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		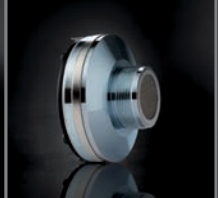	

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—Morel, Ltd.

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China Sourcing Fair: Electronics & Components	Consumer electronics show for sourcing	www.chinasourcingfair.com/hk
CES International	Technology-related consumer electronics trade show	www.cesweb.org
electronica	Europe's leading trade fair for the electronics industry	www.electronica.de
Euronoise	Acousticians and noise experts discuss noise control and soundscape	www.euracoustics.org
GSMA Mobile World Congress	Brings together the full mobile and technology ecosystem	www.mobileworldcongress.com
High End Munich Show	Largest European high-end equipment audio show	www.highendsociety.de
Hong Kong Electronics Fair (HKEF)	Consumer electronics show for sourcing	www.hktdc.com
InfoComm	AV systems for professional commercial applications	www.infocommshow.org
Integrated Systems Europe (ISE)	AV equipment for commercial and residential use	www.iseurope.org
International Broadcasting Convention (IBC)	Electronic media and entertainment technology and content	www.ibc.org
International Funkausstellung (IFA) Berlin	A popular show for consumer electronics and home appliances	www.ifa-berlin.com
International Symposium on ElectroAcoustic Technologies (ISEAT)	Exhibits and technical symposiums for loudspeaker engineers	www.iseat.org
Lone Star Audiofest	High-end audio show	www.lonestaraudiofest.com
Midwest Audiofest	Swap meet, speaker design competition, and sound challenge	midwestaudiofest.com
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NAB Show	Electronic media show covering content across all mediums	www.nabshow.com
NAMM Show	Four days of audio business, education, music, and celebrities	www.namm.org
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The Loudspeaker Sourcing Show	Connecting suppliers with companies that need their services	www.loudspeakersourcingshow.com
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Now more than ever the audio industry needs to be connected and working together. With loudspeakers and all different types of audio transducers used in headphones, earphones, smartphones, and all sorts of personal and home devices, at the core of all major audio applications, the opportunities for our industry have never been greater. And the good news is, applications are expanding and business is growing in most major product segments making this a pivotal time for companies to focus and expand their strategies.

The challenges ahead for audio companies in this time of immense technology changes and fast-moving trends involves finding the best human resources, getting the skills set right for your structure, and being able to move quickly when ideas need to become working concepts, prototypes, and enter production. Being connected means leveraging all opportunities in a timely manner, and for that your network of suppliers and strategic partners is more important than ever.

That is why the annual *Loudspeaker Industry Sourcebook* (LIS) continues to be an essential resource, getting better and stronger every year. Since we completely updated LIS two years ago, and added a dedicated online directory (www.loudspeakerindustrysourcebook.com), this annual publication continues to grow with more categories and more complete listings.

Working together with the Association of Loudspeaker Manufacturing and Acoustics (ALMA) International, and other partner audio industry associations such as the Audio Engineering Society (AES); the Audiovisual and Integrated Experience Association (AVIXA), the producer of InfoComm; and the Custom Electronic Design & Installation Association (CEDIA), the *Loudspeaker Industry Sourcebook* will continue to serve and reflect the diversity of companies and areas of activity that the audio industry entails.

As this 2018 edition of LIS denotes, the audio industry is expanding its application scope in tandem with technology innovations, which enable completely new product categories and much more sophisticated systems to meet the demand for better, more convenient, higher quality, and readily available experiences.

Inside this LIS 2018 and the online directory, you will find the latest updated information with all the contacts that make it an invaluable resource for the industry, reflecting the current market expansion. As always, we have enriched LIS with high-quality Industry Features and Reports, reflecting our industry's trends and evolution in new applications such as voice recognition, smart home integration, room correction, acoustic compensation, new materials, new test and measurement and QC solutions, and new standards, among the many topics addressed.

As we do monthly in the pages of our leading publications *audioXpress* (Audio Engineering & Development Magazine), and *Voice Coil* (Loudspeaker Industry Periodical), we are certain LIS 2018 will be another valuable resource to help you grasp the opportunities ahead.

We hope you enjoy the annual edition of the *Loudspeaker Industry Sourcebook*!

—The Loudspeaker Industry Sourcebook Staff

Audio Industry Embraces Voice and Wireless Opportunities and Challenges

By
Jack Wetherill
(Futuresource Consulting)

Anyone who attended the trade shows that punctuated the past year, such as CEDIA, Integrated Systems Europe (ISE), High End Munich, or CanJam can confirm that the audio industry is in a period of rejuvenated interest. Even those of us who sit in offices, take trains, walk down the street, or watch TV are keenly aware that music listening is more of a priority than ever for consumers. Once again, consumer spending on music (whether on CD/vinyl, streamed or downloaded) grew in 2017 by 11% to $19.7 billion and this demand is reflected in a greater interest in buying the relevant hardware—with headphones and wireless speakers still the most sought-after devices (see **Figure 1**).

Additional Features Fuel the Headphone Market

Extraordinary growth in the headphones market was driven not so much by volume (+4% to 362 million units in 2017) but by the average price, which rose by 24% during the same period. Why are people willing to spend so much more on headphones than they were in the past? It's down to innovation in the category. Dozens of brands have identified their niche in the market and compete with the global giants such as Apple, Sony, Bose, and Beats to really focus on the features that will persuade consumers not to buy their first pair, but in many cases their second, third, or fourth pair. Use-case scenarios have been envisaged to create products that consumers crave. Wireless connectivity, courtesy of Bluetooth, is rapidly becoming an essential feature. Futuresource research shows that 36% of headphones sold last year were wireless, a rise of 76% in terms of volume. True wireless models, most notably from Apple, have been a major contributor to this trend. Futuresource anticipates that 48% of headphones will feature Bluetooth in 2018. Wireless is by no means the only feature appreciated by consumers enjoying music on the move. Demand for Sport models is set to rise by 19% in 2018, while microphones are becoming almost standard fit, likely to reach 78% of sales this year, more innovation is in the pipeline, such as "Smart" features involving advanced user interfaces (e.g., Swipe control and proximity sensors), fitness tracking, and even full-phone features. Vendors will need to be careful not to compromise the all-important factor of battery life when introducing these features.

Voice Control

Turning to speakers, the industry's attention is almost totally consumed by voice control. To date,

Amazon and Google have cornered this market in the Western world, with local players in China and Korea also experiencing large volumes of sales. In 2017, 26.6 million smart speakers shipped, and Futuresource anticipates closer to 51 million smart speakers will ship this year. Alexa and Google Home have driven interest in wireless speakers to an entirely new level. Previously, Bluetooth was the connectivity of choice for wireless speakers, but last year the share of Wi-Fi grew dramatically thanks to the inclusion of voice control, which requires cloud connectivity. Consumers enjoy music from the speakers, but households are also buying multiple speakers to enjoy the benefits not just of music, but of home control (e.g., setting the temperature) or online shopping, or simply listening to the radio.

Dedicated smart speakers are in a golden period of growth, but this could quickly be capped by the roll-out of voice control in other devices in the home, such as Media Streamers, Set-Top Boxes (STBs), and TV sets. As we replace our devices in the coming years—quite likely with ones that feature alternative voice control platforms—our homes will become an increasingly complex environment in terms of voice control. We are unlikely to choose a TV on the basis of its voice control platform being compatible with other products in the home. Meanwhile our STBs are generally supplied by a pay-TV provider, who will make the decision on our behalf.

It remains to be seen whether we will settle upon one voice interface or have to interact with a range of them in the long term. Consumers would ideally like to use their favorite voice control platform across all devices in the home, but it is likely that a range of solutions will co-exist in the foreseeable future.

Smart Speakers Pose Challenge

The arrival of smart speakers has seen Amazon and Google present massive challenges to traditional audio brands. Audio enthusiasts may scoff at the sound quality of smart speakers from Amazon and Google, but will audio brands be able to develop products that are obviously better than Echo and Google Home, for a price that is both attractive to the consumer and viable for themselves? Google- and Amazon-branded speakers are relatively inexpensive as they are being deployed as part of a much larger strategy involving maximizing potential for the online store (Amazon) or targeted advertising and information gathering (Google). Apple's HomePod (see **Photo 1**) is one of the first alternatives to emerge, but this also is partly to address Apple Music subscribers and ultimately Apple's HomeKit program. The benefits for audio brands such as Sonos, Harman, and Bose, meanwhile, are more focused on better user interfaces. Consumer research shows that listening to music is the most popular activity on smart speakers despite all the other options

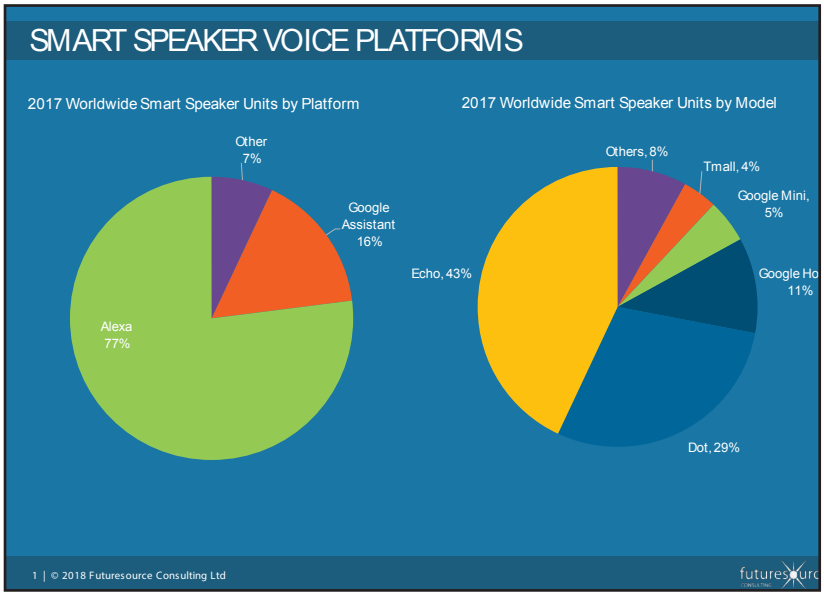

Figure 1: The Smart Speaker market is highly competitive, but Alexa clearly led the way in 2017 with 77% of the market.

Photo 1: Apple HomePod is a breakthrough speaker with step-up sound quality, spatial awareness, Siri intelligence, and smart home control.

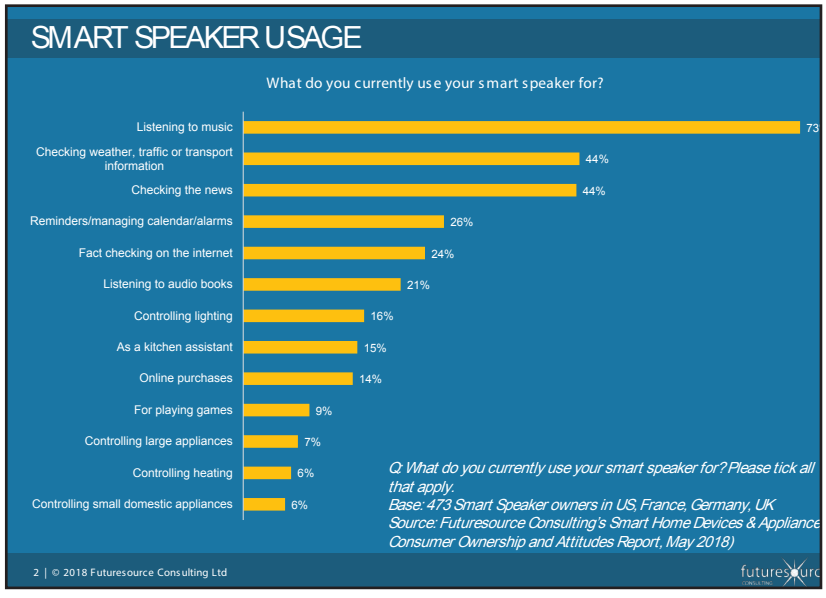

Figure 2: Listening to music is the #1 application, but smart speakers serve many other purposes.

Photo 2: The Wilson WAMM Master Chronosonic is, according to Wilson, the most time-domain correct loudspeaker in Wilson's history. It plumbs new depth in terms of technology and execution. From drivers to cutting-edge composites, from crossover technology to perfecting geometries. Most importantly, the adjustability in the time domain is precise down to five millionths of a second for any installation.

they offer (see **Figure 2**). Brands know that they must make a play in this space to capitalize on the growth in Wi-Fi speaker demand that Amazon and Google have triggered. They also have to decide which platforms to support. With the Sonos One, the market saw the first stated intention to support more than one Voice Assistant (VA) on a device. Although this has not yet been fully realized (only Alexa is currently available), others have moved ahead and provided options for consumers to select their preferred VA by offering models dedicated to each platform. More than 30 audio products with voice control were unveiled at CES alone, so the industry watches with bated breath to see which devices and brands will win out in this highly competitive space.

Loudspeakers

Passive loudspeaker brands are also considering their strategies and role of their products. Is the future going to be ruled by speakers with embedded wireless functionality, bypassing audio components, or will there always be a role for passive speakers hooked up to systems, which themselves are connected to the cloud? Judging by the research Futuresource is gathering for its annual Loudspeaker Market Report, the pressure is most obviously on bookshelf speakers. This category is on the front line of the battle line with wireless speakers, with audio brands experimenting with products that offer wireless connectivity and stereo pairing, such as Kef's LS-50W.

Meanwhile, the higher-end segment of floor-standing speakers is more resilient to the challenge of wireless speakers. Instead, they face the problem of increased focus by homeowners—and interior designers—on simplicity, tidiness, and aesthetics. The latest research would indicate that the average price of floor-standing speakers is rising, even if the overall volumes are declining. So, those consumers who are investing in floor standers are focusing on design as well as performance. One brand told me recently that it needed to develop a product to fulfill a growing demand in the $100,000 per pair category, while Wilson Audio's new $680,000 pair of WAMM speakers (see **Photo 2**) are reportedly selling well.

Demand for home-theater speakers has suffered in recent years, partly the victim of a greater focus on simplicity by consumers, leading to the trend toward soundbars. Last year, 16.9 million soundbars shipped worldwide, up 7%. Some of the more advanced markets are now reaching saturation point (Western Europe and

the US) but—as with headphones—we are seeing a migration to high-end models with better sound quality, immersive audio, and Wi-Fi. As a result, the average selling prices rose by 13%, to $264 in 2017.

Custom Install Market

The custom install (CI) channel is hugely important for both floor-standing and home-theater speakers and Futuresource research with UK installers, conducted on behalf of CEDIA, reveals how influential the installers are in the decision-making process when choosing which brand of hardware to choose.

The strength of the CI channel is also a reason that demand for architectural speakers is on the rise. In this category, too, it appears that average prices are growing, as products become ever more sophisticated, as evidenced by Origin Acoustics' range. It is interesting to note that Origin is also one of the brands that partnered with Amazon to create Alexa compatibility, with heavy publicity at CEDIA in San Diego, CA, last September (see **Photo 3**).

Professional Loudspeakers

Turning to the $2.8 billion Professional Loudspeaker market, Futuresource predicts substantial further growth for this sector, with most optimism in the installed leisure and installed commercial verticals. The flush mount and special/utility category accounts for nearly three-fourths of professional loudspeakers in terms of units, but just 24% of the value. Conversely, line arrays are just 1% of volume, but 24% of value. There is a huge number of manufacturers operating in the Pro Loudspeaker market, ranging from large corporations such as Harman with its JBL brand down to a myriad of smaller local brands, often using the market to secure a foothold in other segments. As the market becomes more competitive, there is the potential for further consolidation with larger brands acquiring smaller vendors. Outside investment is coming into the industry—as seen at d&b audiotechnik, Samsung's acquisition of Harman, and most recently with the acquisition of Loud Technologies by Transom Capital Group.

Back to Voice Control

Audio hardware is made up of multiple product segments, and some are faring better than others. A glance, however, at the High End Munich 2018 show exhibitor list reveals a plethora of companies all vying for space, creating innovative products to carve out their niche in this complex, and a wide ranging market. For many of these companies, voice control brings the biggest challenge, but also the greatest opportunities. ***LIS***

Photo 3: At CEDIA, Origin Acoustics announced that it now offers the integration of Amazon's Alexa voice assistant with its speakers.

About the Author

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About Futuresource Consulting

Futuresource Consulting delivers specialist research and consulting services, providing knowledge, experience, and accuracy to support decision-making processes. Since the 1980s, Futuresource has supported a range of industry sectors, which has grown to include: Broadcast & Pro Video Equipment, Consumer Electronics, Education Technology & Content, Entertainment, Content Delivery & Manufacturing, Professional Displays, Print & Imaging, and Removable Storage. With 60 full-time employees delivering in-depth analysis and forecasts across the entire value chain, Futuresource advises on market, competitive, and technological developments, providing access to the information that helps you produce the best possible results. For more information, visit www.futuresource-consulting.com.

A View of the Loudspeaker Industry

As Seen by Members of ALMA International's Board of Directors, Executive Committee, and Executive Director

Several members of the Association of Loudspeaker Manufacturing and Acoustics (ALMA) International took a moment to share their thoughts on the current state of the loudspeaker industry.

Dan Foley—President and Member of the Board of Directors and the Executive Committee

With a majority of the finished loudspeaker products sold today comprised of Class D amps, sophisticated digital signal processing, wireless chip sets, and microphone arrays, the days of simply testing acoustic performance using classic anechoic-based measurements is long gone.

Testing these highly advanced products requires measurement systems that incorporate a myriad of analog and digital signal paths. With regard to moving audio as ones and zeros on a network or via codecs with specific protocols, audio design engineers also need to know how to use non-audio measurement tools such as network/protocol analyzers.

There are many ways that audio quality can be diminished, which have nothing to do with the loudspeaker transducer itself. In addition to being competent in all the relevant technical disciplines required to design the transducer portion of a finished loudspeaker product, today's transducer engineers need to be cognizant of how each part of the audio signal path impacts sound quality. Without at least a basic understanding of the entire audio signal path, non-optimal sound quality can easily be blamed on the transducer design when the root cause lies elsewhere.

Alan Babb—Vice President and Member of the Board of Directors and the Executive Committee

Lately when I am asked about the state of our industry, my first thought is that it is confusing. But maybe that is too strong a word.

I see our industry as becoming more and more flooded with possibilities and so it is not just the single file line progressing forward anymore. If you look at the last 30 years or so of history in any specialized area of audio you will see the huge strides we have made. From the old school "Wall of Sound" at a rock concert to the Pineapple clusters to modern line arrays with beam steering. Or from large can headphones connected to a battery-powered reel-to-reel morphing into modern media players (e.g., the one in my smart watch) connected to Bluetooth multi-transducer in ear monitors (such as the ones I am wearing while I contemplate this).

So maybe the confusion is just because there are so many divergent paths being taken that it is hard to pick one. Is this a problem? Well, it can be. It can also be a great opportunity. Maybe the

right attitude is that I look forward to taking the occasional wrong turn as I explore this space we call Audio. The one thing that even my wife will agree I am not incorrect or confused about is that audio is here to stay. I look forward to seeing what people are saying about this field in another 20 years.

Mark Beach—Treasurer and Member of the Board of Directors and the Executive Committee

Smart speakers should represent the most robust activity continuing to benefit from DSP, voice recognition, thermally efficient amplifiers, and miniaturization. There should be room for more products with different features, available at higher and lower cost and so on, but expect to see the start of "last in, first out" as the market sorts itself out to find a balance. The wild card would be mergers and acquisitions of media, hardware, and technology suppliers much in the same way AT&T acquired DirecTV. If their merger is successful, expect a flurry of activity akin to musical chairs. Interconnectivity of multiple devices and getting them to "play nice together" is likely to remain a challenge. Although standardization should grow the market overall, it will remain to be seen if a global standard is adopted.

Personal audio is likely to remain strong, benefitting from the some of the same technologies supporting smart speakers. The only paradigm shift, albeit minor overall, may come from Focal's success with a voice-coil-driven membrane; nevertheless, expect balance armature to continue its widespread use anywhere size is a consideration.

Pro sound is interesting with an avalanche of cheap look-alike, knock-off speakers that exhibit huge differences in distortion, directivity, quality of materials, QC, frequency response, BL linearity, and thermal compression. While digital signal processing (DSP) can cover up some flaws, it is not a miracle cure and can further degrade some aspects if not thoughtfully implemented. In the end, the major players still know how to build a quality loudspeaker. If we are talking pro sound, we have to mention Harman/JBL Pro's acquisition by Samsung to gain access to the automotive market. But, what will happen to JBL Pro, Revel, et al, and their amazing talent pool?

Unfortunately, home audio and home theater will continue to struggle with one possible exception: Someone somehow will have to supply sound commensurate with large format (65" and larger) 4k OLED TVs. This need will be met by continued separate soundbar/box speakers vs. onboard audio.

Improvements in automotive sound quality will be pushed hard and unfortunately, pushed even harder for cost reductions. In other words, business as usual for automotive. Conversely, this is the one market that suppliers are responding to the consumer's demand for better sound quality and it's working.

Overall, I'd say the loudspeaker business and its affiliated signal chain are strong but in a huge upheaval resulting from new innovations—but, that's what engineers do, implement new and improved technologies.

Vanessa Rene—Vice President and Member of the Executive Committee

I would like to offer my view of the future of audio from the perspective of ferrofluid applications. Ferrofluids were first introduced into the audio market in the early 1970s as a means to transfer heat and stabilize off-center voice coil assemblies. Typically, these drivers possessed magnet bodies that had relatively low field strengths, and the aim was to produce high concentration fluids that would stay where you put them.

Those days passed quietly away with the introduction of high-field rare earth magnets, and as a side benefit, the sizes of driver units began to shrink. The efficiency and power of these units also increased, and thus, the era of high-performance home theater stereo and automotive audio had a chance to bloom and flourish. This evolution took place over a span of 20 to 30 years, and progressed so quietly that it was not seen as a revolution—but in many ways it truly was. Before this evolution, quality sound reproduction was something for movie theaters or the home systems of high-end audiophiles, but now, as if by magic, it became available to the masses. Ferrofluids played a large part in making this transition possible.

With the new surge in automotive audio systems brought on by this evolution, high temperature stability became extremely important, and new ferrofluids were developed and introduced to meet these demands. Many brands of high-end car audio depend on reliable ferrofluid cooling and signal stabilization, and this trend continues to this day.

There is an offshoot from the technologies used for this first type of mobile audio, though, and it is the driving force in today's market—miniaturized mobile audio in the form of cell

phones, microspeaker units, headphones, earbuds, and other small portable audio devices. These devices see conditions that are not anticipated in other forms of audio systems. They are dropped. They are left in hot cars and on wet or dirty surfaces, and they are exposed to a number of environmental conditions that are totally foreign to fixed audio components. The sizes of the units that can utilize ferrofluids have gone from several centimeters in diameter to a few millimeters, and the power throughput and excursion have changed accordingly. "Good enough" fluid match to operating parameters is no longer acceptable, now we operate in a very tight range of tolerances in our parameters, and reproducibility is paramount.

Not only do we need to consider the possibilities of audio reproduction, but we also have to take into consideration the scope of haptic devices that are flourishing in the industry. Though just in the early stages of consideration, the potential of ferrofluid to contribute in a huge way to the success of a multitude of non-audio mini and micro-devices, incorporated into mobile audio platforms, is the obvious next step in the evolution of ferrofluid manufacturing for the mobile audio industry.

Mark Glazer—Member of the Board of Directors

The 21st century has been challenging for the conventional high-fidelity loudspeaker. In the previous decade, high-definition video produced a demand for corresponding streamline loudspeakers such as soundbars. Next, small computer desk speakers surged in popularity, followed by portable speakers with docking stations.

The next phase of personal stereo saw the immense growth of headphones. And, since 2010, there has been a huge boom (no pun intended) of Bluetooth and Wi-Fi portable speakers, mostly inexpensive and available to the masses. Now, we are experiencing tremendous sales of voice-activated portables.

My prediction is that smaller than conventional, wireless speakers using such technologies as components from the Wireless Speaker & Audio Association (WiSA) will become the norm. This leaves the conventional high-fidelity loudspeaker as a niche market primarily reaching out to new customers in various countries.

Barry Vogel—ALMA International Executive Director

I would like to begin by stating the reports of loudspeakers' demise has been highly exaggerated. Having worked in the audio industry for more than 40 years, I can safely say I have seen my fair share of change. From LP to four-track to eight-track to cassette to CD (and its impending demise), to MP3 to Hi-Res Audio, and so on. Tube amplifiers to solid state, to Class A to Class A/B to Class D, to Class T to hybrids, etc.

Loudspeakers seem to be the irreplaceable category. The materials change. The formulations change. They have become increasingly integrated into the overall signal chain design. No matter how often we hear about replacements for traditional loudspeakers, we always seem to end up back with "old faithful." And yet I often hear how it is a mature category. No excitement here. I could not disagree more!

We have microspeakers that can reproduce voice in a lifelike manner that could not be imagined not so long ago. We have a vibrant premium headphone industry that has exceeded every projection of its expected market penetration and reproduces music with amazing accuracy. Thanks to all of the talk about Hi-Res audio, sound quality is back!

It wasn't long ago that many industry veterans were predicting the demise of sound quality with the popularity of Apple's now ubiquitous ear buds. Rather than electronics and technology stealing the thunder from the loudspeaker industry, I believe that the higher level of performance made possible through signal manipulation and predictive performance has refocused consumers and product development people to produce loudspeakers at an even higher level of performance.

The "cheap speaker" will always grab a lion's share of the market. But any talk about a lack of excitement in the loudspeaker industry is just plain wrong. Your loudspeaker may have a DSP attached to the back of it, or somewhere in the signal chain, but the loudspeaker and its associated performance will continue to be the last, and perhaps the most vital link in the audio signal chain. ***LIS***

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ABOUT ALMA INTERNATIONAL

ALMA (The Association of Loudspeaker Manufacturing and Acoustics) International is the only not-for-profit trade association dedicated to electro-acoustic and audio professionals worldwide. ALMA is dedicated to providing a beneficial environment in which to conduct business, network, increase education and skills, and to build careers in the industry as well as promoting adoption of new technologies and research. ALMA's membership is comprised of electro-acoustic and audio signal path designers and manufacturers as well as suppliers of test and measurement equipment and other products, consultants, and other service providers to the electro-acoustic and audio industry. Individuals, academic institutions, and educators participating in the industry are encouraged to join. ALMA enjoys and welcomes a global membership. The organization was founded in 1961 and continues to grow globally.

Mission Statement:

"ALMA is The Source of commerce, news, networking, and education for technical and business professionals in the acoustics, audio, and loudspeaker industry."
For more information about ALMA, visit www.almaint.org.

Speaker Design Trends

Get Smart! Give Your Speakers Some Brains

Smart speakers are promoting the user case for voice personal assistants (VPAs) and voice recognition applications—given the ideal combination of far-field microphone arrays with a complete audio ecosystem that encompasses digital signal processing, acoustic echo cancellation, noise cancellation, and many other technologies. But what if, instead of just competing in the smart speaker category, we could design our speakers to be smarter, leveraging all the technology that vendors are making available for those platforms?

By
J. Martins
audioXpress Editor-in-Chief

The Google Home might not be the best sounding smart speaker but it helped establish the concept for a voice recognition optimized device.

After all, inside those smart speaker systems—the Amazon Echo, Google Home, Apple HomePod, etc.—are some of the most sophisticated technologies ever available to the consumer electronics industry, and they make total sense when integrated into a modern speaker. The same technologies used to create smart speakers that are optimized for voice recognition can also be used to enhance music listening or simply allowing speakers to become part of a smart home network. That makes the investment on new speaker designs much more attractive.

Using integrated digital signal processing to optimize the speakers' response has been explored for years and the merits in clever crossover designs, creating sophisticated filters, and applying room compensation are widely recognized. With the new development platforms that manufacturers now have for smart speakers, all those tools become available and affordable, with a big difference: The platforms already provide a way to measure the response in real time, making acoustic measurement of the surrounding environment possible, while modern techniques for beamforming mean a single driver array can supply different types of response, depending on the usage.

Exploring those tools opens a completely new field of research and the ability to create new sophisticated designs that adapt to different applications, and also open new markets.

With voice virtual assistants becoming popular, connected systems actually need a loudspeaker connected to an audio amplification system, no matter where they are integrated. Once users start to recognize the use of voice commands, using voice as an interface or frequently engaging with virtual assistants, those voice functions will be well integrated in all sorts of devices—eventually becoming ubiquitous in any connected Internet of Things (IoT) device or smart home.

What is important in this concept is that users can successfully interact with the VPA, no matter where they are in the home. Meaning, if you are away from the smart speaker, but are close to the refrigerator, or washing machine, or TV set, any of those devices can be your interface and can listen to your voice requests/commands. But, to reply and interact with the user, all those other classes of devices will need a decent audio system, similar or even more sophisticated than what we have in current smart speakers—sometimes posing significant challenges in terms of environmental conditions.

And remember, users will expect the same level of consistency they get from a VPA, which will always require connectivity. So, connectivity is the key when designing any product if you want your design to be integrated in any sort of way.

From Voice to Better Audio

To explore the technologies that the market is making available for smart speakers, manufacturers can explore multiple options—from completely integrated platforms or create completely new systems based on embedded modules and powerful computers.

Let's look at the microprocessors for instance. Companies such as NXP Semiconductor are responding to the market trends, where developers are testing the convergence of immersive sensory experiences fueled by voice, video, and audio demands, and launched its i.MX 8M new 64-bit family of application processors, combining expanded media capabilities on one single chip. With this new platform, and many of the compatible expansion modules that other manufacturers are making available for NXP's i.MX system-on-chip (SoC) platforms, consumer electronics manufacturers can explore new concepts, without restrictions. Sonos is just one of several companies exploring that approach—leveraging the integrated computational power and microcontroller features to combine all the needed peripherals that a latest-generation connected speaker would require.

Companies can explore this new integrated solution and make use of extensive digital processing capabilities, without the need to use external DSPs, and make use of all the extensive interface options, including HDMI and high-quality audio, using a single chip. The platform can be used to create smart acoustic compensation features and improving audio quality in new speaker designs, even running proprietary algorithms in the same environment with plenty of processing cores to run separate functions, while having the choice to combine local control features and plenty of options to connect to any of the ecosystems from Google, Amazon, etc.

On the SoC level, Cadence Design Systems also provides its Cadence Tensilica HiFi DSP IP core for designs targeting better voice and audio processing performance for any type of product development. Cadence is powering the latest innovations in home entertainment, supporting audio codecs (e.g., Dolby AC-4 and MPEG-H), which are enabling the transition from channel-based to object-based and enable audio post-processing functions (e.g., Waves Nx 3D audio or Dolby Atmos).

Amazon stepped-up its Echo range with a 2017 update, introducing new models that recognized the fact that many users used it to listen to music.

Cadence's latest HiFi 3z DSP (www.cadence.com/go/hifi3z) provides more than 1.4 times better performance on immersive audio processing, running the most complex algorithms, creating a compelling package for manufacturers working on the latest audio experiences. Tensilica HiFi DSPs are also widely licensed audio/voice/speech processors, with support for more than 200 proven software packages and more than 95 software partners in the Tensilica Xtensions partner program.

Cirrus Logic is another established vendor in this domain, having introduced a development kit for Alexa Voice Service (AVS), optimized for

A typical Sony product, the LF-S50G Wireless Speaker with Google Assistant, combines high-quality sound, with gesture controls, a clock functionality, and an IPX3 splash-proof design with a water-repellant surface. It uses a 360°, vertical two-way facing speaker system for vocal and treble notes, with a dedicated subwoofer and a bass reflex duct.

The Apple HomePod is a high-quality wireless speaker for the home that shamelessly makes use of all the best available technology, including far-field microphones and DSP processing to optimize the built-in drivers.

smart speakers and smart home applications including voice-controlled devices, hands-free portable speakers, and networked speakers. With the Cirrus Logic IC and software design, the Voice Capture Development Kit for Amazon AVS helps manufacturers quickly get to market with new Alexa-enabled products that feature high-accuracy wake-word triggering and command interpretation even in noisy environments and during music playback.

The low power Voice Capture Development Kit for Amazon AVS includes a reference board that features Cirrus Logic's CS47L24 smart codec, CS7250B digital MEMS microphones and SoundClear algorithms for voice control, noise suppression, and echo cancellation. The smart codec uses an on-chip, high-performance digital-to-analog converter (DAC) with a 2 W mono speaker driver to enable high-fidelity audio playback.

The kit, which is available to qualified commercial device manufacturers through Digi-Key, is a complete solution that includes a voice capture board with a high-performance two-microphone array, a Raspberry Pi 3 (RPi3), a speaker, and a microSD card preloaded with all the required firmware for instant productivity.

The ultra-low noise floor and wide dynamic range (130 dB) of Cirrus Logic's MEMS microphones assure precise voice capture in challenging noise conditions, enabling Cirrus Logic's SoundClear algorithms to block noise that would otherwise interfere with Alexa wake word and request accuracy.

Cirrus Logic's portfolio of smart codecs integrates hi-fi DACs, a stereo headphone amp and mono speaker amp to provide OEMs with a low-cost bill of materials for products ranging from high-end speakers to simple digital assistants.

Cirrus Logic's development kit for AVS has other unique features to streamline the development process. The CS47L24 smart codec integrates hi-fi DAC's enhancing audio quality eliminating the need for a separate DAC or codec. The integrated speaker amp also eliminates the need for an external DAC and amp. The entire reference design consumes less than one-fifth the power of solutions with less functions. And the web server-based control and diagnostic console means the device performance can be monitored and optimized remotely from any web browser.

Also, of note for audio product development, Cirrus Logic has introduced the low-power CS43130 MasterHIFI DAC with a headphone amplifier. This new CS43130 DAC operates at four times lower power consumption, supports DSD formats, includes a Non-Oversampling (NOS) filter, and 512 single-bit elements to eliminate unwanted noise from the signal and for the best filter response. The new IC minimizes board space requirements while enabling performance and features to drive design differentiation. This allows support of higher resolution audio "lossless" formats, such as FLAC, ALAC, LDAC, and others, to deliver a higher quality audio experience.

The CS43130 supports Direct Stream Digital (DSD), DSD DoP (DSD over PCM), up to DSD128, and all PCM high-resolution audio formats up to 32-bit 384 kHz. A proprietary DSD processor handles switching between DSD and PCM audio streams, while matching the analog audio output level. The new solution also offers advanced hi-fi filters, allowing OEMs to tune their own signature sound. An analog bypass switch provides easy switching between hi-fi and voice call modes and includes a low power state for voice only. This allows easy integration due to the switch's ability to accept headphone output from a separate codec.

The new CS43130 DAC also features a unique NOS emulation mode—offering a more natural, euphonic sound missing from modern consumer products. The CS43130 features a high impedance of 600 Ω and inter-channel isolation of greater than 110 dB.

This is a gallery of wireless speakers that are based on NXP's platform for voice applications.

To minimize pre-echos and ringing artifacts, the CS43130 is designed with proprietary digital-interpolation filters that support five selectable digital filter responses. Filtering options include low group delay with pseudo-linear phase and a fast or slow roll-off. A minimum phase apodizing low-pass DAC filter reduces pre-ringing, while volume matching of the analog output levels and channel mixing enable a seamless transition between the DSD and PCM playback paths.

The Cirrus Logic CS43130, as well as the DAC-only CS4399 for professional audio, uses 512 individual DACs per channel in an analog/digital filter array to deliver the highest-grade reproduction of high bandwidth, high resolution digital audio sources.

Essential Blocks

For the new generation of smart speakers, Texas Instruments (TI) also offers an extensive portfolio of development solutions and reference designs. TI's audio pre-processing systems designs allow for easy evaluation and development of a DSP-based application for far-field voice processing. TI developed algorithms for beamforming, noise reduction, and other technologies, and offers these designs with reference examples that use different microphone array combinations to acquire the voice signal or perform acoustic response measurements. The evaluation platforms also include GUI-based tools for calculating filter coefficients and easily configuring the input parameters to the DSP—based on the microphone count and array geometry used.

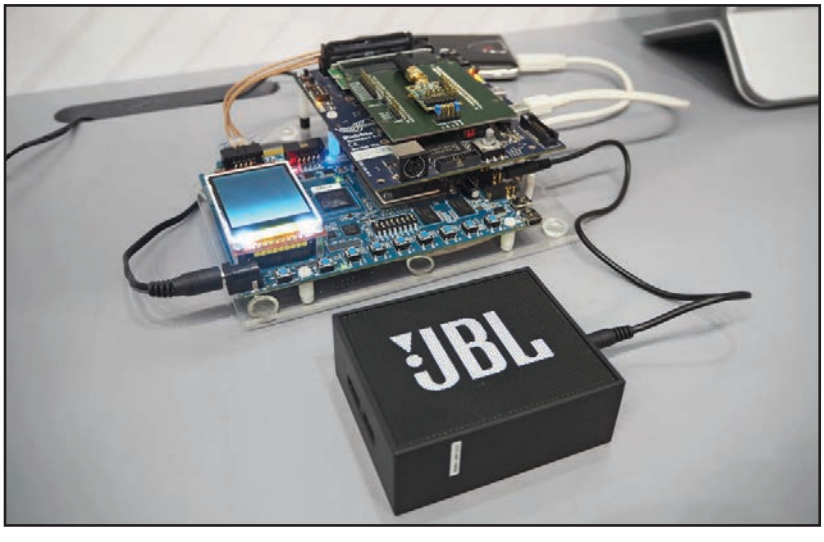
Among TI's current range of solutions, developers can find complete system packages for audio pre-processing with ultra low-power DSP and a four-microphone linear array, audio pre-processing with DSP+ARM SoC, or floating-point DSP, and an eight-microphone circular array, together with the separate four-microphone linear or eight-microphone circular array boards, embedded speech recognition on low-power DSP, and even voice triggering solutions with cloud connections.

TI has developed these flexible platforms for voice processing on DSPs, which work with multiple microphone configurations to help enable voice recognition in voice assistant applications, but also enabling manufacturers to explore beamforming, noise reduction, dynamic range control and more algorithms, with a software application built on TI's Processor SDK, allowing product choice and easy migration among TI's processor portfolio.

Responding to market trends, TI also developed complete system packages for soundbar solutions supporting Dolby Atmos, DTS:X and other immersive audio formats, with an easy-to-use framework and single-chip or multi-chip solutions, and efficient, DSP-based implementations.

Of particular interest in this domain is the extended range of Smart Amplifiers built upon TI's standard Class-D audio amplifiers, providing advanced modeling and algorithms to fully "understand" the target speakers, optimizing the sound without damaging the speaker from either heat or over excursion. TI's Smart Amps also build upon the predictive model by adding real-time, accurate voltage and current sensing to provide feedback to the protection algorithm.

There are many options for product development. ReSpeaker (http://respeaker.io) successfully crowdfunded its open modular voice extension interface that enables interaction with any Internet-equipped device.



New ready-to-use development platforms for smart speakers are now available from many different manufacturers. Pictured is a high-quality audio streaming over BLE reference design from CEVA.

At CES 2018, Qualcomm announced an ambitious program to deliver its Smart Audio Platform with development kits and reference designs to streamline development for manufacturers looking to build smart speaker devices more efficiently.

The Smart Amplifier range includes solutions with high-resolution audio support and superior audio performance, featuring integrated modulators, FETs, and protection to reduce the size and cost of the project.

Another established provider of essential blocks in this field is Synaptics, which has been continuously expanding and perfecting its family of AudioSmart Far-Field Voice DSPs that can be applied in virtually any type of design, from smart speakers to personal audio.

Since Synaptics acquired Conexant Systems in mid 2017, the company added an important portfolio of voice and audio processing solutions, including the company's AudioSmart brand of voice input processors and embedded far-field processing software, currently powering many leading CE products, and including the most popular development kit for Amazon AVS, based on the AudioSmart CX20921 Voice Input Processor.

Libre Wireless Technologies "MAVID" is an entirely new, ultra-low-power embedded voice-enabled multiprotocol wireless connectivity platform

Quickly advancing due to AudioSmart far-field voice technology, Synaptics has been bolstering its industry-leading portfolio of advanced audio hardware and software solutions, including excellent far-field capabilities for voice control of devices from up to five meters away.

According to Synaptics, its AudioSmart two-mic and four-mic advanced voice processing solutions offer comparable performance with fewer microphones, and the company offers complete reference designs, drivers, and tuning tools to expedite product development with any of the voice ecosystems.

Synaptics' AudioSmart four-mic and two-mic development kits enable anyone to quickly prototype and develop high-performance far-field devices with Amazon's Alexa Voice Service (AVS), but Synaptics also offers a complete integrated solution for Microsoft Cortana Devices SDK, with pre-certification for both Cortana and Skype solutions.

Synaptics' far-field voice DSP solution was selected by several leading OEMs because its AudioSmart technology eliminates the requirement for a powerful applications processor and Wi-Fi SoC, reducing cost as well as power—critical in a wireless speaker. Bluetooth speakers using Synaptics AudioSmart far-field voice DSPs can also leverage voice services (e.g., Alexa, Google Assistant, and Bixby), running simply on the users' mobile phone or tablet.

Of interest to speaker designers, Synaptics is able to offer an extended portfolio of sensors and human interface solutions, including touch and gesture recognition, making possible the creation of speakers that are able to automatically adjust and optimize response according to placement, motion, or user interaction.

Chips and Partnerships

The range of development solutions available for smart speakers that can be leveraged by audio manufacturers in general is dramatically expanding, and among some of the most dynamic suppliers we can find are companies focusing on the semiconductor level (e.g., DSP Group, Qualcomm/CSR, ST Microelectronics, XMOS, and Analog Devices), working increasingly in partnerships with the key voice algorithm vendors (e.g., Alango, DSP Concepts, and Sensory) and DSP providers (e.g., Cadence, Ceva, Maxim Integrated Products, Cirrus Logic, and DIRAC).

DSP Concepts (www.dspconcepts.com) is a developer of embedded digital signal processing audio solutions and a specialist in voice UI technologies. Headquartered in Santa Clara, CA, DSP Concepts provides embedded audio digital signal processing solutions delivered through its Audio Weaver platform and specializes in microphone processing as well as playback processing.

Sensory (www.sensory.com) is a leading provider of embedded artificial intelligence (AI) and speech recognition technologies. Sensory's technologies are widely deployed in consumer electronics applications, including mobile phones, automotive, wearables, toys, IoT, and various home electronics. With its TrulyHandsfree voice control, Sensory has set the standard for mobile handset platforms' ultralow-power "always listening" touchless control.

The combination of Sensory's TrulyHandsfree and DSP Concepts' Audio Weaver Voice UI allows for highly accurate, always-listening voice control in battery-powered devices without sacrificing the user experience or battery life.

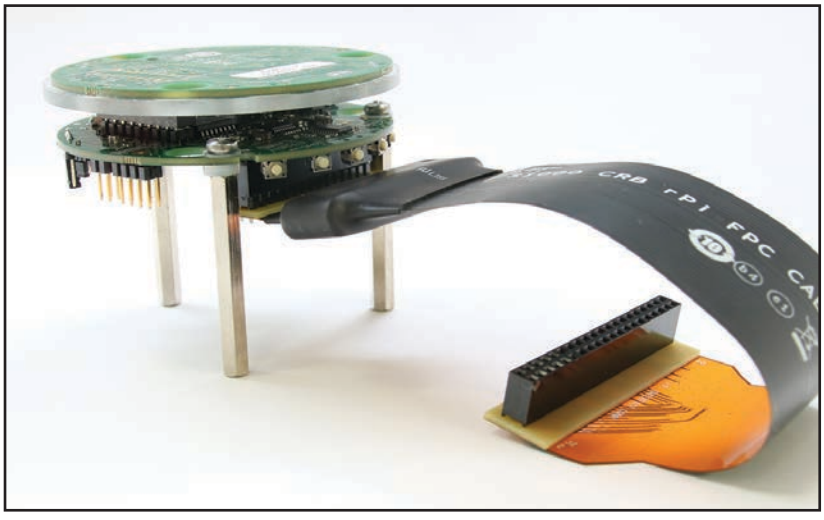
One of the most active technology companies in this domain is a relatively new player, Libre Wireless Technologies (www.librewireless.com), from India.

Libre Wireless first established a strong position in the industry with its scalable Wi-Fi and BlueTooth multi-protocol and multi-source connectivity modules and its extensive LibreSync software, which currently enable many OEMs and ODMs to easily integrate Alexa voice service with their products.

Libre offers a range of Wi-Fi/Bluetooth and voice solutions that deliver optimized media streaming and multi-room audio features along with advanced far field, beamforming, acoustic echo cancellation, wake-word recognition algorithms and on-line/off-line control command recognition to integrate voice at a range of price/performance points. Solutions range from high-performance integrated modules to the smallest and lowest power mic-to-cloud solution for smart home applications.

In 2017, Libre Wireless launched its LS5BV LibreSync module, featuring fully integrated and optimized far-field voice interface capabilities as well as extensive music streaming and multiroom audio features. This small, low power mic-to-cloud module uses DSP Group's SmartVoice technology and HDClear SoC with sophisticated algorithms for detecting and processing far-field voice, including advanced noise reduction, echo cancellation, music barge-in, and audio processing features.

The compact LS5BV module is designed to support one to three microphones, offering flexibility for various applications that can be optimized for cost, front facing 180° or circular 360° applications. The LS5BV offers a clean interface to off-module mics, enabling the product designer ultimate flexibility on mic placement and product integration while providing a simple low-cost interface in a fully integrated mic-to-cloud voice solution. The complete LS5BV smart voice and media streaming platform solution includes support for the LibreSync SDK with it's mic-to-cloud solution and media streaming capability.



In 2017, Intel announced the Intel Speech-Enabling Developer Kit designed for manufacturers and developers to quickly bring new Alexa-enabled products to market. This kit is based on a new DSP architecture from Intel, and features a reference eight-microphone circular array for 360° voice capture, far-field signal processing algorithms, and a custom on-chip wake word engine.

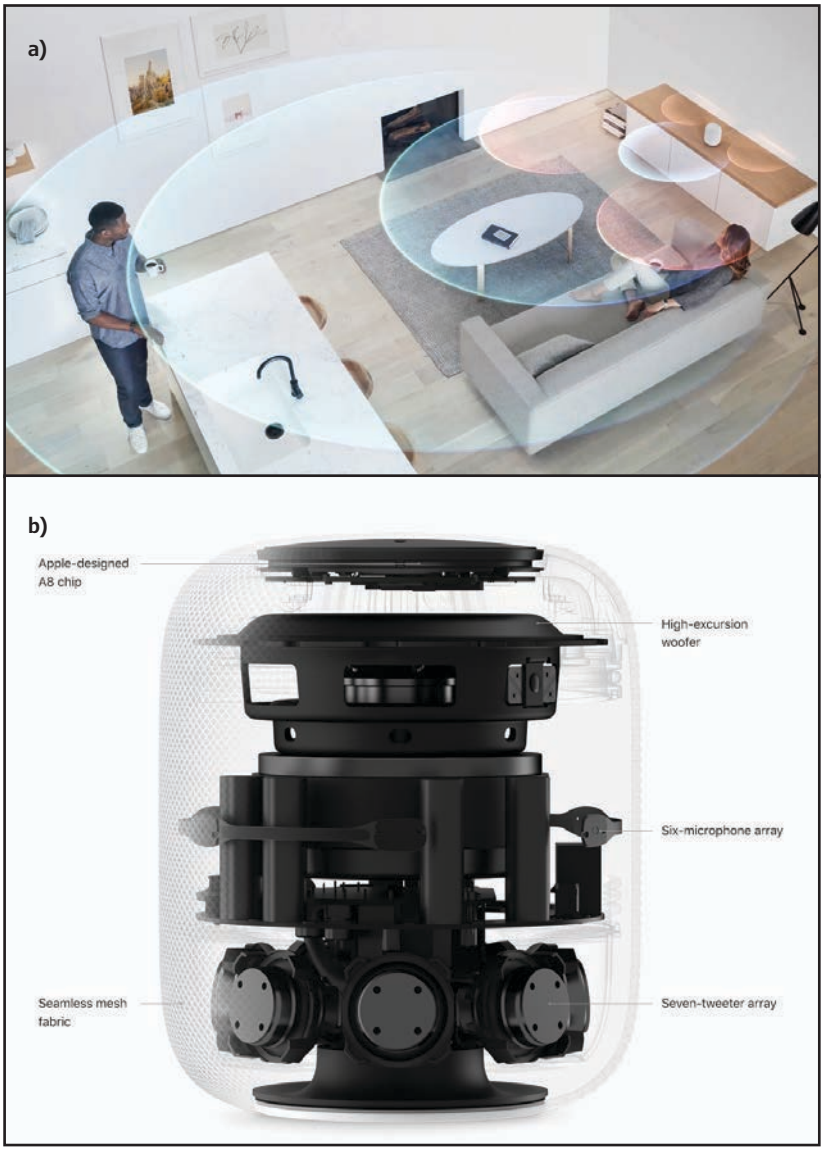
Targeting microphone arrays used in voice-activated systems such as smart speakers, Vesper announced its newest VM2000 high-performance piezoelectric MEMS microphone, ensuring long-term voice performance in harsh environmental conditions. While improving basic specifications for far-field capture, the new VM2000 piezoelectric MEMS microphone adds the strongest level of environmental robustness, further contributing to the reliability of the most demanding applications.

Libre Wireless Technologies also announced its Multiprotocol Audio & Voice IoT Devices (MAVID), an entirely new embedded voice-enabled multiprotocol wireless connectivity and platform to enable OEMs and ODMs to build unique voice-enabled products.

This ultra-low power and incredibly small new device—measuring only 13.5 mm × 13.5mm—incorporates a complete hardware and software solution for embedded voice, IoT, audio, and wireless connectivity, allowing for very small battery-powered, portable, and wearable products. MAVID supports 802.11ac dual band Wi-Fi, Bluetooth audio streaming, BlueTooth Low Energy, far-field voice processing including Automatic Echo Cancellation, beamforming, Wake Word recognition, and Wake-on-voice features along with integrated and embedded memory. MAVID also offers options for adding Zigbee, Thread, LoRa, DECT/ULE, and LTE connectivity for broader interoperability and multiprotocol applications.

This extensive hardware integration is driven by a comprehensive multiprotocol connectivity, all running on a very fast and power-efficient real-time operating system. The MAVID platform also offers scalable device options and software features that enable cost/feature optimized solutions for a myriad of new voice-enabled IoT applications, many of which were not realizable until now.

Supporting Libre Wireless' efforts is DSP Group, which apart from supplying the chip integration, provides its HDClear audio/voice SoC for smart speakers and smart home devices. DSP Group is currently one of the leading providers of wireless chipset solutions, with a broad portfolio of technologies.



The HomePod features a custom array of seven beam-forming tweeters, each with its own amplifier, and with a bottom dispersion waveguide to provide directional control (a). Combined with its "automatic room-sensing technology," the HomePod can quickly learn its position in a room, and within seconds, optimize the driver's response to deliver the best possible music listening experience (b).

