



## Hammer Lite Subwoofer

### Delivering the Rhythmic and Dramatic Foundations of Music and Soundtracks

My Design Concept, by Roy Johnson, designer, Green Mountain Audio, Inc.

I DESIGNED ALL OF our speakers to have enough low bass for most all music and soundtracks for the size of rooms in which they will be most commonly used. However, I know some music and special sound effects require very, very low bass. Rooms with a very high ceiling or an open floor plan allow much low bass to escape. Or you may simply be a bass aficionado. A subwoofer or two is often the best solution for these conditions. Two Hammer Lites are always better than one because they uniformly fill your room to deliver more impact and make the room sound much larger.

A correctly designed and engineered subwoofer produces natural-sounding very-low bass. None of us are used to hearing such a low level of bass, yet it has many interesting and surprising results. A drummer will pound with more power, yet simultaneously, with more subtlety. The string bass will vibrate you with seemingly new harmonics. You will more easily feel the pulse and sway of the rhythm -- not just hear it -- which is an entirely different experience. In an instant you will sense the changing momentum of the band -- and an orchestra's crescendo will be even more majestic. Sound effects will make the floor drop from beneath you. Those are wonderful details to experience and it is too bad that we cannot pick a good subwoofer from their measurements.

Low-bass performance claims are often misleading because most measurements are performed with test-tones that allow the room to help build up the bass response. Others measure very close to the subwoofer's cone, which does not reflect what you will hear out in the room. In some ways, this cannot be blamed on marketing because there is no standard that measures subwoofers (or speakers) in the way you experience them.

Many things are necessary in a subwoofer's design to reach the ideal of effortless low bass. One of the most important is that the subwoofer driver reside in an enclosure that is the correct size. This lets the driver respond with the least resonance, meaning that bass notes stop when they are supposed to, and you do not hear 'one-note bass.' Of course, that enclosure must be extremely rigid, so only the subwoofer's cone moves. This allows maximum impact, the nuances, the exact pitch, and all the harmonic textures to emerge.

That enclosure must be as quiet inside as possible, for the clearest, most agile bass. Should you choose to communicate with your neighbors via the low bass, a subwoofer should exhibit the same ability to quickly start and stop from a 100 Watt level as it did at 10 Watts. This can only come from proper engineering of the motor that pushes and pulls the cone.

There is the question of 'radiation resistance,' which is how much grip the subwoofer has on the air during each stroke. The more resistance, the better -- and this comes from size. A larger cone has more surface area to push against the air, and you hear more initial impact. This resistance can be increased by using a certain-size front panel for the cabinet. More on this later.

The subwoofer(s) also should be blended with the main speakers so that the tone balance during the transition is smooth, of course. This requires the subwoofers to move as closely in time as possible with the main speakers. If they do not, the bass is ill-defined, 'muddy,' and perhaps 'boomy.' Often, the subwoofers will significantly lag

behind the main speakers. This sounds and measures exactly like room problems. Those subwoofers are very difficult to position for the best balance, and that balance requires adjustment on nearly every recording. When the timing is correct, most all of those problems disappear.



## **The driver**

The 12" driver I used in the Hammer Lite is uniquely suited to perform at both ends of the spectrum -- extremely quiet and extremely loud -- and anywhere in between. I feel fortunate to have it at my disposal.

To perform at the loud end of that dynamic range, it has enough electrical stroke -- without any change in distortion -- because of its large magnet, excellent suspension, and large, vented Kapton voice coil. It has just enough stroke to play extremely loud all the way down the scale until it triggers its large bass port, tuned at 34 Hz. The action of a properly-designed port extends the low bass, without 'boom,' and lowers the distortion of any woofer because

its vibration brings the woofer's vibration (stroke) to a halt. The Hammer Lite's 4" port moves a great deal of air efficiently, because of its large diameter and its aerodynamic shape on both its intake and exhaust. This size and shape of port is not seen on many subwoofers because it requires so much space.

To play very softly is much harder for a subwoofer to accomplish, because the key there is that the subwoofer's suspension must be very, very flexible, and that is not found in the 'high-power' subs. The suspension around the front rim of the cone and behind the cone (the spider) are always designed to prevent any woofer's cone from rocking. When a subwoofer is mounted in a small enclosure, then a massive explosion from a DVD leads to unequal pressures behind the cone -- causing it to tilt, or rock -- as it strokes. This creates distortion but mostly jams the voice coil, and at that point, it is goodbye subwoofer! So, these type of designs require a very stiff and rugged suspension to maintain the cone's correct movement in its small enclosure.

That stiffer suspension is not flexible enough to move on very small sounds -- the cone actually stops moving. This is known in physics as a 'sticking' friction. Any material designed to be flexible always reaches a point of minimum motion where it becomes rigid again. One has to 'break it loose' to get it going again. Too much starch on a shirt makes it too stiff until you either wash it again or wear it for a few hours. New front forks on a motorcycle need to hit a railroad track to get moving. Over any lesser bump, they feel stiff.

A softer suspension is not a proper choice for a subwoofer mounted in a small enclosure, but the trouble really began with the marketing department setting a limit for the size of its enclosure. When the enclosure is small, the subwoofer itself has to have a very heavy cone assembly to lower the natural resonance in that box. This greater moving mass requires more power to move and so the efficiency goes down, with at least twice the power required. The small enclosure still limits how low that subwoofer can go, so the built-in amplifiers all have a permanent low-bass boost wired in, before you make any other adjustments to their controls. This boost requires far more power from the amplifier. To keep that amplifier from distorting, there is a subsonic filter also built in, to filter out the extremely low bass, below 20Hz. In many of those amplifiers, that subsonic filter also slides up the scale when the low bass becomes louder, to protect against overload. Many amplifiers also have a built-in limiter that chops off the peak loudness of the incoming bass signal before it becomes 'too loud.'

All of those circuits distort the sound. The built-in bass boost adds more time delay to the low bass, making it sound like it lags more and more behind the main speakers, because that is exactly what is happening. It also sounds like a bass-resonance problem with the room, but that is because the low bass now lasts too long, because it got started too late. The built-in low filter adds its own time-delay and also its own resonance because those are part of how those filters operate. When the subsonic filter slides up the tone scale to filter off more and more low bass as the sound gets louder and louder, then more and more time-delay and resonance are injected, which are then also different than when the sound was softer. The signal limiter compresses the peak dynamics, and when it flattens off (rounds over) the tops of the bass waveforms, that new flattened wave shape comes about from the extra harmonics added to it (because those literally make that flat shape). You hear more 'boom' because those harmonic distortions are still in the bass range, but the sound is not accurate.

To present our logic:

1. Why is Hammer Lite's enclosure somewhat larger than other subwoofers? That came from the Hammer Lite's cone being very light -- about half the moving mass of any other subwoofer.
2. Why is its cone so light? For much more efficiency.
3. Why is higher efficiency a good thing? For taking much less power from your amplifier, therefore creating

much less heat in the subwoofer's voice coil. Heat equals distortion.

4. Less heat means we can use a high-tech 2" voice coil instead of the super-large ones.
5. This leaves us more room to fit a large rear spider.
6. That large rear spider is much softer than the spiders used for the super-large voice coils.
7. That softer spider allows the front suspension to be made very soft, to literally keep the moving cone in balance from front to rear. You do not want stiff springs at the rear of your car and soft ones at the front, for the same reasons. You would spill your coffee.
8. A soft suspension is exactly what allows any cone move on the small signals.
9. Also, a soft suspension is necessary to allow a very light cone to go naturally low.
10. To allow that cone to reach that low frequency, the air cushion inside the enclosure has to be softer. This means a larger enclosure.

You can see why it is easier to say "Twelve-inch woofer in a 15" cube with 1,000-Watt amplifier built in. Shake your house, baby!"

We could have used a 19" cube for the Hammer Lite, but that front face is too wide to let the entire bass tone-range wrap around it uniformly across the scale. Bass wants to wrap around objects, because its wavelengths are 10-30' long. Nothing small gets in their way, only objects approaching their size. Thus, the low bass you hear from any woofer or subwoofer comes always from its cone, and its port, and your floor and the walls nearby, because that is where those longwavelengths go. You cannot stop them. Therefore, this is why we do not hear nearby reflections in the bass as reflections, but only as 'more bass.' The cabinet has to get out of the way as soon as possible, by not being either too wide, deep, or tall.

However, the front face of that cabinet can have too little surface area, because that creates a loss of output in the transition from the middle bass to the high bass notes. As you move up into the high bass, those tones are heard to come more and more from the cone and off of the front surface of the enclosure, before they come back from the room's surfaces. It is how we hear them, and also how the large cone disperses its sound from left to right in that upper-bass range.

A too-small cabinet face, in terms of surface area, does not hold enough of the upper-bass sound pressures right near the cone to let the cone finish pressurizing the air in front of it. A larger face is needed in this upper-bass range, because this is above the middle-bass range where the floor reflection fully kicks in, followed in the lower bass by the reflection from the side wall, and then from the wall behind in the lowest bass. In case anyone wants to check me on this, they need to calculate what is called the 'radiation resistance' of this entire acoustic system, consisting of the woofer's size, its cabinet face's size and proportion, depth and height, and all of their distances to all of the nearest surfaces. Then tie those results to the time-domain process of how our hearing system perceives 'first-arrivals' on tone bursts as we go down the scale.

The Hammer Lite's cone can be moved with just the back of your little finger's nail, making it highly responsive. Its butyl rubber surround on the rim of its cone is very rugged, yet extremely flexible, and will remain that way for decades. It is less than 1mm thick, but you would never know that by touch. The spider behind the cone is very large and again, extremely flexible, in part because only a 2" voice coil lays at its center. The Hammer Lite's voice coil is rated for up to 200 Watts, but that rating allows it deliver the same acoustic power as the typical inefficient subwoofers rated at 500 Watts. This subwoofer is rated at 90dB for 2.83 Volts input (1 Watt). Other subs are much less than half that sensitive.

The chassis of the Hammer Lite is a heavy-gauge rolled steel, reinforced with epoxy, which is then stiffer and better damped than a cast-metal chassis.

The cone is a mixture of select long-aspect ratio spruce fibers, polymers, and carbon fibers. It is extremely light for its size, about half that of other cones. It remains rigid to very high frequencies, above 500Hz, where plastic cones go soft at less than 200Hz. This matters for proper replay of the full spectrum of a DVD's 0.1 LFE channel, which extends to 130Hz before it rolls off. When a cone goes soft near those frequencies, it puts in additional time delays (phase shifts) and resonances into that tone range. It also makes a subwoofer more difficult to blend with the main speakers for two-channel music.

## **Enclosure construction**

Based on the work done first on the Continuum 3, and later on the limited-production Continuum 18SW subwoofer, the 12" woofer in the Hammer lite is supported by a Baltic-birch plywood front panel, laid up on an MDF cabinet with an epoxy/marble/MDF composite bass. It also has a second layer of MDF on the top overlaying all the joinery, preventing torsional vibrations.

Two Golden-Ratio Baffles™ are inside -- one runs from front to rear all around the enclosure, and the other joining it to the top panel. The openings in these baffles break up upper-bass standing waves that will occur in this size of cabinet, and their location and how they are inlaid into every surface adds enormous rigidity.

Four adjustable-point cone feet are bolted through the composite base for maximum resistance to a type of base-panel movement called 'shear distortion.' If feet were simply screwed to the bottom surface of that base panel, then every woofer motion would cause the interior base-panel's skin to move back and forth independently of the external skin actually touching those feet. These two skins are trying to shear away from each other, from front-to-rear. This is a severe source of vibration and a challenge we first conquered with the Continuum 15" Subwoofer in 1997. The problem was eliminated by allowing the feet to be coupled to both the outside and inside skins of the base plate. When this source of vibration was eliminated, it was much easier to accurately assess the strength of various woods and corner-construction methods. After the 15" Subwoofer, this same mounting system all of our other large-woofer designs.

You need an electronic crossover to filter off the voice range from the Hammer Lite. Its settings depend on your main speakers for two-channel music, and are already in your home-theater control center for the LFE channel of DVDs. We do not build amplifiers and do not build one into the Hammer Lite. It is a passive speaker and we recommend using at least a well-built 100 Watt amplifier for smaller homes and a 200W+ unit for large rooms.

## **What it means for you**

In the long term, you will find that subwoofers make all music and films more enjoyable. When your system can reproduce very low bass, even a female voice sounds more real and more like she is actually in the room. This is because the brief 'bump' of air required on every chuff of air from her lungs is one that only subwoofers can deliver. Bright recordings also become completely enjoyable because the low bass you had never heard finally balances out their highs. On concert performances, the sense of a spacious hall is much more apparent since we associate low bass with being indoors (low bass seldom exists outdoors). The larger that hall, the more low-bass reverberation we hear, even at a very subtle level. You do not read much about this effect because the subwoofers used are always grossly out of time with the main speakers and usually the subwoofer is too-highly resonant. Yet both of these conditions obscure the details of the listening experience.

Having subwoofers changes the way you listen to and feel your music and films. And should you choose to scare your neighbors silly, do not do it from 200' away -- invite them over to your house instead and then turn out the lights. Michael Jackson's *Thriller* especially deserves to be heard this way...on Halloween. For the other days of the year? Large-scale symphonic performances...Pink Floyd...Stevie Ray Vaughn...raggae...you get the idea? So, is it worth it to have a subwoofer? You bet. It is the ultimate in musical freedom.

The state of the art in subwoofers moves you closer to reality than you can imagine -- so much so that we cannot be held liable for any damage to property or your hearing if you choose to exercise these subwoofers at or near their maximum output levels. When you hear our Hammer Lite, you will know what we mean.

Hear it all.  
It's about . . . time.