AS3412

Ultra Small ANC Speaker Driver

General Description

The AS3412 is a speaker driver with Ambient Noise Cancelling function for headsets, headphones or ear pieces. They are intended to improve quality of e.g. music listening, a phone conversation etc. by reducing background ambient noise.

The fully analog implementation allows the lowest power consumption, lowest system BOM cost and most natural received voice enhancement otherwise difficult to achieve with DSP implementations. The device is designed to be easily applied to existing architectures.

An internal OTP-ROM can be optionally used to store the microphones gain calibration settings. The AS3412 can be used in different configurations for best trade-off in terms of noise cancellation, required filtering functions and mechanical designs. The AS3412 targeting feed-forward topology is used to effectively reduce frequencies typically up to 2-3 kHz.

The filter loop for the system is determined by measurements, for each specific headset individually, and depends very much on mechanical designs. The gain and phase compensation filter network is implemented with cheap resistors and capacitors for lowest system costs.

Ordering Information and Content Guide appear at end of datasheet.

Key Benefits & Features

The benefits and features of this device are listed below:

Figure 1:
Added Value of Using AS3412

Benefits	Features
• Low noise floor	• Low noise amplifiers
• Integrated music bypass switch	• Depletion mode transistors for passive music bypass
• Smallest ANC form factor	• WL-CSP package (2.2x2.2mm, 0.4mm pitch)

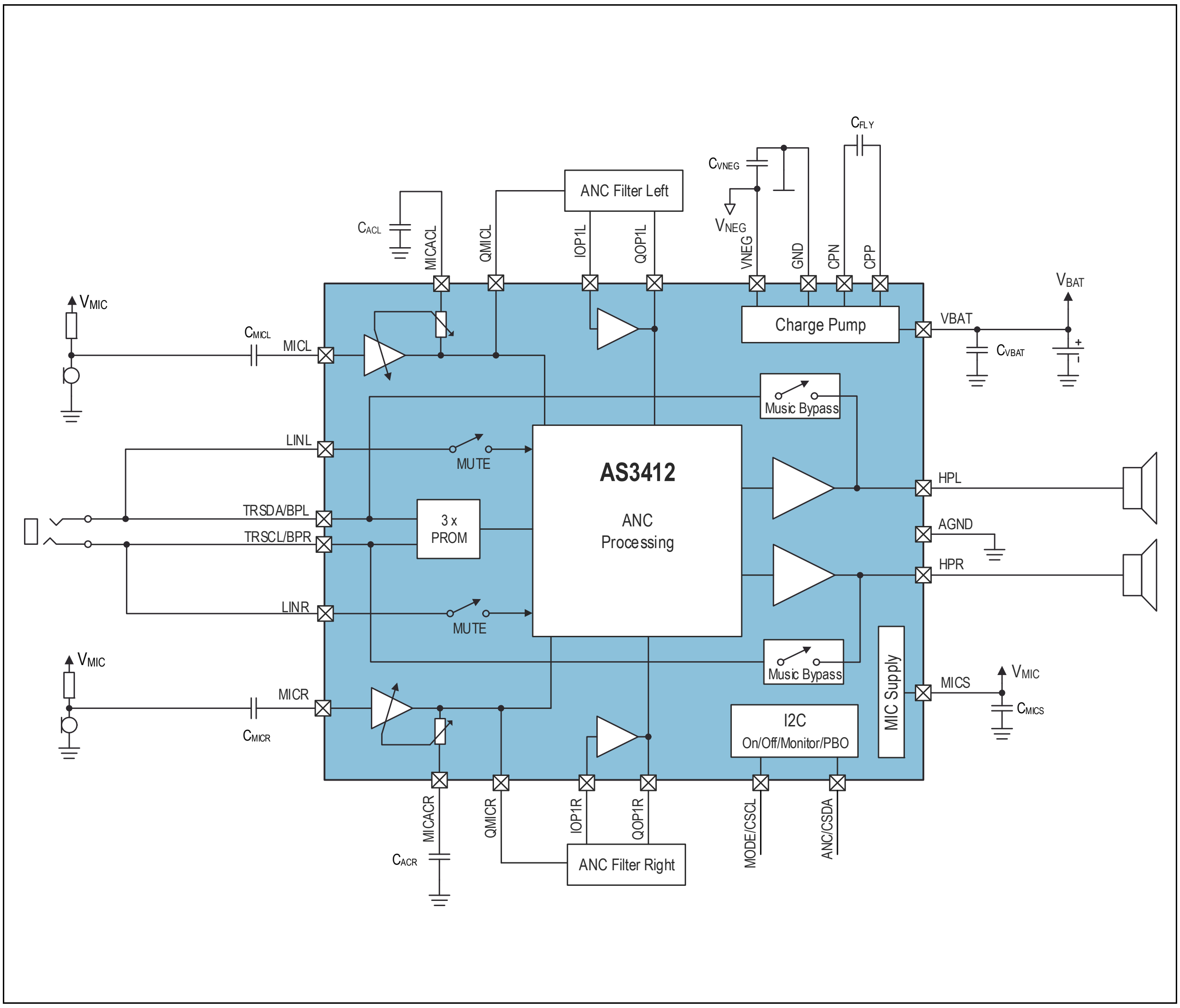
Applications

The devices are ideal for Ear Pieces, Headsets, Hands-Free Kits, Mobile Phones, and Voice Communicating Devices.

Block Diagram

The functional blocks of the AS3412 are shown below:

Figure 2:
Functional Blocks of AS3412

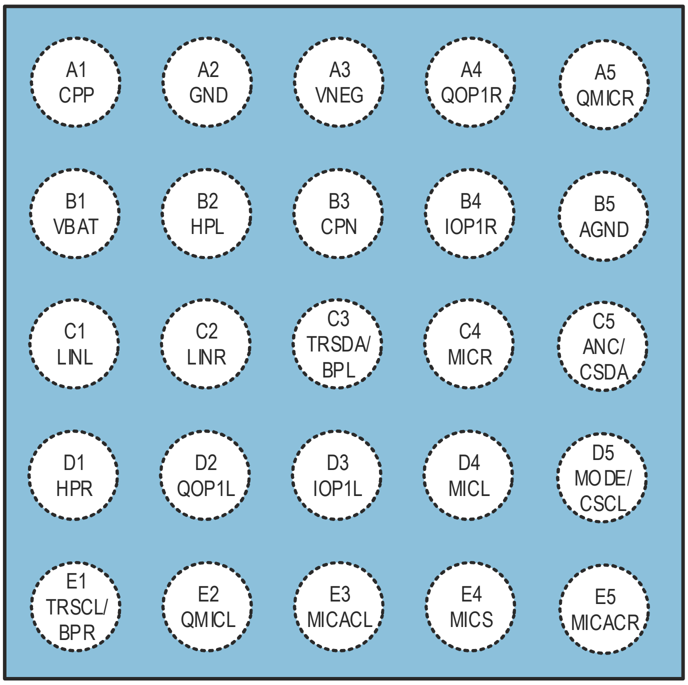


AS3412 Block Diagram: This figure shows the functional blocks of the AS3412.

Pin Assignment

Pin Diagram

Figure 3:
Pin Diagram of AS3412



Pin Description

Figure 4:
AS3412 Pin Assignment

Pin Name	Pin Number	Pin Type	Description
AGND	B5	ANA OUT	Analog reference ground. Has to be connected to GND pin. For better noise performance a star shaped ground concept is the preferred option to connect these pins together.
LINL	C1	ANA IN	Line input EQ left channel.
TRSDA/ BPL	C3	ANA IN/OUT	Data input for production trimming. Can be connected to LINL pin to enable production trimming via 3.5mm audio jack. Furthermore this pin features also music bypass function for the left audio channel in off mode operation in order to replace and external analog switch.

