SECTION 4 – DESIGNING AND BUILDING THE ENCLOSURE
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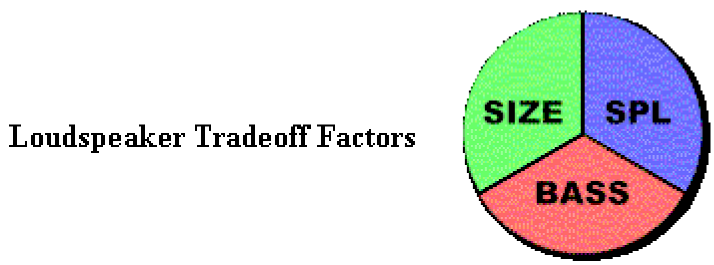
SECTION 4 – DESIGNING AND BUILDING THE ENCLOSURE

(Section Index)

DESIGNING THE ENCLOSURE

Once you have the Thiele Small Parameters, it is time to design the speaker box. You can do this utilizing either Speaker Workshop or Unibox. The latter is a freeware Excel Spreadsheet software written by Kristian Ougaard and which can be found at http://www.pvconsultants.com/audio/boxmodel/unibox.htm. It is a far more comprehensive program than SW is for designing a box. When designing the box and choosing the alignment and type of box, remember that there is always a tradeoff between size, bass response, and power output. John Murphy (TrueAudio.com) demonstrates this with the following graphic:



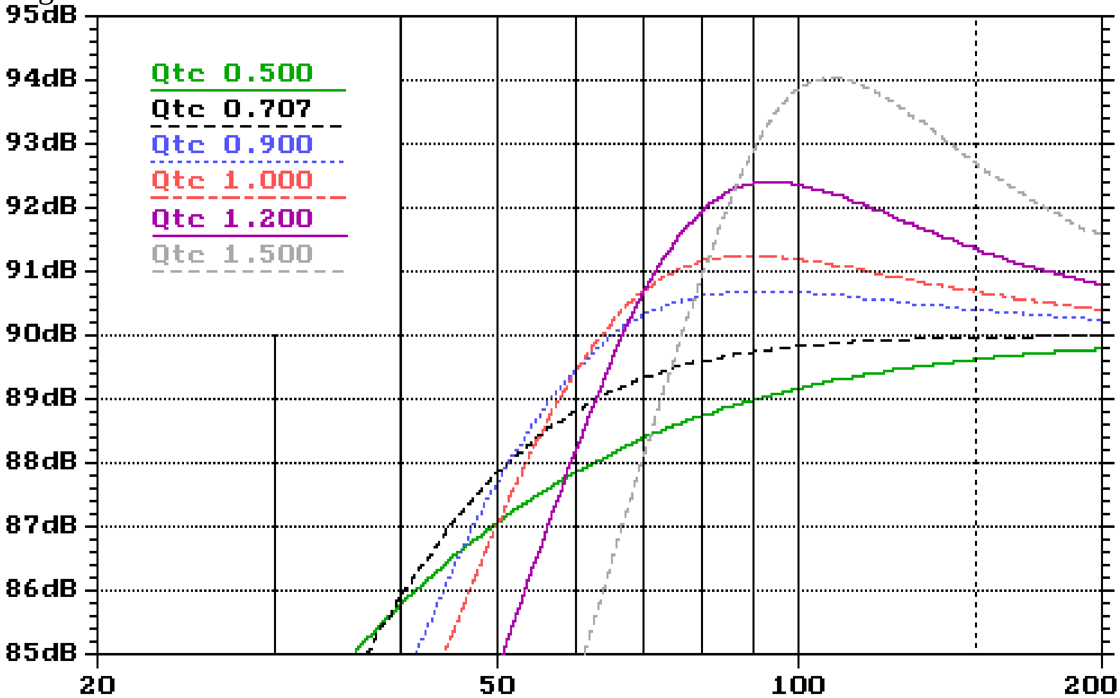
Using Speaker Workshop

Speaker enclosures help to prevent back wave influences on the sound of a speaker. The influence is primarily seen at lower frequencies. Alternate designs that do not have enclosures (such as open baffle dipole speakers) and have both advantages and disadvantages. The volume of the enclosure is of paramount importance in helping to determine the “Q” or the frequency response characteristics of the lower frequency range. There is also a significant impact by the port tuning in vented designs (determined by a combination of enclosure size, port length, and port diameter). The underlying principal of this design is the enclosure and the vent act together to become a Helmholtz resonator at those desired frequencies. A characteristic of the vented design is the significant decrease in driver response at the tuning frequency of the port as the port output accounts for virtually all of the output at that frequency. Also of note is the combined response drops off at 24 dB / octave as opposed to 12 dB / octave for a sealed design. While the f3 of the ported design may be lower than an equivalent sealed design, the f10 may be a higher frequency. The vent does nothing to mitigate standing waves, which must be separately addressed by damping materials or other means. In a sealed box, the filling will tend to increase the apparent volume of the enclosure (up to a point) and this must be taken into account.

Vented boxes

1. Have a 24 dB/octave roll off.
2. The vent increases acoustic load near resonance -> decreased cone motion and increased port output -> decreased IMD and increased power handling
3. Below Fs, there is a sudden unloading of the driver -> increased excursion and distortion, both subsonic (a problem especially with records and occasionally with CD's and DVD's) and IMD.
4. Lower F3 with the same driver
5. Lower excursion requirement for same SpL above resonance
6. Less cone mass and less voice coil overhang is required for the same output due to the theoretically increased output of vented vs. sealed.
7. More sensitive to misaligned parameters.
8. Requires lower Qts than sealed boxes (.2-.5)
9. Tuning lower extends the low frequency roll off and makes it more shallow; this makes the transient response better (more like a closed box system) but also causes the drop off to be more steep below tuning.

For Sealed Boxes, note the following predicted frequency response curves for different alignments:



and how the F3/Fs ratio will be impacted by the relationship between the Qts of the driver and the Qtc of the system design (from Vance Dickason, The Loudspeaker Design Cookbook, 6th Edition).

	Qts			
F3/Fs	*0.2*	*0.3*	*0.4*	*0.5*
Qtc				
1.5	5.2	3.5	2.6	2.1
1.2	4.4	2.9	2.2	1.8
1.1	4.2	2.8	2.1	1.7
1.0	3.9	2.6	2.0	1.6
0.9	3.7	2.5	1.9	1.5
0.8	3.6	2.4	1.8	1.4
0.71	3.5	2.4	1.8	1.4
0.58	3.7	2.5	1.9	2.0
0.50	3.9	2.6	2.0	-

Note that the cut off frequency for a sealed enclosure decreases with increasing enclosure size at or above a Qtc of over .707. Above a Qtc of .707, an increase in box size will increase the cut off frequency.

