3-ANNEX D (informative)

PSYCHOACOUSTIC MODELS

3-D.1. Psychoacoustic Model I

The calculation of the psychoacoustic model has to be adapted to the corresponding layer. This example is valid for Layers I and II. The model can be adapted to LayerIII.

There is no principal difference in the application of psychoacoustic model 1 to Layer I or II.

Layer I: A new bit allocation is calculated for each block of 12 subband or 384 input PCM samples.

Layer II: A new bit allocation is calculated for three blocks totaling 36 subband samples corresponding to 3*384 (1152) input PCM samples.

The bit allocation of the 32 subbands is calculated on the basis of the signal-to-mask ratios of all the subbands. Therefore it is necessary to determine, for each subband the maximum signal level and the minimum masking threshold. The minimum masking threshold is derived from an FFT of the input PCM signal, followed by a psychoacoustic model calculation.

The FFT in parallel with the subband filter compensates for the lack of spectral selectivity obtained at low frequencies by the subband filterbank. This technique provides both a sufficient time resolution for the coded audio signal (Polyphase filter with optimized window for minimal pre-echoes) and a sufficient spectral resolution for the calculation of the masking thresholds.

The frequencies and levels of aliasing distortions can be calculated. This is necessary for calculating a minimum bit rate for those subbands which need some bits to cancel the aliasing components in the decoder. The additional complexity to calculate the better frequency resolution is necessary only in the encoder, and introduces no additional delay or complexity in the decoder.

The calculation of the signal-to-mask-ratio is based on the following steps:

Step 1
- Calculation of the FFT for time to frequency conversion.

Step 2
- Determination of the sound pressure level in each subband.

Step 3
- Determination of the threshold in quiet (absolute threshold).

Step 4
- Finding of the tonal (more sinusoid-like) and non-tonal (more noise-like) components of the audio signal.

Step 5
- Decimation of the maskers, to obtain only the relevant maskers.

Step 6
- Calculation of the individual masking thresholds.

Step 7
- Determination of the global masking threshold.

Step 8
- Determination of the minimum masking threshold in each subband.

Step 9
- Calculation of the signal-to-mask ratio in each subband.

These steps will be further discussed. A sampling frequency of 48kHz is assumed. For the other two sampling frequencies all frequencies mentioned should be scaled accordingly.

Step 1: FFT Analysis

The masking threshold is derived from an estimate of the power density spectrum that is calculated by a 512-point FFT for Layer I, or by a 1024-point FFT for Layers II and III. The FFT is calculated directly from the input PCM signal, windowed by a Hann window.

For a coincidence in time between the bit-allocation and the corresponding subband samples, the PCM-samples entering the FFT have to be delayed:

1. The delay of the analysis subband filter is 256 samples, corresponding to 5.3ms at the 48kHz sampling rate. This corresponds to a window shift of 256 samples.

2. The Hann window must coincide with the subband samples of the frame. For Layer I this amounts to an additional window shift of 64 samples, for Layer II an additional window shift of minus 64 samples.

Technical data of the FFT:

		Layer I	Layer II
-	transform length	512 samples	1024 samples
	Window size if fs = 48 kHz	10.67 ms	21.3 ms
	Window size if fs = 44.1 kHz	11.6 ms	23.2 ms
	Window size if fs = 32 kHz	16 ms	32 ms
-	Frequency resolution	fs/512	fs/1024

- Hann window, h(i):

  $h(i) = * 0.5 * \{1 - \cos[2 * p * (i)/(N-1)]\}$ $\quad 0 <= i <= N-1$

- power density spectrum X(k):

  $X(k) = 10 * \log |1/N h(l) * s(l) * e^{(-j*k*l*2*p/N)}|^2$ dB $\quad k = 0...N/2$

A normalization to the reference level of 96 dB SPL (Sound Pressure Level) has to be done in such a way that the maximum value corresponds to 96dB.

Step 2: Determination of the sound pressure level

The sound pressure level L_{sb} in subband n is computed by:

$$L_{sb}(n) = \underset{X(k) \text{ in subband } n}{MAX}[\, X(k), 20*\log(scf_{max}(n)*32768)-10 \,] \text{ dB}$$

where X(k) is the sound pressure level of the spectral line with index k of the FFT with the maximum amplitude in the frequency range corresponding to subband n. The expression $scf_{max}(n)$ is in Layer I the scalefactor, and in Layer II the maximum of the three scalefactors of subband n within a frame. The "-10 dB" term corrects for the difference between peak and RMS level. The sound pressure level $L_{sb}(n)$ is computed for every subband n.

Step 3: Considering the threshold in quiet

The threshold in quiet LTq(k), also called absolute threshold, is available in the tables "Frequencies, Critical Band Rates and Absolute Threshold" (Tables 3-D.1a, 3-D.1b, 3-D.1c for LayerI; Tables 3-D.1d, 3-D.1e, 3-D.1f for LayerII). These tables depend on the sampling rate of the input PCM signal. Values are available for each sample in the frequency domain where the masking threshold is calculated.

An offset depending on the overall bit rate is used for the absolute threshold. This offset is -12 dB for bit rates >= 96 kbit/s and 0 dB for bit rates < 96 kbit/s per channel.

Step 4: Finding of tonal and non-tonal components

The tonality of a masking component has an influence on the masking threshold. For this reason, it is worthwhile to discriminate between tonal and non-tonal components. For calculating the global masking threshold it is necessary to derive the tonal and the non-tonal components from the FFT spectrum.

This step starts with the determination of local maxima, then extracts tonal components (sinusoids) and calculates the intensity of the non-tonal components within a bandwidth of a critical band. The boundaries of the critical bands are given in the tables "CRITICAL BAND BOUNDARIES" (Tables 3-D.2a, 3-D.2b, 3-D.2c for LayerI; Tables 3-D.2d, 3-D.2e, 3-D.2f for LayerII).

The bandwidth of the critical bands varies with the center frequency with a bandwidth of about only 0.1 kHz at low frequencies and with a bandwidth of about 4 kHz at high frequencies. It is known from psychoacoustic experiments that the ear has a better frequency resolution in the lower than in the higher frequency region. To determine if a local maximum may be a tonal component a frequency range df around the local maximum is examined. The frequency range df is given by:

Sampling rate: 32 kHz

Layer I:	df = 125 Hz	0 kHz	< f <=	4.0kHz
	df = 187.5 Hz	4.0 kHz	< f <=	8.0 kHz
	df = 375 Hz	8.0 kHz	< f <=	15.0kHz
Layer II:	df = 62.5 Hz	0 kHz	< f <=	3.0 kHz
	df = 93.75 Hz	3.0 kHz	< f <=	6.0 kHz
	df = 187.5 Hz	6.0 kHz	< f <=	12.0 kHz
	df = 375 Hz	12.0 kHz	< f <=	24.0 kHz

Sampling rate: 44.1kHz

Layer I:	df = 172.266 Hz	0 kHz	< f <=	5.512kHz
	df = 281.25 Hz	5.512 kHz	< f <=	11.024 kHz
	df = 562.50 Hz	11.024 kHz	< f <=	19.982kHz
Layer II:	df = 86.133 Hz	0 kHz	< f <=	2.756 kHz
	df = 129.199 Hz	2.756 kHz	< f <=	5.512kHz
	df = 258.398 Hz	5.512 kHz	< f <=	11.024 kHz
	df = 516.797 Hz	11.024 kHz	< f <=	19.982kHz

Sampling rate: 48 kHz

Layer I:	df = 187.5 Hz	0 kHz	< f <=	6.0 kHz
	df = 281.25 Hz	6.0 kHz	< f <=	12.0 kHz
	df = 562.50 Hz	12.0 kHz	< f <=	24.0 kHz
Layer II:	df = 93.750 Hz	0 kHz	< f <=	3.0 kHz
	df = 140.63 Hz	3.0 kHz	< f <=	6.0 kHz
	df = 281.25 Hz	6.0 kHz	< f <=	12.0 kHz

df = 562.50 Hz	12.0 kHz	< f <=	24.0 kHz

To make lists of the spectral lines X(k) that are tonal or non-tonal, the following three operations are performed:

(i) Labelling of local maxima

A spectral line X(k) is labelled as a local maximum if

$$X(k) > X(k-1) \quad \text{and} \quad X(k) >= X(k+1)$$

(ii) Listing of tonal components and calculation of the sound pressure level
A local maximum is put in the list of tonal components if

$$X(k) - X(k+j) >= 7 \text{ dB},$$

where j is chosen according to

Layer I:

j = -2, +2	for 2 < k < 63
j = -3, -2, +2, +3	for 63 <= k < 127
j = -6,..., -2, +2,..., +6	for 127<= k <= 250

Layer II:

j = -2, +2	for 2 < k < 63
j = -3, -2, +2, +3	for 63 <= k < 127
j = -6,..., -2, +2,..., +6	for 127 <= k < 255
j = -12,..., -2, +2,..., +12	for 255<= k <= 500

If X(k) is found to be a tonal component, then the following parameters are listed:
- Index number k of the spectral line.
- Sound pressure level $X_{tm}(k)$=X(k-1)+X(k)+X(k+1), in dB
- Tonal flag.

Next, all spectral lines within the examined frequency range are set to -8 dB.

(iii) Listing of non-tonal components and calculation of the power

The non-tonal (noise) components are calculated from the remaining spectral lines. To calculate the non-tonal components from these spectral lines X(k), the critical bands z(k) are determined using the tables, "Critical Band Boundaries" (Tables 3-D.2a, 3-D.2b, 3-D.2c for LayerI; Tables 3-D.2d, 3-D.2e, 3-D.2f for LayerII). In LayerI, 23 critical bands are used for the sampling rate of 32kHz, 24 critical bands for 44.1kHz and 25 critical bands are used for 48kHz. In LayerII, 24 critical bands are used for 32kHz sampling rate, and 26 critical bands are used for 44.1kHz and 48kHz sampling rate. Within each critical band, the power of the spectral lines are summed to form the sound pressure level of the new non-tonal component corresponding to that critical band.

