

Designing a Feedback ANC headset using AS3435

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My previous article (Design an ANC headset using AS3415) provided insight on how to develop an active noise cancelling (ANC) headset based on a feed-forward topology.

Feed-forward headsets typically are more easily developed because the design engineer usually does not have to deal with stability issues. A major drawback of this topology, however, is wind noise, since the ANC microphones are directly exposed to the ambient. An alternative that overcomes this drawback is the use of a *feedback* ANC technology. This article describes the development steps necessary to design a Feed-Back ANC headset based on the AS3435 from ams AG.

Equipment Overview

As in the design of a feed-forward headset, a feedback headset also requires certain equipment, the most important of which is an audio measurement system capable of conducting frequency- and phase-response measurements.

Audio equipment suited for these measurements include, for example, Audio Precision, Brüel&Kjaer and Soundcheck. The artificial ear simulator, to emulate the human ear in terms of acoustic behavior from Head Acoustics, Brüel&Kjaer or GRAS, is highly recommended with different types of artificial ears.

The IEC711 couple for in-ear products such as those in feed-forward headsets typically is not required for this application since 99% of the feedback headsets are typically on-ear and over-ear designs. That's due to the mechanical limitations of the microphone placement in in-ear feedback systems. However, there are in-ear feedback designs available on the market today. In addition to artificial head/ear simulators and the audio measurement equipment capable of conducting gain and phase measurements, these in-ear designs contain everything else needed to successfully characterize a feedback ANC headset. To determine the ANC performance of the headset, a two-way

speaker system -- preferably a two-way coaxial speaker -- also is necessary to expose the ANC headset to noise when performing the measurements.

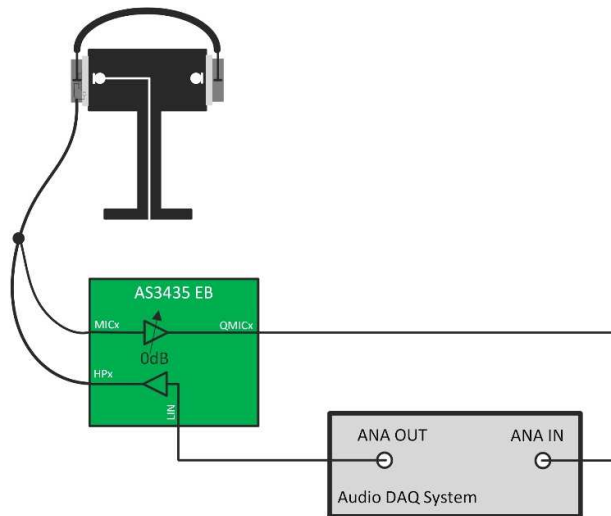
The last element required is an AS3435 evaluation board (EVB) that includes all the necessary connectors and preamplifiers to make the characterization process as smooth as possible.

How to characterize a feed-back headset?

Each ANC headset requires electro-acoustic components such as the speaker and the ANC microphone in addition to mechanical components like the cushion and the speaker cavity. Together, these components define the frequency and phase response of a headset. Different headsets typically have different frequency- and phase responses, so it requires proper characterization to optimize each headset in terms of ANC performance to achieve maximum bandwidth.

In feedback systems, the ANC characterization measurement is rather simple when compared with feed-forward systems. All that is needed is an open loop measurement between the headset speaker and the ANC microphone.

