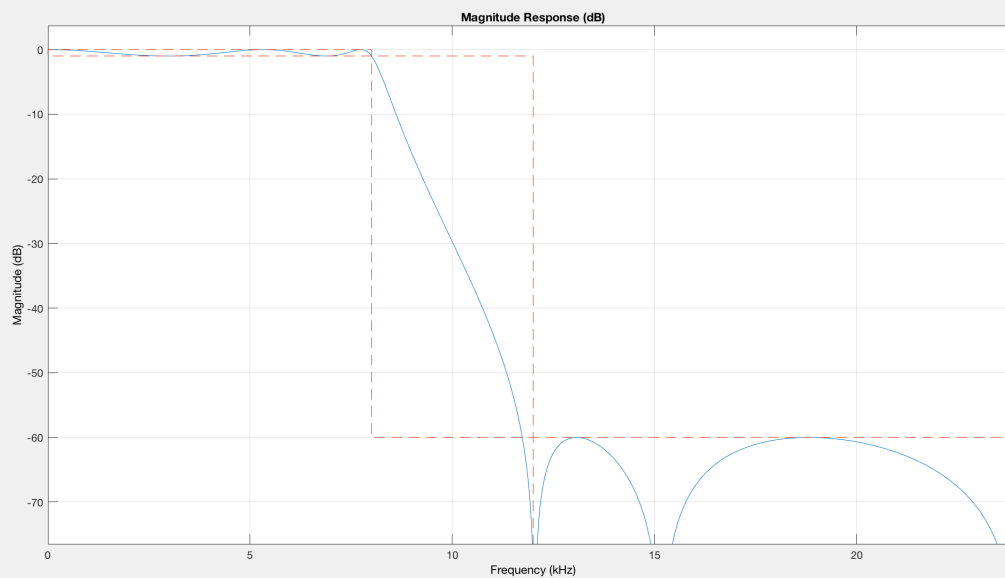# IIR Filter Design and Implementation

Design Filter

```
Fpass = 8000;
Fstop = 12000;
Apass = 1;
Astop = 60;
Fs = 48000;

filtSpec = fdesign.lowpass(Fpass, Fstop, Apass, Astop, Fs);
% list possible filter design methods
methods = designmethods(filtSpec);
filt = design(filtSpec, 'ellip');
fvtool(filt);
```
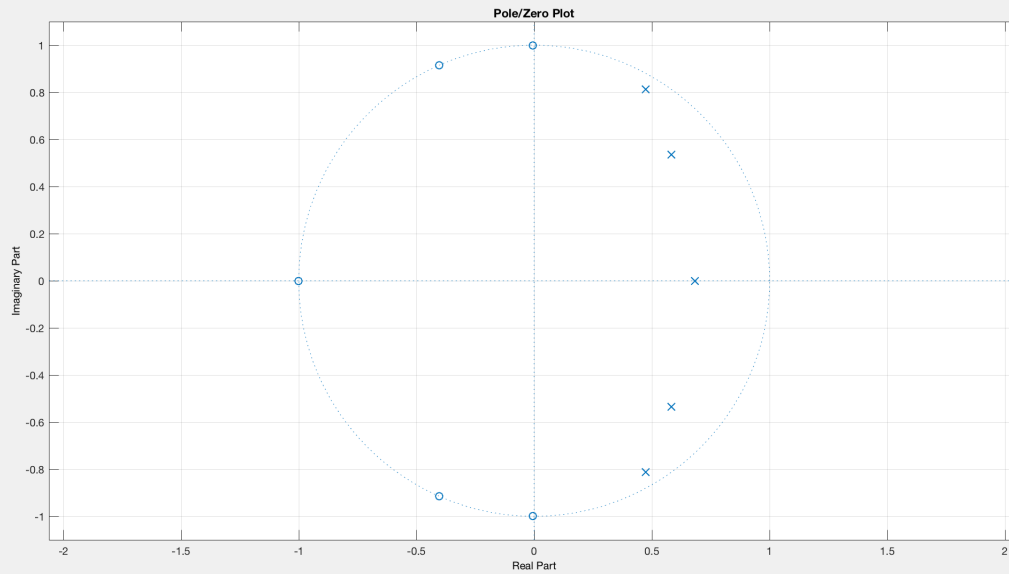

