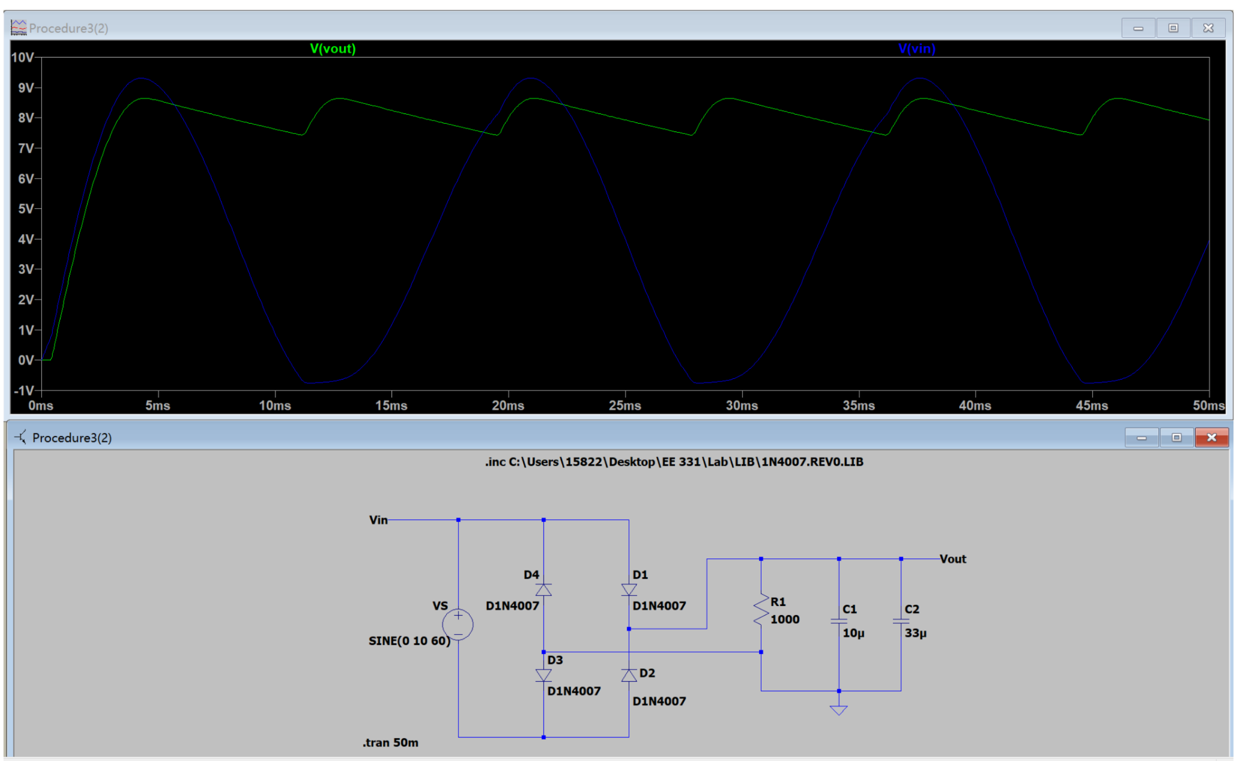


Fig. 19 Full-wave Rectifier with Capacitor C1 and C2

Procedure 5:

In procedure 5, in addition to the circuit of procedure 4, we add a Zener diode voltage regulator and explore the characteristics of the new circuits.

We first test the circuit with RL = 0. LTspice doesn't allow us to select Vout in this case. But we can say that when RL is 0, the R2 should consume all voltage and the path of the Zener diode equals an open circuit and it can no longer regulate voltage.

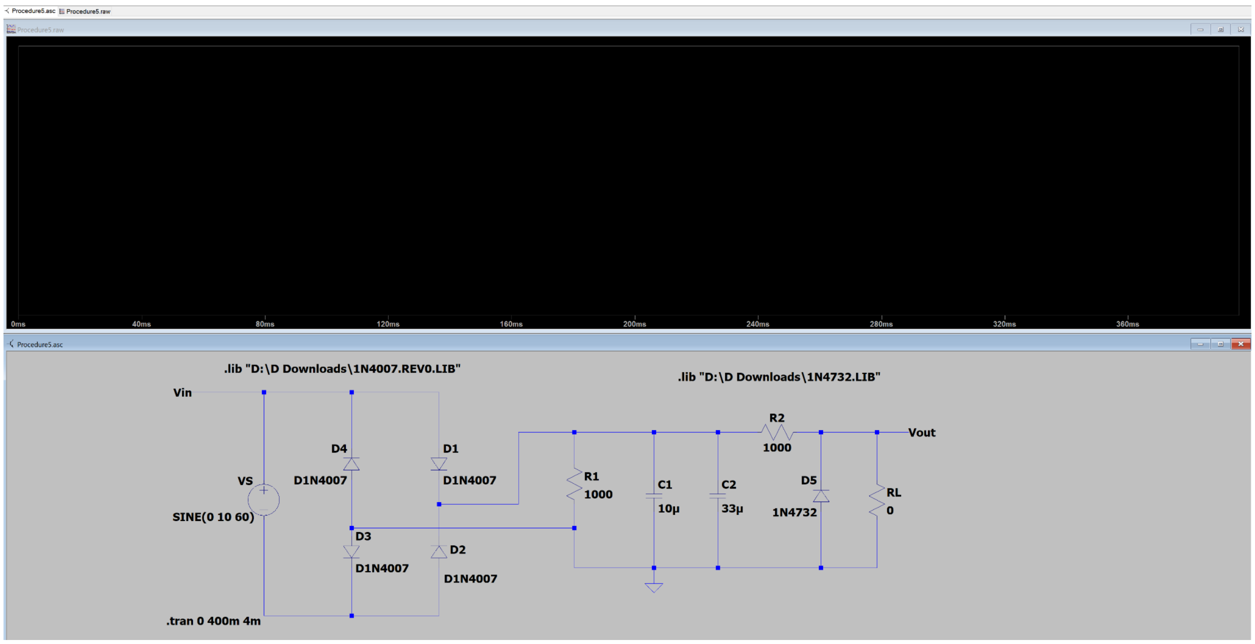


Fig. 20 Full-wave Rectifier with Voltage Regulator and RL = 0

Now we change the RL to 10KOhm

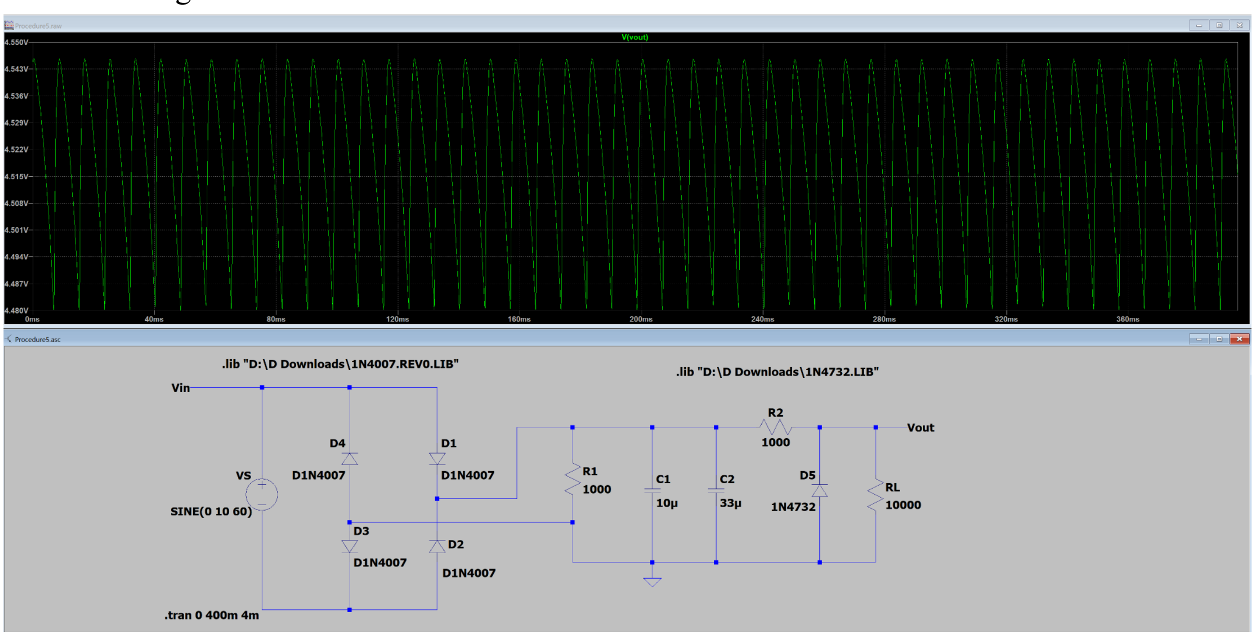


Fig. 21 Full-wave Rectifier with Voltage Regulator and RL = 10K Ohm

We can notice that the Vout now has little fluctuation (4.48-4.55V) which means the Zener diode is regulating the voltage.

Next, we test the output voltage for no load, 470Ohm, 1000 Ohm, and 4700Ohm with an aptitude of 10V input voltage. Since the no load is identical as previous image, I do not post again to save some space.

