

VUE AUDIOTECHNIK'S  
a1-CLASS OF SCALABLE LINE ARRAYS:  
ACOUSTIC LINEARITY DEVELOPED  
AT A SYSTEMS ENGINEERING LEVEL

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REIMAGINE LOUDSPEAKERS

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WHITE PAPER | v. 02.2016 | a1-Class Line Array System  
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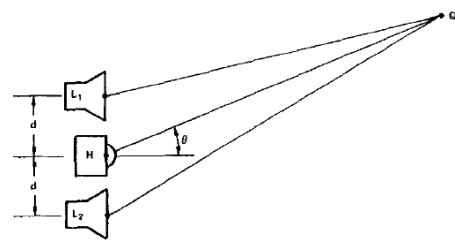
# VUE AUDIOTECHNIK'S al-CLASS OF SCALABLE LINE ARRAYS: ACOUSTIC LINEARITY DEVELOPED AT A SYSTEMS ENGINEERING LEVEL

## INTRODUCTION

Line-source array type systems are a dominant format in the sound reinforcement industry. Both field-deployable, tour-class system packages and permanent systems for use in performance-venue installations now benefit from such array configurations. Line-source array systems have been detailed in prior literature, and numerous options now exist for the professional system designer or operator. While certain differentiating characteristics may be described by various system providers, most such systems are derived from original research ably described during pioneering efforts in the first half of the twentieth century.

With simple column type loudspeakers, it was first observed in 1930 by Wolfe and Malter (1) that a vertical array of radiating devices would produce increased directivity in the vertical plane. In 1940, while investigating how three key variables

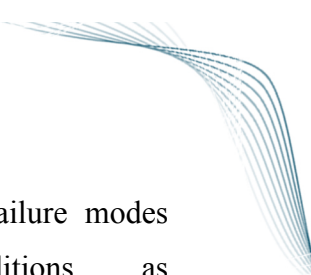
(number of sources, distances between the sources, and frequency wavelength) interact with each other to quantify the narrowing of a sound beam with increasing frequency, Olson (2) described what would eventually become known as the line array effect.



Geometric arrangement for a three-driver, two-way loudspeaker with no lobing error

Fig. 1 - VUE al-Class acoustic elements minimize off-axis lobing and nulls using a well-understood axially-symmetrical transducer arrangement (after D'Appolito, 1983)

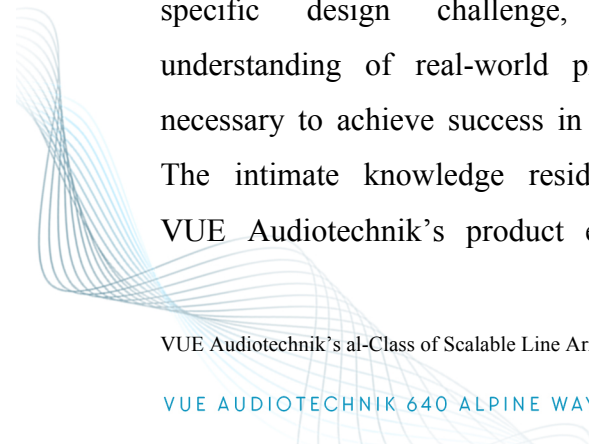
With D'Appolito's explanation (3) in 1983 of how off-axis nulls could be eliminated by using an axially-symmetrical horizontal arrangement of midrange and high frequency components in a two-way system, and how this principle could be extended to three-way systems by adding a pair of flanking low frequency components, the stage was set for wide-scale design and proliferation of line-source array type



systems from a broad range of commercial vendors. Today, careful selection and arrangement of high-performance transducers and crossover optimization is necessary to fully leverage this directivity effect throughout a given system's specified coverage area.

Commonality of general appearance and baseline performance may appear to exist in most such systems, regardless of manufacturer. However, differentiating electroacoustical principles behind various products can vary widely at a systems engineering level. As noted in 2011 by Kossiakoff, Sweet, Seymour and Biemer (4), advancements in technology require inherent competition (evaluating design tradeoffs), and specialization within the system in order to partition building-block components and strictly manage their interfaces and interactions.

These differentiations and tradeoffs are typically designer-dependent. With effective systems engineering resting upon a foundation of discovered solutions for a specific design challenge, a deep understanding of real-world problems is necessary to achieve success in this realm. The intimate knowledge resident within VUE Audiotechnik's product engineering



team of most-likely system failure modes under extreme-use conditions, as experienced during practical field applications is advantageous. That knowledge has guided VUE's development of the al-Class of scalable line arrays.

## 1. VUE GUIDING PRINCIPLES

Acoustic elements and supporting electronics in the al-Class are designed and built using specific guiding principles. These include (a) intuitive user interfaces, (b) direct integration of tightly-coupled digital signal processing and power amplification resources, (c) robust, purpose-built component transducers, (d) consistent acoustical performance results and (e) easily-deployable supporting hardware accessories and tools.

It is VUE's commitment to apply these principles for the creation of unique and useful systems. This is achieved in practice by relying upon a new-product development model that builds upon proven electro-acoustical design theories, while linking VUE's projects to real-world requirements.

Understanding and addressing the differences between theory and practice throughout the research and development

cycle at VUE, and across the product-development spectrum for similar engineering-based organizations, can yield benefits in various areas as noted in 2001 by Krishnan and K. Ulrich (5). These range from product strategy and planning to supply-chain management to assessment of component fault modes. It is this dedication to system-level reliability that enables VUE Audiotechnik products to satisfy the most demanding customer requirements.

A fundamental system development technique informing VUE Audiotechnik product development projects is large signal design. In the performance-audio environments where VUE customers use system products, power levels achieved under large signal conditions can reach sufficient magnitude such that potential nonlinear effects in each component of the system must be considered.

