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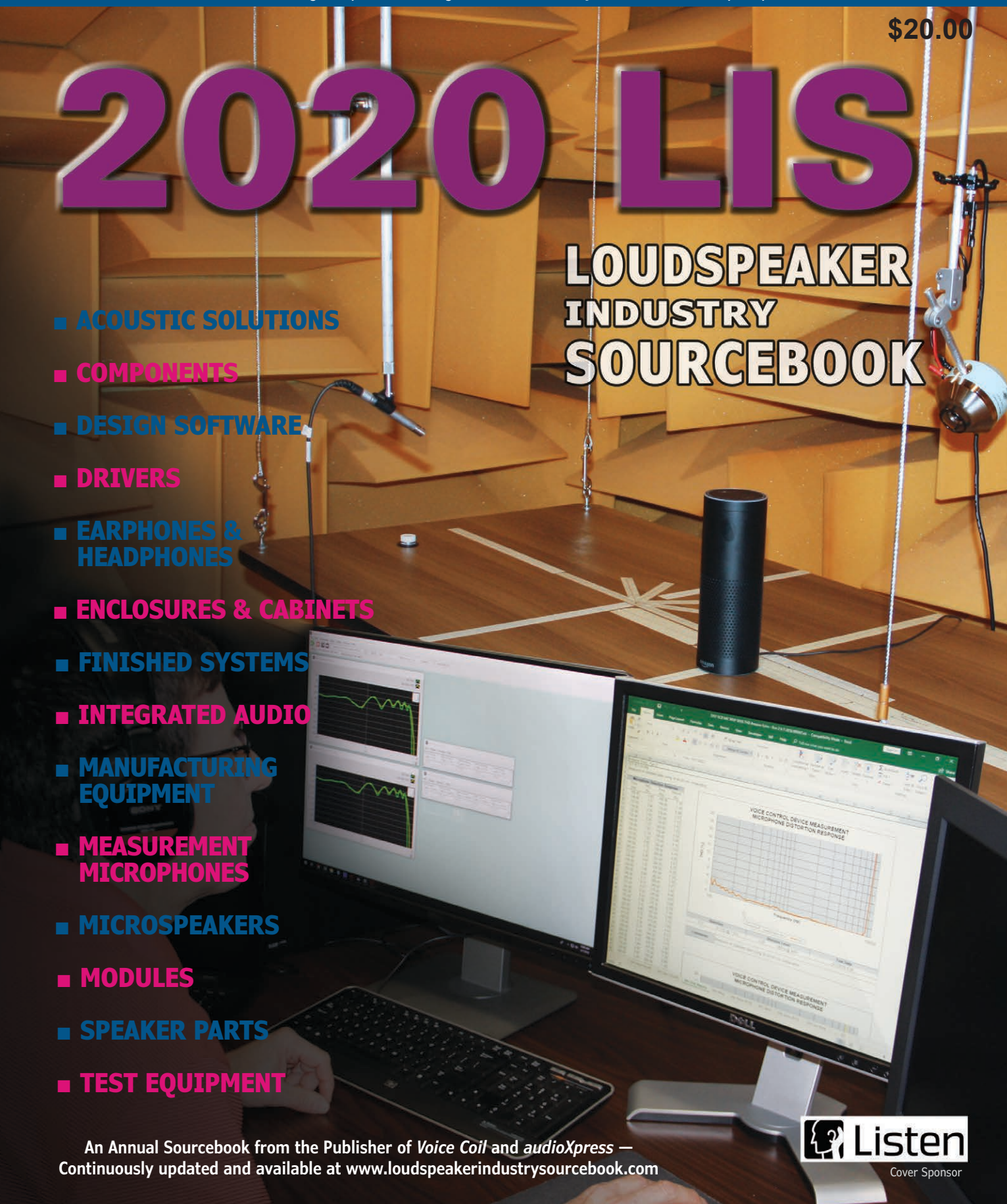

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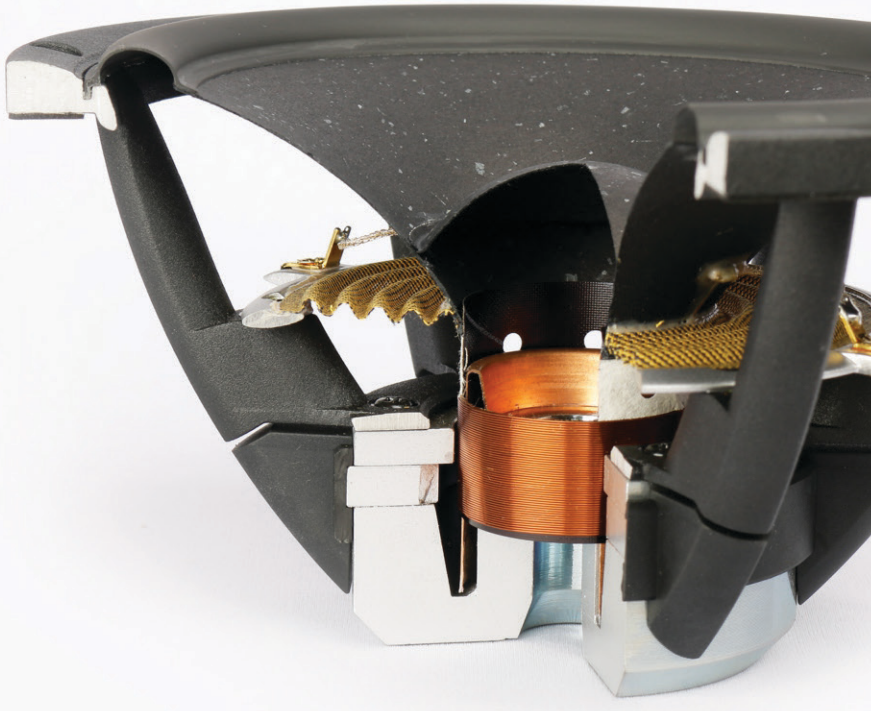

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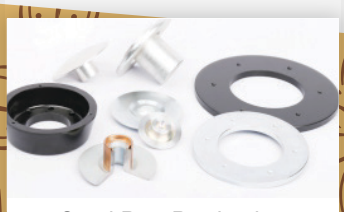

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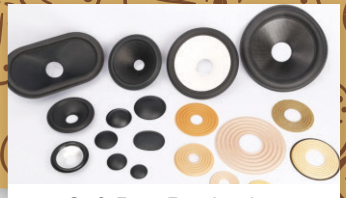

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This year, Listen, Inc. celebrates its 25th anniversary.

Launched in 1995, Listen's flagship product, SoundCheck, was the first professional audio test and measurement system that could be used with any audio interface or sound card. Now on its 18th release, the software has evolved with new algorithms and test methods to keep pace with the changing industry, from basic transducer tests to measuring today's complex audio devices. Over the past decade, Listen has also introduced its own robust test and measurement hardware, specifically designed for accurate measurement, ease of operation, and long life.

The modular software and the range of hardware—which includes audio interfaces, microphone power supplies, amplifiers, and the popular all-in-one AmpConnect—enables a cost-effective system to be configured for any application. On the production line, characteristics such as high throughput, background noise immunity, and external control make it the system of choice for many of the world's largest consumer electronic companies and their suppliers. In the R&D lab, it offers unrivalled power and flexibility, and its compatibility with a wide range of accessories and interfaces make it expandable to test virtually any audio device.

SoundCheck is used to test everything from basic transducers (e.g., speakers and microphones) to complex products, including smart speakers, MEMS microphone arrays, Bluetooth hearables with voice control and active noise cancellation, automotive audio, etc.

The Cover image shows SoundCheck being used to test all aspects of smart speaker functionality (speaker, microphone, and hands-free communications) in an anechoic chamber at Indy Acoustics Research (IAR). IAR is an independent acoustic laboratory that uses SoundCheck to test speakers, microphones, smart devices, headphones, telephones, and more.

—Listen, Inc.

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Some companies did not complete a listing request, but their relevance in the loudspeaker industry should be noted. KCK Media Corp. is publishing these listings as a courtesy to contributors of the loudspeaker industry and is not responsible for any error or omissions to the directory listings/company information.

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

LIS and specifically its printed edition has been published every year for the past 24 years. Of course, this year has been one of the most challenging years, with the uncertainty created by the COVID-19 pandemic. Around the globe, the pandemic has led to significant loss of life and caused many industries to slow or completely shut down. As we all struggle to adjust to "our new normal," LIS wants to serve as a beacon for the audio industry. We are ready to get back to the business of audio and we are moving forward.

As businesses reopen across the globe and supply chains are reshaped, LIS 2020 has been planned and structured to foster great business opportunities. More and more industry professionals are now familiar with LIS and its online directory format, available at www.loudspeakerindustrysourcebook.com, which continuously evolves as the year-round reference resource for everyone working in R&D, manufacturing, sourcing, product management, technical support, marketing, or sales in the loudspeaker and related industries.

One would think that with all the online tools and social media networks currently available to us, industries would be more connected than ever, but the opposite is happening. The ever-evolving global market and supply chain creates a daunting task for professionals trying to identify a new potential source for components, materials, or services—searching a who's who in the never ending maze of online search engines, and now with the additional challenge of trying to determine who is even still in business.

LIS is frequently updated with direct support from industry professionals and the companies themselves. The result makes LIS the best possible compilation of company profiles for the industry in every segment. And this is particularly important to highlight, at a time when our industry is going through the most challenging and disrupting trends, forcing companies to constantly reevaluate their supply chains, consider the logistical challenges, and potential trade-related barriers from all its vendors. It is a time when local contacts and insider knowledge are more important than ever, and the industry needs to work together.

LIS is an essential first tool for contacts. But this annual publication is also a valuable resource for essential knowledge.

As illustrated in this LIS 2020 edition, our editorial team has compiled a valuable series of high-quality Industry Reports and Features covering many audio industry-related topics from known industry experts.

In the 2020 LIS, we learn more about the risks associated with a global pandemic and lessons we should learn from it as well as innovations in audio technology. We can celebrate some of the achievements by companies and industry experts—including Listen, Inc.'s 25th anniversary, the development of Speakerbench by Claus Futtrup and Jeff Candy, and the new MEMS micro loudspeaker, opening up a new category with huge potential.

We sincerely hope the result will inspire and help you succeed in the days and months ahead. We have also created new social media channels and hashtags for people and businesses to use to further engage. The audio industry is stronger together.

Please enjoy this 2020 edition of the *Loudspeaker Industry Sourcebook*!

—The *Loudspeaker Industry Sourcebook* Staff

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Content for the Loudspeaker Industry Sourcebook

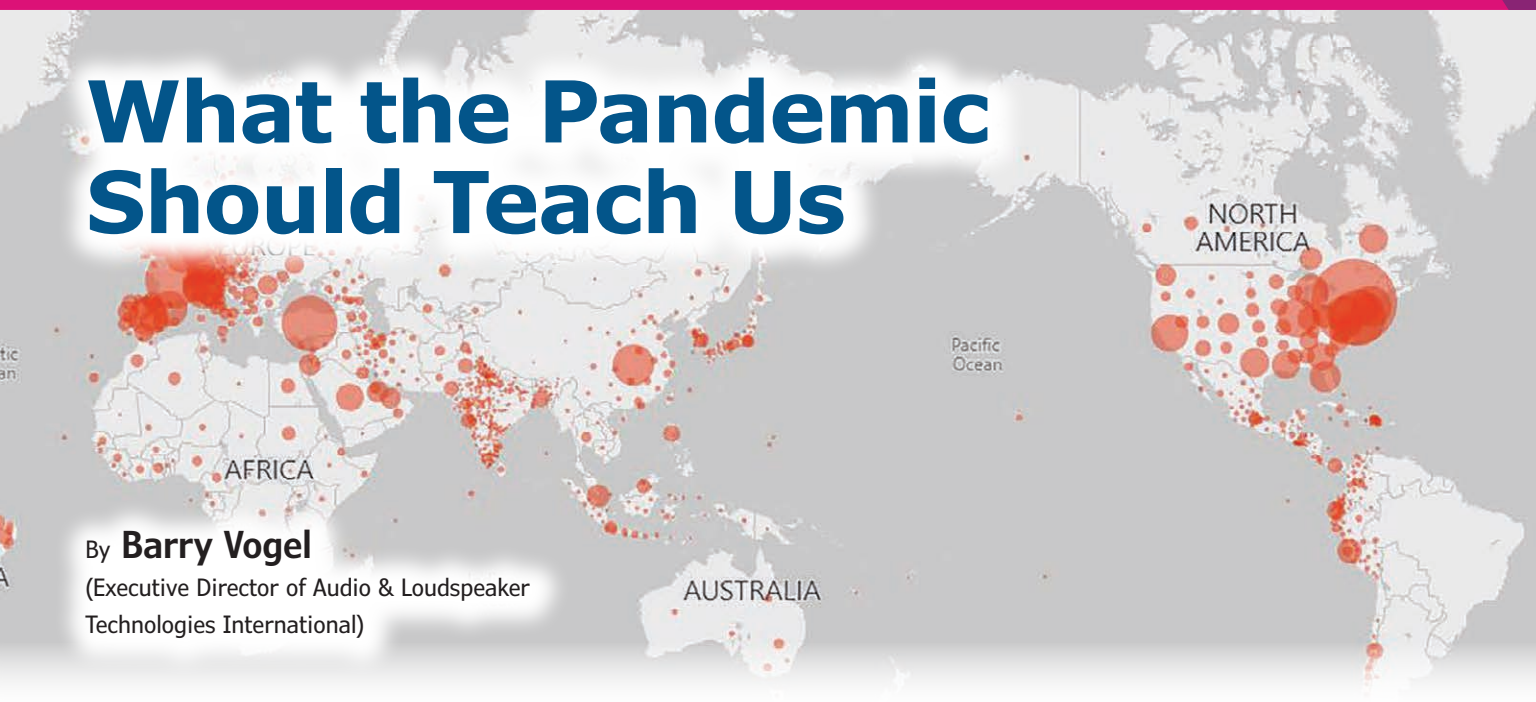
The *Loudspeaker Industry Sourcebook* has been published each year since 1996. Over the past nine years, we have made a concerted effort to grow the editorial content that is provided in the annual publication. Our goal has been to enhance the magazine and offer industry leaders an opportunity to share their research information and projects with the rest of the audio industry as well as take part in a Question & Answer section.

In years' past we have reached out to industry leaders who have graciously agreed to write articles for the magazine. Sometimes, the articles are culled from important papers they have written and presented at Audio Engineering Society (AES) conventions or other notable industry events. Other times, these audio professionals have discussed new technologies. And we greatly appreciate their time and their willingness to take part in our endeavor.

With the 2020 edition of the *Loudspeaker Industry Sourcebook* complete, we wanted to issue an invitation to our readership to begin thinking about potential content that they might want to submit or see included for the 2021 sourcebook.

We appreciate your suggestions and are grateful to be a part of the audio community. For more information, e-mail Shannon Becker at sbecker@audioXpress.com.

What the Pandemic Should Teach Us



By **Barry Vogel**
(Executive Director of Audio & Loudspeaker Technologies International)

In a lifetime filled with life-changing events, the COVID-19 pandemic stands alone. It has blown across the planet largely unabated and has shown us that we are the masters of our destiny. Until nature decides otherwise. Most business and industry has either been entirely shut down or severely curtailed. In the United States, where 68% of the economy is consumer spending, and consumers are largely out of the market due to lay-offs and shelter in place orders, it is hard to imagine it all ever getting back to normal. Whatever "normal" will be after this.

For Audio & Loudspeaker Technologies International (ALTI) and our membership, it feels like the industry is in limbo. Integrated Systems Europe (ISE) in Amsterdam in February was a smaller event than past years. Then came the cascade of trade show cancellations and postponements. Prolight+Sound. Cancelled. InfoComm. Cancelled. ALTI-EXPO. Cancelled. Many more key trade events were also cancelled. Whatever one's feelings about trade shows, they are a vital link for innovators, manufacturers, and consumers. They are also a fairly accurate reflection of the markets. Travel restrictions and corporate cutbacks have put 2020 event planning in question. For now.

Although it may feel like the industry is in limbo, nothing could be further from the truth. There is a full slate of new products, technologies, and innovations ready to go. Right now. Many were set to drop at one or more of the aforementioned trade shows. Smart suppliers are now holding back some of those introductions pending an improving marketplace. It is encouraging to see the increased activity in social networking and outreach to offer encouragement and the promise of better times to come.

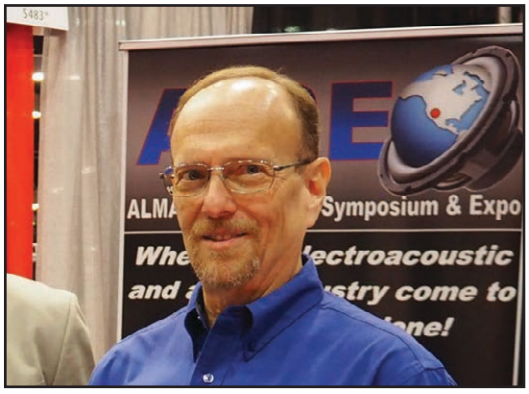
The industry today is about staying top of mind with clients. It goes beyond being empathetic or running ads professing concern and "we're all in this together." It is about concerned suppliers asking "How can I help?". It isn't about platitudes or PR. It is about reinforcing a genuine and consistent concern for customers. Companies that have always practiced this may have a tough time for a while, but they will tend to be the "go to" resources when business resumes.

Post COVID-19

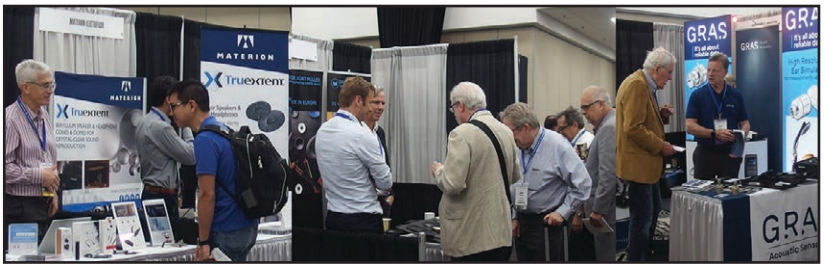
What will the audio and loudspeaker industry look like post COVID-19? While most of us would like to hope that everyone goes back to work and business picks up where it left off, it is highly unlikely that it will go that way. First, most health experts believe that the US and the rest of the

The Association of Loudspeaker Manufacturing & Acoustics (ALMA) International is now the Audio & Loudspeaker Technologies International (ALTI), "Built for and by professionals in the Audio and Loudspeaker Technologies Industry to learn, to teach, to grow and to get business done!"

Ownership and management of Audio & Loudspeaker Technologies International (ALTI)—formerly known as the Association of Loudspeaker Manufacturing & Acoustics (ALMA) International—has been turned over to longtime Executive Director Barry Vogel, effective July 1, 2020.



world will go back to work in stages as health conditions improve regionally or in pockets. The big variable is the very real possibility of flare ups in places where restrictions are lifted too soon. The Center for Disease Control (CDC) also feels it likely that we will be dealing with this pandemic for at least 12 to 18 months. Business must plan to ramp up, but must also proceed with caution. This is one circumstance where being reactive to market conditions may be smarter (and safer!) than trying to predict them. Second, everyone will be cash strapped and many companies could be teetering on the brink by the time we get back to work. Smart suppliers will need to be creative and innovative in working with clients to get back up to speed. Third, learn the lessons that a global pandemic can teach. This is not a once in a lifetime event. The World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and other medical experts are saying that outbreaks like this could easily become more frequent. Let's hope that they are wrong. Let's plan in case they are right.



Last year, 2019, was a much better year for trade shows. During ALMA International's annual Symposium & Expo (AISE 2019) visitors engaged with new and traditional exhibitors, from test and measurement, to manufacturing equipment, driver, transducer, components, and material manufacturers.

Planning for the Future

What might such planning look like? Begin to accumulate an accessible source of cash to cover periods of reduced revenue and maintain it.

Examine inventory control and "just in time" supply chains. There must be a balance between enhancing return on investment and limiting one's vulnerability to market upheaval.

Improve your social media and marketing efforts. Even those who are proficient can improve. Social media is about product and service awareness, news, company updates, and reinforcing relationship building. Hint: It isn't more frequency. It is about posts with quality content. If there is not a dedicated person coordinating social media; get one, or take the time to become proficient. Which leads to several other areas.

Improve one-on-one connections. People have relationships with people. Not companies. We are loyal to people. Not companies. There are those people who believe that personal loyalties are passé. That is simply not true. In trying times, personal relationships can be the difference between survival and failure.

Trade shows are a must. To see and be seen is vital. It is also the starting point for those one-on-one relationships and an ideal place to reinforce them. Few people write big orders at trade shows anymore, but comparing products and companies, side by side is invaluable. Money spent by businesses fall into two categories: Expense and Investment. A trade show should be an investment. If it isn't, you're doing it wrong.

Always be building a network of people one may call upon when needed. Whether it is an employee, a service provider, a leader, or an additional resource—having a wide and varied network of contacts available will make rapid adaptation easier and less painful.

This pandemic will end, or at least abate. The question is what lessons will we learn, and will we remember them? Business will be good again. Be planning for the recovery now. Be nimble enough to make rapid adjustments as needed. And always plan for the inevitable bump in the road. ***LIS***

About the Author

Barry Vogel, now head of Audio and Loudspeaker Technologies International (ALTI), 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. Vogel has 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. Vogel's greatest personal satisfaction has always been derived from helping others to achieve success.

Audio and Loudspeaker Technologies International (ALTI) is an association that enables 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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Loudspeaker Components, LLC
Materion Electrofusion
Menlo Scientific, Ltd.
Minimum Phase, LLC
MISCO
NTi Audio
Ole Wolff Electronics, Inc.
Organic Vibration Audio
Parts Express - Dayton Audio
PCB Piezotronics, Inc.
Planet Venus Audio Technologies LLC
Precision Econowind
PTWUSA
QSC Audio Products, LLC
Radio Sound, Inc.
Resonado, Inc.
Rockford Corp.
Rodgersound Labs, LLC
Snowline Joint United
Sonance
Sonos
Sony Electronics, Inc.
Sound Principals
Sound United
SSI OEM, LLC
Stetron International, Inc.
SubVo
Technomad Audio Communications
Tectonic Audio Labs
The Audio of Things
The Be Co.
Vance Dickason Consulting
Warkwyn

ABOUT AUDIO & LOUDSPEAKER TECHNOLOGIES INTERNATIONAL

Audio & Loudspeaker Technologies International (ALTI), which was formerly known as ALMA International, is an association founded and operated by professionals in the audio and 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'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!

Global Supply Chain Risks

Trade Wars, Pandemics—What's Next?

By
Rosemary Coates
(Executive Director, Reshoring Institute)

Most companies didn't see this coming. Company leadership may have completed some risk assessment and discussed business continuity. However, a crisis the magnitude of the coronavirus (COVID-19) has been a real wake-up call. It's also a double-whammy considering the trade wars and so many executives considering moving out of China to new manufacturing locations.

It all started almost three years ago with the application of punitive tariffs on imported products. First, it was 232 tariffs on steel and aluminum from multiple countries in Asia and Europe and Canada. But these metal tariffs were dwarfed by the 301 tariffs on parts and finished products from China.

