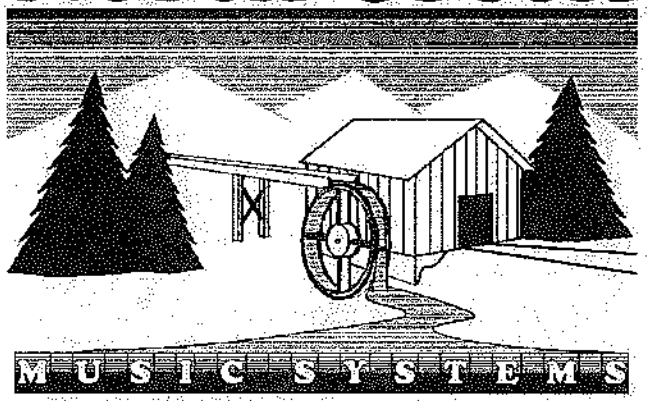
$5.00

North Creek



CABINET HANDBOOK

A guide to building *great* loudspeaker cabinets.

Simply Better Technology

Dear Fellow Audiophile,

I would like to welcome you to the second edition of the *North Creek Music Systems Cabinet Handbook*. This publication was originally written to supplement our kit manuals, explaining in detail our choices of material, dimensions, etc. The *Handbook* has evolved into a set of guidelines for designing and constructing exceptional loudspeaker cabinets, not just for North Creek Music Systems High Performance Loudspeaker Kits, but for loudspeaker systems in general.

Our cabinet philosophy, and consequently the material presented in the *Handbook*, is indicative of our *system-oriented* approach to cabinet design and construction. There is no single element of a loudspeaker cabinet that determines the overall performance; rather, it is the combination of all elements. Excellence in design requires attention to every detail, where *each* specific element is optimized to improve the *total* musical presentation.

It is my hope that the material within these pages provides you with valuable information, whether you are a first time speaker builder or a seasoned veteran. Our goal, as a company, is to make you a better speaker builder.

Happy listening!

George E. Short III

George E. Short III
President

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Contents

Cabinet Philosophy

A loudspeaker is a **system** of which the cabinet and stand are components. The cabinet baffle, sides, top, braces, and the stand all form an integral unit, and that unit makes a substantial contribution to the overall presentation. Knowing that the effect of the cabinet and stand can not be eliminated, the approach we take is to maximize the positive and minimize the negative aspects of audible contributions.

The fundamental purpose of this company is to serve the needs of the loudspeaker hobbyist. Therefore, a further requirement of our loudspeaker cabinets is that they can be successfully constructed by the hobbyist. This imposes two significant limits on our cabinets:

- Difficult to obtain and machine materials, such as honeycomb laminates or synthetic marble, are not considered.
- All cabinets must be easily constructed using *only bench-top equipment and hand tools.*

In a nutshell, these conditions require that North Creek Music Systems cabinets be made of commonly available wood products.

Therefore, over the years we have developed a cabinet construction methodology that takes advantage of modern wood composites, inexpensive and well chosen adhesives, good ears and common sense. When followed, and used with the proper stand, our methodology yields a loudspeaker of exceptional listenability.

The most important thing the home builder should keep in mind is that they can ***always*** build a cabinet better than a manufacturer. First of all, good cabinet construction takes time; time to get the laminations just right, time to let the adhesives cure, time to get the finish perfect, etc. Time is a luxury few manufacturers have, and those that take their time, and produce truly excellent cabinets, charge dearly for them (and they are usually worth it). From our perspective, it's acceptable that it takes a little longer to construct a North Creek-designed cabinet. We include a few extra steps and unusual twists that require a bit more patience. We use adhesives that dry slowly but sound better than those that dry quickly. We use laminated panels of unlike materials to control and eliminate resonances. All of these additional steps require a lot of concentration and extra effort on the part of the builder. Does it mean a better sounding loudspeaker system? You bet.

