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# 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

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

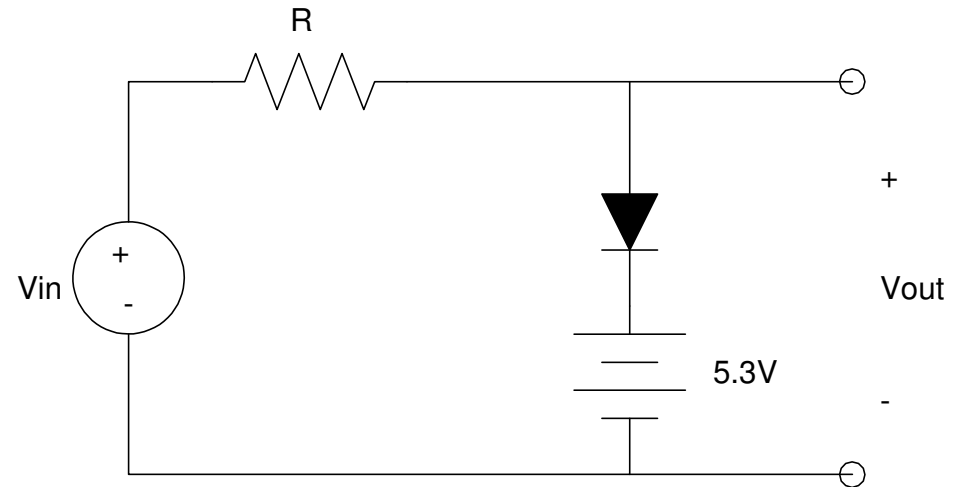
Solution:

$V_{in} < 6$

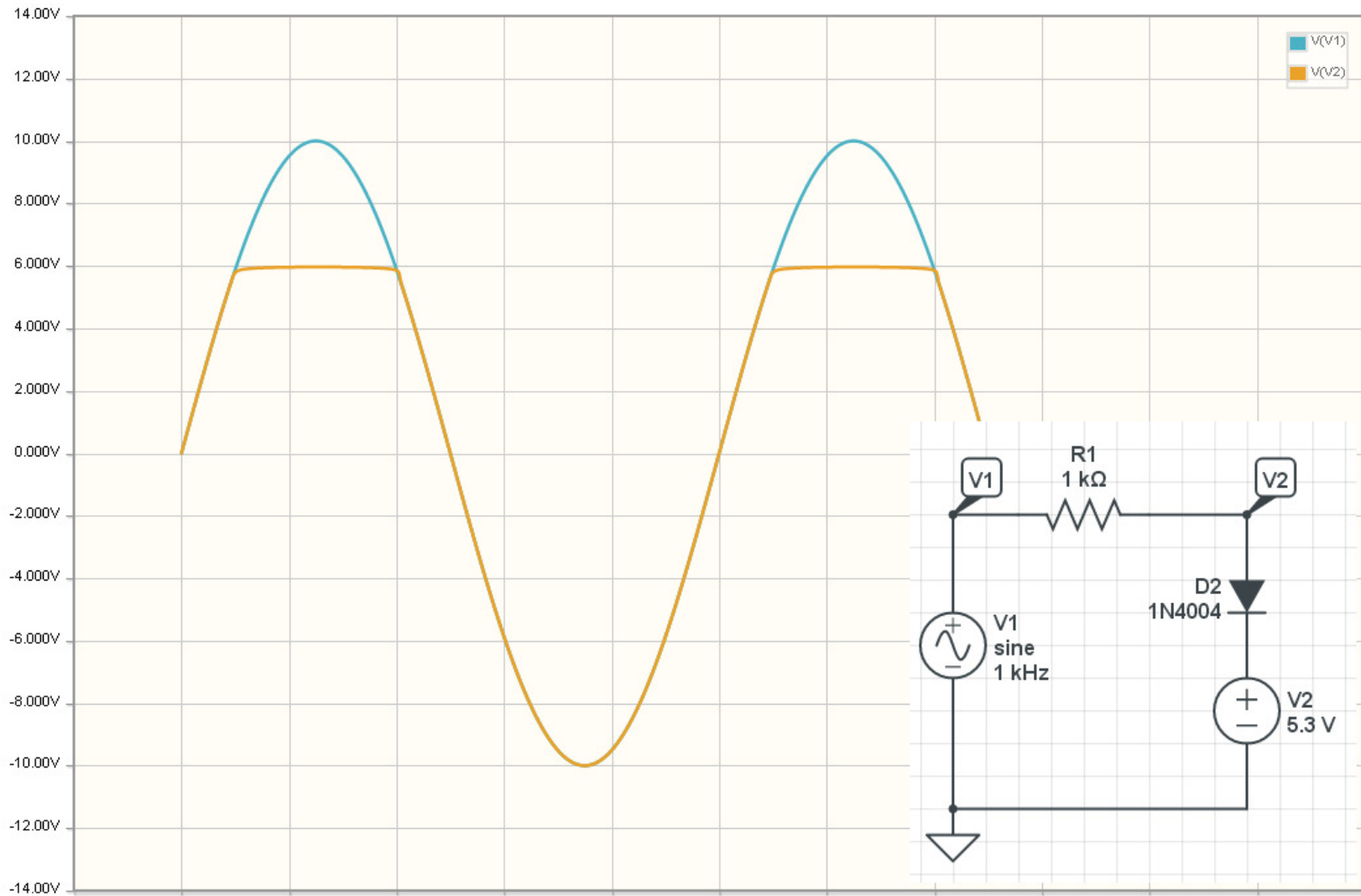
- Diode is off

$V_{in} > 6$

- Diode is on



# Check in CircuitLab (clip at >6V)



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Problem #2: Clip a signal at +1V

