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Bi-quad filters realization on AIC Codecs

ABSTRACT

This application report provides information regarding filter equations and co-efficient format a representation that can be used to realize digital filters on the AIC3xxx mini DSP platform. It also explains ways to update the filter coefficients on the fly using a host processor.

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1 StandardBi-quadfilterequations

1.1 AllPass(Phaseshift)filters

Filterparameters
BW=BandwidthinHz
F_c=CenterfrequencyinHz
F_s=SamplefrequencyinHz

ErrorChecking

$$0 \le BW \le \frac{F_s}{2}$$

$$0 \le F_c \le \frac{F_s}{2}$$

$$0 \le F_s \le 192K$$
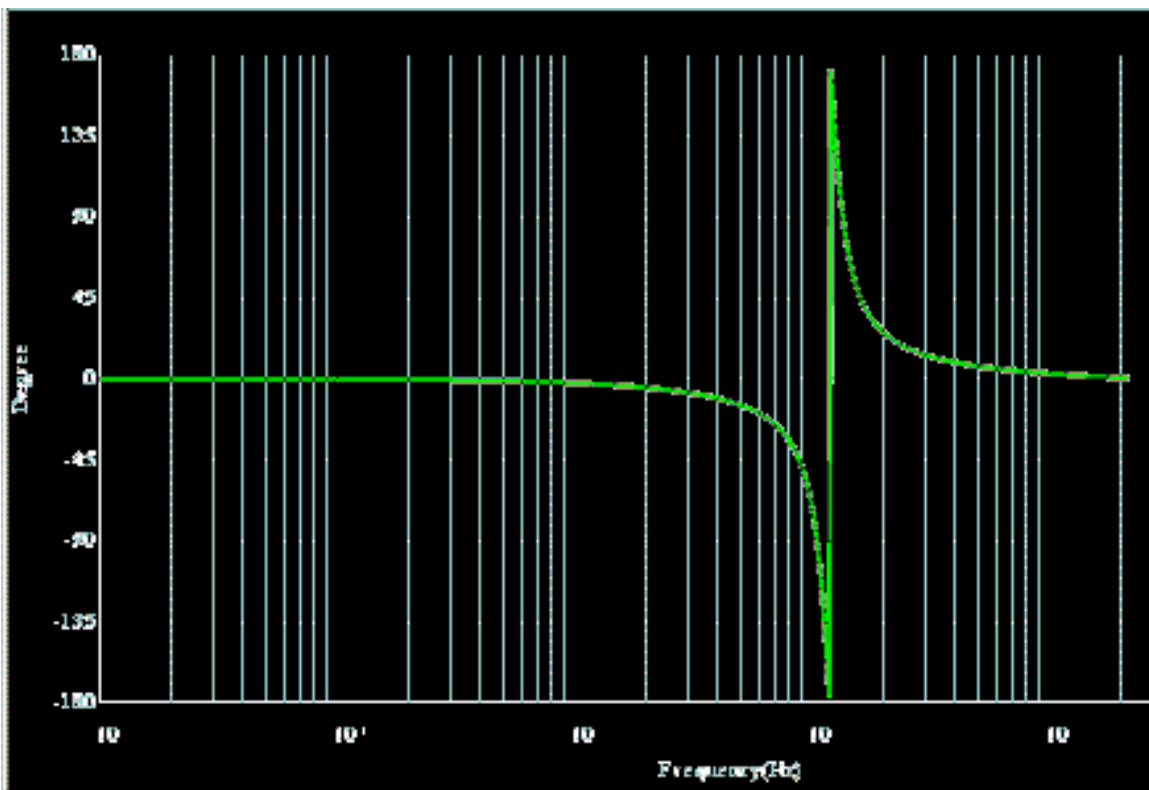
Figure1.   Phaseshiftfilterphaseresponse(F$_c$=1200Hz,BW=300Hz)

Equation

$$a = \frac{1 - \tan\left(\pi \times \dfrac{BW}{F_s}\right)}{1 + \tan\left(\pi \times \dfrac{BW}{F_s}\right)}$$

$$d = -\cos\left(2 \times \pi \times \frac{F_c}{F_s}\right)$$

FilterCoefficients

$b0 = a$

$b1 = d \times (1 + a)$

$a1 = b1$

$b2 = 1$

$a2 = a$

$B = [b0 \; b1 \; b2]$

$A = [1 \; a1 \; a2]$

1.2   Equalizationfilters

FilterParameters

BW=FilterBandwidthinHz

F_c=FilterCenterFrequencyinHz

F_s=SamplerateinHz

G=FilterGainindB

ErrorChecking

$$0 \le BW \le \frac{F_s}{2}$$

$$0 \le F_c \le \frac{F_s}{2}$$

$$0 \le F_s \le 192K$$

$$-140 \le G \le 48$$
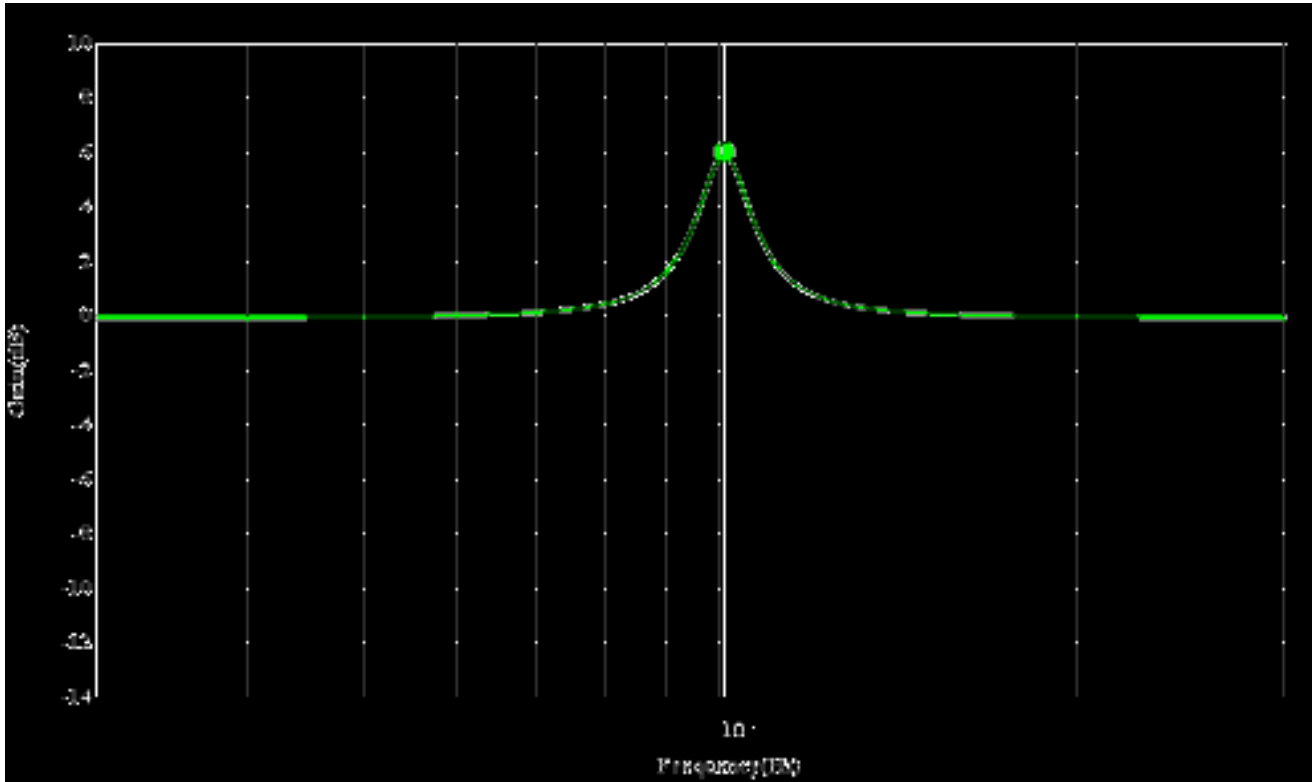
Figure2.   EQfilterwithF $_c$=1kHz,BW=100Hz,G=6dB

