Attachment 1

Table 1: Average normal-hearing loudness function for narrowband signals from N=14 NH listeners as used in Suck et al. [43].

Frequency [Hz]	L_{cut}	m_{low}	m_{high}
250	74.12	0.29	1.08
500	76.09	0.29	1.09
1,000	74.54	0.30	0.98
2,000	72.94	0.30	1.08
4,000	66.23	0.34	1.07
6,000	66.56	0.35	1.06

Table 2: Average frequency and level-dependent loudness function for HI listeners.

	250 Hz			500 Hz			1,000 Hz			2,000 Hz			4,000 Hz			6,000 Hz		
HTL	L_{cut}	m_{low}	m_{high}	L_{cut}	m_{low}	m_{high}	L_{cut}	m_{low}	m_{high}	L_{cut}	m_{low}	m_{high}	L_{cut}	m_{low}	m_{high}	L_{cut}	m_{low}	m_{high}
0	76.44	0.29	2.13	74.89	0.30	1.27	76.60	0.29	1.27	73.28	0.29	1.20	71.00	0.31	1.15	66.71	0.31	0.99
5	77.05	0.31	2.25	75.95	0.31	1.30	77.61	0.30	1.29	74.49	0.31	1.24	72.47	0.33	1.18	68.35	0.33	1.02
10	77.66	0.32	2.37	77.01	0.33	1.43	78.61	0.32	1.32	75.71	0.32	1.27	73.93	0.34	1.22	70.00	0.34	1.06
15	78.27	0.34	2.49	78.08	0.34	1.46	79.61	0.34	1.45	76.92	0.34	1.31	75.39	0.36	1.26	71.65	0.36	1.10
20	78.88	0.36	2.61	79.14	0.36	1.60	80.62	0.36	1.48	78.14	0.36	1.35	76.85	0.38	1.31	73.29	0.38	1.14
25	79.49	0.39	2.83	80.20	0.38	1.64	81.62	0.38	1.61	79.35	0.38	1.39	78.31	0.40	1.36	74.94	0.40	1.28
30	80.11	0.41	2.95	81.26	0.41	1.78	82.62	0.40	1.74	80.57	0.40	1.43	79.78	0.42	1.41	76.58	0.42	1.33
35	80.72	0.45	3.27	82.33	0.43	1.92	83.63	0.43	1.87	81.78	0.43	1.48	81.24	0.45	1.47	78.23	0.44	1.49
40	81.33	0.48	3.49	83.39	0.46	2.07	84.63	0.46	2.01	83.00	0.46	1.53	82.70	0.48	1.53	79.87	0.47	1.65
45	81.94	0.53	3.82	84.45	0.49	2.32	85.63	0.50	2.14	84.21	0.49	1.58	84.16	0.51	1.59	81.52	0.50	1.81
50	82.55	0.58	4.14	85.51	0.53	2.48	86.64	0.54	2.28	85.43	0.53	1.64	85.62	0.55	1.67	83.17	0.54	2.08
55	83.16	0.64	4.67	86.57	0.58	2.84	87.64	0.59	2.52	86.64	0.58	1.80	87.09	0.60	1.74	84.81	0.58	2.36
60	83.77	0.72	5.00	87.64	0.63	3.21	88.64	0.66	2.86	87.86	0.64	1.87	88.55	0.65	1.83	86.46	0.63	2.75
65	84.38	0.82	5.00	88.70	0.69	3.68	89.65	0.73	3.21	89.07	0.70	2.14	90.01	0.72	1.93	88.10	0.69	3.34
70	85.00	0.95	5.00	89.76	0.77	4.36	90.65	0.83	3.66	90.29	0.79	2.32	91.47	0.80	2.03	89.75	0.76	4.25
75	85.61	1.14	5.00	90.82	0.87	5.00	91.65	0.96	4.20	91.50	0.89	2.60	92.93	0.90	2.15	91.40	0.85	5.00
80	86.22	1.42	5.00	91.89	0.99	5.00	92.66	1.14	5.00	92.72	1.03	3.00	94.39	1.03	2.29	93.04	0.96	5.00
85	86.83	1.87	5.00	92.95	1.16	5.00	93.66	1.39	5.00	93.93	1.23	3.40	95.86	1.20	2.64	94.69	1.10	5.00
90	87.44	2.76	5.00	94.01	1.40	5.00	94.66	1.78	5.00	95.15	1.50	4.11	97.32	1.44	3.11			
95										96.36	1.95	5.00	98.78	1.81	3.81			
100										97.58	2.77	5.00	100.24	2.42	4.94			

HTL=hearing threshold level

Table 3: Center (f_C) and edge (f_E) frequencies from [27] as well as level of hearing threshold L_T from [44] the band levels of the IFnoise $L_{IFnoise}$ in dB SPL and dB HL used for the HLC.

f_C [Hz]		250		500		1,000		2,000		4,000		6,000	
f_E [Hz]	0		353		707		1,414		2,828		4,899		22,050
L_T [dB SPL]		11.4		4.4		2.4		–1.3		–5.4		4.3	
$L_{IFnoise}$ [dB SPL]		61.1		61.3		55.5		49.5		44.8		47.0	
$L_{IFnoise}$ [dB HL]		49.7		59.6		53.1		50.8		50.2		42.7	

A1: Example gain calculation with the HLC

The gain at 1 kHz for the IFnoise signal at 65 dB SPL for a listener with a hearing threshold of 40 dB HL should be calculated. Band-level of the IFnoise with a center frequency of 1 kHz corresponds to 55.5 dB SPL and 53.1 dB HL from Table 3. These values correspond to a loudness value of 18.82 CU for the average normal-hearing listeners with the parameters of the loudness function L_{cut}=74.54, m_{low}=0.30, m_{high}=0.98 from Table 1. A HI listener with a hearing threshold of 40 dB HL at 1 kHz has an average loudness function with the parameters L_{cut}=84.63, m_{low}=0.46, m_{high}=2.01 from Table 2. The level that leads to a loudness of 18.82 CU in the HI listeners is 70.67 dB HL. The difference between the NH (53.1 dB HL) and HI (70.7 dB HL) value correspond to the gain of 17.5 dB that is required to compensate for the hearing loss.

A2: Fitting methods to derive loudness functions from raw data

The responses of the categorical loudness scaling procedure are given as pairs of presented levels in dB and loudness ratings in CU. A typical dataset consists of 22–25 response pairs. Due to requirements of the loudness function, different fitting methods to fit a loudness function to the data point exist. For details see [21]. The BY procedure is used when a level should be converted into a loudness value. The BX procedure is used when a loudness value should be transformed into a level. The BX procedure can be extended with a procedure that sets the starting point of the loudness function between “heard” and “not heard” responses and is referred to as BTX. When less than four responses above 35 CU (loud) are given, the upper slope m_{high} of the loudness function can be fixed to avoid a pure extrapolation of the data. This concept is referred to as BTUX. The average slope is signal dependent, and values can be taken from the NH reference functions.

Table 4: Overview of different loudness function estimation methods for the ACALOS procedure [45].

	BY	BX	BTX	BTUX
Error minimization in … direction	Y (loudness)	X (level)	X (level)	X (level)
Threshold estimation by dividing responses into “not heard” and “heard” responses	No	No	Yes	Yes
Estimate uncomfortable loudness level if not enough data is available	No	No	No	Yes