Collection of Setups for Measurements with the R&S®UPV and R&S®UPP Audio Analyzers

Application Note

Products:

- R&S®UPV
- R&S®UPP

A large variety of measurements is performed in audio engineering in order to ensure transmission quality of analog and digital devices. An audio analyzer suitable for all these tasks will, therefore, incorporate a multitude of functions, resulting in a correspondingly large number of settings.

This application note is to help test engineers using the R&S®UPP and R&S®UPV audio analyzers. It presents setting examples for all basic audio measurements to be performed immediately. For each setup, information is given on the type of measurement, the underlying standards, and on how to modify the graphic display results.

ROHDE&SCHWARZ

Application Note

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1 Introductory Note

The following abbreviations are used in this application note for Rohde & Schwarz products:

- The R&S®UPP audio analyzer is referred to as UPP.
- The R&S®UPV audio analyzer is referred to as UPV.

2 Introduction

Being faced with a wide variety of standards and manufacturers' specifications, test engineers may often find it difficult to keep track of necessary audio measurements. With the widespread digital audio techniques, new sources of error and consequently new demands on the measurements are additionally created. An audio analyzer suitable for all these tasks will, therefore, incorporate a multitude of functions, resulting in a correspondingly large number of settings.

This application note is to help test engineers using R&S®UPP and R&S®UPV audio analyzers for the first time. It presents setting examples for all basic audio measurements and thus allows measurements to be performed with UPP and UPV immediately. For each setup, information is given on the type of measurement and underlying standards, and on how to modify the graphical presentations and interpret results.

The setups described here are already supplied with every Rohde & Schwarz audio analyzer.

3 Predefined Example Setups

3.1 Where to Find the Predefined Instrument Setups

To make initial measurements easier for new users, example setups for the basic measurements required in audio engineering are supplied with every audio analyzer. These setups allow the instrument to be used almost immediately.

The setup files are available for the different input/output combinations (analog or digital / I²S) of the generator and analyzer. They are stored in the directory *D:\UPV\Setup Examples* in the subdirectories *AA, AD, Analog-I2S, DA, DD, I2S-Analog*, whereby the generator output is listed first, followed by the analyzer input. The file name indicates the respective application, for example the setup *AD_Freq-Response.set* provides an analog generator output signal and uses the digital analyzer inputs to measure the frequency response.

Many of these example measurements (essentially those at the analog interfaces) can be performed using the basic version of the UPP or UPV audio analyzers. For all measurements at the digital interfaces additional hardware options are required such as UPV-B2, UPV-B41, UPP-B2, etc.

The predefined instrument setups can be loaded from the menu bar. Highlight the "*File*" menu and click the entry "*Load Example Setup*". The file window is opened displaying the directories in which the example measurements can be selected.

3.2 Basic Settings

All of the setups listed here use the same basic settings.

Basic settings for analog inputs/outputs:

- Two channels of the generator and analyzer are active; the balanced generator output with minimum output impedance and the maximum analyzer input impedance are used.
- All inputs/outputs are floating; the auto-range function is activated.
- Frequency sweeps are usually performed logarithmically from 20 Hz to 20 kHz; the appropriate graphical windows are open on the screen; the X-axis is scaled automatically in the associated configuration panels; the Y-axis is permanently set to standard values.
- Voltages are preferably given in Volts; the generator output voltage is set to 1 V; distortion and intermodulation values are given in dB.

Basic settings for digital inputs/outputs:

- Two channels are active; the generator generates 24 bit words (I²S 32 bit); the analyzer analyzes 24 audio bits (I²S 32 bit). The sampling frequency is set to 48 kHz; the Professional format is used according to AES3. The digital pulse amplitude of the generator is 1 V at the BNC outputs; this corresponds to 4 V at the balanced outputs.
- Levels are mostly given in dBFS; audio signals are usually generated at a level of -20 dBFS.

Users can, of course, adapt the used basic settings to their own specific measurement tasks at any time. To do this, the respective setup must be loaded and the appropriate changes are then made in the panels. The setup can then be saved again to keep the modifications.
Please note:
The whole set of application setups is automatically updated whenever a new audio analyzer firmware is installed. Modified setups should therefore be saved under a different file name, otherwise the individual user's modifications will be overwritten with the next instrument update.

Users are also free to create new directories for their customized setups.

3.3 Notes on Measurements

For each application, the measurement conditions and procedure in accordance with the relevant standards are described. In addition, information is given on the purpose of a measurement and on expected results.
Under "Graphic display", the representation of results is described. The user will find hints on how to adapt the display to his specific requirements. Description of the setups includes modifications of measurements for the purpose of adaptation to specific measurement tasks. The user can thus generate, from the setups given here, any setups to suit his requirements. Any information relating to commands or command lines of UPV/UPP are shown in this application note *in italics with a grey background*.

The UPP and UPV audio analyzers provide a large number of instrument settings, numerical and graphical displays. Not to get the screen overloaded, up to five virtual screens can be handled (see the user manual for details).

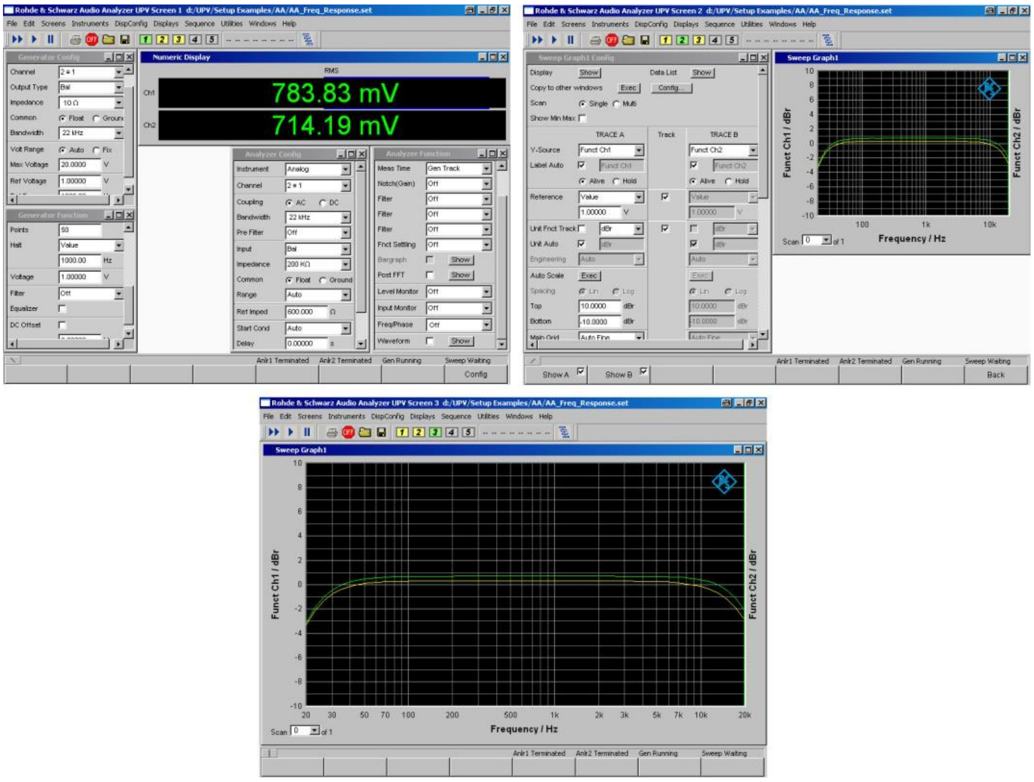


Fig. 1: The example setups always come with the panels arranged in screen 1 to 3

All example setups described in this application note follow the same principle:

- Screen 1 displays Generator Config panel, Generator Function panel, Analyzer Config panel, Analyzer Function panel and the Numeric Display. This screen is mainly used for the basic settings of the measurement.
- Screen 2 displays a graphical presentation of the results (for example Sweep Graph 1) and the corresponding Config panel (here: Sweep Graph 1 Config). This screen is mainly used to adjust the parameters of the graphical presentation by having the Config panel and the graph side by side.
- Screen 3 shows the same graph as screen 2, but in full size mode.

Of course the user is free to modify the arrangement of the different panels at any time.

3.4 Standards

Most of the measurements described in the setups given here are defined in IEC 60268, "Sound system equipment, Part 3: Amplifiers". This standard defines the measurements to be made on amplifiers for professional and household applications. The standard, however, refers to equipment with analog interfaces only.

As regards components with digital only or analog and digital interfaces, many measurements are the same as for components with analog interfaces, but with digital interfaces effects will occur that call for modified or extended measurements. This is taken into account by AES 17, "AES standard method for digital audio engineering - Measurement of digital audio equipment".

Wherever possible, the setups described here are in line with the above standards.

3.5 Nominal Conditions - Standard Test Conditions

Basically, the **nominal conditions** defined by IEC 60268 are to be observed in all measurements. These conditions essentially include operation of the equipment in accordance with the intended use, i.e. observance of the operating temperature range, appropriate power supply, etc.
The **standard test conditions** define the conditions under which measurements are to be performed. For example, the amplitude frequency response of an amplifier is to be measured at 10 dB below the full-scale amplitude since it is assumed that the level of commonly used speech or music signals will on average not exceed this level (see IEC 60268-3).

As an important point, the correct input and output impedances at the DUT must be observed. In professional sound-studio measurements, power matching has been in use for a long time - this means the same impedance (usually 600 Ω) at the source and load -, voltage matching is preferred today. In the latter case, the source is operated at a low impedance (<30 Ω) and the load at a high input impedance (>200 kΩ for balanced lines, >100 kΩ for unbalanced lines). The setups described here use voltage matching.
However, if for example amplifiers intended for operation with loudspeakers are to be measured, appropriate load resistors must be connected to the outputs as otherwise the high input impedance of the measuring instrument would not reflect the true operating conditions of an amplifier.

