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TDA7415CB

Car-radio multimedia signal processor (CMSP)

Features

- 6-channel multimedia approach
- Fully integrated tone control with notch filter
- 7-band spectrum analyzer

Inputs

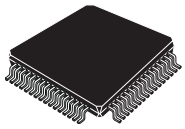
- Three independent signal paths
- Eight single-ended inputs
- Two quasi-differential inputs
- Optional full-differential input
- Level adjust gain-stages
- Independent soft-mute and direct-mute

Outputs

- Three independent signal paths
- Six output channels with soft-step volume
- Output level up to 4VRMS
- Independent soft-mute and direct-mute
- Flexible phone/navigation interrupts
- High-pass and subwoofer low-pass filters

Digital control

- Selectable SPI- or I^2C-bus interface



LQFP64

Description

The TDA7415CB is the first 6-channel multimedia approach in the car-radio signal processor (CSP) family. It features full software programmability of three independent sections. The signal processor combines a three band audio tone control with an additional notch filter, high/low pass filters for subwoofer support and a spectrum-analyzer with the absence of any external components for the internal filters. Versatile input/output stages and an extended signal routing scheme provide all the flexibility that is needed to serve modern 6-channel applications such as required by DVD technology.

Table 1. Device summary

Order code	Temp range, °C	Package	Packing
TDA7415CB	-40 to 85	LQFP64 (10x10x1.4mm)	Tray

Contents

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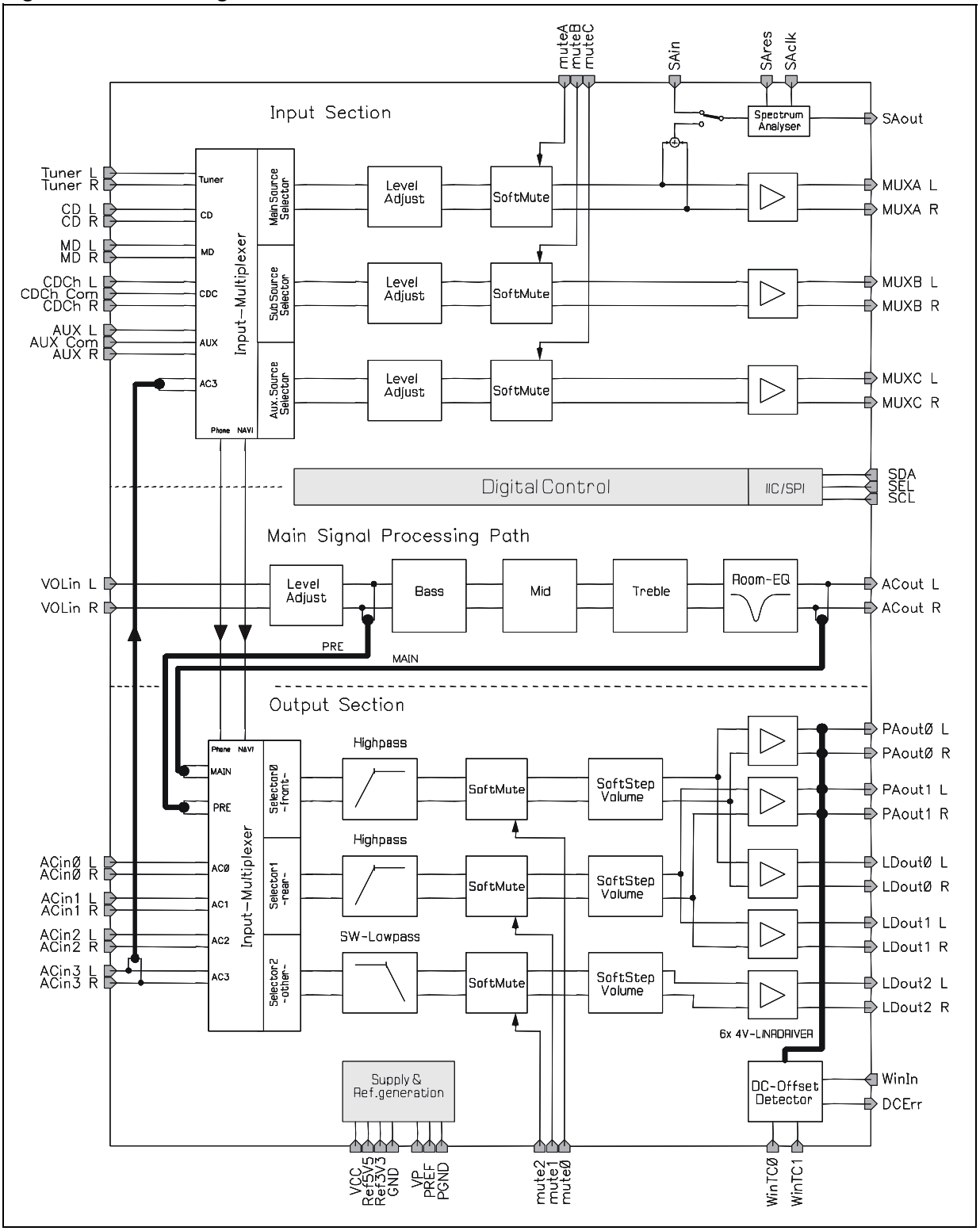
1 Block diagram

Figure 1. Block diagram



2 Pin description

2.1 ESD:

All pins are protected against ESD according to the MIL883 standard.

