



MUSICAL MASTERPIECES

# COMPÁS

SERIAL NUMBERS: \_\_\_\_\_

HANDCRAFTED BY:

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

DESIGNED BY NEIL PATEL FOR AVALON ACOUSTICS



This product is certified to meet the requirements of the European Union (EU) Electromagnetic Compatibility (EMC) Directive (2004/108/EC). Because the permanent magnets attached to the loudspeaker drivers produce magnetic fields, it is recommended that the product not be positioned in very close proximity to computer monitors or television sets.





# Table of Contents

---

<b>1 Introduction</b> .....	<b>5</b>
<b>2 Unpacking Instructions</b> .....	<b>6</b>
Introduction .....	6
Contents .....	6
2.1 Opening the Crate .....	7
2.2 Installing the Grilles .....	8
Orientation of the Felt Anti-Diffraction Mask .....	8
2.3 Replacing Grille Pins .....	8
<b>3 Wiring Instructions</b> .....	<b>11</b>
Introduction .....	11
Connecting the Speaker to the Amplifier .....	11
<b>4 Break-in Period</b> .....	<b>12</b>
<b>5 Maximizing Performance</b> .....	<b>13</b>
Break-in .....	13
Grille Assemblies .....	13
Speaker Placement and Symmetry .....	13
Toe-In .....	14
Apex™ Couplers .....	14
First Reflection Points .....	15
Corner Treatment .....	15
<b>6 Care of Your Loudspeakers</b> .....	<b>16</b>
Cabinet (Hardwood Finish) .....	16
Grille Assembly .....	16
Drivers .....	16
<b>7 Warranty</b> .....	<b>17</b>
In the Event of a Problem .....	17
Warranty Statement .....	18
<b>8 Room Acoustics and Speaker Position</b> .....	<b>20</b>
Introduction .....	20
An Optical Analogy .....	21
Basic Room Acoustics .....	21
8.1 Standing Waves .....	22
8.2 Flutter Echo .....	23
8.3 Early Reflections .....	24
Avoiding Early Reflections .....	25
8.4 Bass reinforcement .....	27
8.5 Summary of Recommendations .....	31
Flutter Echo and Standing Waves .....	31
Speaker Placement .....	32
Early Reflections .....	32
8.6 A Listening Room Example .....	33

<b>9 Accuracy of Bass Reproduction</b> .....	<b>34</b>
Introduction .....	34
9.1 Sensitivity to Time-Related Information .....	35
"Fast Bass" .....	35
9.2 Rationale .....	36
Anechoic vs. In-Room Frequency Response .....	36
9.3 Measurements of Audio Equipment .....	37
A Correlation with Amplifier Measurements .....	37
Loudspeaker Measurements .....	38
Designing for Accurate Bass Reproduction .....	39
Frequency Response Effects .....	40
Listening for Size Distortions .....	40
Transient Response Effects .....	41
9.4 Conclusion .....	42
<b>10 Features</b> .....	<b>43</b>
<b>11 Specifications</b> .....	<b>43</b>
<b>12 Notes</b> .....	<b>45</b>

---

# 1 Introduction

---

## COMPÁS

Inspired by the rhythmic time signature patterns of flamenco music, our COMPÁS illuminates the fundamental structural elements of metre and impulse in all musical genres. Primarily characterized by its dynamic and percussive rhythms, the COMPÁS delivers a disciplined performance with high transient speed and clarity of image definition. This constant Q design generates critically damped driver resonances from octave to octave throughout the audio spectrum. With a Q of 0.5 ringing and transient smearing is eliminated.

Control networks within the crossover designed specifically to target resolution and ambience retrieval under high current conditions are the heart of COMPÁS. Its unique ceramic/honeycomb woofers deliver an authoritative low frequency response with unsurpassed transient accuracy, carefully blending with the highs for a "true to source" sound reproduction. Proprietary low jitter circuitry clarifies image boundaries to a high-resolution standard suitable for professional monitoring where microphone placement and phasing are critical. Utilization of the same diaphragm materials throughout the array adds to the continuity of harmonic structure in a crisp, seamless musical presentation devoid of stored energy; its rock solid imaging presented with a palpable density through accurate and colorful harmonic structures.

All AVALON ACOUSTICS loudspeakers are engineered and built to the highest standards in the audio industry. Handcrafted in Boulder, Colorado by dedicated craftsmen and technicians, each COMPÁS is measured and matched creating perfect symmetry and coherency. Before leaving the factory each of our masterpieces is subjected to a demanding array of quality control and testing procedures to assure flawless and consistent performance. Our creations are a work of art in which we take great pride, designing and building each one exclusively here in the foothills of the Rocky Mountains.

*[www.avalonacoustics.com](http://www.avalonacoustics.com)*

---

## 2 Unpacking Instructions

---

### Introduction

Your AVALON ACOUSTICS loudspeakers were shipped in a heavy-duty crate to ensure their safe arrival. It is recommended to save these crates for possible future use. Due to the weight of the speakers, it will require two persons to un-crate them and position them for listening. Please arrange for your dealer or another able bodied person to assist in this project.

### Contents

The two shipping crate contains the following items:

- two loudspeaker cabinets
- two grille assemblies
- the owner's manual
- one set of six Apex™ Couplers
- an accessory bag

The grille assemblies and owner's manual are contained in an outer compartment on the top of the shipping crates. The Apex™ Couplers and accessory bag are packed together on the bottom of one of the loudspeaker cabinets.

The accessory bag contains replacement grille pins, a small bottle of furniture polish, and two lint-free polishing cloths.

**IMPORTANT:** It is imperative that the Apex™ Couplers are utilized, in order to insure that the bottoms of the loudspeakers are not blocked. This is especially important on thick carpeting.

## 2.1 Opening the Crate

---

The crate features a one-piece top assembly which is fastened to the crate bottom with screws around the lower perimeter. To unpack, remove the screws and lift the upper portion of the crate straight up (this will require two people).

Next, slide each speaker part way off of the crate base so that the plastic bag can be unfastened from the enclosure bottom. Stand the speaker up and the bag can be slid off the top. Please refer to Figure 2.1.

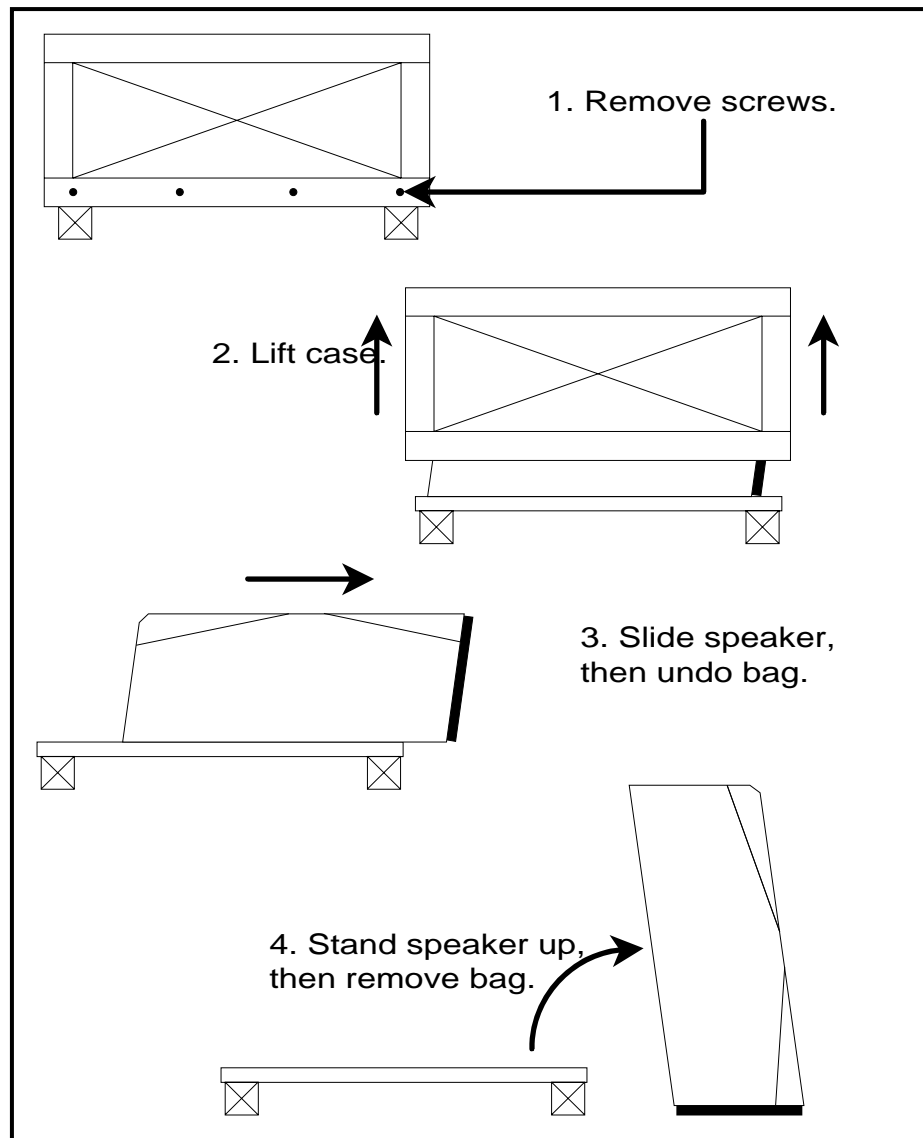


Figure 2.1 - To unpack the loudspeakers.

