P1. Case I, assume $I_D = 0$, $\Rightarrow V_D \leq 0$

$$\begin{cases} V_{out} = (1 + \frac{20k}{2k}) \cdot V_{in} \\ V_D = V_{out} - V_{in} \end{cases} \Rightarrow \begin{matrix} V_{out} = 11 V_{in} \\ V_D = 10 V_{in} \end{matrix}$$

$$\because \left.\begin{matrix} V_D \leq 0 \\ V_D = 10 V_{in} \end{matrix}\right\} \Rightarrow V_{in} \leq 0$$

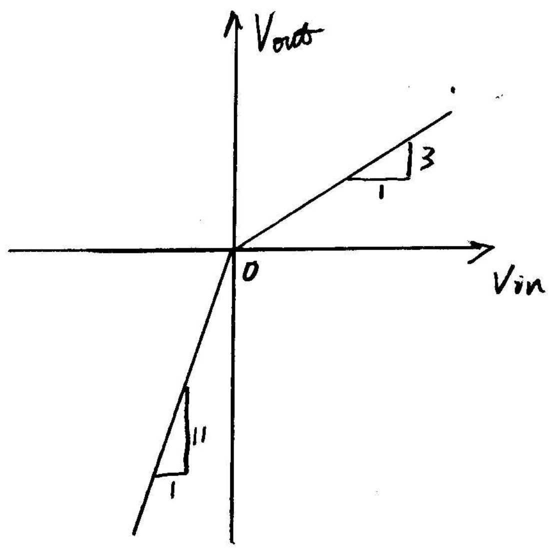
$\therefore$ when $V_{in} \leq 0$ $\quad \frac{V_{out}}{V_{in}} = 11$

Case II. assume $V_D = 0 \Rightarrow I_D > 0$

$$\begin{cases} V_{out} = (1 + \frac{20k /\!/ 5k}{2k}) \cdot V_{in} \\ I_D = \frac{V_{out} - V_{in}}{5k} \end{cases} \Rightarrow V_{out} = 3V_{in}$$

$$I_D = \frac{V_{out} - V_{in}}{5k} > 0 \Rightarrow \frac{2V_{in}}{5k} > 0 \Rightarrow V_{in} > 0$$

$\therefore$ when $V_{in} > 0$ $\quad \frac{V_{out}}{V_{in}} = 3$



P2. Case I, assume $I_D = 0 \Rightarrow V_D \leq 0$

$$\begin{cases} V_{out} = (1 + \frac{20k}{2k}) \cdot V_{in} \\ V_D = V_{in} - V_{out} \end{cases} \Rightarrow \begin{matrix} V_{out} = 11 V_{in} \\ V_D = -10 V_{in} \end{matrix}$$

$$\because \left.\begin{matrix} V_D = -10 V_{in} \\ V_D \leq 0 \end{matrix}\right\} \Rightarrow V_{in} \geq 0$$

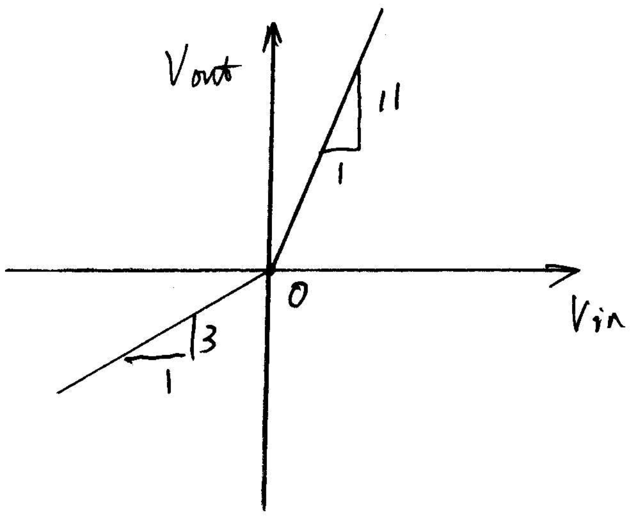
$\therefore$ when $V_{in} \geq 0$, $\frac{V_{out}}{V_{in}} = 11$