4 Linear Distortion Measurements

4.1 Amplitude Frequency Response

Definitions and test conditions:

Measurement of the amplitude frequency response is the classic measurement task. Since this type of measurement is much more frequent than phase frequency response measurement, it is often described simply as the frequency response.
The frequency response of amplifiers is measured in accordance with IEC 60268 at 10 dB below the full-scale amplitude by sweeping an input signal of constant level over the frequency range. The output level is plotted against the frequency.
With digital components, the frequency response is measured in accordance with AES 17 at -20 dBFS.

Graphic display:

The frequency response is represented by displaying the RMS output level in dB along the frequency axis using a logarithmic scale.
In the setups described, the y-axis has been scaled for ±10 dB, which reflects practical requirements in most cases.

If the set y-axis scaling is inappropriate or if results are outside the displayed range, it is best to execute the *Auto Scale* function in the *Sweep Graph Config* panel. As a result, the graphic display on UPV and UPP audio analyzers will be scaled such that, after a single sweep, all results are represented on the display.

IEC 60268 defines a reference frequency of 1 kHz for the level values. This applies however only to analog systems. In accordance with AES 17, a reference frequency of 997 Hz is to be used for digital as well as for analog/digital combined systems.

Notes on measurements:

The amplitude frequency response can be measured in different ways with UPV and UPP audio analyzers. The differences are described in detail in the following.
In any case, levels are represented in dBr. The user must, however, refer levels to 1 kHz or 997 Hz. This is easiest done by executing the *Ref 1000 Hz* function (resp. *Ref 997 Hz* function) in the *Reference* line of the *Sweep Graph Config* panel.

4.1.1 Sweep Measurements Using Signals from UPV/UPP Generator

Setups: **xx_Freq_Response.set**

This measurement is the standard measurement, as it were. The generator supplies a sine wave signal which is swept logarithmically at a constant level over the frequency range 20 Hz to 20 kHz. The RMS output level of the DUT is measured and displayed graphically.

The above setups provide a sweep with 50 frequency points. The set measurement speed is *GENTRACK*, i.e. the analyzer adjusts the measurement time for each point to the cycle time of the generator signal, which results in very high measurement speed.

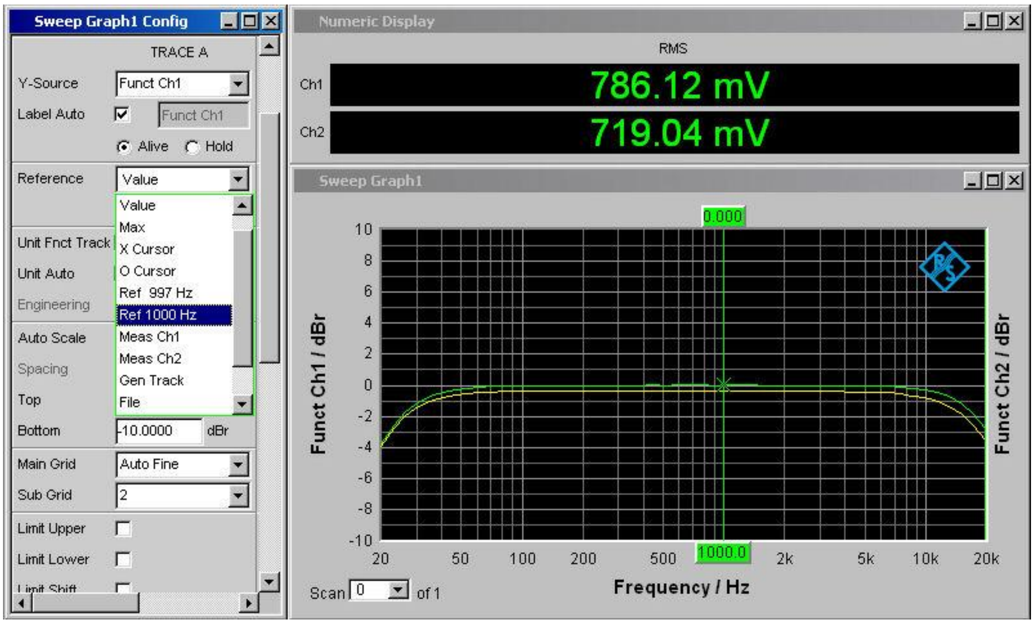


Fig. 2: Display of amplitude frequency response; the reference value is set by means of the *Reference* function

4.1.2 Fast Frequency Response Measurements Using FFT

Setups: **xx_Freq_Resp_FFT.set**

Although UPV and UPP provide extremely fast level measurements, swept frequency response measurements do not always satisfy speed requirements, for example in alignments or production. With the help of FFT analysis and broadband test signals, frequency response can be measured faster than with the traditional sweep method. To avoid measurement errors caused by the windowing of the FFT, a rectangular window is used. This however requires the use of a special test signal. UPV and UPP audio analyzers generate a pseudo noise signal consisting of many discrete frequency lines, each line being an integer multiple of the analysis time window and thus being precisely matched to the bin centres of the FFT analysis. Moreover, the test signal used should have a small crest factor to avoid overdriving of the DUT input by high peak voltage levels, which would be the case with white noise.

In this setup, FFT analysis with 2k points has been selected; this results in frequency response measurement with over 960 points with constant frequency spacing.
The generator signal is produced by means of the *Random* function in frequency domain. This yields a multi-frequency signal whose frequencies are matched to the FFT lines of the analyzer (*Spacing* setting: *Anl Trk*) and whose phases are optimized relative to one another for the smallest possible crest factor.

The measurement is performed at the speed of a single FFT. When the frequency response of the DUT is varied, the variation can be observed on the screen quasi in realtime since all test points are determined simultaneously.

The setup can be adapted to a finer or coarser resolution of the frequency points by selecting a different *FFT size* (max. 8 k). However, the higher the number of frequency lines selected, the longer computation time of the generator prior to the start of the first measurement.

The voltage values of the test points shown in the graphic display are far below the RMS values of the test signal. The latter, however, are the RMS values of the bins of the FFT analysis, and when adding the squares of the discrete level values the RMS value of the total signal is obtained. In this, FFT measurements differ from swept measurements, where the DUT is driven at one frequency only, whereas in measurements using a pseudo noise signal the total energy of the signal is distributed (broadband).

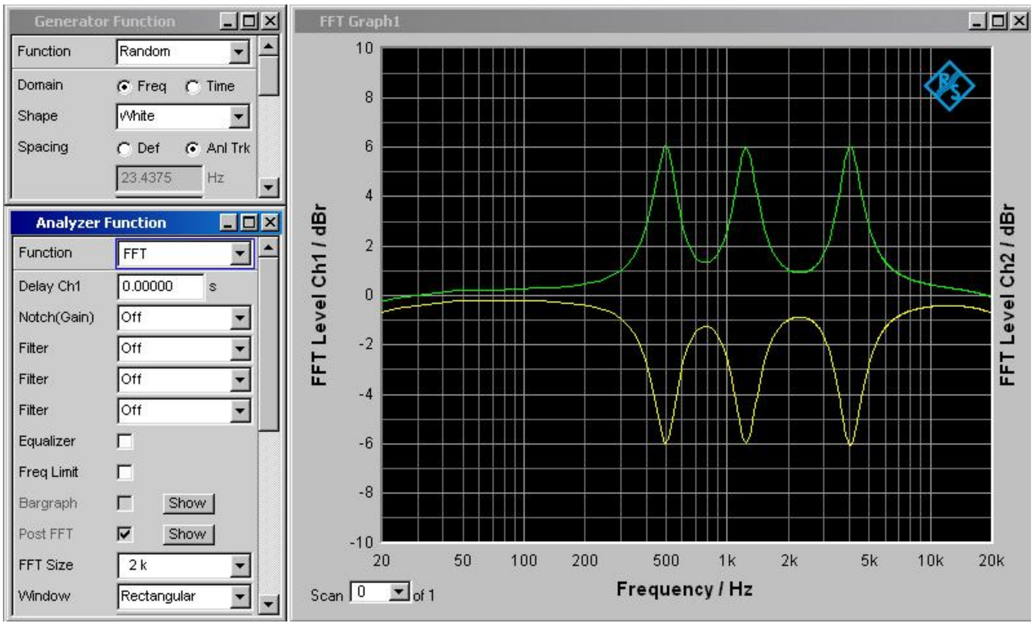


Fig. 3: Frequency response measurement using FFT analysis is very fast tool for example for adjustments

4.1.3 Frequency Response Measurement at Different Levels

Setups: **xx_Freq_Resp_Multi_Lev.set**

In some cases the variation of a parameter as a function of frequency and level is of interest. Fig. 4 shows as an example the level-dependent frequency response of a filter with limiter.

