ROHDE&SCHWARZ

Test and Measurement
Division

Operating Manual

Hearing Aid Test System

UPL-B7

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Contents

1 Use

Audio Analyzer UPL with option UPL-B7 and test program HEARPRO.BAS forms a complete test system for use in production, quality assurance and development of hearing aids.
The installation diskette also generates the program Heartst.bas which is intended for use in the development of hearing aids. The program is described in the Application Note 1GA 34-1. The application note can be requested from the local Rohde & Schwarz sales office.

There are several national and international standards defining measurements on hearing aids and the representation of results. The most important ones at present are the European standard IEC 118, parts 0 to 12, Hearing Aids, and the American National Standard ANSI S3.22, Specification of Hearing Aid Characteristics.

Program HEARPRO measures either in line with the latest IEC 118 -7-1993 or ANSI S3.22-1996 standard. All standard measurement can be performed:

- SSPL curves
- Setting to reference gain
- OSPL curves
- Equivalent input noise
- Distortion
- Current drain from battery
- Output sound pressure versus input sound pressure
- Attack and release time of AGC units
- Frequency response characteristics with selectable input sound pressure level or induction field strength
- Setup for telephone coil measurements on hearing aid
- OSPL curve with telephone coil
- Distortion with telephone coil

The sequence of measurements and associated parameters may be configured in any way and are stored as individual test sequences.

2 Putting into Operation

2.1 Test Setup

Option UPL-B7 includes an acoustic test box, a complete cable set, a 2 cm^3 coupler with built-in microphone and calibration adapter as well as a set of battery adapters for all common battery sizes. The connecting pieces of the coupler are exchangeable to suit behind-the-ear, in-the-ear and detached hearing aids.
An adapter piece is also supplied, allowing the use of commercial ¼ inch test microphones together with the 2 cm^3 coupler. Thus a fully calibrated precision test system is made available to the user.