Equation

$$A = 10^{\frac{G}{20}}$$

$$if\,(A < 1)$$

$$a = \frac{\left(\tan\left(\pi \times \dfrac{BW}{F_s}\right) - A\right)}{\left(\tan\left(\pi \times \dfrac{BW}{F_s}\right) + A\right)}$$

$$else$$

$$a = \frac{\left(\tan\left(\pi \times \dfrac{BW}{F_s}\right) - 1\right)}{\left(\tan\left(\pi \times \dfrac{BW}{F_s}\right) + 1\right)}$$

$$H = A - 1$$

$$d = -\cos\left(2 \times \pi \times \frac{F_c}{F_s}\right)$$

FilterCoefficients

$$b0 = 1 + (1 + a) \times \frac{H}{2}$$

$$b1 = d \times (1 + a)$$

$$b2 = \left(-a - (1 + a) \times \frac{H}{2}\right)$$

$$a1 = b1$$

$$a2 = -a$$

$$B = \begin{bmatrix} b0 & b1 & b2 \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & a1 & a2 \end{bmatrix}$$

1.3 NotchFilters

FilterParameters

BW=NotchBandwidthinHz

F_c=NotchCenterfrequencyinHz

F_s=SamplerateinHz

ErrorChecking

$$0 \le BW \le \frac{F_s}{2}$$

$$0 \le F_c \le \frac{F_s}{2}$$

$$0 \le F_s \le 192K$$
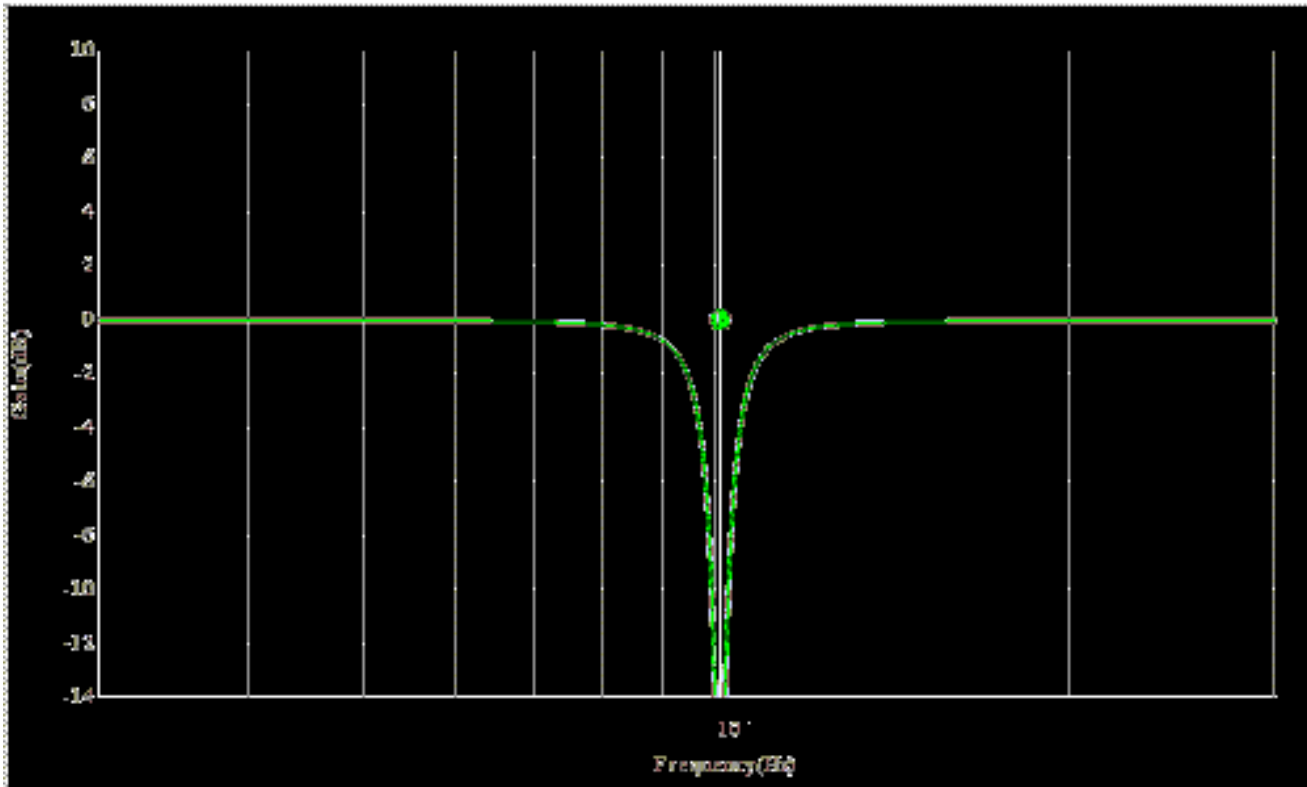
**Figure3.   NotchfiltermagnituderesponsewithF_c=1kHz,BW=100Hz**

Equation

$$a = \frac{1 - \tan\left(\pi \times \frac{BW}{F_s}\right)}{1 + \tan\left(\pi \times \frac{BW}{F_s}\right)}$$

$$d = -\cos\left(2 \times \pi \times \frac{F_c}{F_s}\right)$$

$$b0 = a$$

$$b1 = d \times (1 + a)$$

$$a1 = b1$$

$$b2 = 1$$

$$a2 = a$$

FilterCoefficients

$$B = \begin{bmatrix} b0 & b1 & b2 \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & a1 & a2 \end{bmatrix}$$

