



AUDIO TEST OF USB HEADSETS WITH APx

by Joe Begin

About This Technote

In this Technote we discuss testing the audio performance of USB headsets with APx500 series audio analyzers using open-loop test techniques. We also provide an APx project file (named "USB Headset.approx") that implements the tests on typical hardware.

Note: This Technote, and project file, specifically illustrate measuring the frequency response magnitude of a headset's microphone and earphones using the log-swept sine (chirp) method. Although we focus on frequency response measurement, these same open-loop test techniques can be used in APx to measure a variety of audio quality metrics including noise, level, gain, harmonic distortion, intermodulation distortion, interchannel phase, speech quality, etc. In addition, other methods of measuring frequency response are available, including classic swept sine, multitone analysis and transfer function measurements (using noise, music or speech as a stimulus).

Closed Loop vs Open Loop Audio Test

In a closed-loop audio test, an audio analyzer is typically used to generate a clean reference signal, pass it through the device under test (DUT), and immediately analyze the DUT output signal relative to the reference signal. Open-loop testing is required when a signal cannot be immediately passed through the DUT. For example, to test a media player, a reference file must be created and transferred to the player so that the DUT output signal can be acquired and analyzed during playback. An audio recorder requires the opposite paradigm: the DUT output signal is contained in a recorded file that must be transferred to the audio analyzer for subsequent analysis. Closed-loop testing is usually more convenient than open-loop testing.

While it's possible to test a USB headset in closed-loop configuration, doing so can be inconvenient. For example,

headsets are primarily used for communication, such as VOIP calls. In a VOIP phone call, the signal from a DUT's headset microphone is transmitted over a network to the earpiece or earphones of the other party on the call. Similarly, the signal in the DUT's earphones originates at the microphone of the connected caller's phone and is transmitted over a network. To test a headset in this configuration requires a reference VOIP phone implementation and brings the complications and potential signal degradation of the network into play.

Testing a USB headset is much simpler using an open-loop configuration. To test the earphones, reference audio files are played to the DUT from an audio player application on the PC. To test the headset microphone, signals are recorded using an audio recorder application on the PC and later analyzed with the audio analyzer software. The APx software includes several features which simplify such open-loop tests.

USB Headset Audio Paths

There are two primary audio paths of concern in a USB headset:

1. The **Send** path: acoustic signals picked up by the headset microphone are digitized and transmitted to the PC over USB for further processing.
2. The **Receive** path: digital audio signals in the PC are transmitted over USB to the headset, converted first to analog and then to acoustic signals by the earphone transducers.

Since both paths involve acoustic signals, some specialized acoustic accessories are needed.

Headset Microphone Tests

We'll cover the Send path (microphone tests) first, because it is the more complicated of the two paths.

Acoustic Accessories

The following acoustic accessories are required for headset microphone tests:

- A loudspeaker which is reasonably flat over the frequency range of interest for speech (typically 100 Hz to 8 kHz).
- A power amplifier to drive the loudspeaker (not required if a powered speaker is used).
- A measurement microphone, with suitable microphone power supply, to calibrate the loudspeaker output.
- A sound level calibrator to calibrate the measurement mic.

The type of loudspeaker required to test a headset mic depends on the purpose of the tests. To accurately characterize the performance of the headset microphone as worn by a person, a head and torso simulator (HATS) equipped with a mouth simulator (Figure 1) should be used. A HATS is required to accurately simulate the sound field that the microphone is immersed in, because this could have a large impact on its performance.

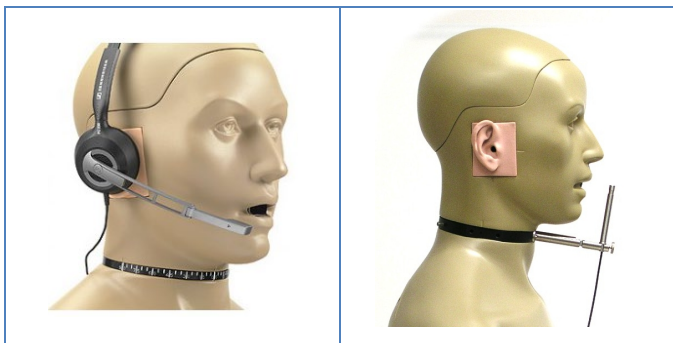


Figure 1. L: A headset mounted on a HATS equipped with a mouth simulator. R: Reference mic at the HATS mouth reference point (MRP).

If the purpose of the tests is simply to measure the sensitivity of the headset mic and to determine its frequency response in general, a simpler test configuration may be used. Figure 2 shows the setup used for measurements illustrated in this technote and the accompanying project file. In this case, the headset was partially disassembled such that the headset mic and attached earphone could be placed in a small acoustic test chamber designed for testing hearing aids. As shown, the DUT microphone is co-located with a reference microphone at the “Test Point” – the center of the blue circle in front of the loudspeaker in the photo.

Headset Microphone Test Overview

At a high level, the following steps are used to test the DUT microphone’s frequency response.

- Calibrate the reference microphone and place it at the Test Point with the DUT microphone.
- Calibrate the acoustic output of the loudspeaker at the Test Point and level it using an EQ curve derived from a closed-loop chirp measurement, such that the frequency response at the Test Point is flat.
- Record a .wav file of the signal from the DUT microphone as it is stimulated by the same chirp signal.
- Analyze the .wav file using the open-loop chirp feature of the APx software.