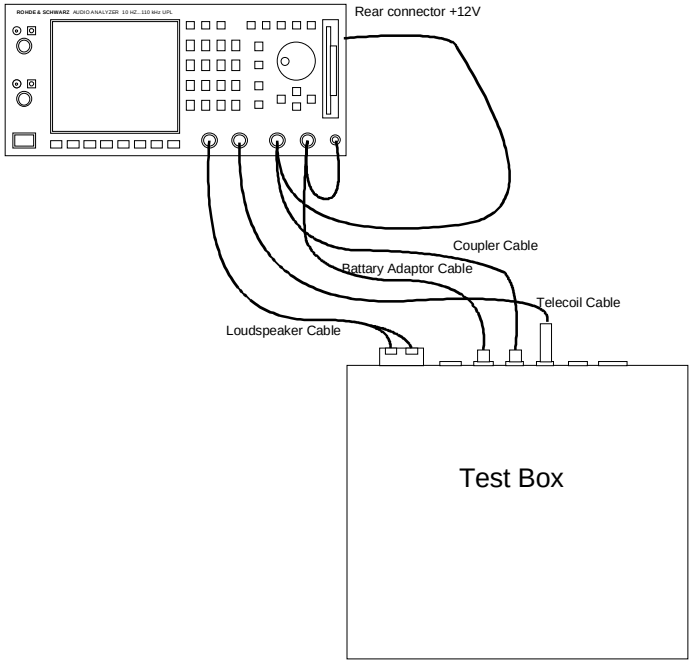

Fig.: 1-1 Connection of test box using coupler with built-in electret microphone

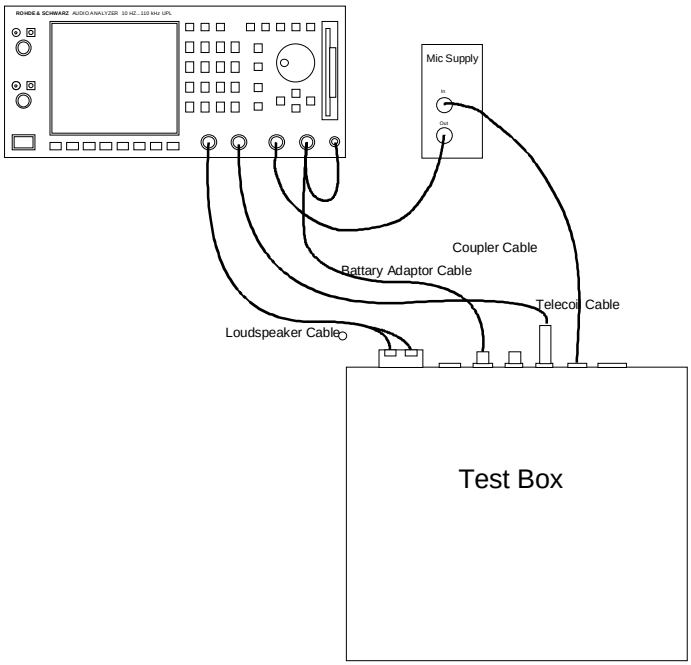

Fig. 1-2 Connection of test box using coupler with 1/4 inch test microphone

If option UPL-B7 is ordered together with Audio Analyzer UPL and Audio Monitor UPL-B5, two modifications are automatically incorporated in the UPL:

The output impedance of the audio monitor option is changed to 0 Ω so that the monitor can be used as a feeder for the hearing aid, and an additional BNC connector is provided at the rear of UPL where a filtered 12 V operating voltage is available for the microphone in the test coupler. Since the output impedance is 220 Ω, this source is only intended for low operating currents. The cable set of UPL-B7 can be used for this configuration.

With option UPL-B5, a programmable precision DC source of low noise is available. The two outputs of cable set UPL-B7 are connected in parallel via 1 Ω so that a source with an impedance of 0.5 Ω and a current of more than 100 mA (typ. 150 mA) is obtained. As the output impedance of the battery adapters is typically 1.7 Ω, the total impedance together with that of the cables is approx. 2.5 Ω. With the 2 Ω current measurement resistor in the cable, a total impedance of approx. 5 Ω is obtained which corresponds to the typical impedance of a battery.
An external keyboard is required for the installation and operation of the test program.

2.2 Firmware Installation

The test program Hearpro.bas and the program Heartst.bas with all setups is supplied on a floppy disk. To carry out the installation, terminate the UPL program (system key), change to drive A: and call up the program named Install. The directory C:\HEARING is created in the UPL. All program routines are copied into this directory. In addition, the directories C:\HEARING\TST and C:\HEARING\RESULTS are created in which the generated test routines or results are stored.

To use the monitor option as a DC voltage source, Audio Analyzer UPL must be started with a call-up parameter -tdcl, which can be entered either in the AUTOEXEC.BAT or the USERKEYB.BAT file. To enable this the UPL call in the AUTOEXEC.BAT file has to be changed to UPL -tdcl or line

Set uplcfg = -tdcl

has to be written into the C.\UPL directory of the USERKEYB.BAT file. The file USERKEYB.BAT is called up automatically on the start-up of the UPL. Drivers for country-specific keyboards can therefore be installed and defined with the variables UPLCFG startup switches. This file must be named USERKEYB.BAT and located in the directory C:\UPL. This method has the advantage that the switch is maintained after a firmware update. The DOS editor EDIT should be used for the above change or the creation of file USERKEYB.BAT in the directory C:\UPL.
(Call-up parameter -tdcl connects the monitoring output to a DC voltage source with a setting range of ± 2 V. With call-up parameter -tdch a setting range of ± 6 V is obtained but in this case the noise is increased by a factor of 3 from typically 50 to 150 µV).

2.3 Measurements

The test program HEARPRO.BAS permits customized test sequences to be defined including the measurement using an inductive coil and the measurement of attack and release times of hearing aids with AGC. The order of the test routines and the measurement parameters can be user-defined and stored as a complete test sequence including a tolerance check. Tolerance curves can be obtained automatically from measured curves and used for series tests.
The following can be measured or performed:

- Output noise pressure level at maximum gain either at an input sound pressure level of 50, 60 and 90 dB or 90 dB only; on request with a tolerance check of the frequency response at 90 dB.
- Routine for setting the reference gain of the hearing aid with the aid of a bargraph.
- Output sound pressure level at reference gain at an input sound pressure level of 50 dB, 60 dB or 50+60+90 dB, on request with a tolerance check of the frequency response at 50 or 60 dB.
- Equivalent input noise referred to 60 dB sound pressure level or to 50 dB sound pressure level if a 50 dB curve is selected for the OSPL measurement.
- Distortion at 70 dB input sound pressure level at 3 selectable frequencies.
- Current drain in the idle state at a sound pressure level of 60 or 65 dB (requires the battery adapter and monitor option UPL-B5 to be used)
- Output sound pressure level versus input sound pressure level (transfer function) in the range 50 to 90 dB at any selectable frequency.
- Attack and release times of AGC with selectable parameters and automatic matching of tolerances for the settling test to IEC or ANSI.
- Frequency response characteristics, eg to display the setting ranges of frequency response adjusting elements at an input sound pressure selectable between 40 and 100 dB or field strength of 1mA/m to 100 mA/m, also combined.
- Routine for setting the hearing aid to induction coil measurement
- Frequency response of output sound pressure with selectable induction field strength
- Distortion with selectable induction field strength using a setting routine for matching the output sound pressure to the acoustically measured value at 70 dB.
- Waiting routine for interrupting the test run.

Since all measurement parameters are stored together with the test routine, eg the associated test procedure for each type of hearing aid can be stored under an appropriate name. The tests generated in this way are stored in directory C:\HEARING\TST and, if required, the path can be modified in the program.

2.4 Performing a Measurement

To load the HEARPRO.BAS program set the UPL to the programming mode using key <F3>. The program is loaded with command LOAD"HEARPRO <RETURN> and started with RUN <RETURN>. With the aid of the utility program UPLSET an automatic sequence control program can be loaded and started in the UPL (see also UPL manual).
Prior to the first measurement the complete test setup has to be calibrated with the aid of a sound level calibrator and a reference microphone (neither supplied), see section 2.5 on calibration. The calibration values are stored in a file and used for all measurements. A recalibration is required if the environment conditions (temperature) significantly change or a calibration interval is stipulated for any other reasons. The error limits of the UPL are extremely low so the calibration interval is solely determined by the stability of the test microphone. The measured values of each calibration are appended to a file. If the calibration has not been taken on the current day, the following message appears after the start of the program:

Last Calibration <Date>

Broadly speaking measurements with all types of test couplers are possible. Supplied are a 2 cm^3 coupler with built-in electret microphone and an adapter for ¼ inch microphone which in place of the coupler is used with the built-in microphone. This setup offers the advantage that the test microphone can be undone from the coupler and thus it can be used to calibrate the test box (no reference microphone is required) or it can be calibrated the same as any test microphone (the frequency response of the built-in microphone cannot be calibrated this way but is only subjected to a small design-specific spread). The adapters for the various hearing aids are usable with both setups.
Measurements with the ear simulator are also possible. The only thing to make sure is that all components find room in the test box.
When using a test microphone with the adapter or ear simulator the preamplifier and the voltage supply of the test microphone will also be required. The output signal from the preamplifier is taken to channel 1 of the UPL in place of the coupler cable.

The hearing aid to be measured is connected to the test adapter and inserted in the test box such that its microphone is about in the center of the (blue) reference area. For measurements via the telephone coil, remove the blue foam rubber and place the adapter in the recess thus obtained. The hearing aid then hangs on the silicone tubing (of a unit behind the ear) and is in a similar position as it would be when carried by the user. Since the telephone coil is fitted below the foam-rubber insert of the test box, the effective field strength depends on the position of the receive coil as the hearing aid is not at the same level as the coil. With an excitation current of 3.33 mA a field strength of 10 mA/m is obtained approx. 20 mm above the rubber insert. The hearing aid should be positioned such that the built-in hearing coil is approx. 20 mm above the rubber insert. To obtain this height a suitable (non-metallic) support may be used.

When the <LOAD> key is pressed upon program start all stored tests are listed. The desired test name has to be entered and confirmed with <RETURN>. The measurement itself is started with the <START> softkey. Manual manipulation, eg setting the reference gain of the hearing aid, will be requested on the screen.

