

General purpose filter engine white paper

Rob MacAulay

Abstract

Recent years have witnessed huge expansion in the market for portable devices with hi-fi audio playback capability such as MP3 players, multimedia phones and handheld games consoles. However, such devices often use low cost transducers, and are operated in noisy environments; hence the audio quality experienced by the user is lower than the inherent quality of the programme material. Mobile telephones are also expected to operate as media players, and have similar requirements, as well as the need to improve legibility during voice calls.

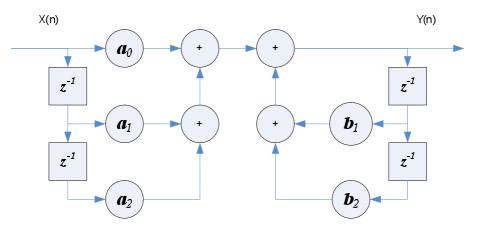
It is possible to improve the perceived audio quality by compensating for transducer frequency response; in mobile phone use, it is possible to suppress some of the environmental noise by judicious use of filtering. These types of filtering operations can usefully be performed in the codec itself, freeing any host processor from the burden of real-time audio filtering. Such filtering operations must be completely programmable however, since the filters required will alter with the application and equipment. A general purpose filtering engine allows these, and many other improvements to be made.

Introduction

The small form factor in portable media devices prohibits proper acoustic design. And, it is important to be able to improve the audio acoustic design late in the product design cycle. Using dedicated IC's to perform DSP take up board space, which is usually at a premium in modern portable devices. Dialog's approach is to offer general purpose filtering within the codec device this allows effects such as bass enhancement, acoustic transducer filtering, ambient noise suppression, equalisation and stereo widening to be implemented without modifying the host processor software.

Programmable filters

One of the most useful general purpose digital filters is the biquad section, which can implement all second-order filter topologies. There are several canonical forms for the biquad. The direct-form type I architecture is straightforward to understand from simple filter theory and has several advantages when used in hardware digital signal processing such as insensitivity to arithmetic overflow during computation. A diagram of the implementation architecture of the biquad is shown below.



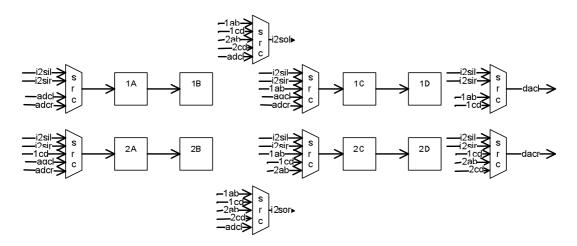
X(n) represents the sampled input to the filter and Y(n) the sampled output at a given sample time, n. The forward coefficients are a_0 , a_1 , a_2 and the reverse coefficients are b_1 , b_2 . A single sample delay is represented by z^{-1} .

Flexibility

In order to perform functions that are useful, the general purpose filtering capabilities provided by a device must satisfy the following criteria:

- Provide a useful number of biquad sections
- Allow biquad sections to be interconnected in a flexible manner.

The DA7210 provides eight independent biquad sections, grouped into four sets; each set may be connected flexibly from multiple input sources, including other filter sections. In addition, a mixing function is provided, that allows various combinations of biquads to be mixed together. The coefficients are represented as 16 bit values, which may be programmed into 8-bit configuration registers on the DA7210. The diagram below shows the four groups of biquads (note that not all possible connections are shown). There are also four paths that can be connected to the filter engine: the left and right DAC output channels, and the digital audio interface channels. Each of these can be connected to the outputs of filter groups, or to the raw digital inputs.



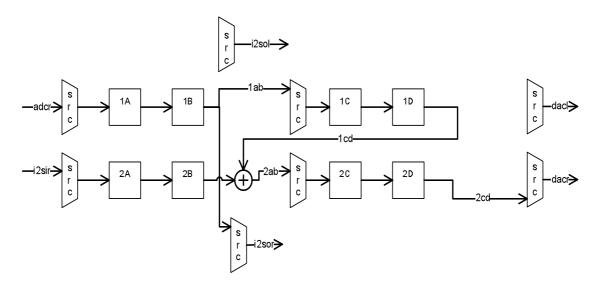
Filter groups may also be disabled in order to reduce power consumption.

The routing capabilities of the filter engine are also available even when all filters are disabled.

