

M A P L E T R E E



AUDIO DESIGN

MAPLE TREE

BRANCHES

Sound advice for Mapletree owners, customers, and DIYs • Issue 4, April, 2006

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Spring makeover special issue: new life for your music system

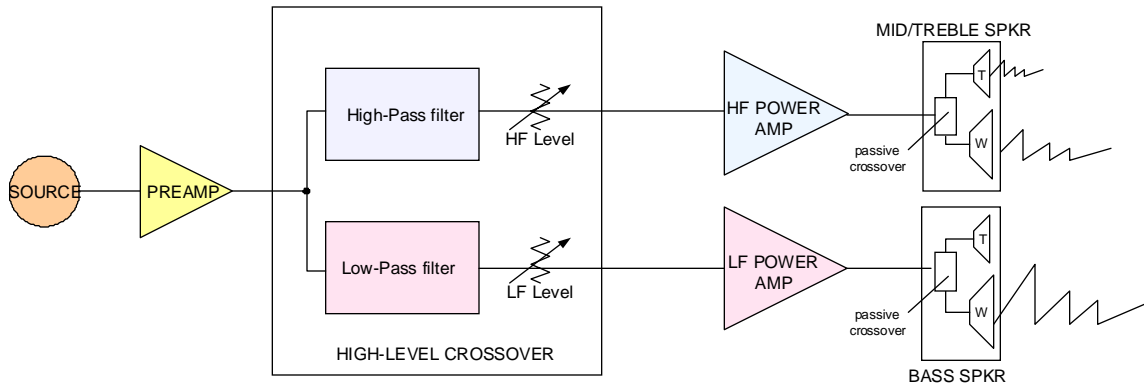
- **A high-level crossover for multiple speaker systems**
- **Subwoofers 101**
- **Ambience recovery with the Hafler speaker connection**

A high-level crossover for multiple speaker systems

Many audiophiles are familiar with the use of *high-level crossovers*, sometimes called *active crossovers* since they use tube or transistor circuits as opposed to strictly passive components—resistors, capacitors, and inductors integral with the speaker system. These provide amplification stages (which typically have unity gain over the frequency range of a particular speaker driver) which feed separate power amplifiers which in turn feed individual speakers in a two or three-way speaker system. The advantages are that you can precisely control the signal to each driver in terms of crossover frequencies and slopes and tailor the characteristics of each power amplifier to suit a particular driver. Of course, it requires as many power amplifiers as there are drivers. The crossover circuitry usually follows the preamp and provides attenuation slopes that are at least 12 dB/octave. This requires fairly complex circuits (second or third-order filters) using precision components. The following is a description of a different approach to high-level crossover intended to drive two different *full-range* speaker systems.

Most two-driver speaker systems have a built-in woofer-tweeter crossover frequency of 1000 Hz or greater. Suppose you design a high-level crossover to deliver low frequencies to one speaker system (call it the “bass speaker”) and high frequencies to another (call it the mid-range/treble speaker”), with a 500 Hz crossover point. Then the bass speaker system’s tweeter will receive negligible power, and the mid-range/treble speaker’s woofer will see power mainly above 500 Hz, really a “mid-range” signal, and its tweeter will see power mainly above its built-in crossover frequency. What results is actually a three-way speaker system employing one active and one passive crossover. Since each speaker system is capable of handling a full range of frequencies, the 500 Hz crossover attenuation slope can be 6 dB/octave, implemented by simple, first-order filters. The block diagram below shows how everything is connected.





FULL-RANGE SPEAKER HIGH-LEVEL CROSSOVER APPLICATION
(Only one of the two stereo channels shown)

Pros:

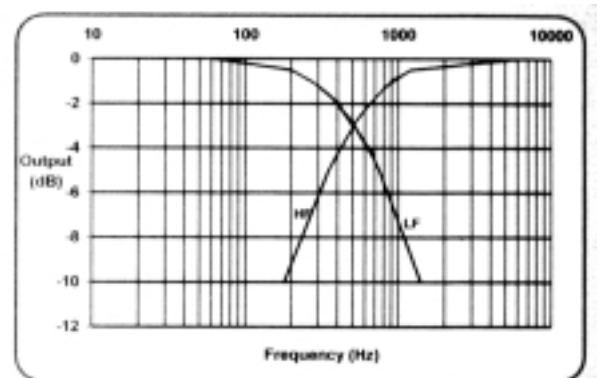
- ◆ Assuming you already have two or more full-range speaker systems, you can choose the system best suited to each frequency range (i.e. play to the strength of each). You can also choose power amps with particular characteristics that are a best match to the speaker systems and/or frequency range.
- ◆ The high-level crossover circuitry is simple, inexpensive, and can be designed to add negligible distortion to the signal.
- ◆ You can implement separate level controls for each frequency band to allow for different speaker efficiencies, room acoustics, or user preferences (welcome back tone controls).

Cons:

- ◆ You need two speaker systems and two stereo amplifiers. In fact, many audiophiles have access to extra speakers and power amps that are looking for an application.
- ◆ There are theoretical issues involved with the use of two different speaker systems delivering an overlapping range of frequencies. Decisions have to be made as to individual speaker placement, etc. to achieve the desired results. Without actual sound level measurements, precise balance between the two systems is a matter of individual estimation/taste. Speaker experts will have a field day with this setup.
- ◆ The sonic character of the two systems may be different enough that the overall results are not as good as for either speaker used as a full range system, although this has not been my experience (see below for an example system configuration).