The procedure is described in detail in the next section. We have elected to use the Acoustic Response measurement in this case, because it offers the option of windowing out acoustic reflections. We have also selected a test level of 94 dB SPL, which is 1 pascal rms. As a result, the RMS Level response also represents the sensitivity of the microphone vs frequency in dB(FS/Pa).



Figure 2. Headset microphone with reference mic in acoustic test box.

The procedure to calibrate the loudspeaker and EQ it flat is described in more detail in Technote 127, Leveled Acoustic Output. As noted in Technote 127, there are two types of EQ in the APx software: Output EQ, which applies to all signals in a Signal Path; and Measurement EQ, which only applies to sine-based measurements (stepped sine, chirp and multitone measurements). Figure 3 shows the results of the two types of EQ for our acoustic test box compared to the response with no EQ. Corresponding measured deviations from flatness for these results are ± 2.83 , ± 0.28 and ± 0.08 dB for no EQ, Output EQ and Measurement EQ, respectively.

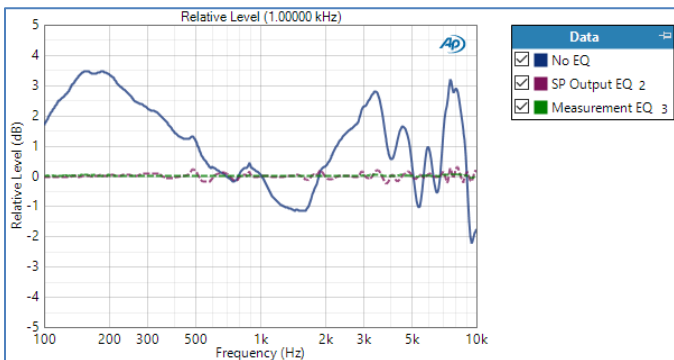


Figure 3. Relative Level at the Test Point in the acoustic test box with No EQ, Signal Path Output EQ and Measurement EQ.

Microphone Detailed Test Procedure

The step-by-step procedure used to test the headset microphone is described here in detail, so that readers can create the tests themselves, if needed. However, for ease of use, the accompanying APx project file automates the process so that very little user intervention is required.

1. Set the analyzer input mode to Acoustic and press the Mic Cal / dB SPL... button to invoke the microphone calibration dialog (Figure 4). Calibrate the reference microphone to measure sound pressure in pascals and sound pressure level (SPL) in dB SPL.

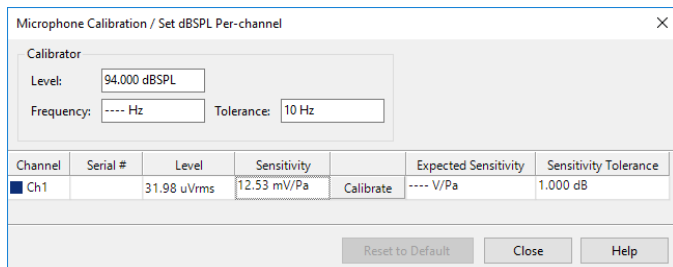


Figure 4. Microphone Calibration dialog.

2. Place the reference microphone and the DUT microphone at the Test Point and close the test chamber.

3. In the next step, the acoustic output level will be calibrated at a reference frequency by regulating the generator to achieve a target SPL. To prepare for this, choose a reference frequency (e.g., 1 kHz) and a target SPL (e.g., 94 dB SPL). Then find suitable Start and Stop Values for the regulation process as follows: in the Verify Connections panel, set the Frequency control to the reference frequency, and initially set the generator Level to a low value that will not overload the speaker. Turn on the generator, and while observing the RMS Level result, gradually adjust the level upward until the SPL at the reference mic exceeds the target SPL. The generator Level at this point may be used as a suitable Stop value. Any generator level that results in an SPL below the target can be used as the Start value.
4. Set the analyzer output mode to Acoustic and use the Set Acoustic Output Level feature (Figure 5) to calibrate the output level at the reference frequency.

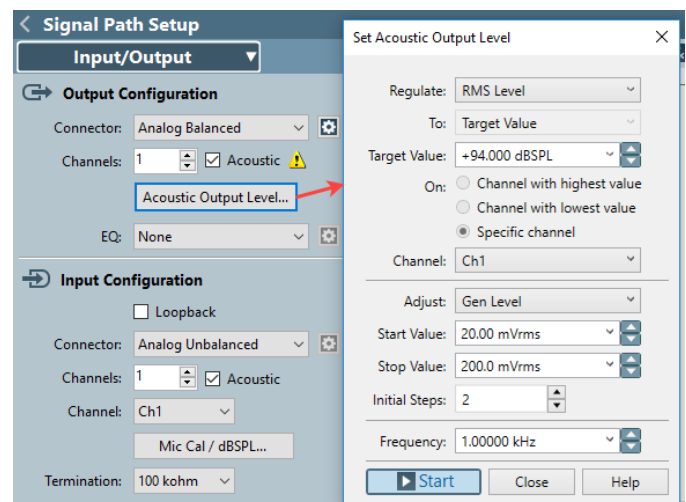


Figure 5. Set Acoustic Output Level dialog.

5. To determine the EQ curve needed to level the loudspeaker response at the Test Point, measure the frequency response and export the Relative Level response to a file. We used the Acoustic Response measurement, which can be used to window out reflections, if required. **Note:** for best results, set the reference frequency of the Relative Level result to the reference frequency chosen for acoustic output regulation in step 3 (e.g., 1 kHz).
6. Create an Output EQ curve in Signal Path Setup by importing and inverting the Relative Level result exported in step 5.
7. Repeat the acoustic output calibration (step 4) with the output EQ curve in place, to ensure output calibration.

