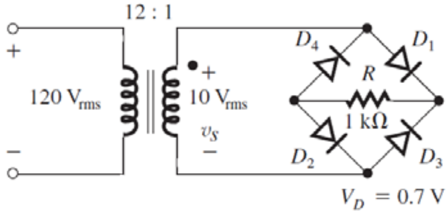
Homework 4 solution:

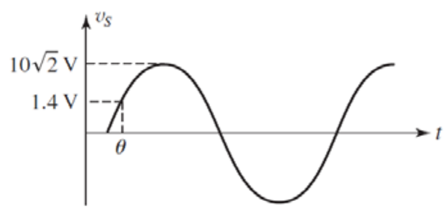
4.72



Peak voltage across $R = 10\sqrt{2} - 2V_D$

$= 10\sqrt{2} - 1.4$

$= 12.74$ V



$$\theta = \sin^{-1}\frac{1.4}{10\sqrt{2}} = 5.68^\circ = 0.1 \text{ rad}$$

Fraction of cycle that D_1 & D_2 conduct is

$$\frac{\pi - 2\theta}{2\pi} \times 100 = 46.8\%$$

Note that D_3 & D_4 conduct in the other half cycle so that there is 2 (46.8) = 93.6% conduction interval.

$$v_{O,\text{avg}} = \frac{2}{2\pi}\int_{\theta}^{\pi-\theta}\left(10\sqrt{2}\sin\phi - 2V_D\right)d\phi$$

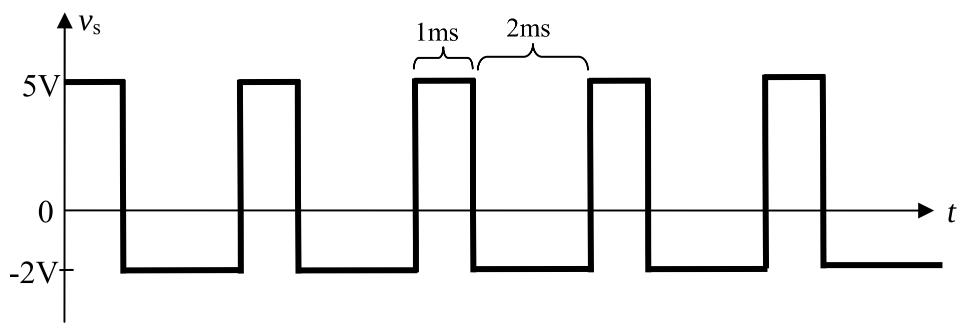
$$= \frac{1}{\pi}\Big[-12\sqrt{2}\cos\phi - 1.4\phi\Big]_{\theta}^{\pi-\theta}$$

$$= \frac{2(12\sqrt{2}\cos\theta)}{\pi} - \frac{1.4\,(\pi - 2\theta)}{\pi}$$

$$= 7.65 \text{ V}$$

$$i_{R,\text{avg}} = \frac{v_{O,\text{avg}}}{R} = \frac{7.65}{1} = 7.65 \text{ mA}$$

2. Consider half-wave, full-wave and bridge rectifier circuits shown in Figure 4.23(a), 4.24(a) and 4.25(a). If the input signal to the rectifier $v_s(t)$ is a rectangle pulse train with 1ms pulse width and 3ms repetition period as shown in the following figure.
Use diode CVD model (0.7V), please find the average output voltage $v_{0,\text{ave}}$ for each of these three rectifiers.



Solution:

For half-wave rectifier, the average output voltage is $v_{0,ave} = (5-0.7)\times\frac{1}{3} = 1.433V$

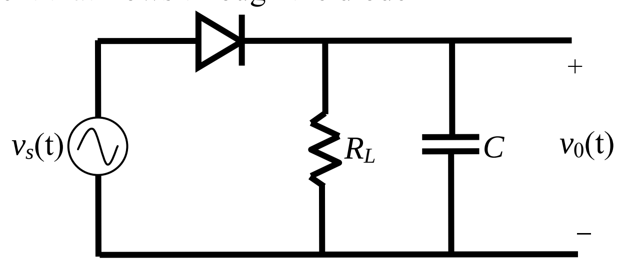
For full-wave rectifier, $v_{0,ave} = (5-0.7)\times\frac{1}{3} + (2-0.7)\times\frac{2}{3} = 2.3V$

