

Product: R&S® UPV

# Calibrating Measuring Microphones and Sound Sources for Acoustic Measurements with Audio Analyzer R&S® UPV

## Application Note 1GA47\_0E

This application note explains how to use acoustic calibrations in order to be able to enter or read sound pressure level directly in the Audio Analyzer R&S® UPV. An application program is described which performs the necessary measurements for the calibration of microphones and loudspeakers, manages the calibration values and enters them into any appropriate user defined setup.



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## 1 Overview

This application note explains how to use acoustic calibrations in order to be able to enter or read sound pressure level directly in the Audio Analyzer R&S® UPV.

An application program is described which performs the necessary measurements for the calibration of microphones and loudspeakers, manages the calibration values and enters them into any appropriate user defined setup.

The Audio Analyzer R&S® UPV is abbreviated to “UPV” for the remainder of this Application Note.

## 2 Introduction

Acoustic measurements involve the measurement of sound pressure level or the generation of a sound field, or both. Typical examples are noise measurements, loudspeaker measurements, microphone measurements and measurements on systems like hearing aids and mobile phones.

A sound level meter, for example, is supposed to directly display the sound pressure level in dBSPL (dB referred to 20 µPa sound pressure). If an audio analyzer like UPV, which measures voltage, is used for this purpose, the sensitivity of the microphone

$$s_M = \frac{\tilde{V}_M}{\tilde{p}}$$

has to be determined, wherein  $\tilde{V}_M$  is the rms value of the microphone output voltage and  $\tilde{p}$  is the rms value of the sound pressure which produced the output voltage. The value of the sound pressure is obtained by dividing the measured voltage by this sensitivity value.

The measurement with which the value of the microphone sensitivity is obtained is commonly called microphone calibration. The sound pressure level for the microphone calibration is generated with a so-called acoustic calibrator which generates a sinewave signal with defined frequency (commonly 1 kHz) and defined sound pressure (usually 1 Pa or 10 Pa).

As measurement microphones are small and have a well-defined mechanical structure, the sensitivity is frequency-independent within a certain frequency range. Therefore calibration at a single frequency is sufficient.

Certain measurements require the generation of a defined sound pressure at a certain point. In order to be able to set a desired sound pressure level in the generator of the UPV, the sensitivity of the loudspeaker

$$s_L = \frac{\tilde{p}_L}{\tilde{V}_G}$$

has to be determined, wherein  $\tilde{p}_L$  is the sound pressure generated by the loudspeaker at the pre-defined measurement point, and  $\tilde{V}_G$  is the generator output voltage which produced the sound pressure.

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As a loudspeaker has a far more complex mechanical structure than a measuring microphone, and radiation effects additionally influence the loudspeaker sensitivity depending on the frequency and on the location of the measurement point, the sensitivity of a loudspeaker usually is frequency dependent. For this reason the calibration of a loudspeaker consists of two steps:

1. Measurement of the absolute sensitivity at one frequency
2. Measurement of the frequency response relative to this frequency.

In order to generate a defined sound pressure at the measurement point, the generator output voltage has to be set to the desired sound pressure divided by the loudspeaker sensitivity, and to be corrected by the inverse frequency response (equalization).

It has to be observed that the loudspeaker calibration is only valid for the point of the calibration, due to the propagation properties of the sound wave.

Note that an equalization in the sense of a frequency dependent amplitude correction is only possible with signals which are defined in the frequency domain, like (swept) sinewave and multisine signals. For the equalization of a complex signal defined in the time domain like speech, a filter is required.

### 3 Use of Reference Values in the UPV

For numerical function results, the microphone sensitivity can be entered in the Function Config Panel as Reference Value:

The screenshot shows the 'Function Config' dialog box with two columns for Channel 1 and Channel 2. The 'Reference' row is highlighted with a red circle. In Channel 1, the Reference Value is -132.500 dBV. In Channel 2, the Reference Value is -133.330 dBV. Other settings include Unit (dBr), Unit Auto (dB SPL), Engineering (Auto), Resolution (4dig / 0.01 dB), Auto Scale (Exec), Spacing (Lin), Left (59.6988 dBr), Right (240.000 dBr), Main Grid (Off), Limit Lower (Off), Limit Upper (Off), and Show Min Max (checked).

