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First, you need to determine how much and what type of material to use on the walls. The best way to do this is to measure your room's reverberant character with test equipment and compare it with the goals for a room of that size. Since we didn't have this test equipment and don't expect too many dealers to have it either, you might use an admittedly crude alternative: trial and error (see Tip #4). First, calculate the room's target RT60 time. Then estimate the room's existing RT60 time using Sabine's equations. (Newer techniques by Eyring or Arau-Puchades may be more accurate but are also more complicated.) Then try combinations of various materials until things sound the way you want them to.

There are two types of acoustic-treatment materials: those that absorb sound and those that diffuse sound. Soft, fuzzy, porous, or resonant materials absorb sound and transform it into heat through friction of the fibers or trap it in their porous or resonant cavities. Diffusive materials preserve most of the sound's energy but reflect it in different directions. Many materials are both reflective and absorptive. For instance, a single layer of regular drywall mounted on two-by-four studs that are placed 16 inches on-center will absorb some sounds below 250 Hz but will reflect most frequencies above that point. One-inch-thick Fiberglas will absorb sound evenly down to about 1 kilohertz. It absorbs less sound between 1 kHz and 500 Hz and considerably less at lower frequencies.

Lining your room's four walls with 1-inch-thick, fabric-wrapped acoustic panels is a common approach to acoustic treatment. However, all three of our experts consider this approach to be less than optimum. While it might eliminate slap echoes and first-order reflections, it also eliminates high-frequency energy and has little or no effect on mid-range and low frequencies. This gives you boomy, bloated sound that lacks sparkle and detail. Instead, consider using a few specially designed bass absorbers in combination with other treatments.

Diffusers are one such treatment. They usually consist of small blocks, curves, or slats placed at varied depths. More-expensive diffusers vary the depth of the blocks, curves, or slats according to mathematical formulae. These diffusers reflect sounds more evenly across the frequency spectrum. A flat, hard surface (like drywall) will reflect sound as well, but the majority of the sound's energy travels in one direction: away from the surface at an angle equal to the angle at which it hit the surface. A diffuser directs sound in multiple directions, with less sound traveling in any one direction. Placing diffusers across from flat surfaces can eliminate slap echoes. Locating diffusers at first-order-reflection points can attenuate the reflection without losing the sound's energy. A stacked bookshelf can be a good diffuser, but only if you place the books at varied depths.

Even in 14 pages, there are a number of things I've glossed over for the sake of space. For descriptions of these and other acoustic techniques, see the third edition of F. Alton Everest's book The Master Handbook of Acoustics. (According to Russ, you should get the second or third edition, since there are numerous math errors in the fourth edition.) Or, you could just hire one of our experts. Hopefully, with the information we've provided, you'll at least be able to tell if the person you hire knows what he or she is talking about.

Tip #1: Make the Air Quiet

Your heating, ventilation, and air-conditioning (HVAC) system can be a significant but overlooked source of ambient noise in your home theater. In many cases, this might be the first place to make improvements. Norm offers the following suggestions for reducing HVAC noise:

1. Position the machinery as far away from the room as possible and isolate the equipment against the structure-borne vibration.

2. Use a low-air-velocity system that will allow 10 to 15 air exchanges per hour, depending on the size and heat load within the room.

3. Use dedicated sends and returns.

4. Place intake and outtake vents away from the listeners and speakers.

5. Use duct liner board, or round metal ducts lined with glass fiber.

6. Include a plenum silencer near the fan discharge.

7. Introduce right-angle bends downstream from the fan and upstream from the outlet.

8. Use isolation hangers to suspend ductwork when possible.

9. Use large, non-tympanic air-terminal diffusers. Avoid multilouvered vents.

10. Apply liberal amounts of acoustic caulking to seal penetrations made to the structure.

11. Eliminate as many obstacles from the air's path as possible.

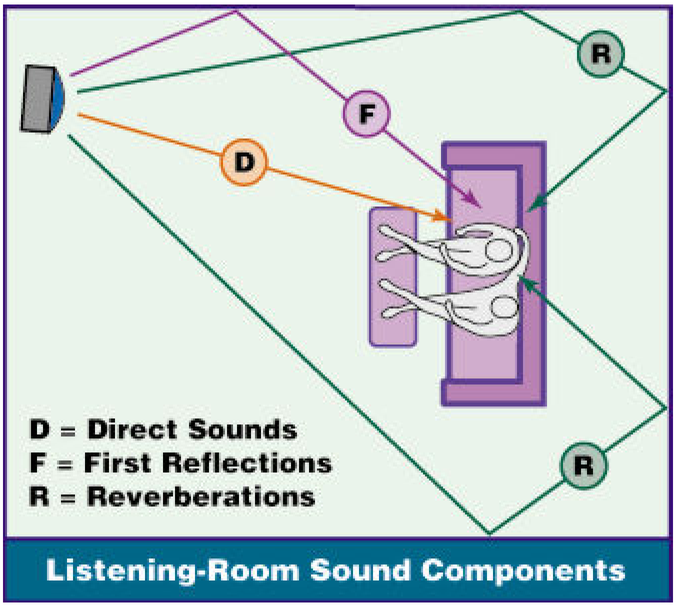
Where possible, we employed a number of his suggestions, which included building a plenum silencer. The silencer consists of a duct-lined box that's larger than the duct that feeds it. It's like a car muffler, only bigger. It has a vent supplying air at one end and an output, which then feeds the room, at the other.