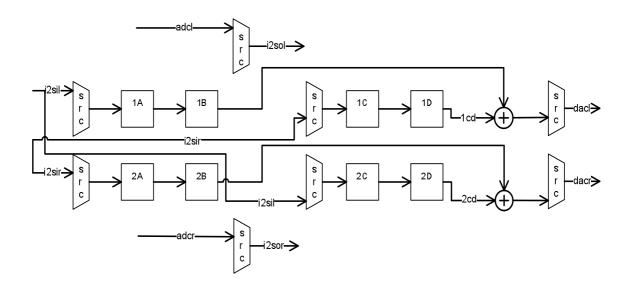
A simple example of the filter topologies that can be realised for equalisation purposes is an eight biquad filter (16^{th} order) that filters a digital input stream before output from a DAC channel whereby each DAC channel may have an eighth order filter applied for stereo playback and each input and output may have a fourth order filter applied for stereo record and playback.

For mobile telephone applications, the general purpose filter engine provides a flexible solution for digital sidetone generation, as shown below. The microphone input is fed from the ADC right channel, then equalised to correct for transducer characteristics, in filter set 1AB. This is sent to the TX channel over the digital audio interface. The RX channel is received over the digital audio interface right channel, equalised in filters 2CD and then sent to the right DAC channel.

The equalised microphone output is also filtered again in filters 1CD and then mixed with the RX data before being equalised for output. The relative gain of the sidetone channel is set by the coefficients for filters 1CD and the frequency characteristics are chosen to eliminate 'howl round' and ambient noise reduction.



Enhanced stereo width control is also possible. In the configuration below, both left and right digital input channels are sent to two sets of filters. The left and right outputs are formed by mixing the outputs from the filtered versions of the left and right input signals. By choosing suitable weightings and frequency responses an enhanced stereo effect is created; this sounds more natural than fully separated left and right signals when listening through headphones.



Design aids

When developing filtering applications for devices it is vital to be able to prototype new filter responses quickly. Whilst there are a plethora of filter design tools available it is most useful to have a tool that can generate the required configuration register values for a specific device. A design tool is available for the DA7210 that can generate the required coefficient values for many standard filters, translate these coefficients into values suitable for programming into the DA7210 and then download them into a device. This considerably shortens the design development time. The tool also understands the many routing and special purpose options in the DA7210 filter engine. A screenshot of the tool is shown below.