One other thing to consider is the room effect. From John Kreskovsky, "As Qtc approaches 1, the fundamental and the harmonics are reproduced with more uniform relative amplitude and greater correspondence with the input signal. If a sealed system is placed into a small, closed room, room gain will occur below the fundamental room resonance. If the speaker's resonance is below that of the room, the speaker will sound boomy due to the enforcement by the room. A low Qtc system has a greater roll off of bass response above resonance so the likelihood of boomy bass from the speaker/room combination is lessened. If the speaker has a resonance well above that of the room, room gain will not augment the initial roll off of the speaker and it will appear weak in this frequency range until room gain kicks in. In this case, a higher Qtc speaker may be desirable."

A rough rule of thumb to determine which type of box is best is to use the Efficiency Bandwidth Product (EBP). EBP = Fs/Qes. If <50 use a sealed box; 50-90 either; >90 use a ported box.

Another method is to look at the Qts. As a general guideline, Qts of 0.4 or below indicates a driver well suited to a vented enclosure. Qts between 0.4 and 0.6 (perhaps up to 0.7) indicates suitability for a sealed enclosure. Qts of 0.6 or above indicates suitability for free-air or infinite baffle applications. Of note, there are some arguments for using a low Qts driver in a sealed box as the back pressure in the box is more effectively blocked with a low Qts driver and this blocks more of the box influence on output however efficiency and output are quite decreased compared to a ported box in this case.

The natural resonance properties of most enclosures will tend to be in the lower frequency ranges. Sound is more easily transmitted through the enclosure walls at these frequencies, which partially defeats the purpose of having an enclosure, as these transmitted sounds will add to a distortion of the sound being reproduced. Bracing the walls assuring that the walls are stiff increases the resonant frequency of the box to the point where damping can more effective absorb the sound energy thereby minimizing the sound transmission through the wall. Damping materials are generally much more effective at absorbing mid to higher frequencies so the combination of bracing and damping is beneficial.

For a subwoofer, bracing may actually be able to increase the resonance of the walls above the frequency response area of the subwoofer such that damping materials may not be necessary.

Subwoofers may be used in a front firing or back firing configuration though for the latter there must be a lot of clearance from the rear reflecting surfaces so as not to introduce compression and distortion. A down firing configuration is also an option. To determine if the driver is right for this type calculate the Sag:

Percentage of Sag=24,849/(Xmax (mm)*Fs^2) and then

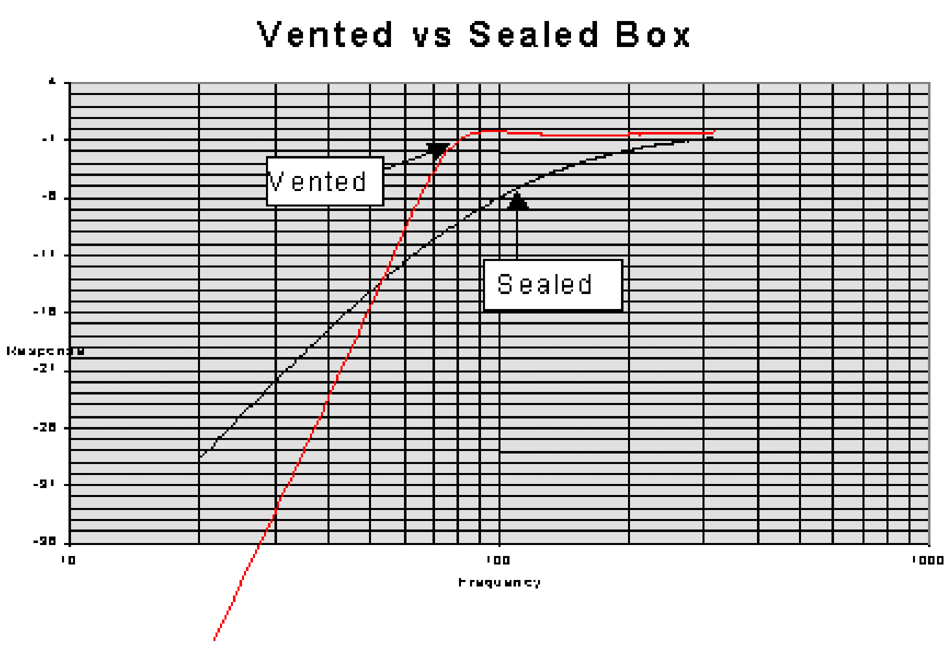
if the percentage of Sag > 5 (%), it is not recommended for a down firing configuration. Example, if you have a subwoofer with a 20 mm Xmax and an FS of 25, the percentage of sag equals 24,849/(20*25^2) = 1.988 (percent) so this woofer would be suitable for a downward firing position.

Supported Enclosures

Speaker Workshop supports two types of box enclosures, ported and sealed. There are advantages to Sealed and Ported Boxes in different applications:

	Sealed	**Vented (Ported)**
Low frequency response	See below	See below
Transient Response	Excellent, may be perfect	May be worse.
Power Handling	Good	Better near port resonance but worse below that, may require a rumble filter
Distortion	Good	Better near port resonance
Box Volume	Smaller	Larger
Tuning	Easy	More difficult due to need to tune both box and port to one another
Driver Qts	Should be over 0.3 to 0.4 and under 0.6	Optimal is less than 0.3 to 0.4
Efficiency Bandwidth Product (Fs/Qes)	Definite: Below 50; may consider if 50-100	Definite: Above 100; may consider if 50-100

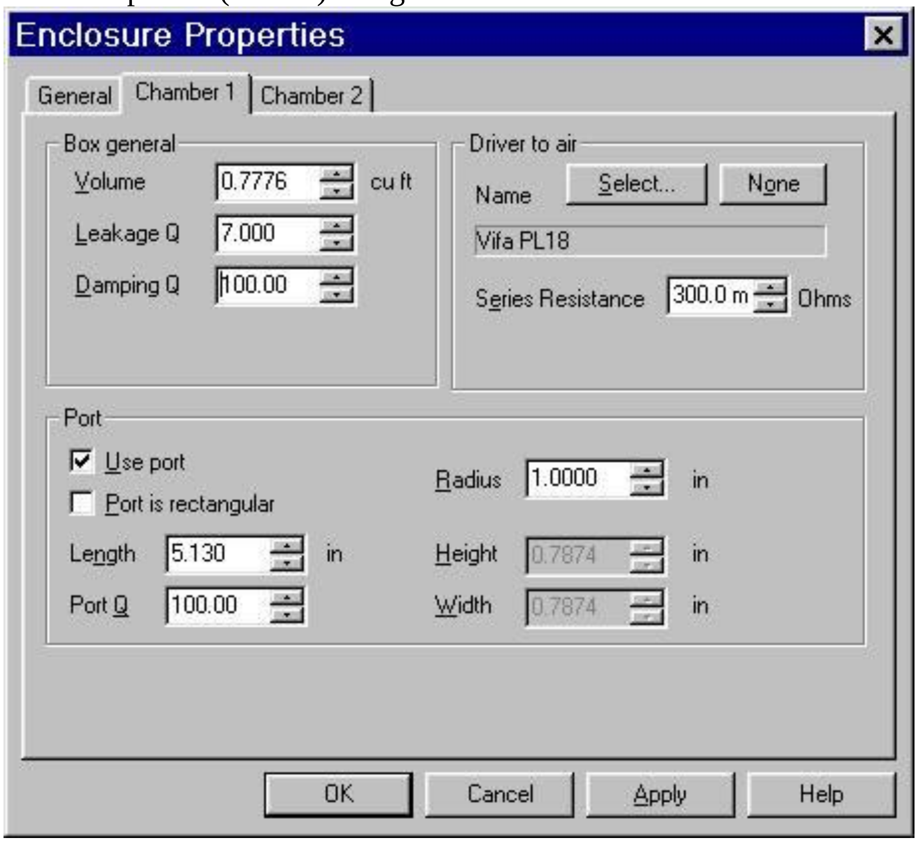
Note: Vented boxes tend to have less fill than sealed boxes and therefore are more sensitive to standing waves inside the cabinet. There are several ratios including the golden ratio (also see Chris Whealy's Spreadsheet in the Appendix) and non parallel sides will decrease this effect by spreading out the standing wave frequencies.



