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REPORT

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PROJECT	Sound Development
Location	Zurich
Country	Switzerland

Created by:

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Dipl. El.-ing. ETH

1. General

This report shows and discusses the results of the acoustical measurements performed in the Studio Rooms of "Sound Development" to document and illustrate the acoustical implications of the facility. The following parameters have been measured:

- Frequency Dependant Reverberation Times
- Frequency Response
- Sound Isolation Values

2. Measurements of Room Acoustics

2.1. Measured RT_{60} Reverberation Times Control Room

Graph 1 shows the resulting reverberation times measured inside the Control Room in its final setup, with all acoustical and technical equipment installed.

For the measurements, four different Loudspeaker/Microphone positions were used. This results in better statistics for low frequency reverberation times, since for frequencies lower than a few hundred Hertz the measurement results show modal decay rather than reverberation times. Frequency Resolution in the graph below is one Octave.

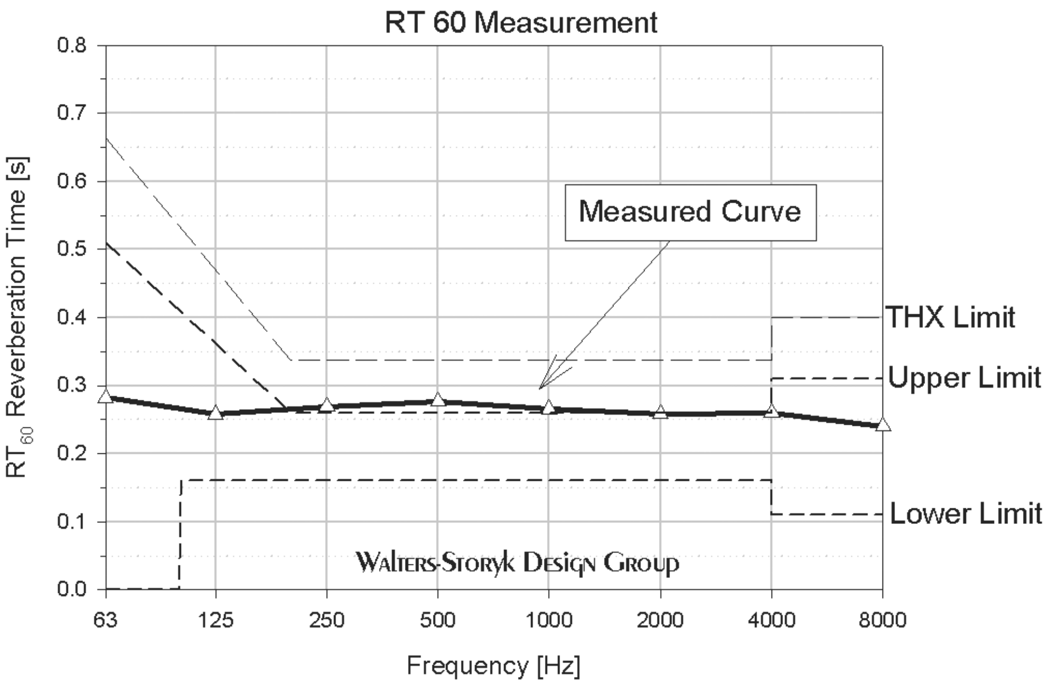


Fig. 1: Reverberation Time vs. Frequency with the recommended limits suggested by ITU and THX
This is for a Control Room of respective volume (about $55m^3$).

The RT_{60} Curve in Fig.1 shows a very flat and even Frequency Response – all values are between 0.25s and 0.28s, even at Frequencies below 200Hz, where the Reverberation Times due to ITU and THX could rise. The general impression is a very well controlled Room at the "live" end of the scale (upper ITU Limit).

2.2. Measured RT_{60} Reverberation Times inside the "Studiobox"

Next to the control room, a "Studiobox" Iso-Booth for Vocal recording is installed. The Reverberation Times are shown in Graph 2. For the measurements, three different Loudspeaker/Microphone Positions were chosen. Frequency Resolution is one Octave.

