YOUR HOME THEATRE
Widescreen Review
The Essential Home Theatre Resource™

Noise Control For Home Theatres

Smoke & Mirrors 101

Harry Alter

During investigative discussions about building a home cinema, you may have heard that noise control is something not to be overlooked, especially if you're looking to create a truly awesome home theatre experience. But what is noise control, how much do you need, and do all those noise-control products out there really make a difference? How do you choose a product, and when you do…will it really work?

Well, we're getting to the bottom of all that in this article. And while we're at it, you'll learn a little about what to look for in noise control products, what questions to ask, and what to be cautious of. So without further ado, let's clear the smoke from the room, work our way through the maze of technical jargon, and remove the mirrors, so everyone can clearly see and hear what a really great home theatre experience is all about.

Where to start? What better place than "Why." Why do we need home theatre noise control in the first place? Two reasons:

1. noise reduction means improved sound quality, and
2. we don't want to disturb others.

The most important reason to design for noise control in the home cinema environment is to create conditions that will first and foremost allow for the re-creation of the cinematic experience intended by the artist(s). Pretty obvious right? "Creating conditions" is really what home cinema noise control is all about. If we fail at creating desirable room conditions, the result can quickly go from disappointing to disastrous. The common aphorism "garbage in, garbage out" holds true throughout the structural and electronic design stages of home cinema. Noise is distortions and/or distractions that are not original to the audio signal.

One of the most important reasons we approve or disapprove of any home cinema experience is the result of our own ability to listen and experience sound with a critical ear. The desire to re-create and understand this experience is probably why you're reading this article. We love it, because we know when the experience is right, likewise, we know when the experience isn't right. We quickly become a discerning audience that knows the difference between awesome and awful, and as a result, become "critical" about our expectations and how we "listen to our surroundings" during the home cinema experience. I emphasize, "listening to our surroundings," because what we hear within the shell of a home cinema is largely influenced by how the walls, floor, doors, and ceiling treat the sound energy generated within, around, and through the space.

So let's begin by taking a closer look at how walls, floors, doors, and ceilings influence your listening experience.

There are three basic ways that rooms (walls, floors, doors, and ceiling partitions) influence sound energy:

1. The partition will absorb sound energy.
2. The partition will transmit sound energy through it.
3. The partition will reflect sound energy back into the listening space.

How sound energy reacts with its surrounding room envelope can vary immensely, depending on how much sound energy travels via each energy path. Changing or varying the energy path for better or for worse depends on a complex array of products, their material properties, and how they are integrated together to form an assembly.

To better illustrate how the flow of sound energy affects the room's listening environment, let's bundle items **1** and **2** (absorption

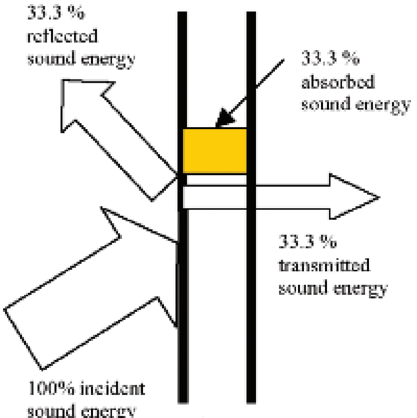


Figure 1

A wall partition illustrating equal trade-offs of reflected, absorbed, and transmitted sound energy.

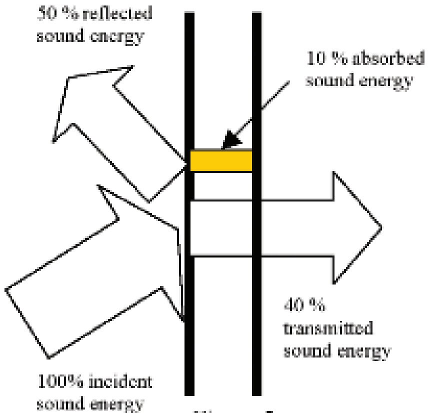


Figure 2

A wall partition illustrating a high % of reflected and transmitted sound energy with little sound absorption.

