IMPLEMENTATION OF ANALOG FILTERS IN MATLAB

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BUTTERWORTH FILTER LOWPASS-→LOWPASS

BWlp2lp.m

```
%ButterWorth lowpass ---> lowpass

fpb=input("passBand freq:");
fsb=input("Stopband freq:");
pb=input("Enter the passband ripple:");
sa=input("Enter the stopband attenuation:");

opb=2*pi*fpb;
osb=2*pi*fsb;

%stopband freq
or=osb/opb;
disp("Stopband freq--normalized LPF")
disp(or)

%order of filter
num=log10(((10^(-pb/10))-1)/((10^(-sa/10))-1));
den=2*log10(1/or);
N=ceil(num/den);
disp("order")
disp(N)

%to suppress warning on terminal
warning("off","all");

s=tf('s');
hsde=1;

%to find poles
for k=0:N-1
    sk(k+1)=exp(1j*pi/2)*exp((1j*(2*k+1)*pi)/(2*N));
    hsde=hsde*(s-sk(k+1));
end

disp('poles')
disp(sk)

%transfer function
num=(1);
den=real(poly(sk));
HaSN=tf(num,den)

%cutoff frequency
```

```
ocn=1/(((10^(-pb/10))-1)^(1/(2*N)));
ocp=ocn*opb;
[b,a]=lp2lp(num,den,ocp);
hslowpass=tf(b,a)
```

Terminal output:

```
>> BWlp2lp
passBand freq:3.183
Stopband freq:4.774
Enter the passband ripple:-2
Enter the stopband attenuation:-10
Stopband freq--normalized LPF
    1.4998

order
     4

poles
  -0.3827 + 0.9239i  -0.9239 + 0.3827i  -0.9239 - 0.3827i  -0.3827 - 0.9239i


HaSN =

                      1
  ----------------------------------------
  s^4 + 2.613 s^3 + 3.414 s^2 + 2.613 s + 1

Continuous-time transfer function.


hslowpass =

                       2.092e05
  -------------------------------------------------
  s^4 + 55.88 s^3 + 1562 s^2 + 2.556e04 s + 2.092e05

Continuous-time transfer function.
```

BUTTERWORTH FILTER LOWPASS-→HIGHPASS

BWlp2hp.m

```
%ButterWorth lowpass ---> highpass

fpb=input("passBand freq:");
fsb=input("Stopband freq:");
pb=input("Enter the passband ripple:");
sa=input("Enter the stopband attenuation:");

opb=2*pi*fpb;
osb=2*pi*fsb;

%stopband freq
or=opb/osb;
disp("Stopband freq--normalized LPF")
```

```
disp(or)

%order of filter
num=log10(((10^(-pb/10))-1)/((10^(-sa/10))-1));
den=2*log10(1/or);
N=ceil(num/den);
disp("order")
disp(N)

%to suppress warning on terminal
warning("off","all");

s=tf('s');
hsde=1;

%to find poles
for k=0:N-1
    sk(k+1)=exp(1j*pi/2)*exp((1j*(2*k+1)*pi)/(2*N));
    hsde=hsde*(s-sk(k+1));
end

disp('poles')
disp(sk)

%transfer function
num=(1);
den=real(poly(sk));
HaSN=tf(num,den)

%cutoff frequency
ocn=1/(((10^(-pb/10))-1)^(1/(2*N)));
ocp=(opb/ocn);
[b,a]=lp2hp(num,den,ocp);
hshighpass=tf(b,a)
```

Terminal Output:

```
>> BWlp2hp
passBand freq:31.830
Stopband freq:15.915
Enter the passband ripple:-2
Enter the stopband attenuation:-20
Stopband freq--normalized LPF
     2

order
     4

poles
  -0.3827 + 0.9239i  -0.9239 + 0.3827i  -0.9239 - 0.3827i  -0.3827 - 0.9239i


HaSN =

                      1
  ----------------------------------------
  s^4 + 2.613 s^3 + 3.414 s^2 + 2.613 s + 1
```

```
Continuous-time transfer function.


hshighpass =

                   s^4 - 8.039e-14 s^3
  ---------------------------------------------------
  s^4 + 488.7 s^3 + 1.194e05 s^2 + 1.709e07 s + 1.224e09

Continuous-time transfer function.
```

