Getting the Most Out of A Reflex-Type Speaker

BENJAMIN B. DRISKO

Design data, constructional ideas, and simple tests for this type of loudspeaker.

THE so-called "bass reflex" or acoustical phase inverter provides one solution to the loudspeaker mounting problem. To those whose available space or funds do not permit the more cumbersome exponential horn it may be made to provide considerably more uniform response than any simple open-backed cabinet and, with a little care in the adjusting procedure, will give less hangover than almost any other type of mounting.

The minimum requirements for utilizing the following procedure are: 1. A suitable loudspeaker of the direct radiator type and an accurate knowledge of its resonant frequency. 2. Some lumber, preferably plywood and a medium amount of carpentry skill. 3. Some acoustical absorbing material; ordinary carpet lining is very satisfactory. 4. A small step function signal generator; a number 6 dry cell is eminently satisfactory and a flashlight cell will do.

Hangover

If one excites the voice coil of the unmounted speaker with constant current at variable frequency and measures the voltage at the voice coil terminals, one finds usually a pronounced rise at some point, generally between 40 and 100 cycles for ordinary speakers. Also it will be noted that the amplitude of the diaphragm motion is a maximum at this frequency. We are observing the primary resonance between the mass of the diaphragm or cone, the voice coil and other moving parts and the stiffness or restoring force provided by the spider, surround, etc. If the impedance curve is carefully plotted, the frequencies of the half-power points may be noted and the Q of the vibrating system computed from the quotient of the resonant frequency by the half-power *b* and width. It will usually be found that this Q is between 4 and 8, and in an infinite baffle will usually drop to about half its free air value. Since critical damping corresponds to a Q=0.5 it is easy to see why this type of speaker is prone to hangover.

By analogy we may compare the above state of affairs to a series LC circuit which is said to be resonant. By this same analogy the reflex enclosure, which is really a Helmholtz resonator driven by the back of the cone, is an anti-resonant circuit similar to a parallel LC combination. This is a step in the right direction toward reducing the effective Q of the system, both by detuning it and by the added radiation resistance of the port of the bass reflex enclosure. If one now repeats the above impedance plot with the speaker in such an enclosure he finds two frequencies where the impedance has a peak on either side of the original resonance peak. If the resonator has been tuned to the same frequency as the diaphragm, the two peaks will be about equal in magnitude and both will have much lower Qs than the infinite baffle. If the tuning is slightly in error, one of the peaks will be higher than the other and will have a higher Q, which, for purposes of this paper is undesirable. With no sound-absorbing lining in the box, the damping will still be much less than critical and one is apt to find little sharp peaks in the impedance curve at frequencies for which some inside dimension is a multiple of a half wavelength.

The anti-resonant frequency of the Helmholtz resonator may be computed from the formula $f=2070\ (A^{1/4}/V^{1/2})$ where A is the area of the port in square inches and V is the volume of the box in cubic inches. The design is still indeterminate inasmuch as there are an infinite number of boxes of different volumes, each with a suitably sized hole and all resonant at the correct frequency. One limitation may be placed by the following. The resonator frequency formula is only good where the maximum dimension is small in comparison with the wavelength. If we interpret small to mean between 1/3 and 1/10 we come out about right. Another rule, this time empirical, is that the area of the port should be beweeen ½ and 1 times the area of the diaphragm. This results in a 4 to 1 latitude for size and it is doubtful if you could tell the difference between any two within those limits. It is considered good practice to keep the shape of the box somewhere near a cube. If the depth, width and height are in 2-3-4 proportion a fairly satisfactory product results, both acoustically and as a piece of furniture of convenient size.