## 2.2 Installing the Grilles

---

The grille assemblies are behind a panel on the outside of the speaker crate. Remove the screws securing the panel, and then carefully pull the grilles straight out. The grilles are installed with friction fasteners and press into place on the speaker cabinets. Please see Figure 2.2.

### Orientation of the Felt Anti-Diffraction Mask

The grille assembly includes a felt anti-diffraction mask. Should the felt mask be removed, be sure to note the correct inside-outside orientation when re-installing it. The tweeter and midrange openings are beveled on the side that faces the listener (away from the speaker).

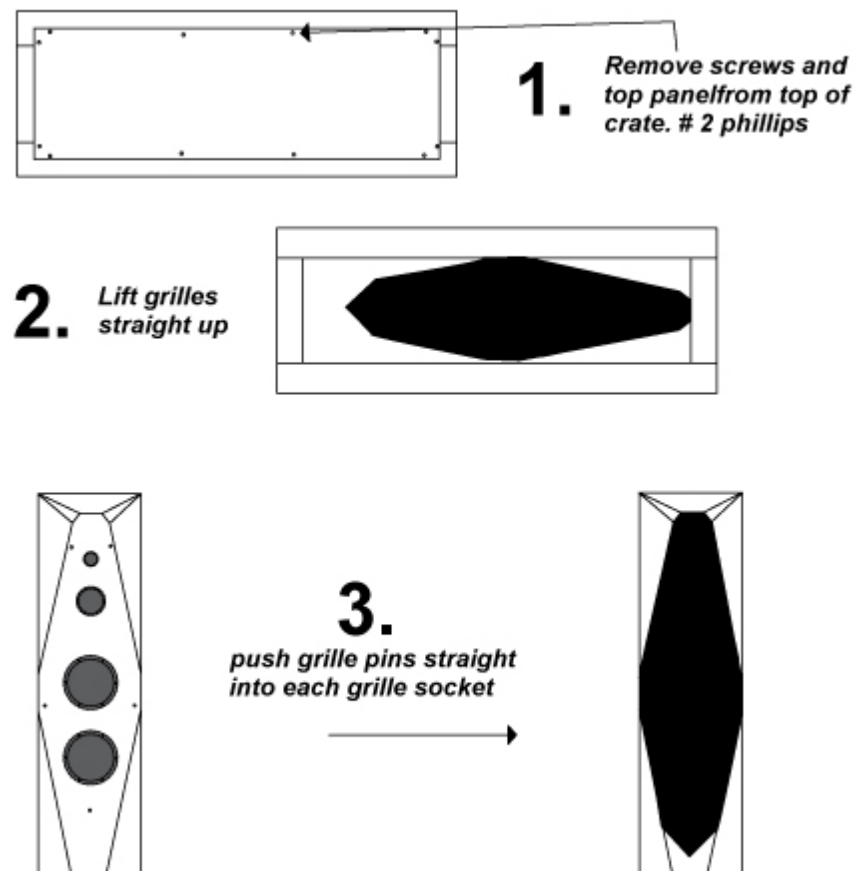


Figure 2.2 - To install the grille assemblies.



## 2.3 Replacing Grille Pins

---

The grille pins installed on the grille assemblies are fragile and can be easily damaged. Should any of the pins break, you may replace them using the following procedure.

1. Place the grille assembly face-down on a padded surface (a towel or carpeting).
2. Remove the damaged grille pin by pulling it straight out with a small pliers or similar tool. Please refer to figure 2.4. Make sure that the complete pin is removed and that there are no pin fragments left in the mounting hole.

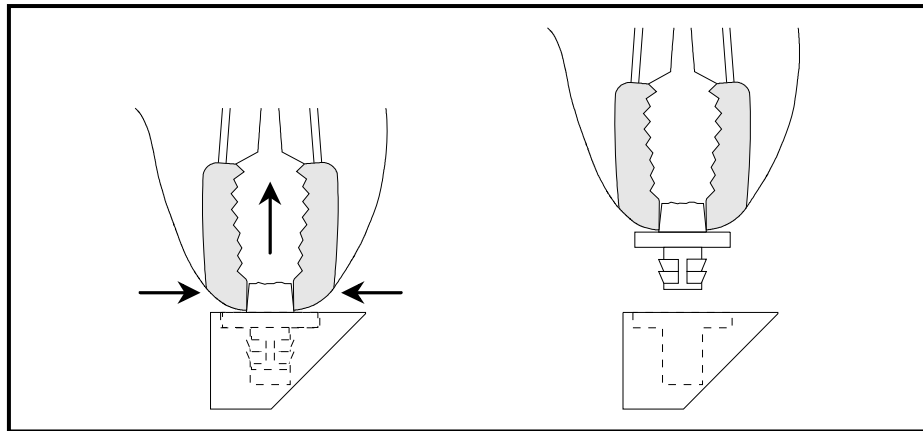


Figure 2.4 - Removal of broken grille pin. Check for pin fragments in the mounting hole.

3. Insert the new grille pin in the grille pin installation tool (see figure 2.5).

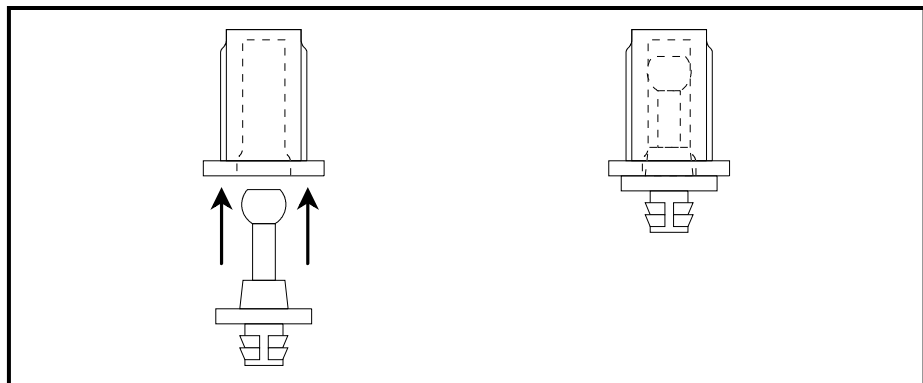


Figure 2.5 - Insertion of new grille pin into installation tool.

- Carefully pull the grille cloth away from the frame mounting hole. The mounting hole must be clear of all obstacles during pin installation.
- Place the exposed end of the grille pin in the open mounting hole. Check to insure that the grille cloth is not trapped between the pin and frame. Use a small hammer and gently tap the new grille pin in place. Then, pull the insertion tool off the new pin and verify that the pin flange is flush with the surface of the grille. Please refer to Figure 2.6.

**WARNING:** Grille pin breakage may result if the grille cloth becomes trapped between the pin and frame during installation.

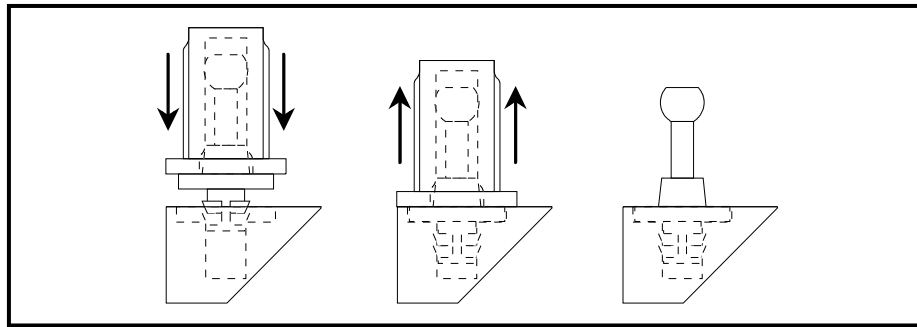


Figure 2.6 - Installing grille pin into COMPÁS grille frame. Note that after installation, the grille pin flange is flush with the surface of the ...

- Reposition the grille cloth that was pulled away from the frame mounting hole in step 4. The cloth should lay flat and wrinkle-free.

# 3 Wiring Instructions

## Introduction

The crossover is encapsulated in a sealed, non-accessible chamber in the bottom of the speaker cabinet, to minimize the effect of vibration on the components. The COMPÁS is equipped with a high-quality binding post for connecting the speaker cables. Spade lugs are recommended for cable termination.

## Connecting the Speaker to the Amplifier

1. Carefully unscrew the large fastening knob on the binding post, allowing the fastening plate to expose the posts (see Figure 3.1).
2. Insert the spades from your speaker cables under the terminal plate.
3. Fasten the spades in place by tightening the large fastening knob.

