The Climax Speaker System

Overview

This design shares a couple of major features of the SEXy Speaker. Both are high-efficiency small boxes with no deep bass, meant to be combined with a pair of commercial powered subwoofers for a complete full-range system. In this way, low-power SET amplifiers can be used in a system of modest size. Both are offered as designs for non-commercial DIY construction.

The Climax project began around 2001 when we first heard a small, inexpensive high-efficiency woofer which we thought had some potential. An early version was part of the Bottlehead system at VSAC 2003 which was awarded “best sound of show” by press observers. It went through many changes over the next 4 years, but now it has come to its end without ever being released or becoming a product. The most recent woofer has been discontinued, and we have no plans at this time to start over with a new one.

Nevertheless, we have decided to make the design available as a community project. The woofer may still be in stock at some retailers, and we would broker an OEM group order if there are enough interested parties.

A document is in work, which will describe the system in its last incarnation. It will include a parts list, crossover description, and some assembly photos. It won't be a full Bottlehead manual of course. It will, however, include extensive discussion of mods and tweaks, reflecting the several years we've worked on this design.

We plan to support development of this system by the community, initially by hosting and participating in discussions on the Bottlehead forum and by providing the document as a download. If there is sufficient interest, we'll provide updates to the document, and we may broker group buys of parts, offer limited-run parts kits, or even produce crossover kits.

Box

The design box is a 0.5 cubic foot ready-made box, available from Parts Express. The front panel is cut as in Figure 1. The rear panel has two pair of binding posts, for the mid-woofer and tweeter. This is to allow either a passive crossover, or an active crossover with separate amplifiers for each driver.

Each box is operated as a sealed box, and stuffed with about 1/2 pound of Acousta-Stuf, which is conveniently available in 1-pound quantities.

Components

Midwoofer

The mid-woofer, Eminence model LA6-MB, has been discontinued by Eminence. Some sources may have remaining stock, and Bottlehead will order a run on an OEM basis if there is sufficient demand. Check the Bottlehead Forum for current status. We have not been able to find a satisfactory substitute.

This woofer was the midbass version of their line array 6.5” speakers. (The midrange model, LA6-MR, is still available but has a much smaller magnet and very little excursion capability –

i is not useful in this application.) Efficiency is rated at 92dB/w/m, which would call for an 8-watt amp such as the Paramount 300B; we have found it satisfactory for most music with the 3.5-watt Paramour as well. If an auxiliary active low frequency crossover is used so the mid-woofer is relieved of bass below 100Hz, a less powerful amp should be acceptably loud. An active high frequency crossover would provide further headroom or a lower minimum power requirement. As always, smaller rooms or more modest loudness requirements will permit substantially smaller amplifiers to work satisfactorily.

In the 0.5 cubic foot sealed box, this driver will have a resonance of about 100Hz and the Q will be about 0.6. Allowing for use with an SET amplifier whose damping factor is 3, and a bit of extra mechanical damping from the dense stuffing, the Q will be close enough to 0.7, a Butterworth response.

Tweeter

The tweeter is the Selenium ST-324, a slot-loaded horn tweeter with phenolic diaphragm. The response of this tweeter is far from flat – it rolls off at 6dB per octave above its low frequency cutoff at 3200Hz, and at 18dB per octave below that frequency, and there is a resonance around 10kHz with a 6dB peak. This behavior is corrected in the crossover.

Several tweaks have been developed to damp mechanical resonances and reduce diffraction effects, and they are recommended but not required.

Passive crossover

A 6dB per octave (first order) high-pass filter with a corner frequency around 20kHz makes the tweeter flat above 3.15kHz and 24dB/octave below that frequency – a perfect fourth-order Linkwitz-Riley response. A shunt resonance trap at 10kHz flattens the 6dB resonance at that frequency. The circuit is shown in Figure 2.

The mid-woofer rolls off at approximately 4000Hz with an approximate maximally-flat (Butterworth) 12dB/octave (second order) response, but with a modest treble lift. Adding another 12dB/octave Butterworth lowpass filter at 2150Hz gives a net response that is very close to the 24dB/octave (fourth order) Linkwitz-Riley filter at 3150Hz.

