2700 Series
ATS-2
APx500 Series

PC Audio Testing

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About This Technote

This Technote discusses the techniques necessary to perform the "Basic Six" audio measurements on consumer-level PC audio devices. This category includes sound systems integrated into notebooks, netbooks, tablets, and PC motherboards, as well as expansion cards and some external devices. It doesn't include USB-connected headsets, nor pro-audio devices with balanced input and output connections.

Instructions are also given for using the APx PC Audio project and associated .wav playbackfiles that accompany this Technote. The project file download is at http://ap.com/display/file/500.

Introduction

In many ways, testing consumer-level PC audio devices is just like testing other digital recorders. However, there are typically a number of special challenges that make it a unique category:

- Level control is normally done only in the digital domain.
- The control points in the signal path, the interactions between controls, and the optimum operating levels vary widely and can be time-consuming to establish.
- The settings that are optimized for repeatable and successful testing may not correlate with the settings users typically select when using a device.
- Input monitoring through a device's outputs may be digitally altered, may have latency, or in some cases may not even be possible.
- Device driver version changes may affect performance.
- Windows operating system versions may affect performance.
- The environment inside the PC, including hard disk activity, power supply fluctuations, EMI, and grounding, can affect performance.

We'll help you to work around some of these challenges to make the basic six audio measurements—level, frequency response, phase, THD+N, crosstalk, and dynamic range. These measurements are often enough to characterize the performance of an audio device. More about the basic six can be found in Technote 104: Introduction to the Six Basic Audio Measurements (http://ap.com/display/file/8).

This Technote does not delve into more comprehensive tests, like maximum and minimum input levels and anti-aliasing filter response, which can detect serious problems that might arise when using a device and when interfacing it to other audio devices. It also does not test for compliance with Microsoft's WHQL (Windows Hardware Quality Labs) requirements to receive the "Certified for Windows" logo.

Software

You will need digital audio recording software loaded on the PC with the DUT (Device Under Test) to enable

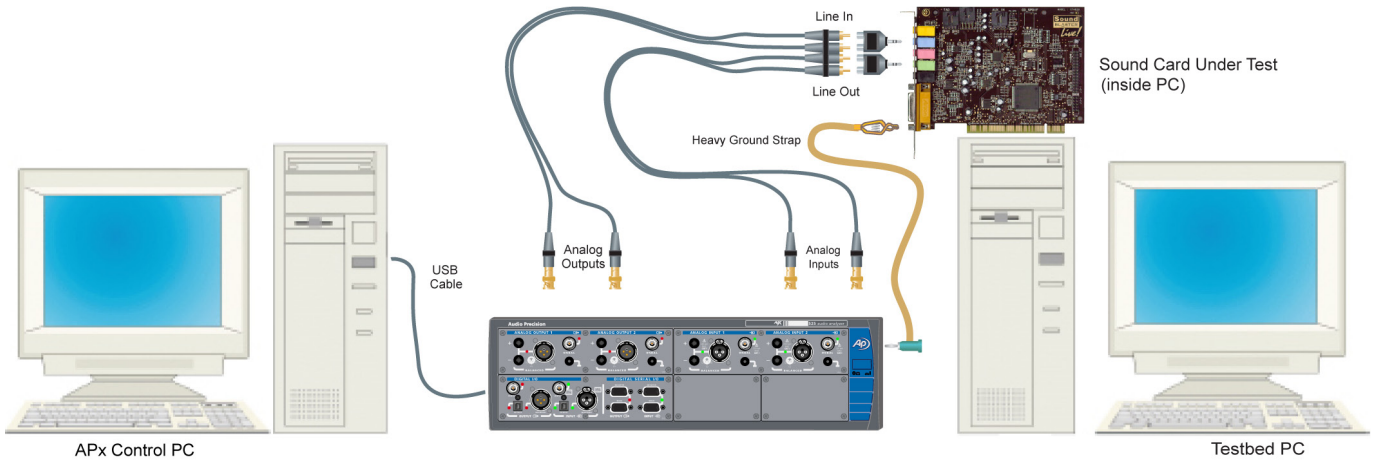

Figure 1. PC Audio connections

recording, playback, and viewing of the waveforms. The audio recording software built into Windows isn't adequate. We use and recommend GoldWave, which is inexpensive and does the job. You can download the fully functional trial version from the GoldWave website (www.goldwave.com). Other choices include the free program Audacity (http://audacity.sourceforge.net), and a multitude of professional Digital Audio Workstation packages.

