Clippers

ECE 320 Electronics I

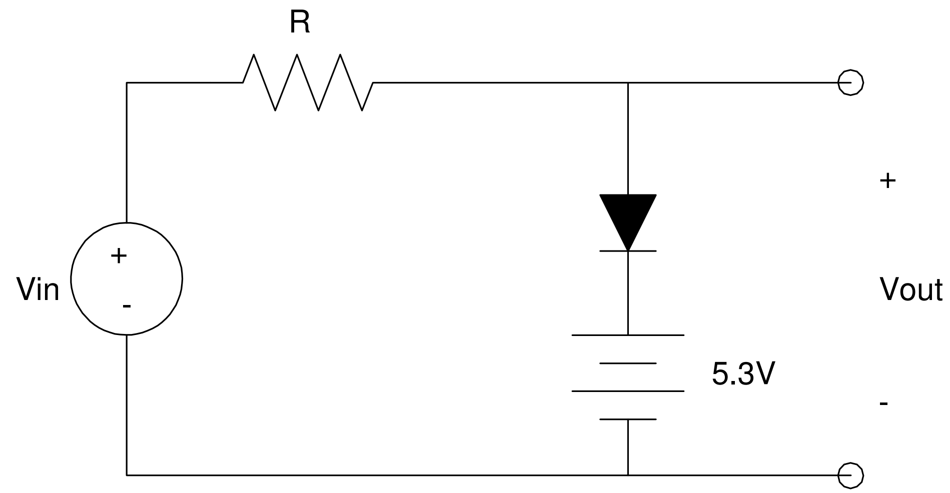
Jake Glower - Lecture #10

Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

Clipper Circuits:

Problem#1: Clip a signal at + 6V

$$V_{out} = \begin{cases} V_{in} & V_{in} < 6 \\ 6 & otherwise \end{cases}$$



Solution:

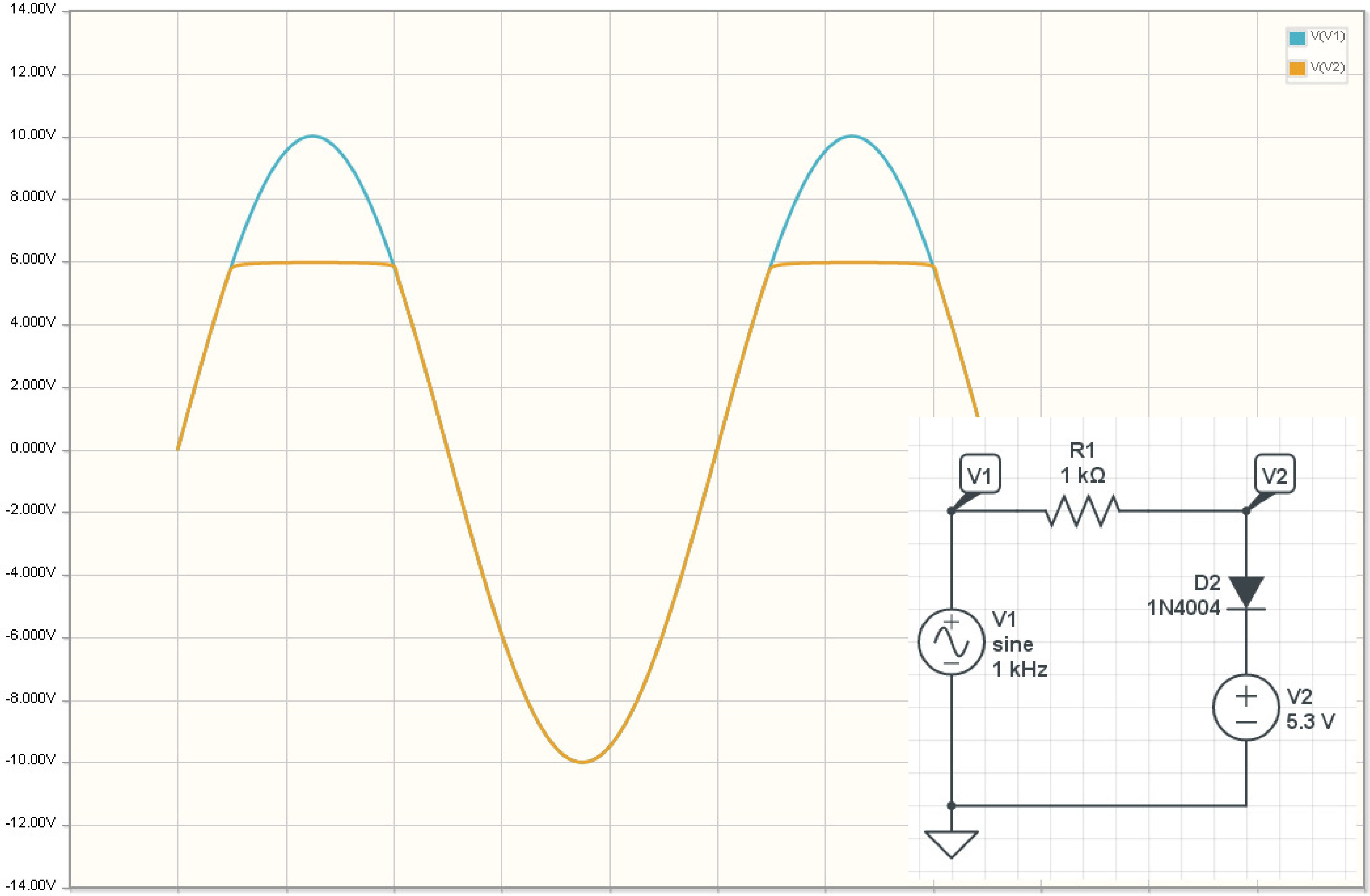
Vin < 6

- Diode is off

Vin > 6

- Diode is on

Check in CircuitLab (clip at >6V)