The woofer uses an RCRC Zobel that is more complex than usual. Woofers rarely have a pure inductance; this woofer has what is very close to a “semi-inductance,” halfway between a resistance and an inductance with a phase angle closer to 45 degrees than the 90 degrees of a true inductance. The Zobel used here is optimized to maintain an 8 ohm resistive impedance through the critical crossover region.

These passive filters are implemented in an external box. The box can be placed near the speakers, or if placed near the power amplifiers, it allows a superior form of bi-wiring to be used.

Bass augmentation

Two commercial powered subwoofers are recommended, one below each Climax. The sealed box mid-woofer rolls off at 12dB per octave below about 100Hz. A commercial “subwoofer” with 12dB/octave crossover that can be adjusted to 100Hz will match well. See the “Bass crossover upgrade” section of this manual for information on converting to a 24dB per octave crossover, which is recommended but not required.

Ideally the crossover will be Linkwitz-Riley, which is 6dB down at the crossover frequency – or in other words the Q is 0.5. The Climax box and midwoofer have a Q of 0.7, which is a bit

too high, so some experimentation with the subwoofer frequency and level may be in order. Make sure the subwoofer phase is correct, or the combination will cancel each other at 100Hz leaving a hole in the bass.

The subwoofer level can be adjusted to provide adequate bass, which will approximate the "baffle step correction" (BSC). A more accurate BSC circuit can be used upstream of the amplifiers if desired – see Appendix 4.

Note that many subwoofers claim to be 24dB/octave and adjustable, when in reality they have on 12dB/octave function that is adjustable in frequency, and another that is fixed, usually in the 100Hz to 150Hz range. These are closer to 12dB/octave when used at a low crossover (less than 50Hz), but at 100Hz where the Climax design crosses, they are more nearly 24dB/octave. This is not ideal unless the Climax has an additional filter as described in the "Bass crossover upgrade" section.

Box tweaks

A different box can easily be used. The sealed box response is not highly sensitive to box size, so a box volume of 0.35 to 0.7 cubic feet is satisfactory. Better boxes might be made that are more rigid, for example. The capacitor in the BSC circuit (if used) will have to change if the cabinet width is significantly different from the 8.5 inches of the specified box.

A deeper front panel with substantial beveled edges would be a good solution to the midrange diffraction issues. See Appendix 5 for an example.

Greater efficiency can be obtained by using two woofers in a box twice as large, or two boxes could be stacked together. This would require some changes to the crossover, and a possible reduction of the high treble unless the system were bi-amped. The Bottlehead Forum would be the best place to ask about these changes.

Tweeter tweaks

The first tweak is to stuff the tweeter horn cavities with plumber's putty. Remove the plastic horn assembly and the cavities will be evident. Don't get any putty in the acoustic chambers, only in the unused spaces!

The second tweak is to smooth the corners of the diffraction slot. A piece of wood "bullnose", ½: thick by 3/4" wide, is recommended. See Figure 3.

The third tweak is to extend the bullnose with wool felt ½ inch thick, also as shown in Figure 3.

All three tweaks are recommended.

Midrange diffraction tweaks

The tweeter diffraction treatment can be continued with more wool felt around the periphery of the front panel. The same felt, 0.5 inch thick by 1.0 inch wide, can be used, but if you can locate some softer felt, F-10, F-11, or F-13, in a square tape 0.75 inch wide by 0.75 inch thick, that would probably work a little better.

A similar result, possibly superior, can be obtained with a thick, beveled front panel as sketched in Appendix 5.

Neither of these tweaks have been tried, listened to, or measured.

Passive crossover tweaks

The prototype passive crossover used a 6-position rotary switch to vary the tweeter series capacitor. Values used were 0.47, 0.51, 0.56, 0.62, and 0.68uF. The effect is to change the tweeter level by a bit less than 1dB per step. We thought the 0.62uF sounded best, but it will of course be room dependent. Experimentation is encouraged.

Different capacitors will have an effect. The tweeter series capacitor is likely to be the most significant; the 4.7uF woofer capacitor second, and the 8.2uF Zobel capacitors probably the least sensitive.

Bass crossover upgrade

The performance of the speaker will be substantially enhanced if the acoustic crossover is 24dB/octave. This is best accomplished with a line level crossover before the amplifiers. The crossover should be 12dB/octave Butterworth. This function, combined with the Climax midwoofer response which is also (nearly) Butterworth, will give a total highpass response that is of the Linkwitz-Riley type. If the powered subwoofer is 24dB/octave Linkwitz-Riley, no additional crossover is needed. If it is 12dB/octave Butterworth, an auxiliary low-pass 12dB/octave Butterworth filter is needed. If it is 12dB/octave Linkwitz-Riley, the auxiliary lowpass filter should have a Q of 1 to give a good approximation to the target function.

In addition to making the solid-state powered subwoofer less audible, the auxiliary filter removes the deep bass from the SET amp power. This allows the system to play substantially louder before the SET amplifier begins clipping.

These filters will hopefully be available as Bottlehead products in some form. One particularly attractive arrangement would be to convert the cathode follower section of a Foreplay III preamp to the high-pass filter, and add an auxiliary low-pass function in solid state form for the subwoofer.

Treble crossover upgrade

Our experience in the high-end mastering studio has convinced us that line-level crossovers with separate amplifiers for each driver are the best approach to speaker performance. Consequently, we would expect the Climax to perform best with such a crossover. In fact, the earliest public version as used in the Bottlehead system at VSAC 2003 was just such an arrangement.

We have not yet built or designed an active crossover to match the most recent passive crossover design with the 10kHz notch. When we do, it will certainly be discussed on the Bottlehead forum.

Figure 1. Front panel cutouts

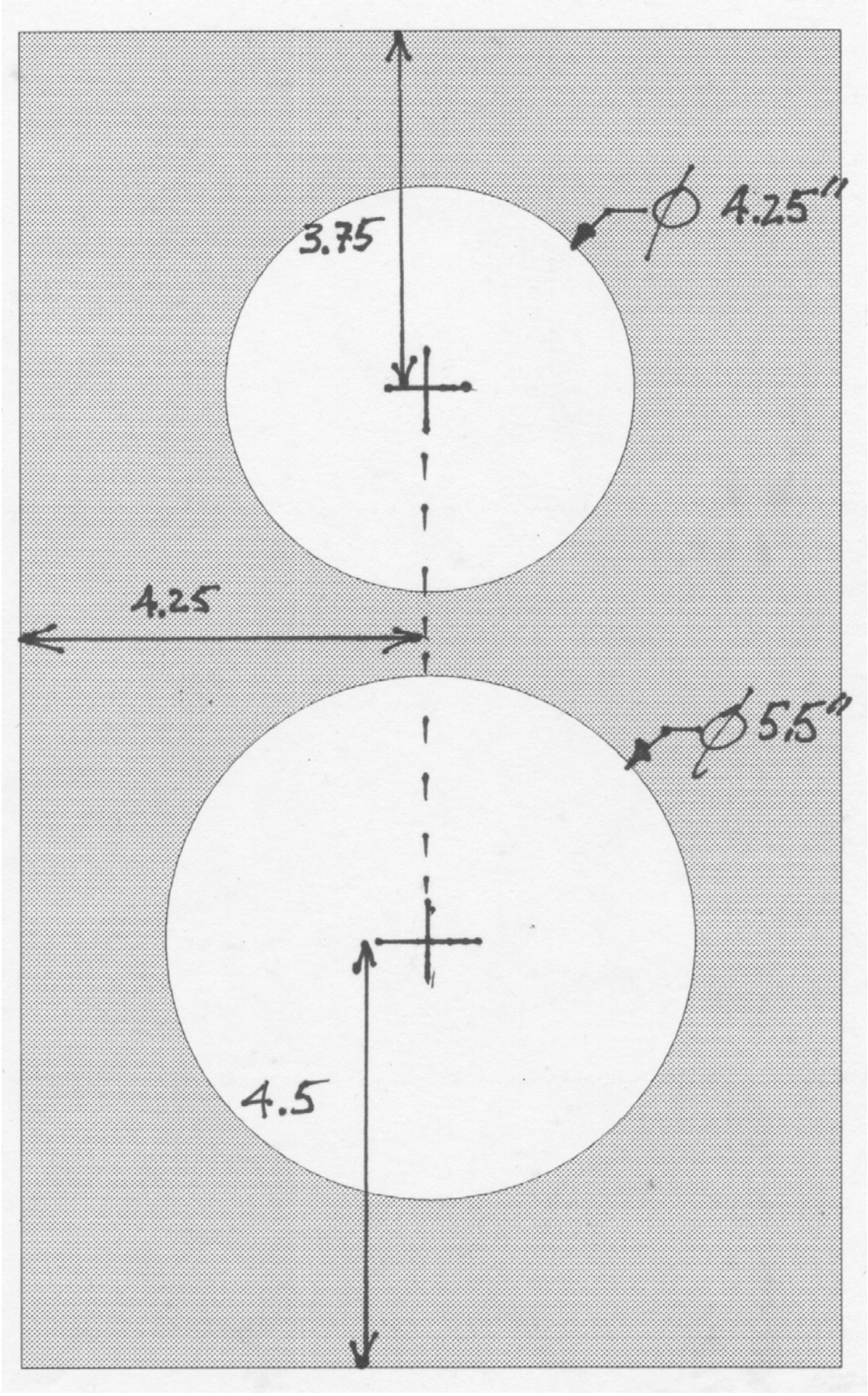
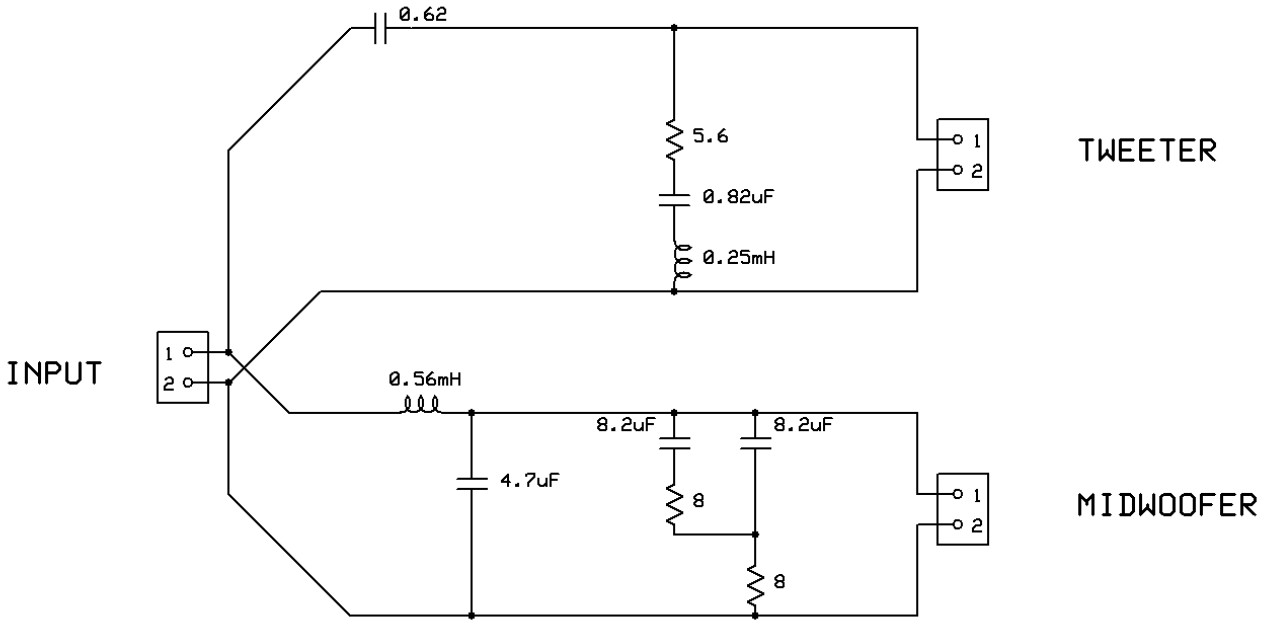


