Generatoare de semnale nesinusoidale

- semnale dreptunghiulare, triunghiulare, dinte de fierastrau, etc

Circuit basculante:

- **astabile** – nu au nicio stare stabila, durata fiecarei stari este predeterminata.

Trecerea dintr-o stare in alta se realizeaza automat fara existenta vreunui semnal de comanda

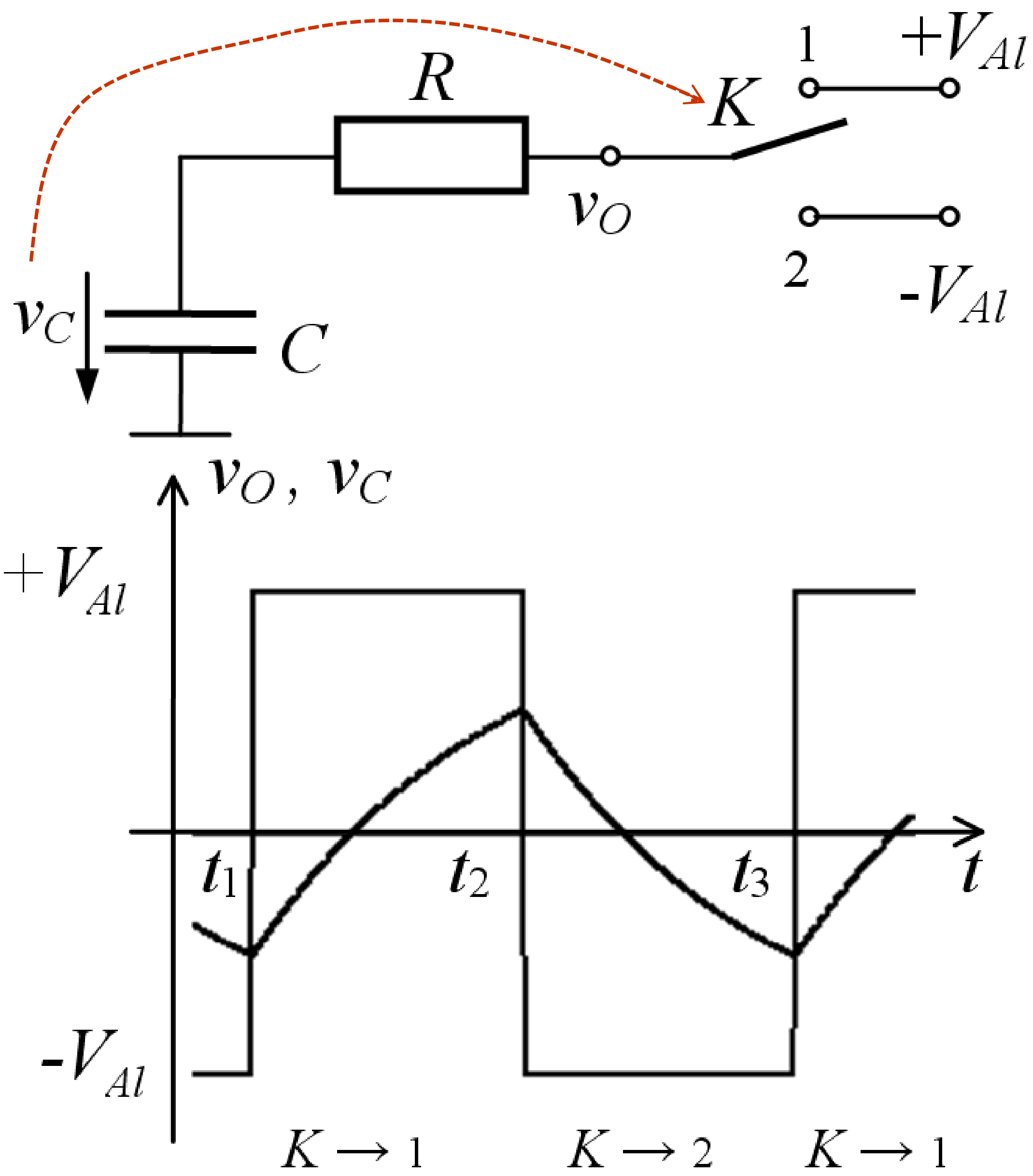
- monostabile – o stare stabila si o stare instabila

Trecerea din starea stabila in cea instabila se realizeaza sub actiunea unui semnal de comanda. Trecerea din starea instabila in cea stabila se realizeaza automat

- bistabile – doua stari stabile

Trecerea dintr-o stare in alta se realizeaza sub actiunea unui semnal de comanda

Circuite basculante astabile CBA (oscilatoare de relaxare)



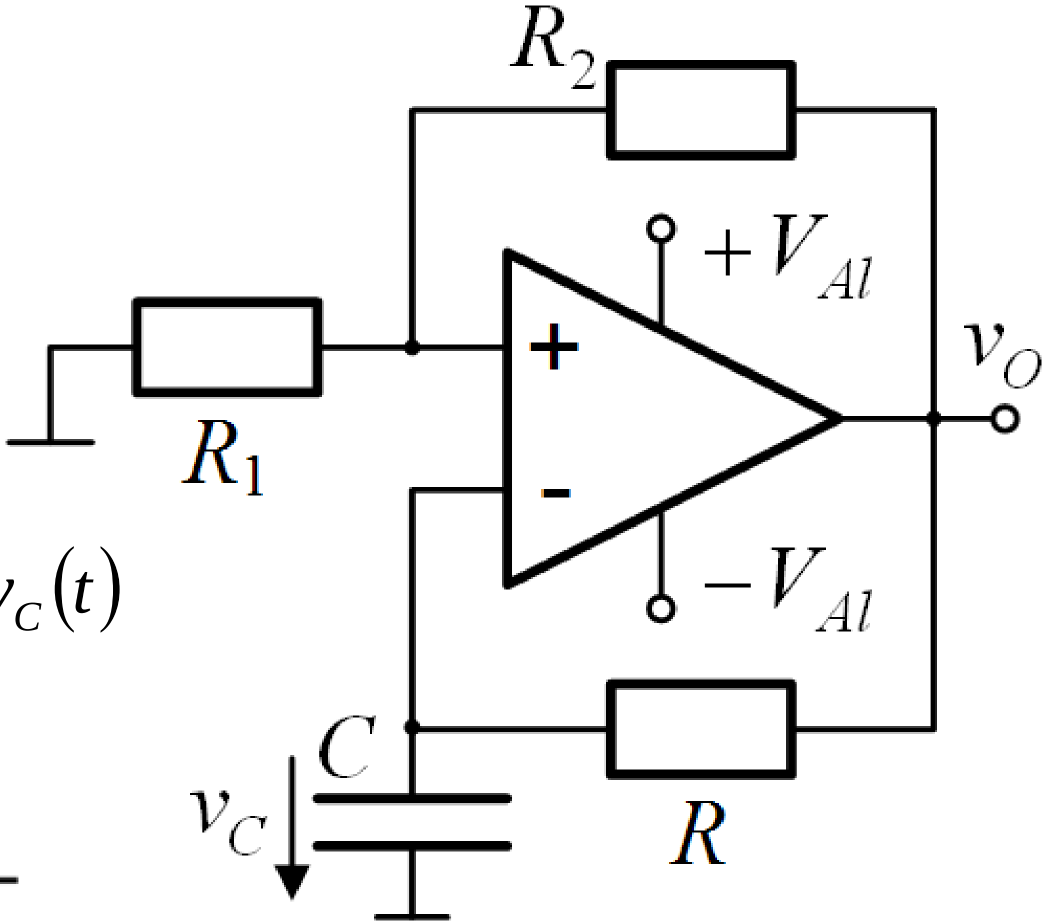
Principiul oscilatoarelor de relaxare

- variatia tensiunii pe condensator este exponentiala

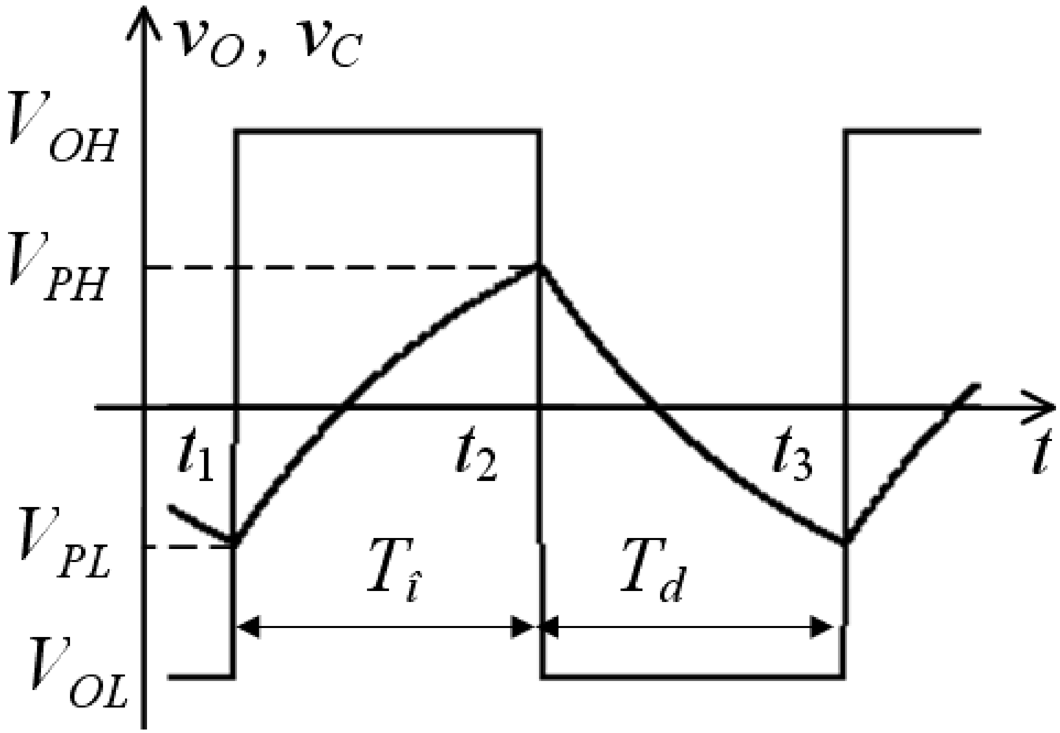
- daca tensiunea de pe condensator este aplicata la intrarea unui comparator cu RP se obtine **semnal dreptunghiular**