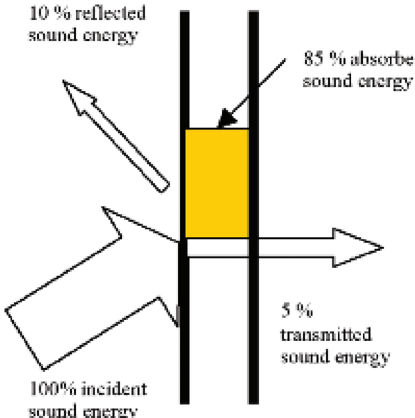


Figure 3

A wall partition designed for high absorption and low reflected and transmitted sound energy.

and transmission) together as all the sound energy that potentially “leaves” the room, and item **3** (reflection) as all the sound energy that remains in or is reflected back into the room. Let’s call the sound energy that leaves the room α (alpha) and that sound energy reflected back into the room ρ (sigma). My high school physics tells me that Newton once said that energy can neither be created nor destroyed. So all the sound energy that is incident to your room’s shell, before any reflection or absorption takes place, is equal to 100 percent of a partition’s incident sound energy. The following equation describes how these principles come together.

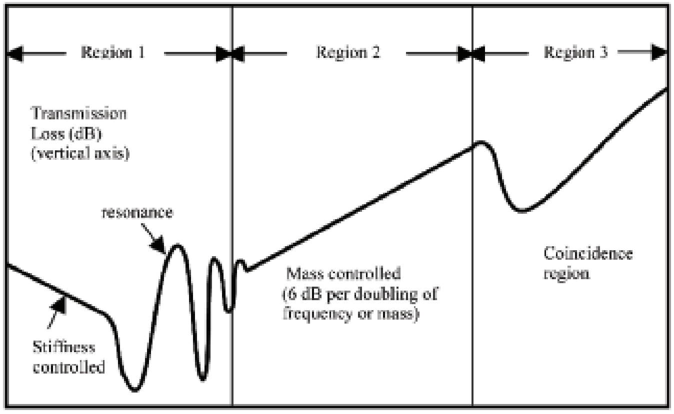
$$\rho + \alpha = 1.0 \quad (100\ \text{percent})$$

Pictorially, let’s look at how different wall partitions can treat sound energy [Figures 1, 2, and 3 on the previous page].

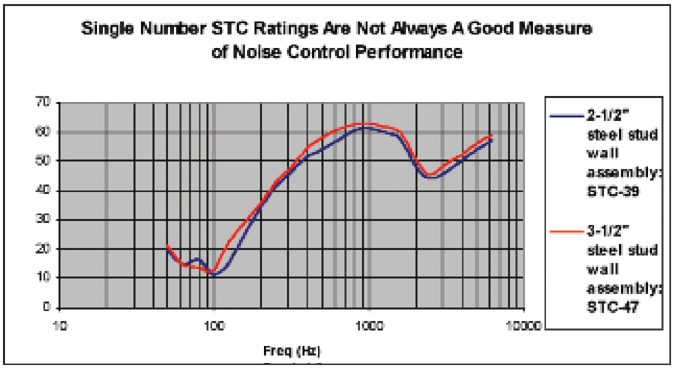
As you can see, Figure 3 provides the best results by utilizing a number of sound absorption characteristics to limit the amount of energy flowing back into the listening space as well as into adjacent rooms. Unfortunately, achieving this is easier said than done. Often the use of too much mass and too little panel absorption provides good sound transmission loss results, at the expense of interior room sound quality, i.e. way too much energy is being pumped back into the room from the un-optimized partition assembly design.

Graph 1 provides a basic overview of how a simple homogeneous panel reacts to sound energy over a broad range of sound frequencies (horizontal axis). The amount of decibels that are transmitted from sound passing through it is generally depicted by the graph. The higher the decibel loss (vertical axis), the greater the panel’s ability to reduce transmitted sound energy. The term for this type of measurement is called “Sound Transmission Loss” or TL for short. Another way to put it is that transmission loss (TL) is the loss in sound power that results when sound travels through a partition. The more energy that is lost, the greater the TL. Sound transmission data is used to determine the single-number sound-performance rating for partitions called the STC (Sound Transmission Class). The higher the number, the better the partition isolates noise from one side to the other.

