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# AS3415/AS3435

## Integrated Active Noise Cancelling Solution with Bypass Feature

## General Description

The AS3415/35 are speaker drivers 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 AS3415/35 can be used in different configurations for best trade-off of noise cancellation, required filtering functions and mechanical designs.

The simpler feed-forward topology is used to effectively reduce frequencies typically up to 2-3 kHz. The feed-back topology with either 1 or 2 filtering stages has its strengths especially at very low frequencies. The typical bandwidth for a feed-back system is from 20Hz up to 1 kHz which is lower than the feed-forward systems.

The filter loop for both systems 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 AS3415/35, Integrated Active Noise Cancelling Solution with Bypass Feature are listed below:

**Figure 1:**
**Added Value of Using AS3415/35**

| Benefits | Features |
| --- | --- |
| All ANC Topologies | Feed Forward, Feed Back and Hybrid |
| No mechanical audio bypass switch | Integrated depletion mode transistors |
| Music EQ functionality | Ultra flexible low power EQ circuit |

| Benefits | Features |
|---|---|
| Longest play time | 10mW @1.5V stereo ANC; <1µA quiescent |
| Highest audio quality | 2x24mW, 0.1% THD+N @ 32Ω, 1.5V supply |
| Smallest package | Two different packages available:<br>• AS3415 QFN32 [5x5mm] 0.5mm pitch<br>• AS3435 QFN36 [5x5mm] 0.4mm pitch |
| Low battery indication | LED driver with selectable driving strength |
| Different control interface options | Push Button-, Slide switch- or $I^2C$ control interface |
| Highly innovative production trimming interface | OTP production trimming via audio interface |
| Active hearing mode with or without ANC and optional voice EQ | Monitor mode function |

## Applications

The devices are ideal for:

- Ear pieces
- Headsets
- Hands-Free Kits
- Mobile Phones
- Voice Communicating Devices

## Block Diagram

The functional blocks of AS3415/35 for reference are shown below:

**Figure 2:**
**AS3415 Block Diagram**

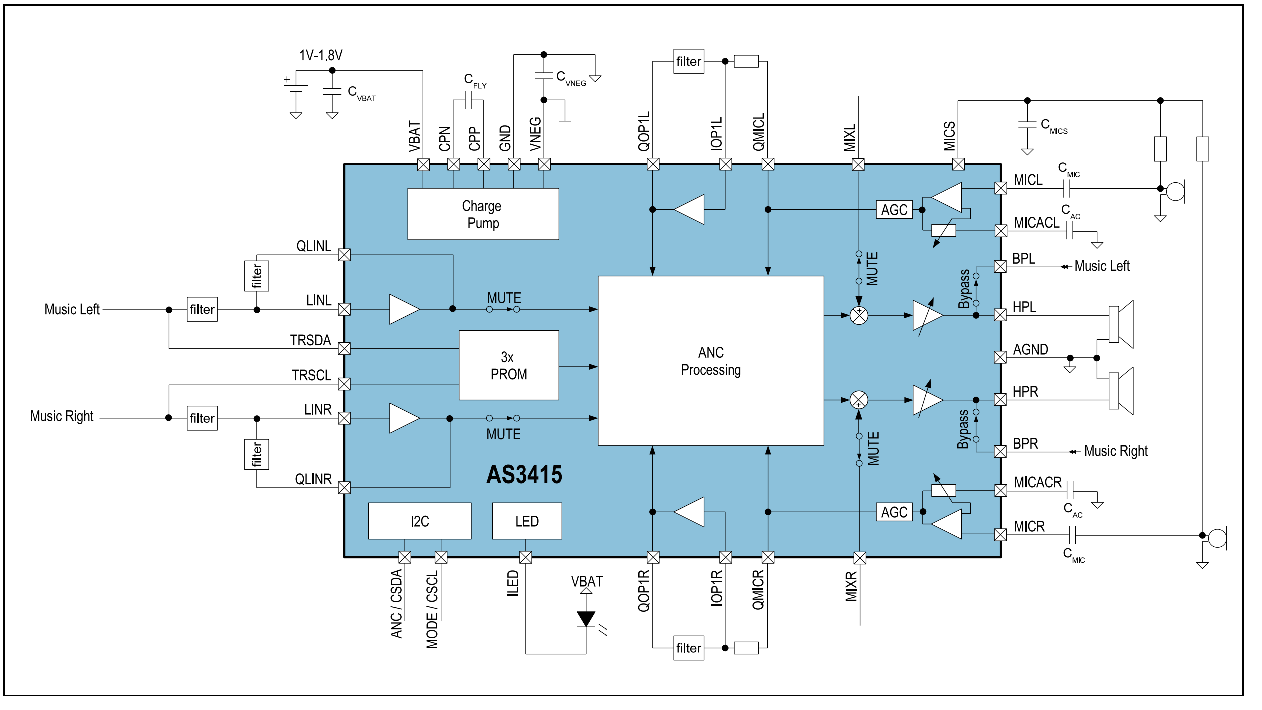
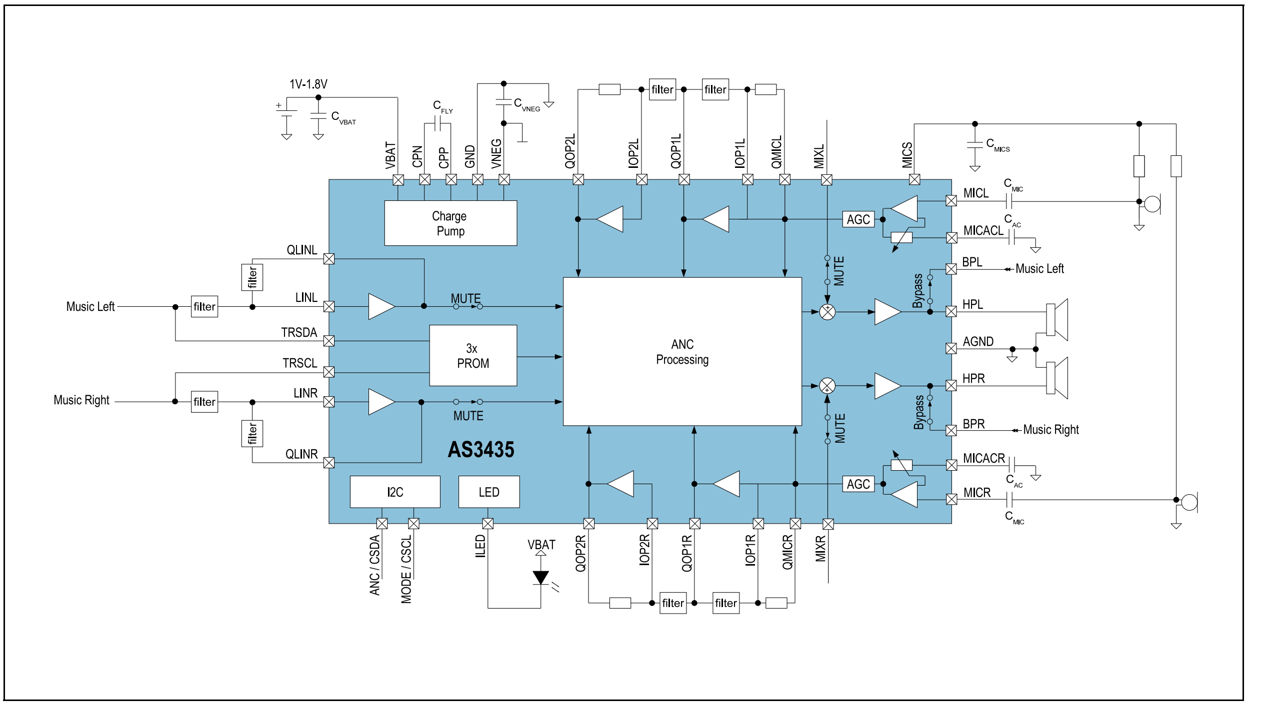



