The Case for Active Speakers

Introduction:

For many years now a revolution has been taking place in the professional audio community. Active speakers are replacing regular passive speakers in the recording studio, the mastering lab, and many other places. Why is that? It is simply a better way to reproduce sound. This paper will endeavor to explain why this is so. Although some of the reasons are intrinsically technical I will try to use language and concepts that are part of the audiophile lexicon. It is with great hope that I write this, because it is the audiophile who stands to benefit the most from this technology.

For the purpose of this paper an active speaker is defined as a speaker that has built-in power amplifiers and an electronic crossover. The crossover operates at the line level, dividing the input signal into two or more signals that are fed to multiple amplifiers.

Better Bass:
When was the last time you saw a non-active subwoofer? You probably cannot find one for sale today. I offer this just to make you think. The people trying to provide you with really deep bass have turned to the active solution. I have prepared a comparison below which uses the same woofer and same size box in two alignments. This is a six-inch woofer in a ported box. The red curve is a passive design and blue is an active design. The active speaker designer has an additional degree of freedom: he can provide the woofer with different voltage drive at low frequencies. The passive speaker designer cannot do this. Any attempt to build a passive filter that lifts the low frequencies by six dB at 30Hz would require giant inductors and capacitors and would probably not even fit in the box. It is not done.
Using –3dB as the standard description for low frequency cutoff, we see that the passive speaker cutoff is 39 Hz, while the active speaker cutoff is 29 Hz. This is an additional four tenths of an octave and a flatter response as well. The following charts show how this has been accomplished.

What you see above is the voltage drive that is applied to the woofers in the two alignments. While the passive alignment (red) is flat, the active alignment (blue) boosts the lower frequencies down to about 30 Hz, and then reduces drive of the sub-sonic frequencies that would just cause the speaker to flap around. The next graph shows how far the speaker will move in these alignments.
Referring to the “Excursion vs Frequency” graph on the preceding page, we see another advantage of the active speaker: reduced subsonic excursion. Both curves indicate a minimum that shows the frequency where each box is tuned. The active speaker is tuned much lower. This would cause a very damped response without increased voltage drive. The real difference is what happens below the tuning frequency where the speaker no longer produces significant output. The passive speaker is moving like crazy, while the active speaker has very little motion. This is part of the beauty of the active design: the equalization that extends the bass also filters out the sub-sons. This filter has to be designed for the speaker; it is not the same as the sub-sonic filter on some preamplifiers.

So there you have it. By designing the speaker to apply more volts where they are needed and reducing the drive where the speaker can no longer produce sound, the result is deeper bass and less distortion. There is less distortion due to less subsonic motion.

**Baffle Effects:**

The simulations you see above show the same system in two different environments. The red curve is what you would measure if the speaker were installed in a giant wall. This is known as an infinite baffle measurement. Since the baffle is infinite, it has no effect except to direct all the energy forward. The blue curve is an anechoic simulation. Anechoic means without echoes. This is like measuring the speaker in outer space (assuming it’s filled with air). What you see is that at low frequencies the anechoic curve is at about ½ the pressure. This is because at low frequencies the bass is expanding in all directions filling up twice the volume, hence half the pressure. As the frequency increases the baffle begins to direct more of the energy forward increasing the SPL. After a bump that depends on the size of the baffle all of the energy is directed forward and the response is similar to the infinite baffle response.
Idealizations of “Infinite baffle” and “Anechoic” measuring environments.

Infinite baffle: The speaker is mounted in an infinite wall.

Anechoic Chamber: The wedges absorb all the energy so that there are no echoes. This is just like measuring the speaker in outer space.
Clearly, if the speaker is not mounted in a giant wall, there are going to be effects related to the baffle. The rise in the higher frequencies must be addressed, or the speaker will have a very thin sound. Both the passive and the active speaker designer have to deal with this problem, but they have different tools to attack it. The active speaker designer can design a filter to boost the lower frequencies in order to make the speaker flat. The passive speaker designer has no ability to boost the lower frequencies; he can only attenuate the higher frequencies.

Attenuating the higher frequencies through the use of a large inductor and resistor can produce the correct response, but it will reduce the sensitivity of the speaker by almost 6 dB. This is huge. It is like wasting 50% of the amplifier’s available voltage swing. Stated another way, it will now take an amplifier four times as large in order to play the midrange and treble at the same loudness level!

You may argue that you do not listen to music in an anechoic chamber. This is true, but flat anechoic response has been proven to be the most preferred by listeners. I highly recommend the excellent research of Floyd Toole, Ph.D. who has proven this with real double blind listening tests. A quick Internet search will reward the interested party with many well-written scientific articles on loudspeakers and rooms.

So again we see the active speaker designer using equalization to achieve a superior low frequency response in ways that the passive speaker designer cannot.

**Active and Passive Crossover Systems:**
On the previous page are typical schematics of a passive and an active loudspeaker system. First let’s make a couple of simple observations. The active loudspeaker system has two power amplifiers. This means (assuming all amplifiers are the same power) that the active system has twice as many volts available to produce sound. Actually there are more than twice as many volts because in the passive speaker system the filters, equalizers and attenuators do their job by reducing the voltage from the power amplifier. There are many reasons why active speakers produce higher sound pressure levels, but having more volts available to do the job is a prime one.

The active speaker has adjustments, while the passive speaker does not. Since the adjustments are done at the signal level, they are far more practical in the active speaker. This is extremely helpful in matching the speaker to the characteristics of the room.

The active speaker has many more equalization sections and steeper filters. This helps to provide a smoother response, and a narrower crossover region.