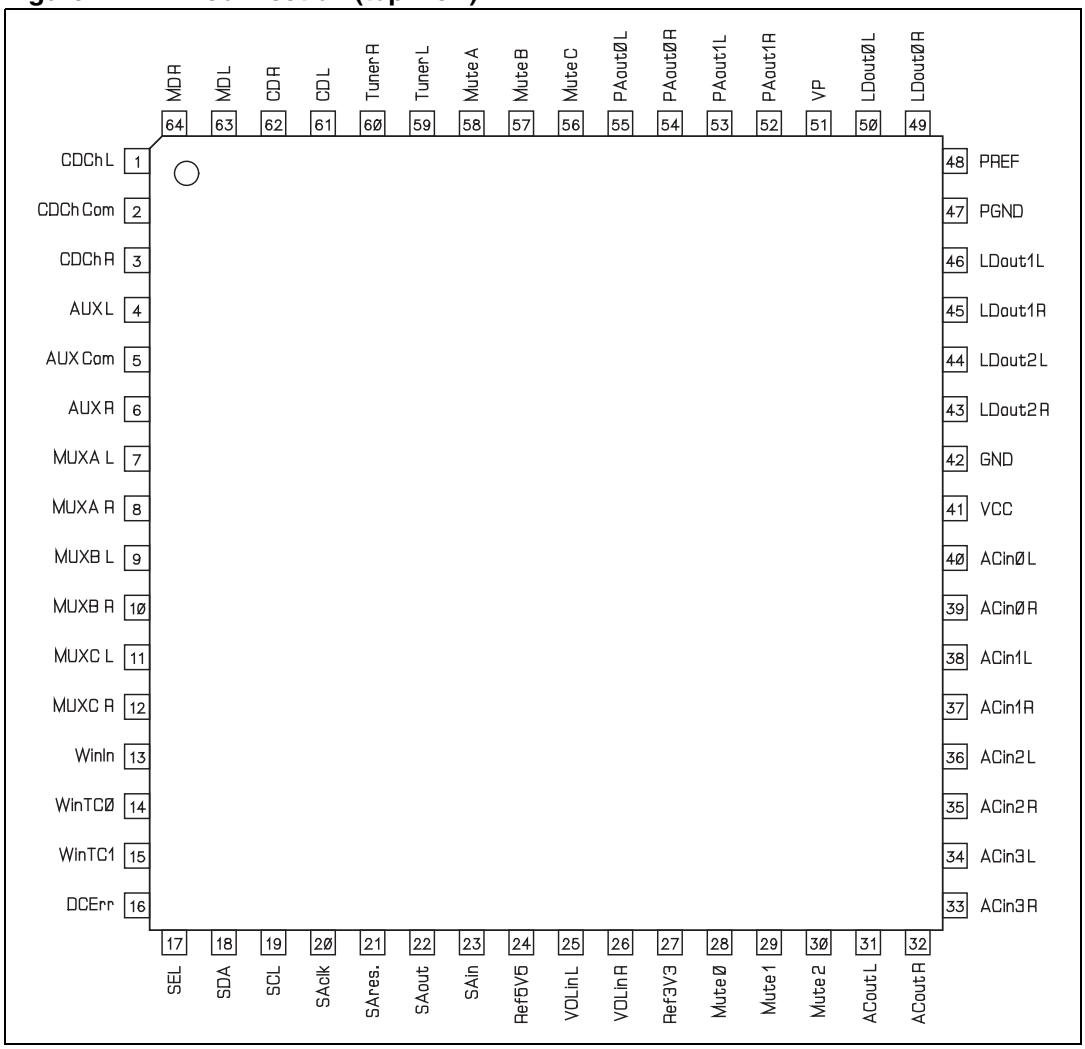
2.2 Thermal data

Table 2. Thermal data

Symbol	Description	Value	Unit
$R_{th\ j\text{-}pins}$	Thermal resistance junction-to-pins	50	°C/W

2.3 Pin assignment

Figure 2. Pin connection (top view)



2.4 Pin function

Table 3. Pin description

PIN	Direction (1)	Name	Description
1	I	CDCh L	CD-changer input, pseudo differential, left channel
2	I	CDCh Common	CD-changer input, pseudo differential common
3	I	CDCh R	CD-changer input, pseudo differential, right channel
4	I	AUX L	Aux./Navigation input, pseudo differential, left channel
5	I	AUX Common	Aux./Navigation input, pseudo differential common
6	I	AUX R	Aux./Navigation input, pseudo differential, right channel
7	O	MUXA L	IN-Section, signal path A output (Main), left channel
8	O	MUXA R	IN-Section, signal path A output (Main), right channel
9	O	MUXB L	IN-Section, signal path B output (Sub), left channel
10	O	MUXB R	IN-Section, signal path B output (Sub), right channel
11	O	MUXC L	IN-Section, signal path C output (Aux.), left channel
12	O	MUXC R	IN-Section, signal path C output (Aux.), right channel
13	I	WinIn	Zero-window Sense input (from power-amp)
14	P	WinTC0	Zero-window comparator 0 time constant
15	P	WinTC1	Zero-window comparator 1 time constant
16	O	DCErr	DC-detector Error output
17	I	SEL	Interface-select; SPI: receive enable
18	I / OC	SDA	I^2C/SPI-bus serial data input/output
19	I	SCL	I^2C/SPI-bus serial clock input
20	I	SAclk	Spectrum analyzer clock input
21	I	SAres.	Spectrum analyzer reset
22	O	SAout	Spectrum analyzer analog voltage output
23	I	SAin	Spectrum analyzer external input
24	P	Ref5V5	5.5V-reference decoupling pin, connects to external capacitor
25	I	VolIn L	Main signal path input, left channel
26	I	VolIn R	Main signal path input, right channel
27	P	Ref3V3	3.3V-reference decoupling pin, connects to external capacitor
28	I	Mute0	OUT-section, signal path 0 (front) direct mute
29	I	Mute1	OUT-section, signal path 1 (rear) direct mute
30	I	Mute2	OUT-section, signal path 2 (other) direct mute
31	O	ACout L	Main signal path output, left channel

Table 3. Pin description (continued)

PIN	Direction (1)	Name	Description
32	O	ACout R	Main signal path output, right channel
33	I	ACin3 R	OUT-section, AC-coupled input 3, right channel
34	I	ACin3 L	OUT-section, AC-coupled input 3, left channel
35	I	ACin2 R	OUT-section, AC-coupled input 2, right channel
36	I	ACin2 L	OUT-section, AC-coupled input 2, left channel
37	I	ACin1 R	OUT-section, AC-coupled input 1, right channel
38	I	ACin1 L	OUT-section, AC-coupled input 1, left channel
39	I	ACin0 R	OUT-section, AC-coupled input 0, right channel
40	I	ACin0 L	OUT-section, AC-coupled input 0, left channel
41	S	VCC	Device supply pin
42	S	GND	Device ground pin
43	O	LDout2 R	Line-driver output, signal path 2 (other), right channel
44	O	LDout2 L	Line-driver output, signal path 2 (other), left channel
45	O	LDout1 R	Line-driver output, signal path 1 (rear), right channel
46	O	LDout1 L	Line-driver output, signal path 1 (rear), left channel
47	S	PGND	Device ground pin (dual supply), connects to system ground
48	P	PREF	Line-driver-reference decoupling pin, connects to external capacitor
49	O	LDout0 R	Line-driver output, signal path 0 (front), right channel
50	O	LDout0 L	Line-driver output, signal path 0 (front), left channel
51	S	VP	Device supply pin (dual supply), Output section
52	O	PAout1 R	Out-section rear output, right channel
53	O	PAout1 L	Out-section rear output, left channel
54	O	PAout0 R	Out-section front output, right channel
55	O	PAout0 L	Out-section front output, left channel
56	I	Mute C	IN-section, signal path 2 (Aux.) direct mute
57	I	Mute B	IN-section, signal path 1 (Sub) direct mute
58	I	Mute A	IN-section, signal path 0 (Main) direct mute
59	I	Tuner L	Tuner input, left channel
60	I	Tuner R	Tuner input, right channel
61	I	CD L	CD input, left channel
62	I	CD R	CD input, right channel
63	I	MD L	Minidisk (mono-differential Phone+) input, left channel
64	I	MD R	Minidisk (mono-differential Phone-) input, right channel

1. I= input, O= output, OC =open collector, P= passive external component, S= supply

3 Deatailed features

The TDA7415CB is composed of four major building blocks. - The IN-section, the spectrum-analyzer, the main signal processing path and the OUT-section; Individually featuring:

IN section

- Three independent signal-paths (front, rear and auxiliary) with independent soft-mute.
- Six stereo inputs; 3 single ended; 1 single ended or full differential mono; 2 quasi-differential.
- ±15dB level-adjust with 1 dB steps.
- Pin-accessible and/or I^2C/SPI-controlled soft-mute (direct mute) for each signal path.