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

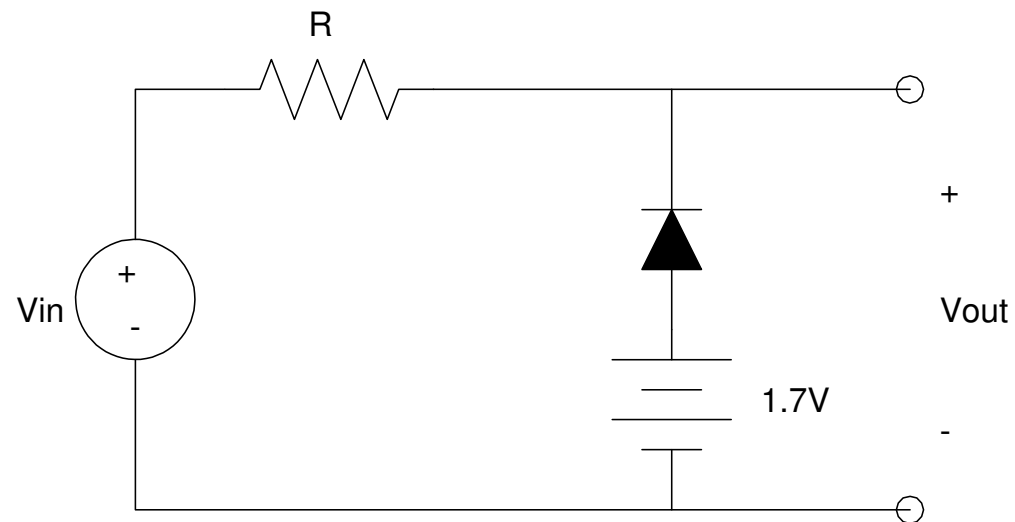
Solution: Flip the diode around

$V_{in} > 1V$

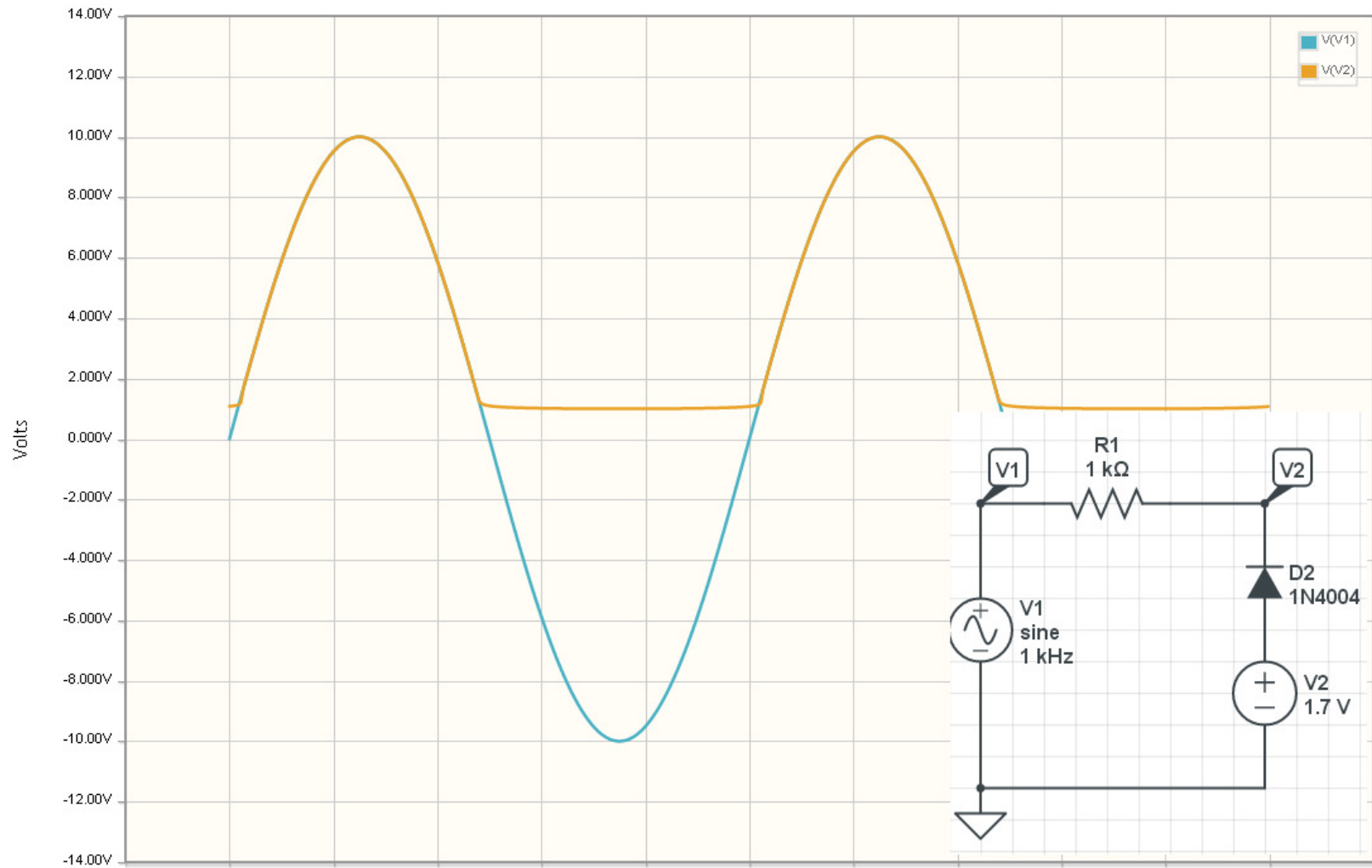
- Diode is off

$V_{in} < 1V$

- 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

$V_{in} < 1V$

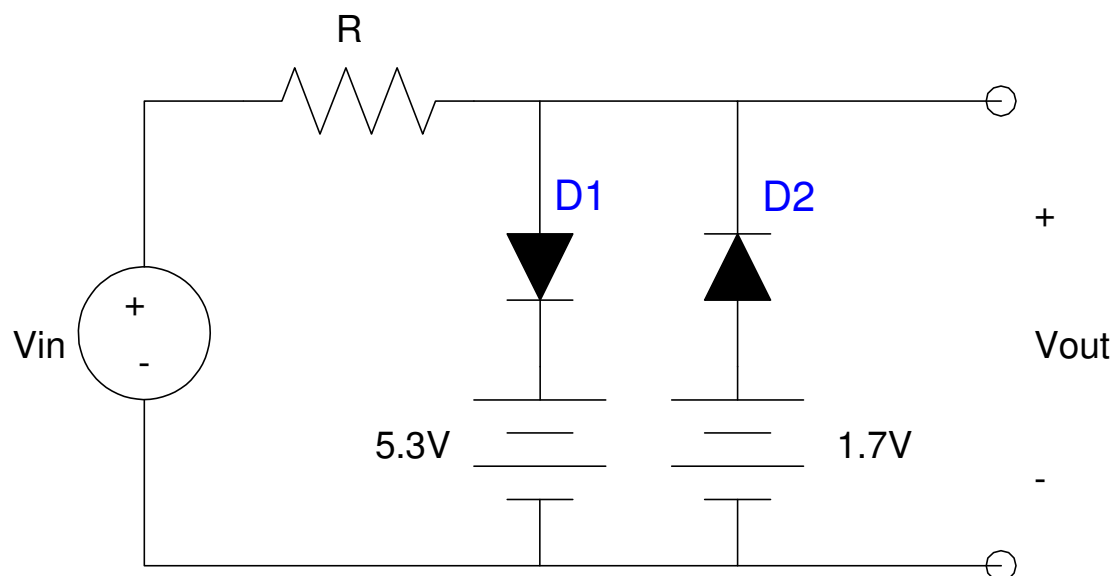
- Diode 2 is on

$V_{in} > 6V$