Before I speak about each of the regions of vibration above, I would like to clarify in more detail the role STC (Sound Transmission Class) and TL (Transmission Loss) play in determining the acoustical performance level of wall, floor, ceiling, or door partitions. TL frequency curves enable you to see if specific wall, ceiling, or door assemblies show any specific frequency weaknesses not evident in a single STC rating. Single-number STC ratings can be misleading, especially if you wish to accurately match the performances of various components making up the shell of your room. Getting apple-to-apple comparisons in noise control assemblies is often a difficult task. When beginning the design process for the shell of a home theatre or studio environment, always try to find the actual test TL data that reflects the STC number being advertised. STC ratings are convenient, but really don’t give you the complete picture. They can even be misleading. For example, let’s look at the STC rating of a 2.5-inch metal stud wall and compare it to the STC rating of a 3.5-inch metal stud wall. Looking only at the STC ratings indicates that the 2.5-inch metal stud wall has an STC-39 and the 3.5-inch metal stud wall has an STC-47. Wow, an 8-point increase. Not bad…but wait, let’s take a closer look and compare the TL contours for these two wall assemblies. See Graph 2.



Graph 1: Transmissions Loss Characteristics for a homogeneous panel.

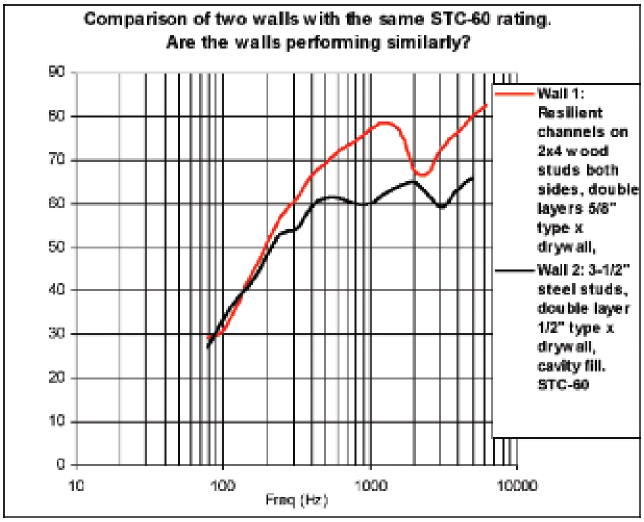


Graph 2: Transmission Loss (TL) contours of two single-number STC ratings.

When we look at the average dB difference across 1/3 octave bands, we only get a difference of about 2 dB. If you were to build these two walls next to each other, you would not hear the difference between them. So why the 8 point jump? STC ratings often pivot around one or two key frequencies. In this case, the key frequency is a 7 dB difference at 125 Hz. So be careful. Just because someone says the wall or floor assembly has an 8 or 10 point STC advantage over the competition doesn’t always mean it’s really performing that much better. You need to look at the TL curves.

While STC is not perfect, TL has its problems too. I’ll explain why shortly. For now, I want to show you how identical STC ratings can also be deceiving.

Home cinema designs often recommend a minimum STC rating of 60, with STC-65 and higher being an often-preferred performance



Graph 3: TL comparison of two walls with the same STC-60 rating.

level. Let’s look at two different types of high-performance walls with the same STC-60 rating to see how their TL curves compare (Graph 3).

It is obvious from looking at the two TL curves that Wall 1 (red) appears to perform better than Wall 2 (black) in the mid- to high-frequencies, and yet, their STC ratings are identical. The average dB difference over the TL spectrum is approximately 8 dB. The region on the graph where these decibel differences occur is located in what is often called the “speech frequency” region of human hearing. These are the frequencies that make up most of human speech, and as a result of human evolution, our ears have become sensitive to the perception of sound falling within these frequencies (approximately 200 through 4,000 Hz). If we were to listen to sounds such as music, conversation, or various movies through these two wall assemblies, we would clearly hear a difference between the two.

So my message here is that while STC ratings are helpful, they are far from perfect. Until reviewing the TL curves for the partition assemblies and doors, we really don’t know what frequencies and at what decibel level the partition assembly will perform. And not knowing that up front could mean disappointment later…expensive disappointment.