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Loudspeaker Stands

The correct choice of loudspeaker stand is as important as any other step in the loudspeaker development process. If this link is weak, the entire system, no matter how carefully designed, will have severely limited performance.

The purpose of a loudspeaker stand is to form a stable platform for the drive units while providing a means of transferring any cabinet vibration to the Earth. This is called "mechanical grounding," and is analogous to electrical grounding in an electrical circuit. (To be historically correct, this should read "electrical grounding is analogous to mechanical grounding in a mechanical circuit", as the principles of mechanical grounding - literally "to the earth" - were well known and understood long before the electrical circuit was discovered.) The most important characteristic of a good stand/loudspeaker combination is its ability to transfer vibration to ground.

The worst case of mechanical loudspeaker grounding is a soft junction, where the loudspeaker sits on a compliant surface, and is not rigidly coupled to anything. Newton's third law dictates the cabinet will float, slipping backward and forward in opposition with the woofer. This is why loudspeakers placed on carpeting generally lack impact; the floating cabinet soaks up all the energy.

Another condition that arises from a poor mechanical ground is excessive or lengthy cabinet panel vibrations. When panel vibrations have no ground path, the only opportunity for energy dissipation is the cabinet's internal damping. As this dissipation is generally via frictional losses by flexure of the cabinet walls, the cabinet by necessity radiates sound as the vibrations slowly decay. A rigid stand and ground path create an alternative means of dissipating vibration energy.

All North Creek Music Systems Loudspeakers call for heavy cabinets, and are designed with high quality stands as part of the system. We generally suggest medium mass, multipillar designs for larger cabinets, and high mass, single pillar stands for monitors. As our cabinets are well damped internally, the choice of stand to properly complement this damping with mechanical grounding is essential.

A good stand makes the difference between a good loudspeaker system and a great one.

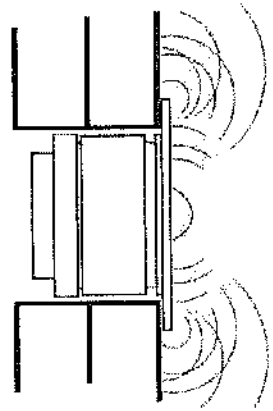
The Front Baffle

The baffle is essentially that surface to which the driver is mounted. Since all North Creek Music Systems loudspeakers use rectangular cabinets, the baffle is the front of the cabinet.

The front baffle adds two characteristics to the sound. The first is cabinet vibration, caused by the baffles own resonances being excited by the motion of the woofer cone. Our method of controlling this contribution is outlined in the "front and rear panels" section.

The Tweeter Flange

The second contribution of the front baffle is early reflections of the tweeter wave-fronts. The earliest reflection is caused by the tweeter not being flush mounted. In this case, the tweeter flange itself is the problem, as waves travelling along the flange "fall" off the edge and are reflected by the baffle. One would think that because this discontinuity is a "step away" rather than a protrusion, its effect would not be noticeable. The reason it is audible is that the tweeter's flange is round, therefore the step is equidistant front the tweeter dome, hence one specific wavelength set is strongly accentuated. The result is response aberrations at a series of frequencies that are harmonically related, a condition to which the ear is very sensitive.



There are three treatments to this particular problem. The first is to spread the aberrations out over a broad band of frequencies, thereby reducing the effect at specific frequencies and their harmonics. This can be accomplished by using a tweeter flange of any shape other than round, rectangular being the most popular choice, although the Tetrahelix® developed by Acoustic Research in the mid 1980's (for precisely this purpose) is much more effective.

The second method, also pioneered by Acoustic Research, is to "soak up" the step by covering the tweeter flange and/or the area directly adjacent to it with a material that is acoustically absorptive, usually a soft wool felt. When implemented properly, this method can be effective, although a "blanket" thicker than the flange is usually required, sometimes creating more problems than it solves.