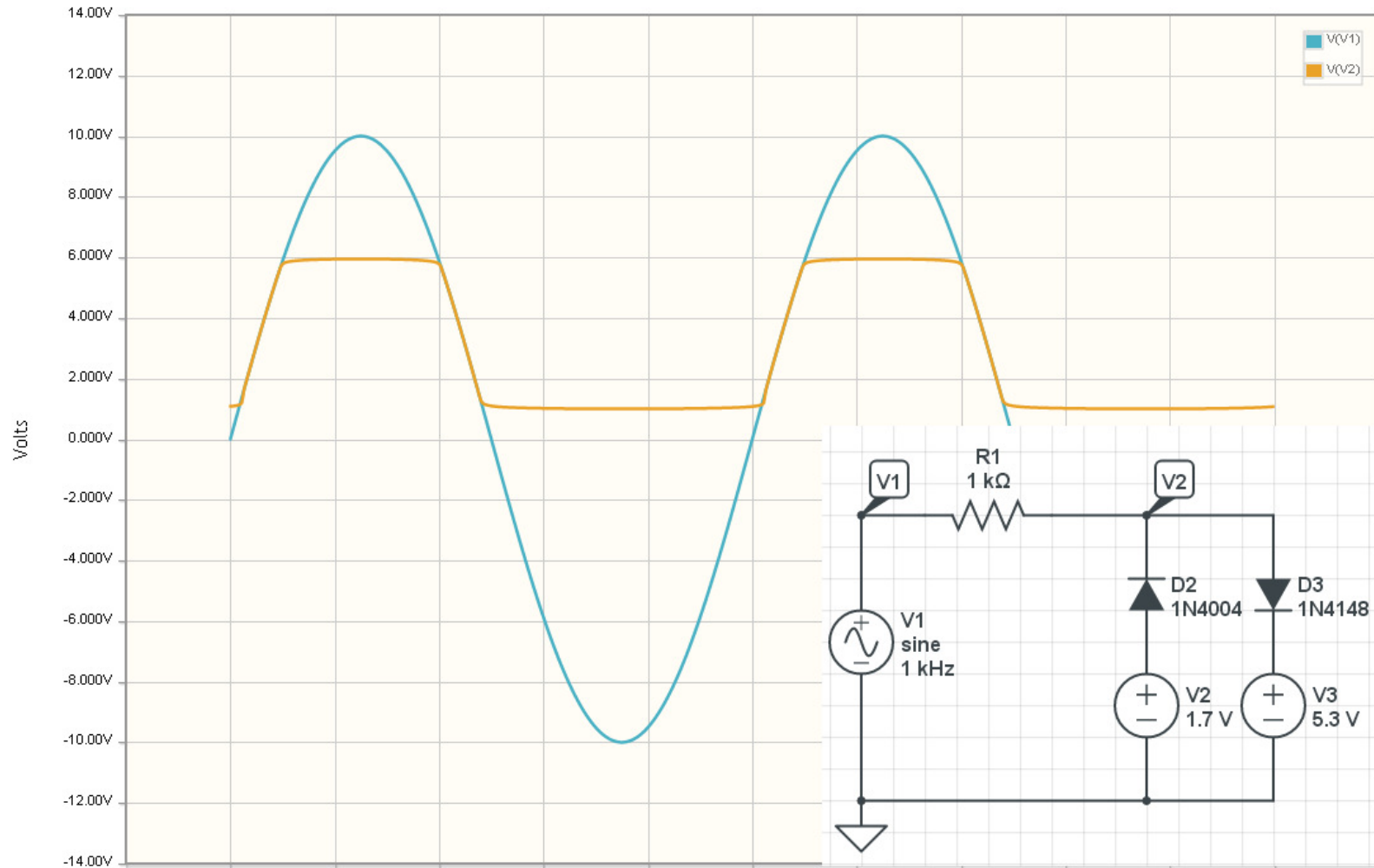
- Diode 1 is on

$1V < V_{in} < 6V$

- Both diodes are off



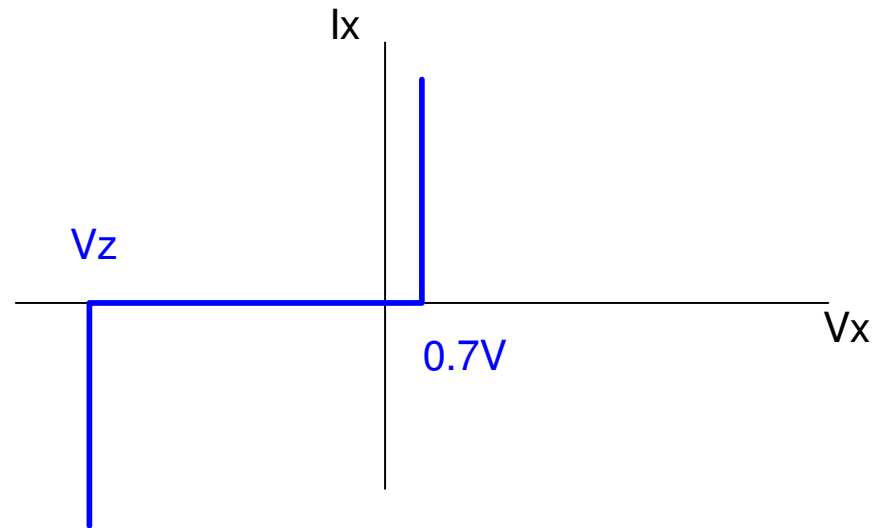
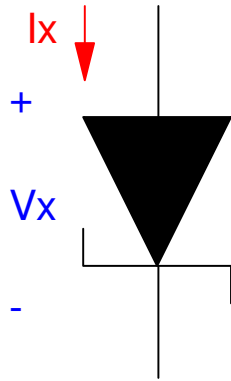
# Check in CircuitLab



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# 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
  - $2.4\text{mV} < V_Z < 390\text{V}$