In five separate tranches, (1, 2, 3, 4a, and 4b) the Trump Administration applied new tariffs approximately 6 months apart in an effort to reduce US business and consumer reliance on Chinese imports and drive manufacturing back to America. In addition, a serious attempt was made to stop intellectual property theft of American technology through sanctions on Chinese companies, including Huawei and ZTE. In retaliation, the Chinese government placed tariffs on American goods imported into China. Tit-for-Tat.

Unfortunately, very little manufacturing was driven back to America. Companies dependent on Chinese parts either endured the 10% to 25% cost increases due to the tariffs or decided to move production and sourcing out of China and into other low-cost countries (e.g., Vietnam, Thailand, Indonesia, India, and Mexico). These reactions may be a temporary shield against rising costs, but they do not substitute for strategic planning and risk reduction.

When the coronavirus hit hard in January, we saw global supply chains affected within a few days. Companies practicing Lean techniques and Just-In-Time inventory practices were hit first. The Hyundai auto plant in Korea closed down manufacturing within a week of the Wuhan lockdown due to parts shortages from China. Other manufacturing sites all over the world began to suffer from parts shortages that left work-in-process orders unable to be completed.

The worst is yet to come. Most manufacturing companies had 30 to 60 days of parts inventory on hand, available from local distributors, or in-transit. This meant that about 6 to 8 weeks after most factories were shut down in China, there were significant shortages of parts around the world. Coupled with worldwide community shutdowns, demand for products has diminished,

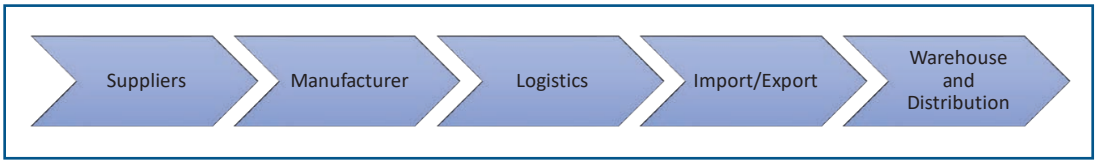


Figure 1: Think about your operations as made up of many links in a global supply chain and evaluate each link separately.

and manufacturers are left with both parts shortages and excess inventory.

Global warming is yet another huge risk that should be addressed. You may have issues with suppliers in low-lying areas, and weather extremes with fires and floods. There may be other natural disasters to consider such as hurricanes, floods, fires, earthquakes, and tsunamis

Strategic Planning in Time of Crisis

These crises, the tariffs and the virus, have been startling wake-up calls for manufacturers. Thinking about what could happen in the future keeps manufacturers up at night. Without a strategic plan and business continuity plan in place, day-to-day operations may stumble. Some companies will make it, and others won't. With planning for potential risks and knowing the alternate pathways, companies have a better chance at survival. So, what should be included in your plan?

Developing a Strategic Plan and Risk Mitigation Plan

Developing a strategic plan is hard work, but not impossible to do. In fact, we recommend that companies develop a Plan B and a Plan C with alternate execution pathways. Strategic planning is no longer simply about products and markets and opportunity. It must include supply chain alternatives to be executed in case of unforeseen roadblocks and disasters. Think about your operations as many links in a global supply chain and evaluate each link separately. Start with the basics as shown in **Figure 1**.

Alternate Suppliers

Many companies, especially small and medium-sized businesses do not have well-developed alternate suppliers outside of China, and finding new suppliers, qualifying them, and scheduling production is no easy task. For complicated parts, this can take 12 to 18 months, and it is not an inexpensive process. In some cases, currently, there are no capable suppliers anywhere in the world outside of China. New suppliers will have to be identified and then developed. As an alternative to foreign suppliers, some companies are pressing their engineers to redesign parts that can be sourced in the US, or at least outside of China. Other companies are giving 3D printing a serious try for the first time.

Manufacturing Sites

Big, global contract manufacturers (e.g., Flextronics and Foxconn) have established manufacturing sites all over the world. Manufacturing can be moved from site to site as necessary for efficiency, reduced cost, or to avoid tariffs from certain countries. These are interesting models to study for ideas on shaping your global manufacturing strategy. Determining the costs and benefits of each site will help to clarify the manufacturing location decision.

Companies should consider the potential risks of where they manufacture today. If one or two alternate manufacturing sites or contract manufacturers could be established, where should they be and how quickly could production shift to these locations in case of emergency?

Logistics Providers

It's relatively easy to find very low-cost operating sites around the world, especially in rural areas. Even rural areas in the US provide low-cost competitive alternatives. In addition to availability of skilled labor, companies must consider the logistics costs, which can quickly become a huge expense. Airfreight and trucking rates to rural areas are typically more expensive with infrequent services. If you are operating in a foreign country, some freight carriers do not serve rural areas, so while you could inexpensively manufacture there, the cost to ship products may be prohibitive.

Import/Export

Importing and exporting processes are full of complicated legal rules and regulations, but the imposition of tariffs is a political decision. In recent years, tariffs have been used as weapons to harm the businesses of a foreign country, and protect domestic enterprise. But trade wars and extraordinary tariffs also raise costs, and in some cases, can be fatal to businesses dependent on foreign parts and products.

As a result of the Trump Administration's trade war with China, many companies are fleeing China for other low-cost production sites in countries, including Vietnam, Thailand, Indonesia, India, and

Mexico. But there is no guarantee that punitive tariffs won't be applied to these countries. In fact, Washington D.C. insiders claim that Vietnam, Korea, and India are all on the short list for 301 tariffs.

In strategic planning, companies should take into consideration the political views on trade with countries being considered. In addition, the stability of the country's government, environmental risk, and currency risk should be evaluated. In addition, it's best to investigate the import/export processes in the countries being considered. These processes may be overwhelming, frustrating, and full of delays. Take Brazil and India as examples of complicated and delayed import procedures. In some cases, it can take as long as one month to process imports into Brazil. In India, the bureaucracy can be infuriating.

Warehousing and Distribution

Warehousing and distribution are other areas often overlooked in strategic plans. If you are manufacturing overseas, you might want to keep finished product stored near your customers. If your customer base is in the US, selecting a central distribution location such as Salt Lake City, UT; Dallas, TX; or Atlanta, GA; will optimize your order fulfilment time and reduce the risk associated with weather and other natural disasters. If you are storing raw materials and parts for production, you should consider the trade-off between working capital tied up in inventory and uninterrupted supply.

Warehousing and distribution are non-trivial aspects of your end-to-end supply chain. Effectively managing shipments to customers and feeding your production lines can mean the difference between profitable, efficient operations versus expensive down time. In today's time-sensitive delivery world, customers expect fast, and sometimes overnight deliveries. Being close to your customer base will help in meeting customer expectations and service-level agreements.

Digital Twins

For help with modeling your alternate plans and evaluating risk, companies can use a digital twin as virtual representation in virtual space of a physical structure in real space. Sometimes digital twins connect the real world to the digital world where configurations and models can be altered on the fly with software, then implemented almost immediately. Information flows between the digital and real worlds for continuous synchronization and updating. Decisions can be made immediately instead of waiting on historical data and recommendations. Software is available for this type of modeling.

Leaving China

One final word if you are leaving China—it's not as easy as you may think. You cannot simply pack up and leave. If you are manufacturing in your own factory or with a contract manufacturer in China, your employees are most likely to be on an employment contract. This means that you must pay out the wages through the end of the contract period, even if you are leaving months or years before the contract ends.

You shouldn't plan on getting your molds, tools, or dies back either. Even if the contract states that these items belong to your company, it's unlikely you will be able to export them from China. Chinese manufacturers typically consider molds, tools, and dies part of their factory infrastructure and the Chinese government may not permit them to be exported. This can result in an extraordinary loss of valuable and often proprietary machinery and models.

Finally, you must file for a legal permit to lay off workers or close a factory in China. If you don't obtain a permit prior to closing, you may be barred from ever entering China again or selling products there. You may also be subject to employee lawsuits that take years to resolve.

Plan for the Future

Strategic planning for global sourcing and manufacturing includes a lot of moving parts and variables. It's best to develop a few different alternatives in case Plan A or Plan B cannot be executed. Make sure your supply chains are resilient. Companies should at the very least, start dual-sourcing critical parts and develop new suppliers in low-risk countries or better yet, in the US. Adding some premium costs to your global sourcing may be far less expensive than the risk of single sourcing in the long run.

Develop alternate plans and refresh them yearly. Discuss how the company will react should disaster, trade wars, or pandemics strike in the future. ***LIS***

About the Author

Rosemary Coates is the Executive Director of the Reshoring Institute and the President of Blue Silk Consulting, a Global Supply Chain consulting firm. She is a best-selling author of five books on global supply chains including: *42 Rules for Sourcing and Manufacturing in China and Legal Blacksmith—How to Avoid and Defend Supply Chain Disputes*. Coates lives in California's Silicon Valley and has worked with more than 80 clients worldwide. She is also an Expert Witness for legal cases involving global supply chain matters. She has been a past speaker at the Association of Loudspeaker Manufacturing & Acoustics (ALMA) International events.

Power of Brand

Our brand expert discusses the importance of creating a brand and sharing that brand story, which he says is the universal equalizer among so many competing companies. Your brand, and what it represents, needs to be woven into the fabric of everything you do and say.

By **Adrian Weidmann**
(Managing Director, StoreStream Metrics)

We all have a passion for music—that's why we're in the business. From musician to design engineer, our passion takes us anywhere along the musical signal path. My path took me from our band in college—Broken Bow—to remote classical and folk recording for Wisconsin Public Radio, to becoming an electroacoustic sales engineer for Brüel & Kjær in Denmark. It is not surprising that my perspective of loudspeakers (and microphones) is through the lens of measurement and quantitative analysis.

Between listening to and recording live music, the goal was to capture and reproduce what I was hearing as accurately as possible. Wherever you may live along the audio technology signal path, we have all, in one way or another, measured the degree of "good" with the ever present "specification sheet." Frequency response curves, the decibel, nominal impedance, sensitivity, and peak power ratings are all valid measurements and numbers yet rarely, if ever, define a product's commercial success or failure.

The *2010 Loudspeaker Industry Sourcebook* listed 360 companies and 10 years later there are now more than 650 companies! With so many new and innovative loudspeaker designs, microphones, digital processing technologies, power amplifiers, audio hardware, and software being introduced to the market how do you differentiate your product or service? How do you compete for business?

Whether you're a single entrepreneur or an enterprise company, creating a brand and sharing that brand story is the universal equalizer. Your brand, and what it represents, needs to be woven into the fabric of everything you do and say.

What is a Brand?

A brand is a promise kept. Put simply, your brand is what your prospect thinks of when he or she hears your brand name. It's everything the public thinks it knows about your name brand offering—factual (or not) and emotional. Your brand name and logo exist objectively—people can see it. It's fixed. The real power and value of your brand is the emotional bond that exists in someone's mind.

You can't create and nurture your brand without understanding the importance of community and experience. A successful brand is a community where people choose to "opt-in" and become an engaged member of that tribe. Belonging to a community is a core element to the human experience. One of the foundational objectives in developing a brand is to create a community in which people want to belong. A brand is a promise kept and a communal experience.

How Do You Build a Brand?

Since we're all passionate about music, the composition of a brand consists of seven "notes": genesis, promise, icons, customs, lyrics, fans, and voice.

Genesis

Identify and understand your beginning—your genesis. What was your inspiration? Your motivation? Why did you start your company and how did you begin? Tell your story. People want to know what drove you to begin this journey. This creation story often reveals your passion and inspiration. Both of which, connect emotionally with people. Your genesis story becomes your

brand providence and it establishes your authenticity and credibility. For example, as a performing musician, Les Paul wanted to be heard, which led to his invention of the electric guitar. And, AirBnB was started by two guys renting air mattresses in order to make rent money.

Promise

Your promise is your theme song. It defines your core principles and everything you represent. Your promise reflects everything you do and positions you in the marketplace. Your promise is often your marketing tag line. Examples include:

- "Just do it"—Nike
- "Think Different"—Apple
- "Better sound through research"—Bose

Icons

While your logo is an important icon for your brand, don't limit yourself. Icons can include a combination of other multiple senses that may trigger an invaluable emotional response. Smell, color, design, sound, physical environment, or even a person or place can become a powerful icon. Take, for instance, these examples:

genesis: rock n roll band started by Mick Jagger and Keith Richards in London with heavy blues influence

promise: world's best rock n' roll band

icon: trademarked logo

customs: 'the strut', 'bad boys', hit songs, dropped tuning

lyrics: honky tonk woman, exile on main street, sticky fingers

fans: fans
critics: The Beach Boys

voice: Mick Jagger, Keith Richards

Figure 1: The seven notes are used to define the iconic rock band, The Rolling Stones.

genesis: started by Steve Jobs and Steve Wozniak building PCs in the garage

promise: think different

icon: logo, iPhone, Genius Bar, The Apple Store

customs: Apple TV+, photos into iPhoto, community

lyrics: Apple, Macbook, iPhone, Catalina, iOS

fans: Users, customers
critics: PC, Microsoft

voice: Steve Jobs, Tim Cook

Figure 2: Here, the seven notes are used to define the Apple brand.

- Smell—Vap-o-Rub and CoCo Chanel perfume
- Color—brown for UPS, blue for IBM, red & white for Coca-Cola, and black & white for Jack Daniels
- Design—the Google home page, Bang & Olufsen, and Nest thermostat
- Sound—Harley-Davidson and the opening two notes of NBC's "Law & Order"

Customs

Customs, as the word is defined, are:

a. A traditional practice or usual way of doing something followed by a social group or people
b. The tradition or body of such practices
c. A habitual practice of a person
d. Habitual manner or practice

You need to create and maintain brand customs. These customs should represent relevant and repeated interactions and exchanges between your customers, prospects, and employees. These customs may appear to be small and inconsequential but do not underestimate their influence. Some select examples include:

- The Google home page—you always expect the same white appearance. Imagine how difficult it is to maintain that empty space given its media value!
- The toilet paper folded to a point in a hotel room—it sends an important message.
- Sending a hand-written thank you note.

Lyrics

The lyrics of your brand refers to a unique vocabulary and language that identify you. The lyrics are often referred to as "lingo." Your brand lyrics allow your community to communicate with each other with pride, giving them a deeper sense of belonging. Conversely, if you don't know the unique brand language, you're not part of the community. Let's look at several examples and see if you're a member of that community.

- Starbuck's—Grande, tall, vente
- Apple—Safari, Keynote, Catalina
- Musicians—Gig, axe, jam, riff
- Loudspeaker designers—Thiele-Small parameters, impedance, port, decibels (dB), spider

Fans (and Critics)

An important element of composing a successful brand is identifying and knowing who your fans are, and conversely, yet equally

important, is identifying and knowing your critics. Your fans are your most powerful advocates. Encourage and reward them to share your brand story and their supporting narrative. The professional audio market has used this successful tactic over the years by way of product endorsements.

Advocates and critics are members of specific, and often competing, communities and understanding who they are and what they represent is invaluable in positioning your brand in the marketplace. Understanding who your critics are, and why they are members of another community, will allow you to further differentiate and amplify your brand story.

Another important factor to remember as you compose your brand when creating your fan base is defining and communicating what you are not and will never want to become, which defines who you actually are and sets your brand's moral compass. This is particularly valuable in today's market where social and environmental responsibility is not only valued by millennial shoppers but often determines purchase decision over any brand loyalty.

Notable examples of the role fans and critics play in developing and maintaining your brand story can be found when choosing:

- Coke or Pepsi
- Ford or Chevy
- Democrat or Republican
- Mac or PC
- Digital or Vinyl (Analog)

Voice

Last but not least is finding your brand voice. Now that you've composed your brand story, it is now time to find your community and tell that story. Your brand message will resonate wider and deeper if it is told by a recognizable, trusted storyteller. A significant element of the rise of Apple as a leading global brand was the persona and voice of Steve Jobs. He was a brilliant visionary who not only inspired but was a fantastic storyteller.

The advertising community knows the value and power of a brand voice. Remember the most interesting man in the world for Dos Equis beer? What about the Old Spice man—the man your man could smell like? One of the best storytelling brands in the world is Red Bull.

Red Bull's 2012 Stratos Project pushed the boundaries of brand storytelling. The company sponsored Austrian skydiver Felix Baumgartner's freefall jump from 24 miles above the earth, breaking five records, according to officials at Guinness World Records. The event was broadcast on nearly 80 TV stations in 50 countries. The live webcast was distributed through 280 digital channels and resulted in more than 52 million views—making it the most-watched live stream to date. While not his intention, Baumgartner and his extraordinary achievement became the voice of Red Bull for that two-year period. Sales of Red Bull rose more than 7% during the following six months.

While these are unique examples, it is important to understand the message here. Despite your size, creating a voice for your brand is an extremely important element in the overall composition of creating a Brand.

Pulling It All Together

Using these seven "notes"—genesis, promise, icons, customs, lyrics, fans/critics, and voice—you too can compose your brand story. Whether you're a single entrepreneur or a small or large company, everyone has, and can compose, a brand story. In keeping with our musical theme, let me draw your attention to **Figure 1** and **Figure 2** as examples of using this simple method to define two internationally recognized brands—The Rolling Stones and Apple.

Creating and building a brand takes time and effort. Not only is it not easy, it is fragile. It can take years to develop and maintain an omnipresent brand—but one false, careless move can shatter all your efforts. Every brand story begins with a passion and a belief in something unique and personal. Take a moment to reflect on what drove you to design that unique product or service. Therein lies the foundation of your brand story that will resonate and connect emotionally with your community.

Start composing your brand today using these first seven notes. As you compose and add dimensions and details to your brand story, it will mature into a complex symphony. That is the power of Brand. ***LIS***

About the Author

Adrian Weidmann, Founder & Managing Director, StoreStream Metrics, based this article on his successful workshop—The Power of Brand. Weidmann was recently elected to the Board of Directors of Audio & Loudspeaker Technologies International (ALTI) to focus on helping entrepreneurs and designers incubate their brands and guide their business processes allowing them to compete on the global stage.

StoreStream Metrics has focused on measurement, analytics, digital content design, and workflow optimization. He recently created Blink325—a predictive viewing analysis service for content and website design using Artificial Intelligence (AI) to his portfolio. Clients include UPS, Dairy Queen, Coca-Cola, and The Home Depot.

The Year of Sound Will Continue Into 2021

By **Marion Burgess and Michael Taroudakis**
(Co-organizers, IYS 2020)

Almost a decade ago, the International Commission for Acoustics (ICA) decided that the initiative of an International Year of Sound would highlight the importance of sound in all aspects of life and lead toward an understanding of sound-related issues at the national and international level. This article describes how it all came to fruition.

The International Commission for Acoustics (ICA) was established in 1951 as an International Scientific Organization and today its membership includes more than 50 national acoustical societies and organizations around the world. The purpose of the ICA is to promote international development and collaboration in all fields of acoustics including research, development, education, and standardization. While acoustics covers the broad spectrum from infrasound through to ultrasound, the majority of the acousticians work on aspects of sound in the part of the spectrum relating to hearing.

The sound environment is so important that it shapes our personal and collective behaviors. Sound is an integral part of culture and society from the basic requirements for human communication and education, awareness of our environment and expression of our culture, through to sophisticated scientific and technological instruments that have been created for a better exploitation of the properties of sound. For all these reasons, sound is, in general, beneficial to human beings and other living organisms. Quality of hearing is an important factor that determines the human health (mental and physical), and it is absolutely necessary for the full appreciation of all the benefits of sound. In this respect, there is the risk of exposure to an environment that makes increasing use of sound and at increasingly high and continuous harmful noise levels. Consequently, the intensification of urbanization, as well as the increasing traffic in our oceans and our sky can make the soundscape a matter of concern for us all.

Almost a decade ago, the ICA decided that the initiative of an International Year of Sound (IYS) would highlight the importance of sound in all

aspects of life and lead toward an understanding of sound-related issues at the national and international level. Following collaboration with La Semaine du Son (The Week of Sound), this has come to fruition as the International Year of Sound 2020 (IYS 2020). The ICA member societies and international affiliates have been mobilized to work toward the goals of the UNESCO resolution "The Importance of Sound in Today's World: Promoting Best Practices."

The Start of IYS 2020

The opening for the IYS 2020 was held in the Grand Amphithéâtre of Sorbonne University in Paris, France on January 31, 2020. This amphitheater was inaugurated in 1889 and registered as a historic monument in 1975. It was indeed a fitting location for the opening of the IYS 2020, and we are grateful to Prof. Jean-Dominique Polack (IYS 2020 co-organizer) who was instrumental in the arrangements for the use of this venue and the support of Sorbonne University. The participation in the opening by representatives from a range of international scientific, cultural, and health organizations highlighted that sound has impact on so many areas of our life.

The Vice President of Sorbonne University, Nathalie Drach-Temam; the President of the International Commission for Acoustics, Mark Hamilton; the International Union of Pure and Applied Physics, Michel Spiro; members of the French Acoustical Society, Vincent Gibiat and La Semaine du Son Christian Hugonnet; as well as World Health Organization representative Shelly Chadha presented short greetings highlighting the importance of sound from their own perspective. Marion Burgess was the plenary speaker of the ceremony presenting the main theme of the IYS 2020 "Importance of Sound for Our World" and Jean-Dominique Pollack presented the structure of the IYS 2020. The ceremony was moderated by Michael Taroudakis.

The opening ceremony included two cultural events aiming at the demonstration of how music, as a cultural expression of sound, can be realized by musical instruments and the human voice. Maxime Perrin and Jean Brice Godet performed in the instrumental part of the ceremony with sponsorship from the French Acoustical Society, while Concert: "Révolutions Vocales" performed by Compagnie VocAliques and Sponsored by Acoustics First, illustrated the importance of the human voice in the composition of musical pieces.

The early attendees at the opening could experience two installations in the foyer of multi-zone sound field reproduction. They were created by researchers from the Institute of Sound and Vibration Research (ISVR—University of Southampton, UK) and the installations were arranged by the UK Acoustics Network (UKAN). One exhibit, commissioned from artist Kevin Walker, demonstrated a multi-zone soundscape set in a variety of acoustic environments. You could stand still and let the soundscape, constructed from field recordings and digital synthesized sounds, take you on a journey or walk around to follow your favorite sound. The second documented the history of acoustics from pre-history to the present day with French and English language soundtracks.

