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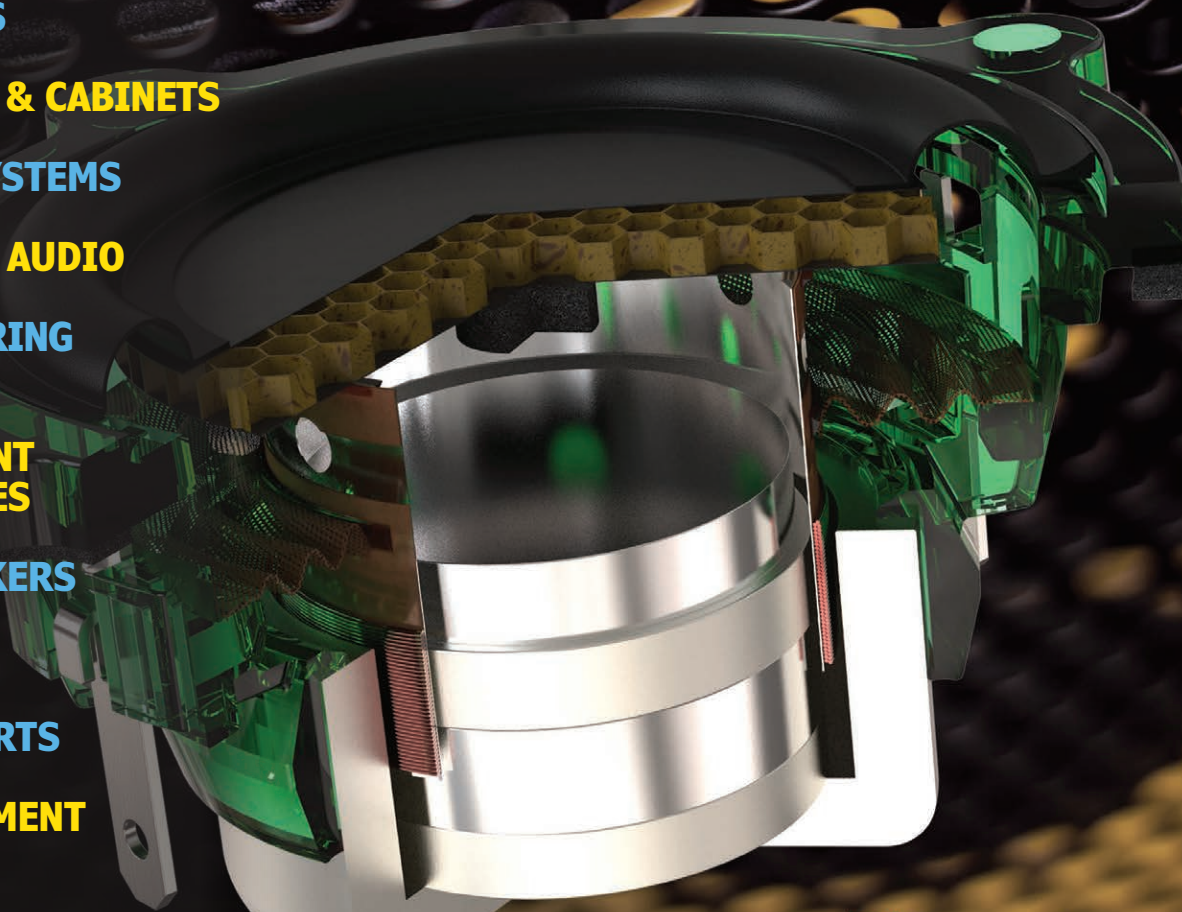

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		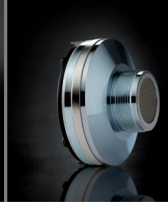	

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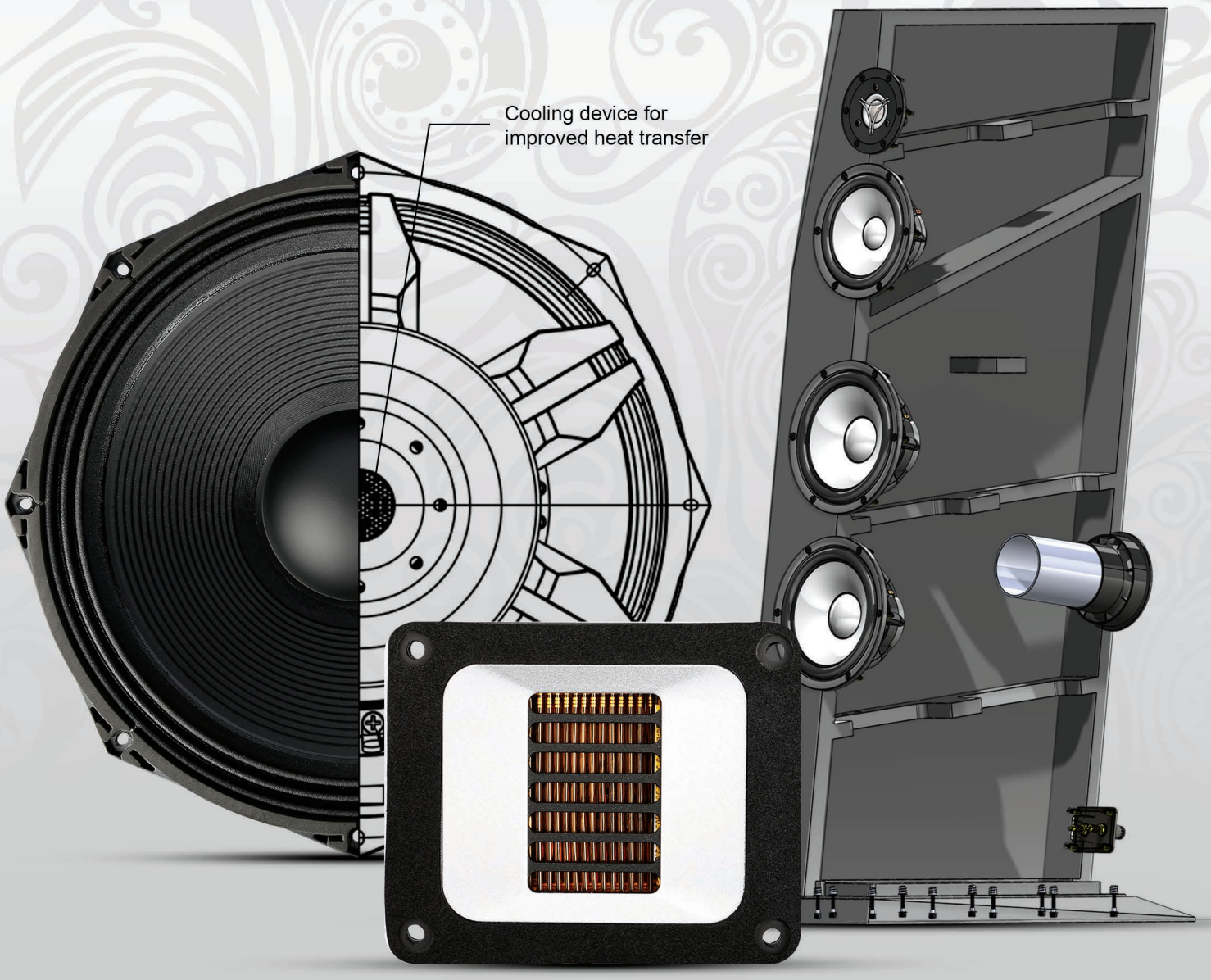

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—Tectonic Audio Labs.
Cover photo courtesy of Tectonic

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2021

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Now more than ever, the *Loudspeaker Industry Sourcebook* (LIS) is the most important resource for the loudspeaker industry—helping companies stay connected!

LIS provides a comprehensive guide of manufacturers and their products and services. As the late Ed Dell, its founding publisher, wrote in his first edition of LIS, "As publishers of *Speaker Builder*, *Voice Coil*, and other audio-related magazines, we recognized the need for a compilation of the many companies involved in speaker manufacturing." The company surveyed the industry, and the result was a 128-page publication listing more than 600 companies, representing almost 30 different countries. "Readers will find this is an indispensable guide in locating products—from adhesives to wires, accelerometers to voice coils. We trust you'll enjoy and learn from this handy sourcebook in your daily business dealings," Ed Dell added.

Since then, LIS has remained a directory that relies on the industry itself to supply the profile information for each company listed. A task that was made considerably easier with email and the Internet, since listings could be submitted online by manufacturers, vendors, and service providers throughout the year. Five years ago, LIS was converted into a dedicated, always-online directory, complementing the annual printed publication, and available at www.loudspeakerindustrysourcebook.com

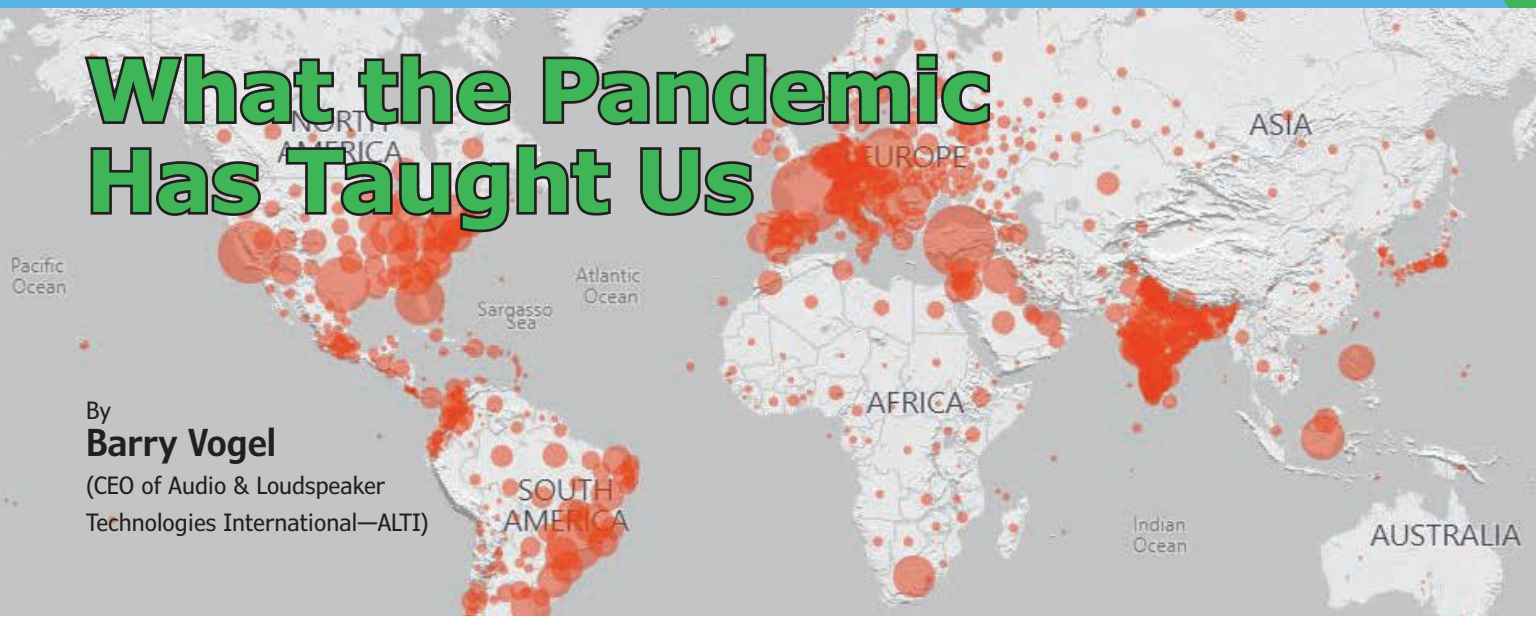
The listings that are submitted online are compiled once a year to generate the printed edition, but the LIS publication and website also contains must-read articles, interviews with audio professionals on trending industry topics, and annual industry reports about the state of the industry. The scope of the directory has also expanded to encompass new product categories and loudspeaker-related applications and technologies, from all the different types of audio transducers used in headphones, earphones, and smartphones, to the electronics and materials that support the latest audio applications.

LIS is a straightforward reference resource for everyone working in R&D, manufacturing, sourcing, product management, technical support, marketing, or sales in the loudspeaker and related industries.

The past year has been one of the most challenging years, with the uncertainty created by the COVID-19 pandemic. Let LIS be a beacon for the audio industry. We are ready to get back to the business of audio and we are moving forward. The audio industry is stronger together. Please enjoy this 2021 edition of the *Loudspeaker Industry Sourcebook*!

— The LIS Staff

What the Pandemic Has Taught Us



By
Barry Vogel
(CEO of Audio & Loudspeaker Technologies International—ALTI)

Barry Vogel looks back at the past year, which was filled with "a lifetime of life-changing events" due to the COVID-19 pandemic, and shares some of the lessons it has taught us. Including the newfound knowledge that "we are the masters of our destiny. Until nature decides otherwise."

A year ago, the realities of the COVID-19 pandemic were sinking in, and the world was on lockdown. At the time, I wrote an article titled "What the Pandemic Should Teach Us." Little did I know that the audio industry would be faced with even more adversity than a catastrophic world health crisis. The last year has been a testament to human resilience, ingenuity, and for those forward-looking people and companies: opportunity.

It wasn't enough to deal with the loss of life and livelihoods due to COVID. It wasn't enough to sustain isolation and a near total disruption of business norms. We had extreme weather at sea lead to container loads of products ending up at the bottom of the ocean. We had chip shortages and vital material shortages. In America, postal service and shipping delays became a daily issue. As of this article, these issues are still impacting the supply chain and sales worldwide.

The Bright Side

However, there is good news to report, made even more substantial due to the issues already addressed. While economies took an initial (and substantial) hit, in most cases those downturns were not as steep or sustained as many predicted. The audio industry actually saw a substantial increase in home, portable, and car audio sales. So much so that product shortages became a normal, if frustrating, occurrence. One can only speculate just how good the audio sales might have been if product were readily available. This is not meant as a criticism of the supply chain. The pandemic was unprecedented—the world has not experienced such an event in more than 100 years. The response by suppliers was in most cases, prudent and well considered.

Lessons Learned

What lessons were learned? They were many, but this list is the most directly applicable to the audio industry.

Dependence on a single source or country for product is a risky proposition even in the best of times. Having more than one source improves the possibility of maintaining supply lines in the face of adversity. Yes, it is more work and more complex to manage. The alternative in tough times could be a greater risk.

Sources closer to home stand a better chance of maintaining supply lines. This does not apply exclusively to America. There are reasons that, for some products, this may not be viable. Or is it? Look beyond manufacturing costs alone. Look at transportation savings, shorter order times, and smaller order quantities as offsets to possible higher costs.

Inventory and supply line integrity needs to be examined. Really examined. On a regular basis.

Not just through the lens of product demand, but also being aware of outside forces that could affect supply and demand.

Establish and maintain multiple, viable, sustainable methods of communication with clients and prospects. Remember when people had no idea what a Zoom meeting was? In the absence of in-person events or sales calls, the ability to see the person one is speaking to takes on much greater significance. Remember: People do not have relationships with companies. They have relationships with people.

And Now

Even as the pandemic begins to abate, plan on maintaining a hybrid presence through physical and virtual communication. BOTH are now a permanent part of the landscape. BOTH are a necessary part of business development.

Get back out there! Looking at the events calendar, September and October are on track to be the busiest two months ever for trade shows. In person, face-to-face events are, and will be, a necessary part of human communication. Most experts are predicting that fall event dates will be safe. Plan to be a major presence at as many of those events as possible. Be sure to formulate a detailed plan to make them productive beyond just showing up.

The office environment may never be the same. That can be a good thing. Remote working is how much of business survived during the pandemic. A large percentage of remote workers are either planning to continue that way, or are hoping for a hybrid model. Now is the time for employers to look for creative ways to accommodate a flex work environment and flex hours. Productivity and employee loyalty may be the reward in addition to the overhead savings to be had.

The worst is hopefully behind us. Let us hope that the many lessons learned stay with us long term. Use the adversity we have endured to plan for a more stable and sustainable future. ***LIS***

About the Author

Barry Vogel has been in the audio industry for more than 40 years serving in almost every capacity at one point or another. He got his start as a retail home and car audio sales person as a teen, and was hooked. He has served in management positions in mass merchants and specialty retail, including ownership of a retail 12 volt business. Barry expanded his experience by working in the manufacturing segment of audio including sales, marketing, and product development to round out his experience before transitioning to association management. Barry's greatest personal satisfaction has always been derived from helping others achieve success.

About Audio and Loudspeaker Technologies International (ALTI)

ALTI is an association that allows Barry Vogel to work with manufacturers, entrepreneurs, management, and technical personnel in the audio industry from around the world, and to help them to maximize their success.

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Audio & Loudspeaker Technologies International (ALTI), which was formerly known as ALMA International, is an association founded and operated by professionals in the audio and loudspeaker technologies industry for the benefit of its members and the industry at large. ALTI members include audio and loudspeaker designers and engineers, business management and marketing professionals, as well as suppliers of test and measurement equipment, consultants, individuals, students, and educators who participate in the industry. ALTI welcomes a global membership and aids its members success by creating a positive atmosphere to promote technology and by promoting business and commerce.

ALTI was founded in 1964 as the American Loudspeaker Manufacturing Association (ALMA). The association has undergone a constant evolution over the last 10 years to reflect its global membership and to promote the interdependency of all facets of the audio signal chain. Today, ALTI members include all technologies related to the audio industry, and all of the business related to that technology. ALTI is a launchpad for new products and technology.

ALTI'S MISSION STATEMENT:

ALTI is built for and by professionals in the Audio & Loudspeaker Technologies Industry to learn, to teach, to grow, and to get business done!

Design, Sourcing, and Reshoring

From an American Manufacturer's Perspective

By
Dan Digre
CEO, MISCO

For the 2021 *Loudspeaker Industry Sourcebook*, we wanted to offer a two-pronged article from both the US and Asian perspective about audio loudspeaker product design, product sourcing, and sustainability. Two industry titans were gracious enough to provide their perspectives. Dan Digre shares the US perspective.

Cliff Digre, MISCO's founder, is shown testing reconed speakers, circa 1950. The Minneapolis Speaker Company (MISCO) is a 72-year-old United States speaker company that continues to thrive today.

Once the center of global loudspeaker manufacturing with dozens of driver manufacturers, cone producers, voice coil winders, metal stampers, and even magnet producers, the United States today has less of a loudspeaker industry and more of a collection of companies with loudspeaker driver and parts manufacturing as their core focus. Yet, these companies are not only surviving but thriving amidst global competition by finding niches, reinvesting in new capabilities, and delivering value to customers in industries as diverse as pro audio, aerospace, home audio, car audio, and many others. They offer both US and global customers alternatives to Asian sourcing and provide many strategic benefits.

My company, MISCO, is one such company. This 72-year-old family business based in Minnesota has grown over the years by leveraging expertise and equipment and by making strategic acquisitions to deliver more turn-key audio solutions at both the OEM level and, more recently, direct to consumers and end-product users.

So too has Eminence Speaker, a 55-year-old driver and system manufacturing company based in Kentucky, which has not only maintained reliable US manufacturing but has set up a manufacturing facility in Dongguan China. With all the engineering done in the US, products produced in either country have the same performance and reliability for which Eminence is known, and likewise include transducers for professional audio, musical instrument applications, cinema, signaling, and a host of other specialty solutions. The company provides both custom designs and a branded product line for distribution throughout the globe.

Loudspeaker Components (LC) of Wisconsin, founded in 1965, has also grown, purchasing a competitor, (Nuway Speaker Products), a supplier (CP Moyen), investing in US greater automation, and setting up manufacturing in Mexico to lower costs and be close to its automotive OEM customers. While there are other US companies making drivers and parts, these three are representative of what is happening in the US and are the subjects of this article.

US Product Design Enabled by Technology

Aside from computer-generated modeling, product design is always better when it is done in conjunction with manufacturing. Design for Manufacturing and

Assembly (DFMA) requires a detailed knowledge of how parts are made and how they best fit together with feedback from the factory floor on what works and what does not. For loudspeakers, which function despite tolerance stack-ups that theoretically do not work, this is especially true. Years of transducer and part manufacturing experience provides a long list of know-how, trade secrets, and equipment with specialized modifications that take, well, years to develop. These mature American speaker companies have that. But added to this experience are modern, cost-effective design tools and equipment, which now allow design engineers to quickly build prototypes using solid models, 3D printers, CNC lathes and mills.

Eminence produces in-house a wide range of voice coils with diameters from 1" to 4" for both engineering and production. LC uses laser trimming of cones and fabricates 3D printed tools to eliminate the need for hard tooling to make prototypes. MISCO 3D prints speaker baskets, magnet housings, and even speaker enclosures, which can be built in the morning and tested in a Klippel Near-Field holographic scanner in the afternoon.

What once had to be sent to an outside supplier along with detailed drawings, signed NDAs (non-disclosure agreements), and the expectation of waiting, can now be done in-house in hours. This use of Vertically Integrated Product Development and Testing (VIPDT) enables discovery to the curious and the imaginative. American speaker engineers, at their core, do not see themselves designing widgets to be mass produced, but a product that can push the performance envelope a bit more than the last one and which will, in the end, bring benefit and enjoyment to another person in addition to profit to their company.

One additional benefit of VIPDT is IP protection. Not only are drawings and product designs secure with only a few going to outside vendors, the knowledge gained in development is kept in-house. How much knowledge has been given away over the years because we did not "do it ourselves"? A lot. Imagine spending months developing an optimized loudspeaker suspension solution with your driver or part supplier only to find that same solution deployed in a competitor's product. What if you could develop that in-house, test it on your Klippel Laser Scanner to verify it works, and then send it out to a supplier to fabricate without also sending them the "how we got here" know-how.

Product development, of course, does not happen in a vacuum away from the parts suppliers. At some point the ideas do have to be communicated via a product specification and drawing and is reliant on the capabilities of the part supplier. With few exceptions,

Eminence, a 55-year-old driver and system manufacturing company, is based in Kentucky.

most loudspeaker supply chains run through China for component parts, raw materials, finished drivers, or complete speaker assemblies. With an enormous assortment of companies from whom to purchase, the challenge is in finding the best suppliers. They may not be the biggest or the most well-known, but the ones that best fit the values and needs.

Jerry McNutt, the product design manager at Eminence, says what they look for in a vendor is "Capability, Reliability, and Stability—Can they make what we need, can they make it that way every time, and will they be here tomorrow?" In addition, US companies benefit from having these Chinese companies be in the same region of China, not only for ease and cost-effectiveness of logistics but also so that parts can then be shipped to either a company's North American or China driver factory in that same region. This assures that products can be made in either place with the same performance and appearance.

Build It Here or Built It There

B2B sales today require more than just delivering a product. They require concierge-level service including managing customer-demand portals,

Eminence produces many of its voice coils in-house, including a wide range of voice coils with diameters from 1" to 4".

LC's Haas-machining center produces cone molds in-house.

customized packaging, shipping methods, multiple delivery locations, cost targets, flexible delivery dates, and quantities. US companies are good at being flexible, and this can be a huge competitive advantage. But it requires a supply chain that is also designed for flexibility.

A substantial part of MISCO's business is from products that are made and delivered outside the US—mostly in Asia. MISCO has developed a supply chain primarily located in Dongguan, which includes both component parts suppliers and contracted driver and finished product assemblers. This allows MISCO the flexibility to build the same products in Asia as it does in the US. While labor costs are higher in the US, the lower Asian part costs provide the ability to make a speaker in the US at a fair price, which delivers high enough value to the end customer. MISCO's premium brands, Bold North Audio and ToneSpeak Guitar speakers, are exclusively built in the US to allow for control over the manufacturing process. And, our Klippel Verified designs come with an "Assembled in the USA" pedigree.

Eminence's 21" pro audio cone was custom built by LC.

LC, through its 2018 acquisition of CP Moyen, can control one of its most critical components: adhesives and treatments. Neil Kirschbaum, President of LC says, "CP Moyen makes proprietary formulations for use in loudspeaker manufacturing and many other markets: epoxy and other crosslinking resins, fire retardants, water resistance, lacquers, primers and damping chemistries." This expanded capability has resulted in attracting new customers, including a substantial amount of business from Asian and European speaker manufacturers.

Eminence DG (Dongguan) is a 72,000 ft^2 factory that was opened in 2006 to service customers in Asia and Europe with both drivers and turnkey solutions including fabricating and loading loudspeaker enclosures. With all design and engineering work done in the US, McNutt says, "Eminence DG allows Eminence to build it here or build it there" and that the Eminence DG facility "is busier than ever meeting customer demand." He adds that all Eminence USA sold product is still built at its headquarters in Kentucky.

More Fun in 2021

While 2020 was an exceedingly difficult year because of the shutdowns and uncertainties caused by the COVID-19 pandemic, 2021 has brought its own challenges, many also brought about by the pandemic.

Chief among them are massive disruptions in freight and logistics in shipments coming from Asia to about anywhere in the world. Delays in getting ships loaded in Asia are compounded by delays in ships docking and being unloaded at busy ports, with additional delays in finding rail capacity. Even local freight yards are so backed up once a container arrives in its destination city, it still may take 5 days to get it delivered when the normal turnaround is 1 to 2 days. This is causing delays in deliveries by 4 to 6 weeks and major challenges in giving customers confirmed ship dates.

Anyone who is trying to buy electronic components for audio amplifiers knows that it is a mad scramble of daily spot-buys to secure enough inventory to meet demand. It is not a well-known fact that MISCO supplies a broad line of audio amplifiers to complement speakers in embedded audio systems. The component shortages have added to the existing challenges of requalifying alternative chips to those supplied by AKM, whose October 2020 fire in Japan has caused massive shortages of those components throughout the audio industry.

A third challenge this year is the large price increases of raw materials. For driver manufacturers, neodymium rare earth magnets have become an

important material in reducing size and weight while often dramatically increasing flux in the magnetic gap. With demand surging for electric cars, the price is now the highest it has been since the 2011 shortage, double what it was at only last fall. With neodymium magnets often the most expensive part in a loudspeaker driver, this increase will require loudspeaker manufacturers globally to either raise prices, eat the increase, or re-design products to use ferrite magnet alternatives. We all wonder if this surge in prices and increased reliance on China-supplied rare earths will finally incentivize the US to supply what it can to itself.

But it is not just magnets that are in short supply. Kirschbaum of LC reports that general material shortages—cloths, foams, and the chemicals to make them—are unlike anything he is seen since 1983. Some raw material costs are up 40% due to these shortages. And because the loudspeaker industry is a small user of most raw materials, it must live with what it can get. It does not often drive material science innovation, it adapts to it.

All these challenges point out how difficult it is today to run the traditional "just-in-time" supply chains that the automotive companies have championed over the past decades. In fact, these ultra-lean, supply chains are one of the reasons the automotive industry is struggling to build enough vehicles today. Until logistics becomes more orderly, ordering materials earlier, air shipping, and increasing safety stock may be the only way to reliably meet customer demand.

One last challenge is a hold-over from 2019: The Section 301 tariffs on goods from China. It is important to note that tariffs are a tax, paid by the American company that is importing it (not the Chinese shipper). Currently, most completed speakers and audio products come in under List 4a, which currently has a 7.5% tariff applied. However, many core components used to build speakers and electronics parts are under List 3, which currently has a 25% tariff applied. This means that to build a speaker in the US with parts made in China, the bill of materials cost is approximately 25% higher—while a finished speaker, made in China, is imported with 7.5% tariff.

This is an example of the non-strategic planning used in the hastily concocted trade war the previous administration escalated with China. While the current administration is in no hurry to remove these tariffs, the List 3 and List 4 tariffs are likely to be bargaining chips in negotiations with China. Hopefully, if tariffs continue, the dysfunctional exclusion process will be revamped to support a more targeted, coherent American trade policy.

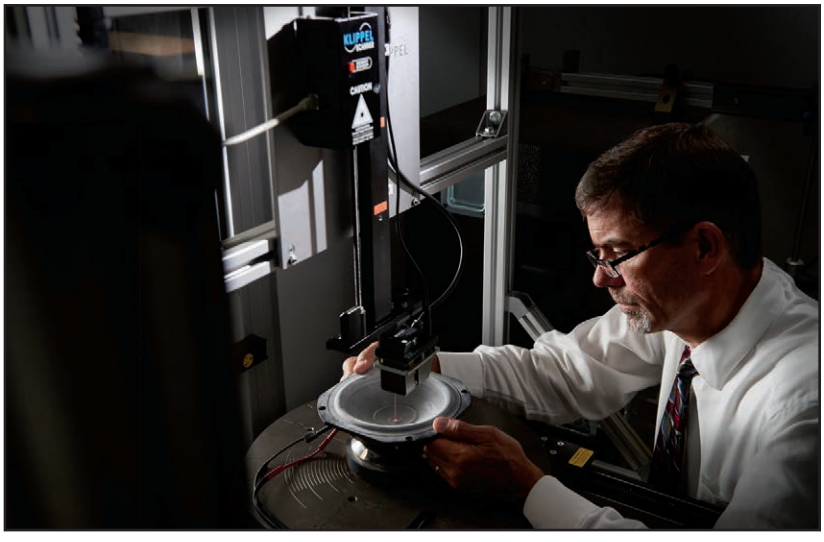
MISCO's speaker manufacturing uses robotics for precision adhesive placement.

China + 1 Supply Chain

There is no question that the loudspeaker industry is centered in China today so efforts to completely avoid it are likely counterproductive; however, companies should adopt a strategy of developing alternative sources outside of China, whether in Asia or North America. Taiwan, Philippines, Indonesia, and Malaysia all have companies with great capabilities. Often the +1 is in house. Eminence still fabricates its own front and back plates, pole pieces, and voice coils. Likewise, Eminence makes over 90% of its stamped steel baskets in the US to reduce dependence on foreign-made parts, decreasing lead times and minimum order quantities.

Reshoring Through Technology

It is easy to see the glass half-empty after the past 15 months. But the US loudspeaker companies I have spoken with are very optimistic about the



Klippel's Laser Scanner assists engineers in designing speaker cones and surrounds.

MISCO is fully vested in keeping its business based in the US and built this new facility in 2019 in St. Paul, MN.

future. Eventually the logistics and the trade war will be resolved and prices will stabilize, but America has learned that trade wars and supply chain risk management are intertwined. It has become painfully clear that the US economy needs a more resilient supply chain and that means looking inward for more of its products. And the American consumer is more open to that as well.

A recent study by the Reshoring Institute found that 65% of American consumers strongly preferred products made in America and that 82% said they would be willing to pay up to 20% more for those products. This represents a significant change from 10 years ago when consumers' strong preference was for price over American made. This gives US companies a target and technology that can help us close the gap in selling both B2B and B2C.

The vice-jaws of distribution, with the manufacturer on one side and the end user on the other, have closed together because of e-commerce. This represents a great opportunity for manufacturers to recover product distribution control and margin by using more direct channels, cutting down on the number of "middlemen" and expanding more direct-to-consumer business.

To help reduce manufacturing costs, automation has become much more affordable. An alternative to expensive, high-volume production lines are ones with flexible, easy-to-program controllers, or collaborative robots working side by side with workers.

Kirschbaum at LC has implemented robotic lasers for trimming cones which require much less set up time, are more accurate than traditional steel dies and speed up the entire cycle time. This not only reduces labor cost but improves downstream efficiency and production capacity. Kirschbaum envisions round the clock, lights-out capabilities at LC when low-cost, high-volume customers come knocking.

LC also has a machine shop consisting mostly of modern Haas Lathes and mills and wire E.D.M. The most recent addition is a five-axis Haas mill. Tool design and manufacturing is done with the latest SolidWorks and MasterCam software. Robotic cone molding and waterborne pulp chemistries are being implemented to eliminate direct labor and avoid the expensive, secondary labor process of chemical cone treating and associated solvents.

Off-shoring happened like a tsunami, but reshoring will return like raindrops. The Coalition for a Prosperous America, a Washington non-profit coalition of American businesses, has created a Reshoring Index looking at the past 15 years of import penetration vs. US manufacturers meeting US product demand. They are seeing a gradual but steady increase in US manufacturing meeting demand. Evaluating supply chains based on national security and resilience could be an accelerant to this trend.

In the end, the expansion of US speaker and parts production will be a more a targeted, value-based approach where factors other than the lowest piece price are considered: Ease of doing business, domestic shipping and flexible shipment quantities, protection of IP, and the ability to supply value-added services such as product development and testing.

MISCO recently completed a turn-key project that not only included designing and manufacturing the driver, enclosure and amplifier but also assembling all the customer's end-of-line test boxes and test equipment, along with training, for the customer's North America and Asian facilities. Complete turnkey service, including a partnering in supply chain management, is one of the most important value-adds American manufacturers can offer to one another. ***LIS***

About the Author

Dan Digre is the CEO of MISCO and has dedicated more than 40 years to the loudspeaker industry working with MISCO and as a past president of ALMA International (now ALTI).

Founded as the Minneapolis Speaker Company in 1949 by Dan's father, industry pioneer, Clifford Digre, MISCO began as a speaker re-coning shop. Working alongside his dad, Dan serviced drive-in theater speakers, which fostered a passion for speaker design and manufacturing that is obvious to all who know him.

Dan's passion for MISCO to become an important contributor to the US audio community, was a driving force that led to his acquisition of Warkwyn Labs in 2015. Dan's vision for Warkwyn is the same as it is for MISCO: to cater to the unique needs of each customer by combining world class tools and people to provide US-based design, manufacturing, and testing of speakers and integrated speaker systems. Through his business endeavors and his volunteer service to the industry Dan's continued focus is to promote a resurgence of the US loudspeaker industry.

An Asian Perspective on Sustaining Product Design and Product Sourcing

For the 2021 *Loudspeaker Industry Sourcebook*, we wanted to offer a two-pronged article from both the US and Asia perspective about audio loudspeaker product design, product sourcing, and sustainability. Two industry titans were gracious enough to provide their perspectives. Helge Kristensen shares the Asian perspective.

By
Helge Kristensen
Vice President, Hansong Technology

Nanjing, April 2021: After some very turbulent years with political tensions, trade wars, and on top of that entering the second year in the shadows of a global pandemic, COVID-19, I believe many people are wondering how this will impact the world both short-term and long-term when it comes to product sourcing, development, and the sustainability in Asia.

As I have been living in China for more than 20 years now I have seen the rise and changes in China's development—from focusing on low-cost manufacturing to being more driven in development and high-end technologies. It has been amazing and unprecedented what China has achieved in a relatively short period of time—the growth to become leading in product development, manufacturing, product sourcing, and now to be leading in certain high-tech areas.

Building the Foundation

The foundation for this development has been the establishment of an infrastructure, which is supported at all the steps in this development process.

The government has been incentivized to support business growth, and this is especially apparent when it comes to the infrastructure of road networks, shipping, and the logistics handling. This has been perfected so China now has the most well-established high-speed road network in the world, which is the key for optimizing manufacturing and supply chains.

The supply chain is well-established and flexible, and again most likely one of the biggest assets in Asia/China manufacturing. The value-added supply chain can cover all aspects in product development and keep it in same region.

Hansong has recently completed a world class 350,000ft² (32,500m²) factory with multiple assembly lines and smaller work cells to meet customer needs, providing the company with more than 51,000m² (550,000ft²) in total manufacturing space.

Since its inception in 1998, Hansong has built its reputation on quality.

This alone provides speed to market, flexibility, innovation, and with that new opportunities.

The Labor force, which is another critical and fundamental part of the equation to sustainable development in the Asia region, is next to none in quantity and has a fantastic quality, with the extensive focus on bringing the brain trust back to Asia to establish a home-grown high technology environment that will further support the region as a natural product sourcing and development hub and will likely continue to be that way mid- to long-term.

But what could impact Asia as the leading region as a development partner and what could change the sustainability of the Asia regions as leading in product supply?

The Geopolitical Impact

The geopolitical situation has had an impact as well as a focus on bettering the living standard with increasing salaries, living cost, and a change in the perception of being a factory worker. We can see and feel the changes coming and believe that we will see trends where companies will become more globally/locally presented.

This is done to minimize the risks in the supply chains and with the regional political or environmental impact. Companies will constantly try to mitigate potential risk or disruptions and we will see some companies move factories from the region due to the above-mentioned factors, but I believe the total impact will be insignificant in the larger scope as the supply chain is too well-established.

As mentioned, to move production and sourcing from Asia/China, is not a simple task. It involves very long-term planning and establishing supply chains, education, and so forth, so instead of moving we alternatively will see factories and companies expanding from the region instead, as part of a more global risk management strategy. Manufacturers will establish what I will call satellite factories/hubs in strategic global locations, which will work as local representatives for the factories on a global scale. This will minimize the risk for disruption in the supply chains, being initiated because of resources, politics, or environment.

About the Author

Helge Kristensen has more than 30 years' experience of high-level management positions in technology companies around the world. The last 20 years he has served as vice president of Hansong Technology, an original device manufacturer of audio/IoT products based in China, and as president of Platin Gate Technology, Ltd., a company with focus on service-branding in lifestyle products as well as pro line products.

His expertise is centered around understanding and applying new and innovative technologies strategically. He serves as a valued long-time board member in several Cross-industry companies in Asia, Europe, and North America, with focus on strategic development and growth.

Helge holds a master's degree in Engineering MSEE and an HD-R, a graduate diploma, in Business Administration (Financial and Management Accounting) from Alborg University in Denmark.

Moving Forward

There is little doubt in my mind that it will have an impact on Asia/China as the manufacturing hub going forward but it will not change the Asia/China region as development/sourcing center, but rather initiate a broader natural expansion of the value-chain, regional/local product customization, as well as risk management. I see this as an opportunity for expansion.

For decades China has built up a complete supply chain infrastructure, which is unparalleled in any other region, and it is difficult to fully shift manufacturing/product sourcing from Asia/China to other regions both short-term and long-term for certain products.

As a result, in the future we will see more regional/local satellite manufacturing hubs going forward to support local trends in product design and speed to market. Local in this context means different global regions.

However, as supply chain infrastructure is crucial for any brand, manufacturing, and innovation, I continue to be positive of the suitability of China as a prime location for product development and sourcing.

Asia and China have changed focus a lot and are now driving high-tech product development more strongly than before. The inflow of incredibly talented resources who are coming back to China driven by the geopolitical situation and incentives, continue to position the Asian region, particularly China, as a very strong partner in manufacturing, development, and sourcing.

The focus from just making a product will change going forward, if it has not already, and we will see a more holistic approach to product development and design. China has all the parts of the puzzle to support this change in approach and it is already happening. Keywords like Cloud, AI, control, connectivity, and sustainable development with the environment in mind, are all key parameters that play an important role in why China will continue to be a center for product development, design, and manufacturing both short- and mid-term.

The clusters of high-tech companies and focus on development in China makes new technologies more approachable and with the well-established supply chain create opportunities for innovative development, which in the end can be transferred to the satellite factories/hubs globally. Again, time to market and a well-established supply chain from brain trust to parts and manufacturing are all fundamental building blocks for a sustainable development/sourcing environment.

Hansong Technology is a privately owned company with assets in Asia and North America. Its headquarters and manufacturing facilities are located in Nanjing China, one of China's principle centers of education, technology research, and culture roughly 300km west of Shanghai on the Yangtze River.

Further, we should not forget the region's market potential is huge, China itself is still one of the biggest markets so that alone will drive innovative product development and a better and cheaper supply chain.

From my perspective the product development and product sourcing in Asia and China will not particularly change short- or mid-term. Long-term, we cannot predict but it will be highly unlike that a so well-established environment will move to other regions entirely. We will see a broader value proposition from manufacturers, brands, and solution providers from being a region-based partner to being a more global partner with local satellite factories/hubs.

Global Technology

Personally, I think in a global environment with technology, manufacturing, sourcing, and product development resources will naturally evolve to be more globally based and the Asian/Chinese work habits combined with a remote work force due to the political and global pandemic opens up opportunities for manufacturers and companies' brands in a much broader context.

I do not beleive China's position as a leading region for product development and product sourcing will be changing short- to mid-term; rather, instead I think it will be expanded. ***LIS***

AUDIO ENGINEERS

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

AUSTRIA
USound GmbH

BELGIUM
Donnet: Loudspeaker Repair

BRAZIL
Advanced Audio Technologies (AAT)
Attack do Brasil
Edgar Prudente da Silva
Newbox Industry & Commerce
Phix Electronics

CANADA
Arteluthe
LMH Loudspeakers
Reference 3A
Space-Tech Lab, Ltd.

CHINA
Dongguan Yuonyunn Membrane Co.
Eastech Holding, Ltd.
Fountek Electronics Co., Ltd.
Pana Sound, Ltd.
Sound Technology Development, Ltd.

DENMARK
Danesian Audio ApS
ICEpower a/s
K & K Development
Loudsoft, Ltd.
PointSource Acoustics

EGYPT
GM Audio

FRANCE
Amplitude Audio
Florent Halgatte Consulting
Kartesian
Seltech
SIEA

GERMANY
Audio Technology Engineering (ATE)
Fraunhofer Institute for Digital Media Technology
Goya Acoustics
HiFi-Tuning
Microtech Gefell GmbH
Mvoid Technologies GmbH
Physical-Lab
Rohde & Schwarz
Voice Point

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

HUNGARY
Bayz Audio

INDIA
TurboSonic Pro Speakers

JAPAN
Etani Electronics Co., Ltd.

LATVIA
Acoustic Power Lab

NETHERLANDS
Aequo Audio
Diluvite
ELTIM audio, BV
Kamperman Engineering
Metaxas & Sins

NEW ZEALAND
Asona

ROMANIA
SC Poweraudio SRL

SINGAPORE
Virtins Technology

SOUTH KOREA
Suntel Co., Ltd.

SPAIN
DAS Audio

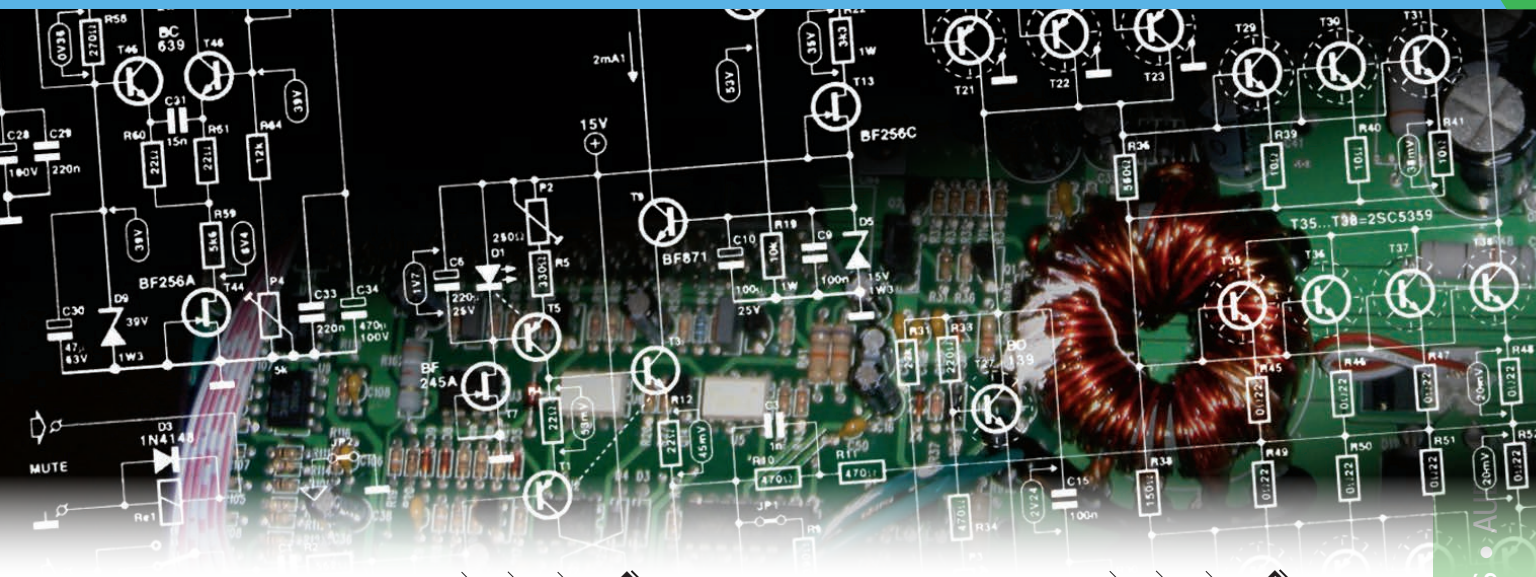
SWITZERLAND
Acustronics Sound-Light-Systems
Lange Loudspeakers

THAILAND
Sanit Audio Engineering Co.

UNITED KINGDOM
Audiolux
Electroacoustic Design Ltd.
EuroTec International, PLC
Fane International, Ltd.
Hill Acoustics
Interfacio, Ltd.
PACSYS, Ltd.
Precision Devices, Ltd.
Tectonic Elements, Ltd.

UNITED STATES
American Music & Sound
Apollonio Consulting
Audio Connection
Audio & Loudspeaker Technologies International (ALTI)
BeStar Technologies, Inc.
Cadillac Audio
Clear Lake Audio
Community Professional Loudspeakers
DMSI
Dragonfire Acoustics
Earthquake Sound Corp.
Geometric Designs, LLC & Geometric Consulting
Globe Audio Design, Inc.
HaiYun Electronic Co., Ltd.
HDSound.us
HEAD acoustics, Inc.
HX Audio Lab
Integrated Audio Technologies, LLC
Io Audio Technologies
Lipinski Sound
Marchand Electronics, Inc.
Meliti Acoustics
North Reading Engineering
Pacific Audio Consulting
PCB Piezotronics, Inc.
PR Audio
Pro Sound Testing, Inc.
Quest Engines, LLC
SoCal Sound Shop
SOUND Product Strategy
Soundoctor
Sounds Unique
SpeakerPower
Studio Electric, LLC
Tectonic Audio Labs
THX, Ltd.
TMI Engineering
TRS Inovations
True Technologies, Inc.
TSG Audio
Vance Dickason Consulting
Westlake Audio, Inc.