I’m going to say a few more things here, not in an attempt to frustrate you but to give you as much information to help you understand the limitations of the information brought before you, so as to ultimately help you through the product or partition selection process. As I wrote a few paragraphs back, even TL has its limitations. Most TL curves are measured at center frequencies of 1/3 octave bands, beginning around 80 to 100 Hz. ASTM standard E-90 states that a laboratory only needs to report data from 125 through 4,000 Hz to get an STC rating. As I’m sure you know, this is far from the total frequency spectrum being reproduced by your standard home theatre system. We all want to know how the walls, floor, ceiling, and doors will react to frequencies down as low as 31 Hz or lower, but unfortunately, test laboratories can only report low-frequency data that can accurately be reproduced in their test facility and have a high level of repeatability and confidence (95 percent confidence to be exact). That means that for testing laboratories to accurately measure low-frequency waves, it is necessary that the test rooms be very large. This is to allow the long wavelengths associated with center frequencies of 31, 50, or 63 Hz to become fully developed and diffuse within the space [Editor’s Note: The wavelength of a 31 Hz signal is 35 feet or more, depending on air temperature]. Sometimes you will see laboratory data listed down to a center frequency of 50 Hz. While this data can be listed, if taken, it will in most cases not meet the 95 percent confidence level required by ASTM. Some data, as I said, only achieves measurable 95 percent confidence levels from 80 Hz and above, and most labs can only report down to 100 or 125 Hz. Bottom line, TL isn’t perfect either, but like STC, it is a tool that can help us understand the capabilities of the partition assemblies under review within its own limitations. (So if someone tells you their product has been tested and is certified down to 50 Hz or less, ask for proof, like a test report. If the report is any good, it will note that the low-frequency data is not within their confidence levels.)

So what do you do when it comes to determining a partition’s performance in the very-low-frequency range? The following discussion looks at the principles governing how partitions vibrate and will, hopefully, help you understand what to look for when selecting effective noise-control products within wall, floor, ceiling, and door (partition) assemblies.

Let’s take a closer look at these important sectors or regions of vibration.

Three basic regions of the frequency spectrum are indicated in Graph 1 on page 40 and show how a barrier reacts to sound energy.

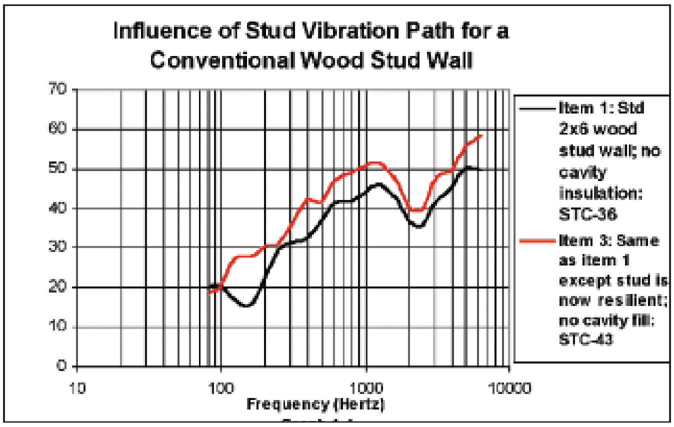
1. Region 1: Stiffness And Mass Resonance

a. Stiffness: The overall stiffness of a barrier influences its ability to radiate sound energy in the low-frequency range, just below the low-frequency resonance region (wavy line area of Graph 1). In this low-frequency region of the sound spectrum, it is stiffness alone that forces the wall into motion. The stiffness of the wall, floor, or ceiling partition is acting as a large spring, which will increase in sound isolation as the frequency of the spring (partition) is reduced. Reducing the overall stiffness of a barrier or partition will improve the partition’s ability to attenuate low-frequency sound energy; however, this is easier said than done. Partition design is always a balancing act between the structural load requirements of the partition (wall, floor, or door), physical space constraints (how thick the partition can be), budgetary constraints, and the desired noise-control performance. It is a game of give and take, where the ultimate goal is to take energy out of the system.