From left: Sergio Luzzi, organizer of the student competition; Christian Hugonnet, President LSdS; Michael Vrlander, Past Past Past President ICA; Marion Burgess, Past Past President ICA; Michael Taroudakis, Past President ICA; Mark Hamilton, President ICA; Jean-Dominique Polack, Board Member ICA

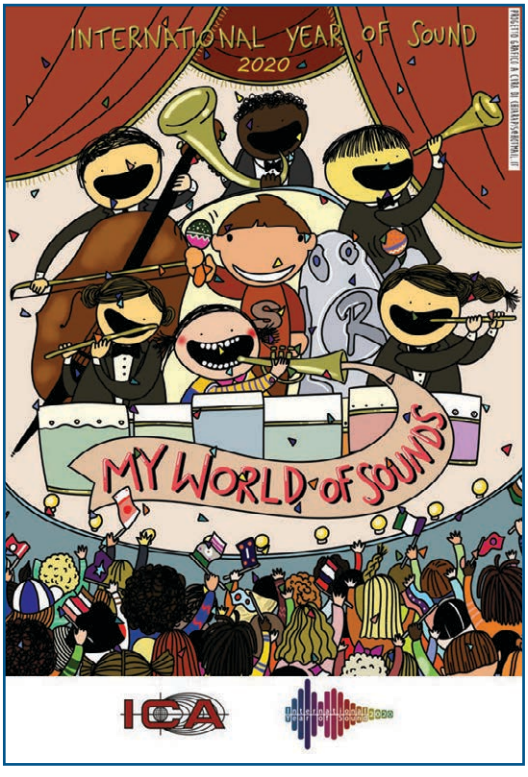
The top of the nearby Tour Zamansky of Sorbonne University was used for an audio installation "The Cloudspeakers." This is a creative work by Michel Risse and Décor Sonore, a French company dedicated to sound productions for public space that challenge the way we listen to our everyday environment. Décor Sonore was experimenting with this installation over the period of La Semaine du Son de l'UNESCO and the opening of the IYS 2020. This audio installation was sponsored by NEXO with assistance from La Semaine du Son and Sorbonne University.

World Events Extended IYS Into 2021

The website (www.sound2020.org) provides the focus for the information about activities being organized around the world for the IYS 2020. All the

ICA member societies, and any organization with any involvement with sound, have been encouraged to host outreach activities. Some directly relating to hearing were scheduled to coordinate with World Hearing Day on March 3. Others were to be coordinated with International Noise Awareness Day on April 29. As well, throughout the year, there were to be events raising awareness of sound in many different ways.

The student competition poster for the International Year of Sound



Of course, the COVID-19 virus has affected the majority of the events planned during the early part of this year. The decision has, therefore, been made to extend the IYS 2020 into 2021. At this time, while it still has the name IYS 2020, it is being considered as a two-year celebration of sound. The extensive listing of planned events can be seen at www.sound2020.org under the events tab.

There is also an international student competition for students of Primary, Middle, and Secondary schools from all over the world and sponsored by HEAD-Genuit Foundation. Also as a result of COVID-19 and school closures around the world, the deadlines for this Schools Competition is being extended to the end of the year. The competition for the younger students is to produce some form of artwork reflecting their world of sound. The older students are asked to write words for the music of "The Sound of the World," which has been especially composed for this competition. Both are to be inspired by the motto of IYS 2020 "Importance of Sound for Society and the World" (https://sound2020.org/society/student-competition).

Other outcomes from the IYS 2020 include the compilation of resources on sound that are freely available from the web. Many of these are education aids and will continue to be available in a centralized location as an ongoing legacy from the IYS 2020. The ICA with the support from the International Institute of Noise Control Engineering has produced a 9-minute and a shorter 3-minute version of a film on "Sounds of Our Life" directed by Antonio Fischetti. This film describes how controlling sound is important for our sound environment and our hearing health. Both versions are freely available for downloading through the IYS 2020 webpage.

Any groups or organizations interested in arranging an outreach event in 2020/2021 or providing an acoustics resource are encouraged to post them to the IYS 2020 website. All events listed will be able to use the IYS 2020 logo to enhance their promotion.

The International Year of Sound is happening and will now continue into 2021. The importance of sound to our life and wellbeing has been highlighted in recent months (and an unforeseen contribution to the IYS 2020) when people living under difficult conditions enforced by COVID-19 have been singing or making group music from their balconies as a way of maintaining social connections. We look toward the future for events of IYS 2020/21 in a world where people will enjoy health and prosperity, and sound will be one of the means to express joy and solidarity. ***LIS***

About the Authors

Marion Burgess is an honorary senior lecturer at University of New South Wales, Australia. Although officially retired she keeps an active interest in environmental and workplace noise. She has also been very involved with the national and international acoustics organizations and is currently the Past Past President of the ICA and Past President of the International Institute of Noise Control Engineering. During her time as ICA President, the concept for an IYS was developed and she continued to work on the preparation as the co-organizer.

Michael Taroudakis is a Professor at the University of Crete, Greece, who works primarily in the area of mathematical modelling as applied to Underwater Acoustics. He has been very much involved with the national and international acoustics organizations and is currently the Past President of the International Commission for Acoustics (ICA). During his time as President, he was heavily involved with the preparatory work for the International Year of Sound (IYS) as the co-organizer.

Both Michael and Marion were pleased to see the IYS become a reality in January 2020 and while the current worldwide crisis has meant postponement of many planned activities, it has also given the impetous for innovative web-based activities and for the celebration of the importance of sound in our world to extend throughout 2021.

Yet Another Stellar Year for Audio

By **Guy Hammett and James Kirby**
(Futuresource Consulting)

Amazon continues to set the bar in the smart speaker category. In 2019, the company expanded the range upward to also appeal to users looking for better quality sound, with the new Echo Studio, described as Amazon's "Best-sounding Echo ever."

Audio continues to become an increasingly important part of our lives—from streaming through headphones while commuting to asking Alexa or Google to play our favorite playlists on smart speakers in the home, through to seeing our favorite artists or acts perform live. Consumer audio experienced record levels of nominal growth in 2019, growing 30% in value across headphones and loudspeakers combined. Meanwhile, professional audio continues to represent a significant opportunity for both pro and consumer brands across a broad range of applications—from live performances to retail, leisure, and commercial installation.

Professional Loudspeakers

Futuresource has been researching the professional audio industries closely for more than five years, and now has dedicated services across loudspeakers, mixers, amplifiers, microphones, studio technology, and headphones. Professional loudspeakers is the largest market in professional audio, with revenues having reached almost $2.8 billion in 2018. It has represented a solid growth opportunity for many brands and covers a range of product applications, including live and touring line array systems and portable PAs to business music solutions and low wattage PA/VA speakers for audio-by-the-acre applications. Before the outbreak of COVID-19, (this article was prepared in early April 2020, while the global confinement to homes is at its height) the overall market was forecast to achieve a compound annual growth rate (CAGR) of 6.9% in revenue from 2018-2023. However especially for the event-centric verticals, the virus will postpone a significant proportion of sales. Nevertheless, demand for professional audio, and more specifically loudspeakers, is expected to return to longer term growth, driven to varying degrees by a broad range of applications, end-users and product segments.

Often the most talked about and glamorous part of the pro-industry industry is touring and rental. This is the home of rock and roll, artists, and performers, which has been driven by consistently increasing consumer demand and changing artist income structures as a result of the streaming economy. Touring speaker manufacturers have significantly benefited from this trend, with substantial increases seen in the number of live events over the past decade.

As times change, the impacts of the streaming economy have begun to dissipate. This is especially true at the high-end, with a limited supply of artists. Many here have had to increase ticket prices to finance impressive LED displays and improved visuals to attract demand. In this phase, audio has not benefited to the same extent. That said, there do remain some interesting opportunities for audio, even in the top grossing tours. Brands such as L-Acoustics, d&b, Meyer Sound, Martin Audio, Astro Spatial Audio, and many others are investing in immersive live sound—an idea that brings audio front and center and offers the opportunity of more speakers per project, both more front hangs, and in a smaller number of cases, satellite surround sound speakers.

Outside of the top grossing tours, there also remains significant demand, with many rental channels having invested in less expensive and more portable line array systems to cater to smaller events. There continues to be more

JBL's PartyBox 300 is a leading wireless party speaker model, one of the few booming areas in the otherwise stagnant non-smart wireless speaker market

opportunity for smaller events, with genre-specific festivals on the rise and corporate events showing positivity for wider AV in the long term. Brands such as RCF, CODA Audio, and FBT are innovators to these markets.

The installation market continues to show the most growth for high-wattage speakers, as venues invest in better house-systems to draw in higher value and more diverse productions and events. Growth areas here include multi-purpose music venues, theaters/performing arts, corporate event spaces, hospitality/cruises, stadiums and houses of worship. However, it is not just high sound pressure level (SPL) systems that are subject to increased install opportunity. Many of the applications mentioned also offer opportunity for concourse, business music, and evacuation speaker systems. This market also extends to a range of smaller premises in the leisure and commercial sectors, including gyms, cafes, restaurants, and retail. All these applications continue to upgrade and drive demand for speaker systems.

Install trade-up is most evident in the larger opportunities of retail and hospitality, where audio and music have become trusted tools for creating desired atmospherics, brand image, influencing customers, and improving engagement. Consumer brands have also seen significant success here over recent years, especially in independent establishments. Meanwhile, across larger projects and in corporate AV settings, DSP solutions continue to become a key gateway to speaker sales for professional brands, being important to projects ranging from video conferencing to large stadiums.

Outside of installation, other segments of the professional loudspeaker industry include portable PA and studio monitors. Portable PAs takes a significant share of overall revenues for the industry, however experiences relatively slow value growth due to an increasingly competitive climate and high penetration of powered solutions among amateur bands/DJs/performers. However, some very positive areas remain, with the latest solutions having impressive built-in DSP and control, and growth opportunity seen in portable column systems and ultra-portable point-source solutions. Here, driver construction materials and Class-D amplification play a significant role. Studio monitors on the other hand is a smaller but more positive growth area, driven by substantial and continued demand from home content creation and solid growth for high-channel-count systems for immersive mixing in post-production studios.

Overall, the professional loudspeaker market is one of consistent positive growth, with some significant areas of opportunity for both professional and consumer brands alike. Technology developments have allowed systems to be more portable and convenient than ever, and enhancements in DSP and networking continue to act as a significant gateway to loudspeaker sales. Although the impacts of COVID-19 will be significant over the next year or so, the industry will return to strong growth, with many more new and exciting opportunities to come. Most importantly, audio is becoming an increasing part of our day-to-day lives, and during the current situation of lockdown, many would agree that the communal leisure and social activities that professional audio helps facilitate, are feeling more important than ever.

Consumer Audio Growth

Sales of consumer audio products (headphones, wireless speakers, soundbars, and hi-fi systems) grew 18% in 2019 to 638 million units with wireless speakers and headphones the star performers. While both products are flourishing in unit terms, consumer expenditure on these two devices is trending in diametrically opposed directions. Away from mainstream audio products, 2019 was a year of evolution not revolution for consumer loudspeakers with architectural speakers and premium options outperforming the market.

Fragmented Home Audio Market

2019 was also a year of contrast for wireless speakers with smart speakers growing 60% versus 1% for non-smart speakers (which comprise Bluetooth-only speakers and Wi-Fi speakers without voice). Audio brands command a small

portion of the smart market with the five tech giants (Amazon, Google, Baidu, Alibaba, and Xiaomi) attaining 92% share. Noticeably, 2019 smart speaker releases from audio brands were marketed as audio-first products with voice control one of many features. Audio quality and related features took primacy in the marketing material. This was a departure from first-generation releases, which were presented as smart speakers first and foremost, demonstrating that these are now two distinct markets with as many differences as similarities, even though a smart speaker from audio and tech brands can perform comparable functions.

First-party devices offer superior voice experiences, consequently consumers prioritizing the "smart" aspect prefer these brands with many retailers positioning smart speakers as Internet of Things (IoT) products, reinforcing the technology credentials. Even the audio brands having relative success aren't attributing this to voice, with some citing voice activation rates below 30%. Nonetheless, while audio brands cannot compete directly with tech brands, there remains increased demand for in-home connected audio as a result of smart speakers. Voice control is the primary motivator for consumers buying smart speakers but the top use case is music listening*. This has led to a paradox where consumers opt for speakers boasting superior voice abilities but use them primarily for audio playback.

The non-smart wireless speaker market had a less dynamic year, growing 1%. This market is saturated in developed countries with new sales largely restricted to replacing old/broken speakers. This has caused consolidation with the top four brands—JBL, Sony, Bose, and Ultimate Ears—accounting for 58% of demand outside China. Prices are coming under pressure, falling 5% to $107, with price the main area of competition and volume growth occurring in less developed markets where cheaper models are popular. There are bright spots, notably the rise of wireless party speakers. Such devices, with power output over 100 W and features such as crossfaders, DJ mixers, and party lighting, grew 147% on 2018 with audio brands pushing these devices as they offer clear points of differentiation from speakers from the tech giants.

Soundbars saw similar divergence in 2019. Sales of models costing less than $200 grew 10% while $300+ increased 12%, thus squeezing the $200 to $299 category into double-digit decline. The lower end still serves demand for basic soundbars as TV accessories; even a less-than-$100 model offers a significant upgrade on built-in TV speakers. However, recent years have seen soundbars evolve to become fully fledged audio devices. The growing $300+ segment emphasizes audio quality with features such as Wi-Fi, multi-room, and immersive audio becoming increasingly common. With 66% of consumers listening to audio-only content through soundbars*, this trend will become increasingly relevant moving forward.

At the intersection between professional and consumer audio, architectural speakers remain a strong market segment, growing 7%. Targeting the connected home and the custom residential integration channel, the Sonos Architectural by Sonance range of products are architectural speakers designed for the Sonos Amp.

Meanwhile, consumer loudspeakers (architectural, home theater, bookshelf, and floorstanding speakers) clocked up $2.3 billion in trade value in 2019. The market has been declining for some years now as music listening habits change and streaming becomes increasingly important at the expense of physical media, and 2019 followed the patterns of 2018.

Unit sales of home theater and bookshelf speakers fell at 9% and 8%, respectively, although demand for floorstanding speakers was down just 3%. Floorstander sales are less vulnerable to being cannibalized by wireless speakers and do not suffer to the same extent. Architectural speakers remain the bright spot, growing 7%, while active wireless loudspeakers performed well. KEF's LS50X had a strong 2019 while loudspeaker stalwart Bowers & Wilkins released its first active loudspeakers. Just under 5% of bookshelf and floorstanding sales were active last year and this number will grow steadily despite the overall market shrinking.

True Wireless Helps the Headphone Market

Aftermarket headphones have been a wildly successfully story over the past decade, but even with this context, 2019 was a standout year. True wireless (TWS) headphones are a phenomenon, pushing total shipments up 17% while value grew 54% on 2018. This form factor has captured consumers' minds with TWS well up in volume (283%) and value (328% growth) and much of this growth incremental. 26% of headphones sold last year were TWS, which translates into an incredible

The true wireless stereo category is seeing a broad range of price points with models like these JLab GO Air selling for just $29.99 (MSRP price), while offering comparable features and specifications of premium models less than a year ago.

48% of aftermarket headphone expenditure. Apple has historically been very dominant, and retains market leadership with 54% of 2019 sales, but last year saw strong growth for other brands driven in part by rocketing sales in China, which increased its share from 3% of TWS demand in 2018 to 17% in 2019. Brands like JBL, up over 900%, Xiaomi, Samsung, and Huawei are leading the charge.

While the TWS story is incredibly positive, it's worth noting that the leading four brands are CE (rather than audio) specialists and have strong stakes in the smartphone market. As with the explosion of smart speakers, the brands traditionally strong in headphones are, on the whole, not the main beneficiaries of this growth. The other notable TWS trend was the broad range of price points with sales of models costing less than $100 growing at 3,280%. At the same time premium models, over $200, grew 985% boasting higher audio quality and features such as noise cancelling.

Excluding TWS, volumes declined in 2019 by 6% versus 4% value growth reflecting that TWS success is primarily cannibalizing in-ear headphones which are generally cheaper than on/over-ear. Noise cancelling is the primary driver of on/over-ear, although this feature is making its way into TWS. Battery-life concerns mean that on/over-ear models still accounted for 66% of noise cancelling volumes in 2019. This will change moving forward as TWS becomes more advanced, and in the longer term TWS is expected to continue increasing its share of headphone sales dramatically. As these devices become increasingly feature-rich offering technologies such as biometric sensors, advanced hearing capabilities, translation and audio augmented reality, the breadth of consumers interested in purchasing headphones will expand significantly. As smart speakers led to consumers with little interest in audio playback buying wireless speakers, advanced features in TWS will have a similar and possibly greater incremental impact on headphone growth.

Rise in Streaming Underpins Consumer Audio Growth

Streaming subscriptions continue to drive growth in the global music market, accounting for more than 70% of consumer spending on music content, (equivalent to $18 billion), with subscriber growth of 28% last year to reach 305 million. Markets where physical media remained strong, such as Germany, Japan, and France, are seeing accelerating adoption while the mature nature of North America and Europe is forcing services to focus on value-added features to differentiate. The rise of immersive audio (e.g., Dolby Atmos Music and Sony 360) is notable as is growth in non-music content such as podcasts.

Spotify and Apple account for a combined 64% of subscriptions, Spotify remains the market leader despite Apple gaining top spot in the US. Amazon Music saw strong growth with multiple streaming plans catering to a wide audience, although subscriptions are closely linked to Echo smart speaker footprint which skews toward the US and UK. Smaller services are struggling in this increasingly saturated market with many pivoting toward specific strategies such as localized services and targeting niche audiences or B2B operations.

A Bright Future for Audio

Despite the coronavirus pandemic, the long-term outlook for both professional and consumer audio remains exceedingly positive. Technological advances will drive sales in the professional space, smart speakers are making great headway in markets where audio spend is not traditionally high and TWS improvements are set to make headphones a must-have accessory for far more than just music listening. As always, there will be winners and losers as markets evolve, but a rising audio tide will lift most industry companies. ***LIS***

**Futuresource's "Audio Tech Lifestyles Consumer Survey," June 2019 (update due June 2020).*

About the Authors

Guy Hammett is a Market Analyst in the Consumer Electronics team at Futuresource Consulting. Hammett joined Futuresource in 2016 and has worked in a variety of different Consumer Electronics areas, both continuous tracking services and one-off custom projects, and has specialised in audio research for the last three years. He currently heads up Futuresource Consulting's quarterly Home Audio tracking reports and twice yearly market reports forecasting out to 2024, in addition to an annual Loudspeaker market report, and regularly represents Futuresource at trade conferences across the globe.

James Kirby originally developed a strong understanding of AV market dynamics through his work in Futuresource's pro displays team. Now the lead analyst of pro audio technologies, Kirby is applying his first-hand knowledge and passion for the industry to develop detailed insights for the live, studio, installation and collaboration components of the professional audio markets.

Connectivity, Streaming, and Other Technologies

Why Portable Speakers Won't Miss a Beat in 2020

By **Kian Rayment**
(SAR Insight & Consulting)

Ultimate Ears portable speakers

Our expert from SAR Insight & Consulting discusses the growing popularity of portable speakers and poses the question of whether 2021 will finally be the year of object-based audio for high-quality streaming.

With a show as large as CES, you are faced with real information overload, especially if you are in attendance for the entirety of the event. While I was in the research stages of a report on portable speakers, one very significant take away was the announcement of the new Bluetooth Low-Energy (BLE) audio codec, LC3.

Fundamentally, unlike other compressed codecs, LC3 is optimized to achieve very high quality at low bitrates, the result of which is a low power codec. After its deployment into sink devices toward the end of this year and source devices soon thereafter, LC3 will subsequently have a noticeable impact on the battery lives of devices.

My colleagues and I have had deep discussions about just how much of an impact the new Bluetooth codec will have on both sink and source devices. The overarching consensus that it is very much dependent on several factors and devices types. We concluded that although hearables should see significant gains, there will be moderate improvements to the battery lives of portable speaker devices. The gains are restricted in several ways, most notably by the fact that a considerable amount of power will be drawn to power speaker drivers.

Although the sink device is receiving a low bitrate signal, ultimately accounting for extra runtime, further gains are contributed thanks to the LC3 broadcasting feature. In theory, a source device could broadcast to multiple sink devices (sink devices being LC3 compatible portable speaker devices). Therefore, if the user is intending to pair devices, power will no longer be used by the master source speaker to share with slave devices (see **Figure 1**).

Water Ingress and Sound Output

Principally, all portable speaker form factors we cover at SAR Insight & Consulting should have generous battery lives, now more so than ever as we are seeing an increase in devices built with a

high ingress protection rating. This is a figure we envisage as being in excess of 50 million sold with protection against liquid and dust (see **Figure 2**). Therefore, more consumers will venture outdoors with their devices to enjoy hours of playback, facilitated greatly by the advent of LC3. On the other hand, with the extended battery life, manufacturers may choose to instead integrate smaller batteries. This could either decrease the overall weight of the device or substitute the additional space with extra technology.

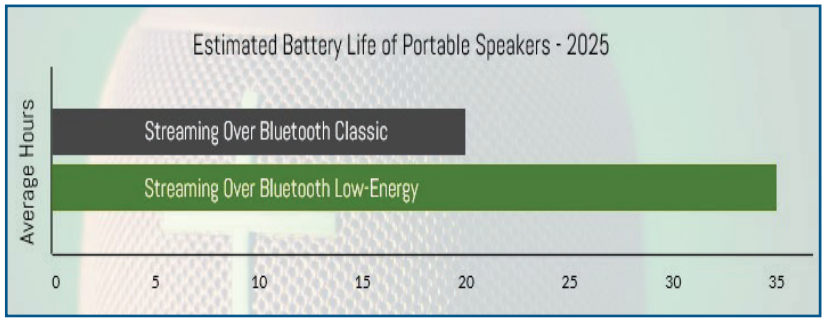


Figure 1: We should see an increase in battery life with devices using LC3. (Source: SAR Insight & Consulting – Portable Speakers)

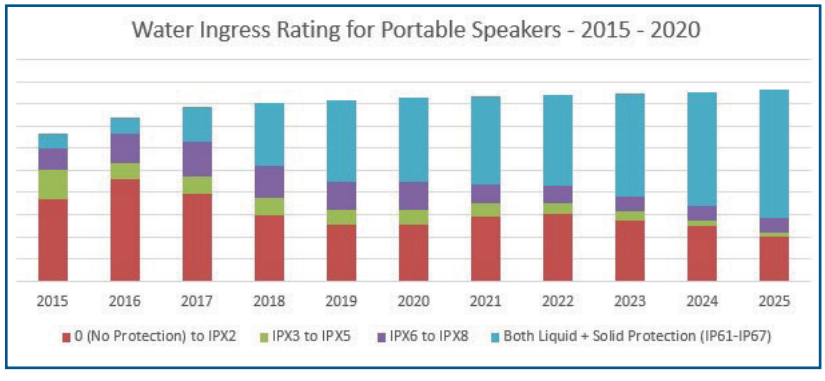


Figure 2: This chart shows SAR's prediction for device water ingress ratings. (Source: SAR Insight & Consulting – Portable Speakers)

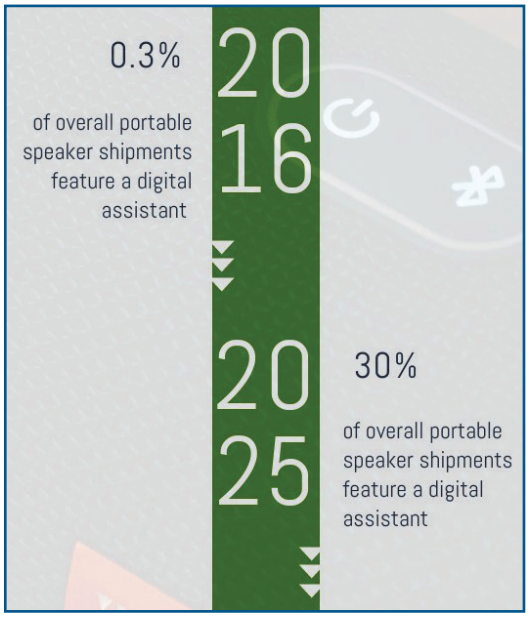


Figure 3: Voice-controlled portable speakers are still in their infancy, however, they are becoming increasingly popular. (Source: SAR Insight & Consulting – Portable Speakers)

Following extensive analysis, one theory emerged that the extra space could be filled with a solution to enhance the speaker's sound output. This is especially important when a device is used in an outdoor environment.

Unlike a closed indoor room, sound waves cannot reflect off surfaces, thus dissipating frequencies very quickly. One way to combat this is to consider the addition of a bass reflex port or passive radiator. The latter is a very efficient way of enhancing the bass frequencies as the entirety of vibrations produced will be converted to sound, with little to no wastage (further contributing to healthier battery efficiency).

For example, at the device market level, brands such as Sonos released its first portable (water-resistant) speaker in 2019. If we break down the construction of the Sonos "Move," we realize the device has undergone extensive development to ensure it disperses sound more omnidirectionally, with help from a downward-facing tweeter. Around the same time, Bose released its portable smart speaker, the "Portable Home Speaker," packed with a plethora of passive radiators to add heavy prominence to sound quality, especially in outdoor environments. Taking these into consideration, there is evidence to suggest that we will see more sophisticated speaker designs, particularly for portable speakers intended for use outdoors.

Digital Voice Assistants

Still in its infancy, the portable speaker market with digital voice assistants built-in will cause downward pressure on devices without voice control capabilities as consumers will enjoy convenience and functionalities—especially when used in conjunction with other smart products. Despite this, there will still be demand for non-voice control devices due to availability and affordability. The digital voice assistant attach rate will be somewhere in the region of 30% in relation to both embedded, enabled, and overall shipments by the end of 2025 (see **Figure 3**).

At the consumer level, the Average Selling Price (ASP) for portable speakers with a built-in voice assistant—a practical purchase only for those who can afford it—currently sits on the expensive side at $279 US. On the plus side, ASP is expected to fall by up to $100 US by the

end of 2025. Even though this is a significant reduction, it pales in comparison to the cost of other smart speakers on the market such as the Amazon Echo Dot and Google Nest Mini retailing for less than $50 US; admittedly not portable and battery-powered, however. The price point, combined with both Google and Amazon's current household penetration, gives credible reasons for us to not over forecast a device that shares very similar features.

While the prospect of a portable speaker with smart capabilities sounds appealing, there are factors that could be impeding growth in the segment. Namely, issues faced with operating in environments that may be hectic and noisy. Without a doubt, operating in rooms with less noise disturbance ultimately contributes to increased accuracy of voice assistants. Be that as it may, with more devices being capable of playback in outdoor environments, it is vital for the integration of more sophisticated voice DSP solutions combined with the addition of multiple microphones to constitute an effective array. This may inhibit the overall uptake due to the cost of more advanced components.

Sound Enhancement

Indisputably, voice assistants are becoming a large part of our lives, both in the home and on the go. At the same time, even in the presence of downward pressure from the voice market, the non-voice-controlled segment of portable speaker devices is to maintain some momentum without completely dissolving. We expect a shortfall of 25% in global revenues by 2025—a seemingly heavy reduction. Nevertheless, total revenue predictions will be in the region of $3 billion US. An essential factor keeping totals afloat is affordability (with the ASP of non-voice-controlled currently resting at $70.60 US) yet there are several other contributing factors having an impact (see **Figure 4**).

First, form-factor becomes a big influencer when there is an oversaturation of cheap portable speakers available on the market. Although an abundance of devices is available, the importance of standing out becomes paramount (see **Photo 1**). This does not require the addition of lasers and eccentric colors: If a design can also enhance the sound and overall functionality of the devices at the consumer level, it adds enticement to the purchasing process. Brands such as POW Audio achieve this with a collapsible/expandable chamber that allows for a heavily increased bass presence. Not only does the device (Una) enhance

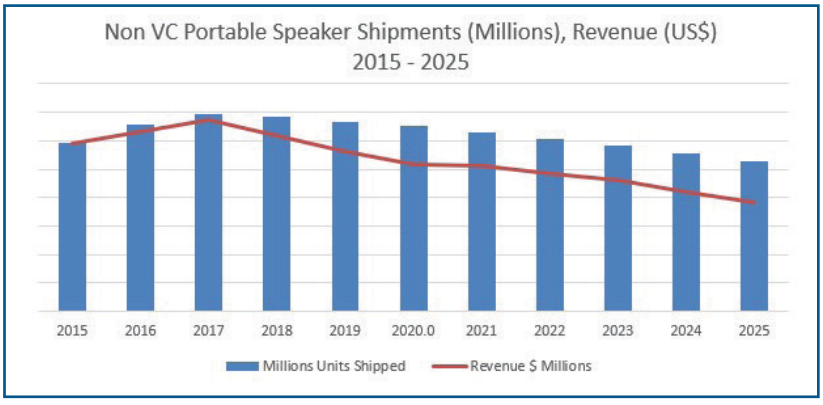


Figure 4: Non-voice-controlled speaker shipments will not dissolve completely. (Source: SAR Insight & Consulting – Portable Speakers)

Photo 1: Portable speakers are becoming widely manufactured with high ingress protection ratings.

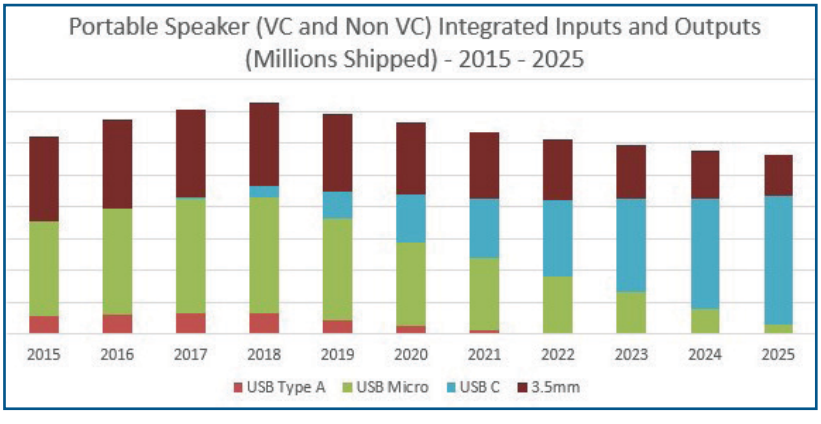


Figure 5: USB-C will be widely integrated in devices succeeding 2025. (Source: SAR Insight & Consulting – Portable Speakers)

the sound, the fact you can shrink the device offers convenience for the consumer.

Technically speaking, there will also be battery life gains as the design acts as a passive radiator. Sony has used a similar principle for its Glass Sound range. They incorporate a passive radiator in the form of a glass cylindrical tube—the resulting sound dispersion is omnidirectional.

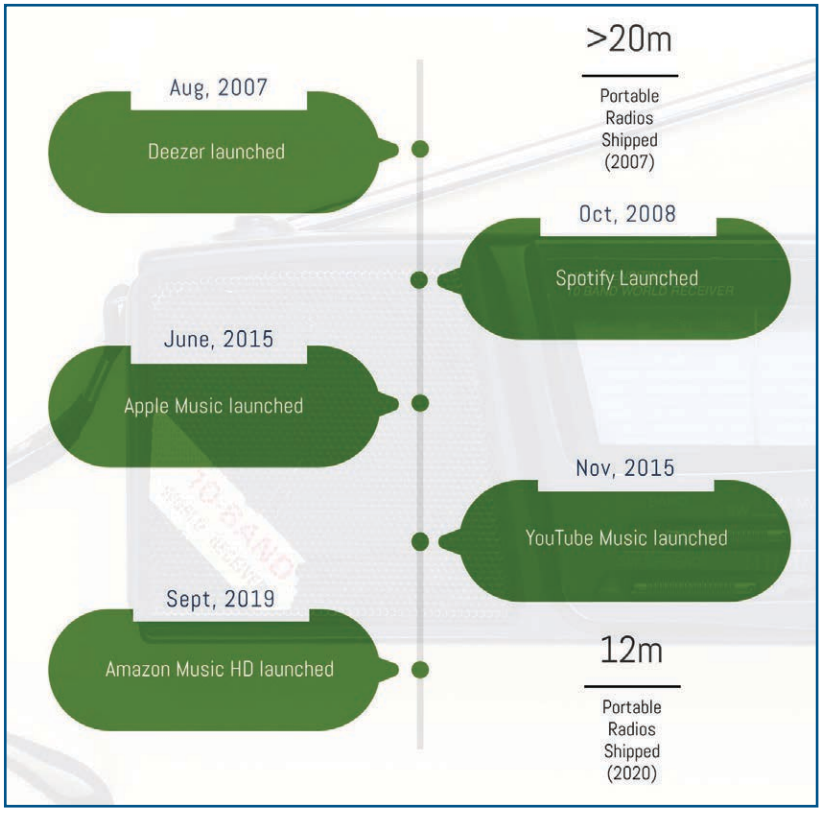


Figure 6: Streaming services have had a detrimental effect on portable radio sales. (Source: SAR Insight & Consulting – Portable Speakers)

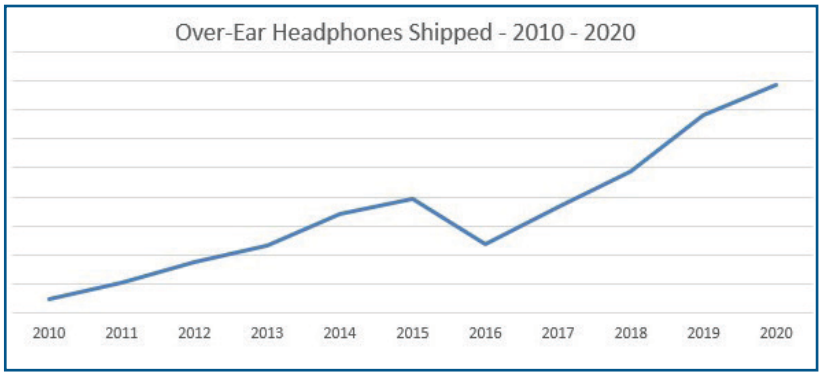


Figure 7: Over-ear headphone shipments globally are less than subscriber numbers of 360 Reality Audio compatible streaming services. 360 Reality Audio will work with other headphones/earphones, however, consumer experience may vary. The format will work with compatible sink devices, such as the Amazon Echo Studio. (Source: SAR Insight & Consulting – Portable Speakers)

Second, after the analysis of varying use-case scenarios, it appears the demand for non-voice-controlled portable speakers is still—and could be for plenty of years to come—very much present. Elaborating on this, if we take into consideration pre-smart televisions (earlier than 2008) and older radios—one could argue, plausibly enough, that there are still such devices in people's homes. The issue highlighted here is people may require better sound from outdated systems, which is where portable speakers become relevant. Similarly, this may also apply to desktop/laptop computer users where external speakers are required.

Thought processes such as these are the driving forces behind our forecasted predictions for integrated device inputs and outputs. For instance, in relation to external speakers for televisions and radios, the likelihood of continuing to include the auxiliary input is moderate to high. Focusing on the chart shown in **Figure 5**, there is a clear uptake of USB-C over the next five years. Of course, when considered with our computer/laptop use-case as previously described, we can appreciate the viability of such predictions due to the convenience and practicality of charging devices from compatible ports.

Streaming and Object-Based Audio

Having so hastily glossed over a small number of factors for the purpose of this article, in a recent SAR Insight & Consulting portable speaker report, I delved into a much deeper analysis of portable speakers by breaking the market down into key segments. These include portable voice-controlled speakers, portable non-voice-controlled speakers, portable PA systems and portable radios. My methodological approach provides easily comparable market data on all segments, with emphasis on why brands choose to integrate certain technology into their products.

The choice to focus on several segments as opposed to a singular analysis is an effort to highlight the impact each market segment has on the other. For instance, how the integration of a voice assistant in portable speakers—enabling fast access to hundreds of radio stations—has had an adverse effect on the portable radio segment. Credit is also due to streaming services—the inevitability of such platforms is a progressing deterrent for purchasing portable radios altogether (see **Figure 6**).

Perhaps further adding to the strain on ageing market segments, streaming services (e.g., Deezer and Amazon Music HD) now offer song playlists encoded using Sony's 360 Reality Audio, which

is based on Fraunhofer's MPEG-H open-source format. Although there is the sense the immersive format has lost its momentum since the announcement last year of the partnership with NXP, Mediatek, and Qualcomm—combined with the release of 360 Reality Audio compatible devices such as the Sony Xperia II—fuels the notion that 360 Reality Audio technology is about to materialize in a multitude of source and sink devices.

Sony succeeded in the procurement of several hit artists for a video to assist in the promotion of the format that conceptually works. However, attempting to advocate an audio format on a purely descriptive basis, with precedent that the target market does not yet own compatible devices, is challenging to say the least.

The combination of paid and free users of 360 Reality Audio compatible streaming services, is around 50 million. Currently, the number of over the ear headphones shipped since 2010 is 38.5 million (see **Figure 7**). Based on this data and Sony's marketing campaign, this gives us the sense that the technology has been contrived to sell more Sony headphones which, I am aware, is slightly obvious. Be that as it may, at a consumer level there is a lack of awareness that one must use compatible sink and source devices in order to benefit from the technology. This can be likened to streaming audio with aptX: It will only work when both devices support the format. A great deal of the time this may not be realized by the end-user.

As well as skepticism concerning the popularity of this technology, there are doubts about the rate of uptake—at least with no real flourish until the end of year Q4, or Q1 of 2021, even with the inevitability of supporting chipsets. Will 2021 be the year of object-based audio for high-quality streaming?

An in-depth analysis of portable speakers and object-based audio will be available from SAR Insight & Consulting. ***LIS***

About the Author

Kian Rayment is a Market Analyst for SAR Insight & Consulting's Home Audio/Visual Equipment & Technologies. Rayment covers the markets for speakers, TVs, and other equipment with a focus on enabling technologies and components. He has a history of working within the music industry in sales and marketing, audio engineering, events management and artist liaison. Having moved to the company from Focusrite Audio Engineering, he has a valuable knowledge of the global product landscape, achieved by working for the company in a sales and marketing capacity. Rayment has a Bachelor of Arts with Honors Degree in Music Business from the University of Westminster. He also holds an Extended Diploma in Music Technology from Exeter College.

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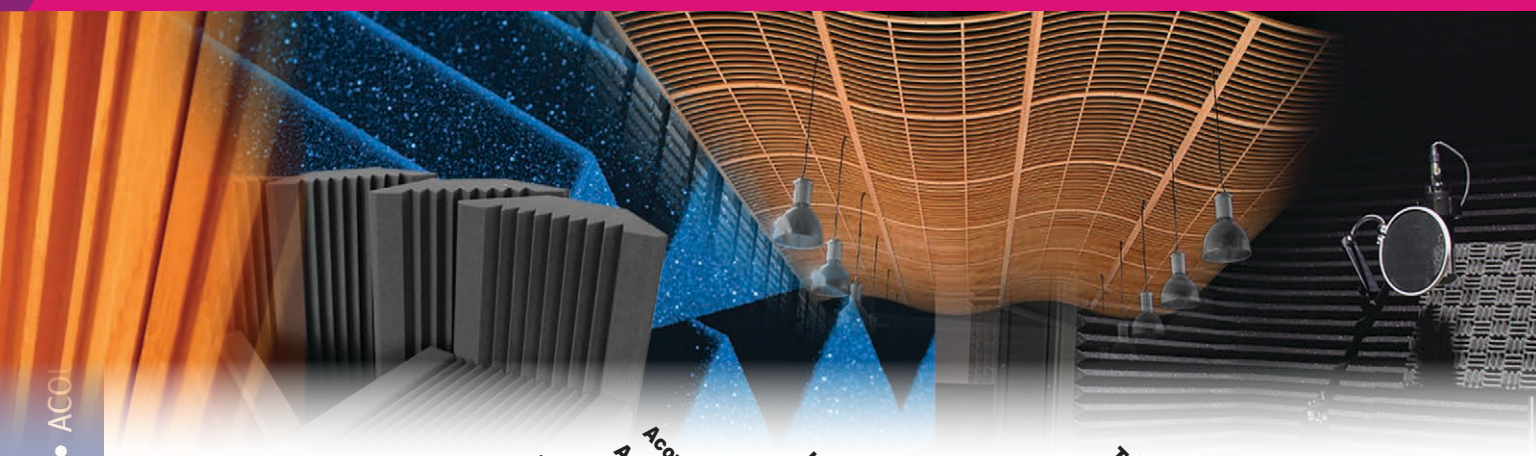

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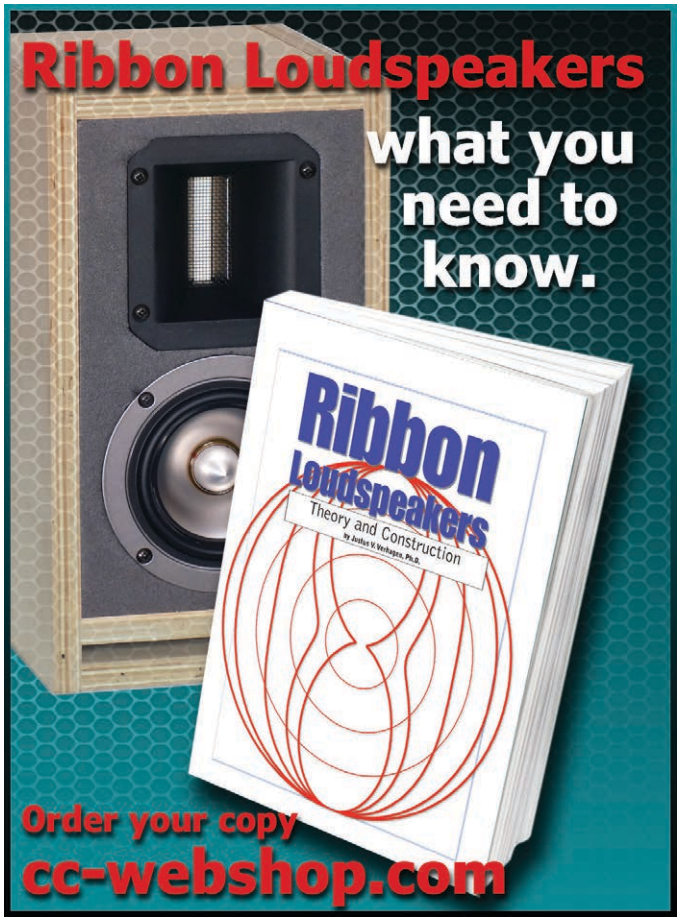
Solen Electronique, Inc.			•								•	
Sziara Sound			•				•					
CHINA												
Junhao Wood Cabinet Factory						•	•	•				
Lumi Audio	•		•				•					
Shenzhen Malata Mobile Communications, Co., Ltd.						•						
Trueanalog Strictly OEM			•			•	•				•	
Xiamen Great Sound Technology						•	•	•				
DENMARK												
Danesian Audio ApS	•		•									
K & K Development			•									
Lyd by Dissing	•					•	•					
PointSource Acoustics	•		•			•						
FRANCE												
Kartesian						•						
KYU Systems	•											
Seltech	•		•			•	•	•	•			
SIEA	•		•			•						
Supravox						•						
GERMANY												
Goya Acoustics	•		•									
Jobst-Audio	•		•			•						
Klippel GmbH			•			•						
Lautsprecher-Produktions-Gesellschaft (LPG)			•									
Mvoid Technologies GmbH	•		•			•			•			
Physical-Lab	•		•			•						

	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	
Soundsgood Pro Audio Solutions	•			•									
Voice Point	•		•	•	•	•	•	•	•	•	•	•	
HONG KONG													
Deep Blue Design	•				•								
Eastern Asia Technology (HK), Ltd.					•								
miniDSP, Ltd.				•	•								
INDIA													
Decibels Audio Private, Ltd.	•				•	•	•					•	
GM Audio Technics, Ltd.	•			•	•								
Power Electronics & Technologies	•					•						•	
TurboSonic Pro Speakers					•								
IRELAND													
Crossover Filter App				•									
ITALY													
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	•												
NEW ZEALAND													
Asona	•		•		•		•	•	•			•	
NORWAY													
SEAS Fabrikker AS				•									
PORTUGAL													
Jocavi Acoustic Panels					•							•	
Vicoustic	•		•	•	•	•	•	•	•	•	•	•	
ROMANIA													
Poweraudio Romania	•			•		•				•			
SPAIN													
Brusi Acoustics	•			•									
Sottovoce Audio	•				•								
SWITZERLAND													
Acustronics Sound-Light-Systems				•									
TAIWAN													
AV Leader Corp.				•		•	•						
Kingstate Electronics Corp.	•			•									
Vansonic Enterprise Co., Ltd.						•	•	•					
Yung International, Inc.							•	•					
THAILAND													
Clarasonic (Thailand) Co., Ltd.												•	

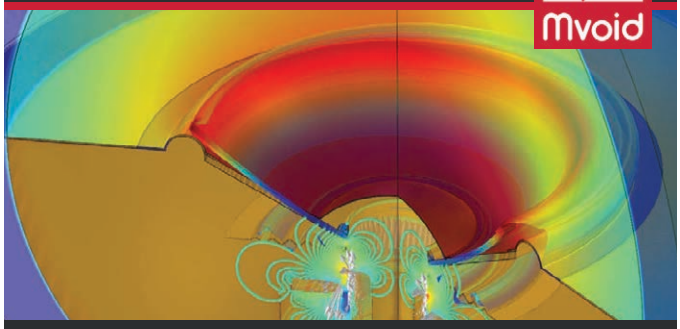
	Acoustic Consultancy Services & Design	Acoustic Doors	Acoustic Measurement	Acoustic Treatment Panels	Electroacoustical System Design	Home Theater Design	TV System Design	Multimedia and	Noise Control	Sound Booths	Sound Isolation	Theater and Concert Hall Design
UKRAINE												
Mag Audio	•		•									
UNITED KINGDOM												
Audiolux	•	•			•	•	•		•	•		•
CE Electro-Acoustics	•											
EuroTec International, PLC			•		•					•		
Interfacio, Ltd.					•							•
Node Audio Research, Ltd.					•	•						•
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	•	•	•	•					•	•	•	
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	•					•						
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.				•	•							
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				•								
Scantek, 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
SensaSound USA						•	•					•
SoundKinetics	•									•		
Soundoctor				•								
Sounds Unique						•						
Speaker Clinic	•			•								
Spectrum Audio					•					•		•
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.							•		•			



Acoustical Virtual Product Development

Mvoid



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- ✓ Minimize risks by enabling safe decisions in the early concept phase
- ✓ Maximize efficient use of resources
- ✓ Ensure competitiveness in all facets of cost, performance and packaging