Problem #2: Clip a signal at +1V

$$V_{out} = \begin{cases} V_{in} & V_{in} > 1 \\ 1 & otherwise \end{cases}$$

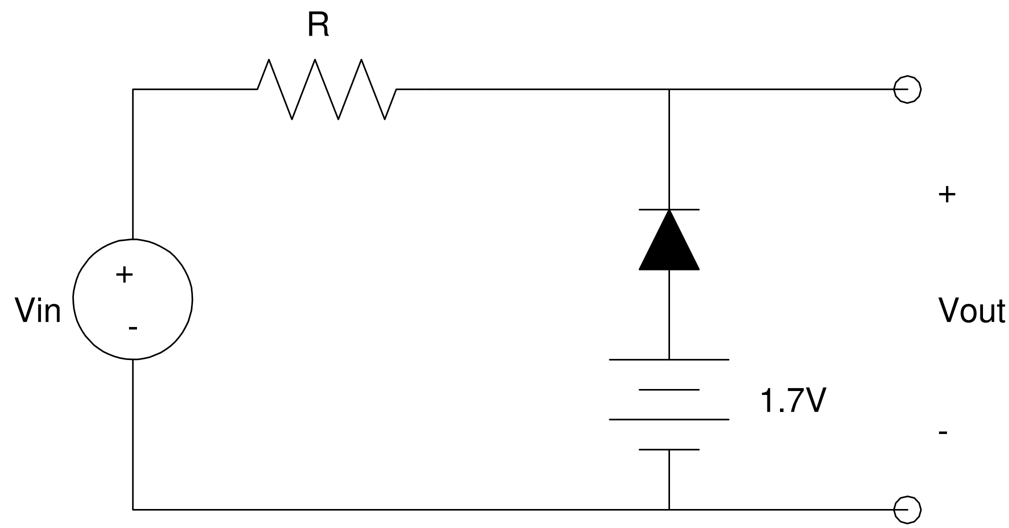
Solution: Flip the diode around

Vin > 1V

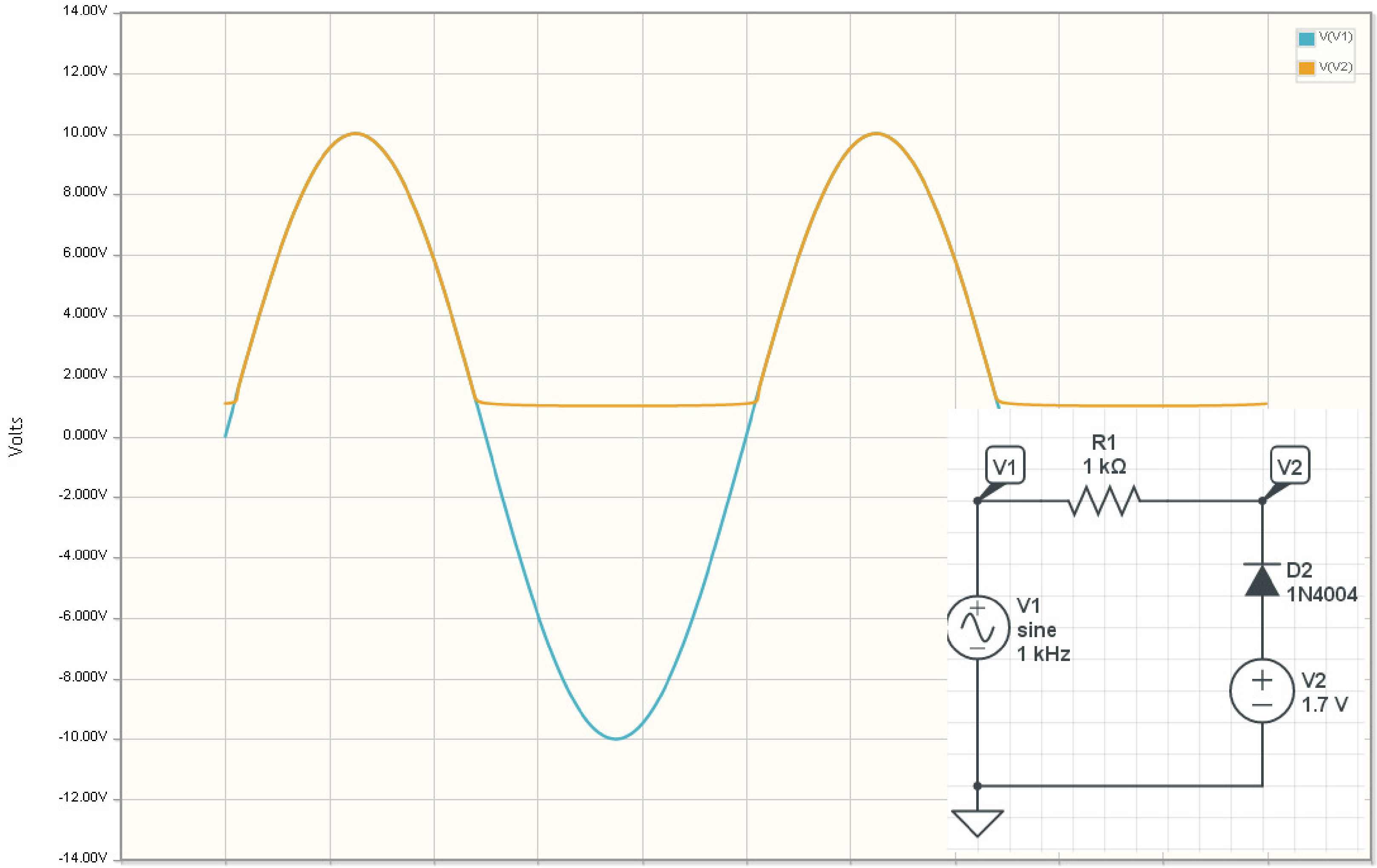
- Diode is off

Vin < 1V

- Diode is on



Check in CircuitLab (clip at <1V)



Problem #3: Clip a signal at +1V and +6V

$$V_{out} = \begin{cases} +6 & V_{in} > 6 \\ V_{in} & -2 < V_{in} < 6 \\ +1 & V_{in} < +1 \end{cases}$$