BUTTERWORTH FILTER LOWPASS-→BANDPASS

BWlp2bp.m

```
%Butterworth lowpass-->Bandpass

f1=input("Enter stopband freq F1:");
f2=input("Enter stopband freq F2:");
fl=input("Enter lower cutoff freq:");
fu=input("Enter upper cutoff freq:");
pb=input("Enter the passband ripple:");
sa=input("Enter the stopband attenuation:");

o1=2*pi*f1;
o2=2*pi*f2;
ol=2*pi*fl;
ou=2*pi*fu;

A=(((-(o1^2))+(ol*ou))/(o1*(ou-ol)));
B=((((o2^2))-(ol*ou))/(o2*(ou-ol)));

%stopband freq
or=min(A,B);
disp("stopband freq --normalized LPF")
disp(or)

%order of filter
num=log10(((10^(-pb/10))-1)/((10^(-sa/10))-1));
den=2*log10(1/or);
N=ceil(num/den);
disp("order")
disp(N)

%to suppress warning on terminal
warning("off","all");

s=tf('s');
hsde=1;

%to find poles
for k=0:N-1
```

```
    sk(k+1)=exp(1j*pi/2)*exp((1j*(2*k+1)*pi)/(2*N));
    hsde=hsde*(s-sk(k+1));
end

disp('poles')
disp(sk)

%transfer function
num=(1);
den=real(poly(sk));
HaSN=tf(num,den)

ocf=sqrt(ou*ol);
obw=ou-ol;
[b,a]=lp2bp(num,den,ocf,obw);
hsbandpass=tf(b,a)
```

Terminal output:

```
>> BWlp2bp

Enter stopband freq F1:20

Enter stopband freq F2:45000

Enter lower cutoff freq:50

Enter upper cutoff freq:20000

Enter the passband ripple:-3

Enter the stopband attenuation:-20

stopband freq --normalized LPF

   2.2545

order

    3

poles

  -0.5000 + 0.8660i  -1.0000 + 0.0000i  -0.5000 - 0.8660i

HaSN =


         1

  ---------------------

  s^3 + 2 s^2 + 2 s + 1

Continuous-time transfer function.
```

hsbandpass =

$$\frac{1.97\text{e}15\ s^3}{s^6 + 2.507\text{e}05\ s^5 + 3.154\text{e}10\ s^4 + 1.989\text{e}15\ s^3 + 1.245\text{e}18\ s^2 + 3.907\text{e}20\ s + 6.153\text{e}22}$$

Continuous-time transfer function.

BUTTERWORTH FILTER LOWPASS-→BANDSTOP

BWlp2bs.m

```
%Butterworth lowpass-->Bandstop

f1=input("Enter stopband freq F1:");
f2=input("Enter stopband freq F2:");
fl=input("Enter lower cutoff freq:");
fu=input("Enter upper cutoff freq:");
pb=input("Enter the passband ripple:");
sa=input("Enter the stopband attenuation:");

o1=2*pi*f1;
o2=2*pi*f2;
ol=2*pi*fl;
ou=2*pi*fu;

A=((o1*(ou-ol))/((-(o1^2))+(ol*ou)));
B=((o2*(ou-ol))/((-(o2^2))+(ol*ou)));

%stopband freq
or=min(abs(A),abs(B));
disp("stopband freq --normalized LPF")
disp(or)

%order of filter
num=log10(((10^(-pb/10))-1)/((10^(-sa/10))-1));
den=2*log10(1/or);
N=ceil(num/den);
disp("order")
disp(N)

%to suppress warning on terminal
warning("off","all");

s=tf('s');
hsde=1;

%to find poles
for k=0:N-1
    sk(k+1)=exp(1j*pi/2)*exp((1j*(2*k+1)*pi)/(2*N));
    hsde=hsde*(s-sk(k+1));
end
```

```
disp('poles')
disp(sk)

%transfer function
num=(1);
den=real(poly(sk));
HaSN=tf(num,den)

ocf=sqrt(ou*ol);
obw=ou-ol;
[b,a]=lp2bs(num,den,ocf,obw);
hsbandstop=tf(b,a)
```