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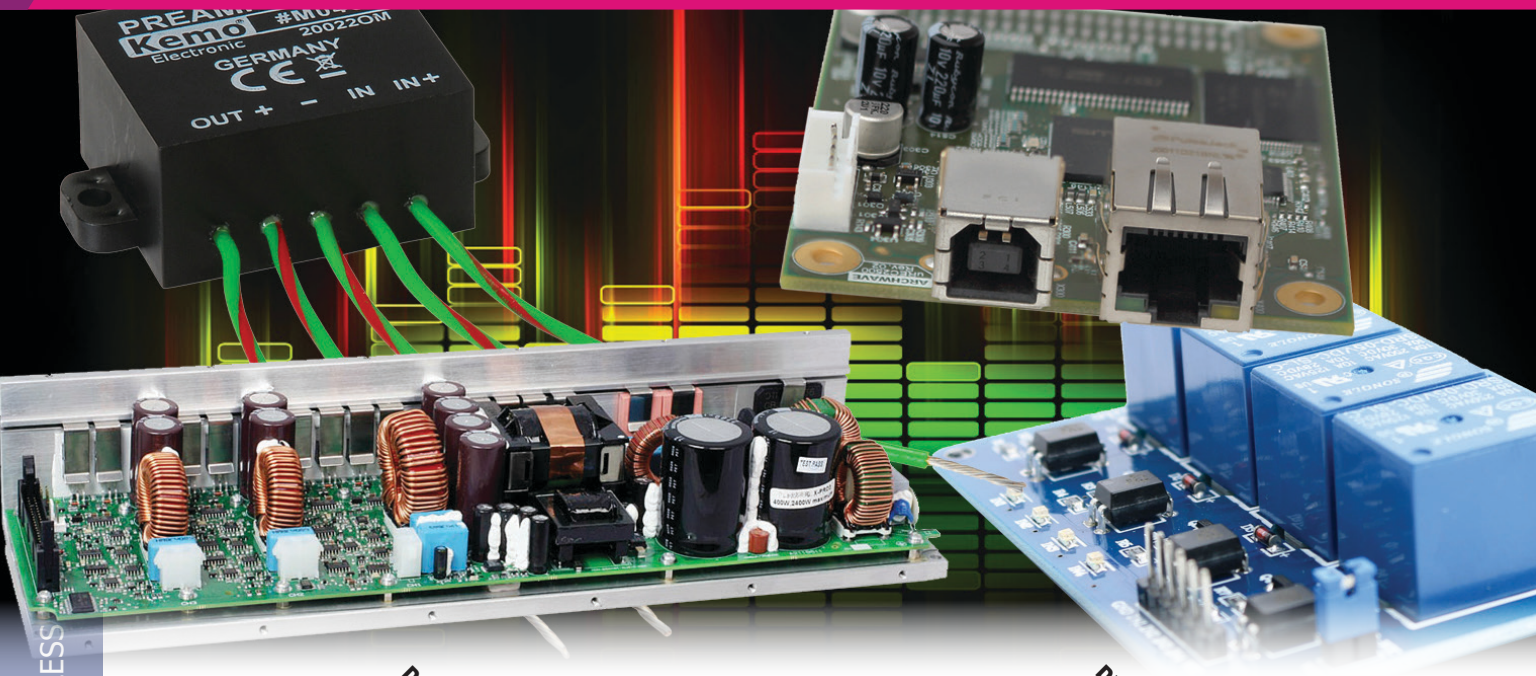
AMP, DSP, NETWORK, AND WIRELESS MODULES



	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
AUSTRALIA				
DEQX, Pty., Ltd.	•	•	•	•
Eclipse Audio		•		
Soundlabs Group, Pty., Ltd.	•			
BELGIUM				
The Innovators Lab Belgium (iLaB)		•		
BRAZIL				
Advanced Audio Technologies (AAT)	•			
AMCP Eletrônica	•			
Attack do Brasil	•	•		
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	•	•	•	•

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
DENMARK				
ICEpower a/s	•			
Pascal a/s	•			
Purifi Audio	•			
FRANCE				
Amplitude Audio	•	•	•	•
IDEA	•			
SIEA	•	•	•	•
GERMANY				
Ascendo Immersive Audio		•	•	
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.		•		•
ITALY				
Axiomedia, SRL	•	•		•
Powersoft, SpA	•	•	•	

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
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			•	
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	•	•		
AtlasIED		•	•	
Audio Advisor, Inc.	•			
Axiim	•	•	•	•
Benchmark Media Systems	•	•		
CE Distribution	•	•		

AMP, DSP, NETWORK, AND WIRELESS MODULES

	Amplification Modules	Digital Signal Processing	Network Connectivity	Wireless Connectivity
Danville Signal Processing, Inc.	•	•	•	•
Digmoda	•	•		
Dragonfire Acoustics	•	•	•	•
DSP Concepts		•		
Eagle Acoustics	•	•	•	•
Emerald Physics	•	•		
Etal Group, AB/Anaview	•			
Fortemedia		•		
Full Compass Systems, Ltd.	•	•		
Globe Audio Design, Inc.	•	•	•	
JL Audio, Inc.	•	•		
Kramer Electronics	•	•	•	•
Lectrosonics			•	•
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	•	•	•	
Sonion		•		•
SpeakerPower	•	•	•	•
US Enclosure Co.	•	•	•	•
Vintage King Audio	•			
VTech	•	•	•	•
Weltronics Corp.	•	•	•	•
Wired 4 Sound, Inc.	•	•	•	•
VIETNAM				
Sound Corp.	•	•		•
Sun Acoustic Vina	•	•	•	•

Are you interested in learning how guitar amps work, as well as how to fix and service an amp?

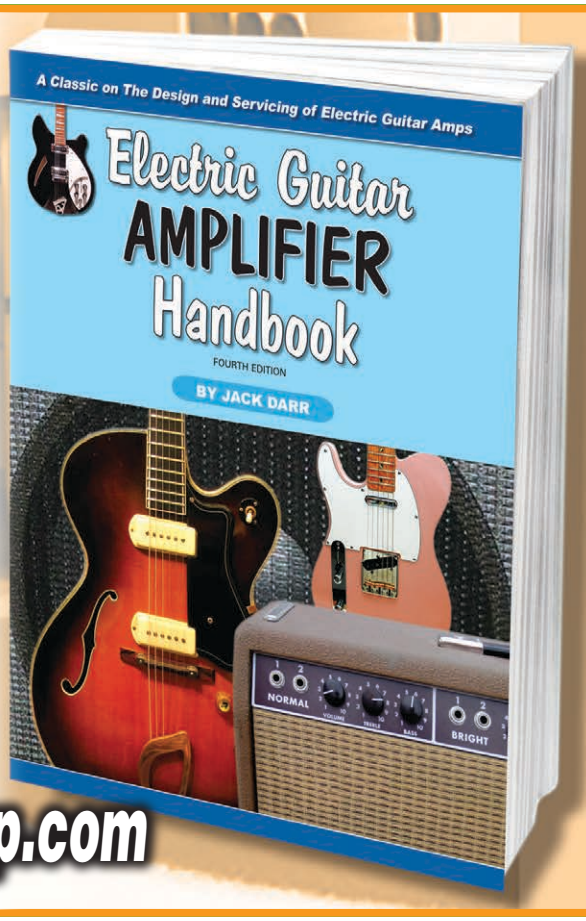
Then this book is for you.

Jack Darr's *Electric Guitar Amplifier Handbook* details the following:

- **How guitar amplifiers work**
- **How to properly and safely make amp repairs**
- **How to troubleshoot tube and transistor amps of all sizes**
- **Details on "typical" amp circuits**

And much more!

Whether you're an audio engineer or a musician with a thirst for knowledge, you'll find the explanations in this book easy to comprehend — all you need is a general interest in electronics and a passion for DIY.



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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.
Shenzhen Malata Mobile Communications, Co., 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
Kartesian
Seltech
SIEA

GERMANY
Fraunhofer Institute for Digital Media Technology
Goya Acoustics
HiFi-Tuning
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
the BEE

NEW ZEALAND
Asona

ROMANIA
Poweraudio Romania

SINGAPORE
Virtins Technology

SOUTH KOREA
Suntel Co., Ltd.

SPAIN
DAS Audio

SWITZERLAND
Acustronics Sound-Light-Systems
Lange Loudspeakers

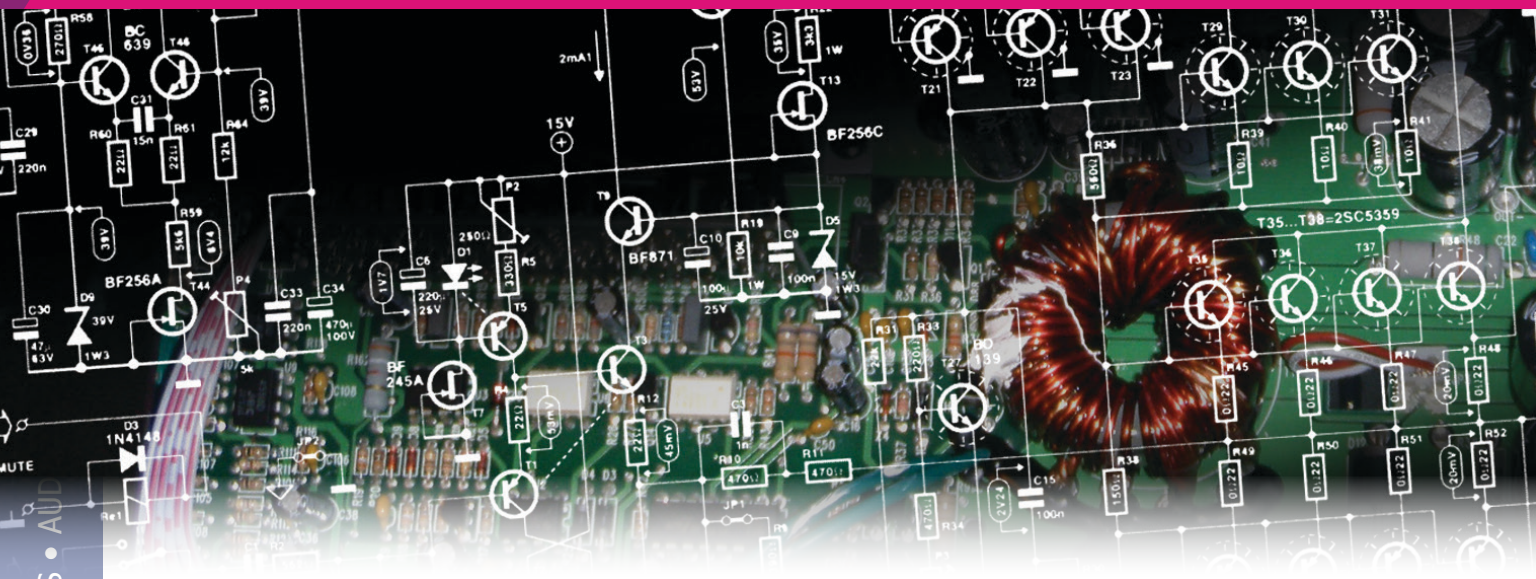
THAILAND
Sanit Audio Engineering Co.

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

UNITED STATES
American Music And Sound
Apollonio Consulting
Audio & Loudspeaker Technologies International (ALTI)
Audio Connection
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
HEAD acoustics, Inc.
HX Audio Lab
Integrated Audio Technologies, LLC
Lipinski Sound
Marchand Electronics, Inc.
Meliti Acoustics
North Reading Engineering
Pacific Audio Consulting
PCB Piezotronics, Inc.
PR Audio
Prism Sound
Pro Sound Testing, Inc.
Quest Engines, LLC
SoCal Sound Shop
SOUND Product Strategy
Soundoctor
Sounds Unique
SpeakerPower
Studio Electric, LLC
THX, Ltd.
TRS Inovations
True Technologies, Inc.
TSG Audio
Vance Dickason Consulting

VIETNAM
Sound Corp.

AUDIO EXPERTS



	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	•	•		
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.	•			
DENMARK				
Danesian Audio ApS	•	•		
Loudsoft, Ltd.	•	•		
Lyd by Dissing	•			
PointSource Acoustics	•	•		
FRANCE				
Amplitude Audio	•	•		
Kartesian	•	•		
KYU Systems	•	•		
Seltech	•	•		
SIEA	•	•		
GERMANY				
Audio Technology Engineering (ATE)	•	•		
Fraunhofer Institute for Digital Media Technology	•	•		
Goya Acoustics	•	•		
Jobst-Audio	•	•		
Klippel GmbH	•	•		
Mvoid Technologies GmbH	•	•		
Physical-Lab	•	•		
Scherer Audio	•	•		
HONG KONG				
BDNC (Holding), Ltd.		•		
Deep Blue Design	•	•		
Ocean Star Electronics (HK) Co., Ltd.	•	•		
Panson Audio	•	•		
WCE Acoustics	•	•		
HUNGARY				
Bayz Audio		•		
INDIA				
Decibels Audio Private, Ltd.	•	•		

	Consultants	Designers	Recruitment Agencies	
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	•	•		
Crystal Cable				
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				
EuroTec International, PLC	•	•		
Fane International, Ltd.	•	•		
Hill Acoustics	•	•		
Interfacio, Ltd.	•			
MJ Acoustics	•	•		
Node Audio Research, Ltd.	•	•		
Precision Devices, Ltd.	•	•		
Sine Audio Systems	•	•		
UNITED STATES				
Acoustic Fields	•	•		
Aempyrean	•	•		
American Bass USA	•	•		

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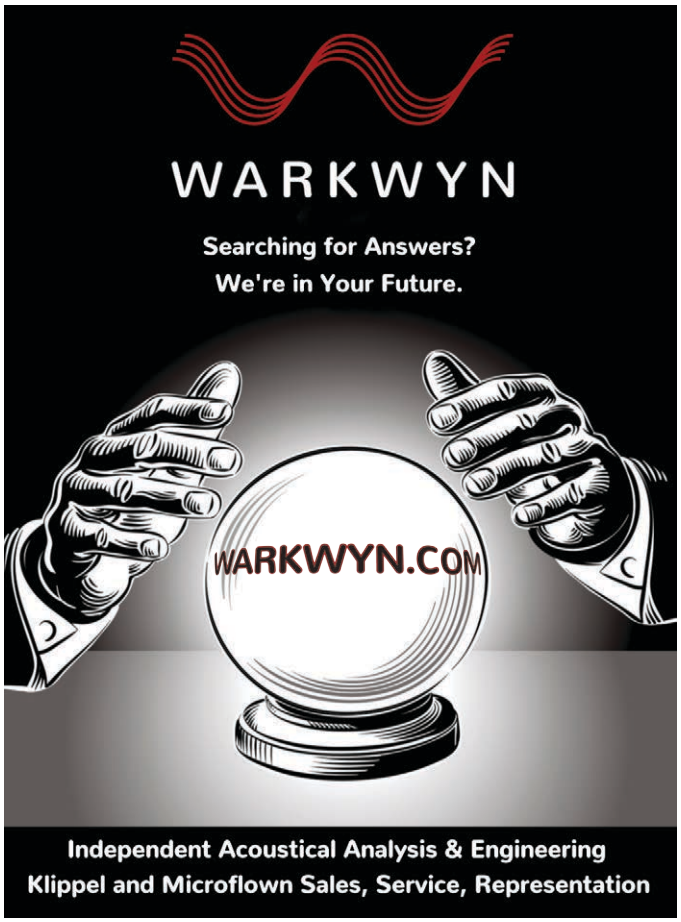
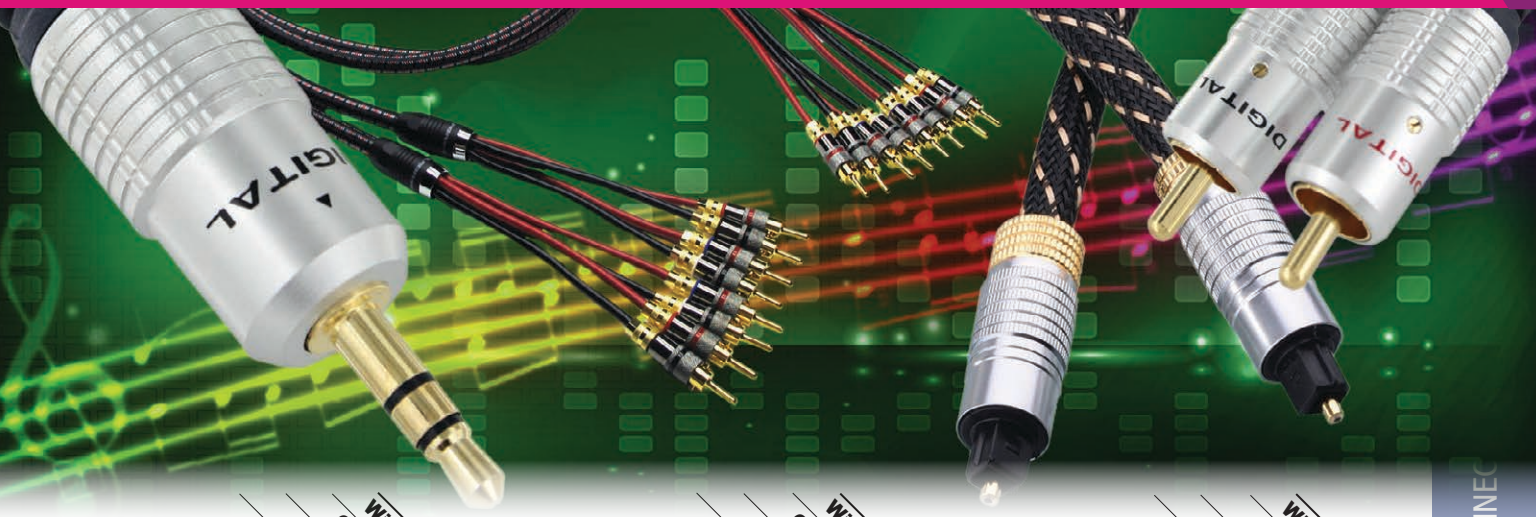


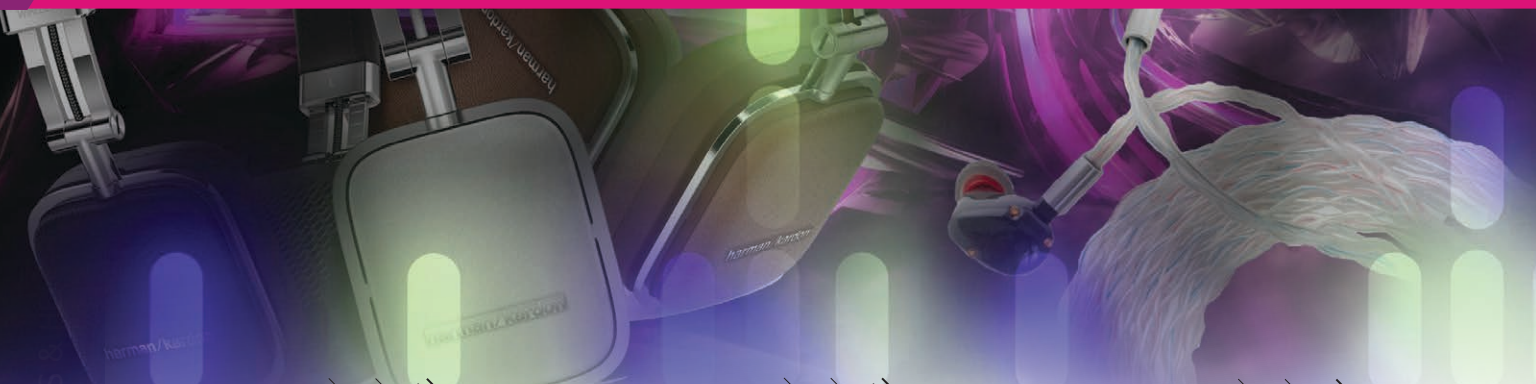
	Consultants	Designers	Recruitment Agencies	
Apollonio Consulting	•			
Audio & Loudspeaker Technologies International (ALTI)	•	•		•
Audio Connection	•	•		
Audio Houze	•	•		
Barefoot Sound, LLC	•	•		
BassBoss		•		
Beach Dynamics	•	•		
Benchmark Media Systems	•	•		
BeStar Technologies, Inc.	•	•		
Bruel & 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	•			

	Consultants	Designers	Recruitment Agencies	
Excelsior Audio Design & Services, LLC	•	•		
Fortemedia	•	•		
Fulcrum Acoustic, LLC		•		
Gauss Loudspeaker	•	•		
Geometric Designs, LLC & Geometric Consulting	•	•		
Globe Audio Design, Inc.	•	•		
GR Research	•	•		
HDSound	•	•		
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		•		
Schwarz Cabrera Holdings	•			
SensaSound USA	•	•		
SG Custom Sound	•	•		
SoCal Sound Shop	•	•		
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.	•	•		
Wired 4 Sound, Inc.	•	•		
Wisdom Audio		•		
VIETNAM				
Sound Corp.	•	•		



	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			
estron a/s	•	•	
Jantzen Audio Denmark	•		
GERMANY			
HiFi-Tuning	•	•	
Klippel GmbH	•		
Soundsgood Pro Audio Solutions	•	•	
Voice Point	•	•	•
HONG KONG			
WCE Acoustics	•	•	
HUNGARY			
Bayz Audio	•		
INDIA			
Power Electronics & Technologies	•	•	
IRELAND			
Crossover Filter App	•		
ITALY			
Axiomedia, 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		•	
SWEDEN			
Audio Pro, AB	•		
TAIWAN			
AV Leader Corp.	•	•	•
Bennic and Company	•		•
Huey Tung International Co., Ltd.	•	•	
Yung International, Inc.	•	•	•
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	•	•	
AMS Audio Enterprises	•	•	
Audio Advisor, Inc.	•	•	
Audio Connection	•	•	•
B&H Foto & Electronics Corp.	•	•	
Blackmore Mobile	•	•	
Broad Bridge Audio, LLC	•		
Carvin Audio	•	•	
CE Distribution	•	•	•
Controlled Thermal Processing, LLC	•	•	•
DTV Installations	•	•	•
Earthquake Sound Corp.	•		
Elektrisola	•		•
Front End Audio, LLC	•	•	
Full Compass Systems, Ltd.	•	•	
GR Research	•	•	
GRAS Sound & Vibration	•	•	
HAVE, Inc.	•	•	•
Herman Pro, AV	•	•	
JL Audio, Inc.	•	•	
Kramer Electronics	•	•	
Lamart Corp.	•	•	•
Loudspeakers Plus		•	
Madisound Speaker Components, Inc.	•		
Mark Lierly	•		
Open Tip	•	•	
Parts Express	•	•	•
PowerPhysics, Inc.	•		
Pro Flix Sales	•	•	
PRV Audio Brazil	•		
Radio Design Labs (RDL)	•	•	•
Redco Audio	•	•	•
Revolution Power	•	•	
Schurter Electronic Components	•	•	
Sound Pure, LLC	•	•	
Soundoctor	•	•	
Stillwater Designs | KICKER	•		
Straight Wire, Inc.	•	•	•
SVS, Inc.	•	•	
Sweetwater Sound	•	•	
Tonian Laboratories	•		
TRS Inovations	•	•	
TSG Audio	•	•	
US Speaker, LLC	•	•	
Vidsonix Design Works	•	•	
Westlake Audio, Inc.	•	•	•
Wired 4 Sound, Inc.	•	•	•
Wireworld Cable Technology	•	•	
Yandas Music	•	•	
Zu Audio	•		
zZounds Music, LLC	•	•	
VIETNAM			
Sound Corp.	•	•	•