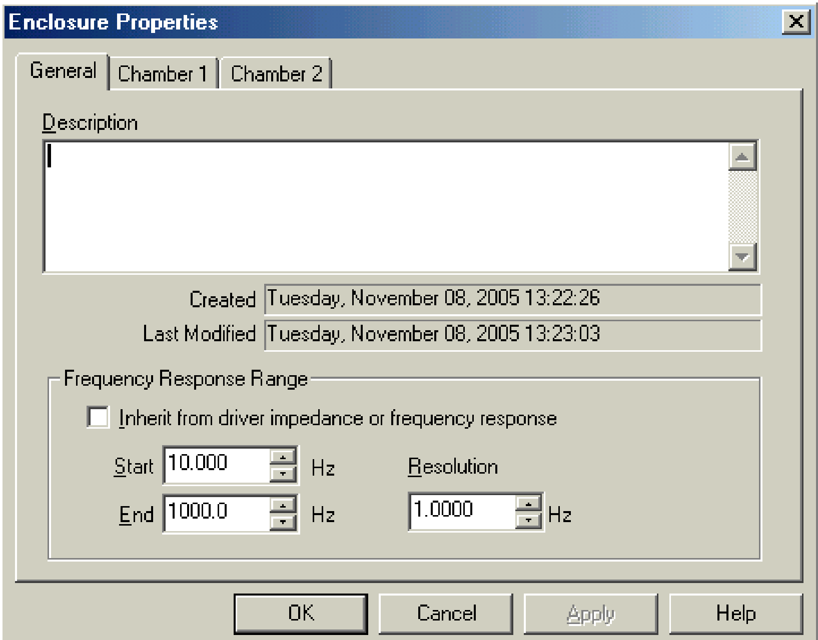
TO DESIGN A BOX IN SPEAKER WORKSHOP

(Section Index)

1. Resource / New / Enclosure. Name it appropriately.
2. Edit / Properties (Ctrl+E) or right mouse button or menu.



3. Go to the Chamber 1 tab and click the Select... button to pick your driver.
4. Make certain to enter a value for the expected series resistance due to inductor DCR and/or cables. Series resistance will have an impact on the calculated box volumes. 100m Ohms or .1 Ohms is fine for most application estimates. You can come back and measure this later if you so desire.
5. Go to the general tab and set the frequency range to 10Hz to 1000 Hz.



6. Click OK to close the properties dialog
7. Prototyping (see Sealed vs. Ported Discussion).
8. Select Your Driver enclosure
    a. *For Sealed Modeling:*

        For a closed box design, a Qtc of .707 is felt by many to be the best balance between transient response and IM distortion. A lower Qtc gives better transient response but more IM distortion and a higher Qtc gives less IM distortion but a worse transient response. As a voice coil temperature increases, resistance increases and damping will decrease so Qtc will increase.

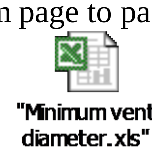
Specified System Q	Characteristics
.5	Critically Damped, requires the largest enclosure, most powerful low bass, lowest power handling, reduced mid bass output, also known as a Bessel Alignment
.707	Good Compromise System, Good Transient Response, no response peaking, reasonably sized enclosure
.85	0.7 dB response peak, reasonable transient response, smaller enclosure size
1.0	1.25 dB response peak, good power handling, compromised transient response, also known as Butterworth Alignment
1.1	1.85 dB response peak, excellent power handling, boomy sound, small enclosure size
1.3	3 dB response peak, very small enclosure size, very boomy sound, outstanding power handling.

b. *For Vented Modeling:*

1. Select Calculate/Vented
2. Choose your alignment (BB4, C4, or QB3).
    a. Alignments are considered flat (SBB4, SC4, and QB3) or Non flat (SQB3, BB4, C4) with flat alignments generally requiring Qts values of less than 0.4 while non flat alignments require higher Qts values and will yield a lower f3 however they have inferior transient and frequency responses. Vance Dickason (The Loudspeaker Design Cookbook, 6th Edition) provides the following comparison amongst the commonly used alignments with a 12" woofer (Qts=0.3) for the flat alignments and a 10" woofer (Qts=0.5) for the non flat alignments:

Alignment Type	**Required box Volume**	**Tuning Box Freq (Hz)**	**F3 (Hz)**	**Slope dB/Octave**
Flat Alignments				
SBB4	2.7	25	36	18
SC4	2.4	27	36	19
QB3	2.0	31	36	20
Non Flat Alignments				
SQB3	7.6	30	34	27
BB4	2.8	37	30	30
C4	5.3	30	27	30