A sample computation follows: Let's say that we are starting with a 12″ speaker whose active diaphragm area is 82.6 in.^{2} and whose resonant frequency is 70 cycles. We decide to make the port about ¾ of the diaphragm or 60 in.^{2} This gives a 6 x 10 opening which will look well below a 10¼″ speaker mounting hole. Rearranging the resonator formula

$$V = \left(\frac{2070}{f}\right)^2 \sqrt{A}$$

or, for our hypothetical case,

$$V = \left(\frac{2070}{70}\right)^2 \sqrt{60} = 6770 \text{ cubic inches}$$

If 2x, 3x and 4x are the depth, width and height respectively of our box, then the volume $=24x^3=6770$ and $X=6.56$ and our box comes out to have inside dimensions of 13⅛″ x 19¾″ x 26¼″. This is not an inconvenient size, so let's go on from there.

Building the Baffle

The next step depends upon your skill as a carpenter. It is probably in order to make some sketches to see how much larger than the above inside dimensions you have to cut the various pieces to get the proper overlap at the corners and also to most economically utilize the available lumber. As to thickness, ⅝″ to ¾″ plywood is considered good practice and yet one made out of ½″ plywood for a dancing teacher who wanted it very portable showed no serious misbehavior. It, of course, had to have corner blocks for structural reasons. While you're in the sketching department, lay out some furring strips, anything from ½″x½″ to 1″ x 1″ will do, and sufficient in quantity and sizes so that all six inside faces of the box can be covered with the carpet lining, hair felt, rockwool or whatever you choose, but attached by means of the furring strips so that there is a dead air space behind each piece of felt, between the felt and the inside of the box and as thick as the furring strip. This takes a bit of doing and may be done in a variety of ways. Be guided by how much the thing will have to be handled and bumped around, inclining toward a minimum volume of furring strips and labor but being sure to get the inside of the box pretty well covered and to have the dead air space between the lining and the box. The purpose of all this is to further reduce the Q and hopefully to achieve critical damping.

It is also considered good practice to have the port as close to the speaker hole as possible. The reasons are a bit obscure, the principal one being to have as near a point source as possible. At this point it might be well to digress for a moment and discuss the final location of the whole outfit. The details are much too long to go into here, but it has been shown with the very best scientific rigor that a corner of the room is by far the best place, and by corner we mean really in the corner with no air spaces between the sides of the box and the walls and floor. This necessitates some elaborations in case there is a projecting base board. But it pays.

There is, however, another alternative. The whole box may be elevated to the upper corner of the room, between the two walls and the ceiling. Furthermore, since the speaker is fairly directional in the upper register it would be desirable to have it pointing in the general direction of the listeners. This calls for a five-sided platform with the cater-cornered side pointing down the long diagonal of the room. For reasons that are not too clear, by far the best-sounding reflex-type speaker which has come to my attention was of this construction and, furthermore, it was noticeably better up against the ceiling than down on the floor. The port was in top end of the box top when it was on the floor (the bottom when it was up against the ceiling) which brings us to the reason for the digression. If you can talk yourself into a corner location for the cabinet as a whole, then there is some precedent for locating the port anywhere you choose, but if the speaker must sit in the middle of a flat wall, then it may be wise to keep the port on the same side as the speaker and closely adjacent thereto.

Tests

Let us now suppose that you have the reflex cabinet completed, the speaker mounted and leads coming out at some appropriate spot. Procure the d-c signal generator, namely one 1½ volt dry cell and attach one voice coil lead to one terminal. Touch the other lead to the other terminal and alternately make and break the circuit a few times. A moment's experimenting will indicate whether the lead and the battery terminal are clean enough to give a sharp, instantaneous make and break. This is important. If either make or break sounds scratchy, try scraping the contacts or better still, if you have a telegraph key handy, use it instead. A plain knife switch might do, but a switch that makes an audible click will not do unless you can have an assistant do the clicking for you at some remote point so you do not hear the switch click.

