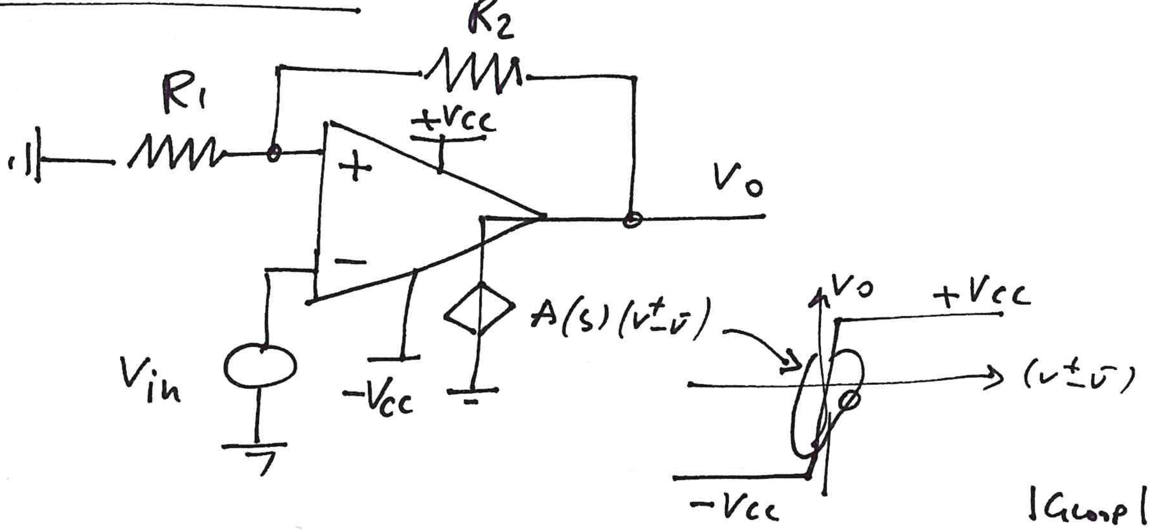
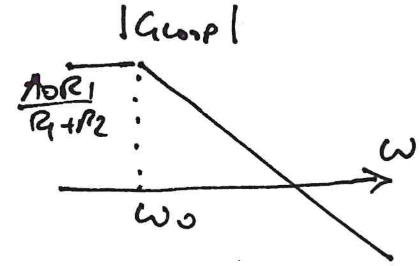
Circuiti a reazione positiva – Trigger di Schmitt

□ TdS invertente

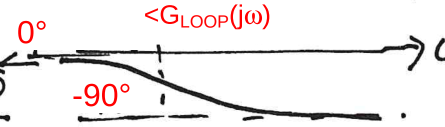


□ Calcolo Gloop, stabilità



$$G_{loop}(s) = +A(s)\,\frac{R_1}{R_1+R_2} = +\frac{A_0R_1}{R_1+R_2}\,\frac{1}{1+s/\omega_0}$$

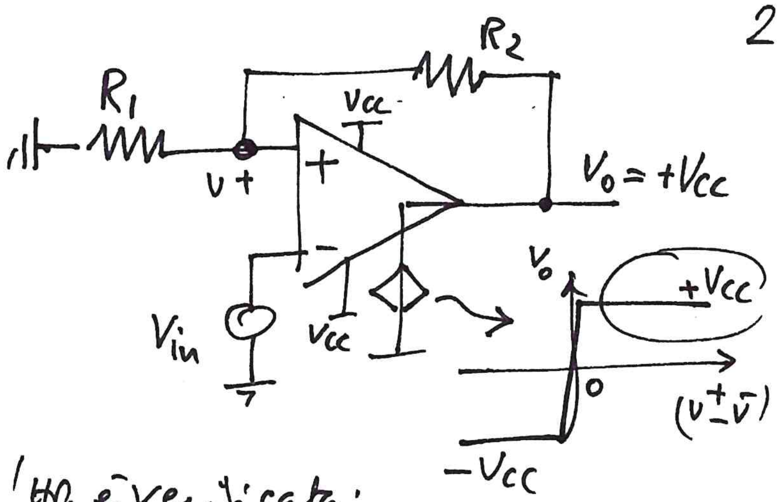
$$|G_{loop}(j\omega^*)| = |G_{loop}(j0)| = \frac{A_0R_1}{R_1+R_2} > 1 \qquad \boxed{\omega^*=0}$$



⇒ SISTEMA INSTABILE ! REAZIONE POSITIVA ($G_{loop}(j0) > 0$)

- Assumendo che V_o sia inizialmente in zona lineare ($v_o = A(v^+-v^-)$), a causa del polo nel semipiano destro (parte reale positiva), diverge e satura a $+V_{CC}$ o a $(-V_{CC})$.
- non è più valida la condizione $(v^+-v^-) \to \emptyset$ per $|A| \to \infty$!
- Escludendo la fase lineare del circuito, durante la quale ha luogo la divergenza verso $\pm V_{CC}$, avremo una delle due possibilità: $V_o = +V_{CC}$ o $V_o = -V_{CC}$. Usiamo questa informazione per l'analisi del circuito.