Generator de semnal dreptunghiular

$$v_C(t)=v_C(0)e^{-\frac{t}{\tau}}+\left(1-e^{-\frac{t}{\tau}}\right)v_C(\infty)$$



$$v_D(t)=v^+-v^-=\frac{R_1}{R_1+R_2}v_O(t)-v_C(t)$$

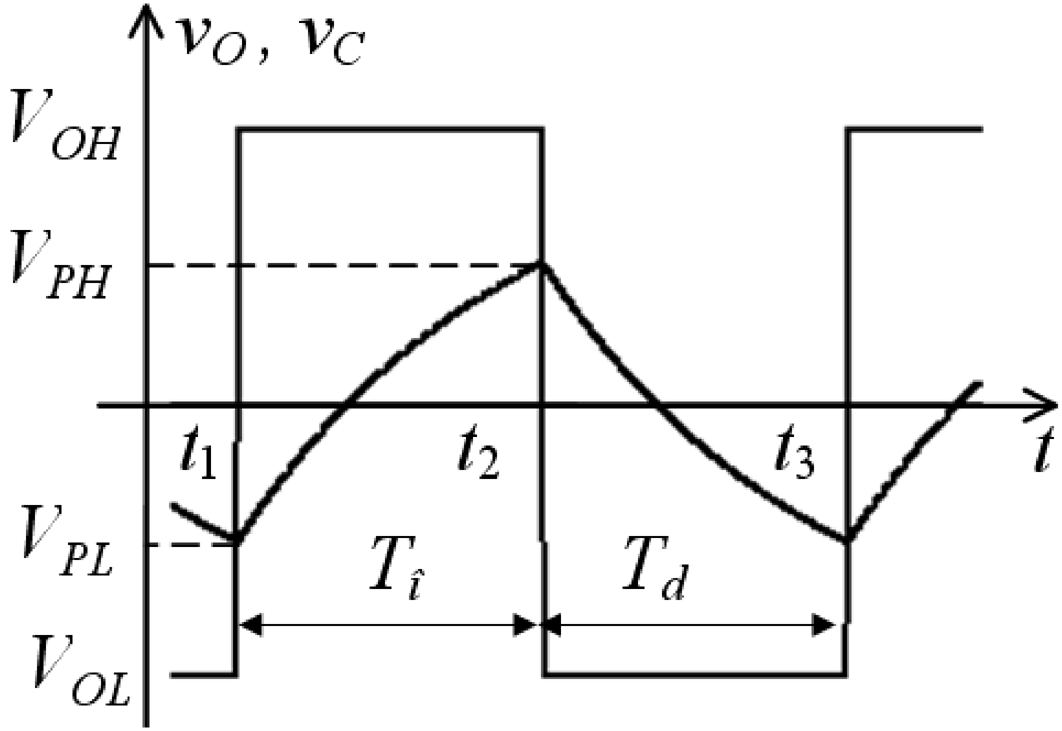


$$V_{PL}=\frac{R_1}{R_1+R_2}V_{OL}=rV_{OL}$$

$$V_{PH}=\frac{R_1}{R_1+R_2}V_{OH}=rV_{OH}$$

$$t \in (t_1,\ t_2) \qquad V_{PH} = V_{PL} e^{-\frac{T_î}{\tau}} + \left(1 - e^{-\frac{T_î}{\tau}}\right) V_{OH}\,; \qquad T_î = \tau \ln \frac{V_{OH} - rV_{OL}}{(1-r)V_{OH}}$$

$$t \in (t_2,\ t_3) \qquad V_{PL} = V_{PH} e^{-\frac{T_d}{\tau}} + \left(1 - e^{-\frac{T_d}{\tau}}\right) V_{OL}\,; \qquad T_d = \tau \ln \frac{rV_{OH} - V_{OL}}{(r-1)V_{OL}}$$



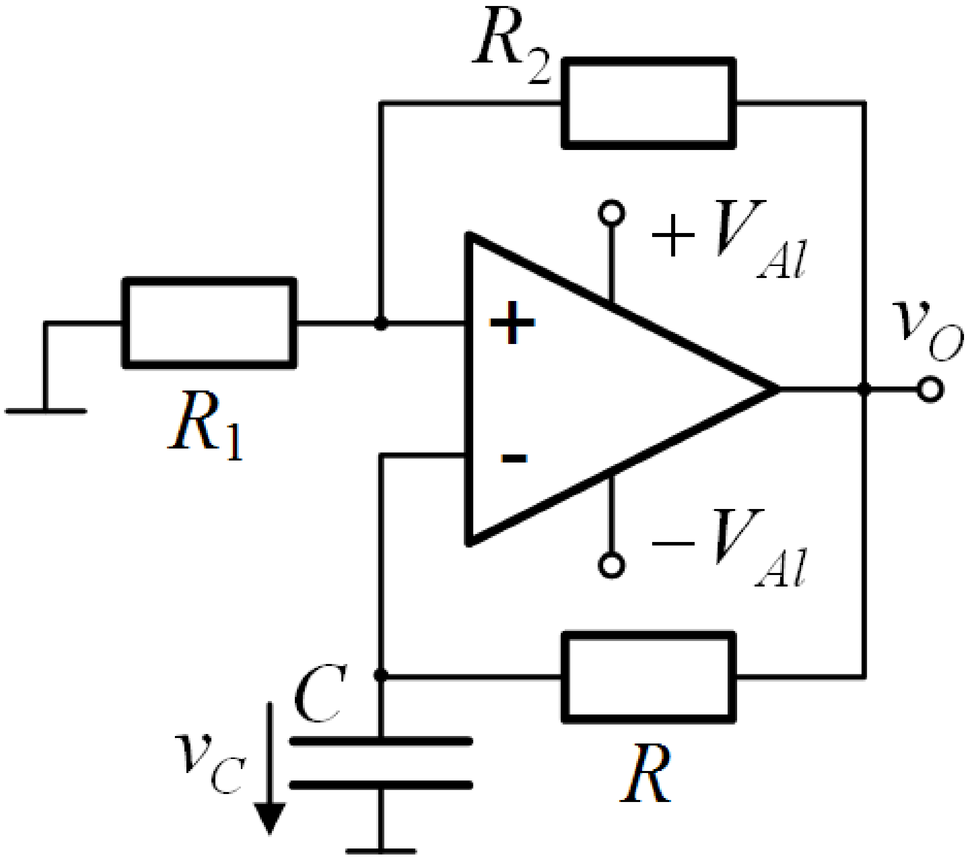
In general $V_{OH} = -V_{OL}$

$$T_î = T_d = \frac{T}{2} = \tau \ln \frac{1+r}{1-r}$$

$$\boxed{T = 2RC \ln \frac{1+r}{1-r}}$$

Daca $R_1 = R_2$

$$\boxed{T = 2RC \ln 3 \approx 2{,}2RC}$$



Problema

Pentru CBA se cunosc: $\pm V_{Al} = \pm 12$V, R_1=10kΩ, R_2=20kΩ, R=7,5kΩ şi C=10nF. AO se consideră de tipul linie la linie.

a) Care sunt valorile minimă şi maximă ale tensiunii pe condensator?

b) Care este frecvenţa semnalului dreptunghiular?

c) Cum trebuie modificat circuitul pentru ca frecvenţa să fie reglabilă între $f_{\min}$=0,8kHz şi $f_{\max}$=8kHz?