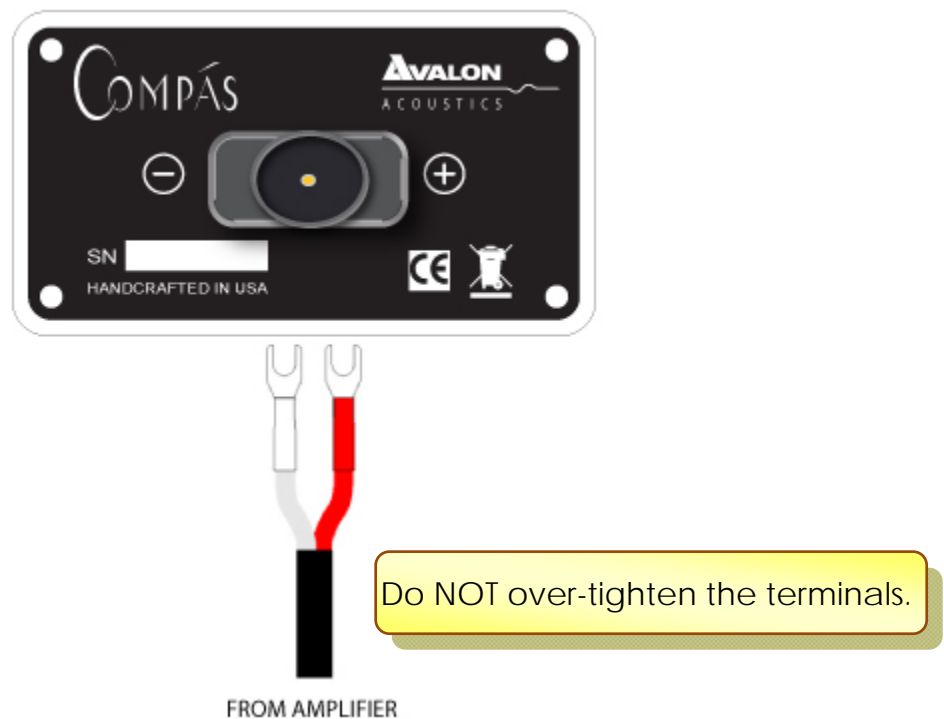


Figure 3.1 - Back view of the speakers showing the connections from the amplifier to the loudspeaker. Check to insure the correct polarity (positive lead connected to the (+) terminal and negative lead connected to the (-) terminal).

---

## 4 Break-in Period

---

Your new AVALON ACOUSTICS loudspeakers have an initial break-in period. They will not perform to their full sonic potential when first installed in your system. This is partially due to a residual polarization of the dielectric materials used in the crossover capacitors and internal wiring.<sup>1</sup> As music is played through the loudspeakers, the electrical signal will gradually anneal these materials. Similarly, the suspensions of the drivers will reach their optimal mechanical properties as the speakers are played. Only after the break-in period will the full performance of your AVALON ACOUSTICS loudspeakers be realized.

The break-in process will occur naturally as music is played through the system. To reduce the time required, it is recommended that the system be played continuously, using either a digital source in the repeat mode or an FM broadcast signal. The recommended break-in procedure is as follows:

- Initial warm-up: three to six hours of quiet music.
- Extended break-in: 200 to 300 hours of loud and dynamic source material (e.g. Tangerine Dream, Optical Race, RCA 2042-2-P).

During the break-in period, the sonic properties of your loudspeakers may undergo several gradual shifts as the various components break-in at different rates. It is therefore suggested that the fine-tuning of the system be delayed until after the break-in period is completed. However, during the final phases of the break-in period, the sonic image will open up, the sound-stage will gain specificity, the bass control and impact will increase, and the overall sound will have a more relaxed, involving presentation.

---

<sup>1</sup> A high-voltage test is applied to wiring and capacitors during their manufacture. This results in a residual polarization of the dielectric materials.

---

# 5 Maximizing Performance

---

These details are imperative to obtaining optimum results from your AVALON ACOUSTICS loudspeakers.

## **Break-in**

The break-in period is critical to maximizing sonic performance and should take place before other adjustments (see the discussion on page 12). The break-in should begin with three to six hours of quiet music, followed by 200 to 300 hours of loud and dynamic source material.

## **Grille Assemblies**

The grille assemblies, with their felt anti-diffraction masks, are integral elements of the loudspeakers' design. Unlike many other products, AVALON ACOUSTICS loudspeakers are designed to be used with the grilles in place while listening, and removing them will degrade the system's performance. It is extremely important that the felt anti-diffraction masks make physical contact with the face of the loudspeakers, as air space between the felt and the speaker face will adversely affect sound quality.

## **Speaker Placement and Symmetry**

Selecting the proper room position for your AVALON ACOUSTICS loudspeakers can dramatically improve their performance. The following points highlight the fundamental concepts in loudspeaker positioning from the in-depth discussion in Chapter 8, Room Acoustics and Speaker Position (beginning on page 20):

- Left to right room symmetry aids in producing a balanced sound stage.
- Image depth is enhanced when the distance to the rear wall is increased.
- The most even bass response will be attained when the distances to the side and rear walls are not overly similar.

## Toe-In

Adjusting the toe-in angle of the speakers is useful in tailoring the sound to best match the characteristics of your system and listening room.

When the speakers are facing straight forward, they tend to create a large, expansive sound-stage, painted with broad brush strokes. As they are rotated toward the listening position, the image becomes more compact, with increased focus, creating a greater sense of intimacy. Pointing the speakers inward is also helpful in situations where strong reflections from the side walls are a problem.

Start with the loudspeakers facing straight forward, and play either a mono source, or a stereo source with a distinct center image, through both channels. Carefully rotate the loudspeakers inward in small increments to bring the image in precise center focus (small adjustments can be made with the speaker on Apex™ couplers). Toe-in adjustment is rather delicate, and experimentation is necessary to achieve the proper angle for your listening situation. The optimum angle is usually between three and ten degrees inward.

## Apex™ Couplers

Supplied with your AVALON ACOUSTICS loudspeakers are six Apex™ couplers, used to couple the speakers to the floor, thereby minimizing time-smearing resonance effects. The result is an increase in focus and solidity of the sonic images.

On hardwood floors, you may protect the floor from the pointed spike using a large coin, such as a quarter. However, the coupling effect of the Apex™ couplers will be reduced.

Once you have located the proper position and toe-in angle for your AVALON ACOUSTICS loudspeakers, place the couplers under the speaker bases. It is easiest to install the couplers with the assistance of a friend. Lean the speaker forward first, and position two couplers pointing downward, one under each rear corner. Then lean the speaker backward and place one Apex™ coupler under the front center of the base.

**IMPORTANT:** It is imperative that the Apex™ Couplers are utilized, in order to insure that the bottoms of the loudspeakers are not blocked. This is especially important on thick carpeting.

### **First Reflection Points**

Since the ear/brain system tends to integrate the sounds arriving within a 10 millisecond time window, it is important to control the early reflections arriving from the sidewalls to the listening position. A hard-surfaced wall can produce a strong frequency-dependent reflection that can interfere with the reproduced sound-stage, as well as change the perceived tonal balance of the system. Therefore, damping these first reflection points is strongly recommended. Please refer to Section 8.3, Early Reflections, beginning on page 24, for further information.

### **Corner Treatment**

It is important to control the first reflections of low frequency sound, which normally occur at the corners behind the loudspeakers. These reflections can cause significant distortions in phase and amplitude, resulting in muddy bass definition and smeared bass transients. Placing DAADS (more information available at [www.acusticaapplicata.com](http://www.acusticaapplicata.com) ) at the room corners can significantly control these bass colorations and restore the quickness of bass transients.

---

## 6 Care of Your Loudspeakers

---

### Cabinet (Hardwood Finish)

AVALON ACOUSTICS' hardwood finished loudspeakers are supplied with a special polish and two lint-free polishing cloths, in order to properly care for the high quality furniture lacquer. The following polishing instructions should be observed:

**IMPORTANT:** Use the supplied furniture polish ONLY. Do NOT use cleaners that contain ammonia, strong solvents, or abrasive materials. Use of these materials can degrade, scratch, or even DESTROY the finish.

Apply the supplied polish to one of the clean, lint-free polishing cloths (or use cotton cloth that is clean and lint-free), and carefully wipe it on the cabinet. Be careful NOT to apply the polish to the loudspeaker drivers.

**WARNING:** Do NOT apply polish to the loudspeaker drivers.

2. Wipe off the excess polish until the desired luster is achieved.

### Grille Assembly

The grille assembly may be removed from the cabinet and gently vacuumed to remove dust. If the felt insert is removed, please note the inside-outside orientation when re-installing it. The hole for the tweeter is beveled on the side toward the listener, to provide optimal dispersion characteristics.

### Drivers

The drivers require no regular maintenance. Do not attempt to clean the tweeter dome, as they are easily damaged. If desired, you may remove dust from the woofer cone by using a small, soft dusting brush.

**WARNING:** The drivers in this transducer are coupled in an intricate manner; SEVERE DAMAGE may result from the removal of these drivers. All service must be performed by an authorized representative of AVALON ACOUSTICS.

On occasion, perhaps once a year, check to insure that mounting screws for all drivers are snug. Vibrations could cause driver mounting screws to loosen. Using the correct device, simply check to see if the screws are snug. Do not overtighten!



---

# 7 Warranty

---

Your AVALON ACOUSTICS loudspeakers are warranted to the original, registered purchaser against defects in workmanship and materials for a period of three years from the date of first purchase, **provided that the enclosed registration card is returned to the factory within seven days of the purchase date.** If the registration card is not returned within the seven day period, this warranty is null and void, and you will not be notified of future updates. In the unlikely event that you did not receive the registration card with your loudspeakers, please contact the factory immediately so that we may send you a replacement card. The warranty period is in effect from the date that the product leaves the factory. This warranty is non-transferable to subsequent purchasers within the original three year period. A complete statement of warranty is given below. Please take the time to fill out and return the enclosed warranty registration card.

