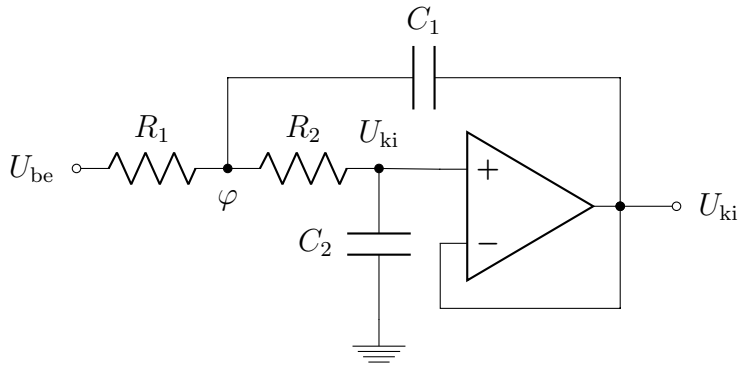
Alkatrésztoleranciák hatásának vizsgálata



Névleges alkatrészértékek és worst-case toleranciák:

$$R_1 = 10\,\text{k}\Omega \pm 1\%$$
$$R_2 = 10\,\text{k}\Omega \pm 1\%$$
$$C_1 = 1\,\text{nF} \pm 5\%$$
$$C_2 = 2\,\text{nF} \pm 5\%$$

Csomóponti egyenletek:

$$\frac{\varphi - U_{\text{be}}}{R_1} + \frac{\varphi - U_{\text{ki}}}{R_2} + \frac{\varphi - U_{\text{ki}}}{\frac{1}{j\omega C_1}} = 0$$
$$\frac{U_{\text{ki}} - \varphi}{R_2} + \frac{U_{\text{ki}} - 0}{\frac{1}{j\omega C_2}} = 0$$

A megoldás mátrixos alakban:

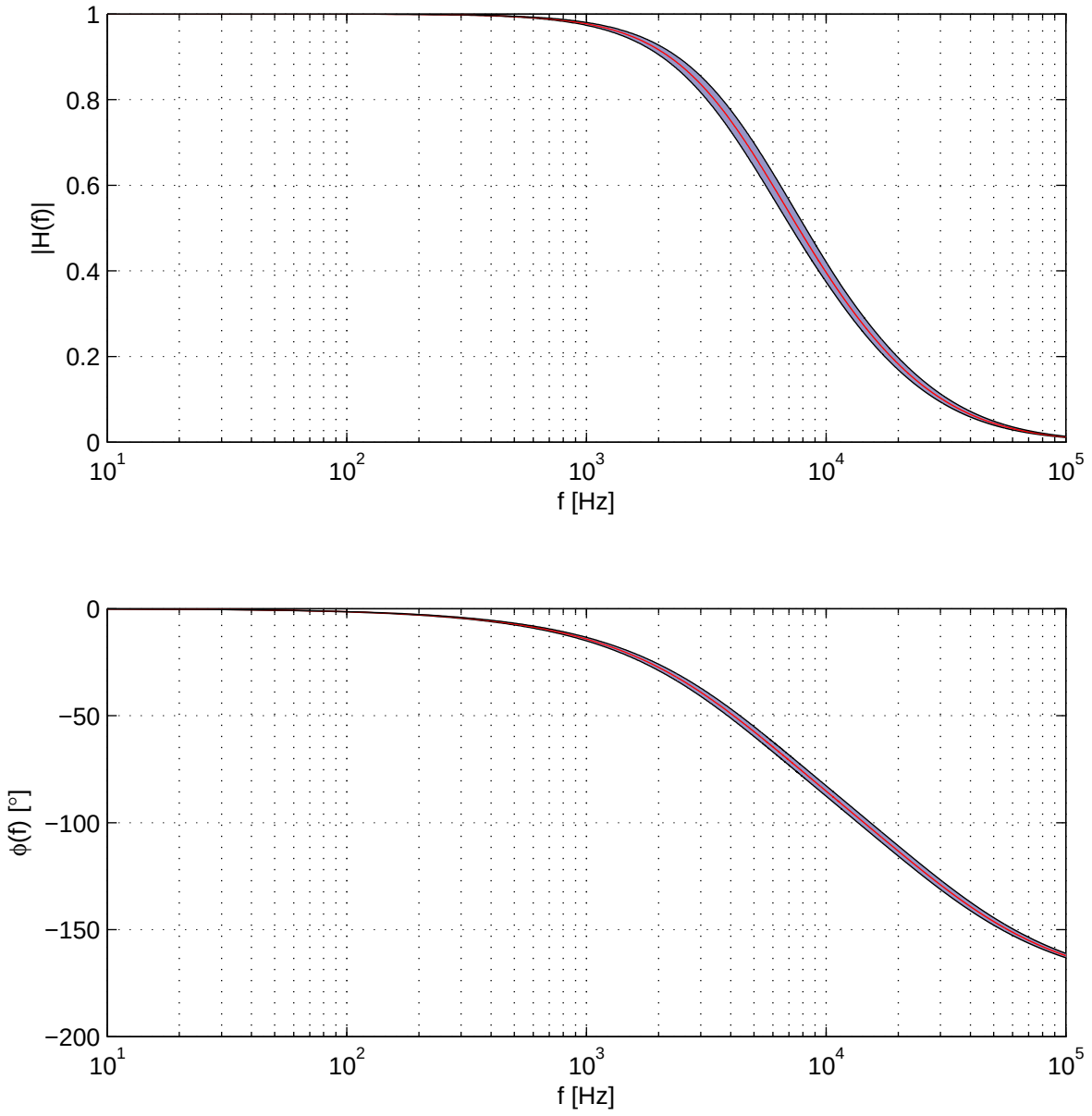
$$\begin{pmatrix} \varphi \\ U_{\text{ki}} \end{pmatrix} = \begin{pmatrix} \frac{1}{R_1} + \frac{1}{R_2} + j\omega C_1 & -\frac{1}{R_2} - j\omega C_1 \\ -\frac{1}{R_2} & \frac{1}{R_2} + j\omega C_2 \end{pmatrix}^{-1} \begin{pmatrix} \frac{U_{\text{be}}}{R_1} \\ 0 \end{pmatrix}$$

