P.AUDIO
LINE ARRAY SYSTEM REQUIREMENTS
APPLICATION GUIDE
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Modern sound reinforcement systems have implemented line array technology as a very effective means of providing coherent and even acoustic coverage in a wide variety of acoustic spaces. Although not suited for all acoustic spaces, line arrays are well suited for applications where wide horizontal coverage and long throw are specified.

Line arrays are simply a collection of individual acoustic sources that obey certain constraints. From a purely technical standpoint, the individual sources must all have the same amplitude and phase and must also be very close to each other (relative to the wavelengths being reproduced by the sources) and the number of sources must be very large. The correct technical description is to require the number of sources to approach infinity and the spacing between the sources to approach zero. Obviously, this condition is not possible in a practical sound reinforcement system, or any other realizable system, but the basic concept is applied to modern systems.

An approximation of the ideal case, stated above, is to have the spacing between sources become very small and the wavelengths always large compared to the center to center spacing of the sources (loudspeakers). This condition usually results in 3 way system designs because it is necessary to "cross over" to a smaller diameter set of transducers when the wavelengths become shorter than the center to center spacing.

As an example, consider a three way design consisting of a 12" (305mm) diameter woofer, a pair of 6.5" (165mm) diameter mid range devices and a high frequency wave guide. In this example, the closest possible center to center spacing for a second 12" woofer is 12" (305mm). This spacing also represents a wavelength of 12" and standard practice is to maintain a crossover...
frequency where the simple equation is, minimum spacing of devices = wavelength/2. When this spacing condition is observed the main polar lobe is well defined and the side lobes are small compared to the main lobe. This relationship implies the crossover between the 12” woofer and the mid range devices should be approximately 565Hz. This is easily achieved and since it is desirable to insure that the spacing is much smaller than the wavelengths being radiated the crossover frequency may easily be selected to be much lower. For a typical 6.5” speaker the, crossover might be 400Hz.

The next crossover frequency, between the 6.5” speakers and the high frequency wave guide, must also satisfy the constraint of the wavelengths being long compared to the device spacing. For the example chosen the, closest possible spacing between two 6.5” diameter mid range speakers is 6.5” (165mm). In order to maintain the wavelength/2, or better, criteria the crossover frequency must be 1044Hz or lower. (Although this is easily accomplished with either active or passive electronics the reliability of many high frequency drivers becomes compromised below 1500Hz). However, this crossover frequency is easily achieved, or at least a crossover point near this frequency.

The great difficulty is encountered when attempting to satisfy these same requirements of the spacing between devices being small compared to the radiated wavelengths at the high frequency limit of the sound reinforcement system. If we limit the high frequency response of a typical system to 16kHz we find the wavelength at that frequency is 0.85” (21.5mm). In order to observe the proper relationship between the device spacing and the wavelengths the high frequency devices must be closer than 0.42” (10.8mm). There are no available devices that can produce the required combination of sound pressure level and reliability for a sound reinforcement system and meet the spacing requirements for good polar response.

Manufacturers have employed a variety of solutions in order to satisfy these requirements in a reasonable way. Ribbon tweeters and combination of ribbon tweeters have been used as well as a variety of acoustic lens methods. The acoustic lens devices have been used in order to allow the high efficiency compression driver acoustic output to be converted from a spherically diverging geometry to a relatively planar wave front with a “ribbon”, or rectangular geometry. Acoustic lens devices are by far the most popular and widely used...
method of achieving very high frequency response and maintaining the required geometry for vertical line sources.

The CL35 is a “converging” acoustic lens and is designed to provide a wave front of the necessary geometrical aspects to satisfy the spacing requirements noted above. The basic converging lens is the PH-CL35. This wave guide presents a vertical height of 7.48” (190mm) and a horizontal width of 0.59” (15mm). The design of the PH-CL35 allows vertical coupling of multiple PH-CL35 devices and will insure minimum spacing between adjacent devices. The narrow horizontal width of the PH-CL35 presents a “diffraction” slot geometry where the width of the slot is small compared to the radiated wavelengths. This allows a variety of user supplied wave guides to be mounted to the front of the PH-CL35 that will provide a horizontal coverage angle with a maximum included angle of 120 degrees. The typical horizontal included angle is between 90 degrees and 120 degrees.

**CL35 Device Types**

The PH-CL35 is a 1.4” (35.5mm) throat device designed to be coupled to any high quality professional compression driver. There are two CL35 based high frequency devices available that utilize very high quality P Audio professional compression drivers. Both devices use the PH-CL35 converging lens wave guide.

**CL35-PreNeo**

The CL35 lens is coupled to a P Audio PreNeo-740N neodymium based compression driver. This combination features a light weight configuration that will produce very high sound pressure levels. The CL35-PreNeo is shown below (without the necessary horizontal wave guide). A full technical data sheet and product description may be found at www.paudiothailand.com.
CL35-PreNeo

(PH-CL35 and PreNeo-740N)

CL35-BMD

The CL35 may also be purchased with a P Audio BM-D740 ferrite based compression driver. The vertical height of the CL35 will allow stacking of additional CL35-BMD modules even with the larger diameter BM-D740 compression driver. (Note: The maximum diameter of a compression driver is 6.7” (170mm). Although the PH-CL35 will accommodate any 1.4” industry standard compression driver, a driver with an outsider diameter greater than 6.7” (170mm) will not allow additional CL35 units to be vertically stacked and still maintain minimum spacing between the acoustical radiation elements. A full description and technical data sheet for the CL35-BMD may be found at www.paudiothailand.com.
Required Horizontal Wave Guides

Line arrays are a very valuable tool for achieving uniform sound pressure levels in both outdoor and indoors acoustic spaces. The vertical system coverage is determined by the total number of enclosures in the vertical axis. The greater the height of the system, the more narrow the vertical included angle. It is important to note that vertical control of low frequency (i.e., long wavelengths) material is only possible when the total height of the array is several times the length of the longest wave to be controlled.
The horizontal included is determined by the design of the individual enclosure. In the examples shown, all the designs are direct radiator with the exception of the high frequency wave guide. These configurations yield fairly wide horizontal included angles in both the low frequency and mid range pass bands and they require associated wide included angles for the high frequency wave guide to match the low frequency and mid range radiation patterns. When mid range horns/wave guides are used it is also important to match the included angles of the mid and high frequency pass bands.

Both the CL35-PreNeo and the CL35-BMD require an additional user supplied horizontal plane wave guide to set the high frequency coverage angle in the horizontal axis. These wave guides may be constructed from either wood, fiberglass or die cast aluminum. This document will provide illustrations and basic recommendations for these additional wave guides.

The CL35 products are designed to enable wide horizontal coverage angles. The exact angle will be a function of both the acoustic requirements of the system and the included angles of the mid range devices. Those angles are typically determined by the line array system manufacturer and are based on estimated optimal horizontal angles for the over-all system design. The CL35 will allow horizontal angles of up to 120 degrees based on the width of the diffraction slot. The acoustic diffraction slot is formed by the horizontal width of the “mouth” of the CL35 and is independent of the compression driver used on the assembly. The CL35 is, of course, capable of much higher Q (narrower included angles)

The illustration below represents a CL35-PreNeo with an aluminum die cast 90 degree horizontal wave guide. Note that in this example the top and bottom of the 90 degree wave guide are open. This configuration allows vertical stacking of multiple CL35’s. This wave guide may also be covered on the top and the bottom for single configurations.
CL35-PreNeo with 90 degree horizontal axis wave guide

As noted, the horizontal wave guide may be made of any sufficiently mechanically rigid material that also offers adequate acoustical damping. Two examples are shown below. Both examples are 18mm plywood wave guides. It should be noted that any horizontal angle may be chosen as long as the angle is 120 degrees or less. The plywood sections are shown in red.

**Warning!** The wood cuts for the 90 degree wave guide are relatively straightforward. The wood cuts for the 120 degree wave guided should be performed by an experienced wood machinist. Alternately, individual wood pieces may be used to achieve the necessary 120 degree angles!
90 Degree included angle

Structural Support for wood configuration (18mm plywood)

120 Degree included angle

Structural Support for wood configuration (18mm plywood)
Sample System Configurations

A wide variety of multi-way system configurations are possible. The most prevalent design is that of a three way system. A common design is a 12” (305mm) three way design that consists of a single 12” woofer, two 6.5” (165mm) mid range drivers and a double stacked CL35. The compression drivers may be either a PreNeo, a BMD, or any other 1.4” high quality professional compression driver. The designs shown below are basic plywood constructions showing plywood wave guides. There are many other possible material choices for both the high frequency wave guides and the enclosures themselves.
As can be seen in the design above, the front baffle sections of the enclosure also act as part of the horizontal wave guide and form the last 0.75” (19mm) of the mouth of the wave guide. In this configuration the wood wave guide is a continuous piece, as shown, even though there are two vertically stacked CL35 assemblies. This 12” three way system is an excellent building block for a medium format line array system. If additional lower mid band and low frequency output is required the system shown above may be expanded with the addition of a second 12” woofer, as shown below.
In the figure shown above the last portion of the high frequency wave guide is provided by the front baffle pieces of the line array enclosure.

It is possible to construct small and medium format line array systems as well. These systems may be three way designs with 10” (254mm) or 8” (203mm) diameter woofers although the recommended low frequency woofer should not be smaller than an 8 inch diameter due to the physical height of the CL35 assemblies. In addition to the three way systems shown and discussed, there are a variety of two way designs that can also yield excellent results for smaller systems.
The system shown below also utilizes a wood wave guide design but in this situation the top and bottom of the wave guide are closed and the enclosure is a more convention construction. Note that in this design the wave guide left and right edges are formed by the enclosure front baffle but the wave guide top and bottom are closed. Also note that in these two way designs only a single CL35 is used per enclosure.

The design shown below is ideal for high performance spoken word and background music. The double 8” design will produce additional low frequency acoustic output and also provides extended low frequency horizontal polar control. Effective design of a system of this configuration requires some frequency shading of the 8” woofer on the right hand side of the enclosure.
A very small format two way design is also possible using a single 8" (203mm) diameter woofer and a single CL35 and is shown below. This design is ideal for spoken word and light to medium duty music material.
Line Array System Components

P Audio designs and manufactures a wide variety of direct radiator and horn loaded devices suitable for use in high performance line arrays.

**Low Frequency Transducers**

12” (305mm)

Note: P Audio offers multiple 12” (305mm) diameter woofers. If the line array system is to be used full range (without a sub woofer) the “LF” labeled products from each series listed below should be used. If the system is to be used with a sub woofer either the “MB” labeled or “LF” labeled woofers can be used.

- Flag Ship Series
- Challenger Series II
- SN Series II
- AM Series
- E Series II
- IMF Series II

**Mid Range/Low Frequency for Compact Enclosures**

- SN-8MB
- SN-10MB

**High Frequency Compression Drivers (1.4”exit)**

- PreNeo-740N
- BMD-740