10V input voltage:
470 Ohm:

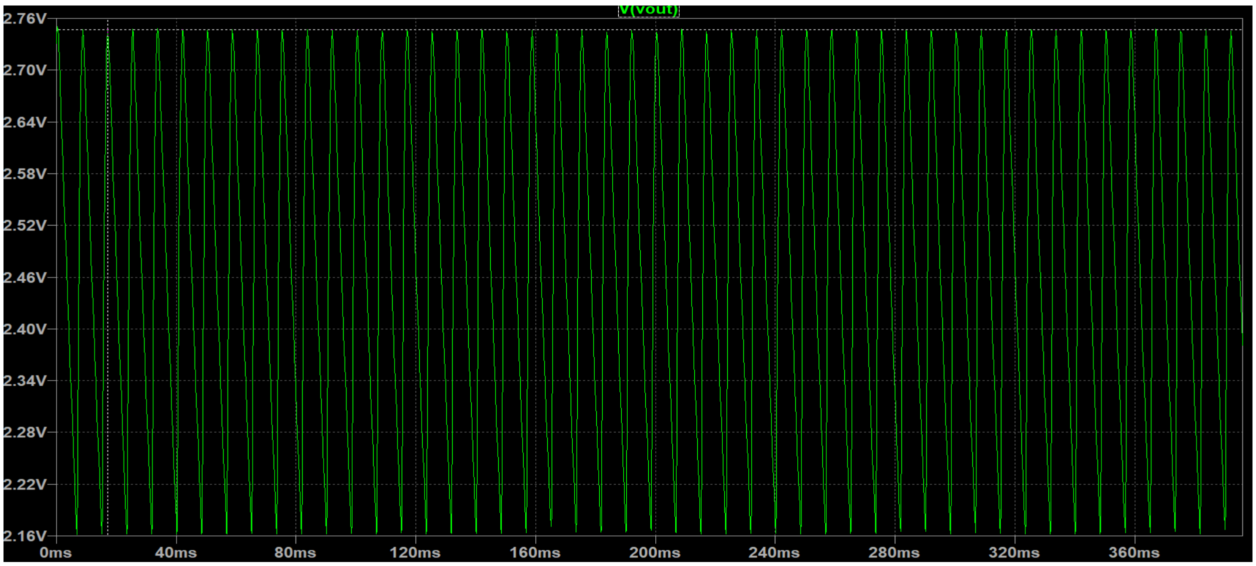


Fig. 22 Full-wave Rectifier with Voltage Regulator and RL = 470Ohm and Vin = 10V

1000 Ohm:

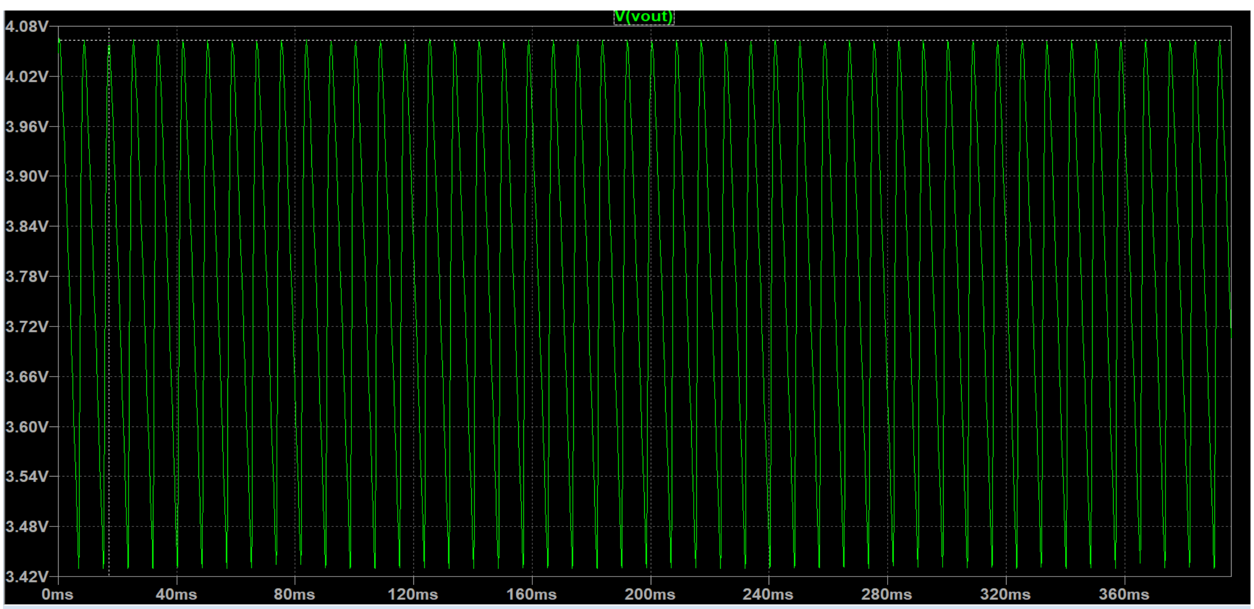


Fig. 23 Full-wave Rectifier with Voltage Regulator and RL = 1000Ohm and Vin = 10V

4700 Ohm:

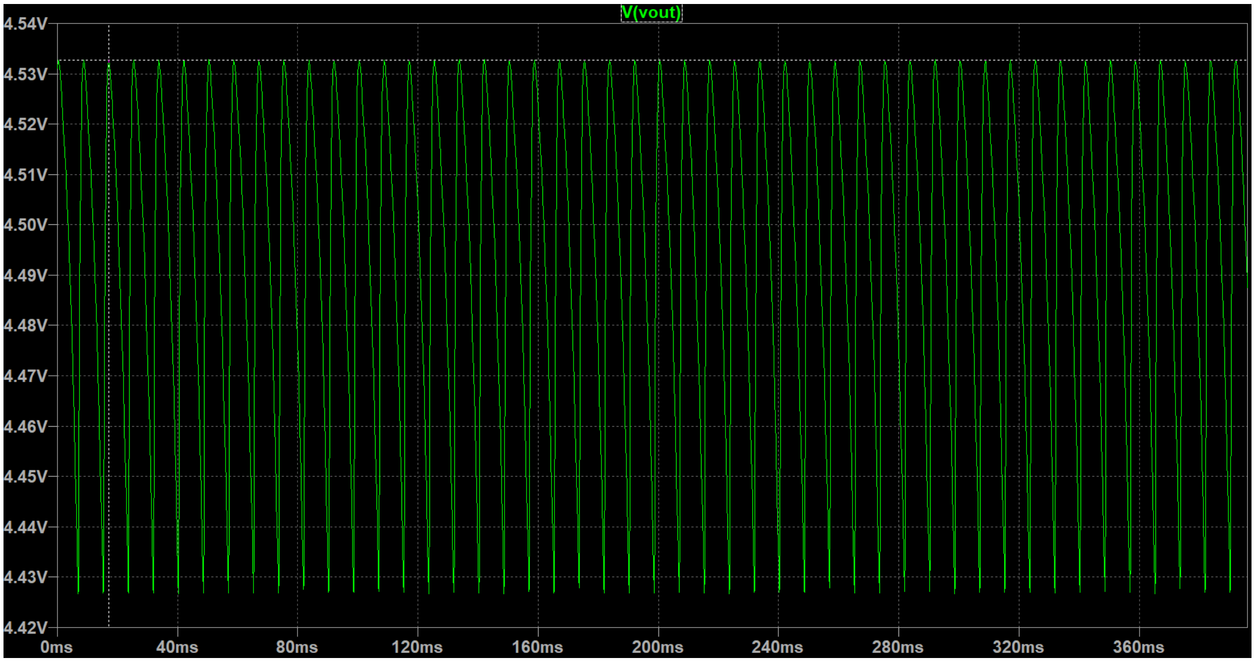


Fig. 24 Full-wave Rectifier with Voltage Regulator and RL = 4700Ohm and Vin = 10V

RL (Ohm)	Avg Vout
470	2.47265
1000	3.78814
4700	4.49457

Now switch to input voltage amplitude to 20V
470 Ohm:

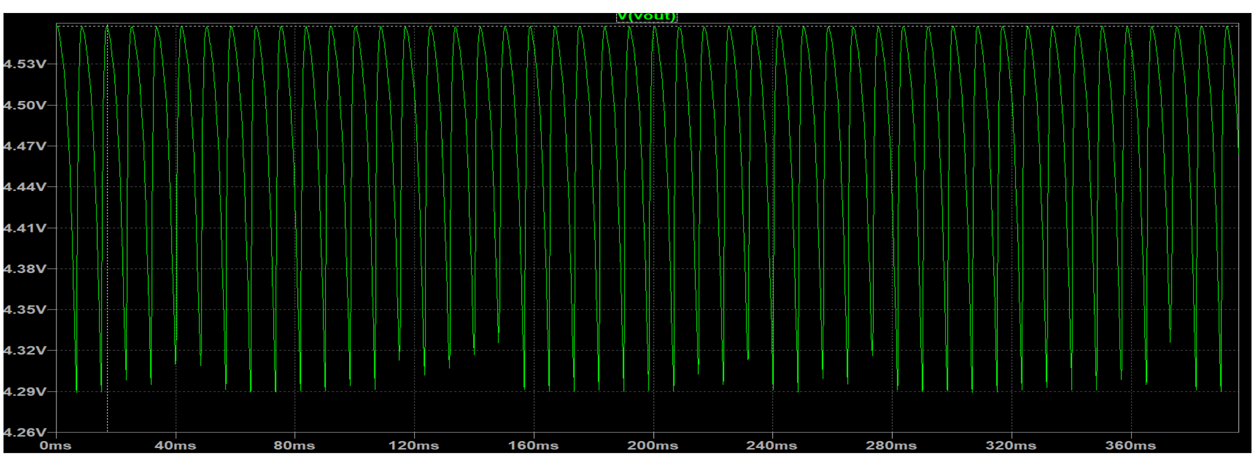


Fig. 25 Full-wave Rectifier with Voltage Regulator and RL = 470Ohm and Vin = 20V

1000 Ohm:

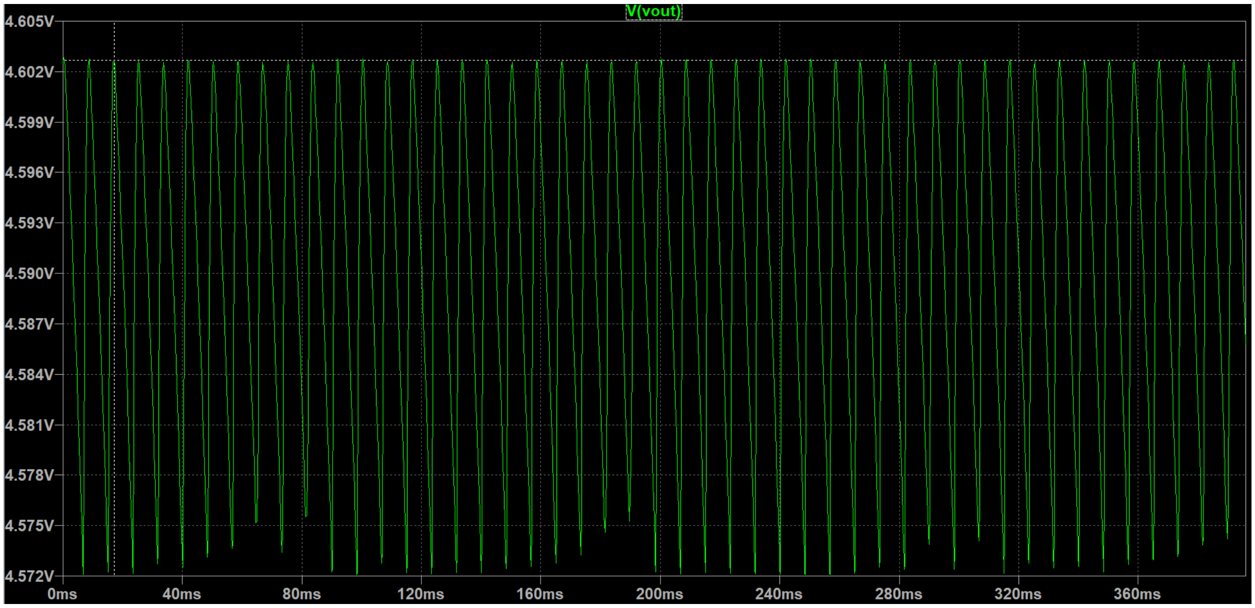


Fig. 26 Full-wave Rectifier with Voltage Regulator and RL = 1000Ohm and Vin = 20V

4700 Ohm:

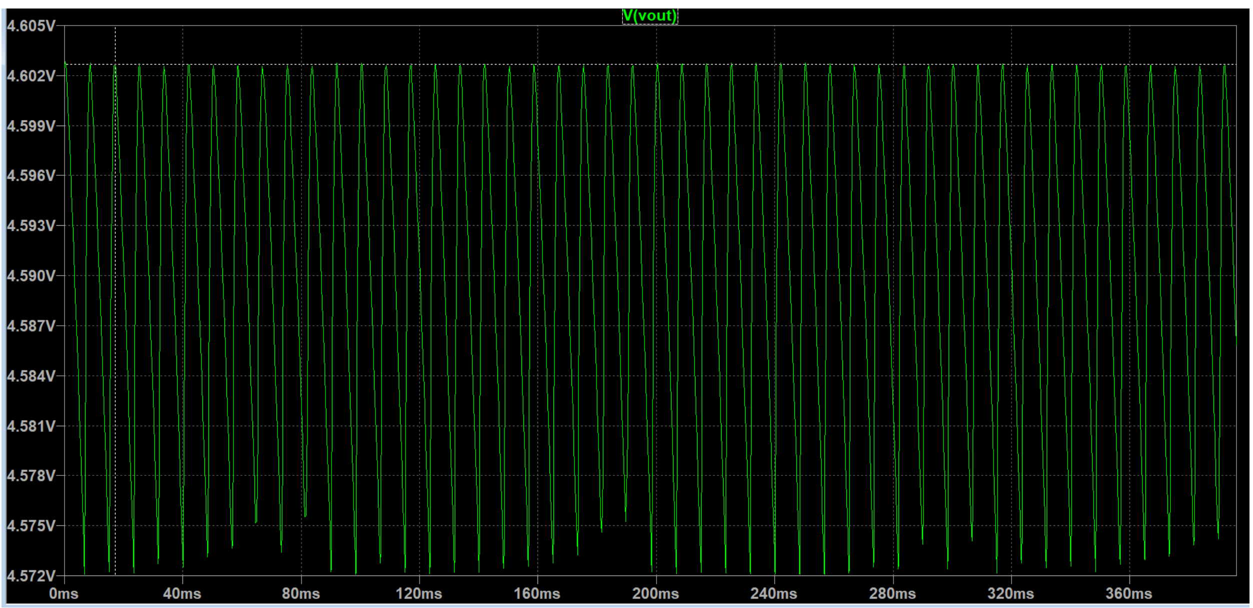


Fig. 27 Full-wave Rectifier with Voltage Regulator and RL = 4700Ohm and Vin = 20V

RL (Ohm)	Avg Vout
470	4.47836
1000	4.59004
4700	4.61084

3. Questions

Questions:

Q1:

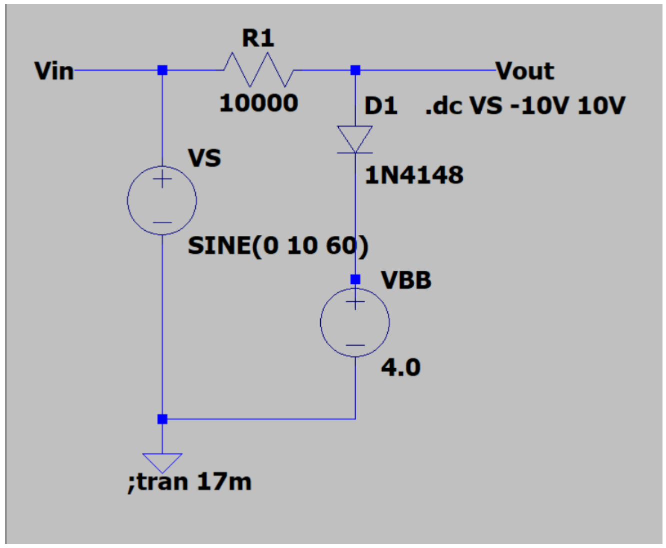


Fig. 28 Schematics for positive-peak positive-level clipper

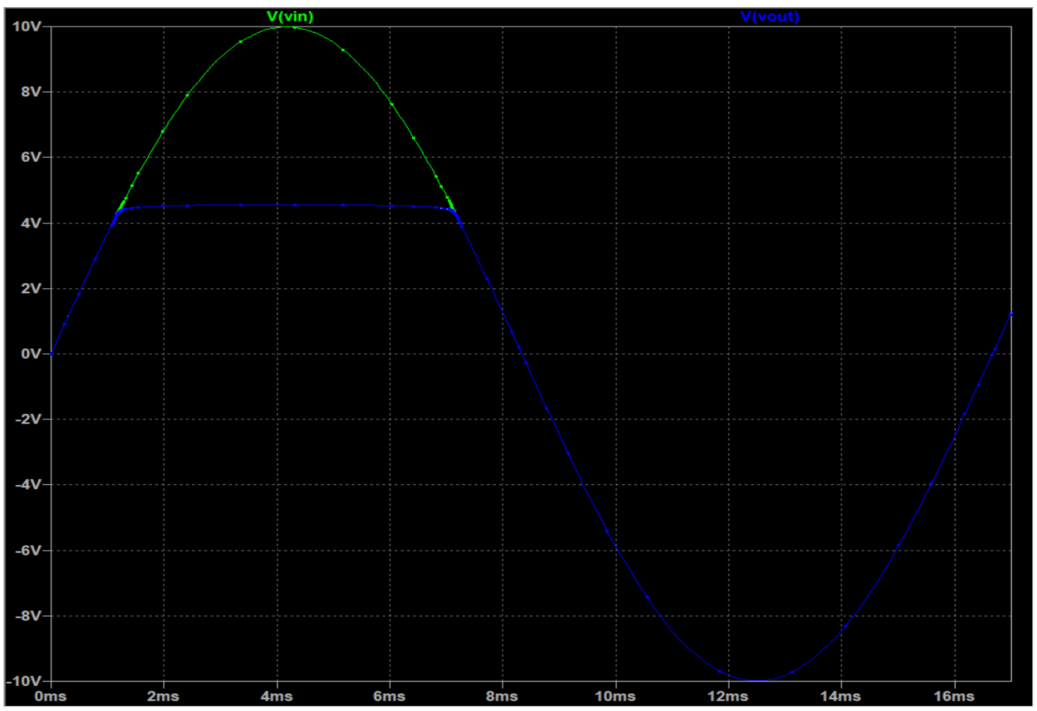


Fig.29 Vout, Vin vs Time for positive-peak positive-level clipper

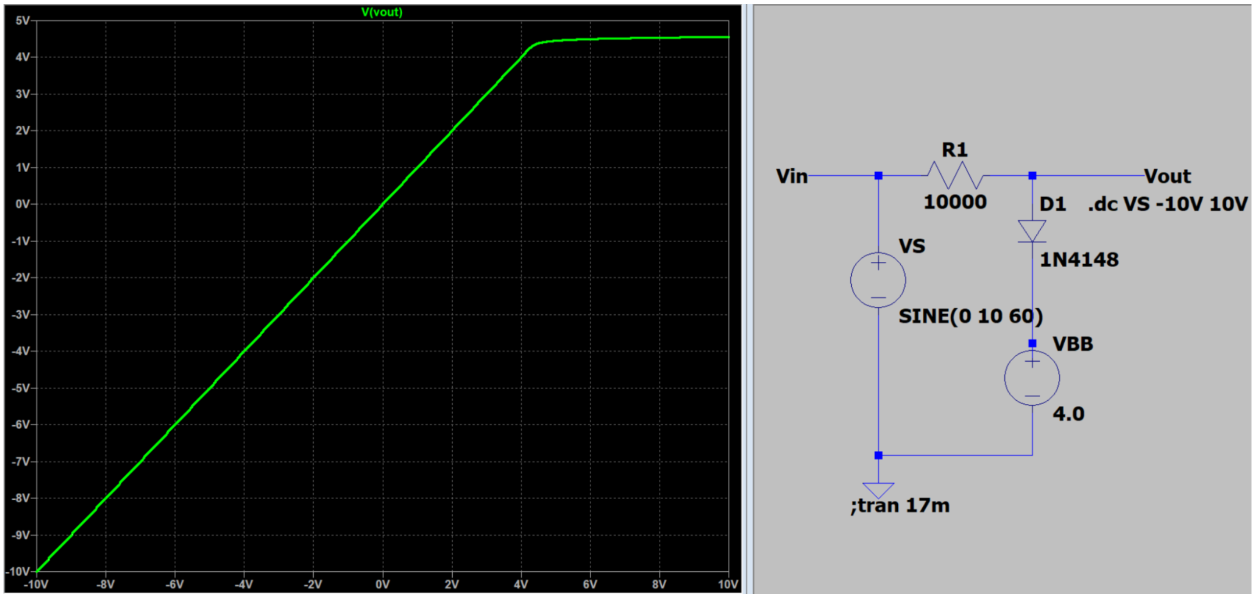


Fig. 30 VTC for positive-peak positive-level clipper

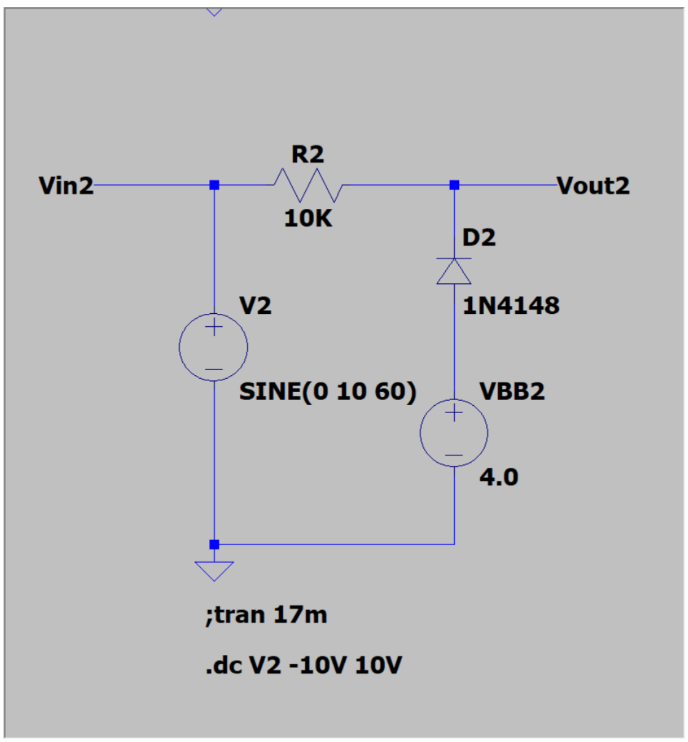


Fig. 31 Schematics for negative peak positive level clipper

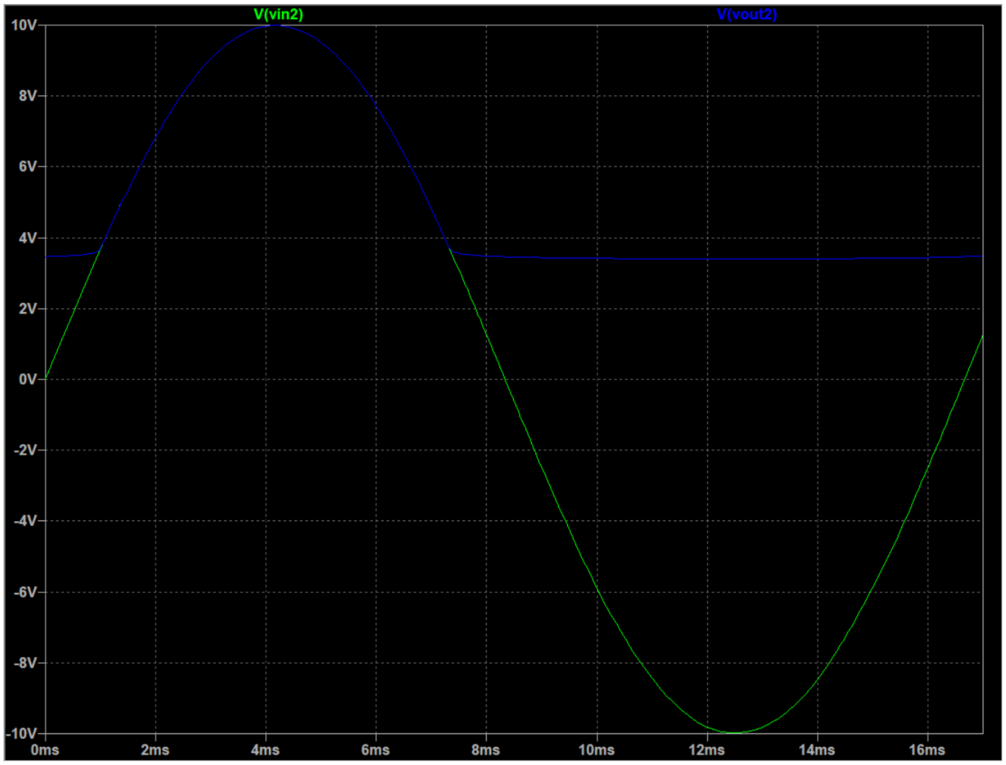


Fig. 32 Vin, Vout vs Time for negative peak positive level clipper

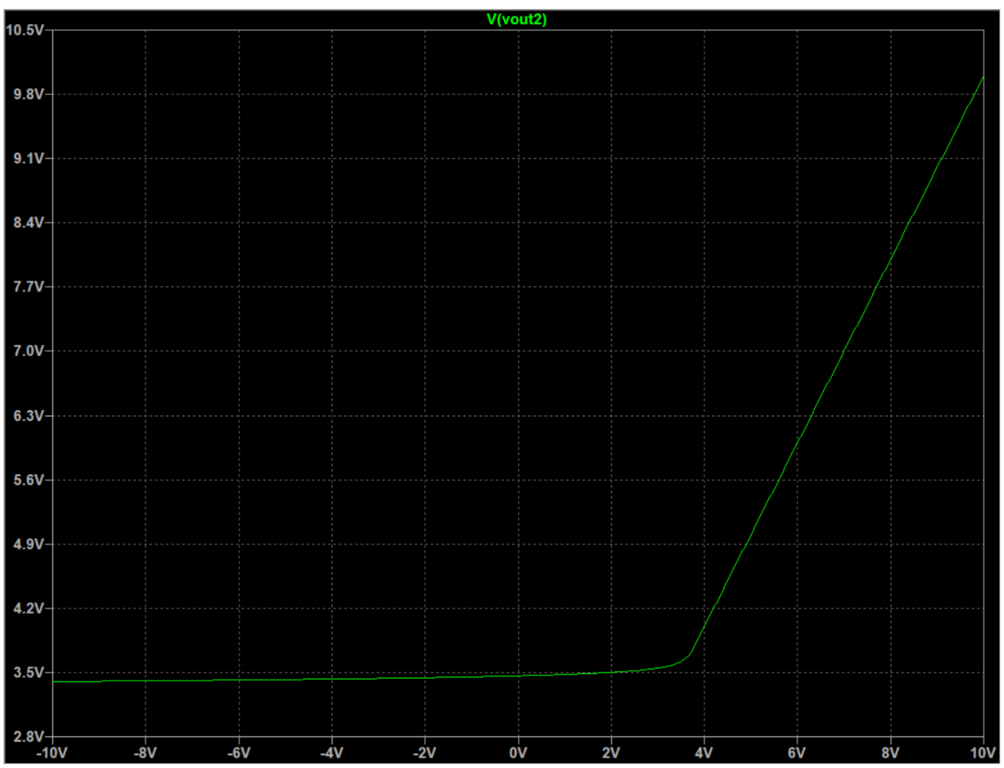


