



# Technical specifications, manufacturer's data

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Senti & Sentiero

## Manufacturer

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## Manual Information

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# 1. General device information

## 1.1 Device

- Device dimensions: 209 x 98 x 52 mm (Handheld), 150 x 210 x 45 mm (Desktop)
- Weight (incl. rechargeable battery pack): ca. 500 g (Handheld), ca. 475 g (Desktop)
- Display: 240 x 320 pixel; graphic LCD 3.5" (Handheld), 5.0" (Desktop)
- Features: resistive touch screen, real time-clock, piezoelectric sound generator
- Interfaces: RS232 (Senti with HW Rev. 33 or lower), USB
- Output voltage and nominal impedance (headphone socket): 5 V<sub>pp</sub>, 32 Ω
- Power consumption: max. 2 W
- Memory capacity: up to 1000 patients, ca. 1000 tests (dependent on test type)

## 1.2 Power Supply, Rechargeable Battery

- Features: auto backlight control, automatic shutoff, double voltage control
- Rechargeable battery pack: 4.8 V NiMH (Handheld), 3.7 V Li-Ion (Desktop)
- Battery voltage limits for correct operation: 4.5 to 6.5 V (Handheld), 3.5 to 4.2 V (Desktop)
- Maximum operating time with fully charged batteries: ca. 6 to 8 hours (dependent on usage)
- Maximum charging cycles: 500 to 1000 (life time > 2 years for normal usage)
- Maximum charging time: ca. 2 hours (Handheld), ca. 8 hours (Desktop)
- Input rating of power supply units:
  - o Sinpro MPU12: 100-240 V, AC, 47-63 Hz, 0.16-0.29 A
  - o Sinpro MPU16: 100-240 V, AC, 47-63 Hz, 0.18-0.33 A
  - o Friwo 7662M/12 (GPP6): 100-240 V, AC, 50-60 Hz, 0.15 A
- Output rating of power supply units: 9V, 1.2 A (Handheld); 9-12 V, 0.4 A (Desktop)

## 1.3 Storage, Transport, and Operating Conditions

Please keep the device and its accessories in the provided carrying case in order to protect the device and its accessories against external forces and environmental impacts. Extreme storage and operating conditions may result e.g. in breakage of the touch screen display (extremely low temperature) or in impairment of the device's and transducer's calibration.

### Transport and storage conditions:

- Transport temperature: -20 to 60 °C (-4 to 140 °F)
- Storage temperature: 0 to 40 °C (32 to 104 °F)
- Relative air humidity: ≤ 90 % non-condensing
- Barometric pressure: 50 to 106 kPa

### Operating conditions:

- Temperature: 10 to 40 °C (50 to 104 °F)
- Relative air humidity: 20 to 90 % non-condensing
- Barometric pressure: 60\* to 106 kPa

\* At locations where the normal air pressure is below 80 kPa (at altitudes of more than 2000 meters), it is recommended to recalibrate the transducers.

Before turning on the device, make sure that the device is warmed up to room temperature, i.e. the operating conditions must be fulfilled.

## 2. General transducer information



Please note that maximum levels given below for each test module may vary dependent on the individual transducer calibration.

The contact pressure for calibration for the different transducers is described in *Table 1*:

Headphone	Pressure [N]
Sennheiser HDA-280	$5.0 \pm 0.5$
Sennheiser HDA-200	$10.0 \pm 1.0$
Sennheiser HDA-300	$8.8 \pm 0.5$
Interacoustics DD-45	$4.5 \pm 0.5$
Interacoustics DD-65	$4.5 \pm 0.5$
Holmco PD-81	$14.5 \pm 1.0$ *
GN Otometrics ME-70	$4.5 \pm 0.5$
RadioEar B-71	$5.4 \pm 0.5$
RadioEar B-81	$5.4 \pm 0.5$

\* No contact pressure tolerance provided in manufacturer's data sheet. Contact pressure tolerance given as for HDA-200.

*Table 1: Contact pressure for different transducers*

For information about RETSPL values please refer to the default levels provided with the PATH Service Tool. For information about sound insulation properties of headphones please refer to the respective transducer data sheet.

## 3. Test modules

For further information about the test modules please refer to the "How-To Manual".

### 3.1 Multiple-Choice Auditory Graphical Interactive Check (MAGIC)

License: MAGIC

- Protocols: Screening, Audio
- Frequencies: 0.25 (cow), 0.5 (bear), 1 (elephant), 2 (cat), 3 (sheep), 4 (mouse), 6 (bird), 8 kHz (dolphin); optional: 5 kHz instead of 6 kHz
- Stimulus levels
  - o Screening: 20, 25, 30, 35, 40, 45, 60 dB HL
  - o Audio: -10 to max. 80 dB HL or transducer limits (see *Table 2*); step size: 5 dB
- Stimulus types: sine, warble tone (sine modulation, modulation depth = 10 %,  $f_{\text{mod}} = 4$  Hz); single tone or two-tone presentation

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Interacoustics DD-65, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP, RadioEar B-71, RadioEar B-81

