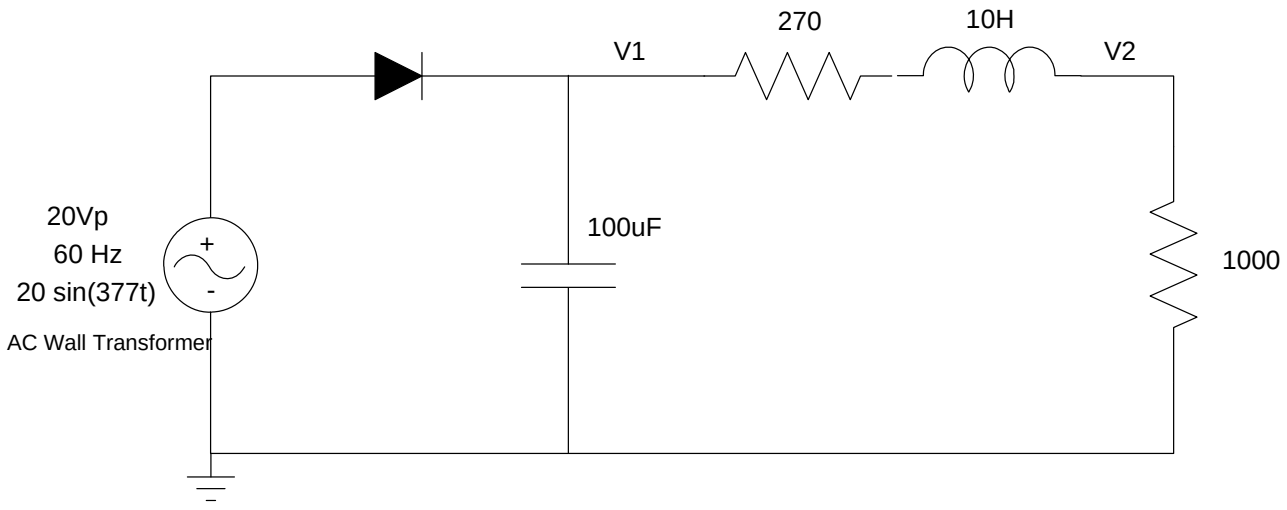
ECE 320 - Homework #4

AC to DC Converters, Min/Max Circuits, Clipper Circuits. Due Monday, February 5th, 2018

AC to DC Converters

1) (Analysis) For the following half-wave rectifier, determine the voltage atV1 and V2



V1:

max(V1) = 19.3V

20V peak - 0.7V across the diode

The current is approximately

$$I \approx \frac{19.3V}{1k\Omega+270} = 15.2mA$$

The ripple is then

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

$$15.2mA = 100\mu F \cdot \frac{dV}{1/60s}$$

$$dV = 2.53V_{pp}$$

The average voltage at V1 is then approximately the average of the max and min

$$\max(V_1) = 19.3V$$

$$\min(V_1) = 19.3V - 2.53V = 16.78V$$

$$V_{1:DC} = \left(\frac{\max(V_1)+\min(V_1)}{2}\right) = 18.03V$$

V2: DC Analysis:

$$V_2 = \left(\frac{1000}{1000+270}\right)V_1$$

$$V_2 = \left(\frac{1000}{1000+270}\right)18.03V$$

$$V_2 = 14.20V$$

AC Analysis

$$\omega = 2\pi \cdot 60Hz = 377\frac{rad}{\sec}$$

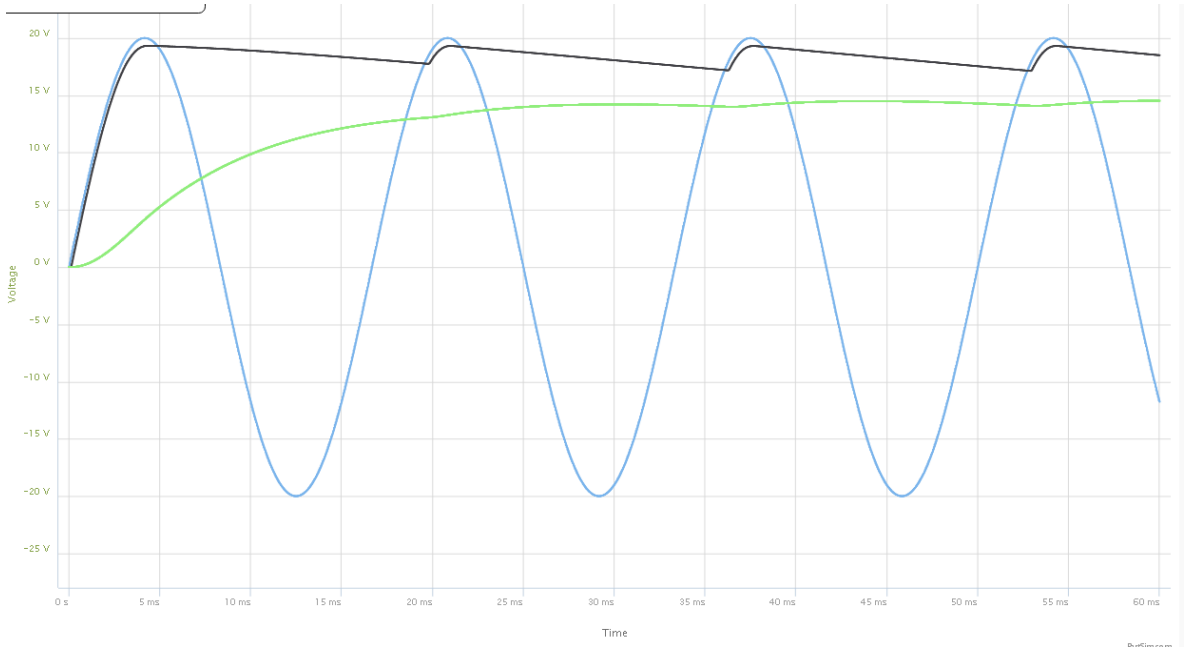
$$L \rightarrow j\omega L = j3770\Omega$$

$$V_2 = \left(\frac{1000}{1000+j3770+270}\right) \cdot 2.53V_{pp}$$

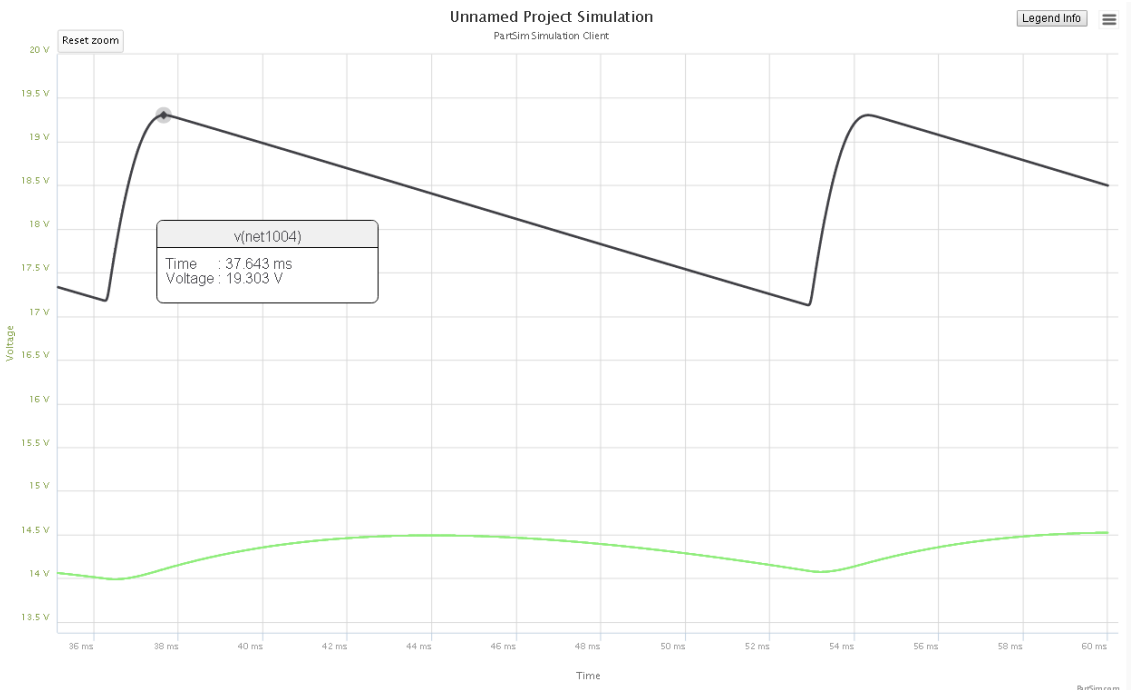
$$V_2 = 0.636V_{pp}$$ (angle doens't matter here)