Upon completion of the measurements defined in the test, all results are displayed on the screen. Typical measurements look like the following:

Fast Hearing Aid Test with Rohde & Schwarz Audio Analyzer UPL

According to IEC 118

	Setting max Gain:	Setting ref Gain:	Setting Telecoil:
Max OSPL90/OSPL90:	124.2 dB	122.3 dB	99.5 dB
OSPL90/OSPL90 REF:	109.7 dB	107.3 dB	90.2 dB
Gain @ 60 dB @ REF:	46.1 dB	33.9 dB	
Gain @ 50 dB @ REF:	54.9 dB	33.9 dB	
Equiv. Inp. Noise @ 60 dB:		26.6 dB	
THD 500 Hz @ 70 dB/ 100 mA/m:		2.2 %	4.0 %
THD 800 Hz @ 70 dB/ 100 mA/m:		1.1 %	1.0 %
THD 1600 Hz @ 70 dB/ 100 mA/m:		0.8 %	0.6 %
Battery Current idle/sound:		1.70 mA / 1.63 mA	
Attack Time:		27.5 ms	
Release Time:		68 ms	

Fig. 1-1 Result display

With the tolerance check switched on, all numerical values (see Fig. 1-1) outside permissible tolerances are marked with an asterisk (*). In addition, FAIL is displayed in red on the screen (on UPL with colour display or external monitor). If tolerances have not been exceeded, PASS is displayed in green. FAIL is also displayed if one of the frequency response curves exceeds the associated limit curve.
The measured numerical values and all measured curves can be stored. The first eight digits of the entered series number are used as a default file name but any other name may of course be chosen, observing the DOS conventions for file names, eg no spaces are allowed in the file name.

By means of the <REPORT> key a test report is output to a Laserjet printer or compatibles (up to 6 graphs for each report) depending on the definition in the test parameters. (If no graphs are output other types of printers may be used. For graphics output the printer is switched to HPGL using an escape sequence, and this is only possible with a Laserjet printer). To be able to print all graphs in the HPGL mode, the printer must have a sufficient memory size. A memory of at least 2 Mbyte is recommended and the printer must be configured for whole pages printing (otherwise an error message may be output on the printer and printout will be incomplete). Error messages from the printer such as no paper generate an error message after printing the report. The printout can be continued with space after troubleshooting or aborted with Q.

Hearing Aid Test with Rohde & Schwarz Audio Analyzer UPL

Test: **iec1.tst** Standard: **EN 60118-7 - 1993**

Device under Test: Tested by: **Mustermann** Date: **07-08-97**
Time: **13:45**

Manufacturer: **Audio Systems** Model: **Audimax5**
Serial No: **001** Circ/Rev: **Spec.1/1.0**

Measuring Results: REF @ 1600 Hz	Setting max Gain:	Setting ref Gain:	Setting Telecoil:
Max OSPL90/OSPL90:	**123.8 dB @ 993 Hz**	**122.6 dB @ 993 Hz**	**105.6 dB @ 993 Hz**
OSPL90/OSPL90 @ REF:	**109.2 dB**	**107.6 dB**	**96.2 dB**
Max. Gain @ 60 dB:	**60.4 dB @ 993 Hz**	**45.2 dB @ 993 Hz**	
Gain @ 60 dB @ REF:	**46.8 dB**	**34.3 dB**	**66.2 dB @ 1mA/m**
Max. Gain @ 50 dB:	**60.3 dB @ 993 Hz**	**45.1 dB @ 993 Hz**	
Gain @ 50 dB @ REF:	**49.3 dB**	**34.3 dB**	
Equiv. Inp. Noise:		**31.2 dB**	
THD 500 Hz @ 70 dB/ 100 mA/m:		**2.2 %**	**3.5 %**
THD 800 Hz @ 70 dB/ 100 mA/m:		**1.1 %**	**1.2 %**
THD 1600 Hz @70 dB/ 100 mA/m:		**0.7 %**	**1.8 %**
Battery Current idle/sound:		**0.98 mA / 1.02 mA**	
Attack Time:		**24.5 ms**	
Release Time:		**75 ms**	