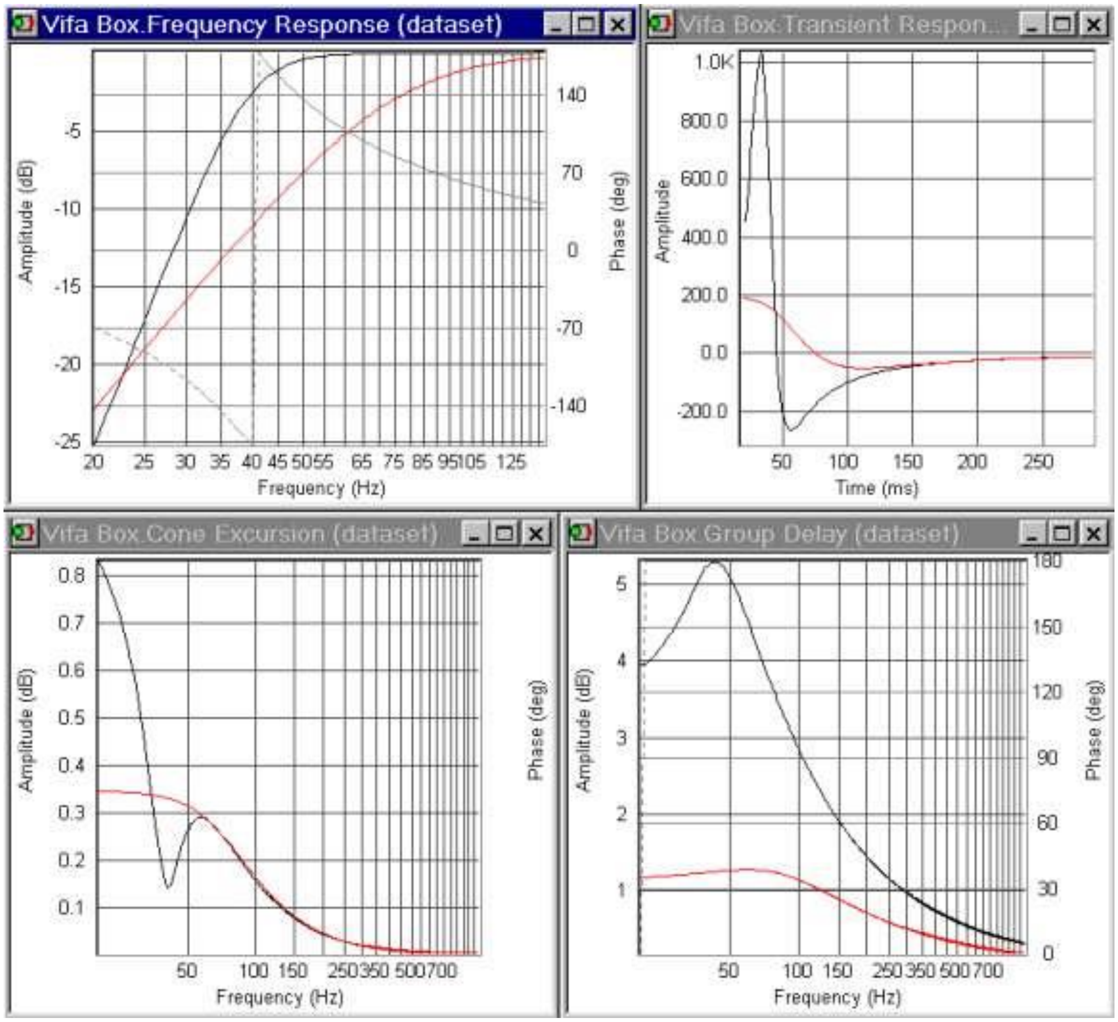
3. Observe port length (longer ports are more subject to resonance though if you decrease the diameter of the port, the required length will decrease at the expense of power handling), box size, transient response and frequency response curves to aid in your decision. The following provides four different ways to estimate port dimensional needs; you can use the 2nd and 3rd pages to assist with reverse modeling of the port (be certain to keep set the temperature, humidity and altitude consistent from page to page):

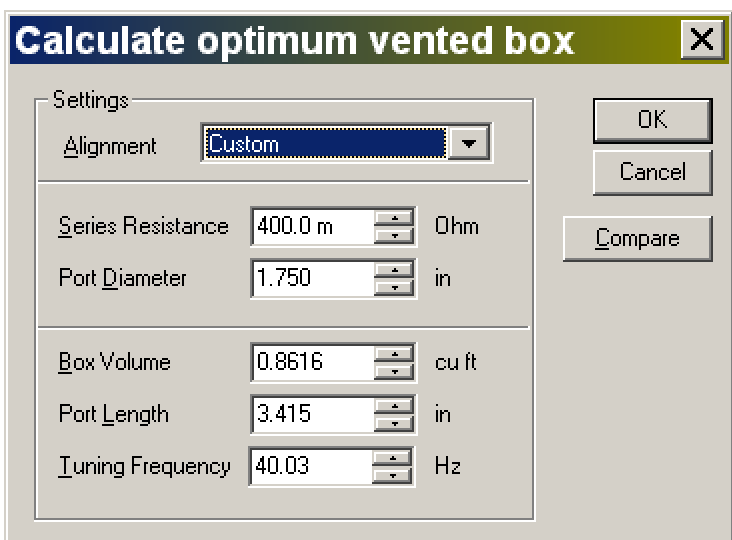


4. A larger box and lower port tuning tend to favor a greater group delay.

*Note: For ports, typically the area of the cone is many times larger than that of the area of the port. Since the volume of air moved needs to be close to equal between the two, the air in the port moves more quickly. At low volumes, speeds are lower due to less of a demand for air movement. This allows for laminar airflow with a measure called a Reynolds number (Re). This number will typically be below 2000 for laminar air flow. Re=r*Vmax*ro/mu where Vmax* *is the peak flow rate, ro is the density of air, mu is the viscosity of air, and r is the radius of the port. The acoustic resistance of the port is linear when Re values are below 2000 and acoustic resistance is typically in the range of 50-200 ohms (considered to be low). As the port diameter decreases, the volume of air movement remains constant so the port air moves more rapidly (up to 50-100 m/s). Eventually, turbulence will develop leading to a non linear resistance. The onset of turbulence begins with Reynolds values around 20K and compression begins around 50K. As compression occurs, it becomes more difficult to move the air through the vent. The acoustic resistance reaches its peak near the lower peak of the input impedance curve with acoustic resistance values in the 5-10 kOhm range. As the volume of air becomes compressed and less capable of movement, leakage losses begin. You can see this with a lowering of the lower impedance peak. When it gets severe, it will almost seem as though there is only one peak.*

Ports are non linear and an increase in power input leads to an increase in F3 and in the resonant frequency of the system. Group Delay will get progressively worse as well. Group Delay curves develop a sharper knee as Transient Response worsens with increased power. An increase in power also lowers the Fl Impedance peak and raises its frequency due to power compression in the port. An increase in power effectively shortens the vent (effectively increasing the tuning) due to turbulence. Flaring the ends will aid in decreasing this turbulence but too much flaring can also cause compression and turbulence. An asymmetrical inlet vs. exhaust flaring on the vents (more shallow on the inlet and wider on the outlet) seems to provide the least amount of distortion and compression. Compression is seen with a decreased Fl impedance peak and an increase in the trough level between Fl and Fh. This evidences the non-linearity. Wider vent radii have more linearity but call for longer vents. Longer vents are more likely to experience pipe resonances but this is of less of a concern than too small a port. As long as the vent area is over 11% of the driver area port linearity will be fairly good and at 25% will be excellent. The closer the diameter of the vent is to the length of the vent, the less likelihood there is of port resonances. Rear placement of the ports helps to decrease the audibility of port noise without a significant impact on bass response. As the diameter of the port increases, one must consider multiple ports. To calculate multiple vents, one would divide the volume of the box by the number of vents and then calculate the length of each port.