## In the Event of a Problem

In the unlikely event of a problem with your AVALON ACOUSTICS loudspeakers, the component most susceptible to failure is one of the driver units. If driver replacement is required, have your dealer contact AVALON ACOUSTICS. The performance curves of the drivers in each pair of loudspeakers are kept on file at the factory. This enables AVALON ACOUSTICS to supply an exact replacement unit, ensuring continued operation at the highest level of performance. The defective driver must then be returned to the factory for inspection to determine the status of the warranty claim. This on-site replacement of the driver units eliminates the time and expense of shipping the entire speaker to the factory for repair. **All warranty claims must be made through an authorized AVALON MULTICHANNEL SYSTEMS/ AVALON ACOUSTICS dealer or distributor.**

## Warranty Statement

1. AVALON ACOUSTICS warrants the materials, workmanship, and proper functioning of this product for a period of three years to the original registered purchaser, **provided that the completed registration card is returned to AVALON ACOUSTICS within seven days of the date of purchase. If the registration card is not returned to the factory within the seven day period, this warranty is null and void.** If any defects are found in the materials or workmanship of this Avalon Acoustics product, or if the product ceases to properly function within the appropriate warranty period from the date of first purchase, the unit will be repaired or replaced by AVALON ACOUSTICS or its authorized agent after receiving authorization from the factory or dealer. This warranty is not transferable.

**Unauthorized dismantling of this product will render this warranty void.**

2. Purchaser must obtain an RMA number by contacting dealer/distributor and return the product, packaged in the original shipping carton, freight prepaid. Shipping address will be provided at the time the RMA number is issued. No returns will be accepted without prior authorization.

3. **AVALON ACOUSTICS reserves the right to inspect any products which are the subject of warranty claim prior to repair or replacement. Final determination of warranty coverage lies solely with AVALON ACOUSTICS and only products which are determined to be covered under this warranty shall be repaired or replaced by AVALON ACOUSTICS. The customer will be informed of any delays and AVALON ACOUSTICS will provide replacement as quickly as possible. Out-of-warranty claims will be billed for labor, materials, return freight, and insurance as required. Any product for which a warranty claim is accepted will be returned to the purchaser and cost of return shipping and insurance will be factory prepaid within the boundaries of the USA. Units to be shipped outside of the USA will be shipped freight collect only. This warranty gives specific legal rights. The purchaser also has implied warranty rights, and may also have other rights which vary from state to state.**

4. This warranty is extended to the original registered purchaser for value.

5. AVALON ACOUSTICS strives to manufacture the very finest possible equipment, and therefore reserves the right to make changes in design and improvements upon its products, without necessarily assuming an obligation to retrofit such changes upon its previously manufactured models. Exclusions, Wood is a natural product subject to the laws of physics. While all effort has been made to create the most stable and perfect product possible, your Avalon cabinet is a live piece of furniture. As is the case with any musical instrument constructed of wood, excessively dry or humid conditions and areas prone to atmospheric changes may cause surface cracking, checking, or joint expansion; this is considered normal and as such is not covered under our warranty. Stable conditions are required for joints on cabinets to remain tight, and a home with properly functioning heating and cooling systems will provide the consistency required to keep your cabinets beautiful for many years. Sunlight, smoke, household cleaners and chemicals, and other environmental pollutants may also affect color and structure over time.

Changes in the product caused by these environmental conditions are not considered defects in workmanship.

6. The above warranty is the sole warranty given by AVALON ACOUSTICS, and is in lieu of all other warranties. All implied warranties, including warranties of merchantability or fitness for any particular purpose shall be strictly limited in duration to three years from the date of shipment from the factory, and upon the expiration of the warranty period (three years), AVALON ACOUSTICS shall have no further obligation of any kind whether express or implied, including but not limited to merchantability. Further, AVALON ACOUSTICS shall in no event be obligated for any incidental or consequential damages as a result of any defect or any warranty claim, whether express or implied. Some states do not allow exclusion or limitation of incidental or consequential damages or limitations on how long implied warranties last, so the above limitations and exclusions may not apply to you.

7. AVALON ACOUSTICS does not authorize any third party, including any dealer or sales representative to assume any liability for AVALON ACOUSTICS, or make any warranty for AVALON ACOUSTICS. The unit must not have been altered or improperly serviced or repaired. The serial number on the unit must not have been altered or removed.

8. Warranty registration cards must be completed and mailed to AVALON ACOUSTICS within seven days of date of purchase; otherwise, this warranty is null and void. AVALON ACOUSTICS may, at its option, require from the purchaser valid proof of purchase (dated copy or photocopy of dealer's original invoice).

9. If this product is used in a commercial or industrial application, then special warranty exclusions may apply. Contact your dealer or AVALON ACOUSTICS for commercial warranty policies.

---

# 8 Room Acoustics and Speaker Position

---

## Introduction

The listening room forms the final link of the playback system, as important as any other component in the chain. Just as an otherwise superb system is handicapped by an inferior pre-amplifier (for example), so can a well-matched system be hindered by poor room acoustics. It is not necessary to listen to your system in a specially-designed sound chamber in order to enjoy it. In fact, a dedicated listening room usually requires additional sound treatment, due to a lack of other items in the room that can help provide good acoustics. However, a degree of attention to set-up can greatly increase your listening satisfaction, no matter what your listening situation.

Listening in a properly set-up room can be a startling experience. Due to the limitations of the two-channel format and the listening environment, the illusion of actually being transported to the recording site cannot usually be achieved. However, an uncanny sense of realism can be created. Perhaps it is best described as if the front half of your listening room has been removed, so that it now opens out into the recording site.

To optimize your equipment set-up and the listening-room acoustics requires a basic understanding of the principles which affect the propagation of sound in the room. Also, we will discuss the way in which our brain interprets spatial cues, and how the room acoustics can affect our sonic perceptions.

## **An Optical Analogy**

Let us use a visual analogy to aid our understanding of acoustics. Imagine that you are in a room that is lit only by a candle in its center. There is (approximately) a uniform amount of light cast in all directions. If a large mirror is held closely to candle, one half of the room becomes darkened, while the other half receives twice as much light. This is because there are effectively two candles now illuminating that half of the room, the real candle, and the virtual (or reflected) candle. The energy that had been sent to both sides of the room has now been concentrated in one side only.

If we repeat the same experiment using a large piece of black cloth instead of a mirror, the results will be somewhat different. The side of the room behind the cloth is darkened, just as before, but the level of light on the side of the candle remains unchanged. This is because the light is absorbed by the cloth, rather than being reflected back into the room.

Thus we can see that the energy can either be absorbed or reflected. A similar situation occurs with sound waves, although we must account for the much greater wavelengths of audible frequencies. Of course no material is a perfect absorber or an absolute reflector. Furthermore, the sonic absorption coefficient of a given material usually varies with frequency.

## **Basic Room Acoustics**

The great majority of all listening rooms are rectangular, with parallel surfaces. The walls and ceiling are typically hard surfaces, which are acoustically reflective. These large areas are the predominating factors in the overall room acoustics, although the other items in the room (furnishings, carpeting, wall hangings, doorways, etc.) will also play a role. Without going into excessive detail, there are four primary areas of potential concern:

- Standing waves.
- Flutter echo.
- Early reflections.
- Bass reinforcement.

The first three items are problems which should be reduced or eliminated. The last item, bass reinforcement, needs to be matched to the entire system for proper tonal balance.

## 8.1 Standing Waves

---

The parallel surfaces of most listening rooms can lead to a potential problem in the low frequencies. A sound wave can be repeatedly reflected from opposing surfaces, back and forth. If the distance between the surfaces is an integral multiple of one-half the sound wavelength, a standing wave will be set up. This means that the incident and reflected waves combine with each other so that a stationary pattern of high and low sound pressures is established in the room. This irregular distribution of sound level is caused by cancellation and reinforcement between the reflected and direct sound waves.

At high frequencies, this pattern of high and low sound pressure levels within the room becomes too finely spaced to be discerned. However, when the dimensions of the room are comparable to the wavelengths of the musical notes, there will be obvious changes in the intensity of certain bass notes in different locations within the room. Additionally, the existence of the standing wave implies a resonant condition where acoustic energy is stored in the room. This energy storage can result in "heavy", "muddy", or "slow" bass.

Since the presence of standing waves is caused by parallel reflective surfaces, practically every listening room suffers from this problem to some degree. However, several factors are working in our favor here. First, as the room size increases, the affected frequencies become lower and thereby less audibly apparent. Second, the presence of shelving or furniture against the walls will break up the large surfaces, reducing the magnitude of the problem. Third, upholstered furniture can absorb a significant amount of bass, diminishing the build-up of resonant energy. Fourth, typical wall construction is not completely reflective at low frequencies.

However, in some cases audibly objectionable standing waves will still be present in the listening room. This can be noted by large variations of the intensity of certain bass notes in different areas of the room. Another indicator is an unevenness of loudness of different bass notes. (This is sometimes what is actually on the recording, so be sure that this is consistently a problem on a variety of recordings.)

If you wish to reduce or eliminate standing waves that may exist in your room, it will be necessary to reduce the low-frequency reflectiveness of at least one of the parallel surfaces of opposing surfaces. The most effective method is to use DAAD's (more information is available at [www.acusticaapplicata.com](http://www.acusticaapplicata.com)). Experimentation will be needed to determine the optimal locations.

## 8.2 Flutter Echo

---

These parallel, reflective surfaces can also produce a different audible problem. If there is little absorption at higher frequencies, a musical transient containing high frequencies, such as a hand clap or the strike of a percussion instrument, can be heard bouncing repeatedly between the surfaces. Called flutter echo (or slap echo), these multiple reflections can obscure musical detail. The situation is analogous to standing between two parallel mirrors, when the outline of your reflection becomes more difficult to discern, due to the additional reflected images present.

