



Technical specifications, manufacturer's data

Senti & Sentiero

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Manual Information

Release date: 2023-12
Revision: 0802_MA_TechnicalSpecifications_EN_19
Valid from: Firmware Rev. 2.9, Mira PC Software Rev. 2.5

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1. General device information

1.1 Device

- 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_{pp}, 32 Ω
- 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)

1.3 Operating Conditions

Warm-up time: The unit does not need any warm-up time.

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 typically by +/- 1 step (in most cases 5 dB) dependent on the individual transducer calibration.

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

Headphone	Pressure [N]
HDA-280	5.3 ± 0.5
HDA-200	10.0 ± 1.0
HDA-300	8.8 ± 0.5
DD-45	4.5 ± 0.5
DD-65	4.5 ± 0.5
DD-65 v2	10.0 ± 0.5
DD450	10.0 ± 0.5
PD-81	14.6 ± 1.0 *
ME-70	4.5 ± 0.5
Bone conductor	Pressure [N]
B-71	5.4 ± 0.5
B-81	5.4 ± 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
- Options: hide level, start with instruction phase (Screening mode), skip animal shelf (Audio mode)

Usable transducers:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A), bone conductor (B-71, B-81)

<i>f</i> [Hz]	250	500	1000	2000	3000	4000	5000	6000	8000
HDA-280	80	80	80	80	80	80	80	80	80
HDA-200	80	80	80	80	80	80	80	80	80
HDA-300	80	80	80	80	80	80	80	80	80
DD-45	80	80	80	80	80	80	80	80	80
DD-65	80	80	80	80	80	80	80	80	80
DD-65 v2	80	80	80	80	80	80	80	80	75
DD450	80	80	80	80	80	80	80	80	80
PD-81	80	80	80	80	80	80	80	80	80
ME-70	80	80	80	80	80	80	80	80	80
PIEP	80	80	80	80	80	80	80	80	80
IP-30	80	80	80	80	80	80	80	80	75
otoInsert	80	80	80	80	80	80	80	80	70
ER-3A	80	80	80	80	80	80	80	80	75
B-71	35	50	60	60	60	50	45	40	35
B-81	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 4: Screening audiometer (DIN EN 60645-1 type 4), *Audio 4A:* Screening audiometer (DIN EN 60645-1 type 4) with extended frequency/level range, *Audio 3:* Diagnostic audiometer (DIN EN 60645-1 type 3), *Audio HF:* frequency extension to any *Audio* license

- Protocols: Screening, Diagnostic; *Audio 3:* + Automatic, Expert
- Frequencies: 0.125, 0.25, 0.5, 0.75, 1, 1.5, 2, 3, 4, 5, 6 kHz; *Audio 4A/3:* + 8 kHz; *Audio HF:* + 8, 9*, 10, 11.2*, 12.5, 14*, 16 kHz (*not available for automatic testing)
- Stimulus levels:
 - o *Audio 4:* -10 to max. 70 dB HL or transducer limits (see *Table 3*); step size: 5 dB
 - o *Audio 4A/3:* -10 to max. 110 dB HL or transducer limits (see *Table*); step size: 5 dB
 - o *Audio HF:* -10 (*Audio 4A/3*) to max. 90 dB HL or transducer limits (see *Table*); 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 3: Expert*): one third octave noise (see *Table* and *Table*)
- Automatic testing (optional for *Audio 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; options: test both ears, skip familiarization
- Uncomfortable level testing (optional for *Audio 3: Expert*)
- Bilateral audiogram view (optional for *Audio 3: Expert*)

Usable transducers:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65, DD-65 v2 (maximum levels not fully compliant to type 3), DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A), free-field loudspeaker (JBL Control 2P); *Audio 3:* + bone conductor (B-71, B-81)

Audio HF transducers: Headphone (HDA-200, HDA-300, DD450)

<i>f</i> [Hz]	125	250	500	750	1000	1500	2000	3000	4000	5000	6000
HDA-280	60	70	70	70	70	70	70	70	70	70	70
HDA-200	60	70	70	70	70	70	70	70	70	70	70
HDA-300	60	70	70	70	70	70	70	70	70	70	70
DD-45	60	70	70	70	70	70	70	70	70	70	70
DD-65	60	70	70	70	70	70	70	70	70	70	70
DD-65 v2	60	70	70	70	70	70	70	70	70	70	70
DD450	60	70	70	70	70	70	70	70	70	70	70
PD-81	60	70	70	70	70	70	70	70	70	70	70
ME-70	60	70	70	70	70	70	70	70	70	70	70
PIEP	60	70	70	70	70	70	70	70	70	70	70
IP-30	60	70	70	70	70	70	70	70	70	70	70
otoInsert	60	70	70	70	70	70	70	70	70	70	70
ER-3A	60	70	70	70	70	70	70	70	70	70	70

f [Hz]	125	250	500	750	1000	1500	2000	3000	4000	5000	6000
Control2P	---	---	70	---	70	---	70	70	70	---	---

