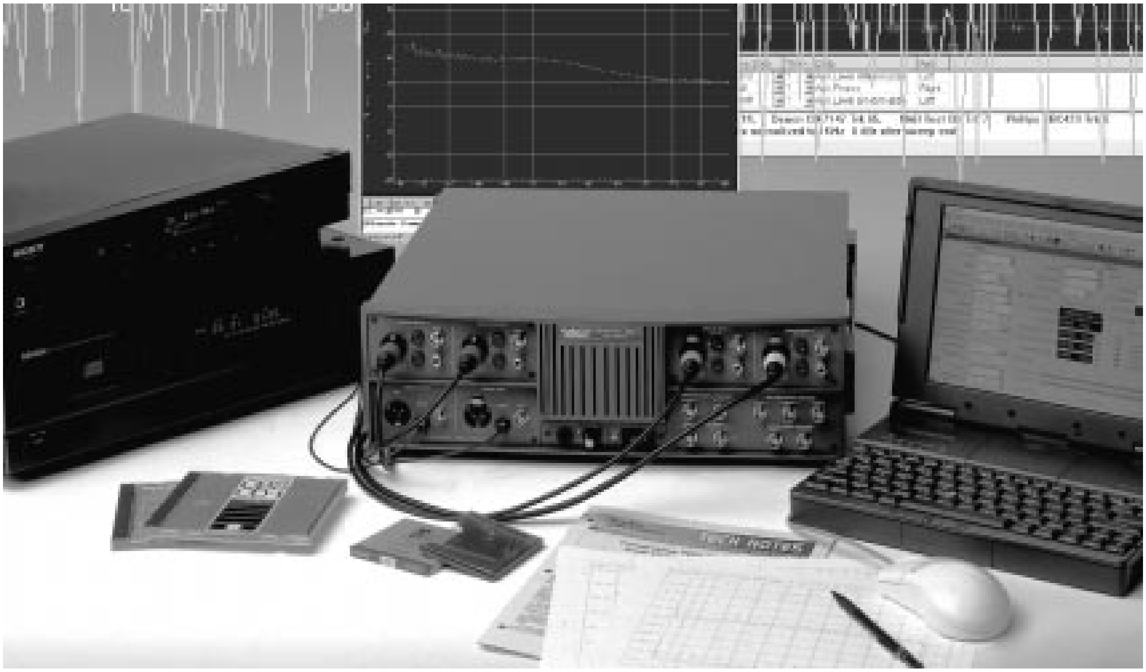
Compact Disc Player Tests

Audio Precision Application Note #1

Audio precision

Compact Disc Player Tests using Audio Precision System One or System Two



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Preface

Rapid and Accurate testing of CD players using APWIN

This expansion and revision of the original Audio Precision Compact Disc Player Testing Application Note (AN-1) includes many new test techniques as well as refinements and improvements on the original tests. Test and procedure files supplied with this application note provide new convenience and ease-of-use for testing CD players using these instruments. Files created for both System One and System Two using APWIN are available. All audio tests are described with an explanation of the critical settings for each test and discussion of interpreting the test results.

New test procedures using the powerful APWIN Basic procedure language streamline and automate test selection, setup and operation. For a fast start select File, Open Procedure CDTEST and Procedure, Run from the toolbar at the top of APWIN. The common audio tests: frequency response, distortion and noise (THD+N), signal-to-noise ratio, crosstalk and interchannel phase - are all available. Also included are specialized and difficult tests such as distortion at low amplitudes, decoder linearity measured to below the Least Significant Bit, quantization noise, dynamic range, SMPTE and twin-tone (CCIF) intermodulation distortion and Wow and Flutter as an impulse noise test. All are explained in detail.

Tests using the DSP and Dual Domain versions of the System One and System Two expand the detail and accuracy available for evaluating modern CD players. These include FFT frequency and amplitude analysis tests for noise components to 80 kHz, SMPTE and twin-tone intermod products to below -110 dBFS and residual noise components after distortion measurement to below -125 dBFS. A waveform display that works like a triggered oscilloscope for viewing special waveforms is also included.

This Application Note uses any of four commercially-available test CDs as the signal test source. A selection dialog in the CDTEST procedure allows the user to choose which test CD is being used. The procedure lists the tests available for your selection from the tracks on the selected CD. Onscreen prompts advise the operator what CD tracks to play. These test procedures make establishing level references, test setups and connection checks nearly foolproof. Accomplishing difficult tests with accuracy can be done easily. Tests can be repeated, printed and saved without interrupting the test procedure. The Visual Basic compatible procedure code contains many examples of code use that can be copied and used in your own procedures. The procedures are fully annotated so that the user can understand the actual operation of the program and find useful code routines for use elsewhere.

CONTENTS

Introduction

Compact Disc player performance is fast and easy to measure with APWIN. In addition to common tests such as frequency response, harmonic and intermodulation distortion, and signal-to-noise ratio, Compact Disc player testing also brings up the opportunity to measure quantization distortion and noise (mechanisms not present in analog audio devices) plus ultra-wide-range linearity. Tests for both System One (.at1 file extension) and System Two (.at2 file extension) are included in the distribution files. Tests that operate very similarly to the tests in the S1 DOS version of this Application Note retain the same root names with different extensions depending on whether they are for System One or System Two. In the distribution files these test titles are in all-capitals. Newer tests written to use the abilities of APWIN have mixed capitalization. Appendix 3 has a useful cross-reference for test function, test names and CD tracks appropriate for specific tests.

In a few cases APWIN Basic procedures are used to automate a test process. Also in one case the additional abilities of a procedure is used to accomplish a test that cannot yield useable results with a test alone (“Fade-to-Noise” low-level linearity). A group of procedures that access and run tests useable with one of the four test CDs listed in Appendix 3 is also provided in the distribution files. An easy “Quick Start” for all of the supplied tests is to Open Procedure CDTEST.apb and run the procedure. The procedures are detailed in Appendix 2.

Configuring APWIN

Some settings in APWIN Configuration should be checked in the Utilities, Configuration drop-down menu. To automatically view the saved data and graphs in the distribution files check Display Data on Test Open. In some of the supplied tests bar graphs are used to display readings during a sweep. For these to be active check the “Keep all readings active during sweeps” box. Note that this can slow down data acquisition in some test situations. If you are using FFTs and wish to take a closer look at your results check—“Reprocess FFT Data on Zoom”. Also, if you are using a Log file to save test results provide the path and file name in the section on Log files and be sure that logging is on. In System One check that the Utility Filters configuration has been done if you are using installed optional filters.

Connection Considerations

The theoretical near 100 dB dynamic range of CD players places more stringent requirements on the quality of interconnections between player and the test system than when measuring many other audio devices. Poor shielding of the interconnect cables and lack of proper grounding between the player and the test system can create a noise “floor” which artificially limits many of the measurements. Since only a few CD players are designed with balanced outputs and nominal 0 or +4 dBu levels the distribution tests are set up for unbalanced inputs to the System with nominal 0 dBFS source (CD output) levels of 2 Volts RMS. The CD source connection is typically an unbalanced, chassis-grounded phono (RCA) connector. Thus testing a CD player requires consideration of grounding connections, prevention of ground loops and shielding the test connections from other potential interference. Care in the test connections can make a substantial difference in test results. See the Signal-to-Noise ratio section on testing for noise using the infinity-zero track available on most test CDs.

System One (.at1) tests use the balanced inputs, either XLR or double-banana. An adapting cable set is required with a male XLR connector at one end and (typically) a Phono (RCA) connector at the other. The cable should be a shielded pair type such as good-quality microphone cable. It is best to retain a balanced structure in the adapter cables. In this case the XLR pin 2 wire (+) connects to the center pin of the phono (RCA) connector using one of the wires of the shielded pair. XLR pin 3 (-) connects to the shell of the phono (RCA) connector using the other wire of the shielded pair. Pin 1 of the XLR connector is connected to the shield of the cable. No cable shield connection is made at the phono (RCA) connector; this should be carefully done so an accidental short does not occur. An optional test cable set in this configuration is available from Audio Precision, part number CAB-XBR. For minimum noise it may be necessary to separately connect the chassis grounds of the System and the unit being tested. This is best done with a larger gauge cable—12 gauge speaker wire is very good and is flexible. Fit a banana plug on one end to connect to the System ground and a large clip to connect firmly to the CD player chassis on the other. System One chassis ground is the banana jack under the BNC Aux Input. System Two chassis ground is any of the four metal jacks under the BNC Unbal connectors.

System Two tests (.at2) are set up with the BNC Unbalanced Inputs chosen as the analyzer source. These can be used with BNC-RCA adapters for connection using high quality shielded phono (RCA) connector cables. The unbalanced inputs in System Two are floating inputs to a differential stage—the BNC shell is not grounded to the chassis. Alternately, the XLR to RCA cable adapters discussed for System One can be used. The BNC Unbal Inputs are recommended for System Two. The separate ground cable discussed above may also be helpful in minimizing low level interference to the tests.

“Sweep Testing” Across a Series of Tracks

Certain tracks lend themselves to a single “spot” measurement, such as intermodulation distortion at a fixed set of frequencies. Many measurements, however, are best made and graphed as a set of measurements versus frequency or amplitude. Examples are frequency response, THD+N versus frequency, interchannel phase versus frequency, and distortion versus amplitude.

All of these test discs were designed to be usable with manual test equipment. They have sets of tracks or indexed segments within a track with sequential frequency or amplitude steps, typically with from 30 seconds to 1 minute of continuous signal at each available frequency or level. To obtain graphs of sets of measurements requires that the CD player reproduces a series of tracks or indexed segments while APWIN measures and graphs the data. APWIN typically requires only 1 to 3 seconds of signal to perform a two-channel pair of measurements. Most of the tests described here are most efficiently made by manually advancing the Compact Disc player from track to track or from index point to index point as APWIN acquires the data. The plotted graph thus results from a “sweep” across perhaps a dozen adjacent tracks or indexed segments. The total time required for the “sweep” is typically more dependent on the Compact Disc player’s track-to-track access time than on the measurement speed of APWIN.

Some discs may have many separately indexed segments within a single track. This reduces the total track count, which may simplify testing with CD players that cannot directly select more than 16 to 20 tracks. On the other hand, use of these discs will significantly slow the testing of any players which do not have indexing capability. In general, each indexed segment is one minute long and a player without indexing facilities must simply be permitted to play through them.

Externally Controlled Sweeps

Since Compact Discs are a playback-only medium, Compact Disc players are principally tested in the External Frequency and External Level sweep modes. On the Sweep Panel this is done by selecting the Source 1 ellipsis button to bring up the Sweep Panel Source 1 browser. Select Anlr on the Instrument window on the left side and check the Show Readings box (lower right) to list the analyzer measurement parameters available. When the Sweep Panel Source 1 field is configured for any meter reading parameter from the Analyzer, the Sweep panel Source 1 area is reconfigured for an external source sweep. Notice that no choices appear in the Source 1 browser for the Analyzer if the Show Readings box is not checked.

Test Discs

This application note refers to the following Compact Discs available, as a convenience, from Audio Precision. These CDs are in common use in audio testing and many users will already have one or more of these discs. Test Procedures that provide easy access to the appropriate tests along with on-screen prompts to assist testing are included with the distribution software—see Appendix 2. The name of the appropriate procedure follows the CD name information.

CBS CD-1 Standard Test Disc
PROCEDURE NAME: CBS.apb

Denon Audio Technical CD 38C39-7147
PROCEDURE NAME: Denon.apb

NAB Broadcast and Audio System Test CD
PROCEDURE NAME: NAB.apb

Philips Audio Signals Disc 1 SBC429
PROCEDURE NAME: Philips.apb

Other Compact Disc test discs that Audio Precision has significant experience with are listed below. Some of these were used in the DOS S1.EXE version of this application note.

EIAJ CD-1 Standard Test Disc (YGDS 13)
Japan Audio Society CD-1 (YDDS-2)
Philips Test Sample 3 (410 055-2)
Sony Test CD Type 3 YEDS-7
Technics CD Test Disc 1 SH-CD001

All contain signals appropriate for measuring frequency response, THD+N versus frequency, and at least one form of intermodulation distortion. Most contain signals suitable for inter-channel phase, stereo separation, noise, and signal-to-noise ratio measurements. Most contain some unique signals not found on the others.

The CBS, Denon, Philips SBC429 and NAB have “glide tone” continuously swept signals across the spectrum, permitting frequency response and interchannel phase versus frequency measurements with the greatest resolution. The CBS disc has the best signals for measuring de-emphasis error of a CD player. The CBS and Philips discs provide fixed-frequency signals over a wide amplitude range for measuring distortion versus amplitude and linearity; the Philips SBC429 provides the most amplitude levels. The CBS is unique among these discs in providing two sets of amplitude—stepped or amplitude—swept signals with dither. The CBS disc thus permits much more thorough exploration of the low-amplitude linearity of CD players than do any of the other discs. Most of the tracks on the Denon disc have signals on only the left or right channel at any one time, limiting its usefulness for phase versus frequency measurements and increasing its utility for stereo separation versus frequency.

Frequency Response Sweeps

Discrete Track Frequency Response

Single tone tracks are available in all listed test CDs. In those CDs with very low frequency tones greater level measurement precision can be realized since the tone length allows more accurately settled readings. Since discrete tones are required in any case for distortion measurement it is possible to set up a single test using System Two that measures THD+N, frequency response and phase.

Setup

This panel setup is illustrated in Figure 1 and stored as FRQRSPD.at2 (FReQuency ReSPonse, Discrete tone tracks) with the supplied files. This test is for External Frequency sweeps across a series of tracks where the frequency increases from track to track. The panels for System One are different in several details. These may be reviewed by loading FRQRSPD.at1 and viewing page one.

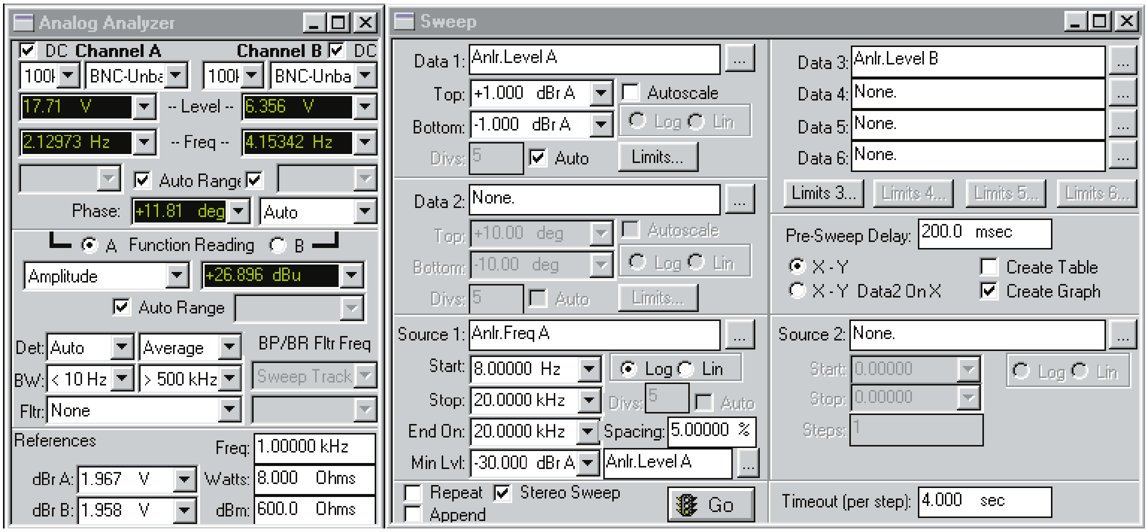
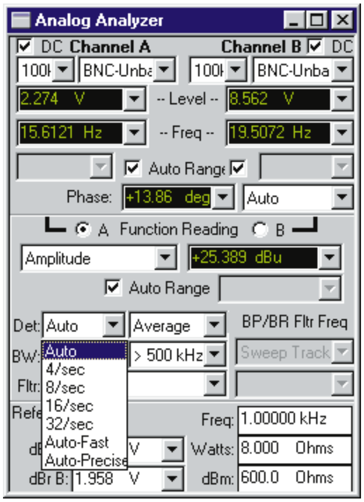


Figure 1 FRQRSPD test - Page 1 panels

The key parameters and factors are:

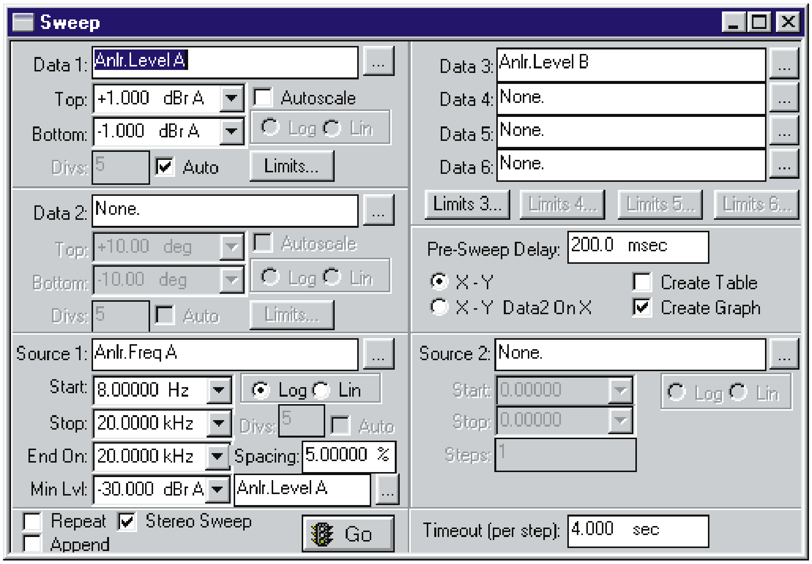
a. Analog Analyzer panel: In both System One and System Two select the Det drop down list box and choose a detector reading rate no faster than 8 per second for full specified accuracy at 20 Hz. Use of "Auto" (16/sec in External Sweep mode) will produce only about 0.1 dB additional potential error at 20 Hz.



The Average detector, which is slightly more accurate at low frequencies, may be selected if desired since the signal is a very pure sine wave. In External sweep modes, the reading rate selected on the Analog Analyzer panel is used throughout the test. This differs from Generator-based sweeps where the reading rate is automatically changed during the sweep as a function of the generator frequency. A 32/sec rate guarantees specified amplitude measurement accuracy down to 50 Hz. The 16/sec rate will produce rated accuracy at 30 Hz and higher. The 8/sec rate provides specified accuracy to 20 Hz.

When using System One set the Function Reading meter to 2-Channel Amplitude mode (2-Ch. Ampl) and select Channel A. When using the Function Reading meter in 2 Channel mode for frequency response measurements set the High-pass filter to Hz and the Low pass filter no lower than 80 kHz since a narrower bandwidth will affect the measured response as a result of the filter skirts. In System Two the two Level meters are used for the response measurement and no filters or bandwidth limitation is available to them. Low frequency reading performance can be improved in System Two by selecting DC coupled inputs (upper corners of the expanded Analog Analyzer panel).

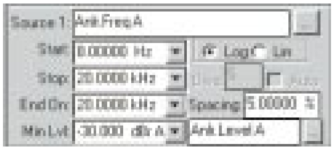
b. Sweep panel: System Two testing uses the two Level meters. Select Anlr.Level A for Data 1. If you wish the displayed response to go through 0 dB at 1 kHz, select the dBr A (relative dB) units for Data 1. Checking the Stereo Sweep box automatically selects the Channel B Level meter for Data 3.



For System One first select 2-Ch.Ampl from the Function Reading meter drop down list (Analog Analyzer panel) with the radio button set to Channel A. Next on the Sweep Panel, choose Anlr.2-Ch Ampl from the Data 1 browser and check the Stereo Sweep box. This sets Data 3 to Anlr.Level B. The Data 2 measurement and right graph axis is available for other readings. Measurements will then be made simultaneously on both channels, with the Function Reading meter measuring the selected channel (A, usually connected to the left channel) while the Level meter measures the alternate (B, or right) channel.

Also on the Sweep panel select Source 1 as Anlr.Freq A (Anlr.Freq for System One) with 8 Hz as the Start and 20 kHz as the Stop frequency. The direction of "sweep" of the signals on the disc must be matched by the direction implied by these Start and Stop frequencies; all of these test CDs have tracks in sequence from low to high frequency.

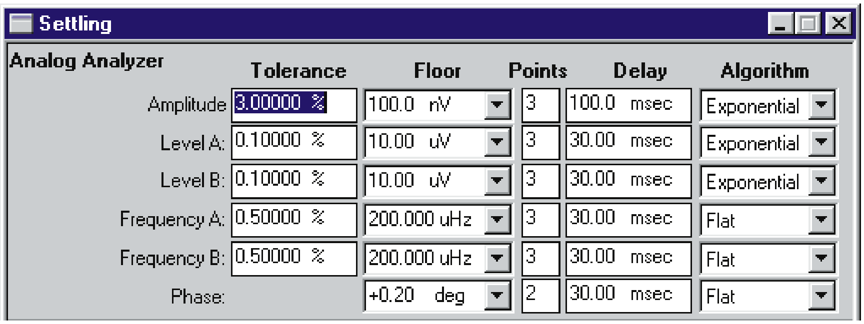
The End On frequency should be set to the next tone that appears after the Stop frequency. This is most often another 1 kHz tone. If the End On frequency tone doesn't exist then the sweep can be stopped by pressing the Stop button or Esc key.



The Spacing parameter determines the minimum percentage change in the frequency required before APWIN will acquire and plot another point. A 5% value is satisfactory for any of the series of CD tracks with discrete frequencies.

Set Min Lvl to a level below the CD signal output level but well above the noise floor. This can be most easily done by selecting the dBr unit (dBr A or B in System Two) and setting the Min Lvl to around -35 dBr. If Min Lvl is set too close to the signal level any readings that fall below the Min Lvl setting will be ignored and not included in the measurements. If Min Lvl is set too low, noise between tracks may be taken as readings. This false data can cause the sweep data to interrupt. If the dBr value is set to the 0 dBFS level from the CD (recommended) the Min Lvl value of -35 dBr will be safely below the typical frequency sweep amplitude but well above the noise level. The dBr settings in the supplied tests have a default value of 2 Volts RMS, typical for unbalanced consumer equipment outputs.

c. Settling panel: Settling panel conditions will vary depending on the specific readings being done and whether the source is a discrete, stable tone or a continuously changing glide tone. In the FRQRSPD test the settings are appropriate for a discrete tone source and frequency response readings. Since response flatness of 0.1 dB and better is not unusual in good CD players, the settling tolerances of the Settling panel should be tightened from their usual default value of 1% (0.1 dB). Values of 0.1% to 0.5% (0.01 to 0.05 dB) are appropriate for both 2-Ch.Ampl and Level meters at a detector rate setting of 8/sec.

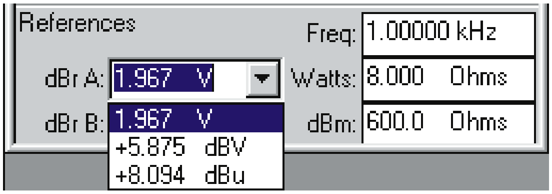


Referencing Frequency Response—the dBr

The supplied test default value for the dBr fields is 2 Volt RMS (+6.02 dBV). There are three methods in APWIN that may be used to set the dBr value to yield results relative to a reference level:

1. Actively setting the dBr reference—To set the analyzer reference to 0 dBr from the CD player select a track with a 1 kHz reference level track of the same level as the frequency sweep being used and press the F4 key while this track is playing. This automatically sets the player’s output levels as the Reference dBr values. There will likely be at least a small difference in graphed level between Channel A and Channel B due to difference in the output level calibration of the CD player. The advantage of using F4 is that the measurement results can be seen on the graph as the sweep progresses.

2. Manually entering the dBr value—If tests are being done to a specification the specification reference value can be entered directly by typing the value into the References dBr fields. Volts RMS, dBu and dBV units are available.



3. After-sweep referencing of data—APWIN can also adjust the measurement data after the sweep so that the reference levels are set to the 0 dBr value based on the actual measured amplitudes at that reference frequency. This is accomplished by using the Compute Normalize function. The sweep data values are changed based on the settings in the Horizontal Value and Target Value boxes in the Compute Normalize window. A possible disadvantage of using Compute Normalize alone is the sweep may not be visible while the sweep is running if the CD output level is much different then the analyzer's current dBr reference value. Also realize that the Compute function replaces the original test data with data changed as defined by the compute function used. This means the original test data is no longer available—there is no "undo". In this case the information lost is the original dBr values in the test.

   To reference readings to the 1 kHz level value: Set 1 kHz in the Horizontal Value window. Set the Target Value to 0 dBr. Indicate which Data columns are to be calculated by checking the appropriate Data To Compute box.—Data 1 and Data 3 in most stereo sweeps. Computation can be done automatically by checking the Apply After Sweep check box in the Compute Normalize window. However, if the sweep has to be stopped by pressing the Stop button (as when there is no End On frequency available), the automatic Apply After Sweep function will not operate since it requires a normally ended, rather than stopped, sweep. With Apply After Sweep checked the data can be seen to center themselves to the reference frequency immediately after the sweep ends.

Testing

Appropriate CD sources for this test setup include tracks 46-55 of the Denon disc, tracks 8-23 of the Philips SBC429 disc, and tracks

15-29 of the NAB Test disc. Tracks 6-10 of the CBS disc are also tested with this setup, but require index advances at some points and track advances at others since they contain indexed segments within each track.

Sequence the CD to the lowest-frequency track, press F9 or GO, and Play the CD. Watch the graph for plots of both newly measured points and advance the player to the next track as each segment is plotted (or the next index point if the test disc used has multiple indexed sections within a track.) Note that since two points are needed for a line, the first point doesn't provide an indication on the graph. If the Data Editor is displayed (APWIN page 3 tab) the readings can be seen accumulating. After each reading the sweep will then wait for the frequency to change by more than the Source 1 Spacing value. While the player could simply be allowed to play through the series of tracks, the fastest testing will result from advancing the player one track (or to the next index point depending on the disc) after each reading is plotted. After acquiring data from the last track, save the test to disk under an appropriate name. You may also wish to change the Data section Top and Bottom units to better display the particular measurements or, while the mouse cursor is on the graph, use the right mouse button menu and pick Optimize Left Only. The Optimized graph settings can also be copied back to the Sweep panel by clicking the mouse right button and selecting Copy to Sweep Panel.