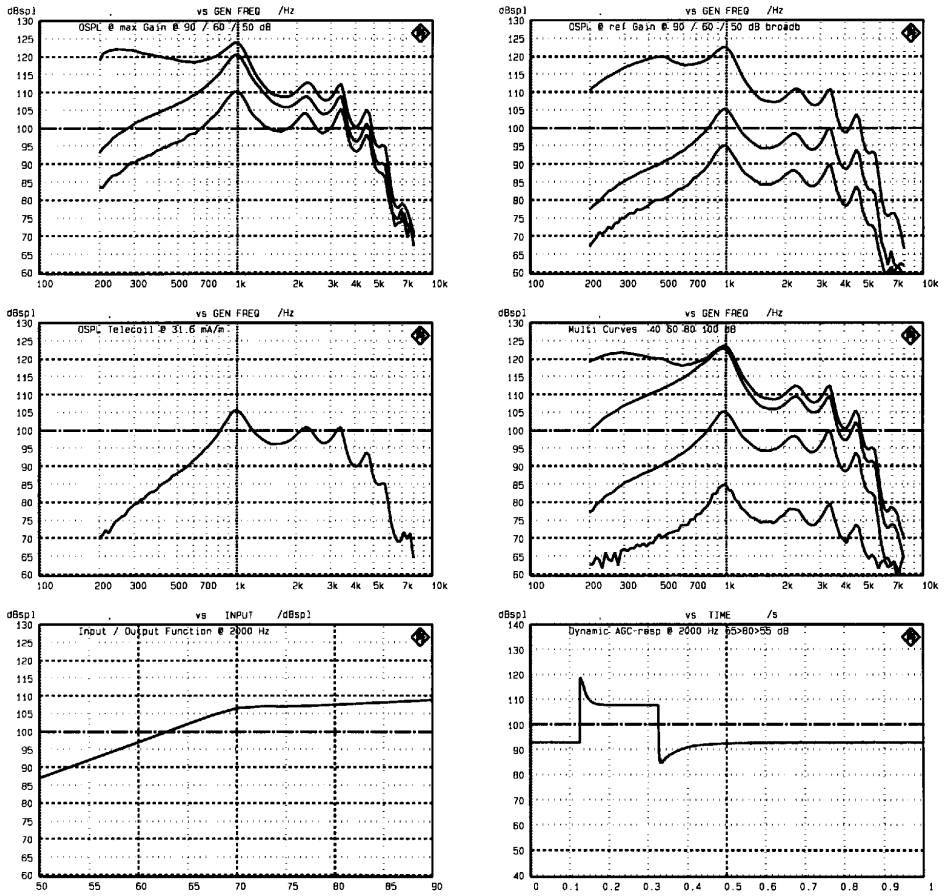

Fig. 1-4 Printout of test report

Another measurement is started with <NEXT> or <REPEAT>. If NEXT is used, the serial number is automatically incremented when this has been selected in the test definition. With REPEAT the measurement is repeated without incrementing the serial number.

With the aid of the <BACK> key the next higher menu level is selected. If this key is pressed in the start menu, the user will be asked whether he wishes to terminate the program. The ESC key is for interrupting a current measurement and results in the start menu displayed on the screen.

2.5 Calibration

Before the test system is put into operation for the first time, the microphones or ear simulators used and the test box must be calibrated with the aid of a sound pressure calibrator, eg Bruel & Kjaer 4231, and a test microphone for the calibration of the test box. A suitable microphone is for example type 40 BF with amplifier 26 AC + feed unit of Messrs. G.R.A.S. Denmark. This microphone which has a total length of approx. 55 m is especially suitable for the calibration. The microphone sensitivity and the frequency response of the test box are to be measured and are entered in a file as calibration value for the following measurements. The frequency response of the test box is referenced to the frequency response of the test microphone whose tolerance must therefore be known for the measurement to be traceable. The absolute sensitivity of the used microphone is measured for each calibration with the sound level calibrator. Traceability is thus referenced to the tolerance of the used sound level calibrator.

After the <CALIB> key has been pressed the user is asked whether one or two microphones will be used.
If one microphone is selected, the microphone of the test coupler is used for calibrating the frequency response of the test box. In this case it is necessary that the microphone is completely disconnected from the coupler. This is the case when the adapter for the ¼ inch microphone is used in the 2 cm^3 coupler. The adapter is to be removed from microphone for calibration. If two microphones are used, microphone 2 is only used for calibration and has to be connected to channel 2 of Audio Analyzers UPL during calibration (instead of the current test cable for the battery adapter).