$$B = 0.5 \times (B + A)$$

1.4   TrebleShelf

FilterParameters

F_c =TrebleShelfCornerfrequencyinHz

F_s =SamplerateinHz

G=TrebleShelfGainindB

ErrorChecking

$$0 \le F_c \le \frac{F_s}{2}$$

$$0 \le F_s \le 192K$$

$$-24 \le G \le 24$$
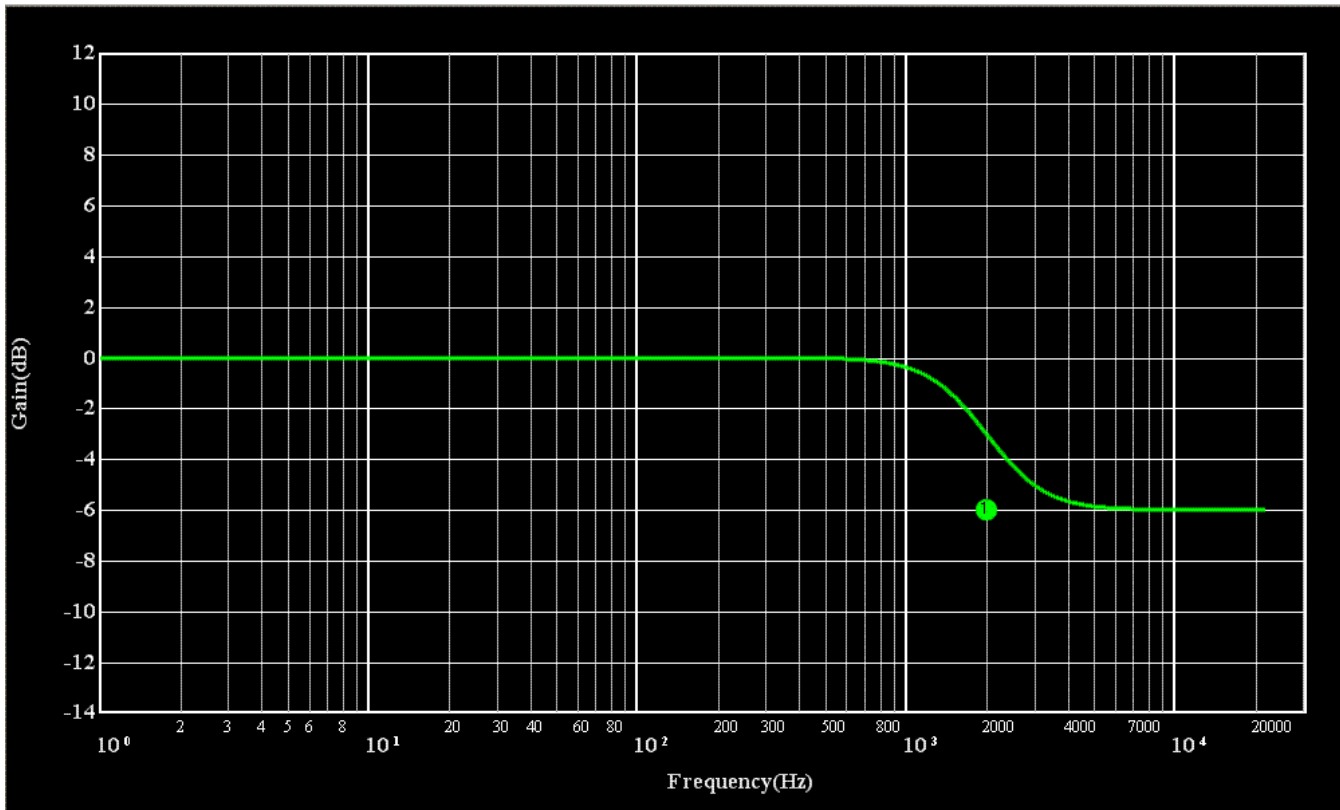
Figure4. Trebleshelffiltermagnituderesponse(F $_c$=2kHz,G=-6dB)

Equation

$$g = 10^{\frac{G}{20}}$$

$$s = \frac{sqrt(2)}{2}$$

$$\rho = \frac{\pi}{2}$$

$$\varphi = \frac{F_c}{F_s} \times \pi$$

$$A = g$$

$$G = 20 \times \log 10(A)$$

```
If G > -6 & G < 6
```
$$F = sqrt(A)$$
```
elseif A > 1
```
$$F = \frac{A}{sqrt(2)}$$
```
else
```
$$F = A \times sqrt(2)$$
```
end
```

$$gd = \sqrt[4]{\frac{(F^2 - 1)}{A^2 - F^2}}$$

$$gn = sqrt(A) \times gd$$

$$a = \tan\left(\pi \times \left(\frac{F_c}{F_s} - \frac{1}{4}\right)\right)$$

$$b0 = \frac{gn^2 \times a^2 + 2 \times s \times gn - 2 \times gn^2 \times a + 1 - 2 \times s \times gn \times a^2 + a^2 + gn^2 + 2 \times a}{1 + gd^2 + 2 \times s \times gd - 2 \times s \times gd \times a^2 + gd^2 \times a^2 - 2 \times gd^2 \times a + a^2 + 2 \times a}$$

$$b1 = \frac{2 - 2 \times gn^2 \times a^2 + 4 \times gn^2 \times a + 4 \times a - 2 \times gn^2 + 2 \times a^2}{1 + gd^2 + 2 \times s \times gd - 2 \times s \times gd \times a^2 + gd^2 \times a^2 - 2 \times gd^2 \times a + a^2 + 2 \times a}$$

$$b2 = \frac{1 + 2 \times s \times gn \times a^2 - 2 \times s \times gn + 2 \times a + a^2 + gn^2 - 2 \times gn^2 \times a + gn^2 \times a^2}{1 + gd^2 + 2 \times s \times gd - 2 \times s \times gd \times a^2 + gd^2 \times a^2 - 2 \times gd^2 \times a + a^2 + 2 \times a}$$

$$a0 = 1$$

$$a1 = \frac{2 - 2 \times gd^2 \times a^2 + 4 \times gd^2 \times a + 2 \times a^2 - 2 \times gd^2 + 4 \times a}{1 + gd^2 + 2 \times s \times gd - 2 \times s \times gd \times a^2 + gd^2 \times a^2 - 2 \times gd^2 \times a + a^2 + 2 \times a}$$

$$a2 = \frac{1 - 2 \times gd^2 \times a + 2 \times a + gd^2 - 2 \times s \times gd + a^2 + gd^2 \times a^2 + 2 \times s \times gd \times a^2}{1 + gd^2 + 2 \times s \times gd - 2 \times s \times gd \times a^2 + gd^2 \times a^2 - 2 \times gd^2 \times a + a^2 + 2 \times a}$$

FilterCoefficients

$$B = \begin{bmatrix} b0 & b1 & b2 \end{bmatrix}$$
$$A = \begin{bmatrix} a0 & a1 & a2 \end{bmatrix}$$

1.5 BassShelfFilters

FilterParameters

F_c =BassShelfCornerfrequencyinHz

F_s =SamplerateinHz

G=BassShelfGainindB

ErrorChecking

$$0 \le F_c \le \frac{F_s}{2}$$

$$0 \le F_s \le 192K$$
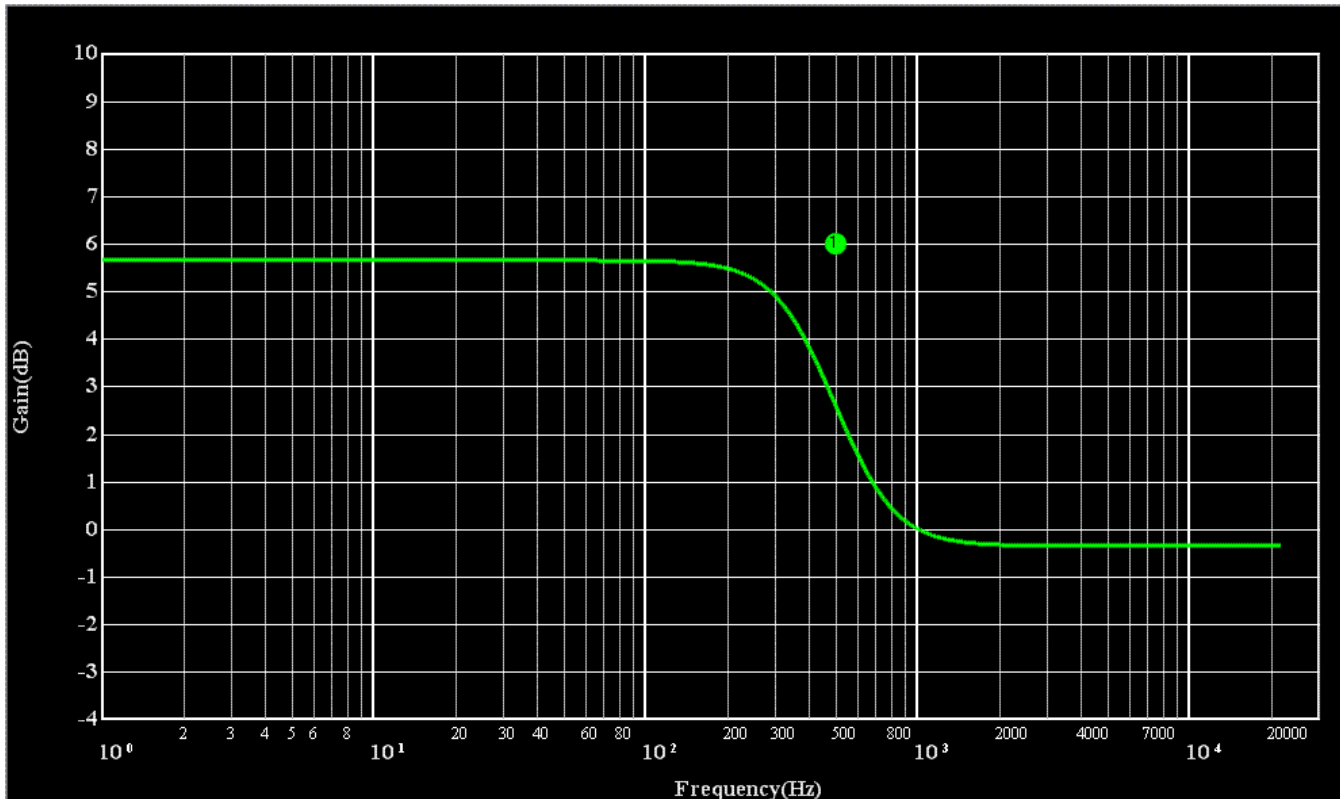
$$-24 \le G \le 24$$