Terminal output:

```
>> BWlp2bs

Enter stopband freq F1:0.1156

Enter stopband freq F2:0.2190

Enter lower cutoff freq:0.0355

Enter upper cutoff freq:0.7120

Enter the passband ripple:-3

Enter the stopband attenuation:-15

stopband freq --normalized LPF

   6.5309

order

    1

poles

  -1.0000 + 0.0000i

HaSN =

    1

  -----

  s + 1

Continuous-time transfer function.

hsbandstop =

      s^2 + 0.9979

  ----------------------

  s^2 + 4.251 s + 0.9979
```

Continuous-time transfer function.

CHEBYSHEV FILTER LOWPASS--->LOWPASS

CHlp2lp.m

```
%chebyshev filter lowpass-->lowpass

fpb=input("passBand freq:");
fsb=input("Stopband freq:");
pb=input("Enter the passband ripple:");
sa=input("Enter the stopband attenuation:");

opb=2*pi*fpb;
osb=2*pi*fsb;

%stopband freq
or=osb/opb;
disp("Stopband freq--normalized LPF")
disp(or)

%order of filter
eps=sqrt((10^(-pb/10))-1);
a=10^(-sa/20);
g=sqrt(((a^2)-1)/(eps^2));
N=log10(g+sqrt((g^2)-1))/(log10(or+sqrt((or^2)-1)));
N=ceil(N);
disp("order")
disp(N)

%to suppress warning on terminal
warning("off","all");

s=tf('s');
hsde=1;
%to find the poles

theta=(1/N)*asinh(1/eps);
a=sinh(theta);
b=cosh(theta);

for k=1:N
    sigma(k)=-a*sin(((2*k-1)*pi)/(2*N));
    omega(k)=b*cos(((2*k-1)*pi)/(2*N));

    sk(k)=sigma(k)+1i*omega(k);
    hsde=hsde+(s-sk(k));
end

disp('poles')
disp(sk)

den=real(poly(sk));
b0=den(N+1);
if(mod(N,2)==0)
    k0=(b0/sqrt(1+(eps^2)));
else
```

```
    k0=b0;
end

num=k0;
HaSN=tf(num,den)

[b,a]=lp2lp(num,den,opb);
hslowpass=tf(b,a)
```

Terminal output:

```
>> CHlp2lp

passBand freq:6.366

Stopband freq:8.276

Enter the passband ripple:-2

Enter the stopband attenuation:-20

Stopband freq--normalized LPF

   1.3000

order

    5

poles

  -0.0675 + 0.9735i  -0.1766 + 0.6016i  -0.2183 + 0.0000i  -0.1766 - 0.6016i  -0.0675 - 0.9735i

HaSN =

                    0.08172

  ------------------------------------------------------------

  s^5 + 0.7065 s^4 + 1.5 s^3 + 0.6935 s^2 + 0.4593 s + 0.08172

Continuous-time transfer function.

hslowpass =

                     8.367e06

  ---------------------------------------------------------------

  s^5 + 28.26 s^4 + 2399 s^3 + 4.438e04 s^2 + 1.176e06 s + 8.367e06

Continuous-time transfer function.
```