Calibration is performed in 5 steps:

- Absolute calibration of microphone 1 or ear simulator
- Absolute calibration of microphone 2, if used
- Calibration of test box
- Entry of required current in mA for a field strength of 10 mA/m of the induction coil in the test box.
- Entry of shunt used with the current measuring device

For absolute calibration, the actual sound pressure level of the calibrator has to be specified, if required by taking into consideration the correction values eg for calibrating the ear simulator. For calibrating the 2 cm^3 coupler with the built-in microphone supplied with UPL-B7 and the associated adapter, a correction value has to be considered.

Depending on the sound level calibrator employed the effect of the volume of the calibration adapter is different.
When calibrating with a pistonphone such as Bruel & Kjaer 4228 the sound pressure given off is reduced by 0.6 dB so that instead of the nominal of 124 dB a calibration value of 123.4 dB (plus correction for the atmospheric pressure) has to be entered.
When calibrating with the calibrator 4230 from Bruel & Kjaer the correction factor is + 2 dB, thus a calibration sound pressure of 96 dB is to be entered.

When calibrating with the calibrator 4231 the correction factor is +1.8 dB and a calibration sound pressure of 95.8 dB is to be entered.
With a setup based on a ¼ inch test microphone for the 2 cm^3 coupler, the microphone for the calibration is to be disconnected from the coupler and connected as usual directly to the sound level calibrator for calibration at the sound pressure level given for the calibrator.
After absolute calibration, the reference microphone (microphone 1 if only one microphone is used, otherwise microphone 2) is placed at the focus of the test box (center of blue foam rubber insert). If required, test coupler and DUT should also be placed in the box for calibrating the sound field with the DUT. When the <RUN> key is pressed, the absolute sensitivity and the frequency response of the box are measured and automatically stored in the form of an equalization file.

In the subsequent query the user is requested to enter the current in mA which produces a field strength of 10 mA/m in the box. For Test Box UPL-B7, 3.33 mA should be entered (for 10 mA/m at 20 mm above the foam rubber insert).
The last query concerns the value of the shunt used for the current measurement of the hearing aid. The cable supplied with the UPL-B7 for measuring the current is fitted with a 2 Ω ±1% resistor. If this value is changed or if another cable is used, the value of the new resistor is to be entered.
After calibration has been completed, all values are stored and reused for all subsequent measurements. When the HEARPRO.BAS program is loaded and started, all calibration data are read in and the calibration date is checked. A reference to the last calibration is displayed when the calibration date does not correspond to the current date.

2.6 Generation of tests

Normally, predefined tests are used in production for testing a specific type of hearing aid. These tests should not be modified by the user. A coded sequence of keys has therefore been integrated to access the test definition menu. The expert mode is called up by pressing twice the key combination <ALT>+<E>. The <DEFINE> key for opening the test generation menu is then displayed in the start menu next to the <LOAD> key. The expert mode is switched off with the O key (character O).

In the define menu predefined tests can be loaded, eg for generating another test through modification.

After pressing the <DEF TST> key the test sequence is displayed and can be confirmed with <OK> or newly defined with <CHANGE>. Enter the number of the desired test step and terminate with <RETURN>. At the right-hand side of the screen the test step is displayed in plain text. The first measurement is always an acoustic (with max. gain also an SSPL) measurement. This may be sufficient for performing a minimum test. The definition of the test sequence is terminated with <RETURN> without specifying numerals.

In the next steps the test conditions for all the measurements can be defined. Values are called up with the respective key and confirmed with <OK> or modified with <CHANGE>. Remember that values in the entry fields **must be confirmed with <RETURN>. Cursor keys will cause a malfunction and must therefore not be used.**

In addition to the usual information, other selection items are offered under the menu item <GENERAL>:

Frequency range	It can be selected whether the frequency response measurement should be performed in 100 steps in the range 200 Hz to 8 kHz or in 150 steps in the range 100 Hz to 10 kHz. Calibration is always performed in the range 100 Hz to 10 kHz to ensure that calibration values are available any time. The measurement speed is somewhat reduced in the wider frequency range because of the greater number of test steps.
Rumble filter	If Y is specified, a 100 Hz highpass filter is used for all measurements. The settling time of the filter slightly slows down the measurement.

Adaptive measurement	All measured values are subjected to an additional settling test. The measurement speed is reduced depending on the settling speed of the DUT. This option is useful if the hearing aid is provided, eg with a relatively slow AGC, which would impair measurement results at the maximum measurement speed.
Selective measurement	A third-octave filter is switched on for selective measurements. Irrespective of this selection, SSPL measurement is always a broadband measurement

The maximum measurement speed is attained with broadband measurement without the rumble filter and adaptive measurement in the frequency range 200 Hz to 8 kHz.