Figure5.   Bassshelffiltermagnituderesponse(F   _c=500Hz,G=6dB)

Equation

$$g = 10^{\frac{G}{20}}$$

$$s = \frac{sqrt(2)}{2}$$

$$\rho = \frac{\pi}{2}$$

$$\varphi = \frac{F_c}{F_s} \times \pi$$

$$A = g$$

$$G = 20 \times \log 10(A)$$

```
If G > -6 & G < 6
```
$$F = sqrt(A)$$
```
elseif A > 1
```
$$F = \frac{A}{sqrt(2)}$$
```
else
```
$$F = A \times sqrt(2)$$
```
end
```

$$gd = \sqrt[4]{\frac{(F^2 - 1)}{A^2 - F^2}}$$

$$gn = sqrt(A) \times gd$$

$$a = \tan\left(\pi \times \left(\frac{F_c}{F_s} - \frac{1}{4}\right)\right)$$

$$b0 = \frac{-(-1 - gn^2 \times a^2 - a^2 - 2 \times gn^2 \times a - gn^2 - 2 \times s \times gn + 2 \times s \times gn \times a^2 + 2 \times a)}{2 \times s \times gd + 1 - 2 \times s \times gd \times a^2 + gd^2 \times a^2 + 2 \times gd^2 \times a + a^2 + gd^2 - 2 \times a}$$

$$b1 = \frac{-(2 - 4 \times a - 4 \times gn^2 \times a - 2 \times gn^2 \times a^2 - 2 \times gn^2 + 2 \times a^2)}{2 \times s \times gd + 1 - 2 \times s \times gd \times a^2 + gd^2 \times a^2 + 2 \times gd^2 \times a + a^2 + gd^2 - 2 \times a}$$

$$b2 = \frac{1 + 2 \times s \times gn \times a^2 - 2 \times a + gn^2 - 2 \times s \times gn + 2 \times gn^2 \times a + a^2 + gn^2 \times a^2}{2 \times s \times gd + 1 - 2 \times s \times gd \times a^2 + gd^2 \times a^2 + 2 \times gd^2 \times a + a^2 + gd^2 - 2 \times a}$$

$$a0 = 1$$

$$a1 = \frac{-2 + 2 \times gd^2 \times a^2 + 4 \times gd^2 \times a - 2 \times a^2 + 2 \times gd^2 + 4 \times a}{2 \times s \times gd + 1 - 2 \times s \times gd \times a^2 + gd^2 \times a^2 + 2 \times gd^2 \times a + a^2 + gd^2 - 2 \times a}$$

$$a2 = \frac{gd^2 \times a^2 - 2 \times a + 1 + 2 \times gd^2 \times a - 2 \times s \times gd + a^2 + 2 \times s \times gd \times a^2 + gd^2}{2 \times s \times gd + 1 - 2 \times s \times gd \times a^2 + gd^2 \times a^2 - 2 \times gd^2 \times a + a^2 + gd^2 - 2 \times a}$$

FilterCoefficients

$$B = \begin{bmatrix} b0 & b1 & b2 \end{bmatrix}$$
$$A = \begin{bmatrix} a0 & a1 & a2 \end{bmatrix}$$

1.6 SecondorderLinkwitzRiley

FilterParameters

F_s =SamplerateinHz

F_c =CutfrequencyinHz

HL=LRFiltertype(high,low)

ErrorChecking

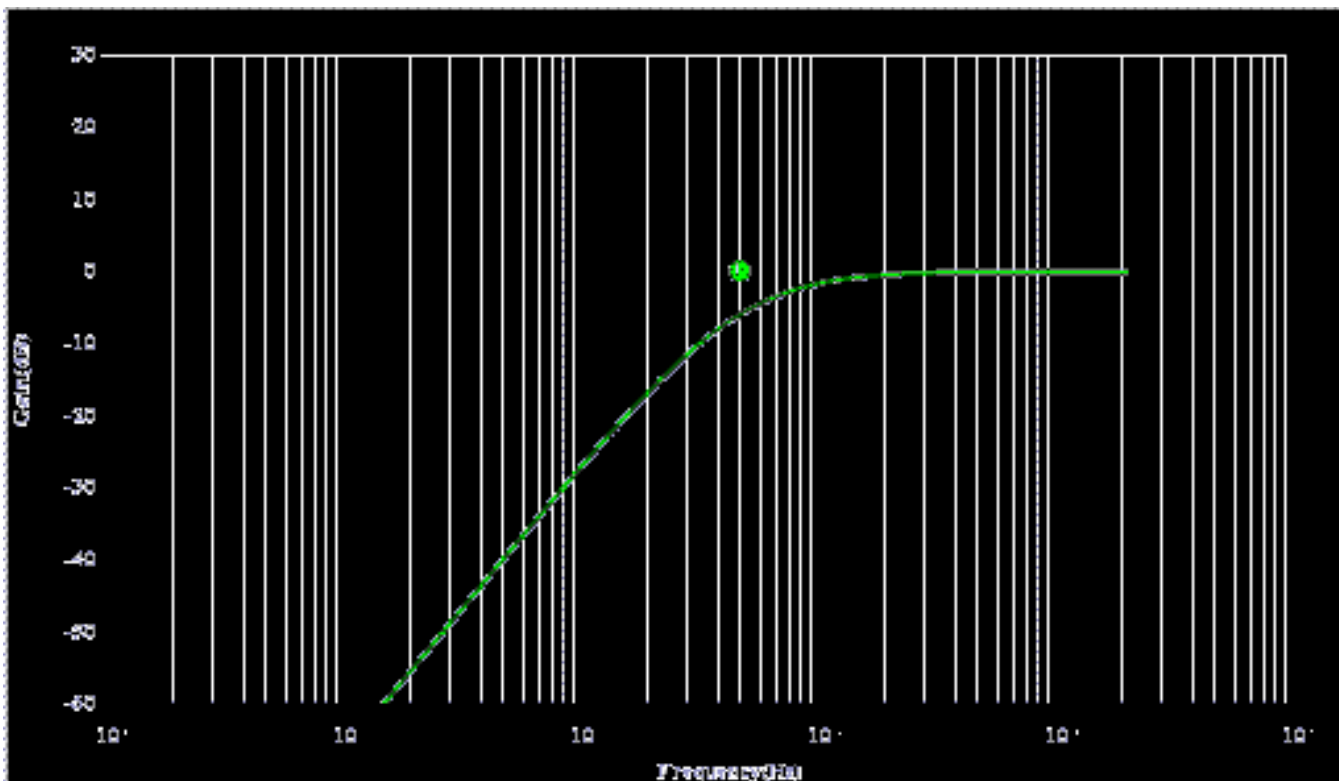$$0 \le F_c \le \frac{F_s}{2}$$

$$0 \le F_s \le 192K$$

$$HL = (high, low)$$

Figure6.   SecondorderLinkwitzRiley(F   c=500Hz,HL=high)