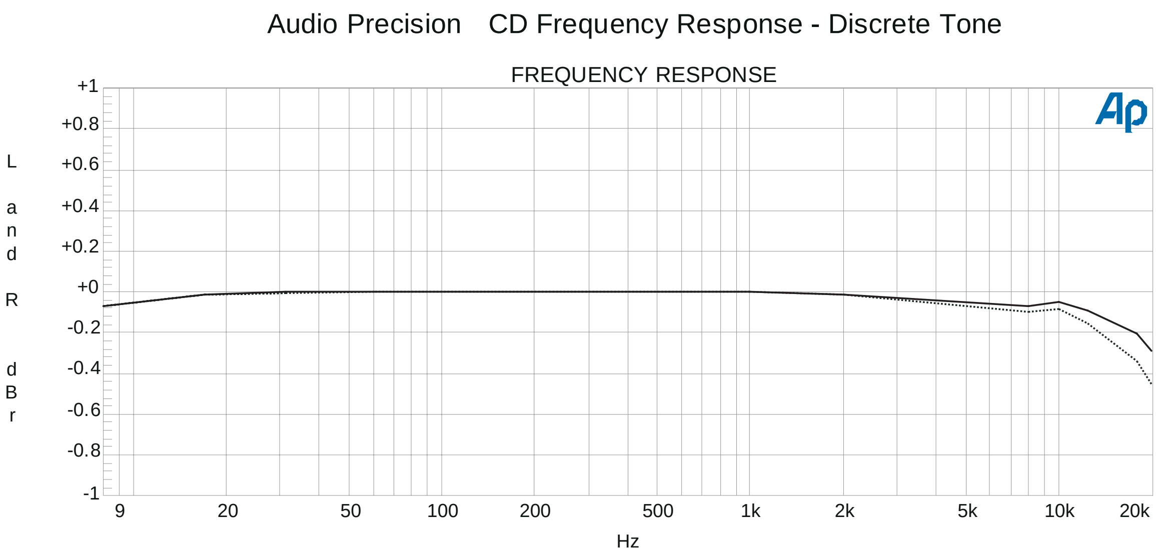


Figure 2 Discrete Frequency Response graph from FRQRSPD test

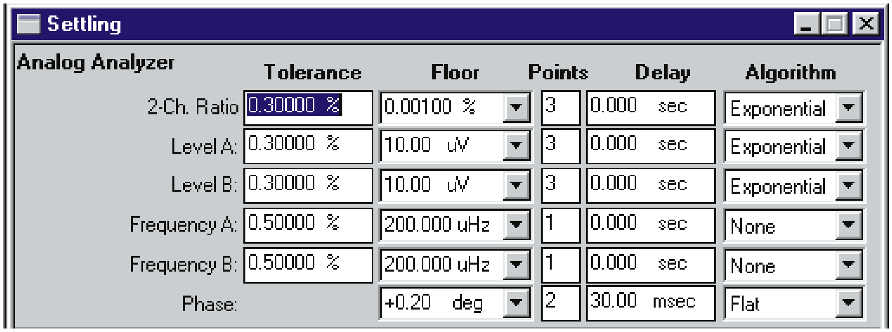
High-Resolution Frequency Response Measurements

The sequence of fixed-frequency tracks on the test CDs limit the frequency resolution to between 10 and 31 points across the spectrum depending on the number of discrete tone tracks available. Many discs permit much higher resolution measurements if they have a continuous analog sweep (glide tone) from 20 Hz or lower to 20 kHz or higher. Note that these continuously changing tones cannot be used for THD+N measurements since the reading cannot be settled properly. Track 11 on the CBS, 65 on the Denon, and 7 on the NAB discs are continuous stereo sweeps from 5 Hz to 22 kHz. Track 5 on the Philips disc is a continuous stereo sweep from 20 Hz to 20 kHz. All of these have total sweep times in the 50 to 70 second range.

This setup and data are supplied in the distribution files as FRQRSPG.at1 or .at2 (FReQuency ReSPonse, Glide tone track) in the distribution files. As in the previous test (FRQRSPD) the System One test is similarly configured to the System Two test. Additional measurements (such as Phase) may be added by using the Data 2 field and the right graph axis.

Setup

In order to make successful External Frequency sweep tests with a continuously changing sweep signal, the Settling panel must be changed. Every meter in APWIN has its own line in the Settling panel. The test setups previously described have software-settling algorithms in use for the data parameters: Anlr.Level A (Anlr. 2 Ch. Ampl in System One); Anlr.Level B and Anlr.Freq A or B. (Anlr.Freq in System One). The default value of 3 Points specifies that three measurement samples of the data parameter must agree within the Tolerance percentage before they are captured and plotted. In these examples the Tolerance value is further adjusted by an exponential weighting function when Exponential is chosen as the Algorithm.



For a glide-tone test, key setup points on the Settling panel are:

a. The reading rate of 16/sec (selected by Auto) may compromise accuracy below 30 Hz, but produces more samples and thus more detail at high frequencies. On System Two DC input coupling should be selected on the Analog Analyzer panel for very low frequency level accuracy.

b. With the continuous “glide tone” sweeps, the Source 1 Spacing value on the Sweep panel will determine how many points are taken across the audio spectrum. Values as low as 1% or 2% may be selected for a maximum number of data points.

c. Since the frequency meter reading—Anlr.Freq A or B—is continuously changing on a “glide tone” track, 3 consecutive frequency samples will never be equal and the APWIN software will not acquire data. For measurements to be taken, the Settling panel Algorithm must be changed from its default setting of Exponential to None. This disables the settling algorithm for the frequency measurement.

d. Depending on the rate of change of the measured parameters—Anlr.Level A (or 2 Ch Ampl in System One) and Anlr.Level B—and the tightness of the Tolerance for these parameters, it is usually desirable to change the Points settings from 3 to 2, or to loosen the Tolerance somewhat from values which are acceptable on the steady-signal tracks. If data is not taken smoothly and continuously all the way to 20 kHz, it is normally because the response is varying rapidly at high frequencies. The settling must consequently be loosened if data is to be obtained.

Figure 3 shows the System Two test (.at2) Analog Analyzer panel, Sweep panel, and the Settling panel from a test for a stereo frequency response measurement from a stereo “glide tone” track. Anlr.Level A (Channel A) is displayed at Data 1 and, after checking the Stereo Sweep check box, Anlr.Level B (Channel B) at Data 3. The Function Reading meter is not used. Figure 4 shows the results of a test that also measures the difference between the amplitudes of the left and right channels. The FR&Diff.at2 (Frequency Response & channel Difference) test displays the left and right frequency response using the left vertical axis and the difference in amplitude between the two channels on the right vertical axis. This test uses the Function Reading meter in 2 Ch Ratio mode and graphs the results as Data 2.

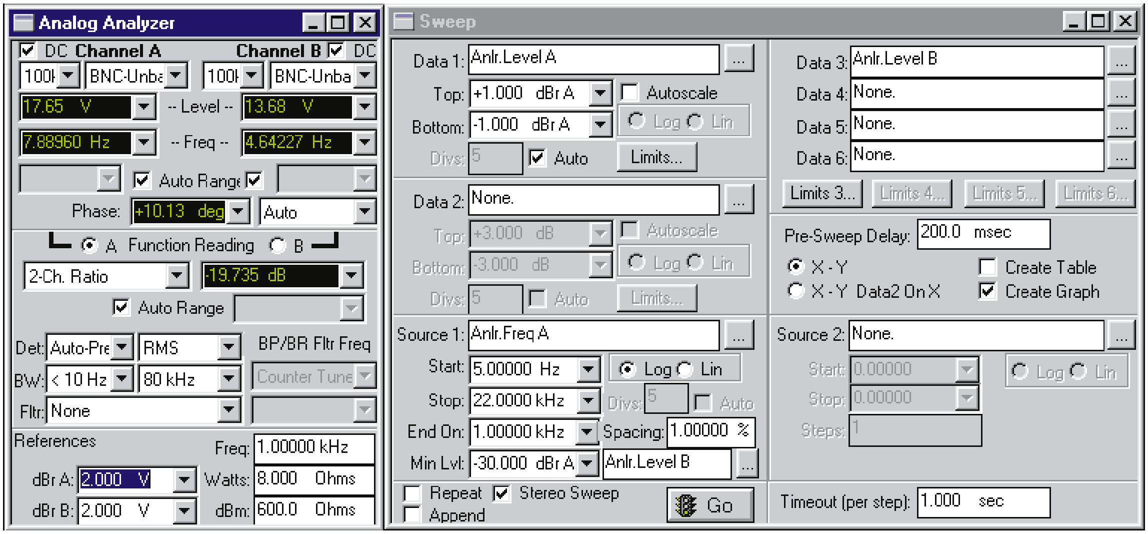


Figure 3 Glide tone sweep set up panels from FRQRSPG.at2

Figures 2 and 4 may also be compared to see the effect of the increased frequency resolution.

Testing

Testing with the continuously swept glide-tone tracks does not require the operator to advance the player after each reading as the discrete tracks do. THD+N measurements cannot be made on these continuously changing frequencies because the notch filter that removes the fundamental tone cannot accurately follow the continuously changing frequency.

To set the dBr value before the sweep, select and play a reference tone at the same level as the sweep and press F4. Some test CDs provide a reference just before the beginning of the sweep. Note that the 1 kHz tone at the beginning of track 65 on the Denon disc is not at the same level as the swept tone. In this case the dBr Reference may be set to the midband value for the CD player by first playing track 65 while watching the Frequency measurement on the Analog Analyzer panel or a Bar Graph displaying the Analog Analyzer frequency reading. As the measured frequency reaches the 1 kHz area, press F4 to store the level measurement from channel A as the dBr REF. Then, reset the CD player to the start of the track, press F9, and start the player. On the Denon disc, the 1 kHz tone lasts for about 8 seconds and data is usually not acquired until the frequency has swept upwards several Hz from the 5 Hz Start. Either 5, 8 or 10 Hz is an appropriate Start selection at Source 1 with the CBS, NAB, and Denon discs, while the Philips disc starts at 20 Hz. System Two has DC coupling input choices available. Selecting DC coupling (upper corners of the Analog Analyzer panel) will improve the accuracy of low frequency level readings.

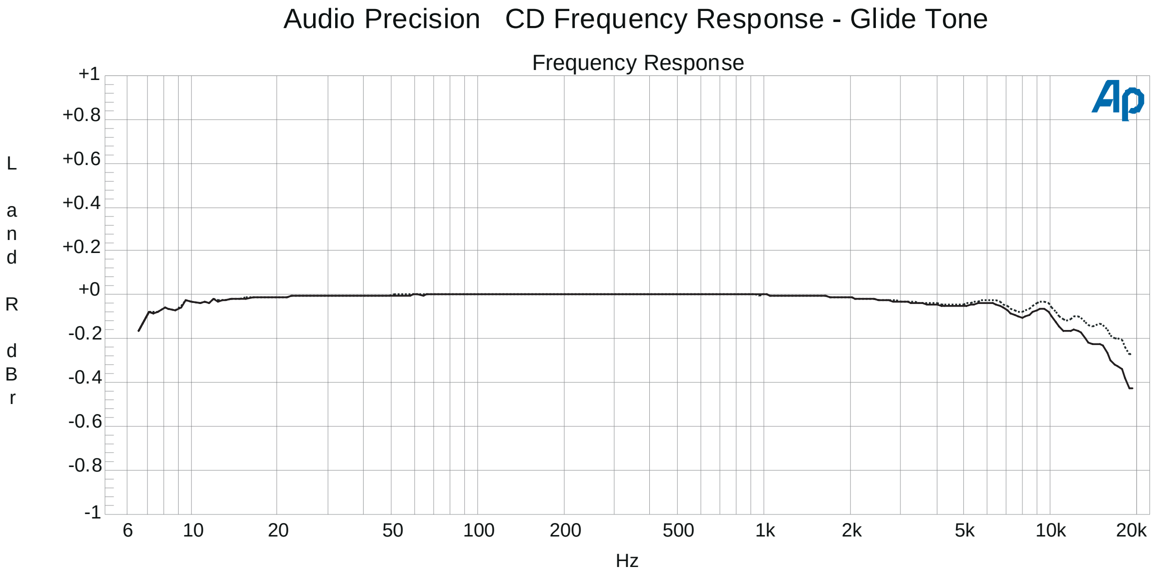


Figure 4 High Resolution frequency response graph from FRQRSPG test.

Results

The graph has a range of only ±1 dB and presents a detailed view of the frequency response. Mouse right-button and Optimize Left can be used to view the data with maximum detail. The response below 20 Hz cannot be attributed purely to the player, due to the 16/sec reading rate and because, in System One, the input coupling flatness is not specified below 10 Hz. On System Two the low frequency accuracy is improved by selecting the DC coupled input mode.

Frequency Response With De-Emphasis

Compact Discs may be recorded with or without pre-emphasis. When pre-emphasis is used, a “flag” is also digitally recorded which tells the CD player to switch in de-emphasis circuitry in order to provide overall flat frequency response. The simplest tests for de-emphasis accuracy can be made with the CBS discs. Track 12 contains five frequencies recorded using pre-emphasis. If the player de-emphasis (and other circuitry) is perfectly accurate, all five frequencies will be reproduced as a flat graph at -20 dB. The same test setup (FRQRSPD.at1 or .at2) used for other frequency response tests may also be used for the de-emphasis accuracy tests. Start the player at the beginning of the track (1 kHz reference) and press the F4 key. Advance the index to 2 (125 Hz) and press F9 to start the test. When the measurement is taken (view the Data Editor) index back to 1 (1 kHz) for the next point. When the measurement is taken (a new line in the Data Editor), index to 3 (4 kHz), then 4 (10 kHz), and finally 5 (16 kHz). This index sequence of 1, 2, 1, 3, 4, 5 is necessary because APWIN software requires a monotonically increasing or decreasing signal to properly graph and the frequencies in track 12 on these discs are not in monotonic order. The final graph is a measurement of the player’s deviation from perfect de-emphasized frequency response including any imperfect frequency flatness of the player circuitry.

If it is desired to further examine only the de-emphasis circuit accuracy without the influence of the CD player’s basic frequency response and channel imbalance, the Compute Delta function can be used to subtract a previously made non-emphasized frequency response measurement on the same unit from the test data. The test source for the Delta information (a previously saved test file) should be opened, then select Save As, Data, name the data (.ada) file and Save it. Next run the response test with the de-emphasis circuitry active (selected CD track has emphasis turned on). Next, on the drop-down Compute Delta window, select the saved reference data file as the Delta Source file. Select the Data to Compute and the Delta Source

Column that is to be subtracted from the new measurement data. For the supplied tests check Data 1 and select Delta Source Column 1; Data 3 and select Data Source Column 2. Figure 5 shows the graphed data after a Compute Delta operation to subtract the basic player frequency response and channel imbalance. This data shows the total deviation from perfect flatness due both to de-emphasis error and to imperfect flatness of the basic player circuitry even when de-emphasis is not in use. It also shows any level imbalance between left and right channels, since the Analyzer dBr reference was set while measuring the left channel in both cases.

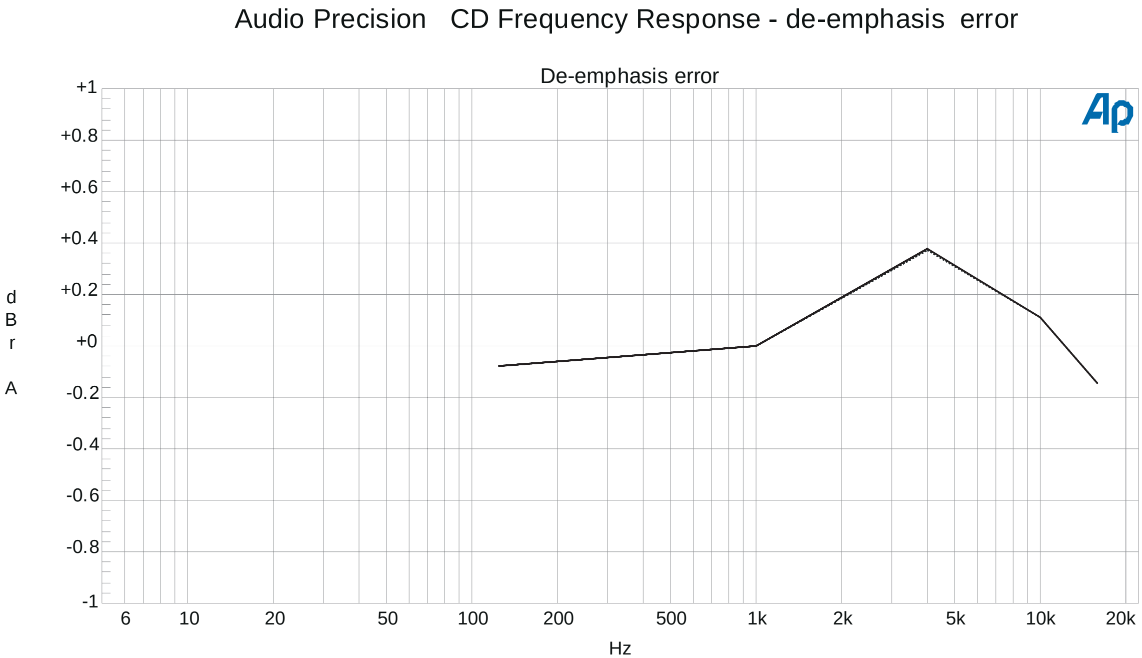


Figure 5 De-emphasis response test with player overall frequency response and channel imbalance removed.

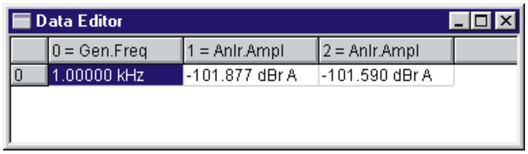
Setup For Noise And Distortion Measurements

It is important to have good connections and correct grounding to measure the extremely low level residual signals in a quality CD player. See the discussion at the beginning on connection considerations. Noise from poor connections or shielding plus analog reproduce channel noise can be measured on the quiet ("infinity zero") tracks. Noise can be expressed as signal-to-noise ratio by first using F4 to set the dBr REF on a maximum level (0 dBFS) track, then playing a quiet track. Quiet tracks include 4 (without emphasis) on the CBS disc, 12 on the NAB disc, 49 (with emphasis) and 50 (without emphasis) on the Philips SBC429 disk and tracks 34 (without emphasis) and 35 (with emphasis) on the Denon disc.

Single Number Signal-to-Noise Ratio

Figure 6 shows APWIN Page 1 with the panel setups after a 0 dBFS track has been played and F4 pressed to capture and set the dBr REF value. The Function Reading meter, in Amplitude mode, has been set up with a bandwidth of 22 Hz to 22 kHz by selecting these values in the BW line on the Analog Analyzer panel. In addition an optional installed filter (Fltr) can be specified such as the 20 kHz lowpass (FLP-20k) or 20 kHz "brick wall" (FLP-A20k) filters. These can make a significant difference in the measured noise if there is high frequency noise present. For weighted noise measurements, such as A weighting (FIL-AWT) or CCIR 468 (FIL-CCR) weighting, specify the required filter in the option filter window. The filter requested must, of course, have been installed in one of the option filter sockets in the System One or Two.

Set Data 1 for Anlr.Ampl and check the Stereo Sweep box for B channel data on Data 3. Check the Single Point box in the Source 1 area to produce a spot pair of measurements and automatically display the Data Editor and the tabular display format. Measurements are made for each channel sequentially.



The lower part of Figure 6 shows the Data Editor with the measurements resulting from pressing F9 while a quiet (infinity zero) track is being played. This test is stored as NOISEWB.at1 or .at2 (NOISE, Wide-Band) in the distribution files. Note that this test produces no information on the digital portions of the CD player since the D-to-A converter is not being exercised and will normally mute outputs when there is no audio data. A different test, DYNRANGE.at2 or at1, is used to measure the CD player noise while the D-to-A converter is active.

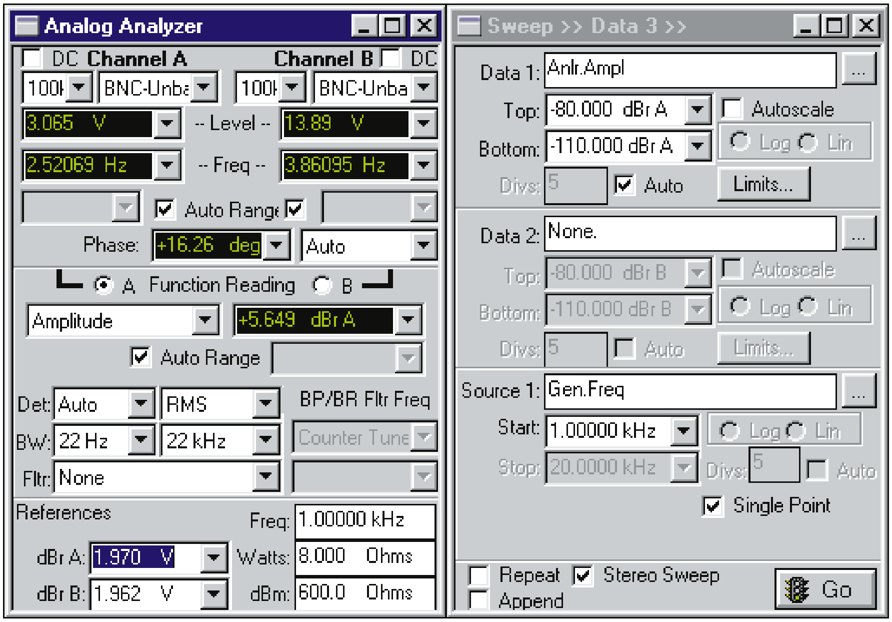


Figure 6 Panels and test results for single-point audio band noise measurement - NOISEWB.at2

Noise Spectrum Analysis

The frequency and amplitude of noise components contributing to the total noise can be determined by using one of the spectrum analysis techniques. There are two basic approaches described here. With FFT analysis the amplitude and frequencies of interfering signal can be accurately determined. However, the maximum frequency and dynamic range is limited by the available sample rates and the number of bits of resolution of the A-to-D converter used. The other, much older method uses the Analog Analyzer tunable Bandpass filter to measure the amplitude of noise components within narrow frequency bands. The frequency resolution is much less than the FFT method since the filter bandwidth (1/3 octave) is much wider than the individual FFT frequency bins. The analog method has the advantage in frequency coverage since the upper frequency can be as high as 200 kHz. Also the amplitude measurement range of the bandpass analyzer function is not limited by bit resolution of the A-to-D converter. This results in a somewhat wider dynamic range of possible amplitude measurements. A combination of both approaches is useful for measuring very low level noise components in the presence of a strong single tone signal. The Analog Analyzer notch filter in THD+N mode can be used to remove the single tone fundamental and the output of the filter analyzed by FFT analysis.

FFT Noise Analysis

A spectral analysis of the CD player's output while playing a quiet ("infinity zero") track will quickly show a great deal of information on potentially limiting noise problems. On an infinity zero track, the D-to-A converter is quiescent and contributes no noise due to conversions (this is the only testing value from an infinity zero track). The analysis will show whether the CD player's power supply is adequately filtered. It will also show whether other noise sources are coupling into the CD player or cables, such as the magnetic field from the deflection circuits of the computer CRT monitor used with APWIN. In a System with DSP ability these measurements can be done by an

FFT of the signal. This will display excellent detail of the frequency components of the noise.

In an FFT analysis the maximum graphed frequency is determined by the sample rate. Just under one-half the sample rate frequency is the maximum frequency useful for an FFT analysis. In System Two the sample rate can be 192 kHz set by selecting a maximum Sample Rate of 48 kHz and selecting the Input to the High BW (4X) A/D which multiplies the sample rate by 4. This makes the maximum band just slightly over 80 kHz. For System One the maximum sample rate is also 192k using the Spectrum Analyzer (fftslide) digital analyzer program.

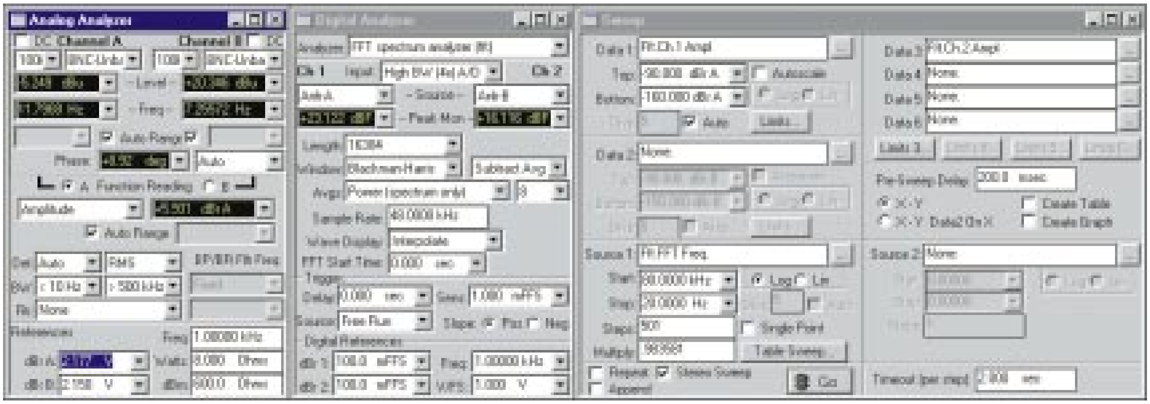
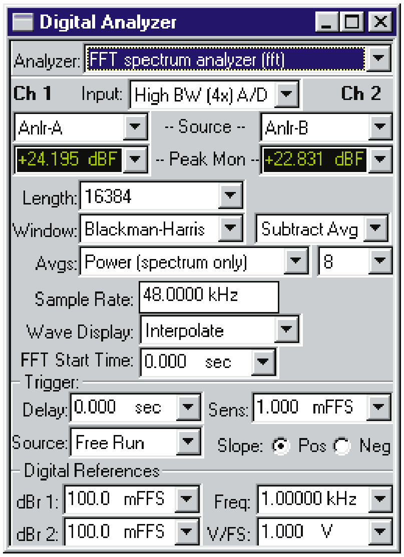


Figure 7 NoiseFFT test Page 1 panels

Setup

The Analog Analyzer is set up for a two channel input level test. Other key factors for FFT spectrum analysis for maximum bandwidth are:

a. For System Two select FFT Spectrum Analyzer from the Analyzer drop-down list on the Digital Analyzer panel. Choose the High BW (4X) A/D as Input. In the Sample Rate field enter 48 kHz. This produces the 192 k sample rate (4 x 48k). For System One, select Spectrum Analyzer (fftslide) from the Analyzer drop-down list.



Select A/D as the Input in the Digital Analyzer and 192k Sample Rate on the Digital I/O panel.

Select Source on the Digital Analyzer panel as Anlr A and Anlr B for either System One or Two. The FFT will receive signal from the Analog Analyzer Level inputs after ranging.

On the System Two Digital Analyzer panel set FFT Length to 16384. Also Subtract Avg will remove any DC component or extremely low frequency components of the signal. If a higher number than one is chosen for Avgs, additional FFT samples are taken. The power spectrum averaged data will lower the variability of the random noise shown while repetitive components are undisturbed. Do not use Synch averaging (System Two) since this requires a discrete tone to use as a synchronization reference. Power spectrum averaging is useful for looking more closely at non-noise data that may be buried in the noise. On System One select Maximum for FFT Length and check Remove DC. Data averaging is not available in fftslide. Averaging is available in Spectrum generator/analyzer (fftgen) but the maximum sample rate is 48 ks.

b. On the Sweep panel set Data 1 to FFT.Chan.1 Ampl and select dBr A for the Unit (dBr in System One). This will plot the noise in dB below the output of the player when playing a maximum-level track. Of course, the dBr value must be set at the 0 dBFS level as discussed previously. Next, check the Stereo Sweep box so that the B channel data is taken as Data 3 (FFT.Chan.2 Ampl). Always fully set up Data 1 before selecting the Stereo Sweep check box. The Top and Bottom fields on the Sweep panel Data 1 of the graph should have low values. Top of -90 dBr and Bottom of -160 dBr are reasonable. In the Source 1 area of the Sweep panel select Fft.FFT Freq and a Start value of 80 kHz and a Stop value of 20 Hz. Set the Steps value to a high number for good sweep detail—500 or more.