EARPHONES & HEADPHONES



	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.		•
Eastern Asia Technology (HK), Ltd.	•	•
Fujikon Industrial Holdings, Ltd.	•	•
INNacoustic	•	•
OCVACO Electronic, Ltd.	•	•
WCE Acoustics	•	•

	Earphones	Headphones
ISRAEL		
Alango Technologies, Ltd.	•	•
ITALY		
RCF, SpA		•
JAPAN		
Etani Electronics Co., Ltd.	•	
Furutech Co., Ltd.	•	•
S'NEXT Co., Ltd.	•	•
Zumi Systems	•	•
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		
Profusion, Ltd.		•

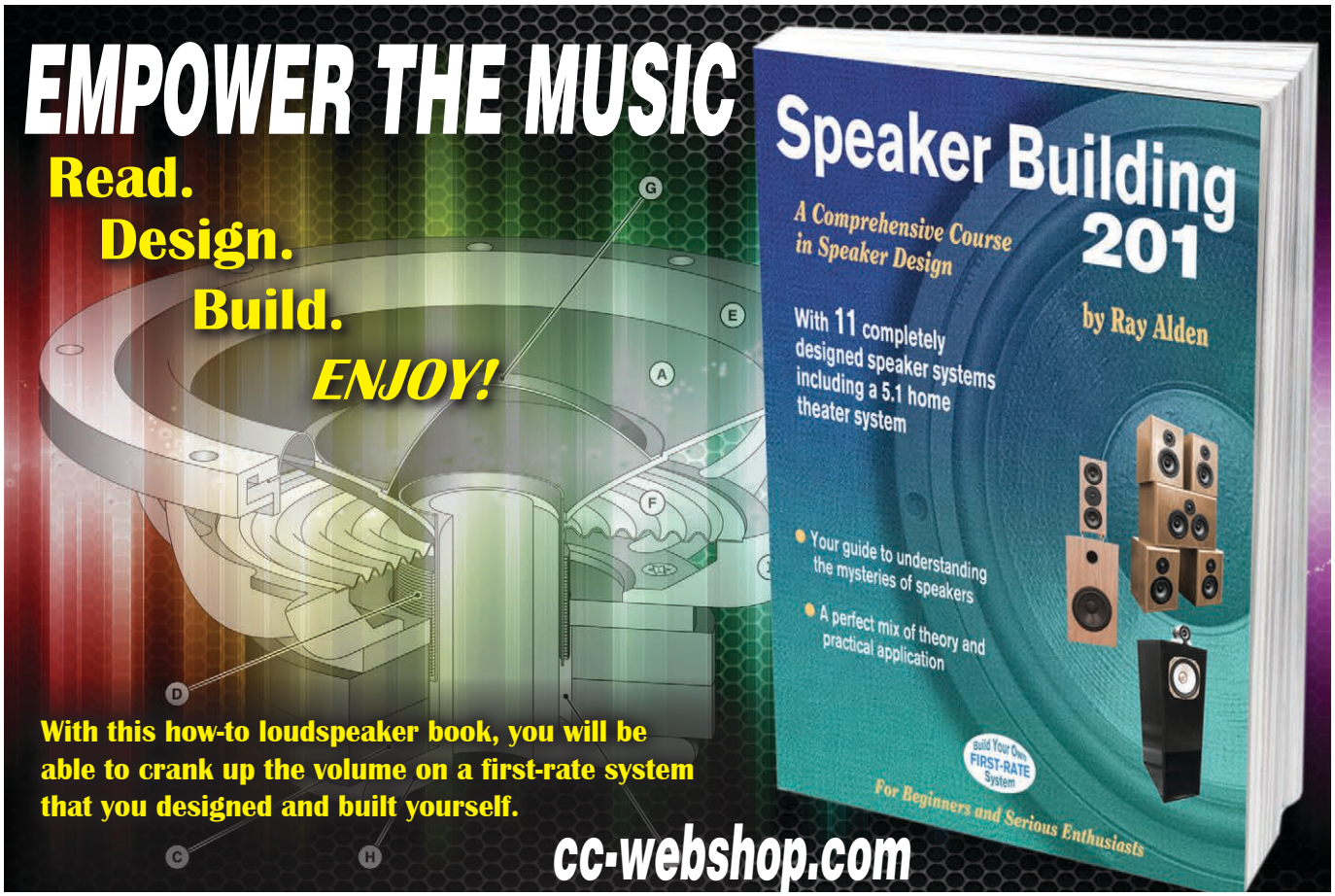
	Earphones	Headphones
UNITED STATES		
1MORE	•	•
American Bass USA	•	•
American Music And Sound	•	•
Audio Advisor, Inc.	•	•
Audio Connection	•	•
AValive		•
B&H Foto & Electronics Corp.		•
BeStar Technologies, Inc.	•	•
Blackmore Mobile		•
Broad Bridge Audio, LLC	•	•
Christensen Audio, LLC		•
Dekoni Audio	•	•
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		•
Open Tip	•	•
Pacific Audio Consulting	•	•
Parts Express	•	•
Peerless by Tymphany (HK), Ltd.		•
PreSonus Audio Electronics, Inc.		•
Pro Flix Sales		•
Puro Sound Labs		•
RBH Sound	•	•
Revolution Power	•	
SAATI	•	•
Shure, Inc.	•	•
Sonion	•	•
Sound Pure, LLC		•
Sound Sources Technology, Inc.	•	•
Stillwater Designs | KICKER	•	•
US Enclosure Co.	•	•
Vintage King Audio		•
VTech	•	•
W.L. Gore & Associates	•	•
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				•															
StudioLAB				•															
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																		•		
Shenzhen Tekzone Loudspeaker Co., Ltd.																		•	•	
Sound Technology Development, Ltd.																		•	•	
Star Audio	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•	•

	Baffles		Finished Cabinets			Sub-Assemblies								Materials			Panels		Rigging
	Ceiling Speaker Plates	In-Wall Plates	Box Arrays (PA)	Boxes	Stands	Bulk Molding Compound	Carpet	Hardwood	MDF (Fiberboard)	Other	Paper/Paper Pulp	Plastic	Plywood	Veneer	Wound Geometric Tubes				
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	•	•	•	•	•	•		•	•	•									
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
HONG KONG																			
Beautiful Enterprise Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fujikon Industrial Holdings, Ltd.																	•		
INNacoustic	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
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																			
Poweraudio Romania			•	•															
SOUTH AFRICA																			
Paks Acoustics				•	•			•	•					•	•		•		

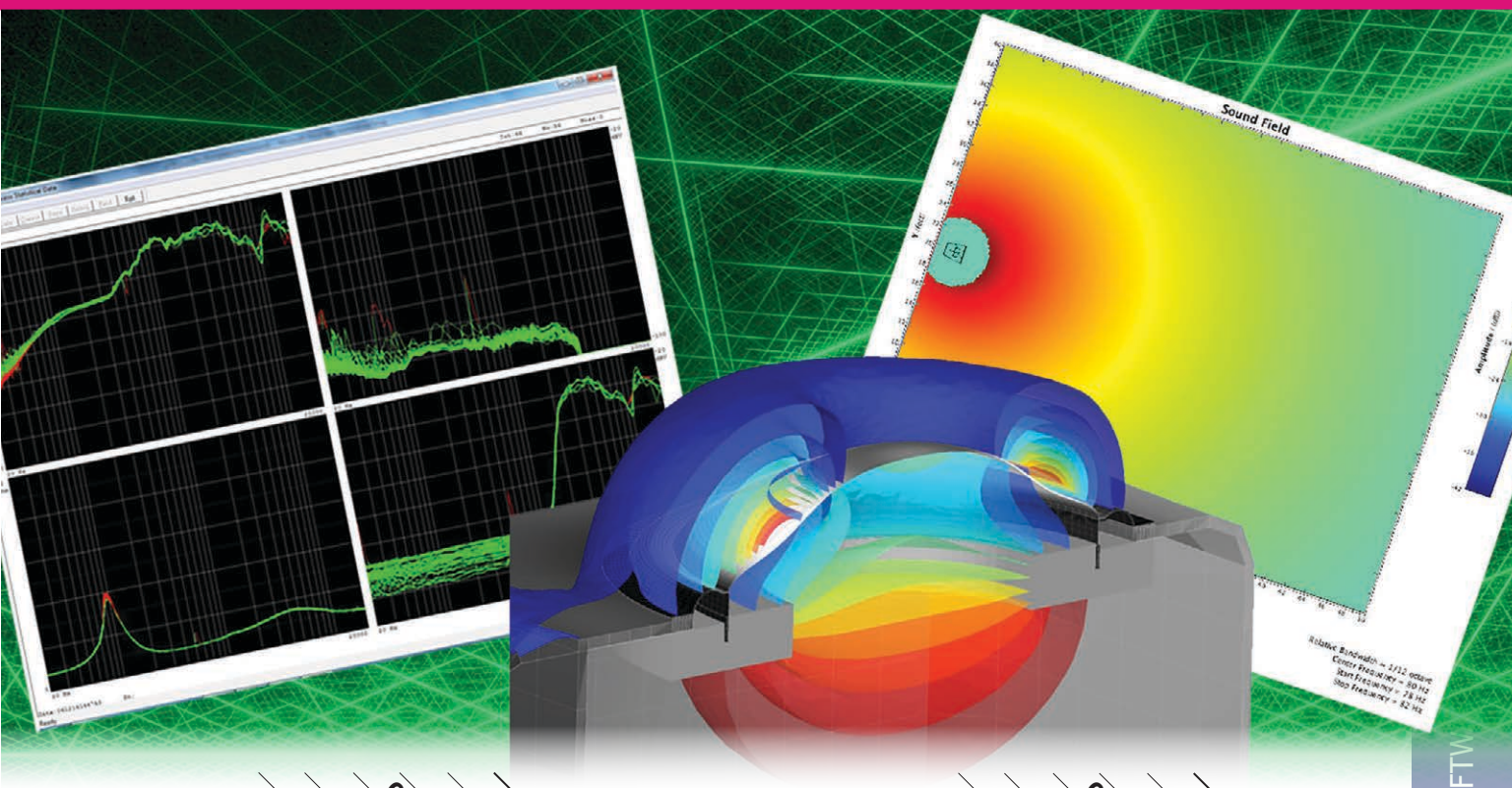
	Baffles: Ceiling Speaker Plates	Baffles: In-Wall Plates	Finished Cabinets: Box Arrays (PA)	Finished Cabinets: Boxes	Finished Cabinets: Bulk Molding Compound	Finished Cabinets: Stands	Sub-Assemblies: Carpet	Sub-Assemblies: Hardwood	Sub-Assemblies: MDF (Fiberboard)	Sub-Assemblies: Other	Sub-Assemblies: Paper/Paper Pulp	Sub-Assemblies: Plastic	Sub-Assemblies: Plywood	Sub-Assemblies: Veneer	Sub-Assemblies: Wound Geometric Tubes	Materials: Panels	Rigging
SPAIN																	
Sottovoce Audio				•	•												
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										•							
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	•	•	•	•	•												
AMS Audio Enterprises	•	•		•	•												
Area 52 R&D				•					•	•			•	•			
Audio Connection								•									
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.	•	•		•													
Mark Lierly			•											•			
Meliti Acoustics	•	•															
Midwest Audio Club				•	•			•	•					•	•		
OAP Audio			•	•										•			
Parts Express	•	•	•	•	•		•		•						•		
Ponderosa Sound Systems			•	•	•												
Portland Audio Lab	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

	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				
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.			•	•	•														
TRS Inovations	•	•	•	•		•	•	•	•	•	•	•	•	•	•			•	•
TSG Audio			•	•	•														
United Gasket Corp.	•	•					•					•						•	
US Enclosure Co.	•	•	•	•	•						•		•		•	•			•
US Speaker, LLC			•	•	•														
Vidsonix Design Works				•						•									
VTech	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•
Wired 4 Sound, Inc.																			•
Yandas Music				•	•														
VIETNAM																			
Sound Corp.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	



	Enclosure Grilles	Enclosure Stuffing				Grille Assemblies			Hardware			
	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									•	•	•	•
Shenzhen Tekzone Loudspeaker Co., Ltd.	•			•								
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	•	•	•	•	•	•	•	•	•	•	•	•
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												
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	•									•	•	•	•
AMS Audio Enterprises	•					•			•			
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.	•	•	•	•	
Shenzhen Tekzone Loudspeaker Co., Ltd.	•	•	•	•	•
Sound Technology Development, Ltd.	•	•	•	•	•
Star Audio		•			
Sun Technique Electric Co., Ltd.	•	•	•	•	•
Trueanalog Strictly OEM		•			•
Xiamen Great Sound Technology		•			

	Acoustic Analysis	Box Design	Crossover Optimizer	Network Design	CAE or CAD
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	•	•		•	

	Acoustic Analysis	Box Design	Crossover Optimizer	Network Design	CAE or CAD
SWEDEN					
Audio Pro, AB	•	•	•	•	
Bohmer Audio	•		•		•
IJData	•	•	•	•	•
SWITZERLAND					
Archwave				•	
TAIWAN					
Kingstate Electronics Corp.	•				•
Vansonic Enterprise Co., Ltd.		•			
UNITED KINGDOM					
EuroTec International, PLC					•
Hill Acoustics	•	•	•		•
PACSYS, Ltd.	•				
Rush PCB UK				•	
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	•	•			
Prism Sound	•	•	•	•	
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		•		
Harman of Brazil	•	•	•	•
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.	•	•		
Shenzhen Tekzone Loudspeaker 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)	•	•	•	•
Eton GmbH	•	•		
HiFi-Tuning		•		•
ic audio			•	•
Lautsprecher-Produktions-Gesellschaft (LPG)	•			
Mvoid Technologies GmbH	•	•		•

	Car Audio	Home Audio	Marine Audio	Pro Audio
Quint Audio				•
Scherer Audio		•		
Voice Point		•	•	•
HONG KONG				
Beautiful Enterprise Co., Ltd.		•		
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.				•
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.	•	•		•
MALAYSIA				
TC Electronics Sdn. Bhd.	•	•		
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		•		•

	Car Audio	Home Audio	Marine Audio	Pro Audio
ROMANIA				
Poweraudio Romania				•
RUSSIA				
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.	•	•	•	
UKRAINE				
Mag Audio				•
UNITED KINGDOM				
Arya Audio Labs, Ltd.	•	•		•
Compbass, 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 And Sound	•	•	•	•
AMS Audio Enterprises		•		•
Analysis Audio USA		•		
Area 52 R&D		•		•
Arion Audio		•		
Audio Houze	•			
Audioengine		•		
B&H Foto & Electronics Corp.		•		•
Barefoot Sound, LLC				•
BassBoss				•
Benchmark Media Systems		•		
Blackmore Mobile		•		•
Broad Bridge Audio, LLC		•		

	Car Audio	Home Audio	Marine Audio	Pro Audio
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	•	•	•	
Fulcrum Acoustic, LLC				•
Gauss Loudspeaker		•		•
Geometric Designs, LLC & Geometric Consulting		•		
GGEC America, Inc.	•	•	•	•
Globe Audio Design, Inc.		•		•
GoldenEar Technology		•		
Halford Loudspeakers		•		•
JL Audio, Inc.	•	•	•	
Levister Audio		•		
Lipinski Sound		•		•
Marchand Electronics, Inc.		•		
Mark Lierly				•
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		•		
SG Custom Sound		•		•
SoCal Sound Shop	•	•	•	•
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 Acoustic Vina	•	•	•	•

SOUNDCORP
YOUR TRUSTED PARTNER IN SOUND

Founded in Vietnam since 1999, we are an experienced OEM/ODM company specialize in manufacturing wide range of audio products. With over 15,000 m2 of modern manufacturing site, allow us to produce the most of product's parts in our own factory. Base on those strong points, we can offer many kinds of completed loudspeakers and electronics products to our customer in term of high quality and reasonable price.

PRODUCTS CATEGORY
- High-Fidelity and Home AV Loudspeakers
- Professional and Karaoke Loudspeakers
- All Kinds of Active and Passive Subwoofers
- Battery Powered Portable Loudspeakers
- Analogue/ Digital Amplifiers and DSP Processors

PRODUCTION PROCESS
- Loudspeaker Transducers/ Cabinets and Cross-overs
- Texture to High-gloss Spraying and Powder E-Coating
- Sheet Metal Process and Plastics Molding/ Injection
- SMT/ DIP PCB Assembly and Final Assembly/ Test Process
- Toroidal/ EI Transformers and Inductors/ Air-core Process

SOUND CORPORATION
Head Office: 53 Ung Van Khiem, Ward 25, Binh Thanh Dist, Ho Chi Minh City, Vietnam
Factory: Binh Chuan 34 Street, Binh Chuan Ward, Thuan An Town, Binh Duong Province, Vietnam
Telephone: +84-909016277 Email: oem@soundcorp.vn
www.soundcorp.vn soundcorp.vn

	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	•	•	•	•	•	•	•
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.		•			•	•	•
Shenzhen Tekzone Loudspeaker 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			•				
FRANCE							
Amplitude Audio	•	•					•
IDEA	•		•				
KYU Systems	•	•	•	•		•	
SIEA	•	•	•				•
GERMANY							
Audio Technology Engineering (ATE)			•	•	•	•	
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	•	•	•			•	
Powersoft, SpA	•	•	•	•			
JAPAN							
Etani Electronics Co., Ltd.	•	•	•		•	•	•
NETHERLANDS							
Aequo Audio	•						
ELTIM audio, BV	•		•				
Hypex Electronics, BV	•	•	•			•	
the BEE	•	•					
PHILIPPINES							
Dai-ichi Electronics Manufacturing Corp.	•	•	•		•	•	•

	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
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			•			•	

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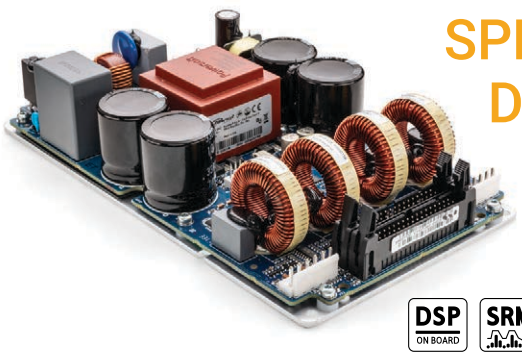

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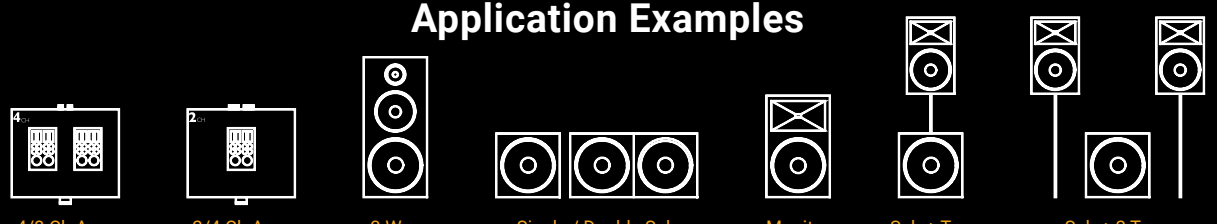
- High channel count applications
- Universal mains PFC equipped power supply
- Comprehensive set of protection and on-board limiters

Application Examples



	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
Revolver Audio, Ltd.	•						
Sine Audio Systems	•		•		•		
Tectonic Elements, Ltd.	•						
UNITED STATES							
AMS Audio Enterprises	•					•	•
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	•		•				

	Amplifiers	DSP (Digital Signal Processing)	High-Power Amplifier Modules	Marine Audio Solutions	Soundbars	Subwoofer Plate Amps	Wireless
Digital Audio Labs	•	•					
Digmoda	•	•	•			•	
DMSI	•	•	•				
Dragonfire Acoustics	•	•	•	•	•	•	•
DTV Installations	•		•		•	•	•
Eagle Acoustics	•			•	•		•
Earthquake Sound Corp.	•		•			•	
Emerald Physics	•	•				•	
Etal Group, AB/Anaview	•		•	•	•	•	
Fortemedia		•					
Fulcrum Acoustic, LLC		•					
Globe Audio Design, Inc.	•	•	•			•	
JL Audio, Inc.	•	•	•	•		•	•
Kramer Electronics	•	•	•			•	•
Lectrosonics							•
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	•					•	
SpeakerAddict	•	•	•	•		•	
SpeakerPower	•	•	•			•	•
SpeakersAndAmps.com	•	•	•	•		•	
Stillwater Designs | KICKER	•	•	•	•			•
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.	•	•	•		•	•	•

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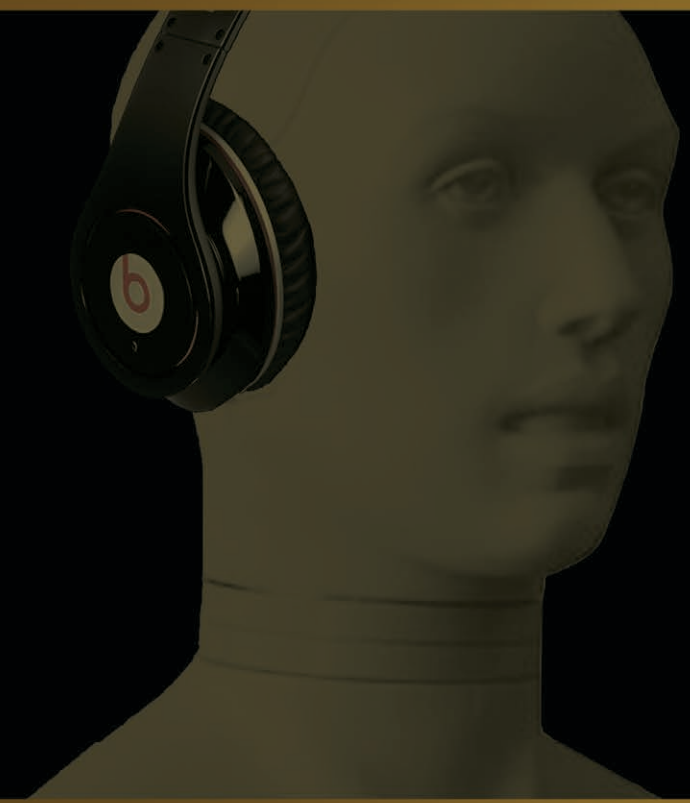

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- Product Development
- Test & Measurement Instrumentation
- Sourcing Guidance

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AUSTRALIA							
Applied Measurement Australia, Pty., Ltd.					•		
Stone Sound Studio					•		
BRAZIL							
Attack do Brasil	•	•	•	•	•	•	•
Newbox Industry & Commerce					•		
CHINA							
OBE Pro Audio Co., Ltd.	•	•	•	•	•	•	
Shenzhen Tekzone Loudspeaker Co., Ltd.	•	•			•	•	
Sound Technology Development, Ltd.	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•
DENMARK							
K & K Development					•		
Loudsoft, Ltd.					•		
GERMANY							
Klippel GmbH					•		
INDIA							
Cruxweld Industrial Equipment, Ltd.					•		
Lakshmi Metal Coils						•	
JAPAN							
Etani Electronics Co., Ltd.					•		
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					•		
Parker LORD	•				•		
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.	•	•			
Shenzhen Tekzone Loudspeaker 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			•		

	Consumer	Field Mics	Lab Instruments	Measuring Mics	Professional
GERMANY					
Klippel GmbH			•	•	
Microtech Gefell GmbH	•	•		•	•
Voice Point	•	•	•	•	•
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	•		•	•	•

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By Robert B. Tomer

Vacuum Tubes—The Important 4/5ths of Tube Circuits

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Like Watching a Play From Backstage

Author "Bud" Tomer, an international authority on tubes, is well-known for his candid "Tech Tip" bulletins and his slide-film presentations to service, military and engineering groups. Within this book you'll find a virtual encyclopedia on vacuum tubes—yet the author has not delved into mathematical details that would be of interest to only a few tube engineers. Everything is focused toward the interest of those who *use* tubes—either for replacement purposes or in o… designs.