We also learned some tips from Steve and Bob at Air Products International, a Van Nuys, California–based company that sold us our HVAC supplies (few places sell to the public). The main concept is that velocity creates noise. Less velocity but more quantity (i.e., more ducts move more air more slowly) will create less noise in the system. We used ducts that consistently got larger or broke off into multiple outputs so that more air could travel through them with less velocity. For a total cost of about $400 in parts, we ended up with an extremely quiet air system.

Tip #2: Add a Door

If your home theater resides in an area that has open archways to other parts of the house, Russ suggests adding a door. Even double French doors enclosing an archway can make a huge improvement. Pre-hung, exterior-grade, solid-core doors include weather stripping around the edges and start at around $200 to $300 (not including installation). Placing a threshold across the bottom creates an airtight seal around the door. A solid-core door placed on a hollow core's frame may eventually rip itself off its hinges. We already had a solid-core door, so we just added exterior-grade weather stripping and a threshold. Although not ideal, it was more within our budget ($40) and does as good a job as we need. (We're already within a larger building and can somewhat control the outside noise.) Enclosing the room will not only improve noise isolation but can substantially improve bass output, as your subwoofer will no longer try to pressurize air throughout your entire house.

Tip #3: Finding First-Order-Reflection Points

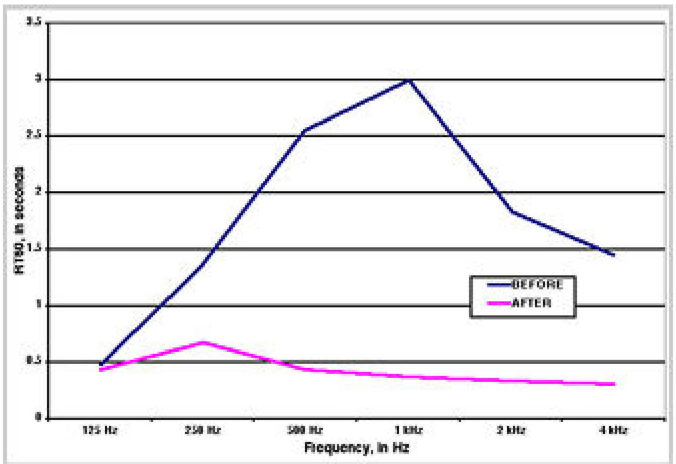


The fancy way to find first-order reflections is with a CAD (computer-aided design) program. In the program, draw a line from each speaker to each wall (including the ceiling) and then to the listening area, making sure the program keeps the angle of incidence to the wall equal to the angle of reflection from the wall. If you don't have this handy, multi-thousand-dollar computer program, grab a friend and a mirror. Have the friend slide the mirror along the walls around the home theater while you sit in the listening position. Mark the point on the walls where you see each speaker's reflection. These are the primary (first) reflection areas. If the distance between you, the mark on the wall, and the speaker is less than 40 feet, there's a good chance you'll want some form of acoustic treatment at that mark.

Tip #4: Calculating RT60 (Without Test Equipment)

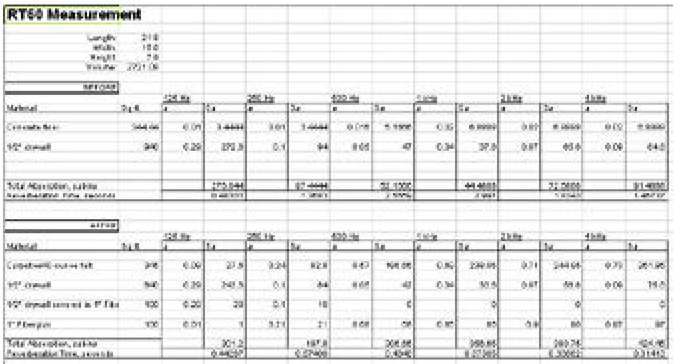
RT60 defines the amount of time it takes an impulse sound at a given frequency to decay by 60 dB and is typically used in large rooms. In small rooms, you can use RT60 calculations to get a general idea of the room's reverberant character. The point is to lower this reverberation level evenly across the entire frequency range without making the room overly dead. To calculate RT60, you must select an ideal reverberation time to aim for, and you need to know the absorption characteristics of various materials at various frequencies, the surface area of those materials, and your total room volume.