The crossover circuit

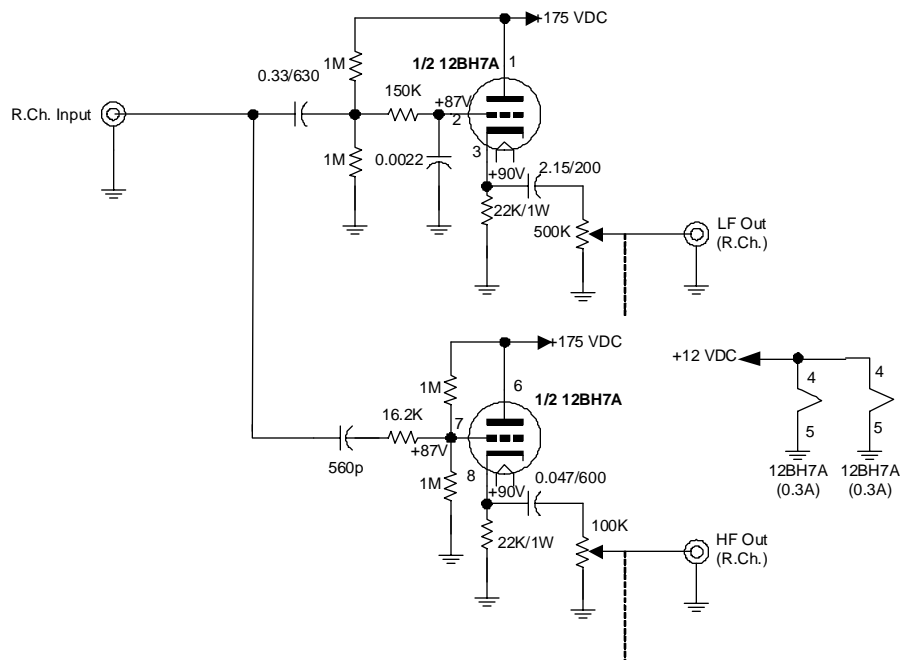
As shown in the block diagram above, the simplest implementation of the high-level filter circuitry consists of two first-order filters—a low-pass filter for the low frequency channel, and a high-pass filter for the high frequency channel (both required in duplicate for stereo). Both filters are designed to have cutoff frequencies of 500 Hz so that each exhibits a 3 dB power loss at 500 Hz. The low-pass filter will exhibit a 45 degree phase lag and the high-pass a 45 degree phase lead at 500 Hz. The net power loss and phase shift at 500 Hz is therefore zero. An issue with any filter implementation is the effect of driving and load impedances on the filter characteristics, since these form part of the filter circuitry. The trick is to make the filter component values



dominant in determining the crossover frequency for a range of external impedances. This is not difficult in terms of the driving impedance, since it is typically low (e.g. the output resistance of a tube preamp is less than 1000 Ohms). However, the input impedance of a power amp can vary from 10k Ohms to 1M Ohm, which is difficult to accommodate. Thus, it is beneficial to use a buffer stage (e.g. cathode-follower) after each filter. This stage will have unity gain and offer a known input impedance (typically high) and a low output impedance to drive the interconnect to the power amps. Due care must be taken in implementing the level controls for each frequency channel (see *Branches* Issue 2 for a discussion of volume controls) so as not to interfere with the filter characteristics or raise the output resistance, especially of the high frequency channel, since loss of high frequencies due to cable capacitance is clearly undesirable. However, normally, both level controls can be operated at or near their maximum settings, depending on the relative power amp sensitivities and speaker efficiencies, so in practice, the controls can be inserted at the output of each frequency channel.



The resulting circuit (right channel) is shown below and can be implemented in a two chassis configuration like the *Line 2A* preamp (using the same *PS 2* power supply) or integrated in one larger chassis. The tubes shown are 12BH7As but can be 12/6SN7s if octal is your preference (actually, miniature tubes such as the 6CG7 and 12BH7A closely rival the 12/6SN7 but that is another story). If you have to drive the input with a high impedance source, then an additional buffer stage (cathode follower) can be added to the input (requires one additional dual triode).



System example

I have used the above crossover circuit for several years, currently with the following components:

Preamp: *Ultra 4A SE*

Low frequency power amp: *Stealth 60* (30 W/channel)

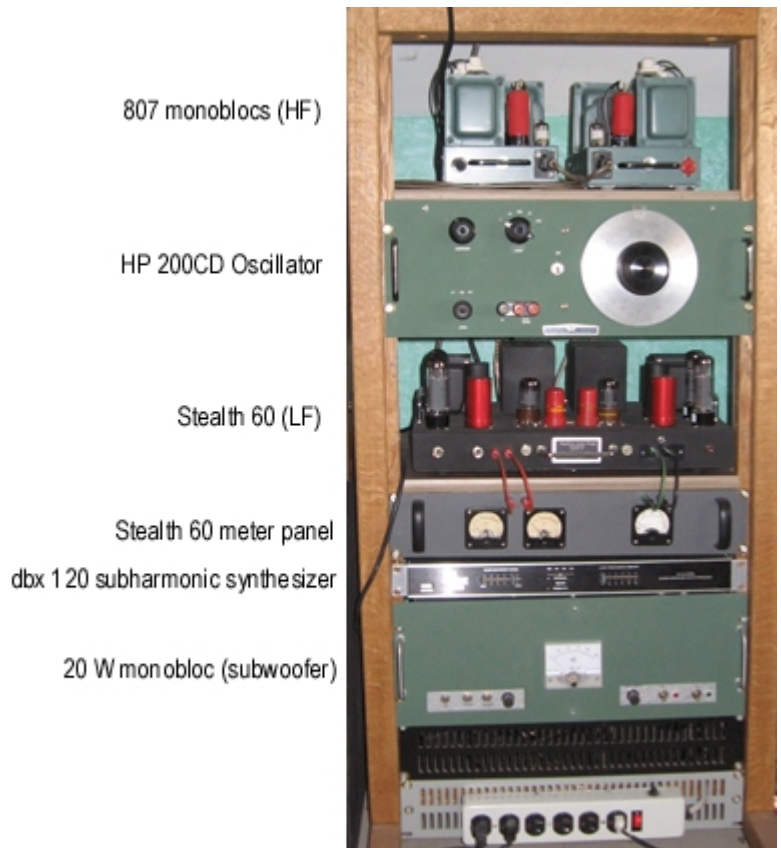
High frequency power amp: monoblocs with 807 triode-connected push-pull output (10 W/channel)