Case II, assume $V_D = 0 \Rightarrow I_D > 0$

$$\begin{cases} V_{out} = (1 + \frac{20k // 5k}{2k}) \cdot V_{in} \\ I_D = \frac{V_{in} - V_{out}}{5k} \end{cases} \Rightarrow V_{out} = 3 V_{in}$$

$$I_D = -\frac{2 V_{in}}{5k} > 0 \Rightarrow V_{in} < 0$$

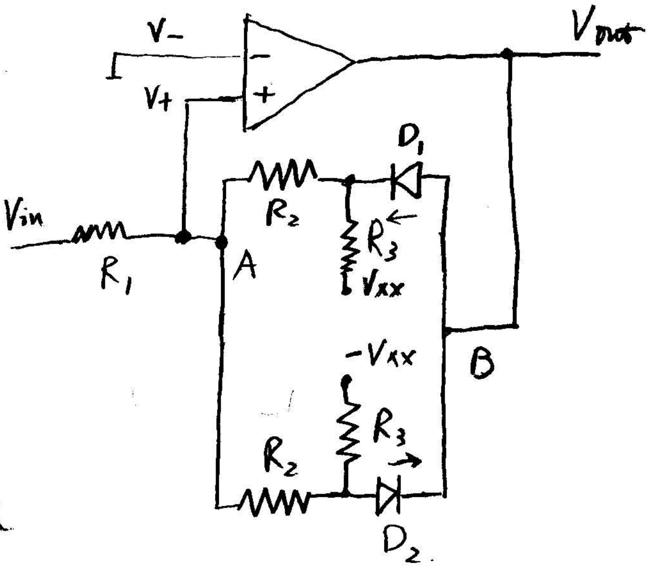
$\therefore$ when $V_{in} < 0$, $\frac{V_{out}}{V_{in}} = 3$



P3. **Case I**

assume D_1 On D_2 Off

$\therefore I_{D_1} \geq 0 \quad V_{D_1} = 0 \qquad I_{D_2} = 0 \quad V_{D_2} \leq 0$



Hence $V_{out} = V_{sath}$, $V_+ > 0$

$$\frac{V_{in} - V_+}{R_1} + \frac{V_{out} - V_+}{R_2} = \frac{V_+ + V_{xx}}{R_2 + R_3}$$

---- KCL at point A.

$$\Rightarrow \frac{V_{in}}{R_1} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2+R_3}\right)V_+ + \frac{V_{xx}}{R_2+R_3} - \frac{V_{sath}}{R_2}$$

$$\xRightarrow{V_+ > 0} \quad V_{in} > \left(\frac{V_{xx}}{R_2+R_3} - \frac{V_{sath}}{R_2}\right) R_1$$

Case II

assume D_1 off D_2 On $\quad \therefore I_{D_1} = 0 \quad V_{D_1} \leq 0, \quad I_{D_2} \geq 0 \quad V_{D_2} = 0$

Hence $V_{out} = -V_{sath}$, $V_+ < 0$

$$\frac{V_{in} - V_+}{R_1} + \frac{V_{xx} - V_+}{R_2+R_3} = \frac{V_+ - V_{out}}{R_2} \quad \text{... KCL at A}$$

$$\Rightarrow \frac{V_{in}}{R_1} = \left(\frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_2+R_3}\right)V_+ + \frac{V_{sath}}{R_2} - \frac{V_{xx}}{R_2+R_3}$$

$$\xRightarrow{V_+ < 0} \quad V_{in} < -\left(\frac{V_{xx}}{R_2+R_3} - \frac{V_{sath}}{R_2}\right) \cdot R_1$$