Figure 2. Crossover



Climax Crossover 8 ohm		
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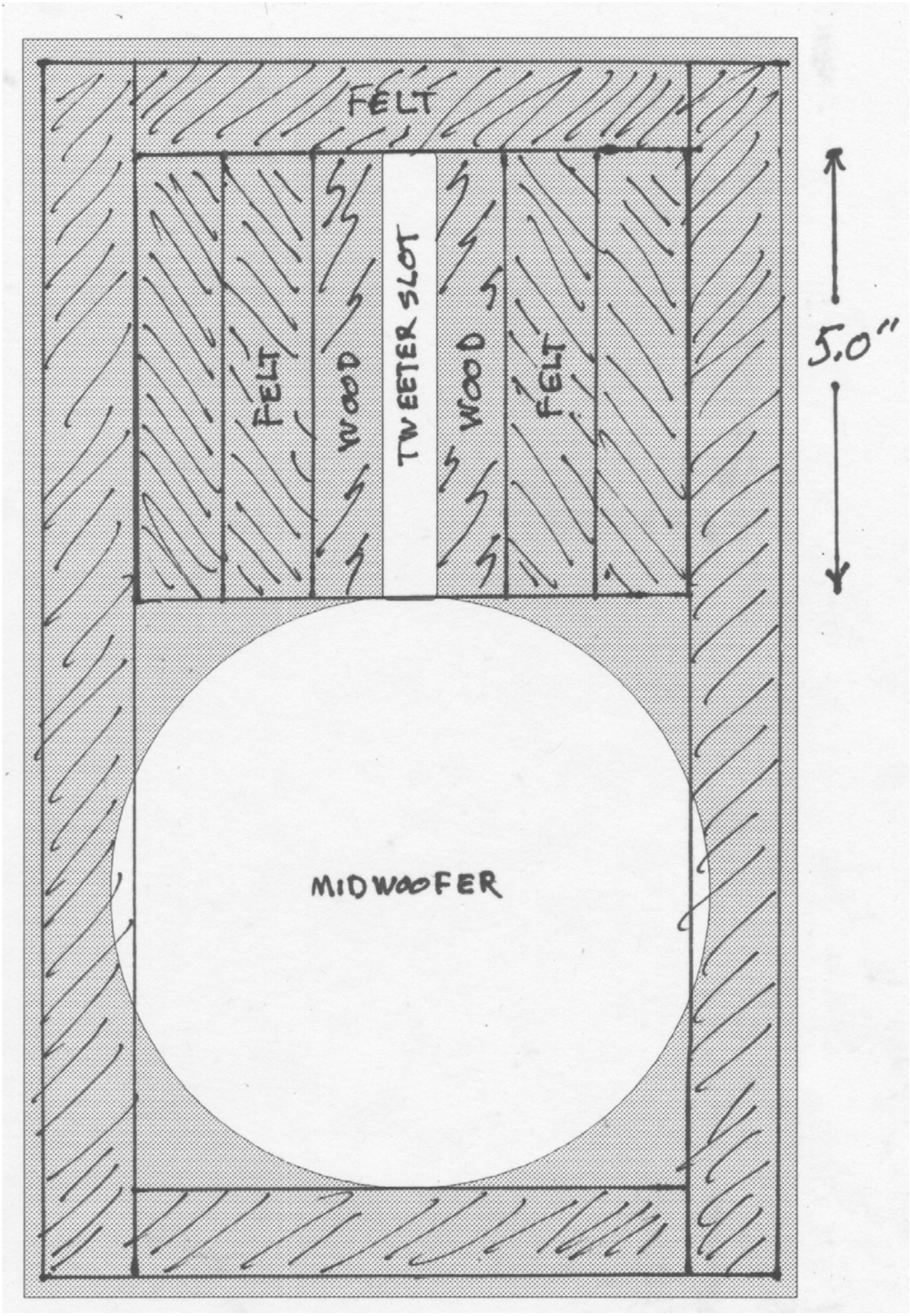
Figure 3. Diffraction treatments



Appendix 1 – parts list for two speakers

Box: (2) Parts Express part number 302-722 (in cherry finish; other finishes and designs are available) or build your own. The front panel is 8.5 inches wide and is the only dimension for which the design is optimized.

