Assignment

Question 1

Design a smoke detection and alarm system using a Schmitt trigger circuit. The input transducer measures smoke opacity and outputs a corresponding voltage. 0% opacity signifies no smoke and 100% opacity signifies complete smoke pervasion. The transducer converts this opacity to a range of 0 to 10V (The conversion constant is **0.1V per 1% opacity**). Design the system such that it blares an alarm when smoke opacity **surpasses 95%** and quiets down **below 5%**. You must satisfy all the mentioned criteria, and assume any component values accordingly.

(a)	**Draw** the **complete circuit** of the smoke detection and alarm system
(b)	**Determine** all the **component values** (resistors, reference voltage)
(c)	**Draw** the voltage transfer characteristics curve (**V_{in} vs V_{out} plot**). Clearly **label** the plot.

<u>Hint</u>: This is a design problem. Draw a schmitt trigger circuit with applied reference voltage, list all the related equations, then according to the given information, determine which variables are known and from there solve for the unknown component values. It might seem that there are not enough equations to solve for every unknown variable, in that case, assume the values of one or more components but make sure that all the mentioned criterias are satisfied. For instance, it is common in design problems to assume the value of one resistor then mathematically solve for the others.

Question 2

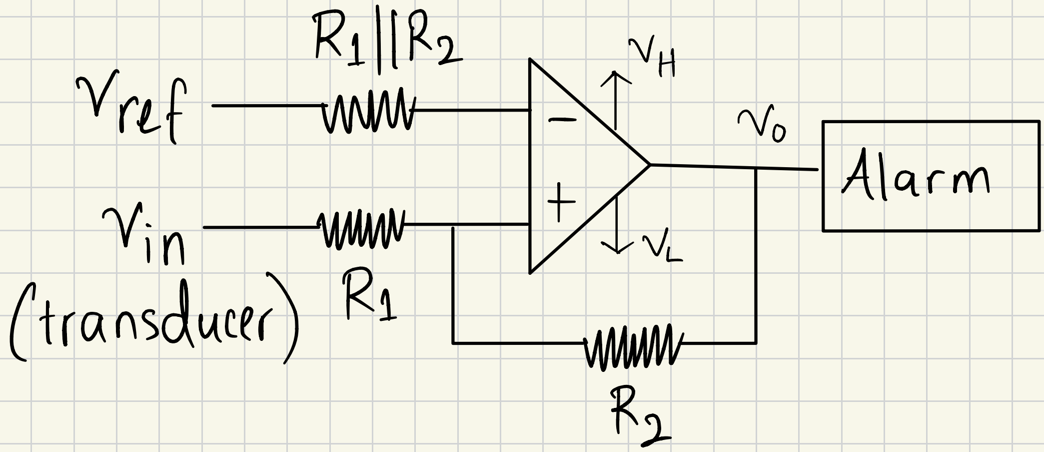
You have a light source that is too bright, so you want to illuminate it at 50% of its total illumination capacity. **Design** a square wave generator that accomplishes this by using **only 12V and 0V voltage sources**. Additionally, you must be careful such that any light flickering is **unnoticeable to the human eye** (Hint: Human eyes can notice flickering up to 500 Hz). You must satisfy all the mentioned criteria, and assume any component values accordingly.

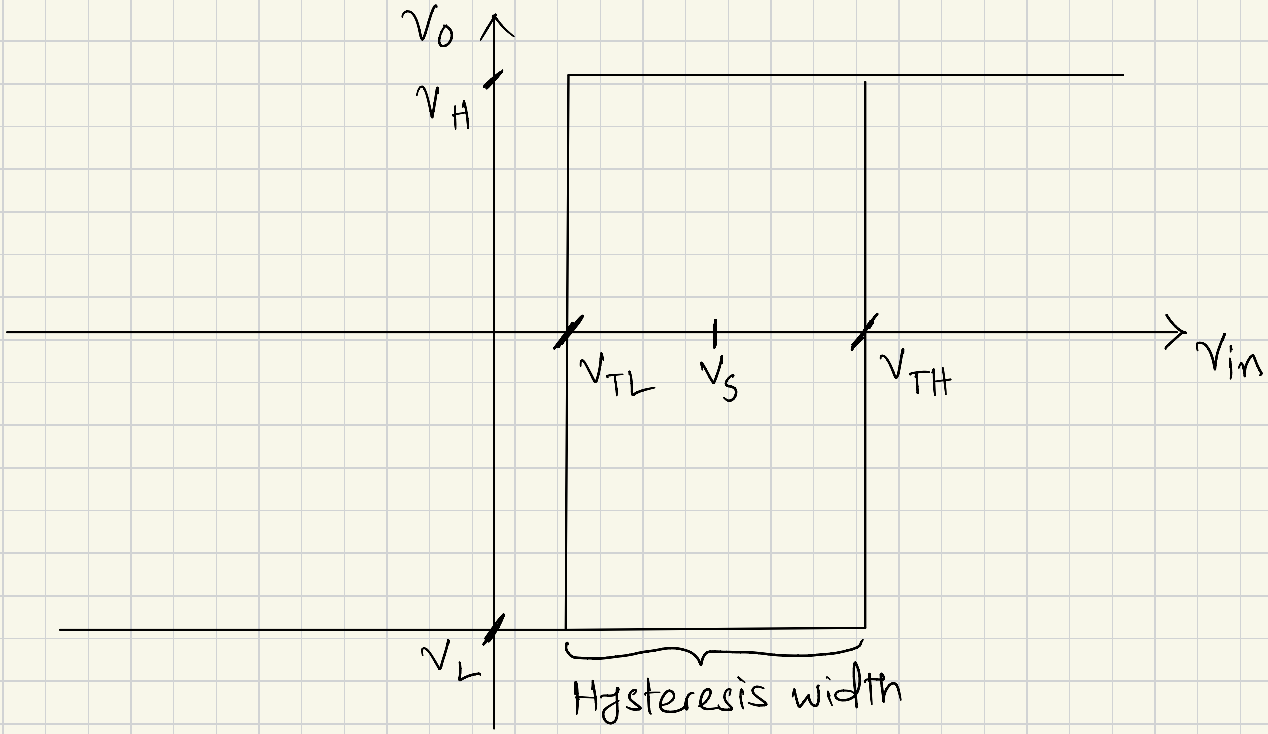
(a)	**Draw** the **complete circuit** of the square wave generator
(b)	**Determine** all the **component values** (resistors, capacitors, saturation voltages)
(c)	**Plot** the time vs output voltage curve (**time vs V_{in}/V_{out} plot**). Clearly **label** the plot.

<u>Hint</u>: Same hint as *Question* 1.

Question 1

we will design a non-inverting schmitt trigger.





According to the question,

$v_{TH} = 9.5 \text{ V}$

$v_{TL} = 0.5 \text{ V}$

For a symmetric response, we consider shift voltage v_s to be in the middle of v_{TH} and v_{TL},

$$v_s = \frac{9.5 + 0.5}{2} = 5 \text{ V}$$

Equations:

(i) $V_{TH} = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) + \left(-\frac{R_1}{R_2}\right)V_L$

(ii) $V_{TL} = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) + \left(-\frac{R_1}{R_2}\right)V_H$

(iii) $V_S = V_{ref}\left(\frac{R_1+R_2}{R_2}\right)$

(iv) Hysteresis width $= V_{TH} - V_{TL}$

Using equation (i) $\Rightarrow$

$V_{TH} = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) + \left(-\frac{R_1}{R_2}\right)V_L$

$\Rightarrow 9.5 = V_S + \left(-\frac{R_1}{R_2}\right)V_L$

$\Rightarrow 9.5 = 5 + \left(-\frac{R_1}{R_2}\right)V_L$

$\Rightarrow \left(-\frac{R_1}{R_2}\right)V_L = 4.5 \quad \cdots\cdots (v)$

Using equation (ii) $\Rightarrow$

$V_{TL} = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) + \left(-\frac{R_1}{R_2}\right)V_H$

$\Rightarrow 0.5 = V_S + \left(-\frac{R_1}{R_2}\right)V_H$

$\Rightarrow 0.5 = 5 + \left(-\frac{R_1}{R_2}\right)V_H$

$\Rightarrow \left(-\frac{R_1}{R_2}\right)V_H = -4.5\ V \quad \cdots\cdots (vi)$

Using equation (iii) $\Rightarrow$

$V_S = V_{ref}\left(\frac{R_1+R_2}{R_2}\right)$

$\Rightarrow 5 = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) \cdots (vii)$

Using equation (iv) $\Rightarrow$

Hysteresis width $= V_{TH} - V_{TL}$

$\Rightarrow 9.5 - 0.5 = \left(-\frac{R_1}{R_2}\right)(V_H - V_L)$

$\Rightarrow 9 = \left(-\frac{R_1}{R_2}\right)(V_H - V_L) \quad \cdots\cdots (viii)$

Let us assume,

$R_1 = 1\,k\Omega$, $R_2 = 4\,k\Omega$

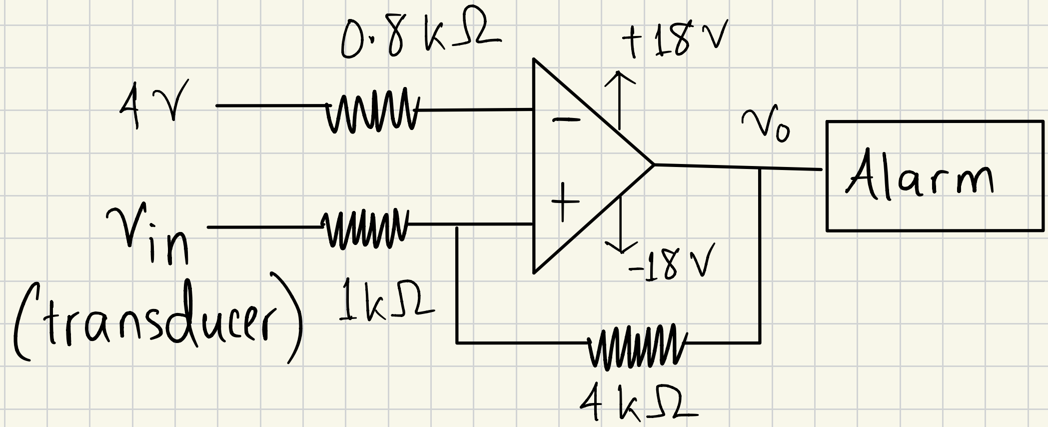
Then, $V_L = -18\,V$ from equation (v)

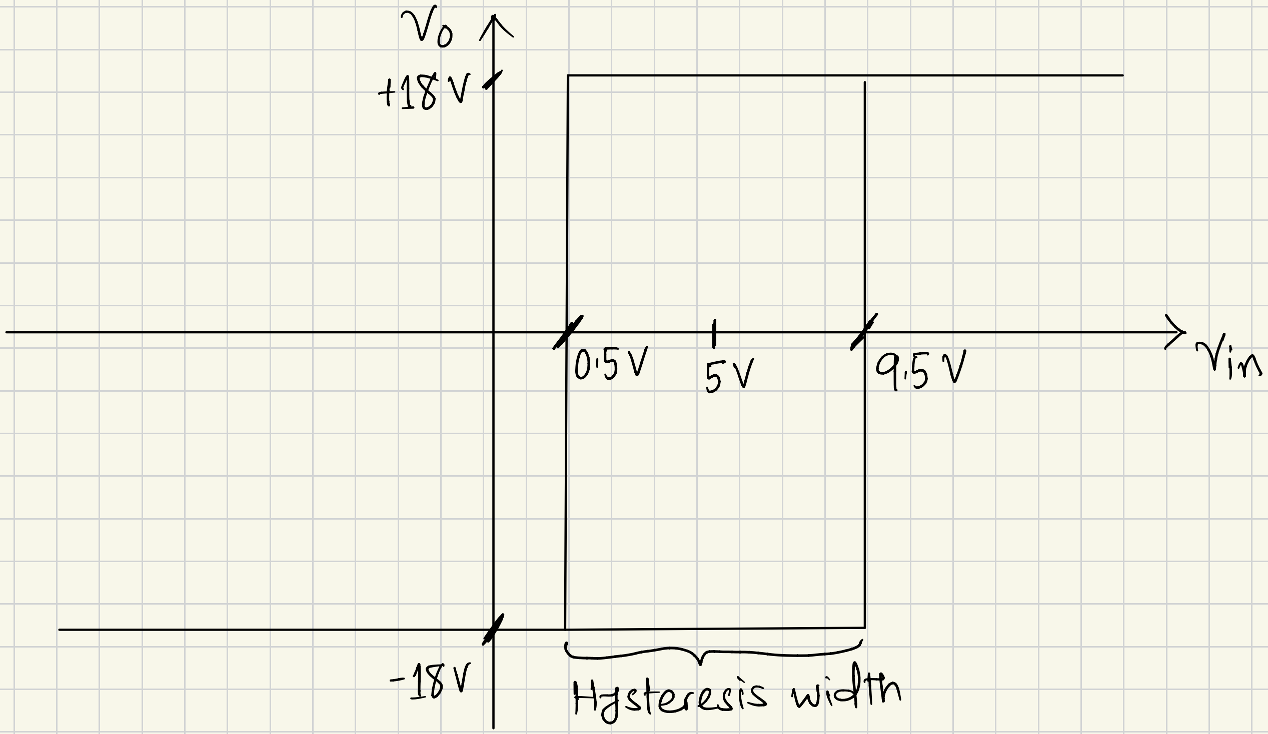
$V_H = 18\,V$ from equation (vi)

$V_{ref} = 4\,V$ from equation (vii)

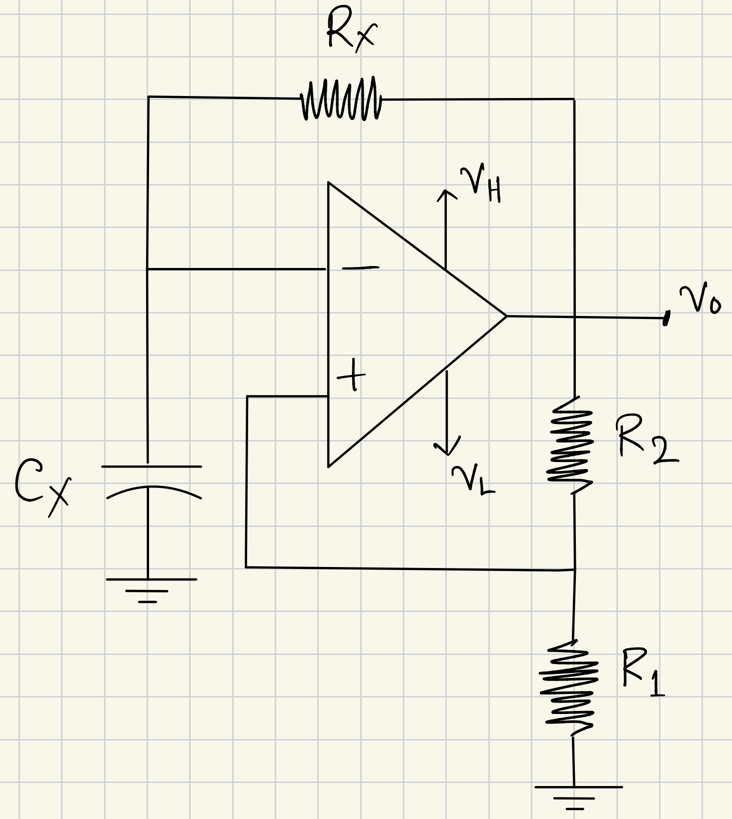
Putting these values into equation (i), (ii) and (iii) we get,

$V_{TH} = 9.5\,V$, $V_{TL} = 0.5\,V$, $V_S = 5\,V$





Question 2



Given, $v_H = 12\,V$

$v_L = 0\,V$

Let us assume $R_1 = R_2$,

$$V_{TH} = V_H \frac{R_1}{R_1 + R_2} = 6\,V$$

$$V_{TL} = V_L \frac{R_1}{R_1 + R_2} = 0\,V$$

Since 50% of total capacity is mentioned,

Duty cycle = 50%

$T_1 = T_2$

$\therefore T = T_1 + T_2$

$= 2T_1$

Given, $f = 500$ Hz

$\therefore T = \frac{1}{500}$

$2T_1 = 2$ ms

$\therefore T_1 = 1$ ms

we use the capacitor voltage equation $\Rightarrow$

$$V_X = V_0 + (V_{initial} - V_0)\, e^{-\frac{t_2 - t_1}{R_X C_X}}$$

$$\Rightarrow 6 = 12 + (0 - 12) e^{-\frac{T_1 - 0}{R_X C_X}}$$

$$\Rightarrow 0.5 = e^{-\frac{T_1}{R_X C_X}}$$

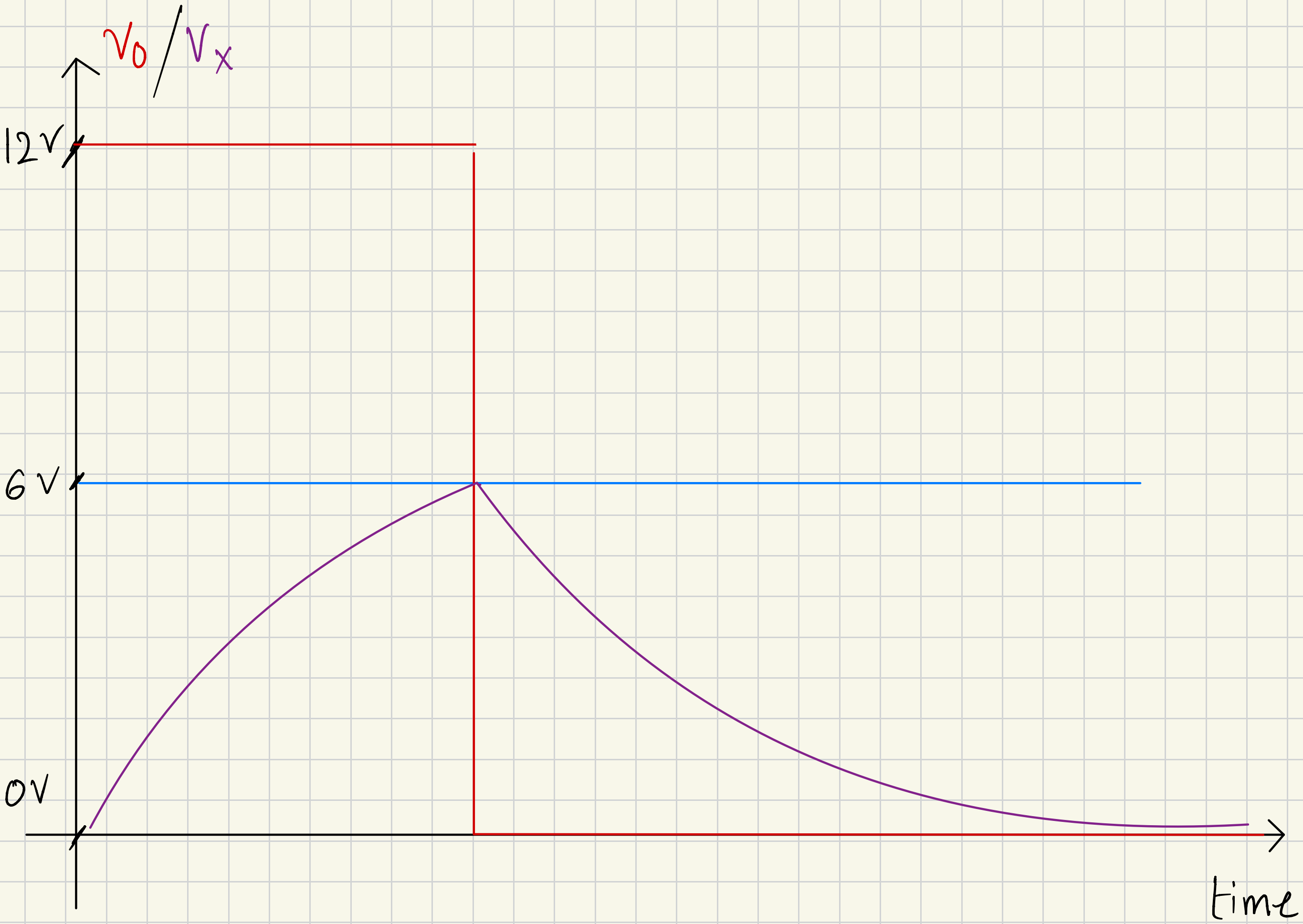
$$\Rightarrow T_1 = -R_X C_X \ln(0.5)$$

$$\Rightarrow 1\ \text{ms} = R_X C_X\, (0.693)$$

Let us assume $C_X = 1\ \mu F$

$$\Rightarrow R_X = 1.443\ k\Omega$$

Since $V_{TL} = V_L$ for this circuit, this won't properly work as a square wave generator; it will get high once and then turn off after 1 ms.



V_0 / V_x
12V
6V
0V
time