MATLAB kód

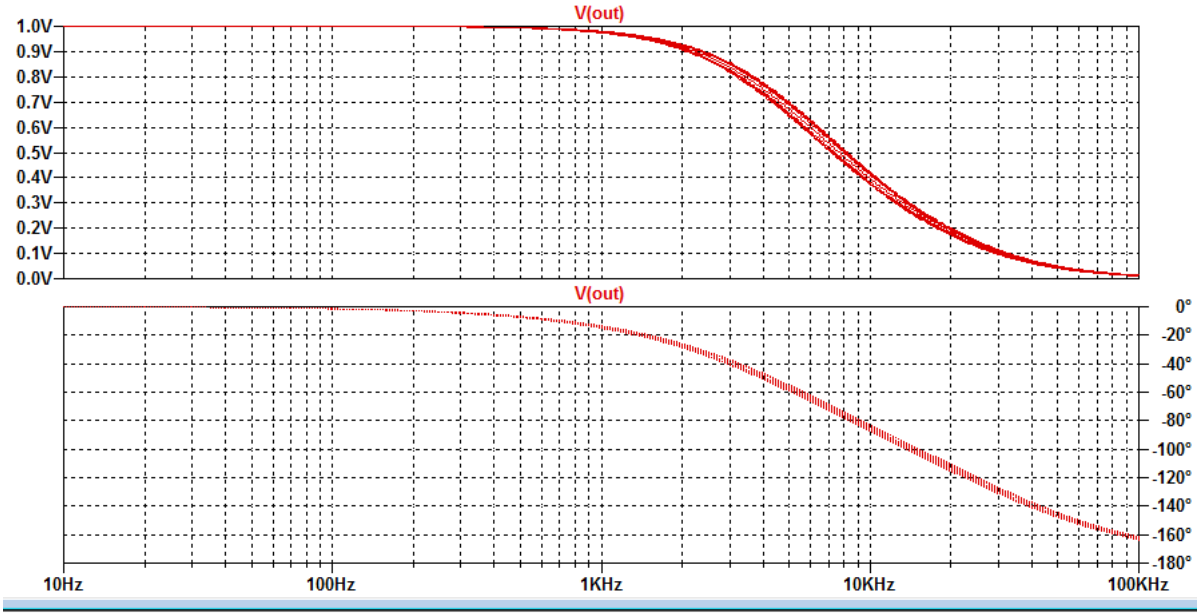
```
%% parameterek
f=10:10:100e3; % frekvencia sweep [Hz]
Ube=1;         % gerjesztes komplex amplitudoja [V]
N=4;           % alkatreszek szama
R1n=10e3; R1tol=0.01;
R2n=10e3; R2tol=0.01;
C1n=1e-9; C1tol=0.05;
C2n=2e-9; C2tol=0.05;

%% szimulacio
mag=zeros(length(f),3);
phase=zeros(length(f),3);
for ii=1:length(f)
    for jj=1:2^N+1
        if jj==2^N+1
            R1=R1n;
            R2=R2n;
            C1=C1n;
            C2=C2n;
        else
            tols=2*de2bi(jj-1,N)-1;
            R1=R1n*(1+tols(1)*R1tol);
            R2=R2n*(1+tols(2)*R2tol);
            C1=C1n*(1+tols(3)*C1tol);
            C2=C2n*(1+tols(4)*C2tol);
        end
        omega=2*pi*f(ii);
        A=[1/R1+1/R2+1j*omega*C1   ,  -1/R2-1j*omega*C1  ;
           -1/R2                   ,   1/R2+1j*omega*C2 ];
        B=[Ube/R1 ; 0];
        x=A\B;
        if jj==1
            mag(ii,1)=abs(x(2));
            mag(ii,3)=abs(x(2));
        elseif jj==17
            mag(ii,2)=abs(x(2));
        elseif abs(x(2))<mag(ii,1)
            mag(ii,1)=abs(x(2));
        elseif abs(x(2))>mag(ii,3)
            mag(ii,3)=abs(x(2));
        end
        if jj==1
            phase(ii,1)=angle(x(2));