CHEBYSHEV FILTER LOWPASS--->HIGHPASS

CHlp2hp.m

```
%chebyshev filter lowpass-->highpass

fpb=input("passBand freq:");
fsb=input("Stopband freq:");
pb=input("Enter the passband ripple:");
sa=input("Enter the stopband attenuation:");

opb=2*pi*fpb;
osb=2*pi*fsb;

%stopband freq
or=opb/osb;
disp("Stopband freq--normalized LPF")
disp(or)

%order of filter
eps=sqrt((10^(-pb/10))-1);
a=10^(-sa/20);
g=sqrt(((a^2)-1)/(eps^2));
N=log10(g+sqrt((g^2)-1))/(log10(or+sqrt((or^2)-1)));
N=ceil(N);
disp("order")
disp(N)

%to suppress warning on terminal
warning("off","all");

s=tf('s');
hsde=1;
%to find the poles

theta=(1/N)*asinh(1/eps);
a=sinh(theta);
b=cosh(theta);

for k=1:N
    sigma(k)=-a*sin(((2*k-1)*pi)/(2*N));
    omega(k)=b*cos(((2*k-1)*pi)/(2*N));

    sk(k)=sigma(k)+1i*omega(k);
    hsde=hsde+(s-sk(k));
end

disp('poles')
disp(sk)

den=real(poly(sk));
b0=den(N+1);
if(mod(N,2)==0)
    k0=(b0/sqrt(1+(eps^2)));
else
    k0=b0;
end

num=k0;
HaSN=tf(num,den)
```

```
[b,a]=lp2hp(num,den,opb);
hshighpass=tf(b,a)
```

Terminal output:

```
>> CHlp2hp
passBand freq:0.3123
Stopband freq:0.1591
Enter the passband ripple:-1
Enter the stopband attenuation:-40
Stopband freq--normalized LPF
   1.9629

order
    5

poles
  -0.0895 + 0.9901i  -0.2342 + 0.6119i  -0.2895 + 0.0000i  -0.2342 - 0.6119i  -0.0895 - 0.9901i


HaSN =

                    0.1228
  ------------------------------------------------------------
  s^5 + 0.9368 s^4 + 1.689 s^3 + 0.9744 s^2 + 0.5805 s + 0.1228

Continuous-time transfer function.


hshighpass =

  s^5 + 2.567e-15 s^4 + 5.878e-16 s^3 - 3.442e-16 s^2 + 2.414e-16 s + 3.724e-14
  ------------------------------------------------------------------------------
         s^5 + 9.274 s^4 + 30.55 s^3 + 103.9 s^2 + 113.1 s + 236.8

Continuous-time transfer function.
```

CHEBYSHEV FILTER LOWPASS--->BANDPASS

CHlp2bp.m

```
%chebyshev filter lowpass--->bandpass
f1=input("Enter stopband freq F1:");
f2=input("Enter stopband freq F2:");
fl=input("Enter lower cutoff freq:");
fu=input("Enter upper cutoff freq:");
pb=input("Enter the passband ripple:");
sa=input("Enter the stopband attenuation:");

o1=2*pi*f1;
o2=2*pi*f2;
```

```
ol=2*pi*fl;
ou=2*pi*fu;

A=(((-(o1^2))+(ol*ou))/(o1*(ou-ol)));
B=((((o2^2))-(ol*ou))/(o2*(ou-ol)));

%stopband freq
or=min(A,B);
disp("stopband freq --normalized LPF")
disp(or)

%order of filter
eps=sqrt((10^(-pb/10))-1);
a=10^(-sa/20);
g=sqrt(((a^2)-1)/(eps^2));
N=log10(g+sqrt((g^2)-1))/(log10(or+sqrt((or^2)-1)));
N=ceil(N);
disp("order")
disp(N)

%to suppress warning on terminal
warning("off","all");

s=tf('s');
hsde=1;
%to find the poles

theta=(1/N)*asinh(1/eps);
a=sinh(theta);
b=cosh(theta);

for k=1:N
    sigma(k)=-a*sin(((2*k-1)*pi)/(2*N));
    omega(k)=b*cos(((2*k-1)*pi)/(2*N));

    sk(k)=sigma(k)+1i*omega(k);
    hsde=hsde+(s-sk(k));
end

disp('poles')
disp(sk)

den=real(poly(sk));
b0=den(N+1);
if(mod(N,2)==0)
    k0=(b0/sqrt(1+(eps^2)));
else
    k0=b0;
end

num=k0;
HaSN=tf(num,den)

ocf=sqrt(ou*ol);
obw=ou-ol;
[b,a]=lp2bp(num,den,ocf,obw);
hsbandpass=tf(b,a)
```

