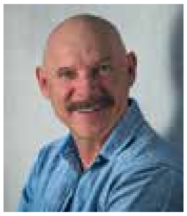


By Bob Carver

All About the Amazing Line Source Loudspeaker

What I wanted from these speakers was a large improvement over the original Cinema Ribbons. When I ran the numbers on the dual side-firing drivers, I knew that the resulting ALS speaker would be superb.

How they work and how they achieved improved sound!

The crossover topology is similar to the Cinema Ribbon speakers, in which the side firing drivers are driven in an extended frequency overlap fashion, and the ribbon is likewise simultaneously driven far down into the side firing driver frequency range. The inter-aural time delay that results from this extended drive, combined with the time displaced drivers, results in the uncanny ability to recover recorded acoustic space in ANY venue.

They can play loud!

In order to get the improved low frequency response, it was necessary to exchange a bit of efficiency (actually sensitivity) for the extra bass. They sport a sensitivity of approximately 90 dB SPL, down about a dB from my earlier design but it's a great trade, allowing the ALS to blend substantially better with almost any sub. With 45 volts RMS drive, these speakers can play over 114 dB. Here's the best part, with two speakers in stereo, the output will be six dB more, or 120 dB total!

They image like nothing else and simultaneously deliver a huge sound stage!

Amazing Line Source speakers image with a sense of precision within a large sound stage, along with a deep-layered front to back depth. Images are behind the speakers, higher than the speaker, to the left of the speakers and to the right of the speakers, with each image located solidly in a particular place within the larger acoustic space.

We wanted the acoustic space to live all around us but largely in a huge arc up front where the speakers are in the room, extending fore and aft plus and minus 2 meters (approximately 4 meters total).

I wanted the images to seem as if they could have existed in that place in space sometime in the past. Not facsimile replication, rather "it could have been so" and therefore will sound in the moment, realistic, believable, and if everything is done right, fun to listen to. Sufficiently realistic that the instrumental locations are believable and plausible even if not delivered as a facsimile.

FAST

I wanted them to have great transient response and spectacular articulation that is hard to believe. To do that requires a wave launch that is associated with the smallest possible "radar" cross- section, and very lightweight moving diaphragms, as light as practical, and along with the low mass, a powerful motor (because Sir Isaac Newton promises $F = ma$, or $a = F/m$).

So, great articulation arises naturally if large accelerations are possible. In these ALS speakers, the mass of the ribbon is on the order of the mass of the air. Actually, slightly less, and if we draw a picture it has the behavior of being all but massless. Therefore, it has the seemingly magical (of course it's not) ability of moving air by magic because it seems to not have any mass. The ribbon is driven down to 200 Hz… more on that later. The woofer is driven up to 8,000 Hz… more on that later. The total moving mass of the woofers is 13 grams. The maximum force that its motor can impart is 103.4 Newtons (23 lbs). The acceleration can be over 9,355 meters per second per second.

This woofer's 13 grams is significantly more than the mass o f the air, and it has to be as a practical matter in the real world. However, its job is to make acoustic space in the Henry Kloss psychoacoustic octave; its job is NOT imaging. That's the job of the ribbon, so it all works out… more on that later.

Power handling

There are two parts to power handling. One is associated with the mechanical limits of moving things back and forth without breaking. The other is a thermal limit associated with getting things so hot that they melt or get too weak and fail.

The woofer is designed to be able to move back and forth almost one full inch peak to peak, and occurs at 53 H z and 45 volts RMS input. At that point, the box pressure, multiplied by the area of the diaphragm is a force that is equal to and opposite the force that is driving the voice coil; the woofer excursion cannot increase. Since it's simple air pressure that does this, the whole system stays linear even if drive n below its 53 Hz limit. When driven with a constant voltage, as the frequency decreases, the woofer excursion increases and the acoustic output remains constant. At 73 Hz, the box pressure causes the excursion to stop increasing, and the frequency response drops below that point. This does not occur until the motion is about 0.93 inches peak to peak (with a 1.78 millimeter safety band) and the drive voltage is 45 volts. So the whole system, for all frequencies from 20 Hz to 20 kHz, will remain linear up to 45 volts or 506 four ohm watts.

Since the to-and-fro motion has been limited by the box pressure, the frequency response has been limited to 73 Hz, and the output falls below that point. That is how the mechanical power handling capacity is accomplished without things going non-linear.

Now back to thermal power handling. The ribbon, as lightweight as it is, is made of Kapton and has a lot of surface area, about 10 square inches each and therefore can dissipate a lot of power.

Kapton was used originally to wrap the moon buggy so when the sun came down on it, it wouldn't be damaged. It's remarkably tough stuff. Since the spectral energy distribution falls at roughly the same rate as the RIAA curve, and the large area of the ribbon serves as a great heat sink, overheating is prevented, even when driven to very high levels.

As a final safety measure in case someone is an animal with his/her 2,000 watt amplifier, an internal automatic clix-on temporarily reduces power. For the woofer, the power handling is arrived at in a far less elegant way. Actually, it's a rather brute force and pedestrian way. Big wire, fat wire, copper wire, big voice coil and big magnets that help heat sink the voice coil. But, the coupe de grace for the power handling of the woofer IS elegant. It is the high-back-EMF that goes along with the high box pressure.... more on that later.

High-back-EMF

A bit of history. For the last 30 years or so, we speaker designers have been taught that there is an optimum *BL*, a Thiele-Small parameter that has an optimum value for any given loudspeaker, as evidenced by Thiele-Small alignments charts and in more modern times, speaker design computer programs based on Thiele-Small teachings. Thiele and Small teach us to choose a box size as large as practical according to our design goals, and then adjust the Bl to get the desired frequency response.

SCIENTIFIC EXTRA CREDIT READING

The moving mass of the ribbon diaphragm is 0.035 grams/square inch. The effective air mass that it puts in motion is approximately 0.038 grams for each square inch of contact.

The total mass of the side-firing woofers is 13 grams. The net box volume is 56 cubic inches for each driver. This compares to a standard “bookshelf” speaker with one and a half or two cubic feet (2,592 or 3,456 cubic inches respectively).

Its impedance is 4 ohms and because of its high-back-EMF, it’s actually easier to drive than normal 4 ohm speakers. That’s because the impedance is dominated by its back EMF and is very high on either side of its minimum impedance, which occurs at 100 Hz.

The low impedance area extends for less than ½ an octave and then soars, averaging substantially higher because of the high-back-EMF. This makes it very easy to drive, and helps both woofer and ribbon voice coils from getting too hot. In addition, for regular music, the power falls with increasing frequency more or less according to the RIAA characte ristic that we have lived with and loved for several decades.

All this conspires to keep the loudspeaker cool. Large area, high-back-EMF, big magnets, lots of air for heat sinking, and lots of area for the Kapton all help keep things cool. A normal speaker with a one inch dome tweeter does not have high-back-EMF, so the voice coil gets hot. In particular, a voice coil that possessed THAT physical size and dimensions would overheat and burn up regardless of how well it were heat sunk if 45 volts were applied to it. It would turn into a white hot light bulb. If there were pinholes in the cabinet, and if you listened in the dark, light beams would go through the pinholes and make a planetarium on your living room walls and ceiling moments before it smoked itself and burned up.