Low frequency speaker system: Dynaco A-25

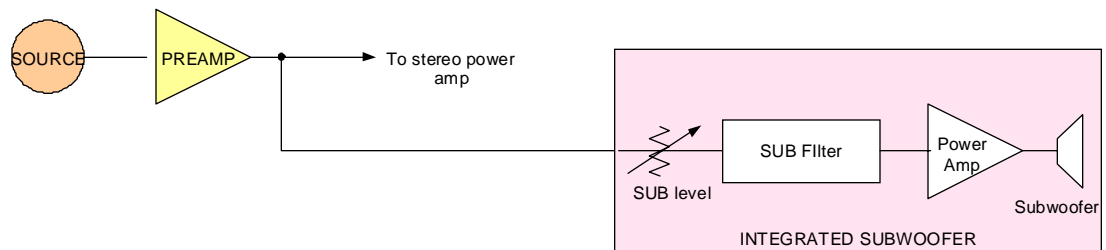
High frequency speaker system: Radio Shack LX 5 with Linaeum dipole tweeter (I have used PSB Alphas as well but they can't match these tweeters).

The speaker cabinets are mounted vertically with their front edges coincident and angled slightly inward, about two feet from the wall. The listening room is small—about 20 ft x 20 ft. With these particular speakers and amplifiers, I have the level controls for each frequency channel set both near the maximum. You can easily achieve a bassier or brighter sound using these controls but experience will dictate the best balance point. I also run a subwoofer fed from the LF outputs, through a dbx subharmonic synthesizer (solid-state!), and 20 W mono 6L6 ultra-linear push-pull amplifier (see below) but only when the source material warrants it. There is nothing exotic or “high-end” about the system components used but no listener has been disappointed with the sonic results. Several points are illustrated with regard to the high-level crossover implementation:

- ◆ The power amp with the higher power output is used for the LF speaker since with most music, greater power is generated in the below 500 Hz frequency range.
- ◆ The HF monoblocs used have an extended high frequency response due in part to the use of excellent old H.H. Scott output transformers. Their mid-range from the triode-connected 807s is also excellent.
- ◆ The tweeter used in the Dynaco A-25 is deficient in most respects, particularly its dispersion characteristics. This is not an issue used as the LF speaker system.
- ◆ The bass response of the LX 5 is weak but above 500 Hz, the mid-range response is quite good. And the dipole tweeters are excellent both in terms of their sonics and 360 degree dispersion characteristic.
- ◆ The speaker systems have similar efficiencies, around 90 dB.



A simple subwoofer addition

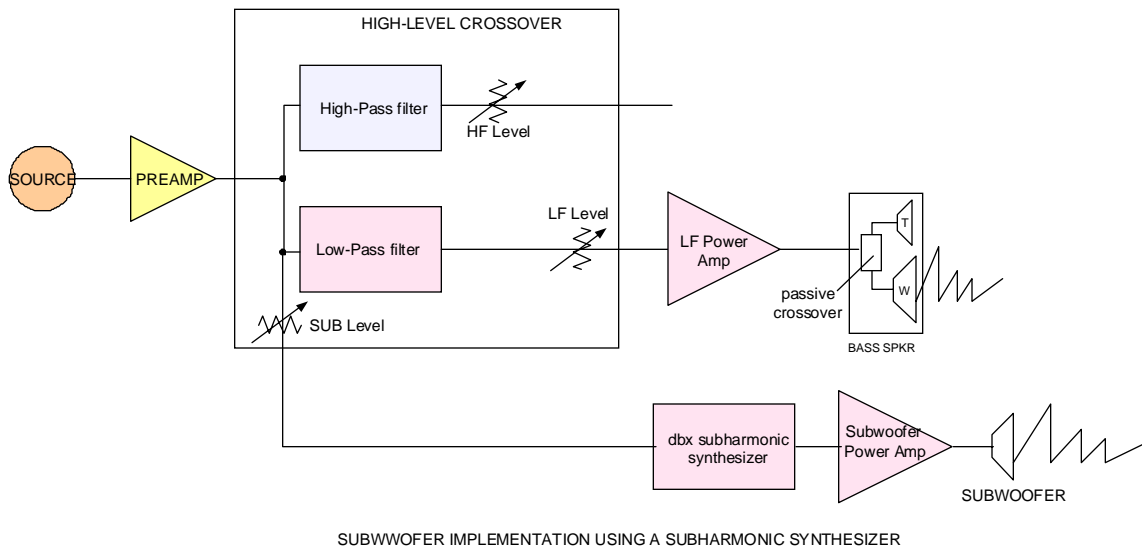


A SIMPLE SUBWOOFER IMPLEMENTATION

Whether as part of a high-level crossover system as described

above or not, many audiophiles are interested in enhancing the bottom end through the use of a subwoofer. A single speaker driver is usually employed since the ear has a limited ability to resolve directional information at very low frequencies. The simplest way to add a subwoofer is to buy the complete package, with built in solid-state power amplifier, filter, and level control, and connect it to the preamp outputs (if dual outputs are not available, use a Y-adaptor). Ideally, the low-pass filter of the subwoofer should approximately match the low frequency roll-off characteristic of the regular woofers (or full-range drivers as the case may be).