Fig. 33 VCT for negative peak positive level clipper

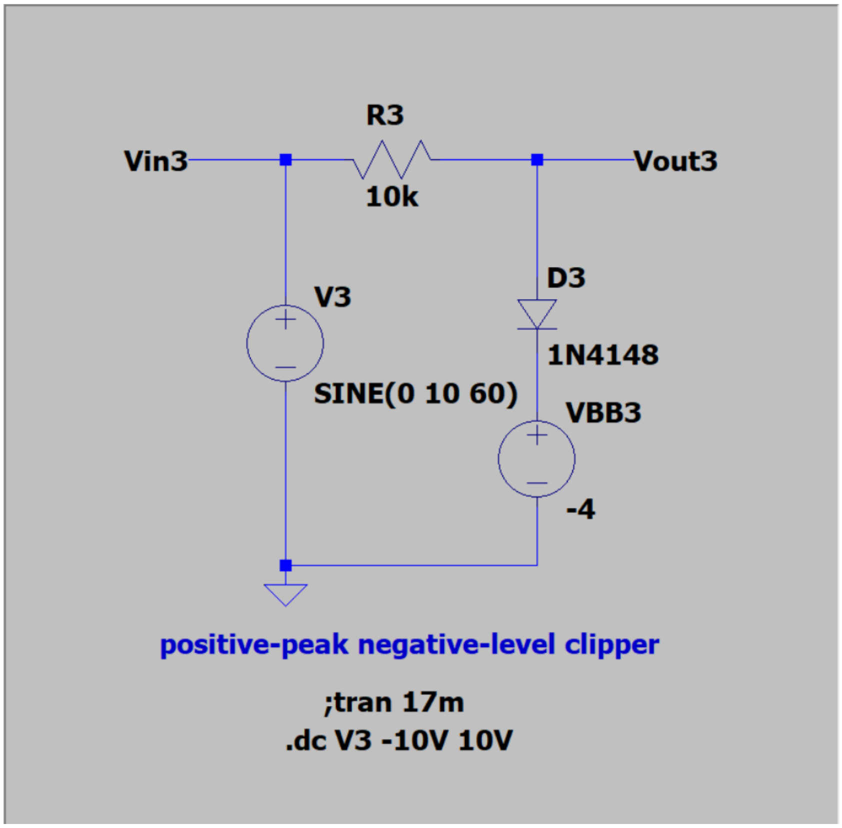


Fig. 34 Schematics for positive-peak negative-level clipper

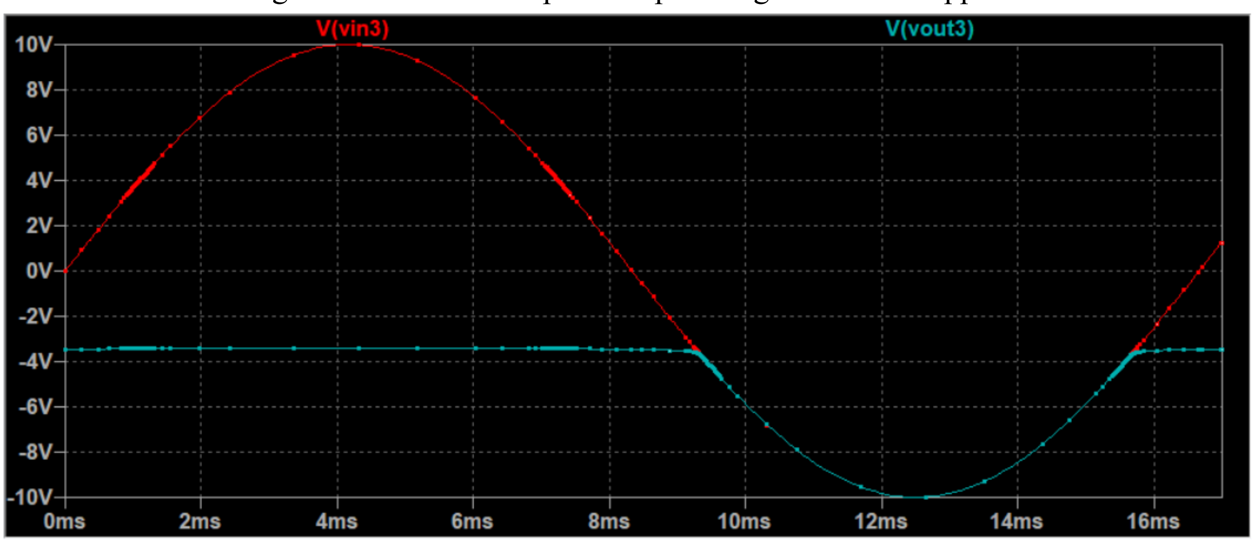


Fig. 35 Vin, Vout vs Time for positive-peak negative-level clipper

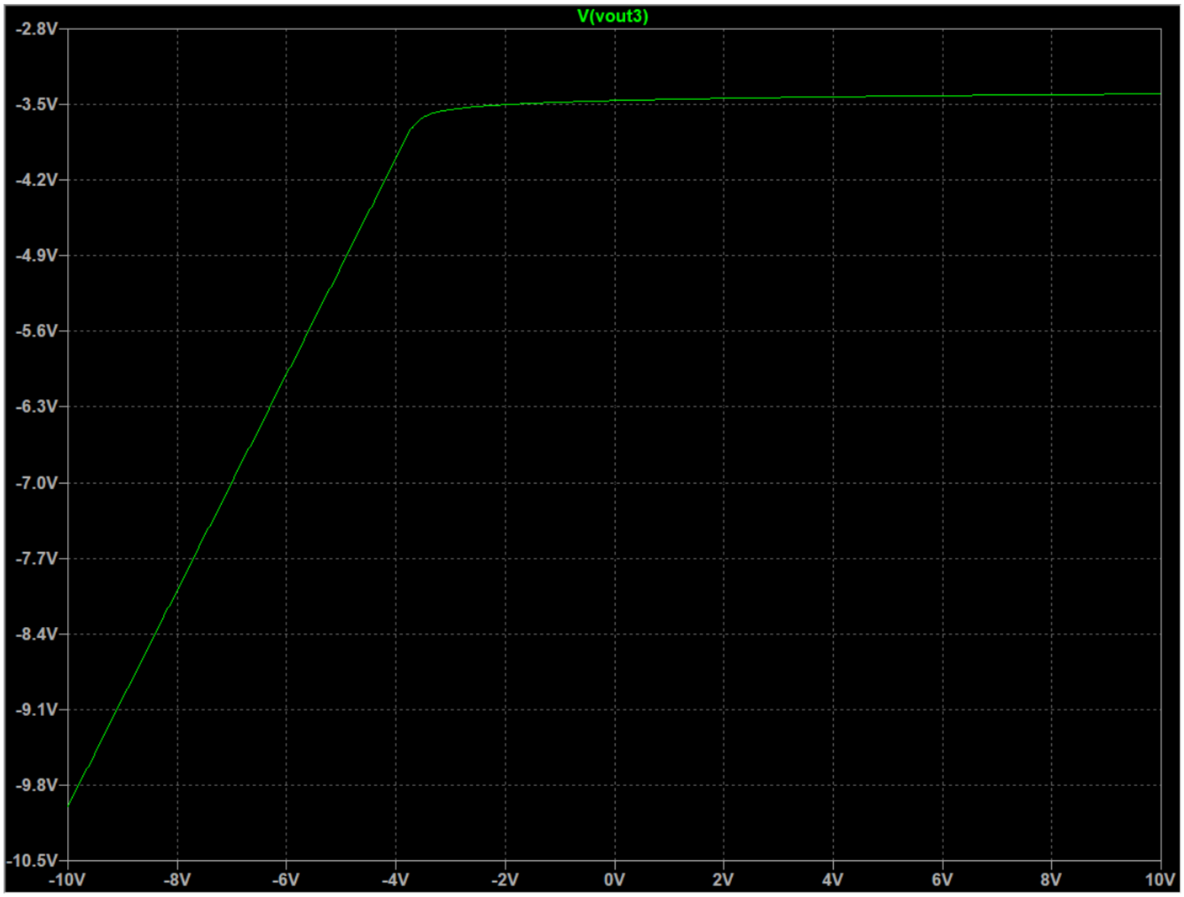


Fig. 36 VCT for positive-peak negative-level clipper

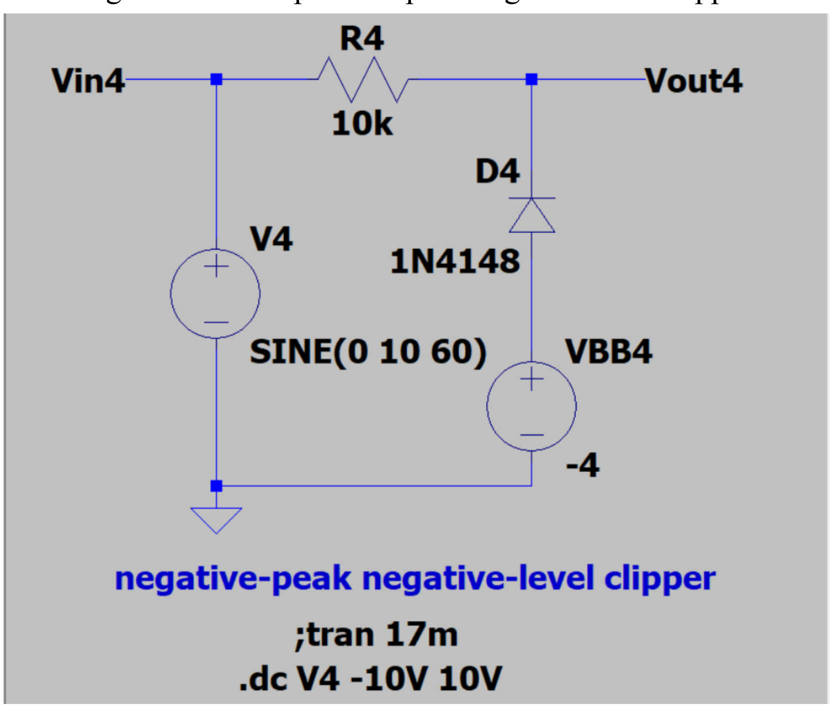


Fig. 37 Schematics for negative-peak negative-level clipper

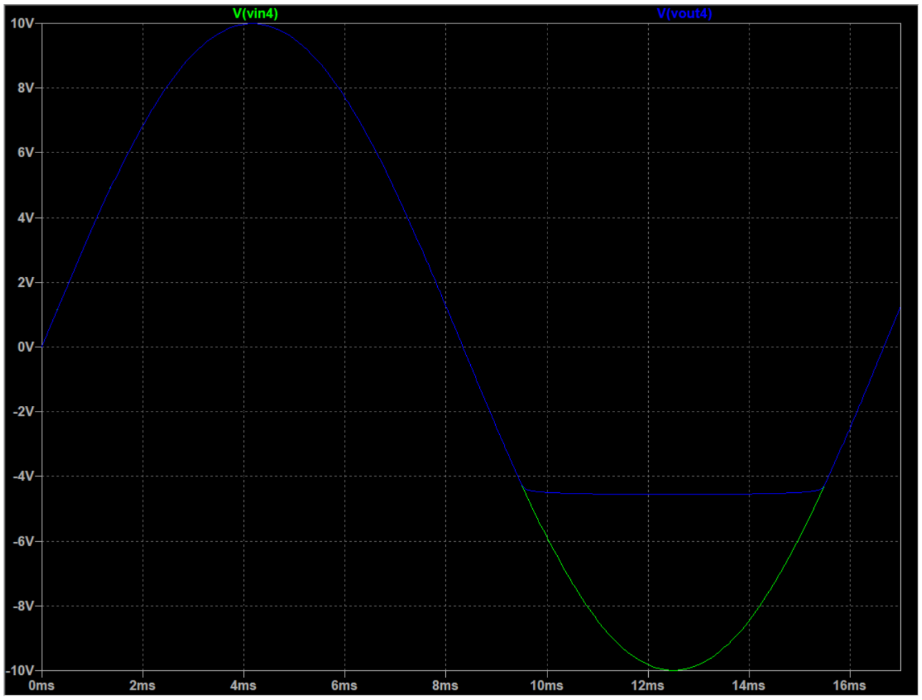


Fig. 38 Vin, Vout vs Time for negative-peak negative-level clipper