Channel 1	Channel 2
Display: Show	Display: Show
Unit: dBr	Unit: dBr
Unit Auto: <input type="checkbox"/> dB SPL	Unit Auto: <input type="checkbox"/> dB SPL
Engineering: Auto	Engineering: Auto
Resolution: 4dig / 0.01 dB	Resolution: 4dig / 0.01 dB
Reference: Value -132.500 dBV	Reference: Value -133.330 dBV
Auto Scale: Exec	Auto Scale: Exec
Spacing: <input checked="" type="radio"/> Lin <input type="radio"/> Log	Spacing: <input checked="" type="radio"/> Lin <input type="radio"/> Log
Left: 59.6988 dBr	Left: 0.00000 dBr
Right: 240.000 dBr	Right: 48.3016 dBr
Main Grid: Off	Main Grid: Off
Limit Lower: <input type="checkbox"/>	Limit Lower: <input type="checkbox"/>
Limit Upper: <input type="checkbox"/>	Limit Upper: <input type="checkbox"/>
Show Min Max: <input checked="" type="checkbox"/>	Show Min Max: <input checked="" type="checkbox"/>

If the value entered as reference value is the microphone output produced by 1 Pa sound pressure, the resulting display value is dBPa (dB referred to 1 Pa). If it is desired to display dB SPL (dB referenced to 20  $\mu$ Pa), the microphone output voltage for 20  $\mu$ Pa has to be entered as reference value. It is obtained by subtracting 94 dB from the voltage level measured at 1 Pa, or by dividing this voltage by 50000.

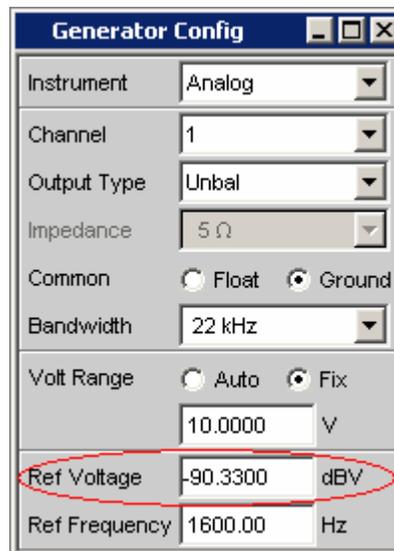
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For a level display, the unit has to be set to “dBr”. For display of sound pressure the unit has to be set to “V/Vr”. The labeling in the display can be adapted to the desired unit if the checkbox “Unit Auto” is unchecked (see example above).

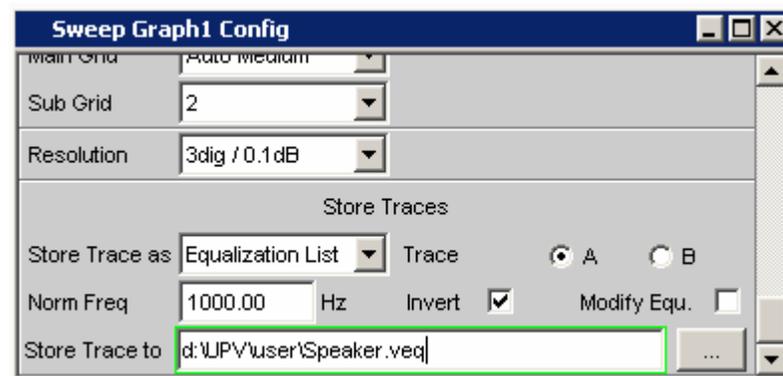
For sweeps, the reference value can be entered in the Sweep Graph Config Panel. Alternatively, “Reference” in the sweep graph config panel can be set to “Meas Panel”. This copies the reference value entered in the Function Config Panel to the sweep. The same applies respectively to FFT spectra (FFT Graph Config Panel) and 1/n octave spectra (Bar Graph Config Panel).