<i>f</i> [Hz]	250	500	1000	2000	3000	4000	5000	6000	8000
<b>HDA-280</b>	80	80	80	80	80	80	80	80	80
<b>HDA-200</b>	80	80	80	80	80	80	80	80	80
<b>HDA-300</b>	80	80	80	80	80	80	80	80	80
<b>DD-45</b>	80	80	80	80	80	80	80	80	80
<b>DD-65</b>	80	80	80	80	80	80	80	80	80
<b>PD-81</b>	80	80	80	80	80	80	80	80	80
<b>ME-70</b>	80	80	80	80	80	80	80	80	80
<b>otoInsert</b>	80	80	80	80	80	80	80	80	70
<b>ER-3A</b>	80	80	80	80	80	80	80	80	75
<b>IP-30</b>	80	80	80	80	80	80	80	80	75
<b>PIEP</b>	80	80	80	80	80	80	80	80	80
<b>B-71</b>	35	50	60	60	60	50	45	40	35
<b>B-81</b>	40	60	75	75	65	70	55	45	40

Table 2: Maximum MAGIC sine stimulus levels for each transducer type

### 3.2 Pure-Tone Audiometry

*Licenses: Audio Class 4: Screening audiometer (DIN EN 60645-1 class 4), Audio Class 4A: Screening audiometer (DIN EN 60645-1 class 4) with extended frequency/level range, Audio Class 3: Diagnostic audiometer (DIN EN 60645-1 class 3), Audio HF: frequency extension to any Audio license*

- Protocols: Screening, Diagnostic; *Audio Class 3: + Automatic, Expert*
- Frequencies: 0.125, 0.25, 0.5, 0.75, 1, 1.5, 2, 3, 4, 5, 6 kHz; *Audio Class 4A/3: + 8 kHz; Audio HF: + 8, 9, 10, 11.2, 12.5, 14, 16 kHz*
- Stimulus levels:
  - o *Audio Class 4: -10 to max. 70 dB HL or transducer limits (see Table 3); step size: 5 dB*
  - o *Audio Class 4A/3: -10 to max. 110 dB HL or transducer limits (see Table 4); step size: 5 dB*
  - o *Audio HF: -10 (Audio Class 4A/3) or 0 (Audio Class 4) to max. 90 dB HL or transducer limits (see Table 4); step size: 5 dB*
- Stimulus types: sine, pulsed sine (repetition rate = 2.25 Hz), warble tone (sine modulation, modulation depth = 10 %,  $f_{\text{mod}} = 4$  Hz)
- Minimum stimulus duration (optional): 1.2 s
- Masking noise (optional for *Audio Class 3: Expert*): third octave noise (see Table 5 and Table 6)
- Automatic testing (optional for *Audio Class 3: Auto / Expert*): Békésy (rate of level change = 5 dB/s), Hughson-Westlake (response window: start of stimulus+200 ms until end of stimulus), stimulus level limited to max. 80 dB HL, workflow according to ISO 8253-1, 6.2 and 6.3

- Uncomfortable level testing (optional for *Audio Class 3: Expert*)
- Bilateral audiogram view (optional for *Audio Class 3: Expert*)

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Interacoustics DD-65, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP, JBL Control 2P; *Audio Class 3:* + RadioEar B-71, RadioEar B-81

Available *Audio HF* transducers: Sennheiser HDA-200, Sennheiser HDA-300

<i>f</i> [Hz]	125	250	500	750	1000	1500	2000	3000	4000	5000	6000
<b>HDA-280</b>	60	70	70	70	70	70	70	70	70	70	70
<b>HDA-200</b>	60	70	70	70	70	70	70	70	70	70	70
<b>HDA-300</b>	60	70	70	70	70	70	70	70	70	70	70
<b>DD-45</b>	60	70	70	70	70	70	70	70	70	70	70
<b>DD-65</b>	60	70	70	70	70	70	70	70	70	70	70
<b>PD-81</b>	60	70	70	70	70	70	70	70	70	70	70
<b>ME-70</b>	60	70	70	70	70	70	70	70	70	70	70
<b>otoInsert</b>	60	70	70	70	70	70	70	70	70	70	70
<b>ER-3A</b>	60	70	70	70	70	70	70	70	70	70	70
<b>IP-30</b>	60	70	70	70	70	70	70	70	70	70	70
<b>PIEP</b>	60	70	70	70	70	70	70	70	70	70	70
<b>Control2P</b>	---	---	70	---	70	---	70	70	70	---	---