            phase(ii,3)=angle(x(2));
        elseif jj==17
            phase(ii,2)=angle(x(2));
        elseif angle(x(2))<phase(ii,1)
            phase(ii,1)=angle(x(2));
        elseif angle(x(2))>phase(ii,3)
            phase(ii,3)=angle(x(2));
        end
    end
end
phase=unwrap(phase)*180/pi;

%% abrazolas
figure(1);
subplot(211);
fill([f f(end:-1:1)],[mag(:,3)' mag(end:-1:1,1)'],[0.59 0.59 0.78],'LineStyle','none');
hold on;
h=plot(f,mag);
hold off;
set(gca,'XScale','log','XGrid','on','YGrid','on');
set(h,{'color'},{'k';'r';'k'});
xlabel('f [Hz]');
ylabel('|H(f)|');
```

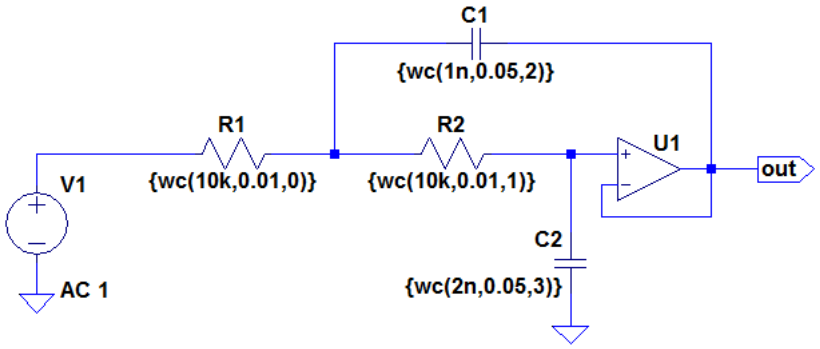
```
67 subplot(212);
68 fill([f f(end:-1:1)],[phase(:,3)' phase(end:-1:1,1)'],[0.59 0.59 0.78],'LineStyle','none');
69 hold on;
70 h=plot(f,phase);
71 hold off;
72 set(gca,'XScale','log','XGrid','on','YGrid','on');
73 set(h,{'color'},{'k';'r';'k'});
74 xlabel('f [Hz]');
75 ylabel('\phi(f) [\circ]');
```

Kimenet



LTspice szimuláció






```
.ac lin 10000 10 100k
.lib opamp.sub
.param numruns=16
.step param run 0 16 1
.func wc(nom,tol,index) if(run==numruns,nom,if(binary(run,index),nom*(1+tol),nom*(1-tol)))
.func binary(run,index) floor(run/(2**index))-2*floor(run/(2**(index+1)))
```