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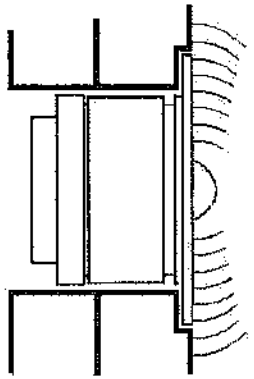
The last method, and the one suggested on all North Creek Music Systems cabinets, is to flush mount the drivers, eliminating the problem altogether.



Other Early Reflections

Any other protrusion from the baffle will cause an early reflection. Small obstacles (screw heads, the woofer frame, and the mushrooms from the grill fasteners, if they are mounted with the mushroom out) cause small aberrations, which in turn are only slightly noticeable. None the less, these should be eliminated as a matter of course.

Baffle Corners

There has been conjecture over the audibility of a sharp vs rounded corner on the front baffle, but subjectively the shape of this corner appears to make no difference at all (provided, of course, it is not a protrusion).

Our smaller cabinet corners are cut at 90° angles. This makes the cabinet easier to veneer or otherwise finish, and creates a clean line when the grille is attached. Our larger cabinets use a rounded baffle.

Woofer Mounting

The woofer should also be flush mounted. Although this is generally for cosmetic purposes, the protrusion of the woofer frame does create some small frequency response aberrations.

All driver frames should be backed with a gasket, and neoprene/rubber closed cell tape is provided with all North Creek Music Systems kits. Mortite® gasket compound also works well, although it is difficult to find in black. Open cell foam tapes, such as those made for weatherstripping, are adequate only if nothing better is available.

Long screws should be used to attach the drivers. The length is important because it is the threads, not the tip, that takes the pressure. Screw tightness also contributes to the system sound, and is often overlooked over time. Screws should be re-tightened every three months.

Tetrahelix® is a registered trademark of Acoustic Research. Mortite® is a registered trademark of 3M.

The Shell

The "shell" is the external surface of the loudspeaker, composed of the front, back, top, bottom, and side panels. Control of the resonance modes within these panels is critical in a high performance cabinet, as any vibration is immediately communicated to the listening room.

It is impossible to completely eliminate vibration within the shell. Therefore, upon accepting the fact that the cabinet, no matter how well constructed, will have a sonic signature, the next best solution is to minimize the negative quantities of this signature. Our method is to force any panel resonances to a high enough frequency that panel damping is effective, and to construct the cabinet in such a fashion that much of the panel vibration energy is channeled through the stand and to mechanical ground.

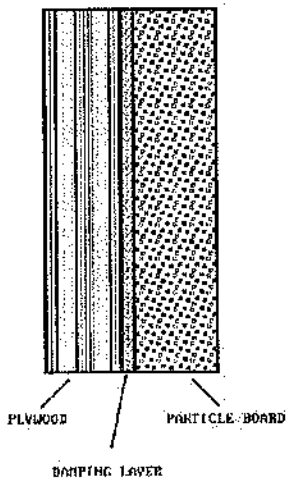
It is important to note that neither raising the panel resonance frequency nor implementing mechanical grounding is sufficient to minimize shell coloration. It is the combination of the two, properly balanced, that controls the problem.

Front and Rear Panels

Because of our style of cabinet, the front and rear panels can not be braced. We therefore require that they be constructed of a composite board that combines rigidity, machineability and internal damping.

Panel Construction

In the case of the front baffle, the driver holes significantly weaken the structure that it must be very well constructed for sufficient rigidity. The rear panel is weakened by the back cup hole, and bracing is precluded by the need to mount the woofer crossover network. Therefore, we suggest a composite panel made of a layer of 3/4" particle board or MDF laminated to a layer of 3/4" Baltic Birch plywood. One is welcome to use thicker layers of either material, if desired. In our largest systems we use a 1¼" MDF/Baltic Birch plywood composite for the front and rear, yielding a panel 2" thick. In all cases, the lamination adhesive should be NCMS soft glue.



Front Baffle

We suggest the MDF layer because the front and rear faces of the cabinet must be finished and painted, and the front face must be machinable, to flush mount the drivers. MDF finishes easily.

