Consumer Technology Association™

ANSI/CTA Standard

Standard Method of Measurement for Subwoofers

ANSI/CTA-2010-B R-2020

Approved American National Standard ANSI

November 2014

NOTICE

(Formulated under the cognizance of the CTA **R3 Audio Systems Committee**.)

Published by
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Technology & Standards Department
www.cta.tech

FOREWORD

The purpose of the tests described in this standard is to provide data that will help the consumer understand how loud in volume, and how low in frequency, the subwoofer is capable of operating. The reporting format of the test results should also help the consumer determine which subwoofers may work well with different full-range loudspeaker systems which carry ANSI/CEA-2034 ratings.

This standard describes how to measure and report the maximum usable sound pressure level of a subwoofer, and how to measure and report the input impedance of a passive subwoofer. It also describes how to calculate and report the required output power of the amplifier needed for the consumer to get the desired SPL from a passive subwoofer.

Finally, it includes a number of informational annexes to help readers gain a more thorough understanding of techniques for acquiring loudspeaker data in both anechoic and non-anechoic environments.

When used properly this standard should assist manufacturers in accurately measuring the capabilities of a subwoofer and specifying them to consumers. Using this in conjunction with ANSI/CEA-2034 Standard Method of Measurement for In-Home Loudspeakers for full-range loudspeaker systems, the ANSI/CEA-2010-B subwoofer ratings should make it easier for the consumer to select, purchase, and enjoy a subwoofer that will complement their main full-range loudspeaker system.

This standard was developed by the Consumer Electronics Association's Audio Systems Committee (CEA R3 Committee).

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Figures

Tables

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STANDARD METHOD OF MEASUREMENT FOR SUBWOOFERS

1 Scope

This standard defines a method for measuring the audio performance of subwoofers, both passive and powered.

2 Revision History

2.1 CEA-2010-A

Increased measurement distance from 1 m to 3 m
Corrected procedure for averaging to be done using pressure
Added Table A-3 showing example invoking rule of non-measurable SPL within one of the bandwidths

2.2 CEA-2010-B

Modified the Forward
Include passive subwoofer
Added section for testing the maximum continuous SPL
Added 80 Hz to 160 Hz test frequencies to the maximum peak SPL test
Modified the distortion threshold for the maximum peak SPL test and separated the thresholds into three separate bands. These thresholds correspond to masking thresholds for test tones of 100 dB SPL.
Added a procedure to correlate the maximum peak SPL results with the maximum continuous SPL in order to derive a broad band (from 20 Hz to 160 Hz) SPL.
Added a section for impedance measurement of passive subwoofers
Added a section for recommended amplifier size for passive subwoofers
Added a section about frequency response overlap between the subwoofer & full-range systems to gauge usefulness together
Added an appendix listing the test equipment required for the measurements specified in CEA-2010-B
Moved the section on Ground Plane Measurements to an appendix
Moved the section on Room Correction Factor to an appendix
Added an appendix for the alternate determination of maximum continuous SPL in a non-anechoic environment
Added a section for matching a subwoofer to a full-range system using ANSI/CEA-2034 ratings
Added a section for consolidated reporting requirements
Added Normative References section
Added Definitions
Added Symbols & Abbreviations
Added requirement for recording environmental conditions during testing

3 References

3.1 Normative References

The following standards contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed here.

3.1.1 Normative Reference List

ANSI/CEA-2034, *Standard Method of Measurement for In-Home Loudspeakers* (2013)

IEC Publication 225, *Octave, Half-Octave, and Third-Octave Band Filters Intended for the Analysis of Sound and Vibration* (1966)

3.1.2 Normative Reference Acquisition

CEA Standards:
Techstreet, 3916 Ranchero Drive, Ann Arbor, MI, USA 48108; Phone 800-699-9277; Fax 734-780-2046; Internet http://www.techstreet.com; Email techstreet.service@thomsonreuters.com

IEC Standards:
International Electrotechnical Commission, IEC Central Office, 3, rue de Varembé
P.O. Box 131, CH - 1211 Geneva 20 – Switzerland; Phone +41 22 919 02 11;
Fax +41 22 919 03 00; Internet http://www.iec.ch

3.2 Informative References

The following references contain provisions that, through reference in this text, constitute informative provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below.

3.2.1 Informative Reference List

Gander, Mark, Ground Plane Acoustic Measurements of Loudspeaker Systems, *Journal of the Audio Engineering Society*, vol. 30, no. 10, p. 723 (1982).

IEC 60268-1 ed2.0 (1985-01), *Sound system equipment. Part 1: General*

IEC 60268-1-am1 ed2.0 (1988-01), *Amendment 1 - Sound system equipment. Part 1: General*

IEC 60268-1-am2 ed2.0 (1988-01), *Amendment 2 - Sound system equipment. Part 1: General*

IEC 60268-2 ed2.0 (1987-06), *Sound system equipment. Part 2: Explanation of general terms and calculation methods*

IEC 60268-2-am1 ed2.0 (1991-05), *Amendment 1 - Sound system equipment. Part 2: Explanation of general terms and calculation methods*

IEC 60268-5 ed3.1 Consol. with am1 (2007-09), *Sound system equipment - Part 5: Loudspeakers*

3.2.2 Informative Reference Acquisition

Audio Engineering Society Journal Articles:
Audio Engineering Society, Inc.; 60 East 42nd Street, Room 2520, New York, New York 10165-2520, USA; Tel: +1 212 661 8528; Fax: +1 212 682 0477; Internet: http://www.aes.org.

IEC Standards:
International Electrotechnical Commission, IEC Central Office, 3, rue de Varembé
P.O. Box 131, CH - 1211 Geneva 20 – Switzerland; Phone +41 22 919 02 11;
Fax +41 22 919 03 00; Internet http://www.iec.ch

3.3 Definitions

Passive Subwoofer	A subwoofer that does not include any active electronics
Powered Subwoofer	A subwoofer that includes an integrated power amplifier
Sound Pressure Level	The level of the acoustic pressure radiated by the device under test (DUT), typically measured at a sufficiently great distance and mathematically converted to an equivalent value for a 1 m free field measurement distance
Subwoofer	A loudspeaker designed to reproduce all or a portion of audio signals below 160 Hz

3.4 Symbols and Abbreviations

CF	Crest Factor
dB	decibel
DUT	Device Under Test
emf	(electro-motive force)
FFT	Fast Fourier Transform
HD+N	Harmonic Distortion + Noise
Hz	hertz
kHz	kilohertz
LF	Low Frequency
LFCS	Low Frequency Calibration Source
m	meter
MIV	Maximum Input Voltage
Pa	pascal
RCF	Room Correction Factor
rms	Root Mean Square
SPL	Sound Pressure Level Note: Throughout this standard all references to “dB SPL” refer to sound pressure level referenced to 20 µPa.
SPL_{MUCO}	Sound Pressure Level Maximum Usable Continuous Output
THD+N	Total Harmonic Distortion + Noise
V	volt

3.5 Compliance Notation

As used in this standard "shall" and "must" denote mandatory provisions of the standard. "Should" denotes a provision that is recommended but not mandatory. "May" denotes a feature whose presence does not preclude compliance, and implementation of which is optional. "Optional" denotes items that may or may not be present in a compliant device.

4 Test Setup and Conditions

> **CAUTION — WEAR EAR PROTECTION!** High sound levels can cause hearing damage with prolonged exposure. The operator is advised to wear appropriate protection such as ear plugs, preferably balanced attenuation devices which will still permit the operator to listen critically for distortion or other signs of distress in the device under test.

4.1 General Test Setup and Conditions

All testing shall be conducted in an anechoic chamber or equivalent environment.

During testing the DUT (device under test) shall be operated as per manufacturer's instructions. Complete systems shall be tested intact.

Testing should be conducted at an ambient temperature of 22 °C ± 5 °C (71.6 °F ± 9 °F) and a relative humidity of 30 % to 80 %. If the conditions are different, they shall be noted at the time of the test. Both of these items shall be recorded at the time of the tests. The ambient atmospheric pressure (in pascals) shall also be recorded.

The rms (root mean square) mains voltage used to power the DUT shall be within 1 % of the rated value specified for use by the DUT (i.e. for a DUT that requires 120 V, the mains voltage used shall be between 118.8 V and 121.2 V).

All test equipment used during the tests shall operate within its linear operating range. For example, amplifiers shall be sufficiently powerful that they rarely clip or distort during any of the tests.

If a crossover or filter network is specified by the manufacturer, it shall be installed according to the manufacturer's instructions and utilized for all tests, including frequency response and maximum SPL tests.

All test equipment shall be properly calibrated, and its calibration shall be documented.

The frequency response measurements shall be a transfer function type measurement employing a dual channel FFT (Fast Fourier Transform) or similar measurement apparatus.

The measurement system shall have an amplitude resolution of at least 0.1 dB.

See Appendix D for a list of all equipment needed to perform the tests in this standard.

4.2 Verification of Frequency Response at DUT Input Terminals

Measure the voltage at the DUT input terminals over the range 20 Hz to 20 kHz and confirm that it is within ± 0.5 dB from the specified voltage. If it deviates more than ± 0.5 dB the appropriate corrective action shall be taken, such as the addition of equalization prior to the input terminals of the DUT.

4.3 Measurement Resolution and Calibration

The measurement resolution shall be no wider than 1/20 octave. The specific bandwidth, resolution and test stimulus used should be documented.

Calibration of the microphone and data acquisition system, and of the post processing of the resulting data, shall be such that the system yields a measured sound level identical to that of a stable pure tone stepped or swept with an rms input voltage of 2.83 V (for passive systems only).

5 Frequency Response and Crossover Category

The frequency response of a subwoofer shall be measured in order to determine how high in frequency it may be used. This should be helpful in determining if a particular subwoofer can be recommended for use with a particular full-range loudspeaker system, or vise-versa. This assumes that a similar low frequency limit is known for the full-range loudspeaker system. Four *Crossover Categories* are introduced to simplify and assist with this matching process.

5.1 Data Acquisition

The loudspeaker (DUT) shall be loaded in a manner similar to that of normal operating conditions.

If there are any adjustable high pass or low pass filters on the DUT the high pass filters shall be set to the lowest frequency possible. The low pass filters shall be set to the highest frequency possible. If the roll-off rate of these filters is adjustable it shall be set to the slowest roll-off rate possible.

A transfer function measurement with a frequency resolution of at least 1/12 octave within the pass band limits of the DUT shall be made. The measurement shall cover the frequency range of 30 Hz (or lower) to 240 Hz (or higher).

5.2 Upper Frequency Limit

The level of the transfer function measurement shall be averaged over the frequency range from 60 Hz to 120 Hz. This level shall be the Average Level of the DUT.

The frequency at which the transfer function has a level of no less than the Average Level minus 3 dB shall be the Upper Frequency Limit of the DUT.

5.3 Crossover Category Qualification

The DUT shall be qualified for each of four crossover categories W, X, Y, and Z. The frequency limit for each of these categories is shown in Table 1.

Table 1: Upper frequency limit of Crossover Categories

Crossover Category			
W	**X**	**Y**	**Z**
80 Hz	100 Hz	120 Hz	150 Hz

If the Upper Frequency Limit of the DUT is higher than the frequency of a crossover category it qualifies for that crossover category.

As an example, a DUT with an Upper Frequency Limit of 130 Hz would qualify for crossover categories W, X, and Y. It would not qualify for crossover category Z.

5.4 Crossover Category Data Presentation

The crossover categories for a subwoofer shall be reported in the following format:

Crossover Categories: W, X, Y, and/or Z

where W, X, Y, and Z represents each of the categories for which the DUT qualifies.

The following statement shall also accompany the report.
"Consult the manufacturers recommended settings for optimizing the response of their products"

For the example given in Section 5.3 the required reporting format would state the following.

Crossover Categories: W X Y
Consult the manufacturers recommended settings for optimizing the response of their products

6 Maximum Usable Sound Pressure Level – Continuous

This test shall be conducted in a calibrated anechoic chamber, in a suitable ground plane environment, in a large calibrated room, or in a true free-field environment.

6.1 Input Signal

The input signal shall be weighted pink noise with a 12 dB crest factor. Its power spectrum shall be as described in Table 2 when measured with one-third octave filters in accordance with IEC Publication 225. This signal may be generated by feeding a pink noise source through the filter processing shown in Figure 2.

Table 2: Power spectrum of input signal

Frequency (Hz)	Relative level (dB)	Tolerance (dB)		Frequency (Hz)	Relative level (dB)	Tolerance (dB)
5	- 24.1	± 2.0		400	0	± 0.5
6.3	- 20.1	± 2.0		500	0	± 0.5
8	- 16.0	± 2.0		630	- 0.1	± 0.5
10	- 12.2	± 2.0		800	- 0.1	± 0.5
12.5	- 8.8	± 1.0		1,000	- 0.2	± 0.6
16	- 5.4	± 1.0		1,250	- 0.4	± 0.7
20	- 3.0	± 1.0		1,600	- 0.6	± 0.8
25	- 1.5	± 0.8		2,000	- 1.0	± 1.0
32	- 0.6	± 0.6		2,500	- 1.5	± 1.0
40	- 0.3	± 0.5		3,150	- 2.3	± 1.0
50	- 0.1	± 0.5		4,000	- 3.5	± 1.0
63	0	± 0.5		5,000	- 4.9	± 1.0
80	0	± 0.5		6,300	- 6.8	± 1.0
100	0	± 0.5		8,000	- 9.1	± 1.0
125	0	± 0.5		10,000	- 11.8	± 1.0
160	0	± 0.5		12,500	- 14.9	± 1.5
200	0	± 0.5		16,000	- 18.2	± 2.0
250	0	± 0.5		20,000	- 21.8	± 3.0
315	0	± 0.5				

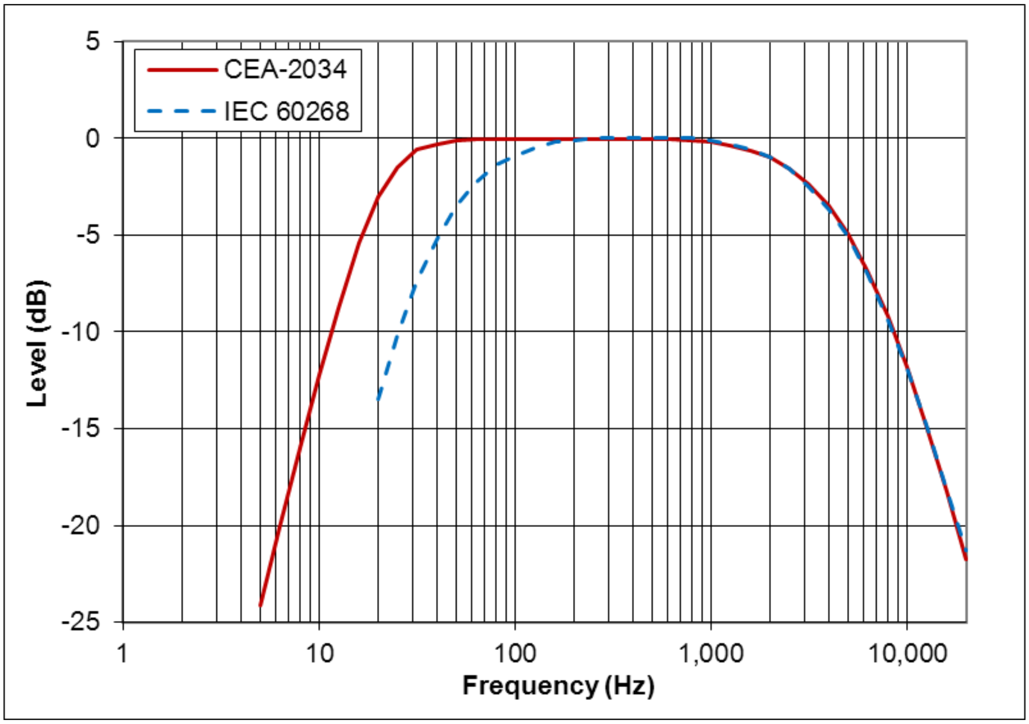


Figure 1: Spectral content of ANSI/CEA-2034 noise compared to IEC 60268 shaped noise

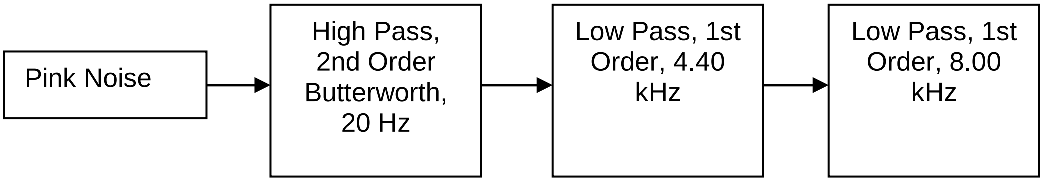


Figure 2: Filter processing blocks for generating input signal

Measure the crest factor (CF) of the input signal to the power amplifier and note the value. The crest factor shall be within the range 11 dB to 13 dB. If the rms voltage output of the power amplifier is operating close to or in excess of 1/8 of its maximum rms output voltage it may clip the output signal, resulting in a lower crest factor. Therefore it is important to measure the crest factor at the input to the DUT, and note its value, at each power level used. It is important to ensure that the amplifier used for testing is capable of cleanly passing the input signal without misbehavior. Misbehavior can best be observed with an oscilloscope - look for unusual spiking, seemingly extended periods of clipping, or mutes. These can often be heard, if the sound of the DUT is audible. Typical crest factors at the input of the DUT should be between 9 dB and 13 dB. A loudspeaker is a high pass filter and its acceleration, and therefore its SPL, may generally have a crest factor a bit higher than the crest factor of the input signal.

6.2 Data Acquisition

6.2.1 Measurement Set-up

The loudspeaker (DUT) shall be loaded in a manner similar to that of normal operating conditions. The test signal to be used shall be the input signal specified in Section 6.1.

A transfer function measurement with a frequency resolution of at least 1/3 octave within the pass band limits of the DUT shall be used to measure the amplitude linearity of the output of the DUT. The reference for the transfer function measurement shall be either the output of the power amplifier directly driving the DUT or the output of the Level Control device used to adjust the amplitude of the test signal.

The signal flow for the measurement shall be that shown in Figure 3. The output of the signal source shall be connected to the input of a level control device as a means to increase or decrease the amplitude of the signal during the test. The output of the level control shall be connected to the input of a power amplifier. The power amplifier will drive the DUT.

A true rms responding voltmeter shall be connected across the output of the power amplifier to measure the signal amplitude while testing the DUT.

The measurement microphone does not have to be in the far-field of the DUT. However, the distance from the DUT to the measurement microphone should be sufficient so that the magnitude of the radiation from one area of the DUT is not overly emphasized compared to the other areas. In no case shall the measurement microphone be less than 3 m from the DUT.

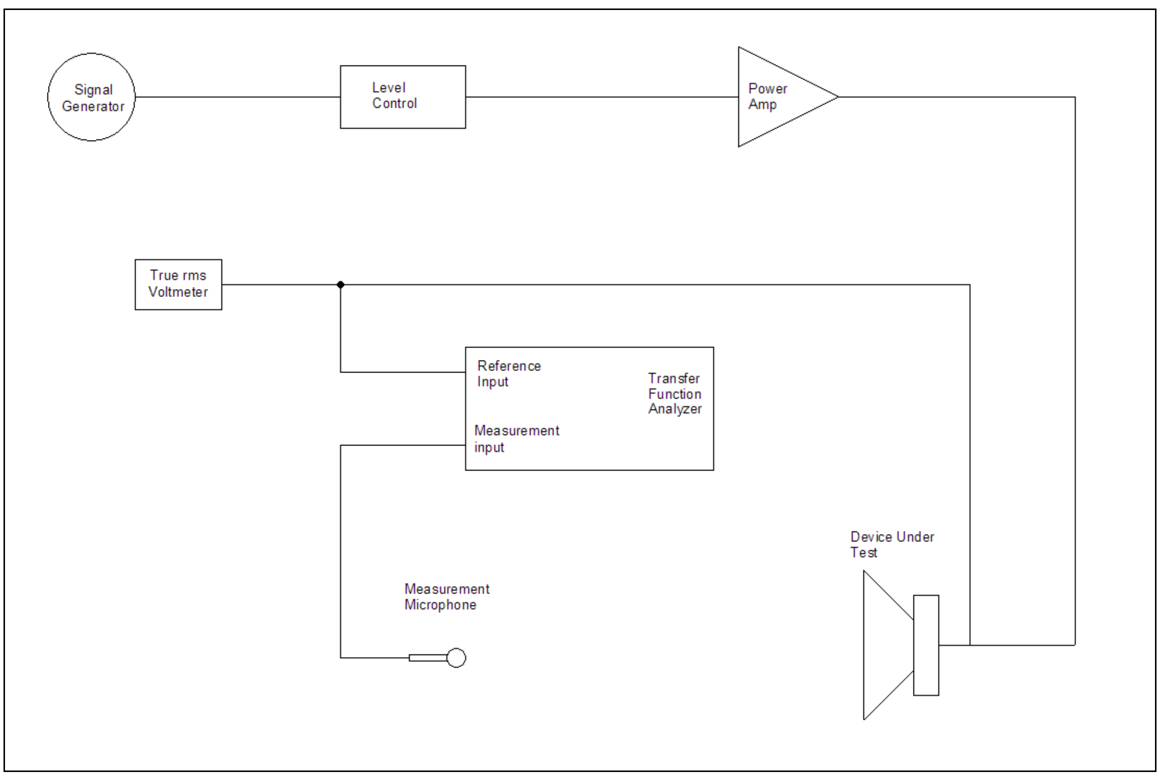


Figure 3: Signal Flow Diagram

6.2.2 Measurement Procedure
The level control shall be adjusted so that the broadband rms voltage of the test signal at the input of the DUT is 1.0 V. A transfer function measurement shall be recorded and stored. This measurement shall be used as the Normalization Reference for all subsequent measurements. By normalizing this to the 1.0 V reference all other measurements will show a flat Normalized Transfer Function at 0 dB as long as there is no deviation in the amplitude response of the DUT.

The level control should be increased 3 dB and the Normalized Transfer Function examined for at least 1 minute to determine the amount of amplitude change in the output of the DUT. If the Normalized Transfer Function has not changed by more than 1 dB, from 0 dB flat, at any point within the pass band limits of the DUT, the level control should be increased by another 3 dB and the Normalized Transfer Function examined for at least 1 minute. This procedure shall be repeated until the Normalized Transfer Function has changed by at least 1 dB from 0 dB flat at any point within the pass band limits of the DUT. The broadband rms voltage at the input of the DUT shall be recorded.

The level control should be increased 1 dB and the Normalized Transfer Function examined for at least 1 minute to determine the amount of change in the output of the DUT. If the Normalized Transfer Function has not changed by more than 3 dB, from 0 dB flat, at any point within the pass band limits of the DUT, the level control should be increased by another 1 dB and the Normalized Transfer Function examined for at least 1 minute. This procedure shall be repeated until the Normalized Transfer Function has changed by approximately 3 dB (but no more than 3.5 dB) from 0 dB flat at any point within the pass band limits of the DUT. The broadband rms voltage at the input of the DUT shall be recorded. This shall be the Maximum Input Voltage, Continuous (MIV continuous) for the DUT.

If the test is being conducted in an anechoic environment the SPL shall be recorded. This SPL shall be referenced to a distance of 1 m for free-field conditions and shall be the Maximum Usable Continuous Output SPL (SPL_{MUCO}) of the DUT.

The transfer function and the Normalized Transfer Function at this input voltage shall also be recorded. This concludes the test and the test signal may be terminated.

As an alternate method to determine the Maximum Usable Continuous Output SPL (SPLmuco) of the DUT if the test is not being conducted in an anechoic environment one of the following procedures can be used.

Method A

1. Apply an appropriate window to the impulse response recorded at the conclusion of the test. This window shall attenuate the level of sound arrivals from any reflecting surfaces to greater than 40 dB below the level of the direct sound from the DUT.

2. Perform an FFT on the windowed impulse response to obtain the anechoic transfer function.

3. Measure the spectral content and level at the input of the DUT at the conclusion of the test.

4. Multiply the transfer function from step 2 by the spectral content and level from step 3.

5. Compute the broadband SPL of the result of step 4 and reference it to 1 m to yield a suitably anechoic representation of the DUT as if it was driven at its MIV continuous.

Method B

1. Use gating or windowing to measure the transfer function of the DUT at a relatively low input voltage (such that no compression effects are occurring) and reference it to an rms voltage of 1.0 V.

2. Multiply (in the frequency domain) this transfer function and the Normalized Transfer Function recorded at the conclusion of the test.

3. Multiply the result of step 2 with the normalized (to 1.0 V broadband) spectral content of the Simulated Program test signal.

4. Add the gain level represented by the increased signal level from the MIV continuous to the result of step 3 [Gain Level = 20 * log(MIV)].

5. Compute the broadband SPL of the result of step 4 and reference it to 1 m to yield a suitably anechoic representation of the DUT as if it was driven at its MIV continuous.

See Appendix C for an example of this procedure.

7 Maximum Usable Sound Pressure Level - Peak

This test shall be conducted in a calibrated anechoic chamber, in a suitable ground plane environment, in a large calibrated room, or in a true free-field environment. (See Appendix B for information about room correction for smaller than required measurement spaces.)

7.1 Input Signal

The input signal shall be 1/3 octave band-limited tone-bursts. This signal can be generated by applying a cosine weighting function to allow only 6.5 cycles of a sine wave with a frequency of the center frequency of the 1/3 octave band to be tested.

If the power amplifier is operating near its maximum level it will likely clip the signal, adding distortion to the signal, therefore it is important to ensure that the amplifier is not clipping. If clipping occurs it may detrimentally affect the results of this test, therefore it is wise to use a sufficiently large power amplifier. The signal at the input to the DUT should not have distortion in excess of 0.5 % THD+N (Total Harmonic Distortion + Noise).

7.2 Data Acquisition

An external power amplifier used for this test should exhibit no individual harmonic distortion components greater than 10 dB lower than those specified in Table 3, at the voltage levels required for the DUT. This will help to assure that the power amplifier does not adversely affect the results of this test. The test procedure in this section can be conducted on the power amplifier alone to validate it as a suitable amplifier to use for this test.

The DUT shall be tested at ISO 1/3 octave center frequencies within the range 20 Hz to 160 Hz. See Table 2 in Section 6.1 for a list of frequencies within this range.

With the input of the DUT connected to the preamplifier, or with its input shorted to ground, and without any input signal presented to the DUT, its volume control shall be set to the maximum position and the sound pressure level from the DUT and the background noise of the environment and test equipment shall be measured. If the smoothed root mean square (rms) slow sound pressure level (SPL) (i.e., the rms SPL determined using a slow integration time and then 1/12 octave smoothed) exceeds 50 dB (flat/unweighted) at any test frequency (even though no input signal is present) the DUT, test environment, and equipment does not comply with ANSI/CEA-2010-B, and the reporting method described in Section 13 shall not be used for the DUT. Also, no reporting method that might be confused with the reporting method described in Section 13 shall be used for the DUT.

For each test frequency, a 1/3 octave band-limited tone-burst centered at the test frequency shall be fed to the DUT. The SPL at the tone-burst test frequency f_1 (fundamental) and over the frequency range bounded by 1.26 x f_1 and no less than 2.0 kHz, where harmonic (and non-harmonic) distortion and noise (HD+N) occurs, shall be monitored. The signal level presented to the DUT shall be increased until the peak SPL of a 1/12 octave smoothed individual component of HD+N exceeds the level specified in Table 3 and illustrated in Figure 4. The signal level presented to the DUT shall then be decreased to just below the occurrence of the above set of conditions. The peak SPL of the fundamental shall then be recorded. That is, the peak SPL is the level of the highest peak sound pressure within the 1/3 octave of the tone-burst stimulus fundamental frequency range, f_1.

Time windowing the output signal of the DUT is allowed. However, the window applied to the output signal from the DUT shall not be shorter than twice the length of the test signal itself. Additionally, the window shall not attenuate any data in the time domain between the initial output of the stimulus and twice the period of the stimulus.

This SPL shall be referenced to a 1 meter free-field level. If the SPL of the fundamental cannot be recorded due to low output signal level or low signal-to-noise ratio using a singletone-burst, averaging techniques shall be used to increase the signal-to-noise ratio of the measurement. Averaging shall be done in the time domain, or vector averaging shall be done in the frequency domain, prior to spectral smoothing. Inability to measure the fundamental output is most likely to occur at the lowest frequencies. If it is not possible to measure the peak SPL at a particular frequency band a peak SPL of 0 dB shall be recorded for that frequency band.

This procedure shall be repeated for each test frequency. The recorded SPL shall be repeatable to within ± 1.0 dB.

Some subwoofers never surpass the HD+N threshold but begin to limit and/or compress the output at some frequencies. If this is the case the peak SPL of the fundamental at the test frequency shall be entered.

Note: In developing the above test procedure a goal was to take into account the fact that higher frequency noise that is not harmonically related to the fundamental can have a negative impact on perceived loudspeaker performance. It is assumed that the higher in frequency the noise, the more annoying it will be to the listener. It is also assumed that noise that is closer in frequency to the fundamental will be more easily masked within the human hearing system, and can therefore be somewhat higher in level and still be acceptable.

Table 3: Peak SPL Limits

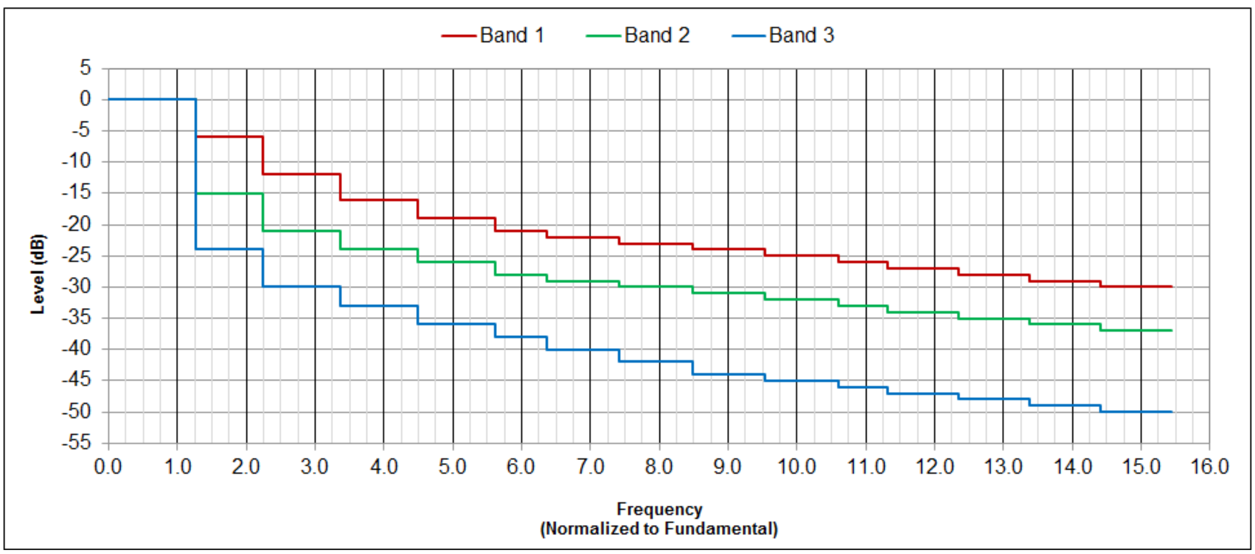
Attenuation of harmonics for fundamentals of 20 - 32 Hz	Attenuation of harmonics for fundamentals of 40 - 63 Hz	Attenuation of harmonics for fundamentals of 80 - 160 Hz	Lower Frequency Limit (Hz)	Upper Frequency Limit (Hz) (not to exceed 20 kHz)[1]	Notes
0 dB	0 dB	0 dB	16	1.26 x f_1	Bandwidth from 16 Hz to 1/3 octave above fundamental
- 6 dB	- 15 dB	- 24 dB	0.8909 x f_2	1.1225 x f_2	Bandwidth from 1/6 octave below to 1/6 octave above 2nd harmonic
- 12 dB	- 21 dB	- 30 dB	0.8909 x f_3	1.1225 x f_3	Bandwidth from 1/6 octave below to 1/6 octave above 3rd harmonic

[1] The upper frequency for analysis for all fundamental frequencies and harmonics shall be that specified in Table 3 or 20 kHz, whichever is lower.

- 16 dB	- 24 dB	- 33 dB	0.8909 x f_4	1.1225 x f_4	Bandwidth from 1/6 octave below to 1/6 octave above 4th harmonic
- 19 dB	- 26 dB	- 36 dB	0.9439 x f_5	1.0595 x f_5	Bandwidth from 1/12 octave below to 1/12 octave above 5th harmonic
- 21 dB	- 28 dB	- 38 dB	0.9439 x f_6	1.0595 x f_6	Bandwidth from 1/12 octave below to 1/12 octave above 6th harmonic
- 22 dB	- 29 dB	- 40 dB	0.9439 x f_7	1.0595 x f_7	Bandwidth from 1/12 octave below to 1/12 octave above 7th harmonic
- 23 dB	- 30 dB	- 42 dB	0.9439 x f_8	1.0595 x f_8	Bandwidth from 1/12 octave below to 1/12 octave above 8th harmonic
- 24 dB	- 31 dB	- 44 dB	0.9439 x f_9	1.0595 x f_9	Bandwidth from 1/12 octave below to 1/12 octave above 9th harmonic
- 25 dB	- 32 dB	- 45 dB	0.9439 x f_{10}	1.0595vf_{10}	Bandwidth from 1/12 octave below to 1/12 octave above 10th harmonic
- 26 dB	- 33 dB	- 46 dB	0.9715 x f_{11}	1.0293 x f_{11}	Bandwidth from 1/24 octave below to 1/24 octave above 11th harmonic
- 27 dB	- 34 dB	- 47 dB	0.9715 x f_{12}	1.0293 x f_{12}	Bandwidth from 1/24 octave below to 1/24 octave above 12th harmonic

- 28 dB	- 35 dB	- 48 dB	0.9715 x f_{13}	1.0293 x f_{13}	Bandwidth from 1/24 octave below to 1/24 octave above 13th harmonic
- 29 dB	- 36 dB	- 49 dB	0.9715 x f_{14}	1.0293 x f_{14}	Bandwidth from 1/24 octave below to 1/24 octave above 14th harmonic
- 30 dB	- 37 dB	- 50 dB	0.9715 x f_{15}	1.0293 x f_{15}	Bandwidth from 1/24 octave below to 1/24 octave above 15th harmonic

Figure 4: Harmonic Distortion + Noise Threshold vs. Frequency



7.3 Maximum Peak SPL Data Post-Processing for Broadband Peak SPL

1. The recorded peak SPL at each 1/3 octave band shall be weighted by the power spectrum given in Table 2 (Section 6.1).
2. The Average Weighted SPL shall be calculated by averaging the weighted SPL values from 40 Hz to 80 Hz, inclusive.
3. The weighted SPL for any 1/3 octave band exceeding the Average Weighted SPL by 3 dB shall be reduced to a value of the Average Weighted SPL plus 3 dB.
4. The weighted & limited SPL in each 1/3 octave band shall be converted to its squared-pressure value (p^2 = 10^(SPL/10))
5. The sum of all of the squared-pressure values for each 1/3 octave band shall be calculated.
6. The SPL of the summed squared-pressure shall be calculated (SPL = 10 * log(sum(p^2)).
7. The Broadband Peak SPL shall be the SPL of the summed squared-pressure minus 10 dB.

8 Maximum SPL Data Presentation

Subtract the Maximum Usable Continuous Output SPL (Section 6.2.2) from the Broadband Peak SPL (Section 7.3). If the result is 9 dB or greater, the Maximum Usable Continuous Output SPL shall be reported as the Maximum SPL of the DUT. If the result is less than 9 dB the reported Maximum SPL shall be the Broadband Peak SPL minus 9 dB.

The computed broadband Maximum SPL for the DUT shall be reported using the following format:

Maximum Sound Pressure Level: xx dB SPL referenced to 1 m.

The information presented to the consumer shall include the following statement in a prominent location:

CAUTION: High sound levels can cause hearing damage with prolonged exposure. Wear appropriate protection such as ear plugs and/or ear muffs when listening to loud audio.

9 Powered Subwoofer Rating

The suitability for use of a subwoofer in four different listening levels shall be determined. This calculation shall use the maximum usable SPL as its basis. The target subwoofer SPL for the listening levels shall be computed using the following assumptions.

1. One subwoofer in a listening room (with an SPL of + 10 dB relative to the target SPL of the listening level for full-range loudspeakers based on ANSI/CEA-2034).
2. The listening position shall be at 4 meters from the loudspeakers.
3. The listening room is partially reflective so there is a “room gain” of 6 dB compared to the direct sound only.

The four listening levels and their corresponding average SPL shall be:

Listening Level[2]	Required Target Subwoofer SPL
Quiet	85 dB
Moderate	95 dB
Loud	105 dB
Very Loud	115 dB

It is possible that some of these listening levels may not be attainable with some subwoofers.

9.1 Calculation

Calculate the Maximum In-Room SPL at a distance of 4 meters from one subwoofer in a room. For this calculation use the Maximum SPL at 1 m from Section 8.

$$SPL_{In\text{-}Room} = MaxSPL + 6\ dB - 12\ dB$$

9.2 Data Presentation

The results shall be reported in the following format.

Listening Levels: Quiet, Moderate, Loud, and/or Very Loud

Where Quiet, Moderate, Loud, and Very Loud represents each of the categories for which the DUT qualifies.

In addition to the above required reporting presentation, an optional expanded reporting may be published. This should include the format detailed in the table below.

[2] This standard provides a method for measuring loudspeaker output signals at different signal levels at a distance of 4 m. The provision of a method for measuring loudspeaker outputs at high levels shall not be interpreted as a recommendation that people listen to audio at these high levels. Some loudspeaker applications naturally prevent people from listening at a distance of 4 m from the loudspeaker, such as the case when a loudspeaker is mounted at the top of a tall mast at an outdoor venue. This standard provides a method for testing such loudspeakers, but does not recommend that people listen to audio at dangerously high levels. People conducting tests in accordance with this standard shall take appropriate precautions, including the use of appropriate ear protection, to avoid exposure to high audio levels.

Table 4: Subwoofer In-Room Listening Level

Listening Level	Full-Range Required SPL at 4 m	Subwoofer Required SPL at 4 m	Subwoofer Recommended for this SPL
Quiet	75 dB	85 dB	Yes
Moderate	85 dB	95 dB	Yes
Loud	95 dB	105 dB	No
Very Loud	105 dB	115 dB	No

* The “No” recommendation indicates a subwoofer system with higher SPL capability should be selected to achieve this Listening Level.

10 Impedance

10.1 Data Acquisition

The impedance of a passive subwoofer shall be determined as follows:

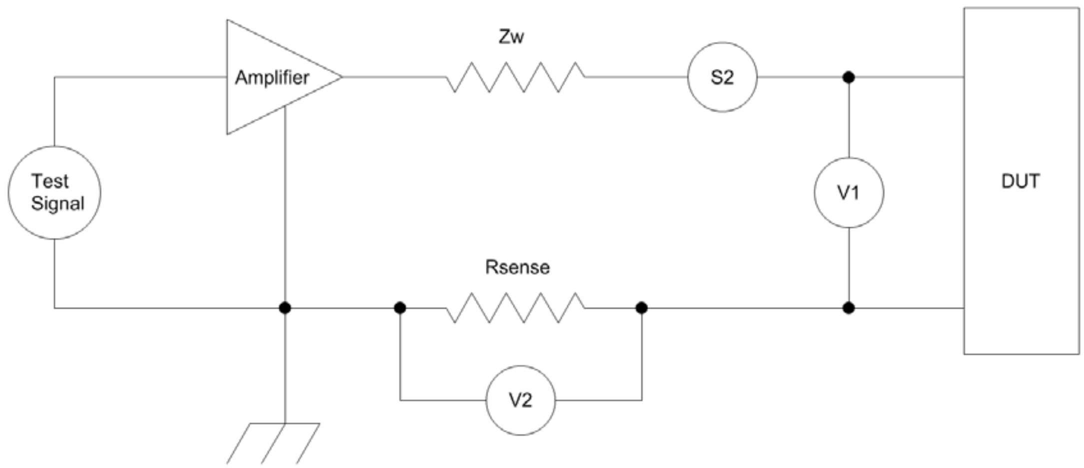


Figure 5: Impedance measurement schematic, R_{Sense} method

OR

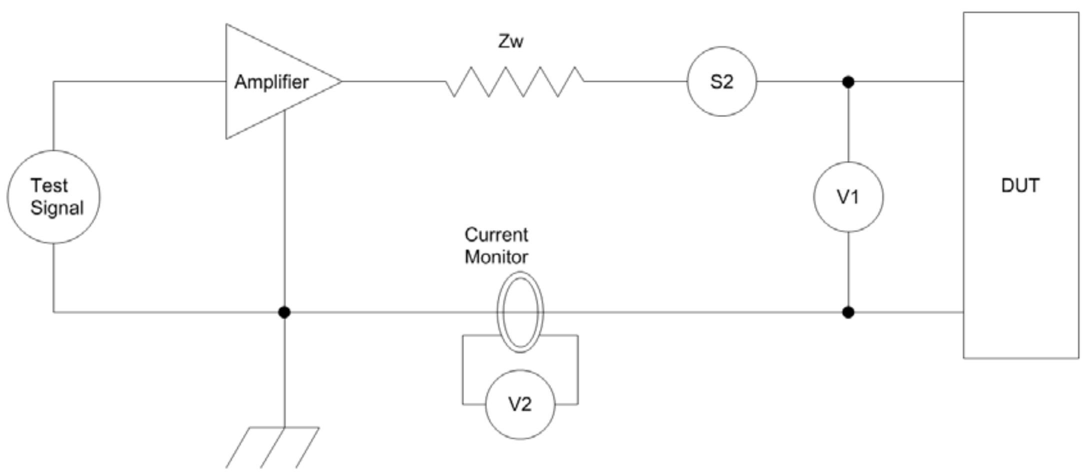


Figure 6: Impedance measurement schematic, current monitor method

The voltmeters, especially V2 across the R_{Sense} resistor or the current monitor, shall have high resolution and high sensitivity, such as 5.5 digits or greater with sensitivity in the microvolt range. Both voltmeters must have flat voltage as a function of frequency response in the 20 Hz to 20 kHz range. Additionally, both voltmeters shall be able to derive complex data with respect to each other, such as a dual-channel FFT measurement system. Use a low inductance sense resistor, tested to have insignificant inductance in the 20 Hz to 20 kHz range. Resistors are available with a 4-wire Kelvin configuration for better accuracy. Zw is any impedance of any wire(s) within the measurement loop. It should not be a part of the measured speaker impedance and shall be kept to a value no greater than 5 % of the Rdc of the DUT. The measurement error as a result of Zw can be minimized by measuring V1 directly at the speaker cabinet terminals. S2 is any voltage due to back emf (electro-motive force), thermal noise and the speaker acting as a microphone.

Before applying any desired signal, record the voltmeter values.

Apply the desired signal (discrete spot frequencies, pink noise, swept sine, etc.) such that the signal-to-noise ratio is at least 40 dB. Verify the speaker is not driven into a non-linear range. This can be verified by testing at several drive levels above and below the minimum drive level determined to provide the 40 dB signal-to-noise ratio, and comparing the impedance curves to see if they change. If the impedance curves are different then measurements at lower drive levels need to be made to determine the highest drive level that can be used in the linear range of the DUT. If this drive level does not allow at least 40 dB of signal-to-noise ratio, appropriate measures need to be taken (such as averaging) to ensure at least 40 dB of signal-to-noise ratio without increasing the drive level.

Measure the voltages, V1 and V2
Calculate the current as $I = V2 / R_{Sense}$ or determine I from current monitor
Calculate complex impedance as V1 / I

A single frequency shall be reported as the minimum impedance frequency. The impedance measurement shall not be smoothed to any greater than 1/12 of an octave. The minimum impedance frequency reported shall be within the range 10 Hz to 200 Hz.

If the same minimum impedance occurs at multiple frequencies within the range of 30 Hz to 100 Hz, the frequency of minimum impedance with the highest absolute value of the angle of impedance shall be reported as the minimum impedance frequency.

If the minimum impedance occurs at multiple frequencies outside of the range of 30 Hz to 100 Hz, and there are no occurrences of the minimum impedance within the range of 30 Hz to 100 Hz, the frequency of minimum impedance closest to the range of 30 Hz to 100 Hz shall be reported as the minimum impedance frequency.

Practical measurements of complex impedance will typically be performed with computer controlled analog or digital 2 channel analyzers, including some that use high quality 2 channel sound boards with appropriate commercially available software.

Any measurement system setup must be checked for accuracy by measuring a known value non-inductive resistor, which should have a flat resistance magnitude in ohm and a flat phase response of zero degrees. Special auxiliary software such as Macros are provided by some manufacturers for use with their instruments to perform the complex mathematical calculations to obtain phase as well as magnitude, and to scale the impedance to ohm using the value chosen for the current sense resistor, typically 0.100 Ω.

10.2 Data Presentation

The rated and minimum impedance for the DUT shall be reported using the following format:

Rated Impedance: x Ω
Minimum Impedance: y.y Ω at zzz Hz
The rated impedance shall be given as an integer number.

The minimum impedance shall be reported to the nearest one-tenth ohm.

The frequency for the minimum impedance shall be reported as an integer value.

11 Required Power Amplifier Size

The required power amplifier size shall be calculated for an average SPL in four different listening levels. This calculation shall use the maximum usable continuous SPL and the voltage required to achieve this SPL in Section 6 as its basis. The SPL shall be computed using the following assumptions.

1. One subwoofer in a listening room (with an SPL of + 10 dB relative to the target SPL of the listening level for full-range loudspeakers based on ANSI/CEA-2034).
2. The listening position shall be at 4 m from the loudspeakers.
3. The listening room is partially reflective so there is a “room gain” of 6 dB compared to the direct sound only.

The four listening levels and their corresponding average SPL shall be:

Listening Level[3]	Required Target Subwoofer SPL
Quiet	85 dB
Moderate	95 dB
Loud	105 dB
Very Loud	115 dB

It is possible that some of these listening levels may not be attainable with some subwoofers.

11.1 Calculation

Prior to calculating the required amplifier power, the Adjusted Maximum Input Voltage should be confirmed. If the Maximum SPL is the same as the SPL_{MUCO} (Maximum Usable Continuous Output) the Adjusted MIV shall be the same as the measured MIV. If the Maximum SPL is different than the SPL_{MUCO}, the Adjusted MIV level shall be the MIV level minus the difference between the SPL_{MUCO} and the Maximum SPL

$$\text{MIV Level} = 20 * \log(\text{MIV})$$

$$\text{Adjusted MIV Level} = \text{MIV Level} – (SPL_{MUCO} – \text{Maximum SPL})$$

$$\text{Adjusted MIV} = 10\text{^}(\text{Adjusted MIV Level}/20)$$

The following steps shall be used to calculate the required amplifier power.

1. Calculate the Maximum In-Room SPL at a distance of 4 m from one subwoofer in a room. For this calculation use the Maximum SPL at 1 m from Section 8
   $SPL_{In\text{-}Room} = \text{MaxSPL} + 6\text{ dB} – 12\text{ dB}$

2. Subtract the $SPL_{In\text{-}Room}$ from the Target SPL to get the Required Gain
   $\text{Required Gain} = \text{Target SPL} – SPL_{In\text{-}Room}$

[3] This standard provides a method for measuring loudspeaker output signals at different signal levels at a distance of 4 m. The provision of a method for measuring loudspeaker outputs at high levels shall not be interpreted as a recommendation that people listen to audio at these high levels. Some loudspeaker applications naturally prevent people from listening at a distance of 4 m from the loudspeaker, such as the case when a loudspeaker is mounted at the top of a tall mast at an outdoor venue. This standard provides a method for testing such loudspeakers, but does not recommend that people listen to audio at dangerously high levels. People conducting tests in accordance with this standard shall take appropriate precautions, including the use of appropriate ear protection, to avoid exposure to high audio levels.

3. Calculate the Required Voltage (rms) using the Adjusted MIV and the Required Gain.
   Required E_{rms} = AdjustedMIV * 10^(Required Gain / 20)

4. Calculate the Required Voltage (peak) by multiplying the Required Voltage by 4 to account for a 12 dB crest factor in the program material.
   Required E_{peak} = 4 * Required E_{rms}

5. Calculate the Equivalent Sine Voltage (rms) for the Required Voltage (peak)
   Equivalent Sine E_{rms} = Required E_{peak} / 10^(3/20)

6. Calculate the Required Power for the amplifier channel by dividing the square of the Equivalent Sine Voltage (rms) by the rated impedance of the subwoofer.
   Required Power = (Equivalent Sine E_{rms})^2 / Z_{Rated}

11.2 Data Presentation

The results shall be reported in the following format.

The value of the Required Power shall be reported as an integer number.

Table 5: Required Amplifier Power and Voltage

Listening Level	Full-Range Required SPL at 4 m	Subwoofer Required SPL at 4 m	Subwoofer Recommended for this SPL	Power Amplifier Required at 8 Ω	Amplifier Voltage (rms) Required	Amplifier Voltage (peak) Required
Quiet	75 dB	85 dB	Yes	16 W	4 V	16 V
Moderate	85 dB	95 dB	Yes	159 W	13 V	51 V
Loud	95 dB	105 dB	No	N/A	N/A	N/A
Very Loud	105 dB	115 dB	No	N/A	N/A	N/A

* The "No" recommendation indicates a subwoofer system with higher SPL capability should be selected to achieve this Listening Level.

12 Matching a Subwoofer to a Full-Range Loudspeaker System

A subwoofer would be a good candidate for matching with a full-range loudspeaker system when the following occur.

- Both the subwoofer and the full-range loudspeaker system have at least one overlapping Crossover Category in common. That is, they share one or more of the same Crossover Categories (see Section 5).
- Both the subwoofer and the full-range loudspeaker system have the desired Listening Level in common (see Section 9 or Section 11).

As an example, a subwoofer and full-range system with the following ratings for use in the Moderate listening level would be good candidates to be matched with each other.

Subwoofer
Crossover Categories: W X Y
Listening Levels: Quiet and Moderate

Full-Range
Crossover Categories: X Y Z
Listening Levels: Quiet, Moderate, and Loud

Alternatively, a subwoofer and full-range system with the following ratings for use in the Loud listening level would ***not*** be good candidates to be matched with each other. Note also that they have no crossover categories in common.

Subwoofer
Crossover Categories: W X
Listening Levels: Quiet and Moderate

Full-Range
Crossover Categories: Y Z
Listening Levels: Quiet, Moderate, and Loud

13 Consolidated Reporting Requirements – Example Data Sheet

This section includes all of the reporting requirements from all of the other sections, and explains how data should be reported to consumers in a combined format.

An example of the consolidated reporting required is shown below. This includes the following.

1. The Rated Maximum SPL referenced to 1 meter
2. *For passive subwoofers only* – the Rated Impedance and the Minimum Impedance, along with the frequency at which the Minimum Impedance occurs.
3. *For passive subwoofers only* – the table detailing the Recommended Amplifier Size to achieve the four Listening Levels at 4 meters (Section 11.2)
4. The Listening Levels for which the subwoofer qualifies. Optionally, the expanded reporting of the table (Section 9.2) may be included.
5. The Crossover Categories for the subwoofer

The Rated Maximum SPL shall be an integer number.

The Rated Impedance shall be reported as an integer number.
The Minimum Impedance shall be reported to the nearest one-tenth ohm.
The frequency at which the Minimum Impedance occurs shall be reported as the nearest integer value in hertz.

The values of the Required Power shall be reported as integer numbers.

Example Reporting for a Passive Subwoofer

Maximum SPL
Rated Maximum Sound Pressure Level: 102 dB SPL referenced to 1 m

Impedance
Rated Impedance: 8 ohms
Minimum Impedance: 6.7 ohms at 147 Hz

Required Amplifier Size (*for passive subwoofers only*)

Listening Level	Full-Range Required SPL at 4 m	Subwoofer Required SPL at 4 m	Subwoofer Recommended for this SPL	Power Amplifier Required at 8 Ω	Amplifier Voltage (rms) Required	Amplifier Voltage (peak) Required
Quiet	75 dB	85 dB	Yes	16 W	4 V	16 V
Moderate	85 dB	95 dB	Yes	159 W	13 V	51 V
Loud	95 dB	105 dB	No	N/A	N/A	N/A
Very Loud	105 dB	115 dB	No	N/A	N/A	N/A

* The “No” recommendation indicates a loudspeaker system with higher SPL capability should be selected to achieve this Listening Level.

CAUTION: High sound levels can cause hearing damage with prolonged exposure. Wear appropriate protection such as ear plugs when listening to loud audio.

Listening Levels
Quiet and Moderate

Crossover Category
Crossover Categories: W X Y

Consult the manufacturers recommended settings for optimizing the response of their products

Example Reporting for a Powered Subwoofer

Maximum SPL
Rated Maximum Sound Pressure Level: 102 dB SPL referenced to 1 m

Subwoofer In-Room Listening Level

Listening Level	Full-Range Required SPL at 4 m	Subwoofer Required SPL at 4 m	Subwoofer Recommended for this SPL
Quiet	75 dB	85 dB	Yes
Moderate	85 dB	95 dB	Yes
Loud	95 dB	105 dB	No
Very Loud	105 dB	115 dB	No

* The "No" recommendation indicates a loudspeaker system with higher SPL capability should be selected to achieve this Listening Level.

CAUTION: High sound levels can cause hearing damage with prolonged exposure. Wear appropriate protection such as ear plugs when listening to loud audio.

Listening Levels
Quiet and Moderate

Crossover Category
Crossover Categories: W X Y

Consult the manufacturers recommended settings for optimizing the response of their products

Appendix A. Ground Plane Test Procedure

Place the DUT on the floor oriented so that its major radiating element faces towards the microphone, which also rests on the floor (see Figure 7). Measurement distance shall be at least 3 m (9.8 ft.).

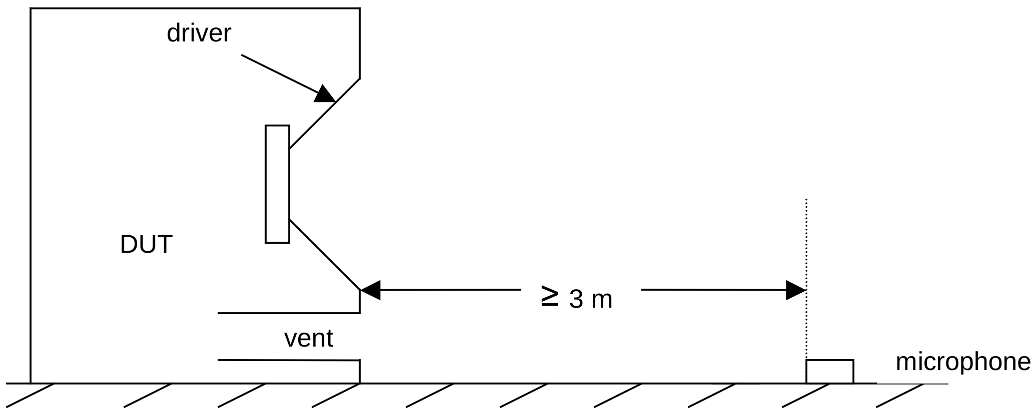


Figure 7: Basic ground plane measurement set-up for a subwoofer system whose driver and port are located on the same face of the enclosure (cut-away side view)

The following considerations should be taken into account when planning and executing measurement set-up:

a. The DUT and microphone should be placed as far as possible from walls and any other large acoustic reflective surfaces to maximize reflection times and thereby ensure the lowest possible measurement cutoff frequency. The measurement's time-domain window length (interval bounded by arrivals of the direct source and major reflections) determines the lower bound of the measurement pass band. Thus maximum reflection time ensures the best possible low-frequency extension. To keep measurement error to less than 1 dB, the nearest reflective object shall be no closer to the DUT or the measurement microphone than 5 times the DUT-to-microphone spacing. Increasing this distance to 10 times the DUT-to-microphone distance will allow reflection errors to be less than 0.5 dB.

b. Size of acoustic space, particularly the distance between the DUT and measurement microphone from room boundaries, governs the low-frequency limit associated with a ground plane (2π or half-space) measurement. The frequency at which 0.75 λ equals the DUT-to-room-boundary or microphone-to-room-boundary distance, where λ is acoustic wavelength (λ = speed of sound divided by frequency), is the low frequency limit for a particular measurement arrangement. Table 6 tabulates the minimum DUT- or microphone-to-room boundary distance for the standard 1/3 octave frequencies below 80 Hz. Application of an appropriately derived room correction factor (RCF), as described in Appendix B, greatly extends the low-frequency limits obtainable via the ground plane methods.

Table 6: Minimum required distance between DUT and acoustically reflective boundaries (walls)[1]

LF limit (Hz)	0.75 λ [min. distance to boundary m (ft.)]
16.0	14.7 (48.2)
20.0	11.8 (38.7)
25.0	9.4 (30.8)
31.5	7.5 (24.6)
40.0	5.9 (19.4)
50.0	4.7 (15.4)
63.0	3.7 (12.1)

[1]Distance between measurement microphone and walls similarly dictates the low-frequency limit of ground plane measurements, unless room-correction factor is derived.

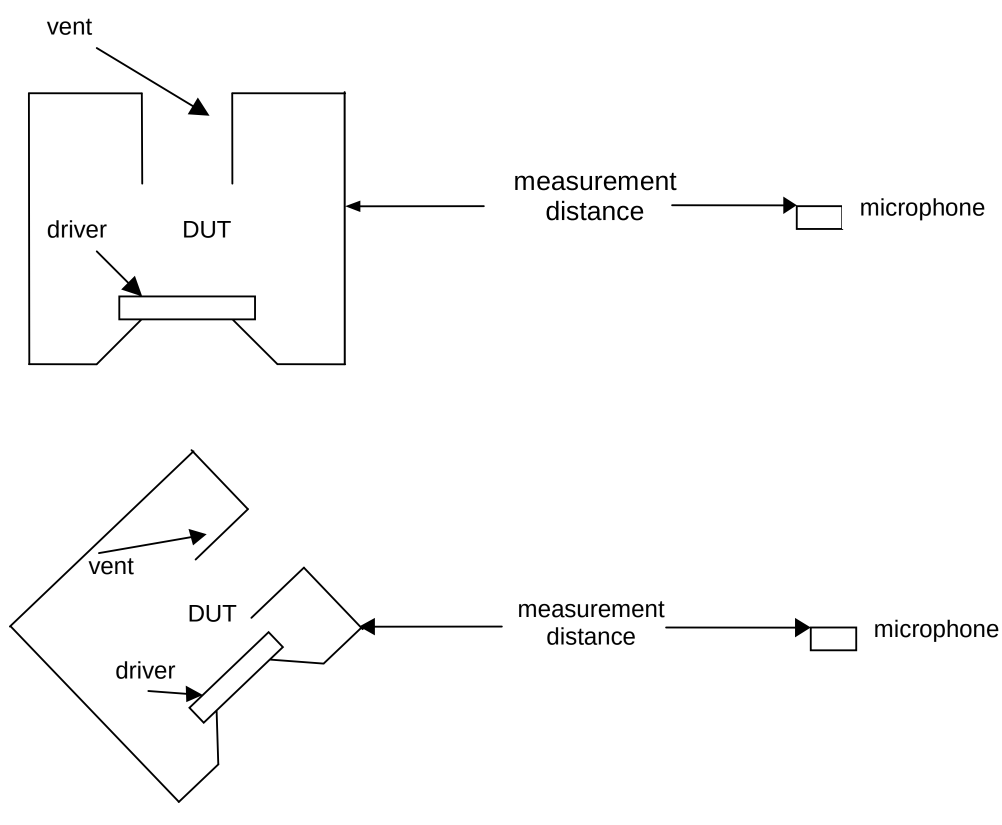


Figure 8: Two examples of ground plane measurement set-ups for subwoofer systems with major radiating elements on multiple faces of their enclosures (cut-away view from above)

c. Calibration: It is important to ensure that all devices in the measurement chain – specifically the microphone, microphone pre-amp and any other devices – are appropriately calibrated. Further, measurement practitioners shall follow good engineering practices and take care to record device settings and any other pertinent measurement conditions. Sufficient information about the test setup shall be recorded to enable a third party to repeat the tests.

Appendix B. Calibrating the Amplitude Response of Anechoic Chambers and Other Spaces (Room Correction Factor)

Use only for on-axis frequency response (sensitivity) measurements. This is not valid for directivity measurements.

Because few acoustic spaces are sufficiently large to permit measurements down to a high-performance DUT's low-frequency cutoff and because room effects are generally important well above that frequency, measurement accuracy and low-frequency extension may be greatly enhanced by applying a known room correction factor (RCF) to data acquired indoors. The acoustic space in which measurements are taken will affect the low frequency response of a loudspeaker. Therefore, the purpose of the RCF is to "remove the room" from the measurement so that only the "true" magnitude response of the device under test (DUT) remains.

The means by which one may derive the RCF for a particular acoustic space and measurement setup are as follows:

1. In accordance with good engineering practices, measure the free field ground plane response of a sealed box subwoofer whose low-frequency extension at least matches or exceeds that of the DUT. If no such low frequency calibration source (LFCS) exists, it may be necessary to design and build one.
    a. For an anechoic measurement space
    Place the measurement microphone on the ground plane in a free field to make the reference measurement for the calibration. The LFCS shall be placed in the free field, above the ground plane at least one-quarter (1/4) wavelength of the lowest frequency to which the calibration will be valid.

    b. For a hemi-anechoic measurement space
    Place the measurement microphone on the ground plane in a free field to make the reference measurement for the calibration. The LFCS shall also be placed on the ground plane in the free field.

2. Place the LFCS and measurement microphone in the measurement room at the intended measurement locations of the DUT and microphone, taking into account proximity of major acoustic reflectors (*e.g.*, walls) to maximize reflection times.

3. Measure the in-room ground plane magnitude response of the LFCS in an accepted manner.

4. Compute the RCF from the dB magnitude difference between results of steps (c) and (a) above.

The RCF need not be derived more than once for a particular measurement space so long as it's major features (*e.g.* placement of reflectors, room absorption) and the measurement set-up (*e.g.* source and receiver location in the room, temperature and placement of major acoustic reflectors) are constant. One simply applies the once- derived RCF to the DUT's "in-room" GP magnitude response in order to derive its true magnitude response.

Appendix C. Calculating Maximum Usable Continuous SPL in a Non-Anechoic Environment

An example of the alternate procedure for calculating the SPL using Method A from Section 6.2.2 is shown below. The steps for Method B would be similar.

Step 1
Apply an appropriate window to the impulse response recorded at the conclusion of the test. This window shall attenuate the level of sound arrivals from any reflecting surfaces to greater than 40 dB below the level of the direct sound from the DUT.

Any reflections from walls, the ceiling, or any other objects must be eliminated from the measurement results. Figure 9 below shows the windowed and unwindowed impulse response (IR) of the DUT. In this case the IR window (Half Blackman) began at 10 ms and ended at 20 ms. During this time span the magnitude of the IR was gradually attenuated until it was zero at 20 ms and thereafter.

The windowing times cited are for measurements of full-range loudspeaker system (e.g. those referenced in ANSI/CEA-2034). The windowing times for a subwoofer would need to be considerably longer.

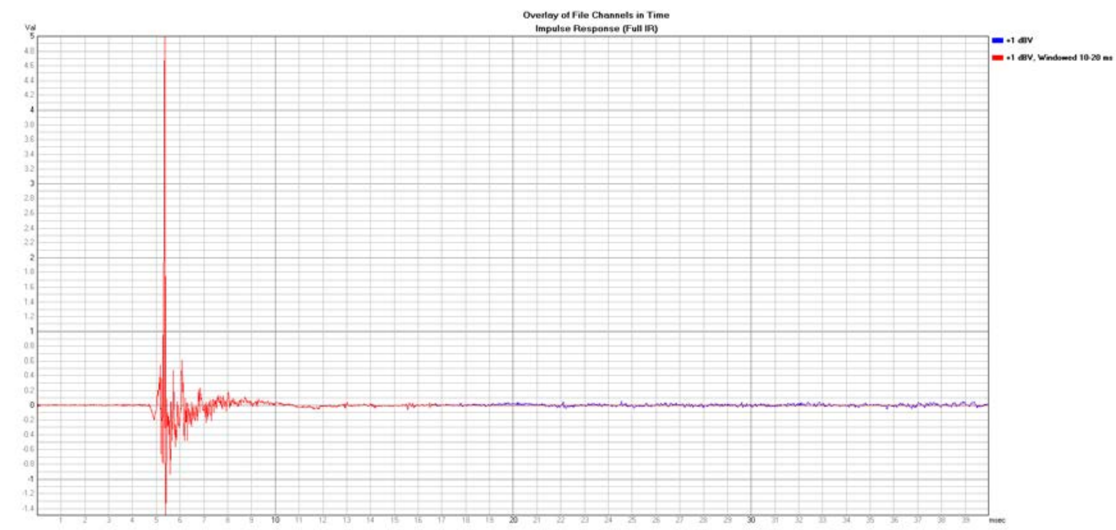


Figure 9: Windowed & Unwindowed IR of the DUT

Step 2
Perform an FFT on the windowed impulse response to obtain the anechoic transfer function.

This will yield the frequency response of the DUT at the termination of the test (Figure 10).

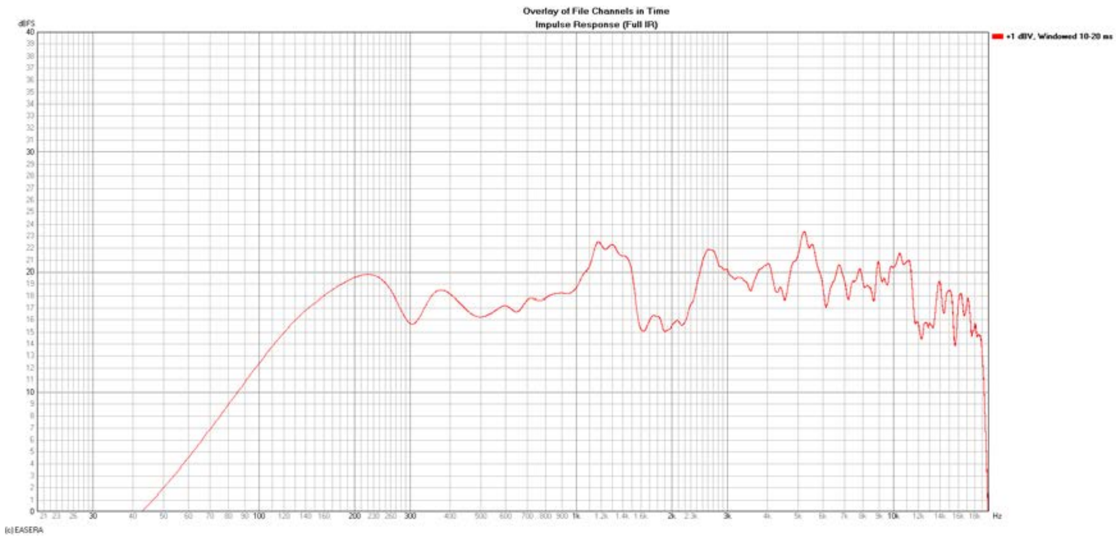


Figure 10: FFT of the windowed IR from Step 1

Step 3
Measure the spectral content and level at the input of the DUT at the conclusion of the test.

In the Figure 11 below the spectral content of the test signal is shown. This does not resemble the typical spectrum of the test signal which is usually displayed as the level on a unit bandwidth basis. Here it is displayed as the level on a unit frequency basis.

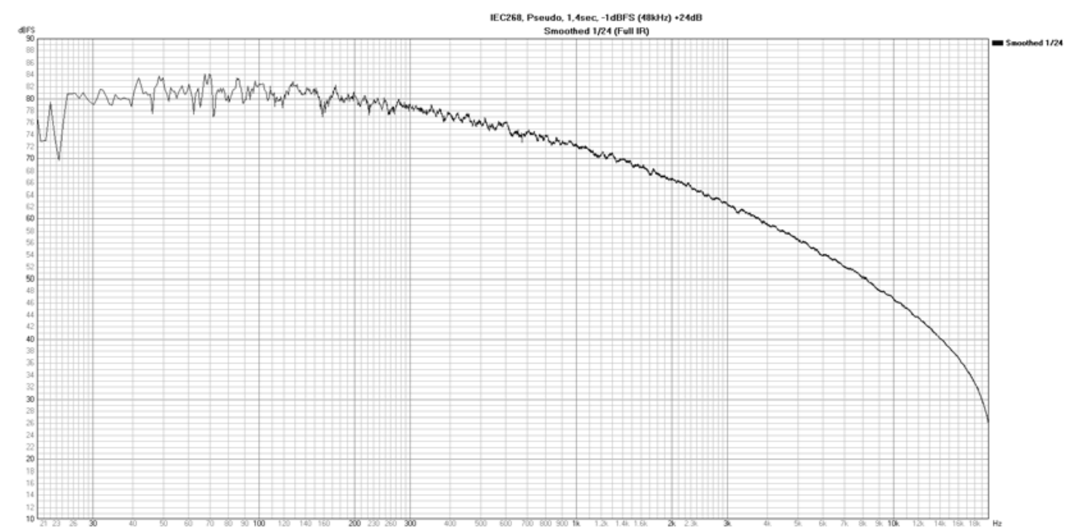


Figure 11: Spectral content of the test signal

Step 4
Multiply the transfer function from step 2 by the spectral content and level from step 3.

The measurements from steps 2 and 3 are show to scale in Figure 12. These are to be multiplied together in the frequency domain. (Note that this is identical to them being convolved in the time domain.) The result of this multiplication is shown in Figure 13.

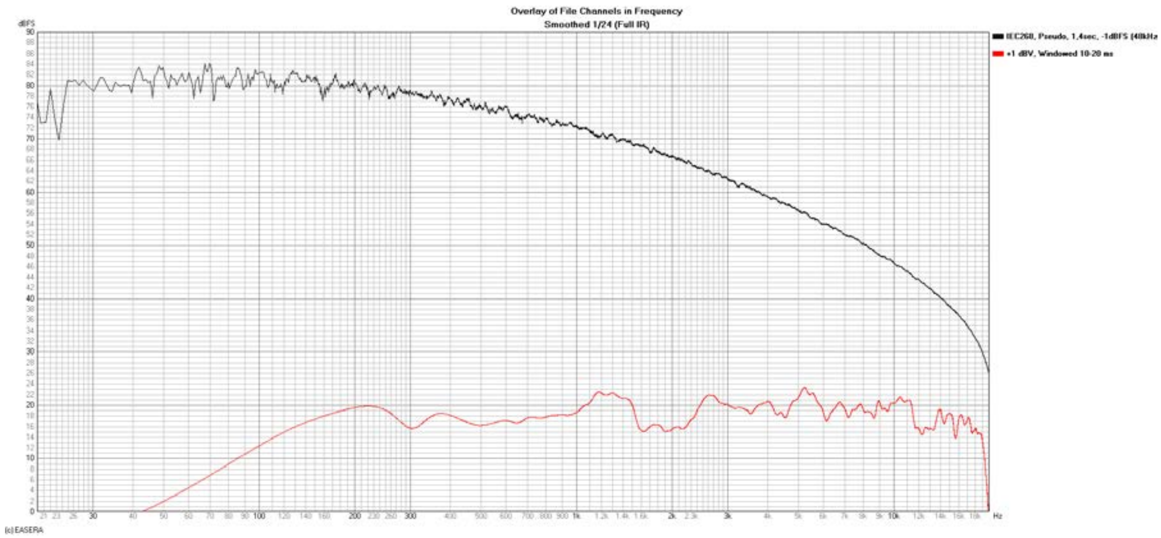


Figure 12: Spectral content of the test signal and the frequency response of the DUT

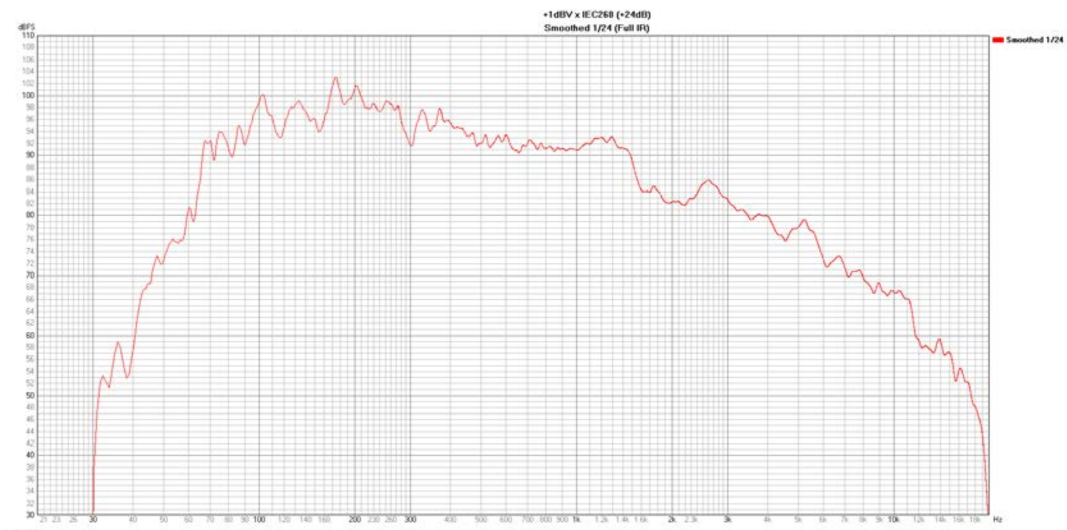


Figure 13: Calculated spectral content of the output from the DUT at the termination of the test

Step 5
Compute the broadband SPL of the result of step 4 and reference it to 1 m to yield a suitably anechoic representation of the DUT as if it was driven at its MIV continuous.

The data from Figure 13 is exported in text format at 1/24 octave frequency spacing and copied into a spreadsheet application where further calculations can be made using the data. The following calculations are made.

A. At each frequency the squared pressure is calculated from the SPL.

B. The pressure squared for all the frequency data points are summed together to get the total pressure squared.

C. The total SPL is calculated from the total pressure squared.

D. The total SPL is then referenced to a 1 m, free-field level.

For the example given here the following are the calculated values.

Total Pressure^2 = 1.85 x 10^{11} Pa^2
Total SPL = 112.7 dB

The measurement was made at 3 m with the microphone placed using a ground plane measurement technique.

Level adjustment for 3 m to 1 m = + 9.5 dB
Level adjustment for Ground Plane to Free-Field = - 6 dB
Total Level Adjustment = + 3.5 dB

SPL_{MUCO} = 112.7 dB + 3.5 dB
SPL_{MUCO} = 116.2 dB

Appendix D. List of Equipment Needed to Perform Tests Described in This Standard

Section 5 - Frequency Response and Crossover Category

- Sufficiently large reflection-free environment – a qualified anechoic chamber or outdoors
- Tape measure, or similar tool, to measure distance
- Type 2 or better measurement microphone
- Constant voltage source (power amplifier) capable of producing sufficient voltage at frequencies from 20 Hz to 240 Hz (for passive DUT only)

Section 6 - Maximum Usable Sound Pressure Level – Continuous

- ANSI/CEA-2034 noise source
- Level control
- Constant voltage source (power amplifier) capable of producing sufficient voltage at frequencies from 20 Hz to 240 Hz (for passive DUT only)
- True rms voltmeter with adequate crest factor compliance and bandwidth
- Peak reading voltmeter
- Transfer function analyzer
- Type 2 or better measurement microphone

Section 7 - Maximum Usable Sound Pressure Level - Peak

- 1/3 octave tone-bursts
- Level control
- Constant voltage source (power amplifier) capable of producing sufficient voltage at frequencies from 20 Hz to 240 Hz
- Type 2 or better measurement microphone
- FFT analyzer with usable bandwidth to 20 kHz and a frequency resolution of 5 Hz or finer

Section 10 - Impedance

- Transfer function analyzer
- Constant voltage source (power amplifier) capable of producing sufficient voltage at frequencies from 20 Hz to 20 kHz
- True rms voltmeter with adequate crest factor compliance and bandwidth

Consumer Technology Association Document Improvement Proposal

If in the review or use of this document a potential change is made evident for safety, health or technical reasons, please email your reason/rationale for the recommended change to standards@CTA.tech.

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