Trends to Watch

Loudspeaker designers and manufacturers cannot ignore the proliferation of smart speakers in the last two years, and the fact that music streaming services have already caused the largest turnaround in music consumption since file downloads have replaced the CD as the mainstream distribution format. According to the Recording Industry Association of America (RIAA), growth in revenues from music subscription streaming services in 2017 continued to offset declines in traditional unit-based sales.

Digital revenues were 82% of the total industry in 2017, and overall digital revenues were up 22% in 2017. In 2017, revenues from recorded music in the US increased 16.5% at an estimated retail value to $8.7 billion, continuing the growth from the previous year. These increases came primarily from growth in paid music subscriptions to services such as Spotify, Amazon, Tidal, AppleMusic, Pandora, and others, which grew by more than 50%. This is the first time since 1999 that US music revenues grew materially for two years in a row. At $8.7 billion, the industry has taken a decade to return to the same overall revenue level as 2008, and is still 40% below peak levels from 1999, as the growth from streaming has been offset by continued declines in revenues from both physical and digital unit-based sales.

But there's another strong reason for being

optimistic in the increase in music consumption, and that's directly caused by the smart speaker impact. In the US, UK, and other markets where smart speakers have been widely available (English-speaking countries), the installed base of wireless speakers has quadrupled in just one year. Also, according to market research firm Futuresource, spending on dedicated audio hardware is back in vogue, with the continuing growth in the headphones market, and the smart speaker segment driving digital music consumption. And Futuresouce's consumer research indicates that 30% of smart speaker owners use it to discover new music, while over three-quarters of these do so every day.

Futuresource predicts that the smart speaker category is set to double once more in 2018. In large markets, such as China, the smart speaker market exploded in the first months of 2018, with Chinese platforms Alibaba, Baidu, and many others striving to replicate Amazon Alexa's success.

Apple HomePod Reference

Apple launched its $349 HomePod on February 9, 2018. Much in the same way as the first iPhone was limited and didn't actually support the absolutely needed broadband connectivity, now the HomePod is a great speaker that sounds better than anything in its class but is being received with criticism because of its limitations. And yet, the HomePod actually delivers on introducing the latest technology that defines a "smart speaker" such as using the latest sensors for spatial awareness (tuning itself to optimize reproduction) and far-field voice detection.

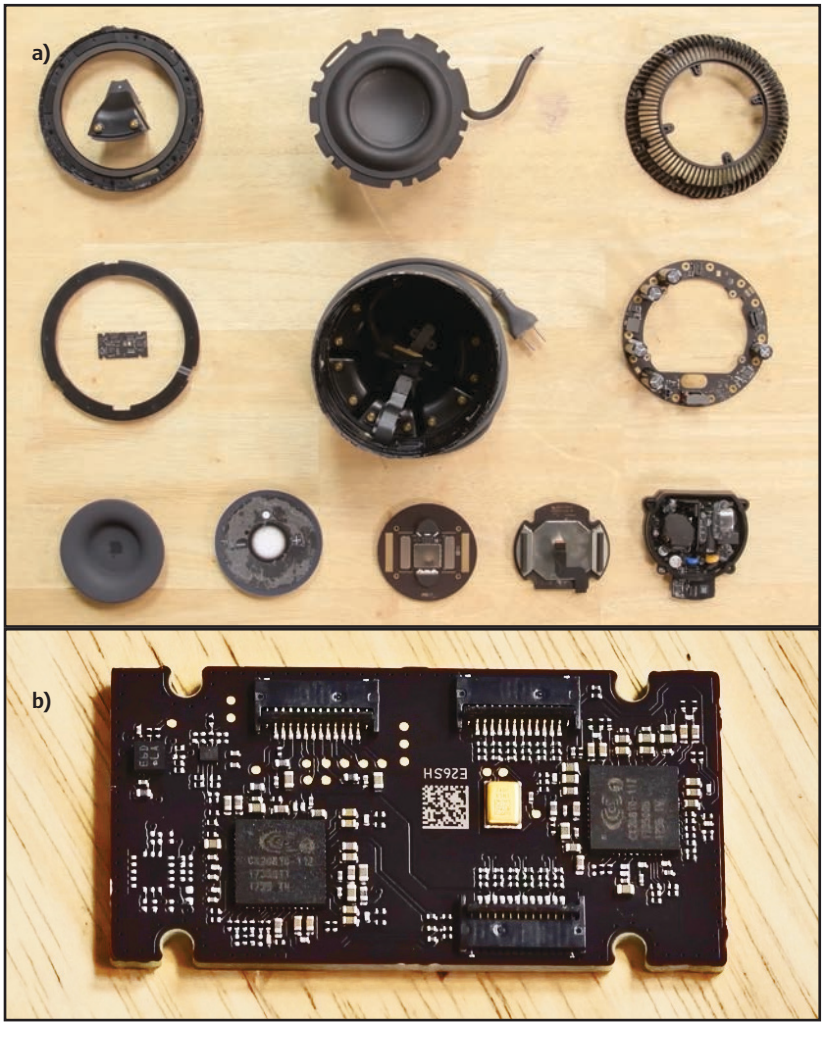
With the introduction of AirPlay 2, the HomePod will gain essential features (e.g., stereo pairing and multi-room connectivity). Other speaker brands such as Sonos, Bang & Olufsen, Naim, Bose, Devialet, Dynaudio, Polk, Denon, McIntosh, Marantz, Bowers & Wilkins, Libratone, Definitive Technology, BlueSound, and Apple's own Beats will all have AirPlay 2 compatible speakers.

Also, as many reviewers already noted, when Siri works in far-field mode on the HomePod, it can truly shine in terms of voice recognition—but unfortunately, it is not yet connected to the world of services that a Google search engine can provide and is not able to be Alexa with its "box of tricks" provided by third-party skills and voice-commands.

In general, HomePod's construction is a wonder—the fabric mesh, the drivers, and the microphone array. No wonder HomePod reviewers all acknowledge the stunning design, the quality of construction, its robustness, the performance, and the sound quality, unlike any other in the "smart speaker" category.

The HomePod is able to fill any room with sound wherever it is placed and performs much better than larger speakers (e.g., the Google Home Max or any Alexa-enabled or Google Assistant available speaker) with much less distortion when pushed to its loudest. In that regard, Apple's speaker designers did their job. Also, the microphone array and the ability to detect the wake-up words "Hey Siri" and understand voice commands while the music is playing seems to be superior to all rival systems.

On the other hand, it's impossible not to note that since it can only be used with Apple Music—for now—its appeal compared with any other similar device is severely restricted.



a: The Apple HomePod teardown. b: In detail is the Apple HomePod's internal low-frequency calibration microphone module for automatic bass correction. We can recognize the Conexant Systems logo, now a subsidiary of Synaptics (Photos courtesy of iFixit)

Still, as reviewers have noted, the HomePod does best what is supposed to do well—playing music! Our friend Brian Hamilton from NTi Audio did some measurements for Fast Company and "surprise, surprise," the HomePod is "legit" and remarkably good! The most relevant of measured performance being its remarkably low distortion. What else would you expect from Apple's team, and the combination of the most cutting-edge internal calibration for automatic response correction, direct and ambient audio beamforming, and the best-available dynamic processing ever integrated on a speaker? Fast Company's conclusion is that "Apple's definition of 'smart' speaker might simply be different than the common understanding," meaning "sound smart."

The HomePod will get better with an upgrade, and the HomePod 2 (or the Plus) will eventually be the a true market reference. By that time, hopefully, everyone will already understand exactly what you can do with voice commands and, eventually the real race for natural language recognition will seriously start. By then, no one will remember the earlier efforts with voice... Apple knows that voice recognition is in its infancy, and like always, will tune its strategy depending on those very things that users will actually use and value.

With the HomePod, Apple focused on the fundamentals. This is a reference design using all the available tools that have been available to the audio industry for some time, and have put together very well. This speaker makes other respectful products sound dull in comparison, and audio manufacturers will do better to step up their designs and be "sound smart." ***LIS***

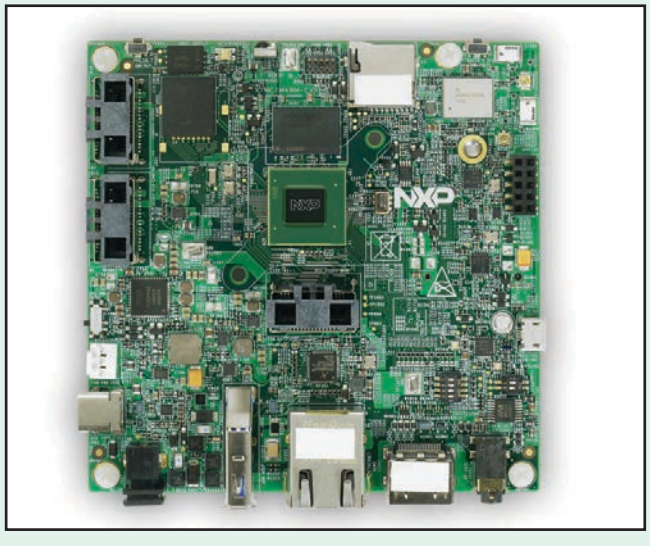
NXP i.MX 8M Application Processors

During CES 2018, NXP Semiconductors had the most impressive presence among semiconductor manufacturers. To address the convergence of immersive sensory experiences fueled by voice, video, and audio demands, NXP has launched the i.MX 8M family of applications processors, combining robust media capabilities on one single chip.

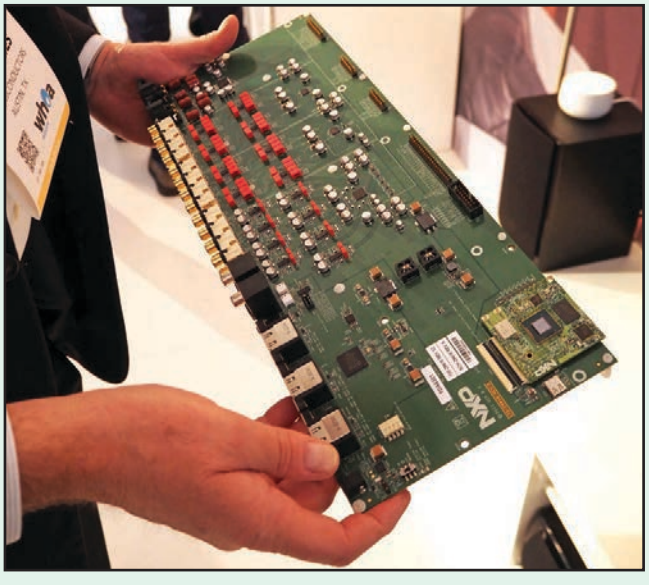
The NXP i.MX 8M 64-bit processors address designers' requirements for one platform that combines A/V and machine learning to create connected products that can be controlled via voice command. The chips provide the process technology and edge computing needs to manage and reduce the command and question response time of smart connected devices.

Designed for scalability and pin-and-power compatibility, NXP's i.MX 8M family combines full 4K Ultra HD resolution, high dynamic range (HDR), and the highest levels of pro-audio fidelity, with up to four 1.5 GHz Arm Cortex-A53 cores, flexible memory options, and high-speed interfaces for flexible connectivity, and advanced Human Machine Interface (HMI) applications.

www.nxp.com



Evaluation Kit for the i.MX 8M Applications Processor. The board enables HDMI out, offers LPDDR4, eMMC, QSPI, SDMicro memory options, 10/100/1000 Ethernet port, USB 3.0 connectors, and PCIe Interface high-speed interfaces. The system supports 32-bit audio with up to 768 kHz sampling rate.



Detail of the new soundbar reference design from NXP, featuring the new i.MX.8M processor.

XMOS Advanced True Stereo Voice Interface Solutions

XMOS is a leading supplier of voice and audio solutions to the consumer electronics market, with a unique silicon architecture and highly differentiated software for audio and voice processing. XMOS VocalFusion voice processors deliver sophisticated voice digital signal processing (DSP) including a full duplex acoustic echo canceller (AEC) with barge-in capability that enables users to interrupt or pause a device that's playing music, and an adaptive beamformer that follows a speaker. Additional sophisticated dereverberation, automatic gain control, and noise suppression provide crystal clear voice interaction experiences even in noisy environments, in a single device. The processor interfaces directly to four PDM microphones in a linear array with 33.33 mm inter-mic spacing—making it ideal for integration into flat screens and products found "at the edge of the room."

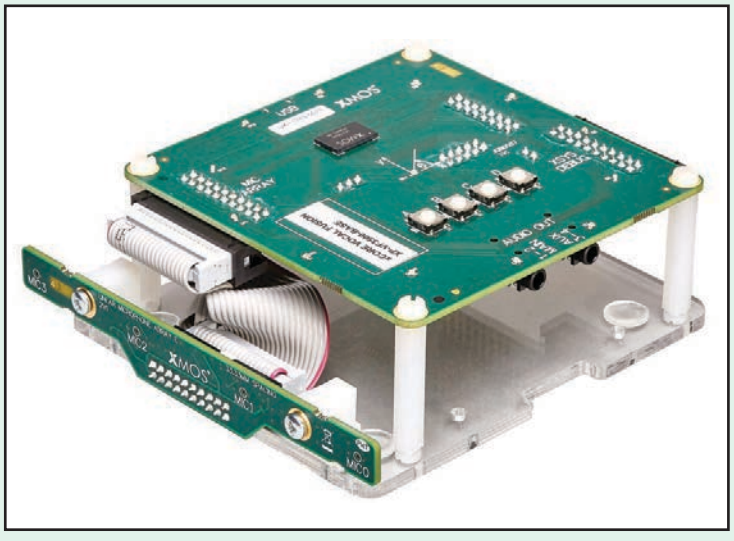
The company's extensive portfolio of VocalFusion true stereo voice capture solutions is already powering multiple far-field voice-enabled stereo smart TVs, soundbars, and set-top boxes (STBs) in the market. More recently, XMOS previewed its next-generation VocalSorcery advanced blind source separation technology, capturing voice commands for use in Alexa, Google, DuerOS or other voice enabled AI and IoT systems.

In home electronics devices, the VocalFusion Stereo Development Kit accurately captures voice commands from across the room, even in complex noisy environments, and when the same audio appliance is playing content at high volume. This development kit is the world's first stereo acoustic echo cancellation (AEC) far-field linear microphone array solution. Uniquely, the solution also supports configurable AEC latency, where the AEC reference signals can be accurately calibrated, and the latency adjusted, to enable after-market far-field voice accessories for existing consumer electronics products.

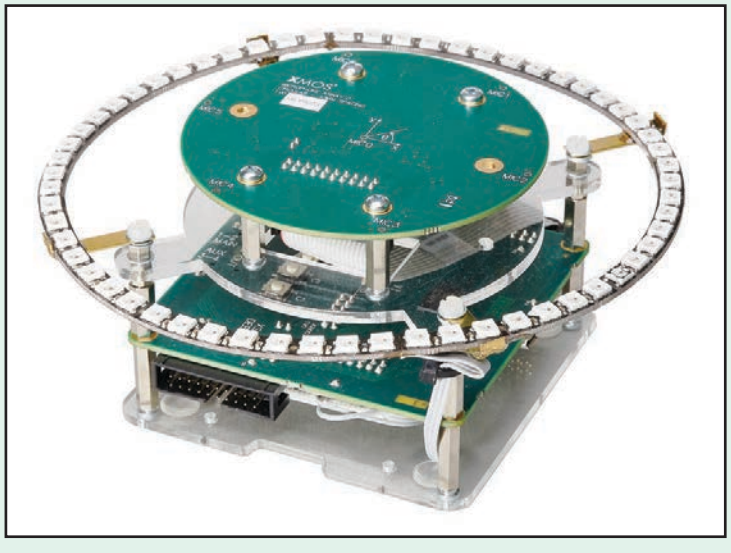
VocalSorcery is an advanced blind sound source signal separation technology that spatially identifies individual speakers or conversations within a crowded noisy audio environment to optimize voice capture and input into speech recognition systems. This technology elegantly solves the cocktail party problem, and opens up a wide variety of applications from video and conference calls to automotive. The technology could be used for example to diarize voice conferences, and give a full transcript, by speaker of multi-person conversations, and ensure that all speakers on a conference call are heard with equal volume.

Anyone who has seen the private demonstrations of XMOS' new stereo-AEC voice capture and blind sound source separation technologies understands why the British company is leading the market in advanced embedded voice and audio solutions to the consumer electronics market.

www.xmos.com



XMOS VocalFusion Stereo Evaluation Kit (XK-VF3500-L33) delivers two-channel full duplex acoustic echo cancellation (AEC), along with the world's first stereo AEC far-field linear microphone array solution.



The XMOS VocalSorcery demonstration kit enables source signal separation technology within a crowded noisy audio environment.

Qualcomm Smart Audio Platform and Speaker Development Kits

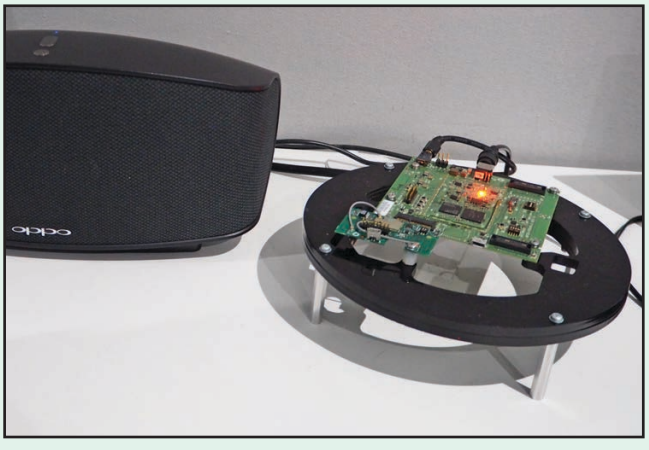
Following earlier demonstrations at CES 2018, Qualcomm introduced a series of new platforms, SoC and development kits targeting new advanced audio applications and smart speakers, including the support of key wireless technologies, voice, and cloud ecosystems. Solutions include its Smart Audio Platform optimized for smart speakers, a six-microphone far-field voice platform qualified for Amazon AVS, Dolby Audio implementations for wireless speakers and much more.

Providing technologies and complete development solutions for manufacturers based on Qualcomm's key platforms has been a focus for the San Diego, CA, company in the last two years. With market requirements for smart speakers now high on the priority list, Qualcomm has accelerated the introduction of development platforms for all market needs. This includes platforms with support for Alibaba AI Voice, Amazon Alexa, Baidu DuerOS, Google Assistant, and Microsoft Cortana.

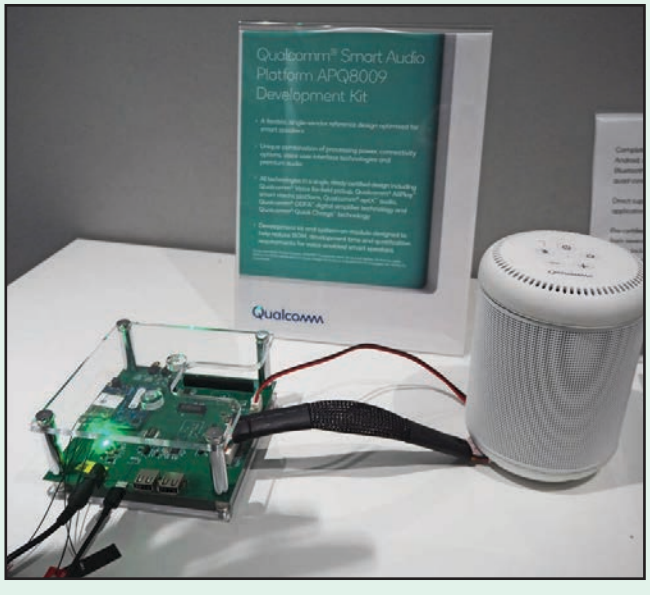
Originally announced in June 2017, Qualcomm's Smart Audio Platform was designed to help manufacturers accelerate the development and commercialization of smart and networked speakers. The platform offers integrated hi-fi audio playback and post-processing algorithms for premium sound quality, Qualcomm AllPlay multi-room and multi-channel networking solution for whole-home synchronized audio streaming, and advanced application processing capabilities for a customizable and responsive user experience.

The flexible solution offers two Qualcomm SoC options based on APQ8009 and APQ8017, with a range of software configurations that are designed to enable OEMs to create optimized smart speakers across various product tiers and categories. The integrated platform brings together a unique combination of processing capability, connectivity options, voice user interfaces, and premium audio technologies to help meet increasing consumer demand for comprehensively featured, highly intuitive smart speakers.

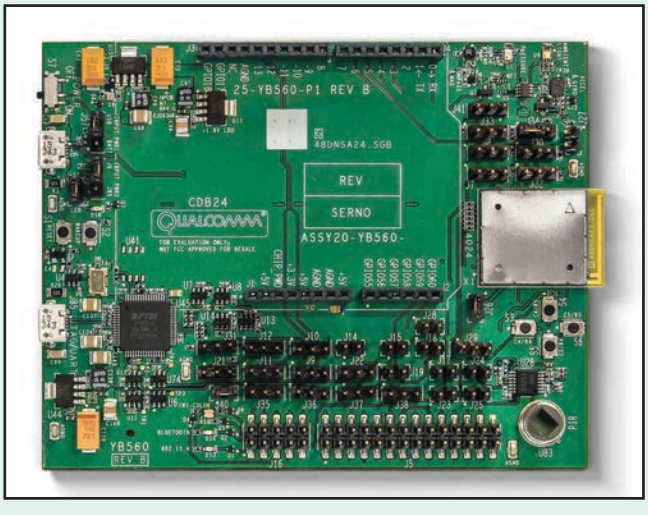
The platform is designed to be a unique end-to-end single-vendor smart speaker solution integrating Qualcomm's unique and powerful processing, as well as proprietary audio technologies engineered for high-resolution audio, networked



A demonstration of Dolby Audio for Wireless Speakers running on the Hexagon DSP with APQ8009 SoC, integrated in Qualcomm's Smart Audio Platform.



Built on Qualcomm's Smart Audio Platform, this development kit features a Wi-Fi certified System-on-Module (SoM) that integrates the key system components, helping to reduce development time and overall design cost.



Qualcomm QCA4024's development kit board

Some of the products in the market using Qualcomm's Smart Audio Platform include the Cleer Space Smart Home Speaker and the Raven H intelligent device with Baidu's DuerOS conversational AI operating system.

audio, echo cancellation, beamforming, noise suppression, and barge-in wake-word detection. With support for both Linux and Android Things operating systems, as well as voice services from major cloud providers, the Smart Audio Platform offers manufacturers a variety of choices to help them participate in the growing smart speaker opportunity.

The available development kit includes schematics and design files to support easier customization and differentiation in the manufacturers' products. Manufacturers can use a single design for different SKUs with varying operating systems and capabilities, which helps to improve cost efficiency and reduce development time.

Qualcomm Smart Audio Platform is already qualified by Amazon for the Alexa Voice Service (AVS).

Additionally, the development kit offers a reference design for smart speaker devices. This reference design features a six-microphone array and speaker housing to support far-field voice interface and high-performance wake-word detection—including barge-in capabilities supported by echo cancellation technology, pre-tuned to the hardware. The speaker housing is designed for a rich 360° sound experience.

Other key features of the Qualcomm Smart Audio Platform include a quad-core ARM A53 processor and integrated Qualcomm Hexagon audio DSP, dual band 802.11ac Wi-Fi (1x1 and 2x2 options), Bluetooth 4.2 + Bluetooth Low Energy (BLE) with support for key profiles such as A2DP source/sink, AVRCP, SPP, HFP, PAN, NAP, AVCTP, AVDTP, PBAP, RSP/Wake on BLE, and high-performance audio encode/decode with Qualcomm aptX and aptX HD. Audio playback supports a wide range of industry audio codecs including MP3, AAC, Ogg Vorbis, FLAC, AIFF, WAV, PCM, ALAC, with high-performance Bluetooth/Wi-Fi coexistence for optimal audio performance.

More recently, Qualcomm introduced its new highly integrated development kits based on QCA4020 and QCA4024 system-on-chips (SoCs—https://developer.qualcomm.com/qca402x), designed to help developers and device manufacturers create unique connected products that work in concert with a wide variety of other devices and cloud ecosystems. These specific kits are designed for all sort for connected applications in all types of home entertainment devices.

www.qualcomm.com

Knowles Offers Machine Learning Optimized Audio Processor for Complex Voice Interactions

When mentioning smart speaker development and voice recognition in general, Knowles is known as a leading supplier of MEMS microphones for such applications. But recently Knowles has considerably expanded its reach with the announcement of a new audio processor platform, the IA8508 open DSP, combining four high-performance, power efficient, heterogeneous cores, and 5.7 MB of shared memory for a variety of new use cases.

The Knowles IA8508 advanced audio processor is optimized for performance and power in both near- and far-field voice applications—making it a perfect solution for ear-worn products, and any digital assistant devices, including smart speakers.

The IA8508 platform improves recognition especially in far-field and high noise environments, enabling context awareness, and increasing local processing capability. Of particular interest is the fact that the solution enables developers to move audio processing to the edge of the network—embedding intelligence into the device where it is closer to the user and the environment.

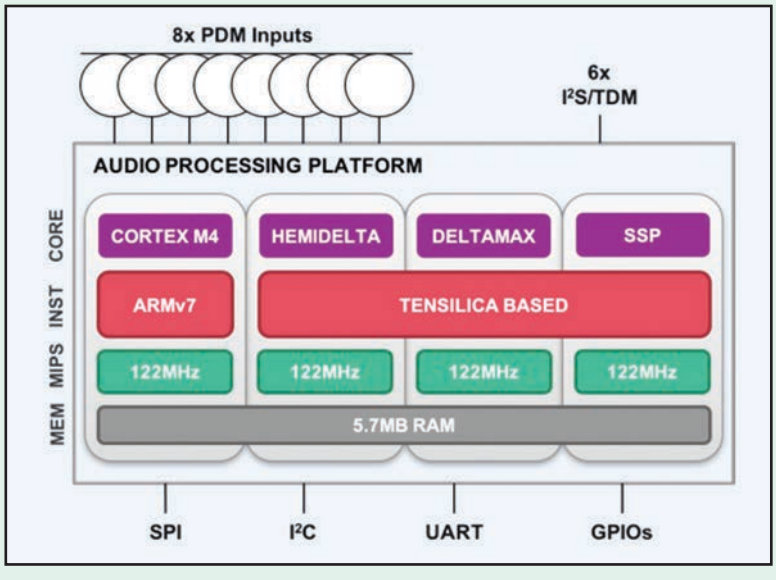
Furthermore, the IA8508 is designed for Machine Learning (ML) through Deep Neural Network (DNN) hardware acceleration, optimized architecture and proprietary instruction set. As a result, the new Knowles' audio processor can perform specific machine learning tasks very efficiently. In addition, the IA8508 leverages lightweight floating point operations, enabling ease of programmability, high dynamic range, and low power comparable to fixed point operations.

Knowles' unique combination of four heterogeneous processors sets the IA8508 apart in four major ways. First, to solve issues related to noise and distance, device makers need the ability to combine a multi-microphone array with large memory, powerful computing, and sophisticated algorithm features including acoustic echo cancellation (AEC), dynamic beamforming, steering, sound classification, and noise suppression.

Second, latency. Many audio applications require low-latency real-time processing (e.g., active noise cancellation and asynchronous sample rate conversion) for mixing of various different audio signal sources. The IA8508 has an optimized single sample processor (SSP) core, guaranteeing low latency.

Third, power consumption. Voice user-interfaces require always-listening devices. The IA8508 features a low power core to listen to a variety of key phrases concurrently. In addition, complex audio processing and ML run more efficiently due to the optimized instruction set. The Hemi-Delta core (HMD) is tailored to guarantee low power dynamic processing. In addition, proprietary memory architecture and dynamic voltage scaling guarantee low stand-by power consumption.

And fourth, integration. While the above DSP cores are optimized for performance, latency, and power efficiency, the IA8508 also includes an industry standard ARM Cortex M4 core for general purpose controller capability, allowing for immediate porting of existing legacy solutions.



The IA8508 is a multi-core, high-performance, ultra-low power audio processing platform optimized for mobile, ear-worn and IoT products with Open DSP flexibility and a host of connectivity options.

Open DSP Partner Program

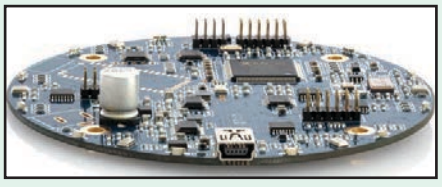
In 2017, Knowles announced the world's first smart mic with an embedded open DSP, the IA-610. Since then, the company has continued to add world-class partners to leverage its open DSP platforms, and successfully enabled integration of Sensory's TrulyHandsfree technology, while DSP Concepts provided a graphical audio design framework for their OpenDSP architecture.

The Knowles OpenDSP platform environment also enables integration of Audio Analytic's ai3 sound recognition software, while sensor specialists Prontoly provides audio-based secure connection, distance measurement, pairing, and authentication between devices.

Knowles plans to continue expanding this program, collaborating with algorithm and cloud partners to develop and run code on its processors for solving complex audio problems.

www.knowles.com/IA8508

miniDSP UMA-8 USB Microphone Array for Voice-Activated Applications



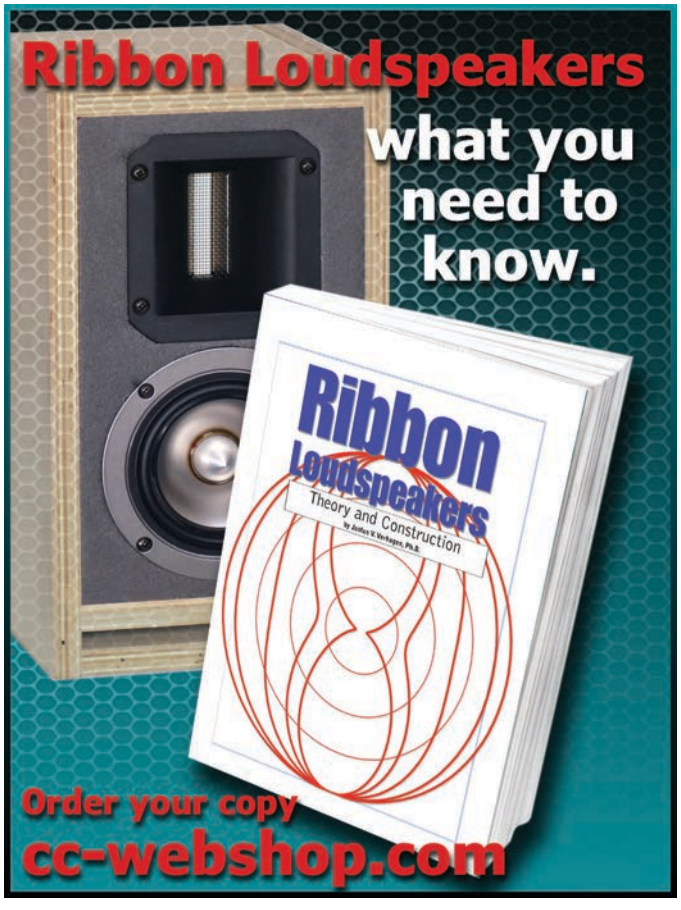
The miniDSP UMA-8 is a high-performance, yet low-cost multi-channel USB microphone array built around XMOS multicore technology, designed for voice-recognition application development. Seven high-performance MEMS microphones are configured in a circular arrangement to provide high-quality voice capture for a wide range of applications. Leveraging the onboard DSP processing, the UMA-8 supports voice algorithms including beamforming, noise reduction, acoustic echo cancellation, and de-reverb.

Developed with applications in voice-activated control, smart assistants, robotics, conferencing, and more in mind, the UMA-8 pocket-size platform targets both DIYers and the OEM market, and was engineered for flexibility in firmware, software, and hardware. All the resources are available for application development, including precompiled firmware versions, expansion connectors providing connectivity for additional PDM microphones, I²S in/out expansion, and GPIO. According to miniDSP, this will allow even non-technical users to enjoy a plug & play experience, while advanced users can fine-tune all the DSP parameters with a real-time Win/Mac GUI for optimum performance.

For advanced users, full control and configuration of the DSP array processing parameters are available with a real-time GUI. This can be used to fine-tune the various algorithms: acoustic echo cancellation, noise reduction, voice activation detect, and so on, dramatically improving voice pickup. The UMA-8 board is a fully compliant UAC2 audio interface with driverless support for Mac/Linux and ASIO drivers for Windows. With its USB API for direction of arrival, eight-channel raw audio mode via USB Audio, and PDM to I²S conversion, the new miniDSP board offers the level of flexibility demanded by developers.

The UMA-8 is available at $95 US per unit on miniDSP's webshop. Step-by-step application notes are available for set up and configuration of the UMA-8 with the most common smart assistants currently available, including Amazon Alexa Voice + Raspberry Pi, Microsoft Cortana, and Apple Siri.

www.minidsp.com/products/usb-audio-interface/uma-8-microphone-array



The (Wireless) Home Theater Revolution

By
Tony Ostrom
(President of WiSA)

Movies. Music. Gaming. Sports. Concerts. These all represent different pockets of over-the-top (OTT) content that comes into our homes in surround-sound formats and continues to dominate the entertainment industry. OTT sources supporting surround sound formats account for approximately 70% of OTT viewing time in households and billions of hours in programming every week (see **Figure 1**).

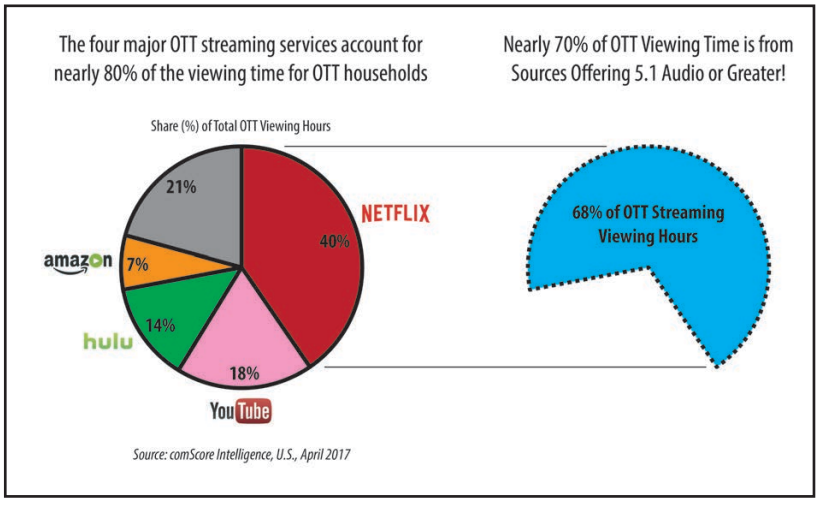


Figure 1: The four major OTT streaming services account for nearly 80% of the viewing time for OTT households.

This shift in entertainment consumption over the last decade has created steady demand for simple and easy-to-use powered audio solutions. However, these devices all too often don't present the same levels of power and definition comprised of component speakers, elevating the demand for high-quality home theater solutions.

This easy access to surround sound content and desire for powerful audio has placed the true home theater industry on the brink of a resurgence. With new studies revealing that manufacturers and retailers need to make high-definition audio systems a higher priority, home theater systems are poised to pave a new foundation of profitability.

However, for the home theater industry to truly be successful, the installation and control experience needs to be extremely simple for consumers. Simply put, it needs to be free from complexities, including time consuming setup and running speaker wires (**see Figure 2**).

The Demand for Wireless, High-Definition Home Theater

The days of complex, passive systems with multiple wire runs continue to fade away. Today's

consumers desire simple, powered solutions that improve the home theater experience and promote high-quality audio while also assuring interoperability among their favorite products and brands.

With the wireless audio marketplace expected to almost double from $16.13 billion in 2017 to $31.80 billion in 2023 (marketsandmarkets.com), this industry shift has provided speaker manufacturers and retailers with vast potential to create an extremely simple yet exceptional home theater experience that is uncompromising on performance. Yet, most home theater systems still require a myriad of wires and are often complicated to connect and install.

Fortunately, the consumer electronic (CE) industry has access to innovative technology that improves the home theater experience by standardizing and promoting quality, multi-channel, wireless audio while assuring interoperability. Numerous early adopters—including Bang & Olufsen, Klipsch, Enclave, and Axiim—have already integrated this technology into high-performance systems, which have been well-received by a large consumer audience.

The wireless industry will continue to see more speaker brands creating an assortment of products as well as "source brands," such as TV and gaming system manufacturers, incorporating the transmission of wireless home theater audio. This momentum will make it easier for consumer electronics retailers to sell interoperable sources and speakers that enable consumers to build systems that are right for their needs and budgets.

Fueling the Wireless Revolution

The wireless revolution has never been louder as it continues its climb alongside many catalysts to helping position it at the frontline of the industry. And while many key factors are contributing to the burgeoning appetite of consumers who demand more convenient, high-performance wireless audio, heightened adoption and implementation across the industry is necessary for the resurgence of true home theater.

This makes it vital for retailers, manufacturers, and industry influencers to be committed to accelerating the process by effectively communicating the benefits of interoperable, high-definition, wireless home theater and integrating the technology into future systems. By working together, we can create a truly simple yet exceptional home theater experience that is uncompromising in performance and adheres to the desires of consumers worldwide. ***LIS***

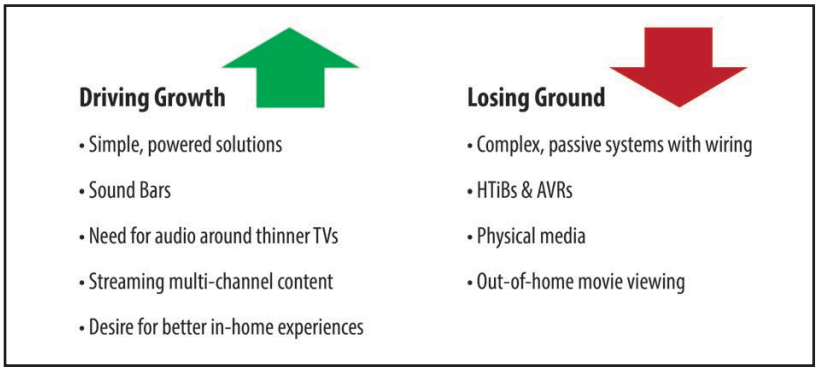
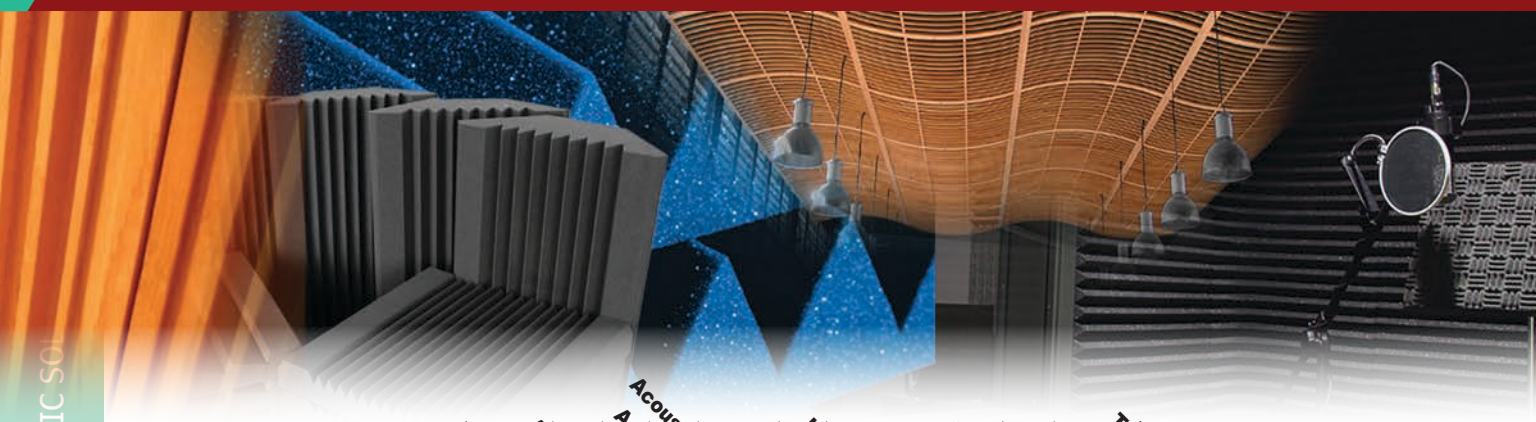


Figure 2: The ability to continue growth and address weaknesses will determine the success of the home theater industry.

About the Author

Tony Ostrom is president of the Wireless Speaker & Audio (WiSA) Association, an industry group dedicated to bringing the industry's only fully interoperable, high resolution, multi-channel wireless audio capability to consumer and professional products. His 25-year career in the consumer electronics industry has been focused on product planning and development, consumer research, go-to-market planning, technology integration, marketing, and training.



	Acoustic Consultancy Services & Design	Acoustic Doors	Acoustic Measurement	Acoustic Treatment Panels	Electroacoustical System Design	Home Theater Design	TV System Design	Multimedia and	Noise Control	Sound Booths	Sound Isolation	Theater and Concert Hall Design	
AUSTRALIA													
DEQX Pty., Ltd.									•				
Soundlabs Group Pty., Ltd.					•								
BELGIUM													
Premium Sound Solutions						•							
BRAZIL													
Phix Eletronics	•						•		•			•	
CANADA													
DLC Loudspeaker R&D Group	•			•									
Rutherford Audio, Inc.				•	•		•				•		
Solen Electronique, Inc.				•								•	
CHINA													
Lumi Audio	•			•			•						
Shenzhen Malata Mobile Communications, Co., Ltd.						•							
Trueanalog Strictly OEM				•		•	•					•	
DENMARK													
K & K Development				•									
PointSource Acoustics ApS	•			•		•							
FRANCE													
KYU Systems	•												
Supravox						•							
The Concrete Family	•						•		•				
GERMANY													
Klippel GmbH				•									
Lautsprecher-Produktions-Gesellschaft (LPG) mbH				•									
Physical Lab	•			•									
Soundsgood Pro Audio Solutions	•			•									
Voice Point	•		•	•	•	•	•		•	•	•	•	
HONG KONG													
Eastern Asia Technology (HK), Ltd.						•							
miniDSP				•	•								
INDIA													
GM Audio Technics, Ltd.	•			•	•								
Power Electronics & Technologies	•						•						
IRELAND													
Crossover App				•									

	Acoustic Consultancy Services & Design	Acoustic Doors	Acoustic Measurement	Acoustic Treatment Panels	Electroacoustical System Design	Home Theater Design	TV System Design	Multimedia and	Noise Control	Sound Booths	Sound Isolation	Theater and Concert Hall Design	
ISRAEL													
Chorus Audio				•		•	•	•					
ITALY													
RCF, SpA	•												
SpeakerLAB	•			•									
JAPAN													
Etani Electronics Co., Ltd.				•						•		•	
LATVIA													
Acoustic Power Lab				•		•	•	•					
MEXICO													
Aletheia, AV	•											•	
NETHERLANDS													
Kamperman Engineering	•			•						•			
Sound Projects	•												
NEW ZEALAND													
Asona	•		•		•		•	•	•				
NORWAY													
SEAS Fabrikker, AS				•									
POLAND													
Resnatura Audio				•									
PORTUGAL													
Jocavi Acoustic Panels, Lda.					•							•	
Vicoustic	•		•	•	•	•	•	•	•	•	•	•	
ROMANIA													
SC Poweraudio, SRL	•			•		•				•			
SPAIN													
Brusi Acoustics	•			•									
TAIWAN													
Kingstate Electronics Corp.	•			•									
Yung International, Inc.								•	•				
THAILAND													
Clarasonic (Thailand) Co., Ltd.												•	
UKRAINE													
Mag Audio	•			•									
UNITED KINGDOM													
CE Electro-Acoustics	•												
EuroTec International, Plc.				•		•					•		
Interfacio, Ltd.						•							
Tectonic Elements, Ltd.	•												
UNITED STATES													
AcousTex Fabrics			•		•			•					
Acoustic Fields	•		•	•	•			•		•	•	•	
Acoustics First Corp.	•			•	•			•		•	•	•	
Adrian Acoustics, Inc.					•								
American Bass USA	•									•		•	

	Acoustic Consultancy Services & Design	Acoustic Doors	Acoustic Measurement	Acoustic Treatment Panels	Electroacoustical System Design	Home Theater Design	TV System Design	Multimedia and	Noise Control	Sound Booths	Sound Isolation	Theater and Concert Hall Design
AtlasIED										•		•
Audio Precision, Inc.				•								
Audio-Optix	•				•			•				•
B&H Photo Video					•					•		•
Barefoot Sound, LLC						•						
Beach Dynamics	•	•		•	•					•	•	•
Broad Bridge Audio, LLC											•	•
Campanella Associates & Acculab	•			•				•		•		•
Carl Tatz Design, LLC	•	•		•	•					•	•	•
D. L. Adams Associates, Inc.	•					•			•	•		•
Dayton Audio	•											
Dragonfire Acoustics	•							•	•			
DTV Installations, LLC										•		
ETS-Lindgren	•	•		•	•					•	•	•
Excelsior Audio Design & Services, LLC						•						
Front End Audio, LLC					•					•		•
Full Compass Systems, Ltd.		•		•	•					•		
GGEC America, Inc.				•								
HDSound	•							•				
HEAD acoustics, Inc.				•								
Hearing Components, Inc. (Comply Memory Foam Tips)										•		•
HX Audio Lab	•			•		•				•		•
J&F Wood Products					•							
JP Electronics Design	•			•		•		•	•			
Meyer Sound Laboratories, Inc.					•	•						
MSC Software Corp.				•						•		
NedLab	•											
NTi Audio, Inc.				•								
ORCA Design And Manufacturing					•							
Parts Express				•						•	•	•
PCB Piezotronics, Inc.				•						•		
Ponderosa Sound Systems	•				•	•		•		•		•
PR Audio				•								
RealTraps, LLC	•				•							
Redco Audio					•							
Scantek, Inc.				•						•		
Soundoctor				•								
Speaker Clinic	•			•								
Spectrum Audio					•					•		•
Stetron International, Inc.	•			•								
Studio Six Digital				•								
SVS, Inc.												•
Sweetwater Sound		•			•					•		•
THX, Ltd.								•				
TMI Engineering	•	•		•	•	•		•	•	•	•	•
True Technologies, Inc.	•			•		•						
US Enclosure Co.	•	•			•					•	•	•
Vintage King Audio					•					•		•
Warkwyn	•			•								
Westlake Audio, Inc.	•											
Wired 4 Sound, Inc.	•				•			•	•	•		•
Wisdom Audio								•				

Engineering Consulting for the Audio Community

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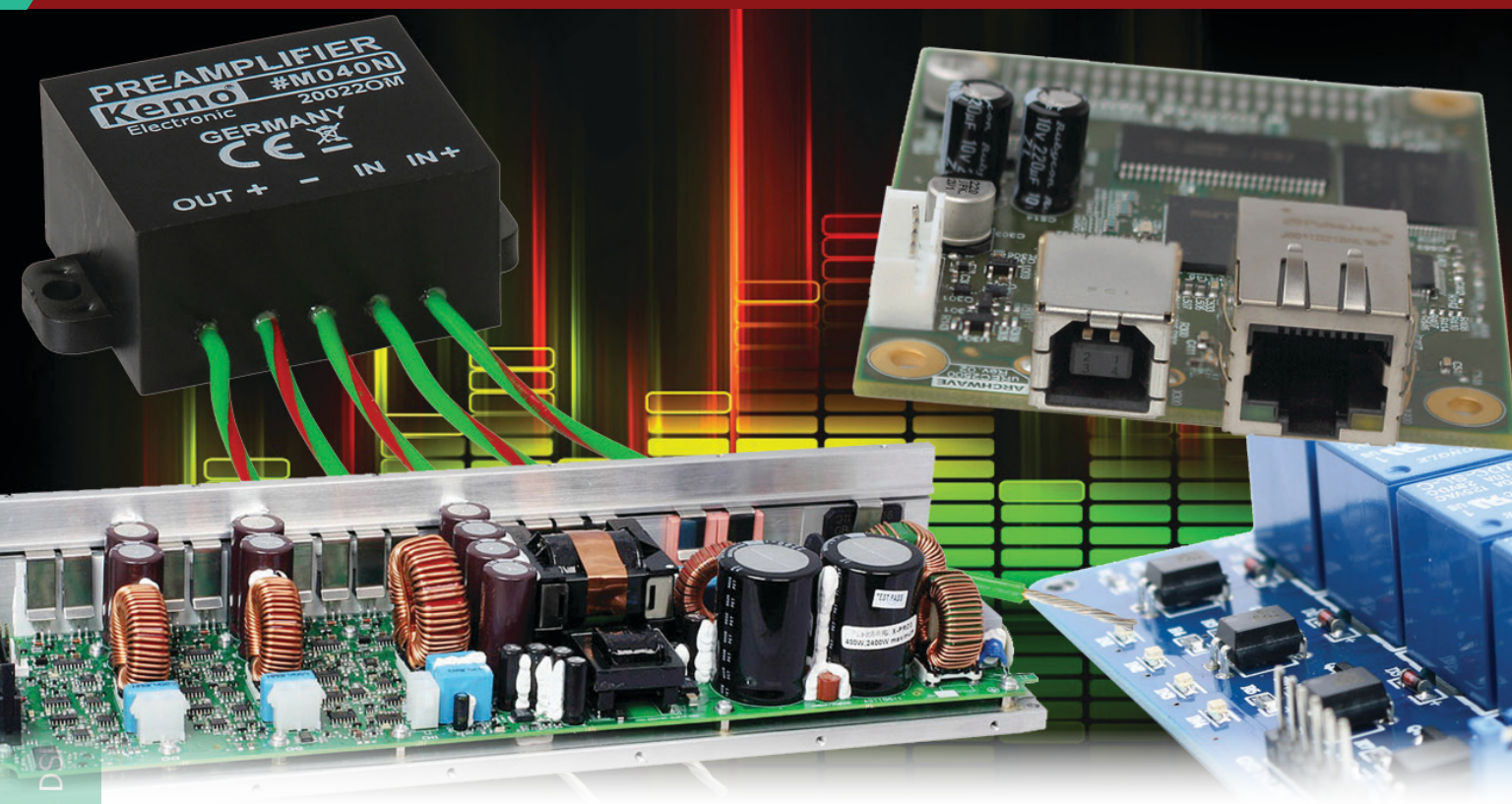
AMP, DSP, NETWORK, & WIRELESS MODULES



	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
AUSTRALIA				
DEQX Pty., Ltd.	•	•	•	•
Eclipse Audio		•		
Soundlabs Group Pty., Ltd.	•			
BRAZIL				
Advanced Audio Technologies (AAT)	•			
AMCP Electronica	•			
CANADA				
Harbottle Audio	•	•		
Solen Electronique, Inc.	•	•	•	•
Space-Tech Lab, Ltd.	•	•		•
CHINA				
Fountek Electronics Co., Ltd.	•	•		•
Panasound Technology Co., Ltd.	•	•		•
DENMARK				
ICEpower, AS	•			
Pascal, AS	•			
Purifi ApS	•			
FRANCE				
IDEA	•			

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
HONG KONG				
Eastern Asia Technology (HK), Ltd.	•			•
miniDSP	•	•	•	
INDIA				
GM Audio Technics, Ltd.	•	•	•	
ITALY				
Axiomedia, SRL	•	•		•
Powersoft Audio, SpA	•	•	•	
JAPAN				
Etani Electronics Co., Ltd.	•	•		
S'NEXT Co., Ltd.	•	•		
NETHERLANDS				
ELTIM audio, BV	•			
Hypex Electronics, BV	•	•		
SWEDEN				
Bohmer Audio, AB	•	•	•	•
SWITZERLAND				
Archwave			•	

As loudspeaker manufacturers we know a secret:

Hi-res audio has not happened

Specifically, CTA says: “High-res audio is lossless audio capable of reproducing the full range of sound from recordings mastered from a better-than-CD-quality music source”

Yet almost no consumer loudspeaker comes close to delivering this hi-res audio spec. With 1% THD and serious impulse response errors considered normal for consumer speakers, there’s much room for improvement. Meanwhile, hd-media is often promoted as if it can actually deliver hi-res audio by itself.

