Swept Harmonic Distortion Measurements
Application Note

Products:

| R&S®UPV

| R&S®UPV66

| R&S®UPV-K1

This application note provides a program which allows to record total harmonic distortion, single harmonic distortion factors and level with one generator sweep. The executable may be installed and used without caring about programming. The source code is provided as basis for custom modifications.

ROHDE&SCHWARZ

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1 Harmonic Distortion Measurements

1.1 Introduction

Harmonic distortion measurements are usually performed on passive components like loudspeakers, headphones and earphones, and on active components like amplifiers. Particularly with acoustic devices like loudspeakers, headphones and earphones, harmonic distortion may vary strongly over frequency. Investigating the cause of total harmonic distortion, it is often desired to determine and display also distortion factors for single harmonics over frequency. In addition, the frequency response of the tested component is almost always of interest.

This application note provides a program which allows to record and display total harmonic distortion, single harmonic distortion factors and level with one generator sweep.

1.2 Theory

1.2.1 Nth Order Distortion Factor

Nth order distortion factor is defined e.g. in different parts of IEC 60268 as the ratio between the RMS voltage of the nth harmonic and the total RMS voltage of the signal:

$$d_n = \frac{V_{RMS,n}}{V_{RMS,total}} * 100\%$$

or in logarithmic unit

$$d_n = 20 * \log\left(\frac{V_{RMS,n}}{V_{RMS,total}}\right) dB$$

1.2.2 Total Harmonic Distortion

Accordingly, the total harmonic distortion (THD) is defined as the ratio between the RMS voltage of all distortion products and the total RMS voltage of the signal:

$$d_n = \frac{\sqrt{V_{RMS,2}^2 + V_{RMS,3}^2 + ... + V_{RMS,n}^2}}{V_{RMS,total}} * 100\%$$

and in logarithmic unit

$$d_n = 20 * \log \left(\frac{\sqrt{V_{RMS,2}^2 + V_{RMS,3}^2 + ... + V_{RMS,n}^2}}{V_{RMS,total}} \right) dB$$

This definition is taken as basis for the analyzer function "THD" in the UPV. It delivers distortion values ≤ 100 % corresponding to negative dB values. It should be noted that an alternative definition exists, wherein the RMS value of the distortion products is related to the RMS value of the fundamental instead of the total RMS value. This definition allows distortion values beyond 100 % and also positive dB values.

1.2.3 Measurement Method

The total RMS voltage of the distorted signal is measured.

The RMS value of the nth order harmonic is suggested to be measured at the output of a suitable band-pass filter.

1.3 Implementation in Audio Analyzer R&S® UPV

1.3.1 General

Harmonic distortion measurement is implemented in the audio analyzer R&S® UPV in analyzer function "THD". Function result is the total harmonic distortion factor calculated from the harmonics specified in the "Meas Mode" field. Alternatively to the harmonic distortion factor, the absolute level of the specified distortion products can be determined and displayed. Nth order distortion factors or levels can be displayed simultaneously in one of the bargraph displays.

1.3.2 Spectral Analysis

The bandpass functionality required to determine the RMS values of the harmonics is implemented in this analyzer function in the form of a Fast Fourier Transform (FFT).

The FFT spectrum used for the THD calculation can be displayed in the R&S® audio analyzer UPV as "Post FFT".

1.3.3 Nth Order Harmonic Distortion

The levels of the harmonics are determined from the FFT spectrum. Nth order distortion factors are calculated like defined above and can be displayed in one of the two bargraph displays.

1.3.4   Function Result

The function result of analyzer function "THD" is the total harmonic distortion, calculated from the levels of the harmonics specified in the "Meas Mode" combobox. It can include either all harmonics up to the 9th or a selection of them.

1.3.5   Swept THD Measurement

Like all analyzer function results, the THD can be displayed over frequency or voltage in one of the four sweep graphs. The sweep is configured in the generator function "Sine". For each sweep step, the bargraph displays the distortion factors of the harmonics. However, in the standard user interface only one distortion factor can be recorded per sweep. To display e.g. THD, 2nd order and 3rd order harmonic distortion factors, three subsequent sweeps would be required.