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

f [Hz]	125	250	500	750	1000	1500	2000	3000	4000	5000	6000	8000
HDA-280	60	80	110	110	110	110	110	110	110	100	95	90
HDA-200	60	80	100	105	105	100	100	105	100	95	95	90
HDA-300	60	80	110	110	110	110	110	110	105	100	95	95
DD-45	60	80	100	110	110	105	105	110	105	100	95	90
DD-65	60	80	100	105	105	105	105	110	100	95	90	95
DD-65 v2	60	80	95	95	100	105	100	100	100	90	85	75
DD450	60	80	105	105	105	100	100	100	95	90	90	85
PD-81	60	80	110	110	110	110	110	110	105	100	100	90
ME-70	60	80	100	105	105	105	105	105	105	100	100	90
PIEP	60	80	110	110	110	110	110	110	110	100	95	85
IP-30	60	80	105	105	110	110	110	110	105	95	90	75
otoInsert	60	80	100	105	110	105	105	105	105	90	80	70
ER-3A	60	80	105	110	110	110	110	110	105	95	85	75
Control2P	---	---	80	---	80	---	80	80	70	---	---	---
B-71 m/f (Audio 3)	---	35	50	55	60	60	60	60	50	45	40	35
B-81 mast. (Audio 3)	---	50	70	70	80	80	80	80	70	65	55	50
B-81 foreh. (Audio 3)	---	40	60	65	75	80	75	65	70	55	45	40

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

f [Hz]	9000	10000	11200	12500	14000	16000
HDA-200	90	85	80	70	70	55
HDA-300	80	90	80	70	70	60
DD450	85	80	80	70	70	50

Table 4 continued: Maximum Audio 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

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

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 continued: Audio 3 and Audio HF masking noise lower/upper band limits

<i>f</i> [Hz]	125	250	500	750	1000	1500	2000	3000	4000	5000	6000	8000
HDA-280	50	70	80	80	80	80	80	80	80	70	70	70
HDA-200	50	70	80	80	80	80	80	80	80	70	70	70
HDA-300	50	70	80	80	80	80	80	80	80	70	70	70
DD-45	50	70	80	80	80	80	80	80	80	70	70	70
DD-65	50	65	80	80	80	80	80	80	80	70	70	70
DD-65 v2	50	70	80	80	80	80	80	80	80	70	70	65
DD450	50	70	80	80	80	80	80	80	80	70	70	70
PD-81	50	70	80	80	80	80	80	80	80	70	70	70
ME-70	50	70	80	80	80	80	80	80	80	70	70	70
PIEP	50	70	80	80	80	80	80	80	80	70	70	70
IP-30	50	70	80	80	80	80	80	80	80	70	70	70
otoInsert	50	70	80	80	80	80	80	80	80	70	70	70
ER-3A	50	70	80	80	80	80	80	80	80	70	70	70

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

<i>f</i> [Hz]	9000	10000	11200	12500	14000	16000
HDA-200	50	50	50	50	50	40
HDA-300	50	50	50	50	50	50
DD450	50	50	50	50	50	35

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

3.3 Tinnitus Matching

License: Tinnitus Matcher

- Number of independent stimulus channels: 2
- Stimulus types: sine, pulsed sine (repetition rate = 2.25 Hz), warble tone (sine modulation, modulation depth = 10 %, $f_{\text{mod}} = 4$ Hz), narrow band noise (one third octave noise)
- Stimulus level: -10 to 80 dB HL; step size 1 dB
- Frequency: 125 Hz to 10 kHz; step sizes 0.1 to 100 Hz, 1 octave

Usable transducers:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450), insert earphone (PIEP); for transducer specific maximum levels see *Table 2* and *Table 6*.

3.4 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
- Ipsilateral masking noise: broad-band noise (BBN), low pass noise (LPN) (for Predefined protocol fixed to BBN)

- Options: display “please listen”, enable “training” button, enable “binaural” button
- 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:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450 PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A), free-field loudspeaker (JBL Control 2P) (free field loudspeaker calibration via CCITT noise)

Calibration type	IEC	ANSI
HDA-280	80	80
HDA-200	80	75
HDA-300	80	80
DD-45	80	80
DD-65 v2	80	75
DD450	80	75
PD-81	80	80
ME-70	80	80
PIEP	80	80
IP-30	80	80
otoInsert	80	70
ER-3A	80	75
Control 2P	80	70

Table 7: Maximum SUN speech levels for each transducer type

3.5 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, 5 dB (adaptive mode: min./max. level)
- Languages: German; for validation: English, French, Spanish, Russian, Turkish, Italian, Slovenian, Polish, Hungarian – additional languages upon request
- Options: ipsilateral masking noise with fixed level (65 dB), show status in header, manual item selection

