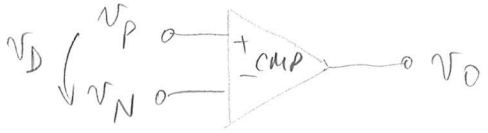
Ch 9 | Part 1

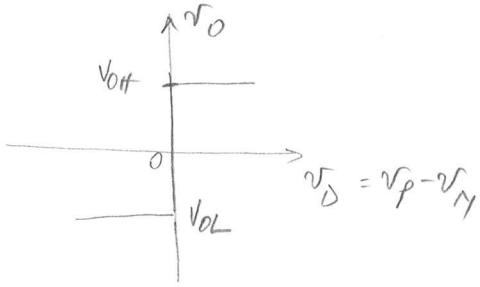
Nonlinear circuits

9.1. Voltage comparators

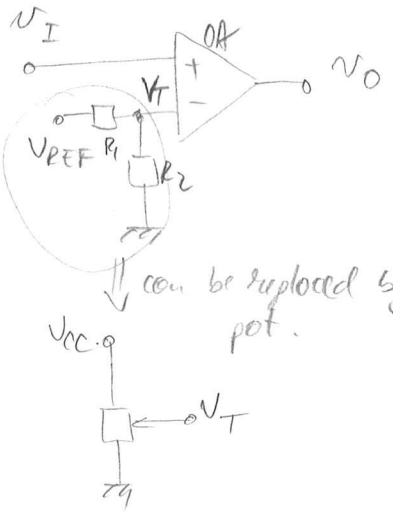
key 1

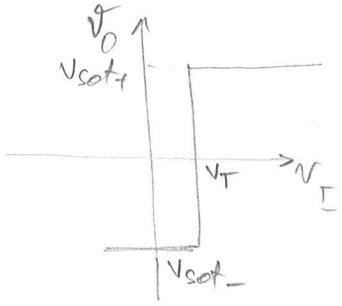
- Same symbol as an Opamp!

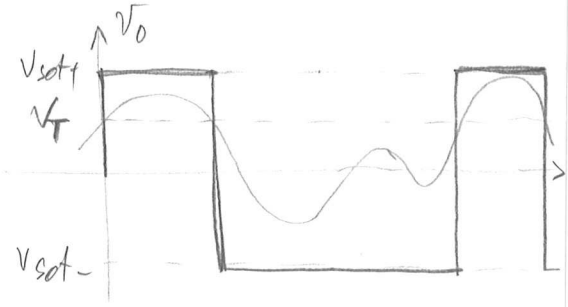




The simplest comparator is an Opamp! Limitation: works for low freq's only.





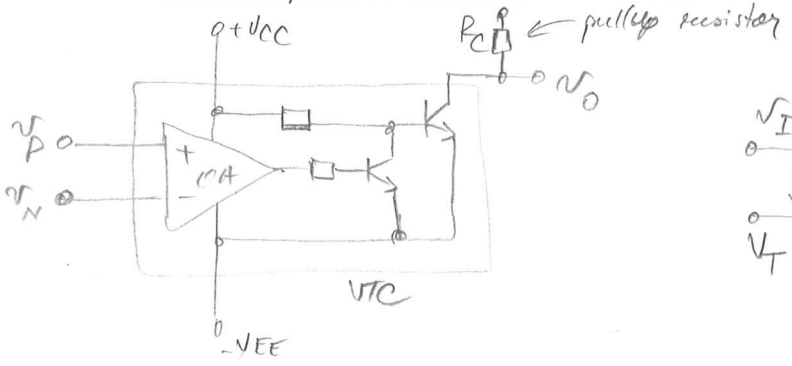


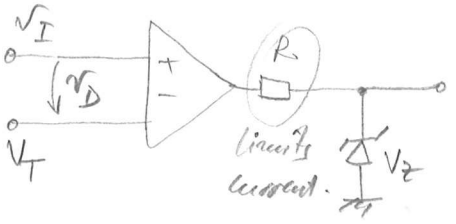
≙ Threshold detector!

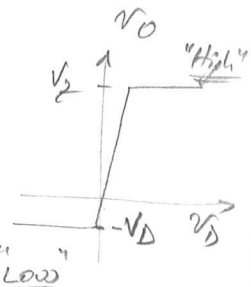
- Opamps are intended to work in neg. feedback circuits.
- Their output cannot be interfaced directly with digital circuits.

⇒ Voltage comparators were designed specifically!
They are manufactured as dedicated IC!

Simplified implementation details





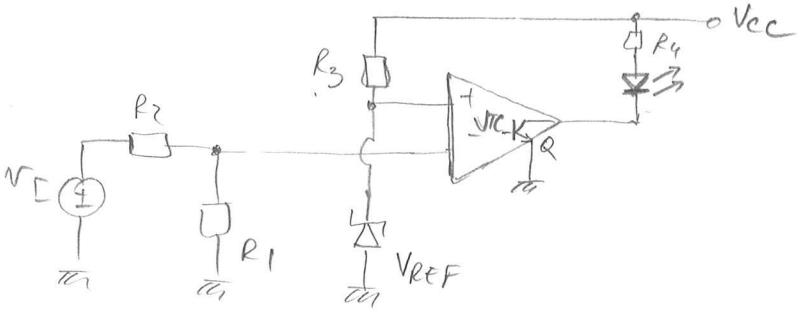


9.2 VTC Applications

- AD converters
- waveform generators
- High voltage digital logic gates.

Level Detectors (threshold detector)

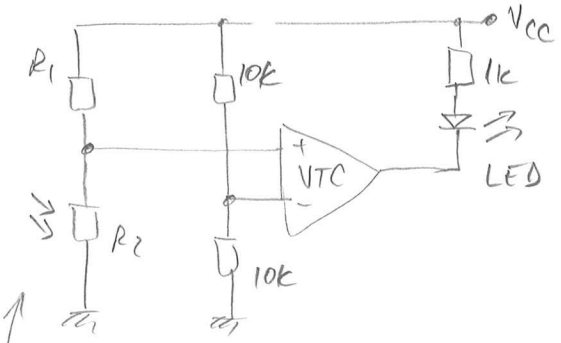
Monitor a physical variable that can be expressed as a voltage signal!



$\frac{R_1}{R_1+R_2} V_I \gtrless V_{REF}$. The threshold voltage is $V_T = \left(1+\frac{R_2}{R_1}\right) V_{REF}$.

$\begin{cases} V_I < V_T \Rightarrow Q \text{ is off} \Rightarrow \text{LED is off.} \\ V_I > V_T \Rightarrow Q \text{ is saturated} \Rightarrow \text{LED will glow!} \end{cases}$

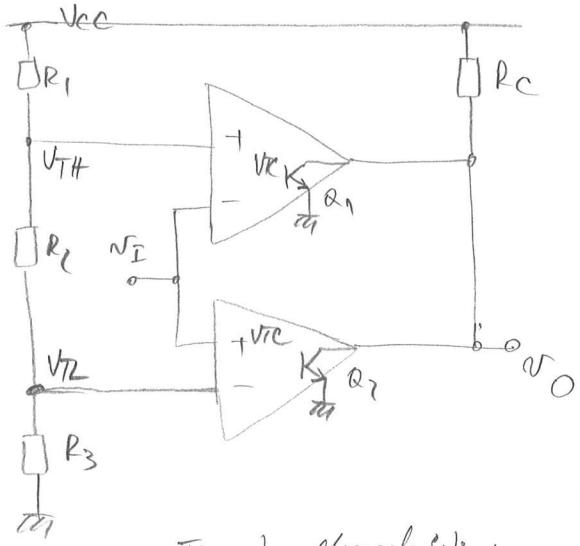
Example: photo cell circuit.

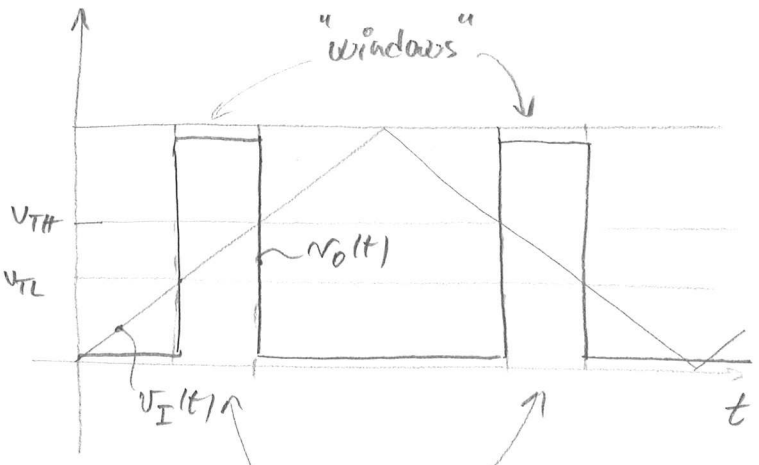


LED is off when photo cell is covered!

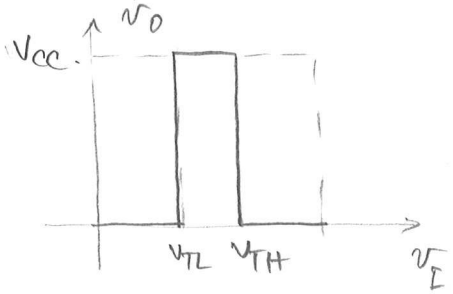
Sensor can be for temperature, pressure, strain, fluidic level, light and sound intensity!

Voltage window detector (window comparator)





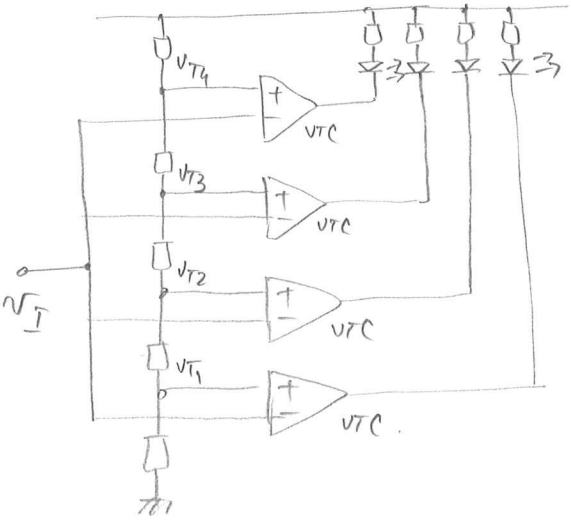
Transfer characteristic:



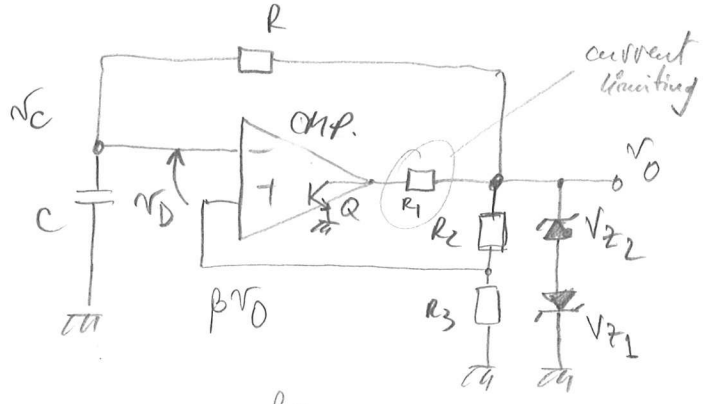
Q_1, Q_2 are both off and R_c pulls up v_o to V_{cc}

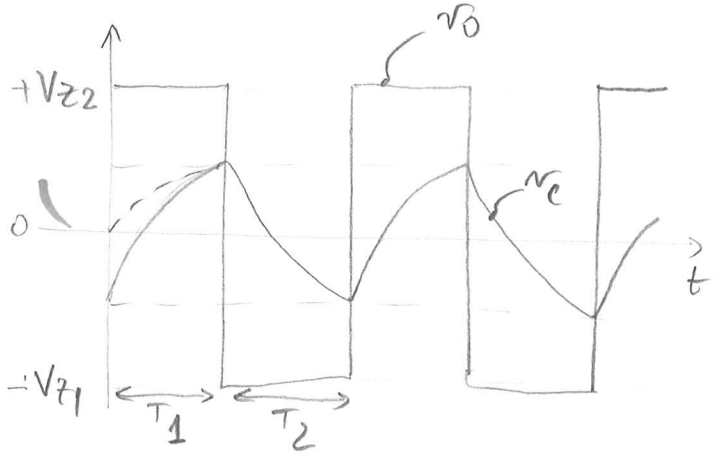
Bar-graph meters (∃ actually as dedicated chips: LM3914)

Example: 4 level-voltage detector.



(a) Square-wave generator ← Skip This





$$\begin{cases} \beta = \dfrac{R_3}{R_2+R_3} \\ v_D = \beta v_O - v_C \\ V_{Z1} = V_{Z2} = V_Z \end{cases}$$

$$v_C(t) = V_Z\left[1-(1+\beta)\,e^{-\frac{t}{RC}}\right]$$

$$T_1 = T_2 = T/2 \Rightarrow \boxed{T = 2RC\,\ln\frac{1+\beta}{1-\beta}}$$

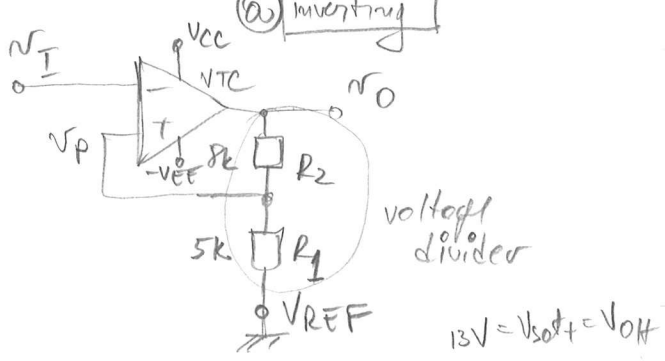
independant of V_Z!

- Frequency range: 10 Hz ÷ 10 kHz; after that slew-rate becomes important.
- Circuit can be operated without the zener diodes => swing between $V_{sat-} \div V_{sat+}$ (key 2)

See (4') page for triangular wave generator!

9.3 Schmitt trigger – Positive feedback

(a) inverting



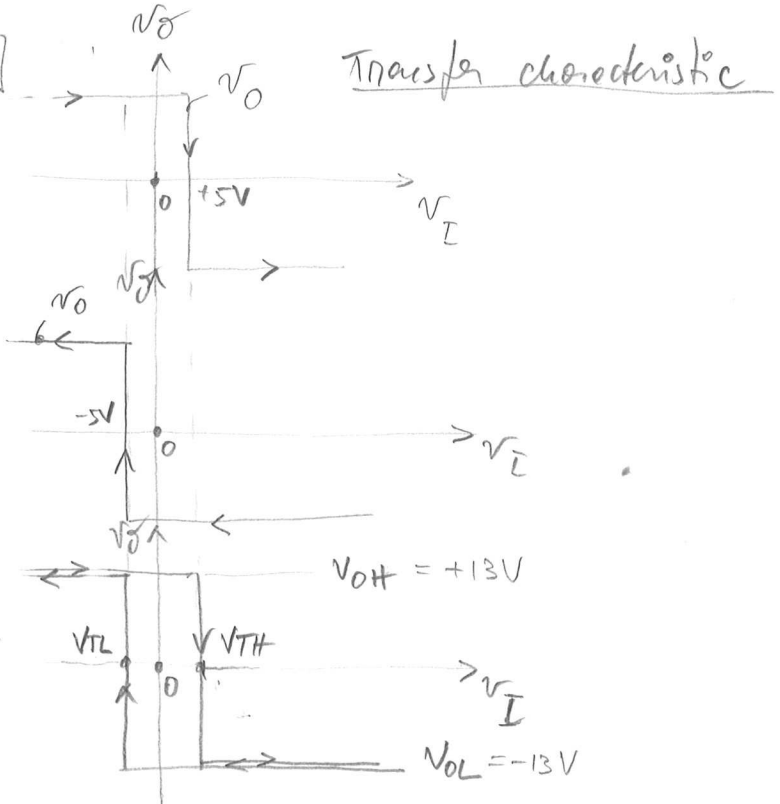
$13V = V_{sat+} = V_{OH}$

$$\begin{cases} v_1 = \dfrac{R_2}{R_1+R_2}V_{REF} + \dfrac{R_1}{R_1+R_2}V_{OH} = V_{TH} \\ v_2 = \dfrac{R_2}{R_1+R_2}V_{REF} + \dfrac{R_1}{R_1+R_2}V_{OL} = V_{TL} \end{cases}$$

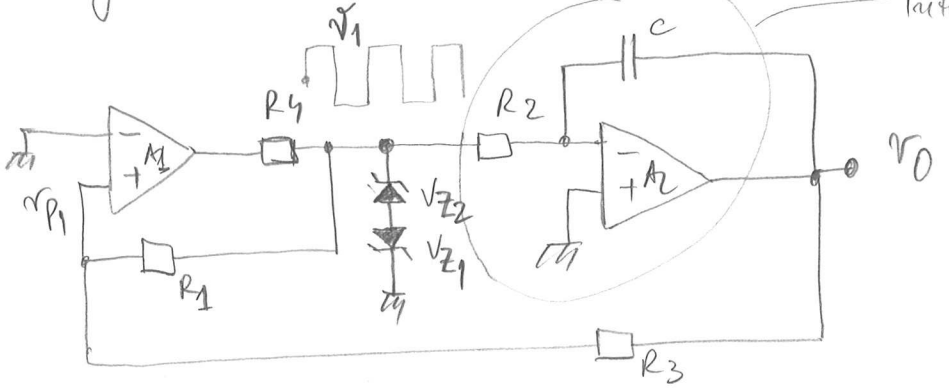
$-13V = V_{sat-} = V_{OL}$

Hysteresis voltage $\boxed{V_H \triangleq V_{TH} - V_{TL}}$

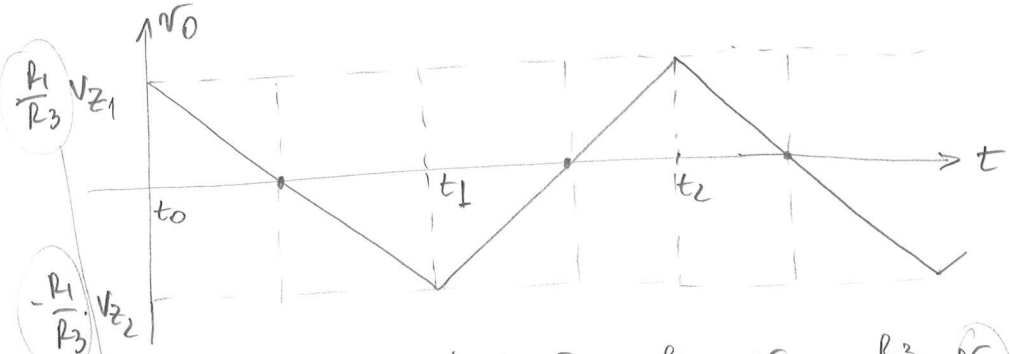
Transfer characteristic



(6) Triangular Waveform Generator ← Skip this

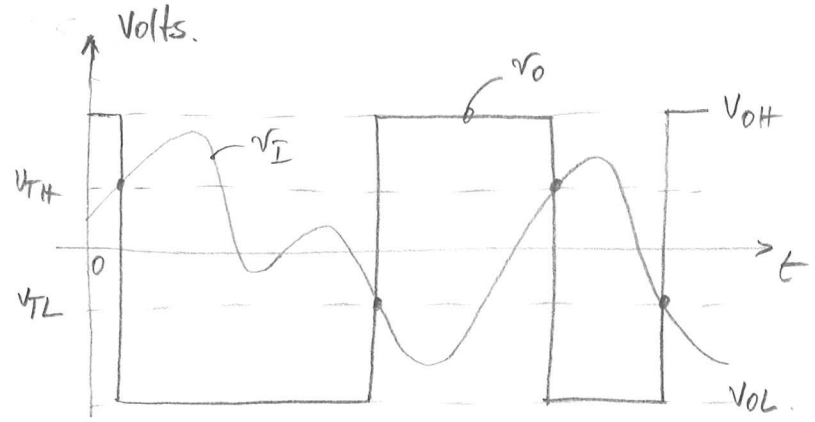


integrator has inversion ⇒ feedback to "+" terminal of OA_1.



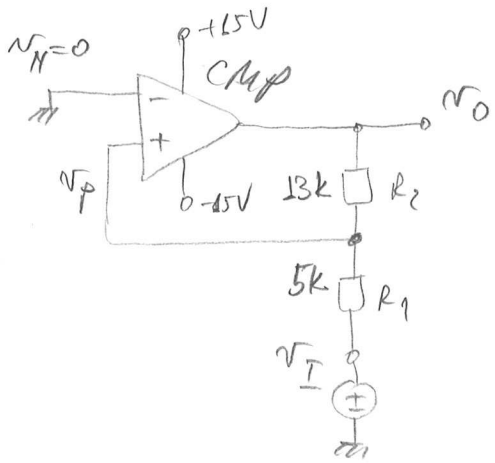
Obtained by observing that $v_{P_1} = \frac{R_1}{R_3+R_1} \cdot v_0 + \frac{R_3}{R_1+R_3} v_1$ crosses zero in up or down directions

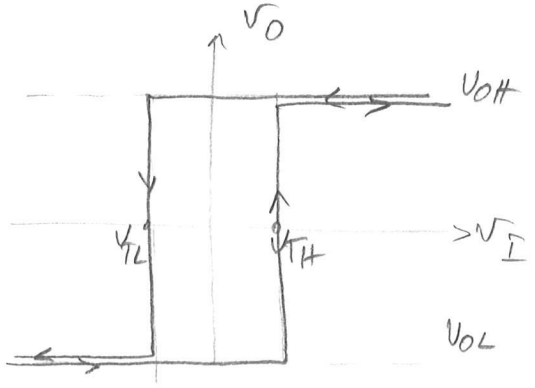
$= V_{Z_1}$ or V_{Z_2}



If $V_{REF} = 0 \Rightarrow V_H = V_{TH} - V_{TL} = \frac{R_1}{R_1+R_2}(V_{OH} - V_{OL}) = \Delta V_T$

⑥ Noninverting Schmitt Trigger





- $v_I \ll 0 \Rightarrow v_O = V_{OL}\ (-13V)$

$$v_P = \frac{R_2}{R_1+R_2} v_I + \frac{R_1}{R_1+R_2} v_O$$

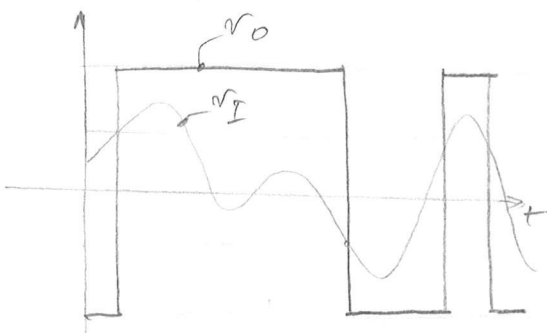
To switch v_O to V_{OH} we have to raise v_I so that v_P approaches and crosses $v_N = 0$. $\Rightarrow$

$$0 = \frac{R_2}{R_1+R_2} V_{TH} + \frac{R_1}{R_1+R_2} V_{OL}$$

$$\Rightarrow \boxed{V_{TH} = -\frac{R_1}{R_2} V_{OL}}$$

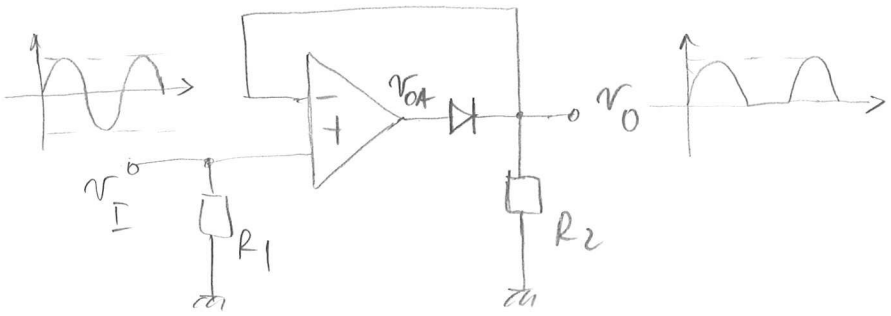
- Similarly: $\boxed{V_{TL} = -\frac{R_1}{R_2} V_{OH}}$

Hysteresis: $V_H = \Delta V_T = \frac{R_1}{R_2}(V_{OH} - V_{OL})$



Half Wave Precision Rectifier ← Skip this (go to next notes, part 2)