The application program provided with this application note does a sweep consisting of a number of single measurements, collects all available distortion results up to the 9th harmonic from the single measurements and displays them in a table. THD, 2nd order distortion, 3rd order distortion and RMS level are displayed in the sweep graph panels on screens 2 to 5 of the UPV window.

2 Using the Application Program

2.1 Prerequisites

Running the application program requires option UPV-K1 "Universal Sequence Controller" to be installed. The Visual Basic .NET development environment delivered with this option is not required to run the installed application program.

2.2 Installation

Copy the installer "1GA56.msi" to the UPV hard disk, e.g. to "D:\R&S_Software\ Applications". Run the installer and follow the instructions on the screen.

The installer creates an application folder "1GA56" in "C:\Program Files\Rohde&Schwarz". Shortcuts are installed on the desktop and in the programs menu in subfolder "R&S UPV Applications".

The application folder also contains example setups called "THD_Swp.set", "THD_Swp_dB.set" and "THD_Swp_Pct.set". This setup is copied to folder "D:\UPV\Setups" upon start of the program unless a file of this name is already existing there.

The program can be started from the shortcut "1GA56 THD Sweep" which can be found both on the desktop and in subfolder "R&S UPV Applications" in the Programs menu.
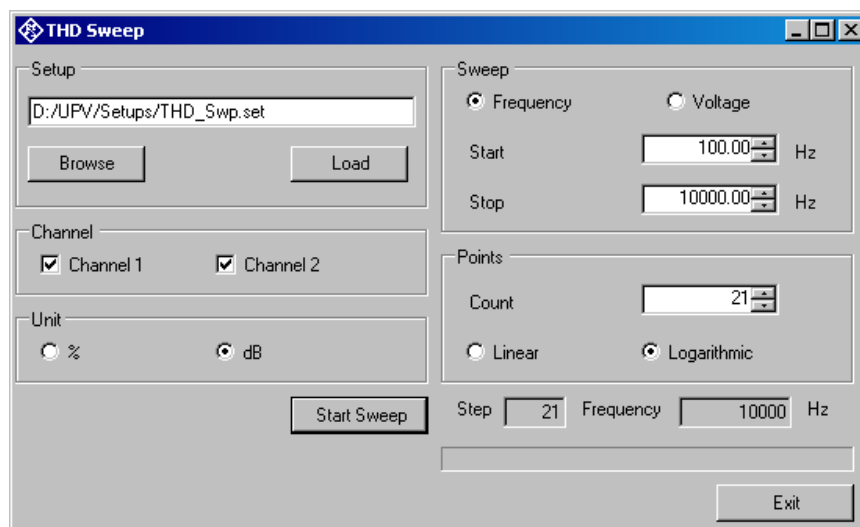
2.3 User Interface

Figure 1: User interface of the application program

2.3.1   Loading a setup and customizing the measurement

The sweep cannot be started before a setup has been loaded by clicking the "Load" button in the "Setup" field. The path name for the setup to be loaded is written in the text box above the buttons. It can be directly typed or pasted there or filled in using the "Browse" button.
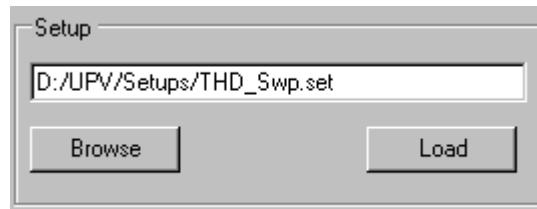

Figure 2: "Setup" field

After the setup has been loaded, it can be customized in the UPV window. All parameters with the exception of analyzer channel, distortion unit and sweep parameters are taken from the setup. Particularly the generator parameter which is not swept has to be set in the setup, i.e. the voltage for a frequency sweep or the frequency for a voltage sweep, respectively. Make sure not to change the generator function to another than Sine, and not to activate the sweep in the setup.
These settings can be saved as new setup under different name (menu item "File →
Save Setup as …" in the UPV window) before starting the sweep. The setup can be loaded later on when the settings are to be re-used.