Pin Name	Pin Number	Pin Type	Description
TRSCL/ BPR	E1	ANA IN/OUT	Clock input for production trimming. Can be connected to LINR pin to enable production trimming via 3.5mm audio jack. Furthermore this pin features also music bypass function for the right audio channel in off mode operation in order to replace an external analog switch.
LINR	C2	ANA IN	Line input EQ right channel.
ANC / CSDA	C5	DIG IN	Serial interface data for I^2C interface and ANC control to enable/disable ANC.
MODE / CSCL	D5	DIG IN	Serial Interface Clock for I^2C interface and control pin for power up/down and Monitor mode.
MICACL	E3	ANA OUT	Microphone preamplifier AC coupling ground terminal. This pin requires a 10µF capacitor connected to AGND pin.
MICL	D4	ANA IN	ANC microphone input left channel.
MICS	E4	SUP OUT	Microphone Supply output. This pin needs an output blocking capacitor with 10µF.
MICR	C4	ANA IN	ANC microphone preamplifier input right channel.
MICACR	E5	ANA OUT	Microphone preamplifier AC coupling ground terminal. This pin requires a 10µF capacitor connected to AGND pin.
QMICR	A5	ANA OUT	ANC microphone preamplifier output right channel.
IOP1R	B4	ANA IN	ANC filter OpAmp1 input right channel.
QOP1R	A4	ANA OUT	ANC filter OpAmp1 output right channel.
HPL	B2	ANA OUT	Headphone amplifier output left channel
HPR	D1	ANA OUT	Headphone amplifier output right channel
VBAT	B1	SUP IN	Positive supply terminal of IC.
CPP	A1	ANA OUT	V_{NEG} charge pump flying capacitor positive terminal.
GND	A2	GND	V_{NEG} charge pump ground terminal. Has to be connected to AGND pin. For better noise performance a star shaped ground concept is the preferred option to connect these pins together.
CPN	B3	ANA OUT	V_{NEG} charge pump flying capacitor negative terminal.
VNEG	A3	SUP OUT	V_{NEG} charge pump output.
QOP1L	D2	ANA IN	Filter OpAmp1 output left channel.
IOP1L	D3	ANA OUT	Filter OpAmp1 input left channel.
QMICL	E2	SUP IN	ANC microphone preamplifier output left channel.

Absolute Maximum Ratings

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under Electrical Characteristics is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Figure 5:
Absolute Maximum Ratings of AS3412

Symbol	Parameter	Min	Max	Units	Comments
Electrical Parameters					
V_{GND_MAX}	Ground Terminals	-0.5	0.5	V	Applicable for pin AGND and GND
V_{SUP_MAX}	Supply Voltage to Ground	-0.5	2.1	V	Applicable for pin VBAT
V_{NEG_MAX}	Negative Terminals	-2.0	0.5	V	Applicable for pin VNEG
V_{CP_MAX}	Charge Pump Terminals	V_{NEG}-0.5	V_{NEG}+0.5	V	Applicable for pins CPN and CPP
V_{HP_MAX}	Headphone Pins	V_{NEG}-0.5	V_{NEG}+0.5	V	Applicable for pins HPR and HPL
V_{ANA_MAX}	Analog Pins	V_{NEG}-0.5	V_{NEG}+0.5	V	Applicable for pins LINL, LINR, MICL/R, HPR, HPL, QMICL/R, IOP1x, QOP1x, CPP, CPN, TRSCL/BPR, TRSDA/BPL, MICACL and MICACR
V_{CON_MAX}	Control Pins	V_{NEG}-0.5	5	V	Applicable for pins ANC/CSDA and MODE/CSCL
V_{OTHER_MAX}	Other Pins	V_{NEG}-0.5	5	V	Applicable for pins MICS
I_{SCR}	Input Current (latch-up immunity) (1) (2)	±100		mA	JEDEC 17
Continuous Power Dissipation (T_A = 70°C)					
P_T	Continuous power dissipation	-	tbd	mW	
Electrostatic Discharge					
ESD_{HBM}	Electrostatic Discharge HBM	± 2000		V	JEDEC JESD22-A114C
Temperature Ranges and Storage Conditions					
R_{THJA}	Junction to Ambient Thermal Resistance	tbd	tbd	°C/W	

Symbol	Parameter	Min	Max	Units	Comments
T_J	Operating Junction Temperature		85	°C	
T_{STRG}	Storage Temperature Range	-55	125	°C	
T_{BODY}	Package Body Temperature		260	°C	IPC/JEDEC J-STD-020 The reflow peak soldering temperature (body temperature) is specified according to IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices."
RH_{NC}	Relative Humidity (non-condensing)	5	85	%	
MSL	Moisture Sensitivity Level	1			Unlimited floor lifetime

Note(s):

1. Latch-up test was performed with VBAT supplied and both AGND and GND grounded.
2. VNEG, CPP, CPN, MICACL and MICACR are not Latch-up stressed because these are passive pins.

Electrical Characteristics

V_{BAT} = 1.6V to 1.8V, T_A = -20ºC to 85ºC. Typical values are at V_{BAT} = 1.6V, T_A = 25ºC, unless otherwise specified. All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

Figure 6:
Electrical Characteristics of AS3412

Symbol	Parameter	Condition	Min	Max	Unit
T_A	Ambient Temperature Range		-20	85	°C
		Supply Voltages			
GND	Reference Ground		0	0	V
V_{BAT}	Battery Supply Voltage		1.6	1.8	V
V_{NEG}	Charge Pump Voltage		-1.8	-1.45	V
V_{DELTA}	Difference of Ground Supplies GND, AGND	To achieve good performance, the negative supply terminals should be connected to a low impedance ground plane.	-0.1	0.1	V
		Other Pins			
V_{MICS}	Microphone Supply Voltage	MICS	0	3.7	V
V_{ANALOG}	Analog Pins	MICACL, MICACR,LINR, LINL, HPR, HPL, QMICL, QMICR, IOP1x, and QOP1x	V_{NEG}	V_{BAT}	V
$V_{CONTROL}$	Control Pins	MODE/CSCL, ANC/CSDA	0	3.7	V
V_{CP}	Charge Pump pins	CPN and CPP	V_{NEG}	V_{BAT}	V
V_{TRIM}	Application Trim Pins	TRSCL/BPR and TRSDA/BPL	V_{NEG} -0.3 or -1.8	V_{BAT} +0.5 or 1.8	V
V_{MIC}	Microphone Inputs	MICL and MICR	V_{NEG}	V_{BAT}	V

Figure 7:
Electrical Characteristics (continued)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
		Block Power Requirements				
I_{OFF}	Off mode current	MODE/CSCL pin low, device switched off	0.4	1	10	µA
I_{SYS}	Reference supply current	V_{BAT} = 1.8V; Bias generation, oscillator, POR; V_{NEG} disabled	0.16	0.25	0.3	mA
I_{MIC}	Mic gain stage current	V_{BAT} = 1.8V; no signal, stereo, normal mode	0.82	1.4	2	mA
		V_{BAT} = 1.8V; no signal, stereo, ECO mode	0.58	1.1	1.4	mA
I_{HP}	Headphone stage current	V_{BAT} = 1.8V; no signal, normal mode	1.5	2.4	3.1	mA
		V_{BAT} = 1.8V; no signal, ECO mode	1.18	2.0	2.9	mA
I_{MICS}	MICS charge pump current	V_{BAT} = 1.8V; no load	0.36	0.5	0.9	mA
		V_{BAT} = 1.6V; no load	0.36	0.4	0.85	mA
I_{OP1}	OP1 supply current	V_{BAT} = 1.8V; OP1L and OP1R enabled, normal mode	0.85	1.25	1.75	mA
		V_{BAT} = 1.8V; OP1L and OP1R enabled, ECO mode	0.65	0.9	1.37	mA
		V_{BAT} = 1.6V; OP1L and OP1R enabled, normal mode	0.8	1.2	1.68	mA
		V_{BAT} = 1.6V; OP1L and OP1R enabled, ECO mode	0.6	0.85	1.32	mA
		Typical System Power Consumption				
P_{FF}	Typical power consumption feed forward application	OP1L, OP1R enabled, Microphone supply enabled, no load, V_{BAT}=1.6V		10		mW
P_{FF_ECO}	Typical power consumption feed forward application in ECO mode	All blocks in ECO mode OP1L, OP1R enabled Microphone supply enabled, no load, V_{BAT}=1.6V		8		mW

Electrical Characteristics: Shows the electrical characteristics like typical supply voltages as well as system current consumption.