Again, it is only necessary to reduce the reflectiveness of one of the surfaces in each pair of surfaces to eliminate flutter echo. Since we are concerned with the high frequencies, any soft material is appropriate. Drapery or fabric wall hangings are quite effective on the walls. Bookshelves also work well by breaking up the flat surfaces. Carpeting should eliminate potential problems between the floor and ceiling.

## 8.3 Early Reflections

---

Another situation that can reduce the subjective quality of reproduced sound is the presence of early reflections. By early reflections, we are referring to reflected sound waves that reach the listener within 10 to 20 milliseconds of the direct signal from the loudspeaker.

When a reflected sound reaches the listener more than 40 milliseconds later than the direct sound, the reflection is heard as a discrete echo. However, if the reflected sound arrives within around 20 milliseconds of the direct sound, the ear/brain system integrates the two sounds so that only one sound is heard. This integration is done in such a way that spatial information is preserved, providing an acoustical "picture" of the physical space that created the reflections.

However, the source recording also contains ambient information that portrays the original recording site. Early reflections in the listening room will tend to obscure the ambient information in the recording, leading to a loss of dimensionality or spaciousness. Secondary arrivals within the first 10 milliseconds are especially problematic, becoming less troublesome as the arrival time lengthens to 20 milliseconds or so.



## Avoiding Early Reflections

The speed of sound is approximately one foot (30 cm) per millisecond. Therefore, to preserve the natural soundstage on your recordings, there should be no reflected sounds arriving at the listening position with a path length less than ten feet (3 meters) longer than the direct path from speaker to listener (see Figure 8.1). This means that if the speaker or listener is placed closer than about 5 feet to a wall or other surface, that surface should be covered with sonically absorbent material.

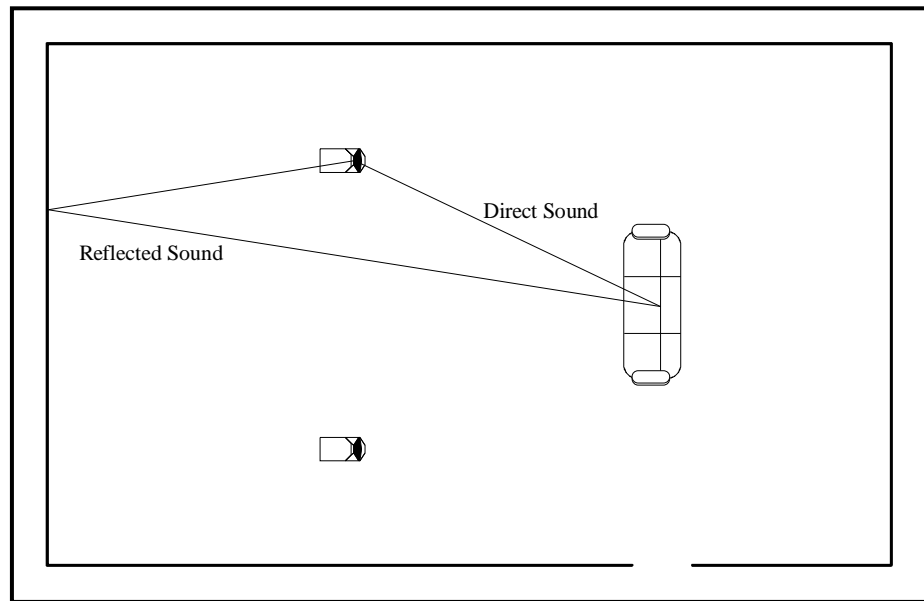


Figure 8.1 - The reflected sound must travel further than the direct sound, and therefore reaches the listener at a later time.

Since the floor is within 5 feet of the speaker, it is best to have a carpeted floor to absorb floor reflections. A thick, dense carpet and pad will absorb lower frequencies more effectively than a thin one. Due to their complex structure, carpets and pads of natural materials, such as wool and jute, will exhibit a more uniform absorption over the frequency spectrum than synthetic materials will.

It is not necessary to acoustically treat the entire room to achieve good results. Strategic treatment of specific locations can realize considerable benefits. Remember that when sound waves reflect from a flat surface, the angle of reflection is equal to the angle of incidence, just as a mirror reflects light waves. Therefore, the most important location for sound absorbing material is the point where the sound waves reflect to the listener (see Figure 8.2).

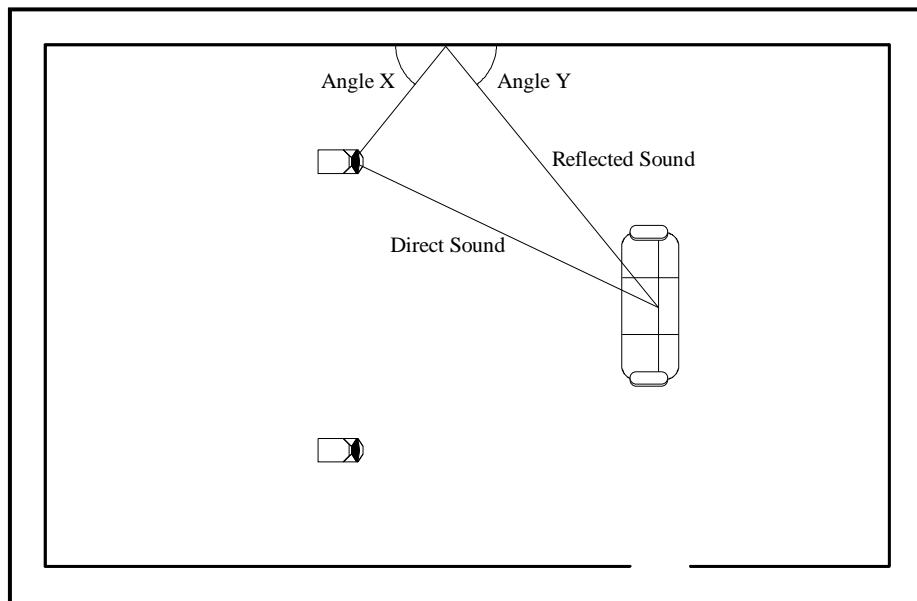


Figure 8.2 The sound is reflected at the same angle that it struck the surface; i.e.,  $\text{Angle } X = \text{Angle } Y$ . Since light waves obey this same rule, a mirror can be used to find the point which can be acoustically damped to avoid early reflections.

## 8.4 Bass reinforcement

---

By bass reinforcement, we mean the effect of the room boundaries on the propagation of sound. It is widely known that speaker placement relative to the floor and walls can affect the relative amount of bass that the system produces.

To make this interaction more clear, let us refer to the optical analogy of the candle. Similar to the way that the mirror reflected the light of the candle, so can the surfaces near the loudspeaker reflect the sound waves back into the listening room. However, when the path length difference of the reflected wave is short relative to the wavelength of the sound, the reflected wave is substantially in-phase with the original wave. When this condition is met, **the coupling coefficient between the speaker diaphragm and the air increases, and the speaker efficiency increases. This changes the actual frequency response of the speaker, and is not attributable to standing waves or other room resonances.**

By selecting the distance from the speaker to the reflective surface, we can determine the frequency at which the bass reinforcement takes effect. Please see Figures 8.3 and 8.4. Furthermore, there are typically three reflective surfaces near each speaker, the floor, the rear wall and the side wall. Each of these surfaces produces its own reflection, and hence additional bass reinforcement.

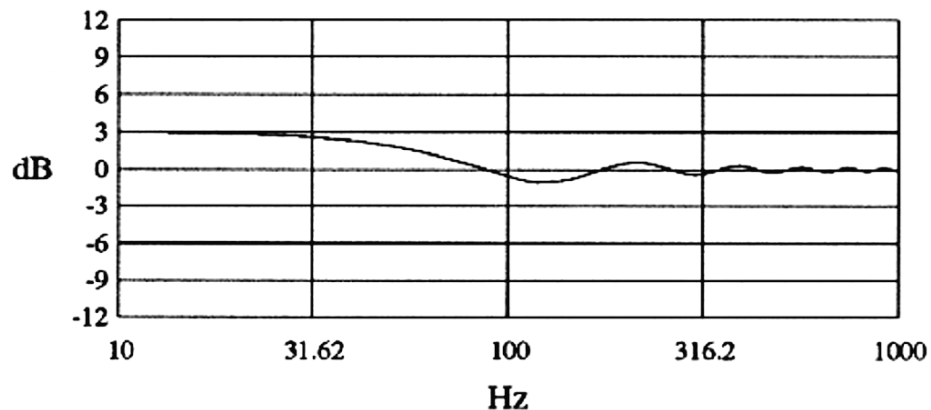


Figure 8.3 - Change in frequency response resulting from placement of speaker 3.3 feet from a reflective surface (relative to an anechoic environment).

