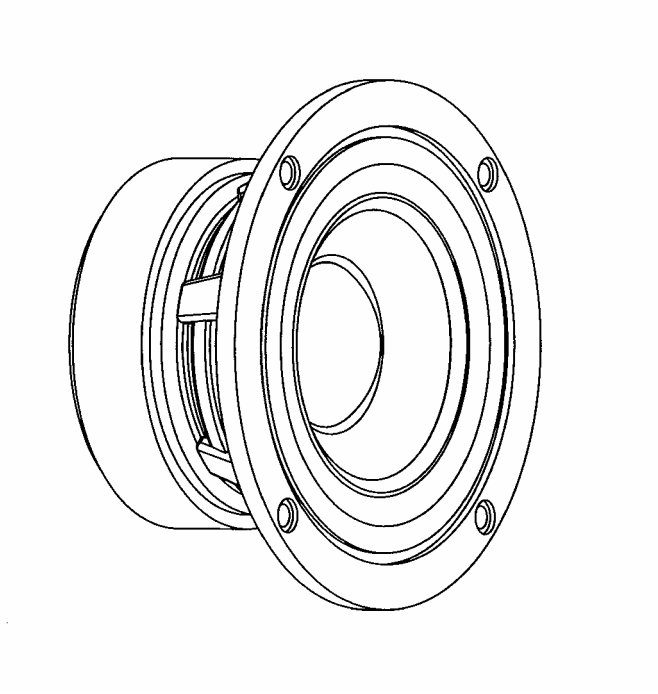
HYBRID AUDIO TECHNOLOGIES



Legatia™ L3
3″ Wide Bandwidth Transducer

User's Manual and Car Audio Reference Handbook

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Congratulations on your purchase of the Legatia-series 3” diameter wide-bandwidth midrange drivers, and welcome to the world of Hybrid Audio Technologies, where high end mobile audio louspeaker development is our passion! We are certain that these speakers, when installed and set-up properly, will make a remarkable improvement in the sound quality of any car audio sound system.

It is our goal, through the publication of this user’s manual and reference guide, to assist the professional installer and “do it yourself” enthusiast to get the highest level of performance out of these drivers using the practical application of timeless acoustic principles. As you begin to read this document, you’ll quickly realize that this is not your typical user’s manual. This manual has been written to be more or less a miniature car audio reference guide that can be used to better any sound system, and in particular, a system that utilizes the wide-bandwidth Legatia L3 midrange. Keep it handy throughout your installation process, and any time you go to improve your audio system with other Hybrid Audio Technologies products. We are confident that if the principles explained in this manual are exercised in your own vehicular installations, you will be ecstatic with the sound quality outcome!

We realize that you have a choice in loudspeakers, and are thrilled that you have chosen Hybrid Audio Technology’s Legatia-series to fulfill your needs. For more information about our other Legatia-series products, please visit us online at www.hybrid-audio.com.

The most logical place to begin the Legatia L3 user's manual is to highlight its features, design considerations, and parameters. Once an understanding is gained as to why the speaker was built the way it was, and why certain materials were used in the physical construction, the better prepared the installer will be when it comes to installation, set-up, and tuning of the Legatia 3" wide-bandwidth drivers.

Speaker Design Considerations (Introduction)

The Legatia L3 is an electrodynamic driver that is comprised of a diaphragm (cone) that is set in motion by a motor system that has both electrical and mechanical components. The Legatia L3 is made up of four fundamental and inter-related systems: the motor (voice coil, T-yolk, front plate, and magnet); diaphragm (cone and dustcap); suspension (surround and spider); and the speaker frame/basket.

The Motor

The motor of the design is a very complimentary design which utilizes a 1" voice coil, ferrite magnet, and a unique T-yolk to improve the speaker's nominal and thermal power handling.

One of the main tenets of the design of the Legatia L3 is its over-sized voice coil; the larger coil provides for improved nominal and thermal power handling. The voice coil was attached to the voice coil former, which was in turn attached to the inside edge of the speaker cone. The former aids in transfer of heat away from the coil into the T-yolk, which also improves power handling. The thermal power handling for the Legatia L3 driver is 50 watts with 3 dB of power compression without a crossover, and up to 200 watts with a crossover. In the non-crossover testing sequence mode, our power testing of this driver was performed by using pink noise from 20 Hz to 20,000 Hz, with the L3 tested in "free air" for eight hours. In the crossover testing sequence mode, our power testing of this driver was performed by using pink noise from 250 Hz to 20,000 Hz, with a fourth order (24 dB/octave) highpass crossover at 250Hz, and with the speakers once again tested in "free air" for eight hours. While this is a rather conservative test, we feel as if it is representative and realistic power handling ratings and approximates "real-world" conditions and the anticipated use of this driver as a dedicated midrange transducer.

How much amplitude a speaker can reproduce depends on the volume of air it excites without overheating. The volume of air that a speaker excites is determined by the surface area of the cone and the excursion capability of the motor system. Xmax is defined as the width of the voice coil that extends beyond the front plate, and relates to how far the speaker can move in either direction without appreciable distortion. The Legatia L3 boasts an impressive 2.6mm one-way linear excursion (Xmax), one of the highest commercially-available Xmax ratings for a true 3" driver.

The Diaphragm

The diaphragm of the Legatia L3 speaker includes its cone and dust cap. The shape, weight and strength of the Legatia L3 cone and dustcap relate directly to the extended frequency response of the speaker. The cone and dustcap are both untreated pressed paper. Convex shaped cones typically have a peak in the upper range of the frequency response (e.g. dome midranges), so we decided on a concave cone for the smoother frequency response. And contrary to common belief, most convex cones have a narrow directivity pattern. The concave cone of the Legatia L3 has a wider directivity pattern, and is excellent for use in “off-axis” applications.