For bridge rectifier, $v_{0,ave} = (5-1.4)\times\frac{1}{3} + (2-1.4)\times\frac{2}{3} = 1.6V$

3. A peak rectifier shown below is based on a half-wave rectifier circuit with a filter capacitor. The voltage source $v_s(t)$ is a 60Hz sinusoid with 10V *rms* voltage. The load resistance is $R_L = 1\text{k}\Omega$, and the capacitor is $C = 200\mu\text{F}$. Use diode CVD (0.7V) model please find,

(a) peak-to-peak voltage variation of the output $v_O(t)$

(b) maximum current that flows through the diode



Solution:

For the source of 10V *rms* voltage, the peak voltage is $V_s = 10\sqrt{2} = 14.14V$

Because of the 0.7V voltage drop when diode is forward biased, the peak voltage of the output $v_O(t)$ is $V_p = 14.14 - 0.7 = 13.44V$

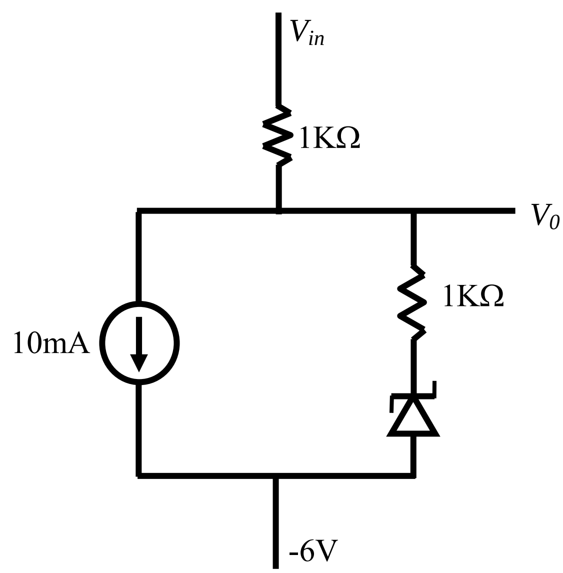
(a) peak-to-peak voltage variation of the output $v_O(t)$ is,

$$V_r = \frac{V_p}{fCR_L} = \frac{13.44}{60 \times 200 \times 10^{-6} \times 10^3} = 1.12V$$

(b) maximum current that flows through the diode is,

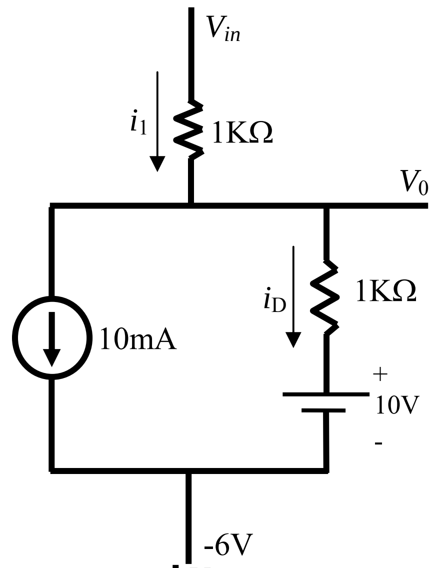
$$i_{\max} = I_L\left(1 + 2\pi\sqrt{\frac{2V_p}{V_r}}\right) = \frac{V_p}{R_L}\left(1 + 2\pi\sqrt{\frac{2V_p}{V_r}}\right) = \frac{13.44}{10^3}\left(1 + 2\pi\sqrt{\frac{2 \times 13.44}{1.12}}\right) = 0.414A$$

4, For the following circuit the breakdown voltage of the Zener diode is $V_{zk} = 10\text{V}$. Please determine the transfer function for the limiter shown below. In other words, determine V_O as a function of V_{in}.