What you should hear on both make and break may best be described as a "bong." It is more than an instantaneous click, inasmuch as it has a recognizable pitch. If there is a piano near-by you could, in a few tries, find the note that matches it. The motion of the diaphragm and/or air is not yet critically damped. In pulse circles, this is called "ringing," a most satisfactory word. This ringing can be cured by application of the proper acoustic resistance to the port. So far as I know, the rules have not yet been worked out—from here on in you're on your own and its strictly cut-and-try.

It may well be argued that you should hear ringing anyhow unless you are in an anechoic chamber, because even if the speaker is perfect, the acoustic click produced by the speaker will excite the room in one or more modes and you will hear the room ring. To these scoffers I hasten to point out that the evidence that it can be done is that it has been done, twice to my knowledge, once with benefit of audio oscillator and v.t.v.m. for plotting impedance curves as above and once without. The oscillator helps, but is not a necessity. If you listen in the opposite end of the room, and if it is a very live room, then you do undoubtedly hear mostly room ringing, but conversely if your ear is a foot or two from the diaphragm and the room is reasonably dead, then you are to all intents and purposes listening to the speaker ringing. One way of evaluating the deadness of the room in a rough way is to get some people into it and in conversation. Get as far away as possible still within the room however, and alternately plug and unplug one ear. The difference between binaural and monaural listening is much greater in a live room. In other words if you can still understand the conversation perfectly when listening with one ear the room is plenty dead enough for this experiment. It is, however, wise to keep fairly close to the speaker.

So now we're ready to go to work on the port. What we want is something with many small interstices that will cause acoustic losses. If the holes get smaller and smaller and the intervening material gets heavier we finally wind up with a solid rigid member. If you place a piece of board over the port you will still hear ringing, and probably indistinguishable in pitch from that heard with the port open, but somewhere between completely open and completely closed there is a material that has just the right resistance. It might be an old sweater, a turkish towel, a burlap bag or a few layers of window screening. Here's where the oscillator helps. If you have plotted two curves, one with the port open (double hump) and one with the port closed (single hump) then as you try each new material you can tell at a glance whether it is too heavy or too light and what to try next is somewhat simplified. However, it's still cut-and-try anyway you look at it.

The amount of audible ringing depends upon the total amount of damping in the system and a not inconsiderable portion may be supplied by the generator feeding the voice coil. When the battery circuit is closed the voice coil is practically short circuited, i.e., the electrical damping is very high. When the battery circuit is broken the voice coil is open-circuited and the electrical damping is zero. We may therefore in the course of our experimenting find a material such that the sum of the dampings produced by it and the battery together will be critical. In this circumstance we will hear a "tick" when the circuit is made and a "bong" when it is broken. Make no mistake about the difference between the tick and the bong. You have to listen sharp but it is a very real difference, the tick being cleaner and sharper and without the slightest taint of any pitch whatsoever. So if we hear tick-bong-tick-bong as we close and open the switch we know that we are very close and on the low side and in one to two more moves we should hear tick-tick-tick-tick. In one case we started out with a loosely knitted, light, woolen sweater. One layer did practically nothing. Four layers got us to the tick-bong stage. The only thing we could find at the moment that was heavier than 4 layers of sweater was a piece of the ozite we had used for lining. It was too heavy, giving almost the same curve as a plain board. We then found that the ozite could be split and one half thickness of ozite turned out to be just the right combination. In another instance two layers of coarse burlap did a very good job. In both cases the final results were such that with an assistant to handle the switch it was impossible for the listener to distinguish the difference between the make and the break and both said tick. It helps to have the material stretched or so secured that it doesn't vibrate, otherwise it may contribute reactance as well as resistance.

Unsolicited and uncoached comments regarding the comparison between the reflex type cabinet with and without critical damping as per above might be summed up as follows: On organ music (steady tones), no difference, on percussion or lows with transients, pizzicato, etc., the damped speaker puts out somewhat less total volume of lows but the various low-frequency instruments stand out much more clearly. Several records with what formerly sounded like kettle drums turned out to be plucked strings. Male speaking voices reproduced 20db too loud lose most of the rain-barrel effect.