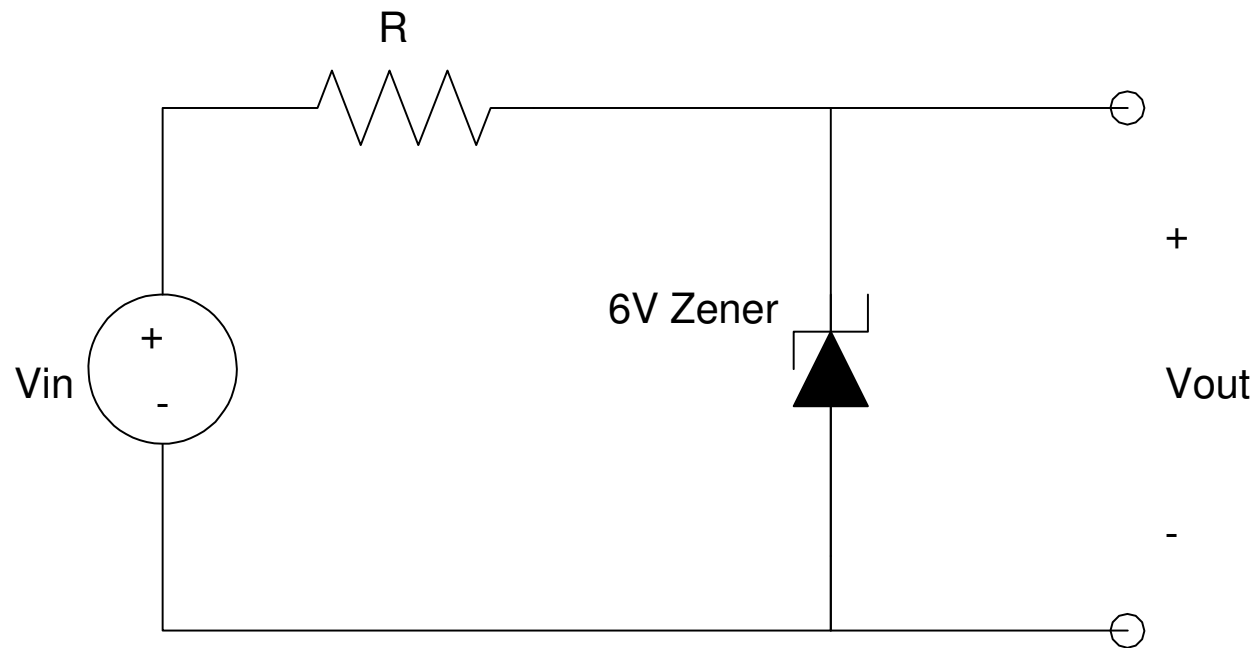




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Repeat: Clip at +6V

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



## Check in CircuitLab

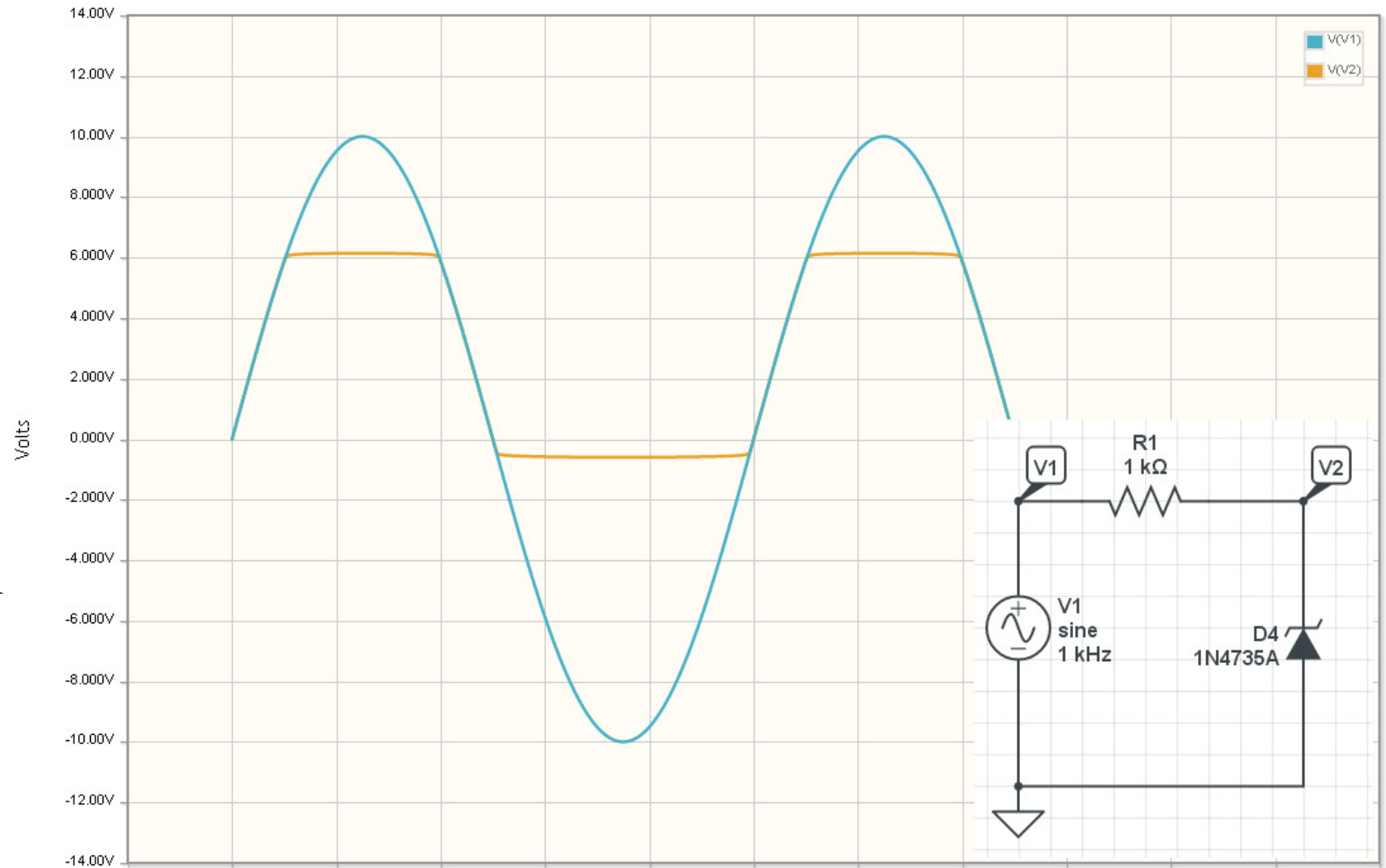
- $V_Z = 6.2V$
- Can be changed

## Clips at +6.2V

- reverse bias
- Zener voltage

## Clips at -0.7V

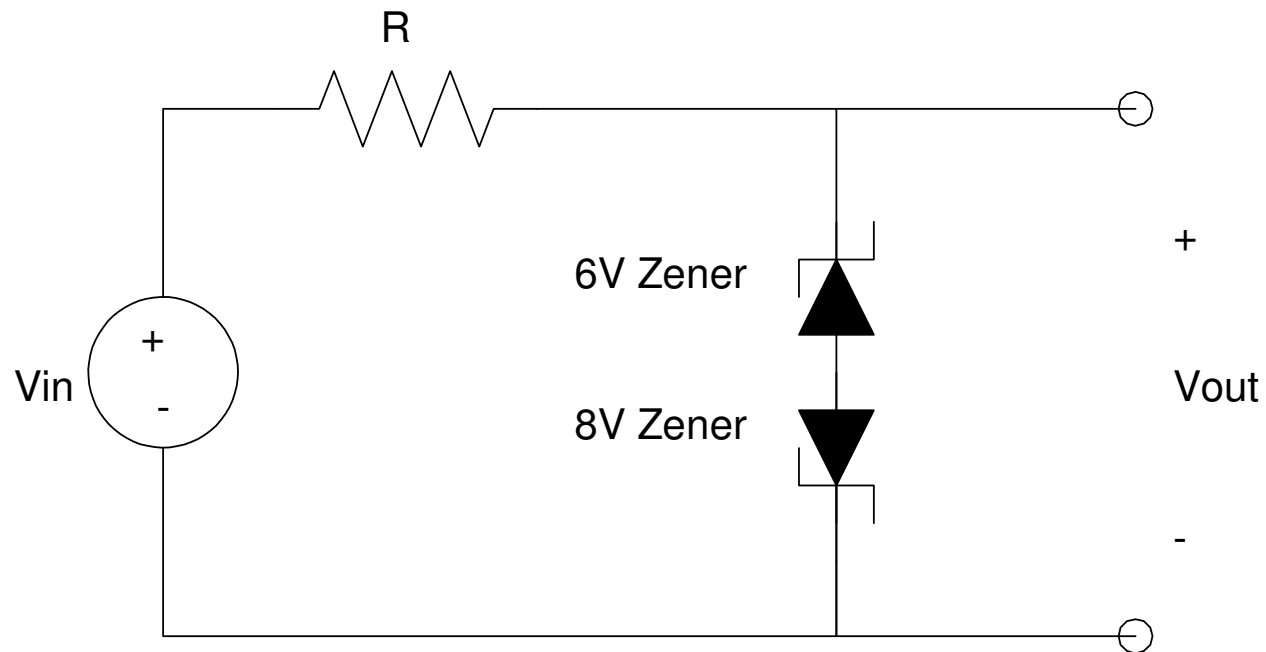
- forward biased di



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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  $-8V < V_{out} < +6V$