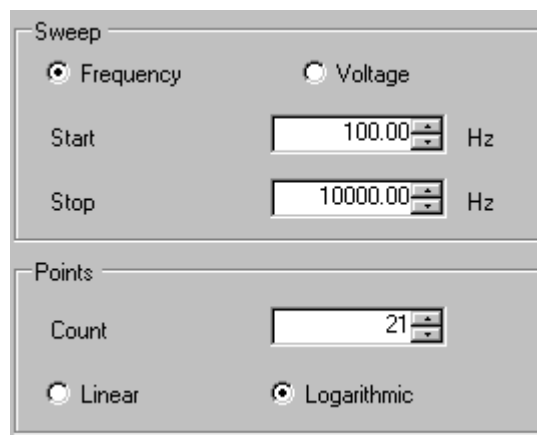### 2.3.2   Configuring the Sweep

Figure 3: Sweep parameters in the user interface

Sweeps of the THD measurement can be done over frequency or voltage. For a frequency sweep the unit is always Hz. For a voltage sweep the unit is V for linearly equally spaced points and dBV for logarithmically equally spaced points (i.e. constant dBV step size).

Configure start frequency, stop frequency and point count according to the desired frequency range and frequency resolution.

2.3.3   Running a Sweep

When all the settings have been made in the UPV window, consider to save a copy of this setup for subsequent use. Then a sweep can be started with the "Start Sweep" button. The fields besides the buttons show the number of the current sweep step and the current value of the swept magnitude. A progress bar shows the ratio of completed sweep points related to the total point count.
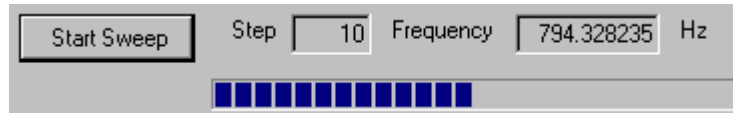
Start Sweep	Step	10	Frequency	794.328235	Hz

Figure 4: Sweep status information in the user interface

During the sweep, the controls of application program and UPV window are locked. Do not attempt to change any settings during this time.

2.3.4   Viewing and Saving Results

After a sweep has terminated, a new window opens with a table containing all available results. The data can be stored to a Tab-separated txt file or a comma-separated csv file by clicking the "Save as ..." button. Both formats can easily be imported into spreadsheets.

Result Table 1

X / Hz	Lev Ch1/DBV	Lev Ch2/DBV	THD Ch1/dB	THD Ch2/dB	d2 Ch1/dB	d2 Ch2/dB	d3 Ch1/c
398.1071705	-38.29822158	-38.30919265	-50.39229583	-50.40935134	-62.7906	-62.7517	-51.3375
501.1872336	-37.81682205	-37.83135986	-49.97264862	-49.97568130	-61.5847	-61.4728	-51.0648
630.9573444	-37.01867294	-37.03270721	-50.76074600	-50.78469085	-62.5839	-62.5403	-51.7676
794.3282347	-38.62074279	-38.63153839	-42.96356964	-43.11734008	-50.5492	-50.8036	-44.4977
1000	-36.56216812	-36.57626342	-48.34679031	-48.35018539	-61.5629	-61.5345	-48.9587
1258.925411	-36.16443252	-36.17857360	-57.87908554	-57.84941864	-64.4851	-64.5117	-62.0465
1584.893192	-36.37246704	-36.38658523	-54.04897308	-54.04605865	-68.5346	-68.6128	-66.2407
1995.262314	-38.91600418	-38.92684555	-50.99563980	-52.40948486	-60.7164	-62.3973	-57.8064
2511.886431	-41.69022750	-41.70100021	-45.82158279	-46.61056518	-58.854	-60.9456	-53.7395
3162.277660	-45.38811111	-45.42710113	-43.68204879	-44.40268325	-55.6412	-57.1635	-51.1718
3981.071705	-46.71459960	-46.72560501	-43.79356765	-44.80531692	-53.4284	-54.7603	-53.4021
5011.872336	-49.24582672	-49.25754547	-39.62765884	-40.41863250	-51.9745	-53.549	-47.4336
6309.573444	-48.41349411	-48.42399597	-40.81150436	-41.27713012	-45.8119	-46.0298	-48.4545
7943.282347	-46.80255508	-46.81624984	-38.93718719	-38.93746948	-55.5975	-55.6465	-55.1752
10000	-49.17409896	-49.10185241	-38.64308166	-39.10568237	-49.0277	-50.0705	-50.2402

Save as ...		Close

Figure 5: Result table

Each result table is an independent new instance. It can be kept open while a new sweep is running. For better identification the result tables are numbered in the title bar in the order or their creation.

