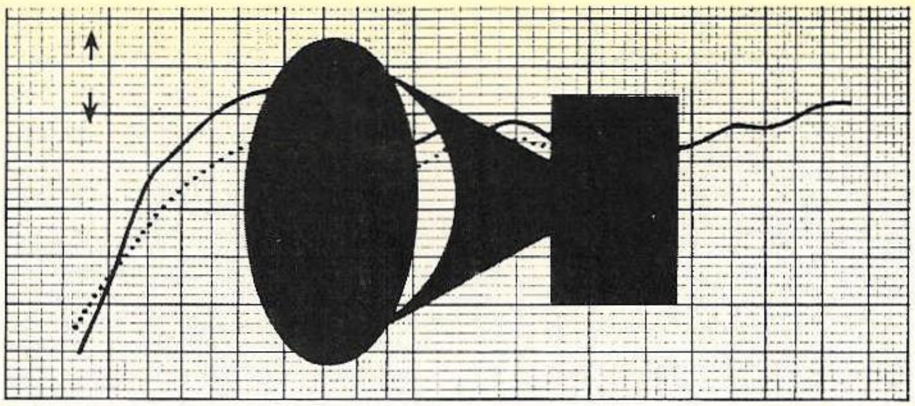


# The Importance of Speaker Efficiency

By GEORGE L. AUGSPURGER

The case in favor of the high-efficiency hi-fi loudspeaker system is presented here by one of its proponents. How does this system compare with its low-efficiency rival?

SOME audiophiles insist that all low-efficiency loudspeaker systems sound "flat" and "mushy." Others believe that all high-efficiency systems sound "harsh" and "piercing." While it is wasted time to try to change some people's opinions, most of us would like to know what effect efficiency *does* have on the performance of a loudspeaker system.

One misconception can be cleared up immediately—there is no particular characteristic sound *necessarily* associated with either high-efficiency or low-efficiency loudspeakers. You can find a loudspeaker to suit your personal taste from either group. If this is true, you may say, why should anyone buy a low-efficiency loudspeaker. The answer is simply that a good low-efficiency system can be made much smaller physically than its high-efficiency counterpart.

### Loudspeaker Efficiency

To understand this a little better, let's first of all establish what we mean by loudspeaker efficiency. This can be boiled down to simple terms: efficiency is nothing more nor less than the ratio of power in to power out. If we must pump 20 watts of electric power into a loudspeaker to get 1 watt of acoustic power out, it is obviously 5% efficient.

It isn't really quite so simple because the frequency response and distribution pattern of a loudspeaker both affect its apparent over-all efficiency. Moreover, an audio amplifier tends to feed constant voltage (rather than constant power) to a speaker load. For general purposes, however, we can talk about efficiency comparisons between loudspeaker systems as long as we understand that these are based on what we hear rather than measurements.

The general order of loudspeaker efficiency is about 1 to 10 per-cent. High-quality horn-loaded systems may run as high as 25 or 30 per-cent. Remember that if one loudspeaker has half the efficiency of another, it requires twice as much electrical power to produce the same sound intensity. When this means the difference between buying a 30- or a 60-watt amplifier, it becomes something to think about.

### Bass Performance

The loudest arguments about low- *vs* high-efficiency loudspeakers center about which woofer delivers the solidest whump. So, to keep from getting tangled in excessive complications, let's talk about low-frequency units only.

Rather than start with theoretical design considerations (which are available in standard texts), let's take a look at what happens in practice.

Fig. 1 shows the free-field response of two 15-inch loudspeakers, each mounted on an infinite baffle. The speakers have the same resonant frequency and are driven by the same voltage. Speaker *A* is a high-quality, very efficient loudspeaker designed for horn or reflex loading. *B* is designed specifically for use on infinite baffles or in large sealed enclosures. (The curves of Fig. 1A and B were run using analogue circuits of representative loudspeakers. For further information on this subject, refer to the article "Application of Electric Circuit Analogies to Loudspeaker Design Problems" by B. N. Locanthi in the *Proceedings of the IRE-PGA,* March, 1952.)

The output of *B* at 40 cps is only 5 db less than at 400 cps—its bass response is smooth and extended. Speaker *A*, on the other hand, is down 13 db at 40 cycles compared to its output at 400 cps. If uniform bass response in a large sealed box is the only criterion, *B* is obviously the better unit.

Yet, speaker *B* does not have *more* bass than *A*. Rather, its efficiency above 40 cps is held down in proportion. And since linear bass response is achieved at the expense of 10 db through the rest of its range, *B* requires ten times as much electrical power to deliver the same average loudness!

The preceding example gives no clue to the various factors which affect efficiency. Do not be misled into thinking that just because a particular loudspeaker is inefficient, its bass response must be smooth. It is quite easy to lose on both counts. Conversely, a high-efficiency system can be made to exhibit excellent low-frequency characteristics. This seems to be a contradiction of what is shown by Fig. 1, but these two loudspeakers, remember, are mounted on an infinite baffle.

A single loudspeaker mounted on an infinite baffle (or in a sealed enclosure) is always comparatively inefficient in the bass range. The reason is that the cone is not big enough to move much air at low frequencies. It is almost like trying to paddle a canoe with an iced-tea spoon.

### Bringing Up the Bass

Suppose that instead of attenuating the mid-range, we try to bring up bass efficiency by making the cone move more air. There are three practical ways to do this:

1. Use more than one loudspeaker. Some of the finest custom installations employ banks of four or more high-efficiency loudspeakers for really impressive bass reproduction.

2. Use the speaker to drive an exponential horn. A full-size horn, however, must be immense to reproduce really low frequencies efficiently. Even the size reduction allowed by corner placement does not result in an inconspicuous piece of furniture. Fig. 5 shows the construction of a rear-loading theater horn which houses two high-efficiency 15-inch drivers.

3. Mount the loudspeaker in a matched reflex enclosure. A correctly designed reflex enclosure adds considerable air loading to the cone in the 30- to 60-cycle region. If everything is properly worked out, the cone doesn't have to move any farther at 50 cps than it does at 500 cps to generate the same sound intensity.

But even reflex enclosures must be fairly large. About 5 cubic feet is the minimum internal volume which will achieve good bass balance from an efficient 15″ speaker.

For those who have very little space available and still want quality sound reproduction, some other type of system must be found. Suppose we take a low-efficiency speaker such as that of *B* in Fig. 1 and make the cone suspension so compliant that its free-air resonance lies in the 15-20 cps region. We now install this speaker in a fairly small sealed box.

The springiness of the air trapped in the box will add to the springiness of the speaker's mechanical suspension. But the loudspeaker can't tell the difference between mechanical stiffness and pneumatic stiffness—springiness is springiness. So it behaves exactly as if it had a higher resonant frequency and were mounted on an infinite baffle.

In such a system, the mass and compliance of the loudspeaker cone assembly must be established in relation to the internal volume of the enclosure. A 10-inch speaker in a one-cubic-foot enclosure can be made to have smooth bass response down to 35 or 40 cps if desired.

This sounds impressive, but it doesn't tell the whole story. The maximum efficiency which can be achieved in the low bass region is still a function of the size of the cone, and a 10″ cone has to move awfully far to generate much sound at 40 cps. In practice, the speaker is at an even greater disadvantage since the effective cone diameter is always less than the rated size. A 10-inch speaker usually has an effective radiating diameter of about 8½ inches.

The advantage of a large radiating area is clearly demonstrated in Fig. 2. The curves show the free-field response of two high-quality woofers, both designed for closed box installation. The 10-inch speaker is mounted in a 1.2-cubic-foot enclosure and the 15-inch unit is mounted in a 6-cubic-foot enclosure. Note that with the same power input the 15″ speaker is about 4 db more efficient than the smaller unit.

In terms of power requirements, 12 watts into the small speaker will produce the same sound intensity as only 5 watts in the big speaker.

If we lighten the cone of the smaller speaker so that its mid-range efficiency is 4 db higher, bass response will seem thin by comparison. In relation to efficiency at 500 cps, bass will start to droop around 80 cps instead of 50 cps.

So, if a loudspeaker is to be designed for use in a small box, the choice has to be made between efficiency and the usable low-frequency limit. And no matter how the various factors are juggled, the efficiency of this type of high-fidelity loudspeaker system re-

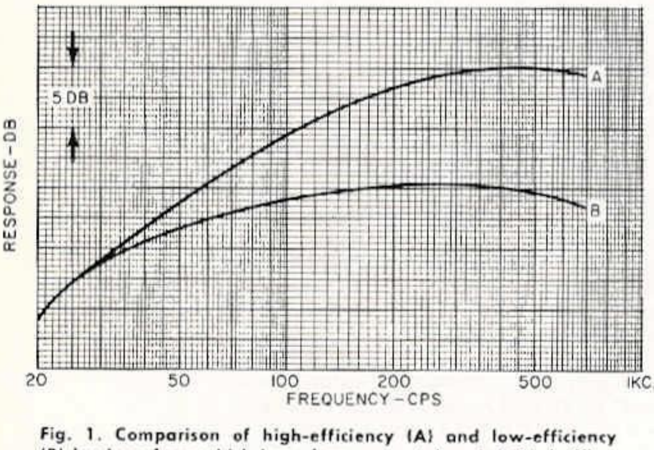



**Fig. 1. Comparison of high-efficiency (A) and low-efficiency (B) loudspeakers which have been mounted on infinite baffles.**

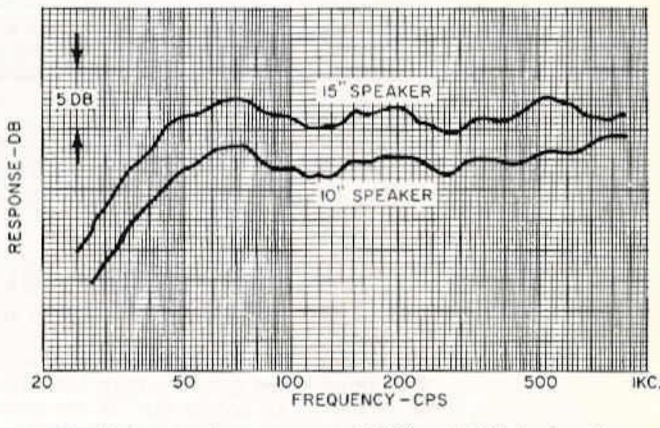



**Fig. 2. Comparative responses of 10″ and 15″ loudspeakers showing the advantage to be gained by larger radiating area.**

**Fig. 3. Medium-efficiency 8″ speaker in 1 cubic foot enclosure.**

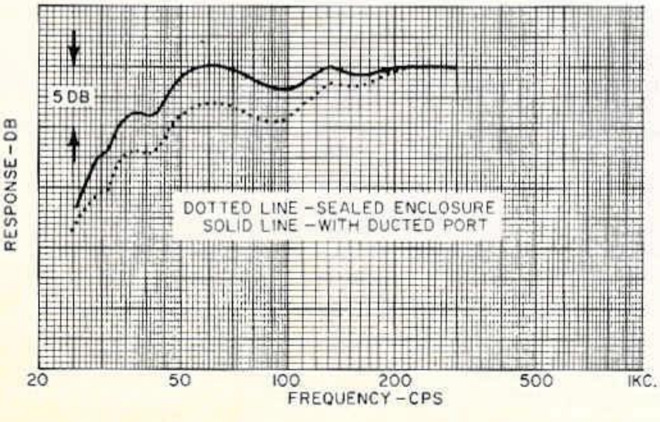
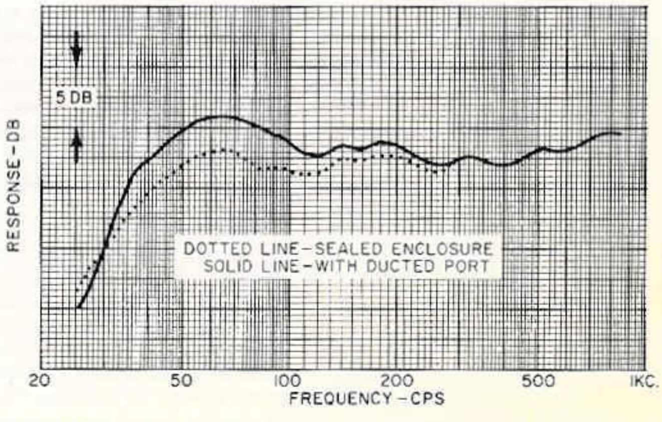



**Fig. 4. Ten-inch speaker response in a 1.2 cubic foot enclosure.**



mains comparatively low at best.

### Adding a Vent

You may ask, since a reflex enclosure enables us to get good bass from a high-efficiency system, why can't we put a vent in a small box to raise efficiency?

We can. But the area of the port has to be quite small (even with an added duct) to tune the cabinet to the optimum frequency. When port area is considerably smaller than cone area, the increased radiation at low frequencies is quite a bit less than that realized from more conventional reflex designs. Nevertheless, a useful gain in bass efficiency can often be achieved.

Fig. 3 shows the response of a small commercial system using a full-range 8-inch loudspeaker in a one-cubic-foot enclosure. The system was measured in a fairly large listening room. Note that the ducted port in this system clearly improves performance through the 40-100 cps region. Porting the cabinet is actually doubly worthwhile because both bass efficiency and power handling ability are increased.

If we try the same technique with the 10-inch woofer in its 1.2-cubic-foot enclosure a similar usable increase in bass efficiency is realized. Fig. 4 shows the response of this combination with and without a small ducted port. The added radiation from the port gives a little hump in bass response around 60 cps.

The bump can be smoothed out by making the speaker a little more efficient, bringing up the response above 100 cps. In commercial practice, however, the bump is more apt to be left in at the expense of over-all efficiency. Speaker manufacturers have learned the truth of the comment that most people like the sound of a little bump in the bass as long as the advertising copy assures them that the speaker is "really" flat.

This discussion of low-efficiency systems does not begin to cover all the design factors involved, but it should help to clarify two important points:

1. There is no magic in the design of small low-frequency loudspeaker systems. The basic characteristics are determined by physical laws which stubbornly refuse to change.

2. Extended bass response in a small loudspeaker system is always achieved at the expense of over-all efficiency.

In connection with the latter point, it should be emphasized again that there is a difference between "necessarily inefficient" and "wasteful." Some bookshelf speaker systems are inefficient simply because they are wasteful. It is extremely important that all design factors be carefully correlated for optimum results, and that extremely close tolerances are imposed during manufacture. A *Cadillac* uses more gasoline than a *Volkswagen*, but a car which gets less than 40 miles to the gallon is not necessarily a *Cadillac*.

The main differences between low- and high-efficiency loudspeaker systems should now be clear. To sum up thus far:

*A high-efficiency system raises bass efficiency by utilizing some sort of additional acoustic loading.*

*A low-efficiency system accepts the limitations of the unaided speaker at low frequencies. The efficiency of the rest of its range is deliberately reduced in proportion.*

### Amplifier Power

While a good 30-watt amplifier is ordinarily adequate to drive an inefficient loudspeaker in a home installation, the overload margin is not great. Instantaneous peaks in ordinary program material can easily reach the equivalent of 15 or 20 watts, even at "normal" listening level. Consequently, the overload characteristics of the amplifier are important when it is used to drive a low-efficiency loudspeaker. If the amplifier recovers from overload quickly and smoothly, chances are that such momentary peaks will not be heard as distortion even when the peak power rating is exceeded. But if the amplifier goes to pieces when overdriven, all sorts of audible mush will be heard when the system is pushed too hard.

Since the efficient loudspeaker system delivers the same listening level at a fraction of the power input, amplifier characteristics are not so critical. In an actual test, a 50-watt high-quality amplifier was used to drive one of the small low-efficiency speakers and the gain turned up until musical peaks were overloading the amplifier. The speaker was then replaced by a highly efficient corner horn and the system run at the same loudness. Under the latter condition, instantaneous peaks required less than the equivalent of 4 watts from the amplifier!

This important difference in power requirements is indirectly responsible for a difference in dynamic range as well. A loudspeaker can be built to take just so much electrical power. Even though a low-efficiency speaker may be capable of long cone travel, it cannot generate the audible intensity of a high-efficiency system: the great amount of power required for high intensity may damage the voice coil. Consequently, even with unlimited electrical power available, the dynamic range of a small speaker system cannot approach that of a good big system.

In fairness, this limitation in dynamic range is of little interest to many listeners. At "average" loudness, neither type of system is apt to be momentarily overloaded. But the difference can be easily demonstrated under the right conditions. The man who wants to hear the smash of cymbals, the "bite" of a *Steinway* grand, at full concert intensity, will not be able to duplicate these sounds readily with a bookshelf-type loudspeaker system.

"This is all very interesting, no doubt," says the prospective customer, "but you still haven't told me which type of system is better."

The answer is that if all other considerations can be ignored, a good big system is almost always better than a good small system.

An interesting trend recently has been the introduction of new loudspeaker systems which make the best of both design philosophies. A 15-inch medium-efficiency woofer capable of long linear cone excursions can generate really awesome bass in an enclosure no larger than 6 cubic feet. In conjunction with matched high-frequency transducers, this makes a deluxe speaker system which, while not "bookshelf size," is not inordinately large. Several manufacturers have introduced such systems and acceptance by critical listeners has been extremely good. ▲

**Fig. 5. A rear-loading J. B. Lansing theater horn which will bring out the full bass capabilities of a pair of fifteen-inch high-efficiency bass drivers.**