VIETNAM
Sound Corp.



	Consultants	Designers	Recruitment Agencies	
ARGENTINA				
Laufer Speaker Electronics	•	•		
AUSTRALIA				
Applied Measurement Australia, Pty., Ltd.	•			
Audinate, Pty., Ltd.	•	•		
DEQX, Pty., Ltd.	•	•		
Lenard Audio, Pty., Ltd.	•	•		
Stone Sound Studio	•			
BELGIUM				
Donnet: Loudspeaker Repair	•	•		
Premium Sound Solutions		•		
The Innovators Lab Belgium (iLaB)	•			
BRAZIL				
Advanced Audio Technologies (AAT)	•	•		
Edgar Prudente da Silva	•	•		
Newbox Industry & Commerce	•	•		
Phix Electronics	•	•		
CANADA				
Arteluthe	•	•		
Divergent Technologies		•		
Kravchenko-Audio	•	•		
Planet10-HiFi	•			
Reference 3A		•		
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.	•	•		
MYIR Tech, Ltd.	•	•		
Pana Sound, Ltd.	•	•		
Sound Technology Development, Ltd.	•	•		
Sun Technique Electric Co., Ltd.	•	•		
Trueanalog Strictly OEM	•			
Vormag Electronics Co., Ltd.	•			
CZECH REPUBLIC				
Elfton		•		
DENMARK				
Danesian Audio ApS	•	•		
ICEpower a/s	•	•		
Loudsoft, Ltd.	•	•		
Lyd by Dissing	•			
PointSource Acoustics	•	•		
FRANCE				
Amplitude Audio	•	•		
Florent Halgatte Consulting	•	•		
Kartesian	•	•		
KYU Systems	•	•		
Seltech	•	•		
SIEA	•	•		
GERMANY				
Audio Technology Engineering (ATE)	•	•		
AudioChiemgau	•	•		
Fraunhofer Institute for Digital Media Technology	•	•		
Goya Acoustics	•	•		
Jobst-Audio	•	•		
Klippel GmbH	•	•		
Microtech Gefell GmbH	•	•		
Mvoid Technologies GmbH	•	•		
Physical-Lab	•	•		
Scherer Audio	•	•		
HONG KONG				
BDNC (Holding), Ltd.		•		
dB Enterprises	•	•		
Deep Blue Design	•	•		
Ocean Star Electronics (HK) Co., Ltd.	•	•		
Panson Audio	•	•		
WCE Acoustics	•	•		
HUNGARY				
Bayz Audio		•		

	Consultants	Designers	Recruitment Agencies	
INDIA				
Decibels Audio Private, Ltd.	•	•		
Power Electronics & Technologies	•	•		
SFT Technologies	•			
TurboSonic Pro Speakers		•		
ITALY				
Audiomatica, SRL	•	•		
Audioxplus, SRL	•	•		
Axiomedia, SRL	•	•		
JAPAN				
Etani Electronics Co., Ltd.	•	•		
LATVIA				
Acoustic Power Lab	•			
MEXICO				
Oldman Sound		•		
NETHERLANDS				
Aequo Audio	•	•		
Diluvite	•	•		
ELTIM audio, BV	•	•		
Kamperman Engineering	•	•		
Metaxas & Sins		•		
REC Sound	•	•		

	Consultants	Designers	Recruitment Agencies	
NEW ZEALAND				
NZ Audio Solutions	•	•		
SINGAPORE				
Virtins Technology	•	•		
SOUTH KOREA				
Suntel Co., Ltd.	•	•	•	
SPAIN				
Sottovoce Audio		•		
UNITED KINGDOM				
Electroacoustic Design Ltd.	•	•		
EuroTec International, PLC	•	•		
Fane International, Ltd.	•	•		
Hill Acoustics	•	•		
Interfacio, Ltd.	•			
MJ Acoustics	•	•		
Node Audio Research, Ltd.	•	•		
Precision Devices, Ltd.	•	•		
Sine Audio Systems	•	•		
Spectral Measurement	•	•		
UNITED STATES				
Acoustic Fields	•	•		
Aempyrean	•	•		
American Bass USA	•	•		
Apollonio Consulting	•			
Audio & Loudspeaker Technologies International (ALTI)	•	•	•	
Audio Connection	•	•		
Audio Houze	•	•		
AvileTech	•	•		
Barefoot Sound, LLC	•	•		
BassBoss		•		
Beach Dynamics	•	•		
Benchmark Media Systems	•	•		
BeStar Technologies, Inc.	•	•		
Bruel & Kjaer Sound & Vibration North America, Inc.	•	•		
Cadillac Audio		•		
CGN Audio Labs	•	•		
CJS Labs	•	•		
CommonSense Audio	•	•		
Community Professional Loudspeakers	•	•		
Creative Sound Solutions, LLC	•	•		
Danley Sound Labs	•	•		
Danville Signal Processing, Inc.	•	•		
dB Design	•	•		
DMSI	•	•		
Dragonfire Acoustics	•	•		
DTV Installations	•	•		
Earthquake Sound Corp.	•	•		
eMagineFactory, LLC	•	•		
Emerald Physics	•			
Excelsior Audio Design & Services, LLC	•	•		
Fortemedia	•	•		
Fulcrum Acoustic, LLC		•		
Gauss Loudspeaker	•	•		
Geometric Designs, LLC & Geometric Consulting	•	•		
Globe Audio Design, Inc.	•	•		
GR Research	•	•		
HDSound.us	•	•		

	Consultants	Designers	Recruitment Agencies	
HEAD acoustics, Inc.	•	•		
HX Audio Lab	•	•		
Integrated Audio Technologies, LLC	•	•		
JP Electronics Design	•	•		
Linkplay	•	•		
Lowther Speakers USA	•	•		
MAAT, Inc.	•			
Marchand Electronics, Inc.	•	•		
McKinney & Associates, LLC	•	•		
Meliti Acoustics	•	•		
Menlo Scientific, Ltd.	•	•		
Midwest Audio Club	•	•		
NedLab	•	•		
ORCA Design and Manufacturing		•		
Pacific Audio Consulting	•	•		
PCB Piezotronics, Inc.		•		
Planot, LLC	•	•		
Ponderosa Sound Systems	•	•		
Portland Audio Lab	•	•		
PQN Audio		•		
PR Audio	•	•		
Pro Sound Testing, Inc.	•	•		
Quest Engines, LLC	•	•		
RCF USA, Inc.	•	•		
RIVA Audio		•		
SensaSound USA	•	•		
SG Custom Sound	•	•		
SoCal Sound Shop	•	•		
Sound Audio Manufacturing, LLC	•	•		
SOUND Product Strategy	•	•		
SoundKinetics	•	•		
Soundoctor	•	•		
Sounds Unique		•		
Speaker Clinic	•	•		
SpeakerPower		•		
SpeakersAndAmps.com	•	•		
Stroud Audio, Inc.	•	•		
Studio Electric, LLC	•	•		
T&T Shanghai Tianai Acoustics Co., Ltd.	•	•		
TMI Engineering	•	•		
True Technologies, Inc.	•	•		
TSG Audio	•	•		
US Enclosure Co.	•	•		
Vance Dickason Consulting	•	•		
Warkwyn	•	•		
Wehner Technical, Inc.	•	•		
Westlake Audio, Inc.	•	•		
Wired 4 Sound, Inc.	•	•		
Wisdom Audio		•		
VIETNAM				
Sound Corp.	•	•		

Bluetooth and Wireless Audio Evolution

Bluetooth technology is undergoing a major transition to an updated set of specifications that finally reflect the fact that wireless audio remains its largest and most popular application. With the expected completion of the Bluetooth LE Audio specifications in 2021, there are many reasons for audio developers to fully explore the possibilities. This article provides a detailed perspective.

By
J. Martins

Diverting from the previous strategy, in 2021 Sonos introduced Sonos Roam, an ultra-portable Bluetooth speaker designed for both working at home and outdoors. It can be fully connected to the Sonos system on Wi-Fi at home, and automatically switch to Bluetooth when the user is on the go.

When the Apple HomePod was introduced to the world in June 2017, it was a very simple proposition for music listening, supporting direct streaming from Apple Music's own streaming service via Wi-Fi (802.11ac with MIMO), plus offering multiroom speaker support with AirPlay 2, including a unique peer-to-peer mode for guest access. The only wire was the power cable.

Apple's HomePod was recently discontinued by Apple. And one of the reasons why the product didn't meet expectations was the fact that it didn't offer support for Bluetooth audio sources. Even though Apple specified the device with Bluetooth 5, it was never designed as a Bluetooth speaker—Bluetooth was simply used for device pairing and app control, with audio always streamed directly via Wi-Fi to the device—and from a limited number of third-party music services.

When visitors to a home equipped with a HomePod wanted to share their music playlist from their Android smartphone, they were surprised to find out it wasn't possible (sometimes, it even surprised the owners themselves). And that was a problem, because Bluetooth is perceived as universal… and ubiquitous.

A Must-Have

As the Bluetooth Special Interest Group (SIG) reveals, there are more than four billion Bluetooth-enabled devices entering the market every year (2019 and 2020 figures). Users have gotten so used to selecting music from their devices and streaming it to a speaker via Bluetooth, that they don't expect that to be an obstacle.

Although Wi-Fi is and will remain prevalent in the home for wireless audio, and it supports higher quality audio streaming than will ever be supported in Bluetooth, 98% of users don't know and don't care about which technology they are using. They want to use whatever they find most convenient or they are most familiar. And that is the main reason why, even for professional audio applications, many leading manufacturers identified Bluetooth audio support as one of the most requested features.

As another example of ubiquity, until very recently, televisions were not required to support Bluetooth. The product segment adopted the Smart TV concept and Wi-Fi became a requirement for connectivity in the home, first for convenience, but more recently, even totally replacing an

Ethernet cable connection (limited in most cases to 100Mbps data transfer, while Wi-Fi 6 is already able to sustain data rates of 1.2Gbps (1200Mbps) per stream, helpful in homes with broadband services now getting >200Mbps). Consumers that, until very recently, wanted to connect Bluetooth headphones to a TV were required to purchase complicated adapters, made even more expensive by the fact that TVs and set-top boxes (STBs) normally only offer optical or HDMI for audio output. With the extraordinarily fast adoption of Bluetooth headphones in the last five years (Apple removed the headphone jack from the iPhone in 2016), and particularly over the last two years with the mainstream adoption of true wireless earbuds, supporting Bluetooth became a basic requirement on any new TV. In fact, the segment is expected to reach 150 million annual shipments in 2025 and all will offer Bluetooth.

Outside the home, Bluetooth has reigned supreme for more than a decade now. Since Bluetooth 4.0 and Bluetooth Low Energy (BLE) were introduced in 2010, consumer adoption for audio applications increased exponentially. The consensus, until recently, was that Wi-Fi would remain the preferred data and device network technology wherever there was a power source available, and that Bluetooth would be mainly adopted for battery-powered and low-power mobile applications.

In reality, that perception is changing fast with Bluetooth also becoming prevalent in mains-powered applications and bring-your-own-device practices in the corporate world. And product designers, particularly in speaker manufacturers for the home market, face the challenge of having to support multiple connectivity, wireless audio, streaming services, and codec options.

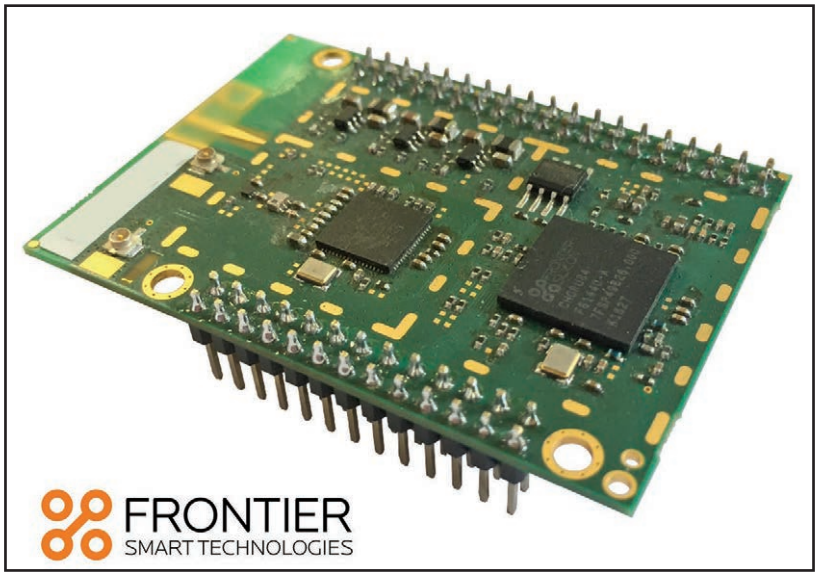
Fortunately, companies such as Frontier Smart, Linkplay, StreamUnlimited, and Libre Wireless make things easier for manufacturers, by providing ready-to-use modules that support all connectivity modes via Wi-Fi and Bluetooth and are authorized certification partners, which means doing all certification testing for Spotify Connect, shortening certification timelines, and time to market.

Frontier's latest Venice X platform is a perfect example of a module that delivers Bluetooth, FM, DAB+, and Internet connectivity via Wi-Fi—already supporting newer lossless streaming services and direct streaming, such as Spotify Connect. Libre Wireless Technologies offers solutions for fully featured Wi-Fi/Bluetooth audio speakers, including LibreSync connectivity modules and software SDK featuring Spotify Connect and Google's Chromecast Built-In.

The now discontinued HomePod was never intended to work as a Bluetooth speaker and that was its main design flaw.

All these companies are also important engineering partners for speaker manufacturers that also have to integrate voice assistants, such as Amazon Alexa. Again, voice recognition until now has relied directly on Wi-Fi connectivity to deliver the response that is to be expected by personal voice assistants, which are supported by cloud services. With the transition to edge-AI and voice recognition on-device, as well as to support always-on applications in battery-powered devices, Bluetooth has become a key part of the overall architecture, connecting devices that are directly connected to the Internet (e.g., a smartphone) to devices that are not—such as home automation and smart home devices where privacy is a priority for consumers.

"LE Audio opens the doors for so many audio capabilities that were previously extremely difficult."—Vincent Nallatamby, Tempow



The latest Venice X platform from Frontier Smart Technologies is a high-quality SmartRadio module, supporting Bluetooth, FM, DAB+, and Internet connectivity via Wi-Fi.

Helping to deal with all the options available for connected (or smart) speaker designs, StreamUnlimited is an Austrian company with vast experience on wireless audio, and it was successful in expanding the range of integration options for manufacturers. Those frequently include advances in AI and voice recognition, immersive audio technologies, smart home integration, 5G connectivity and supporting brands in the transition to the latest Bluetooth audio specifications. The company's StreamSDK software solution is portable to various classes of silicon, which includes the Qualcomm Smart Audio 400 Platform, allowing new designs to add support to the latest Spotify Connect, Tidal Connect, Amazon Music, Qobuz, and TuneIn Hi-Fi music streaming options, and for high-end audio codecs including Qualcomm's aptX, which is a valued Bluetooth option for high-end speaker designs.

Following the acquisition of Cypress, Infineon launched its latest AIROC CYW5557x Wi-Fi 6/6E combo SoC solutions, with support for the latest Bluetooth 5.2 specification for high-quality video and audio streaming applications.

The Bluetooth SIG expects that IoT, wearable devices, and smart home (Data Transfer and Device Networks) will evolve as the dominating application areas for the technology, even if Bluetooth audio streaming remains today the most popular and most visible application for consumers in general. And yet the technology evolution with Bluetooth Mesh and emerging Location Services, will also open up many new possibilities in consumer electronics and automotive applications.

Bluetooth Evolution

The fact that Bluetooth is available everywhere allowed the technology to overcome many of its original limitations, and perceived low reliability. Particularly since Bluetooth 4.2 was widely adopted, and most certainly after Bluetooth 5 was introduced, consumers expect it to just work. Its popularity in mobile devices and portable speakers explains the fact that Bluetooth is now a convenient, widely accepted, and recognized technology.

But the technology has also been evolving according to the use cases enabled by the different Bluetooth radio modes, BLE, Bluetooth Classic, and dual-mode (Bluetooth LE + Bluetooth Classic)—each one designed to meet different connectivity requirements. BLE is obviously the fastest growing implementation, given the number of new wearable and mobile wireless products that are being launched, but for speaker designs dual-mode is clearly the way to go, allowing more demanding and robust applications (e.g., in multiroom applications for the home or pro audio applications). This is obviously supported depending on the radio Class implementation.

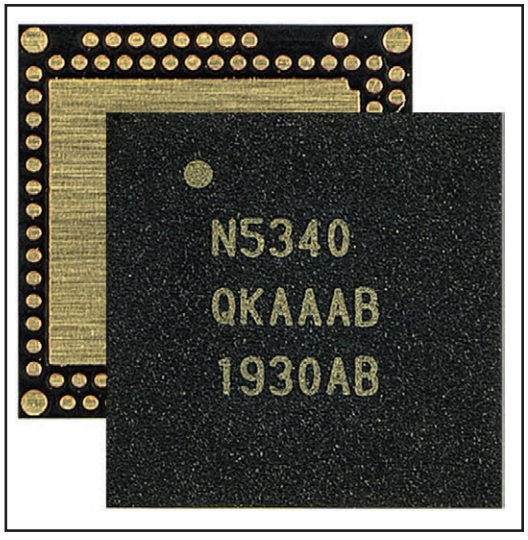
Most Bluetooth applications are battery-powered Class 2 devices, with a limited range around 10 meters (33'). It is possible to extend the range of the data link with both higher sensitivity and transmission power while still keeping the design within the specifications of a Class 2 device. The key metric is the maximum power output of the Bluetooth radio, which is limited at 100mW for Class 1, and 2.5mW for Class 2. This difference in power is what enables two Class 1 devices to reach a range up to 100 meters, or much more in

open-field applications. And using some improved antenna designs in Class 1, it is possible to reach a range of around 30 meters (100 feet) and still keep it relatively low power and in compliance with the Bluetooth Core Specification.

The trade-off is that the wide number of legacy Bluetooth products coexisting in the market and supporting different levels of the specification are one of the reasons why consumers often complain about their poor experiences. Recently, I was surprised by a friend who compalined that he had bought Apple AirPods Pro and that the experience was unreliable, with frequent interruptions in the audio signal, even at close distance. The culprit, we later discovered, was the fact that he was using an old computer as the audio source, specified with Bluetooth 4.0 (and probably a very poor antenna implementation). When he switched to using an iPhone as the source, behavior was flawless and very robust, and the audio quality was much higher (the AAC codec doing its part in contrast with SBC).

Bluetooth 5 was announced in 2016, improving the overall robustness as a result of the increase in transmissions, and a much better experience for many users as a result of its 2Mbps burst speed at the expense of range, or up to fourfold the range at the expense of data rate. This specification was updated in January 2019 with Bluetooth 5.1 with important technical updates that didn't have an impact on audio performance, and finally with the announcement of Bluetooth 5.2 in December 2019. This was the specification that introduced a major update to improve audio applications—recognized by the Bluetooth SIG as the one with the most impact in the overall market.

For reference, according to the organization's 2021 Market Update, even with the unique circumstances of the global pandemic, there were 1.1 billion Bluetooth audio streaming devices shipped in 2020 (practically the same as in 2019), with estimates growing to 1.3 billion in 2021. Audio continues to be the largest Bluetooth technology solution area, and the growth is driven by strong demand for wireless headphones and speakers. While there were 152 million Bluetooth wireless earbuds shipped in 2020 alone (and those numbers are expected to climb to 521 million annual device shipments by 2025), demand for Bluetooth is also forecasted to remain strong, as 94% of all speakers shipped already include Bluetooth technology, demonstrating high consumer confidence in wireless audio. The Bluetooth SIG forecasts that almost 350 million Bluetooth speakers will ship in 2021, increasing



Nordic Semiconductor launched its nRF5340 high-end multiprotocol Bluetooth 5.2 System-on-Chip (SoC), a dual Arm Cortex-M33 wireless solution for the next generation of connected audio applications, including support for Bluetooth 5.2 and LE Audio technologies. It also supports Bluetooth mesh, Thread, and Zigbee protocols.

to 423 million annual shipments by 2025. And this will be motivated by the evolution in speaker designs with updated technology, but also because of the effect of general availability of more source devices supporting the latest Bluetooth LE Audio specifications.

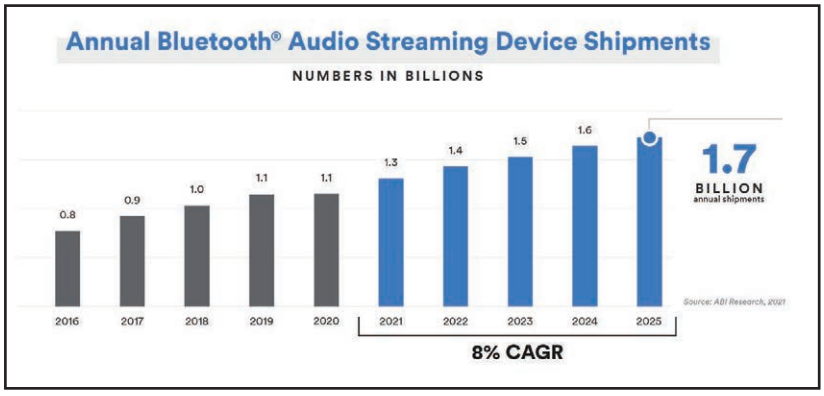
As the latest Bluetooth 2021 Market Update states, "The anticipated completion of the LE Audio specifications in 2021 will further strengthen the Bluetooth ecosystem and drive greater demand for Bluetooth earbuds, speakers, and hearing accessibility devices, resulting in 1.5× growth in annual Bluetooth Audio Streaming device shipments from 2021 through 2025." Bluetooth is already everywhere, but now it is becoming an even stronger component of connectivity with the more recent specification updates.

Bluetooth 5 speakers are now in the market and showing differentiated features in wireless audio design for both home and portable applications. Pictured is the House of Marley Get Together Duo.

Even professional audio applications, including audio-over-IP networking systems are responding to the market requirements to support Bluetooth audio streaming. Pictured are the new Dante AVIO Bluetooth adapters, enabling the connection of a Dante networked device directly to a Bluetooth 5 source and sink device, wirelessly.

BLE Audio

Announced at CES 2020, BLE Audio was added to the Bluetooth 5.2 specification and was designed primarily to expand the possibilities of the BLE radio in battery-powered devices, allowing the protocol to carry sound and add features such as one set of headphones connecting to multiple audio sources or multiple headphones connecting to one source. While other Bluetooth profiles are currently still in development and should be announced at the end of 2021/early 2022, BLE Audio has already introduced the new, more advanced, and efficient Low Complexity Communication Codec (LC3) codec, which among other things will help support a significant evolution in true wireless consumer devices and hearing aids. And while support for LC3 will be mandatory, LE Audio will also allow for the addition of optional codecs, as well as the use of custom codecs. It also introduces an improved Enhanced Attribute Protocol (EATT), LE Power Control features, and most importantly, LE Isochronous Channels.



The Bluetooth market for audio streaming applications with projections for 2021-2025 (Source: Bluetooth 2021 Market Update—ABI Research)

Compared with Classic Audio (also known as the Bluetooth BR/EDR radio), LE Audio introduces LE Isochronous Channels as one of the key features enabling innovative new uses cases, such as Multi-Stream Audio and Broadcast Audio for Audio Sharing. Multi-Stream Audio enables the transmission of multiple, independent, synchronized audio streams between an audio source device, such as a smartphone, and one or more audio sink devices like earphones or speakers, also improving switching between multiple audio source devices. This also enables use cases for the transmission of multiple audio streams from devices capable of both wireless data transfer and audio streaming using a single-mode Bluetooth LE radio.

Broadcast Audio enables Audio Sharing, which can be personal or location-based. With personal Audio Sharing, people will be able to share their Bluetooth audio experiences with others around them; for example, sharing music from a smartphone with family and friends. Location-based Audio Sharing will be potentially very interesting for public venues (e.g., airports, bars, gyms, cinemas, and conference centers) where audio offered via Bluetooth can be shared to all visitors.

These applications are supported by the new Connected Isochronous Group (CIG) and Connected Isochronous Stream (CIS) models, enabling a point-to-point, data transportation stream between a central and peripherals, using a bidirectional communication protocol. In Audio Sharing applications, an audio source device is able to broadcast one or more audio streams to an unlimited number of audio sink devices. This is supported by new Broadcast Isochronous Group (BIG) and Broadcast Isochronous Stream (BIS) for one-to-many data transportation stream models. These depend upon two new types of devices: An Isochronous Broadcaster and a Synchronized Receiver. Audio Sharing will support the communication of time-bound data to one or more devices for time-synchronized processing. And these audio broadcasts can be open, allowing any in-range sink device to participate, or closed, only for authorized sink devices. Again, these descriptions will be detailed further and possibly expanded when the LE Audio specification is completed.

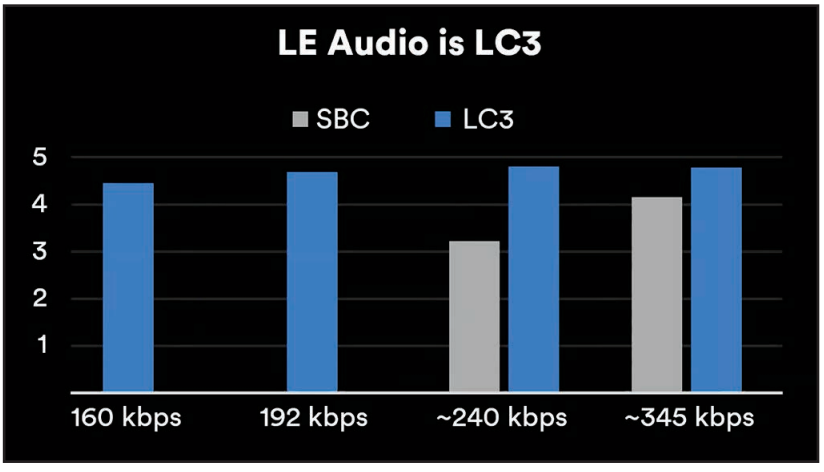
There is no doubt the impact of BLE Audio will be felt immediately in the earbuds and hearing aids market. With its new low-power, high-quality, efficient new codec and support for true multistream audio, LE Audio is expected to boost shipments of true wireless earbuds even further. And LE Audio will accelerate the adoption of Bluetooth hearing assistance devices, making them more affordable and easier to configure for the 1.5 billion people around the world who live with some form of hearing loss.

And with the evolution of BLE Audio, the number of use cases will even overlap with many of the situations where Wi-Fi (or proprietary wireless audio technologies) are today the only option. While these wireless technologies will probably never replace each other and will coexist for quite some time (Wi-Fi is also evolving and adopting modes that bring it closer to the typical Bluetooth use case today), there is no doubt that particularly in speakers, both wireless audio technologies will need to live together for some time.

Wireless audio technologies are a common thread to all cutting-edge efforts in audio technologies. For the home, we are increasingly reliant on Wi-Fi, and out of home all our lives are increasingly dependent on broadband cellular networks, with 5G starting to change everyone's perception of how much wireless can change our world. And as global and wide area coverage networks are fast evolving, we are also increasingly reliant on close range and personal area networks, where Bluetooth plays a pivotal role.

New Possibilities

BLE Audio introduces an entirely new architecture for supporting wireless audio applications and paves the way for a series of updates to the specifications. More than a year since the announcement by the Bluetooth SIG, Bluetooth LE Audio is now reaching the market and will reinforce our notion of what can be done with wireless audio. It's not just a new level of robustness that will change people's confidence in using it. It's the fact that BLE Audio will enable new experiences, made possible by the new audio sharing possibilities. As the first BLE Audio solutions reach the market in 2021, there will also be a series of exciting announcements to come, since much of the planned architecture updates are actually completing development. There are more than 20 new Bluetooth specifications, some of which are still in process, as the Bluetooth SIG confirms.



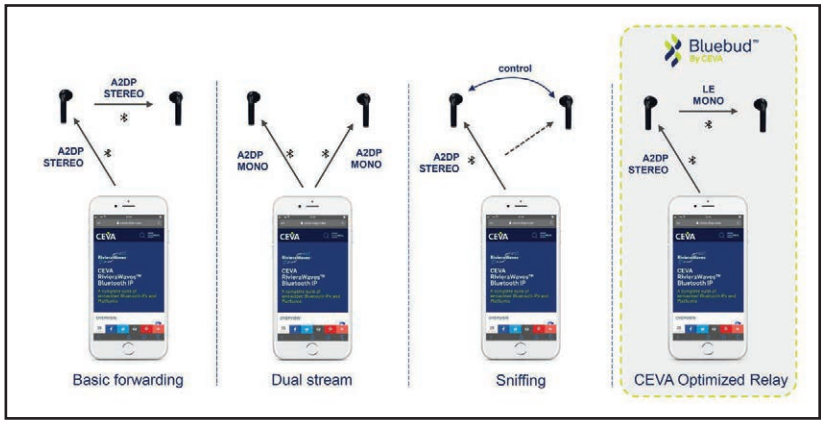
The new, high-quality, low-power Low Complexity Communications Codec (LC3) audio codec now part of LE Audio, enables product developers to make better design trade-offs between key product attributes, such as audio quality and power consumption.

According to Nick Hunn—member of the Bluetooth Working Group Summit and key contributor to the development of the LE Audio specification, currently chairing the Hearing Aid Working Group, and vice-chair of the Generic Audio Working Group developing the LE Audio specifications—the work in progress is completing a set specifications that supports more flexible speaker grouping and surround or spatial sound modes, and using Bluetooth for controlling remote devices with voice commands. "You're going to be able to stream music from a device at the same time you're talking to it or talking to something else. So, that possibility of how we start to interact with multiple devices and how we mix up music and voice is going to liberate designers to go out and do some really innovative things," he stated.

And some of the possibilities described in this work in progress include things such as hearing aids being able to receive audio from multiple sources at the same time (the user selecting the best one), or the dual stream that enables audio to be sent to both left and right channels in a low power mode and with lower latency. This is something that manufacturers have been working hard to accomplish in different ways for speakers and true wireless earbuds, but will now be fully supported by the specifications, meaning full interoperability between devices.

AUDIO SHARING™

Bluetooth Audio Sharing is enabled by Broadcast Audio, a new feature of LE Audio that will allow an audio source device to broadcast one or more audio streams to an unlimited number of audio sink devices.



Different TWS Bluetooth connection approaches can be used to solve the "one source, two sinks" challenge of true wireless earbuds, including the new CEVA Optimized Relay mode.

Some of the companies that developed solutions for those use cases, and successfully created proprietary approaches over Bluetooth, are now at the forefront of the BLE Audio implementation efforts and product ramp-up. One of those companies is Tempow, specializing in software-only solutions to enhance the core Bluetooth protocol. The French company recently announced the release of a new Bluetooth Software Stack for LE Audio implementation in hearables and speakers.

Tempow's first product—the Tempow Audio Profile (TAP)—was an updated Bluetooth protocol allowing any Bluetooth chip to stream audio on multiple Bluetooth audio outputs simultaneously. This 100% software solution that works with any brand of Bluetooth speaker, on any chip, enabled some companies to create "party modes" between synchronized devices of the same model or the same brand. Tempow was one of just 10 companies invited by the Bluetooth SIG to participate in the official LE Audio launch event, and it is now developing a dual-mode solution that enables brands to move to LE Audio with almost zero disruptions to Bluetooth functionality. Tempow's new Bluetooth Software Stack will automatically determine which audio protocol needs to be used based on the device being connected.

Another of the leading technology companies in this space, CEVA was one of the first in the market to confirm availability of LE Audio-ready solutions. Immediately following the Bluetooth announcement at CES 2020, CEVA licensed and deployed its CEVA's RivieraWaves BLE IP to Goodix Technology, the company that acquired NXP's Voice and Audio Solutions (VAS) business and a major player in the mobile space. Goodix GR551x series SoCs were the first to offer CEVA's software protocol stack to support all of the latest features of Bluetooth, including full support for the next-generation of BLE isochronous architecture.

More recently, CEVA announced Bluebud, a highly integrated wireless audio hardware and software platform aimed at standardizing DSP-enabled Bluetooth audio IP for fast-growing applications, including True Wireless Stereo (TWS) earbuds, hearables, gaming headsets, smart watches, and other wearable devices. The solution fully supports Bluetooth 5.2 and LE Audio design and is ready to support brands in the transition from Bluetooth Classic.

Bluebud offers advanced, value-add software and toolkits optimized for the onboard CEVA-BX1 DSP, including audio codecs, voice assistants, spatial audio, in-ear detection, tap control, activity classification and even full support for TensorFlow Lite Micro machine learning models. It allows developers to complete projects with support for the Classic Audio software stack, while expanding the design with the complete LE Audio software stack, including LC3 codec support.

And critical for TWS designs, on the Bluetooth audio side, the CEVA Bluebud platform solves the current challenges of bad Bluetooth link quality, poor audio quality, and unstable left/right synchronization. Bluebud offers a new and exclusive approach to the always-challenging requirements of true wireless stereo connectivity. It combines an integrated Bluetooth 5.2 dual stream mode with a unique CEVA Optimized Relay solution. Together these modes address the "one source, two sinks" problems that have always affected Bluetooth true wireless designs and are not natively supported by the Bluetooth Classic standard. The Bluetooth SIG has addressed this in LE Audio by implementing a natively supported true wireless

TWS Implementation Comparison

Architecture	Bluetooth type	Battery Life	High Fidelity Audio Support	Stability	Compatibility
1. Basic A2DP Forwarding	Bluetooth Classic (BR/EDR)	1	No	Poor	All devices
2. Sniffing/Eavesdropping		+ 28%	Yes	Excellent	All devices
3. Dual Stream		+ 70%	Yes	Excellent	Compatible phones only
4. CEVA Optimized Relay		**+22%**	Yes	Excellent	All devices
5. LE Audio	Bluetooth LE 5.2	**> +80%**	Yes	Excellent	All devices

CEVA Optimized Relay ≈ sniffing at system level
Do not forget the power consumption of speakers and microphones!

This chart shows the implementation comparison of true wireless stereo (TWS) products, including CEVA's latest Optimized Relay mode and the new Bluetooth LE Audio dual stream mode.

mode with dual stream, which is excellent and very efficient, but will require Bluetooth LE 5.2 support on the source side. The CEVA Optimized Relay implementation also works with Bluetooth Classic (BR/EDR) source devices, and offers a connection from one earbud to the other, similar in nature to the "sniffing" approach used by Apple and other manufacturers, with excellent stability, tight left/right synchronization (5µs) and very similar battery life efficiency. This will help manufacturers better support all Bluetooth source devices, existing and future, with their new designs.

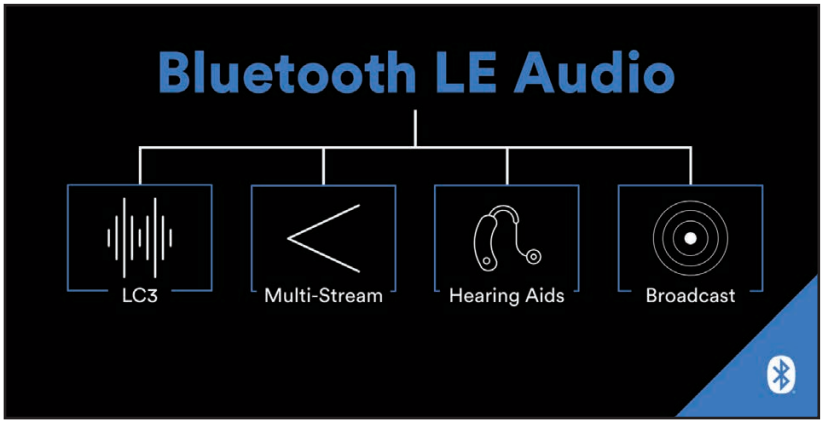
The dual-stream approach now added to the LE Audio specification sends the signals independently to the left- and right-channel devices (hearing aids, earbuds, or paired speakers) and, at the same time, provides a synchronization signal with a really low latency (within 20µs). Supporting developments using these new approaches, companies such as Ellisys, which provide test and analysis solutions for Bluetooth and other wireless and wired communications technologies, are already able to offer features that help analyze the isochronous traffic on connected and broadcast links, as well as supporting new audio profiles.

The new audio transports types that are supported in the BLE Audio isochronous physical channel—Broadcast Isochronous Streams and Connected Isochronous Streams—also present new challenges because of the new protocol requirements involving the establishment and security of isochronous connections. Ellisys engineers have already developed tzero Tracking, a proprietary technology that delivers high-fidelity capture of isochronous traffic, without gaps or any other limitations. This technology is now available on the Ellisys Bluetooth Vanguard Advanced Wireless Analysis System, which also includes Capture Diversity, a technique important for audio development, and auto-detection of LC3 audio.

Unfortunately, COVID-19 and the resulting pandemic effectively shifted growth in Bluetooth annual device shipments out by one year, and also delayed the roll out of new Bluetooth technology and products. While annual shipments of Bluetooth products will already outpace pre-pandemic levels in 2021, the expected completion of the LE Audio specifications in 2021 will further strengthen the demand for Bluetooth earbuds and speakers. As the work continues, the new and enhanced specifications are certain to propel exciting developments. ***LIS***

www.bluetooth.com

In addition to supporting the development of the same types of products and use cases as Classic Audio, which operates on the Bluetooth Classic radio, LE Audio, which operates on the Bluetooth Low Energy radio, will introduce new audio capabilities, but will co-exist for some time in dual mode systems.



LE Audio will significantly expand the development of new products and use case profiles, and exciting new features, which will be detailed when the more than 20 new specifications are completed, including a new Basic Audio Profile and a new Common Audio Profile.

Resources

Bluetooth SIG, Inc. | www.bluetooth.com

CEVA, Inc. | www.ceva-dsp.com/product/ceva-bluebud

Ellisys | www.ellisys.com

Fraunhofer IIS | www.iis.fraunhofer.de

Frontier Smart Technologies, Ltd. | www.frontiersmart.com

Libre Wireless Technologies, Inc. | www.librewireless.com

Nordic Semiconductor | www.nordicsemi.com

Packetcraft, Inc. | www.packetcraft.com

Qualcomm Technologies, Inc. | www.qualcomm.com

Shenzhen Goodix Technology Co., Ltd. | www.goodix.com

Tempow | www.tempow.com

Home Cinema

Due to the global pandemic, for more than a year, most people around the world have been forced to spend much of their time at home. An unintended result of the ongoing COVID-19 pandemic has been an increase in sales in the consumer electronics (CE) industry, which has forced the home cinema category to become more accessible to consumers and offer a wide range of affordable products.

The SoundSend, an HDMI (or optical)-connected wireless audio transmitter, is WiSA's first branded product.

By
Tony Ostrom
(President, WiSA Association)

COVID-19 has created a situation in which more people are forced to stay home, and as a result are analyzing lifestyle improvements within their own four walls. With this pivot, it is more important than ever that the consumer electronics (CE) industry, worth more than $838 billion globally according to Grand View Research, continues to innovate and deliver the home entertainment solutions needed to create fully immersive experiences fed by the growing amount of high-definition streaming content containing multichannel audio soundtracks.

A large portion of the money that was once spent in restaurants, sporting arenas, and shopping malls is now being spent on items to be used in or around the home. Home improvement projects, remote working, and evenings spent within the home are becoming increasingly popular as the world navigates COVID-19. Regarding leisure activities during the pandemic, 71% of Americans chose to watch more TV than usual, according to Statista. As consumers become more familiar with their own devices, or lack thereof, home audio and adjacent consumer electronics manufacturers are presented with a meaningful opportunity to attract new customers seeking a home cinema upgrade or introduction.

With that, though, brings forth questions such as what kind of TV or audio product is right for a certain family or use case, what kind of streaming platform will deliver the desired content, is a home cinema setup affordable—you get the idea. Brands across the board must work hard, and work together, to amplify the home cinema category overall and showcase the improvements in ease of use and accessibility.

Streaming Made Easy

How one consumes movies, games, sports, and really any other entertainment via a screen has changed drastically over the years. The days of complicated setups with wires, DVDs, and people physically going to the theater are continuing to fade. 2020 prompted leading CE manufacturers and Hollywood producers to get even more creative when it comes to how people can experience movies right at home. While some films have opted to wait out the pandemic before being released, many this past year (e.g., *Wonder Woman 1984* and *Mulan*) went on with their planned releases, landing on the popular HBO Max and Disney+ content platforms. Since going to the theater to enjoy a film on the big screen hasn't been much of an option lately, the big screen experience is being replicated in the home.

An IndieWire article recently stated that the average American subscribes to four streaming services and streams around 8 hours of content daily. Ultimately, people want easy access to their favorite pastime entertainment. Be it

movies, TV, sports, gaming or the news, it's not a secret that consumers want more safe, stay-at-home entertainment with less interruption and hassle. Hulu, Amazon, HBO Max, and more are working to keep viewers up-to-date with content that is largely available in immersive, multichannel audio formats, presenting an ideal opportunity for surround sound integration in home setups.

As streaming platforms become the preferred means for content aggregation, selection, and viewing, consumers will become more and more comfortable relying on streaming to bring them higher percentages of their entertainment. The streaming service market will undoubtedly continue to surge in 2021—especially as more movies and shows continue to go direct to the home and offer complete seasons at a time. Consumers can expect to witness more and more streaming services and the shows they offer being made available directly through the user interface and on-board applications of TVs in the growing smart TV market.

Amplifying the TV and Audio Experience

Owning a smart TV isn't such a novelty anymore as the majority of homes in the US have at least one due to the range of sizes, styles, and more affordable price points. Smart TVs are the new center of the home cinema experience, playing the role of the content aggregator and controller. According to Statista, as of 2018, 70% of the TVs being sold around the world were smart TVs. And from 2012 to 2020, there was an increase from 9% to 60% of total smart TV household penetration. This increase in smart TV ownership has led to the demand of simple and easy-to-use audio solutions.

In order for smart TV owners to truly capitalize on all that streaming services and smart TVs have to offer, a dedicated home audio system presents the ideal upgrade. Fortunately, the cost and installation of a surround sound system no longer present the barriers they once did. Everything from high-end wireless audio Bang & Olufsen tower speakers to complete 5.1 solutions in a box with wireless audio functionality are enticing consumers to invest in their own entertainment systems.

In addition, the Wireless Speaker and Audio (WiSA) Association has been hard at work creating a universal wireless audio standard. This standardization of wireless audio technology and communication enables TVs, transmitters, and speakers to easily connect and communicate providing simple and reliable system creation for those desiring amazing home entertainment experiences without the classic complications of installation and setup.

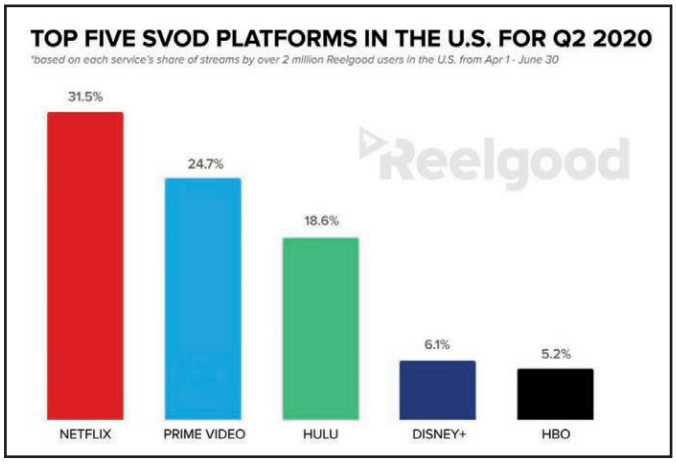
For example, WiSA's first branded product, the SoundSend wireless audio transmitter, is a universal wireless multichannel home cinema audio transmitter that works with all WiSA Certified speakers and is designed to enable simple, yet amazing, home entertainment experiences in minutes from any smart TV.

As the home theater category continues to evolve in the areas of ease-of-use, accessibility, wireless connectivity, and more, it's safe to assume that every home has the capability of becoming a cinema-like space. What's more, wireless technology enables consumers to easily build an audio system from scratch with interoperable products of their choice. If someone wants a smart TV to sync to a specific speaker system without the hassle of wires, it's now possible. Homeowners can easily choose what type of system they want, where they want and what level of performance they desire and make it happen with ease.

Looking Ahead to the Future of CE

As the cinema experience moves into the home and more consumers uncover the new and improved choices available to them, the CE and home theater industries are presented with great potential. Top TV and audio brands, many of which are WiSA Association members, will continue to push the technology and design envelopes of cutting-edge smart TVs and speakers so that they can work seamlessly together and provide the best experiences possible with high-resolution and multichannel audio. Simplistic yet high-quality home cinema solutions will drive industry growth and an expanded audience.