Case III assume both D_1 and D_2 are On

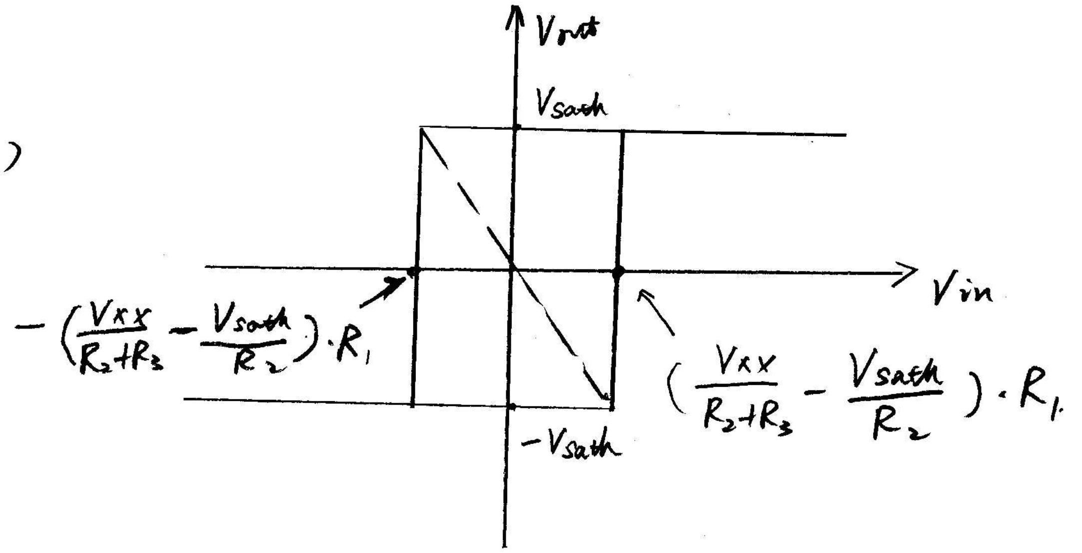
$$\frac{V_{in}-V_+}{R_1}+\frac{V_{out}-V_+}{R_2}+\frac{V_{out}-V_+}{R_2}=0$$

$$\Rightarrow V_{out}=-\frac{R_2}{2}\left(\frac{V_{in}}{R_1}+\left(\frac{1}{R_1}+\frac{2}{R_2}\right)V_+\right)$$

from case I and II, in Case III

$$-\left(\frac{V_{xx}}{R_2+R_3}-\frac{V_{sath}}{R_2}\right)R_1 < V_{in} < \left(\frac{V_{xx}}{R_2+R_3}-\frac{V_{sath}}{R_2}\right)R_1$$

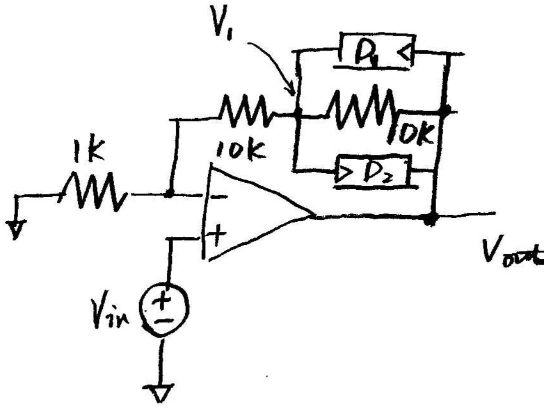
Hence (a)



(b) $\text{Width}=\left(\frac{V_{xx}}{R_2+R_3}-\frac{V_{sath}}{R_2}\right)\cdot 2R_1$

Center $=0$

P4 **Case I** assume D1 & D2 both off



$-0.6 < V_1 - V_{out} < 0.6$ must holds

$\because V_1 = \frac{1}{2}(V_{out} + V_{in})$

$\Rightarrow -0.6 < \frac{V_{in}}{2} - \frac{V_{out}}{2} < 0.6$

$\because D_1$ & D_2 are off

$V_{out} = V_{in}\left(1 + \frac{20k}{1k}\right) = 21 V_{in}$

$\Rightarrow$ when $|V_{in}| < 0.06V$, $V_{out} = 21 V_{in}$

Case II

D_1 is On, D_2 is off

$V_{out} - V_1 = 0.6$ and $V_{out\,max} = 15V$

$\therefore \frac{V_{out} - 0.6}{10K} = V_{in}\left(\frac{1}{10k} + \frac{1}{1k}\right)$

$\Rightarrow V_{out} = 11 V_{in} + 0.6$ if $V_{out} \leq 15V$ and $V_{out} - V_1 \geq 0.6$

$$\Rightarrow V_{out} = \begin{cases} 11 V_{in} + 0.6 & 0.06 < V_{in} \leq 1.309 \\ 15 & V_{in} \geq 1.309 \end{cases}$$

Case III

D_1 is off, D_2 is on.

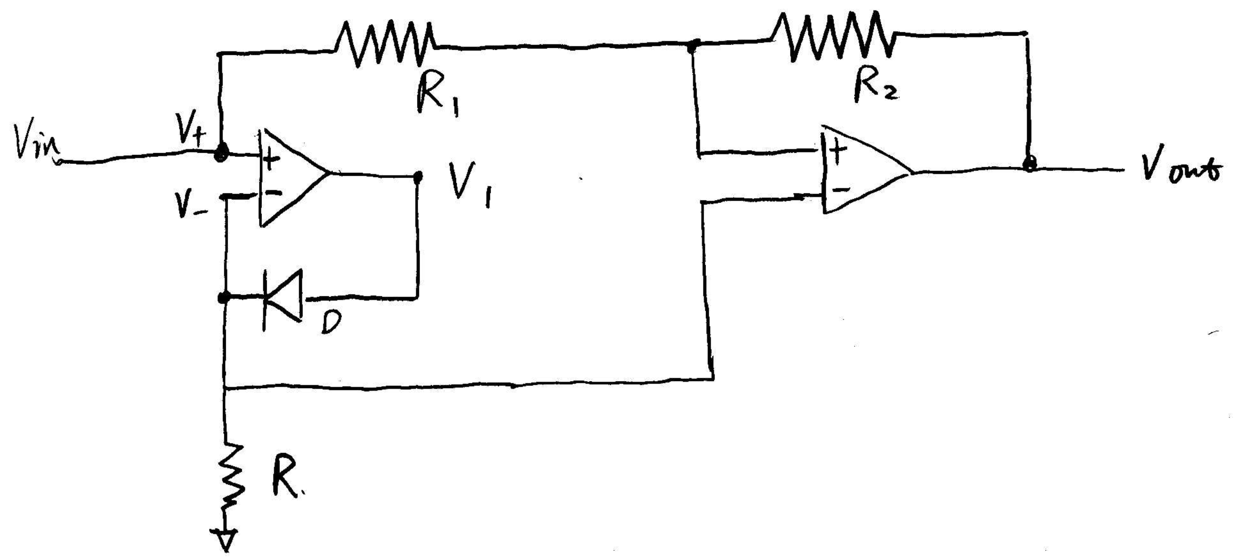
$V_1 - V_{out} = 0.6$ and $V_{out\,min} = -15V$

$\frac{V_{out} + 0.6}{10K} = V_{in}\left(\frac{1}{10K} + \frac{1}{1k}\right)$

$\Rightarrow V_{out} = 11 V_{in} - 0.6$ if $V_{out} > -15V$ and $V_1 - V_{out} \geq 0.6$

$$\Rightarrow V_{out} = \begin{cases} 11 V_{in} - 0.6 & -1.309 \leq V_{in} < -0.06 \\ -15 & V_{in} \leq -1.309 \end{cases}$$

P5



Case I, assume diode is on., $I_D > 0$

$V_1 - V_- = V_1 - V_{in} = V_{on} = 0.6\,V$

$\Rightarrow \quad V_1 = V_{in} + 0.6$

$\because \; V_{1\,max} = 15\ V$ when $V_{in} \geq 0$

$\therefore \begin{cases} V_1 = V_{in} + 0.6 & \text{if } 0 \leq V_{in} \leq 14.4V \\ V_1 = +15 & \text{if } V_{in} \geq 14.4V \end{cases}$

Case II assume diode is off

then $V_- = 0$, because no current go through R.

We need $V_1 - V_- < 0.6$ as diode is off

which holds when $V_{in} < 0$ and $V_1 = -15$

$\therefore \; V_1 = -15$ if $V_{in} < 0$

$V_{out} = V_- (1 + \frac{R_2}{R_1}) - V_{in} (\frac{R_2}{R_1})$ when $V_{in} > 0$ $V_- = V_{in}$

$\Rightarrow V_{out} = V_{in}$

when $V_{in} < 0$ $V_- = 0$

$\Rightarrow V_{out} = -3\,V_{in}$

$$\therefore \quad V_{out} = \begin{cases} 2 \sin 1000t & 0 < V_{in} < 14.4 \\ -6 \sin 1000t & V_{in} < 0 \end{cases}$$

P 6 **when diode is ideal**

Case I. diode is On.

$$\frac{V_{out}}{V_{in}} = \frac{1}{2} \qquad V_{in} \geq 0$$

Case II diode is off

$$V_{out} = 0, \qquad V_{in} < 0$$

when diode is not ideal

Case I diode is on.