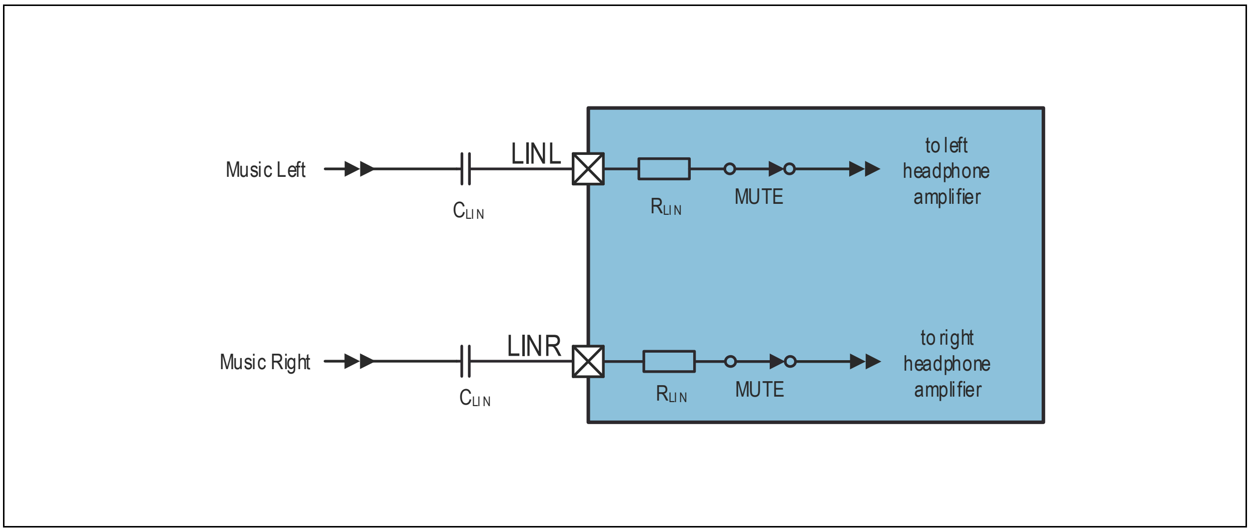
Detailed Description

This section provides a detailed description of the device related components.

Audio Line Input

The chip features one stereo line input for music playback. In monitor mode the line inputs can also be muted in order to stop music playback and increase speech intelligibility.

Figure 8:
Stereo Line Input



Stereo Line Input: This diagram shows the internal structure of the line input.

If there is a high pass function desired in an application, to block very low frequencies that could harm the speaker, or eliminate little offset voltages a simple capacitor C_{LIN} could do this function. The implementation is shown in Figure 8. The correct capacitor value for the desired cut-off frequency can be calculated with the following formula:

(EQ1)
$$C_{LIN} = \frac{1}{2 \cdot \pi \cdot R_{LIN} \cdot f_{cut-off}}$$

A typical cut-off frequency in an audio application is 20Hz. With an input impedance R_{LIN} of typ. 2k and a desired cut off frequency of 20Hz the input capacitor should be bigger than 4µF. Therefore a typical value of 4.7µF is recommended.

Parameter

V_{BAT}=1.65V, T_A= 25ºC unless otherwise specified

Figure 9:
Line Input Parameter

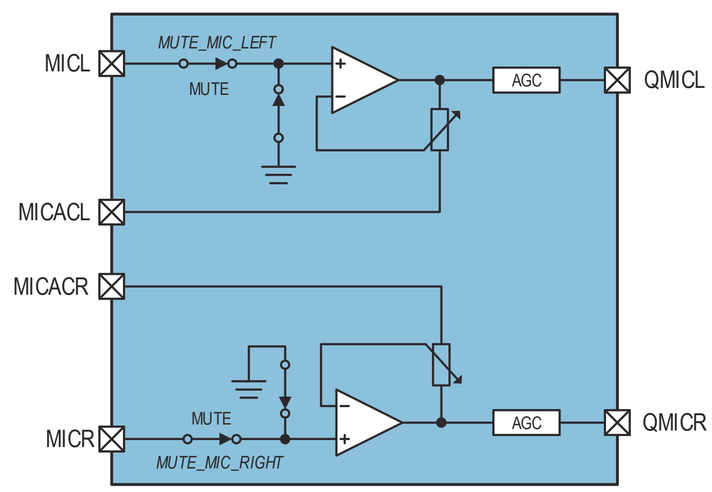
Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{LIN}	Input Signal Level			0.9*V_{BAT}		V_{PEAK}
R_{LIN}	Input Impedance			2		kΩ

Line Input Parameter: This table shows the detailed electrical characteristics of the line input.

Microphone Inputs

The AS3412 offers two low noise microphone inputs with full digital control and a dedicated DC offset cancellation pin for each microphone input. In total each gain stage offers up to 63 gain steps of 0.5dB resulting in a gain range from 0dB to +31dB. The microphone gain is stored digitally during production on an OTP memory. Besides the standard microphone gain register for left and right channel, the chip features also two additional microphone gain registers for monitor mode. Thus, in monitor mode, a completely different gain setting for left and right microphone can be selected to implement voice filter functions in order to amplify the speech band for better speech intelligibility.

Figure 10:
Stereo Microphone Input



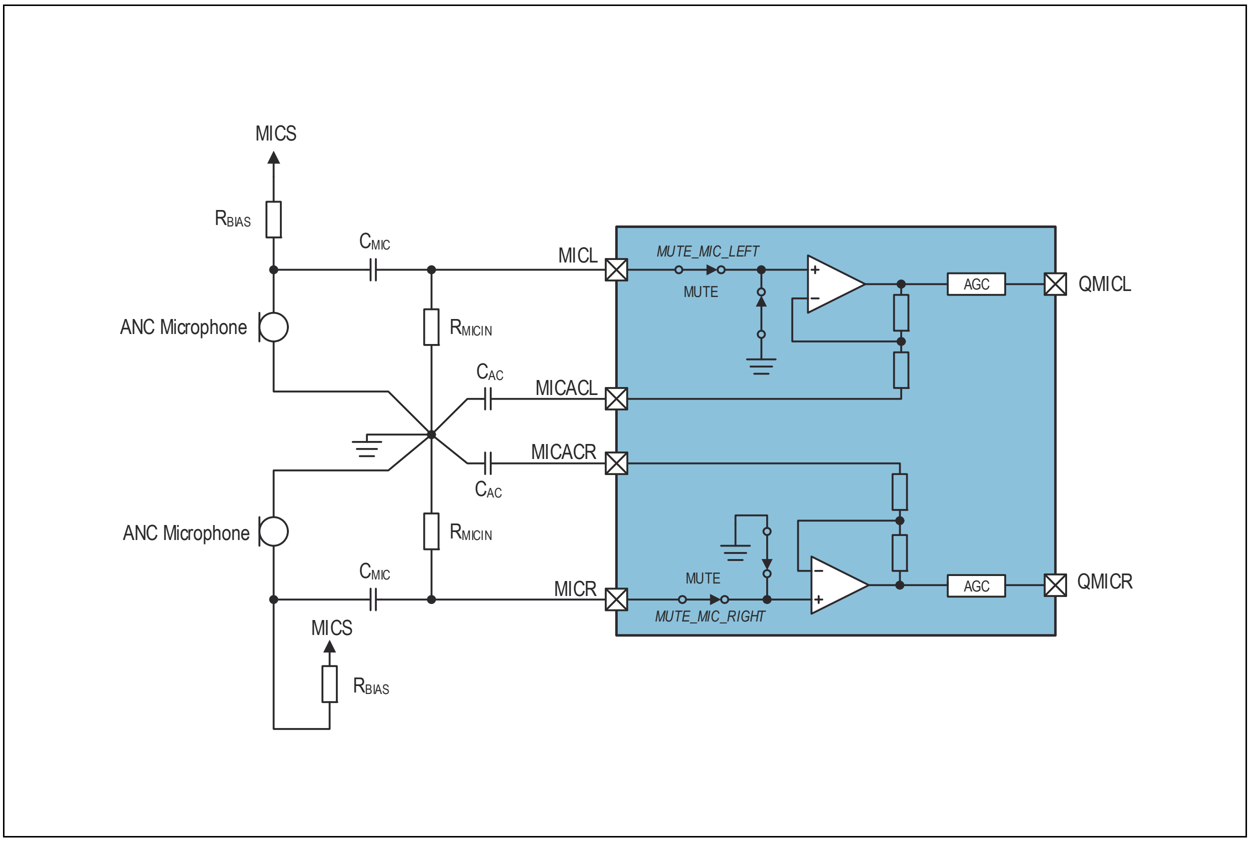
Stereo Microphone Input: This diagram shows the internal structure of the stereo microphone preamplifier including the mute switch as well as the automatic gain control (AGC).

To avoid unwanted start-up pop noise, a soft-start function is implemented for an automatic gain ramping of the device. In case of an overload condition on the microphone input (e.g. high sound pressure level), an internal state machine reduces the microphone gain automatically. For some designs it might be useful to switch off this feature. Especially in feed-back systems very often infrasound can cause an overload condition of the microphone preamplifier which results in low frequency noise. This behavior can be avoided by disabling the AGC function.