It is important for system engineers to understand and resolve potential failure modes – at both the component and system level – not only in the design laboratory, but also in real-world use cases like live concerts and major special events. Advance knowledge of potential failure modes enables VUE engineers to act decisively during the design phase. Which components

or technologies are robust enough to be shared across product variants? How are the often differential requirements of cost and maximum performance capability resolved?



Fig. 2 - Unique underlying electro-acoustical technology platforms are leveraged in VUE's al-Class of line array systems

Ultimately, this model of system platform development at VUE (simultaneously coupling proven design theory with an intimate knowledge of best in-field practices) leads to an over-arching technology concept that integrates the acoustical output and mechanical assembly of multi-box arrays.

This concept articulates a unique technical characteristic of arrays assembled from the various models in VUE Audiotechnik's al-Class. In practical terms, it explains how the most recently-developed al-12 2x12" three-way acoustic element can be reliably and efficiently combined in hybrid arrays when desired in combination with its companion acoustic elements, the smaller al-8 and highly compact al-4.



Fig. 3 - The al-12 three-way 2x12" acoustic element is the newest addition to the al-Class of scalable line

## 2. ACOUSTIC LINEARITY

Multi-element line source arrays are often deployed in groups of identically-sized enclosures. Under common use conditions and for many applications it is advantageous to extend the size of the system, or length of the array. Variables can include factors such as ceiling height, weight-bearing capacities, optimum depth of the listening environment, down fill coverage angles and such.

It was articulated in 1986 by Lipschitz and Vanderkooy that both pressure-velocity and diffractive aspects of a linear array are relevant, and that the fundamentally different radiating characteristics of low frequency elements compared to high frequency elements in a linear array must be taken into account when summary acoustical results of a given array in a listening area are to be quantified (6).

Considering the increased directivity of the mid/high section in an array when compared to its low frequency section, it follows that when acoustic element types in the same array are mixed, the most linear and acoustically-consistent results will be obtained when the mid/high section of each element has common design attributes and is geometrically aligned in the vertical axis.

Unique among systems of this type, linear arrays constructed from VUE Audiotechnik al-Class acoustic elements meet this criteria. All front baffles and high-frequency apertures of the al-12, al-8 and al-4 acoustic elements are in the same plane.

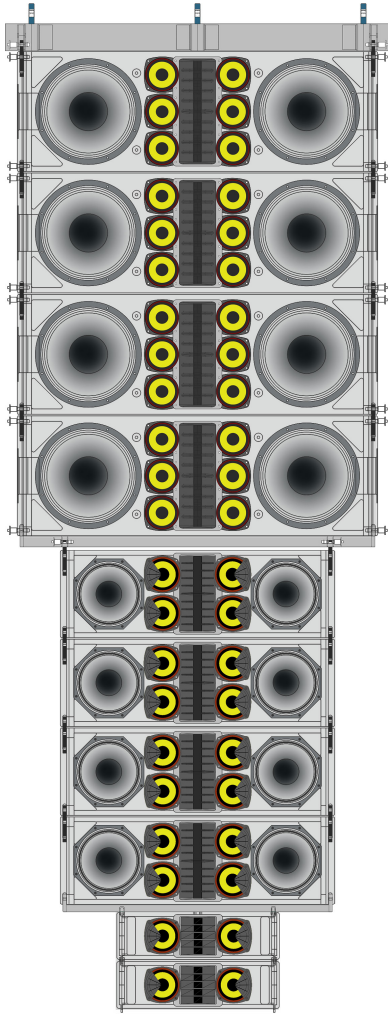


Fig. 4 - In mixed or hybrid arrays, al-12, al-8 and al-4 acoustic elements maintain mid/high frequency coherency.

Acoustic Linearity therefore reliably supports the assembly of larger multi-box arrays with expanded vertical coverage and increased output power made of mixed elements. Performance benefits include coherency maintained as elements in the array transition from one size to another, and mechanical symmetry minimizing the need for corrective signal processing in mixed-box arrays.

### 3. FIELD-OPTIMIZED SUSPENSION HARDWARE

A hallmark of portable systems acceptable for touring use is a suspension hardware design that is intuitive to assemble and easy to use and maintain. With hardware intended for use in the overhead suspension of loudspeakers, the design engineering attributes, material choices and assembly specifications and manufacturing tolerances are all critical.



Fig. 5 - Inter-box coupling system on VUE al-12 acoustic elements includes load-rated stainless steel quick-release pins.

VUE Audiotechnik's al-Class systems are based upon a suspension design philosophy that is deceptively simple: The al-12, al-8, al-4 with companion subwoofer systems and supporting suspension frames and bars use standard, readily-available and familiar parts when able while also maintaining a minimum design factor that meets or exceeds ANSI Standard E-1.8-2012 for Suspension of Overhead Speakers (7), to ensure maximum mechanical integrity of the array.

Each model in the al-Class line is engineered to reliably couple with differently-sized elements within the same array.

al-Class acoustic element	Inter-box coupling points per element
al-4	3
al-8	3
al-12	4

Fig. 6 - All al-Class acoustic elements are designed to consistently support the integrity of multi-box arrays

Pre-hang selection of the inter-box splay angles for each individual acoustic element is readily achieved by selecting numbered holes and inserting tethered stainless-steel quick-release pins.

al-Class acoustic element	Quick-release pin size	Stainless Steel Characteristic
al-4	6mm (1/4")	8,000-lb. double shear rating per pin
al-8	10mm (3/8")	18,000-lb. double shear rating per pin
al-12	10mm (3/8")	18,000-lb. double shear rating per pin

Fig. 7 - al-Class suspension hardware quick-release pins

The al-4 and al-8 elements rely on a single-stage numbered hole selection and pinning function. To support higher-resolution splay angle adjustments for longer-throw conditions, the larger al-12 has an additional set of half-degree pin locations, yielding up to 16 separate splay angle choices for adjacent coupled boxes.

al-Class acoustic element	Inter-box pinning options	Inter-box splay angle choices
al-4	7 points	0°, 1°, 2.5°, 3.5°, 5°, 6°, 7.5°
al-8	11 points	0°, 1°, 2°, 3°, 4°, 5°, 6°, 7°, 8°, 9°, 10°
al-12	16 points	0°, .5°, 1°, 2°, 2.5°, 3°, 4°, 4.5°, 5°, 6°, 6.5°, 7°, 8°, 8.5°, 9°, 10°

Fig. 8 - Acoustic element suspension hardware incremental splay-angles enable an array's mechanical configuration.

Captive sliding link arms on the al-12 enable quick and reliable inter-box couplings, with a lock position for array assembly and stow position for travel.



Fig. 9 - Suspension hardware fittings for VUE al-12 acoustic elements include a sliding link arm for quick adjustments.

To effectively couple al-Class arrays to temporary or permanent overhead points, array suspension bars are engineered to support each available size of acoustic element along with companion subwoofers.

All VUE al-Class suspension accessories incorporate graded steel and certified welding processes. The available suite of al-Class suspension accessories comprises a reliable toolbox for use in the planning and assembly of mixed-format arrays.

This enables practitioners to select the desired type and quantity of acoustic elements and companion subwoofer enclosures for specific array applications.

al-Class Suspension hardware component	Suspension hardware component function with standard of hybrid arrays
al-4FB	suspend arrays of al-4 elements
al-4-fbl	long bar for greater down angle and al4-SB support
al-4SBFB	use with al4-SB subwoofers in an end-fire cardioid configuration
al-8-ufb	suspend al-4 beneath al-8
al-8FB	suspend arrays of al-8 elements
al-8SBFB	for use with al8-SB subwoofers
al-12-ufb	suspend al-8 beneath al-12
al-12FB	suspend arrays of al-12 elements including al-12SB subwoofers

Fig. 10 - al-Class suspension hardware accessories for use in the assembly of hybrid arrays including integrated subwoofers.

## 4. PURPOSE-BUILT COMPONENT TRANSDUCERS AND WAVEGUIDES

Moving-coil loudspeakers for low frequency, mid frequency and high frequency applications in sound reinforcement systems have tended to follow a traditional design format for over 100 years. Today, well-understood structural parts like the basket (frame), diaphragm (cone), suspension (spider) and magnet with voice coil (electromagnet) are at first appearance little changed from their early predecessors.

It is the ongoing search for improved performance that continually drives innovations in the areas of advanced materials for magnets and cones, improved heat-transfer mechanisms to reduce power compression, and refined geometry for phase plugs and exit apertures in compression drivers used to deliver high frequency program content.

VUE Audiotechnik incorporates unique and proprietary transducer designs into each al-Class acoustic element. Every individual component design project carefully weighs numerous design tradeoffs, as optimum parameters are specified for size and weight,

output capability, frequency response, heat dissipation, duty-cycle reliability, and power compression characteristics.

A key design goal of all VUE loudspeaker products is to be able to maintain linear output capabilities with minimum power compression during high-demand usage. Each individual component transducer is designed to combine with others at a system level so that even after hours of extended use, the frequency response and output capabilities of the system remain constant.

An effective way to achieve this type of performance in a loudspeaker while also reducing both weight and mass is to use rare earth metal magnets, with neodymium compounds (Nd-Fe-B) being the most common. Neodymium magnets have significantly improved conductivity coefficients compared to earlier alnico (Al-Ni-Co) magnets, as noted in 1989 by Parker and Guthrie (8).

In both cone and compression driver transducers, the use of neodymium provides greater output voltage and improved signal-to-noise ratios, and the increased strength of the magnetic field in such magnets reduces the distortion content as well when voice coils are driven outside the magnetic gap.

When mass and weight reductions are combined with these improved electromagnetic properties, the use of neodymium magnets in most component transducers developed for use in VUE Audiotechnik's al-Class acoustic elements is warranted.

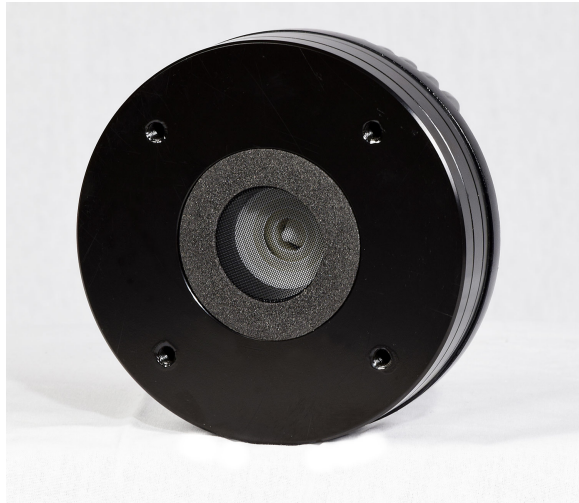


Fig. 11 - Neodymium magnet structures are used for most component transducers in VUE al-Class acoustic elements (shown: al-12 high frequency compression driver)

All ten of the component transducers in the VUE al-12 (two 12" low frequency drivers, six 4" midrange drivers, and two 3" voice-coil high frequency compression drivers) are designed with neodymium magnets.

The use of Kevlar® cones, isobutylene isoprene rubber or impregnated linen surrounds, and beryllium high frequency diaphragms with a high stiffness factor for greater acceleration and extended response all contribute to the ability of VUE's purpose-built component transducers to

deliver high output, accurate source reproduction and long-term reliability in the often stressful use environments of performance-audio systems.

#### 4.1 TRUEXTENT® BERYLLIUM HIGH FREQUENCY DRIVER DIAPHRAGMS

Accurate and detailed high frequency reproduction in compression drivers is a key design goal. The lower the mass of the diaphragm material, the more accurate will be the high frequency performance. A challenge is finding materials for this purpose that are low-mass and rigid yet durable when stressed. Of the most acoustically useful light metals commonly used for compression driver diaphragms, beryllium foil offers the lowest mass, the highest stiffness, the highest speed of sound and highest tensile strength.

Physical properties of this material when used in acoustical devices are markedly superior to the other two most common light metals, aluminum and titanium.

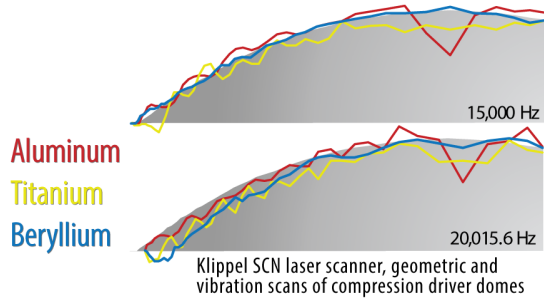


Fig. 12 – comparison of vibration response characteristics of aluminum, titanium and beryllium.

As noted in 2011 by Andrews, Buck, Saye and Simmons (9), the use of beryllium foil in this application leads to a much higher frequency of the first bending stiffness mode of the diaphragm for any given driver design. What this means to the designer of large format compression drivers is over one full octave of useful, non-resonant frequency range compared to the same driver geometry with other materials.

All of VUE Audiotechnik’s proprietary compression drivers incorporate Truextent® beryllium-foil diaphragms for increased stability under high loads and extended, more accurate high frequency reproduction, with significantly lower distortion above 8 kHz.

## 4.2 CONTINUOUS SOURCE TOPOLOGY (CST™): HIGH FREQUENCY WAVEGUIDE PRINCIPLES

The quest for improved high frequency source fixtures for modern multi-way linear array systems has been ongoing. Electrical energy from the high frequency driver must be converted into acoustical output, while summing well with similar adjacent devices.

In pursuit of optimum high frequency waveguide fixtures for use in such systems, progress in the field of acoustical diffraction has tended to follow developments in the fields of optics and microwave theory, where a precision understanding of diffraction is critical due to shorter signal wavelengths. As noted by Geddes (10) in 1993, the central problem in determining mouth radiation characteristics of any acoustic waveguide is that of the diffraction of sound by its aperture.

In linear array type systems, which combine multiple identical array elements that each contain high frequency waveguides, individual horn devices will ideally be made to behave like a finite length line source, with a design goal for seamless integration of the output of its several apertures. Yet

these must also couple effectively with neighboring devices as vertical arrays are constructed.

In such arrays, spacing between adjacent elements needs to be less than the wavelength of sound emitted from individual devices in order to effectively combine. As just one example, with a target frequency of 10kHz, the corresponding wavelength is approximately 34.6 mm (1.36 in.). This relatively small wavelength poses a challenge for spacing of adjacent high frequency devices, since there are physical limitations on how small they can be.

Considering that each high-performance driver assembly will likely be of a size with a center-to-center spacing larger than 1.36", the waveguide design must therefore be able to output high frequency sound waves in a manner that increases the vertical dimension of the composite aperture transmitting such wavefronts, while maintaining overall phase coherency of the summed output of its individual smaller apertures.

Thus a viable mechanical solution is needed to optimize high frequency output and maintain coherent, extended high frequency output from each individual waveguide over the entire vertical length of its own sectored

diffraction slot aperture. It should also maintain this time-coherent acoustical output characteristic over the greater vertical length achieved by combining quantities of like units into a multi-element array.



Fig. 13 - High-frequency waveguide assemblies incorporate path-length optimized internal channels to create a time-coherent pressure wave across the entire exit aperture.

A well-designed diffraction-slot type waveguide with such internal, path-length optimized channels can yield a time-coincident pressure wave along the entire vertical length of the exit aperture. This requirement is now well understood in industry and was effectively described in 2002 by M. Adams (11).

High frequency waveguides designed using this general format, or topology, can satisfy the requirements for a continuous line source that optimizes high frequency output

within each individual unit. This same principle can be supported as multiple waveguides are coupled in adjacent boxes to incrementally extend the length of the array. Such devices can therefore be reliably combined into very large vertical arrays with other similar devices, while minimizing destructive interferences that could lead to phase discontinuities.



Fig. 14 - The al-12's proprietary high-frequency waveguide with CST™ (Continuous Source Topology) enables assembly of a single, coherent line source in large multi-box arrays

VUE Audiotechnik's proprietary high frequency waveguides used in the al-Class of scalable line arrays conform to this topology. They are engineered to enable the

assembly of larger mixed-element arrays wherein large, medium and small acoustic elements all can be combined if desired to allow the summary larger array to maintain a continuous vertical line or 'virtual ribbon' of high frequency radiating elements.

This concept is described as VUE's CST™ (Continuous Source Topology). Inherent within each VUE high frequency waveguide, and maintained in multiple groups of them, CST™ supports and contributes to the al-Class's fundamental principle of Acoustic Linearity across the entire mid-frequency and high-frequency bandpass regions.

### 4.3 ACOUSTIC SHADE FOR MID-HIGH BANDPASS INTEGRATION IN al-CLASS ARRAYS

Further integrating high-frequency section output with mid-frequency section output of the smaller al-4 and al-8 acoustic elements, VUE's proprietary acoustic shade partially masks the radiating surface of each midrange component in those systems.

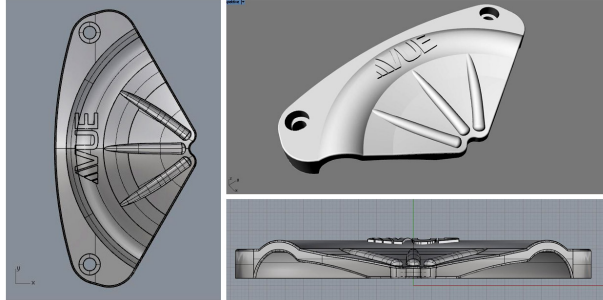


Fig. 15 - VUE's acoustic shade optimizes off-axis directivity results for the mid-to-high bandpass transition in the al-8 and al-4.

Acoustic shades optimize off-axis directivity results for the mid-to-high bandpass transition in systems with higher crossover frequencies related to smaller-format (34mm voice coil, 25mm/1" exit) compression drivers. Such fixtures are not required in the larger al-12 system due to its inclusion of larger-format (75mm voice coil, 36mm/1.4" exit) compression drivers, with an associated lower mid-to-high crossover point.

#### 4.4 MID AND HIGH LOW FREQUENCY TRANSDUCER ATTRIBUTES

VUE's al-Class acoustic elements each include low-frequency component transducers with relatively long-throw excursion capabilities and overall design characteristics optimized to achieve maximum performance efficiencies within a vented, direct-radiating type enclosure.



Fig. 16 - Proprietary VUE 100mm (4") midrange components are performance-optimized for specific bandpass requirements in the al-4, al-8 and al-12 acoustic elements.

Low frequency transducers in the al-12 and al-8 are each 16-ohm devices with 76mm (3") voice coils. Each component is chambered separately, and ported. The smaller al-4 incorporates a pair of 8-ohm hybrid low/mid devices with Kevlar cone and isobutylene, isoprene rubber surrounds.

Mid-range elements in all al-Class models have common size and design characteristics. Each is specified with varying voice coil geometries, and magnetic assemblies optimized for specific operating bandpasses and output capabilities.

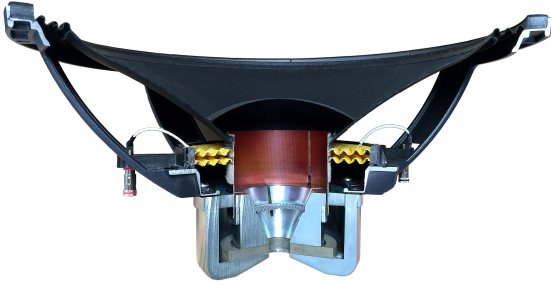


Fig. 17 - The 457mm (18") neodymium-magnet woofer as used in the al-8SB flyable subwoofer.

## 5. VLF (VERY LOW FREQUENCY) SUPPORT PLATFORMS

Each acoustic element in the al-Class of scalable line arrays is supported by a companion subwoofer, engineered for integration into suspended full-range arrays. They can also be used separately, depending upon the desired application. Integral suspension hardware enables the reliable coupling of multiple enclosures. The flyable subwoofers in the al-Class are characterized as direct-radiating ported enclosures, employing long-excursion dual-spider drivers with neodymium magnets. The individual subwoofer designs, whether intended for use with the al-4, al-8 or al-12 scalable line array acoustic elements, are optimized for their intended dimensions and output capabilities. The largest and most capable subwoofer unit in the line, the al-12SB flyable subwoofer incorporates two

457mm (18") neodymium-magnet drivers with 5" voice coils in individual chambers to deliver maximum low frequency response in an enclosure size-optimized for use in al-12 arrays.

While enclosure size and shape for more compact subwoofers like the al-8SB and al-4SB are variations on a basic rectangular theme, there are design methodologies for transducer mounting that offer improved output and more linear operating characteristics under high-performance conditions. VUE's al-4SB flyable subwoofer and the larger as-418 incorporate a differentiating design advantage, isobaric transducer mounting, to achieve optimum results from highly compact enclosures.

### 5.1 ISOBARIC SUBWOOFER DESIGN

As noted in 1950 by Olson (12), the principal factors which influence the performance of direct-radiating low frequency enclosures are the energizing mechanism (loudspeaker), the outside configuration of the enclosure, and the acoustical impedance presented to the back of the loudspeaker by the enclosure. The volume of the cabinet and the internal damping both play important roles in

determining the acoustical impedance presented to the back of the loudspeaker. More effective management of the acoustical impedance behind the loudspeaker(s) through a unique loudspeaker mounting configuration is the design path chosen by VUE to achieve optimum performance in several of its subwoofers.

Isobaric type loudspeaker mounting configurations (paired elements of the same weight or pressure) are systems with two identical transducers operating simultaneously with a common enclosed air mass adjoining one side of each transducer's diaphragm. This design's unique qualities allow a pair of tightly coupled woofers to work as if they were a single unit in a vented box having double the internal volume. The net result is a decrease in the box size needed for both maximum output over a defined bandpass, and low-end frequency response.

In the VUE al-4 compact flyable subwoofer, for example, transducers are placed in a front-to-front, isobaric (push-pull) configuration. The isobaric pair of two 381mm (15") drivers is in effect acting as a single motor with twice the magnetic circuit and moving mass. This approach requires

opposite cone motion, so the woofers are wired in reverse polarity from one another.

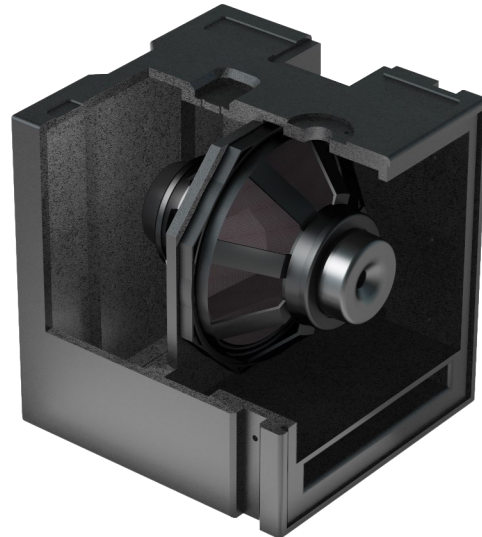


Fig. 18 - Isobaric transducer mounting technique enables a pair of coupled woofers to work as if they were a single unit.

This opposing cone motion has the additional benefit of cancelling any suspension non-linearities (differences in inward and outward suspension control) from each individual woofer, further reducing distortion. The resulting system has response down to 45 Hz with twice the power handling of a similarly-sized single 15-inch system.

## 5.2 ACM™ (ACTIVE COMPLIANCE MANAGEMENT)

VUE's Active Compliance Management is another differentiating low-frequency technology. ACM™ combines the attributes of direct-radiating and bandpass box alignments in the same enclosure, reducing distortion and increasing sound pressure output while minimizing box size.

VUE subwoofers incorporating this hybrid electro-acoustic technology, such as the hs-28 dual 18" subwoofer system, include two woofers that share a common vented chamber. One woofer's frontal radiation is direct, while the second woofer is offset by 90 degrees to drive a second vented chamber that has fourth-order response characteristics.



Fig. 19 - VUE as-215 subwoofer and the al-4s are dimensionally compatible to simplify ground-stacking. Same is true for the hs-28 subwoofer (with ACM™) and the al-8 system.

Each woofer is energized with its own amplifier channel and DSP control. This yields a substantial increase in amplitude over conventional designs, with the summed output of drivers and vents maintaining flat phase response and exhibiting low distortion while occupying a more compact enclosure.

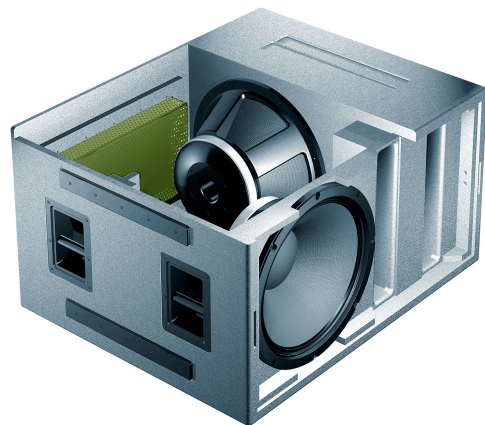


Fig. 20 – Above VUE hs-221 subwoofer with ACM™ includes two 534mm (21") woofers sharing a common vented chamber – VUE hs28 subwoofer with ACM™ includes two 457mm (18") woofers sharing a common vented chamber

## 6. VUEDrive SYSTEMS ENGINES

To power and control VUE al-Class acoustic elements, the VUEDrive amplification and processing platform provides a standardized means of energizing and inter-connecting all speakers in the line. VUEDrive includes (a) multi-channel power amplification, (b) advanced digital signal processing, and (c) Ethernet-based networked audio and control connectivity. These primary elements are housed within electronics packages classified as VUEDrive Systems Engines. There are several variants, with V4 and V6 Systems Engines applicable to al-Class systems. Optional front panel LCD (touring) or non-LCD (install) versions are available.



Fig. 22 – V4-d with LCD Display and Rotary Encoder for simple front panel control

Model	VUEDrive Systems Engine I/O Configuration
V3	1-in 3-out DSP tri-amplifier
V4-i	2-in 4-out DSP bi-amplifier
V4-d	2-in 4-out DSP bi-amplifier (with front panel display)
V6-i	2-in 6-out DSP tri-amplifier
V6-d	2-in 6-out DSP tri-amplifier (with front panel display)

Fig. 21 - VUEDrive Systems Engine configurations

Each VUEDrive Systems Engine is a 2U rack-mount amplifier/DSP package. All Systems Engines incorporate a universal integrated UREC™ mains power supply for reliable worldwide operation within the range of 85-268V.

All variants of the VUEDrive Systems Engine include electronics verified for EMC Compliance, have a common, modular circuit topology, and possess the same underlying design characteristics. These include true PFC (Power Factor Correction), and high burst-power capabilities to ensure accurate transient-signal response.

## 6.1 COMPREHENSIVE DIGITAL SIGNAL PROCESSING: BEYOND SIMPLE EQUALIZATION

As digital signal processing circuitry has become more powerful in recent years, loudspeaker system designers have learned how to better take advantage of its capabilities.

The comprehensive management of complex multi-way loudspeakers, including the changing response of drivers at high sound levels, was once just a future concept, as noted by Cabot (13) in 1988, who envisioned the expansion of programmable equalizer functionality when linked to a computer user interface.

Today such solutions are commonplace. What is not so common is VUE's thorough understanding of how to achieve maximum performance levels while protecting components under stress and without degrading sound quality.

To accomplish this each Systems Engine is internally equipped to handle all system processing and management functions, including loudspeaker protection, system-

optimized alignment of EQ, time and crossover functions, and application-specific configuration settings for various types and combinations of arrays and supporting subwoofers.

VUE engineering leverages the full capabilities of the Systems Engine's advanced DSP section to optimize the performance of each component transducer group to achieve well-behaved results and maximum performance at a system level. System design criteria includes the engineering of factory DSP files with highly refined out-of-bandpass crossover optimization with alignment of both level and phase to achieve optimized off-axis performance.



Fig. 23 - Integrated DSP for processing and system management functions in all VUE Drive Systems Engines variants

VUE Drive Systems Engines incorporate a 96k Hz sample rate, mixed-mode 64-bit digital processing and advanced A-to-D/D-to-A converters providing more than 120 dB of dynamic range. A maximum input level of +23 dBu facilitates the effective interface with any professional mixing or other input

source system, with extremely low throughput delay (typically <1ms, 640 microseconds).

Users can control each input level, employing up to 10 parametric EQ filters for each output, and adjust signal-path delays up to 2,000 milliseconds. VUE Drive Systems Engine circuitry includes a true RMS compressor and a Zero-Attack Limiter, with system-specific values set to protect componentry without hindering performance or negatively affect dynamic range.

This powerful integrated DSP platform, factory-configured for use with VUE al-Class systems, handles all required processing and system management functions. The platform is common to all variants in the VUE Drive Systems Engines group. It is used across multiple VUE product lines, including the h-Class powered loudspeakers.

In addition to the comprehensive equalization and other signal processing functions inherent in the platform, VUE Drive Systems Engines provide intelligent, load-responsive monitoring and protection of key amplifier functions including over-power, voltage fluctuations and temperature levels.

## 6.2 HIGHLY EFFICIENT CLASS D POWER AMPLIFICATION

Class D power amplifier modules are used in each VUE Drive system engine, regardless of channel count or output power levels. Class D (switching) amplifiers employ transistors to operate as electronic switches, rather than as linear gain devices as in older, more traditional designs. Analog signals are converted to a series of pulses, which are then re-converted after pulse modulation.

The benefits of Class D amplifier technology, including very high efficiency for audio level performance with superior heat-dissipation characteristics, were clearly highlighted in 1999 by Dapkus, Darling and Score (14). The broad range of Class D amplification benefits for sound reinforcement applications are now well-understood in industry.

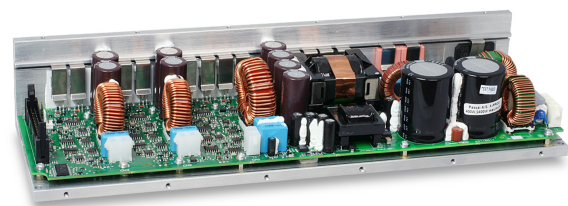


Fig. 24 - Class D type amplifier circuit benefits include very high operating efficiency with improved heat dissipation.

The VUE Drive V4 Systems Engine supplies two channels at 1600W RMS (sine wave)

for low frequencies, and two additional channels at 550W RMS for high frequency loads. The V6 supplies two 1600W channels for low frequency loads, two at 550W for mid frequencies, and two at 550W for high frequencies. The V6 is also configurable to provide four channels optimized for cardioid subwoofer applications.

This consistent drive electronics platform enables an identical user interface to access and configure all VUE DSP and networking functionality regardless of product class or system type. With all pre-configured, speaker-specific factory files protected, the operator-level user interface provides access to required variables in a simple and reliable format.



Fig. 25 - VUEDrive Systems Engines provide standardized networking connectivity with SystemVUE onboard.

## 7. SystemVUE SOFTWARE AND DIGITAL USER INTERFACE

SystemVUE network connects any VUE DSP-enabled product via Ethernet, Windows, Macintosh or iOS computer via a wired or wireless Ethernet connection.

Compatible with standard IP protocols, a computer loaded with SystemVUE software will link to the product or groups of them, automatically recognizing and connecting over any kind of IP configuration, including DHCP-based networks, a fixed IP network, or an ad hoc network connection without the use of a network switch (linking directly to a computer via Ethernet cable).

Since SystemVUE uses standard TCP-IP and UDP networking for control, it is typically compatible with standard Ethernet hubs and switches. It also works over Wi-Fi as long as the wired network with VUE system products is bridged via an access point to the Wi-Fi network. SystemVUE sends control signals only so it is not a significant drain on network bandwidth.

VUEDrive Systems Engines are fitted with an internal network switch, and native Ethernet connecting ports to assist with the simplified assembly of networked systems

that include large numbers of devices. In addition to the initial controlling device (computer), up to 255 Systems Engines or other network-compatible VUE products can be combined to create a single integrated system.

With SystemVUE relying upon well-established communication industry standards, the robust and proven cable and connector parameters such as specified in TIA/EIA 568-5-A apply. Cat 5 or Cat 6 cables can be used for inter-connecting VUE systems, for a maximum length of 100m (328 feet) without an active repeater or switch.

Applications requiring longer distances can use Ethernet switches with fiber interfaces to extend cable runs up to 2km with 50um or 62.5um Multimode 1300mm fiber.

## 7.1 SystemVUE SOFTWARE CAPABILITIES

SystemVUE software provides control and monitoring for VUE Drive Systems Engines and VUE h-Class powered loudspeaker systems. It enables remote control and monitoring from computers equipped with an Ethernet wired interface or on a Wi-Fi

network bridged to a wired Ethernet network.

The software accepts VUE Factory files (product-specific, bundled firmware settings, not user-addressable) and Preset files (individual DSP settings for use with specific VUE system product or groups of them in combination, such as al-12 main line arrays with al-8 or al-4 group under hangs and al-12SB subwoofers).



Fig. 26 - SystemVUE software interface (unit control, EQ shown)

The software user interface provides full access to a network browser window, a unit control window with IP address and configuration settings, system fault detection, and other expected functional operations such as system input, delay, phase and fully parametric EQ filters. A high pass filter (40, 60, 80, 100Hz) can be engaged.

Group master controls with setup mode and naming functionality are user-accessible.

This enables large, multi-device networked systems to be configured and managed.

## 7.2 DIGITAL AUDIO NETWORK CONNECTIVITY

VUE al-Class systems, as with other lines such as the h-Class powered loudspeaker products, can benefit from the clean, reliable signal transport facilities afforded by networked digital audio.

Networked audio systems have found important application in the concept of live performance, where audio signal transport is time-sensitive, as noted in 2009 by AESTD1003V1 (15). VUE Drive System Engines accept industry-standard AES/EBU digital audio signals, and from 2016 include Dante digital audio inputs as well.

Users can integrate a Dante interface device if desired to extend the network and combine with other compatible devices. Dante Controller software is available to manage digital audio channel assignments, and VUE devices are auto-recognized and user-addressable for naming individual system elements to suit specific applications (for instance, *front fill group 1* or *main left subs*, etc.).

When VUE products are inter-connected as a digital audio network, a Systems Engine or other VUE product auto-configures to any sample rate connected to the AES digital input. Within SystemVUE, the digital input detection circuit offers two levels of redundancy (Dante as first priority to AES digital audio default, and AES to analog default). The channel indicator in each unit control window advises the user whenever no digital audio signal is being detected. Under this condition, the Systems Engine will automatically switch to its analog input for the affected power amplifier channel(s) to avoid signal interruption.

## 7.3 VUE Point BEAM STEERING CAPABILITIES

Vertically adjustable line array systems provide a considerable level of control over the vertical coverage pattern and overall system output, provided a given array has a sufficient number of elements. This is one of their key benefits. As a general rule, arced arrays with adjustable box-to-box splay angles will have less need for the electronic ‘steering’ of beams from individual loudspeaker enclosures, or individual elements within them.

In some instances, it can be advantageous to more highly optimize the coverage characteristics of loudspeaker arrays, particularly when a system will be permanently installed for use a venue with complex architectural features such as a performing-arts facility, house of worship or sports complex.

In situations where avoidance of non-listening areas in a specific venue is a criteria due to its architecture, VUE al-Class systems can be configured with higher-resolution coverage patterns using VUEPoint, a data-inputting and DSP-configuring process that combines specific key technologies into a unified workflow.

The process is initiated with design input of detailed venue and system size and location parameters into a commonly-available and industry-standard acoustical design application (EASE Focus 3). A model of the output and coverage expectations for the system in that particular venue is generated. Parameters such as array configuration and target listening areas can be manipulated to fine-tune coverage of the system in the audience area.

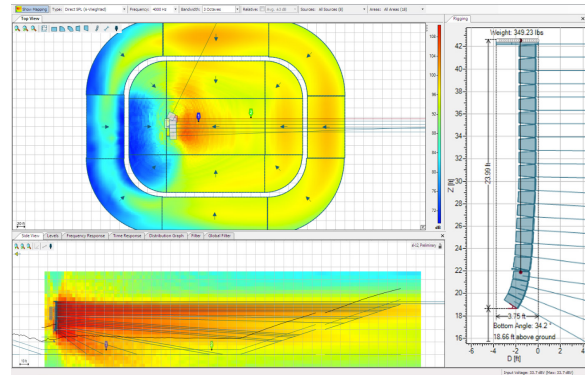


Fig. 27 - AFMG's EASE Focus 3 enables advance coverage predictions, FIR filter generation for beam steering and calculation of the array's mechanical characteristics.

The EASE Focus 3 model is then used to calculate an ideal FIR (Finite Impulse Response) DSP file using AFMG Technologies' integrated FIRmaker. Within this calculating platform, a set of custom DSP filters is generated that can be uploaded to VUEDrive Systems Engines, matching the designer's intention and coupling the line array system's coverage, response and overall output characteristics to the specific requirements of the venue.

Each VUE al-Class scalable line array system is compatible with the VUEPoint workflow process. Existing DSP architecture native to VUEDrive Systems Engines are capable of accepting the venue-specific FIR-filter coefficient files generated by VUEPoint.

## 8. FIELD APPLICATION CONSIDERATIONS

VUE multi-element line array systems offer a wide range of configuration options, and can be used to address most commonly-encountered sound reinforcement system application requirements. A hallmark of such systems is their vertical orientation, making height and even total system weight a concern under some conditions.



Fig. 28 - VUE al-Class systems are readily assembled into mixed-box arrays (shown: al-12, al-8 and al-4 acoustic elements).

The al-Class of scalable line arrays systems enables users to mitigate some of these constraints, enabling a broader range of use cases for VUE systems.

- If limited ceiling height is a consideration for al-12 line array constructions, al-8 and/or al-4 acoustic elements in a smaller size format can be used to populate the array with additional elements while staying within the constraints of the available suspension height.
- As suspension weight limits are encountered with arrays potentially made of larger VUE acoustic elements, SPL and vertical coverage requirements can be maintained by incorporating smaller units within the same array, as under-hung units.
- When available overhead suspension height limitations are not an issue, al-Class flyable subwoofers can be integrated into the same array with full-range elements to maximize available floor space.
- When extreme down-tilt angles from a single array are required, smaller al-Class enclosures can be tightly wrapped beneath the larger primary array

elements while staying within the maximum target length for the composite array.

- When remote signal-delayed arrays are required in field applications, but overhead suspension facilities far from the main stage are not as substantial, smaller al-Class arrays can be used to maintain an acoustic signature similar to the main system.

If maximum SPL and throw capability is required from the upper segments of a given array, and more moderate output is acceptable for areas closer to the array, mixing larger al-12 acoustic elements with smaller al-8 or al-4 units provides a very consistent mid/high acoustic signature due to VUE's Acoustic Linearity system design.

## 9. CONCLUSION

Taken together, the al-Class of scalable line array systems with flyable subwoofers and supporting VUE Drive Systems Engines with SystemVUE networking and control capabilities offer a useful and flexible suite of sound reinforcement tools to address a wide range of field applications.

VUE's guiding engineering principles and systems engineering design platforms,

coupled with practical suspension techniques, ensure a consistent acoustical signature regardless of acoustic elements selected.

Advanced DSP and networking connectivity within SystemVUE have been integrated into the entire al-Class, ensuring an advanced user interface enabling professional sound system practitioners in both portable and fixed applications to reliably design event- or venue-specific solutions.

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