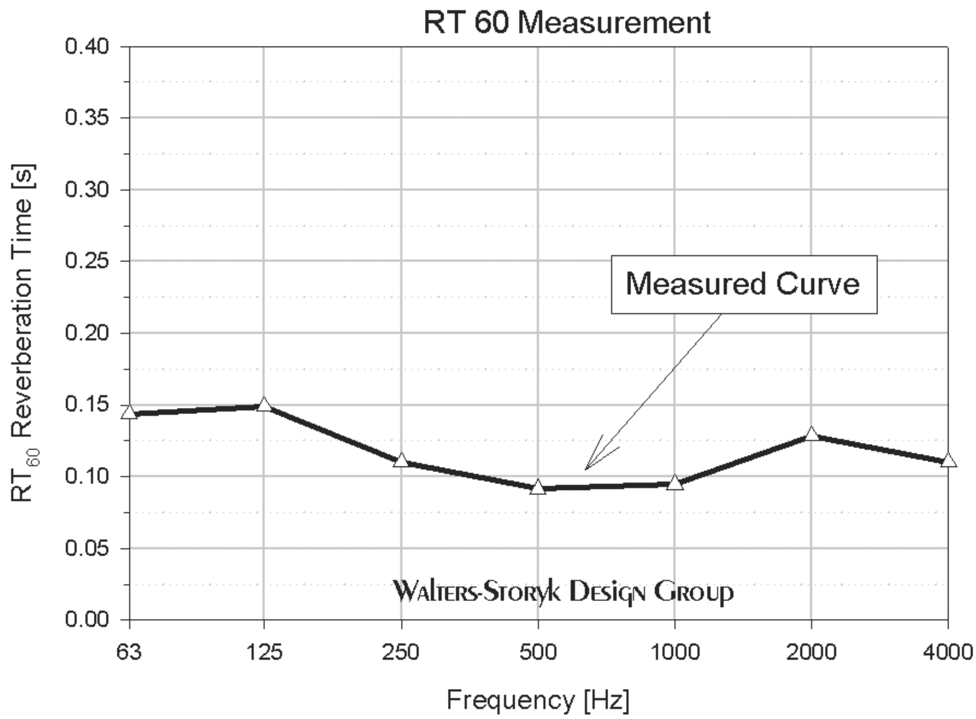


Fig. 2: Reverberation Times inside the „Studiobox".

Reverberation Times are very well balanced for the Studiobox, too: In all Frequency Bands the RT_{60} values never exceed 0.15s. It is remarkable that for higher frequencies the Reverberation Times do not fall below 0.1s which enables recordings that do not sound too dry or even "dead", without risking a "roomy" sound.

2.3. Frequency Response of Main Monitors

Another critical parameter for the acoustical quality of an audio control room is the frequency response of the main monitors. Ideally this would be an even response with low cut off frequency in Bass and high cut off frequency for Treble. For this specific case with Dynaudio AIR Loudspeakers installed in the studio, the internal digital parametric filters could be used for the perfection of the Frequency Response at the listening position.

The measurements were performed at ear height (1.20m) at the listening position. The initial filter settings were set to "flat". Numerous measurements were performed for proper averaging.

Graph 3 shows the Frequency Response of the original Setup with already optimized Loudspeaker positioning and linear EQ-Settings as measured at listening position. Noticeable: There is a dip in level at around 80Hz, a rise around 200Hz and a peak at 1.2kHz. High Frequency Response from 2kHz upwards is very linear, which implies no discreet early reflections at listening position.

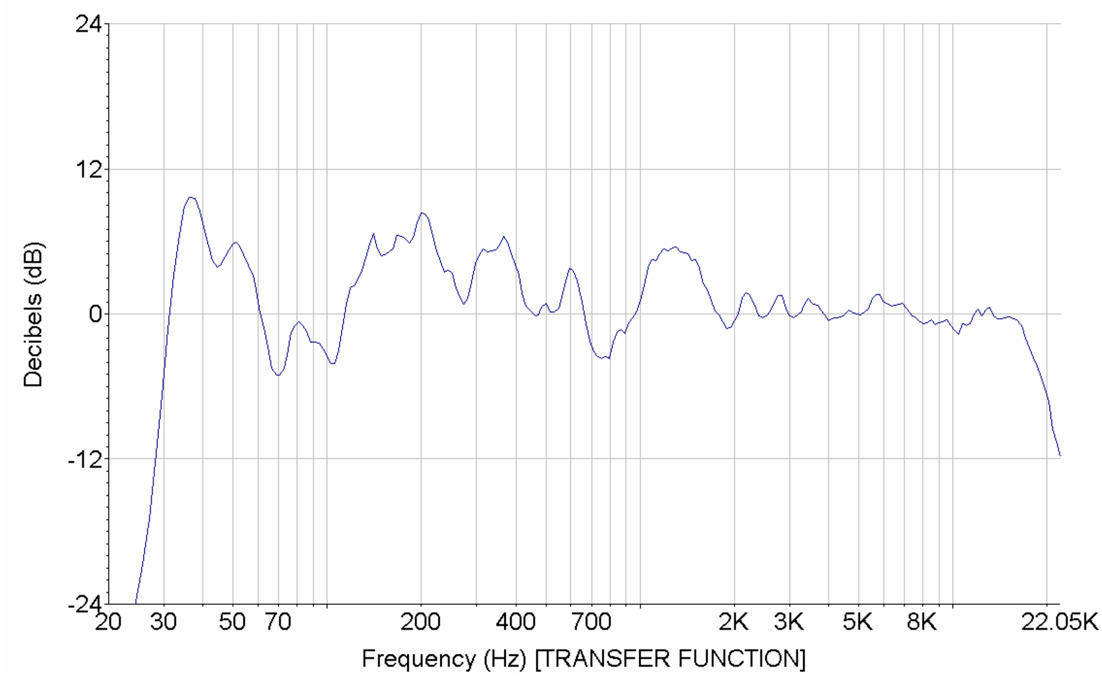


Fig. 3: Frequency Response left Main Monitor, optimized position, EQ linear

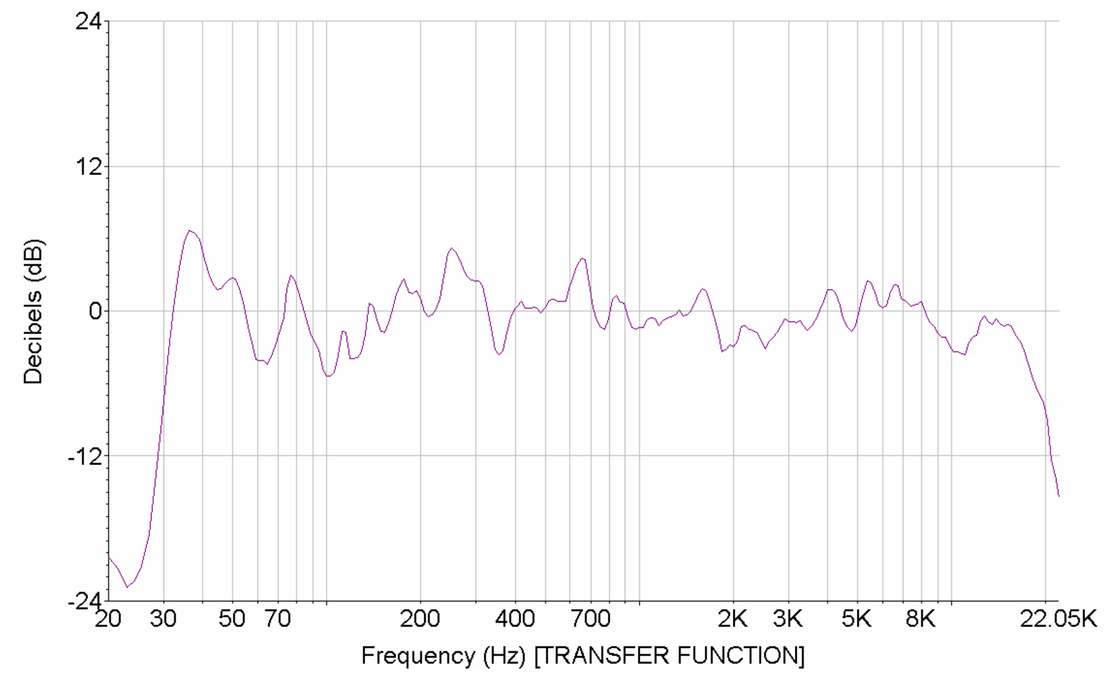


Fig. 4: Frequency Response left Main Monitor, optimized position, EQ WSDG-E Setup

Thanks to the ability to use parametric equalizers, the Frequency Response at the listening position could be linearized as shown in Graph 4. Between 32Hz and 18kHz, the Frequency Response shows extremely linear behaviour (high resolution, no Time-Window used).

In Graph 5 one can see the measurements of both left and right main Monitors together. The Frequency Response at low frequencies is even more equal now. The attenuation at high Frequencies (above 8kHz) results from phase differences between left and right Speaker at the Mic Position and is not audible.

The Settings of the internal Dynaudio AIR Equalizer are shown in the Appendix C.

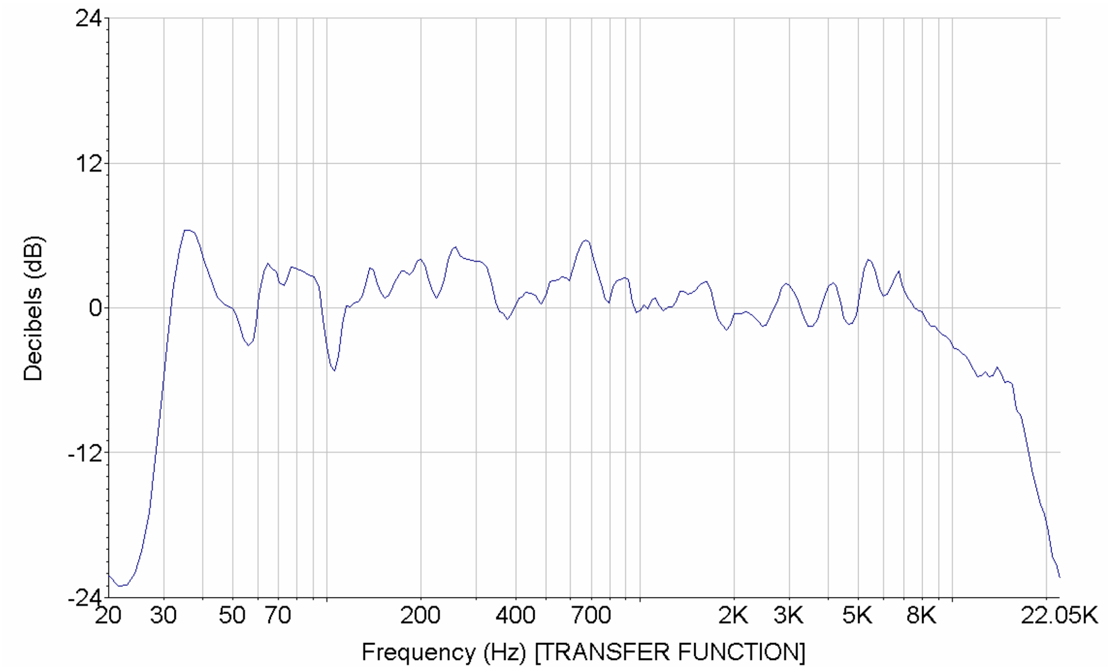


Fig. 5: Both Dynaudio Monitors with WSDG EQ. Attenuation at high Frequencies due to measurement system.

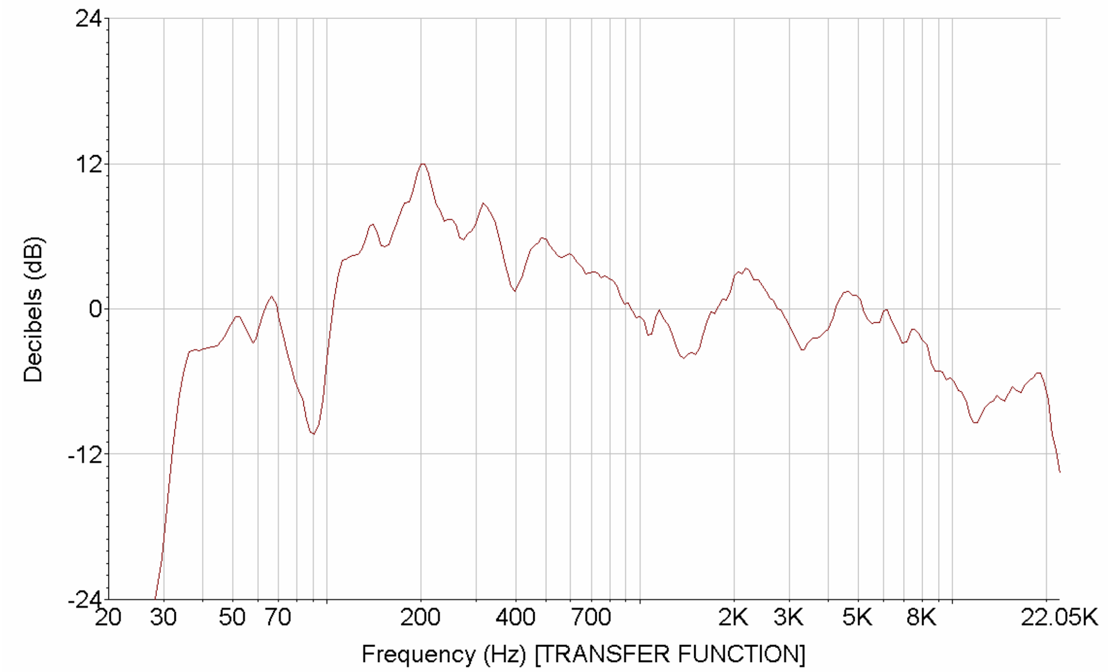


Fig. 6: Both Genelec Monitors with WSDG setting for internal Dip-Switches. Attenuation at high Frequencies due to measurement system.

Graph 6 shows the Frequency Response of the Genelec Monitors that are used as alternative loudspeaker pair. Quite obvious is the influence of the positioning on the table: The Level around 200Hz rises up to 12dB compared to the rest of the Frequency Bands. Since these Speakers are used not as reference speakers but just as an alternative selection, this behaviour is not dramatic. At a later stage the addition of a parametric equalizer could be discussed.

2.4 Sound Isolation Measurements

To verify the Sound Isolation Values $D_{nT,w}$ between the Iso-Booth (Studiobox) and the Control Room, two different measurements were performed: One shows the Sound Isolation of the Studiobox to the room its positioned in, the other measurement represents the Sound Isolation between Studiobox and Control Room. The results are measured in $D_{nT,w}$ (analogue to Sound Transmission Class, STC) and are shown below.

	Sound Isolation Value (analogue to STC) $D_{nT,w}$
Studiobox – Control Room	64dB
Studiobox - Office Room	37dB

The exact frequency dependent measurement curves are shown in appendix D.

3. Summary

3.1. Measurements

2.5.1 Reverberation Times

To judge the measured RT60 times of the Control Room, recommended limits specified by ITU[1] and THX were considered. The resulting curve (Graph 1) is very linear around 0.26 seconds, from low frequencies (63Hz) up to higher frequencies (8kHz) without any peaks or dips. This outperforms the ITU specifications for linearity, mainly in the low frequencies.

As a result of the acoustical design and as illustrated by these measurements one can expect a very natural sounding room rather than often heard “dead” rooms.

In the RT_{60} graph for the Studiobox (Graph 2) one can observe similar behaviour: The Frequency Response of the Reverberation Times is very linear on a low, well controlled level. Even at low Frequencies the RT_{60} times do not rise above 0.15 seconds which is very special for such a small room. This leads to a neutral acoustical environment that prevents coloration of tone in recordings.

2.5.2 Frequency Response

The Frequency Response curves as presented in Graphs 3 – 5 are very broadband from 30Hz up to 18kHz. The following observations can be made:

- Linearity was optimized through re-positioning of the speakers (mainly linearity of the low frequency area)
- The use of internal digital EQ enabled a very flat Frequency Response at the Listening Position. A total of four parametric bands were needed for each channel.
- The differences in Level between the left and right Monitors are mainly in the low frequency band. This is due to not entirely symmetrical room-load at low frequencies.

[1] International Telecommunication Union

2.5.2 Sound Isolation

The Sound Isolation Values of the Studiobox to the control room (and vice versa) are high enough to fulfil the requested specification. Only very high level sources such as Guitar Amplifiers will probably be heard in the Control Room.

At frequencies below 200Hz, Sound Isolation gradually becomes less. So during critical recording sessions it is recommended to control the level inside the control room to prevent spill into the Studiobox.

To improve Sound Isolation, the entrance door into the control room could be replaced with an approved sound isolation door that completely seals when closed. It is not a major issue to make this upgrade later when needed.

3.2. Recommendations

All measured acoustical parameters meet high standards and allow working on a professional level with a wide area of setups and recording tasks. The rooms are future proof since during conceptual phase an upgrade to Surround Sound (5.1) was already taken into consideration. The equipment can easily be expanded or replaced with respective technology. This however would bring forward the need of re-calibrating all monitor loudspeakers at due time.

The large room, currently used as office space, lounge and rehearsal room, will be converted into a recording space at a later date. It is recommended to perform acoustical measurements to correctly specify necessary acoustical treatment in the room to optimize Room Acoustics. Possibly a concept introducing variable acoustics could be used to change the Reverberation Times according to the material and/or instruments to be recorded. Especially with modern 5.1 Surround-Sound Recordings (5 or more Room Microphones) the acoustics of a recording space gain importance.

((End of Report))

It was a pleasure working with you all on this project, and we are happy that your positive impression of the result meets ours: The Studio Facilities of “Sound Development” meets professional standards. We hope you will create numerous successful productions and are looking forward to work with you all again.

With warm regards,

Checked by:

Gabriel Hauser
Dipl. El.-Ing. ETH

Dirk Noy
Dipl. Phys.

APPENDIX

A. Acoustical Measurements

A.1. General

Acoustical measurements were performed to retrieve the Impulse Responses of the Loudspeaker-Room-Combination. This characteristical data includes all parameters needed for the analysis of internal acoustics (such as Frequency Response, Reverberation Times, Reflection Pattern and so on). All Sound-Level-Difference Measurements were also performed this way.

The standards SIA181, DIN 15996, DIN 1522210 and ISO 140 were the basis for all performed measurements and calculations.

A.2. Technical Equipement

Measurements for internal acoustics were performed using the acoustical measurement software *“SIA-SMAART”* that was running on a PC-compatible laptop computer. As microphone preamplifier and 24bit Analog-to-Digital Converter a *“Sounddevices USB Pre”* USB device was used. The signal was received by a measurement microphone *“Earthworks M30”*, equipped with a 1/4” microphone-capsule. The used measurement signal, Pink Noise, was either sent to the monitor loudspeakers that were installed in the room or to the *“Komet KO55”* powered Omni-Speaker.

For Reverberation Time Measurements different measurement position were chosen in order to obtain correct statistical measurement results. Those four measured Impulse-Responses were then averaged for analysis.

A.3. Procedure

A.3.a Reverberation Times – Frequency Response – Impulse Response

Measurements were performed at different Sender-Receiver positions in order to determine the correct Room-Impulse-Response. The measurement signal was reproduced by the speaker and the computer based measurement system calculated the Impulse Response via convolution of the input with the original Pink Noise Signal. The received data was afterwards analyzed with different frequency resolutions.

A.3.b Sound-Level-Difference $D_{nt,w}$

As source for these measurements, an active JBL PA-Loudspeaker was used in order to reproduce Sound-Levels up to 120dB. The used measurement signal was Pink Noise. After having performed the reference measurement in the Sending Room, the microphone was positioned in the Receiving Room and the measurement was repeated. This allows absolute accurate calibration between the two measurements since they use the same microphone with the exact same Preamplifier-A/D-Converter. From these two curves and the Reverberation Time for the Receiving Room, the Standard-Sound-Level-Difference D_{nT} and the Single-Value $D_{nT,w}$ were calculated.

B. Reverberation Time – Impulse Response

The RT_{60} Reverberation Time is a widely used parameter to characterize the reverberation behavior of a room. It describes the time in seconds that passes after shutting off a sound source until the sound level in the room is reduced by 60dB. This duration is obtained from analyzing the slope of a straight line that approximates the decay of the sound-energy in the room. RT_{60} times usually are frequency dependant, i.e. it varies with the pitch. Standard is an analysis of RT_{60} times is done in eight octave-bands between 63Hz and 8kHz.

As an example the figure below (B1) shows the decay of sound-energy in a room at f=1kHz with its respective approximating straight line.

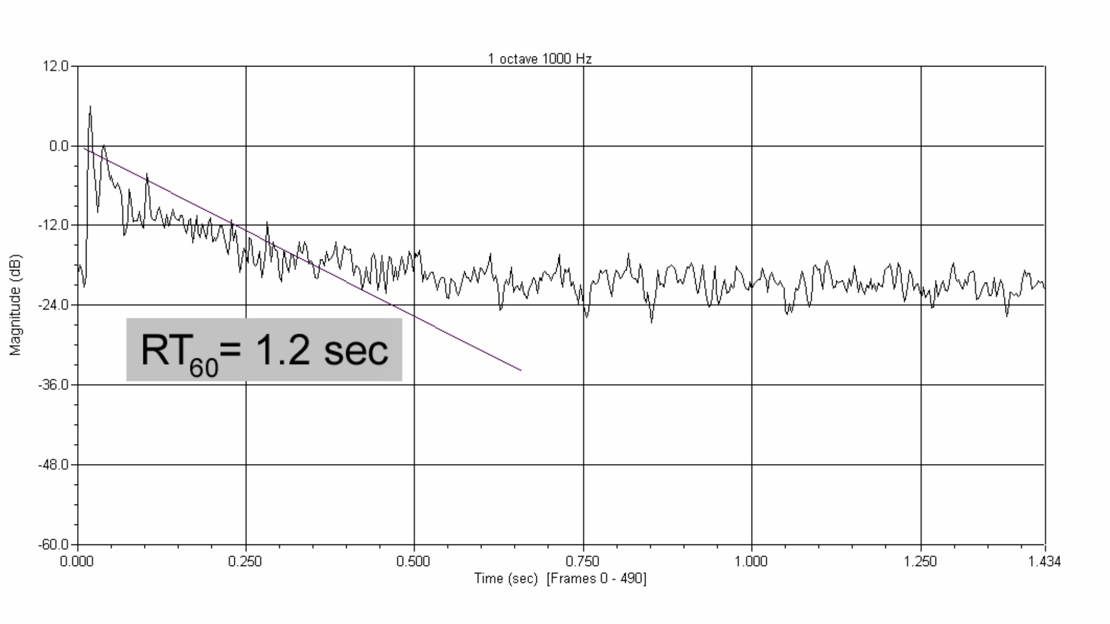


Fig. B1: Representation of a RT-60 Reverberation Time evaluation.
The slope of the Sound-Level-Decay determines the RT-60 value.

The charts below (B1-B2) show the measured Reverberation Times (1/3 octave) for all rooms.

RT60 [s]	Position 1	Position 2	Position 3	Position 4	Position 5	*Average*
40Hz	0.75	0.48	0.60	0.48	0.86	0.63
50Hz	0.63	0.42	0.26	0.53	0.70	0.51
63Hz	0.43	0.31	0.31	0.37	0.45	0.37
80Hz	0.28	0.26	0.31	0.26	0.30	0.28
100Hz	0.25	0.27	0.36	0.27	0.29	0.29
125Hz	0.30	0.25	0.24	0.45	0.30	0.30
160Hz	0.30	0.26	0.19	0.34	0.24	0.27
200Hz	0.23	0.28	0.26	0.24	0.24	0.25
250Hz	0.28	0.33	0.29	0.33	0.29	0.31
315Hz	0.37	0.28	0.28	0.24	0.22	0.28
400Hz	0.22	0.36	0.34	0.18	0.29	0.28
500Hz	0.22	0.26	0.33	0.25	0.23	0.26
630Hz	0.23	0.27	0.27	0.25	0.20	0.24
800Hz	0.22	0.28	0.24	0.26	0.30	0.26
1000Hz	0.29	0.31	0.32	0.25	0.22	0.28
1250Hz	0.23	0.34	0.28	0.23	0.25	0.27
1600Hz	0.25	0.28	0.29	0.26	0.26	0.27
2000Hz	0.29	0.24	0.28	0.21	0.25	0.26
2500Hz	0.26	0.25	0.34	0.21	0.28	0.27
3150Hz	0.27	0.24	0.32	0.21	0.27	0.26
4000Hz	0.26	0.23	0.30	0.21	0.26	0.25