Equation

$$wc = 2 \times \pi \times F_c$$

$$if \ HL(1:3) =='low'$$

$$Ba = \begin{bmatrix} 0 & 0 & wc^2 \end{bmatrix}$$

$$Aa = \begin{bmatrix} 1 & 2 \times wc & wc^2 \end{bmatrix}$$

$$else$$

$$Ba = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$$

$$Aa = \begin{bmatrix} 1 & 2 \times wc & wc^2 \end{bmatrix}$$

$$end$$

$$k = 2 \times \pi \times \frac{F_c}{\tan\left(\pi \times \frac{F_c}{F_s}\right)}$$

$$B = \begin{bmatrix} Ba(1) \times k^2 + Ba(3) + Ba(2) \times k, -2 \times Ba(1) \times k^2 + 2 \times Ba(3), -Ba(2) \times k + Ba(1) \times k^2 + Ba(3) \end{bmatrix}$$

$$A = \begin{bmatrix} Aa(1) \times k^2 + Aa(3) + Aa(2) \times k, -2 \times Aa(1) \times k^2 + 2 \times Aa(3), -Aa(2) \times k + Aa(1) \times k^2 + Aa(3) \end{bmatrix}$$

FilterCoefficients

$$B = \frac{B}{A(1)}$$

$$A = \frac{A}{A(1)}$$

1.7   SecondOrderVariableQFilter

FilterParameters

F_s =SamplerateinHz

F_c =CutfrequencyinHz

HL=LRFiltertype(high,low)

$$Q=FilterQ \ \left(s^2 + \frac{wc}{Q} \times s + wc^2 \right)$$

ErrorChecking

$$0 \le F_c \le \frac{F_s}{2}$$

$$0 \le F_s \le 192K$$
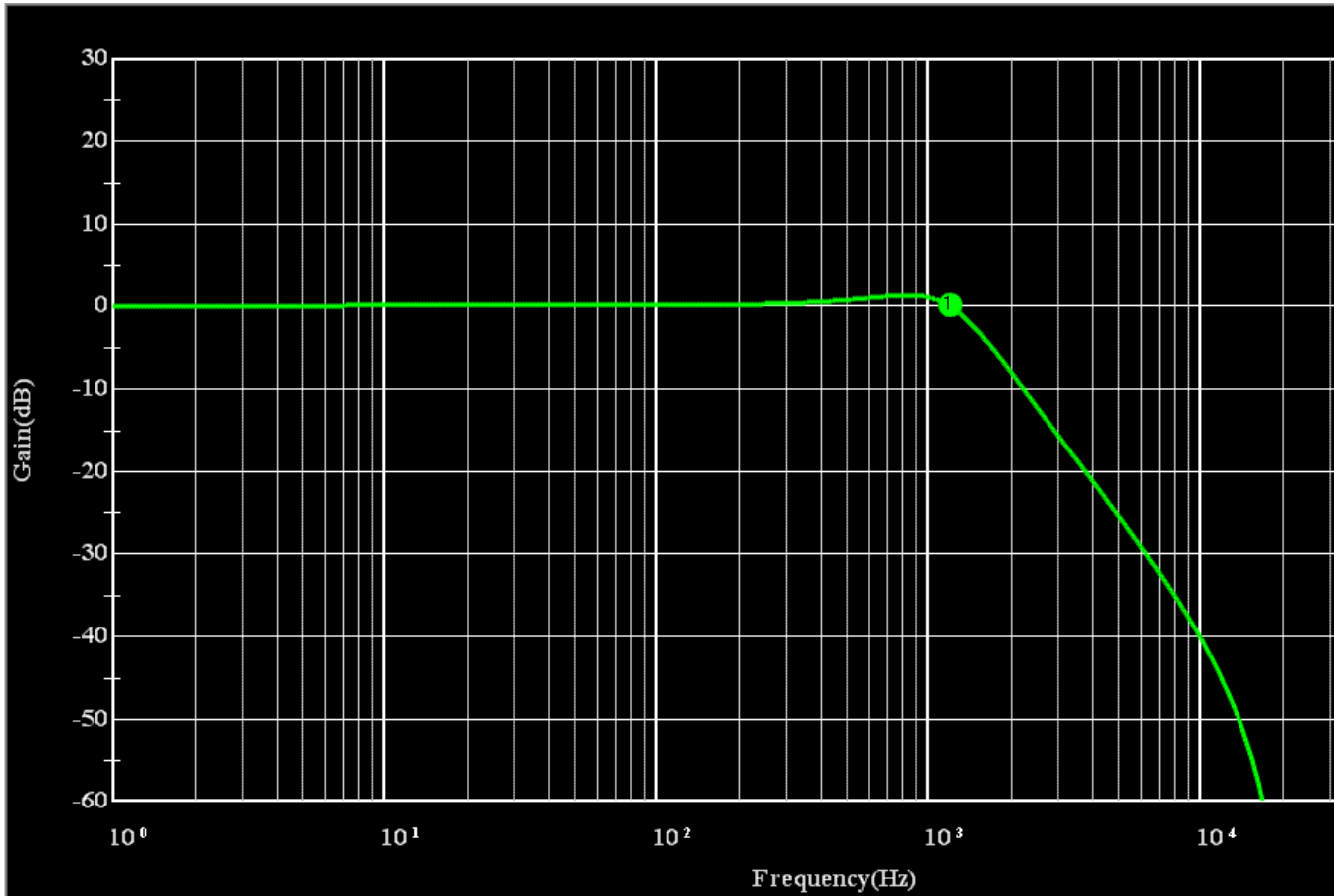
$$HL = (high, low)$$

$$0 \le Q \le 100$$

Figure7. SecondordervariableQfilter(F $_c$=1200Hz,Q=1,HL=low)

Equation

$$wc = 2 \times \pi \times F_c$$

$$if \ \ HL(1:3) =='low'$$

$$Ba = \begin{bmatrix} 0 & 0 & wc^2 \end{bmatrix}$$

$$Aa = \begin{bmatrix} 1 & \dfrac{wc}{Q} & wc^2 \end{bmatrix}$$

$$else$$

$$Ba = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$$

$$Aa = \begin{bmatrix} 1 & \dfrac{wc}{Q} & wc^2 \end{bmatrix}$$

$$end$$

$$k = 2 \times \pi \times \dfrac{F_c}{\tan\left(\pi \times \dfrac{F_c}{F_s} \right)}$$

$$B = \begin{bmatrix} Ba(1) \times k^2 + Ba(3) + Ba(2) \times k, & -2 \times Ba(1) \times k^2 + 2 \times Ba(3), & -Ba(2) \times k + Ba(1) \times k^2 + Ba(3) \end{bmatrix}$$

$$A = \begin{bmatrix} Aa(1) \times k^2 + Aa(3) + Aa(2) \times k, & -2 \times Aa(1) \times k^2 + 2 \times Aa(3), & -Aa(2) \times k + Aa(1) \times k^2 + Aa(3) \end{bmatrix}$$

FilterCoefficients

$$B = \frac{B}{A(1)}$$

$$A = \frac{A}{A(1)}$$

1.8 SecondorderButterworthFilterfromVariable Q

SecondorderButterworthfiltercanberealizedbyusin gvariableQfilterwithQ=0.707

1.9 SecondorderBesselFilterfromVariableQ

SecondorderBesselfiltercanberealizedbyusingvari ableQfilterwithQ=0.5

1.10 FirstOrderButterworthFilters

FilterParameters

F_s =SamplerateinHz

F_c =CutfrequencyinHz

HL=LRFiltertype(high,low)

