# Ch. 9 Part 2

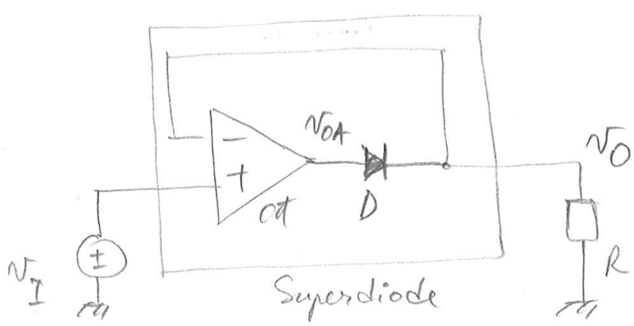
- Finish talking about Schmitt triggers

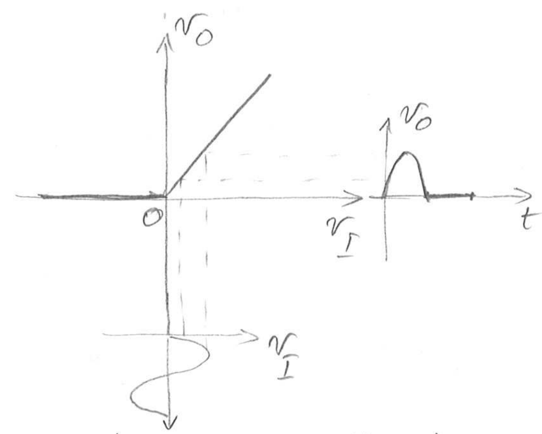
## 9.4 Precision Rectifiers

Half-wave rectifier (HWR)      Full-wave Rectifier (FWR)

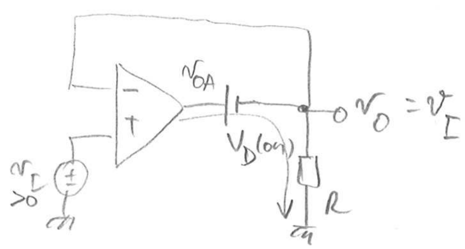
implemented using nonlinear devices, such as diodes.

### Half-wave rectifiers: Superdiode



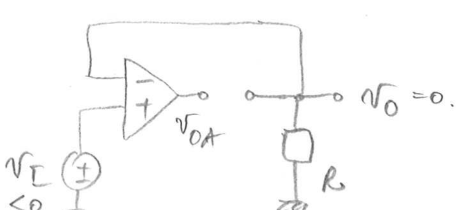




case: $v_I > 0 \Rightarrow v_{OA}$ will swing toward $V_{OH} \Rightarrow D = ON \Rightarrow$ Negative feedback (∃)



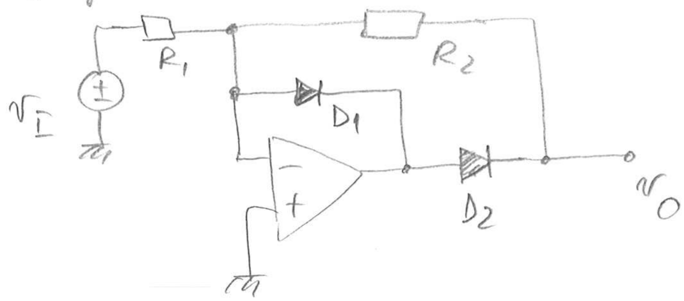

$$v_{OA} = v_O + v_D \cong v_O + 0.7\,V$$

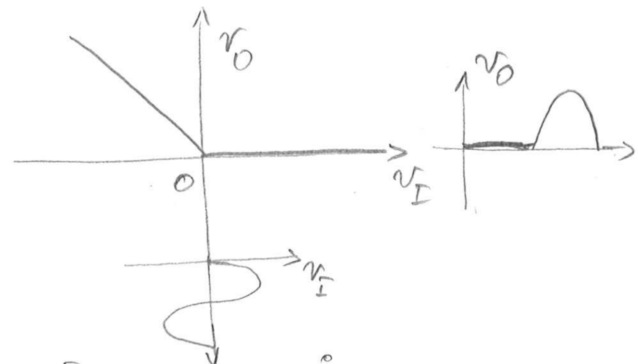
case: $v_I < 0 \Rightarrow v_{OA}$ will swing toward $V_{OL} \Rightarrow D = OFF$




$$v_{OA} = V_{OL}$$

## Improved HWR



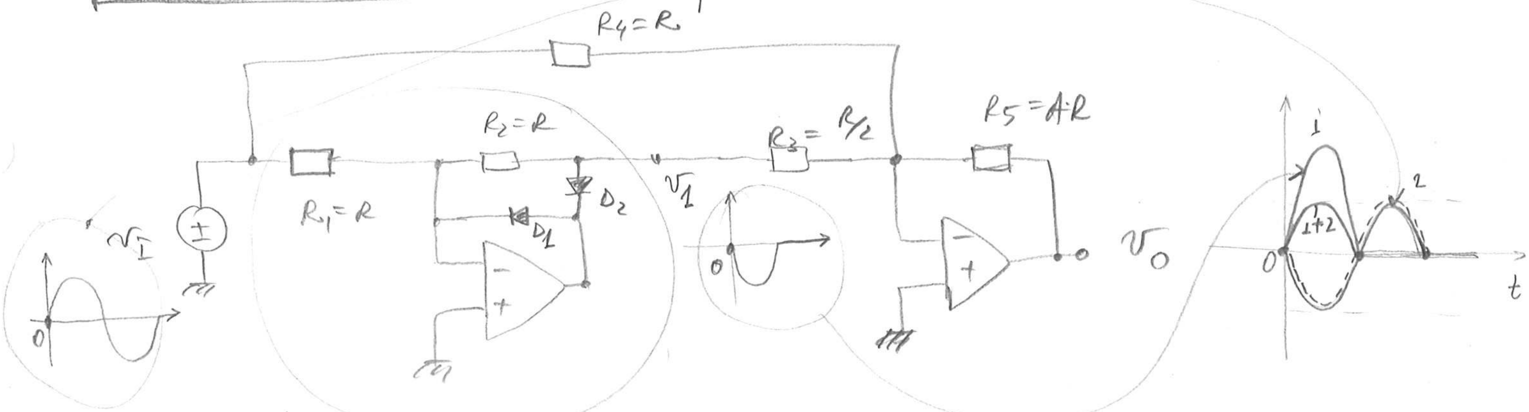




Case 1: $v_I > 0 \Rightarrow D_1 = ON$, $D_2 = OFF \Rightarrow v_O = 0$ as $i_{R_2} = 0$.

Case 2: $v_I < 0 \Rightarrow D_1 = OFF$, $D_2 = ON \Rightarrow (\exists)\, i_{R_2} : \frac{v_O - 0}{R_2} = \frac{0 - v_I}{R_1}$

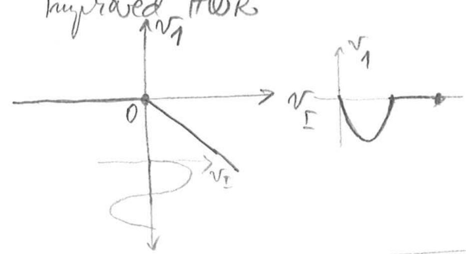
$$v_O = -\frac{R_2}{R_1} v_I$$

## Full-Wave Rectifier (FWR)




$$v_O = -\frac{R_5}{R_4} v_I - \frac{R_5}{R_3} v_1$$

Improved HWR



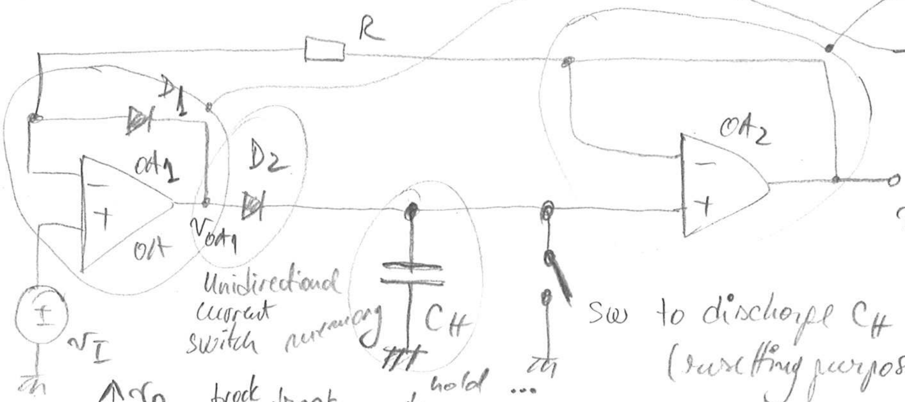

$$\begin{cases} v_O = A_p \cdot v_I, & v_I > 0\ \text{V} \\ v_O = -A_n v_I, & v_I < 0\ \text{V} \end{cases}$$

$$A_p = \frac{R_2 R_5}{R_1 R_3} - A_n, \quad A_n = \frac{R_5}{R_4}$$

We want $|A_n| = |A_p|$, and w/ the values shown in the figure we achieve an amplification of $A$.

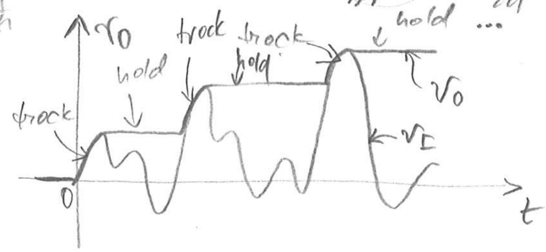
Note: application is ac-dc converters.

# 9.6. Peak detectors (test and measurement instrumentation)




$OA_2$ separates/buffers out load to prevent discharge of $C_H$

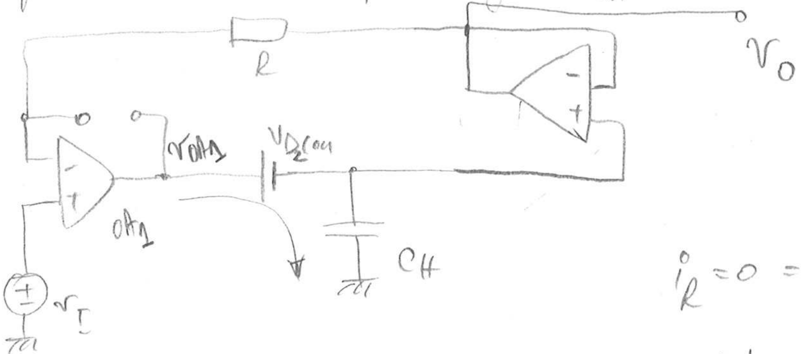
$OA_1$ follower to track the input $v_I$ when it goes higher than the currently stored.




Applications: test and measurement instrumentation.

## Track mode:

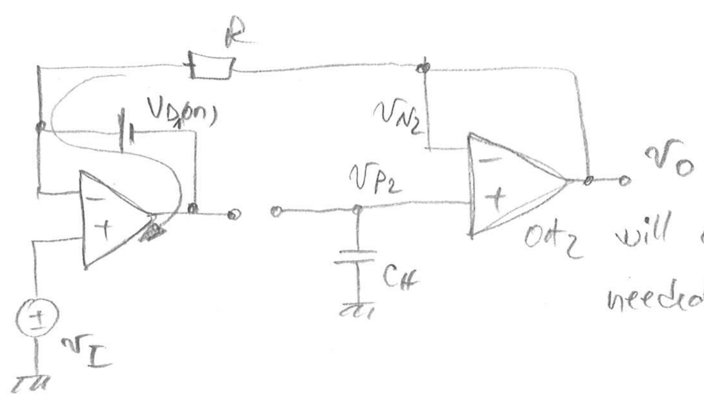
A new peak arrives => $OA_1$ swings $v_{OA}$ toward $V_{OH}$ => $D_1$ = OFF, $D_2$ = ON




$i_R = 0$ => $v_O$ follows $v_I$ via $OA_1$ with negative feedback $v_{D_2} - OA_2 - R$.

## Hold mode

After peaking $v_I \downarrow \Rightarrow v_{OA_1} \downarrow$ => $D_1$ = ON, $D_2$ = OFF => $OA_1$ has an alternative feedback via $D_1$



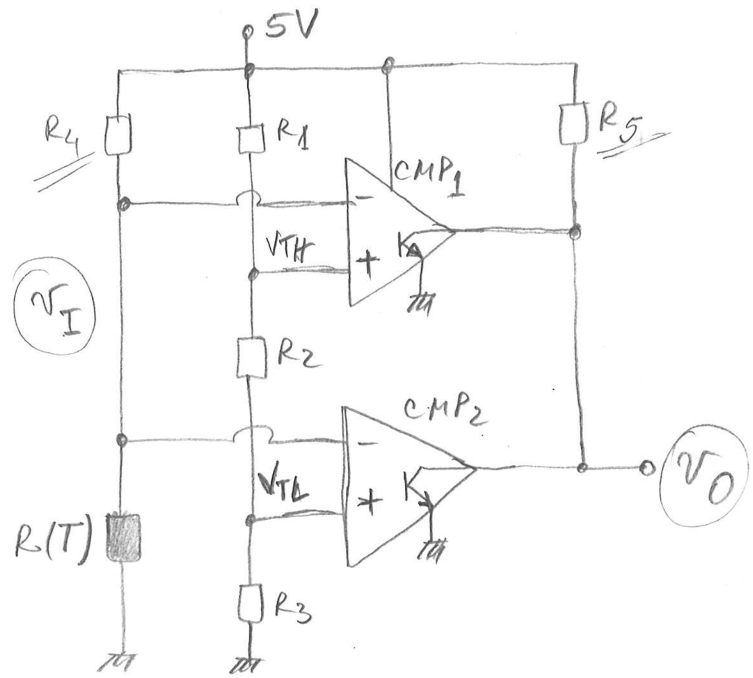

$OA_2$ will output whatever current is needed to keep $v_O$ equal to $v_{P_2}$.

Problem 9.4. Using

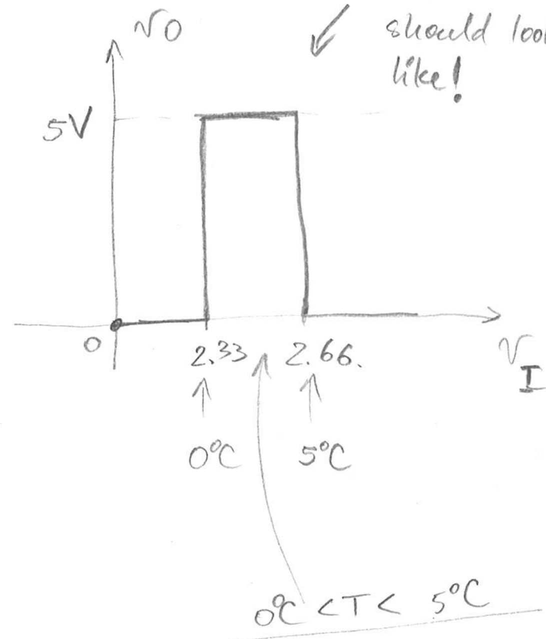
- 2 comparators of type 339
- thermistor : $R(T) = R(T_0) \cdot \times e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)}$ , $T_0$ some reference temp.
  - $B = 4000\,°K$
  - $R_0(25°C) = 10\,k\Omega$ ← $T_0$

Design a circuit that yields:

$v_O \cong \begin{cases} 5V, & 0°C < T < 5°C \\ 0, & \text{otherwise} \end{cases}$




This how NTC should look like!



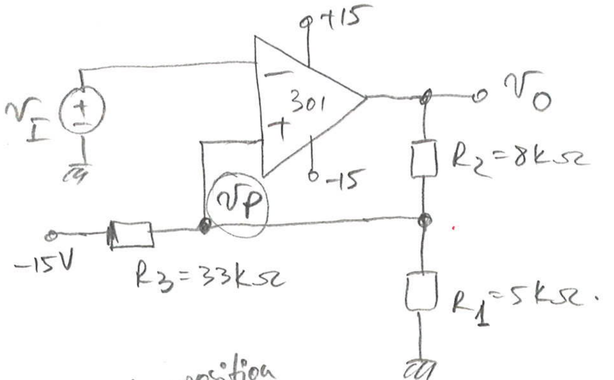

$$\begin{cases} R(0°) = 10\,k\Omega \times e^{4000\left(\frac{1}{273} - \frac{1}{298}\right)} \cong 34.12\,k\Omega. \\ R(5°) = 26.23\,k\Omega. \end{cases}$$

Let $R_4 = 30\,k\Omega$ => $\begin{cases} V_{TL} = 5V \cdot \frac{26.23}{26.23 + 30} = 2.33\,V \\ V_{TH} = 5V \cdot \frac{34.12}{34.12 + 30} = 2.66\,V \end{cases}$

Use $\begin{cases} R_3 = 23.2\,k\Omega \\ R_2 = 3.32\,k\Omega \\ R_3 = 23.4\,k\Omega \end{cases}$ to implement $V_{TL}$, $V_{TH}$ !

Problem [9.12]:

ⓐ Sketch the VTC of this new modified Schmitt trigger.



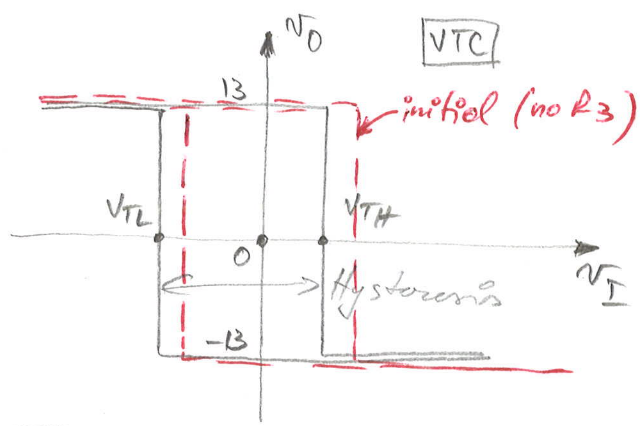

[Fig. 9.20. inverting Schmitt trigger. modified with $R_3$]

Exercise: what if $R_1$ is pulled and connected to $V_{REF}$?

superposition

$$v_P \overset{\downarrow}{=} \frac{33\|5}{33\|5 + 8} \cdot v_O + \frac{8\|5}{8\|5 + 33} \cdot (-15) \cong 0.352\, v_O - 1.279V$$

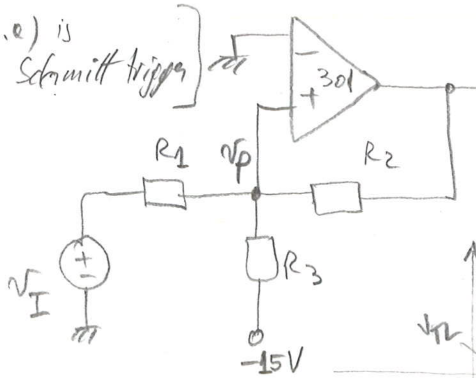
$$\begin{cases} V_{TH} = v_P \big|_{v_O = 13V} = 3.29V \\ V_{TL} = v_P \big|_{v_O = -13V} = -5.85V \end{cases}$$

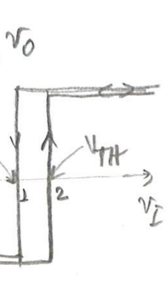



ⓑ Modify the circuit of (Fig. 9.21 a) so that it gives $V_{TL} = 1V$, $V_{TH} = 2V$: wanted!

Observation: we have to add -15V via a resistor to $v_P$.

[Fig. 9.21.a) is noninverting Schmitt trigger]




$v_P = 0$ in two cases:

Case 1: $v_O = V_{OL}$ & $v_I = V_{TH}$

$$\frac{2-0}{R_1} = \frac{0-(-15)}{R_3} + \frac{0-(-13)}{R_2}$$

Case 2: $v_O = V_{OH}$ & $v_I = V_{TL}$ $\Rightarrow$

$$\frac{13-0}{R_2} + \frac{1-0}{R_1} = \frac{0-(-15)}{R_3}$$

=> these are 2 equations, 3 unknowns.

=> Fix $R_1 = 10k\Omega$, then $R_3 = 100k\Omega$, $R_2 = 260k\Omega$ use $261k\Omega$.