Solution: Put the previous two solutions in parallel

Vin < 1V

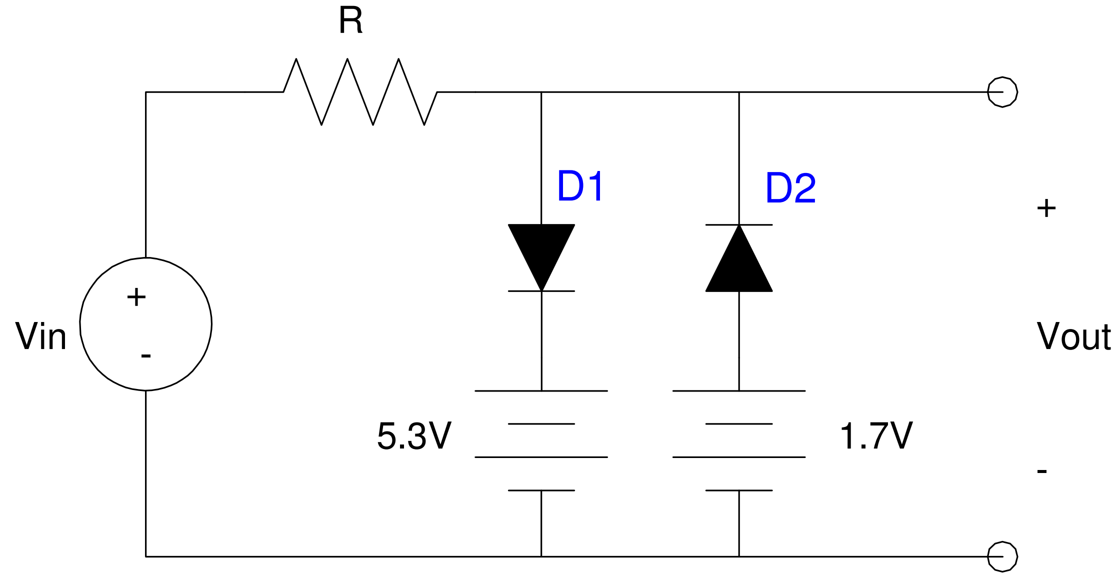
- Diode 2 is on

Vin > 6V

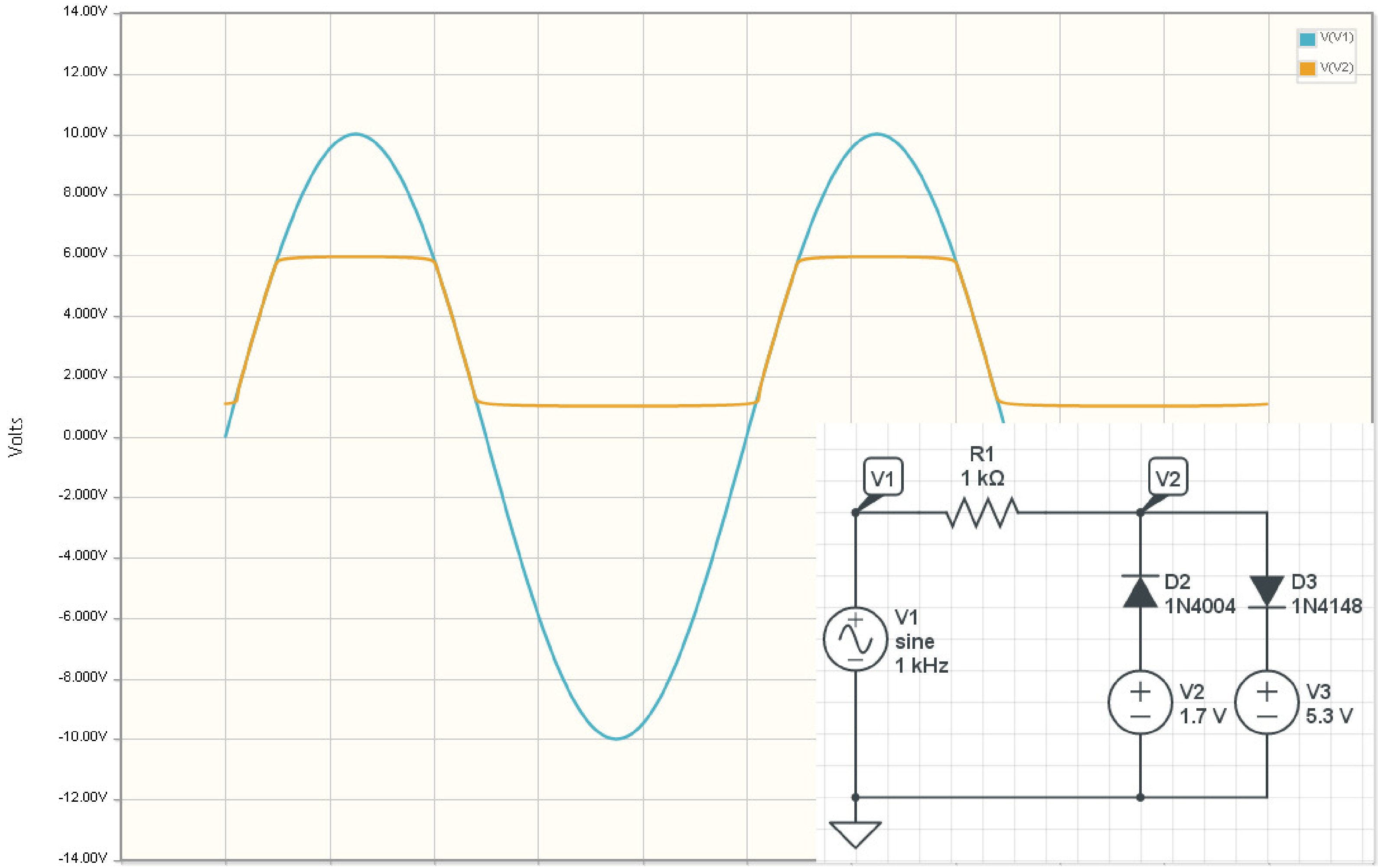
- Diode 1 is on

1V < Vin < 6V

- Both diodes are off

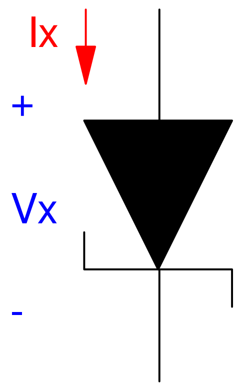


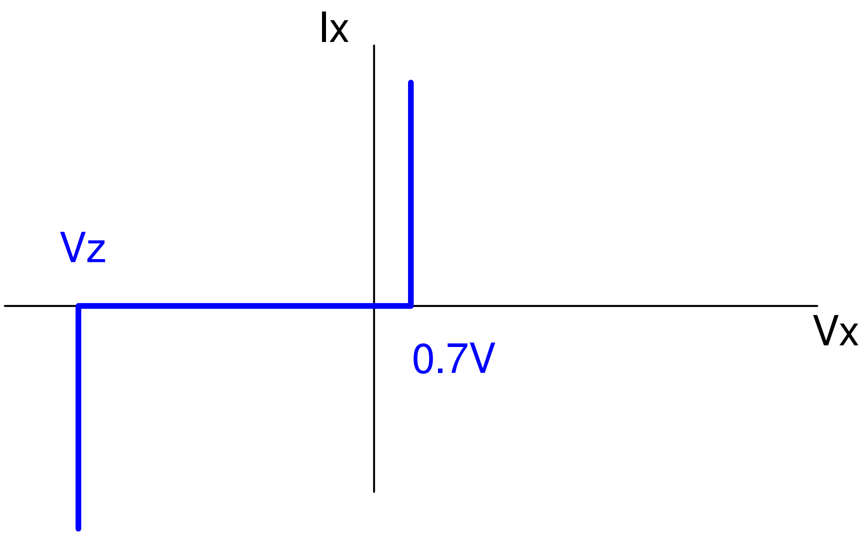
Check in CircuitLab



Zener Diodes

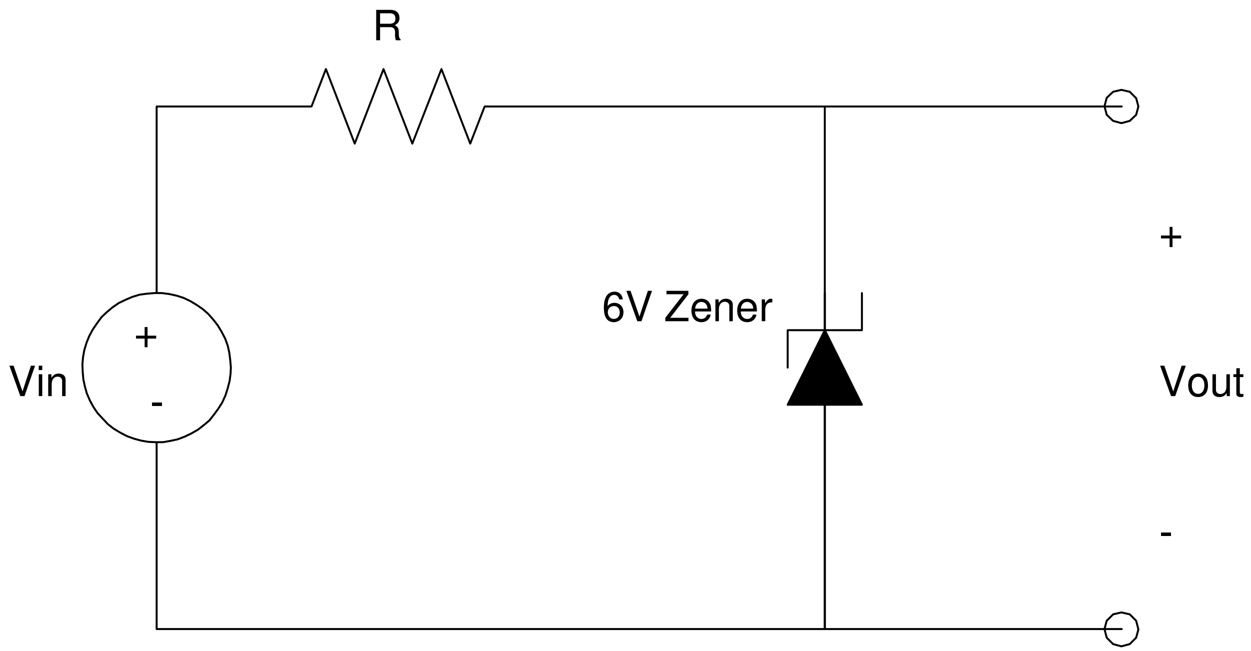
- Easier Solution
- Doesn't require an odd power supply (like 5.3V)
- Available in about any voltage
  - Digikey has 64,000+ in stock
  - 2.4mV < Vz < 390V