ErrorChecking

$$0 \le F_c \le \frac{F_s}{2}$$
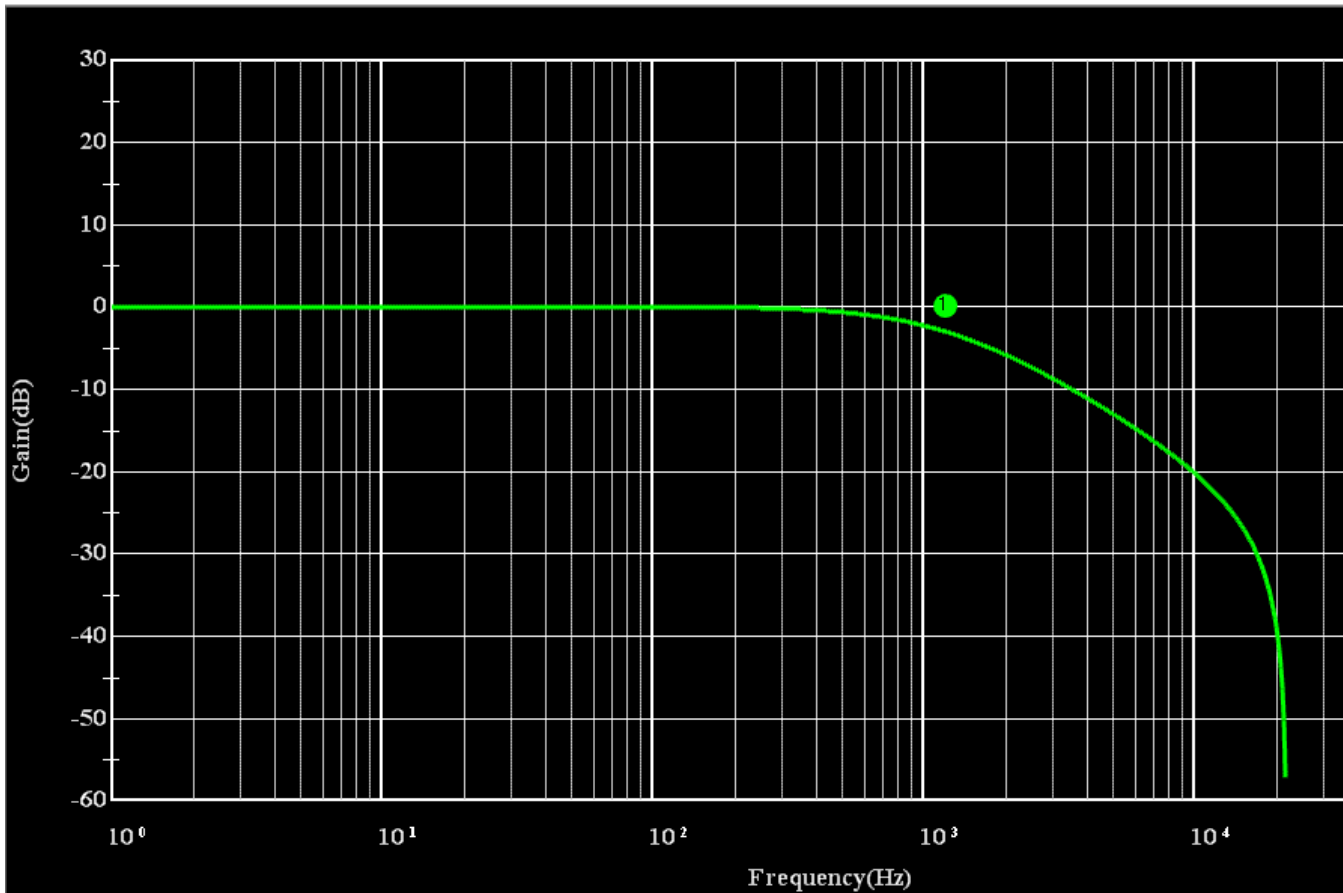
$$0 \le F_s \le 192K$$

$$HL = (high, low)$$

Figure8.   FirstorderButterworth(F $_c$=1200Hz,HL=low)

Equation

$$k = \frac{2 \times \pi \times F_c}{\tan\left(\dfrac{\pi \times F_c}{F_s}\right)}$$

$$Wc = 2 \times \pi \times F_c$$

$If\ HL(1:3) = 'low'$

$$b0 = \frac{Wc}{k + Wc}$$

$$b1 = \frac{Wc}{k + Wc}$$

$else$

$$b0 = \frac{k}{k + Wc}$$

$$b1 = -\frac{k}{k + Wc}$$

end

$$a1 = \frac{Wc - k}{k + Wc}$$

FilterCoefficients

$$B = \begin{bmatrix} b0 & b1 & 0 \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & a1 & 0 \end{bmatrix}$$

1.11 SecondorderChebychev

FilterParameters

F_s=SamplerateinHz

rip=RipplespecificationindB

typ=Filtertype(high,low,stop)

```
if typ(1:3) == 'sto'
        Fc=Stop band Input Lower and upper frequencies [f1,f2]
Else
        Fc=Cutoff frequency in Hz
        If Scale peak to 0dB
                    Nrm=1
        If Scale PB to 0dB
                    Nrm = -1
```
$$if \quad nrm \cong 1$$
$$rip = rip \times -1$$
$$end$$
```
End
```

ErrorChecking

$$0 \le F_c \le \frac{F_s}{2}$$
$$0 \le F_s \le 192K$$
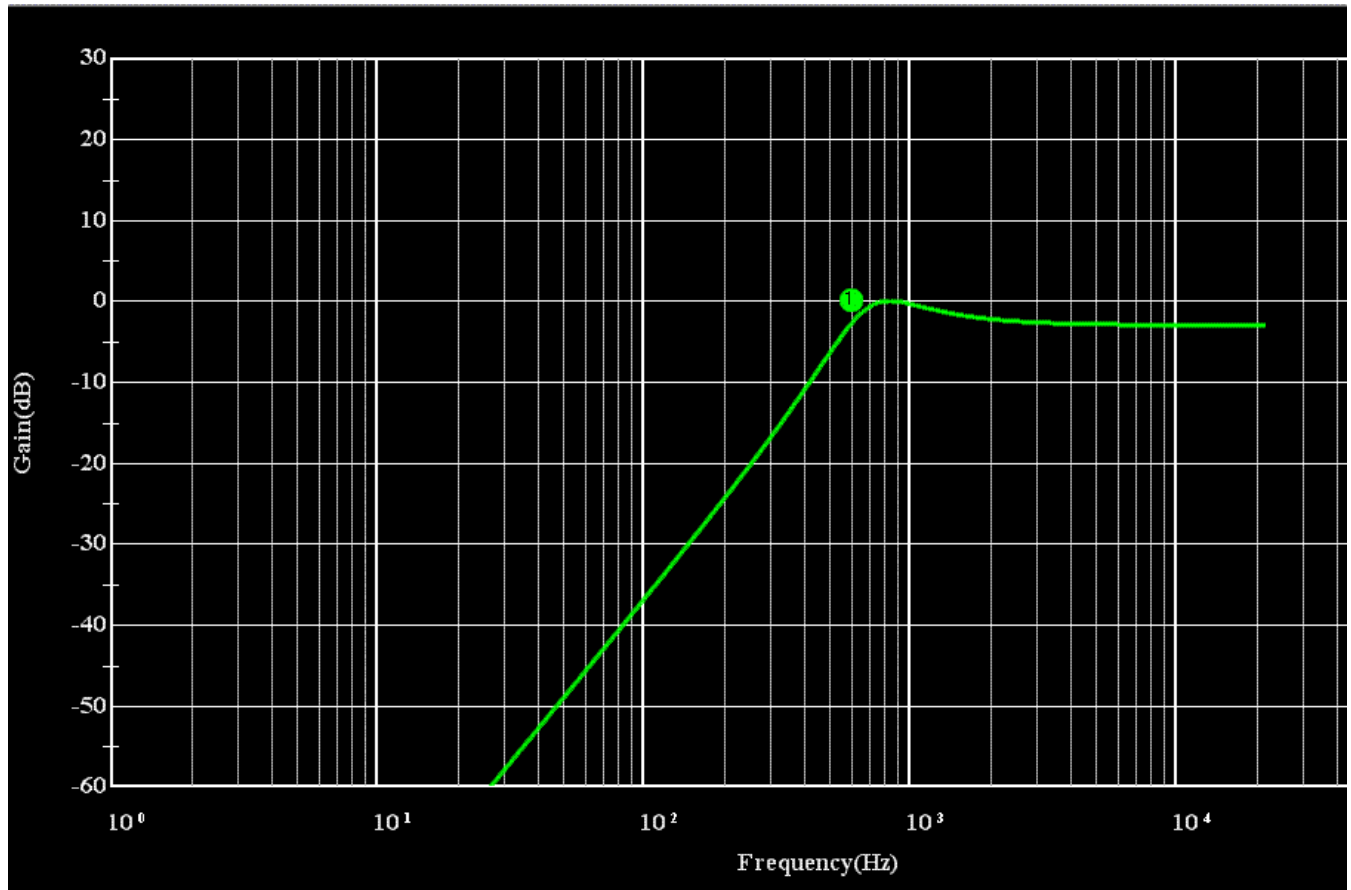$$0 \le rip \le 10$$
$$Nrm = 1, -1$$
$$HL = (high, low, stop)$$