Usable transducers:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A), free-field loudspeaker (JBL Control 2P) (free field loudspeaker calibration via CCITT noise)

Calibration type	IEC	ANSI
HDA-280	100	85
HDA-200	90	80
HDA-300	100	85
DD-45	95	80
DD-65 v2	90	75
DD450	90	75
PD-81	100	90
ME-70	95	80
PIEP	100	100
IP-30	95	80
otoInsert	85	75
ER-3A	85	75
Control 2P	85	70

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

3.6 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:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A)

3.7 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: 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
- Number of trials: 9 to 24 (speech-based), 18 to 42 (non-speech-based); step size: 3
- Reversals: 4 to 12; step size: 2

Usable transducers:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A)

3.8 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; step size: 5 dB), offset (-30 to +30 dB; step size: 5 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:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A), free-field loudspeaker (JBL Control 2P) (free field loudspeaker calibration via CCITT noise)

Calibration type	IEC	ANSI
HDA-280	100	85
HDA-200	90	80
HDA-300	100	85
DD-45	95	80
DD-65 v2	90	75
DD450	90	75
PD-81	100	90
ME-70	95	80
PIEP	100	100
IP-30	95	80
otoInsert	85	75
ER-3A	85	75
Control 2P	85	70

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

3.9 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:

Headphone (HDA-280, HDA-200 HDA-300, DD-45, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A)

3.10 Transient Evoked Otoacoustic Emissions (TEOAE)

License: TEOAE Quick, TEOAE Diagnostic

- 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) or if less than 4 out of 8 significant points are detected after half of the maximum test time is reached
 - o 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 (optional): 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:
 - o TEOAE Quick: 85 dB peSPL
 - o 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 μ s rectangular click
- Stimulation protocol: nonlinear
- Test time (TEOAE Diagnostic): 15 s, 30 s, 60 s, Automatic
- Cartoon mode (optional)

Usable transducers: Ear probe (EP-TE, EP-DP, EP-VIP*, EP-TY*, EP-LT)

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

3.11 Distortion Product Otoacoustic Emissions (DPOAE)

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

- Modules: Quick, Diagnostic, Threshold (for details see separate module sections)
- Noise detection: narrow band noise around $2f_1-f_2$
- Residual noise calculation: weighted averaging, summed weighting factors
- Artifact rejection: weighted averaging
- Response detection: phase-statistics-derived spectral SNR criterion
- Leak check (optional): 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):
 - o Frequency-modulated DPOAE ($f_m = 1.4-1.6$ Hz, modulation depth = 50 Hz at 1 kHz, 100 Hz at 4 kHz)
 - o Multi-frequency 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
- Cartoon mode (optional)

Usable transducers: Ear probe (EP-DP, EP-VIP*, EP-TY*, EP-LT)

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

3.11.1 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

3.11.2 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); user-specific start/stop frequency and frequency step size in aforementioned ranges
 - 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); user-specific start/stop frequency and frequency step size in aforementioned ranges
- 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, -15, -10, -8, -5, 0 dB
- Measurement time: adaptive timeout, manual minimum/maximum timeout (2 to 120 s)
- Options: automatic retest; static pressure offset (Sentiero Desktop only)

3.11.3 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: 25 to 60 dB SPL; step size: 5 dB
- L_2/L_1 relation: automatic (scissor paradigm)
- Option: allow retry

3.12 Spontaneous otoacoustic emissions (SOAE)

License: SOAE

- Frequency range: 0.4 to 9.6 kHz
- Recording of spontaneous OAE possible in both ears at the same time with 2 ear probes

Usable transducers: Ear probe (EP-DP, EP-VIP*, EP-TY*, EP-LT)

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

3.13 Auditory Brainstem Responses (ABR)

License: Quick ABR, ABR; feature upgrades: ABR-BIN, ABR-FS, aEPS

- Modules: Standard, Quick ABR (for details see separate module sections)
- Artifact rejection: weighted averaging, notch filter (50, 60 Hz or 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)
- Leak check (optional for measurement with ear probe; active during ear probe calibration, for Quick ABR also active during test)
- ABR low-pass for trace smoothing (optional)
- Stimulus presentation during pause: on, off

Usable transducers:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450, PD-81, ME-70), insert earphone (IP-30, PIEP, otoInsert, ER-3A), ear probe (EP-TE, EP-DP, EP-VIP*, EP-TY*, EP-LT), bone conductor (B-71/B-81: not Quick ABR), ear coupler cable (PECC-01: Quick ABR only, PECC-HP)

