In-ceiling Loudspeakers

Design Guide

English

Overview

Introduction

Using this design guide, you will be able to create designs for applications that utilize in-ceiling loudspeakers. We offer additional design guides for surface-mount and pendant-mount loudspeakers, as well as dedicated design guides for EdgeMax and FreeSpace 3 sub-satellite systems. To learn more about our loudspeakers and technology capabilities, as well as access additional trainings and tutorials, visit **BoseProfessional.com**.

System Design Resources

In addition to this guide, we offer the following tools at **BoseProfessional.com** on the software and individual loudspeaker product pages:

Modeler: Advanced acoustical design simulation tool, with direct and reflected energy, and Speech Transmission Index (STI). Free to download at **BoseProfessional.com/Modeler**

EASE GLL files: For use in the AFMG EASE application, and the EASE GLL Viewer application. EASE allows the simulation of reverberation times, speech intelligibility, and other acoustical parameters. EASE is a paid download. EASE GLL Viewer is free to download.

EASE Address files: For use in the AFMG EASE Address (2D tool, direct field coverage) or EASE Evac. EASE Address is free to download.

BIM files: Includes the Revit format. Revit is a paid download.

Overview

All system designs begin with a set of requirements. The system requirements can be as simple as, “it has to sound great” or as detailed as, “it must play background-level music at 5 dB above the ambient noise level of the restaurant's main dining room, which is 65 dB.” The challenge is to gather the right set of requirements, and then turn them into a set of criteria that you can use to create your design. It is important to remember that you are the designer and should use your own intuition and decision skills when planning a project in addition to calculations. Applications with mounting heights between 2.4 meters and 10 meters (8 feet and 32 feet) are supported through the in-ceiling loudspeaker models listed in this guide.

There are four key requirements that need to be identified to deliver the right system:

Loudness: What sound pressure level (SPL) is required for this application?

Ceiling Height: What loudspeakers will work best for my room’s ceiling height?

Response: What bandwidth is required for the type of program material that will be used?

Coverage: How consistent must the sound be across the entire coverage area?

Each of these requirements can be easily converted into a specification that we can use to create our system design. If we understand the customer’s needs in these four areas, we can deliver a design that will — at a minimum — meet their needs and — at best — exceed their expectations.

For the purposes of this design guide, we will assume that you are familiar with the system requirements for a commercial audio system and are ready to focus on loudspeaker selection, creation of a loudspeaker layout, and defining the necessary amplifier power needed to power the design.

Design Guidelines

When creating a design, you should consider the following:

Ceiling Height

Maximum SPL for the application (for example 70 dB-SPL, Z-weighted)

Design Worksheet

Use the following worksheet to create a design using Bose Professional loudspeakers.

Choosing a Model

Step 1: Loudness

Maximum SPL Capability

Confirm that your chosen loudspeaker model will meet your loudness requirement. Find your ceiling height and follow the column down until you reach your desired maximum continuous output level. Models with a higher sensitivity and higher tap settings will be able to play at higher levels. Individual model tap charts are available at the end of this document.

Example: *For a ceiling height of 5 meters (16 feet) in a project that requires 90 dB, you would choose FS4CE.*