Figure9.   SecondorderChebychev(F $_c$=600Hz,typ=high,rip=3dB)

Equation

```
If typ(1:3)=='sto'
```

$$\text{Call cheby1(ord,rip,} \frac{2 \times F_c}{F_s} \text{,HL)}$$

```
else
        Call soCHBI(Fc,Fs,rip,HL)
End
```

```
Function soCHBI(Fc,Fs,rip,HL)

        If sign(rip)>0
                    Sf=1
        Else
                    Sf=0
        End
```

$$R = |rip|$$

If $R == 0$

$\quad B = [1\ 0\ 0]$

$\quad A = [1\ 0\ 0]$

else

$\quad wc = 2 \times \pi \times F_c$

$\quad \varepsilon = \sqrt{10^{\frac{R}{10}} - 1}$

$\quad \alpha = \dfrac{a\sinh\left(\dfrac{1}{\varepsilon}\right)}{2}$

$\quad \beta 1 = 3 \times \dfrac{\pi}{4}$

$\quad \beta 2 = 5 \times \dfrac{\pi}{4}$

$\quad s1 = \sinh(\alpha) \times \cos(\beta 1) + \cosh(\alpha) \times \sin(\beta 1) \times i$

$\quad s2 = \sinh(\alpha) \times \cos(\beta 2) + \cosh(\alpha) \times \sin(\beta 2) \times i$

$\quad a = real(s1 + s2)$

$\quad b = real(s1 \times s2)$

$\quad c = b$

if sf

$\quad\quad c = \dfrac{c}{\sqrt{1 + \varepsilon^2}}$

end

if $HL(1:3) ==$ 'low'

$\quad\quad Ba = [0\ \ 0\ \ c \times wc^2]$

$\quad\quad Aa = [1\ \ wc \times a\ \ b \times wc^2]$

Else

$\quad\quad Ba = \left[\dfrac{c}{b}\ \ 0\ \ 0\right]$

$\quad\quad Aa = \left[1\ \ wc \times \dfrac{a}{b}\ \ \dfrac{wc^2}{b}\right]$

End

$$k = 2 \times \pi \times \frac{F_c}{\tan\left(\pi \times \frac{F_c}{F_s}\right)}$$

$$B = \left[Ba(1) \times k^2 + Ba(3) + Ba(2) \times k, -2 \times Ba(1) \times k^2 + 2 \times Ba(3), -Ba(2) \times k + Ba(1) \times k^2 + Ba(3)\right]$$

$$A = \left[Aa(1) \times k^2 + Aa(3) + Aa(2) \times k, -2 \times Aa(1) \times k^2 + 2 \times Aa(3), -Aa(2) \times k + Aa(1) \times k^2 + Aa(3)\right]$$

$$B = \frac{B}{A(1)}$$

$$A = \frac{A}{A(1)}$$

End

2 Numberrepresentationformatforfiltercoefficie nts

AICcodecscomesintwoflavors.The"standard"versionof theMiniDSPusesa16bit coefficientanda24bitdatawordforminiDSP_Aand 28bitdatawordforminiDSP_Dwhilethe "enhanced"versionoftheMiniDSPusesa24bitcoefficie ntanda32bitdataword.The AIC3254andAIC3204areenhanceddevices.TheTSC2117, AIC36,AC3110,AIC3111,and AIC3120arestandarddevices.

AlloftheAICcodecdevicesusea3.xdataformat(3.21 forthestandarddevicesand3.29for theenhanceddevices).Thispermitsonlytwomagnitude bitsofheadroomforsignalsthatare greaterthen1.Toreducethechanceofclippingthesi gnalintheAICdevices,theoverallgainof thefilterismoderatedbyscalingthenumeratorvalu ebaseduponthevalueoftheb0term.

ThecoefficientsizeintheAICcodecfamilyis16bit1. 15formatforthestandarddevicesanda 24bit1.23formatfortheenhancedAICdevices.With theseformatstheMiniDSPcoefficients areabletorepresentamaximumpositivegainof1-2^{-15}fora16bitcoefficientand1-2^{-23}fora24 bitcoefficient.Whenfiltercoefficientsarecomputedf oranAICcodec,thegainofthefilter responseisscaledtopermitthevaluestoberepresented ina1.23ora1.15format.

Oncewehavecomputedthefilterequationsfromabove wethenmustperformacoupleofsteps priortoloadingthecoefficientsintothecodec.

IntheAICcodecsuseaspecificbiquadimplementationto accommodatethe1.15and1.23 coefficientdataformat.

$$y(n) = b_0 \times x(n) + 2 \times b_1 \times x(n-1) + b_2 \times x(n-2) + 2a_1 \times y(n-1) + a_2 \times y(n-2)$$

1. Forformatwefirstmustscalethebtermsbytheb0 value.Theb0,b1,andb2termsare multipliedbyascalingvaluetolimittheoverallga inofthefilter.

   – Ifb0isgreaterthan1,thenthedefaultvaluefo rthescalingvalueis1/b0,otherwiseitis 1

   – Thescalingfactoristhenappliedtotheb0,b1,and b2termsofthefilter.

   – Thisdefaultvalueiscomputedanddisplayedinauser modifiablefieldwhenthefilter coefficientsarecomputed.

   – Theuserispermittedtochangethisvaluetoasmal lervalue.Howeveriftheyattemptit setittoalargervaluethanthedefaultscalingvalu ethenthevaluewillsnaptothe defaultscalingvalue.

2. Thenboththenumeratoranddenominatorcoefficie ntsarescaledbyaconstantvalue

   – Ifthecoefficientsarebeingcomputedfora"standa rd"devicethen

   Theb0,b1,b2,a1,anda2termsaremultipliedby 2^{15}androundedtointeger

   – Ifthecoefficientsarebeingcomputedforan"enhan ced"devicethen

   Theb0,b1,b2,a1,anda2termsaremultipliedby 2^{23} androundedtointeger.