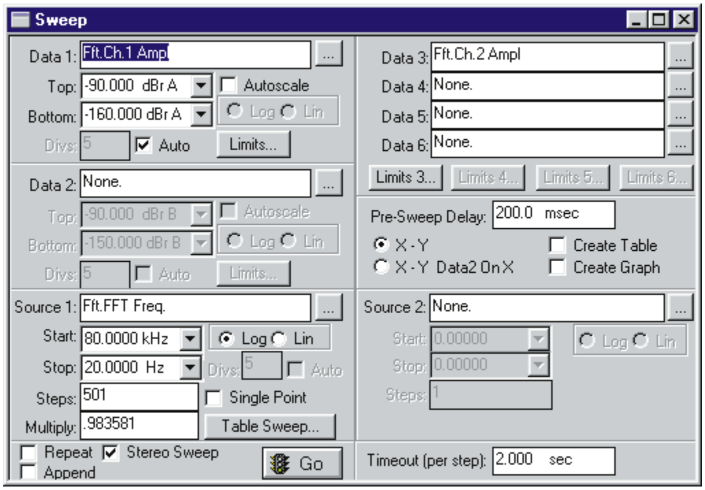


Figure 6 shows the panels for an FFT to 80 kHz using FFT Spectrum Analyzer of System Two. This test uses eight readings to reduce the variance of random noise components so that specific frequency spikes can be more clearly seen. This test is in the distribution software as NoiseFFT.at2. A similar test without reading averaging for System One is NoiseFFT.at1.

A variation of this test is useful for looking at mains and power supply related interference. Set the A to D converter sample rate to the 8 k sample rate by selecting Low BW(/4) A-D for Input and set the Sample Rate to 32 kHz. Change the Sweep panel

Source 1 Start and Stop frequencies to low frequency values such as 720 Hz to 10 Hz. The highest frequency possible with this configuration is slightly below 4 kHz—half the sample rate.

Testing

First calibrate the dBr reference by playing a 0 dBFS track and set the dBr reference (F4). Select a track with an "infinity zero" signal, without emphasis if available, and Play the track. An FFT is made when F9 or a GO button is pressed.

Audio Precision CD FFT Noise Spectrum 80 kHz - 20 Hz No filters, ref 0 dBFS 8 avgs

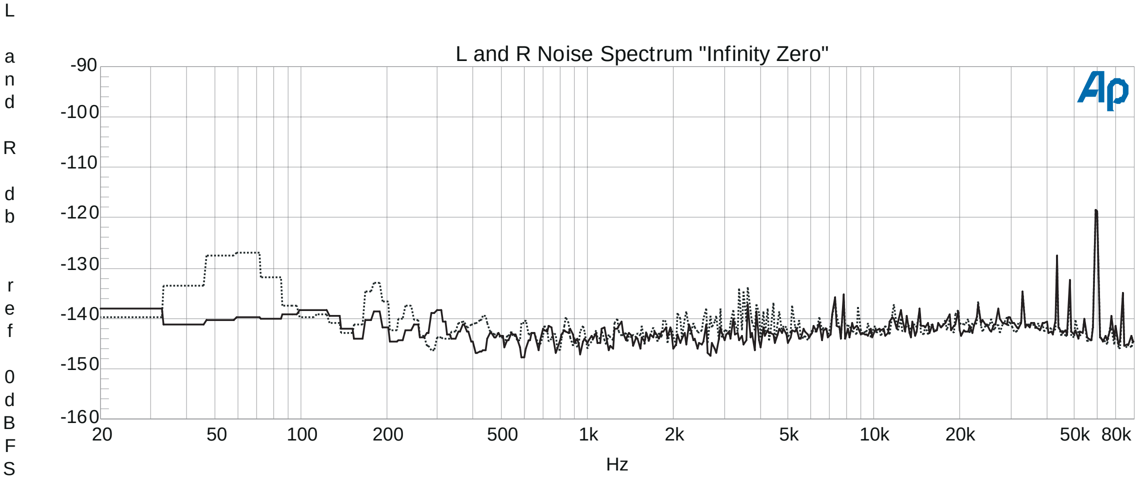


Figure 8 Graph of FFT of noise components - NoiseFFT.at2

Results

Figure 8 is the graph from a NoiseFFT test. The appearance of mains (AC power) frequencies of 60 (or 50) Hz can indicate either grounding connection problems or magnetic interference. Some mains frequency interference is often not avoidable. The appearance of second harmonic of the mains frequency is often associated with inadequately filtered or shielded power supplies. Sometimes the difference in these numbers indicates which channel is physically closest to the power supply or AC mains entrance within the chassis.

The computer monitor itself can be a major source of both mains related interference and horizontal scan rate interference. In computer monitors the vertical and horizontal rates are determined by the monitor's characteristics and signal configuration. In a similar way a strong video source of interference can show a horizontal rate spike at 15,734 Hz for NTSC and 15,625 Hz for PAL video. An undithered digital signal will display a lower noise floor than a correctly dithered signal but it will also show spikes at every harmonic of the fundamental. Another signature to be aware of is the presence of odd harmonics as an indicator for the onset of clipping. The internal clock frequencies of digital equipment and computers can beat against each other and produce intermodulation products within the audio band. Oversampling and sigma-delta converters often create spikes at a multiple of the sample rate.

Analog Bandpass Filter Noise Analysis

For Systems without DSP ability, the Analog Analyzer in Bandpass filter mode can produce useful, though less detailed, results. The Bandpass filter may be swept by the Sweep panel and measure narrowed (1/3 octave) bands of the noise level for evaluation of the noise level. NOISSPEC.at1 or at2 (NOISe SPECtrum) displays the noise bandpass spectrum to 20 kHz. If the analysis extends to sufficiently high frequencies, it may also show signal leakage from an internal CD clock at 44.1 kHz, 88.2 kHz (double oversampling), or 176.4 kHz (quadruple oversampling) frequencies. NoiSwpWB.at1 or .at2 (Noise Sweep Wide Band) has an extended upper end to 200 kHz.

Setup

Figure 9 shows the panels for a spectral analysis to 200 kHz using the Analog Analyzer Bandpass mode of System Two.

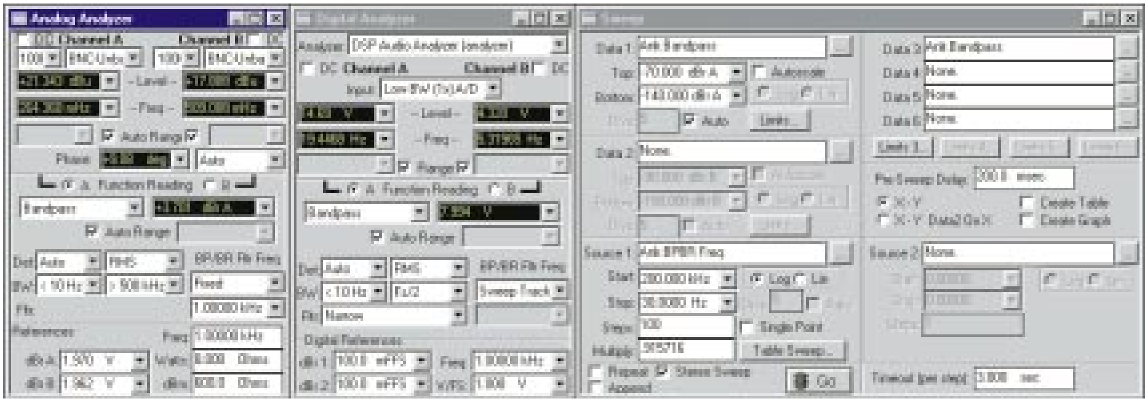
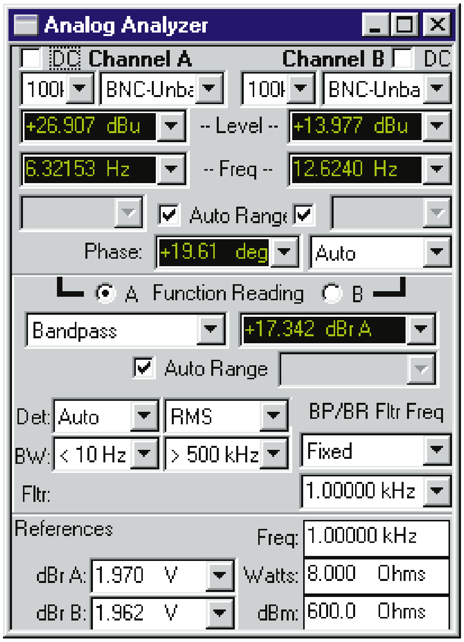


Figure 9 Set up panels for a Analog Analyzer Bandpass filter sweep to 200 kHz.

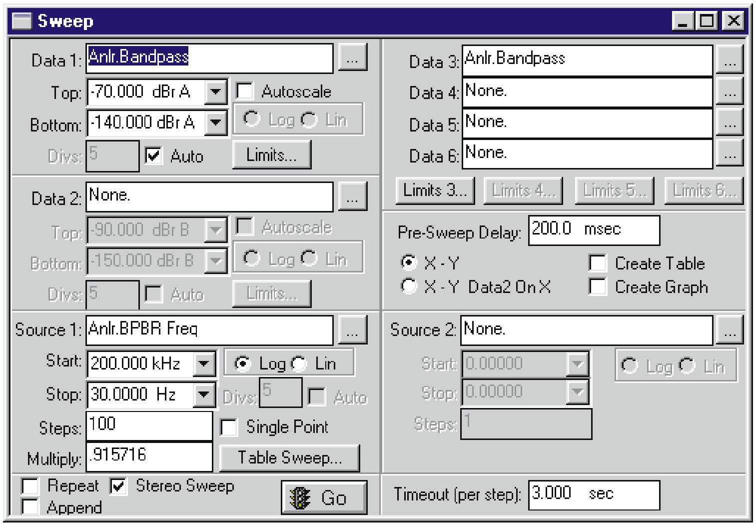
Key factors for analog bandpass spectrum analysis are:

a. On the Analog Analyzer select Bandpass as the Analog Analyzer Function Reading meter measurement mode. Set the BP/BR Fltr Freq drop-down list box to Fixed. This selection assures that the Sweep Source 1 controls the bandpass filter frequency.



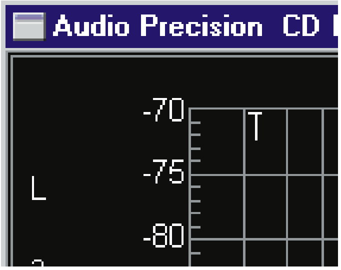
No high-pass or low-pass filters are selected on the BW line in the Analog Analyzer.

b. Sweep panel Data 1 is set to Anlr.Bandpass and select dBr to plot the noise in dB below the output of the player when playing a maximum-level track. The Top and Bottom fields on the Sweep panel Data 1 of the graph should have low values. Top of -70 dBr and Bottom of -140 dBr are reasonable. Next, check the Stereo Sweep box so that the B channel data are taken as Data 3. Always fully set up Data 1 before selecting the Stereo Sweep check box. Data 1 and Data 3 are displayed with Anlr.Bandpass, which is the bandpass-filtered signal.



Source 1 is selected as an (Anlr.BPBR Freq) sweep from 200 kHz to 30 Hz.

c. At low noise levels the amplitude measurements will normally not repeat accurately from sample to sample due to the random nature of noise. For faster settling and to avoid Timeout flags (a "T" displayed at the top of the graph), set the Bandpass Tolerance on the Settling panel to a relatively loose value such as 10% (1 dB). This test setup is in NoiSwpWB.at1 or at2 in the distribution files.



Testing

First calibrate the Analog Analyzer dBr reference by playing a 0 dBFS track and set the dBr reference (F4). Select a track with an “infinity zero” signal, without emphasis if available, and Play the track. A sweep is done when F9 or a GO button is pressed. The bandpass filter first sweeps Channel A, switches the Function Reading meter to Channel B and then sweeps Channel B.

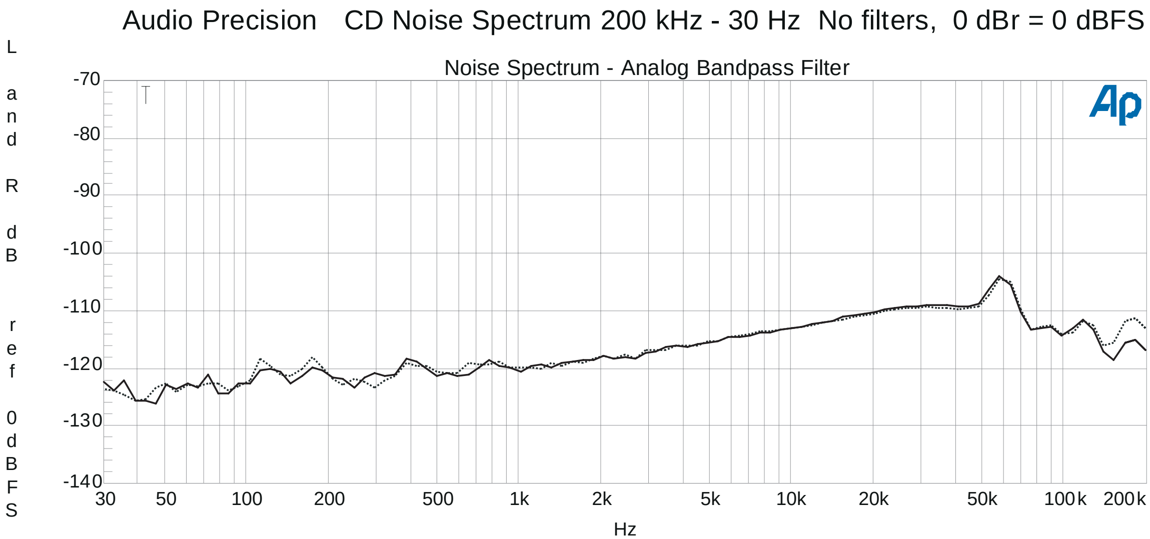


Figure 10 Analog Function Reading meter Bandpass filter sweep of noise to 200 kHz - See the discussion after the FFT noise spectrum in the previous section on interpretation of results.

D-to-A Converter Noise

D-to-A converters normally are in a muted state when the digital signal is zero (infinity zero) so a traditional signal-to-noise measurement will measure only the analog circuit performance after the muted stage. Dynamic Range is a test for measuring the noise floor while the D-to-A converter is active with a low level signal. Quantization noise is tested using a low frequency full scale 0 dBFS signal. FFT analysis of the residual components of either of these test approaches can be done using the LoLvlFFT (.at1 or .at2) test described in the Distortion and Linearity section.

Dynamic Range

Some testing methods define dynamic range measurement of a CD player as a THD+N measurement on a -60 dB track, corrected by adding 60 dB. Document CP-307 of the Electronic Industries Association of Japan (EIAJ) list this specification. This method eliminates any distortion introduced at higher levels in the CD player. This test is a more valid measurement of actual operating noise since the D to A converter is active due to the presence of signal and, consequently, no muting occurs as is the case with an infinity zero track.

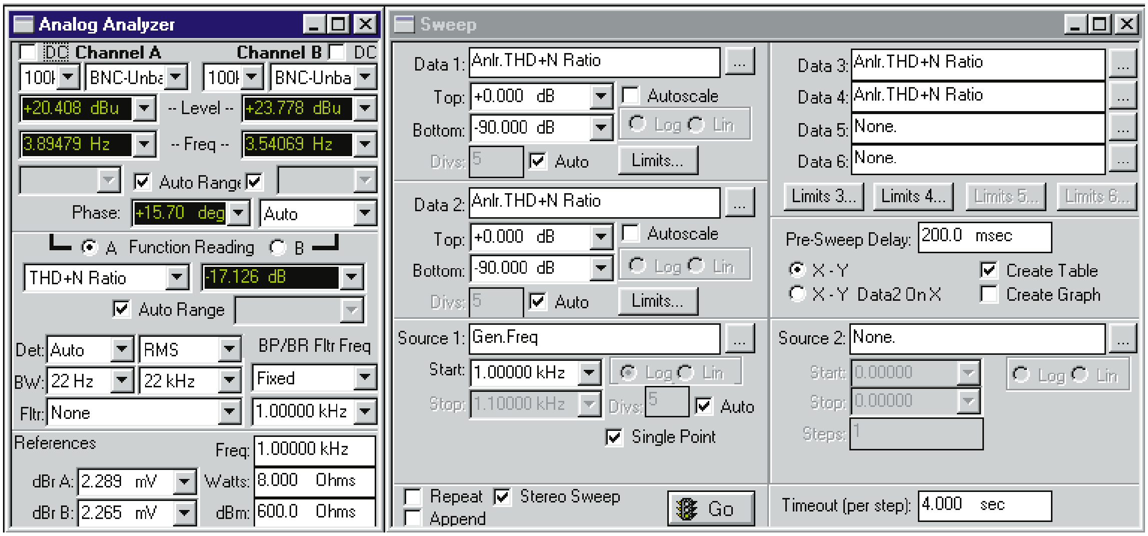
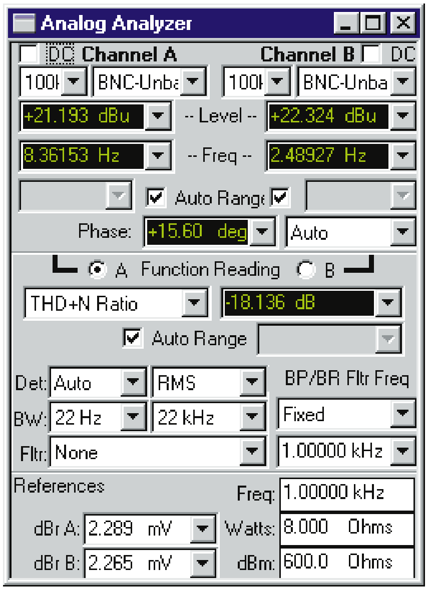


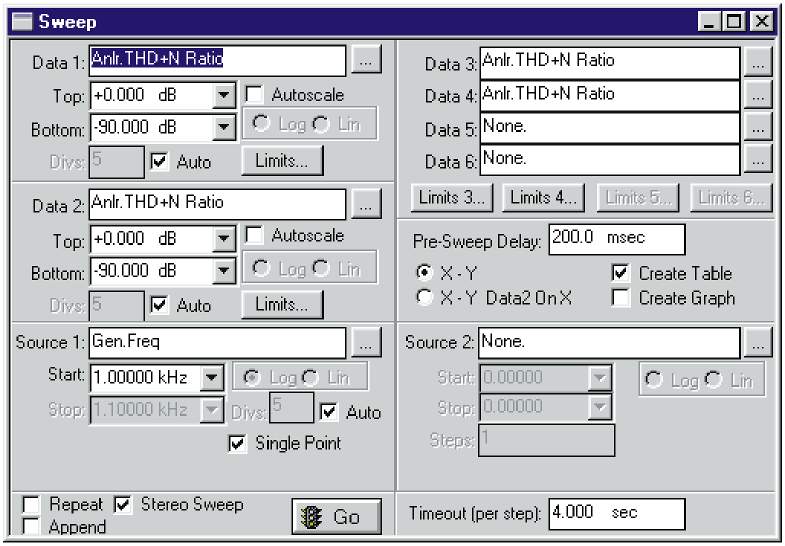
Figure 11 Dynamic Range test panels - Results of a measurement using the -60 dB 1 kHz track 5 of the CBS disc. The Data Editor displays the original data for channel A and B in Data 1 and 3 and the adjusted data in Data 2 and 4. After the measurement Data 2 and Data 4 are automatically adjusted by Compute Delta adding 60 dB, which should result in dynamic range measurements in the 90 plus dB range.

Figure 11 shows the test setup to make a single point measurement directly with System Two. Key factors for Dynamic Range testing are:

a. On the Analog Analyzer panel select THD+N Ratio and Channel A for the Function Reading meter. Fixed and 1.000 kHz should be selected in the BP/BR Fltr Freq fields. This will steer the notch filter used by the THD+N Function Reading meter accurately to the -60 dB tone frequency. The 22 kHz low-pass filter and RMS detector should be selected. The other bandwidth limiting optional filters discussed under noise and THD+N measurements would also be appropriate here. The A-weighting filter is specified by the EIAJ for this test, since it is really more akin to a noise measurement than a distortion measurement and it is desired that the results be directly comparable to A-weighted noise measurements. The optional A weight filter is required for this specification (part number FIL-AWT).



b. This test provides an example of the use of multiple copies of the same data in different columns so that post-sweep computation can be done. On the Sweep panel select Anlr.THD+N Ratio for Data 1 and Data 2 and dB as the unit for both. Check Single Point in the Source 1 area and the Stereo Sweep check box at the bottom. In this test Channel A data will be taken in both Data 1 and Data 3 and Channel B measurements in Data 2 and Data 4. Source 1 is set as Gen.Freq with the test frequency of 1 kHz entered in the Start field. The value entered into the Source 1 Start field appears as the first column value for the only row of readings taken in this test. This provides a record of what source-tone frequency was used.



c. In the Compute Delta drop-down a Delta file has been specified that was made with the Data Editor and Saved as a Data (.ada) file. This file (60dB.ada) has values of 60 dB in the two data columns; the (only) row is given as 1000 Hz. Compute Delta automatically applies these values to the data taken in the Data 2 and Data 4 columns with Apply after Sweep right after the test is done. This test is supplied as DYNRANGE.at1 or .at2 (DYNamic RANGE). The test also requires the data file 60db.ada which is the reference file for the Compute Delta operation.

Quantization Noise

Quantization noise measurement in a digital system also differs fundamentally from noise measurement on a quiet (infinity zero) track by exercising the D-to-A converter with a 0 dBFS low frequency signal. A maximum amplitude (zero dBFS) signal must be played to properly measure quantization noise. This single point measurement also uses THD+N Amplitude on the Function Reading meter to remove the fundamental component of this signal. In this test all low-to-moderate order harmonics are also removed with a high-pass filter in order to prevent actual harmonic distortion products from obscuring the quantization noise measurement. A zero dB level track with a low frequency signal, preferably 20 Hz or lower, must be selected. On the CBS disc track 6 index 3 is 17 Hz. NAB track 15 is 20 Hz. Philips SBC429 track 9 is 16 Hz. On the Denon disc the left track is 26 and the right is 27, both are 21.5 Hz. Uncheck Stereo Sweep if using the Denon disc source.

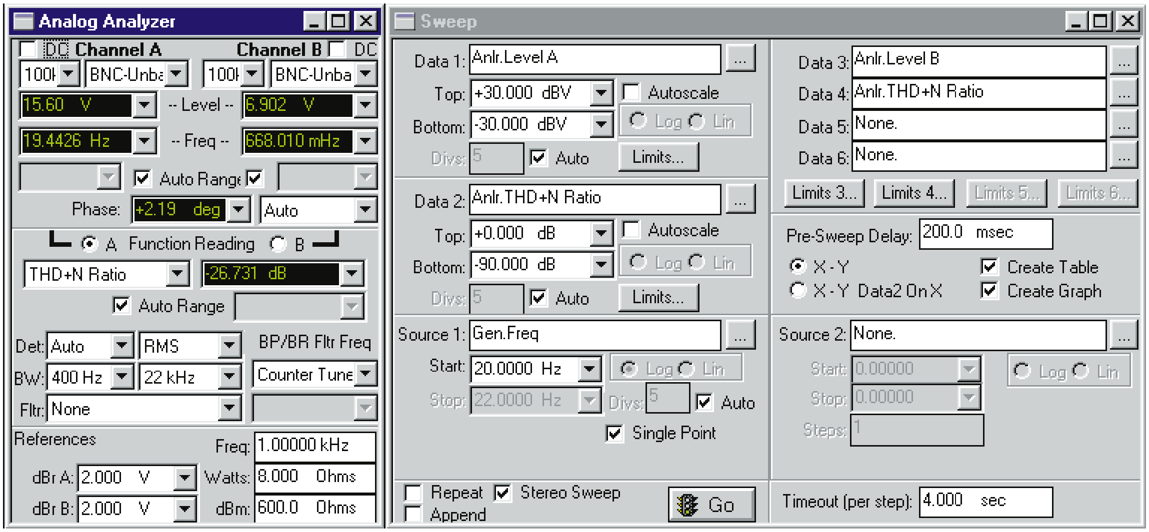
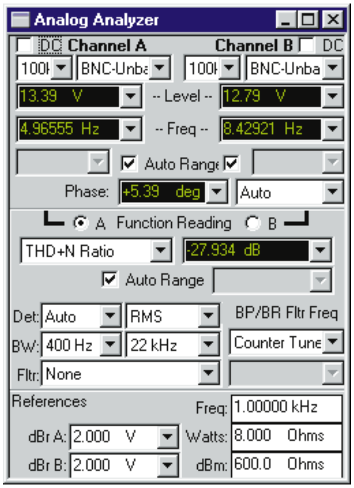


Figure 12 shows the Quantization Noise test panel setups and the test results in the Data Editor. This test is supplied as QNTZNOIS.at1 or .at2 (QuaNTiZation NOISe) in the distribution files.

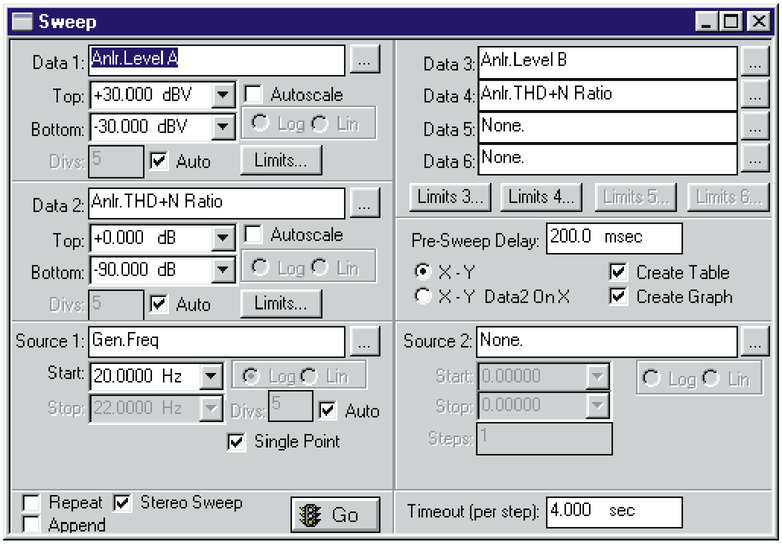
Setup

a. On the Analog Analyzer panel select THD+N Ratio for the Function Reading meter. The BP/BR Fltr Freq should be set to Counter Tuned to respond to the low frequency fundamental used as the test tone. The 400 Hz high-pass filter selection attenuates low and moderate order harmonics of the 20 Hz signal before the Function Reading meter; any signals below 200 Hz will be attenuated by 20 dB or more. Only quantization noise across the audio spectrum above 400 Hz up to the 22 kHz filter low pass filter cutoff will be measured.



b. On the Sweep panel select Anlr.THD+N Ratio as Data 1 and dB as the unit choice. At Data 2 choose Anlr.Level A and select an appropriate unit such as dBV, V. or dBu. Check the Stereo Sweep box. A Single Point selection at Source 1 provides a single spot measurement on each channel, as shown in Figure 12. Also type in the CD track frequency used in the Source 1 Start field so that it will appear included in the Data Editor in the left hand column. This will display the complete test results and signal conditions in the five Data Editor columns after running the test.