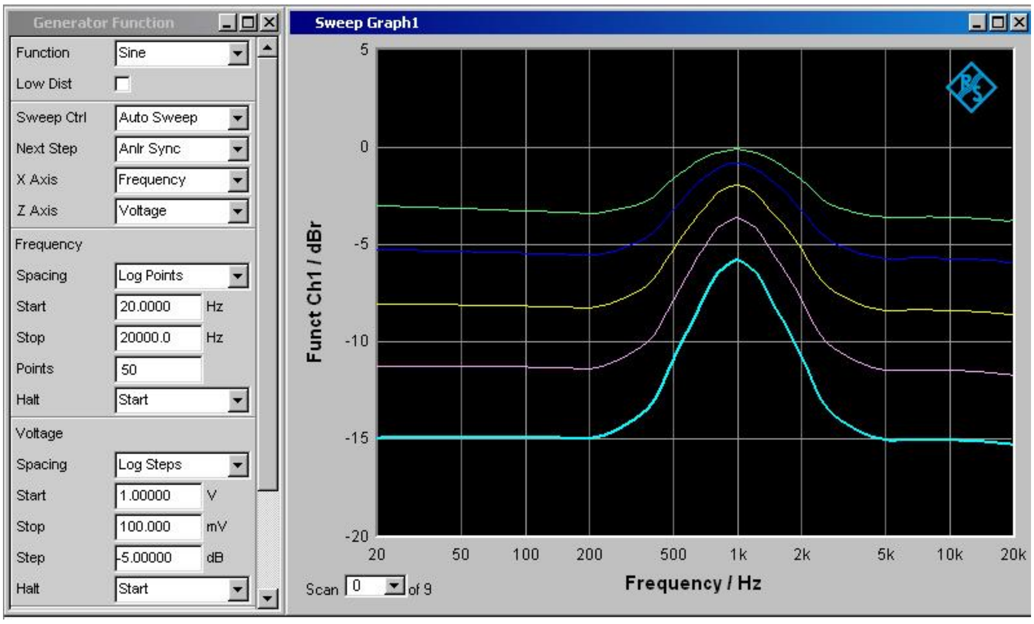


Fig. 4: Display of frequency response of filter with limiter at different levels

As mentioned under 4.1.1, the generator signal is swept over a frequency range from 20 Hz to 20 kHz. Moreover, a second sweep parameter can be activated in the *Generator Function* panel; for this setup, the parameter *Z Axis Voltage* has been selected. The start level is 1 V, the stop level 0.1 V and the step width -5 dB. The first frequency sweep is performed at a level of 1 V, in each following sweep the level is reduced by 5 dB.
As a result, five traces are obtained. Single-channel representation has been selected for this setup in the interest of a clear-cut display. The second channel can be displayed by activating *TRACE B* in the *Sweep Graph Config* panel.

In this way, any number of scans can be displayed. For each channel, the last 20 scans can be stored. The measured data of the last 20 scans can further be evaluated using the cursors.

4.2 Phase and Group-Delay Measurements

Definitions and test conditions:

Measurement of the phase frequency response of amplifiers is also defined by IEC 60238-3.
Same as amplitude frequency response, phase frequency response is measured under standard test conditions. The input signal is swept over the frequency range at a constant level; results are graphically displayed versus frequency.

In the standard, a differentiation is made between two measurements:

- Determination of the **phase frequency response,** the phase difference between the input and the output of a DUT is measured and displayed versus frequency.
- Determination of the **phase difference,** the phase difference between the two stereo output channels of a DUT is measured and displayed graphically.

4.2.1 Measurement of Phase Frequency Response

Setup: **xx_Phase_Response.set**

With this setup, a logarithmic sweep with 50 frequency points is performed from 20 Hz to 20 kHz.
UPV/UPP always measures the phase difference between its input channels where one channel can be selected as the reference channel. In dual-channel UPV audio analyzer, always channel 1 is used as the reference channel; in the UPP audio analyzer family (as well as with UPV using 8-channel UPV-B48 option) the reference channel can be selected in the line *Ref Channel* in *Analyzer Config* panel.
The example setups use channel 1 as the reference. Fig. 5 shows an example for a phase response measurement.

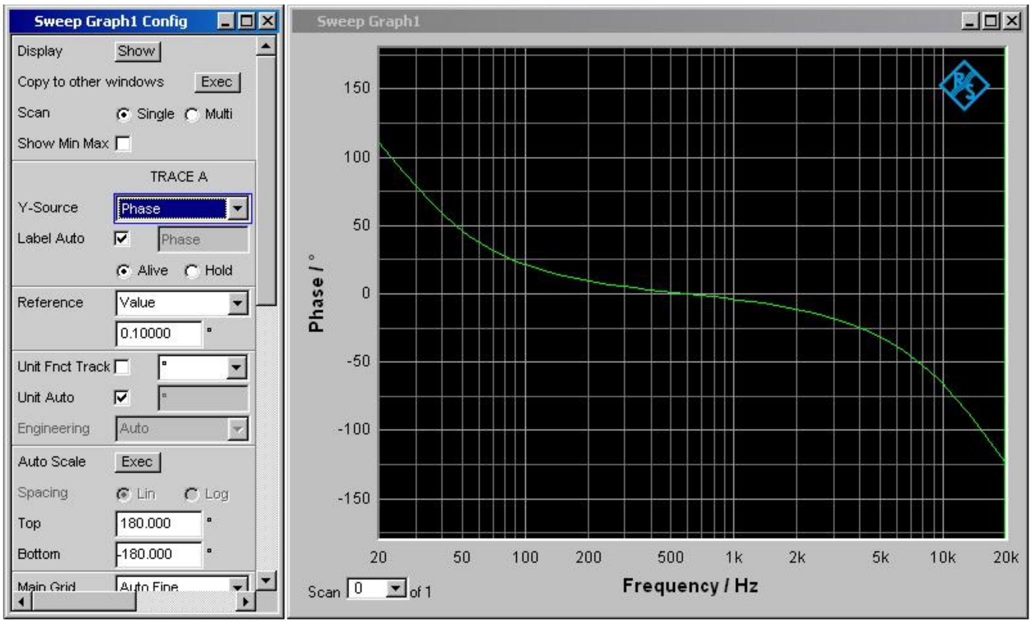


Fig. 5: Setting for measurement of phase frequency response

4.2.2 Measurement of Phase Difference between Two Stereo Channels

The procedure is similar to that described under 4.2.1 except that in this case both output channels of the DUT are connected to the inputs of UPV/UPP. The phase difference between the two stereo channels is displayed with channel 1 taken as a reference.

4.2.3 Measurement of Group Delay versus Frequency

Setup: **xx_Group_Delay.set**

For measuring the group delay, the information given under 4.2.1, "Measurement of Phase Frequency Response", applies analogously. Instead of phase measurement, the *Freq & Grp Del* setting is selected in the *Freq/Phase* line of the *Analyzer Function* panel.

4.3 Combined Measurements

In the following setups, the results of amplitude and phase/group delay frequency response measurements are combined in one graphic display. For measurement procedures see relevant sections above.

4.3.1 Amplitude and Phase Frequency Response in One Display

Setups: **xx_Freq_Phase_Resp.set**

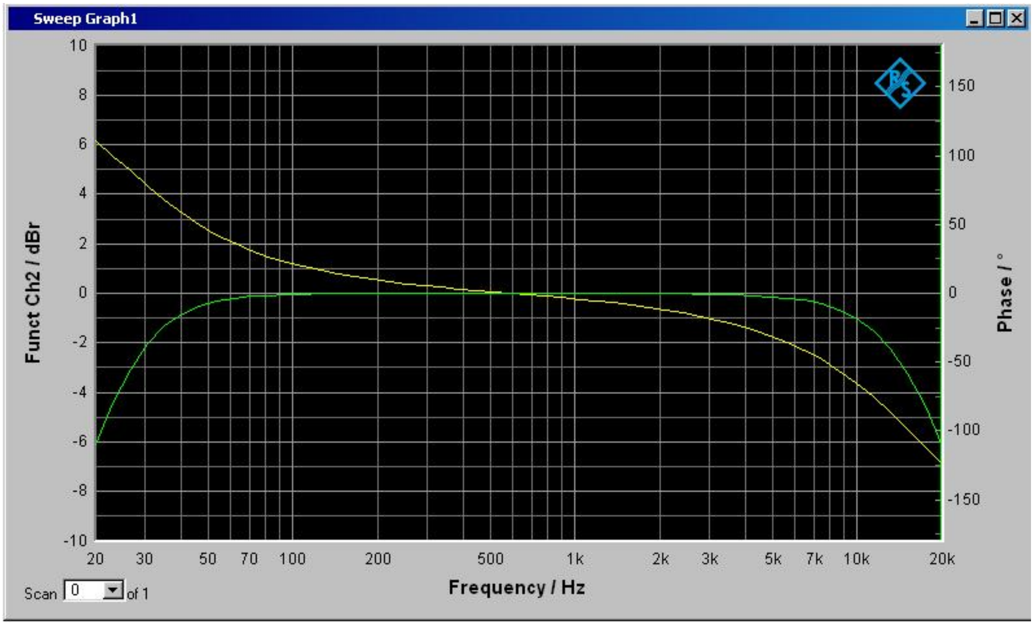


Fig. 6: Example of amplitude (green) and phase (yellow) frequency response measurements combined in one graph

4.3.2 Group Delay and Amplitude Frequency Response in One Display

Setups: **xx_Freq_GrpDel_Resp.set**

Display of group delay and amplitude frequency response combined in one graph.

5 Nonlinear Distortion Measurements

Nonlinear distortion is a variation of the signal shape caused by amplification in the transmission system as a function of the amplitude. In contrast to linear distortion, frequency components that are not contained in the input signal are generated.

5.1 Total Harmonic Distortion (THD)

Setups: **xx_THD.set**

Definitions and test conditions:

Distortion is defined by IEC 60268-2. To measure distortion, an amplifier is driven with a sinusoidal signal under standard test conditions.

To determine total harmonic distortion, the amplitudes of the harmonics at the output of the DUT are measured selectively, their RMS values added and a ratio is formed to the total signal.
The result is indicated as total harmonic distortion in % or in dB.

Total harmonic distortion as a function of amplitude or frequency is measured analogously.

Measurement of nth-order distortion is performed in the same way except that in this case it is not the RMS value of all harmonics that is determined but only individual harmonics are determined or combinations of specific harmonics used for calculating distortion.
An example of such a measurement is the 3rd harmonic specified for tape recorders.

