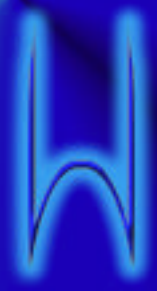

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Sound IS the Experience !™

PERFORMANCE AND COST FACTORS IN MOTION PICTURE SOUND SYSTEMS

BY

JOHN F. ALLEN

HIGH PERFORMANCE STEREO™

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JOHN F. ALLEN

Presented at SHOWEST, February 6, 1991

On February 8th, 1985, in cooperation with Plitt Theatres and Walt Disney Studios, we introduced digital sound to theatergoers for the first time with a full digital stereo presentation of FANTASIA. We wanted to show not only how beautiful a film could sound, but how many people would buy tickets to see and hear it. I also thought it would be fun... and it was!

Music and sound have a poetry all their own. They are connections to our feelings. The digital presentation of FANTASIA at the Century Plaza Theatre, grossed five times the national average for the film and played four times longer. This past summer's digital presentations of DICK TRACY were also quite successful. In short, digital sound with motion picture films can sell tickets.

How then do we best exploit this major breakthrough? Certainly we must be sure the audience can hear the difference and this means playback systems vastly superior to those we've become accustomed to. We must be absolutely sure that the audience can hear the difference between hearing a film in a real theatre, or in their home theatre; something I feel strongly about.

DIGITAL DEMANDS

Whether digital or analog, motion picture soundtracks have a large, yet finite dynamic range. Each channel of a theatre's sound system must be able to deliver to the listener's ears, everything from the softest whispers to the loudest audio peaks, and do so without distortion. To reproduce true impact or punch, dynamic sound Systems must be able to deliver very large sound pressures very fast.

Among other features, it is these important peaks that digital and high performance

analog systems can record. But this is only half the story. The authentic playback of these magnificent lifelike recordings places totally new demands on the speakers and amplifiers required in movie theatres; especially the speakers.

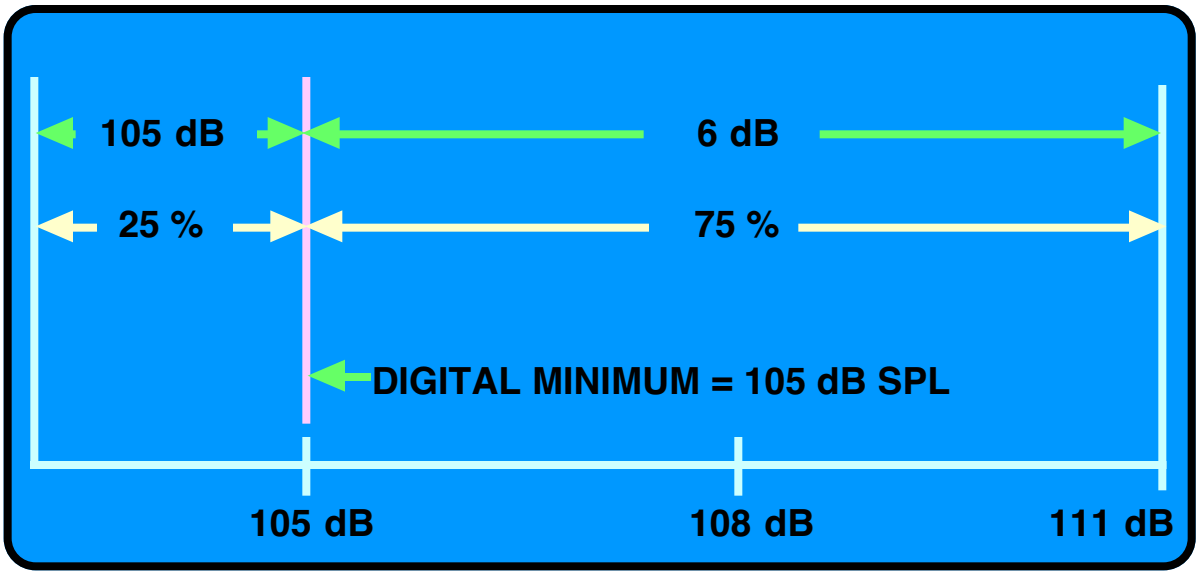
LOUDSPEAKER EFFICIENCY: POWER OUT vs. POWER IN

A speaker's sole function is to move air. They are air pumps; and represent a most vital link in the audio chain. Being the only things we are actually listening to, they cannot be taken lightly.

One of the single most important attributes to be considered when designing high performance sound systems is loudspeaker efficiency. It is hard to imagine another factor which has more impact on a sound system's performance, simplicity, clarity or cost.

Unfortunately, as they convert electricity into sound, loudspeakers are far from efficient. As much as 98 percent of our carefully installed amplifier power is completely wasted.

In the center of a theatre, the peak sound level per channel for a 70 MM magnetic release is usually about 103 decibels (or dB). Digital is said to peak at about 105 dB. Once we know this peak level, we then add an additional amount as a safety margin so the amplifiers never run out of power and distort.



PEAK SOUND PRESSURE LEVEL PER CHANNEL REQUIRED IN DIGITAL THEATRES

Figure 1

Figure 1 shows what this means to an amplifier. If we add a moderate safety margin of 4 to 6 dB, our peak sound level capability becomes 109 to 111 dB per channel at full amplifier power. A 4 to 6 dB difference is a noticeable but not huge difference in sound level. It's about the difference in raising your voice, but it requires four times the amplifier power to do it because each three decibel increment is a full doubling of power.

As we see in Figure 1, the safety margin can become as much as 75 percent of the amplifier power required for a modern theatre sound system. This is neither unusual or excessive. Rather, the extra power, or headroom as it is called, is an ordinary everyday design practice, or at least we should hope so.

Figure 2 shows the relationships of speaker efficiency and low frequency radiating area of two contemporary theatre speakers. In loudspeakers, high efficiency is about 20 percent. This means that 100 amplifier watts into such a speaker yields 20 acoustic watts out of the speaker. Lower efficiency speakers are in the 2 to 2 1/2 percent range. 100 watts in, yields about two acoustic watts out. This is a ten to one difference. Small speakers often used for surrounds, can be as little as 1/10 of one percent efficient. Such loudspeakers might more appropriately be called "quiet-speakers".

The radiating area is the actual area of a speaker which acts on the air in the room. The less efficient low frequency speaker, or woofer, has a radiating area of 1.6 square feet. The larger and more efficient woofer has 10 1/4 square feet. Now, 10 1/4 square feet is 30 percent more radiating area from just one speaker than we get in an entire 70 MM or digital sound system equipped with five of the less efficient woofers. This is, of course, an enormous acoustical difference.

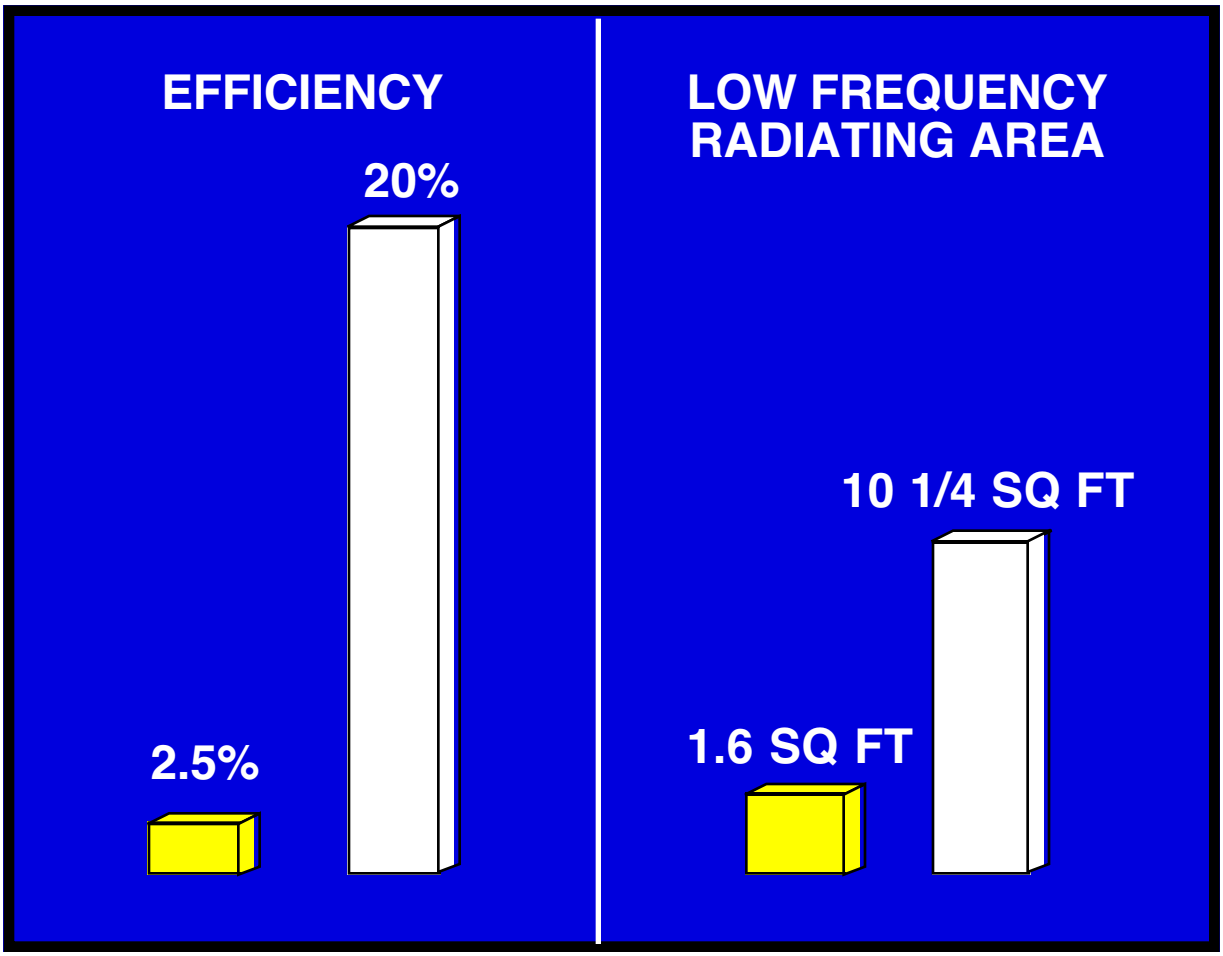


Figure 2

As you can see in Figure 2, the relationships between speaker size and efficiency in modern speakers are nearly identical. This has not always been the case in the past, and indicates a high degree of speaker design skill. In fact, today's higher efficiency speakers are half the size and weight of their predecessors and can even offer ten times more low bass output. We've come a long way.

Well, what about cost? The more efficient speakers will, by themselves, usually cost more. However, this fact is extremely misleading as there are major performance and other differences.

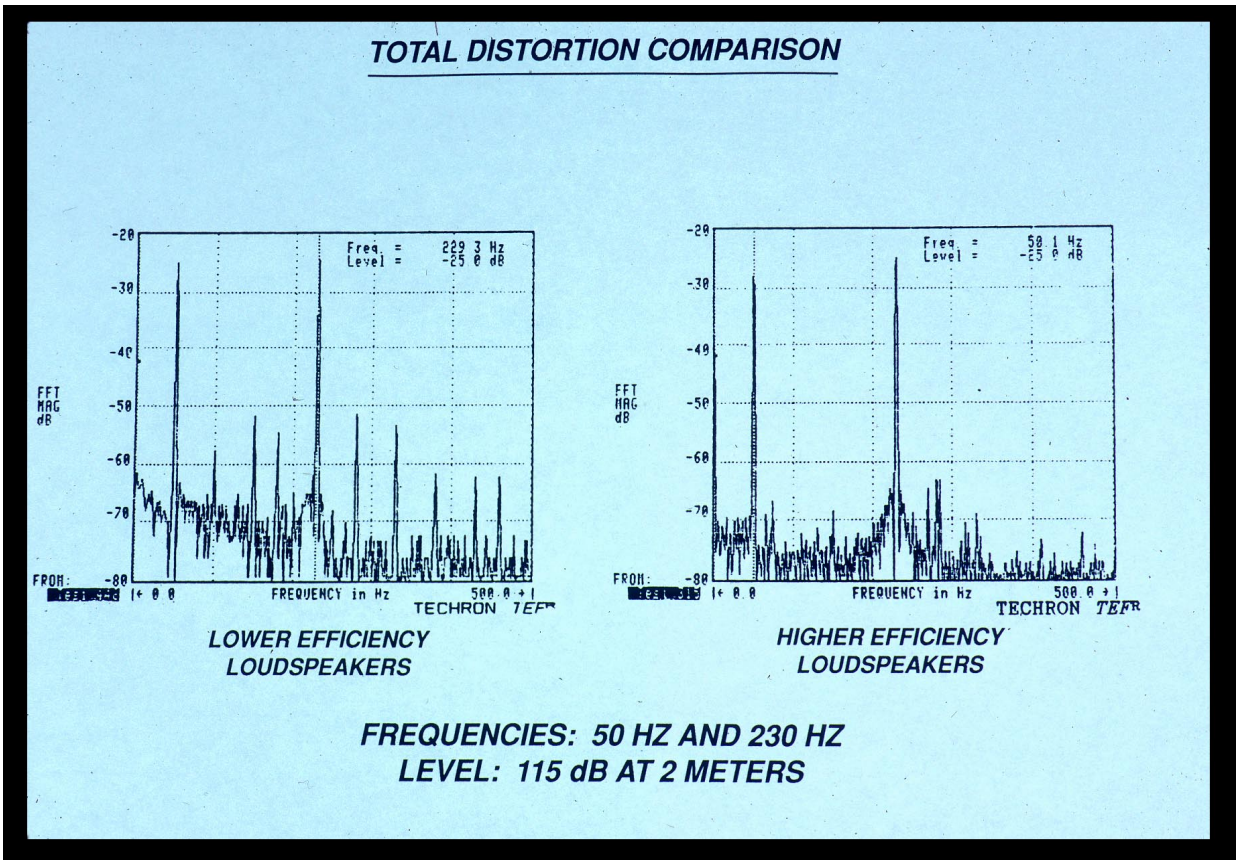


Figure 3

For instance, Figure 3 shows a comparison in distortion levels produced by two low frequency speakers of different efficiencies. To make the test completely fair and accurate, both woofers were measured with the same two 15 inch drivers installed in each cabinet. Tests were conducted with each woofer playing two tones simultaneously at levels of 115 dB, measured at a distance of two meters. This corresponds to a level of about 95 to 100 dB in the middle of a 100 foot long theatre; in other words, a moderate level for bass frequencies.

In a perfect speaker, the only spikes you should see above the noise, are those indicating the two tones. All the other spikes you see here indicate distortion produced by the woofers themselves, and nothing else.

The ten times greater distortion seen in the less efficient woofer, is entirely due to its lower efficiency and the fact that it must work so much harder. We doubt that any amplifier would be acceptable if it produced this much distortion. Yet speakers like this are common.

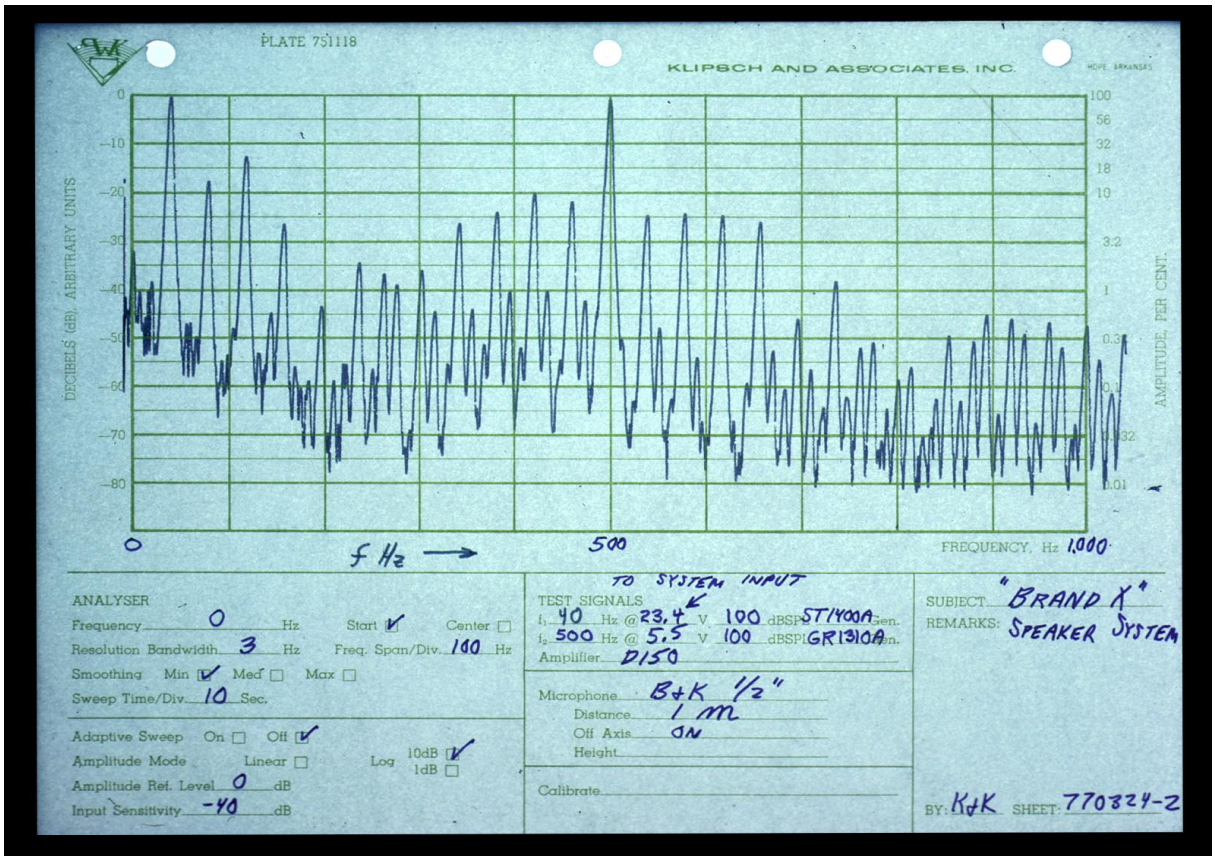
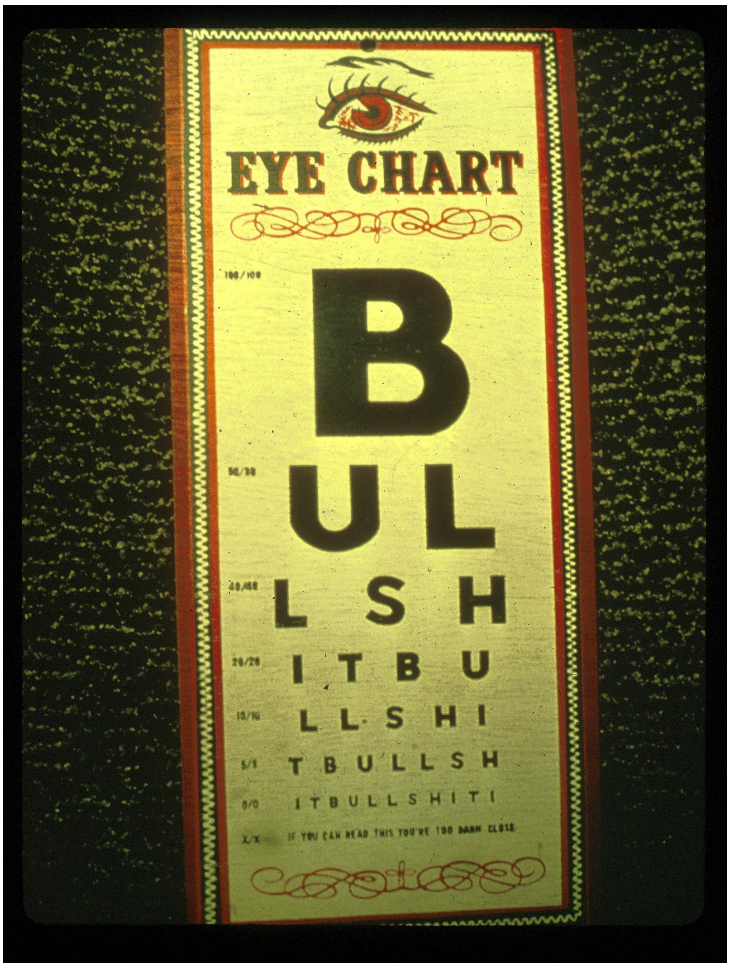


Figure 4

Figure 4 shows how some less efficient speakers can exhibit unbelievably gross distortion.

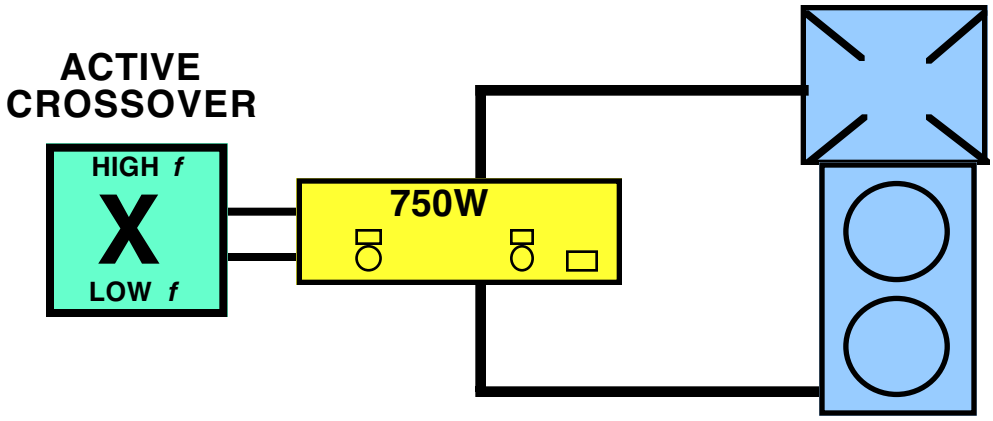
One of the most common refrains heard, is that amplifier power is cheap. Therefore, an inefficient speaker simply needs a ten times bigger amplifier and it will sound just as good as its more efficient counterpart.



Folklore like this has inspired our -ah- company motto.

SPEAKER AMPLIFIER CONFIGURATIONS

We should examine the total number of sound system components required for one screen channel using either the higher or lower efficiency speaker systems and their cost. These examples assume a typical theatre with dimensions of 100 by 50 feet and perhaps 500 to 600 seats.



MAXIMUM OUTPUT AT 50 FT / 16.5 M = 105 dB SPL

Figure 5

In the example shown in Figure 5, a lower efficiency system is bi-amplified according to standard industry practice for such designs. A separate amplifier is required for each of the bass and treble sections of the loudspeaker. The active crossover separates the bass and treble frequencies. The speaker has an efficiency of about 2 1/2 percent at its lowest and highest ranges.

The amplifiers deliver a total of 550 watts and the system has a maximum level in the center of the theatre of 103 dB. This is less than our prudent design goal of 109 to 111 dB. This system is too small.

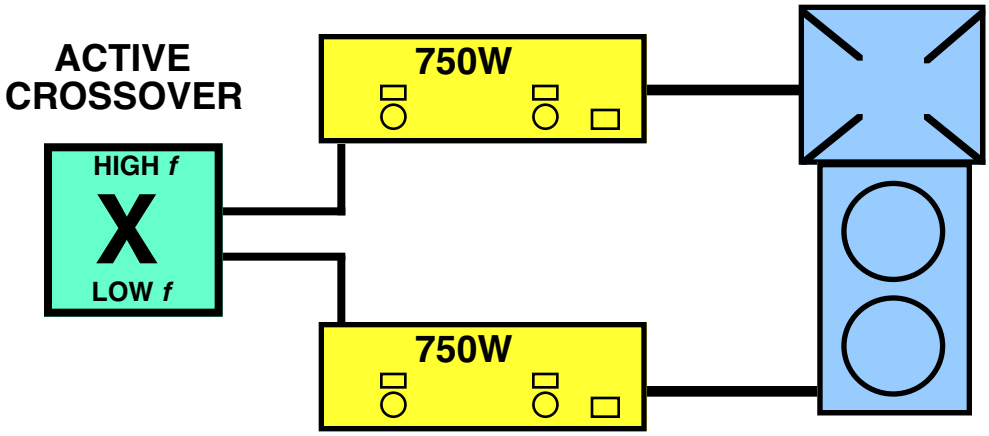
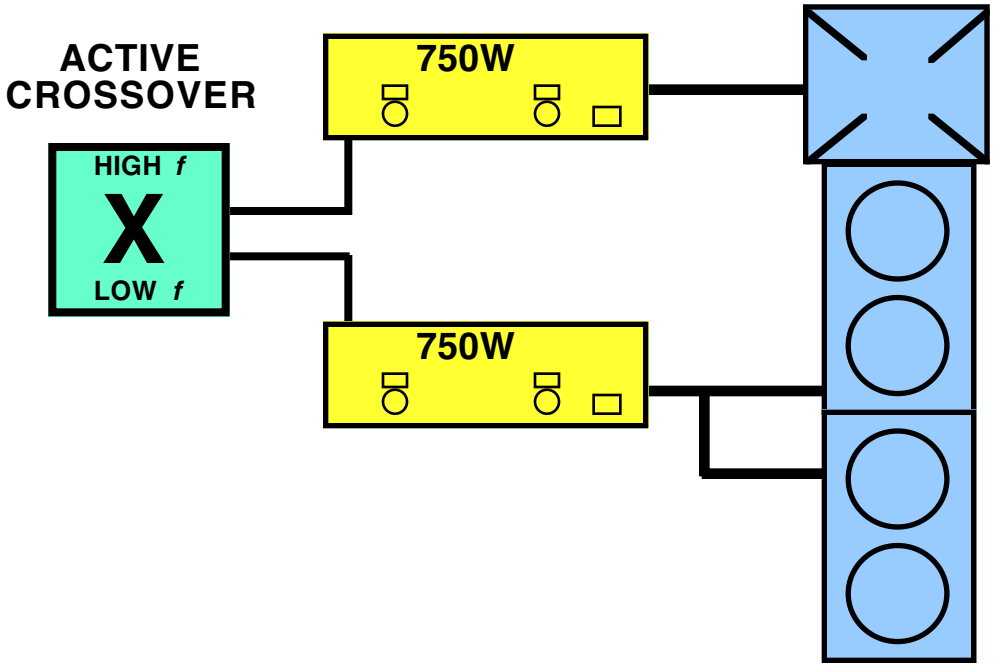


Figure 6

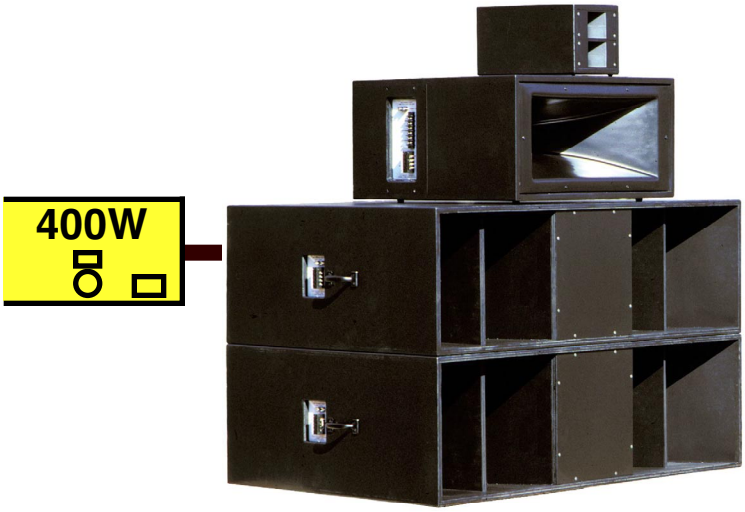
System 2, shown in Figure 6, adds another amplifier, but triples the power. Since we can operate these two channel (or stereo) amplifiers in a single channel mode yielding 800 watts each, the total amplifier power becomes 1600 watts and brings the maximum output of the system up to about 108 dB, which is at least in the ball park.



MAXIMUM OUTPUT AT 50 FT / 16.5 M = 111 dB SPL

Figure 7

In the Figure 7 example, we double the number of woofer cabinets. This corresponds to recommendations for theatres of this size and is certainly a step in the right direction. First, it doubles the radiating area of the bass speakers to 3.2 square feet. The efficiency and output of the system are also doubled. So now, with the same 1600 watts, we get a maximum output of 111 dB in the middle of our theatre; just what we are looking for. However, with the second woofer cabinet, this speaker will now actually cost more than a higher efficiency model.



MAXIMUM OUTPUT AT 50 FT / 16.5 M = 108 dB SPL

Figure 8

The more efficient speaker shown in Figure 8, needs only a fraction of the amplifier power. Along with its 10 1/4 square foot low frequency radiating area and lower distortion, the speaker is efficient enough that it does not need to be bi-amplified. Just one half of a stereo amplifier delivering only 400 watts is all that's required to yield a maximum output level of 111 dB in the theatre's center.

COMPARING COMPONENTS REQUIRED AND COSTS

Though they will not sound the same, both of the last two examples represent current theatre sound system design technologies. Both systems meet our maximum output design goal for digital and analog sound systems of 109 to 111 dB. As stated before, the efficient speaker usually costs more. However, the choice of more efficient loudspeakers results in a substantial and dramatic reduction in the total sound system cost.

DIGITAL STEREO
STAGE SPEAKERS
COMPONENTS REQUIRED AND 1991 RETAIL COST

	LOW EFFICIENCY		HIGH EFFICIENCY	
3 STAGE SPEAKERS	$8700.00		6852.00	
AMPLIFIERS	9234.00	(6)	2308.00	(1 1/2)
ACTIVE CROSSOVERS	1250.00			
SUBWOOFERS AND AMPLIFIERS	5700.00		3552.00	
BAFFLE (ESTIMATED)	1500.00		500.00	
TOTAL COST	$26,384.00		$13,212.00	(-50%)

ASSUMED THEATRE DIMENSIONS: 100 x 50 FEET
MAXIMUM OUTPUT PER CHANNEL: 111 DB SPL
IN THE THEATRE's CENTER

Table 1

Behind the screen, the less efficient system is outlined in table 1 and has a total 1991 retail value of $26,384.00. It includes our three double woofer stage speakers, six amplifiers, the active crossovers required for bi-amplification, two subwoofers and the recommended baffle behind the screen.

The more efficient system requires only 1 1/2 amplifiers, no active crossovers and only a minor baffle. Its total system cost is $13,212.00, or 50 percent less.

While the efficient system has less distortion, remember, the peak output capabilities of these two systems are the same.

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DIGITAL STEREO
SURROUND SPEAKERS
COMPONENTS REQUIRED AND 1991 RETAIL COST

	.3% EFFICIENCY		1.5% EFFICIENCY	
10 SURROUND SPEAKERS	**$2450.00**		**3540.00**	
AMPLIFIERS	**10995.00**	**(5)**	**1539.00**	**(1)**
TOTAL COST	**$13,445.00**		**$5,079.00**	**(-62%)**

ASSUMED THEATRE DIMENSIONS: 100 x 50 FEET
MAXIMUM OUTPUT IN CENTER: 106.5 dB 111.0 dB

Table 2

More efficient surround speakers yield even greater economies while providing even larger improvements in performance. Referring to Table 2, ten surround speakers of about .3 percent efficiency driven by a total of 3,500 watts, or 350 watts each, will (technically) deliver a maximum level of 108 dB in the middle of our 100 by 50 foot theatre. Such a system of ten speakers and the necessity of five of the most powerful amplifiers available will cost $13,445.00. I must also add that these surround speakers will be so overpowered they will ultimately self destruct. Unfortunately, such inefficient surround speakers are an epidemic in many of today's theatres. You'd be shocked to hear what's missing.

In contrast, increasing the efficiency of the surround speakers to about 1 1/2 percent increases the cost of the speakers, but saves four amplifiers. Indeed, it allows us to use only a single and smaller amplifier. It delivers our maximum level goal of 111 dB and costs $5,079.00; a savings of 62 percent, yet with twice the performance plus complete reliability.

As we have seen, amplifier power is indeed not at all cheap. With digital motion pictures now a welcome reality, the careful consideration of fundamental issues like loudspeaker efficiency can have a huge and positive impact on both a sound system's performance and total cost.

My thanks to Bob Sunshine and the Theatre Equipment Association for this opportunity to address SHOWEST this morning and I thank you very much for your attention.

John F. Allen is the founder and president of High Performance Stereo in Newton, Mass. He is also the inventor of the HPS-4000® cinema sound system and in 1984 was the first to bring digital sound to the cinema. John Allen can be reached by E-mail at JohnFAllen@aol.com.