For the input monitor and the level monitor the reference can be set according to the numeric function result in the Input Config Panel or Level Mon Config Panel, respectively. The only difference is that there is one common reference value for both channels.

On the generator side the sensitivity is entered as reference value in the Generator Config Panel.

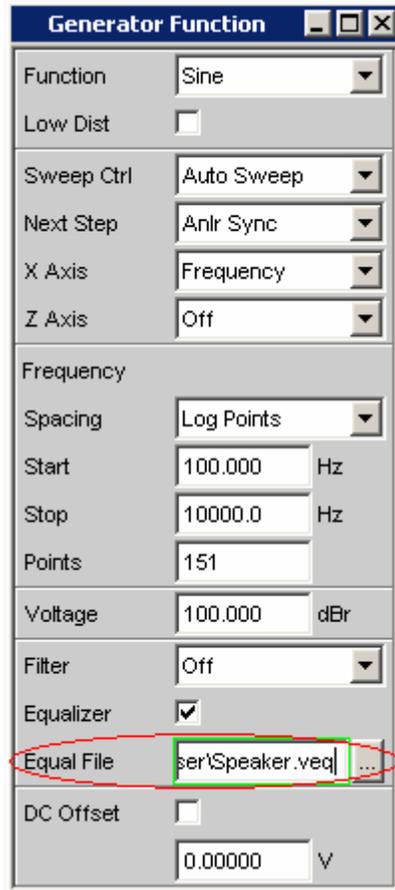


The loudspeaker frequency response can be stored from the Sweep Graph Config Panel as equalization list:



The checkbox “Invert” has to be ticked in order to invert the measured frequency response for the equalization. “Norm Freq” has to be set to the frequency at which the absolute sensitivity had been measured.

The stored equalization list can then be opened as equalization file in frequency-defined generator signals:



For each frequency the amplitude is individually corrected by the factor given in the equalization file, whereby frequencies are interpolated between those present in the file.

## 4 Installation of the Application Program

The use of the application program requires option UPV-K1 to be installed. The application program can be installed as executable program or opened as a project in the IDE of Visual Basic.NET for modification and new compilation.

For just using the executable, copy the installer files "CalibrationTool.msi", "Config.ini", "dotnetfx.exe", "Settings.ini" and "Setup.exe" to the hard disk of your UPV and start "Setup.exe" by double-clicking. If the DotNet runtime framework is already present on the UPV (e.g. when the VB.NET IDE is installed or other DotNet application programs had been previously installed), it is sufficient to copy and start "CalibrationTool.msi".

The program is stored in the program files folder under "Rohde&Schwarz\CalibrationTool\CalibrationTool.exe". The installer also creates a shortcut on the desktop of the UPV.

Furthermore, the installer copies the necessary setup files to the program folder, and the program installs a folder D:\UPV\Calibrations automatically at its first startup.

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If the program is compiled and started from the IDE, the folder "Calibrations" in D:\UPV has to be created in advance, and the two setups "MicCal.set" and "SourceCal.set" have to be copied to it.