Figure 1: Feed-Back headset characterization



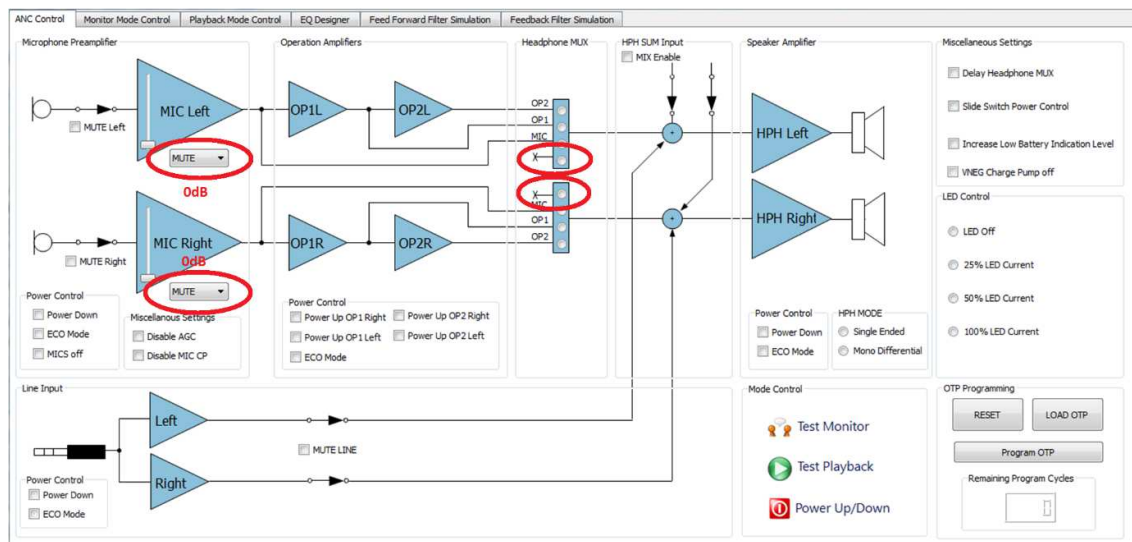
The measurement setup that includes the Audio DAQ system, artificial head and the ANC headset is shown in *Figure 1*. The signal output of the Data Acquisition (DAQ) system is connected to the line input of the AS3435 evaluation board. The speaker of the ANC headset must be connected to the headphone amplifier output of the AS3435 evaluation board. The ANC microphone connects to the microphone input of the EVB. The necessary microphone bias voltage is provided by the EVB, therefore there are no external additional components required for the microphone connection.

The final important and necessary connection goes from the QMICx pin (microphone preamplifier output) of the EVB to the analog audio input of the DAQ system. Before measurement can begin, the AS3435 EVB must be configured correctly. A screen shot of the EVB software is shown in

Figure 2. It is important for the measurements to set the microphone preamplifier gain to 0dB to later match the ams filter calculation templates.

It also is necessary to configure the headphone multiplexer input to the “not connected” position, which helps

Figure 2: Software configuration feed-back characterization



avoid feedback of the microphone signal to the speaker. This is, of course, desired during ANC operation but not for the open loop characterization measurement.

Once the EVB is configured correctly, a sine sweep signal from 20kHz to 20Hz can be generated by the audio DAQ system. The gain and phase response at the microphone preamplifier output is then measured at the input of the DAQ system. This measurement includes all relevant information necessary for a first feedback filter design.

ANC Filter Calculation

The ANC filter calculation for a feedback circuit is fairly simple and can be calculated as follows:

$$A_{Filter}(f) = A_M(f) * (-1) \quad [dB]$$

$A_{Filter}(f)$ Ideal ANC filter gain response

$A_M(f)$... Measured open loop frequency response

The ideal phase response is calculated as follows:

$$\varphi_{Filter}(f) = \varphi_M(f) * (-1) \quad [DEG]$$

$\varphi_{Filter}(f)$ Ideal ANC filter phase response

$\varphi_M(f)$... Measured open loop phase response

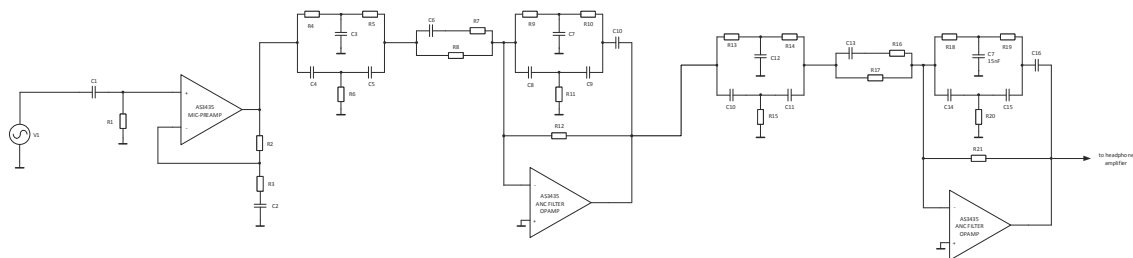
As these figures demonstrate, the desired filter calculation is just an inversion of the gain and phase response. The calculation can be done conveniently in a Microsoft Excel spreadsheet. A template for the calculation is included in the AS3435 evaluation kit.

Filter Development

The next –and perhaps most important --step in the development chain is the ANC filter development. Knowing the characteristic of the ANC headset with the filter calculation mean this information can be used in developing an ANC filter.

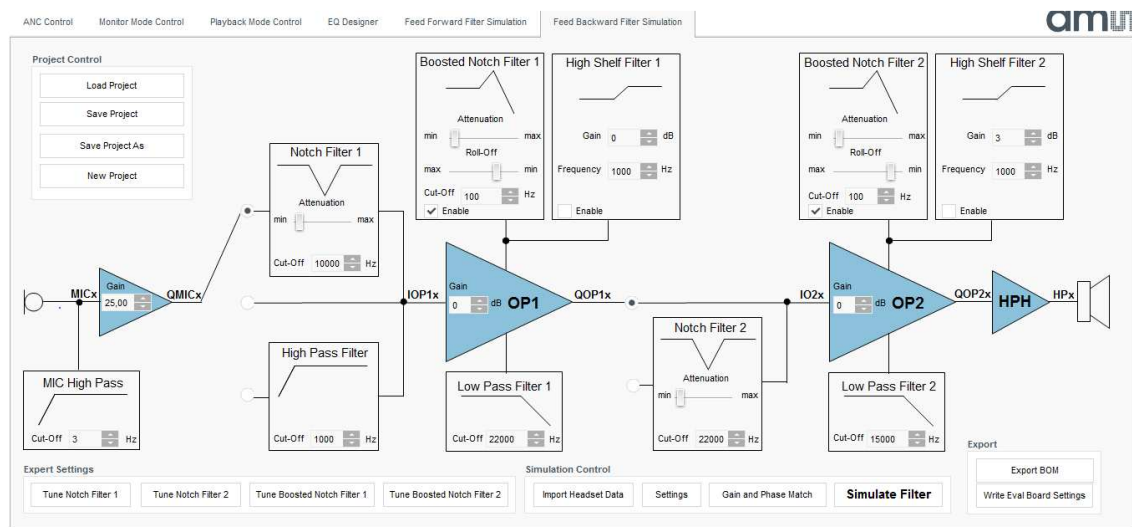
There are many feedback ANC headsets on the market but most of the designs simply invert the feedback signal, resulting in rather low ANC performance. Therefore it is important to know where to put emphasis during the filter development. This involves knowing and understanding the limits of the system. Experienced engineers can use a spice simulation tool to design the ANC filter. This procedure requires already a lot of experience especially on filter topologies and filter calculation. Such an ANC filter example is shown in *Figure 3*.

Figure 3: Spice filter simulation example



The example shows the complete ANC signal chain with the inverting amplifiers and RC networks that define the frequency and gain response of the ANC filter. To make filter design a bit more convenient for engineers, ams has developed a filter simulation tool as part of the AS3435 evaluation suite. A screen shot of the simulation tool is shown in Figure 4.

Figure 4: AS3435 filter simulation tool

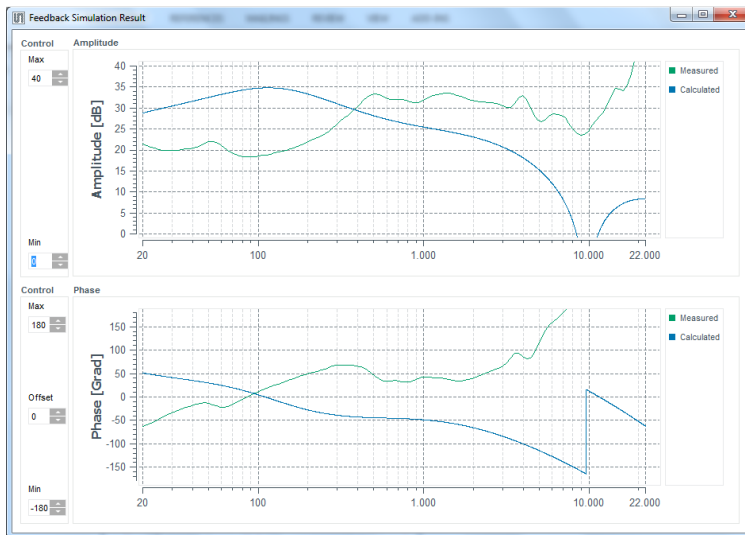


The tool also uses a spice simulator but comes with a graphical user interface (GUI) that makes filter development especially for “untrained” ANC filter design engineers much easier. It allows the designer to define various gains and cut-off frequencies with a pre-defined set of filter topologies. The system is not as flexible as a spice simulator where the user defines the filter topology as well as the resistor and capacitor values, but it is a good starting point. It is expected to help engineers better understand the design hurdles that come with an ANC filter design.

The simulation window in Figure 5 shows the result of the filter simulation settings setup in the simulation window. The green curve represents the ideal feedback filter based on the inverted open loop measurement. The blue curve identifies the results of the spice simulation. The difference in the feedback filter simulation compared with the feed-forward simulation shows it is not enough to match just the frequency and phase response. In the feedback system a higher gain results in better ANC performance, whereas in feed-forward system a too-high gain results in amplification of noise rather than canceling it. In feedback systems, the focus is generally on lower frequency

regions from 20Hz up to 800Hz with the peak in the range of 100Hz depending on the acoustics of the headset. Higher frequencies are also difficult to cancel because it is difficult/impossible to match the phase response. Therefore it is important to attenuate higher frequencies as well as possible to avoid oscillation of the system.