$$\frac{V_{out}}{1K} = \frac{V_{in} - (V_{out} + 0.6)}{1K} \Rightarrow V_{out} = \frac{V_{in} - 0.6}{2}$$

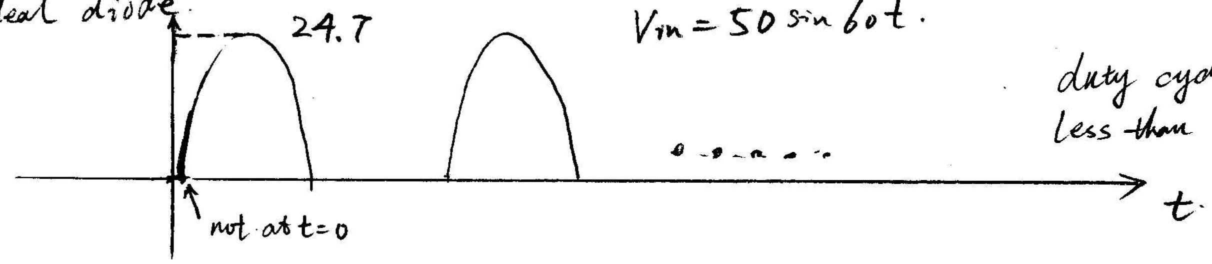
and $I_d > 0$ if $\frac{V_{in} - (V_{out} + 0.6)}{1K} > 0 \Rightarrow V_{in} > 0.6\ V$

Case II diode is off

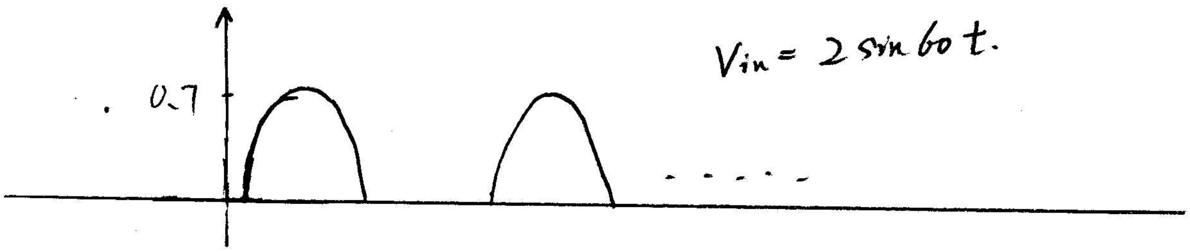
$V_{out} = 0$ and $V_{in} - V_{out} \leq 0.6V \Rightarrow V_{in} \leq 0.6V$

The plot when diode is ideal is omitted

Non ideal diode

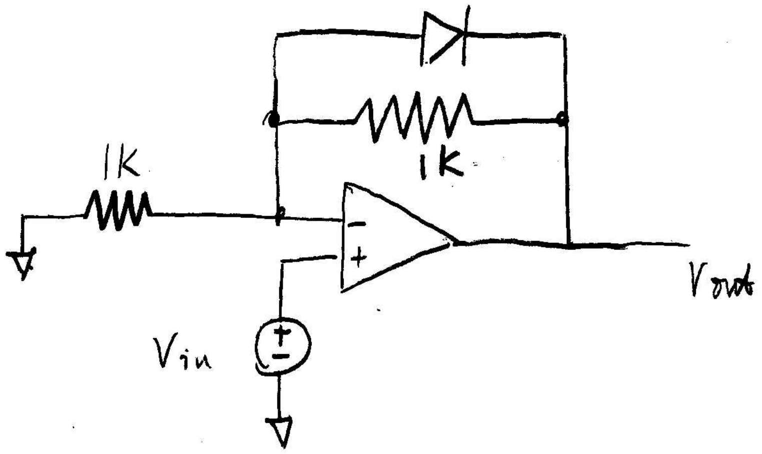


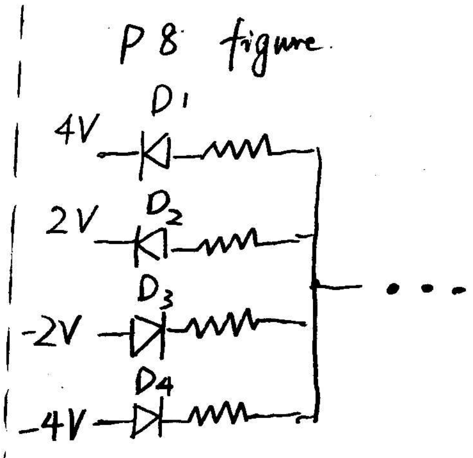
duty cycle is less than 50% but close to



$V_{out} = 0$ if $V_{in} = 0.5 \sin 60t$.