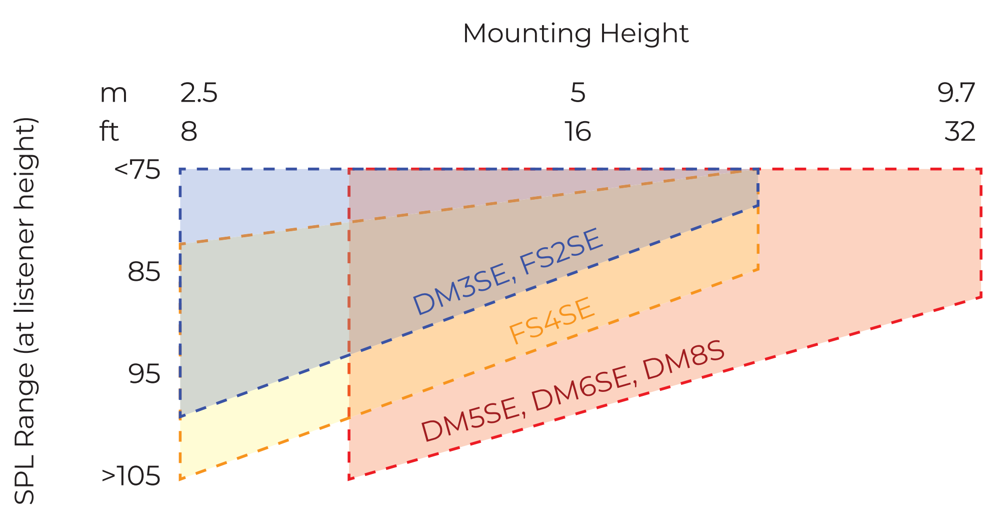
In-ceiling Models: Maximum Continuous Output Level														
Ceiling Height		m	2.4	2.7	3	3.7	4	4.3	5	5.5	6	6.7	8	9.8	
		ft	8	9	10	12	13	14	16	18	20	22	26	32	
DM2C-LP	9W tap		94	92	90	87	86	85	83	82	80	79	77	75	dB-SPL
	16W / 16Ω		97	94	92	89	88	87	85	84	83	82	80	78	
DM3C	25W		98	95	93	90	89	88	86	85	84	83	81	79	
FS2C	16W		99	96	94	91	90	89	87	86	85	84	82	84	
FS4CE	40W		105	102	100	97	96	95	93	92	91	90	88	86	
DM5C	50W		105	102	100	97	96	95	93	92	91	90	88	86	
DM6C	80W		108	105	103	100	99	98	96	95	94	93	91	89	
	100W / 8Ω		109	106	104	101	100	99	97	96	95	94	92	90	
DM8C	80W		111	108	106	103	102	101	99	98	97	96	94	92	
	125W / 8Ω		113	110	108	105	104	103	101	100	99	98	96	94	

Note: *The above table assumes standing ear height at 1.5 meters (5 feet), in minimum overlap configuration. Room reverberation could add as much as 4 dB system gain, which is not factored into the measurements above. Use of the transformer on 70/100V systems will introduce an insertion loss of 1 to 2 dB.*

Step 2: Ceiling Height

Average Conical Coverage and Woofer Sizes

Smaller woofer models have wider average conical coverage and provide better results in low ceilings. Larger woofer models with narrower average coverage angles are better suited for higher ceilings. Choose the models that will work with your ceiling heights and rule out the other models.



Woofer Size	Model	Sensitivity (dB)	Highest Tap / Power Handling	Recommended Ceiling Heights
2–4 in	DM2C-LP (70/100V)	84	9W	2.5 m–6.1 m (8'–20')
	DM2C-LP (16Ω)		16W	
	DM3C	83	25W	
	FS2C	86	16W	
	FS4CE	88	40W	
5–8 in	DM5C	87	50W	3 m–10 m (10'–32')
	DM6C (70/100V)	88	80W	
	DM6C (8Ω)		100W	
	DM8C (70/100V)	91	80W	
	DM8C (8Ω)		125W	

Step 3: Response

Confirm that the chosen loudspeaker will meet your low frequency response requirement.