In his refreshing, down-to-earth style, Mr. Tomer shed… "Why so many tube types?" "What About Tube Testers?", etc.

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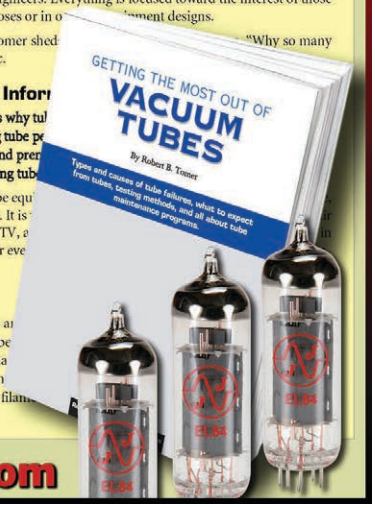
- Predicting tube pe…
- Selected and prer…
- Lengthening tub…

Anyone who has anything at all to do with tube equ… design, or proper use—should read this book. It is … and maintain consumer goods such as radio, TV, a… production and manufacturing processes—or eve… puters and radar gear.

You'll also learn about

- **Catastrophic failures**—what they are, when a…
- **Degenerative failures**—what happens to tube…
- **Subjective failures**—why a seemingly norma…
- **Characteristic variables**—differences that m…
- **Special-purpose tubes**—considerations for filam… and thyratron types.



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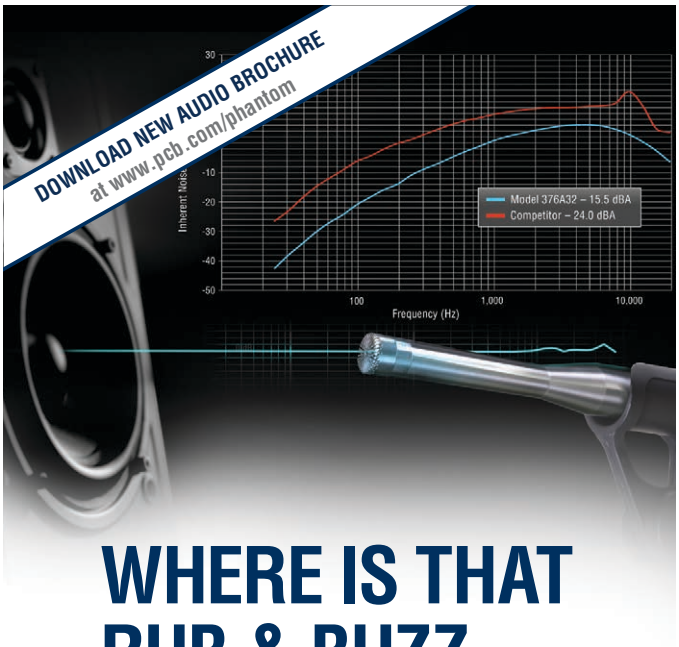
Suntel Co., Ltd.	•	•	•	•	•
SWEDEN					
Audio Pro, AB			•	•	
SWITZERLAND					
SoundChip			•		
TAIWAN					
AV Leader Corp.	•	•	•	•	•
Kingstate Electronics Corp.	•				
UNITED KINGDOM					
EuroTec International, PLC			•	•	•
GRAS Sound & Vibration UK		•	•	•	
UNITED STATES					
ACO Pacific, Inc.		•	•	•	•
Audio 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.	•	•			•
Gold Line			•	•	
GRAS Sound & Vibration	•	•	•	•	•
iSEMcon, LLC	•	•	•	•	•
JLI Electronics, Inc.	•	•	•	•	•
Lectrosonics				•	•
Listen, Inc.				•	
Mark Lierly					•
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.	•				•



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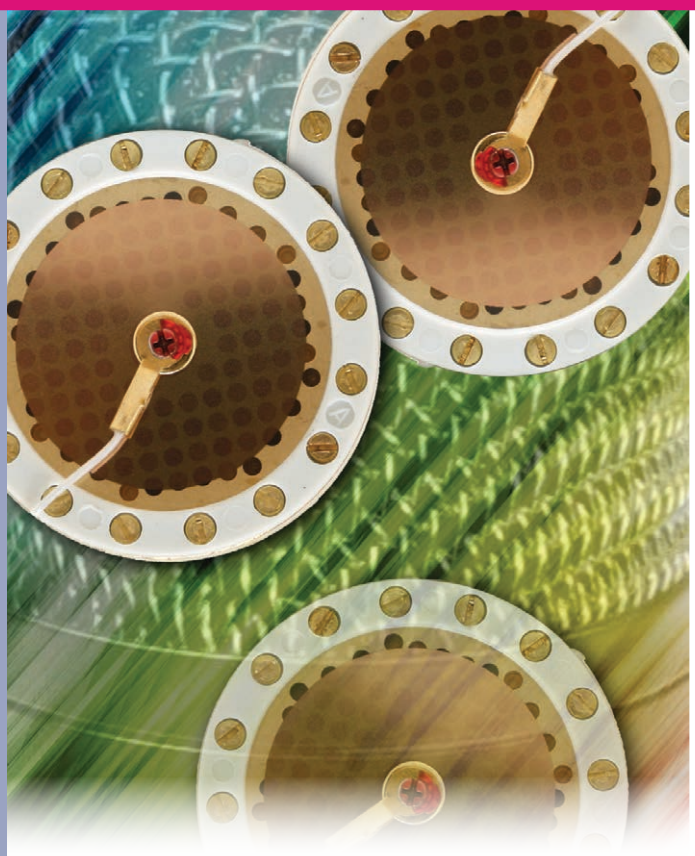

	Dynamic Capsules	ECM	LDC	MEMS	True Condenser
AUSTRALIA					
RØDE Microphones	•	•	•		•
AUSTRIA					
Austrian Audio	•	•	•		•
USound GmbH				•	
CHINA					
BSWA Technology Co., Ltd.		•			
Gettop Acoustic Co., Ltd.	•	•		•	
GoerTek Co., Ltd.	•	•		•	
Haoyin					
MicW Audio	•	•	•		•
Shenzhen Horn Audio Co., Ltd.	•	•			
Shenzhen Tekzone Loudspeaker Co., Ltd.	•				
Sound Technology Development, Ltd.	•				
Sun Technique Electric Co., Ltd.	•	•	•	•	•
Tonly Electronics Holdings	•	•			

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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.					•
SOUTH KOREA					
Suntel Co., Ltd.	•	•	•	•	•
SWEDEN					
Audio Pro, AB	•	•			
TAIWAN					
AV Leader Corp.	•	•	•	•	•
Kingstate Electronics Corp.		•		•	
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Stetron International, Inc.		•			
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Vintage King Audio	•	•	•	•	•
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GoerTek Co., Ltd.	•	•	•
Grand Will Enterprise Co., Ltd.	•	•	•
M-Sound Electronics Co., Ltd.			•
Shenzhen Horn Audio Co., Ltd.	•	•	•
Shenzhen Tekzone Loudspeaker 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			
Eastern Asia Technology (HK), Ltd.		•	•
INNacoustic	•	•	•
WCE Acoustics	•	•	•
SOUTH KOREA			
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- Small stereo

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- Walkie-talkie
- Alarm
- Helmet voice system
- Medical device

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TAIWAN			
AV Leader Corp.	•	•	•
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Kingstate Electronics Corp.	•	•	•
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Dayton Audio	•	•	•
Dragonfire Acoustics	•	•	•
GGEC America, Inc.	•	•	•
GraphAudio	•	•	
Parts Express	•	•	•
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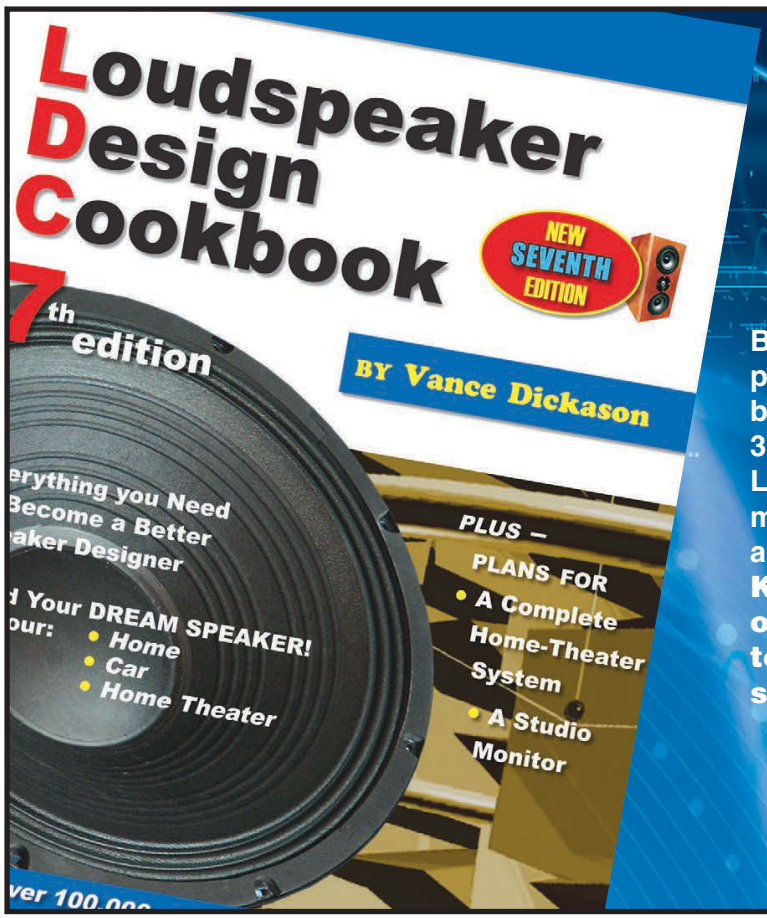
Resonado, Inc.		•	•
Sound Sources Technology, Inc.	•		
Stetron International, Inc.		•	•
The Digital PCH	•	•	•
Trade Moon	•	•	•



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AUSTRIA		
USound GmbH	•	•
BELGIUM		
Donnet: Loudspeaker Repair	•	•
BRAZIL		
Attack do Brasil	•	•
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		
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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.	•	•
Shenzhen Tekzone Loudspeaker Co., Ltd.		•
Sonos, Inc.		•
Sound Technology Development, Ltd.	•	•
Star Audio	•	•
Sun Technique Electric Co., Ltd.	•	•
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Tonewinner (Guangzhou) Electronics	•	
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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		
Beautiful Enterprise Co., Ltd.		•
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.		•
R H Sound Technology, Ltd.	•	
MALAYSIA		
TC Electronics Sdn. Bhd.		•

	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		
Poweraudio Romania		•
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.	•	•
AMS Audio Enterprises		•
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		•
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)	•	
J&F Wood Products	•	•
JL Audio, Inc.		•
Lowell Manufacturing Co.		•
Mark Lierly		•
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.	•	•
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: Electrostatic: Tweeters	Compression Drivers: Electrostatic: Midrange	Compression Drivers: Electrostatic: Woofers	Compression Drivers: Full Range	Horns: Tweeters	Horns: Midrange	Horns: Woofers
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						•		
Dong Guan Dalang Queen Voice					•		•	
Eastech Holding, Ltd.		•	•	•	•	•	•	•
Enkor Electronics Co., Ltd.				•				
Fountek Electronics Co., Ltd.						•	•	
Grand Will Enterprise Co., Ltd.				•		•		
Guangzhou Lingyin Electronic Co., Ltd.					•	•		
Haoyin					•	•		
LaVoce, Co., Ltd.					•	•	•	
Mpio					•	•		

PUNKTKILDE™
Designed by Scan-Speak Transducers

Patented "Dual-Suspensions" Series

Breaking the rules on traditional suspension transducers,
to deliver high excursion and extremely low distortion.
With this new break-through innovation on transducer design,
now you can design small, compact systems without compromising performance.

Ultra-thin Hybrid Carbon Fiber Series

To challenge the design and sound performance boundaries on Soundbar architectures, our new series of Ultra-thin transducers utilizes advanced design tools to enable us to innovate by using our patented suspension design on this series of Ultra-thin transducers, as thin as 20.8mm.

Magnesium-Lithium Alloy Cone Series

This unique alloy material has good damping property, low cone density,
high stiffness, and low moving mass,
delivering good pistonic behavior and fast transient response.
Available from the sweetie 1"Dome tweeter to the high performance 8"woofer.

Headphone Transducers

We have strived and extended our journey
on audio excellence towards
headphones transducer innovation and design.

Proudly produced by EASTECH

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	Air Motion Transformer (AMT)	Compression Drivers: Electrostatic: Tweeters	Compression Drivers: Electrostatic: Midrange	Compression Drivers: Electrostatic: Woofers	Compression Drivers: Full Range	Compression Drivers: Horns
M-Sound Electronics Co., Ltd.					•	•	•
OBE Pro Audio Co., Ltd.					•	•	
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					•	•	•
Lautsprecher-Produktions-Gesellschaft (LPG)						•	
Physical-Lab						•	
Voice Point		•	•	•	•	•	•
Wolf von Langa		•			•	•	
HONG KONG							
BDNC (Holding), Ltd.						•	
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.						•	
ITALY							
ABM Bobine, SRL					•	•	
Audioxplus, SRL					•	•	
Axiomedia, SRL					•	•	•
B&C Speakers, SpA					•	•	•

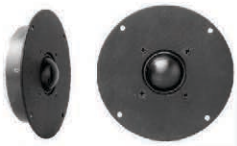
	Air Motion Transformer (AMT)	Compression Drivers: Tweeters	Compression Drivers: Midrange	Electrostatic	Compression Drivers: Woofers	Full Range	Horns
Ciare					•	•	•
Eighteen Sound					•		•
FaitalPRO					•	•	•
LaVoce, Co., Ltd.					•	•	•
Professional Audio, Snc.					•	•	•
RCF, SpA					•	•	•
Sica Altoparlanti					•	•	•
MALAYSIA							
TC Electronics Sdn. Bhd.				•			
NETHERLANDS							
Audio Components, BV						•	
Diluvite						•	
ELTIM audio, BV		•				•	•
Good Hifi VOF		•					
NORWAY							
SEAS Fabrikker AS						•	
RUSSIA							
Star Sound Technologies						•	
SPAIN							
Acustica Beyma					•	•	•

LA PASSION DU HAUT-PARLEUR

AUDAX

HAUT-PARLEUR - LOUDSPEAKER - LAUTSPRECHER

TW034X0



PR170M0

Dome tweeters, Midranges, Woofers

Tweeter Line : 1" - 1 1/4", Soft and Metal Domes, ...
Prestige Series : Die Cast Chassis, HDA Cones ...
References Series : Die Cast Chassis, Paper and Carbon Cones, ...
Classic Series : Stamped Steel Chassis, Paper, Fiberglass, Kevlar Cones, ...
Professional Line : High Efficiency, High Power Handling, ...

High Quality Loudspeakers - Made in France

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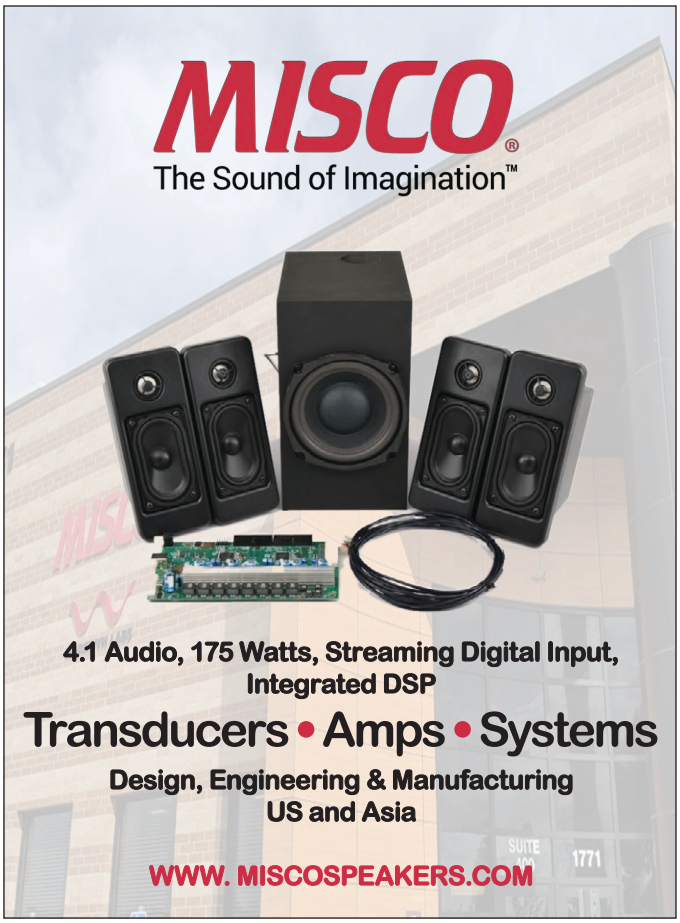
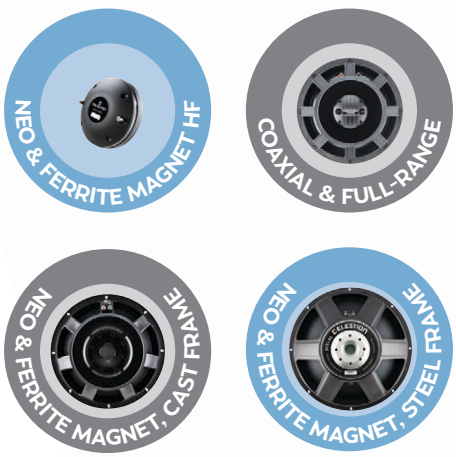
	Air Motion Transformer (AMT)	Electrostatic: Tweeters	Electrostatic: Midrange	Electrostatic: Woofers	Compression Drivers	Full Range	Horns	
SWEDEN								
Audio Pro, AB					•	•	•	
SWITZERLAND								
Lange Loudspeakers						•		•
TAIWAN								
AV Leader Corp.		•	•	•	•		•	
Dongguan Sheng-Yang Electronics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



DESIGNATED DRIVER

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)	Electrostatic: Tweeters	Electrostatic: Midrange	Electrostatic: Woofers	Compression Drivers	Full Range	Horns	
Compbass, 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 And Sound					•			
AMS Audio Enterprises						•	•	•
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						•	•	•

High-End
Loudspeaker Transducers

LEX series

beyma

18LEX1000Nd
subwoofer

2000W

Light weight
7.5 kg

Deep and precise response
efficiently designed motor structure and suspension system

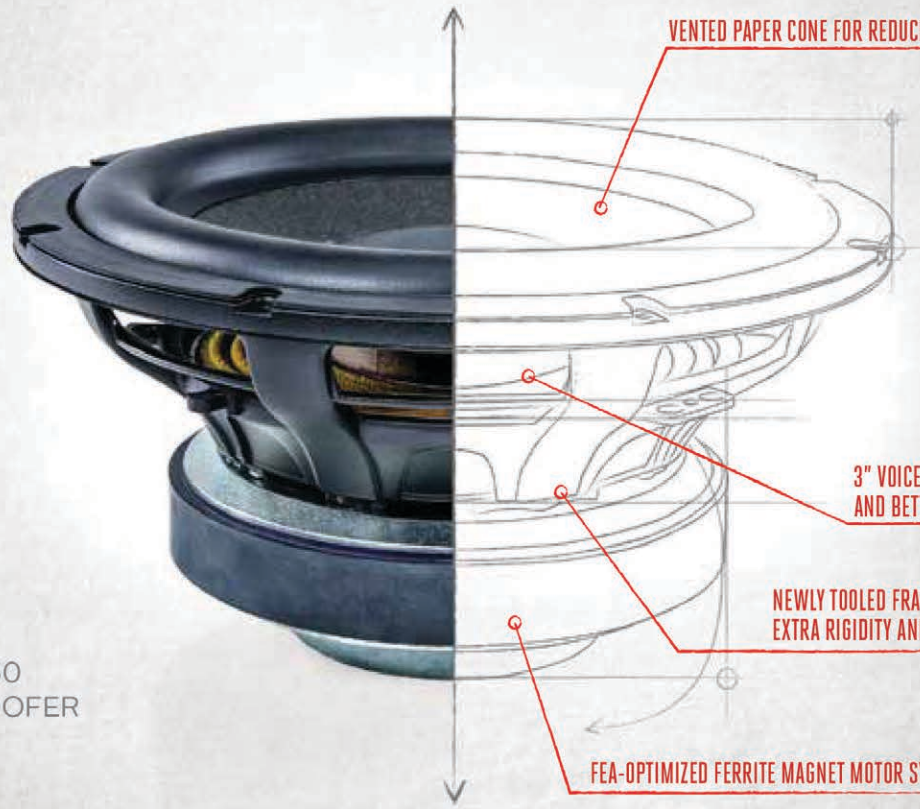
Also available in other sizes/magnet type/power

European drivers since 1969

	Air Motion Transformer (AMT)	Electrostatic: Tweeters	Electrostatic: Midrange	Electrostatic: Woofers	Compression Drivers	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.							•	
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			•					
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.						•	•	•
Tone Tubby, Inc.							•	
Tonian Laboratories							•	
TSG Audio					•	•	•	•
Ulbrich Stainless Steels & Special Metals						•		
US Speaker, LLC						•		•
Vidsonix Design Works							•	
Western Electric		•	•	•				
Yandas Music						•		
VIETNAM								
Sound Corp.						•	•	•
Sun Acoustic Vina		•	•	•	•	•	•	•

Peerless
by TYMPHANY

DEFINING NEW STANDARDS



SDF-250
10" WOOFER

SINCE 1926, Peerless has continued to push the boundaries of what's possible in acoustics, material science, and design. Here's a look at some of our most recent developments.

STW

188mm Voice Coil for More Bass in Smaller Enclosures

DA

High-Performance Corundum-Dome Tweeters

PMT

Bigger Sound from a Small Footprint

NCP

More Power Handling for Professional Systems

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	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	•	•	•	•	•					•	•	•	•	•
Dong Guan Dalang Queen Voice						•							•	
Eastech Holding, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Enkor Electronics Co., Ltd.	•	•								•	•		•	

DS Series
Deeper. Louder. Cleaner.

