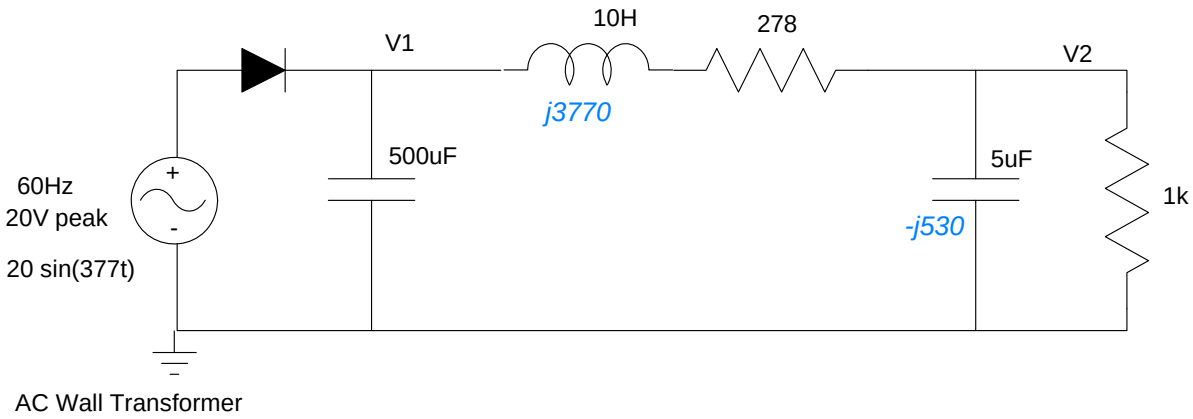
ECE 320 - Homework #4 (rev 2)

AC to DC Converters, Max/Min Circuits, Clipper Circuits. Due Monday, September 17th, 2018

AC to DC Circuits

1) Determine the DC voltage and the peak-to-peak ripple at V1 and V2 for the following AC to DC circuit.



Peak at V1 = 19.3V (20Vp minus 0.7V from the diode)

DC Current:

$$I = \left(\frac{19.3V}{1278\Omega}\right) = 15.10mA$$

DC voltage at V2:

$$V_2 = \left(\frac{1k}{1k+278}\right) \cdot 19.3V = 15.1V$$

AC: Ripple at V1

$$I = C\frac{dV}{dt}$$

$$15.1mA = 500\mu F \cdot \frac{dV}{1/60s}$$

$$dV = 503mV_{pp}$$

Ripple at V2:

$$5\mu F \rightarrow \frac{1}{j\omega C} = -j530\Omega$$

$$10H \rightarrow j\omega L = j3770\Omega$$

Adding the capacitor and resistor in parallel:

$$Z_1 = \left(\frac{1}{1000} + \frac{1}{-j530}\right)^{-1} = 219 - j413\Omega$$

$$V_2 = \left(\frac{219-j413}{(219-j413)+(278+j3770)}\right) \cdot 0.503V_{pp}$$

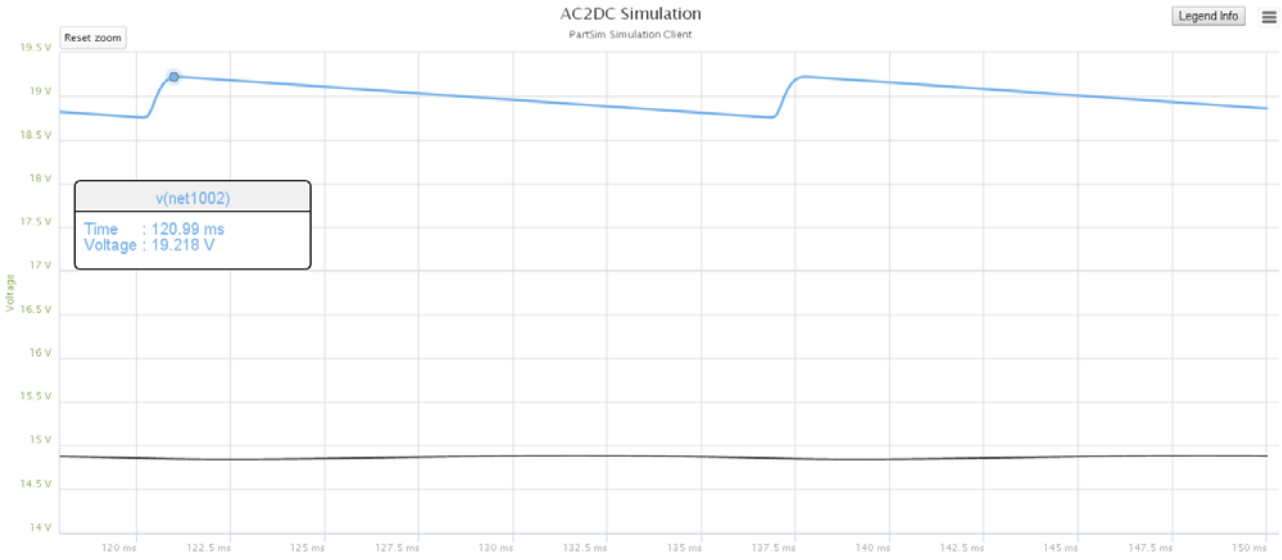
$$V_2 = 69mV_{pp}$$

(angle doesn't matter - it tells you that the peak in V2 is delayed from the peak in V1)

Net Result:

- **V1 = 19.3V (max)** **V2 = 15.1V (avg)**
- **503mVpp** **69mVpp**

Check in PartSim (not requried)



Simulation Result: V1 (blue) and V2 (black)
V1 = 19.206V (max), 464mVpp
V2 = 14.86V (avg), 44mVpp

2) Determine R, L, and C so that the circuit

- Draws 10mA at the load
- Has a 2Vpp ripple at V1, and
- Has a 500mVpp ripple at V2

Solution: For 10mA

$$R_{total} = \frac{19.3V}{10mA} = 1930\Omega$$

$$R_{load} = 1930\Omega - 278\Omega = 1652\Omega$$

For 2Vpp ripple at V1

$$I = C\frac{dV}{dt}$$

$$10mA = C\frac{2V_{pp}}{1/60s}$$

$$C = 83.3\mu F$$

For 500mVpp ripple at V2, assume C2 = 0. The ripple due to the inductor is

$$V_2 = \left(\frac{1652}{1652+278+j3770}\right) \cdot 2V_{pp}$$

$$V_2 = 0.78V_{pp}$$

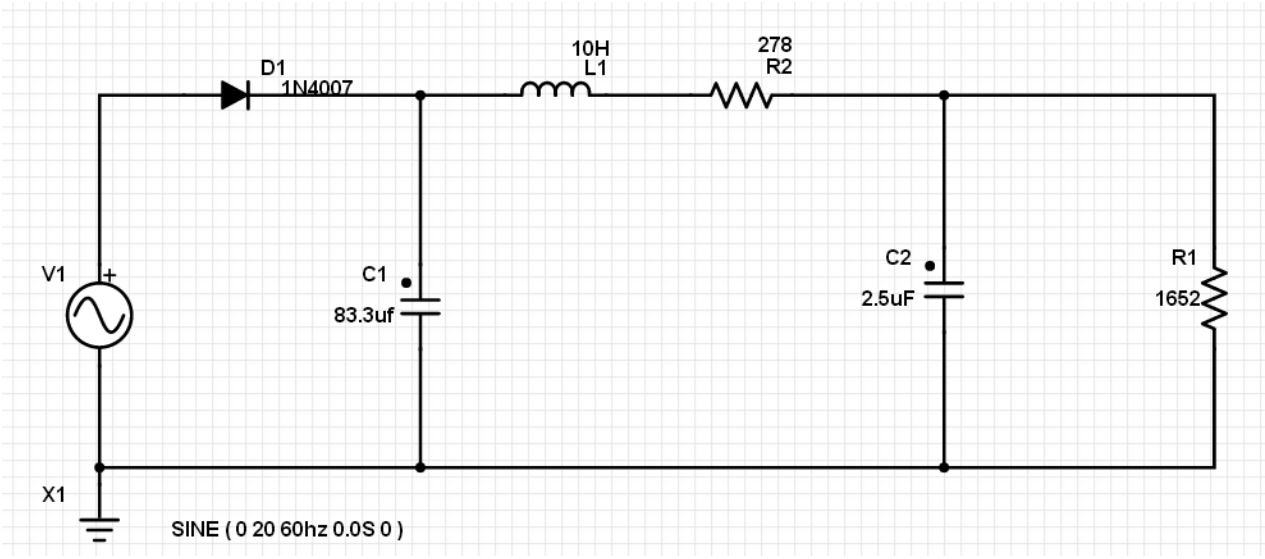
To bring this down to 0.5Vpp, the capacitor should be