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

3.13.1 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
- Tone burst ramp: linear, Blackman
- Stimulus polarity: condensation, rarefaction, alternating, alternating double-trace
- Stimulus rate: 10.1, 11.1, 20.1, 27.7, 30.7, 37.1, 40.3, 47.1, 69.9, 81.2, 90.4 Hz (default) + user-specific entry 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 (may be extended up to ten traces during test); up to three repetitions per rate)
- Stimulus levels: 0 to max. 100 dB nHL or transducer limits (see *Table*), no stimulus; step size: 5 dB; single or multiple selection of up to eight traces per test sequence (may be extended up to ten traces during test), up to three repetitions per level; rate mode: 10 to 90 dB in steps of 5 dB, user-specific entry in aforementioned range
- Masking noise offset levels (white noise): -40 to +40 dB; step size: 5 dB
- Averages: 1000 up to 20000; step size: 1000; user-specific entry in aforementioned range
- Noise stop criterion (optional): 10, 15, 20, 30, 40, 50, 60, 80 nV; user-specific entry from 0 (=off) to 80 nV
- Automated wave 5 detection (optional) with optional minimum wave 5 criterion: 20, 30, 40, 50, 70, 100, 150, 200 nV_{pp}; user-specific entry from 0 (=off) to 200 nV
- Artifact threshold (optional): 5, 7, 10, 15, 20, 50, 100 μV; user-specific entry in aforementioned range
- Recording window: 16 / 25 ms
- Plot range (fixed): 0 to inter-stimulus interval + 1.5 ms (minimum 10.5 ms, maximum: 16 / 25 ms dependent on recording window)
- Additional parameters: Spread spectrum, invert order, auto proceed, auto stop, rate mode, 30 Hz/80 Hz high-pass cutoff

Stim. Type	Click	Chirp	Low-Chirp	Mid-Chirp	High-Chirp
HDA-280	90	95	95	95	85
HDA-200	80	85	80	85	75
HDA-300	80	85	100	90	85
DD-45	85	90	85	90	85
DD-65 v2	75	80	75	80	75
DD450	75	80	85	80	75
PD-81	90	95	90	95	90
ME-70	80	85	85	85	85
PIEP	95	95	95	100	90
IP-30	80	85	85	95	75
otoInsert	80	85	85	90	75
ER-3A	80	85	85	90	75
PECC-HP	70	80	60	75	80
EP-DP ^{(R1) *}	85	90	70	90	85
^(R2)	85	90	80	95	80
EP-VIP, -TY ^{(R1) *}	100	100	85	100	100
EP-LT *	90	100	90	100	85

Stim. Type	Click	Chirp	Low-Chirp	Mid-Chirp	High-Chirp
B-71	55	60	55	65	50
B-81	55	65	55	70	50

* Occluded ear simulator. Dependent on ear canal volume, the actual level may be lower (big ear canal volume) or higher (small ear canal volume). R1: SN30xxx/33xxx, 40xxx/43xxx, 50xxx/53xxx, 60xxx/63xxx, 80xxx, 90xxx/93xxx; R2 (alternative loudspeaker setup): SN41xxx/42xxx, 51xxx/52xxx, 81xxx/82xxx, 91xxx/92xxx.

Table 10: Maximum ABR stimulus levels for each transducer type

Stim. Type	TB 0.5	TB 0.75	TB 1k	TB 1.5k	TB 2k	TB 3k	TB 4k
HDA-280	100	100	100	100	100	95	90
HDA-200	90	90	90	85	90	85	75
HDA-300	100	100	100	95	95	95	90
DD-45	95	95	95	90	90	95	85
DD-65 v2	85	85	85	85	85	85	80
DD450	95	90	90	85	85	85	75
PD-81	100	100	100	100	100	95	90
ME-70	95	95	95	95	90	90	85
PIEP	100	100	100	100	100	100	100
IP-30	90	90	100	95	95	100	85
otoInsert	90	90	95	95	90	95	85
ER-3A	90	90	95	95	90	95	85
PECC-HP	70	75	85	85	80	80	75
EP-DP ^{(R1) *} _(R2)	60 70	65 75	65 75	75 85	75 80	85 90	85 85
EP-VIP, -TY ^{(R1) *}	75	80	80	90	90	100	100
EP-LT *	80	85	85	90	90	90	90
B-71	60	60	65	70	70	65	60
B-81	65	65	70	75	75	60	60

* Occluded ear simulator. Dependent on ear canal volume, the actual level may be lower (big ear canal volume) or higher (small ear canal volume). R1: SN30xxx/33xxx, 40xxx/43xxx, 50xxx/53xxx, 60xxx/63xxx, 80xxx, 90xxx/93xxx; R2 (alternative loudspeaker setup): SN41xxx/42xxx, 51xxx/52xxx, 81xxx/82xxx, 91xxx/92xxx.