Harmonic distortion or THD is a measure of quality mainly in the lower and middle frequency ranges. For a fundamental frequency of 8 kHz, for example, the 2nd harmonic of 16 kHz is already at the limit of hearing. The 3rd harmonic of 24 kHz is outside the audio transmission range. Harmonic distortion is therefore not suitable for describing nonlinear characteristics at higher frequencies.

Graphic display:

Total harmonic distortion can be indicated by means of a single measured value. With UPV/UPP, however, the spectral distribution of distortion products can be displayed, see Fig. 7.
Distortion as a function of frequency, for example, will be shown as a graph similar as for frequency response.

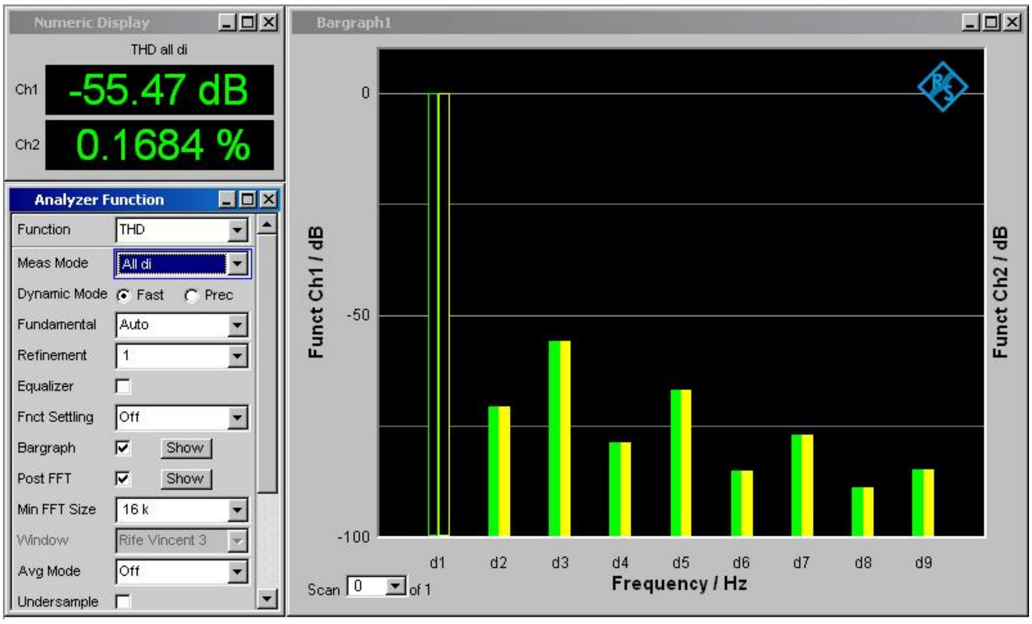


Fig. 7: THD measurement with display of distortion products

Notes on measurements:

In practice, DUTs frequently have a quadratic or cubic characteristic. This means that even-numbered or odd-numbered distortion products are predominant in the spectrum. This allows conclusions to be drawn as to the cause of harmonic distortion:

- Quadratic characteristic is obtained with unsymmetric distortion. Example: different gain for positive and negative halfwaves of a push-pull stage.
- Cubic characteristic is obtained with symmetric distortion; this is typical of any type of overdriving. Example: saturation with tape recorders.

UPV and UPP audio analyzers allow distortion measurement up to the 9th harmonic as shown in the setups presented here. If a single harmonic is to be taken into account, this is selected in the *Meas Mode* line in *Analyzer Config* panel. The components used for measurement are indicated in the measured-value display.

5.2 Total Harmonic Distortion plus Noise (THD+N)

Setups: **xx_THDN.set**

Definitions and test conditions:

Same as THD measurements, THD+N measurements use a sinusoidal signal to drive the DUT. However, in THD+N measurements, all spurious signals are taken into account in the result. This means that, in addition to harmonic distortion and noise, other signal components such as intermodulation products formed with the clock frequency in digital signal processing are taken into account in the result. To evaluate

such spurious signals, spectral analysis should be performed in addition to THD+N measurement.
When comparing measurements the bandwidth must be taken into account.

In accordance with AES 17, THD+N are to be performed at a level of -1 dBFS and -20 dBFS. The measurement bandwidth is limited to half the sampling frequency.

In the setups described here a measurement bandwidth of 100 Hz to 20 kHz has been selected, the analog output level is 1 V, the digital level -1 dBFS.

Graphic display:

The THD+N value can be indicated by means of a single measured value. With UPV/UPP, however, the spectral distribution of output products can be displayed using the post-FFT function and harmonics marked automatically as shown in Fig. 8. This enables non harmonic signal components to be detected very easily.

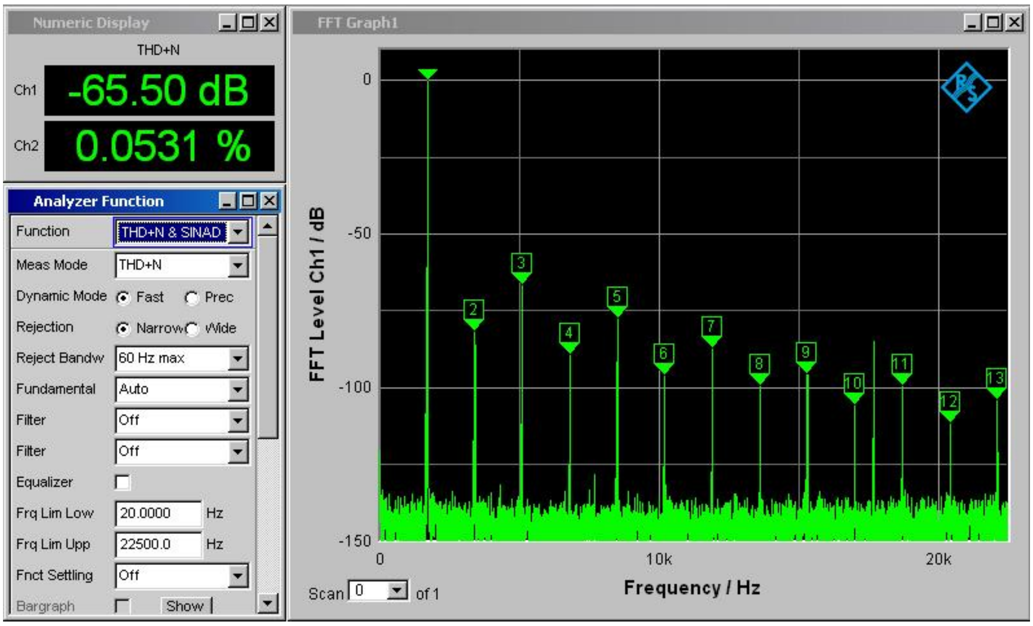


Fig. 8: THD+N measurement with distortion products marked

Notes on measurements:

This parameter too can be measured as a function of frequency or level.

5.3 Intermodulation

Setups: **xx_ModDist.set**

Definitions and test conditions:

Instead of a single sinusoidal signal, a signal composed of two frequencies, f_1 and f_2, is used, which yields not only the harmonics mf_l and nf_2 described above but also combination signals with the frequencies ($mf_1 \pm nf_2$). The occurrence of these signals is referred to as intermodulation.

To determine the modulation distortion in accordance with IEC 60268-3, an amplifier is operated under standard test conditions and driven with a two-tone signal. The frequencies of the two sinusoidal input signals should be such that f_1 is 0.5 to 1.5 octaves above the lower limit and f_2 0.5 to 1.5 octaves below the upper limit of the transmission range. The level ratio is 4:1. To calculate modulation distortion, the squares of the four intermodulation products formed by the 2nd-order intermodulation distortion ($f_2 + f_1$ and $f_2 - f_1$) and the 3rd-order intermodulation distortion ($f_2 + 2f_1$ and $f_2 - 2f_1$) are added up and the result referred to the level of signal f_2 with the higher frequency.
The result is indicated in % or in dB.

Graphic display:

As in the case of distortion measurements, the spectral distribution of the components can be displayed in addition to the measured value.

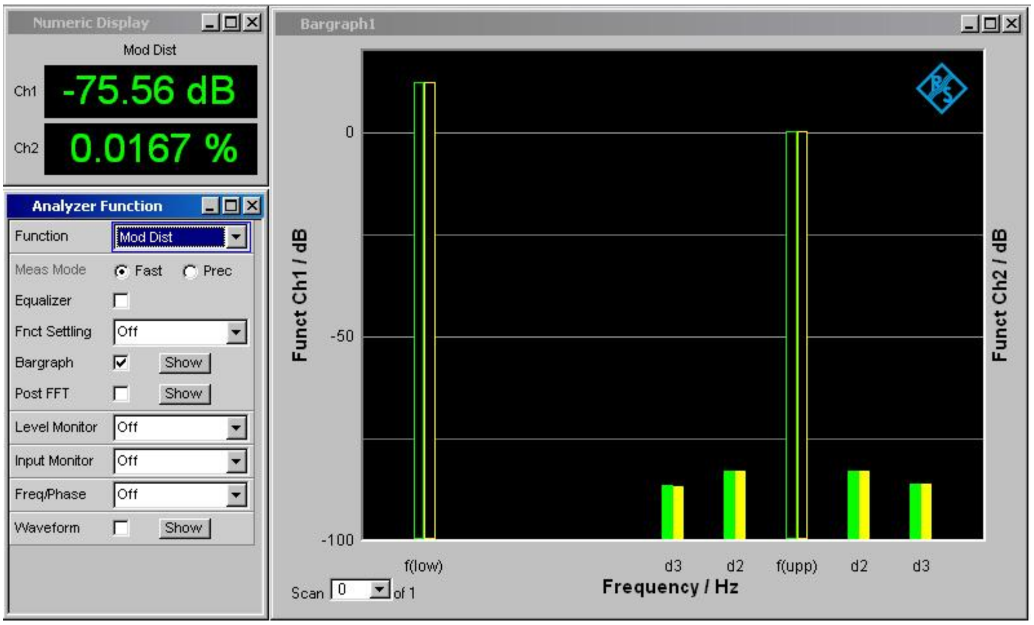


Fig. 9: Measurement of modulation distortion with graphic display of intermodulation products

Notes on measurements:

In the setups, a level ratio of 4:1 of the sinusoidal signals is selected. Setup AA_ModDist.set uses 60 Hz and 7 kHz with a total voltage of 1 V. All setups for digital interfaces use 41 Hz and 7993 Hz with full-scale amplitude of the DUT, the latter in compliance with AES 17.