Panel Rigidity

The MDF and plywood panels are rigidly coupled, and the resulting panel is substantially stiffened. The Baltic Birch plywood also offers additional stiffness because of its grain and highly layered construction. Stiffness is proportional to the square of panel thickness, therefore the composite panel is at least *four times as stiff* as a single MDF layer.

One could argue that a thicker front panel would provide even better performance than the two layer composite we suggest for most of our cabinets. We would agree, and in our largest systems we specify additional thickness. Those who wish to use three or more layers are welcome to do so; our only caveat is that the area near the rear of the woofer be sufficiently (and smoothly) flared to allow uninhibited airflow.

Panel Resonances

Because the MDF and plywood have different density, sound velocity and damping characteristics, the resonances in one layer of the panel will not match those of the other. This and the discontinuity of driver and back cup cut outs allow few standing wave modes to achieved stability. The great majority of the panel vibration energy is quickly transferred to the rest of the cabinet, through the stand and to ground.

In all of our systems, the front and rear panels are only slightly wider than the woofer frame. This results in a relatively narrow baffle, therefore short (and easier to control) panel resonance wavelengths.

Panel Damping

Rigidity is the key issue of the front and rear panels, therefore excessive internal damping is not required. The layer of NCMS soft glue is generally sufficient. In some cases, overdamping the front and rear may actually compromise panel rigidity.

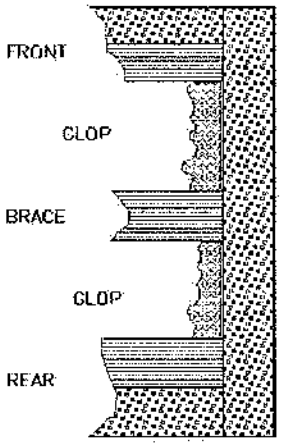
Side Panels

We suggest 3/4" MDF for the side, top and bottom panels. 3/4" particle board or 5/8" particle board also works well, and 3/4" plywood is a fine forth choice. For floor standing loudspeakers, a 1 1/2" bottom panel may be required to give adequate thickness for spike countersinks.

MDF (or particle board) is the ideal material for the side walls because of its internal damping, machineability and glueability. Our bracing strategy eliminates the need for excessive rigidity.

Panel Bracing

All of our cabinets are multiply internally braced. Our bracing method eliminates most standing waves in the side and end panels while insuring the cabinet behaves as a single solid unit. This bracing structure is absolutely necessary to properly control the panel resonances.



Side Panel
(viewed from top)

Panel Resonances

The addition of the bracing structure moves the first panel resonance up in frequency. Those standing waves that find stability are generally at a frequency well above the unbraced panel's fundamental resonance. The nature of vibration within panels tends to "bleed" energy from one side to the other, therefore a standing wave in one side will migrate to the other, where it is unstable. The panel damping and stand ground path provide the means of energy dissipation.

Panel Damping

After construction is completed, all of our cabinet side walls are coated internally with a layer of NCMS soft glue blended with pre-mixed drywall compound. This mixture forms a counter layer that does not add significant weight to the panel, yet greatly increases its internal damping. The mixture is applied with a "glop trowel", or by hand, in a layer approximately ¼" thick. The mixture cures to an extremely dead counterlayer, about 1/8" at its greatest depth.

Braces

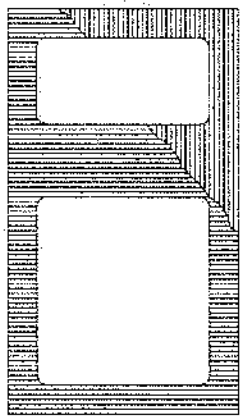
Braces serve the purpose of increasing the rigidity of the cabinet walls, top and bottom, without substantially adding to their mass. In our cabinets, the function of the brace is to enable further control of panel resonance, both by increasing the panel's fundamental resonance frequency and by creating additional ground paths to the loudspeaker stand. Good bracing is **essential** for a great sounding loudspeaker cabinet.