For a more detailed analysis of the noise components using FFTs see the test description in FFT Noise Analysis. The low level residual FFT spectrum analysis file LoLvlFFT.at1 or .at2 may be used with Quantization Noise test tracks to display the residual spectrum relative to 0 dBFS. In this case the source signal from the CD should have frequency above 15 Hz so that the low frequency bandpass of the System does not make control of the notch filter frequency too difficult.


Sweep
Data 1: Anlr.Level A
Top: +30.000 dBV
Autoscale
Bottom: -30.000 dBV
Log Lin
Divs: 5
Auto
Limits...
Data 2: Anlr.THD+N Ratio
Top: +0.000 dB
Autoscale
Bottom: -90.000 dB
Log Lin
Divs: 5
Auto
Limits...
Source 1: Gen.Freq
Start: 20.0000 Hz
Log Lin
Stop: 22.0000 Hz
Divs: 5
Auto
Single Point
Repeat
Stereo Sweep
Append
Go
Data 3: Anlr.Level B
Data 4: Anlr.THD+N Ratio
Data 5: None.
Data 6: None.
Limits 3...
Limits 4...
Limits 5...
Limits 6...
Pre-Sweep Delay: 200.0 msec
X - Y
Create Table
X - Y Data2 On X
Create Graph
Source 2: None.
Start: 0.00000
Log Lin
Stop: 0.00000
Steps: 1
Timeout (per step): 4.000 sec

Distortion Measurements

Sources contributing to distortion and noise in a CD player include:

1. The theoretical quantization distortion and noise of the D-to-A conversion process. This is a direct function of the number of bits in a linear PCM system, such as a CD, with -98.08 dB being the theoretical value for 16 bits. Dither in the recording process can convert quantization distortion to quantization noise by redistributing the quantization error energy from specific harmonics into a broad distribution similar to white noise. The CBS and Philips SBC429 test discs include dithered signals.
2. Distortion due to practical imperfections of the D-to-A
3. Distortion and noise in the sample and hold circuitry
4. Non-linearity and noise in the analog sections

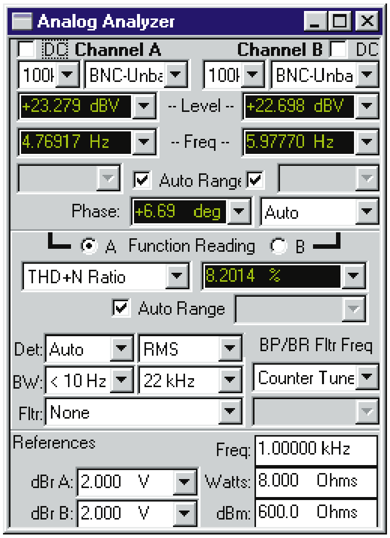
Most of these mechanisms cannot be cleanly separated from one another by measurements of a complete CD player, but inferences can often be made. Analog section distortion is likely to make the greatest contribution at maximum signal levels. Analog noise can be separated from digitally generated noise sources by measuring an “infinity-zero” track, as described earlier. Measuring THD+N vs. amplitude can show D-to-A converter problems.

THD + N versus Frequency

Setup

Key factors for a THD+N distortion versus frequency test are:

a. Select THD+N Ratio for the Function Reading meter mode on the Analog Analyzer panel, with dB or percent as units. Select the RMS detector. Make an appropriate choice of low-pass filter frequency in the BW line. The 22 kHz selection will produce maximum rejection of the CD player clock and out-of-band components. More rejection of these signals can be obtained by use of the optional 20 kHz low pass filter (part number FLP-20000) with 50 dB rejection at 40 kHz. Also available is a “Brick wall” 20 kHz low pass filter (FLP-A20K) with 35 dB attenuation at 24 kHz and over 90 dB beyond 30 kHz. If a weighted measurement is required select the desired installed weighting filter in the Fltr window. Note that only one option filter may be used at a time. The frequency of the THD+N notch filter should be set by the frequency counter while measuring the input. To do this, set BP/BR Freq to Counter Tuned in the drop-down list box.



b. On the Sweep panel select Anlr.THD Ratio as the displayed measurement at Data 1. Appropriate values of Data 1 Top and Bottom for most CD players are 0.1% and 0.001% or -60 dB and -100 dB, respectively. Check the Stereo Sweep check box instead of setting Data 2 to “Anlr.THD Ratio” so that both channels will be measured and plotted at each step of the frequency sweep. The second channel data will be in Data 3. Set Source 1 to Anlr.Freq A for System Two or Anlr.Freq for System One. Figure 13 shows the panels for this test.

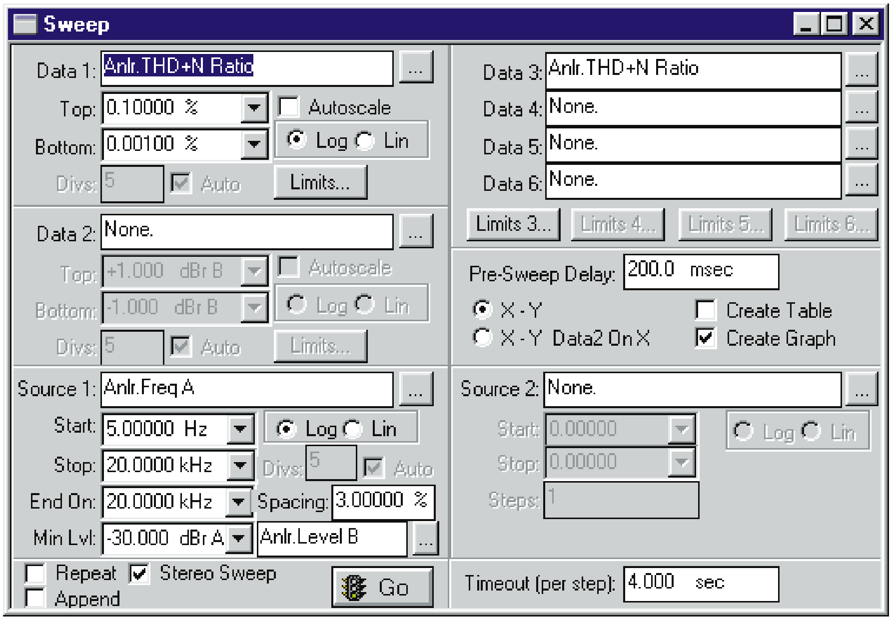


Figure 13 Distortion (THD+N) versus Frequency test set up panels - THDFREQ.at2 Data 1 (and 3) may also either % or dB.

Testing

Select the first track (lowest frequency) of the series of tracks recorded at 0 dBFS level. Press F9 and Play the CD. Watch the graph for plots of newly measured points on both channels and advance the player to the next track (or the next index point if the test disc used has multiple indexed sections within a track). If the Data Editor is displayed the readings can be seen accumulating. Following the final track in the series, you may save the test setup and results or optimize the display by right clicking the mouse and choosing Optimize Left. Figure 14 is a THD+N measurement using System One's 22 kHz low-pass filter. This test setup and data are stored as THDFREQ.at1 or .at2 in the distribution files available as a companion to this applications note.

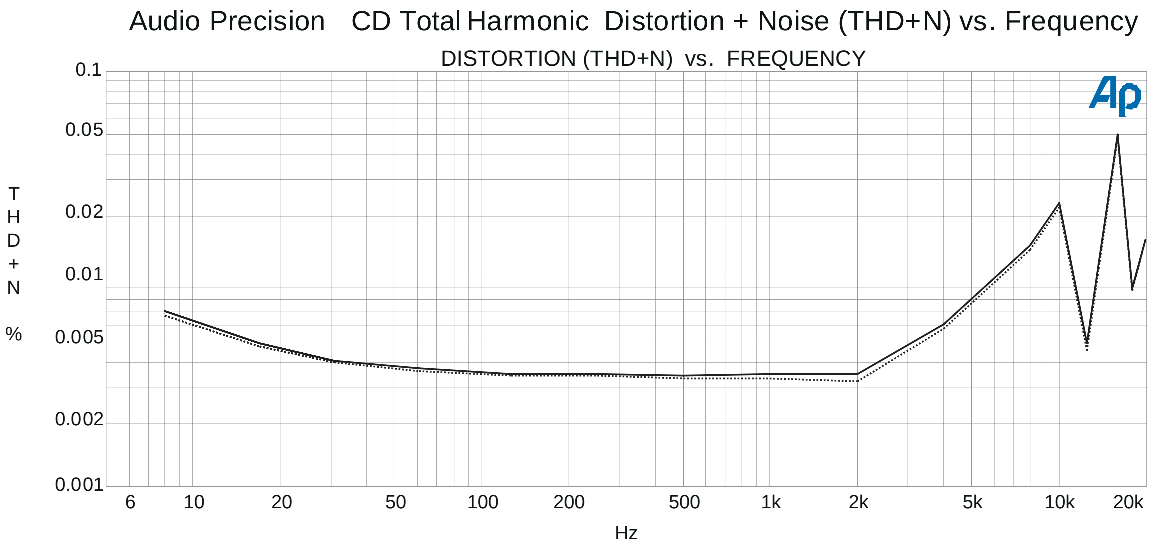


Figure 14 Distortion vs. Frequency graph (THDFREQ.at2)

Results

Note that the levels of THD+N obtainable from good CD players (0.0025% to 0.003%, or -90 to -92 dB) are lower than those measurable through a complete digital recording (A-to-D) and playback (D-to-A) cycle with professional 16-bit PCM or 16-bit consumer machines such as RDAT. This is because most of the signals on the test CDs never existed as an analog signal and thus never passed through the theoretical and practical imperfections of A-to-D conversion. Instead, the test CDs contain computer-generated signals whose total RMS quantization error is at the theoretical levels. Dither is not used on any of the high amplitude tracks on any of these test discs. The distortion measured thus results from theoretical quantization distortion and noise in the D-to-A conversion plus imperfections in the D-to-A conversion and non-linearity in the analog sections of the player.

Low Level Spectral Analysis

Another approach to quantization distortion measurement is to perform spectral analysis of the CD player's signal, thereby separating broadband quantization noise from discrete harmonic distortion. The ability of Audio Precision Systems to do an FFT analysis of the output of the Analog Analyzer Function Reading meter allows a very detailed look at the distortion components of a signal after the THD+N notch filter has removed the fundamental frequency. In LoLvlFFT.at1 and .at2 a THD+N measurement is set up in the Analog Analyzer Function Reading meter and the Digital Analyzer has Anlr Rdg Ampl selected for the channel 1 Source. The graph range of 60 to 160 dBFS is appropriate for the results of this FFT analysis. If the FFT is set for a number of spectrum averages the random noise component is reduced in the results so that the actual distortion or other interference components can be clearly seen even at extremely low levels.

Setup

The basis for the low level residual FFT tests LoLvlFFT.at1 and .at2 is the discrete tone THD test. The Analog Analyzer is set up as it is in the THDFREQ. Test—see Figure 13.

The additional key factors are:

a. Digital Analyzer is the FFT Spectrum Analyzer (fftslide in System One). The Ch 1 Source is set to Anlr Rdg Ampl and Ch 2 Source is None. This means the FFT analyzer will be looking at the output from the Analog Analyzer after the notch filter doing the THD+N analysis has removed the fundamental tone. This results in the input to the A to D converter being scaled by the peak value of the resulting distortion components (and noise) so that a “magnified” FFT of that amplitude range is produced. The remainder of the Digital Analyzer panel is set up in the same way as in the NoiseFFT tests above.

b. Data 1 should be set to Fft Ch1 Ampl with units and Top and Bottom values of -60 to -160 dBr A. Source 1 is set to the 20 Hz to 20 kHz range. The Lin (linear) check box is often chosen since harmonically related frequencies appear as easily seen multiples. To view a particular fundamental’s related harmonics you can change the Source 1 sweep range to scale conveniently the frequency harmonics of interest.

Last check the Stereo Sweep box at the bottom of the Sweep panel. In this configuration the FFT data are taken through the Analog analyzer notch filter sequentially one channel at a time. The Analog Analyzer switches inputs after the first channel's FFT is done and acquires the second channel FFT. If multiple acquisitions are requested, as for power spectrum averaging, all of the acquisitions are done before the Analog Analyzer switches channels.

Testing

This test is designed to view the frequency components of a single tone. From the discrete frequencies used for the THD+N versus frequency test select a tone. Play the selected track and acquire the FFT sample by using F9. If averaging is being used there will be additional acquisitions—see lower left corner of the APWIN window after the F9 button has been keyed.

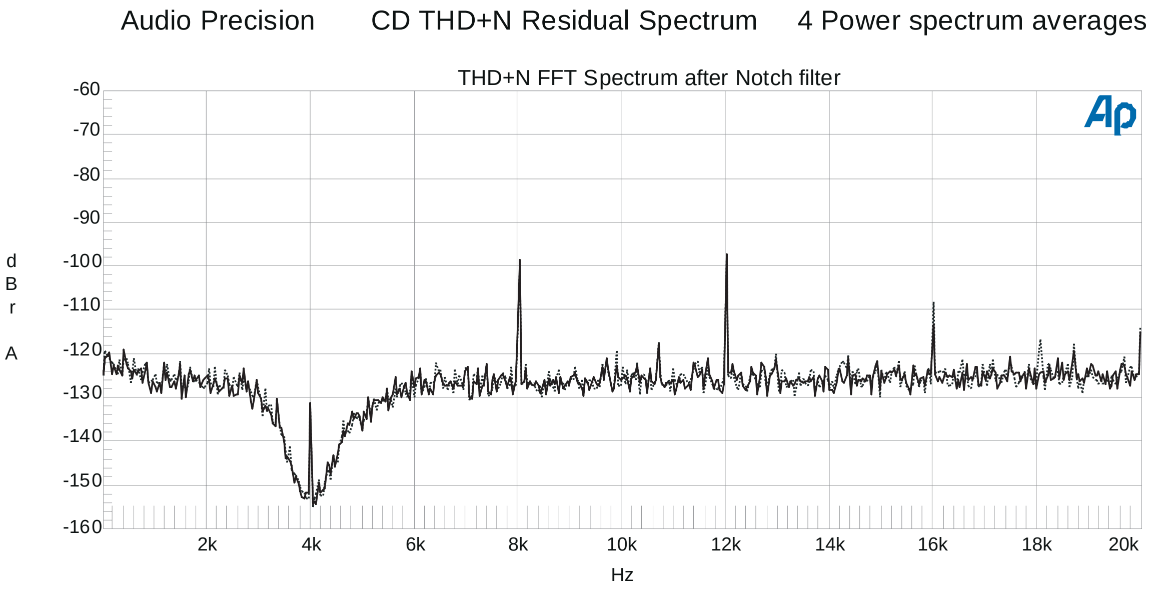


Figure 15 FFT (LoLvlFFT.at2) of the low level after the 4 kHz fundamental has removed in the Analog Analyzer.

Results

In Figure 15 the fundamental used for this test was located at 4 kHz. This can be easily seen in the data by the depression around that frequency. This is an “upside down” view of the filter skirts of the Analog Analyzer notch filter with the residual amplitude of the test tone seen at the center of the depression. Second, third and fourth and fifth harmonic components can be clearly seen to the right of the fundamental and above the noise floor of about -125 dBFS.

THD + N vs. Amplitude Measurements

Quantization distortion and noise are due to errors (“binary round-off”) when converting an analog signal amplitude to the nearest available binary number during the digitization process. If all other forms of distortion were negligible, quantization noise and distortion would set a floor of -98.08 dB for the 16-bit linear system of CDs. This floor would be constant in absolute magnitude across the entire dynamic range of the Compact Disc player. Some players show a rise in distortion at high signal amplitudes, most likely due to distortion in their analog amplifier sections.

Stereo distortion-versus-amplitude measurements can be made using track 18 (13 indexed segments) of the CBS disc or tracks 32 through 48 of the Philips SBC429 disc. These start with a 0 dBFS high amplitude signal and move downward to the -90 dBFS level. All have closely-spaced amplitudes at the higher levels and move to larger steps at lower levels. The CBS disc and Philips SBC429 discs have high resolution, with 10 dB steps from -10 to -90 dB.

Three different tests for accomplishing measurement of distortion (THD+N) versus amplitude are described here. The first of these uses only the Analog Analyzer hardware to determine the amplitude level changes of the tracks being played. A Level meter reading is used to increment the sweep based on measured amplitude changes. Since the Level meters have high bandwidth (greater than 500 kHz) measurements can be handicapped by frequency components above 22 kHz and the noise performance of the CD player being tested. The second variation uses the DSP hardware to control the amplitude sweep by using the DSP Bandpass function in the Digital Audio Analyzer to reduce sharply any noise and high frequency interference to detection of the audio tone. This variation requires the DSP version of System Two-System One with DSP cannot be used for this test variation. The third test variation can be used if the CD player has a digital audio output. The Dual Domain version of either System is also required. The amplitude changes of the CD test track control the sweep amplitude steps directly by using the digital audio signal without D-to-A conversion. Since both analog and digital versions of the same signal are simultaneously available direct measurement of the D-to-A and analog output sections of the CD player are possible.

The test tone frequency used can be a factor in the validity of test results. A synchronous relationship between signal and clock will not test linearity of every state of the player's D-to-A converter, since the points at which the signal waveform will be sampled repeat after a relatively small number of cycles. The non-synchronous relationships are theoretically preferable since the waveform "wanders" through a variety of timing relationships with the clock, causing every state of the converter to be exercised. Some test discs use a reference frequency slightly different than the traditional 1000 Hz frequency reference since the 1 kHz frequency is synchronous with the clock frequency at a ratio of 44.1:1. The Denon, for instance, uses a 1001 Hz reference tone to avoid the synchronous relationship. On single tone tracks both the CBS and the Denon discs use frequencies slightly off the ISO frequencies. For example, 10 kHz becomes 10,007 Hz.

Distortion across the 90 plus dB dynamic range of a Compact Disc player is impossible for many distortion analyzers to measure. This measurement requires holding the fundamental rejection notch fixed at the signal fundamental frequency even when the signal amplitude is as low as approximately 60 microVolts (90 dB below a typical 2 Volt maximum output). Other analyzers with a notch lock-up feature may not maintain the correct setting for the time required to complete this test. System One and System Two architecture makes this straightforward, since the notch frequency may be programmed at any desired frequency.

THD + N vs. Amplitude-Analog Analyzer only

Setup

Figure 16 shows the Analog Analyzer, Sweep, and Settling panels for a distortion versus amplitude test using the Analog Analyzer abilities.

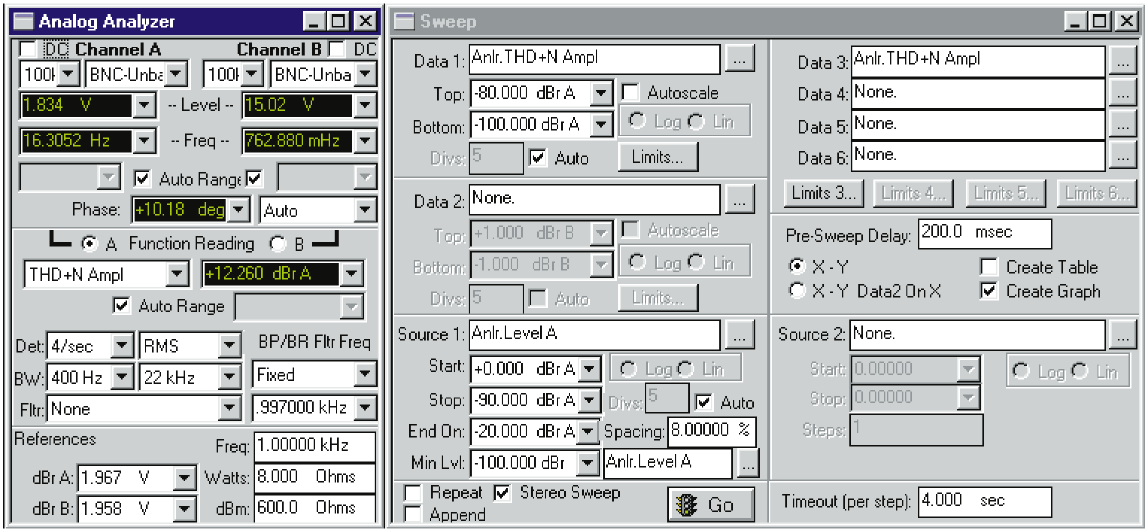


Figure 16 Set up panels for an Analog Distortion vs. Amplitude sweep

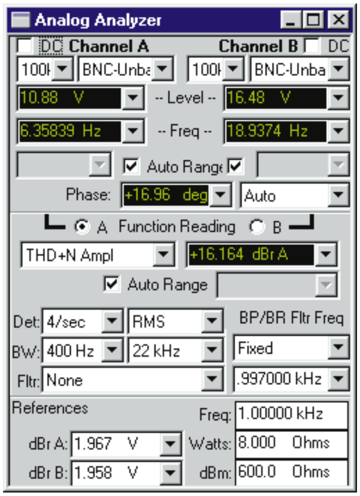
The key factors and parameters in making these measurements on Compact Disc players are:

a. THDAMPL.at1 or .at2 are supplied in the distribution files for this application note. In the expanded Analog Analyzer panel:

Select THD+N Ampl for the Function meter mode and RMS for the detector. For the Function meter absolute amplitude units (Volts, dBu, dBV, etc.) rather than the relative units % or dB are used. Measuring and graphing THD+N in an absolute unit (Ampl) will help separate the fixed quantization distortion mechanism and show steps in distortion due to errors that occur at particular bit levels. Both % and dB express distortion products relative to the total signal amplitude at each measurement point. At very low amplitudes in a digital or other noise-limited system, distortion expressed as a percentage approaches 100% (0 dB). This obscures the fact that the fundamental quantization distortion and noise mechanism (on linear PCM converter systems) is essentially independent of signal amplitude.

In this External Level sweep the test is driven by, and horizontal axis data obtained from, the Level voltmeter. The Level voltmeter does not have low-amplitude performance equal to the Function meter, but its resolution is maximized by selecting the 4/sec reading rate instead of Auto on the Detector line of the Analog Analyzer panel. The Level meter resolution at the 4/sec rate is about 3.2 microVolts in the lowest (80 milliVolt) range of System One and 1 microVolt in the lowest (40 milliVolt) range of System Two

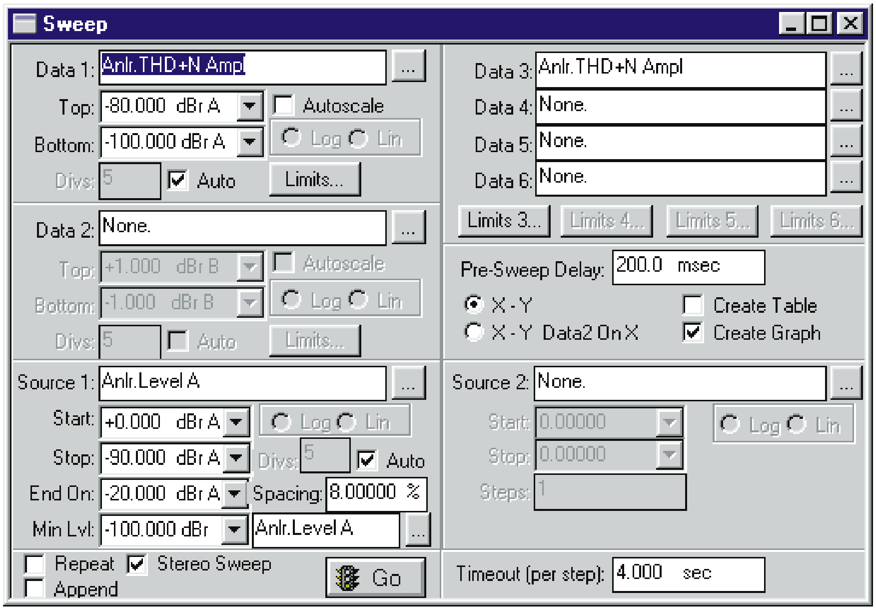
In the Function Reading meter select the 400 Hz high-pass and 22 kHz low-pass filters for minimum noise bandwidth. Set the BP/BR Fltr Frq to Fixed and set the frequency for the track sequence used—997 Hz for CBS track 18 and 1 kHz for Philips track 32.



At the bottom of the Analog Analyzer panel the References dBr values must be correct for the 0 dBFS level signal for valid horizontal axis graph values. Check that the levels appearing in the two Level meters during the 0 dBFS track are the same as those entered into the References dBr fields. (System One—Channel A Level meter and the single Reference dBr field.) If different, enter the measured maximum output amplitude of the CD player on channel A as the References dBr value near the bottom of the expanded Analog Analyzer panel. The default value is 2 Volts in the supplied test (THDAMPL.at1 or .at2)—typical for most consumer CD players. Do not use the F4 key while THD+N Ampl is selected in the Function Reading meter because an incorrect dBr reference will result. If you wish to capture (F4 key) the dBr reference from the first track of this test sequence you must change the Function Reading meter to Amplitude, play the 0 dBFS track (Trk 18.1 on the CBS, Trk 32 on the Philips), and take a reference with the F4 key. Reset the Function Reading meter to THD+N Ampl.

b. On the Sweep panel:

Select Anlr.Level A sweep mode at Source 1, with the Source 1 Start and Stop points implying a downward sweep. The most useful horizontal axis calibration is "dBr"—dB relative to maximum output. To accomplish this calibration, set 0 dBr for Start and -90 dBr for Stop. Check the Stereo Sweep check box for second channel in Data 3. Absolute amplitude calibrations are also possible for the horizontal axis. Most CD players with consumer level outputs have an output amplitude of about 2 Volts at maximum recorded signal level (0 dBFS). To calibrate the horizontal axis of the graph in Volts, select 2.0 Volts for Start and 50 microVolts for Stop. To calibrate in dBV(for typical unbalanced output consumer players), select +6 dBV for Start and -84 or -90 dBV for Stop.



In External sweeps, APWIN collects new data each time the Source 1 parameter changes to a new settled value which differs from the previous settled value by at least the Spacing value. Enter a Source 1 Spacing value (near the bottom of Sweep panel) only slightly smaller than the smallest percentage change in voltage between tracks. On the CBS, and Philips discs, the 0 dB to 1 dB step is the smallest change (approximately 10%) and a Spacing value of 8% or 9% is appropriate. The Spacing value should be set as large as possible to improve metering on the -90 dB track. Note that in External mode and a Stereo Sweep, APWIN re-checks the Source 1 value after acquiring the right channel data (Data 3) at each step. If the Source 1 value is not within the Spacing percentage of its earlier reading at that step, the right channel data will not be plotted. The system assumes that the track may have ended before the right channel reading was completed. In System One the Level meter repeatability can be a more difficult issue. System One Level meter resolution at the lowest input levels (80 mV range) is about 3.2 microVolts. With a level of -90 dBFS the input levels are nominally around the 60 microVolt level and sample-to-sample variations of one bit will just fall within an 8% Spacing value. Two-bit repeatability (6.4 microVolts) will fall within a 15% Spacing. This is not a problem with System Two with its improved Level meter resolution of about 1 microVolt per bit at 4 and 8 readings per second at the lowest input levels (40 mV range).

CD players have some finite value of noise output even when muted during their transitions from track to track. If possible, the minimum level (MinLvl) parameter on the Sweep panel should be set to a value above this “inter-track noise” output (as measured by the Level voltmeter of the System One or System Two in use) to prevent the measurement system from mistaking that noise as a legitimate low-amplitude signal track. In external sweep mode, APWIN suspends data acquisition and plotting whenever the signal level measured by the Level voltmeter drops below the minimum level value.