Input Capacitor Selection

The microphone preamplifier needs one bias resistor (R_{Bias}) per channel as well as DC blocking capacitors (C_{MIC}). The capacitors C_{AC} are DC blocking capacitors to avoid DC amplification of the non-inverting microphone preamplifier. This capacitor has an influence on the frequency response because the internal feedback resistors create a high pass filter together with the capacitor C_{AC}. The typical application circuit is shown in Figure 11 with all necessary components.

Figure 11:
Microphone Capacitor Selection Circuit



Microphone Capacitor Selection Circuit: This diagram shows a typical microphone application circuit with all necessary components to operate the amplifier.

The corner frequency of this high pass filter is defined with the capacitor C_{AC} and the gain of the headphone amplifier. Figure 12 shows an overview of typical cut-off frequencies with different microphone gain settings.

Figure 12:
Microphone Cut-Off Frequency Overview

Microphone Gain	R_1	R_2	$F_{cut\text{-}off}$
0dB	22.2kΩ	0Ω	1.7Hz
3dB	15716Ω	6484Ω	1.9Hz
6dB	11126Ω	11074Ω	2.2Hz
9dB	7877Ω	14323Ω	2.7Hz
12dB	5576Ω	16623Ω	3.5Hz
15dB	3948Ω	18252Ω	4.5Hz
18dB	2795Ω	19405Ω	6.1Hz
21dB	1979Ω	20221Ω	8.4Hz
24dB	1400Ω	20800Ω	11.5Hz
27dB	992Ω	21208Ω	16.3Hz
30dB	702Ω	21498Ω	22.7Hz

Microphone Cut-Off Frequency Overview: This table shows an overview of the different cut-off frequencies with C_{AC}=10µF, C_{MIC}= 2.2µF and R_{MICIN}=22kΩ of the microphone preamplifier.

Filter Simulations: It is important when doing the ANC filter simulations to include all microphone filter components to incorporate the gain and phase influence of these components.

In the cut-off frequency overview, capacitor C_{AC} was defined as 10µF which results in a rather low cut-off frequency for best ANC filter design. If a different capacitor value is desired in the application, the following formula defines the transfer function of the high pass circuit of the microphone preamplifier:

(EQ2) $$|A| = \frac{\sqrt{4 \cdot C_{AC}^2 \cdot f^2 \cdot (R_1 + R_2)^2 \cdot \pi^2 + 1}}{\sqrt{4 \cdot C_{AC}^2 \cdot f^2 \cdot R_1^2 \cdot \pi^2 + 1}}$$

The simplified transfer function does not include the high pass filter defined by C_{MIC} and R_{MICIN}. With the recommended values of 2.2µF for C_{MIC} and 22kΩ for R_{MICIN} this filter can be neglected because of the very low cut-off frequency of 1.5Hz.

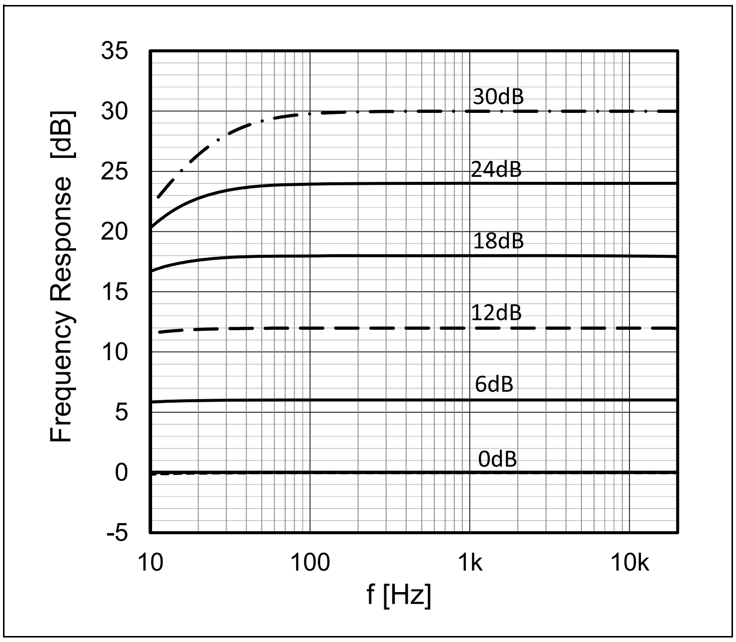
The cut-off frequency for this filter can be calculated with the following formula:

(EQ3)
$$f_{cut-off} = \frac{1}{2 \cdot \pi \cdot R_{MICIN} \cdot C_{MIC}}$$

The simulated frequency response for the microphone preamplifier with the recommended component values is shown in Figure 13.

Figure 13:
Simulated Microphone Frequency Response

Microphone Frequency Response: This graph shows the frequency response of the microphone preamplifier with different gain settings with C_{AC}=10µF, C_{MIC}=2.2µF and R_{MICIN}=22kΩ.



In application with PCB space limitations it is also possible to remove the capacitors C_{AC} and connect MICACL and MICACR pins directly to A_{GND}. In this configuration AC coupling of the QMICR and QMICL signals is recommended.

Parameter

V_{BAT}=1.8V, T_A= 25ºC, C_{AC}=10µF, C_{MIC}=4.7µF and R_{MICIN}=2.2kΩ unless otherwise specified.

Figure 14:
Microphone Parameter

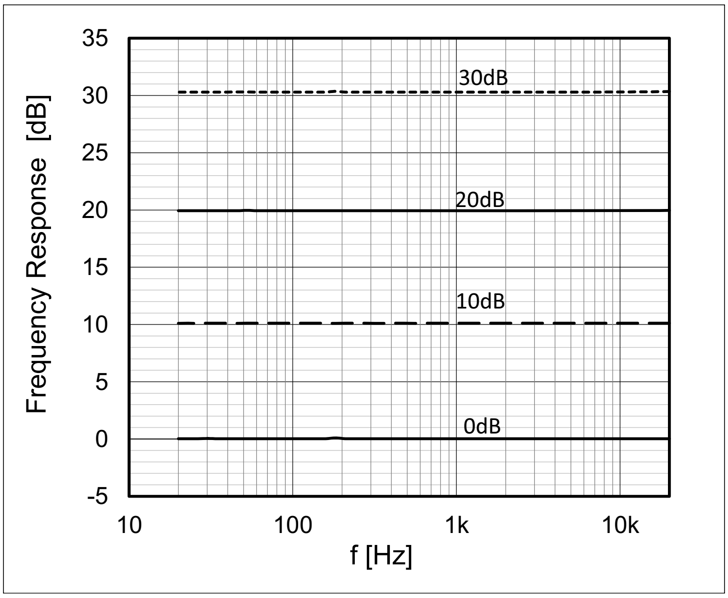
Symbol	Parameter	Condition	Min	Typ	Max	Unit
$V_{MICIN}0$	Input Signal Level	A_{MIC} = 10dB		80		mV_{RMS}
$V_{MICIN}1$		A_{MIC} = 20dB		40		mV_{RMS}
$V_{MICIN}2$		A_{MIC} = 30dB		10		mV_{RMS}
SNR	Signal to Noise Ratio	0dB gain, High quality mode, AGC off		118.5		dB
		10dB gain, High quality mode, AGC off		109		dB
		20dB gain, High quality mode, AGC off		99.5		dB
		0dB gain, ECO mode, AGC off		117		dB
		10dB gain, ECO mode, AGC off		107		dB
		20dB gain, ECO mode, AGC off		98		dB
$V_{NOISE-A}$	A-Weighted Output Noise Floor	0dB gain, 20Hz – 20kHz bandwidth, high quality		1.2		µV
		10dB gain, 20Hz – 20kHz bandwidth, High quality		4.2		µV
		20dB gain, 20Hz – 20kHz bandwidth, High quality		13.5		µV
		0dB gain, 20Hz – 20kHz bandwidth, ECO mode		1.4		µV
		10dB gain, 20Hz – 20kHz bandwidth, ECO mode		4.6		µV
		20dB gain, 20Hz – 20kHz bandwidth, ECO mode		14.8		µV
I_{MIC}	Block Current Consumption	V_{BAT} = 1.8V; no signal, stereo, normal mode	0.82	1.4	2	mA
		V_{BAT} = 1.8V; no signal, stereo, ECO mode	0.58	1.2	1.4	mA

Symbol	Parameter	Condition	Min	Typ	Max	Unit
A_{MIC}	Programmable Gain	Discrete logarithmic gain steps	0		+31	dB
	Gain Steps Size			0.5		dB
	Gain Step Precision				0.2	dB
Δ_{AMIC}	Gain Ramp Rate	V_{PEAK} related to V_{BAT} or V_{NEG}		1		ms/step
V_{ATTACK}	Limiter Activation Level	V_{PEAK} related to V_{BAT} or V_{NEG} 64 @ 0.5dB		0.40		1
V_{DECAY}	Limiter Release Level			0.31		1
$A_{MICLIMIT}$	Limiter Minimum Gain			0		dB
t_{ATTACK}	Limiter Attack Time			5		µs/step
t_{DECAY}	Limiter Decay Time			1		ms/step

Microphone Parameter: This table shows the detailed electrical characteristics of the microphone preamplifier gain stage.