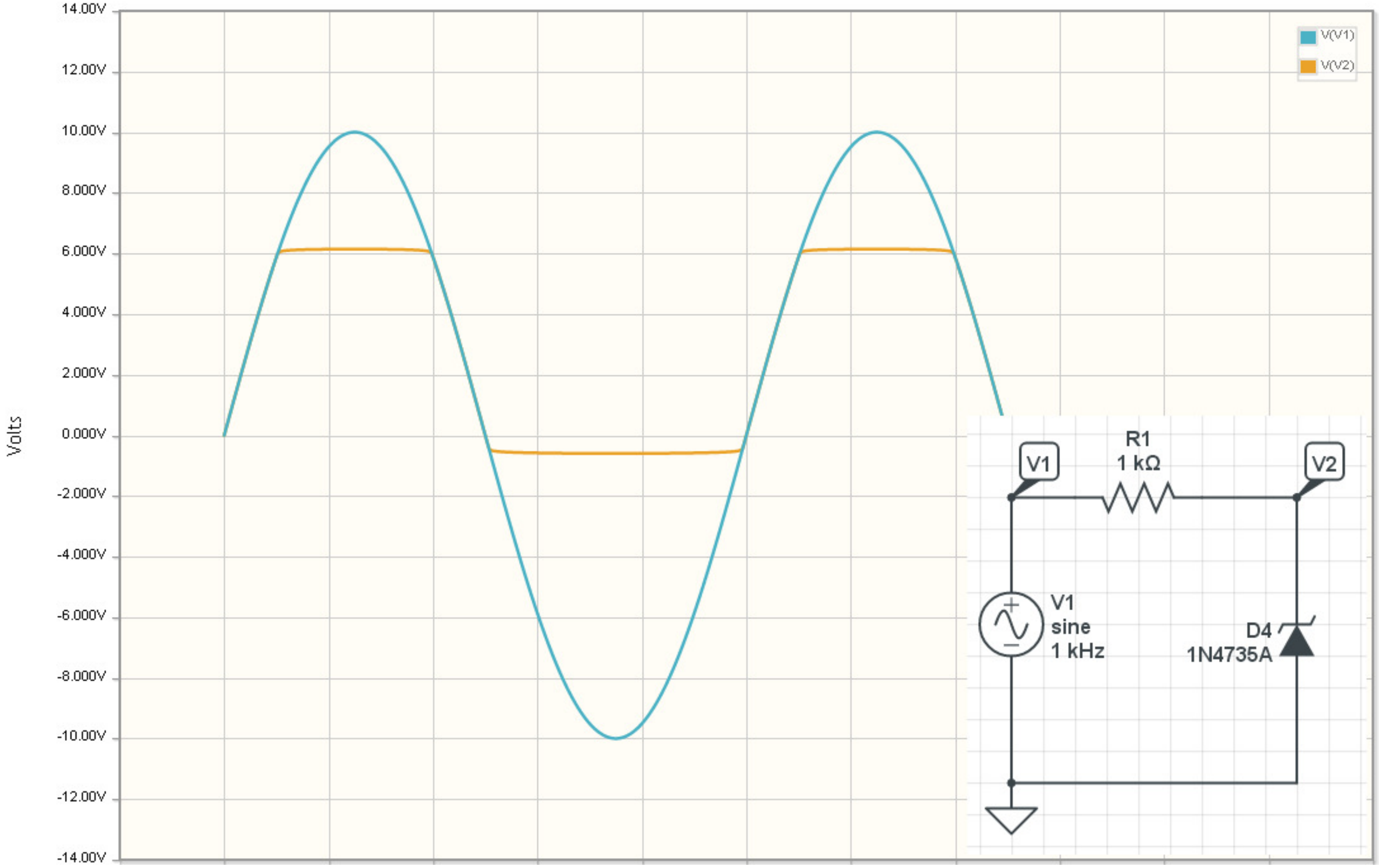
Repeat: Clip at +6V

$$V_{out} = \begin{cases} +6 & V_{in} > 6 \\ V_{in} & -0.7 < V_{in} < 6 \\ -0.7 & V_{in} < 0.7 \end{cases}$$