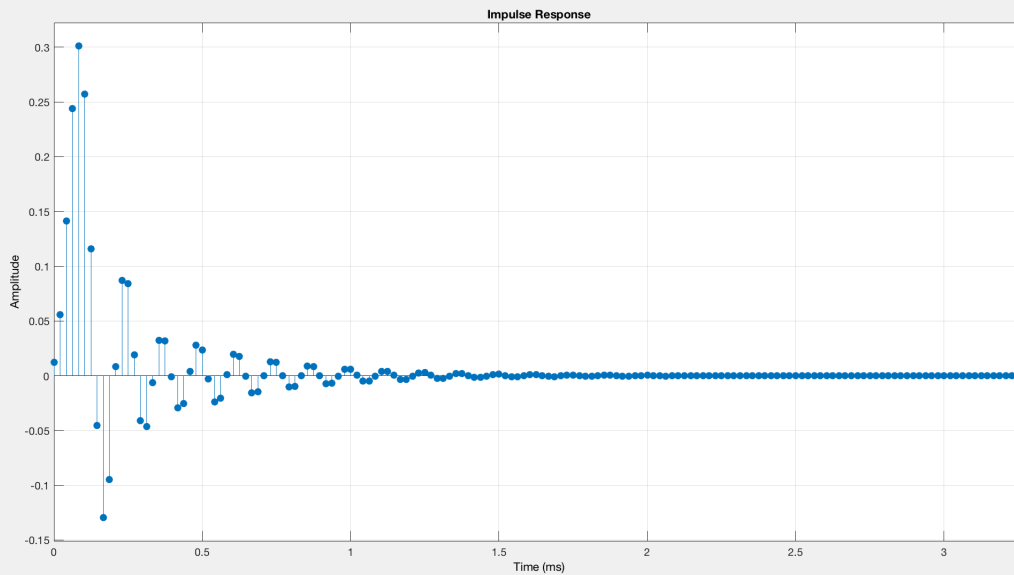
- Von welcher Ordnung ist das Filter?

```
N = 5;
```

- Wo liegen die Pole und Nullstellen des Filters?

```
h = fvtool(filt);
h.Analysis = 'polezero';
```

Pole/Zero Plot

- Wie sieht die Impulsantwort des Filters aus?

```
h = fvtool(filt);
h.Analysis = 'impulse';
```


Impulse Response

Struktur und Skalierung

```
% Zerlegung in Biquads (second order structures SOS)
SOS = filt.sosMatrix;
G = filt.ScaleValues;
```

$$\text{SOS} = \begin{bmatrix} b_{01} & b_{11} & b_{21} & 1 & a_{11} & a_{21} \\ b_{02} & b_{12} & b_{22} & 1 & a_{12} & a_{22} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ b_{0L} & b_{1L} & b_{2L} & 1 & a_{1L} & a_{2L} \end{bmatrix}$$

```
% Biquads extrahieren
b = SOS(:,1:3);
a = SOS(:,4:6);

% frequenzgänge berechnen
[h1, w1] = freqz(b(1,:), a(1,:));
[h2, w2] = freqz(b(2,:), a(2,:));
[h3, w3] = freqz(b(3,:), a(3,:));

% plotten
figure()
semilogy(w1, [abs(h1) abs(h2) abs(h3)])
grid on
title('3 Biquads')
xlabel('Frequency [rad]')
ylabel('abs')
legend('SOS 1','SOS 2','SOS 3')
```
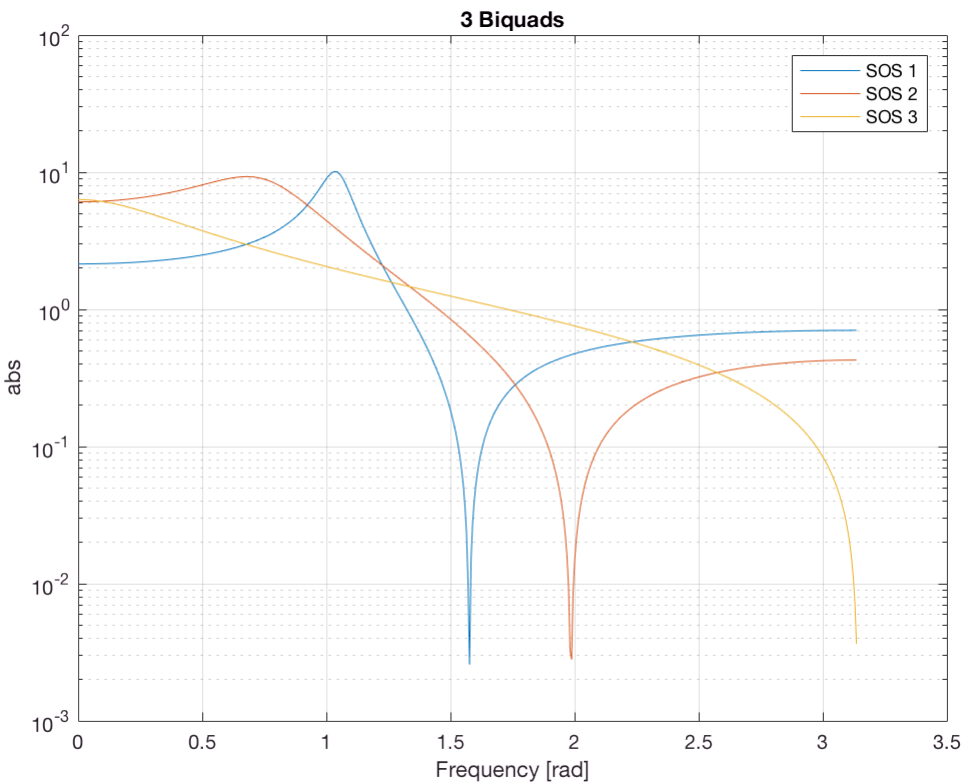