Woofer: (2) Eminence LA6-MB, now discontinued.

Tweeter: (2) Selenium ST324-SLF slot tweeter with phenolic diaphragm

Stuffing: One pound (0.5 pound per box) of Acousta-Stuf

Terminals: Eight terminals (two pair per box), builder's choice.

Wire: Builder's choice, to connect the woofer to its terminals and the tweeter to its terminals.

Bullnose: (4) 5-inch lengths of wood ½ x ¾ inch bullnose

Felt: 10 feet of F-7 wool felt tape, 1 inch wide by ½ inch thick. Available from McMaster-Carr.

Crossover

Capacitor, 0.62uF (2)

Capacitor, 0.82uF (2)

Capacitor, 4.7uF (2)

Capacitor 8.2uF (4)

Resistor, 5.6 ohms 5+ watts (2)

Resistor, 8.2 ohms, 5+ watts (4)

Choke, 0.25mH (2)

Choke, 0.56mH (2)

Terminals (6 pair)

Enclosure (builder's choice)

Terminal strips with solder lugs (builder's choice)

Appendix 2 – LA6-MB specification

See separate PDF file.

Appendix 3 – ST-324 specification

See separate PDF file.

Appendix 4 – passive BSC

An adjustable, line-level baffle step correction circuit is shown on the SEXy Speaker pages. It goes at the input of the power amplifier, and provides a bass boost to compensate the baffle diffraction losses in the bass. The components are chosen to work well with the 8.5 inch width of the Climax front panel. It is adjustable between 0 and 6dB bass boost; 3dB to 4dB is most often used.