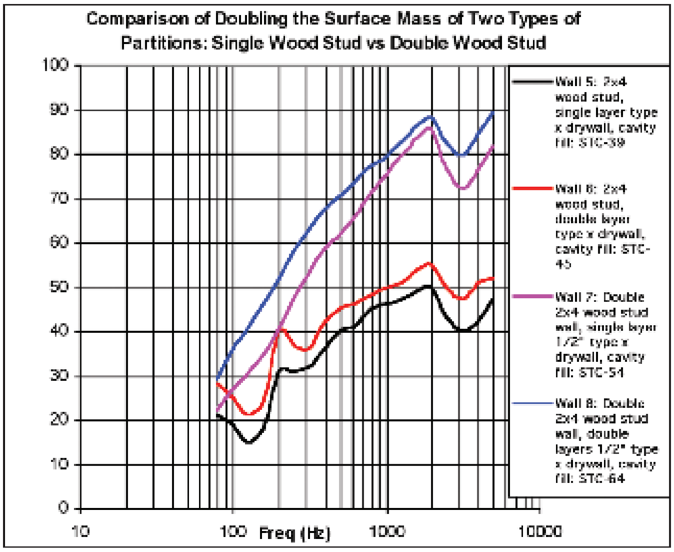
b. Resonance: As we move up the frequency spectrum, still in the low-frequency region, we find many low-frequency frequency resonances that are driven not only by stiffness but are now also driven by the mass of the overall structure. I will write a lot about mass and its influence on partition movement, however, we should be aware that low-frequency resonances are not always attributed to mass alone. Wave velocity within the various materials (such as drywall), the size and thickness of the partition, the use (or lack) of structural vibration connections, and cavity air space are just a few features that can attribute to low-frequency resonances. Unfortunately, nothing is as simple as we would like it to be, but with a little work we can boil things down and begin to digest pieces of the puzzle.

To illustrate the influence of various vibration paths through a wall (Graph 4), let’s look at the Transmission Loss curve for a conventional 2x6 wood stud wall with no cavity insulation, and compare it to that same wall where the direct vibration path through the stud has been broken using resilient technology (resilient studs or resilient channels).

The black (Item 1) TL contour in Graph 4 looks very much like the general TL contour of Graph 1. We can see that there is a definite low-frequency resonance occurring at around 160 Hz. When we isolate the vibration path through the stud (Item 3, red TL contour) we can see the detrimental influence a conventional stud or joist plays to directly pass vibrations from one side of a partition to the other. Isolating vibrations from passing into the stud or joist means that the gypsum board (or subfloor) energizes or vibrates less to produce



Graph 4: Influence of stud vibration path for a conventional wood stud wall.



Graph 5: Comparison of doubling the surface mass of two types of partitions: single-wood stud versus double-wood stud.

sound. The partition becomes quieter, not only at resonance, but across a wide band of frequencies above the low-frequency resonance as well. So, studs and joists, when directly connected (coupled) to gypsum board and/or subfloors, are a dominant path for vibrations to freely pass from one side of the partition to the other.

Another technology that can be used for both low- and high-frequency resonance is viscoelastic damping. One of the benefits from the proper use of this technology is to reduce the amplitude of vibrations within the sheet material (say drywall or plywood) at resonant frequencies. That means that viscoelastic design looks at the properties of the vibrating material and determines the resonant frequencies that are prevalent, with the viscoelastic product designed to specifically address those frequencies. It may sound easy, but proper damping requires a number of features and attributes to be successful. Viscoelastic materials are typically a thin layer of semi-flexible (temperature-dependant) compounds that convert the bending shear stresses of a vibrating layer into heat. Again, the proper combination of system design, such as proper placement of mass, viscoelastic damping, and stiffness (or lack of) can provide excellent results.

2. Region 2: Mass Controlled

The mass controlled region, as the description indicates in Graph 1, is based on the influence of the overall weight or mass that a partition plays to control the transmission of sound energy. The "Mass Law" as it is called, is based on the premise that each small section of a panel or partition oscillates independently from the other. As a result, for every doubling of the mass or frequency in this region, the TL performance is expected to improve by 6 dB. Unfortunately, in real life, each small section of a pane is connected with a relative stiffness between them. As a result, the doubling of mass in the field does not always fit the 6 dB ideal of the Mass Law (often 4 or 5 dB improvements are seen). 6 dB is clearly discernable to the human ear, and it often makes sense to double the weight of a partition via the drywall, at least once. But opting to add more mass can quickly become wasteful and create more of a problem than it's worth (including driving more low-frequency sound energy back into the listening space, but we'll talk more about that later). Suddenly, you have a very muddy sounding room.