**Figure 3:**
**AS3435 Block Diagram**

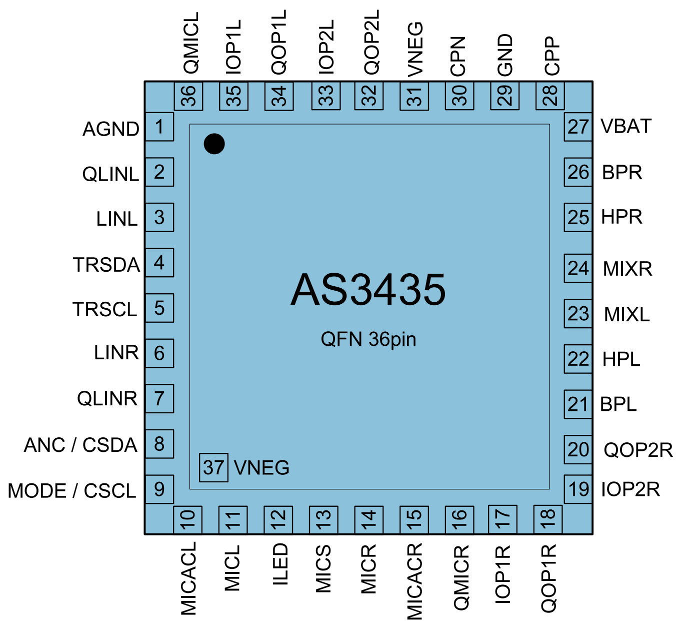


## Pin Assignment

The AS3415 and AS3435 pin assignments are described below.

**Figure 4:**
**Pin Assignments**

**Warning: Exposed pad must be connected to VNEG. Exposed pad must NOT be unconnected!**

## Pin Description

The following figure shows the pin description for AS3415/35.

**Figure 5:**
**Pin Description**

| Pin Name | Pin Number | | Pin Type | Description |
|---|---|---|---|---|
| | AS3435 | AS3415 | | |
| AGND | 1 | 32 | ANA OUT | Analog reference ground. Do not connect this pin to power or digital ground plane. |
| QLINL | 2 | 1 | ANA OUT | Line input EQ gain stage output left channel. |
| LINL | 3 | 2 | ANA IN | Line input EQ left channel. |
| TRSDA | 4 | 3 | ANA IN | Clock input for production trimming. Can be connected to LINL pin to enable production trimming via 3.5mm audio jack. |
| TRSCL | 5 | 4 | ANA IN | Data input for production trimming. Can be connected to LINR pin to enable production trimming via 3.5mm audio jack. |
| LINR | 6 | 5 | ANA IN | Line input EQ right channel. |
| QLINR | 7 | 6 | ANA IN | Line input EQ gain stage output right channel. |
| ANC / CSDA | 8 | 7 | DIG IN | Serial interface data for $I^2C$ interface and ANC control to enable/disable ANC. |
| MODE / CSCL | 9 | 8 | DIG IN | Serial Interface Clock for $I^2C$ interface and control pin for power up/down and Monitor mode. |
| MICACL | 10 | 9 | ANA OUT | Microphone preamplifier AC coupling ground terminal. This pin requires a 10µF capacitor connected to AGND pin. |
| MICL | 11 | 10 | ANA IN | ANC microphone input left channel. |
| ILED | 12 | 11 | ANA IN | Current sink input for on-indication LED. |
| MICS | 13 | 12 | SUP OUT | Microphone Supply output. This pin needs an output blocking capacitor with 10µF. |
| MICR | 14 | 13 | ANA IN | ANC microphone preamplifier input right channel. |
| MICACR | 15 | 14 | ANA OUT | Microphone preamplifier AC coupling ground terminal. This pin requires a 10µF capacitor connected to AGND pin. |
| QMICR | 16 | 15 | ANA OUT | ANC microphone preamplifier output right channel. |
| IOP1R | 17 | 16 | ANA IN | ANC filter OpAmp1 input right channel. |
| QOP1R | 18 | 17 | ANA OUT | ANC filter OpAmp1 output right channel. |

| Pin Name | Pin Number | | Pin Type | Description |
|---|---|---|---|---|
| | AS3435 | AS3415 | | |
| IOP2R | 19 | - | ANA IN | ANC Filter OpAmp2 input right channel. |
| QOP2R | 20 | - | ANA OUT | ANC filter OpAmp2 output right channel. |
| BPL | 21 | 18 | ANA IN | Left audio bypass terminal input. |
| HPL | 22 | 19 | ANA OUT | Headphone amplifier output left channel |
| MIXL | 23 | 20 | ANA IN | Headphone amplifier external summation input terminal left channel. |
| MIXR | 24 | 21 | ANA IN | Headphone amplifier external summation input terminal right channel. |
| HPR | 25 | 22 | ANA OUT | Headphone amplifier output right channel |
| BPR | 26 | 23 | ANA OUT | Right audio bypass terminal input. |
| VBAT | 27 | 24 | SUP IN | Positive supply terminal of IC. |
| CPP | 28 | 25 | ANA OUT | $V_{NEG}$ charge pump flying capacitor positive terminal. |
| GND | 29 | 26 | GND | $V_{NEG}$ charge pump ground terminal. |
| CPN | 30 | 27 | ANA OUT | $V_{NEG}$ charge pump flying capacitor negative terminal. |
| VNEG | 31 | 28 | SUP OUT | $V_{NEG}$ charge pump output. This pin must be connected to exposed pad of QFN package. |
| QOP2L | 32 | - | ANA OUT | ANC Filter OpAmp2 output left channel. |
| IOP2L | 33 | - | ANA IN | ANC Filter OpAmp2 input left channel. |
| QOP1L | 34 | 29 | ANA IN | Filter OpAmp1 output left channel. |
| IOP1L | 35 | 30 | ANA OUT | Filter OpAmp1 input left channel. |
| QMICL | 36 | 31 | SUP IN | ANC microphone preamplifier output left channel. |
| VNEG | 37 | 33 | SUP IN | Exposed Pad: Must be connected to VNEG pin 31(AS3435) or 28(AS3415). |