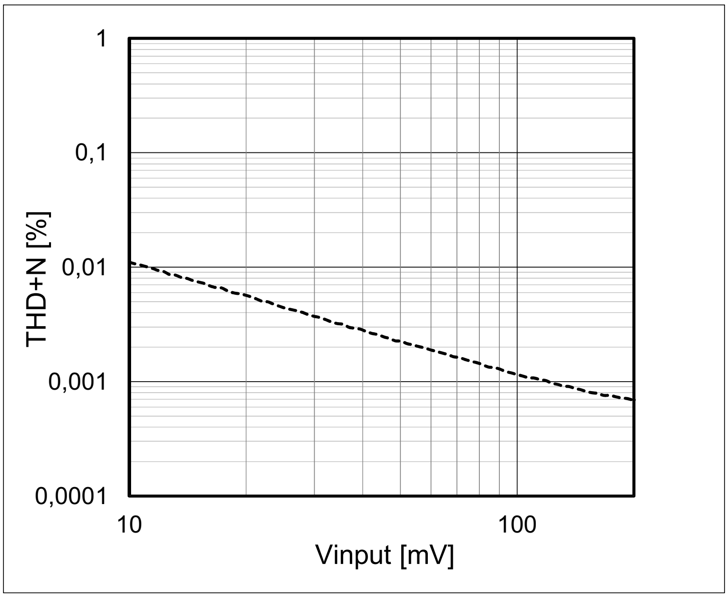
Figure 15:
Microphone Frequency Response

Microphone Frequency Response: This graph shows the frequency response of the microphone preamplifier with different gain settings without R_{MICIN} resistor, C_{AC} capacitor (MICACx pin connected to A_{GND}) and C_{MIC}=10uF.



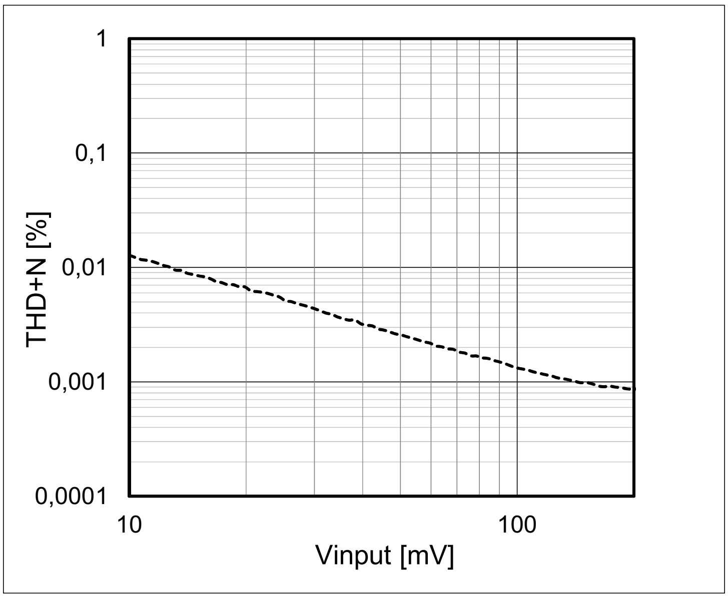
Microphone THD+N vs. Vinput: This graph shows the A-weighted THD+N versus input voltage of the microphone preamplifier with 0dB gain and V_{BAT}=1.8V.

Figure 16:
Microphone THD+N vs. V_{input}



Microphone THD+N vs. Vinput: This graph shows the A-weighted THD+N versus input voltage of the microphone preamplifier with 0dB gain and V_{BAT}=1.8V. The amplifier runs in ECO mode.

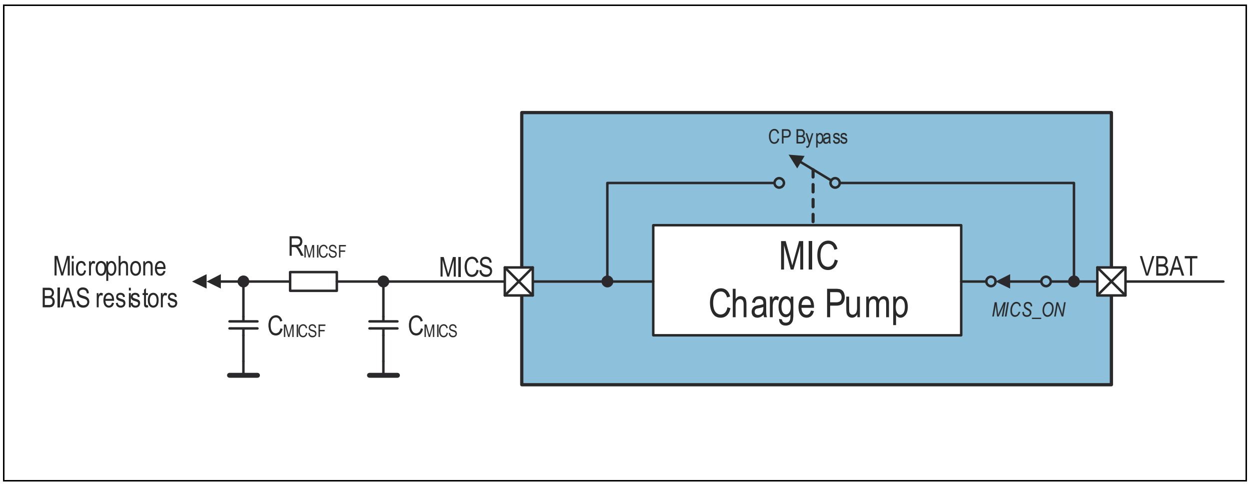
Figure 17:
Microphone THD+N vs. V_{input} ECO Mode



Microphone Supply

The AS3412 features an integrated microphone supply charge pump. This charge pump provides the proper microphone supply voltage even with a 1.8V chip supply voltage in order to increase the sensitivity of the microphone.

Figure 18:
Microphone Supply



Therefore the integrated charge pump generates a microphone supply voltage which is typically 2.7V. The microphone supply voltage is also used to switch off the integrated music bypass switch of the AS3412 is in active mode. Therefore, during normal operation the microphone supply must not be switched off if the TRSDA/BPL and TRSCL/BPR pins are in use.

Bypass Switch Operation: When using the TRSDA/BPL and TRSCL/BPR pins you must not switch off the microphone supply!

Parameter

V_{BAT}=1.8V, T_A= 25°C, C_{MICS} = 22µF, C_{MICSF} = 47µF and R_{MICSF} = 220Ω unless otherwise specified.

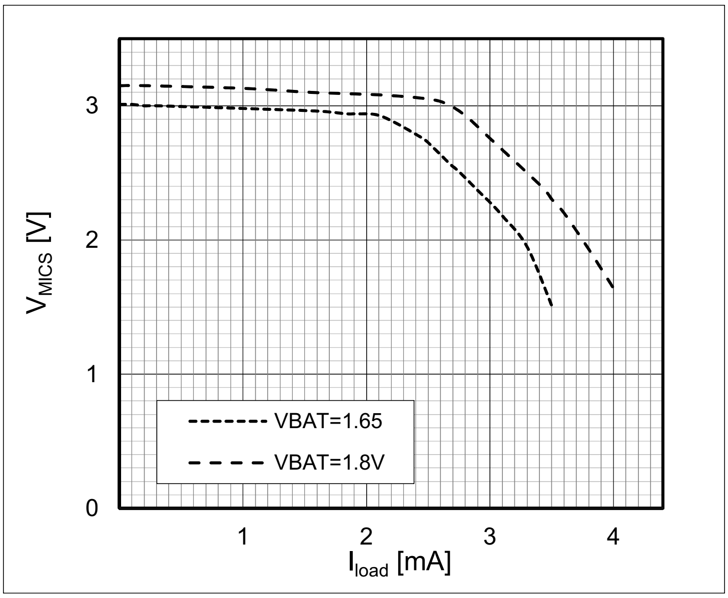
Figure 19:
Microphone Supply Parameter

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{MICS}	Microphone Supply Voltage	V_{BAT} = 1.8V, no load		3.4		V
		V_{BAT} = 1.65V, no load		3.2		V
I_{MICS}	Block Current Consumption	V_{BAT} = 1.8V; no load	0.36	0.5	0.9	mA
		V_{BAT} = 1.65V; no load	0.36	0.4	0.85	mA
$V_{Noise-A}$	Microphone Supply Noise	A-Weighted, 500µA load		1.4		µV
		A-Weighted, 550µA load, only C_{MICS} = 22uF assembled		11		µV
		A-Weighted, 500µA load, only C_{MICS} = 10uF assembled		15		µV

Microphone Supply Parameter: This table shows the detailed electrical characteristics of the microphone supply.