Tab. B1: Reverberation Times Control Room

RT60 [s]	Position 1	Position 2	Position 3	*Average*
40Hz	0.43	0.39	0.19	0.34
50Hz	0.36	0.31	0.16	0.27
63Hz	0.17	0.16	0.16	0.16
80Hz	0.16	0.14	0.16	0.15
100Hz	0.16	0.14	0.15	0.15
125Hz	0.13	0.12	0.12	0.13
160Hz	0.11	0.11	0.14	0.12
200Hz	0.12	0.15	0.09	0.12
250Hz	0.13	0.10	0.11	0.11
315Hz	0.10	0.10	0.08	0.09
400Hz	0.09	0.10	0.06	0.08
500Hz	0.09	0.09	0.05	0.08
630Hz	0.10	0.12	0.09	0.10
800Hz	0.11	0.09	0.06	0.09
1000Hz	0.10	0.10	0.06	0.09
1250Hz	0.09	0.11	0.08	0.09
1600Hz	0.10	0.11	0.13	0.11
2000Hz	0.12	0.13	0.12	0.12
2500Hz	0.12	0.13	0.14	0.13
3150Hz	0.12	0.13	0.13	0.13
4000Hz	0.10	0.13	0.12	0.12

Tab. B2: Reverberation Times Studiobox

C. Equalizer Settings Dynaudio AIR20

WSDG-Setup	Filter Type	Frequency	Bandwidth	Slope	Gain
Band #1	2	100	0.2oct	9	+10dB
Band #2	1	1200	1.0oct	9	-3dB
Band #3	1	200	2.2oct	9	-4dB
Band #4	1	730	1.4oct	5	+4dB

D. Sound Level Difference $D_{n,T}$

D.1. General

The Standard Sound-Level-Difference D_{nT} describes the acoustical isolation of an acoustical boundary in third octave frequency bands between 100Hz and 3150Hz. The calculation for the frequency dependant Standard-Sound-Level Difference D_{nT} is as follows:

$$D_{nT} = L_1 - L_2 + 10 \cdot \log\left(\frac{T \cos \vartheta}{T_0}\right)$$

D_{nT}	Standard-Sound-Level-Difference [dB]
L_1	Level in sender room [dB SPL]
L_2	Level in receiver room [dB SPL]
T	Average reverberation time [s]
T_0	Reference reverberation time [s]
ϑ	Angle of Incident [°]

The higher the values for Standard-Sound-Level-Difference D_{nT} the better the isolation, the lower the values the higher the transmission rate.

To determine the single value $D_{nT,w}$ of an acoustical boundary, its normalized Sound Level Differences in the 16 octave bands are compared with those of the reference contour. This reference curve is shifted vertically relative to the test data until the following conditions are fulfilled: (1) the sum of the deviations below the contour does not exceed 32dB and (2) the maximum deviation at a single test frequency shall not exceed 8dB. The Standard Sound-Level-Difference at the intersection of the shifted contour and the 500Hz ordinate defines the single value Standard-Sound-Level-Difference $D_{nT,w}$.

D.2. Sound-Level-Difference ($D_{n,T}$) in Third Octave Frequency Bands

All obtained measurement-curves are listed below. The values plotted in the graph may differ slightly from the numbers in the chart below. This is due to the fact that the chart incorporates rounded values but for the graph the exact numbers were used.

For all calculations the exact measuring values were used because as soon as calculations are done, the rounding errors accumulate and can result in shifts of several decibels.

Graph D1 shows the frequency dependant Sound Level Difference. The **64dB** of Sound Isolation between Studiobox and Control Room can be rated as “good”, especially when taking into consideration that the door to the control room is not a sound proofing door. So with replacing that door with an acoustical door some additional decibels of Sound Isolation can be gained.

The measurement of the Studiobox itself (Graph D2) rates at 37dB of Sound Isolation and meets the manufacturer’s specifications. The Sound Isolation Value of still 21dB at 100Hz is considerable.

Standard-Schallpegeldifferenz D_{nT} und $D_{nT,w}$

nach SIA 181 - ISO 140/IV - DIN 522210/5

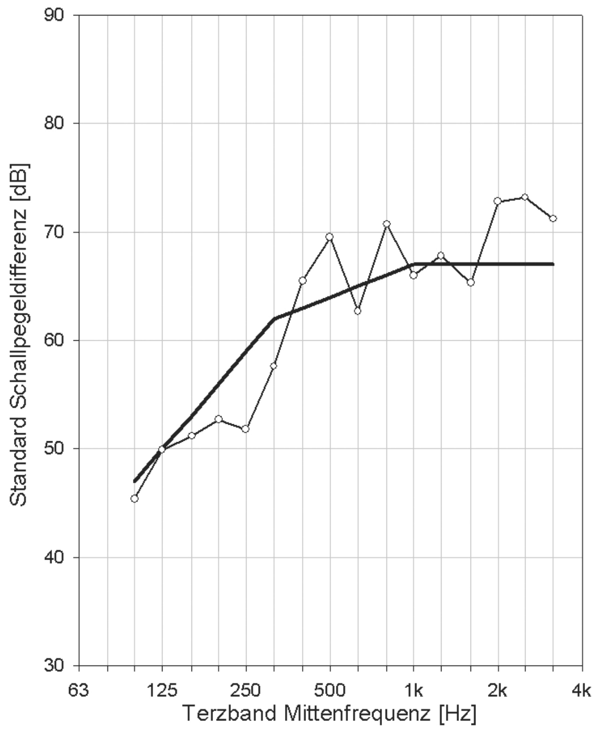
Projekt: Sound Development
Datum: 29.9.03
Erstellt durch: GH