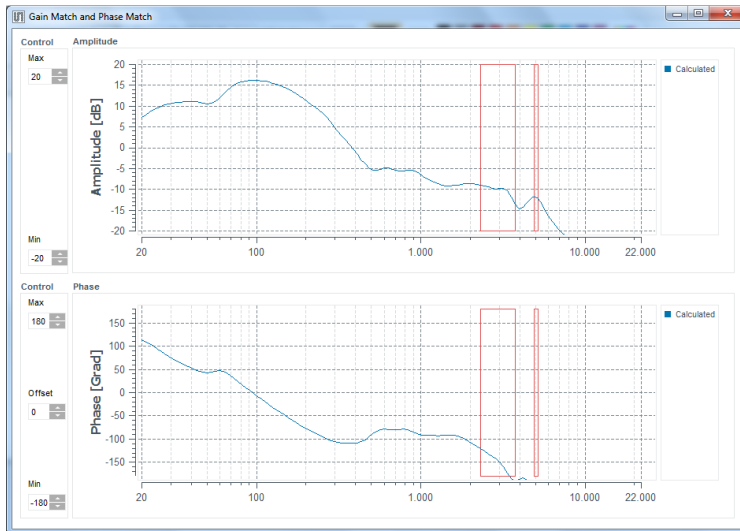
Figure 5: Filter Simulation result



If the gain is too high and the phase mismatch between the simulated filter and the ideal filter is too big (typ. 120°) the headset can run into oscillation. The AS3435 filter simulation software provides a stability check function that automatically displays the gain and phase mismatch between the calculated ANC filter and the simulated ANC filter. The result of the simulation is shown in

Figure 6. In regions where the phase mismatch is bigger than 120° and the gain is higher than -12dB , the tool indicates the critical area with a red box. The probability for oscillation in this frequency region is rather high.

Figure 6: Stability Check Function



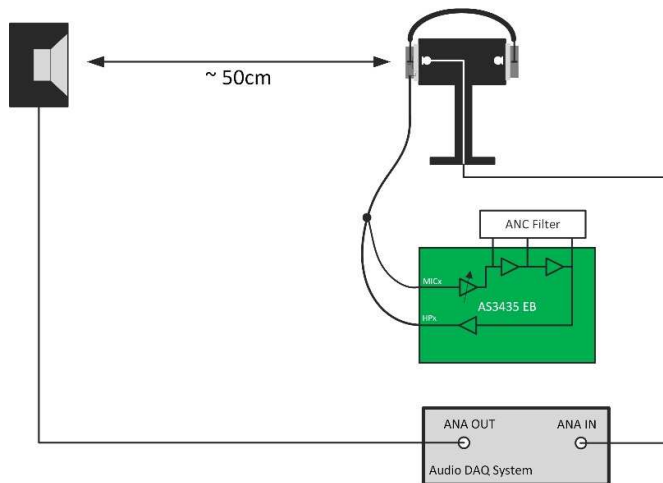
In regions where the phase mismatch is high, the filter design engineer must be sure the gain is as low as possible. Oscillation typically occurs at higher frequencies, however there is also the possibility of oscillation in the 1Hz range.

Filter Verification and ANC test

Once the design engineer has found a filter design that appears stable over the complete frequency range, the ANC filter can be exported. The tool has a Bill of Material (BOM) export function integrated based on standard E24 components. Furthermore, it is directly linked to the evaluation board

of the AS3435. The components listed in the BOM can be soldered to the EVB directly since the reference designators match those of the evaluation board.

Figure 7: ANC performance measurement setup



The ANC performance measurement consists of two measurements and no longer requires phase measurement. The first measurement is a passive attenuation measurement of the headset fitted to the artificial head. The second one is the same measurement, but this time with the AS3535 switch on and configured for the feedback application with the simulated microphone preamplifier gain. The ANC performance can be calculated from the two measurements as follows:

$$A_{ANC}(f) = (A_{passive}(f) - A_{active}(f)) * (-1) \quad [dB]$$

$A_{ANC}(f)$... Active noise reduction level

$A_{active}(f)$... Active attenuation with ANC on

$A_{passive}(f)$... Passive attenuation with ANC off

The calculation can be done with an Excel spreadsheet, creating a plot of the ANC performance-over frequency which is very common in the industry.

Development tools, application notes and templates for the ANC headset development using the AS3435 are available upon request.

For more information, please visit www.ams.com.

For further information

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