Think of it this way, to move anything that gets heavier and heavier, more and more effort (energy) will be required. If the amount of energy is insufficient to set a massive barrier into motion, the partition will be unable to vibrate sufficiently to radiate any significant sound energy at that frequency.

It is often said that mass is "king" in the world of noise control because it is so often the first choice of attach and is considered a safe approach when all else fails. Wall and floor STC performance can easily be increased through the use of doubling or tripling the layers of drywall, but at what cost?

Let's look at a couple of wall systems and see what happens when we double the surface mass by adding layers of drywall.

Graph 5 is intended to show you the relative change in transmission loss due to doubling the mass of the gypsum board surface. You can see from these tests that the shift is fairly similar, around 5 to 6 dB. While this gives you a good sense of how mass effects partition performance, I must emphasize that no two partition assemblies are alike. Remember, always check a partition's TL to see how the partition performs as the mass of the partition is increased. The key is that we are building partition systems that address a number of relevant frequencies, and mass plays a major role across a broad spectrum.

3. Region 3: Coincidence

When the bending sound waves form within the surface sheets of a wall, floor, or ceiling partition and coincide with the incident sound wave striking the panel, a resonance forms called "coincidence." It is quite typical in TL curves to see a fairly narrow but major dip in the TL performance. In Graphs 2 through 4 you can find the coincidence dip in the upper-frequency range between 2,000 and 3,000 Hz. The location and magnitude of this dip is primarily dependent on the density of the material, its modulus of elasticity, and the material thickness. For a given material such as drywall, the density and modulus of elasticity is constant, therefore, the driving factor is typically thickness.

Table 1 is a list of materials and their coincidence frequency.

As you can see, the coincidence frequency can easily shift, depending on the type and thickness of the material used as the surface sheet material.

There are a number of ways to reduce or shift the coincidence frequency. Elastomeric treatments work very well in this region. Introducing other materials and changing the thickness of the material reduces coincidence. A common remedy is to change out thicker gypsum boards with the application of multiple thinner layers.

As you can guess, gypsum wall board is a major player for most of the surface treatment of wall and ceiling partitions in the United States. The critical frequency for gypsum board can be calculated using the formula:

$$f_C \times t = 30.8$$

where "fc" is the critical frequency in Hz and "t" is the thickness of the gypsum board in meters. Table 2 shows how the coincidence dip changes relative to the thickness of the gypsum board.

Reflected Room Energy

An item I would like to write about before closing this article is the potential sound energy that walls, floors, and ceilings can reflect back into the listening room, due to poor partition design. As I noted at the beginning of this article, the best assemblies are those that gain the most sound absorption over a broad frequency range, using a variety of noise control options and techniques. A frequent problem is relying too much on mass. A good example of this is the reverberation times depicted in Graph 6, showing how a wall can

Table 1: Coincidence frequency of common materials.

Material	Thickness (millimeters)	Thickness (inches)	Coincidence Frequency (Hz)
Steel	3	1/8	4,000
Aluminum	3	1/8	4,000
Concrete	200	8	110
Brick	200	8	115
Glass	3	1/8	5,000
Gypsum	13	1/2	2,422
Lead	3	1/8	17,000
Plywood	13	1/2	1,700
Vinyl	3	1/8	10,000

push energy back into the room, based on its construction. The plots are of two walls that have very similar STC performance but very different contributions to the reverberation times within the room. One promotes the control of low-frequency energy from being reflected back into the room, while the other pumps too much low-frequency sound back into the listening environment, destroying the sound quality.