## Implementierende Reihenfolge

1. SOS3
2. SOS2

3. SOS1

Skalierung

```matlab
% Maximum gain von SOS3 und skalieren
g3 = max(abs(h3));
b(3,:) = b(3,:) .* 1/g3;
[h3, w3] = freqz(b(3,:), a(3,:));

% Block 1 und 2
g32 = max(abs(h3) .* abs(h2));
b(2,:) = b(2,:) .* 1/g32;
[h2, w2] = freqz(b(2,:), a(2,:));

% Block 1,2 und 3
g321 = max(abs(h3) .* abs(h2) .* abs(h1));
b(1,:) = b(1,:) .* 1/g321;
[h1, w1] = freqz(b(1,:), a(1,:));

% Alle plotten
figure()
semilogy(w1, [ (abs(h1).*abs(h2).*abs(h3))  abs(h1) abs(h2) abs(h3)])
grid on
title('3 Biquads normalized')
xlabel('Frequency [rad]')
ylabel('abs')
legend('Sum SOS','SOS 1','SOS 2','SOS 3')
```
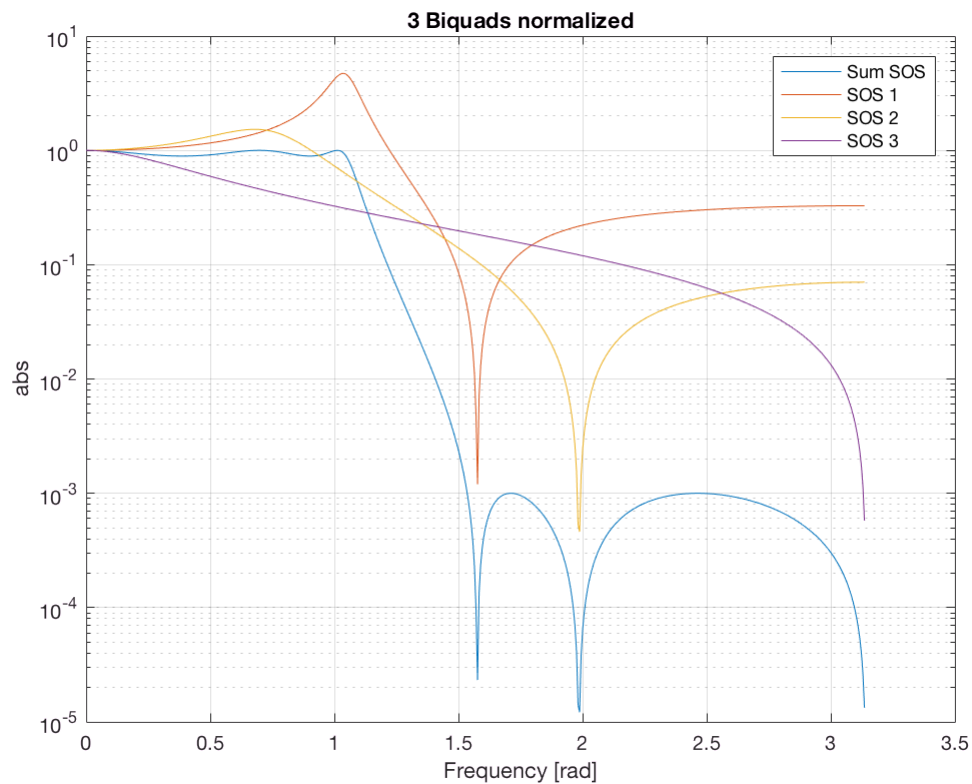

SOS zusammensetzen

```
SOSscaled = [b, a]
```

SOSscaled =
0.4662	0.0046	0.4662	1.0000	-0.9460	0.8828
0.1644	0.1324	0.1644	1.0000	-1.1665	0.6278
0.1582	0.1582	0	1.0000	-0.6836	0