The following parameters are listed:
- Index number k of the spectral line nearest to the geometric mean of the critical band.
- Sound pressure level $X_{nm}(k)$ in dB.
- Non-tonal flag.

Step 5: Decimation of tonal and non-tonal masking components

Decimation is a procedure that is used to reduce the number of maskers which are considered for the calculation of the global masking threshold.

(i) Tonal $X_{tm}(k)$ or non-tonal components $X_{nm}(k)$ are considered for the calculation of the masking threshold only if:

$$X_{tm}(k) >= LT_q(k) \quad \text{or} \quad X_{nm}(k) >= LT_q(k)$$

In this expression, $LT_q(k)$ is the absolute threshold (or threshold in quiet) at the frequency of index k. These values are given in the Tables 3-D.1a, 3-D.1b, 3-D.1c for LayerI; Tables 3-D.1d, 3-D.1e, 3-D.1f for LayerII.

(ii) Decimation of two or more tonal components within a distance of less then 0.5 Bark: Keep the component with the highest power, and remove the smaller component(s) from the list of tonal components. For this operation, a sliding window in the critical band domain is used with a width of 0.5 Bark.

In the following, the index j is used to indicate the relevant tonal or non-tonal masking components from the combined decimated list.

Step 6: Calculation of individual masking thresholds

Of the original N/2 frequency domain samples, indexed by k, only a subset of the samples, indexed by i, are considered for the global masking threshold calculation. The samples used are shown in Tables 3-D.1a, 3-D.1b, 3-D.1c for LayerI; Tables 3-D.1d, 3-D.1e, 3-D.1f for LayerII.

Layer I:
For the frequency lines corresponding to the frequency region which is covered by the first six subbands no subsampling is used. For the frequency region corresponding to the next six subbands every second spectral line is considered. Finally, in the case of 44.1 and 48 kHz sampling rates, in the frequency region corresponding to the remaining subbands, every fourth spectral line is considered up to 20 kHz. In the case of 32 kHz sampling rate, in the frequency region corresponding to the remaining subbands, every fourth spectral line is considered up to 15 kHz (See also Tables 3-D.1a, 3-D.1b, 3-D.1c "Frequencies, Critical Band Rates and Absolute Threshold" for LayerI.)

Layer II:
For the frequency lines corresponding to the frequency region which is covered by the first three subbands no subsampling is used. For the frequency region which is covered by next three subbands every second spectral line is considered. For the frequency region corresponding to the next six subbands every fourth spectral line is considered. Finally, in the case of 44.1 and 48 kHz sampling rates, in the remaining subbands every eighth spectral line is considered up to 20 kHz. In the case of 32 kHz sampling rate, in the frequency region corresponding to the remaining subbands, every eighth spectral line is considered up to 15 kHz. (See also Tables 3-D.1d, 3-D.1e, 3-D.1f "Frequencies, Critical Band Rates and Absolute Threshold" for LayerII.)

The number of samples, i, in the subsampled frequency domain is different depending on the sampling rates and layers.

32 kHz sampling rate:	i = 108 for Layer I	and	i = 132 for Layer II
44.1 kHz sampling rate:	i = 106 for Layer I	and	i = 130 for Layer II
48 kHz sampling rate:	i = 102 for Layer I	and	i = 126 for Layer II

To every tonal and non-tonal component the index i in the subsampled frequency domain is assigned, which is closest in frequency to the original spectral line X(k). This index i is given in Tables 3-D.1a, 3-D.1b, 3-D.1c for LayerI; Tables 3-D.1d, 3-D.1e, 3-D.1f for LayerII, "Frequencies, Critical Band Rates and Absolute Threshold".

The individual masking thresholds of both tonal and non-tonal components are given by the following expression:

$$LT_{tm}[z(j),z(i)] = X_{tm}[z(j)] + av_{tm}[z(j)] + vf[z(j),z(i)] \quad \text{dB}$$
$$LT_{nm}[z(j),z(i)] = X_{nm}[z(j)] + av_{nm}[z(j)] + vf[z(j),z(i)] \quad \text{dB}$$

In this formula LT_{tm} and LT_{nm} are the individual masking thresholds at critical band ratez in Bark of the masking component at the critical band rate z_m in Bark. The values in dB can be either positive or negative. The term $X_{tm}[z(j)]$ is the sound pressure level of the masking component with the index number j at the corresponding critical band rate z(j). The term av is called the masking index and vf the masking function of the masking component $X_{tm}[z(j)]$. The masking index av is different for tonal and non-tonal masker (av_{tm} and av_{nm}).

For tonal maskers it is given by

$av_{tm} = - 1.525 - 0.275 * z(j) - 4.5$ dB,

and for non-tonal maskers

$av_{nm} = - 1.525 - 0.175 * z(j) - 0.5$ dB.

The masking function vf of a masker is characterized by different lower and upper slopes, which depend on the distance in Bark dz = z(i)- z(j) to the masker. In this expression i is the index of the spectral line at which the masking function is calculated and j that of the masker. The critical band rates z(j) and z(i) can be found in Tables 3-D.1a, 3-D.1b, 3-D.1c for LayerI; Tables 3-D.1d, 3-D.1e, 3-D.1f for LayerII, "Frequencies, Critical Band Rates and Absolute Threshold". The masking function, which is the same for tonal and non-tonal maskers, is given by:

$vf = 17 * (dz + 1) - (0.4 * X[z(j)] + 6)$ dB	for $-3 <= dz < -1$ Bark
$vf = (0.4 * X[z(j)] + 6) * dz$ dB	for $-1 <= dz < 0$ Bark
$vf = - 17 * dz$ dB	for $0 <= dz < 1$ Bark
$vf = - (dz - 1) * (17 - 0.15 * X[z(j)]) - 17$ dB	for $1 <= dz < 8$ Bark

In these expressions X[z(j)] is the sound pressure level of the j'th masking component in dB.
If dz < -3 Bark, or dz >= 8 Bark, the masking is no longer considered (LT_{tm} and LT_{nm} are set to -8dB outside this range).

Step 7: Calculation of the global masking threshold LTg

The global masking threshold $LT_g(i)$ at the i'th frequency sample is derived from the upper and lower slopes of the individual masking threshold of each of the j tonal and non-tonal maskers, and in addition from the threshold in quiet $LT_q(i)$. This is also given in Tables 3-D.1a, 3-D.1b, 3-D.1c for LayerI; Tables 3-D.1d, 3-D.1e, 3-D.1f for LayerII "Frequencies, Critical Band Rates and Absolute Threshold". The global masking threshold is found by summing the powers corresponding to the individual masking thresholds and the threshold in quiet.

$LT_g(i) = 10 \log (10^{LT_q(i)/10} + +)$

The total number of tonal maskers is given by m, and the total number of non-tonal maskers is given by n. For a given i, the range of j can be reduced to just encompass those masking components that are within -8 to +3 Bark from i. Outside of this range LT_{tm} and LT_{nm} are -8 dB.

Step 8: Determination of the minimum masking threshold

The minimum masking level LTmin(n) in subband n is determined by the following expression:

$$LT_{min}(n) = \min_{f(i) \text{ in subband } n} [LT_g(i)] \text{ dB}$$

where f(i) is the frequency of the i'th frequency sample. The f(i) are tabulated in the Tables 3-D.1a, 3-D.1b, 3-D.1c for LayerI; Tables 3-D.1d, 3-D.1e, 3-D.1f for LayerII of "Frequencies, Critical Band Rates and Absolute Threshold". A minimum masking level $LT_{min}(n)$ is computed for every subband.

Step 9: Calculation of the signal-to-mask-ratio

The signal-to-mask ratio

$$SMR_{sb}(n) = L_{sb}(n) - LT_{min}(n) \quad \text{dB}$$

is computed for every subband n.

Table 3-D.1a.: Frequencies, Critical Band Rates and Absolute Threshold

Table is valid for Layer I at a sampling rate of 32.0 kHz.

Index Number i	Frequency [Hz]	Crit.Band Rate [z]	Absolute Thresh. [dB]
1	62.50	.617	33.44
2	125.00	1.232	19.20
3	187.50	1.842	13.87
4	250.00	2.445	11.01
5	312.50	3.037	9.20
6	375.00	3.618	7.94
7	437.50	4.185	7.00
8	500.00	4.736	6.28
9	562.50	5.272	5.70
10	625.00	5.789	5.21
11	687.50	6.289	4.80
12	750.00	6.770	4.45
13	812.50	7.233	4.14
14	875.00	7.677	3.86
15	937.50	8.103	3.61
16	1000.00	8.511	3.37
17	1062.50	8.901	3.15
18	1125.00	9.275	2.93
19	1187.50	9.632	2.73
20	1250.00	9.974	2.53
21	1312.50	10.301	2.32
22	1375.00	10.614	2.12
23	1437.50	10.913	1.92
24	1500.00	11.199	1.71
25	1562.50	11.474	1.49
26	1625.00	11.736	1.27
27	1687.50	11.988	1.04
28	1750.00	12.230	.80
29	1812.50	12.461	.55
30	1875.00	12.684	.29
31	1937.50	12.898	.02
32	2000.00	13.104	-.25
33	2062.50	13.302	-.54
34	2125.00	13.493	-.83
35	2187.50	13.678	-1.12
36	2250.00	13.855	-1.43
37	2312.50	14.027	-1.73