The home cinema category continues to become more accessible to consumers across the globe with a wide range of affordable products. In the years to come, expect even more user-friendly and revolutionary audio solutions to make their way into the spotlight. ***LIS***



These are currently the most popular streaming services. (Image source: Reelgood)

About the Author

Tony Ostrom is president of the Wireless Speaker and Audio (WiSA) Association, an industry group dedicated to bringing the industry's only fully interoperable, high-resolution, multichannel 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.

About WiSA

WiSA is an international trade association comprised of leading audio, CE, and manufacturing brands who collectively define world-wide standards for wireless, high resolution, multichannel audio.

Introducing the Audio Product Education Institute (APEI)

By
Scott Leslie

Learn more about APEI, an audio industry organization that is dedicated to improving the knowledge and skills of professionals involved in the development of audio products, from concept to delivery.

The Audio Product Education Institute (APEI) was formed as an initiative of the Audio Engineering Society (AES) in February of 2020. The goal of APEI is to be the destination for the world's audio product developers to learn and teach the multidimensional skills and knowledge required to develop and sell audio products today. Given the tremendous growth of audio in the consumer and automotive markets, these are the focus of APEI currently.

If you are responsible for the one or more areas in bringing audio products to market from product management to engineering to manufacturing to supply chain and beyond, you will benefit greatly from APEI. You will gain hands on experience that will allow you to immediately increase your skillset in the areas in which you focus.

If you supply products or services to audio product manufacturers and/or brands, you will increase your visibility and find new customers and partners. We encourage you to present your know-how, methods, and technologies to our development world.

While AES focuses on audio, mostly from a creative and scientific perspective, APEI concentrates on technology implementation and realization of those products that incorporate audio from music to communication to health care, security, and beyond. We believe this is still "Audio Engineering" but on a different plane.

The majority of the APEI audience is not the same as the AES audience, which means a net new opportunity for AES. This audience represents

more than $100 billion in annual revenue, meaning the opportunity is large and broad. Interactive voice products by themselves are well above $25 billion and growing, expanding into multiple niches and super niches. Due to mobile phones, earbuds, headphones, smart speakers, automotive entertainment systems, and streaming services among others, we now live in an audio market the size of which none of us who grew up in the CD era could have imagined!

The huge growth in the number of development jobs in audio products has resulted in a situation where demand significantly outweighs supply. As a consultant to audio product companies, the #1 question I get is "Where can I find qualified development professionals?" A quick survey of LinkedIn shows more than 700 job openings in audio products at Sonos, Bose, Apple, Amazon, and Harman. All of them need additional people to get products to market.

Unlike the previous era where supply and demand were fairly balanced, product companies today need to develop a strategy on how to develop and release products to market based on the supply of talent available.

Product Development Education

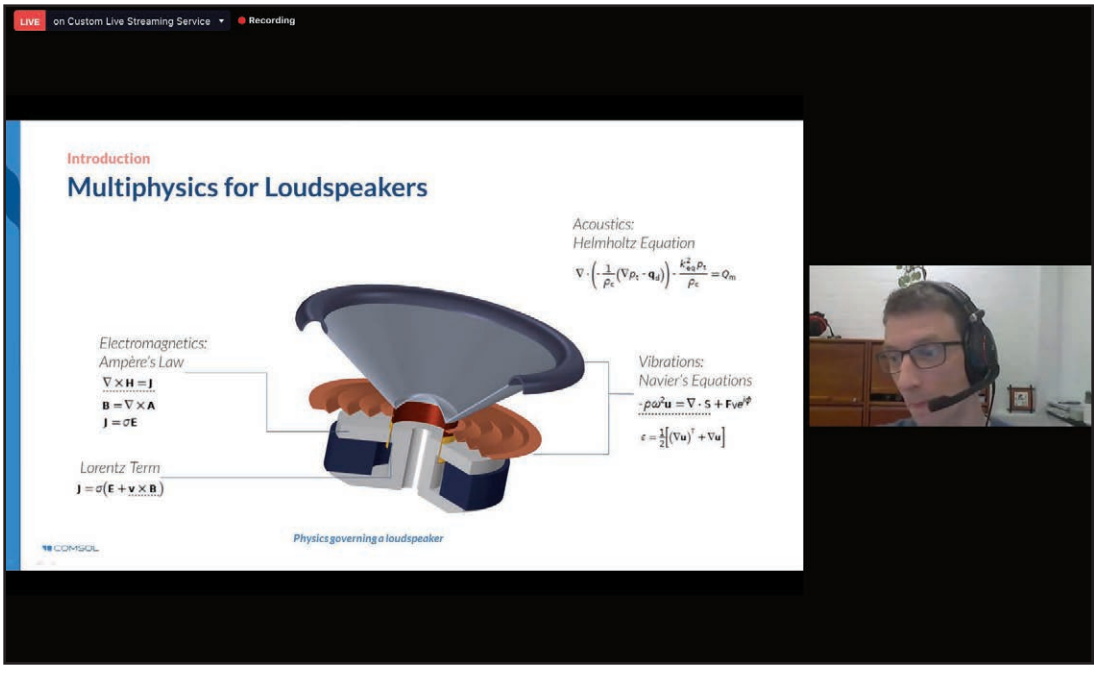
Traditionally, it takes years to become a solid contributor in the product development field, but today we don't have those years. We also are seeing the retirement of many of the senior and highly experience product engineers and related professionals.

When I managed large engineering teams, I faced the hiring and training challenges every day, it was a far greater part of my job than I could have imagined. I was given large training and education budgets and corporate requirements for employee developments. Typically, large companies have programs for educating and training employees. However these programs are usually quite generic in areas such as project management, science, technology, workplace dynamics, and many others. It is up to the employee to figure out how to apply this knowledge to their job.

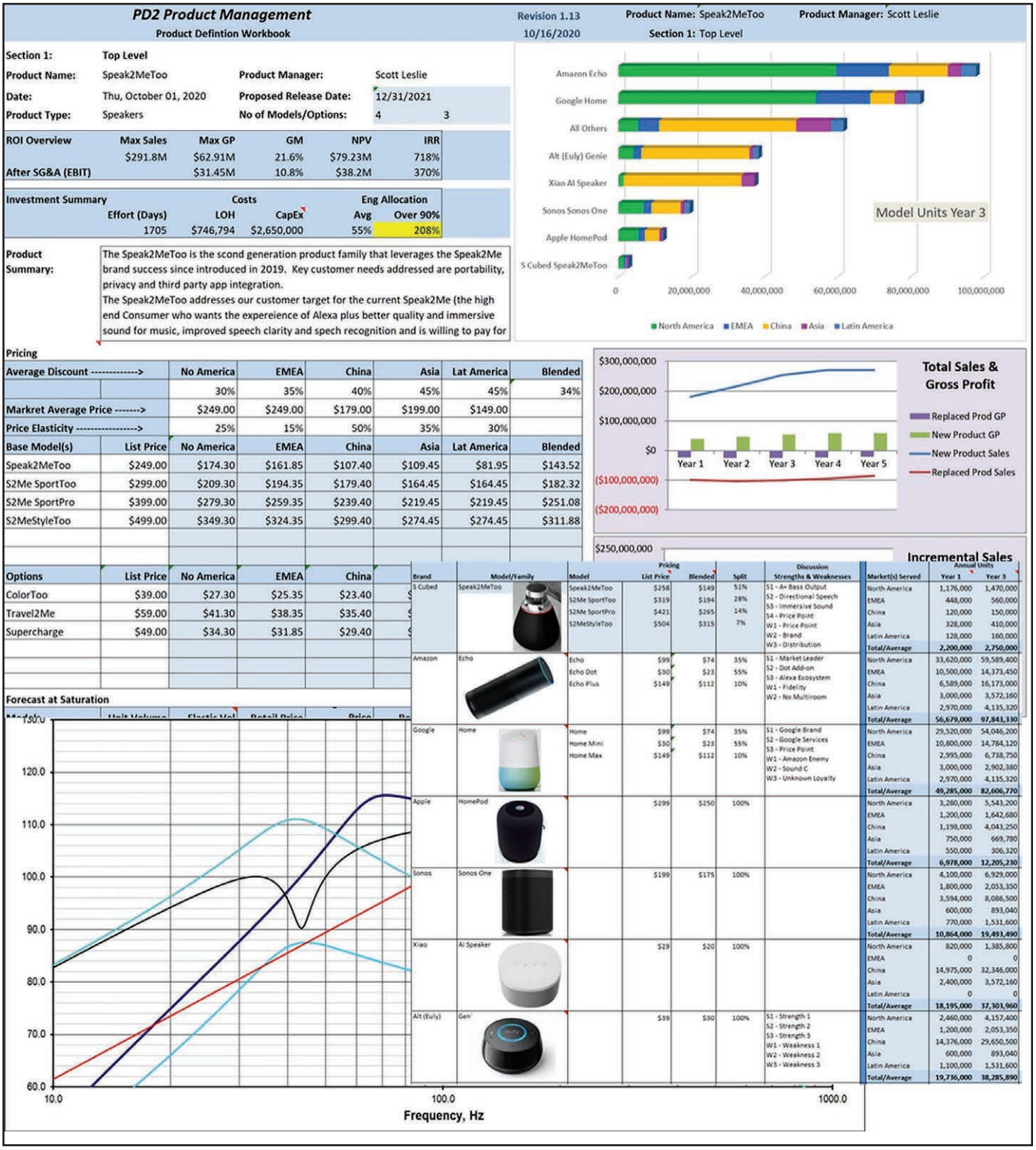
Universities provide great education in science, engineering, math, and business. This provides the foundation required for an individual to be successful in a product development career. What's missing is the hands-on experience and skill development necessary to execute the tasks of the job. Commonly, this type of education was called "on-the-job training." When products were simpler and there was experience in house to learn and ample time (years) to learn "the trade," companies developed their talent into productive positions.

Today, we don't have the luxury of time. We face an ever-growing complexity of products, technologies, and development methods. The number of people we need on our team is also increasing. Our team members need crash courses in audio product development!

At one point in my career, I was approached by the CFO of my company who asked me how much more money I would need to spend in R&D to



Mads Herring Jensen (COMSOL) discusses the Art and Trends in Transducer Simulation and Virtual Prototyping in one of the first Modeling and Measurement webinars.



Here is a Product Management Workbook Sample (Courtesy of PD Squared)

bring more products to market. We had very high financial returns on the products we introduced and there was no limit to market demand. My answer was I could only spend as much money as I had qualified people to pay to do the work. My challenge was to hire and train as fast as possible. All audio product companies face this today. You can see job openings posted and unfilled for many months.

When I attended an AES event in New York a number of years ago, I sat through many sessions that were anywhere from somewhat to quite interesting from an audio perspective. But at the end of it, I realized there was really very little I could take back to my engineering team that would change and improve how we developed products. It was at this point I realized there needed to be specific education that could be directly applied (and fast!) to my team. It was the single biggest factor holding us back from releasing more and better products to the market.

The AES Product Development Track

In 2014, I was asked if I would revive the Product Design Track for AES. I accepted and renamed it the Product Development Track to reflect the current environment of what it takes to develop great products. At the 2014 event in Los Angeles, CA, we offered four days of sessions covering a wide variety of topics and I unofficially called it "Top Gun." We recruited presenters from across the globe who had great experience and skills and the desire to educate.

In 2016, we conducted a "Super Saturday—How to develop a killer audio product in one day," an ambitious all-day session during which a panel of experts working as a team for weeks prior, each presented a discipline for a proposed smart speaker (the "Speak to Me"). That day, we discussed product management, industrial design, user experience, acoustic, mechanical and electrical engineering, DSP, modeling and measurement, and supply chains. The session was over attended and we received "over the top" reviews. I knew this is what my peers in audio product wanted and needed.

The Track continued to grow in content and attendance until the event in 2019. At that time, AES was looking to expand its reach into new areas and I was asked to join a task force to consider options. I proposed what was to become the Audio Product Education Institute (APEI), and we launched this as an AES initiative in February of 2020.

APEI, as with most of AES, is a volunteer organization. We have a very experienced and committed team of audio product professionals. The foundation of APEI is our pillar Chairs and our media and marketing leader.

The Education Pillars

Building on the AES Product Development Track, we organized APEI around educational pillars. Our goal is to provide the education that covers all aspects of product development. My intent was to reach beyond engineering and leave no stone unturned in the important disciplines that make up product development today. I often ask our members and attendees to think of the times that they participated in a product kick-off meeting and all of the areas of the company represented from engineering to manufacturing to supply chain to finance to marketing and beyond. The people from all of these areas must do a great job for the product to be a success. At APEI, we have constructed seven pillars to educate your entire team!

Product Management

Product Management (PM) arguably has become the most important function in product companies today. The windows of opportunity for products in the market can be short and at the same time quite large. A 360-degree view of a product is key for its success in today's complex and competitive market. Formalized methods and principles have been developed by Steven Haines (Sequent Learning) and others over the last 20 years. Many companies still suffer from time to market, pricing, competition, market misses, and many other challenges due to poor product management. APEI's PM pillar brings the specifics of audio products to this subject. Steven Haines has provided support, advice, and has presented material at APEI events.

Supply Chain and Sourcing

The supply chain of audio products is extremely complex and dynamic, especially in the consumer and automotive space where the APEI focus is. Companies cannot afford to keep doing what they are doing to stay competitive and deliver great products. Topics in this area cover:

- Selecting and managing suppliers
- Understanding geo-politics and geo-economics
- Managing quality
- Risk management
- Integrating external partners in all aspects of product development

Voice and DSP

Interactive voice products now dominate the global market in terms of unit volume and revenue with the market estimated more than $25 billion last year and growing. These products are remarkable in their use of audio from voice recognition to virtual conversation to room acoustics modeling to worldwide source streaming and beyond. There are tens of thousands of developers in this market today, which represents the single largest opportunity for APEI in its mission. So many of these development professionals are new to audio and even to product development, which means many companies will be looking for education destinations for these people.

Modeling and Measurement

The science and technology behind modeling and measurement has advanced greatly over the last decade. The capability to create complex "digital twins" of products now includes electronic, electromagnetic, mechanical, acoustic, and thermal domains. In other words, we can now represent the complete working model of a product in the virtual domain. This completely changes the product engineering process and methods associated. We at APEI see that modeling and simulation is becoming mainstream and an essential element of all audio product development.

Artificial Intelligence and Machine Learning

This field has exploded in all areas today and the opportunity for audio products span virtually all product characteristics. Smart audio products already have integrated Artificial Intelligence (AI) and Machine Learning (ML) into the interactive functions of their products whether embedded or cloud deployed. Like modeling, the tools and technologies for designing and integrating AI/ML into audio products make it ready for mainstream product development. This is the fastest growing need APEI is fulfilling.

Business Management

The business world of audio products is quite complex and requires a broad set of skills and experience to ensure product success. This pillar was recently added to cover these important areas, which include:

- Contracts and agreements
- Business structures and organization
- Intellectual property and other legal issues
- Financial modeling
- Mergers and acquisitions
- Angel, Venture Capital, Private Equity, and other funding sources

Automotive

This new pillar was recently added as we saw the need to address the specifics of the automotive market. This pillar draws from all of the other (horizontal) pillars to bring great content that is tailored to the application in automotive. Over the last 20 years, Automotive Audio has changed dramatically, and today some of the most advanced sound technologies are being developed and applied. With the transition to electric vehicles, sound systems are used to design the sound of the car itself and its motion. The impact of streaming, ride-share, autonomy and more could have a profound effect on the way we think about sound in and around vehicles. The mission of the APEI Automotive Pillar is to explore and explain the practical approach and development of all the products that are conceived, planned, designed, and implemented in automotive car audio.

The APEI Online Webinar Series

Each of the pillars hosts a series of online events focusing on a particular subtopic of their pillar. We have a growing calendar of events being added. Visit www.audioproducteducationinstitute.org to see the upcoming events.

When the time is right, APEI will hold in-person events where attendees can dig in and get real hands-on education, get the answers they are looking for, network with their peers, and see what technologies and methods are available to them to better do their job.

APEI and You, the Product Developer

As a leader in product development both as

About the Author

Scott Leslie is the Audio Engineering Society (AES) Product Development Chair, and Audio Product Education Institute (APEI) Managing Director. He is chief architect and strategist at PD Squared, a consultancy business focused on improving and redefining product development for the audio industry. PD Squared stands for "Process Development of Product Development Organizations." Scott's career includes multiple sales, engineering, and product management positions with companies such as Altec Lansing, JBL Professional (Harman), Renkus-Heinz, Tektronix, and Sun Microsystems. In 2002, Scott founded Evidant Corporation, a company specializing in Process Analytics and Business Intelligence that he now also leads as Chief Architect. Scott holds a Bachelor's degree in Electrical and Electronics Engineering from California State Polytechnic University-Pomona, a Masters (MSEE) in Audio and Acoustics from Georgia Institute of Technology, and an MBA in Operations Research and Statistics, from the University of California, Irvine—The Paul Merage School of Business.

an employee and as a consultant, I have seen many companies searching for a way to develop their people, others trying to hire it, and some who believe the only way to educate is by "doing the job."

Companies that have committed themselves to talent development do so in a way that benefits both the employee and the company equally. This means that the education must be valuable to both. This is where APEI comes in.

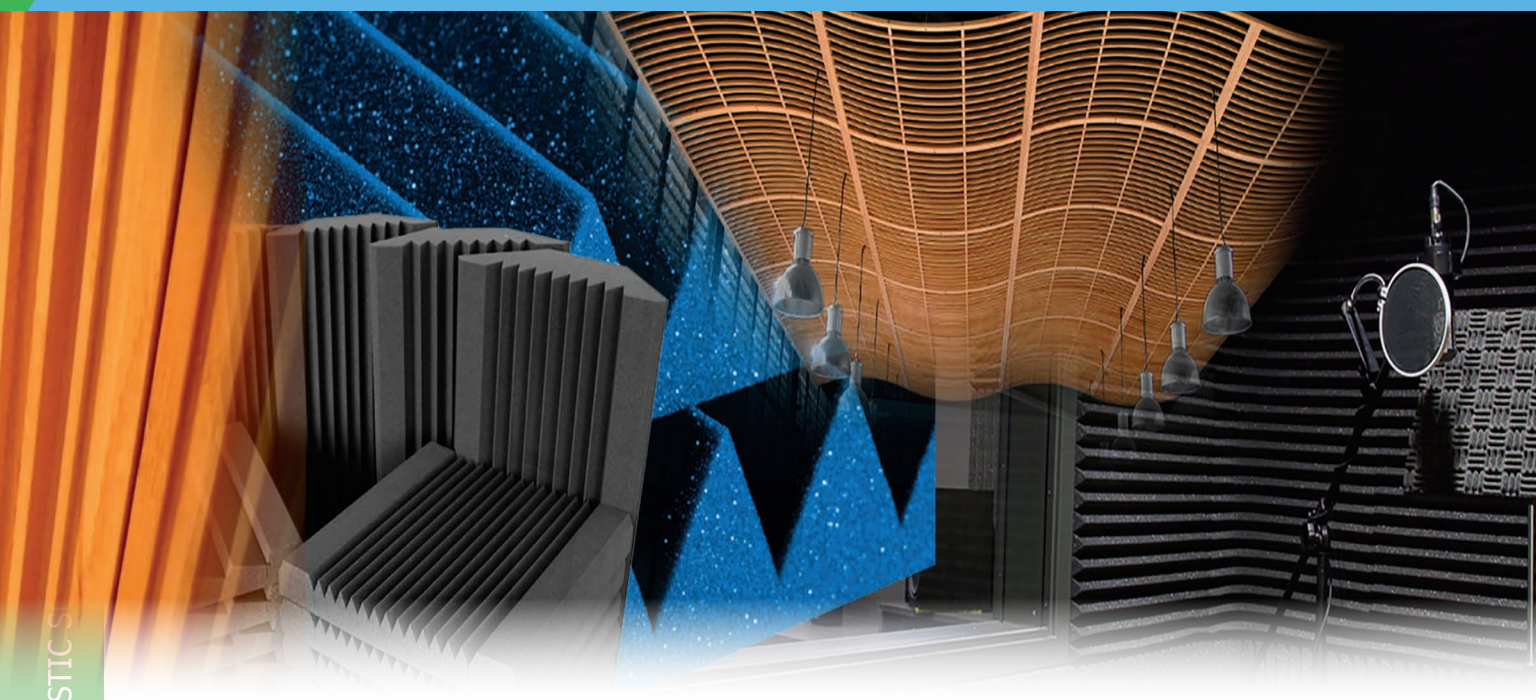
Executives and leaders in Product Management, Engineering, Supply Chain, Finance, Business and Marketing should put a plan for themselves and their team's development. We suggest attending as many of these events as possible, including ones that are outside your job function. The more you know about audio product development, regardless of your position, the better you will be at it. Bring your questions and think of new ones while attending. We have lively Q&A sessions and make every attempt to answer all of them. As our participant base grows, we see members of the audience providing insightful answers that sometimes surprise our presenters.

APEI and You, the Supplier

Suppliers include the companies and people that supply components and sub-assemblies, manufacturing, software development and software platforms/components, industrial design, product design, market research, and many others. We encourage suppliers to present in one of our pillars so that they can educate and gain visibility from our audience. We have many companies providing valuable education by showing how they work and how they succeed with their customers. ***LIS***

Author's Acknowledgements: Being part of APEI is a great experience for a great cause, the betterment of audio products and their developers worldwide. I would like to acknowledge our core team of Mike Klasco, João Martins, Dave Lindberg, Roger Shively, Steve Willonberg, Steve Hutt, Mia Johansson, Mads Jensen, Colleen Harper, and many of the team at the AES. They are all so talented and have worked hard to build the APEI from its humble beginnings. I would also like to thank those who inspired and supported me in starting this initiative and the AES Product Development Track: Dave Scheirman, Agnieszka Roginska, Jonathan Wyner, Michael Macdonald, Mark Trainer, Paul and Chin Beckmann, Doug Button, and especially Mark Gander.

The first APEI webinar on Interactive Voice and DSP live from DSP Concepts headquarters in Santa Clara, CA.



	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													
Applied Measurement Australia, Pty., Ltd.	•												
DEQX, Pty., Ltd.									•				
Lenard Audio, Pty., Ltd.	•					•	•						
Soundlabs Group, Pty., Ltd.					•								
BELGIUM													
Premium Sound Solutions						•							
The Innovators Lab Belgium (iLaB)	•					•	•		•				
BRAZIL													
Newbox Industry & Commerce	•	•		•	•	•	•		•	•	•	•	•
Phix Electronics	•						•		•			•	
CANADA													
Rutherford Audio, Inc.				•	•		•				•		•
Solen Electronique, Inc.				•								•	
Sziara Sound				•			•						
CHINA													
Junhao Wood Cabinet Factory						•	•		•				
Lumi Audio	•			•			•						
Trueanalog Strictly OEM				•		•	•					•	
Xiamen Great Sound Technology						•	•		•				
DENMARK													
Danesian Audio ApS	•			•									
K & K Development				•									
Lyd by Dissing	•					•	•						
PointSource Acoustics	•			•		•							

	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
FRANCE												
Florent Halgatte Consulting	•			•		•						
Kartesian						•						
KYU Systems	•											
Seltech	•			•		•	•	•	•	•		
SIEA	•			•		•						
Supravox						•						
GERMANY												
Audio Technology Engineering (ATE)	•	•		•	•	•			•	•	•	•
Goya Acoustics	•			•								
Jobst-Audio	•			•		•						
Klippel GmbH				•		•						
Lautsprecher-Produktions-Gesellschaft (LPG)				•								
Mvoid Technologies GmbH	•			•		•				•		
Physical-Lab	•			•		•						
Soundsgood Pro Audio Solutions	•			•								
Voice Point	•	•		•	•	•	•	•	•	•	•	•
HONG KONG												
Deep Blue Design	•					•						
Eastern Asia Technology (HK), Ltd.						•						
miniDSP, Ltd.				•	•							
WCE Acoustics	•											
INDIA												
Decibels Audio Private, Ltd.	•					•	•	•				•
GM Audio Technics, Ltd.	•			•	•							
Indiq Audio LLP	•						•					
Power Electronics & Technologies	•						•					•
TurboSonic Pro Speakers						•						
IRELAND												
Crossover Filter App				•								
ITALY												
Outline SRL												•
RCF, SpA	•											•
SpeakerLAB	•			•								
JAPAN												
Etani Electronics Co., Ltd.				•						•		•
LATVIA												
Acoustic Power Lab				•		•	•	•				•
MEXICO												
Aletheia, AV	•											•
Oldman Sound	•											
NETHERLANDS												
Aequo Audio						•						
Diluvite	•			•	•					•		
Kamperman Engineering	•			•						•		
Sound Projects	•											

	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
NEW ZEALAND											
Asona	•	•		•		•	•	•			•
NORWAY											
SEAS Fabrikker AS			•								
PORTUGAL											
Jocavi Acoustic Panels				•						•	
Vicoustic	•	•	•	•	•	•	•	•	•	•	•
ROMANIA											
SC Poweraudio SRL	•		•		•			•			•
SPAIN											
Brusi Acoustics	•		•								
Sottovoce Audio	•				•						
Tecnare/Exel Acoustics SL					•						
SWITZERLAND											
Acustronics Sound-Light-Systems			•								
TAIWAN											
AV Leader Corp.			•		•	•					
Kingstate Electronics Corp.	•		•								
Vansonic Enterprise Co., Ltd.					•	•	•				
Yung International, Inc.						•	•				
THAILAND											
Clarasonic (Thailand) Co., Ltd.										•	
UKRAINE											
MAG Audio	•		•								
UNITED KINGDOM											
Audiolux	•	•			•	•	•	•		•	•
CE Electro-Acoustics	•										
DBS Audio					•						
EuroTec International, PLC			•		•				•		
Interfacio, Ltd.					•						•
Node Audio Research, Ltd.					•	•					•
Spectral Measurement	•		•		•						
Tectonic Elements, Ltd.	•										
UNITED STATES											
Acoustic Fields	•	•	•	•		•		•	•	•	•
Acoustics First Corp.	•		•	•		•		•	•	•	•
Adrian Acoustics, Inc.				•							
American Bass USA	•							•		•	
AtlasIED								•		•	
Audio Precision, Inc.			•								
B&H Foto & Electronics Corp.				•				•		•	
Barefoot Sound, LLC					•						
BassBoss											•
Beach Dynamics	•	•	•	•				•	•	•	
Broad Bridge Audio, LLC									•	•	
Campanella Associates & Acculab	•		•			•		•		•	•
Carl Tatz Design, LLC	•	•	•	•				•	•	•	

	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
Creative Sound Solutions, LLC	•			•							
D. L. Adams Associates	•					•		•	•		•	•
Dayton Audio	•										
Dragonfire Acoustics	•						•	•			
DTV Installations									•		
ETS-Lindgren	•	•	•	•					•	•	•	
Excelsior Audio Design & Services, LLC						•					
Front End Audio, LLC					•				•		•	
Full Compass Systems, Ltd.		•	•	•					•			
GGEC America, Inc.				•								
HDSound.us	•						•					
HEAD acoustics, Inc.				•								
Hearing Components (Comply Memory Foam Tips)									•		•	
Hendrick Manufacturing									•			
HX Audio Lab	•			•		•			•		•	•
Intelligent Audio Products					•							
J&F Wood Products					•							
JP Electronics Design	•			•		•	•	•				
Meliti Acoustics	•	•	•	•	•	•	•	•	•	•	•	•
Meyer Sound Laboratories, Inc.					•	•						

	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
MSC Software Corp.				•						•		
NedLab		•										
NTi Audio				•								
OAP Audio							•					•
ORCA Design and Manufacturing					•							
Parts Express				•						•	•	•
Ponderosa Sound Systems		•			•	•	•	•		•		•
Portland Audio Lab						•						
PR Audio				•								
PUI Audio						•	•					
RealTraps, LLC		•			•							
Redco Audio					•							
San Antonio Home Theater Pros		•					•	•				
Scantek, Inc.				•						•		
SensaSound USA						•	•					•
SoundKinetics		•								•		
Soundoctor				•								
Sounds Unique						•						
Speaker Clinic		•		•								
Stetron International, Inc.		•		•								
Studio Six Digital				•								
SVS, Inc.											•	
Sweetwater Sound			•		•					•		•
T&T Shanghai Tianai Acoustics Co., Ltd.						•						
THX, Ltd.							•					•
TMI Engineering		•	•	•	•	•	•	•	•	•	•	•
True Technologies, Inc.		•		•		•						
US Enclosure Co.		•	•		•					•	•	•
Vintage King Audio					•					•		•
Warkwyn		•		•								
Westlake Audio, Inc.		•										
Wired 4 Sound, Inc.		•			•		•	•		•		•
Wisdom Audio							•					
VIETNAM												
Sound Corp.							•		•			

AMP, DSP, NETWORK, AND WIRELESS MODULES

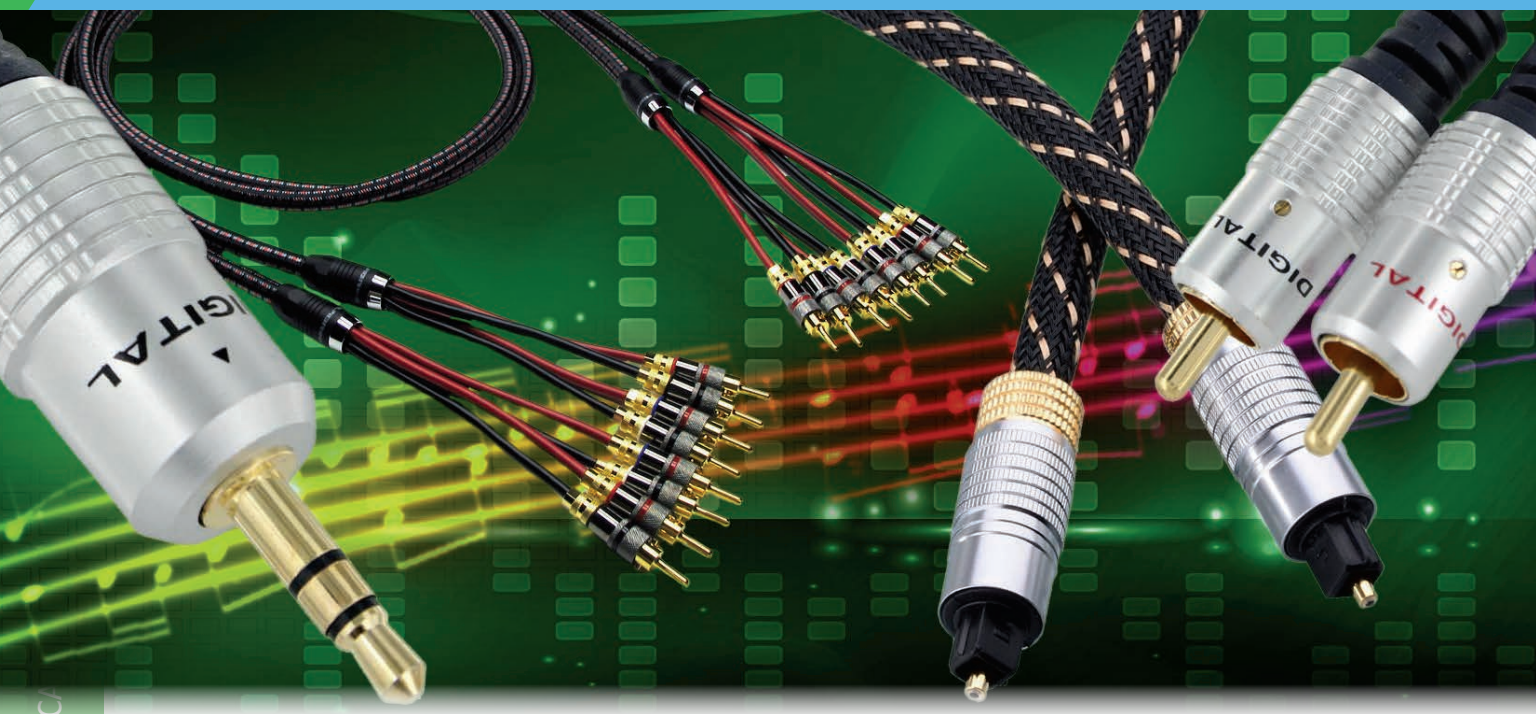
	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
AUSTRALIA				
DEQX, Pty., Ltd.	•	•	•	•
Eclipse Audio		•		
Soundlabs Group, Pty., Ltd.	•			
BELGIUM				
APEX	•	•	•	
The Innovators Lab Belgium (iLaB)		•		
BRAZIL				
Advanced Audio Technologies (AAT)	•			
AMCP Eletrônica	•			
Attack do Brasil	•	•		
Magna Audio	•			
Newbox Industry & Commerce	•	•	•	•
CANADA				
Harbottle Audio	•	•		
Solen Electronique, Inc.	•	•	•	•
Sonavox Electronics Canada	•	•	•	•
Space-Tech Lab, Ltd.	•	•		•
CHINA				
Eastech Holding, Ltd.			•	•
Fountek Electronics Co., Ltd.	•	•		•
GoerTek Co., Ltd.	•	•	•	•
Hansong (Nanjing) Technology	•	•	•	•
MYIR Tech, Ltd.	•	•	•	•
Pana Sound, Ltd.	•	•		•
Shenzhen Horn Audio Co., Ltd.	•	•	•	•
Telefield	•	•	•	•
Tonewinner (Guangzhou) Electronics	•		•	
Tonly Electronics Holdings	•	•	•	•
Tristar Electronics	•	•	•	•
Vistron Audio Equipment	•	•	•	•
DENMARK				
ICEpower a/s	•	•	•	
Pascal a/s	•			
Purifi Audio	•			
FRANCE				
Amplitude Audio	•	•	•	•
IDEA	•			
SIEA	•	•	•	•
GERMANY				
Ascendo Immersive Audio		•	•	
Audio Technology Engineering (ATE)	•	•	•	•
AudioChiemgau	•	•	•	•
Fraunhofer Institute for Digital Media Technology		•	•	•
Klippel GmbH	•	•		
HONG KONG				
Eastern Asia Technology (HK), Ltd.	•			•
INNacoustic	•	•	•	•
miniDSP, Ltd.	•	•	•	
OCVACO Electronic, Ltd.	•	•	•	•
PlastoForm	•	•	•	•
INDIA				
GM Audio Technics, Ltd.	•	•	•	
SFT Technologies				•
ISRAEL				
Alango Technologies, Ltd.		•		•

AMP, DSP, NETWORK, AND WIRELESS MODULES

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
ITALY				
Axiomedia, SRL	•	•		•
Outline SRL		•		
Powersoft, SpA	•	•	•	
JAPAN				
Etani Electronics Co., Ltd.	•	•		
S'NEXT Co., Ltd.	•	•		
NETHERLANDS				
Aequo Audio	•	•	•	
ELTIM audio, BV	•			
Hypex Electronics, BV	•	•		
PHILIPPINES				
Dai-ichi Electronics Manufacturing Corp.	•	•	•	•
SWEDEN				
Bohmer Audio	•	•	•	•
SWITZERLAND				
Archwave			•	

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
TAIWAN				
AV Leader Corp.		•		•
ChiaPing Enterprise		•		•
Jetvox Acoustic Corp.	•	•	•	•
Meiloon Industrial Co., Ltd.	•	•	•	•
Merry Electronics	•	•	•	•
Palm Garden Enterprises Corp.	•	•	•	•
Taiwan Solidex Corp.				•
TOONG IN Electronic Corp.	•	•	•	•
Turbo Tide Electronics Co., Ltd.	•	•	•	•
UKRAINE				
MAG Audio	•			
UNITED KINGDOM				
EuroTec International, PLC	•	•		
MJ Acoustics	•			•
Profusion, Ltd.	•	•	•	•
Tectonic Elements, Ltd.	•			
UNITED STATES				
Area 52 R&D	•	•		

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
AtlasIED		•	•	
Audio Advisor, Inc.	•			
Axiim	•	•	•	•
Benchmark Media Systems	•	•		
CE Distribution	•	•		
Danville Signal Processing, Inc.	•	•	•	•
Digmoda	•	•		
Dragonfire Acoustics	•	•	•	•
DSP Concepts		•		
Eagle Acoustics	•	•	•	•
Emerald Physics	•	•		
Fortemedia		•		
Full Compass Systems, Ltd.	•	•		
Globe Audio Design, Inc.	•	•	•	
JL Audio, Inc.	•	•		
Kramer Electronics	•	•	•	•
Lectrosonics			•	•
Linea Research USA	•	•		
Linear Tube Audio	•			
Linkplay				•
MAAT, Inc.		•		
Marchand Electronics, Inc.	•			
Meyer Sound Laboratories, Inc.		•		
MISCO	•	•		
North American Solidex, LLC	•	•		•
PowerPhysics, Inc.	•	•		
Pro Flix Sales	•	•	•	•
RCF USA, Inc.	•	•	•	
RIVA Audio	•		•	•
SensaSound USA	•	•	•	
Senzar Acoustics	•	•		
Sonion		•		•
Sound Audio Manufacturing, LLC	•	•		•
SpeakerPower	•	•	•	•
US Enclosure Co.	•	•	•	•
Vintage King Audio	•			
VTech	•	•	•	•
Weltronics Corp.	•	•	•	•
Wired 4 Sound, Inc.	•	•	•	•
VIETNAM				
Sound Corp.	•	•		•
Sun Technique	•	•	•	•

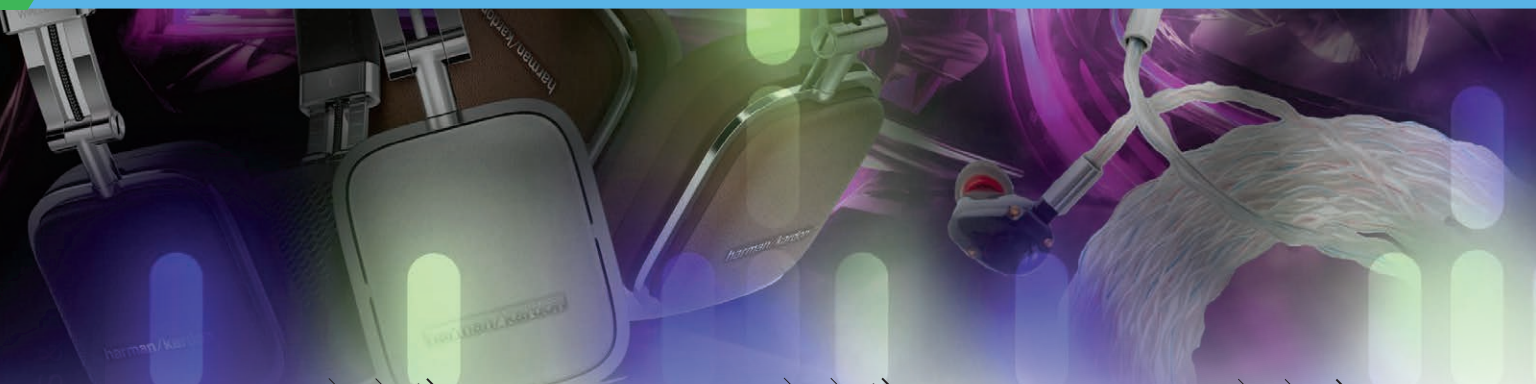


	Cables	Connectors	Wire Channel
AUSTRALIA			
Soundlabs Group, Pty., Ltd.	•	•	
Stone Sound Studio	•	•	
BRAZIL			
Attack do Brasil	•	•	
Newbox Industry & Commerce	•	•	•
CANADA			
Canadian Speaker Works	•	•	
Rutherford Audio, Inc.	•		
Solen Electronique, Inc.	•	•	
CHINA			
BSWA Technology Co., Ltd.	•	•	•
Sound Technology Development, Ltd.	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•
DENMARK			
Duelund Coherent Audio	•		
estron a/s	•	•	
Jantzen Audio Denmark	•		
Mundorf EB GmbH	•		•
GERMANY			
Cordial GmbH Sound & Audio Equipment	•	•	
HiFi-Tuning	•	•	
Klippel GmbH	•		
Mundorf EB GmbH	•	•	
Soundsgood Pro Audio Solutions	•	•	
Voice Point	•	•	•

	Cables	Connectors	Wire Channel
HONG KONG			
dB Enterprises		•	
WCE Acoustics	•	•	
HUNGARY			
Bayz Audio	•		
INDIA			
Power Electronics & Technologies	•	•	
IRELAND			
Crossover Filter App	•		
ITALY			
Axiomedia, SRL	•	•	
Yter Laboratorium SRL	•	•	
JAPAN			
Etani Electronics Co., Ltd.	•	•	
Furutech Co., Ltd.	•	•	
S'NEXT Co., Ltd.	•	•	
MEXICO			
Aletheia, AV	•		
NETHERLANDS			
Crystal Cable	•	•	
Diluvite	•	•	
ELTIM audio, BV	•	•	
Good Hifi VOF		•	
RUSSIA			
Deluxe Acoustics	•		

	Cables	Connectors	Wire Channel
SWEDEN			
Audio Pro, AB	•		
SWITZERLAND			
Ghielmetti AG	•	•	
Vovox AG	•	•	
TAIWAN			
AV Leader Corp.	•	•	•
Bennic and Company	•		•
Huey Tung International Co., Ltd.	•	•	
Yung International, Inc.	•	•	•
THAILAND			
Van den Hul B.V.	•	•	
UKRAINE			
MAG Audio	•	•	
UNITED KINGDOM			
Arya Audio Labs, Ltd.	•		
EuroTec International, PLC	•	•	•
GRAS Sound & Vibration UK	•	•	
Hifi Collective, Ltd.	•	•	•
MJ Acoustics	•		
Revolver Audio, Ltd.	•		
UNITED STATES			
A. Schulman, Inc.		•	
American Bass USA	•	•	
Audio Advisor, Inc.	•	•	
Audio Connection	•	•	•

	Cables	Connectors	Wire Channel
Avanti Audio	•	•	
B&H Foto & Electronics Corp.	•	•	
Belden, Inc.	•	•	
Blackmore Mobile	•	•	
Broad Bridge Audio, LLC	•		
Cardas Audio	•	•	•
Carvin Audio	•	•	
CE Distribution	•	•	•
Controlled Thermal Processing, LLC	•	•	•
DH Labs Silver Sonic	•	•	
DTV Installations	•	•	•
Earthquake Sound Corp.	•		
Elektrisola	•		•
Fingerprint Audio	•	•	
Front End Audio, LLC	•	•	
Full Compass Systems, Ltd.	•	•	
GR Research	•	•	
GRAS Sound & Vibration	•	•	
HAVE, Inc.	•	•	•
Herman Pro, AV	•	•	
Hosa Technology, Inc.	•	•	
Io Audio Technologies	•	•	•
JL Audio, Inc.	•	•	
Kimber Kable	•	•	
Kramer Electronics	•	•	
Kubala-Sosna Research, LLC	•	•	
Lamart Corp.	•	•	•
Madisound Speaker Components, Inc.	•		
Morrow Audio	•	•	
Nordost	•	•	
Parts Express	•	•	•
PowerPhysics, Inc.	•		
Pro Flix Sales	•	•	
ProCo Sound	•	•	
PRV Audio Brazil	•		
Radio Design Labs (RDL)	•	•	•
Redco Audio	•	•	•
Revolution Power	•	•	
Schurter Electronic Components	•	•	
Sommer Cable	•	•	
Sound Pure, LLC	•	•	
Soundoctor	•	•	
Stillwater Designs | KICKER	•		
Straight Wire, Inc.	•	•	•
SVS, Inc.	•	•	
Sweetwater Sound	•	•	
Tonian Laboratories	•		
Transparent Audio, Inc.	•		
TRS Inovations	•	•	
TSG Audio	•	•	
US Speaker, LLC	•	•	
VH Audio, Inc.	•	•	
Vidsonix Design Works	•	•	
Westlake Audio, Inc.	•	•	•
Wired 4 Sound, Inc.	•	•	•
Wireworld Cable Technology	•	•	
Yandas Music	•	•	
Zu Audio	•		
zZounds Music, LLC	•	•	
VIETNAM			
Sound Corp.	•	•	•