ANALISI



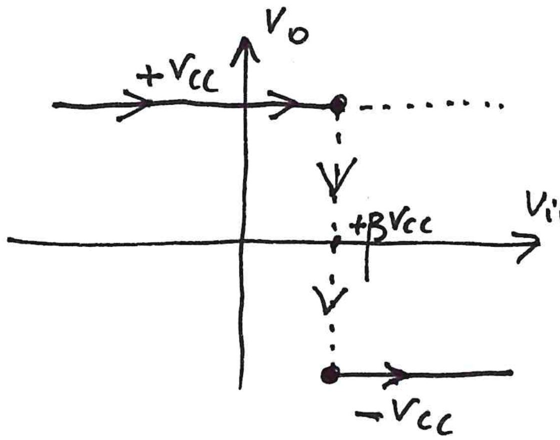
□ Hp. $V_o = +V_{cc}$

↳ $v^+ = V_{cc} \dfrac{R_1}{R_1 + R_2}$

▣ Verifichiamo quando e' Hp. è verificata:

$(v^+ - v^-) = (v^+ - V_{in}) > 0$

$\Rightarrow V_{in} < v^+ = V_{cc} \underbrace{\dfrac{R_1}{R_1+R_2}}_{=\beta} = +\beta V_{cc}$



▣ Condizione di "scatto" a $(-V_{cc})$:

$(v^+ - v^-) = (v^+ - V_{in}) \leq 0$

↳ $\boxed{V_{in}} \geq v^+ = V_{cc} \dfrac{R_1}{R_1+R_2} = \boxed{+\beta V_{cc}}$ SOGLIA DI SCATTO A $(-V_{cc})$

▣ ora mi trovo nella nuova condizione $V_o = (-V_{cc})$

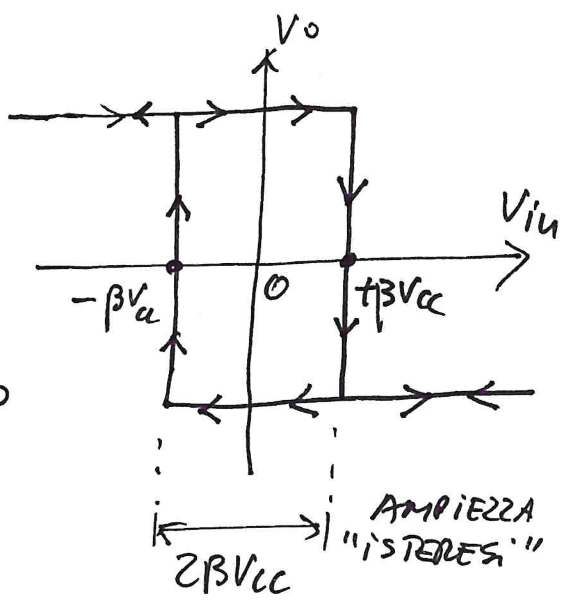
↳ $v^+ = (-V_{cc}) \dfrac{R_1}{R_1+R_2}$ ($\to v^+$ "segue" V_o!)

▣ Condizione di scatto a $(+V_{cc})$:

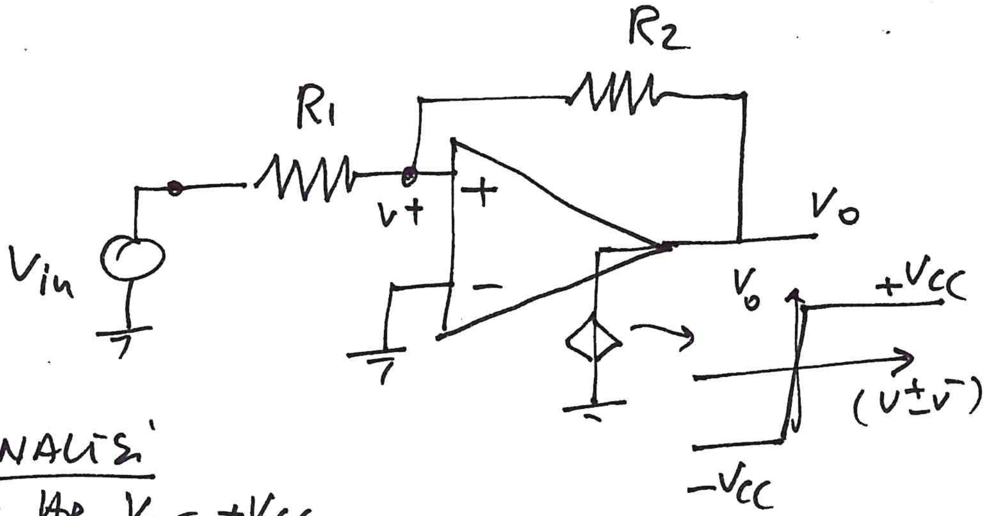
$(v^+ - v^-) = (v^+ - V_{in}) \geq 0$

$\Rightarrow \boxed{V_{in}} \leq v^+ = (-V_{cc}) \dfrac{R_1}{R_1+R_2} = \boxed{-\beta V_{cc}}$

SOGLIA DI SCATTO A $(+V_{cc})$



□ TdS non-invertente



<u>ANALISI</u>

□ <u>Ip.</u> $V_o = +V_{cc}$

↳ $V^+ = V_{in}\frac{R_2}{R_1+R_2} + \underbrace{\boxed{V_o}}_{=V_{cc}}\frac{R_1}{R_1+R_2} = V_{in}\frac{R_2}{R_1+R_2} + V_{cc}\frac{R_1}{R_1+R_2}$

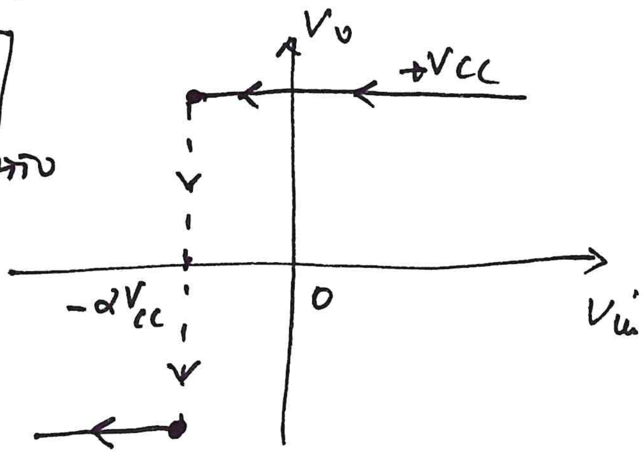
▪ verifica Ip. $V_o = V_{cc}$:

$(V^+ - V^-) \geq 0 \rightarrow V_{in}\frac{R_2}{\cancel{R_1+R_2}} + V_{cc}\frac{R_1}{\cancel{R_1+R_2}} \geq 0 \rightarrow V_{in} \geq -\overset{\alpha}{\boxed{\frac{R_1}{R_2}}}V_{cc}$

▪ Condizione di scatto a $V_o = -V_{cc}$:

$(V^+ - V^-) \leq 0 \rightarrow \boxed{V_{in} \leq -\alpha V_{cc}}$

<u>SOGLIA DI SCATTO</u>



▪ Ora <u>$V_o = -V_{cc}$</u>

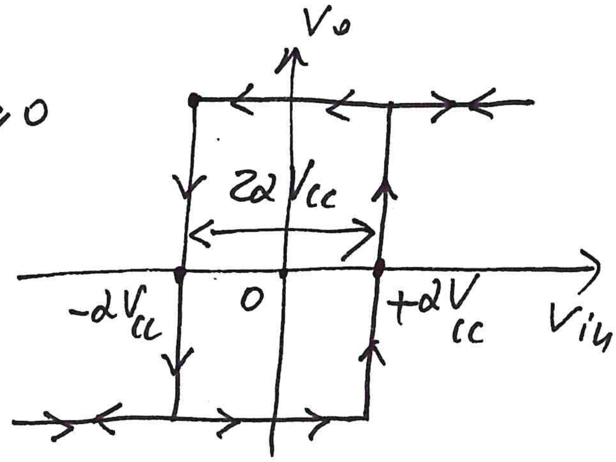
↳ $V^+ = V_{in}\frac{R_2}{R_1+R_2} - V_{cc}\frac{R_1}{R_1+R_2}$

▪ Condizione di scatto a $(+V_{cc})$:

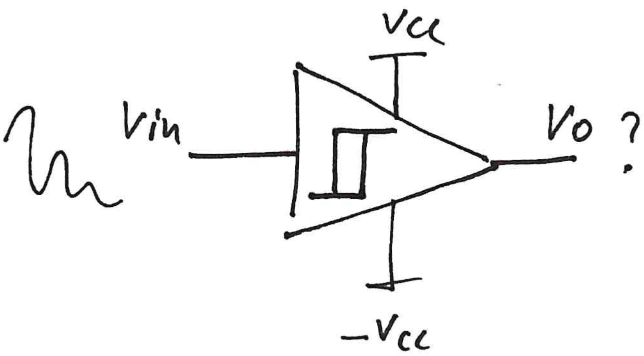
$(V^+ - V^-) \geq 0 \rightarrow V_{in}\frac{R_2}{\cancel{R_1+R_2}} - V_{cc}\frac{R_1}{\cancel{R_1+R_2}} \geq 0$

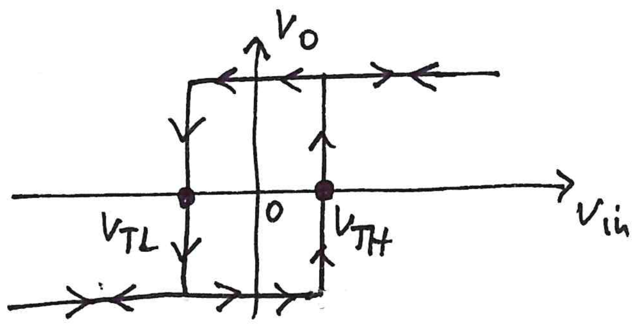
$\Rightarrow V_{in} \geq \overset{=\alpha}{\boxed{\frac{R_1}{R_2}}}V_{cc} = +\alpha V_{cc}$