If other test signals are to be used, the relevant lines in the *Generator Function* panel are to be changed accordingly. No modifications are required in the *Analyzer function* panel; the analyzer automatically adjusts to the test signal.

5.4 Difference Frequency Distortion (DFD)

Setups: **xx_DFD.set**

Definitions and test conditions:

The difference frequency distortion is determined in a similar way as modulation distortion but using a test signal composed of two sinusoidal frequencies f_l and f_2 of equal amplitude. The difference between the two frequencies is smaller than the lower frequency value. The voltage of the spectral component at the difference frequency $f_2 - f_1$ is measured whose position in the spectrum does not change as long as the frequency difference remains constant (2nd-order DFD). The 3rd-order DFD is determined from mixture products $2f_1 - f_2$ and $2f_2 - f_1$.

Modern audio analyzers employ FFT analysis for this type of measurement, results are calculated automatically in line with standards.

Measurement of difference frequency distortion is defined by various standards that differ as follows:

- For measurements on amplifiers, IEC 60268-3 defines the test signals on the basis of a fixed frequency spacing (mainly 80 Hz) and the arithmetic mean frequency. Results are referred to twice the output voltage of f_2, the absolute values of the two components $2f_1 - f_2$ and $2f_2 - f_1$ being added for determination of the 3rd-order DFD.

- IEC 60118 defines the DFD for measurements on hearing aids. Here, the upper frequency and the difference frequency are specified.
  Results are referred to output voltage f_2, and the 3rd-order DFD is determined by means of component $2f_1 - f_2$ only.

  The results obtained with the two standards thus differ by 6 dB for d_2 and are equal for d_3 provided the levels of $2f_1 - f_2$ and $2f_2 - f_1$ do not substantially differ from each other.

- For measurements on digital components, differential frequency distortion measurement is defined by AES 17, the measurement being in this case referred to as intermodulation measurement. The standard defines as test frequencies the upper limit frequency based on the selected sampling rate as well as the frequency 2 kHz below the limit frequency. The peak value of the total signal is to be adjusted such that it is equal to the peak value of a sinusoidal signal at full-scale amplitude. As with IEC 60268, results are referred to the total output signal of the DUT.

Graphic display:

Similar as with modulation distortion analysis.

Notes on measurements:

The setup for measurements on purely analog components is in line with IEC 60268-3, the center frequency is 7 kHz, the difference frequency 1 kHz. If other frequencies are to be used, the relevant lines in the *Generator Function* panel are to be changed. No modifications are required in the *Analyzer Function* panel; the analyzer automatically adjusts to the test signal.
For measurements to IEC 60118, the relevant lines *Mode* in the *Generator Function* panel and *Meas Mode* in the *Analyzer Function* panel are to be changed.

The setups for measurements on digital components give a test signal with a 6 kHz and an 8 kHz tone at full-scale amplitude.

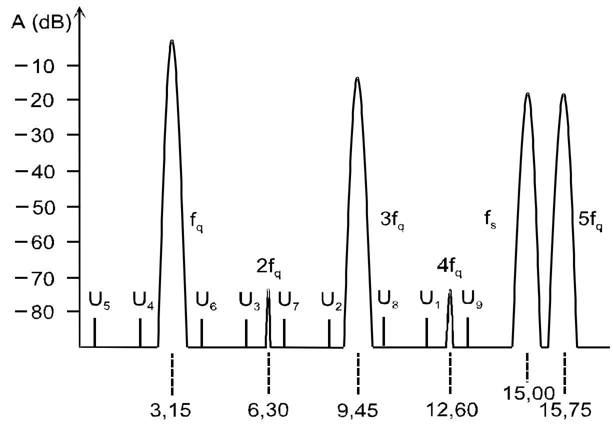
5.5 Dynamic Intermodulation (DIM)

This measurement function is implemented in the UPV audio analyzer. In addition, Option UPV-B3 is required for measurements on analog interfaces.
DIM functionality is not available in the UPP audio analyzer.

Setups: **AA_DIM.set**

Definitions and test conditions:

To determine dynamic intermodulation distortion in line with IEC 60268-3, the amplifier is operated under nominal conditions (i.e. at full-scale amplitude) and driven with an input signal consisting of a rectangular and a sinusoidal signal.



Intermodulation components Frequency	Voltage	Frequency kHz
$5f_q - f_s$	U_5	0,75
$f_s - 4f_q$	U_4	2,40
$6f_q - f_s$	U_6	3,90
$f_s - 3f_q$	U_3	5,55
$7f_q - f_s$	U_7	7,05
$f_s - 2f_q$	U_2	8,70
$8f_q - f_s$	U_8	10,20
$f_s - f_q$	U_1	11,85
$9f_q - f_s$	U_9	13,35

Fig. 10: Test signal for DIM distortion and intermodulation products to be measured

The rectangular signal has a fundamental frequency of 3.15 kHz and is band-limited to 30 kHz by means of a single-pole lowpass filter (100 kHz are also permissible). The sinusoidal signal has a frequency of 15 kHz and a level 12 dB below that of the rectangular signal.

The nine intermodulation products in the audible range are measured selectively, the sum of the squares of the products is formed, referred to the RMS value of the sinusoidal signal, and indicated in % or dB.

DIM distortion is obtained due to the short rise time of the rectangular signal which causes the amplifier to be driven dynamically to the limit of its slew rate. This test signal is to provide a better correlation between subjective hearing tests and measured results since in this case, similar as with music containing pulses, the amplifier output voltage changes very rapidly. Low-distortion amplification of the 15 kHz signal must be performed at the same time. Especially amplifiers with unfavourably designed negative feedback will respond with distortion.

Graphic display:

The UPV audio analyzer can display the spectral distribution of the components in addition to the measured value.

Notes on measurements:

The setups for measuring dynamic intermodulation are based on IEC 60268-3. In sound broadcasting, a rectangular/sinewave signal combination of 2.96/14 kHz is used instead of the 3.15/15 kHz frequency combination. The 2.96/14 kHz test signal can also be generated and analyzed with UPV.

5.6 FFT Analysis

Setups: **xx_FFT.set**

FFT analysis is used where the spectral composition of a signal is to be examined. The UPV and UPP audio analyzers provide a highly efficient tool for this purpose.

The setups described here generate a 1 kHz or 997 Hz test signal with a level of 1 V or -20 dBFS which can be applied to the DUT. The FFT analysis itself requires a minimum of settings. *FFT Size* defines the number of samples on which calculation is based. Higher *FFT Size* values give higher frequency resolution but at the same time entail longer measurement times. The setups were generated for 8k FFT; due to the high measurement speed of UPV/UPP it will only very rarely be necessary to select a lower number of points and thus obtain an even faster measurement.

Various *Windows* are available to accommodate for a wide variety of applications. The setups use the Rife-Vincent window, which is characterized by steep slope of the bell lobe and excellent far-off interference suppression.

With noisy signals, spectral averaging may be useful sometimes. This can be performed using the *Avg Mode* function; the type and number of averaging measurements can be entered.

6 Measurement of Interference

6.1 S/N Ratio

Setups: **xx_SN_AWeight.set**
AA_SN_CCIR_QPeak.set
xx_SN_CCIR2k.set

Definitions and test conditions:

The S/N ratio is the ratio in dB of the nominal output voltage to the sum of the broadband or weighted measured output voltages with the source EMF set to zero.
To determine the S/N ratio, the output voltage of the amplifier is measured under nominal conditions (i.e. the nominal output voltage V_{2ref} at full-scale amplitude of the DUT is measured). Then the source EMF is reduced to zero and the noise voltage V_2' is measured.
The result is indicated as noise level V_2' or as S/N ratio 20 lg (V_{2ref}/V_2') dB.
The UPV and UPP audio analyzers provide S/N ratio measurements as automatic test sequences.

S/N ratio measurements are covered by a variety of test standards and procedures. These differ mainly in:

- The type of weighting filter used for simulating hearing sensitivity as a function of frequency.
- The type of detector used which exhibit a different meter response for the noise under examination.

For unweighted audio noise voltage measurements, the unweighted RMS noise voltage is measured in accordance with DIN 45412 "Noise measurements for radio receivers and similar equipment". In this measurement, a bandpass filter of 22.4 Hz to 22.4 kHz is used for limiting the measurement bandwidth approximately to the range of audibility.

DIN 45412 further defines a commonly used method of S/N ratio measurement in which an A-filter is used and the RMS noise voltage determined.
The standard prescribes the use of an RMS detector, so the average noise power is measured.

However, the ear is very sensitive to sound containing pulses (noise peaks, clicking noise). Therefore, use is made of a quasi-peak detector to ITU-R BS.468-4 (originally CCIR 468-4) or DIN 45405.
A measurement method with quasi-peak indication has to be adopted; with this kind of measurement the waveform of the spurious signal is taken into account.

The standard DIN 45405 "Noise level measurement in sound systems" technically coincides with ITU-R BS.468-4 "Measurement of audio-frequency noise voltage level in sound broadcasting". It defines, for example, filter curves for weighted and unweighted measurements.
For unweighted noise level measurements, the same bandpass filter as defined by DIN 45412 is used.