Most suitable in audio circuits

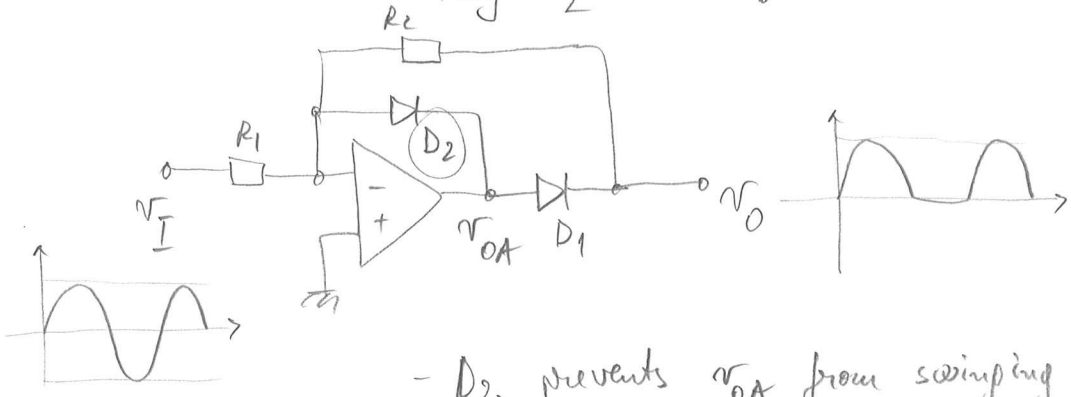


- Low frequency, on positive values => voltage follower!
- input signal negative => Op Amp has no feedback

$$\begin{cases} v_{OA} \to -V_{EE} \text{ (actually } V_{sat-}) \\ v_O \to 0 \text{ as } R_2 \text{ cannot draw current from anywhere.} \end{cases}$$

Main limitation: works well for low frequencies < 10kHz

Improved version - idea is to eliminate large swings for v_{OA}, because they require time!

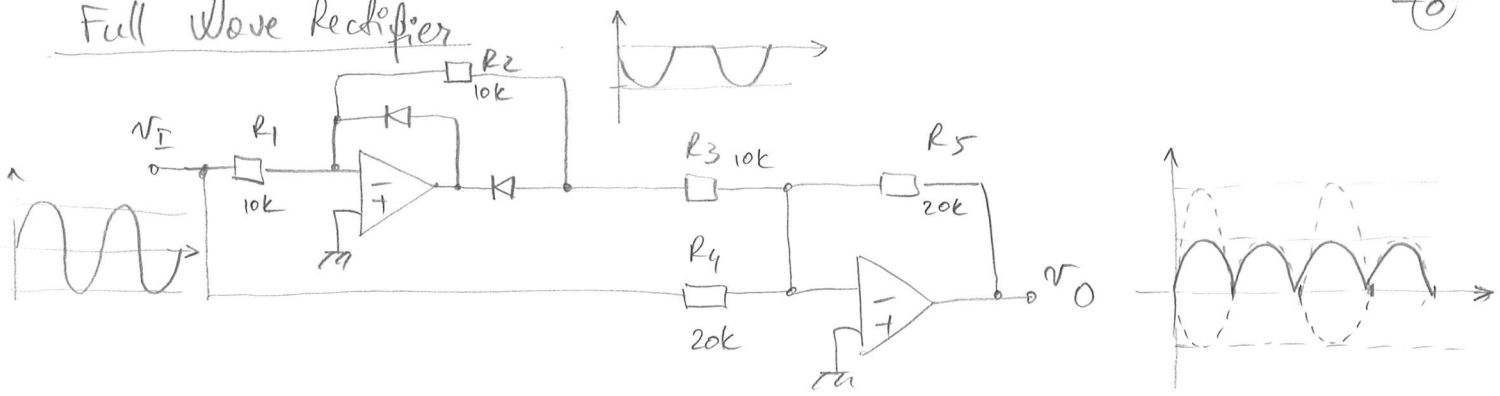


- D_2 prevents v_{OA} from swinging to the negative rail $-V_{EE}$

Limitations

- input resistance low (depends on R_1)

Full Wave Rectifier



Limitation :- input loading
- limited frequency response

Simplified alternative