Table 3: Maximum *Audio Class 4* sine stimulus levels for each transducer type

<i>f</i> [Hz]	125	250	500	750	1000	1500	2000	3000	4000	5000	6000	8000
<b>HDA-280</b>	60	80	110	110	110	110	110	110	110	100	95	90
<b>HDA-200</b>	60	80	100	105	105	100	100	105	100	95	95	90
<b>HDA-300</b>	60	80	110	110	110	110	110	110	105	100	95	95
<b>DD-45</b>	60	80	100	110	110	105	105	110	105	100	95	90
<b>DD-65</b>	60	80	100	105	105	105	105	110	100	95	90	95
<b>PD-81</b>	60	80	110	110	110	110	110	110	105	100	100	100
<b>ME-70</b>	60	80	100	105	105	105	105	105	105	100	100	90
<b>otoInsert</b>	60	80	100	105	110	105	105	105	105	90	80	70
<b>ER-3A</b>	60	80	105	110	110	110	110	110	105	95	85	75
<b>IP-30</b>	60	80	105	105	110	110	110	110	105	95	90	75
<b>PIEP</b>	60	80	110	110	110	110	110	110	110	100	95	85
<b>Control2P</b>	---	---	80	---	80	---	80	80	70	---	---	---
<b>B-71</b> (Class 3)	---	35	50	55	60	60	60	60	50	45	40	35
<b>B-81 mast.</b> (Class 3)	---	50	70	70	80	80	80	80	70	65	55	50
<b>B-81 foreh.</b> (Class 3)	---	40	60	65	75	80	75	65	70	55	45	40

$f$ [Hz]	9000	10000	11200	12500	14000	16000
<b>HDA-200</b>	90	85	80	70	70	55
<b>HDA-300</b>	80	90	80	70	70	60

Table 4: Maximum Audio Class 4A/3 and Audio HF sine stimulus levels for each transducer type

$f_{center}$ [Hz]	125	250	500	750	1000	1500	2000	3000	4000	5000	6000	8000
$f_L$ [Hz]	111	223	445	668	891	1340	1780	2670	3560	4450	5350	7130
$f_U$ [Hz]	140	281	561	842	1120	1680	2240	3370	4490	5610	6730	8980

$f_{center}$ [Hz]	9000	10000	11200	12500	14000	16000
$f_L$ [Hz]	8020	8910	9980	11140	12470	14250
$f_U$ [Hz]	10100	11220	12570	14030	15710	17960

Table 5: Audio Class 3 and Audio HF masking noise lower/upper band limits

$f$ [Hz]	125	250	500	750	1000	1500	2000	3000	4000	5000	6000	8000
<b>HDA-280</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>HDA-200</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>HDA-300</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>DD-45</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>DD-65</b>	50	65	80	80	80	80	80	80	80	70	70	70
<b>PD-81</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>ME-70</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>otoInsert</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>ER-3A</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>IP-30</b>	50	70	80	80	80	80	80	80	80	70	70	70
<b>PIEP</b>	50	70	80	80	80	80	80	80	80	70	70	70

$f$ [Hz]	9000	10000	11200	12500	14000	16000
<b>HDA-200</b>	50	50	50	50	50	40
<b>HDA-300</b>	50	50	50	50	50	50

Table 6: Maximum Audio Class 3 and Audio HF masking noise levels for each transducer type

### 3.3 Speech Understanding in Noise (SUN)

License: SUN + language speech license

- Protocols:
  - o Fixed/predefined: constant speech level, adaptive noise level (SNR groups)
  - o Adaptive: adaptive speech level, constant noise level
- Speech level: 40 to max. 80 dB HL or transducer limits (see Table 7); step size: 5 dB



- Languages (pronunciations of logatoms): Italian, German, English; for validation: French, Spanish, Russian – additional languages upon request
- Character set: Latin, Greek, Farsi, Hindi, Cyrillic, Czech (not all character set / language combinations available)

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP, JBL Control 2P (free field loudspeaker calibration via CCITT noise)

<b>Calibration type</b>	<b>IEC</b>	<b>ANSI</b>
<b>HDA-280</b>	80	80
<b>HDA-200</b>	80	75
<b>HDA-300</b>	80	80
<b>DD-45</b>	80	80
<b>PD-81</b>	80	80
<b>ME-70</b>	80	80
<b>otoInsert</b>	80	70
<b>ER-3A</b>	80	75
<b>IP-30</b>	80	80
<b>PIEP</b>	80	80
<b>Control 2P</b>	80	70

Table 7: Maximum SUN speech levels for each transducer type

### 3.4 Mainzer Audiometric Test for Children (MATCH)

License: MATCH + language speech license

- Protocols:
  - o Fixed: constant speech level; optional with ipsilateral noise
  - o Adaptive: adaptive speech level; optional with ipsilateral noise
- Speech level: -10 to max. 100 dB or transducer limits (see Table 8); step size: 1 dB
- Languages: German; for validation: English, French, Spanish, Russian, Turkish, Italian, Slovenian – additional languages upon request
- Options: ipsilateral masking noise with fixed level (65 dB), manual item selection

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP, JBL Control 2P (free field loudspeaker calibration via CCITT noise)

<b>Calibration type</b>	<b>IEC</b>	<b>ANSI</b>
<b>HDA-280</b>	100	85
<b>HDA-200</b>	90	80
<b>HDA-300</b>	100	85
<b>DD-45</b>	95	80

<b>Calibration type</b>	<b>IEC</b>	<b>ANSI</b>
<b>PD-81</b>	100	90
<b>ME-70</b>	95	80
<b>otoInsert</b>	85	75
<b>ER-3A</b>	85	75
<b>IP-30</b>	95	80
<b>PIEP</b>	100	100
<b>Control 2P</b>	85	70

Table 8: Maximum MATCH speech levels (without ipsilateral noise) for each transducer type