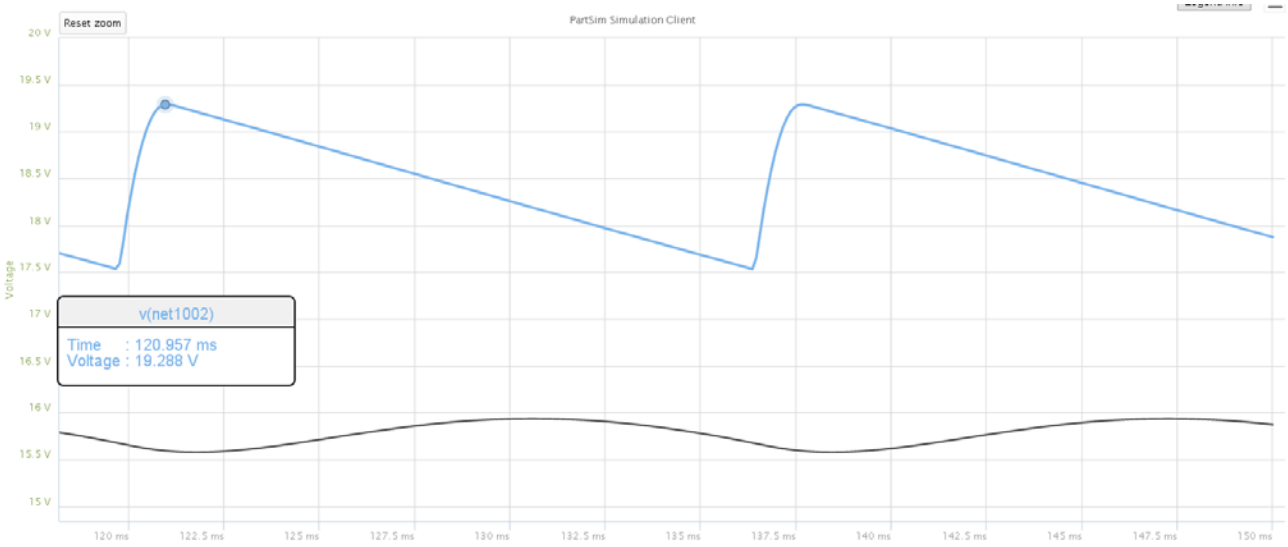
$$Z_c = \left(\frac{0.5V}{0.78V}\right) \cdot 1652\Omega$$

$$Z_c = 1058\Omega = \frac{1}{j\omega C}$$

$$C = 2.5\mu F$$

3) Check your answer for problem #2 in PartSim using a 4007 diode.