Spectrum analyzer

- 7-band, fully integrated 2^{nd}-order band-pass filters with programmable filter quality for different visual behavior.
- Dedicated one or two-wire serial port for analog data-readout.
- Analog output voltage 3.3 V-µP compatible.

Main signal processing path

- ±15dB level-adjust with 1dB steps.
- Fully integrated bass-, middle- and treble-tone control. All filters offer 2^{nd}-order frequency response with programmable filter quality and center frequency.
- Room-acoustics notch filter (Room-EQ) allows the suppression of primary car-body resonance.

OUT section

- Three independent signal-paths (front, rear and others) with individual soft-mute.
- Four AC-coupled, single ended stereo inputs.
- Pin-accessible soft-mute (direct mute), for each signal path.
- I^2C/SPI-controlled soft-mute, independent for all six (mono) channels
- Main signal path monitor-select (pre/post tone control).
- L/R-channel independent phone, navigation or phone/navigation-mix signal interrupts for front signal path; L/R-channel independent phone or navigation interrupts for rear- and others-path.
- 2^{nd}-order frequency response high-pass filters for front- and rear-signal path.
- 2^{nd}-order frequency response subwoofer low-pass filter for others-signal path.
- Soft-step volume with 79 to 25 dB range for each signal path.
- Four dedicated outputs for an internal (on-board) power amplifier.
- Six $4V_{RMS}$ line-driver outputs for an external (remote) power amplifier.
- Offset voltage detection circuit for on-board power amplifier failure diagnosis.

4 Electrical specification

4.1 Supply

Table 4. Supply

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{CC}	Supply voltage	-	7.5	8.5	9.5	V
V_P	Supply current (line driver)	-	7.5	12	13	V
I_{total}	Total supply current	V_{CC} = 8.5 V; V_P = 12V	-	45	-	mA
SVRR	Ripple rejection @ 1 kHz	Audio processor (all filters flat)	-	60	-	dB

4.2 Absolute maximum ratings

Table 5. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Operating supply voltage	10	V
V_P	Operating supply voltage	13	V
T_{amb}	Operating temperature range	-40 to 85	°C
T_{stg}	Storage temperature range	-55 to +150	°C

4.3 Electrical characteristcs

4.3.1 Input section

V_{CC} = 8.0 V; V_P = 12.0 V; T_{amb} = 25 °C; R_L =10 kΩ ; all gains = 0 dB; f = 1 kHz; unless otherwise specified.

Table 6. Input section

Symbol	Parameter	Test conditions / remark	Min.	Typ.	Max.	Unit
R_{in}	Input Impedance	Single-ended inputs	70	100	130	kΩ
		Differential inputs	70	100	130	kΩ
		MD-input, differential mode	35	56	65	kΩ
V_{CL}	Input Clipping Level (THD ≤ 0.1%)	Single ended inputs	1.4	1.5	-	V_{RMS}
		Differential inputs; (1)	2.0	2.2	-	V_{RMS}
CMRR	Common mode rejection ratio Differential inputs (CD, AUX.)	V_{CM} = 1 V_{RMS} @ 1 kHz	40	70	-	dB
		V_{CM} = 1 V_{RMS} @ 10 kHz	40	60	-	dB

Table 6. Input section (continued)

Symbol	Parameter	Test conditions / remark	Min.	Typ.	Max.	Unit
$CMRR_{MD}$	Common mode rejection ratio Mono differential input (MD)	V_{CM} = 1 V_{RMS} @ 1 kHz	40	66	-	dB
		V_{CM} = 1 V_{RMS} @ 10 kHz	40	56	-	dB
S_{IN}	Input separation	-	80	100	-	dB
$G_{IN\ MIN}$	Min. input gain	input to output, (1)	-16	-15	-14	dB
$G_{IN\ MAX}$	Max. input gain		14	15	16	dB
G_{STEP}	Gain-adjust step resolution	-	0.5	1	1.5	dB
V_{DC}	DC-offset steps	Adjacent gain steps	-	0.5	6	mV
		G_{MIN} to G_{MAX}	-	5	35	mV
ATT_{MUTE}	Mute attenuation	-	80	100	-	dB
t_{SMC}	Soft-mute completion time, ramp-up or -down	T1	0.1	0.24	0.4	ms
		T2	0.25	0.48	0.75	ms
		T3	7	10.2	13	ms
		T4	16	20.4	26	ms
V_{NO}	Output-noise, MUX-Outputs	20 Hz - 20 kHz; all flat, 0 dB	-	8	15	µV
$V_{OUT,max}$	Maximum output level	$R_{LOAD} \geq 2$ kΩ; THD ≤ 0.1 %	1.4	1.5	-	V_{RMS}
RL	Output load resistance	THD ≤ 0.1 %	1.0	-	-	kΩ
C_L	Output load capacitance	-	-	-	10	nF
R_{OUT}	Output impedance	-	-	24	100	Ω
V_{DC}	DC voltage level	-	3.1	3.3	3.5	V
Spectrum Analyzer (see figure 21)						
R_{in}	Input impedance	-	70	100	130	kΩ
V_{SAin}	Max. Input level, SAin-pin	3.3V full scale at SAout-pin	-	1.0	-	V_{RMS}
V_{SAout}	Output Voltage Range	$R_{LOAD} \geq 1$MΩ; $V_{SAin} \leq 1V_{RMS}$	0	-	3.3	V
f_{C1}	Center Frequency, band 1 (2)	-	55	62	69	Hz
f_{C2}	Center Frequency, band 2 (2)	-	141	157	173	Hz
f_{C3}	Center Frequency, band 3 (2)	-	356	396	436	Hz
f_{C4}	Center Frequency, band 4 (2)	-	0.9	1	1.1	kHz
f_{C5}	Center Frequency, band 5 (2)	-	2.26	2.51	2.76	kHz
f_{C6}	Center Frequency, band 6 (2)	-	5.70	6.34	6.98	kHz
f_{C7}	Center Frequency, band 7 (2)	-	14.4	16.0	17.6	kHz
Q_f	Filter Quality Factor (2)	Q_1	1.40	1.75	2.10	-
		Q_2	2.80	3.5	4.20	-
f_{SAclk}	Read-out clock frequency	-	1	-	100	kHz
t_{SAdel}	Analog output delay time	C_{Load} at SAout-pin ≤ 100 pF	-	1	2	µs

Table 6. Input section (continued)

Symbol	Parameter	Test conditions / remark	Min.	Typ.	Max.	Unit
t_{repeat}	Read-out cycle repeat time	Recommended refresh rate	50	-	-	ms
t_{intres}	Internal reset time	Auto-reset mode enabled	3	4	5	ms
t_{SAres}	Reset pulse width	Auto-reset mode disabled	500	-	-	ns