### 3.5 Munich Auditory Screening Test for Processing Disorders (MAUS)

License: MAUS + speech license

Copyright: Westra Elektroakustik GmbH 2003/2004. Details in separate MAUS manual. Authors: A. Nikisch, C. Heuckmann, T. Burger

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP

### 3.6 Bochum Auditory Speech Discrimination Test (BASD)

License: BASD + speech license

- Differentiation modes: Consonants (Ba/Ga, Ga/Ka), frequency, duration, sound intensity, amplitude modulation (modulation depth = 100 %, reference modulation frequency = 20 Hz)
- Initial differences: sound intensity (5 to 20 dB; step size: of 5 dB), duration (100 to 300 ms; step size: 50 ms, frequency (0.05, 0.1, 0.2, 0.4, 0.8, 1.6 Oct), amplitude modulation (80 Hz)
- Presentation modes: Monaural, binaural, dichotic, interaural
- Stimulus level: 30 to max. 100 dB HL; step size: 5 dB
- Frequency (not for consonant differentiation tests): 0.5, 1 kHz

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP

### 3.7 Universal Speech Test (UST)

License: UST + sub-module speech license

- Speech level: 0 to max. 100 dB or transducer limits (see Table 9); step size: 5 dB
- Word lists: UT01: Dr. Tato (Spanish); UT02: Freiburger (German); UT06: Govorni (Slovenian); UT09: Hungarian speech test (Hungarian); UT08: Spondees child, UT10: Spondees adult, UT11: NU-6, UT12: CID W-22, UT13: PBK, UT15: Maryland CNC (English); UT14: Mots français CAD (French) – additional word lists upon request
- Contralateral or ipsilateral noise (optional): fixed (0 to max. 100 dB), offset (-30 to +30 dB)
- Pre-test phases (optional): voice hearing, word understanding

- Auto Proceed (optional): next word is automatically played when moving to next item and after scoring the word or after 3 seconds without user input

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP, JBL Control 2P (free field loudspeaker calibration via CCITT noise)

<b>Calibration type</b>	<b>IEC</b>	<b>ANSI</b>
<b>HDA-280</b>	100	85
<b>HDA-200</b>	90	80
<b>HDA-300</b>	100	85
<b>DD-45</b>	95	80
<b>PD-81</b>	100	90
<b>ME-70</b>	95	80
<b>otoInsert</b>	85	75
<b>ER-3A</b>	85	75
<b>IP-30</b>	95	80
<b>PIEP</b>	100	100
<b>Control 2P</b>	85	70

Table 9: Maximum UST speech levels (without ipsilateral noise) for each transducer type

### 3.8 Live Speech

License: Live Speech

- Level setting: 0 to 80 dB HL; step size: 5 dB
- Modes: Speech detection threshold (SDT), speech recognition threshold (SRT), word recognition (WR)
- Options: microphone sensitivity adjustment (according to VU meter), scoring entry

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP

### 3.9 Transient Evoked Otoacoustic Emissions (TEOAE)

License: TEOAE

- Modules: Quick, Diagnostic
- Noise detection: root mean square (RMS) of non-stimulus intervals
- Residual noise calculation: weighted averaging, summed weighting factors
- Artifact rejection: weighted averaging
- Response detection:
  - o TEOAE Quick: 8 values with changing sign fulfilling a 3 sigma criterion (representing 99.7 % statistical significance)

- TEOAE Diagnostic: user-defined stop criterion (SNR: 6 or 9 dB) in 3, 4, or 5 out of 5 frequency bands (1, 1.5, 2, 3, 4 kHz)
- Leak check: analysis of feedback signal (440 Hz probe tone)
- Probe check: limit of maximum sound pressure (“stimulus”), comparison across speakers (“symmetry”), leak check (“probe fit”)
- Calibration: in-the-ear calibration with ear canal volume adjustment
- Sample rate: 48 kHz (stimulus), 16 kHz (response)
- Window of analysis: 5 to 13 ms post-stimulus
- Simultaneous measurement on left/right ear possible when connecting two ear probes
- Stimulus level:
  - TEOAE Quick: 85 dB peSPL
  - TEOAE Diagnostic: 60 to 85 dB peSPL; step size: 5 dB
- Stimulus types: short-term stimulus without direct component (0.7-6 kHz); TEOAE Diagnostic: + 100  $\mu$ s rectangular click
- Stimulation protocol: nonlinear
- Test time (TEOAE Diagnostic): 15 s, 30 s, 60 s, Automatic

Usable transducers: PATH EP-TE, PATH EP-DP, PATH EP-VIP\*, PATH EP-TY\*

\* Available for Sentiero Desktop, EP-VIP with lighting function for Sentiero (PCB 71), Sentiero Advanced (PCB  $\geq$  70)

### 3.10 Distortion Product Otoacoustic Emissions (DPOAE)

*License: DPOAE Quick/Diagnostic, DPOAE Threshold; feature upgrades: FMDPOAE, DPHIRES*