At the same time, sweeps are written back into the four UPV sweep graphs. The sweep graphs 1 to 4 are open on virtual screens 2 to 5 in the UPV window. The virtual screens can be changed using the "Screen" buttons on the UPV front panel, the "Screens" menu in the UPV window or the numbered screen buttons in the toolbar.
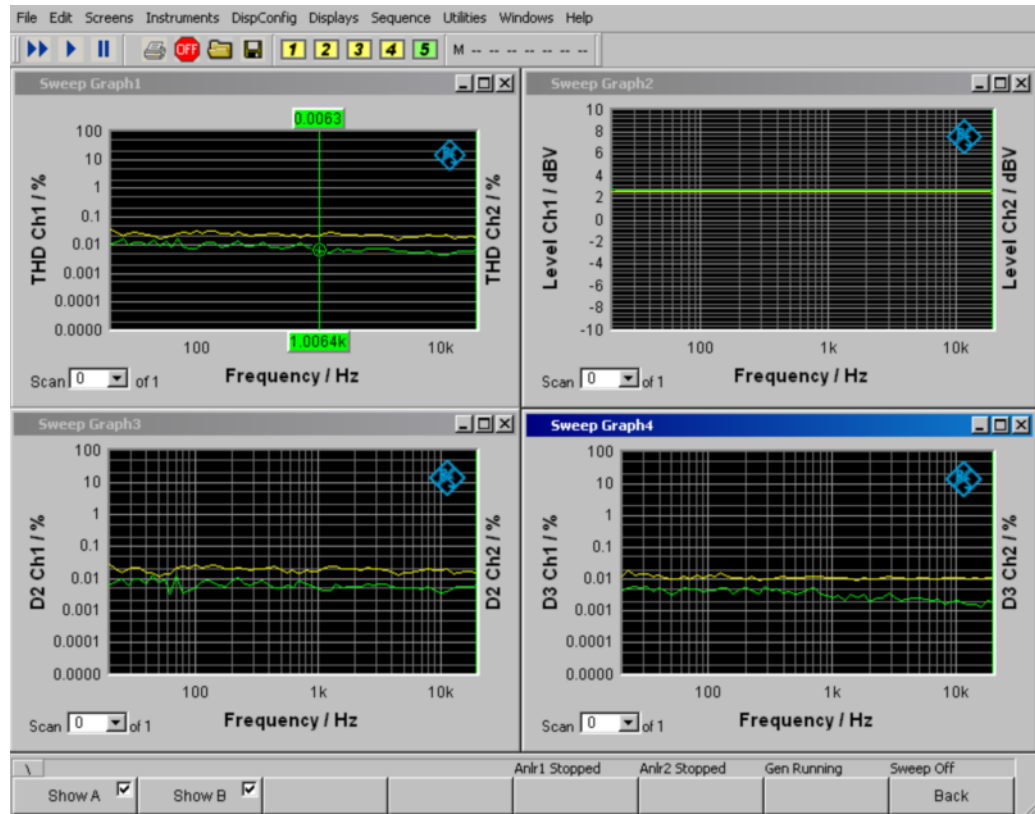

Figure 6: UPV window with result curves

Sweep graph 1 on screen 2 shows the total harmonic distortion. Sweep graph 2 on screen 3 shows the measured RMS level. Sweep graphs 3 and 4 on screens 4 and 5 show 2nd order and 3rd order harmonic distortion, respectively.

The scaling of the sweep graphs can be changed in the respective config panels which can be opened either from the "DispConfig" menu or by right-clicking into the respective graph and choosing "Config" in the context menu. Trace files can also be stored from the sweep graph config panels.

Hardcopies of the graphs can be printed or stored to file by pressing the "H COPY" button on the front panel. Source, destination and format of the hardcopy can be configured in the options panel (menu item "Utilities → Options"). For details see the UPV manual or the online documentation.

3 Working with the Source Code

3.1 Extracting and Storing the Project Files

Select and download the zipped source code "1GA56_VBxxxx.zip" according to version xxxx of the Visual Basic .NET programming environment installed on your UPV. Extract the archive to a folder on the UPV hard disk. It is recommended to use partition "D:", for example "D:\Visual Studio Projects" or "D:\UPV\VBExamples".