Vocal-range	Low Frequency (–10 dB)
DM2C-LP	85 Hz
FS2C	83 Hz
DM3C	75 Hz

Full-range	Low Frequency (–10 dB)
FS4CE	70 Hz
DM5C	65 Hz
DM6C	59 Hz
DM8C	52 Hz

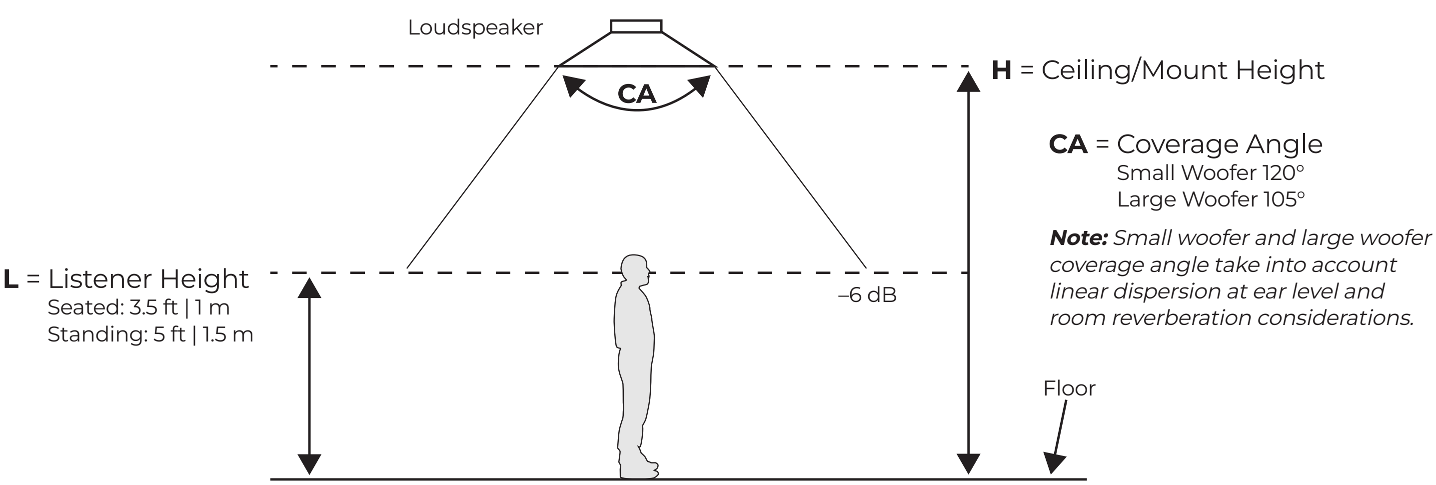
Extended-range	Low Frequency (–10 dB)
FreeSpace 3 system	40 Hz
EdgeMax EM90/EM180	45 Hz
Any vocal-range or full-range loudspeaker combined with DM8C-SUB subwoofer	38 Hz

Step 4: Coverage

Determining Loudspeaker Quantity and Spacing

The goal is to fill a rectangle-shaped room with coverage circles at your desired density. Using the graph paper on the last page, create a sketch layout of the room. Using your sketch of the room, follow the steps below to create a layout with the loudspeaker spacing that meets your coverage requirement. Calculators or software can simplify this process. Medium-sized or larger distributed installed systems for background music or voice typically have four or more ceiling loudspeakers in a room. Use **Loudspeaker Spacing Distance (LSD)** for small rooms that only need one.

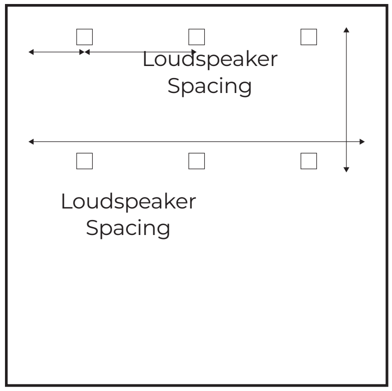
A. Calculate the Loudspeaker Spacing Distance (LSD)

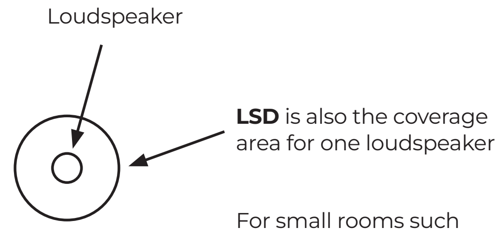


LSD = Spacing Distance

M = Multiplier

LSD = (H – L) × M





For small rooms such as bathrooms, you may only need one or two loudspeakers to cover the room; look at **LSD**

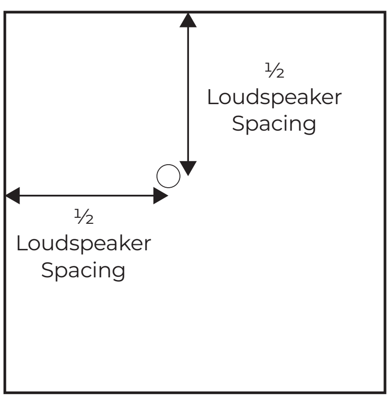
2–4 in Small Woofer Coverage	M (multiplier)	Models
Edge-to-edge	3.46	FS2C DM2C-LP DM3C FS4CE
Minimum Overlap	2.45	
Center-to-center	1.73	