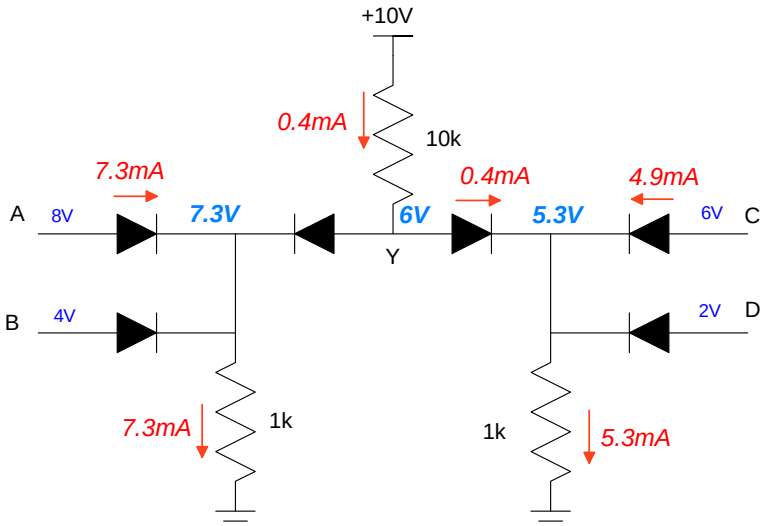




	V1			V2		
	Calculated prob 2	Simulated prob 3	Measured prob 9	Calculated prob 2	Simulated prob 3	Measured prob 9
DC	19.3V (max)	19.288V		16.52V	15.759V	
AC	2Vpp	1.751Vpp		500mVpp	356mVpp	

Max/Min:

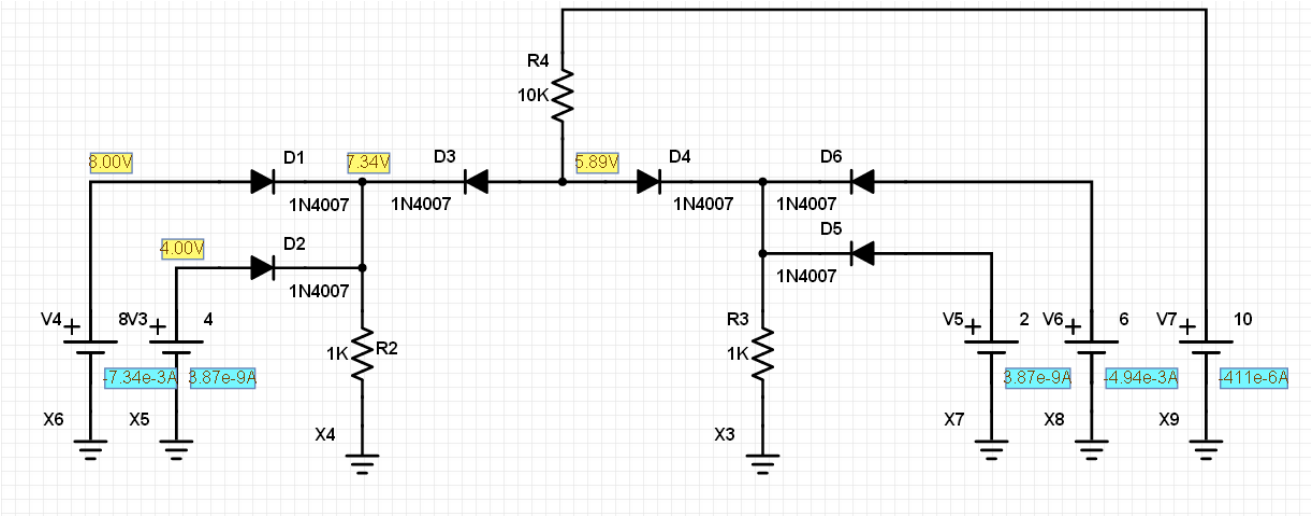
4) Determine the voltages and currents for the following max/min circuit. What function does this circuit implement? Y = f(A, B, C, D)