Brace Material

Bracing material must possess qualities very different from side wall material. The purpose of a brace is to prevent the side walls from bowing sympathetically with the woofer. Therefore, the job of a brace is to remain dimensionally stable under the forces of tension and compression.

It was shown by Tappan in 1962 that solid soft wood is not suitable along its width for bracing material[1]. Modern composite boards, such as particle board and MDF, possess far *less* tension and compression strength than solid soft wood, and therefore make far *poorer* braces.

The correct material to use for internal bracing is multidirectional plywood. Plywood is very strong in any direction under tension, because wood does not stretch along the grain. Although not as strong under compression, it is still superior to soft wood and far superior to composite board.


BRACE (MULTIDIRECTIONAL PLYWOOD)

Brace Shape

Panel rigidity can be increased by bracing it along its length. Panel rigidity can also be increased by rigidly coupling its ends. Therefore, if an *internal brace* is the panel in question, two ways of the making it more "bracing" is to brace it along its length (in this case, by gluing it to the cabinet top and bottom) and to couple its edges, by gluing it to both cabinet side panels. The end result is a "figure 8" as the optimum choice for brace shape. This shape can be made either from a single machined section of plywood, or strips glued at right angles (ladder bracing).

Brace Adhesive

For a brace to be effective, it must allow no movement at the panel junction. This requires a very hard adhesive, such as Titebond.

Minimum Brace Width

To withstand the flexure pressure from the side panels, the brace should be a minimum on 1" wide along the cabinet walls, with the cross piece of the "8" at least 3" wide. All cut outs should have well rounded corners. For sealed box cabinets, we do not recommend the top half of the "8" (the part behind the tweeter) be cut at all. In fact, in some of our systems we use this region to mount the tweeter crossover board.

Brace Thickness

Because tension and compression strength is the main issue, the thickness of the brace stock is not of great importance. We use 19 mm (¾") Baltic Birch plywood.

Brace Damping

Although plywood has poor internal damping qualities, the holes cut from its surface usually allows few stable standing waves modes. Coupled with the fact that it is inside the cabinet usually makes its panel resonances inconsequential.

Other Considerations

Smaller cabinets requiring large crossover boards must have adequate space to allow the crossover to be passed through the woofer cut out and mounted to the cabinet rear. Therefore, the brace edge immediately behind the woofer cut out may need to be cut closer to the side walls than usually required.

Those cabinets that are designed for bass reflex alignments require careful positioning of the opening in the brace near the port tube. Air turbulence caused by the brace can adversely affect the low frequency performance at high volume levels, and should be avoided. A good rule of thumb is to leave an area at least one additional port diameter larger than the port tube clear of any obstructions.

1. Tappan, "Loudspeaker Enclosure Walls", JAES, July 1962.

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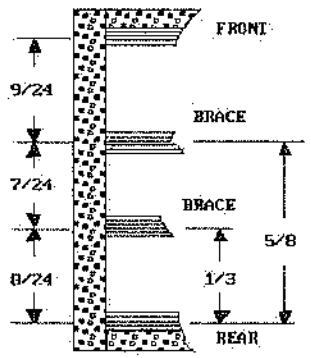
Brace Position

Proper brace positioning is at least as important as the bracing material itself. Although bracing is rarely a liability, in some cases an improper brace location may result in trading one set of problems for another.

The positioning method originally suggested by Tappan is to install the braces inside the cabinet in such a way to minimize the diameter of the largest circle that could be drawn between the brace and next panel. When using circumference bracing on rectangular panels, this method results in each panel being divided precisely in half, doubling of the fundamental resonance frequency and equally exciting both halves. Therefore, Tappan suggests a 5% misalignment to spread the resonance frequencies.[1]

The **North Creek Method**, derived from accelerometer measurements, mathematics and experience, is to place the brace seven-sixteenths the way along the unsupported region of the panel. If two braces are used, the correct positions are at five-eights and one-third the way along. This creates two (or three) regions of different width, therefore different resonance frequencies, within the same panel. In the case of two braces, the first common wavelength (therefore stable standing wave) occurs at 24 times the unbraced panel's fundamental, although resonances of low Q will find limited stability at much lower frequencies.