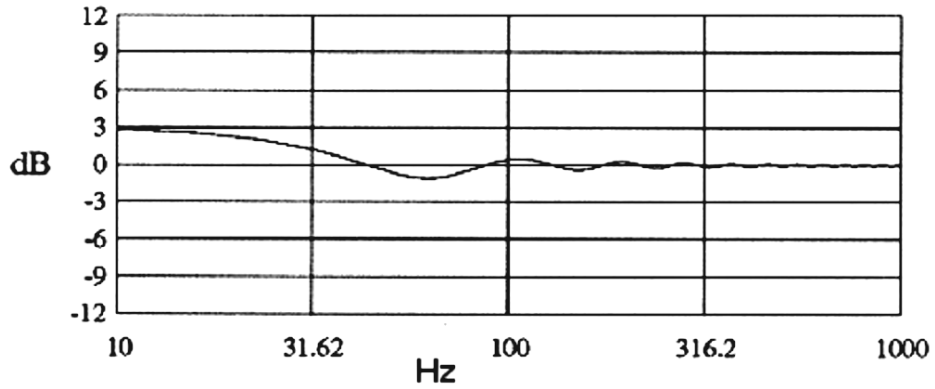


Figure 8.4 - Same conditions as above, except speaker is 6.6 feet from the reflecting surface. Note how the reinforcement now occurs at a lower frequency.

By properly selecting the distances to each surface, we can extend the in-room bass response of the speaker much deeper than its anechoic response. Please see Figure 8.5. This is because the bass reinforcement provides a boost which is complementary to the bass roll-off that would be present in an anechoic chamber.

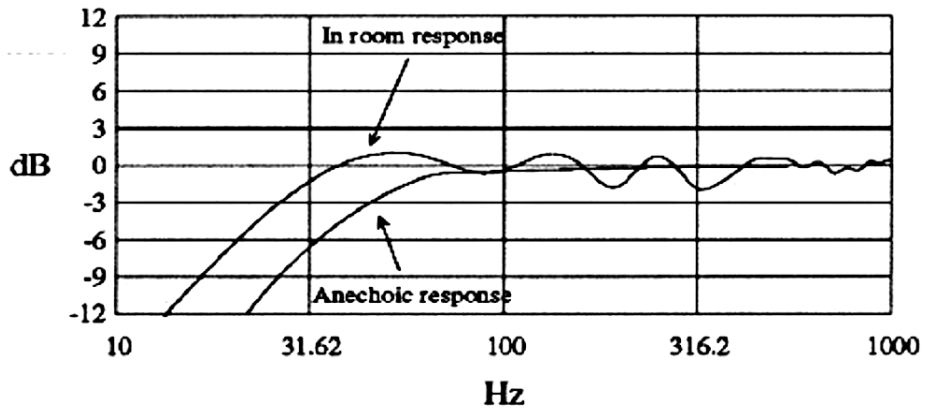


Figure 8.5 - Anechoic response, and in-room response with the speaker placed 4.6 feet from the rear wall, and 3.0 feet from the side wall. Note how the bass response is extended by the room reinforcement.

Conversely, improper placement of the loudspeakers can result in uneven frequency response. This results in diminished bass quality. Please refer to Figure 8.6.

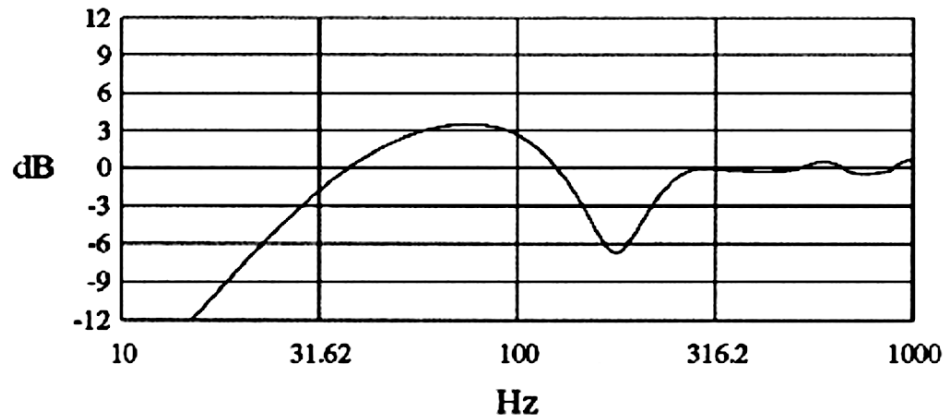


Figure 8.6 - Uneven frequency response caused by improper placement of the speakers. In this case, the speaker is 2.0 feet from both the side and rear walls.

As frequency increases and wavelength becomes more similar to the distance to the boundary, the phase difference between original and reflected waves increases, and the air coupling effect is diminished. In particular, when the wavelength equals about four times the distance to the boundary, the reflected wave is antiphase to the original wave, resulting in a cancellation (dip) in the output. At frequencies above this level, the effect becomes less significant and creates similar but smaller variations in output. Figures 8.7 and 8.8 illustrate these concepts.

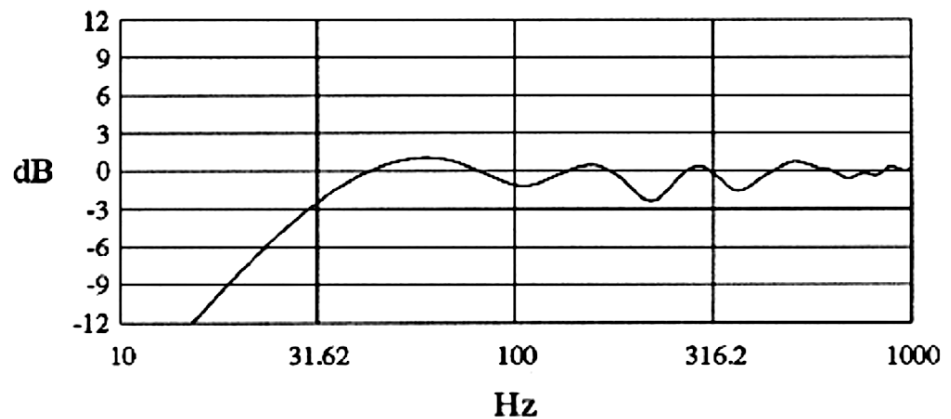


Figure 8.7 - In-room response when the speaker is placed 2.3 feet from the side wall, and 3.9 feet from the rear wall.

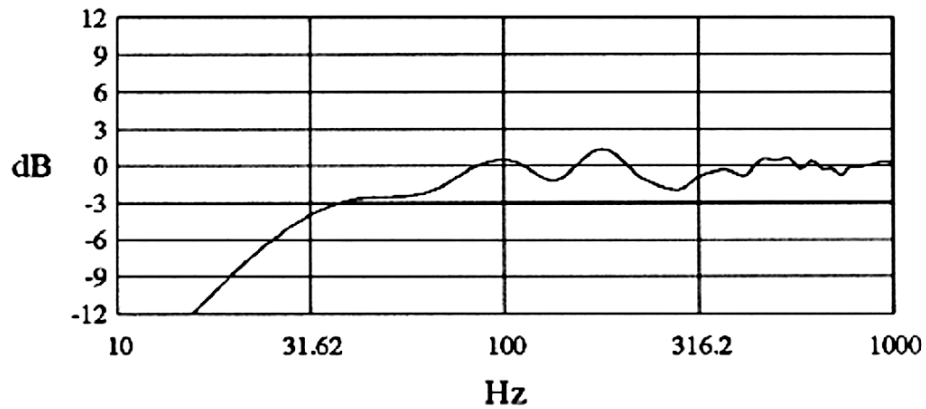


Figure 8.8 - In-room response when the speaker is placed 3.6 feet from the side wall, and 6.6 feet from the rear wall.

There are typically three reflective surfaces near each speaker: the floor, the rear wall, and the side wall. Each of these surfaces produces its own reflection, and hence its own cancellation and reinforcement. By properly selecting the distances to each surface, we can provide a uniform and extended bass response. Conversely, improper placement of the loudspeakers can result in uneven frequency response, resulting in diminished bass quality.

In order to take full advantage of bass reinforcement and to provide the most uniform and extended bass response, it is recommended that the loudspeaker be placed between two and five feet from one of the walls (side or rear), and between three and ten feet from the other wall. The measurements are made from the wall to the center of the woofer cone. The exact distances are not overly critical, although the two distances should not be within about 33% of each other.

A good rule of thumb in establishing the lateral position of COMPÁS is to apply the ratio 4 : 10 : 4. In other words, the distance to the side wall is 4/18 (or about 22.2%) of the room width, and the distance from speaker to speaker is 10/18 (or about 55.5%) of room width.

## 8.5 Summary of Recommendations

---

Now that we have looked at some of the common problems of listening rooms, as well as their cures, let us summarize our findings and recommendations.

### Flutter Echo and Standing Waves

These situations are the result of the room having parallel, reflective surfaces. The potential problems are independent of the audio system, and need to be addressed at the source. This means that at least one surface in an opposing pair of surfaces needs to be made less reflective and/or non-parallel.

- Low Frequency Absorption

If a problem exists with standing waves, it is the low frequencies that will need to be addressed. Remember that the absorption spectrum of different materials and objects is not uniform. That is, some items will absorb only high frequencies, and some objects may only absorb the middle frequencies. At low frequencies, about the only common item that can absorb a meaningful amount of energy is heavily upholstered furniture. Another effective means of absorption is the use of DAAD's, (more information is available at [www.acusticaapplicata.com](http://www.acusticaapplicata.com) )

- High Frequency Absorption and Room Symmetry

Since flutter echo is a high-frequency effect, it becomes much easier to manage potential problems in this area. Almost any item attached to the walls will be less reflective at high frequencies than the bare walls themselves. Draperies, wall hangings, paintings, bookshelves and other items will normally be present in the room, and will usually eliminate any possible problems. If flutter echo is still audible, a fabric wall hanging provides an effective and attractive cure.