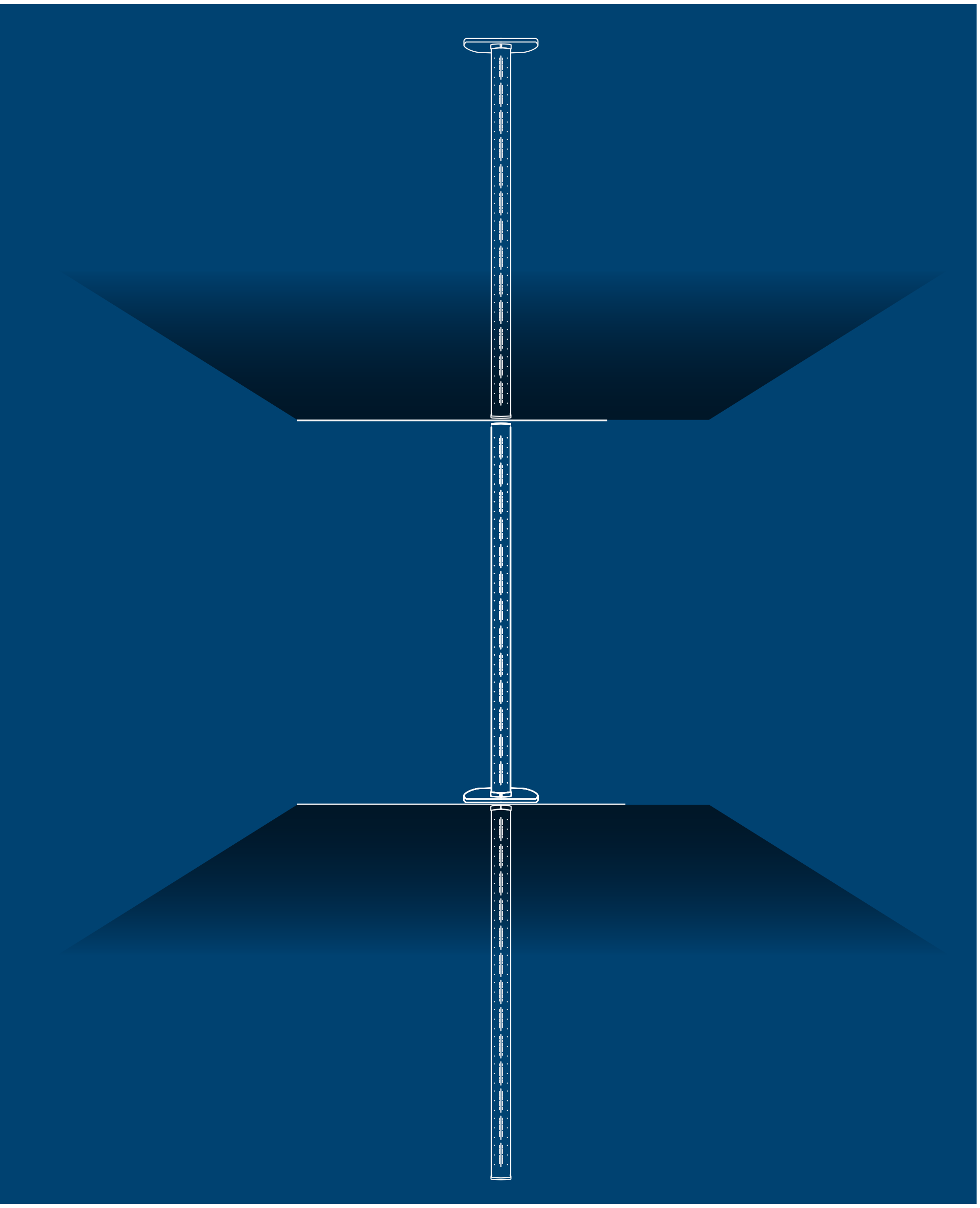
A one inch dome tweeter, because it is not driven with uniform force -over-area must have a very light voice coil that is made of gossamer thin wires, like human hairs, and represents a wire wound resistor that’s good for about 3 watts, 10 watts with ferrofluid and 15 watts with ferrofluid and high temperature adhesives.

It cannot hold a candle to these ribbons, which can dissipate about 2000 watts because the surface area of the ribbons, compared to a very high quality ¾ inch dome tweeter, is larger by about 240 times. Surface area translates into the ability to remove heat, thereby keeping itself cool and not getting too hot. Enjoy the music!

Our way is to choose a BL as large as practical, and adjust the box size and therefore the box pressure for the desired response. What a simple concept, but nobody, as far as I know, ever thought of doing it that way. I think the reason is that during the time of those early guys, only low powered tube amps existed, and it was necessary to keep the back pressure, (box pressure) as low as possible so that the woofer could move back and forth easily. Our way yields small size, high efficiency, and lots of low -end output. All three at once. Not just two, with the third not a choice, but something that emerges as a consequence of the other two choices we made.

This is often called **Hoffman’s Iron Law**. Guess what? The high-back-EMF and high box pressure approach allows us to choose all three at once, each choice independent of the other. Put as much Bl as you can in your speaker design. The more the better. Forget everything your mother told you about moderation, we cannot have enough Bl in our speaker designs. The magnets are so large and so powerful that they barely fit through the holes in the cabinet. When the voice coil is in motion, it makes a very high-back-EMF; this dramatically reduces the voice coil heating, not by a little bit, but in this case by approximately eightfold, because the heating effect of the voice coil is inversely proportional to the back-EMF squared.

So, that's how, from a thermal point of view, this loudspeaker is capable of absorbing very high power. The fat copper wire and the big voice coil are the pedestrian components of the power handling capacity and its high-back-EMF is the elegant component of its high power handling capacity.



Space and imaging

Back to space and imaging. Henry Kloss taught us that the acoustic space that we feel and sense lives in the octave centered at approximately 300 Hz. It's actually an octave on either side, and in order to make the acoustic space, the speakers use drivers that interact with the room and use the room acoustics in conjunction with their almost omni-directional wave launch within Henry's psychoacoustic octave by bouncing sound off of the walls. If the distance from the speaker to the back wall is a meter and a half, that will generate approximately a nine millisecond first delay; our ear-brain system turns that delay and the multiple delays that follow into a sense of space.

The space exists mostly in the front of the room where the speakers are and extends beyond them, toward and beyond the back wall, a little bit in front, and as a large arc that extends from the sidewalls up and over the loudspeakers. We sense and feel this space. It is palpable, it is real, but we cannot touch it, it lacks substance. Still it is

there. These qualities are generated by venue cues and clues and are put together inside of our heads psychoacoustically.