3. Thenwescaletheb1anda1termsby0.5.

   AppendixAillustratesthegenerationofcoefficientsusi ngtheaboveprocedure.

2.1 Filtercoefficientnormalization

Filtercoefficientnormalizationisperformedtolimit thesizeofthecoefficientvalues,as describedabove,andtolimitthemaximumgainofthe filtertoavoidclipping.

Therearetwoplaceswhereclippingcanoccur.

1. Internalsignallevelsandclipping

   TheminiDSPisabletointernallyrepresentadatava lueusinga3.29or3.21format.This permitssignallevelsaslargeas12dBtoberepresent ed.However,theintermediategains insideofafiltercanbehigherthanthesignallevel sthatarevisibleattheoutputofa component.Toaccountforthis,filtergainsaretypi callyscaledtoreservepartorallofthis 12dBasheadroomforinternalcomputations.

2. Outputsignallevelsandclipping

   Themaximumsignallevelthatcanbeoutputwithoutcl ippingbythel2SoutputortheDAC interpolatorisadatavaluerepresentedasabya1. 29or1.21value(0.99and-1.0).This correspondstoasignallevelof0dB.

Coefficientscalingcanbeusedtoavoidclippingduring internaloperationsandwhenthesignalissent tothel ^{2}Sorinterpolatoroutputs.

Forexample,wewishtouseanEQfilterthathasagain of15dBat500Hz.Thisfilterresponseis shownasthebluecurveinFigure10.Toavoidoverf lowforourinternalrepresentation,we normalizedthefiltercoefficientssothatthesignalth atisoutputdoesnotexceed5dB.Inthis example,thefiltergainisscaledby10dB(multipl yingthecoefficientsby0.316227766).Thescaled filterresponseisshownbytheredcurveinFigure10.

Similarlytoavoidclippingwhenthesignalwasoutput ,thefiltergainshouldbescaledsothatitdoes notexceed0dB.Inthisexample,thefiltergainis scaledby15dB(multiplyingthecoefficientsby 0.177827941)..ThisisshownbythegreencurveinFig ure10.
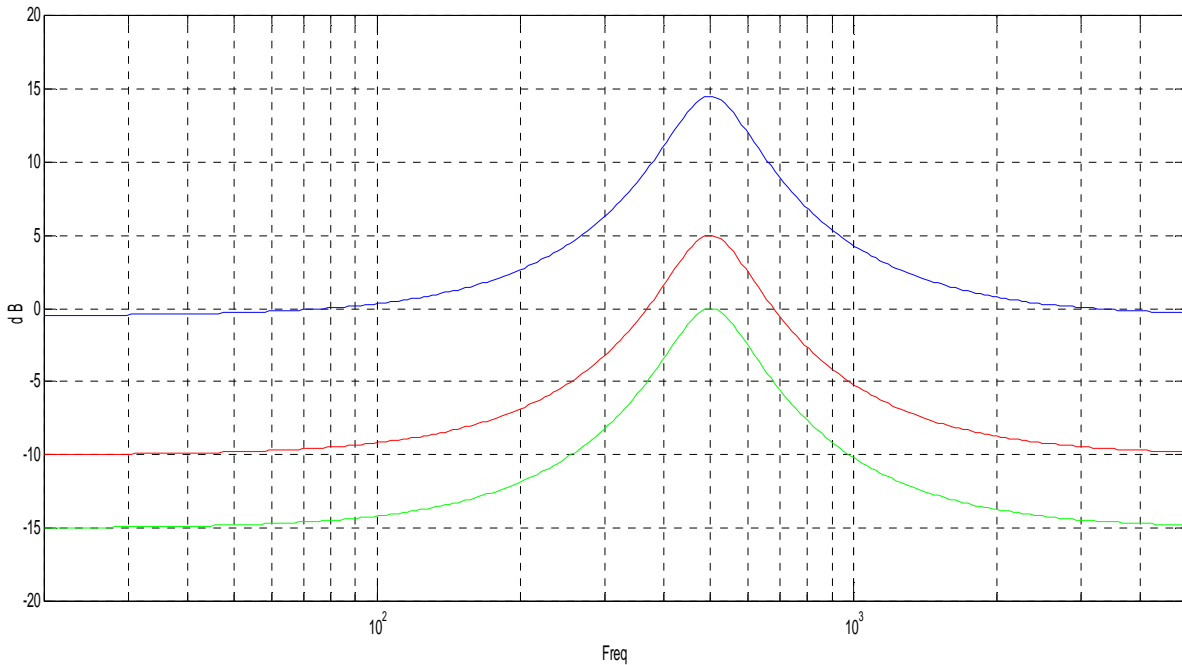

Figure10. Normalizingfilterresponse

3   Updatingthecodecfiltercoefficients

Ahostcontrollerneedstoprovidethefiltercoeffici entvaluesoverI2CtotheAICcodecs.Onthe controller,thecoefficientvaluesneedtobeprecomput edandstoredinatable.Thehost controllerwillreadthevaluesfromthetableanddo wnloadthecoefficientvaluesinasequence thatstartsatthecurrentbiquadfiltersettingtoth edesirednewvaluewhenanupdateis requested.Thechangeofgainsmustbeinincrements/de crementsof¼dBtoavoidpopsand clicks.Forinstance,ifanEQfilterat200Hzneedstob eoperatedbetweenrangesof-8dBto 8dB,thehostcontrollerneedstomaintainatableof b0,b1,b2,a1anda2termsthrough-8db,- 7.75dB,-7.5dB…7dB,7.25dB,7.5dB,7.75dB,8dB.

Table 1. EQ Filter coefficient table in host controller for "enhanced" codecs

	b0	b1	b0	a1	a2
-8dB	0x7F5119	0x812FC5	0x7E69BC	0x7ED03B	0x82452A
-7.75dB					
-7.5dB					
-7.25dB					
…					
0dB	0x7FFFFF	0	0	0	0
…					
7.5dB					
7.75dB					
8dB	0x7F6664	0x81C7F3	0x7D23F5	0x7F7E70	0x80E89C

AppendixA.Biquadcoefficientscomputationexample

Thisappendixillustratesthecomputationbiquadcoeffici ents andconvertingthemintoformat requiredtoloadinAICcodecs.

1. FilterSpecification:EQfilterwithF$_c$=5000Hz,Gain=6dBandQ=2.87(BW=1742Hz)on AIC3254.

    Applyingtheequationsinsection1.2wegetthebiquad coefficientsas

    $b0 = 1.03381744095486$

    $b1 = -1.85413395878212$

    $b2 = 0.898225719031722$

    $a1 = 1.85413395878212$

    $a2 = -0.932043159986584$

    Beforewritingthesecoefficientstocodecmemory,couple ofnormalizationstepsmustbe performedbasedontheirvaluesaccordingtosection2.

2. Sinceb0>1,weneedtoscalethenumeratorcoeffici entsbyscalefactor $\frac{1}{b0}$

    $b0 = 0.992464542388916015625$

    b1 = - 1.77996826171875

    b2 = 0.86229658126831054687 5

3. Scaletheb1anda1by0.5.

    $b0 = 0.992464542388916015625$

    b1 = -0.889984130859375

    b2 = 0.86229658126831054687 5

    a1 = 0.92706697939106

    a2 = -0.932043159986584

4. Sincethecoefficientsaretobecomputedfor'enhance d'device,weneedtoscaleitby 2^{23} and roundedtonearestinteger.Hencethefinalcoefficient hexadecimalvaluesthathastobeloaded ontotheAIC3254are

    $b0 = 0x7F0914$

    b1 = 0x8E1500

    b2 = 0x6E5FBC

    a1 = 0x76AA20

    a2 = 0x88B2D1