1. All differential inputs or differential configurations have -3 dB input gain.

4.3.2 Main signal processing path

Table 7. Main signal processing path

Symbol	Parameter	Test conditions / remark	Min.	Typ.	Max.	Unit
R_{in}	Input impedance	-	35	50	65	kΩ
V_{CL}	Input clipping level	THD ≤ 0.1 %	1.4	1.5	-	V_{RMS}
$G_{IN\ MIN}$	Min. input gain	input to output; all filters flat	-16	-15	-14	dB
$G_{IN\ MAX}$	Max. input gain	-	14	+15	16	dB
G_{STEP}	Gain-adjust step resolution	-	-	1	-	dB
V_{DC}	DC-offset steps	Adjacent gain steps	-	0.5	6	mV
		G_{MIN} to G_{MAX}	-	5	30	mV
$V_{OUT,max}$	Maximum output level	R_{LOAD} ≥ 2 kΩ; THD ≤ 0.1 %	1.4	1.5	-	V_{RMS}
R_L	Output load resistance	THD ≤ 0.1 %	1.0	-	-	kΩ
C_{OUT}	Output load capacitance	-	-	-	10	nF
R_{OUT}	Output impedance	-	-	24	36	Ω
V_{DC}	DC voltage level	-	3.1	3.3	3.5	V
Bass Control						
G_{RANGE}	Gain control range	-	±13	±15	±17	dB
A_{STEP}	Step resolution	-	0.5	1	1.5	dB
f_C	Center frequency (1)	f_{C0}	30	40	50	Hz
		f_{C1}	40	50	50	Hz
		f_{C2}	50	60	70	Hz
		f_{C3}	60	70	90	Hz
		f_{C4}	60	80	100	Hz
		f_{C5}	80	100	120	Hz
		f_{C6}	100	120	140	Hz
		f_{C7}	120	150	170	Hz

Table 7. Main signal processing path (continued)

Symbol	Parameter	Test conditions / remark	Min.	Typ.	Max.	Unit
Q_{BASS}	Quality factor (1)	Q_1	0.9	1	1.1	-
		Q_2	1.13	1.25	1.38	-
		Q_3	1.35	1.5	1.65	-
		Q_4	1.8	2	2.2	-
DC_{GAIN}	Bass DC-gain	DC-mode= off	-1	0	1	dB
		DC-mode= on	3.5	4.4	5.5	dB
MID control						
G_{RANGE}	Gain control range	-	±13	±15	±17	dB
A_{STEP}	Step resolution	-	0.5	1	1.5	dB
f_C	Center frequency (2)	f_{C1}	450	500	550	Hz
		f_{C2}	0.9	1	1.1	kHz
		f_{C3}	1.35	1.5	1.65	kHz
		f_{C4}	1.8	2	2.2	kHz
Q_{MID}	Quality factor (2)	Q_1	0.5	1	1.1	-
		Q_2	1.8	2	2.2	-
Treble Control						
G_{RANGE}	Gain control range	-	±13	±15	±17	dB
A_{STEP}	Step resolution	-	0.5	1	1.5	dB
f_C	Center frequency (1))	f_{C1}	6.4	10	13.6	kHz
		f_{C2}	8.0	12.5	17	kHz
		f_{C3}	9.6	15	20.4	kHz
		f_{C4}	11.2	17.5	23.8	kHz
ROOM-EQ (acoustics notch-filter)						
G_{RANGE}	Gain control range	-		-0…9	-	dB
A_{STEP}	Step resolution	Non-uniform, see description	1	-	2	dB
f_C	Notch frequency (1)	f_{N1}	162	180	198	Hz
		f_{N2}	180	200	220	kHz
		f_{N3}	198	220	242	kHz
		f_{N4}	216	240	264	kHz
Q_{EQ}	Quality factor(1)	Q_1	0.9	1	1.1	-
		Q_2	1.8	2	2.2	-

1. Min and Max values are calculated according to simulation results; Functionality is guaranteed by measuring a directly correlated parameter

4.3.3 Output section

V_{CC} = 8.0 V; V_P = 12.0 V; T_{amb} = 25 °C; R_L =10 kΩ ; all gains = 0 dB; f = 1 kHz; unless otherwise specified

Table 8. Output section

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
R_{in}	Input impedance	AC0…3 inputs	35	50	65	kΩ
V_{CL}	Input Clipping Level	THD ≤ 0.1%	1.4	1.5	-	V_{RMS}
ATT_{MUTE}	Mute Attenuation	-	80	100	-	dB
t_{SMC}	Soft-mute completion time, ramp-up or -down	T1	0.21	0.24	0.26	ms
		T2	0.43	0.48	0.52	ms
		T3	10.47	11.5	12.45	ms
		T4	5.23	5.76	6.22	ms
Volume (Soft-step)						
G_{MAX}	Max. gain	-	-	25	-	dB
A_{MAX}	Max. attenuation	-	-82	-79	-76	dB
A_{STEP}	Step resolution	-	0.5	1	1.5	dB
E_A	Attenuation set error	G= -20 to +20 dB	-1.25	0	+1.25	dB
		G= -20 to -60 dB	-3	0	3	dB
E_T	Tracking error	-	-	-	2	dB
V_{DC}	DC steps	Adjacent attenuation steps	-	0.1	3	mV
		From 0dB to G_{MIN}	-	0.5	5	mV
High Pass						
f_C	Center frequency (1)	f_{C0}	34	40	46	Hz
		f_{C1}	52	60	68	Hz
		f_{C2}	72	80	88	Hz
		f_{C3}	90	100	110	Hz
		f_{C4}	108	120	132	Hz
		f_{C5}	135	150	165	Hz
		f_{C6}	162	180	198	Hz
		f_{C7}	198	220	242	Hz
Q_{HP}	Quality factor (2)	Butterworth characteristics	0.665	0.707	0.750	-
Subwoofer low pass						
f_C	Center Frequency (2)	f_{C0}	44	50	56	Hz
		f_{C1}	54	60	66	Hz
		f_{C2}	72	80	88	Hz
		f_{C3}	90	100	110	Hz
		f_{C4}	108	120	132	Hz
Q_{HP}	Quality Factor (2)	Butterworth characteristics	0.665	0.707	0.750	-
Audio outputs						
$V_{PA,max}$	Max. output level; PA-outputs	R_{LOAD} ≥ 2 kΩ; THD ≤ 0.1 %	1.88	2	-	V_{RMS}

Table 8. Output section (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{LD,max}$	Max. output level; LD-outputs	as above; V_{CC} = 8.0 V	2.20	2.75		V_{RMS}
		as above; V_P = 12 V	3.75	4		V_{RMS}
R_L	Output load resistance	THD ≤ 0.1 %; all outputs	1.0			kΩ
C_L	Output load capacitance	All outputs			10	nF
R_{OUT}	Output impedance	All outputs		24	100	Ω
V_{DC}	DC voltage level	PA-outputs	3.8	4.0	4.2	V
		LD-outputs	V_P / 2 -200mV	V_P / 2	V_P / 2 +200mV	V