Fortunately, that’s about to change: new 64-bit ARM processors have the speed, resolution and memory that DEQX 3rd-gen ‘active’ requires, with options for IoT media streaming, wireless autonomy and room correction. You need only add hi-res (low distortion) drivers, amplifiers and cabinet to create affordable hi-res loudspeakers. And development will be fast and easy using our DEQXcloud measurement, analysis and calibration resource.

DEQX will offer these IoT, hi-res enabling platforms in late 2018 to demonstrate the difference between hi-fi and hi-res audio. It will amaze your customers.

DEQX HD processor module

YOUR REQUIRED I/O FOR HD-ACTIVE (or passive) CALIBRATION HERE

POWER AMPLIFIER/S

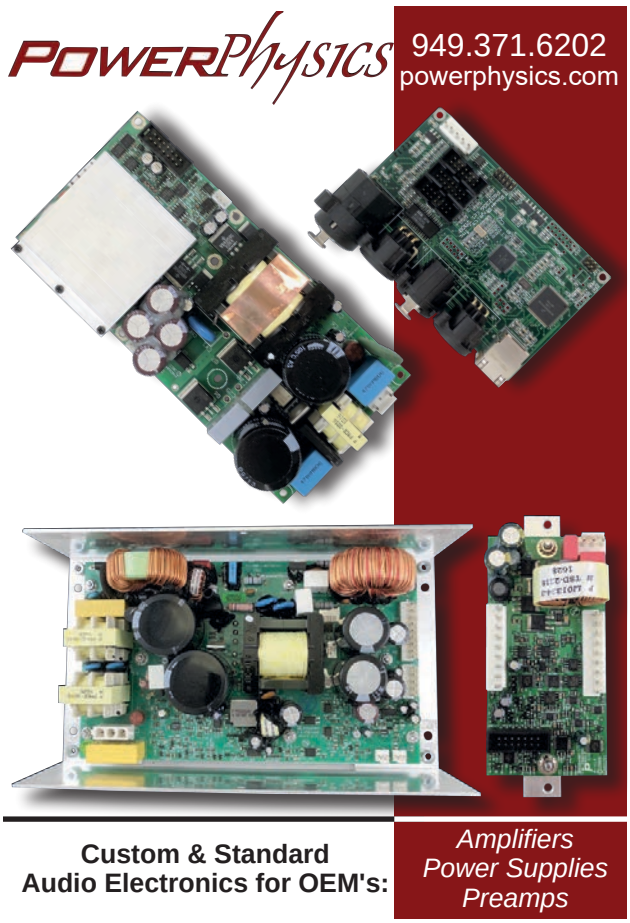
e.g. ICEpower, Hypex

Learn more at **DEQXoem.com**

DEQX™

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
TAIWAN				
Taiwan Solidex Corp.				•
UKRAINE				
Mag Audio	•			
UNITED KINGDOM				
EuroTec International, Plc.	•	•		
MJ Acoustics	•			•
Profusion, plc	•	•	•	•
Tectonic Elements, Ltd.	•			
UNITED STATES				
Area 52 R&D	•	•		
AtlasIED		•	•	
Audio Advisor, Inc.	•			
Danville Signal Processing, Inc.	•	•	•	•
Digmoda	•	•		
Dragonfire Acoustics	•	•	•	•
Eagle Acoustics	•	•	•	•

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
Etal Group, AB/Anaview	•			
Full Compass Systems, Ltd.	•	•		
Globe Audio Design, Inc.	•	•	•	
JL Audio, Inc.	•	•		
Kramer Electronics	•	•	•	•
Linear Tube Audio	•			
Linkplay				•
Marchand Electronics, Inc.	•			
Meyer Sound Laboratories, Inc.		•		
MISCO	•	•		
PowerPhysics, Inc.	•	•		
Pro Flix Sales	•	•	•	•
Spectrum Audio	•			
US Enclosure Co.	•	•	•	•
Vintage King Audio	•			
Weltronics Corp.	•	•	•	•
Wired 4 Sound, Inc.	•	•	•	•



AUSTRALIA
Audinate, Pty., Ltd.
DEQX Pty., Ltd.

AUSTRIA
Usound GmbH

BELGIUM
Donnet Sound and Vision

BRAZIL
Advanced Audio Technologies (AAT)
Edgar Prudente da Silva
Phix Eletronics

CANADA
Arteluthe
LMH Loudspeakers
Space-Tech Lab, Ltd.

CHINA
Dongguan Yuonyunn Membrane Co.
Fountek Electronics Co., Ltd.
Panasound Technology Co., Ltd.
Shenzhen Malata Mobile Communications, Co., Ltd.
Sound Technology Development, Ltd. (Factory)

DENMARK
Danesian Audio ApS
ICEpower, AS
K & K Development
LOUDSOFT, Ltd.
PointSource Acoustics ApS

GERMANY
HiFi-Tuning
Physical Lab
Rohde & Schwarz
Voice Point

HONG KONG
Acoustic Development International
Eastern Asia Technology (HK), Ltd.
Panson Audio
WCE Acoustics

HUNGARY
Bayz Audio

LATVIA
Acoustic Power Lab

NETHERLANDS
ELTIM audio, BV
Kamperman Engineering
Metaxas & Sins BV
the BEE

NEW ZEALAND
Asona

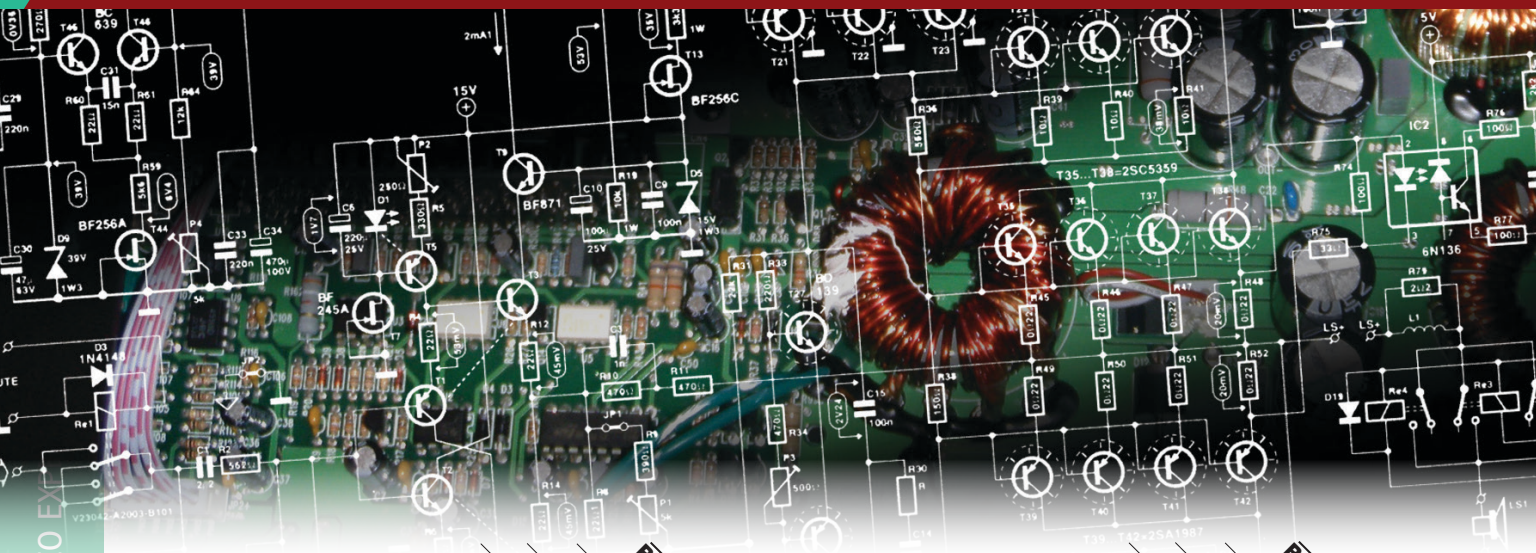
ROMANIA
SC Poweraudio, SRL

SOUTH KOREA
Suntel Co., Ltd.

THAILAND
Sanit Audio Engineering Co.

UNITED KINGDOM
EuroTec International, Plc.
Fane International, Ltd.
Hill Acoustics
Interfacio, Ltd.
PA Workshop, Ltd.
PACSYS, Ltd.
Precision Devices, Ltd.
Tectonic Elements, Ltd.

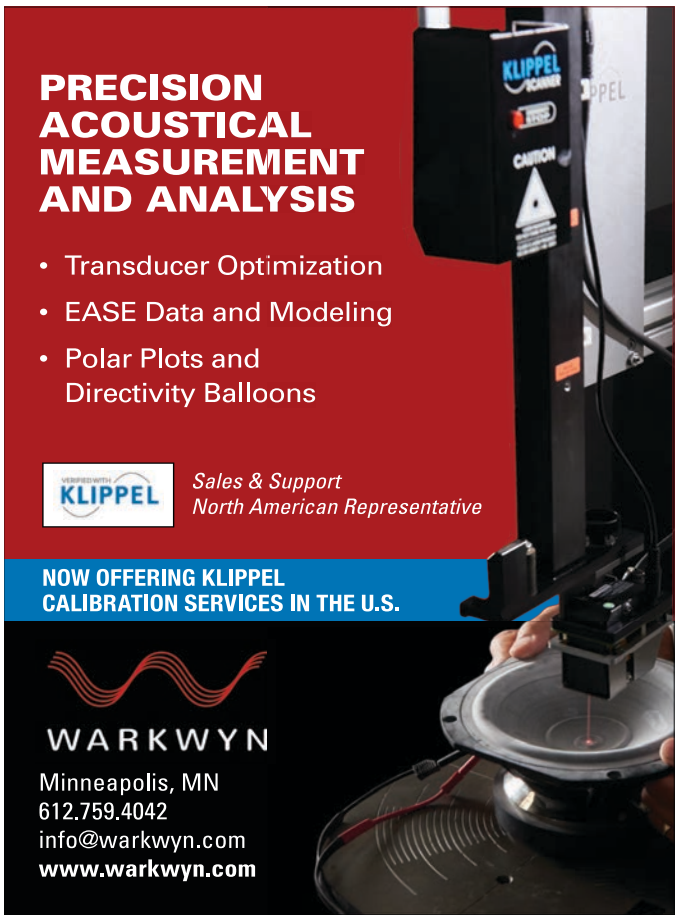
UNITED STATES
American Music And Sound
AmericanPowerLight.com
Apollonio Consulting
Association of Loudspeaker Manufacturing and Acoustics (ALMA) International
Audio Connection
BeStar Technologies, Inc.
Bob Young and Associates
Clear Lake Audio
Community Professional Loudspeakers
DMSI
Dragonfire Acoustics
Earthquake Sound Corp.
Geometric Designs, LLC & Geometric Consulting
HDSound
HEAD acoustics, Inc.
HX Audio Lab
Integrated Audio Technologies, LLC
Lipinski Sound
North Reading Engineering
Pacific Audio Consulting
Prism Media Products, Inc. (Prism Sound/ MASELEC/SADiE/Loudsoft)
Pro Sound Testing, Inc.
SoCal Sound Shop
Soundoctor
Studio Electric - David MacPherson
THX, Ltd.
True Technologies, Inc.
TSG Audio
Vance Dickason Consulting



	Consultants	Designers	Recruitment Agencies	
ARGENTINA				
Laufer Speaker Electronics	•	•		
AUSTRALIA				
Audinate, Pty., Ltd.	•	•		
DEQX Pty., Ltd.	•	•		
Stone Sound Studio	•			
BELGIUM				
Donnet Sound and Vision	•	•		
BRAZIL				
Advanced Audio Technologies (AAT)	•	•		
Edgar Prudente da Silva	•			
Phix Eletronics	•	•		
CANADA				
Arteluthe	•	•		
Canadian Speaker Works	•	•		
DLC Loudspeaker R&D Group	•	•		
Kravchenko-Audio	•	•		
Planet10-HiFi	•			
Solen Electronique, Inc.	•	•		
Space-Tech Lab, Ltd.	•	•		
Studio Reference Monitors	•	•		
Thompson by Design	•	•		
CHINA				
B.W. Audio Guangzhou Co., Ltd.	•	•		
BSWA Technology Co., Ltd.	•	•		
Dongguan Yuonyunn Membrane Co.	•	•		
Fountek Electronics Co., Ltd.	•	•		
Panasound Technology Co., Ltd.	•	•		
Sound Technology Development, Ltd. (Factory)	•	•		
Sun Technique Electric Co., Ltd.	•	•		
Trueanalog Strictly OEM	•			
CZECH REPUBLIC				
Elfton, S.R.O.		•		

	Consultants	Designers	Recruitment Agencies	
DENMARK				
Danesian Audio ApS	•	•		
LOUDSOFT, Ltd.	•	•		
PointSource Acoustics ApS	•	•		
FRANCE				
KYU Systems	•	•		
GERMANY				
Klippel GmbH	•	•		
Physical Lab	•	•		
Scherer Audio	•	•		
Wolf von Langa		•		
HONG KONG				
Acoustic Development International	•	•		
Ocean Star Electronics, Ltd.	•	•		
Panson Audio	•	•		
WCE Acoustics	•	•		
HUNGARY				
Bayz Audio		•		
INDIA				
Power Electronics & Technologies	•	•		
ITALY				
Audiomatica, SRL	•	•		
AXP	•	•		
LATVIA				
Acoustic Power Lab	•			
NETHERLANDS				
ELTIM audio, BV	•	•		
Kamperman Engineering	•	•		
POLAND				
Resnatura Audio	•	•		
SOUTH KOREA				
Suntel Co., Ltd.	•	•	•	

	Consultants	Designers	Recruitment Agencies
UNITED KINGDOM			
EuroTec International, Plc.	•	•	
Hill Acoustics	•	•	
Interfacio, Ltd.	•		
MJ Acoustics	•	•	
UNITED STATES			
Acoustic Fields	•	•	
Aempyrean	•	•	
American Bass USA	•	•	
Apollonio Consulting	•		
Association of Loudspeaker Manufacturing and Acoustics (ALMA) International	•	•	
Audio Connection	•	•	
Audio Nirvana	•	•	
Barefoot Sound, LLC	•	•	
BASSBOSS		•	
Beach Dynamics	•	•	
BeStar Technologies, Inc.	•	•	
Bob Young and Associates	•	•	
Bruel & Kjaer Sound & Vibration North America, Inc.	•	•	
CGN Audio Labs	•	•	
CJS Labs	•	•	
Community Professional Loudspeakers	•	•	
Danville Signal Processing, Inc.	•	•	
dB Design	•	•	
DMSI	•	•	
Dragonfire Acoustics	•	•	
DTV Installations, LLC	•	•	
Earthquake Sound Corp.	•	•	
eMagineFactory, LLC	•	•	
Excelsior Audio Design & Services, LLC	•	•	
Fulcrum Acoustic, LLC		•	
Geometric Designs, LLC & Geometric Consulting	•	•	
Globe Audio Design, Inc.	•	•	
HDSound	•	•	
HEAD acoustics, Inc.	•	•	
HX Audio Lab	•	•	
Integrated Audio Technologies, LLC	•	•	
JP Electronics Design	•	•	
Linkplay	•	•	
Lowther Speakers USA	•	•	
Marchand Electronics, Inc.	•	•	
McKinney & Associates, LLC	•	•	
Menlo Scientific, Ltd.	•	•	
Midwest Audio Club	•	•	
NedLab	•	•	
Pacific Audio Consulting	•	•	
Planot, LLC	•	•	
Ponderosa Sound Systems	•	•	
PR Audio	•	•	
Pro Sound Testing, Inc.	•	•	
Seneschal	•	•	
SoCal Sound Shop	•	•	
Soundoctor	•	•	
Speaker Clinic	•	•	
SpeakersAndAmps.com	•	•	
Stroud Audio, Inc.	•	•	
Studio Electric - David MacPherson	•	•	
TMI Engineering	•	•	
True Technologies, Inc.	•	•	
TSG Audio	•	•	
US Enclosure Co.	•	•	
Vance Dickason Consulting	•	•	
Warkwyn	•	•	
Wehner Technical, Inc.	•	•	
Wired 4 Sound, Inc.	•	•	
Wisdom Audio		•	



	Cables	Connectors	Wire Channel
AUSTRALIA			
Soundlabs Group Pty., Ltd.	•	•	
Stone Sound Studio	•	•	
CANADA			
Canadian Speaker Works	•	•	
DLC Loudspeaker R&D Group	•	•	
Rutherford Audio, Inc.	•		
Solen Electronique, Inc.	•	•	
The Canadian Loudspeaker Corp.		•	
CHINA			
BSWA Technology Co., Ltd.	•	•	•
Sound Technology Development, Ltd. (Factory)	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•
DENMARK			
Estron, a/s	•	•	
Jantzen Audio Denmark	•		
GERMANY			
HiFi-Tuning	•	•	
Soundsgood Pro Audio Solutions	•	•	
Voice Point	•	•	•
Wolf von Langa	•		
HONG KONG			
WCE Acoustics	•	•	
HUNGARY			
Bayz Audio	•		
INDIA			
Power Electronics & Technologies	•	•	
IRELAND			
Crossover App	•		
ITALY			
Axiomedia, SRL	•	•	

	Cables	Connectors	Wire Channel
JAPAN			
Furutech Co., Ltd.	•	•	
S'NEXT Co., Ltd.	•	•	
MEXICO			
Aletheia, AV	•		
NETHERLANDS			
ELTIM audio, BV	•	•	
Good Hifi VOF		•	
POLAND			
Resnatura Audio	•	•	
RUSSIA			
Deluxe Acoustics, Ltd.	•		
SWEDEN			
Audio Pro, AB	•		
TAIWAN			
Huey Tung International Co., Ltd.	•	•	
Yung International, Inc.	•	•	•
UKRAINE			
Mag Audio	•	•	
UNITED KINGDOM			
EuroTec International, Plc.	•	•	•
MJ Acoustics	•		
Revolver Audio, Ltd.	•		
UNITED STATES			
A. Schulman, Inc.		•	
Radio Design Labs (RDL)	•	•	•
American Bass USA	•	•	
AMS Audio Enterprises, Inc.	•	•	
Audio Advisor, Inc.	•	•	
Audio Connection	•	•	•
B&H Photo Video	•	•	
Blackmore Mobile	•	•	
Carvin Audio	•	•	

	Cables	Connectors	Wire Channel
Controlled Thermal Processing, Inc.	•	•	•
DTV Installations, LLC	•	•	•
Earthquake Sound Corp.	•		
Front End Audio, LLC	•	•	
Full Compass Systems, Ltd.	•	•	
GRAS Sound & Vibration	•	•	
HAVE, Inc.	•	•	•
Herman Pro, AV	•	•	
JL Audio, Inc.	•	•	
Kramer Electronics	•	•	
Lamart Corp.	•	•	•
Loudspeakers Plus		•	
Madisound Speaker Components, Inc.	•		
Open Tip	•	•	
Parts Express	•	•	•
PowerPhysics, Inc.	•		
Pro Flix Sales	•	•	
PRV Audio Brazil	•		
Redco Audio	•	•	•
Revolution Power	•	•	
Sound Pure, LLC	•	•	
Soundoctor	•	•	
Spectrum Audio	•	•	
Stillwater Designs | KICKER	•		
Straight Wire, Inc.	•	•	•
SVS, Inc.	•	•	
Sweetwater Sound	•	•	
Tonian Laboratories	•		
TSG Audio	•	•	
US Speaker, LLC	•	•	
Vidsonix Design Works	•	•	
Westlake Audio, Inc.	•	•	•
Wired 4 Sound, Inc.	•	•	•
Wireworld Cable Technology	•	•	
Yandas Music	•	•	
Zu Audio	•		
zZounds Music, LLC	•	•	

	Earphones	Headphones
AUSTRALIA		
Stone Sound Studio		•
AUSTRIA		
Usound GmbH	•	•
BRAZIL		
Harman of Brazil, Ltda.	•	•
CANADA		
DLC Loudspeaker R&D Group	•	•
Focal North America		•
Solen Electronique, Inc.	•	•
CHINA		
Enkor Electronics Co., Ltd.		•
Lumi Audio (China) OEM/ODM		•
Sound Technology Development, Ltd. (Factory)	•	•
HONG KONG		
Eastern Asia Technology (HK), Ltd.	•	•
WCE Acoustics	•	•
ITALY		
RCF, SpA		•
JAPAN		
Furutech Co., Ltd.	•	•
S'NEXT Co., Ltd.	•	•

	Earphones	Headphones
SOUTH KOREA		
Suntel Co., Ltd.	•	•
SWEDEN		
Audio Pro, AB		•
TAIWAN		
Huey Tung International Co., Ltd.	•	•
Kingstate Electronics Corp.	•	•
Yung International, Inc.	•	•
THAILAND		
Sanit Audio Engineering Co.		•
UNITED KINGDOM		
Profusion plc		•
UNITED STATES		
1MORE	•	•
American Bass USA	•	•
American Music And Sound	•	•
Audio Advisor, Inc.	•	•
Audio Connection	•	•
AValive		•
B&H Photo Video		•
BeStar Technologies, Inc.	•	•
Blackmore Mobile		•
Bob Young and Associates	•	•
Dragonfire Acoustics	•	•
Earthquake Sound Corp.	•	•

	Earphones	Headphones
Echobox Audio, LLC	•	•
ESS Laboratories, LLC		•
Front End Audio, LLC		•
Full Compass Systems, Ltd.	•	•
HAVE, Inc.		•
Hearing Components, Inc. (Comply Memory Foam Tips)	•	•
Materion Electrofusion		•
Open Tip	•	•
Pacific Audio Consulting	•	•
Parts Express	•	•
Peerless by Tymphany HK, Ltd.		•
PreSonus Audio Electronics, Inc.		•
Pro Flix Sales		•
Puro Sound Labs		•
RBH Sound	•	•
Revolution Power	•	
Seltech	•	•
Shure, Inc.	•	•
Sound Pure, LLC		•
Sound Sources Technology, Inc.	•	•
Spectrum Audio	•	•
Stillwater Designs | KICKER	•	•
US Enclosure Co.	•	•
Vintage King Audio		•
Yandas Music	•	•
Zu Audio		•
zZounds Music, LLC		•

	Baffles		Finished Cabinets			Sub-Assemblies							Materials			Panels	Rigging
	Ceiling Speaker Plates	In-Wall Plates	Box Arrays (PA)	Boxes	Stands	Bulk Molding Compound	Carpet	Hardwood	MDF (Fiberboard)	Other	Paper/Paper Pulp	Plastic	Plywood	Veneer	Wound Geometric Tubes		
AUSTRALIA																	
Stone Sound Studio																•	•
BELGIUM																	
Donnet Sound and Vision	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Premium Sound Solutions	•			•													
BRAZIL																	
Advanced Audio Technologies (AAT)				•													
CANADA																	
Canadian Speaker Works																•	•
Harbottle Audio	•	•	•	•							•		•			•	
Planet10-HiFi				•													
Solen Electronique, Inc.	•	•		•	•												
Studio Reference Monitors				•													
CHINA																	
Lumi Audio	•	•		•	•					•		•					
OBE Pro Audio Co., Ltd.																	•
Shenzhen Tekzone Loudspeaker Co., Ltd.																•	•
Sound Technology Development, Ltd. (Factory)																•	•
Sun Technique Electric Co., Ltd.																•	•
Trueanalog Strictly OEM				•	•				•	•		•			•		
DENMARK																	
KVART & BØLGE				•													
FRANCE																	
KYU Systems			•	•									•		•	•	
GERMANY																	
Soundsgood Pro Audio Solutions	•	•	•	•	•	•		•	•	•							
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Wolf von Langa				•				•	•			•	•			•	

	Baffles: Ceiling Speaker Plates	Baffles: In-Wall Plates	Finished Cabinets: Box Arrays (PA)	Finished Cabinets: Boxes	Finished Cabinets: Bulk Molding Compound	Finished Cabinets: Stands	Sub-Assemblies: Carpet	Sub-Assemblies: Hardwood	Sub-Assemblies: MDF (Fiberboard)	Sub-Assemblies: Other	Sub-Assemblies: Paper/Paper Pulp	Sub-Assemblies: Plastic	Sub-Assemblies: Plywood	Sub-Assemblies: Veneer	Sub-Assemblies: Wound Geometric Tubes	Materials	Panels	Rigging
HONG KONG Ocean Star Electronics, Ltd.	•	•	•	•	•		•	•	•				•	•	•	•		
HUNGARY Bayz Audio										•							•	
INDIA GM Audio Technics, Ltd.			•	•														
ITALY Axiomedia, SRL				•	•		•										•	
MEXICO Aletheia, AV			•	•	•					•	•							
NETHERLANDS ELTIM audio, BV				•														
Sound Projects			•	•														•
POLAND Sveda Audio				•	•													
ROMANIA SC Poweraudio, SRL			•	•														
SPAIN Sottovoce Audio				•	•													

	Baffles		Finished Cabinets			Sub-Assemblies							Materials			Panels	Rigging
	Ceiling Speaker Plates	In-Wall Plates	Box Arrays (PA)	Boxes	Stands	Bulk Molding Compound	Carpet	Hardwood	MDF (Fiberboard)	Other	Paper/Paper Pulp	Plastic	Plywood	Veneer	Wound Geometric Tubes		
SWEDEN																	
Audio Pro, AB																•	•
TAIWAN																	
Hi-Tech Sound System Co., Ltd.	•	•															
Huey Tung International Co., Ltd.	•	•	•	•	•	•	•		•			•					
Yie Feng Technology Enterprise Co.												•					•
Yung International, Inc.			•	•	•				•			•		•			
UNITED KINGDOM																	
Bishopsound			•	•	•				•				•				
EuroTec International, Plc.	•		•	•								•					
Hill Acoustics										•							
MJ Acoustics				•				•						•			
PA Workshop, Ltd.				•									•			•	
UNITED STATES																	
Acry-Tech Coatings, Inc.																•	
Adrian Acoustics, Inc.	•	•	•	•	•			•	•	•			•	•			
American Bass USA	•	•	•	•	•												
AMS Audio Enterprises, Inc.	•	•		•	•												
Area 52 R&D				•					•	•			•	•			
Audio Connection									•								
Campanella Associates & Acculab										•							
Carvin Audio			•	•													
CGN Audio Labs			•	•						•							
Dayton Audio				•													
Eagle Acoustics			•	•	•		•		•			•					•
Eminence Speaker, LLC			•	•													
Fulcrum Acoustic, LLC				•													
Full Compass Systems, Ltd.	•	•					•									•	
GGEC America, Inc.				•			•	•	•			•	•	•			
Global Audio Source, Inc.				•	•												
Globe Plastics, Inc.	•	•		•		•				•		•					
Inlow Sound				•				•			•		•	•			
J&F Wood Products	•	•	•	•	•		•	•	•				•	•			
Levister Audio				•													
Lowell Manufacturing Co.	•	•		•													
Midwest Audio Club				•	•			•	•				•	•			
Parts Express	•	•	•	•	•		•		•					•			
Ponderosa Sound Systems			•	•	•												
Precision Sound Products, Inc.										•							
RBH Sound	•	•		•					•	•		•					
SoCal Sound Shop			•	•													
Sound Anchors					•												
Sound Sources Technology, Inc.	•	•	•	•	•		•										
SpeakersAndAmps.com			•	•													
Studio Electric - David MacPherson			•	•				•	•					•			
Tone Tubby, Inc.				•													
TSG Audio			•	•	•												
United Gasket Corp.	•	•					•				•					•	
US Enclosure Co.	•	•	•	•	•					•		•		•	•		•
US Speaker, LLC			•	•	•												
Vidsonix Design Works				•						•							
Wired 4 Sound, Inc.			•	•													•
Yandas Music				•	•												

	Enclosure Stuffing		Grille Assemblies			Hardware						
	Enclosure Grilles	Fiberglass	Foam	Synthetic	Wool	Fabric Suppliers	Foam Suppliers	Perforated Metal Suppliers	Corners	Handles	Name Plates	Fasteners & Other
AUSTRALIA												
Soundlabs Group Pty., Ltd.		•		•	•	•	•	•	•			•
Stone Sound Studio		•										
BRAZIL												
Phix Eletronics		•	•	•	•	•	•	•	•	•	•	•
CANADA												
Canadian Speaker Works		•		•	•		•	•	•	•	•	•
Solen Electronique, Inc.		•	•	•	•	•		•				•
Tortech Sound, Inc.		•										
CHINA												
Lumi Audio									•			
OBE Pro Audio Co., Ltd.		•								•	•	
Shenzhen Tekzone Loudspeaker Co., Ltd.		•			•							
Sound Technology Development, Ltd. (Factory)		•	•	•	•	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.		•	•	•	•	•	•	•	•	•	•	•
Trueanalog Strictly OEM											•	
FRANCE												
KYU Systems		•		•		•	•	•	•	•		
GERMANY												
Hubert Stueken GmbH & Co., KG									•			
Voice Point		•	•	•	•	•	•	•	•	•	•	•

	Enclosure Stuffing					Grille Assemblies			Hardware			
	Enclosure Grilles	Fiberglass	Foam	Synthetic	Wool	Fabric Suppliers	Foam Suppliers	Perforated Metal Suppliers	Corners	Handles	Name Plates	Fasteners & Other
HONG KONG												
Ocean Star Electronics, Ltd.	•											
INDIA												
GM Audio Technics, Ltd.			•									
ITALY												
Axiomedia, SRL							•	•		•	•	•
NETHERLANDS												
Good Hifi VOF				•			•					
SWEDEN												
Audio Pro, AB	•	•	•	•	•		•		•	•		•
TAIWAN												
Taiwan Solidex Corp.	•										•	
Yie Feng Technology Enterprise Co.	•		•					•				
UKRAINE												
Mag Audio	•											
UNITED KINGDOM												
EuroTec International, Plc.	•	•	•	•			•	•	•			
UNITED STATES												
A. Schulman, Inc.	•											
Accurate Perforating Co., Inc.	•								•			
AcousTex Fabrics	•						•					
Acry-Tech Coatings, Inc.												•

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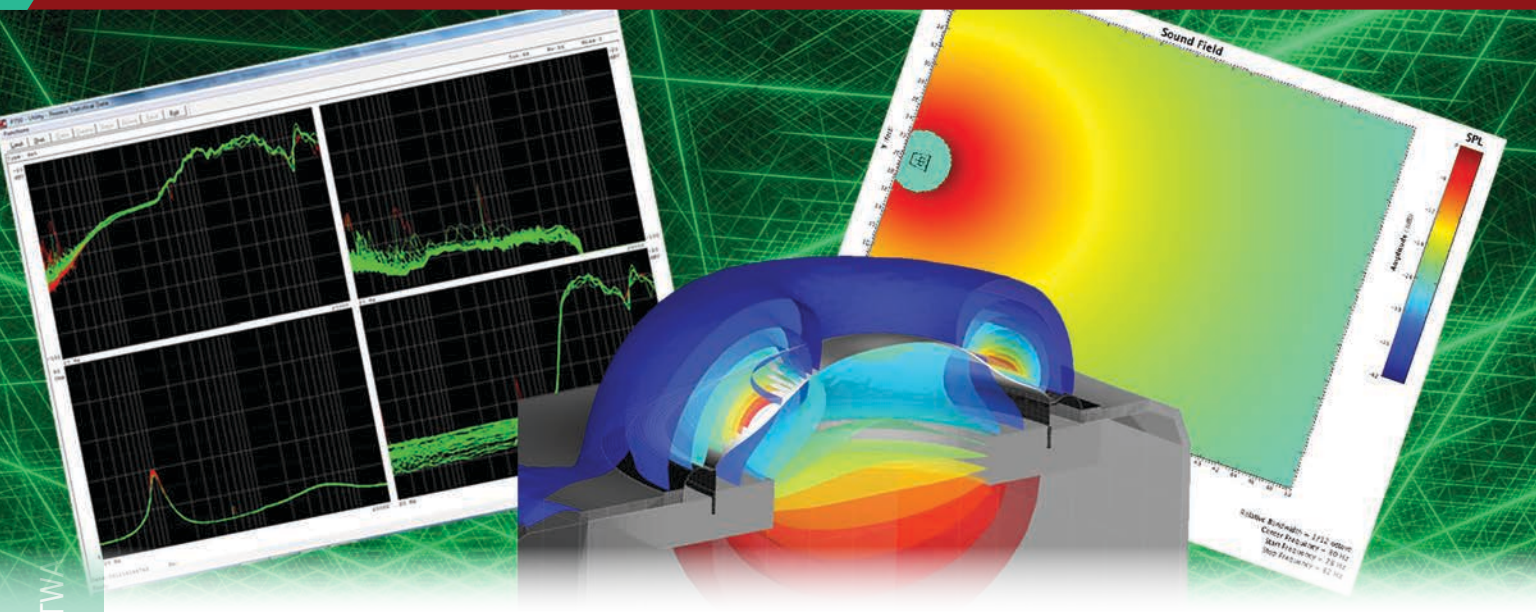
	Enclosure Stuffing		Grille Assemblies			Hardware					
	Enclosure Grilles	Fiberglass	Foam	Synthetic	Wool	Fabric Suppliers	Foam Suppliers	Perforated Metal Suppliers	Corners	Handles	Name Plates	Fasteners & Other
Adrian Acoustics, Inc.	•	•	•	•	•	•	•		•		•	
American Bass USA	•								•	•	•	•
AMS Audio Enterprises, Inc.	•					•		•				
Carvin Audio									•	•		•
Dayton Audio	•											
Full Compass Systems, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•
Global Audio Source, Inc.	•											
Globe Plastics, Inc.	•								•	•		
J&F Wood Products	•	•				•						
Lowell Manufacturing Co.	•							•				
Meniscus Audio Group, Inc.			•	•								
MetalEX	•							•				
ORCA Design And Manufacturing					•							
Precision Sound Products, Inc.												•
RBH Sound	•											
SpeakerAddict	•	•	•	•	•	•		•	•	•		•
United Gasket Corp.			•	•	•	•	•					
US Enclosure Co.	•	•	•	•	•	•	•	•			•	
US Speaker, LLC									•	•	•	•
Vidsonix Design Works	•								•			

ENGINEERING SOFTWARE



	Acoustic Analysis	Box Design	Crossover Optimizer	Network Design	CAE or CAD
AUSTRALIA					
Audinate, Pty., Ltd.	•	•	•	•	•
Audiosoft	•	•	•	•	
DEQX Pty., Ltd.	•		•	•	
Eclipse Audio			•		
AUSTRALIA					
Stone Sound Studio	•	•	•		•
BELGIUM					
Donnet Sound and Vision	•	•	•		
CANADA					
Canadian Speaker Works	•	•			•
DLC Loudspeaker R&D Group	•	•	•	•	
Solen Electronique, Inc.	•	•	•		
Space-Tech Lab, Ltd.	•				
CHINA					
BSWA Technology Co., Ltd.	•				
Shenzhen Tekzone Loudspeaker Co., Ltd.	•	•	•	•	•
Sound Technology Development, Ltd. (Factory)	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•
Trueanalog Strictly OEM		•			•
DENMARK					
K & K Development	•				
LOUDSOFT, Ltd.	•	•	•		
FRANCE					
KYU Systems	•		•	•	•
GERMANY					
Klippel GmbH	•				

	Acoustic Analysis	Box Design	Crossover Optimizer	Network Design	CAE or CAD
R&D Team	•	•	•	•	
Soundsgood Pro Audio Solutions	•	•			•
Voice Point	•	•	•	•	•
HONG KONG					
Ocean Star Electronics, Ltd.	•	•			•
INDIA					
GM Audio Technics, Ltd.	•				
IRELAND					
Crossover App			•		
ISRAEL					
Coby Speakers	•	•	•	•	•
ITALY					
Audiomatica, SRL	•				
SpeakerLAB	•				•
JAPAN					
Etani Electronics Co., Ltd.	•	•			•
LATVIA					
Acoustic Power Lab	•		•		
NETHERLANDS					
ELTIM audio, BV		•	•		
SOUTH KOREA					
Suntel Co., Ltd.	•	•	•	•	•
SPAIN					
Brusi Acoustics	•	•		•	

	Acoustic Analysis	Box Design	Crossover Optimizer	Network Design	CAE or CAD
SWEDEN					
Audio Pro, AB	•	•	•	•	
Bohmer Audio, AB	•		•		•
SWITZERLAND					
Archwave				•	
TAIWAN					
Kingstate Electronics Corp.	•				•
UNITED KINGDOM					
EuroTec International, Plc.					•
Hill Acoustics	•	•	•		•
PACSYS, Ltd.	•				
UNITED STATES					
Bruel & Kjaer Sound & Vibration North America, Inc.	•				
Community Professional Loudspeakers	•	•	•	•	•
Danville Signal Processing, Inc.	•		•	•	
Digmoda			•		

	Acoustic Analysis	Box Design	Crossover Optimizer	Network Design	CAE or CAD
Dragonfire Acoustics	•	•	•		•
Geometric Designs, LLC & Geometric Consulting		•	•		•
Globe Audio Design, Inc.			•		
HEAD acoustics, Inc.	•				
HX Audio Lab	•	•	•	•	•
Listen, Inc.	•				
MSC Software Corp.	•		•		•
NedLab		•	•	•	
Parts Express	•	•			
Prism Media Products, Inc. (Prism Sound/MASELEC/SADiE/Loudsoft)	•	•	•	•	
Scantek, Inc.	•				
Soundoctor	•		•		
Speaker Clinic		•	•		•
Studio Six Digital	•				
True Technologies, Inc.	•				
Warkwyn	•	•	•	•	•

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FINISHED SYSTEMS (OEM/ODM)

	Car Audio	Home Audio	Marine Audio	Pro Audio
AUSTRALIA				
Stone Sound Studio	•	•		•
BELGIUM				
Donnet Sound and Vision	•	•	•	•
Premium Sound Solutions	•	•		
BRAZIL				
Advanced Audio Technologies (AAT)		•		
AMCP Electronica		•		
Harman of Brazil, Ltda.	•	•	•	•
CANADA				
Canadian Speaker Works				•
Focal North America	•	•		•
Harbottle Audio		•	•	•
LMH Loudspeakers	•	•		•
Newform Research, Inc.		•		•
Planet10-HiFi		•		
Solen Electronique, Inc.	•	•		•
Space-Tech Lab, Ltd.		•		
Studio Reference Monitors				•
The Canadian Loudspeaker Corp.	•	•		•
CHINA				
Audiostar Electronics Co., Ltd.	•	•		•
B.W. Audio Guangzhou Co., Ltd.				•
Enkor Electronics Co., Ltd.		•		
Fountek Electronics Co., Ltd.	•	•		•

	Car Audio	Home Audio	Marine Audio	Pro Audio
Lumi Audio		•		•
OBE Pro Audio Co., Ltd.				•
Shenzhen Tekzone Loudspeaker Co., Ltd.		•		•
Sonos, Inc.		•		
Sound Technology Development, Ltd. (Factory)		•		•
Speakerhu Electronic Co., Ltd.	•	•		
Sun Technique Electric Co., Ltd.	•	•		•
Trueanalog Strictly OEM	•	•	•	•
Zeng Ben Industrial Corp., Ltd.	•	•		•
Zhuhai HiVi Technology Co., Ltd.	•	•		•
DENMARK				
ICEpower, AS	•	•		•
Kvart & BØLGE		•		
Pascal, AS				•
Scan Speak, AS	•			
FRANCE				
Crista Technologies		•		
KYU Systems				•
Supravox		•		•
The Concrete Family		•		•
Waterfall Audio		•		•
GERMANY				
Eton GmbH	•	•		
HiFi-Tuning		•		•

	Car Audio	Home Audio	Marine Audio	Pro Audio
ic audio GmbH			•	•
Lautsprecher-Produktions-Gesellschaft (LPG) mbH	•			
Marlok Automotive GmbH	•			
Scherer Audio		•		
Voice Point		•	•	•
Wolf von Langa		•		
HONG KONG				
Acoustic Development International	•	•		
Eastern Asia Technology (HK), Ltd.	•	•	•	•
miniDSP	•	•		•
Ocean Star Electronics, Ltd.		•		•
WCE Acoustics		•		
HUNGARY				
Bayz Audio		•		•
INDIA				
GM Audio Technics, Ltd.				•
Power Electronics & Technologies		•		•
INDONESIA				
SB Acoustics		•		
IRELAND				
Crossover App	•	•	•	•
ISRAEL				
Chorus Audio		•		•
Coby Speakers	•	•	•	•
Morel	•	•		

FINISHED SYSTEMS (OEM/ODM)

	Car Audio	Home Audio	Marine Audio	Pro Audio
ITALY				
Powersoft Audio, SpA				•
JAPAN				
Etani Electronics Co., Ltd.	•	•		•
MALAYSIA				
TC Electronics, Sdn., Bhd.	•	•		
MEXICO				
Aletheia, AV		•		
NETHERLANDS				
ELTIM audio, BV		•		•
Sound Projects				•
NEW ZEALAND				
Theophany Loudspeakers, Ltd.		•		
NORWAY				
SEAS Fabrikker, AS		•		
POLAND				
Sveda Audio		•		•
ROMANIA				
SC Poweraudio, SRL				•
RUSSIA				
Deluxe Acoustics, Ltd.		•		
Star Sound Technologies	•	•		•
SOUTH KOREA				
Suntel Co., Ltd.	•	•		•
SPAIN				
Sottovoce Audio		•		•
SWEDEN				
Audio Pro, AB	•	•		•
TAIWAN				
Huey Tung International Co., Ltd.	•	•		•
Hurray Co., Ltd.	•	•		•
Kingstate Electronics Corp.	•	•		
UKRAINE				
Mag Audio				•

	Car Audio	Home Audio	Marine Audio	Pro Audio
UNITED KINGDOM				
CompBass, Ltd.		•		•
EuroTec International, Plc.	•		•	•
Fane International, Ltd.				•
Ferguson Hill Studios, Ltd.		•		•
MJ Acoustics		•	•	•
Precision Devices, Ltd.				•
Tectonic Elements, Ltd.	•	•		•
UNITED STATES				
Aempyrean	•	•		•
Ambiance Acoustics		•		•
American Bass USA	•			
American Music And Sound	•	•	•	•
AMS Audio Enterprises, Inc.		•		•
Analysis Audio USA		•		
Area 52 R&D		•		•
Audio Nirvana		•		•
Audioengine		•		
Audio-Optix		•		•
B&H Photo Video		•		•
Barefoot Sound, LLC				•
BASSBOSS				•
Blackmore Mobile		•		•
Broad Bridge Audio, LLC		•		
Carvin Audio		•		
CGN Audio Labs				•
Clear Lake Audio				•
Dayton Audio		•		
dBTechnologies				•
Digital Audio Labs				•
Digmoda		•		•
Eagle Acoustics	•	•	•	•
Earthquake Sound Corp.	•	•	•	•
Eminence Speaker, LLC				•
ESS Laboratories, LLC	•	•		
Fulcrum Acoustic, LLC				•
Geometric Designs, LLC & Geometric Consulting		•		
GGEC America, Inc.	•	•	•	•
Global Audio Source, Inc.	•	•		•
Globe Audio Design, Inc.		•		•
GoldenEar Technology		•		
Halford Loudspeakers		•		•

	Car Audio	Home Audio	Marine Audio	Pro Audio
JL Audio, Inc.	•	•	•	
Levister Audio		•		
Lipinski Sound		•		•
Marchand Electronics, Inc.		•		
Meyer Sound Laboratories, Inc.		•		•
MISCO		•		•
NHT Audio, LLC		•		
ORCA Design And Manufacturing	•	•		
Parts Express	•	•		•
Pazandeh Audio Designs		•		•
Peerless by Tymphany HK, Ltd.	•	•		•
Performance Audio, LLC				•
Phoenix Engineering, LLC		•		
PranaFidelity		•		
Precison Transducer Engineering (PTE)		•		•
Pro Flix Sales				•
Purist Sonics		•		•
RBH Sound		•		
Rock The Boat			•	
RSL Speaker Systems		•		
SoCal Sound Shop	•	•	•	•
Sound & Lighting Systems				•
Sound Sources Technology, Inc.	•	•		
SpeakersAndAmps.com	•	•		•
Spectrum Audio				•
Studio Electric - David MacPherson		•		•
Tone Tubby, Inc.				•
Tonian Laboratories		•		•
TSG Audio	•	•		•
US Speaker, LLC	•	•		•
Vidsonix Design Works	•	•	•	
Weltronics Corp.		•		
Westlake Audio, Inc.		•		•
Wired 4 Sound, Inc.		•		•
Wisdom Audio		•		
Yandas Music				•
Zu Audio		•		

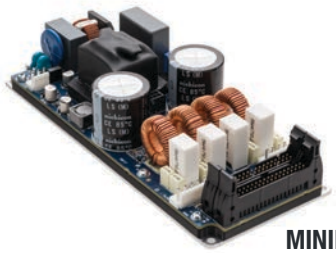
INTEGRATED AUDIO

	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
AUSTRALIA							
DEQX Pty., Ltd.	•	•	•	•			•
Eclipse Audio		•					
Soundlabs Group Pty., Ltd.	•		•			•	•
Stone Sound Studio	•	•	•			•	•
BELGIUM							
Donnet Sound and Vision				•	•	•	
BRAZIL							
Advanced Audio Technologies (AAT)	•		•			•	•
BRAZIL							
Harman of Brazil, Ltda.	•	•	•	•	•	•	•
CANADA							
DLC Loudspeaker R&D Group	•	•	•		•	•	
Harbottle Audio	•	•	•			•	
Rutherford Audio, Inc.	•		•				
Solen Electronique, Inc.	•	•	•		•	•	•
Studio Reference Monitors	•	•					
Tortech Sound, Inc.	•						
CHINA							
Enkor Electronics Co., Ltd.					•		
Fountek Electronics Co., Ltd.	•	•	•				•
Lumi Audio	•		•			•	•
OBE Pro Audio Co., Ltd.	•	•				•	
Panasound Technology Co., Ltd.	•	•	•		•	•	•
Shenzhen Tekzone Loudspeaker Co., Ltd.	•					•	
Sound Technology Development, Ltd. (Factory)	•		•		•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•
DENMARK							
ICEpower, AS	•	•	•			•	
Kvart & BØLGE	•						•
Pascal, AS			•				
FRANCE							
IDEA	•		•				
KYU Systems	•	•	•	•		•	
GERMANY							
ic audio GmbH				•			•
Klippel GmbH		•					
Physical Lab	•	•				•	
Voice Point	•	•	•	•	•	•	•
HONG KONG							
Eastern Asia Technology (HK), Ltd.	•	•	•	•	•	•	•
miniDSP	•	•				•	
WCE Acoustics					•		•
INDIA							
Power Electronics & Technologies	•		•			•	
ISRAEL							
Coby Speakers	•	•	•	•	•	•	•

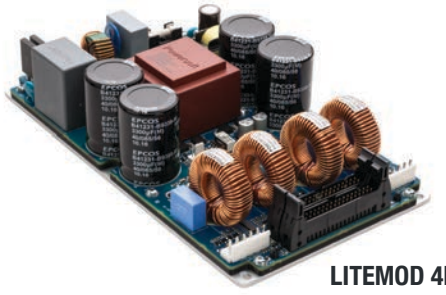
	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
ITALY							
Axiomedia, SRL	•	•	•			•	
Powersoft Audio, SpA	•	•	•	•			
JAPAN							
Etani Electronics Co., Ltd.	•	•	•		•	•	•
NETHERLANDS							
ELTIM audio, BV	•		•				
Hypex Electronics, BV	•	•	•			•	
the BEE	•	•					
SWEDEN							
Audio Pro, AB		•	•		•	•	•
Bohmer Audio, AB	•	•	•			•	•
TAIWAN							
Kingstate Electronics Corp.	•				•		•
Yung International, Inc.	•					•	•

	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
UNITED KINGDOM							
EuroTec International, Plc.	•		•	•			
Ferguson Hill Studios, Ltd.	•	•	•				•
Kleio Audio, Ltd.	•						
MJ Acoustics			•			•	
Revolver Audio, Ltd.	•						
Tectonic Elements, Ltd.	•						
UNITED STATES							
AMS Audio Enterprises, Inc.	•					•	•
Area 52 R&D	•	•	•			•	
Audio Advisor, Inc.	•						
Audio Nirvana	•						
Audio-Optix	•	•			•		•
Barefoot Sound, LLC	•	•	•				
Carvin Audio	•	•					•
CGN Audio Labs							•
Danville Signal Processing, Inc.	•	•	•	•		•	

Powersoft AUDIO



MINIMOD 4



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	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
Dayton Audio	•	•	•		•	•	•
Digital Audio Labs	•	•					
Digmoda	•	•	•			•	
DMSI	•	•	•				
Dragonfire Acoustics	•	•	•	•	•	•	•
DTV Installations, LLC	•		•		•	•	•
Eagle Acoustics	•			•	•		•
Earthquake Sound Corp.	•		•			•	
Etal Group, AB/Anaview	•		•	•	•	•	
Fulcrum Acoustic, LLC		•					
Globe Audio Design, Inc.	•	•	•			•	
JL Audio, Inc.	•	•	•	•		•	•
Kramer Electronics	•	•	•			•	•
Linear Tube Audio	•		•				
MISCO	•	•	•		•		
Parts Express	•	•	•		•	•	•
Peerless by Tymphany HK, Ltd.	•	•	•		•		•
Ponderosa Sound Systems	•						

	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
PowerPhysics, Inc.	•	•	•			•	
Pro Flix Sales	•						
Radio Design Labs (RDL)	•		•				
RBH Sound	•					•	
SpeakerAddict	•	•	•	•		•	
SpeakersAndAmps.com	•	•	•	•		•	
Spectrum Audio	•						•
Stillwater Designs | KICKER	•	•	•	•			•
TSG Audio	•	•	•		•	•	
US Enclosure Co.	•	•	•		•	•	•
US Speaker, LLC	•						
Vidsonix Design Works				•			
Weltronics Corp.	•	•	•				
Western Electric	•						
Wired 4 Sound, Inc.	•	•			•		•
Wisdom Audio		•			•		

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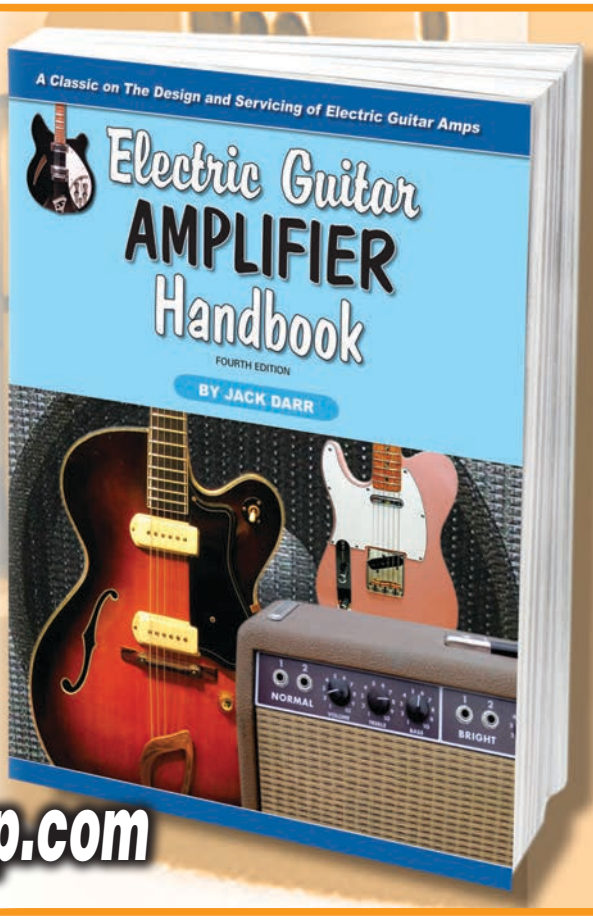

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Stone Sound Studio					•		
CANADA							
Canadian Speaker Works	•	•		•		•	
CHINA							
OBE Pro Audio Co., Ltd.	•	•	•	•	•	•	
Shenzhen Tekzone Loudspeaker Co., Ltd.	•	•			•	•	
Sound Technology Development, Ltd. (Factory)	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•
DENMARK							
K & K Development					•		
LOUDSOFT, Ltd.					•		
GERMANY							
Klippel GmbH					•		
INDIA							
Lakshmi Metal Coils						•	
JAPAN							
Etani Electronics Co., Ltd.					•		
SWEDEN							
Audio Pro, AB					•		
SWITZERLAND							
Kisling, AG	•						
Megatec, AG		•		•	•	•	•
THAILAND							
Clarasonic (Thailand) Co., Ltd.	•	•	•				
UNITED KINGDOM							
EuroTec International, Plc.	•	•	•	•	•	•	•
Hill Acoustics					•		

	Adhesive Dispensers	Conveyors	Curing Ovens	Lead Out Wire Termination	Production Line Equipment	Magnetizers/Demagnetizers	Ultrasonic Assembly Equipment
UNITED STATES							
Acoustic Design, Inc.						•	
Adrian Acoustics, Inc.		•			•		
Astro Machine Works, Inc.					•		•
Bruel & Kjaer Sound & Vibration North America, Inc.					•		
Conveyor Systems & Engineering, Inc.		•					
Delta H Technologies, LLC			•				
Dragonfire Acoustics						•	
Dukane Northeast Technical Center					•		•
Dymax Corp.	•						
Dynavox Electronics, Inc.						•	
Ellsworth Adhesives	•						
Fisnar, Inc.	•						
Fluid Metering, Inc.	•				•		
Glenro, Inc.			•				
Global Finishing Solutions, LLC			•				
Hernon Manufacturing, Inc.	•	•	•		•		
Krayden, Inc.	•						
LEWCO, Inc.		•	•				
Metzgar Conveyors		•					
Nordson Corp.	•						
NTi Audio, Inc.					•		
Parts Express	•						
PRV Audio Brazil					•		
Sealant Equipment	•						
The Eraser Co.					•		
Uni-Pak Corp.		•					
Valley Design Corp.					•		•
Wisconsin Oven			•				
WSF Industries, Inc.			•				

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CANADA					
Canadian Speaker Works				•	•
Solen Electronique, Inc.	•	•		•	
CHINA					
BSWA Technology Co., Ltd.		•	•	•	•
CRY Sound Co., Ltd.		•	•	•	•

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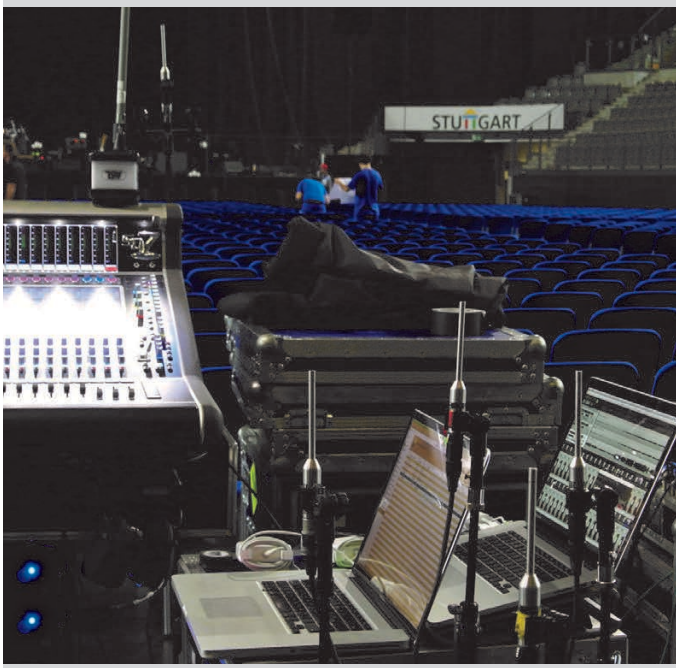

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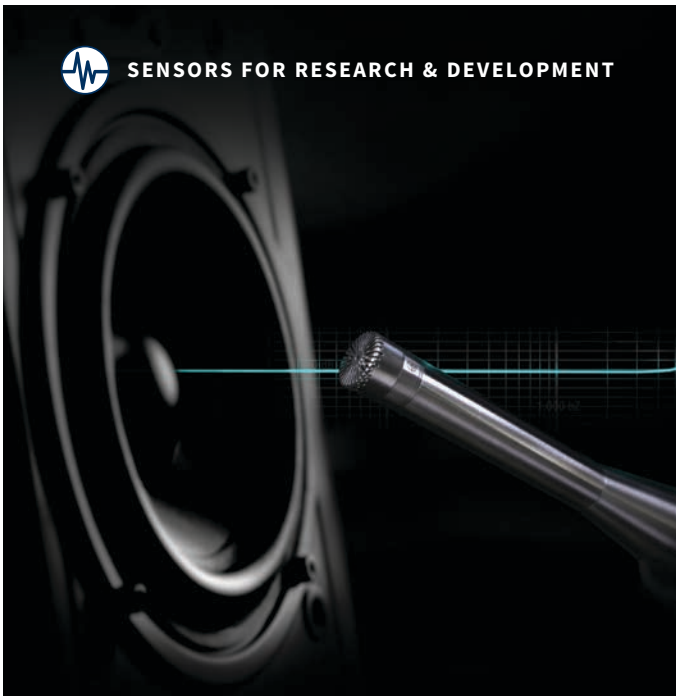

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Sound Technology Development, Ltd. (Factory)					•
Sun Technique Electric Co., Ltd.	•	•	•	•	•
DENMARK					
Jantzen Audio Denmark	•				
K & K Development				•	
FRANCE					
KYU Systems			•	•	
GERMANY					
Klippel GmbH				•	
Microtech GEFELL	•	•		•	•
Voice Point	•	•	•	•	•
HONG KONG					
miniDSP				•	
WCE Acoustics	•				•
INDIA					
GM Audio Technics, Ltd.				•	
JAPAN					
Etani Electronics Co., Ltd.		•	•	•	
SOUTH KOREA					
Suntel Co., Ltd.	•	•	•	•	•
SWEDEN					
Audio Pro, AB			•	•	
TAIWAN					
Kingstate Electronics Corp.	•				
UNITED KINGDOM					
EuroTec International, Plc.			•	•	•
UNITED STATES					
ACO Pacific, Inc.		•	•	•	•
Audio Precision, Inc.			•		
Audix	•			•	•
AValive	•				•
B&H Photo Video	•				•
Bruel & Kjaer Sound & Vibration North America, Inc.			•	•	
Dayton Audio	•	•	•	•	•
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NTi Audio, Inc.			•	•	•
Parts Express	•	•	•	•	•
PCB Piezotronics, Inc.		•	•	•	
PreSonus Audio Electronics, Inc.				•	
Scantek, Inc.		•	•	•	•
Sound Pure, LLC	•				•
Speaker Clinic				•	
Spectrum Audio	•				•
Studio Six Digital			•	•	
Sweetwater Sound	•				•
Vintage King Audio	•			•	•
Wired 4 Sound, Inc.	•	•		•	•
Yandas Music	•				•
zZounds Music, LLC					•

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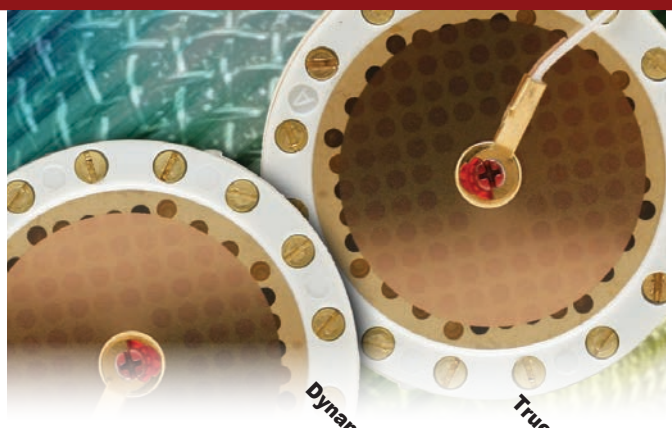

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CHINA				
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Sound Technology Development, Ltd. (Factory)	•			
Sun Technique Electric Co., Ltd.	•	•	•	•	•
FRANCE				
KYU Systems		•		•	
GERMANY				
Microtech GEFELL	•	•	•	•	•
SOUTH KOREA				
Suntel Co., Ltd.	•	•	•	•	•
SWEDEN				
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TAIWAN				
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UNITED STATES				
ACO Pacific, Inc.		•			
AValive	•	•	•	•	•
B&H Photo Video	•	•	•	•	•
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Front End Audio, LLC	•	•	•	•	•
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Sound Pure, LLC	•	•	•	•	
Spectrum Audio	•	•	•	•	•
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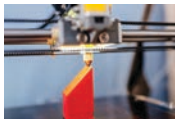

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CANADA			
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CHINA			
M-Sound Electronics Co., Ltd.			•
Shenzhen Tekzone Loudspeaker Co., Ltd.		•	
Sound Technology Development, Ltd. (Factory)	•	•	•
Speakerhu Electronic Co., Ltd.	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•
Wavecor, Ltd.		•	
GERMANY			
Voice Point		•	•
HONG KONG			
Eastern Asia Technology (HK), Ltd.		•	•
WCE Acoustics	•	•	•
SOUTH KOREA			
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TAIWAN			
Huey Tung International Co., Ltd.	•	•	•
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UNITED STATES			
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Broad Bridge Audio, LLC	•	•	•
Dayton Audio	•	•	•
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GGEC America, Inc.	•	•	•
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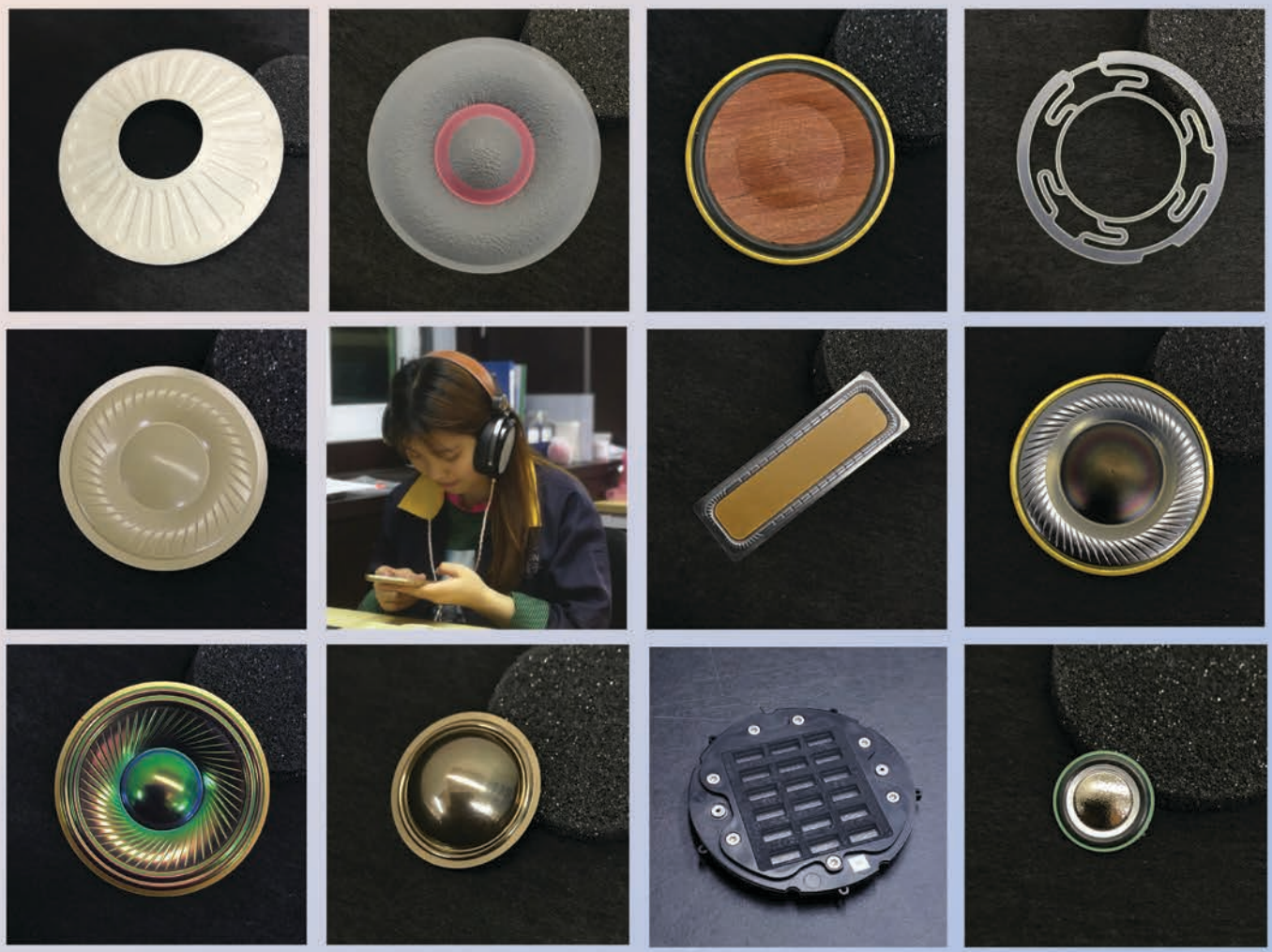

Application

Consumer Products	Electronic Components	Industrial / Medical
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BELGIUM		
Donnet Sound and Vision	•	•
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DLC Loudspeaker R&D Group	•	•
Excelitas Canada, Inc.		•
LMH Loudspeakers		•
Planet10-HiFi		•
Solen Electronique, Inc.	•	•
Studio Reference Monitors		•
The Canadian Loudspeaker Corp.	•	•
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B.W. Audio Guangzhou Co., Ltd.		•
Enkor Electronics Co., Ltd.		•
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M-Sound Electronics Co., Ltd.		•
OBE Pro Audio Co., Ltd.	•	•
Panasound Technology Co., Ltd.		•
Shenzhen Tekzone Loudspeaker Co., Ltd.		•
Sonos, Inc.		•
Sound Technology Development, Ltd. (Factory)	•	•
Speakerhu Electronic Co., Ltd.		•
Sun Technique Electric Co., Ltd.	•	•
Trueanalog Strictly OEM	•	•
Zhuhai HiVi Technology Co., Ltd.		•
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FRANCE		
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Audax		•
KYU Systems	•	
GERMANY		
Soundsgood Pro Audio Solutions		•
Wolf von Langa		•
HONG KONG		
Eastern Asia Technology (HK), Ltd.	•	•
Ocean Star Electronics, Ltd.		•
WCE Acoustics	•	•
INDIA		
GM Audio Technics, Ltd.	•	•
Power Electronics & Technologies		•
INDONESIA		
SB Acoustics	•	•

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NORWAY		
SEAS Fabrikker, AS		•
ROMANIA		
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Taiwan Solidex Corp.		•
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Yung International, Inc.	•	•
THAILAND		
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Ferguson Hill Studios, Ltd.		•
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Area 52 R&D		•
Arnold Magnetic Technologies/ Precision Thin Metals/	•	

	Acoustic Materials	Finished Goods
Audio Connection		•
Audioengine		•
Audio-Optix	•	•
Barefoot Sound, LLC		•
Bob Young and Associates	•	•
Broad Bridge Audio, LLC	•	•
Campanella Associates & Acculab		•
Dayton Audio		
Digmoda		•
Dynavox Electronics, Inc.		•
Earthquake Sound Corp.		•
Eminence Speaker, LLC		•
Fulcrum Acoustic, LLC		•
Geometric Designs, LLC & Geometric Consulting		•
GGEC America, Inc.	•	•
Hearing Components, Inc. (Comply Memory Foam Tips)	•	
J&F Wood Products	•	
JL Audio, Inc.		•
Lowell Manufacturing Co.		•
MISCO		•
Monaero Engineering, Inc.		•
MSC Software Corp.	•	
ORCA Design And Manufacturing	•	
Parts Express	•	•
Pierce Audio Products	•	•
PranaFidelity		•
SoCal Sound Shop		•
Sound Sources Technology, Inc.		•
SpeakersAndAmps.com		•
Stetron International, Inc.		•
Stillwater Designs | KICKER		•
Studio Electric - David MacPherson		•
SVS, Inc.		•
Tone Tubby, Inc.		•
TSG Audio		•
United Gasket Corp.	•	
US Enclosure Co.	•	•
US Speaker, LLC		•
Westlake Audio, Inc.		•

	Air Motion Transformer (AMT)	Compression Drivers: Electrostatic	Compression Drivers: Tweeters	Compression Drivers: Midrange	Compression Drivers: Woofers	Full Range	Horns
AUSTRALIA							
Soundlabs Group Pty., Ltd.					•	•	•
Stone Sound Studio						•	
BELGIUM							
Donnet Sound and Vision	•	•	•	•	•	•	•
Premium Sound Solutions						•	
BULGARIA							
Oberton					•	•	
CANADA							
Canadian Speaker Works							•
DLC Loudspeaker R&D Group					•	•	•
Kravchenko-Audio						•	•
ORA Graphene Audio, Inc.					•	•	
Planet10-HiFi						•	
Solen Electronique, Inc.					•	•	•
Space-Tech Lab, Ltd.				•		•	•
Studio Reference Monitors					•	•	•
The Canadian Loudspeaker Corp.					•	•	•
CHINA							
Audiostar Electronics Co., Ltd.							•
B.W. Audio Guangzhou Co., Ltd.					•		
Enkor Electronics Co., Ltd.				•			
Fountek Electronics Co., Ltd.						•	•
LaVoce Co., Ltd.					•	•	•
M-Sound Electronics Co., Ltd.					•	•	•
OBE Pro Audio Co., Ltd.					•	•	
Panasound Technology Co., Ltd.	•				•	•	•
Sound Technology Development, Ltd. (Factory)					•	•	•
Speakerhu Electronic Co., Ltd.					•		
Sun Technique Electric Co., Ltd.				•	•	•	•
Wavecor, Ltd.						•	
Zhuhai HiVi Technology Co., Ltd.						•	
DENMARK							
Puriti Transducer Technology ApS						•	

18

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[te·tra· kɔɪl]

(noun)

1. Eighteen Sound's unique transducer technology, integrating four voice coils in a dual gap motor structure, reaching unmatched power handling and acoustic output, reduced power compression, and improved cone control at Xmax.
2. Eighteen Sound loudspeaker family offering Tetracoil technology in a complete range of solutions for low frequency reproduction, from subwoofers (21''/18''/15'' Neodymium/Ferrite) to mid-bass applications (12''/15'' Neodymium).

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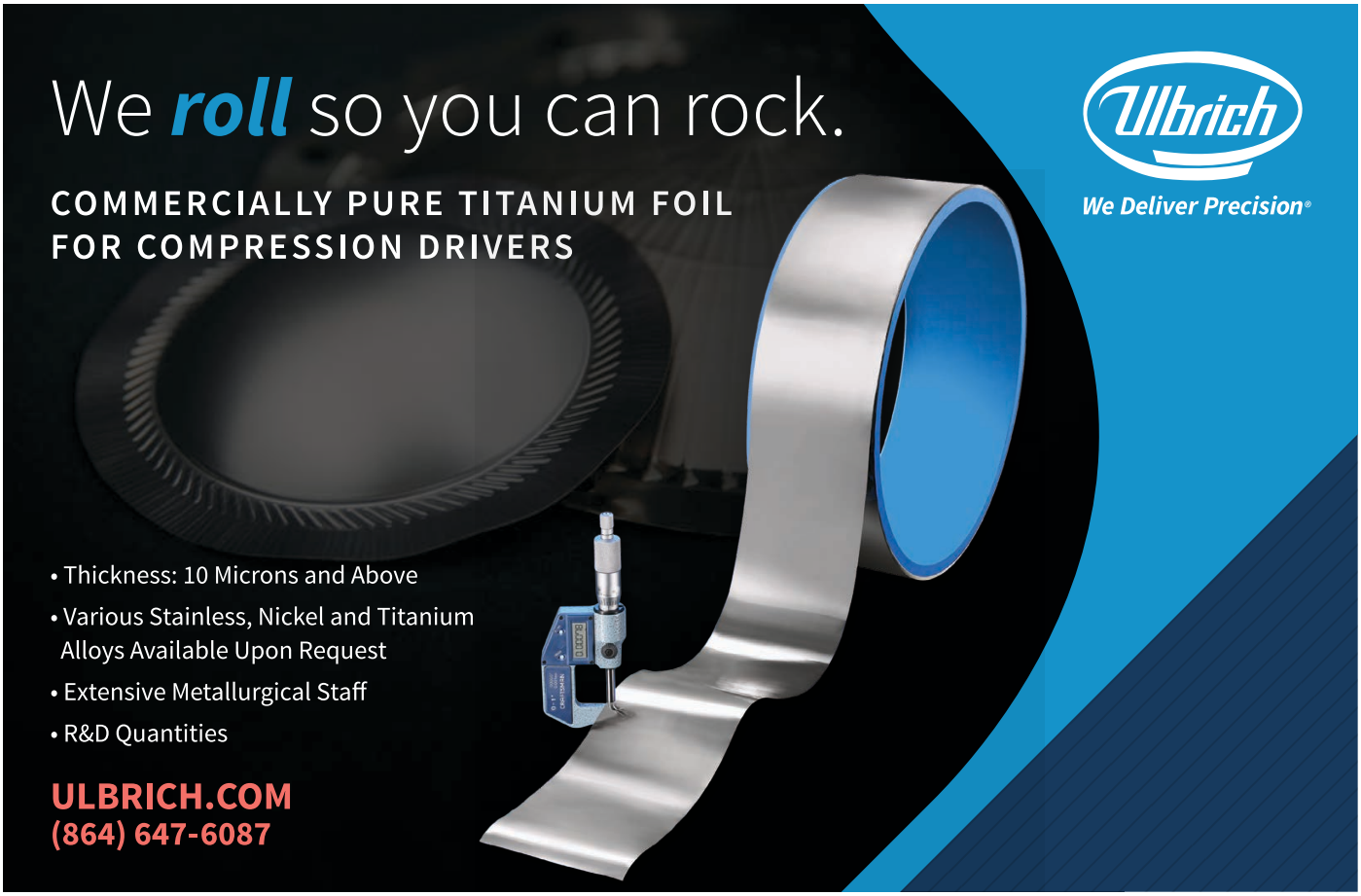
	Air Motion Transformer (AMT)	Compression Drivers: Electrostatic	Compression Drivers: Tweeters	Compression Drivers: Midrange	Compression Drivers: Woofers	Full Range	Horns
FRANCE							
Audax						•	•	•
KYU Systems						•	•	•
PHL Audio							•	
Supravox							•	•
Waterfall Audio					•			
GERMANY							
BMS Speakers GmbH						•	•	•
ic audio GmbH						•	•	•
Lautsprecher-Produktions-Gesellschaft (LPG) mbH							•	
Physical Lab							•	
Voice Point	•	•	•	•	•	•	•	•
Wolf von Langa	•					•	•	
HONG KONG							
Eastern Asia Technology (HK), Ltd.					•		•	
Ocean Star Electronics, Ltd.							•	
WCE Acoustics					•		•	•
HUNGARY							
Bayz Audio							•	



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Even before we finished building it

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CF1025C

From a range of small-diameter, high performance Celestion professional drivers

MANUFACTURERS

Contact Celestion to request a sample

	Air Motion Transformer (AMT)	Electrostatic	Compression Drivers	Full Range	Horns
	Tweeters	Midrange	Woofers			
INDIA						
GM Audio Technics, Ltd.				•	•	•
INDONESIA						
SB Acoustics				•	•	
ISRAEL						
Coby Speakers				•	•	•
Morel					•	
ITALY						
Axiomedia, SRL				•	•	•
AXP				•	•	
B&C Speakers, SpA				•	•	•
CIARE				•	•	•
Eighteen Sound, SRL				•		•
FaitalPRO				•	•	•
Professional Audio, Snc.				•	•	•
RCF, SpA				•	•	•
MALAYSIA						
TC Electronics, Sdn., Bhd.				•		

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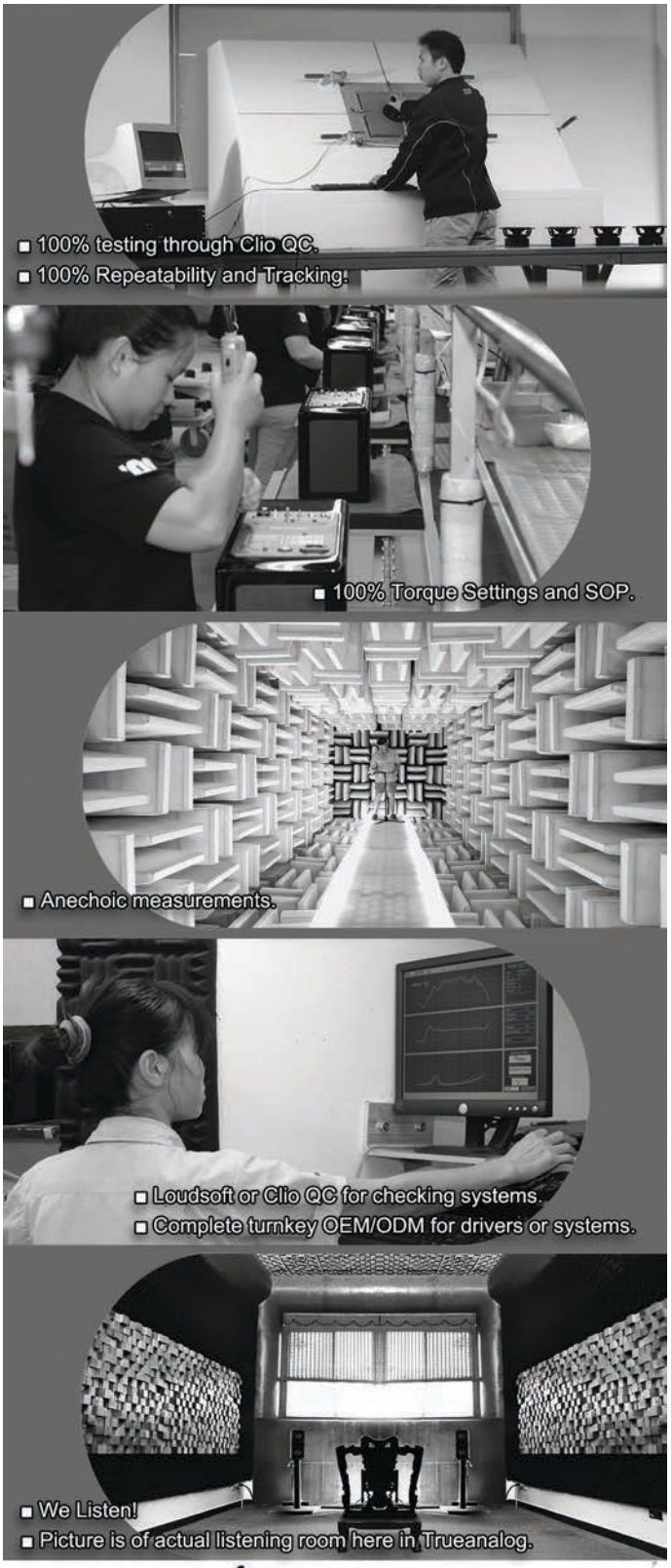

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	Air Motion Transformer (AMT)	Tweeters	Midrange	Woofers	Electrostatic	Compression Drivers	Full Range	Horns
NETHERLANDS								
Audio Components, BV							•	
ELTIM audio, BV		•					•	•
Good Hifi VOF		•						
NORWAY								
SEAS Fabrikker, AS							•	
RUSSIA								
Star Sound Technologies							•	
SPAIN								
Acustica Beyma, S.L.						•	•	•
SWEDEN								
Audio Pro, AB					•	•	•	
TAIWAN								
Hi-Tech System Co., Ltd.		•	•	•	•		•	
Huey Tung International Co., Ltd.					•	•	•	•
Hurray Co., Ltd.		•					•	•
TB Speaker Co., Ltd.							•	
UKRAINE								
Mag Audio						•	•	•
UNITED KINGDOM								
Arya Audio Labs, Ltd.							•	
Bishopsound						•	•	
Celestion						•	•	•
CompBass, Ltd.						•		
EuroTec International, Plc.					•	•	•	•
Fane International, Ltd.						•	•	•
MJ Acoustics					•			
Precision Devices, Ltd.						•	•	
Tectonic Elements, Ltd.							•	
Volt Loudspeakers, Ltd.							•	
UNITED STATES								
Acoustic Design, Inc.						•		•
American Bass USA					•	•	•	•
American Music And Sound					•			
AMS Audio Enterprises, Inc.						•	•	•
Analysis Audio USA		•	•					
Arion Audio		•	•	•				
Audio Nirvana							•	
Beyma Pro Audio		•	•		•	•	•	•
Broad Bridge Audio, LLC		•	•				•	
CGN Audio Labs							•	
Dayton Audio						•	•	•
DC Gold Audio							•	
Dragonfire Acoustics			•	•	•		•	
Dynavox Electronics, Inc.						•	•	•
Earthquake Sound Corp.						•	•	•
Eminence Speaker, LLC					•	•	•	•
ESS Laboratories, LLC					•			
GGEC America, Inc.						•	•	•
Global Audio Source, Inc.						•	•	
Knowles Electronics, LLC							•	

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SCALE
1:1

B&C SPEAKERS®

	Air Motion Transformer (AMT)			Electrostatic	Compression Drivers	Full Range		Horns
	Tweeters	Midrange	Woofers					
Loudspeakers Plus						•	•	•
Lowther Speakers USA							•	
Martin Sound Products (MSP), LLC						•	•	•
MISCO						•	•	
NedLab							•	
Parts Express	•	•			•	•	•	•
Peerless by Tymphany HK, Ltd.						•	•	
Sanming Sound						•		•
Seltech							•	
Simply Speakers						•		
SoCal Sound Shop						•	•	
SpeakerAddict					•	•	•	•
SpeakersAndAmps.com						•	•	•
Stetron International, Inc.							•	
Stillwater Designs | KICKER						•	•	
SVS, Inc.							•	
Tonian Laboratories							•	
TSG Audio					•	•	•	•
Ulbrich Stainless Steels & Special Metals, Inc.						•		
US Speaker, LLC						•		•
Vidsonix Design Works							•	
Western Electric	•	•	•					
Yandas Music						•		

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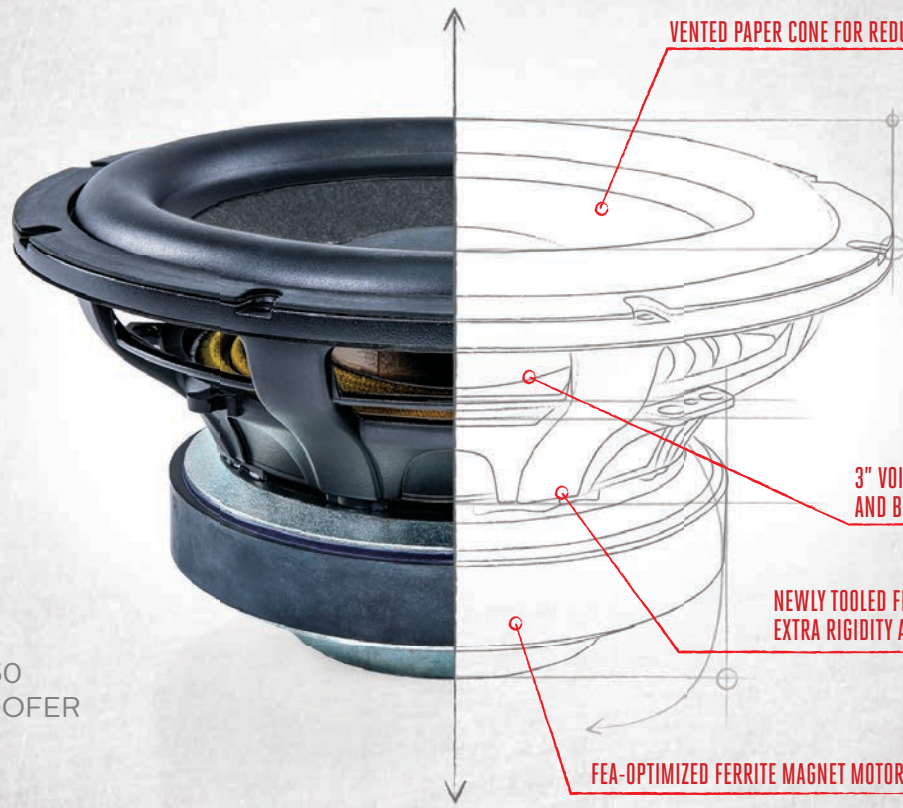

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	Midrange						Siren/Voice Warning				Tweeters				
	Cone	Dome	Electrostatic	Planar	Ribbon	Paging Horns	Piezo	Planar	Cone		Cone	Dome	Electrostatic	Ribbon	Woofers
AUSTRALIA															
Soundlabs Group Pty., Ltd.	•	•					•				•	•		•	•
Stone Sound Studio	•	•			•	•	•				•	•		•	•
BELGIUM															
Donnet Sound and Vision	•	•	•		•	•	•	•	•	•	•	•	•	•	•
Premium Sound Solutions	•	•									•	•		•	•
BULGARIA															
Oberton	•								•						•
CANADA															
Canadian Speaker Works															•
DLC Loudspeaker R&D Group	•	•	•		•	•		•	•		•	•	•	•	•
Harbottle Audio															•
Kravchenko-Audio					•				•			•			•
Newform Research, Inc.						•								•	
ORA Graphene Audio, Inc.	•	•			•				•		•	•			•
Planet10-HiFi															•
Solen Electronique, Inc.	•	•							•		•	•		•	•
Space-Tech Lab, Ltd.	•	•									•	•		•	•
Studio Reference Monitors	•											•			•
The Canadian Loudspeaker Corp.	•											•			•
CHINA															
Audiostar Electronics Co., Ltd.															•
B.W. Audio Guangzhou Co., Ltd.															•
Enkor Electronics Co., Ltd.	•	•									•	•			•

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	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Cone	Dome	Electrostatic	Ribbon			
Fountek Electronics Co., Ltd.												•	•	
LaVoce Co., Ltd.	•	•								•	•		•	
M-Sound Electronics Co., Ltd.		•			•					•	•		•	
OBE Pro Audio Co., Ltd.														•
Panasound Technology Co., Ltd.	•	•								•	•		•	•
Shenzhen Tekzone Loudspeaker Co., Ltd.	•	•									•		•	•
Sonos, Inc.	•	•								•	•			•
Sound Technology Development, Ltd. (Factory)	•	•				•	•			•	•			•
Speakerhu Electronic Co., Ltd.	•	•								•	•			•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Wavecor, Ltd.	•	•								•	•			•
Zhuhai HiVi Technology Co., Ltd.		•								•	•		•	•
DENMARK														
Hiquphon											•			
Puriti Transducer Technology ApS	•										•			•
Scan Speak, AS	•	•								•	•	•		
FRANCE														
Audax	•	•								•	•			•
KYU Systems	•			•				•						•
PHL Audio	•										•			•

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	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Cone	Dome	Electrostatic	Ribbon			
Supravox	•								•	•				•
Waterfall Audio														•
GERMANY														
BMS Speakers GmbH	•			•				•	•					•
ic audio GmbH						•								
Lautsprecher-Produktions-Gesellschaft (LPG) mbH	•									•				•
Physical Lab										•				
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Wolf von Langa	•	•												•
HONG KONG														
Eastern Asia Technology (HK), Ltd.	•	•								•	•			•
Ocean Star Electronics, Ltd.	•	•								•	•			•
WCE Acoustics	•	•	•	•	•	•	•	•	•	•	•			•
HUNGRY														
Bayz Audio								•						
INDIA														
GM Audio Technics, Ltd.	•	•								•				•

LA PASSION DU HAUT-PARLEUR

AUDAX

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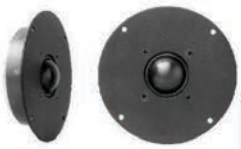

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	Midrange						Tweeters								
	Cone	Dome	Electrostatic	Planar	Ribbon	Paging Horns	Piezo	Planar	Siren/Voice Warning	Cone	Dome	Electrostatic	Ribbon	Woofers	
INDONESIA															
SB Acoustics	•	•					•			•	•		•	•	
ISRAEL															
Coby Speakers	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Morel	•	•									•			•	
ITALY															
Axiomedia, SRL	•	•									•		•	•	
AXP	•	•								•	•			•	
B&C Speakers, SpA	•										•		•	•	
CIARE														•	
Eighteen Sound, SRL														•	
FaitalPRO	•	•								•	•			•	
Professional Audio, Snc.	•	•								•	•			•	
RCF, SpA														•	
MALAYSIA															
TC Electronics, Sdn., Bhd.	•	•								•	•			•	
NETHERLANDS															
Audio Components, BV		•									•			•	
ELTIM audio, BV	•	•									•			•	
Good Hifi VOF	•									•	•			•	

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	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Cone	Dome	Electrostatic	Ribbon	
NORWAY														
SEAS Fabrikker, AS	•	•								•				•
RUSSIA														
Star Sound Technologies	•	•								•	•			•
SPAIN														
Acustica Beyma, S.L.	•									•			•	•
SWEDEN														
Audio Pro, AB	•	•		•	•		•	•		•	•		•	•
TAIWAN														
BESTON Technology Corp.				•	•			•					•	
Hi-Tech System Co., Ltd.	•	•								•	•			•
Huey Tung International Co., Ltd.	•	•	•				•		•	•	•	•		•
Hurray Co., Ltd.														•
Kingstate Electronics Corp.							•		•					
Taiwan Solidex Corp.							•						•	•
TB Speaker Co., Ltd.	•	•			•					•	•		•	•
Yie Feng Technology Enterprise Co.	•													
UKRAINE														
Mag Audio	•													•

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	Midrange					Paging Horns		Tweeters					Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Siren/Voice Warning	Cone	Dome	Electrostatic	Ribbon	
UNITED KINGDOM													
Arya Audio Labs, Ltd.													
Bishopsound													•
Celestion	•								•				•
CompBass, Ltd.													•
EuroTec International, Plc.	•	•	•						•	•	•	•	•
Fane International, Ltd.	•									•	•		•
MJ Acoustics													•
Precision Devices, Ltd.	•										•		•
Tectonic Elements, Ltd.													
Volt Loudspeakers, Ltd.	•	•											•
UNITED STATES													
Acoustic Design, Inc.		•											
Aempyrean								•					
American Bass USA	•	•	•	•	•	•		•	•	•	•	•	•	•
American Music And Sound													•
AMS Audio Enterprises, Inc.	•	•								•	•		•
Analysis Audio USA					•			•				•	
Area 52 R&D	•										•		•
Arion Audio													
Arnold Magnetic Technologies/ Precision Thin Metals		•									•		

	Midrange					Tweeters								
	Cone	Dome	Electrostatic	Planar	Ribbon	Paging Horns	Piezo	Planar	Siren/Voice Warning	Cone	Dome	Electrostatic	Ribbon	Woofers
BeStar Technologies, Inc.								•						
Beyma Pro Audio	•	•	•	•	•	•	•			•	•	•	•	•
Broad Bridge Audio, LLC				•	•			•					•	
Carvin Audio														•
CGN Audio Labs													•	•
Dayton Audio	•	•		•	•	•		•		•	•		•	•
DC Gold Audio	•													
Dragonfire Acoustics			•	•	•			•				•	•	•
Dynavox Electronics, Inc.	•	•			•	•	•	•	•	•	•		•	•
Earthquake Sound Corp.														•
Electro Mavin	•	•									•			•
Eminence Speaker, LLC	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ESS Laboratories, LLC														•
Full Compass Systems, Ltd.	•	•	•							•	•	•	•	•
GGEC America, Inc.	•	•					•		•	•	•	•	•	•
Global Audio Source, Inc.										•	•			•
HDSound								•					•	•
JL Audio, Inc.	•													•
Loudspeakers Plus	•													•
Martin Sound Products (MSP), LLC	•						•							•
Meniscus Audio Group, Inc.														•
MISCO	•							•		•	•	•		•
NedLab	•	•								•	•			•

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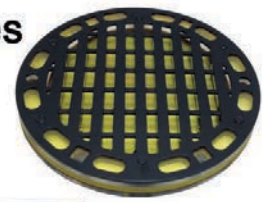

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	Passive Components												Finished Passive Crossover Nets		
	Attenuators	Capacitors: Ceramic	Capacitors: Electrolytic Non-Polar	Driver Protection Devices	Driver Protection Devices: Film	Inductors	Inductors: Air Core	Inductors: Iron Core	Plugs & Jack Dishes	Resistors	Solder	Terminal Plates	Transformers	Electronic Crossovers	Wire & Wiring Harnesses
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Solen Electronique, Inc.		•		•	•	•	•		•	•	•	•			•
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GM Audio Technics, Ltd.													•	•	
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R. H. Sound Technology, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•		•	•
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JAPAN															
Furutech Co., Ltd.											•				•
MEXICO															
Aletheia, AV														•	•
NETHERLANDS															
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ELTIM audio, BV	•		•	•		•	•		•	•	•	•	•	•	•
POLAND															
Resnatura Audio				•								•			•
ROMANIA															
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Bennic Components	•		•	•		•	•		•		•			•	
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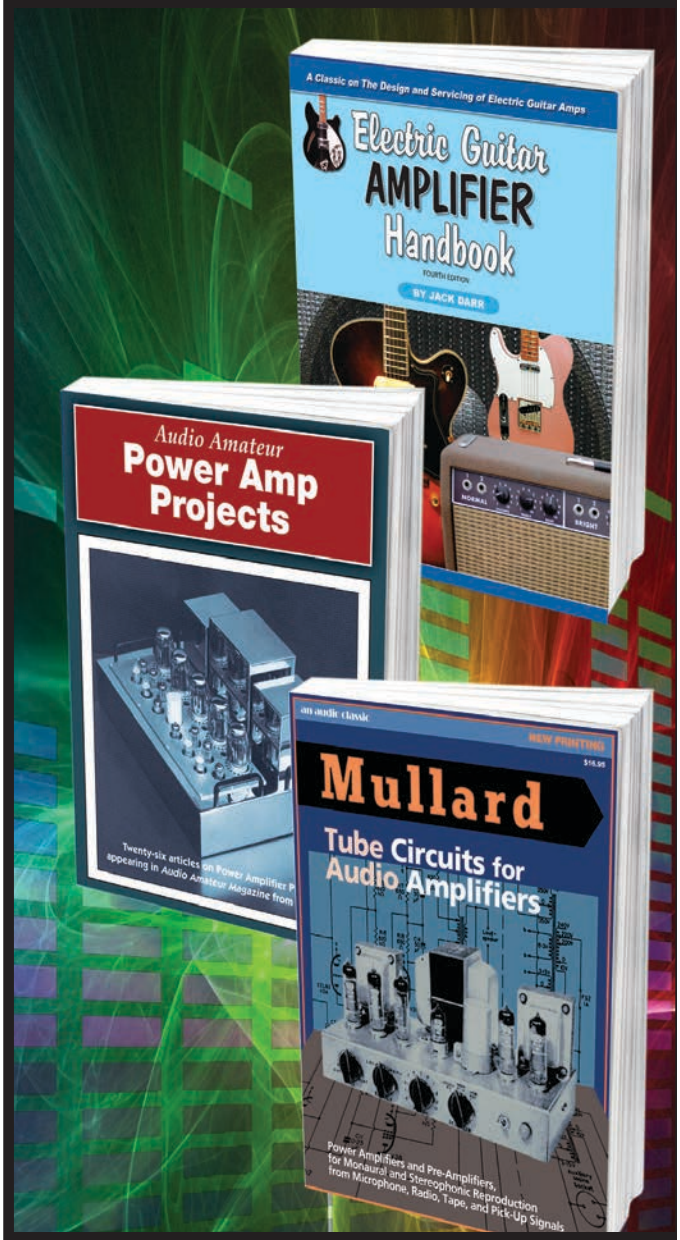

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		Ceramic	Electrolytic Non-Polar	Film		Air Core	Iron Core										
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Vidsonix Design Works	•					•						•					•
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Whitmor Wirenetics																	•
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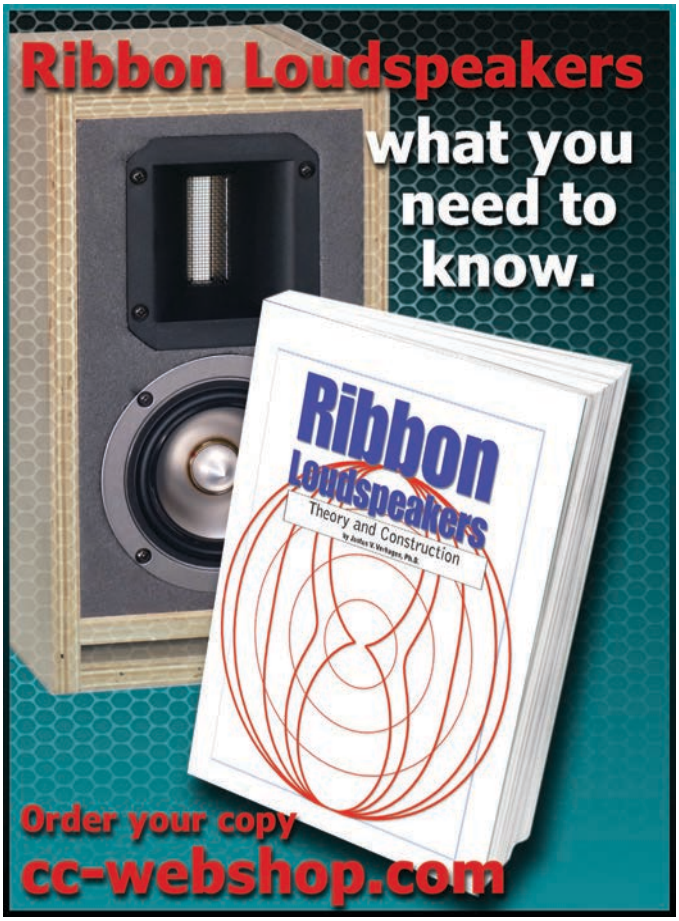

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												Cones				Domes			Spiders	Surrounds		
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AUSTRALIA																						
Soundlabs Group Pty., Ltd.							•		•													
BELGIUM																						
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CANADA																						
Canadian Speaker Works	•	•				•	•	•		•		•	•							•	•	•
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Tianyi Electronic Co., Ltd.												•	•	•	•	•	•	•	•	•	•	•
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	Adhesives & Glues					Cone Additives & Other Treatments					Cone & Suspension Components										
											Cones			Domes			Spiders	Surrounds		
	Acrylic Adhesives	Epoxy	Infra-Red Cure	Instant Adhesives	Water & Vinyl Based	Damping	Fire Resistance	Lacquers	Waterproofing	Wet Lock	Composite	Paper Pulp	Plastic	Aluminum/Titanium/Metal	Fabric/Mylar/Resin/Soft	Phenolic & Other Domes		Fabric	Foam	Rubber
FRANCE																				
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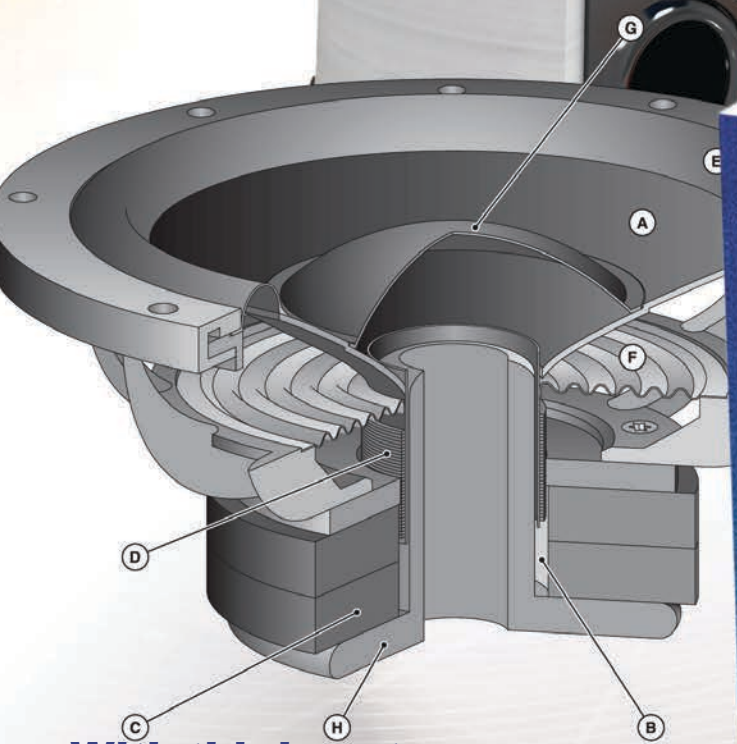