- Modules: Quick, Diagnostic, Threshold (for details see separate module sections)
- Noise detection: narrow band noise around  $2f_2-f_1$
- Residual noise calculation: weighted averaging, summed weighting factors
- Artifact rejection: weighted averaging
- Response detection: F-test, F-value at a single point ( $F_{sp}$ ) dependent on settings
- Leak check: analysis of feedback signal (440 Hz probe tone)
- Probe check: limit of maximum sound pressure (“stimulus”), comparison across speakers (“symmetry”), leak check (“probe fit”)
- Calibration: in-the-ear calibration with ear-canal volume adjustment
- Frequency ratio  $f_2/f_1$ : 1.22
- Minimum DPOAE level criterion:  $L_1 - 70$  dB
- Sample rate: 48 kHz (stimulus, response)
- Measurement interval: 4096 samples
- Stimulus modes (with *FMDPOAE* license):
  - Frequency-modulated DPOAE ( $f_m = 1.4-1.6$  Hz, modulation depth = 50 Hz at 1 kHz, 100 Hz at 4 kHz)
  - Multi-channel DPOAE (simultaneous measurement of DPOAEs at up to two  $f_2$  frequencies at a time)
- Simultaneous measurement on left/right ear possible when connecting two ear probes

Usable transducers: PATH EP-DP, PATH EP-VIP\*, PATH EP-TY\*

\* Available for Sentiero Desktop, EP-VIP with lighting function for Sentiero (PCB 71), Sentiero Advanced (PCB  $\geq$  70)

### 3.10.1 DPOAE Quick

*License: DPOAE Quick/Diagnostic; feature upgrade: FMDPOAE*

- Frequencies  $f_2$ : 1, 1.5, 2, 3, 4, 5, 6, 8 kHz
- Stimulus level  $L_2$ : 30 to 65 dB SPL; step size: 5 dB
- $L_2/L_1$  relation: automatic (scissor paradigm:  $L_1 = 0.4 L_2 + 39$  dB SPL, Kummer et al. 1998)
- SNR stop criterion: 6, 9, 12 dB
- Overall stop criterion: x out of y (with y = number of selected frequencies,  $x = y/y-1/y-2$  &  $x > y/2$ ) with "as fast as possible" option, i.e. stop as soon as overall criterion is fulfilled or cannot be fulfilled anymore
- Maximum number of recalibrations until stop: 0, 1, 3, 10
- Manual retest

### 3.10.2 DPOAE Diagnostic

*License: DPOAE Quick/Diagnostic; feature upgrades: FMDPOAE, DPHIRES*

- Frequencies  $f_2$  (standard): 1, 1.5, 2, 3, 4, 5, 6, 8 kHz
- Frequencies  $f_2$  (with DPHIRES license):
  - o Linear: 0.8 to 10 kHz (step size: 0.5 kHz from 1 to 10 kHz), steps: 10 to 1000 Hz (step size: 10 Hz, minimum step size depends on start and stop frequency)
  - o Logarithmic: 0.8 to 10 kHz (step size: 0.5 kHz from 1 to 10 kHz), steps: 1 to 30 points per octave (step size: 1 point per octave)
- Stimulus levels  $L_2$ : 30 to 65 dB SPL; step size: 5 dB (single and multiple selections possible)
- $L_2/L_1$  relation: automatic (scissor paradigm),  $L_1=L_2$ ,  $L_1=L_2+5$  dB,  $L_1=L_2+10$  dB (max.  $L_1$  limited to 65 dB SPL)
- SNR stop criterion: 6, 9, 12 dB
- Minimum DPOAE level criterion (optional): -20 to 0 dB; step size: 5 dB
- Measurement time: adaptive timeout, manual minimum/maximum timeout (2 to 120 s)
- Options: automatic retest; static pressure offset (Sentiero Desktop only)

### 3.10.3 DPOAE Threshold

*License: DPOAE Threshold; feature upgrade: FMDPOAE*

- Frequencies  $f_2$ : 1, 1.5, 2, 3, 4, 5, 6, 8 kHz
- Stimulus level  $L_2$ : 15 to 65 dB SPL (automated threshold detection algorithm)
- Minimum stimulus level  $L_2$ : 15 to 30 dB SPL; step size: 5 dB
- Initial stimulus level: 30 to 60 dB SPL; step size: 5 dB
- $L_2/L_1$  relation: automatic (scissor paradigm)
- Option: allow retry

## 3.11 Auditory Brainstem Responses (ABR)

*License: ABR; feature upgrades: ABR-BIN, ABR-FS*

- Modules: Standard, Quick ABR (for details see separate module sections)

- Artifact rejection: weighted averaging, notch filter (50/60 Hz, self-tuning)
- Residual noise calculation: collecting noise energy from each frame, calculating residual noise level (absolute RMS value in nV)
- Response detection: auto peak-marker setting via template matching
- Normative latencies for different age groups and transducer types
- Display and storage of waveform, impedance, residual noise, averages; standard mode: + peak marker (editable)
- Electrode impedance check:
  - o Continuous monitoring of electrode impedance
  - o Auto start after impedance OK (optional):  $R \leq 4 \text{ k}\Omega$ ,  $\Delta R \leq 2 \text{ k}\Omega$
  - o Allow manual start:  $R \leq 6 \text{ k}\Omega$ ,  $\Delta R \leq 3 \text{ k}\Omega$ ; allow skip:  $R \leq 12 \text{ k}\Omega$ ,  $\Delta R \leq 6 \text{ k}\Omega$ ; stop during test:  $R > 7 \text{ k}\Omega$ ,  $\Delta R > 4 \text{ k}\Omega$ ; stop during test (if skipped):  $R > 13 \text{ k}\Omega$ ,  $\Delta R > 7 \text{ k}\Omega$
- Sample rate: 48 kHz (stimulus), 16 kHz (response)
- Simultaneous measurement on left/right ear (with *ABR-BIN* license)