	Earphones	Headphones
AUSTRALIA		
Stone Sound Studio		•
AUSTRIA		
USound GmbH	•	•
BELGIUM		
The Innovators Lab Belgium (iLaB)		•
BRAZIL		
Harman of Brazil	•	•
Newbox Industry & Commerce	•	•
CANADA		
Focal North America		•
ORA Graphene Audio, Inc.	•	•
Solen Electronique, Inc.	•	•
CHINA		
Able-One Technology, Ltd.	•	•
Cosonic Acoustic Technologies Co., Ltd.	•	•
Dongguan Chao Tai Sponge Co., Ltd.	•	•
Dongguan Sunwe Electronic	•	•
Eastech Holding, Ltd.	•	•
Enkor Electronics Co., Ltd.		•
Gettop Acoustic Co., Ltd.	•	•
GoerTek Co., Ltd.	•	•
Grand Will Enterprise Co., Ltd.	•	•
Lumi Audio		•
Pana Sound, Ltd.	•	•
Shenzhen Horn Audio Co., Ltd.	•	•
Shenzhen R-Foam Technology	•	•
Sound Technology Development, Ltd.	•	•
Tonly Electronics Holdings	•	•
Vormag Electronics Co., Ltd.	•	•
Weide Electronics Co., Ltd.	•	•
Zhongshan K-Mate General Electronics Co., Ltd.	•	•
FRANCE		
Seltech	•	
HONG KONG		
BDNC (Holding), Ltd.		•
dB Enterprises	•	•
Eastern Asia Technology (HK), Ltd.	•	•
Fujikon Industrial Holdings, Ltd.	•	•
INNacoustic	•	•
Neutek International	•	•
OCVACO Electronic, Ltd.	•	•
WCE Acoustics	•	•
ISRAEL		
Alango Technologies, Ltd.	•	•
ITALY		
RCF, SpA		•
JAPAN		
Etani Electronics Co., Ltd.	•	
Furutech Co., Ltd.	•	•
S'NEXT Co., Ltd.	•	•
NETHERLANDS		
Diluvite		•
PHILIPPINES		
Dai-ichi Electronics Manufacturing Corp.	•	•
SOUTH KOREA		
Suntel Co., Ltd.	•	•
SWEDEN		
Audio Pro, AB		•
Oxeon AB/Textreme		•
SWITZERLAND		
SoundChip	•	•
TAIWAN		
AV Leader Corp.	•	•
ChiaPing Enterprise	•	•
Cotron Corp.	•	•
Dongguan Sheng-Yang Electronics	•	•
Fortune Grand Technology Inc.	•	•
Huey Tung International Co., Ltd.	•	•
Jetvox Acoustic Corp.	•	•
Kingstate Electronics Corp.	•	•
Merry Electronics	•	•
Palm Garden Enterprises Corp.	•	•
TOONG IN Electronic Corp.	•	•
Turbo Tide Electronics Co., Ltd.	•	•
Yung International, Inc.	•	•
THAILAND		
Clarasonic (Thailand) Co., Ltd.	•	•
Sanit Audio Engineering Co.		•
UNITED KINGDOM		
Electroacoustic Design Ltd.		•
Profusion, Ltd.		•
UNITED STATES		
1MORE	•	•
American Bass USA	•	•
American Music & Sound	•	•
Audio Advisor, Inc.	•	•
Audio Connection	•	•
AValive		•
B&H Foto & Electronics Corp.		•
BeStar Technologies, Inc.	•	•
Blackmore Mobile		•
Broad Bridge Audio, LLC	•	•
Christensen Audio, LLC		•
Dekoni Audio	•	•
Dragonfire Acoustics	•	•
Earthquake Sound Corp.	•	•
Echobox Audio, LLC	•	•
ESS Laboratories, LLC		•
ESTec America	•	•
Front End Audio, LLC		•
Full Compass Systems, Ltd.	•	•
GraphAudio	•	•
HAVE, Inc.		•
Hearing Components (Comply Memory Foam Tips)	•	•
Materion		•
Pacific Audio Consulting	•	•
Parts Express	•	•
Peerless by Tymphany (HK), Ltd.		•
PreSonus Audio Electronics, Inc.		•
Pro Flix Sales		•
Puro Sound Labs		•
RBH Sound	•	•
Revolution Power	•	
SAATI	•	•
Shure, Inc.	•	•
Sonion	•	•
Sound Pure, LLC		•
Sound Sources Technology, Inc.	•	•
Stillwater Designs | KICKER	•	•
Tectonic Audio Labs		•
US Enclosure Co.	•	•
Vintage King Audio		•
VTech	•	•
W.L. Gore & Associates	•	•
Western Electric		•
Yandas Music	•	•
Zu Audio		•
zZounds Music, LLC		•

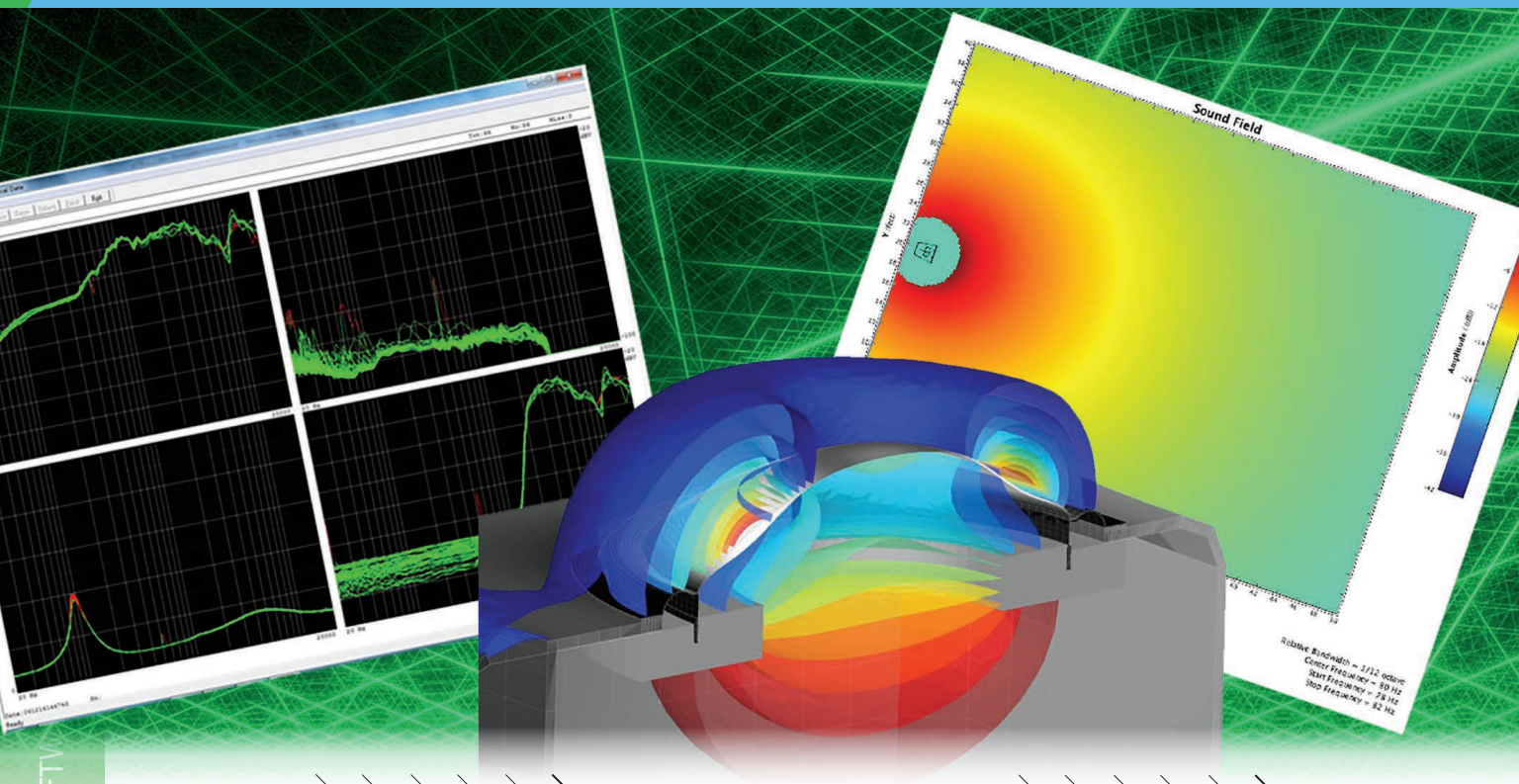
	Baffles		Finished Cabinets			Sub-Assemblies						Materials				Panels	Rigging	
	Ceiling Speaker Plates	In-Wall Plates	Box Arrays (PA)	Boxes	Stands	Bulk Molding Compound	Carpet	Hardwood	MDF (Fiberboard)	Other	Paper/Paper Pulp	Plastic	Plywood	Veneer	Wound Geometric Tubes			
AUSTRALIA																		
Stone Sound Studio																•	•	
BELGIUM																		
Donnet: Loudspeaker Repair	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Premium Sound Solutions	•			•							•		•					
BRAZIL																		
Advanced Audio Technologies (AAT)				•														
Attack do Brasil			•	•		•		•	•	•						•		•
Newbox Industry & Commerce	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•
CANADA																		
Canadian Speaker Works				•	•													•
Divergent Technologies			•	•	•													
Harbottle Audio	•	•	•	•							•		•			•		
Planet10-HiFi				•														
Solen Electronique, Inc.	•	•		•	•													
Sonavox Electronics Canada	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Studio Reference Monitors				•														
Sziara Sound				•	•			•	•					•		•		
CHINA																		
Bozhen Acoustic, Co., Ltd.				•														
Dongguan Chao Tai Sponge Co., Ltd.																•		
Eastech Holding, Ltd.			•	•	•													
GoerTek Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Hansong (Nanjing) Technology	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Jun Hao Audio Productions	•	•	•	•	•				•	•				•				
Junhao Wood Cabinet Factory	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Kadeton Audio	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Lumi Audio	•	•		•	•				•			•						
OBE Pro Audio Co., Ltd.																		•
Renyi Castings						•	•	•	•	•	•	•	•	•	•			•
Shenzhen Horn Audio Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Shenzhen R-Foam Technology																•		
Sound Technology Development, Ltd.																•	•	
Star Audio	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.																•	•	
Telefield	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Tonewinner (Guangzhou) Electronics			•	•	•	•	•	•	•	•	•	•	•	•	•			•
Tonly Electronics Holdings	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Tristar Electronics	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Trueanalog Strictly OEM				•	•			•	•		•			•				
Vistron Audio Equipment	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Vormag Electronics Co., Ltd.																•		
Xiamen Great Sound Technology	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
DENMARK																		
Kvart & Bølge				•														
FRANCE																		
Amplitude Audio	•	•		•														
KYU Systems			•	•									•		•	•		
Seltech				•														
GERMANY																		
Audio Technology Engineering (ATE)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Soundsgood Pro Audio Solutions	•	•	•	•	•	•		•	•	•								

	Baffles		Finished Cabinets			Sub-Assemblies										Materials			Panels	Rigging
	Ceiling Speaker Plates	In-Wall Plates	Box Arrays (PA)	Boxes	Bulk Molding Compound	Stands	Carpet	Hardwood	MDF (Fiberboard)	Other	Paper/Paper Pulp	Plastic	Plywood	Veneer	Wound Geometric Tubes					
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
HONG KONG																				
Beautiful Enterprise Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dB Enterprises																			•	
Fujikon Industrial Holdings, Ltd.																		•		
INNacoustic	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Neutek International																		•		
Ocean Star Electronics (HK) Co., Ltd.	•	•	•	•	•		•	•	•			•	•	•	•					
PlastoForm	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
HUNGARY																				
Bayz Audio										•								•		
INDIA																				
Arulsound							•	•						•				•		
GM Audio Technics, Ltd.			•	•																
Laysant Audio Private, Ltd.	•	•	•	•	•			•	•					•	•			•	•	
INDONESIA																				
Premiere Wood Manufacturing (PWM)	•	•	•	•	•			•	•	•		•	•	•				•	•	•
ITALY																				
Axiomedia, SRL				•	•		•											•		
JAPAN																				
Etani Electronics Co., Ltd.				•																
MEXICO																				
Aletheia, AV			•	•	•					•	•									
NETHERLANDS																				
Aequo Audio	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	
Diluvite	•	•		•	•	•		•	•	•	•	•	•	•				•	•	
Metaxas & Sins	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Sound Projects			•	•																•
PHILIPPINES																				
Dai-ichi Electronics Manufacturing Corp.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
POLAND																				
Sveda Audio				•	•															
ROMANIA																				
SC Poweraudio SRL			•	•																
SOUTH AFRICA																				
Paks Acoustics				•	•			•	•					•	•			•		
SPAIN																				
Sottovoce Audio				•	•															
Tecnare/Exel Acoustics SL			•	•	•															•
SWEDEN																				
Audio Pro, AB																		•	•	
TAIWAN																				
Huey Tung International Co., Ltd.	•	•	•	•	•	•	•		•				•							
Meiloon Industrial Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
TOONG IN Electronic Corp.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	
Turbo Tide Electronics Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	
Vansonic Enterprise Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Yie Feng Technology Enterprise Co., Ltd.													•						•	
Yung International, Inc.			•	•	•					•			•		•					
THAILAND																				
Clarasonic (Thailand) Co., Ltd.											•							•		
UNITED KINGDOM																				
BishopSound			•	•	•					•				•						
EuroTec International, PLC	•		•	•									•							
Hifi Collective, Ltd.							•	•	•	•	•	•	•	•	•	•				
Hill Acoustics											•									

	Baffles: Ceiling Speaker Plates	Baffles: In-Wall Plates	Finished Cabinets: Box Arrays (PA)	Finished Cabinets: Boxes	Sub-Assemblies: Bulk Molding Compound	Sub-Assemblies: Stands	Sub-Assemblies: Carpet	Sub-Assemblies: Hardwood	Sub-Assemblies: MDF (Fiberboard)	Sub-Assemblies: Other	Sub-Assemblies: Paper/Paper Pulp	Sub-Assemblies: Plastic	Materials: Plywood	Materials: Veneer	Materials: Wound Geometric Tubes	Materials: Other	Panels	Rigging
MJ Acoustics				•					•						•			
Sine Audio Systems				•		•												
UNITED STATES																		
3M (Industrial Adhesives & Tapes Division)																	•	
A List Wood Works, Inc.	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•
Acry-Tech Coatings, Inc.																	•	
Adrian Acoustics, Inc.	•	•	•	•	•			•	•	•			•	•				
American Bass USA	•	•	•	•	•													
Area 52 R&D				•						•	•			•	•			
Audio Connection									•									
AvileTech				•														
Cadillac Audio			•	•										•				•
Campanella Associates & Acculab											•							
Carvin Audio			•	•														
CGN Audio Labs			•	•							•							
Danley Sound Labs			•	•	•													
Dayton Audio				•														
Dekoni Audio																	•	
Eagle Acoustics			•	•	•		•			•			•					•
Emerald Physics	•	•																
Eminence Speaker, LLC			•	•														
Fulcrum Acoustic, LLC				•														
Full Compass Systems, Ltd.	•	•					•											•
GGEC America, Inc.				•			•	•	•				•	•	•			
Globe Plastics, Inc.	•	•		•		•				•			•					
Inlow Sound				•				•			•			•	•			
Intelligent Audio Products		•	•	•	•		•		•	•				•	•			•
J&F Wood Products	•	•	•	•	•		•	•	•	•				•	•		•	•
Levister Audio				•														
Lowell Manufacturing Co.	•	•		•														
Meliti Acoustics	•	•																
Midwest Audio Club				•	•			•	•					•	•			
OAP Audio			•	•										•				
Parts Express	•	•	•	•	•		•		•						•			
Ponderosa Sound Systems			•	•	•													
Portland Audio Lab	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Precision Sound Products, Inc.											•							
Quest Engines, LLC											•							
Rapid Die & Molding	•	•															•	
RBH Sound	•	•		•						•	•		•					
RCF USA, Inc.			•						•				•	•				
REDCATT			•	•						•			•	•	•			
SAATI																	•	
SoCal Sound Shop			•	•														
Sound Anchors					•													
Sound Sources Technology, Inc.	•	•	•	•	•		•											
SpeakersAndAmps.com			•	•														
SSI Manufacturing, Inc.			•	•						•				•				
Studio Electric, LLC			•	•					•	•					•			
T&T Shanghai Tianai Acoustics Co., Ltd.			•	•	•													
TMI Engineering											•							
TRS Inovations	•	•	•	•		•	•	•	•	•	•	•	•	•	•		•	•
TSG Audio			•	•	•													
United Gasket Corp.	•	•					•					•					•	
US Enclosure Co.	•	•	•	•	•						•		•		•	•		•
US Speaker, LLC			•	•	•													
VH Audio, Inc.			•															
Vidsonix Design Works				•						•								
VTech	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•
Wired 4 Sound, Inc.																		•
Yandas Music				•	•													
VIETNAM																		
Sound Corp.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	

	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												
Newbox Industry & Commerce	•	•	•	•	•	•	•	•	•	•	•	•
Phix Electronics	•	•	•	•	•	•	•	•	•	•	•	•
CANADA												
Canadian Speaker Works	•						•	•		•	•	
Reference 3A	•					•						
Solen Electronique, Inc.	•	•	•	•	•	•		•				•
Tortech Sound	•											
CHINA												
GoerTek Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•
Hansong (Nanjing) Technology	•	•	•	•	•	•	•	•	•	•	•	•
Junhao Wood Cabinet Factory						•	•	•				
Kadeton Audio	•	•	•	•	•	•	•	•	•	•	•	•
Lumi Audio								•				
OBE Pro Audio Co., Ltd.	•								•	•		
Renyi Castings									•	•	•	•
Sound Technology Development, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•
Trueanalog Strictly OEM											•	
Xiamen Great Sound Technology						•	•	•				
FRANCE												
KYU Systems	•		•		•	•	•	•	•			
Seltech		•	•	•	•	•	•	•				
GERMANY												
Audio Technology Engineering (ATE)	•	•	•	•	•	•	•	•	•	•	•	•
Hubert Stüken GmbH								•				
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•
HONG KONG												
Beautiful Enterprise Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•
INNacoustic	•	•	•	•	•	•	•	•	•	•	•	•
Neutek International	•	•	•	•	•							
Ocean Star Electronics (HK) Co., Ltd.	•											
INDIA												
Arulsound	•	•	•	•	•	•	•	•	•	•	•	•
GM Audio Technics, Ltd.			•									
Laysant Audio Private, Ltd.	•										•	
ITALY												
Axiomedia, SRL						•	•		•	•	•	

	Enclosure Grilles	Enclosure Stuffing: Fiberglass	Enclosure Stuffing: Foam	Grille Assemblies: Synthetic	Grille Assemblies: Wool	Grille Assemblies: Fabric Suppliers	Grille Assemblies: Foam Suppliers	Grille Assemblies: Perforated Metal Suppliers	Hardware: Corners	Hardware: Handles	Hardware: Name Plates	Hardware: Fasteners & Other
NETHERLANDS												
Diluvite								•				
Good Hifi VOF				•		•						
PHILIPPINES												
Dai-ichi Electronics Manufacturing Corp.	•	•	•	•	•	•	•	•	•	•	•	•
SOUTH KOREA												
SOtM Audio						•	•	•	•	•	•	•
SWEDEN												
Audio Pro, AB	•	•	•	•	•	•		•	•			•
TAIWAN												
Shining Jins Enterprise Co., Ltd.											•	•
Taiwan Solidex Corp.	•										•	
Vansonic Enterprise Co., Ltd.						•	•	•				
Yie Feng Technology Enterprise Co., Ltd.	•		•				•					
UKRAINE												
MAG Audio	•											
UNITED KINGDOM												
EuroTec International, PLC	•	•	•	•		•	•	•				
Hifi Collective, Ltd.										•	•	•	•
UNITED STATES												
A List Wood Works, Inc.	•	•	•	•	•	•	•	•	•	•	•	•	•
A. Schulman, Inc.	•											
Accurate Perforating Co., Inc.	•								•			
Acry-Tech Coatings, Inc.												•
Adrian Acoustics, Inc.	•	•	•	•	•	•	•					
American Bass USA	•									•	•	•	•
C.P. Moyen		•	•	•	•							
Carvin Audio										•	•		•
Dayton Audio	•											
Dynavox Electronics, Inc.										•	•		
Eminence Speaker, LLC	•	•	•	•	•	•	•	•	•	•	•	•	•
Foam Speaker Grilles	•						•						
Full Compass Systems, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•
Globe Plastics, Inc.	•									•	•		
Hendrick Manufacturing									•				
J&F Wood Products	•	•	•	•	•	•			•	•	•		•
Lowell Manufacturing Co.	•								•				
Meliti Acoustics	•	•	•	•	•	•	•						
Meniscus Audio Group, Inc.			•	•									
MetalEX	•								•				
ORCA Design and Manufacturing					•								
Precision Sound Products, Inc.													•
Quest Engines, LLC													•
RBH Sound	•												
SAATI	•	•	•	•	•								
SpeakerAddict	•	•	•	•	•	•			•	•	•		•
TRS Inovations	•	•	•	•	•	•	•	•	•	•	•	•	•
United Gasket Corp.			•	•	•	•	•						
US Enclosure Co.	•	•	•	•	•	•	•	•				•	
US Speaker, LLC										•	•	•	•
Vidsonix Design Works	•								•				
VIETNAM												
Sound Corp.	•	•	•	•	•	•	•	•	•	•	•	•	•



	Acoustic Analysis	Box Design	Crossover Optimizer	Network Design	CAE or CAD
AUSTRALIA					
Audinate, Pty., Ltd.	•	•	•	•	•
Audiosoft	•	•	•	•	
DEQX, Pty., Ltd.	•		•	•	
Eclipse Audio			•		
Stone Sound Studio	•	•	•		•
BELGIUM					
Donnet: Loudspeaker Repair	•	•	•		
BRAZIL					
Newbox Industry & Commerce	•	•	•	•	•
CANADA					
Solen Electronique, Inc.	•	•	•		
Space-Tech Lab, Ltd.	•				
CHINA					
BSWA Technology Co., Ltd.	•				
Eastech Holding, Ltd.	•	•			•
GoerTek Co., Ltd.	•	•	•	•	
Hansong (Nanjing) Technology	•	•	•	•	•
Junhao Wood Cabinet Factory		•			
Kadeton Audio		•			•
Pana Sound, Ltd.	•	•	•	•	
Sound Technology Development, Ltd.	•	•	•	•	•
Star Audio		•			
Sun Technique Electric Co., Ltd.	•	•	•	•	•
Trueanalog Strictly OEM		•			•
Xiamen Great Sound Technology		•			
DENMARK					
K & K Development	•				
Loudsoft, Ltd.	•	•	•		
FRANCE					
KYU Systems	•		•	•	•
Seltech	•	•	•	•	
SIEA	•	•	•	•	•
GERMANY					
Audio Technology Engineering (ATE)	•	•	•	•	•
Klippel GmbH	•	•		•	•
Mvoid Technologies GmbH	•				•
R&D Team Software Development	•	•	•	•	
Soundsgood Pro Audio Solutions	•	•			•
Voice Point	•	•	•	•	•
HONG KONG					
Beautiful Enterprise Co., Ltd.	•	•	•	•	•
INNacoustic	•	•	•	•	
Ocean Star Electronics (HK) Co., Ltd.	•	•			•
INDIA					
GM Audio Technics, Ltd.	•				
TurboSonic Pro Speakers					•
IRELAND					
Crossover Filter App			•		

	Acoustic Analysis	Box Design	Crossover Optimizer	Network Design	CAE or CAD
ITALY					
Audiomatica, SRL	•				
SpeakerLAB	•				•
JAPAN					
Etani Electronics Co., Ltd.	•	•			•
LATVIA					
Acoustic Power Lab	•		•		
Sonarworks	•				
PHILIPPINES					
Dai-ichi Electronics Manufacturing Corp.	•	•	•	•	•
SINGAPORE					
Virtins Technology	•				
SOUTH KOREA					
SOtM Audio		•			
Suntel Co., Ltd.	•	•	•	•	•
SPAIN					
Brusi Acoustics	•	•		•	
SWEDEN					
Audio Pro, AB	•	•	•	•	
Bohmer Audio	•		•		•
IJData	•	•	•	•	•
SWITZERLAND					
Archwave				•	
TAIWAN					
Kingstate Electronics Corp.	•				•
Vansonic Enterprise Co., Ltd.		•			
UNITED KINGDOM					
Electroacoustic Design Ltd.	•	•	•		•
EuroTec International, PLC					•
Hill Acoustics	•	•	•		•
PACSYS, Ltd.	•				
Rush PCB UK				•	
Spectral Measurement	•				
UNITED STATES					
A List Wood Works, Inc.		•			
Audio Precision, Inc.	•				
Bruel & Kjaer Sound & Vibration North America, Inc.	•				
Community Professional Loudspeakers	•	•	•	•	•
COMSOL	•				•
Danville Signal Processing, Inc.	•		•	•	
Digmoda			•		
Dragonfire Acoustics	•	•	•		•
Geometric Designs, LLC & Geometric Consulting		•	•		•
HEAD acoustics, Inc.	•				
HX Audio Lab	•	•	•	•	•
Listen, Inc.	•				
Meliti Acoustics	•	•	•	•	•
MSC Software Corp.	•		•		•
NedLab		•	•	•	
Parts Express	•	•			
Portland Audio Lab	•	•			
Scantek, Inc.	•				
Soundoctor	•		•		
Speaker Clinic		•	•		•
Studio Six Digital	•				
True Technologies, Inc.	•				
Warkwyn	•	•	•		
VIETNAM					
Sound Corp.		•	•	•	•

	Car Audio	Home Audio	Marine Audio	Pro Audio
AUSTRALIA				
Lenard Audio, Pty., Ltd.		•		•
Stone Sound Studio	•	•		•
BELGIUM				
Donnet: Loudspeaker Repair	•	•	•	•
Premium Sound Solutions	•	•		
BRAZIL				
Advanced Audio Technologies (AAT)		•		
AMCP Eletrônica		•		
Attack do Brasil				•
Audiopax Audio Systems		•		
Harman of Brazil	•	•	•	•
Magna Audio		•		
Newbox Industry & Commerce	•	•	•	•
CANADA				
Acora Acoustics Corp.		•		
Canadian Speaker Works				•
Divergent Technologies		•		
Focal North America	•	•		•
Harbottle Audio		•	•	•
LMH Loudspeakers	•	•		•
Newform Research, Inc.		•		•
Planet10-HiFi		•		
Reference 3A		•		•
Solen Electronique, Inc.	•	•		•
Sonavox Electronics Canada		•		
Space-Tech Lab, Ltd.		•		
Studio Reference Monitors				•
StudioLAB		•		
CHINA				
Audiostar Electronics Co., Ltd.	•	•		•
B.W. Audio Guangzhou, Co., Ltd.				•
Eastech Holding, Ltd.	•	•	•	•
Enkor Electronics Co., Ltd.		•		
Fountek Electronics Co., Ltd.	•	•		•
GoerTek Co., Ltd.	•	•		
Hansong (Nanjing) Technology	•	•	•	•
Jun Hao Audio Productions		•		
Junhao Wood Cabinet Factory	•	•	•	
Lumi Audio		•		•

	Car Audio	Home Audio	Marine Audio	Pro Audio
OBE Pro Audio Co., Ltd.				•
Shenzhen Horn Audio Co., Ltd.	•	•		
Sonos, Inc.		•		
Sound Technology Development, Ltd.		•		•
Sun Technique Electric Co., Ltd.	•	•		•
Telefield		•		
Tonly Electronics Holdings	•	•		
Tristar Electronics		•		
Trueanalog Strictly OEM	•	•	•	•
Vistron Audio Equipment		•		
Weide Electronics Co., Ltd.		•		
Xiamen Great Sound Technology	•	•	•	
Zeng Ben Industrial Corp., Ltd.	•	•		•
Zhongshan K-Mate General Electronics Co., Ltd.		•		
Zhuhai HiVi Technology Co., Ltd.	•	•		•
DENMARK				
Dynaudio		•	•	•
ICEpower a/s	•	•		•
Kvart & Bølge		•		
Lyd by Dissing		•		
Pascal a/s				•
FINLAND				
Genelec Oy		•		•
FRANCE				
Crista Technologies		•		
KYU Systems				•
Seltech	•	•		•
Supravox		•		•
T&T Acoustic Speakers		•		
Waterfall Audio		•		•
GERMANY				
Ascendo Immersive Audio		•		•
Audio Technology Engineering (ATE)	•	•	•	•
AudioChiemgau		•		
Eton GmbH	•	•		
HiFi-Tuning		•		•
ic audio			•	•
Lautsprecher-Produktions-Gesellschaft (LPG)	•			
Mvoid Technologies GmbH	•	•		•
Quint Audio				•

	Car Audio	Home Audio	Marine Audio	Pro Audio
Scherer Audio		•		
Voice Point		•	•	•
Wolf von Langa		•		
HONG KONG				
Beautiful Enterprise Co., Ltd.		•		
dB Enterprises	•	•	•	•
Eastern Asia Technology (HK), Ltd.	•	•	•	•
Fujikon Industrial Holdings, Ltd.	•	•	•	
INNacoustic	•	•		
miniDSP, Ltd.	•	•		•
Ocean Star Electronics (HK) Co., Ltd.		•		•
PlastoForm		•		
WCE Acoustics		•		
HUNGARY				
Bayz Audio		•		•
INDIA				
Decibels Audio Private, Ltd.		•		
GM Audio Technics, Ltd.				•
Indiq Audio LLP		•		
Laysant Audio Private, Ltd.	•	•		
Power Electronics & Technologies		•		•
INDONESIA				
SB Acoustics		•		
IRELAND				
Crossover Filter App	•	•	•	•
ISRAEL				
Morel, Ltd.	•	•		
ITALY				
Powersoft, SpA				•
JAPAN				
Etani Electronics Co., Ltd.	•	•		•
MEXICO				
Aletheia, AV		•		
NETHERLANDS				
Aequo Audio		•		
Diluvite	•	•	•	•
ELTIM audio, BV		•		•
Metaxas & Sins		•		•
Sound Projects				•
NEW ZEALAND				
Theophany Loudspeakers		•		
NORWAY				
SEAS Fabrikker AS		•		
PHILIPPINES				
Dai-ichi Electronics Manufacturing Corp.	•	•	•	•
POLAND				
Sveda Audio		•		•
ROMANIA				
SC Poweraudio SRL				•

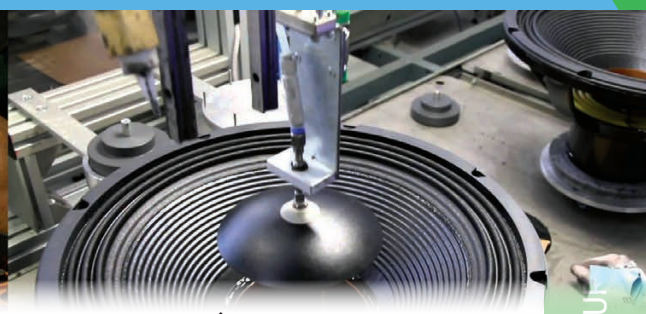
	Car Audio	Home Audio	Marine Audio	Pro Audio
RUSSIA				
Deluxe Acoustics		•		
Star Sound Technologies	•	•		•
SOUTH KOREA				
Suntel Co., Ltd.	•	•		•
SPAIN				
DAS Audio				•
Sottovoce Audio		•		•
SWEDEN				
Audio Pro, AB	•	•		•
SWITZERLAND				
Lange Loudspeakers		•		•
TAIWAN				
AV Leader Corp.				•
Bennic and Company	•	•	•	•
Cotron Corp.		•		
Huey Tung International Co., Ltd.	•	•		•
Kingstate Electronics Corp.	•	•		
Meiloon Industrial Co., Ltd.	•	•	•	
TOONG IN Electronic Corp.		•		
Turbo Tide Electronics Co., Ltd.		•		
Vansonic Enterprise Co., Ltd.	•	•	•	

	Car Audio	Home Audio	Marine Audio	Pro Audio
UKRAINE				
MAG Audio				•
UNITED KINGDOM				
Arya Audio Labs, Ltd.	•	•		•
Compbass, Ltd.		•		•
Electroacoustic Design Ltd.	•	•	•	•
EuroTec International, PLC	•		•	•
Fane International, Ltd.				•
Ferguson Hill Studios, Ltd.		•		•
MJ Acoustics		•	•	•
Node Audio Research, Ltd.		•		
Precision Devices, Ltd.				•
Sine Audio Systems		•		
Tectonic Elements, Ltd.	•	•		•
UNITED STATES				
Aempyrean	•	•		•
Ambiance Acoustics		•		•
American Bass USA	•			
American Music & Sound	•	•	•	•
Analysis Audio USA		•		
Area 52 R&D		•		•
Arion Audio		•		
Audio Houze	•			
Audioengine		•		
AvileTech				•
B&H Foto & Electronics Corp.		•		•
Barefoot Sound, LLC				•
BassBoss				•
Benchmark Media Systems		•		
Blackmore Mobile		•		•
Broad Bridge Audio, LLC		•		
Cadillac Audio				•
Carvin Audio		•		
CE Distribution			•	
CGN Audio Labs				•
Clear Lake Audio				•
CommonSense Audio		•		•
Creative Sound Solutions, LLC		•		
Danley Sound Labs				•
Dayton Audio		•		
dBTechnologies				•
DC Audio	•			
Digital Audio Labs				•
Digmoda		•		•
Eagle Acoustics	•	•	•	•
Earthquake Sound Corp.	•	•	•	•
Emerald Physics		•		
Eminence Speaker, LLC				•
ESS Laboratories, LLC	•	•		
ESTec America	•	•	•	
Fluid Audio				•
Fulcrum Acoustic, LLC				•
Gauss Loudspeaker		•		•
Geometric Designs, LLC & Geometric Consulting		•		
GGEC America, Inc.	•	•	•	•
Globe Audio Design, Inc.		•		•
GoldenEar Technology		•		
Halford Loudspeakers		•		•
Io Audio Technologies	•	•	•	•
JL Audio, Inc.	•	•	•	
Levister Audio		•		
Linea Research USA				•
Lipinski Sound		•		•
Marchand Electronics, Inc.		•		
Meliti Acoustics	•	•		•
Meyer Sound Laboratories, Inc.		•		•
MISCO		•		•
NHT Audio, LLC		•		
North American Solidex, LLC		•		•
OAP Audio		•		•
ORCA Design and Manufacturing	•	•		
Parts Express	•	•		•
Pazandeh Audio Designs		•		•
Peerless by Tymphany (HK), Ltd.	•	•		•
Performance Audio, LLC				•
Phoenix Engineering, LLC		•		
Portland Audio Lab	•	•	•	•
PranaFidelity		•		
Precison Transducer Engineering (PTE)		•		•
Pro Flix Sales				•
Purist Sonics		•		•
RBH Sound		•		
RCF USA, Inc.				•
REDCATT		•		•
RIVA Audio		•		
Rock The Boat			•	
RSL Speaker Systems		•		
Salk Sound		•		
SensaSound USA		•		
Senzar Acoustics		•	•	•
SG Custom Sound		•		•
SoCal Sound Shop	•	•	•	•
Sound Audio Manufacturing, LLC	•	•	•	•
Sound Lab		•		
Sound Sources Technology, Inc.	•	•		
Soundfield Audio		•		
Sounds Unique	•	•		•
SpeakerPower		•		•
SpeakersAndAmps.com	•	•		•
SSI Manufacturing, Inc.		•		•
Studio Electric, LLC		•		•
T&T Shanghai Tianai Acoustics Co., Ltd.	•	•	•	•
TitanAudio		•		•
Tonian Laboratories		•		•
TRS Inovations	•	•	•	•
TSG Audio	•	•		•
US Speaker, LLC	•	•		•
Vidsonix Design Works	•	•	•	
VTech		•		•
Weltronics Corp.		•		
Westlake Audio, Inc.		•		•
Wired 4 Sound, Inc.		•		•
Wisdom Audio		•		
Yandas Music				•
Zu Audio		•		
VIETNAM				
Sound Corp.		•		•
Sun Technique	•	•	•	•

	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
AUSTRALIA							
DEQX, Pty., Ltd.	•	•	•	•			•
Eclipse Audio		•					
Lenard Audio, Pty., Ltd.	•						
Soundlabs Group, Pty., Ltd.	•		•			•	•
Stone Sound Studio	•	•	•			•	•
BELGIUM							
Donnet: Loudspeaker Repair				•	•	•	
The Innovators Lab Belgium (iLaB)			•				
BRAZIL							
Advanced Audio Technologies (AAT)	•		•			•	•
Attack do Brasil	•	•	•				
Harman of Brazil	•	•	•	•	•	•	•
Magna Audio	•				•	•	
Newbox Industry & Commerce	•	•	•	•	•	•	•
CANADA							
Harbottle Audio	•	•	•			•	
Rutherford Audio, Inc.	•		•				
Solen Electronique, Inc.	•	•	•		•	•	•
Sonavox Electronics Canada	•	•	•		•	•	•
Studio Reference Monitors	•	•					
Tortech Sound	•						
CHINA							
Eastech Holding, Ltd.	•	•	•	•	•	•	•
Enkor Electronics Co., Ltd.					•		
Fountek Electronics Co., Ltd.	•	•	•				•
Gettop Acoustic Co., Ltd.	•	•	•				•
GoerTek Co., Ltd.	•	•	•		•	•	•
Hansong (Nanjing) Technology	•	•	•		•	•	•
Lumi Audio	•		•			•	•
MYIR Tech, Ltd.		•					•
OBE Pro Audio Co., Ltd.	•	•				•	
Pana Sound, Ltd.	•	•	•	•	•	•	•
Shenzhen Horn Audio Co., Ltd.		•			•	•	•
Sound Technology Development, Ltd.	•		•		•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•
Telefield	•	•	•		•	•	•
Tonewinner (Guangzhou) Electronics	•		•			•	
Tonly Electronics Holdings		•			•		•
Tristar Electronics	•	•	•		•	•	•
Vistron Audio Equipment	•	•	•		•		•
DENMARK							
ICEpower a/s	•	•	•			•	
Kvart & Bølge	•						•
Pascal a/s			•				
Purifi Audio	•		•				
FRANCE							
Amplitude Audio	•	•					•
IDEA	•		•				
KYU Systems	•	•	•	•		•	
SIEA	•	•	•				•
GERMANY							
Audio Technology Engineering (ATE)	•	•	•	•	•	•	
AudioChiemgau	•	•	•		•		
ic audio				•			•
Klippel GmbH	•	•					
Physical-Lab	•	•				•	
Voice Point	•	•	•	•	•	•	•
HONG KONG							
Beautiful Enterprise Co., Ltd.	•	•	•		•	•	•
Eastern Asia Technology (HK), Ltd.	•	•	•	•	•	•	•
Fujikon Industrial Holdings, Ltd.		•			•		•
INNacoustic	•	•	•		•	•	•
miniDSP, Ltd.	•	•				•	
OCVACO Electronic, Ltd.		•					•
PlastoForm	•		•		•	•	•
WCE Acoustics					•		•
INDIA							
Laysant Audio Private, Ltd.					•		
Power Electronics & Technologies	•		•			•	
TurboSonic Pro Speakers						•	

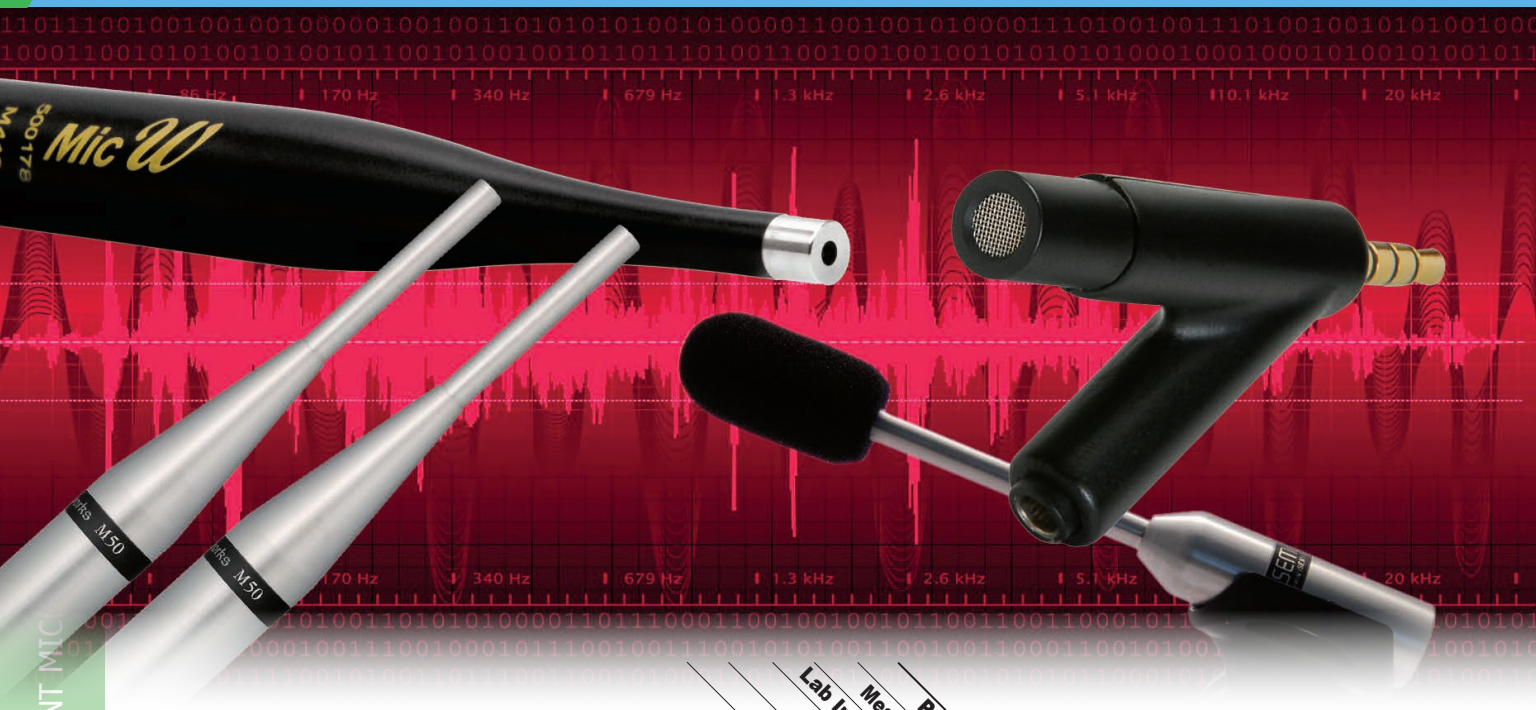
	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
INDONESIA							
Premiere Wood Manufacturing (PWM)	•	•	•	•	•	•	•
ISRAEL							
Alango Technologies, Ltd.		•					•
ITALY							
Axiomedia, SRL	•	•	•			•	
Outline SRL	•	•		•			
Powersoft, SpA	•	•	•	•			
JAPAN							
Etani Electronics Co., Ltd.	•	•	•		•	•	•
NETHERLANDS							
Aequo Audio	•						
ELTIM audio, BV	•		•				
Hypex Electronics, BV	•	•	•			•	
PHILIPPINES							
Dai-ichi Electronics Manufacturing Corp.	•	•	•		•	•	•
SPAIN							
Tecnare/Exel Acoustics SL	•	•					
SWEDEN							
Audio Pro, AB		•	•		•	•	•
Bohmer Audio	•	•	•			•	•
TAIWAN							
AV Leader Corp.		•			•	•	•
ChiaPing Enterprise		•					•
Jetvox Acoustic Corp.		•					•
Kingstate Electronics Corp.	•				•		•
Meiloon Industrial Co., Ltd.	•		•		•	•	•
Merry Electronics		•					•
Palm Garden Enterprises Corp.		•					•
TOONG IN Electronic Corp.		•			•	•	•
Turbo Tide Electronics Co., Ltd.		•			•	•	•
Yung International, Inc.	•					•	•
UNITED KINGDOM							
EuroTec International, PLC	•		•	•			
Ferguson Hill Studios, Ltd.	•	•	•				•
Kleio Audio, Ltd.	•						
MJ Acoustics			•			•	
Revolver Audio, Ltd.	•						
Sine Audio Systems	•		•		•		
Tectonic Elements, Ltd.	•						
UNITED STATES							
Area 52 R&D	•	•	•			•	
Arion Audio	•						
Audio Advisor, Inc.	•						
Avel Lindberg	•						
Axiim	•	•	•	•	•	•	•
Barefoot Sound, LLC	•	•	•				
Benchmark Media Systems	•	•					
Broad Bridge Audio, LLC	•				•		
Cadillac Audio			•				
Carvin Audio	•	•					•
CE Distribution	•	•	•		•		•
CGN Audio Labs							•
CommonSense Audio	•						
Danville Signal Processing, Inc.	•	•	•	•		•	
Dayton Audio	•	•	•		•	•	•
DC Audio	•		•				
Digital Audio Labs	•	•					
Digmoda	•	•	•			•	
DMSI	•	•	•				
Dragonfire Acoustics	•	•	•	•	•	•	•
DTV Installations	•		•		•	•	•
Eagle Acoustics	•			•	•		•
Earthquake Sound Corp.	•		•			•	
Emerald Physics	•	•				•	
Fortemedia		•					
Fulcrum Acoustic, LLC		•					
Globe Audio Design, Inc.	•	•	•			•	
JL Audio, Inc.	•	•	•	•		•	•
Kramer Electronics	•	•	•			•	•
Lectrosonics							•
Linea Research USA	•	•	•				
Linear Tube Audio	•		•				
MISCO	•	•	•		•		
North American Solidex, LLC	•	•				•	•
OAP Audio	•	•	•				
Parts Express	•	•	•		•	•	•
Peerless by Tymphany (HK), Ltd.	•	•	•		•		•
Ponderosa Sound Systems	•						
PowerPhysics, Inc.	•	•	•			•	
Pro Flix Sales	•						
Radio Design Labs (RDL)	•		•				
RBH Sound	•					•	
RCF USA, Inc.	•	•	•				
RIVA Audio	•	•	•		•	•	•
SensaSound USA	•					•	
Senzar Acoustics	•	•	•		•	•	
Sound Audio Manufacturing, LLC	•	•	•	•		•	
SpeakerAddict	•	•	•	•		•	
SpeakerPower	•	•	•			•	•
SpeakersAndAmps.com	•	•	•	•		•	
Stillwater Designs | KICKER	•	•	•	•			•
Transducer Lab, LLC							
TRS Inovations	•	•	•	•	•	•	•
TSG Audio	•	•	•		•	•	
US Enclosure Co.	•	•	•		•	•	•
US Speaker, LLC	•						
Vidsonix Design Works				•			
VTech	•	•	•		•	•	•
Weltronics Corp.	•	•	•				
Western Electric	•						
Wired 4 Sound, Inc.	•	•			•		•
Wisdom Audio		•			•		
VIETNAM							
Sound Corp.	•	•	•		•	•	•





