CINEMA SOUND SYSTEM MANUAL

January, 1998

JBL CINEMA SOUND SYSTEM MANUAL

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I. INTRODUCTION

The decade of the 1980's saw many improvements in the quality of cinema sound. Dolby Laboratories had begun the cinema sound revolution during the middle 1970's with the introduction of noise reduction and equalization of cinema loudspeaker systems. In 1981, JBL demonstrated the first flat power response loudspeaker systems at the Academy of Motion Picture Arts and Sciences. In 1983, Lucasfilm introduced the THX® system, along with their program of cinema certification. As the 1980's progressed, Dolby stereo optical sound tracks gained in favor, increasing the number of stereo houses significantly. The application of Dolby Spectral Recording (SR) to cinema release prints represented another step forward in sound quality.

By the mid 1990s, three digital systems had been introduced into the cinema, Dolby SR-D. Digital Theater Sound (DTS), and Sony Dynamic Digital Sound (SDDS). These systems have similar digital performance characteristics, and they all provide analog stereo optical tracks for overall compatibility and operational redundancy, should the digital portion of the system fail, or momentarily go into a mute mode. DTS makes use of a synchronized CD-ROM for its digital program, while the other two include the digital information on the print itself.

As new cinema complexes are being pianned and constructed, acoustical engineers are now more than ever before being engaged to deal with problems of architectural acoustics and sound isolation between adjacent exhibition spaces. More attention is being paid to the specification of sound equipment and its careful integration into the cinema environment.

JBL has a strong commitment to the cinema sound market. We have become the acknowledged leader in the field, and our products are routinely specified for major studios and post-production houses throughout the world. JBL continues its rapid pace in new product development aimed at increasing performance levels in the cinema.

This manual has several goals. First, it will provide a background in basic systems concepts, and then move on to acoustical considerations in the cinema. The subject of electroacoustical specification will be discussed, as will the problems of mounting and aiming of the components. Electrical interface and system checkout will be covered in detail. JBL believes that the more dealers and installers know about the basics of sound in the cinema, the better will be the results of their work in all areas.

II. BASIC SYSTEM CONCEPTS

A. Analog Film Formats

There are two film sizes for theatrical exhibition: 35 mm and 70 mm. The most common projection image aspect ratios (horizontal vs. vertical) for 35 mm can be either 1.851 ("flat") or 2.35:1 ("scope"). Seventy mm prints are normally projected at a ratio of 2.2:1. The advantages of 70 mm have, in the past, been the availability of six magnetic tracks and large image area. The cost of a 70 mm print is quite high, and these prints have normally been made in limited quantities for exhibition in premier houses in large metropolitan locations. Today, the general practice with 70 mm is to use three channels behind the screen (left, center, and right) and a single surround channel feeding multiple loudspeakers. Options are to use the two remaining magnetic tracks for subwoofer signals and/or split (dual channel) surrounds.

The 35 mm format was modified during the 1950's to handle four magnetic tracks: three screen channels and a single surround channel. At the same time, the standard monophonic variable area optical track was maintained. Figures 1A and B show the channel layout for both 70 mm and 35 mm magnetic standards. At present, the 35 mm magnetic standard is no longer in general use.

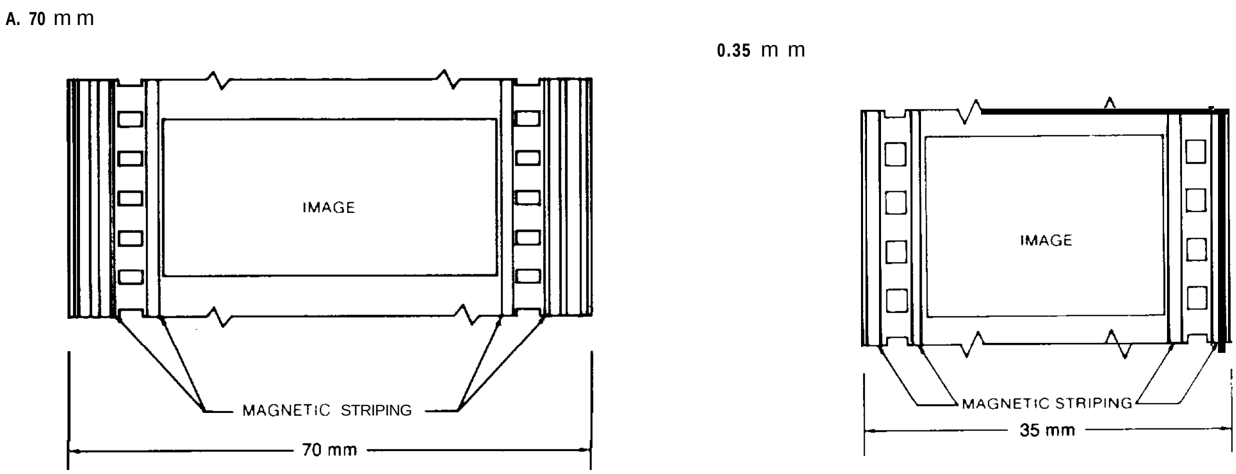


Figure 1. 70mm six-track magnetic format (A); 35mm four-track magnetic format (B)

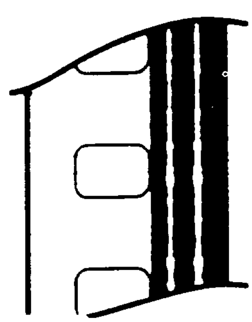


Figure 2A. 35mm Dolby Stereo Optical format

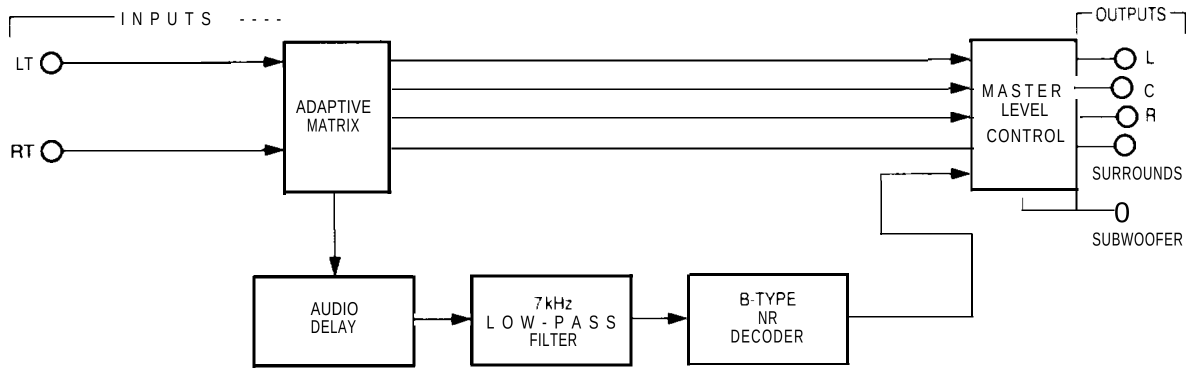


Figure 2B. Block diagram of the Dolby Stereo Optical playback matrix

Today, the Dolby Stereo Optical system is virtually a standard format on non-digital 35 mm film. In this process, the dual bilateral variable area optical sound tracks, which were formerly modulated with a monophonic signal, are now modulated in stereo, as shown in Figure 2A. Recording on the two sound tracks is accomplished through a matrix, which accepts inputs for the three screen channels and the single surround channel. The signals intended primarily for the left and right screen loudspeakers are fed to the left and right channels. Program material intended for the center screen loudspeaker, including most on-screen dialog, is fed to both stereo channels in phase. The in-phase relationship between the stereo channels triggers the playback matrix to steer that information primarily to the center screen loudspeaker, through a combination of gain control and altering of separation coefficients within the matrix. In a similar manner, information intended for the surround channels is fed to both stereo channels so that there is a 180” phase relationship between them. This phase relationship triggers the playback matrix to steer that information primarily to the surround loudspeaker array.

Figure 2B shows details of the playback matrix used in Dolby Stereo Optical soundtracks. The surround channel is delayed relative to the other channels so that, by the precedence (or Haas) effect, the surround channel will not dominate the perceived sound field in the middle and back of the house. The reason for this is that the matrix output contains certain “leakage” signals that may be disturbing to a listener if such signals were to be heard from the surround loudspeakers. in practice, the surround channel is delayed with respect to the screen channels so that the most distant listener in the cinema will hear that channel delayed by a minimum of 20 milliseconds. Since the ear will “lock in” on earlier arrival sounds, localization will be maintained in the direction of the screen for all patrons, while effects intended only for the surround channel will be clearly heard from the surround loudspeakers. This problem is further addressed by rolling off the response of the surround channel above about 7 kHz.

B. Digital Film Formats

The Dolby SR-D format, introduced in 1992, is shown in Figure 3A. It has exactly the same optical sound tracks as shown in Figure 2A with the addition of digital information located in the otherwise unused space between sprocket holes. This new digital format provides the usual three screen channels plus a split surround pair and a single low frequency (subwoofer) channel limited to

100 Hz. This is commonly referred to as a "5.1" channel system and uses an elaborate perceptual encoding process known as AC-3.

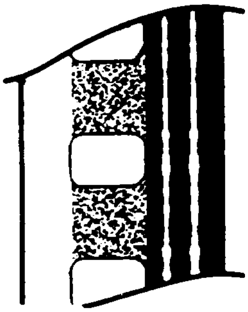


Figure 3A. Dolby SR-D

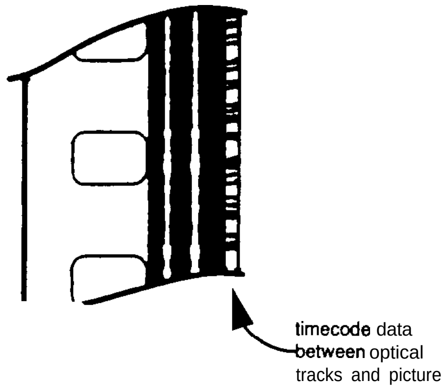


Figure 3B. DTS

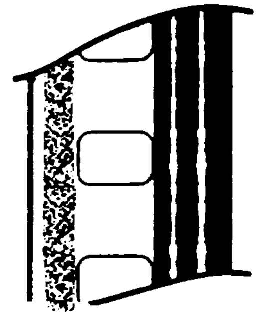


Figure 3C. SDDS

Figure 3B shows the format used in DTS. Here we see only the stereo optical tracks and a sync channel for maintaining control of the associated CD ROM player.

Figure 3C shows the format used with SDDS. In addition to the stereo optical tracks, there are two digital tracks, one at each edge of the film.

Like Dolby SR-D, DTS and SDDS make use of perceptual encoding methods for reducing the amount of digital data required for system operation. DTS and SDDS support the 5.1 channel format used in most cinemas, but SDDS also supports as many as 5 screen channels for special applications.

All digital formats discussed here have a fall-back (failsafe) mode in which the analog tracks will be used in case of failure of the digital portion of the systems.

C. A- and B-chains

For convenience in defining responsibilities for system specification and alignment, the playback chain is customarily broken down into the A-chain and the B-chain, as shown in Figure 4. The A-chain is comprised of the preamplifiers (optical or magnetic), light source (optical), magnetic heads, solar cells (optical), associated equalization (signal de-emphasis), and noise reduction and directional decoding required for flat electrical output at the end of that chain. For digital reproduction, a digital optical reader is used and the digital signal is fed to a digital-to-analog conversion system. The analog A-chain is shown in Figure 4A, and the digital A-chain is shown at B. The B-chain, including split surround channels, is shown at C.

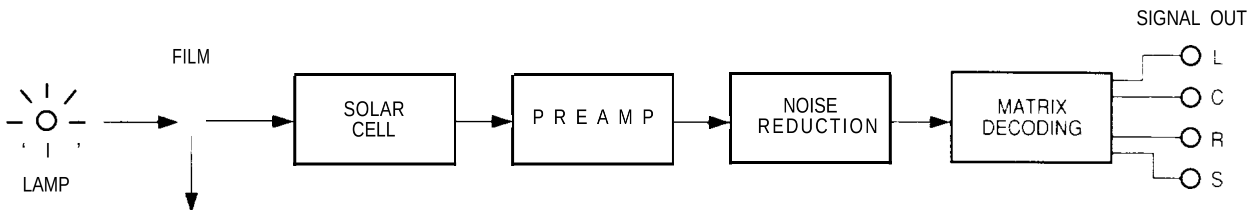


Figure 4A. Block diagram of analog A-chain

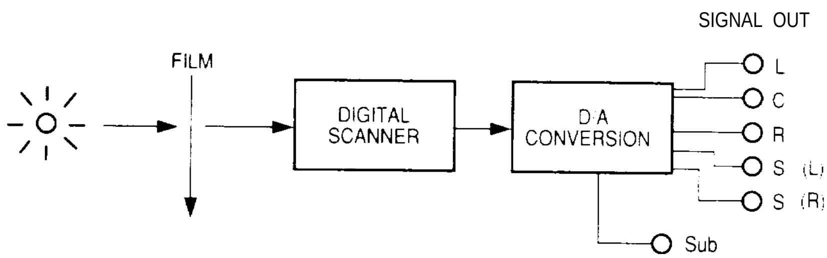


Figure 4B. Block diagram of digital A-chain

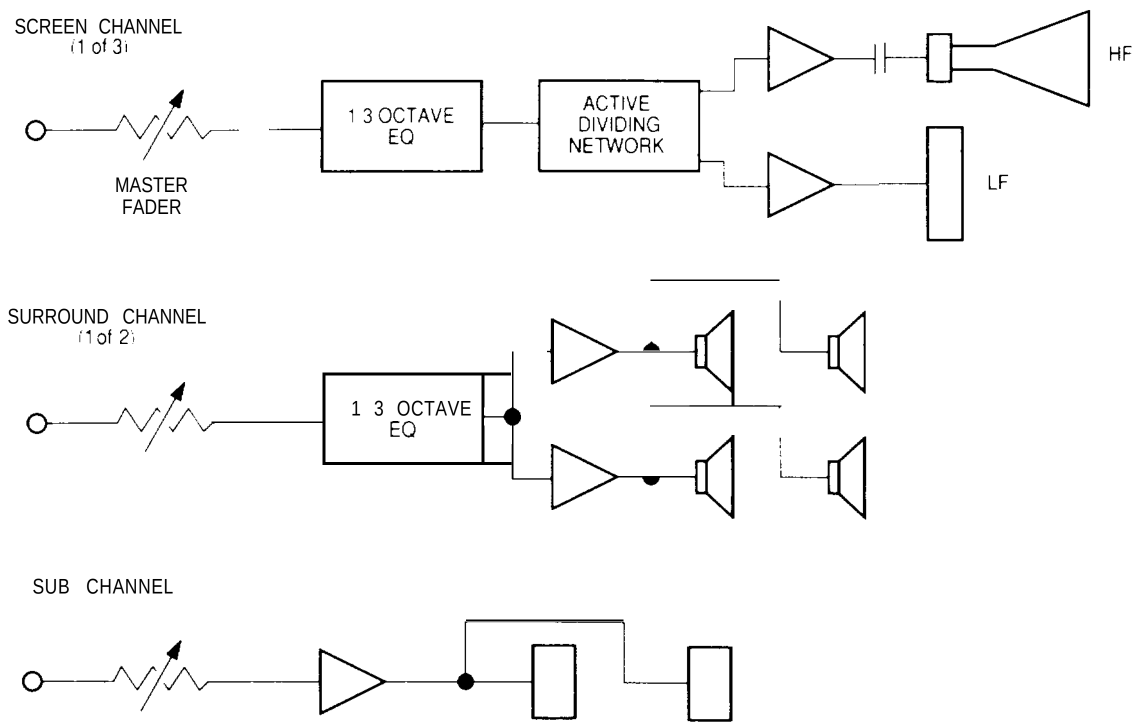
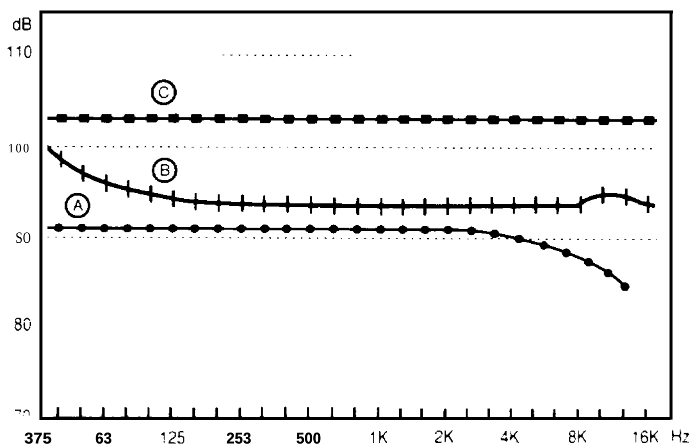


Figure 4C. Block diagram of B-chain with split surrounds

The B-chain is comprised of one-third octave equalization, dividing networks (low- or high-level), power amplification, and loudspeakers. JBL Professional products are used extensively used in the B-chain of the system.

D. Evolving Dynamic Range Requirements in the Cinema

Figure 4D shows details of the headroom requirements of current and future cinema formats. According to Dolby Laboratories, the level of dialog in the cinema will remain as it currently is, while the added headroom will be used primarily for more realistic peak levels for sound effects and music. Depending on specific signal content, the peak level capability of Dolby SR analog tracks can be 3 dB greater in the mid-band than with Dolby A, rising to about 9 dB at the frequency extremes. The digital formats can provide 12 dB headroom relative to Dolby A, with overall characteristics that are flat over the frequency band. This peak capability translates into acoustical levels, on a per-channel basis, of 103 dB-SPL in the house. All of the loudspeaker systems discussed in this manual will meet these new specifications, consistent with the size of the cinema for which the systems will be specified.



Peak power levels *(A) A-type. (B) SR. (C) SR·D*

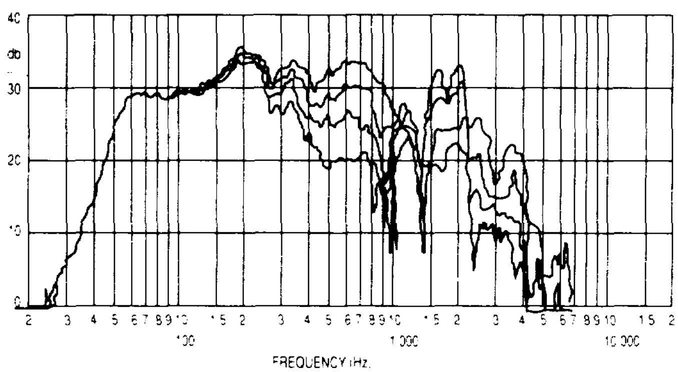
Figure 4D. Dynamic range requirements for Dolby-A, Dolby SR and Dolby SR-D formats

E. Integration of Loudspeakers into the Acoustical Environment

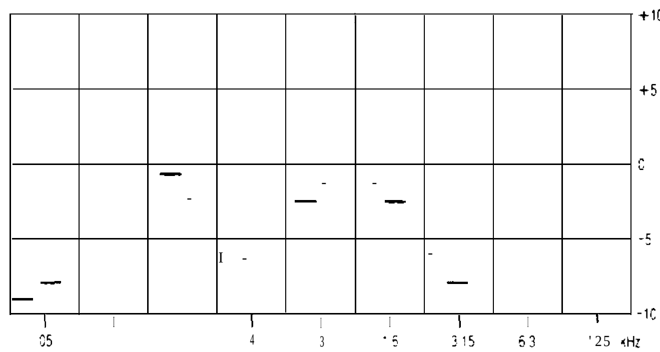
In order to present a clear picture of the interaction of loudspeakers and the acoustical environment, we will begin with the previous era in cinema loudspeaker design. Through the end of the 1970's, the loudspeaker systems which were current in the cinema were the tried and true two-way designs composed of multicellular or radial high-frequency horns and hybrid horn/reflex low-frequency systems. These systems had been developed by Bell Laboratories as far back as the 1930's, and the versions used until just a few years ago were essentially the same as has been developed and refined by Lansing and Hilliard (1). These systems were well engineered in terms of efficiency, ruggedness, and low distortion, given the acoustical performance demands of the day. Their designers had also successfully coped with the problems of frequency division and arrival time differences between high and low frequency sections. The chief weakness of these systems was their lack of uniform coverage. System design stressed output conversion efficiency, because of the small power amplifiers available at the time.

Figure 5A shows the on- and off-axis curves of a typical horn/reflex system, while polar response of a typical multicellular horn is shown at B. Note that the off-axis response of the low-frequency system falls off considerably at higher frequencies. The typical reverberant room response of a system composed of these elements is shown at C. Note here the double hump, which indicates that the total power output of the system is far from uniform. At the same time, however, the on-axis response of the system may be fairly flat, when measured under non-reflective conditions.

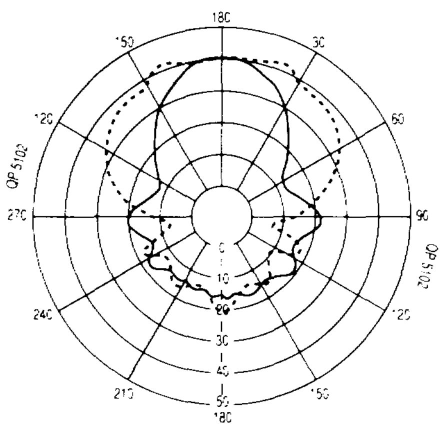
A. Off-axis response of ported horn system



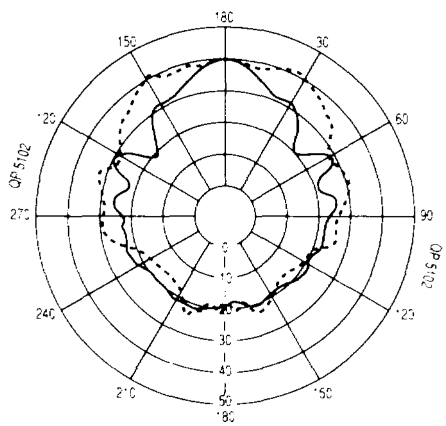
C. Reverberant (power) response of a cinema system composed of elements similar to those shown in Figures 5A and 5B



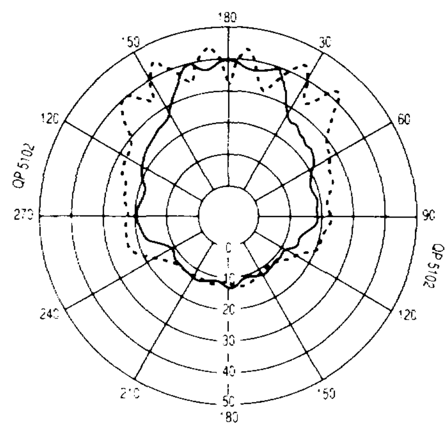
B. Polar characteristics of a 2 x 5 multicellular horn



Multicellular horn (2 x 5) 1000 Hz vertical (so/id); horizontal (dashed)



Multicellular horn (2 x 5) 2000 Hz vertical (solia); horizontal (dashed)



Multicellular horn (2 x 5) 10 kHz vertical (solid); horizontal (dashed)

Figure 5. Theatre equalization of old-style cinema system

If any attempt is made to equalize the response of this system in the cinema, then the response along the major axis of the system will be anything but flat. This is precisely the problem which Dolby Laboratories encountered when they introduced equalization into cinemas during the 1970's.

F. Power Response and Power-Flat Systems

The discrepancy between on-axis and reverberant room response in the older systems was solved with the introduction of a new family of systems based on uniform coverage high-frequency horns and simple ported low-frequency enclosures. Figure 6A shows the horizontal off-axis response of the JBL 4648A low-frequency system. Note that the response is uniform below 500 Hz over a wide angle. At 6B we show the vertical off-axis response of the 4648A system. Note that the response begins to narrow just below 200 Hz. The net result of this pattern narrowing in the horizontal and vertical planes is that they make a good match for the pattern control of the JBL 2360A horn at the normal crossover frequency of 500 Hz.

Figure 6C shows the off-axis response curves for the 2360A Bi-Radial horn, coupled to a JBL 2446J high-frequency driver which has been equalized for flat power response. Note that the off-axis curves are essentially parallel, indicating that the horn produces a solid radiation angle which is uniform with respect to frequency. The need for equalization of the compression driver comes as a result of the natural high frequency roll-off which occurs in high frequency drivers above about 3.5 kHz. This frequency is known as the “mass break point” and is a function of diaphragm mass and various electrical and magnetic constants in the design of the driver.

When the 4648A or 4638 low-frequency system and the 2360/2446 combination are integrated into a full range system for cinema use, the -6 dB beamwidth above 500 Hz is smoothly maintained at 90” in the horizontal plane and 40” in the vertical plane out to 12.5 kHz. At lower frequencies, the system’s coverage broadens, eventually becoming omnidirectional in the range below 100 Hz.

A B

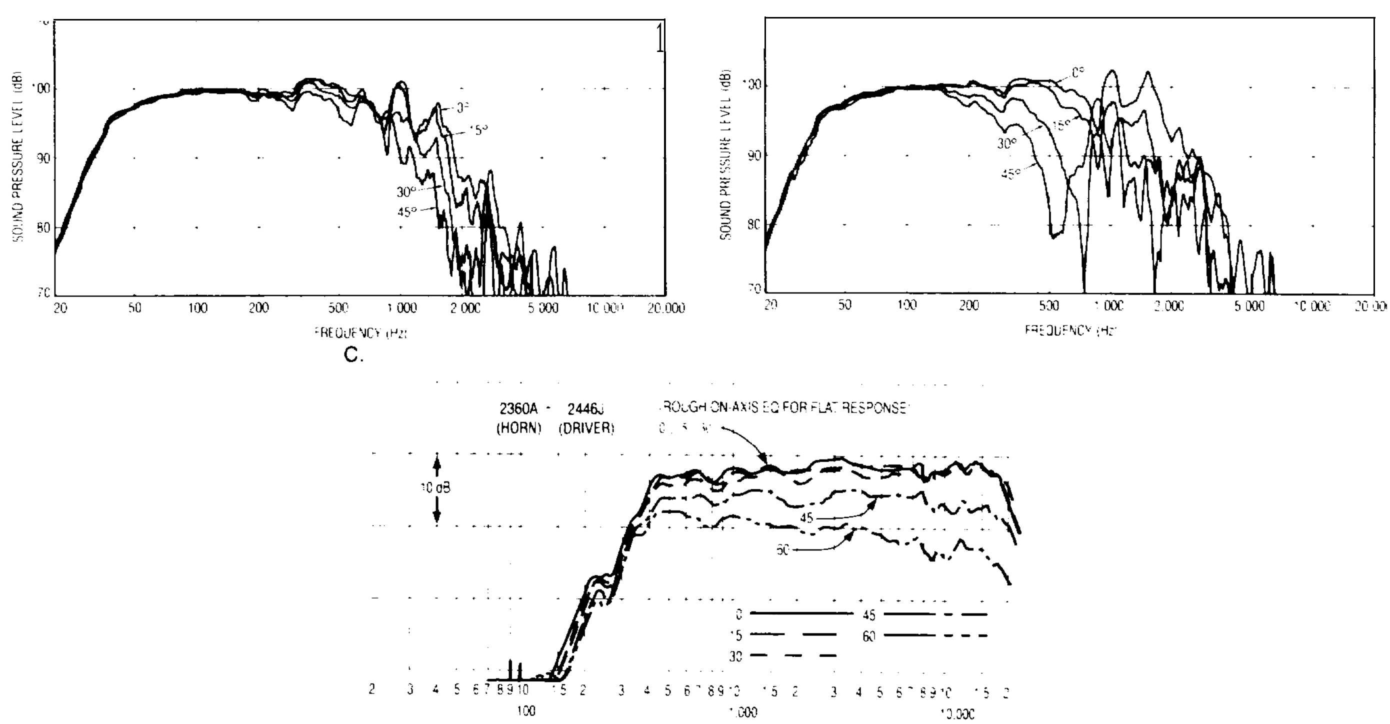


Figure 6. (A) Horizontal response; (B) Vertical response; (C) Off-axis response of a JBL 236OA horn equalized for flat power response

When the system described above is equalized in a typical cinema environment, both direct sound and reverberant sound can be maintained quite smoothly, as shown in Figure 7A. The system's reverberant response is proportional to its power output, or to its power response, and the matching of the system's on-axis and power response indicate that the reflected sound field in the cinema will have the same spectral characteristics as the direct sound from the loudspeaker. When this condition exists, sound reproduction, especially dialog, will sound extremely natural. (The frequency response contour shown in Figure 7B is the so-called "X-curve" recommended for cinema equalization, as specified in ISO Document 2969.)

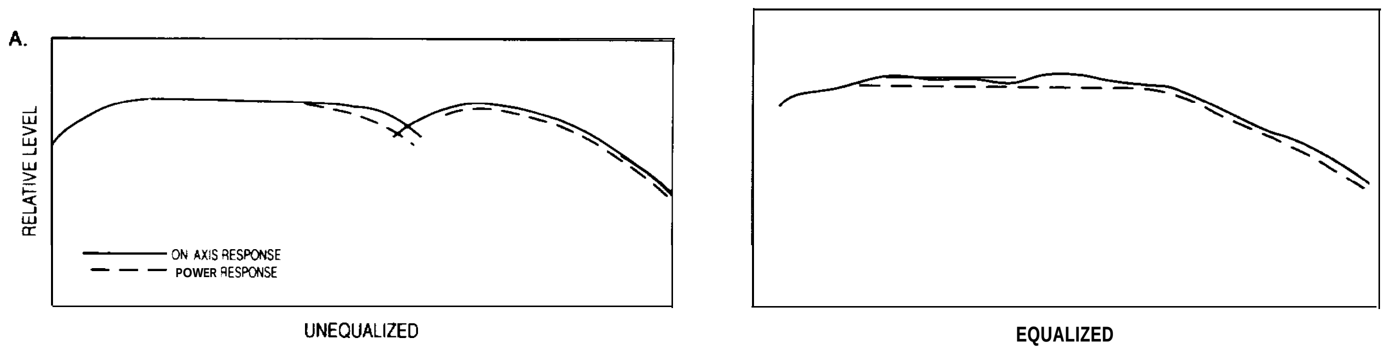


Figure 7. Cinema equalization of power flat systems

JBL pioneered the concept of flat power response in the cinema (2,3). It has become the guiding principle in much of JBL's product design, and it has been adopted by the industry at large.

G. Coverage Requirements for Proper Stereo Reproduction

In the cinema, it is expected that all patrons will be able to appreciate convincing stereo reproduction. By contrast, standard two-channel stereo in the home environment often imposes strict limitations on where the listener must sit in order to perceive correct stereo imaging. The factor that makes the big difference in the cinema is the presence of the center channel. Not only does the center loudspeaker lock dialog into the center of the screen, it further reduces the amount of common mode information the left and right channels must carry, thus making it possible for listeners far from the axis of symmetry to hear the three channels with no ambiguity or tendency for the signal to "collapse" toward the nearer loudspeaker. In the Dolby stereo matrix, the same convincing effect is largely maintained through gain coefficient manipulation during playback.

Ideally, each patron in the house should be within the nominal horizontal and vertical coverage angles of *all* the high-frequency horns. This requirement can usually be met by using horns with a nominal 90" horizontal dispersion and by toeing in the left and right screen loudspeakers. In very wide houses, the spreading of high frequencies above approximately 5 kHz, as they pass through the screen at high off-axis angles, actually helps in providing the desired coverage.

Another desirable condition is maintaining levels as uniformly as possible throughout the house. We have found that aiming the screen systems, both high- and low-frequency, toward the back wall helps in this regard, by offsetting normal inverse square losses with the on-axis "gain" of the screen systems. Measurements made at the Goldwyn Theater of the Academy of Motion Picture Arts and Sciences in Beverly Hills, California, show that, over most of the frequency range, front-to-back levels in the house are maintained within a range of 5 dB. By contrast, aiming the high-frequency elements toward the audience would produce front-to-back level variations of up to 10 to 12 dB. An important requirement here is that the back wall of the cinema be as absorptive as possible. If the rear wall is not highly absorptive, then tilt the high frequency loudspeakers down, with the horn's axis pointing at the seating area two-thirds of the way back in the house.

This performance is seen in Figure 8. At A, we show in plan view the direct field coverage given by a JBL 2360 horn aimed at the absorptive back wall of a large theater with sloped floor. Coverage at 2 kHz is within a range of +/- 3dB, front to back. If the horn is aimed downward to a point two-thirds the distance from front to back, the coverage is as shown at B, and coverage at the rear of the house is compromised. The coverage given by one of the outside horns, aimed at the rear wall, is shown at C. It is customary to toe in the left and right systems toward the center, whether or not the screen itself is curved, and the aim is to provide adequate coverage for all patrons, with response maintained within a total range of 6 dB.

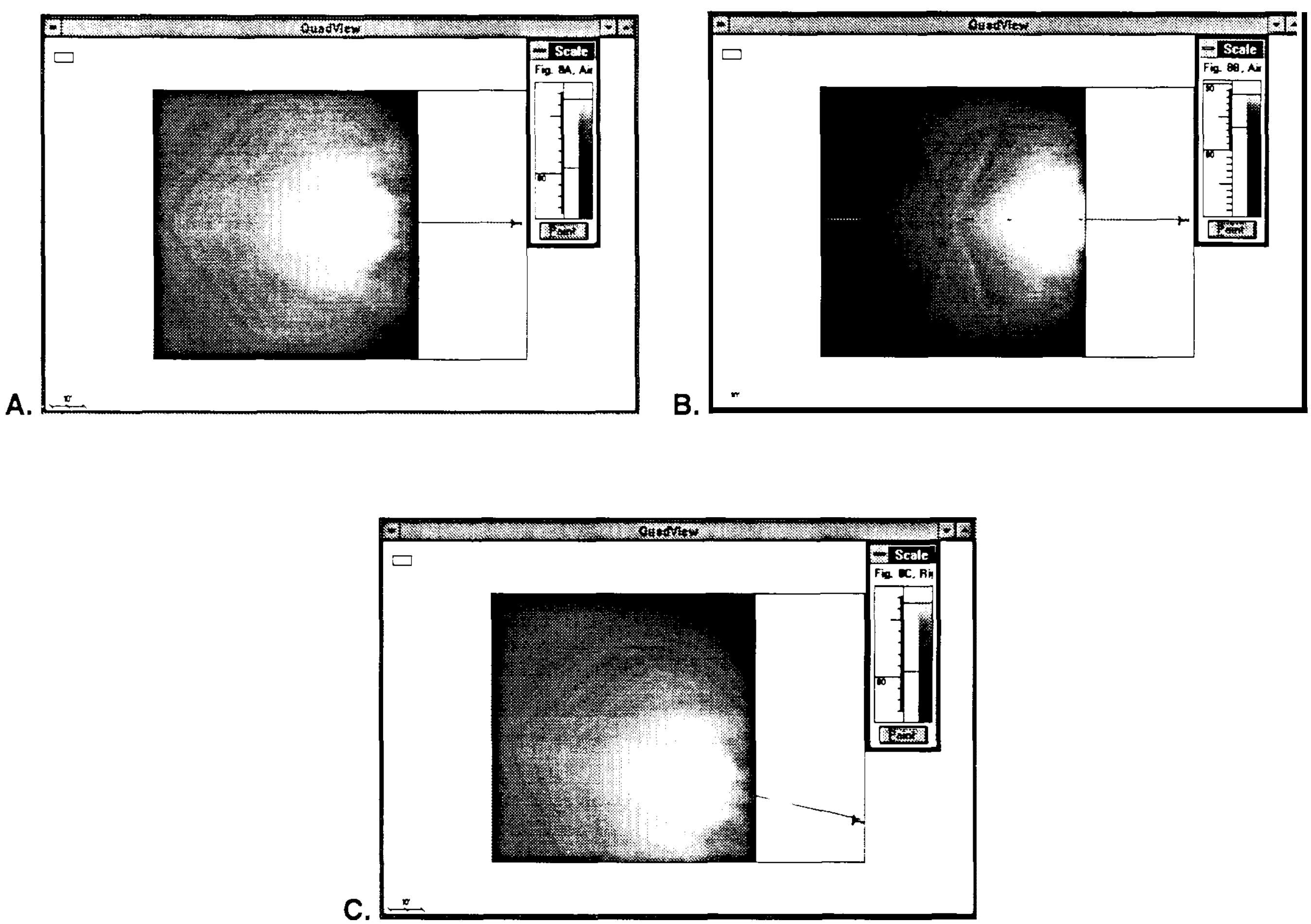


Figure 8. (A) Direct field coverage at 2kHz, aimed at rear wall; (B) Same, horn aimed 2/3 distance front to back; (C) Coverage of single outside horn.

The surround ensemble of loudspeakers, if properly specified, can easily produce a sound field that is uniform throughout the back two-thirds of the house, and level variations can often be held within a range of 2 to 3 dB. Details of surround system specification will be covered in a later section.

When all of the above points are properly addressed, the sound in a cinema can approach that which we take for granted in a post-production screening facility - which is, after all, how the picture director intended it to sound. It is only when such details as these have been carefully worked out that the effects intended by the sound mixer can be appreciated by the viewing audience.

III. ACOUSTICAL CONSIDERATIONS

A. Noise Criterion (NC) Requirements

The usual sources of noise in a cinema, outside of the patrons themselves, are air handling and transmission of noise from the outside. In the case of multiplex installations, there can be leakage from adjacent cinemas as well. Not much can be done about a noisy audience, but it is true that at the post-production stage, mixing engineers take into account certain masking noise levels which may be encountered in the field and even do the final mix under simulated noisy conditions (4).

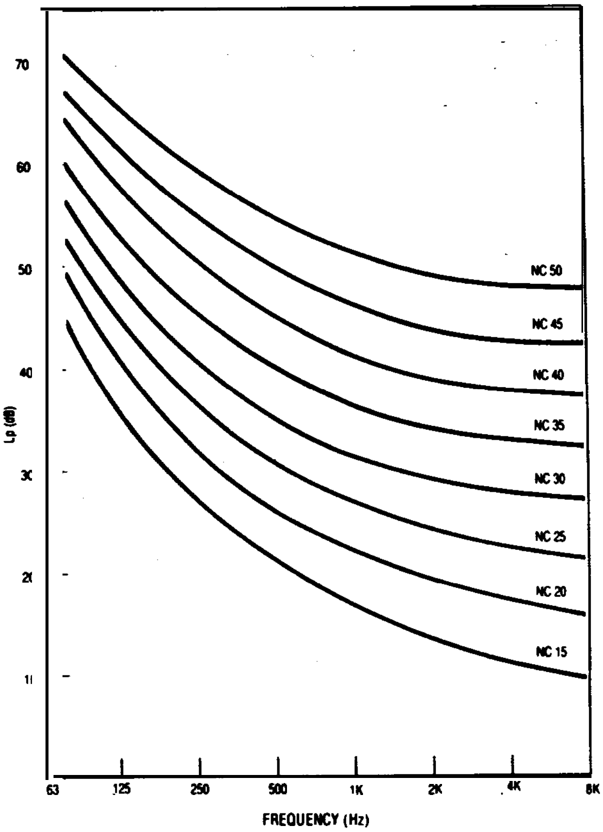


Figure 9. Noise Criterion (NC) curves, octave band data

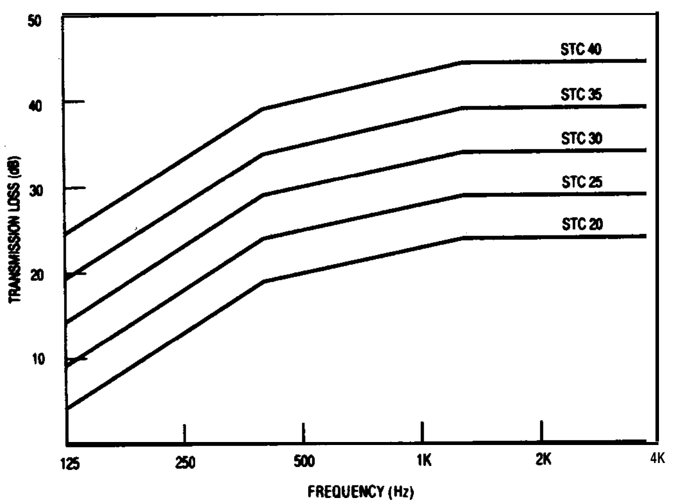


Figure 10. Sound Transmission Curves

Acoustical engineers make use of what are called Noise Criterion (NC) curves in attempting to set a noise performance goal for cinemas. The octave band values of these curves are shown in Figure 9. In implementing this data, the acoustical designer settles on a given criterion and then determines the cost and other factors involved in realizing it. Low-noise air handling requires large ductwork and is expensive. Even more likely to be a problem is through-the-wall isolation from adjacent cinemas. The general recommendation made by Lucasfilm Limited (5) is that interference from adjacent cinemas should be audible no more than 1% of the time. Considering that NC-30 may represent a typical air conditioning noise level for a cinema, the desired degree of isolation between adjacent spaces does not represent a hardship in terms of wall construction. The need for improving NC standards in cinemas is a natural consequence of better recording technology and is the only way that the benefits of Dolby SR and digital formats can be fully appreciated.

As an example of what may be required, let us assume that the normal maximum levels in a multiplex cinema are 95 dB-SPL, with levels exceeding this value only about 1% of the time. It is clear that the isolation from an adjacent cinema must be on the order of 65 dB if the NC-30 criterion is to be met, and this will call for a wall structure that will satisfy a Sound Transmission Class (STC) of 65 dB. There are a number of double wall, or single concrete block wall, constructions that will satisfy this requirement, and economic considerations usually take over at this point. Acoustical engineers and consultants are usually on firm scientific ground in these matters. Typical standard STC curves are shown in Figure 10 .

The isolation task is certainly easier with new construction, since buffer areas can be designed between adjacent exhibition spaces. The most difficult problems occur when older spaces are to be subdivided to make multiplex cinemas, inasmuch as the chances of coupling through walls or through common air handling are compounded.

It is obvious that the architect must work closely with an acoustical engineer if the job of isolating adjacent spaces is to be done correctly. All of this yields to straightforward analysis, but the job is often a tedious one.

B. Control of Reverberation and Discrete Reflections

After the problems of sound isolation have been addressed, the acoustical engineer then turns to those problems that are generated entirely *within the* cinema itself; i.e., reverberation and echoes. The acoustical 'signature' of a cinema should be neutral. Reverberation per se is not generally apparent in most houses, and any perceived sense of reverberation or ambience during film exhibition normally comes as a result of surround channel program.

This is not to say that the cinema environment should be absolutely reflection-free. Strong initial reflections from the sides of the house may be beneficial in a concert hall, where they are needed to produce a sense of natural acoustical space; however, in the cinema, pronounced initial reflections from any direction should be eliminated.

Traditionally, reverberation time in auditoriums increases at low frequencies and decreases at high frequencies. This is a natural consequence of the fact that many surfaces that are absorptive at middle and high frequencies are not very effective sound absorbers at low frequencies. At higher frequencies, there is additional absorption due to the air itself, and this excess attenuation of high frequencies tends to lower the reverberation time. Figure 11 shows the normal range of reverberation time, as a function of the value at 500 Hz, while Figure 12 shows the acceptable range of reverberation at 500 Hz as a function of room volume.

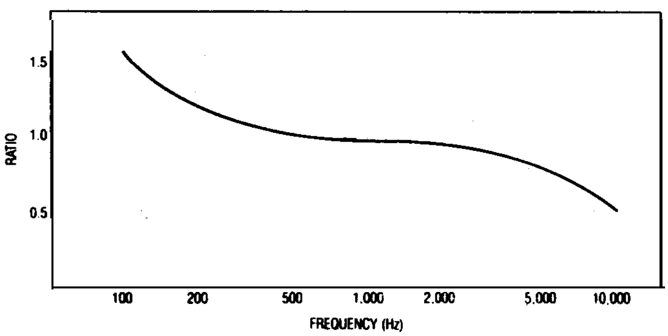


Figure 11. Variation of reverbera tion time with frequency

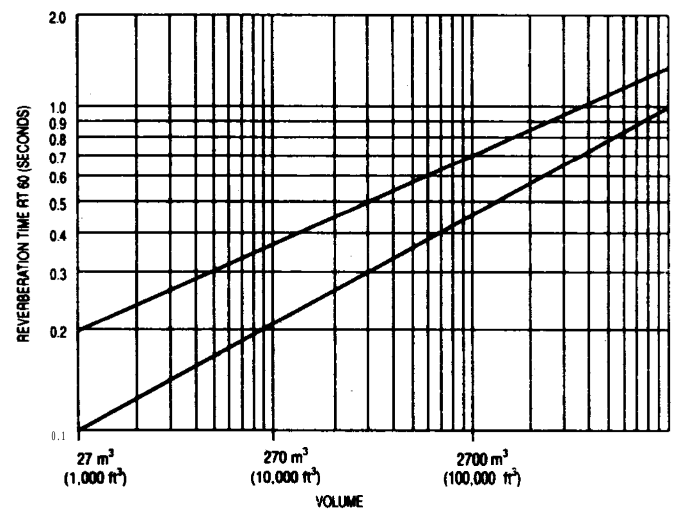


Figure 12. Suggested range of reverberation

The requirements of specifying the right finishing materials, along with any special needs for added low-frequency absorption, fall squarely in the hands of the acoustical designer. In smaller houses, there is often little choice but to make the space acoustically 'dead;' however, some degree of reflectivity, even though it may not be perceived as such, will be beneficial.

Discrete reflections are likely to be a problem only if they clearly are displaced from the direct sound in both time and spatial orientation. Side wall reflections are usually perceived by the listener well within a time interval which does not allow them to be heard-as such. However, a reflection off the back wall can rebound from the screen itself, creating a 'round trip' echo that may be delayed by as much as 100 milliseconds. The effect here is to render dialog difficult to understand. In older cinemas with balconies, such reflections were often generated by the balcony front (or fascia) itself. Substantial acoustical damping had to be placed on that surface in order to diminish the problem.

In most cinemas constructed today, echo problems can generally be dealt with by ensuring that the back wall is very absorptive and that substantial damping is installed behind the screen on the baffle adjacent to the loudspeakers.

C. The Role of the Acoustical Consultant

An acoustical consultant should be chosen on the basis of previous jobs well done. There is much that is learned simply by having encountered-- and solved -- many problems. Stating it another way, an experienced consultant has probably seen most of the common mistakes and knows how to spot them before they become problems. While much of what a consultant does may seem obvious, and even simple, it is the breadth of experience that qualifies a good consultant to take on a difficult task and succeed at it.

In addition to the points discussed so far in this section, the consultant will look for potential difficulties in the following areas:

1. Flankina leakage paths. When acoustical isolation has been addressed in wall construction, flanking paths through, or around, the wall may become significant. For example, sound often leaks through electrical or air conditioning conduit, even though the wall itself may act as a good barrier to sound transmission. Such paths can crop up in many places and need to be identified early in the construction phase of the project.

2. Intearitv in construction. Many building contractors routinely take shortcuts, and somebody needs to watch them carefully. The acoustical isolation of double wall construction can be nullified by the presence of material left between them bridging the air barrier between the two sections.

3. Imoact and structure-borne noise. These are some of the most difficult problems to fix, since they are literally 'built in.' Plumbing noises, elevator motors, and air handling machinery located on the roof are just a few of the offenders here. Once the installation has been made, the problem is very expensive to correct, and a good consultant will have an eye out for such things at the design stage of the project. Related problems, such as projector noise and other noises associated with concession activities need to be identified early in the project and corrected before construction begins.

As standards for film exhibition continue to improve, such points as we have raised here will become more important. In a 1992 monograph(5), loan Allen of Dolby Laboratories stressed the need for noise ratings in the cinema lower than NC-25, with NC-30 representing the worst acceptable case.

IV. SPECIFYING THE CORRECT LOUDSPEAKERS AND AMPLIFIERS

A. Hardware Class vs. Room Size

In all but the smallest cinemas, dual low-frequency systems, such as the JBL 4670D and the **4675C,** should be specified. Normally, there will be three of the systems behind the screen in left, center, and right positions. The 4670D has the Flat-Front **Bi-Radial 2380A** horn, while the **4675C** has the large 2360A Bi-Radial horn. The differences in performance are basically high-frequency vertical pattern control in the range from 500 to 1000 Hz. Whenever possible, the 4675C systems should be specified, but there are situations where space behind the screen is limited, and the smaller horn must be used.

Both systems are capable of the same acoustical output, inasmuch as they are both limited by the power handling capabilities of their identical low-frequency sections. Table 1 indicates the sustained maximum sound pressure level in the reverberant field which these systems can produce, based on room volume. Levels for a single unit, as well as for the three units, are given. Median reverberation times as given in Figure 11 are assumed in these calculations, as are system directivity index and estimated room surface area.

Volume	Level, single unit	Level, three units	Typical seating	Power required, single unit
270 m^3 (10,000 cu. ft.)	116 dB	121 dB	75 to 100	800 W
540 m^3 (20,000 cu. ft.)	113	118	150	800W
1350 m^3 (50,000 cu. ft.)	108	113	300	800W
2700 m^3 (100,000 cu. ft.)	108	111	500	800W
5400 m^3 (200,000 cu. ft.)	104	109	1000	800W

Table 1A: Maximum Reverberant Levels[1] for
JBL 4670D and 4675C Systems in Cinsmas
of various sizes (non-b&m plified mode)

Taking the information presented in Table 1A, we can now determine the actual power requirements to produce target levels in the house of 105 dB per channel:

Volume	Typical seating	Power required	Recommended amplifier
270 m^3 (10,000 cu. ft.)	75 to 100	100 W	JBL MPX300 (one channel)
540 m^3 (20,000 cu. lt.)	150	250 W	JBL MPX600 (one channel)
1350 m^3 (50,000 al. ft.)	300	400W	JBL MPX600 (one channel)

Table 1 B: Power Requirements for
Target Reverberant Levels[1] of 105 dB
in Smaller Houses (non-biamplified mode)

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[1]Reverberant levels, as calculated in Tables 1 A, B, and C, represents the maximum level that would exist at a point about two-thirds from the front of the house to the back.

For spaces of 2700 m^3 or greater, JBL recommends that the model 4675C be specified in biampiified mode.

Volume	Level, single unit	Level, three units	Typical seating	Power required, single unit
2700 m^3 (100,000 cu. ft.)	108 dB	113 dB	500	[2]LF: 400 W HF: 250 W
5400 m^3 (200,000 cu. ft.)	106	111	1000	LF: 400 W HF: 250 W

. _ Table 1C. Maximum Reverberant Levels[1] for JBL 4675C Systems in Large Cinemas (biamplified mode).

B. Advantages of Biamplification

The importance of biampiification in large cinemas cannot be overestimated. Even though the systems detailed in Table 1 B use the same amplifier model as the systems detailed in Table 1 A, the reallocation of the power through biampiification has important beneficial effects. Specifically, intermodulation distortion is reduced at-high operating levels, and available power can be more directly matched to the specific HF or LF load.

C. Cinema Playback Level Calibration

The actual level requirements in the film maker's dubbing cinema are established by relating them directly with modulation level on the recorded medium. For magnetic media, this is established as 85 dB-SPL in the house when the modulation on the tape is so-called 'zero level,' or 185 nanowebers/meter. This last quantity has to do with recording technology, and we need not concern ourselves with it further, except to note that modulation peaks often exceed zero level by 8 to 10 dB. Thus, the peak output per loudspeaker may be only 95 dB. Good engineering practice allows additional headroom of 6 to 8 dB above this, so it is clear that the values we have listed in Tables 1A and B are not excessive in the cases of the larger houses. in the smaller houses, we can certainly make do with smaller amplifiers than indicated in the table; but even then, the cost of the added power is very slight, and the benefit substantial. The powers recommended in Tables 1A and B are in accordance with the suggestions made by Lucasfilm Limited (6) in the specification of THX systems.

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[2]JBL amplifier model MPA400 with appropriate front-end frequency division and power response equalization, is recommended for these applications. The LF loudspeaker section presents a 4-ohm load, to which the amplifier can deliver 400 watts; the HF section presents an S-ohm load, for whii the ampliier can deliver 275 watts.

D. New JBL Driver Developments

Our studies have indicated that, in passive systems, maximum power input to the screen loudspeakers is essentially network limited. As a result of this, many cinema applications ordinarily will not require the high power Vented Gap **Cooling™ (VGC)** performance designed into the JBL 2226 driver. A more recent model, the 2035, was subsequently designed with a 76 mm (3 in.) voice coil, retaining the same sensitivity of the 2226. Resulting economies can thus be passed on to the user.

In biamplified systems for larger houses we strongly recommend that the 2226 transducers be used, because of their higher peak power and transient capabilities.

Figure 13 shows the on-axis response of the dual low frequency 4638 system, which incorporates two of the 2035 transducers.

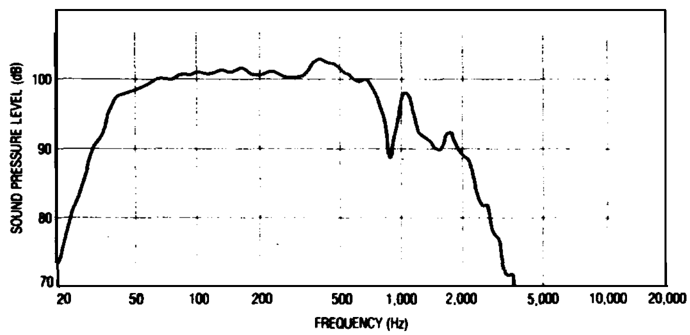


***Figure 13**. On-axis response of dual 360 mm* (15 *in.) 4636TH LF system.*

E. Mechanical Details of JBL Screen Loudspeaker Systems

The main JBL loudspeakers recommended for behind-screen use are discussed in this section. Since all of these systems are intended for field assembly, we will show them in exploded views, along with a parts list and a wiring diagram for use with a high-level dividing network.

Figure 14 shows dimensional aspects on field assembled 4670D and **4675C** systems, clearly indicating their overall space requirements. The models**4670D-HF,** 4671 B, **4673B, 4675C-HF,** and 4638TH are shown, respectively, in Figures 15 through 19.

Passive network hook-up details are shown in Figure 20. Wiring instructions for biamplification will be discussed in a later section.

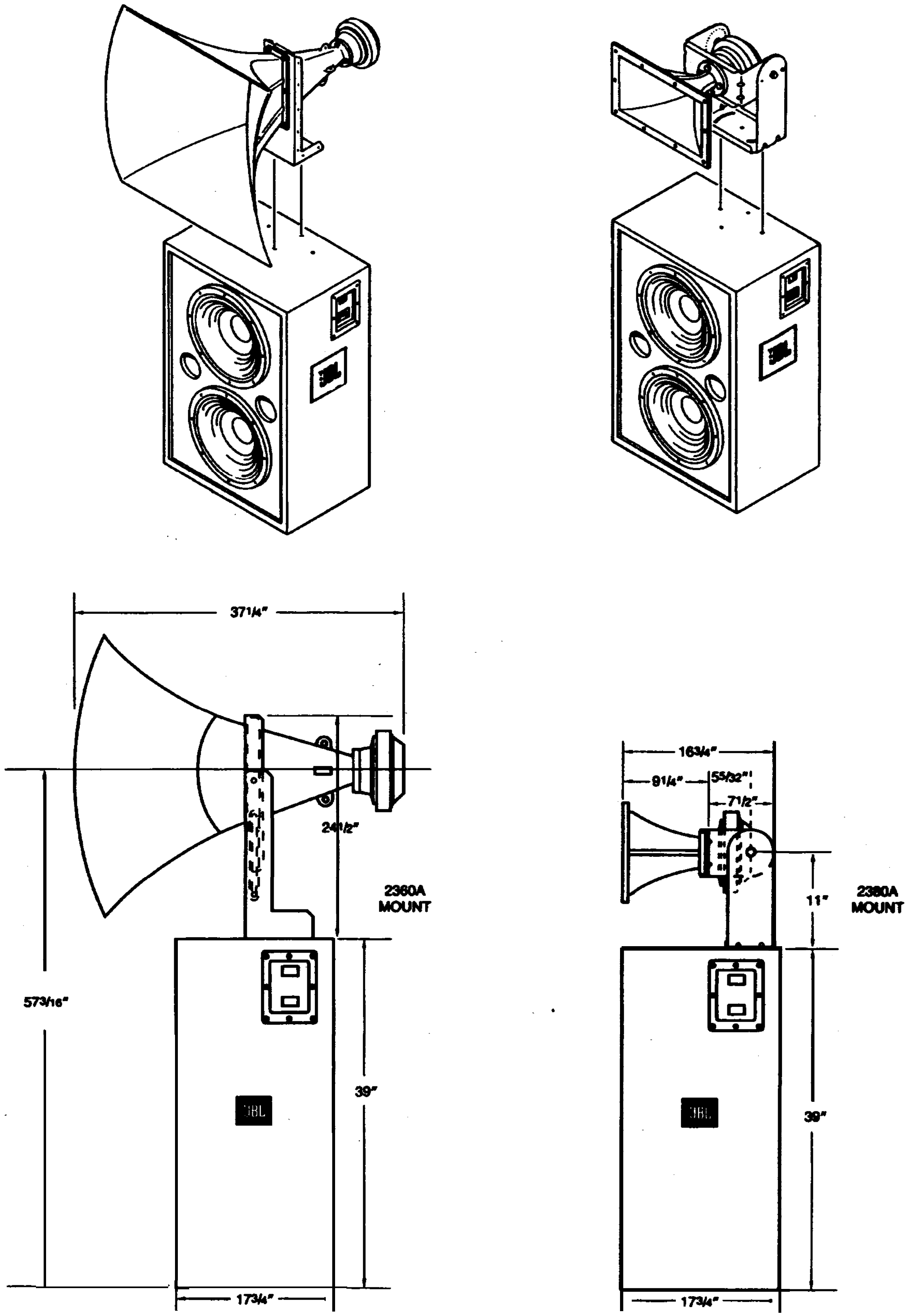
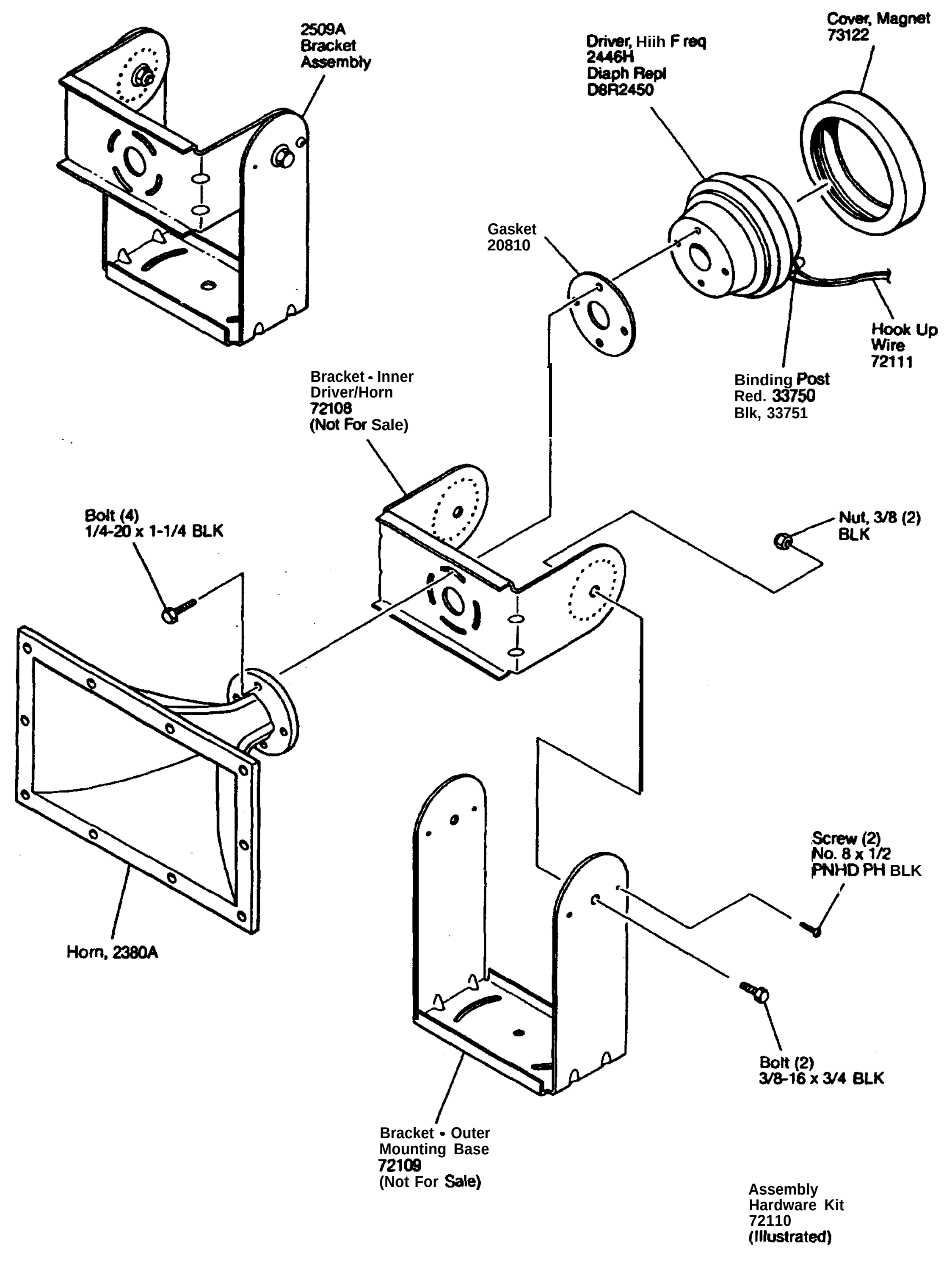


Figure 14. Complete system assembly diagram for 46700 and 46756.

COMPONENT EXPLODED VIEW



COMPONENT EXPLODED VIEW

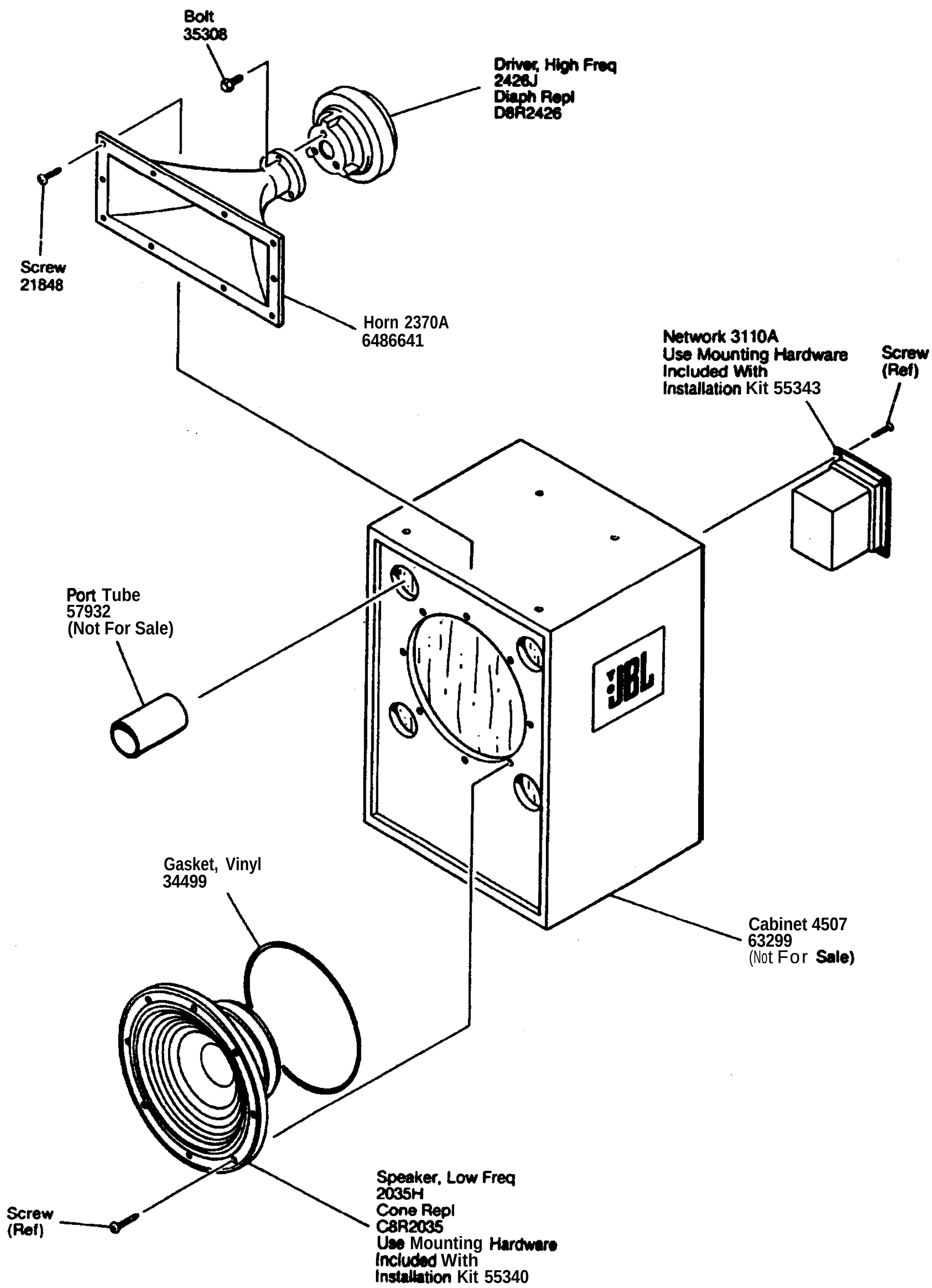


Figure 17

JBL4673B

COMPONENT EXPLODED VIEW

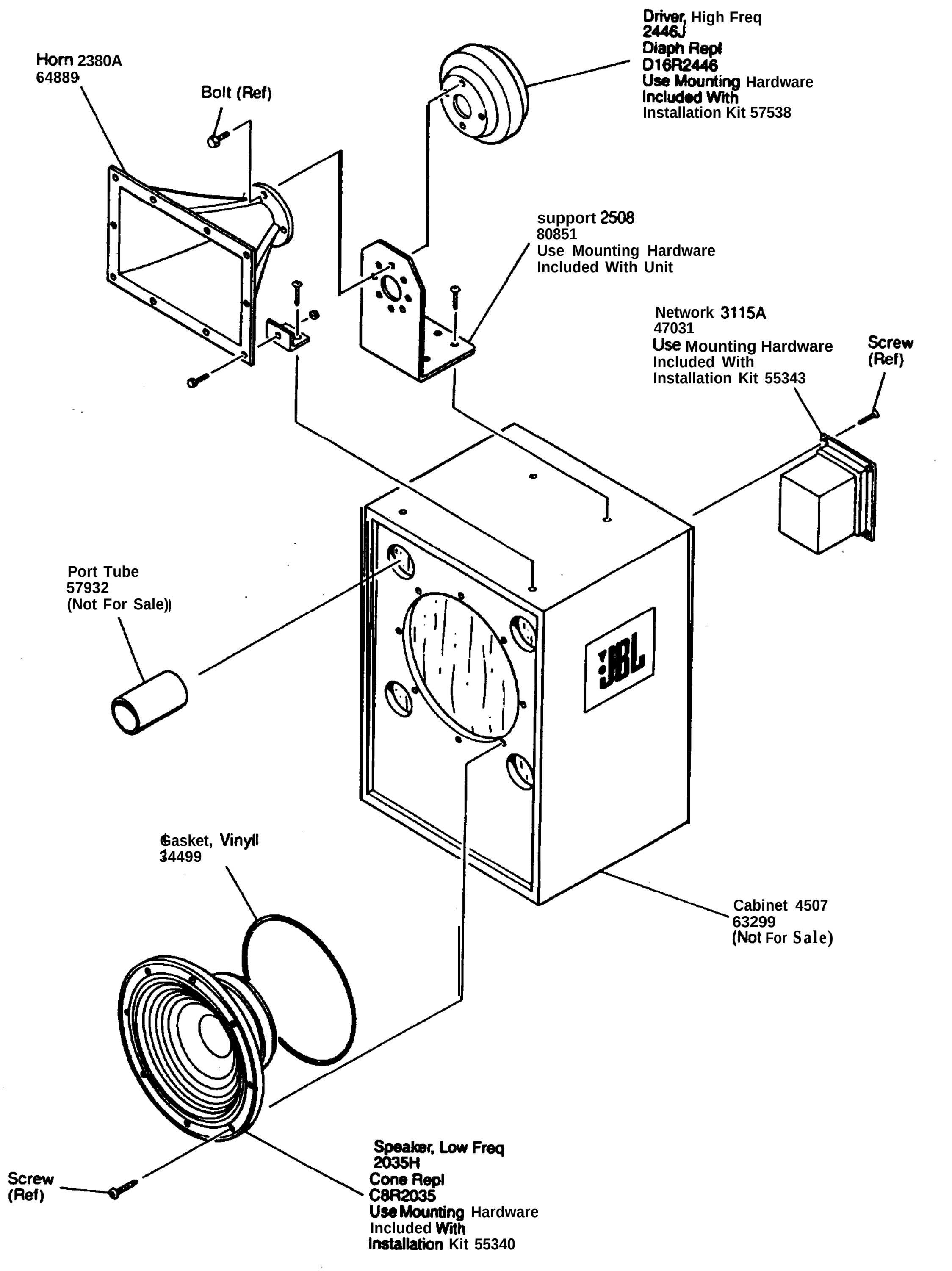
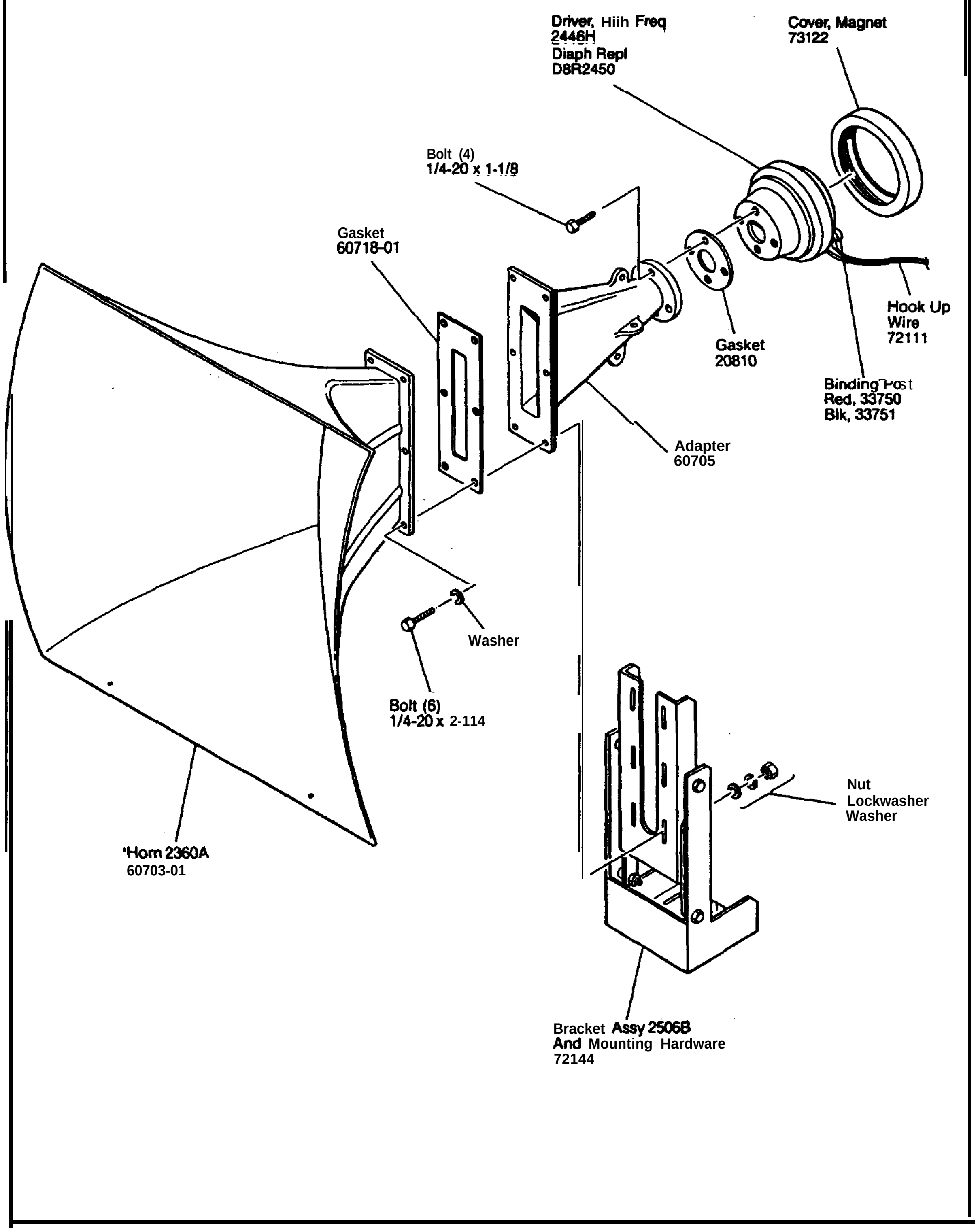


Figure 18

COMPONENT EXPLODED VIEW



COMPONENT EXPLODED VIEW

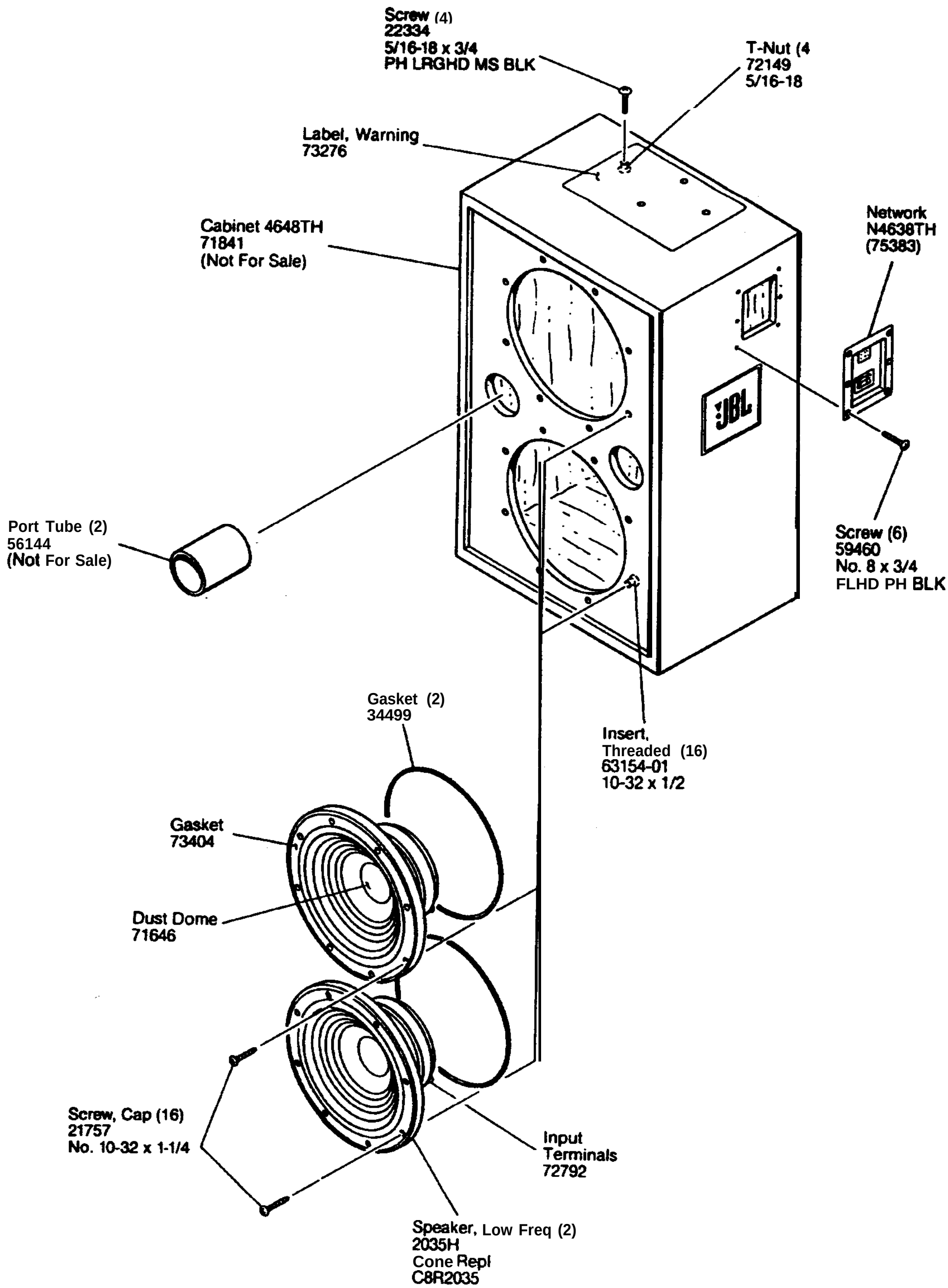
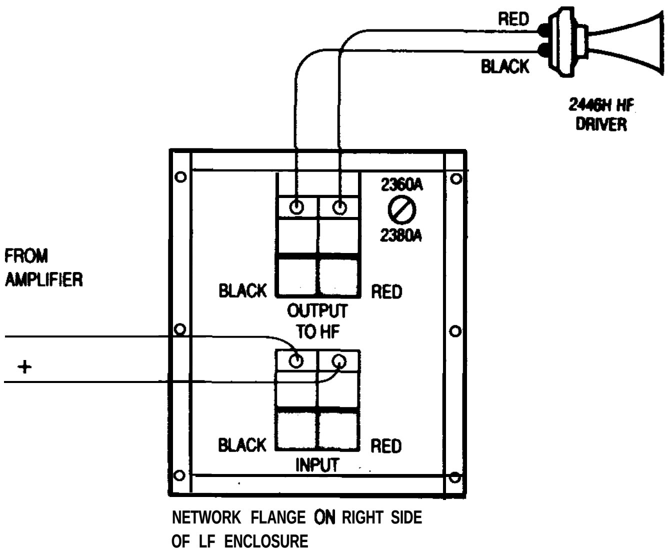
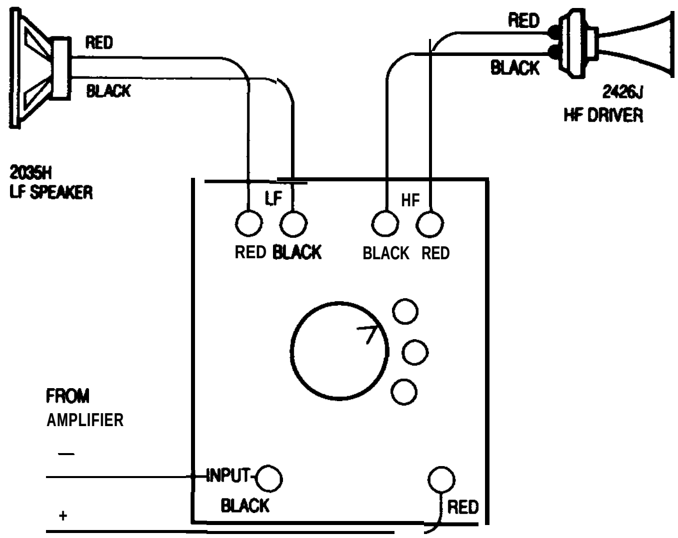


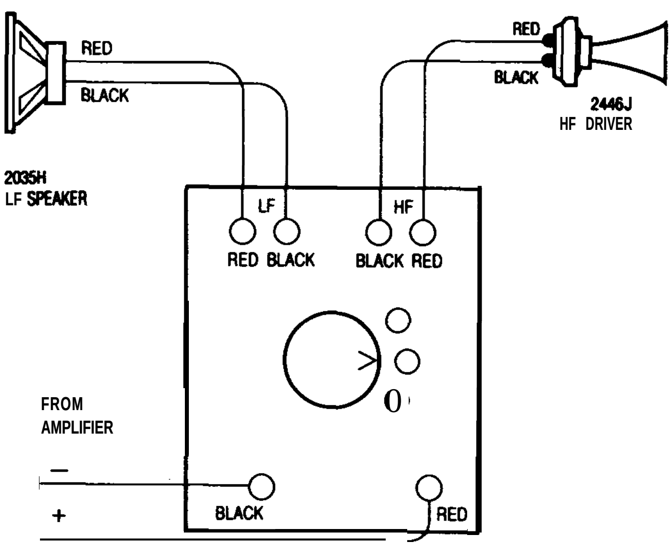
Figure 20



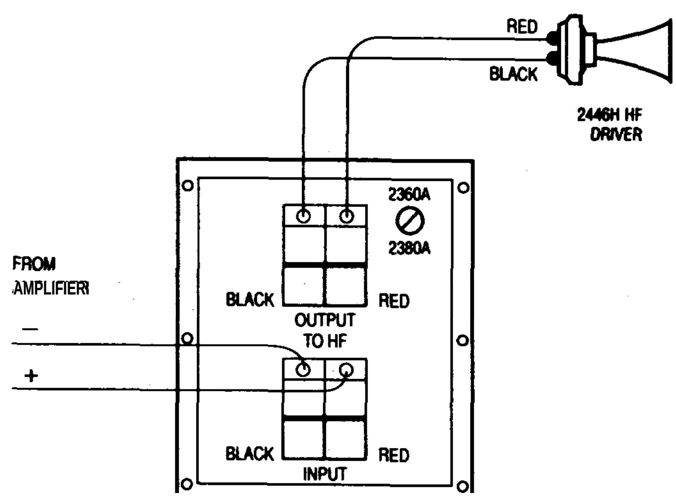
46700 wiring diagram



4671 B wiring diagram



46738 wiring diagram



4675C wiring diagram

NOTE:
Input connections as shown here provide correct EIA polarity.

F. Subwoofers

Subwoofers are an integral part of cinema loudspeaker systems installed in mid- and large-size houses. In specifying them, the designer must take into account the reduced sensitivity of the ear to low frequency sounds. Figure 21 shows the Robinson-Dadson equal loudness contours. Note that, for a reference level of 85 dB at 1 kHz, frequencies in the range of 30 to 40 Hz will have to be reproduced 15 to 20 dB louder in order to be perceived at the same subjective level.

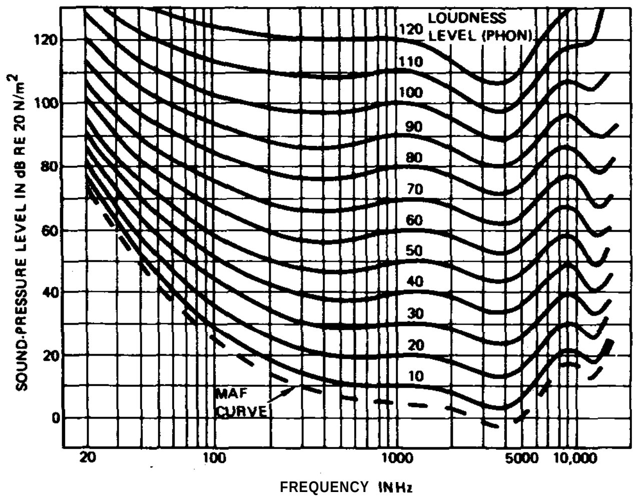


Figure 21. Robinson-Dadson equal loudness contours.

Since low frequencies are essentially nondirectional, we commonly specify subwoofer hardware by calculating the acoustical power requirements in the cinema for a given sound pressure level. Assuming that the reverberation times in modern cinemas follow the data presented in Figures 11 and 12, we can present the data shown in the following table:

Volume	Acoustical power required for 110 dB SPL[3]
270 m³ (10,000 cu. ft.)	10
540 m³ (20,000 cu. ft.)	15
1350 m³ (50,000 cu. ft.)	20
2700 m³ (100,000 cu. ft.)	40
5400 m³ (200,000 cu. ft.)	100

Table 2: Acoustical Power versus Cinema Volume

[3] Derived from the reverberant level requirements, based on average reverberation times in houses with the tabulated volumes.

When the proper room volume has been determined, the designer then can go to the following table and pick the required quantity of subwoofer modules that will ensure the needed acoustical power output:

Number of 2242 transducers:	Efficiency[4] %	Electrical power input (watts):	Acoustical power output[5] (watts):
1	4	800	16
2	6	1600	64
4	12	3200	192
8	16	6400	500

Table 3: Nominal Efficiency and Acoustical Power Output of Multiple Subwoofer Systems.

The designer should choose the next ***higher*** increment if the power requirement, based on room volume, falls between two increments in the above table.

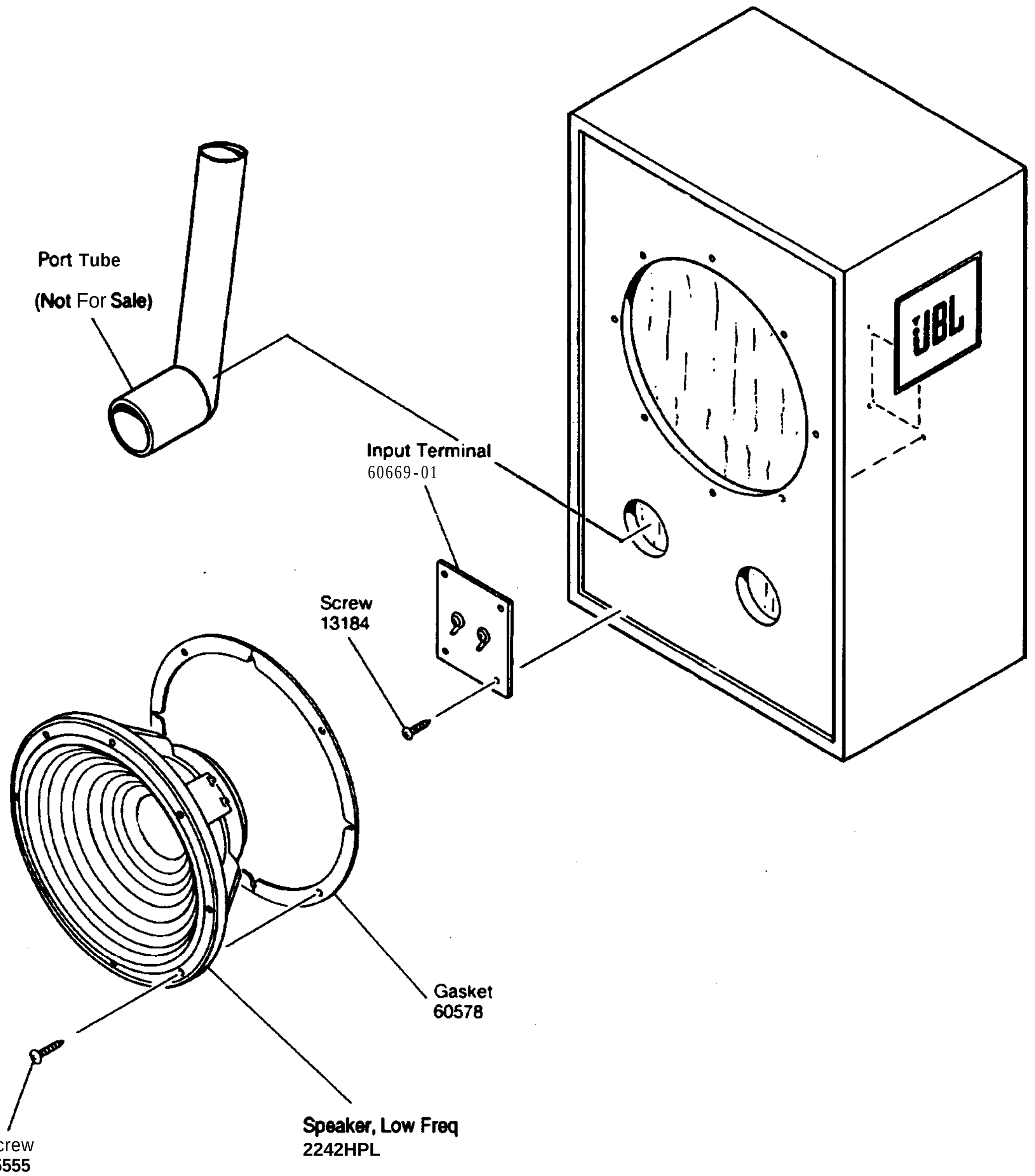
Figure 22 shows an exploded view of the JBL 46458 subwoofer module. Each subwoofer module should be driven with its own amplifier capable of producing up to 800 continuous watts of sine wave power into a rated impedance of 8 ohms. A pair of subwoofer modules can be driven by a single JBL model **MPX1200** amplifier, which is capable of producing continuous sine wave power of **600** watts into each of two **8-ohm** loads.

[4] **Actual efficiency ofcombined units will vary depending on the spacing among them. Numbers given here are** reasonable estimates.

[5] **Acoustical** output **power has been derated, considering the high-level, longterm effects of dynamii compression under steady state subwoofer conditions. Peak values may be 3 dB higher, depending on nature of program.**

Figure 22

COMPONENT EXPLODED VIEW

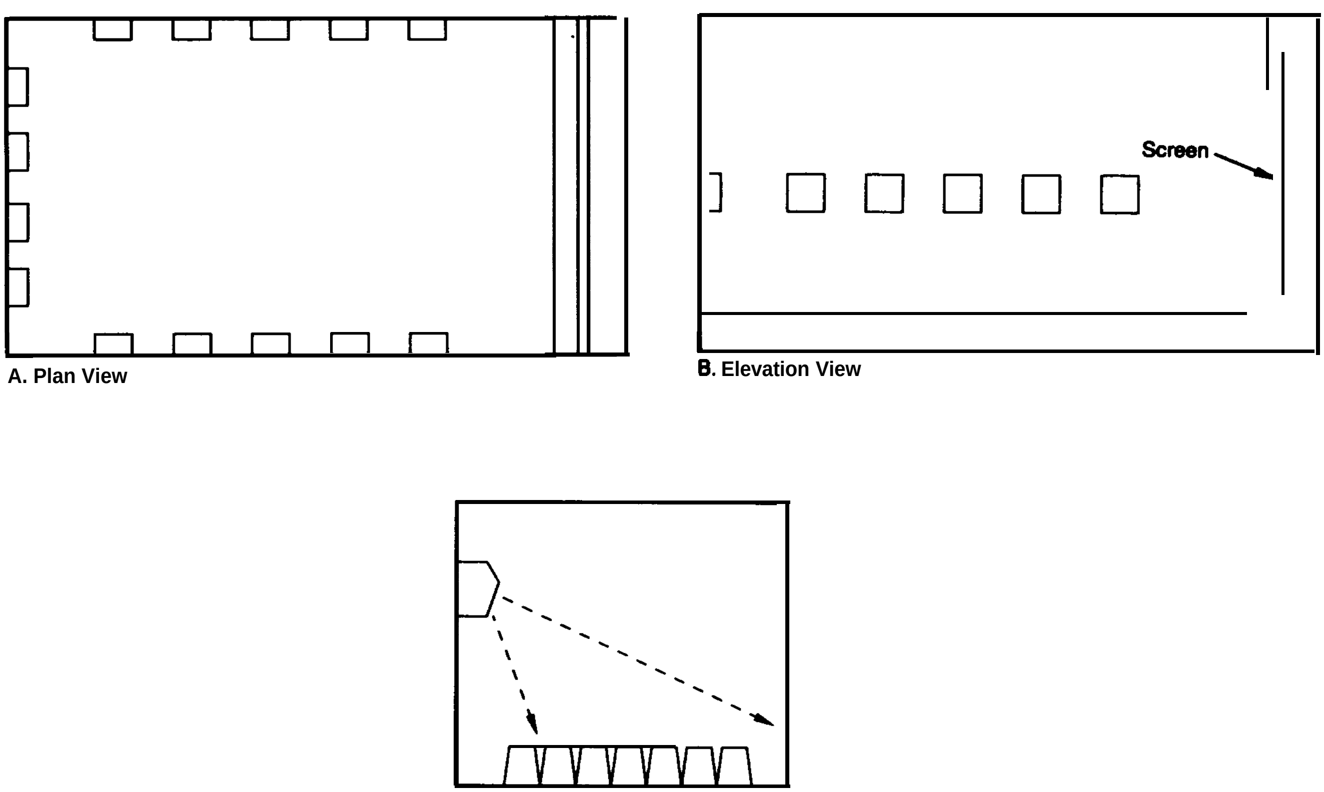


G. Surround Requirements

As a general rule, the total ensemble of surround loudspeakers should be capable of producing as much acoustical power as a single screen channel. Today, the new JBL 8340 surround loudspeaker is capable of producing total acoustical power output in the range of about 2 watts. Since a typical dual woofer JBL screen loudspeaker is capable of producing continuous acoustic power output of 28 watts, it is clear that 14 of the **8340's** will be required for power matching. Typically, in a large house, 12 units will suffice. The careful designer should not go below this quantity.

The enclosure of the 8340 is similar to the older 8330, and the baffle has a downward slope of **15°,** making it possible to mount the rear of the enclosure flush with the walls, while providing smooth coverage over the seating area. Generally, four of the units are placed on the back wall and four each on the side walls.

Good surround operation depends on 'a significant quantity of insignificant sources.' That is to say, a patron in the cinema should not be able to identify any one unit, but rather sense the sound **field created** by all of them. While practice may vary, the surround loudspeakers are generally mounted only in the back two-thirds of the house. The height is often dictated by decor, but they generally should be at a height of 3 to 4 meters (10 to 13 feet), so that the tilted axis of the 8340 is pointed at the farthest patrons across the cinema. When this is done, the smoothness of surround response in the cinema can be maintained within ± 2 **dB.** Details of surround location are shown in Figure 23.



A. Plan View

B. Elevation View

C. Section View, as seen from back of cinema

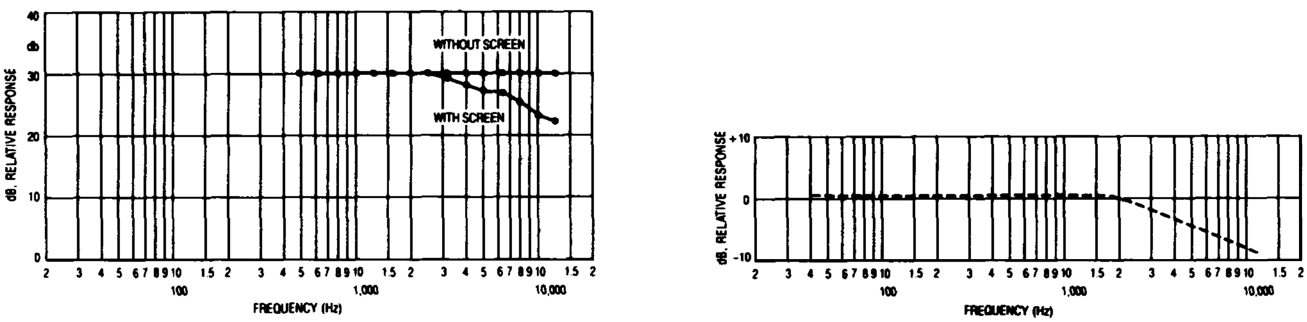
Figure 23. Plan, elevation, and section views of typical surround installation

For digital cinemas with two (“split”) surround channels, we recommend that the minimum number of loudspeakers per channel be set at 8, making a total of 18 loudspeakers. A series-parallel hook-up will be useful for each surround channel. Specific power requirements for the surround channels will be discussed in Section VI-C.

H. Screen Losses

Through-the-screen losses are complex to analyze in detail. The on-axis loss appears to be a 6 **dB/octave rolloff** commencing at about 5 **kHz.** However, off-axis response is quite different. At certain angles, high frequencies are transmitted through the screen with relatively little loss. When an on-axis HF boost is applied to the signal for proper system response on-axis, patrons seated toward the sides (off-axis) will hear more HF than those listeners on-axis. This, coupled with the normal **off-**axis fall-off of the horn’s response, tends to maintain a good balance of high and mid frequency program and enables patrons seated to the sides to enjoy good dialog intelligibility.

With the newer high frequency hardware, the overall required system equalization is substantially the requirement for flat system power response. When this is provided, the diffuse field response measured in the house at a distance one-half to two-thirds back often fits the **ISO** 2969 **X-**curve rather closely. Details of this are shown in Figure 24.



A. On-axis **response,** with **and** without **perforated screen**

B. **ISO 2969 curve**

Figure 24. Screen losses and house equalization

From a design viewpoint, the engineer must ensure that there is adequate electrical headroom in the high frequency drivers to attain flat power response above 3**kHz.** This usually requires that the signal be boosted 6 **dB/octave** above 3 **kHz,** and this means that the drive level at 12 **kHz** will be 12 **dB** greater than at mid frequencies. A driver must be specified which can handle this increased input -- and at the same time be able to provide a good match with the low frequency system. All JBL cinema systems have been engineered with this requirement in mind.

In mid-size screening rooms there is less air loss to deal with, and it is often the case that no more than a 10-dB boost is required to meet the equalization requirements above 10 kHz. Many conservative engineers feel that a 10-dB boost should never be exceeded.

I. Use of Multiple High Frequency Elements

In some very large old-style houses with balconies, a nominal high frequency coverage angle of 40° is not sufficient to provide vertical coverage. Some systems have been installed with multiple high-frequency horns to take care of this problem, but the difficulty of interference, or 'lobing,' in the combining of the two horns remains, creating difficulties in system equalization. There are experiments under way to use stereo synthesizers as a method of alleviating gross effects of interference, but these experiments are only in the beginning stage (8). For the present, we do not recommend that horn stacking be applied in the cinema -- unless it is specified by a competent consultant who will take responsibility for overall system performance.

V. MOUNTING REQUIREMENTS

A. General Comments

The following rules generally **apply** to screen loudspeakers:

1. They should be located vertically so that the horns are between one-half and two-thirds the height of the screen.
2. They should be placed so that the horn flanges are within a distance of 5 to 7 cm (2 to 3 in) of the screen.
3. All reflective details, such as logos and polished frames, should be painted matte black so that they will not show through the screen.
4. Platforms for loudspeaker mounting should be rigid and completely free from rattles; all exposed vertical surfaces should be finished with sound absorptive materials.
5. All other wall areas behind the screen should be finished with sound absorptive materials.

B. Platform and Baffle Construction

If a THX system is specified, all details of the vertical baffle will be taken care of. Where there is no such specification, the installer will have to construct one large platform, or a number of smaller ones, depending on costs. Figure 25 shows a detail of a platform for behind-screen use. The loudspeakers should be mounted on sections of carpet, or some other such material, to inhibit rattles. Enclosures should be secured with angle brackets so that they have no tendency to move.

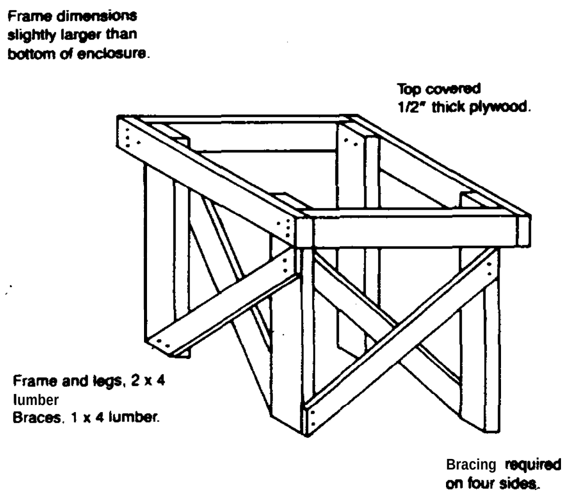


Figure 25. Isometric view of a ***platform.***

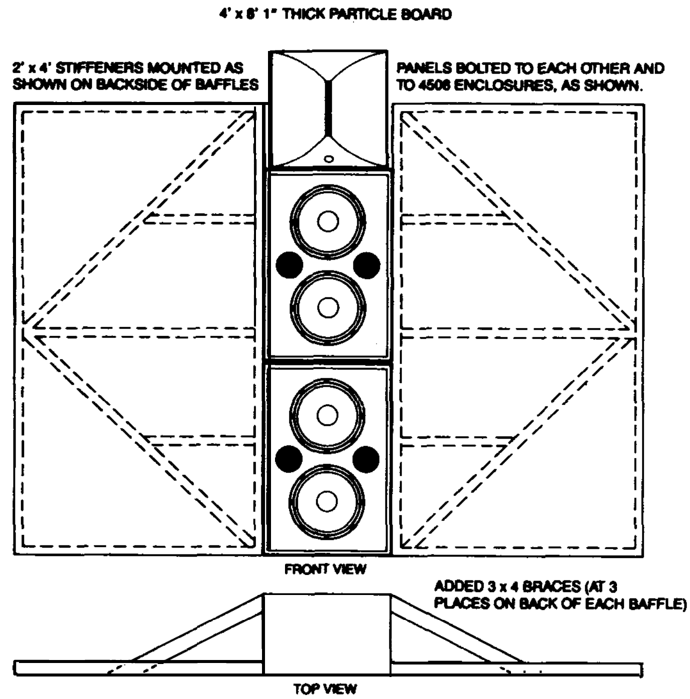


Figure 26. wings between screen loudspeakers.

When possible, large wings should be mounted between systems, as shown in Figure 26. The surfaces should ideally be finished with sound absorptive material, **as should** any exposed wall areas behind the screen should be finished with sound absorptive materials.

The screen loudspeakers should be spaced laterally so that good stereo imaging is ensured. All of the screen loudspeakers should be oriented so that they point to a location on the centerline of the house at a distance about two-thirds the length of the house. This will require that the left and right screen loudspeakers be toed in regardless of screen curvature. This will ensure that proper stereo imaging will be perceived by those patrons seated toward the sides of the house. Taking into account the requirements for masking for various aspect ratios, the spacing between left and right loudspeakers should be broad enough to produce ideal stereo for the widest format. Acoustically transparent masking material should be used so that, when masking is in place, there is negligible high frequency loss. The wider loudspeaker spacing, when used for a narrower format, will be quite acceptable, even desirable (5).

C. Subwoofer Mounting

For best results, the subwoofers should be placed on the floor below the screen loudspeakers and, if possible, against a vertical wall or baffle. They should be clustered together, rest on rubber pads, and be free of rattles.

D . **Surround Mounting**

The JBL 2502 mounting bracket will accommodate both the 8330 and the 8340 surround systems. The user has a choice of mounting the loudspeakers for horizontal projection or fo**15°** downward projection.

The electrical response switch on the 8330 and 8340 surrounds should be placed in the **ISO** 2969 X-curve position for cinema application. Figure 27 shows details of surround mounting, and Figure 28 shows an exploded view of the 8340.

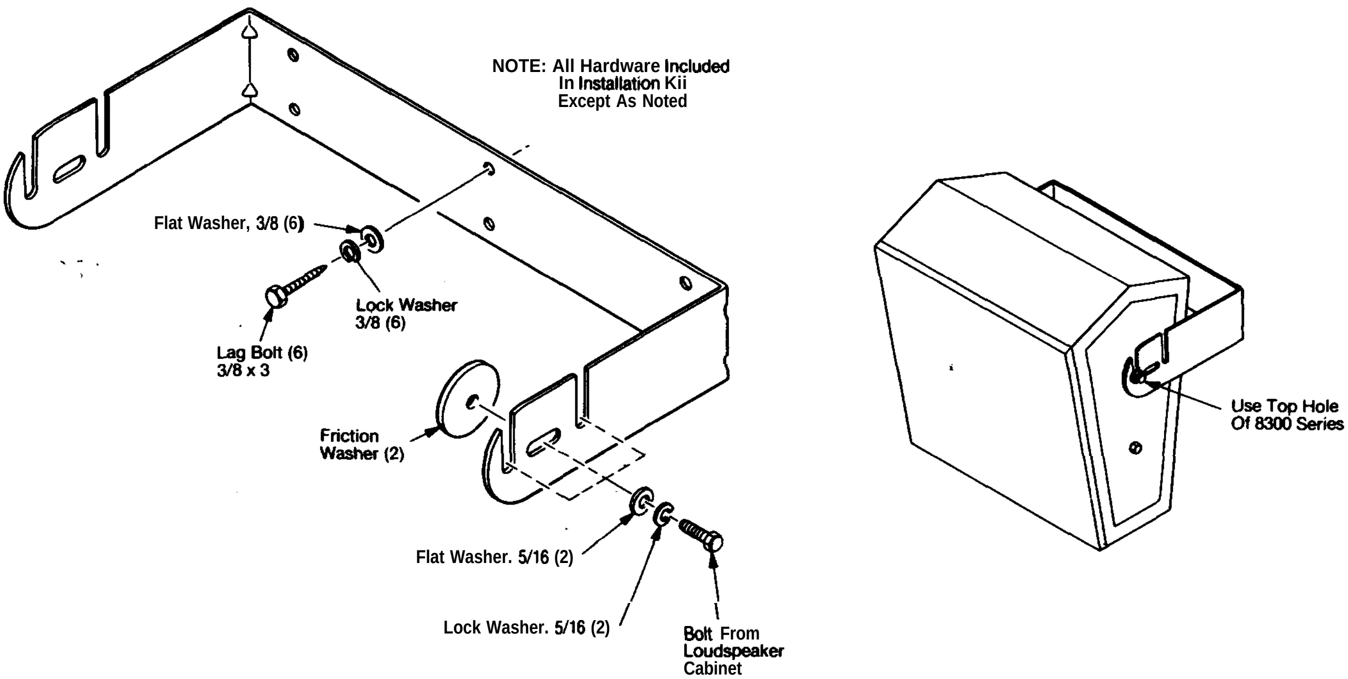
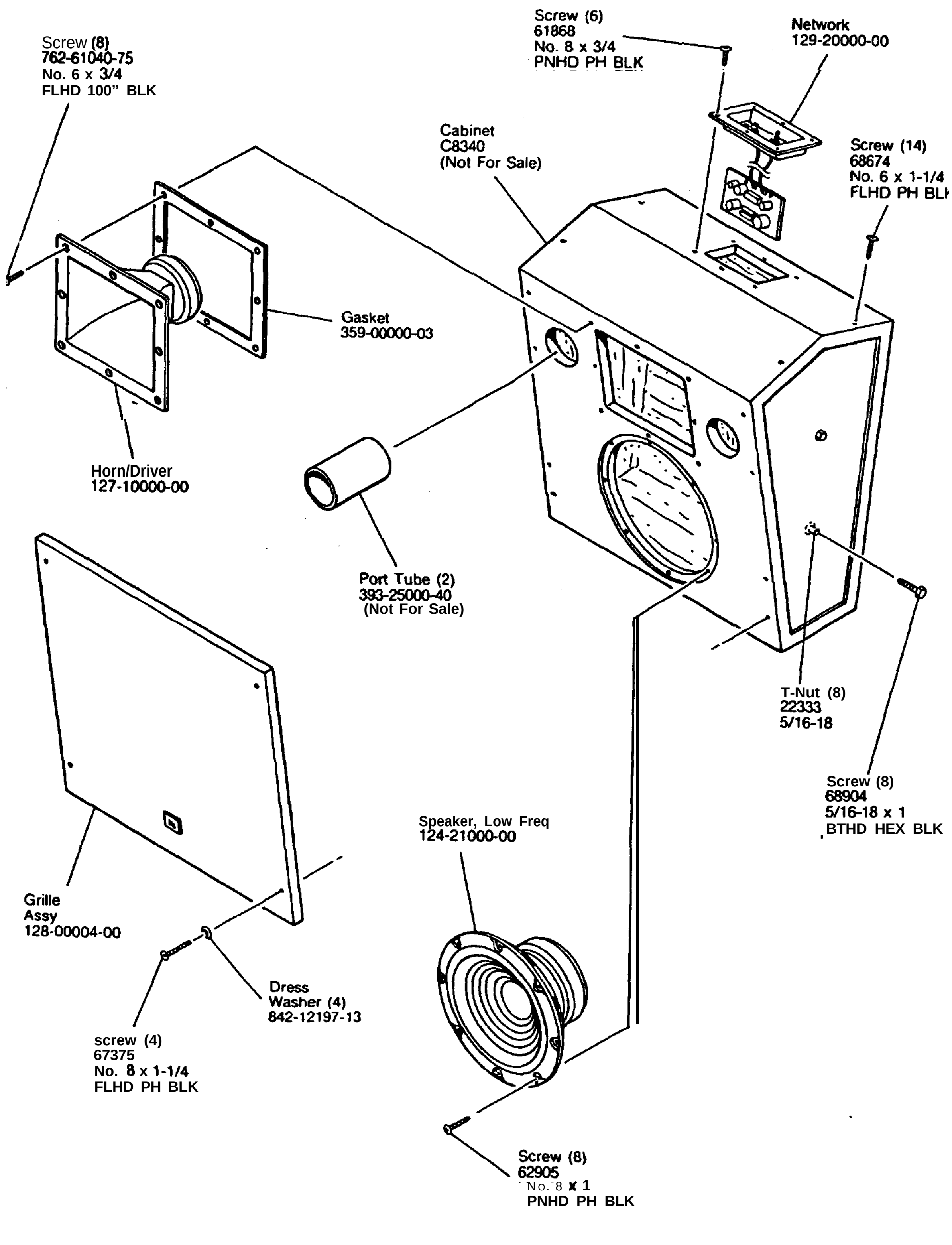


Figure 27. 2502 Wall Mount bracket used with ***8300 series surround*** *speakers*

Figure 28

COMPONENT EXPLODED VIEW



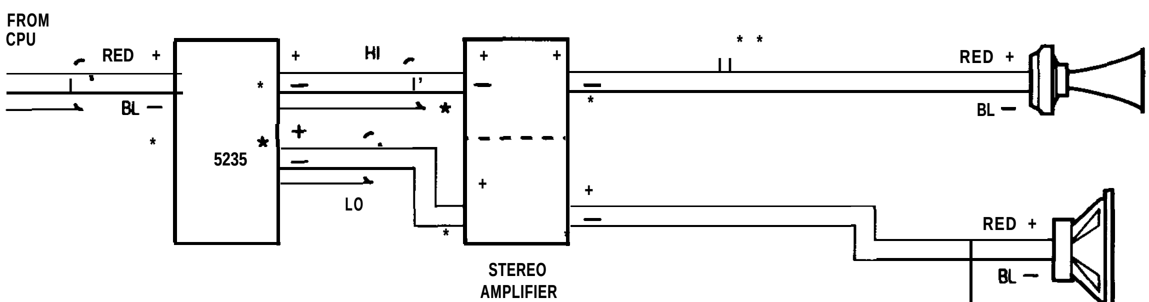
VI. ELECTRICAL INTERFACE

A. Wiring for Non-biamplified Installations

All wiring diagrams shown thus far in this manual are for non-biamplified, single amplifier application. Care should be taken that all connections are properly served with tinned wires or spade lugs, if required. The wire should be chosen on the basis of that gauge that will result in no more than 0.5 **dB** loss between the amplifier and the loudspeaker. Details of wire loss calculation are given in Section VI-D.

B. Wiring Diagram for a Biamplified Installation

Figure 29 shows a wiring diagram for one of three screen channels of a biamplified installation. Here, we have shown a generic electronic dividing network with HF and LF outputs. This approach is now giving way to stereo amplifiers that include electronic frequency division as an input feature, such as the IM-12 module that is included in the 'Open Input Architecture' options available for **JBL's** MPA-series power amplifiers.



*All wires to barrier strips to be sewed with spade lugs

** BLOCKING CAPACITOR VALUES FOR DRIVER PROTECTION

CAPACITOR VALUE	JBL PART NUMBER	FOR OPTIMUM RESULTS AT THESE CROSSOVER FREQUENCIES*
36 µF	62772-0360	500 Hz
24 µF	62772-0240	800 Hz

*16 ohm OPERATION ASSUMED

Figure 29. Wiring diagram for a bi-amp/i&d system

A complete biamplified installation would require five stereo amplifiers. Three of these would be used for the screen channels, and one each for the surround and subwoofer channels. A stereo amplifier dedicated to the surround channel would facilitate reconfiguration of. that channel for stereo operation (split surrounds).

Figures 30 and 31 show block diagrams for typical three channel passive and biamplified cinema systems respectively. These examples should serve as guidelines for system specification, and the exact configuration of the system should be left to a qualified cinema systems engineer.

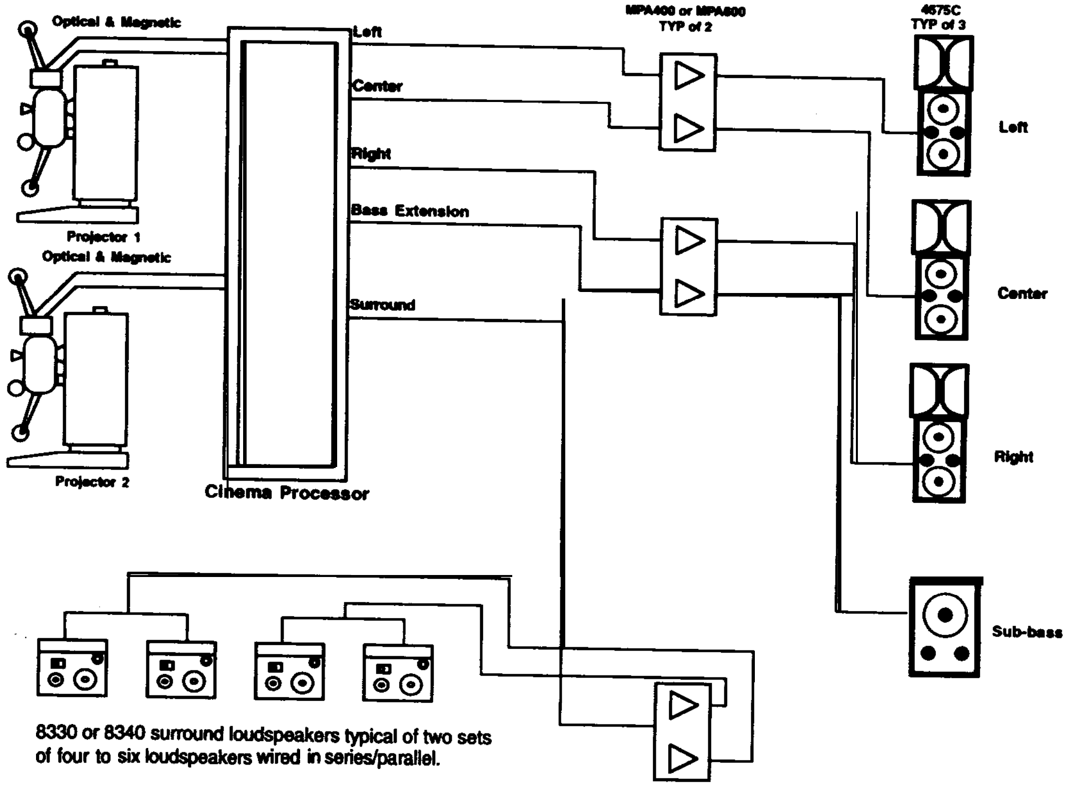


Figure 30. Typical passive network cinema system

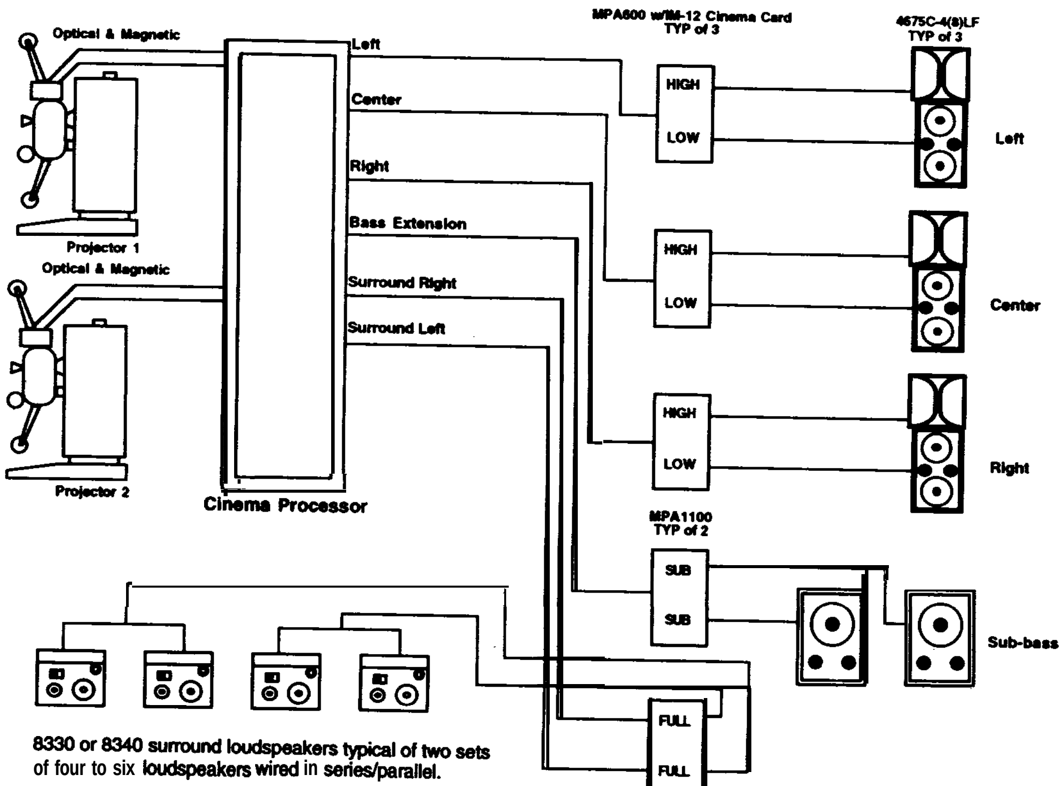


Figure 31. Typical biamplified cinema system

C. Wiring for Surround Channels

JBL recommends that a stereo amplifier be used for surround power, whether or not split surrounds will be used. The reason is simply that this will generally result in betteamplifier-loudspeaker matching as well as facilitating eventual split surround usage.

If there are twelve 4 ohm loudspeakers in the surround array, they can be series-parallel wired in the booth to give a resulting impedance per side of 6 ohms, as shown in Figure 32A. Twelve 6 ohm loudspeakers, such as the JBL 6340, can be series-parallel wired to give a resulting impedance per side of 5.3 ohms. Both wiring arrangements provide equal feed to all loudspeakers.

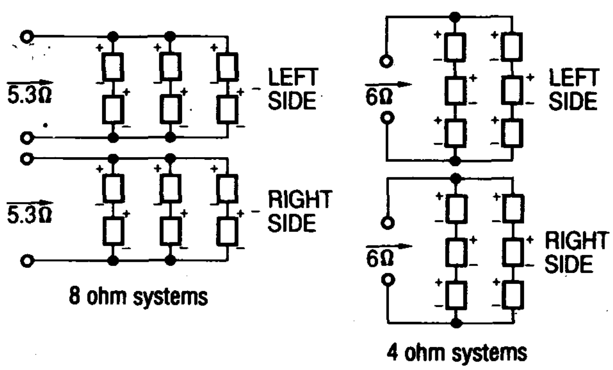


Figure 32A. Series-parallel hook-up

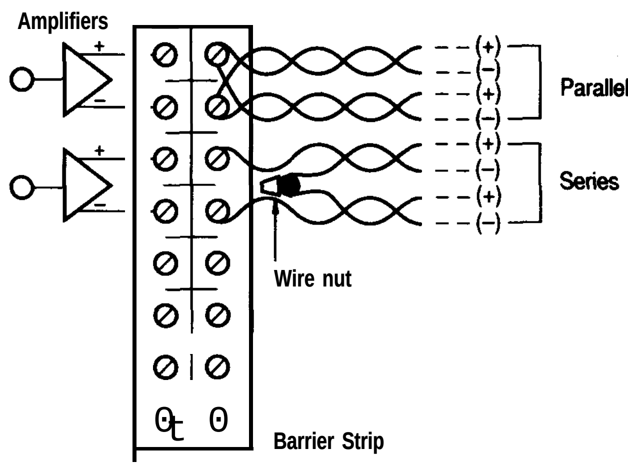


Figure 32B. Wiring at barrier strip in the booth

For each 6340,100 to 150 watts should be allocated. Thus, for the 5.3 ohm per side configuration a single model MPX1200 will be appropriate, with each side feeding a 5.3 ohm load and delivering approximately 150 watts per loudspeaker.

For the 6 ohm per side configuration, we can specify a single MPA750 amplifier to deliver about 100 watts per loudspeaker.

In general, determining series-parallel loading of surround loudspeakers is about as complicated as cinema systems engineering will get in the field. The system designer must carefully note manufacturer's specifications regarding amplifier loading. Since most modem transistor amplifiers carry a 4 ohm rating, the designer needs only to ensure:

1. That the amplifier will not be overdriven in normal operation, and

2. That the individual loudspeakers will receive a signal input within their power rating.

Figure 32A and B detail the series-parallel wiring for both the JBL 6330 and 6340 systems.

D. Wire Gauges and Line Loss Calculations

Good engineering practice requires that line losses result in no greater than a level loss of 0.5 dB at the load. In making the calculations to determine the smallest wire gauge that will ensure adherence to this, the engineer must keep in mind that the loss at the loudspeaker is due to actual losses in the wiring as well as to losses due to impedance mismatching caused by the added resistance in the line. The following equation can be used to determine the loss in dB at the loudspeaker, taking both factors into account:

$$\text{Loss (dB)} = 20 \log \{R_1/(R_L + 2R_1)\},$$

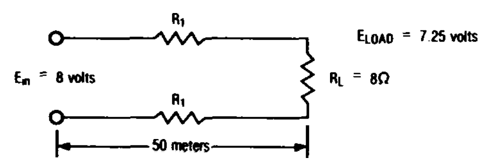
where R_1 is the resistance in each of the two wire runs to the load and RL is the nominal load impedance.

Details of the calculation method are shown in Figure 33. The simplest way to deal with wire losses is by an iterative design process of selecting a trial gauge of wire, solving for the loss, and then moving up or down in wire gauge as required to meet the design criterion.

INTERNATIONAL (mm^2)	AMERICAN WIRE GAUGE (AWG)	RESISTANCE PER SINGLE RUN. 300 METERS (1000 FEET) OF COPPER (IN OHMS)
6.00	10	1.0
6.00	11	1.2
2.50	12	1.6
2.50	13	2.0
1.50	14	2.5
1.50	15	3.2
1.00	16	4.0
1.00	17	5.0
.75	18	6.3
.75	19	8.0
.50	20	10.0

NOTE.
Paralleling two identical AWG gauges reduces effective gauge by 3.

EXAMPLE:
Find the power loss at an 8Ω load due to a 50 meter run of AWG#14 wire.



$R = (\frac{50}{300}) \times 2.5 = 0.416\ \Omega$

$E_{LOAD} = \frac{8}{8 + (2 \times .416)} \times 8 = 7.25$ volts

Power in load $= \frac{(7.25)^2}{8} = 6.56$ watts

dB loss $= 10 \log (\frac{6.56}{8}) = .86$ dB

Figure 33. Wire loss calculations

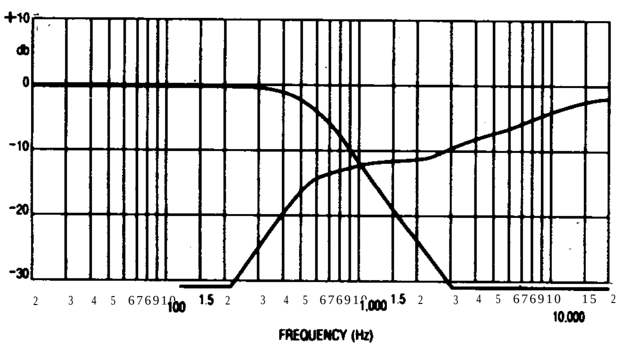
E. Dividing Network Characteristics

The primary purpose of a passive dividing network is to feed various parts of the frequency range into the intended transducers. In addition, practical networks provide for some degree of level adjustment (usually for the high frequency section only) so that elements of various sensitivities can be used together. Recent network designs provide additional high frequency power response equalization, and a very few passive networks provide some degree of time offset (normally in the low frequency section) to enable specific high and low frequency elements to combine response properly at the crossover frequency. Active networks accomplish their various operations electronically and are used in biamplification.

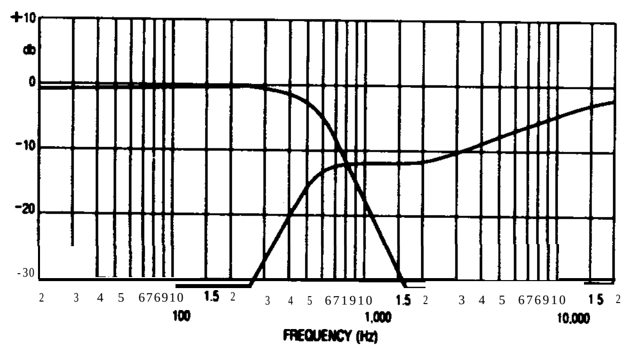
The cutoff slope of a network is defined by its order. For each degree of order, the cutoff rate is 6 **dB/octave.** Thus, a third order network will provide transitions in the crossover range of 16 **dB/octave,** and a fourth order network will provide transitions of 24 **dB/octave.**

The most common mistake made in field assembly of non-biamplified JBL cinema loudspeaker systems is mis-wiring of the dividing network. The data presented in Figure 20 should be studied carefully, inasmuch all network details are spelled out clearly.

Figure 34A and B shows typical HF and LF response curves for electronic dividing networks used for cinema applications. The curves shown at A have **12-dB/octave** slopes with HF power response equalization for 2360 series uniform coverage horns. Curves shown at B are for 16 **dB/octave** slopes.



A. **500 Hz** 12 **dB/octave,** with power **response** correction for **2360A Series horns**



B. 500 Hz 18 dB/octave, with power response correction for 2360A Series horns

Figure 34. Typical HF and LF response curves for active frequency dividing networks

F. **System Setup and Checkout**

The vast majority of system performance problems can be avoided through proper design procedures and proper assembly. If all has gone well, the system will work, and the field crew can proceed with final calibration and equalization of the system. Some points seem obvious:

1. When a loudspeaker has been assembled, either in the shop or in the field, it should be tested with as oscillator-amplifier combination to ensure that there are no buzzes or rattles. Any defective components should be replaced.

2. As each pair of loudspeaker lines is laid, the ends at the loudspeaker should be shorted and a resistance check made at the booth. Any discrepancies should be corrected.

3. Set up a gain-loss diagram for the system prior to making any adjustments on the system. An example is given in Figure 35. Here we have shown the divisions of gains and losses in a screen channel for a non-biamplified system. Since most cinema systems have the same basic architecture, it is only necessary to establish the norms once.

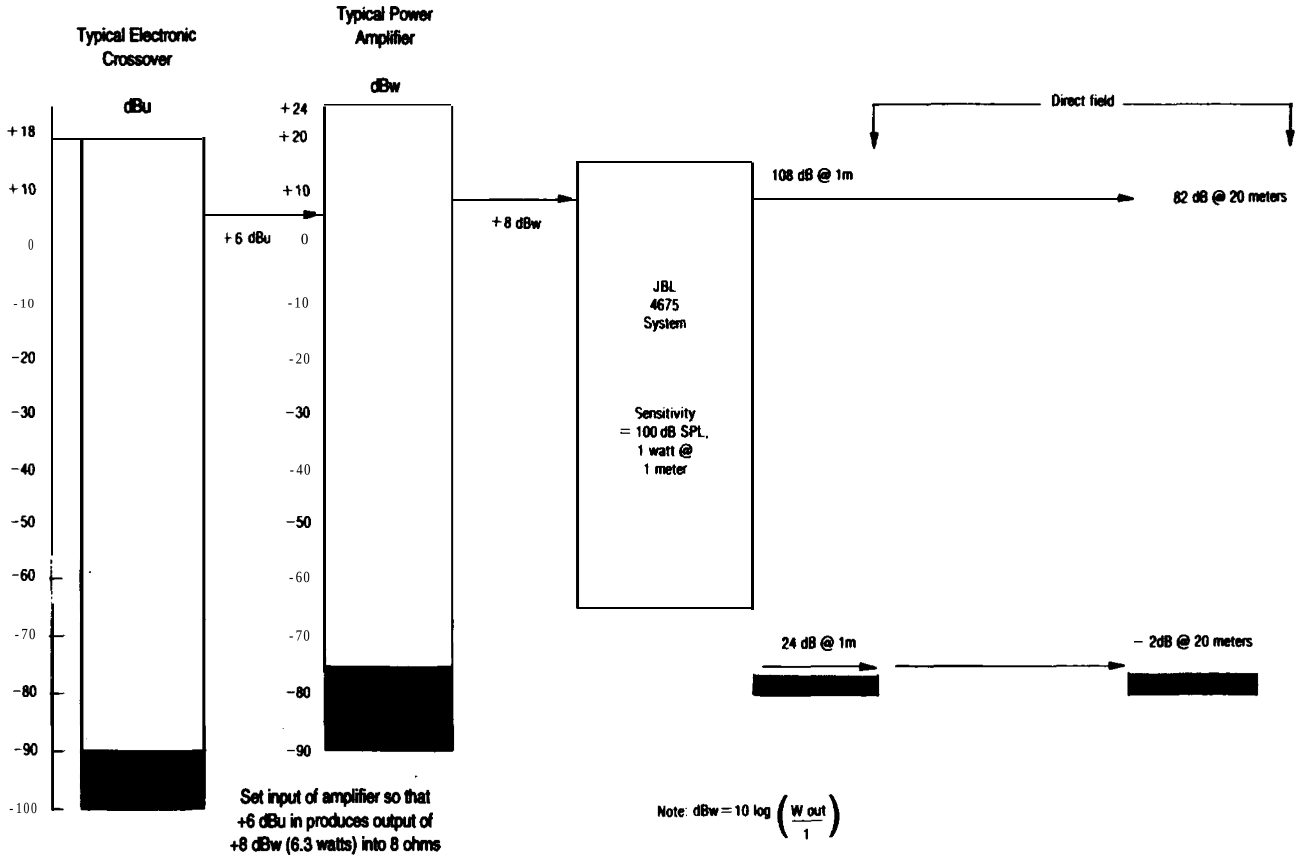


Figure 35. ***Typical*** *gain-loss diagram for the B-chain of a cinema system*

Note that the gain-loss diagram for this system indicates clearly maximum output levels of each component in the system as well as the noise floor of each component. The goal in proper systems engineering is to ensure that the widest possible dynamic range is preserved through the chain. No electronic device ahead of the power amplifier should be driven into distortion before the power amplifier itself has reached its maximum output capability. Additionally, the noise floor of the system, once it has been established at the preamp, should not be compromised by allowing the signal level to fall too low at any subsequent point in the chain. The gain-loss diagram is a convenient means of ensuring all these points.

All aspects of A-chain calibration should be performed according to the methods laid down in the various manuals supplied by the manufacturer's of the cinema processing equipment.

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