8. Measure the frequency response with the EQ applied to verify that the speaker has been calibrated and leveled. For a target SPL of 94 dB, the reference microphone response should be a flat line at 94 dB SPL.
9. Make a copy of the Signal Path using the right-click menu context and change the output connector to File (Digital Units). This creates a Signal Path with calibrated acoustic output with which to stimulate the DUT microphone.
10. In the new Signal Path, configure the Acoustic Response measurement for an open-loop microphone test (e.g., as shown in Figure 6).
11. On the PC, open the Windows Sound configuration dialog from Control Panel. Select the Recording tab, then click on the DUT microphone to select it and set it as the default device (Figure 7).
12. Click the Properties button to open the Microphone Properties dialog. Use the Levels tab to set the Microphone Level (Figure 8), then click on the Advanced tab and note the Default Format for recording – e.g., 16-bit, 44.1 kHz, as shown in Figure 7. Be sure to disable any unwanted special effects such as noise reduction, etc., which could impact the microphone’s frequency response. Close the Microphone Properties and Sound dialog windows.
13. Open a .wav file recording program and prepare it to record a .wav file at the bit-depth and sample rate used by the DUT microphone, as noted in step 11. The file should be 2 to 3 seconds longer than the open-loop chirp signal duration (Pilot Tone + Post-Pilot Silence + Pre-Sweep + Sweep).
14. In the audio recording program, start the recording and immediately click the Generate button in the Acoustic Response measurement in APx. You may need to increase the length of the recording to ensure the entire chirp signal is acquired.
15. Using the File List control in the Analyzer section of the Acoustic Response measurement, select the recorded .wav file for analysis.
16. Click the Analyze button to analyze the recorded .wav file.

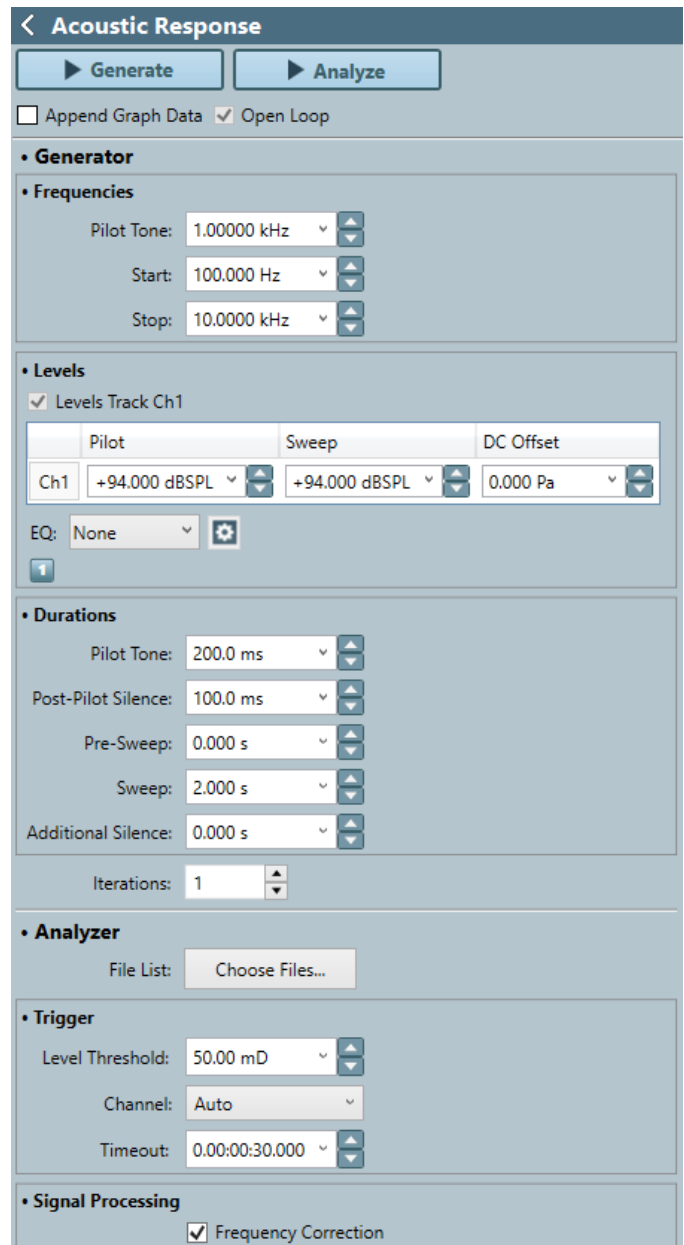


Figure 6. Example configuration of an open-loop Acoustic Response measurement.