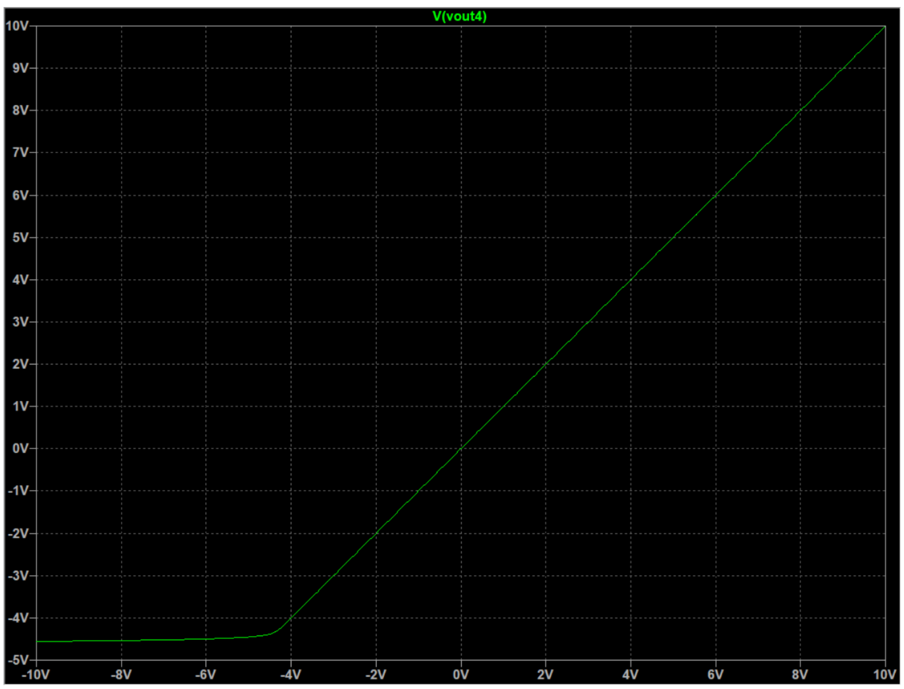


Fig. 39 VCT for negative-peak negative-level clipper

Question 2:

a)

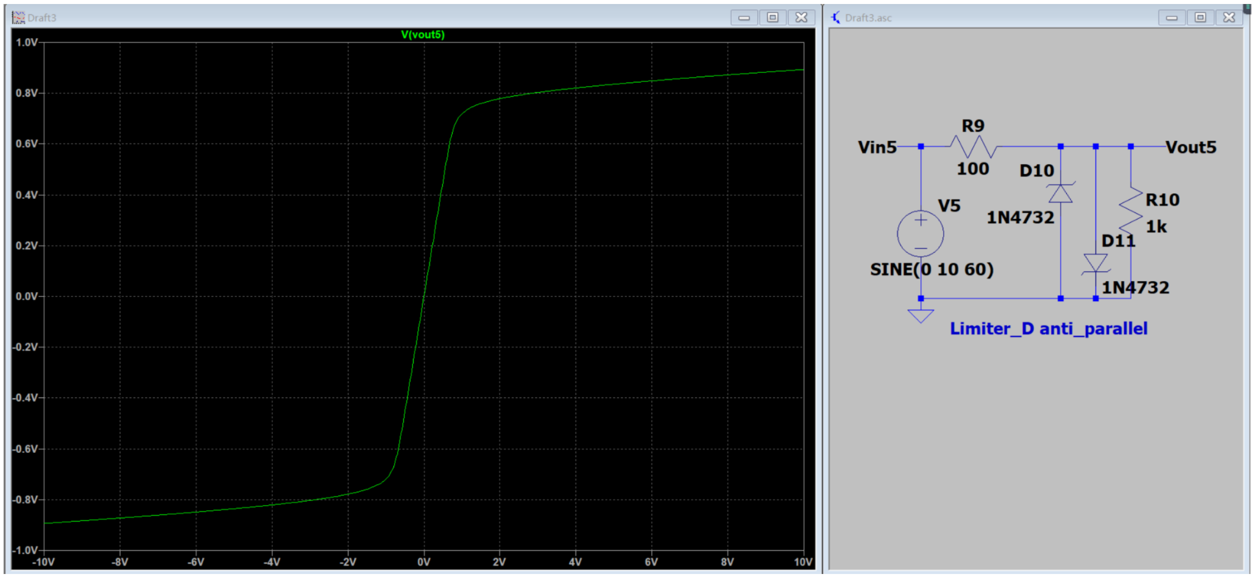


Fig. 40 limiter circuit with Zener diodes were connected in anti-parallel

When the zener diodes are connected in anti-parallel, it has shrinked voltage output and we observe the voltage change happens more rapidly.

b) Current path for Vin = +3V:

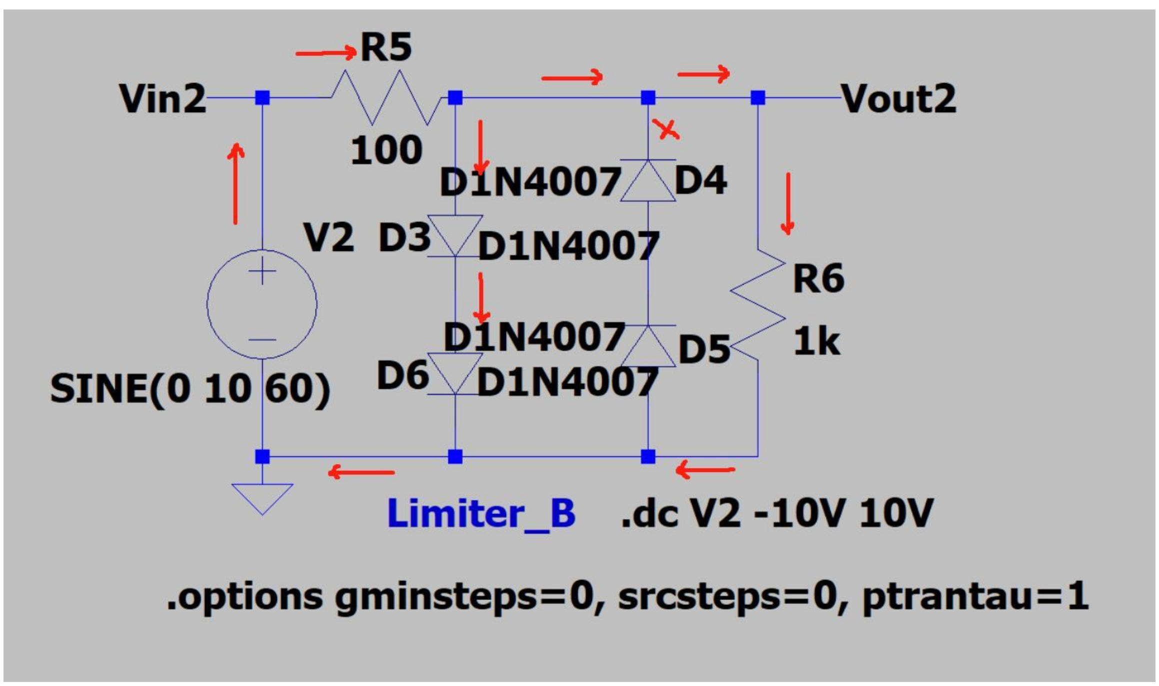


Fig 41. Current Path for Vin = +3V

Current path for Vin = -3V:

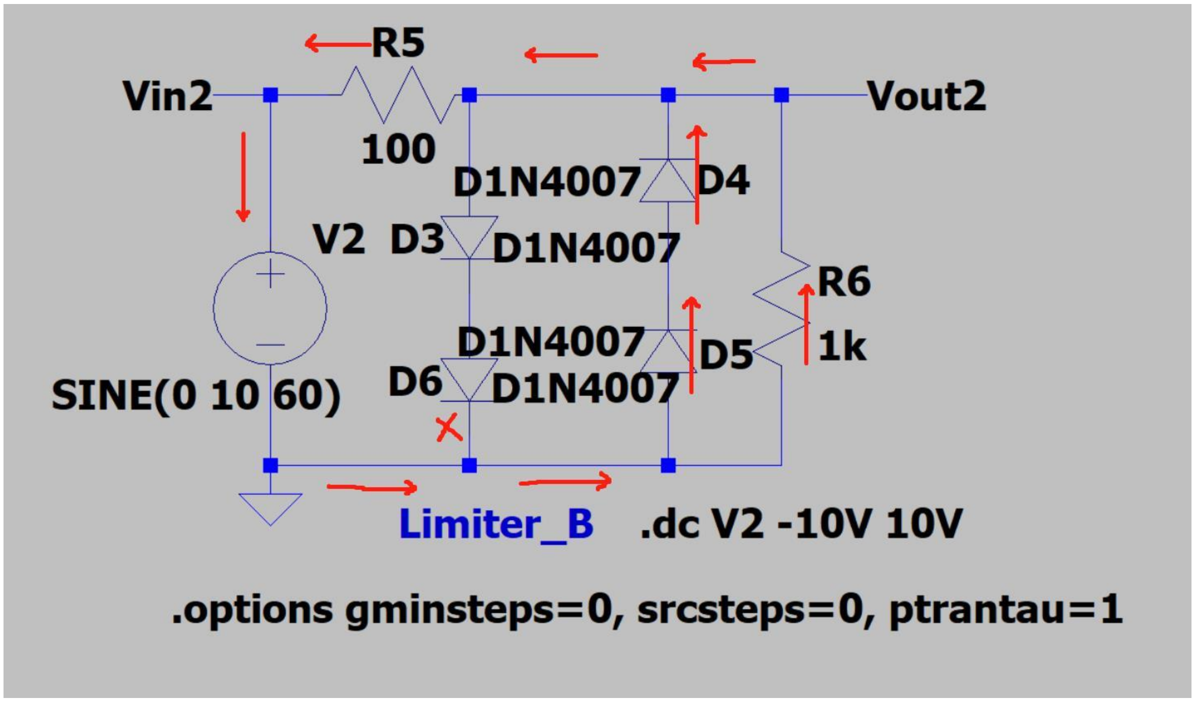


Fig 42. Current Path for Vin = -3V

c)