-										
ilter Setup	Coefficients	EQ & Vo	lice							
	GP1 FILTERS	EDEOLIENI		ICC.			GP2 FILTERS	EREQUENC	YRESPONSE	
20.000 -	OPTFILTERS	FREQUEN	GT REOPUN	OC	Initialise USB	20-				1
10.000 -					\bigcirc	10-				
0.000 -						0-				_
10.000-						-10-				
B-20.000-					DACL Source	90 - 20 -				
ğ -30.000 -					GPIAB	-30 -				
- 10.000 -					DACR Source					
~-50.000-					GP1CD	-50 -				
-60.000 -						-60 -				
-70.000 -						-70-				
-60.000 -	2500 5000	7500 10000	12500 15000 1	17500 20500 22600	FR Windowing	-80 -	2500 5000 75	00 10000 12	500 15000 17500	20000 22000
-60.000 -	i 2500 5000	7500 10000 Frequen		17500 20000 22000	FR Windowing		2500 5000 75	ob Loodd 12 Frequency	500 15000 17500 [Hz]	20000 22000
-60.000 -	in trade of			17500 20000 22000	Hanning To establish bandpass		2500 5000 75			20000 22000
-60.000 -	[] [] [] [] [] [] [] [] [] [] [] [] [] [Frequen		17500 20500 22600	Hanring To establish bandpass and bandstop filters it is necessary to use 1st		2500 5000 75	Frequency	[Hz]	Second Second Second
-60.000 - Frequency (F Attenuation)	6] @ [<u>12</u>]; xi	Frequen			Hanning To establish bandpass and bandstop filters it is necessary to use 1st order cetting in each individuel filter			Frequency	[Hz] Frequency [Hz] Attenuation [dB]	6 1 <u>12</u> 2.23
-60.000 - Frequency (F Attenuation)	98] Ø "15, rvå 6] Ø "15, rvå	Frequen	ky (H2)		Hanning To establish bandpass and bandstep filters it is necessary to use 1st order setting in each	C Filter 2A Specil Topology		Frequency	[Hz] Frequency [Hz] Attenuation [dB]	6 92 x.35
-60.000 - Frequency (F Attenuation) able 1A/1B	te) () () () () () () () () () () () () ()	Frequen	Filter 18 Speci	fications	Hanning To establish bandpass and bandstop filters is is necessary to use 1st order setting in each individuel filter specification block Mix GP1CD	C Filter 2A Special Topology	fications	Filter 28 Spec Topology	(Hz) Frequency (Hz) Attenuation (dB) (fications	6 125 2.85 6 12 2.85 Enable 2A/28
E0.000 Froquency (P Attornation) able 1A/18 1AB Source	te) & "Lia" + ** de) & "Li" + ** Filter 1A Specificat Topology Butterworth Type O	Prequen	Filter 18 Speci Topology Butterworth Type	fications Order	Hanning To establish bandpass and bandstop filters it is necessary to use 1rt order setting in each individual filter specification block	C Filter 2A Special Topology Dutteworth Type	Reations	Filter 28 Spec Topology Dutterworth Type	[Hz] Frequency [Hz] Attenuation [dB] iffications	EP2AB Source
-60.000 Froquency (F Attenuation) able 1A/18	te) (b) (12) (2.25) de) (b) (12) (2.25) Filter 1A Specificat Topology) Butterworth Type (C) Lowbass (2)	Precuen	Filter 18 Speci Topology Butterworth Type Lowpass	fications Order	Hanning To establish bandpass and bandstop filters is is necessary to use 1st order setting in each individuel filter specification block Mix GP1CD	G Filter 2A Special Topology Butterworth Type Lowpass	Reations	Filter 28 Spec Topology Datterworth Type Lowpass	[Hz] Frequency [Hz] Attenuation [dt] ific ations Order 2	6 125 2.85 6 12 2.85 Enable 2A/28
-60.000 Froquency (F Attenuation) able 1A/18	t2 0 12 2 2 de 0 12 12 Filter 1A Specificat Topology Ditterworth Type 0 Lowcass 2 Lower Fc L	Prequen	Filter 18 Speci Topology Butterworth Type	fications Order	Hanning To establish bandpass and bandstop filters is is necessary to use 1st order setting in each individuel filter specification block Mix GP1CD	C Filter 2A Special Topology Dutteworth Type	Reations	Filter 28 Spec Topology Dutterworth Type	[Hz] Frequency [Hz] Attenuation [dB] iffications	the training to the training
Frequency (h Attenuation) able 1A/18 1AB Source DAL_L	te] 0 12 * 19 de 0 12 * 19 Filter 1A Specificat Topology Dubrevorth Type 0 Lower Fc L 2000k FC L 2000k S	Frequentions	Filter 18 Speci Topology Dute worth Type Lower Fit 20.00k PB Ripole	fications Criter 2 Upper FC ()0.00 32 Attenuation	Harring To establish bandpas and bandstop filters if order setting in each apacification block mith GPIAD with GPIAD SUBMIT	Filter 2A Special Topology Distrements Type Lower Fc 20.00k PB Ripole	Drder 2 Upper Fc 0.00 5B Attenution	Filter 28 Spec Topology Datterword Type Datter	Det] Frequency (Hz) Attenuation (Hz) afficiations Order 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	EP2AB Source
Frequency (h Attenuation) able 1A/18 1AB Source DAL_L	te] 0 12 * 19 de 0 12 * 19 Filter 1A Specificat Topology Dubrevorth Type 0 Lower Fc L 2000k FC L 2000k S	Precuenting to the second seco	Filter 18 Speci Topology Dutterworth Type Longess Lower Fc 20.00k	Acations	Hanning The establish bandpass and bandstop filters its order estation as ach order estation back with GP2AB with GP2AB	Filter 2A Special Topology Electroworth Type Lower Fc 20,00k	Drder Drder Drger Ft Door	Fiequency Filter 28 Spec Topology Datterworth Type Coopass Lower Fr 20 ock	Criterian (Hz) Frequency (Hz) Attenuation (Hz) Frequency (Hz) Attenuation (Hz) Frequency (Hz) Criterian Cr	12 12 12 14 13 14 14 14 15 14 16 14 17 14 17 14 18 16 19 14 10 14 10 14 10 14 10 14