## 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 "Operating Conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

**Figure 6:**
**Absolute Maximum Ratings**

| Parameter | Min | Max | Units | Comments |
|---|---|---|---|---|
| Reference Ground | | | | Defined as in GND |
| Supply terminals | -0.5 | 2.0 | V | Applicable for pin VBAT |
| Ground terminals | -0.5 | 0.5 | V | Applicable for pin AGND |
| Negative terminals | -2.0 | 0.5 | V | Applicable for pins VNEG |
| Charge Pump pins | $V_{NEG}$-0.5 | $V_{BAT}$+0.5 | V | Applicable for pins CPN and CPP |
| Headphone pins | $V_{NEG}$-0.5 | $V_{BAT}$+0.5 | V | Applicable for pins HPR and HPL |
| Analog pins | $V_{NEG}$-0.5 | $V_{BAT}$+0.5 | V | Applicable for pins LINL, LINR, MICL/R, HPR, HPL, QMICL/R, QLINL/R, IOPx, QOPx, CPP, CPN, TRSCL, TRSDA, MICACL, MICACR, MIXR, MIXL, BPL, BPR and ILED |
| Control Pins | $V_{NEG}$-0.5 | 5 | V | Applicable for pins MICS, ANC/CSDA, MODE/CSCL |
| Other Pins | $V_{NEG}$-0.5 | 5 | V | Applicable for pin MICS |
| Input Current (latch-up immunity) | -100 | 100 | mA | Norm: JEDEC 17 |
| **Continuous Power Dissipation ($T_A$ = +70ºC)** | | | | |
| Continuous Power Dissipation | - | 200 | mW | PT[(1)] for QFN32/36 package |
| Electrostatic Discharge | | | | |
| Electrostatic Discharge HBM | | ± 2 | kV | Norm: JEDEC JESD22-A114C |

| Parameter | Min | Max | Units | Comments |
|---|---|---|---|---|
| **Temperature Ranges and Storage Conditions** | | | | |
| Junction Temperature | | +85 | ºC | |
| Storage Temperature Range | -55 | +125 | ºC | |
| Humidity non-condensing | 5 | 85 | % | |
| Moisture Sensitive Level | 3 | | | Represents a max. floor life time of 168h |
| Package Body Temperature | | 260 | ºC | The reflow peak soldering temperature (body temperature) specified is in accordance with IPC/JEDEC J-STD-020"Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices". |

**Note(s) and/or Footnote(s):**

1. Depending on actual PCB layout and PCB used

## Electrical Characteristics

All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

$V_{BAT}$ = 1.0V to 1.8V, $T_A$ = -20°C to +85°C. Typical values are at $V_{BAT}$ = 1.5V, $T_A$ = +25°C, unless otherwise specified.

**Figure 7:**
**Electrical Characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $T_A$ | Ambient Temperature Range | | -20 | | +85 | °C |
| **Supply Voltages** | | | | | | |
| GND | Reference Ground | | 0 | | 0 | V |
| $V_{BAT}$ | Battery Supply Voltage | Normal operation | 1.0 | | 1.8 | V |
| | | Two wire interface operation | 1.4 | | 1.8 | V |
| $V_{NEG}$ | Charge Pump Voltage | | -1.8 | | -0.7 | 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, MIXL, MIXR, HPR, HPL, QMICL, QMICR, QLINL, QLINR, IOPx, QOPx, BPL, BPR | $V_{NEG}$ | | $V_{BAT}$ | V |
| $V_{CONTROL}$ | Control Pins | MODE/CSCL, ANC/CSDA | $V_{NEG}$ | | 3.7 | V |
| $V_{LED}$ | ILED current source | ILED | $V_{NEG}$ | | $V_{BAT}$ | V |
| $V_{CP}$ | Charge Pump pins | CPN, CPP | $V_{NEG}$ | | $V_{BAT}$ | V |
| $V_{TRIM}$ | Application Trim Pins | TRSCL and TRSDA | $V_{NEG}$ -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 |
| $I_{leak}$ | Leakage current | $V_{BAT}$<0.8V | | | 20 | µA |
| | | $V_{BAT}$<0.6V | | | 10 | µA |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Block Power Requirements @ 1.5V $V_{BAT}$** | | | | | | |
| $I_{OFF}$ | Off mode current | MODE pin low, device switched off | | 1 | | µA |
| $I_{SYS}$ | Reference supply current | Bias generation, oscillator, POR | | 0.46 | | mA |
| $I_{VNEG}$ | $V_{NEG}$ Charge Pump | | | 0.36 | | mA |
| $I_{LIN}$ | LineIn gain stage current | No signal, stereo, normal mode | | 1.4 | | mA |
| | | No signal, stereo, ECO mode | | 1 | | mA |
| $I_{MIC}$ | Mic gain stage current | No signal, stereo, normal mode | | 1.5 | | mA |
| | | No signal, stereo, ECO mode | | 1.1 | | mA |
| $I_{HP}$ | Headphone stage current | No signal, normal mode | | 2.4 | | mA |
| | | No signal, ECO mode | | 2 | | mA |
| $I_{MICS}$ | MICS charge pump current | No load | | 400 | | µA |
| $I_{OP1}$ | OP1 supply current | OP1L and OP1R enabled, normal mode | | 1.4 | | mA |
| | | OP1L and OP1R enabled, ECO mode | | 1 | | mA |
| $I_{OP2}$ | OP2 supply current | OP2L and OP2R enabled, normal mode | | 1.4 | | mA |
| | | OP2L and OP2R enabled, ECO mode | | 1 | | mA |
| **Typical System Power Consumption** | | | | | | |
| $P_{FF}$ | Typical power consumption feed forward application | OP1L, OP1R enabled<br>OP2L, OP2R disabled<br>500µA microphone load<br>ILED disabled | | 13.5 | | mW |
| $P_{FF\_ECO}$ | Typical power consumption feed forward application in ECO mode | All blocks in ECO mode<br>OP1L, OP1R enabled<br>OP2L, OP2R disabled<br>500µA microphone load<br>ILED disabled | | 10.5 | | mW |
| $P_{FB}$ | Typical power consumption feed forward application | OP1L, OP1R enabled<br>OP2L, OP2R enabled<br>500µA microphone load<br>ILED disabled | | 15.5 | | mW |
| $P_{FB\_ECO}$ | Typical power consumption feedback application in ECO mode | All blocks in ECO mode<br>OP1L, OP1R enabled<br>OP2L, OP2R enabled<br>500µA microphone load<br>ILED disabled | | 13 | | mW |

# 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. Due to the fact that the line input gain stage operates as an inverting amplifier, with access to the negative input pin and the output pin, the gain can be freely configured. In monitor mode the line inputs can also be muted in order to interrupt the music playback and increase speech intelligibility.