To determine the noise level from the player during transitions from track to track, observe the Level (in Volts) on the Analog Analyzer panel while operating the track advance control of the player. Enter a value a few dB higher than this inter-track noise level into the MinLvl (Minimum Level) field of the Sweep panel. (In System One use a value of 4 to 8 microVolts above the average noise value.) On players with rapid track change, it may be difficult to obtain a good reading of this value. When this is the case, observe the Level reading while playing the -90 dB track (index 13 of track 19 on the CBS disc, and track 46 or 48 on the Philips test discs). Since it is desired to measure this track, enter a value a few dB below the measured level into the MinLvl field. (In System One this setting should be about 4 microVolts lower than the reading.)

c. On the Settling panel:

Set the Level Tolerance to 15% and the Level Floor to 1 microVolt (4 microVolts in System One). In System One this permits the Level meter measurements to be accepted as settled even with one or two bits of Level meter reading variation with a

-90 to -100dB signal.) The THD+N Ampl line should be set to a 5% tolerance. Delay should be enough to allow any mechanical or switching instability to settle. A 500 milli-second amount is useful at noisy low levels. Delay may also be used to prevent readings between tracks or if the CD player track selection mechanism is slow. Some CD players have been measured in which the “inter-track noise” is actually higher than the recorded signal on the -90 dB (or even -80 dB) tracks. If the minimum level (MinLvl) is set higher than this value, those tracks cannot be measured. Alternate test techniques using the DSP bandpass filter (next test section) or a CD digital output (“THD+N vs. Amplitude—Digital Input controlled Sweep”) to control the sweep steps are the best approach to this problem. If restricted to the Analog Analyzer only, Settling Delay may be used to disable data acquisition for a sufficient period each time the CD player is sequenced to the next track, permitting the MinLvl to be set to a value lower than the player output on the -90 dB track. Set the Level meter Delay on the Settling panel to a value somewhat longer than the time required by the CD player to provide output on the next track when the track advance control is operated. Each time APWIN finds the Source 1 value to be settled it invokes this Settling Delay before it attempts to find settled data. Thus, even if APWIN accepts the noise level between tracks as a legitimately settled Source 1 value, the Settling Delay prevents immediately taking data. The next track then begins with a new value of Source 1 amplitude, the settling algorithm discards the value from the inter-track noise, and the algorithm Starts again to obtain settled measurements on the desired signal from the track. Settling Delay is also invoked after changing channels on a stereo test, so the measurement time per track will be increased by approximately twice the Settling Delay value.

Testing

Initiate the test by F9 or a Go button while playing the 0 dBFS—track 32 on the Philips disk, 18 on the CBS. The first data is taken when two new line listings appear in the Graph legend. This is more easily seen on the Data Editor panel (pg. 3). After the data has been taken for both channels the next track or index can be selected.

Again wait for both channels to be read, continue with the next pair of readings at the next lower amplitude step. At a certain point one of the data channels may not plot or indicate a “B” in the Data Editor. This indicates that the data is not valid. This is the lowest practical amplitude that acceptable readings can be made in that channel. The sweep will not automatically stop, you must press either a Stop button or the Esc key. To replace the Source 1 horizontal axis (first column) data with the exact values from the CD test disc see the section “Replacing Horizontal Axis Data with Actual Amplitudes”

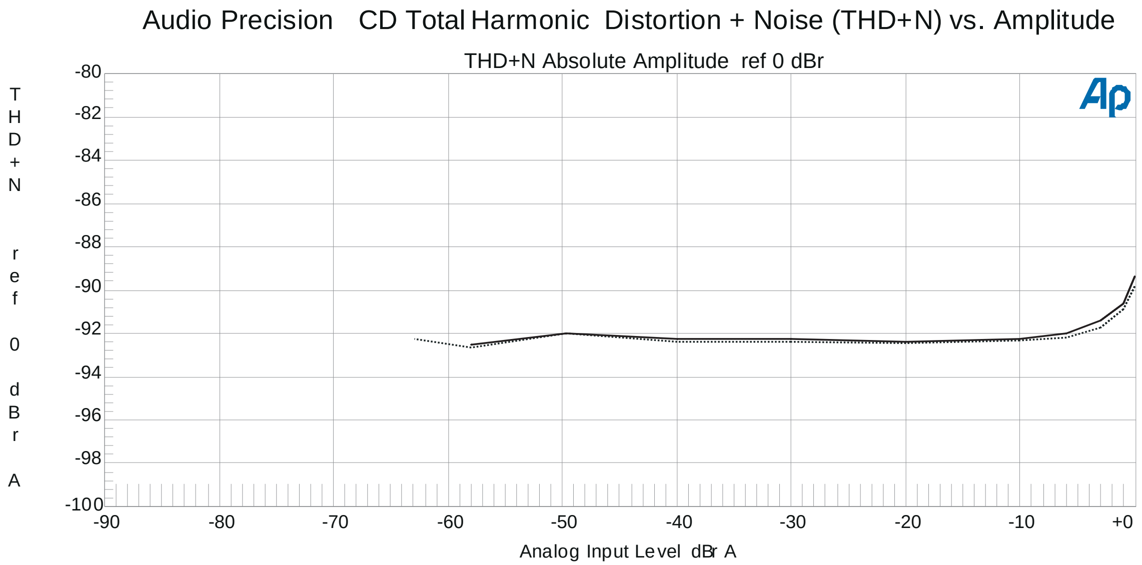


Figure 17 Graph of THD+N distortion vs. Amplitude - THDAMPL.at2

Results

Figure 17 shows the THD+N distortion from the 0 dBFS level down to the point that is the limit for the Level meter to detect the change in Amplitude within the Settling panel tolerances. Increased distortion near the maximum amplitude in the analog output of the CD player is related to circuitry after the D-to-A converter. At low levels noise interferes causing the meters to be inaccurate. Where strong high frequency noise above the audio range exists the Level meter can be inaccurate since it has bandwidth to above 500 kHz.

THD + N vs. Amplitude—DSP controlled Sweep

CD players with large amounts of clock signal leakage may prevent External Level sweeps to the -90 dB area, since the Level meter is a wideband voltmeter and will "see" the clock signal the same as the recorded signal. CD players have been measured with clock signal as high as -60 dB, preventing distortion vs. amplitude and linearity measurements at low amplitudes using analog techniques. These high frequency components and the general noise level in the wide band meter contribute to the inability of the Level meter to control the sweep in the previous setup when signal levels are low. Better sweep control can be realized by using the DSP audio analyzer available in DSP and Dual Domain versions of both Systems. The DSP based analysis of the signal using Bandpass mode provides a very tightly controlled bandwidth allowing accurate determination of the signal tone well below the wideband noise floor. The Bandpass measurement specification for the DSP implemented filter is considerable sharper than the Analog analyzer bandpass filter. The DSP narrow band filter is a 10 pole with a bandwidth of 5.3% of the frequency whereas the analog bandpass filter is a class II 1/3 octave 4 pole. The DSP signal is not used to produce the analog measurements of distortion but only to control the sweep and determine the signal amplitudes plotted on the horizontal axis.

Setup

This test variation is only applicable to System Two either with DSP or Dual Domain. This test setup is supplied as THDAmpl2.at2. The setup for Analog Analyzer and Sweep panels for the DSP controlled variation is very similar to the Analog only version (THDAMPL.at2). The addition of the Digital Analyzer panel and appropriate changes to the Source 1 area of the Sweep panel are the principal differences. See Figure 18

a. The Digital Analyzer panel requires the selection of a DSP program before any panel settings can be done. Select DSP Audio Analyzer in the Analyzer window. This digital analyzer is configured to make most measurements that can be done in the analog analyzer in either the digital domain or with analog audio signals through the A-to-D converters. In this case our interest is in tightly controlling the bandwidth so that the sweep can be well controlled to levels well down in the noise. At Input select Low BW (1x) A/D and Bandpass from the Function Reading meter drop-down list. The default settings for the BW (bandwidth) and Detector can remain. Set the BP/BR Fltr Freq to Fixed and set the frequency window to the frequency of the track used—997 Hz for the CBS and 1 kHz for the Philips.

b. Change the Sweep panel Source 1 settings so that Source 1 is DSP Audio Anlr.Bandpass. Start and Stop sweep amplitudes can be about the same as before or down a little farther to -95 dB. For Min Lvl select the DSP Audio Anlr.Bandpass as the source and -100 dB dBr A for the Min Lvl amplitude.

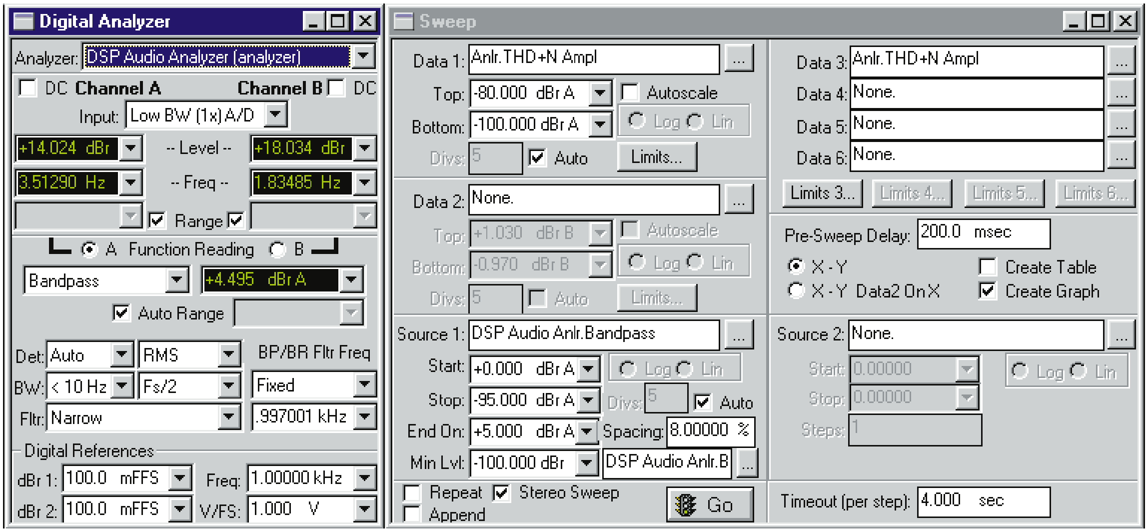


Figure 18 Panels for the DSP controlled version of a distortion vs. amplitude sweep - THDAmpl2.at2.

Testing

As in the test above initiate the test by F9 or a Go button while playing the 0 dBFS—track 32 on the Philips disk, 18 on the CBS. The first data is taken when two new line listings appear in the Graph legend. After the data has been taken for both channels the next track or index can be selected. Again wait for both channels to be read, select the next amplitude and take another pair if readings. The sweep will continue to take data down to the last track of the sequence at about a -90 dB level (CBS track 18.13, Philips track 46). The sweep will not automatically stop, you must press either a Stop button or the Esc key.

Results

Fig. 19 shows the results from measuring a 5 disc carousel CD player. Compare with the Analog Analyzer Level meter controlled sweep in Figure 17. The Data Editor indicates horizontal axis values differ less than 0.1 dB from the CD manufacturer's data sheet down to the -90 dBFS point where the reading error is still less than 2 dB. The additional upper lines between -80 and -90 dB are from tracks 47 and 48 from the Philips disc which have dither added. The effect is clear—less of a "zig-zag" from the undithered signal but a higher noise level about the same as the undithered signal at -70 dB.

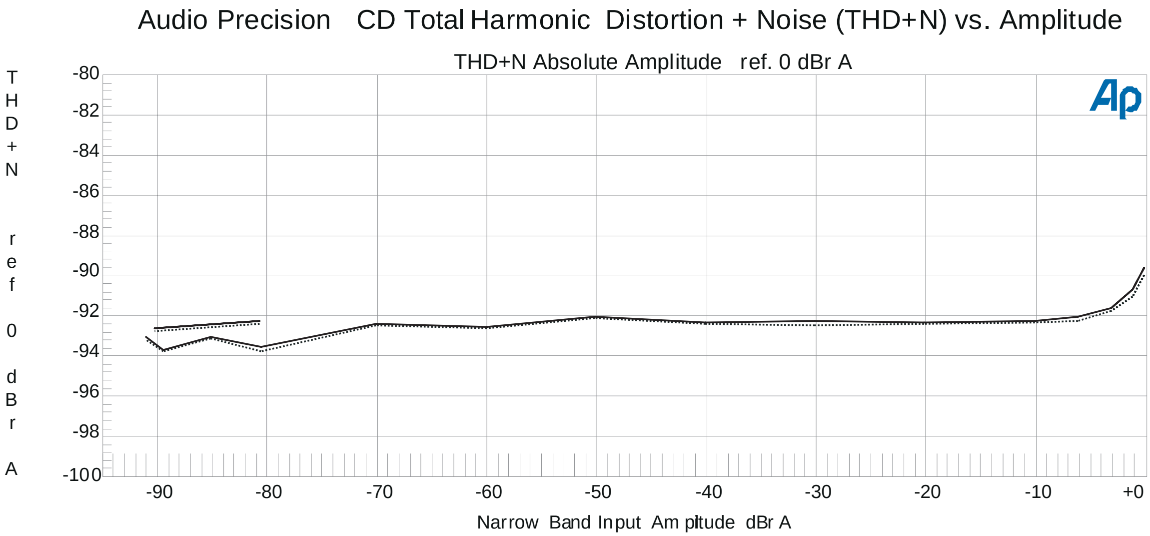


Figure 19 Graph of DSP bandpass filter controlled sweep of distortion vs. amplitude.

THD + N vs. Amplitude—Digital Input controlled Sweep

The above two tests both use the analog signal to determine the horizontal axis of the sweep. If the CD player has a digital output direct access to the digital data is possible using the Dual Domain System One or System Two. The digital data can be used to increment the Source 1 horizontal axis data more accurately. Since this data is not subject to the noise present in the analog signal or to D-to-A converter non-linearity the Sweep panel Source 1 can be set to look at a DSP Digital Audio Analyzer Level meter to increment the sweep.

Setup

THDAmplD.at1 and at2 also use the Analog Analyzer panel settings unchanged from their condition in THDAMPL.at1 or .at2. The additional panels used are the Digital Analyzer and Digital I/O panel.

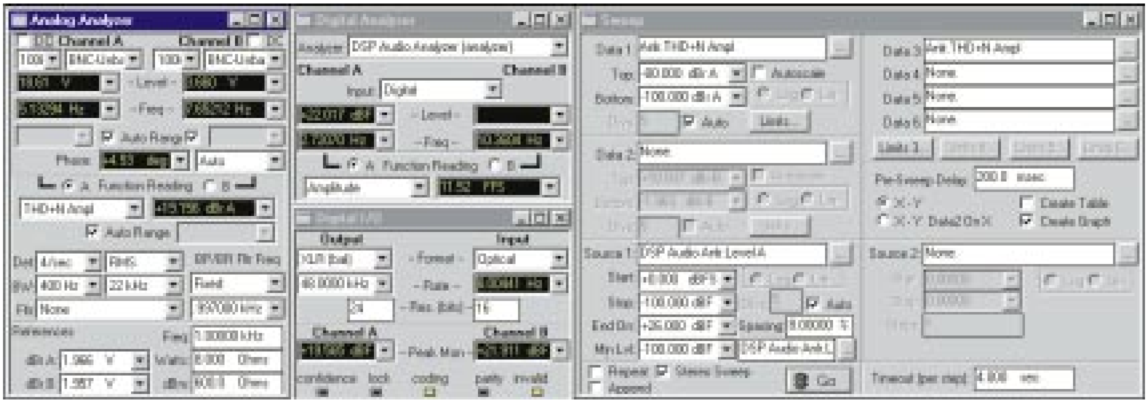
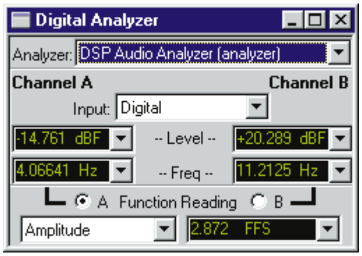
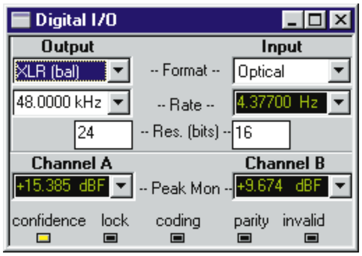


Figure 20 Panels for digital audio input control of distortion vs. amplitude sweep

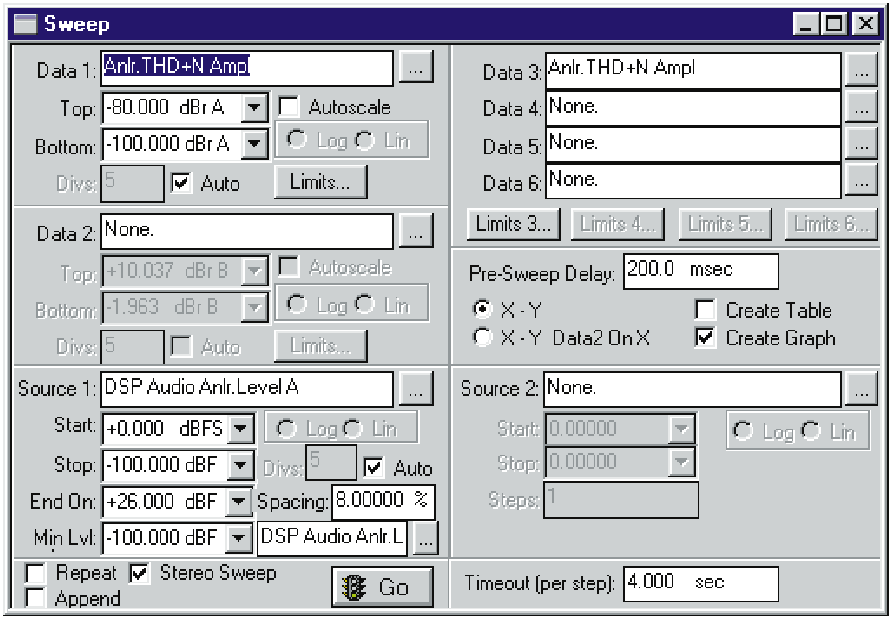
a. The Digital Analyzer panel requires the selection of a DSP program before any panel settings can be done. Select DSP Audio Analyzer in the Analyzer window (Digital domain audio tester (genanlr) in System One). The Source should be Digital (System Two only). The remainder of the panel setup can be ignored since only the digital Level meter is used.



b. Select the digital signal input appropriate to the type of digital output from the CD on the Digital I/O panel Input field. In System Two there are three likely choices: Select BNC (unbal) if you have an SPDIF source—you will require a BNC to Phono (RCA) adapter. Select Optical for the TOSlink connection. If an AES3 interface is available use either XLR(Bal) or the BNC(unbal) input as needed. On the Digital I/O panel in System One set the Input Format to Serial and set the Serial Type to AES/EBU & SPDIF. The optical TOSlink connection is active in this setup also.



c. Select the DSP Audio Anlr.Level A for Source 1 on the Sweep panel (Genanlr.Level A or B in System One). Set Start to 0 dBFS and Stop to -95 dBFS for the same sweep range as in the above tests. Set MinLvl to -100 dBFS and set End On to some unrealistic high number such as +5 dBFS to prevent stopping the sweep. 8% Spacing is still appropriate.



Testing

Initiate the test by F9 or a Go button while playing the 0 dBFS—track 32 on the Philips disk, 18 on the CBS. The first data is taken when two new line listings appear in the Graph legend. Select the next level or let the CD run. The sweep will continue to take data down to the last track of the sequence at about a -90 dB level (CBS track 18.13, Philips track 46). The sweep will not automatically stop, you must press either a Stop button or the Esc key.

Replacing Horizontal Axis Data with Actual Amplitudes

The end results of the distortion vs. amplitude and linearity tests include a horizontal axis consisting of the actual amplitudes recorded on the test disc. If we use the Analog Analyzer Level meter to control the sweep there is no theoretical way in which these amplitudes can be accurately measured, since they are recoverable only through the CD player that is being tested and which may be to some extent non-linear. The distortion (vertical graph axis) will not be in error since distortion is measured with the wide-range Function Reading meter. However, the Source 1 Level readings in the Analog Analyzer may be plotted a few dB in error horizontally from the -80 dB and -90 dB lines on the graph. The Analog Analyzer Level voltmeter performance is specified only down to 5 milliVolts in System Two and 10 milliVolts in System One. It may have several dB of linearity error at the 60 microVolt level. Wideband noise also contributes error since the Level meter has a bandwidth in excess of 500 kHz. The CD player D-to-A converter non-linearity is also a major factor. Using either the DSP bandpass analyzer variation of the test (THDAmpl2.at2) or the digital audio output sweep control test (THDAmplD.at2 or .at1) provide much greater horizontal data accuracy, but leaves the CD player D-to-A converter non-linearity.

Since the test CD track amplitudes are stated by the CD manufacturer, the Data Editor may be used to manually substitute them for the measured values. For the THD vs. Amplitude tests this is method to achieve greater accuracy in the horizontal values of the graph. It may not be needed if either the DSP or digital input version of the THD versus Amplitude tests is used. In the Linearity tests Source 1 horizontal axis data replacement is required to produce the actual versus measured plot of amplitudes.

To review the Source 1 amplitude errors select the Data Editor at the conclusion of a test. In the Data Editor the Source 1 (Anlr.Level A) data is in the first column, Channel A (normally left channel) data is in the second column (Anlr.THD Ampl) and Channel B data in the third column (also Anlr.THD Ampl). The second (Data 1) and third columns (Data 3) were measured with the Function Reading meter which has specified accuracy to much lower levels than the lowest available from CD players. At the higher amplitudes, typically down through the -60 dBFS track (about 2 milliVolts), the first column should match the values given by the test CD manufacturer except for any systematic offset due to not setting the dBr REF value correctly on a 0 dBFS track. Increasing errors will typically be seen at lower levels.

Data Editor

	0 = DSP Audio Ar	1 = Anlr.THD+N Ampl	2 = Anlr.THD+N Ampl
0	+0.000 dBr A	-89.968 dBr A	-89.576 dBr A
1	-1.000 dBr A	-91.033 dBr A	-90.700 dBr A
2	-3.000 dBr A	-91.782 dBr A	-91.619 dBr A
3	-6.000 dBr A	-92.226 dBr A	-92.075 dBr A
4	-10.000 dBr A	-92.334 dBr A	-92.269 dBr A
5	-20.000 dBr A	-92.401 dBr A	-92.313 dBr A
6	-30.000 dBr A	-92.467 dBr A	-92.291 dBr A
7	-40.000 dBr A	-92.378 dBr A	-92.334 dBr A
8	-50.000 dBr A	-92.118 dBr A	-92.075 dBr A
9	-60.000 dBr A	-92.647 dBr A	-92.557 dBr A
10	-70.000 dBr A	-92.467 dBr A	-92.378 dBr A
11	-80.590 dBr A	-93.762 dBr A	-93.557 dBr A
12	-85.240 dBr A	-93.114 dBr A	-93.066 dBr A
13	-89.460 dBr A	-93.762 dBr A	-93.659 dBr A
14	-91.240 dBr A	-93.211 dBr A	-93.066 dBr A

Data Editor

	0 = DSP Audio Ar	1 = Anlr.THD+N Ampl	2 = Anlr.THD+N Ampl
0	-0.132 dBr A	-89.968 dBr A	-89.576 dBr A
1	-1.131 dBr A	-91.033 dBr A	-90.700 dBr A
2	-3.132 dBr A	-91.782 dBr A	-91.619 dBr A
3	-6.133 dBr A	-92.226 dBr A	-92.075 dBr A
4	-10.133 dBr A	-92.334 dBr A	-92.269 dBr A
5	-20.137 dBr A	-92.401 dBr A	-92.313 dBr A
6	-30.137 dBr A	-92.467 dBr A	-92.291 dBr A
7	-40.138 dBr A	-92.378 dBr A	-92.334 dBr A
8	-50.135 dBr A	-92.118 dBr A	-92.075 dBr A
9	-60.078 dBr A	-92.647 dBr A	-92.557 dBr A
10	-70.135 dBr A	-92.467 dBr A	-92.378 dBr A
11	-80.601 dBr A	-93.762 dBr A	-93.557 dBr A
12	-85.218 dBr A	-93.114 dBr A	-93.066 dBr A
13	-89.438 dBr A	-93.762 dBr A	-93.659 dBr A
14	-91.039 dBr A	-93.211 dBr A	-93.066 dBr A

Figure 21 The Data Editor first column shows the readings from the test before (left) and after (right) correction. Data from the CD documentation is typed into the Source 1 fields.

To manually correct the data, The measured values in the first column can be replaced with the values from the test CD documentation. With the mouse, highlight the cell in the first column that needs to be corrected and type in the documented value. Digits beyond 0.01 dB are not significant. When the first column data has been corrected, re-save the test.

For more automatic operation, a procedure can be run which will replace the sweep horizontal axis (Source 1) measured values with the theoretical values furnished by the test disc manufacturer. A general purpose procedure for changing the horizontal axis data (first column—Source 1) is provided as EditCol1.apb. See Appendix 2 on CD procedures for a description.

Linearity

Linearity is a measurement of actual output amplitude versus the known amplitudes on the test disc. The same sets of decreasing amplitude tracks used for distortion versus amplitude may also be used for linearity measurements with either System One or System Two. Furthermore, additional tracks on the CBS and Philips discs provide still more measurement capabilities at very low amplitudes.

After running the test the graph horizontal axis data must be replaced with the correct data from the CD test disk documentation. This data provides the expected output level for perfect linearity in the CD player.

Since deviation from perfect linearity is the desired end measurement, the data should be further operated upon by the Compute Linearity function. Compute Linearity first calculates a best-fit straight line (using the least-squares method) to a specified section of the data. It then calculates the deviation of every data point from that straight line. In these tests the amplitudes within the -6 dBFS to -40 dBFS range are used for the reference since linearity deviation of only around 0.01 dB is typical of CD player output in this amplitude range. The result is a graph of deviation from perfect linearity that may normally be displayed with a high resolution of only a few dB. This provides much better indication of the actual CD player linearity than attempting to interpret a graph with a 90 dB range.

Full-Range Linearity Tests

The structure of the linearity tests supplied with distribution files is very similar to the THD versus amplitude tests. Instead of measuring distortion our interest in a linearity test is comparing the actual output amplitudes with the ideal amplitudes as listed in the data for the CD test disc tracks used. These tests acquire duplicate measured amplitude data on both the vertical and horizontal axes. The horizontal (Source 1) data in the first column must be replaced with the correct levels from the CD data sheet. The CD test track amplitudes are substituted for the corresponding measured amplitude steps by using the Data Editor. A procedure is also supplied for doing this more easily—EditCol1.apb.