Frequency (h Attenuation) able 1A/18 1AB Source DAL_L	e a 116 e 2 d 1 16 e 2 Fiter 1 A specificat Topology Distereorth Distereorth	Interest Control of Co	Filter 18 Speci Topokgy Dutterworth Type Downer Fr Downer Fr	Order 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Funning To establish bandpose and bandpos (filter, Jacobi contex cetting in each understand filter sectification block Misc CP1CD with GP2AD	Filter 2A Special Topology Butteworth Type Lower Fc 20.00k PB Ripple 0.03 Filter 2C Special	Conterned Dider 2 Upper FC 30 Attenucion 5 Ranco	Fiequency Filter 28 Spec Topology Dutterworth Type Lowpass Lowersc Lowots Lowots Lowots Lowots Filter 20 Spec Filter 20 Spec	Perj Frequency (Hz) Attenuation (H2) iffications Critien 2 2 4 4 2 2 4 4 9 0 0 0 5 8 4 1 2 4 1 9 0 0 5 8 4 1 2 1 9 1 9 1 9 1 9 1 1 1 1 1 1 1 1 1 1	12 12 12 14 13 14 14 14 15 14 16 14 17 14 17 14 18 16 19 14 10 14 10 14 10 14 10 14
Frequency (h Attenuation) able 1A/18 1AB Source DAL_L	c) (12) + 2) d) (12) + 2) Filter 1A Specificat Filter 1A Specificat Dubreach Concerning Concerni	Interest Control of Co	Filter 18 Speci Topology Dutterworth Type Type Dutterworth Type Dutterwort	Arctions	Promo	Filter 2A Special Topology Dictleworth Type Lower FC 20.00k PB Ropie Ropole Filter 2C Special Topology	Conterned Dider 2 Upper FC 30 Attenucion 5 Ranco	Fiequency Filter 28 Spec Topology Platterworth Type Coupass Lower Fc Coupass Lower Fc Coupass Lower Fc Coupass Filter 20 Spec Topology	http://tecuercy.itel Frequency.itel Attenuation (#) ifications Order 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	12 12 12 14 13 14 14 14 15 14 16 14 17 14 17 14 18 16 19 14 10 14 10 14 10 14 10 14
Frequency (h Attenuation) able 1A/18 1AB Source DAL_L	C A 14 12 12 G A 14 12 Fite 1 A Specificat Topology Different A Specificat Topology Different A Specificat Topology Different C Specificat Topology Fiter 1 C Specificat	Frequent	Filter 18 Speci Topokgy Durbersorth Type Durbersorth Type Durbersorth Type Durbersorth Type Durbersorth Filter 10 Speci Topolog Durberworth	Acations Coder 2 Upper Fc 3: Attenuation 5: 0:0 Stations	Percent The stability bendpoor and the stability of the and the stability of the and the stability of the stability	Filter 2A Special Topology Catterworth Tope Lower Fc 20.00k PB Nocle Catter 2C Special Topology	Acations Order 2 Upper Fc 30 Attonuction 5 B Attonuction 5 B attonuction Cations	Filter 28 Spec Filter 28 Spec Data and the second Type Data and the second Type Data and the second Data an	http://www.commercestory.comme	12 12 12 14 13 14 14 14 15 14 16 14 17 14 17 14 18 16 19 14 10 14 10 14 10 14 10 14
Encuency (P Attornation) able 1A/18 Altornation IAB Source DACL In: GP1AB htt GP1AB	C A LA PARTICIPAL CONTRACTOR CONT	Frequent ions ions ions ions ions B Altonuction 50.00 B Altonuction ions Altonuction	Filter 18 Speci Topology Dutterworth Type Type Dutterworth Type Dutterwort	Arctions	Promo	Filter 2A Special Topology Dictleworth Type Lower FC 20.00k PB Ropie Ropole Filter 2C Special Topology	Conterned Dider 2 Upper FC 30 Attenucion 5 Ranco	Fiequency Filter 28 Spec Topology Platterworth Type Coupass Lower Fc Coupass Lower Fc Coupass Lower Fc Coupass Filter 20 Spec Topology	http://tecuercy.itel Frequency.itel Attenuation (#) ifications Order 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	a 126 1×32 a 127 ×33 a 127 ×33 Enable ZA/28 GP2AB Source DAL P. Mik-GP2AB with GP2AB With GP2AD GP2CD Source
-60.000 - Frequency (F	E A LE ALL AT A LE ALL Flor 1A Specificat Topology Defense the town Fr. FR 1C Specificat Topology Defense S Defense S Defe	Frequent Frequent torns Frequent	Filter 18 Specia Topology Durberworth Topology Durberworth Topology Topology Filter 10 Speci Construction Filter 10 Speci Construction Constructi	Creations	Prome Provide a start of the s	C Filter 2A Speci Toology Dutresorth Donges	Order 2 9 Attraution 8 Attraution Realism	Fice_cory Fiker 28 Spec Topolay Fiker 28 Spec Topolay Fiker 28 Spec Topolay Fiker 20 Spec Topolay Fiker 20 Spec Fiker 20 Spec Datamato	HE] Frequency [Hz] Attenuation (#) ific attons Coder 2 Coder 2 0 00 50 Attenuation 6 Coder 3 Coder 2 Coder	à 14 143 à 11 143 Enable 2A/28 GPZAB Source DALR With GPZAB with GPZAB with GPZD
Endersy (F Atterusion able 1A/18 TAB Source DAC_L TAB Source DAC_L TAB Source TAB Source TAB Source	C A	Frequent toms	Filter 18 Special Filter 18 Special Dutterworth Topology Dutterworth Type 20 c0k P8 Bipele 20 c0k P8 Bipele 20 c0k Filter 10 Speci Topology Duterworth Topology Duterworth Topology	Actions Conter 2 Upper FC 0.00 SF Attenuation Sf Attenuation afficiations Order 0.2 Order	France France of the second s	C Filter 2A Special Topology Dateworth Dames Lower F: Co. Col. PB Racb Col. PB Racb Col. PB Racb Col. PB Racb Col. PB Racb Col. Col. Topology Col. Topology Col. Topology Col. PB Racb Col. Col. Col. Col. Col. Col. Col. Col.	Reations	Fire 28 Spec Filter 28 Spec Topology Datterwatt Type Dauger 5c Coology Titler 20 Spec Coology Titler 20 Spec Topology Titler 20 Spec Topology Titler 20 Spec Topology Topology Datterwatt Type Dauger 5c Datterwatt Type Datterwatt Type Datterwatt Type Datterwatt Datterwatt Type	He J Frequency [He] Attenusion (df) ific ations Order 2 Upper Fic 0 000 50 Attenuation 60.00 ific ations	a 126 1×32 a 127 ×33 a 127 ×33 Enable ZA/28 GP2AB Source DAL P. Mik-GP2AB with GP2AB With GP2AD GP2CD Source