I have used a dbx subharmonic synthesizer as a subwoofer filter for a number of years. This is an analog (solid-state) device that generates output frequency information at half the input frequency. The frequency at which synthesis begins is adjustable. It accepts left and right stereo inputs and supplies left and right stereo outputs which can be fed to a subwoofer power amp which adds the two signals to produce a single subharmonic output. The sonic advantage is that the subwoofer does not compete with the regular woofers at normal bass frequencies (e.g. above 50 Hz) but rather adds a underpinning to the bass which is felt, not heard. You can often find dbx subharmonic synthesizers on ebay although they are in demand by DJs to create mind-numbing bass effects.



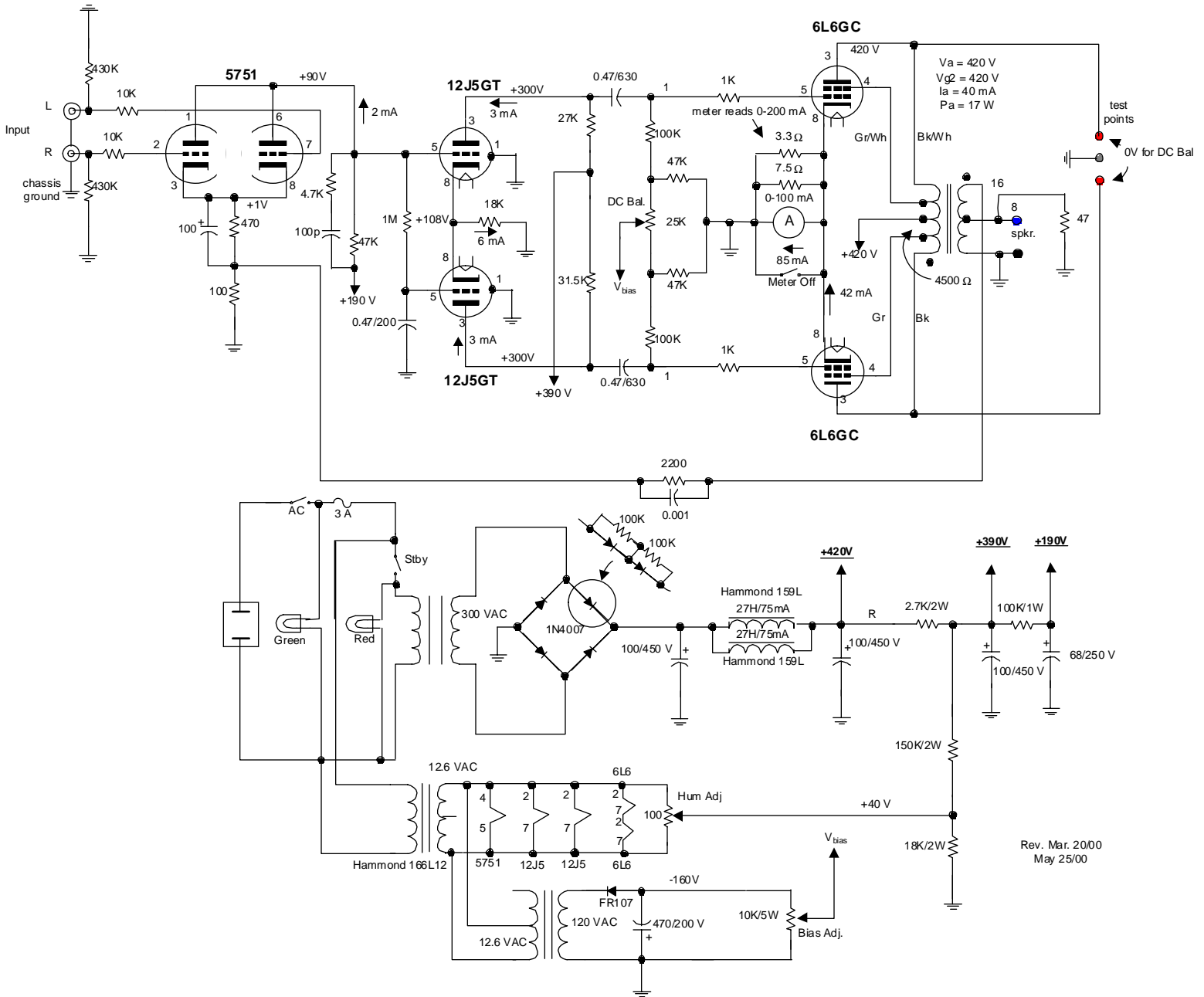
A subwoofer tube amplifier

If you wish to implement a custom subwoofer implementation using a specifically designed or available power amp, there are a few considerations to keep in mind.

- ◆ First, you need sufficient power output to drive the subwoofer to the desired level at low distortion. A subwoofer implemented as a tuned bass reflex enclosure will have relatively high efficiency, so 20 W or more from a tube amp will usually suffice.
- ◆ Solid-state power amps are quite effective as subwoofer amps due to their high power output, and high damping factor, which results in well controlled bass transient response. If you use a tube power amp, look for a damping factor greater than 20 (the output impedance of the amp is 1/20 that of the speaker). Of course, you also want extended bass frequency response with low distortion.
- ◆ If you are designing a tube subwoofer amp, you should look for a physically large output transformer (you only need one) which has sufficient primary inductance to ensure good bass response at low distortion. You don't need to worry about its high frequency characteristics. You will also have to provide sufficient negative feedback to achieve the high damping factor with a good stability margin. The good news is that you can band-limit the amplifier at the high end to whatever degree will ensure stable feedback operation, since you are only interested in low frequency behaviour.