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP, PATH EP-TE, PATH EP-DP, PATH EP-VIP\*, PATH EP-TY\*, RadioEar B-71 (not QuickABR), RadioEar B-81 (not QuickABR), Ear Coupler Cable (QuickABR only)

\* Available with lighting function for Sentiero Advanced (PCB  $\geq 70$ )

### 3.11.1 ABR

*License: ABR; feature upgrades: ABR-BIN, ABR-FS*

- Stimulus types: Click (0.7 to 6 kHz), Chirp (broadband, 1 to 8 kHz); with *ABR-FS* license: + Low-Chirp (100 to 850 Hz), Mid-Chirp (850 Hz to 3 kHz), High-Chirp (3 to 10 kHz), Tone Burst (500 Hz, 750 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz)
- Tone burst stimulus waveform: up-plateau-down periods: 1-0-1, 1-1-1, 1-2-1, 2-0-2, 2-1-2
- Stimulus polarity: condensation, rarefaction, alternating
- Stimulus rate: 10.1, 11.1, 20.1, 27.7, 30.7, 40.3, 69.9, 81.2, 90.4 Hz (default) + user-specific stimulus rate from 10 to 100 Hz; rate mode: 10, 20, 30, 40, 69, 81, 90 Hz (single or multiple selection of up to eight traces per test sequence; up to three repetitions per rate)
- Stimulus levels: 0 to max. 95 dB nHL or transducer limits (see *Table 10*), no stimulus; step size: 5 dB; single or multiple selection of up to eight traces per test sequence, up to three repetitions per level; rate mode: 10 to 90 dB in steps of 5 dB
- Masking noise offset levels (white noise): -50 to +50 dB
- Averages: 1000 up to 20000; step size: 1000
- Noise stop criterion (optional): 0, 10, 15, 20,30, 40, 50, 60 80 nV
- Automated wave 5 detection (optional) with optional minimum wave 5 criterion: 0, 20, 30, 40, 50, 70, 100, 150, 200 nV<sub>pp</sub>
- Plot range (fixed): 0 to inter-stimulus interval + 1.5 ms (minimum 10.5 ms, maximum: 15 ms)
- Additional parameters: Spread spectrum, auto proceed, auto stop, rate mode

<i>Stim. Type</i>	Click	Chirp	Low-Chirp	Mid-Chirp	High-Chirp
<b>HDA-280</b>	85	90	90	90	85
<b>HDA-200</b>	80	85	85	85	80

<b>Stim. Type</b>	<b>Click</b>	<b>Chirp</b>	<b>Low-Chirp</b>	<b>Mid-Chirp</b>	<b>High-Chirp</b>
<b>HDA-300</b>	85	90	90	90	85
<b>DD-45</b>	85	90	85	90	85
<b>PD-81</b>	85	90	90	90	80
<b>ME-70</b>	80	85	85	85	85
<b>otoInsert</b>	80	85	85	90	75
<b>ER-3A</b>	85	90	85	90	80
<b>IP-30</b>	85	90	85	90	80
<b>PIEP</b>	90	95	95	95	90
<b>EP-DP</b> (R1) *	80	85	70	90	80
(R2)	85	90	80	90	75
<b>EP-VIP, -TY</b> (R2) *	90	90	85	90	80
<b>B-71</b>	55	65	55	70	50
<b>B-81</b>	60	65	60	70	50

\* Example adult ear. Dependent on ear canal volume, the actual level may be lower (big ear canal volume) or higher (small ear canal volume). R1: SN40xxx, 50xxx, 80xxx; R2 (updated loudspeaker setup): SN41xxx/42xxx, 51xxx/52xxx, 81xxx/82xxx.

<b>Stim. Type</b>	<b>TB 0.5</b>	<b>TB 0.75</b>	<b>TB 1k</b>	<b>TB 1.5k</b>	<b>TB 2k</b>	<b>TB 3k</b>	<b>TB 4k</b>
<b>HDA-280</b>	90	90	90	90	90	90	90
<b>HDA-200</b>	80	80	85	85	90	90	90
<b>HDA-300</b>	90	90	90	90	90	90	90
<b>DD-45</b>	85	85	90	90	90	90	90
<b>PD-81</b>	90	90	90	90	90	90	90
<b>ME-70</b>	80	85	90	90	90	90	90
<b>otoInsert</b>	85	85	90	90	90	90	90
<b>ER-3A</b>	85	90	90	90	90	90	90
<b>IP-30</b>	85	85	90	90	90	90	90
<b>PIEP</b>	95	95	95	95	95	95	95
<b>EP-DP</b> (R1) *	60	65	65	75	75	85	85
(R2)	70	75	75	80	80	85	80
<b>EP-VIP, -TY</b> (R2) *	75	80	80	90	85	90	90
<b>B-71</b>	65	65	70	70	75	65	65
<b>B-81</b>	70	65	70	80	75	65	65

\* Example adult ear. Dependent on ear canal volume, the actual level may be lower (big ear canal volume) or higher (small ear canal volume). R1: SN40xxx, 50xxx, 80xxx; R2 (updated loudspeaker setup): SN41xxx/42xxx, 51xxx/52xxx, 81xxx/82xxx.

Table 10: Maximum ABR stimulus levels for each transducer type

### 3.11.2 Quick ABR

License: ABR; feature upgrade: ABR-BIN

- Stimulus type: Chirp (broadband, 1 to 8 kHz)
- Stimulus polarity: alternating

- Stimulus rate: 85 Hz  
Stimulus level: 35 to 55 dB eHL (step size: 5 dB), ask before test (enables additional stimulus levels 25 and 30 dB eHL) (ECC: max. level 40 dB eHL)  
Please note: dB eHL = dB nHL + 10 dB (typical ABR detection threshold for normal hearing subject at 0 dB eHL)
- Spread spectrum

### 3.12 Electrically Evoked Auditory Brainstem Responses (E-ABR)

*License: GSEA*

- Averages: 1000 up to 20000; step size: 1000
- Plot range: start: -1 ms (fixed), stop: 5 to 10 ms, step size: 0.5 ms
- Automated wave 5 detection (optional)
- No impedance check during measurement (optional)
- Use change in trigger as skip (optional)
- Trigger at lower voltage (optional)
- Trigger input: each impulse, each second impulse (trigger 2), each fourth impulse (trigger 4)

### 3.13 Electrocochleography (ECochG)

*License: ECochG*

- Stimulus type: click, tone burst (500 Hz, 1 kHz, 2 kHz, 4 kHz)
- Tone burst rise/fall time: 1 to 4 ms; step size: 1 ms
- Tone burst plateau time: 1 to 10 ms, step size: 1 ms
- Stimulus level: 45 to 90 dB nHL
- Stimulus rate: 8.0, 10.0, 11.1, 16.0, 20.1, 27.7, 30.0, 40.0, 69.9, 80.0, 90.4 Hz (default) + user-specific stimulus rate from 5 to 100 Hz
- Averages: 1000 up to 20000; step size: 1000
- Plot range: start: -1.5 ms (fixed), stop: 4 to 12 ms, step size: 0.5 ms
- Additional parameters: Spread spectrum (optional)

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP

### 3.14 Auditory Steady-State Responses (ASSR)

*License: ASSR*

- Protocols:
  - o Fixed level procedure
  - o Adaptive level procedure (threshold estimation)
- Stimulus bandwidths: ½ octave, 1 octave, 2 octaves
- Stimulus rate: 41 ± 1.5 Hz (40 Hz ASSR) and 85 ± 1.5 Hz (80 Hz ASSR), automatic (37 to 163 Hz, dependent on frequency); spread spectrum: ± 2%
- Stimulus level:
  - o Fixed: 10 to max. 100 dB nHL or transducer limits (see *Table 11* for ½ octave stimuli); single or multiple level selections possible; step size: 10 dB



- Adaptive: 10 to max. 100 dB nHL or transducer limits (see *Table 11* for ½ octave stimuli); step size: 10 dB
- Response detection: weighted averaging, phase statistics including up to 7 overtones
- Frequencies: 0.25, 0.5, 1, 1.5, 2, 3, 4, 6, 8 kHz (with increasing stimulus bandwidth, less frequencies are available)
- Number of averages: 45 to 900 s; step size: 15 s
- Noise stop criterion: 0 to 20 nV; step size: 1 nV
- Display and storage of statistics graph, impedance, artifact threshold, modulation frequency
- Contralateral masking noise (optional): 0 to 60 dB nHL; step size: 5 dB
- Electrode impedance check: see ABR

Usable transducers:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, RadioEar IP-30, PIEP, PATH EP-DP, PATH EP-VIP\*, PATH EP-TY\*, RadioEar B-71, RadioEar B-81

\* Available with lighting function for Sentiero Advanced (PCB ≥ 70)

<i>f</i> [Hz]	250	500	1000	1500	2000	3000	4000	6000	8000
<b>HDA-280</b>	90	100	100	100	100	100	90	80	80
<b>HDA-200</b>	80	90	90	90	90	90	80	80	80
<b>HDA-300</b>	90	100	100	90	90	100	90	80	80
<b>DD-45</b>	80	90	90	90	90	100	90	80	80
<b>PD-81</b>	90	100	100	100	100	100	90	90	100
<b>ME-70</b>	80	90	90	90	90	90	90	90	80
<b>otoInsert</b>	80	90	90	90	90	90	90	70	60
<b>ER-3A</b>	80	90	100	100	100	100	90	70	70
<b>IP-30</b>	90	90	100	100	100	100	90	80	70
<b>PIEP</b>	100	100	100	100	100	100	100	90	80
<b>EP-DP</b> (R1) *	80	70	70	80	80	90	90	80	80
(R2)	80	80	80	90	90	90	90	70	70
<b>EP-VIP, -TY</b> (R2) *	90	90	90	90	100	100	100	80	80
<b>B-71</b>	40	60	70	70	70	70	70	40	40
<b>B-81</b>	40	70	70	70	70	70	70	40	40

\* Example adult ear. Dependent on ear canal volume, the actual level may be lower (big ear canal volume) or higher (small ear canal volume). R1: SN40xxx, 50xxx, 80xxx; R2 (updated loudspeaker setup): SN41xxx/42xxx, 51xxx/52xxx, 81xxx/82xxx.

*Table 11: Maximum ASSR stimulus levels for each transducer type (single frequency measurement only – simultaneous measurement at multiple frequencies may reduce the maximum stimulus level).*

### 3.15 Middle Ear Tests

License: Tymp Class 1, Tymp Class 2; feature upgrade for Tymp Class 2: Tymp 1k

- Probe tone: 226 Hz ±1 % at 85.3 dB SPL ± 3 dB
- Artefact detection

Usable transducers: PATH EP-TY

### 3.15.1 Tympanometry

*License: Tymp Class 1, Tymp Class 2; feature upgrade for Tymp Class 2: Tymp 1k*

- Additional probe tones (class 1 only): 678 Hz  $\pm$  1 % at 72 dB SPL  $\pm$  3 dB, 800 Hz  $\pm$  1 % at 70.6 dB SPL  $\pm$  3 dB, 1000 Hz  $\pm$  1 % at 69 dB SPL  $\pm$  3 dB (1000 Hz can be added to *Tymp Class 2* license with *Tymp 1k* license)
- Multi-frequency measurement (*Tymp Class 1*: 226, 678, 800, 1000 Hz, *Tymp Class 2 + Tymp 1k*: 226, 1000 Hz)
- Compliance Range: 0 to 5 ml
- Compliance Accuracy :  $\pm$ 5 % or 0.1 ml (whichever is greater)
- Pressure Range: +300 to -300 daPa (*Tymp Class 2*), +400 to -600 daPa (*Tymp Class 1*); minimum: -600 to -100 daPa, maximum: +200 to +400 daPa; step size: 50 daPa
- Pressure Accuracy:  $\pm$ 10 % or 10 daPa (whichever is greater)
- Pump speed: 50, 100, 150, 200 daPa/s  $\pm$  10 daPa/s, as fast as possible (up to 600 daPa/s, automatic reduction to 200 daPa/s at steep rise of tympanometric curve)
- Tympanometry + Acoustic Reflex sequence (see [3.15.2 Acoustic Reflex](#))
- *Tymp Class 1* options:
  - o Y (admittance) / B (susceptance) / G (conductance) components view
  - o Auto Stop function (finish recording if valid peak is detected)
  - o Manual pressure control (pressure steps: 1, 5, 10, 50 daPa)
  - o Multiple trace memory (up to three traces in one measurement)

### 3.15.2 Acoustic Reflex

*License: Tymp Class 1, Tymp Class 2*

- Modes: automatic reflex threshold; *Tymp Class 1*: + manual reflex test, reflex decay test
- Automatic reflex screening levels: 70 to 100 dB HL; step size: 5 dB
- Automatic reflex start after tympanometry options: never, always, if peak within norm (for 226 Hz probe tone only)
- Stimulus presentation modes: ipsilateral, contralateral (if 2<sup>nd</sup> transducer is connected)
- Pressure offset: taken over from tympanometry measurement, editable (see pressure range in section [3.15.1: Tympanometry](#))
- Acoustic reflex stimuli (using EP-TY probe): 500, 1000, 2000, 3000, 4000 Hz, up to 100 dB HL; Broadband noise (CCITT) up to 90 dB HL; low-pass noise (LPN: 891-1120 Hz), high-pass noise (HPN: 3560-4490 Hz) up to 90 dB HL
- Acoustic reflex stimulus duration: 2 s, 14 s for reflex decay
- Acoustic reflex stimulus signal time multiplexed with probe tone (106 ms on, 53 ms off)

Usable transducers for contralateral reflex:

Sennheiser HDA-280, Sennheiser HDA-200, Sennheiser HDA-300, Interacoustics DD-45 / DD-45 monaural, Interacoustics DD-65, Holmco PD-81, GN ME-70, GN otoInsert, Etymotic Research ER-3A, Etymotic Research ER-3C monaural, RadioEar IP-30 / IP-30 monaural, PIEP / PIEP monaural, Audio Mouldings GBE, PATH EP-VIP

### 3.15.3 Eustachian Tube Function Tests

*License: Tympanometry Class 1*

- Modes:
  - Non-perforated ear drum (Williams test)
  - Perforated ear drum (Toynbee test)
  - Patulous Eustachian tube (continuous sensitive impedance measurement)

## 4. Accessories

Accessories (e.g. headphones, insert earphones, electrode cables, electrodes, label printer) may include separate manuals and/or data sheets which may contain important information. Please refer to these documents for further information about the respective accessory.

Contact information from distributor/service partner:

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