a)

$$V_{PL} = \frac{R_1}{R_1 + R_2} V_{OL} = \frac{10}{10+20}(-12) = -4\text{V}$$

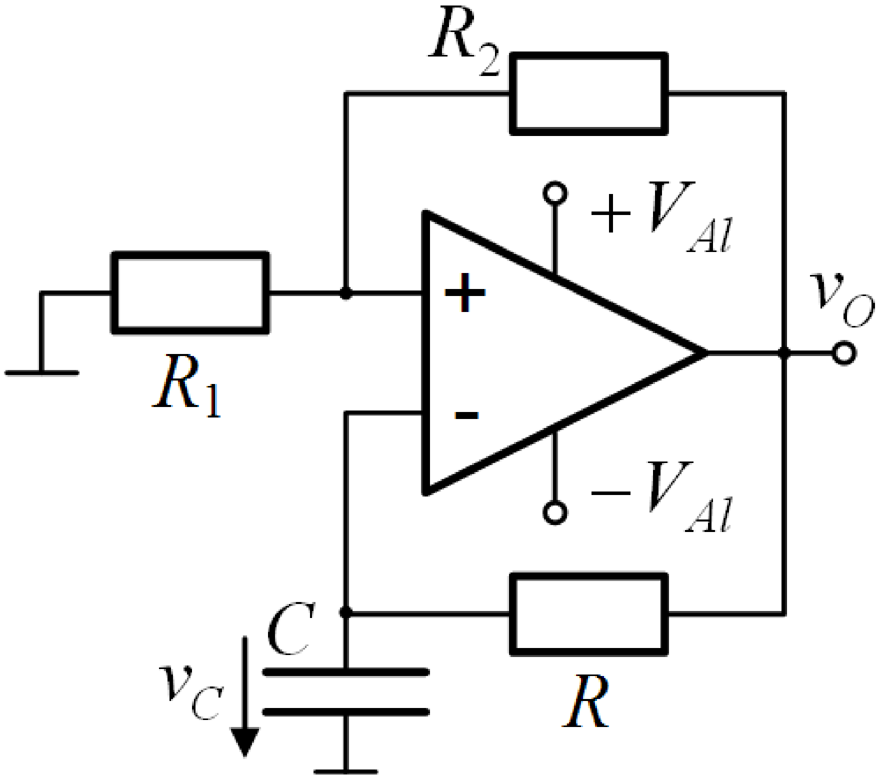
$$V_{PH} = \frac{R_1}{R_1 + R_2} V_{OH} = \frac{10}{10+20} \cdot 12 = 4\text{V}$$

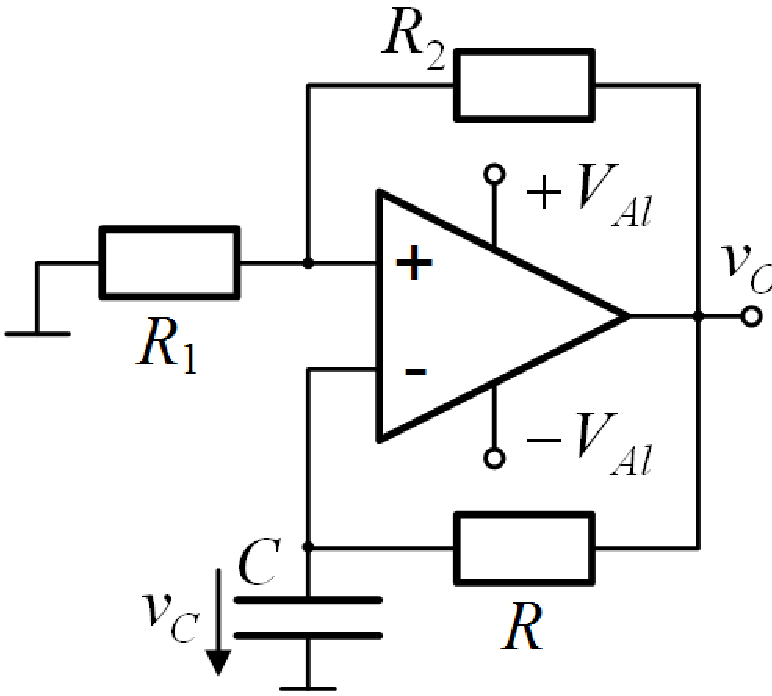
b) $$r = \frac{R_1}{R_1 + R_2} = \frac{10}{10+20} = \frac{1}{3}$$

$$T = 2RC \ln \frac{1+r}{1-r} = 2 \cdot 7{,}5\,\mathrm{k\Omega} \cdot 10\,\mathrm{nF} \cdot \ln \frac{1+1/3}{1-1/3} = 104\,\mu\mathrm{s}$$

$$f = \frac{1}{T} = \frac{1}{104} = 9{,}6\,\mathrm{kHz}$$

$$T = 1{,}386RC$$

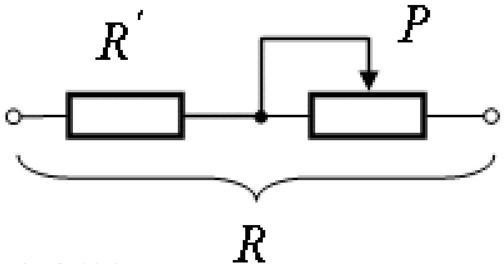




c) $$T = 2RC\ln\frac{1+r}{1-r} = 2RC\ln 2 = 1.386RC$$

$$T_{\min} = \frac{1}{f_{\max}} = 1{,}386R'C$$

$$R' = \frac{1}{1{,}386 f_{\max} C} = \frac{1}{1{,}386\cdot 8\text{kHz}\cdot 10\text{nF}} = 9\,\text{k}\Omega$$



Alegem
R'=8,87kΩ (1%).

$$T_{\max} = \frac{1}{f_{\min}} = 1{,}386\left(R' + P\right)C$$

$$R' + P = 90\,\text{k}\Omega; \quad P = 90 - 8.87 = 81.13\,\text{k}\Omega$$

Alegem P=100kΩ

Verificare. Recalculare.

Cum poate fi modificat circuitul astabil anterior pentru a putea genera un **semnal triunghiular**?

In circuitul astabil, condensatorul este incarcat/descarcat intr-un circuit *RC* serie sub tensiune constanta => curent variabil prin *C*

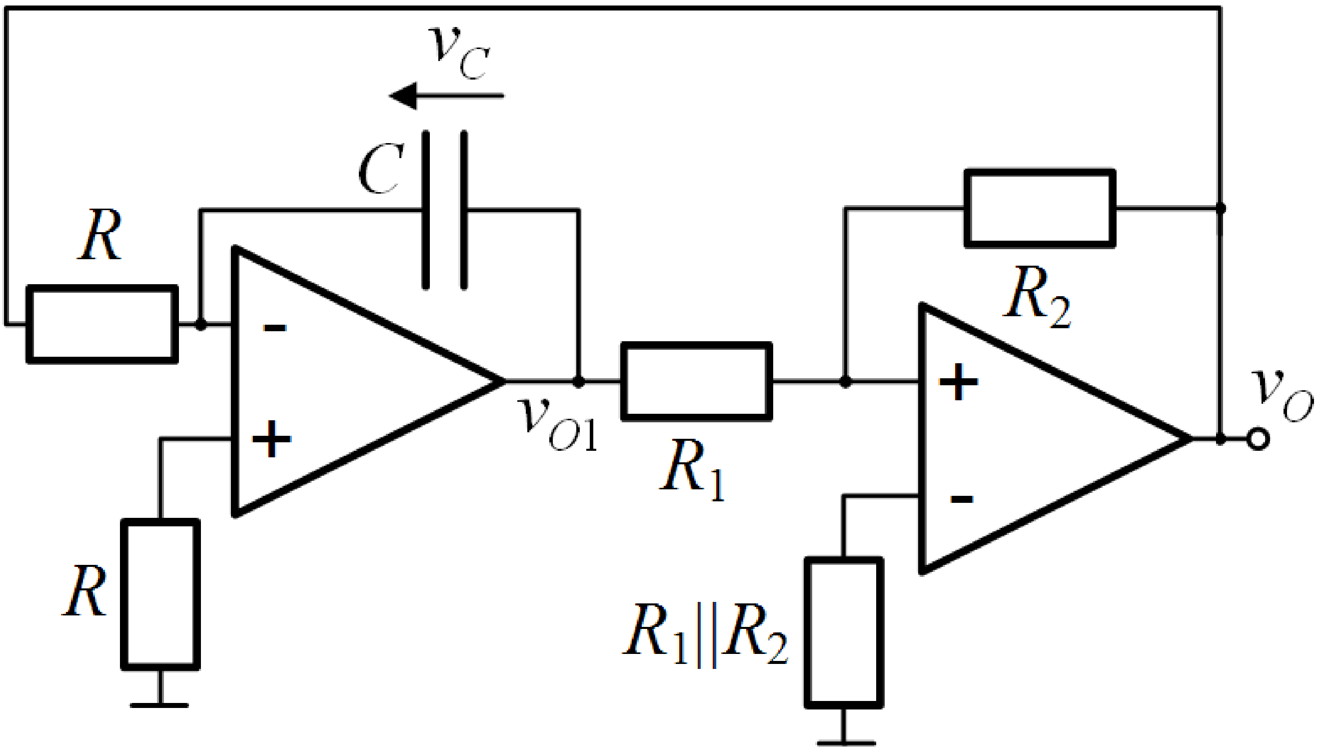
$$C dv_c = i_c dt; \;\; v_c(t) = \frac{1}{C}\int_{t_1}^{t_2} i_c dt$$