Setup

There are again three variations (two for System One) of these linearity tests depending on the method used to control the sweep: Linarty.at1 or .at2—uses the Analog Analyzer only; Linarty2.at2—uses the DSP Digital Audio Analyzer in Bandpass mode to control the sweep; and LinartyD.at1 or.at2—uses the CD digital output to control the sweep. In all three cases the panels are set up very similarly to the panels in the THDAmpl tests. Refer to the setup descriptions above for details. The differences in these tests are:

a. The Analog Analyzer Function Reading meter is set to Bandpass mode to minimize the effects of noise and high frequencies. Note that a detector reading rate of 4/second rather than Auto is critical. At 1 kHz, Bandpass mode will produce an approximate 20 dB reduction of noise compared to Amplitude mode with the minimum 22 kHz bandwidth, since the bandpass filter Q of approximately 4.32 results in a bandwidth of about 230 Hz when tuned to a 1 kHz center frequency. The BP/BR filter is set to Fixed with the frequency set for the CD track used—997 Hz for CBS track 18 and 1 kHz for Philips tracks 32 to 46.

   Reference dBr values previously set in Amplitude mode or with the Level meter cannot be used in Bandpass mode, since the bandpass filter may have a gain error compared to Amplitude mode or the Level meter. This reference error in System Two is typically 0.1 dB with a specification limit of 0.2 dB (up to 0.5 dB in System One). To set the 0 dBr Reference, be sure the Function Reading meter unit is set to dBr, play the first (0 dBFS) track in the test CD sequence, and press the F4 key.

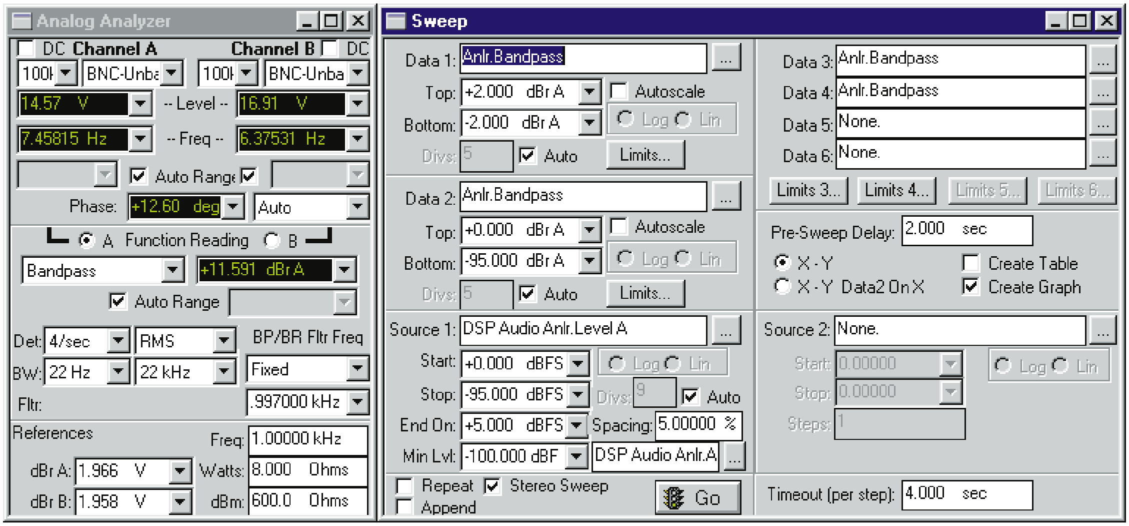


Figure 22 Set up panels for linearity testing. Changes are made to the THDAmpl tests as shown in all three versions of the linearity tests.

b. The tests that use the Digital Analyzer and the Digital I/O panels use the same panel settings as the THD vs. amplitude tests of the same type.

c. Sweep panel—Two different approaches for displaying the data can be found in the supplied test files. Either Sweep panel configuration can be used.

The first case—Linarty.at2 is an example—has the Sweep panel Data 1 set to Anlr.Bandpass with Top set to 0 dBr A and Bottom set to -95 dBr A (dBr in System One). Check the Stereo Sweep box after setting Data 1. The test data is seen on the graph during the test as a line progressing from the upper right corner down to the lower left corner. After the test is run and horizontal data corrected Compute Linearity converts the data into a nearly horizontal line at the top of the graph. To view the linearity data in great detail select the right mouse button and Optimize Left. This expands the vertical axis to display the full range of the linearity error.

The DSP controlled sweep test—Linarty2.at2—uses a duplicate data approach. The Sweep panel Data 1 (Anlr.Bandpass) is set to +2 dBr for the Top value and -2 dBr for the Bottom value. Data 2 (also Anlr.Bandpass) Top is set to 0 dBr and Bottom is set to -95 dBr. At this point check the Stereo Sweep box. The result is duplicate data on Data 1 and 2 (Channel A) and Data 3 and 4 (Channel B) but with different vertical axis scaling. As the test progresses data is seen on the graph as a line progressing from the upper right corner down to the lower left corner. Initial test results are scaled on the graph right axis. After the test the Horizontal data is corrected in the Data Editor and the Compute Linearity function applied to Data 1 and Data 3 for a linearity error view of the data. The expanded scale on the left axis is used to read the error.

d. The Compute Linearity drop-down should be set to compute Data 1 and Data 3 with linearity range set to -6 dBFS Start and -40 dBFS Stop values. Compute Linearity should not be done until the first column (Source 1—horizontal axis) data has been replaced with the amplitude data for the CD tracks used. See “Replacing Horizontal Axis Data with Actual Amplitudes” above.

Testing

Play the 0 dBFS reference—track 32 on the Philips disk, 18 on the CBS and take a new dBr reference value by pressing F4. Initiate the test by pressing the F9 or a Go button. Since the graph scale has been set for a narrow amplitude range for display after linearity has been computed the data will not appear for most of the test. Instead, set APWIN to pg. 1 and coordinate the CD track changes with the data as it collects in the Data Editor. Select the next level or let the CD run. Note that it is faster to manually step the CD to the next amplitude. The sweep will continue to take data down to the last track of the sequence at about a -90 dB level (CBS track 18.13, Philips track 46). The sweep will not automatically stop, you must press either a Stop button or the Esc key.

Next go to the Data Editor panel and replace the first column values with the corrected amplitudes from the test CD documentation. The EditCol1.apb procedure may be used to expedite this process.

Last select Compute Linearity from the Compute drop-down list and press the Compute and Close button.

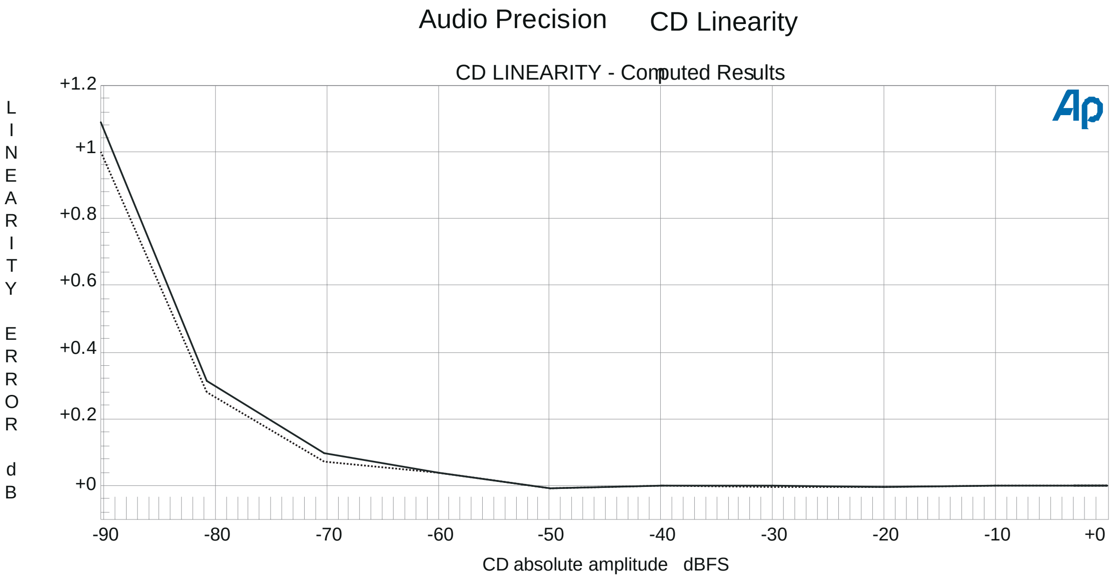


Figure 23 Graph of Analog Level meter controlled sweep from Linarty.at2 Horizontal axis (first column) data has been replaced with the actual values and Compute Linearity done.

Results

The Fig. 23 full-range linearity graph shows the increasing non-linearity at low levels with high resolution amplitude scaling on the vertical axis. The "zig-zag " of a non-dithered signal is evident. Left vertical axis scaling may need to be changed for variation in CD player performance—right-button mouse menu and select Optimize Left.

Linearity Tests with Dither

Dither is a low-amplitude noise signal of at least ±1/2 LSB amplitude. While dither reduces the ultimate signal-to-noise ratio of the system, it effectively reduces distortion (improves linearity) at low amplitudes and extends linear operation below the undithered theoretical limit. Signals below 1/2 LSB in peak amplitude would never be converted (recorded) in a non-dithered system. With dither, signals at arbitrarily low amplitudes are still converted and recorded since the dither acts to assure the LSB is continually being toggled. On a frequency domain basis, dither can be thought of as spreading the quantization noise across the spectrum, rather than having that energy all concentrated at harmonics of the signal frequency. In practice, most digitally recorded program material contains dither, either via deliberate addition, or simply from noise inherent in the analog equipment (pre-amplifiers, consoles, etc.) used prior to the A-to-D conversion

Track 19 on the CBS disc contains four dithered signal levels for linearity testing at low amplitudes. Three are the same amplitudes as the last three sections of undithered track 18—at -70.31, -80.77, and -90.31 dB. The fourth signal on track 19 is at a -100 level. Dither is 1/2 LSB with a uniform probability distribution.

The Philips disc adds two additional low-level amplitude signals with dither after the conclusion of the stepped amplitude sweep without dither (Tracks 32 through 46). These tracks (Tracks 47 and 48) are at -80.70 and -90.31 dBFS levels and are clearly seen in figure 19 as the additional upper pair of lines between the -80 to -90 points on the graph. These tracks are not at a low enough level to see the significance of dither to a signal below the theoretical noise floor.

Track 19 of the CBS disk and the dithered low amplitude signals on the Philips disk can be tested using a modification of the full range linearity tests described above. The most accurate is Linarty2.at2. The LinartyD.at2 or .at1 test is not useable down to the -100 level since the presence of dither is a requirement for the existence of this amplitude.

"Fade-to-Noise" Low Level Amplitude Linearity

The CBS test disc is unique among those listed in that it contains a low level "Fade to Noise" track with dither added. Track 20 contains a 500 Hz signal, which begins at a -60 dBFS level, and then fades linearly with time to a -120 dBFS level. The dither has a triangular probability distribution. The signal fades linearly from -60 dB to -120 dB during 30 seconds (2 dB per second rate) and then repeats a second time. This is the only CD track known to Audio Precision which permits linearity measurement with better than 10 dB resolution at low amplitudes.

This track cannot be directly measured with an External Level sweep selection at Source 1 External Level sweeps use amplitude changes as measured by the Level voltmeter to drive the data acquisition process. The Level voltmeter has a bandwidth of greater than 500 kHz, unaffected by the bandpass filter or any other filter selection in APWIN. On the lower portions of the fade-to-noise signal on track 20, the signal is below the wideband noise level and the Level meter will not detect changes. Instead, this track is measured with an External Time test. Since the signal fade rate is linear with time, the time information may then be used to compute the signal amplitude. Procedures that do this amplitude vs. time measurement and then calculate the equivalent linearity are supplied with the test files as CBS20_S1.apb for System One and CBS20_S2.apb for System Two. See Appendix 2 CD Test Procedures for a description of these procedures.

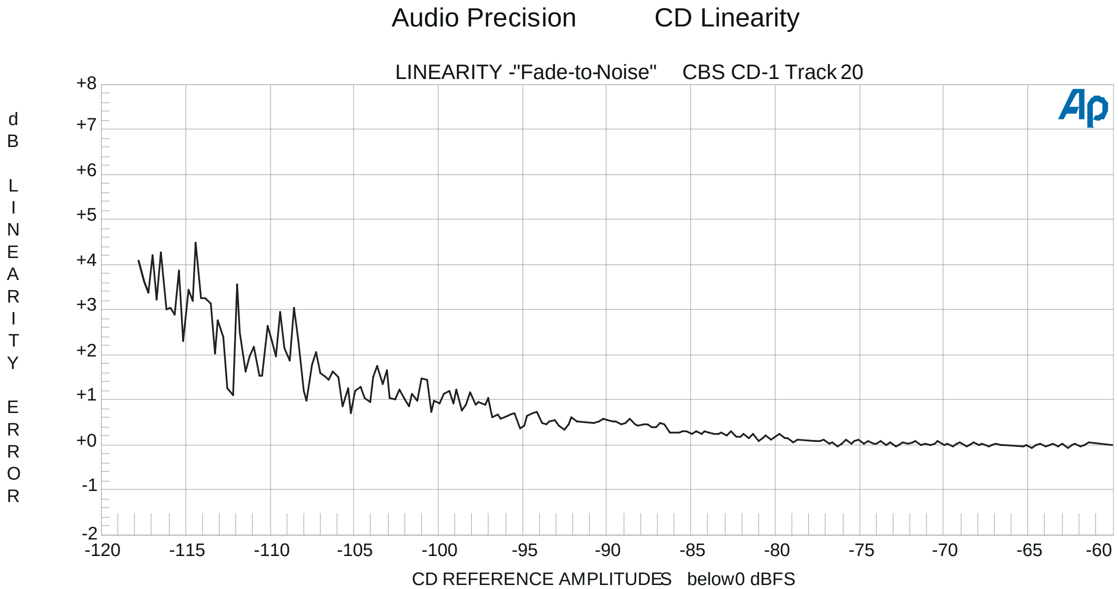


Figure 24 “Fade-to-Noise” linearity test result from CBS20_S1.apb using track 20 of the CBS disc. More than 200 measurements are graphed.

InterModulation Distortion

System One or System Two with intermodulation analysis options (Sys 1 IMD, Sys 2 S2-IMD) installed can measure most of the intermodulation distortion test signals on the discs discussed. With IMD signals of fixed frequency and amplitude, a “spot” measurement of both channels is appropriate. This provides an integrated measurement of all IMD products within the analysis bandwidth. This is most easily accomplished by selecting Single Point at Source 1, even though the generator will not be used. Single Point automatically uses the Data Editor display format even though Create Graph may be selected on the Sweep panel, and produces a single point measurement on one or both channels.

Setup for SMPTE/DIN/IEC IMD Measurements

Figure 25 shows the panel setups for measuring a SMPTE-like or DIN-like pair of signals with one low-frequency tone (40 Hz to 500 Hz) and one high-frequency tone (2.5 kHz or higher), with the amplitude ratio of the signals anywhere from 5:1 to 1:1 (low-frequency amplitude to high-frequency amplitude). Example tracks are 13 index 1 on the CBS, and 54 on the Philips disc, which are standard SMPTE 60 Hz and 7 kHz mixed 4:1 with maximum at 0 dBFS. Track 40 and 41 on the Denon disc use a very different frequency pair: 250 and 8020 Hz, again with a 0 dBFS maximum. Track 30 index 1 on the NAB disk is also a standard 4:1 60 Hz and 7 kHz but is recorded 6 dB below maximum level. Figure 25 is an example of the measurements made with track 54 of the Philips CD. This single point sweep setup is supplied in the distribution files as SMPTSPOT.at1 and .at2 in the distribution files.

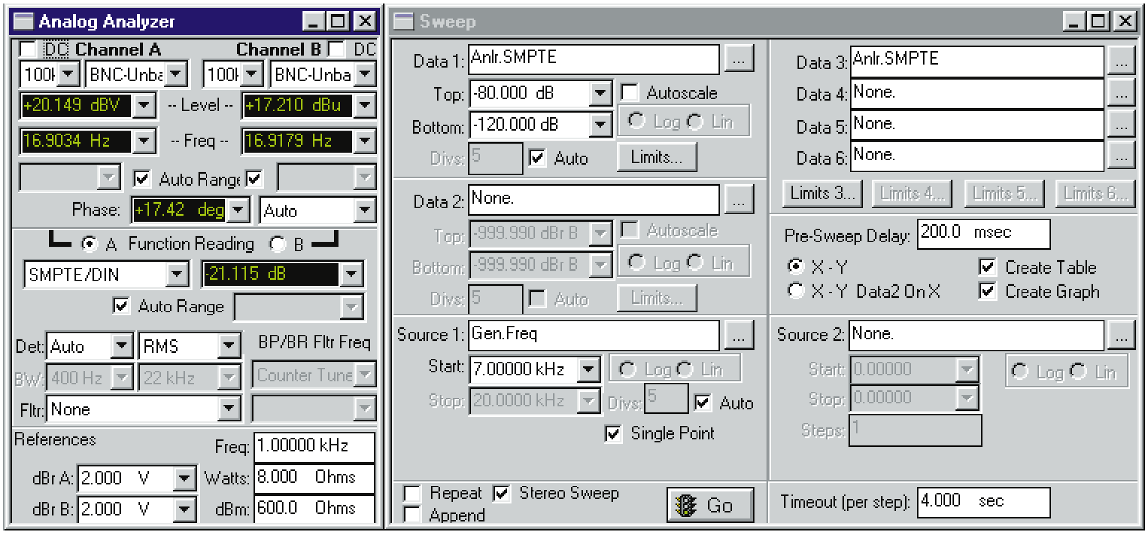


Figure 25 Set up panels and single-point test result of a SMPTE intermodulation distortion test - SMPTSPOT.at2

SMPTE—Spectral Analysis of Intermodulation Products

The distribution file SmpteFFT.at1 or .at2 is an example of using the System's ability to analyze a signal after the Function Reading meter filters have acted. In this case the residual distortion and noise components can be seen down to extremely low levels since the full-range of the FFT digital analyzer is applied to the signal remaining after the Analog Analyzer has removed the fundamental test tones.

The panel setup for this FFT has several interesting features. In System Two the Digital Analyzer panel should have the FFT spectrum analyzer (fft) loaded. Set up the Input field to Low BW (/4) A/D and the Sample Rate field set to 32 kHz. This sets up the actual sample rate to 8 kHz. With FFT length of 16384 point this will produce excellent resolution of the 20 to 720 Hz band set up in the Sweep panel Source 1 area. Using the Blackman-Harris window set Subtract Avg in the adjacent window. Just below the Avg field is set to 4. This will take 4 sets of data and average the data together thus lowering the variability of the random noise component of the displayed spectrum.

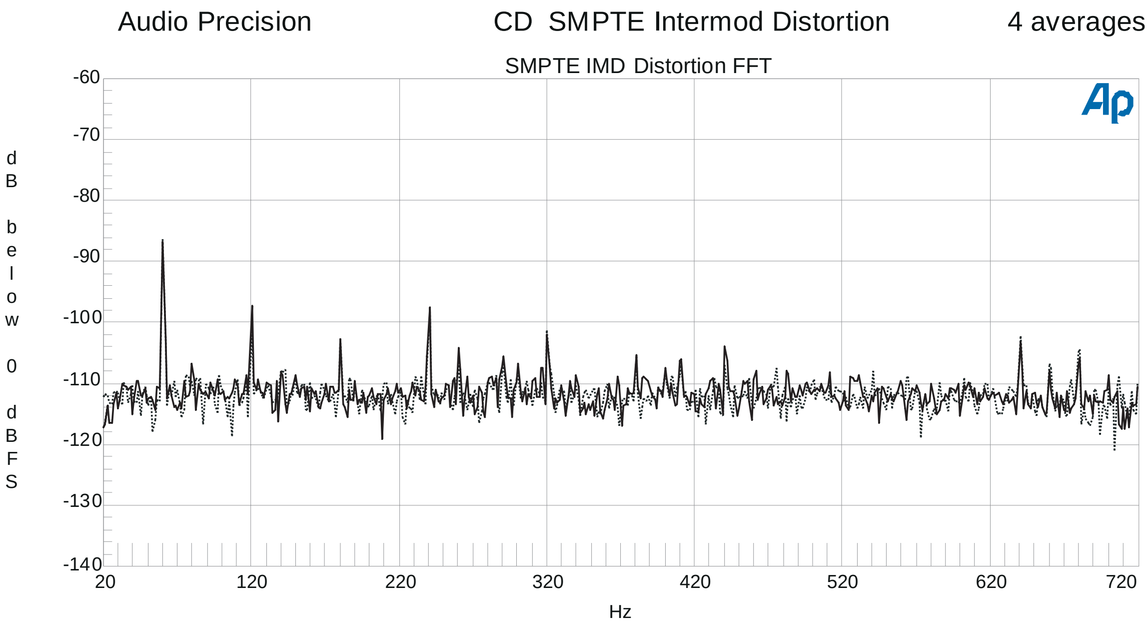


Figure 26 FFT of low level components after the Analog Analyzer SMPTE IMD function analyzer has removed the 60 Hz and 7 kHz tones.

CCIF and DFD IMD Measurements

Figure 27 has the panel setup for CCIF-type measurements with two equal amplitude, closely spaced tones at a relatively high frequency. Sometimes called twin-tone this test is usually done with two frequencies near the upper frequency bandwidth limit of the system under test. A maximum frequency difference of 1000 Hz is allowed. The low frequency second order intermodulation product (difference tone) is analyzed by use of a low pass filter. This test does not include the third order symmetrical products around the twin tone frequencies in the measurement result. For the DFD (Difference Frequency Distortion) version change the Function Reading meter to the DFD choice. A DFD test will typically produce a number about 6 dB better due to the 6.02 dB calibration difference (IEC 268).

CCIFSPOT.at1 or .at2 is a single point test for CCIF measurements. The Function Reading meter can be changed to DFD mode to adjust for the calibration difference in that standard. This setup is supplied in the distribution files as CCIFSPOT.at1 or .at2 in the distribution files.

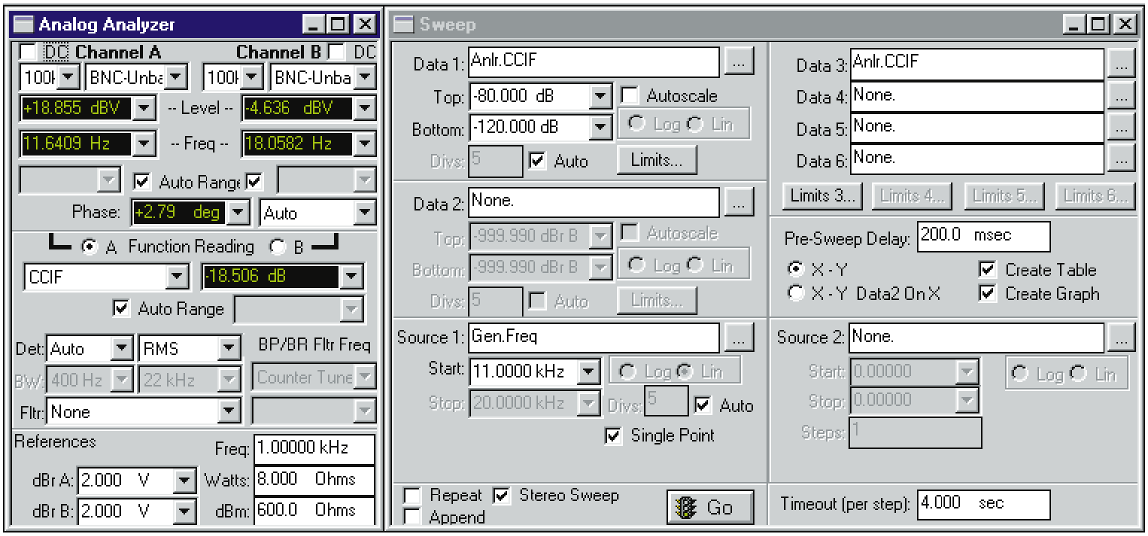
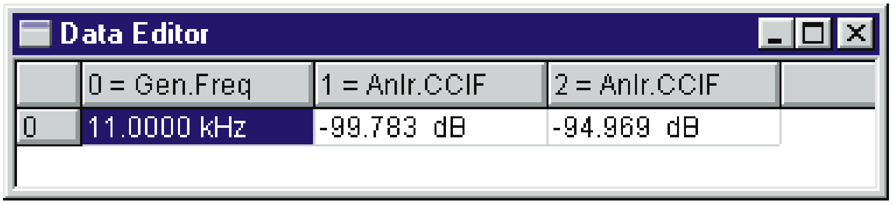


Figure 27 Set up panels and single point test of a CCIF twin-tone intermodulation distortion test.

Testing

CD sources providing 11 and 12 kHz at a 1:1 ratio are—track 13 index 2 on the CBS disc; 43 (left) and 44 (right) on the Denon disc. On the Nab disk track 35 provides 11 and 12 kHz at a -6 dBFS level. Track 55 on the Philips disc has 19 and 20 kHz frequencies at 0 dBFS.

Results



Spectral Analysis of Harmonics, Intermodulation and Noise

More information from several of these specialized tests is available by doing a spectral analysis of the signal using the DSP based FFT analyzer. Dynamic range and twin-tone (CCIF/DVD) inter modulation distortion (IMD) are examples of tests where the distortion and noise components can be usefully seen in detail at very low levels. The distribution files test SpectFFT.at1 and .at2 are general purpose FFTs using the Digital Analyzer. The test uses a 48 kHz sample rate for a two-channel FFT of the spectrum including the fundamental and residuals.

Results

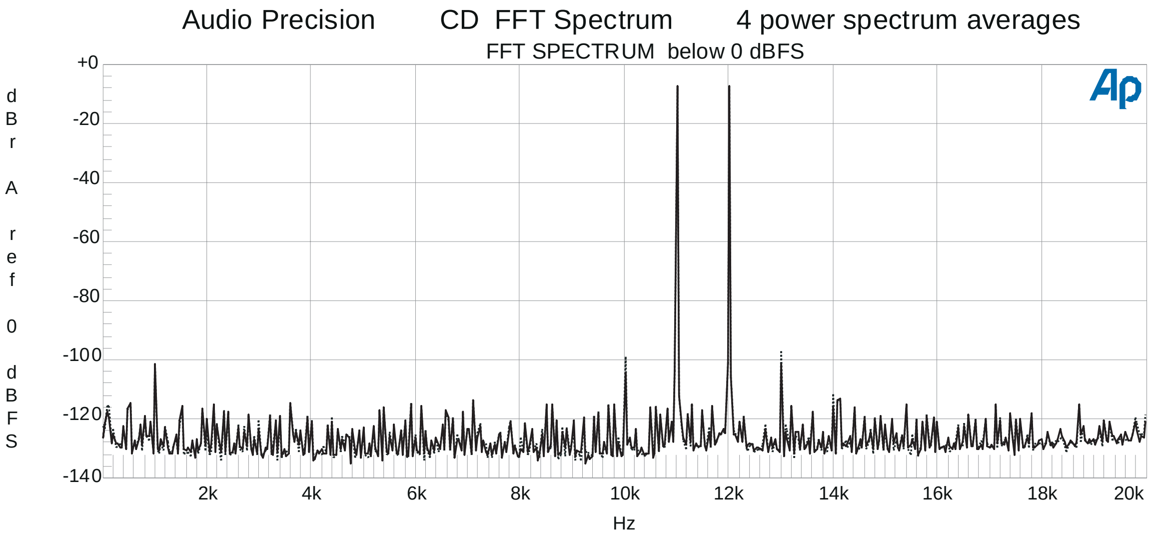


Figure 28 shows the results of SpectFFT.at2 used with a twin tone IMD test. The two tones are clearly seen at 11 and 12 kHz. IMD tones at 1 and 2 kHz spacing can also be seen at -90 and below. Odd order IMD products can be seen at -90 and below; when 11k and 12k are f1 and f2 the odd order harmonics would be 10k + 13 k, 9k + 14k, etc. The graph data can be made relative to the peak value of the test tones by using Compute Normalize and setting either the 11k or 12k value to 0 dBr.

