

Altri argomenti riguardanti gli Amplificatori operazionali

*Corso di Metodi di Trattamento del
Segnale*

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1. Analisi statica

il guadagno dell'OP-AMP è dato dalla pendenza di questa curva. Il guadagno si annulla quando l'OP-AMP va in saturazione (la tensione di uscita raggiunge la tensione di alimentazione)

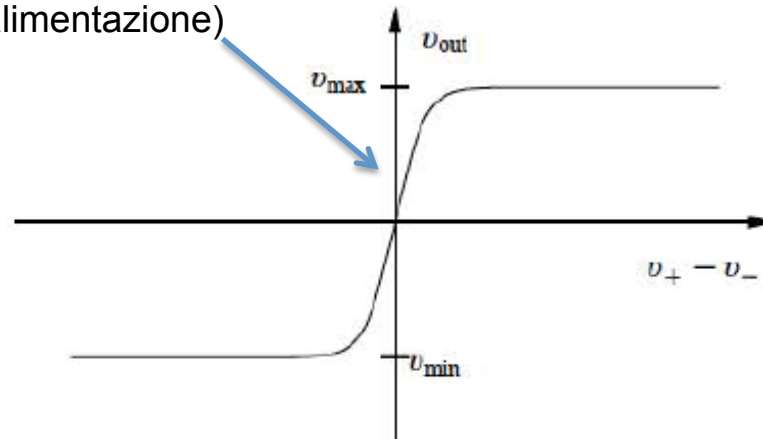


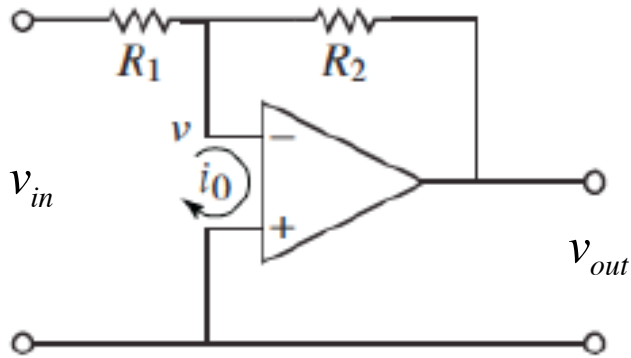
Figure 3.8: Input/output characteristics of an operational amplifier. The differential input is given by $v_+ - v_-$. The output voltage is a linear function of the input in a small range around 0, with saturation at v_{min} and v_{max} . In the linear regime the op amp has high gain.

$$\text{sat}(x; a, b) = \begin{cases} a & x < a \\ x & a \leq x \leq b \\ b & x > b \end{cases}$$

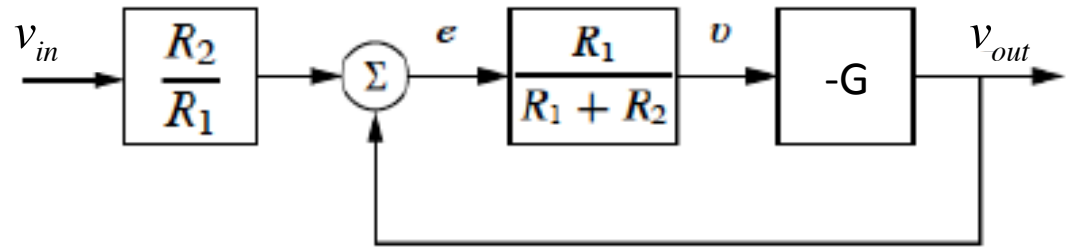


approssimazione spline della caratteristica di ingresso-uscita dell'OpAmp

analisi con guadagno infinito



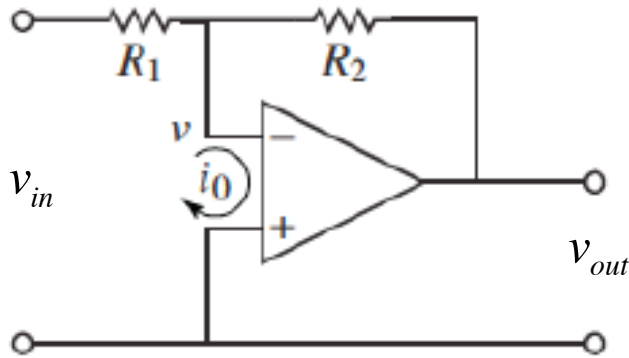
(a) Amplifier circuit



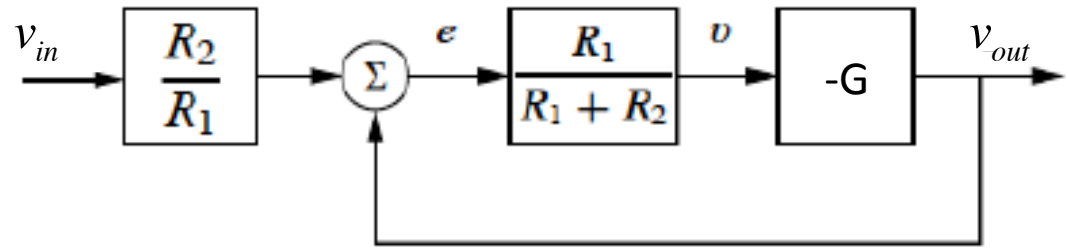
(b) Block diagram

$$v \approx 0; \quad I_1 = \frac{v_{in}}{R_1}; \quad I_2 = \frac{v_{out}}{R_2}; \quad I_1 + I_2 \approx 0 \quad \Rightarrow \quad v_{out} = -\frac{R_2}{R_1} v_{in}$$

