Introduction - What is it with Open Baffles?

The very first speaker enclosure that a cone speaker was mounted in was very probably a piece of plywood. This provided a surface to separate the front and back waves of the cone which would otherwise cancel each other out, and it dramatically improved the performance. A bigger baffle improved the separation, as did a baffle with sides, and then horns and then closed boxes. Later, clever ways were invented to vent closed boxes to coax a little more bass response. Then in the '60's closed boxes came back in style. Lately we have seen a resurgence of flat pieces of plywood, also known as open baffles.

Interestingly, just as the first enclosure was merely a flat open baffle, the first cone speaker in it was a “full range” driver, expected to reproduce the full audio range. If you listened to the ones that came out Bell Labs in the early days, you would probably be amazed at how good they were. While the most basic concept of a speaker driver is a piston which pushes air to make sound, a rigid piston surface is nearly impossible to make and would have limited bandwidth if you did. The art of cone loudspeakers partly resides in the choice of structures and materials that bend gracefully to the needs of full range of frequencies that make up music.

Inevitably, other types of drivers were invented and full range drivers were improved, but primarily drivers became specialized – woofers for bass, midranges, and tweeters for high frequencies. This relaxed the bandwidth requirements for individual drivers and made the rigid piston model more practical as amplifiers got more powerful.

With all the technical advances to drivers, enclosures (and amplifiers), there seems to have always been a contingent of audiophiles embracing the “old ways”, building loudspeakers with full range drivers and open baffles. Lately there seems to be more of that than ever.

While these sorts of speakers have flaws and limitations, they also have a unique character that many audiophiles like. The rear wave “illuminates” the room differently, creating a larger space and a less boxy quality. Because there is no box, the drivers do not suffer the internal reflection, resonance and reverberation of their rear waves which come back and influence the motion of the cone. Open baffles have different edge diffraction effects – box enclosures have edges which set up additional wave source, but flat baffles see wave cancellation at the edges. And open baffle owners enjoy people who proclaim “That can't work!”

But it does work, and properly executed, these speakers are always charming and occasionally spectacular.

History seems to be helical – we repeat ourselves but with a twist. Having embraced open baffles and full range drivers we find ourselves ultimately complaining about the lack of deep bass, and so of course now it's time to add a woofer....
FIRST WATT B5

The B5 is an active crossover specifically designed for open baffle enclosures with full range drivers and woofers. What do we mean by this?

By open baffle we typically mean that the enclosure is a flat piece of wood 18 to 36 inches wide and 40 to 60 inches high. Usually the woofer is mounted near the floor in the center of the baffle and the full range driver is mounted somewhere above that. There is a lot of variation in what people do for enclosures – if you go to the internet you can see all sorts of different things that roughly match this description.

Here's an example of one of my favorites, which is a pair of baffles 36 inches wide and 60 inches high. It's made of ¾ inch birch plywood and you can see the side panels that both hold it up at an angle slightly off vertical and also provide some extra baffle width for the woofers. Construction details and choice of drivers is up to you. Many people can't spare this much space, but it is possible to get good performance from a similar but smaller baffle, say 24 inches wide and 48 inches high.

A popular woofer is the Eminence 15 inch beta – it has the right Qts (about 0.7), sounds good and is cheap. Some prefer a higher Qts for the woofer which gives some bass bump, but they aren't quite to my taste. Basically though, you should feel free to try anything you like.

I have tried about 30 or so different full range drivers in this sort of baffle, and the B5 will work with all of them. My favorites are the (expensive) PM5A and PM6A Lowthers and the Feastrex D9nf. In these cases the B5 low pass is set to 70 or 80 Hz, and the high pass is set to about 150 Hz with 12 dB/oct. The drivers are biamped, wired in phase.
The B5 has been made sufficiently adjustable to operate with a wide range of open baffle designs and different drivers. It can also be used with more conventional enclosures and a wide range of different power amplifiers.

It features a two pole (12 dB/oct) low pass filter variable from 20 to 300 Hz in 20 Hz steps, and a high pass filter with 1 or 2 poles (6 or 12 dB/oct) which is also variable from 20 to 300 Hz in 20 Hz steps.

The woofer channel also has a 2 pole high pass filter for the woofer with a 6 dB equalization “bump” at 20 Hz. This is useful for extracting a bit more output at the bottom of the audio range of any loudspeaker, particularly open baffles, and functions as a subsonic filter below 15 Hz.

The full range high pass channel offers choices of shelving equalization curve (also known as “baffle step correction”) for full range drivers, variable from 250 Hz to 2.5 Khz with shelving at 0, -2, -4, -6 and -8 dB.

The active circuits are JFET buffers, most of them simple source followers without feedback. The distortion and noise are quite low, and the bandwidth is very wide.