	Adhesive Dispensers	Conveyors	Curing Ovens	Lead Out Wire Termination	Production Line Equipment	Magnetizers/Demagnetizers	Ultrasonic Assembly Equipment
AUSTRALIA							
Applied Measurement Australia, Pty., Ltd.						•	
Stone Sound Studio						•	
BRAZIL							
Attack do Brasil	•	•	•	•	•	•	•
Newbox Industry & Commerce						•	
CHINA							
OBE Pro Audio Co., Ltd.	•	•	•	•	•	•	
Sound Technology Development, Ltd.	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•
DENMARK							
K & K Development						•	
Loudsoft, Ltd.						•	
GERMANY							
Klippel GmbH						•	
preeflow by ViscoTec Pumpen- u. Dosiertechnik GmbH	•						
INDIA							
Cruxweld Industrial Equipment, Ltd.						•	
Lakshmi Metal Coils							•
JAPAN							
Etani Electronics Co., Ltd.						•	
SPAIN							
Tecnare/Exel Acoustics SL						•	
SWEDEN							
Audio Pro, AB						•	
SWITZERLAND							
Kisling AG	•						
Megatec AG		•		•	•	•	•
TAIWAN							
Hurray Co., Ltd.	•					•	
THAILAND							
Clarasonic (Thailand) Co., Ltd.	•	•	•				
UNITED KINGDOM							
EuroTec International, PLC	•	•	•	•	•	•	•
GRAS Sound & Vibration UK						•	
Hill Acoustics						•	
Silcoms, Ltd.		•					

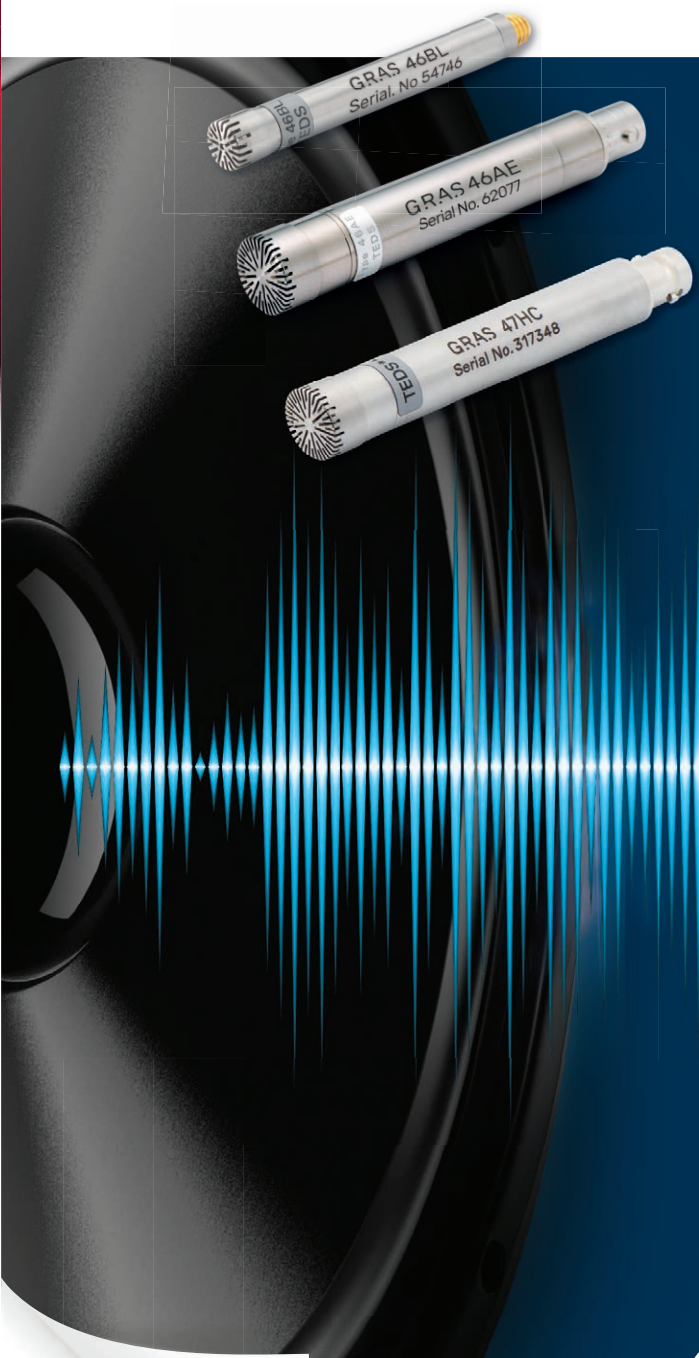
	Adhesive Dispensers	Conveyors	Curing Ovens	Lead Out Wire Termination	Production Line Equipment	Magnetizers/Demagnetizers	Ultrasonic Assembly Equipment
UNITED STATES							
3M (Industrial Adhesives & Tapes Division)	•		•				
Acoustic Design, Inc.							•
Adrian Acoustics, Inc.		•			•		
Alliance, LLC							•
Astro Machine Works, Inc.					•		•
Bostik	•						
Bruel & Kjaer Sound & Vibration North America, Inc.					•		
C.P. Moyen	•						
Conveyor Systems & Engineering, Inc.		•					
Cotronics Corp.	•						
DELO Industrial Adhesives, LLC	•				•		
Delta H Technologies, LLC			•				
Dragonfire Acoustics							•
Dukane Northeast Technical Center					•		•
Dymax Corp.	•						
Dynavox Electronics, Inc.							•
Eberhard Manufacturing Co.	•				•		
Elektrisola				•			
Ellsworth Adhesives	•						
EXACT Dispensing Systems	•				•		
Fisnar, Inc.	•						
Fluid Metering, Inc.	•				•		
Glenro, Inc.			•				
Global Finishing Solutions, LLC			•				
Hernon Manufacturing, Inc.	•	•	•		•		
Huntsman Advanced Materials	•				•		
Integrated Dispensing Solutions	•				•		
Krayden, Inc.	•						
LEWCO, Inc.		•	•				
Metzgar Conveyors		•					
Nordson EFD	•				•		
NTi Audio					•		
Parts Express	•						
PRV Audio Brazil					•		
Sealant Equipment	•						
The Eraser Co.					•		
The Hose Co.					•		
Uni-Pak Corp.		•					
Valley Design Corp.					•		•
Valves Only	•				•		
Wisconsin Oven			•				
WSF Industries, Inc.			•				



	Consumer	Field Mics	Lab Instruments	Measuring Mics	Professional
AUSTRALIA					
DEQX, Pty., Ltd.				•	
RØDE Microphones	•			•	•
AUSTRIA					
Austrian Audio			•	•	
BRAZIL					
Newbox Industry & Commerce	•	•		•	•
CANADA					
Solen Electronique, Inc.	•	•		•	
CHINA					
BSWA Technology Co., Ltd.		•	•	•	•
CRY Sound Co., Ltd.		•	•	•	•
Lumi Audio	•	•		•	
Shenzhen Horn Audio Co., Ltd.	•	•			
Sound Technology Development, Ltd.					•
Sun Technique Electric Co., Ltd.	•	•	•	•	•
Tonly Electronics Holdings	•	•			
DENMARK					
DPA Microphones		•		•	•
Jantzen Audio Denmark	•				
K & K Development				•	
FRANCE					
KYU Systems			•	•	
Seltech			•		
GERMANY					
Klippel GmbH			•	•	
Microtech Gefell GmbH			•	•	•
Voice Point	•	•	•	•	•

Whatever your testing challenge, GRAS has the right solution

Capture reliable data–the first time, every time



A superior line of standard and custom products is available dedicated to your loudspeaker testing:

- Overall SPL
- Frequency response
- Rub and buzz
- THD
- Speech intelligibility

GRAS Sound & Vibration

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Audio precision

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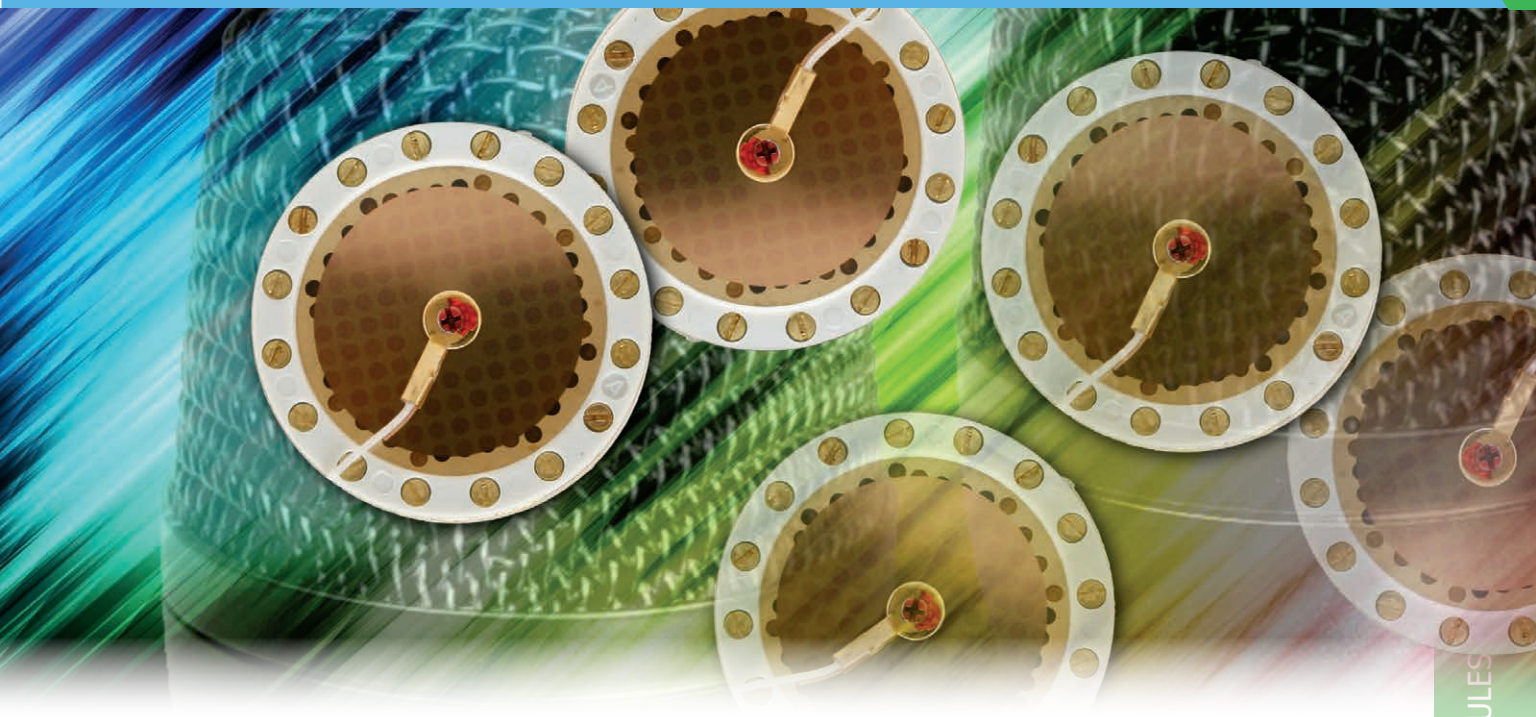
	Consumer	Field Mics	Lab Instruments	Measuring Mics	Professional
HONG KONG					
miniDSP, Ltd.				•	
WCE Acoustics	•				•
INDIA					
GM Audio Technics, Ltd.				•	
ISRAEL					
Audio Pixels, Ltd.		•	•		•
JAPAN					
Etani Electronics Co., Ltd.		•	•	•	
LATVIA					
Sonarworks				•	
SINGAPORE					
Virtins Technology	•		•	•	•
SOUTH KOREA					
Suntel Co., Ltd.	•	•	•	•	•
SWEDEN					
Audio Pro, AB			•	•	
SWITZERLAND					
SoundChip			•		

	Consumer	Field Mics	Lab Instruments	Measuring Mics	Professional
TAIWAN					
AV Leader Corp.	•	•	•	•	•
Kingstate Electronics Corp.	•				
UNITED KINGDOM					
DBS Audio				•	
EuroTec International, PLC			•	•	•
GRAS Sound & Vibration UK		•	•	•	
Spectral Measurement			•	•	•
UNITED STATES					
ACO Pacific, Inc.		•	•	•	•
Audio Precision, Inc.			•	•	
Audix	•			•	•
AValive	•				•
B&H Foto & Electronics Corp.	•				•
Behringer				•	•
Bruel & Kjaer Sound & Vibration North America, Inc.			•	•	
Dayton Audio	•	•	•	•	•
Earthworks, Inc.	•	•	•	•	•
Front End Audio, LLC	•	•	•	•	•
Full Compass Systems, Ltd.	•	•			•

	Consumer	Field Mics	Lab Instruments	Measuring Mics	Professional
Gold Line				•	•
GRAS Sound & Vibration	•	•	•	•	•
iSEMcon, LLC	•	•	•	•	•
JLI Electronics, Inc.	•	•	•	•	•
Lectrosonics				•	•
Listen, Inc.				•	
NTi Audio			•	•	•
Parts Express	•	•	•	•	•
PCB Piezotronics, Inc.	•	•	•	•	•
PreSonus Audio Electronics, Inc.				•	
Scantek, Inc.		•	•	•	•
Sound Pure, LLC	•				•
Speaker Clinic				•	
Studio Six Digital			•	•	
Sweetwater Sound	•				•
Vintage King Audio	•			•	•
Wired 4 Sound, Inc.	•	•		•	•
Yandas Music	•				•
zZounds Music, LLC					•
VIETNAM					
Sound Corp.	•				•



	Dynamic Capsules	ECM	LDC	MEMS	True Condenser
AUSTRALIA					
RØDE Microphones	•	•	•		•
AUSTRIA					
Austrian Audio	•	•	•		•
USound GmbH				•	
CHINA					
BSWA Technology Co., Ltd.		•			
Gettop Acoustic Co., Ltd.	•	•		•	
GoerTek Co., Ltd.	•	•		•	
MicW Audio	•	•	•		•
Shenzhen Horn Audio Co., Ltd.	•	•			
Sound Technology Development, Ltd.	•				
Sun Technique Electric Co., Ltd.	•	•	•	•	•
Tonly Electronics Holdings	•	•			
DENMARK					
DPA Microphones	•	•			
FRANCE					
KYU Systems		•		•	
Seltech		•		•	
GERMANY					
Fraunhofer Institute for Digital Media Technology				•	
Microtech Gefell GmbH	•				•
HONG KONG					
INNacoustic	•	•		•	
ISRAEL					
Audio Pixels, Ltd.				•	
JAPAN					
Etani Electronics Co., Ltd.					•

	Dynamic Capsules	ECM	LDC	MEMS	True Condenser
SOUTH KOREA					
Suntel Co., Ltd.	•	•	•	•	•
SWEDEN					
Audio Pro, AB	•	•			
TAIWAN					
AV Leader Corp.	•	•	•	•	•
Kingstate Electronics Corp.		•		•	
UNITED KINGDOM					
Electroacoustic Design Ltd.	•	•		•	
EuroTec International, PLC	•	•			•
GRAS Sound & Vibration UK					•
UNITED STATES					
ACO Pacific, Inc.		•			
AValive	•	•	•	•	•
B&H Foto & Electronics Corp.	•	•	•	•	•
Bruel & Kjaer Sound & Vibration North America, Inc.					•
Front End Audio, LLC	•	•	•	•	•
GraphAudio					•
GRAS Sound & Vibration	•	•	•	•	
JLI Electronics, Inc.	•	•			
Josephson Engineering					•
Microphone-Parts.com			•		•
Pro Flix Sales	•	•	•	•	•
Shure, Inc.	•				•
Sound Pure, LLC	•	•	•	•	
Stetron International, Inc.		•			
Sweetwater Sound	•	•	•	•	•
Vintage King Audio	•	•	•	•	•
Yandas Music	•	•	•	•	•

	Cell Phone	Laptop	Tablet/MID
AUSTRIA			
USound GmbH	•	•	•
CANADA			
Solen Electronique, Inc.	•	•	•
CHINA			
Dongguan Yuonyunn Membrane Co.	•	•	•
Gettop Acoustic Co., Ltd.	•	•	•
GoerTek Co., Ltd.	•	•	•
Grand Will Enterprise Co., Ltd.	•	•	•
M-Sound Electronics Co., Ltd.			•
Pana Sound, Ltd.	•	•	•
Shenzhen Horn Audio Co., Ltd.	•	•	•
Sound Technology Development, Ltd.	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•
Tonly Electronics Holdings	•	•	•
Wavecor, Ltd.		•	
YunQi Science Technology Development	•	•	•
FRANCE			
Seltech	•	•	•
GERMANY			
Voice Point		•	•
HONG KONG			
dB Enterprises	•	•	•
Eastern Asia Technology (HK), Ltd.		•	•

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- Capability with quality
- Skilled and professional engineers

Application

Consumer Products

- Mobile Speaker / Receivers
- Digital Camera
- Personal media player
- Headphones

Electronic Components

- Television / projectors
- Game console
- Cookers / Fridge
- Small stereo

Industrial / Medical

- Aircraft / yacht component
- Walkie-talkie
- Alarm
- Helmet voice system
- Medical device

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	Cell Phone	Laptop	Tablet/MID
INNacoustic	•	•	•
WCE Acoustics	•	•	•
SOUTH KOREA			
Bujeon Components Co., Ltd.	•	•	•
Suntel Co., Ltd.	•	•	•
SWEDEN			
Oxeon AB/Textreme	•	•	•
TAIWAN			
AV Leader Corp.	•	•	•
Fortune Grand Technology Inc.	•	•	•
Huey Tung International Co., Ltd.	•	•	•
Kingstate Electronics Corp.	•	•	•
THAILAND			
Clarasonic (Thailand) Co., Ltd.	•	•	•
UNITED KINGDOM			
Electroacoustic Design Ltd.	•	•	•
UNITED STATES			
Adafruit Industries	•	•	•
BeStar Technologies, Inc.	•	•	•

	Cell Phone	Laptop	Tablet/MID
Broad Bridge Audio, LLC	•	•	•
Dayton Audio	•	•	•
Dragonfire Acoustics	•	•	•
GGEC America, Inc.	•	•	•
GraphAudio	•	•	
Parts Express	•	•	•
Peerless by Tymphany (HK), Ltd.		•	•
Resonado, Inc.		•	•
Sound Sources Technology, Inc.	•		
Stetron International, Inc.		•	•
The Digital PCH	•	•	•
Trade Moon	•	•	•

	Acoustic Materials	Finished Goods
AUSTRALIA		
Stone Sound Studio	•	•
AUSTRIA		
USound GmbH	•	•
BELGIUM		
Donnet: Loudspeaker Repair	•	•
BRAZIL		
Attack do Brasil	•	•
Magna Audio		•
Newbox Industry & Commerce	•	•
CANADA		
Canadian Speaker Works		•
Excelitas Canada		•
LMH Loudspeakers		•
Planet10-HiFi		•
Reference 3A		•
Solen Electronique, Inc.	•	•
Sonavox Electronics Canada	•	•
Studio Reference Monitors		•
Sziara Sound	•	•
CHINA		
Audiostar Electronics Co., Ltd.	•	
B.W. Audio Guangzhou, Co., Ltd.		•
Eastech Holding, Ltd.	•	•
Enkor Electronics Co., Ltd.		•
Fountek Electronics Co., Ltd.		•
GoerTek Co., Ltd.	•	•
Hansong (Nanjing) Technology	•	•
Junhao Wood Cabinet Factory	•	•
Kadeton Audio	•	
Lumi Audio		•
M-Sound Electronics Co., Ltd.		•
OBE Pro Audio Co., Ltd.	•	•
Pana Sound, Ltd.		•
Shenzhen Horn Audio Co., Ltd.	•	•
Sonos, Inc.		•
Sound Technology Development, Ltd.	•	•
Star Audio	•	•
Sun Technique Electric Co., Ltd.	•	•
Telefield	•	•
Tonewinner (Guangzhou) Electronics	•	
Tonly Electronics Holdings	•	•
Tristar Electronics	•	•
Trueanalog Strictly OEM	•	•
Vistron Audio Equipment	•	•
Vormag Electronics Co., Ltd.	•	
Xiamen Great Sound Technology	•	•
Zhuhai HiVi Technology Co., Ltd.		•
FRANCE		
Applications Acoustiques de Composites (AAC)		•
Audax		•
Kartesian	•	•
KYU Systems	•	
Seltech	•	
GERMANY		
Audio Technology Engineering (ATE)	•	•
Soundsgood Pro Audio Solutions		•
HONG KONG		
BDNC (Holding), Ltd.	•	
Beautiful Enterprise Co., Ltd.		•
dB Enterprises	•	•
Eastern Asia Technology (HK), Ltd.	•	•
Fujikon Industrial Holdings, Ltd.	•	•
INNacoustic	•	•
Ocean Star Electronics (HK) Co., Ltd.		•
PlastoForm	•	•
WCE Acoustics	•	•
INDIA		
GM Audio Technics, Ltd.	•	•
Power Electronics & Technologies		•
INDONESIA		
SB Acoustics	•	•
ISRAEL		
Morel, Ltd.		•
RH Sound Technology, Ltd.	•	

	Acoustic Materials	Finished Goods
MEXICO		
Aletheia, AV		•
NETHERLANDS		
Aequo Audio	•	
Diluvite	•	•
ELTIM audio, BV	•	
NORWAY		
SEAS Fabrikker AS		•
PHILIPPINES		
Dai-ichi Electronics Manufacturing Corp.	•	•
ROMANIA		
SC Poweraudio SRL		•
RUSSIA		
Star Sound Technologies		•
SOUTH AFRICA		
Paks Acoustics	•	•
SWEDEN		
Audio Pro, AB	•	•
SWITZERLAND		
Lange Loudspeakers		•
TAIWAN		
AV Leader Corp.	•	•
Huey Tung International Co., Ltd.	•	•
Kingstate Electronics Corp.		•
Meiloon Industrial Co., Ltd.	•	•
Shining Jins Enterprise Co., Ltd.	•	
Taiwan Solidex Corp.		•
TB Speaker	•	•
Vansonic Enterprise Co., Ltd.	•	•
Yung International, Inc.	•	•
THAILAND		
Clarasonic (Thailand) Co., Ltd.	•	•
UKRAINE		
MAG Audio		•
UNITED KINGDOM		
EuroTec International, PLC	•	•
Fane International, Ltd.		•
Ferguson Hill Studios, Ltd.		•
MJ Acoustics		•
Precision Devices, Ltd.		•
Revolver Audio, Ltd.		•
Tectonic Elements, Ltd.		•
Volt Loudspeakers, Ltd.		•
UNITED STATES		
A Brown		•
A List Wood Works, Inc.		•
A. Schulman, Inc.	•	
Adrian Acoustics, Inc.	•	•
Area 52 R&D		•
Arion Audio		•
Arnold Magnetic Technologies/Precision Thin Metals	•	
Audio Connection		•
Audioengine		•
Barefoot Sound, LLC		•
Broad Bridge Audio, LLC	•	•
Campanella Associates & Acculab		•
Danley Sound Labs		•
DC Gold Audio		•
Digmoda		•
Dynavox Electronics, Inc.		•
Earthquake Sound Corp.		•
Eminence Speaker, LLC		•
Fulcrum Acoustic, LLC		•
Geometric Designs, LLC & Geometric Consulting		•
GGEC America, Inc.	•	•
Hearing Components (Comply Memory Foam Tips)	•	
Io Audio Technologies		•
J&F Wood Products	•	•
JL Audio, Inc.		•
Lowell Manufacturing Co.		•
Materion	•	
Meliti Acoustics	•	•
MISCO		•
Monaero Engineering, Inc.		•
MSC Software Corp.	•	
North American Solidex, LLC		•
OAP Audio		•
ORCA Design and Manufacturing	•	
Parts Express	•	•
Pierce Audio Products	•	•
Portland Audio Lab	•	
PQN Audio		•
PranaFidelity		•
Rapid Die & Molding	•	
RCF USA, Inc.	•	•
SoCal Sound Shop		•
Sound Sources Technology, Inc.		•
SpeakersAndAmps.com		•
SSI Manufacturing, Inc.		•
Stetron International, Inc.		•
Stillwater Designs | KICKER		•
Studio Electric, LLC		•
SVS, Inc.		•
T&T Shanghai Tianai Acoustics Co., Ltd.	•	•
Tectonic Audio Labs	•	•
Tone Tubby, Inc.		•
TSG Audio		•
United Gasket Corp.	•	
US Enclosure Co.	•	•
US Speaker, LLC		•
VTech	•	•
Westlake Audio, Inc.		•
VIETNAM		
Sound Corp.	•	•

	Air Motion Transformer (AMT)	Compression Drivers: Midrange	Compression Drivers: Tweeters	Compression Drivers: Woofers	Electrostatic	Full Range	Horns	
AUSTRALIA								
Soundlabs Group, Pty., Ltd.					•		•	•
Stone Sound Studio							•	
BELGIUM								
Donnet: Loudspeaker Repair		•	•	•	•	•	•	•
Premium Sound Solutions							•	
BRAZIL								
Attack do Brasil					•			
Newbox Industry & Commerce		•	•	•	•		•	•
BULGARIA								
Oberton					•		•	
CANADA								
Kravchenko-Audio							•	•
ORA Graphene Audio, Inc.							•	
Planet10-HiFi							•	
Solen Electronique, Inc.					•		•	•
Space-Tech Lab, Ltd.						•	•	•
Studio Reference Monitors					•		•	•
CHINA								
Audiostar Electronics Co., Ltd.								•
B.W. Audio Guangzhou, Co., Ltd.					•			
Bozhen Acoustic, Co., Ltd.					•			•
Dayun							•	
Dongguan Queen Voice Electronics					•			•
Eastech Holding, Ltd.		•	•	•	•	•	•	•
Enkor Electronics Co., Ltd.						•		
Fountek Electronics Co., Ltd.							•	•
Grand Will Enterprise Co., Ltd.						•	•	
Haoyin					•		•	
LaVoce, Co., Ltd.					•		•	•
Mpio					•		•	
M-Sound Electronics Co., Ltd.					•		•	•
OBE Pro Audio Co., Ltd.					•		•	

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RESONADO LABS

	Air Motion Transformer (AMT)	Compression Drivers: Midrange	Compression Drivers: Tweeters	Compression Drivers: Woofers	Electrostatic	Full Range	Horns	
Pana Sound, Ltd.		•	•		•		•	•
Qikang					•		•	
Renyi Castings								•
Sound Art Electronic					•		•	
Sound Technology Development, Ltd.					•		•	•
Sun Technique Electric Co., Ltd.					•	•	•	•
Wavecor, Ltd.							•	
Yuesheng Electronic					•		•	
YunQi Science Technology Development					•		•	
Zhuhai HiVi Technology Co., Ltd.							•	
DENMARK								
Puriti Transducer Technology							•	
Scan-Speak							•	
FRANCE								
Audax					•		•	•
Kartesian		•	•		•		•	•
KYU Systems					•		•	•
PHL Audio							•	
Seltech							•	
Supravox							•	•
Waterfall Audio						•		
GERMANY								
Audio Technology Engineering (ATE)					•	•	•	•
BMS Speakers GmbH					•		•	•
ic audio					•		•	•

	Air Motion Transformer (AMT)	Compression Drivers: Midrange	Compression Drivers: Tweeters	Compression Drivers: Woofers	Electrostatic	Full Range	Horns	
Lautsprecher-Produktions-Gesellschaft (LPG)							•	
Physical-Lab							•	
Voice Point	•	•	•	•	•	•	•	•
Wolf von Langa		•			•		•	
HONG KONG								
BDNC (Holding), Ltd.							•	
dB Enterprises							•	
Eastern Asia Technology (HK), Ltd.						•	•	
Fujikon Industrial Holdings, Ltd.	•	•	•	•	•	•	•	•
Ocean Star Electronics (HK) Co., Ltd.							•	
WCE Acoustics						•	•	•
HUNGARY								
Bayz Audio							•	
INDIA								
Audiotone Professional					•		•	
Dakshin Speaker Manufacturing Private, Ltd. (DSMPL)					•		•	•
GM Audio Technics, Ltd.					•		•	•
TurboSonic Pro Speakers						•	•	
INDONESIA								
SB Acoustics					•		•	
ISRAEL								
Morel, Ltd.							•	

	Air Motion Transformer (AMT)	Electrostatic: Tweeters	Electrostatic: Midrange	Electrostatic: Woofers	Compression Drivers	Full Range	Horns
ITALY							
ABM Bobine, SRL					•	•	
Audioxplus, SRL					•	•	
Axiomedia, SRL					•	•	•
B&C Speakers, SpA					•	•	•
Ciare					•	•	•
Eighteen Sound					•		•
FaitalPRO					•	•	•
LaVoce, Co., Ltd.					•	•	•
Professional Audio					•	•	•
RCF, SpA					•	•	•
SICA Altoparlanti					•	•	•
NETHERLANDS							
Audio Components, BV						•	
Diluvite						•	
ELTIM audio, BV			•			•	•
Good Hifi VOF			•				
NORWAY							
SEAS Fabrikker AS						•	
RUSSIA							
Star Sound Technologies						•	
SPAIN							
Acustica Beyma					•	•	•

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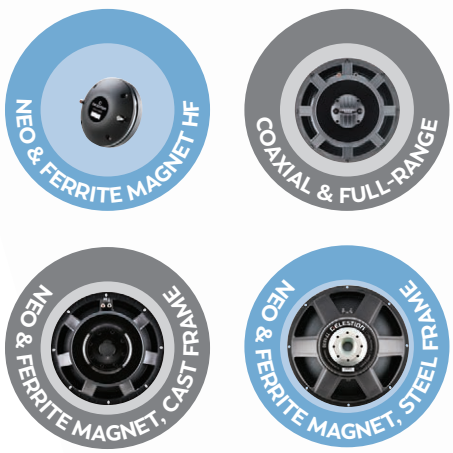
Leading Pro Audio brands choose Celestion

Innovation, performance and reliability make Celestion the drivers of choice for a growing number of big-name PA brands. So when you need superior quality compression drivers or professional loudspeakers, check out about the speakers the pros use.



	Air Motion Transformer (AMT)	Compression Drivers: Midrange	Compression Drivers: Tweeters	Compression Drivers: Woofers	Electrostatic	Full Range	Horns
SWEDEN							
Audio Pro, AB					•	•	•
SWITZERLAND							
Lange Loudspeakers					•		•
TAIWAN							
AV Leader Corp.		•	•	•		•	•
Chien-Yuan Electronic Co. (CYE)							•
Dongguan Sheng-Yang Electronics					•		•
Hakken Enterprise							•
Hi-Tech Sound System Co., Ltd.		•	•	•		•	•
Huey Tung International Co., Ltd.					•	•	•
Ruhwa Electronic Co., Ltd.					•		•
Shining Jins Enterprise Co., Ltd.		•	•	•	•	•	•
TB Speaker							•
THAILAND							
A-TON (Thailand) Co., Ltd.					•		•
Clarasonic (Thailand) Co., Ltd.							•
UKRAINE							
MAG Audio					•		•
UNITED KINGDOM							
Arya Audio Labs, Ltd.		•	•	•	•		•
BishopSound					•		•

HiVi

More than 25 years of experience in audio industry.
Design manufacturer of acoustic products.
Seamless manufacturing: from raw drivers to fully finished speaker systems.
Piano lacquer finished / natural wood veneer finished / solid wood / PVC speaker cabinets.
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HiVi - hear the difference

HiVi OEM / ODM Department
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Tel: +86-756-6268133 Fax: +86-756-6268068 Website: www.hivi.us E-mail: oem_odm@hivi.com

	Air Motion Transformer (AMT)	Compression Drivers: Midrange	Compression Drivers: Tweeters	Compression Drivers: Woofers	Electrostatic	Full Range	Horns	
Celestion					•		•	•
Compbass, Ltd.					•			
Electroacoustic Design Ltd.					•		•	•
EuroTec International, PLC					•	•	•	•
Fane International, Ltd.					•		•	•
MJ Acoustics						•		
Precision Devices, Ltd.					•		•	
Sine Audio Systems							•	•
Tectonic Elements, Ltd.							•	
Volt Loudspeakers, Ltd.							•	
UNITED STATES								
Acoustic Design, Inc.					•			•
American Bass USA					•	•	•	•
American Music & Sound						•		
Analysis Audio USA		•	•					
Arion Audio		•	•	•				
Beyma Pro Audio		•	•		•	•	•	•
Broad Bridge Audio, LLC		•	•				•	
Cadillac Audio					•			•
CE Distribution		•	•	•	•	•	•	•
CGN Audio Labs							•	
Christensen Audio, LLC		•	•		•			
CommonSense Audio							•	
Danley Sound Labs							•	•
Dayton Audio					•		•	•

SICA loudspeakers ®

Made in Italy

The ability to develop custom-tailored products, together with high quality schedules and short processing times are key factors in SICA's workflow. These, together with highly engineered assembly lines, that merge precision and quality with the typical creativity of the *made in Italy*, enabled SICA to expand into the international markets, establishing a relevant presence in the five continents.

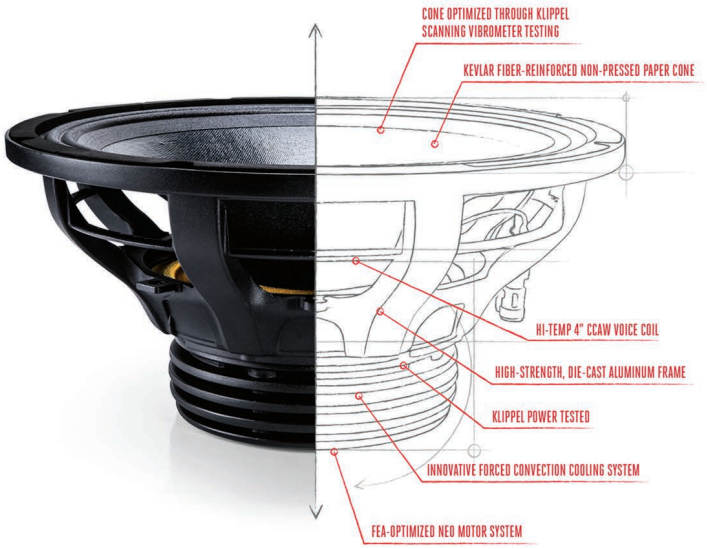
SICA Altoparlanti s.r.l. | Mail info@sica.it

	Air Motion Transformer (AMT)	Compression Drivers: Midrange	Compression Drivers: Tweeters	Compression Drivers: Woofers	Electrostatic	Full Range	Horns	
DC Gold Audio							•	
Dragonfire Acoustics		•		•		•	•	
Dynavox Electronics, Inc.					•		•	•
Earthquake Sound Corp.					•		•	•
Eminence Speaker, LLC					•	•	•	•
ESS Laboratories, LLC						•		
ESTec America		•	•	•	•	•	•	•
Gauss Loudspeaker					•		•	•
GGEC America, Inc.					•		•	•
Hartley Loudspeakers, Inc.							•	
Io Audio Technologies		•	•	•	•	•	•	•
Knowles Electronics, LLC							•	
Loudspeakers Plus					•		•	•
Lowther Speakers USA							•	
Materion					•			
MISCO					•		•	
NedLab							•	
North American Solidex, LLC					•		•	•
NOU Audio							•	
Parts Express		•	•		•	•	•	•
Peerless by Tymphany (HK), Ltd.					•		•	
PQN Audio							•	
PUI Audio					•		•	•
Radian Audio Engineering, Inc.		•	•	•	•	•	•	•
RBH Sound			•					
Recycled Sound		•						

	Air Motion Transformer (AMT)	Compression Drivers: Midrange	Compression Drivers: Tweeters	Compression Drivers: Woofers	Electrostatic	Full Range	Horns	
REDCATT					•		•	•
Resonado, Inc.						•	•	
Sanming Sound					•			•
Simply Speakers					•			
SoCal Sound Shop					•		•	
Sound Lab						•		
SpeakerAddict					•	•	•	•
SpeakersAndAmps.com					•		•	•
Stetron International, Inc.							•	
Stillwater Designs | KICKER					•		•	
SVS, Inc.							•	
T&T Shanghai Tianai Acoustics Co., Ltd.					•		•	•
Tectonic Audio Labs							•	
Tone Tubby, Inc.							•	
Tonian Laboratories							•	
TSG Audio					•	•	•	•
Ulbrich Stainless Steels & Special Metals					•			
US Speaker, LLC					•			•
Vidsonix Design Works							•	
Western Electric		•	•	•				
Westlake Audio, Inc.								•
Yandas Music					•			
VIETNAM								
Sound Corp.					•		•	•
Sun Technique		•	•	•	•	•	•	•

	Midrange					Paging Horns			Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon		Piezo	Planar		Cone	Dome	Electrostatic	Ribbon		
AUSTRALIA															
Soundlabs Group, Pty., Ltd.	•	•				•					•	•		•	•
Stone Sound Studio	•	•			•	•	•				•	•		•	•
BELGIUM															
Donnet: Loudspeaker Repair	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Premium Sound Solutions	•	•							•	•	•	•		•	•
BRAZIL															
Attack do Brasil															•
Newbox Industry & Commerce	•	•	•			•	•		•		•	•	•	•	•
BULGARIA															
Oberton	•								•						•
CANADA															
Canadian Speaker Works															•
Harbottle Audio															•
Kravchenko-Audio					•				•			•			•
Newform Research, Inc.						•								•	
ORA Graphene Audio, Inc.															•
Planet10-HiFi															•
Reference 3A												•			•
Solen Electronique, Inc.	•	•							•		•	•		•	•
Space-Tech Lab, Ltd.	•	•									•	•		•	•
Studio Reference Monitors	•											•			•
CHINA															
Audiostar Electronics Co., Ltd.															•
B.W. Audio Guangzhou, Co., Ltd.															•
Bozhen Acoustic, Co., Ltd.						•								•	•
Dayun	•	•	•	•	•						•	•	•	•	•
Dongguan Queen Voice Electronics							•								•
Eastech Holding, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Enkor Electronics Co., Ltd.	•	•									•	•			•
Fountek Electronics Co., Ltd.														•	•
Grand Will Enterprise Co., Ltd.								•							
Haoyin	•	•	•	•	•						•	•	•	•	
LaVoce, Co., Ltd.	•	•									•	•			•
Mpio	•	•	•	•	•						•	•	•	•	•
M-Sound Electronics Co., Ltd.		•			•						•	•		•	
OBE Pro Audio Co., Ltd.															•
Pana Sound, Ltd.	•	•	•			•	•			•	•	•		•	•
Qikang	•	•	•	•	•						•	•	•	•	•
Sonos, Inc.	•	•									•	•			•
Sound Art Electronic	•	•	•	•	•						•	•	•	•	•
Sound Technology Development, Ltd.	•	•				•	•				•	•			•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Peerless



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ANC

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DFM

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FSL

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	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar		Cone	Dome	Electrostatic	Ribbon		
Wavecor, Ltd.	•	•								•	•			•
Yuesheng Electronic	•	•	•	•	•					•	•	•	•	
YunQi Science Technology Development	•	•	•	•	•					•	•	•	•	•
Zhuhai HiVi Technology Co., Ltd.		•								•	•		•	•
DENMARK														
AudioTechnology	•													•
Hiquphon											•			
Purifi Audio	•	•												•
Puriti Transducer Technology	•										•			•
Scan-Speak	•	•									•			•
FRANCE														
Audax	•	•								•	•			•
Kartesian	•	•	•							•	•			•
KYU Systems	•			•				•						•
PHL Audio	•										•			•
Seltech	•	•	•				•	•	•	•	•			•
Supravox	•									•	•			•
Waterfall Audio														•
GERMANY														
Audio Technology Engineering (ATE)	•	•	•	•	•			•		•	•	•	•	•
BMS Speakers GmbH	•			•				•	•					•
ic audio						•								
Lautsprecher-Produktions-Gesellschaft (LPG)	•										•			•
Physical-Lab											•			

	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Cone	Dome	Electrostatic	Ribbon			
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Wolf von Langa	•													•
HONG KONG														
BDNC (Holding), Ltd.	•	•						•		•	•			•
dB Enterprises	•									•				•
Eastern Asia Technology (HK), Ltd.	•	•								•	•			•
Fujikon Industrial Holdings, Ltd.	•	•	•	•	•	•		•	•	•	•	•	•	•
Ocean Star Electronics (HK) Co., Ltd.	•	•								•	•			•
WCE Acoustics	•	•	•	•	•	•	•	•	•	•	•			•
HUNGARY														
Bayz Audio								•						
INDIA														
Audiotone Professional														•
Dakshin Speaker Manufacturing Private, Ltd. (DSMPL)	•	•	•	•	•	•	•			•	•	•	•	•
GM Audio Technics, Ltd.	•	•								•				•
TurboSonic Pro Speakers	•	•	•	•	•									•
INDONESIA														
Premiere Wood Manufacturing (PWM)								•						
SB Acoustics	•	•					•			•	•		•	•
ISRAEL														
Morel, Ltd.	•	•									•			•
ITALY														
ABM Bobine, SRL	•	•	•	•	•					•	•	•	•	•

	Midrange					Paging Horns			Tweeters					Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Siren/Voice Warning	Cone	Dome	Electrostatic	Ribbon		
Audioxplus, SRL	•	•								•	•			•
Axiomedia, SRL	•	•									•		•	•
B&C Speakers, SpA	•										•		•	•
Ciare														•
Eighteen Sound														•
FaitalPRO	•	•								•	•			•
LaVoce, Co., Ltd.	•	•								•	•			•
Powersoft, SpA														•
Professional Audio	•	•								•	•			•
RCF, SpA														•
SICA Altoparlanti	•	•	•	•	•					•	•	•	•	•
NETHERLANDS														
Audio Components, BV		•									•			•
Diluvite	•	•								•	•			•
ELTIM audio, BV	•	•									•		•	•
Good Hifi VOF	•									•	•			•
NORWAY														
SEAS Fabrikker AS	•	•									•			•
RUSSIA														
Star Sound Technologies	•	•								•	•			•
SOUTH KOREA														
Bujeon Components Co., Ltd.							•							
SPAIN														
Acustica Beyma	•										•		•	•
SWEDEN														
Audio Pro, AB	•	•		•	•		•	•		•	•		•	•
SWITZERLAND														
Lange Loudspeakers											•			•
TAIWAN														
AV Leader Corp.	•	•	•	•	•	•	•	•		•	•	•	•	
BESTON Technology Corp.				•	•			•					•	
Chien-Yuan Electronic Co. (CYE)	•	•	•	•	•					•	•	•	•	•
Dongguan Sheng-Yang Electronics	•	•	•	•	•					•	•	•	•	•
Hakken Enterprise	•	•	•	•	•					•	•	•	•	•
Hi-Tech Sound System Co., Ltd.	•	•								•	•			•
Huey Tung International Co., Ltd.	•	•	•				•		•	•	•	•		•
Kingstate Electronics Corp.							•		•					
Ruhwa Electronic Co., Ltd.			•	•	•					•	•	•	•	•
Shining Jins Enterprise Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Taiwan Solidex Corp.							•						•	•
TB Speaker	•	•			•					•	•		•	•
Yie Feng Technology Enterprise Co., Ltd.	•													
THAILAND														
A-TON (Thailand) Co., Ltd.	•	•	•	•	•					•	•	•	•	•
Clarasonic (Thailand) Co., Ltd.	•	•								•	•			•
UKRAINE														
MAG Audio	•													•
UNITED KINGDOM														
Arya Audio Labs, Ltd.				•	•								•	
BishopSound														•
Celestion	•								•					•
Compbass, Ltd.														•
Electroacoustic Design Ltd.	•	•		•	•	•	•	•	•	•	•		•	•
EuroTec International, PLC	•	•	•						•	•	•	•	•	•

	Midrange					Paging Horns		Siren/Voice Warning	Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar		Cone	Dome	Electrostatic	Ribbon	
Fane International, Ltd.	•									•	•		•
MJ Acoustics													•
Precision Devices, Ltd.	•										•		•
Sine Audio Systems	•	•								•	•		•	•
Volt Loudspeakers, Ltd.	•	•												•
UNITED STATES														
Acoustic Design, Inc.		•												
Aempyrean								•						
American Bass USA	•	•	•	•	•	•		•	•	•	•	•	•	•
American Music & Sound														•
Analysis Audio USA					•			•					•	
Area 52 R&D	•										•			•
Arnold Magnetic Technologies/Precision Thin Metals		•									•			
BeStar Technologies, Inc.							•							
Beyma Pro Audio	•	•	•	•	•	•	•			•	•	•	•	•
Broad Bridge Audio, LLC				•	•			•		•	•		•	•
Cadillac Audio	•													•
Carvin Audio														•
CE Distribution	•	•	•	•	•		•	•		•	•	•	•	•
CGN Audio Labs													•	•
Danley Sound Labs						•			•					
Dayton Audio	•	•		•	•	•		•		•	•		•	•
DC Gold Audio	•													
Dragonfire Acoustics			•	•	•			•				•	•	•
Dynavox Electronics, Inc.	•	•			•	•	•	•	•	•	•		•	•

	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar		Cone	Dome	Electrostatic	Ribbon		
Earthquake Sound Corp.														•
Electro Mavin	•	•									•			•
Eminence Speaker, LLC	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ESS Laboratories, LLC														•
ESTec America	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Full Compass Systems, Ltd.	•	•	•							•	•	•	•	•
Gauss Loudspeaker	•	•	•	•	•					•	•	•	•	•
GGEC America, Inc.	•	•					•		•	•	•	•	•	•
GraphAudio										•	•	•	•	
Hartley Loudspeakers, Inc.	•	•	•	•	•					•	•	•	•	•
HDSound.us								•					•	•
Io Audio Technologies	•	•	•	•	•	•	•	•	•	•	•	•	•	•
JL Audio, Inc.	•													•
Loudspeakers Plus	•										•			•
Meniscus Audio Group, Inc.														•
MISCO	•						•		•	•	•			•
NedLab	•	•								•	•			•
North American Solidex, LLC	•	•		•				•		•			•	•
NOU Audio	•	•	•	•	•					•	•	•	•	•
ORCA Design and Manufacturing	•				•						•		•	•
Parts Express	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Peerless by Tymphany (HK), Ltd.	•	•								•	•			•
Pierce Audio Products														•
PUI Audio	•	•	•	•	•	•	•		•	•	•	•	•	•
Radian Audio Engineering, Inc.	•	•	•	•	•		•	•		•	•	•	•	•

	Midrange					Paging Horns		Tweeters						Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Siren/Voice Warning	Cone	Dome	Electrostatic	Ribbon		
RBH Sound	•									•				•
REDCATT	•	•		•				•		•	•			•
Resonado, Inc.			•											•
Sanming Sound						•			•					
Simply Speakers	•	•					•			•	•			•
SoCal Sound Shop														•
SpeakerAddict	•	•	•	•	•	•	•	•	•	•	•	•	•	•
SpeakersAndAmps.com	•	•		•	•	•		•		•	•		•	•
Stetron International, Inc.		•									•			•
Stillwater Designs | KICKER	•										•			•
Studio Electric, LLC														•
SVS, Inc.	•										•			•
T&T Shanghai Tianai Acoustics Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Tectonic Audio Labs														•
Tonian Laboratories													•	•
Transducer Lab, LLC											•			
TSG Audio	•	•	•	•	•	•	•	•	•	•	•	•	•	•
US Speaker, LLC							•							•
Vidsonix Design Works	•										•			•
Westlake Audio, Inc.	•		•								•			•
Wisdom Audio								•						
Yandas Music	•	•								•	•			•
VIETNAM														
Sound Corp.	•	•								•	•			•
Sun Technique	•	•	•	•	•			•	•	•	•	•	•	•

	Attenuators	Capacitors: Ceramic	Capacitors: Electrolytic Non-Polar	Driver Protection Devices	Inductors: Film	Inductors: Air Core	Inductors: Iron Core	Plugs & Jack Dishes	Resistors	Solder	Terminal Plates	Transformers	Electronic Crossovers	Finished Passive Crossover Nets	Wire & Wiring Harnesses
AUSTRALIA															
Soundlabs Group, Pty., Ltd.	•			•	•	•	•			•	•	•			•	•
Stone Sound Studio	•	•		•			•		•	•				•	•	
BRAZIL															
Advanced Audio Technologies (AAT)														•		
Newbox Industry & Commerce	•			•	•	•	•	•	•	•	•	•	•	•	•	•
CANADA															
Reference 3A					•											
Solen Electronique, Inc.	•			•	•	•	•		•	•	•	•			•	•
Space-Tech Lab, Ltd.														•	•	
CHINA															
Sound Technology Development, Ltd.				•		•	•	•	•	•				•	•	•
Sun Technique Electric Co., Ltd.	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
DENMARK															
Duelund Coherent Audio			•	•	•		•	•		•						•
Jantzen Audio Denmark				•	•		•	•		•						
FRANCE															
KYU Systems	•				•	•	•	•		•			•	•	•	•
Seltech						•								•		
GERMANY															
ic audio													•			
Jobst-Audio												•			•	
Voice Point									•	•	•	•	•		•	•

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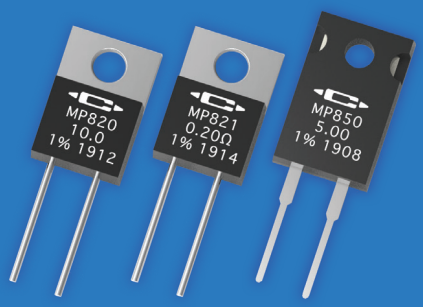
Power Film Resistors

Caddock's Power Film Resistor Technologies bring unique power resistor constructions to the audio system designer. The materials and non-inductive designs of these power resistor products provide outstanding low reactance for power switching systems, high frequency circuits, and other reactance sensitive applications.

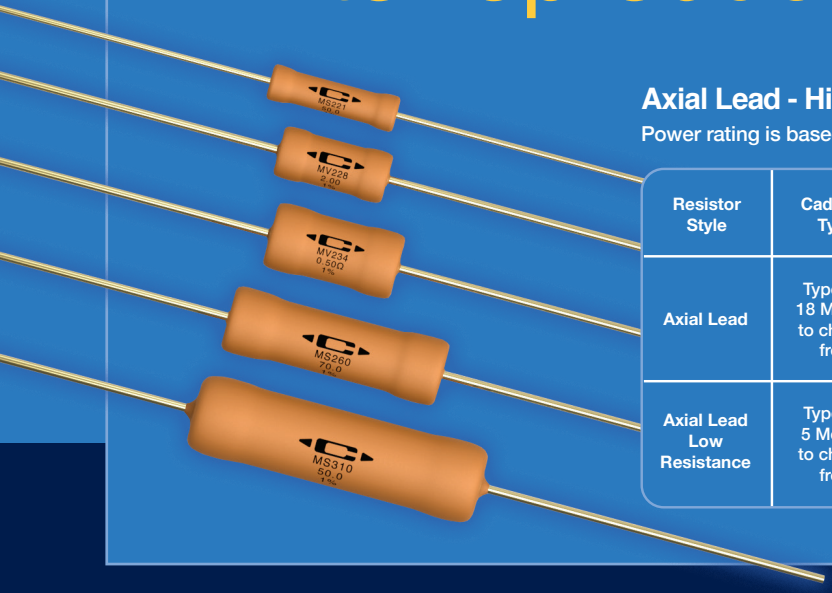


Heat Sink Mountable *with Non-Inductive Design*

Power rating is based on a +25°C case temperature. The thermal mounting issues are the same as with power semiconductors.

Resistor Style	Model No.	Power Rating at +25°C Case Temp.	Resistance Range	Comments
TO-220 Style Package	MP820	20 Watts	10 Ω to 10K	Metal Mounting Tab
	MP821	20 Watts	0.02 Ω to 9.99 Ω	Metal Mounting Tab
	MP850	50 Watts	0.2 Ω to 10K	Copper Heat Sink Integral in the Molded Package

For speakers that strive to reproduce LIVE sound



Axial Lead - High Power *with Non-Inductive Design*

Power rating is based on +25°C ambient, derated at higher ambient temperature.

Resistor Style	Caddock Type	Power Rating	Resistance Range	Comments
Axial Lead	Type MS 18 Models to choose from	0.5 Watt up to 22 Watts	20 Ω up to 30 Meg	These non-inductive resistors are about as inductive as a straight piece of wire the length of the resistor body. Standard tolerance 1%
Axial Lead Low Resistance	Type MV 5 Models to choose from	1.5 Watts up to 10 Watts	0.10 Ω up to 50 Ω	Low Resistance with EXTREMELY low inductance. Standard tolerance 1% (5% and 10% available)

High Performance Film Resistors from

CADDOCK
ELECTRONICS, INCORPORATED

For Samples and more Information contact Applications Engineering:

Sales Office - USA and Canada
Applications Engineering
17271 N. Umpqua Hwy.
Roseburg, Oregon 97470-9422
phone: 541-496-0700
email: sales@caddock.com

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RoHS
product information at www.caddock.com

	Passive Components												Finished Passive Crossover Nets		
	Attenuators	Capacitors: Ceramic	Capacitors: Electrolytic Non-Polar	Driver Protection Devices: Film	Inductors	Inductors: Air Core	Inductors: Iron Core	Plugs & Jack Dishes	Resistors	Solder	Terminal Plates	Transformers	Electronic Crossover	Wire & Wiring Harnesses	
HONG KONG															
WCE Acoustics															•
INDIA															
GM Audio Technics, Ltd.													•	•	
INDONESIA															
Premiere Wood Manufacturing (PWM)			•		•		•							•	
ISRAEL															
RH Sound Technology, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•		•	•
ITALY															
Axiomedia, SRL	•		•	•		•	•	•	•	•	•			•	
Boxal, SRL															•
JAPAN															
Furutech Co., Ltd.										•					•
MEXICO															
Aletheia, AV														•	•
NETHERLANDS															
Audio Components, BV	•		•			•	•	•	•	•	•			•	
ELTIM audio, BV	•		•	•		•	•		•	•	•	•	•	•	•
ROMANIA															
SC Poweraudio SRL													•	•	
SWEDEN															
Audio Pro, AB	•				•	•				•			•		
TAIWAN															
AV Leader Corp.													•	•	
Bennic and Company	•		•	•		•	•			•		•		•	•
Huey Tung International Co., Ltd.										•			•		
Kingstate Electronics Corp.		•													
THAILAND															
A-TON (Thailand) Co., Ltd.															•
UNITED KINGDOM															
EuroTec International, PLC					•								•	•	•
Hifi Collective, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sine Audio Systems													•		
Volt Loudspeakers, Ltd.						•	•								
UNITED STATES															
Arizona Capacitors				•	•					•			•	•	
AtlasIED	•											•			
Avel Lindberg	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Caddock Electronics										•					
Cardas Audio															•
Carvin Audio													•		
CE Distribution	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

	Passive Components												Finished Passive Crossover Nets	Electronic Crossover	Wire & Wiring Harnesses
	Attenuators	Capacitors: Ceramic	Capacitors: Electrolytic Non-Polar	Driver Protection Devices	Inductors	Inductors: Air Core	Inductors: Iron Core	Plugs & Jack Dishes	Resistors	Solder	Terminal Plates	Transformers			
Danville Signal Processing, Inc.													•		
Dayton Audio				•	•				•	•			•	•	
DMSI													•		
Dragonfire Acoustics						•							•		
Dynavox Electronics, Inc.				•	•		•	•		•		•	•		
Electro Mavin														•	
Elektrisola															•
Eminence Speaker, LLC						•								•	
ESS Laboratories, LLC													•		
Full Compass Systems, Ltd.	•						•	•				•	•	•	•
Geometric Designs, LLC & Geometric Consulting													•	•	
Globe Audio Design, Inc.													•		
GR Research				•			•			•					
Hearing Components (Comply Memory Foam Tips)	•														
Jupiter Condenser Co.				•	•		•			•	•				•
Lamart Corp.											•		•		•
Lowell Manufacturing Co.													•		
Madisound Speaker Components, Inc.				•	•		•	•		•				•	
Marchand Electronics, Inc.	•												•	•	
Meniscus Audio Group, Inc.				•	•		•	•		•	•	•		•	•
NedLab														•	
North American Solidex, LLC														•	
Orban Audio Speaker Repair													•		
ORCA Design and Manufacturing				•											
Parts Express	•	•		•	•	•	•	•	•	•	•	•	•		•
Quest Engines, LLC									•						
Radian Audio Engineering, Inc.						•						•	•		
Recycled Sound	•														
REDCATT													•	•	
Redco Audio									•		•				•
Schurter Electronic Components									•				•		•
SG Custom Sound													•	•	
Simply Speakers	•													•	
SpeakersAndAmps.com						•							•		
Studio Electric, LLC														•	
T&T Shanghai Tianai Acoustics Co., Ltd.													•	•	
TRS Inovations	•	•		•	•	•			•	•	•	•	•	•	
UpTone Audio, LLC				•											
Vidsonix Design Works	•					•						•			•
Vintage King Audio													•		
Whitmor Wirenetics															•
Yandas Music													•		
VIETNAM															
Sound Corp.							•	•	•			•	•	•	•

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Solen Fast Capacitors™ & Solen Perfect Layer Inductors, often imitated, sometimes copied - even counterfeited - yet never equaled.

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SOLEN CAPACITORS

Metallized Polypropylene Flim Fast Capacitors™
-First to use the "Fast Capacitors"™
-First to use bi-axially oriented metabolized polypropylene film
-Lowest dissipation factor, lowest dielectric absorption
-Widest range of values, from 0.01uf to 330uf
-Widest range of voltages, from 250Vdc to 630Vdc
Metallized Teflon™ Film - 0.22uf to 10uf, 1300Vdc
Silver Metallized Polypropylene Film - 0.10uf to 56uf, 700Vdc
Teflon™ Film & Foil - 0.033uf to 0.82uf, 1000Vdc
Polypropylene Film & Tin Foil - 0.01uf to 8.2uf, 100Vdc to 1200Vdc
Metallized Polypropylene Can Type - 22uf, 33uf, 51uf & 100uf, 630Vdc
Metallized Polyester Film - 1.0uf to 47uf, 160Vdc
Non-Polar Electrolytic .5% DF - 10uf to 330uf, 100Vdc
Polarized Electrolytic - .33uf to 33000uf, 63Vdc to 450Vdc

SOLEN INDUCTORS

Perfect Layer Hexagonal Winding Air Core
-First to use Perfect Layer Hexagonal winding technique
-First to use Hepta-Litz seven strand insulated wire
-First to use H49-Litz forty-nine strand insulated wire
-Zero distortion air core, lowest dc resistance
-Widest range of values 0.05mH to 85mH
-Wide range of wire diameters, from 0.8mm (20awg) to 3.1mm (8awg)

SOLEN RESISTORS

Wire wound 10w 5% - 0.5 ohm to 82 ohm
Metal Oxide Link 10w 5% non inductive - 1 ohm to 47 ohm
AchrOhmiC 16w 2% MIL Spec non inductive - 0.5 ohm to 82 ohm

SOLEN TUBES

-Electro Harmonix -Genalex Gold Lion
-Mullard -Sovtek -Tesla JJ -Tung-Sol

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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	
AUSTRALIA																						
Soundlabs Group, Pty., Ltd.							•		•													
BELGIUM																						
Donnet: Loudspeaker Repair							•		•	•	•	•	•	•	•	•	•	•	•	•	•	•
BRAZIL																						
Attack do Brasil	•	•	•	•	•							•	•	•	•	•	•	•	•	•	•	•
Newbox Industry & Commerce												•	•	•	•	•	•	•	•	•	•	•
CANADA																						
ORA Graphene Audio, Inc.												•	•	•	•	•	•	•	•	•	•	•
Reference 3A	•	•		•								•							•			•
Solen Electronique, Inc.							•				•											
CHINA																						
Audiostar Electronics Co., Ltd.				•																		
BOWI Industry, Co., Ltd.												•	•	•	•	•	•	•	•	•	•	•
Dayun							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Dongguan Queen Voice Electronics												•	•	•	•	•	•	•	•	•	•	•
Dongguan Yen Lung Electronics Co., Ltd.												•	•					•				
Guangzhou Istaray Trading Co., Ltd.												•	•	•			•	•		•	•	•
Haoyin												•	•	•	•	•	•	•	•	•	•	•
Lumi Audio												•	•	•	•	•	•	•	•	•	•	•
Mpio												•	•	•	•	•	•	•	•	•	•	•
Ningbo Xiangyang Economic & Trade Co., Ltd.												•	•	•	•	•	•	•	•	•	•	•

	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	
Qikang											•	•	•	•	•	•	•	•	•	•	
Shenzhen Guangnan Electronic Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Sound Art Electronic											•	•	•	•	•	•	•	•	•	•	
Sound Technology Development, Ltd.	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Tianyi Electronic Co., Ltd.											•	•	•	•	•	•	•	•	•	•	
TopOne Loudspeaker Cone Co., Ltd.												•									
Vormag Electronics Co., Ltd.		•																			
Yuesheng Electronic							•	•	•	•	•	•	•	•	•	•	•	•	•	•	
YunQi Science Technology Development							•	•	•	•	•	•	•	•	•	•	•	•	•	•	
DENMARK																					
Jantzen Audio Denmark							•														
FRANCE																					
Applications Acoustiques de Composites (AAC)							•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Kartesian											•	•		•	•	•	•	•	•	•	

	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 Look	Composite	Paper Pulp	Plastic	Aluminum/Titanium/Metal	Fabric/Mylar/Resin/Soft	Phenolic & Other Domes		Fabric	Foam	Rubber
KYU Systems	•	•	•	•	•	•					•	•	•	•	•	•		•	•	•	•
Seltech						•	•	•	•	•											
GERMANY																					
Centrotec Composites						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Dr. Kurt Müller											•	•	•	•	•	•	•	•	•	•	•
Henkel Corp.	•	•	•	•	•																
Hubert Stüken GmbH														•	•						
Propex Fabrics GmbH											•		•						•		
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
HONG KONG																					
BDNC (Holding), Ltd.											•						•				
dB Enterprises						•			•												
WCE Acoustics											•	•	•	•	•	•	•	•	•	•	•
HUNGARY																					
ViktorSound											•	•	•	•	•	•	•	•	•	•	•
INDIA																					
Audiotone Professional											•	•	•					•	•	•	•
Dakshin Speaker Manufacturing Private, Ltd. (DSMPL)											•	•	•	•	•	•	•	•	•	•	•
TurboSonic Pro Speakers						•			•												
Wizard India Private, Ltd.											•	•	•			•	•	•	•	•	•
INDONESIA																					
SB Acoustics												•			•	•		•		•	•
ISRAEL																					
RH Sound Technology, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ITALY																					
ABM Bobine, SRL						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Boxal, SRL											•	•	•	•	•	•	•	•	•	•	•
OEB, SRL											•	•						•	•	•	•
Professional Audio											•		•	•	•		•	•	•	•	•
MALAYSIA																					
Eternal Power Sdn. Bhd.						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Shu Kae Industrial	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
U-Sonics Power Cone											•	•	•	•	•	•	•	•	•	•	•
NETHERLANDS																					
Audiofriends											•	•	•	•	•	•	•	•	•	•	•
Diluvite	•	•				•					•	•	•	•	•	•	•				
Good Hifi VOF		•			•										•	•	•		•	•	•
Teijin Aramid						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
NORWAY																					
Soundcare AS						•								•							

	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	
PHILIPPINES																							
Dai-ichi Electronics Manufacturing Corp.												•	•	•	•	•	•	•	•	•	•	•	
SOUTH KOREA																							
Suntel Co., Ltd.												•	•	•	•	•	•	•	•	•	•	•	
SWEDEN																							
Audio Pro, AB						•						•	•	•	•	•	•	•	•	•	•	•	
Oxeon AB/Textreme												•						•					
SWITZERLAND																							
Kisling AG	•	•			•																		
TAIWAN																							
AV Leader Corp.							•	•	•	•	•												
Chien-Yuan Electronic Co. (CYE)							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Dongguan Sheng-Yang Electronics							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Hakken Enterprise												•	•	•	•	•	•	•	•	•	•	•	•
Hi-Tech Sound System Co., Ltd.												•		•		•	•						•
Huey Tung International Co., Ltd.												•	•	•	•	•	•	•	•	•	•	•	•

	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 Look	Composite	Paper Pulp	Plastic	Metal	Aluminum/Titanium/Metal	Fabric/Mylar/Resin/Soft	Phenolic & Other Domes		Fabric	Foam	Rubber
Ruhwa Electronic Co., Ltd.											•	•	•	•	•	•	•	•	•	•	•
Shiuh Sheng Electronics Factory											•	•	•	•							
Sonic Electronic Co., Ltd.											•	•	•			•	•				
Yie Feng Technology Enterprise Co., Ltd.											•		•					•	•		•
THAILAND																					
A-TON (Thailand) Co., Ltd.						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Clarasonic (Thailand) Co., Ltd.						•					•					•					
FSK (Thailand) Co., Ltd.											•		•		•						
Sanit Audio Engineering Co.	•	•									•					•			•	•	•
UNITED KINGDOM																					
EuroTec International, PLC	•					•	•	•	•	•	•	•	•		•	•	•	•	•	•	•
Freudenberg Sealing Technologies, Ltd./Metflex																					•
Volt Loudspeakers, Ltd.														•							
UNITED STATES																					
3M (Industrial Adhesives & Tapes Division)	•	•	•	•	•	•	•	•	•	•											
AcousTex Fabrics																			•		
Arnold Magnetic Technologies/ Precision Thin Metals																•					
Bostik	•	•	•	•	•	•	•	•	•	•											
C.P. Moyen	•	•	•	•	•	•	•	•	•	•											
Cotronics Corp.	•	•	•	•	•	•	•	•	•	•											
DELO Industrial Adhesives, LLC	•	•	•	•																	
Dragonfire Acoustics						•		•	•												
Dymax Corp.	•	•	•	•	•																
Dynavox Electronics, Inc.											•	•	•	•	•	•	•	•	•	•	•
Ellsworth Adhesives	•	•	•	•	•																
Engineered Fibers Technology						•	•		•												
EXACT Dispensing Systems	•	•	•	•	•	•	•	•	•	•											
Fulcrum Acoustic, LLC									•												
Full Compass Systems, Ltd.					•																
Gold Line	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
GraphAudio											•	•	•	•	•	•	•	•	•	•	•
Hawley Products						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Hernon Manufacturing, Inc.	•	•	•	•	•																
Huntsman Advanced Materials	•	•	•	•	•	•	•	•	•	•											
Integrated Dispensing Solutions	•	•	•	•	•	•	•	•	•	•											
J&F Wood Products					•	•															
Krayden, Inc.	•	•		•	•																
Lamart Corp.	•			•	•											•	•				
Loudspeaker Components, LLC											•	•	•	•	•	•	•	•	•	•	•
Master Bond, Inc.	•	•	•	•	•																
Materion															•	•					
MISCO								•													
NedLab											•			•	•	•	•		•	•	•
Orban Audio Speaker Repair											•	•	•	•	•	•	•	•	•	•	•

	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
Parts Express		•			•																
Permabond Engineering Adhesives	•	•			•																
Pierce Audio Products		•										•	•		•			•	•	•	•
Quick Draw & Machining, Inc.															•	•					
Radian Audio Engineering, Inc.												•	•	•	•	•	•	•	•	•	•
Rapid Die & Molding												•	•	•	•	•	•	•	•	•	•
REDCATT																•		•			
Rigid Flex PCB																•					
RTP Co.		•			•			•		•											
Sherwood Industries, Inc.																				•	•
Simply Speakers	•	•			•	•				•	•		•	•					•	•	•
State Of The Art (SOTA) Applications	•	•	•		•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•
TRS Inovations	•	•			•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
United Gasket Corp.						•														•	•
US Enclosure Co.						•					•							•			
Vidsonix Design Works										•											
Western Electric												•									

	Frames & Baskets						Lead Out Wire					
	Cast Alloy	Frame Gaskets	Stamped Steel	Damped Metal	Bumped	Double Bumped	Range of Diameters	Braided	Flat Strip	Beryllium Copper	Phosphor Bronze	Litz	Stranded	Termination/Crimps	Lead Out Wire
BELGIUM															
Donnet: Loudspeaker Repair									•	•	•	•	•		•
BRAZIL															
Attack do Brasil													•	•	
Newbox Industry & Commerce	•	•	•	•	•	•			•	•	•	•	•		•
CANADA															
Canadian Speaker Works	•												•	•	
Reference 3A	•								•						•
CHINA															
BOWI Industry, Co., Ltd.	•	•	•	•	•	•			•	•	•	•	•		•
Lumi Audio	•	•	•	•	•	•									
Ningbo Xiangyang Economic & Trade Co., Ltd.	•	•	•	•	•	•									
Renyi Castings	•	•	•	•	•	•									
Sound Technology Development, Ltd.	•		•	•					•	•	•	•	•		•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•			•	•	•	•	•		•
Zhuhai HiVi Technology Co., Ltd.	•														
DENMARK															
Duelund Coherent Audio									•	•	•				
estron a/s													•	•	•
FRANCE															
KYU Systems	•	•								•					
Seltech		•													
GERMANY															
Hubert Stüken GmbH	•	•	•	•	•	•									
Voice Point									•	•	•	•	•		•
HONG KONG															
Eastern Asia Technology (HK), Ltd.	•	•	•	•	•	•									
WCE Acoustics													•		

	Frames & Baskets						Lead Out Wire					
	Frame Gaskets		Stamped Steel				Flat Strip			Braided		Lead Out Wire Termination/Crimps
	Cast Alloy		Bumped	Damped Metal	Double Bumped	Range of Diameters	Beryllium Copper	Phosphor Bronze		Litz	Stranded	
INDIA												
Audiotone Professional							•	•	•	•	•	•
Dakshin Speaker Manufacturing Private, Ltd. (DSMPL)	•	•	•	•	•	•						
Vidyut Teletronics, Ltd.							•				•	
Wizard India Private, Ltd.	•	•										
INDONESIA												
SB Acoustics			•	•	•	•					•	
ISRAEL												
RH Sound Technology, Ltd.							•	•		•	•	•
ITALY												
ABM Bobine, SRL							•	•	•	•	•	•
Axiomedia, SRL							•	•	•		•	
Boxal, SRL							•	•	•	•	•	•
FaitalPRO	•	•									•	•
Professional Audio	•	•	•	•	•	•	•	•	•	•	•	•

	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		
JAPAN												
Furutech Co., Ltd.										•		
MALAYSIA												
U-Sonics Power Cone	•	•	•	•	•	•						
NETHERLANDS												
Diluvite	•		•	•	•	•						
PHILIPPINES												
Dai-ichi Electronics Manufacturing Corp.	•	•	•	•	•	•						
SWEDEN												
Audio Pro, AB	•	•	•	•	•	•	•	•		•		•
TAIWAN												
Huey Tung International Co., Ltd.	•	•	•	•	•	•	•	•			•	
Maeden Innovation Co., Ltd.							•			•	•	•
Yie Feng Technology Enterprise Co., Ltd.		•										
THAILAND												
A-TON (Thailand) Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•
UNITED KINGDOM												
EuroTec International, PLC	•	•	•	•	•	•	•	•	•			•
UNITED STATES												
A. Schulman, Inc.	•											
American Bass USA	•	•	•	•	•	•	•	•	•	•	•	•
Cardas Audio							•	•	•	•	•	•
Dynavox Electronics, Inc.	•	•	•	•	•	•	•			•	•	
Elektrisola							•	•	•	•	•	•
Gold Line	•	•	•	•	•	•	•	•	•	•	•	•
Herman Pro, AV							•	•	•	•	•	•
Materion								•				
NedLab	•	•										
New England Wire Technologies							•	•	•	•	•	•
North Reading Engineering	•	•	•	•	•	•	•	•	•	•	•	•
Pierce Audio Products	•	•	•		•	•						
Quick Draw & Machining, Inc.	•			•	•	•						
Radian Audio Engineering, Inc.	•	•	•	•	•	•						
Rapid Die & Molding	•	•	•	•	•	•						
RDS Wire & Cable							•	•	•	•	•	•
Redco Audio											•	
Simply Speakers							•					
Standard Wire & Cable Co.							•	•	•	•	•	•
TRS Inovations	•	•	•	•	•	•						
United Gasket Corp.		•										
Western Electric							•				•	
Whitmor Wirenetics							•	•	•	•	•	•
VIETNAM												
Sound Corp.		•	•	•	•	•						

	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids	Pole Pieces	T-Yokes 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																•
BRAZIL																
Newbox Industry & Commerce	•	•	•	•	•	•	•			•		•	•	•	•	•
CANADA																
Canadian Speaker Works	•			•			•	•								
Reference 3A													•			
Solen Electronique, Inc.				•						•					•	•
Studio Reference Monitors															•	
Tortech Sound															•	
CHINA																
Audiostar Electronics Co., Ltd.								•	•	•	•	•	•	•		
BOWI Industry, Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Changzhou Xiantong Magnetic Materials Co., Ltd.		•	•	•												
Lumi Audio															•	•
Ningbo Xiangyang Economic & Trade Co., Ltd.								•	•	•	•	•	•	•	•	•
OBE Pro Audio Co., Ltd.															•	•
One Magnet Electronic Co., Ltd.		•	•	•												
Pana Sound, Ltd.															•	•
Shenzhen Guangnan Electronic Co., Ltd.								•	•	•	•	•	•	•	•	•
Sound Technology Development, Ltd.	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Tianyi Electronic Co., Ltd.		•	•	•	•		•									
Tonly Electronics Holdings																•
Trueanalog Strictly OEM	•					•	•									

	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids		Pole Pieces	T-Yokes 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 Amplifier for	Subwoofer Plate Amplifier
Vistron Audio Equipment																•
Vormag Electronics Co., Ltd.		•		•	•						•					
Zeng Ben Industrial Corp., Ltd.						•	•									
Zenith Audio Electronics Co., Ltd.											•		•	•	•	
FRANCE																
Kartesian								•					•			
KYU Systems	•			•	•	•	•	•			•		•			•
GERMANY																
Audio Technology Engineering (ATE)								•			•		•	•	•	•
Voice Point	•	•	•	•	•	•	•									
HONG KONG																
Eastern Asia Technology (HK), Ltd.													•	•	•	•
WCE Acoustics	•	•	•	•			•	•	•	•	•	•	•	•		•
INDIA																
Audiotone Professional								•					•	•	•	
Dakshin Speaker Manufacturing Private, Ltd. (DSMPL)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids	Pole Pieces	T-Yokes 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
Lakshmi Metal Coils														•		
Power Electronics & Technologies															•	•
TurboSonic Pro Speakers				•								•	•	•		
Vidyut Teletronics, Ltd.										•	•	•	•			
Wizard India Private, Ltd.				•			•									
INDONESIA																
SB Acoustics	•			•	•		•	•	•			•	•	•		
ISRAEL																
RH Sound Technology, Ltd.								•	•	•	•	•	•	•	•	•
ITALY																
ABM Bobine, SRL								•	•	•	•	•	•	•	•	•
Axiomedia, SRL				•											•	•
Boxal, SRL								•	•	•	•	•	•	•	•	•
FaitalPRO	•			•	•		•	•					•			
OEB, SRL													•	•		
Powersoft, SpA															•	
Professional Audio	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•

	Magnetic Assemblies					Voice Coil Components								
	Back Plates	Magnets: Alnico	Magnets: Ferrite	Magnetic Fluids: Neodymium	Pole Pieces	T-Yokes Top Plates	Bobbins/Formers	Collars	Magnet Wire	Polyimide Tape for Collars	Voice Coil Assemblies: Flat Wire	Voice Coil Assemblies: Round Wire	Voice Coil Stacks	Amplifiers: Powered Speakers	Amplifiers: Amplifier for Subwoofer Plate Amplifier
MALAYSIA															
Shu Kae Industrial								•	•	•	•	•	•	•	•
NETHERLANDS															
Diluvite	•					•	•	•							
ELTIM audio, BV														•	
Hypex Electronics, BV														•	•
Teijin Aramid								•	•	•	•	•	•	•	•
PHILIPPINES															
Dai-ichi Electronics Manufacturing Corp.								•	•	•	•	•	•	•	•
POLAND															
Sveda Audio														•	
SOUTH AFRICA															
Paks Acoustics	•	•	•	•		•	•								
SOUTH KOREA															
Suntel Co., Ltd.								•	•	•	•	•	•	•	•

	Magnetic Assemblies							Voice Coil Components								
	Back Plates	Magnets		Magnetic Fluids		Pole Pieces	T-Yokes Top Plates	Bobbins/Formers	Polyimide Tape for Collars	Magnet Wire	Voice Coil Assemblies			Amplifiers		
		Alnico	Ferrite	Neodymium				Collars			Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Amplifier for Subwoofer Plate Amplifier	
TAIWAN																
Huey Tung International Co., Ltd.	•	•		•	•	•	•	•		•		•	•	•	•	•
Kingstate Electronics Corp.															•	
Po Yun Enterprise Co., Ltd.								•	•	•	•	•	•	•	•	•
Shining Jins Enterprise Co., Ltd.	•					•	•									
THAILAND																
A-TON (Thailand) Co., Ltd.	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
FSK (Thailand) Co., Ltd.								•			•					
UNITED KINGDOM																
BishopSound															•	•
EuroTec International, PLC	•	•		•	•	•	•	•	•	•	•	•	•	•		•
Precision Devices, Ltd.	•			•	•	•	•	•		•		•	•			
Volt Loudspeakers, Ltd.													•			
UNITED STATES																
Acoustic Design, Inc.	•					•	•					•	•	•		
Alliance, LLC	•	•		•	•	•										
American Bass USA	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•

	Magnetic Assemblies					Voice Coil Components										
	Back Plates	Magnets		Magnetic Fluids	Pole Pieces	Bobbins/Formers	T-Yokes Top Plates	Magnet Wire	Polyimide Tape for Collars	Collars	Voice Coil Assemblies	Flat Wire	Round Wire	Voice Coil Stacks	Amplifiers	Amplifier for Powered Speakers	Subwoofer Plate Amplifier
		Alnico	Ferrite	Neodymium													
Area 52 R&D	•			•	•		•	•								•	•
Arnold Magnetic Technologies/ Precision Thin Metals		•		•	•												
Cadillac Audio	•				•		•	•								•	•
CE Distribution																	•
CommonSense Audio																•	
Dayton Audio																•	•
DMSI																•	
Dragonfire Acoustics													•	•	•	•	•
Dynavox Electronics, Inc.	•	•		•		•	•	•	•	•				•		•	•
Elektrisola								•	•	•	•	•	•	•	•	•	•
FerroTec (USA) Corp.					•												
Gold Line	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•
Lamart Corp.											•						
Marchand Electronics, Inc.																•	•
Materion								•									
MISCO																•	
NedLab								•									
Pierce Audio Products	•			•	•		•	•					•	•			

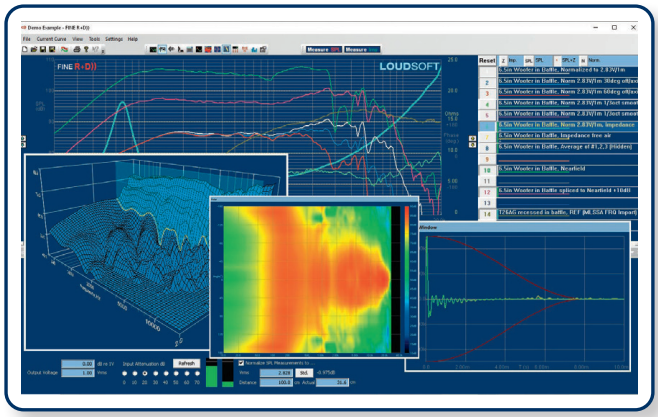
	Magnetic Assemblies							Voice Coil Components							
	Back Plates	Magnets		Magnetic Fluids		Pole Pieces	T-Yokes Top Plates	Bobbins/Formers	Polyimide Tape for Collars	Magnet Wire	Voice Coil Assemblies			Amplifiers	
		Alnico	Ferrite	Neodymium					Collars		Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Subwoofer Plate Amplifier
Precision Converting—HISCO											•	•	•	•	
Precision Econowind, LLC									•	•	•	•	•	•	
PRV Audio Brazil				•	•										•
Radian Audio Engineering, Inc.	•	•		•	•	•	•	•							
Radio Design Labs (RDL)															• •
RBH Sound															•
RCF USA, Inc.															•
Senzar Acoustics															• •
Simply Speakers						•									
Sound Sources Technology, Inc.															• •
SpeakerAddict															•
SpeakersAndAmps.com															• •
Transducer Lab, LLC	•			•	•	•	•	•							
TRS Inovations												•	•		• •
US Enclosure Co.															• •
Vidsonix Design Works				•	•										
Whitmor Wirenetics										•					
VIETNAM															
Sound Corp.															• •

	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
AUSTRALIA																						
DEQX, Pty., Ltd.				•																		
RØDE Microphones																					•	
Soundlabs Group, Pty., Ltd.									•			•										
Stone Sound Studio	•			•		•		•	•				•	•	•		•			•	•	
AUSTRIA																						
Austrian Audio				•																	•	
BELGIUM																						
Donnet: Loudspeaker Repair		•		•		•		•		•		•		•		•		•		•		•
BRAZIL																						
Attack do Brasil	•	•		•		•		•		•		•		•		•		•				
Newbox Industry & Commerce	•	•		•		•		•		•		•		•		•						
CANADA																						
Solen Electronique, Inc.				•												•						
Space-Tech Lab, Ltd.				•						•		•		•								
Sziara Sound																						
CHINA																						
BSWA Technology Co., Ltd.	•															•						
CRY Sound Co., Ltd.		•		•					•			•				•		•				

LOUDSOFT

FINE R+D)) ™ 100khz

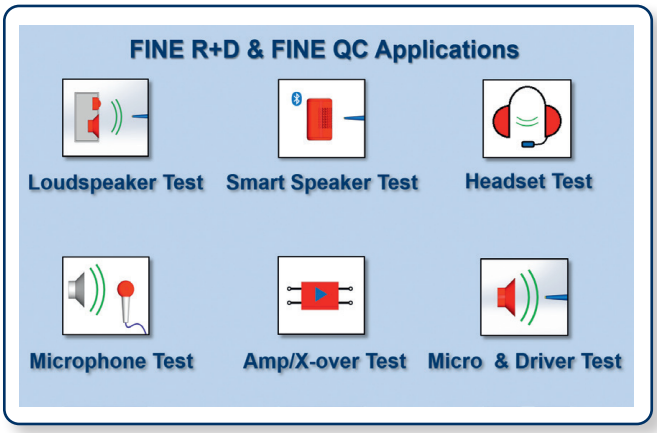
- Freq. range ~ 100 kHz: s 48,96 and 192 kHz
- **Anechoic measurements in normal rooms**
- LO (current) and HI (current) Impedance
- Microphone measurements (rel. to Ref mic)
- Amplifier Measurements 10 ~ 100kHz
- Crossover Measurements 10 ~ 100kHz
- Auto-save Time= Change window +smooth
- Bluetooth measure w Delay compensation
- FINE Hardware3: 25W amp + GRAS mics

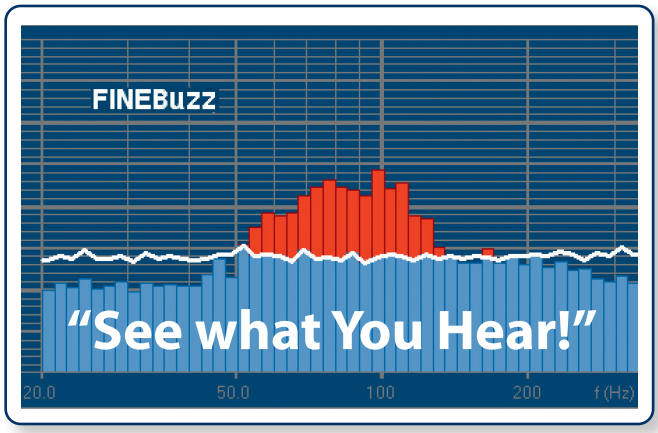


FINE QCX ™ 2020

- **QC Test: SPL, Pol, Imp, Fs, THD, Rub/Buzz**
- **Rub/Buzz: Customers say:"Best in Industry"**
- Measure Good / Bad sets R&B limits
- Automatic "Golden Average unit"
- Auto-saved Statistics & Pair Matching
- Amplifier & Crossover Measurements
- Bluetooth measure w Delay compensation
- FINE Hardware3: 25W amp +GRAS mics

Modules: **Full Automation to / from Prod.**
Multi-step / Sequences
Digital S/PDIF Output





	Accelerometers	Anechoic Chambers	Audio Analyzers	Gaussmeters	LCR Bridges	MLS	Multimeters	Oscilloscopes	Resistance Bridges	Signal Generators	Sine/Square Wave Oscillators	Speaker Turntables	Speaker Parts	Spectrum Analyzers	1/3 Octave	FFT	Heterodyne	TDS	Stroboscopes	Test Mics	Testing Cabinets	Turns Counters
MicW Audio																				•		
Pana Sound, Ltd.			•	•										•						•	•	
Sound Technology Development, Ltd.			•	•					•			•	•	•	•	•	•	•		•		
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
DENMARK																						
DPA Microphones																				•		
K & K Development				•								•	•									
Loudsoft, Ltd.				•			•					•				•	•			•	•	
PointSource Acoustics			•	•				•	•			•	•	•		•	•		•	•		
FRANCE																						
KYU Systems				•		•	•							•			•			•	•	
GERMANY																						
Fraunhofer Institute for Digital Media Technology																					•	
Klippel GmbH				•	•		•					•		•	•	•	•	•		•		
Mvoid Technologies GmbH				•																		
Physical-Lab	•	•	•																	•		

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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	Stroboscopes: TDS	Stroboscopes	Test Mics	Testing Cabinets	Turns Counters
Rohde & Schwarz			•					•	•						•	•	•	•			•
HONG KONG																					
dB Enterprises			•																		
ISRAEL																					
RH Sound Technology, Ltd.						•		•	•	•	•		•								
ITALY																					
Audiomatica, SRL	•		•			•	•	•		•	•	•			•	•		•		•	
Axiomedia, SRL						•															
Outline SRL														•							
SpeakerLAB			•																		
JAPAN																					
Etani Electronics Co., Ltd.		•	•				•	•				•		•	•	•				•	•
LATVIA																					
Sonarworks																				•	
NETHERLANDS																					
Audio Components, BV			•												•	•					
SINGAPORE																					
Virtins Technology	•		•			•	•	•	•			•	•	•	•	•	•	•		•	
SWEDEN																					
Audio Pro, AB	•		•			•									•	•		•			
Bohmer Audio			•				•					•	•		•	•		•			
SWITZERLAND																					
Megatec AG				•																	
SoundChip			•																		
UNITED KINGDOM																					
DBS Audio	•		•																	•	
EuroTec International, PLC		•	•				•	•	•			•	•	•	•	•				•	•
GRAS Sound & Vibration UK		•																		•	•
Hill Acoustics		•																			•
Spectral Measurement		•	•				•					•	•		•	•	•	•		•	•
UNITED STATES																					
ACO Pacific, Inc.													•							•	
Adafruit Industries	•								•	•											
Alliance, LLC					•																
Allied Electronics, Inc.			•						•	•		•									
Amplitrex Audio Products, LLC			•																		
Audio Advisor, Inc.														•							
Audio Precision, Inc.			•									•								•	
Audix																				•	
Beach Dynamics		•																			
Behringer																				•	

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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
Bruel & Kjaer Sound & Vibration North America, Inc.	•	•		•								•		•	•	•	•			•	•
Danville Signal Processing, Inc.	•			•								•			•	•				•	
Dayton Audio				•									•							•	
Fotronic Corp.	•			•		•			•	•		•			•	•	•	•	•		
Geometric Designs, LLC & Geometric Consulting				•																	
GL Communications, Inc.				•								•								•	
Gold Line				•		•				•		•	•							•	
GRAS Sound & Vibration																				•	•
HEAD acoustics, Inc.				•																	
Herman Pro, AV		•		•								•									
HX Audio Lab																					•
IK Multimedia																				•	
Kramer Electronics												•									
Listen, Inc.				•			•	•	•			•			•	•	•	•		•	
Marchand Electronics, Inc.				•								•	•								
Markertek Video Supply	•			•				•	•			•		•							
MCM Electronics				•		•		•	•			•	•	•	•	•	•				
Meniscus Audio Group, Inc.	•												•								
Meyer Sound Laboratories, Inc.				•																	
NedLab	•				•			•				•	•		•						
Neobits, Inc.						•		•	•			•							•		
NTi Audio				•								•	•	•	•		•			•	
Parts Express				•				•												•	
PCB Piezotronics, Inc.	•	•		•																•	
Performance Audio, LLC				•								•								•	
Phoenix Engineering, LLC													•								
PRV Audio Brazil																					
Radio Design Labs (RDL)				•		•				•	•	•	•		•	•	•	•			
Redco Audio									•			•		•							
Scantek, Inc.	•														•	•					
Smith and Larson Audio				•		•					•	•	•							•	
Soundoctor												•	•								
Studio Six Digital				•											•	•		•		•	
Techni-Tool				•					•	•		•			•	•	•	•	•		
TEquipment						•			•	•		•									
US Enclosure Co.													•								•
Vidsonix Design Works				•																	
Vintage King Audio						•				•		•								•	
Warkwyn				•								•	•		•	•	•	•			
VIETNAM																					
Sound Corp.													•								

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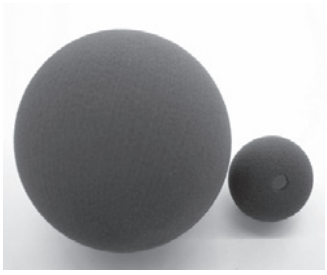

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By
Andrew Taylor
(Klippel GmbH)

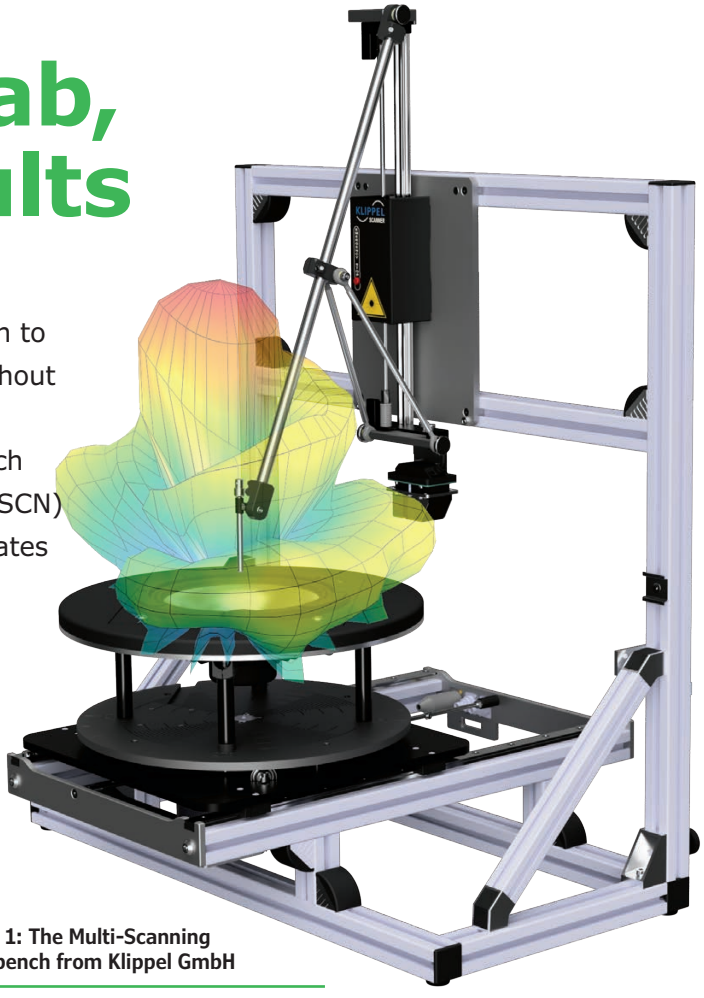

Photo 1: The Multi-Scanning Workbench from Klippel GmbH

Speaker testing, from individual components to transducers to complete active audio systems, usually requires a lot of different equipment, which can lead to an expansive and expensive measurement setup. One way to downsize your R&D laboratory without compromising your measurement capabilities or accuracy is to use the unified solution offered by the Multi-Scanning Workbench from Klippel GmbH. This modest setup works in a normal work or home office, dispensing with the need for a large baffle and anechoic room. With the work-from-home model seemingly here to stay to some extent even after the COVID threat is sufficiently reduced, this becomes even more helpful. Results of an example transducer measured with this all-in-one setup are used throughout this article to illustrate the capabilities of the Multi-Scanning Workbench and the advantages compared to traditional testing methods.

Multi-Domain Measurements

Fully characterizing and evaluating speakers throughout the entire design phase requires measuring across many different domains. It is important to measure different signals in parallel because the effects and the root cause of a specific phenomenon often lie in separate domains. Being able to trace symptoms across domains is necessary for a deep understanding of the loudspeaker behavior.

Test Setup

Performing multi-domain measurements places a large set of needs on the measurement equipment and setup used. While there are plenty of high-end consumer and professional audio analysis tools available today, these solutions usually only combine electrical and acoustical testing. When using these options, sound radiation measurements conforming to international standards are typically performed using a baffle in an anechoic room. However, the accuracy of low-frequency measurements is highly dependent on the sizes of the room, transducer, and baffle, and on the effectiveness of the low-frequency absorption. Another problem is baffle vibrations. To combat this, baffles can be made from solid steel or concrete, but the increased weight can lead to handling problems.

The all-in-one Multi-Scanning Workbench equipped with the Scanning Vibrometer System (SCN) Near Field Add-On, as seen in **Photo 1**, is a complete but compact solution. This hardware facilitates electrical, acoustical, mechanical, and magnetic testing. Measuring in these domains in parallel or switching between them is smooth and uncomplicated. The newly released acoustical scanning ability utilizes the same direct sound separation technique used in the Near-Field Scanner (NFS), which also supports larger audio devices [1]. This technology has several advantages compared to normal

far-field measurements, such as obtaining the full 3D sound radiation data in both the near and far fields in a shorter amount of time than could be accomplished with turntables and minimal microphone arrays. On top of that, a large baffle and an anechoic room are no longer needed.

A small round baffle is sufficient because the signal processing can remove the influence of diffraction at the edges, acoustic shortcuts, and room reflections. By removing the traditional restricting factors of room and baffle size, this technology can be very accurate at low frequencies even when placed in a normal work or home office. This solution is perfect for comprehensive speaker analysis because it integrates everything that is needed into a space- and cost-efficient unified hardware that can quickly perform multi-domain measurements.

Magnetic Measurements

The magnet is an important part of the motor structure that determine the large signal performance of the final speaker. The magnetic properties can be measured with the BFS Sensor, a small Hall sensor, attached to the laser housing of the Multi-Scanning Workbench (**Photo 2**). This thin sensor fits into the air gaps of most transducer motor structures. It is possible to verify FEM simulations or to inspect magnetic field inconsistencies in the air gap, which can lead to rocking modes. Different coil setups and resulting Bl curves can also be simulated from the resulting B-Field scans. The flux density and flux density deviation of the magnet from the example transducer are shown in **Figure 1** and **Figure 2**, respectively.

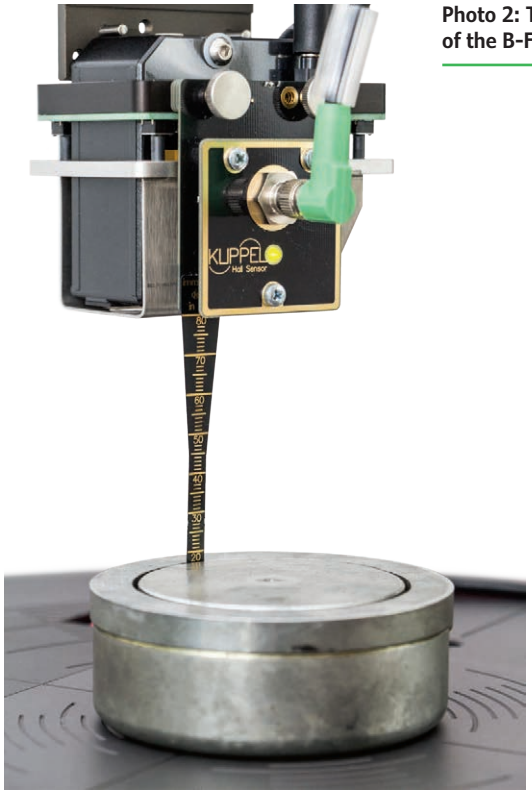

Photo 2: The BFS Sensor of the B-Field Scanner

Electrical Measurements

There are several different ways to measure the Thiele-Small (T-S) parameters and the impedance curve, including delta mass and delta compliance methods that only use electrical signals. However, using a laser displacement sensor in addition to identifying the displacement is faster, easier, and more precise [2]. Moving on, with electrical sensors and an optional laser, measuring the lumped parameters of a large-signal model and nonlinear curves such as force factor, stiffness, and inductance is a straightforward task [3].

Using the Multi-Scanning Workbench with the laser pointed at the center of the diaphragm, the impedance, T-S parameters, and large signal parameters and curves of the example transducer

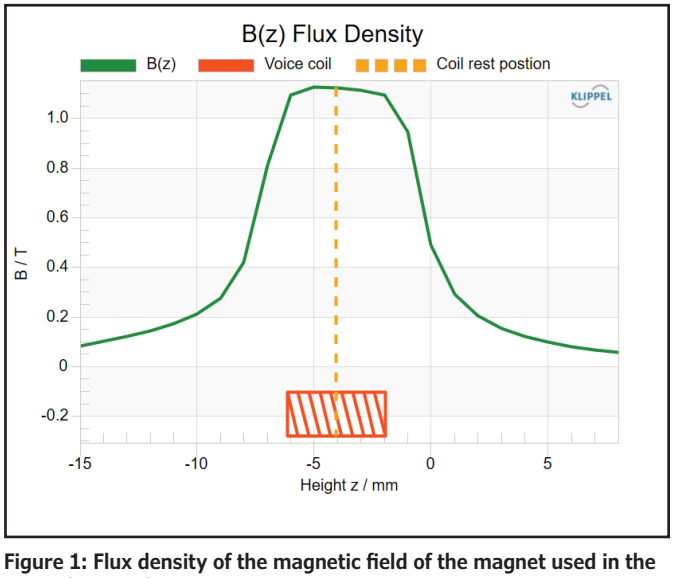

Figure 1: Flux density of the magnetic field of the magnet used in the example transducer

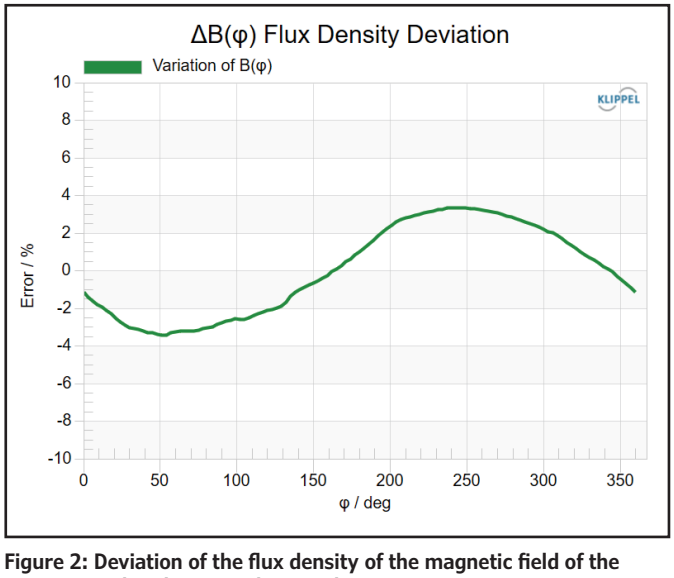

Figure 2: Deviation of the flux density of the magnetic field of the magnet used in the example transducer

were quickly obtained (**Table 1**). **Figure 3** shows a flat and symmetrical force factor characteristic thanks to the underhung voice coil design.

Acoustical Scanning

Measuring and analyzing sound radiation to extract sound power and directivity with high angular resolution is usually very time-consuming. However, by performing a holographic measurement with direct sound separation using the SCN Near-Field Add-On, a complete scan of the example transducer up to 20 kHz was accomplished in only five minutes (Table 1) with the assumption of rotational symmetry, which greatly reduces the number of measurement points needed for round drivers placed in round baffles. From this scan, the sound pressure output at any point in 3D half space, in either the near or far field, can be generated. These quick but complete measurements are also perfect for investigating the influence of different grills, horns/waveguides or clamping/mounting options as well as compact complete audio systems such as portable devices.

A contour plot of the horizontal sound pressure output (**Figure 4**) was generated in the far field (10m distance). This measurement can be done in any normal semi-reverberant room, and the measurement principle is shown in **Figure 5**, where the room and baffle reflections are removed from the measured response to extract the direct sound.

In contrast, similar data (1° angular resolution) using turntables and a single measurement microphone would require up to 32,400 measurement points and take between three and four days, leading to a time reduction factor of ~1,000! Aside from the time savings, this measurement would either need to be done in a large anechoic chamber or outside, which leads to other issues such as wind, ambient noise, and temperature variations that can corrupt the data.

Single-Point Measurements

For some acoustical measurements, such as equivalent input distortion or impulsive distortion (also known as Rub & Buzz), it is always recommended to place the microphone in the near field in order to maximize SNR and sufficiently reduce any room influence [4], [5]. For others such as on-axis response and total harmonic distortion (THD), they are usually done at the standard distance of 1m or farther to ensure the measurement is in the far field. However, after performing an acoustical scan, a (room) correction curve can be generated that compensates for the position of the measurement microphone and any unwanted effects of baffles or non-anechoic rooms. Therefore, the microphone

Characteristics	Sensor	Measurement Time
Thiele-Small Parameter	Voltage/Current, Laser	1 minute
Nonlinearities	Voltage/Current, Laser	10 minutes
SPL Response (Any point in 3D half space, directivity, sound power etc.)	Microphone (single)	5 minutes*
Diaphragm vibration, mode shapes, etc.	Laser	8 minutes*
Magnetic field properties	Hall	8 minutes
*Assuming rotational symmetry		

Table 1: Time spent for different measurements of the example driver using the Multi-Scanning Workbench

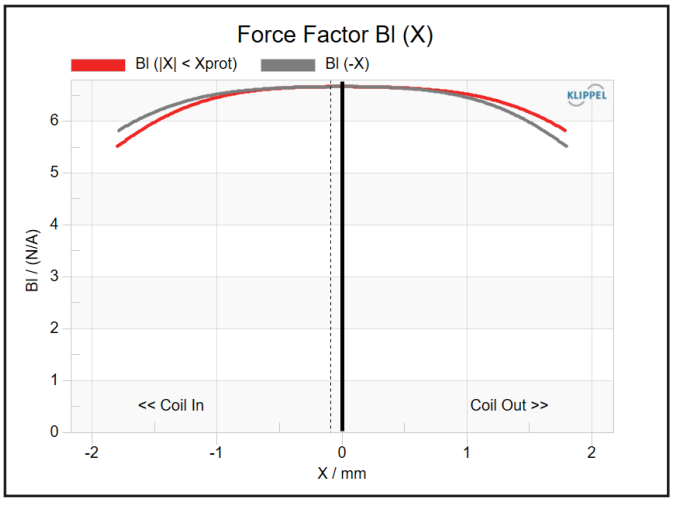

Figure 3: Example transducer Bl(X) curve.

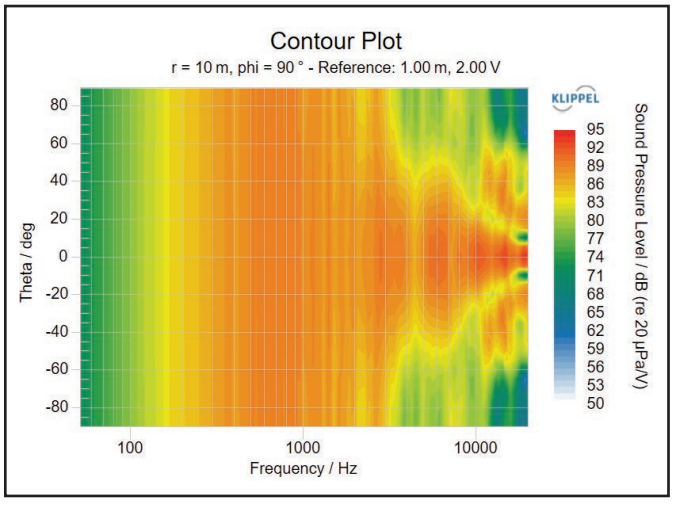

Figure 4: Example transducer horizontal plane contour plot

can be positioned in the near field to maximize the signal-to-noise ratio (SNR) while measuring in a reverberant room while the virtual evaluation point is at another distance, such as in the far field. This means that standard measurements at an evaluation point much farther away, even farther than the physical dimensions of the room, can be done in a normal work or home office while keeping a single microphone in a fixed position. For example, **Figure 6** shows the transformed on-axis response and harmonic distortions at 1m distance, even though the microphone was placed at 10cm distance.

Mechanical Scanning

Using a laser displacement sensor to assess the diaphragm vibration of a speaker can be very helpful in most applications.

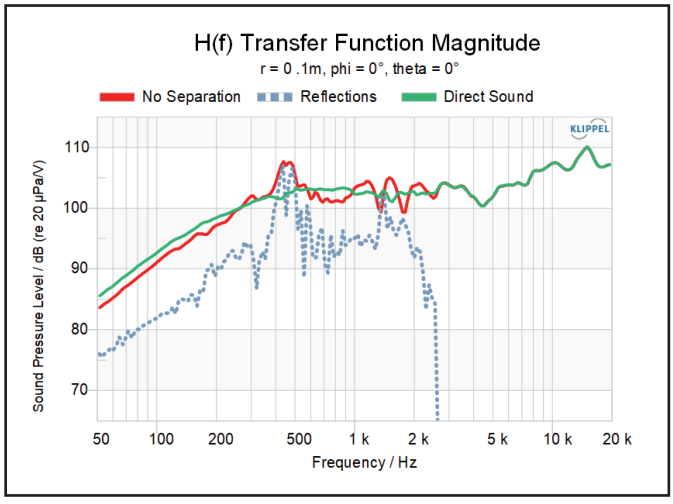

Figure 5: Example transducer measured near-field frequency response, direct sound response and separated reflections

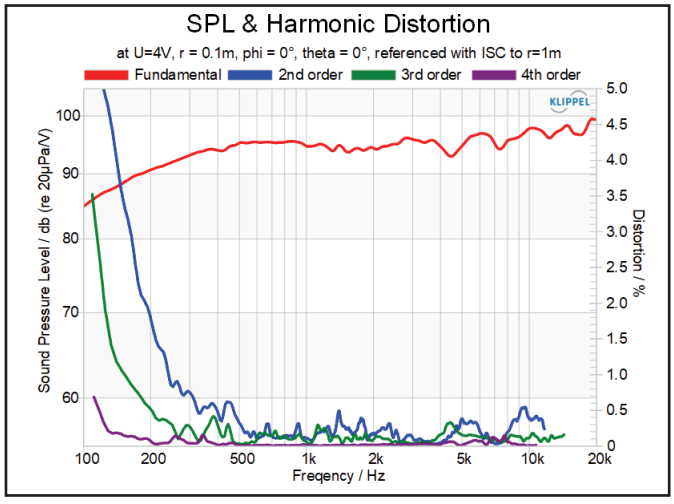

Figure 6: Example transducer fundamental on-axis response and harmonic distortion components

After a scan, it is easy to see the contributions of radial vs. circular displacement components or how the in-phase, anti-phase, and quadrature components are affecting the sound pressure level, which can become complex at higher frequencies due to the modes induced by cone breakup [6].

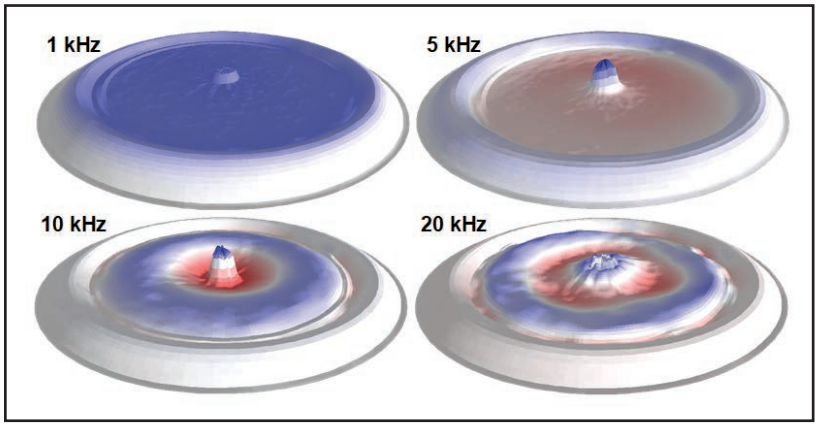

Figure 7: Example transducer measured near-field frequency response, direct sound response, and separated reflections

The vibration data of the example transducer, with several vibration patterns being shown in **Figure 7**, was obtained in just 8 minutes (see Table 1). Additionally, analyzing rocking modes caused by mass, stiffness, or force factor imbalances is especially important for small drivers with simple suspensions [7]. While not expanded upon in this article, these small suspensions can be investigated on the component level as well using the Micro Suspension Part Measurement (MSPM) Bench, which can be attached to the Workbench.

Conclusion

The Multi-Scanning Workbench is a physically small but mighty tool for comprehensive speaker testing. Due to the operation across four domains (acoustical, mechanical, electrical, and magnetic) as well as the unique advantages of the holographic scanning with direct sound separation, the total space, cost, and measurement time can be greatly reduced compared to other solutions that combine different tools for each domain and use anechoic chambers and large baffles. The Multi-Scanning Workbench is ideal for anyone who wants to test speakers in any part of the design phase including: components (magnet, suspension); transducers; transducers + partial systems (with different grills, horns/waveguides or clamping/mounting); compact complete systems (e.g., portable speakers or mobile phones), even in a non-anechoic environment such as a work or home office. ***LIS***

About the Author

Andrew Taylor received his Bachelor's degree in electrical engineering at the University of Kansas in Lawrence, KS in 2015. As he finished his master's in electrical engineering with a concentration in musical acoustics and signal processing at the University of Rochester in Rochester, NY, he interned at Klippel GmbH in 2016. He has been a full-time employee at Klippel since 2017, where he now splits time between audio analyzer hardware development and technical writing and content creation.

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[1] C. Bellman and W. Klippel, "Holographic Nearfield Measurement of Loudspeaker Directivity", Audio Engineering Society Convention Paper 9598, September 2016.

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Resources

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SCN Near-Field Add-On (SCN-NF), Klippel, www.klippel.de/products/rd-system/modules/scn-nf-scn-near-field-add-on.html

Designing the Gold Standard of Immersive Audio for Virtual Reality Gaming

Tectonic Audio Labs created a state-of-the-art balanced mode radiator speaker using electromagnetics and mechanical and acoustics simulation. The speaker was implemented into a virtual reality (VR) headset for Valve Corp. and is now regarded as the gold standard for VR audio.

By
Julia Abrams
(COMSOL)

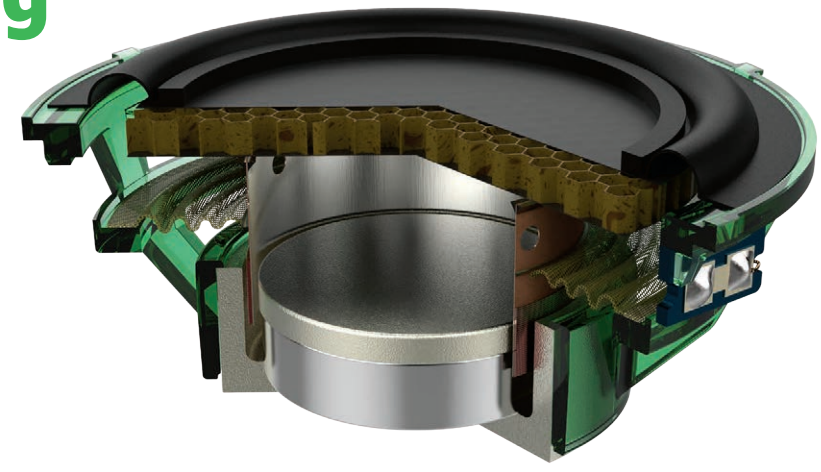


Figure 1: Cutaway view of the BMR speaker

Virtual reality (VR) is meant to immerse the user in the virtual world as much as possible by making it feel as real as can be. When virtual reality is done right, you could visit a historical site from your couch, experience a habitat from eons past at a museum, or explore Mars or the Moon from the comfort of your living room.

The gaming industry is making great strides in VR development, but one challenge that game developers have encountered is how to effectively obtain suspension of disbelief in the virtual world.

Whether you're using VR to study an asteroid approaching Earth or playing a game where you have to fire missiles at it, the more immersive the experience, the better. Other entertainment fields, (e.g., literature and film) face the same challenge of suspension of disbelief, but there's something exclusive to VR: audio immersion.

Achieving Audio Immersion in the Valve Index Headset

Valve Corp.—a leading developer in the gaming industry, creating games, gaming platforms, and gaming hardware—sought to develop the Valve Index VR headset that could provide suspension of disbelief. To do so, Valve engineer Emily Ridgway and her team had to figure out how to create an immersive audio experience.

While playing video games, people often wear stereo headphones to determine where the sound is coming from relative to their character in the game. If the source is to the left of the character, the player will hear the sound through the left headphone speaker, and vice versa. The Valve team decided against using traditional headphones, because headphones are designed to isolate sound, cancel noise, and exaggerate frequency responses—not to create audio immersion.

Ridgway was concerned that the very physical design of headphones could counteract audio immersion. For one, headphones put sound directly into the ear canal, so the sound can feel imagined (known as an internalized auditory source), coming from within the person's head, or otherwise "not real." Also, headphones can be physically uncomfortable, and this discomfort can draw a user out of the gaming experience. Some people opt for loudspeakers instead of headphones. While loudspeakers mitigate some of these issues, they come with their own problems. The sound of a loudspeaker is affected by the geometry and acoustics of the real room. Another reason is

that loudspeakers have a "sweet spot" that the player would need to stay in for the best sound quality, but when people experience VR, they tend to move around.

Ridgway's solution? A pair of ultra-near-field, full-range, off-ear (extra-aural) headphones.

Ridgway and her team went through several types of audio speakers for the headset. None quite fit their goals; none, that is, until they found Tectonic Audio Lab's balanced mode radiator (BMR) speakers (**Figure 1**). Ridgway "immediately noticed several positive benefits," she wrote in a blog post. "They reduced coloration due to speaker mispositioning, were almost within range of our weight target, had great frequency response in high-mid ranges (important for binaural simulations), and were much thinner than traditional speaker drivers." Valve teamed up with Tectonic Audio Labs to harness these benefits and design custom speakers for their VR headset.

What Is BMR Speaker Technology?

In traditional speakers, audio is generated by a cone diaphragm moving pistonically. This movement transfers energy along the axis of movement and creates sound. BMR speakers are different, in that they utilize bending waves: waves that are moving perpendicular to the propagation direction. This means that they have more interaction with the surrounding air, so they are able to transfer more energy.

Higher frequencies can be difficult for traditional speakers to handle, as they can cause the traditional diaphragm to ripple or bend, also known as cone breakup. The subsequent peaks and troughs decrease audio quality and increase placement sensitivity. While most speakers try to avoid bending waves, BMR embraces them (**Figure 2**).

"We embrace the bending modes and want them to occur. We can control where they occur, and it's those bending modes that preserve the off-axis output. We're using resonance breakup to our advantage," said Tim Whitwell, vice president of engineering at Tectonic Audio. "In many ways, BMR goes against the thinking of traditional acoustic engineering."

BMR technology is able to exploit this high-frequency rippling through the optimization of several characteristics, such as material selection and mass loading. Through this exploitation of the bending modes, and the superposition of both the bending and piston modes, sound is evenly propagated in the BMR speaker.

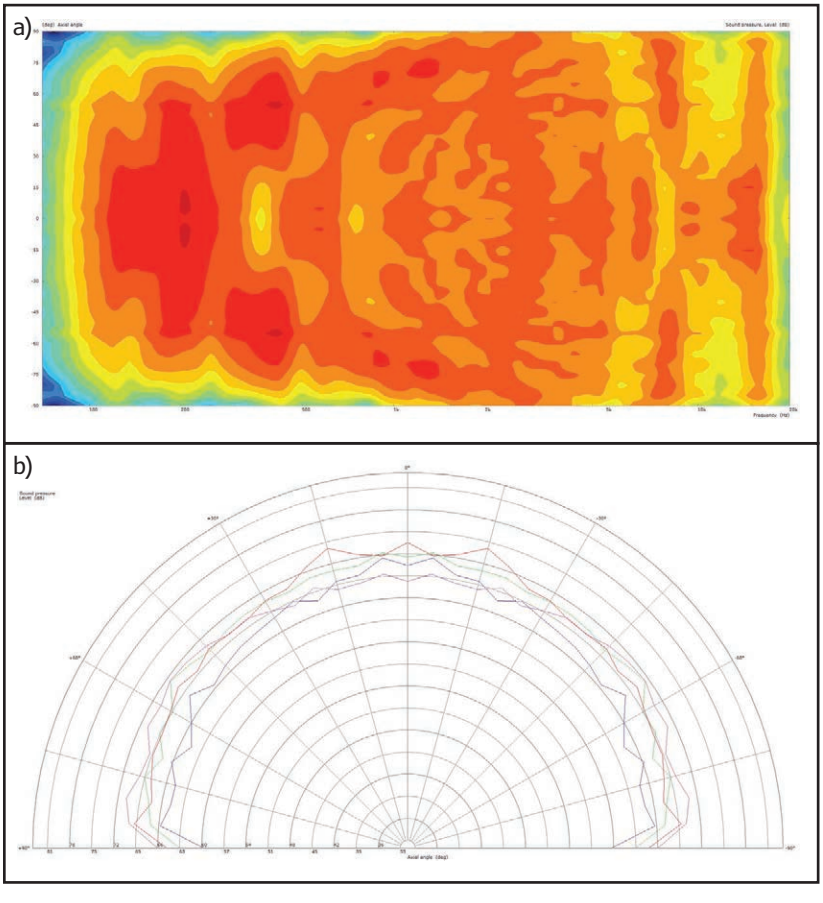


Figure 2: Directivity (a) and polar plots (b) for the BMR speaker analysis

Creating the Gold Standard

The team at Tectonic Audio Labs got to work on the audio speakers for the Valve Index VR headset. "For us, the starting point is to analyze the modal structure of the diaphragm," Whitwell said. "What's really important for us with the BMR is to make sure that the modal behavior begins right when the pistonic behavior begins beaming." Once beaming is about to start, the bending modal behavior begins, which "fills in" the off-axis output that the beaming neglects.

In order to optimize this behavior, the Tectonic team first had to figure out where in the disc bending modal behavior occurs and how many bending modes occur across the bandwidth. They used the COMSOL Multiphysics software to perform an eigen frequency analysis of this behavior. From there, the team was able to control the bending modes through optimizing the thickness and material of the disc. By making sure this behavior occurs precisely where and when they want it to occur, Tectonic Audio is able to preserve the speaker's wide directivity output throughout the range.

Tectonic also analyzed the motor design, performing an electromagnetics analysis to optimize the voice coil. "You can add many turns to your voice coil wire to increase your conversion of electromagnetic to mechanical energy, but your weight goes up, and so you have competing constraints there," Whitwell explained. "All of that optimization we do within COMSOL."

The mechanical and electromagnetics models were processed and optimized separately.

Tectonic Audio Lab's next step was to bring the two together for a coupled analysis. Because nearly everything in the model is axisymmetric, they were able to model the coupling in a 2D axisymmetric space, saving computational resources. The diaphragm material is the exception. "The diaphragm material itself is actually orthotropic; it has different stiffnesses in different directions," Whitwell said, "The Solid Mechanics interface in COMSOL Multiphysics lets us model the orthotropic nature of the material within the 2D axisymmetric space, which is really fantastic."

After the team developed the fully coupled model (**Figure 3**), they introduced other elements, like the spider suspension, which centers the coil and controls its movement. At the same time, they continued optimizing the fully coupled model to ensure that the diaphragm's behavior would be balanced—which is the key to the BMR technology, allowing it to work properly in the Valve Index VR headset and provide a great experience for different users.

Once the speakers are fully dialed in, the suspension is the next focus, and its geometry is analyzed in a nonlinear study. "We deform the suspension geometry up and down, to see how the stiffness of those components changes with displacement," Whitwell said. "And again, there's a lot of optimization required there." Whitwell emphasized that this optimization was particularly important in this project, "Any noise in the drive unit or distortions would be very, very obvious to the listener." After the suspension is fully optimized, it goes back into the coupled model.

"We make sure that everything is still giving us the performance we desire," Whitwell said, "And then we can go and build a prototype."

The "King" of VR Headsets

After Tectonic Audio Lab's design optimization and prototyping were successful, Valve Corp. was able to bring its headset to market. Since then, it has earned many, many positive reviews.

One example is a beloved and popular YouTube channel called "Linus Tech Tips," run by the titular Linus. Video topics range from explaining if more RAM makes your computer faster to reviewing recently released wireless keyboards, and even building a PC tower case out of cardboard. And, of course, they review different VR headsets.

In August 2019, Linus uploaded a video called "Maybe VR isn't dead after all..." in which he reviewed the Valve Index Headset. He was initially ambivalent to the speakers, but after a day of using the headset, Linus was impressed.

"Credit to the speakers," he said, somewhat incredulously. "They actually sound shockingly good!" Linus spends the rest of the video going over the headset's specifications.

At the end of the video, Linus holds up the Valve Index Headset and looks directly into the camera, saying "This is absolutely the king of VR gaming headsets." ***LIS***

Editor's Note: Valve Index is a registered trademark of Valve Corp.

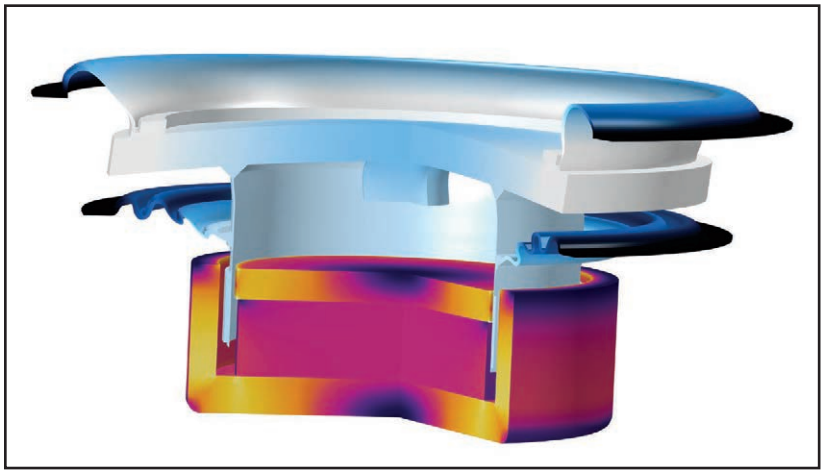


Figure 3: Fully coupled BMR model

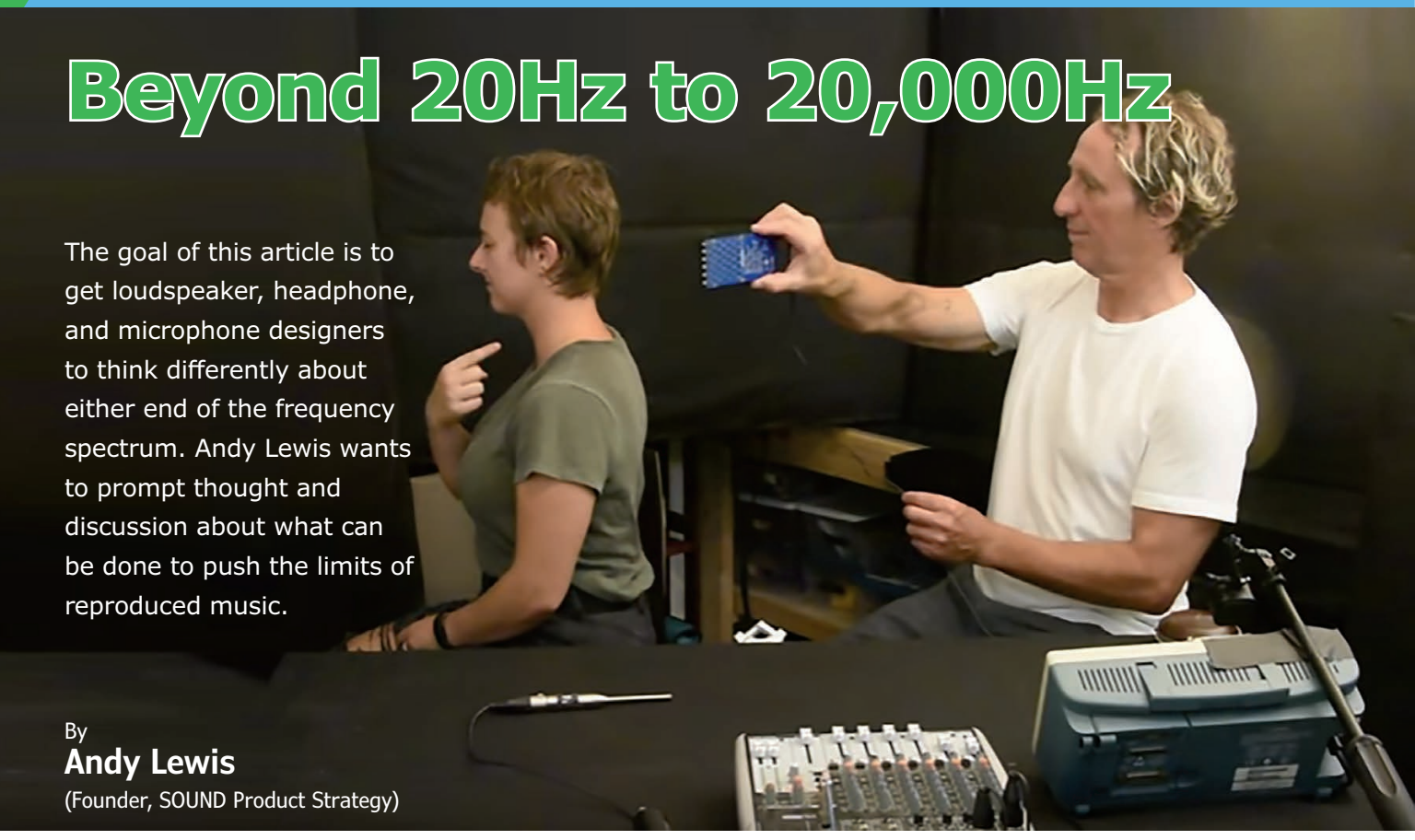
About COMSOL

COMSOL is a global provider of simulation software for product design and research to technical enterprises, research labs and universities. Its COMSOL Multiphysics product is an integrated software environment for creating physics-based models and simulation apps. A particular strength is its ability to account for coupled or multiphysics phenomena.

Add-on products expand the simulation platform for electromagnetics, structural, acoustics, fluid flow, heat transfer, and chemical applications. Interfacing tools enable the integration of COMSOL Multiphysics simulations with all major technical computing and CAD tools on the CAE market.

Simulation experts rely on COMSOL Compiler and COMSOL Server to deploy applications to their design teams, manufacturing departments, test laboratories, and customers throughout the world. Founded in 1986, COMSOL has 19 offices worldwide and extends its reach with a network of distributors.

Beyond 20Hz to 20,000Hz



The goal of this article is to get loudspeaker, headphone, and microphone designers to think differently about either end of the frequency spectrum. Andy Lewis wants to prompt thought and discussion about what can be done to push the limits of reproduced music.

By
Andy Lewis
(Founder, SOUND Product Strategy)

Dave and Sammy Rat perform an experiment to see if she can perceive a 40,000Hz tone.

We, the audio world, are at a very interesting point in history with studio master quality files now widely available in the home. Various high-resolution (Hi-Res) download sites, as well as streaming services such as Tidal and Qobuz, offer a huge selection of high-resolution music. These Hi-Res files are virtually distortion- and noise-free and have a potential frequency response from near DC to over 100,000 Hz. The Japan Audio Society (JAS) defines Hi-Res as requiring a frequency response to beyond at least 40,000 Hz. SONY DSD is 1 bit with a 2.8224-MHz sampling rate. The Super Audio CD (SACD) format can deliver a dynamic range of 120dB from 20Hz to 20,000Hz and an extended frequency response up to 100,000Hz—though most current players list an upper limit of 80,000Hz to 90,000Hz. New loudspeakers and headphones for recording studios and home audiophile systems should be engineered to take full advantage of this great new content.

Conventional audio industry wisdom tells us that high-fidelity reproduction requires the 10 octaves from 20Hz to 20,000Hz. As shown in **Figure 1**, the human ear can only hear frequencies in the range in the vocal range region. This data was taken by playing single tones at various frequencies and having the listeners indicate when they heard a tone. Music is much more complex than a simple combination of tones.

There are also charts that show the ranges of frequencies covered by musical instruments (**Figure 2**). These ranges only consider the fundamentals of each note of the instrument and do not take into consideration the upper harmonics that make up the rich variety of tones instruments create. Many instruments overlap in frequency coverage and can play the "same" note; however, each instrument sounds very different due to its unique harmonic signature. Upper harmonics are what makes one violin sound very different from another even when playing the same note.

Is There Anything Above 20,000Hz?

Dan Foley of Audio Precision wrote an excellent article "Limiting Audio Reproduction Bandwidth to 20,000Hz May Also Be Limiting Your Potential Market," in the 2019 issue of the *Loudspeaker Industry Sourcebook*. He worked with students who used three types of microphones, including an extended bandwidth 1/4" GRAS 46BF microphone, to

record and analyze a variety of musical instruments and female vocals to see if there was measurable content above 20,000Hz. They measured trumpet, conga drum, violin, nylon-string guitar and female soprano vocals. All of these recordings, with the exception of the trumpet, showed significant content above 20,000Hz. I have included a spectrogram of a solo violin (**Figure 3**) showing significant ultrasonic energy above 20,000Hz indicated by the red dotted line. Clearly there is plenty of information above 20,000Hz occurring in music.

Can We Detect Content Above 20,000Hz?

Dave Rat is a famous system designer and live sound engineer, who is a respected authority on all things sound and the founder of Rat Sound Systems. He has a great YouTube channel where he does short videos on various audio topics that are typically hands-on experiments, often conducted with his daughter Sammy. Two interesting episodes explore the idea that humans can perceive frequencies above 20,000Hz. Dave takes a very directional parametric speaker playing a very loud pure 40,000Hz tone and asks Sammy to indicate when, and from what direction, she senses the tone. For readers, who would like more information about this concept, I recommend these specific videos: "Can humans actually hear beyond 20,000 Hz? Do we have a 3rd 'ear'?" and "What Frequencies Can Our Bodies Really Perceive?"

Auditory perception does more than just hear simple sine waves. We use the arrival time of impulses at each ear to perceive direction. Evolution has enabled us to hear a stick break behind us and know if it is slightly to the left or the right. We use interaural time difference (ITD), the difference in arrival time at each ear, to detect direction of sounds. The normal human threshold for detection of an ITD is a time difference of as little as 10µs (microseconds). To resolve such miniscule time differences an audio system must have a bandwidth of at least 100,000Hz.

When I visited Scan-Speak a few years ago, the engineers shared an interesting concept as we discussed reproduction of frequencies higher than 20,000Hz. They said a good way to demonstrate the ability to detect information above 20,000Hz is to compare an 8,000Hz sine wave to an 8,000Hz square wave. They sound very different. Square waves are comprised of the fundamental and their subsequent odd harmonics. The first odd harmonic of 8,000Hz is 24,000Hz. The more upper odd harmonics you add the sharper the square wave. The audibility of the square wave indirectly acknowledges the ability to detect 24,000 Hz and higher tones.

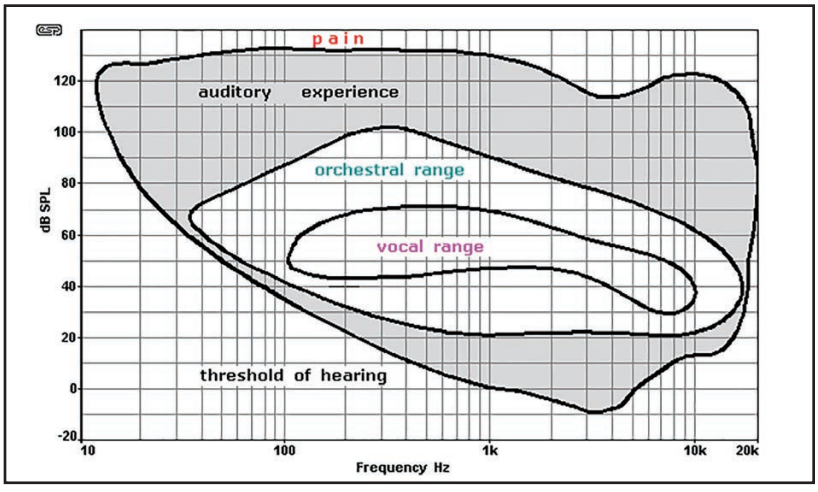


Figure 1: The range of audibility of human ear

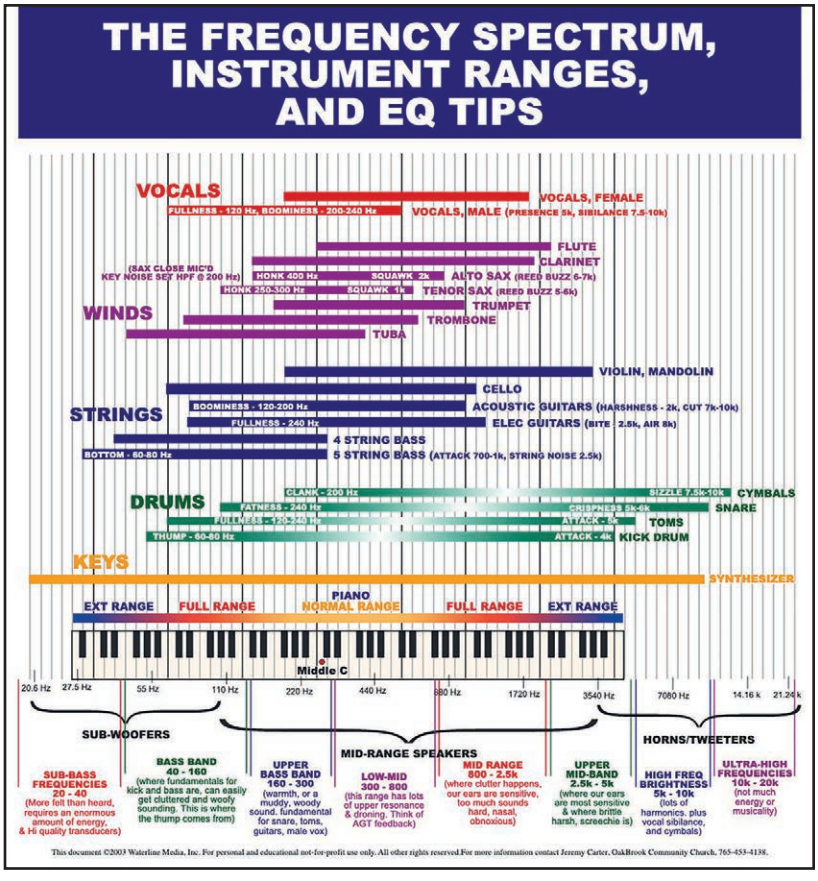


Figure 2: Frequency ranges covered by musical instruments and vocals and loudspeakers

Resources

D. Foley, "Limiting Audio Reproduction Bandwidth to 20,000Hz May Also Be Limiting Your Potential Market," the *Loudspeaker Industry Sourcebook*, 2019.

D. Rat, "Can humans actually hear beyond 20,000Hz? Do we have a 3rd 'ear'?" YouTube, November 2020, www.youtube.com/watch?v=tNpPFEwX6Y4

D. Rat, "What Frequencies Can Our Bodies Really Perceive?" YouTube, November 2020, www.youtube.com/watch?v=6rX4mXVfaFU

Loudspeakers and Headphones Above 20,000Hz

Tweeters can be engineered to provide at least an octave above 20,000Hz of pure pistonic motion by using advanced materials such as beryllium (from companies such as Focal, Paradigm, Magico, Revel, JBL, and others), or diamonds (from companies such as Bowers & Wilkins and Tidal) for the domes. Other brands use alternative tweeter designs with well-behaved extension such as ribbon, planar, or air motion transformer (AMT) tweeters to go beyond 20,000Hz.

Many headphones have a frequency response from below 20Hz to well above 20,000Hz. Stax electrostatic headphones have been considered one of the best for many years, and the new flagship STAX SR-009S has a published frequency response of 5Hz to 42,000 Hz. The Focal Utopia headphones use pure beryllium dynamic drivers and have a frequency response of 5Hz to 50,000 Hz. Sony has published Audio Engineering Society (AES) papers that explore the importance of having 120kHz bandwidth and introduced its MDR-Z1R headphones (**Photo 1** and **Photo 2**) to support this. Sony includes a magnesium dome in the center of its dynamic driver to achieve this performance.

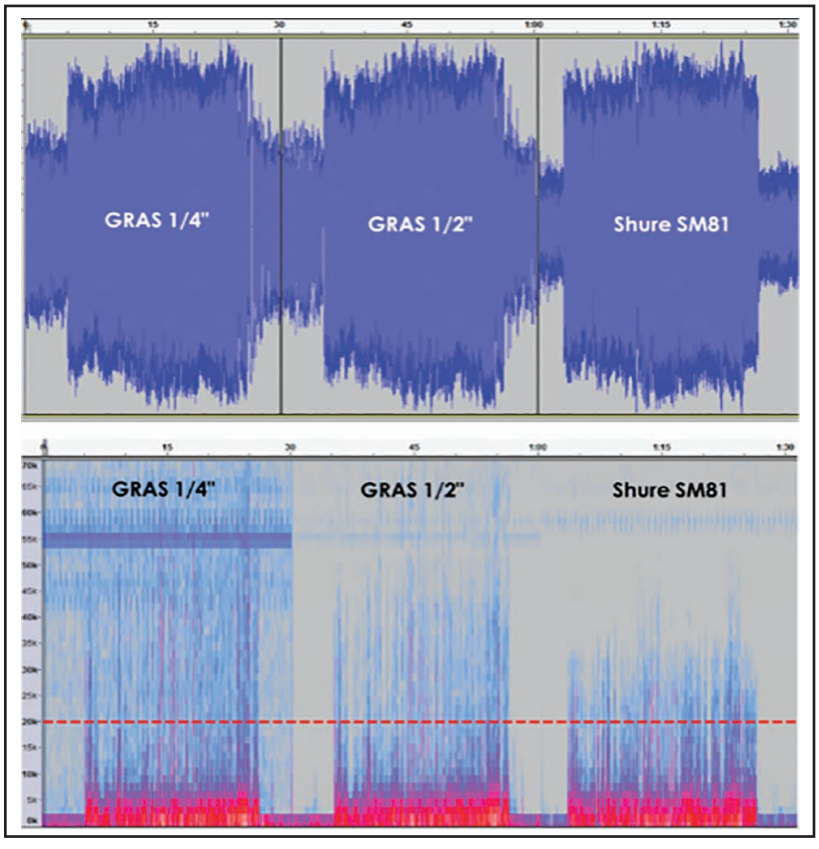


Figure 3: Spectrogram results of a solo violin

What Happens Below 20Hz?

Early in my audio career, I had the honor of being lead engineer on what was considered by many at the time to be the finest audiophile loudspeakers ever produced: the Apogee Grands (**Photo 3**). These cost-is-no-object speakers were launched in 1991. Each of the 600-pound ribbon hybrid loudspeakers incorporated dual 12" subwoofers in acoustic suspension cabinets with dedicated 600W Krell amplifiers providing extension to below 18Hz with a gentle roll-off below that.

While developing these speakers, the entire Apogee team had a revelation. We were used to enjoying the ability of ribbon speakers that we designed to recreate holographic images of full symphonies or to transport you to a smoky jazz club if you closed your eyes, but this was something new. The extremely well-controlled and damped subsonic low-frequency extension enabled the speakers to convey the size of the concert hall the recording was made in, even before the first

Photo1: Sony's MDR-Z1R hi-res headphones

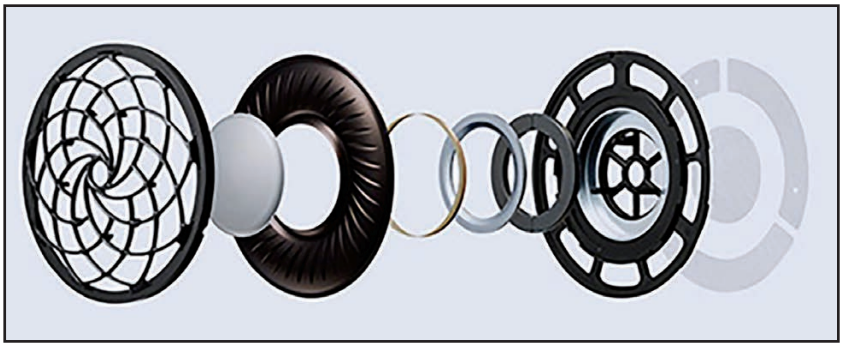


Photo 2: Sony's MDR-Z1R driver

note was played. You may have experienced this while walking from a small vestibule into a concert hall. You could be blindfolded yet detect the size of the room just by the "feel" of it. Perhaps it is the pressure or low-frequency content of the noise floor. This strange sixth-sense ability can be achieved with properly designed subwoofers.

Well-known mastering engineer Bob Katz talked about the "Sub Harmonics size of a Hall" in a December 30, 2020 Facebook post. He said: "What does sub 30Hz response sound like if no one is playing any notes down there?" Answer: "Solidity." The deep feel, especially the thump and impact of some of the percussion. The impact of the upright bass. In classical, orchestral music played in a large room, the feel of the room. The room ambience. There's information down there, even if no one is playing those notes. It took me a little while to figure out what's normal, what's excessive, and what's right when I first extended my system all the way to 17Hz at 0dB and 15Hz at -3dB—it took me about a day. After that, it was a revelation. When mastering, I make decisions down in the lower frequencies as to the extent of whether or not to filter, how much to filter, and whether there is any musical harm in not filtering.

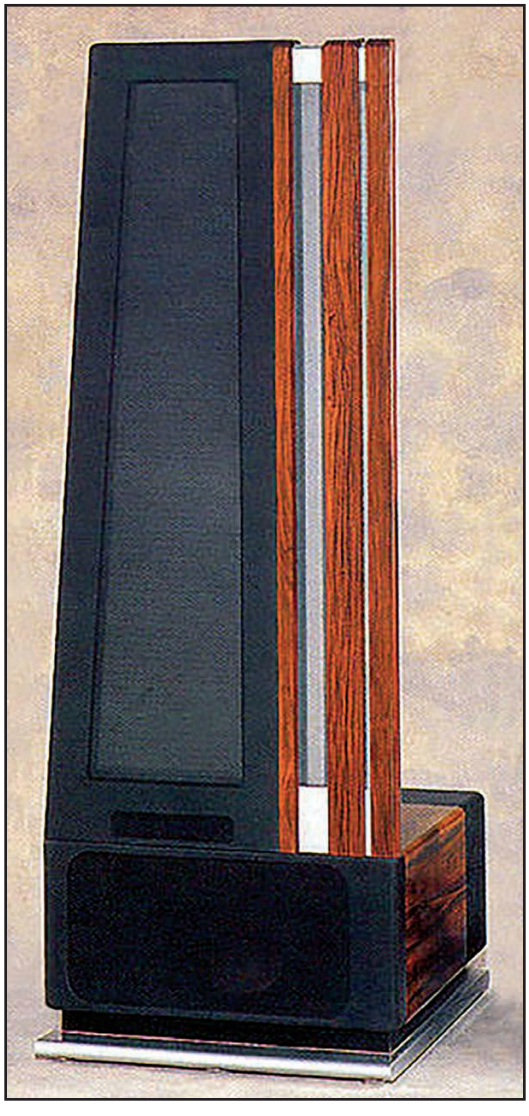


Photo 3: Apogee Grand loudspeakers were considered by many people at the time to be the finest audiophile loudspeakers ever produced.

Bob Katz uses two JL Audio 12" Fathom F112 subwoofers in his studio (**Photo 4**), and they are crossed over with a steep, linear-phase Neville Thiele Crossover. The mating of satellites and subs is seamless and perfectly calibrated by use of Acourate loudspeaker and room-correction software from AudioVero. Acourate corrects phase, impulse response, and time alignment. Response is ±1dB to a target from 17Hz to 20kHz. It is -3 B at 15Hz!

Conclusion

The human body is very complex, and we can sense sounds and vibrations in a variety of ways. Therefore, to provide the most realistic reproduction of a live event an audio system must go above and below the conventionally agreed-upon frequency limits. I hope this article challenges loudspeaker, headphone, and microphone engineers to consider this advice when designing products that re-create the ultimate listening experience. ***LIS***

Photo 4: JL Audio F112 V2 subwoofer

About the Author

Andy Lewis is the founder of SOUND Product Strategy. He has been in the audio industry for more than 35 years and has a broad background in loudspeaker and electronics design, product management, technical sales and consulting. Andy is a member of the Audio Engineering Society (AES), CEDIA and ALTI (Formerly ALMA), and has many close ties to the audio industry. He has an engineering degree from Northeastern University of Boston, MA and has worked with AR (Acoustic Research), Signet, B&W Loudspeakers, EAW Eastern Acoustic Works, Apogee Acoustics and, most recently, was Materion's Global Sales Manager for beryllium speaker and headphone components. SOUND Product Strategy provides consulting services to audio companies and has been recently appointed as the North American sales agent for LoudSoft CAD software and test equipment.

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(91) 22-6742-6600
www.indiamart.com/sft-technologies

TurboSonic Pro Speakers
www.turbosonicspeakers.com

Vidyut Teletronics, Ltd.
(91) 9829015502
www.vidyutwire.com

Wizard India Private, Ltd.
(91) 141-2731-531 /532 /533
www.wizardindia.com

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Premiere Wood Manufacturing (PWM)
(62) 8478674525

SB Acoustics
(62) 317480011
www.sbacoustics.com

IRELAND

Crossover Filter App
(353) 831779010
www.crossoverfilter.com

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Alango Technologies, Ltd.
(972) 4-8580-743
www.alango.com

Audio Pixels, Ltd.
(972) 0-73-232-4444
www.audiopixels.com.au

Morel, Ltd.
(972) 8-9301161
www.morelhifi.com

RH Sound Technology, Ltd.
(972) 3-6733334
www.loudspeakers.co.il

ITALY

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(39) 081-576-3527

Audiomatica, SRL
(39) 0556599036
www.audiomatica.com

Audioxplus, SRL
(39) 3276142621
www.axpaudio.com

Axiomedia, SRL
(39) 2051560
www.axiomedia.it

B&C Speakers, SpA
(39) 05565721
www.bcspeakers.com

Boxal, SRL
www.boxal.it

Ciare
(39) 05221861800
www.ciare.com

Eighteen Sound
(39) 0522-1861800
www.eighteensound.com

FaitalPRO
(39) 025277031
www.faitalpro.com

LaVoce, Co., Ltd.
(39) 0733-870840
www.lavocespeakers.com

OEB, SRL
(39) 0716620109
www.oeb.it

Outline SRL
(39) 030-35-81-341
www.outline.it

Powersoft, SpA
(39) 055-7350230
www.powersoft-audio.com

Professional Audio
(39) 80-4058436
www.professionalaudio.it

RCF, SpA
(39) 0522-274-411
www.rcf.it

SICA Altoparlanti
(39) 071-7958072
www.sica.it

SpeakerLAB
www.speakerlab.it

Yter Laboratorium SRL
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www.laboratorium-yter.com

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www.etani.co.jp

Furutech Co., Ltd.
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www.furutech.com

S'NEXT Co., Ltd.
(81) 8023423555
https://snext-final.com

LATVIA

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(371) 29418549
http://aplaudio.com

Sonarworks
(371) 22572285
https://sonarworks.com

MALAYSIA

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www.eternalpower.net

Shu Kae Industrial
(60) 4-4686261
http://shukae.com

U-Sonics Power Cone
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www.u-sonics.com

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www.aletheia-av.com

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www.oldmansound.com

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www.aequoaudio.com

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www.audiocomponents.nl

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www.audiofriends.com

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www.crystalcable.com

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www.diluvite.com

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www.eltim.eu

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www.speakerrepairshop.nl

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www.hypex.nl

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www.kamperman-engineering.nl

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www.metaxas.com

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Sound Projects
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www.asona.co.nz

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www.seas.no

Soundcare AS
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www.soundcare.no

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www.jocavi.net

Vicoustic
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www.vicoustic.com

ROMANIA

SC Poweraudio SRL
(40) 766332366
www.poweraudio.ro

RUSSIA

Deluxe Acoustics
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www.deluxe-a.com

Star Sound Technologies
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https://starsound.ru

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Virtins Technology
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www.dasaudio.com

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Tecnare/Exel Acoustics SL
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www.profusionplc.com

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www.rushpcb.co.uk

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www.silcoms.com/conveyor-chain-division

Spectral Measurement
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USA: (1) 817-514-4900
www.spectralmeasurement.com

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www.voltloudspeakers.co.uk

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https://usa.1more.com

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www.3m.com/bonding

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www.ABrown.com

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https://alistwoodworks.com

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www.accurateperforating.com

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www.acoustex.com

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www.acousticfields.com

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www.acousticsfirst.com

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www.acrytech.com

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(1) 718-312-8690
www.adafruit.com

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www.adrianacoustics.com

Aempyrean
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www.lab4me8.wixsite.com/ibeam/speaker-series

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https://allianceorg.com

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www.alliedelec.com

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www.ambianceacoustics.com

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www.americanbassusa.com

American Music & Sound
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Amplitrex Audio Products, LLC
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Area 52 R&D
(1) 740-223-6551

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www.arionaudio.com

Arizona Capacitors
(1) 520-573-0221
www.arizonacapacitors.com

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(1) 585-385-9010
www.arnoldmagnetics.com/speakers-microphones

Astro Machine Works, Inc.
(1) 717-738-4281
www.astromachineworks.com

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(1) 972-875-8413
www.atlasied.com

Audio & Loudspeaker Technologies International (ALTI)
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https://altiassoc.org

Audio Advisor, Inc.
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www.audioadvisor.com

Audio Connection
(1) 973-239-1799
www.audioconnect.com

Audio Houze
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www.audiohouze.com

Audio Precision, Inc.
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www.ap.com

Audioengine
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www.audioengineusa.com

Audix
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www.audixusa.com

AValive
(1) 866-93-PRO-AV
www.avalive.com

Avanti Audio
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https://avantiaudio.com

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(1) 860-355-4711
www.avellindberg.com

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www.bhphotovideo.com

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www.barefootsound.com

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www.bestartech.com

Beyma Pro Audio
(1) 877-72-BEYMA
https://beymaamerica.com

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CE Distribution
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CGN Audio Labs
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Christensen Audio, LLC
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CJS Labs
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www.cjs-labs.com

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CommonSense Audio
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COMSOL
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Cotronics Corp.
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Creative Sound Solutions, LLC
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www.css-audio.com

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Danley Sound Labs
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DTV Installations
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Fortemedia
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Fotronic Corp.
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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 respond. The following content contains the questions and their responses.

Brian Youngil Cho

Co-Founder and CEO, Resonado Labs

RESONADO LABS

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months and what were the main trends and factors (good and bad) affecting your business?

Cho: Our business has evolved over the past 12 months from focusing on developing the foundational architecture of Resonado Labs' first driver technology, Flat Core Speaker (FCS) technology, to optimizing it for commercial applications. On the automotive product side, we announced our first commercial partnership with Airstream, a premium American RV brand. FCS technology drivers enabled more flexible transducer placement for seamless design integration while also enhancing the acoustic experience.

In the greater automotive space, with the advent of electric vehicles and the demand for new technologies enabling individual sound zones, Resonado Labs has seen greatly increased interest from automotive transducer suppliers due to the flexible placement FCS technology drivers enable while maintaining high acoustic performance to improve the in-ride experience.

As for the main factors affecting our business, the biggest one is still COVID-19. From a macroeconomic standpoint, it had both positive and negative consequences to not just the audio industry but also to other adjacent industries such as the consumer electronics and automotive industries. The positive side of COVID-19 was that it further accelerated the mass-market adoption of audio-enabled products such as soundbars, home audio systems, personal conferencing equipment, and smart speakers. This market trend is expected to continue as individuals become further distributed and increase their reliance on audio-enabled devices for communication.

On the other hand, negative trends have centered on supply chain disruptions caused by COVID, and the resulting imbalance between the supply and demand of audio products. While such imbalance was later resolved on a positive note as many businesses ended up having more demand than they had available inventories, the resulting backorder subsequently pushed out the introduction of new products with FCS solutions embedded in them.

Question 2: What are the perspectives for your business in the next 12 months?

Cho: Looking at the big picture, Y2021 will be the beginning of the "return to normalcy" where suppressed customer spending in Y2020 will exhibit itself in the form of "revenge spending" in Y2021—driving the demand for new products and premium experiences. Concurrently, the accelerated global adoption of work from home (WFH) culture from COVID-19 will continue to

fuel many companies' continued shift toward a distributed workforce, giving incentives for further innovation in both conferencing devices and other related audio products for Y2021 and subsequent years.

Specific to our business, we foresee demand for slim, sleek, and minimalistic mass-market consumer electronics to continue accelerating over the next 12 months, which will further increase the need for FCS technology. Unit sales of these devices, from soundbars to smart speakers, have grown exponentially as the consumer demographic shifts. The majority of dollars spent on audio products will continue transitioning from going to luxury goods purchased by high-income audiophile consumers to being spent on modern necessities such as smart speakers and soundbars bought by mass-market consumers—and these consumers who make up the bulk of the mass market place emphasis first on the design and seamless integration into their living spaces than anything else, creating a need for slimmer and sleeker products.

We have seen brands adapting to this trend with the use of conventional high-aspect-ratio transducers to reduce the height and bulkiness of their products, such as in smart speaker, portable, and home audio devices by Sonos, Samsung, Harman, and others. And we expect this trend to continue accelerating, as long as there are innovative solutions that will continue to enable slimmer form factors and greater acoustic performance. This trend undoubtedly supports Resonado Labs' high-performance racetrack drivers designed with FCS technology.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Cho: As previously mentioned, more dollars in the industry are being sunk into mass-market products and less into traditional high-end systems sought by audiophiles. However, at the same time, luxury high-end products have been placing a greater emphasis on enhancing the sound systems they provide as big spenders place more value on audio experiences—they want movie theater audio experiences in their living rooms and studio experiences in their cars. This is made evident when you look at industry announcements such as the first THX-certified home theater system by PerListen or the Lucid Air becoming the first car to feature Dolby Atmos. The Lucid × Dolby announcement is in line with trends in the automotive industry toward taking more advantage of spatial audio technology for more personalized sound systems per passenger for both enhanced immersion and safety on the road. Although a completely different trend than what's going on in consumer electronics, the result is the same in that the trend demands more drivers in tighter spaces, hence increased use of racetrack drivers.

One sound system released in the past 12 months that reflects this was the ELS Studio 3D, which utilizes a unique line-up of transducers and electronics to create a fully surround sound experience for all passengers. Featured in new Acuras, the major differentiator of this system is the four roof-mounted conventional racetrack drivers, which enable high frequencies to be projected directly to each passenger while avoiding reflections normally experienced with more conventional placement. With FCS drivers having both a slim structure ideal for tighter spaces in addition to a wider bandwidth of pistonic behavior than traditional racetrack drivers, they're particularly well suited to improve the audio performance for this type of application, and is something Resonado Labs is actively exploring with FCS technology network partners.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Cho: There's a lot to be excited about for the audio industry in the future, from the creation of entirely novel market segments with the advent of flying vehicles, material innovations in the loudspeaker space, virtual reality, the clash of titans at the intersection of health and technology, and homes becoming sentient with smart devices. As new industries and products create unique challenges for the loudspeaker industry, we'll be relying on material innovations to solve problems and enhance performance. TeXtreme, for example, has already proven to be crucial to the trend of bringing high-end audio into the home, and KEF's exploration into metamaterials with its Metamaterial Absorption Technology is sure to be a catalyst for more metamaterial innovations in years to come for the loudspeaker industry.

A final interesting trend to keep a pulse on will be at the intersection of health and smart technology, particularly in the home. An industry kickstarted by Apple with the Apple Watch, it has now bloomed into a diverse range of wearable and smart home devices such as fitness bands, smart health patches, smart mirrors, and smart fitness devices, all of which of course require speaker drivers to communicate with users. It will also be interesting to watch how driver usage evolves for additional features beyond communicating with users or playing music in the smart device industry, such as with Google's latest smart speakers using ultrasonic sound to detect user presence. And as the list of products that become modern necessities grows and take up more space in the home, I expect the product miniaturization trend we've already been seeing to continue its trajectory.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Cho: As my time at home has been extended beyond normal due to the pandemic, I've found myself moving from listening to music on convenient devices, such as my AirPods or smart speakers, to taking the time to set up and listen to a full surround system and I've found myself investing in a conference system for my home office setup for Zoom calls so as to avoid the fatigue of having to wear earbuds or headphones all day. ***LIS***

Jann U. Evers

Sales Director, Scan-Speak

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months and what were the main trends and factors (good and bad) affecting your business?

Evers: The past year has been a challenge in many ways due to the pandemic. The first impact from the pandemic started in February 2020 as parts we source from China were delayed due to the COVID-19 lockdown there. In March our own country—Denmark—got locked down by our government. For Scan-Speak, this meant that everyone who could do their jobs from home had to stay home and those who could not carry out their tasks from home could only come to the company if enough social distance could be provided. That meant only about half of our factory workers could come to the factory until restrictions were lifted in June.

At the end of our lockdown, we saw orders flowing in at an unexpected pace, which made us very busy. By the end of the year, we managed to catch up most of the business we lost in the spring and early summer, ending 2020 at our 2019 level. 2021 started with very good sales and now a few months in, we are more than 20% ahead of our expectations and previous years, and we are seeing this trend continue as long as the borders are closed and people are forced to stay more at home. So despite the pandemic and the horrible impact it has on many things, it seems to be good for the audio industry, as well as it is for most other manufacturers of things that are used in our homes.

Question 2: What are the perspectives for your business in the next 12 months?

Evers: During these pandemic times it is very difficult to predict anything, but as long as the pandemic continues to keep borders closed and forces people to stay home most of the time I expect audio sales to continue at a higher level than normal that will give us a fantastic year during which we could probably set a new sales record.

When the pandemic releases its grip on the world and we get back to a (new) normal situation, I think most people are so desperate to go to restaurants, bars, concerts, and to travel that all their focus and disposal income will be spent away from home and they could lose focus on products in our segment, so at that point I expect a drop in sales that probably, for a little while, will set us back to a level a little below normal, but let's see....

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Evers: Exciting things besides the pandemic and its impact on the world were very limited, especially as we could not travel or meet people and it became more difficult share information and experience new developments outside of our own offices/homes. So probably the most exciting development was that we learned how to use video conference calls as a replacement for travelling.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Evers: I think we will see more and more products with streaming capabilities, both as a music source and as a distribution channel inside our homes. The Internet is now so stable and fast in most of the world that we can listen to streamed music without any drop-outs and we can benefit from the convenience it offers, having all the music in the world available from a tablet or smartphone. I also see many cables disappearing from our homes as music can be wirelessly distributed directly to the speakers in a similar quality to what we found using fancy cables.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Evers: With more time at home and closer to my audio gear, I listened to more music than usual and since in the previous year, I added streaming from Tidal, I now have almost all music available with just a few taps on my smartphone. ***LIS***

Daniel Knighten

General Manager, Audio Precision

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months and what were the main trends and factors (good and bad) affecting your business?

Knighten: Although it feels like a misnomer or understatement to refer to COVID-19 as either a trend (misnomer) or a factor (understatement), it was the dominant element affecting our business, along with every business on the planet, in the past year. Adapting to the new paradigm brought on by this global event warranted actions that will be common themes to most, or all, readers: adjusting to remote work models and virtual collaboration; modifying work environments to maintain safety while continuing to build and ship product; and changing how we engage with, and support, customers around the world as face-to-face events, in-person training, and on-site visits dropped to zero. All of which existed under the shadow of an economic slowdown, and then evolved in the face of a surprisingly rapid recovery—with associated supply chain issues—in the technology sector. Meteorological analogies abound for the experience of the past 12 months and I'm extremely proud of how the Audio Precision team weathered the storm.

Question 2: What are the perspectives for your business in the next 12 months?

Knighten: The pandemic-driven need for "remote work" and "virtual collaboration" are viewed in many circles as here to stay and this will continue to drive an intense spike in demand for personal teleconferencing. While this means headsets of all kinds, along with virtual office technology, will remain at the fore, the "everything at home" model—work, entertainment, social gatherings—translates to a strong 2021 outlook for technologies that support that model.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Knighten: Although not in keeping with the 12-month limit of this question, I believe smart devices remain one of the most exciting trends—in the context of audio—and one that continues to march along.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Knighten: Building upon my previous answer, the smart device trend holds great promise for the audio industry as it fundamentally means adding speakers and microphones (or at least one of each) to any device you want to make "smart." On a more personal note, and as a licensed private pilot, the advancing voice recognition capabilities in aviation radios is especially fun and exciting.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Knighten: Increased teleconferencing and remote work mean I'm wearing a headset a great deal more. However, this doesn't extend to my music listening, which remains steadfastly speaker-oriented. However, the upside to the home office means I'm getting to listen to music more. ***LIS***

Nancy Knowlton

CEO, Nureva

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months, and what were the main trends and factors (good and bad) affecting your business?

Knowlton: The big impact on the past year is without a doubt the pandemic. It was a roller coaster with business almost stopping in the early days of the pandemic to an upswing later in the year as all types of organizations were attempting to prepare for the new normal.

Question 2: What are the perspectives for your business in the next 12 months?

Knowlton: We see an incredible opportunity in the next 12 months. Organizations have become very educated about the experience that they want to deliver to their remote participants. Even as people go back to the office and classroom, the remote experience is paramount in everyone's thinking as they know firsthand the challenges. With people now being remote at least part of the time, there is no compromising on the quality of that experience.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Knowlton: The biggest thing has been the acceptance of working from home (WFH). The pendulum swung from a small percentage of people WFH to the majority WFH. There were early almost euphoric reports about productivity gains from that mode of working. As time has progressed, there is a more balanced perspective—namely, some activities can be done well from home and others benefit from face-to-face interaction.

On a technology front, the conversation has moved from video to audio. While video is important, there is no communication without great audio.

There's also an elevated conversation about collaboration tools—how can people actually work together? There is much more examination of the process of work and the tools to enable it.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Knowlton: It won't be any surprise that I think the audio innovations we are bringing to the market with our patented Microphone Mist technology is at the leading edge of the audio industry. The additional functionality that we can deliver from this platform through both firmware and software is truly breakthrough.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Knowlton: We have had no change to our listening habits to music over the last number of months. We listen to our music subscriptions on a variety of connected devices throughout our home. ***LIS***

Dave Lindberg

CEO, dB Enterprises HK, Ltd.

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months, and what were the main trends and factors (good and bad) affecting your business?

Lindberg: The largest transition was shifting from in-person to using our networks and technology to deliver on sales projects and harvest new business. Specifically, we have an established team of associates in China, Taiwan, the Philippines, and Thailand so bringing new technologies into the products has not suffered for us as it has for others. Second, our business has grown online with video presentations, by establishing our own THD podcast on YouTube, plus we have our new relationship with the Audio Engineering Society (AES) for its Audio Product Education Institute (APEI).

Question 2: What are the perspectives for your business in the next 12 months?

Lindberg: The outlook for the next 12 months is to utilize our strategic location and network to support brands that cannot travel with our established team in Asia, and expand our product development projects. Further, we will continue to market our clients' technologies and network with other product development elements via our online presence.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Lindberg: For the last year, the expansion of complete product development was the most exciting business segment. We will see at least three new audio products from three different brands that dB managed from start to finish hit the shelves this year.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Lindberg: Some technology highlights coming for the next year include VM Sound's liquid silicon rubber drivers for ANC headphones, putting ultra-thin Rohacell-based diaphragms in microspeakers from Clarasonic, and Zumi Systems' test and measurement system, which is truly a multimeter for audio engineers. In fact, all these technologies are focused on either the headphone or the microspeaker space, which is the future. Louder and more linear from less—the 3 Ls.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Lindberg: Seriously, I listen to music on a variety of current and legacy speakers and products that we have worked on. They include everything from Boston Acoustics to KEF to UE Boom to Jaybird earbuds to B&O True Wireless Stereo (TWS) to some of the prototypes for upcoming products. My habits haven't really changed at all. ***LIS***

Igor Levitsky

President, Arrow Acoustics

Arrow Acoustics Inc.

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months and what were the main trends and factors (good and bad) affecting your business?

Levitsky: My business is in transducers, speaker systems, and headphone design and consulting. I have been doing this for both professional/commercial and consumer markets. It is fascinating to observe different trends. Commercial customers that I worked with struggle with new market realities and are looking for survival strategies. The lucky ones preserved their human capital and are trying to diversify into pro-sumer and residential markets with some success (which I very much welcome). The ones that weren't prepared for this "black swan" pandemic event, well, they are just surviving to say the least.

The few projects that I have been doing for commercial customers stopped, but I am hopeful that they will continue R&D activities and innovation in these lean times. In contrast, it seems that the consumer market is doing well. Fortunately, in this pandemic situation, people need quality speakers and headphones to work, communicate, and be entertained. I am seeing a big push toward higher quality gear in this market. Things look very good for headphones. The residential market is very strong or at least robust, depending on the product category. It seems that people have realized how fleeting life is and without the opportunity to enjoy travel and other life-fulfilling activities they spend their money on better domestic tools and toys that make their life more vibrant and memorable. I also suspect that financial "easing" helps to boost buying in this market.

I am developing a new line of ribbon/planar magnetic drivers with my production partner. I am very optimistic that the market for higher quality products will grow and evolve. There is some kind of metaphysical essence in this. Even though a lot of R&D work can be done on the computer and in my lab, the challenge is that I cannot travel. I used to fly to Asia at least once every two months over the last 10 years. Speakers and headphones cannot be fully simulated and developed remotely. I need to be there, with the production team and see a product "cooking" from a raw prototype into a ready-to-go mass production item. Not being there is a challenge. Experience, proper communication, and understanding with the factory team helps to overcome this in most cases.

Question 2: What are the perspectives for your business in the next 12 months?

Levitsky: I think that our perspectives are very exciting. The current market situation, I am sure, made most brands revisit their strategies. This will trigger new product development since in the race for market share, the most aggressive and agile companies will try to adjust to new realities and diversify and/or improve their market position with new products and innovations. This always means greater interest in new tech, more R&D, and more aggressive product development.

On the other hand, I see an on-going trend in our industry. Small companies that grew out of certain innovative technologies with in-house R&D and manufacturing are acquired by larger brands or distribution majors, which are hungry for profits and want to expand market penetration and leverage their established dealer networks to maximum. They tend to grab more and more market segments and engulf more related technologies, integrating everything into their own "tech ecosystems." Often, this leads to losing focus in R&D and innovation capabilities. Moving production to Asia for additional profit

and producing more commodity products under market price pressure spreads resources thin. This creates more challenges for leading-edge research and innovation that require time, diligence, and focus. I see so many "suboptimal" products launched by those large entities. Therefore, a specialized independent R&D lab can stay ahead in innovation, free of pressure of often ineffective corporate culture and its bureaucracy. This is especially true, as in my case, if it partners with an agile manufacturer with extensive, vertically integrated in-house capabilities. Therefore, things look good for my business, regardless of the current challenges.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Levitsky: The headphone market is very strong. We had a new aggressive company picking up planar magnetic headphone technology that we have been developing for many years. They cannot get enough drivers from us to keep up with demand. Apparently, people want and value higher quality sound during these difficult times. We are also developing another concept of planar magnetic headphone drivers with my production partner. I have had a few different ideas on this for a long time and now I have a chance to get these ideas tested. I am continuing to develop new transducers, including electrodynamic and planar ribbon drivers for pro and consumer markets.

With travel restrictions, I have more time to look at various ideas that I have had for many years, but was unable to pursue due to ongoing projects. I am finally working on a prototype of my "dream" speaker system that I had in my mind for many years. This dream system is a no-compromise, hybrid (planar ribbon and dynamic) design with a new idea of controlling and integrating dispersion patterns and sound in a room via gradual transitioning from pure dipole to cardioid down to nearly omnipolar. I think that this is the best solution to a well-known and very challenging task of integrating thin film dipole drivers with low-frequency dynamic woofers. So far, I am extremely excited with the results.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Levitsky: I think personal audio will evolve with more AI and seamless connectivity and control further developing within smart device + wireless headphone/earphone system. More ergonomic, more comfortable, and longer lasting materials should be used. Material and comfort feature innovation will continue in headphones. Sound quality of Class-D amps should be improved. They are getting better and yet are far from what we can get from Class A and especially from hybrid designs. I think sound quality refinement will incrementally continue in personal audio. The reason is that once we have very good sound quality with low distortion and low listening fatigue, we tend to spend more time listening and get more long-term pleasure from it. It is important that even people with very limited knowledge of audio, regardless of age, can differentiate good sound from mediocre sound in the long term, even if the difference is not immediately apparent.

New better materials will continue to drive transducer evolution. I do not think the few "new" concepts that surfaced over the last few years will beat established designs. Too many factors are involved and a common dynamic driver is very hard to beat, especially in the lower frequency band. Thin film drivers will expand their market share in high quality and premium product categories especially in headphones. I see a new model of in-ear headphones using planar magnetic technology just announced from one of the leading brands and this is great news.

In the traditional two-channel market, I think we will see a more active transition to the integrated system approach with electronics and speakers optimized as a complete system ,taking advantage of DSP control that allows better performance than in passive systems. Streaming and ease of use of such systems will facilitate this transition.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Levitsky: Most of the time I listen to speaker and headphone prototypes that I work on at that moment. Since I started working on my dream system during the weekends, I have had a chance to recalibrate my ears and enjoy the highest level of reproduction as well, which is essential. When I do CAD work at my workstation, I mostly listen to open-back planar magnetic cans with a dedicated desktop headphone amp. My habits did not change dramatically in the last year. I listen to various media on a wide range of devices. I am lucky that listening is part of my work. ***LIS***

Jean-Marc Luneau

Audio Engineering and Product Manager, 7 Sensing

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months and what were the main trends and factors (good and bad) affecting your business?

Luneau: In the past 12 months, 7 Sensing's audio business moved from early concept products for superior voice calling and hearing augmentation on True Wireless Stereo (TWS) earbuds, to product-ready libraries demoed and being integrated in customer devices.

The main trends affecting our business have been:

- ANC on TWS, enabling the fast adoption of in-ear/feedback microphones for voice calling
- Generalization of work from home and conference calls has showed the need for much better voice calling on earbuds
- Launch of headphone hearing accommodation features by Apple on AirPods Pro with iOS 14, creating enormous traction for our Hearing Augmentation product

Question 2: What are the perspectives for your business in the next 12 months?

Luneau: In the next 12 months, we anticipate to gain a lot of market share with our Pure Voice calling solution on medium and high-end TWS segments pushing us steps closer to perfect noise reduction and speech preservation.

As for Hearing Augmentation, many OEMs will be using our solution, pushing us to deliver even more features toward multi-modal and AI-controlled hearing enhancement/assistance.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Luneau: TWS chipsets and audio platforms are all racing for innovation, providing a very fertile ground for software innovation and differentiation. Advances in machine learning capacity processed on the edge is opening new doors for TWS earbuds for exciting signal processing.

The increasing presence of new sensors for vital signs monitoring is also very interesting, showing a glimpse of what the future of hearable is going to be.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Luneau: For TWS earbuds, I think interesting technologies include:

- Adaptive ANC
- New Bluetooth (BT) audio codecs and ultra-wide band (UWB) for TWS
- Bone vibration sensors
- MEMS speakers

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Luneau: I listen to music mostly streaming (Spotify connect) on a Hi-Fi system (Marantz/Arcam) or via a wireless speaker (AudioPro).

The biggest change for me has been from listening to music a lot in the car, to using TWS earbuds (AirPods Pro) as work from home replaced commuting. ***LIS***

Claus Neesgaard

Director, Co-Owner, Purifi Audio

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months and what were the main trends and factors (good and bad) affecting your business?

Neesgaard: The past 12 months marked Purifi's first year actively engaged on the commercial side of our transducer and amplifier business. Prior years were spent primarily on research, establishing an IP portfolio and developing products initially for selected customers only. Giving birth to our first amplifier and transducer products wasn't fast or easy. As an example, no measurement equipment existed that could characterize and decompose transducer performance to the level we needed in order to gain enough understanding. So we had to invent our own measurement system. This development alone took several years of engineering work, but the result is astounding and without it we would not have been able to identify and fix the performance-limiting flaws of existing transducer technology. The result is a (growing) line of transducers with unrivaled low distortion and intermodulation distortion (IMD).

Question 2: What are the perspectives for your business in the next 12 months?

Neesgaard: We continue to expand our product portfolio in parallel with developing new exciting IP. Our R&D approach is based on first principles: gain a deep understanding of the problems at hand, then solve them one by one. The effort is anchored deeply in scientifically proven facts and data-driven forward momentum, and we shy away from the trial-and-error pitfalls that often don't help much in order to gain understanding. We consider this approach a large upfront investment but with the return being faster product development down the road, and more importantly, of products that could not have been created by means of trial-and-error.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Neesgaard: In the transducer space, we are experiencing an increased interest in analyzing, discussing, and understanding the scientific reasons for good vs. bad audio performance. We are beginning to see independent sites testing and comparing drivers based on a broader set of objective metrics. This is an important step toward raising the bar for loudspeaker design and for performance to be more on par with the rest of the audio signal chain, which has enjoyed continuous enhancements over many years.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Neesgaard: We have established a growing IP portfolio to address a combination of undiscovered or forgotten transducer design problems. Results are clear in both subjective and objective metrics, as more and more people have a chance to experience and judge the resulting sound quality, we are convinced that PURE SOUND will be on the uptrend. It is our wish to make products based on Purifi technology accessible for as many people to enjoy as possible.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Neesgaard: When I first listened to our Eigentakt amplifier technology back in late 2017—in the form of an early prototype—my interest in high-end audio instantly reignited and I was well pleased to find confirmation that amplifier technology had reached the next level—not only in measurements but most definitely also based on subjective listening tests. The spark turned to fire when, about a year later, we were finally able to listen to the first PTT6.5X transducer prototype and experience how its extraordinary low intermodulation distortion worked wonders for the perceived audio quality. I'm yet to obtain a Purifi-based setup at home, so these days I do most of my listing at work together with dear colleagues. ***LIS***

Mark Thomsen

International Sales and Marketing Manager, SB Acoustics, SB Audience, Sinar Baja Electric

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months and what were the main trends and factors (good and bad) affecting your business?

Thomsen: Well, we have seen a significant decline in professional audio-related sales with everything relating to large venues being under severe pressure with Covid-19 restrictions. On the positive side, we have seen strong growth and increased interest in consumer and lifestyle audio.

Question 2: What are the perspectives for your business in the next 12 months?

Thomsen: We are in the final stages of some large exciting projects with manufacturing and delivery happening during this year. Also, niche market high-end hi-fi is on the rise with increased interest in custom OEM solutions.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Thomsen: There is a definite market increase in high sound quality alternatives to the usual low-cost soundbars and lifestyle solutions. Luxury brands are moving into this space with a lot more focus on high-quality sound. Custom installs for new luxury homes and renovations with impressive custom cinemas and whole-house audio now becoming the norm.

Technology-wise we have a new flagship series of thin-ply carbon diaphragm products being released, setting a new standard in the high-end segment.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Thomsen: Smart home and smart speaker integration are the most promising technologies all across the line. This is already available from the usual giants but will be adopted to most audio-related products from third-party brands all the way up to high end. I also see seamless integration and hassle-free setup with your choice of home automation. This will truly enable whole-house smart audio in every room without the huge cost or hassle to set it up.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Thomsen: I used to travel a lot using headphones for music, but since that has not been possible, I enjoy a nice high-quality stereo setup in my home office. I must admit I am spoiled with good quality speakers, which makes it quite hard to listen to the typical pod-speaker. ***LIS***

Vikrant Singh Tomar

Founder and CTO, Fluent.ai

fluent.ai

Question 1: Challenges and Opportunities. How did your current business evolve in the past 12 months and what were the main trends and factors (good and bad) affecting your business?

Tomar: The last year has seen many ups and downs. First of all, the pandemic impacted every aspect of life, including business. At first, we at Fluent.ai saw many of our OEM customers impacted by the pandemic. But, as things evolved, a side-effect of the pandemic was an increase in the demand for touch-less interfaces, which in turn created new opportunities for voice-based interfaces, such as voice commands in elevators, high touch interfaces in factory settings, and even in transit systems in some places around the world.

Another important thing that has been going on for the past few years and has really picked up pace recently is the interest in machine learning on low-power edge devices, or Edge AI. This includes devices where the voice commands are processed and recognized offline, directly on the devices instead of sending voice commands to the cloud. Most of the current generation of smart speakers send all the voice data to a cloud server for processing/recognition, causing many privacy concerns among consumers. We're seeing increased demands for Edge AI for voice, for a variety of use cases ranging from smart speakers and smart remotes to industrial applications. This year's flagship conference for Edge AI called "TinyML Summit" (www.tinyml.org/event/summit-2021) happened in late March, with Fluent.ai involved as one of the companies presenting their innovations in bringing machine learning to the edge.

Question 2: What are the perspectives for your business in the next 12 months?

Tomar: We have been working with a number of OEMs as well as low-power chip manufacturer partners to bring new and interesting use cases with voice interfaces to the market. Some examples of these are: use of voice in factory settings to control machines (factory settings are typically very noisy, making it harder for conventional speech recognition systems to work successfully), and voice for wearable devices, smart home automation, and smart enterprises. As people and businesses become increasingly aware of what is possible with our technology for speech recognition with offline devices, we expect to see more and more avenues opening for Fluent.ai.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your activity's space over the last 12 months?

Tomar: The current generation of smart speakers, such as Amazon Echo and Google Home, have brought more awareness about the capabilities of current speech recognition technology to the masses. Recent developments have also made people more aware of the privacy concerns that these Internet-connected smart assistant devices raise. This has led to a higher demand for privacy-conscious voice interfaces inside homes and business. Edge AI provides a good solution because none of the user's data leaves the device. This results in a lot more demand for local voice AI. In fact, we are only at the beginning of the Edge AI wave. We will see many more applications of Edge AI in general and particularly voice AI on the edge in the near future.

Question 4: What technology innovations and trends do you consider to be the most promising in the audio industry for the future?

Tomar: There is a lot happening in smart audio on a number of fronts. Smart assistants or smart speakers are just the beginning. We are seeing more and more efforts put toward how to make audio sound better to humans (i.e., on the output/speaker side), as well as better quality audio (i.e., on the production or audio generation side). For the former, we are seeing efforts from existing smart speaker companies to launch products that provide high-fidelity audio (e.g., Apple HomePod, Google Home Max, etc.). We are also seeing traditional speaker companies, such as Sonos and Bose, launching smarter products. I am excited about the use of AI in really personalizing audio experience, where, for example, the smart speaker could recognize you from your voice, play your favorites, and even go further by automatically adjusting the equalizer depending on your likes and the type of music playing. Innovation in technology is also making it easy for musicians to create new experiences, whether that is by hi-fi audio reconstruction or by allowing them to automatically tune and master their tracks. There is also a lot of progress happening on digital signal processing for spatial audio to make audio sound better in a given environment. Examples of these exist in home as well as in other areas, such as simulated reverb and binaural experiences in homes with fewer speakers. Further, companies such as Porsche are investing in audio processing companies (DSP Concepts) to improve the audio experience in cars. On the hardware side, we see important work happening on graphene-based components to provide hi-fi sound from smaller speakers.

Questions 5: How do you currently listen to music the most? Did your music listening habits change in the last 12 months?

Tomar: I have a good set of speakers from Altec Lansing that are my daily music drivers. The bass is loud, and the sound is crisp on all frequencies. I subscribe to one of the streaming music companies, which has been great. It allows me to easily take all my music with me on all my devices. But the biggest impact has been that it makes it very easy to discover new music. Even though I have a smart-speaker/assistant setup at home, I don't use it. It can rarely understand my music requests. I also prefer the sound quality of my other speakers. As for the last 12 months, because we have been mostly working from home, I can listen to music on speakers while working without worrying about it disturbing other co-workers; so it has meant less use of headphones and more speakers when it comes to music. ***LIS***

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