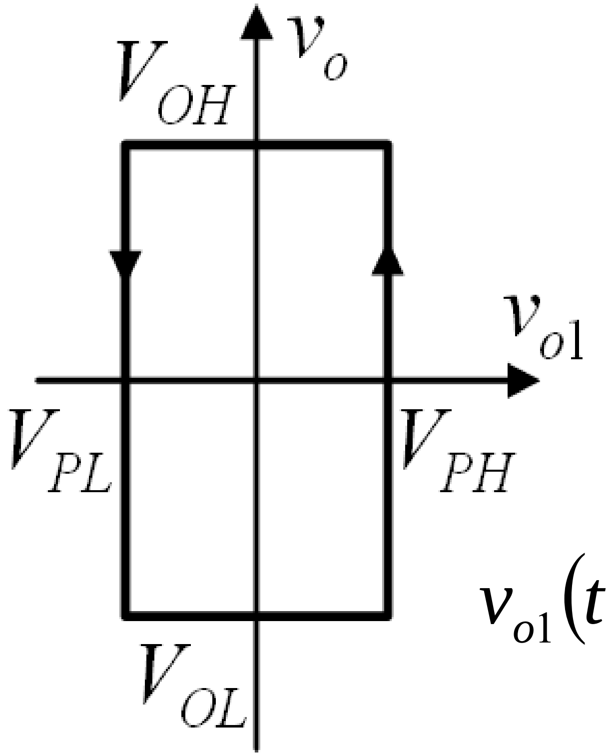
$$\text{Daca am} \quad \text{avea} \;\; i_c = I_C = \text{cst.} \qquad v_c(t) = \frac{1}{C} I_c t \Big|_{t_1}^{t_2}$$

Rezulta o variatie liniara in timp a tensiunii pe condensator, adica un semnal trinunghiular.

Pentru a se genera semnal triunghiular, condensatorul trebuie incarcat/descarcat cu un curent constant.