If a designer wishes, it is possible to calculate filter coefficients for a special purpose filter, and then input these coefficients. The tool will then provide a graphical calculation of the frequency response, and translate the values for the DA7210.

Summary

Consumers expect both improved audio quality and increased functionality from mobile audio products. While individual components are constantly being developed to improve quality and performance it is often challenging to deliver these without increasing the load on the system processor, which would lead to increased power drain. The DA7210 enables the system designer to deliver enhanced audio at the codec, without the need to burden the system processor. The DA7210 family of audio codecs offer exceptionally low power and high quality enhanced audio.

Dialog Semiconductor Worldwide Offices

Germany (Headquarters)

Tel: (+49) 7021 8050 Fax: (+49) 7021 805 100

Japan	Korea	Taiwan	United Kingdom	USA
Tel: (+81) 3 3769 8123	Tel (+82 2 6007 2303	Tel: (+886) 37 598166	Tel: (+44) 1793 757766	Tel: (+1) 888 909 3816
Fax: (+81) 3 3769 8124	Fax (+82)2 6007 2001	Fax: (+886) 37 595026	Fax: (+44) 1793 757700	Fax: (+1) 408 328 9275

Dialog Semiconductor Worldwide

This publication is issued to provide outline information only, which (unless agreed by Dialog Semiconductor in writing) may not be contract or be regarded as a representation relating to products or services concerned. Dialog Semiconductor reserves the right to alter without notice the specification, design, pr ice or conditions of supply of the product. Customer takes note that Dialog Semiconductor's products are not designed for use in devices or systems intended for supporting or monitoring life nor for surgical implants into the body. Customer shall notify the company of any such intended use so that Dialog Semiconductor may determine suitability. Customer agrees to indemnify Dialog Semiconductor for all damages that may be incurred due to use without the company's prior written permission of products in such applications.