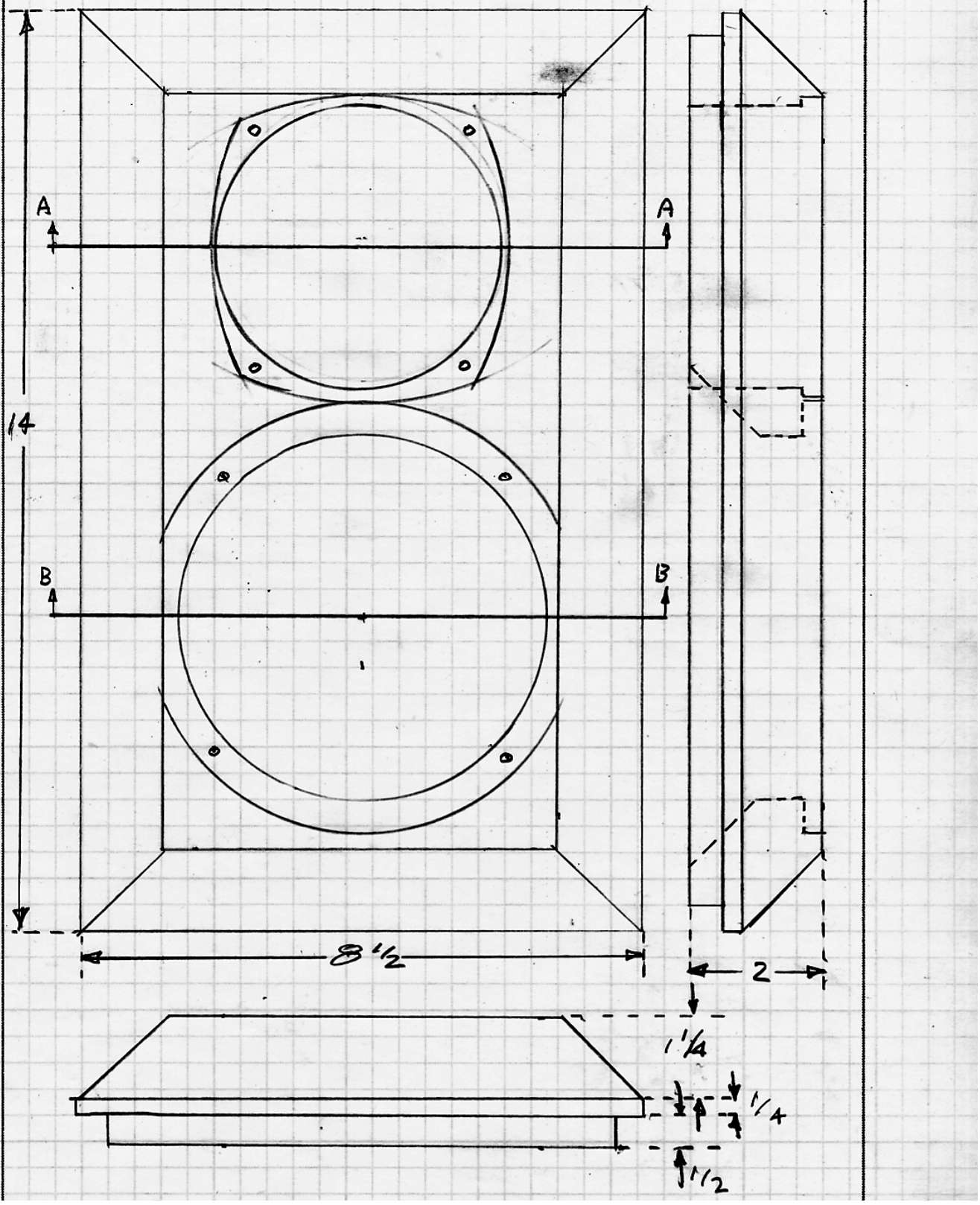
Note that it is often satisfactory to increase the subwoofer level to provide this compensation, instead of using this circuit, even though the compensation produced will occur an octave lower than theoretically optimum. With this circuit, the subwoofer level should be reduced so that the bass is not boosted twice.

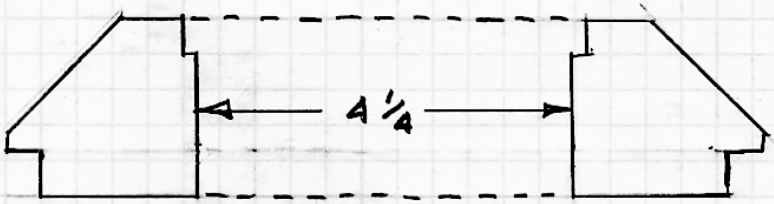
Appendix 5 – beveled front panel

These two images were used to evaluate the possibility of having a front panel cast from aluminum or magnesium, or from a suitable structural plastic. It proved not to be feasible economically, but this design might be made from wood, MDF, or other material by an ambitious DIYer. The panel material is 2 inches thick. Note that the tweeter is recessed so its front surface is flush with the panel; the area around the front surface should of course be filled in with something. The bullnose and immediately adjacent felt pads are recommended, but the large bevelled edges eliminate the need for the full-panel felt outline.

Note the internal bevel around the midwoofer hole. This is to eliminate the column resonance of a round hole, and should not be omitted.

Speaker Front Panel | Scale 1:2 | BF Feb 9, 2007 | 1/2





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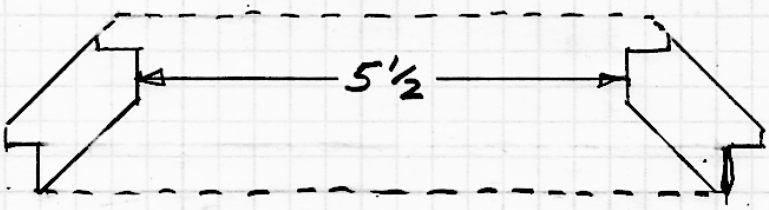

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