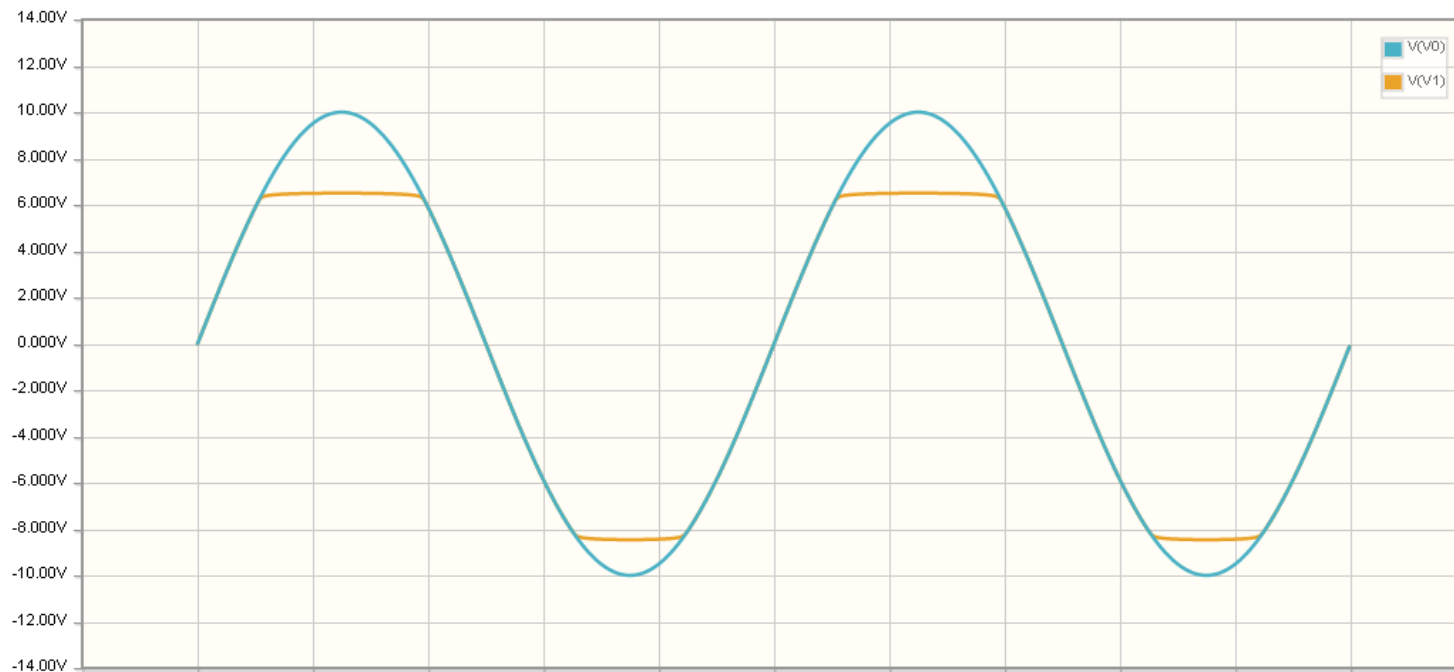
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# CircuitLab Simulation

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)

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# Function Approximation

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

Assume  $V_{z2} > V_{z1}$ .

$Y < V_{z1}$ : Both zener diodes are off

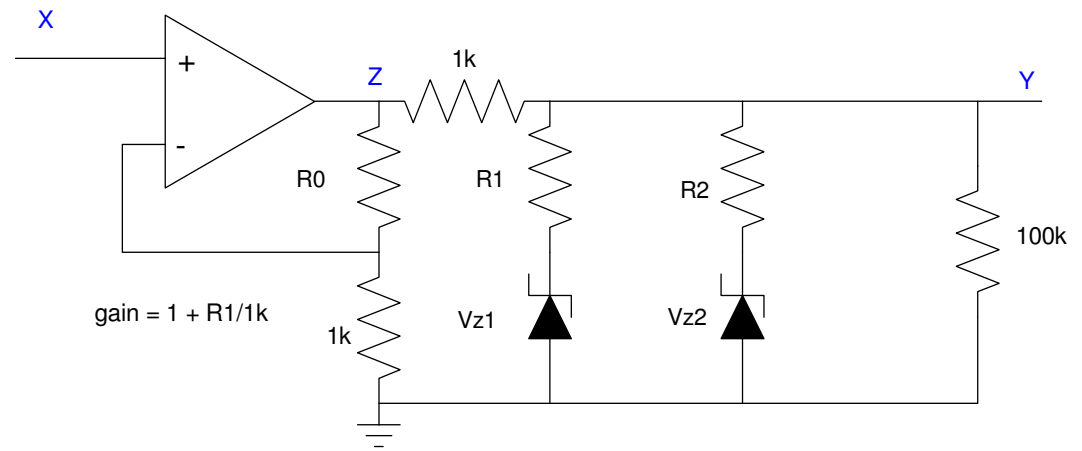
$$Y = kX = \left(1 + \frac{R_0}{1k}\right)X$$

$V_{z1} < Y < V_{z2}$ : Zener #1 is on

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

$Y < V_{z2}$ : Both zeners are on

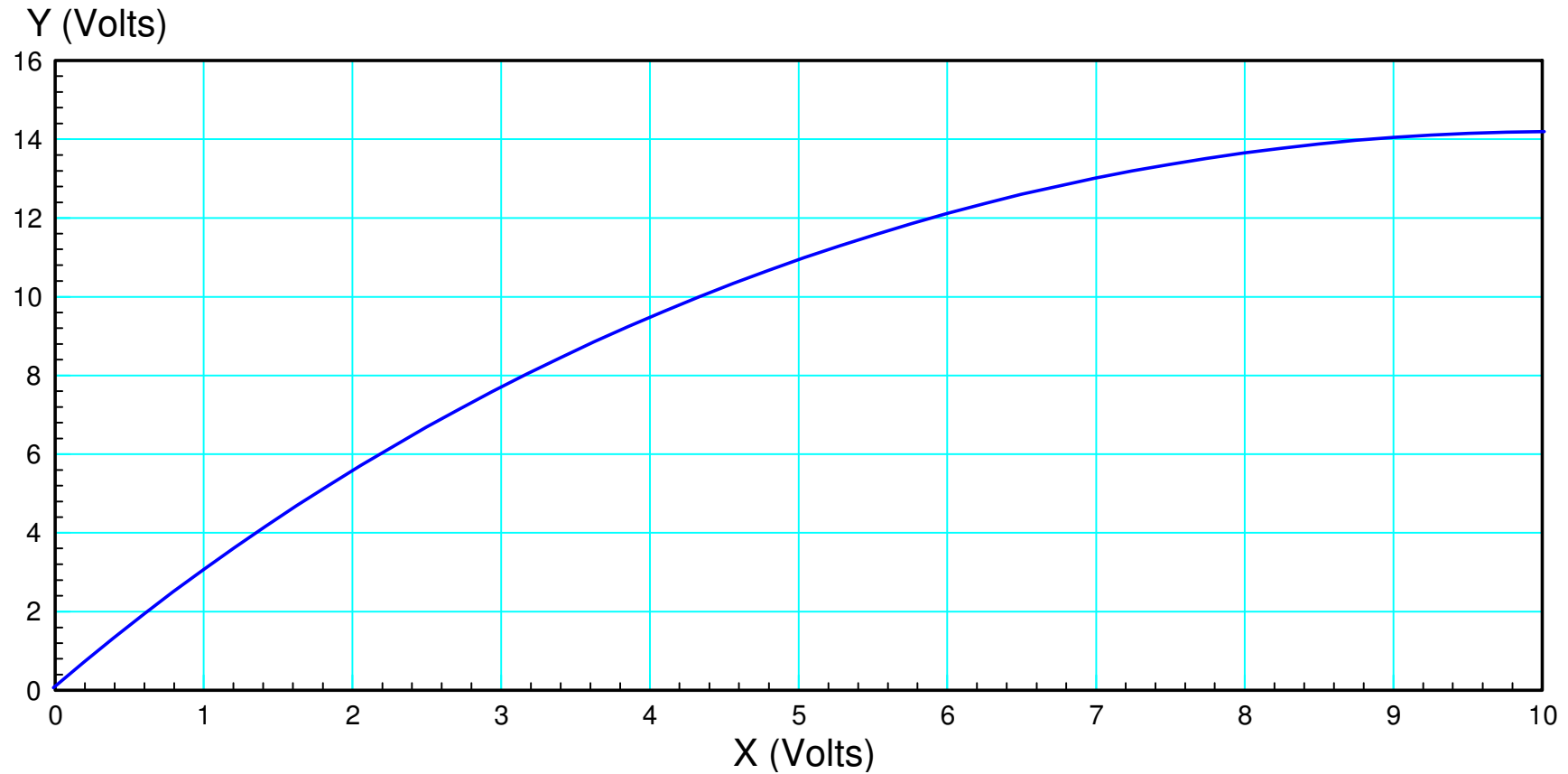
$$\text{Slope} = k \left( \frac{R_1 || R_2}{R_1 || R_2 + 1k} \right)$$



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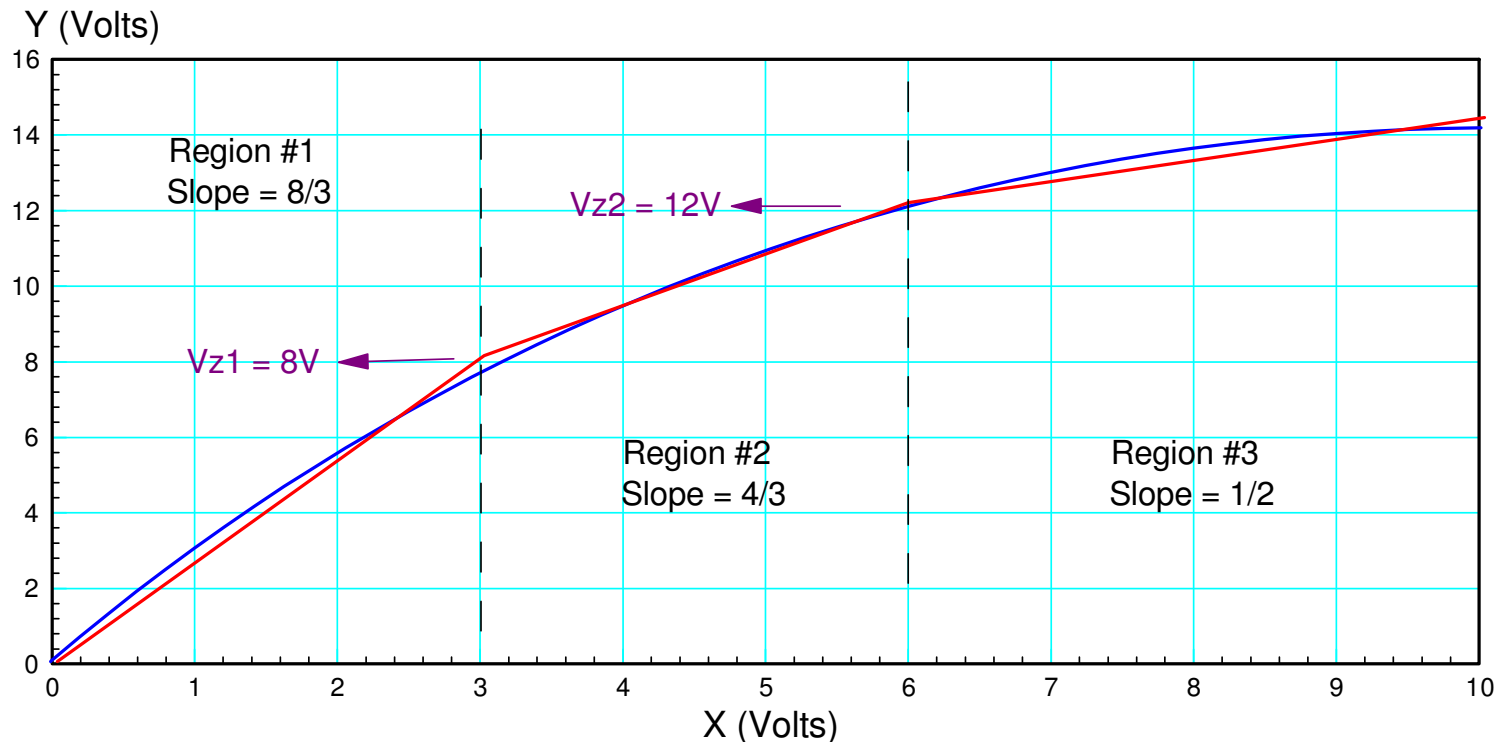
Example: Design a circuit to implement  $y = f(x)$

- Tolerance:  $\pm 0.5V$



## Solution:

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

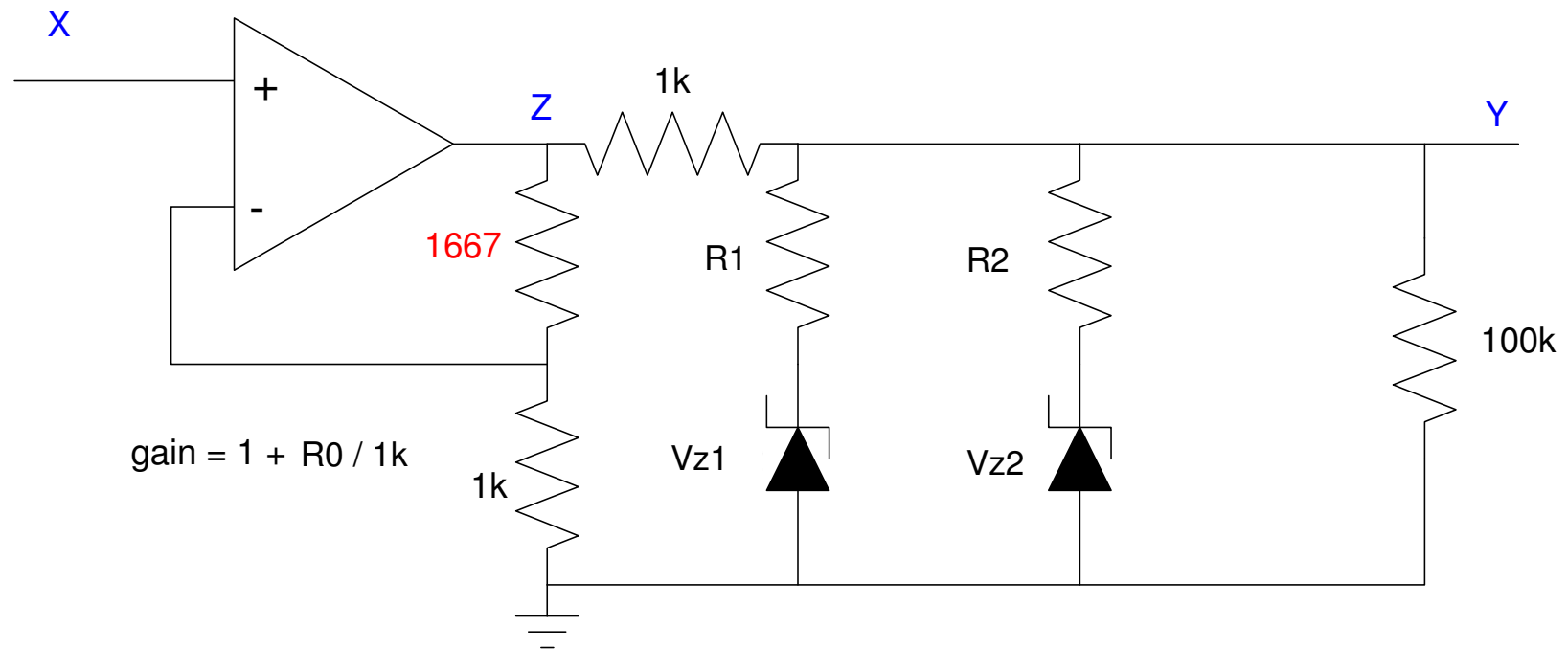


Approximate the function (blue) with straight lines (red)

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

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

$$R_0 = 1667\Omega$$





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

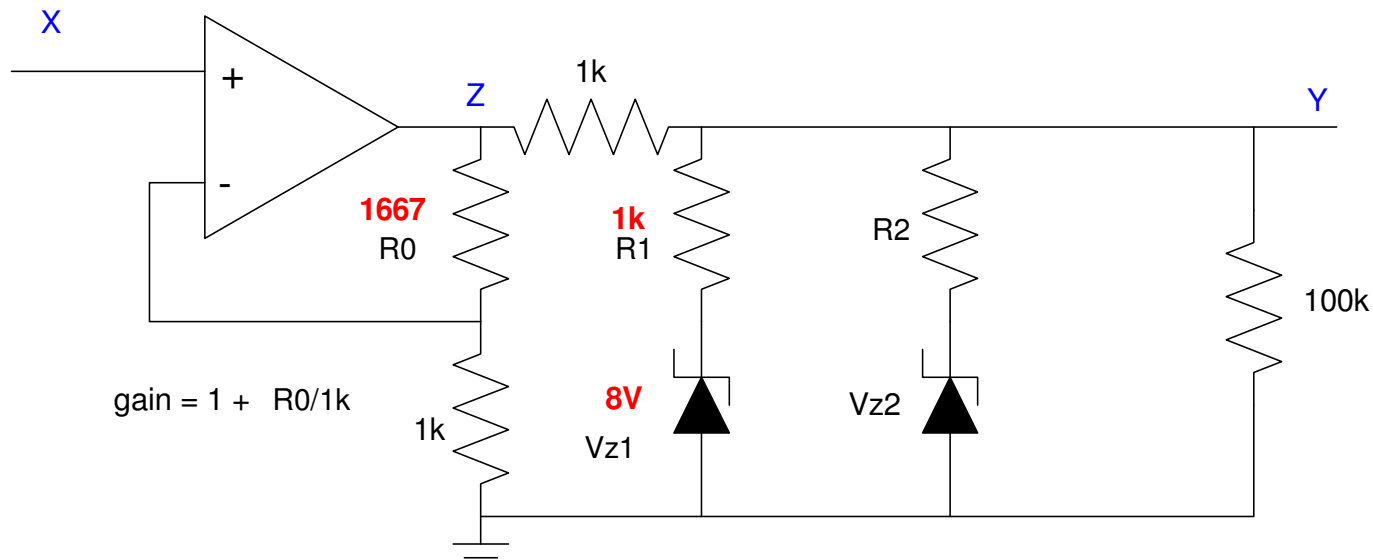
The zener voltage is the voltage at the output (y-axis) where the slope changes