Optimum Brace Positions

None the less, these bracing arrangements and the nature of vibration within panels prevents most standing waves from forming, and transfers the majority of vibration energy from one region into the other regions, hence to the other panels and through the stand to ground. While not precisely satisfying Tappan's criteria, subjectively it is very effective.

When arranging the braces, the builder should keep in mind that the positioning guidelines are for the *center* of the brace, and the reference is the dimensions of the *unsupported region*.

1. Tappan, "Loudspeaker Enclosure Walls", JAES, July 1962.

Cabinet Assembly

Pre-Assembly

Always do a "test-fit" pre-assembly of both cabinets to make sure the panels fit together properly. Label each panel both to which cabinet it belongs (left, right), and which edge is the top. Always label on the rear-facing surface.

Panel Junctions

The glue joints between adjacent panels (top-side, side-front, top-front) should be of a hard glue, like Elmer's Carpenters' Wood Glue. The purpose of these joints is to rigidly couple one panel to all adjacent panels, which mutually strengthens all panels and adequately conducts any vibrations through the panels, hence to the stand and the mechanical ground. Butt joints are sufficient when using hard glue.

Soft panel glue joints work well in cases where little other damping is present, provided the glue joint area is of sufficient size to maintain its strength under vibration. Reinforced butt joints or dado joints are suggested when using a soft glue.

All North Creek Music Systems Kits are supplied with adequate internal damping coating material, hence require hard glue joints.

The "Two Drill" Method

This procedure works well and greatly speeds up the final cabinet assembly process. Requires two drills, a phillip's head bit, a "pilot hole and countersink" bit, and a box of 1¼" drywall screws.

1) glue and assemble one panel, clamping the ends tightly
2) mark a line on the outside of the cabinet that lines up with the center of the newly glued panel
3) using the drill with a "pilot hole and countersink bit", drill pilot holes with countersinks every 4" along the new panel line.
4) using the second drill, with the phillip's head bit, drive in 1¼" drywall screws. The drywall screws should pull the glue joint tight.
5) remove the clamps.
6) after the finished cabinet has been allowed a minimum of 24 hours for the glue to dry, remove the screws.
7) fill the countersinks with Plastic Wood.

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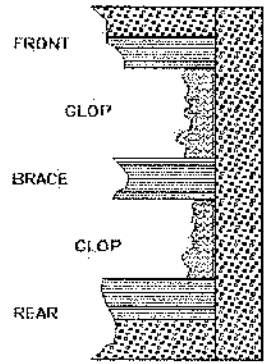
Glop

Glop, a mixture of NCMS soft glue and pre-mixed drywall compound, performs the valuable function of energy dissipation through self-damping. Because of its intimate contact with the cabinet walls, any panel vibration is transferred into the volume of the glop. We suggest drywall compound as the filler because its medium density allows the volume of the glop to be substantially increased without greatly increasing the effective mass of the panel. Also, when the glop cures, the calcium and silicate in the mixture reduce its compliance but do not alter its damping. The combination of the semi-rigid damping layer and a rigid stand with a clean ground path yield a superior loudspeaker.

Glop Application

1) In a large cup (we use 20 oz plastic cups), pour in one cup of NCMS soft glue. Slowly add ½ cup of drywall compound, mixing thoroughly. Mix the glop about twice as long as you feel you need to; it is important to uniformly blend the two materials into one.
2) With the cabinet on its side, trowel the glop onto the cabinet side wall and press it on. A small piece of cardboard works well in spreading the mixture. The center portion of the cabinet, between the braces, should be covered in a layer up to least ¼" thick. The glop is most effective away from the cabinet corners, so there is no need to twist and turn to cover the entire wall.



Side Panel
(viewed from top)

3) Allow a **minimum of 24 hours** for the glue to set. The glop surface may crack when it cures, and should be expected.
4) Rotate the cabinet and repeat step (2).