Measurement of noise as defined by IEC 60268 provides for measurements using A filters and RMS weighting as well as measurements to ITU-R BS.468-4.

S/N measurement especially on digital audio components is defined in AES 17. A so-called CCIR ARM filter is used for this measurement; it has the same characteristic as the weighting filter according to ITU-R BS.468-4, but its 0 dB reference point lies at 2 kHz. Quite often, this filter is referred to as CCIR 2k filter. According to AES 17 the measurement is carried out with an RMS detector.

Although the original recommendation CCIR 468-4 has been adopted by the ITU, all the filters used for S/N measurements are commonly still called “CCIR filters”.

Notes on measurements:

Setups xx_SN_AWeight.set measure the S/N ratio as a weighted RMS value using an A-filter, setups xx_SN_CCIR2K.set use the RMS detector combined with the CCIR 2k weighting filter.
Setup AA_SN_CCIR_QPeak.set (available in UPV only) uses a quasi-peak detector and a CCIR 1k filter. It should be noted that the quasi-peak detector requires a settling time of approx. 3 s to supply valid results. This time is set in the setup.

Apart from the filters used in the above S/N ratio measurements, a wide variety of other weighting filters is in use in practice. In the *Analyzer Function* panel, any other weighting filter can be selected in the *Filter* line.

A comparison of results of noise voltage measurements is possible only if the test conditions regarding detectors, weighting filters and measurement bandwidth are observed. Depending on the type of measurement, deviations of more than 10 dB may be obtained.

6.2 Crosstalk (Inter-channel Separation)

Setups: **xx_Crosstalk.set**

Definitions and test conditions:

In accordance with IEC 60268-3, the level difference between the output signal of a fully driven channel and the output signal of a channel that is not driven is measured. The measurement is prescribed for both directions, and the results may differ due to asymmetries of the setup. The measurement is mandatory at the reference frequency and optional at further frequencies. Often measurements are made over the entire frequency range and results displayed graphically.

Both broadband and selective measurements are possible. Since with high-quality DUTs, the crosstalk level is in the vicinity of noise, only selective measurements are expedient in this case.

For crosstalk, measured values will always be < 1 (negative dB value) since the measured voltage is referred to the nominal output voltage.
For crosstalk attenuation which is likewise specified, values > 1 (positive dB values) will be obtained since the reference used is reversed.

AES 17 defines the inter-channel crosstalk ratio measurement, also called inter-channel separation. It is measured at a level of -20 dBFS. The level of the driven channel is referred to the level of the undriven channel, resulting in positive dB values.

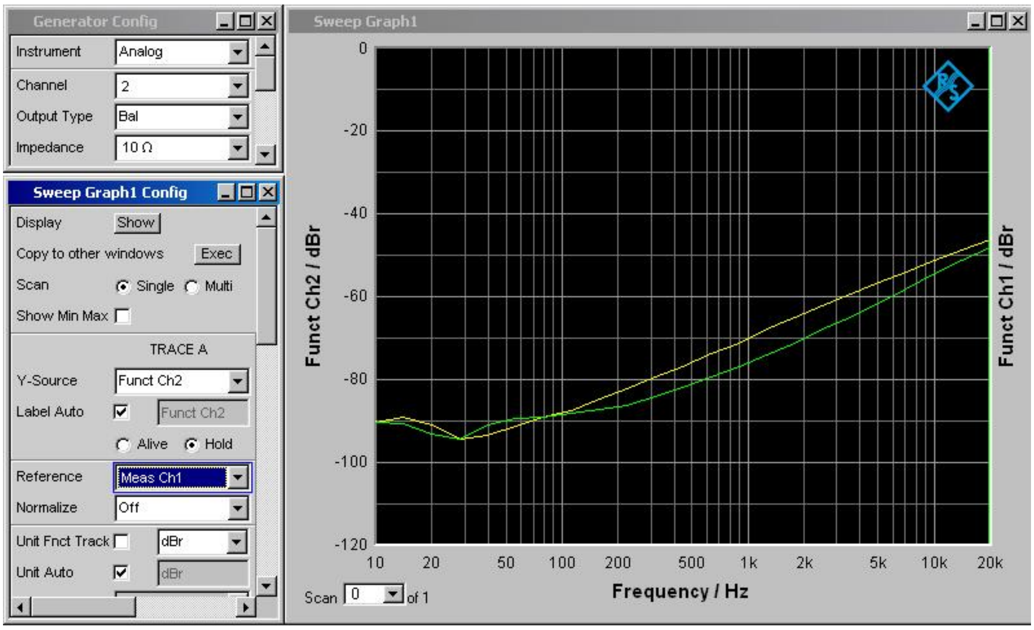


Fig. 11: Example of crosstalk measurement with required settings

Notes on measurements:

Crosstalk measurement is not a separate measurement function on the UPV and UPP audio analyzers, it is performed as a level measurement, with results being referred to the level values obtained for the other channel in each case.

The setups determine crosstalk in both directions. Measurements are made selectively with the aid of the sweep function from 10 Hz to 20 kHz. The following additional settings are to be made to get the results of both directions into one graph:

- In the basic setting of the setup, the test signal is output to channel 1 only. The level for the "analog" setups is at 1 V and must be set to maximum level of the DUT.
  For all other setups, the level is to be set to -20 dBFS.
- The sweep is started and crosstalk coupled into channel 2 displayed graphically. In the measurement, the level of channel 2 is determined and continuously referred to the level measured for channel 1 (setting: *Reference* to *Meas Ch1*).
- To measure the other direction, set the *Channel* line in the *Generator Config* panel from *1* to *2* so that the other channel will be driven.
- Now set *TRACE A* to *Hold* in the *Sweep Graph Config* panel and activate *TRACE B* to display the results of channel 1.
- UPV: Set the reference for the results of channel 1 to *Meas Ch2* in the *Reference* line.
  UPP: Set the reference for the results of channel 1 to *Meas Ref Ch* in the *Reference* line and set channel 2 as the reference channel in the line *Ref Channel* in the *Analyzer Config* panel.
- When the sweep is restarted, the crosstalk from channel 2 to channel 1 will be displayed in the same diagram.

7 Measurements on Analog/Digital Interfaces

7.1 Clipping Level

Setups: **AD_Clipping_Level.set**
AI_Clipping_Level.set

Definitions and test conditions:

Components using internal digital signal processing must not be overdriven since any loading in excess of the digital level range would result in strong distortion of the signal (clipping level). The full-scale amplitude therefore plays a far more important role in digital than in analog applications.
The clipping level must be determined for all digital components with analog input stage. If digital outputs are accessible, this is accomplished by increasing the level of a 997 Hz sinusoidal input signal until the peak value of the digital output signal equals the largest data word (full scale).

The level thus obtained defines the full-scale amplitude of the digital system and is used as a reference value in a variety of measurements.

Notes on measurements:

The setups supply an analog output signal of 997 Hz. The level is set to 1 V.

As the clipping level serves as a reference in a variety of other measurements, it is expedient to use the *Ref Voltage* function in the *Generator Config* panel of UPV/UPP. The data can then be entered in dBr in the *Voltage* line of the *Generator Function* panel, which avoids the need for constantly converting the levels to the clipping level.

To determine the full-scale amplitude as described above, the level of the generator signal is increased in the *Ref Voltage* line until the analyzer indicates the peak value of 0 dBFS. In doing this, it must be ensured that the full-scale value is not exceeded in none of the channels.
The clipping level thus obtained can then be transferred to all setups used for measurements on that particular DUT; any other level entries are made in dBr in the *Voltage* line.

7.2 Linearity of A/D Converters

Setups: **AD_Linearity.set**
AI_Linearity.set

Definitions and test conditions:

A 997 Hz sinusoidal signal is applied to the input of the DUT. The level of this signal is decreased in steps of 5 dB starting from the full-scale amplitude. The output signal is measured and represented graphically versus the input signal. As the signal disappears in the noise with decreasing level, narrowband measurement using a third-octave bandpass filter is performed.

In the setup described here, converter linearity is measured by means of a level sweep from 0 dBr to -120 dBr. With a linear response of the converter, a diagonal is obtained as shown in the graphic display of Fig. 12.

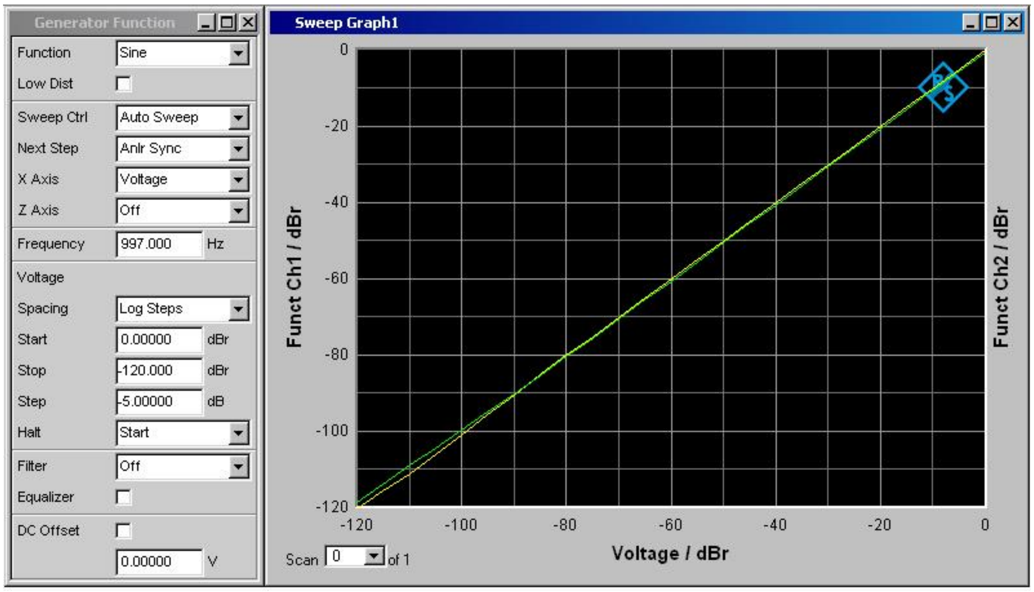


Fig. 12: Linearity measurement of A/D converter

Since deviations from the nominal characteristic are difficult to recognize in the above type of representation, linearity deviation is measured in most cases, which is described in the next setup.

