Immersion Technologies: An introduction

Immersion Technologies International plc ("Immersion") is a total audio solution provider incorporated in the United Kingdom with patented technologies referred to as HD-A® technology. HD-A® technology is a trademark used by Immersion to refer to both revolutionary electrostatic loudspeakers ("ESL") and award-winning conventional cone loudspeakers ("CCL").

The principle benefits offered by Immersion's HD-A® technology are:

- ESL: superior acoustic performance in combination with flexibility in size, shape and form, combined with flexible manufacturing options; and
- CCL: mechanically tuned/filtered enclosures coupled with revolutionary new driver designs achieve reduced THD, high SPL and power consumption as low as 1 watt per 100dB.

The integration of HD-A® ESL and HD-A® CCL in combined systems achieve what Immersion considers to be a new level of high definition audio and has registered trademarks to reflect this standard internationally High Definition – Acoustics HD-A®.

Both HD-A® ESL and HD-A® CCL technologies have already received industry recognition, as follows:

Innovations 2006 Award (Design & Engineering) (ALPINE PLT-5)

Innovations 2007 Awards Honourees (WHISE HA1500)

PAM™, NTM® and VR/UR™ are more of Immersion's patented technologies that supplement the superior performance provided by HD-A® technology.

- PAM™ technology uses acoustic modelling and mechanical filtering techniques to control audio quality. This technology was incorporated into the award winning

Whise Profunder™ subwoofer, the world's first TMH Qualified subwoofer (Tomlinson Holman developed THX and 5.1 for George Lucas's Star Wars).

- NTM® digital crossover (an acronym for the Neville Thiele Method – the Small/Thiele parameters are used for all speaker enclosure design since 1956) enables precise control of frequency signals (specifically used for crossover control) giving Immersion a proprietary advantage over competitors with conventional alternatives. This technology is currently licensed in BSS Audio products (a Harman International, Inc brand) (USA).

- VR/UR™ technology enables low frequency CCL to be incorporated into unconventional locations within passenger vehicles or other industrial or commercial applications. This technology is currently incorporated in prestigious British and Swedish motor vehicles under licence through Alpine Electronics UK. It is also licensed to Alpine Electronics (USA) for its aftermarket retail products such as the award winning LAT PLT-5 produced in conjunction with Tymphany Corporation and Alpine's PLV-7.

Alpine PLV-7	Whise HA1500®	BSS - Minidrive	Whise Profunder
			

The major advantages of HD-A® audio devices are summarised as follows:

HD-A® - ESL

- Extremely low audible distortion with superior audio performance relative to conventional ESL;
- 80 microsecond transient response time – we believe a world first;
- Thin technology, high quality/ flat profile typically 16mm or less;
- Extremely scalable, almost any size or shape;
- Less volume deterioration – sound wave differences reduce volume losses over distance compared to CCL (i.e. sub-woofer);
- Less sound penetration – sound wave differences reduce unwanted noise pollution;
- Dual Purpose – high performance functioning in both stereo and surround sound roles with electronically adjustable wide and narrow dispersion – we believe another world first;
- Use of high performance (expensive) amplifiers is not required;
- Passive electronic bass correction – bass is enhanced electrically and electronically;
- Radical bass baffling extension – enforces low frequencies;
- Elimination of requirement for a low frequency CCL on larger models;
- Reduction of air turbulence between grids; and
- Compression (not clipping) of damaging peak transient signals.

HD-A® – CCL

- Extremely low THD with superior audio performance relative to traditional CCL (endorsed by Neville Thiele & Tomlinson Holman);
- Flexible enclosure design – design can be adapted to available space;
- Smaller than conventional low frequency devices;
- High efficiency – significantly reduced power required to achieve high sound pressure volume:
- External sound pollution cancellation; and
- Integration – seamless integration with HD-A® ESL ie, the Nakamichi Dragon® ESL.

Immersion considers existing CCL and ESL manufacturers to compete in a relatively static market where product differentiation occurs in three mutually exclusive areas – aesthetics, performance and price. Immersion believes that of the worldwide audio market, there are very few products, if any, that excel in all three areas. HD-A® challenges this with flat, stylish designs, superior audio performance at a cost that is competitive with the traditional ESL and CCL technology.

Immersion is the '*new kid on the block*' and is unique compared to all conventional audio technologies. Immersion considers its HD-A® technologies to be unrivalled in the market for audio reproduction devices.

Immersion Technologies:

The Automotive Advantage

Immersion Technologies International plc ("Immersion") has a diversity of proprietary patented technologies for Conventional Cone Loudspeakers ("CCL"). These technologies provide superior acoustic performance in traditional applications or in specialized applications such as automotive audio. These technologies include:

- **HYBRID ACOUSTIC FILTERS™**
- **ACOUSTIC STUBS™**
- **NEVILLE THIELE METHOD CROSSOVERS ("NTM®")**
- **VELOCITY REFLEX SUBWOOFERS ("VR™")**
- **PARAMETRIC ACOUSTIC MODELLING ("PAM™")**

Individually, each of these technologies are revolutionary and when combined in the format known as the Immersion 3 Way System™ they provide a unique high performance audio solution for the automotive industry.

IMMERSION 3 WAY SYSTEM™

The Immersion 3 Way System™ is a new concept in loudspeaker system design. It:

- should not be confused with tri-amped systems where the costs outweigh the benefits resulting in restricted applications; and
- is more sophisticated than a tri-amped system without the cost (cost advantage).

The Immersion 3 Way System™ is based around matching the loudspeaker system to the demands of the source material in the most efficient way. One of the most notable characteristics is the ability to provide sufficient output capability over the whole frequency range to play the loudest sounds and yet minimise the input power to quite low levels.

The Immersion 3 Way System™ is fundamentally dependent on low distortion as this determines both the quality of the audio and the directional clues it provides. Distortion determines the frequency at which, for example, a subwoofer can crossover without providing directional clues to a listener. With ultra low distortion, it becomes possible to run monophonic loudspeakers well above 100 Hz without detracting from the bass, stereo or surround effects. In conjunction with other Immersion technologies, distortion can be substantially eliminated.

There are also other factors that determine the optimum crossover frequencies and it is ideal if these are aligned with the maximum possible monophonic frequency. These other factors are related to matching the power demands of music to the output capability of the system. There is a proprietary algorithm that determines the optimum crossover frequencies and the resulting amplifiers required. Correctly applied, it will identify the minimum amplifier size to give minimum overall cost and power consumption while at the same time ensuring sufficient output capability at all frequencies as required. An Immersion 3 Way System™ in its simplest form has two active mono stages and one active mid-high stage.

Immersion 3 Way System™ is a proprietary patent pending system and its advantages include:

- low cost
- small size
- low power
- high clarity
- ample output capability
- use of Class A amplifiers

Class A amplifiers are commonly accepted as being the most accurate, linear and undistorted amplifiers available. Notwithstanding, they have 2 serious drawbacks, namely:

- high expense; and
- high dissipation of heat.

Immersion now has the ability to produce inexpensive Class A amplifiers which when used in conjunction with the Immersion 3 Way System™, significantly reduces heat dissipation whilst retaining the benefits of Class A amplification.

The Immersion 3 Way System™ is not suitable as an after market product or as a drop in replacement product. To provide the best result the system needs to be integrated with the head unit with specifically designed dash and door mouldings.

Consequently, the Immersion 3 Way System™ is ideal as an OEM product for new model vehicles where the dash/door mouldings, head unit amplifiers and filters are designed for the new vehicle. When applied in this manner the results include:

- Cost advantages
- Space occupied will be reduced
- Power consumption will be significantly reduced allowing use of small Class A amplifiers for the best quality of sound
- Music clarity will be improved
- Speech intelligibility will be improved
- Audio quality will be improved partly through the use of Hybrid Acoustic Filters, partly through the use of Class A amplifiers
- Output capability will be ample

HYBRID ACOUSTIC FILTER™

Hybrid Acoustic Filters™ are simple low pass acoustic filters that directly fit over the diaphragm of CCL's or are constructed as an integral part of the CCL driver basket or speaker enclosure.

Fundamentally, Hybrid Acoustic Filters™ have 2 main functions:

- Reducing THD and the effect of IMD
- Controlling polar patterns

Hybrid Acoustic Filters™ remove distortion components from the whole signal path including source material, pre-amp decoding and signal processing, amplifier and loudspeaker, all of which introduce unwanted harmonics.

Direct radiating loudspeakers are inherently distorted even with motional feedback because there is nothing to clean up driver mechanical colouration or air noise. Hybrid Acoustic Filters™ are a low cost solution that operate post the loudspeaker cone. Properly designed they can be tuned to filter out harmonics:

- coming through the system; and
- harmonics produced by the mechanical or air noises of the driver.

Proper design of the acoustic filter involves the inter-related issues of choosing an appropriate frequency band, tuning the filter and at the same time creating an optimal polar response.

Ideally a loudspeaker system should have consistent polar response. In other words, the frequency response and SPL should not vary over the typical angles at which the listener may be seated. Hybrid Acoustic Filters™ provide an effective solution to inconsistent polar patterns and substantially reduce the frequency range where beaming may occur.

The filters can be used effectively in single drivers, coaxial drivers and split systems.

Advantages

- Reduces distortion
- Controls polar pattern
- Protects driver from damage
- Hides driver in case of in-wall installations
- Low cost construction
- Suitable as a modular component
- Simplifies design of loudspeaker

ACOUSTIC STUBS™

Acoustic Stubs™ are an analogue version of Radio Frequency stubs. In acoustics, a stub is a waveguide in the form of a tube or duct of specific length L metres chosen in the case of a blind duct (a quarter wave stub) to produce a cancellation of acoustic waves of frequency 1372/L, and in the case of open ducts (a half wave stub) to produce a cancellation of acoustic waves of frequency 686/L.

Vented loudspeaker boxes have an anomaly in their frequency response caused by the duct resonance and subsequent harmonics of the loudspeaker port. One or more Acoustic Stubs of appropriate size can be placed with their open ends adjacent to the internal end of the loudspeaker port to correct the response.

Acoustic Stubs™ can also be used to correct any other resonant peaks in the response of a vented loudspeaker by placing the open end of an appropriate sized stub adjacent to the internal end of the loudspeaker port.

If a resonant peak occurs in-band, an acoustic stub can be used to restore a flat frequency response whereas if a resonant peak occurs out of band, an acoustic stub can be used to remove the peak and thus prevent any out of band harmonics or cross talk.

Acoustic Stubs™ can be used out of band to increase the effectiveness of a Hybrid Acoustic Filter™ and in fact can form part of an acoustic NTM® crossover. They can also be used out of band to generally lower the acoustic response of a loudspeaker and thus minimise distortion.

The placement of stubs is very often determined by the structure of a loudspeaker box and ideally consumes space that is otherwise wasted. Acoustic Stubs™ are almost invariably placed inside the speaker box rather than externally where their effectiveness is reduced.

NEVILLE THIELE METHOD CROSSOVER ("NTM®")

NTM® crossovers (an acronym of the **N**eville **T**hiele **M**ethod) are exact summing, steep roll off crossovers. They have the rare advantage of providing a steep roll off with low group delay and have a well behaved phase response.

The steep slope is achieved by the introduction of transmission zeros in the filters. Other crossover systems have attempted this, but without the means of selecting values for flat response. The main feature of NTM® is that it provides correct component values for exact summing to flat response at the same time as ensuring that the drivers stay in phase with each other.

In the transfer functions for an NTM® crossover the denominators of the high pass and low pass functions are made identical and the numerators comprise terms that in each individual filtering function are either all of even order or all of odd order, so that a constant phase difference is maintained between the high pass and low pass outputs. Also the sum of the two numerators is made to have the same squared magnitude as their common denominator in order to make the response of the combined outputs sum to unity at all frequencies.

Advantages

- NTM® crossovers substantially reduce the breadth of interference region between bands to the extent that interference becomes negligible.
- NTM® crossovers have significantly reduced group delay variation compared to conventional crossovers of equivalent steepness.
- In analogue implementations, NTM® crossovers have substantially lower component counts than conventional systems of equivalent steepness. This is because low order NTM® crossovers give steep roll offs, whereas with conventional systems a high order crossover is required to get a steep roll off.
- The designer has the flexibility to choose the order of the filter and thus trade off ultra steep roll off for additional group delay and additional component count.
- The designer also has the flexibility to trade off steepness for attenuation of recovery humps in the response for a given order of filter without other penalties.

NTM® crossovers may be implemented as analogue or digital systems and in active or passive implementations. Simple passive NTM® crossovers may use the well known Sallen Key topologies.

A steep roll off is desirable because:

- To prevent spikes and anomalies from outside the band affecting frequency response
- To eliminate superposition of time and phase mismatched signals from outside the band.
- To eliminate interference effects

Group delay variations cause audible distortion in the response of a filter. The lower the variation in group delay the cleaner the sound.

VELOCITY REFLEX ("VR™")

VR™ is a subwoofer technology originally developed for vehicles. VR™ is an acoustically filtered infinite baffle system. It has the capability of providing quite high SPL at low frequencies with a small enclosure size. It also has the unique advantage of providing high SPL inside the vehicle without causing nuisance sound outside the vehicle.

The advantages of VR™ to manufacturers are numerous:

- It can be hidden away, for example below the rear parcel shelf.
- It minimises cutting of the vehicle as it requires only a small duct into the passenger compartment of the vehicle.
- It is smaller and lower cost than competing systems of equivalent performance.
- It has the feature of low nuisance sound outside the vehicle.
- It has impressive performance.

For optimal performance it has a characteristic rising response combined with a Hybrid Acoustic Filter™ and other proprietary design features.

It requires some alignment with the acoustics of the vehicle and so is better suited to an OEM application than an aftermarket application.

VR™ wider applications

VR™ has wider applications. It is the perfect solution for in-wall, under floor, in-ceiling or hidden subwoofers. For example an under floor subwoofer can be ducted into a room through a vent similar to a ducted heating vent. An in-ceiling subwoofer can be ducted into a room through a relatively small duct perhaps 90mm diameter and ideally flared to seamlessly integrate with a wall surface.

VR™ provides a solution for discos and night clubs where sub bass music passes through the walls and causes nuisance to nearby residents.

VR™ technology in cars

VR™ subwoofers sit behind one of the natural barriers of a vehicle. The preferred location in most cases is in the boot (trunk) space below the rear parcel shelf. In such a situation the subwoofer enclosure does not consume important luggage space and does not protrude into passenger space. The rear seats and parcel shelf may need some reinforcement to provide a secure baffle between the boot and the passenger compartment. Except for leakage it is an infinite baffle. Sound produced on each side of the baffle is out of phase and the baffle prevents direct cancellation of sound between front and back of the speaker. However sound does escape from

the boot and passenger compartment to the outside world almost to the same extent, and this sound field does cancel.

The VR™ subwoofer efficiency is determined by the enclosure size. The nearest approximation to enclosure size is vehicle boot size. Obviously the VR™ subwoofer has a significant efficiency advantage over a conventional speaker box situated in the boot space consuming valuable luggage space.

For optimal performance the VR™ subwoofer has an acoustic rising response which is equalised electrically. The acoustic rising response amplifies out of band harmonics. The VR™ technology removes the out of band harmonics through acoustic filtering.

PARAMETRIC ACOUSTIC MODELLING ("PAM™")

PAM™ is a computer aided modelling technique for loudspeakers. It is an advance on all pre-existing loudspeaker simulation applications in that it represents waveguides as distributed parameters. Superficially this may seem a trivial advance, but it enables the simulation of impedance discontinuities to behave correctly and thus has enormous significance for all forms of waveguides. In particular it enables waveguides to be structured with custom profiles for particular applications and it provides the designer with significant flexibility to tailor the response of a loudspeaker in a predictable way.

PAM™ design manifests in loudspeakers as waveguides with one or more selective impedance discontinuities. The impedance discontinuities may be a consequence of changes in cross section, or a consequence of junctions in the waveguide.

PAM™ can be used to make the response of a loudspeaker flat and at the same time minimise cone excursion by inserting multiple cone minima in the pass band. Accordingly PAM can be used as the basis of high fidelity, low distortion loudspeakers and subwoofers.