About The Author

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But This Goes to 11…

Welcome to the world of bass rigs.

A boat in a bass mag? Fear not, you haven't mistakenly picked up that popular title 'Bass Boat Magazine'! So why's it here? This month we're going to try to pick apart the curious machinations of the ubiquitous loudspeaker, and for that we shall go in armed with a fresh new analogy. So here's the run-down of the components in our boat and what they relate to in our loudspeaker cabinet:

1. The sails (speaker cones) - the bigger the sail, the bigger the cone area
2. The rigging (the excursion-limited power handling of the loudspeaker) - the stronger the rigging, the more low-frequency power the speaker can handle without excessive distortion
3. The mast (the thermally limited power handling of the loudspeaker) – the stronger the mast, the more continuous power the speaker can handle before breaking
4. The weight of the boat (the low-frequency response of the loudspeaker cab) - the heavier the boat, the lower the cab goes
5. The speed of the wind (the power from the amp) - the stronger the wind, the more power from the amp
6. The speed of the boat (the loudness coming from the cab) – the faster the boat is moving, the greater the dB SPL output

An obvious conclusion we can take from this analogy is that if we make our sails (cone area) larger, then it takes less wind (power) to reach a given speed (loudness). OK, maybe it isn't that obvious, as you might think that it ta kes more power to move more cone area, but fortunately that isn't the case. Note that this analogy is effectively the reverse of what is happening with a speaker cab - with a speaker we have cone movement causing air to move, in this case we have air movement causing the boat to move. Think of a desk fan looking a lot like a wind turbine - one moves air, one is moved by air, but the principle remains the same.

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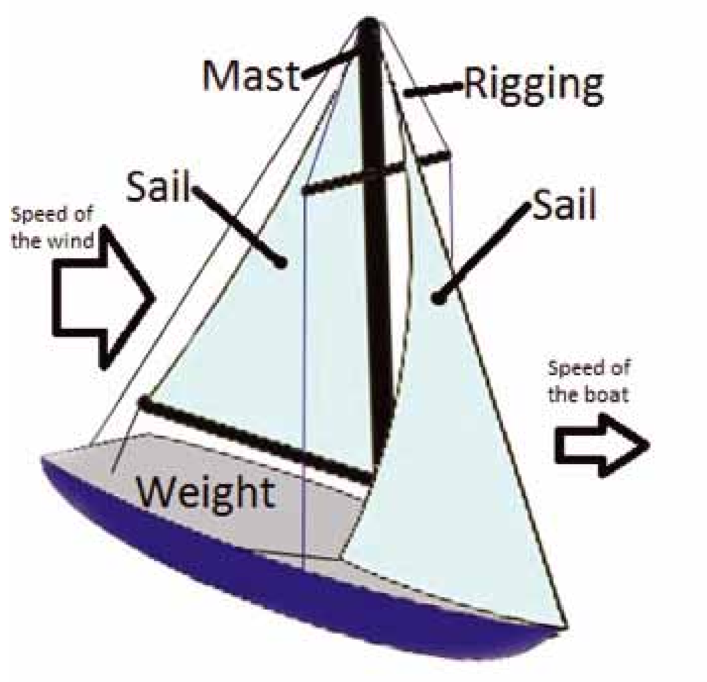

We can also see that there are two forms of power handling limiting the speed of our boat - and the one quoted in manufacturers' specs is the thermally limited power handling. Unfortunately, the excursion-limited power handling tends to be the lower of the two, which is why you can get most cabs to make nasty sounds with much less power than you'd expect. In fact, our mast might be rated at a 100 mph gale but our sail and rigging might fail at a mere 30 mph stiff breeze. If we make the boat heavier, then it will take more wind to move it, because the boat will sit lower in the water and suffer more drag and its greater mass will require more force to accelerate. So the deeper the cab goes, the more power it takes to push it to a given loudness. However, all is not lost, as some speakers that are designed to go lower are also designed to handle more power, like having a tougher sail and rigging on a heavier boat. Thus, by having greater excursion-limited power handling it can compensate for being less easily moved.

'Hopefully you've noticed that bass instruments are tuned an octave lower than guitars and thus our amplification needs to reach twice as low, so for us to get away with the same power as our guitarist friends we would need speaker cabs eight times as big.'

One speaker design challenge that this analogy does not cover is the interaction between cone size and enclosure size. To understand this we need to look at what the air behind the cone is actually doing. For a practical example of this you need to track down a bike pump. Experiment No 1 involves pushing the plunger in most of the way, then putting your finger over the valve to stop the air escaping, holding the pump upright with the handle uppermost, and then giving the handle a quick, sharp tap inwards. Note how the handle moves in briefly, then the air inside the pump acts as a spring pushing it back out, then it goes back in again but not as far, then out and in and so on, until it comes to rest. Now take your finger off the valve, pull the plunger out most of the way, block the valve again and repeat. You will observe that the handle vibrates in and out with a slower frequency because the air inside the pump is acting as a softer spring.

When it comes to speakers, the frequency that they naturally vibrate at when mounted inside an enclosure is called the 'resonant frequency', and the lower this is, the lower they go. Thus the bigger you make the cab, the softer the air spring and the lower the resonant frequency. However, making the cone area larger is like making the spring harder, because there is more air pushing back on the cone. So if you get two cabs of equal size, the one with the smaller cone area will go lower but will be less sensitive. Likewise, if we get two cabs with equal cone area, the one with the larger enclosure will go lower with no loss of sensitivity.

How are we getting more lows from a cab without adding speakers? Experiment No. 2: Take your trusty bike pump, slide the plunger halfway in, then put your finger over the end to stop the air coming out and see how much effort it takes to push the plunger another 1 cm inwards. Then take your finger off the outlet, pull the plunger out all the way, block the valve again and try to push the plunger in 1 cm again. Notice how much easier it is when there is more air space inside the pump. Same thing for speakers – and the lower the frequency, the more the speaker has to move; thus by enlarging the enclosure we both lower the resonant frequency of the system and make it easier for the speaker to move at deeper frequencies. JA Hoffman realised this many decades ago and coined a succinct law, sometimes misquoted as 'loud, light, low, pick any two.' A more accurate statement is 'sensitive, small, low, pick any two.' Thus, a speaker can be small and go low, but if so, it will have low sensitivity (ie will need more power to reach a given SPL). Or a speaker cab can be sensitive and go low, but to do so it will have to be big. In the world of bass cabs most are fairly similar, being quite sensitive, neither being tiny nor huge and going fairly low (but not as low as most think or the specs would lead you to believe).

An interesting factoid that helps to put the (depressing) reality of speakers into perspective is that if you want a cab to go an octave lower (ie twice as low) but maintain the same sensitivity, you will have to make the cab eight times as large – in other words, making it twice as tall, twice as wide and twice as deep. Hopefully you've noticed that bass instruments are tuned an octave lower than guitars and thus our amplification needs to reach twice as low, so for us to get away with the same power as our guitarist friends we would need speaker cabs eight times as big. And even an Ampeg 8x10" isn't eight times as large as a Fender Twin, let alone a Marshall 4x12"!

We can fight 'Hoffman's Iron Law' by using corrective EQ to boost the lows on small, loud cabs, or by using low-sensitivity speakers with high power handling so they still go loud, but there's only so much you can do with brute force. Size matters.

Going back to our sails and speaker cones, it's easy to come to the wrong conclusions about cone area – for instance, 2x15=30 and 4x10=40 so a 4x10" cab has more area than a 2x15". Wrong! We're dealing with the area, so the diameter needs to be squared, so the sum should be 2x152=450 and 4x102=400 so the 2x15" cab has more area than a 4x10". However, that isn't the whole picture – the nominal size of a speaker isn't actually the diameter of the actual moving speaker cone, it's the approximate diameter of the outside of the speaker frame. For a typical bass guitar speaker we need to knock about 2" off the nominal diameter to get the working diameter. Repeat that sum and we see that it's more accurately 2x132=338 and 4x82=256, leaving the 4x10" trailing in the dust when it comes to cone area. When you think about it, that explains why 2x15" cabs tend to be larger, about the size of 6x10"s, and indeed 6x82=384, which makes sense, as similar-quality 6x10"s tend to be slightly louder than 2x15"s. You may have noticed that power is very much a secondary consideration – why is this? Well, continuing our maritime theme, assume we're up a creek (in a canoe) without a paddle. We want our canoe to move and we might have all the power of a professional oarsman, but without a paddle (speaker) to push against the water (air) the canoe ain't going nowhere (ie silence!). Now let's get a paddle and paddle really quickly – say at a frequency of 200 times a second (ie 200 Hz). To move the canoe at 5 mph the paddle can get away with being very small in area, and we don't need to sweep it back far because we're using lots of short, quick impulses to push against the water. Now let's paddle half as fast, so only at 100 Hz. To push the canoe at the same speed, we either have to sweep the paddle four times as far through the water, or quadruple the area of the paddle, or double the size of the paddle and move it twice as far. Why is this? We're pushing half as often and moving the paddle half as fast, thus we need to move more water a greater distance to get the same power transfer. Drop another octave and our speaker is now moving 16 times as far to hit the same SPL at 50 Hz as at 200 Hz.

So that's three big learnings in two pages:

1. When you add more speakers to your rig you need less power to push them to a given SPL, not more.
2. Hoffman's Iron Law: sensitive, small, low, pick any two.
3. If we have to move x cubic centimetres (cc) of air to reach y dB SPL at z Hz, we have to move 4x cc air to reach y dB at z/2 Hz.