Check in CircuitLab

- Vz = 6.2V
- Can be changed



Clips at +6.2V

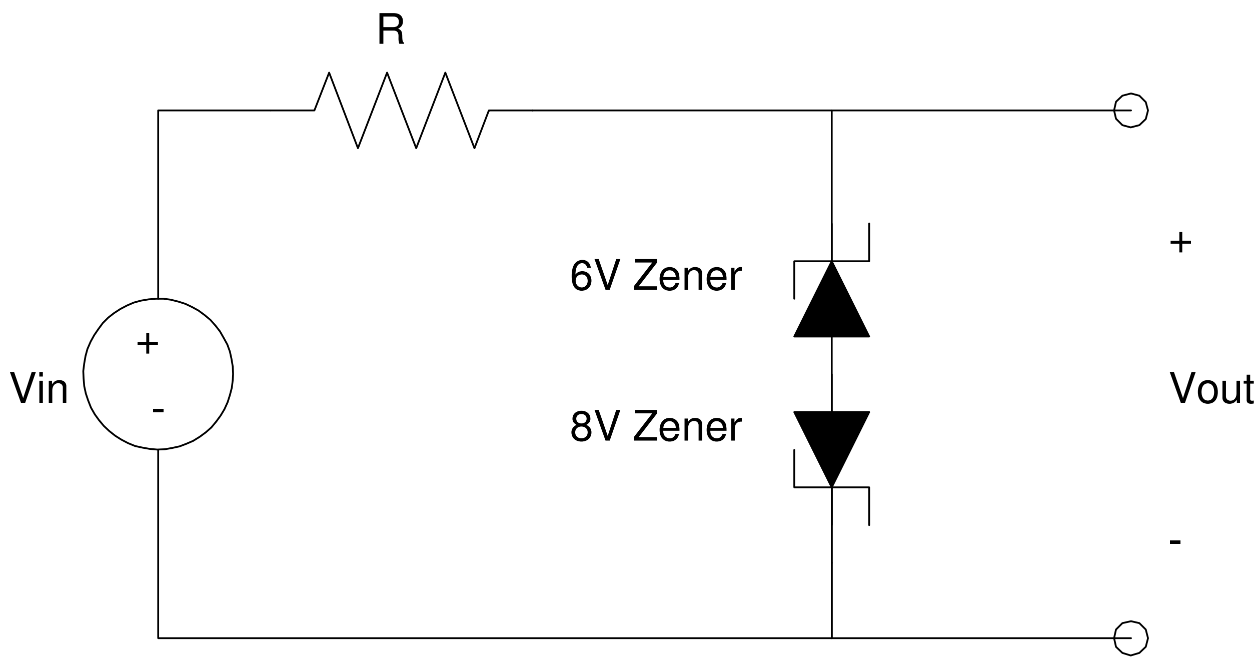
- reverse bias
- Zener voltage

Clips at -0.7V

- forward biased di

Repeat: Clip at -8V and +6V

- Place the zener diodes in series
- In parallel, you clip at +/- 0.7V

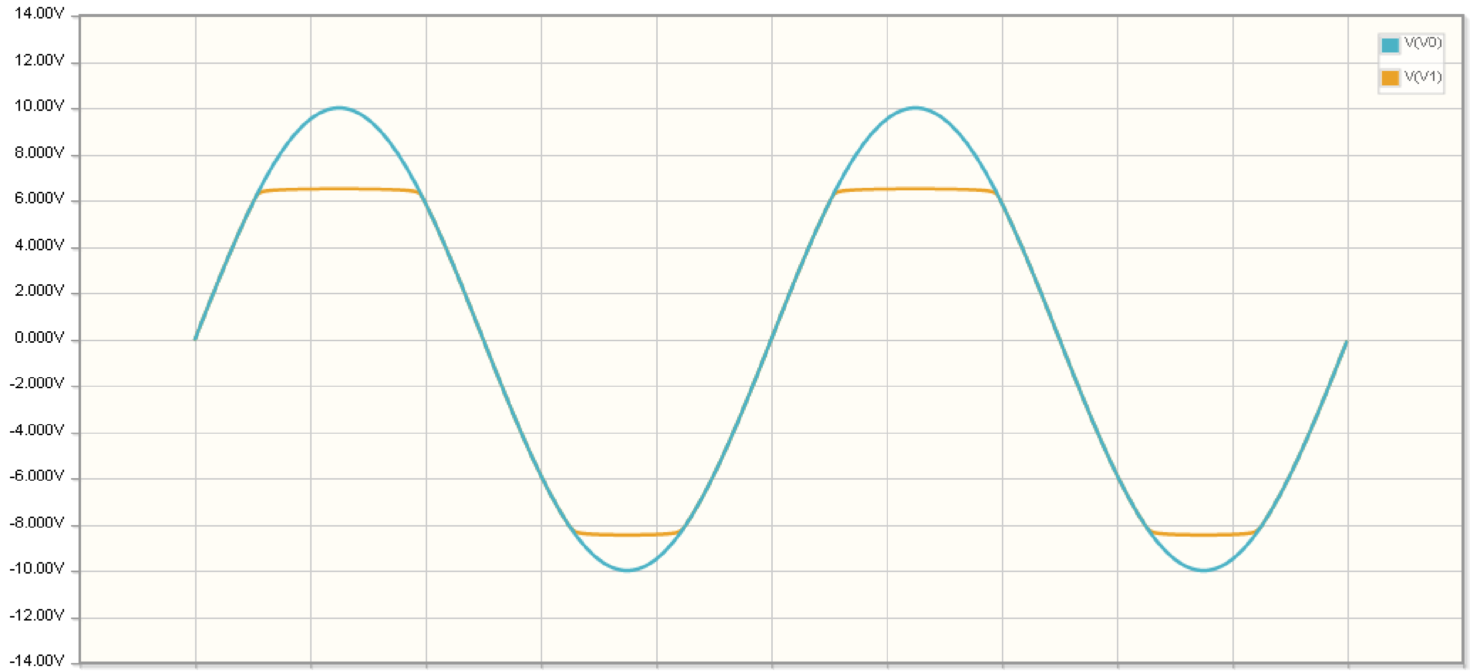


Clipper circuit which limits the output to -8V < Vout < +6V

CircuitLab Simulation

Doesn't clip at *exactly* -8V and +6V

- There is a 0.7V drop across the Zener diode when forward biased (it's still a diode)
- Zener diodes are not ideal: More current produces a slightly larger voltage drop

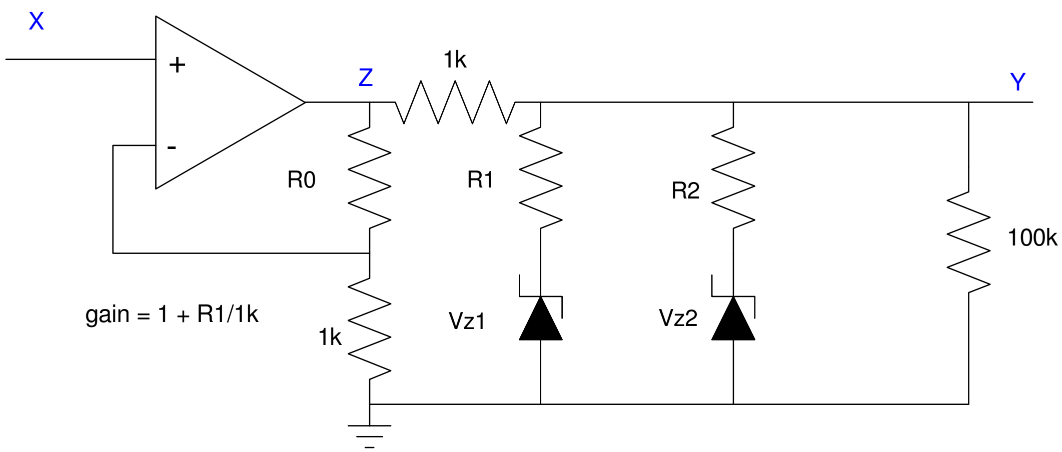


10V sine wave (blue) clipped at -8V and +6V (orange)

Function Approximation

- Use a clipper to approximate y = f(x)

Assume Vz2 > Vz1.



Y < Vz1: Both zener diodes are off

$$Y = kX = \left(1 + \frac{R_0}{1k}\right)X$$

Vz1 < Y < Vz2: Zener #1 is on

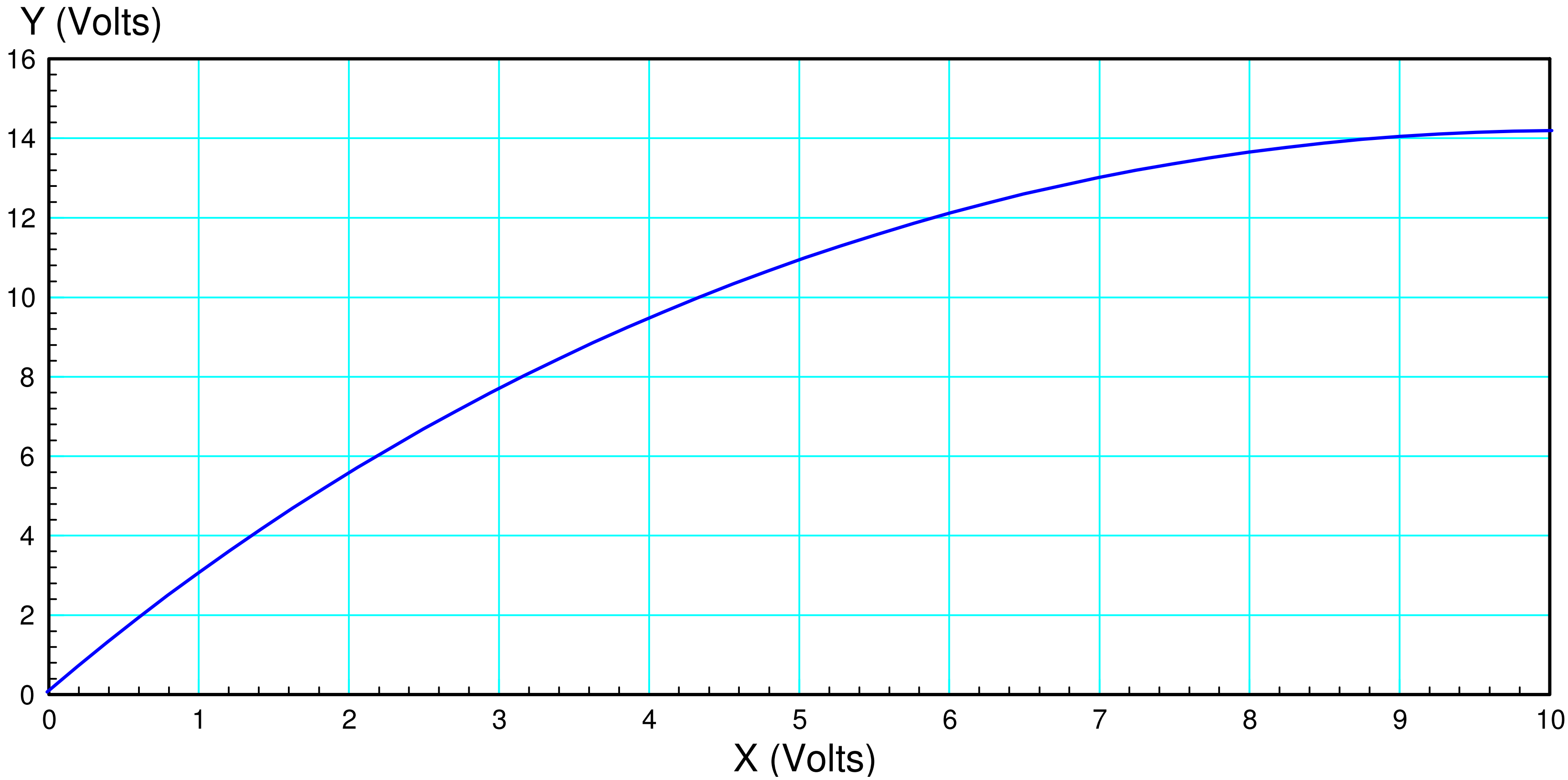
$$Slope = k\left(\frac{R_1}{R_1 + 1k}\right)$$