Operation of the balance control is independent for each channel, left and right. Turning the control clockwise increases the level of the bass output. If you find that you can’t get enough bass, there are internal fixed attenuator switches to set the gain range of the high pass (full range) system at 0, -5 db, -10 db, -15 db, and -20 db. This should get you to get into the appropriate range to allow matching of bass and full range levels.

**Woofer Low Pass Filter**

Each channel of this filter has a dip switch assembly with 8 switches, 4 switches each for the two poles setting the frequency.

The frequency of each pole of the filter is variable from 20 Hz to 300 Hz in 20 Hz steps, and the switches are labeled 20, 40, 80, and 160 Hz. The switch body indicates the OFF position.
with a label and an arrow. The ON position is the on opposite side. The filter frequency will be the sum of the switches that are put in the ON position. For example, if the 80 and 20 are in the ON position, then the frequency of the filter is 100 Hz.

The frequency values of POLE 1 and POLE 2 should be set to the same value. You won't break anything by experimenting with different values, and if it sounds better that way, feel free to do that.

A typical value on this filter with a woofer in an open baffle system is 60 to 100 Hz, but if your baffle is small you may elect to go all the way to 300 Hz, which is all switches in the ON state.

Here is the family of curves for this filter:
Woofer Equalization

Even with large open baffles you will get some roll-off at the lowest frequencies, and if you use vinyl you may also experience some issues with subsonics, so by popular demand I have included some equalization on the woofer as seen in the following curve:

![Bass Equalization Curve](image)

This filter follows the low pass filter. You see that it provides a 6 dB bump at 20 Hz and filters out subsonics. I’ve had this circuit around for 40 years, and it really works.

Full Range High Pass Filter

This filter has a bypass jumper and a jumper for 6 or 12 dB/octave filter. There is a dip switch assembly with 8 switches, 4 switches each for the two poles setting the frequency.
The frequency of each pole of the filter is variable from 20 Hz to 300 Hz, and the switches are labeled 20, 40, 80 and 160 Hz. As with the low pass filter system, the switch body indicates the OFF position with a label and an arrow - ON is the opposite side. The filter frequency will be the sum of the switches that are put in the ON position. For example, if the 80 and 20 are in the ON position, then the frequency of the filter is 100 Hz. The filters are designed for both poles set at the same frequency. You can do otherwise, and you will get different curves.
Baffle Step Equalization

The baffle step filter is a shelving filter having a lower gain at high frequencies above a nominal frequency, and is used to equalize the upper midrange of the full range driver with a broad brush. You usually set the step filter to taste when you find the upper midrange too "shouty". There is a dip switch assembly with a total of 8 switches, 4 switches for the frequency setting and 4 for the amount of high frequency attenuation. You can set the turnover frequency at 250, 500, 1000, and 2000 Hz. You can set the attenuation for 0, -2, -4, and -6 dB. Probably best if you only set one frequency and attenuation value at a time, although you won’t break anything. Setting the filter with no attenuation or no frequency setting (all switches off) will disable the step filter.

Here is the characteristic with different frequencies and the attenuation fixed at -6 dB:

FULL RANGE EQUALIZATION VS FREQUENCY @ -6 DB
Here is the characteristic for different attenuation values and the frequency fixed at 250 Hz:

**FULL RANGE EQUALIZATION @ 250 HZ**

Here's the same for 500 Hz:

**FULL RANGE EQUALIZATION @ 500 HZ**
The response for 1 Khz:

FULL RANGE EQUALIZATION @ 1 KHZ

And finally, for 2.5 Khz:

FULL RANGE EQUALIZATION @ 2.5 KHZ
Using the Full Range Attenuator

The knobs on the front panel are used to adjust the level of the woofer system. Sometimes, depending on the gain of the amplifiers and the sensitivity of the speakers, you may find that you can't turn the bass up high enough to balance the system. For this, inside behind the front panel are some fixed resistor switches that you can use to attenuate the full range output from 0 to -20 dB in 5 dB steps. It is designed for you to use one pair of switch values at a time, but you can turn them all on at once if you want and it won't hurt anything.

Other Performance Information

The B5 has some pretty decent specifications with regard to bandwidth and distortion. Here's the distortion curve of the high pass circuit at 1 Khz versus output voltage:

HIGH PASS DISTORTION VS AMPLITUDE
Here's the harmonic distortion vs frequency at 1 volt output:

![High Pass Distortion vs Frequency](image)

High Pass Distortion vs Frequency

Similar figures for the low pass filter system:

![Low Pass Distortion vs Amplitude](image)

Low Pass Distortion vs Amplitude

These curves are the result of simple discrete JFET circuits operated in single-ended Class A without negative feedback. (The exception is the bass equalization circuit which requires some feedback to get the curve needed).
Additional Specifications:

- Input impedance: 100 Kohms
- Output Impedance: 150 ohms
- High frequency bandwidth: -0.5 dB @ 100 KHz
- Power consumption: 4 watts

Some Helpful Hints

Finding the best settings for the crossover on a given system usually requires time and patience. If you know what you like when you hear it, then you could simply go through all permutations of the frequency and slope settings (and flipping the phase of drivers). There are over 1,000 such combinations on the B5, not counting level adjustment and full range equalization settings.