Terminal output:

```
>> CHlp2bp

Enter stopband freq F1:0.0252

Enter stopband freq F2:0.1591

Enter lower cutoff freq:0.0517

Enter upper cutoff freq:0.1156

Enter the passband ripple:-1

Enter the stopband attenuation:-10

stopband freq --normalized LPF

   1.9020

order

    2

poles

  -0.5489 + 0.8951i  -0.5489 - 0.8951i

HaSN =

       0.9826

  ---------------------

  s^2 + 1.098 s + 1.103

Continuous-time transfer function.

hsbandpass =

                  0.1584 s^2

  -------------------------------------------------

  s^4 + 0.4407 s^3 + 0.6496 s^2 + 0.104 s + 0.05567

Continuous-time transfer function.
```

CHEBYSHEV FILTER LOWPASS--->BANDSTOP

CHlp2bs.m

```
%chebyshev filter lowpass--->bandstop

f1=input("Enter stopband freq F1:");
f2=input("Enter stopband freq F2:");
fl=input("Enter lower cutoff freq:");
fu=input("Enter upper cutoff freq:");
```

```
pb=input("Enter the passband ripple:");
sa=input("Enter the stopband attenuation:");

o1=2*pi*f1;
o2=2*pi*f2;
ol=2*pi*fl;
ou=2*pi*fu;

A=((o1*(ou-ol))/((-(o1^2))+(ol*ou)));
B=((o2*(ou-ol))/((-(o2^2))+(ol*ou)));

%stopband freq
or=min(abs(A),abs(B));
disp("stopband freq --normalized LPF")
disp(or)

%order of filter
eps=sqrt((10^(-pb/10))-1);
a=10^(-sa/20);
g=sqrt(((a^2)-1)/(eps^2));
N=log10(g+sqrt((g^2)-1))/(log10(or+sqrt((or^2)-1)));
N=ceil(N);
disp("order")
disp(N)

%to suppress warning on terminal
warning("off","all");

s=tf('s');
hsde=1;
%to find the poles

theta=(1/N)*asinh(1/eps);
a=sinh(theta);
b=cosh(theta);

for k=1:N
    sigma(k)=-a*sin(((2*k-1)*pi)/(2*N));
    omega(k)=b*cos(((2*k-1)*pi)/(2*N));

    sk(k)=sigma(k)+1i*omega(k);
    hsde=hsde+(s-sk(k));
end

disp('poles')
disp(sk)

den=real(poly(sk));
b0=den(N+1);
if(mod(N,2)==0)
    k0=(b0/sqrt(1+(eps^2)));
else
    k0=b0;
end

num=k0;
HaSN=tf(num,den)

ocf=sqrt(ou*ol);
```

```
obw=ou-ol;
[b,a]=lp2bs(num,den,ocf,obw);
hsbandstop=tf(b,a)
```

Terminal output:

```
>> CHlp2bs

Enter stopband freq F1:0.0349

Enter stopband freq F2:0.0659

Enter lower cutoff freq:0.0172

Enter upper cutoff freq:0.1591

Enter the passband ripple:-1

Enter the stopband attenuation:-15

stopband freq --normalized LPF

   3.2613

order

    2

poles

  -0.5489 + 0.8951i  -0.5489 - 0.8951i

HaSN =

       0.9826

  ---------------------

  s^2 + 1.098 s + 1.103

Continuous-time transfer function.

hsbandstop =

         0.8913 s^4 + 0.1926 s^2 + 0.0104

  -------------------------------------------------

  s^4 + 0.8877 s^3 + 0.9371 s^2 + 0.0959 s + 0.01167

Continuous-time transfer function.
```