Besides setting the gain with a resistor network, it is also possible to do simple EQ functions for sound enhancement. The EQ function can also be used to compensate for low frequency bass losses in ANC headset with a feed-back topology. For feed-forward headsets it can be used for sound enhancement to compensate for example a lack of bass because of physical design constraints of a headset.

### *Line Input Gain Setting*

The line input gain can be configured with two external resistors, $R_1$ and $R_2$, per channel as shown in Figure 8. The gain can be calculated with the following formula:

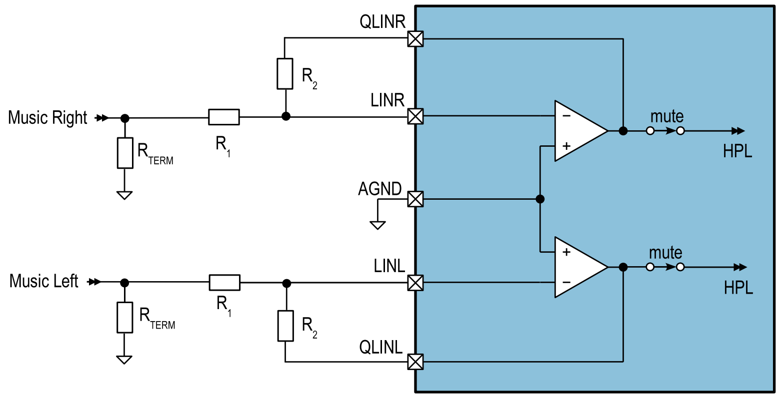
$$A_{Line} = 20 \cdot \log\frac{R_2}{R_1} \text{...[dB]}$$

The resistors $R_1$ and $R_2$ should be in the range from 1kΩ to 100kΩ. If the application requires a gain of +6dB the resistor value can be calculated as follows:

$$R_2 = R_1 \cdot 10^{\frac{A_{Line}}{20}} = 10k\Omega \cdot 10^{\frac{6}{20}} = 20k\Omega$$

For this example, a resistor value for $R_1$ was defined as 10kΩ This +6dB calculation yields a value for $R_2$ of 20kΩ.

**Figure 8:**
**Stereo Line Input**




**Stereo Line Input:** Internal structure of the stereo line input preamplifier.

### *High Pass EQ Function*

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 $C_{HP}$ could do this function. The implementation is shown in Figure 10. The correct capacitor value for the desired cut-off frequency can be calculated with the following formula:

$$C_{HP} = \frac{1}{2 \cdot \pi \cdot R_1 \cdot f_{cut-off}}$$

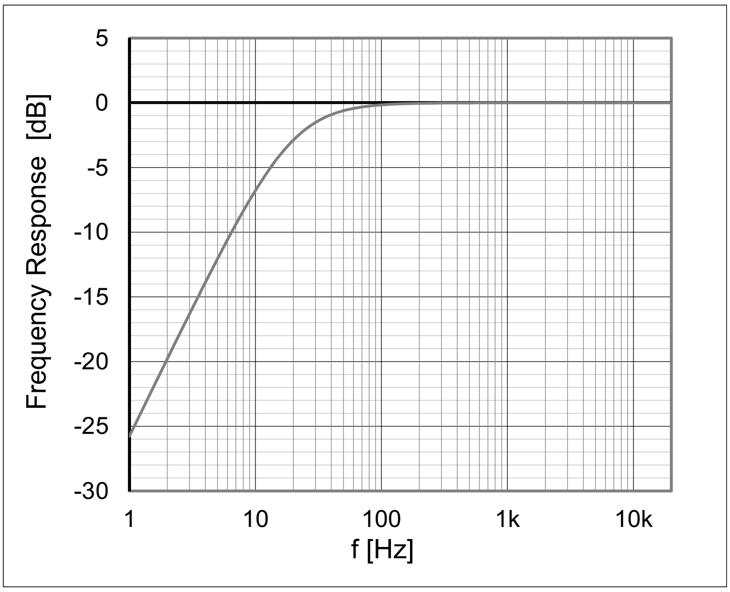
A typical cut-off frequency in an audio application is 20Hz. The resistor value of $R_1$ in this example is 10kΩ.

$$C_{HP} = \frac{1}{2 \cdot \pi \cdot 10k\Omega \cdot 20Hz} = 796nF$$

The result of the calculation is a capacitor with a value of 796nF. Because such a capacitor is not available on the market a capacitor close to the calculated value should be selected. This would be 750nF or 820nF.

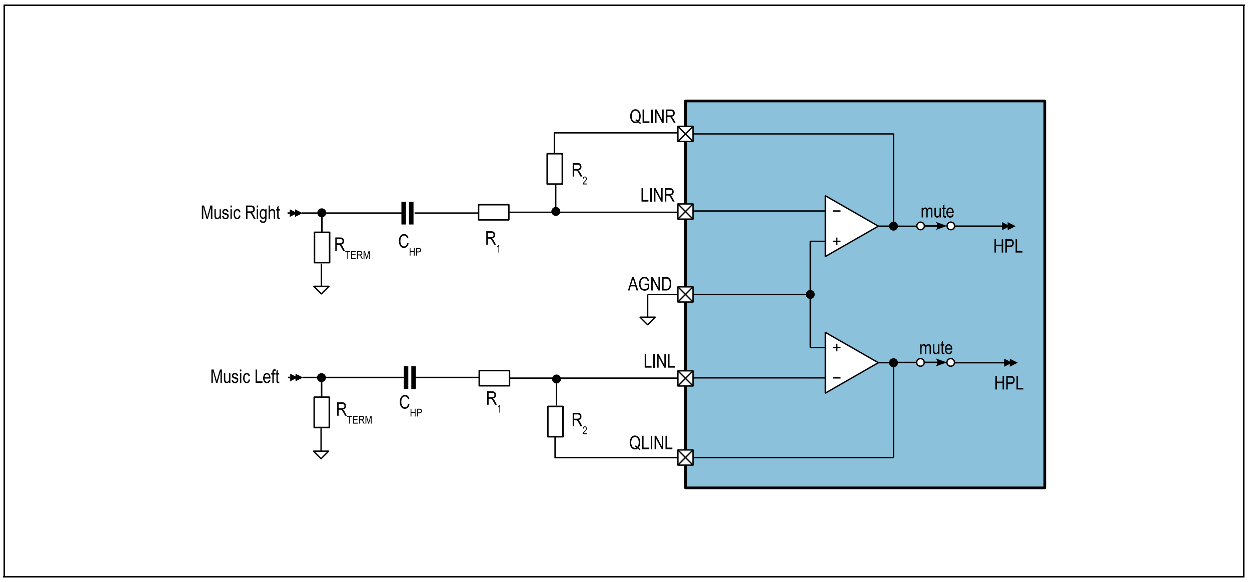
Figure 9:
Frequency Response Line Input High Pass

**Frequency Response Line Input High Pass:** This diagram shows the frequency response of the calculated line input high pass with $C_{HP}$=820nF and $R_1$=10kΩ.




The frequency response shown in Figure 9 shows the transfer function of the filter calculation. The cut-off frequency is close to 20Hz even though we selected a slightly different capacitor than the calculated one. Therefore it is no problem for an application to select an approximated component value.

Figure 10:
High Pass EQ Circuit



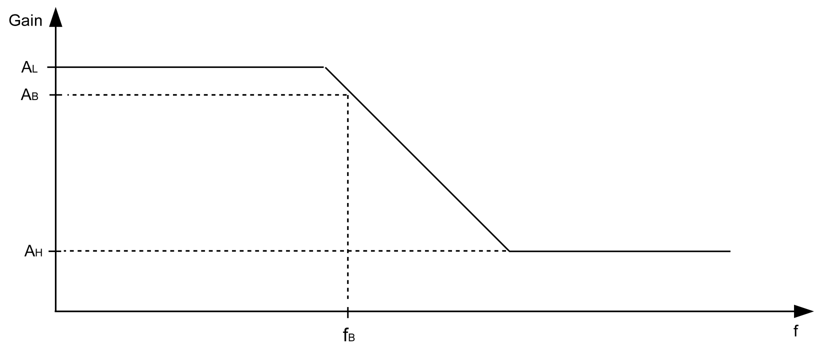

**Stereo Line Input:** This figure shows the circuit diagram for the line input high pass EQ circuit.

### *Bass Boost EQ Function*

**Complex EQ Filtering:**
**It is also possible to do even more complex EQ filtering than is shown in the example with the integrated EQ amplifier. For details please contact our local support team.**

Some applications may require low frequency compensation. This function can either help to compensate low frequency loses due to an ANC feedback circuit or just to help compensate for a lack of low frequency presence in a headset. In order to amplify low frequencies there are three parameters that can be selected by the design engineer. These are shown in Figure 11 below.

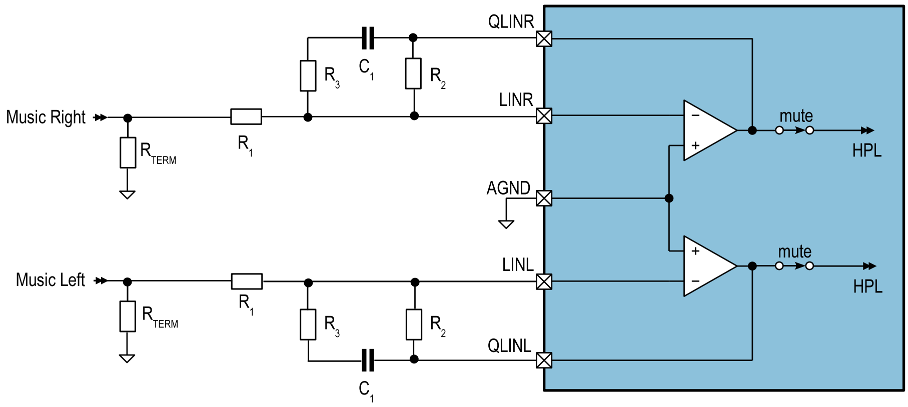
**Figure 11:**
**Bass Boost Definition**




**Bass Boost Definition:** This figure shows the typical shape of a bass boost transfer function with the key parameters for the definition of it.

The first parameter is the desired gain level at the lower frequencies. This parameter is called $A_L$ and defines the gain below the defined cut-off frequency. The second parameter is $A_H$. This defines the gain at the higher frequencies. The boost frequency, $f_B$, defines the attenuation at which the low frequency starts to roll off. The design engineer can define the desired attenuation level at the boost frequency. Depending on the overall gain distribution of the system the boost frequency is not the same as the cut off frequency with 3dB attenuation. The application circuit of the bass boost function is shown in Figure 12 below.

**Figure 12:**
**Bass Boost Circuit**




**Bass Boost Definition:** This figure shows the circuit diagram for the line input bass boost EQ circuit.

The component values for $A_L$ can be calculated with the following formula:

$$A_L = \frac{R_2}{R_1} \text{...[dB]}$$

The component values for $A_H$ can be calculated with the following formula:

$$A_H = \frac{R_2 \cdot R_3}{R_1 \cdot (R_2 + R_3)} \text{...[dB]}$$

An example for a typical bass boost is 6dB gain at the low frequency. If we select for $R_1$ a value of 10kΩ we can calculate $R_2$ as follows:

$$R_2 = 10^{\frac{A_L}{20}} \cdot R1 = 10^{\frac{6}{20}} \cdot 10k\Omega = 20k\Omega$$

In this example, the gain for the higher frequency should be 0dB.This allows us to calculate R3 as follows:

$$R_3 = \frac{-A_H \cdot R_1 \cdot R_2}{A_H \cdot R_1 - R_2} = \frac{-10^{\frac{0}{20}} \cdot 10k\Omega \cdot 20k\Omega}{10^{\frac{0}{20}} \cdot 10k\Omega - 20k\Omega} = 20k\Omega$$

The last component to be calculated for the example is capacitor $C_1$. This capacitor defines the cut-off frequency of the bass boost circuit. The desired gain level $A_{cut\text{-}off}$ at the cut-off frequency can be defined by the engineer together with the frequency. In this example, we select a cut-off frequency of 400Hz and a gain level of 5dB. Thus we get an attenuation of 1dB at a frequency of 400Hz. The necessary capacitor can be calculated with the following formula:

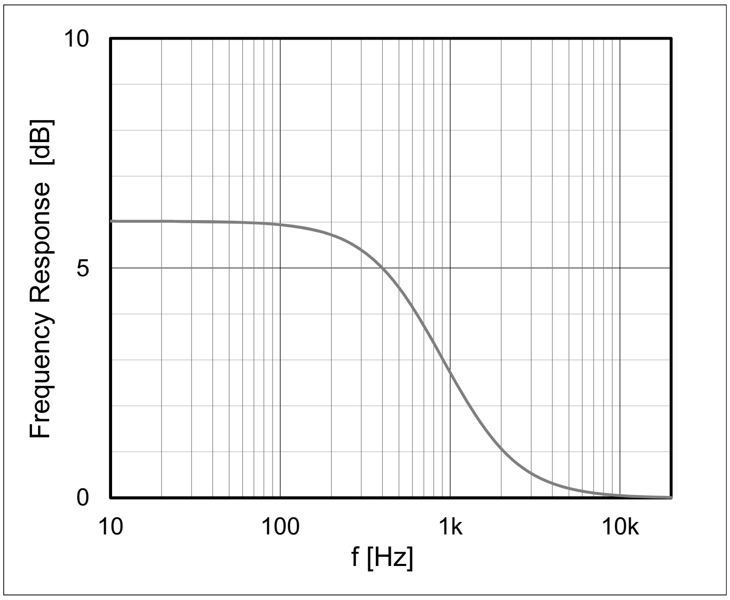
$$C_1 = \frac{\sqrt{R_2^2 - A_B^2 \cdot R_1^2}}{\sqrt{A_B^2 \cdot R_1^2 \cdot (R_2+R_3)^2 \cdot (2 \cdot \pi \cdot f_B)^2 - R_2^2 \cdot R_3^2 \cdot (2 \cdot \pi \cdot f_B)^2}}$$

$$C_1 = \frac{\sqrt{20000^2 - 10^{\frac{5}{20}} \cdot 10000^2}}{\sqrt{\left(10^{\frac{5}{20}}\right)^2 \cdot 10000^2 \cdot (20000+20000)^2 \cdot 2 \cdot \pi \cdot 400 - 20000^2 \cdot 20000^2 \cdot 2 \cdot \pi \cdot 400}} = 6.3nF$$

The Spice simulation for the calculated resistor and capacitor values is shown in Figure 13. The simulation shows exactly at 400Hz an attenuation of 1dB.

**Figure 13:**
**Frequency Response Bass Boost**

**Frequency Response Bass Boost:** The diagram shows the Spice simulation result of the bass boost calculation example done in this chapter with $C_1$=6.2nF, $R_1$=10k, $R_2$=20kΩ and $R_3$=20kΩ.



***Parameter***

$V_{BAT}$=1.5V, $T_A$= 25ºC, $R_1$=1kΩ, $R_2$=1kΩ unless otherwise specified

**Figure 14:**
**Line Input Parameter**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{LIN}$ | Input Signal Level | Gain=0dB | | 0.9* $V_{BAT}$ | | $V_{PEAK}$ |
| SNR | Signal to Noise Ratio | 10kΩ load, Gain = 0dB, $V_{BAT}$=1.8V, High Quality Mode | | 121 | | dB |
| | | 10kΩ load, Gain = 0dB, $V_{BAT}$=1.5V High Quality Mode | | 119 | | dB |
| | | 10kΩ load, Gain = 0dB, $V_{BAT}$=1.0V High Quality Mode | | 115 | | dB |
| | | 10kΩ load, Gain = 0dB, $V_{BAT}$=1.8V, ECO Mode | | 115 | | dB |
| | | 10kΩ load, Gain = 0dB, $V_{BAT}$=1.5V, ECO Mode | | 113 | | dB |
| | | 10kΩ load, Gain = 0dB, $V_{BAT}$=1.0V, ECO Mode | | 109 | | dB |
| $I_{LIN}$ | Block Current Consumption | No load, Gain = 0dB, $V_{BAT}$=1.8V, High Quality Mode | | 1.4 | | mA |
| | | No load, Gain = 0dB, $V_{BAT}$=1.5V, High Quality Mode | | 1.3 | | mA |
| | | No load, Gain = 0dB, $V_{BAT}$=1.0V, High Quality Mode | | 1.1 | | mA |
| | | No load, Gain = 0dB, $V_{BAT}$=1.8V, ECO Mode | | 1.1 | | mA |
| | | No load, Gain = 0dB, $V_{BAT}$=1.5V, ECO Mode | | 950 | | µA |
| | | No load, Gain = 0dB, $V_{BAT}$=1.0V, ECO Mode | | 700 | | µA |
| $V_{NOISE-A}$ | Input Referred Noise Floor A-Weighted | High Quality Mode | | 900 | | nV |
| | | ECO Mode | | 1.9 | | µV |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{offset}$ | DC offset voltage | | | | 2 | mV |
| $C_L$ | Load Capacitance | | | | 100 | pF |
| $R_L$ | Load Impedance | | 1 | | | kΩ |

**Line Input Parameter:** This table shows the detailed electrical characteristics of the line input gain stage like maximum input signal level and audio parameter like SNR.

**Figure 15:**
**Line Input Frequency Response**

**Line Input Frequency Response:** The diagram shows the frequency response measurement of the line input amplifier with 0dB gain and $V_{BAT}$=1.5V, $R_1$=10kΩ and $R_2$=10kΩ. The solid line represents the default high quality mode and the dashed line shows the frequency response in ECO mode.

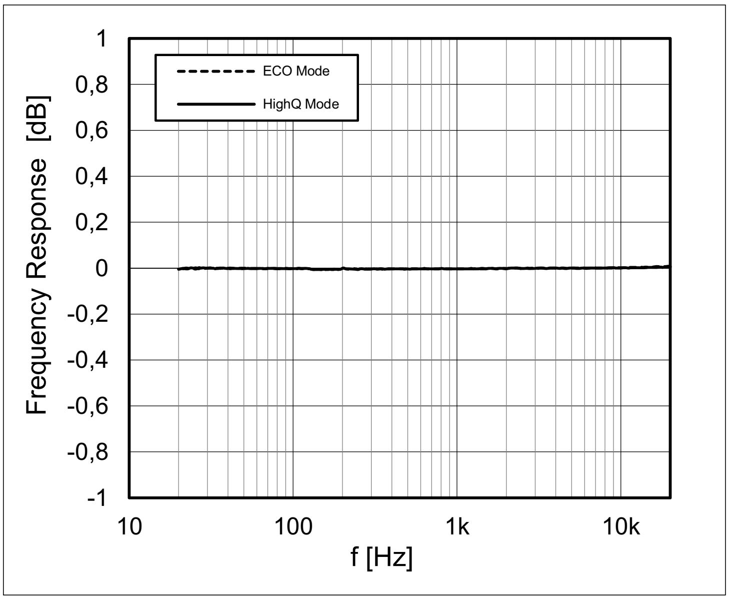



**Figure 16:**
**Line Input THD+N vs. Frequency $V_{BAT}$ = 1V**

**Line Input THD+N vs. Frequency:** The diagram shows the A-weighted THD+N measurement of the line input amplifier with 0dB gain and $V_{BAT}$=1.0V, $R_1$=10kΩ and $R_2$=10kΩ. The solid line represents the default high quality mode and the dashed line shows the frequency response in ECO mode.