Table 10 continued: Maximum ABR stimulus levels for each transducer type

3.13.2 Quick ABR

License: Quick ABR, ABR; feature upgrade: ABR-BIN, aEPS

- Stimulus type: Chirp (broadband, 1 to 8 kHz)
- Stimulus polarity: alternating
- Stimulus rate: 85 Hz
- Stimulus level: 25 to 55 dB nHL or eHL (step size: 5 dB), ask before test (PECC-01: 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

3.14 Electrically Evoked Auditory Brainstem Responses (E-ABR)

License: eABR

- Averages: 100 up to 20000; step size: 1000; user-specific entry in aforementioned range
- 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)
- Baseline mode: Off, Frame DC, Pre-stimulus DC
- Electrode impedance check: see chapter 3.13; allow extended skip (for use with simulators): $R \leq 39 \text{ k}\Omega$

3.15 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: 50 to max. 95 dB nHL; step size: 5 dB; ask before test
- Stimulus rate: 8.0, 10.0, 11.1, 16.0, 20.1, 27.7, 30.0, 40.0, 69.9, 80.0, 87.0, 90.4 Hz (default); user-specific entry from 5 to 100 Hz
- Averages: 1000 up to 20000; step size: 1000; user-specific entry in aforementioned range
- Plot range: start: -1.5 ms (fixed), stop: 4 to 12 ms, step size: 0.5 ms
- Additional parameters: Spread spectrum (optional), 10 Hz/80 Hz high-pass cutoff
- Electrode impedance check:
 - o Continuous monitoring of electrode impedance
 - o Auto start after impedance OK (optional): $R \leq 6 \text{ k}\Omega$, $\Delta R \leq 4 \text{ k}\Omega$
 - o Allow manual start: $R \leq 14 \text{ k}\Omega$, $\Delta R \leq 6 \text{ k}\Omega$; allow skip: $R \leq 18 \text{ k}\Omega$, $\Delta R \leq 17 \text{ k}\Omega$; stop during test: $R > 15 \text{ k}\Omega$, $\Delta R > 7 \text{ k}\Omega$; stop during test (if skipped): $R > 19 \text{ k}\Omega$, $\Delta R > 18 \text{ k}\Omega$
- Stimulus presentation during pause: on, off

Usable transducers:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A)

3.16 Auditory Steady-State Responses (ASSR)

License: Quick ASSR, ASSR; feature upgrade: aEPS

- Response detection: weighted averaging, phase statistics including up to 7 overtones
- Electrode impedance check: see ABR
- Stimulus presentation during pause: on, off
- Leak check (optional for measurement with ear probe; active during ear probe calibration)

Usable transducers:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, IP-30, otoInsert, ER-3A), ear probe (EP-DP, EP-VIP*, EP-TY*, EP-LT), bone conductor (B-71, B-81: not Quick ASSR), ear coupler cable (PECC-01: Quick ASSR only, PECC-HP)

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

3.16.1 ASSR

License: ASSR

- Protocols:
 - o Fixed level procedure
 - o Adaptive level procedure (threshold estimation)
- Stimulus bandwidths: ½ octave, 1 octave, 3 band (0.3-1 kHz, 1-3 kHz, 3-10 kHz), broadband (0.25-8kHz)
- 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
 - o Adaptive: 10 to max. 100 dB nHL or transducer limits (see *Table 11* for ½ octave stimuli); step size: 10 dB
- Frequencies: 0.25, 0.5, 1, 1.5, 2, 3, 4, 6, 8 kHz (with increasing stimulus bandwidth, less frequencies are available); with bone conductor 0.25, 6, and 8 kHz are not available
- Number of averages: 240 to 900 s; step size: 30 s; user-specific entry in aforementioned range
- Noise stop criterion: 0 to 20 nV; step size: 1 nV (disabled in “Fixed” protocol)
- Artifact threshold (optional): 4, 5, 6, 8, 10, 12, 15, 20 μV
- Display and storage of statistics graph, impedance, artifact threshold, modulation frequency
- Contralateral masking noise (optional): 0 to 60 dB nHL; step size: 5 dB; user-specific entry in aforementioned range
- Frequency-dependent maximum time (optional): allows longer test times for low frequencies

<i>f</i> [Hz]	250	500	1000	1500	2000	3000	4000	6000	8000
HDA-280	90	100	100	100	100	100	100	90	80
HDA-200	90	90	90	90	90	90	80	80	80
HDA-300	100	100	100	100	100	100	100	80	80
DD-45	80	90	100	100	100	100	90	90	80
DD-65 v2	80	90	90	90	90	90	90	70	60
DD450	90	95	95	90	90	95	90	80	80
PD-81	90	100	100	100	100	100	100	90	80
ME-70	80	90	100	100	100	100	90	90	80
PIEP	100	100	100	100	90	100	100	90	80
IP-30	90	100	100	100	100	100	100	80	60
otoInsert	90	90	90	100	100	100	90	70	60
ER-3A	90	90	100	100	100	100	90	70	60
PECC-HP	60	70	90	90	90	90	90	80	70
EP-DP (R1) *	80	80	80	80	90	100	100	90	90