The passive speaker has two network sections known as a Zobel. These components tame the impedance of the woofer and the tweeter to produce a more resistive load for the crossover network, and help suppress the fundamental resonance of the tweeter. They may not always be needed, but represent a typical design. They are not needed in an active design.

Finally I note that the speaker wires in the active system are much shorter and included in the loudspeaker itself. Given the prices audiophiles pay for speaker wire, this is a significant advantage.

Music contains many frequencies simultaneously. In the passive system the power amplifier must produce all of these, while in the active system the load is shared between two amplifiers. I note here that there will be much less intermodulation distortion in the active speaker’s amplifiers. The standard test of 60 Hz and 7 kHz will produce virtually no distortion because the crossover filters will not allow both frequencies to enter either amplifier simultaneously.

Another point is that the active speaker has a very short speaker wire and no resistance due to inductors. This will provide a higher damping factor to the woofer, which may give a slightly tighter bass.

**Time Alignment and Allpass Networks:**

In advanced active speakers, an effort can be made to ensure that the energy from the woofer and the tweeter arrive at the listener simultaneously. In a digital crossover this can be done with a simple delay mechanism. In an analog crossover this can be done with an allpass filter, or a chain of them. Here again the passive filter designer is at a disadvantage, because even the most basic network contains two inductors and two capacitors. Basically the allpass filter is a phase shifter. The analog allpass filter can simulate delay at low frequencies with good efficiency, but at high frequencies only the smallest amount of delay can be simulated. In the PTE Statement loudspeaker we use a four-section allpass filter to delay the output of the woofer so that it arrives in time with the compression driver which is physically behind the woofer. This greatly enhances the dynamic impact of the speaker. On the following page see the actual circuits and parts to make a passive and an active allpass filter. Both circuits have the same response.
Let's compare allpass filters in passive and active networks. Below see the circuits and their physical incarnations. These circuits and pictures are for one allpass section.

Active allpass single section.

Passive allpass single section

Passive allpass parts single section $15.80 Actual size

Active allpass single section parts $2.92 Actual size

Clearly the active implementation is superior in both size and cost. In fact, allpass filters are quite rare in passive loudspeaker crossovers.
**Higher SPL:**
I have mentioned that an active speaker will play louder than the same speaker implemented passively. This is not a subtle effect. In this section I will try to explain why this is so. I have mentioned that the active speaker has two amplifiers, and hence twice the voltage available at any moment. In order to show that both of the amplifiers are being used I did a simple experiment. In the picture below I took the electronics of our active speaker and applied a 1500 Hz Square wave to the input. You can see the outputs from the power amps in the picture below.

![Picture of electronics and oscilloscope readings](image)

The picture and equation show that a square wave can be described as a sum of sine waves. In the picture above the 1500 Hz fundamental sine wave has been sent to the woofer amplifier. The next harmonic at 4500 Hz has been sent to the tweeter along with all the other harmonics. While this is not a musical sound, it shows how the active speaker makes use of both amplifiers to reproduce sound. The woofer amp is producing 20V peak and the tweeter amp 28.2V peak.

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f(x) = \frac{4}{\pi} \sum_{n=1,3,5,...}^{\infty} \frac{1}{n} \sin\left(\frac{n \pi x}{L}\right).
\]
So in terms of voltage, the active bi-amplified speaker can apply these voltages to the speaker with a peak voltage of only 28.2 volts, but a passive system would require a peak of 40 volts. (I measured this by summing channel 1 and 2) What this means is that the active system requires an amplifier of only 50 watts while the passive system would require an amplifier of 100 watts. The situation is really worse than this because of factors already mentioned primarily the losses in the passive network due to level matching attenuators and inductor resistance. Let’s estimate this loss at 3.5 dB and add this to the power differential of 10 log (100/50)=3 dB. We see that the total difference is 6.5 dB. So what does this mean? Let’s say that the active speaker is built with 100W amplifiers. How many watts would the passive amplifier need to have in order to play this loud?

10 log (x/100)=6.5 dB. Solving for x we find that it would take **446 watts**! It is no wonder that people are always commenting on the dynamic sound of active speakers. This analysis will vary depending on the content of the musical signal.

There is another reason that active speakers sound cleaner. When an amplifier clips it generates many high frequency harmonics, (like the square wave) and in a passive speaker these are sent straight to the tweeter. This clipping is quite audible since the tweeter is adept at reproducing the high frequencies. When the bass amplifier clips in an active speaker it is quite difficult to hear it for two reasons. First the harmonics are being reproduced by a woofer, and second and more importantly the tweeter amplifier is reproducing clean treble energy that masks the sound of this clipping.

Have no doubt about this. As an active loudspeaker designer for well over 20 years, I have spent many hours looking at the oscilloscope output of active systems while listening to their sound.

**Final Thoughts:**

I have shown a few of the many reasons that powered speakers sound better and play louder. There is one question remaining. Why haven’t more audiophiles discovered these speakers? The active speaker obviates the need for the large expensive power amplifier. Those who long for the sound of a single ended triode might never understand the powered speaker. However, the real music lover who likes to play his rock jazz or classical music at live levels will find that the active speaker is a more accurate machine.

My philosophy of amplifier design is that the electronics should essentially have no sound. They should simply multiply their input voltage. I use modern class AB amplifiers with generous output devices that will provide current well in excess of whatever demands their loads require. The active filters are so good that their distortion cannot be measured with an Audio Precision analyzer. The power of the amplifiers is determined such that the probability of transducer damage is low.

It is my hope that this paper has increased your desire to hear what the active loudspeaker can do for your system. If you want to read more please visit our website at

[www.pteacoustics.com](http://www.pteacoustics.com).

Happy Listening

Jim Rush

[jimrush@cox.net](mailto:jimrush@cox.net)