Y < Vz2: Both zeners are on

$$Slope = k\left(\frac{R_1 || R_2}{R_1 || R_2 + 1k}\right)$$

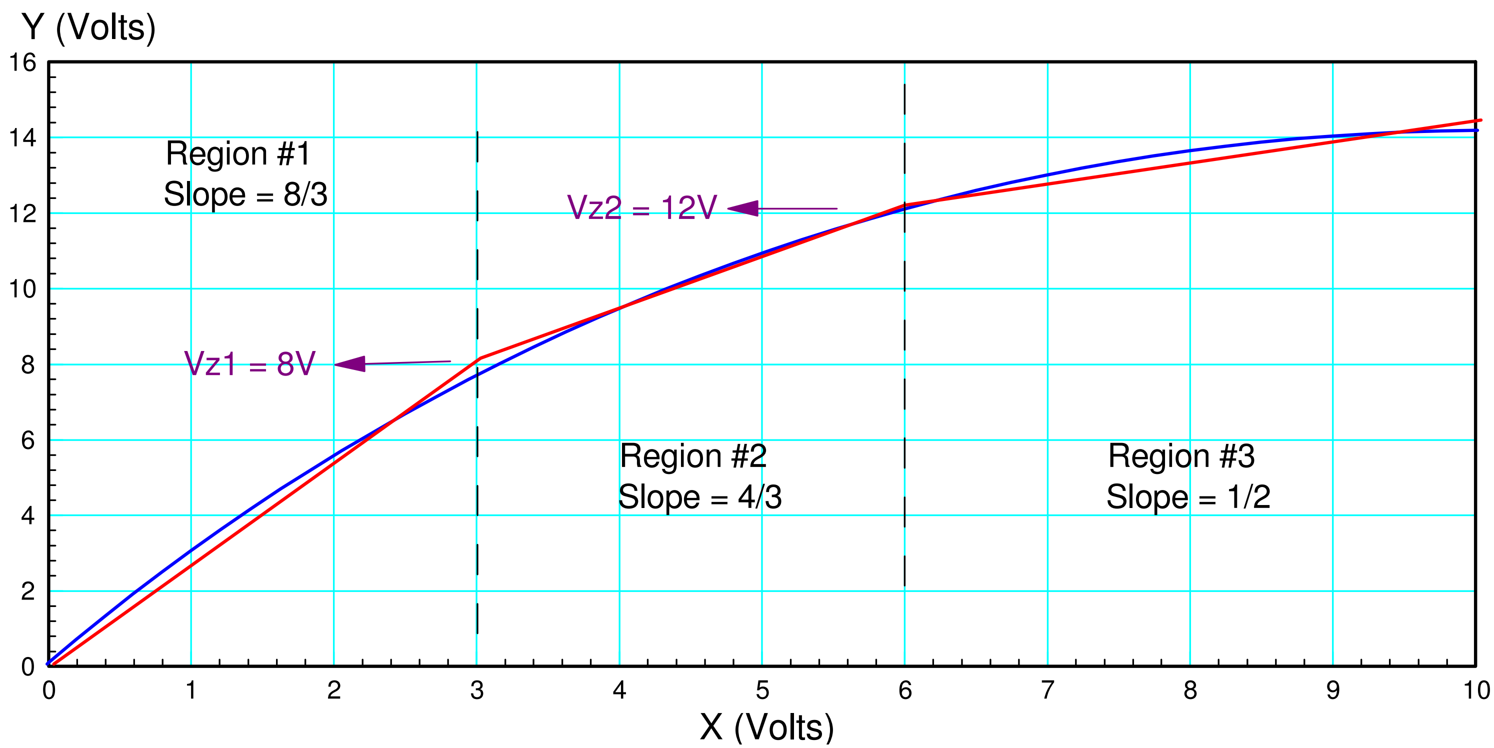
Example: Design a circuit to implement y = f(x)

- Tolerance: +/- 0.5V



Solution:

Step 1: Approximate this curve with straight lines. If a line deviations from the function by more than 0.5V (the tolerance), add another straight line.