Generator de semnal dreptunghiular si triunghiular

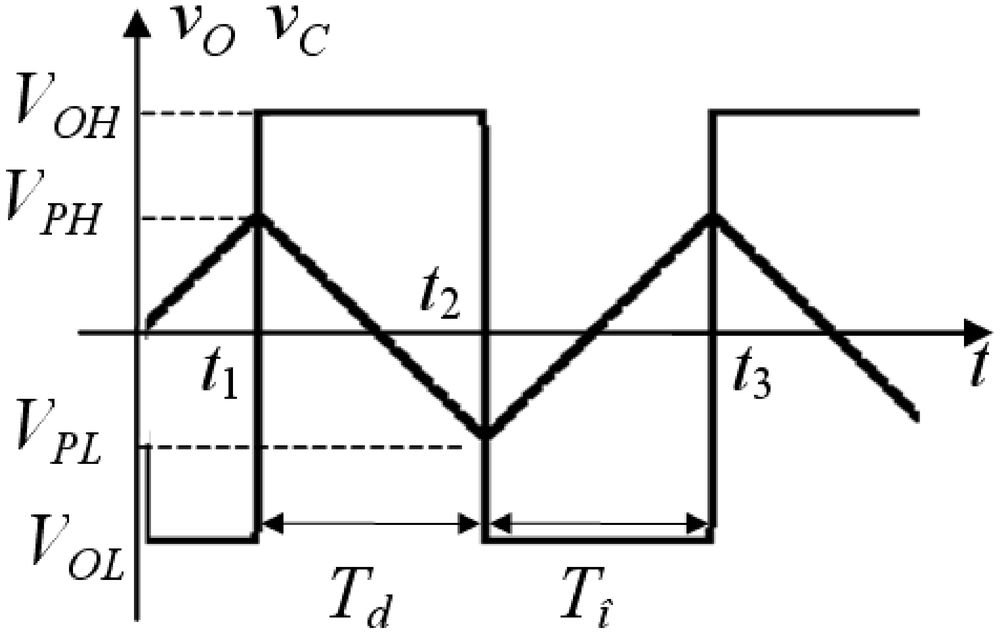


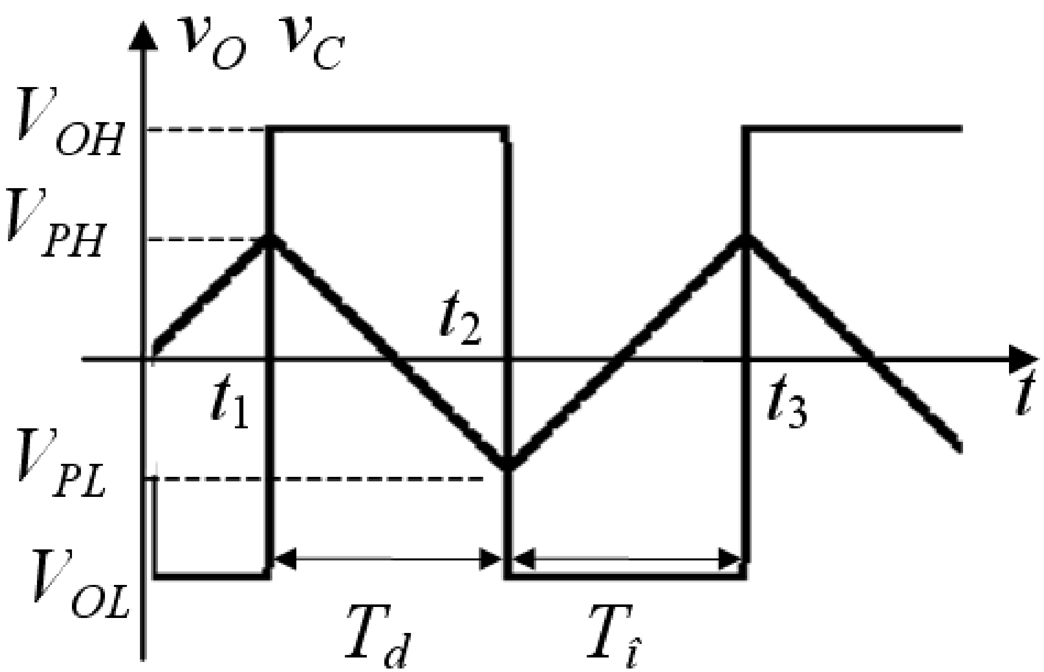


$$v_{o1}(t)=v_C(t)$$

$$V_{PL}=-\frac{R_1}{R_2}V_{OH}$$

$$V_{PH}=-\frac{R_1}{R_2}V_{OL}$$





$$C\Delta v_C = i_C \Delta t$$

descarcare $i_C = \dfrac{0 - V_{OH}}{R} = -\dfrac{V_{OH}}{R}$

$$\Delta v_C = V_{PL} - V_{PH};$$

$$\Delta t = t_2 - t_1 = T_d$$

$$T_d = RC\frac{V_{PH} - V_{PL}}{V_{OH}}$$

$$T = T_d + T_î$$

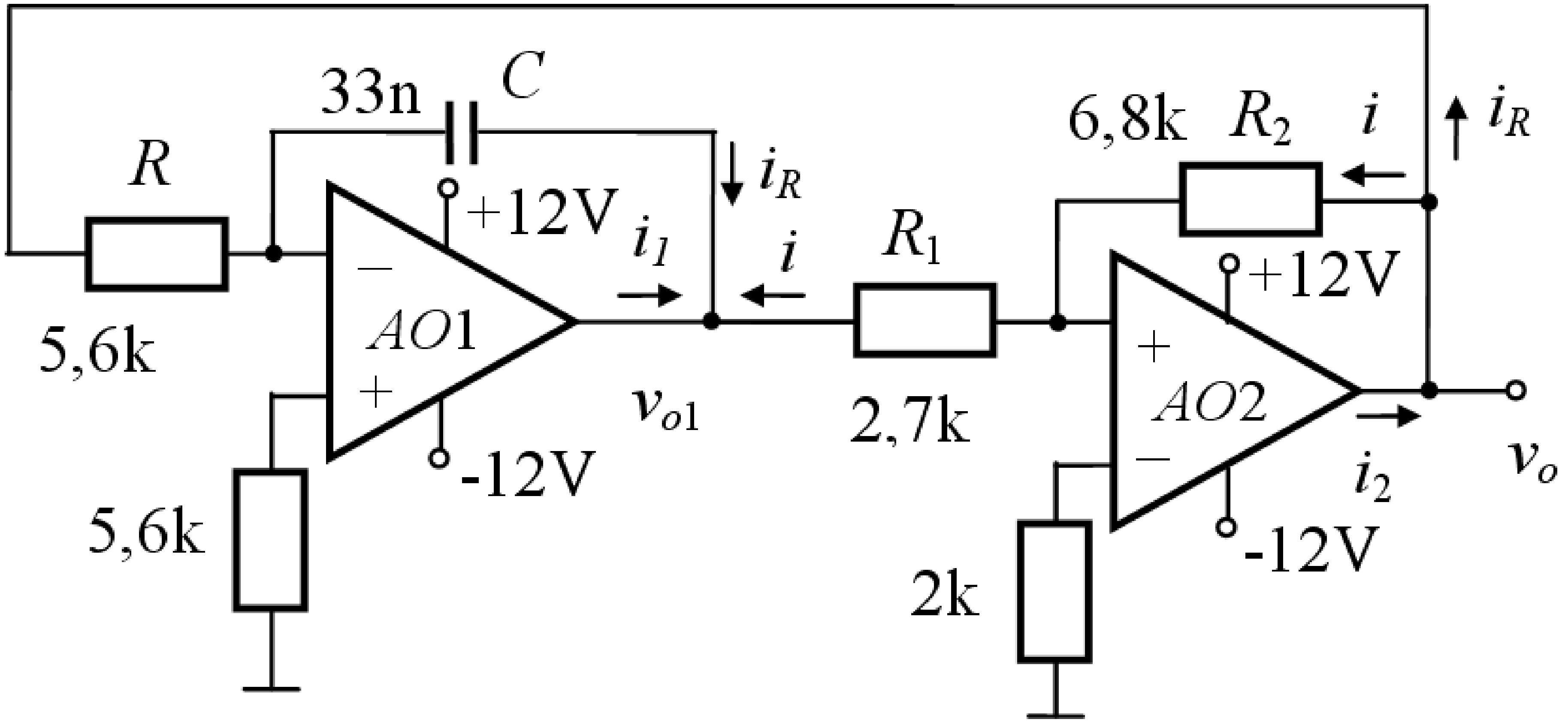
In general $V_{OH} = -V_{OL}$

$$T_î = RC\frac{V_{PH} - V_{PL}}{-V_{OL}}$$

$$\boxed{T = 2RC\frac{V_{PH} - V_{PL}}{V_{OH}} = 4RC\frac{R_1}{R_2}}$$

Daca $R_1 = R_2$ $\quad T = 4RC \quad f = \dfrac{1}{4RC}$

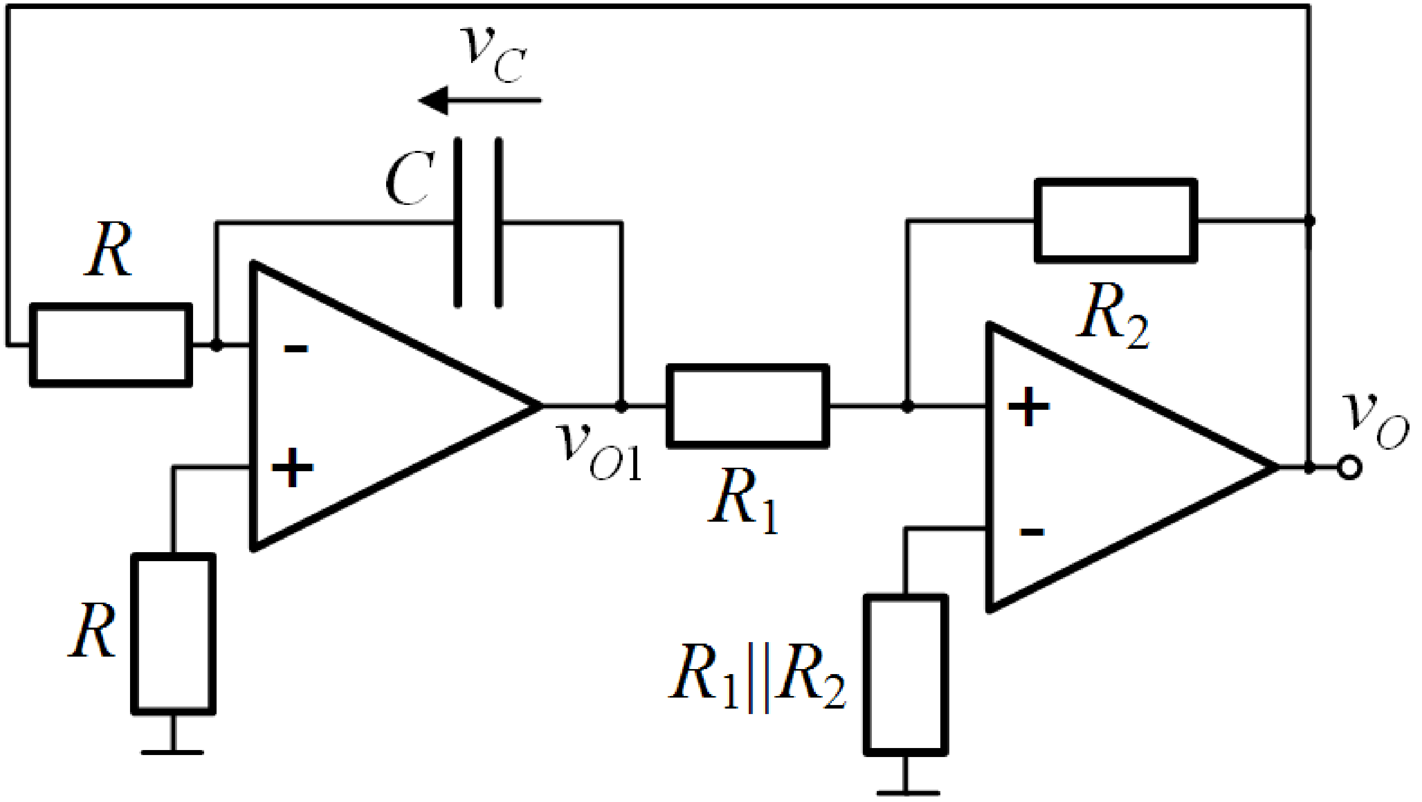
Problema



La saturaţie tensiunile la ieşirea amplificatoarelor operationale diferă cu 1V faţă de tensiunile de alimentare.

a) Care este amplitudinea tensiunii triunghiulare?
b) Care este frecvenţa semnalelor generate?
c) Care este valoarea maximă a curenţilor prin ieşirile AO?

Reglarea frecvenţei



$$C\Delta v_C = i_C \Delta t$$

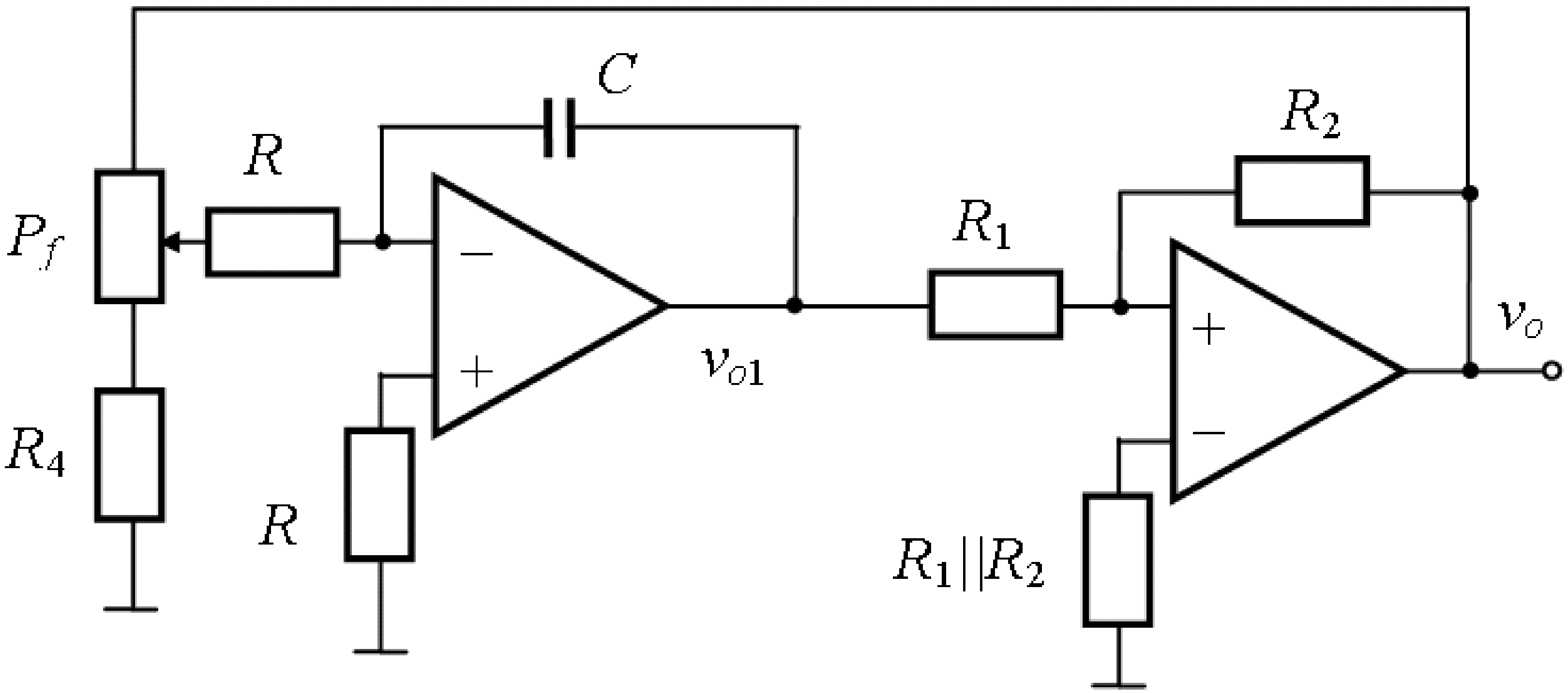
$$\Delta t = \frac{C\Delta v_C}{i_C}$$

- Reglaj in trepte: comutarea *C*
- Reglaj continuu: reglarea curentului prin condensator