Make sure that all signal processing options in the software and device drivers, including EQ, echo, and simulated surround sound, are turned off before testing.

Connections

Although it is possible to use the same PC to host the device under test and the APx500 software, we recommend using two PCs to reduce the processor load, and to maintain the independence of the test instrument environment from the software configuration and sound drivers on the testbed.

Using good quality cables, connect the APx unbalanced analog outputs (left and right) to the DUT's analog inputs. If the DUT has both microphone and line level inputs, then start with the line input and retest afterwards using the microphone input. The APx generator output should be set to 600 Ω impedance and AC coupling when feeding a consumer-type microphone input, and low impedance with either AC or DC coupling otherwise.

Connect the DUT's analog outputs to the APx unbalanced analog inputs (left & right). If the DUT has both line and headphone outputs, test first with the line output, and then retest later with the headphone output driving a 32 Ω load. Using cable with two conductors plus shield will result in lower noise than using a single conductor plus shield. The shields should be connected only at one end.

A heavy ground strap (large gauge multi-strand copper wire) between the DUT's chassis and one of the ground lugs on the APx may reduce noise by minimizing ground potential between them. On the other hand, sometimes it can make things worse by adding an additional ground path. Therefore, it's necessary to try both ways while measuring the noise, to determine the best method before performing any additional testing. Plugging the PC and the computer into the same AC outlet may also reduce noise. Never remove or lift the AC power plug's safety ground on the PC or the audio analyzer—it's there to prevent you from getting a shock should an electrical fault occur.

Setting the DUT Levels

Accurately setting PC audio levels can be a challenge. Sometimes multiple sliders control the same gain stage, and adjustments are often in coarse steps without any indication of the optimal setting range.

If possible, we recommend setting the input and output level controls to their maximum levels. This takes their setting variables out of the equation, reducing the chance of input overload and resulting in more repeatable measurement results. The analyzer output level is then adjusted to obtain a recording level as close to full scale as possible. Alternative level-setting methods include setting the controls to a nominal position (like 70%), and using a fixed generator level (such as +10 dBV) while setting the controls for a proper recording level.

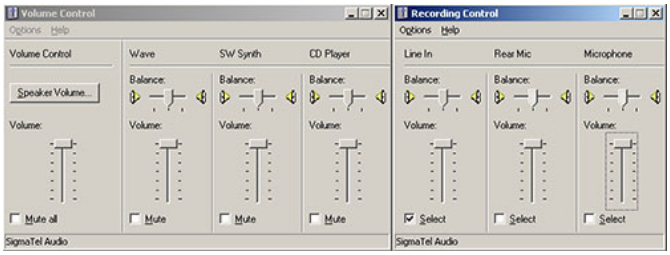

Figure 2. Windows mixer.

Setting levels using the recording level meters in the recording software does not guarantee distortion-free recordings. It is necessary to make a test recording to check for clipping. Note that some PC audio devices may clip before reaching full-scale recording—this should be noted, as it indicates a defect in the DUT.

Make sure that only one input is selected, and that any unused outputs are muted, to eliminate extra noise.

Launch your recording software, and open a new file for recording in uncompressed wave (.wav) format at a 48 kHz sample rate with 16-bit resolution. You may also wish to choose other settings, or make multiple test passes using different sample rates and bit depths for each one. The playback files included with the APx project that accompanies this Technote are recorded at 48 kHz/16-bit. You can use the APx Waveform Generator Utility (http://ap.com/display/file/273) to generate playback files at other sample rates and bit depths.

Open the APx project file "PC_Check.approjx", provided in the Technote 108 download (http://ap.com/display/file/500), and select Signal Path Setup in the #1_Record_to_File signal path. Set the DUT's input and output levels to maximum. Turn on the APx Generator, and then start recording. While the signal is being recorded, you will be able to monitor the signal level through the DUT's outputs.

Adjust the APx Generator level, first using the increment/decrement buttons, and then by typing a level into the dropdown box to adjust by tenth decibel increments. When the APx generator units are set to Vrms, the increment/decrement controls change the generator value by about 2 dB. If you switch the units to dBV, the increments are only 1 dB.

Getting the level as high as possible without any clipping will produce the best possible signal to noise ratio. Common practice is to set the level slightly below full scale, at -0.3 or -1.0 dBFS, because of the difficulty of precisely setting 0.0 dBFS, and because some converters show an increase in distortion and go into compression just before clipping. It may take a few iterations of this process to find the optimum level..

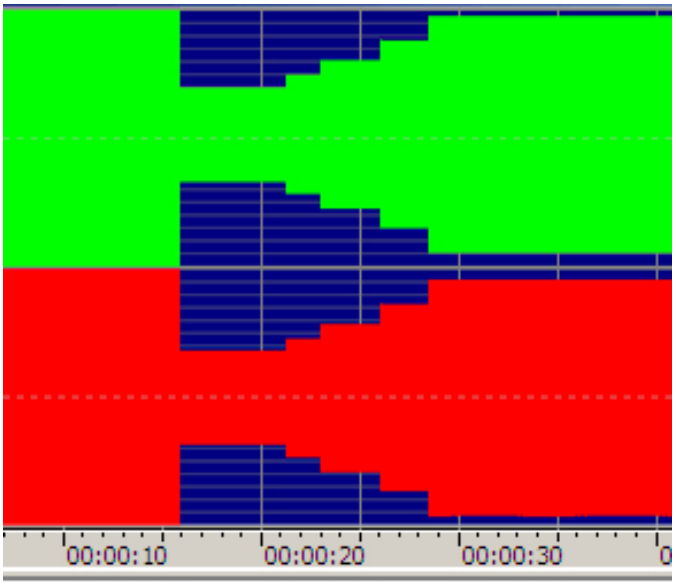

Figure 3. Adjusting levels to find the clipping point.

Figure 3 shows the graphic view of a file recorded using the procedure just explained. You can see where the level adjustments were made over time, and that they end just before 0 dB full scale. Zoom in on the recorded waveform (using zoom tool in your recording software) to look for clipping.

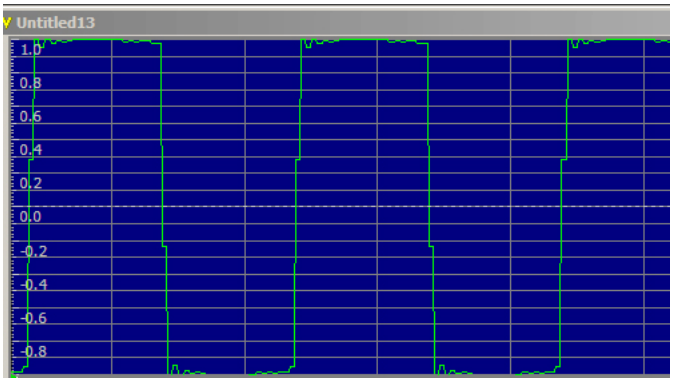

Figure 4. Clipped signal.

Figure 4 shows a clipped signal, and Figure 5 shows a clean (unclipped) signal.

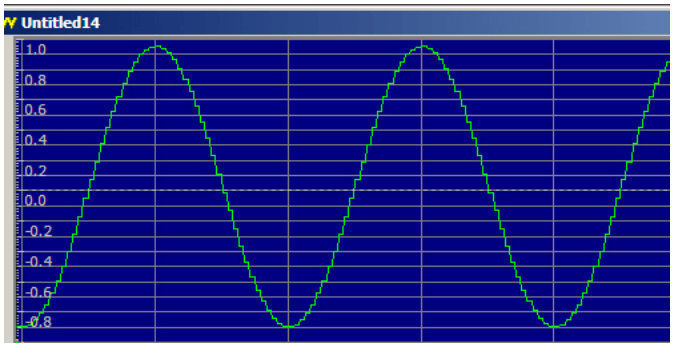

Figure 5. Non-clipped signal.

When you are satisfied that your level is optimized, make note of the generator level, as well as any changes you made to the DUT level controls.

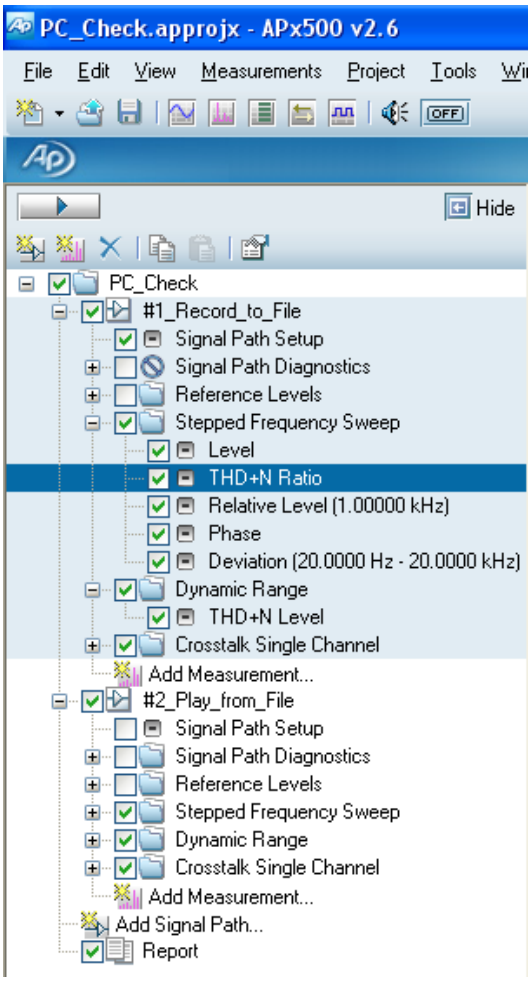

Figure 6. APx PC Audio project.

Signal Paths

There are four basic signal paths that can be checked on a PC audio device:

1. Record to file.
2. Play from file.
3. Record and play a file.
4. Input to Output (no recording).

In all cases we will be using the analog inputs and outputs, which will enable us to test the A/D and D/A converters. If the PC audio device has S/PDIF digital I/O, you can test this as well, but we won't be covering that here.

Record to File

These tests, located in the #1_Record_to_File signal path, measure the recording performance of the PC audio device. We'll first make a recording through the DUT's analog inputs, and then we'll use the APx500 measurement software to directly analyze the recorded wave file. The advantage of directly analyzing the wave file is that there is no chance of the signal getting altered, which can happen when playing back through a digital output or when re-routing the signal at the driver level. Follow these steps to perform the tests:

1. Make the connections and set the levels, as described in the previous sections.
2. Select the Stepped Frequency Sweep measurement and set the generator level to the previously established value.
3. In the audio recording software, open a new .wav file for recording. To match the project defaults and supplied files, choose 48 kHz sample rate and 16 bit resolution.
4. 4. Start the recording, and then click the Start button in APx500. When the sweep is completed, stop the recording and save the file.
5. Click the File List button and then Add Files to locate and select the .wav file you just recorded. If the DUT is on a different PC than the APx analyzer,

it will be necessary to have a network connection, or else to copy the file over to the PC running APx500.

6. Click the Analyze button to make the measurements and display the results.

7. Follow the same procedure to make the Dynamic Range and Crosstalk measurements. If the PC audio device only has a monaural input, then record-to-file crosstalk measurements can not be performed.

Play from File

These measurements use precisely generated files to test playback ability. Copy the PC_Audio_Waveforms folder supplied with this Technote to the PC hosting the DUT, so that the files will be available for playback.

Before making measurements, it is necessary to set our reference levels. Select the Reference Levels measurement in the #2_Play_From_File signal path. In the audio recording software, open and play the file "Reference Level_0dB 48.16.wav" or "Reference Level_0dB 48.24.wav".

Start with the output level slider in the Windows mixer at full. Check that the playback signal is not distorted due to excessive playback volume. If necessary, reduce the level with the slider until clipping ceases. If it is not possible to reduce the level enough to eliminate excessive distortion, then the DUT is defective and not capable of playing back a full level recording. In this case, try a reference level recorded at -1.0 dBFS and see if this cures the problem.

Once playback levels are adjusted, continue playing the reference signal and click the Set dBr button in the APx500 software to open the reference setting window. Click the SetA and SetB buttons to capture the levels for channels 1 and 2 respectively and close the window. This procedure sets 0 dBrA and 0 dBrB to equal full scale recording level.

Use the following instructions to do the file playback tests using the supplied project file. All playback tests are located in the #2_Play_from_File signal path.

1. Select the Stepped Frequency Sweep measurement in the project, and load "Freq_sweep_31_0dB_48.16.wav" into the PC audio software. Click Start in APx, and then hit Play in the audio software to start the file playback. Once the measurement completes, the results will be visible in the Results Selector (Filmstrip) under the graph.

2. Select the Dynamic Range measurement in APx500. Load the file "Reference_Level_-60dB_48.16.wav" in the audio software and start playing it. Then click Start in APx500 to take the measurement.

3. Select the Crosstalk measurement and load the file Crosstalk_left_only_48.16.wav in the audio software. Start the file playing, and click Start to make the measurement.

4. Select the Crosstalk measurement and load the file Crosstalk_right_only_48.16.wav in the audio software. Start the file playing, and click Start to make the measurement.

Record and Play a File.

This signal path is really the first and the second paths combined. To do these tests, take the files that were recorded in the section "Record a File," and use them in place of the supplied pre-recorded files for the "Play a File" tests. The results will be a combination of both the recording and playback deficiencies of the system.

Note that you can derive the record/playback results for frequency response and random noise by simply adding the results of the "Record to File" and "Play from File" tests together. However, because distortion products, crosstalk, and non-random noise may add or subtract from each other in ways that depend on their spectral distribution and phase, the results of these record/playback tests may differ from those obtained by simple addition.

Analog Inputs to Analog Outputs

The internal signal path of PC audio devices varies—in many devices the audio goes through A/D and D/A conversion before reaching the outputs. This path is useful for monitoring the input signal, and for determining the points at which the analog inputs and outputs clip. The same measurements that are made on the other signal paths can be done here as well. These tests are not, however, included with the supplied project file.

Reports

After running some or all of the tests, click on Report at the bottom of the APx500 project navigator to display the customized report. You may modify the custom report to your own requirements if you have Microsoft Word 2007 or 2010 installed. To do so, right-click on Report and select Edit Properties.

As long as the APx project is not closed, the report will contain the results of all the measurements that have been performed. To save the results of the measurements, open and save the report as a PDF file, or export the measurement data.

Further Testing

Comprehensive PC audio testing often includes making measurements at all the common sample and bit rates supported by a device. The APx Waveform Generator can be used to create reference playback files at additional sample rates and bit depths. Other useful tests that aren't part of this project included maximum and minimum input levels, anti-alias filter response, distortion vs. level, and linearity.

Automation can speed up the testing process. The GoldWave software described earlier can be controlled via the APx500 Sequence command line prompt. For details on running external programs from within APx, download the APx Run External Program Project (http://ap.com/display/file/369). More elaborate automation can be done using the APx API or LabVIEW drivers.

Related Downloads:

Technote 108: PC Audio Testing
http://ap.com/display/file/500

APx Waveform Generator Utility
http://ap.com/display/file/273

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