$$V_{z1} = 8V$$

The slope is determined by R1 by voltage division

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

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



### 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

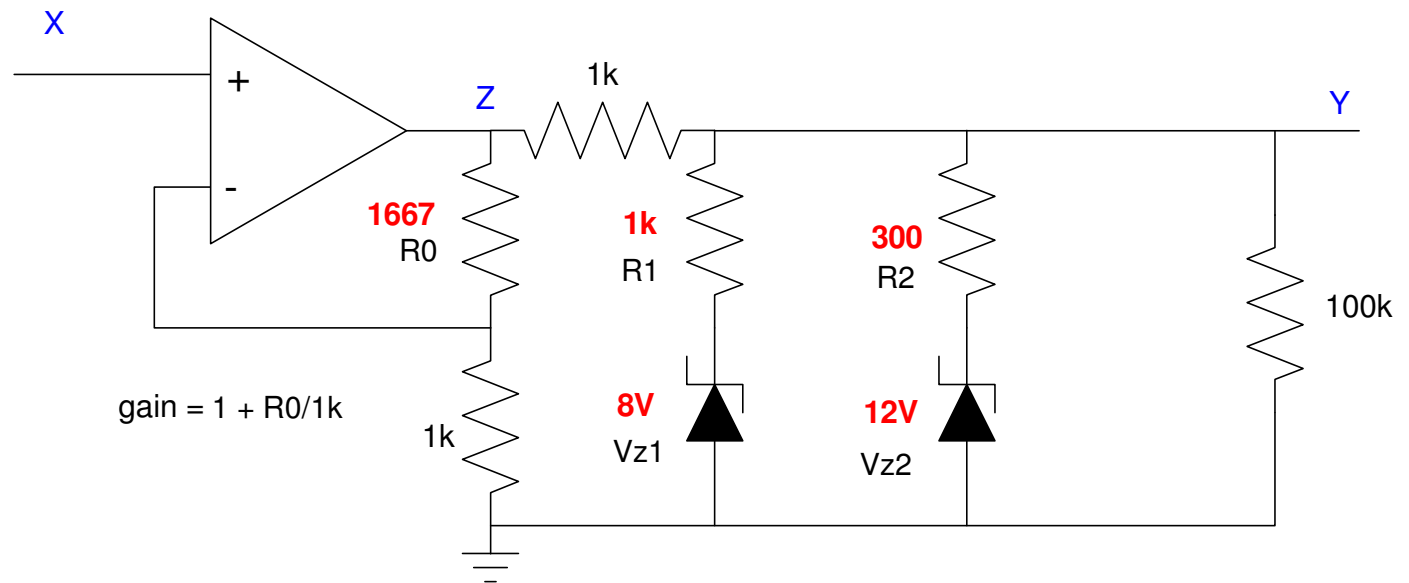
$$\text{slope} = k \left( \frac{R_1 || R_2}{R_1 || R_2 + 1k} \right) = \frac{1}{2}$$

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

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.

The image displays a CircuitLab simulation interface. On the left, a circuit diagram is shown on a grid background. It features an operational amplifier (op-amp) with a gain of 2081. The op-amp's non-inverting input is connected to a voltage source labeled  $V_z$ . The op-amp's output is connected to a resistor  $R_{18}$  (1 k $\Omega$ ), which is in series with a resistor  $R_{19}$  (1 k $\Omega$ ). This series combination is connected to a zener diode  $D_1$  (1N4733A) and a resistor  $R_{17}$  (1 k $\Omega$ ). The other terminal of  $R_{17}$  is connected to ground. A second zener diode  $D_2$  (1N4733A) is connected in parallel with  $D_1$ . The circuit also includes a resistor  $R_{16}$  (1.666 k $\Omega$ ) connected to the op-amp's output and a resistor  $R_{17}$  (1 k $\Omega$ ) connected to ground. A voltage source  $V_y$  is connected across the series combination of  $R_{18}$  and  $R_{19}$ .

On the right, a device model configuration panel is open. It shows a list of zener diode models under "My Device Models":

- Zener4V
- Zener2V
- Zener4p6
- Zener8V
- Zener12V

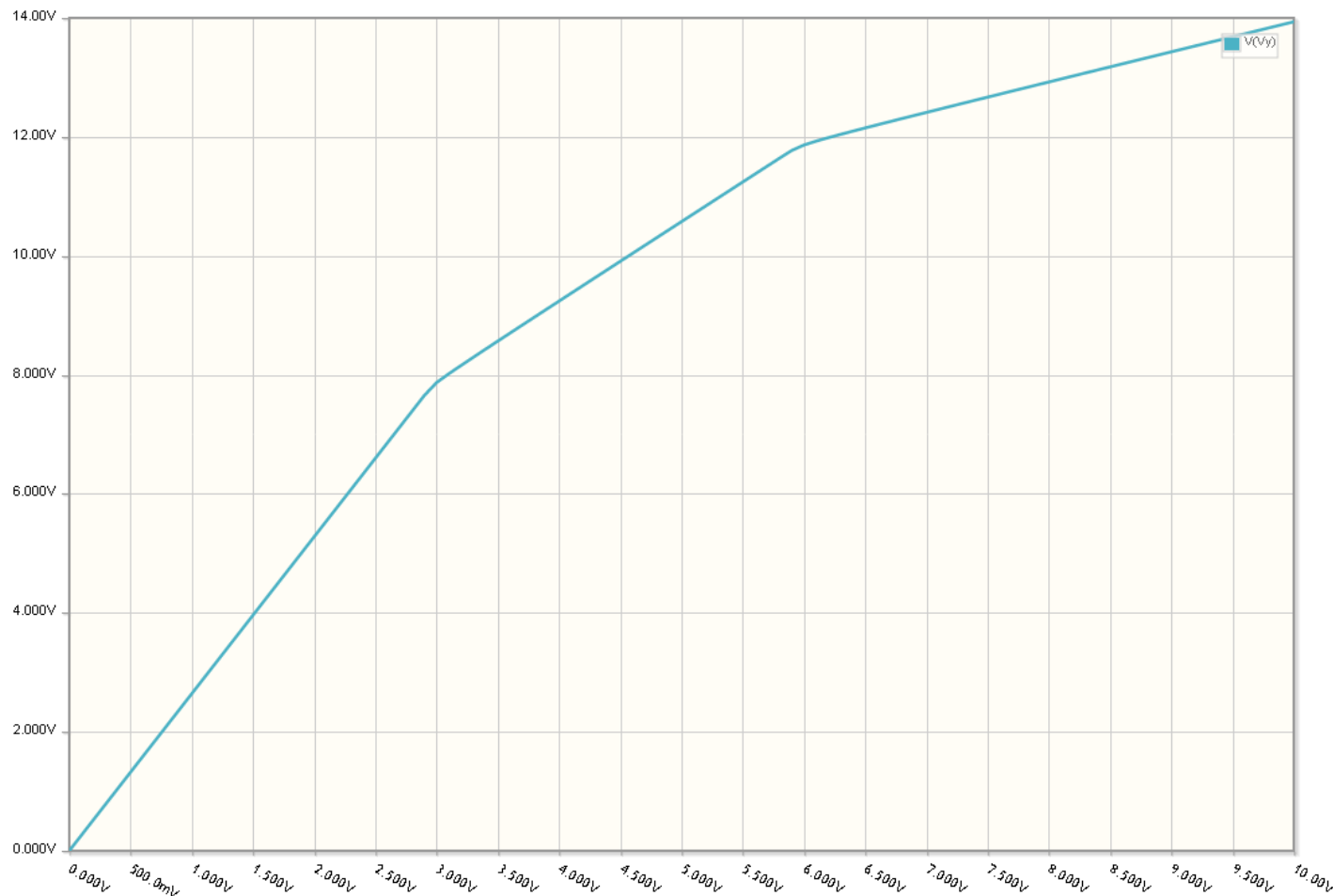
Each model has a "Datasheet" button and a "Buy" button. Below this list is a "Standard Device Models" section. A "View All Zener Diodes In Stock" button is located at the bottom of the panel.

The configuration panel for the selected device (D1) shows the following parameters:

- name: D1
- Part#: 1N4733A
- $V_z$ : 8 V
- $I_z$ : 0.049 A
- $R_S$ : 1  $\Omega$

A "Save Custom Device Model" button is located at the bottom of the configuration panel.

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  $Y = f(X)$

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## 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
- $V_{(on)} = V_Z$  when reverse biased
  - Really how they're intended to be used
- $V_Z$  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
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