A Little More Info...

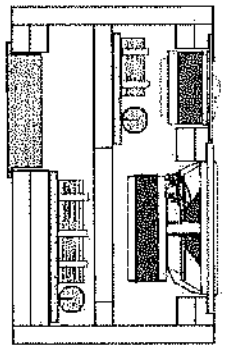
- It is often easier to pile the glop between the braces, then spread it. NCMS soft glue is non-toxic and washes off skin with water.
- Uniform coverage of the panel with glop is not required. Since glop has no effect near the cabinet corners, it is not necessary to go to extremes to coat them.

The Crossover

All North Creek Music Systems crossover networks are provided with the woofer and tweeter sections assembled on completely separate boards. The crossover network must be mounted far enough from the woofer to minimize coupling between the woofer magnet structure and any crossover inductors.

The Woofer Board

In general, the best place to mount the woofer network is on the cabinet rear, as close as possible to the back cup. We generally extend the woofer inductor lead directly to the positive binding post, so the network must be mounted close enough that the wiring is not overly cumbersome.



Okara
network placement

The Tweeter Board

The tweeter network usually requires a board about half the size of the woofer board, and can be mounted on the rear panel as far as possible from the woofer board, or in some cases on the brace directly behind the tweeter cut out. The major consideration when mounting the tweeter network is that any inductors are far enough from the woofer inductor not to interact. In general, the farther, the better.

Crossover Mounting Adhesive

We suggest "Liquid Nails" (or its equivalent) as an adhesive between the crossover board and cabinet. Although this adhesive requires at least 24 hours to cure, it has excellent open time, high strength, and fills gaps without difficulty. The glue joint between the crossover board and cabinet should be rigid, therefore silicone and other soft adhesives are not recommended.

Crossover Board Material

All North Creek Music Systems crossover networks are hard wired on ¼" perforated Masonite; the same material used to hang tools on shop walls. The holes in the masonite provide a means of running nylon tie-wraps through the board and around the inductors without difficulty.

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The Grille

Grilles are necessary to protect the drivers from accidental damage.

Grille Frames

The protrusion of grille frame from the front baffle causes early reflections. Although this frame is rarely equidistant from the tweeter, its thickness is usually on the scale of tweeter wavelengths (10kHz ≈ 1¼" wavelength). Wavefronts produced by the tweeter literally *collide* with the grille frame, the resulting reflection resembling a "secondary source" type phenomenon. This is one cause of "image drag", where images with substantial high frequency content (most notably sibilants) suddenly shift to the loudspeaker positions.

Some manufacturers recess the grille frame into the baffle to combat this problem. For reasons outlined below, we prefer a conventional, removable grill.

Grille Cloth

Most manufactures use either synthetic fabric or semi-rigid foam as grille cloth material. This is always a compromise born of aesthetics, as both materials tend to dull transients. The *only* grille material we have found that does not significantly effect tweeter sound quality is tightly stretched fiberglass window screen.

Our Attitude

Because loudspeakers are furniture, window screen grilles are generally aesthetically unacceptable. Because loudspeakers are **LOUDSPEAKERS**, grille frames are unacceptable. The function/form solution is select the grille material purely to flatter the environment, *regardless of its acoustic qualities*, and remove the grilles altogether for serious listening.

Mounting the Grille Frame

This method always works: after the cabinet is constructed and the grilles cut out, line up each grille frame with its cabinet and clamp it on. Then, drill the mushroom clip pilot holes through the frame and into the cabinet. When the cabinets and grilles are finished, the mounting hardware will precisely line up.

An example:

The Okara

The *Okara* was developed conceptually as a mini-monitor that could be used as a stand-alone system (albeit with limited bass performance) or as monitors with a subwoofer. The system is based on the Scan-Speak D2905 1" fabric dome tweeter and Vifa P13WH-00-08 5" polypropylene cone woofer, two of the finest drivers available on the world market.