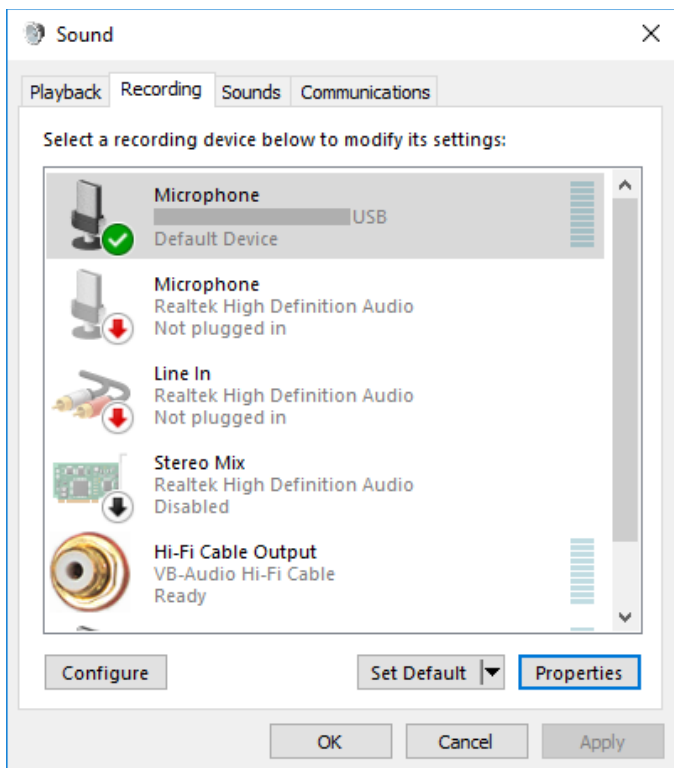


Figure 7. Windows 10 Sound configuration dialog.

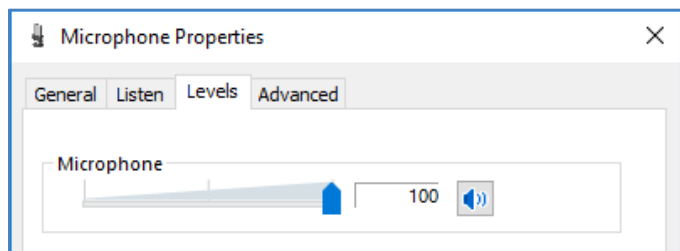


Figure 8. The Levels tab of the Microphone Properties dialog.

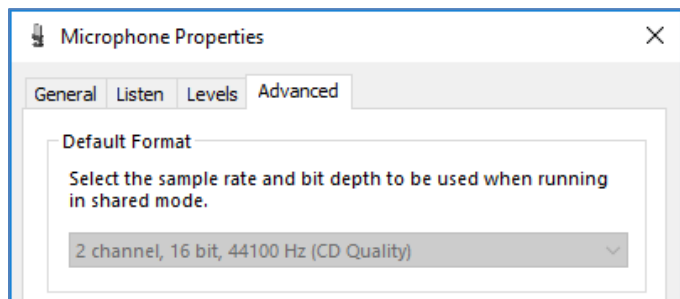


Figure 9. The Advanced tab of the Microphone Properties dialog. (Note: This device does not have any “effects” settings that must be disabled.)

Figure 10 shows the measured RMS Level response. Because the DUT was stimulated at 94 dB SPL, this curve also represents the sensitivity versus frequency in dB(FS/PA). At 1 kHz, the sensitivity of this headset microphone is -11.8 dB(FS/PA).

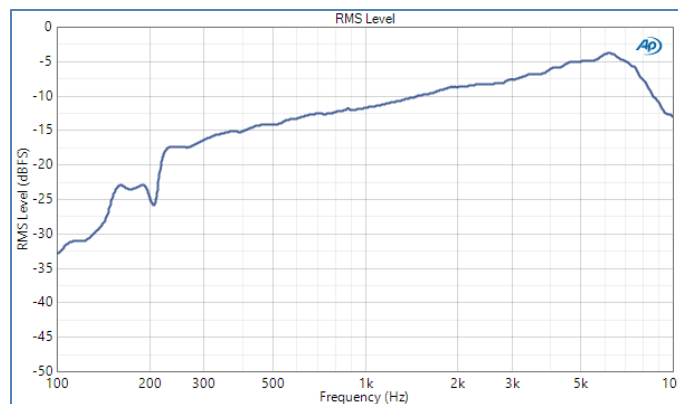


Figure 10. Frequency Response of the DUT mic measured with open loop Acoustic Response at 94 dB SPL (or 1 Pa).

Microphone Test in the Project File

The USB Headset project file has a Sequence named “Headset Mic” that automates the headset microphone test. To automate recording and playback of .wav files, the project file uses a third-party audio editing program for Windows called GoldWave (see the Resources section at the end of this Technote). The main reason for using GoldWave is that it has a command line interface, which means it can be invoked from an APx Run External Program sequence step. This enables .wav files to be recorded to, and played from, the PC automatically from the Sequencer, with no user intervention.

A sequence in APx is simply a collection of checked items in the project file; when a selected sequence is run, all checked signal paths, measurements and sequence steps are executed, and all checked results flow into the sequence report. The Headset Mic sequence uses three signal paths.