1. All differential inputs or differential configurations have -3dB input gain.
2. Min and Max values are calculated according to simulation results; Functionality is guaranteed by measuring a directly correlated parameter

4.3.4 General

Table 9. General

Symbol	Parameter	Test conditions / remark		Min.	Typ.	Max.	Unit
V_{NO}	Output noise	BW = 20 Hz to 20 kHz	output mode	-	10	15	μV
		unveighted	all flat, 0 dB	-	12	20	μV
S/N	Signal to noise ratio	all flat, 0 dB; V_O= 1.5 V_{RMS}		-	110	-	dB
		All tone filters +10 dB; A-weighted; V_O= 1.5 V_{RMS}		-	84	-	dB
d	Distortion	V_{OUT}= 1 V_{RMS}; all stages 0 dB		-	0.01	0.1	%
		All tone filters +10 dB; A-weighted; V_O= 1.5 V_{RMS}		-	0.05	0.1	%
S_C	Channel separation L/R	-		80	100	-	dB
E_T	Total tracking error	A_V = 0 to -20 dB		-	0	1	dB
		A_V = -20 to -60 dB		-	0	2	dB
V_{POR}	Internal POR Voltage	-		-	-	3.4	V

4.3.5 Bus and control inputs

Table 10. Bus and control inputs
(I^2C/SPI, spectrum analyzer, direct-mute, offset detector)

Symbol	Parameter	Test conditions / remark	Min.	Typ.	Max.	Unit
V_{IL}	Input low voltage	*SDA-, SCL-, SEL-, WinIn*-pin	-	0.8	0.7	V
V_{IH}	Input high voltage	-	2.5	2.4	-	V
V_{TH}	Input threshold voltage	*SAres-, SAclk-, all Mute*-pins	-	1.5	-	V
V_{TH}	Input threshold hysteresis	-	-	100	-	mV
I_{IN}	Input current	V_{IN}= 0.4V; *SDA-, SCL*-pin	-5	-	5	µA
$V_{TH,SPI}$	SPI-mode threshold voltage	(1)	-	-	5.5	V
$V_{O,ACK}$	SDA-acknowledge output volt.	I_O= 1.6mA	-	-	0.4	V
R_{PULLUP}	Pull-up resistance	*WinIn*-pin	30	50	70	kΩ
I_{PULLUP}	Pull-up current	V_{IN}= 0V, all Mute-pins	50	100	150	µA
f_{SCKmax}	Maximum clock speed	SPI-mode	-	-	2000	kbit/s
		I^2C-mode	-	-	800	kbit/s

1. pull-up is needed for I^2C Mute

4.3.6 DC offset detector

Table 11. DC offset detector

Symbol	Parameter	Test conditions / remark	Min.	Typ.	Max.	Unit
V_{th}	Zero comp. window size	V1	-	±25	-	mV
		V2	-	±50	-	mV
		V3	-	±75	-	mV
		V4	-	±100	-	mV
τ_{sp}	Max. rejected spike length	τ1	-	7.5	-	µs
		τ2	-	15	-	µs
		τ3	-	22.5	-	µs
		τ4	-	30	-	µs
$I_{Err,charge}$	DCErr charge current	-	1	5	10	µA
$I_{Err,discharge}$	DCErr discharge current	-	2.5	5	7.5	mA
V_{OutH}	DCErr high voltage	-	2.5	3.3	-	V
V_{OutL}	DCErr low voltage	-	-	150	300	mV

5 Description of the audio processor

As can be seen from the block diagram in *Figure 1*, the Audio processor is composed of three building blocks. - The INPUT-Section, the MAIN-SIGNAL-PROCESSING-path and the OUTPUT-Section.

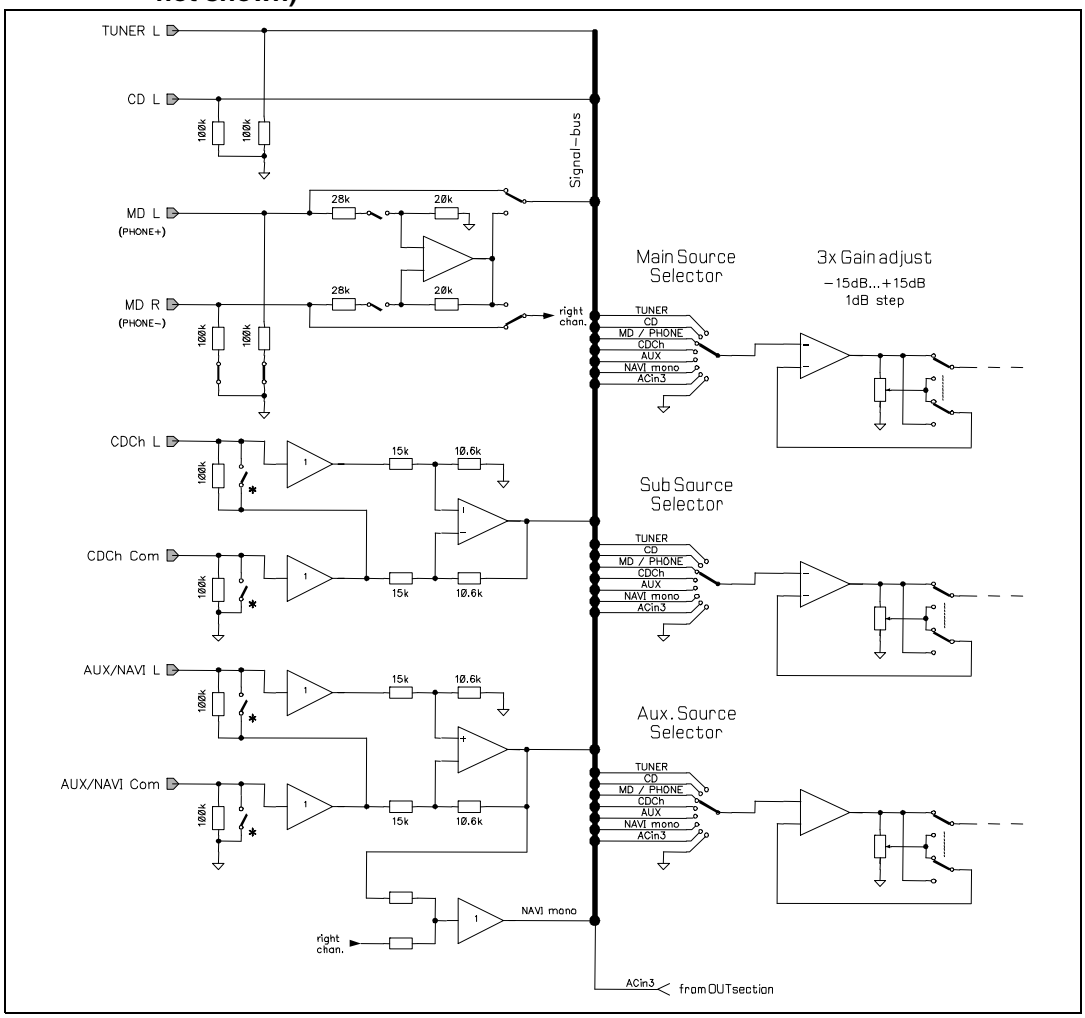
This chapter will give more insight into the different blocks and describe their function.