The P13WH has two characteristics that make it ideally suited for mini-monitor use: its enormous motor structure makes it reasonably sensitive (88 dB/2.83V) while realizing a low Q_{tc} in an acoustic suspension enclosure, so it can be used with most subwoofers, and its extended voice coil (14 mm) and progressive suspension will keep the cone under control under high excursions, if used without a subwoofer.

Cabinet Volume

We chose a $Q_{tc} = 0.66$ for the *Okara*, so its initial low end roll off would be nearly first order and the mid-bass would be textured and well detailed. This is a delicate balance; as the system resonance is in the neighborhood of 100 Hz, a Q_{tc} above 0.75 will have a tendency to obscure many instrument fundamentals, while a Q_{tc} below 0.57 would be too lightweight.

The required box volume is:

$$V_{ab} = \frac{V_{as}}{(Q_{tc}/Q_{ts})^2 - 1}$$

$V_{as} = 10\ l$
$Q_{ts} = 0.33$
$Q_{tc} = 0.66$

Therefore $V_{ab} = 3.33\ l$, or 203 in^3.

Because we require ease of construction and minimum baffle width, we set the height of the cabinet at 11½ (a standard width for particle board shelving stock) and the width of the internal front baffle at 5¾", just larger than the woofer frame. Therefore, the total cabinet width (internal width plus two side thicknesses) equals 5¾+1½, or 7¼".

The internal cross section area equals the internal height (cabinet height minus top and bottom thicknesses) times the internal baffle width, or (11½-1½) x 5¾ = 57.5 in^2.

The internal depth is the required volume divided by the cross section, or 203/57.5 = 3.53 in. We use 1½" MDF/Baltic Birch plywood laminates

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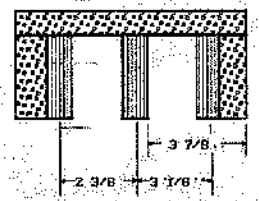
for the front and rear, plus one single ⅜" plywood brace which is 50% open area, plus about 20% to compensate for the crossover, driver and glop volumes. Therefore, the additional depth required is 1½ + 1½ + ⅜ + 0.71, or 4.09", and the total cabinet depth 3.53 + 4.09 ≈ 7¾".

Brace Design and Placement

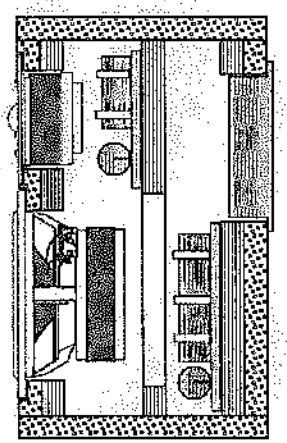
Since this is a small cabinet, only a single brace cut-out is required. For best results, the cut out should line up with the woofer, and should have a minimum area equal to the woofer cone area. Only the bottom part of the "figure 8" is cut, leaving ¾" on the sides, a 4¼" x 5¼" opening.



The best location for the tweeter crossover board is attached to the region of the brace directly behind the tweeter. To allow room for the inductor, the brace should be offset to the rear of the cabinet. The open depth from the plywood layer centers is 7¾-1½-¾ = 5½, therefore the brace center is located at 5½ x 9/16 ≈ 3⅛ from the center of the front plywood panel. Correcting for panel thicknesses, the forward edge of the brace is located 3⅞ from the front edge of the cabinet.

Crossover Placement

The only available space for the woofer crossover board is on the back wall directly behind the woofer. This is necessitated by the size of the woofer series inductor, which is 12 AWG and over 4" in diameter. This leaves the upper portion for the rear panel for the back cup and binding posts, and the region of the brace behind the tweeter for the tweeter crossover board.



The Result

This loudspeaker is exceptionally massive for its small size, the cabinet alone weighing more than many small loudspeakers. The system was designed for medium to high mass 24" stands, spiked on top and bottom, with a non-compliant junction. This combination is very well controlled, allowing the drivers and crossover to function at their full potential.