Calculating your ideal reverberation time requires a little experience with a scientific calculator. The formula is as follows: 0.3 times the cube root of (volume of your room/3,532)

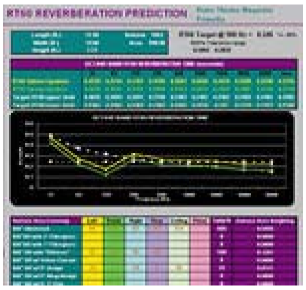


Determine your room's volume by multiplying the height by the width by the length, then divide that number by 3,532. If your calculator doesn't have a cube-root function, you can use the "y to the x power" function. With this, use the previous total for y and use 0.333 for x. The calculations for our room came to about 0.25 seconds.

Next, you need to find the absorption characteristics of the materials in your room. This may be easier said than done, as they're not usually listed with the products at your local hardware store, and the government document called the Compendium of Materials for Noise Control (NIOSH #80-116) is now out of print. We've listed the absorption characteristics for basic materials in figure 1. You may also find them in acoustic texts like F. Alton Everest's *The Master Handbook of Acoustics*. The formula is simple: Multiply the material's absorption characteristic at each frequency by the material's surface area, in square feet, to get the subtotal of absorption for that material (in sabins). Then add all of the subtotals for the room's different materials at each given frequency. Multiply the room's total volume by a constant (0.049) and divide that number by the total absorption figure.


RT60 Measurement

The problem with these calculations is that they are only as accurate as the number of surfaces accounted for. For example, it's not likely that the entire carpet is exposed, so you have to subtract a certain amount for those areas of the carpet that are covered with other items. Then you have to calculate the absorption of those items, assuming that you can find absorption specifications for them. Also, some materials may partly obscure others. Since 1-inch-thick Fiberglas mostly absorbs frequencies above about 750 Hz, frequencies below this point travel through to the material behind the Fiberglas. Therefore, you'll need to figure that the drywall that's covered by the Fiberglas will retain its absorption characteristics up to about 750 Hz. In most cases, the most difficult frequencies to absorb will be below 500 Hz. We may discuss options for these frequencies in a future issue



As part of their home theater design, A/V Room Service, Russ Herschelmann Designs, and Performance Media Industries calculate more-precise reverberation times and create acoustic-material layout plans. We followed PMI's suggestions for our room (see figure 2 for the layout plan and figure 3 for reverberation times). If you do the calculations on your own, remember that the Sabine equation creates crude estimates that you should only use as a guide. They can at least give you an idea of how various materials react to sound. You can always experiment from there.

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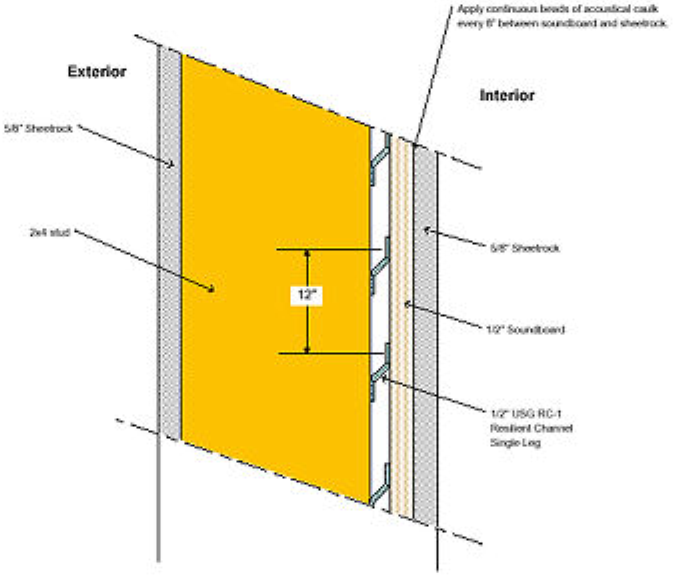
AV Interior How To

Design the Ultimate Home Theater– On a Budget Correction

Correction

In November's "Design the Ultimate Home Theater - On a Budget" we failed to give Performance Media Industries copyright credit for their drawings, figure G, I, 2 and 3 on pages 40, 42 and 44, respectively. We've also had numerous questions about installing resilient channel, as the drawings are somewhat contradictory. See PMI's revised drawing, which is for an ideal situation (the original drawing related to our existing room, which already had drywall). Ideally, resilient channel should be installed horizontally across the bare studs. In an existing room, use a sawzall to cut out the drywall in the spaces between the studs and attach the resilient channel to the remaining drywall-covered studs. The openness and depth of the space behind the resilient channel contributes to its effectiveness.

Side View



Top View