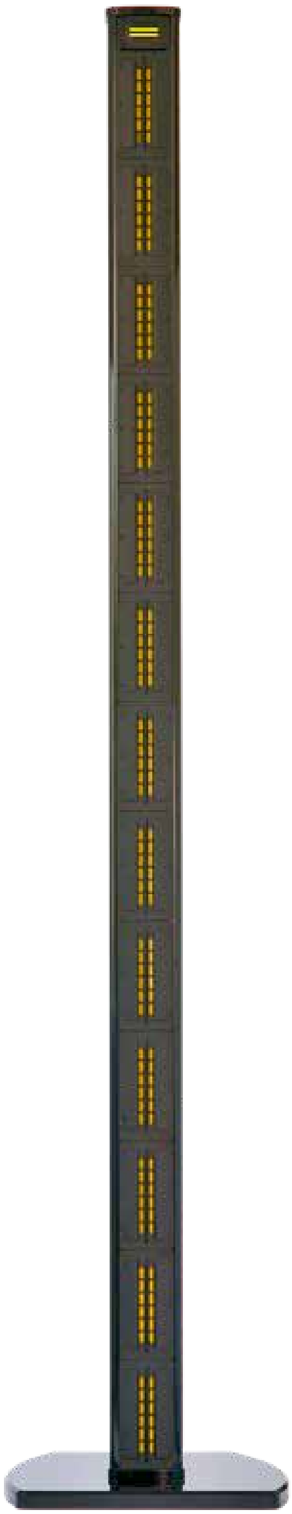
Now, inside of this large acoustic space, the job of the loudspeaker is to build pristine images. In order to produce a pristine image, it's necessary to have an associated wave launch from the ribbon that has the following properties: For each sonic event that the ribbon reproduces and launches into the room, the speaker as a whole must not launch additional waves into the room, or at least as few as possible.

Therefore, reflections, refractions, and diffractions that are normally associated with the cabinet must be held to a minimum, because over a millennia of evolutionary adaptation our ear-brain system has learned to build space inside of our heads when we hear only two arrivals per sonic event (one per ear). Four arrivals is worse than two, eight arrivals is worse than four, 16 arrivals is worse than eight, and beyond that the image almost totally collapses and into more or less a flat curtain of sound strung between two speakers.

The ribbon is designed to launch the sound into the room with a minimum of secondary wave launches, and the cabinet in particular has a very, very low radar cross section. I designed this cabinet by performing a set of experiments that taught me the way, even though I copied this cabinet from a drawing published in a classic research paper by the RCA Laboratories. Its shape is the second best in this paper, and there were about 20 to choose from. The best one wasn't practical, but this final design is very close to the first best.

The sense of layered depth, the perception of depth in a sound stage works exactly the same way that our perception of depth for our binocular vision operates. Sounds that arrive at our ears, if displaced in time and phase, one to the other, will result in a spatial (space) effect inside of our heads. It turns out that if the timing of two sound arrivals is such that it is within about 800 microseconds of one another, it will produce a very powerful sense of image location within an acoustic space.

If unwanted sound arrivals are close to the inter-aural time delay, our ear-brain system becomes confused and collapses the image. For



arrivals that are far outside of the inter-aural time delay, our ear-brain system tells us something about the venue in which the sound is occurring. So for long delays, we can tell whether we're outdoors, in an indoor swimming pool, a concert hall, or our living room. Long delays can be good, as they can add sumptuousness and truly majestic realism.

Putting it all together

Imaging within the acoustic space is derived from the ribbons. The Henry Kloss Space is derived from the side-firing woofers interacting with the room acoustics. The ribbon is driven down to below 200 Hz and the side-firing woofers are driven beyond 8 kHz. Even though their respective acoustic outputs are approximately 30 dB down at those frequency extremes, they still produce space inside of our heads by virtue of the inter-aural time delays associated with the differing path lengths from their acoustic centers to our ears. They do this down to minus 40 dB, amazingly enough!

Output SPL (sound pressure level)

So, we find that this speaker can produce 120 dB SPL when driven at 53 volts RMS, at any frequency over its entire operating spectrum, and remains linear up to the 45 volts at any frequency.

We claim that this speaker can play as loud, image as well, absorb as much power, and stay more linear up to its maximum output than any other large floor standing conventional loudspeaker.

So, what's the catch? Believe it or not, there is none, assuming a good subwoofer that can go to 100Hz. If it's a high pressure subwoofer, the woofer itself will be very small.

Bob Carver CORPORATION

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