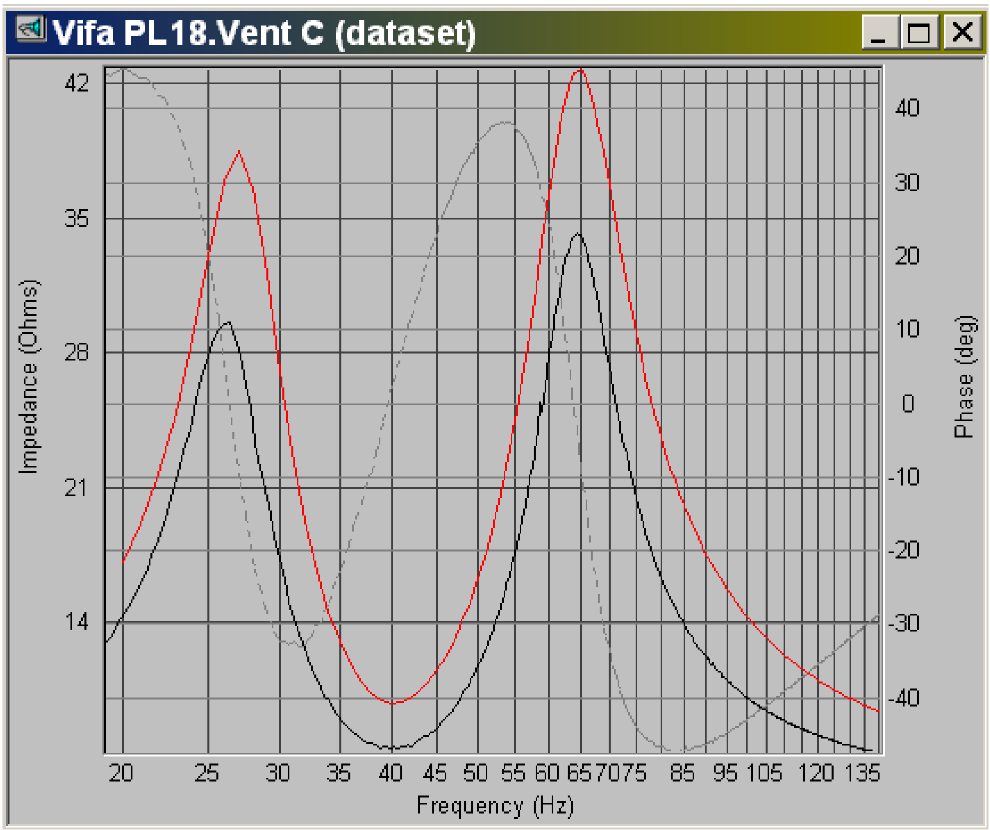




5. Make certain to enter a value for the expected series resistance due to inductor DCR and/or cables. Series resistance will have an impact on

the calculated box volumes. 100 mOhms is reasonable for most set ups.

6. The next step is to prototype the enclosure and start measuring frequency response and checking the port alignment.



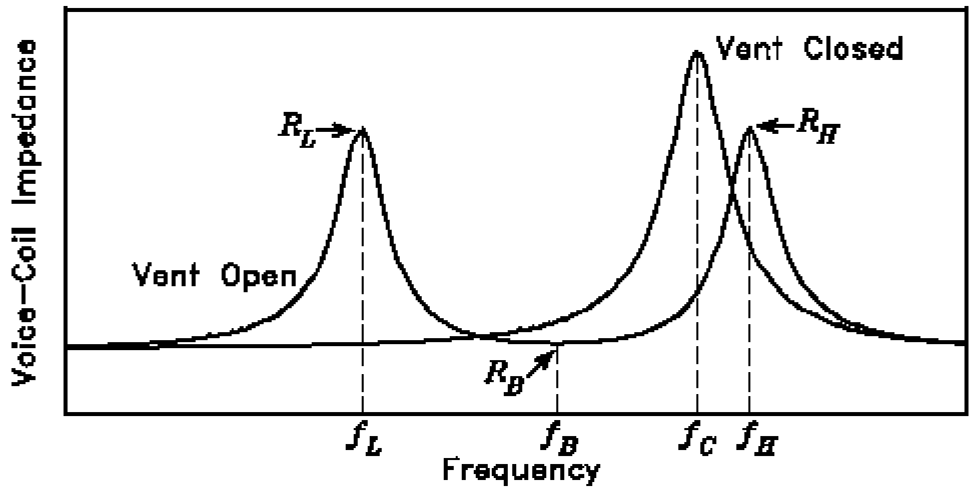
Note: If you just want to check an existing enclosure

7. Enter values manually using the Edit Properties command.
8. Fiddle with the parameters9. Select alignment, Q, series resistance and use the compare button to compare results with your current box definition. See appendix for more information on box design.

A note regarding Q:

Ql = losses due to leakage of the box; the bigger the box the greater the loss and the lower the Q. A value of 7 is medium.
Qa = losses due to the damping material; the more damping material used, the greater the loss.
Qp = losses due to the vent.
The total Q is the reciprocal of the sum of the reciprocal of the Q's (1/Qt= 1/Ql+ 1/Qa + 1/Qp).

The enclosure will have sound losses based upon the size of the enclosure compared to the predicted ideal box size for a particular alignment. Alignment refers to vented boxes, as it is the particular box size and tuning combination. For vented boxes, a typical loss figure is Ql of 7. Ql > 7 *increases bass extension but increases the size of the hump before the knee so you would want to consider adding a filler to the box to make it smaller. Additional bracing is one method of doing this. Ql < 7 consider increasing the box size or adjusting the stuffing inside the box. As you decrease Vb from the expected size, your loss figure decreases such that Ql=20. If you increase the box beyond predicted flat, your loss figure increases towards 3.*



Dick Van Nierop's spreadsheet calculates Q (Ql) and the apparent volume from Fc, Qec, Qmc, and Qtc (sealed or closed) values. The apparent volume divided by the physical volume equals the percentage of increased volume from stuffing. The spreadsheet calculates box frequency (Fb), Qa (box loss), and apparent volume from the combination of the above results and then from the vented measurements, the two impedance peaks (Fl and Fh) as well as the frequency and value of the impedance minimum between the peaks (Fm and Rm).

"T.S parameters.xls"

or Ql can be calculated with this spreadsheet, which also provides some slightly different information: "Ql ported sealed(1)1.xls"

USING UNIBOX

(Copyright 2000 - 2004 by Kristian Ougaard)

(Section Index)

This is freeware and is probably the most powerful box modeling software you can find for establishing ideal box volume/port dimensions. It may be downloaded at http://home20.inet.tele.dk/kou/ubmodel.html. Full instructions are found at that site. The author preferred that I not include the program or instructions here.

BUILDING THE ENCLOSURE

(Section Index)

1. The following program written by Yavuz Aksan, with the help of PJay Smith may be of great assistance in designing your Speaker Box:

   boxycad2e.xls

2. The following spreadsheet will assist you in calculating the volume of the driver and the space displaced by the port(s):

   "Volume Estimator1.xls"

3. If your system calls for the use of ports, these can be placed on any side of the enclosure, once the intended location meets the following requirements:
   a. The exit of the port should be at least one port diameter away from any external surface.
   b. The entrance of the port should be at least one port diameter away from any internal surface, including the driver.