Additionally, it is desirable to maintain a degree of left/right symmetry in the room to preserve a balanced acoustic "space". For example, if your listening room has full length draperies along the right wall, and the left wall is bare, slap echo will not be a problem. Nonetheless, the sound-stage may be somewhat distorted, and it could be beneficial to place a fabric hanging or tapestry on the wall opposite the draperies.

- Parallel Surfaces

Although it is not generally possible to make the walls non-parallel, the same effect is achieved by breaking up the large, flat surfaces with furniture and shelving.

## **Speaker Placement**

Although your AVALON ACOUSTICS loudspeakers may be placed in a wide variety of positions relative to the walls of the room, it is still wise to experiment a bit to achieve optimal results. The suggested minimum distances for the COMPÁS are 3 feet from one wall (side or rear), and 5 feet from the other (all distances are measured to the center of the woofer cone). This will provide the proper degree of bass reinforcement, as well as minimize early reflections.

There is no suggested upper limit for the distances to the walls. Even a distance of 10 feet to one wall and 15 feet to the other wall will provide suitable bass reinforcement, and problems due to early reflections will be non-existent. However, regardless of the absolute numbers used, the most even bass response will be attained if the distances from the side wall and the rear wall are not overly similar.

## **Early Reflections**

When arranging the furnishings in your listening room, remember that reflective objects should not be within a five foot radius of either the speaker or listener to avoid early reflections. This suggests the possibility of a dual-purpose room, with one end devoted to music reproduction, and the other end for another use, such as a study or office. In this way, the area behind the listener will contain items that will reduce problems with standing waves and/or flutter echo, while the zone around the speakers remains relatively free from reflective objects.

If you wish to achieve an even more spacious sound-stage, it may be useful to place a sonically absorbent material on the side and rear walls near the speakers. This can be particularly effective at the points where the sound wave is directly reflected to the listening position (a mirror can be used to determine these points, as illustrated in Fig. 8.2). As the distance to the wall becomes smaller, the suppression of these reflections becomes more important.

Early reflections will tend to diminish the soundstage in the direction of the reflections, i.e. early reflections from the side walls tend to reduce sound-stage width, while early reflections from the back wall will reduce image depth. We have found that a strong sense of depth enhances the feeling of involvement when listening, due to the three-dimensional solidity of images. Therefore, it is more important to have a greater distance from the speakers to the rear wall than to the sides walls. Typically, this is easier to achieve if the speakers are placed along the short wall of the listening room.



## 8.6 A Listening Room Example

In order to make these points more clear, an example of a room layout is given in Figure 8.9, illustrating the principles we have given.

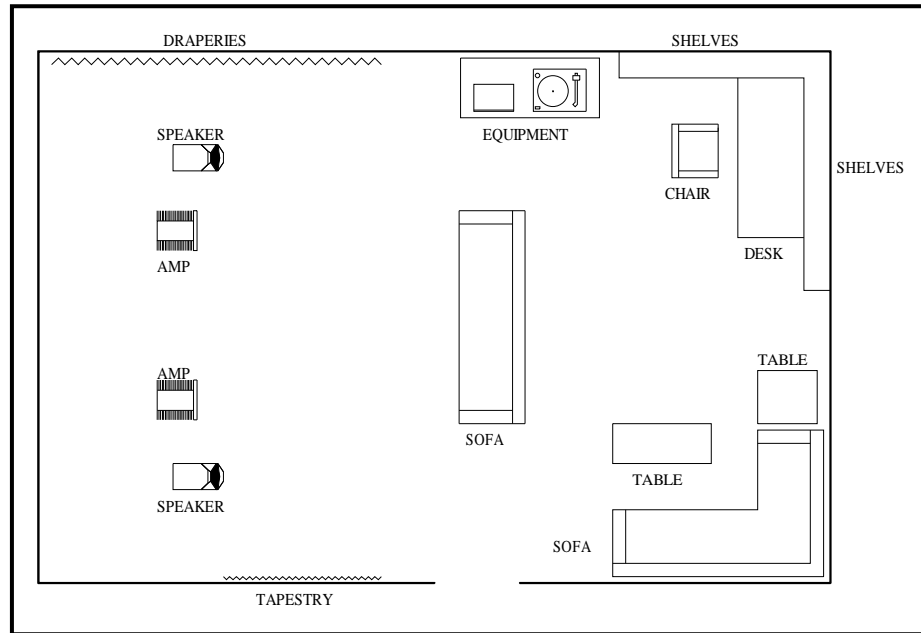


Figure 8.9 - Example listening room. The area around the speakers is free of objects that would produce early reflections. A tapestry is hung opposite the draperies to absorb the reflection from the side-wall and to help maintain left-right symmetry. The area behind the listening position contains items which help break-up standing waves and flutter echoes. Heavily upholstered sofas will help avoid low-frequency standing waves, while a carpet absorbs early reflections from the floor.

---

# 9 Accuracy of Bass Reproduction

---

## Introduction

We have all had the experience of listening to speakers with poor bass quality. Perhaps the bass was muddy, or ill-defined. Possibly the bass was exaggerated or bloated. In any case, these type of distortions are distracting and can keep us from enjoying the full measure of the performer's intent.

Concerning the reproduction of low frequencies, AVALON ACOUSTICS pursues a different design goal than most other speaker manufacturers. Specifically, we believe that the complete absence of stored resonant energy is of paramount sonic importance. First, we will discuss some of the technical aspects of bass reproduction and perception, and then explain how this relates to the listening experience.

## 9.1 Sensitivity to Time-Related Information

---

It is widely known that the human ear/brain system is extremely sensitive to time-related distortions. This can be understood when one realizes that directional and spatial information is provided by inter-aural time (and phase) differences. During the period of man's evolution, the ability to accurately determine the direction and distance of sound sources conferred a decided survival advantage, hence our present day aural sensitivity to time-related information.

This sensitivity to time-related information can be observed when listening to audiophiles discussing the quality of a system's bass reproduction. Many of the terms refer to temporal properties. A system with poor transient bass response is described as "boomy", "heavy", "sluggish", or "slow". When the transient response is accurate, the bass is characterized as "tight", "clean", "quick", or "fast".

### "Fast Bass"

The term "fast bass" would seem to be an oxymoron on the surface. After all, it is the "slowness" of a note that makes it a low frequency. Nonetheless, the term provides an accurate description of our subjective impression. Many people have erroneously ascribed "fast bass" to the use of a light diaphragm or the use of a powerful energizing system.<sup>1</sup> In fact, it is not how fast the diaphragm can be set into motion that imparts a speaker with "fast" bass. Rather, it is how fast that motion can be stopped, how quickly the stored energy can be dissipated, that results in the sensation of "fast" bass.

---

<sup>1</sup> The acceleration of an object is equal to the force exerted upon it, divided by the mass of the object. Since a loudspeaker is used above its fundamental resonance, it operates in what is known as the mass-controlled region. In this region, high acceleration (large driving force and/or small driven mass) does not imply extended high frequency response or fast transient response. Instead, high acceleration confers high efficiency.

## 9.2 Rationale

---

There is an old saying, "There's no such thing as a free lunch." There are many trade-offs in speaker design, as in almost any area one can think of. In this case, the trade off is between transient response and anechoic frequency response (the speaker's frequency response in an anechoic chamber). Almost all manufacturers have chosen to sacrifice transient response for improved anechoic frequency response.

At AVALON ACOUSTICS, we have chosen to pursue a goal of complete freedom from resonances and stored energy to ensure transient accuracy. We feel that the resulting gain in areas **not** traditionally measured results in audibly superior overall performance.

### **Anechoic vs. In-Room Frequency Response**

It must be remembered that very little listening actually takes place in anechoic chambers. Placement of the speakers in a real-world listening room will boost the bass response of the speaker, as explained in Section 8, Room Acoustics and Speaker Position, beginning on page 20. Since a loudspeaker with perfectly flat anechoic frequency response will exhibit a low-frequency boost in a normal listening environment, a loudspeaker with a gradual bass roll-off (in an anechoic chamber) can exhibit more accurate in-room frequency response. Avalon loudspeakers are carefully designed taking these factors into account. When placed in a variety of representative positions in the room, Avalon loudspeakers will produce deep, accurate, and unexaggerated bass response, with complete freedom from stored resonant energy.

## 9.3 Measurements of Audio Equipment

---

It should be recognized that measurements are not the final arbiter of sound quality of audio components. Often times a measurement standard has evolved because it is easily performed, or because it is easily repeatable, or it has shown some link to certain audible characteristics. Unquestionably, it is the latter criterion which is the most important one. After all, the listener is not concerned with how a piece of audio equipment measures, he is only concerned with the faithful recreation of the original musical event.

On the other hand, measurement techniques that correspond to audible effects are an invaluable tool to the designer. However, it is the degree of correlation with the subjective experience which is important, and anechoic bass response does not have a high correlation with musical accuracy in the listening room. In-room frequency response and transient accuracy are both significant factors in determining subjective quality. Nevertheless, anechoic frequency response is by far the most prevalent measurement used to characterize speakers.