Messung A

Studiobox - Regieraum

Einzahlbewertete Standard-Schallpegeldifferenz

$D_{nT,w}$ = 64 dB



- Lautsprecher möglichst nahe am Boden
- Schalleinfallswinkel ϕ = 45° +/- 5°
- Prüfschall: Breitbandrauschen
- Bestimmung Sendepegel L_1: 5 bis 10mm vor Prüffläche
- Bestimmung Empfangspegel L_2: Mittelwert, mehrere Messpositionen
- Berechnung D_{nT} = $L_1 - L_2 + 10 \times \log((T \times \cos\phi) / T_0)$
- T: Nachhallzeit RT_{60} im Empfangsraum
- T_0: Bezugsnachhallzeit RT_{60} (gemäss SIA 181)

MESSUNG																		
Frequenz	f	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	Hz
Durchschn. Sendepegel	L1	93	88	92	88	82	84	90	93	86	93	87	90	87	94	95	93	dB
Durchschn. Empfangspegel	L2	42	33	36	31	25	21	20	18	18	17	16	17	17	16	16	17	dB
Nachhallzeit	T	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	s
10 log T/T0		-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	
Standard Schallpegeldifferenz	DnT	45	50	51	53	52	58	66	70	63	71	66	68	65	73	73	71	dB

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Fig. D1: Sound Isolation Measurement: Studiobox – Control Room

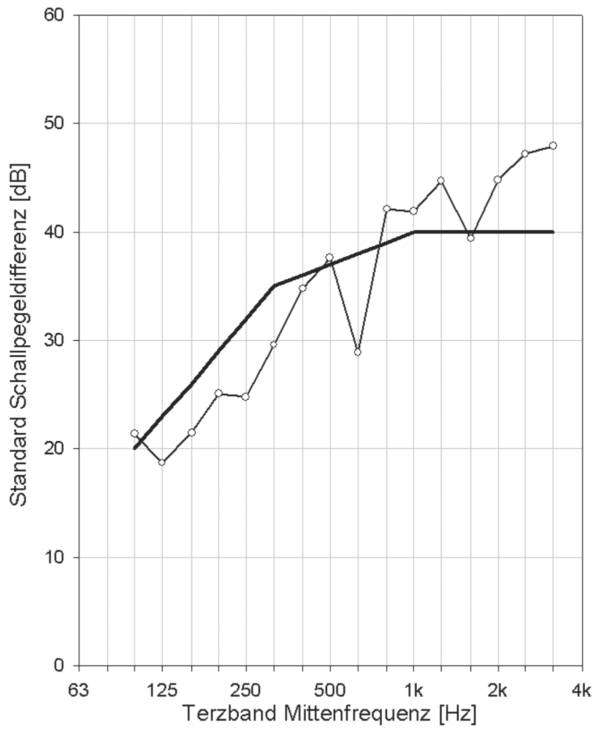
Standard-Schallpegeldifferenz D_{nT} und $D_{nT,w}$

nach SIA 181 - ISO 140/IV - DIN 522210/5

Projekt: Sound Development
Datum: 29.9.03
Erstellt durch: GH

Messung B

Studiobox



Einzahlbewertete Standard-Schallpegeldifferenz

$D_{nT,w}$ = 37 dB

- Lautsprecher möglichst nahe am Boden
- Schalleinfallswinkel ϕ = 45° +/- 5°
- Prüfschall: Breitbandrauschen
- Bestimmung Sendepegel L_1: 5 bis 10mm vor Prüffläche
- Bestimmung Empfangspegel L_2: Mittelwert, mehrere Messpositionen
- Berechnung D_{nT} = $L_1 - L_2 + 10 \times \log((T \times \cos\phi) / T_0)$
- T: Nachhallzeit RT_{60} im Empfangsraum
- T_0: Bezugsnachhallzeit RT_{60} (gemäss SIA 181)

MESSUNG																		
Frequenz	f	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	Hz
Durchschn. Sendepegel	L1	93	88	92	88	82	84	90	93	86	93	87	90	87	94	95	93	dB
Durchschn. Empfangspegel	L2	69	67	69	61	55	52	54	53	56	49	44	45	47	47	45	43	dB
Nachhallzeit	T	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.6	0.5	0.5	0.4	s
10 log T/T0		-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	0	-1	-2	-2	-2	
Standard Schallpegeldifferenz	DnT	21	19	22	25	25	30	35	38	29	42	42	45	39	45	47	48	dB

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von 2

Fig. D2: Sound Isolation Measurement: Studiobox