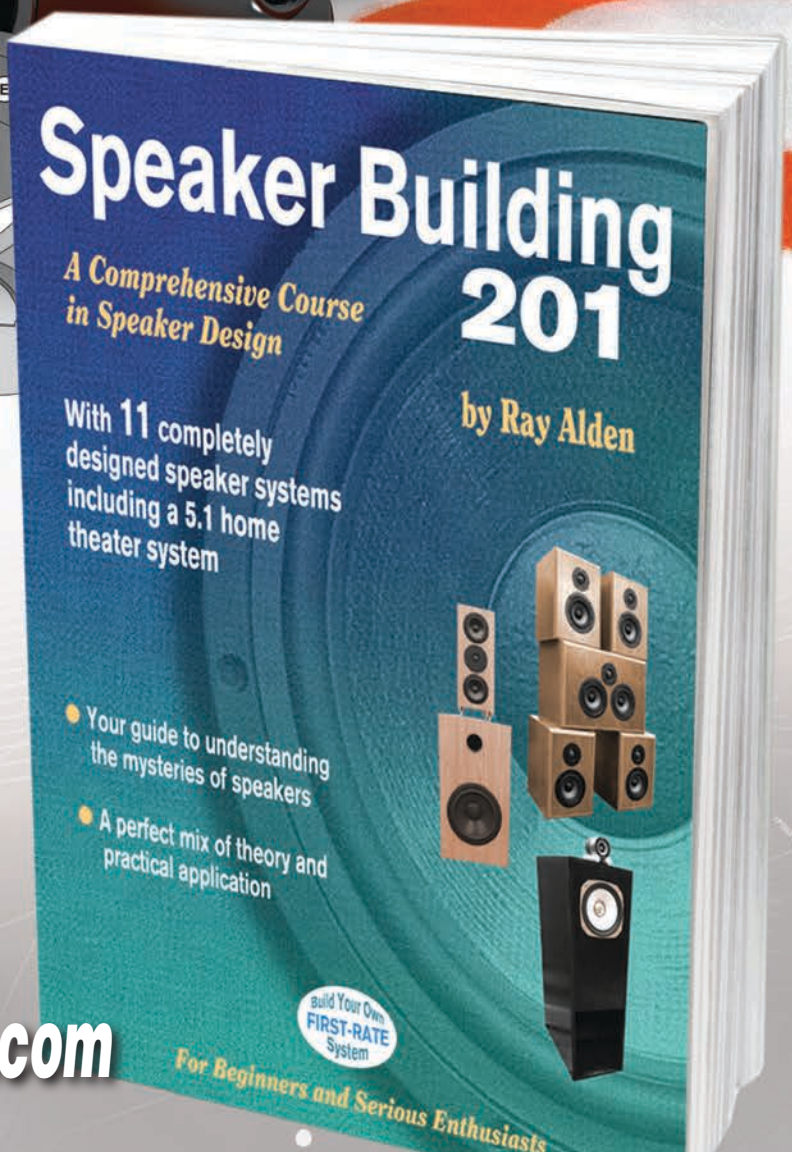

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Hi-Tech System Co., Ltd.											•		•			•	•			•
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	Adhesives & Glues					Cone Additives & Other Treatments				Cone & Suspension Components										
										Cones			Domes			Spiders	Surrounds			
	Acrylic Adhesives	Epoxy	Infra-Red Cure	Instant Adhesives	Water & Vinyl Based	Damping	Fire Resistance	Lacquers	Waterproofing	Wet Lock	Composite	Paper Pulp	Plastic	Aluminum/Titanium/Metal	Fabric/Mylar/Resin/Soft	Phenolic & Other Domes		Fabric	Foam	Rubber
UNITED STATES																				
AcousTex Fabrics																		•		
Arnold Magnetic Technologies/ Precision Thin Metals															•					
Dragonfire Acoustics						•		•	•											
Dymax Corp.	•	•	•	•	•															
Dynavox Electronics, Inc.											•	•	•	•	•	•	•	•	•	•
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Fulcrum Acoustic, LLC									•											
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											Cones			Domes			Spiders	Surrounds		
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Loudspeaker Components											•	•	•	•	•	•	•	•	•	•
Master Bond, Inc.	•	•	•	•	•															
Materion Electrofusion														•	•					
MISCO							•													
NedLab											•		•	•	•	•	•		•	•
Parts Express		•		•																
Pierce Audio Products		•									•	•		•				•	•	•
Quick Draw & Machining, Inc.														•	•					
RTP Co.		•		•			•		•											
Sherwood Industries, Inc.																			•	•
Simply Speakers	•	•		•	•				•	•		•	•					•	•	•
United Gasket Corp.						•													•	•
US Enclosure Co.						•					•							•		
Vidsonix Design Works									•											

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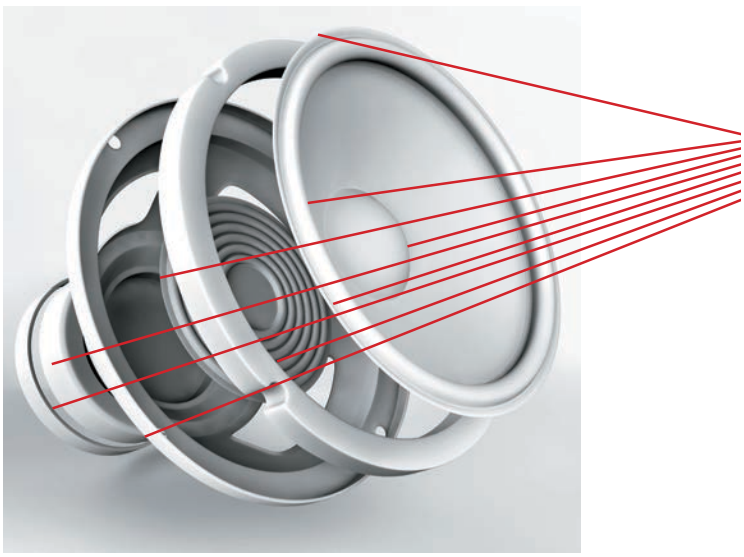

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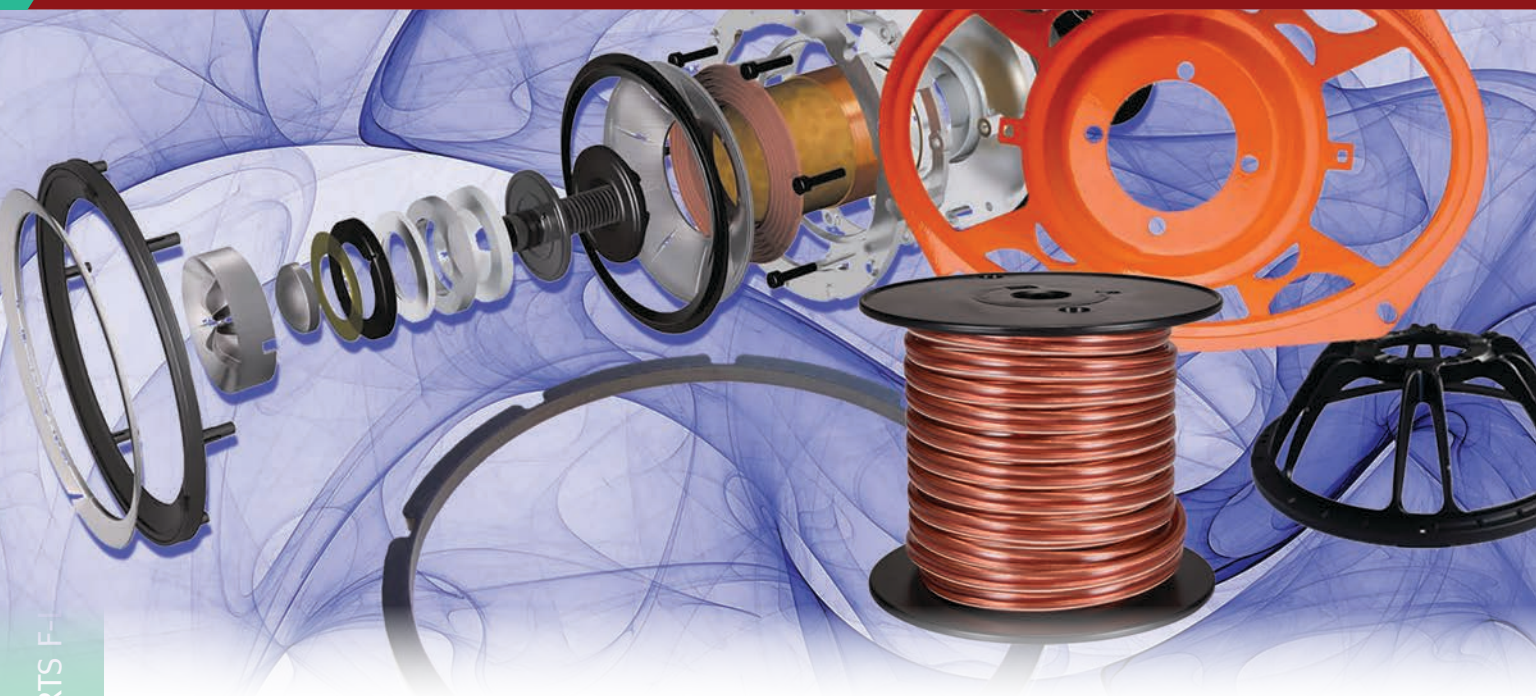

	Frames & Baskets						Lead Out Wire					
	Stamped Steel						Flat Strip			Termination/Crimps		Lead Out Wire
	Frame Gaskets						Braided					
	Cast Alloy	Bumped	Damped Metal	Double Bumped	Range of Diameters		Beryllium Copper	Phosphor Bronze	Litz	Stranded		
BELGIUM												
Donnet Sound and Vision							•	•	•	•	•	•
CANADA												
Canadian Speaker Works	•									•		•
DLC Loudspeaker R&D Group							•			•	•	
CHINA												
Lumi Audio	•	•	•	•	•	•						
Sound Technology Development, Ltd. (Factory)	•		•	•			•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•
Zhuhai HiVi Technology Co., Ltd.	•											
DENMARK												
Estron, a/s										•	•	•
FRANCE												
KYU Systems	•	•						•				
GERMANY												
Hubert Stueken GmbH & Co., KG	•	•	•	•	•	•						
Voice Point							•	•	•	•	•	•
Wolf von Langa	•						•					
HONG KONG												
Eastern Asia Technology (HK), Ltd.	•	•	•	•	•	•						
WCE Acoustics										•		
INDIA												
Vidyut Teletronics, Ltd.							•				•	
Wizard India Private, Ltd.	•	•										

	Frames & Baskets						Lead Out Wire					
	Frame Gaskets		Stamped Steel				Flat Strip			Termination/Crimps	Lead Out Wire	
	Cast Alloy		Bumped	Damped Metal	Double Bumped	Range of Diameters	Braided	Beryllium Copper	Phosphor Bronze	Litz	Stranded	
INDONESIA												
SB Acoustics			•	•	•	•				•		
ISRAEL												
Chorus Audio	•							•	•	•		
Coby Speakers	•	•	•	•	•	•	•	•	•	•	•	•
R. H. Sound Technology, Ltd.							•	•		•	•	•
ITALY												
Axiomedia, SRL							•	•	•		•	
FaitalPRO	•	•									•	•
Professional Audio, Snc.	•	•	•	•	•	•	•	•	•	•	•	•
JAPAN												
Furutech Co., Ltd.											•	
SWEDEN												
Audio Pro, AB	•	•	•	•	•	•	•	•		•		•
TAIWAN												
Hi-Tech Sound System Co., Ltd.		•	•									
Huey Tung International Co., Ltd.	•	•	•	•	•	•	•	•			•	
Maeden Innovation Co., Ltd.							•			•	•	•
Yie Feng Technology Enterprise Co.		•										
UNITED KINGDOM												
EuroTec International, Plc.	•	•	•	•	•	•	•	•	•			•
Precision Devices, Ltd.	•	•					•					
UNITED STATES												
A. Schulman, Inc.	•											
American Bass USA	•	•	•	•	•	•	•	•	•	•	•	•
AMS Audio Enterprises, Inc.	•	•				•						•
Dynavox Electronics, Inc.	•	•	•	•	•	•	•			•	•	
Global Audio Source, Inc.	•	•	•	•	•	•						
Globe Audio Design, Inc.	•	•	•	•	•	•						
Herman Pro, AV							•	•	•	•	•	•
Materion Electrofusion								•				
NedLab	•	•										
New England Wire Technologies							•	•	•	•	•	•
North Reading Engineering	•	•	•	•	•	•	•	•	•	•	•	•
Pierce Audio Products	•	•	•		•	•						
Quick Draw & Machining, Inc.	•			•	•	•						
RDS Wire & Cable							•	•	•	•	•	•
Redco Audio											•	
Simply Speakers							•					
Standard Wire & Cable Co.							•	•	•	•	•	•
United Gasket Corp.		•										
Western Electric							•				•	
Whitmor Wirenetics							•	•	•	•	•	•
Wireworld Cable Technology											•	

	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids	Pole Pieces	T-Yoke Top Plates	Bobbins/Formers	Collars	Magnet Wire	Polyimide Tape for Collars	Voice Coil Assemblies				Amplifiers	
		Alnico	Ferrite	Neodymium							Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Amplifier for Subwoofer	Plate Amplifier
AUSTRALIA																
Soundlabs Group Pty., Ltd.															•	
Stone Sound Studio																•
CANADA																
Canadian Speaker Works	•			•	•	•	•					•	•	•	•	•
DLC Loudspeaker R&D Group	•				•	•	•	•	•	•	•	•	•	•	•	•
Solen Electronique, Inc.				•						•					•	•
Studio Reference Monitors															•	
Tortech Sound, Inc.															•	
CHINA																
Audiostar Electronics Co., Ltd.								•	•	•	•	•	•	•		
Changzhou Xiantong Magnetic Materials Co., Ltd.		•		•	•											
Lumi Audio (China) OEM/ODM															•	•
OBE Pro Audio Co., Ltd.															•	•
One Magnet Electronic Co., Ltd.		•		•	•											
Sound Technology Development, Ltd. (Factory)	•			•	•	•	•	•	•	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
Tianyi Electronic Co., Ltd.		•		•	•		•									
Trueanalog Strictly OEM	•					•	•									

	Magnetic Assemblies					Voice Coil Components										
	Back Plates	Magnets		Magnetic Fluids	Pole Pieces	T-Yoke Top Plates	Bobbins/Formers	Collars	Magnet Wire	Polyimide Tape for Collars	Voice Coil Assemblies			Amplifiers		
		Alnico	Ferrite	Neodymium							Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Amplifier for Subwoofer Plate Amplifier
Zeng Ben Industrial Corp., Ltd.						•	•									
Zenith Audio Electronics Co., Ltd.										•		•	•	•		
FRANCE																
KYU Systems	•			•	•	•	•	•		•		•			•	•
GERMANY																
Voice Point	•	•	•	•	•	•	•									
Wolf von Langa	•					•	•	•				•	•			
HONG KONG																
Eastern Asia Technology (HK), Ltd.												•	•	•	•	•
WCE Acoustics	•	•	•	•			•	•	•	•	•	•	•	•		•
INDIA																
Lakshmi Metal Coils													•			
Power Electronics & Technologies															•	•
Vidyut Teletronics, Ltd.										•	•	•	•			
Wizard India Private, Ltd.			•				•									
INDONESIA																
SB Acoustics	•		•	•		•	•	•				•	•	•		

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	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids	Pole Pieces	T-Yoke Top Plates	Bobbins/Formers	Collars	Magnet Wire	Polyimide Tape for Collars	Voice Coil Assemblies			Amplifiers		
		Alnico	Ferrite	Neodymium							Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Amplifier for	Subwoofer Plate Amplifier
ISRAEL																
Chorus Audio	•	•		•	•		•	•								
Coby Speakers	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
R. H. Sound Technology, Ltd.								•	•	•	•	•	•	•	•	•
ITALY																
Axiomedia, SRL				•											•	•
FaitalPRO	•			•			•	•					•			
OEB, SRL												•	•			
Powersoft Audio, SpA															•	
Professional Audio, Snc.	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
MALAYSIA																
Million Interwork Sdn., Bhd.	•					•	•									
NETHERLANDS																
ELTIM audio, BV															•	
Hypex Electronics, BV															•	•

	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids		Pole Pieces	T-Yoke Top Plates	Bobbins/Formers	Collars	Magnet Wire	Polyimide Tape for Collars	Voice Coil Assemblies			Amplifiers	
		Alnico	Ferrite	Neodymium								Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Subwoofer Plate Amplifier
POLAND																
Resnatura Audio										•		•	•	•		
Sveda Audio															•	
SOUTH KOREA																
Suntel Co., Ltd.								•	•	•	•	•	•	•	•	•
TAIWAN																
Hi-Tech Sound System Co., Ltd.															•	•
Huey Tung International Co., Ltd.	•	•	•	•	•	•	•	•		•		•	•	•	•	•
Kingstate Electronics Corp.															•	
THAILAND																
FSK (Thailand) Co., Ltd.								•			•					
UNITED KINGDOM																
Bishopsound															•	•
EuroTec International, Plc.	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•
Precision Devices, Ltd.	•		•	•	•	•	•	•		•		•	•			
Volt Loudspeakers, Ltd.													•			

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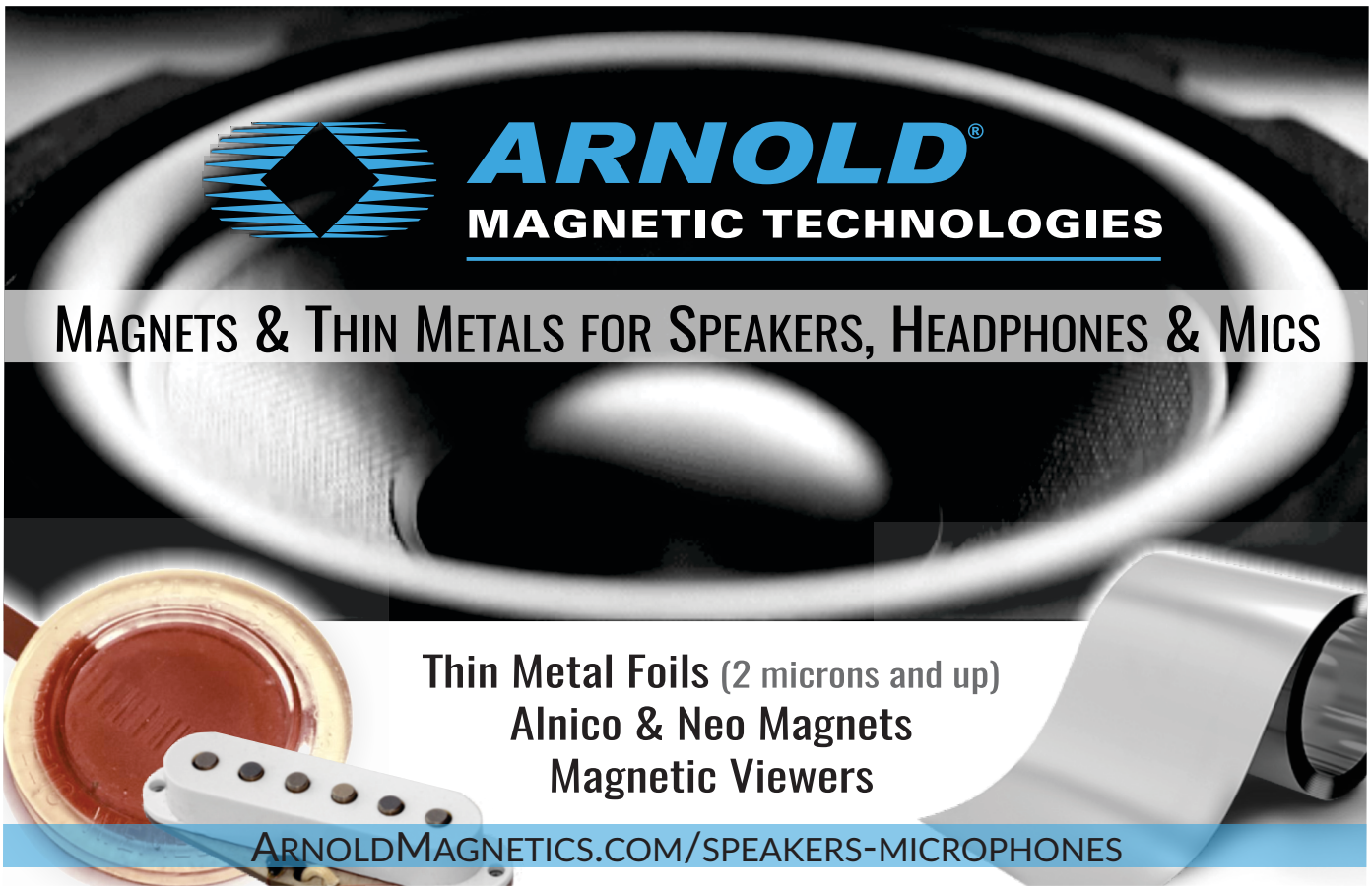
	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids		Pole Pieces	T-Yoke Top Plates	Bobbins/Formers	Magnet Wire	Polyimide Tape for Collars	Collars	Voice Coil Assemblies		Amplifiers		
		Alnico	Ferrite	Neodymium								Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Subwoofer Plate Amplifier
UNITED STATES																
Acoustic Design, Inc.	•						•	•					•	•	•	
American Bass USA	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
AMS Audio Enterprises, Inc.	•	•		•	•	•	•							•		•
Area 52 R&D	•			•		•	•									•
Arnold Magnetic Technologies/ Precision Thin Metals		•		•	•											
Audio Nirvana																•
Dayton Audio																•
DMSI																•
Dragonfire Acoustics													•	•	•	•
Dynavox Electronics, Inc.	•	•		•	•	•	•	•	•	•				•		•
Etal Group, AB/Anaview																•
Ferrotec (USA) Corp.					•											
Global Audio Source, Inc.	•	•		•	•	•	•									
Globe Audio Design, Inc.	•	•		•	•	•	•	•	•	•	•					
HISCO-Precision Converting											•	•	•	•		
Lamart Corp.											•					



	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids		Pole Pieces	T-Yoke Top Plates	Bobbins/Formers	Polyimide Tape for Collars	Magnet Wire	Collars	Voice Coil Assemblies			Amplifiers	
		Alnico	Ferrite	Neodymium								Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Subwoofer Plate Amplifier
Marchand Electronics, Inc.																•
Materion Electrofusion									•							
MISCO																•
NedLab									•							
Pierce Audio Products	•			•	•		•	•					•	•		
Precision Econowind, LLC									•	•	•	•	•	•	•	
PRV Audio Brazil				•	•											•
Radio Design Labs (RDL)																•
RBH Sound																•
Simply Speakers						•										
Sound Sources Technology, Inc.																•
SpeakerAddict																•
SpeakersAndAmps.com																•
Transducer Lab, LLC	•			•	•	•	•	•								
US Enclosure Co.																•
Vidsonix Design Works				•	•											
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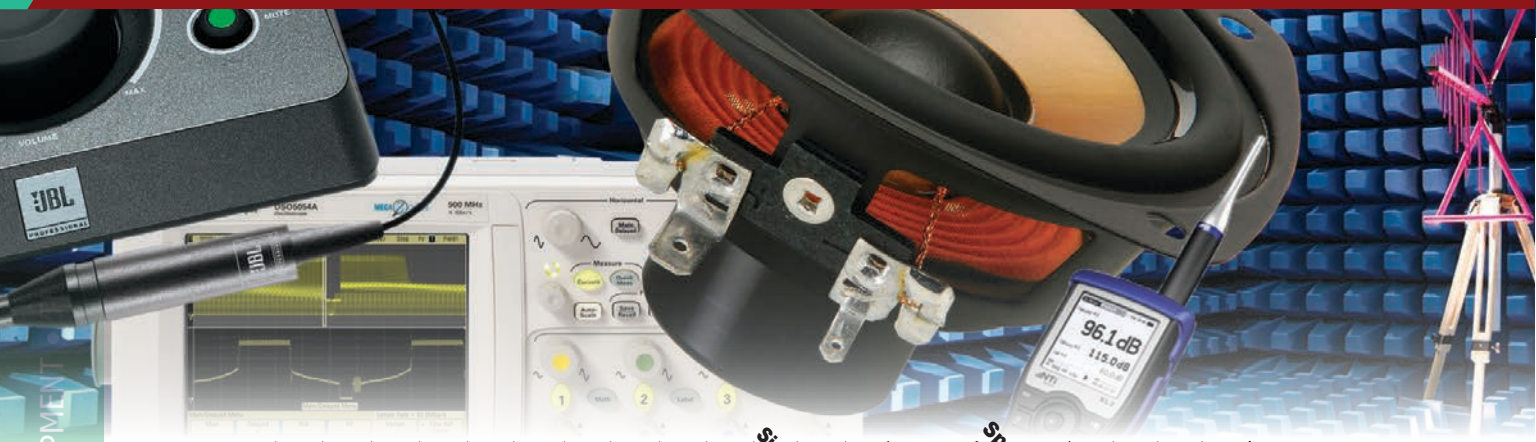

	Accelerometers	Anechoic Chambers	Audio Analyzers	Gaussmeters	LCR Bridges	MLS	Multimeters	Oscilloscopes	Resistance Bridges	Signal Generators	Sine/Square Wave Oscillators	Speaker Parts	Speaker Turntables	Spectrum Analyzers: 1/3 Octave	Spectrum Analyzers: FFT	Spectrum Analyzers: Heterodyne	Spectrum Analyzers: TDS	Stroboscopes	Test Mics	Testing Cabinets	Turns Counters
AUSTRALIA																					
DEQX Pty., Ltd.				•																	
Soundlabs Group Pty., Ltd.								•			•										
Stone Sound Studio	•			•		•		•				•	•	•		•			•	•	
BELGIUM																					
Donnet Sound and Vision		•		•		•

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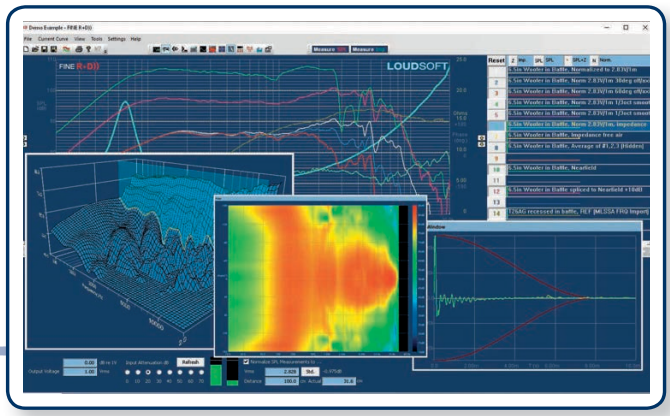
- Amplifier Measurements 10 ~ 100kHz
- Crossover Measurements 10 ~ 100kHz
- Auto-save Time Measurements
- FINE Hardware 3 w 25W amp +GRAS mics



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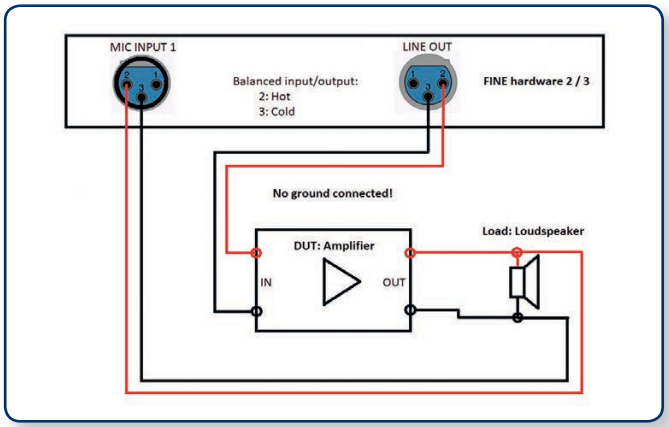
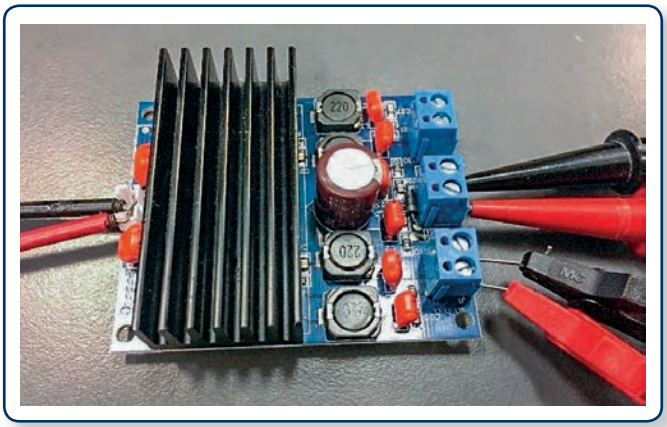
- Automatic "Golden Average unit"
- Auto-saved Statistics
- Amplifier Measurements
- Crossover Measurements
- FINE Hardware 3 w 25W amp +GRAS mics





	Accelerometers	Anechoic Chambers	Audio Analyzers	Gaussmeters	LCR Bridges	MLS	Multimeters	Oscilloscopes	Resistance Bridges	Signal Generators	Sine/Square Wave Oscillators	Speaker Parts	Speaker Turntables	Spectrum Analyzers	1/3 Octave	Heterodyne	FFT	Stroboscopes	TDS	Test Mics	Testing Cabinets	Turns Counters
JAPAN																						
Etani Electronics Co., Ltd.		•	•				•	•			•			•	•	•					•	•
NETHERLANDS																						
Audio Components, BV			•												•	•						
SWEDEN																						
Audio Pro, AB	•		•		•										•	•		•				
Bohmer Audio, AB			•				•				•	•			•	•		•				
SWITZERLAND																						
Megatec, AG				•																		
UNITED KINGDOM																						
EuroTec International, Plc.		•	•				•	•	•		•	•	•		•	•					•	•
Hill Acoustics		•																				•
UNITED STATES																						
ACO Pacific, Inc.												•									•	
Adafruit Industries	•							•	•													
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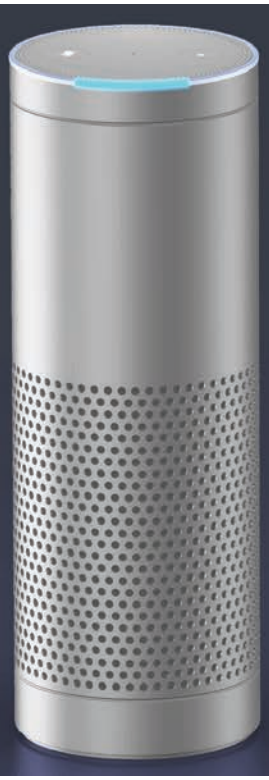

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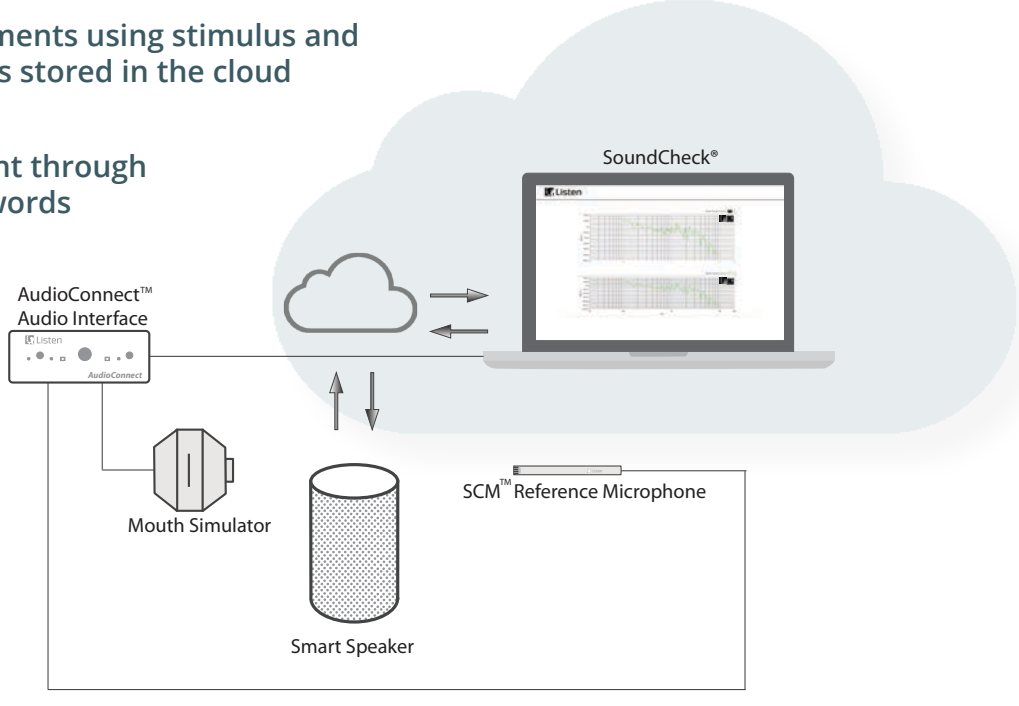

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	Accelerometers	Anechoic Chambers	Audio Analyzers	Gaussmeters	LCR Bridges	MLS	Multimeters	Oscilloscopes	Resistance Bridges	Signal Generators	Sine/Square Wave Oscillators	Speaker Parts	Speaker Turntables	Spectrum Analyzers	1/3 Octave	FFT	Heterodyne	TDS	Stroboscopes	Test Mics	Testing Cabinets	Turns Counters
Bob Young and Associates																						•
Bruel & Kjaer Sound & Vibration North America, Inc.	•		•	•	•							•			•		•	•	•		•	•
Danville Signal Processing, Inc.	•			•								•				•	•				•	
Dayton Audio				•										•							•	
ETS-Lindgren			•									•				•	•	•	•			
Fotronic Corp.	•			•			•		•		•	•				•	•	•	•	•		
Geometric Designs, LLC & Geometric Consulting				•																		
GL Communications, Inc.				•								•									•	
GRAS Sound & Vibration																					•	•
HEAD acoustics, Inc.				•																		
Herman Pro, AV			•	•								•										
HX Audio Lab																						•
iT Parts Depot									•		•											
Kramer Electronics												•										
Listen, Inc.				•				•	•		•	•				•	•	•	•		•	
Marchand Electronics, Inc.				•								•	•									
Markertek Video Supply	•			•					•		•	•		•								
MCM Electronics				•		•			•		•	•	•	•		•	•	•	•			
Meniscus Audio Group, Inc.	•													•								
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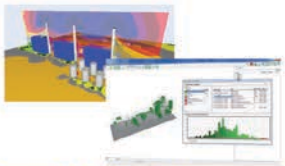

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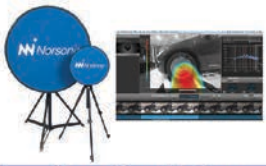

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Neobits, Inc.					•		•	•		•										•		
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Limiting Audio Reproduction Bandwidth to 20 kHz May Also Be Limiting Your Potential Market

Photo 1: Each instrument was recorded individually in a professional voice-over booth similar to this one.

By
Dan Foley
(Eastern Region Sales, Audio Precision and WPI Adjunct Faculty Member)

For decades, 20 Hz to 20 kHz has been the frequency range for recording and playing back music. Because of this, audio reproduction technology, in particular the tweeter, has been designed to have a relatively flat response to 20 kHz before rolling off. When recording technology moved from analog to digital, sampling rates of 44.1 kHz and 48 kHz were, and still are, the sampling rates of choice for recording and playback since the Nyquist frequency will not exceed 24 kHz.

In the past several years, there has been a great deal of interest in providing music to the consumer that has been recorded at sample rates well above 48 kHz. However, the vast majority of tweeters and finished loudspeakers currently on the market do not provide frequency response much beyond 20 kHz. In addition, there is a lot of controversy as to whether or not recording above 20 kHz is even worth the effort.

Such a premise makes sense if the instruments being recorded (e.g., percussion, brass, strings, and even vocals) produce little-to-no acoustic energy above 20 kHz. Why bother trying to record a signal that does not exist? But what if these instruments do produce energy above 20 kHz? To determine if this is the case, I supervised a student research project in 2010 conducted by two students from Worcester Polytechnic Institute (WPI) located in Worcester, MA. The purpose of this project was to answer two basic questions:

- Does acoustic music created by common instruments contain ultrasonic energy?
- If yes, how high in frequency is this energy and what is the corresponding level?

We chose to record the following instruments:

- Trumpet
- Conga drum
- Violin
- Nylon string guitar
- Female soprano vocalist

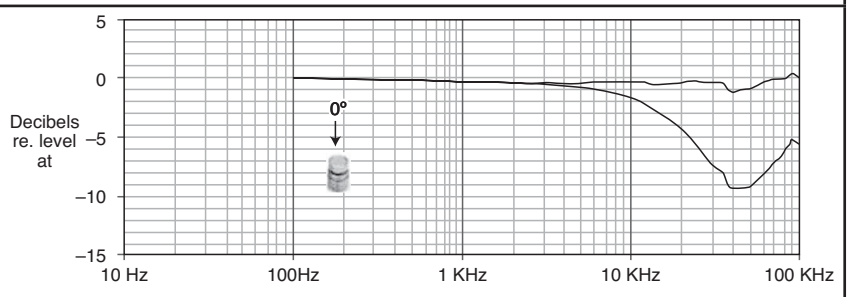
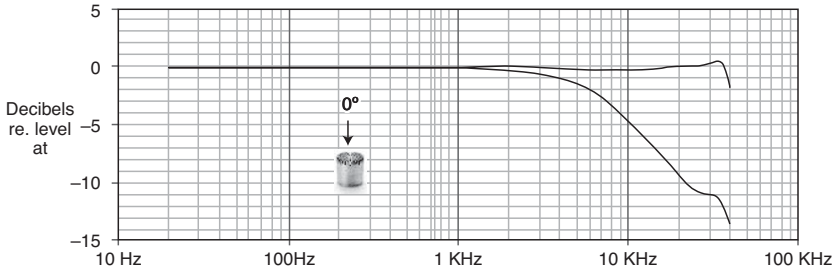
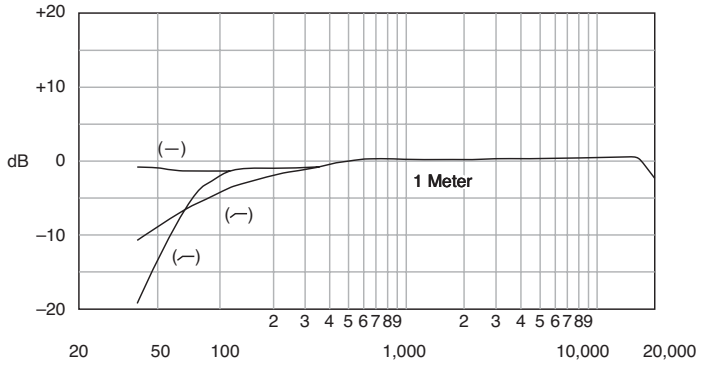
Model	Sensitivity (mv/Pa)	Frequency Response
46BF	4	
46AC	12.5	
SM81	5.6	

Table 1: The microphone frequency response and sensitivity are shown for the three different microphones. For the GRAS 46BF and the GRAS 46AC, the flat response corresponds to free-field measurements (zero-degree incidence) and the other curve corresponds to the pressure response.

Each instrument was individually recorded in a professional voice-over booth similar to that shown in **Photo 1**. A Prism Sound Orpheus was used as the analog-to-digital converter (ADC) as it can record up to eight channels simultaneously at 192 kHz, 24-bit. Three microphones were used in a side-by-side configuration and were placed at typical distances used for close-mic recording of these instruments. The microphones used were the GRAS Sound & Vibration 46BF 1/4" microphone set, the GRAS 46AC 1/2" microphone set, and the Shure SM81 microphone. **Table 1** shows the corresponding frequency response curves and sensitivities for these microphones.

The musician would enter the voice-over recording booth and position his or her instrument a few inches away from the side-by-side microphones. The musician would then play a musical passage, or in the case of the vocalist sing a passage, that would be 30 seconds to 50 seconds in length.

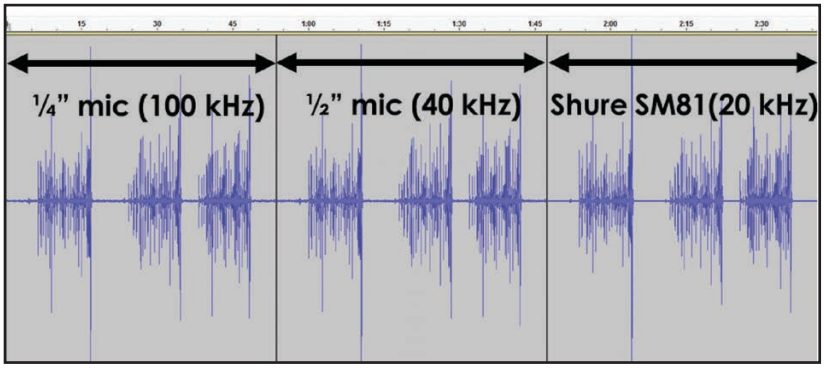


Figure 1: Audacity track layout with microphone bandwidth shown in parentheses

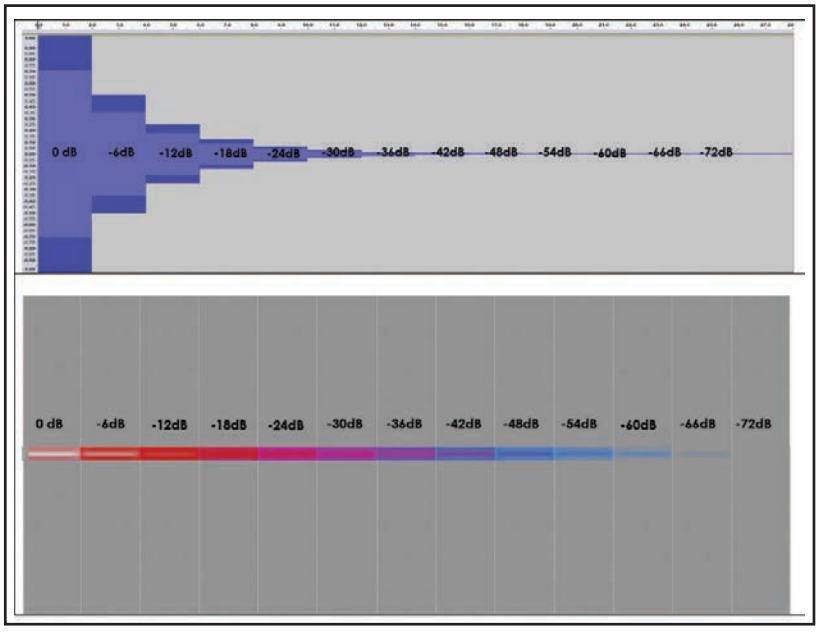


Figure 2: This is the color scale of spectrogram plots that I created with Audacity.

Audacity—a shareware program used for audio recording, editing, and mixing—was used to generate spectrogram plots of the corresponding 192 kHz recordings. To easily view the spectrogram of each instrument, a blank track was created to contain the three separate .wav files. This track was comprised of three sections—the GRAS 1/4" microphone recording, the GRAS 1/2" microphone recording, and the Shure SM81 recording.

Figure 1 shows the track layout using the conga drum as an example. Although each of the three .wav files may have small variances from one another, they are all the same take for each instrument including the soprano vocals.

The spectrogram function was used to determine whether or not ultrasonic energy is present in these recordings, especially in the transient portions of the music signal. A spectrogram uses Fast Fourier Transform (FFT) analysis, except that instead of displaying magnitude on the Y-axis and frequency on the X-axis, a third dimension (time) is also displayed. The Audacity spectrogram displays elapsed time on the X-axis and frequency on the Y-axis. Magnitude is displayed as a spectrum of colors with white representing magnitude at or close to 0 dBFS and blue representing levels that are -60 dBFS or more.

The Recording Results

To better interpret the color scale, I created a stepped-level sine sweep in Audacity with the first part at 0 dBFS and each subsequent level attenuated by 6 dB. **Figure 2** shows the corresponding stepped-level track along with its associated spectrogram. The white represents a signal with a magnitude at or close to 0 dBFS, white with a small amount of red mixed in is a signal at-6 dBFS, and so on until the very light blue represents levels that are 60 dB or more below digital full scale. The spectrogram settings were as follows:

- FFT buffer of 128 samples (667 µs total buffer length) so as to ensure the least amount of smearing of transient energy

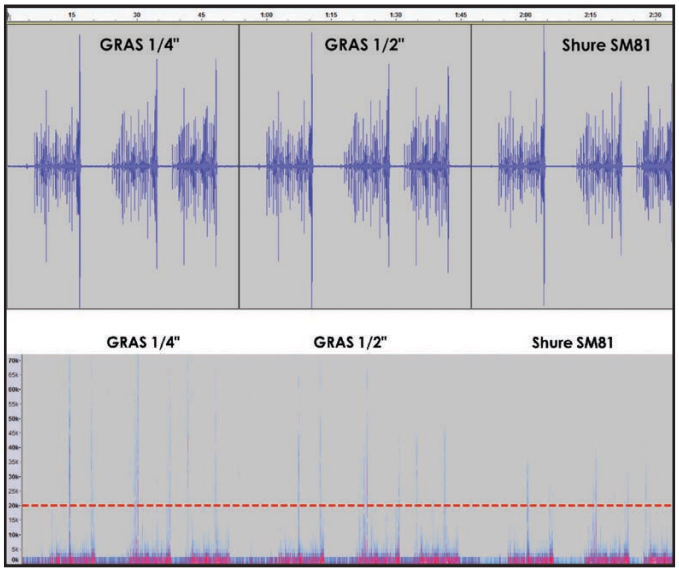


Figure 3: Spectrogram of conga drum

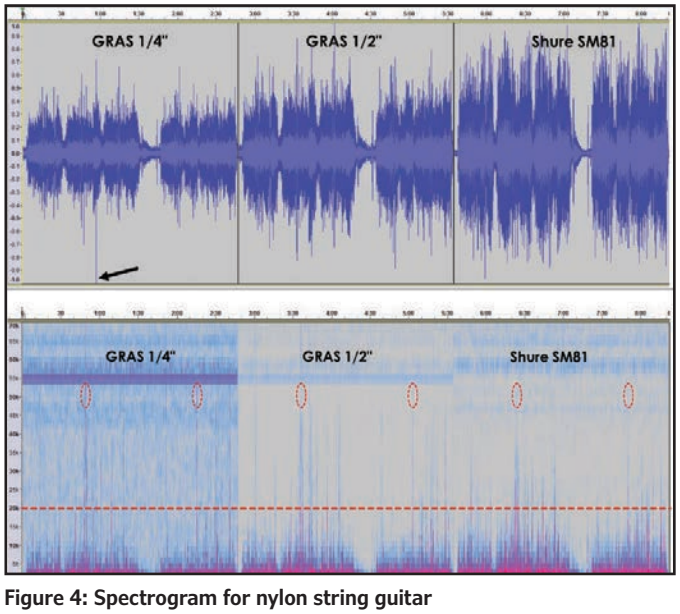


Figure 4: Spectrogram for nylon string guitar

- Linear frequency scale (Y-axis) from 0 Hz to 70 kHz
- Hanning window

Figure 3 shows the spectrogram of the conga drum. The dashed red line is positioned at 20 kHz and the majority of the higher-intensity acoustic energy is within the audio range. However, it is very apparent that ultrasonic energy is present especially during the initial transient of the hand/fingers hitting the conga drum head. Since the GRAS 1/4" microphone has a flat response out to 100 kHz, it better captured the ultrasonic energy present in the conga drum transients. The Shure SM81, designed to roll off above 20 kHz, did not capture any ultrasonic energy above 40 kHz. Surprisingly, the GRAS 1/2" microphone did capture a fair amount of this energy despite it starting to roll off at 40 kHz.

Figure 4 shows the resulting spectrogram for a nylon string guitar where the musician was playing a flamenco-style piece. The spectrogram for the GRAS 1/4" mic recording shows a lot of noise present. This is due to a combination of low microphone sensitivity and the recording gain being set so that the peak levels would be well below the clipping level of the Orpheus ADC. A combination of low recording gain and low microphone sensitivity, compared to the other two microphones, resulted in more electronic noise in the recordings made with the GRAS 1/4" microphone.

Despite the low sensitivity of the GRAS 1/4" microphone, it did capture higher levels of ultrasonic energy of two specific guitar transients. The dotted-line red ovals show a reddish color in the 47-kHz-to-52-kHz range whereas the GRAS 1/2" microphone is a very light blue, corresponding to around -60 dBFS, and the Shure SM81 barely captures any of this energy.

I cannot explain the "noise" at 55 kHz for the GRAS 1/4" and the GRAS 1/2" recordings, other than this could have been caused by electrical interference from other equipment in the recording studio operating during the session. I consulted with a well-respected converter designer about this and he said he had seen similar behavior in A-D and D-A converter boxes and attributed it to switching power supply interference. Despite this electrical/electronic interference, this source of noise did not mask any of the ultrasonic energy contained in the guitar transients.

Figure 5 shows the resulting spectrogram for the soprano vocalist. This was the most surprising result from this research as it showed how a

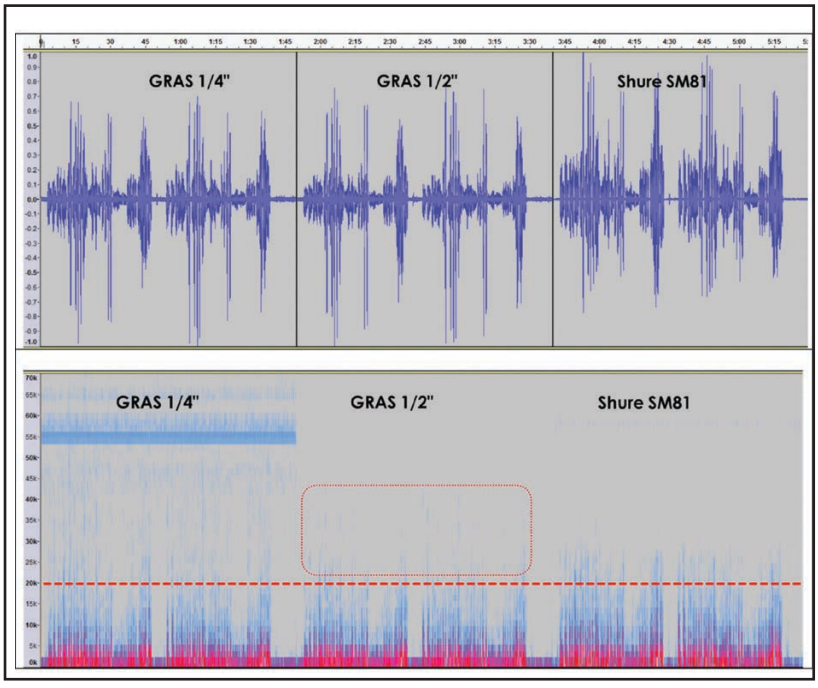


Figure 5: The most surprising results came from the spectrogram for the soprano vocalist.

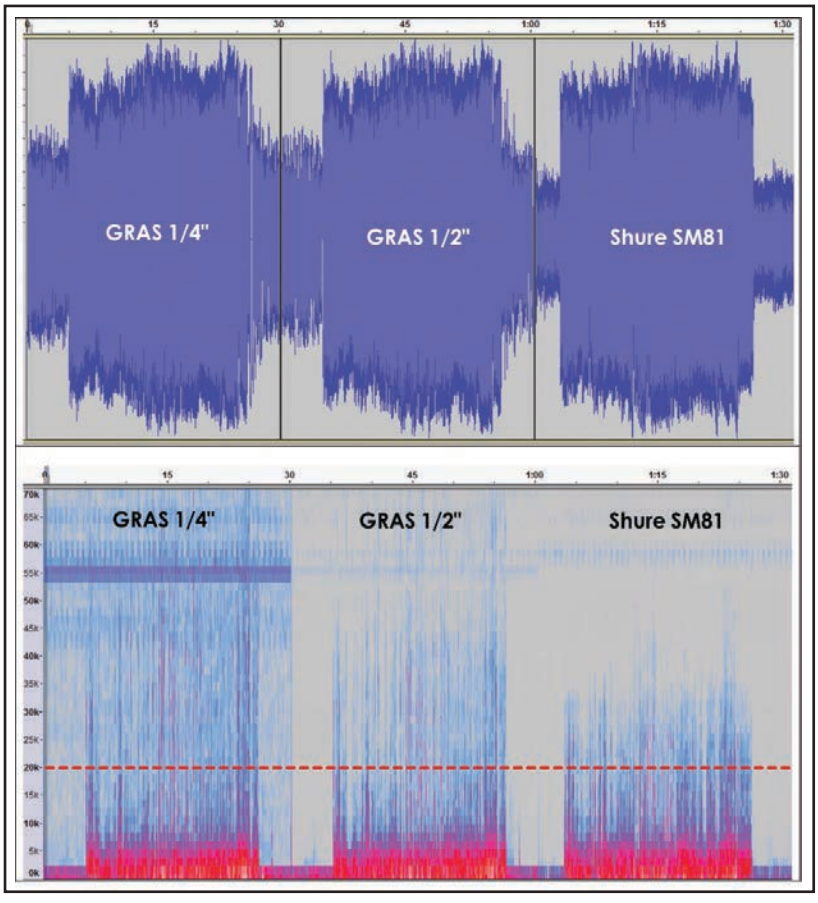


Figure 6: Spectrogram results of the solo violin

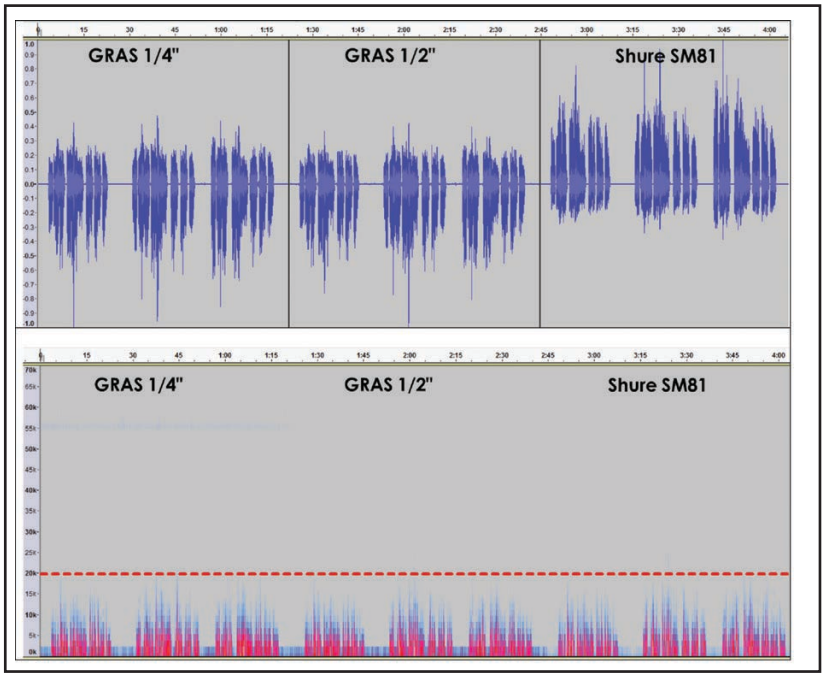


Figure 7: Little-to-no ultrasonic energy was produced by the musician playing his trumpet.

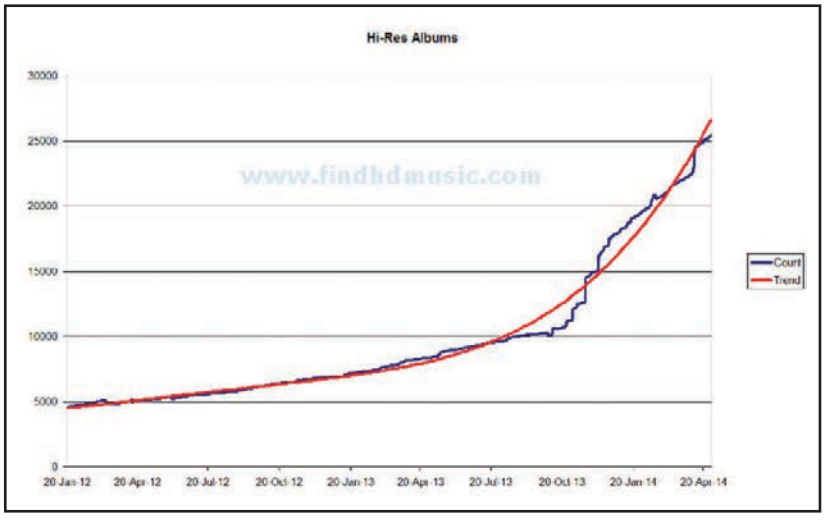


Figure 8: The growth of high-resolution albums is on the rise. This graph shows the total number of high-resolution albums listed by FindHDmusic between January 20, 2012 and April 30, 2014.

cappella female vocals can generate ultrasonic energy albeit at very low levels. This is more evident with the GRAS 1/2" microphone recording as shown in the dotted-line square.

Figure 6 shows the spectrogram results of a solo violin. The musician was playing very fast (presto) throughout this recording. From the spectrogram, one can conclude that this particular playing style generates a lot of ultrasonic energy. Even at 70 kHz, the GRAS 1/2" microphone recording shows dozens of ultrasonic "bands" even though its frequency response could be attenuated by 10 dB or more in that frequency range.

Figure 7 shows that little-to-no ultrasonic energy was produced by the musician playing his trumpet. The reason that the .wav file of Shure SM81 recording is flipped is that the other microphones invert the acoustic signals. Although practically no ultrasonic energy is shown in the spectrogram, this does not necessarily mean that a trumpet will never produce energy above 20 kHz. There can be many reasons for this such as playing technique, the piece being played, and so forth. More trumpet recordings will need to be studied before concluding that this particular instrument does not generate acoustic energy above 20 kHz.

Impact of These Findings

How do these results impact the loudspeaker industry? Sales of recordings with sampling rates at or above 96 kHz have been increasing for the past several years.

Figure 8 is from findhdmusic.com (http://www.findhdmusic.com/article/growth-in-high-resolution-audio-2012-2014/300) showing the growth in availability of high-resolution albums. Although this graph is a bit dated, it clearly shows the growth in these types of recordings.

Given this growth and the results of this study, how should the loudspeaker industry respond? I think the industry should make an effort to develop and market transducers and finished products that have a reasonable frequency response above 20 kHz. The term "reasonable" is deliberately used since there are cost implications when designing and manufacturing transducers that are flat to 50 kHz or higher vs. a transducer that may be several decibels down at 30 kHz. However, this effort has to also go hand-in-hand with the recording industry providing true high-resolution recordings to the consumer.

Figure 9 shows a percussion-only .wav file and corresponding spectrogram plot of a 192 kHz, 24-bit album downloaded from a reputable website devoted to the sales and marketing of

high-resolution albums. This particular album has many tracks of various genres specifically for the purpose of consumers being able to audition high-end, audiophile-level playback hardware.

Despite this file being sampled at 192 kHz, there is virtually no energy above 20 kHz. If the original recording was made at 192 kHz, there would be some amount of energy above 20 kHz as was shown in several of the previous recordings made with the Shure SM81. In particular, the end of this recording should have a great deal of ultrasonic energy (areas enclosed by dotted-line red ovals) but nothing exists above 20 kHz. Either this recording was originally sampled at 44.1 kHz or 48 kHz and was upsampled to 192 kHz, or 20 kHz low-pass filters were used somewhere in the tracking/mixing/mastering phases or a combination of sample rate and low-pass filtering used in post-production.

Figure 10 shows the .wav file and corresponding spectrogram of a snare drum track I recorded at 192 kHz using a high-bandwidth microphone. Such recording methods do capture the energy that is created by the snare drum. The limited number of A-B comparisons I made so far with professional musicians hearing their performances recorded at 192 kHz using high-bandwidth microphones shows that these recordings are preferred when compared to similar recordings made at lower sample rates using conventional microphones. The most common response is that the 192 kHz recordings sound more like the instrument(s) they play.

One may argue as to whether or not capturing this ultrasonic energy results in a snare sound preferred by the consumer but if the acoustic energy is present when the stick hits the drum head, the author feels it should be accurately captured in recordings.

As such recordings begin to proliferate whereby the ultrasonic energy generated is not filtered out due to anti-aliasing filters, mixing/mastering techniques and/or the recording microphones themselves, transducer engineers will have access to proper source material for subject and objective assessment of their true high-resolution designs. Given the growth in high-res audio, this could bode well for higher-end, and more profitable, transducers and finished loudspeaker products. ***LIS***

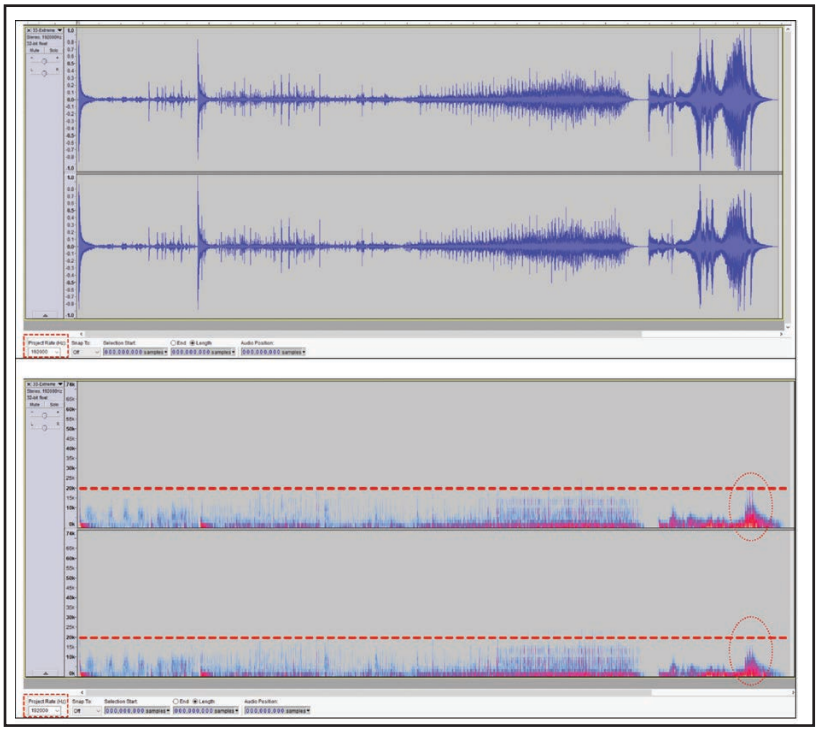


Figure 9: This percussion-only .wav file and corresponding spectrogram plot of a 192 kHz, 24-bit album was downloaded from a reputable website devoted to the sales and marketing of high-resolution albums.

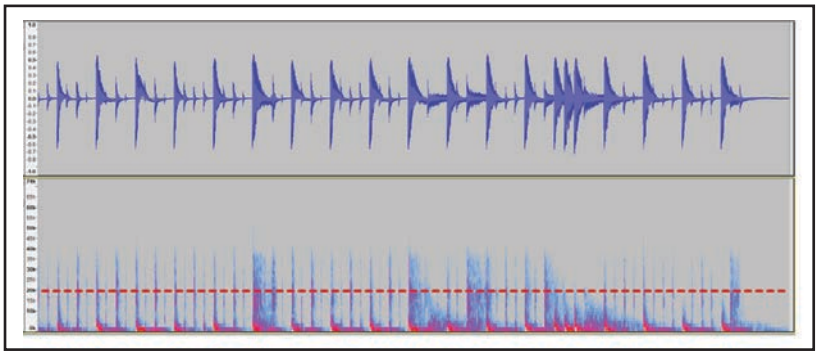


Figure 10: Here is a .wav file and corresponding spectrogram of a snare drum track that I recorded at 192 kHz, 24-bit using a high-bandwidth 1/2" microphone.

About the Author

Dan Foley has worked in the audio test and measurement industry for more than 35 years and has a broad background in analog and digital audio test, acoustics, electro-acoustics, telecom audio, as well as vibration measurement and analysis. He is a member of the Audio Engineering Society (AES) and the Institute for Electronics and Electrical Engineers (IEEE), and has many close ties to the audio industry, having worked for the likes of Bose, Listen, and Brüel & Kjær. Foley has developed and taught seminars regarding digital signal processing techniques used in acoustic, vibration and audio test, and measurement applications. He currently serves on the IEEE Transmission Access & Optical Systems Committee as well as AES standards committees. Foley is also an Adjunct Faculty Member at Worcester Polytechnic Institute where he is developing a curriculum in audio product design engineering. Dan is a published author of ASME and AES and has an engineering degree from the University of Hartford, West Hartford, CT.

Objective Testing of High-End Audio Systems

The high-end audio equipment market is filled with extraordinary products. Although the engineering and the materials utilized are often the finest available, the quality control of such systems is frequently done subjectively, rather than objectively. This article shows some best practice examples of how to deploy effective quality measurement systems through the complete life cycle (R&D, QC, installation, and repair) of high-end audio systems.

Photo 1: The Art Déco Acoustics Monitor M15 is a two-way passive loudspeaker in an aluminum enclosure with a stainless steel stand.

By
Gregor Schmidle
(NTi Audio, Inc.),
Gerd Köck
(Art Déco Acoustics),
and Brian MacMillan
(NTi Audio, Inc.)

When looking at the high-end audio market, there's a variety of products ranging from well-designed top-notch audio devices with solid technical specifications to gadgets that appear rather esoteric and whose results cannot be objectively evaluated. The latter are not within the scope of this article. Only audio devices and systems that are designed based on solid audio engineering work are considered. Although there are a few reputable large enterprises that have a high-end audio product line, the majority of high-end audio companies are small with only a few employees. As a result, quite often a single person takes on several technical responsibilities, ranging from R&D, purchasing, incoming Quality Control (QC), assembly, end-of-line (EOL) testing, as well as service, maintenance, and QC management. Also, more often than not, small companies have only limited access to appropriate testing resources (e.g., acoustically optimized testing facilities).

One way to overcome the lack of proper measurement is to communicate the performance of a high-end audio system on an emotional rather than a technical level, using colorful but nebulous language. After all, high-end audio systems are life-style products. Leading companies sustain market share by emphasizing longevity in the mechanical design and sound quality. Besides the sound experience, the customer also wants a piece of equipment that is designed to please the eye. Both the sound and the appearance are subjective qualities to the customer (see **Photo 1**).

Following the maxim that a quality product is easier to sell, the sound quality can be quantified by appropriate objective measurements. This article describes best practice examples of

objective measurements on high-end audio devices. The measurement applications that follow are viewed from two angles.

The first view describes the typical measurements on the various devices along the signal chain, from the signal source to the amplifier over the cables to the loudspeakers and finally the room in which the system is installed. The main concern is to provide a very linear, low-noise and low-distortion signal through the entire signal chain.

The second view covers the distinctive measurements at different life-cycle stages of the various devices, from R&D to incoming QC, end-of-line (EOL) QC, and installation of the system as well as service and maintenance.

R&D

The R&D phase builds the foundation of a high-quality product. Any shortcomings not solved or managed at this early stage of the product development will be passed through to all the later stages. This applies to the complete signal chain covered by the product.

Electrical Signal Path

Any unwanted noise before or within the amplifier will be irreversibly audible at the loudspeakers. This means it is essential to keep the signal clean from the very beginning of the signal chain.

Distortion—In most systems, distortion is an unwanted effect and is avoided at all costs as it affects the perception of sound quality. It's important to realize that distortion is mainly a result of the system reaching an upper limit of operation. Thus, the testing shall be executed close to these limits. The distortion can be quantified as total harmonic distortion (THD) or as individual harmonic distortion values.

Some tube amplifiers produce a significant amount of even-numbered harmonic components (k2, k4, and k6). Advocates argue that this creates a more pleasant sound.

Hum & Noise—The presence of noise or hum can cover fine details of sound. So, providing a low-noise circuit design is one of the most important tasks in the R&D phase. Noise can be measured with or without the presence of a test signal. In either case, it is important to realize that amplifier stages amplify both, the signal and the noise. Therefore, a high signal-to-noise ratio (SNR) is desired. When using balanced analog audio channels, it is important to measure the Common Mode Rejection Ratio (CMRR) as this determines the ability to cancel out cable-inducted noise or hum. Noise and especially hum can also be introduced from the system power supply. Therefore, it is recommended to perform these measurements with different mains-power conditions and settings.

Bandwidth—The bandwidth is measured with a frequency response measurement. The measured level has to be within the expected limits throughout the specified frequency bandwidth. Modern sound systems cover bandwidths up to ultra-sonic frequencies.

Linearity—All the previously mentioned measurements can be influenced by the amplitude of the input signal, as well as the power of the output signal. An appropriate way to verify this system behavior is to run an amplitude sweep signal at the system input. The amplitude shall range from zero to the maximum allowed input signal. The output signal is measured with level and distortion and shall be within the expected limits through the input signal range.

Channel Balance and Separation—The spatial awareness of the listener is based on having more than one sound source (e.g., stereo). It is vital that all channels behave as uniformly as possible. All the previously mentioned measurement results shall be compared for all channels of the system.

Furthermore, the influence of one channel on other channels (e.g., caused by unwanted electro-magnetic induction or capacitive coupling) must be checked. This is done with a Crosstalk measurement.

Acoustic Signal Path

In the R&D phase, the developer has to contend with loudspeaker drivers as well as loudspeaker systems. Besides the acoustical parameters, the electrical parameters are of interest. However, before any measurement results can be assumed to be reliable, new bass and midrange loudspeakers need to be operated for a certain time in order to have the suspension material reach its final characteristics.

Woofer and Midrange Driver Conditioning—Several burn-in procedures for loudspeaker drivers are known. The proposed test signals range from noise to music. Practical experience at Art Déco Acoustics showed that a low-frequency sine wave signal delivered excellent results. The loudspeakers' suspension is displaced in a very controlled and predictable way, while not producing bothersome loud noise.

Burn-In Signal Frequency

The signal shall be at a low frequency, so that the driver suspension gets properly displaced. Also, the frequency shall have ample distance from the free air resonance frequency, so that the generator can properly control the driver.
For bass loudspeakers,

$$f_{burn\text{-}in} = f_0 \times 0.33$$

For midrange loudspeakers,

$$f_{burn\text{-}in} = f_0 \times 0.50$$

whereas:

$f_{burn\text{-}in}$ is the signal frequency in Hertz (Hz)

f_0 is the free-air resonance frequency of the loudspeaker in Hertz (Hz)

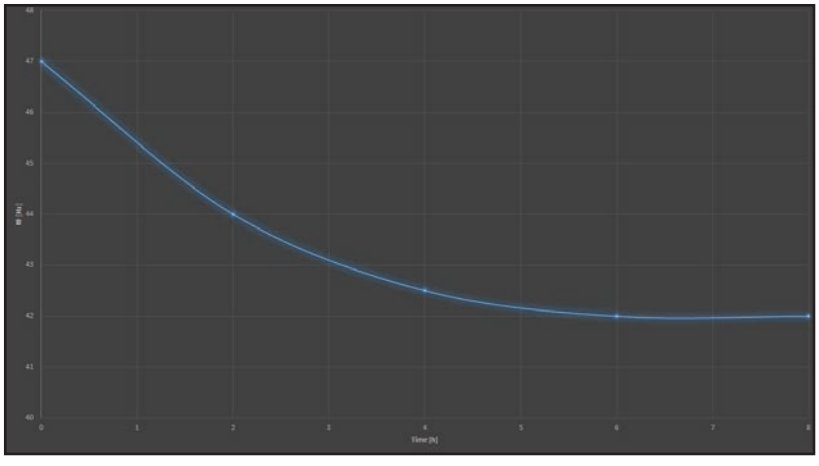


Figure 1: f_0 vs. time

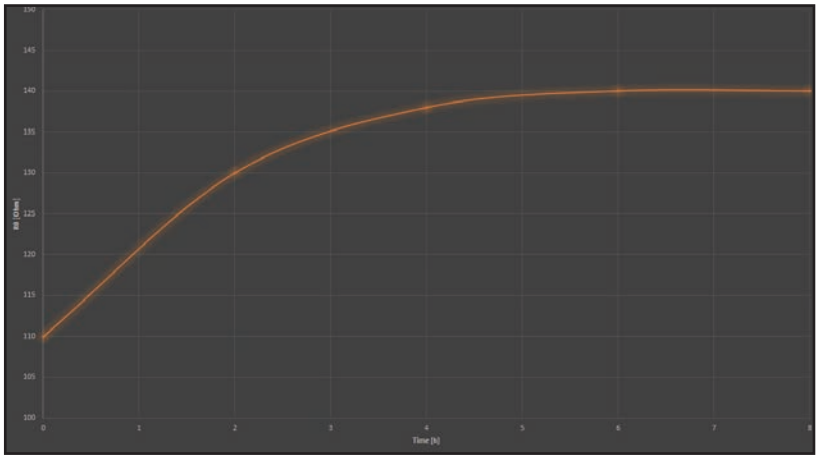


Figure 2: R_0 vs. time

Burn-In Signal Power

The required power for exciting the loudspeaker to the desired X_{max} value in a controlled way can be calculated with this formula:

$$P_{burn-in} = \frac{(x_{max})^2 \times Z_I}{(C_{ms} \times BL)^2 \times 2}$$

whereas:

$P_{burn\text{-}in}$ is the power of the burn-in signal in watts (W)
X_{max} is the peak displacement in one direction in meters (m)
Z_I is the rated impedance in ohms (Ω)
C_{ms} is the mechanical compliance in meters/Newtons (m/N)
BL is the force factor Newtons/Amperes (N/A)

Burn-In Duration

The goal of the burn-in process is to achieve settled and stable mechanical conditions. The required period of time to reach those conditions is different for each loudspeaker model, and therefore, must be individually evaluated. A practical way to proceed is to apply the burn-in signal and measure the f_0 (free-air resonance frequency) and R_0 (free-air resonance impedance) values initially and then every two hours, until they become settled. To avoid interference with the loudspeakers thermal behavior, it is advised to allow the loudspeaker to cool off before performing f_0 and R_0 measurements (see **Figure 1** and **Figure 2**).

Depending on the individual loudspeaker model, typical burn-in times are 6 to 36 hours for bass loudspeakers, and 6 to 24 hours for midrange loudspeakers.

Loudspeaker Measurements—The R&D phase requires all of the classic loudspeaker measurements. The bass, midrange, and high-frequency drivers are rated individually, electrically, and acoustically. The Thiele-Small (T-S) parameters of the drivers are used to determine and optimize the loudspeaker's housing dimensions. The system's acoustic performance shows the interaction of all individual components. It is characterized by measuring frequency response, distortion response, and sensitivity. Also the directional characteristic of the complete system can be measured and optimize in the R&D phase.

All acoustic measurements must be executed in a defined and reproducible acoustic environment. The use of a calibrated measurement microphone is recommended. The microphone distance and position relative to the loudspeaker must be

kept constant. In case of frequency response ripples caused by imperfections of the testing environment, a smoothing filter (e.g., 1/3 octave bandwidth) can be applied.

Income QC

Electrical Components—IQC testing of electrical components is required when the component plays a critical role in the signal path, and the headroom of the component's specified vs. requested accuracy is low. Quite often, these are parts used in the loudspeaker crossover network, such as:

Inductance inductor value, distortion vs. current, distortion vs. frequency, and capacitance vs. capacitor value

Depending on long-term experience and significance, these tests can be either executed as sample tests (e.g., a few components from one batch delivered) or as a 100% income test.

Acoustic Components—While in less sensitive markets a loudspeaker system will eventually reach its final characteristics during its normal usage, this is not an option for high-end audio manufacturers. Therefore, a crucial initial procedure for all new incoming bass and midrange loudspeakers is to perform the burn-in procedure as previously described.

Loudspeaker Pairing—The settled results of the burn-in test can be used to place loudspeakers into groups with similar behavior. This is important for using more than one driver of the same type in one loudspeaker, as well as building left and right loudspeaker pairs that show identical behavior. The accepted deviation of f_0 and R_0 within the same group depends on the enclosure in which the loudspeaker will be used:

Vented enclosures or horn enclosures
- f_0 within 2 Hz
- R_0 < 15% relative different

Not vented enclosures
- f_0 within 10 Hz
- R_0 < 50% relative difference

Manufacturing QC

Device Testing

In this stage, the individual devices of the high-end audio system are tested against their specifications.

Amplifier Final Test—The completed amplifier devices run through a thorough set of tests, such as frequency response, output power, distortion response, hum and noise rejection ratio, channel separation ratio, spectral noise analysis, channel balance, inter-channel phase, slew rate, and common mode rejection ration (CMRR). This set of tests is performed at several gain settings. Where applicable, user controls (e.g., LED, switches, or dial controls) are tested for mechanical and functional performance.

Loudspeaker Final Test—The final assembled loudspeakers are electrically tested for impedance response. Special attention is paid to the device resonance frequencies and resonance impedances. The acoustic test for final assembled loudspeakers contain frequency response, distortion response, diversity, sensitivity and Rub & Buzz. The latter is especially crucial as even the slightest objectionable audible effects would not be accepted by the customer.

Although each individual loudspeaker driver has already been tested for Rub & Buzz, this stage of testing reveals any noise coming from problems in the mechanical assembly of the loudspeaker, such as vibrating pieces or air leakages in sealed cavities. As in all previous acoustic test stages, it is vital to have a test fixture that allows reproducible results with minimum influence from outside noise.

Acceptance Limit Finding—The applied limits for passing or failing a measurement have to be calculated for each individual measurement function. Whenever possible, absolute limits evaluated from a component's datasheet are preferred. However, some measurement functions are not suitable for absolute limits. This is often the case for acoustic measurements (e.g., Rub & Buzz) when either no specification is available, or the acoustic conditions during test are different than those used for specification.

For such measurement functions, one or several reference measurements are taken and overlain with a headroom. The amount of headroom depends on the number of references taken, and the allowed mean variation.

System Testing

Finally, the individual devices get put together to the final system configuration. In this final stage, the test depth can be reduced as the individual system devices are already tested thoroughly. The interaction between amplifier, left and right loudspeaker is tested with a few simple acoustic sensitivity and frequency response measurement. At this point, it is also appropriate to perform a subjective listening test at a defined listener position, using well-known listening material.

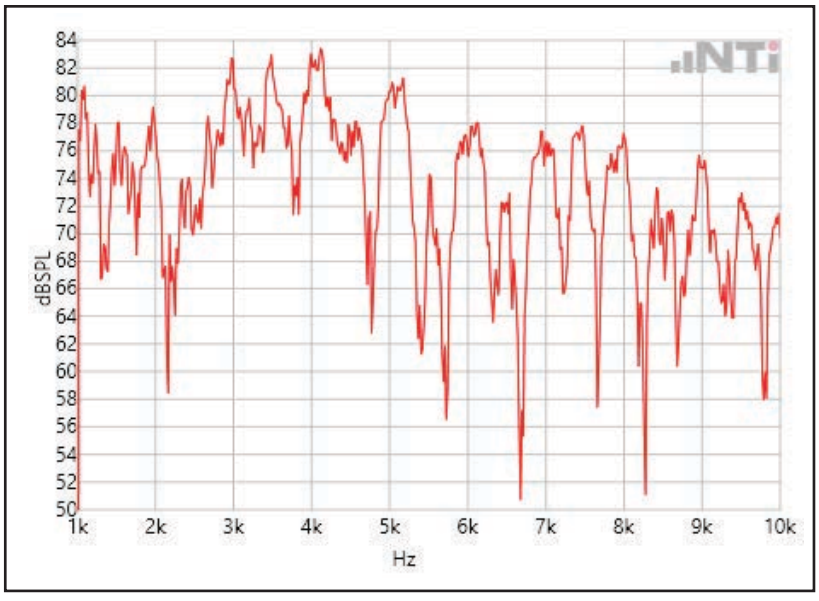


Figure 3: Comb filter fast Fourier transform (FFT) spectrum

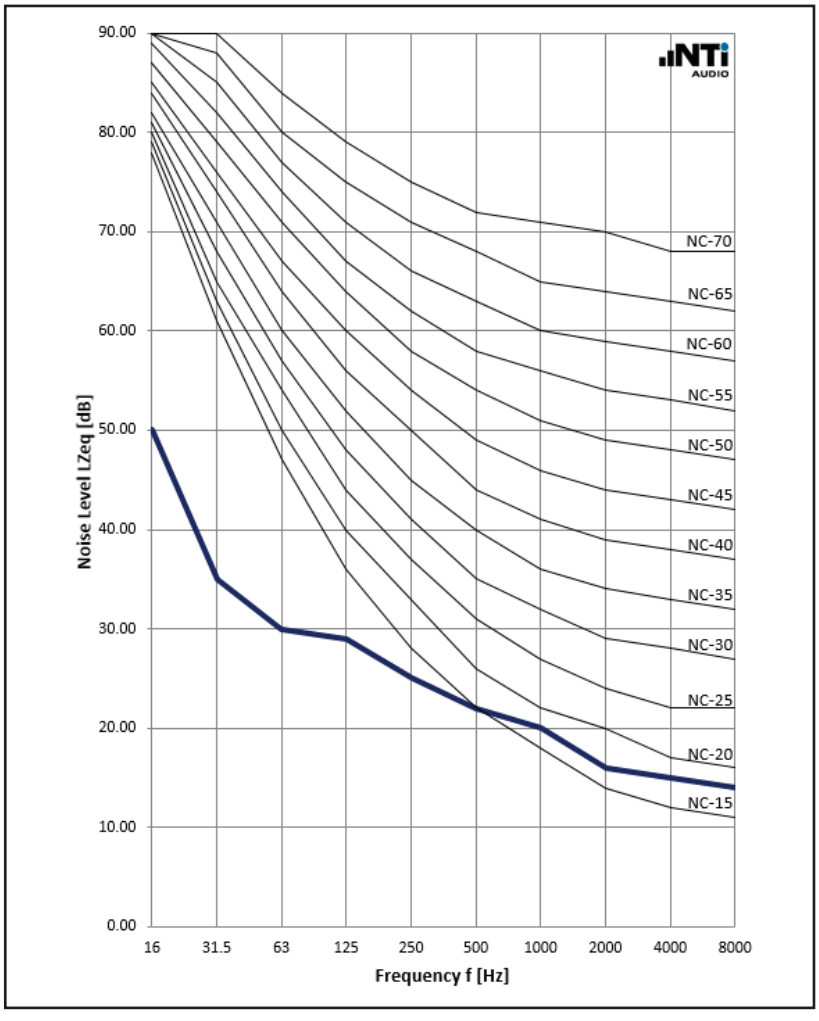


Figure 4: Noise criteria (NC) curves

Installation

All the efforts of manufacturing a perfect high-end audio system can become worthless when the system is used in an environment that is not suitable for listening.

Reverberation—Too much of reverberation in a listening room can ruin the listening experience, likewise an absence of reverberation is also not pleasing to the ear. The optimum reverberation depends on the room size. For typical living room size applications, a RT60 time of 0.3 to 0.5 s for all frequency bands is recommended. The RT60 measurement is determined by either using a gated pink noise signal applied to the sound system, or alternatively an impulsive sound (e.g., a bursting balloon).

Room Reflections

Low frequencies/standing waves—The room resonance frequency can be calculated:

$$f_0 = \frac{v_s}{2 \times l}$$

whereas:

f_0 is room resonance frequency in Hertz (Hz)
v_s is speed of sound in meters/seconds (m/s)
l is room dimension in meters (m)
(length/width/height)

For typical living room sizes, resonance frequencies will appear in the range of 20 Hz to 100 Hz. The presence of room resonances can be measured by applying the room resonance frequency to the sound system, and then measure the acoustic level at different positions in the room. If the measurement varies greatly, low frequency reflections are present and need to be eliminated by applying appropriate acoustic treatments for low frequencies to the room.

Mid and High Frequencies—Reflections of mid and high frequencies appear as a comb filter effect. This effect is not only audible, but also easily measurable. To identify comb filter effects in a room, white noise is applied to the sound system. Then, the spectrum of the sound is measured in the room, using a high-resolution fast Fourier transform (FFT). When the spectrum of the room with linear scaled X-axis shows equi-distance notches, this is an indication for room reflections (see **Figure 3**).

Ambient Noise

Since high-end systems are supposed to

reproduce every little detail of the original sound, overlapping hum or noise from the environment is not acceptable. The ambient noise can be measured as a simple A-weighted sound level reading.

A more sophisticated way is to use noise curves measurements. Noise curves follow the sound level vs. octave band course where the loudness of noise is perceived equally.

Recommended noise criteria (NC) level values for Recording Studios, Concert halls and similar listening applications are NC 15-20 (see **Figure 4**).

Repair & Service

With repair or service of a high-end audio system, the existing set of measurements from manufacturing QC testing can be applied to identify a faulty system component. Usually the failed measurement indicates the type of failure. When fault diagnostics on circuit board level is required, an audio analyzer with standard functionality such as level, distortion, and FFT is most useful.

When critical parts are exchanged, it is important to match the characteristics of the replaced part. After the repair, the regular device tests defined before are performed for the repaired device. Before shipping, the manufacturing QC system test is executed.

Quality Control Management Aspects

Test Environment

For acoustic measurements in the R&D, incoming QC, and manufacturing QC, an acoustically stable test environment is the foundation for reliable and reproducible test data. Exact positioning of all loudspeaker models as well as the measurement microphone are crucial. Ambient noise should be held as low as possible. Reflections from room boundaries or obstacles must be covered with acoustic treatment material, or managed by the test system by applying time-window functionality.

Documentation

Every measurement procedure in each phase of the product must be documented in a clear and unambiguous manner, making it executable by any technician in the company. When a measurement is performed, the data shall be logged with the serial number of the device or system under test. This allows comparison of results in case of a repair and also indicates the quality of the products over the course of time. Having a complete and traceable set of significant measurement data for each product ever shipped is an important and valuable asset to a company.

Calibration

To ensure the accuracy of the measurement system, all relevant devices such as the audio analyzer and the measurement microphone should be calibrated according to the manufacturer's recommendation. Measurement microphone are sensitive to temperature and humidity changes. Therefore, a more frequent periodic calibration with a microphone calibrator is advised.

Wrap Up

Consistent and appropriate measurements during the complete high-end audio product life cycle lead to high, objective, and constant product quality. Measurements shall comprise the complete signal path from the signal source to the loudspeakers. Objective measurement values are a better selling proposition than imaginative descriptions. A suitable measurement system covers all requirements for electric and acoustic measurements. And finally, a complete set of measurement data of all shipped products is a valuable company asset. ***LIS***

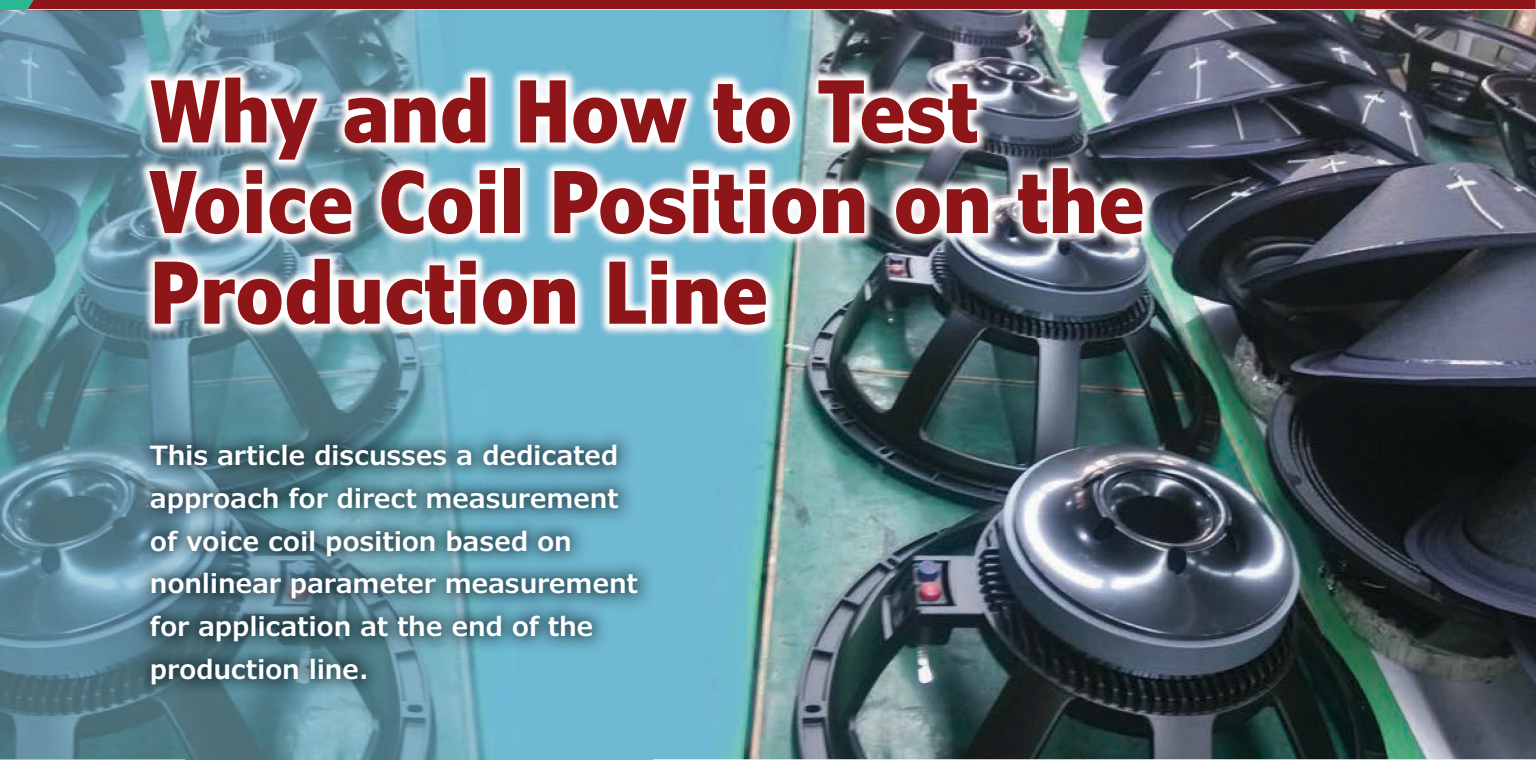
About the Authors

Gregor Schmidle is Product Manager at NTi Audio in Schaan, Liechtenstein. He completed a Bachelor of Science degree at the Interstate University of Applied Sciences of Technology in Buchs, Switzerland in 1992 and a Master of Science degree at the University of Applied Sciences in Dornbirn, Austria in 2004. Gregor has been in the audio and acoustic Test & Measurement industry for more than 25 years. After working several years at NEUTRIK as a hardware and software developer, he continued his career at NTi Audio as an applications support engineer. In his current position, Gregor is in charge of NTi Audio's industrial key customers worldwide.

Gerd Köck started his carrier as a telecommunication technician at Siemens AG in Stuttgart until 1981. Then he studied BSEE (till 1986), Computer Science at Esslingen (DE) University with focus on digital signal processing, switching to technology and numerical analysis. He was responsible for the development (analog, power, DSP algorithms) and final acceptance of a main power disturbance and net quality event recorder system for electrical power nets (1998). He then directed to sales at Infineon (an automotive controller and power till 2001), and Conti (an automotive infotainment and instrument cluster till 2007). At Telit Wireless, he introduced the automotive grade 2G/3G wireless modules (till 2009). From 2009 on, Gerd founded Art Déco Acoustics and started development of loudspeakers and amplifiers. In parallel, he worked as freelance consultant in the automotive industry in wireless and lighting technologies.

Brian MacMillan is General Manager for NTi Audio US office in Portland, OR. Brian has worked in sound and vibration instrumentation for more than 25 years in local sales and support and as a Product Manager. He has worked with a variety of customers and markets in the US, Denmark, and the United Kingdom.

Why and How to Test Voice Coil Position on the Production Line



This article discusses a dedicated approach for direct measurement of voice coil position based on nonlinear parameter measurement for application at the end of the production line.

By
Robert Werner
(Klippel GmbH)

The large signal behavior of electrodynamic loudspeaker transducers at medium to high excursions is characterized by various nonlinear mechanisms, mainly related to the suspension and the motor. They define the sound quality, stability and peak performance of the final audio system (see **Figure 1**). The nonlinear characteristics of a transducer are already set during the design phase—restrictions are related to price, size, weight, and the target market. The employed materials and geometry of motor and suspension mainly define the overall large signal performance.

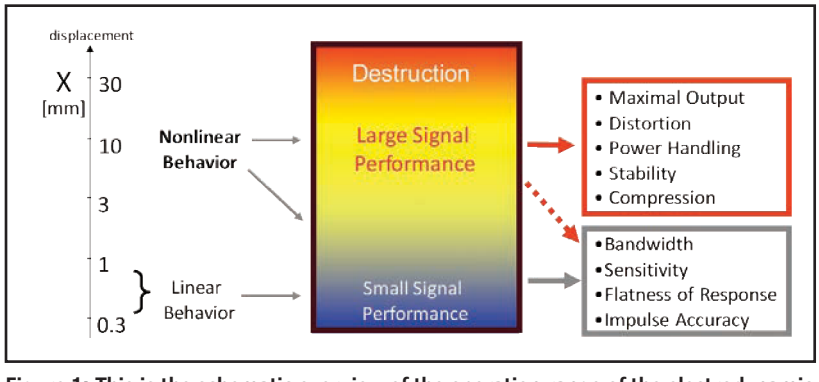


Figure 1: This is the schematic overview of the operation range of the electrodynamic transducer between small signal performance and overload depending on peak displacement.

These physical limitations make the transducer the weakest part in the audio system, while the suspension is the weakest part of the transducer. Although many nonlinear characteristics can be considered stable in manufacturing because components such as the magnet and pole plates have a fixed geometry, variation in the moving parts may cause a bias or even alter the characteristics.

The soft parts are subject to significant variation that must be considered during assembly in order to ensure optimal voice coil position and to prevent suspension asymmetries as well as bias in the interaction of spider and surround. A simple voice coil offset from its ideal position can dramatically degrade the overall performance of the audio system, especially for highly efficient transducers with very nonlinear motors.

In consequence, a production test system must not only ensure that the product is free from severe defects but also that it fulfills the specified performance related to audio quality, stability, maximal excursion, and output. Most test systems mainly rely on testing the nonlinear (harmonic) distortion in the acoustical output of the device under test (DUT). However, such well-established methods are not always critical enough, barely provide root cause information, and may even be

misleading in some cases. Optimal coil position for maximal symmetrical peak excursion cannot be ensured by plain distortion tests, especially for microspeakers and headphone transducers.

The goal is detecting systematic motor and suspension problems as early as possible for immediate root cause analysis and effective process control to ensure consistent product quality, dealing with varying quality of the soft parts.

Effects of Uncontrolled Voice Coil Position

In electrodynamic transducers, the nonlinear force factor Bl(x) is considered the main root cause of distortion and stability problems at high excursions together with the nonlinear suspension stiffness Kms(x).

Figure 2 illustrates an example for the nonlinear force factor depending on the displacement of the voice coil relative to its rest position (at x = 0 mm). The voice coil is centered in the magnetic field, resulting in an almost symmetrical characteristic with its sensitivity maximum close to zero displacement. Any displacement introduced by an audio signal with low-frequency content applied to the voice coil can instantaneously and continuously alter the effective force factor. Compression and nonlinear signal distortion (i.e., harmonic distortion and intermodulation distortion) in the sound pressure output are the consequences, as shown in **Figure 3**.

If the voice coil rest position is altered from its optimal position, the Bl(x) characteristic is shifted on the displacement axis and an additional asymmetry with respect to the rest position is introduced, resulting in mainly second (even) order harmonic distortion (HD) of up to 5% of the total signal. A much more critical effect of Bl(x) is broadband intermodulation distortion (IMD) that can easily reach amounts of 20% to 40% when a bass tone and a voice tone are played simultaneously with high amplitude, especially when the coil rest position is located on the steep slopes of the Bl(x) curve. As a consequence, the sound quality is significantly impaired compared to a driver with a well-centered coil. Consequently, distortion measurements seem to be a useful strategy in order to detect a voice coil offset by its symptoms.

Another effect of the nonlinear force factor is dynamic DC displacement, a very important factor for the stability of the transducer. The major causes are motor asymmetries (e.g., as a consequence of non-optimal coil position). The example shown in **Figure 4** illustrates how a positive and negative

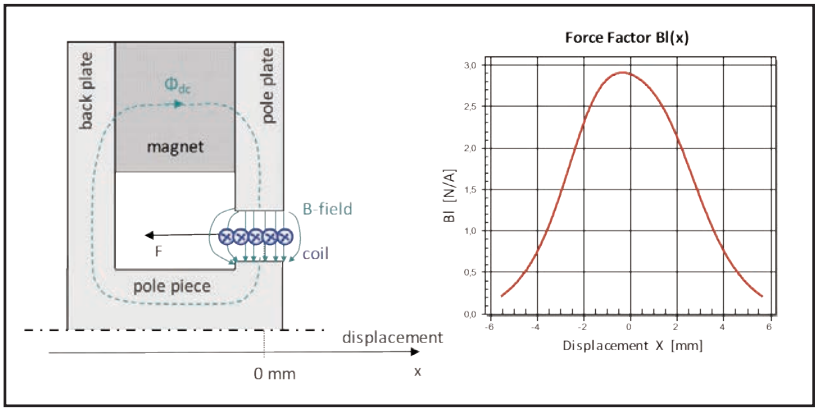


Figure 2: Here is the cross-section of an electrodynamic transducer motor and the corresponding nonlinear force factor Bl(x).

coil shift affects the direction and the amount of dynamically generated DC displacement, depending on input voltage of a critical signal. If the audio signal contains frequencies between the driver's resonance fs and 2 × fs, the center point of the AC coil movement may be shifted significantly away from the rest position. In bad cases, the amount of DC displacement generated may have the same magnitude as the AC amplitude. It directly corresponds to the amount of asymmetry of the force factor defined by the coil rest position or field asymmetry.

Distortion and stability problems may not always be critical for linearly designed motors. Still, the voice coil position matters in terms of displacement limiting, defined by geometrical

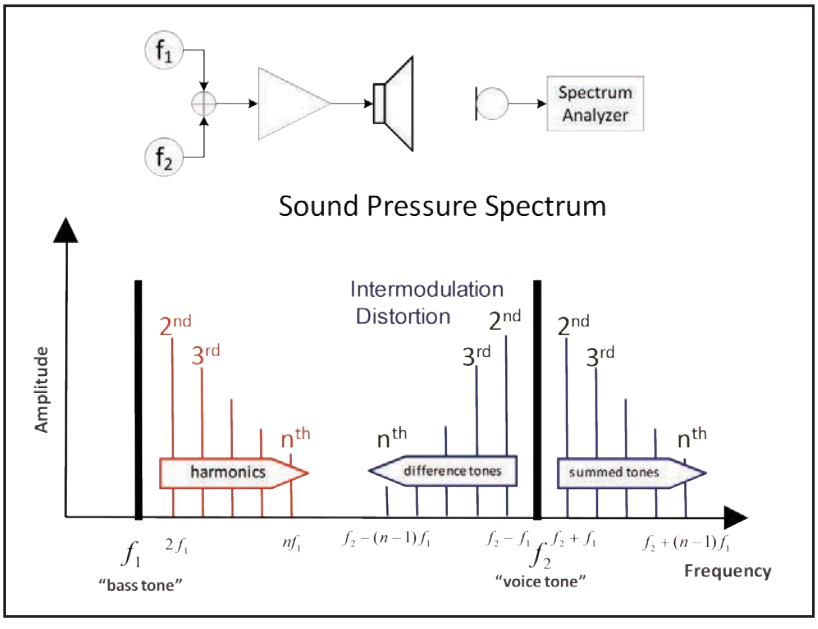


Figure 3: Sound pressure output of two-tone signal played through a loudspeaker at high excursion

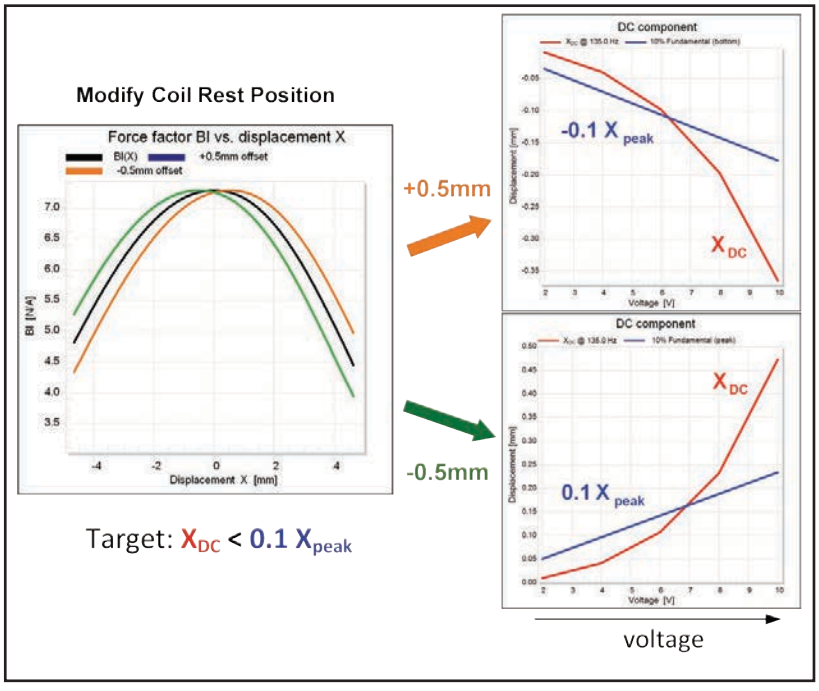


Figure 4: This illustration shows the simulated effect of a positive and negative voice coil offset on the generated dynamic DC displacement. At high input voltages, the displacement DC component exceeds 10% of the AC peak value. The direction of the generated DC corresponds to the direction of coil offset—the coil is shifted even further away from the optimal rest position.

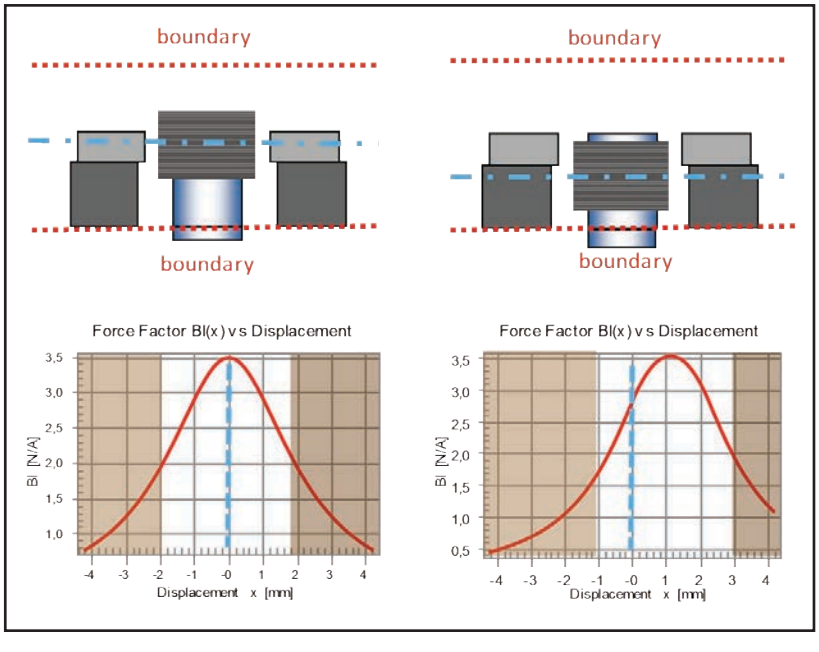


Figure 5: Influence of a non-optimal coil position on the usable negative and positive peak displacement limited by geometrical boundaries

boundaries as depicted in **Figure 5**. Microspeakers especially do not have a self-limiting suspension, for the most part, and most signal limiter algorithms assume a certain symmetrical excursion range. The safety margins related to coil position variation in manufacturing need to be relatively high because mechanical limiting must be avoided under all conditions to prevent destruction or impulsive distortion. The consequence is less available AC peak displacement and eventually less output.

Drawbacks of Traditional Distortion Test Methods

Since the nonlinear force factor and its asymmetry related to coil position is one of the main causes of signal distortion in the sound pressure output, HD and IMD measurements are a straightforward approach for evaluation—commonly used in both R&D and end-of-line (EOL) testing. The basic assumption is that any offset from the optimum coil rest position increases output signal distortion levels that can be simply measured with a microphone and an audio analyzer. Limits may be applied to the distortions levels in order to distinguish good from bad devices.

This assumption is mostly true for IMD, which is the main effect of the nonlinear force factor and can be effectively measured using two-tone signals (bass or voice tone sweep). This approach is a useful tool in R&D, but due to the limited test time and poor use for measuring other characteristics, it is usually not applied in EOL testing.

Multi-tone stimuli are an alternative choice to get a broad-band distortion fingerprint of the tested device. All mechanisms that create distortion are activated, but the diagnostic value is very limited. However, multi-tone signals are useful for nonlinear parameter measurement, which is addressed in the next section.

Pure harmonic distortion measurements can be realized in a more efficient way using sinusoidal signals with varying frequency, such as stepped sine signals or continuous sweeps (chirps). Such stimuli—especially the chirp—is more suitable for EOL testing since meaningful measurements can be performed in very short time. In addition, common characteristics such as frequency response, polarity, impulsive distortion (e.g., rub & buzz or loose particles), and impedance may be measured simultaneously. Also, single harmonics or total harmonic distortion (THD) can be obtained. Second-order distortion is a useful indicator for asymmetries in the nonlinear characteristics, such as Bl(x) asymmetry caused by coil offset.

However, harmonic distortion (HD) is not a unique

characteristic of the motor, as shown in **Figure 6**. In many cases the nonlinear stiffness of the suspension is the main cause of harmonics below the driver's resonance frequency. Therefore, the distortion test only reflects a mix of various and partly independent root causes. If both the suspension and the motor have asymmetrical characteristics, a coil offset may even reduce distortion, as depicted in the example in **Figure 7**. The transducer may pass the harmonic distortion test, although the displacement clearance and stability is significantly reduced.

Even in those cases where the THD or the second-order HD measurement indicate that the DUT has a different nonlinear behavior than the golden reference device, it still lacks some basic diagnostic information:

- What was the root cause of the failed test and how to fix it?
- Was it a problem of the suspension part, the voice coil, or the assembly?
- If it was related to coil position and the problem is systematic, by how much and in which direction must the position be adjusted (in millimeters)?

In order to answer these questions using traditional test methods, the failed units must be evaluated by experts in a diagnostics station or even in the R&D lab. This is very time-consuming and often not practical. In the meantime, the yield rate may drop, significantly reducing profit.

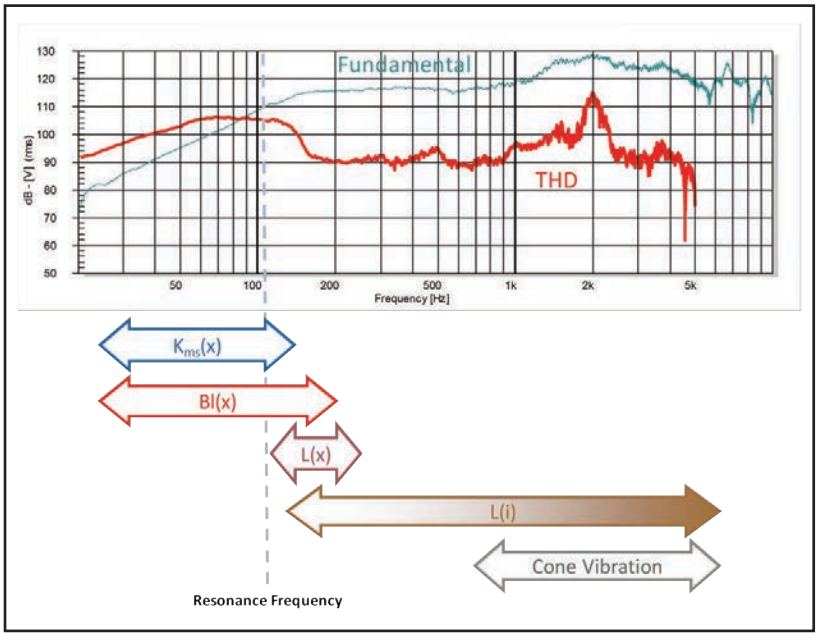


Figure 6: These are some of the major causes of harmonic distortion in sound pressure output of electrodynamic transducers over frequency.

Testing Voice Coil Position Based on Nonlinear Parameter Measurement

Since pure output distortion tests have various drawbacks, it is desirable to measure the voice coil position directly. Mechanical sensors are mostly not applicable to an assembled transducer and they are hardly suitable to evaluate the optimal positioning of the voice coil with respect to the magnetic field.

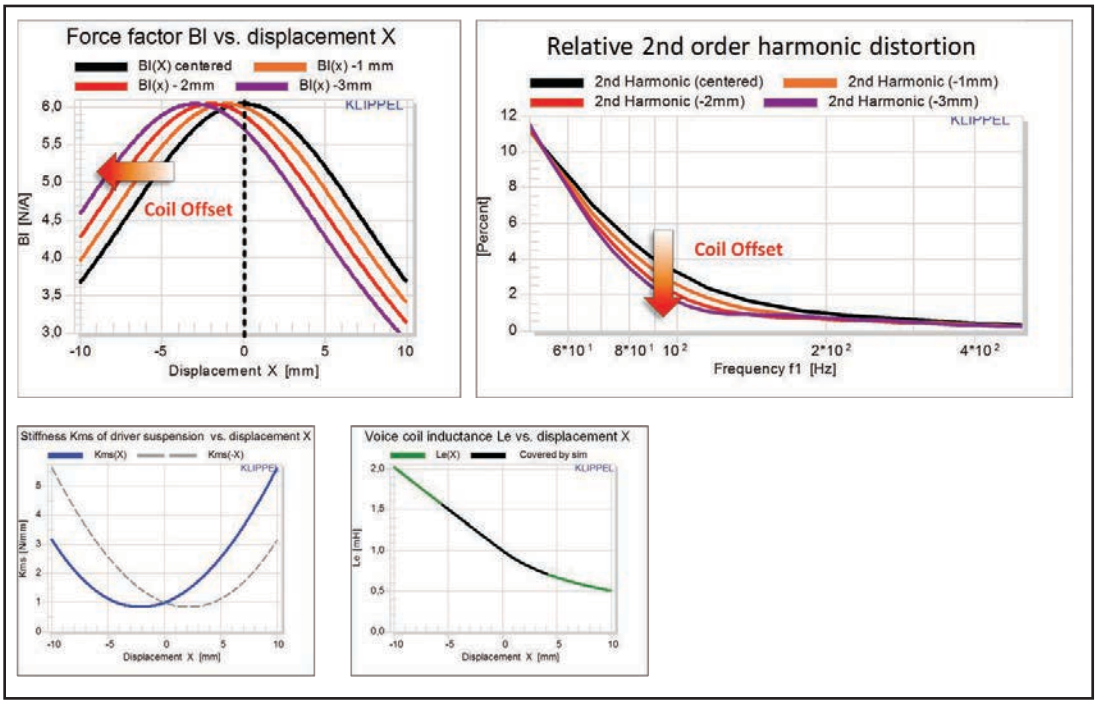


Figure 7: Simulated second order harmonic distortion vs. coil offset—the distortion is reduced with increasing offset due to asymmetric suspension stiffness.

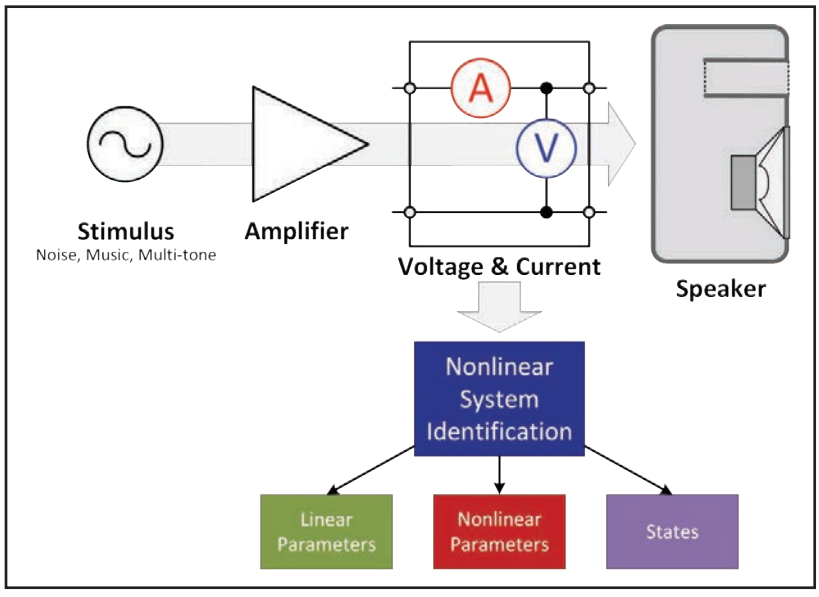


Figure 8: Measurement of transducer nonlinear parameters based on measurement of terminal voltage and input current

As previously stated, the voice coil rest position reflects in the nonlinear force factor Bl(x). Therefore, measuring this nonlinear transducer parameter is suggested as a superior approach to pure output-based distortion testing. Since the linear transducer model, based on Thiele-Small (T-S) parameters, is only valid at very small excursions, a nonlinear transducer model is required for this purpose. Such parameter-based models have been developed and successfully applied in transducer design, diagnostics and control. In R&D and prototype evaluation, nonlinear transducer parameter measurements are a common tool in the loudspeaker industry.

Due to the coupling of electro-mechanics, the speaker itself can be used as a sensor to identify the linear and nonlinear parameters by exploiting the terminal voltage and input current measured at high amplitudes (see **Figure 8**). For absolute calibration of the mechanical parameters, an optional laser displacement sensor may be used or a previously measured (typical) moving mass or Bl(0) can be imported.

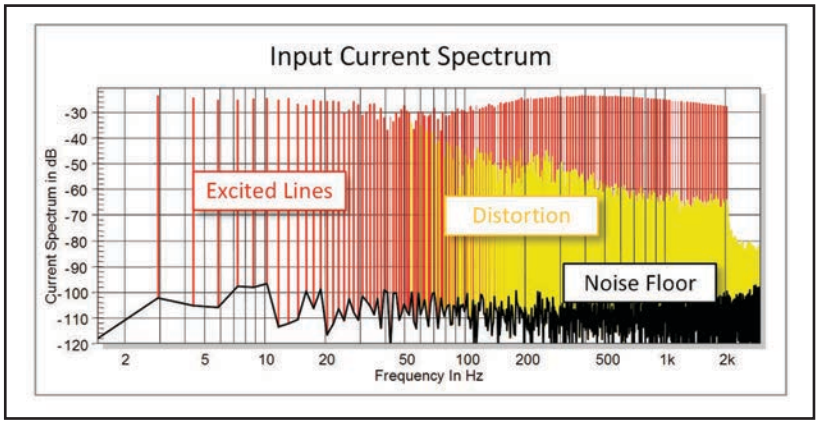


Figure 9: The multi-tone input current spectrum of a transducer operated at high amplitudes

Virtually any broadband audio signal stimulus may be used for nonlinear parameter identification, but for high-speed testing in the production line, a multi-tone complex is the optimal test signal in order to excite nonlinearities efficiently and separate resulting distortion easily while keeping the test as short as possible. **Figure 9** shows an example frequency spectrum of the transducer input current. The distortion generated by the transducer nonlinearities are shown between the sparse, excited frequency lines in the signal spectrum.

The nonlinear parameters, such as Bl(x) or Kms(x) are identified by fitting the transducer model to the measured data. In R&D, those parameters have a high diagnostic value, but they are not suitable for EOL testing. Single value parameters like voice coil offset in millimeters or stiffness asymmetry in percent are more suitable for limit setting and process control.

In order to determine the coil offset from the Bl(x) curve, two methods are suggested as shown in **Figure 10**: the Bl(x) symmetry point and the coil offset relative to a reference DUT. The symmetry point according to The International Electrotechnical Commission (IEC) standard 62458 is a universal tool to evaluate any kind of asymmetry in the curve. Starting at the curve maximum, it equals the center point value on the X-axis between two points having the same Bl value. Thus, the value depends on amplitude and may be different at low and high excursions. For motors with symmetric motor topology, the symmetry point is relatively constant over amplitude and indicates the coil position directly (with negative sign), which ideally should be close to zero.

For transducers with inherent asymmetry in the magnetic field or linear motor designs with overhung coil as shown in the example in **Figure 11**, the symmetry point can be misleading. In order to estimate the coil position, it should only be read at maximum amplitude where the main Bl(x) slopes are dominant. A symmetry point equal to zero is not always desirable for optimal performance at small or medium amplitudes. For some motor topologies, this method is too ambiguous or not applicable at all.

In such cases, a preferable method is based

on comparing the Bl(x) characteristic to a known reference DUT of the same type (e.g., a "Golden" DUT). Based on the assumption that the inherent curve shape is mainly defined by the motor geometry and thus stable, the offset is determined by estimating only the curve shift. This approach is the most universal method, but always requires an approved reference unit that defines the optimal or desired coil position.

For a typical automotive woofer, the additional test time for the nonlinear parameter test is between 1 s and 2 s. An additional small signal impedance test may be omitted, because effective linear T-S parameters can be determined at high amplitudes as well. Additional pre-excitation signals for transducer break-in can also be skipped and replaced by the high level nonlinear test. Using high-speed chirp signals for additional acoustical tests, the overall test time can be optimized to be 2 s to 3 s while gaining much better diagnostic information for process control.

Conclusion

Ensuring an optimal voice coil rest position is essential for the audio quality, stability, and displacement clearance of loudspeaker transducers, especially for small or highly efficient ones. The coil position varies significantly in manufacturing due to systematic variation of the soft parts and moving parts assembly. Modern EOL test systems should be able to directly or indirectly test large signal characteristics to ensure desired target product quality and to guarantee specified peak performance. Traditional harmonic distortion tests can be a simple approach to check motor and suspension problems qualitatively, but results can be very ambiguous or even misleading and have low diagnostic value.

Directly testing the voice coil position by nonlinear parameter measurement is a superior method to identify the root cause of distortion, instability, and peak displacement limitation with high accuracy. Quantitative information is provided that can be used for immediate process control in order to fix systematic problems as early as possible. The diagnostic value saves time and money by reducing manual analysis effort and increasing yield rate through early defect detection. This balances the additional test time spent while the overall time is kept low, using efficient stimuli and test sequences.

Since the soft parts are the most critical and variable component of the loudspeaker, a critical EOL test for controlled manufacturing is required. However, optimal performance over the product's lifetime can only be ensured using adaptive, nonlinear speaker control to overcome production variance, aging, and environmental influence in the final application.

The presented approach is not only applicable to electrodynamic loudspeakers, but with modification also to other transducer types (e.g., balance armature drivers) in order to test the armature offset within very short time for optimal and reproducible audio quality. ***LIS***

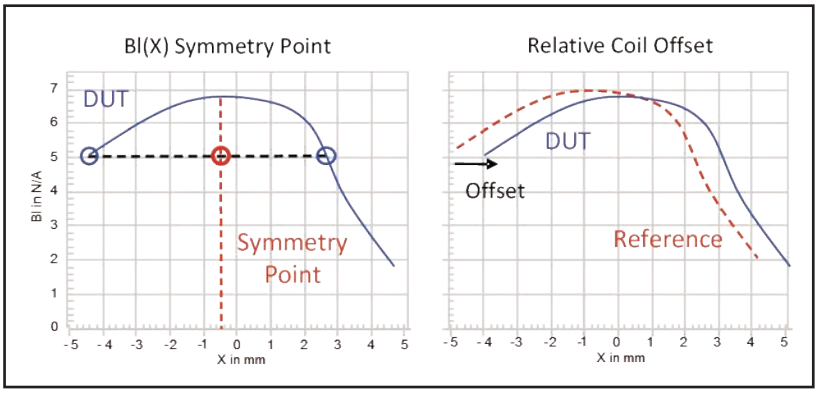


Figure 10: These two methods are suggested for measuring voice coil position based on nonlinear force factor Bl(x).

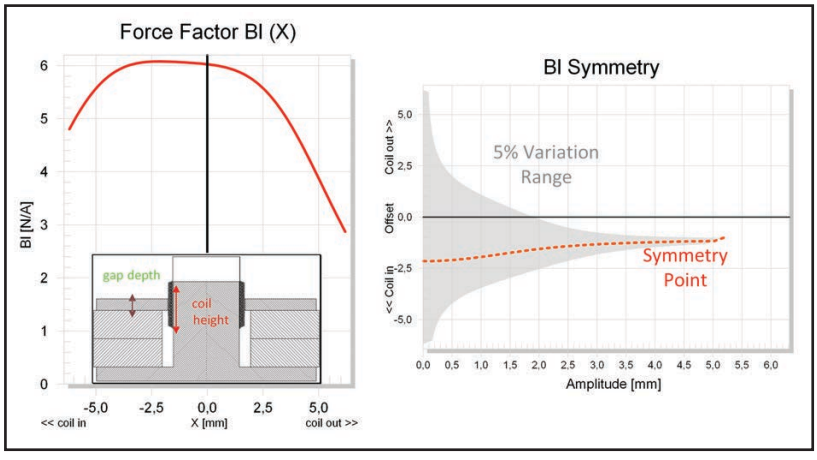
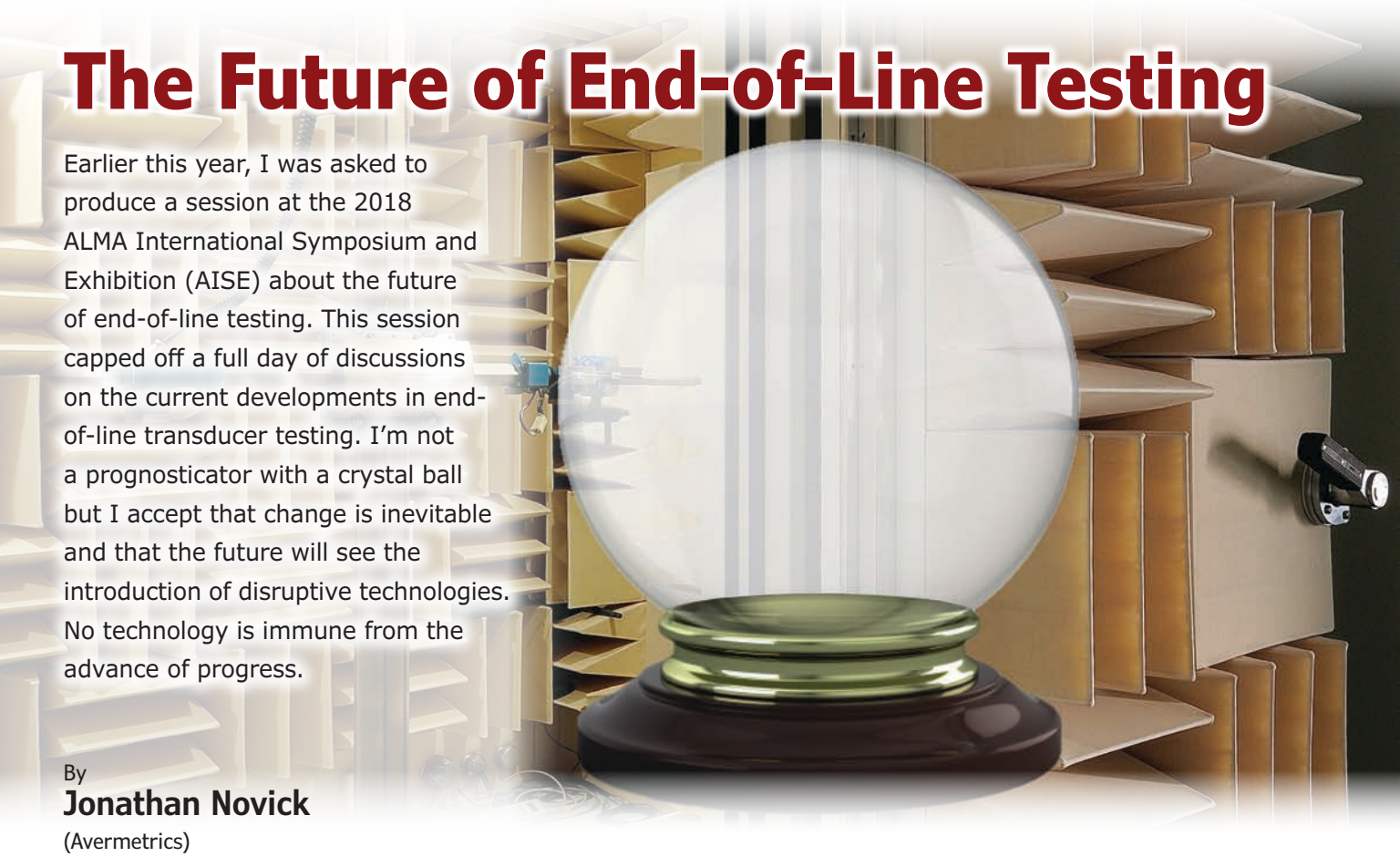


Figure 11: This graph shows the Bl symmetry point for a transducer with overhung coil design.

About the Author

Robert Werner was born in Nordhausen, Germany, in 1984. He studied electrical engineering at the Dresden University of Technology with a focus on acoustics and signal processing. In 2009, he received a degree for his thesis "Detection and localization of flow noise and other impulsive distortion for quality control of loudspeaker systems," which was supervised by Dresden Technical University and the Klippel GmbH in Dresden. After his graduation, he joined Klippel GmbH where he is currently engaged in the research and development of loudspeaker measurement systems with a focus on QC applications.

The Future of End-of-Line Testing



Earlier this year, I was asked to produce a session at the 2018 ALMA International Symposium and Exhibition (AISE) about the future of end-of-line testing. This session capped off a full day of discussions on the current developments in end-of-line transducer testing. I'm not a prognosticator with a crystal ball but I accept that change is inevitable and that the future will see the introduction of disruptive technologies. No technology is immune from the advance of progress.

By
Jonathan Novick
(Avermetrics)

Scientific historian James Burke once had a TV series, *Connections*, where he traced the roots of modern innovations to centuries old developments. These connections were clear to see in the mirror of history as presented on the show. However, foresight is never as clear as hindsight. For instance, could Joseph Marie Jacquard have foreseen in 1804 that his automated loom would lead to developments in modern computing in the mid-20th century? Very doubtful.

Smaller steps along the path of innovation are often much easier to predict and sometimes by looking at many of these at once as well as market needs, the possibility for real breakthrough becomes more evident. In that spirit, my session explored existing technologies that could be the seeds for future disruptions in end-of-line (EOL) transducer testing. This wasn't detailed research designed to woo investments into a new technology. It was just a means to provoke an interactive discussion with some out-of-the-box thinking among the attendees. Discussion is not possible with an article, but I will share some of the ideas presented at AISE to stimulate the imagination of readers.

Paradigm Shift?

The only industries that are immune to change are obsolete ones. There is no reason to believe that the loudspeaker industry is obsolete. EOL transducer testing has seen continual evolution. Acoustic tests have become faster, more comprehensive, and more accurate. However, the basic paradigm has remained unchanged. Build a transducer, acoustically test it, install it in a speaker system, and acoustically test it again. There is no reason to believe that this paradigm is immune to change. In fact, it is easy to see possible ways in which it might.

Acoustic testing is expensive. Tests require acoustic isolation and take a nontrivial amount of time to perform. Increasing speed, accuracy, and reliability requires investments to be made in the latest technology. Such investments could also be applied toward improving the manufacturing process itself to lower failure rates to the point where acoustic testing is not as important. Perhaps a more likely scenario is one where a combination of faster optical, X-ray, mechanical, or electrical testing methodologies obviates the need for traditional acoustic tests. Such developments,

should they occur, will most likely impact high-volume production parts (e.g., the microspeakers used in cell phones). Larger drivers made in smaller numbers may not gain such advantages for a much longer time.

Built-In Self-Test

Microspeakers have given rise to an interesting innovation—off-the-shelf integrated circuit amplifiers with built-in I-V sense capability. Such amplifiers are commonly found within cell phones to insure the microspeakers can achieve maximum output without exceeding their mechanical and thermal limits. It is not hard to imagine that with additional signal processing such sensing becomes the basis for a full blown built-in self-test (BIST) capability that could supplant traditional test equipment. There are certainly technical challenges to conquer along this path. However, the incentive of such an approach rises with the production volume of the part.

BIST development will most likely require more than just improved I-V monitoring techniques. Additional sensors may need to be employed. Luckily, the Internet-Of-Things (IoT) devices are causing a proliferation of low-cost microelectromechanical systems (MEMS) sensors. The added cost of the sensors could be offset in reduced test time and in simplification of test fixtures.

"Smart" Transducers

If sensors were to be placed into transducers, it would be a pity to restrict their use to just production tests. In fact, they could be used to provide continual monitoring and real-time feedback to the signal processing functions within a powered speaker system. This isn't an entirely new concept. Servo-feedback subwoofers have been commercially available since the 1980s. Modern sensors and processing can do a lot more than 1980s technology. And, it is easy to see why a market might develop for such a "smart" transducer.

Reduced product cycle times almost beg for smart transducers. Contemporary products are often pieced together from functional modules with a power supply from one vendor, an amplifier from another, a Bluetooth radio from a third, and so forth. The engineer's job becomes one of packaging the various blocks rather than designing them. A smart transducer armed with sensors paired to modern signal processing could speed a product to market. The engineer would not need to be an expert on transducer selection and the design itself could be more tolerant of part variations—a benefit to any manufacturer. And of course, for all these added benefits, the transducer manufacturers themselves could charge a nice premium.

Transducers With Built-In Datasheets

One doesn't have to look very far to see where "smart" transducers are today. Modern measurement microphones already contain Transducer Electronic Data Sheets (TEDS). The TEDS chip inside the microphone tells the measurement system unique information about the microphone such as its model number, sensitivity, and calibration date. This is particularly useful for people working with large microphone arrays. It is not hard to imagine a driver with a TEDS-like function.

Speaker arrays and headphones need matched sensitivity drivers. Many are already self-powered and have a built-in DSP. A transducer with a built-in datasheet could insure the drivers match performance as required without any pre-testing or binning of the drivers. This could greatly reduce test time and production waste, while making the overall listener experience better.

Conclusion

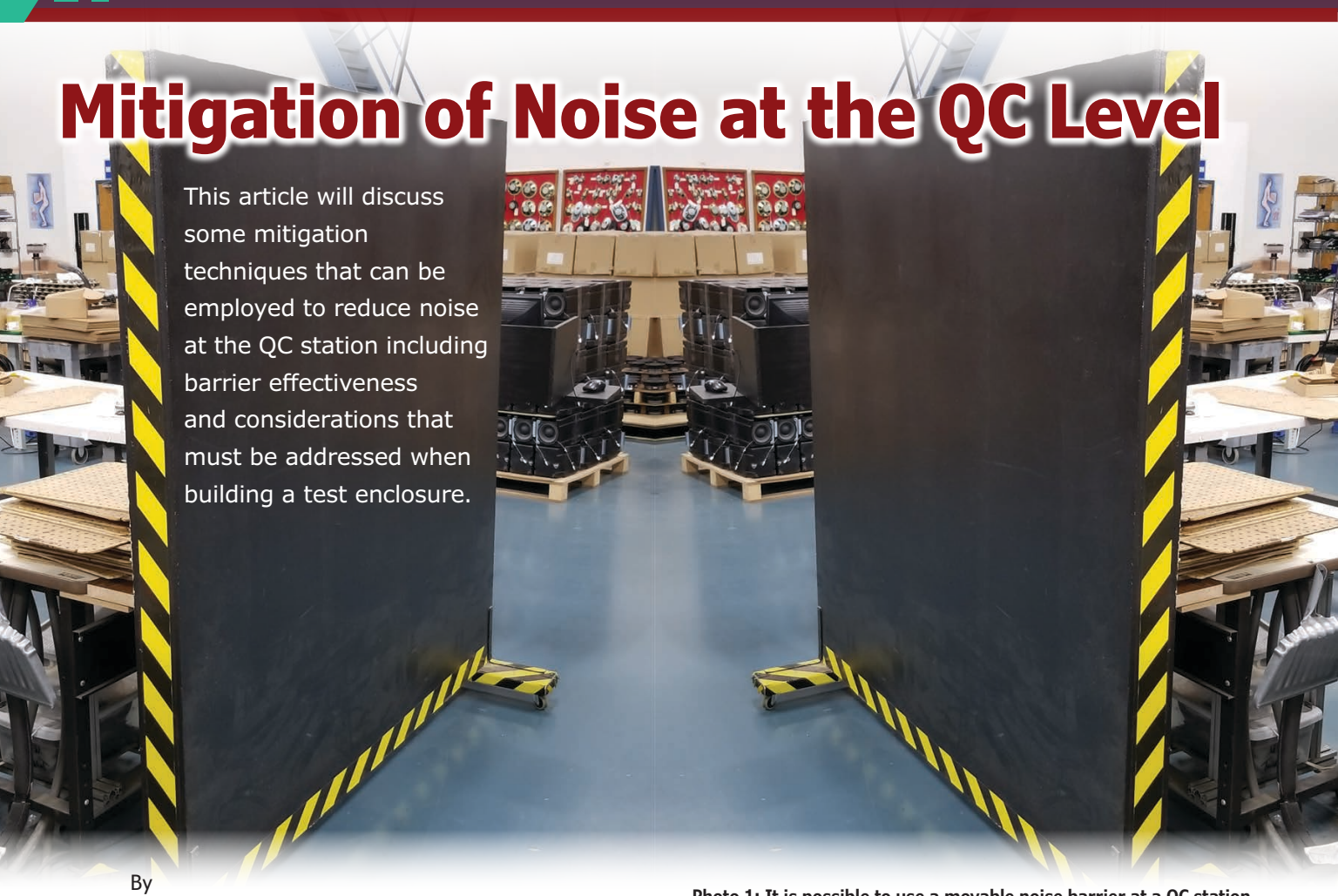
I have presented a handful of what-if and what-could-be scenarios given minor extensions of existing technologies. While the chances of the exact ideas presented here being tomorrow's next big breakthrough is low, the probability of significant change remains high. Any such ideas will greatly impact the EOL testing of the transducers themselves.

If acoustic testing is supplanted with other forms of testing, entirely new measurement equipment is needed. If sensor-laden transducers with BIST capabilities come into vogue, the sensors themselves may need testing as part of the production process. And if datasheets are embedded into transducers, existing acoustic tests may become even more rigorous. All this leads to one significant conclusion. The nature of EOL testing may change but the act of testing itself is not likely to go away. One should always monitor trends and be ready to make the necessary investments to ride the next technological wave. ***LIS***

About the Author

Jonathan Novick is vice president of sales and marketing at Avermetrics, a manufacturer of highly scalable affordable test equipment for production lines and laboratories. He is an electrical engineer with almost three decades of RF, microwave, and audio test and measurement experience at companies such has HP/Agilent and Audio Precision. He is a past governor and vice president of the Audio Engineering Society (AES) and sits on several standards committees within the Consumer Technology Association.

Mitigation of Noise at the QC Level



This article will discuss some mitigation techniques that can be employed to reduce noise at the QC station including barrier effectiveness and considerations that must be addressed when building a test enclosure.

By
Kent Peterson
(Warkwyn)

Photo 1: It is possible to use a movable noise barrier at a QC station.

Quality Control (QC) is the river that separates your beloved product from the great unwashed masses. It's at this moment that everything has come together—the idea inception, the months (if not years) of R&D, prototyping, listening, redesign, more R&D, marketing ballyhoo, first articles, production meetings, assembly, packaging, and then getting the first systems down the line to this critical point, QC.

QC can be examined in many ways, including controlling the uncontrollable. Taking time to understand your QC environment—and getting a handle on things you can control—can go a long way to confidently delivering your baby into the hands of the consumer the way you intended.

One of the greatest and most obvious of concerns is the testing environment. How noisy is it on your production floor? Are atmospheric conditions going to be a problem from season to season? Are fine particulates common in the QC area? Addressing noise is a good and obvious place to start.

Noise Barriers

Depending on your QC needs, a noise barrier could be considered an inexpensive way of mitigating factory noise at a QC test station. However, there are some intricacies about noise barrier design that must be considered lest you build a wall that does nothing but create line of sight problems.

Some rules of thumb come into play when specifying a barrier and some may seem more obvious than others. For example, a noise barrier must break the line of sight. In the instance of speaker QC, "line of sight" may be from the device's perspective.

But, it also may benefit the QC operator if factory noise is fatiguing and intrudes on that person's ability to comfortably perform their job. This only works if factory conditions are such that safety issues aren't raised when walling off personnel. And with that in mind, barriers can also be made mobile with casters increasing the barrier's use and flexibility.

Taking a page (literally) from our friends at the Federal Highway Administration (FHWA- they build a lot of noise barriers), there are some useful guidelines in the specification and eventual efficacy of a barrier.

First, to reduce noise from one side of a barrier to another (a minimum of 5 dB), the line of sight must be broken (see **Photo 1**). This could be just from the perspective of the device under test (DUT) and the related noise. Each additional meter in barrier height added above the receiving location results in an additional 1.5 dB of attenuation. In most instances, it will only benefit the QC process to raise the barrier height to include the controller.

For example, consider a QC process that takes place on a bench that is 1 m in height. Adding a 2-m barrier only results in 5 dB attenuation. Adding another meter will increase attenuation to 6.5 dB. Although 6.5 dB does not sound like a great reduction in noise levels from one location to another, it is clearly noticeable and it just may gain you enough reduction to decrease false positives during your QC (see **Figure 1**).

Height isn't the only consideration where barriers are concerned—flanking paths and acoustic shortcuts need to be taken into account. A barrier must be wide enough to offer effective noise reduction. This is relatively simple. Make sure that your measurement apparatus is within the shadow zone of the barrier (see **Figure 2**).

The essential key to maximizing the attenuation of a barrier is to make sure that your QC apparatus is as close to the barrier as possible. Then, using the distance to the barrier as a guideline, make sure the width of the barrier is at least eight times that distance and at a minimum angle of incidence of 80° to the edge of the barrier—this minimizes the flanking path around the barrier.

Noise barriers that work well for traffic in an outdoor environment are not always applicable indoors. Environmental noise barriers don't have to contend with all of the reflected surfaces often encountered on a factory floor. To reduce reflective pathways and increase the noise reduction a barrier may afford, try turning both ends of the barrier inward—toward the operator at a minimum distance (D) of D × 2. This begins to enclose the operator and should offer upward of 8 dB attenuation given proper placement of the barrier and a height of 2 m.

Barrier build materials are straight forward—build the barrier from high mass materials. Lead filled and grouted concrete come to mind—but of course that's ridiculous. Actually 3/4" MDF built on a 2' × 4' wood frame will suffice. Seal air gaps, fill the void with insulation, and seal it with another layer of MDF. Even 3/4" gypsum in place of the MDF will offer a reasonable amount of sound transmission reduction.

At this point if noise is still corrupting your QC, it may be time to enclose the entire station! Or, in the case of many QC end-of-line (EOL) configurations, enclose the QC process in total.

QC Test Box

When we say "Test Box," there is more than one configuration that can fit that description. In the complete system QC process—a speaker mounted within a cabinet that is going through QC—a "pass through" test box system can be employed that encloses an assembly line belt (see **Figure 3**).

In this type of QC system, the finished speaker system moves down the assembly line and into a test enclosure, which is situated over the delivery system. A fixed mic within the enclosure takes the

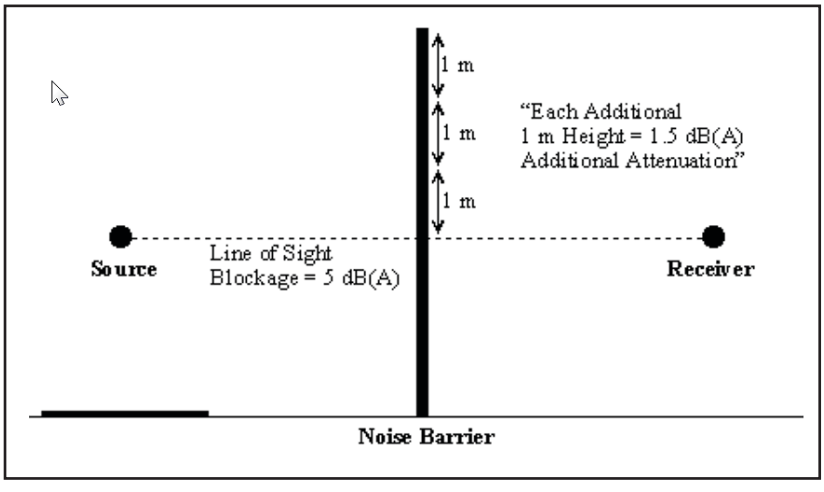


Figure 1: For example, consider a QC process that takes place on a bench that is 1 m in height. Adding a 2-m barrier only results in 5 dB attenuation. Adding another meter will increase attenuation to 6.5 dB. (Source: *FHWA Noise Barrier Design Handbook*, 2017)

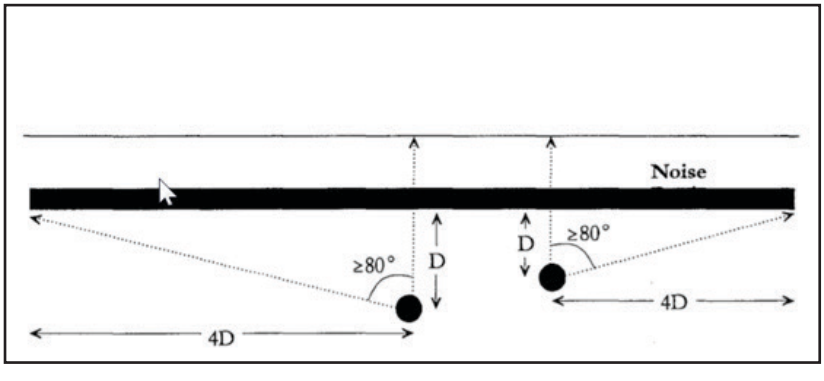


Figure 2: A barrier must be wide enough to offer effective noise reduction. (Source: *FHWA Noise Barrier Design Handbook*, 2017)

measurement and the speaker moves down the line to final packaging.

This setup has a number of advantages. It's simple, it's inexpensive to operate and maintain, there is no handling by the operator (unless failure), and it enables the operator to monitor the QC test in real time. However, the microphone within the enclosure is directly exposed to factory noise. Also, workers up the line must make sure that each device proceeding toward QC is positioned exactly where it should be on the belt, minimizing distance variation to the microphone for each and every test.

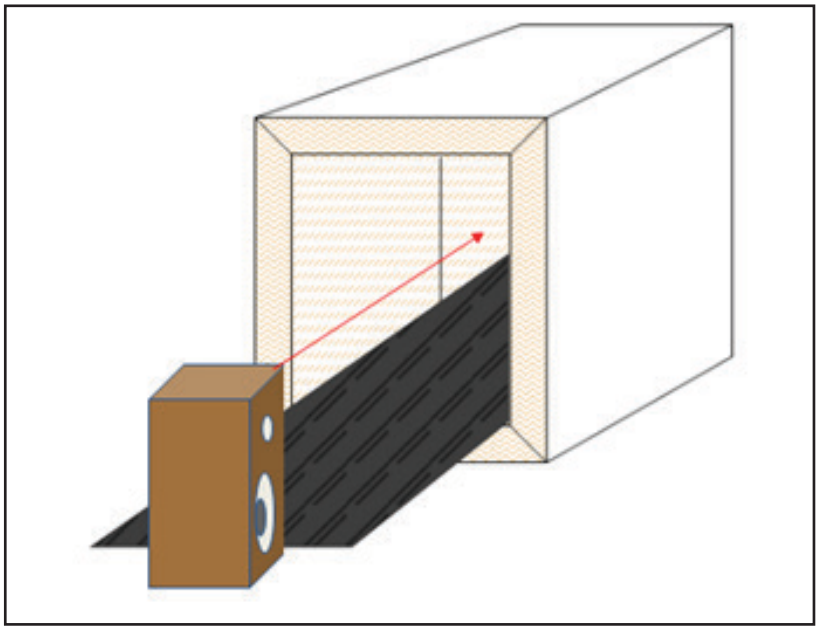


Figure 3: A finished systems QC test enclosure, which encloses the assembly line belt, can be employed.

Photo 2: This is an example of a soundbar QC test enclosure with pneumatically closing door.

Some systems of this type also include a door, which closes on either end—further enhancing isolation from production noise (see **Photo 2**). But this usually brings about much more interaction from the operator as failures are encountered.

Probably more common to readers is the completely enclosed woofer QC test box, which utilizes a baffle board system to QC individual transducers. This is the *Loudspeaker Industry Sourcebook* after all.

While these systems are commercially available, it is possible to build your own QC test box, and we've built a few at Warkwyn. Here are some pitfalls and build techniques that we have encountered while building QC test boxes for our clients.

The Big Box Build

Above all, EOL testing is meant to be fast and efficient. Before designing a test box, the most important mechanical system in the entire process has to be addressed—the comfort and efficiency of the operator. Operating a QC station can be a grueling ordeal if the operator is constantly exposed to loud stimuli, must bend their body for each pass, or is standing directly on a concrete floor.

Just as important as to how the test box works is how the employee works with the test box. So try to situate the QC system so that the operator is not bending at the waist to pick up transducers and is not wasting movement on each and every pass.

The height of the test box is also important—does it align with the delivery system? Does it allow smaller statured operators the same easy access as taller operators?

Once these critical questions are addressed, it is time to work on to the box itself. We recommend starting the build with a frame of 80/20, T-slotted extruded aluminum. This will allow you to build shelving, cable guides, and provide a sturdy frame as the build progresses.

Box volume is determined by the low-frequency limit of the DUT. Since the low-frequency wavelength will more than likely be larger than your dimensions, determine the appropriate box size based upon your space requirements.

Some key considerations for the build include:

- Affix heavy duty rubber casters with locks to the frame early on. These will reduce structure-borne noise and make working around the box easier. Once the outer box has been manufactured and mounted on the frame, it becomes difficult to turn the entire

system upside down to mount them.

- Secure all internal bolts with Loctite. As an added precaution, use a non-hardening rubber coating on all the bolts to ensure that through the life of the box, vibrations won't loosen the bolts and cause rattles.
- Be vigilant about what may fall into the cabinet—pens, pencils, bolts, washers, or glasses (it's happened). These things can get lost and are painful to find, especially once the box is sealed and something is heard rattling during measurements!
- The internal box must have no parallel walls to mitigate standing waves (see **Figure 4**). This can be one of the most difficult components in the build. A well-stocked wood shop with a capable cutting table is needed as a minimum. A CNC table is highly recommended in order to design and cut the multiple compound angles needed.
- All the seams need to be glued tight and screwed into place for an airtight fit. Application of a rubber-based gasket material on all connecting seams is beneficial, reducing the odds of squeaks and rattles.
- There must be sufficient damping of the internal walls. Acoustic wedges can be manufactured quite simply to mitigate internal reflections. In our experience, Owens Corning 703-2" and 3" panels are excellent in terms of usability, ability to hold shapes, and sound absorption (see **Table 1**).

Anechoic wedges should be cut into cone shapes that are a quarter wavelength in depth and at the lowest frequency possible. The internal volume of the box will limit your actual well depth.

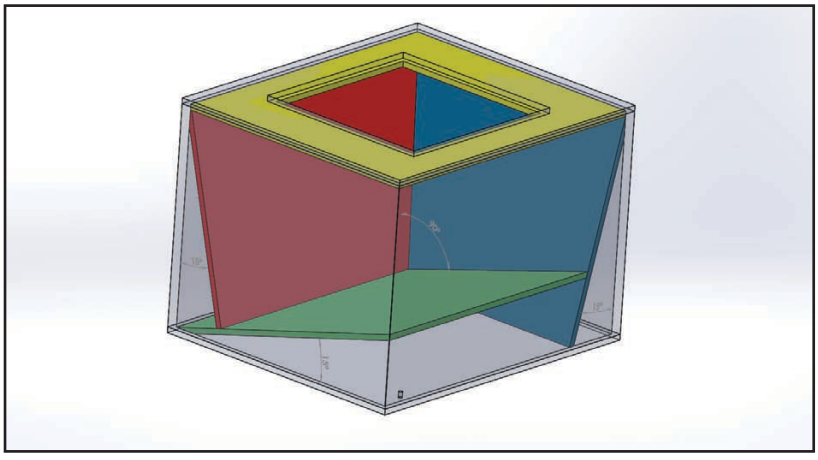


Figure 4: The internal box structure should have no parallel walls.

Once an appropriate cone height is determined, MDF can be cut into the cone pattern and the Owens Corning product can be sandwiched, clamped, and cut with a serrated blade (see **Photo 3**).

Disconnection of internal structures is needed to eliminate structure-borne noise and vibrations, which can cause false failures during QC. Our QC boxes are built using a floating internal asymmetrical box. That floating structure needs to be disconnected from the external walls of the QC box. Rubber straps (1/4") can be used to mount the internal box to the external structure in a fashion that completely decouples the box. The rubber is affixed vertically to the corners of the internal box via screws and washers and then mounted in the same fashion directly to the 80/20 and slotted T-nuts (see **Photo 4**).

Sound Absorption Coefficients

ASTM C423; Mounting: Type A—Material placed against a solid backing.

Product Type	Thickness		Octave Band Center Frequencies, Hz						
	in.	(mm)	125	250	500	1000	2000	4000	NRC
703 Unfaced	1	25	0.03	0.25	0.65	0.93	0.99	0.89	0.70
	2	50	0.10	0.71	1.14	1.14	1.03	0.95	1.00
	3	75	0.31	1.07	1.26	1.15	1.05	0.97	1.15
	4	100	0.51	1.19	1.24	1.13	1.04	0.94	1.15

Table 1: In our experience, Owens Corning 703-2" and 3" panels are excellent in terms of usability, ability to hold shapes, and sound absorption. (Source Owens Corning https://dcpd6wotaa0mb.cloudfront.net/mdms/dms/EIS/10021736/10021736-Fiberglas-703-and-705-Series-Insulation-Product-Data-Sheet.pdf)

Disconnection of materials in direct contact with the QC box is a recurring theme. If it comes into any contact with the internal structure, it needs to be disconnected. This includes:

- Microphone mounting. The measurement microphone should be positioned within the test box in an asymmetrical position and mounted within a shock mount (see **Photo 5**). The distance the mic should be to the DUT should equal the diameter of the DUT. When calibrating the QC test box, it is important to know the pressure levels within the cabinet and select the proper mic, as very high pressure levels are common within a QC box.
- Computers and peripherals. In this day and age proper QC can't be done accurately enough without a computer. If the computer needs to be mounted on the QC box structure, decouple the computer by mounting the framework to the base of the QC box.
- Speaker leads and gator clips need to be managed as these items rattling against the cabinet can be a source of false Rub & Buzz results. One solution is to hang the speaker leads from above and over the baffle board opening. This leaves the clips in direct access to the operator and alleviates the cables from ever coming into contact with the cabinet (see **Photo 6**).

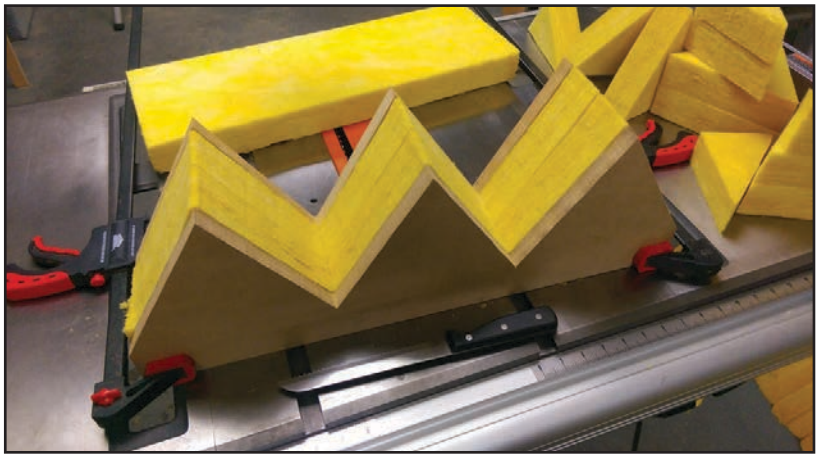


Photo 3: Cutting acoustic cones for the internal volume of the test box with the serrated bread knife my wife keeps asking about

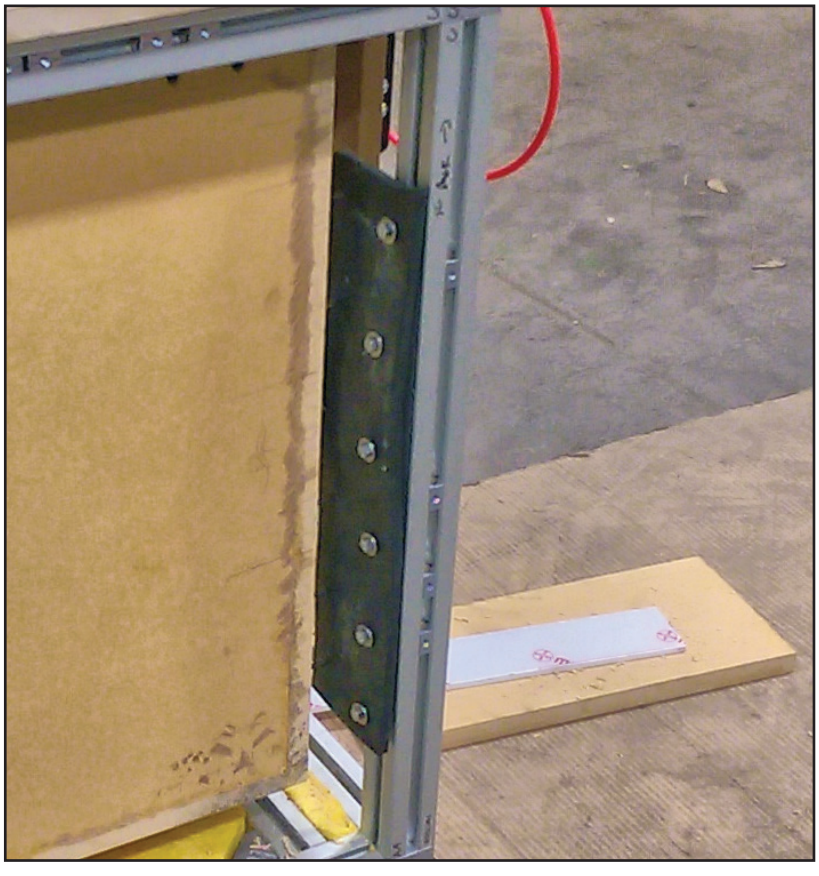


Photo 4: Rubber straps hold the internal box floating in-place for disconnection.

Place latching speed clamps on the housing for baffle board mounting. A gasket should be installed around the baffle board aperture so that no rattling between the baffle board and the QC box top is encountered during testing. Additionally in some noisier environments, a cover can come down to enclose the transducer under test. This

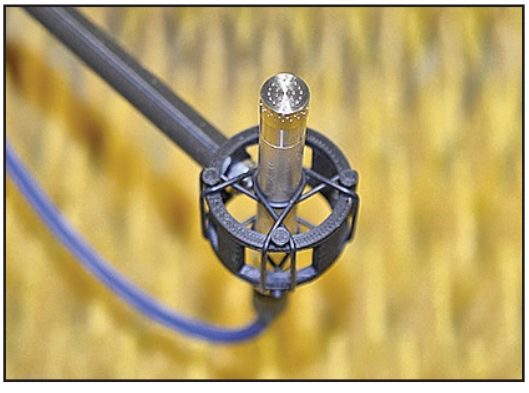


Photo 5: Use a 3D printed shock mount with the microphone mount.

About the Author

Kent Peterson is the sales and marketing manager for Warkwyn. He's spent almost three decades in the audio/acoustics business beginning with Electro-Voice. Then , he spent a decade with a few engineering firms as an acoustical and noise project manager, before returning to the "less controversial" field of speaker manufacture and consulting.

can further mitigate ambient noise and also protect your operator from high sound pressure levels.

Production Noise Immunity

If factory noise continues to intrude on your QC testing, the Klippel Production Noise Immunity (PNI) module may be the way to go. PNI is a unique and patented measurement module that allows the measurement to proceed while it might otherwise be contaminated by production noise. It does this by use of an additional microphone positioned at least a meter away from the test box, which monitors the ambient noise in real time (see **Figure 5**).

A noise prediction algorithm is then used to monitor and predict the impact of ambient noise at the measurement microphone within the QC test box. During the QC test process and when the desired stimuli is induced, the PNI algorithm compares the measured signal against the known signature of the transducer from that production run (the "Golden" Unit) and any external noise. If noise is encountered that is high enough to corrupt the test, the sweep is repeated for a pre-programmed amount of time while merging sections of frequency response which are not corrupted—until a complete frequency response curve is collected.

The process is remarkably fast allowing for collection of valid QC data in noisy environments within only a few seconds. The system has proven quite successful at a few automobile manufacturers while the vehicles speaker systems are QC'd in-situ, where speed of measurement is extremely important as the automobile moves down the line.

Not only is this module effective with the use of enclosed test boxes. It has also proven to be valuable during the QC of complete systems that cannot be placed within an enclosed test box, and must be measured in free-air due to size.

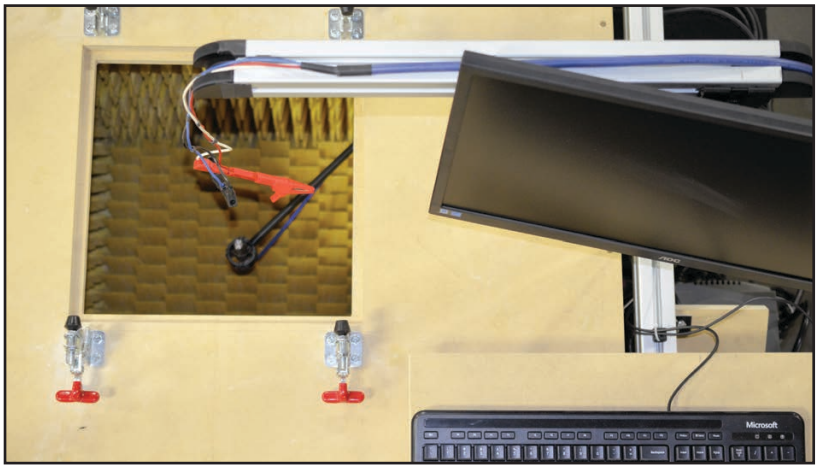


Photo 6: This is the top of the QC box. Note the speaker leads descending from above via 80/20 and also the 80/20 computer shelving to the right. These elements are connected directly to the 80/20 frame base and do not touch the QC box at all.

Measurements that are susceptible to noise and for which PNI can greatly benefit include:

- Frequency Response
- Level (average level)
- Polarity
- THD, second to fourth harmonic distortion
- Rub & Buzz
- Air Leak Detection results (if the Air Leak Detection module is used).

For more information, visit www.klippel.de/products/qc-system/additional-modules/pni-production-noise-immunity.html. ***LIS***

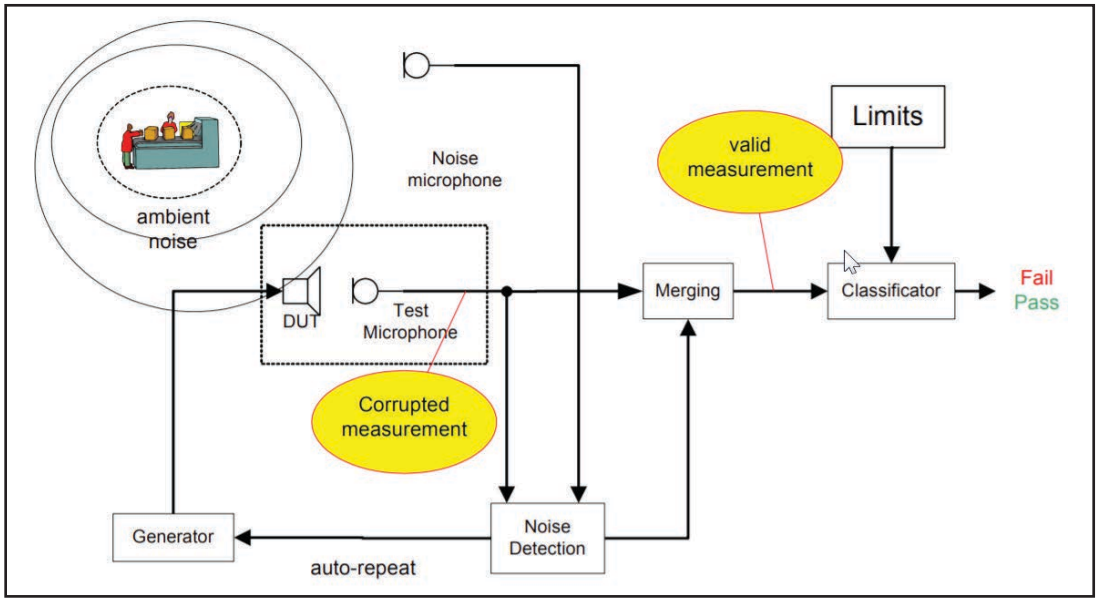


Figure 5: This is the Production Noise Immunity flow diagram.

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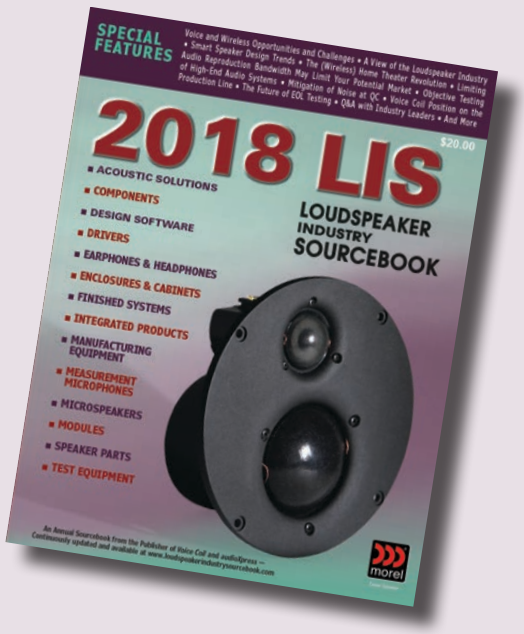

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Editor's Note: For the Questions & Answers interviews, we sent several notable industry professionals a list of questions and asked them to select the ones that they wanted to answer. The following content contains the questions they selected and their responses.

Andrew Bellavia

Director of Market Development, Commercial Audio, Knowles Electronics

LIS: Does your company have plans for voice implementation in 2018 and beyond?

BELLAVIA: We are deeply engaged in enabling voice user interfaces across applications. This of course includes smart speakers but also a wide range of standalone products. All these voice-controlled devices are often lumped into the IoT category though not everything need be connected to the Internet.

There is a drive to execute commands locally at the edge. Do I need a distant server to turn my lights on when I speak to the switch? Does it take the cloud to adjust my car's climate control? Response times are faster and more reliable when handled at the edge. Foregoing the Internet connection can reduce costs and increase security and privacy.

Knowles sees rapid growth ahead and is investing considerable resources to enable the effective use of voice interfaces both using the cloud and at the edge with true smart mics (mic + integrated DSP), audio DSPs with up to four purpose-built cores, and algorithms to support advanced voice control functionality.

LIS: Do you see the headphone market continuing to grow? In which product segments?

BELLAVIA: Definitely. We especially see the trend toward higher performance and more advanced features. Consumers are more willing to pay for better audio quality than ever before. The increasing penetration of devices with multiple drivers is one indication—even to the point where Samsung now includes a two-driver earphone with every Galaxy phone.

Wireless earphones and headphones are gaining shares over wired models. It is not yet completely clear if USB-C and Lightning devices will gain significant traction or if consumers are moving directly to Bluetooth so quickly that they will remain niche products. My own opinion is that audiophiles will stay with wired earphones for some time but that mainstream consumers will for the most part adopt wireless.

Wire-free earphones (no wire between the ears) are another growing segment. Though the market is dominated by one player today, legitimization has come to the category and other major audio brands are releasing products. For us, the open question is what smart features will gain wide adoption, and how quickly. Today wire-free music players dominate but there is a lot of work going on in the areas of language translation, true voice assistant integration (not just passing through the user's voice to a phone) adaptive ANC/hearing

enhancement, and biometrics for sport or health monitoring. Intelligent hearables are moving out of the experimental stage with the more successful startups gaining a foothold and larger companies coming in. Even if the adoption rate of smart features is not yet clear, we believe the category will grow.

LIS: With new exciting developments in MEMS speakers, multiple balanced armature, and even planar magnetic in the in-ear segment, do you think this market has the potential to expand to high quality/higher price models?

BELLAVIA: The market is already driving increased price points for in-ears as people gravitate toward quality sound. The consensus on why this is true centers around the idea that more people are consuming more audio and video content on-the-go. The audio quality they have at home puts generic earbuds to shame, driving the demand for high quality models.

Consumer demand for higher quality is driving innovation in the transducer space. We see it in increased demand for multiple balanced armature (BA) assemblies in different transducer and tuning configurations, which is in turn driving our developments. There is also a lot of work going on in other technologies to support the same trend, most notably dynamic drivers with advanced materials such as graphene. These are not necessarily mutually exclusive as the increasing number of dynamic-BA hybrid models attests. On the high end of the price range, the innovation options expand to include planar magnetic, electrostatic, and others.

LIS: We've seen Sennheiser selling a $55,000 headphone/preamp combo, the Sonoma Model One planar headphones with a dedicated preamp for $5,000 and many other manufacturers launching new flagship headphone models in the $8,000 to $3,000 price range. Do you see this category expanding? Or do you think these are limited proof-of-concepts and the technologies developed for those models will gradually be made available in the mid-high end space ($500 to $1000 range)?

BELLAVIA: In certain respects, audio is similar to automotive product positioning. Car companies sometimes build exotics which, although they sell in only small quantities, attract customers to the brand. They are more than proof-of-concepts in that respect. Also like automotive, advanced audio technologies have and will continue to migrate to lower price points as they mature. The good news for consumers is that audio quality keeps going up at any given price point. Even so, there will always be an "exotic" category in audio.

LIS: Many audio companies are experimenting with Audio Augmented Reality and hearing enhancements concepts, exploring the latest technologies in consumer earbuds, truly wireless earbuds, and hearables (smart earbuds that can also include interaction with voice or connection to a voice assistant). What do you think of this concept?

BELLAVIA: As the hardware technology improves it is expected that more and more earphones will adopt smart features. When the Bragi Dash was first released I tried an experiment. I had Google Maps giving commands through the Dash, helping me navigate on foot as I visited several shops near the Marienplatz. Not needing to look down at my phone while turn-by-turn instructions played in my ear was much appreciated on the busy streets of central Munich.

This is only the beginning. People used to interacting with their voice assistants at home will want the same when out and about. Adaptive noise reduction will provide a more pleasant experience and protect hearing in noisy urban environments. Music and web services will be controlled by voice alone. It is expected that a niche once served primarily by startups will become mainstream very soon. It is the reason Knowles is placing multiple bets on smart mics, audio-specific DSPs, and tiny balanced armature drivers specifically designed for intelligent ear-worn products.

LIS: Will hearing-aid companies leverage their technology and expertise to create products for that expanded Personal Sound Amplification Products (PSAP) market? Or will we see consumer-electronics companies (established and startups) conquering this space with a differentiated approach?

BELLAVIA: Regarding hearing enhancement or correction devices (and by this I mean both medically regulated hearing aids and consumer products) achieving a high rate of successful outcomes takes more than selling a product. I have seen enough examples to conclude that not everyone knows how to properly self-fit an ordinary earphone or hearable device. Those who would sell over-the-counter (OTC) hearing instruments on a self-serve basis will have to thoughtfully address this issue. The ones that do will have a head start in the OTC space. Certainly some of the larger brands such as Bose, to give just one example, have the experience to excel in this arena.

This is an area where the hearing aid delivery system has an advantage by working with customers to discern their need, assist in fitting, and provide training in operating the device. It is well known that only a small percentage of people suffering from hearing loss get treatment, and when they do it is often only after hearing loss has become debilitating. The argument has been made for audiologists to include OTC hearing instruments in their practice as a way of beginning the customer's journey earlier and more successfully than with self-fitting, gaining higher adoption rates, and lessening the stigma when later on that customer would benefit from stepping up to a full hearing aid. How will this play out? Nuheara is testing the concept in an expanding number of audiology shops.

In terms of device features both the hearing aid companies and consumer products manufacturers are working to achieve a differentiated offering. There are hearable devices with voice assistant integration and language translation skills. There are hearing aids that interact with smart home devices and have machine learning capability to fine-tune settings in different situations on an individual basis.

The two segments are converging on one another and in some cases forming partnerships. There will be no "conquest," but an evolution in both the hardware and how they are delivered to consumers. In the ideal case, the end result will be that more people who need hearing treatment will get it with high rates of successful outcomes, while at the same time enjoying a range of smart features that enhance their life experience. Hugh Knowles founded his company specifically to improve people's lives through better hearing. We remain committed to that goal today regardless of the form specific products take.

LIS: Other than smart-speakers, what other device categories do you believe are a natural expansion market for voice-based applications? Which ones make more sense in far-field applications?

BELLAVIA: Smart speakers were the first devices to bring voice-based user interfaces into the mainstream. Now a wide variety of devices are adopting the use of voice commands—appliances, light switches, and set-top boxes to name a few. The need to touch something to control its operation will diminish over time.

Another fascinating far-field application is not voice at all but sound recognition. Companies such as Knowles partner Audio Analytic are building algorithms that can recognize sounds (e.g., police sirens and breaking glass), opening the possibility for a wide range of intelligent decision making based on sound. In the industrial space, acoustic equipment monitoring can spot problems such as impending bearing failure before it happens. Sound recognition (voice and non-voice) has a bright future.

LIS: Test and measurement companies have launched or have confirmed to be launching solutions to increase reliability of audio frequency measurements to and above 20 kHz. What consequences do you think this will have for audio product development?

BELLAVIA: We see it as a plus for in-ears. The present coupler, commonly called the IEC711 coupler, has a sharp resonance peak that renders measurements above about 8 kHz suspect. It can also cause false total harmonic distortion (THD) peaks at sub-harmonics of the resonance. These result in a low correlation between what the measurements say and the actual listening experience, especially in the treble range. It also makes correlating measurements between companies in the supply chain more difficult.

The present coupler measurements also create a conundrum for those who publish their IEM technical specs. Should one publish the raw measured curve or smooth it out to reflect what is believed to be the perceived response? The adoption of a more accurate coupler across the audio spectrum will help resolve this issue. The question of whether or not customers understand what they are seeing is another matter but the availability of more accurate measurements cannot be a bad thing for those who choose to publish curves.

LIS: What about headphones? Do you think it will be a Bluetooth-only world? Is NFMI the solution to overcome existing technical limitations? Or do you think that, like speakers at home, earbuds will become IoT radio-enabled devices in the future and will be able to receive direct streaming from 5G/mesh networks (no need to pair with other mobile devices)?

BELLAVIA: There are different considerations for wireless headphones as compared to wire-free earphones. It is easy to envision earphones and headphones with direct network connectivity; Vinci is already shipping devices with mobile network access. In a headphone or neckband configuration there is enough room for the hardware, and most important, a big enough battery. But that configuration will take a long time to materially penetrate the market. Until then Bluetooth will be the primary solution.

Wire-free earphones have a set of demands that are much harder to reconcile, especially those that go beyond playing music. They need to be small and comfortable, have long enough battery life, good sound, and low latency/no dropouts between the ears. While Bluetooth from source to master ear works the same as with any wireless headphone, the link from master to slave ear can be problematic. The RF signal cannot pass through one's head but relies on reflections from external objects. Especially outdoors, good reflections can be hard to come by.

Today that problem is solved with NXP's near-field magnetic induction (NFMI) system originally developed to link hearing aids. The NFMI signal passes through the head quite readily and, therefore, is not subject to dropouts from lack of signal. In the future stereo BLE may become a viable option by directly streaming to both ears but it is hard to see the point when a mobile network radio is viable in wire-free in-ears. The physical size and power demands are just too great.

LIS: What do you think of all the work that's currently being done with audio processing algorithms for mobile devices, smart-speakers, ANC, earphones, etc.? What will be the impact for loudspeaker development process in general?

BELLAVIA: The use cases for intelligent audio products are multiplying rapidly, fueled in part by advances in both audio DSPs and the algorithms that run on them. I've discussed the proliferation of voice-controlled devices in another question—these are driven by the increasing sophistication of audio DSPs and software.

The expanding universe of both in-house development and also partners porting to Knowles' open DSP are indicative of the coming applications. These include more reliable barge-in (ability to issue commands over loud music or noise), wind noise rejection (outdoor applications including speakers, smart doorbells, etc.), specific voice recognition (personalization and security), low-power keyword recognition (wake-on-keyword in hearables), and sound recognition (your smart speaker recognizes that your home is being burgled).

There are also interesting applications that enhance the listening experience such as loudspeaker tuning to the room acoustics, adaptive ANC that reduces annoying noise while maintaining situational awareness, and edge-based voice control of common playback functions (e.g., "skip track" and "pause"). All of these will in their own way improve the audio experience for consumers.

As people come to expect these smart features the day will not be long in coming when most audio devices contain a DSP of one sort or another. Tomorrow's successful acoustic team will understand the DSP landscape and creatively integrate advanced audio functionality into their products.

LIS: Already in its fourth year, *The Audio Voice* newsletter is a weekly email service created to update *audioXpress* and *Voice Coil* communities with the latest news and articles. Do you receive it? What do you think of it?

BELLAVIA: I do receive it and appreciate the breadth and depth of the articles within. ***LIS***

Luc Guillaume

Chief Business Development Officer, Wisdom Audio

LIS: How did your current business evolve in the past 12 months? What are the perspectives for the next 12 months?

GUILLAUME: Wisdom Audio provides high-performance entertainment solutions with a focus on technology and design. Founded in 1996, Wisdom Audio is privileged to work with leading custom integrators, architects, interior designers and engineers from around the world on some of the most challenging and beautiful homes and super yachts across the globe to deliver a truly unforgettable entertainment experience to clients. In the past 12 months, Wisdom Audio has seen a 25% growth in business and we are looking at a very promising 2018.

LIS: With regard to speaker design, components, drivers and materials, what developments, products, or technologies impressed the most in a positive way from the last 12 months?

GUILLAUME: We design, engineer, and manufacture a wide range of loudspeaker systems incorporating advanced thin-film planar magnetic technologies. Our portfolio features in-wall, in-ceiling, on-wall and in-room architectural solutions as well as high-performance dedicated home theaters. Many of our products can be tailored and made to order in custom sizes and custom colors. With great attention to detail and respect of lead time, all of our products are designed, engineered and manufactured in the U.S. Our main goal is to combine clarity, dynamic and precision to achieve the ultimate in music and film sound reproduction so one of the most important developments, to us is that the Immersive Format has become the new standard and the old 5.1 and 7.1 systems are now Atmos 9.4.4 and 11.4.6.

LIS: Do you see the headphone market continuing to grow?

GUILLAUME: I think the headphone market will continue to grow and remain a strong market, at least for the next few years, until it reaches saturation.

LIS: What do you think of personalization/calibration technologies for headphones? (Examples Nura: www.nuraphone.com; Aumeo: aumeoaudio.com; Even Earprint: www.geteven.co; Mimi Technologies: mimi.io/en/home/; Hefio: www.hefio.com, etc.)

GUILLAUME: Personalization/calibration technologies for headphones is a trend that is here to stay and grow, particularly as the headphone market continues to grow.

LIS: We've seen Sennheiser selling a $55,000 headphone/preamp combo, the Sonoma Model One planar headphones with a dedicated preamp for $5,000 and many other manufacturers launching new flagship headphone models in the $8,000 to $3,000 price range. Do you see this category expanding? Or do you think these are limited proof-of-concepts and the technologies developed for those models will gradually be made available in the mid-high end space ($500 to $1000 range)?

GUILLAUME: The market for high price headphones is a niche and trickling down to mid market will be challenging with these technologies.

LIS: Do you think that features introduced in smart-speakers (voice assistants, smart home integration, etc.) could make sense in other speaker and audio product categories (i.e., home-theater systems, installed solutions)?

GUILLAUME: Not really, at least not in a dedicated home theater where you are really there to be immersed in a movie rather than a media room where various activities can be done.

LIS: Test and measurement companies have launched or have confirmed to be launching solutions to increase reliability of audio frequency measurements to and above 20 kHz. What consequences do you think this will have for audio product development?

GUILLAUME: Arguably none. Super tweeters and other means of passing 20 kHz have been on the market for many years but never really broke through.

LIS: Do you think whole-home and multiroom solutions are better left to the custom-install market? Or do you think Apple, Amazon, Sonos, and others will conquer this market with a commoditized approach?

GUILLAUME: Sonos already broke into this market and I expect larger companies will most likely continue the trend using smart speakers.

LIS: Will 2018 finally see the immersive formats—Dolby Atmos, DTS:X, Auro 3D and MPEG-H - taking off in the home market?

GUILLAUME: The immersive formats have definitely made the turn with the high-end segment with a large focus on the Atmos format, as the others failed to secure content.

LIS: Already in its fourth year, *The Audio Voice* newsletter is a weekly email service created to update *audioXpress* and *Voice Coil* communities with the latest news and articles. Do you receive it? What do you think of it??

GUILLAUME: Yes, I receive it and I think it is a great resource to see new trend product launches. ***LIS***

Oren Mordechai

CEO and Head of R&D, Morel

LIS: How did your current business evolve in the past 12 months? What are the perspectives for the next 12 months?

MORDECHAI: The last 12 months have been very exciting for Morel. The most recent events were the launch of our partnership with Geely Automotive, the owner of Volvo, Lotus, and London Taxi in addition to their recent acquisition of 10% of Daimler AG (Mercedes Benz).

Morel also launched a new brand called Nomadic Audio, creating an entirely new personal audio category with the development of a unique carry–on suitcase that transforms into a large portable hi-fi system.

Morel is continuing its R&D on new flat woofers and point-source drivers and other new product expected to release new variations within Q2.

LIS: Which technologies, products, innovations, or trends impressed you the most in the audio industry in the past year?

MORDECHAI: The integration of technology into the audio segment has truly transformed the way we develop products. This connected technology and artificial intelligence (AI) is affecting the premium speaker industry as well. It is interesting to

see how it penetrated the market so quickly and the high adaptation rate we experience in the market amongst consumers.

LIS: With regard to speaker design, components, drivers and materials, what developments, products, or technologies impressed you the most in a positive way from the last 12 months?

MORDECHAI: For us, the most impressive technologies include the ability to break the physical barrier and produce speakers that are small and shallow while preserving high performance levels. The new products that are coming to market, demand this type of transducer and as a result it's becoming a big part of our business. Our ability to rise with new materials and design topologies enables us to achieve our design and growth.

LIS: Does your company have plans for voice implementation in 2018 and beyond? VPA connected or local voice commands?

MORDECHAI: The VPA feature has offered great flexibility for many. It's all about the user experience and ease of use—the VPA achieves both and makes technology accessible to many more consumers that were not technology savvy. We will monitor how these segments develop and see how we can integrate it into our future products.

LIS: Many manufacturers had success with soundbars in 2017 and we are seeing soundbars evolving also for corporate (conference room) applications. Do you think this trend will continue?

MORDECHAI: Yes. The soundbar category has transformed from an audio solution into a very professional product that integrates many of the more advanced technologies to provide an audio visual experience for commercial applications. It's a great all-in-one solution that is highly adaptable to any commercial and residential application.

LIS: Do you think whole-home and multiroom solutions are better left to the custom-install (CI) market? Or do you think Apple, Amazon, Sonos and others will conquer this market with a commoditized approach?

MORDECHAI: One would be foolish to think that this segment will be left alone to the CI market. A few years ago, streaming services were laughed at among the audiophile community, while today one will have a hard time finding one audiophile that is not enjoying the service. Technology is stronger than any single sector and it transcends to all aspects of our lives. Like it or not, it's a reality.

Like many other changes that are happening, we need to embrace it and ensure that we offer consumers the best possible solutions for their needs. I think it opens a new era to the CI segment and the companies who will adapt will flourish, those who don't will be left behind.

LIS: In the last six months, we've seen significantly less crowdfunding campaigns for new audio products in the most popular platforms, while companies still struggle to deliver on the winning pitches from 2016 and 2017. Is crowdfunding over? Time to go back to venture capital? Or is it just a phase?

MORDECHAI: We actually used crowdfunding to launch the Nomadic Audio brand and the new Speakase. For us, it was not necessarily the funding aspect of it, but beneficial for us to enter a new segment by interacting with real consumers. Of course this is not a typical crowd funding project, but overall, I find it an incredible platform for people and companies to bring their ideas forward and make them happen. What people don't realize is that it is not easy to transform a product idea into a real product and I think this is why many of the funded projects are stuck.

LIS: Do you think new speaker technologies are needed for automotive applications (i.e., flat panels)?

MORDECHAI: The advancement in the automotive industry is changing every aspect of the car as we know it. From material composition to technology platforms, everything is changing. Very much like the home audio industry, car audio is being revolutionized in how it is integrated into cars today.

As cars become more advanced the need for a higher end speaker system is created. Weight and space are becoming very critical elements in system design and therefore the need for shallower and lightweight solutions is in demand. We work diligently to develop such solutions, similar to our Virtus nano woofer and Integra speakers.

LIS: Already in its fourth year, *The Audio Voice* newsletter is a weekly email service created to update *audioXpress* and *Voice Coil* communities with the latest news and articles. Do you receive it? What do you think of it?

MORDECHAI: I do and I love it. It keeps me up-to-date on the latest news in a very concise format. ***LIS***

Mark Valentino

Product Marketing Manager, PCB Piezotronics, Inc.

PCB PIEZOTRONICS INC.
MTS SYSTEMS CORPORATION

LIS: How did your current business evolve in the past 12 months? What are the perspectives for the next 12 months?

VALENTINO: At PCB, our company continues to grow thanks to advances in technology within and outside our corporation. We are historically focused on the Automotive, Aerospace and Defense, R&D Test Houses, Universities, Industrial and Energy markets. In the past 12 months, we have placed a greater priority on delivering lab-grade test and measurement microphones and accelerometers to the audio market. I see that continuing in the next 12 months.

LIS: With regard to speaker design, components, drivers, and materials, what developments, products, or technologies impressed the most ifrom the last 12 months?

VALENTINO: The advances in technology for high-end audio speakers, virtual reality, headphone design and Voice Personal Assistants (VPA) have been the most impressive to me. PCB is very interested in helping improve the THD of products and educating the products' manufacturers on the benefits of testing them past the human audible range of 20 kHz, which we believe will help make the sound crisper and help with transients.

With a noisy sensor, test engineers are limited in determining if the noise is coming from their product or the sensor used to test the product. A low-noise, lab-grade microphone will allow you to more accurately distinguish the noise floor coming from the product (example a loudspeaker) and enable improvements.

By testing the vibration of speaker and cabinet with test and measurement accelerometers, manufacturers can analyze resonant frequencies and extend the life expectancy of the cone or product.

LIS: Does your company have plans for voice implementation in 2018 and beyond? VPA connected or local voice commands? Is voice recognition a must-have for your company's audio products in 2018?

VALENTINO: I believe we are just scratching the surface with VPAs. This market has huge growth potential. I can envision many companies being creative and taking advantage of the benefits that VPAs provide. Automobiles will greater utilize voice recognition commands to do many functions we have traditionally done manually, such as starting a car, driving it for us on voice commands, calling a friend, playing the radio, changing the temperature, using GPS, etc.

In health care, for example, the injured, elderly, and blind can improve their quality of life with voice recognition. Simple things that many of us take for granted that may be difficult for people with physical or mental challenges, can enhance the quality of life. Someone in a wheelchair can turn on their lights, change the temperature on their furnace, start a dinner in an oven, play a favorite song, call a friend, or order necessities on line through voice recognition, without ever leaving their chair.

With the lab-grade test and measurement microphones, the intelligibility of systems can quickly improve and make these products more consistent and even easier to use. I can envision our company using VPAs in teleconferencing and networking. One concern with VPAs is privacy, so that will have to be addressed.

LIS: With new exciting developments in MEMS speakers, multiple balanced armature, and even planar magnetic in the in-ear segment, do you think this market has the potential to expand to high quality/higher price models?

VALENTINO: Not only will audiophiles want better sound quality coming from headphones and earbuds, but it is becoming commonplace for almost everyone who uses a cell phone or listens to music to expect better sound quality.

Consumers want smaller and more lightweight packages, which is a selling feature for MEMS microphones. Travelers want quieter rides and improved sound isolation achieved with better sealing methods and noise cancellation techniques using multiple microphones/speakers. Musicians and runners want improved sound quality in a wireless package. Multiple balanced armatures will allow musicians with in-ear systems to have better definition of all the instruments they prefer to hear.

LIS: What do you think of personalization/calibration technologies for headphones? (Nura: www.nuraphone.com; Aumeo: aumeoaudio.com; Even Earprint: www.geteven.co; Mimi Technologies: mimi.io/en/home/; Hefio: www.hefio.com, etc.)

VALENTINO: Personalization/Calibration allows us to make sure the headphone is pleasing to each individual and provides traceability. It also provides the capability to understand the characteristics of the product and any deviations that may have occurred to the headphone. The end user is

willing to pay higher prices for these models if the quality they require and perceived value is provided.

LIS: We've seen Sennheiser selling a $55,000 headphone/preamp combo, the Sonoma Model One planar headphones with a dedicated preamp for $5,000 and many other manufacturers launching new flagship headphone models in the $8,000 to $3,000 price range. Do you see this category expanding? Or do you think these are limited proof-of-concepts and the technologies developed for those models will gradually be made available in the mid-high end space ($500 to $1,000 range)?

VALENTINO: There will always be early adopters and consumers in the marketplace who want the best and are willing to pay for it, no matter the cost. But in my opinion, the people in the market for a $55,000 headphone are few compared to the many who will make up the bulk of the sales and want headphones in the mid to high-end space priced in the $500 to $1,000 range.

LIS: Given the increase in users performing their own measurements and sharing those with user communities and social media, do you think headphone manufacturers should always make their lab measurements available from the moment the product is launched?

VALENTINO: I believe that the headphone manufacturers should have the ability to choose whether they make the lab measurements available at the moment the product is launched. As a consumer, I would appreciate the additional information, so I can make an educated buying decision. If the measurements are perceived as a selling point, then they would have no reason not to display them.

LIS: Will hearing-aid companies leverage their technology and expertise to create products for that expanded Personal Sound Amplification Products (PSAP) market? Or will we see consumer-electronics companies (established and startups) conquering this space with a differentiated approach?

VALENTINO: The need for a hearing aid product where the user can take advantage of interacting with voice or connection to a voice assistant, along with a preference for smaller and truly wireless earbud models, will fuel the much needed development.

It has been my experience that even though the hearing-aid companies are more in tune of what is most beneficial to the end users, the consumer-electronics companies are better equipped to introduce products from concept, through development to launch faster. It will be interesting to see if the hearing aid companies or the consumer-electronics companies will be first to come to market with an accepted product. It will also be interesting which audiologists will prefer and recommended to their patients.

LIS: Biometric sensors are being used in headphones/earphones. Wearable devices must have some sort of audio integration. Is this a still untapped opportunity for the audio industry?

VALENTINO: Biometric sensors will become more prevalent in the future. My smart watch can check my blood pressure and heart rate. I can see advantages of having these in headphones and earphones. Wearable devices that can monitor our health provides an opportunity for headphone and earbud manufacturers. Being able to measure the temperature and vibrations on ones face, adding voice recognition or picking up noise and providing noise cancellation, are all desirable features that consumers will appreciate.

LIS: Are you (finally) planning to implement USB-C (or Thunderbolt 3) on your products for 2018?

VALENTINO: I wish more manufacturers utilized the USB-C format. I have it on my phone and the symmetrical feature is easier to plug in, and multi-pin offers manufacturers of products a lot of flexibility using this style of connection. I can envision more manufacturers using this in 2019.

LIS: Automotive and infotainment systems are another dynamic segment due to the connected car trend. How should the loudspeaker industry position itself to leverage this?

VALENTINO: New designs for high-tech infotainment centers will continue to come to market for enhancing the driving experience. It was not that very long ago when we only had a radio/CD player in our car.

Now we can make calls from our cars, find directions through GPS, play music from external sources wirelessly and more. Consumers want high-tech computers in our cars with voice activation to open windows, drive us places, change the temperature in our cars or on our seats, change to four-wheel drive, turn on lights and more. This will provide opportunities for speaker manufacturers and VPAs.

LIS: Is the evolution to (nearly noiseless) electric and potentially autonomous vehicles an opportunity for the audio industry?

VALENTINO: Through Noise, Vibration, and Harshness (NVH) testing, vehicles are becoming quieter. The adoption of the electric vehicles is further reducing the noise around the car making for a more pleasurable driving experience. Using multiple microphones/speakers, noise cancellation techniques are being improved and implemented.

LIS: Do you think new speaker technologies are needed for automotive applications (i.e., flat panels)?

VALENTINO: Loudspeakers will have to keep up and reduce rub and buzz noise. Auto manufacturers and their tiered suppliers test integral components from motors, locks, and pumps to speakers inside anechoic chambers. If the loudspeaker does not keep up, the loudspeaker manufacturer will lose their automotive business to one of their competitors who is working on these features, in addition to new speaker technologies to reduce size, weight and noise.

LIS: Already in its fourth year, *The Audio Voice* newsletter is a weekly email service created to update *audioXpress* and *Voice Coil* communities with the latest news and articles. Do you receive it? What do you think of it?

VALENTINO: I enjoy receiving *The Audio Voice*, *audioXpress* and *Voice Coil* because they help keep me up-to-date with the latest technologies that I am interested in from both a personal (as a musician and consumer) and also professional (as a manufacture of sensors) standpoint. ***LIS***

Steve Temme

President, Listen, Inc.

LIS: Do you see the headphone market continuing to grow? In which product segments?

TEMME: Yes, it will continue to grow, but perhaps not at the explosive rate we have seen the past few years. I suspect the main growth area will be in higher-end devices and smart wearables—fitness devices, hearing assistive devices and, to a lesser extent, translation devices. I suspect the amount of on-board electronics will also increase and connecting to a voice controlled assistant directly via headphones will become commonplace.

LIS: Given the increase in users performing their own measurements and sharing those with user communities and social media, do you think headphone manufacturers should always make their lab measurements available from the moment the product is launched?

TEMME: Yes, I think measurements are useful for customers, and it would be great if all manufacturers provided them. However, along with providing measurements, it is important that manufacturers also specify how they are measured, for example, what test equipment, in particular what ear simulators and to what standards (e.g. IEC 60268-7), otherwise it is hard for the consumer to make meaningful comparison between products. Similarly, review websites are meaningless without full details of the measurement setup. A good example of a website that clearly explains how they test headphones is Reviewed.com, part of *USA Today*.

LIS: Many audio companies are experimenting with Audio Augmented Reality and hearing enhancements concepts, exploring the latest technologies in consumer earbuds, truly wireless earbuds and hearables (smart earbuds that can also include interaction with voice or connection to a voice assistant). What do you think of this concept?

TEMME: I think this is a great concept and an exciting new market for audio companies, both manufacturers and test and measurement companies. While FDA-approved hearing aids are very expensive and there is still some stigma about wearing them, virtual and augmented reality have mostly been used in lower cost applications, such as making video games more realistic and exciting. There is a real potential here to combine the technologies to create useful and affordable products that can help just about anyone with their day to day needs, ranging from correcting hearing loss and attenuating annoying background noise to improved communications and musical playback quality. Again, this can be a real challenge to measure objectively and correlate to human perception, and much research is needed.

LIS: Do you think voice assistants, smart home integration, voice queries to search engines, hands-free communications, room correction, acoustic compensation, stereo pairing, multi-room, compatibility with multiple streaming services, etc., now available in smart speakers make sense in other speaker and audio product categories (i.e., home-theater systems, installed solutions)?

TEMME: Smart speakers and other smart devices such as watches and home appliances are further proof how important high quality audio is in everybody's life. Voice-enabled speech recognition, which is becoming more and more pervasive in all audio products, only works well if the microphone or microphone array is good quality (i.e., good signal-to-noise ratio, not overloading, and directional when needed). Excellent all-round acoustic knowledge is a "must" for designing good smart devices! Despite the massive explosion predicted in 2018 for this market, we should remember that this market is still very much in its infancy and there is plenty of room for both incremental and large-scale improvement.

From an audio test perspective, there are many challenges due to a smart speaker's omni-functional nature. Aside from validating speaker and microphone design, there are voice intelligibility and recognition issues, background noise challenges, and since such devices are also being used for communications they also need to be tested like a hands-free phone! To further complicate the issues, they are constantly communicating with the cloud, which involves audio latency issues and challenging situations regarding playing and retrieving test signals.

LIS: Test and measurement companies have launched or have confirmed to be launching solutions to increase reliability of audio frequency measurements to and above 20 kHz. What consequences do you think this will have for audio product development?

TEMME: I don't think it will have a lot of impact on the low end of the market, but I believe that a flat frequency and phase response is desirable in higher-end products. This requires speakers to be designed with wider bandwidth but in such a way that intermodulation distortion is not increased at higher frequencies that beat down into the audible frequency range. Naturally, this means that measurements need to be made up to and beyond 20 kHz.

LIS: What test and measurement tools are still missing that you would like to see in the market?

TEMME: I would love to see more realistic ear simulators, especially at the low-cost end of the market. Both Brüel & Kjaer and G.R.A.S. have recently launched high-frequency head-and-torso simulators, but the cost of these are prohibitive for start-ups/small companies, and they are not a suitable production line test solution. Additionally, the new test challenges (e.g., earphones, which only turn on when they come in contact with a real pinna) add a whole new dimension to the complexity that is required from a text fixture. There is also still much work to be done in correlating physical measurements to human perception. This is an area that we are focusing on, but it is a complex and interesting challenge.

LIS: Biometric sensors are being used in headphones/earphones. Wearable devices most have some sort of audio integration. Is this a still untapped opportunity for the audio industry?

TEMME: It's an opportunity, but I am not so sure it's an untapped one since most wearable devices already contain sensors. I suspect we will see an interesting battle between those new companies coming at it with an audio background (e.g., Bragi), those coming at it from a biometrics background, and then the established audio and fitness companies both expanding their product portfolio with such products. All the added DSP in wearable devices presents measurement challenges as the sine waves conventionally used as test signals may get severely attenuated when played through a codec. More complex and realistic test signals are required. This presents an opportunity for the test and measurement industry to develop tests and algorithms for this rapidly expanding market.

LIS: Is the evolution to (nearly noiseless) electric and potentially autonomous vehicles an opportunity for the audio industry?

TEMME: Absolutely! As automobiles become quieter, higher quality audio becomes more important. Manufacturers are already responding to this with ever increasing numbers of speakers in their audio systems (more than 20 in some cases). In addition, telematics systems mean that every car has a microphone array, speech recognition, some kind of noise reduction system and Bluetooth connectivity. Furthermore, many electric cars generate imitation engine noise, and new regulations in 2020 will require silent cars to make sound while traveling at low speeds. This adds up to: 1) a large number of transducers in the car; 2) a lot of audio DSP; and 3) many and complex audio test requirements—all of which are great opportunities for the audio industry.

LIS: Already in its fourth year, *The Audio Voice* newsletter is a weekly email service created to update *audioXpress* and *Voice Coil* communities with the latest news and articles. Do you receive it? What do you think of it?

TEMME: Yes, I receive it and I like it. The newsletter contains a good roundup of news stories. ***LIS***

Mark Lippett

CEO, XMOS

LIS: How did your current business evolve in the past 12 months? What are the perspectives for the next 12 months?

LIPPETT: 2017 was a game-changer for XMOS. We pivoted from our traditional space in audio solutions to focus on pioneering far-field voice capture solutions. And we were quick to establish strong credentials, with our launch of the first linear mic array development kit qualified by Amazon for far-field performance. Today, we're still the only company to provide a stereo-AEC far-field linear development kit for the Alexa Voice Service, qualified by Amazon.

Building on strong growth through 2017,

we completed a major funding round and secured a new, strategic partnership with Infineon, which complements our vision and delivers exciting synergies for our clients.

Over the next 12 months, we expect the physical space around us to transform into a more intelligent environment. Voice will help drive that shift, with an increasing number of voice-enabled devices coming to market, especially thin-client form factor, high-performance devices such as stereo home entertainment and wall-mounted audio-visual equipment. The future is an ever more convenient, more intuitive connection with everyday technology.

LIS: Is voice recognition a must-have for your company's audio products (or your client's companies) in 2018?

LIPPETT: Yes. Voice is the new modality. Today we see Amazon Echo, Google Home, Apple HomePod, and other smart speakers all competing for space. But very soon people will control most of their major appliances vocally—and it'll revolutionize the way we interact with technology.

LIS: Many manufacturers had success with soundbars in 2017 and we are seeing soundbars evolving also for corporate (conference room) applications. Do you think this trend will continue?

LIPPETT: The soundbar delivers a single, simple solution for an immersive experience across TV, music, and game console. Experts across the market expect our love affair with the soundbar to continue, with sales predicted to increase—and prices to hold.

With media control standing out as the killer application for smart speakers today, it's hardly surprising that manufacturers want to add embedded voice control to soundbars. It adds a natural, compelling user experience and opens the door for extended applications across home and corporate environments. The soundbar is definitely one to watch.

LIS: How important are smart speakers for your business?

LIPPETT: As the gateway product for voice, smart speakers are important to our business today. However, that will diminish over time as voice becomes the ubiquitous interface for technology (and as the interface moves to the edge of the room).

LIS: How rapidly do you see smart speakers and other voice-enabled devices expanding globally?

LIPPETT: Voice is still in the early phase of the hype cycle. We expect the adoption curve to increase dramatically over the coming months.

LIS: What features introduced in smart-speakers do you think will be more important for the category moving forward?

LIPPETT: While the number of voice-enabled products coming to market is increasing, that increase will be matched by a growing demand for a more natural, conversational, "sensing" voice interface.

LIS: Do you think any those abilities could make sense in other speaker and audio product categories (i.e., home-theater systems, installed solutions)?

LIPPETT: Absolutely, yes. We believe that all home theater, sound, and light solutions will be voice enabled in future. The home will be a smart, sensing environment where our everyday interaction with technology is conversational and intuitive.

LIS: Other than smart-speakers, what other device categories do you believe are a natural expansion market for voice-based applications? Which ones make more sense in far-field applications?

LIPPETT: Today, the obvious device categories are smart TVs, soundbars, audio equipment, lighting, and security solutions. As technology moves to the edge of the room, far-field capture becomes increasing critical. Given that the voice-enabled patio umbrella is already a thing of today, the expansion market for far-field is vast and varied.

LIS: Do you think whole-home and multiroom solutions are better left to the custom-install (CI) market? Or do you think Apple, Amazon, Sonos and others will conquer this market with a commoditized approach?

LIPPETT: Consumer demand will determine the answer to this. It's hard to imagine that a closed ecosystem will dominate. It's far more likely that everyone will have to learn how to get along. And that opens up interesting opportunities for new solution providers.

LIS: In 2017, we have seen speakers using sensors to adjust its coverage width, depending placement or on different wedge angles. Is this an exciting idea? What do you think about the use of sensors in audio products to make them "smarter"?

LIPPETT: We think sensors are fundamental to the future of the voice interface. By fusing "sensory" data with voice data, we can capture identity and emotion. This multi-modal context will lead to a more natural, conversational interface with individual (and family) recognition.

LIS: Already in its fourth year, *The Audio Voice* newsletter is a weekly email service created to update *audioXpress* and *Voice Coil* communities with the latest news and articles. Do you receive it? What do you think of it?

LIPPETT: Yes. We're a long-standing consumer of *The Audio Voice*. Although we've pivoted away from our traditional space in audio solutions, we believe the publication will remain very valuable to us with its commentary on voice-capture solutions. ***LIS***

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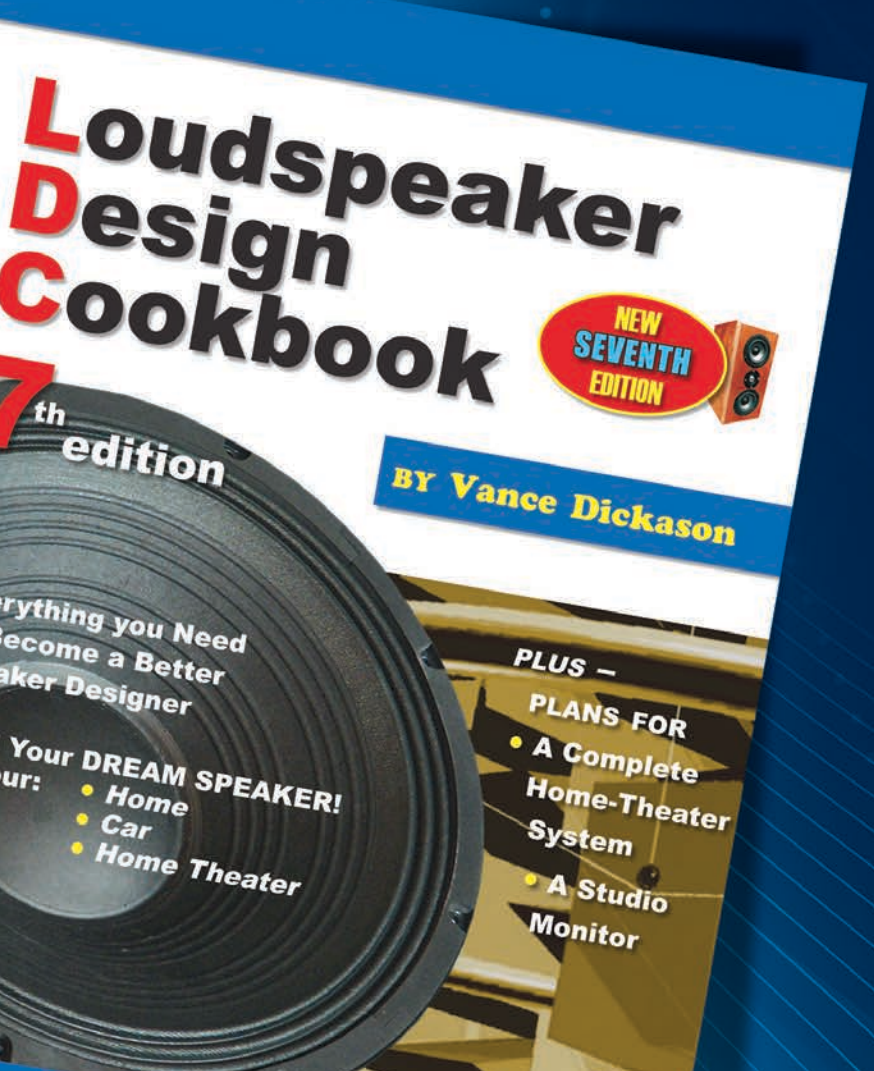

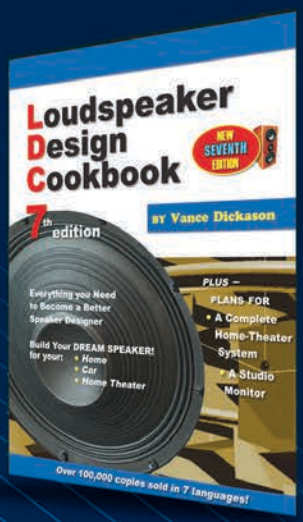

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