5.1 Input section

The Input-Section of the TDA7415CB incorporates three independent stereo signal paths, where each can connect to a variety of inputs and the AC3 input from the Output-section for monitoring purposes. For simplicity only the left inputs are shown.

After selection by the Main-, Sub-, and/or Auxiliary-source selector, the signal passes a gain-adjust amplifier, a soft-mute stage and finally a buffer before it is output at the device output-pins. The soft-mute circuit will be described later.

Figure 3. Signal-flow input-section (the following soft-mute and output buffer are not shown)



The CD-Changer- and Auxiliary/Navigation-inputs are quasi-differential inputs, where the 'out-of-phase' or ground signals of both channels share one common input. The Minidisk-input (MD) may be reconfigured for a true mono differential input as required by many phone units. Please note that all differential inputs dampen the signal by 3dB.

Additionally, each differential input-pin features a 'fast charge'-switch (*) allowing quickly charging external, large coupling capacitors upon power-on of the device. For normal operation, these switches **need to be released** by programming the corresponding bit.

For programming of the Input-section, see the programming chapter

5.2 Main signal processing path

The main-signal-processing path incorporates a classical three-band tone control (bass, mid and treble) that is preceded by a gain-adjust amplifier and completed by a dedicated room acoustics notch-filter (Room-EQ, see figure 1) that allows defeating the main car-body resonance.

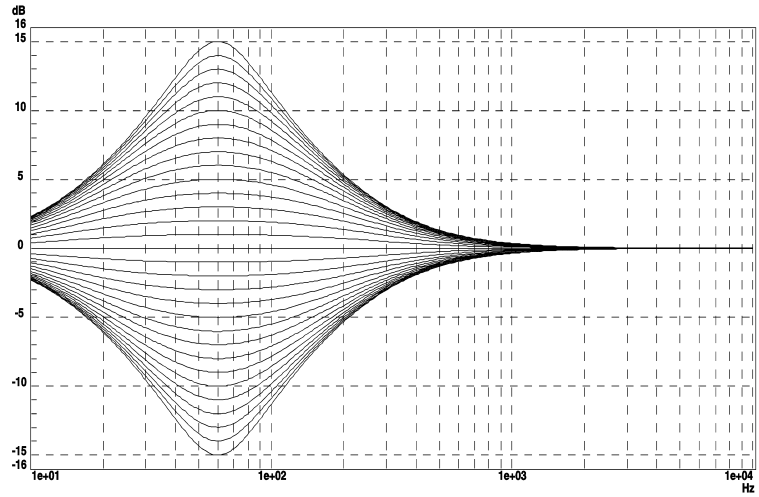
Hereafter, the filters composing the tone control and room-EQ will be presented.

5.2.1 Bass filter

There are four parameters programmable in the bass-filter stage.

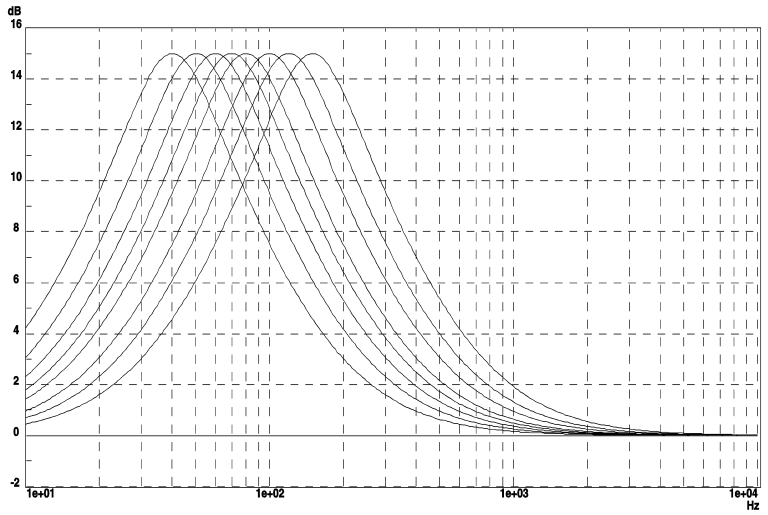
1. ***Control range:*** *Figure 4* shows the control range in the frequency domain at 60Hz center frequency.

Figure 4. Bass control range; f_C= 60Hz, Q= 1.0



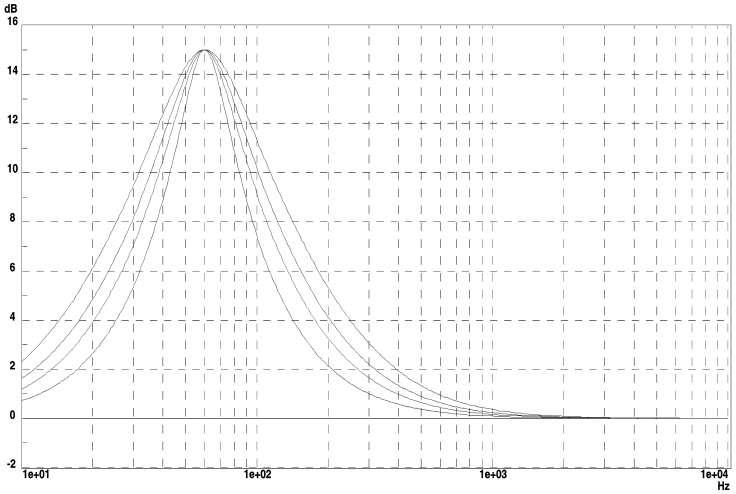
2. ***Center frequency:*** *Figure 5* shows all the selectable center frequencies at a gain of 15dB

Figure 5. Bass center frequencies; gain= 15dB, Q= 1.0



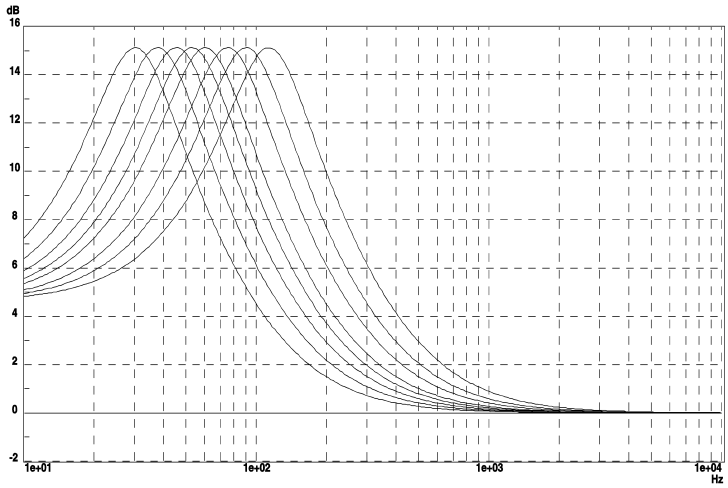
3. ***Quality factor:*** *Figure 6* shows the four selectable filter quality factors at a gain of 15dB

Figure 6. Bass filter quality factors; f_C= 60Hz, gain= 15dB.



