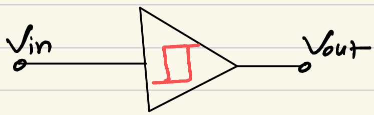
③ & ④ can be used to change the transition voltage by tuning R_1 and R_2. They are building block of schmitt trigger.

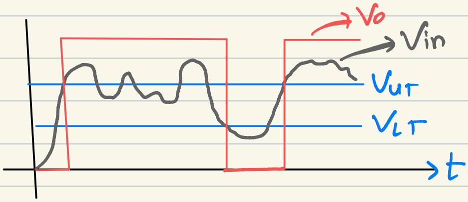
Schmitt Trigger:

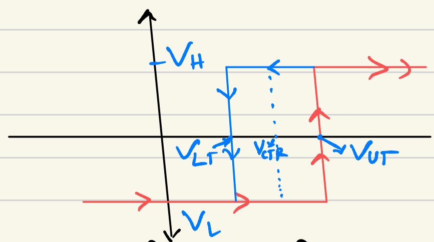
- Comparator with hysteresis
- has two threshold voltages (References)
  - V_{UT} → upper threshold voltage.
  - V_{LT} → Lower " "

Non-Inverting Schmitt trigger:

- V_{UT} → low to high transition.
- V_{LT} → high to low transition.

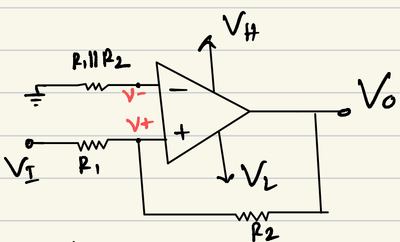






Transfer char. of Non. Inv. S.T.

⊛ Non. Inv. S.T. ckt



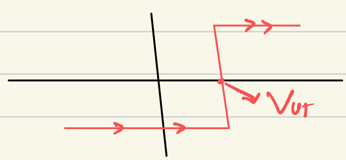
$$\begin{cases} V_- = 0 \\ V_+ = V_o \dfrac{R_1}{R_1+R_2} + V_I \dfrac{R_2}{R_1+R_2} \end{cases}$$

when $V_+ < V_- \rightarrow V_o = V_L$

$\therefore V_+ = V_L \dfrac{R_1}{R_1+R_2} + V_I \dfrac{R_2}{R_1+R_2} < 0$

$\therefore \boxed{V_I < \left(-\dfrac{R_1}{R_2}\right) V_L}$ → $\boxed{V_o = V_L}$

$\therefore \boxed{V_{UT} = -\dfrac{R_1}{R_2} V_L}$ ✗



When $V_+ > V_-$ $\rightarrow$ $V_o = V_H$

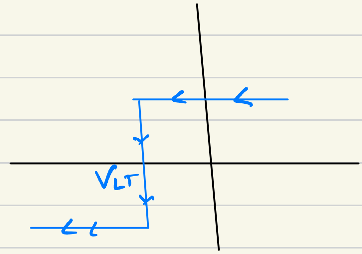
$\therefore$ $V_- = 0$

$$V_+ = V_H \frac{R_1}{R_1+R_2} + V_I \frac{R_2}{R_1+R_2}$$

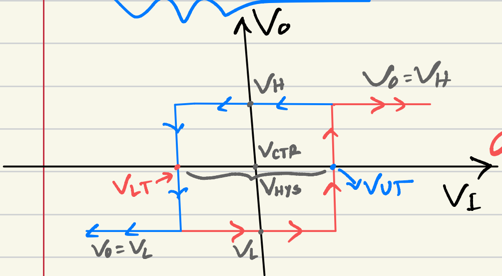
$V_+ > V_-$

$$\Rightarrow \boxed{V_I > \left(-\frac{R_1}{R_2}\right)V_H} \rightarrow V_o = V_H$$

$$\therefore \boxed{V_{LT} = \left(-\frac{R_1}{R_2}\right)V_H}$$



Combined characteristics



** $\therefore$ Formulas

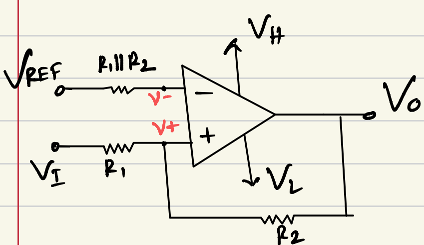
$$V_{UT} = \left(-\frac{R_1}{R_2}\right)V_L$$

$$V_{LT} = \left(-\frac{R_1}{R_2}\right)V_H$$

$V_{HYS} = V_{UT} - V_{LT}$ $\longrightarrow$ Hysteresis width

$V_{CTR} = \dfrac{V_{UT}+V_{LT}}{2}$ $\longrightarrow$ Center voltage.

Non. Inv. S.T. with applied voltage. (V_{REF})



$$V_- = V_{REF}$$

$$V_+ = V_o \frac{R_1}{R_1+R_2} + V_I \frac{R_2}{R_1+R_2}$$

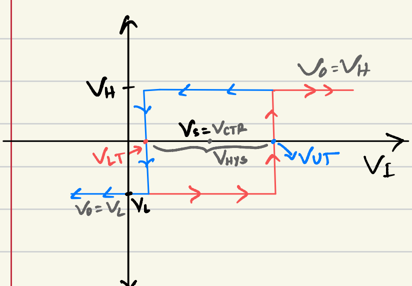
**

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

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

$$V_{HYS} = V_{UT} - V_{LT}$$

$$V_{CTR} = \frac{V_{UT}+V_{LT}}{2} = V_s$$

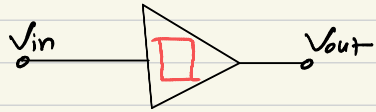


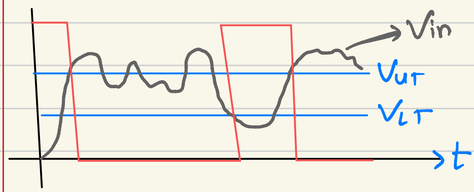
shift voltage, V_s

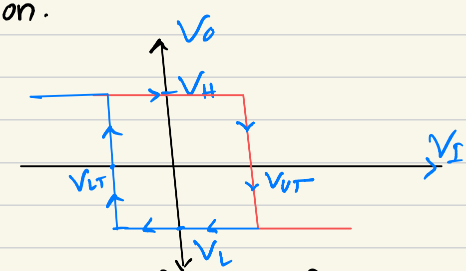
$$V_s = \frac{R_1+R_2}{R_2} V_{REF}$$

Inverting Schmitt trigger:

- $V_{UT} \rightarrow$ high to low transition.
- $V_{LT} \rightarrow$ low to high transition.

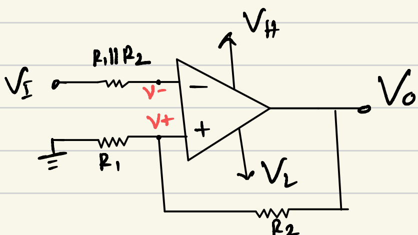






Transfer char. of Inv. S.T.

Inv. S.T. ckt



$$V_- = V_I$$
$$V_+ = V_o \frac{R_1}{R_1+R_2}$$

When $V_- > V_+ \rightarrow V_o = V_L$

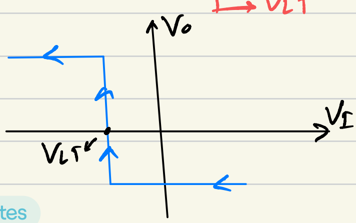
$V_- = V_I$

$V_+ = V_L \frac{R_1}{R_1+R_2}$

$V_- > V_+$

$V_I > V_L \frac{R_1}{R_1+R_2} \rightarrow V_o = V_L$

$\hookrightarrow V_{LT}$



when $V_- < V_+ \rightarrow V_o = V_H$

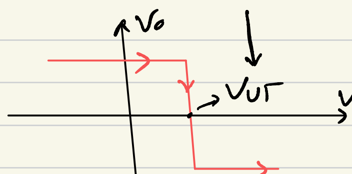
$V_- = V_I$

$V_+ = V_H \frac{R_1}{R_1+R_2}$

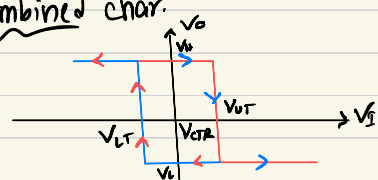
$V_- < V_+$

$V_I < V_H \frac{R_1}{R_1+R_2} \rightarrow V_o = V_H$

$\hookrightarrow V_{UT}$



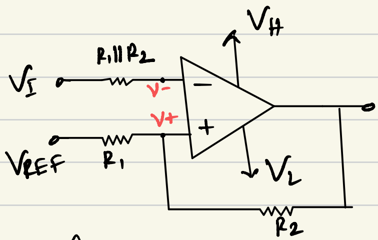
combined char.

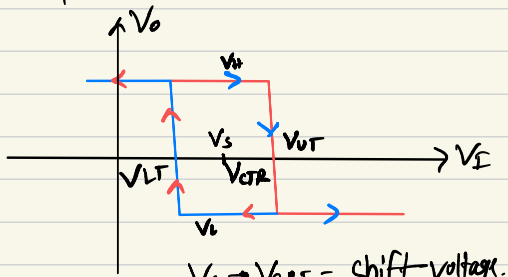


** Formulas

$$V_{UT} = V_H \frac{R_1}{R_1+R_2}$$
$$V_{LT} = V_L \frac{R_1}{R_1+R_2}$$
$$V_{HYS} = V_{UT} - V_{LT}$$
$$V_{CTR} = \frac{V_{UT}+V_{LT}}{2}$$

Inv. S.T. ckt with applied voltage (V_{REF})





$V_s \to V_{CRT}$ = shift voltage.

$$\begin{cases} V_- = V_I \\ V_+ = V_o \dfrac{R_1}{R_1+R_2} + V_{REF} \dfrac{R_2}{R_1+R_2} \end{cases}$$

** Formulas

$$V_{UT} = V_H \frac{R_1}{R_1+R_2} + V_{REF} \frac{R_2}{R_1+R_2}$$

$$V_{LT} = V_L \frac{R_1}{R_1+R_2} + V_{REF} \frac{R_2}{R_1+R_2}$$

$$V_{HYS} = V_{UT} - V_{LT}$$

$$V_S = V_{CTR} = \frac{V_{UT}+V_{LT}}{2} = V_{REF} \frac{R_2}{R_1+R_2}$$

Practice problem

$R_1 = 10k\Omega$, $R_2 = 90k\Omega$, $V_H = 10V$, $V_L = -10V$

i) Determine the followings for non-inverting schmitt trigger.
↳ $V_{UT}, V_{LT}, V_{HYS}, V_{CTR}$

ii) Determine the values for inverting schmitt trigger.

Scmitt Trigger → Bistable multivibrator

because it has two stable states → $V_o = V_H$ & V_L

Application
- → Smoke Detector
- → Street Light control

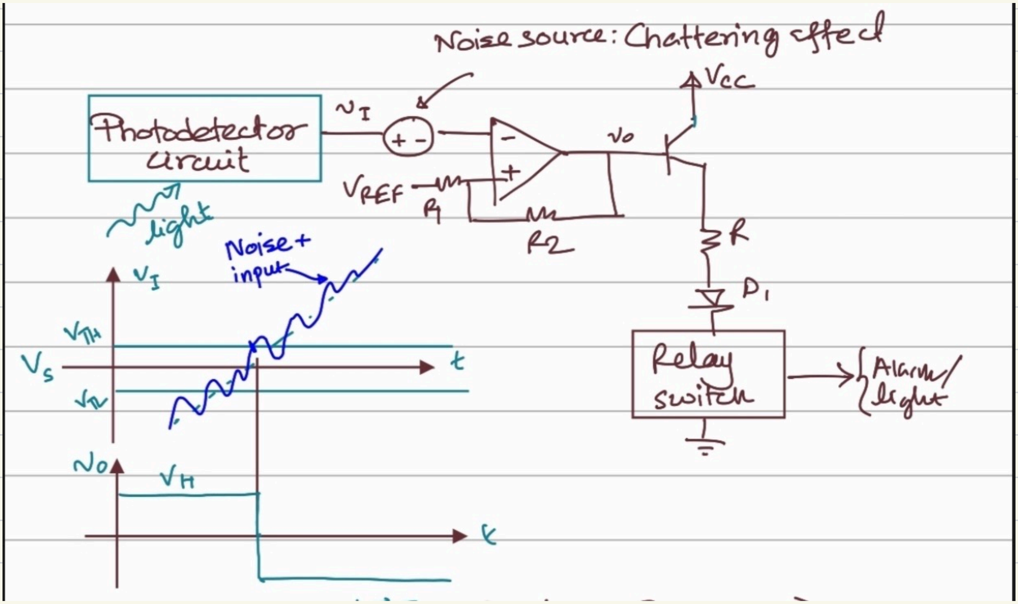


Fig: Smoke Detector ckt

** Naemen → Design problem 15.7 → (final Exam)