Here is a power amp I assembled from my junk box to drive a custom built 12" subwoofer.

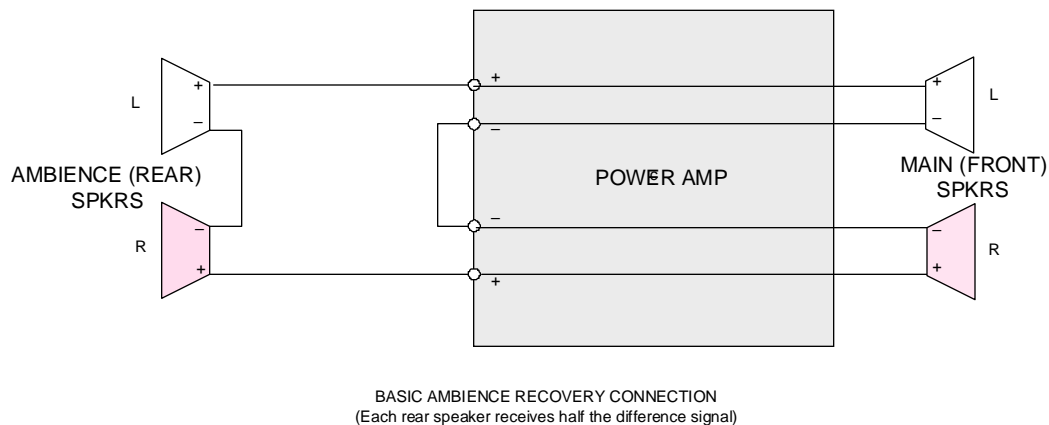
20 W Subwoofer Power Amplifier



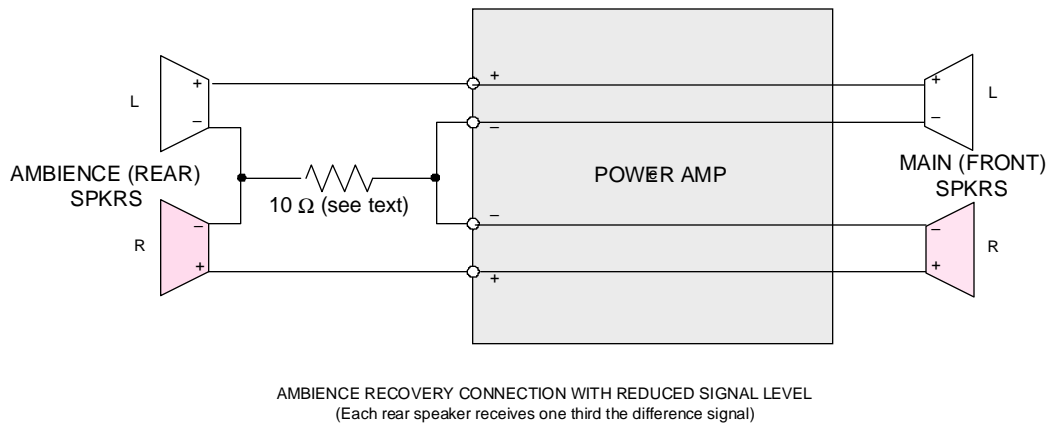
Ambience recovery

The last item on the spring tune up list is simple yet effective: the Hafler ambience recovery speaker connection. In the early 1970s, David Hafler of Dynaco proposed a simple bridging circuit that permitted delivery of phase-reversal stereo information and to a pair of rear-mounted speakers. The circuit was sold as the *Dynaco Quadaptor* which facilitated the speaker and amplifier connections and provided level and function controls. You can often find these for sale on ebay but the basic idea is so simple that it is just as easy (and cheaper) to do it yourself.

What is often lacking in normal stereo reproduction is the sense of space that would be present if the music were heard live in a room, club, or concert hall. Ambience is the collective term for the presence of reflected sound waves that add or subtract from the direct sound waves to provide the ear with a complex sonic mix. Of course, sound waves reflect from your listening room as well, but these are not related to those in the original environment (think for now in terms of a live recording as opposed to a studio, although ambience can be simulated in that case as well). Reflected sound waves are usually phase-shifted versions of the direct waves and the ear uses this information as well as relative sound levels to construct the overall sound field. This 3-dimensional sound field can be re-created in some cases using multi-speaker home theatre systems, if the ambient information is actually encoded, as opposed to strictly directional sound effects. What Hafler's circuit does is derive some phase-shifted information from a normal stereo recording and feed it to a pair of rear speakers, which radiate it as reflected sound waves, creating some of the sense of ambience present in a live music situation. In its basic form, it is implemented at the power amp speaker outputs and requires no additional amplifiers or power capability. The circuit is shown below.