5–8 in Large Woofer Coverage	M (multiplier)	Models
Edge-to-edge	2.61	DM5C DM6C DM8C
Minimum Overlap	1.84	
Center-to-center	1.30	

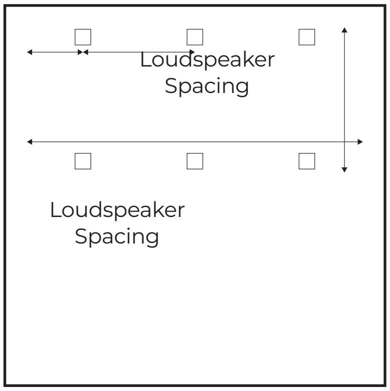
Multipliers are created from **Coverage Angles (CA)**. These are multipliers we have found to work for most applications. For more precise results, and to adjust for obstructions, use **Modeler**, **EASE**, **EASE Address**, or **EASE Evac** software, or another calculator.

Edge-to-edge coverage can provide fidelity in fixed-location seating/standing and can generally work well for installations on a budget. It also works well for ambient-level and low-level background music. Center-to-center installations will have higher density and can accommodate people listening in many different positions and moving floor plans due to uniform coverage. They will also have fewer dead zones. Minimum overlap (or center-to-center) may also be needed if critical communication is happening over the system. **Modeler** or **EASE Evac** software can help with speech intelligibility evaluation.

B. Place the first loudspeaker at ½ LSD from any corner of the room.

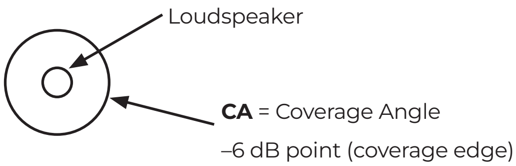


C. The remaining loudspeakers are arranged on a square grid pattern using the LSD. If a loudspeaker would be placed on or beyond the perimeter of the room, delete that row/column of loudspeakers.



D. After the last loudspeaker is placed, center the loudspeakers in that row to create new offset distances out from each wall, which may be unique from ½ LSD.

E. (Optional) To quickly calculate the total **Loudspeaker Quantity (LQ)** needed to fill the rectangular room without using graph paper, follow this method. In square layouts, the final total is sometimes slightly reduced as you lay out rows. You can also determine final quantity by following Step B on graph paper until the room is filled.

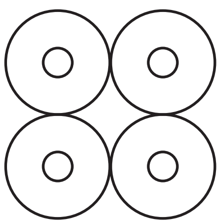


Area = Square footage of room (Length × Width)

$$LQ = \frac{\textbf{Area}}{[(\textbf{H} - \textbf{L})\frac{\textbf{M}}{2}]^2}$$

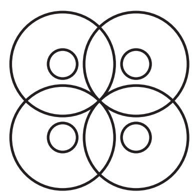
Edge-to-edge = LQ/4

–6 dB touching



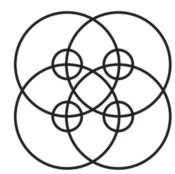
Minimum overlap = LQ/4

–3 dB touching



Center-to-center = LQ/4

–1.5 dB touching



Subwoofers: Quantity and Placement of Subwoofers

The number of subwoofers to use, where to position them, and how loud to set them can vary depending on the individual situation. Details such as placement, boundary loading, room size, coupling quantity of multiple loudspeakers to subwoofers, type of music, type of activity, budget, and the expectations of the listeners should all be considered. The following guidelines are general rules to follow.

Add one subwoofer for every group of four vocal- or full-range loudspeakers.

Subwoofer spacing should be as far apart as is practical. 12.2 meters (40 feet) or greater subwoofer-to-subwoofer spacing distance within the same zone is desirable.

When the suggested subwoofer count is two within a single zone, it may be preferable to use either one in a corner to avoid audible interference; or increase the count to three, which creates more audible interference locations but limits them to smaller sizes where the reverberant field (added room reflections) tends to mask them.