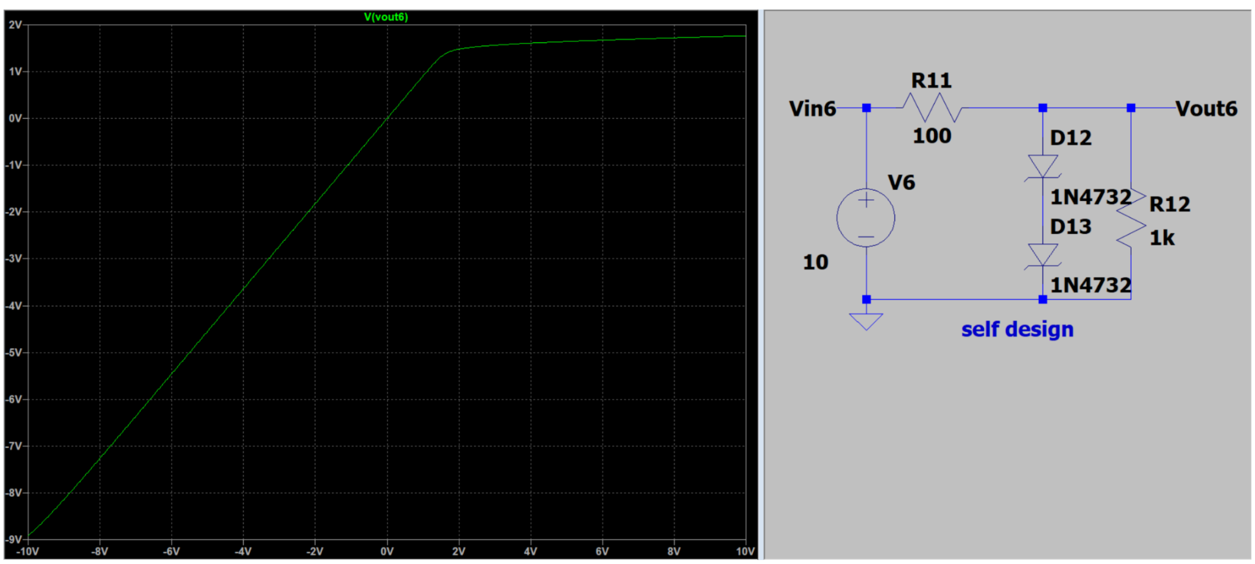


Fig 43. Schematics and Simulation of 2C

Question 3:

a)

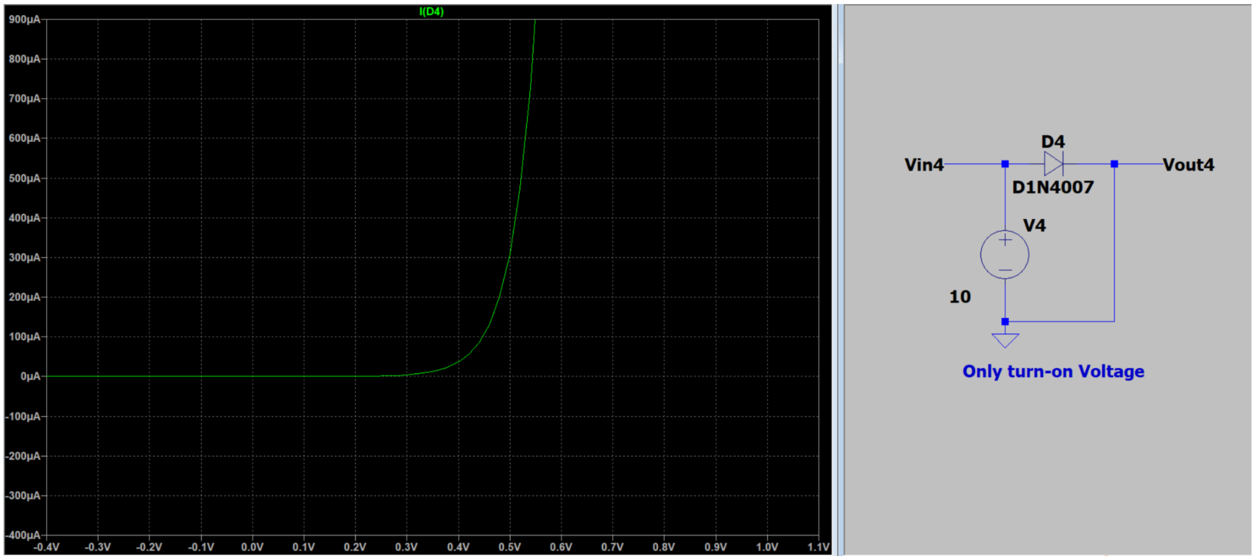


Fig 44. Half-wave rectifier with no Capacitor

Performing a DC sweep on the circuit using both C1 and C2 for capacitive filtering, we find the turn on voltage for diode 1N4007 to be approximately 0.30V. Thus, Vmax = Vs - Vturn-on = 10V - 0.30V = 9.70V.

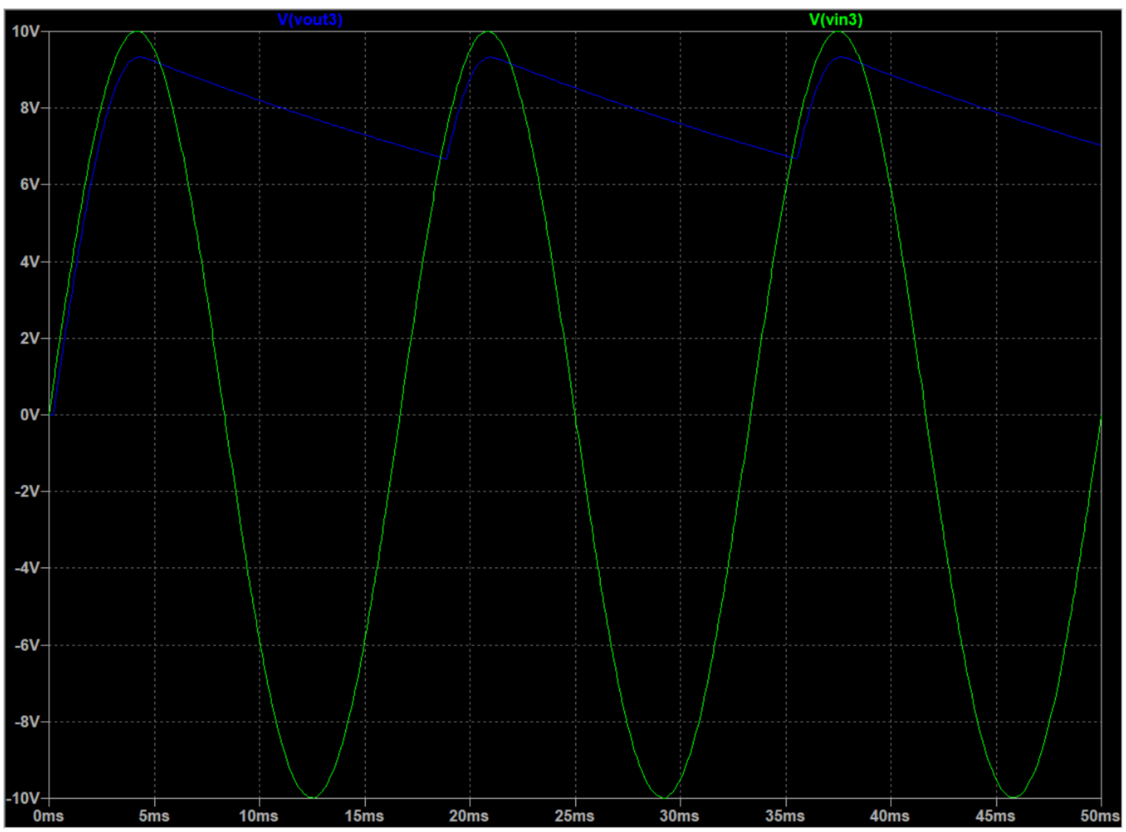


Fig 45. Half-wave rectifier with Capacitor

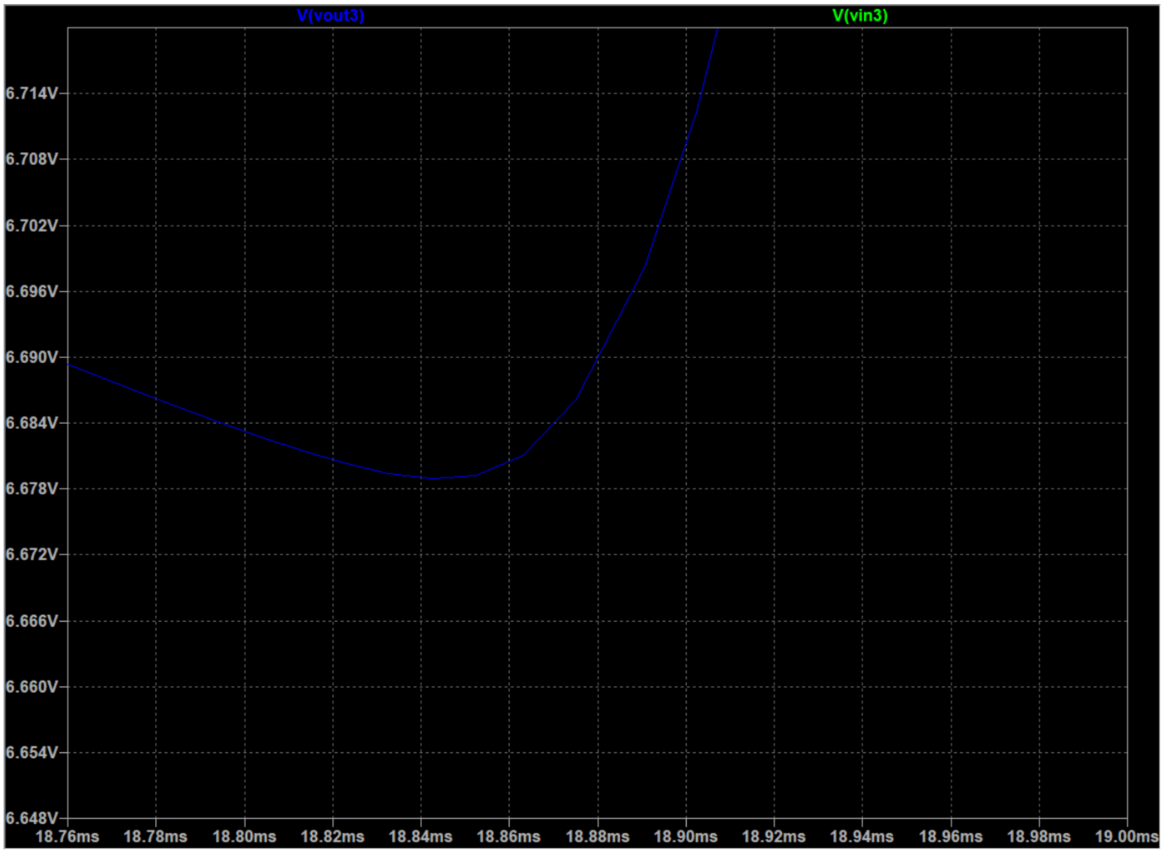


Fig 46. Zoom for Checking Period

Since Vmin = Vmax * exp(-t'/RC), and from the simulation, we observe that 5/4T = 18.84 ms, T = 15.072ms, we can compute the minimum voltage. Vmin = 9.70V * exp(-15.072ms / (1k ohm * (33uF + 10uF))) = 6.832V.

