

SigmaStudio Filter Coefficient Calculations

This document shows how to calculate B0, B1, B2, A1, and A2 for various IIR filter types in SigmaStudio.

Sin = sine, **Cos** = cosine, **Tan** = tangent, **Sinh** = hyperbolic sine, **Log** = base 10 logarithm

Parametric EQ Calculation

Values from Control:

boost (boost of filter)

frequency (center frequency)

Q (Q of filter; must be greater than or equal to 0.01)

gain (linear gain applied to the signal)

Fs (sample rate of project)

In the case that boost = 0,

```
gainlinear = 10(gain / 20)  
B0 = gainlinear  
B1 = 0  
B2 = 0  
A1 = 0  
A2 = 0
```

If boost is not 0,

Create 5 new variables: a0, omega, sn, cs, alpha, Ax

```
Ax = 10(boost / 40)  
omega = 2 * PI * frequency / Fs  
sn = Sin(omega)  
cs = Cos(omega)  
alpha = sn / (2 * (Q))  
  
a0 = 1 + (alpha / Ax)  
A1 = -( 2 * cs) / a0  
A2 = (1 - (alpha / Ax)) / a0  
gainlinear = 10(gain / 20) / a0  
  
B0 = (1 + (alpha * Ax)) * gainlinear  
B1 = -( 2 * cs) * gainlinear  
B2 = (1 - (alpha * Ax)) * gainlinear
```

Tone Control

Values from Control:

Freq_T (treble cutoff frequency)

Boost_T (treble boost)

Freq_B (bass cutoff frequency)

Boost_B (bass boost)

Fs (sample rate of project)

$$\text{Boost_T} = 10^{(\text{Boost_T} / 20)}$$

$$\text{Boost_B} = 10^{(\text{Boost_B} / 20)}$$

$$A_T = \text{Tan}(\text{PI} * \text{Freq_T} / \text{Fs})$$

$$A_B = \text{Tan}(\text{PI} * \text{Freq_B} / \text{Fs})$$

$$\text{Knum_T} = 2 / (1 + (1 / \text{Boost_T}))$$

$$\text{Kden_T} = 2 / (1 + \text{Boost_T})$$

$$\text{Knum_B} = 2 / (1 + (1 / \text{Boost_B}))$$

$$\text{Kden_B} = 2 / (1 + \text{Boost_B})$$

$$a10 = A_T + \text{Kden_T}$$

$$a11 = A_T - \text{Kden_T}$$

$$b10 = A_T + \text{Knum_T}$$

$$b11 = A_T - \text{Knum_T}$$

$$a20 = (A_B * \text{Kden_B}) + 1$$

$$a21 = (A_B * \text{Kden_B}) - 1$$

$$b20 = (A_B * \text{Knum_B}) - 1$$

$$b21 = (A_B * \text{Knum_B}) + 1$$

$$a0 = a10 * a20$$

$$A1 = ((a10 * a21) + (a11 * a20)) / a0$$

$$A2 = a11 * a21$$

$$/ a0$$

$$\text{gainlinear} = 10^{(\text{cell_gain} / 20)}$$

$$B0 = (b10 * b20) / a0 * \text{gainlinear}$$

$$B1 = ((b10 * b21) + (b11 * b20)) / a0 * \text{gainlinear}$$

$$B2 = (b11 * b21) / a0 * \text{gainlinear}$$

For double 1st Order Filter cells, simply use 2 Cascaded 1st Order Filters

All Pass

Values from control:

frequency (center frequency)

Q (Q of filter)

gain1 (linear gain)

fs (sample rate of project)

```
gain1 = 10(gain / 20)
omega = 2 * PI * frequency / fs
sins = Sin(omega)
coss = Cos(omega)
alpha = sins / (2 * Q)

norm = 1 + alpha

B0 = gain1 * (1 - alpha) / norm
B1 = gain1 * (- 2 * coss) / norm
B2 = gain1 * (1 + alpha) / norm
A1 = - 2 * coss / norm
A2 = (1 - alpha) / norm
```

Notch Filter

Values from control:

frequency1 (center frequency)

Q (Q of filter)

g (gain)

fs (sample rate of project)

```
omega = frequency1 * 2 * System.PI / fs
deltaomega = omega / Q
b = 1 / (1 + Tan(deltaomega / 2))
gain = 10(g / 20)
B0 = gain * b
B1 = gain * (- 2 * b * Cos(omega))
B2 = gain * b
A1 = - 2 * b * Cos(omega)
A2 = (2 * b - 1)
```

Chebyshev Low Pass

Values from control:

frequency (cutoff frequency; must be 1 Hz or greater)

gain (linear gain)

ripple (ripple of filter; must be 0.1 or greater)

Fs (sample rate of project)

```
wp = (2 * PI * frequency) / Fs
Omegap = Tan(wp / 2)
epass = (10(0.1 * ripple) - 1)0.5
alpha = (0.5) * Log(1 / epass + (1 / (epass2 + 1))0.5)
Omega0 = Omegap * Sinh(alpha);
theta = (PI / 4) * 3
Omega1 = Omegap * Sin(theta)
H0 = (1 / (1 + epass2))0.5
Den = 1 - (2 * Omega0 * Cos(theta)) + Omega02 + Omega12
G = (Omega02 + Omega12) / Den

A1 = (2 * (Omega02 + Omega12 - 1)) / Den
A2 = (1 + (2 * Omega0 * Cos(theta)) + Omega02 + Omega12) / Den
B0 = H0 * G * 10(gain / 20)
B1 = B0 * 2
B2 = B0
```

ChebyshevHighPass

Values from control:

frequency (cutoff frequency; must be 1 Hz or greater)

gain (linear gain)

ripple (ripple of filter; must be 0.1 or greater)

Fs (sample rate of project)

```
wp = (2 * PI * frequency) / Fs
Omegap = 1 / Tan(wp / 2)
epass = (10(0.1 * ripple) - 1)0.5
alpha = (0.5) * Log(1 / epass + (1 / (epass2) + 1))0.5
Omega0 = Omegap * Sinh(alpha)
theta = (PI / 4) * 3
Omega1 = Omegap * Sin(theta)
H0 = (1 / (1 + (epass2)))0.5
Den = 1 - 2 * Omega0 * Cos(theta) + (Omega02) + (Omega12)
G = ((Omega02) + (Omega12)) / Den

A1 = (- 2 * ((Omega02) + (Omega12) - 1)) / Den
A2 = (1 + 2 * Omega0 * Cos(theta) + (Omega02) + (Omega12)) / Den
B0 = H0 * G * (10(gain / 20))
B1 = - B0 * 2
B2 = B0
```

Linkwitz-Riley - 12 dB/oct = 2 cascaded 1st order butterworths (2 biquads)

frequency (the cutoff frequency)

First Order **type** (the type of filter, can be lowpass, highpass, or allpass)

g (the linear gain)

fs (the sample rate of the project)

1st Order Butterworth

$$\text{gain} = (10^{(g / 20)})$$

omega, sn, cs, alpha, a0

$$\text{omega} = 2 * \text{PI} * \text{frequency} / \text{fs}$$

$$\text{sn} = \text{Sin}(\text{omega})$$

$$\text{cs} = \text{Cos}(\text{omega})$$

$$\text{a0} = \text{sn} + \text{cs} + 1;$$

For a First Order **lowpass**...

$$\text{A1} = (\text{sn} - \text{cs} - 1) / \text{a0}$$

$$\text{B0} = \text{gain} * \text{sn} / \text{a0}$$

$$\text{B1} = \text{gain} * \text{sn} / \text{a0}$$

For a First Order **highpass**...

$$\text{A1} = (\text{sn} - \text{cs} - 1) / \text{a0}$$

$$\text{B0} = \text{gain} * (1 + \text{cs}) / \text{a0}$$

$$\text{B1} = - \text{gain} * (1 + \text{cs}) / \text{a0}$$

For a First Order **allpass**...

$$\text{A1} = (2.7^{(-2 * \text{PI} * \text{frequency} / \text{fs})})$$

$$\text{B0} = - \text{gain} * \text{A1}$$

$$\text{B1} = \text{gain}$$

Linkwitz-Riley - 24 dB/oct = 2 cascaded 2nd order butterworths (2 biquads)

frequency (the cutoff frequency)

gain (the linear gain)

Fs (the sample rate of the project)

2nd Order LOWPASS

$\omega = 2 * \text{PI} * \text{frequency} / \text{Fs}$

$\omega = 2 * \text{PI} * \text{frequency} / \text{Fs}$

$\text{sn} = \text{Sin}(\omega)$

$\text{cs} = \text{Cos}(\omega)$

$\alpha = \text{sn} / (2 * (1 / (2)^{0.5}))$

$a_0 = 1 + \alpha$

$A_1 = -(2 * \text{cs}) / a_0$

$A_2 = (1 - \alpha) / a_0$

$B_1 = (1 - \text{cs}) / a_0 * (10^{(\text{gain} / 20)})$

$B_0 = B_1 / 2$

$B_2 = B_0$

2nd Order HIGHPASS

$\omega = 2 * \text{PI} * \text{frequency} / \text{Fs}$

$\omega = 2 * \text{PI} * \text{frequency} / \text{Fs}$

$\text{sn} = \text{Sin}(\omega)$

$\text{cs} = \text{Cos}(\omega)$

$\alpha = \text{sn} / (2 * (1 / (2)^{0.5}))$

$a_0 = 1 + \alpha$

$A_1 = -(2 * \text{cs}) / a_0$

$A_2 = (1 - \alpha) / a_0$

$B_1 = -(1 + \text{cs}) / a_0 * (10^{(\text{gain} / 20)})$

$B_0 = -B_1 / 2$

$B_2 = B_0$

Linkwitz-Riley - 36 dB/oct = 2 cascaded 3rd order butterworths

3rd order butterworth is implemented by cascading a "HigherOrder" + 1st order

1st Filter: [HigherOrder] orderindex = 3, i = 0

2nd Filter: 1st Order Butterworth

3rd Filter: [HigherOrder] orderindex = 3, i = 0

4th Filter: 1st order Butterworth

frequency (the cutoff frequency)

gain (the linear gain)

Fs (the sample rate of the project)

orderindex (described above... changes based on type)

i (described above)

LOW PASS HIGHER ORDER

omega, sn, cs, alpha, a0 , orderangle

omega = 2 * PI * frequency / Fs

sn = Sin(omega)

cs = Cos(omega)

orderangle = (PI / orderindex) * (i + 0.5)

alpha = sn / (2 * (1 / (2 * Sin(orderangle))))

a0 = 1 + alpha

A1 = -(2 * cs) / a0

A2 = (1 - alpha) / a0

B1 = (1 - cs) / a0 * (10^(gain / 20))

B0 = B1 / 2

B2 = B0

HIGH PASS HIGHER ORDER

omega = 2 * PI * frequency / Fs

sn = Sin(omega)

cs = Cos(omega)

orderangle = (PI / orderindex) * (i + 0.5)

alpha = sn / (2 * (1 / (2 * Sin(orderangle))))

a0 = 1 + alpha

A1 = -(2 * cs) / a0

A2 = (1 - alpha) / a0

B1 = -(1 + cs) / a0 * (10^(gain / 20))

B0 = - B1 / 2

B2 = B0

Linkwitz-Riley - 48 dB/oct = 2 cascaded 4th order butterworths

4th order butterworth is implemented by cascading 2 2nd "Higher Order" using equations shown above.

1st Filter: orderindex = 4, i = 0

2nd Filter: orderindex = 4, i = 1

3rd Filter: orderindex = 4, i = 0

4th Filter: orderindex = 4, i = 1

Butterworth 12 dB/oct = One 2nd order butterworth

Butterworth 18 dB/oct = One Higher order butterworth + One 1st Order

Filt 1: [HigherOrder]: orderindex = 3, i = 0

Filt 2: 1st Order butterworth

Butterworth 24 dB/oct = 2 Higher order butterworths

Filt 1: orderindex = 4, i = 0

Filt 2: orderindex = 4, i = 1

Bessel 12 dB/oct = One 2nd order Bessel

frequency,

gain,

Fs

Low Pass Bessel

```
omega, sn, cs, alpha, a0
omega = 2 * PI * frequency / Fs
sn = Sin(omega)
cs = Cos(omega)
```

```
alpha = sn / (2 * (1 / (3)0.5))
```

```
a0 = 1 + alpha
A1 = -(2 * cs) / a0
A2 = (1 - alpha) / a0
B1 = (1 - cs) / a0 * (10(gain / 20))
```

```
B0 = B1 / 2
```

```
B2 = B0
```

High Pass Bessel

```
omega = 2 * PI * frequency / Fs
sn = Sin(omega)
cs = Cos(omega)
```

```
alpha = sn / (2 * (1 / (3)0.5))
```

```
a0 = 1 + alpha
A1 = -(2 * cs) / a0
A2 = (1 - alpha) / a0
B1 = -(1 + cs) / a0 * (10(gain / 20))
```

```
B0 = - B1 / 2
```

```
B2 = B0
```

Bessel 18 dB/oct = one 2nd order Bessel + One 1st order Butterworth

Bessel 24 dB/oct = Two 2nd order Besels