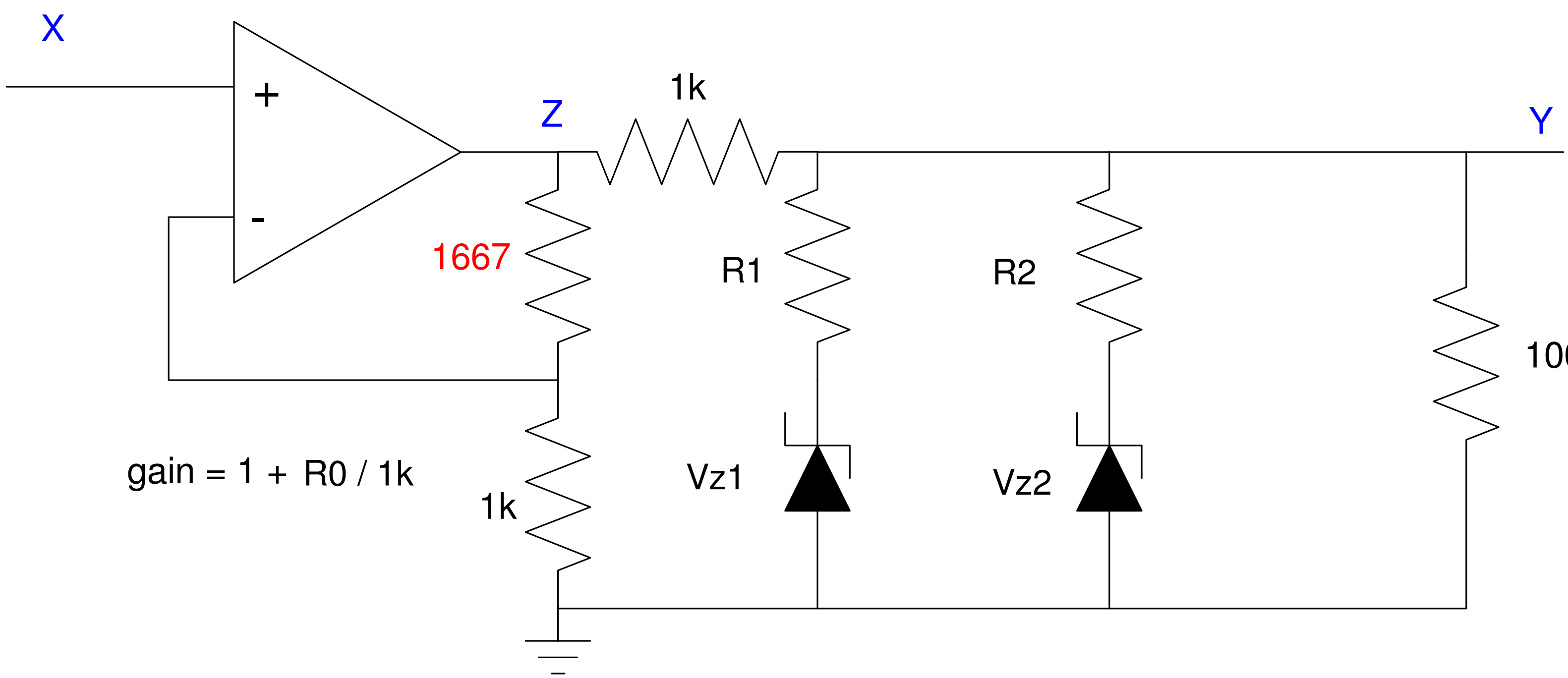


Approximate the function (blue) with straight lines (red)

Step 2) Find R1 (Set the slope in region #1)

$$Slope = k = 1 + \frac{R_0}{1k} = \frac{8}{3}$$

$$R_0 = 1667\Omega$$



Step 3) Find R1 and Vz1 (Region #2)

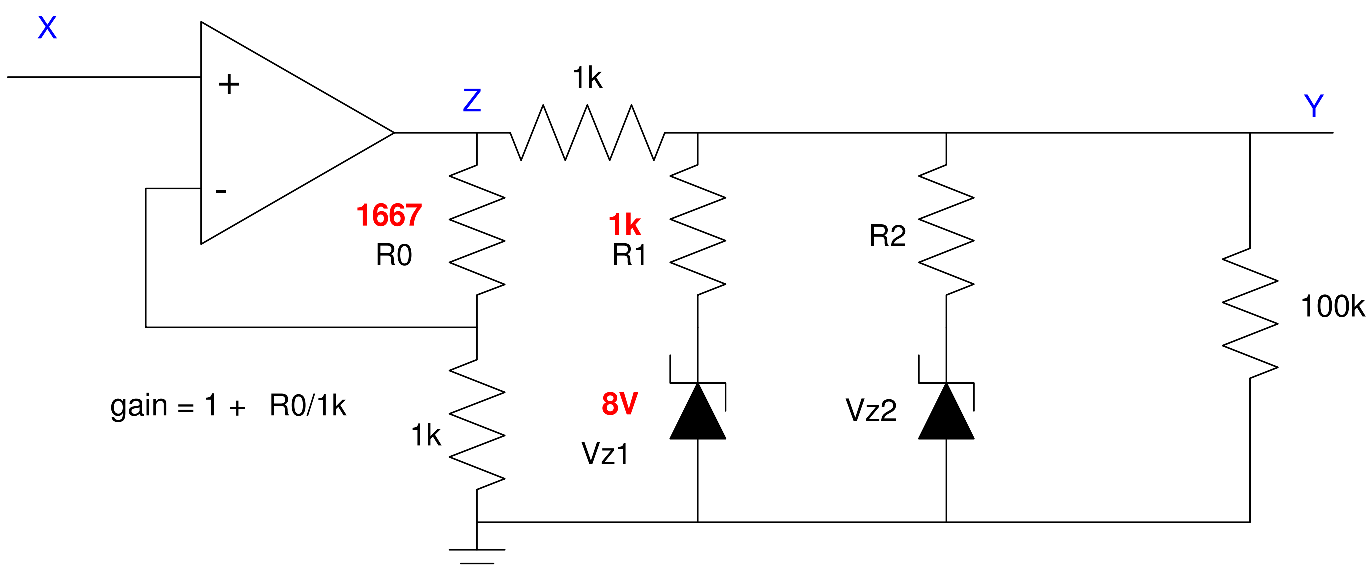
The zener voltage is the voltage at the output (y-axis) where the slope changes

$$V_{z1} = 8V$$

The slope is determined by R1 by voltage division

$$slope = k\left(\frac{R_1}{R_1+1k}\right) = \frac{4}{3}$$

$$R_1 = \left(\frac{4/3}{k-4/3}\right)\ 1k = 1k\Omega$$



Step 4: Find R2 and Vz2 (Region #3)

The zener voltage is the voltage at the output (y-axis) where the slope changes

$$V_{z2} = 12V$$

The slope is determined by R2 || R3 by voltage division

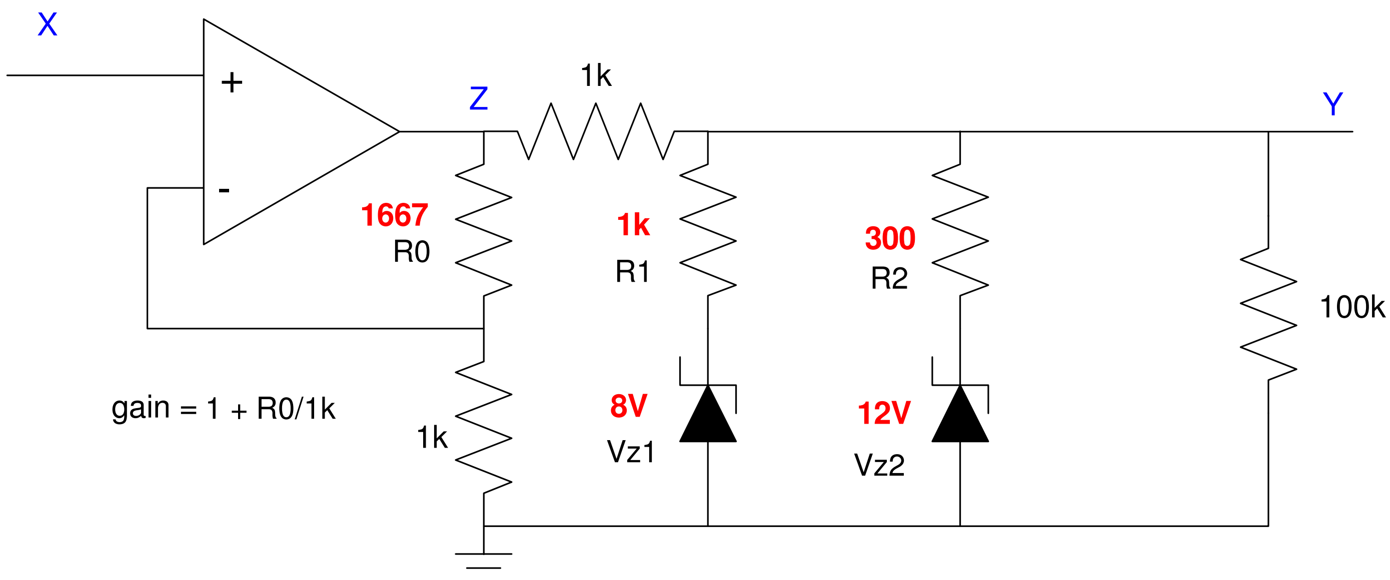
$$slope = k\left(\frac{R_1||R_2}{R_1||R_2+1k}\right) = \frac{1}{2}$$