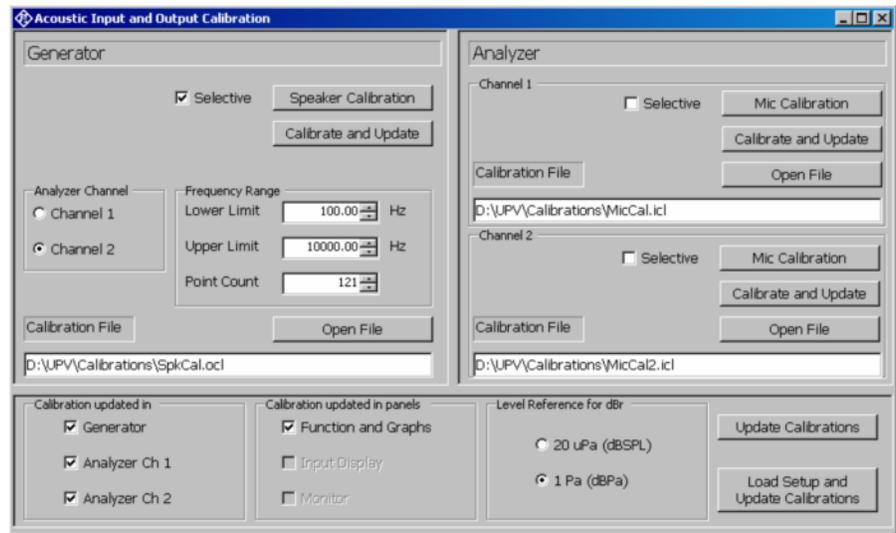
For editing and compiling the source code, unzip the project folder and copy it to the hard disk of the UPV (e.g. in "D:\Visual Studio Projects"). Click "Open Project" on the start page of the Visual Basic IDE, browse to the folder and open "AcousticCalibration1.sln".

## **5 Operation of the Application Program**

The use of the application program requires the respective measurement setup to be prepared for the entry and application of the reference values. For details please see section 3 above. The application note comprises also an example setup "SweepExample.set" for calibration of a loudspeaker and two different microphones.

In particular, channels for which a microphone calibration is to be entered by the tool, have to be active in the setup. The references of graphs should be set to "Meas Panel". In order to enable proper loudspeaker calibration, "Equalizer" should be checked in the Generator Function Panel. Furthermore dB<sub>r</sub> amplitude values in the Generator Function Panel should be set in the setup sufficiently low not to overrange the Generator. Any illegal operation condition caused by the entry of the calibration values produces an error window and closes the application program.

Starting "AcousticCalibration1.exe" opens the following entry window on the UPV:



The window is divided into three panels: One for the loudspeaker calibration, one for the microphone calibration and one for updating stored calibration values to the UPV setup.

### **Microphone Calibration**

The microphone calibration is available for each of the two input channels. "Mic Calibration" starts the calibration routine. Once the calibration routine has successfully finished, a file can be specified to store the results. This file name is simultaneously entered into the "Calibration File" text box which specifies the file from which the calibration value to be entered into the UPV setup is taken. "Calibrate and Update" automatically enters the value in the

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Function Config Panel for the respective channel. To select a calibration value from a file without performing the calibration routine, use “Open File”.

To calibrate a microphone, connect it to the desired analyzer input. Insert the microphone into an acoustic calibrator and switch on the calibrator. After clicking the “Mic Calibration” button of the respective channel a window opens which queries the SPL produced by the calibrator. If “Selective” is activated, the calibration measurement is performed with a fast 3<sup>rd</sup> octave band pass filter. Therefore in this case also the frequency of the signal produced by the calibrator has to be entered. After that a series of voltage measurements is started. If the single results are sufficiently consistent, the sensitivity of the microphone is displayed, and a file selector box is opened for entering the file name to store the value.

### Loudspeaker Calibration

Loudspeaker calibration requires a valid microphone calibration to exist for the analyzer channel used for the speaker calibration measurement. The used channel has to be selected in “Analyzer Channel”. “Lower Limit”, “Upper Limit” and “Point Count” specify the parameters for the frequency response sweep done during the calibration measurement. “Selective” toggles between wideband and selective loudspeaker measurement.

To calibrate a loudspeaker, connect it to one of the UPV outputs. If required, a power amplifier can be inserted. Connect a microphone to one of the analyzer inputs and calibrate the microphone or load a valid calibration for this microphone from a file. Select the correct analyzer channel for the loudspeaker calibration. Place the microphone at the point in front of the loudspeaker for which the calibration should be valid. After clicking “Speaker Calibration”, the SPL for the calibration has to be entered. Due to nonlinearities of loudspeakers there may be deviations in sensitivity and frequency response between calibrations executed at different levels. It is also possible to perform calibrations for a set of different levels and store them under different file names. After the level has been confirmed, the calibration starts with first determining the absolute sensitivity at 1 kHz, then measuring the relative frequency response. In a second run the obtained equalization is checked and corrected before a third sweep is done to verify the result of the calibration. After completion of the measurement, a file name has to be specified for storing the calibration values. Subsequently the UPV is returned to local control and the calibration tool window is minimized in order to show the sweeps:



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After the “Source Sensitivity” window has been closed by clicking “ok”, the calibration tool window re-appears and the previous setup of the UPV is restored.