Notes on measurements:

To drive the DUT at full-scale level, the clipping level determined in the previous measurement is to be entered into the *Ref Voltage* line of the *Generator Config* panel. This level serves as a reference for all level values defined in dBr in the generator's sweep lines.

To scale the graphic display correctly, the clipping level is also used as the reference level for the x-axis and therefore has to be entered in the line *Ref Value* of the *Sweep Graph Config* panel (see picture).

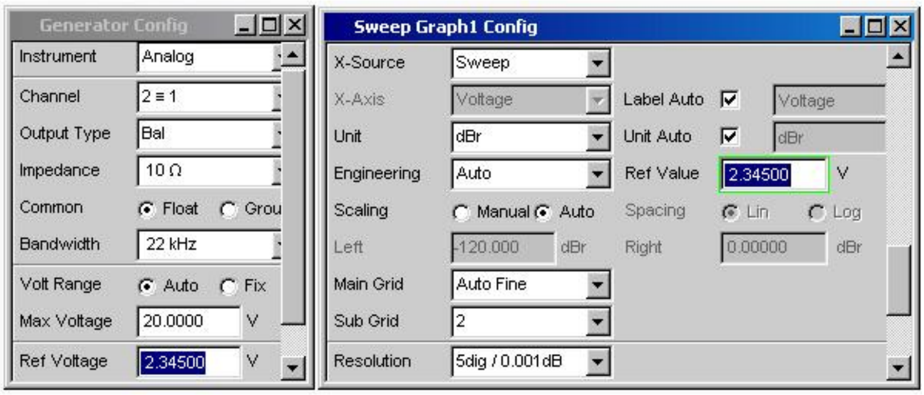


Fig. 13: The clipping level of the A/D converter is used as the reference level in Generator Config and Sweep Graph Config panels as marked in blue

7.3 Linearity Deviation of A/D Converters

Setups: **AD_Linearity_Deviation.set**
AI_Linearity_Deviation.set

Definitions and test conditions:

In principle the measurement of linearity deviation works the same way as the linearity measurement described before. However the graphical presentation shows a better visibility by referring the deviation from the ideal characteristic.

This type of measurement is defined by AES 17 where it is called “Gain non-linearity”. A linearity measurement is performed, the first result is however recorded at -5 dBFS. For each test step, the logarithmic gain, i.e. ratio of output amplitude to input amplitude, is to be determined and represented graphically versus the input level. The resulting diagram shows the deviation of the converter transmission characteristic from the ideal linearity characteristic.

Measurements are to be performed selectively using a third-octave bandpass filter.

Notes on measurements:

For this measurement, too, the clipping level determined in accordance with 7.1 "Clipping Level" is to be entered into the *Ref Voltage* line of the *Generator Config* panel and in the line *Ref Value* of the *Sweep Graph Config* panel.

In the ideal case, a straight line is obtained in the graphic display, any deviation from the ideal characteristic of the converter can be read in dB.

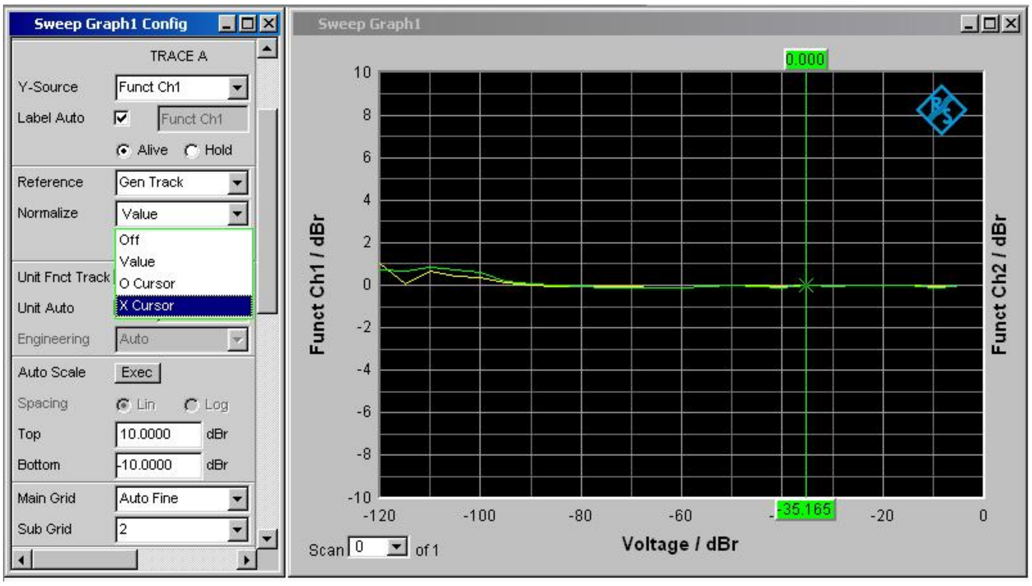


Fig. 14: Linearity deviation of A/D converter, the cursor value is transferred by means of the *Normalize* function

This type of measurement however involves a physical problem, i.e. referring the digital output voltage of the converter to the analog input voltage at every test point. The UPV and UPP audio analyzers have an internal "conversion factor" of 1 FS ≙ 1 V. With this factor, a straight line would be obtained but it would not coincide with the zero line. The gain factor of the DUT must, therefore, be taken into account in addition. This is done by means of the *Normalize* function, which is included in the *Sweep Graph Config* panel (see Fig. 14). Here the gain can be entered directly, it is however easier in most cases to transfer this value from the graphic display. To this end, a cursor is placed on the linear section of the curve and the cursor value is transferred to the *Normalize* line by selecting the item *x Cursor*.

7.4 Linearity of D/A Converters

Setups: **DA_Linearity.set**
IA_Linearity.set

Definitions and test conditions:

For linearity measurements of D/A converters, the information given under 7.2 "Linearity of A/D Converters" applies analogously.

Notes on measurements:

The reference value used for graphic display of the level values in dBr is obtained from the gain ratio of the converter, i.e. the ratio of digital input amplitude to analog output amplitude. With this setup, the reference value is easiest taken from the *Reference* line in the *Sweep Graph Config* panel by selecting the *Max* item. The maximum value measured will thus be taken as a reference. In this setup, this value corresponds to maximum level of the DUT since the generator sweep is started at 0 dBFS.

7.5 Linearity Deviation of D/A Converters

Setups: **DA_Linearity_Deviation.set**
IA_Linearity_Deviation.set

Definitions and test conditions:

This measurement too is defined by AES 17, called “Gain non-linearity”. The information given under 7.3 "Linearity Deviation of A/D Converters" applies analogously.

Notes on measurements:

The measurement procedure is the same as described under 7.3 for "Linearity Deviation of A/D Converters".
Also in this case, the *Normalize* function is needed; the gain of the converter is easiest transferred from the graphic diagram as described for the A/D converter above.

7.6 Signal Delay in Analog and Digital Systems

Setups: **xx_Delay.set**

Definitions and test conditions:

This measurement is used to determine the signal delay between the input and the output of a digital system. A pulse-shaped signal is applied to the DUT. The input and the output signal are displayed on an oscilloscope from which the delay can be read. The measurement is used whenever digital signal processing takes place, also on DUTs with analog or analog/digital interfaces.

Notes on measurements:

The measurement is performed with the UPP and UPV audio analyzers by using the *Waveform* function.
The Waveform function can be triggered not only to the measurement channels, but also to a burst signal supplied by the generator. This measurement function ensures that the measurement is started exactly time-synchronously with the issue of the test signal. Since the test signal is applied to the input of the DUT, exact triggering to the input signal of the DUT is performed. Internal delays of UPP/UPV are taken into account and do not affect results.

For this test, a sine burst with a level of -20 dBFS is generated. The burst consists of a 1 kHz signal which is output 10 times, followed by a pause of 90 ms.

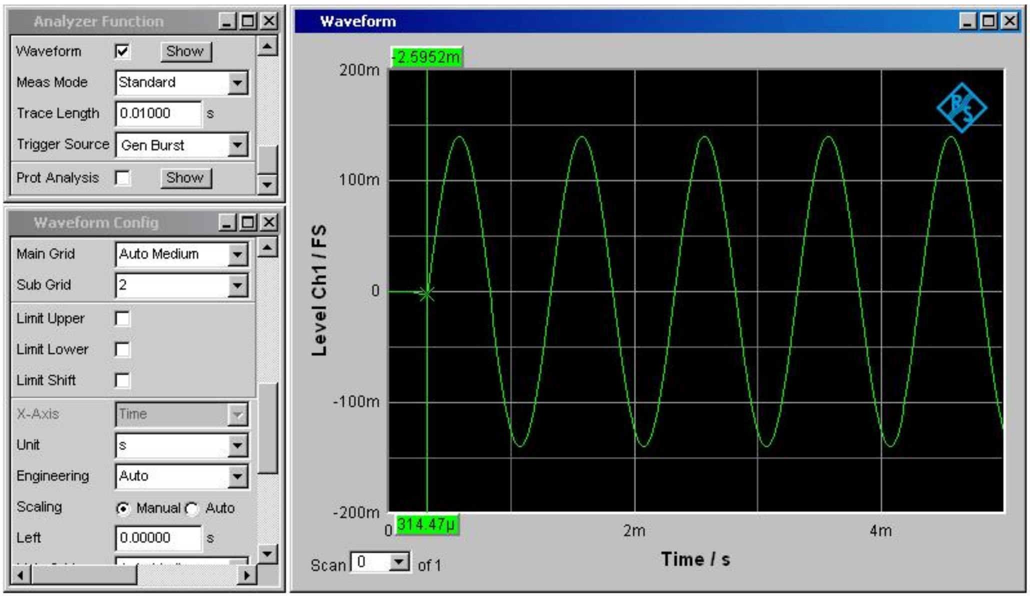


Fig. 15: Measurement of signal delay in digital systems

The signal delay is measured with the aid of the cursor. To this end, the cursor is placed at the point at which the signal departs from the zero line. The graphic window shows the level measured for each cursor position, so this procedure is very easy to perform. The delay is then indicated directly in the second cursor display window (the zero point in the graphic display corresponds to the start of the test signal).