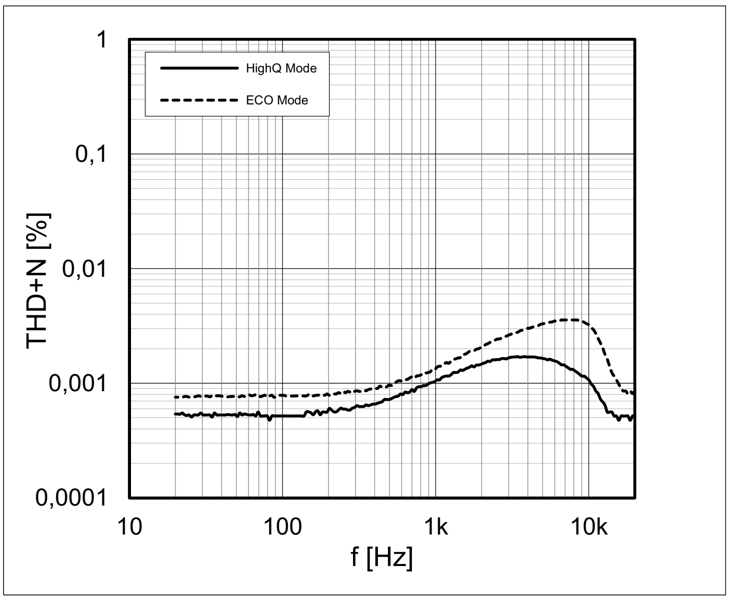


Figure 17:
**Line Input THD+N vs. Frequency $V_{BAT}$ = 1.5V**

**Line Input THD+N vs. Frequency:** The diagram shows the A-weighted THD+N measurement of the line input amplifier with 0dB gain and $V_{BAT}$=1.5V, $R_1$=10kΩ and $R_2$=10kΩ. The solid line represents the default high quality mode and the dashed line shows the frequency response in ECO mode.

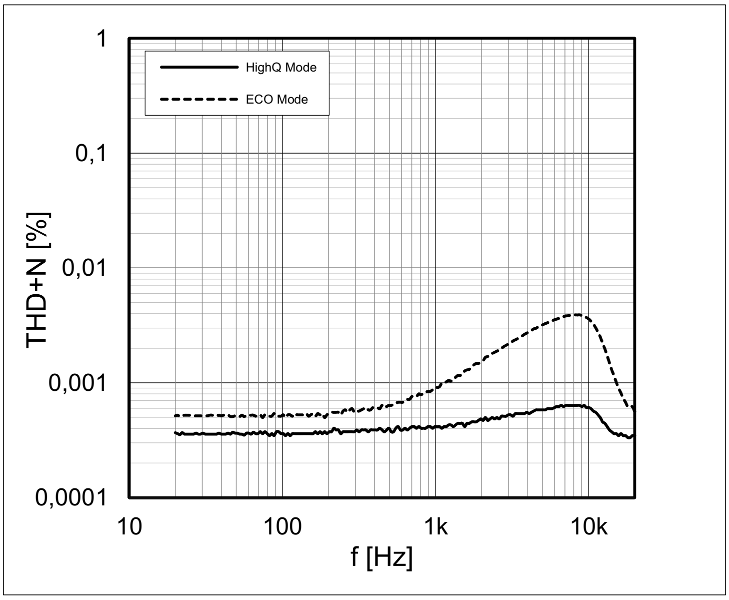
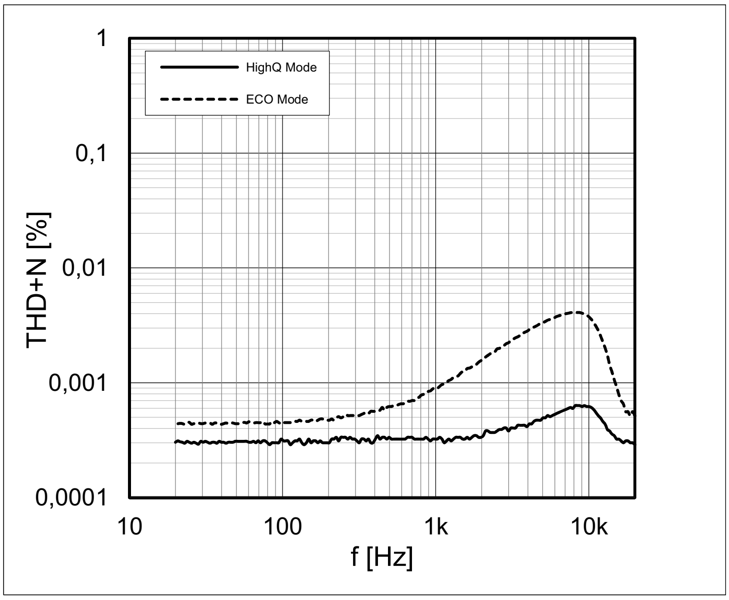



Figure 18:
**Line Input THD+N vs. Freqeuncy $V_{BAT}$ = 1.8V**

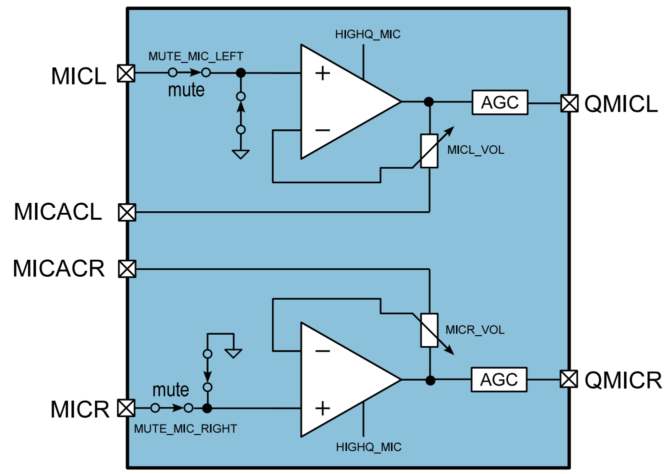
**Line Input THD+N vs. Frequency:** The diagram shows the A-weighted THD+N measurement of the line input amplifier with 0dB gain and $V_{BAT}$=1.8V, $R_1$=10kΩ and $R_2$=10kΩ. The solid line represents the default high quality mode and the dashed line shows the frequency response in ECO mode.