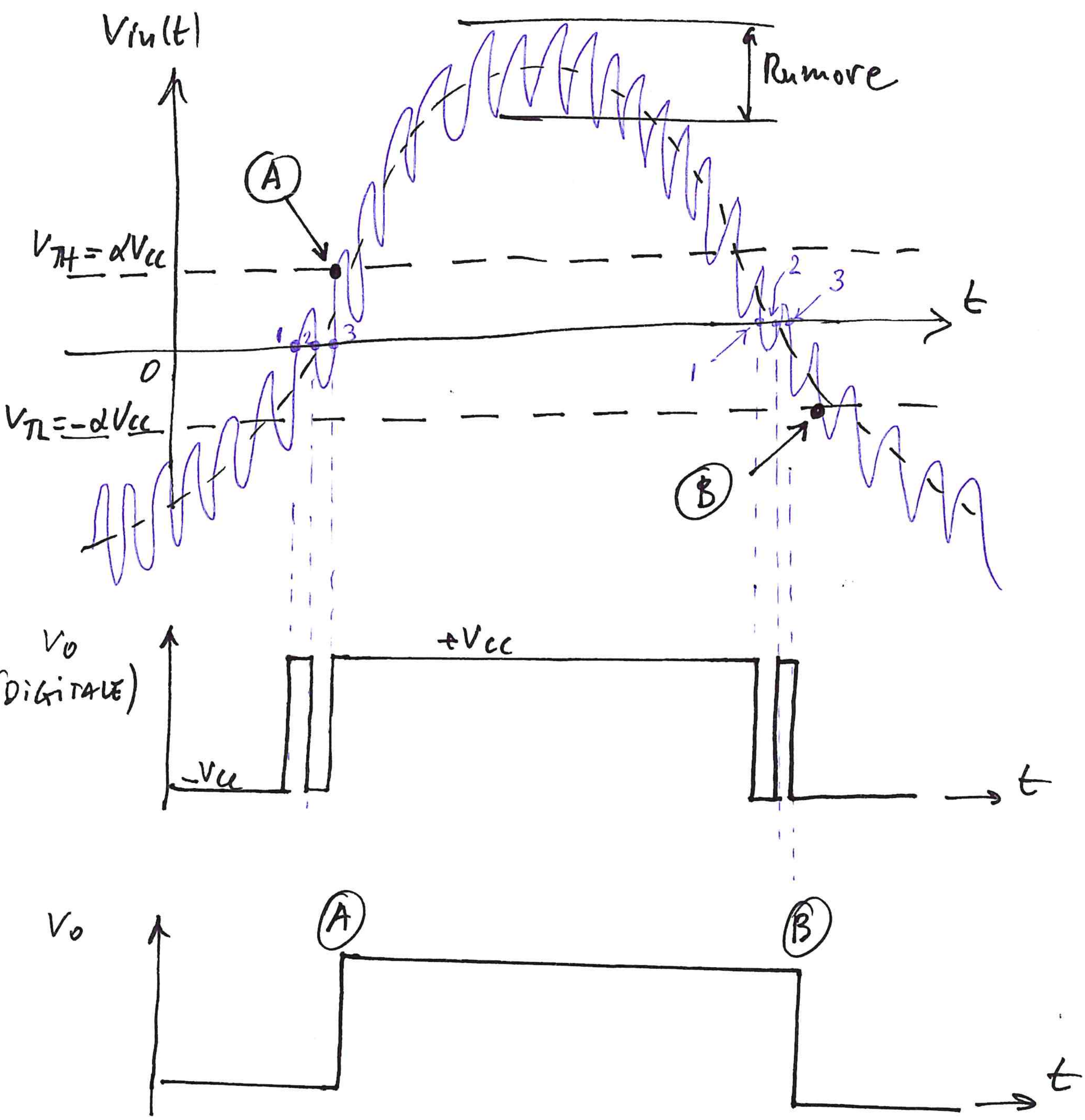
<u>SOGLIA DI SCATTO</u>



☐ APPLICAZIONE: COMPARATORE CON "ISTERESI"

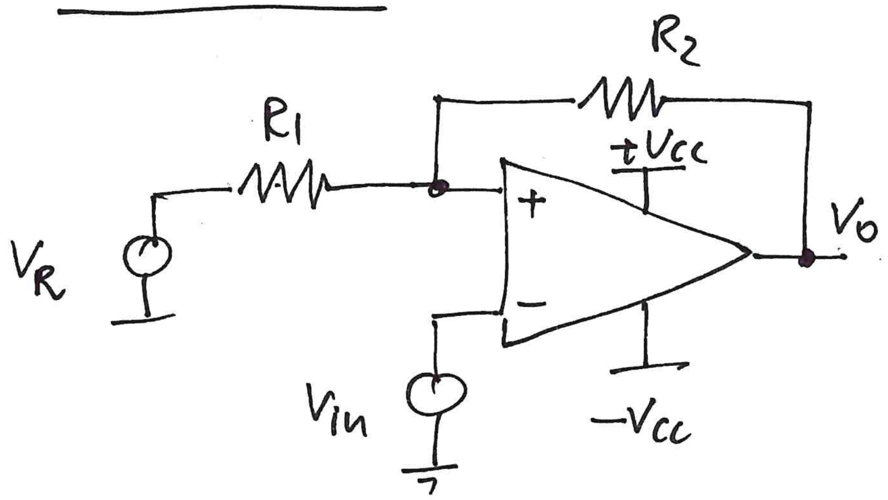


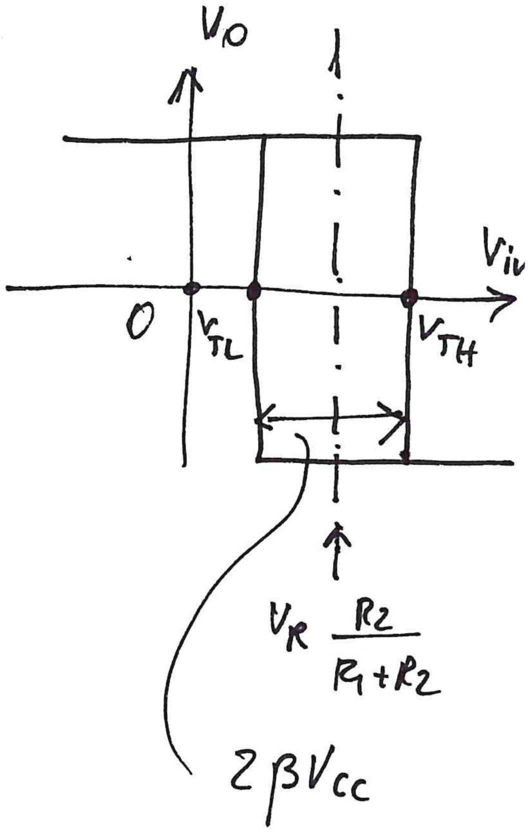




☑ SCEGLIERE AMPIEZZA DELL'ISTERESI $(V_{TH} - V_{TL}) >$ RUMORE
Per evitare commutazioni spurie.