Thus, Vmin = 6.832V from our calculation.

b) As mentioned in part a), Vmax = Vs - Vturn_on = 10V - 0.30V = 9.70V.

c) Vr = Vmax - Vmin = 9.70V - 6.832V = 2.868 V,
$\Delta T = 1 / \omega * \text{sqrt}(2 * Vr / Vp) =$ 2.01ms

d)

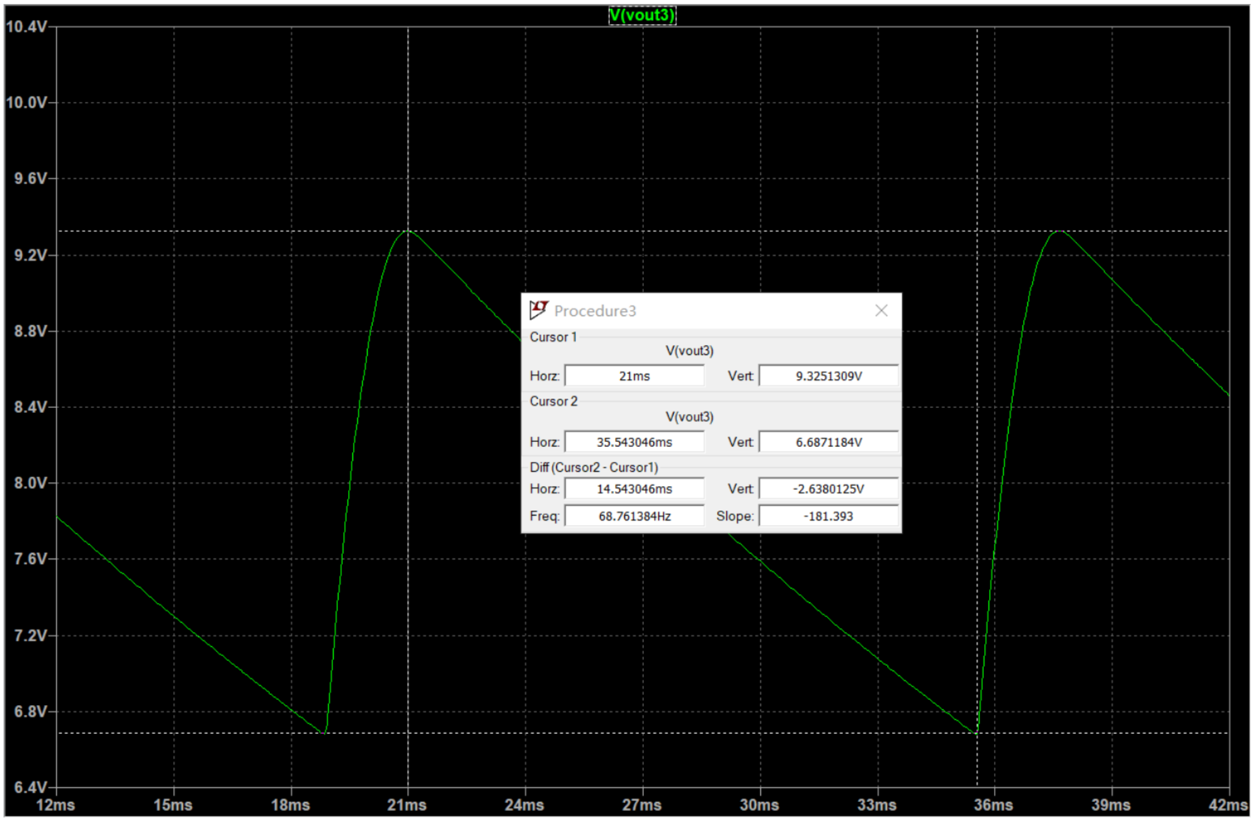


Fig. 47 Checking max Vout

Vmax_measured = 9.3251V, Vmin_measured = 6.6871V,
Vr_measured = Vmax_measured - Vmin_measured = 9.3251V - 6.6871V = 2.638V
The measured ripple voltage does not have a big difference compared to the calculated ripple voltage. The two only have a error% = | (2.638 - 2.868) | / 2.868 * 100% = 8.02%.

Procedure 4:

Question:

(a) turn-on voltage for 1N4007 = 0.3V. Vmax = Vs - 2Von = 9.4V. However, there is a diode between voltage source and diode. The actually Vmax is
Since Vmin = Vmax * exp(-t'/2RC), Vmin = 9.40V * exp(-15.1ms / (1k ohm * 2 * (33uF + 10uF))) = 7.887V.
Thus, Vmin = 7.887 from our calculation.

(b) As mentioned in part a), Vmax = Vs - Vturn_on = 10V - 0.60V = 9.40V.

(c) ripple voltage = Vmax - Vmin = 9.4V - 7.887V = 1.513V
ΔT = 1 / ω * sqrt(2 * Vr / Vp) = 1.51ms

(d)

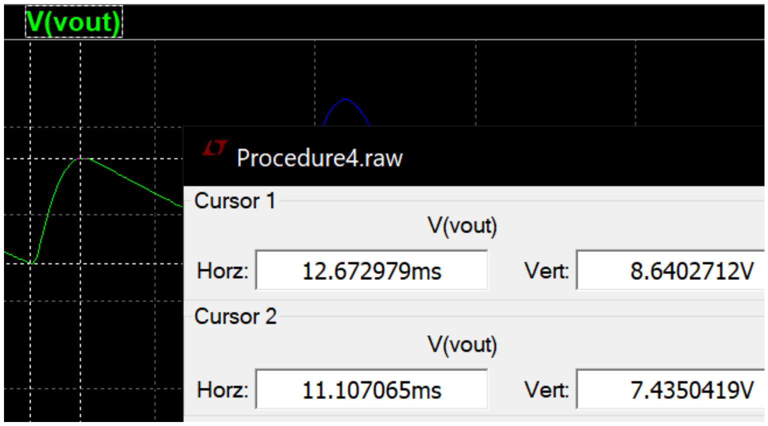


Fig. 48 Observe Ripple Voltage via Cursors

Simulated ripple voltage = 8.64 - 7.44 = 1.2V
Error between simulated ripple voltage and calculated voltage = |1.51-1.2|/1.51 * 100% = 20.5%.

(e)
The advantage of the full-wave rectification is that the capacitor can be charged more frequently so that the ripple voltage is smaller. The disadvantage is that the extra diodes cause additional loss of voltage on turn on voltage so the full-wave rectifier is less efficient.

Procedure 5:
(a)
Vout at 10V

RL (Ohm)	Avg Vout
470	2.47265
1000	3.78814
4700	4.49457

Vout at 20V

RL (Ohm)	Avg Vout
470	4.47836
1000	4.59004
4700	4.61084

RL (Ohm)	I(RL) (mA) at 10V	I(RL) (mA) at 20V

470	5.2609	9.52842
1000	3.78814	4.59004
4700	0.956291	0.98103

Load Regulation = Delta Vout / Delta I load

Between 470Ohm to 1000Ohm at 10V AC source, load regulation is -893.2

Between 1000Ohm to 4700Ohm at 10V AC source, load regulation is 249.5

Between 470Ohm to 1000Ohm at 20V AC source, load regulation is -22.61

Between 1000Ohm to 4700Ohm at 20V AC source, load regulation is -5.7634

(b)

Line Regulation = Delta Vout / Delta I load

When RL = 470Ohm, line regulation is 0.2006

When RL = 1000Ohm, line regulation is 0.08019

When RL = 4700Ohm, line regulation is 0.011627

(c)

The two regulation performance measures reflect the characteristics of the Zener diode. The load regulation reflects the change of output voltage with the change of the load current. The line regulation reflects the change of output voltage with the change of the input voltage. These characteristics are actually infected by the internal resistance of the Zener diode.

4. Conclusion

In this report, various applications of diodes are included. Now the team is familiar with the voltage clipper, the voltage limiter, half-wave rectifier, full-wave rectifier, and voltage regulator. Many applications are not discussed during the lecture. Thus, team members learn an unexceptional amount of knowledge in this lab. In procedure 1, we adjust different voltage bias and direction of diodes to create positive-peak positive-level clipper, negative-peak positive-level clipper, positive-peak negative-level clipper and negative-peak negative-level clipper. In procedure 2, we follow the lab specifications and set up various voltage limiters and understand the underlying principles of the voltage limiter. In procedure 3, we make a half-wave rectifier and test its behavior with different capacitors attached to the circuit and notice that the ripple voltage is smaller with larger capacitance. However, the half-wave rectifier wastes the negative peak of AC sources. In procedure 4, we create a full-wave rectifier in which the ripple voltage is even smaller because the capacitors are charged during negative peaks so that it is a better AC-DC converter. In procedure 5, we add a Zener diode to the full-wave rectifier and the circuit is able to regulate the output voltage due to the special breakdown properties of Zener diodes. The applications of diodes introduced in this lab are extremely important in the power system.

Almost all electronics require voltage limiters and AC-DC converters to avoid burnout and maintain stability. We can find these applications everywhere, such as chargers.