4. ***DC-mode:*** *Figure 7* shows the effect of the DC-mode at a filter gain of 15dB. In this mode the DC-gain is increased by 4.4dB. In addition the programmed center frequencies and quality factors are decreased by 25%, which realizes alternative frequency responses.

Figure 7. Bass DC-mode frequency responses; gain= 15dB, Q= 1.5

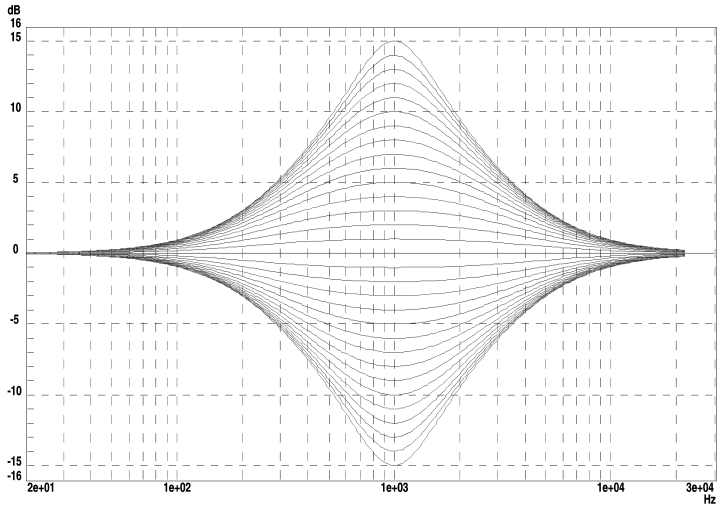


5.2.2 Mid filter

There are three parameters programmable in the mid-filter stage.

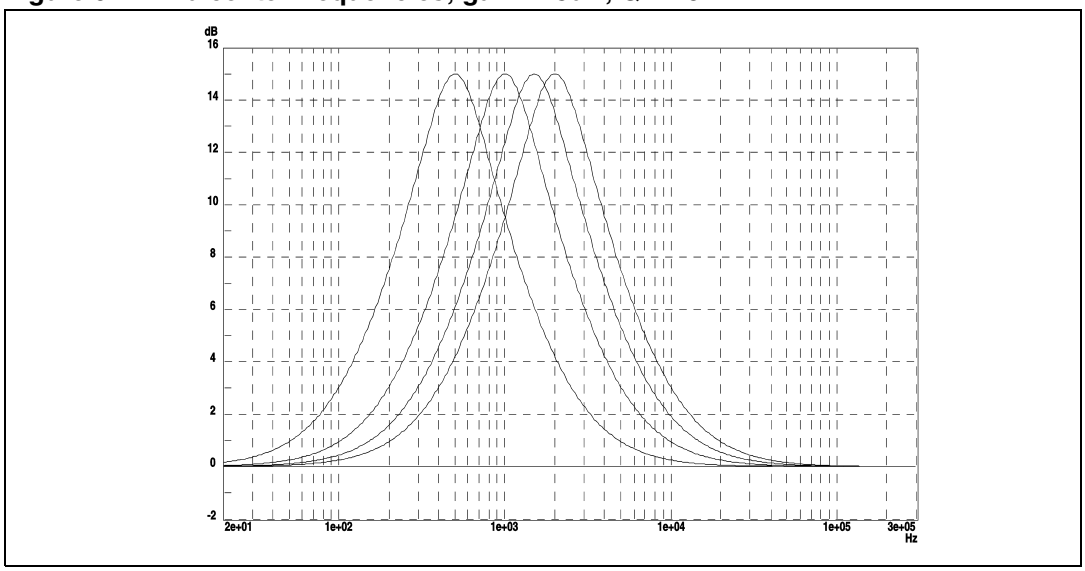
1. ***Control Range:*** *Figure 8* shows the control range in the frequency domain at 1kHz center frequency.

Figure 8. Mid control range; f_C= 1kHz, Q= 1.0



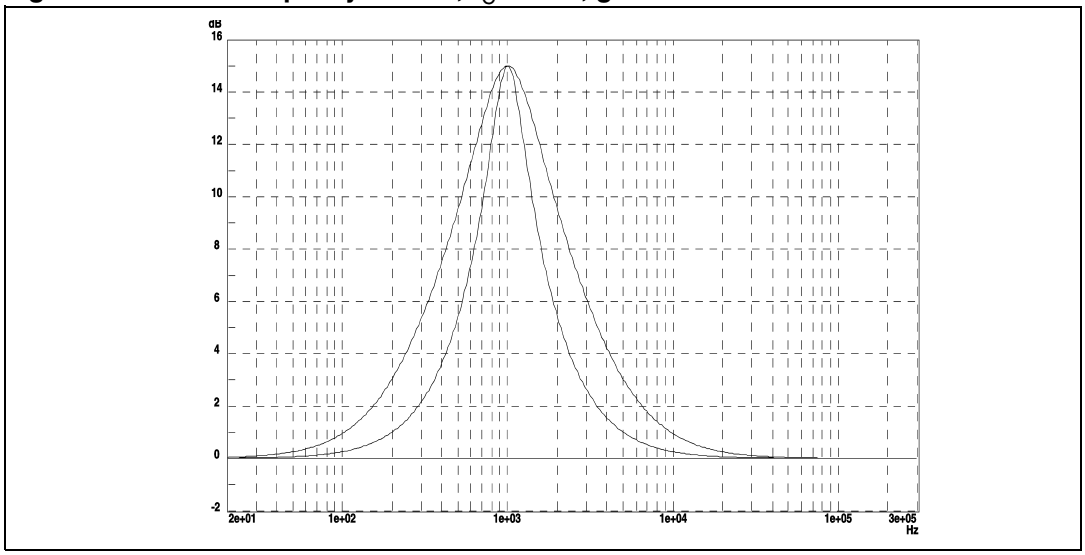
2. **Center frequency:** *Figure 9* shows the four selectable center frequencies at a gain of 15dB.

Figure 9. Mid center frequencies; gain= 15dB, Q= 1.0



3. ***Quality Factor:*** *Figure 10* shows the two selectable filter quality factors at a gain of 15dB.

Figure 10. Mid filter quality factors; f_C= 1kHz, gain= 15dB

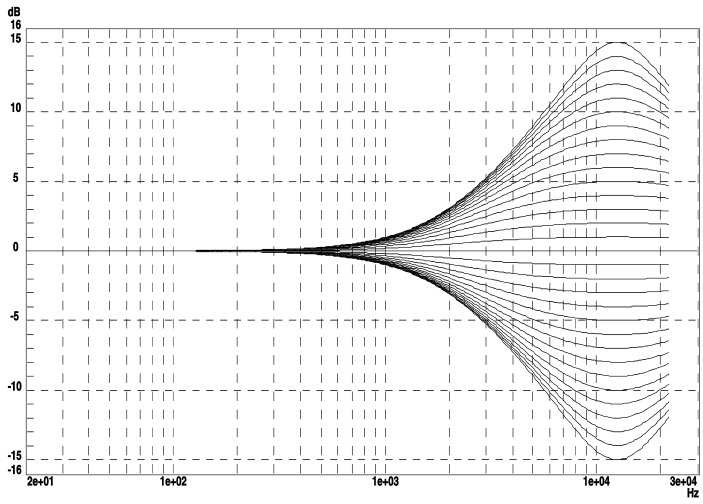


5.2.3 Treble filter

There are two parameters programmable in the treble-filter stage.