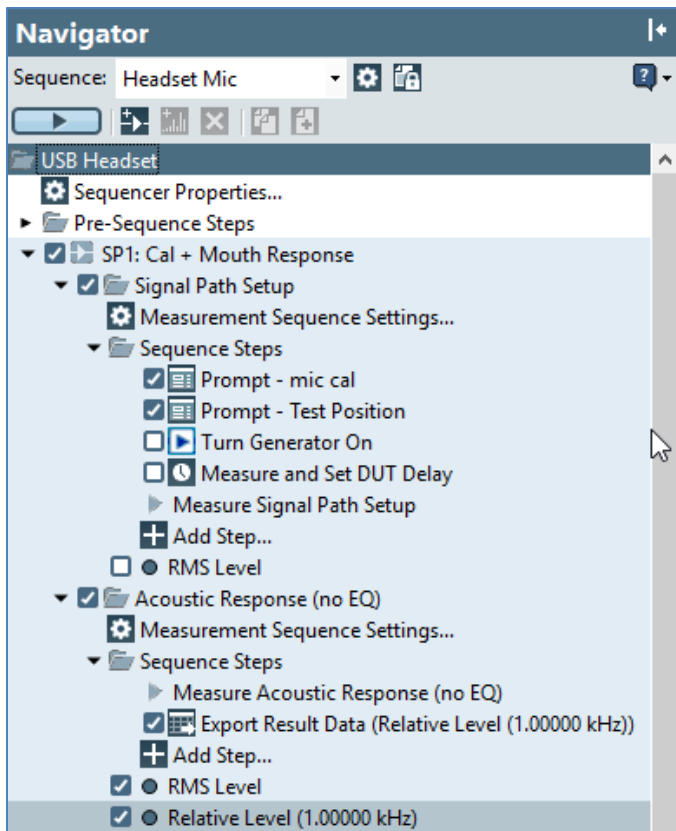


Figure 11. The first signal path in the Headset Mic sequence.

The first signal path, named “SP1: Cal + Mouth Response” (Figure 11), is used to calibrate the reference microphone and measure the frequency response of the loudspeaker at the test point. Automation features include:

- Prompts in Signal Path Setup to calibrate the microphone and place the reference microphone at the test point.
- Auto Set Generator Level is checked in the Measurement Sequence Settings panel of Signal Path Setup. As such, the output regulation to calibrate the loudspeaker will be run after the microphone is calibrated and placed at the Test Point. Note: Measurement Sequence Settings are accessible by double-clicking on the node of the same name in the Sequencer.
- In the measurement named “Acoustic Response (no EQ)”, a sequence step is used to export the Relative Level result from Acoustic Response to a file in the folder containing the project file.

The second signal path, named “SP2: EQ Mouth” is used to EQ the loudspeaker at the Test Point. Automation features in this signal path include:

- The Measurement Sequence Settings node of Signal Path Setup is configured to copy references from the first signal path (Figure 12). This ensures that the microphone calibration and acoustic output sensitivity are set correctly for measurements here.

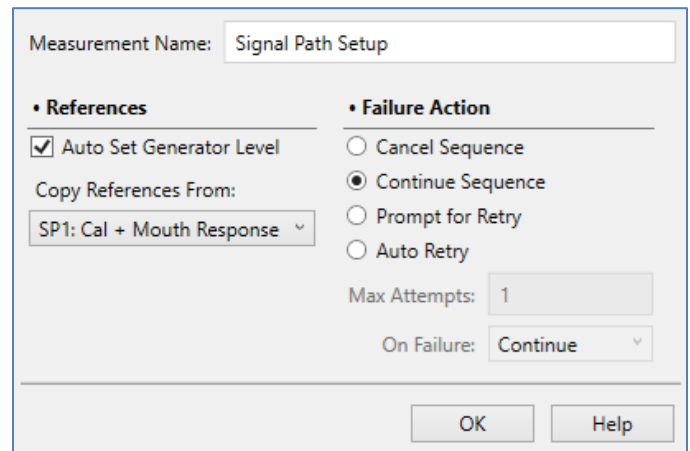


Figure 12. Measurement Sequence Settings for Signal Path Setup in the signal path SP2: EQ Mouth.

- In Signal Path Setup, an Import Output EQ Curve sequence step (Figure 13) is used to import the Relative Level response exported in the first signal path, invert it and apply it as an output EQ, to level the speaker output.

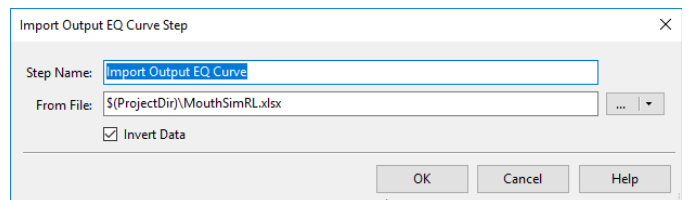


Figure 13. The Import Output EQ Curve sequence step in signal path SP2: EQ Mouth.

- The Auto Set Generator Level checkbox in Measurement Sequence Settings (Figure 12) is also checked, to re-run the output regulation, because sometimes, applying the EQ requires that the output sensitivity be re-measured.

The third signal path, named “SP3: Headset Mic” conducts the DUT mic measurement. This signal path is configured for Acoustic Output, and its Input Connector set to File (Digital Units). It also imports the measured response as an Output EQ Curve and copies References from the second

signal path. Additional automation features in its Acoustic Response measurement include the following sequence steps:

- A Run Program Step to open GoldWave.
- A Delay (for timing).
- A Run Program Step to record a .wav file in GoldWave (Figure 14). Note: GoldWave must be configured to automatically save the file when closed (from the GoldWave menu select Options – Control Properties – Record tab, then check Auto Save). The command line arguments are:
 - -new: creates a new file named “HeadsetRecord.wav” be created, 3 seconds long with a sample rate of 44.1 kHz and 1-channel.
 - -record: records audio to the file.
 - -close: closes GoldWave when done
- The Working Folder is set such that the file is recorded to the folder containing the APx project file.
- The Generate step is checked, followed by a 1 second Delay and then the Analyze step.