If the measurement is to be performed for both channels, *TRACE B* is to be set to the *Level Ch2* measurement function. The second cursor can then be used for channel 2. It is further possible to display the time difference between the two cursors directly by appropriate setting using the softkeys at the bottom of the screen.

In addition to signal delay, determination of the polarity between the input and the output signal can be checked with this setup. Polarity reversal is indicated if the displayed output signal does not start with the positive half-wave as is the case with the test signal from the generator.

Annex: Overview of Setups Used

The setups described here are supplied with every Rohde & Schwarz audio analyzer.

The setup files are available for the different input/output combinations (analog or digital / I²S) of the generator and analyzer. They are stored in the directory *D:\UPV\Setup Examples* in the subdirectories *AA, AD, Analog-I2S, DA, DD, I2S-Analog*, whereby the generator output is listed first, followed by the analyzer input. The file name indicates the respective application, for example the setup *AD_Freq-Response.set* provides an analog generator output signal and uses the digital analyzer inputs to measure the frequency response.

Linear Distortion Measurements	
Amplitude frequency response	
Sweep measurement using signal from internal generator	
AA_Freq_Response.set **AD_Freq_Response.set** **AI_Freq_Response.set** **DA_Freq_Response.set** **IA_Freq_Response.set** **DD_Freq_Response.set**	Logarithmic frequency sweep from 20 Hz to 20 kHz at constant level, graphic display of amplitude frequency response
Fast frequency response measurement using FFT	
AA_Freq_Resp_FFT.set **AD_Freq_Resp_FFT.set** **AI_Freq_Resp_FFT.set** **DA_Freq_Resp_FFT.set** **IA_Freq_Resp_FFT.set** **DD_Freq_Resp_FFT.set**	Display of frequency response using 2k FFT
Frequency response measurements at different levels	
AA_Freq_Resp_Multi_Lev.set **AD_Freq_Resp_Multi_Lev.set** **AI_Freq_Resp_Multi_Lev.set** **DA_Freq_Resp_Multi_Lev.set** **IA_Freq_Resp_Multi_Lev.set** **DD_Freq_Resp_Multi_Lev.set**	Logarithmic frequency sweep from 20 Hz to 20 kHz with additional level sweep from 1 V to 0.1 V, graphic display of amplitude frequency response curves
Phase and group-delay measurements	
Measurement of phase frequency response	
AA_Phase_Response.set **AD_Phase_Response.set** **AI_Phase_Response.set** **DA_Phase_Response.set** **IA_Phase_Response.set** **DD_Phase_Response.set**	Logarithmic frequency sweep from 20 Hz to 20 kHz at constant level, graphic display of phase frequency response

Measurement of group delay versus frequency	
AA_Group_Delay.set **AD_Group_Delay.set** **AI_Group_Delay.set** **DA_Group_Delay.set** **IA_Group_Delay.set** **DD_Group_Delay.set**	Logarithmic frequency sweep from 20 Hz to 20 kHz at constant level, graphic display of group delay versus frequency

Combined measurements	
Amplitude and phase frequency response in one display	
AA_Freq_Phase_Resp.set **AD_Freq_Phase_Resp.set** **AI_Freq_Phase_Resp.set** **DA_Freq_Phase_Resp.set** **IA_Freq_Phase_Resp.set** **DD_Freq_Phase_Resp.set**	Logarithmic frequency sweep from 20 Hz to 20 kHz at constant level, combined display of amplitude and phase frequency response
Group delay and amplitude frequency response in one display	
AA_Freq_GrpDel_Resp.set **AD_Freq_GrpDel_Resp.set** **AI_Freq_GrpDel_Resp.set** **DA_Freq_GrpDel_Resp.set** **IA_Freq_GrpDel_Resp.set** **DD_Freq_GrpDel_Resp.set**	Logarithmic frequency sweep from 20 Hz to 20 kHz at constant level, combined display of group delay and amplitude frequency response 1

Nonlinear Distortion Measurements	
Total harmonic distortion (THD)	
AA_THD.set **AD_THD.set** **AI_THD.set** **DA_THD.set** **IA_THD.set** **DD_THD.set**	Measurement of THD; simultaneous display of spectrum up to 9th harmonic
THD+N	
AA_THDN.set **AD_THDN.set** **AI_THDN.set** **DA_THDN.set** **IA_THDN.set** **DD_THDN.set**	Measurement of THD+N value; simultaneous display of spectrum with harmonics marked
Intermodulation	
AA_ModDist.set **AD_ModDist.set** **AI_ModDist.set** **DA_ModDist.set** **IA_ModDist.set** **DD_ModDist.set**	Measurement of intermodulation; spectral display of intermodulation products

Difference frequency distortion (DFD)	
AA_DFD.set **AD_DFD.set** **AI_DFD.set** **DA_DFD.set** **IA_DFD.set** **DD_DFD.set**	Measurement of difference frequency distortion; spectral display of 2nd-order DFD
Dynamic intermodulation (DIM) - UPV only	
AA_DIM.set	Measurement of dynamic intermodulation distortion to IEC 60268-3; spectral display of intermodulation products
FFT analysis	
AA_FFT.set **AD_FFT.set** **AI_FFT.set** **DA_FFT.set** **IA_FFT.set** **DD_FFT.set**	Spectral display by means of FFT analysis; generator supplies 1 kHz / 997 Hz test signals

Measurement of Interference	
S/N ratio	
AA_SN_AWeight.set	Display of S/N ratio weighted with A filter; measurement by means of RMS detector
AA_SN_CCIR_QPeak.set (UPV only)	Display of S/N ratio weighted with CCIR1k filter; measurement by means of quasi-peak detector
AD_CCIR2k.set **AI_CCIR2k.set** **DA_CCIR2k.set** **IA_CCIR2k.set** **DD_CCIR2k.set**	Display of S/N ratio weighted with CCIR2k filter; measurement by means of RMS detector
Crosstalk (inter-channel separation)	
AA_Crosstalk.set **AD_Crosstalk.set** **AI_Crosstalk.set** **DA_Crosstalk.set** **IA_Crosstalk.set** **DD_Crosstalk.set**	Graphic display of crosstalk from channel 2 to channel 1 and vice versa; frequency sweep from 20 Hz to 20 kHz

Measurements on Analog/Digital Interfaces	
Clipping level	
AD_Clipping_Level.set **AI_Clipping_Level.set**	Setup for determining clipping level of A/D converters
Linearity of A/D converters	
AD_Linearity.set **AI_Linearity.set**	Graphic display of converter linearity, determined with level sweep 0 dBr to -120 dBr
Linearity Deviation of A/D converters	
AD_Linearity_Deviation.set **AI_Linearity_Deviation.set**	Similar to linearity of A/D converters, but with display of deviation from ideal characteristic
Linearity of D/A converters	
DA_Linearity.set **IA_Linearity.set**	Graphic display of converter linearity, determined with level sweep 0 dBr to -120 dBr
Linearity Deviation of D/A converters	
DA_Linearity_Deviation.set **IA_Linearity_Deviation.set**	Similar to linearity of D/A converters, but with display of deviation from ideal characteristic
Signal delay in analog and digital systems	
AA_Delay.set **AD_Delay.set** **AI_Delay.set** **DA_Delay.set** **IA_Delay.set** **DD_Delay.set**	Measurement of signal delay in analog and digital systems using the *Waveform* function; determination of delay and polarity

8 Literature

- R&S®UPP audio analyzer operating manual
- R&S®UPV audio analyzer operating manual
- IEC 60268-1 “Sound system equipment, Part 1: General”
  International Electrotechnical Commission,
  Geneve, Switzerland
- IEC 60268-2 “Sound system equipment, Part 2: Explanation of general terms and calculation methods”
  International Electrotechnical Commission,
  Geneve, Switzerland
- IEC 60268-3 “Sound system equipment, Part 3: Amplifiers”
  International Electrotechnical Commission,
  Geneve, Switzerland
- AES-17 “Measurement of digital audio equipment”
  Audio Engineering Society, New York City, USA
- Recommendation ITU-R BS.468-4 (originally CCIR 468-4)
  “Measurement of audio-frequency noise voltage level in sound broadcasting”
  International Telecommunication Union, Geneva, Switzerland
- DIN 45412 “Noise measurements for radio receivers and similar equipment”
  Deutsches Institut für Normung, Berlin, Gemany
- DIN 45405 “Noise level measurement in sound systems”
  Deutsches Institut für Normung, Berlin, Gemany

9 Ordering Information

Please visit the Rohde & Schwarz product websites at www.rohde-schwarz.com for ordering information on the following Rohde & Schwarz products:

- R&S®UPP audio analyzer
- R&S®UPV audio analyzer

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