P7





P8 case 1. when $\frac{1}{5}V_{in} \geq 4V$ D_1 D_2 on, D_3 D_4 off

$$V_{out} = \frac{1}{5}V_{in}\left(1+\frac{10k}{10k//10k}\right) - 4\cdot\frac{10k}{10k} - 2\frac{10k}{10k}$$

$$= \frac{3}{5}V_{in} - 6$$

case 2, when $2V \leq \frac{1}{5}V_{in} < 4V$ D_2 on, D_1 D_3 D_4 off

$$V_{out} = \frac{1}{5}V_{in}\left(1+\frac{10k}{10k}\right) - 2\frac{10k}{10k}$$

$$= \frac{2}{5}V_{in} - 2$$

case 3 when $-2V \leq \frac{1}{5}V_{in} < 2V$ all diodes are off

$$V_{out} = \frac{1}{5}V_{in}$$

case 4 when $-4V \leq \frac{1}{5}V_{in} < -2V$ D_1 D_2 D_4 off D_3 on.

$$V_{out} = \frac{1}{5}V_{in}\left(1+\frac{10K}{5k}\right) - (-2)\cdot\frac{10k}{5k}$$

$$= \frac{3}{5}V_{in} + 4$$

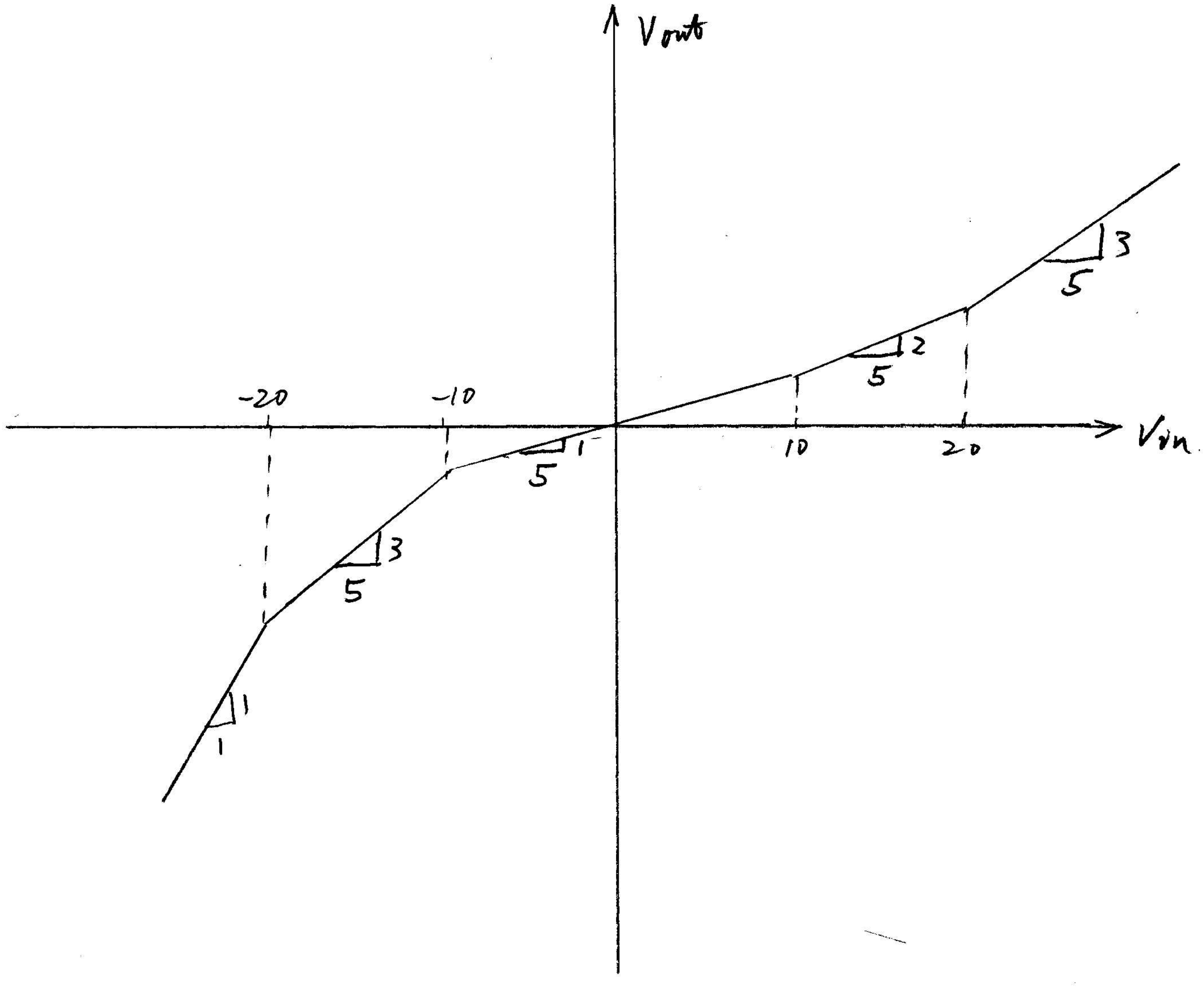
case 5 when $\frac{1}{5}V_{in} < -4$ D_1 D_2 off, D_3 D_4 on.