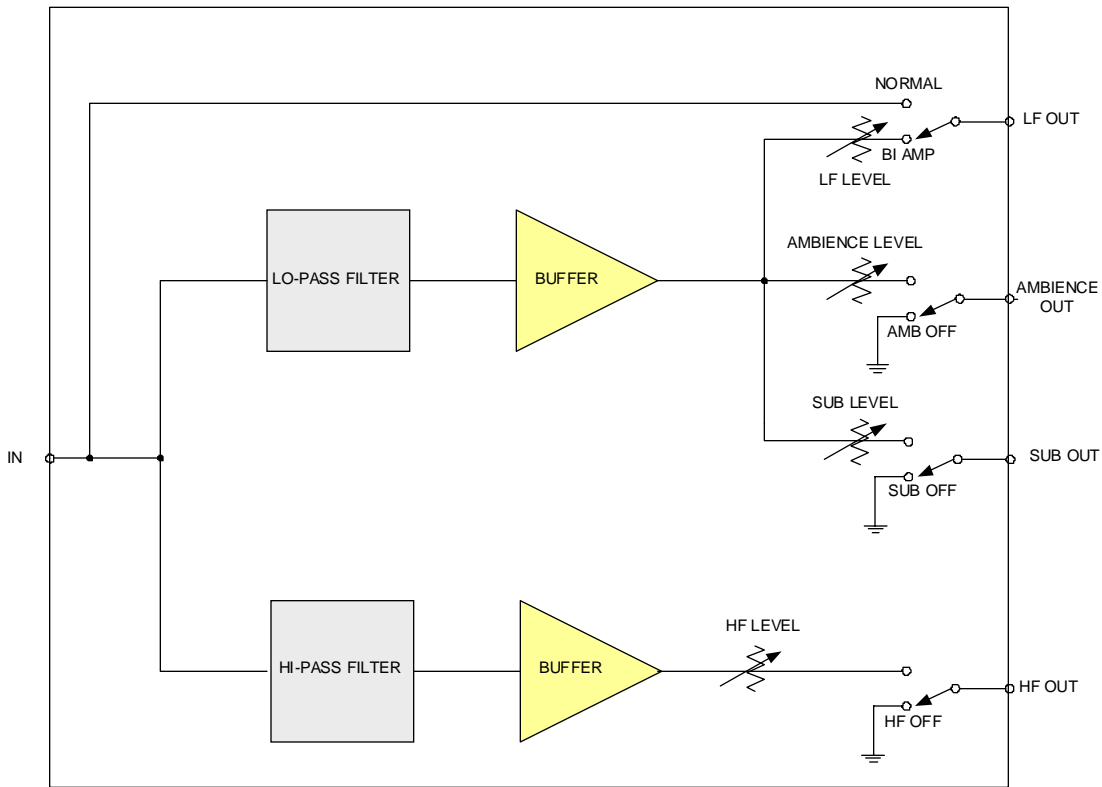
Note that the right rear speaker receives $\frac{1}{2}(R - L)$ information and the left rear speaker receives $\frac{1}{2}(L - R)$ information. Since the rear speakers will be nearer the listener, a resistor is usually added to reduce the rear speaker phase shifted levels. This resistor also increases the net impedance load seen by the amplifier. With or without the resistor, the net impedance is always greater than 4 Ohms for 8 Ohm speaker impedances. It works well with most tube amps designed for 8 Ohm speakers and solid-state amps that can drive loads as low as 4 Ohms. With a 10 Ohm resistor, the right rear speaker receives $(0.64R - 0.36L)$ and the left rear speaker receives $(0.64L - 0.36R)$. The only other requirement is that the power amp must have a common speaker ground connection.



Note that in the form shown above, there is no attempt to project directional information from the rear speakers. In fact, the phase-shifted information is reversed left-to-right. The ambience sensation is confined mainly to the presence of lower-frequency information from the rear speakers. So, they should be full-range and have close to the same sensitivity and sonic character as the main speakers. Toward this end, Dynaco introduced the A-10 speaker system to complement with the A-25 when used with the Quadaptor. I am currently using PSB Alpha mini-monitors mounted on the rear wall, angled inwards, along with the high-level crossover and subwoofer systems described above (7 speakers!). The results are amazing in terms of the increase in apparent room size and three-dimensionality of the sound-stage. It does make one want to listen to long-forgotten LPs and CDs all over again.

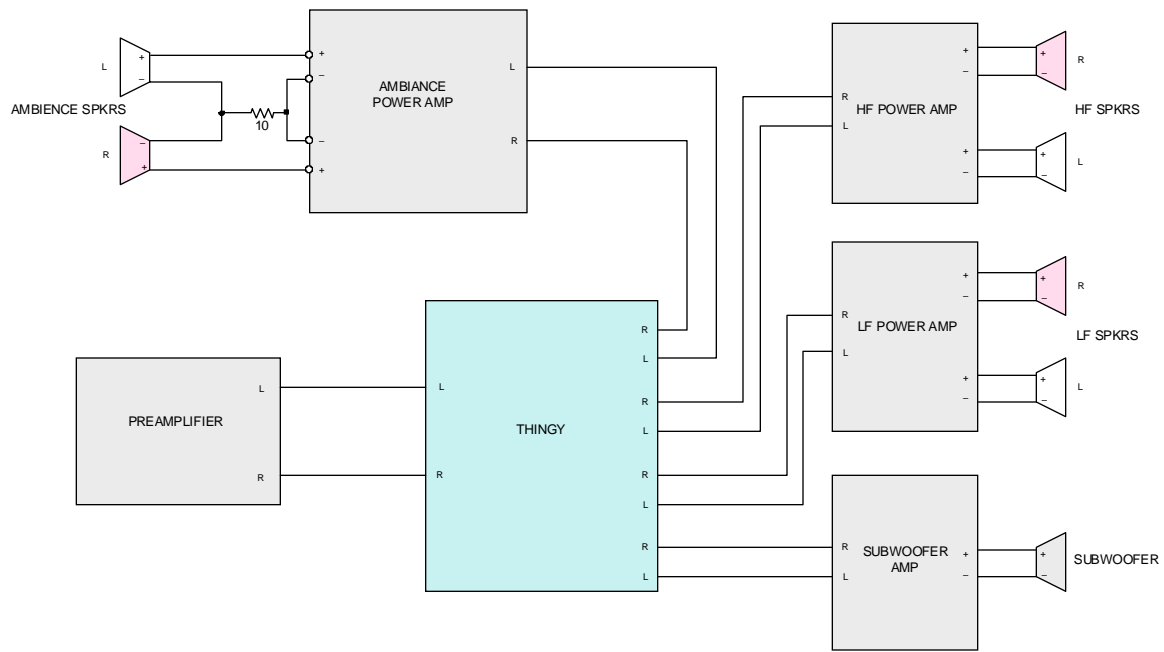
An all-in-one solution

The natural next step in all this is to bring together the high-level crossover, subwoofer driver, and ambience recovery systems in one convenient component. The block diagram for such a unit (I call it the *Thingy*) is shown below.