Solution:

(1) If the Zener diode is in breakdown, the equivalent circuit is,



$V_{in} - i_1 \times 1k - i_D \times 1k - 10 = -6$, and $i_1 = 10 + i_D$

Combine them,

$V_{in} - (10 + i_D) \times 1k - i_D \times 1k - 10 = -6$

In order for the diode to be in breakdown $i_D > 0$ is required, that is,

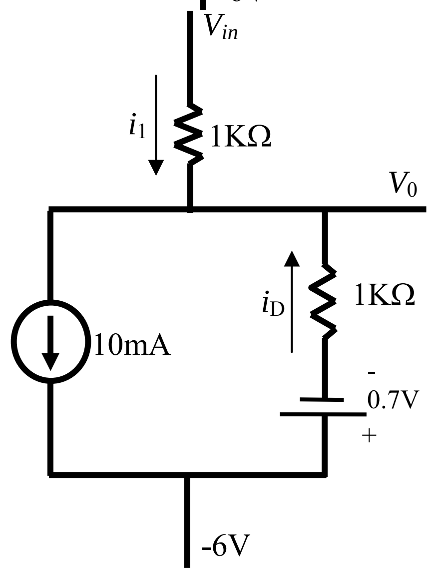
$V_{in} > 14\text{V}$

Under this condition, the output voltage can be found using,

$i_D = \dfrac{V_{in}}{2} - 7$, and $V_0 = -6 + 10 + i_D \times 1k$

That is, $V_0 = 4 + \dfrac{V_{in}}{2} - 7 = \dfrac{V_{in}}{2} - 3$

(2) Then, if the Zener diode is forward biased, the equivalent circuit is,



$V_{in} - i_1 \times 1k + i_D \times 1k + 0.7 = -6$,

and $i_1 = 10 - i_D$

Combine them,

$V_{in} - (10 - i_D) \times 1k + i_D \times 1k + 0.7 = -6$

In order for the diode to be in forward bias $i_D > 0$ is required, that is,

$V_{in} < 3.3\text{V}$

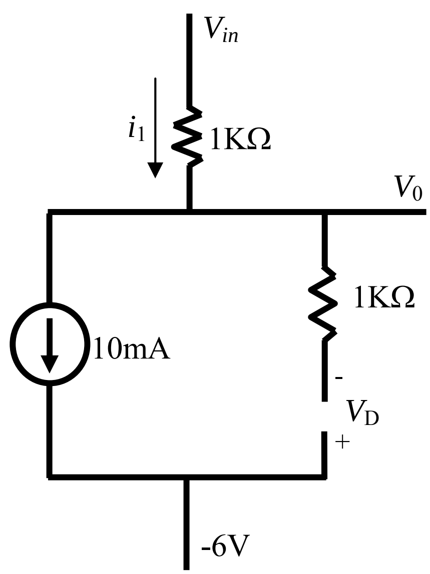
Under this condition, the output voltage can be found using,

$i_D = \dfrac{3.3 - V_{in}}{2}$, and $V_0 = -6 - 0.7 - i_D \times 1k$

That is,

$$V_0 = -6.7 - \frac{3.3 - V_{in}}{2} = \frac{V_{in}}{2} - 8.35$$

(3) Then, if the Zener diode is reverse biased, the equivalent circuit is,



$i_1 = 10mA$ and $V_0 = V_{in} - 10V$

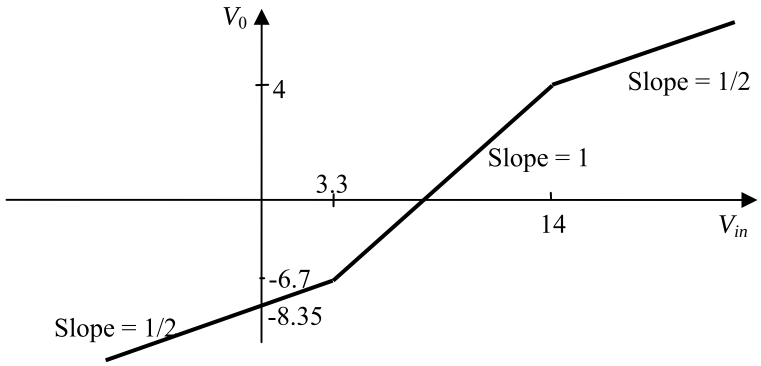
In order for the diode to be in reverse bias -10 < V_D < 0.7 is required, that is,