Y = min(max(A, B), max(C, D))

Y = (A+B)(C+D)

5) Check your results in PartSim

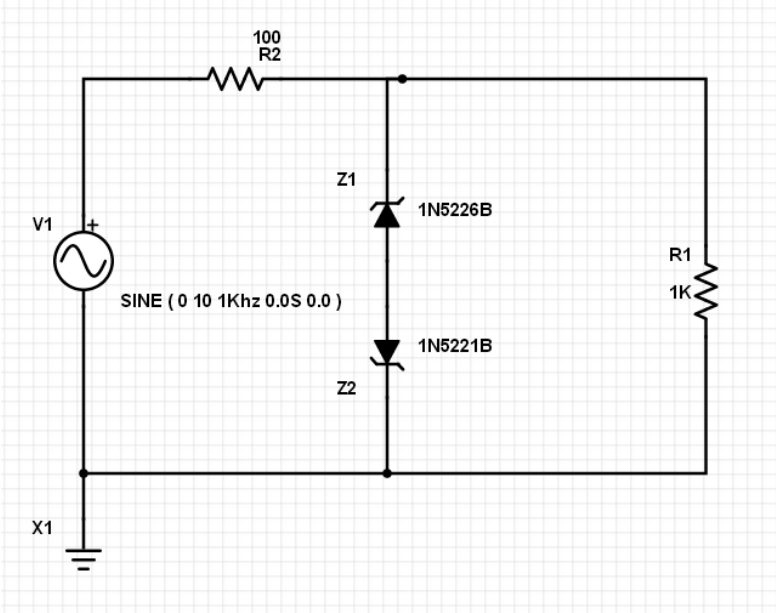


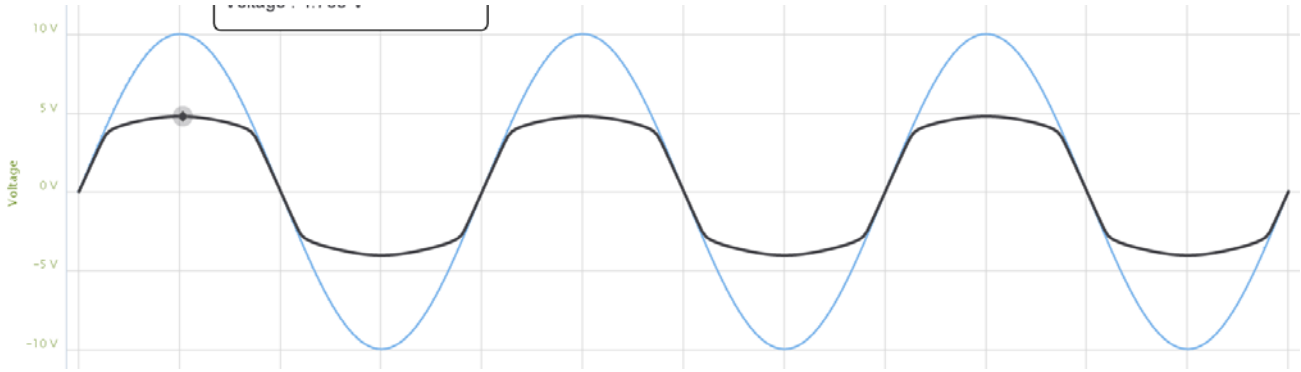
Clipper Circuits:

6) Design a circuit which meets the following requirements:

- Input: -10 .. +10V, capable of 100mA
- Output: 1k resistor
- Relationship:

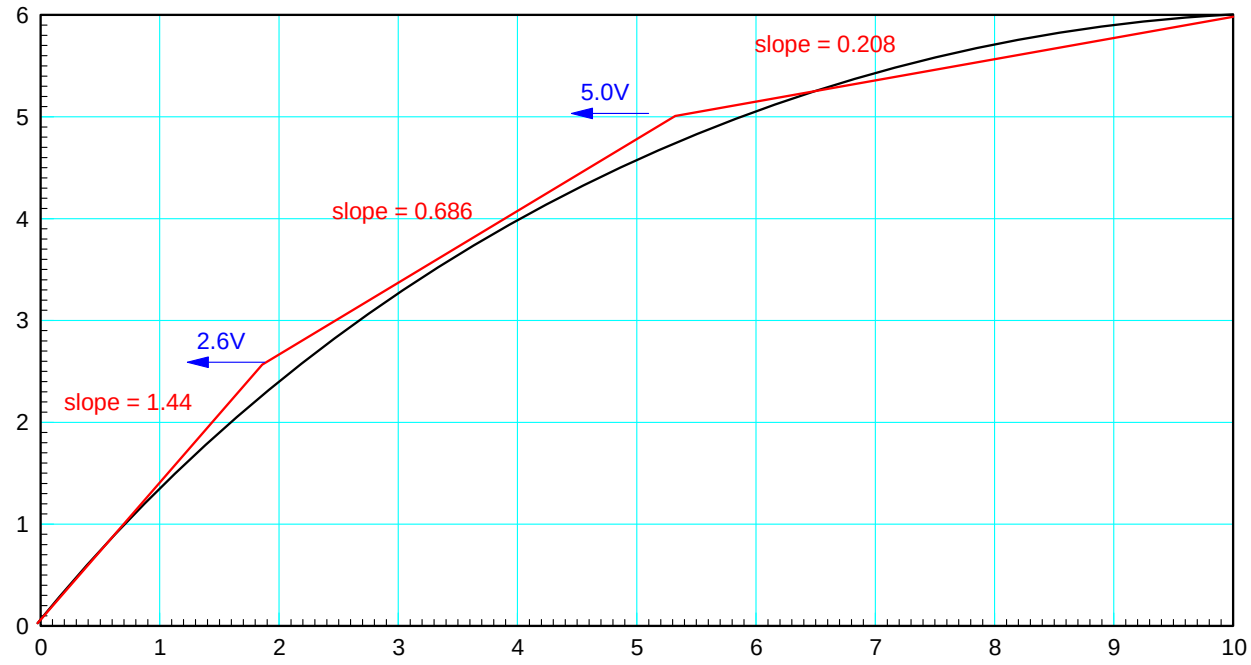
$$V_{out} = \begin{cases} +4V & V_{in} > +4V \\ V_{in} & -3V < V_{in} < +4V \\ -3V & V_{in} < -3V \end{cases}$$





7) Design a circuit to approximate the following function subject to the following requirements:

- Input: 0 .. 10V, capable of 100mA
- Output: 100k resistor
- Relationship: Graph below, +/- 200mV



Step 1: Draw in straight lines to approximate the waveform. If the line deviates by more than 200mV, add a new line (shown in red).

Step 2: Add in the stages

Stage 1: Slope = 1.44

$$gain = 1 + \frac{R_0}{1k}$$

$$R_0 = 440\Omega$$

Stage 2: Add a resistor at the output of the op-amp which is much smaller than the load. (1k)

Turns on when Y = 2.6V. Make the zener diode 2.6V.

The slope is 0.686

$$0.686 = 1.44 \cdot \left(\frac{R}{R+1000}\right)$$

$$R = \left(\frac{\left(\frac{0.686}{1.44}\right)}{1-\left(\frac{0.686}{1.44}\right)}\right) 1000 = 909\Omega$$

$$R_1 = 909$$

Stage 3:

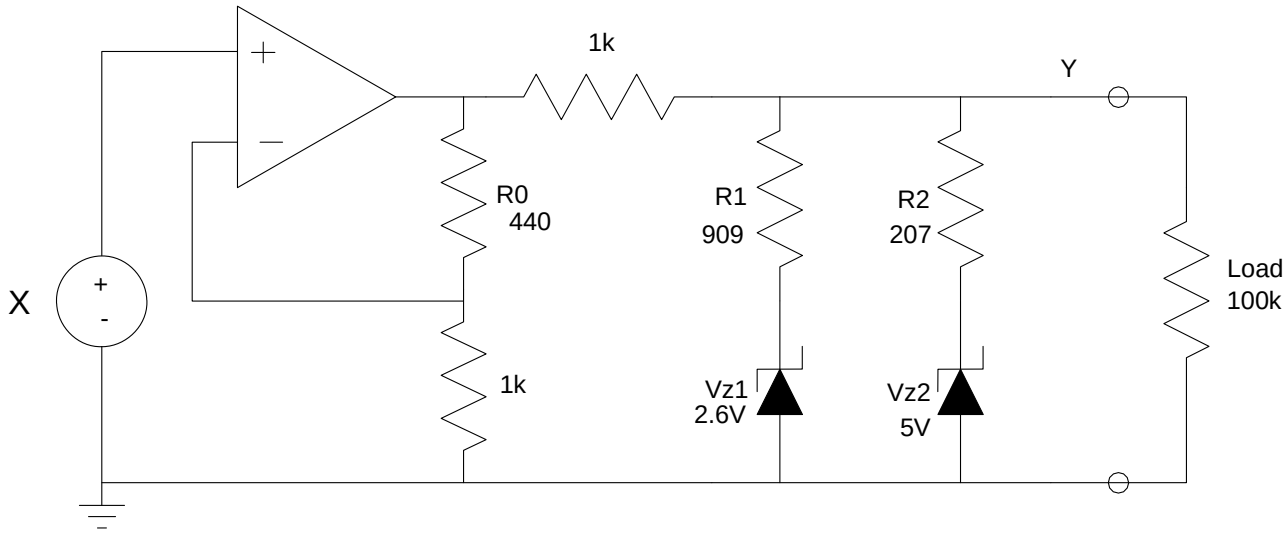
Turns on when Y = 5V. Make the zener diode 5V.

The slope is 0.208

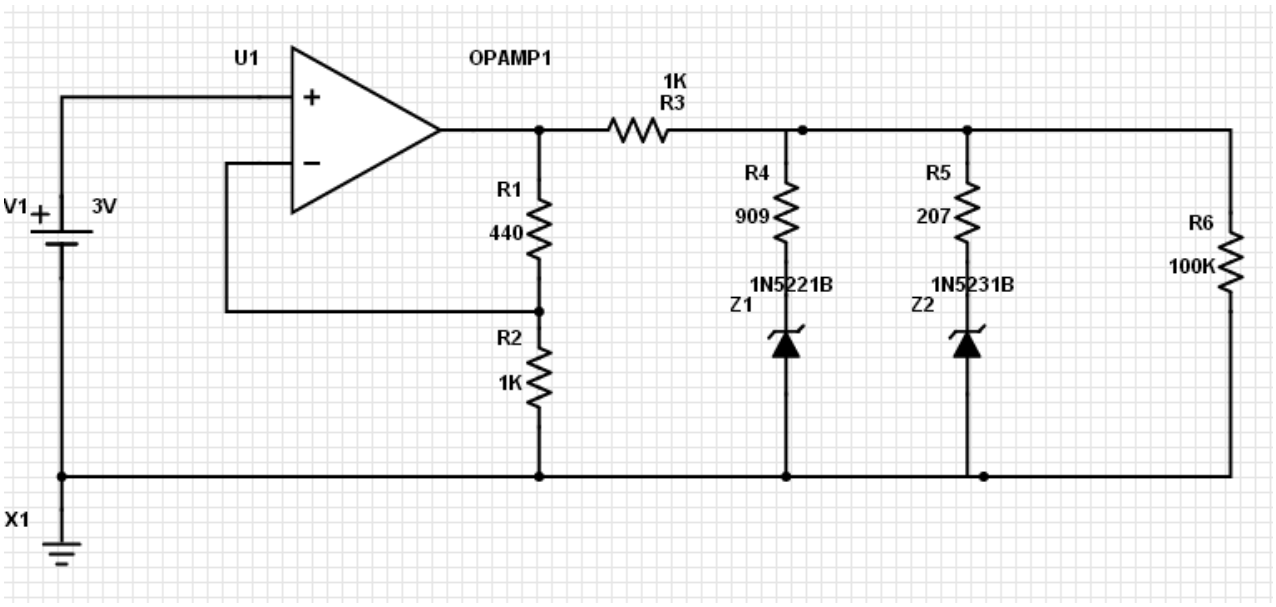
$$R = \left(\frac{\left(\frac{0.208}{1.44}\right)}{1-\left(\frac{0.208}{1.44}\right)} \right) 1000 = 168.8\Omega$$