## Microphone Inputs

The AS3415/35 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, in OTP on the ANC chipset. Besides the standard microphone gain register for left and right channel, the chip also features 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 to amplify the speech band for better intelligibility.

**Figure 19:**
**Stereo Microphone Input**



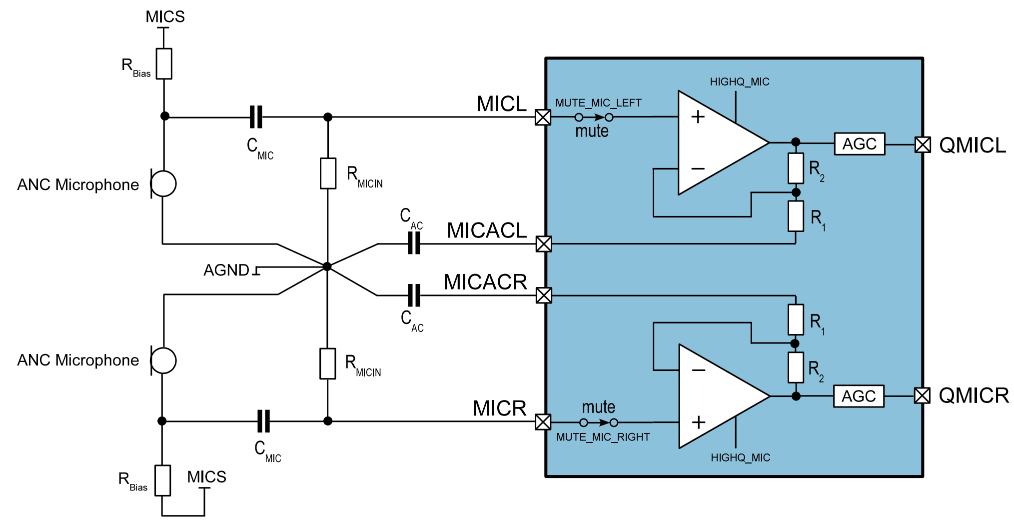

**Stereo Microphone Input:** This diagram shows the internal structure of the stereo microphone preamplifier including the mute switch as well as the automatic gain control (AGC).

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 which can be avoided by disabling the AGC.

### *Input Capacitor Selection*

The microphone preamplifier needs a 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. The typical application circuit is shown in Figure 20 with all necessary components.

**Figure 20:**
**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 21 shows an overview of typical cut-off frequencies with different microphone gain settings.

**Figure 21:**
**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:

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

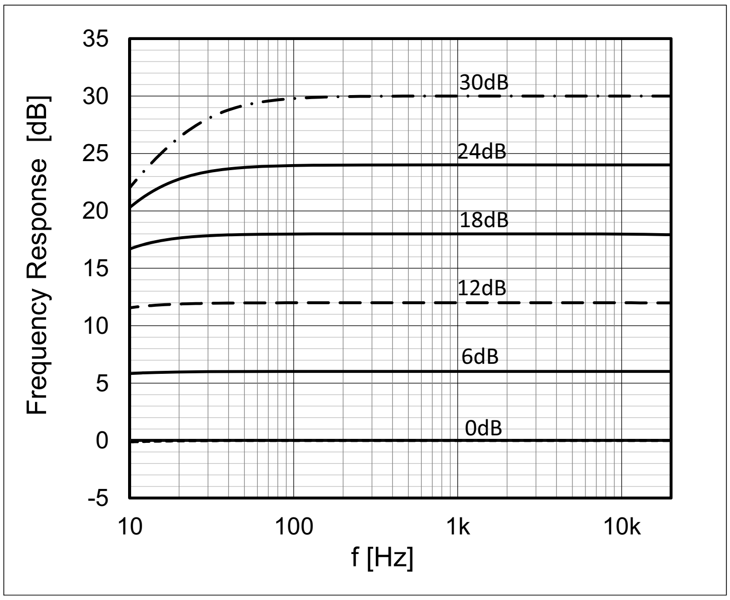
The simplified transfer function does not include the high pass filter defined by $C_{MIC}$ and $R_{MICIN}$. With the recommended values of 2.2µF for $C_{MIC}$ and 22kΩ for $R_{MICIN}$ this filter can be neglected because of the very low cut-off frequency of 1.5Hz. The cut-off frequency for this filter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

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

The simulated frequency response for the microphone preamplifier with the recommended component values is shown in Figure 22.

Figure 22:
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***

$V_{BAT}$=1.5V, $T_A$= 25ºC , $C_{AC}$=10µF, $C_{MIC}$=2.2µF and $R_{MICIN}$=22kΩ unless otherwise specified.

**Figure 23:**
**Microphone Parameter**

| Symbol | Parameter | Conditions | 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 | | 115 | | dB |
| | | 10dB gain, High quality mode, AGC off | | 108 | | dB |
| | | 20dB gain, High quality mode, AGC off | | 98 | | dB |
| | | 0dB gain, ECO mode, AGC off | | 113 | | dB |
| | | 10dB gain, ECO mode, AGC off | | 105 | | dB |
| | | 20dB gain, ECO mode, AGC off | | 96 | | dB |
| $V_{NOISE-A}$ | A-Weighted Output Noise Floor | 0dB gain, 20Hz – 20kHz bandwidth, High quality | | 1.3 | | µV |
| | | 10dB gain, 20Hz – 20kHz bandwidth, High quality | | 4.2 | | µV |
| | | 20dB gain, 20Hz – 20kHz bandwidth, High quality | | 13 | | µV |
| | | 0dB gain, 20Hz – 20kHz bandwidth, ECO mode | | 1.6 | | µV |
| | | 10dB gain, 20Hz – 20kHz bandwidth, ECO mode | | 5.5 | | µV |
| | | 20dB gain, 20Hz – 20kHz bandwidth, ECO mode | | 16.5 | | µV |
| $I_{MIC}$ | Block Current Consumption | No load, normal mode | | 1.4 | | mA |
| | | No load, ECO mode | | 1 | | mA |
| $A_{MIC}$ | Programmable Gain | Discrete logarithmic gain steps | 0 | | +31 | dB |
| | Gain Step Size | | | 0.5 | | dB |
| | Gain Step Precision | | | | 0.2 | dB |
| $\Delta_{AMIC}$ | Gain Ramp Rate | $V_{PEAK}$ related to $V_{BAT}$ or $V_{NEG}$ | | 1 | | ms/step |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{ATTACK}$ | 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 24:**
**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 $C_{MIC}$=2.2µF.