Placing a ceiling subwoofer within 0.9 meters (3 feet) of a wall increases its output by 3 dB. Placing it within 0.9 meters (3 feet) of a corner increases its output by another 3 dB (6 dB total) and also reduces reflections that can create audible interference (bass cancellations) in the listening area.

Listening positions located below the subwoofer should be supported by a nearby vocal- or full-range loudspeaker to provide better tonal balance in the low-frequency pressure zone.

Step 5: Calculate Required Amplifier Size

All FreeSpace FS, DesignMax, and EdgeMax loudspeakers are compatible with 70-volt, 100-volt, and low-impedance amplifiers.

Use the Tap Charts to determine which loudspeaker tap is required for this design

A. Locate the loudspeaker tap chart and find the column for mounting height for this design.

B. Follow the column to the desired maximum SPL.

C. Follow the row across the chart to determine the required loudspeaker tap.

D. Calculate the required amplifier power:

__________ × __________ = __________

Number of Loudspeakers Required | Required Loudspeaker Tap | Power Required

E. Calculate the required amplifier size:

__________ × 1.10 = __________

Power Required | Headroom | Amplifier Size

Amplifiers: Example Amplifier Configurations

Modern amplifiers come in a variety of channel counts and configuration options to allow for different output configurations, zoning options, and varying loudspeaker quantities. A properly optimized system may only need a low 1- or 2-watt tap setting to achieve 70 dB in a typical room. The below example lists how many FS2C loudspeakers can be handled at the loudspeaker's highest 70/100V tap setting.

FreeSpace FS2C Loudspeaker Amplifier Example	Maximum Loudspeakers at Higher Tap Settings	EQ Preset	Average SPL*
FreeSpace IZA 190-HZ	5 at 16W, 10 at 8W tap	FS2C/SE/P	87 dB at 16W, 84 dB at 8W
FreeSpace IZA 2120-HZ	5 at 16W, 13 at 8W	FS2C/SE/P	
PowerShare PS404D	22 at 16W, 45 at 8W	FS2C	
PowerSpace P4150+	8 at 16W, 17 at 8W	FS2C	

* 3 meter (10 foot) ceiling height room with edge-to-edge density, standing listener, 12 dB crest factor of pink noise/compressed music, direct-field, no room gain.

SmartBass: Application of SmartBass processing

If your design is using a PowerSpace+ amplifier; or your design utilizes a dedicated Bose Professional DSP, such as the Commercial Sound Processor CSP models; or any of the ControlSpace ESP or EX models; you have the option of applying SmartBass to your loudspeaker output channel. This uses Bose Professional EQ presets, dynamic EQ, and excursion limiting tuned to each model and room calibration. This will prevent lower background-level music from sounding thin, but also ensures the sound is consistent at various SPL levels. At louder levels, SmartBass also allows for more musical limiting than traditional voltage limiters.

Tap Charts

Individual Loudspeaker Continuous Output Level

Note: *The following tap charts assume standing ear height at 1.5 meters (5 feet) in minimum overlap spacing. Room reverberation could add as much as 4 dB system gain, which is not factored into the measurements. Designing without room gain will ensure you don't under-plan your design, and amp attenuation is possible at the job site if you exceed the average room SPL target during measurement. Values below 70 dB are omitted, select a higher tap.*

DM2C-LP

DM2C-LP (standing listener height)														
Ceiling Height		m	2.4	2.7	3	3.7	4	4.3	5	5.5	6	6.7	8	9.8	
		ft	8	9	10	12	13	14	16	18	20	22	26	32	
TAP	1.2W		85	83	81	78	77	76	74	73	72	70	—	—	dB-SPL
	2.3W		88	86	84	81	80	79	77	76	74	73	71	—	
	4.5W		91	89	87	84	83	82	80	79	77	76	74	72	
	9W		94	92	90	87	86	85	83	82	80	79	77	75	
	16Ω		97	94	92	89	88	87	85	84	83	82	80	78	

FS2C

FS2C (standing listener height)														
Ceiling Height		m	2.4	2.7	3	3.7	4	4.3	5	5.5	6	6.7	8	9.8	
		ft	8	9	10	12	13	14	16	18	20	22	26	32	
TAP	1W		87	84	82	79	78	77	75	74	73	72	—	—	dB-SPL
	2W		90	87	85	82	81	80	78	77	76	75	73	75	
	4W		93	90	88	85	84	83	81	80	79	78	76	78	
	8W		96	93	91	88	87	86	84	83	82	81	79	81	
	16W		99	96	94	91	90	89	87	86	85	84	82	84	
	8Ω		99	96	94	91	90	89	87	86	85	84	82	80	

DM3C

DM3C (standing listener height)														
Ceiling Height		m	2.4	2.7	3	3.7	4	4.3	5	5.5	6	6.7	8	9.8	
		ft	8	9	10	12	13	14	16	18	20	22	26	32	
TAP	3W		88	86	84	81	80	79	77	76	75	73	72	—	dB-SPL
	6W		91	89	87	84	83	82	80	79	78	76	75	72	
	12W		94	92	90	87	86	85	83	82	81	79	78	75	
	25W		98	95	93	90	89	88	86	85	84	83	81	79	
	8Ω		98	95	93	90	89	88	86	85	84	83	81	79	

FS4CE

FS4CE (standing listener height)														
Ceiling Height		m	2.4	2.7	3	3.7	4	4.3	5	5.5	6	6.7	8	9.8
		ft	8	9	10	12	13	14	16	18	20	22	26	32
TAP	2.5W		93	90	88	85	84	83	81	80	79	78	76	74
	5W		96	93	91	88	87	86	84	83	82	81	79	77
	10W		99	96	94	91	90	89	87	86	85	84	82	80
	20W		102	99	97	94	93	92	90	89	88	87	85	83
	40W		105	102	100	97	96	95	93	92	91	90	88	86
	8Ω		105	102	100	97	96	95	93	92	91	90	88	86

dB-SPL

DM5C

DM5C (standing listener height)														
Ceiling Height		m	2.4	2.7	3	3.7	4	4.3	5	5.5	6	6.7	8	9.8
		ft	8	9	10	12	13	14	16	18	20	22	26	32
TAP	3W		92	90	88	85	84	83	81	80	79	77	76	73
	6W		95	93	91	88	87	86	84	83	82	80	79	76
	12W		98	96	94	91	90	89	87	86	85	83	82	79
	25W		102	99	97	94	93	92	90	89	88	87	85	83
	50W		105	102	100	97	96	95	93	92	91	90	88	86
	8Ω		105	102	100	97	96	95	93	92	91	90	88	86

dB-SPL

DM6C

DM6C (standing listener height)														
Ceiling Height		m	2.4	2.7	3	3.7	4	4.3	5	5.5	6	6.7	8	9.8
		ft	8	9	10	12	13	14	16	18	20	22	26	32
TAP	2.5W		93	90	88	85	84	83	81	80	79	78	76	74
	5W		96	93	91	88	87	86	84	83	82	81	79	77
	10W		99	96	94	91	90	89	87	86	85	84	82	80
	20W		102	99	97	94	93	92	90	89	88	87	85	83
	40W		105	102	100	97	96	95	93	92	91	90	88	86
	80W		108	105	103	100	99	98	96	95	94	93	91	89
	8Ω		109	106	104	101	100	99	97	96	95	94	92	90

dB-SPL

DM8C

DM8C (standing listener height)														
Ceiling Height	m	2.4	2.7	3	3.7	4	4.3	5	5.5	6	6.7	8	9.8	
	ft	8	9	10	12	13	14	16	18	20	22	26	32	
TAP	2.5W	96	95	107	104	103	102	101	99	98	97	95	93	dB-SPL
	5W	99	96	94	91	90	89	87	86	85	84	82	80	
	10W	102	99	97	94	93	92	90	89	88	87	85	83	
	20W	105	102	100	97	96	95	93	92	91	90	88	86	
	40W	108	105	103	100	99	98	96	95	94	93	91	89	
	80W	111	108	106	103	102	101	99	98	97	96	94	92	
	8Ω	113	110	108	105	104	103	101	100	99	98	96	94	

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Graph Paper

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20