Numeric measurement results and frequency response curves may be subjected to a tolerance check. The frequency response check is defined for SSPL or OSPL, a check of numeric values in the <GENERAL> menu. Limit curves for SSPL and OSPL must be given different names when the two limit curves are to be used in the same test, since the files cannot be distinguished by their extensions. A file for testing the tolerance of numeric values has always the extension .tol so that it may have the same name as a limit file for a frequency response measurement or the test. When generating a tolerance mask for checking numeric values, individual tests may be disabled by entering 0 (zero) as the upper limit value or -100 dB as gain value. In this case the respective value is not checked.

2.7 Generation of limit curves

It is assumed that a "golden device" is used in this case, which corresponds to the mean value for the tolerance of the DUT.
Menu item <LIM CURV> may be called up for defining limit curves, the UPL is then set, all calibration values are considered and the manual control mode is selected. The desired generator level (dBr directly corresponds to dBspl) must be set, eg for a 90 dB curve. Pressing the <SINGLE> key triggers an accurate frequency measurement (averaging of 20 values). After completion of the measurement, which may be repeated any time with <SINGLE>, return to the test program with <F3> or <BACKSP>. A query is displayed as to the number of tolerance segments to be contained in the measured curve. Three segments for instance permit higher tolerances at low frequencies, narrower tolerances at medium frequencies and higher tolerances again at high frequencies. First the desired frequencies are entered, then the permissible tolerances in dB (without sign). The values may be corrected again. After confirmation with <Y> the limit files are calculated and stored under the specified name. The upper limit file is given the extension .LUP, the lower one the extension .LLW.

Cursor keys should not be used here for entering values.

With the definition completed, the whole test should be stored under a meaningful name for ease of recall later on.

Special features

During the test run it may be useful to briefly interrupt the measurement, eg for a closer examination of a test curve. Pressing the <W> key triggers a stop at the end of a frequency sweep and the measurement is continued when any key is pressed. During attack and release measurements, pressing W causes the graph of a settling characteristic to be displayed. Again the measurement is continued by pressing any key. The measurement is interrupted by pressing the ESC key and the start menu is displayed.

Format of stored measurements

Measured values are stored sequentially in ASCII format in a file under the selected name with the extension .VAL. The order of the values is predefined. The file can be edited with any editor and

evaluated by other programs. In the HEARPRO.BAS program the path for storing results is entered in line 150. This path is normally C:\HEARING\RESULTS. The user may enter another path and store the program under the same or a new name. The entered path and the directory must both exist. The path for storing and calling up tests can be entered in the same way in the next line. Thus programs, tests and results can be stored separately.
Order of entries in the result file:

Filename
Date
Time
Company
Serial No.
Circuit
Revision
Name of tester
Auto increment
Sspl90max
Frequency @ Sspl90 max
Ospl90max
Osplmax mit telecoil
Frequency @ Ospl90max
Sspl90 @ ref
Ospl90 @ ref
Ospl telecoil @ ref
Gainmax @ 60 dB
Gainref @ 60 dB
Gainmax @ 50 dB
Gainref @ 50 dB
Noise
Distortion 1, frequency 1
Distortion 1 telecoil
Distortion 2, frequency 2
Distortion 2 telecoil
Distortion 3, frequency 3
Distortion 3 telecoil
Current sound
Current idle
Attack time
Release time
Maxgain @ 60 dB @ Maxgain
Frequency @ Maxgain @ 60 dB
Maxgain @ 50 dB @ Maxgain
Frequency @ Maxgain @ 50 dB
Maxgain @ 60 dB @ ref. Gain
Frequency @ Maxgain @ 60 dB ref.
Maxgain @ 50 dB @ ref. Gain
Frequency @ Maxgain @ 50 dB ref.

In addition, all curves are stored in files under same name as the result file but with the following extensions:

- .ssp for SSPL curves
- .osp for OSPL curves
- .trn for transfer curves
- .agc for attack and release curves
- .mul for multiple curves
- .ost for OSPL curves with telephone coil