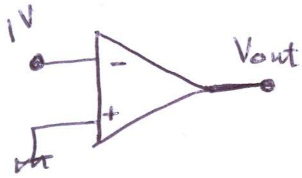
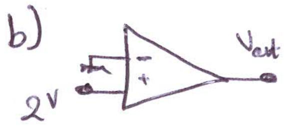
2

a)



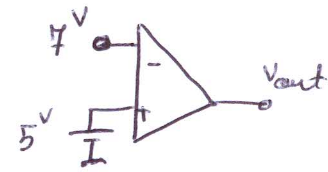
V_{out} = Maximum negative as $V^- > V^+$

b)



V_{out} = Maximum Positive as $V^+ > V^-$

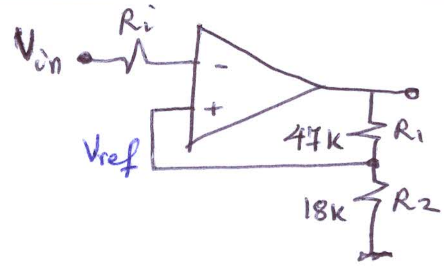
c)



V_{out} = Maximum negative as $V^- > V^+$

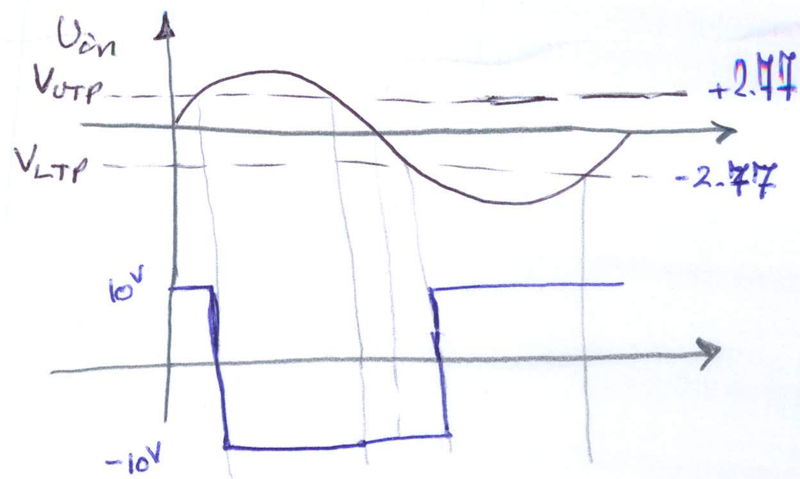
3

$V_{out(max)} = \pm 10^V$



$$V_{UTP} = \frac{R_2}{R_1+R_2} V_{out(max)} = \frac{18}{18+47} * 10 = 2.769 \text{ V}$$

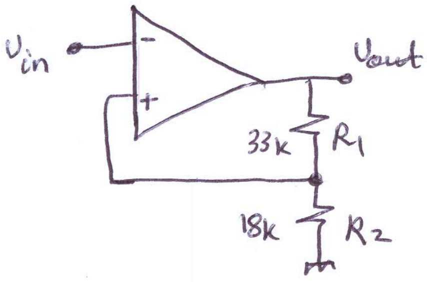
$$V_{LTP} = \frac{R_2}{R_1+R_2}\left(-V_{out(max)}\right) = \frac{18}{47+18} * (-10) = -2.769 \text{ V}$$



maximum output = ±11 V

6

a)



$$V_{HYS} = V_{UTP} - V_{LTP}$$

$$\because V_{UTP} = \frac{R_2}{R_1+R_2}(V_{out(max)})$$

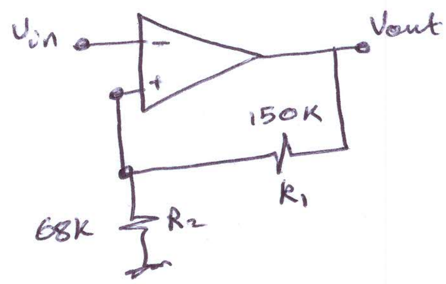
$$= \frac{18}{33+18}(11) = 3.88\text{ V}$$

$$V_{LTP} = \frac{R_2}{R_1+R_2}(-V_{out(max)})$$

$$= -3.88\text{ V}$$

$$\therefore V_{HYS} = 3.88-(-3.88)$$

$$\therefore \boxed{V_{HYS} = 7.76\text{ V}}$$



$$V_{UTP} = \frac{R_2}{R_1+R_2}(V_{out(max)})$$

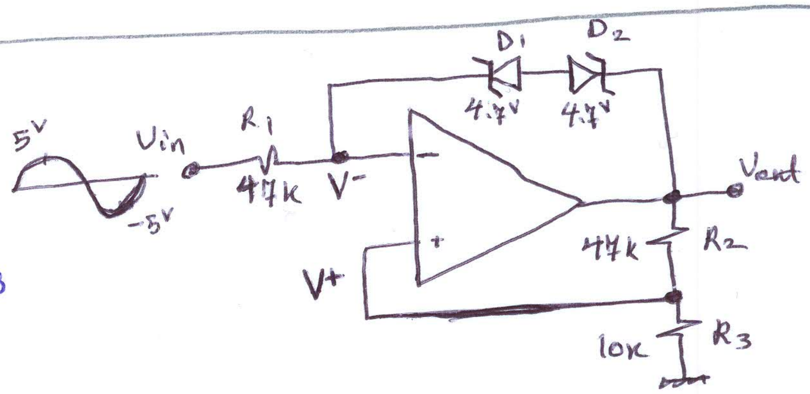
$$= \frac{68}{150+68}(11)$$

$$= 3.43\text{ V}$$

$$V_{LTP} = -3.43\text{ V}$$

$$\therefore \boxed{V_{HYS} = 3.43-(-3.43) = 6.86}$$

8



$$\because V^- = \begin{cases} -0.7-4.7+V_{out}, & D_1 \text{ is FB } \& \ D_2 \text{ is RB} \\ 4.7+0.7+V_{out}, & D_1 \text{ is RB } \& \ D_2 \text{ is FB} \end{cases}$$

$\therefore$ at any time :

$$V^- = V_{out} \pm 5.4$$

$$\because V^+ \simeq V^- = V_{out} \pm 5.4 \rightarrow ①$$

$$\because V^+ = \frac{R_3}{R_2+R_3} V_{out} = \frac{10}{47+10} V_{out} = 0.175 V_{out} \rightarrow ②$$

from ① & ②

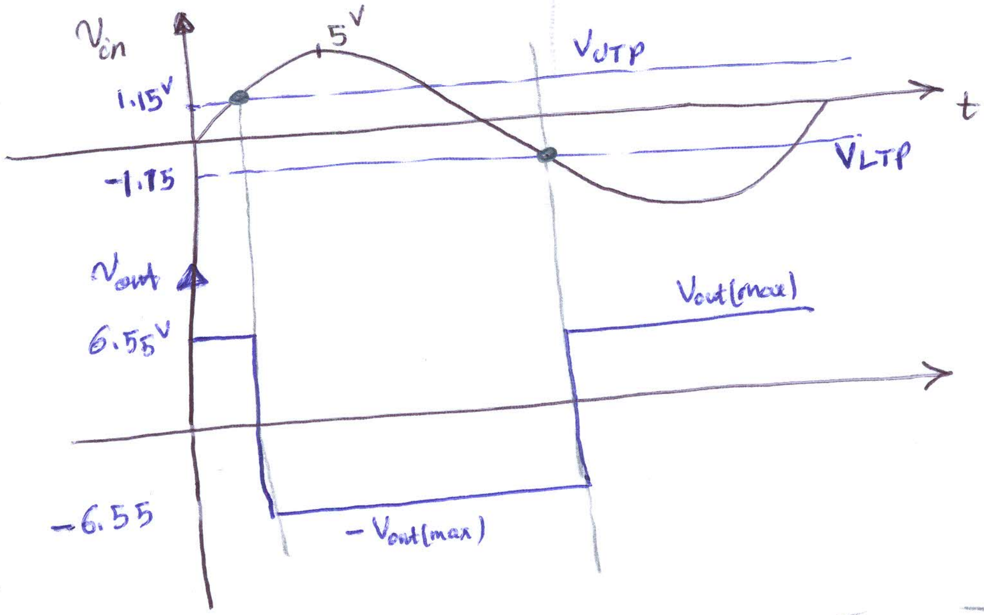
$$\therefore 0.175\, V_{out} = V_{out} \pm 5.4$$

$$\therefore V_{out} = \frac{\pm 5.4}{0.175-1} = \mp 6.55 \qquad \therefore V_{out(max)} = \underline{\underline{6.55}} \ \& \ -(V_{out(max)}) = \underline{\underline{-6.55}}$$

$$\because V_{UTP} = \frac{R_3}{R_2+R_3} V_{out(max)} = 0.175 * 6.55 = \underline{\underline{1.15^V}}$$

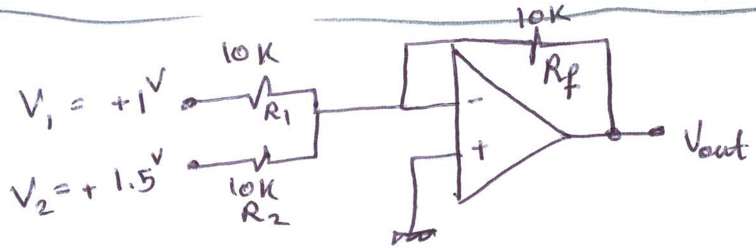
$$V_{LTP} = \frac{R_3}{R_2+R_3}(-V_{out(max)}) = 0.175*(-6.55) = \underline{\underline{-1.15^V}}$$

The output voltage waveform is shown below:



9

a)

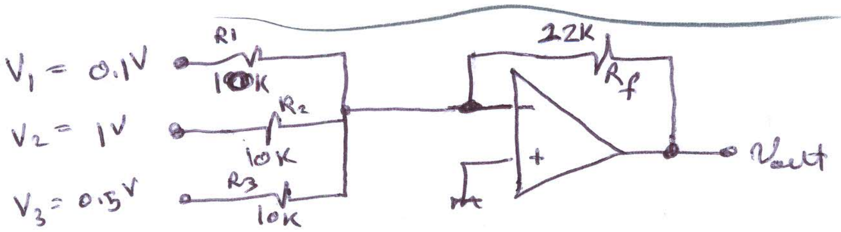


$$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right) \quad ; \quad R_1 = R_2 = R_f = 10\,K\Omega$$

$$\therefore V_{out} = -(V_1 + V_2) = -(1 + 1.5) = -2.5\,V$$

$$\therefore \boxed{V_{out} = -2.5\,V}$$

b)



$R_f = 22\,K\Omega$

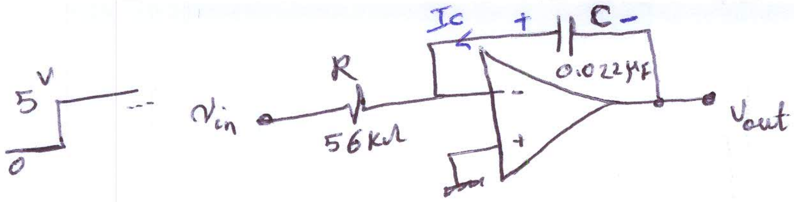
$R_1 = R_2 = R_3 = 10\,K\Omega$

$$V_{out} = -(22K)\left[\frac{0.1}{10K} + \frac{1}{10K} + \frac{0.5}{10K}\right] = -\frac{22}{10}(0.1 + 1 + 0.5)$$

$$= -2.2 * 1.6 = -3.52\,V$$

$$\therefore \boxed{V_{out} = -3.52\,V}$$

15



rate of change of the output $\left(\frac{\Delta V_{out}}{\Delta V_{in}}\right) = -\frac{I_c}{C} = \frac{-V_i}{RC}$

$$\therefore \frac{\Delta V_{out}}{\Delta V_{in}} = -\frac{5}{(56*10^3)*(0.022*10^{-6})} = -4058.44 \text{ V/s}$$

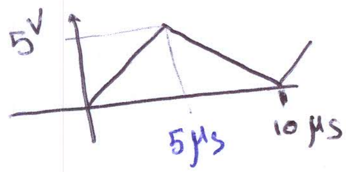
$$= -4058.44 * \frac{10^{+3}}{10^{6}}$$

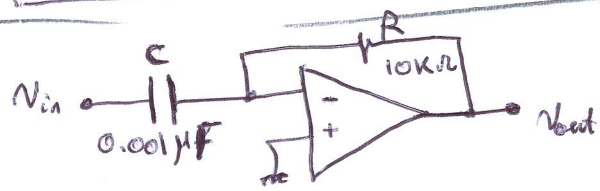
for mV

for μs

$$\therefore \boxed{\frac{\Delta V_{out}}{\Delta V_{in}} = 4.06 \text{ mV/}\mu\text{s}}$$

16





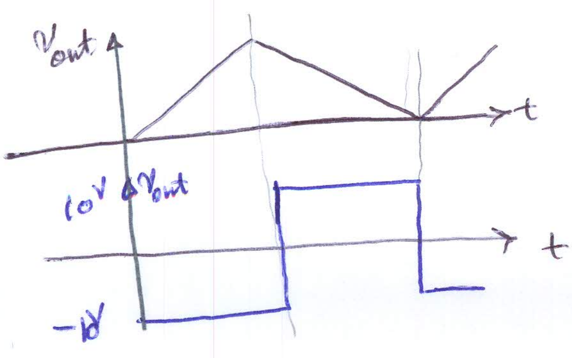
⇐ Differentiator

As the output is Propotional to derivative of Vin, then Vout should be a square wave.

$$\therefore V_{out} = -\left(\frac{\Delta V_{in}}{\Delta t}\right) RC$$

$$\therefore V_{out} = \begin{cases} -\left(\frac{5-0}{5\mu-0}\right) * 10K * 0.001\mu, & 0 < t \leq 5\mu s \\ -\left(\frac{0-5}{10-5\mu}\right) * 10K * 0.001\mu, & 5\mu s < t < 10\mu s \end{cases}$$

$$= \begin{cases} -10 \text{ V}, & 0 < t \leq 5\mu s \\ +10 \text{ V}, & 5\mu s < t < 10\mu s \end{cases}$$



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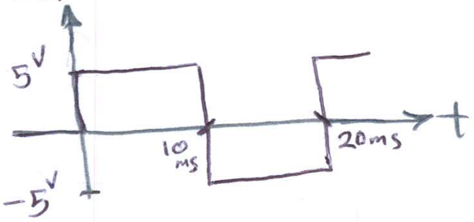

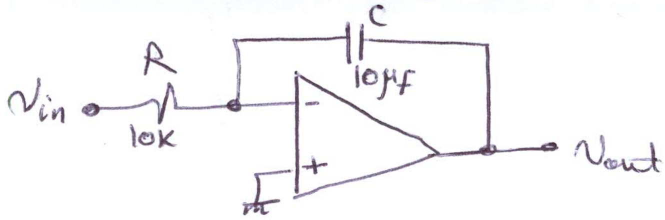

$$\because \quad \frac{\Delta V_{out}}{\Delta t} = -\frac{V_{in}}{RC}$$

$$= \begin{cases} -\dfrac{(5)}{10*10^{3}*10*10^{-6}} , & 0 < t \leq 10\,ms \\ -\dfrac{(-5)}{10*10^{3}*10*10^{-6}} , & 10ms < t \leq 20\,ms \end{cases}$$

$$= \begin{cases} -50 \ V/s , & 0 < t \leq 10\,ms \\ +50 \ V/s , & 10ms < t \leq 10\,ms \end{cases}$$

$$= \begin{cases} -50 * \dfrac{1}{10^3} \ V/ms , & 0 < t \leq 10ms \\ +50 * \dfrac{1}{10^3} \ V/ms , & 10ms < t \leq 20\,ms \end{cases}$$

$$= \begin{cases} -0.05 \ V/ms , & 0 < t \leq 10ms \\ +0.05 \ V/ms , & 10ms < t \leq 20ms \end{cases}$$

at $t = 10ms$: $V_{out} = 0 - 0.05 * 10 = -0.5\,V$

at $t = 20ms$: $V_{out} = -0.5 + 0.05 * (20-10) = 0\,V$