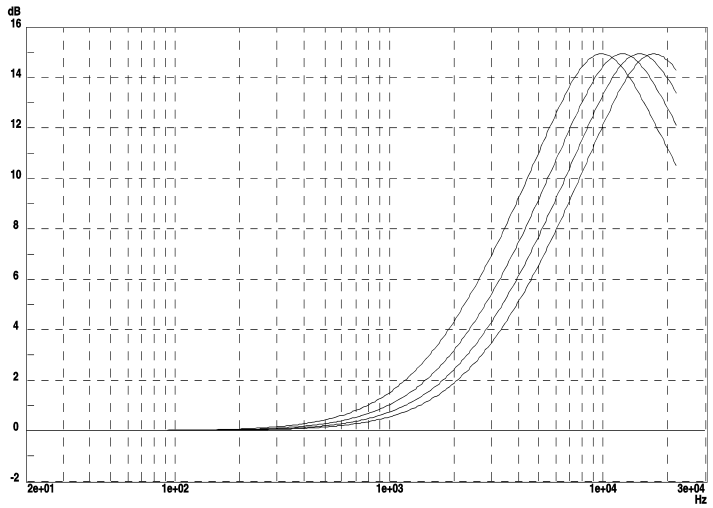
1. ***Control Range:*** *Figure 11* shows the control range in the frequency domain at 12.5kHz center frequency.

Figure 11. Treble control range; f_C= 12.5kHz, Q= 1.0



2. ***Center frequency:*** *Figure 12* shows the four selectable center frequencies at a gain of 15dB

Figure 12. Treble center frequencies; gain= 15dB, Q= 1.0

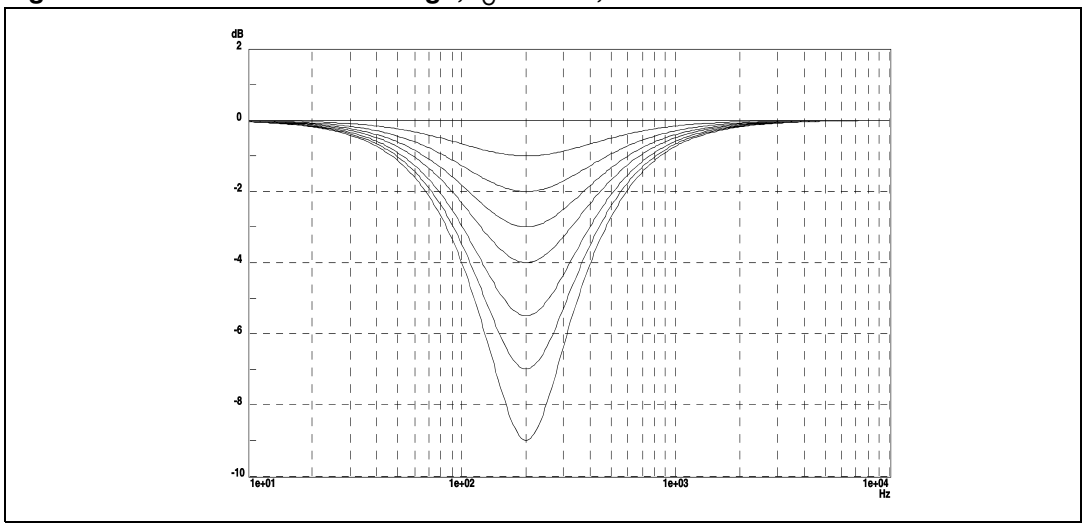


5.2.4 Room EQ filter

There are three parameters programmable in the room-EQ stage.

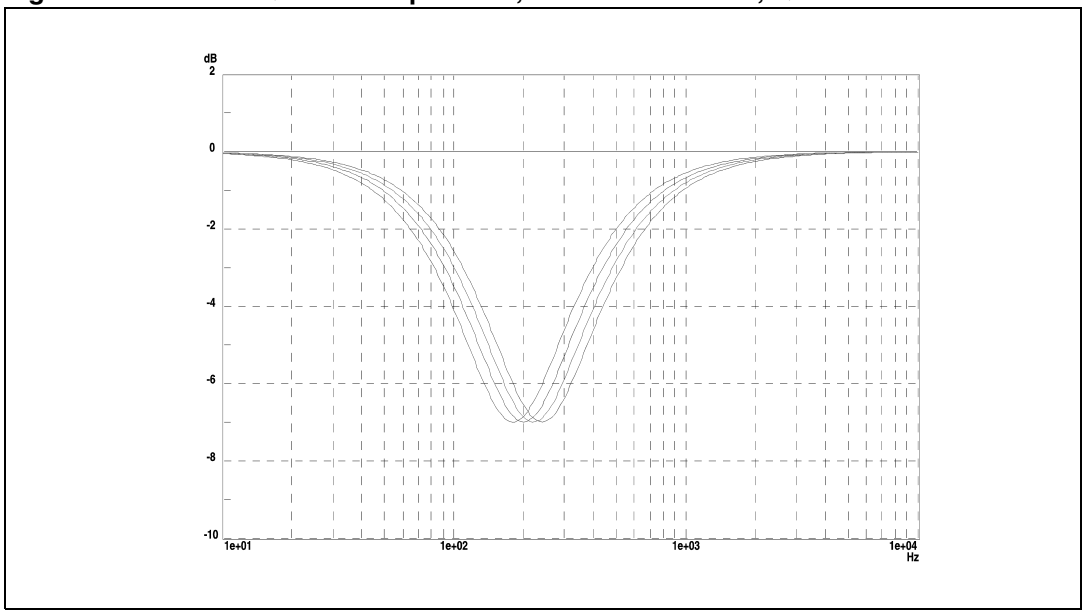
1. ***Control range:*** *Figure 13* shows the control range in the frequency domain at 200Hz center frequency. The filter has intentional non-uniform attenuation steps. These are 1dB, 2dB, 3dB, 4dB, 5.5dB, 7dB and 9dB.

Figure 13. Room-EQ control range; f_C= 200Hz, Q= 1.0



2. ***Notch frequency:*** *Figure 14* shows the four selectable notch frequencies at a gain of 15dB

Figure 14. Room-EQ notch frequencies; attenuation= -7dB, Q= 1.0.



3. ***Quality factor:*** *Figure 15* shows the two selectable filter quality factors at a gain of 15dB

Figure 15. Room-EQ notch filter quality factors; f_C= 200Hz, attenuation= 7dB.