Our approach to point-sourcing is to allow the midrange driver to effectively play the majority of the human vocal range; having virtually all imaging cues emanating from one set of drivers in an installation ensures stable stereo imaging across the fundamental frequencies which define image placement and definition. The paper cone is critical to tame unwanted cone modes, resonances, and the classic "cone breakup" associated with most composite cones, but still be rigid enough for upper midbass response. The ability of the diaphragm to produce low frequency information is bound by its resonant frequency (129 Hz), and high frequency information is bound by the radiation impedance and the diameter of the L3’s cone (65mm). The Legatia L3 was meant to be used as a dedicated midrange driver in a three-way front stage system. The three-way designs offer elevated power handling capability, better midrange transient response, and lower upper frequency distortion over its sibling two-way system.

The Suspension

Rounding out the face of the driver is an inverted high-loss rubber surround that, in concert with the spider, provides the compliance needed for the 3" midrange to play upper midbass frequencies with authority. The spider is attached to the voice coil former and the basket. The spider acts as a centering device and a restoring force for the voice coil. The surround, which acts as an air seal between the cone and the basket, adds to the restoring force of the spider. Another function of the surround is to absorb cone flexure waves as they are transferred up the cone. You'll also know a Legatia midrange and midbass design by its inverted surround; this design feature allows for the use of a smaller height grille, and more flexibility in mounting options.

The Frame/Basket

The basket is a high-quality cast aluminum design, which plays a critical role in aligning the voice coil and the magnetic circuit. In the case of the Legatia L3, it uses an aluminum basket instead of a stamped steel frame to ensure idealized clamping strength to the baffle where the speaker will be mounted and less chance of flex/warping. Finally, a pair of gold-plated terminals and high-gauge tinsel leads ensure adequate connection.

Thiele/Small Parameters

Acoustics pioneers Neville Thiele and Richard Small developed a way to predict speaker performance and frequency response. These parameters are known collectively as "Thiele/Small Parameters", and are divided into physical characteristics and response parameters:

The Physical Characteristics of a speaker are:

Re:	The D.C. resistance of the voice coil measured in Ohms.
Sd:	The surface area of the speaker's cone.
BL:	The magnetic strength of the motor structure.
Mms:	The total moving mass of the speaker including the small amount of air in front of and behind the cone.
Cms:	The stiffness of the driver's suspension.
Rms:	The losses due to the suspension.

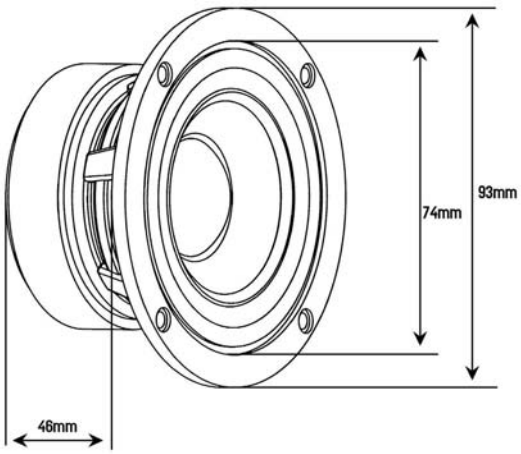
The Thiele/Small Response parameters are:

Re:	The D.C. resistance of the voice coil measured in Ohms.
Sd:	The surface area of the speaker.
Fs:	The resonant frequency of the speaker.
Qes:	The electrical "Q" of the speaker.
Qms:	The mechanical "Q" of the speaker.
Qts:	The total "Q" of the speaker.
Vas:	The volume of air having the same acoustic compliance as the speaker's suspension.

The mechanical and electrical parameters of the Legatia L3 driver are amenable to a variety of different installations and speaker locations. The high Qms and Qts of the driver will allow it to be used in an infinite baffle configuration. Hybrid Audio has also had great success using this driver in a dipole configuration, a.k.a "open baffle", and in larger vented enclosures. The size of the unit allows it to be mounted in locations previously unheard of with other speakers. This driver can be mounted on a-pillars, in dashboards or kick panels, or anywhere your imagination takes you. The design goes hand in hand with fool-proof, high-end sound quality with minimal work.

The following are the mechanical and electrical parameters for the Legatia L3 midrange:

Overall diameter:	93mm
Mounting depth:	46mm
Total depth:	50mm
Magnet diameter:	65mm
Mounting hole:	74mm
Power handling (without crossover):	50W, 3 dB power compression
Power handling (with crossover):	200W
Frequency range:	129Hz - 10,000Hz
Sensitivity:	85dB 1w/1m
Mms:	2.274g
BL:	2.961 T*m
Voice coil diameter:	25.5mm (1")
Impedance:	4 Ohm
Fs:	129Hz (free air)
Qms:	3.468
Qes:	0.717
Qts:	0.594
Xmax:	2.6mm
Vas:	0.63L
Sd:	2733mm^2



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Initial In-Car Set-Up; Lessons Learned

Lesson One: Off-Axis Response

When a speaker like the Legatia L3 is placed in an automotive environment we hear the direct (shortest path) and reflected (longer path) sounds, such as resonances and reverberations. The two sounds are processed by the brain as one sound, and this influences our perception of height, width, and depth of soundstage, as well as rearward ambience. For this reason, the off-axis radiation pattern of any speaker in a car environment has a significant influence on how natural the music sounds. In general, the closer the vehicle approaches semi-anechoic conditions (see "Acoustic Treatments" below), the less off-axis response plays a roll in the visceral experience. The lesson to learn here is that most car audio sound systems benefit greatly from having the front stage speakers at least partially off-axis.

Lesson Two: Equalization of Pathlength Differences

Quite possibly the most important functional consideration that an installer or do-it-yourself (DIY) enthusiast should give to the Legatia L3 speaker placement is to optimize, as best as possible, pathlength differences (PLD's) in the vehicle. PLD's are defined mathematically as follows (this example assumes a right-hand driven vehicle---PLD's are always a positive number):

$$X - Y = Z$$

Where:
X = distance of the center of the left speaker from your left ear.
Y = distance of the center of the right speaker from your right ear.
Z = pathlength difference.

Applying this formula, assume that the distance of the left speaker from your left ear is 140cm, and the distance of the right speaker from your right ear is 100cm, then the pathlength difference is 40cm.

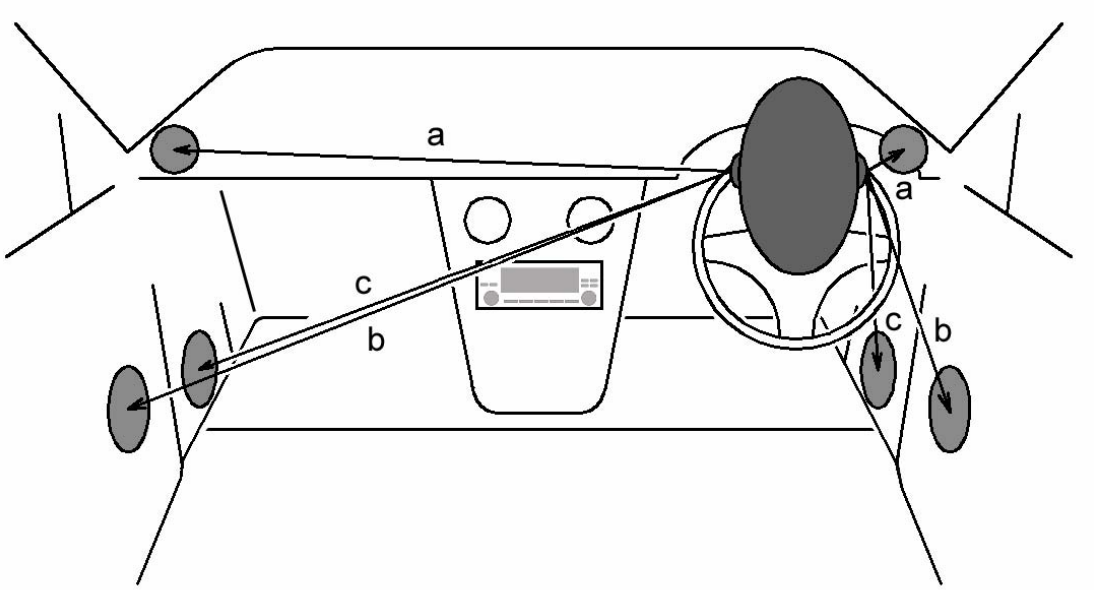
Good stereo imaging is completely dependent on arrival times of the fundamental vocal frequencies. Differences as little as 10 microseconds can be detected by the brain. A PLD of 30 centimeters equates to the sound from the nearest channel arriving about 9 milliseconds earlier than the furthest channel. It is Hybrid Audio's opinion that the installer should try to keep PLD's to less than 30 centimeters in a vehicle which is intended to have good imaging and staging character from both seated positions.

The best way to go about evaluating certain locations in your vehicle is, in general, to look for the potential locations as far forward and away from you as possible, but with still a "line of sight" to the speakers (if you can't see the speakers, this might not be an ideal location). An easy way to test various potential locations is to have a friend help you hold a tape measure or

other measurement device from the potential speaker mounting locations, and measure those locations with respect to your ears.

Reference Figure 1. In this scenario, three potential locations for the mounting of the L3 midrange driver are shown:

Figure 1



In scenario “a”, we show the installation of the L3’s in the dashboard or a-pillars. As you can see from the diagram, the PLD’s between the left and right speakers are large, due to the proximity of the listener to the near-side speaker. While the mounting of primary drivers in the dashboard or a-pillars has become increasingly popular, this configuration will undoubtedly require both time and intensity domain equalization in most vehicles to ensure a good, focused center image, properly located in the center of the vehicle for one seated position. There are, however, some rare exceptions, and you may actually find that the dashboard locations provide the best equalized PLD of the available mounting locations. Conversely, should the PLD’s not be ideal, you may still want to consider this scenario if you have the ability to digitally manipulate both time and intensity; you may find that mounting the L3 drivers in this way to be the best compromise for stable stage height, focused images, and excellent tonality.

In scenario “b”, a typical door installation location is shown, and in many vehicles represents a mild improvement in PLD’s from the dashboard and a-pillar location identified in scenario “a.” However, great care must be taken to protect the L3 in a door installation, given its untreated cone and dust cap. Additionally, the door speaker installation scenario will likely also require some amount of time and intensity equalization to ensure a centered image in most vehicles.

The third and final potential mounting location as shown in this diagram (scenario "c") represents a kick panel installation, where the L3's are placed far forward in the A-frame cavity of the kick panels, present in most vehicles. While it is not immediately obvious looking at a two-dimensional drawing, in many cases the kick panel location affords the best equalization of pathlength differences for most vehicles.

The lesson to be learned here is that by taking a few moments to evaluate the potential mounting locations in your vehicle, in a very short period of time, you will be able to find the best location for your L3's by determining the location with the smallest PLD.

Lesson Three: The Effect of HRTF, ITD, and IID

Head-related transfer function (HRTF), interaural intensity differences (IID), and interaural time delay (ITD) all play a key role in the optimum placement location for the Legatia L3. A sound wave approaching the eardrum from your chosen speaker location is shaped by interactions with the size and shape of your head, torso, and outer ear, resulting in the HRTF. More specifically, the HRTF is the ratio between the sound pressure of the wave at the eardrum, as compared to the sound pressure that would exist at the center of the head if the head were removed. In general, the sound arriving at the ear further from the source is attenuated and delayed relative to the sound arriving at the ear closer to the source. This generates an interaural intensity difference (IID) and an interaural time delay (ITD). As a sound approaches the head, the ratio of distances from the speaker location to the near and far ears increases, and the effects of head-shadowing are amplified, causing the IID to increase. The spectral shaping caused by the head and the shape of the outer ear may also change. The ITD, which results from the absolute difference in path length from the source to the ears, remains approximately constant as distance decreases. From this we learn:

- ITD is the dominant factor for frequencies below about 500 Hz;
- A combination of ITD and IID are dominant for frequencies between approximately 500 Hz and 2,000 Hz; and
- IID, in concert with HRTF, are dominant above about 2,000 Hz.

These are generalizations, and are subject to the size and shape of one's head and torso, and size and shape of the outer ear (the folds and ridges of the ear), but in general, the above is a good guideline for establishing ITD, IID and HRTF thresholds for the human auditory system.

Because the L3's ability to play into the sub-200 Hz range, an effect clearly dominated by ITD, up to and including frequencies exceeding 8,000 Hz, an effect clearly dominated by IID and HRTF, placement of this driver is extremely important. The driver should be placed as far forward as possible in the vehicle to optimize ITD. Lateral (forward to back) placement is much more important than horizontal placement (up and down). This is because of the brain's ability to process sounds such as spectral envelope cues, and use a phenomenon as the "precedence effect"; the brain can be easily "fooled" into thinking a sound stage is high with kick panel or floor-mounted speakers (a word to the wise: the best place to put a set of

speakers is not always “up high”, as most vehicles do not offer an amicable location in the dashboard or a-pillars for good image placement for both seated passengers, especially in the critical frequencies sub-500 Hz). In addition to the time equalized placement of the drivers, the installer must also consider that above approximately 2,000 Hz, intensity plays a key role in good sound staging and imaging. Therefore, the Legatia L3’s should be placed in an area where intensity differences can be equalized, either mechanically or electronically, to ensure good imaging and sound staging.

The lesson to be learned is that, like Lesson Two, the Legatia L3’s should be placed as far forward from your listening position as possible, and every effort should be made to optimize time and intensity domain characteristics of the installation.

Lesson Four: Point-Sourcing

The term “point-sourcing” is often used to describe the technique of having a single pair of speakers in an installation cover the majority of the critical middle band frequencies. In many installation scenarios, the Legatia L3 could be considered a point-source speaker driver, because it has the ability to reproduce six octaves of tones. Point-sourcing, if done correctly, can lend itself to a variety of valuable attributes, including precise image definition and stable sound staging character. By applying Lessons 1-3 above, and with correct filtering to cover the vocal spectrum (as detailed in the “Crossover” section following), the Legatia L3 can be used as a point-source midrange driver to achieve excellent staging and imaging results. The lesson to be learned here is that the L3, given its wide-bandwidth design, can faithfully reproduce as much as six octaves of tones, and would make a valuable addition to any sound system as a point-source driver for the spectrum comprising vocal imagining cues.

Lesson Five: Reference

One of the most important things to do before reading the next section and completing your Legatia L3 installation is to get a reference for your future listening tests. To really know what a snare drum sounds like, you must go and listen to one, in person, live and un-amplified. There is no substitute for the visceral impact and emotion of live music. Nothing else in life can touch your soul the way music does. Whether it’s a 200-member orchestra, or a four-piece fusion band, nothing compares to the phenomenon of live music. Take this as Hybrid Audio’s official request: become a student of music and your playback car audio sound system will be better for it. We want nothing more than to know there are great sounding audio systems around the world using our products, and you’d make us all very proud if you became a student of music and learned its beauty and passion.

Legatia L3 Enclosure Requirements

The Legatia L3 is an infinite baffle-capable speaker, and must be mounted in an "infinitely large enclosure" with unrestricted access to airspace to ensure the speaker's ability to effectively reproduce its wide frequency bandwidth. The reason why the speaker was designed in this way is highly empirical. When a speaker is mounted in a small closed box, it radiates as much energy forward of the cone as it does rearward of the cone. All speaker cones and dust caps (diaphragms) are a weak sound barrier at best, and the result of the high amount of energy being "pushed" into a small enclosure is the energy transmitting through to the outside of the cone (an additive phenomenon to the incidental wave). It is conjectured that this effect is most notable in the low hundreds of Hz region, where acoustical stuffing materials are ineffective and the internal dimensions are not small enough for the internal air volume to act as a pure compliance. Consequently, Hybrid Audio has designed this speaker to work well without an enclosure, and as such, should not be significantly prone to enclosure back-pressure and sound coloration when placed infinitely baffled. The "infinitely large" enclosure, per se, improves spectral response and power response variation between high and low frequencies. And in the case where an infinite baffle operation is difficult or impossible to achieve in your car's environment, we highly suggest the use of acoustic resistors (aperiodic membranes or trade name Variovents®) in sealed enclosures to help dissipate the backwave energy. If you absolutely must use a sealed enclosure, we recommend a volume of at least 2.5L. Hybrid Audio has also encouraged the use of transmission line enclosures for the L3's, and has seen great results with TL's "tuned" to between 120 and 150 Hz to work extremely well in the car environ. In all cases, the use of loosely-packed fibrous damping materials, such as fiberglass, Dacron, or long-fiber wool will also significantly improve the final installation, no matter what type of baffle and enclosure configuration is chosen.

While infinite baffle or resistive sealed enclosures are highly recommended for this driver, you might find that in the rare instance the L3 driver can be placed in a completely open baffle, i.e. dipole. A word of caution: an L3 mounted in an open baffle has to move more air than an L3 in an infinite baffle, just simply for the fact that there's a progressive acoustic short circuit between front and back below the speaker's Fs in the open baffle configuration. Great care must be taken in this instance, because there is no acoustic compliance afforded in a dipole configuration, and the speaker will reach its mechanical limits much quicker (and will net increased distortion). However, in certain instances, a dipole-style midrange may work well in a vehicular installation, in that radiation from the rear of the baffle, having undergone enough phase shift as it comes around to the front, adds to the total sound at off-axis angles. Of great importance in the dipole midrange configuration is the setting up of crossovers and weighing the negative effects of distortion of elevated amplitude levels.

Legatia L3 Mounting Baffle Requirements

The baffle that the Legatia L3 is mounted in should be small in dimension if at all possible. The purpose of using a small baffle is to avoid the potential for low amplitude diffracted sound waves becoming summed with the incidental waves. A narrower baffle also becomes

increasingly important into the Legatia L3's upper bandwidth, where the power response is more uniform, and incident and reflected waves are indistinguishable. In layman's terms, keep baffle dimensions small with respect to the size of the Legatia L3, chamfer or round sharp edges (including, in particular, the mounting hole's rear inner edge), flush-mount the speaker whenever possible, and use shallow, surface-mounted hardware. Also, remove all unnecessary protrusions from the baffle surface.

In addition to the baffle's construction requirements, it should also be either secured extremely well to the car's body, or completely isolated from the car's body. The reasoning is that the speaker baffle panel will vibrate, excite baffle modes, and thus will radiate sound. Small vibrations such as this can result in the baffle itself radiating more sound than the actual speaker at certain frequencies. In either installation scenario, the baffle should be damped with a layer of typical sound damping to reduce the Q of the baffle and lower its vibrational resonance frequency below the range of the driver's frequency response. In many cases, using thicker baffle panel in concert with asphaltic-style sound damping can also be advantageous, providing the rearward wave of the speaker has no obstructions created by the baffle itself. Finally, if possible, the speaker should be mechanically decoupled from the baffle. This can be something as simple as a layer of self-adhesive foam tape, to more exotic examples of decoupling, including rubberized rings or multiple-layer septum shielding.

Crossovers

One of the most fundamental and important considerations in the final tweaking of a car audio system is the set-up of the speaker's crossovers. The Legatia L3 utilizes a rigid paper cone that exhibits little if any cone breakup in its upper frequency bandwidth. However, it is still important to utilize crossovers, especially active crossover networks to suit the speaker system to the car's acoustic signature. It has been Hybrid Audio's philosophy to tune the speaker system to the vehicle's acoustic signature using just active crossovers, and only a very minor amount of equalization. Our very best world championship vehicles have always had one thing in common: creative use of active crossover filters and very minimal equalization. Use your crossovers to tune your car, and the equalizer to suit the vehicle's speaker response to your own tastes.

The first thing to remember is that every speaker exhibits some sort of a natural roll-off. This rolloff typically amounts to about 12 dB/octave, and needs to be taken into account, especially when designing passive crossover systems. Simply adding a capacitor and inductor in series (6 dB/octave bandpass filter) to the Legatia L3 does not necessarily mean that you'll see a phase coherent 6 dB/octave bandpass filter at its crosspoints. In fact, summing the effect of the L3's natural bandpass roll-off, you might actually be approaching a theoretical 18 dB/octave bandpass filter. Not only this, but the speaker could potentially begin to exhibit significant intermodulation distortion as the cone becomes non-linear trying to reproduce the lowest octave of tones, not to mention irregular polar radiation patterns between the Legatia L3 and it's mated tweeter and midbass with wide frequency overlap.

Given the large uncertainty of low-order passive crossover systems, Hybrid Audio recommends the use of higher-order passive crossover systems, namely fourth order (24 dB/octave) filters, and ideally, electronic crossovers so that fine tuning can be done electronically. The active network benefits from easy correction of different speaker sensitivities and equalizing not only the individual drivers but the combined response as well. Not having to account for the speaker's impedance verses frequency, as well as the passive device impedance and phase shift makes the active filter superior to most passive crossover networks, due to the fact that each and every aspect can be tailored to better suit the individual installation's requirements. However, we understand that in some cases that passive filters are required, if not even desired in certain circles, and although the work involved to make them right might be more difficult than that of an active network, the results can be made to be the same. In our humble opinion, however, the ideal crossover system for most users, is an active one that takes into account the Legatia L3 driver location and its characteristics, in concert with the polar radiation patterns of other speakers involved, all the while balancing linear and non-linear distortion (non-linear harmonic distortion is the product of all small midrange designs, and the Legatia L3 is no different. Typically, distortion increases with sound pressure level or cone displacement, and thus, crossover frequency is critical and can be vehicle and user dependent).

As mentioned previously in "Lesson Three", imaging cues of near-field (within 3m) sources come from effectively two auditory methods: Interaural Time Delay (ITD) and Interaural Intensity Difference (IID). ITD is the time it takes for sound to reach the far ear after reaching the near ear. Typical adult male heads have an ITD maximum of approximately 400 microseconds. IID is the measure of intensity difference of the far ear as compared to the near ear. ITD is typically used by the brain to localize low frequency sources below 500 Hz. IID is typically used by the brain to localize high frequency sources, above 2,000 Hz. Head Related Transfer Function (HRTF) is also used in conjunction with IID. Above approximately 4,000 Hz, the higher frequencies are attenuated by the head for the far side ear. A sound to your left will have a different spectral content for the left ear as compared to the right ear. The HRTF is unique for each individual (based upon shape and size of the head and torso) but typically occurs at around 4,000-5,000 Hz. HRTF will affect the IID at even higher frequencies, more so than simple average SPL. Above 6,000 Hz or so, the HRTF portion of IID becomes the dominant factor. The spoken word (human voice) comprises a fundamental frequency range of approximately 150 Hz to 6,000 Hz.

Taking the above into account, your desired crossover frequency for the Legatia L3 should be one that allows the L3 to play as much of the audible spectrum of the spoken voice to ensure point-source delivery of the tones and pinpoint image definition. In many cases, this would be around 200-250 Hz for high pass, and around 6,000 Hz, or higher, for low pass. In very controlled circumstances, Hybrid Audio has achieved excellent results with a passband of 140 Hz to 8,000 Hz with L3's aimed on-axis to the listener. However, the low crossover point will limit amplitude ability and potentially increase distortion, and was meant for a user with realistic expectations of a small diameter driver and realistic listening levels. To summarize, in all cases, the chosen crossover frequencies should be evaluated for sonic character, while

balancing distortion and power compression at high amplitude levels. For the casual listener and enthusiast, we recommend a passband of 200-250 Hz to 6,000 Hz at fourth order filters (24 dB/octave).

Time Correction

It is our humble opinion that time correction should only be used in three different circumstances:

1) When the installer recognizes that a vehicle cannot image properly from both seated positions and it seems more plausible to make the vehicle stage and image well from only one seated position.

2) To counter the effects of group delay.

3) Time alignment between pairs of drivers.

Scenario 1

The first scenario is rather elementary. If a vehicle is too small to achieve equalized PLD's, it doesn't lend itself well to equalized PLD's, or the vehicle's owner doesn't wish to embark on physical reconstruction of the car to achieve optimized PLD's, it is a good use of time correction to make the vehicle image well from the single seated position. It should be noted that it is Hybrid Audio's opinion that it is always better to improve the car mechanically and attempt to fix mechanical problems with mechanical solutions, than it is use to electronics to fix mechanical problems. However, we realize that there is the occasion when there is little desire to try to mechanically optimize one's listening space, and electronic manipulation is desired. It is important to recognize that, given the fundamentals of ITD and IID discussed previously, time alignment is rendered virtually useless for frequencies above approximately 2,000 Hz.

Scenario 2

In the second scenario, the use of time correction is much more cognitive, and shows great promise for countering the effects of group delay. Group delay is impulse response over time. Group delay increases significantly at low frequencies, and is considerable in larger midwoofers and subwoofers. An excellent use of time correction would be to delay the Legatia L3's and tweeters with respect to the midwoofers and subwoofers, so that the low frequency delay of these drivers is synchronized in the time domain with the output of the midrange and treble frequencies.

Scenario 3

The final scenario is time alignment between pairs of drivers. When employing multiple drivers in order to achieve a unified listening experience within a vehicle, it's usually a requirement to install the drivers at physically separated locations; for example, your midbass may be located in the doors, and the midrange and tweeter may be located in the dashboard or a-pillar. In order to compensate for this, you might choose to selectively delay certain speakers in the installation so that all of the tones reach your ears at the same time (note that as previously alluded to, time alignment of your tweeters would be rendered useless).

Amplitude Equalization

An excellent use of today's dual-mono equalizers and advanced digital signal processing is the ability to equalize amplitude anomalies between speakers and sets of speakers. In a vehicular installation, the frequency response of drivers can sometimes be manipulated for the betterment of the system using independent left and right amplitude adjustment. Virtually any good car audio system can be made better with judicious use of a minor amount of equalization. And while equalization will not cure phasing anomalies in a car, usually the product of vehicular mechanics, they can certainly be helpful in fine-tuning the system to your own personal taste or in the quest for playback accuracy to the original musical composition.

One important consideration of amplitude equalization (also known in some circles as "amplitude alignment") is the ability to tune those frequencies above about 500 Hz that are not completely affected by time correction. The very best vehicles have some sort of amplitude equalization between the left and right speakers to account for IID and HRTF. After your L3's are mounted and you're satisfied with them from a tonal perspective, you may wish to attempt some minor amplitude equalization between the two Legatia L3 midrange drivers to achieve a more stable image that is not frequency dependent, or perhaps to improve image placement or stage coherency.

Acoustic Treatment

A considerable benefit can be made to any car audio system with the select placement of acoustic treatments. The purpose of using acoustic treatments is to reduce the amount of reflected energy in the hostile automotive environment, and hear more of the direct sound being emanated from the speaker. It is akin to the signal to noise (S/N) ratio in a piece of electronics, where the signal could be considered the direct energy coming from the speaker, and the noise could be considered the reflected waves off of nearby surfaces, such as windows, hard center consoles and door panels, windscreens, and etc. In our quest to find the best piece of electronics, one of the most popular measurements to look at is the S/N ratio, so why not spend at least an equal amount of time developing the S/N ratio of our acoustic listening space as well? A word of warning though: there is a fine line between too little and too much room treatment; just as some cars can benefit from some selectively applied treatments, there is a point where the vehicle can begin to approach semi-anechoic

conditions, and lose its liveliness. We don't live in an anechoic world, so why try to recreate anechoic conditions in our cars? Reflections are all around us, and are a part of our day-to-day lives. It is our opinion that some lateral reflection is a good thing; it helps to establish stage boundaries, and gives the recoded playback and more visceral and "believable" sound.

The first principle to understand is that below 200 Hz, acoustic treatments are rendered virtually useless. It is Hybrid Audio's assertion that only those frequencies above 200 Hz benefit from the use of treatments, given that a 200 Hz waveform is about 1.7 m long; 1.7 meters is less than or equal to most vehicle widths. This is also the frequency where we believe *pure tones* in the vehicle are going to be difficult, if not impossible to localize. Finally, most vehicles exhibit a Shroeder Frequency (Fs) between 50 at 120 Hz; the Fs (or cabin-gain frequency) is vehicle dependent, and is the frequency at which resonances become so tightly packed in frequency and space that the room behaves quite uniformly.[1]

Acoustic treatment can be very effective above 200 Hz, depending mostly on the polar radiation pattern of the speaker. In the case of the Legatia L3, a small cone midrange driver, the polar radiation pattern is quite large at lower frequencies, with a narrowing of the radiation pattern ("beaming") at frequencies into the treble bandwidth. While it would be convenient to only have to worry about the speaker itself, we also must be concerned with crossover and baffle design as well (see Legatia L3 Mounting Baffle Requirements section).

Should the Legatia L3's be placed in the kick panel locations, one may find that a notable improvement can be made by adding acoustical treatments, such as open-cell foam, into the underside of the dashboard. Likewise, should the L3's be placed up high on a-pillars, or in the dashboard, where comb filtering (reflective summation and cancellation off of a hard surface, such as a windscreen) may become an issue, a dashboard "mat" or other soft furnishing may be a noticeable improvement. It will require trial and error to get it right, but the learning is in the experimentation!

Physical Installation of the L3's

We hope that by now you feel more comfortable in the actual physical installation process. Unfortunately, there are no rules in car audio, only several hypothesis and theorems that seem to work for *most* vehicles. Your vehicle may be different, and defy everything we know, and everything written in this manual. You may find that getting that rich, detailed sound that you crave may require some experimentation and a lot of work to make it right. Or you might be fortunate to have a vehicle that sounds excellent with minimal work. Have patience and work through the issues; the result will be a rewarding musical experience in your car!

The L3's can now be mounted in the location deemed to be the best for your vehicle, using the tenets outlined in this manual. Connect the speaker's large terminal to the amplifier's positive speaker output and the speaker's small terminal to the amplifier's negative speaker

[1] As an aside, one significant benefit of car audio sound systems is that frequencies below the lowest room resonance increase at a theoretical 12 dB/octave...it's no wonder car audio systems have such great bass!

output (however, this may change, as detailed in the "Setting Acoustic Phase" section later in this manual). We use the largest gauge speaker wire possible; for this installation, we would recommend at least 13-gauge pure oxygen free cable (POFC) be used. If you are comfortable with soldering, we recommend that the speaker wires be soldered directly to the speaker's terminals using silver-content solder. Great care must be taken however, as over-heating the terminal may result in physical damage to the speaker's terminals, or disconnection of the speaker's tinsel leads, which are not covered under the limited warranty. We recommend that only those individuals with experience in soldering heat-sensitive electronics attempt this procedure. If you're not, then the use of female slide terminals would be a more ideal choice for connection. In the case of the use of female slide terminals, be careful in the connection process, as the negative terminal on the speaker can be fragile given its small size.

With the speakers connected, install them into their new locations, and turn the page for detailed ideas for set-up and tuning of your L3's.

Fine Tuning

We hope that by now you have either installed your Legatia L3's, or now have a plan to install them and get the most performance possible out of them. Now it's time to indulge what might become one of the more time-consuming aspects of the Legatia L3 installation: fine tuning the L3's to your car's own acoustic signature. All cars are different, and present both challenges and unforeseen advantages to the installer during fine tuning. Some vehicles will sound absolutely incredible "right out of the box", while others might require fine tuning and tweaking to get the desired results.

Setting Crossovers and Speaker Break-In

Before you start the system for the first time, please double-check that all crossover systems are engaged and active. If you are using a passive crossover network, please verify all connections and cross-reference the schematic to be sure that the filters are wired correctly. The absolute minimum crossover frequency that can be used for the Legatia L3, assuming very controlled circumstances for the discerning listener with realistic expectations of a small diameter driver and realistic listening levels, is 140 Hz at 24 dB/octave. We suggest an initial start-up frequency of 250 Hz at 24 dB/octave, and then work down from there, if necessary, based upon the taste of the listener, and the polar response and mounted location of the midbass used. But in no case should the crossover be lower than 140 Hz at 24 dB/octave.

With the system on, and the amplitude ("volume") adjustment at zero, double check the crossovers one final time, and then begin to advance the amplitude on a dynamic track with good midbass impact. You may find that the gain structure of the system will need to be re-adjusted with the addition of the Legatia L3 to an existing system. A quick and easy way to do this is to advance the volume knob to just slightly below maximum, and adjust the amplifier's gain just before audible distortion is heard. Listen for audible distortion from the L3, and visually observe its excursion. The driver has the capability of 2.6mm of one-way Xmax, so some excursion at very high amplitude levels is perfectly acceptable. However, too much excursion will lead to power compression and elevated distortion, so please adjust the crossovers for the L3 to suite your tastes as well as your anticipated typical amplitude levels, all the while cognoscente of the L3's abilities.

You will find that the driver will begin to perform well after approximately 25 hours of break-in time. This can be as simple as 25 hours worth of normal listening, or exercising the speaker for the first 25 hours of operation with pink noise set to about 80-82 dB. In either case, the true performance of the L3 will be revealed only after a thorough break-in period where the speaker is exercised for an extended period of time.

Setting Acoustic Phase

Upon completion of the crossover setting and speaker break-in period, you will now need to critically listen to the Legatia L3's for acoustical phase. Even though you are sure that the L3's

were wired in absolute phase (speaker positive to amplifier positive, and speaker negative to amplifier negative), there may be acoustical anomalies in your vehicle that manifest themselves as phasing issues. In a car, a host of things are working to interfere with the driver's output: reflections, path length differences, arrival times, etc. The result is that, although the drivers are moving in unison, they don't sound like they are in phase from the listening position. By the time the sound reaches your ear, some of the waves are out of phase to each other, creating "blurring" of the image, loss of midbass, holes in the frequency response, etc.

To check for acoustical phase, you can use media that you are familiar with that contains a strong center image. Does the center image seem coherent and focused, or does it seem confused and difficult to locate? If the center image (such as a vocalist) seems confused, blurred, or difficult to locate, the Legatia L3's may be acoustically out of phase. If you are unsure, you can purchase a test CD (readily available from most places) that includes an "in phase" and "out of phase" track to quickly identify if the system's acoustic phase is correct. We use the International Auto Sound Challenge Association (IASCA) Set-Up and Test CD, which divides the phasing coherency tracks into three intuitive frequency bandwidths: 20 - 200 Hz, 200 - 2,000 Hz, and 2,000+ Hz to easily check if pairs of speakers are in-phase or out of phase.

Should you find in your testing sequence that the system appears to be acoustically out of phase, you might be able to quickly remedy this situation by reversing one speaker's polarity by switching the positive and negative wires on the speaker, so that they sound in phase from the listening position. You might find that all speakers on one side of a vehicle (midbass, midrange, and tweeter) need to have their polarities switched to create a focused center image. Another remedy might include the provision of acoustical treatments, as explained earlier, to help absorb reflections, which may alter the acoustical phase of the sound. Finally, there are higher order physical reconstructions that can be done to the listening space, such as removing hard surfaces that create early reflections, nodes and antinodes, by changing the interior of the vehicle to better accommodate more ideal pathlength differences and removing obstructions to the direct sound wave.

Time Correction and Amplitude Equalization

With crossovers and acoustic phase sorted, it is now time to tune the system with some time correction, if necessary, as well as some amplitude equalization, if you have the hardware available in your system to do this.

There really is no science to setting time correction "in the field" without expensive test equipment. If you have test equipment, it is much more an objective measurement function, but alas, more often than not, it is more of an art that requires trial and error. The best advice is to approach time correction carefully and use only the minimum to achieve the results you desire. And it should be noted that you may find that adjusting the time correction will effect the acoustical phase you just got done setting as well.

The final step in the set-up and tuning process is some amplitude adjustment/equalization to achieve the desired tonal character, as well as to help stabilize image definition. Hybrid Audio strongly encourages the users of the Legatia L3's to use only a minimum amount of equalization. If you find that more than four or five decibels of equalization are needed, there is likely another, more invasive and underlying problem with the system, such as a nodal or phasing issue that cannot be corrected with any amount of equalization. Use the equalizer only to cater the system to your own taste and your impression on what best represents accurate reproduction of the original source. And the only way to know exactly what your system should sound like is to get a musical reference.

The use of a Real Time Analyzer (RTA) is a valuable tool for learning frequency response character of your Legatia L3's, and should be used for nothing more than a tool, and not a mechanism to tune your car audio system. Your ears, combined with the processor, your brain, are the most advanced test instrument in the world. The RTA, although a valuable tool, cannot differentiate between direct and reflected waves, and basically sums the frequency response of the speakers and all of its reflections. At Hybrid Audio, we recommend using the RTA for setting a "type curve" (a curve we anticipate to sound good), and the use of the device in "active mode" to evaluate problem tones identified by ear. All intermediate and final tuning should be done by ear with a good reference.

Listening Tests

The final stop on the path to achieving good results from your Legatia L3 midrange drivers is to just simply listen to them with as many types of familiar media as possible. Listen for the nuances in the music, and the passion the playback envelopes. This is by far the most laborious part of the installation, but also by far the most rewarding! You know that you're approaching the high fidelity you want when you're spending more time in your car than anywhere else!

Thank You!

Hybrid Audio Technologies is delighted that you have chosen the Legatia L3 midrange for your high-end car stereo sound system. We are convinced that a great product offering, backed up with unsurpassed customer service and technical support will advance the Hybrid Audio Technologies namesake in the coming years. We are pleased that you have joined us in our "new generation of in-car audio."

If there is anything we can do to help you get the most out of your Legatia installation, please do not hesitate to contact us at info@hybrid-audio.com, or by visiting us on line at http://www.hybrid-audio.com

Hybrid Audio Technologies One Year Limited Warranty

Hybrid Audio Technologies, LLC (HAT) guarantees its products to be free from defective material and/or workmanship for a period of one (1) year from date of sale, and will repair or replace, at our sole discretion, defective products under this warranty when the defect occurs under normal installation and use - provided the product is returned to our factory via pre-paid transportation with a copy of proof of purchase (i.e., sales receipt). This warranty provides that the examination of the return product must indicate, in our judgment, a manufacturing defect. This warranty does not extend to any product which has been subjected to misuse, neglect, accident, or improper installation. HAT shall not be liable for incidental and/or consequential damages.

In the event of a warranty return, please send the products postage pre paid to:

Hybrid Audio Technologies, LLC
Attention: Returns
6775 Payton Road
Cumming, GA 30041 USA

This warranty gives you specific legal rights. This limited warranty is freely transferable during the term of the warranty period. The customer may have additional rights, which vary from state to state in the United States, as well as by international law.

Contact us at 770.888.8200 for additional information.

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