□ TdS invertente con tensione di riferimento V_R





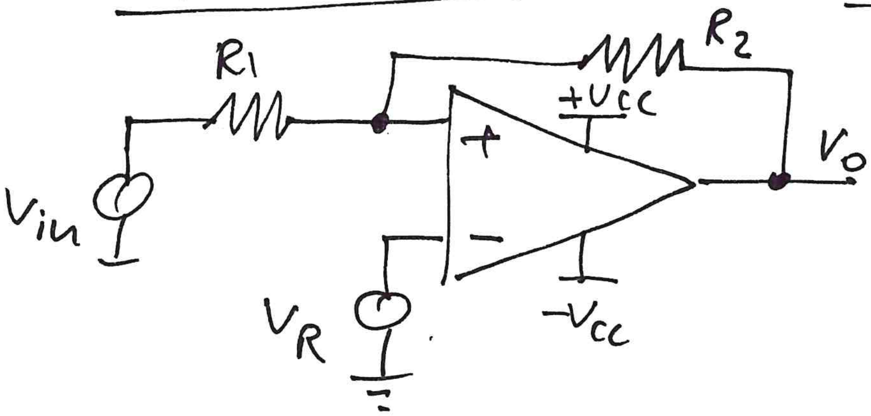
$$V_{TH} = V_R \frac{R_2}{R_1+R_2} + V_{cc}\frac{R_1}{R_1+R_2}$$

$$V_{TL} = V_R \frac{R_2}{R_1+R_2} - V_{cc}\frac{R_1}{R_1+R_2}$$

$$(V_{TH} - V_{TL}) = 2\, V_{cc} \overbrace{\frac{R_1}{R_1+R_2}}^{=\beta} = 2\beta V_{cc}\,.$$

$$\frac{V_{TH}+V_{TL}}{2} = V_R \cdot \frac{R_2}{R_1+R_2}$$

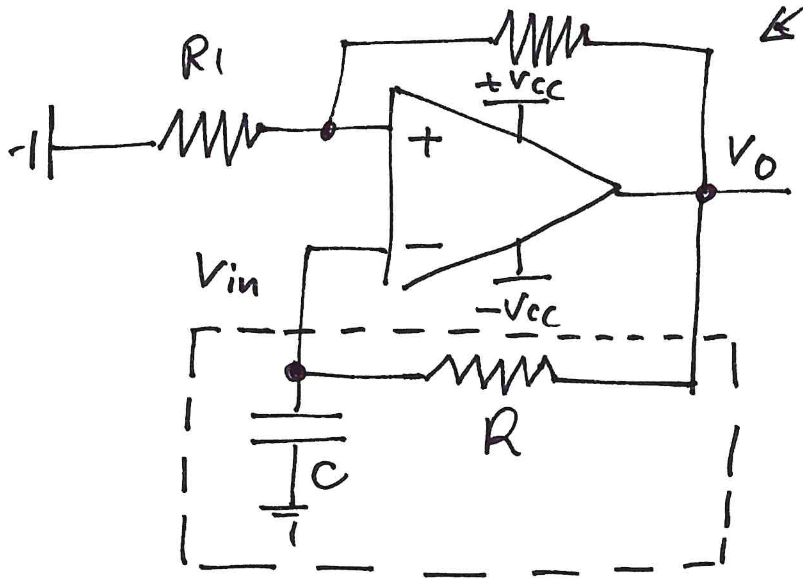
▷ TdS non invertente con tensione V_R

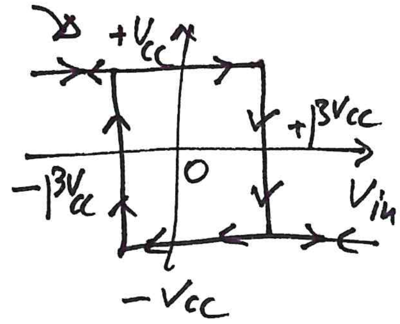


$V_{TH} = ?$

$V_{TL} = ?$

OSCILLATORE A RILASSAMENTO (ASTABILE)

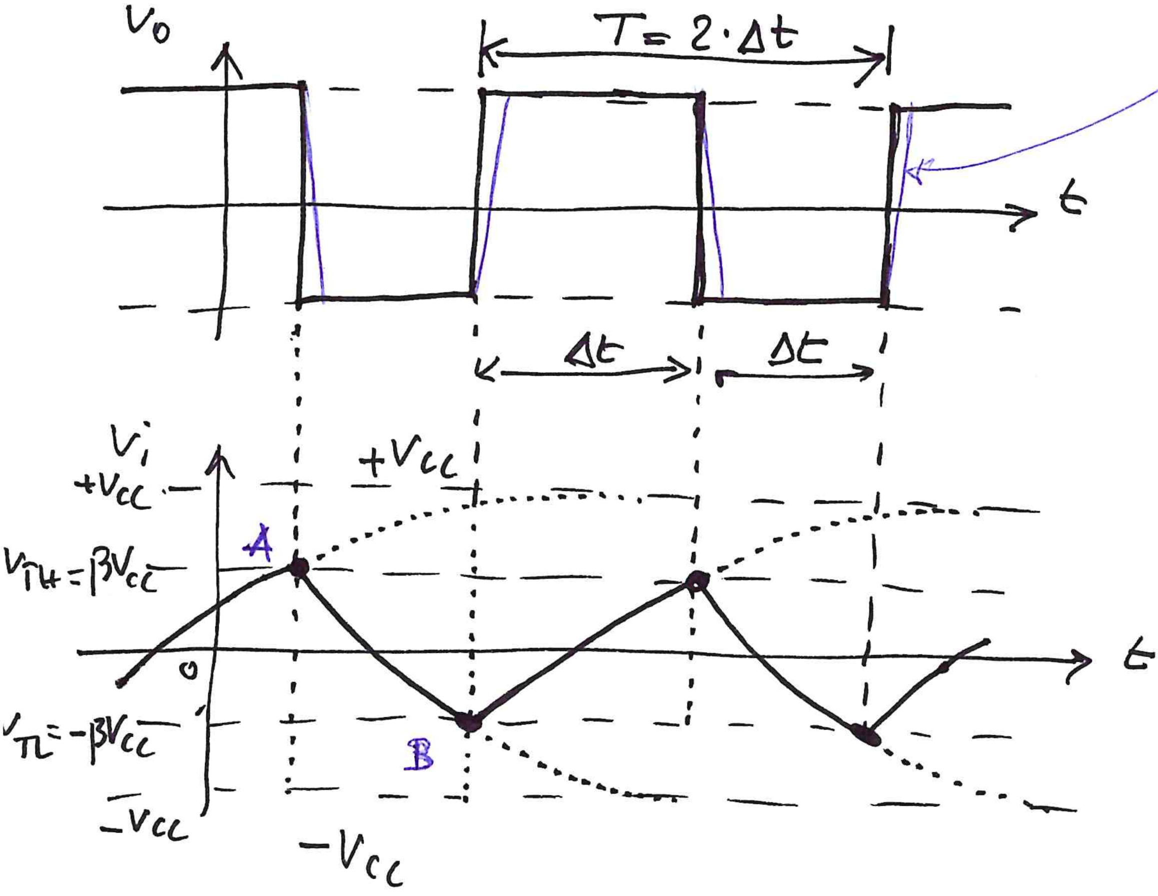




ANALISI

Hp. $V_0 = +V_{cc}$ → $V^+ = V_0 \frac{R_1}{R_1+R_2} = V_{cc} \frac{R_1}{R_1+R_2} = \beta V_{cc}$

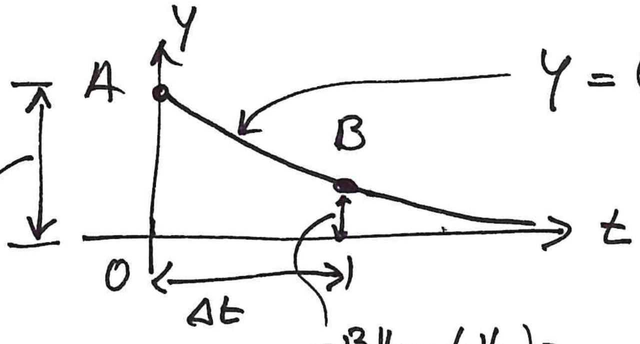
→ C si carica verso V_{cc} con $\tau = RC$



Limitazioni di SR in $V_0(t)$!

III Calcolo Δt (tratto esponenziale)

Per il calcolo scrivo l'eq. del tratto esponenziale AB discendente (ad. es.), riferendo la comodità il livello a regime a $\emptyset$ (traslazione rigida).



$$y = (1+\beta)V_{cc} \cdot e^{-t/\tau}$$

$\beta V_{cc} - (-V_{cc}) = (1+\beta)V_{cc}$

$-\beta V_{cc} - (-V_{cc}) = (1-\beta)V_{cc}$

passaggio per B:

$$(1+\beta)\cancel{V_{cc}}\, e^{-\Delta t/\tau} = (1-\beta)\cancel{V_{cc}}$$

$$\hookrightarrow e^{-\Delta t/\tau} = \frac{1-\beta}{1+\beta}$$

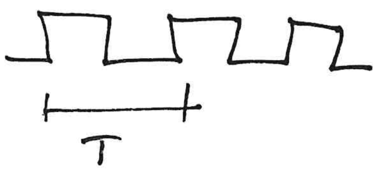
$$\hookrightarrow \Delta t = \tau \ln\left(\frac{1+\beta}{1-\beta}\right)$$

$$\Rightarrow T = 2 \cdot \Delta t = 2 \underbrace{(RC)}_{\tau} \ln\left(\frac{1+\beta}{1-\beta}\right)$$

↳ T variabile con $\tau = RC$ ($T \doteq RC$)

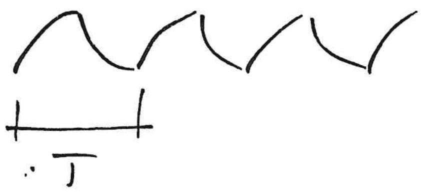
↳ T debolm. variab. con $\beta = \frac{R_1}{R_1+R_2}$

↳ forma d'onda "quadra"



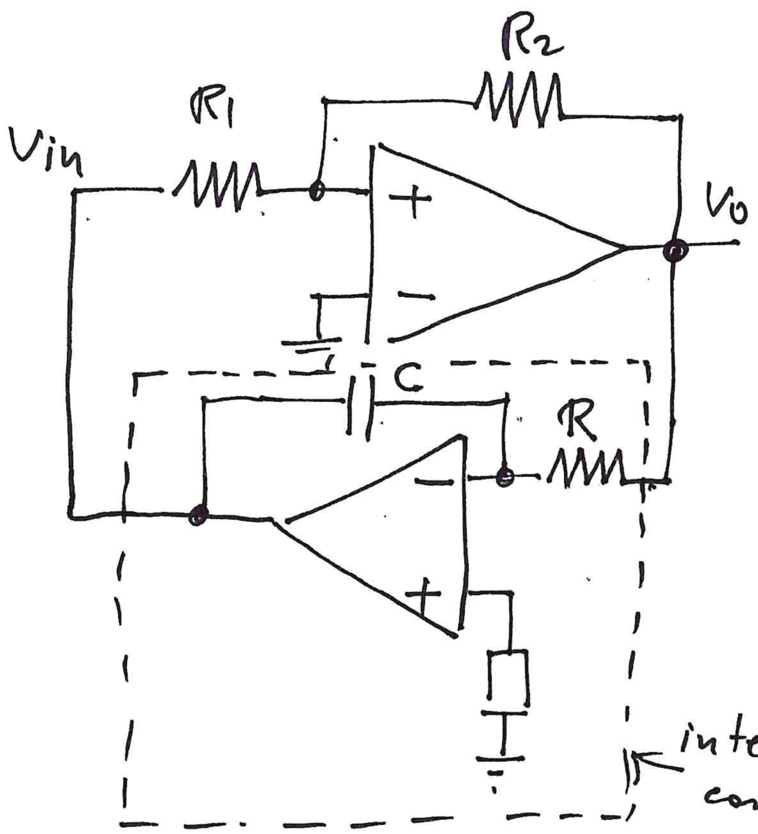
$f = \frac{1}{T}$ $V_o(t)$

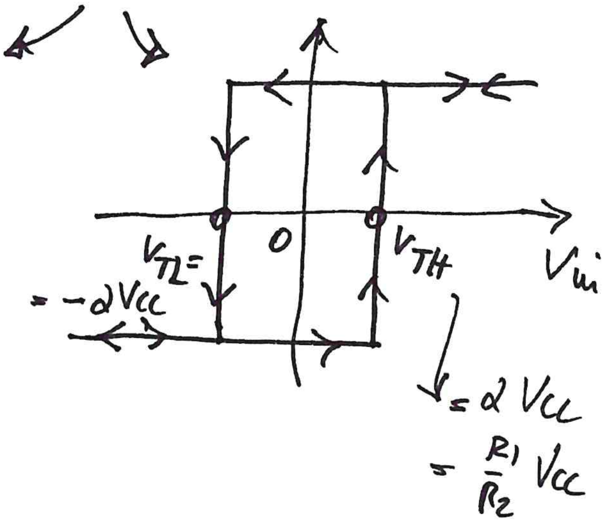
↳ forma d'onda "triang. approx"



$V_i(t)$

GENERATORE ONDA QUADRA E ONDA TRIANGOLARE

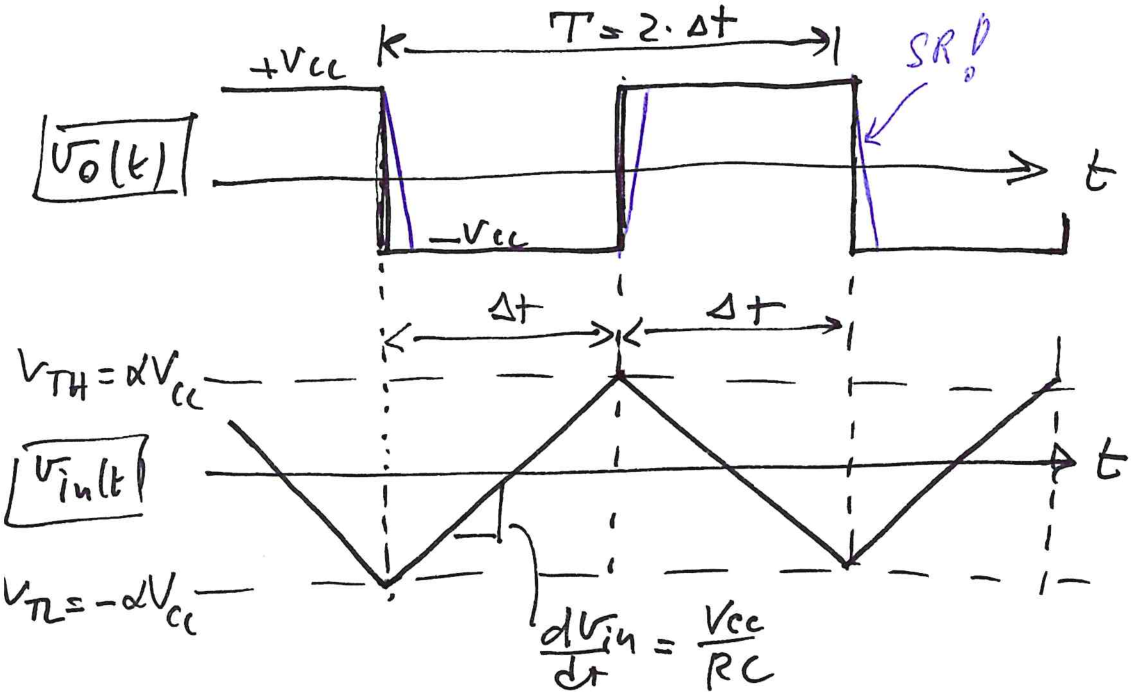




- integratore ideale: $V_{in} = -\frac{1}{sRC} V_0$

↳ $V_{in}(t) - V_{in}(t_0) = -\frac{1}{RC}\int_{t_0}^{t} \underbrace{V_0}_{=\pm V_{CC}}\,dt = \mp V_{CC}\frac{(t-t_0)}{RC}$

↳ $\frac{dV_{in}}{dt} = \mp \frac{V_{CC}}{RC}$



- $\Delta t = \frac{(V_{TH} - V_{TL})}{dV_{in}/dt} = \frac{2\alpha V_{CC}}{V_{CC}/RC} = \boxed{2\alpha RC}$

↳ $T = 2\Delta t = 4\alpha RC$

- limitazioni di SR in $V_0(t)$.

Otto Schmitt (1913-1998)

- Otto Shmitt was a prolific intellectual creator with over 60 patents and more than 300 scientific and technical publications produced during his lifespan. In addition, he left an enormous amount of manuscripts, letters, and equipment of different types.
- Before he turned 22, he already wanted to offer a theory of nerve impulse propagation. The subject inspired his doctoral dissertation titled "An Electrical Theory of Nerve Impulse Propagation" presented to the Departments of Physics and Zoology, Washington University, Saint Louis, Missouri, in June 1937.
- Such interest marked the invention and beginning of a device that turned out to become far-reaching in applications.

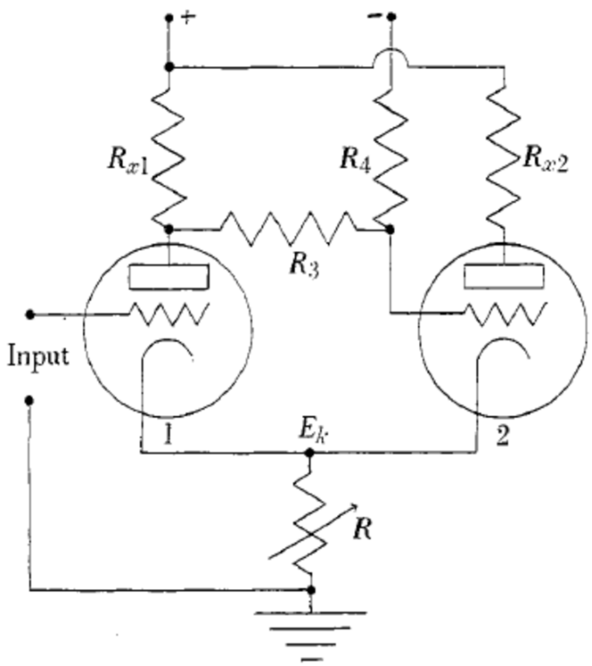
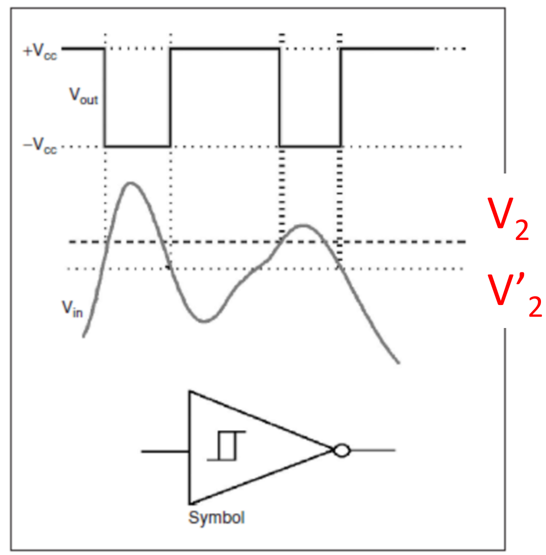


Fig. 1. Thermionic trigger circuit

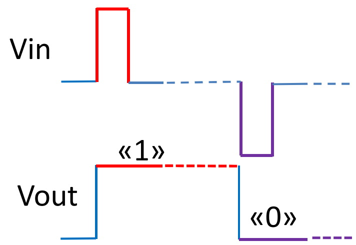


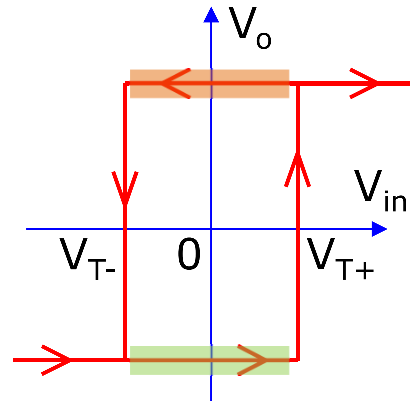
M. E. Valentinuzzi, IEEE Engineering in Medicine and Biology Magazine nov/dec 2004

When the signal crosses upwards of the V2 level, the circuit switches. When it crosses below the V'2 threshold, it switches back. Changes kept always above V2 or below V'2 are not "seen" by the circuit.

Applications of the Schmitt trigger

- typically used in open loop configurations for *noise immunity* and closed loop configurations to implement *function generators*.
- **Analog to digital conversion:** 1 bit A/D converter.
- **1 bit memory:** bistable circuit





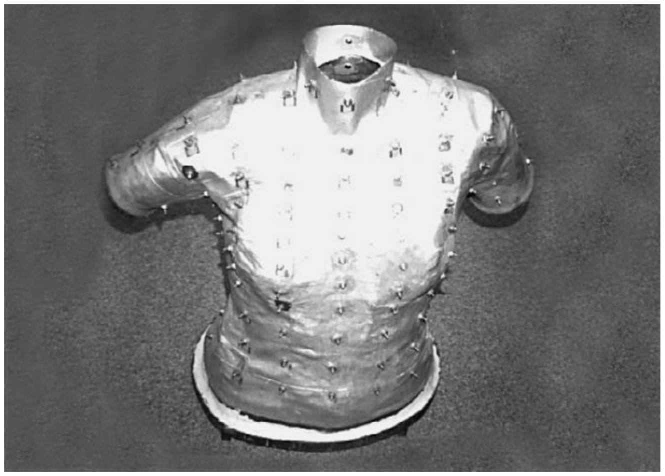
Otto Schmitt had many other interests…..

Elettrophysiology

- The trigger intended to model the membrane behavior. Otto aimed at a synthetic nerve, hoping to solve the equations of such circuit in order to understand the physiological response.
- The propagation of the action potential ended in many publications, some of them with Nobel Prize winner Bernard Katz.

Electromagnetics

- Electromagnetic fields and their possible actions on biological tissues were also a matter of his research.
- In one article we read, "I vividly remember accidentally demonstrating the visual *magnetophosphenes* on myself many years ago by accidentally exciting a Helmholtz coil in which I had stuck my head to examine a vacuum system with full line voltage on a coil wound for excitation at 1.5 V….."



A human torso, modeled after his wife Viola's, used by Otto to make ***electrocardiographic measurements.*** *(Courtesy of The Bakken Museum, Minneapolis, Minnesota.)*