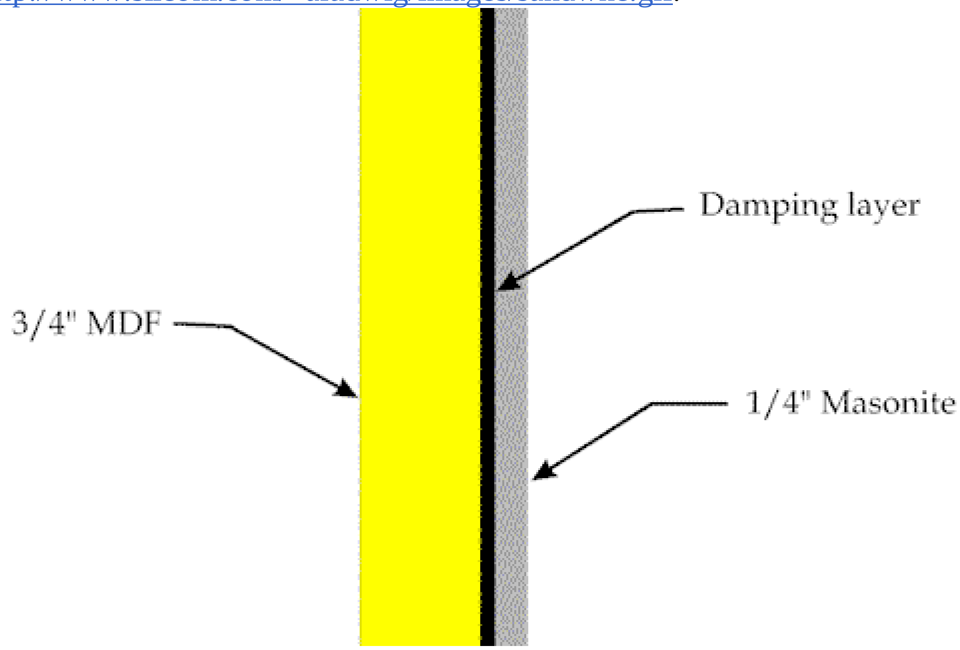
SPEAKER BOX CONSTRUCTION HINTS

(Section Index)

1. For a subwoofer, the dimensional ratios of the box of not of much importance as the wavelengths are so long that standing waves are less of an issue. For low frequencies, the mass and stiffness of the enclosure are the most important features to minimize enclosure sound coloration.
2. You can decrease the volume required for a particular sealed alignment by using a stuffing material such as fiberglass, wool, polyfill in the cabinet and roofing felt or open cell egg crate foam on the walls (these additions also help to reduce standing waves. Reductions of up to 30% in volume requirements are possible. Make sure that you add the volume displaced by the driver and bracing to arrive at a final enclosure volume. Too much stuffing will effectively decrease the box volume so there is a balance and a law of diminishing returns.
3. If you plan to stuff the enclosure, use 0.75*Vb as the net volume for the enclosure. When you add stuffing to the enclosure, the resonance frequency should decrease. Continue adding stuffing until the resonance frequency stops decreasing.
4. One of the goals in building an enclosure is to decrease the amount of coloration from the enclosure. Bracing increases the resonant frequency of the box thereby decreasing the amount of low frequency energy radiated by the box, which muddies low frequency sound reproduction (the resonant frequency being the frequency most easily reproduced by the box).
   a. Cabinet bracing issues:
      i. Little panel movement is noted from frequencies above 1200 Hz.
      ii. Bracing frequently and asymmetrically appears to be optimal.
      iii. Bracing the baffle is very helpful at raising the box panel vibration frequency
      iv. Bracing is more effective than damping material at decreasing panel excitation
      v. High density hardwood braces outperform low density bracing.
      vi. Damping treatment to the walls is meant to “absorb” some of the energy to decrease resonant energy. This may actually work against bracing which is attempting to raise the resonant frequency of the panel to bring it away from the lower frequency signals where it is more likely to be heard. A little bit is likely to be helpful but too much may become a problem.
      vii. Make certain that braces are rigidly attached with screws and glue.
      viii. When using a brace, don’t center it but rather set it off from the center just a little so as not to have both subsections resonating at the same frequency thus spreading out the distortion.
5. A separate midrange compartment can decrease intermodulation distortion.
6. Absorption of sound inside the box assists in decreasing the internal standing waves of a low frequency driver, which could cause dips, and ringing. Damping absorbs energy and it assists in decreasing midrange frequencies from exiting through the cone. Stuffing generally decreases mid range signal strength by

converting energy to heat and is most effective if the wave is going through a distance in the material equal to at least ¼ of it's wavelength.

7. Low frequency sound transmission is best diminished by sandwich type construction of loudspeaker enclosures. From http://www.silcom.com/~aludwig/images/sandwhc.gif.



Many different types of sandwich construction may be attempted with different effects. There are 2 mechanisms involved in sound transmission through a partition: Non-resonant and resonant transmission. In non-resonant transmission the incident sound wave strikes the partition causing the transmitted sound. The partition is NOT resonating and does not store potential energy, it is simply moving because it is being pushed. This is (usually) the dominant transmission mechanism at low frequencies. Because there is no potential energy, the only attenuation is provided by the inertia of the partition. This means that (to a reasonable approximation) non-resonant transmission loss is affected ONLY by the MASS of the partition (the so called "mass law"). More mass = more attenuation. At higher frequencies, the resonant transmission loss may start to dominate over the non-resonant. Resonant transmission occurs when a sound wave strikes the partition in such a way that the pressure distribution matches one of the resonances of the loudspeaker. Some of the sound wave energy is now transferred to the panel and is stored as potential energy. On the other side of the panel, the air moves and transfers the stored energy to the transmitted sound wave. Because the panel now contains potential energy, the damping of the fibrous filling or a damping material between the panels can now have an effect; it will absorb the amount of stored energy in the resonating partition which will decrease radiated sound energy resulting in more sound transmission loss. For more information see: http://barracudatec.com.br/pdf/acoustic.pdf#search='sound%20transmission%20sandwich' as well as http://www.audioholics.com/techtips/audioprinciples/loudspeakers/mechanicalnoi sefloor.php and http://www.audioholics.com/techtips/audioprinciples/loudspeakers/MechanicalNoiseLoudspeaker.php.