$$V_{out} = \frac{1}{5} V_{in}\left(1 + \frac{10k}{5k /\!/ 5k}\right) - (-4)\frac{10k}{5k} - (-2)\frac{10k}{5k}$$

$$= V_{in} + 12$$

Hence

$$V_{out} = \begin{cases} \frac{3}{5} V_{in} - 6 & V_{in} \geq 20V \\ \frac{2}{5} V_{in} - 2 & 10V \leq V_{in} < 20V \\ \frac{1}{5} V_{in} & -10V \leq V_{in} < 10V \\ \frac{3}{5} V_{in} + 4 & -20V \leq V_{in} < -10V \\ V_{in} + 12 & V_{in} < -20V \end{cases}$$



P9. Case I assume both diodes are on

$V_{out} = 2V$, $\frac{V_{in} - V_{out}}{4K} - \frac{V_{out}}{1K} = I_{d_2} > 0$

$\Rightarrow V_{in} > 10V$

case II assme D_1 on D_2 off

$V_{out} < 2V$ $\frac{V_{in} - V_{out}}{4k} = \frac{V_{out}}{1K} \Rightarrow V_{out} = \frac{1}{5} V_{in}$

$I_{D_1} > 0 \Rightarrow V_{in} - V_{out} > 0 \Rightarrow V_{in} > 0$

$\therefore$ $V_{out} = \frac{1}{5} V_{in}$ if $0 < V_{in} < 10V$

Case III both off

$V_{out} = 0$, valid when $V_{in} < 0$

(a) When $V_{in} = 5V$ $V_{out} = 1V$

(b) $$V_{out} = \begin{cases} 0 & V_{in} < 0V \\ \frac{1}{5} V_{in} & 0V < V_{in} < 10V \\ 2 & V_{in} > 10V \end{cases}$$

P10 case I assme both are on.

$V_{out} = 2.6V \qquad \frac{V_{in} - 2.6}{4K} - \frac{2.6}{1K} = I_{d_2} > 0 \Rightarrow V_{in} > 13.6V$

Case II assume D_1 on D_2 off

$V_{out} < 2.6V \qquad \frac{V_{in} - V_{out} - 0.6}{4k} = \frac{V_{out}}{1k} \Rightarrow V_{out} = \frac{1}{5}(V_{in} - 0.6)$

$I_{D_1} > 0 \Rightarrow V_{in} - 0.6 - V_{out} > 0 \Rightarrow V_{in} > 0.6$

so $V_{out} = \frac{1}{5}(V_{in} - 0.6)$ if $0.6 < V_{in} < 13.6$

Case III assume both off

$V_{out} = 0$, valid when $V_{in} - 0.6 < 0$

(a) when $V_{in} = 5V \quad V_{out} = 0.88V$

(b) $V_{out} = \begin{cases} 0 & V_{in} < 0.6V \\ \frac{1}{5}(V_{in} - 0.6) & 0.6V < V_{in} < 13.6V \\ 2.6V & V_{in} > 13.6V \end{cases}$