$$|\, i_C \,| = \frac{V_O}{R} \quad (V_O = V_{OL} \text{ sau } V_O = V_{OH})$$

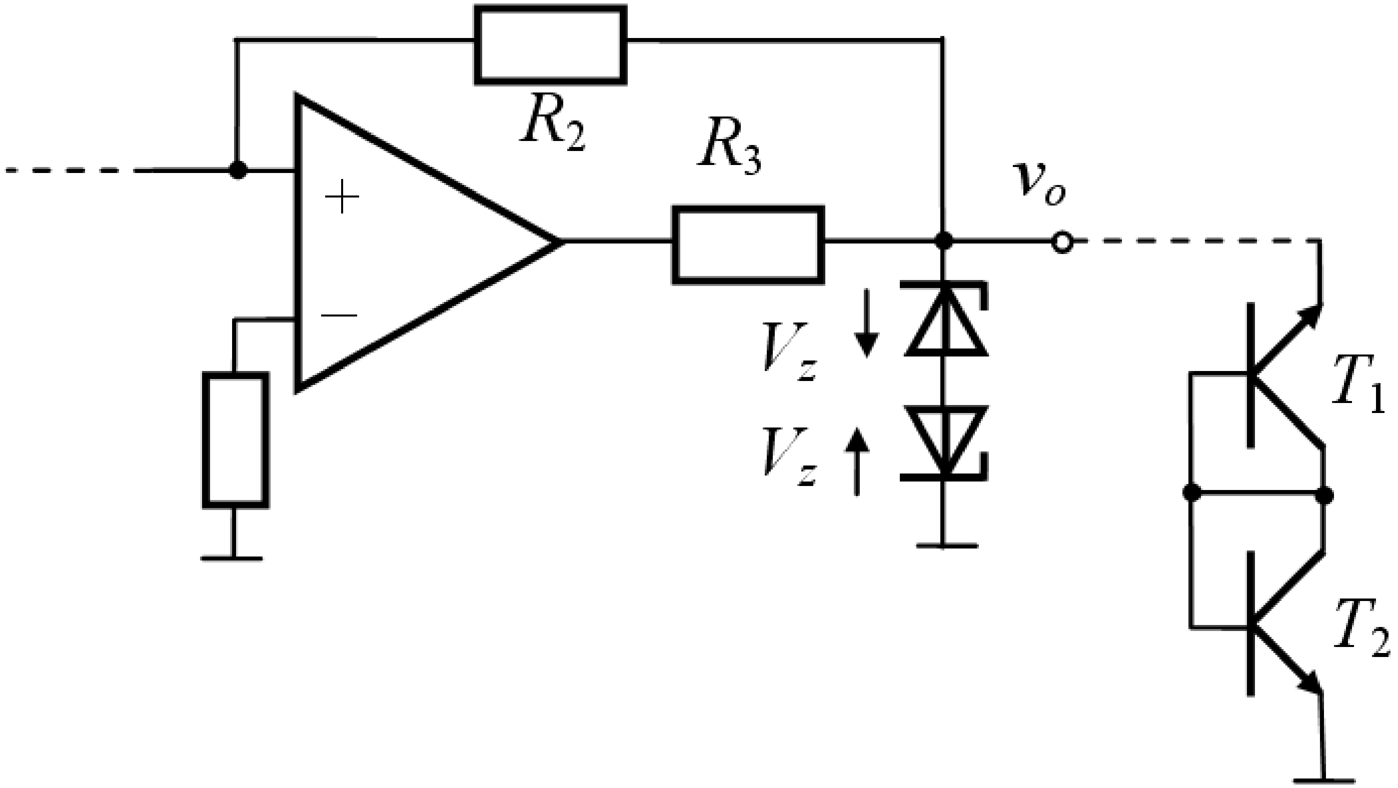
  - *R* – reglabil (*R’* +*P*)
  - Tensiunea aplicata pe *R* reglabila

Reglarea frecvenţei –
variatia tensiunii aplicate pe *R*



$$f_{\max} = \frac{1}{4RC}\frac{R_2}{R_1};\qquad f_{\min} = \frac{1}{4RC}\frac{R_2}{R_1}\frac{R_4}{R_4 + P_f}$$

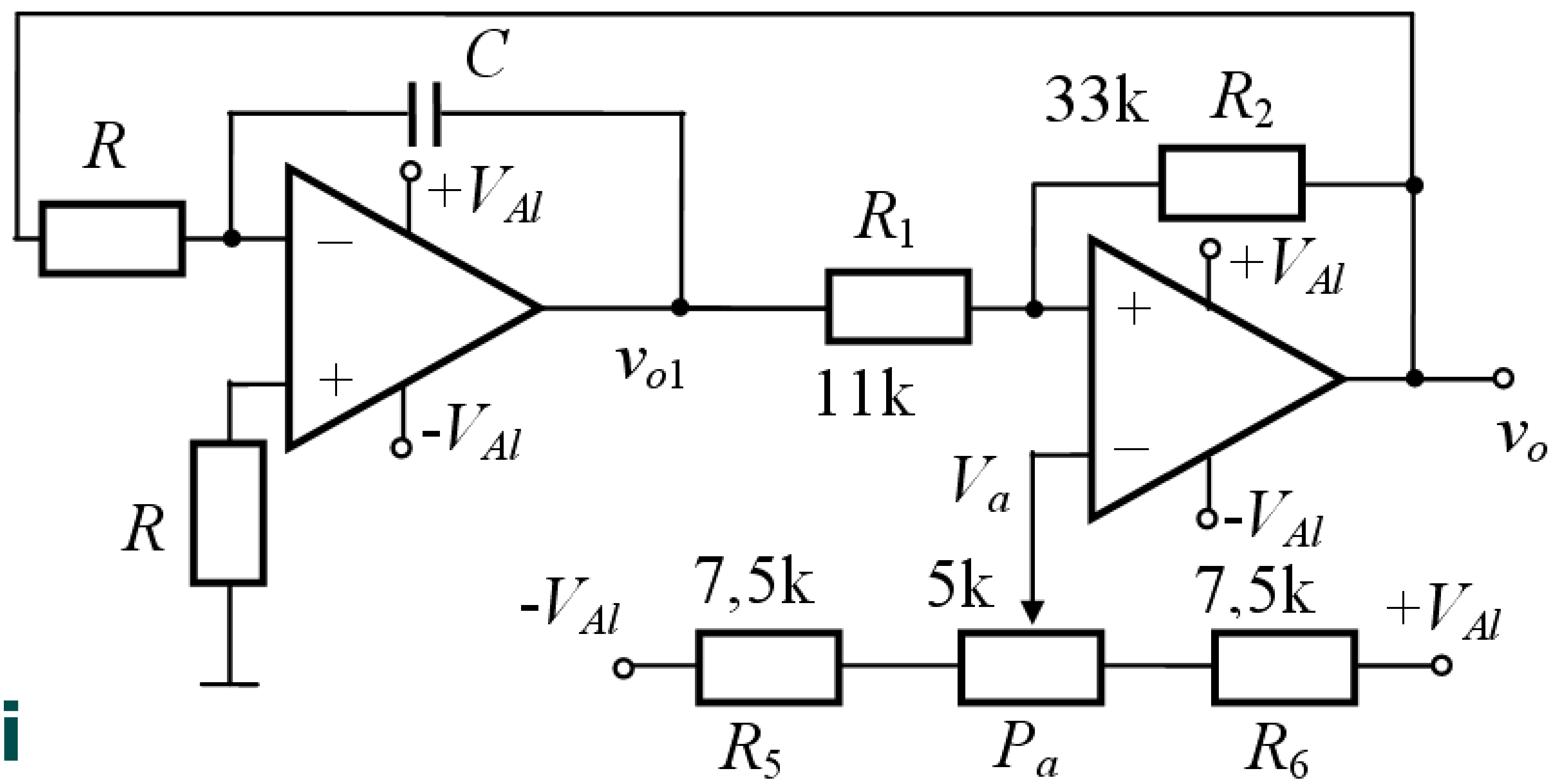
Independenţa faţă de tensiunile de alimentare



$$V_{OH} = V_Z + 0{,}7\text{V}; \qquad V_{OL} = -V_Z - 0{,}7\text{V}$$

Care este rolul rezistorului R_3?