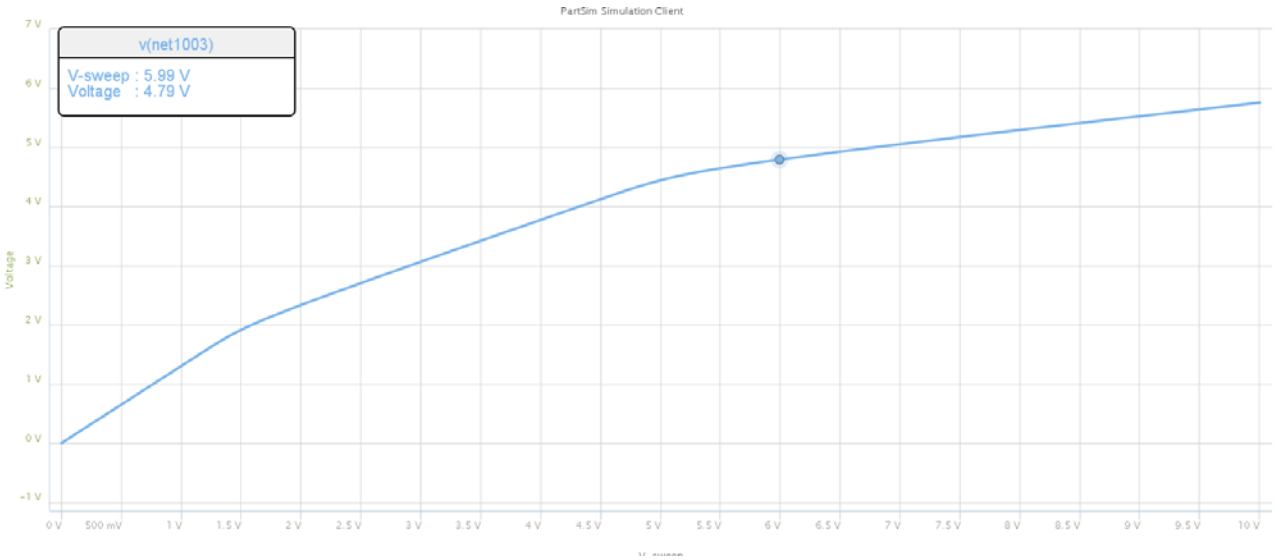
$$R = R_1 || R_2$$

$$R_2 = 207\Omega$$



8) Check your design in PartSim.





	Requirement	Calculated problem 7	Simulated problem 8	Measured problem 9
Vin = 2V	2.6V	2.73V	2.22V	
Vin = 4V	4.0V	4.1V	3.31V	
Vin = 6V	5.2V	5.2V	4.31V	
Vin = 8V	5.8V	5.6V	4.79V	

Lab:

9) Build one of these circuits in lab and collect data to verify your design.