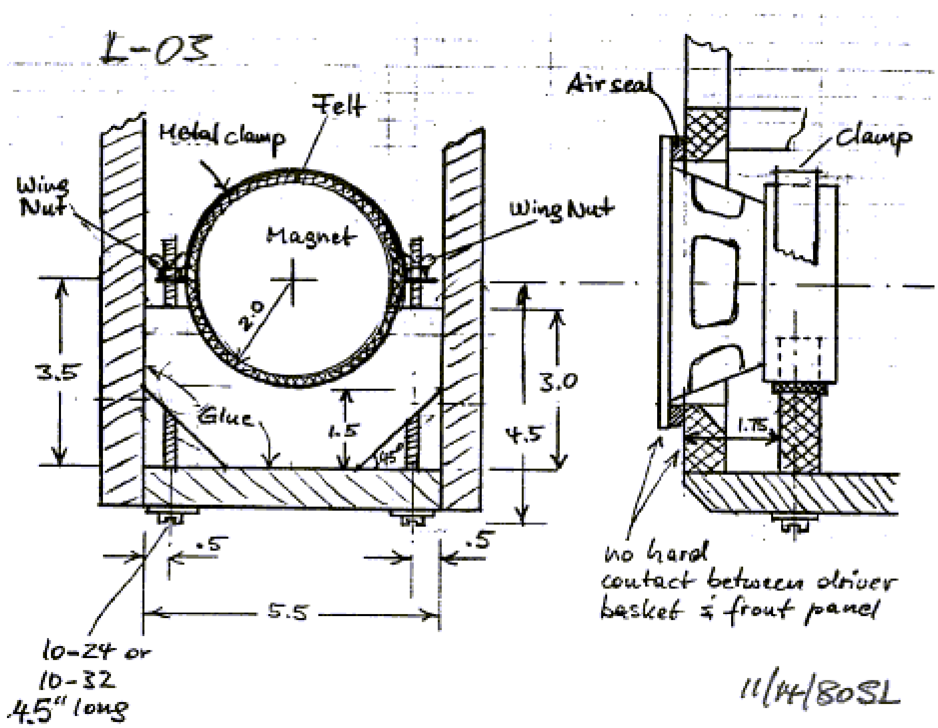
8. So if you have increased the resonant frequency of the box, bracing, damping and stuffing, your enclosure will have a minimum of coloration.
9. In constructing enclosures, Moriyasu has studied different techniques and he described his findings in AudioXpress, 2002 . I have attempted to summarize his findings in Excel format through summation of resonant nodes. This is only a rough estimate and there may be better ways to evaluate his findings (such as reading the article and looking at the actual graphs) but I believe that this summation will provide a fairly good representation of his findings:

"Damping Studies Moriyasu.xls"

10. MDF is commonly used because of excellent characteristics for speaker building with the following thickness baffle walls:

Volume in ft^3	<1	1-2	2-3	3-5	>5
Baffle thickness (inches)	.75	1	1.5	2	2.5-3

11. Mortite, a non-hardening paddy usually found in rolls at hardware stores as a window sealant, can be applied to the back of a speaker basket to decrease some of the ringing (energy storage which leads to poorer transient response and distortion).
12. Securing the drivers will also help to decrease coloration. Below is from http://www.linkwitzlab.com/frontiers_2.htm:



with another example posted by Mac at http://www.madisound.com/cgi-bin/archive_discuss.cgi?read=338437

13. Sound transmission loss will increase about 6 dB for each doubling of mass (Mass Law) and will increase about 6 dB for each doubling of frequency so assuring that the box is of adequate mass and raising the resonant frequency of the box through good solid bracing will substantially improve imaging through a decrease in box sound production.
14. It is usually best to first build your internal box and then do external aesthetics such as veneer, laminate, paint, cloth, sprayed texture, etc.
15. Be cautious about applying hardwood to MDF as expansion may differ when exposed to differences in temperature and humidity. One thing that could be done which may assist in damping sound transmission by effectively forming a sandwich outer wall is to use a non hardening glue to attach an outer wall to an inner wall. In essence, you build a floating box inside of a box by doing this.
16. Seal all joints to assure that they are airtight. This can be done with caulking or the foam rubber window insulation strips. Drivers (where they attach to the box) and removable sections of the cabinet should also be insulated with a seal. One suggestion is that instead of using a foam gasket to mount the drivers, hand cut a gasket made from 1/16" cork sheet.
17. All joints should be glued and the addition of screws that can be counter sunk and covered will provide added stability. Some form of locking wood joint will also add to stability.
18. As the sound waves become longer than the front baffle, there will be a drop off in amplitude of frequencies because of changes from full-space to half-space. When the sound wavelength is much larger than the front baffle dimensions then the sound works in full-space or 4pi (wraps around the speaker and radiates in all directions). When the sound wavelength is less than the front baffle dimensions the sound works in half-space or 2pi, most of the sound is radiated towards the front. This causes a 6dB step in the response at the frequency where the

wavelength switches from greater than to less than the baffle dimensions. Baffle step losses in a 4pi space would lead to a gradual 6 dB drop in the bass frequency response centered at f3 ~ 4560/Wb where Wb is the width of the front baffle in inches and f3 is calculated in Hz. Not only is there a frequency response step, but also the radiation pattern obviously changes at that frequency.

  a. To minimize this effect, make the front baffle as narrow as possible and round over the edges as much as possible.
  b. Leave enough wood material on the corners of the baffle to allow for rounding over the edges. The larger the radius or bevel, the lower in frequency the diffraction will go. So a larger bevel or radius spans a larger wavelength. This causes more but smaller amplitude steps leading to a more gradual baffle diffraction, which is easier to compensate, less phase smearing, and improved imaging. The more round over you can introduce, the better.
  c. The ideal baffle would have each point on the baffle edge a unique distance from the driver. An effective method would be to assume some 'golden ratio' of distance from the driver to the 3 closest baffle edges to minimize the number of equidistant points. .6/1/1.6, 2/3/5, 3/5/7, etc., spreading the effect of the baffle step.
  d. There are advantages and disadvantages to offsetting drivers on the baffle (i.e., not having them on the same vertical axis). The advantage is that you further add to the distribution of the diffraction effect. The disadvantage is that the horizontal dispersion pattern may be adversely impacted due to non-alignment of the vertical acoustic center.
  e. Driver separation on the baffle should be less than the wavelength of the frequency of the crossover between those two drivers "Frequency vs wavelength1.xls" or roughly center to center spacing should be less than 13560/crossover frequency in inches.
  f. There are reports that wool felt application to the front baffle improves imaging through an impact on the baffle diffraction effects by spreading the frequency range over which it occurs (see http://www.speakerdesign.net/home.html). The use of (synthetic) felt rings improves the perceived sound. It is recommended to use real wool felt (SAE Type F-11 or F-13) available from many sources. As a porous absorber, it is effective at absorbing wavelengths up to 4 times its own thickness or up to 4 inches wavelength (approximately over 3400 Hz) if it is one inch thick.

19. Flush mounting drivers will decrease aberrant reflections.
  a. For flush mounting irregular face plates, see http://www.audiodiycentral.com/nt_ireg-drvrcutouts.shtml for a tutorial by James Yeung.
20. Ports should be placed at least one diameter away from any adjacent walls. If this is not possible to do this, the tuning frequency for a given port length will be

lower than that predicted by the equations, and this may adversely affect the results.