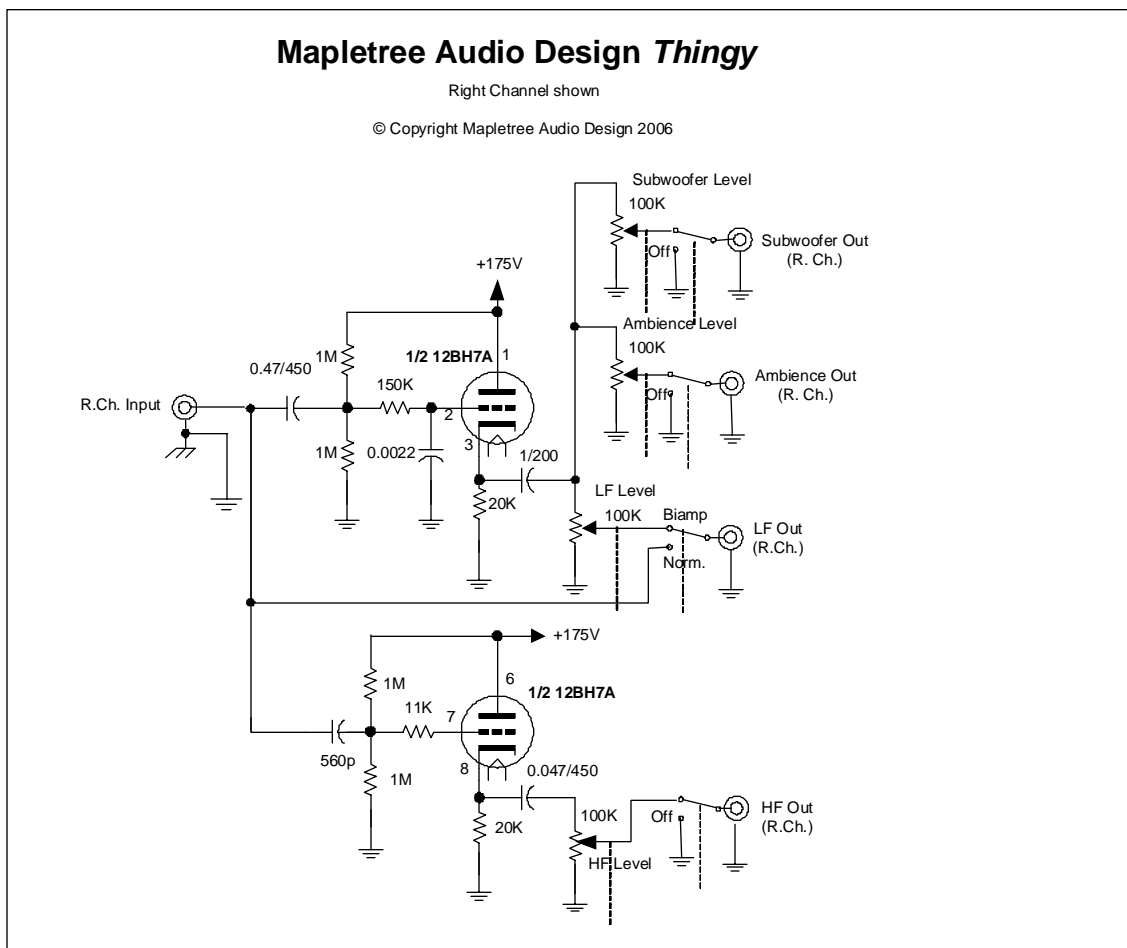


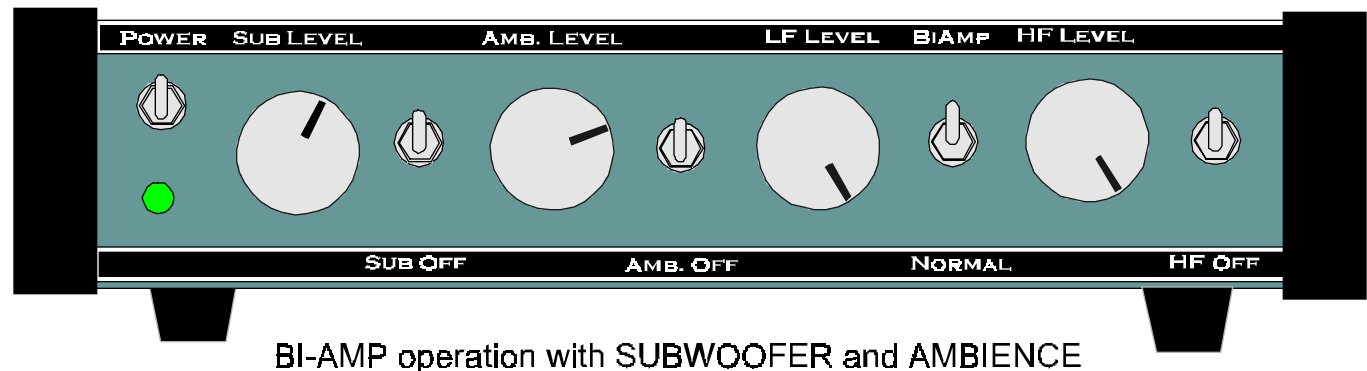
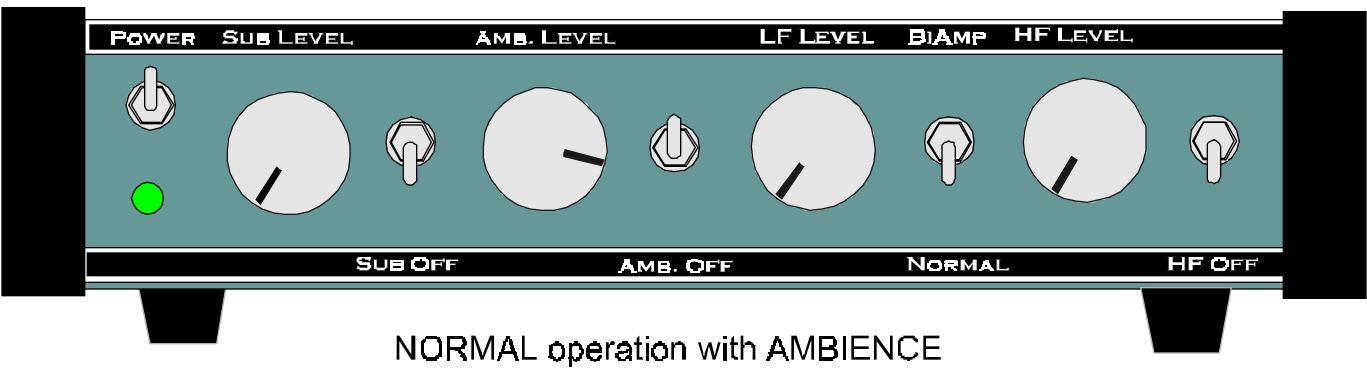
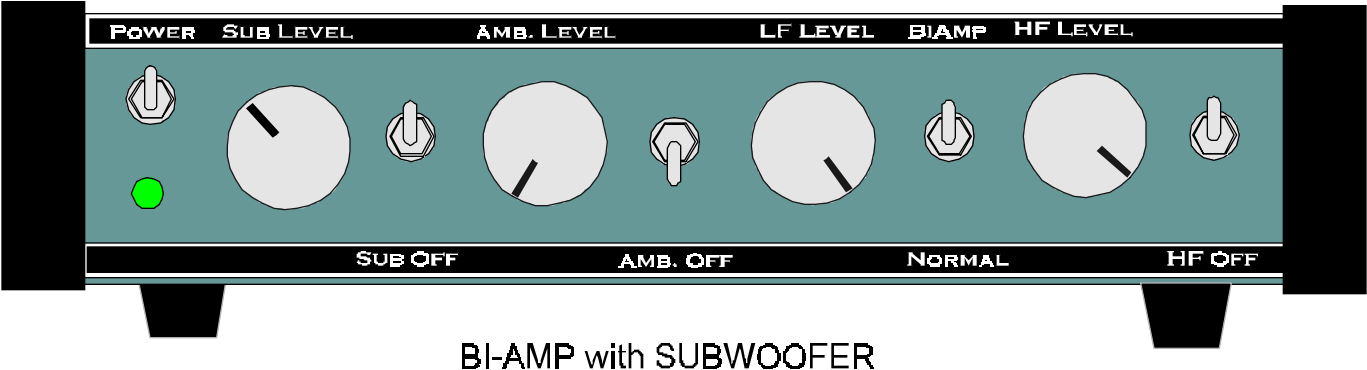
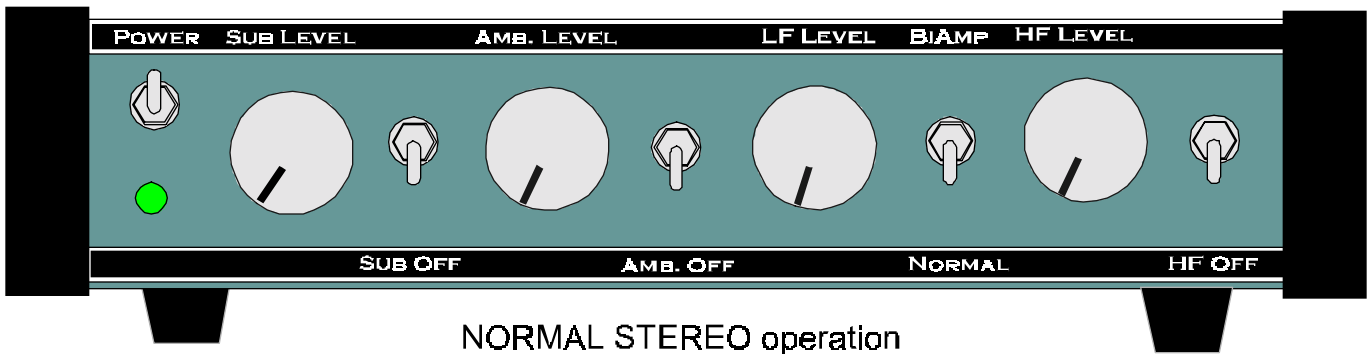
THINGY Functional Block Diagram

Both the ambience and subwoofer outputs are derived from the low frequency crossover output. The ambient information is still recovered at the speaker level, but level control is achieved within the processor. A total of 7 power amplifier channels is required. System interconnection is shown below. The 10 Ohm resistor is employed at the output of the ambience power amps to increase the net speaker load impedance. The circuit shown is based on the original high-level crossover with the extra outputs and level controls added. A possible front panel layout and several operating modes is also shown. I would be happy to provide a prototype of the *Thingy* at reasonable cost for any adventurous folks who want to put to use a lot of audio gear that is currently gathering dust.



THINGY System Connections





Coming in the next issue: Customer input on customization, tube and passive component mods/listening tests, and a selection of CDs and LPs that you can't live without.