### A Correlation with Amplifier Measurements

A striking parallel exists in the measurement of audio amplifiers. The power output and distortion of an amplifier is invariably measured into an eight-ohm resistor. It is widely acknowledged that this standard is far removed from the actual conditions in which the amplifier will be used. One doesn't listen to resistors, one listens to loudspeakers, and the load that the speaker presents to the amplifier is nearly always highly reactive (varies with frequency). The eight-ohm resistive load has developed as a standard because it somewhat approximates a speaker load, is easily reproducible by different testing facilities, and it represents something of a lowest common denominator. That is, while everybody recognizes that a different load should be used for amplifier testing, nobody can agree as to what that alternative should be.<sup>2</sup>

In the last decade, there has been a growing awareness of the importance of an amplifier's capability to drive a real-world loudspeaker. This is the reason we have seen the emergence of amplifiers with high current output capabilities, and a lack of current-limiting or similar protection circuitry. The ability to drive reactive loads has been accepted as having a higher correlation with audible qualities than the traditional measurement into a load resistor.

---

<sup>2</sup> The cynic will also note that a resistive test load produces the most impressive measurements for use in advertisements.

## Loudspeaker Measurements

Returning to loudspeakers, a similar situation has developed. Although nobody listens to music in an anechoic chamber, loudspeaker measurements are commonly performed in them.<sup>3</sup> Although various proposals have been made for performing low frequency measurements in a more realistic setting, there has been no agreement as to what that setting should be. Loudspeakers continue to be measured in a test chamber that is equivalent to the **absence** of any room at all.

There is a developing appreciation that this traditionally performed measurement is not an accurate predictor of the performance actually attained in the listener's room. Certainly, in-room frequency response is more important than anechoic response in determining a speaker's tonal accuracy. Placement of the speaker within a room will cause changes in the frequency response compared to the anechoic condition.<sup>4</sup> At lower frequencies, the speaker's output is modified by the acoustic loading presented by the walls and floor. However, when making measurements, it is difficult to separate the effects of a room's bass reinforcement from standing waves and other resonances associated with that room.

- 
- <sup>3</sup> Since an anechoic chamber which performs accurately to low frequencies is extremely large and expensive, other measurement methods are also commonly used. These include near-field measurements, when the microphone is extremely close to the driver, and half-space measurements, when the speaker under test is buried with its front baffle flush with the ground, facing upwards. Both of these methods are equivalent to anechoic measurements below the frequency at which the speaker baffle appreciably changes the acoustic load to the woofer, typically between 100 and 200 Hz. Note that these conditions are also non-representative of an actual listening situation.
- <sup>4</sup> Since this discussion is concerned with the reproduction of low frequencies, we will not delve deeply into the high-frequency variations between the anechoic response and the in-room response of a loudspeaker. Briefly, the interaction of the dispersion pattern of the speaker with the reflective surfaces in the room (and the variation of both with frequency) creates an in-room frequency response that may vary markedly from the anechoic response.

## Designing for Accurate Bass Reproduction

How, then, does one arrive at the goal of a loudspeaker that provides tonal accuracy in the listening room? The answer, in large part, comes in the form of the digital computer. It is possible to create a mathematical model of a listening room, and predict the response of a given speaker in that room. With the computer model, it is quite easy to change the position of the speaker in the room, or other parameters of the model. In this way, a composite picture can be created of a wide variety of rooms and speaker locations. This enables one to design the speaker so that it interfaces properly with the listening environment and provides correct bass response in real-world environments.

The accuracy of the computer model must also be tested in the physical world, using pink noise, warble tones, and time-delay spectrometry for verification. The final, and most important check, is the listening test. Theory and measurements become useless if they do not agree with what our ears tell us. Even the best measurement methods provide little more than a simplified, one-dimensional translation of what is, in reality, an extremely complex, multi-dimensional experience. Again, the goal is the recreation of a musical event, and the faithfulness of that recreation can only be determined through listening.

## 9.4 Listening Qualities

---

We have seen how many speaker systems store resonant bass energy, resulting in ringing and poor transient accuracy. Now we will turn our attention to the listening experience, and describe how these measurable properties correlate with our subjective impressions.

There are two main factors which affect subjective low-frequency accuracy, frequency response and transient response. At low frequencies, these two descriptions are different aspects of the same event.<sup>5</sup> Nevertheless, for the purposes of this discussion, we will treat these two topics separately as much as is possible.

### Frequency Response Effects

As you listen to music, images of the instruments that created the sounds are elicited. For instance, one can tell the approximate size of a drum from the sound it produces. On a high-resolution playback system, finer details can be heard; i.e., is the head made of plastic or calfskin? Is the player using light sticks or heavy ones?

A relatively broad-band emphasis (or de-emphasis) of a given frequency range can tend to exaggerate (or diminish) the relative size of the instruments playing in that range. A useful tool for evaluating these distortions of size is a recording of a small group of unamplified acoustic instruments made with a simple microphone set-up.

### Listening for Size Distortions

Play a recording of this type, with the volume adjusted to achieve a natural playback level. As you listen, create a mental image of the players based on sounds being recreated. Then ask yourself, "Does this sonic image correspond to the musical instruments that generated these sounds?"

Is the portrait a natural one, or are certain elements distorted? Does a stand-up bass sound like the correct size, or is it exaggerated, sounding like it is ten feet tall, or as if the strings are the size of ropes? A speaker with excessive in-room bass response can create these effects. On the other hand, a speaker system with rolled-off bass can shrink the size of instruments, turning the same stand-up bass into a cello-sized instrument.

---

<sup>5</sup> Below about 200 Hz, virtually every woofer operates as a minimum-phase device. This means that the responses in the time-domain and the frequency-domain are inextricably linked, and that the one generates the other. Thus, two woofers with the same frequency response will necessarily exhibit the same time (phase) response. However, many crossover networks display non-minimum phase response, and will thereby alter the phase response of the woofer in the speaker system.



## Transient Response Effects

A speaker with poor transient response will store energy, releasing it after the initial musical transient has passed. This causes a loss of detail and obscures important musical information. Also associated with poor transient response is a narrow-band resonance, which can emphasize specific notes.

When listening for the low-frequency transient accuracy of a speaker, it will be useful to utilize a broad variety of recordings. Try playing a rock or jazz group, and listen to the interplay between the drummer and the bassist. Is it easy to distinguish the kick drum from the bass, or is there a blurring of low-frequency detail caused by the speaker's time-smear?

To listen for narrow-band low frequency resonances, use a recording with the bass line played by a synthesizer. As you listen to the bass line, are the individual notes of equal level, or are some of them more prominent than others? Electronic instruments can be more useful for this test since acoustic instruments have resonances of their own which can hide flaws in the speaker, unless you are intimately familiar with the instrument and the recording. Similarly, an electric bass that has been recorded by miking its speaker/amplifier will exhibit the resonances of its speakers, which are inevitably considerable, masking defects in the loudspeaker under evaluation.<sup>6</sup>

---

<sup>6</sup> There is a technique known as "direct injection" where the signal from an electric instrument is connected directly from the amplifier to the recording console, bypassing the speakers. In this instance, an electric bass will prove to be a consistent low-frequency source. The difference between direct injection and miking of the speaker/amplifier is easily audible with high-quality speakers.

## 9.4 Conclusion

---

Most loudspeakers have been designed to perform well in the frequency domain when measured in an anechoic test chamber. We have seen how this design paradigm produces audible bass distortion and exaggeration. While these exaggerations may sometimes seem impressive in the short term, they quickly prove to be distracting from the musical intentions of the composer. At AVALON ACOUSTICS, we design all of our speakers to minimize resonance and stored energy, thereby ensuring transient accuracy. As you listen to music on AVALON ACOUSTICS loudspeakers, your enjoyment of the music will grow as you hear the full measure of low-frequency detail, without exaggeration, and come close to the heart of the artist's intent.

---

# 10 Features

---

- Advanced ultra-light weight ceramic/honeycomb driver diaphragm materials minimize energy storage and time-domain distortion
- Stored energy elimination (SEE) technology produces clear stable imaging and black backgrounds even under heavy SPL demands
- Purely pistonic wavefront generation with smooth open lobing characteristics
- Custom designed ultra-high magnetic flux density drivers for unsurpassed transient speed; each individually tested and matched for optimum performance
- Smooth, wide polar response without confluence node behavior for superlative multi-channel blending and imaging capabilities
- Non-reactive, fully damped impedance characteristic allows for ideal interface with any amplifier
- Crossover circuitry is hard-wired with surface-only conductors, eliminating deleterious sonic effects of printed-circuit boards
- Proprietary jitter reduction circuitry for unsurpassed image definition and stability
- Careful crossover control of all magnetic field interaction
- Proprietary magnetics technology increases energy transfer and reduces noise floor
- Constrained-mode damping system absorbs cabinet vibrations
- Unique cabinet form and structure provides equivalent three dimensional polar response
- Acoustically-engineered grille assembly decreases edge diffraction effects

---

# 11 Specifications

---

<b>Driver Complement</b>	(1) 1" Inverted Ceramic Dome Tweeter (1) 4.5" Concave Ceramic Midrange (2) 9.5" Ceramic/Honeycomb Woofers
<b>Sensitivity</b>	91 dB @ rated impedance
<b>Impedance</b>	4 Ohms Nominal
<b>Frequency Response</b>	27Hz to 24kHz
<b>Recommended Power</b>	50 to 500 Watts
<b>Wiring Methods</b>	Two Position Binding Post
<b>Dimensions</b>	46" (117 cm) High 11" (28 cm) Wide 17" (43 cm) Deep
<b>Weight</b>	152 pounds (68 kg) each

---

# 12 Notes

---