It is essential that the test configuration (gain of the power amplifier, positioning of loudspeaker and device to be measured) is not altered between the calibration and the measurement in which the calibration is to be used.

### **Using Calibration Values**

“Update Calibrations” enters the calibration values from the files specified in the three text boxes as reference values for the ticked generator and analyzer channels. An update to input and monitor display is only possible in single channel mode. It can be chosen whether the “dBr values” in the setup and displays should be interpreted as dB SPL (relative to 20 uPa) or as dB Pa (relative to 1 Pa).

“Load Setup and Update Calibrations” allows to load a UPV setup and automatically enter the activated calibration values as reference values into the loaded setup.

The application program returns the UPV firmware to local control after termination of each action. Therefore it can be kept open during the use of the UPV. However, it is not possible to run another remote control application while the calibration tool window is open. The window is minimized after loading and updating the setup and can be retrieved from the Windows task bar.

## **6 Hardware and Software Requirements**

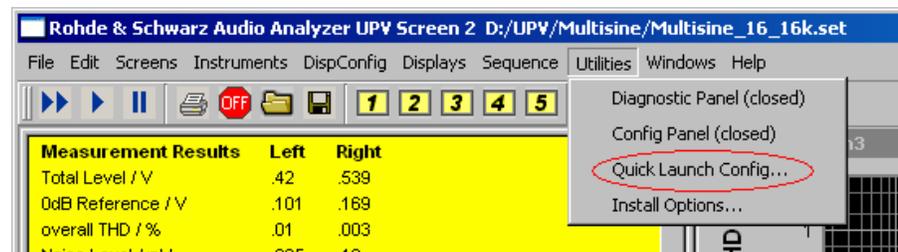
The Audio Analyzer UPV needs firmware version 1.4.1 or higher installed.

For the use of the application program, option UPV-K1 (Sequence Control) is required.

## **7 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.

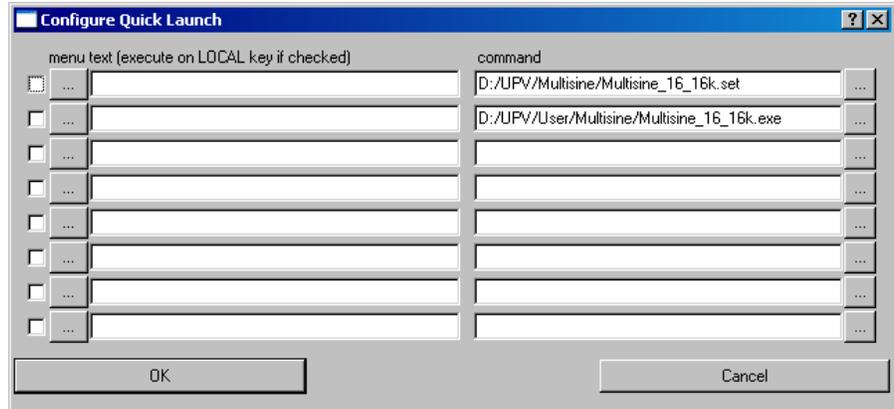
The assignment of the buttons can be defined in “Utilities → Quick Launch Config ...”:



**Fig. 1** Starting the Quick Launch Config Panel

This menu opens the following configuration panel:

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**Fig. 2** 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.

## 8 Ordering information

<b>UPV</b> Audio Analyzer	DC ... 250 kHz	1146.2003.02
<b>UPV-K1</b> Sequence Controller		1401.7009.02

For additional information about audio analyzers and other measurement equipment, see the Rohde & Schwarz website [www.rohde-schwarz.com](http://www.rohde-schwarz.com).



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