Figure 20:
Microphone Supply Load Characteristic

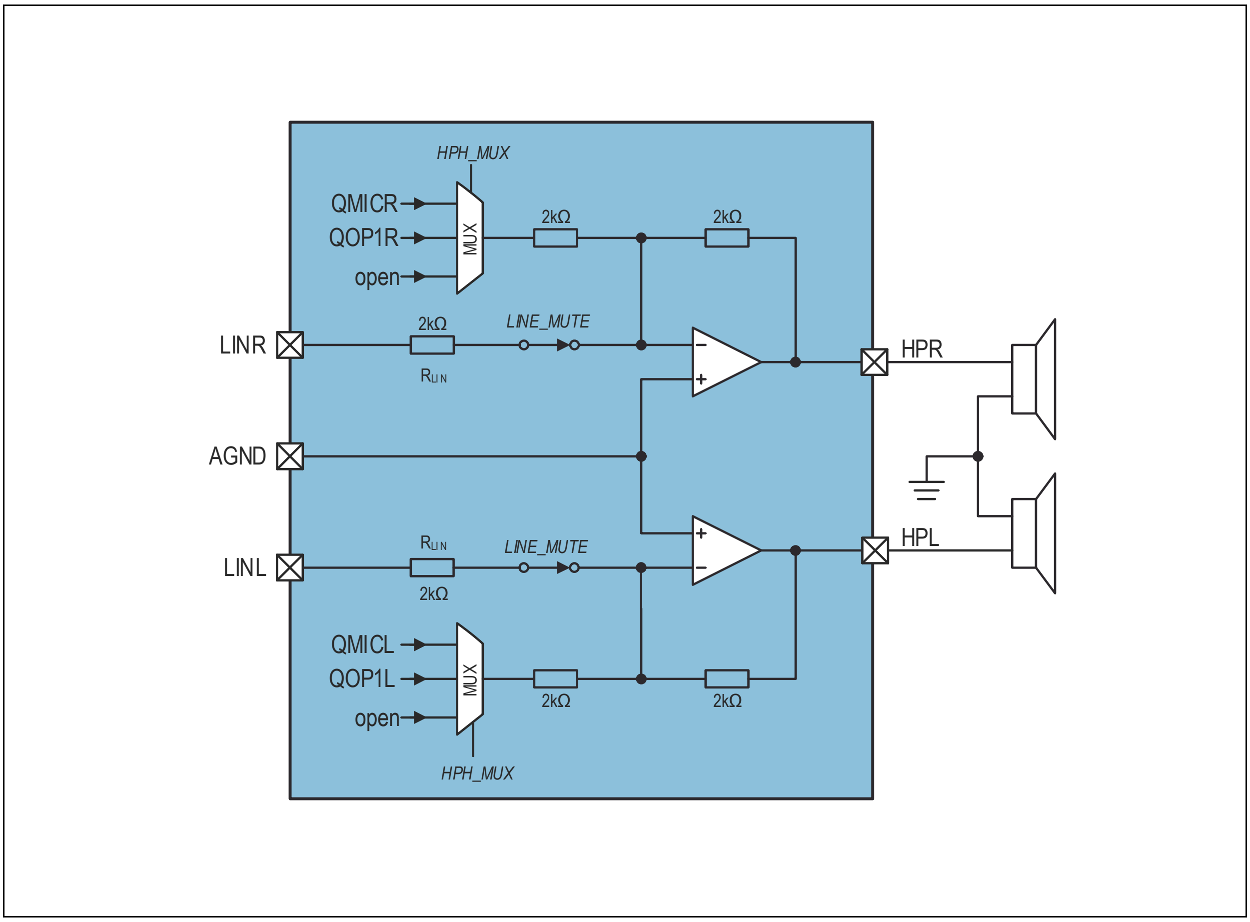
Microphone Supply Load Characteristic: This diagram shows output voltage of the microphone supply vs. output load on the microphone supply.



Headphone Amplifier

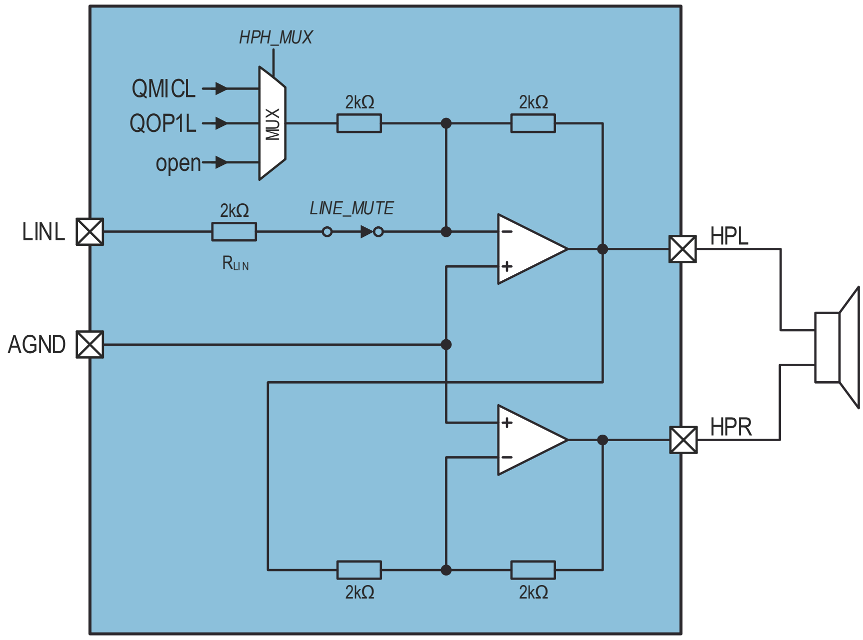
The headphone amplifier is a true ground output using V_{NEG} as negative supply. It is designed to feature an output power of 2x34mW @ 32Ω load. For higher output requirements, the headphone amplifier is also capable of operating in bridged mode. In this mode the left output is carrying the inverted signal of the right output shown in Figure 22. With a V_{BAT} voltage of 1.8V, a maximum output power of 90mW can be achieved. This is required for over- and on ear headsets with higher output power requirements. The amplifier itself features various input sources. The line input signal is directly connected to the headphone amplifier. The input multiplexer supports three different input signals which can be configured according to the *HPH_MUX* register. The “Open” setting is being used to disable the active noise cancelling function.

Figure 21:
Headphone Amplifier Single Ended



Headphone Amplifier Single Ended: This figure shows the block diagram of the headphone amplifier including the integrated music bypass switches as well as the summation input of the amplifier in single ended configuration.

Figure 22:
Headphone Amplifier Differential



Headphone Amplifier Differential: This figure shows the block diagram of the headphone amplifier including the integrated music bypass switches as well as the summation input of the amplifier in differential output mode.

Parameter

V_{BAT} =1.8V, T_A= 25ºC, unless otherwise specified.

