Simple Sizing of the Components in a Baffle Step Correction Circuit
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Introduction :

Over the past few years, I have become very aware of the baffle step phenomenon associated with drivers mounted in rectangular shaped baffles. My first quarter wavelength designs suffered from a relatively weak bass response and a dominating midrange and high end response. Shortly after completing my ML TQWT speaker article, I started to get private e-mails pointing out the possibility of a baffle step diffraction problem inherent in the design. I received several recommendations for changing the shape and size of the front baffle to push the frequency at which the sound field transitions, from radiating into 4π space to radiating into 2π space, lower in the frequency range. The SPL of the midrange frequencies, radiating in 2π space, when compared to the SPL of the low bass frequencies, radiating into 4π space, can in theory present a 6 dB SPL mismatch at the listening position. In a real listening room environment, the theoretical 6 dB SPL mismatch is realistically more like 3 to 4 dB once the room's reinforcement of the bass frequencies is taken into account.

Method of Calculation :

From a given driver's Thiele / Small parameters, the SPL at a 1 m distance for a 1 watt input can be determined. For example, a typical 8 inch diameter mid-bass might be listed by the manufacturer as being 88 dB efficient. Manufacturers typically measure their driver's response in 2π space using a very large baffle. If the same driver were placed in a rectangular enclosure and mounted in an anechoic space, the measured efficiency for the driver below the baffle step transition, the bass frequencies, would be 82 dB (88 dB – 6 dB). The efficiency would then increase to 88 dB as the baffle step phenomenon comes into play for the midrange frequencies. The frequency midpoint of the transition from 4π space to 2π space can be approximated by the following relationship.

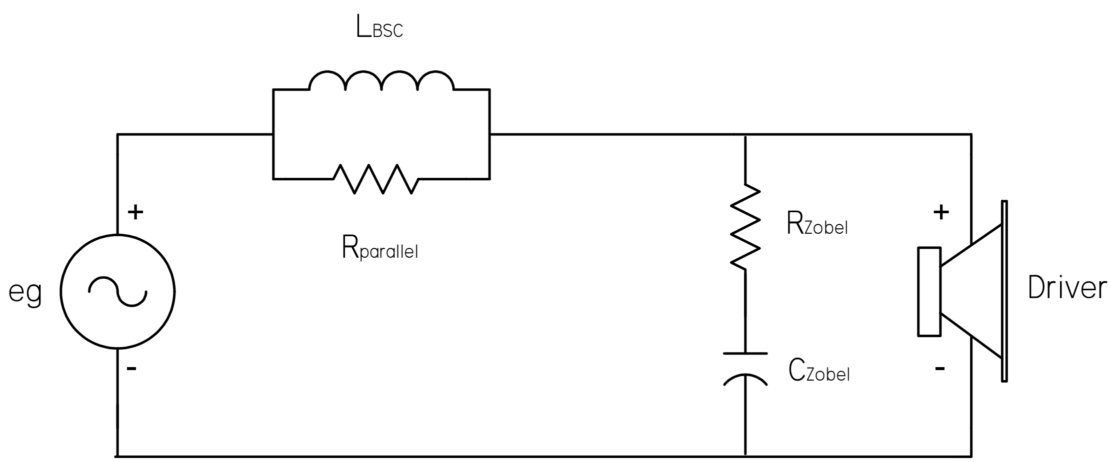
$$f_3 = 4560 / W_B$$

where

W_B = width of the baffle in inches

Correcting for the baffle step loss at low frequencies can be handled in at least two ways. First, one could extend the baffle width W_B to a very large value pushing the transition frequency below the operating range. This would lead to an extremely large baffle if a flat SPL response was required down to 40 Hz. A second method is to apply a passive filter between the amplifier and the driver as shown in the schematic at the top of the following page. I have used the second method in all of my speaker designs and found it to be a very simple, elegant, and powerful tool for adjusing the balance of the SPL response across the entire frequency range.

Schematic of a Baffle Step Correction Circuit



There are different ways to design this filter. In the past, I use the finished speaker's measured impedance and SPL response as input into a MathCad worksheet for simulating the impact of the circuit and arrive at an initial filter design. Then after the filter is constructed and installed, I fine tune the values by listening to the speaker located in my room. Listening is always the final proof test.

But most DIY speaker builders do not have the measurement tools required to design the baffle step correction circuit this way. Recently, I put together a simple calculation that I use as a sanity check on my MathCad simulations. It also occurred to me that this simple calculation method might be helpful for others looking to size baffle step correction circuits.

There are two parts to the circuit schematic shown above. First, there is a Zobel correction circuit placed across the driver's input terminals to flatten out any rising impedance due to the voice coil inductance. Generally accepted equations for sizing the Zobel circuit components are shown below.

$$R_{Zobel} = 1.25 \times R_e \qquad \text{ohms}$$

$$C_{Zobel} = L_{vc} / (1.25 \times R_e)^2 \qquad \text{farads}$$

where

R_e = driver's DC resistance in ohms

L_{vc} = driver's voice coil impedance in henries

The second part is the baffle step correction circuit components denoted by L_{BSC} and $R_{parallel}$ in the schematic shown at the top of the previous page. To calculate the values of these two components, the following equations are provided.

$f_3 = 4560 / W_B$ Hz

$L_{BSC} = R_e / (2 \times \pi \times f_3)$ henries

$R_{parallel} = R_e \times (10^{dB/20} - 1)$ ohms

where

W_B = width of the baffle in inches

R_e = driver's DC resistance in ohms

$\pi = 3.141592......$

dB = amount of attenuation required

Using these relationships, a baffle step correction circuit is sized in the following sample problem.

Sample Problem :

Given the driver and enclosure parameters :

$R_e = 8$ ohms

$L_{vc} = 0.4$ mH

$W_B = 10$ inches

Zobel Circuit Elements :

$R_{Zobel} = 1.25 \times 8 = 10$ ohms

$C_{Zobel} = 0.0004 / (1.25 \times 8)^2 = 4$ uF

Baffle Step Correction Circuit Elements :

$f_3 = 4560 / 10 = 456$ Hz

$L_{BSC} = 8 / (2 \times \pi \times 456) = 2.8$ mH

dB = 3 db assumed

$R_{parallel} = 8 \times (10^{3/20} - 1) = 3.3$ ohms

Final Tweaking :

Using these calculated values of circuit components, a filter can be constructed and installed between the amp and the driver as shown in the schematic. Now you need to listen and tweak until it is just right for your room, system, and personal taste. I usually perform the following steps to arrive at the final configuration.

1. Adjust the value of $R_{parallel}$
   a. If the bass is still too weak, then the amount of attenuation is too little. The value of $R_{parallel}$ should be increased until the bass seems to be balanced with the rest of the SPL spectrum.
   b. If the speaker sounds dull and lifeless, the value of $R_{paralllel}$ is too high. Reduce the value of $R_{parallel}$ to bring life back into the music.
   c. Continue adjusting $R_{parallel}$ until the speakers sound right to your ears. It is probably best to use acoustic music as a reference during this adjustment period.
   d. To remove the effect of the baffle step correction circuit completely, substitute a piece of speaker wire for $R_{parallel}$.
2. Adjust the value of L_{BSC}
   a. Sometimes the calculated value of L_{BSC} is a little high. This sets the frequency range over which the baffle step filter attenuates the midrange and high frequencies. If the mid bass sounds depressed, then a lower value of L_{BSC} should be used. I typically perform this adjustment last once I am satisfied with the balance, between the very low bass and the midrange, I have achieved with the resistor.
   b. Decreasing the value of $L_{\mathbf{BSC}}$ will tend to warm the sound of the speaker if the previous value produced a depressed mid bass response.
   c. Always round down to the next available inductor size, having too low of an inductor value is a lot less problematic then having too large of an inductor value.
3. Final location of the circuit
   a. I usually spend many hours, over several days if not weeks, swapping resistor and inductor values until I am satisfied with the results.
   b. It is a real advantage to mount the circuit temporarily outside the enclosure during this time period.
   c. When the final version is ready, the circuit can be mounted inside the enclosure and soldered into place in the positive internal speaker lead.

Conclusion :

The preceding calculations and tweaking suggestions are intended to get you started down the path to an optimized baffle step correction circuit. There is no single answer for every speaker system and installation, be prepared to tweak until you are completely satisfied. You are the final judge and the only person that needs to be comfortable with the results.