$-10 < -6 - (V_{in} - 10V) < 0.7$

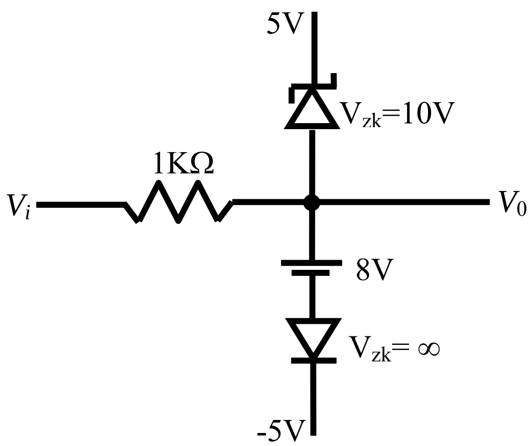
Or, $3.3 < V_{in} < 14$

So that the overall transfer function is,

$$V_0 = \begin{cases} \frac{V_{in}}{2} - 8.35V & for \quad V_{in} < 3.3V \\ V_{in} - 10V & for \quad 3.3V < V_{in} < 14V \\ \frac{V_{in}}{2} - 3V & for \quad V_{in} > 14V \end{cases}$$



5, The circuit shown below is a diode limiter. Determine and draw the transfer characteristics (V_0 versus V_i). Be sure and label all relevant values (slope, intercept points, maximum values, etc.).



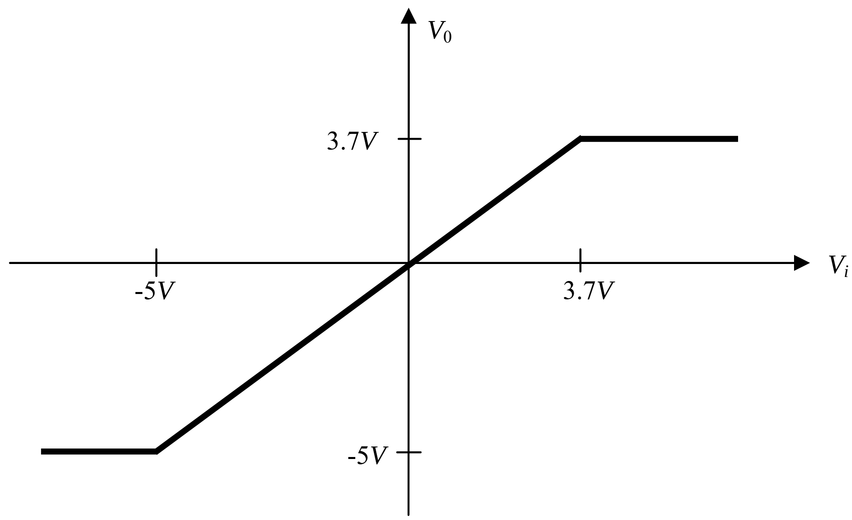
Solution:

(1) If zener diode is in breakdown (the regular diode is reverse biased), $V_0 = 5V - 10V = -5V$. This requires $V_i < -5V = V_0$

(2) If the regular diode is in forward bias (the zener diode is reverse biased), $V_0 = -5V + 0.7V + 8V = 3.7V$. This requires $V_i > 3.7V = V_0$

(3) If zener diode is in forward bias (the regular diode is reverse biased), $V_0 = 5V + 0.7V = 5.7V$. This requires $V_i > 5.7V$, which will never happen because the regular diode will be in forward biased condition. So the zener diode will never be in forward bias.

(4) If both diodes are reverse biased, $V_0 = V_i$. This requires $-5V < V_i < 3.7V$


V0
3.7V
-5V
Vi
-5V
3.7V