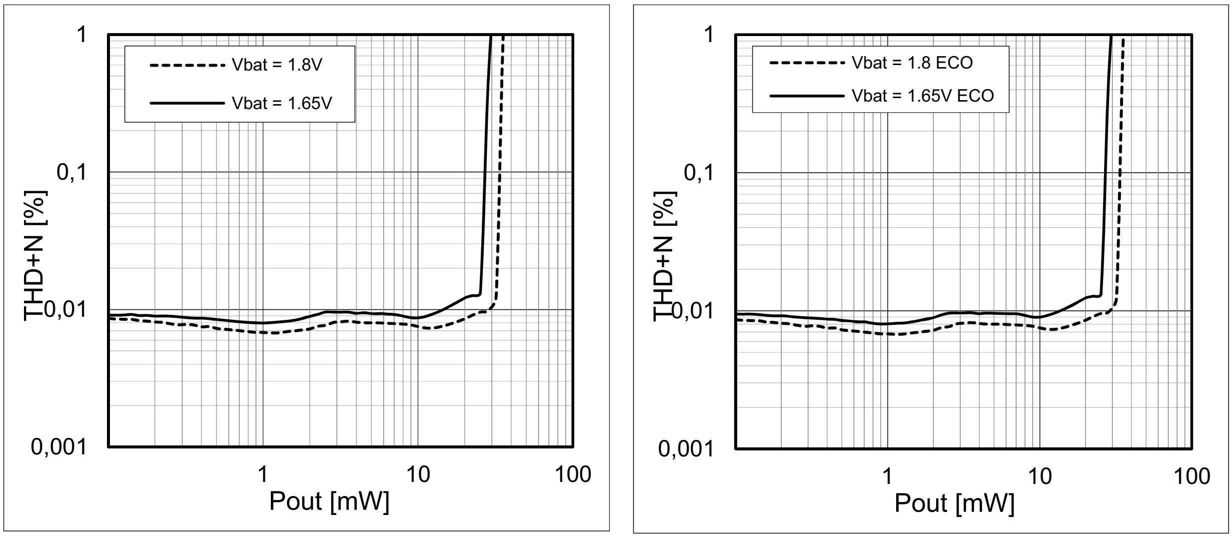
Figure 23:
Headphone Amplifier Parameter

Symbol	Parameter	Condition	Min	Typ	Max	Unit
R_{L_HP}	Load Impedance	Stereo mode	16	32		Ω
		Mono	32			Ω
C_{L_HP}	Load Capacitance	Stereo mode			100	pF
P_{HP}	Nominal Output Power Stereo Mode	V_{bat} = 1.8V; 32Ω load; THD<0.1%		34		mW
		V_{bat} = 1.65V; 32Ω load; THD<0.1%		29		mW
		V_{bat} = 1.8V; 16Ω load; THD<0.1%		50		mW
		V_{bat} = 1.65V; 16Ω load; THD<0.1%		41		mW
P_{HP_BRIDGE}	Nominal Output Power Differential Mode	V_{bat} = 1.8V; 32Ω load		90		mW
		V_{bat} = 1.65V; 32Ω load		75		mW
I_{HPH}	Supply current	V_{BAT} = 1.8V; no signal, normal mode	1.5	2.4	3.1	mA
		V_{BAT} = 1.8V; no signal, ECO mode	1.18	2	2.9	mA
P_{SRRHP}	Power Supply Rejection Ratio	1kHz		100		dB
SNR	Signal to Noise Ration	High Quality Mode, Line Input -> HPH stereo in phase test signal; 32Ω load; V_{BAT} = 1.8V;		111.5		dB
		High Quality Mode, Line Input -> HPH stereo out of phase test signal; 32Ω load; V_{BAT} = 1.8V;		112.5		dB
		ECO Mode, Line Input -> HPH stereo in phase test signal; 32Ω load; V_{BAT} = 1.8V;		109.5		dB
		ECO Mode, Line Input -> HPH stereo out of phase test signal; 32Ω load; V_{BAT} = 1.8V;		110.5		dB
Channel Separation		32Ω load		93		dB

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$V_{Noise-A}$	Output Noise Floor A-Weighted	High Quality Mode; 32Ω load; *HP_MUX* = nc; LINx connected to ground		2.5		µV
		ECO Mode; 32Ω load; *HP_MUX* = nc; LINx connected to ground		3.1		µV

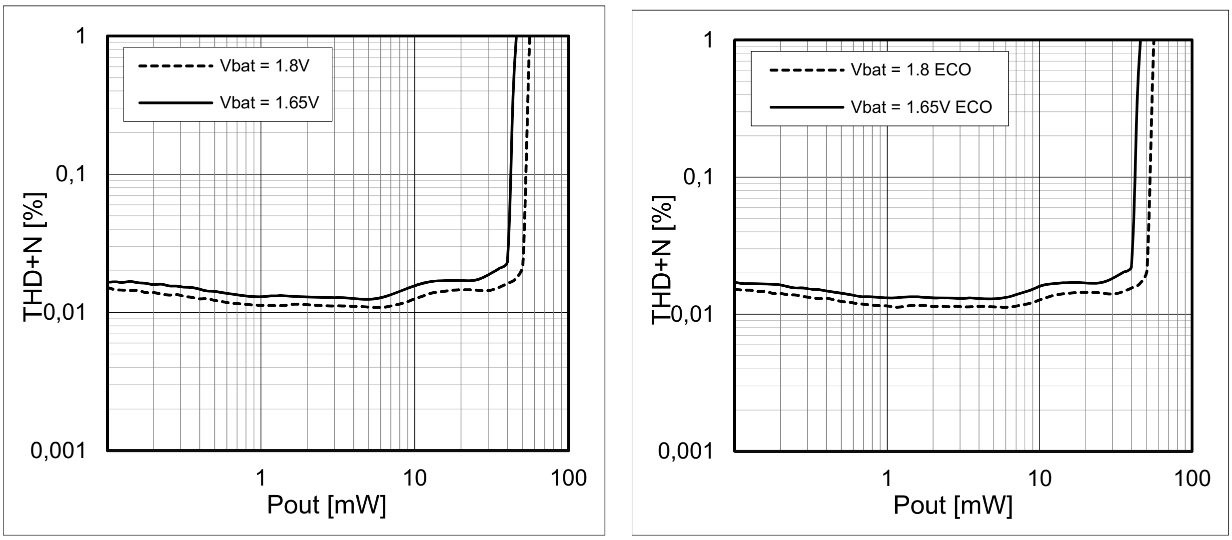
Headphone Amplifier Parameter: This table shows the detailed electrical characteristics of the headphone amplifier like output power, SNR and channel separation.

Figure 24:
Headphone THD+N vs. Output Power 32Ω Stereo



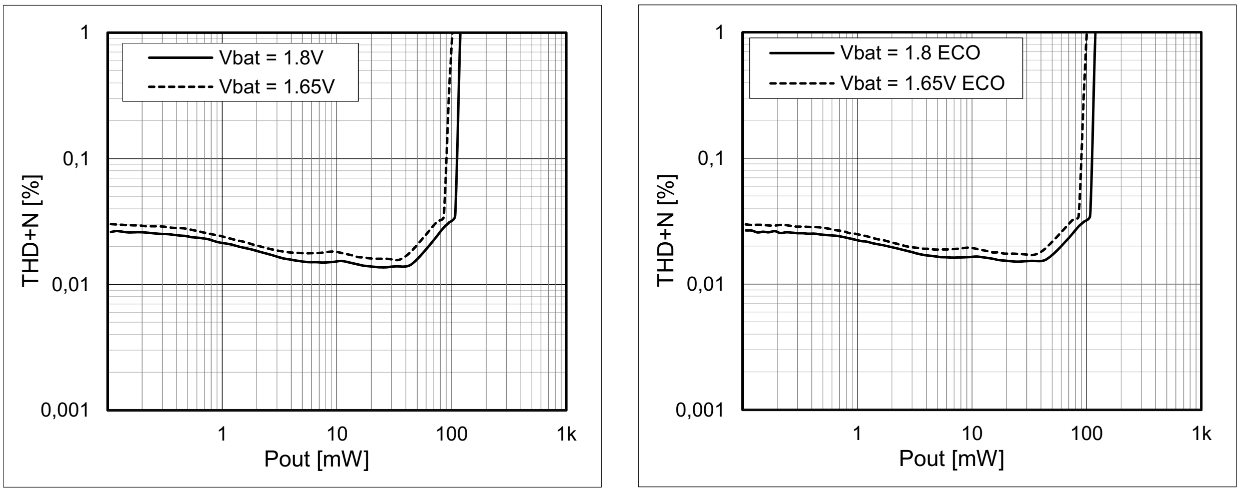
Headphone THD+N vs. Output Power: These figures shows the THD+N measurements of the headphone amplifier with different supply voltages in normal mode and ECO mode. The amplifier gain is 0dB with 32Ω load.