	DC	AC (60 Hz)
V1(t)	18.03V	2.53Vpp
V2(t)	14.20V	0.636Vpp

2) (Simulation) Simulate this circuit in PartSim to verify your calculations.



Zooming in on V1 and V2 after 3 cycles



	V1 (black)		V2 (green)	
	Calculated	Simulated	Calculated	Simulated
DC (Vavg)	18.03	18.2	14.2	14.29
AC (Vpp)	2.53 Vpp	2.17 Vpp	0.636Vpp	0.418 Vpp

3) (Validation) Build this circuit in lab to verify your simulations and calculations

4) Design a half-wave rectifier (i.e. specify R, L, C) to meet the following requirements:

Input: Wall transformer

- 20Vp, 60Hz, capable of 500mA

Output: A load which draws 100mA

Relationship:

- The ripple at V1 (across the capacitor) is 1Vpp when the load draws 100mA
- The ripple at V2 (across the load) is 0.1Vpp when the load draws 100mA

DC Voltage at V1

max(V1) = 19.3V

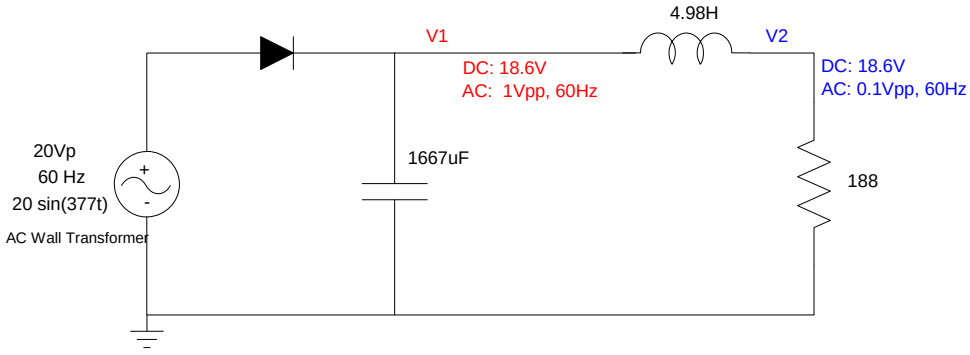
min(V1) = 18.3V (1Vpp)

avg(V1) = 18.8V

With an ideal inductor (RL = 0), this is also the DC voltage at V2

R (Load)

$$R = \frac{18.8V}{100mA} = 188\Omega$$



C:

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

$$100mA = C\frac{1V_{pp}}{1/60s}$$

$$C = 1,667\mu F$$

L:

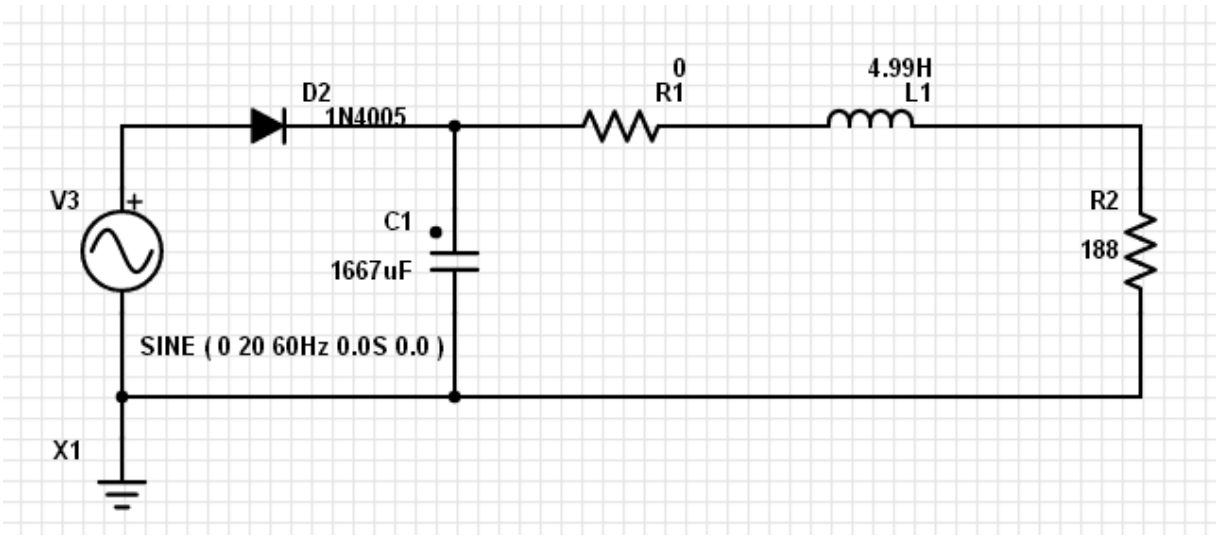
The ripple at V2 is 10x smaller than the ripple at V1

$$|j\omega L| \approx 10R$$

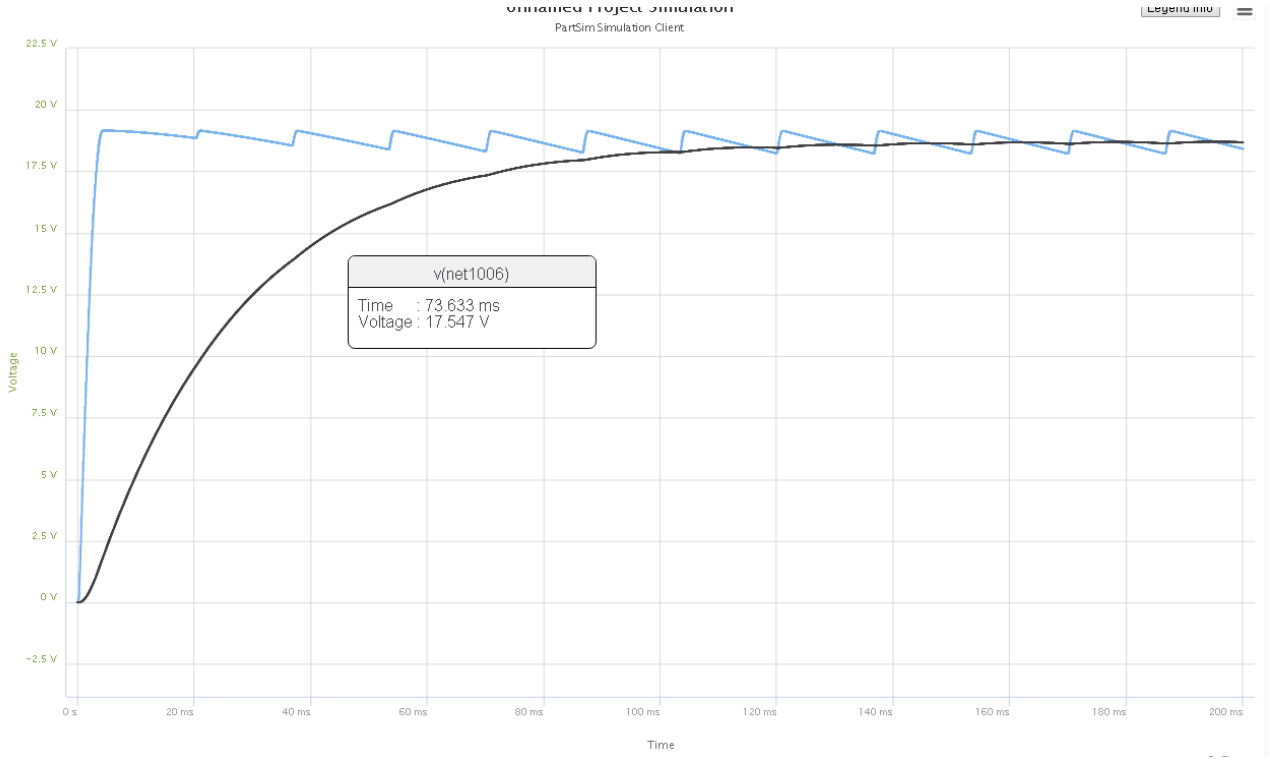
$$\omega L = 1880$$

$$L = \frac{1880}{377} = 4.98H$$

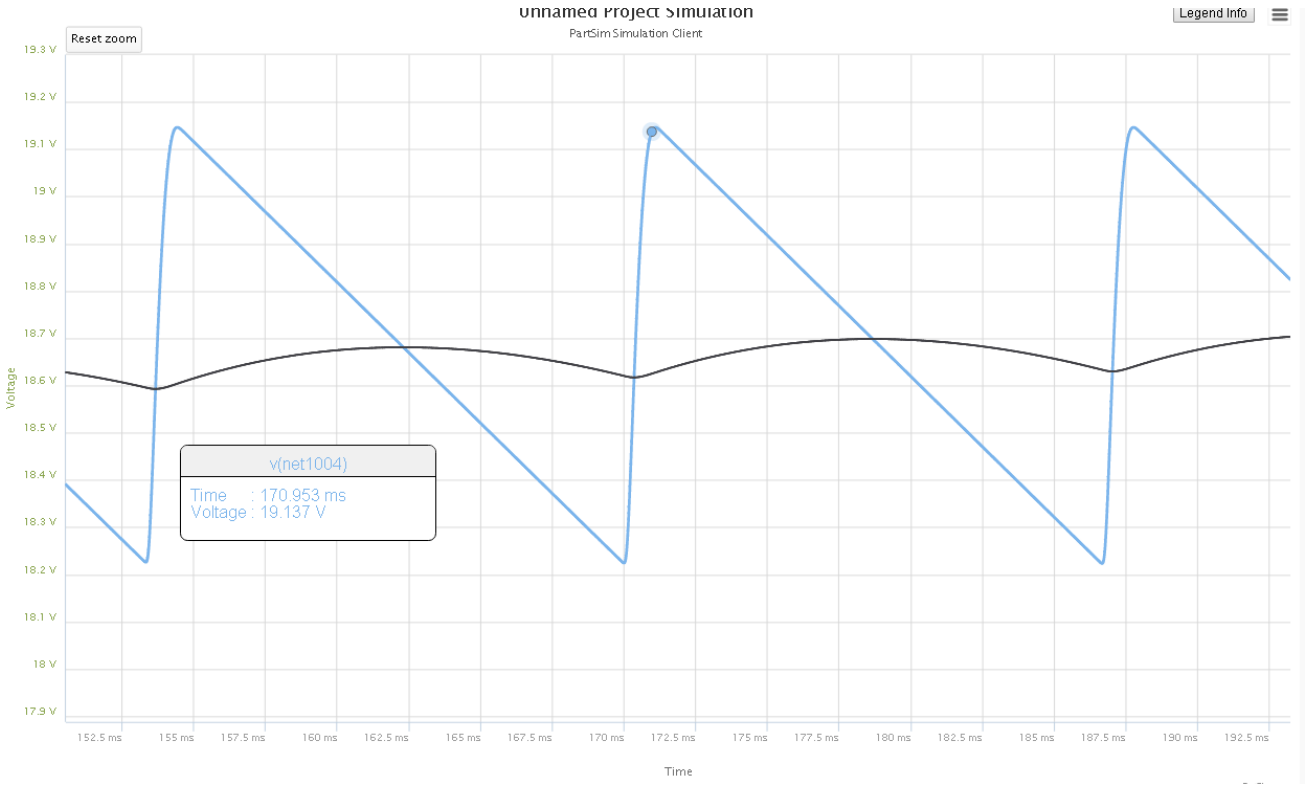
5) Check your design for problem #4 with a simulation using PartSim (or similar program)



Let the simulation run for 20 cycles to reach stedy-state



Zoom in on the last three cycles



	V1 (blue)		V2 (black)	
	Calculated	Simulated	Calculated	Simulated
DC (Vavg)	18.8	18.68	18.8V	18.65 V
AC (Vpp)	1.00 Vpp	0.914 Vpp	100 mVpp	64 mVpp

Min/Max Circuits

Assume ideal silicon diodes.

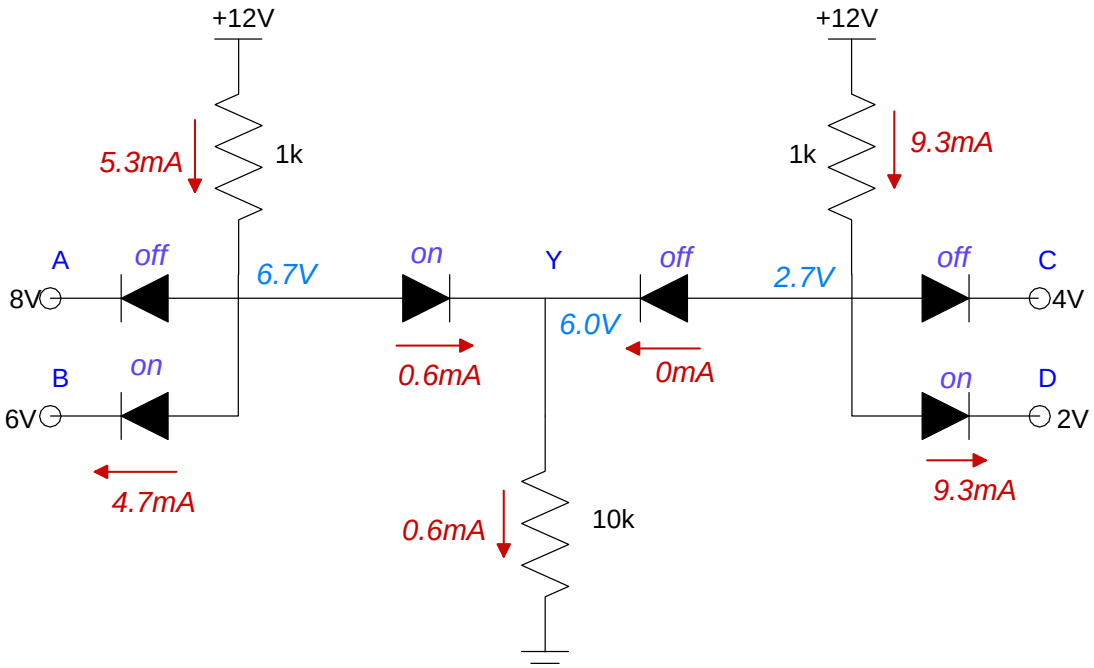
6) Determine the voltages for the following max/min circuit with R2 = 10k

7) What logic function does this circuit implement?

Y = f(A, B, C, D)

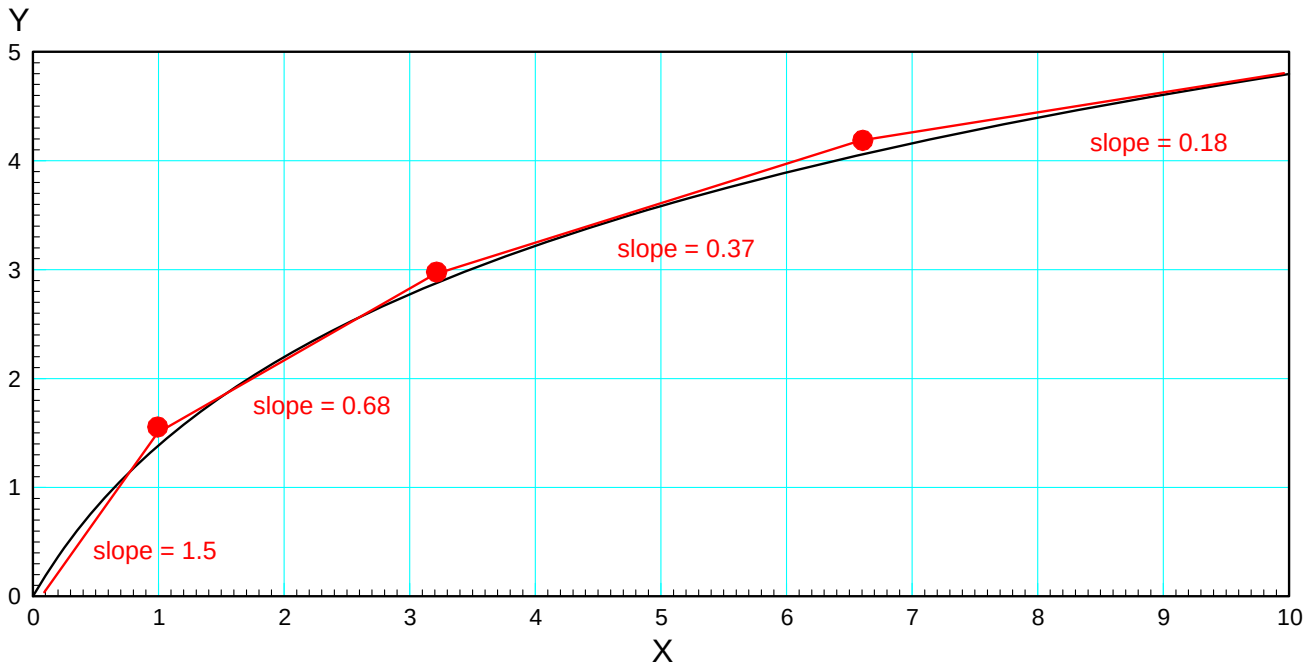
Y = max(min(A, B), min(C, D))

Y = AB + CD



Clipper Circuits

8) Design a clipper circuit which can drive a 100k Ohm load to approximate the following function



Region 1: Slope = 1.5

Add an amplifier with a gain of 1.5

Add a 1k resistor at the output so that you can drive a 1M load

Region 2: Slope = 0.68

$$\left(\frac{R_1}{R_1+1000}\right)\cdot 1.5 = 0.68$$

$$\left(\frac{R_1}{R_1+1000}\right) = 0.453$$

$$R_1 = \left(\frac{0.453}{1-0.453}\right)\cdot 1000 = 829\Omega$$

Turn on voltage is when Y = 1.5V

Vz1 = 1.5V

Region 3: Slope = 0.37

$$\left(\frac{R_{12}}{R_{12}+1000}\right)\cdot 1.5 = 0.37$$

$$\left(\frac{R_{12}}{R_{12}+1000}\right) = 0.246$$

$$R_{12} = \left(\frac{0.246}{1-0.246}\right)\cdot 1000 = 327\Omega$$

$$R_{12} = R_1 || R_2 = 327\Omega$$

$$R_2 = 541\Omega$$

Turn on voltage is when Y = 3.0V

Vz2 = 3.0V

Region 3: slope = 0.18

$$\left(\frac{R_{123}}{R_{123}+1000}\right) \cdot 1.5 = 0.18$$

$$\left(\frac{R_{123}}{R_{123}+1000}\right) = 0.12$$

$$R_{123} = \left(\frac{0.12}{1-0.12}\right) \cdot 1000 = 136\Omega$$

$$R_{123} = R_1 || R_2 || R_3$$

$$R_3 = 234\Omega$$

Turn on voltage for region 3 is when Y = 4.2V

Vz3 = 4.2V

Net Design: