

ALTEC LANSING APPLICATIONS NOTES

AN-9

POLARITY AND PHASE

by Ted Uzzle

Introduction

New attention is being paid today to the polarity and phase response of acoustical devices. This Applications Note discusses several important topics within the subject in a way that is intended to be directly practical.

Polarity markings

In the days of Western Electric loudspeaker components, the driver terminals were marked L1 and L2. Terminal L1 went to that turn of the voice coil farthest inside the magnet, while terminal L2 went to the last turn of the voice coil outside the magnet. Thus, a positive voltage to L1 tended to push the voice coil out of the gap, away from the magnet. In paper cone low frequency drivers the magnet and gap are behind the cone: pushing the voice coil out of the magnet pushes it towards the listener at the front of the loudspeaker cabinet, creating a compression wave. In high frequency compression drivers the aluminum dome diaphragm is behind the magnet and the sound actually travels through a hole in the magnet. Pushing the voice coil out of the magnet in these drivers pushes it away from the listener at the front of the horn, creating a rarefaction wave.

The same electrical polarity at L1 and L2 of older high and low frequency drivers will therefore create the same "motor polarity," but will create the opposite acoustic polarity at the listener position. Allowance must be made for this fact by all users of component terminals marked L1 and L2.

Altec Lansing inherited this arrangement from Western Electric and continued it until the late 1960s, when an overall conversion program was begun. At that time, Altec Lansing began marking one terminal in red, so that a positive voltage to the red terminal would always

create a compression wave at the listener position. For a few years during the changeover the terminals were also marked L1 and L2, in addition to the color coding.

Today, Altec Lansing's leadership in this system is embodied in the Audio Engineering Society's new standard for specification of acoustical components used in sound reinforcement. Paragraphs 2.1.5 (for high frequency drivers) and 4.1.5 (for low frequency drivers) read thus:

A description of electrical connectors, color coding, and polarity of the device. Standard practice is that terminals be red and black; a positive voltage at the red terminal shall cause a positive pressure at the output of the device.

Absolute polarity

We ordinarily think of polarity of audio systems, both the electronic and acoustical parts, as ultimately unimportant, just so long as all loudspeaker drivers are in the same relative acoustic polarity. Today, however, it is coming to be appreciated in highly critical listening situations that reversing the polarity of all the loudspeakers changes the listening character of the system. The change is often immediately noticeable, but intangible and hard to describe in words. Many listeners will express a vehement preference for one polarity over another.

Why should this be so? Think a moment. In nature, many impulsive sounds are compression waves: gunfire, the clash of cymbals, and so on. In running speech, expletive consonants (t, p, b) and fricative consonants (f, s) are formed by expelling air through the lips and tongue. It may be that with program material full of transients the ear can sense whether it is hearing a sudden rarefaction or compression of the air, and prefer the naturalness of the latter.

Loudspeaker users who do critical listening over a long period of time may find it useful to do polarity reversal listening tests for the entire system.

Phase of an acoustic device

Reactive devices, whether electrical or mechanical, introduce phase shifts into the signals passing through them. The more reactive, the more the phase shift.

In 1977 W. J. Trott, a scientist at the Naval Research Laboratory in Washington (he was writing of sonar systems at the time) proposed that the effective acoustic center of a transducer be the apparent center of the sphere of radiation, with both magnitude and phase taken into account [W. J. Trott, "Effective acoustic center redefined", *J. Acoust. Soc. Am.*, vol. 62, no. 2, p 468 (August 1977)]. This means that phase shifts within a loudspeaker driver can be directly translated into an apparent relocation of the driver, backwards or forwards.

In air, 500 Hz has a wavelength of 2 feet 2-1/4 inches. One-eighth of this wavelength is 3-1/4 inches, and one-eighth of a sine wave is 45°. Thus, a phase shift in a driver of 45° lag at 500 Hz will apparently move the driver 3-1/4 inches farther away from the listener.

The phase response of a driver will wander back and forth as frequency changes, and obviously has a lot to do with the imaging of a loudspeaker system. Loudspeaker drivers are quite reactive devices, some more than others, and some violently so. Altec Lansing components are particularly mild-mannered in this regard.

Phasing loudspeakers at crossover

The first step in phasing loudspeaker systems at crossover is putting the voice coils in mechanical alignment; that is, the high frequency voice coil directly over the low frequency voice coil. Table 1 shows the spacing in inches from the front cabinet edge of Altec Lansing low frequency cabinets, to the voice coils of drivers mounted in them. The voice coil of the high frequency driver should be set this same number of inches back from the front edge of the bass cabinet. The voice coil of an Altec Lansing large-format driver (288, 290, or 291) is four inches behind the face that mounts on the horn throat. For an Altec Lansing small-format commercial driver (902 or 908) this dimension is 1-1/2 inch.

Mechanical alignment is only the first step in the phasing of loudspeaker systems at crossover; there are certain to be phase shifts in both high frequency and low frequency drivers that must be compensated for. Once the voice coils are aligned, deliberately wire the high frequency driver with reversed polarity. Set up your real-time analyzer as you would for equalization, but place the display where you can see it while sliding the high frequency horn back and forth, as shown in Figure 1. This is quite easy behind the screen in a motion-picture theatre, but for loudspeaker clusters hung overhead in a reinforcement installation it can be impossible. In this situation, an assistant with a walkie-talkie or (better) a headphone intercom may be able to move the high frequency horn.

Playing pink noise through the system (either wide range or limited to a band in the crossover region), slowly move the high frequency horn until the crossover

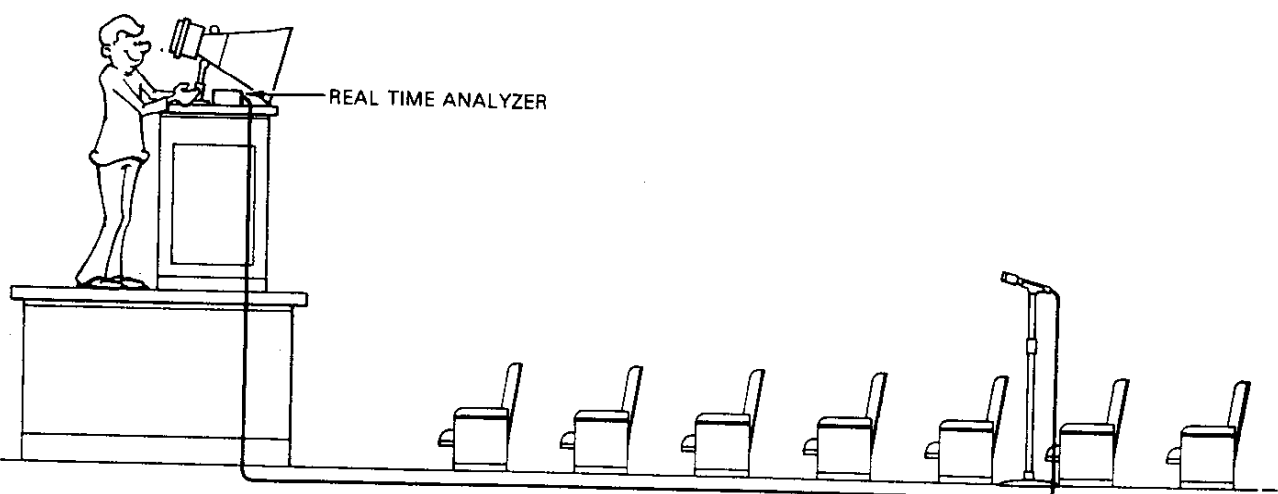


Figure 1.

notch appears in the real-time analyzer. Watch carefully: there is an area only a couple of inches deep in which the notch appears. Position the high frequency horn so that you show the deepest notch you can get. The depth of this notch is a figure of merit for phase matching at crossover; 6 or 8 dB is excellent. You will notice that moving the horn only one-half inch either way will reduce the notch by several decibels. Now, reverse the polarity of the high frequency driver and the system will be phased at crossover (Altec Lansing is indebted to theatre designer Boyce Nemec for this technique).

This method is very easy, very fast, and very accurate. Altec Lansing has found that the variations from one system to another can amount to several inches. Whenever a real-time analyzer is at a job site to equalize (or even just a sound level meter), it is just this easy to set the exact phasing for the systems *in situ*.

In conclusion

The careful sound system designer and installer will want to understand and control every aspect of his system and its components. Phasing and polarity are no longer arcane esoterica; everyday instrumentation allows the quick and accurate manipulation of these important sound system characteristics.

Altec Lansing Model Number

Spacing in inches, front edge of cabinet to voice coil

210 (A1,A2,A4)	34.2
211	34.5
815A	28.8
816A (1235)	19.2
817A	19.4
828G (A5,A7,1236)	19.3
930	6.25
8124	3.75
8127	3.75
8227	3.75
8154	5.5
8156	5.5
8256	5.5
8182	6.5
8184	6.5

Table 1. Spacing in inches from the front cabinet edge of Altec Lansing low frequency cabinets to the voice coils of drivers mounted in them.



ALTEC
LANSING

LOUDSPEAKER PHASING

OPERATING INSTRUCTIONS

GENERAL

In building a two-way loudspeaker system, it is essential to maintain proper phasing relationship between the low and high frequency units at the region of crossover. The low and high frequency transducers are two separate and distinct sound sources; at the crossover point, they should both radiate equal intensities. If the phase of these units is incorrectly maintained, their outputs may cancel or combine in an improper phase relationship. For optimum performance in a two-way loudspeaker system, both the high and low frequency drivers must be in phase at the crossover region.

In the case of two-way systems comprised of individual components, proper phasing of the high and low frequency units may best be accomplished by following the wiring diagrams in figures 1, 2, 3, 4 and 5, dependent upon the components used. These diagrams illustrate the electrical connections between the low and high frequency drivers and the associated dividing network. The engineering, design, and manufacture of such networks provide a simple means of phasing a two-way loudspeaker system. It is virtually impossible to establish and maintain proper phase relationships in three or four way systems; for this reason, Altec two-way loudspeaker systems, which cover the entire audible frequency range, are preferred over three or four way systems in all professional broadcast and recording applications.

In addition to the proper electrical phasing required in a loudspeaker system, further improvement may sometimes be achieved by shifting the relative positions of the high and low frequency units until maximum smoothness at crossover is determined by measurements or listening tests.

The principal objective is to establish the voice coils of the high and low frequency drivers in the same vertical plane. In the larger Altec loudspeaker systems, including the A7 and A7-500, this is accomplished by means of a front loaded horn (which also greatly improves the directivity of the bass frequencies) for the LF driver. For home music systems, however, the increased size of such a cabinet occasionally precludes its esthetic value, hence a minor compromise is necessary in those speaker systems which employ a high frequency horn and driver with a low frequency transducer mounted in a straight bass reflex enclosure. All Altec loudspeaker systems of this type are carefully engineered so that proper phasing is maintained within the correct vertical angle required for excellent reproduction of sound for the enclosure.

When Altec high-frequency drivers and horns are used with low frequency transducers of other manufacture, it is best to first connect them as shown on pages 1 and 2, dependent on the network employed. Then, when the system is in operation, the wires connected to the low frequency reproducer should be reversed while the sound continues; one may then judge the proper phase relationship by choosing the connection which produces the best musical quality.

In two way systems, it is advantageous for the listener to be able to adjust the volume level of one component with reference to the other; provision is made for this on all Altec dividing networks, as well as on all of the larger Altec two way loudspeaker systems. The listener is therefore able to attenuate (or 'shelve') the high frequency driver in order to establish the best balance to individual room acoustics.

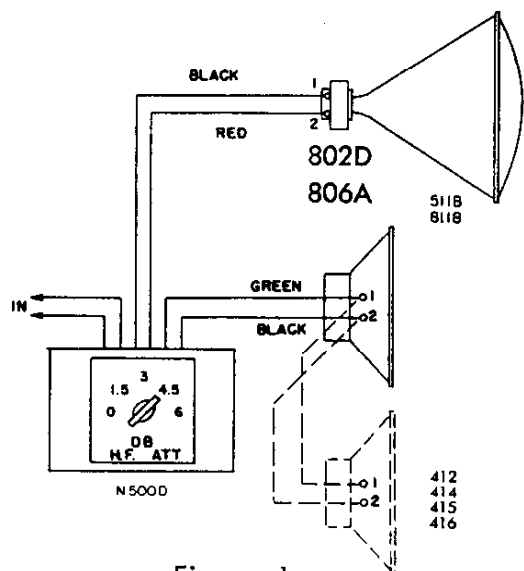
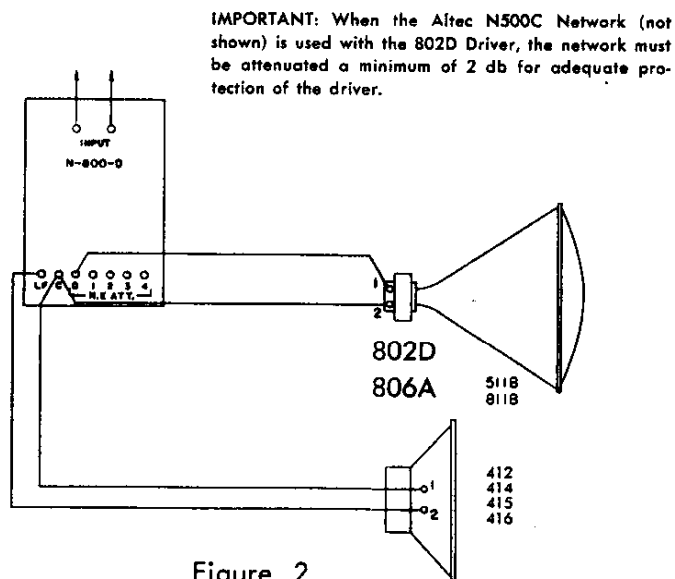


Figure 1



IMPORTANT: When the Altec N500C Network (not shown) is used with the 802D Driver, the network must be attenuated a minimum of 2 db for adequate protection of the driver.

Figure 2

Note: In the Altec A7-500 and A7 'Voice of the Theatre' Systems, the leads to the high frequency driver are connected as shown in Figures 1 and 2; in loudspeaker systems other than these, wherein the voice coils of the high and low frequency reproducers are in differing vertical planes, the leads to the high frequency drivers should be reversed from the connections indicated above.



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METHOD OF PHASING LOUDSPEAKER SYSTEMS IN STEREO INSTALLATIONS:

The relative phasing of the right and left hand loudspeakers in a stereophonic home music system is essential, in order that sound meant to emanate from the center appears to originate from a point midway between the two systems. Many elaborate methods for determining the correct phase are available but, by using a constant amplitude frequency record (available from most record dealers) it becomes a simple matter. The 100 cycle frequency band is recommended for this purpose.

STEPS FOR PHASING STEREO SPEAKERS:

Maintain constant polarity in loudspeaker wiring, carefully following the instructions furnished with your loudspeakers.

- (1) Listen to the system by standing directly between the two side speakers in the correct listening area.
- (2) Reverse the polarity of either side speaker; the proper connections are found when the volume level of the speakers increases.

It is easily understood, therefore, that, to receive the ultimate in stereophonic sound reproduction, three principal factors must be observed:

- I: Correct phasing between the components of each individual loudspeaker system.
- II. Correct phasing of each complete loudspeaker system, relative to the other system(s) used for multi-channel reproduction.
- III. Proper placement of the speaker systems within the listening area.

STEREO LOUDSPEAKER PLACEMENT:

Proper positioning of loudspeakers and speaker systems for the reproduction of monophonic sound has seldom posed a problem but care should be exercised in loudspeaker placement for stereophonic reproduction. Audience perspective is important and may best be accomplished by following a few simple, yet necessary, rules in the selection and placement of loudspeakers.

To realize the optimum performance from your stereo system, it is important that the loudspeakers be placed in definite locations within the listening area.

Two separate channels which originate from a dual amplifier are fed to the separate loudspeakers or speaker systems; this provides the time and intensity difference which gives the 'spatial' quality to stereophonic sound. If the speakers are too closely spaced — as in a single enclosure housing two speakers only a few feet apart — the time and intensity difference is so small that spatial quality is severely limited. Except in a very small room, eight feet is considered minimum spacing between speakers for good stereo. In a two channel system, good stereophonic listening begins a distance in front of the speakers equal to their separation and continues for twice this distance. For example, if the speakers are placed eight feet apart, the optimum stereo effect extends from eight to sixteen feet in front of the speakers. In three channel systems, the center speaker (which receives the sum of the signals being fed to each side speaker) should be located as near midway between the two side speakers as possible and, ideally, in line. The use of the third, or center channel speaker, allows wider spacing of the side speakers and a correspondingly broader listening area.

The majority of high quality music power amplifiers provide connections for a center channel speaker. When such an arrangement is used, the sound which originated from the center of the recording stage (such as a solo instrument or voice) will actually emanate from all three speakers or speaker systems but will appear to be confined to the center channel. When two speakers not widely separated are employed, this effect is preserved without the center speaker; the latter will, however, permit a much wider separation of the side systems without an undesirable 'hole in the middle' effect.

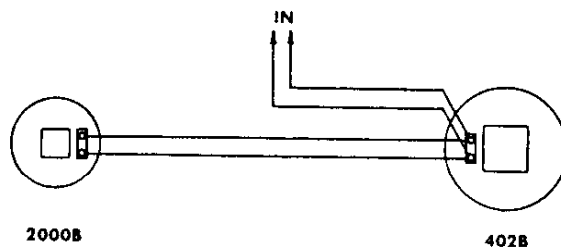


Figure 3

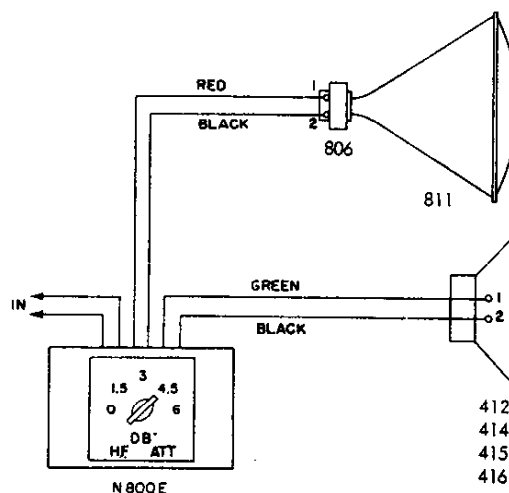


Figure 4

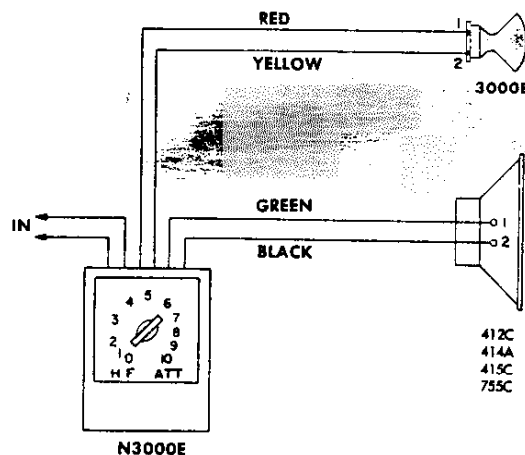


Figure 5

As the distance between loudspeakers increases, the listening area is 'moved back' proportionately; listening too near the speakers gives the impression of two distinct sources of sound; listening too distant produces a nullified effect, with regard to the stereophonic time and intensity difference, and the reproduced sound will appear to differ little from a monophonic system.

If speakers or speaker systems are substantially separated, it is generally best practice to angle the side speakers toward the center of the listening area.

system impedance is treated similarly.

ACOUSTIC PHASING

A two-way (HF horn and LF woofer) loudspeaker system must be phased properly to obtain a smooth response in the cross-over region. This acoustic phasing refers to the phase relationship between the horn-loaded HF driver and the LF loudspeaker. To achieve proper phasing, the electrical phase relationship between the HF horn-loaded driver and the LF loudspeaker may require adjustment.

ALTEC electrical coding establishes that a positive voltage applied to Terminal 1 moves the diaphragm assembly away from the magnet structure. Because magnet structures of LF loudspeakers are mounted behind the diaphragm and magnet structures of VOTT HF drivers are mounted in front of the diaphragm, the following voltage and terminal designations are established:

VOTT HF Drivers: Terminal 1 (+) positive
Terminal 2 (-) negative

LF Loudspeakers: Terminal 1 (+) positive
Terminal 2 (-) negative

Figures 5A and 5B are acoustically in-phase. The directional relationship of the cone (speaker) and diaphragm (driver) creates the acoustic in-phase condition. Figure 5C requires an out-of-phase acoustic connection to obtain proper balance (phase), due to the LF and HF (cone and diaphragm) directional relationship.

In the ALTEC A7-500 and A7 'Voice of the Theatre' systems, the leads to the HF horn-loaded driver are connected as shown in Figure 5A. Current ALTEC systems such as the 873, 878 and 846U & B, use the stepped horn/driver plane relationship of Figure 5B. This is ALTEC's recommended design for optimum performance. Where cabinets cannot be adapted conveniently to the 'stepped' design, Figure 5C is the preferred alternate.

STEREO PHASING

Proper system acoustic phasing of the left and right loudspeaker units in a home stereo music system is essential. Many elaborate methods for determining correct phase are available. This can be done easily in the home by making a simple test.

Listen to the system in the monophonic mode, or with a mono sound source. The sound should emanate directly from between the speaker systems. If any stereo effect is still heard, reverse the polarity of one system; this should restore the apparent sound source to the single desired point. When the sound appears to be at this mid-point in the mono mode, it will have the correct acoustic phasing for stereo.

EFFICIENCY MATCHING WITH ALTEC 411-8A

Additional attenuation is needed to match the relative efficiencies of the drivers when 'Voice of the Theatre' high frequency units are used with an ALTEC 411-8A LF loudspeaker. This may be obtained by increasing the network attenuator to position 8, or by using ALTEC 30904 Attenuator/Equalizer Network between the passive dividing network and the drivers of each speaker unit.

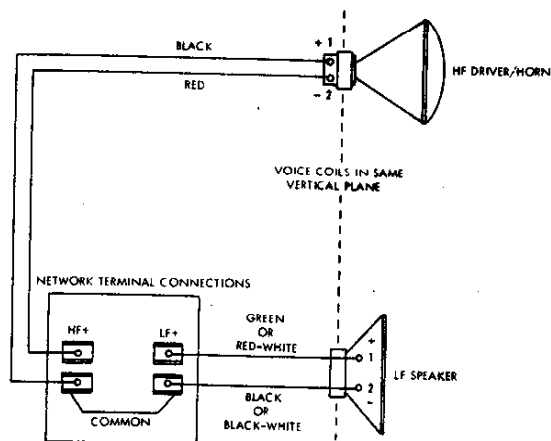


Figure 5A. Voice Coil In-Plane Connections

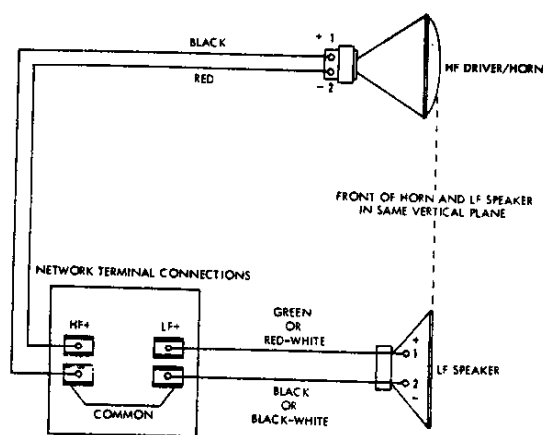


Figure 5B. Stepped Horn/Driver Plane

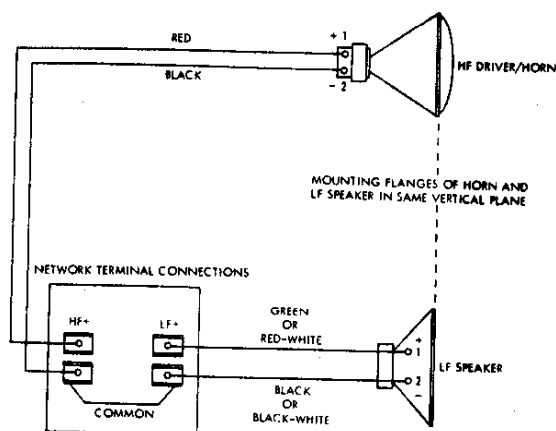


Figure 5C. Mounting Flange In-Plane

Figure 5. Acoustic System Phasing