38	2375.00	14.193	-2.04
39	2437.50	14.354	-2.34
40	2500.00	14.509	-2.64
41	2562.50	14.660	-2.93
42	2625.00	14.807	-3.22
43	2687.50	14.949	-3.49
44	2750.00	15.087	-3.74
45	2812.50	15.221	-3.98
46	2875.00	15.351	-4.20
47	2937.50	15.478	-4.40
48	3000.00	15.602	-4.57
49	3125.00	15.841	-4.82
50	3250.00	16.069	-4.96
51	3375.00	16.287	-4.97
52	3500.00	16.496	-4.86
53	3625.00	16.697	-4.63
54	3750.00	16.891	-4.29
55	3875.00	17.078	-3.87
56	4000.00	17.259	-3.39
57	4125.00	17.434	-2.86
58	4250.00	17.605	-2.31
59	4375.00	17.770	-1.77
60	4500.00	17.932	-1.24
61	4625.00	18.089	-.74
62	4750.00	18.242	-.29
63	4875.00	18.392	.12
64	5000.00	18.539	.48
65	5125.00	18.682	.79
66	5250.00	18.823	1.06
67	5375.00	18.960	1.29
68	5500.00	19.095	1.49
69	5625.00	19.226	1.66
70	5750.00	19.356	1.81
71	5875.00	19.482	1.95
72	6000.00	19.606	2.08
73	6250.00	19.847	2.33
74	6500.00	20.079	2.59
75	6750.00	20.300	2.86
76	7000.00	20.513	3.17
77	7250.00	20.717	3.51
78	7500.00	20.912	3.89
79	7750.00	21.098	4.31
80	8000.00	21.275	4.79
81	8250.00	21.445	5.31
82	8500.00	21.606	5.88
83	8750.00	21.760	6.50
84	9000.00	21.906	7.19
85	9250.00	22.046	7.93
86	9500.00	22.178	8.75
87	9750.00	22.304	9.63
88	10000.00	22.424	10.58
89	10250.00	22.538	11.60
90	10500.00	22.646	12.71
91	10750.00	22.749	13.90
92	11000.00	22.847	15.18

93	11250.00	22.941	16.54
94	11500.00	23.030	18.01
95	11750.00	23.114	19.57
96	12000.00	23.195	21.23
97	12250.00	23.272	23.01
98	12500.00	23.345	24.90
99	12750.00	23.415	26.90
100	13000.00	23.482	29.03
101	13250.00	23.546	31.28
102	13500.00	23.607	33.67
103	13750.00	23.666	36.19
104	14000.00	23.722	38.86
105	14250.00	23.775	41.67
106	14500.00	23.827	44.63
107	14750.00	23.876	47.76
108	15000.00	23.923	51.04

Table 3-D.1b.: Frequencies, Critical Band Rates and Absolute Threshold

Table is valid for Layer I at a sampling rate of 44.1 kHz.

Index Number	**Frequency**	**Crit.Band Rate**	**Absolute Thresh.**
i	**[Hz]**	**[z]**	**[dB]**
1	86.13	.850	25.87
2	172.27	1.694	14.85
3	258.40	2.525	10.72
4	344.53	3.337	8.50
5	430.66	4.124	7.10
6	516.80	4.882	6.11
7	602.93	5.608	5.37
8	689.06	6.301	4.79
9	775.20	6.959	4.32
10	861.33	7.581	3.92
11	947.46	8.169	3.57
12	1033.59	8.723	3.25
13	1119.73	9.244	2.95
14	1205.86	9.734	2.67
15	1291.99	10.195	2.39
16	1378.13	10.629	2.11
17	1464.26	11.037	1.83
18	1550.39	11.421	1.53
19	1636.52	11.783	1.23
20	1722.66	12.125	.90
21	1808.79	12.448	.56
22	1894.92	12.753	.21
23	1981.05	13.042	-.17
24	2067.19	13.317	-.56
25	2153.32	13.578	-.96
26	2239.45	13.826	-1.38
27	2325.59	14.062	-1.79
28	2411.72	14.288	-2.21
29	2497.85	14.504	-2.63
30	2583.98	14.711	-3.03
31	2670.12	14.909	-3.41
32	2756.25	15.100	-3.77
33	2842.38	15.284	-4.09

34	2928.52	15.460	-4.37
35	3014.65	15.631	-4.60
36	3100.78	15.796	-4.78
37	3186.91	15.955	-4.91
38	3273.05	16.110	-4.97
39	3359.18	16.260	-4.98
40	3445.31	16.406	-4.92
41	3531.45	16.547	-4.81
42	3617.58	16.685	-4.65
43	3703.71	16.820	-4.43
44	3789.84	16.951	-4.17
45	3875.98	17.079	-3.87
46	3962.11	17.205	-3.54
47	4048.24	17.327	-3.19
48	4134.38	17.447	-2.82
49	4306.64	17.680	-2.06
50	4478.91	17.905	-1.32
51	4651.17	18.121	-.64
52	4823.44	18.331	-.04
53	4995.70	18.534	.47
54	5167.97	18.731	.89
55	5340.23	18.922	1.23
56	5512.50	19.108	1.51
57	5684.77	19.289	1.74
58	5857.03	19.464	1.93
59	6029.30	19.635	2.11
60	6201.56	19.801	2.28
61	6373.83	19.963	2.46
62	6546.09	20.120	2.63
63	6718.36	20.273	2.82
64	6890.63	20.421	3.03
65	7062.89	20.565	3.25
66	7235.16	20.705	3.49
67	7407.42	20.840	3.74
68	7579.69	20.972	4.02
69	7751.95	21.099	4.32
70	7924.22	21.222	4.64
71	8096.48	21.342	4.98
72	8268.75	21.457	5.35
73	8613.28	21.677	6.15
74	8957.81	21.882	7.07
75	9302.34	22.074	8.10
76	9646.88	22.253	9.25
77	9991.41	22.420	10.54
78	10335.94	22.576	11.97
79	10680.47	22.721	13.56
80	11025.00	22.857	15.31
81	11369.53	22.984	17.23
82	11714.06	23.102	19.34
83	12058.59	23.213	21.64
84	12403.13	23.317	24.15
85	12747.66	23.415	26.88
86	13092.19	23.506	29.84
87	13436.72	23.592	33.05
88	13781.25	23.673	36.52

89	14125.78	23.749	40.25
90	14470.31	23.821	44.27
91	14814.84	23.888	48.59
92	15159.38	23.952	53.22
93	15503.91	24.013	58.18
94	15848.44	24.070	63.49
95	16192.97	24.125	68.00
96	16537.50	24.176	68.00
97	16882.03	24.225	68.00
98	17226.56	24.271	68.00
99	17571.09	24.316	68.00
100	17915.63	24.358	68.00
101	18260.16	24.398	68.00
102	18604.69	24.436	68.00
103	18949.22	24.473	68.00
104	19293.75	24.508	68.00
105	19638.28	24.542	68.00
106	19982.81	24.574	68.00

Table 3-D.1c. Frequencies, Critical Band Rates and Absolute Threshold

Table is valid for Layer I at a sampling rate of 48 kHz.

Index Number i	Frequency [Hz]	Crit.Band Rate [z]	Absolute Thresh. [dB]
1	93.75	.925	24.17
2	187.50	1.842	13.87
3	281.25	2.742	10.01
4	375.00	3.618	7.94
5	468.75	4.463	6.62
6	562.50	5.272	5.70
7	656.25	6.041	5.00
8	750.00	6.770	4.45
9	843.75	7.457	4.00
10	937.50	8.103	3.61
11	1031.25	8.708	3.26
12	1125.00	9.275	2.93
13	1218.75	9.805	2.63
14	1312.50	10.301	2.32
15	1406.25	10.765	2.02
16	1500.00	11.199	1.71
17	1593.75	11.606	1.38
18	1687.50	11.988	1.04
19	1781.25	12.347	.67
20	1875.00	12.684	.29
21	1968.75	13.002	-.11
22	2062.50	13.302	-.54
23	2156.25	13.586	-.97
24	2250.00	13.855	-1.43
25	2343.75	14.111	-1.88
26	2437.50	14.354	-2.34
27	2531.25	14.585	-2.79
28	2625.00	14.807	-3.22
29	2718.75	15.018	-3.62
30	2812.50	15.221	-3.98
31	2906.25	15.415	-4.30

32	3000.00	15.602	-4.57	
33	3093.75	15.783	-4.77	
34	3187.50	15.956	-4.91	
35	3281.25	16.124	-4.98	
36	3375.00	16.287	-4.97	
37	3468.75	16.445	-4.90	
38	3562.50	16.598	-4.76	
39	3656.25	16.746	-4.55	
40	3750.00	16.891	-4.29	
41	3843.75	17.032	-3.99	
42	3937.50	17.169	-3.64	
43	4031.25	17.303	-3.26	
44	4125.00	17.434	-2.86	
45	4218.75	17.563	-2.45	
46	4312.50	17.688	-2.04	
47	4406.25	17.811	-1.63	
48	4500.00	17.932	-1.24	
49	4687.50	18.166	-.51	
50	4875.00	18.392	.12	
51	5062.50	18.611	.64	
52	5250.00	18.823	1.06	
53	5437.50	19.028	1.39	
54	5625.00	19.226	1.66	
55	5812.50	19.419	1.88	
56	6000.00	19.606	2.08	
57	6187.50	19.788	2.27	
58	6375.00	19.964	2.46	
59	6562.50	20.135	2.65	
60	6750.00	20.300	2.86	
61	6937.50	20.461	3.09	
62	7125.00	20.616	3.33	
63	7312.50	20.766	3.60	
64	7500.00	20.912	3.89	
65	7687.50	21.052	4.20	
66	7875.00	21.188	4.54	
67	8062.50	21.318	4.91	
68	8250.00	21.445	5.31	
69	8437.50	21.567	5.73	
70	8625.00	21.684	6.18	
71	8812.50	21.797	6.67	
72	9000.00	21.906	7.19	
73	9375.00	22.113	8.33	
74	9750.00	22.304	9.63	
75	10125.00		22.482	11.08
76	10500.00		22.646	12.71
77	10875.00		22.799	14.53
78	11250.00		22.941	16.54
79	11625.00		23.072	18.77
80	12000.00		23.195	21.23
81	12375.00		23.309	23.94
82	12750.00		23.415	26.90
83	13125.00		23.515	30.14
84	13500.00		23.607	33.67
85	13875.00		23.694	37.51
86	14250.00		23.775	41.67

87	14625.00	23.852	46.17
88	15000.00	23.923	51.04
89	15375.00	23.991	56.29
90	15750.00	24.054	61.94
91	16125.00	24.114	68.00
92	16500.00	24.171	68.00
93	16875.00	24.224	68.00
94	17250.00	24.275	68.00
95	17625.00	24.322	68.00
96	18000.00	24.368	68.00
97	18375.00	24.411	68.00
98	18750.00	24.452	68.00
99	19125.00	24.491	68.00
100	19500.00	24.528	68.00
101	19875.00	24.564	68.00
102	20250.00	24.597	68.00

Table 3-D.1d.: Frequencies, Critical Band Rates and Absolute Threshold

Table is valid for Layer II at a sampling rate of 32.0 kHz.