$$R_1||R_2 = \left(\frac{1/2}{k-1/2}\right)\ 1k = 230.77\Omega$$

Since R1 = 1k

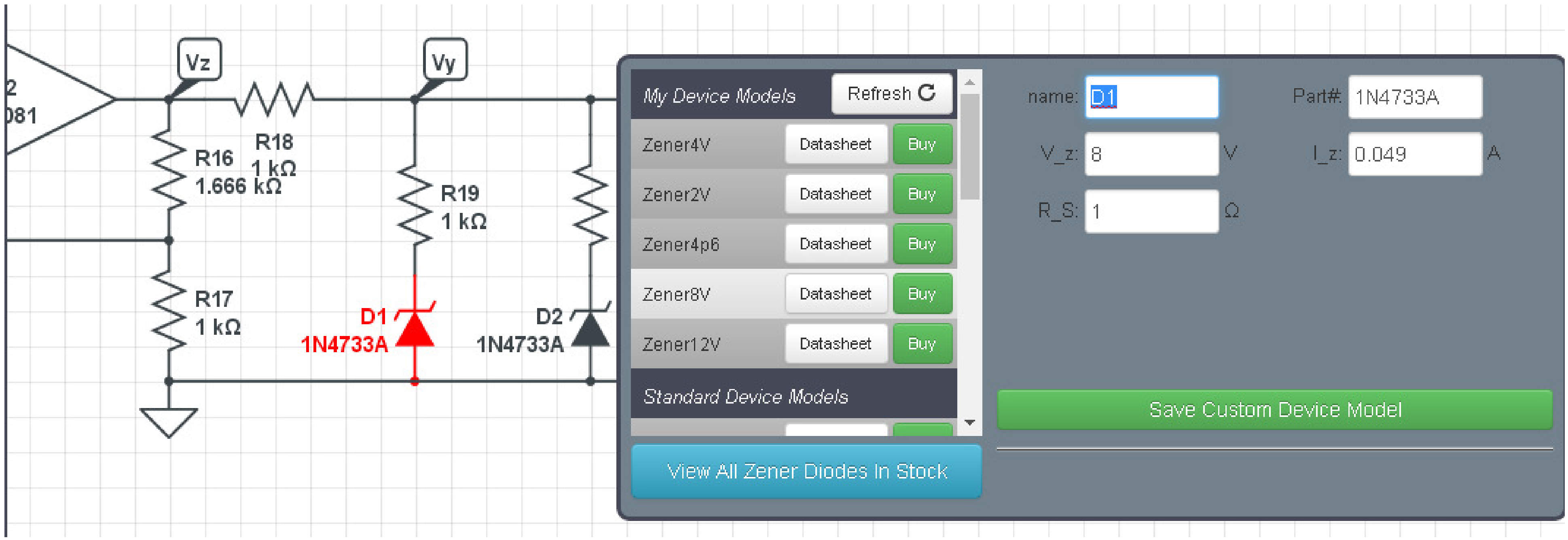
$$\frac{1}{R_1}+\frac{1}{R_2} = \frac{1}{230.77}$$

$$R_2 = 300\Omega$$

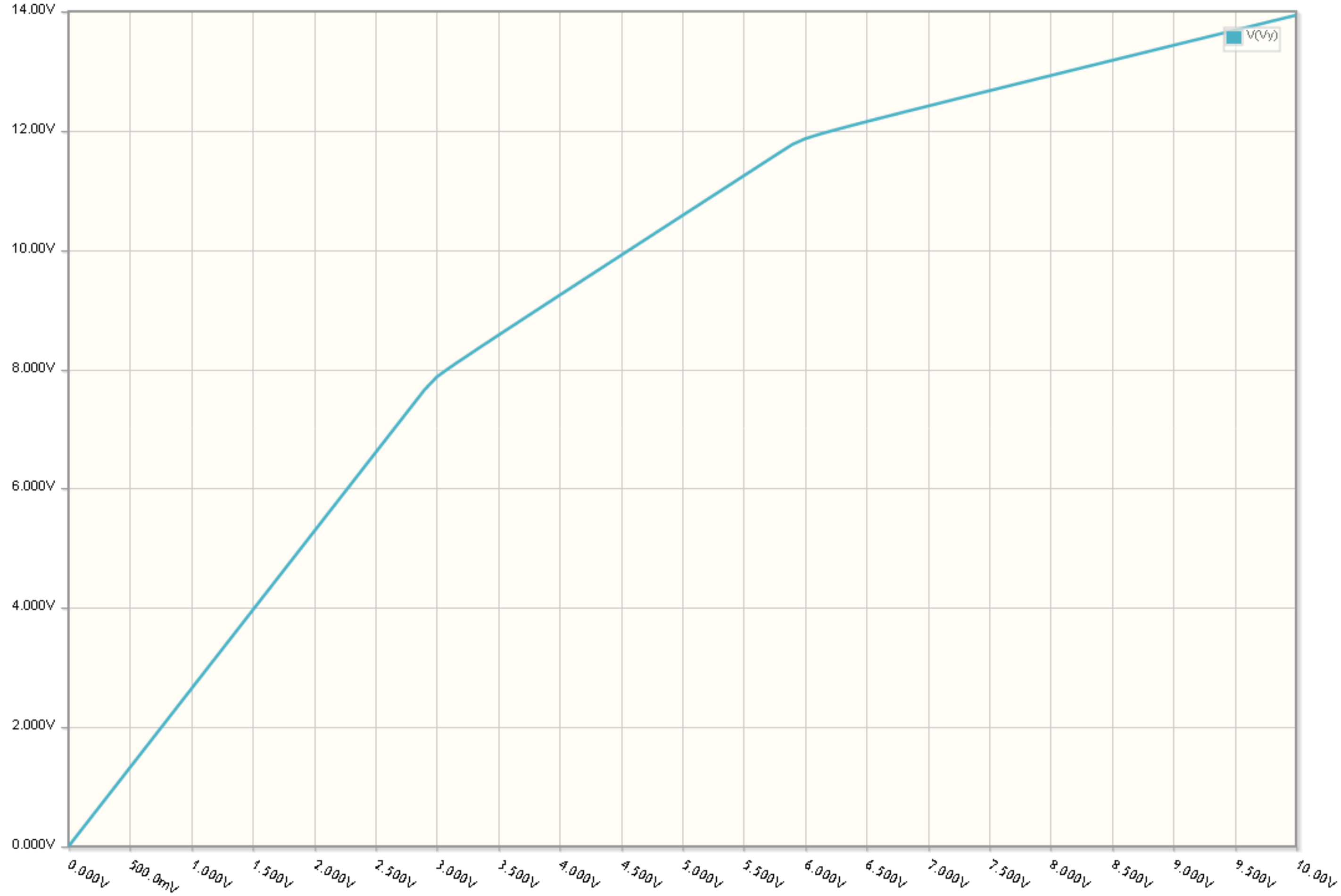


CircuitLab Simulation

CircuitLab doesn't have 8V and 12V zener diodes. You can modify a part to make these, however, by double clicking on the part.



Setting the zener voltages to 8V and 12V, and then sweeping the input voltage from 0V to 10V results in the following voltage plot at Y:



Clipper circuit implementation of Y = f(X)

Summary

Diodes can be used to clip voltages

- Protects circuitry from over-voltage

Zener diodes are easier to use for this purpose

- V(on) = 0.7V when forward biased
    - Zener diodes are diodes
- V(on) = Vz when reverse biased
    - Really how they're intended to be used
- Vz can be pretty much any voltage
    - 0.1V increments

With zener diodes, you can approximate functions y = f(x)

- Must be monotonically increasing
- Slope must be decreasing