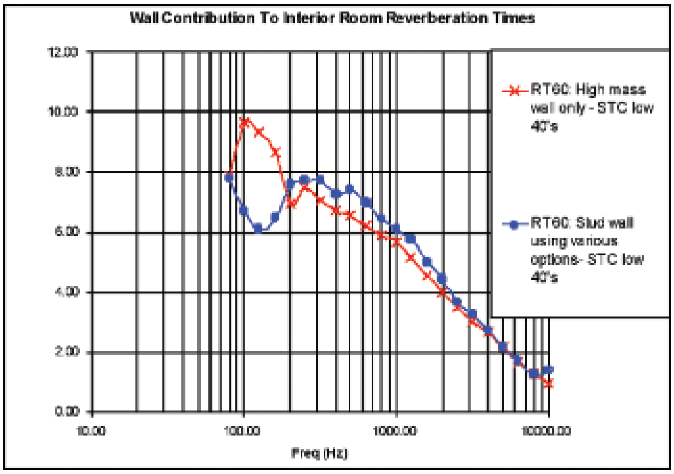
Table 2

t, inches	t, meters	f_c, Hertz
1/4	0.0064	4844
1/2	0.0127	2422
5/8	0.0159	1940
1	0.0254	1211

By combining various construction elements and effective products, one can greatly reduce potential design problems or failures.

The following is a list of elements often considered to optimize partition absorption, transmission, and reflection.

1. Increase stud/joist spacing
2. Change stud/joist type (wood versus metal)
3. Increase depth of cavity
4. Fill cavity with acoustical insulation
5. Increase mass of surface boards (careful, don't go overboard!)
6. Introduce multiple layers of surface board
7. Reduce thickness of surface boards while maintaining overall thickness
8. Vary thickness of surface boards
9. Introduce resilient isolation between surface boards and studs/joists
10. Introduce damping compounds between layers of surface boards
11. Change the material and/or component properties of the surface boards
12. Introduce vibration breaks wherever possible
13. Reduce hard surface-to-surface connections between floors and walls
14. Seal any and all gaps or penetrations to reduce air movement through the partition
15. Introduce a noise-rated door or double-door assembly
16. Refrain from introducing regions with little air space available (i.e. center septums or resilient channels fastened over existing gypsum board. These often make things worse instead of better)



In closing, this is a basic start, which I hope you have found valuable toward understanding more about the importance and science of noise control. The article does offer design tips but should convey the need for professional assistance due to the importance and complexity of acoustics. I'm sure you have many questions, like how many dB will each of the items listed above provide to my home theatre design, and how many is enough? I hope that future articles will delve deeper into questions like these, as well as address the importance of controlling flanking noise, impact insulation, HVAC noise, and other design issues. Remember that noise control is a two-way street: sound that leaves the space, and sound that enters it. Noise control partitions are system approaches to principals incorporating block, break, isolation and/or absorption of sound waves and vibrations. These systems must adhere to the unique governing weight, thickness, décor, budgetary and/or even "green" requirements of the project. These systems must be designed to address each unique noise-control issue; for example, maybe there is going to be a water pump for a pool adjacent to the cinema or a child's bedroom above. Different sound-energy levels and their frequency ranges must be understood in order for noise mitigation to be designed appropriately. Means of acoustic computer modeling (if new construction) or testing and modeling (if existing) will increase the likelihood of solving problems through proper acoustic design, resulting in a higher performance cinema and a greater experience. WSR

Harry Alter is the Senior Noise Control Agent for A/V RoomService, Ltd. A graduate of Columbia University in NYC, Mr. Alter has over 20 years of extensive experience in vibration control, acoustics, and business management. His expertise spans numerous disciplines in the field of acoustics, including all aspects of both sound quality and noise-control engineering. Mr. Alter's expertise has provided comprehensive design recommendations for such environments as acoustic test facilities, auditoriums, studios, cinema, places of worship, home cinema, and various other residential and commercial acoustic applications.

He is a Senior Engineer at the Owens Corning Science & Technology Center, supporting their growth in acoustics for the Acoustical Systems Business. Prior to being hired by Owens Corning, Harry designed their new fully/hemi anechoic chamber (one of the few NVLAP-accredited facilities in North America), while working for Industrial Acoustics Company.

With several patents to his name, including revolutionary acoustic treatment systems for the home theatre industry, he continues to promote sound quality, noise control, and customer satisfaction through cutting-edge technology. Mr. Alter is an active member of ASTM (Committee E-33 on Environmental Acoustics) and is an active member of the Acoustic Society of America.