Files "THD_Swp.set", "THD_Swp_dB.set" and "THD_Swp_Pct.set" should be additionally copied to folder "D:\UPV\Setups".

3.2 Opening the Solution

Use item "File → Open Project" in the programming environment menu or button "Open Project" on the start page, browse to "THD_Sweep.sln" and open it.

To open the source code, right-click on "Form1.vb" in the Solution Explorer and click "View Code". To edit the graphic user interface, select "View Designer" in the same context menu. The code for the window showing the results is in item "ResultTable.vb".

3.3 Running the Program in the Debugger

For running the program in the debugger, the configuration in the IDE (Integrated Development Environment) must be set to "Debug". Start the program with menu item "Debug → Start" or with the start button in the debug toolbar. Every start in the debugger is preceded by a new compilation of the code so that modifications of the source code have an immediate effect. While the program is running in the debugger, the editor windows for the source code are locked.

4 Appendix: Using the Quick Launch Buttons

The UPV offers 8 quick launch buttons which can be utilized either for loading pre-defined setups or for starting pre-defined macros.
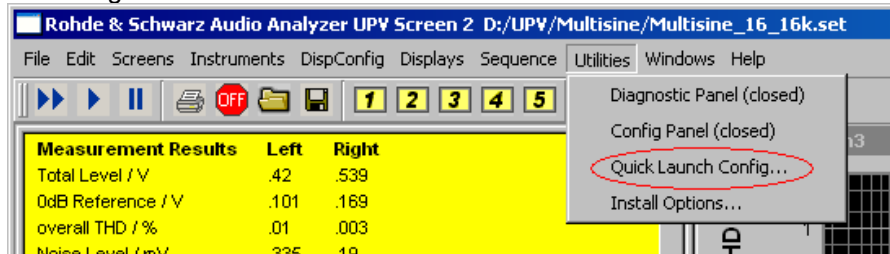The assignment of the buttons can be defined in "Utilities → Quick Launch Config …":

Figure 7: Starting the Quick Launch Config Panel
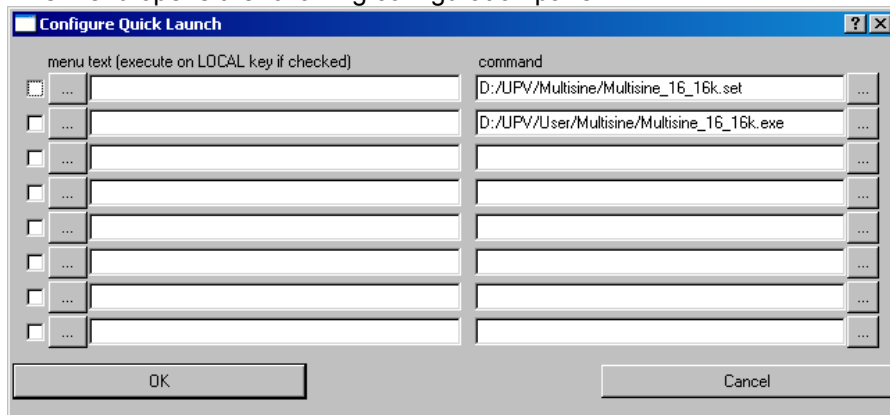
This menu opens the following configuration panel:

Figure 8: Quick Launch Config Panel

Use the "…" buttons on the right side to browse to the setup file or exe file which should be called by the respective button. The "…" buttons on the left side can be utilized to specify icons on the buttons. Text entered in the text box on the left side will be displayed as tool tip text for the respective button when the mouse cursor is staying on the area of the button.

5 Literature

- IEC 60268-3:2001 Sound system equipment - Part 3: Amplifiers
- IEC 60268-4:2010 Sound system equipment - Part 4: Microphones
- IEC 60268-5:2003 Sound system equipment - Part 5: Loudspeakers
- R&S UPV Operating Manual

6 Ordering Information

Audio Analyzer		
Type	**Designation**	**Order No.**
UPV	Audio analyzer, analog interfaces, DC to 250 kHz	1146.2003.02
UPV66	Audio analyzer, without display, keyboard and CD drive	1146.2003.66
UPV-K1	Universal sequence controller	1401.7009.02

About Rohde & Schwarz

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- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system

Certified Quality System
ISO 9001

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