În polarizare inversă joncţiunea bază-emitor se comportă ca o diodă Zener, stabilizând tensiunea la o valoare ce depinde de tipul de tranzistor şi de curentul prin tranzistor (in jur de 5 … 8V)

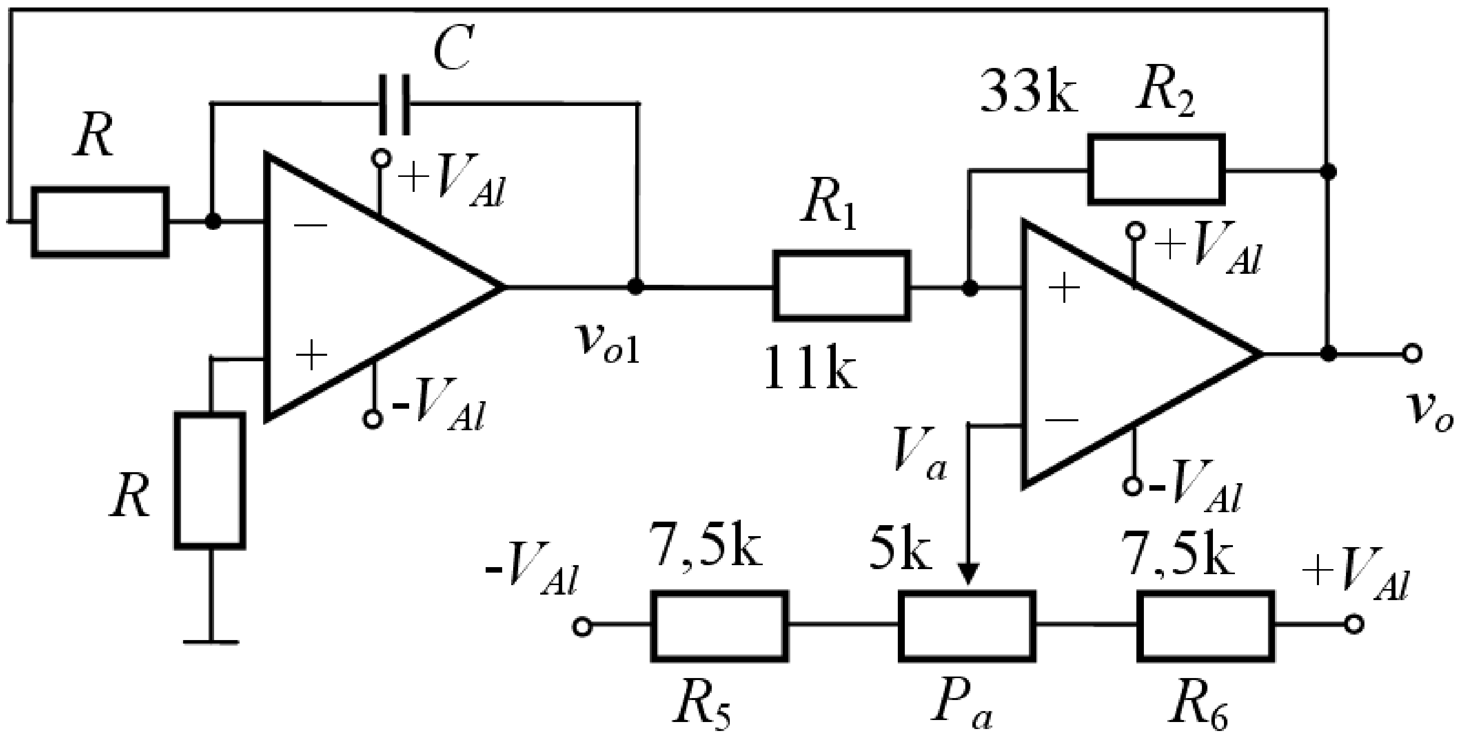


Axarea tensiunii triunghiulare

$$V_{PL} = \left(1+\frac{R_1}{R_2}\right)V_a - \frac{R_1}{R_2}V_{OH} \qquad V_{PH} = \left(1+\frac{R_1}{R_2}\right)V_a - \frac{R_1}{R_2}V_{OL}$$

$$V_{a\max} = \frac{P_a + R_5}{R_5 + P_a + R_6}V_{Al} + \frac{R_6}{R_5 + P_a + R_6}\left(-V_{Al}\right) = 3.75\mathrm{V}$$

Axarea tensiunii triunghiulare



$$V_{a\min}=\frac{R_5}{R_5+P_a+R_6}V_{Al}+\frac{P+R_6}{R_5+P_a+R_6}\left(-V_{Al}\right)=-3{,}75\text{V}$$

Componenta continuă V_{o1} se poate regla în limitele

$$V_{o1\max}=\left(1+\frac{11}{33}\right)\cdot 3{,}75=5\text{V};\qquad V_{o1\min}=\left(1+\frac{11}{33}\right)\cdot(-3{,}75)=-5\text{V}$$

Circuite integrate specializate pentru generarea de semnale

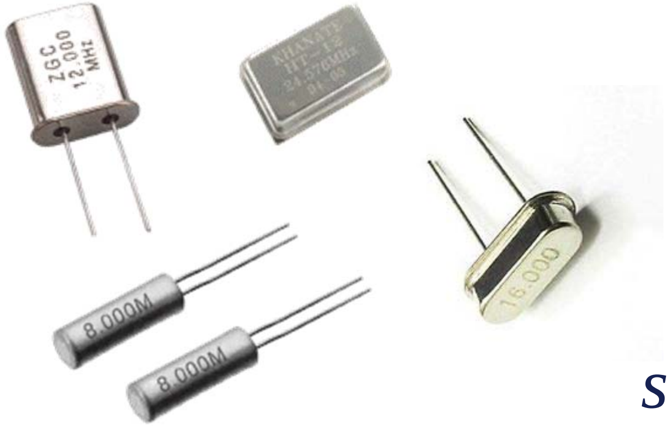
- 8038 - Precision Waveform Generator/Voltage Controlled Oscillator (triangular, square,sine, sawtooth, pulse) OBSOLETE PRODUCT

- NE566 - Function generator VCO, square, triangular - 1MHz

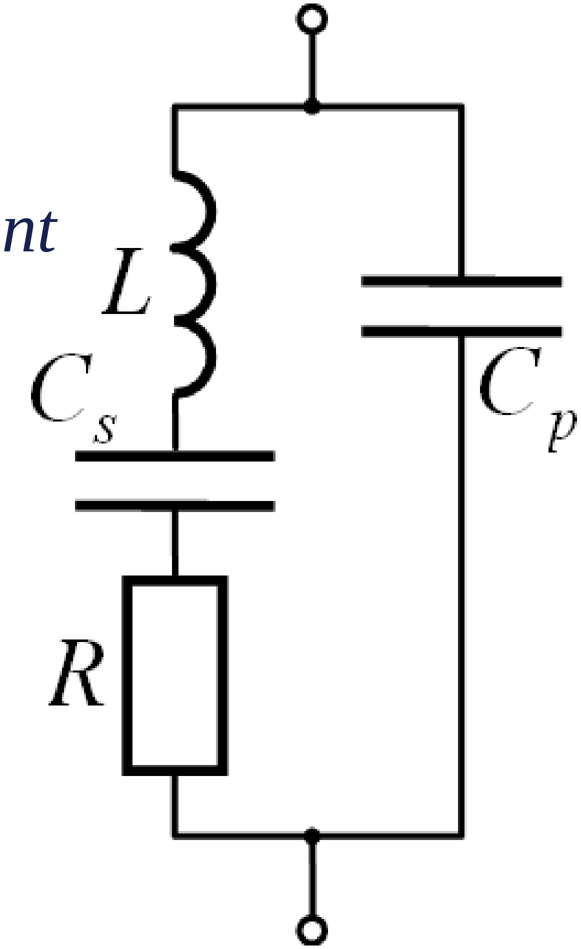
- AD9833 - Low power, programmable waveform generator: sine, triangular, and square wave. No external components. Frequency and phase are software programmable. 3-wire serial interface. Power-down function (SLEEP). 0 MHz to 12.5 MHz output frequency range.

- 555 - highly stable device for generating accurate time delays (monostabile) or oscillation (astable)

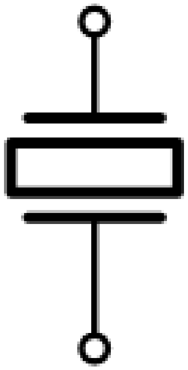
Cristalul de cuarţ



circuit electric echivalent



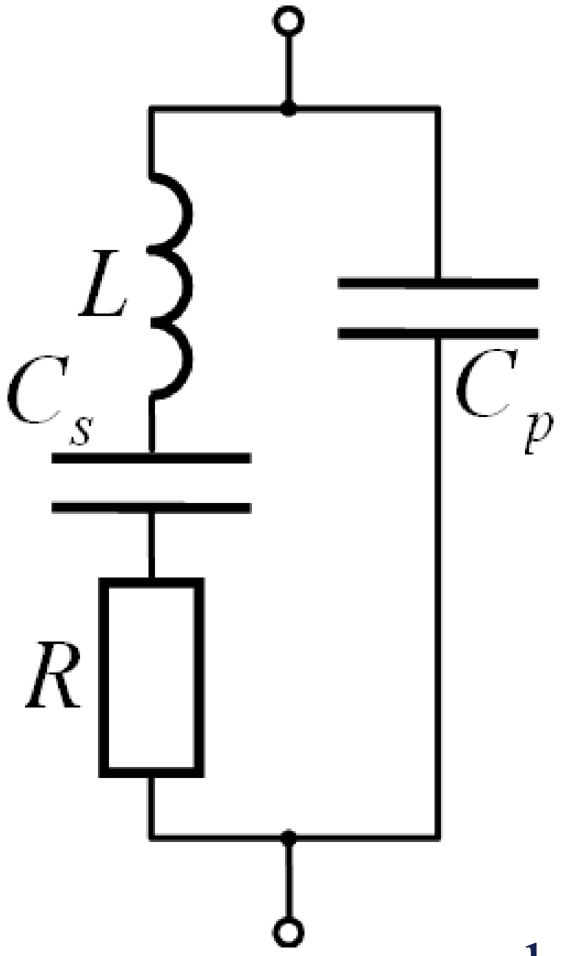
simbol de circuit



Cuarțul (dioxid de siliciu, cunoscut și sub denumirea științifică α-Cuarț) este al doilea cel mai răspândit mineral din scoarța terestră.