Most of the time you will have some idea of where to start, but it should be emphasized that experimentation with values and listening over time are nearly always necessary to extract the best possible performance.

If you have the ability to measure the response curve of the woofer / full range combination you can speed up the process. You can assume that you are looking for flat response in the crossover region which is usually somewhere in the two octaves between 75 and 300 Hz. Myself, I usually put the microphone about 1 meter from the baffle at the level between the woofer and full range drivers and measure the response in this region.

Ideally the response will be pretty flat with both drivers wired in-phase. If not, try flipping the phase of the full range. If that doesn't flatten it out, then you can start fooling with different crossover frequencies and slopes until it is reasonably flat.

You might think you're done, but maybe not. It's possible for the response to be flat and still have flawed sound because the drivers are not truly agreeing with each other on phase, and this is a frequency region where phase response is particularly important.

Having done this a lot, I have a simple procedure that gets me close to where I want to be fairly quickly. I put the drivers in phase and I fool around with the filter values until I get the flattest response I can in the crossover region. Then I measure the woofer alone (with the full range off) and then the full range alone. If you have software that allows you to overlay the three plots of the two drivers alone along with the summed response, then you are looking for the following characteristics – the woofer and full range should meet at the crossover point in such a way that each is about -5 dB from the value of the summed response.
The curve below is a good illustration of this. Focusing only on the region between 75 and 300 Hz (the sampling frequency is 2 Khz) we see three curves, the dark one being the summed response between a Lowther PM5A and an Eminence 15 beta woofer. You can also see the individual response of the drivers, and that they meet at 150 Hz at about -5 dB below the summed response.

If you can get a curve that looks like this, you are probably close to being done, and only need a few small tweaks (if any). Below is an example of a system which measures pretty flat, but does not obey this rule:

Here we see a fairly flat summed response, but the full range driver has a more elevated response between 100 and 200 Hz without the woofer, in other words, the two drivers are not in good agreement on phase, and the woofer is subtracting some energy. The result does not sound very good in the bass region – ill defined and lacking a coherent transient attack.
Here is the same system with different crossover settings and the phase flipped on the full range driver:

You will note that the individual drivers response is not greater than the summed response, and I can tell you that the sound was very much better.

This is a simple way of speeding up the process of getting the system to sound its best, in other words, it's usually a good starting point. Don't rely too much on simply flat response when adjusting crossover networks, and be prepared to use your ears over an extended amount of time to get it just right. Also, be aware that flat response at 1 meter will usually give you too much bass in the actual listening position – you will probably want to turn the bass down a few dB.

The same sort of thinking applies to the use of the full range equalization networks in the B5. A common complaint with full range drivers is that they are “shouty” or bright in the upper midrange and high end. Often this is improved by listening to the drivers slightly off-axis by 10 or 15 degrees. Commonly speakers are “toed-in” so that they face the listener in the “sweet spot”, but if you face the speakers straight out into the room, you will put the listener slightly off axis, which attenuates the upper mid and top. With open baffle systems, this often improves the apparent imaging, so it's worth playing around with where you point your speakers.

If this doesn't work, then you will want to try the step filter provided. Keep in mind that for this the best sounding setting is often not the one that measures best. If your upper mid shows up as elevated by 8 dB, there is a very good chance that the -4 dB equalization setting will be the best one. You will find that when applying corrections that halfway is often the best, so be certain to try out the possibilities rather than going purely by the meters.

While I'm mentioning speaker positioning, let me note that open baffle speakers like big rooms. The 36" by 60" baffles mentioned before are very happy in my 30' X 30' room with high ceilings. Smaller rooms seem to appreciate smaller open baffles, but it remains true that large rooms will give the best results.
An important issue that comes up is the distance of the open baffle from the wall behind it. Again, this appears to be partly a function of the size of the baffle, but you need to allow considerable distance. I use 4' to 5' with big baffles, and you should be prepared for 3' for even modest baffle sizes.

Your results will vary, but the important thing is that you consider these issues and try out various positions for your speakers just as you would try out different crossover and equalization settings.

So good luck and have fun. If you Google “open baffle loudspeaker” you'll get about 3 million results. Here's some to check out:

www.firstwatt.com
www.passlabs.com
www.diyaudio.com
www.lowther-america.com
www.blackdahlia.com
www.linkwitzlab.com
www.6moons.com
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