Phase Measurements

Interchannel phase may be measured and displayed as Data 1 or Data 2. This will produce a vertical axis display of the degree unit. Simultaneous collection of the phase data may also be done with other measurements that use a frequency sweep such as frequency response or THD+N vs. frequency. In these cases the phase data could be taken by using Data 2 after the Stereo Sweep box has been checked as in the FR&Phase test. See Appendix 1 on setting up stereo sweeps.

Most CD players now use dual D-to-A converters with very small phase error between the channels. The test PHASE.at1 or .at2 displays phase (5 degrees full scale from a glide tone frequency sweep. This can be further optimized by mouse right-button click and select Optimize Left which expands the graph scaling to better display the results. The dual-purpose test FR&Phase measures both frequency response in stereo and interchannel phase from a glide tone in a single sweep.

The phase measurement may give an indication of whether the player has a single D-to-A converter multiplexed between the channels or two separate converters, though a multiplexed player with time delay compensation will obscure that fact. If a single D-to-A converter without delay compensation is used, the amount of measured phase shift at 20 kHz can indicate whether the player is a single sampling (44.1 kHz clock), double oversampling (88.2 kHz clock), or quadruple oversampling (176.4 kHz clock) design. A 44.1 kHz multiplexed unit with no other significant sources of interchannel time or phase delay will show about 82 degrees phase shift at 20 kHz. This number derives from a delay of one-half clock period (11.338 microseconds at the 44.100 kHz clock frequency). At the 50 microsecond period of a 20 kHz signal, the Phase meter expresses the result as (11.338/50.000)*360 or 81.632 degrees. An 88.2 kHz clocked converter may show about 41 degrees at 20 kHz (5.7 microseconds delay), and a 176.4 kHz unit about 20 degrees (2.8 microseconds). The delay between channels will cause loss of high frequency response if the two channels are summed for monaural reproduction, as happens often in broadcasting.

Setup

Figure 29 shows the Sweep and Settling panels for the inter-channel phase measurement, assuming that a glide tone sweep track will be used.

The setup for a glide tone phase test is based on the glide tone frequency response setup as discussed in the High Resolution Frequency Response Measurements section. Panel setup is illustrated in Fig. 3. Referring to the FRQRSPG.at2 test the changes made for the Phase versus frequency test are on the Sweep panel: set Data 1 to Anlr.Phase and Top and Bottom values of ±5 degrees respectively. These are the same parameters that are entered into Data 2 in the FR& Phase.at1 or .at2 tests.

Testing

Use the glide tone sweep used for the frequency response test. CBS track 11, Denon track 65, NAB track 7 or Philips track 5 or 6.

Results

Figure 29 is a test graph made with track 5 of the Philips disc, displaying inter-channel phase of a small portable oversampling player. This test setup and data is stored as PHASE.at1 or .at2 in the distribution files. On most players measured, the departure from linear phase difference is less than five degrees at high frequencies.

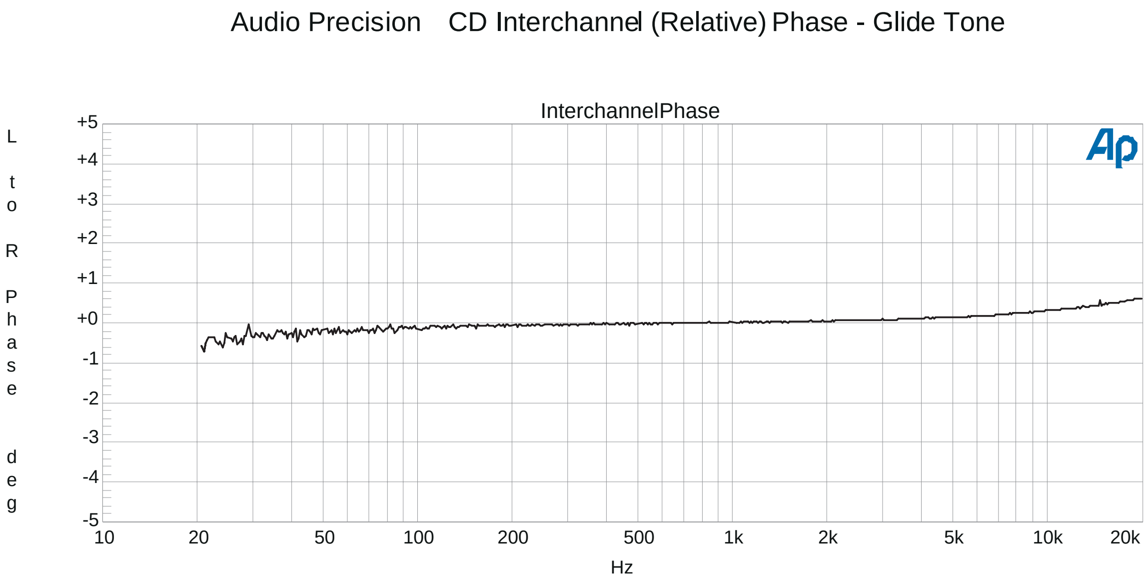


Figure 29 Simple inter-channel phase test - PHASE.at2. This test can be easily added to a glide-tone frequency response measurement - see FR&Phase.at1 or at2.

Stereo Separation

Stereo separation can be measured using any CD track or series of tracks with test frequencies recorded at maximum level on only one channel. CD sources are CBS CD-1 track 2 and 3, Denon tracks 18 through 27 and Philips tracks 66 through 73. In the CBS disc the tones are not in monotonic order and consequently require index selections out of order. The Denon disc alternates left and right channel signals so that every other track must be selected for a sweep. The Philips disc tracks are in ascending frequency order but there are only four frequencies available.

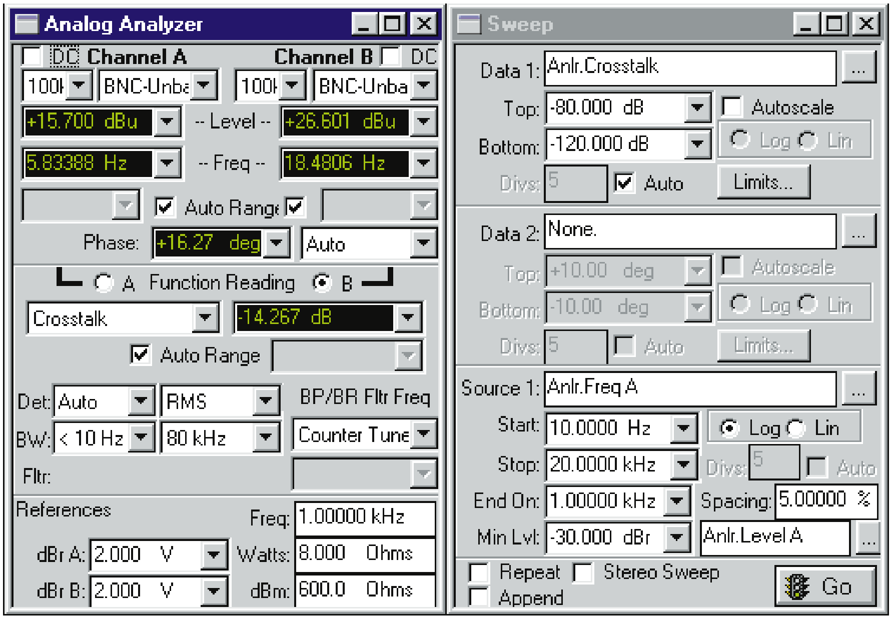
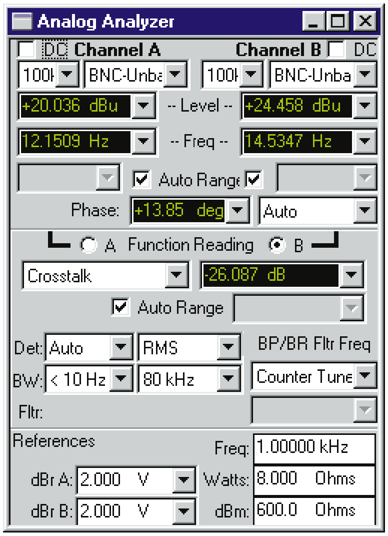


Figure 30 shows the panels for a separation test. SEP_L-R.at1 or .at2 (SEParation_Left-Right) in the distribution files has the test setup shown.

Setup

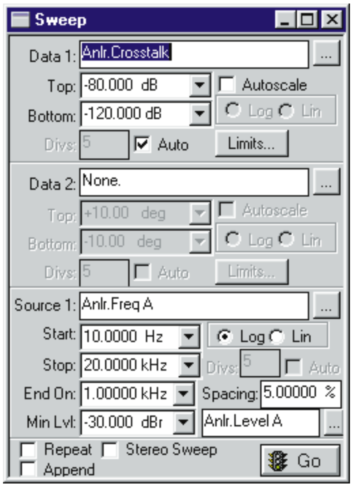
a. On the Analog Analyzer panel select Crosstalk from the Function Reading meter drop-down list and set the Function Reading meter channel to the input which does not have signal recorded

(B channel in this case). Assuming that the CD player left channel is connected to the systems A input and right channel to the B input, select B Crosstalk while playing tracks recorded on the left channel only. In Crosstalk mode, the Function Reading meter in Bandpass mode is connected to the selected channel, while the Level meter and frequency counter are connected to the alternate channel. The frequency counter can thus steer the bandpass filter to the frequency of the recorded signal on the driven track, the Level meter measures the amplitude of the driven track, and the Function Reading meter measures the non-driven track with the bandpass filter selectivity discriminating against wideband noise.



The BP/BR must be set to Counter Tuned to permit the filter to be steered by the frequency counter.

b. On the Sweep panel select Anlr.Crosstalk for Data 1 and select the dB unit. This directly measures the difference in amplitude between the Function Reading and Level meters. The level in the driven channel is the reference.



The Source 1 settings are nearly identical to all the other External Frequency sweeps across a series of fixed-frequency tracks described earlier.

c. Select an Amplitude Tolerance on the Settling panel such as 10% (1 dB) to provide rapid settling on the noisy signal on the non-driven channel.

To measure separation from right to left, change the channel selection for the Function Reading meter on the Analog Analyzer panel from B to A. This test is supplied as SEP_R-L.at1 or at2. To display both measurements on the same plot change the channel from B to A, check the Append box at the bottom of the Sweep panel and test (F9 or GO).

Testing

The Separation tests present some problems since some CDs do not present the single channel tones in a consistent frequency order. The easiest is the Philips disc where tracks 66 through 69 are played in order for Left-to-Right measurements and 70 through 73 are played for Right-to-Left measurement. On the CBS disc index changes are required to access the tracks in the correct order. The Left-to-Right test must be done by playing track 2 index 2 first followed by index 2.1, skip 2.2, then play 2.3 and 2.4. Similarly, the Right-to-Left test is done by first playing track 3 index 2 followed by 3.1 and then 3.3 and 3.4.

On the Denon disc track changes are required: For Left to-Right start with 26, then in order, tracks 22, 18, 20, 24. For the Denon Right-to-Left test first play 27, then in order, 23, 19, 21, 25.

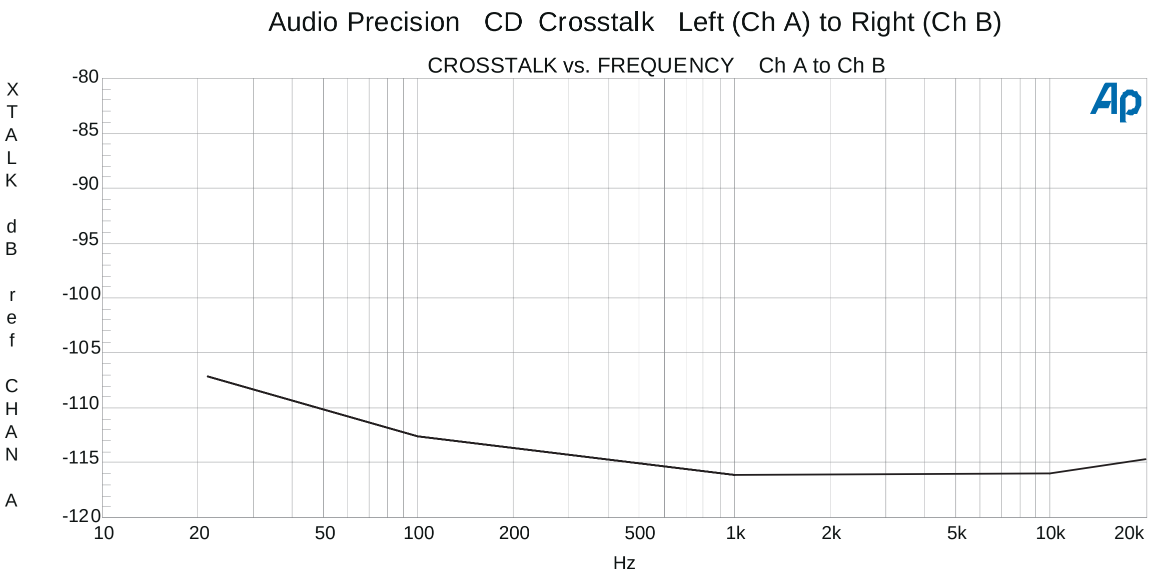


Figure 31 is a graph of left-to-right separation using the CD left channel only signals.

Results

Since a CD is not based on magnetic media the low frequency crosstalk mechanism of analog tape recorders caused by low frequency magnetic fields being read by adjacent tracks is not present. However, AC power mains related frequencies can increase readings at low frequencies. Testing for electronic crosstalk is sometimes done as a single frequency test at 10 kHz or higher since normally electronic crosstalk increases with frequency. Complex factors can influence crosstalk so it is still worthwhile to investigate the whole spectrum.

Frequency Accuracy

The measured frequency accuracy of most tracks, test discs and CD players is quite high. Figure 32 shows the panel setup and measurement result of a CD player frequency accuracy test using the System's relative frequency measurement capability. The Data Editor shows the directly measured frequency in column 2 and the difference in percent from the reference frequency in column 3. The reference frequency value is in the References Freq. field in the section at the bottom of the expanded Analog Analyzer panel. This test is supplied in the distribution files as FREQACUR.at1 or at2. The CBS disc contains track 10 with a precision 19997 Hz signal. The Denon disc track 24 and NAB track 5 are 19,999 Hz. The Philips SBC429 is 20 kHz. The same test could be used with other frequencies by changing the value in the References Freq. field to correspond to the CD data for the track in use. It is also useful for future reference to set the Start frequency field in the Sweep panel so that the frequency reference is in the Data Editor in column one. Other CD tracks that may be used are listed in the legend in the FREQACUR. tests.

Setup

a. On the Analog Analyzer panel enter the reference frequency from the CD data sheet for the track to be used in the Analog Analyzer References Freq field and as the Start value for Source 1 in the Sweep panel.

b. On the Sweep panel select Anlr.Freq.A at Data 1 with delta % as the units (use Anlr.Freq for System One). This expresses the measured frequency in terms of percentage deviation from the References Freq value. Select the same measurement again for Data 2 but use Hz as the unit to include the actual measured frequency in the data. Select Single Point at Source 1 for a single point measurement. Enter the reference frequency from the CD track used in the Source 1 Start field so that the reference frequency is also part of the test data. This setup then lists the reference frequency, the measured frequency difference in per cent and the measured frequency in Hz in a single line of data in the Data Editor panel when the test is run.

c. On the Settling panel enter a tight Tolerance such as 0.001% for Frequency A (Frequency in System One).

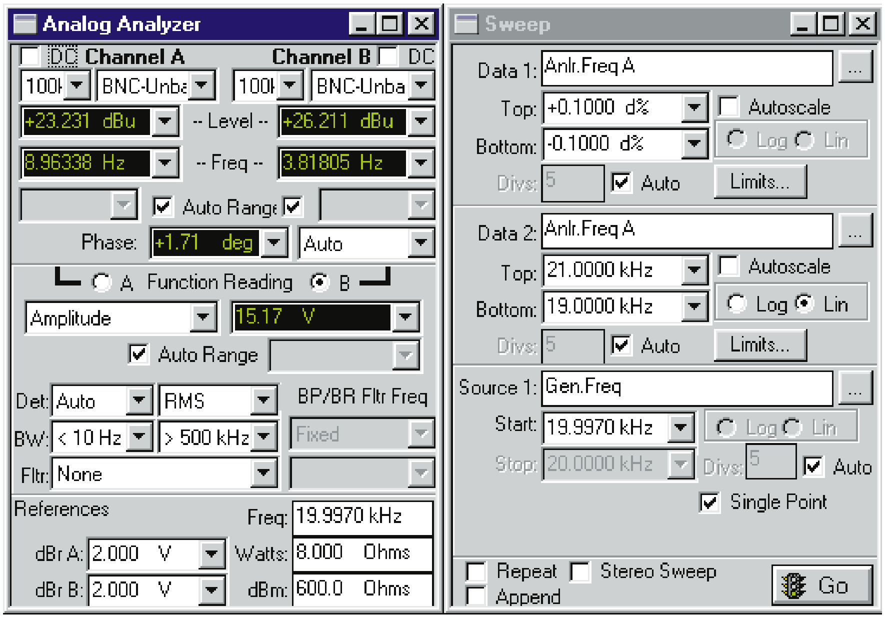


Figure 32 Set up panels and single-point test results for frequency accuracy - FREQACUR.at2.

Testing and Results

Play the CD track and press F9. Figure 32 is the result of this test on a common CD player. The accuracy of the internal reference oscillator of the CD player is the variable in this test. These are usually crystal locked but, damage or circuit failure is possible. Page 2 of the test has been set up with two bar-graphs to display the frequency and the frequency delta percentage.

Wow And Flutter Tests

The fundamental physical mechanisms that produce wow and flutter in analog tape machines and turntables do not exist in CD players. Even if there were instantaneous short-term variations in the speed of the disc rotation, they would not translate into pitch (frequency) changes since data is actually clocked into the D-to A converter(s) at a quartz-crystal-based rate. However, the EIAJ has detailed a test procedure for wow and flutter. Many discs have tracks intended for use as a source for the 3 kHz or 3.15 kHz frequency used for Wow and Flutter tests of other devices. The CBS CD-1 track 14, Denon track 91 and NAB track 72 provide the 3150 Hz tone used for this test.

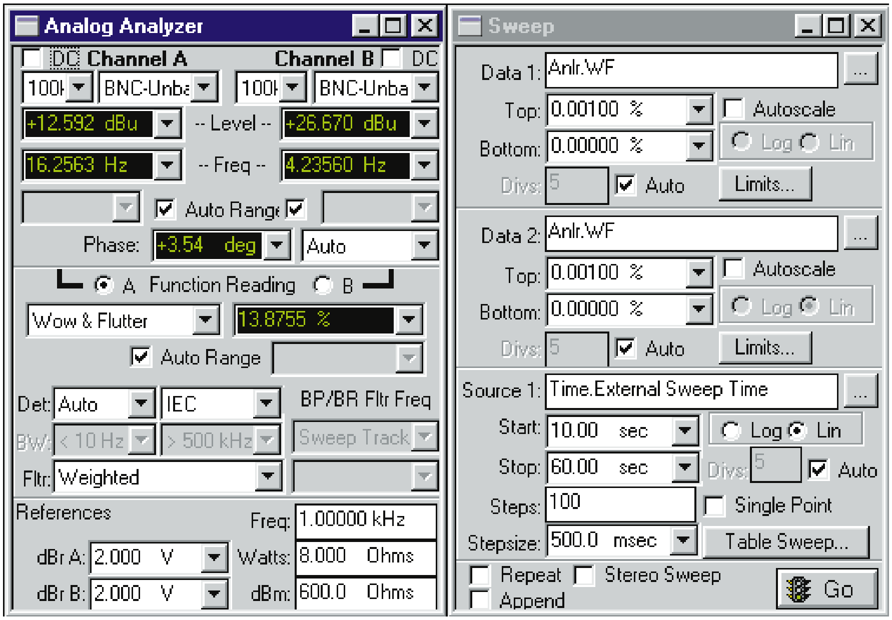


Figure 33 Wow and Flutter test panels

Setup

Figure 33 shows the panels for WOW&FLUT.at1 or .at2 in the distribution files which makes the measurement as specified by the

EIAJ standard. This standard refers to the IEC 386 standard (peak detector, weighted) for wow and flutter measurement specifications. WOW&FLUT.at1 or .at2 is a time chart recording for 20 seconds. The EIAJ specifies measurements to be made for at least 5 but not more than 30 seconds. Note that the long time constant required of a wow and flutter detector will produce a decaying transient at the beginning of most wow and flutter tests. It is thus normally desirable to set the time chart axis to not begin until perhaps five seconds after the beginning of the test so that this transient can die away.

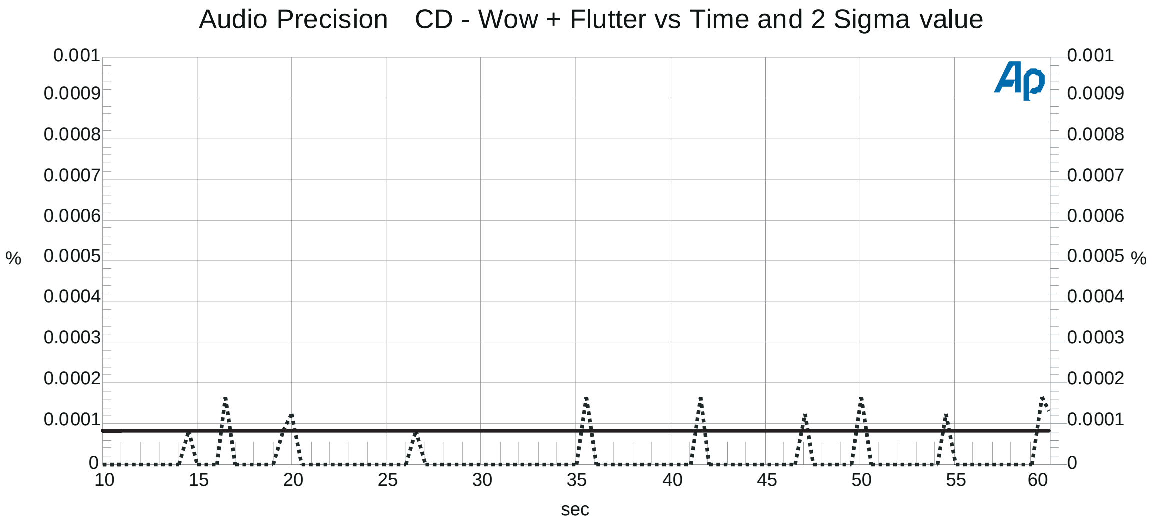


Figure 34 is a graph of a wow and flutter measurement versus time - WOW&FLUT.at2.

Results

A plotted graph line below the System One or Two guaranteed residual of 0.001% is typical for high quality players, unless an isolated noise impulse causes a spike. The EIAJ specifies that spikes occurring less than twice in ten seconds should be ignored. An alternative to manual interpretation of the graph is use of the Compute 2-Sigma function. The 2-Sigma value for a series of wow and flutter measurements is defined as the magnitude value which is exceeded exactly five percent of the time. The WOW&FLUT.at1 or .at2 tests in the distribution files displays both the raw data and the 2 Sigma computed value. Noise spikes may be clearly seen while the 2-Sigma value is usually zero.

Waveform Display

An additional test is supplied in the distribution files that requires the DSP or Dual Domain version of the Systems for display of waveform information in an oscilloscope style display. O'scope.at2 and .at1 is setup as a repeating sweep and is useful for viewing square wave response and polarity and impulse test signals. Principal factors involved in setup are:

a. Notice that the Analog Analyzer panel is set with fixed Level meter ranging of 10 Volts. This prevents the Level meters from "chasing" a low frequency voltage and prevents range switching within a sweep. Since Auto Range is off some care must be observed if higher voltage inputs are planned. A safe way of determining range is check the Level meter's Auto Range boxes, supply the signal to be used at it's maximum amplitude and, while the signal is present, uncheck the Auto Range boxes. This captures the correct range for the meters. The Analog Analyzer DC check boxes at the upper corners of the expanded panel control whether the input signal to the DSP is AC or DC coupled.

b. The FFT Spectrum Analyzer (Spectrum Analyzer (fftslide) in System One) program is used in the Digital Analyzer with the low BW (1x) A/D selected (A/D in System One). Note that in System Two the other two A-to-D converters can also be used to give a wide choice of possible measurements and resolution. If either the /4 or the 4x A-to-D converters is used the actual sample rate will be either one-fourth or four times respectively that shown in the Sample Rate window. Anlr A and Anlr B are selected as the Sources for the FFT. The maximum FFT Length available should be selected. Wave Display is set to interpolate. The Trigger sub-section allows control of triggering similar to oscilloscope trigger control.

c. On the Sweep panel Data 1 (left vertical axis) Top is set with positive Voltage values and Bottom in negative Voltage values. These settings can also be used to asymmetrically offset the zero voltage level. A dual trace can be set up by either selecting the

Stereo Sweep check box—which will show two traces on the left axis—or setting up Data 2 (right vertical axis) to shift the 0 voltage level or set a different amplitude range. Source 1 is set to fft.FFT Time for a time display on the horizontal axis. The time range will vary depending on the waveforms viewed. A large number of points (500 or more) will display better detail.

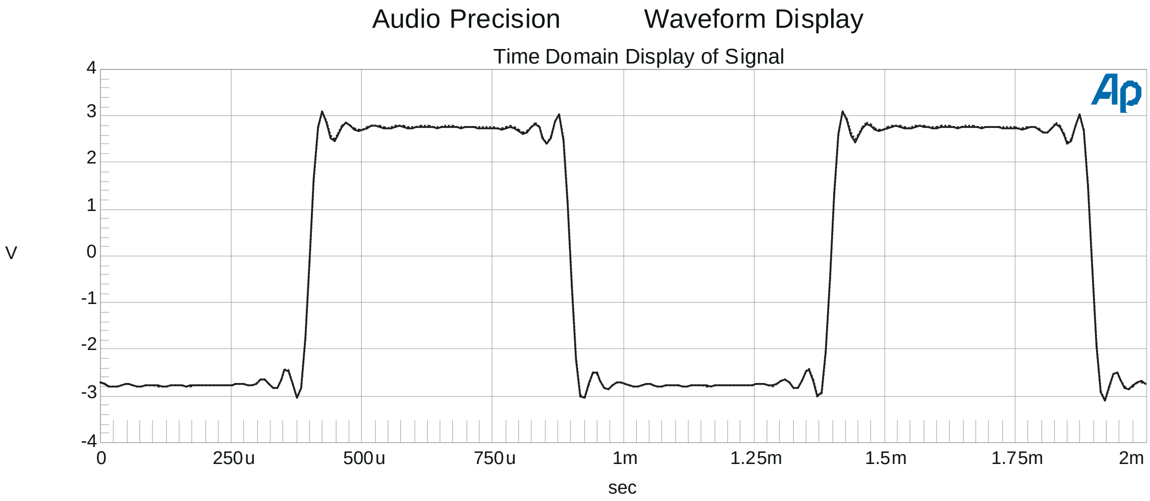


Figure 35 Square wave waveform display from O'scope.at1

An interesting signal for testing group delay is provided on the Philips disc (track 74). This signal contains a 1 kHz signal on the left channel and a 20 kHz signal on the right channel with coherent phasing of the two signals. Every tenth zero crossing of the 20 kHz wave should exactly align with the zero crossing of the 1 kHz wave. If this is so the group delay (frequency-dependent phase) is the same for both frequencies. This is the waveform saved in the O'scope.at2 file as supplied.

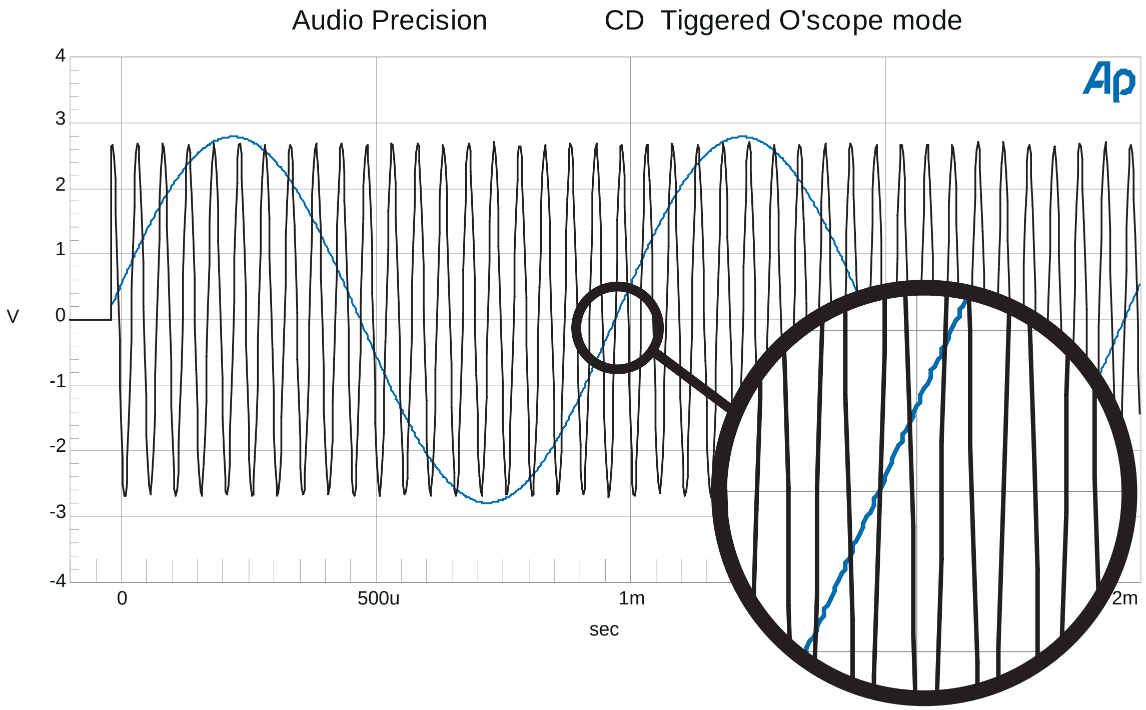


Figure 36 Two different frequencies (1k and 10k) on different channels from the Philips disc track 74. The zero cross of both signals should coincide with no offset when phase vs. frequency and interchannel phase is correct.

Special Problems

Occasionally compact disc players are found with defects that require special measurement techniques in order to obtain data.

Excessive Inter-Track Noise

As noted earlier, some CD players have noise output while seeking between tracks that is larger than their signal output on low amplitude tracks such as -80 and -90 dB. This condition makes it more difficult for the system to perform linearity and THD+N versus amplitude tests, since the system may interpret the inter-track noise as a legitimate low-amplitude signal. If restricted to using a System without DSP or digital input ability (assuming the CD player has a digital output) the options for achieving these low level measurements are limited. One solution is to increase the Settling Panel Delay beyond the time required for the player to seek from track to track. The software will then discard data during that interval, and will capture and plot properly the measurement from the next track. A disadvantage of this approach is overall measurement speed. Settling Delay is invoked at every measurement, on both stereo channels. If, for example, the CD player is very slow in track seeking and requires a 5 second Settling Delay to operate properly in a linearity test, the cumulative effect will be 130 seconds of delay while testing both channels of a player across 13 amplitude levels.

If a System Two with DSP is used test versions that use this ability are preferred—THDAmpl2.at2 and Linarty2.at2. If the CD player has a digital output the Dual Domain version of either System can be used with the “D” versions of these tests—THDAmplD and LinartyD.

Excessive Clock Signal Leakage

Several CD players have been measured with a rather high level of leakage from oversampling and sigma-delta converters. In at least two cases, this signal (at the audio output connectors) was only 60 dB below full output. At low signal levels the Level meter sees this signal since the Level voltmeter bandwidth is greater than 500 kHz. The

Level voltmeter will thus be unable to drive a test if the recorded amplitudes go below the -60 dBFS level. In tests at low levels this can produce multiple independent data points which can be seen on the Data Editor but do not produce a useable (or any) graph. At low levels reduced bandwidth measurement is required to remove these high frequency signals from consideration. This requires the use of the Function Reading meter with its bandwidth setting and optional filter abilities. The DSP bandpass filter or digital input controlled sweeps are the most reliable means to accomplish this.

These high frequency components are outside of the audible audio band but many high-quality audio power amplifiers will also amplify these signals because of their extended power-bandwidth. Since high frequency speakers have much less power handling ability than the low and mid range components the possibility exists that these high frequency out-of-band signals could cause tweeter damage or reduce their range (and probably contribute to distortion) by modulating in-band audio signals.

Appendix 1 Setting up Stereo Sweeps in APWIN

The Stereo Sweep check box at the bottom-center of the Sweep panel should be used to set up the Sweep panel for stereo and multiple function sweeps.

SIMPLE STEREO SWEEP - First set up Data 1 using the browser to select the source of the data, then specify the measurement unit to be used and, last, specify the Top and Bottom values for the range of interest. To make these become stereo measurements check the Stereo Sweep box which will then make the Data 3 area the second channel measurement as set up in Data 1. Data 3 through 6 are only visible when the Sweep panel is expanded. Always completely set up the first channel of stereo measurements before checking the Stereo Sweep box.

Example: In System Two select Anlr.Level A as Data 1 and check the Stereo Sweep box. Data 3 then has Anlr.Level B as the data source. Using System One, select Anlr.Ampl (2-Chan) as Data 1 and set the Function Reading meter to A on the Analyzer panel. Checking the Stereo Sweep box enters Anlr.Level B as the Data 3 data source. Note that if the Function Reading meter in 2 Channel mode has been set to channel B as the Source this action will make Data 3 correctly display Anlr.Level A as the data source.

FUNCTION READING METER SWEEP OPERATION - If a Function Reading meter measurement is requested in stereo it must be done using the Stereo Sweep check box to initiate the channel-switching sweep that is necessary to take Function Reading meter readings from both Channel A an Channel B. In Generator controlled stereo sweeps of the Function Reading meter the two channels are measured in two consecutive sweeps with the Function Reading meter channel switched to the second input for the second sweep. In External source Stereo sweeps both channels of measurement are done whenever the Spacing requirement is met indicating a step in the signal. After the Spacing requirement is met the meter data must satisfy the Settling requirements to take a measurement of the first channel. Next the Function Reading meter input switches to the other channel, settling requirements met once again and the second channel measured to complete the stereo measurement. The Function Reading meter input is then switched back to the initial channel setting and the process repeats for the next step in the sweep after the Spacing requirement is again met.

STEREO FFT of the FUNCTION READING METER OUTPUT - This powerful measurement technique applies an FFT to the signal after the notch filter in the Function Reading meter. Set up the Digital Analyzer with FFT spectrum analyzer (fftslide in System One) as the Analyzer. For Input Ch 1 select Anlr Rdg Ampl from the drop-down box. Set Input Ch 2 to None - if this isn't set to None no stereo measurement will be done! Set Source 1 on the Sweep panel normally: FFT Ch 1 Ampl for Data 1 and check the Stereo Sweep box. With this setup an FFT of the analog analyzer Function Reading meter output is done (with multiple samples if Power Spectrum Averaging is used) for the first channel in the analog Function Reading meter. For the second channel measurement the analog Function Reading meter switches input channels and the second channel FFT is done and graphed sequentially.

IF Stereo Sweep CHECK BOX ISN'T USED - When a Function Reading meter measurement is entered directly as Data 1 and entered again as Data 2 without checking the Stereo Sweep box the result is two identical sets of data from the first channel and no measurement from the second channel.

MORE MEASUREMENTS, SAME SWEEP - Adding a Phase measurement to Data 2 after checking the Stereo Sweep box sets up the right vertical graph axis for display of phase in degrees and adds an additional data column in the Data Editor. A second set of stereo measurements can also be made in the same test. For example, additional sources could be: a different meter, the same meter with different scaling, both Level and Function Reading meter readings in the same test. To do this, set up both Data 1 and Data 2 before checking the Stereo Sweep box. The measurement Units, and Top and Bottom values chosen for Data 1 and Data 2 control, respectively, the left and right vertical axis of the graph. When the Stereo Sweep box is checked after setting up Data 1, Data 3 uses the same graph axis and values. Similarly, the Data 2 setup controls Data 4.

Example: To add a phase meter reading to the sweep, select Anlr.Phase in the Data 2 area, but only after the Stereo Sweep box has been checked. In this example two active meters are used and the test will plot both data results on a single sweep. The Level scale is on the left axis and the Phase measurement scale is on the right axis.

EVEN MORE MEASUREMENTS - If Data 1 and Data 2 have already been used for different left and right vertical axes and additional data from a different meter or using different units is requested the additional data will not plot on the graph but will be available in the Data Editor.

Example: Select Anlr.Level A in Data 1 and Anlr.THD+N in Data 2, select Stereo Sweep and add Phase in Data 5. The Phase meter data would be available only in the Data Editor because no units are available for the vertical graph axis. This setup would accomplish stereo measurement (with System Two) of Levels, THD+N and relative interchannel Phase.

MULTIPLE DATA COPIES - Sometimes copies of identical data are requested by selecting the same source for more than one Data choice. This is useful for Computed operations after the sweep. This technique is used in some of the supplied CD tests.

Example: In System Two select Anlr.Level A for Data 1, 3 and 5 and Anlr.Level B for Data 2, 4 and 6. The Stereo Sweep check box can be used to set up Data 3 and 4, but Data 5 and 6 must be set up directly. Next pull down the Compute Maximum and check Data 3 and 4 and Apply after Sweep. Also pull down Compute Minimum and check Data 5 and 6 and Apply after Sweep. The sweep result graph shows the Max and Min computed values displayed as flat straight lines and the original response data between them. In this full stereo Level measurement this results in 6 data lines from a single sweep measurement. In the Data Editor columns 3 through 6 are now single numbers corresponding to the flat graph lines.

Appendix 2 CD Test Procedures

Listed in approximate "call" order. All procedures are fully line-by-line commented. In these procedures the procedure editor is made invisible in one of the first few lines of code. To make it visible again so you can follow the process press the Procedure editor icon button. Following the procedure logic using the "Step Into" button is a good technique for understanding the processes within the procedure. "Step Into" executes one line for each press of the button.

CDTEST.apb - Main procedure for CD testing

Determines if System One or System Two software is running and runs either CDTESTS1.apb or CDTESTS2.apb. Note that this does not determine if the System hardware is connected and running - only which software is active.

CDTESTS1.apb and CDTESTS2.apb - Main sub procedure for System One or System Two

Called by CDTEST depending on which system software is active in APWIN. The variable values set in these procedures are used to set up all tests as they are opened. The first menu dialog allows the input connection type to be specified for System Two. User-entered text may be entered for attachment to every test graph or data printout. This can be used to enter the CD player model, serial number or any other user notes. Also optional is an input switcher setup. This is provided as a programming example for setting variables used later to set the switcher positions for each test as it is opened. The next menu asks the user to select which of four common test CDs is being used. If the user is not using any of these four than a menu with test descriptions is available. Next, a prompt tells the user to load the selected test CD and opens the appropriate procedure.

S1_CBS.apb, S1_Denon.apb, S1_NAB.apb, S1_PHIL.apb Test selectors for System One for specific test CDs.

S2_CBS.apb, S2_Denon.apb, S2_NAB.apb, S2_PHIL.apb - Test selectors for System Two for specific test CDs.

S1_Other.apb and S2_Other.apb - Test selectors by track description for System One or System Two

In each of these procedures the sequence is the same:

- The procedure first determines if the correct APWIN System software is running and ends if it isn't. This software check uses the IsAPSys function located in the Util.apb file which contains several general purpose functions and subs.
- A prompt tells the user to play the track number that corresponds to the 0 dBFS level on the disk. The function LvlChk is called (also in Util.apb) to test for actual input within a level tolerance and within a time limit. If the requirements are not met the procedure loops to the "Play track number" prompt and tries again.
- If LvlChk is satisfied a measurement of the 0 dBFS values is made and saved in variables used to set the dBr values in all tests as they are opened.
- Next, the Test Menu lists all tests that can be done with the CD currently selected. A short description with the tracks used is displayed. A check mark in the box at the end of the description selects the test for execution. All checked tests are done in order. Each test is done by calling the TestRun sub. Several parameters are set for TestRun depending on the test selected. These include the test file name, the text to be used in a "Play track.." prompt, whether the test is a graph or single point measurement and if a Compute is to be done and, if so, which one.
- The description of Sub TestRun is in the comments for this sub-procedure located at the end of each of these of these procedures. This sub opens the test to be done and sets the switcher, input type (in System Two only) and dBr references. Next the test is run, the comments text attached and any Computes specified done. Last a small dialog box appears with

choices for Continue, Save, Print, Retest or Cancel All. If Continue is selected the procedure returns to the next test checked in the TestMenu and continues.

CBS20_S1.apb and CBS20_S2.apb - “Fade-to-Noise” Linearity Test Procedure using CBS CD-1 Track 20.

Low level linearity tests are done by APWIN Basic procedure CBS20_S1.apb for System One or CBS20_S2.apb for System Two. The initial conditions are set in the CBSTrk20.at1 or .at2 tests. The procedure begins with prompts indicating track number to be played for calibration of the 500 Hz 0 dBFS level through the Function Reading meter. This level is captured for each channel for use as the reference level. Next the operator is requested to begin playing the CBS disc track 20. The procedure critically determines the beginning of the signal in time by using a very rapid Level meter reading. When the signal begins, the Function Reading meter in Bandpass mode takes readings versus Time within the requirements of the Settling panel. The test running time is displayed on an updating prompt. Over 200 measurements are made in the 30 second running time of the test. At the conclusion of the CD amplitude sweep the data is manipulated to convert the time data to an equivalent amplitude. A temporary data file is made by the procedure to contain the computed results. This data file (Data.adx) is then imported (File Import ASCII data) into the ViewData.at1 or .at2 test used as the framework to display the processed data. The difference between the ideal and the measured amplitudes is displayed as Linearity Error. The procedure allows selection of either channel of the CD player to be tested in sequential tests.

UTIL.apb - Contains Functions and Subs used by other procedures.

Contains LvlChk, IsAPSys and EditCol1. Descriptions are in the comment lines at the beginning of each routine in Util.apb.

Appendix 3 Tests, Test File Names and CD Track Number Reference

Tests for both System One and System Two are listed without an extension. Tests for System Two only have an .at2 extension. Tests structured similarly to those in the DOS version App. Note 1 have names all in Caps. Tests with gray background require DSP. APWIN Basic procedures have an .apb extension. Track not available -"na" Track and Index is shown as #.#, “6.2" - Track 6 Index 2.

Test For	Signal Type	Test File Name	CBS CD-1 Standard Test Disc	Denon Audio Technical CD C39-7147-EX	NAB Broadcast & Audio System Test CD	Philips Audio Signal Disc 1 SBC 429
			Track Number			
Maximum Level 1kHz reference	0 dBFS	MaxLvl.	1	49 (1001Hz)	3 (1001 Hz)	1
Frequency Response (0 dBFS)	Single Tones	FRQRSPD.	6.2 - 10 (8-19,997)	46 - 55 (40-19,999)	15 - 29 (20-20k)	8 - 23 (8-20k)
Frequency Response	Glide Tone	FRQRSPG.	11 (5-22,050)	65 (5-22k) -15dB	7 (5-22k) -15dB	5 (20-20k)
Freq. Response + Chan Diff.	Glide Tone	FR&Diff at2	11	65	7	5
Freq. Response + Phase	Glide Tone	FR&Phase.	11	65	7	5
Signal-to-Noise Ratio (SNR)	Infinity zero	NOISEWB.	4	34-no emph, 35	12	49-no emph, 50
FFT of Noise - to 80kHz	Infinity zero	NoiseFFT.	4	34 or 35-emph.	12	49 or 50-emph.
Noise Spectrum - to 200kHz	Infinity zero	NoiSwpWB.	4	34 or 35	12	49 or 50
Noise Spectrum - to 20 kHz	Infinity zero	NOISSPEC.	4	34 or 35	12	49 or 50
THD+N (%) vs Frequency	Single Tones	THDFREQ.	6.2 thru 10	46 thru 55	15 thru 29	8 thru 23
FFT of THD+N residual	Single Tones	LoLvlFFT.	6.1 thru 10	46 thru 55	15 thru 29	8 thru 23
THD+N vs Amplitude analog anlr	Level Sweep	THDAMPL.	18 (997Hz)	na	na	32 thru 42 (1k)
THD+N vs Amplitude DSP	Level Sweep	THDAmpl2.at2	18 - no dither	na	na	32 thru 46
THD+N vs Amplitude Digital out	Level Sweep	THDAmplD.	18	na	na	32 thru 46
Output Linearity analog analyzer	Level Sweep	Linarty.	18 (997Hz)	na	na	32 thru 46 (1k)
Output Linearity DSP controlled	Level Sweep	Linarty2.at2	18 - no dither	na	na	32 thru 46
Output Linearity Digital out	Level Sweep	LinartyD.	18	na	na	32 thru 46
Fade-to-Noise with Dither	Fade-to-Noise	CBS20_S2(or S1).apb	20	na	na	na
Dynamic Range	1 kHz -60 dBFS	DYNRANGE.	5	63 (1001 Hz)	68.13 (400 Hz)	41
FFT - Dynamic Range	1 kHz -60 dBFS	SpectFFT.	5	63 (1001 Hz)	68.13 (400 Hz)	41
Quantization Noise	Low Freq 0 dBFS	QNTZNOIS.	6.3 (17 Hz)	26(L),27(R)(21.5Hz)	15 (20 Hz)	9 (16 Hz)
FFT - Quantization Noise	Low Freq 0 dBFS	LoLvlFFT.	6	26 (L), 27 (R)	15	9
SMPTE IMD (60+7k 4:1 0 dBFS)	SMPTE Tones	SMPTSPOT.	13.1	40,41 (250 + 8020)	30.1 (-6 dBFS)	54
SMPTE IMD FFT of residual	SMPTE Tones	SmpteFFT.	13.1	40,41 (250 + 8020)	30.1 (-6 dBFS)	54
CCIF IMD (11k+12k 1:1 0 dBFS)	Twin Tones	CCIFSPOT.	13.2	43 (L), 44 (R)	35 (-6 dBFS)	55 (19k+20k)
FFT - IMD	SMPTE or CCIF	SpectFFT.	13.1, 13.2	40,41,43,44	30.1, 35	54, 55
Interchannel Phase	Glide Tone	PHASE.	11	65	7	5
Separation / Crosstalk L-R	L. Single Tones	SEP_L-R.	2.2, 2.1, 2.3,4,5	26,22,18,20,24	na	66 thru 69
Separation / Crosstalk R-L	R. Single Tones	SEP_R-L.	3.2,3.1,3.3,4,5	27,23,19,21,25	na	70 thru 73
Frequency Accuracy	Hi Freq. Tone	FREQACUR.	10 (19,997)	24 (19,999)	5 (19,999)	23 (20,000)
Wow + Flutter (Noise impulse)	3150 Hz Tone	WOW&FLUT.	14	91	72	na
O'scope - view waveforms	various	O'scope.	16,17	71 thru 77	11,69,93, 94	56,57,58,74,75

Appendix 4 Distribution File Names

All of these tests are designed as "external" tests. They work with a source of the test tone or tone-sequences that is not controlled by the Audio Precision System used. The System generators in these tests have not necessarily been set up to generate the tones or sequences used.

APWIN System One Tests

CBSTrk20.at1	Used to collect data for CBS20_S2.apb "Fade-to-Noise" test procedure.
CCIFSPOT.at1	Single number CCIF (twin tone) intermodulation distortion test.
DYNRANGE.at1	Measures THD+N below -60 dBFS signal and computes full scale value.
FR&Phase.at1	FRQRSPG with added, simultaneously measured, interchannel phase.
FREQACUR.at1	Frequency accuracy - indirectly compares CD clock to System 1 clock.
FRQRSPD.at1	Discrete tone frequency response sweep.
FRQRSPG.at1	Glide-tone frequency response sweep.
LinartyD.at1	Linearity test for CD player with Digital output used to control the sweep.
Linarty.at1	Full range amplitude linearity test using Analog Level sweep control.
LoLvlFFT.at1	FFT of distortion components after analog notch filter removes the tone.
MaxLvl.at1	Maximum analog output level from a 0 dBFS tone.
NoiseFFT.at1	80 kHz Wideband FFT spectrum for noise analysis.
NOISEWB.at1	Single number signal-to-noise ratio - 22 - 22k Hz bandwidth

NOISSPEC.at1	20 - 20k Hz analog bandpass filter sweep for noise analysis.
NoiSwpWB.at1	20 - 200k Hz analog bandpass filter sweep for noise analysis.
O'scope.at1	DSP digital waveform display for repetitive waveforms.
PHASE.at1	Channel A to Channel B (interchannel) phase vs. frequency.
QNTZNOIS.at1	Special variation of THD+N test. Looks for noise above 400 Hz.
SEP_L-R.at1	Channel B Analog Bandpass Crosstalk/separation test - Ch. A driven.
SEP_R-L.at1	Channel A Analog Bandpass Crosstalk/separation test - Ch. B driven.
SmpteFFT.at1	FFT spectrum after removal of SMPTE test tones.
SMPTSPOT.at1	Single number SMPTE intermodulation distortion test.
SpectFFT.at1	20 - 20k Hz general purpose stereo FFT spectrum, analog input.
THDAMPL.at1	Distortion vs. Amplitude, controlled by Analog Level meter.
THDAmplD.at1	Distortion vs. Amplitude, controlled by CD that has a digital output.
THDFREQ.at1	Distortion (THD+N) versus Frequency using discrete tones.
ViewData.at1	Test used by CBS20_S2.apb to present finished data.
WOW&FLUT.at1	WOW and Flutter testing, includes sigma 2 computation.

APWIN System Two Tests

CBSTrk20.at2	Used to collect data for CBS20_S2.apb "Fade-to-Noise" test procedure.
CCIFSPOT.at2	Single number CCIF (twin tone) intermodulation distortion test.
DYNRANGE.at2	Measures THD+N below -60 dBFS signal and computes full scale value.
FR&Diff.at2	FRQRSPG with added channel difference (balance) measurement.
FR&Phase.at2	FRQRSPG with added, simultaneously measured, interchannel phase.
FREQACUR.at2	Frequency accuracy - indirectly compares CD clock to System 2 clock.
FRQRSPD.at2	Discrete tone frequency response sweep.
FRQRSPG.at2	Glide-tone frequency response sweep.
Linarty2.at2	Full range amplitude linearity test using DSP notch filter sweep control.
LinartyD.at2	Linearity test for CD player with Digital output used to control the sweep.
Linarty.at2	Full range amplitude linearity test using Analog Level sweep control.
LoLvlFFT.at2	FFT of distortion components after analog notch filter removes the tone.
MaxLvl.at2	Maximum analog output level from a 0 dBFS tone.
NoiseFFT.at2	80 kHz Wideband FFT spectrum for noise analysis.
NOISEWB.at2	Single number signal-to-noise ratio - 22 - 22k Hz bandwidth
NOISSPEC.at2	20 - 20k Hz analog bandpass filter sweep for noise analysis.
NoiSwpWB.at2	20 - 200k Hz analog bandpass filter sweep for noise analysis.

O'scope.at2	DSP digital waveform display for repetitive waveforms.
PHASE.at2	Channel A to Channel B (interchannel) phase vs. frequency.
QNTZNOIS.at2	Special variation of THD+N test. Looks for noise above 400 Hz.
SEP_L-R.at2	Channel B Analog Bandpass Crosstalk/separation test - Ch. A driven.
SEP_R-L.at2	Channel A Analog Bandpass Crosstalk/separation test - Ch. B driven.
SmpteFFT.at2	FFT spectrum after removal of SMPTE test tones.
SMPTSPOT.at2	Single number SMPTE intermodulation distortion test.
SpectFFT.at2	20 - 20k Hz general purpose stereo FFT spectrum, analog input.
THDAMPL.at2	Distortion vs. Amplitude, controlled by Analog Level meter.
THDAmpl2.at2	Distortion vs. Amplitude, controlled by DSP bandpass filter.
THDAmplD.at2	Distortion vs. Amplitude, controlled by CD that has a digital output.
THDFREQ.at2	Distortion (THD+N) versus Frequency using discrete tones.
ViewData.at2	Test used by CBS20_S2.apb to present finished data.
WOW&FLUT.at2	WOW and Flutter testing, includes sigma 2 computation.

APWIN Basic Procedure Files

Procedure files are well annotated. View them by using the Procedure editor.

CDTEST.apb	Main procedure for CD testing.
CDTESTS1.apb	Main sub procedure for System One. Called by CDTEST.
CDTESTS2.apb	Main sub procedure for System Two. Called by CDTEST.
CBS20_S1.apb	System One test procedure for “Fade-to-Noise” linearity with CBS CD-1.
CBS20_S2.apb	System Two test procedure for “Fade-to-Noise” linearity with CBS CD-1.
S1_CBS.apb	Test selector for CBS CD-1 using System One
S2_CBS.apb	Test selector for CBS CD-1 using System Two
S1_Denon.apb	Test selector for Denon C39-7147-EX using System One
S2_Denon.apb	Test selector for Denon C39-7147-EX using System Two
S1_NAB.apb	Test selector for NAB Broadcast & Audio Test CD using System One
S2_NAB.apb	Test selector for NAB Broadcast & Audio Test CD using System Two
S1_Other.apb	Test selector by track description using System One
S2_Other.apb	Test selector by track description using System Two
S1_PHIL.apb	Test selector for Philips SBC 429 using System One
S2_PHIL.apb	Test selector for Philips SBC 429 using System Two
UTIL.apb	Contains various Functions and Subs used by other procedures.

Other Files

60dB.ada	60 dB data used with Compute Delta in the dynamic range tests (DYNRANGE).
CBSTk18.ada	Exact amplitude values from CBS CD-1 track 18. Used in linearity and distortion tests.
PHIL3248.ada	Exact amplitude values from Philips SBC429 tracks 32 through 48.
Data.adx	Test data from linearity test procedure using CBS CD-1 track 20.
CDLinRef.ada	Reference data for linearity test procedure using CBS CD-1 track 20.
CDLinRef.adx	Exported reference data from linearity test procedure using CBS CD-1 track 20.

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