<i>f</i> [Hz]	250	500	1000	1500	2000	3000	4000	6000	8000
(R2)	90	90	90	90	100	100	100	90	90
EP-VIP, -TY (R1) *	100	100	100	100	100	100	100	100	100
EP-LT *	100	100	100	100	100	100	100	90	90
B-71	---	50	60	60	70	60	60	---	---
B-81	---	60	60	70	70	60	60	---	---

* Occluded ear simulator. Dependent on ear canal volume, the actual level may be lower (big ear canal volume) or higher (small ear canal volume). R1: SN30xxx/33xxx, 40xxx/43xxx, 50xxx/53xxx, 60xxx/63xxx, 80xxx, 90xxx/93xxx; R2 (alternative loudspeaker setup): SN41xxx/42xxx, 51xxx/52xxx, 81xxx/82xxx, 91xxx/92xxx.

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).

3.16.2 Quick ASSR

License: Quick ASSR; feature upgrade: aEPS

- Stimulus bandwidths: 3 band (0.3-1 kHz, 1-3 kHz, 3-10 kHz), broadband (0.25-8kHz)
- Stimulus rate: automatic (37 to 163 Hz, dependent on frequency); spread spectrum: $\pm 2\%$
- Stimulus level: 25 to max. 50 dB nHL or eHL; step size: 5 dB
Please note: dB eHL = dB nHL + 10 dB
- Number of averages: 300 to 600 s; step size: 60 s; user-specific entry in aforementioned range

3.17 Vestibular Evoked Myogenic Potentials (VEMP)

License: VEMP (license may be available only in specific countries)

- Cervical VEMP (cVEMP) and ocular (oVEMP)
- Electromyographic (EMG) response monitoring and automated invalid EMG rejection
- Stimulus types: click, chirp, tone burst
- Tone bursts parameters: frequency: 500 Hz to 4 kHz; window: linear or Blackman; up-plateau-down periods: 1-0-1, 1-1-1, 1-2-1, 2-0-2, 2-1-2
- Stimulus Level: 20 to max. 95 dB nHL (in-test up to max. 110 dB nHL)
- Stimulus Polarity: Condensation, rarefaction, alternating, randomized
- Stimulus Rate: 2, 3, 4, 5, 6, 10 Hz; user-specific entry in aforementioned range
- Averages: 20 to 500; step size: 10; user-specific entry in aforementioned range
- Plot range: 40 to 100 ms; step size: 10 ms; user-specific entry in aforementioned range
- Additional parameters: Spread spectrum, auto proceed, invert right ear trace polarity, allow intertest frequency change
- EMG monitoring:
 - o Myo min 1 to 100 μV ; step size: 1 μV ; user-specific entry in aforementioned range; Myo min < Myo max;
 - o Myo max 10 to 1000 μV ; step size: 1 μV (< 100 μV), 10 μV (>100 μV); user-specific entry in aforementioned range

Usable transducers:

Headphone (HDA-280, HDA-300, DD-45, DD450, PD-81), insert earphone (PIEP, PIEP monaural), bone conductor (B-81); for transducer specific maximum levels see *Table 10*.

3.18 Middle Ear Tests

License: Tymp 1 (DIN EN 60645-5 type 1), Tymp 2 (DIN EN 60645-5 type 2); feature upgrade for Tymp 2: Tymp 1k

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

Usable transducers:

Ear probe (EP-TY) for Sentiero Desktop, tympanometry add-on (TY-MA) for Sentiero/Sentiero Advanced

3.18.1 Tympanometry

License: Tymp Type 1, Tymp Type 2; feature upgrade for Tymp Type 2: Tymp 1k, ETF

- Additional probe tones (Type 1 only): 678 Hz ± 1 % at 72 dB SPL ± 3 dB, 800 Hz ± 1 % at 70.6 dB SPL ± 3 dB, 1000 Hz ± 1 % at 69 dB SPL ± 3 dB (1000 Hz can be added to *Tymp Type 2* license with *Tymp 1k* license)
- Multi-frequency measurement (*Tymp Type 1*: 226, 678, 800, 1000 Hz, *Tymp Type 2* + *Tymp 1k*: 226, 1000 Hz)
- Compliance Range: 0 to 5 ml
- Compliance Accuracy : ± 5 % or 0.1 ml (whichever is greater)
- Pressure Range: -600 to +300 daPa (*Tymp Type 2*), -600 to +400 daPa (*Tymp Type 1*); minimum: -600 to -100 daPa, maximum: +200 to +400 daPa; step size: 50 daPa
- Pressure Accuracy: ± 10 % or 10 daPa (whichever is greater)
- Pump speed: 50, 100, 150, 200 daPa/s ± 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 [3.18.2 Acoustic Reflex](#))
- Cartoon mode (optional)
- Auto store (optional): proceeds to result view after test so that immediate data export is possible
- *Tymp Type 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)

3.18.2 Acoustic Reflex

License: Tymp Type 1, Tymp Type 2

- Modes: automatic reflex threshold; *Tymp Type 1*: + manual reflex test, reflex decay test
- Automatic reflex screening levels: 70 to 100 dB HL; step size: 5 dB
- Manual reflex levels: 45 to 105 dB HL, step size: 5 and 1 dB (contralateral reflex levels: up to 110 dB HL, see maximum level table for Audio 3)

- Reflex resolution: <0.001 ml (registration), 0.0025 ml (data storage)
- Automatic reflex start after tympanometry options: never, always, if peak within norm (for 226 Hz probe tone only)
- Automatic reflex detection amplitude: 0.02 ml, 0.03 ml; repeat to confirm (optional)
- Stimulus presentation modes: ipsilateral, contralateral (if 2nd transducer is connected)
- Pressure offset: taken over from tympanometry measurement, editable (see pressure range in section [3.18.1: Tympanometry](#))
- Acoustic reflex stimuli (using EP-TY probe): 500, 1000, 2000, 3000, 4000 Hz, up to 105 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 (*not available for selection for automatic reflex)
- 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)
- Cartoon mode (optional)

Usable transducers for contralateral reflex:

Headphone (HDA-280, HDA-200, HDA-300, DD-45, DD-45 monaural, DD-65, DD-65 v2, DD450, PD-81, ME-70), insert earphone (PIEP, PIEP monaural, IP-30, IP-30 monaural, otoInsert, ER-3A, ER-3C monaural, GBE), ear probe (EP-VIP)

3.18.3 Eustachian Tube Function Tests

License: *Tymp Type 1, ETF*

- Modes:
 - o Non-perforated ear drum (William's test)
 - o Perforated ear drum (Toynbee test)
 - o Patulous Eustachian tube (continuous sensitive impedance measurement)

4. Accessories

Accessories (e.g. headphone, insert earphone, ear probe, bone conductor, electrode cable, ear coupler cable, electrodes, label printer) may include separate manuals and/or data sheets with important information. Please refer to these documents for further information about the respective accessory.

5. Normative Data

5.1 DPOAE

Normative DPOAE levels L_{dp} [dB] (mean \pm standard deviation = max./min.):

L_2 / f_2	1.5 kHz	2 kHz	3 kHz	4 kHz	5 kHz	6 kHz	8 kHz
65 dB	19.9	21.1	21.5	22.6	23.5	21.2	17.3
Max./min.	5.5	7.2	11.5	11.8	15.2	11.7	2.4
45 dB	16.8	15.1	13.1	15.2	18.1	14.6	8.6

Max./min.	2.4	0.5	1.7	2.9	7.6	1.4	-7.4
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Normative noise floor levels L_{nf} [dB] (mean \pm standard deviation = = max./min.):

L_2 / f_2	1.5 kHz	2 kHz	3 kHz	4 kHz	5 kHz	6 kHz	8 kHz
65 dB	-14.5	-15.8	-16.2	-14.8	-19.5	-22.0	-22.8
Max./min.	-18.3	-19.1	-18.9	-17.4	-21.7	-23.8	-24.8
45 dB	-14.2	-16.3	-15.9	-15.2	-20.0	-22.2	-23.8
Max./min.	-18.0	-19.5	-19.0	-17.4	-21.5	-23.8	-25.0

For levels between $L_2 = 65$ and 45 dB, the normative values are interpolated.

5.2 ABR

Normative ABR latencies [ms] for adults with repetition rate 10 Hz (mean \pm standard deviation = max./min.):

Headphone, Click			
Level / wave	I	III	V
80 dB nHL	1.4 - 1.8	3.4 - 3.7	5.3 - 5.7
70 dB nHL	1.5 - 2.0	3.5 - 3.8	5.4 - 5.8
60 dB nHL	1.6 - 2.1	3.8 - 4.2	5.6 - 6.0
50 dB nHL	1.9 - 2.6	4.2 - 4.7	5.9 - 6.4
40 dB nHL	---	4.5 - 5.1	6.3 - 6.8
30 dB nHL	---	4.9 - 5.7	6.8 - 7.4
20 dB nHL	---	5.5 - 6.1	7.3 - 8.2
10 dB nHL	---	---	8.1 - 9.1
Headphone, Chirp			
Level / wave	I	III	V
80 dB nHL	---	3.9 - 4.5	5.6 - 6.2
70 dB nHL	---	4.0 - 4.6	5.7 - 6.3
60 dB nHL	---	4.3 - 4.8	6.0 - 6.7
50 dB nHL	---	5.0 - 5.7	6.6 - 7.3
40 dB nHL	---	5.6 - 6.2	7.2 - 7.8
30 dB nHL	---	6.4 - 7.3	8.0 - 8.7
20 dB nHL	---	---	8.6 - 9.5
10 dB nHL	---	---	9.4 - 10.4
Headphone, High Chirp			
Level / wave	I	III	V
80 dB nHL	---	---	---

70 dB nHL	---	2.6 - 3.0	4.4 - 4.8
60 dB nHL	---	3.0 - 3.5	4.7 - 5.2
50 dB nHL	---	3.3 - 3.9	5.1 - 5.7
40 dB nHL	---	3.7 - 4.5	5.5 - 6.2
30 dB nHL	---	4.2 - 4.9	6.0 - 6.8
20 dB nHL	---	---	6.5 - 7.3
10 dB nHL	---	---	7.2 - 8.1
Headphone, Mid Chirp			
Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	5.9 - 6.9
60 dB nHL	---	---	6.3 - 7.3
50 dB nHL	---	---	6.7 - 7.8
40 dB nHL	---	---	7.2 - 8.0
30 dB nHL	---	---	7.6 - 8.4
20 dB nHL	---	---	7.8 - 8.9
10 dB nHL	---	---	8.4 - 9.4
Headphone, Low Chirp			
Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	8.4 - 9.1
60 dB nHL	---	---	8.7 - 9.7
50 dB nHL	---	---	9.4 - 10.5
40 dB nHL	---	---	10.1 - 11.0
30 dB nHL	---	---	10.4 - 11.4
20 dB nHL	---	---	11.1 - 12.2
10 dB nHL	---	---	11.8 - 13.3
Headphone, Tone Burst 500 Hz			
Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	8.4 - 9.1
60 dB nHL	---	---	8.7 - 9.7
50 dB nHL	---	---	9.4 - 10.5
40 dB nHL	---	---	10.1 - 11.0
30 dB nHL	---	---	10.4 - 11.4
20 dB nHL	---	---	11.1 - 12.2
10 dB nHL	---	---	11.8 - 13.3
Headphone, Tone Burst 750 Hz			

Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	7.4 - 8.1
60 dB nHL	---	---	7.7 - 8.7
50 dB nHL	---	---	8.4 - 9.5
40 dB nHL	---	---	9.1 - 10.0
30 dB nHL	---	---	9.4 - 10.4
20 dB nHL	---	---	10.1 - 11.2
10 dB nHL	---	---	10.8 - 12.3
Headphone, Tone Burst 1000 Hz			
Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	6.6 - 7.2
60 dB nHL	---	---	7.0 - 7.6
50 dB nHL	---	---	7.4 - 8.1
40 dB nHL	---	---	7.7 - 8.5
30 dB nHL	---	---	8.1 - 8.9
20 dB nHL	---	---	8.3 - 9.4
10 dB nHL	---	---	8.9 - 9.9
Headphone, Tone Burst 1500 Hz			
Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	6.3 - 6.9
60 dB nHL	---	---	6.7 - 7.3
50 dB nHL	---	---	7.1 - 7.8
40 dB nHL	---	---	7.4 - 8.2
30 dB nHL	---	---	7.8 - 8.6
20 dB nHL	---	---	8.0 - 9.1
10 dB nHL	---	---	8.6 - 9.6
Headphone, Tone Burst 2000 Hz			
Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	6.1 - 6.7
60 dB nHL	---	---	6.5 - 7.1
50 dB nHL	---	---	6.9 - 7.6
40 dB nHL	---	---	7.2 - 8.0
30 dB nHL	---	---	7.6 - 8.4
20 dB nHL	---	---	7.8 - 8.9

10 dB nHL	---	---	8.4 - 9.4
Headphone, Tone Burst 3000 Hz			
Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	5.9 - 6.5
60 dB nHL	---	---	6.3 - 6.9
50 dB nHL	---	---	6.7 - 7.4
40 dB nHL	---	---	7.0 - 7.8
30 dB nHL	---	---	7.4 - 8.3
20 dB nHL	---	---	7.6 - 8.7
10 dB nHL	---	---	8.2 - 9.2
Headphone, Tone Burst 4000 Hz			
Level / wave	I	III	V
80 dB nHL	---	---	---
70 dB nHL	---	---	5.8 - 6.4
60 dB nHL	---	---	6.2 - 6.8
50 dB nHL	---	---	6.6 - 7.3
40 dB nHL	---	---	6.9 - 7.7
30 dB nHL	---	---	7.3 - 8.1
20 dB nHL	---	---	7.5 - 8.6
10 dB nHL	---	---	8.1 - 9.1

Please note that the latency is corrected by +0.1 ms per increase of 10 Hz in repetition rate.

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