Figure 25:
Headphone THD+N vs. Output Power 16Ω Stereo



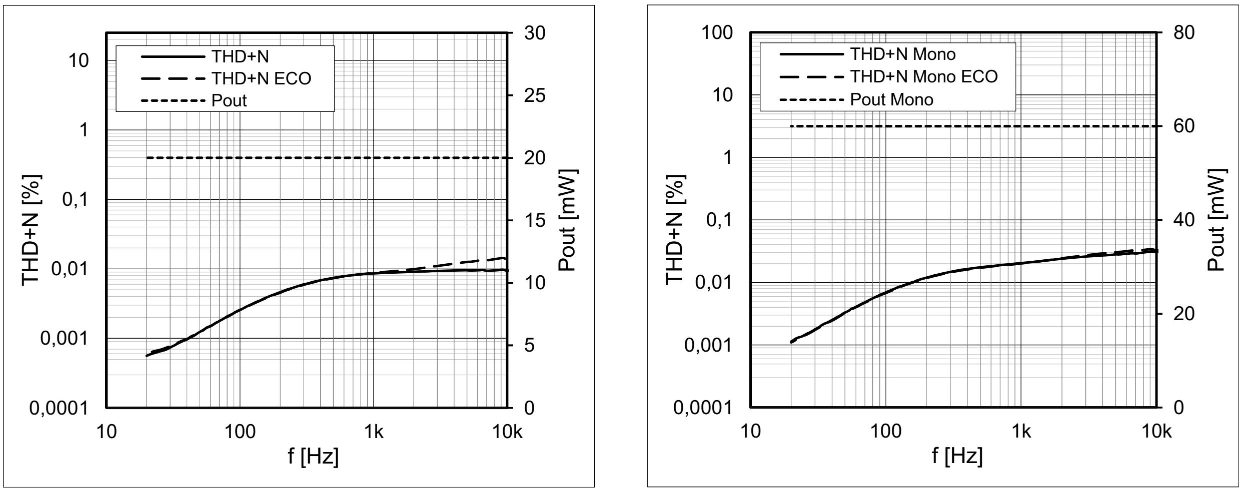
Headphone THD+N vs. Output Power: These figures shows the THD+N measurements of the headphone amplifier with different supply voltages in normal mode and ECO mode. The amplifier gain is 0dB with 16Ω load.

Figure 26:
Headphone THD+N vs. Output Power 32Ω Mono



Headphone THD+N vs. Output Power: These figures shows the A-weighted THD+N measurements of the headphone amplifier with different supply voltages in normal mode and ECO mode. The amplifier gain is 6dB with 32Ω load in mono configuration.

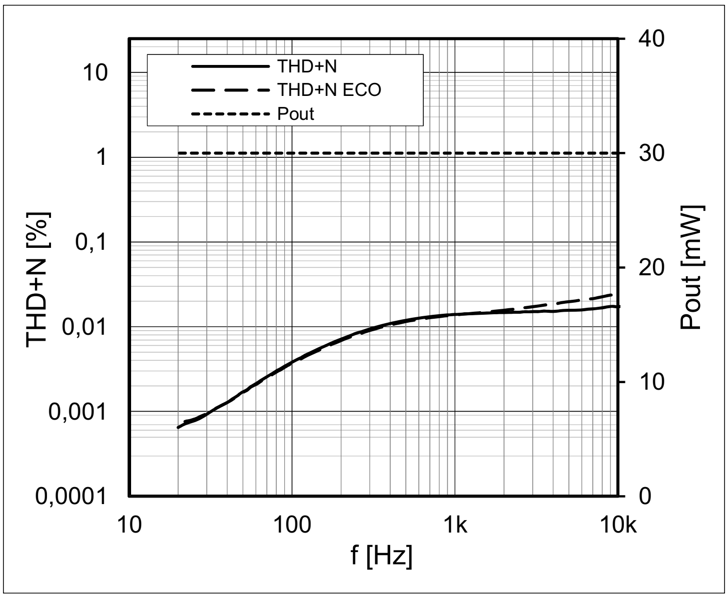
Figure 27:
Headphone THD+N vs. Frequency 32Ω Stereo/Mono



Headphone THD+N vs. Frequency: These figures shows the A-weighted THD+N measurements over frequency in stereo and mono differential mode with V_{BAT}=1.8V. The amplifier gain is 0dB and the load in both modes is 32Ω with 1mW and 5mW output power.

Figure 28:
Headphone THD+N vs. Frequency 16Ω Stereo

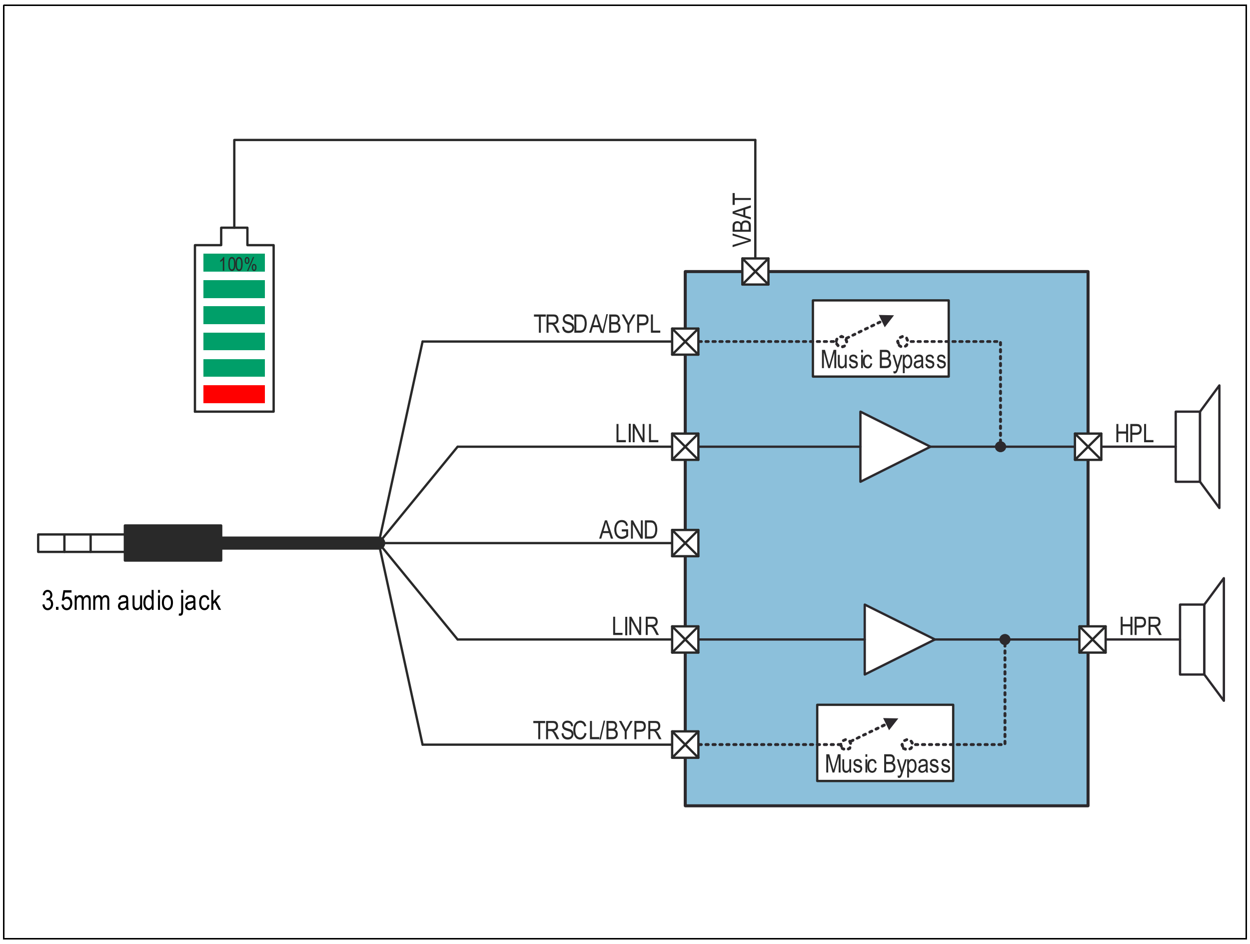
Headphone THD+N vs. Frequency: These figures shows the A-weighted THD+N measurements over frequency in stereo mode with V_{BAT}=1.8V. The amplifier gain is 0dB and the load is 16Ω.



Integrated Music Bypass Switch

If the AS3412 is switched off, the device features a unique integrated music bypass function. The bypass switches can be used to replace a mechanical switch to bypass the music signal in off mode or if the headset runs out of battery. Figure 29 shows the basic music playback path of the AS3412 with a full battery. In this mode the line input signal is feed to the headphone amplifier. The integrated bypass switches are automatically disabled in this operation mode.

Figure 29:
Bypass Mode Inactive



Bypass Mode Active: This block diagram shows the general music playback path of AS3412 with the integrated music bypass switches disabled.

Figure 30 shows the AS3412 in off mode with an empty battery. This is basically the same use case as no battery at all. In this mode the internal bypass switch becomes active. The headphone amplifier is not powered because the headset has run out of battery and the bypass switch becomes active. Thus the music signal coming from the 3.5mm audio jack is routed through the ANC chip, without any power source connected to the device, to the speakers.