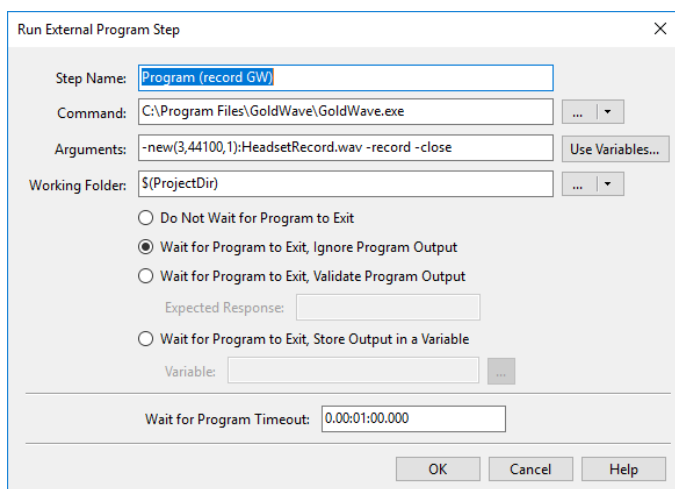


Figure 14. The Run External Program step to record a .wav file in GoldWave.

Note: In the File List control in the Analyzer section of the measurement, the file to analyze is set to the path of the file recorded by GoldWave.

Once GoldWave is installed and configured for Auto Save as noted above, you can run the Headset Mic sequence in APx

and follow the prompts to automatically complete all the steps needed to measure the headset mic’s frequency response.

Headset Earphone Tests

Now we’ll cover the Receive path (earphone tests).

Acoustic Accessories

The main acoustic accessory required for the headset earphone tests is a test fixture with ear simulators. The ear simulator is a small coupler with an integrated pressure response microphone designed to have an acoustic impedance equivalent to that of a typical human ear. In addition to providing a means to measure the sound pressure level from the earphone, it ensures that the earphone is properly loaded during tests.

For insert-type earphones, an ear simulator can be used with an adaptor that simulates the ear canal (Figure 15). For earphones that fit on or over the outer ear (called the pinna), a test fixture with realistic pinnae is required. One option is to use a HATS (Figure 1) equipped with ear simulators. The AECM206 Headphone Test Fixture (Figure 16) is a less expensive alternative to a HATS. This fixture has ear simulators with realistic pinnae, and is equivalent to a HATS insofar as headphone testing is concerned.



Figure 15. AECM304 Occluded Ear Simulator.

Another useful acoustic accessory for headphone testing is a sound level calibrator (Figure 17), used to accurately set the sensitivity of each ear simulator microphone. For this application, a calibrator that operates at 250 Hz is preferred over the more typical 1 kHz, due to the effect of the coupler’s cavity resonance on higher frequencies. And a microphone power supply is required for each ear simulator.



Figure 16. The AECM206 Headphone Test Fixture.



Figure 17. A CAL250 sound level calibrator is used to calibrate the ear simulator microphones.

Headset Earphone Test Procedure

The step-by-step procedure used to test the headset earphones is described here in detail, so that readers can create the tests themselves, if needed. But again, for ease of use, the accompanying APx project file automates the process so that very little user intervention is required.

1. Configure the analyzer for open loop acoustic measurements: Output Connector = None (External); Input Connector = Analog; Acoustic Input mode enabled.
2. Calibrate the left and right ear simulators.
3. Configure an open loop Acoustic Response measurement (e.g., Figure 18).

Acoustic Response (1 position)

▶ Generate ▶ Analyze

Append Graph Data Open Loop

• **Generator Signal**

• **Audio File Settings**

Sample Rate: 44.1000 kHz

Channels: 2

• **Frequencies**

Pilot Tone: 1.00000 kHz

Start: 40.0000 Hz

Stop: 20.0000 kHz

• **Levels**

Levels Track Ch1

	Pilot	Sweep
Ch1	-6.000 dBFS	-6.000 dBFS

EQ: None

1 2

• **Durations**

Pilot Tone: 500.0 ms

Post-Pilot Silence: 100.0 ms

Pre-Sweep: 0.000 s

Sweep: 2.000 s

Additional Silence: 0.000 s

Iterations: 1

• **Analyzer**

• **Trigger**

Level Threshold: 100.0 mPa

Channel: Auto

Timeout: 0.00:00:30.000

• **Signal Processing**

Frequency Correction

Figure 18. Acoustic Response measurement used to test the headset earphones in the USB Headset project file.

Note the following settings in Figure 18:

- The sample rate has been set to 44.1 kHz – the sample rate used by this USB headset for playback to the device.
 - The measurement has been configured for a sweep from 40 Hz to 20 kHz, with a 1 kHz pilot tone.
 - The level of the sweep and pilot tone is –6 dBFS.
 - A pilot tone duration of 500 ms is used. This is partly to allow for time synchronization when the process is automated.
 - A sweep duration of 2 seconds with a post-pilot silence of 100 ms has been set.
 - The Trigger Level Threshold has been set to 100 mPa.
 - Frequency Correction has been enabled. As a result, the APx software will automatically correct for the DUT's sample rate, by recreating the stimulus waveform at the measured sample rate.
4. Create a .wav file of the Acoustic Response stimulus and save it on the PC. Note: Clicking the Generate button will open a dialog for this purpose.
 5. Adjust the Windows Sound properties. Locate the DUT on the Playback tab of the Windows Sound dialog and open its Properties. Check that Playback Levels are set as required, and that enhancements and Spatial Sound are disabled.
 6. Load the stimulus .wav file into an audio playback program.
 7. Start the Acoustic Response analysis.
 8. Play the .wav file from the PC and analyze the DUT response. When the analyzer detects the pilot tone, it will trigger on the signal and complete the analysis.

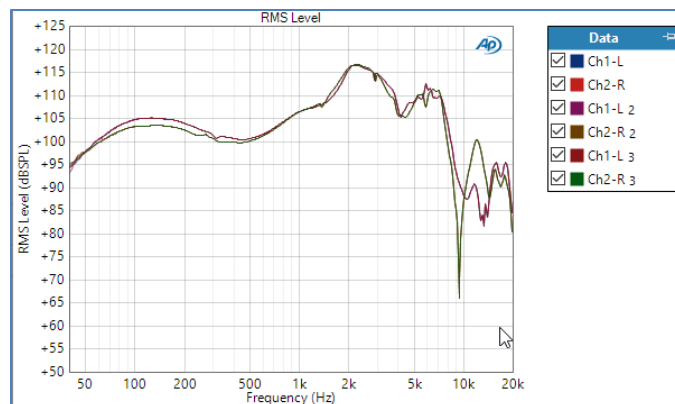


Figure 19. Headset earphone frequency response measured with Acoustic Response (three measurements, no re-positioning).

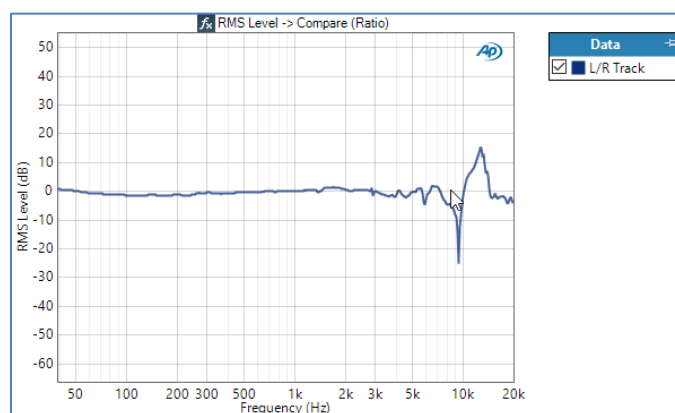


Figure 20. Left/Right Tracking response determined using a Compare derived result between the right and left channels.

When testing headset earphones, the fit of the device on the test fixture can have a significant effect on frequency response. One typical practice is to repeat the measurement several times with the headset being re-positioned on the test fixture each time. Figure 21 shows the results of such a measurement with five repetitions. Derived results are available in APx to conduct a power average of the traces for each channel.

The Acoustic Response measurement used for these tests has several results which are useful when testing earphones. For example, the Level and Distortion result (Figure 22) shows on one graph the frequency response of the fundamental signal, the Total Harmonic Distortion (THD) and the second and third harmonics (H2 and H3). The Distortion Product Ratio result (Figure 23) can be used to display the frequency response of any individual harmonic or of a sum of selected harmonics. And the Rub and Buzz result (Figure 24) displays metrics known as the Rub and Buzz Crest Factor and Peak Ratio, which can be used to detect rub and buzz defects in transducers.

Figure 19 shows a measurement from the USB Headset Project file. In this result, the measurement has been conducted three times without adjusting the headset, to test for repeatability. Figure 20 shows a Compare derived result which compares the right and left traces of one of the measurements in Figure 19.

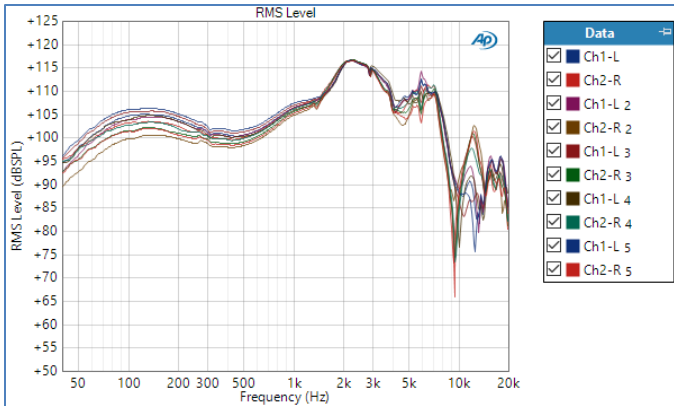


Figure 21. Left and right earphone response measured five times with re-positioning.

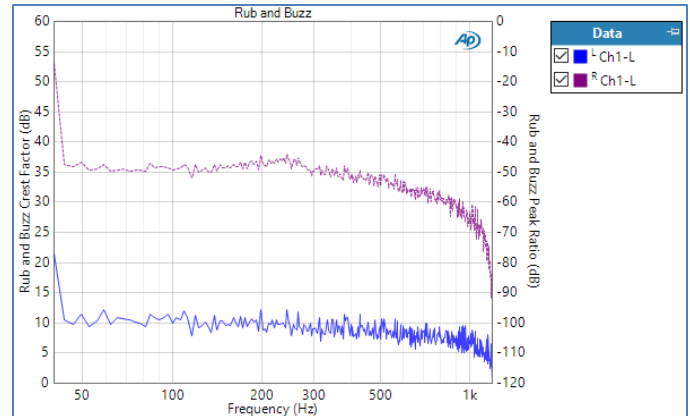


Figure 24. The Acoustic Response Rub and Buzz result showing the Rub and Buzz Crest Factor and Peak Ratio versus frequency.

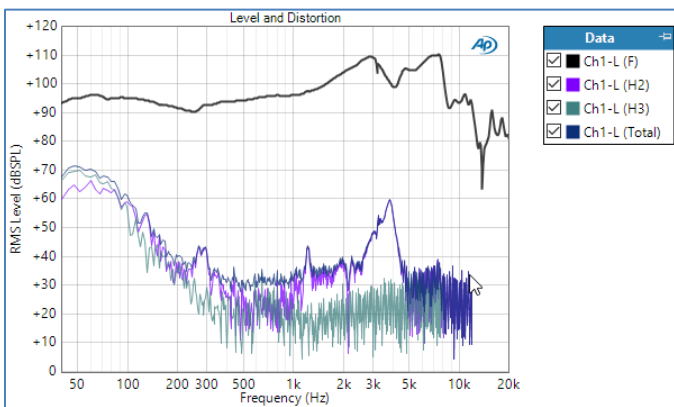


Figure 22. The Acoustic Response Level and Distortion result, showing on one plot the fundamental signal, harmonics H2 and H3 and the Total Harmonic Distortion.

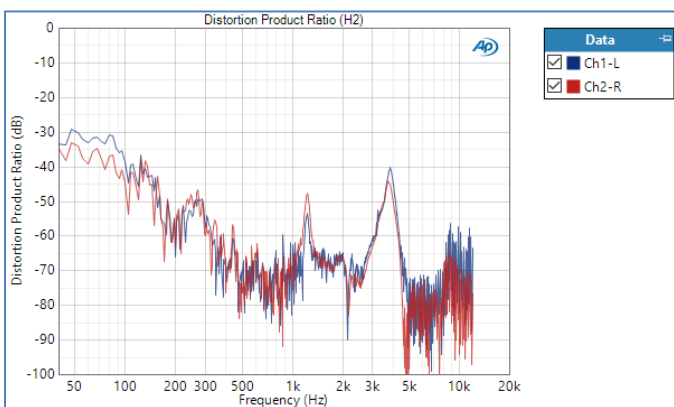


Figure 23. The Distortion Product Ratio result, showing the second harmonic versus frequency for both earphones.

Earphone Tests in the Project File

The USB Headset project file has a Sequence named “Headset Earphones” that runs the signal path named “SP4: Headset Earphones”. This automates the headset earphone frequency response test. Here again, APx Run External Program sequence steps that invoke GoldWave are used to automate the process – in this case by playing a .wav file.



Calibrate the Right Ear Simulator

Place the calibrator on the right ear canal extension of the AECM206 and click OK when the adaptor is properly seated and the level has stabilized

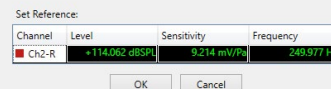


Figure 25. Ear simulator calibration prompt.

Automation features of the Headset Earphones sequence include:

- Prompt sequence steps in Signal Path Setup to calibrate the left and right ear simulators (Figure 25).
- Prompt sequence steps to position and re-position the headset on the test fixture.
- A sequence step in the Acoustic Response Measurement to save the generator waveform to a .wav file (Figure 26). As shown, this step uses the APx system variable ProjectDir to save the .wav file to the folder containing the project file.
- Sequence steps to play the generator waveform from the PC using GoldWave (Figure 27). The last -play step in each measurement has a -close argument, which closes GoldWave.
- Sequence steps to make Appended measurements.

Sequence to automatically conduct the earphone measurement in the project file.

This concludes our discussion of USB headset audio testing. Although this Technote has focused on frequency response measurements, these same open-loop measurement techniques can be used for many other audio quality measurements of USB audio devices.

Resources

The accompanying project file uses GoldWave digital audio editing software, available from goldwave.com. This inexpensive program has many useful features, including a command line interface, which enables playback and recording of .wav files from an APx Run External Program sequence step.

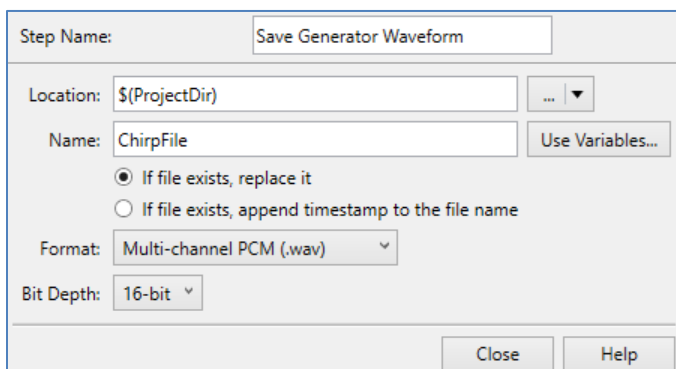


Figure 26. The sequence step to save the Acoustic Response generator waveform to a .wav file.

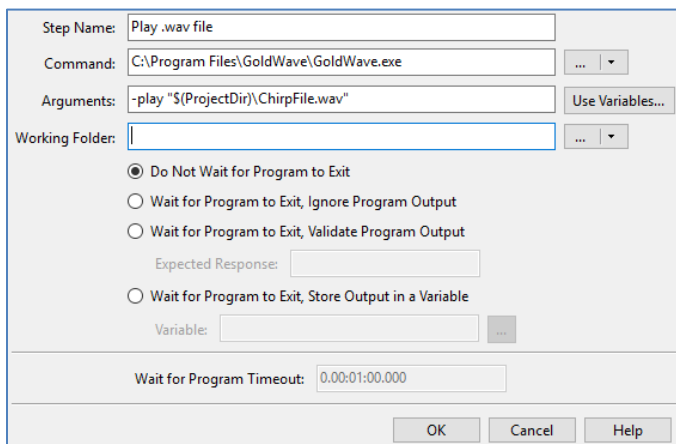


Figure 27. A sequence step to play the .wav file containing the Acoustic Response stimulus using GoldWave.

Once GoldWave is properly installed, select the Headset Earphones sequence in the APx Navigator and run the



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