Cristalul de cuarț are compoziția chimică SiO_2 și cristalizează în sistem cristalin trigonal (romboedric).

Cristalul de cuarţ



$$C_p >> C_s$$

R – valoare foarte scazuta

Se poate neglija

- Rezonanta serie

$$f_s = \frac{1}{2\pi\sqrt{LC_s}}$$

domeniu: zeci KHz … sute MHz

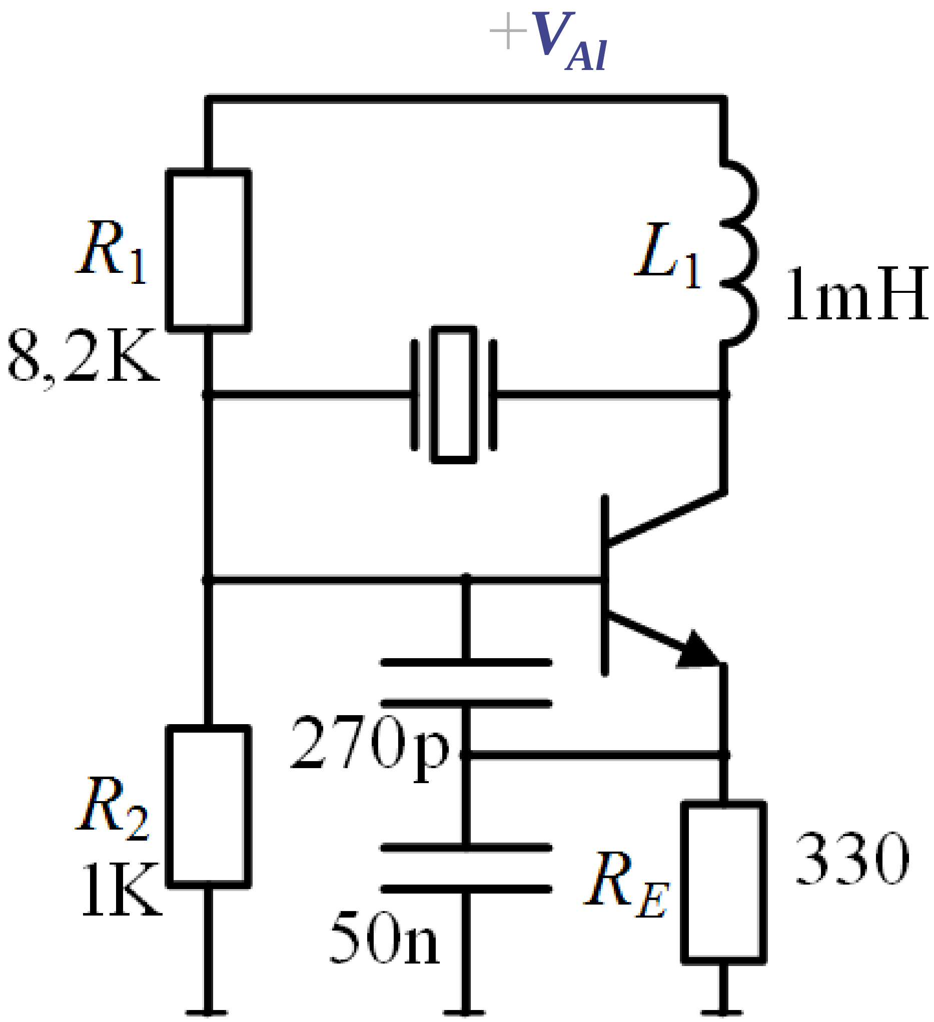
- Rezonanta paralel

$$f_p = \frac{1}{2\pi\sqrt{L\left(\frac{C_p C_s}{C_p + C_s}\right)}}$$

$$f_p \approx \frac{1}{2\pi\sqrt{LC_s}} = f_s$$

Optional

oscilator sinusoidal cu cuarţ



- avantaj: **frecventa foarte stabila**, factor de calitate ridicat
- dezavantaj: oscileaza pe frecventa fixa (frecvența cuarțului)

Quartz is amongst one of the most common minerals in the Earth's continental crust. It has a hexagonal crystal structure made of trigonal crystallized silica (silicon dioxide, SiO_2)

The crystal oscillator circuit sustains oscillation by taking a voltage signal from the quartz resonator, amplifying it, and feeding it back to the resonator. The rate of expansion and contraction of the quartz is the resonant frequency and is determined by the cut and size of the crystal.

During startup, the circuit around the crystal applies a random noise (ac) signal to it, and purely by chance, a tiny fraction of the noise will be at the resonant frequency of the crystal. The crystal will therefore start oscillating in synchrony with that signal. As the oscillator amplifies the signals coming out of the crystal, the crystal's frequency will become stronger, eventually dominating the output of the oscillator. Natural resistance in the circuit and in the quartz crystal filter out all the unwanted frequencies.

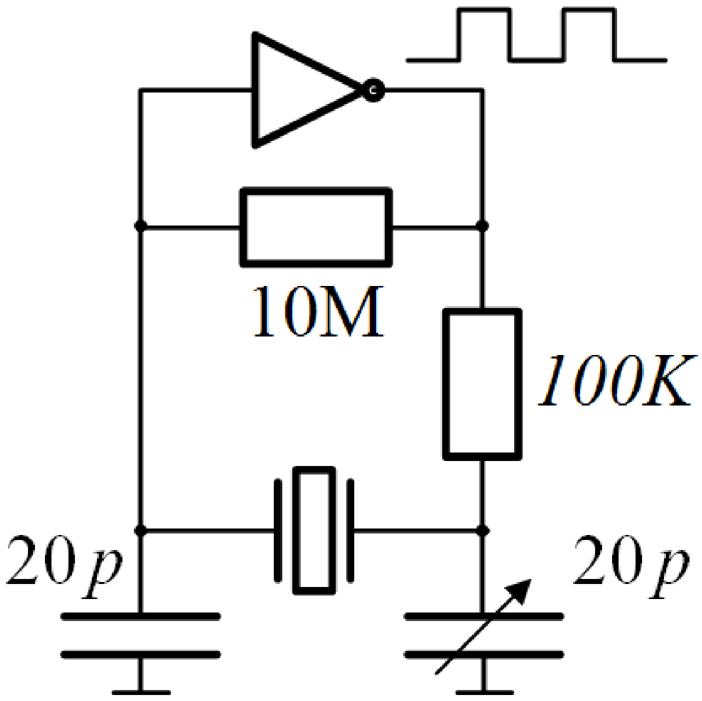
Generatoare de tact (ceas)

- **cu cuarţ**

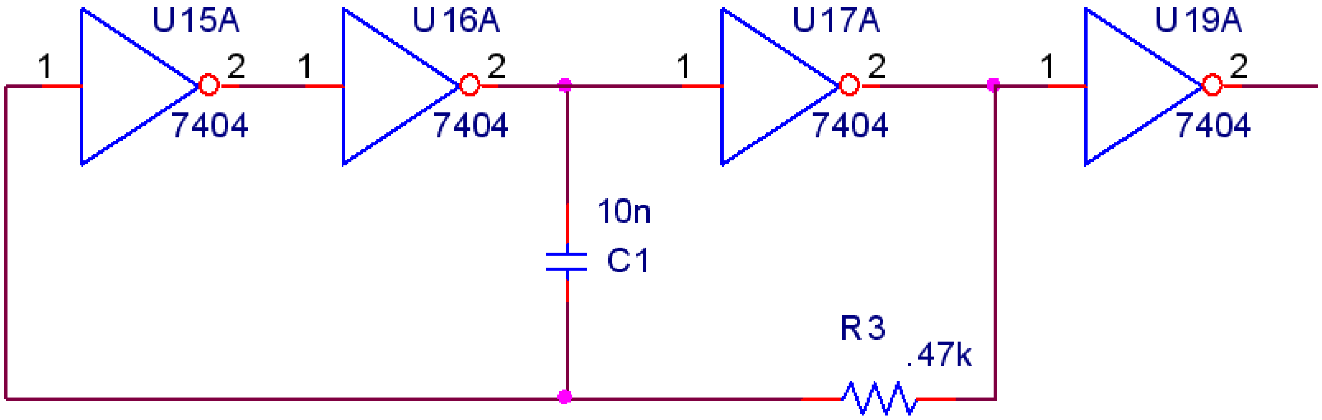
f_0=1, 2, 4, 5, … , 20MHz

f_0=14,31818MHz - adaptor video in calculatoare

f_0 = 32 768 Hz - ceas cu cuartz; divizat cu 2^{15} se obtine 1Hz (1 s)



- **cu inversoare**



- **in inel**

$$f=\frac{1}{2t_d\cdot n}$$

t_d - întarzierea unui inversor