analisi con guadagno finito



(a) Amplifier circuit

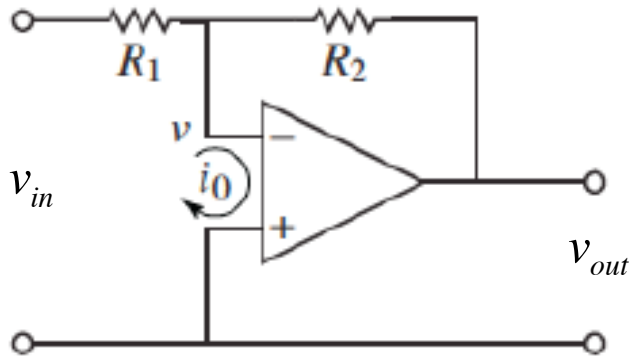


(b) Block diagram

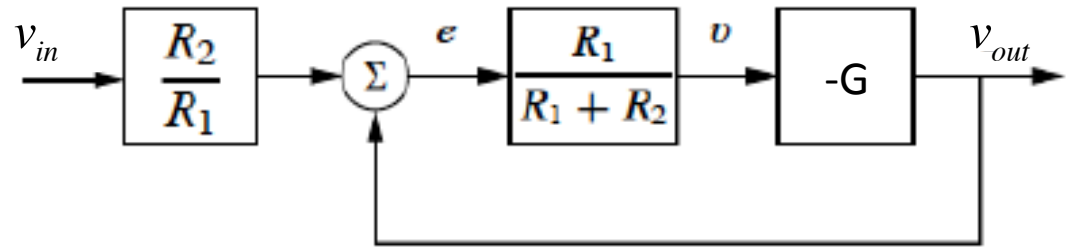
$$I_1 = \frac{v_{in} - v}{R_1}; \quad I_2 = \frac{v_{out} - v}{R_2}; \quad I_1 + I_2 \approx 0; \quad v_{out} = -Gv$$

$$\Rightarrow \frac{v_{in}}{R_1} + \frac{v_{out}}{R_2} = \frac{R_1 + R_2}{R_1 R_2} v \quad \Rightarrow \quad v = \frac{R_1}{R_1 + R_2} \left(\frac{R_2}{R_1} v_{in} + v_{out} \right)$$

analisi con guadagno finito (cont.)



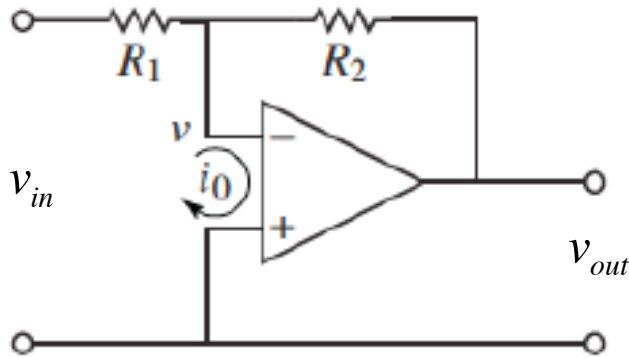
(a) Amplifier circuit



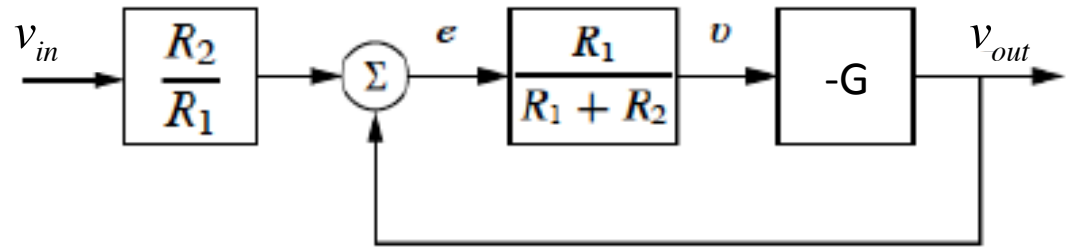
(b) Block diagram

$$v_{out} = -\frac{R_2}{R_1} \left(\frac{R_1 G}{R_1 G + R_1 + R_2} \right) v_{in}$$

2. dinamica degli op-amp



(a) Amplifier circuit



(b) Block diagram

Espansione in serie

$$v_{out}(t + \Delta t) \approx v_{out}(t) + \frac{dv_{out}}{dt} \Delta t$$

Tempo di propagazione attraverso l'OpAmp

$$= \alpha v_{out}(t) - \beta v(t)$$

Descrizione del feedback



$$\begin{aligned} \frac{dv_{out}}{dt} &= -\frac{1-\alpha}{\Delta t} v_{out}(t) - \frac{\beta}{\Delta t} v(t) \\ &= -\frac{1}{\tau} v_{out}(t) - bv(t) \\ &= -Bv_{out}(t) - bv(t) \end{aligned}$$

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\frac{dv_{out}}{dt} &= -\frac{1-\alpha}{\Delta t} v_{out}(t) - \frac{\beta}{\Delta t} v(t) \\
&= -\frac{1}{\tau} v_{out}(t) - bv(t) \\
&= -Bv_{out}(t) - bv(t)
\end{aligned}$$

nel caso statico $v_{out} = -b\tau v = -\frac{b}{B} v = -Gv$

B è l'inverso di un tempo caratteristico e corrisponde quindi ad una frequenza caratteristica e inoltre $b = BG = \text{gain-bandwidth product (GBP)}$

Inoltre, da

$$\frac{dv_{out}}{dt} = -Bv_{out}(t) - bv(t) = -Bv_{out}(t) - BGv(t)$$

si trova anche

$$\begin{aligned} v(t) &= -\frac{1}{G} \left(v_{out}(t) + \tau \frac{dv_{out}}{dt} \right) \\ &= -\frac{\tau}{G} \left(Bv_{out}(t) + \frac{dv_{out}}{dt} \right) = -\frac{1}{BG} e^{-Bt} \frac{d}{dt} \left(e^{Bt} v_{out}(t) \right) \end{aligned}$$

e quindi

$$v_{out}(t) = -BGe^{-Bt} \int_0^t e^{Bt'} v(t') dt' = -BG \int_0^t e^{-B(t-t')} v(t') dt'$$

Rianalisi dell'amplificatore invertente con il modello dinamico appena trovato

$$I_1 = \frac{v_{in} - v}{R_1}; \quad I_2 = \frac{v_{out} - v}{R_2}; \quad I_1 + I_2 \approx 0;$$

$$v(t) = -\frac{1}{BG} \left(Bv_{out}(t) + \frac{dv_{out}}{dt} \right)$$

$$\Rightarrow \frac{v_{in}}{R_1} + \frac{v_{out}}{R_2} = \frac{R_1 + R_2}{R_1 R_2} v = -\frac{1}{BG} \left(\frac{R_1 + R_2}{R_1 R_2} \right) \left(Bv_{out}(t) + \frac{dv_{out}}{dt} \right)$$

$$\Rightarrow v_{in} = -\left[\frac{R_1}{R_2} + \frac{R_1 + R_2}{GR_2} \right] v_{out} - \frac{R_1 + R_2}{BGR_2} \frac{dv_{out}}{dt}$$

Ponendo

$$\gamma\delta = \frac{R_1}{R_2} + \frac{R_1 + R_2}{GR_2}; \quad \delta = \frac{R_1 + R_2}{BGR_2}$$

si trova

$$v_{in} = -\gamma\delta v_{out} - \delta \frac{dv_{out}}{dt} = -\delta \left(\gamma v_{out} + \frac{dv_{out}}{dt} \right) = -\delta e^{-\gamma t} \frac{d}{dt} \left(e^{\gamma t} v_{out} \right)$$

e quindi

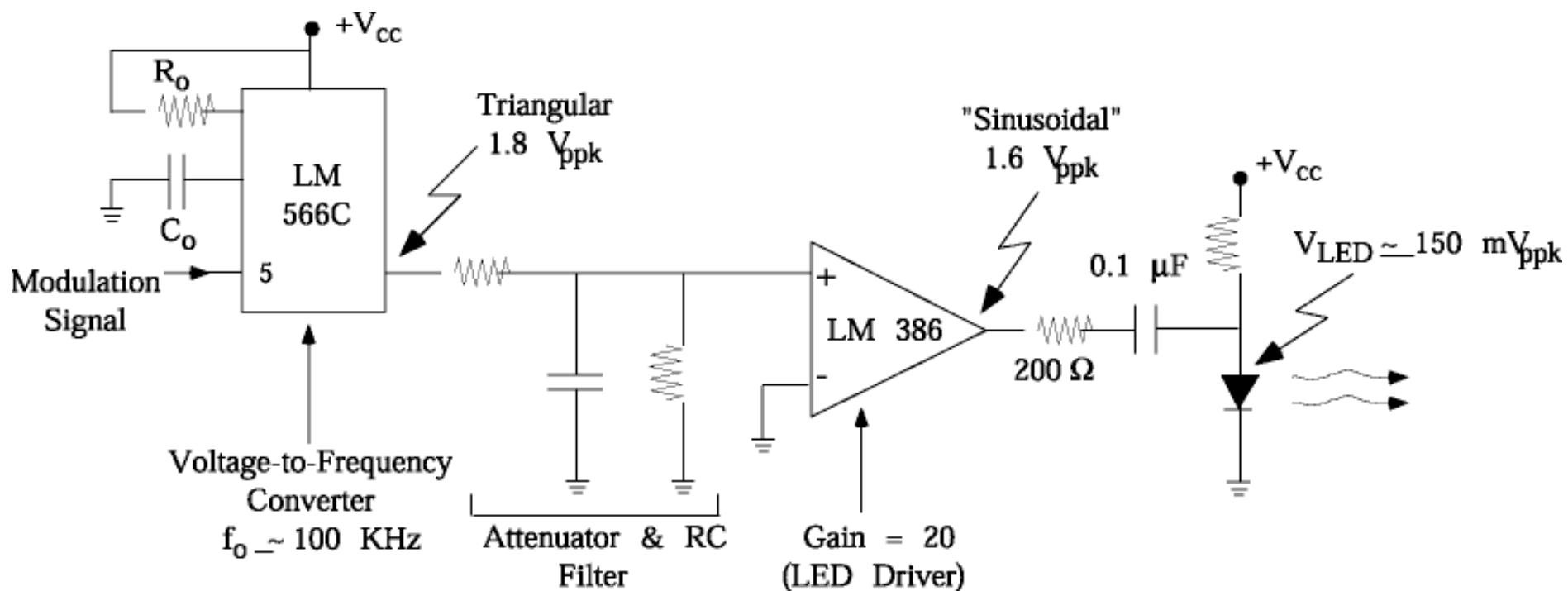
$$v_{out}(t) = v_{out}(0) - \frac{1}{\delta} \int_0^t e^{-\gamma(t-t')} v_{in}(t') dt'$$

quindi il circuito si comporta come un filtro RC passa basso con costante di tempo

$$\frac{1}{\gamma} = \frac{R_1 + R_2}{B(GR_1 + R_1 + R_2)}$$

3. TRASMISSIONE FM

Trasmettitore con modulazione FM



LM566C Voltage Controlled Oscillator

General Description

The LM566CN is a general purpose voltage controlled oscillator which may be used to generate square and triangular waves, the frequency of which is a very linear function of a control voltage. The frequency is also a function of an external resistor and capacitor.

The LM566CN is specified for operation over the 0°C to +70°C temperature range.

Features

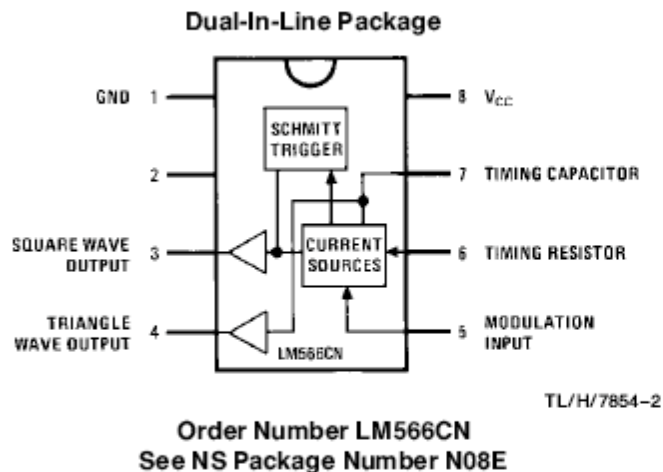
- Wide supply voltage range: 10V to 24V
- Very linear modulation characteristics

- High temperature stability
- Excellent supply voltage rejection
- 10 to 1 frequency range with fixed capacitor
- Frequency programmable by means of current, voltage, resistor or capacitor

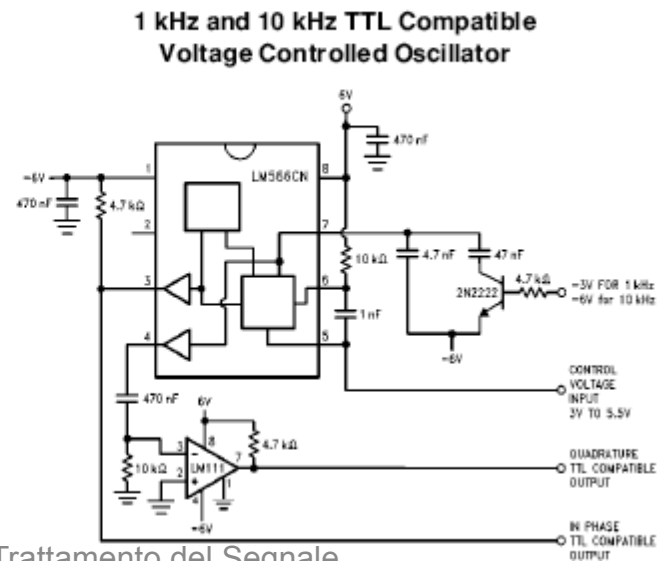
Applications

- FM modulation
- Signal generation
- Function generation
- Frequency shift keying
- Tone generation

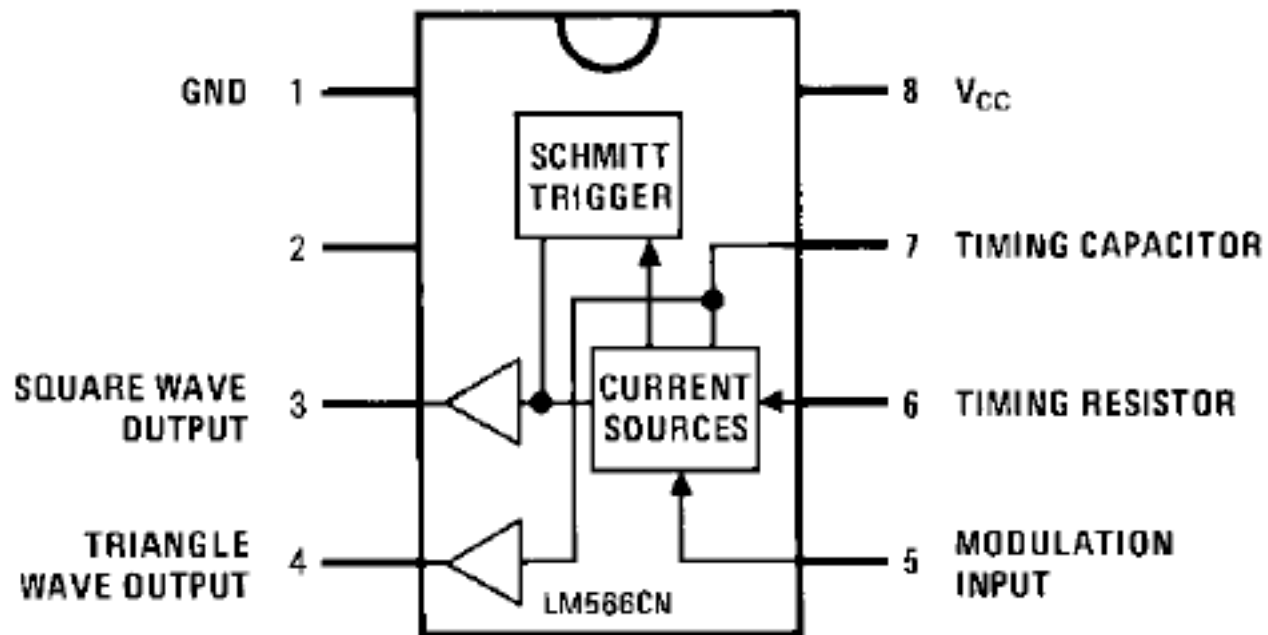
Connection Diagram



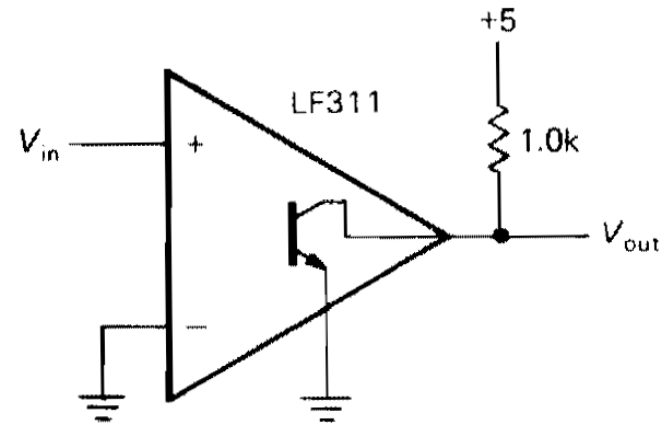
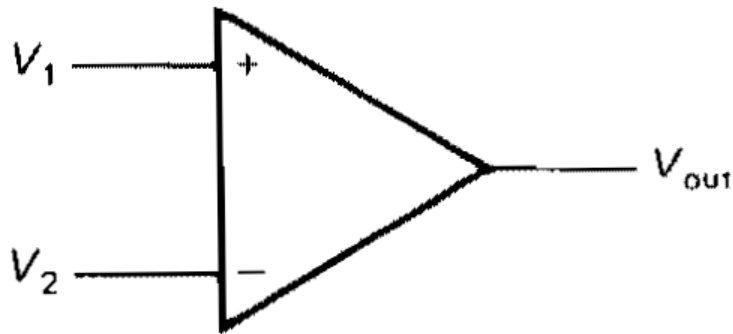
Typical Application



Dual-In-Line Package

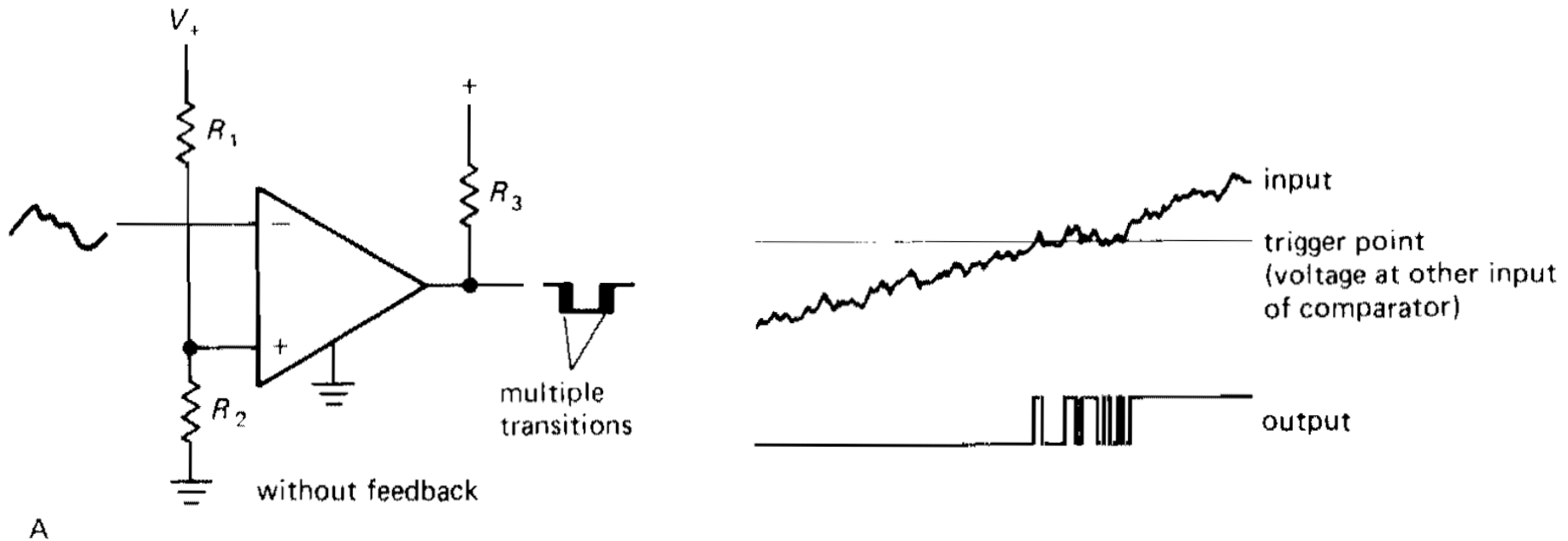


Il trigger di Schmitt: 1. comparatori



L' esempio più semplice di comparatore: un amplificatore differenziale ad alto guadagno (V_{out} corrisponde alla tensione di saturazione = $\pm V_{cc}$)

Il trigger di Schmitt: 2. comparatori



Comparatore con una rete di input che definisce il valore della tensione di soglia: in questo caso il rumore in prossimità della soglia rende instabile il passaggio dallo stato basso allo stato alto.

Il trigger di Schmitt: 3. feedback

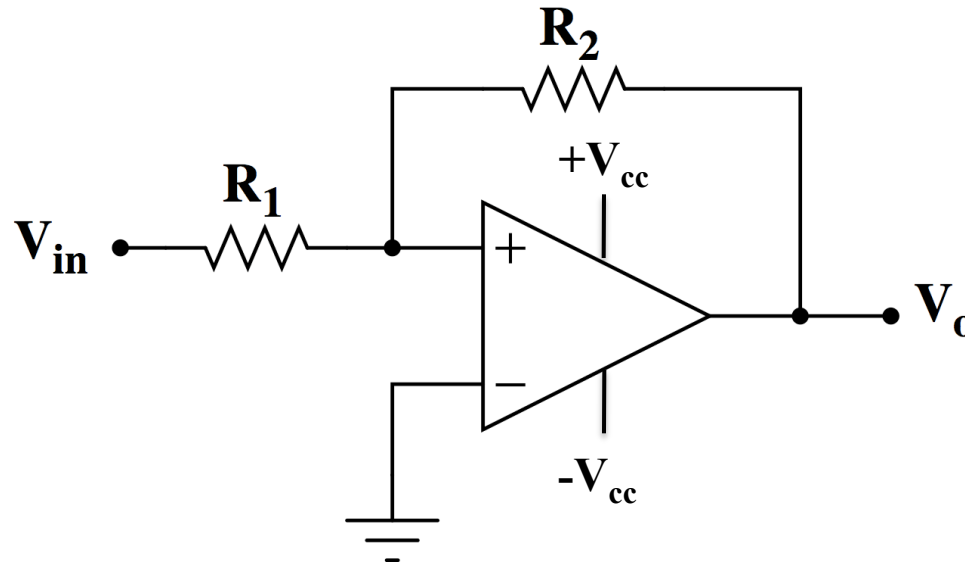
Il guadagno dell'amplificatore con feedback è dato genericamente da

$$G' = \frac{G}{1 - \alpha G} \rightarrow -\frac{1}{\alpha}$$

e quindi se G è molto alto, si trova – **sia nel caso di feedback negativo che di feedback positivo** – che il segnale all'ingresso dell'amplificatore diventa trascurabile

$$S_{in} + \alpha S_{out} \approx S_{in} + \alpha \left(-\frac{1}{\alpha} \right) S_{in} = 0$$

Il trigger di Schmitt: 4. comparatori con feedback positivo



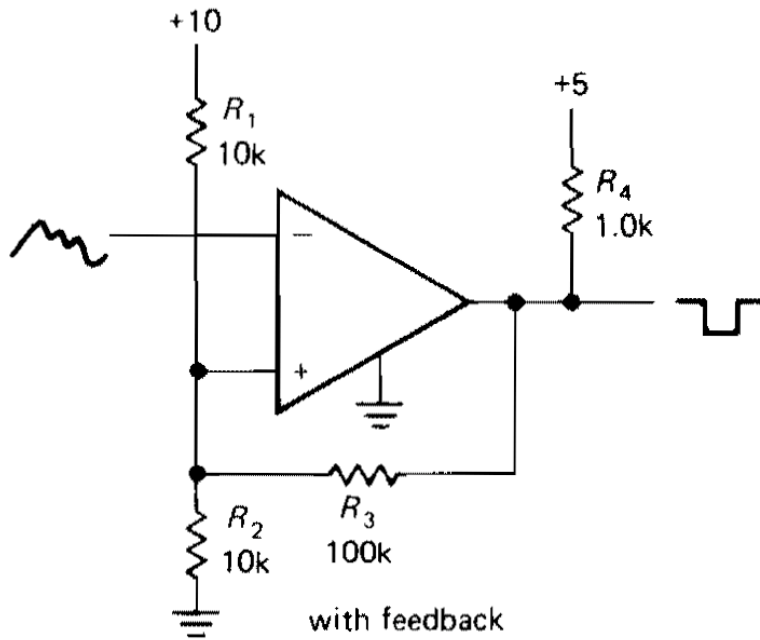
SE $V_o = V_{cc}$ (stato alto) allora V_{in} definisce la tensione di soglia in ingresso, con le correnti che sommano a 0

$$\frac{V_{in}}{R_1} + \frac{V_{cc}}{R_2} = 0 \quad \Rightarrow \quad V_{in} = -\frac{R_1}{R_2} V_{cc}$$

SE $V_o = -V_{cc}$ (stato basso) allora V_{in} definisce la tensione di soglia in ingresso, con le correnti che sommano a 0

$$\frac{V_{in}}{R_1} - \frac{V_{cc}}{R_2} = 0 \quad \Rightarrow \quad V_{in} = \frac{R_1}{R_2} V_{cc}$$

Il trigger di Schmitt: 5. comparatori con feedback positivo



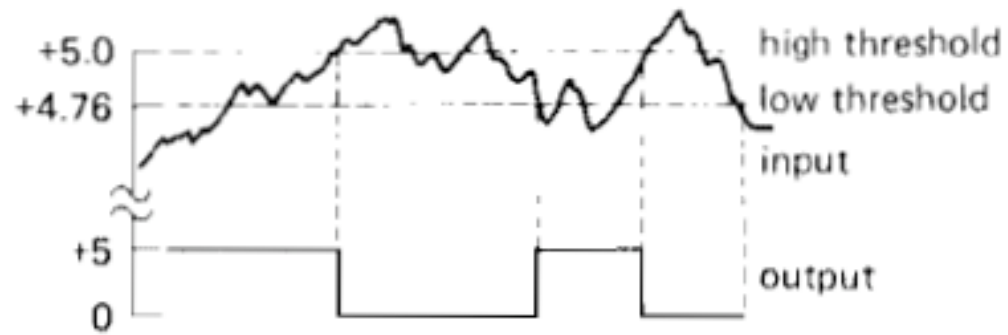
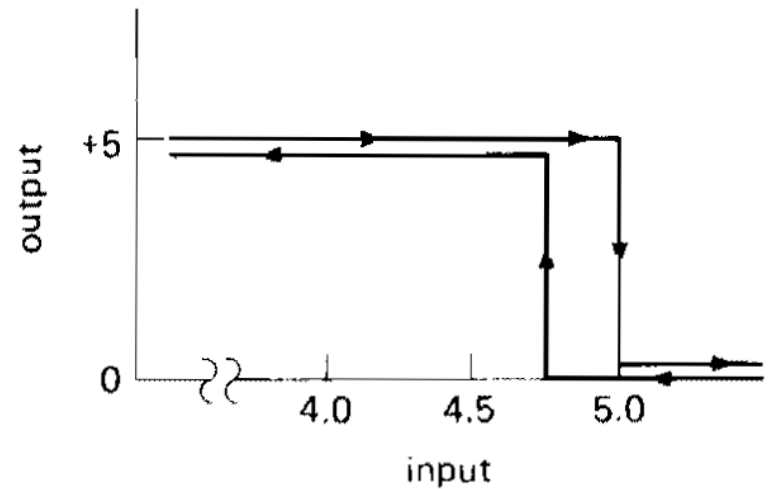
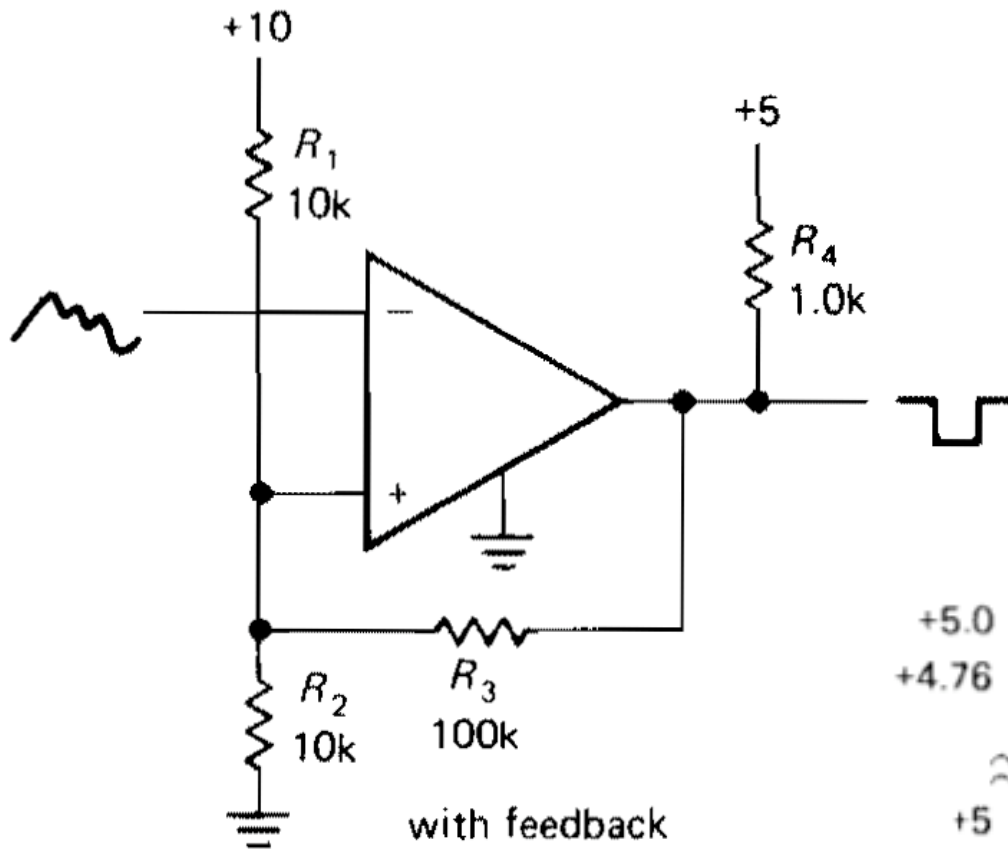
$$\text{SE } V_o = 5V \quad \frac{V_{in} - 10V}{R_1} + \frac{V_{in} - 5V}{R_3} + \frac{V_{in}}{R_2} = 0$$

$$V_{in} \left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_2} \right) = \left(\frac{10V}{R_1} + \frac{5V}{R_3} \right) \Rightarrow V_{in} = 5V$$

$$\text{SE } V_o = 0V \quad \frac{V_{in} - 10V}{R_1} + \frac{V_{in} - 5V}{R_3} + \frac{V_{in}}{R_2} = 0$$

$$V_{in} \left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_2} \right) = \left(\frac{10V}{R_1} + \frac{5V}{R_3} \right) \Rightarrow V_{in} = 4.762V$$

Il trigger di Schmitt: 5. comparatori con feedback positivo

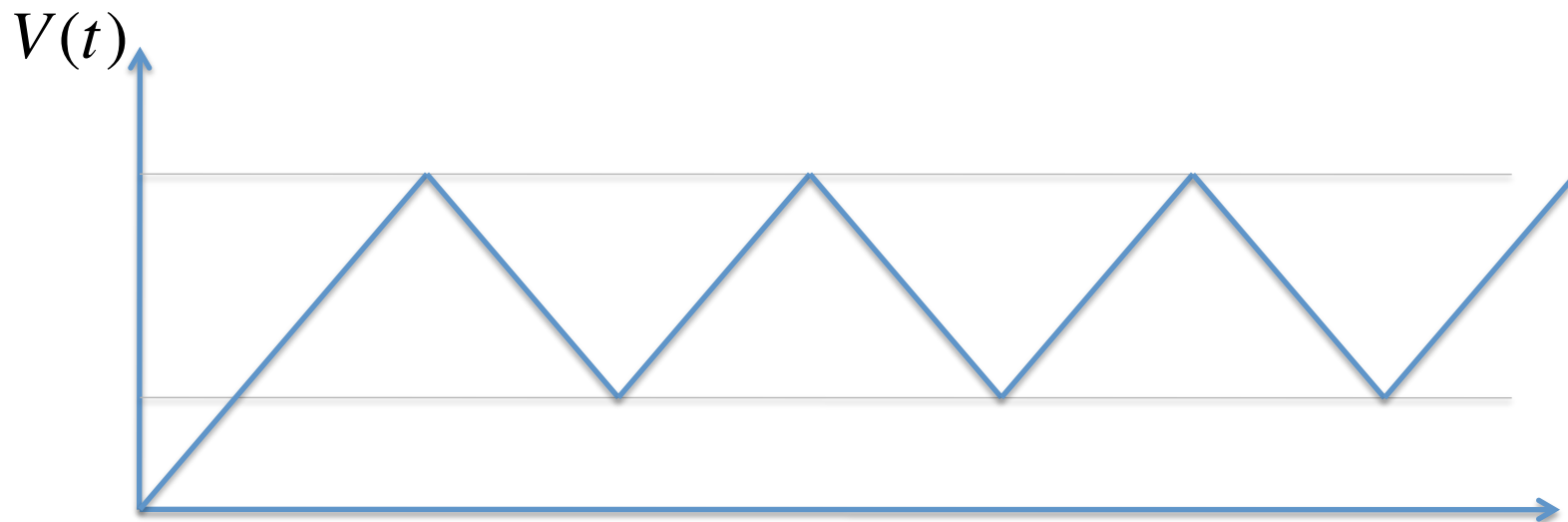


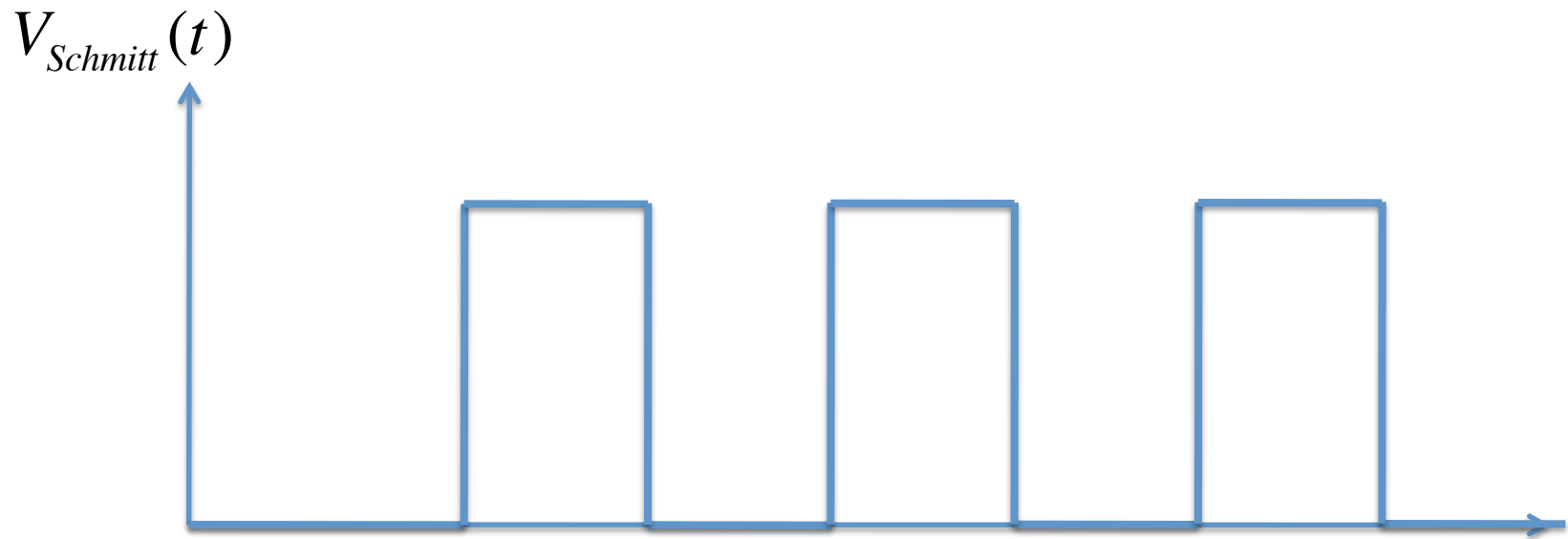
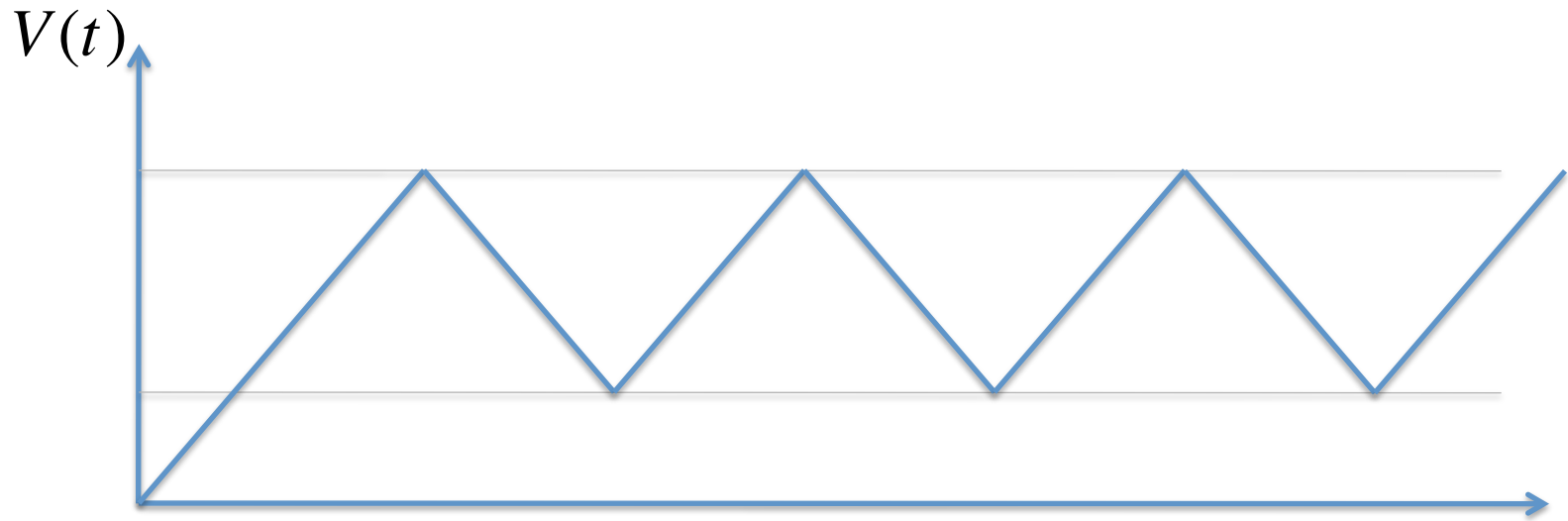
Sorgenti di corrente e condensatori

$$\frac{dQ}{dt} = \frac{1}{C} \frac{dV}{dt} = I_0 \quad \Rightarrow \quad \frac{dV}{dt} = I_0 C \quad \Rightarrow \quad V(t) = V_0 + I_0 C \cdot t$$

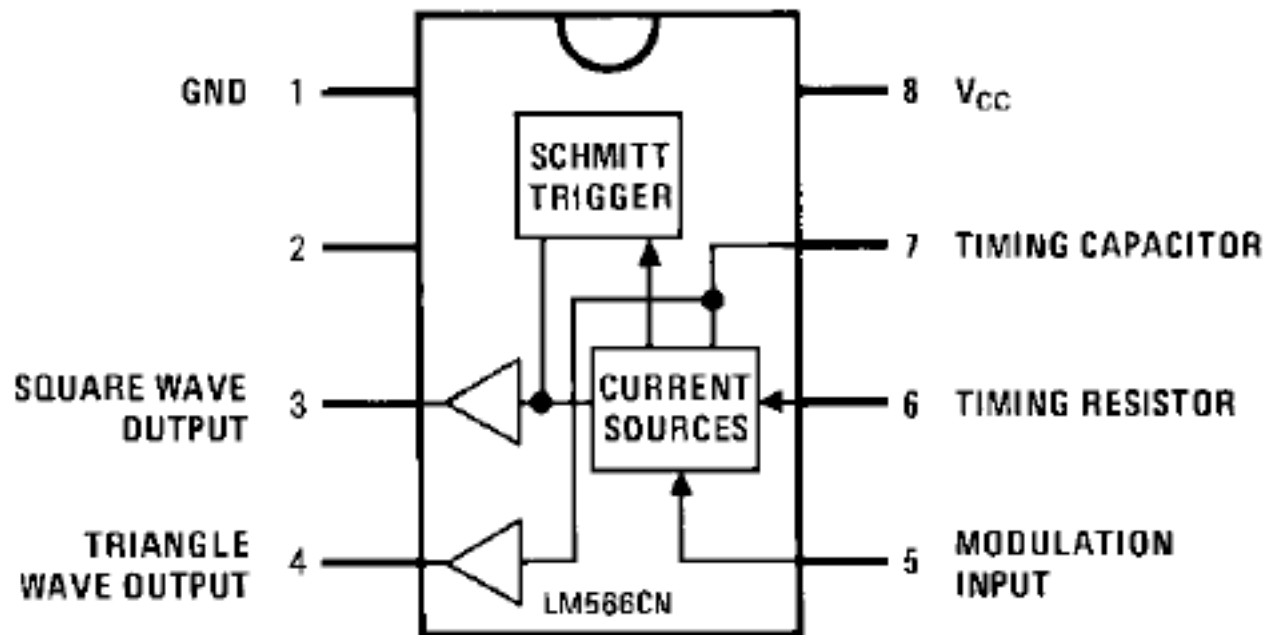
Qui supponiamo che l'uscita del trigger di Schmitt faccia cambiare la polarità della corrente quando vengono attraversate le soglie

Se I_0 dipende da V_{in} allora la frequenza dell'onda triangolare è funzione di V_{in}
Questo si può fare con un transistor





Dual-In-Line Package



Trasmittitore con modulazione FM

