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Powersoft M-System

From Switched-Mode Amps to a Novel Transducer



Powersoft's M-System combines the M-Force motor transducer and the M-Drive switching-mode amp module, taking advantage of Differential Pressure Control (DPC) technology among several other company innovations. The project is the result of the company's continued search for new technologies and ideas from innovative concepts. In this article, we follow the effort—from a Eureka moment to a well-devised solution, which is now available to the OEM market.

By
João Martins
(Editor-in-Chief)

After 20 years convincing the market that Class-D could replace existing linear amplifiers designs, Powersoft has reached a milestone in loudspeaker engineering. But just how did an amplifier company decide to develop a transducer?

Founded in 1995 and headquartered in Florence, Italy, Powersoft designs and manufactures technologies and solutions for the professional audio industry. Mainly recognized for its lightweight, high power, energy efficient, switched-mode technology Class-D amplifiers, Powersoft is also recognized as a "rich" company in terms of developments, and not just in the field of pure amplification technologies.

As Matteo Bianchini, Powersoft's OEM Account Manager states, "We're well aware that amplification is just a link in the audio chain, and any technical progress cannot bring a real major benefit if it doesn't involve, in some way, other elements of such a complex system."

That statement, might help us understand how Powersoft got involved in such innovative projects as the DEVA multifunctional device, which is basically a speaker equipped with several sensors (i.e., a microphone, a presence detector, a twilight switch, and an accelerometer), a video camera, LED lights, and everything needed to combine public address with audio messaging and video capturing. This

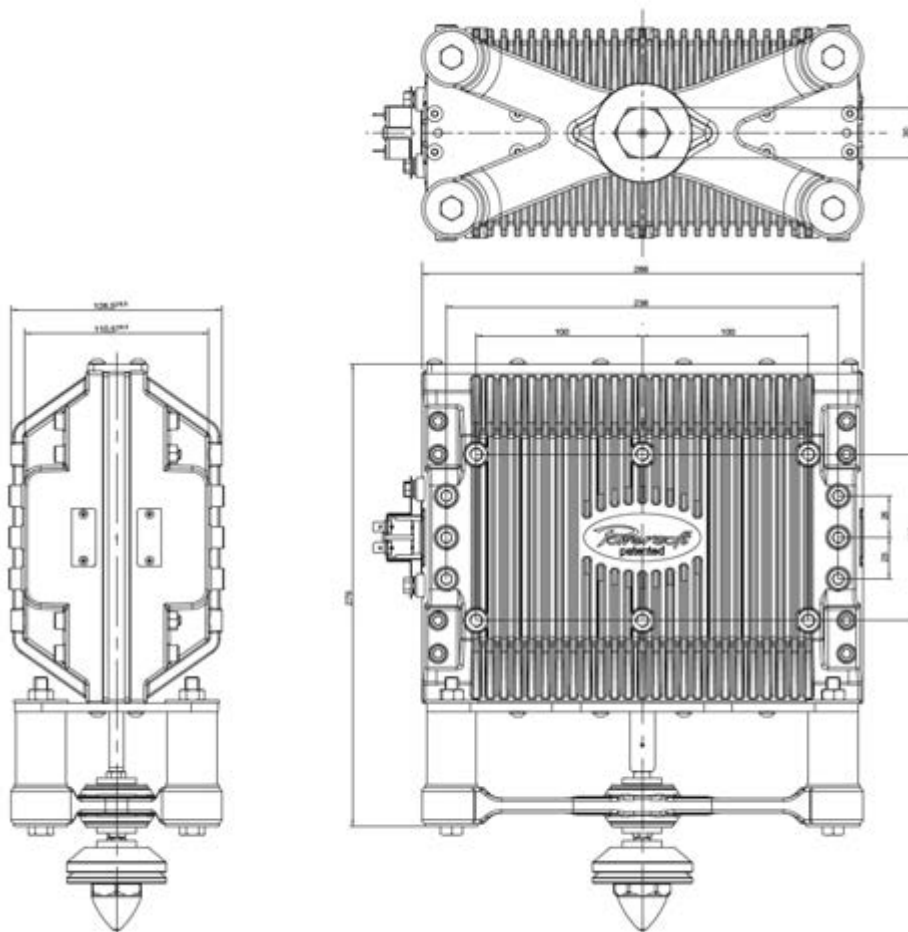
device would be, in itself, a remarkable concept, combining an original design with a complete rethinking of the applications, which the DEVA addresses. However, Powersoft also refined the electronic design to minimize power consumption, enabling uninterrupted use, powered by an internal rechargeable battery that can be quickly recharged using a latest-generation solar panel.

We highly recommend a look at the DEVA. It has a multiple enclosure finish that emphasizes its exquisite raindrop-shaped design that is specifically intended to protect the internal circuitry from exposure to the atmospheric elements, making it an ideal solution for outdoor applications (IP 65). The DEVA system even features a GSM/UMTS communications module, GPS, dual band Wi-Fi, Bluetooth, and wired Ethernet connectivity.

Inside, we find Powersoft's renowned Class-D amplifier modules, making the DEVA a unique solution for background music and paging applications, combined with video and/or audio surveillance.

This project is a fine indicator of Powersoft's engineering department's capabilities and willingness to bring to market. It also serves as the ideal introduction to the topic of this R&D article. But first, we need to examine some of Powersoft's fundamental technologies.

The M-Force transducer features “push-pull” technology, an extremely powerful motor, and unique displacement capabilities.



Rethinking the Audio Chain

Powersoft was one of the first companies to successfully introduce pulse width modulation (PWM) technology in a way that enabled its products to achieve a previously unthinkable level of efficiency and power, with power factor correction (PFC) technology integrated into switching mode power supplies.

Synonymous with Powersoft’s beginnings in 1995, this technology was gradually adopted in professional audio applications worldwide due to its extremely high efficiency, which enables it to transform all the energy drawn from the mains into usable power and recycle the reactive energy coming back from the loudspeakers (back EMF energy recovery, which typically can be damaging for traditional linear amplifiers). The combination of those technologies produces equipment with useful features for touring and fixed installation equipment, allowing for a drastic reduction of the required energy for the same output power, less energy wasted on cooling systems, and certainly fewer amplifiers in less space.

Powersoft has previously used PFC to improve performance and contain mains current draw and consumption, enabling 40% energy savings and important efficiencies including the size of the electric generators used in shows and fewer cable sections due to lower RMS currents, which in turn allows for less hum and induced distortion. PFC-

based audio amplifiers also seem to be immune to mains voltage fluctuations and load impedance since the power supply automatically regulates itself, allowing amplifiers to be used worldwide, whatever the mains voltage.

Powersoft also leveraged the benefits of Smart Rails Management (SRM) technology. In any amplifier output stage, the efficiency is a function of the difference in the output voltage delivered to the load with the rails voltage delivered from the power supply. This is true for any amplifier topology but Powersoft’s SRM implements real-time voltage tracking in the power supply, minimizing the differences between the output voltage rails voltage to improve overall efficiency. The SRM system feeds back the output signal to the power supply and modulates the rails voltage to reduce heat dissipation and improve efficiency, which includes reducing switching losses and EMC problems. It also provides a noise floor reduction on the output stage.

But the PWM technology, the PFC, and the SRM were only the beginning for Powersoft. The Italian company gradually gained recognition because of its lightweight, high power, Class-D amplifiers with reliable “green” credentials, and the company’s ability to continuously innovate new products.

Year after year, Powersoft introduced smaller, lighter amplifier modules and racks, gradually introducing advanced DSP modules, network connectivity, and management software. Signal

Powersoft's DEVA automated audio messaging and video device is a remarkable engineering feat, demonstrating the Italian company has more to offer than amplification.



processing in the digital domain enabled Powersoft to modify the audio response to optimize its own products' audio quality and efficiency. Powersoft also designed more complex systems and increased its products' market appeal by providing integrated processing tools in response to the needs of speaker manufacturers and audio engineers.

Powersoft was also one of the first amplifier manufacturers to experiment with networked

control and software tools. First, it introduced KAESOP, an optional board for its popular K Series and Installation amplifiers for remote control and audio networking. The company also experimented with combining Ethernet protocol for remote control functions with a recognized digital audio protocol (e.g., AES3) to use the same CAT5 cable remote control and two channels of AES3 audio, which can be converted to four analog channels. Even before other audio networking protocols became popular (e.g., Audinate's Dante, which Powersoft currently implements), Powersoft was already pioneering software for remote control and monitoring for all its products.

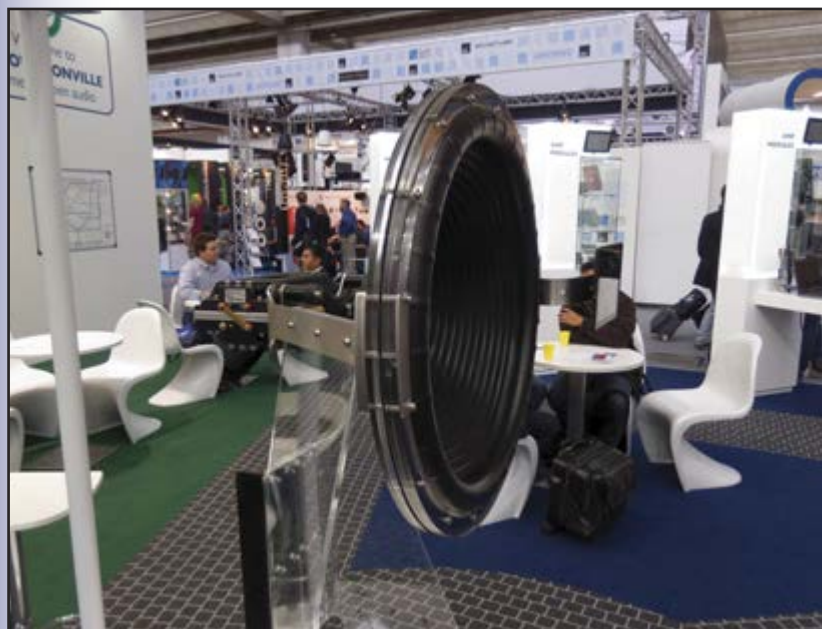
Powersoft's Armonía is a fine example of total system integration, offering full online or offline system setup and tuning, real-time management and monitoring of all vital functions from a remote computer (and now mobile devices) via a single intuitive graphical user interface (GUI). Above all, Powersoft's software offered another way to significantly improve sonic performance and system reliability, allowing for innovations such as Active Damping Control to compensate for speaker wire losses and improve cone control with a virtually negative output impedance, and efficiently limit the amplifier's output power at safe levels depending on the varying load impedance over frequency.

So, it's not surprising that Powersoft invests more than 10% of its turnover in research and development, encouraging experimentation. The company believed in active speakers and it pioneered its technologies in amplifier modules that could be integrated into the speakers. All those things were the necessary prelude to the company's M-System project, which started in late 2008.

Revolutionary New Concept

Next, Powersoft started working on a new amplifier module, the M-Drive (originally called the SUB-Drive) and the patented differential pressure control (DPC) concept, allowing for close integration between the amplifier and the speaker. The concept was originally named IPAL, which stands for Integrated Powered Adaptive Loudspeaker, and consists of "a combination of a high-power, high performance Switching Mode Amplifier in conjunction with an embedded DSP that performs the double operation of both managing the loudspeaker system processing and taking care of the Differential Pressure Feedback Loop Control implemented on it."

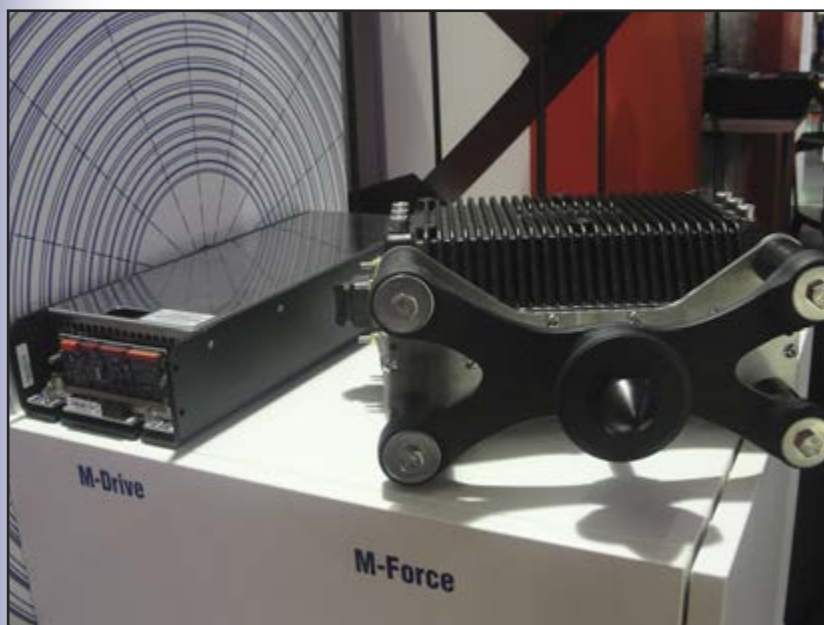
Powersoft introduced this concept in 2011, at the 131st Audio Engineering Society (AES) convention in New York, presenting a paper titled "Practical



Powersoft displays the M-Force concept as an innovative and unique transducer based on a patented moving magnet linear motor structure at Prolight+Sound 2013 in Frankfurt, Germany.



As co-founder and R&D Development Director of Powersoft, Claudio Lastrucci's fields of expertise include electric power, audio amplification, signal processing, acoustic design, and other areas. (Photo courtesy of Powersoft)



Powersoft's M-System combines the M-Force motor transducer and M-Drive switching-mode amp module, taking advantage of Differential Pressure Control (DPC) technology to establish a global feedback between the electrical and the acoustic domains. The Zero Latency DSP performs real-time processing of the differential pressure control signal to adaptively correct the diaphragm displacement.

Applications of a Closed Feedback Loop Transducer System Equipped with Differential Pressure Control." The paper was co-authored by Fabio Blasizzo (then a freelance transducer engineer who conducted practical measurements in the early stages of the project), Mario Di Cola, Paolo Desii, and Claudio Lastrucci. Desii is one of Powersoft's R&D engineers, responsible for embedded systems development and software. Lastrucci is Powersoft's co-founder, President, and Research & Development Director—he is also the driving force of the company's technologies. According to Lastrucci, Di Cola was involved in the evaluation of the first prototypes "as soon as there was something to test," which means about three years after the project started.

Basically, the paper described a closed feedback loop transducer system dedicated to very low frequency reproduction. As stated, "The use of a feedback control loop can be very helpful to overcome some of the well known transducer limitations and to improve some of the acoustical performances of most subwoofer systems. The feedback control of this system is based on a differential pressure control sensor. The entire system control is performed by a 'Zero Latency DSP' application, specifically designed for this purpose in order to be able to process the system with real-time performances."

The M-Drive, used in conjunction with DPC was the technology at the core of IPAL systems, with a specifically designed transducer to implement the novel approach of a closed feedback loop for direct control over the system's acoustical output.

The first amp module—equipped with DPC and a PFC-equipped power supply—delivered up to 8,500 W and was tested by several speaker manufacturers. Italian company B&C Speakers was among the first companies to introduce two IPAL high-efficiency transducers. B&C Speakers developed two different IPAL compatible speakers, the 21IPAL (21") and the 18IPAL (18"). The 21IPAL was intended for use with single speaker applications and the 18IPAL was recommended for 2x18" configurations. Eighteen Sound, another Italian speaker manufacturer, also developed its own design with IPAL-compatible products.

The original AES paper introduced the concept of Virtual Speaker Modeling, again leveraging the company's expertise in software and DSP control to take advantage of the DPC concept and create a so called "Virtual transducer." This powerful software tool makes the real transducer behave as a "user defined" transducer, synthesized by the speaker designer with a dashboard to manage the desired driver's Thiele-Small (T-S) or electromechanical

parameters, based on a mathematical model.

Previous attempts at motor-driven speakers had some elements of Powersoft's concept, but lacked much of the refinement. Some readers may remember Tom Danley's motor driven speakers and their distance cousin, the Phoenix Gold Cyclone. Moving magnet shakers include the Bodysonic, the Clark, the Earthquake, and others.

From Concept to M-Force

We specifically asked Lastrucci about the "genesis" for the whole M-Force project. And, Lastrucci admitted this was a "eureka moment." "The moment we imagined something not axisymmetric but 'planar' in the magnetic design. However, the move for a different transducer technology came from the knowledge of switch-mode amplifiers, their native properties and the desire to fully exploit the real benefits of the native energy recycling capabilities. No switch-mode amplifier, no M-Force..."

As previously described, the M-Force evolved from the earlier efforts to optimize a transducer for subwoofers. As Matteo Bianchini's stated to



"We don't like to use too big words, but M-System really 'risks' to be one of the few big things happened in audio transduction in the past decades," says Matteo Bianchini, Powersoft's OEM Account Manager.

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audioXpress, “In our R&D efforts, we always tried to take into account the interaction of our technology with “adjacent domains,” especially the world of transducers and the actual effects of this interaction in the acoustical domain. As a consequence, some of the technologies are more complex than the simple amp, and involve many perspectives, from processing to transduction, as well as acoustic design and, of course, high power electronics.”

He adds, “The first things you might notice are the very high output figures (310 V_{PEAK}, 200 A_{PEAK}), making it able to drive lower-than-1-Ω loads, but there’s much more than that: The M-Drive, despite compatible with applications using traditional transducers, was designed in order to fully drive the

M-Force, an innovative low frequency transducer (a linear motor based on a moving magnet approach) that no other amplifier would be able to push to the limits.”

After showing it at multiple shows and providing samples to some exclusive partners, Powersoft decided to make it available for OEM projects.

The M-Force was the second stage of Powersoft’s R&D efforts, following the M-Drive amp module and the IPAL concept. In 2014, Powersoft presented another paper at the 136th AES convention in Berlin, Germany, explaining how the company designed “A Novel Moving Magnet Linear Motor.” The paper, presented by Lastrucci describes how the company explored a new “electrical to acoustic conversion approach” combining “new technologies in the electronic amplification domain and latest magnetic materials.” The new transducer is presented as a “new electrodynamic device that considerably improves electrical to acoustical conversion efficiency, sound quality, robustness and power handling,” based on a “fully balanced and symmetrical moving magnet motor design, along with anisotropic magnetic compound integration,” to deliver substantial performance improvements in terms of “acceleration, linearity and efficiency, providing additional degrees of freedom in high quality professional speaker design,” different from the “ubiquitous moving coil approach.”

The topology is closer to a bass shaker than a conventional subwoofer. In crude terms, the M-Force is a bass shaker coupled to a spider, a cone, and a surround. However, the response is far more linear than a shaker with some benefit from the servo-control feedback circuitry.

The new transducer leverages a specific radiating element developed to cope with the high force and displacement provided by the motor “using large-size vacuum-formed conical polymeric diaphragms that embeds in a single material piece, the piston, the connecting elements, and the outer surround as the load for the motor and the coupling device to the acoustical domain.”

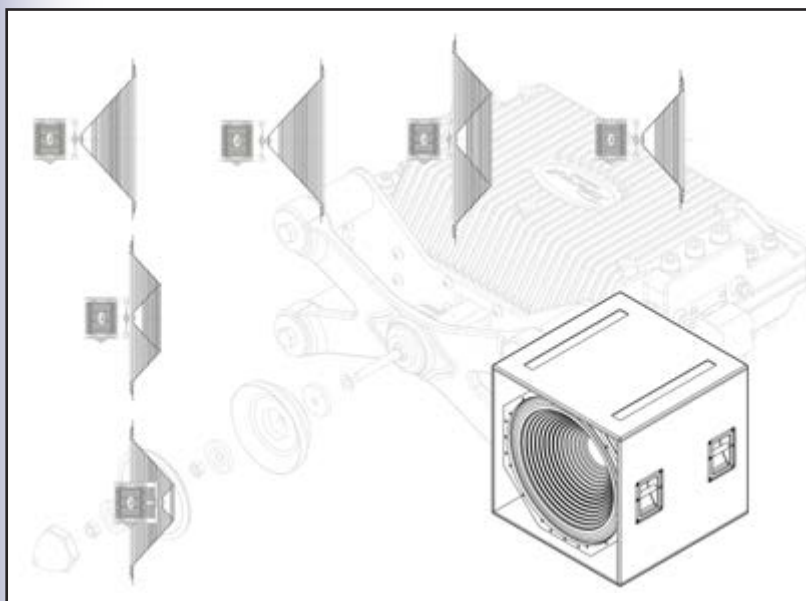
This paper describes the M-Force system introduced at the 2013 Prolight+Sound and InfoComm shows. It features an impressive 40” diaphragm, as well as 22” and 30” variations. The 40” unit reportedly is able to generate a maximum radiating surface up to 6,500 cm², or the equivalent radiating surface of four 21” drivers.

Powered by the powerful new “piston” motor, the system effectively opened the way for powerful low-frequency cabinets with “a much smaller form factor for a given SPL performance and low-end extension.”

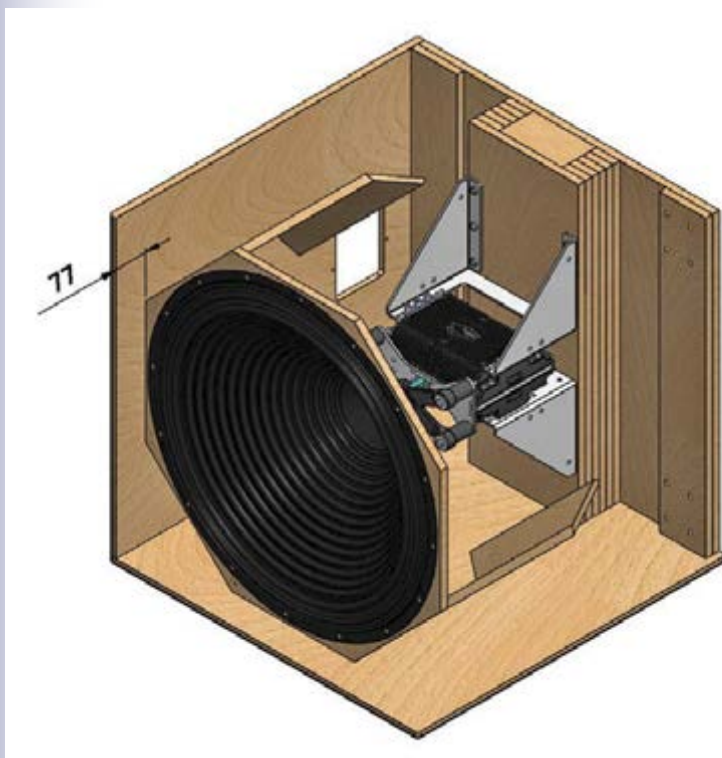


The complete M-System was presented at the 2014 Prolight+Sound show, when several manufacturers were already working on practical implementations.





Powersoft provides a range of two motors and six M-System diaphragms models for very low-end subwoofer (40") and low-frequency applications (30" and 22").



This Powersoft subwoofer reference design features M-Force.

Powersoft also noted other possible fields of application in materials stress testing, vibrational active damping control, mechanical to electrical conversion, and even mechanical energy harvesting.

The M-Force Drive

According to the paper presented at AES Berlin, the "motor structure" uses forces generated by current and magnetic field interaction, the same as on a conventional moving coil actuator. "However the stationary reference has been moved from the magnet and yoke assembly to the exciting coils, which become the "heavy" part of the system," Lastrucci details.

Powersoft has written three complementary papers, which can be accessed from the AES website (www.aes.org). As for the new system, it is "based on two parallel bars of NdFeB magnets, facing to a common plane but with opposed magnetic field orientation. Two coils are placed facing the bars of magnet in a way to create a sandwich structure that holds the magnet within the coils."

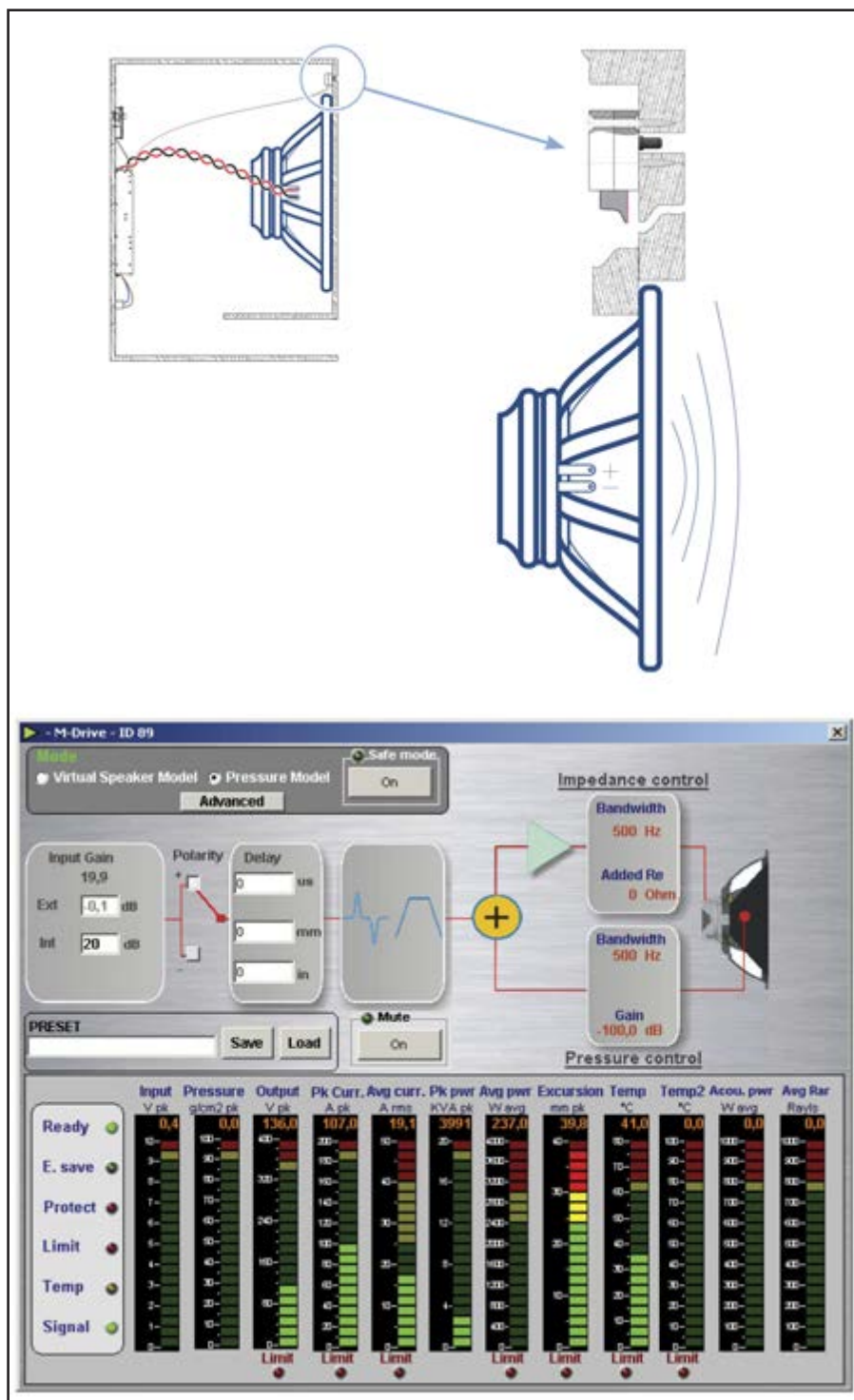
"The coils are wound using a ribbon of solid conductor, forming a winding of rectangular shape. The magnetic field generated by the magnets is forced to cross the conductor of the coils, producing, once the coils are subjected to current, a relative force between the coils and the magnet bars. This force linearly depends on the intensity of the field generated by the magnets and the current flowing into the coils."

The paper also describes how the symmetrical design is surrounded by an outer ferromagnetic shell "to allow easy circulation of the steady field generated by the magnet bars and to create a defined path for the variable flux produced by the current flowing in the coils," and "a frame of composite material" to "provide a mechanical connection to the radiating part of the complete acoustical transducer."

Lastrucci says "this can be considered a real push-pull device, where both magnet bars and coils work completely symmetrical in respect to the axial displacement and each portion of the conductors provide either push or pull action on each magnet bar in a complementary fashion to the other specular portion of the motor," while the most evident feature is the absence of conductors in the moving portion of the motor.

"The forces are provided by the interaction of the field that is generated by the steady coils and the field generated by the magnets that are not energized by any connection," allowing for a "free and very reliable operation even with extreme acceleration and displacement" and thermal stability.

To optimize such a system, and specifically its peak force to mass ratio, over a linear displacement of 30-mm peak to peak, Powersoft applied all the technology from its M-Drive amplifier module with on-board DSP to achieve actively synthesized values from $-10\ \Omega$ to $+10\ \Omega$ resistance and $-2\ \text{mH}$ to $+2\ \text{mH}$ induction. To create global



The differential pressure control (DPC) measures the difference in pressure between the front and the rear sides of the radiating diaphragm and uses this information to alter the transducer's behavior, according to the actual boundary conditions.

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The Avalon Hollywood club now has a new improved audio system, featuring “the world’s largest subwoofer club installation ever” with new subwoofers powered by Powersoft’s new M-Force technology and 40” cones.

feedback in the system, Powersoft used a differential pressure sensor to detect the overall pressure acting on the radiating surface of the radiating diaphragm. The DPC measures the difference in pressure between the front and the rear sides of the radiating diaphragm and uses this information to alter the transducer’s behavior, according to the actual boundary conditions. Via software, it’s even possible to weigh and customize the feedback between the electrical and the acoustic domains.

“This method allows the definition of a

predictable behavior in the electrical–mechanical–acoustical signal chain, and allows reduction in the sensitivity of the system performance against aging and boundary condition,” says Lastrucci.

All the main parameters of the transducers are supervised. The voltage, the current, the power, the pressure, the displacement, and the forces are maintained within the safety conditions and limited within a global amplifier and transducer combination. Power management uses a combination of energy recycling output stage and PFC integrated into the power supply.

The M-System in Practice

A new paper, presented in 2014 at the 137th AES Convention in Los Angeles, CA, titled “Subwoofer Design with Moving Magnet Linear Motor” and co-authored by Di Cola (Audio Labs Systems), Lastrucci, and Lorenzo Lombardi (Powersoft), takes the new electro-dynamic transducer described in Lastrucci’s previous paper and details specific proposals in subwoofer design using this technology. Among the designs, we find a high output, high Q vented box design tuned at 30 Hz, a small-size compact vented design tuned at 34 Hz and a hybrid short transmission line. The paper details actual measurements from those units and provides advice on system optimization using the available tools.

Powersoft also released a series of documents that includes “Loudspeaker Project Examples” for subwoofer designs based on M-Force. The company has also been expanding the information it provides to manufacturers, including information for two M-Force models, one for extremely low frequency applications with $(BI)^2/Re = 2215 (T \cdot m)^2/\Omega$ and maximum acceleration of 3800 m/s^2 ; and another with $(BI)^2/Re = 3000 (T \cdot m)^2/\Omega$ and maximum acceleration of 4800 m/s^2 . Details of different diaphragm designs are also provided in Powersoft’s literature.

Since its launch, AV specialists and integrators including ATK Audiotek, Maryland Sound International (MSI), and others have used Powersoft’s M-Force and M-Drive solutions in a variety of high-profile applications.

Meanwhile, the first commercial implementation examples have also become public. One of those involves the world’s largest subwoofer club installation, in a collaborative project with Eastern Acoustic Works (EAW) at the Avalon club, a Hollywood, CA, historic venue.

John Lyons, Avalon Hollywood’s owner and audio expert is known for the design and the installation of audio systems at some of the world’s leading nightclubs, restaurants, and lounges across the

globe, including the Avalon clubs in Hollywood, Singapore, San Diego, CA, and Boston, MA. Lyons and EAW's co-founder Ken Berger worked together on the original Avalon loudspeaker system's design launched in 1997.

The system was redesigned from the ground up as the "Avalon by EAW" Sound System, and re-launched in 2011. Avalon Hollywood's Avalon-series system has now



Spanish manufacturer D.A.S. Audio introduced its new Sound Force Series line-up of dance systems at the 2015 Prolight+Sound show in Frankfurt, Germany. The series includes the SF-30A, a M-Force powered ultra-low system, using 30" diaphragms, that provide 7,500 W of continuous power.



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been improved with the help of Powersoft's latest technology, implemented in a new range of Avalon subwoofers.

The innovative setup was unveiled at Avalon's Grand Reveal 2014, replacing the original Avalon EAW system, which was recognized as a world reference and can still be heard in hundreds of nightclubs around the globe. Each speaker cabinet now includes a 40" Powersoft diaphragm and M-Force, resulting in a cleaner, more powerful sound than was previously possible to produce.

Each subwoofer cabinet (there are six in total in the reference installation) is powered by two Powersoft M-Drive modules that are used to supply power to the M-Force motor, the cone, and each of the traditional speakers, generating 15,000 W at 2 Ω.

Another example about to reach the market is the Sound Force Series of club systems by Spanish manufacturer D.A.S. Audio.

The new Sound Force Series of dance systems is aimed at top-level clubs and discos. The system is comprised of four speaker models for mid-high, mid bass, and two subwoofer options, including the impressive SF-30A, a M-Force powered ultra-low

system, using 30" diaphragms, offering 7,500 W of continuous power.

Other M-Force powered systems are currently in development from other manufacturers but no details have become public at the time of writing.

Open Applications

Powersoft has been extensively promoting the M-Force concept in different forums. Lastrucci introduced the technology also at the Association of Loudspeaker Manufacturing & Acoustics (ALMA) International's Winter Symposium 2015, in Las Vegas, NV, convincingly demonstrating the efficiency of the new moving magnet linear motor technology in subwoofers and detailing working methodologies, cabinet design, and loudspeaker application scenarios.

According to Lastrucci, the M-System is currently an exciting new platform for OEM applications. "As soon as the results on the initial prototypes provided some effective performances, we started to pursue a process of optimization and engineering that led to a finished product. Since our goal, as Powersoft, is not to be a speaker manufacturer but a supplier



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of components for their products, this was naturally in line with the company's vision."

Another surprising aspect was how the concept was quickly converted into actual products. According to Lastrucci, "We do like to have and maintain a tight relationship with our existing partners and users, always listening to their needs and looking for their feedback on our "crazy" ideas: speaker manufacturers, rentals and FOH all have their own unique perspective on a system and it is important to verify that a new technology brings some real benefits to all of them. With M-Force it was exciting to see the reaction when we started to

talk about this new technology, and above all, after getting them listening to it and playing with the first samples. We know well that new technologies take a very long time to be accepted in our industry (it happened so many times to us...) but it sounds like this time the word is spreading faster... Maybe the industry is beginning to trust we can make crazy ideas real."

Lastrucci adds, "The technology is intended also for other applications, not necessarily to produce sound... Likely, otherwise, to remove it... This is a field of application [active noise canceling] we are investigating for a considerable period of time and foreseeing interesting possibilities."

Apart from high power and energy efficient subwoofers, Powersoft says its M-System is currently being tested for diverse applications such as steerable low-frequency arrays, low-frequency noise, and standing waves active removal systems and dipole low-frequency acoustic generation. "We are already working on other fields of application for the technology, there is a kind of market that is demanding large forces and medium stroke, typical of the M-Force technology," concludes Lastrucci. 

Resources

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