21. Use the largest port possible for the ported designs. This will reduce power compression effects and port noise caused by turbulence. Increased compression decreases the apparent effective port length: this will increase the port frequency.
22. Flared ports also decrease power compression. Asymmetrical ports with a shallow inlet end and a larger exhaust end provide the best balance of decreased distortion and compression. Port tuning is only slightly impacted by the flare (see Minimum_Driver_Vent_Radius, Helmholtz pages).
23. A larger box and lower tuning tend to favor a greater group delay.
24. A smaller box tends to lead to a better transient response.
25. If the VAS of the driver is larger than the box, the transient response is better.
26. Build the grill by making a solid frame that is reinforced. Drill holes through the grill frame into the box (don't penetrate the box) to align for grill guides if you plan to use them and then using contact cement to adhere the grill cloth.
27. Construct the crossover by first laying out a diagram and then using perforated hardwood to attach the components to. Tightly twist the connections, using few or no jumper cables (if possible), and then use silver based solder to assure sound electrical connections. Do not use acid core solder, as this will oxidize in time. Place the components on a thin piece of weather stripping prior to attaching them to the board to help to prevent sliding. Connect the components to the board with hot melt glue (you should substitute a more permanent glue once the crossover is finalized) and/or lock ties.
28. The "Golden Ratio" of box dimensions is based upon the Fibonacci Series and assists in minimizing internal standing waves. The "Golden Ratio"= 0.618 : 1 : 1.618. This ratio actually helps to distribute wave modes more evenly. For larger enclosures in which the dimensions are more able to support lower frequency standing waves, Trevor Cox from the University of Salford in Manchester, UK has defined somewhat different dimensions. These are identifiable on Chris Whealy's spreadsheet in the Appendix on the page room ratios. With this, by adjusting dimensions under Room H, you can see how to minimize the amount of bass resonance, which has more energy to color the sound through the walls of the enclosure than higher frequency sound.
29. A layout program for wood cutting can be downloaded at http://www.sheetlayout.com/download.htm. In the free version, only 8 lines are allowed, with up to a quantity of 4 pieces per line and 32 parts maximum which is plenty for speakers, in general.

SURROUND SPEAKERS

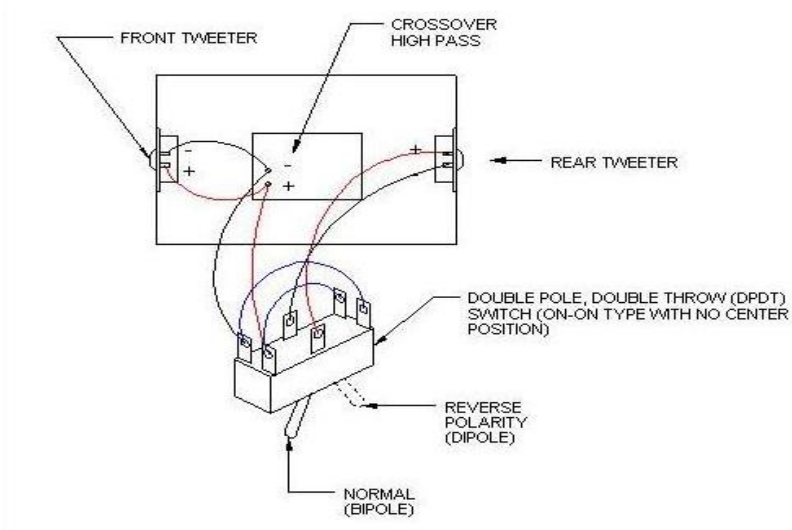
(Section Index)

Dipole Surrounds - One driver is out of phase with the other. This means that when one cone moves outward, it compresses the air molecules, while the other cone moves inward, resulting in a rarefaction or expansion of air molecules. These opposing bass waves cancel at the sides of the speaker, producing a "null" in the listening area (to the sides), whereas the midrange and treble sounds fire forward and to the rear, resulting in a reflected and ambient wash of sound much like that heard in a big movie auditorium. Dipole woofers work best if each is compartmentally separated from one another to avoid signal cancellation. The positive phased side wall dipole woofers should face the front speakers (the woofer that will move outward with connection to the positive terminal of a battery).

Bipole - A speaker design that generates equal amounts of sound both forward and backward, with the two sounds being in phase. Generally speaking bipoles are more directional then dipoles but less directional then direct speakers. Bipoles provide more localization than Dipoles.

There are many inconsistent opinions regarding Dipole and Bipole utilization in surround systems. Generally, Dipoles to the side and either Dipoles, Bipoles or direct radiators to the back are recommended. If the sides are to be Dipoles, the speakers are typically located above ear level to the sides of the listening position. When placed high on the sidewalls, a dipole spreads sound throughout the listening area (mostly toward the front and back of the room), with relatively little sound aimed directly at the listeners, promoting a sense of spaciousness and making it harder to pinpoint the speaker. Action scenes are better with direct radiators. Ambient sounds are better with Dipoles. One consideration is to maintain woofers as Bipoles and have a tweeter select switch for Bipole vs. Dipole to increase or decrease localization.

Dave Brown has designed a circuit for surround speakers that allows for a switchable Bipole/Dipole design. From:
http://users.d-web.com/dbrown/db1661/db1661_files/switch.jpg



You might consider mounting the terminal cup and switch somewhere else on the speaker that you can reach when the speaker is wall mounted.

From http://www.audioholics.com/FAQs/THXp2.html, the following recommendations are made:

In a large room where film is the primary medium:

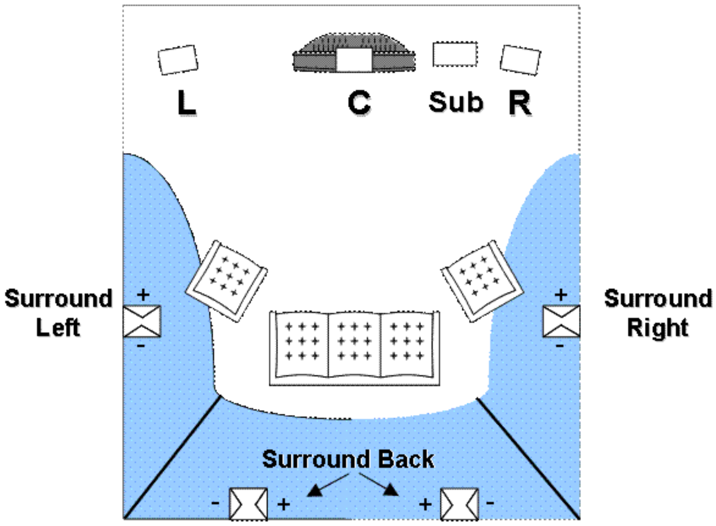


Figure 1: Large Room Speaker Placement

For music and movies, the sides would be switchable between dipoles and bipoles: