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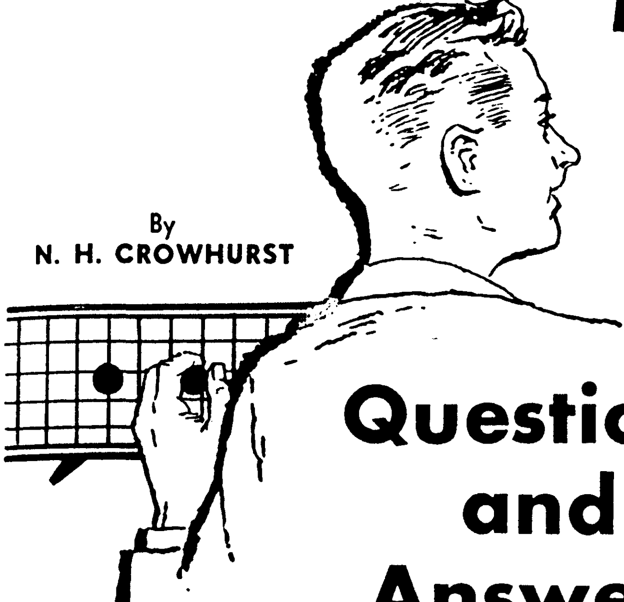
High Power vs Low Power Amplifiers

Questions and Answers



By
N. H. CROWHURST

An excellent article that should go a long way in settling the power argument for some time to come.

AMONG high-fidelity people, whether by that term you imply the manufacturer or the user of the equipment, there are two very definite schools of thought, as soon as the question of power output from an amplifier is raised. One says the trend toward big, powerful amplifiers (30, 50, or 100 watts) is quite unnecessary, all you need for the average living room is, at the most, 2 watts, with maybe some "headroom," so perhaps you should get an amplifier with a 10 to 15 watt rating.

The other school says you don't have sufficient headroom to handle transients and special effects in the musical program unless you do go to high power amplifiers, rated at 30, 50, or 100 watts (the higher the better). There are very definitely two points of view here, but each protagonist presents his own viewpoint as if it were the only one.

One writer will tell the reader he really doesn't need an amplifier with 30 watts output, let alone *more* than that, while another writer comes along and tells the reader that any amplifier with less than a 30-watt output is totally inadequate. This leaves the unfortunate layman (Mr. Average American) in a state of confusion.

A simple way to tackle this problem seems to be to deal with the most basic questions from which it derives, so each reader can judge for himself.

Question 1: Why do some recommend high power, say 50 to 100 watts, when an amplifier with 10 to 15 watts sounds quite good?

Let's simplify the issue a little by just taking the two extreme wattages. The contrast for ratings in between this will be that much less. Take an amplifier of 10 watts as compared with an amplifier of 100 watts. To the newcomer, this gives the impression that the 100-watt amplifier should sound 10 times as loud as the 10-watt amplifier. Unfortunately this is not true, due to a law, considered elementary by physiologists, called Fechner's Law.

This says that the sensation of loudness, like any other human sensation, is dependent upon the logarithm of the intensity of stimulus. Simply stated, the change in *sensation* of loudness is proportional to intensity *ratio*, not intensity *difference*, or the ratio between one power and another. As the human loudness sensation, at 1000 cycles at any rate, extends over a power ratio of 1,000,000,000,000 to 1, this means a ratio of 10 to 1 is just 1/12th the loudness "difference" between being just audible and the maximum intensity audible as sound. (Fig. 1.)

Expressed this way, even a 10 to 1 ratio, from 10 watts up to 100 watts, represents not a very big change in loudness. A change from 25 to 50 watts becomes only just perceptible—it is 3 db, and a change from 10 watts to 100 watts is only very little more than 3 times as much "difference" in loudness sensation—10 db, although one is a step-up of 2 to 1 in power, while the other is 10 to 1. This should help to set the stage for what follows and explains why the loudness sensations created by amplifiers at different power ratings are not as different as might be expected just by considering the power rating. A 50-watt amplifier gives 5 times as much power as a 10-watt amplifier, but this is only 7 db.

Larger power *can* be a disadvantage, unless the amplifier has a lower hum level. If the hum level is the same in each case, the hum from a 100-watt amplifier will be 10 db higher than that from a 10-watt amplifier. And loudness sensation at 60 or 120 cycles, the hum frequencies, is about three times as sensitive, so 10 db here is equivalent to 30 db at 1000 cycles. It can be the difference between an inaudible hum and one that is quite annoying during quiet passages.

Question 2: How is it that some 15-watt amplifiers sound louder and cleaner than some 50-watt amplifiers?

The hum question, just mentioned, can be a factor. There are others, but without getting involved in amplifier design and performance characteristics in detail, this depends on what is termed the "overload characteristic" of the amplifier.

Many amplifiers, rated to give 50-watt output, certainly do give 50 watts output. But try to make them give 51 watts and you might as well strive for the moon! It is not just that they refuse to give more than the 50 watts, but when the input is increased beyond that required to give 50 watts, the waveform becomes completely dis-

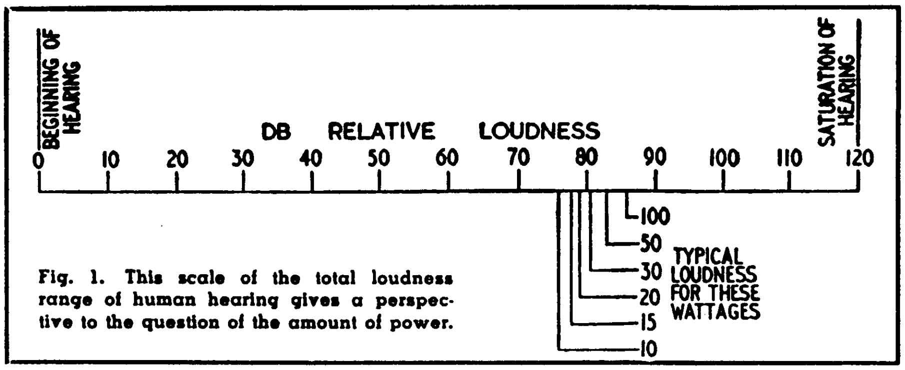


Fig. 1. This scale of the total loudness range of human hearing gives a perspective to the question of the amount of power.

torted. It is suddenly extremely evident to the listener that the amplifier has reached "the top."

On the other hand, many 15-watt amplifiers use quite a different kind of circuit. They may not give too much more than 15 watts before running into distortion troubles. They may become considerably distorted if you try to push 20 watts out of them. But the difference is that you can push in perhaps twice as much input and get a *reasonably* distorted output of 20 watts. (Fig. 2.)

If you push twice the voltage into a 15-watt amplifier, this would give 60 watts *if the amplifier continued amplifying more without distortion.*

Instead, you get 20 watts of tolerably distorted output. But, because you turned the voltage up this much, all of the lower level parts of the program sound like a 60-watt amplifier, and the peaks which should have 60 watts available to amplify them *without distortion* come out at about 20 watts without too serious distortion.

On the other hand, putting the same input into the 50-watt amplifier goes over the 50-watt level and produces *extreme* distortion, so you have to turn the input down to make quite sure the peaks *never* go beyond the 50-watt point. Program material that uses an average power of 5-15 watts with peaks running to 60 watts, will have *occasional* peaks running to 120 watts or more. The so-called 50-watt amplifier may need to be turned down to an average of only 2-6 watts to compare favorably with the 15 watter.

Question 3: Does the kind of loudspeaker you use have anything to do with the power needed from the amplifier?

It certainly does, and this is a point often overlooked in discussing the subject. A high-efficiency loudspeaker, of a type used in home high-fidelity systems, will have an efficiency of not more than 20%. This efficiency would mean an output of 50 watts will give not more than 10 watts actual acoustic power. More often the efficiency will be not more than 10%.

But even with this much efficiency, about 2 watts of electrical output will give you all you need in the living room for the sound to become almost deafening at loud passages. It is quite true as claimed by the "low-power" people, that the actual sound energy you need in the living room is only a matter of hundreds of milliwatts at the peak.

But some loudspeakers, instead of running in the region of 10% efficiency, which is still relatively high for a loudspeaker, only achieve 1 or 2% efficiency. Take a 2% efficient speaker in comparison with a 10% efficient speaker. Obviously, a 10-watt amplifier with a 10% efficient speaker will produce the same acoustic output into the room as will a 50-watt amplifier with a 2% efficient speaker. Both will give a maximum of just 1 watt into the room.

Question 4: Is the use of electronic dividing networks of any advantage in making do with less power?

The whole problem in power rating on amplifiers is one of providing for *peaks*. The average power is quite a small fraction, probably not more than 1/10th, of the peak power necessary to handle the composite audio waveform adequately.

Consider an idealized case, in which the audio composite consists of a single sine-wave frequency in each of the frequency ranges handled by a three-way loudspeaker system. (Fig. 3.) The highest frequency can be considered as riding on the medium frequency, and then this composite can be considered as riding on the lowest frequency. Assume, for simplicity, that each of these waveforms has a peak amplitude of 10 volts across an impedance of 10 ohms, representing a *peak* power of 10 watts or an *average* power of 5 watts.

Table 1. Maximum watts needed. Powers are those normally used as "average" ratings.

ROOM CLASSIFICATION	A		B		C	
PROGRAM CLASSIFICATION	1	2	1	2	1	2
High-Efficiency Speaker (15%)	.25	1	1.25	5	6	25
Medium-Efficiency Speaker (5%)	.75	3	4	15	18	75
Low-Efficiency Speaker (1.5%)	2.5	10	12	50	60	250

Then the total peak voltage will be 3 times 10, or 30 volts, representing a peak power of 90 watts, or an average power of 45 watts. This is what the amplifier rating would have to be to handle the composite signal. And yet the actual total power is only the sum of the three average powers, $5 + 5 + 5 = 15$ watts. So, for this idealized example, we need an amplifier with a *rating* of 45 watts, which means it will handle 90 watts peak, to satisfactorily accommodate the three 5-watt sine waves one on top of the other.

If we separate these three sine waves with an electronic dividing network, before we get to the power stage, so they are handled by separate power amplifiers, each amplifier will only need to handle its own 5 watts individually. This is the kind of argument put forward to show the advantage of an electronic dividing network. Of course, it will also reduce the possibility of intermodulation in the amplifiers and provides other advantageous features, but here we are discussing its possible advantage in making do with less total power.

What the argument just presented does not say is, how you would like a program consisting of just one sine wave in each of the frequency bands handled by your three-way system? It certainly would not sound much like music.

Typical musical programs will normally consist of: a single frequency, maybe with some harmonics, in the woofer range; a composite of several tones in the mid-frequency range, representing chords or the harmony of the music; while the tweeter or high-frequency range will only be carrying a comparatively small amount of power—just a few milliwatts—to give "definition" to the low- and mid-range material.

The biggest amount of power is probably required in the low and middle ranges. So from the standpoint of power division we can consider the problem as being essentially a two-way system. Sometimes there may be no low-frequency component but then the bulk of the power will be presented in the mid-range. This often occurs in musical programs. On the other hand, when there is a predominant low-frequency component, such as when a pleasant string bass "foundation" predominates, the other instruments are usually considerably quieter or at least do not require maximum power.

If you use your system exclusively for reproducing a string quartet, you probably could save on the total power required by using an electronic dividing network system. But if you play a more varied kind of composite material, then this advantage for using it seems to disappear, because on some occasions you will need to present the total power of the system through the mid-range channel. You will probably finish up needing an amplifier, for *both* the low- and mid-range channels, as big as a single amplifier would be to handle the full range.

The high-frequency channel, it is true, can use considerably less power, but there is little possibility of achieving any worthwhile power economy by using electronic dividing networks here.

This does not argue, of course, against their use for reducing possible intermodulation distortion and providing other features that do not come within the scope of this article.

Question 5: Must the amplifier and loudspeaker power ratings be matched? For example, must I use a 30-watt amplifier with a 30-watt loudspeaker?

This question, with variations, often crops up. It is surprising how often someone wants to know why the 30-watt loudspeaker doesn't sound louder than the 10-watt loudspeaker, when both are operated from a 5-watt amplifier, although the latter piece of information is *not* usually volunteered, because it "seemed irrelevant." *The wattage rating of a loudspeaker is not an indication of how loud it will sound, but of how much power can be put into it.*

It does not mean the loudspeaker with the bigger rating will sound any louder if only 2 or 5 watts are actually delivered to it by the amplifier. This is dependent, not upon the *power rating* of the loudspeaker, but on its *efficiency.* If one loudspeaker has an efficiency of 2% and another of 10%, then the 10% loudspeaker will sound louder than the 2% one, *with the same power delivered to it.*

To answer the question directly, the only possible reason why amplifier and loudspeaker power ratings should be matched is to insure the loudspeaker is not damaged by being overworked. For example, a 50-watt amplifier fed into a 10-watt loudspeaker could burn out the voice coil or cause other damage to the loudspeaker. On the other hand, a 10-watt amplifier, worked into a 30-watt loudspeaker, will never cause any damage, because the loudspeaker can never get enough power to fully drive it.

Question 6: Is there any connection between the efficiency and power rating of a loudspeaker?

Only that you need to take both these properties into account to determine how loud the loudspeaker can go. For example, a 30-watt loudspeaker with 5% efficiency will accept 30 electrical watts from the amplifier before causing any serious damage to itself. The fact that it is 5% efficient means that 1/20th *of the 30 watts* or whatever power it actually gets from the amplifier is delivered to the room as acoustic energy (a maximum of about 1.5 watts). This should be more than loud enough for any living room, but to get the 1.5 watts *you will need a 30-watt amplifier.*

On the other hand, a 20-watt loudspeaker may have an efficiency of 15%. This means the loudspeaker will accept 20 electrical watts and, being 15% efficient, will convert these into 3 acoustic watts. Although the power rating of the loudspeaker is lower than the other one it will give a bigger acoustic output into the room from a smaller amplifier (needing only a 20-watt amplifier in place of the previous 30-watt unit).

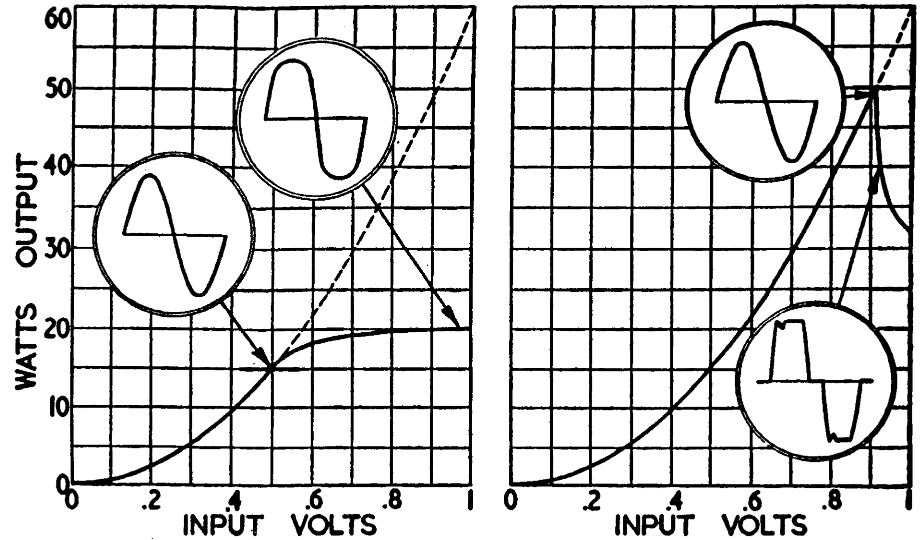


Fig. 2. The power output characteristics of a 15-watt amplifier (A) and a 50-watt amplifier (B) to show reason for difference sometimes noticed. The waveforms inset show output quality up to maximum output and beyond it, in each case.

This says that, in considering the power needed for a system, you need to take into account not only the power rating, but also the efficiency of a loudspeaker. Beyond this there is no connection between the two. If a loudspeaker has a higher power rating it is not an indication, automatically, that it is either less or more efficient.

Some high power compression driver type units, for outdoor use broadcasting from aircraft and similar application, have been built with an efficiency of 50% and a power rating in the region of 150 watts. This means they are capable of delivering some 75 acoustic watts into the air. Of course, they need it to overcome the background noise of aircraft motors. But for high-fidelity use, you could never live in the same room with a loudspeaker like that! This fact is only quoted to illustrate the lack of basic relationship between the efficiency and power rating of a loudspeaker.

Question 7: Can you give me some idea how much power I shall need for my system?

As the foregoing questions have shown, this depends on a number of factors. To try and be specific, we will give a comparative table that shows a range of maximum power required for various typical conditions. Note that Table 1 gives figures ranging from a quarter of a watt to 250 watts, which covers the entire range recommended by both the high-power and the low-power advocates.

Three typical room classifications are listed: *A* is a typical room with tiled floor, smooth walls, and furnishings without much, if any, upholstery —a modern American recreation room —with quiet background, not too near a railroad track; *B* is an average room, with carpet on the floor (not necessarily wall-to-wall), well-draped or open windows, possibly some drapes at entrance to another room, and some upholstered furniture; *C* is a well damped room of considerable size, with wall-to-wall carpeting, plenty of heavy drapes, on walls as well as at windows, and a quantity of well upholstered furniture—a real "plush" suite. Ambient noise from the neighborhood will make some difference here, as well as the size of the room and the number of listeners.

Program classification takes into account two extremes, which might be described as "highbrow" and "lowbrow"! Under these columns the figures are based on the relative peak power rating needed to give a similar impression of peak loudness with the two types. Column 1 is for jazz music, or any variety where the general level remains fairly constant, or compression is used in recording. Column

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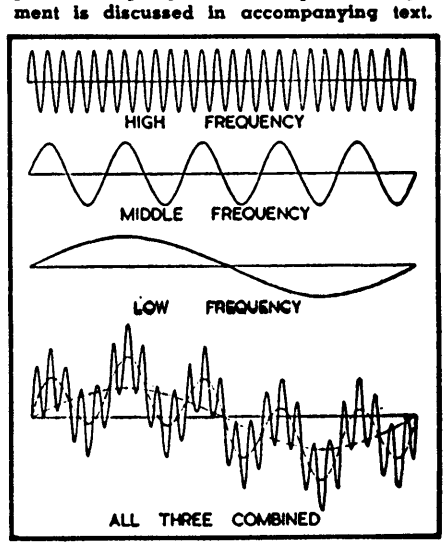
Fig. 3. The waveforms shown here illustrate the argument that the use of an electronic dividing network saves on the total power rating required. Validity of this argument is discussed in accompanying text.



2 is for a recording possessing wide dynamic range, high quality orchestral material.

Three rows of figures are given for different average efficiencies of loudspeaker. The percentages given are average, as no loudspeaker has constant efficiency at all frequencies. As few loudspeakers come with an efficiency rating, this does not help too much, except to give some idea of range, and we hope, some idea where to expect yours to come.

The table is based on approximately equal loudness impression under the different circumstances described. This cannot take into account the difference in loudness at which different people like to listen, and we would rather stay out of that, because differences of opinion are apt to exist on whether a person's choice of level is loud or quiet!

From the answers to these questions, I hope you will be able to decide how many watts you need, approximately at least. It is evident there is no simple rule on the matter. It depends on many things: the efficiency and power handling capacity of your loudspeaker system; the kind of system; how big is your living room and how loud you like your music; what kind of program material you like; how "fussy" you are about minimizing distortion; and how the particular amplifier you choose, to get however many watts you decide on, happens to overload.