Index Number	Frequency	Crit.Band Rate	Absolute Thresh.
i	**[Hz]**	**[z]**	**[dB]**
1	31.25	.309	58.23
2	62.50	.617	33.44
3	93.75	.925	24.17
4	125.00	1.232	19.20
5	156.25	1.538	16.05
6	187.50	1.842	13.87
7	218.75	2.145	12.26
8	250.00	2.445	11.01
9	281.25	2.742	10.01
10	312.50	3.037	9.20
11	343.75	3.329	8.52
12	375.00	3.618	7.94
13	406.25	3.903	7.44
14	437.50	4.185	7.00
15	468.75	4.463	6.62
16	500.00	4.736	6.28
17	531.25	5.006	5.97
18	562.50	5.272	5.70
19	593.75	5.533	5.44
20	625.00	5.789	5.21
21	656.25	6.041	5.00
22	687.50	6.289	4.80
23	718.75	6.532	4.62
24	750.00	6.770	4.45
25	781.25	7.004	4.29
26	812.50	7.233	4.14
27	843.75	7.457	4.00
28	875.00	7.677	3.86
29	906.25	7.892	3.73
30	937.50	8.103	3.61
31	968.75	8.309	3.49
32	1000.00	8.511	3.37
33	1031.25	8.708	3.26

34	1062.50	8.901	3.15
35	1093.75	9.090	3.04
36	1125.00	9.275	2.93
37	1156.25	9.456	2.83
38	1187.50	9.632	2.73
39	1218.75	9.805	2.63
40	1250.00	9.974	2.53
41	1281.25	10.139	2.42
42	1312.50	10.301	2.32
43	1343.75	10.459	2.22
44	1375.00	10.614	2.12
45	1406.25	10.765	2.02
46	1437.50	10.913	1.92
47	1468.75	11.058	1.81
48	1500.00	11.199	1.71
49	1562.50	11.474	1.49
50	1625.00	11.736	1.27
51	1687.50	11.988	1.04
52	1750.00	12.230	.80
53	1812.50	12.461	.55
54	1875.00	12.684	.29
55	1937.50	12.898	.02
56	2000.00	13.104	-.25
57	2062.50	13.302	-.54
58	2125.00	13.493	-.83
59	2187.50	13.678	-1.12
60	2250.00	13.855	-1.43
61	2312.50	14.027	-1.73
62	2375.00	14.193	-2.04
63	2437.50	14.354	-2.34
64	2500.00	14.509	-2.64
65	2562.50	14.660	-2.93
66	2625.00	14.807	-3.22
67	2687.50	14.949	-3.49
68	2750.00	15.087	-3.74
69	2812.50	15.221	-3.98
70	2875.00	15.351	-4.20
71	2937.50	15.478	-4.40
72	3000.00	15.602	-4.57
73	3125.00	15.841	-4.82
74	3250.00	16.069	-4.96
75	3375.00	16.287	-4.97
76	3500.00	16.496	-4.86
77	3625.00	16.697	-4.63
78	3750.00	16.891	-4.29
79	3875.00	17.078	-3.87
80	4000.00	17.259	-3.39
81	4125.00	17.434	-2.86
82	4250.00	17.605	-2.31
83	4375.00	17.770	-1.77
84	4500.00	17.932	-1.24
85	4625.00	18.089	-.74
86	4750.00	18.242	-.29
87	4875.00	18.392	.12
88	5000.00	18.539	.48

89	5125.00	18.682	.79
90	5250.00	18.823	1.06
91	5375.00	18.960	1.29
92	5500.00	19.095	1.49
93	5625.00	19.226	1.66
94	5750.00	19.356	1.81
95	5875.00	19.482	1.95
96	6000.00	19.606	2.08
97	6250.00	19.847	2.33
98	6500.00	20.079	2.59
99	6750.00	20.300	2.86
100	7000.00	20.513	3.17
101	7250.00	20.717	3.51
102	7500.00	20.912	3.89
103	7750.00	21.098	4.31
104	8000.00	21.275	4.79
105	8250.00	21.445	5.31
106	8500.00	21.606	5.88
107	8750.00	21.760	6.50
108	9000.00	21.906	7.19
109	9250.00	22.046	7.93
110	9500.00	22.178	8.75
111	9750.00	22.304	9.63
112	10000.00	22.424	10.58
113	10250.00	22.538	11.60
114	10500.00	22.646	12.71
115	10750.00	22.749	13.90
116	11000.00	22.847	15.18
117	11250.00	22.941	16.54
118	11500.00	23.030	18.01
119	11750.00	23.114	19.57
120	12000.00	23.195	21.23
121	12250.00	23.272	23.01
122	12500.00	23.345	24.90
123	12750.00	23.415	26.90
124	13000.00	23.482	29.03
125	13250.00	23.546	31.28
126	13500.00	23.607	33.67
127	13750.00	23.666	36.19
128	14000.00	23.722	38.86
129	14250.00	23.775	41.67
130	14500.00	23.827	44.63
131	14750.00	23.876	47.76
132	15000.00	23.923	51.04

Table 3-D.1e.: Frequencies, Critical Band Rates and Absolute Threshold

Table is valid for Layer II at a sampling rate of 44.1 kHz.

Index Number i	Frequency [Hz]	Crit.Band Rate [z]	Absolute Thresh. [dB]
1	43.07	.425	45.05
2	86.13	.850	25.87
3	129.20	1.273	18.70
4	172.27	1.694	14.85

5	215.33	2.112	12.41
6	258.40	2.525	10.72
7	301.46	2.934	9.47
8	344.53	3.337	8.50
9	387.60	3.733	7.73
10	430.66	4.124	7.10
11	473.73	4.507	6.56
12	516.80	4.882	6.11
13	559.86	5.249	5.72
14	602.93	5.608	5.37
15	646.00	5.959	5.07
16	689.06	6.301	4.79
17	732.13	6.634	4.55
18	775.20	6.959	4.32
19	818.26	7.274	4.11
20	861.33	7.581	3.92
21	904.39	7.879	3.74
22	947.46	8.169	3.57
23	990.53	8.450	3.40
24	1033.59	8.723	3.25
25	1076.66	8.987	3.10
26	1119.73	9.244	2.95
27	1162.79	9.493	2.81
28	1205.86	9.734	2.67
29	1248.93	9.968	2.53
30	1291.99	10.195	2.39
31	1335.06	10.416	2.25
32	1378.13	10.629	2.11
33	1421.19	10.836	1.97
34	1464.26	11.037	1.83
35	1507.32	11.232	1.68
36	1550.39	11.421	1.53
37	1593.46	11.605	1.38
38	1636.52	11.783	1.23
39	1679.59	11.957	1.07
40	1722.66	12.125	.90
41	1765.72	12.289	.74
42	1808.79	12.448	.56
43	1851.86	12.603	.39
44	1894.92	12.753	.21
45	1937.99	12.900	.02
46	1981.05	13.042	-.17
47	2024.12	13.181	-.36
48	2067.19	13.317	-.56
49	2153.32	13.578	-.96
50	2239.45	13.826	-1.38
51	2325.59	14.062	-1.79
52	2411.72	14.288	-2.21
53	2497.85	14.504	-2.63
54	2583.98	14.711	-3.03
55	2670.12	14.909	-3.41
56	2756.25	15.100	-3.77
57	2842.38	15.284	-4.09
58	2928.52	15.460	-4.37
59	3014.65	15.631	-4.60

60	3100.78	15.796	-4.78	
61	3186.91	15.955	-4.91	
62	3273.05	16.110	-4.97	
63	3359.18	16.260	-4.98	
64	3445.31	16.406	-4.92	
65	3531.45	16.547	-4.81	
66	3617.58	16.685	-4.65	
67	3703.71	16.820	-4.43	
68	3789.84	16.951	-4.17	
69	3875.98	17.079	-3.87	
70	3962.11	17.205	-3.54	
71	4048.24	17.327	-3.19	
72	4134.38	17.447	-2.82	
73	4306.64	17.680	-2.06	
74	4478.91	17.905	-1.32	
75	4651.17	18.121	-.64	
76	4823.44	18.331	-.04	
77	4995.70	18.534	.47	
78	5167.97	18.731	.89	
79	5340.23	18.922	1.23	
80	5512.50	19.108	1.51	
81	5684.77	19.289	1.74	
82	5857.03	19.464	1.93	
83	6029.30	19.635	2.11	
84	6201.56	19.801	2.28	
85	6373.83	19.963	2.46	
86	6546.09	20.120	2.63	
87	6718.36	20.273	2.82	
88	6890.63	20.421	3.03	
89	7062.89	20.565	3.25	
90	7235.16	20.705	3.49	
91	7407.42	20.840	3.74	
92	7579.69	20.972	4.02	
93	7751.95	21.099	4.32	
94	7924.22	21.222	4.64	
95	8096.48	21.342	4.98	
96	8268.75	21.457	5.35	
97	8613.28	21.677	6.15	
98	8957.81	21.882	7.07	
99	9302.34	22.074	8.10	
100	9646.88	22.253	9.25	
101	9991.41	22.420	10.54	
102	10335.94		22.576	11.97
103	10680.47		22.721	13.56
104	11025.00		22.857	15.31
105	11369.53		22.984	17.23
106	11714.06		23.102	19.34
107	12058.59		23.213	21.64
108	12403.13		23.317	24.15
109	12747.66		23.415	26.88
110	13092.19		23.506	29.84
111	13436.72		23.592	33.05
112	13781.25		23.673	36.52
113	14125.78		23.749	40.25
114	14470.31		23.821	44.27

115	14814.84	23.888	48.59
116	15159.38	23.952	53.22
117	15503.91	24.013	58.18
118	15848.44	24.070	63.49
119	16192.97	24.125	68.00
120	16537.50	24.176	68.00
121	16882.03	24.225	68.00
122	17226.56	24.271	68.00
123	17571.09	24.316	68.00
124	17915.63	24.358	68.00
125	18260.16	24.398	68.00
126	18604.69	24.436	68.00
127	18949.22	24.473	68.00
128	19293.75	24.508	68.00
129	19638.28	24.542	68.00
130	19982.81	24.574	68.00

Table 3-D.1f.: Frequencies, Critical Band Rates and Absolute Threshold

Table is valid for Layer II at a sampling rate of 48.0 kHz

Index Number	**Frequency**	**Crit.Band Rate**	**Absolute Thresh.**
i	**[Hz]**	**[z]**	**[dB]**
1	46.88	.463	42.10
2	93.75	.925	24.17
3	140.63	1.385	17.47
4	187.50	1.842	13.87
5	234.38	2.295	11.60
6	281.25	2.742	10.01
7	328.13	3.184	8.84
8	375.00	3.618	7.94
9	421.88	4.045	7.22
10	468.75	4.463	6.62
11	515.63	4.872	6.12
12	562.50	5.272	5.70
13	609.38	5.661	5.33
14	656.25	6.041	5.00
15	703.13	6.411	4.71
16	750.00	6.770	4.45
17	796.88	7.119	4.21
18	843.75	7.457	4.00
19	890.63	7.785	3.79
20	937.50	8.103	3.61
21	984.38	8.410	3.43
22	1031.25	8.708	3.26
23	1078.13	8.996	3.09
24	1125.00	9.275	2.93
25	1171.88	9.544	2.78
26	1218.75	9.805	2.63
27	1265.63	10.057	2.47
28	1312.50	10.301	2.32
29	1359.38	10.537	2.17
30	1406.25	10.765	2.02
31	1453.13	10.986	1.86
32	1500.00	11.199	1.71
33	1546.88	11.406	1.55
34	1593.75	11.606	1.38

35	1640.63	11.800	1.21
36	1687.50	11.988	1.04
37	1734.38	12.170	.86
38	1781.25	12.347	.67
39	1828.13	12.518	.49
40	1875.00	12.684	.29
41	1921.88	12.845	.09
42	1968.75	13.002	-.11
43	2015.63	13.154	-.32
44	2062.50	13.302	-.54
45	2109.38	13.446	-.75
46	2156.25	13.586	-.97
47	2203.13	13.723	-1.20
48	2250.00	13.855	-1.43
49	2343.75	14.111	-1.88
50	2437.50	14.354	-2.34
51	2531.25	14.585	-2.79
52	2625.00	14.807	-3.22
53	2718.75	15.018	-3.62
54	2812.50	15.221	-3.98
55	2906.25	15.415	-4.30
56	3000.00	15.602	-4.57
57	3093.75	15.783	-4.77
58	3187.50	15.956	-4.91
59	3281.25	16.124	-4.98
60	3375.00	16.287	-4.97
61	3468.75	16.445	-4.90
62	3562.50	16.598	-4.76
63	3656.25	16.746	-4.55
64	3750.00	16.891	-4.29
65	3843.75	17.032	-3.99
66	3937.50	17.169	-3.64
67	4031.25	17.303	-3.26
68	4125.00	17.434	-2.86
69	4218.75	17.563	-2.45
70	4312.50	17.688	-2.04
71	4406.25	17.811	-1.63
72	4500.00	17.932	-1.24
73	4687.50	18.166	-.51
74	4875.00	18.392	.12
75	5062.50	18.611	.64
76	5250.00	18.823	1.06
77	5437.50	19.028	1.39
78	5625.00	19.226	1.66
79	5812.50	19.419	1.88
80	6000.00	19.606	2.08
81	6187.50	19.788	2.27
82	6375.00	19.964	2.46
83	6562.50	20.135	2.65
84	6750.00	20.300	2.86
85	6937.50	20.461	3.09
86	7125.00	20.616	3.33
87	7312.50	20.766	3.60
88	7500.00	20.912	3.89
89	7687.50	21.052	4.20

90	7875.00	21.188	4.54
91	8062.50	21.318	4.91
92	8250.00	21.445	5.31
93	8437.50	21.567	5.73
94	8625.00	21.684	6.18
95	8812.50	21.797	6.67
96	9000.00	21.906	7.19
97	9375.00	22.113	8.33
98	9750.00	22.304	9.63
99	10125.00	22.482	11.08
100	10500.00	22.646	12.71
101	10875.00	22.799	14.53
102	11250.00	22.941	16.54
103	11625.00	23.072	18.77
104	12000.00	23.195	21.23
105	12375.00	23.309	23.94
106	12750.00	23.415	26.90
107	13125.00	23.515	30.14
108	13500.00	23.607	33.67
109	13875.00	23.694	37.51
110	14250.00	23.775	41.67
111	14625.00	23.852	46.17
112	15000.00	23.923	51.04
113	15375.00	23.991	56.29
114	15750.00	24.054	61.94
115	16125.00	24.114	68.00
116	16500.00	24.171	68.00
117	16875.00	24.224	68.00
118	17250.00	24.275	68.00
119	17625.00	24.322	68.00
120	18000.00	24.368	68.00
121	18375.00	24.411	68.00
122	18750.00	24.452	68.00
123	19125.00	24.491	68.00
124	19500.00	24.528	68.00
125	19875.00	24.564	68.00
126	20250.00	24.597	68.00

Table 3-D.2a. Critical Band Boundaries

This table is valid for Layer I at a sampling rate of 32.0 kHz.
The frequencies represent the top end of each critical band.

no	**index of table F&CB**	**frequency [Hz]**	**Bark [z]**
0	1	62.500	.617
1	3	187.500	1.842
2	5	312.500	3.037
3	7	437.500	4.185
4	9	562.500	5.272
5	11	687.500	6.289
6	13	812.500	7.233
7	15	937.500	8.103
8	18	1125.000	9.275
9	21	1312.500	10.301
10	24	1500.000	11.199

11	27	1687.500	11.988
12	32	2000.000	13.104
13	37	2312.500	14.027
14	44	2750.000	15.087
15	50	3250.000	16.069
16	55	3875.000	17.078
17	61	4625.000	18.089
18	68	5500.000	19.095
19	74	6500.000	20.079
20	79	7750.000	21.098
21	85	9250.000	22.046
22	94	11500.000	23.030
23	108	15000.000	23.923

Table 3-D.2b. Critical Band Boundaries

This table is valid for Layer I at a sampling rate of 44.1 kHz.
The frequencies represent the top end of each critical band.

no	index of table F&CB	frequency [Hz]	Bark [z]
0	1	86.133	.850
1	2	172.266	1.694
2	3	258.398	2.525
3	5	430.664	4.124
4	6	516.797	4.882
5	8	689.063	6.301
6	9	775.195	6.959
7	11	947.461	8.169
8	13	1119.727	9.244
9	15	1291.992	10.195
10	17	1464.258	11.037
11	20	1722.656	12.125
12	23	1981.055	13.042
13	27	2325.586	14.062
14	32	2756.250	15.100
15	37	3186.914	15.955
16	45	3875.977	17.079
17	50	4478.906	17.904
18	55	5340.234	18.922
19	61	6373.828	19.963
20	68	7579.688	20.971
21	75	9302.344	22.074
22	81	11369.531	22.984
23	93	15503.906	24.013
24	106	19982.813	24.573

Table 3-D.2c. Critical Band Boundaries

This table is valid for Layer I at a sampling rate of 48.0 kHz.
The frequencies represent the top end of each critical band.

no	indexof tableF&CB	frequency[Hz]	Bark[z]
0	1	93.750	.925
1	2	187.500	1.842
2	3	281.250	2.742

3	4	375.000	3.618
4	5	468.750	4.463
5	6	562.500	5.272
6	7	656.250	6.041
7	9	843.750	7.457
8	10	937.500	8.103
9	12	1125.000	9.275
10	14	1312.500	10.301
11	16	1500.000	11.199
12	19	1781.250	12.347
13	21	1968.750	13.002
14	25	2343.750	14.111
15	29	2718.750	15.018
16	35	3281.250	16.124
17	41	3843.750	17.032
18	49	4687.500	18.166
19	53	5437.500	19.028
20	58	6375.000	19.964
21	65	7687.500	21.052
22	73	9375.000	22.113
23	79	11625.000	23.072
24	89	15375.000	23.991
25	102	20250.000	24.597

Table 3-D.2d. Critical Band Boundaries

This table is valid for Layer II at a sampling rate of 32.0 kHz.
The frequencies represent the top end of each critical band.

no	**indexof tableF&CB**	**frequency[Hz]**	**Bark[z]**
0	1	31.250	.309
1	3	93.750	.925
2	6	187.500	1.842
3	10	312.500	3.037
4	13	406.250	3.903
5	17	531.250	5.006
6	21	656.250	6.041
7	25	781.250	7.004
8	30	937.500	8.103
9	35	1093.750	9.090
10	41	1281.250	10.139
11	47	1468.750	11.058
12	51	1687.500	11.988
13	56	2000.000	13.104
14	61	2312.500	14.027
15	68	2750.000	15.087
16	74	3250.000	16.069
17	79	3875.000	17.078
18	85	4625.000	18.089
19	92	5500.000	19.095
20	98	6500.000	20.079
21	103	7750.000	21.098
22	109	9250.000	22.046
23	118	11500.000	23.030

24	132	15000.000	23.923

Table 3-D.2e. Critical Band Boundaries

This table is valid for Layer II at a sampling rate of 44.1 kHz.
The frequencies represent the top end of each critical band.

no	indexof tableF&CB	frequency[Hz]	Bark[z]
0	1	43.066	.425
1	2	86.133	.850
2	3	129.199	1.273
3	5	215.332	2.112
4	7	301.465	2.934
5	10	430.664	4.124
6	13	559.863	5.249
7	16	689.063	6.301
8	19	818.262	7.274
9	22	947.461	8.169
10	26	1119.727	9.244
11	30	1291.992	10.195
12	35	1507.324	11.232
13	40	1722.656	12.125
14	46	1981.055	13.042
15	51	2325.586	14.062
16	56	2756.250	15.100
17	62	3273.047	16.11
18	69	3875.977	17.079
19	74	4478.906	17.904
20	79	5340.234	18.922
21	85	6373.828	19.963
22	92	7579.688	20.971
23	99	9302.344	22.074
24	105	11369.531	22.984
25	117	15503.906	24.013
26	130	19982.813	24.573

Table 3-D.2f. Critical Band Boundaries

This table is valid for Layer II at a sampling rate of 48.0 kHz.
The frequencies represent the top end of each critical band.

no	index of table F&CB	frequency [Hz]	Bark [z]
0	1	46.875	.463
1	2	93.750	.925
2	3	140.625	1.385
3	5	234.375	2.295
4	7	328.125	3.184
5	9	421.875	4.045
6	12	562.500	5.272
7	14	656.250	6.041
8	17	796.875	7.119
9	20	937.500	8.103
10	24	1125.000	9.275
11	27	1265.625	10.057
12	32	1500.000	11.199
13	37	1734.375	12.170

14	42	1968.750	13.002
15	49	2343.750	14.111
16	53	2718.750	15.018
17	59	3281.250	16.124
18	65	3843.750	17.032
19	73	4687.500	18.166
20	77	5437.500	19.028
21	82	6375.000	19.964
22	89	7687.500	21.052
23	97	9375.000	22.113
24	103	11625.000	23.072
25	113	15375.000	23.991
26	126	20250.000	24.597

3-D.2 Psychoacoustic Model II

Psychoacoustic Model II is an independent psychoacoustic model that can be adjusted and adapted to any ISO-MPEG-Audio layer. This annex presents the general Psychoacoustic Model II, and provides sufficient information for implementation of Model II with Layers I and II. The Layer III Psychoacoustic Model is based on this implementation, with adaptations as described in the Layer III encoder clause.

The threshold generation process has three inputs. They are:

1. The shift length for the threshold calculation process, *iblen*, where 384<*iblen*<640. This *iblen* must remain constant over any particular application of the threshold calculation process. If (as in Layer III), it is necessary to calculate thresholds for two different shift lengths, two processes, each running with a fixed shift length, will be necessary. In the case of *iblen* outside the range of 384 to 640 it may be necessary to calculate the psychoacoustic thresholds with a different window length as well as shift length. There are two ways to do this:

    - Use a different length transform, and recalculate the startup coefficients for the model, or

    - Use the same length transform, but a substantially shorter Hann window, appropriate to the data and problem at hand.

    The choice of these is left to the implementation.

2. The newest *iblen* samples of the signal, with the samples delayed (either in the filter bank or psychoacoustic calculation) such that the window of the psychoacoustic calculation is centered in the time-window of application.

3. The sampling rate. There are sets of tables provided for the standard sampling rates. Sampling rate, like *iblen*, must necessarily remain constant over one implementation of the threshold calculation process.

There is one output from Psychoacoustic Model II, a set of Signal to Masking Ratios, *SMRn*, which are adapted to the layers as described below.

Before running the Model initially, the array used to hold the preceding FFT source data window and the arrays used to hold r and f should be zeroed to provide a known starting point.

In Layer II, the psychoacoustic masking ratios must be calculated twice during each coder frame. The more stringent of each pair of ratios is used for bit allocation as shown in the software simulation model for Layers I and II with Psychoacoustic Model II.

Comments on Notation

Throughout this threshold calculation process, three indices for data values are used. These are:

- *w* - indicates that the calculation is indexed by frequency in the FFT spectral line domain. An index of 1 corresponds to the DC term and an index of 513 corresponds to the spectral line at the Nyquest frequency.

- *b* - indicates that the calculation is indexed in the threshold calculation partition domain. In the case where the calculation includes a convolution or sum in the threshold calculation partition domain, *bb* will be used as the summation variable. Partition numbering starts at 1.

- *n* - indicates that the calculation is indexed in the coder bit (or codebook) allocation domain. An index of 1 corresponds to the lowest band in the subband filter bank.

The "Spreading Function"

Several points in the following description refer to the "spreading function". It is calculated by the following method:

$tmpx = 1.05\ (j-i)$,

Where i is the bark value of the signal being spread, j is the bark value of the band being spread into, and $tmpx$ is a temporary variable.

$x=8\ minimum\ ((tmpx-0.5)^2-2(tmpx-0.5),0)$

Where x is a temporary variable, and minimum (a,b) is a function returning the more negative of a or b.

$tmpy=15.811389+7.5(tmpx+0.474)-17.5(1.0+(tmpx+0.474)^2)^{0.5}$

where $tmpy$ is another temporary variable.

if $(tmpy<-100)$ then $\{sprdngf\,(i,j)=0\}$ else $\{sprdngf\,(i,j)=10^{(x+tmpy)/10}\}$

Steps in Threshold Calculation

The following are the necessary steps for calculation of the *SMRn* used in the coder.

1. Reconstruct 1024 samples of the input signal.

   iblen new samples are made available at every call to the threshold generator. The threshold generator must store 1024-*iblen* samples, and concatenate those samples to accurately reconstruct 1024 consecutive samples of the input signal, *si,* where i represents the index, $1 < i < 1024$ of the current input stream.

2. Calculate the complex spectrum of the input signal.

   First, *si* is windowed by a 1024 point Hann window, i.e. $swi=si$ * (0.5-0.5cos()). Note that in Layer III, a shorter window may be used when window switching is active, with appropriate centering of the window, per the Layer III encoder description.

   Second, a standard forward FFT of *swi* is calculated.

   Third, the polar representation of the transform is calculated. *rw* and *fw* represent the magnitude and phase components of the transformed *swi,* respectively.

3. Calculate a predicted *r* and *f*.

A predicted magnitude, *^rw*, and phase, *^fw* are calculated from the preceding two threshold calculation blocks' *r* and *f*:

^rw =2.0rw (t-1)-rw (t-2)

^fw =2.0fw (t-1)-fw (t-2)

where *t* represents the current block number, *t-1* indexes the previous block's data, and *t-2* indexes the data from the threshold calculation block before that.

4. Calculate the unpredictability measure *cw*

cw, the unpredictability measure, is:

$cw=(((rw \cos fw - \hat{}rw \cos \hat{}fw)^2+(rw \sin fw - \hat{}rw \sin \hat{}fw)^2)^{0.5}) / (rw+ abs(\hat{}rw))$

By sacrificing performance, this measure can be calculated on only a lower portion of the frequency lines. Calculations should be done from DC to at least 3kHz and preferably to7kHz. An upper limit of less than 5.5kHz may considerably reduce performance from that obtained during the subjective testing of the audio algorithm. The *cw* values above this limit should be set to 0.3. Best results will be obtained by calculating cw up to 20kHz.

5. Calculate the energy and unpredictability in the threshold calculation partitions.

The energy in each partition, *eb*, is:

$eb= {}_{w=wlowb}{}^{whighb} \sum rw^2$

and the weighted unpredictability, *cb*, is:

$cb= {}_{w=wlowb}{}^{whighb} \sum rw^2\, cw$

The threshold calculation partitions provide a resolution of approximately either one FFT line or 1/3 critical band, whichever is wider. At low frequencies, a single line of the FFT will constitute a calculation partition. At high frequencies, many lines will be combined into one calculation partition. A set of partition values is provided for each of the three sampling rates in Table 3-D.3."Calculation Partition Tables". These table elements will be used in the threshold calculation process. There are several elements in each table entry:

1. The index of the calculation partition, *b*.

2. The lowest frequency line in the partition, *wlowb.*

3. The highest frequency line in the partition, *whighb*.

4. The median bark value of the partition, *bvalb.*

5. A lower limit for the SNR in the partition that controls stereo unmasking effects, *minvalb*.

6. The value for tone masking noise (in dB) for the partition, *TMNb*.

A largest value of *b,bmax*, equal to the largest index, exists for each sampling rate.

6. Convolve the partitioned energy and unpredictability with the spreading function.

$ecbb= {}_{bb=1}{}^{bmax} \sum ebb * sprdngf(bvalbb,bvalb)$

$ctb= {}_{bb=1}{}^{bmax} \sum cbb * sprdngf(bvalbb,bvalb)$

Because *ctb*. is weighted by the signal energy, it must be renormalized to *cbb*.

$cbb=ctb/ecbb$

At the same time, due to the non-normalized nature of the spreading function, *ecbb* should be renormalized and the normalized energy *enb*, calculated.

$enb=ecbb * rnormb$

The normalization coefficient, *rnormb*. is:

$rnormb=1/ ({}_{bb=0}{}^{bmax} \sum sprdngf(bvalbb,bvalb))$

7. Convert *cbb* to *tbb* .

tbb = -0.299-0.43loge (cbb)

Each tbb is limited to the range of $0<tbb<1$.

8. Calculate the required SNR in each partition.

$NMTb$ = 5.5dB for all *b*. $NMTb$ is the value for noise masking tone (in dB) for the partition. The required signal to noise ratio, $SNRb$, is:

$SNRb$ =maximum($minvalb, \; tbb * TMNb + (1-tbb) \; NMTb$)

Where maximum (a,b) is a function returning the least negative of a or b.

9. Calculate the power ratio.

The power ratio, bcb , is:

$bcb = 10^{-SNRb/10}$

10. Calculation of actual energy threshold, nbb .

$nbb=enb \; bcb$

11. Spread the threshold energy over FFT lines, yielding nbw .

$nbw = nbb / (whighb-wlowb+1)$

12. Include absolute thresholds, yielding the final energy threshold of audibility, *thrw*

$thrw$ = max($nbw, absthrw$)

The dB values of *absthr* shown in Tables 3-D.4. "Absolute Threshold Tables" are relative to the level that a sine wave of ± ½ lsb has in the FFT used for threshold calculation. The dB values must be converted into the energy domain after considering the FFT normalization actually used.

13. Pre-echo control

For Layer III , pre-echo control occurs at this point. The actual control is described as part of the Layer III encoder specification. This step is omitted for Layers I and II.

14. Calculate the signal-to-mask ratios, *SMRn*.

Table 3-D.5. "Layer I and II Coder Partition Table" shows:

1. The index, *n*, of the coder partition.

2. The lower index *wlown*, of the coder partition.

3. The upper index, *whighn* of the coder partition.

4. The width index, *widthn*, where *widthn*=1 for a psychoacoustically narrow scalefactor band, and *widthn*=0 for a psychoacoustically wide scalefactor band. A psychoacoustically narrow scalefactor band is one whose width is less than approximately 1/3 critical band.

The energy in the scalefactor band, *epartn* , is:

$$epartn = \sum_{w=wlown}^{whighn} rw^2$$

Then, if (*widthn* = 1), the noise level in the scalefactor band, *npartn* is calculated as:

$$npartn = \sum_{w=wlown}^{whighn} thrw$$

else,

$$npartn = \text{minimum}(thr_{wlown}, \ldots, thr_{whighn}) * (whighn - wlown + 1)$$

Where, in this case, minimum (a,...,z) is a function returning the smallest positive argument of the arguments a...z.

The ratios to be sent to the coder, *SMRn* , are calculated as:

$$SMRn = 10 \log_{10} (\text{epart}_n/\text{npart}_n)$$

Table 3-D.3a. Calculation Partition Table

This table is valid at a sampling rate of 32.0 kHz.

Index	wlow	whigh	bval	minval	TMN
1	1	1	0.00	0.0	24.5
2	2	4	0.63	0.0	24.5
3	5	7	1.56	20.0	24.5
4	8	10	2.50	20.0	24.5
5	11	13	3.44	20.0	24.5
6	14	16	4.34	20.0	24.5
7	17	19	5.17	20.0	24.5
8	20	22	5.94	20.0	24.5

9	23	25	6.63	17.0	24.5
10	26	28	7.28	15.0	24.5
11	29	31	7.90	15.0	24.5
12	32	34	8.50	10.0	24.5
13	35	37	9.06	7.0	24.5
14	38	41	9.65	7.0	24.5
15	42	45	10.28	4.4	24.8
16	46	49	10.87	4.4	25.4
17	50	53	11.41	4.5	25.9
18	54	57	11.92	4.5	26.4
19	58	61	12.39	4.5	26.9
20	62	65	12.83	4.5	27.3
21	66	70	13.29	4.5	27.8
22	71	75	13.78	4.5	28.3
23	76	81	14.27	4.5	28.8
24	82	87	14.76	4.5	29.3
25	88	93	15.22	4.5	29.7
26	94	99	15.63	4.5	30.1
27	100	106	16.06	4.5	30.6
28	107	113	16.47	4.5	31.0
29	114	120	16.86	4.5	31.4
30	121	129	17.25	4.5	31.8
31	130	138	17.65	4.5	32.2
32	139	148	18.05	4.5	32.5
33	149	159	18.42	4.5	32.9
34	160	170	18.81	4.5	33.3
35	171	183	19.18	4.5	33.7
36	184	196	19.55	4.5	34.1
37	197	210	19.93	4.5	34.4
38	211	225	20.29	4.5	34.8
39	226	240	20.65	4.5	35.2
40	241	258	21.02	4.5	35.5
41	259	279	21.38	4.5	35.9
42	280	300	21.74	4.5	36.2
43	301	326	22.10	4.5	36.6
44	327	354	22.44	4.5	36.9
45	355	382	22.79	4.5	37.3
46	383	420	23.14	4.5	37.6
47	421	458	23.49	4.5	38.0
48	459	496	23.83	4.5	38.3
49	497	513	24.07	4.5	38.6

Table 3-D.3b. Calculation Partition Table

This table is valid at a sampling rate of 44.1.0 kHz.

Index	wlow	whigh	bval	minval	TMN
1	1	1	0.00	0.0	24.5
2	2	2	0.43	0.0	24.5
3	3	3	0.86	0.0	24.5
4	4	4	1.29	20.0	24.5
5	5	5	1.72	20.0	24.5
6	6	6	2.15	20.0	24.5
7	7	7	2.58	20.0	24.5
8	8	8	3.01	20.0	24.5

9	9	9	3.45	20.0	24.5
10	10	10	3.88	20.0	24.5
11	11	11	4.28	20.0	24.5
12	12	12	4.67	20.0	24.5
13	13	13	5.06	20.0	24.5
14	14	14	5.42	20.0	24.5
15	15	15	5.77	20.0	24.5
16	16	16	6.11	17.0	24.5
17	17	19	6.73	17.0	24.5
18	20	22	7.61	15.0	24.5
19	23	25	8.44	10.0	24.5
20	26	28	9.21	7.0	24.5
21	29	31	9.88	7.0	24.5
22	32	34	10.51	4.4	25.0
23	35	37	11.11	4.5	25.6
24	38	40	11.65	4.5	26.2
25	41	44	12.24	4.5	26.7
26	45	48	12.85	4.5	27.4
27	49	52	13.41	4.5	27.9
28	53	56	13.94	4.5	28.4
29	57	60	14.42	4.5	28.9
30	61	64	14.86	4.5	29.4
31	65	69	15.32	4.5	29.8
32	70	74	15.79	4.5	30.3
33	75	80	16.26	4.5	30.8
34	81	86	16.73	4.5	31.2
35	87	93	17.19	4.5	31.7
36	94	100	17.62	4.5	32.1
37	101	108	18.05	4.5	32.5
38	109	116	18.45	4.5	32.9
39	117	124	18.83	4.5	33.3
40	125	134	19.21	4.5	33.7
41	135	144	19.60	4.5	34.1
42	145	155	20.00	4.5	34.5
43	156	166	20.38	4.5	34.9
44	167	177	20.74	4.5	35.2
45	178	192	21.12	4.5	35.6
46	193	207	21.48	4.5	36.0
47	208	222	21.84	4.5	36.3
48	223	243	22.20	4.5	36.7
49	244	264	22.56	4.5	37.1
50	265	286	22.91	4.5	37.4
51	287	314	23.26	4.5	37.8
52	315	342	23.60	4.5	38.1
53	343	371	23.95	4.5	38.4
54	372	401	24.30	4.5	38.8
55	402	431	24.65	4.5	39.1
56	432	469	25.00	4.5	39.5
57	470	513	25.33	3.5	39.8

Table 3-D.3c. Calculation Partition Table

This table is valid at a sampling rate of 48.0 kHz.

Index	wlow	whigh	bval	minval	TMN
1	1	1	0.00	0.0	24.5

2	2	2	0.47	0.0	24.5
3	3	3	0.94	0.0	24.5
4	4	4	1.41	20.0	24.5
5	5	5	1.88	20.0	24.5
6	6	6	2.34	20.0	24.5
7	7	7	2.81	20.0	24.5
8	8	8	3.28	20.0	24.5
9	9	9	3.75	20.0	24.5
10	10	10	4.20	20.0	24.5
11	11	11	4.63	20.0	24.5
12	12	12	5.05	20.0	24.5
13	13	13	5.44	20.0	24.5
14	14	14	5.83	20.0	24.5
15	15	15	6.19	20.0	24.5
16	16	16	6.52	17.0	24.5
17	17	17	6.86	17.0	24.5
18	18	20	7.49	15.0	24.5
19	21	23	8.40	10.0	24.5
20	24	26	9.24	7.0	24.5
21	27	29	9.97	7.0	24.5
22	30	32	10.65	4.4	25.1
23	33	35	11.28	4.5	25.8
24	36	38	11.86	4.5	26.4
25	39	41	12.39	4.5	26.9
26	42	45	12.96	4.5	27.5
27	46	49	13.56	4.5	28.1
28	50	53	14.12	4.5	28.6
29	54	57	14.62	4.5	29.1
30	58	62	15.14	4.5	29.6
31	63	67	15.67	4.5	30.2
32	68	72	16.15	4.5	30.7
33	73	77	16.58	4.5	31.1
34	78	83	17.02	4.5	31.5
35	84	89	17.44	4.5	31.9
36	90	95	17.84	4.5	32.3
37	96	103	18.24	4.5	32.7
38	104	111	18.66	4.5	33.2
39	112	120	19.07	4.5	33.6
40	121	129	19.47	4.5	34.0
41	130	138	19.85	4.5	34.3
42	139	149	20.23	4.5	34.7
43	150	160	20.63	4.5	35.1
44	161	173	21.02	4.5	35.5
45	174	187	21.40	4.5	35.9
46	188	201	21.76	4.5	36.3
47	202	219	22.12	4.5	36.6
48	220	238	22.47	4.5	37.0
49	239	257	22.83	4.5	37.3
50	258	283	23.18	4.5	37.7
51	284	309	23.53	4.5	38.0
52	310	335	23.88	4.5	38.4
53	336	363	24.23	4.5	38.7
54	364	391	24.58	4.5	39.1
55	392	423	24.93	4.5	39.4
56	424	465	25.27	4.5	39.8

57	466	507	25.61	3.5	40.1
58	508	513	25.81	3.5	40.3

Table 3-D.4a. Absolute Threshold Table

This table is valid at a sampling rate of 32.0 kHz.

A value of 0 dB represents a level in the absolute threshold calculation of 96 dB below the energy of a sine wave of amplitude +-32760.

index (line) lower	higher	absthr (dB)
1	1	58.23
2	2	33.44
3	3	24.17
4	4	19.20
5	5	16.05
6	6	13.87
7	7	12.26
8	8	11.01
9	9	10.01
10	10	9.20
11	11	8.52
12	12	7.94
13	13	7.44
14	14	7.00
15	15	6.62
16	16	6.28
17	17	5.97
18	18	5.70
19	19	5.44
20	20	5.21
21	21	5.00
22	22	4.80
23	23	4.62
24	24	4.45
25	25	4.29
26	26	4.14
27	27	4.00
28	28	3.86
29	29	3.73
30	30	3.61
31	31	3.49
32	32	3.37
33	33	3.26
34	34	3.15
35	35	3.04
36	36	2.93
37	37	2.83
38	38	2.73

39	39	2.63
40	40	2.53
41	41	2.42
42	42	2.32
43	43	2.22
44	44	2.12
45	45	2.02
46	46	1.92
47	47	1.81
48	48	1.71
49	50	1.49
51	52	1.27
53	54	1.04
55	56	.80
57	57	.55
59	60	.29
61	62	.02
63	64	-.25
65	66	-.54
67	68	-.83
69	70	-1.12
71	72	-1.43
73	74	-1.73
75	76	-2.04
77	78	-2.34
79	80	-2.64
81	82	-2.93
83	84	-3.22
85	86	-3.49
87	88	-3.74
89	90	-3.98
91	92	-4.20
93	94	-4.40
95	96	-4.57
97	100	-4.82
101	104	-4.96
105	108	-4.97
109	112	-4.86
113	116	-4.63
117	120	-4.29
121	124	-3.87
125	128	-3.39
129	132	-2.86
133	136	-2.31
137	140	-1.77
141	144	-1.24
145	148	-.74
149	152	-.29
153	156	.12
157	160	.48
161	164	.79
165	168	1.06
169	172	1.29
173	176	1.49
177	180	1.66

181	184	1.81
185	188	1.95
189	192	2.08
193	200	2.33
201	208	2.59
209	216	2.86
217	224	3.17
225	232	3.51
233	240	3.89
241	248	4.31
249	256	4.79
257	264	5.31
265	272	5.88
273	280	6.50
281	288	7.19
289	296	7.93
297	304	8.75
305	312	9.63
313	320	10.58
321	328	11.60
329	336	12.71
337	344	13.90
345	352	15.18
353	360	16.54
361	368	18.01
369	376	19.57
377	384	21.23
385	392	23.01
393	400	24.90
401	408	26.90
409	416	29.03
417	424	31.28
425	432	33.67
433	440	36.19
441	448	38.86
449	456	41.67
457	464	44.63
465	472	47.76
473	480	51.03

Table 3-D.4b. Absolute Threshold Table

This table is valid at a sampling rate of 44.1 kHz.

A value of 0 dB represents a level in the absolute threshold calculation of 96 dB below the energy of a sine wave of amplitude +-32760.

index lower	(line) higher	absthr dB
1	1	45.05

2	2	25.87
3	3	18.70
4	4	14.85
5	5	12.41
6	6	10.72
7	7	9.47
8	8	8.50
9	9	7.73
10	10	7.10
11	11	6.56
12	12	6.11
13	13	5.72
14	14	5.37
15	15	5.07
16	16	4.79
17	17	4.55
18	18	4.32
19	19	4.11
20	20	3.92
21	21	3.74
22	22	3.57
23	23	3.40
24	24	3.25
25	25	3.10
26	26	2.95
27	27	2.81
28	28	2.67
29	29	2.53
30	30	2.39
31	31	2.25
32	32	2.11
33	33	1.97
34	34	1.83
35	35	1.68
36	36	1.53
37	37	1.38
38	38	1.23
39	39	1.07
40	40	.90
41	41	.74
42	42	.56
43	43	.39
44	44	.21
45	45	.02
46	46	-.17
47	47	-.36
48	48	-.56
49	50	-.96
51	52	-1.37
53	54	-1.79
55	56	-2.21
57	58	-2.63
59	60	-3.03
61	62	-3.41
63	64	-3.77

65	66	-4.09
67	68	-4.37
69	70	-4.60
71	72	-4.78
73	74	-4.91
75	76	-4.97
77	78	-4.98
79	80	-4.92
81	82	-4.81
83	84	-4.65
85	86	-4.43
87	88	-4.17
89	90	-3.87
91	92	-3.54
93	94	-3.19
95	96	-2.82
97	100	-2.06
101	104	-1.33
105	108	-.64
109	112	-.04
113	116	.47
117	120	.89
121	124	1.23
125	128	1.51
129	132	1.74
133	136	1.93
137	140	2.11
141	144	2.28
145	148	2.45
149	152	2.63
153	156	2.82
157	160	3.03
161	164	3.25
165	168	3.49
169	172	3.74
173	176	4.02
177	180	4.32
181	184	4.64
185	188	4.98
189	192	5.35
193	200	6.15
201	208	7.07
209	216	8.10
217	224	9.25
225	232	10.54
233	240	11.97
241	248	13.56
249	256	15.30
257	264	17.23
265	272	19.33
273	280	21.64
281	288	24.15
289	296	26.88
297	304	29.84
305	312	33.04

313	320	36.51
321	328	40.24
329	336	44.26
337	344	48.58
345	352	53.21
353	360	58.17
361	368	63.48
369	376	69.13
377	384	69.13
385	392	69.13
393	400	69.13
401	408	69.13
409	416	69.13
417	424	69.13
425	432	69.13
433	440	69.13
441	448	69.13
449	456	69.13
457	464	69.13

Table 3-D.4c. Absolute Threshold Table

This table is valid at a sampling rate of 48.0 kHz.

A value of 0 dB represents a level in the absolute threshold calculation of 96 dB below the energy of a sine wave of amplitude +-32760.

index (line) lower	**higher**	**absthr. dB**
1	1	42.10
2	2	24.17
3	3	17.47
4	4	13.87
5	5	11.60
6	6	10.01
7	7	8.84
8	8	7.94
9	9	7.22
10	10	6.62
11	11	6.12
12	12	5.70
13	13	5.33
14	14	5.00
15	15	4.71
16	16	4.45
17	17	4.21
18	18	4.00
19	19	3.79
20	20	3.61
21	21	3.43
22	22	3.26
23	23	3.09
24	24	2.93

25	25	2.78
26	26	2.63
27	27	2.47
28	28	2.32
29	29	2.17
30	30	2.02
31	31	1.86
32	32	1.71
33	33	1.55
34	34	1.38
35	35	1.21
36	36	1.04
37	37	.86
38	38	.67
39	39	.49
40	40	.29
41	41	.09
42	42	-.11
43	43	-.32
44	44	-.54
45	45	-.75
46	46	-.97
47	47	-1.20
48	48	-1.43
49	50	-1.88
51	52	-2.34
53	54	-2.79
55	56	-3.22
57	58	-3.62
59	60	-3.98
61	62	-4.30
63	64	-4.57
65	66	-4.77
67	68	-4.91
69	70	-4.98
71	72	-4.97
73	74	-4.90
75	76	-4.76
77	78	-4.55
79	80	-4.29
81	82	-3.99
83	84	-3.64
85	86	-3.26
87	88	-2.86
89	90	-2.45
91	92	-2.04
93	94	-1.63
95	96	-1.24
97	100	-.51
101	104	.12
105	108	.64
109	112	1.06
113	116	1.39
117	120	1.66
121	124	1.88

125	128	2.08
129	132	2.27
133	136	2.46
137	140	2.65
141	144	2.86
145	148	3.09
149	152	3.33
153	156	3.60
157	160	3.89
161	164	4.20
165	168	4.54
169	172	4.91
173	176	5.31
177	180	5.73
181	184	6.18
185	188	6.67
189	192	7.19
193	200	8.33
201	208	9.63
209	216	11.08
217	224	12.71
225	232	14.53
233	240	16.54
241	248	18.77
249	256	21.23
257	264	23.94
265	272	26.90
273	280	30.14
281	288	33.67
289	296	37.51
297	304	41.67
305	312	46.17
313	320	51.04
321	328	56.29
329	332	61.94
333	340	68.00
341	348	68.00
349	356	68.00
357	364	68.00
365	372	68.00
373	380	68.00
381	388	68.00
389	396	68.00
397	404	68.00
405	412	68.00
413	420	68.00
421	428	68.00

Table 3-D.5. Layer I and Layer II Coder Partition Table

Index	ωlown+1 ωhighn	widthn
0	1	0
1	17	0
2	33	0
3	49	0

4	65	0
5	81	0
6	97	0
7	113	0
8	129	0
9	145	0
10	161	0
11	177	0
12	193	0
13	209	1
14	225	1
15	241	1
16	257	1
17	273	1
18	289	1
19	305	1
20	321	1
21	337	1
22	353	1
23	369	1
24	385	1
25	401	1
26	417	1
27	433	1
28	449	1
29	465	1
30	481	1
31	497	1
32	513	1