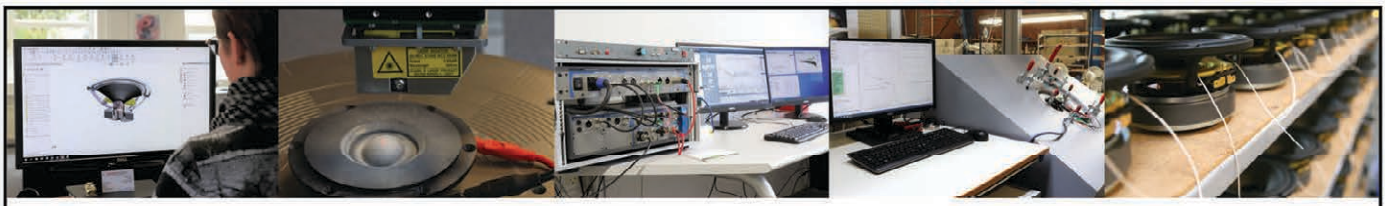
The new DS Series subwoofers combine an extremely strong motor for excellent cone control and efficiency, with the latest suspension materials for long excursion and durability. Now available with a lower price point 4" (100mm) diameter voice coil in 15" and 18" frame sizes, with the field proven durability and performance you expect from B&C Speakers.

B&C SPEAKERS®

www.bcspeakers.com

made in Italy

	Midrange					Paging Horns	Siren/Voice Warning	Tweeters					Woofers	
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Cone	Dome	Electrostatic	Ribbon			
Fountek Electronics Co., Ltd.											•		•	
Grand Will Enterprise Co., Ltd.							•							
Guangzhou Lingyin Electronic Co., Ltd.	•	•	•	•	•				•	•	•		•	•
Haoyin	•	•	•	•	•				•	•	•		•	
LaVoce, Co., Ltd.	•	•							•	•			•	
Mpio	•	•	•	•	•				•	•	•		•	•
M-Sound Electronics Co., Ltd.		•			•				•	•			•	
OBE Pro Audio Co., Ltd.													•	
Pana Sound, Ltd.	•	•				•			•	•			•	•
Qikang	•	•	•	•	•				•	•	•		•	•
Shenzhen Tekzone Loudspeaker Co., Ltd.	•	•								•			•	•
Sonos, Inc.	•	•							•	•			•	
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														
AudioTechnology	•												•	
Hiquphon										•				
Puriti Transducer Technology	•									•			•	
Scan-Speak	•	•								•			•	



- World leading loudspeaker transducer developer & manufacturer
- The industry's most extensive product range with proprietary technologies
- World class engineering and facilities
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- Ability to help customer with product development
- Hand build highend transducers made in Denmark since 1970

SCANSPEAK

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	Midrange					Paging Horns		Siren/Voice Warning		Tweeters			Woofers	
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Cone	Dome	Electrostatic	Ribbon			
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											•			
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Wolf von Langa	•												•	
HONG KONG														
BDNC (Holding), Ltd.										•			•	
Eastern Asia Technology (HK), Ltd.	•	•								•	•		•	
Fujikon Industrial Holdings, Ltd.	•	•	•	•	•	•		•	•	•	•	•	•	•
Ocean Star Electronics (HK) Co., Ltd.	•	•								•	•		•	
WCE Acoustics	•	•	•	•	•	•	•	•	•	•	•		•	

BIG BASS IN A SLIM BOX

bdnc

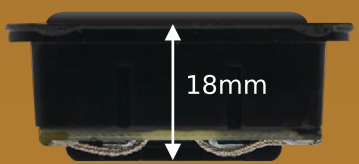
STAPEZ™ Glass Diaphragm Speaker

Glass-composite-diaphragm woofer (BGF-46166-18-4-003)

- 0.2mm ion strengthened glass diaphragm by Schott AG
- 18mm ultra low profile glass woofer with 4mm Xmax
- High motor force (6.64 kgf) for small box
- Reproducing down to 55Hz in 1400ml box & 70Hz in 800ml box
- DSP correction friendly design
- Depth of box can down to 22mm

40mm glass cone full range speaker (BFC-D40-22-4-002)

- 0.23mm 3D Dragontrail™ Glass by AGC Inc
- Excellent treble performance
- Worldwide patented diaphragm structure



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www.newbdnc.com

	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar		Cone	Dome	Electrostatic	Ribbon		
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	•	•	•	•	•					•	•	•	•	•
Audioxplus, SRL	•	•								•	•		•	
Axiomedia, SRL	•	•									•		•	•
B&C Speakers, SpA	•										•		•	•
Ciare													•	
Eighteen Sound													•	
FaitalPRO	•	•								•	•		•	
LaVoce, Co., Ltd.	•	•								•	•		•	
Powersoft, SpA													•	
Professional Audio, Snc.	•	•								•	•		•	
RCF, SpA													•	
Sica Altoparlanti	•	•	•	•	•					•	•	•	•	•
MALAYSIA														
TC Electronics Sdn. Bhd.	•	•								•	•		•	
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.				•	•			•				•		
Dongguan Sheng-Yang Electronics	•	•	•	•	•					•	•	•	•	•
Hakken Enterprise	•	•	•	•	•					•	•	•	•	•
Hi-Tech Sound System Co., Ltd.	•	•								•	•		•	
Huey Tung International Co., Ltd.	•	•	•				•		•	•	•	•	•	

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	Midrange					Paging Horns		Siren/Voice Warning	Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Cone	Dome	Electrostatic	Ribbon		
Kingstate Electronics Corp.							•	•					
Ruhwa Electronic Co., Ltd.			•	•	•				•	•	•	•	•
Taiwan Solidex Corp.							•				•	•	
TB Speaker	•	•			•				•	•		•	•
Yie Feng Technology Enterprise Co., Ltd.	•												
Yuan Ta Electronics 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.												•	
EuroTec International, PLC	•	•	•					•	•	•	•	•	•
Fane International, Ltd.	•								•	•		•	
MJ Acoustics												•	
Precision Devices, Ltd.	•									•		•	
Sine Audio Systems	•	•							•	•		•	•
Volt Loudspeakers, Ltd.	•	•										•	

	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				Woofers
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar	Cone		Dome	Electrostatic	Ribbon		
UNITED STATES														
Acoustic Design, Inc.		•												
Aempyrean								•						
American Bass USA	•	•	•	•	•	•		•	•	•	•	•	•	•
American Music And Sound													•	
AMS Audio Enterprises	•	•								•	•		•	
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.	•	•			•	•	•	•	•	•	•		•	•
Earthquake Sound Corp.													•	
Electro Mavin	•	•									•		•	

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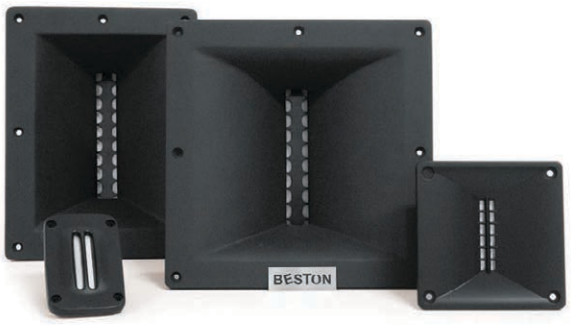
Planar Headphones



BESTON Technology Corporation
Address: 4F, No.99, Lide St., Zhonghe Dist., Taipei 23556, Taiwan
TEL: (886)-2-23892956 FAX: (886)-2-23892952
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- *Multi-Folded Symmetrical Driving Technology*
- *Very Small Counterforce on the Panel*
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- *No Roll-off from 100Hz to Fs Point*
- *Lower Bass Extension with Good Transiency*
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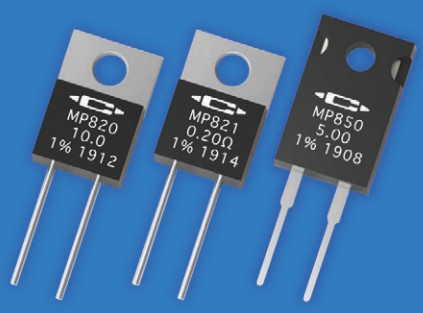
	Midrange					Paging Horns		Siren/Voice Warning		Tweeters				
	Cone	Dome	Electrostatic	Planar	Ribbon	Piezo	Planar			Cone	Dome	Electrostatic	Ribbon	Woofers
Eminence Speaker, LLC	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ESS Laboratories, LLC													•	
ESTec America	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Full Compass Systems, Ltd.	•	•	•							•	•	•	•	•
Gauss Loudspeaker	•	•	•	•	•					•	•	•	•	•
GGEC America, Inc.	•	•					•		•	•	•	•	•	•
GraphAudio										•	•	•	•	
Hartley Loudspeakers, Inc.	•	•	•	•	•					•	•	•	•	•
HDSound								•				•	•	
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.	•	•	•	•	•		•	•		•	•	•	•	•
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.	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Tonian Laboratories												•	•	
Transducer Lab, LLC											•			
TSG Audio	•	•	•	•	•	•	•	•	•	•	•	•	•	•
US Speaker, LLC							•						•	
Vidsonix Design Works	•										•		•	
Wisdom Audio								•						
Yandas Music	•	•								•	•		•	
VIETNAM														
Sound Corp.	•	•								•	•		•	
Sun Acoustic Vina	•	•	•	•	•			•	•	•	•	•	•	•

	Attenuators	Capacitors: Ceramic	Capacitors: Electrolytic Non-Polar	Driver Protection Devices: 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														
Jantzen Audio Denmark			•	•		•	•		•					
FRANCE														
KYU Systems	•			•	•	•	•		•			•	•	•
Seltech					•							•		
GERMANY														
ic audio												•		
Jobst-Audio										•			•	
Voice Point								•	•	•	•	•	•	•

CADDOCK
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.

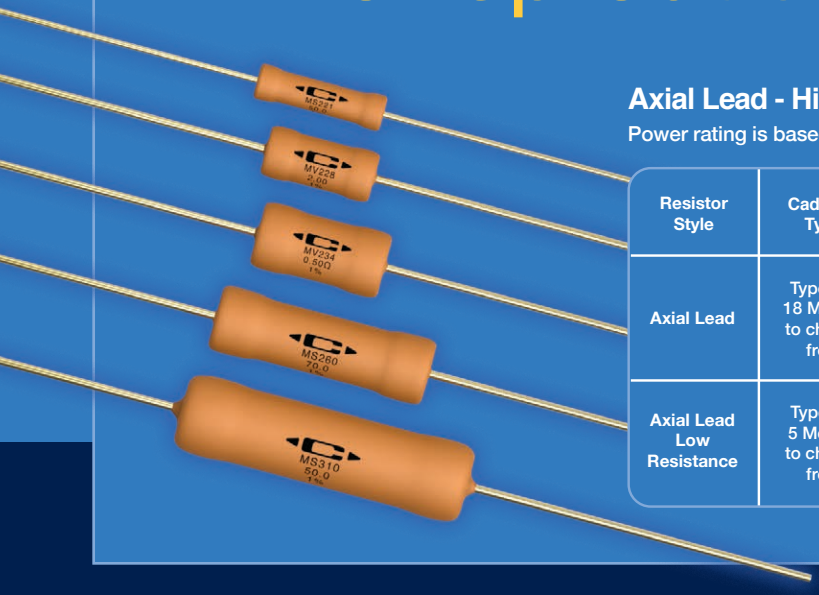


Heat Sink Mountable *with Non-Inductive Design*

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

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For Samples and more Information contact Applications Engineering:

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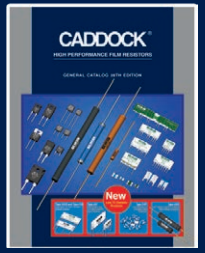
Applications Engineering
17271 N. Umpqua Hwy.
Roseburg, Oregon 97470-9422
phone: 541-496-0700
email: sales@caddock.com

For Distributors listed by country see caddock.com/contact/dist.html

The Caddock product line includes specifications on over 250 models of high performance resistor products. See the full range of our products online at caddock.com



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															
R H Sound Technology, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•		•	•
ITALY															
Axiomedia, SRL	•		•	•		•	•	•	•	•	•			•	
Boxal, SRL															•
JAPAN															
Furutech Co., Ltd.										•					•
MEXICO															
Aletheia, AV														•	•
NETHERLANDS															
Audio Components, BV	•		•			•	•	•	•	•	•			•	
ELTIM audio, BV	•		•	•		•	•		•	•	•	•	•	•	•
ROMANIA															
Poweraudio Romania													•	•	
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															
AMS Audio Enterprises	•		•	•	•	•		•	•		•	•		•	•
Arizona Capacitors				•	•				•				•	•	
AtlasIED	•											•			
Avel Lindberg	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Caddock Electronics									•						
Carvin Audio													•		

	Passive Components												Finished Passive Crossover Nets		
	Attenuators	Capacitors: Ceramic	Capacitors: Electrolytic Non-Polar	Capacitors: Film	Driver Protection Devices	Inductors: Air Core	Inductors: Iron Core	Plugs & Jack Dishes	Resistors	Solder	Terminal Plates	Transformers	Electronic Crossover	Wire & Wiring Harnesses	
CE Distribution	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
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)	•														
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

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Metallized Polypropylene Flim Fast Capacitors™
-First to use the "Fast Capacitors"™
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-Widest range of voltages, from 250Vdc to 630Vdc
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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

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Web: www.bennic.com.tw

	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							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Dong Guan Dalang Queen Voice											•	•	•	•	•	•	•	•	•	•	•
Dong Guan Yen Lung Electronics Co., Ltd.											•	•					•				
Guangzhou Lingyin Electronic Co., Ltd.											•	•	•	•	•	•	•	•	•	•	•
Haoyin											•	•	•	•	•	•	•	•	•	•	•
Lumi Audio											•	•	•	•	•	•	•	•	•	•	•
Mpio											•	•	•	•	•	•	•	•	•	•	•
Ningbo Xiangyang Telecommunication Component											•	•	•	•	•	•	•	•	•	•	•
Qikang											•	•	•	•	•	•	•	•	•	•	•
Shenzhen Guangn Nan Electronic Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sound Art Electronic											•	•	•	•	•	•	•	•	•	•	•
Sound Technology Development, Ltd.	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•
Sun Technique Electric 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	
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											•	•		•	•	•	•	•	•	•	•
KYU Systems	•	•	•	•	•	•					•	•	•	•	•	•		•	•	•	•
Seltech						•	•	•	•	•											
GERMANY																					
Centrotec Composites						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Dr. Kurt Müller											•	•	•	•	•	•	•	•	•	•	•
Henkel Corp.	•	•	•	•	•																
Hubert Stüken GmbH														•	•						
Propex Fabrics GmbH											•		•						•		
Voice Point	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

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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	Metal	Aluminum/Titanium/Metal	Fabric/Mylar/Resin/Soft	Phenolic & Other Domes		Fabric	Foam	Rubber
HONG KONG																					
BDNC (Holding), Ltd.											•										
WCE Acoustics											•	•	•	•	•	•	•	•	•	•	•
HUNGARY																					
ViktorSound											•	•	•	•	•	•	•	•	•	•	•
INDIA																					
Audiotone Professional											•	•	•					•	•	•	•
Dakshin Speaker Manufacturing Private, Ltd. (DSMPL)											•	•	•	•	•	•	•	•	•	•	•
TurboSonic Pro Speakers							•			•											
Wizard India Private, Ltd.											•	•	•			•	•	•	•	•	•
INDONESIA																					
SB Acoustics												•			•	•		•		•	•
ISRAEL																					
R H Sound Technology, Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ITALY																					
ABM Bobine, SRL							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Boxal, SRL											•	•	•	•	•	•	•	•	•	•	•

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• Distortion Reduction • Reduction of Power Compression

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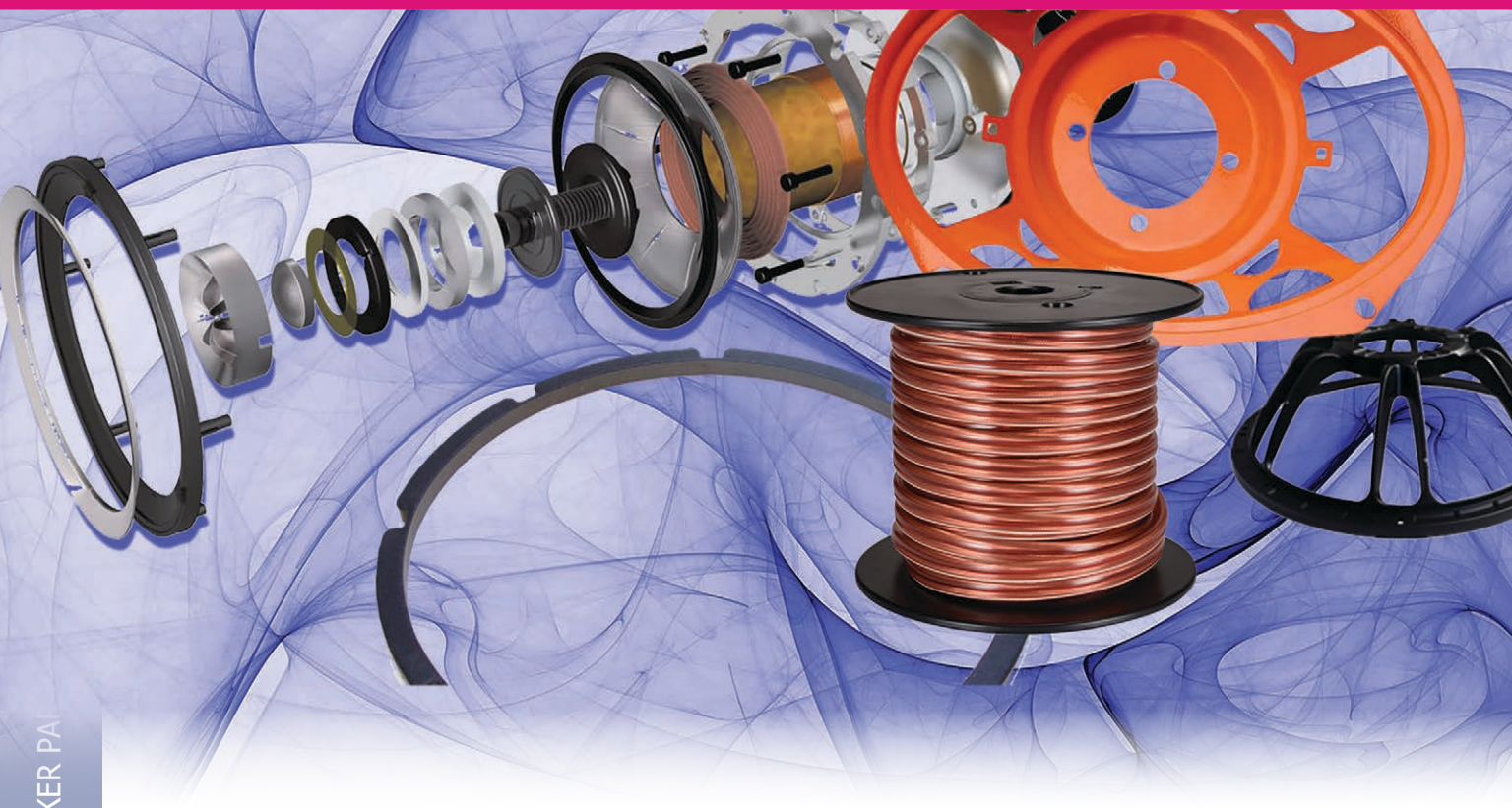
Image by Peggy und Marco Lachmann-Anke

	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	Metal	Fabric/Mylar/Resin/Soft	Phenolic & Other Domes		Fabric	Foam	Rubber
OEB, SRL											•	•						•	•	•	•
Professional Audio, Snc.											•		•	•	•		•	•	•	•	•
MALAYSIA																					
Eternal Power Sdn. Bhd.							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Shu Kae Industrial	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
U-Sonics Power Cone											•	•	•	•	•	•	•	•	•	•	•
NETHERLANDS																					
Audiofriends											•	•	•	•	•	•	•	•	•	•	•
Diluvite	•	•					•				•	•	•	•	•	•	•				
Good Hifi VOF		•				•									•	•	•		•	•	•
Teijin Aramid							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
NORWAY																					
Soundcare AS							•								•						
PHILIPPINES																					
Dai-ichi Electronics Manufacturing Corp.											•	•	•	•	•	•	•	•	•	•	•
SOUTH KOREA																					
Suntel 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
SWEDEN																					
Audio Pro, AB					•						•	•	•	•	•	•	•	•	•	•	•
Oxeon AB/Textreme											•						•				
SWITZERLAND																					
Kisling AG	•	•		•																	
TAIWAN																					
AV Leader Corp.							•	•	•	•	•										
Dongguan Sheng-Yang Electronics							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Hakken Enterprise											•	•	•	•	•	•	•	•	•	•	•
Hi-Tech Sound System Co., Ltd.											•		•		•	•					•
Huey Tung International Co., Ltd.											•	•	•	•	•	•	•	•	•	•	•
Ruhwa Electronic Co., Ltd.											•	•	•	•	•	•	•	•	•	•	•
Shiuh Sheng Electronics Factory											•	•	•	•							
Sonic Electronic Co., Ltd.											•	•	•			•	•				
Yie Feng Technology Enterprise Co., Ltd.											•		•					•	•		•
Yuan Ta Electronics 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											•	•	•	•	•	•	•	•	•	•	•

	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
Master Bond, Inc.	•	•	•	•	•															
Materion														•	•					
MISCO							•													
NedLab											•		•	•	•	•	•		•	•	•
Orban Audio Speaker Repair											•	•	•	•	•	•	•	•	•	•	•
Parker LORD	•	•	•	•	•	•	•	•	•	•											
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										•											



	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		
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 Telecommunication Component	•	•	•	•	•	•						
Renyi Castings	•	•	•	•	•	•						
Sound Technology Development, Ltd.	•		•	•			•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•
Zhuhai HiVi Technology Co., Ltd.	•											
DENMARK												
estron a/s										•	•	•

	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	
FRANCE												
KYU Systems	•	•						•				
Seltech		•										
GERMANY												
Hubert Stüken GmbH	•	•	•	•	•	•						
Voice Point							•	•	•	•	•	•
HONG KONG												
Eastern Asia Technology (HK), Ltd.	•	•	•	•	•	•						
WCE Acoustics										•		
INDIA												
Audiotone Professional							•	•	•	•	•	•
Dakshin Speaker Manufacturing Private, Ltd. (DSMPL)	•	•	•	•	•	•						
Vidyut Teletronics, Ltd.							•				•	
Wizard India Private, Ltd.	•	•										
INDONESIA												
SB Acoustics			•	•	•	•				•		
ISRAEL												
R H Sound Technology, Ltd.							•	•		•	•	•
ITALY												
ABM Bobine, SRL							•	•	•	•	•	•
Axiomedia, SRL							•	•	•		•	
Boxal, SRL							•	•	•	•	•	•
FaitalPRO	•	•									•	•
Professional Audio, Snc.	•	•	•	•	•	•	•	•	•	•	•	•
JAPAN												
Furutech Co., Ltd.											•	
MALAYSIA												
Shu Kae Industrial												
U-Sonics Power Cone	•	•	•	•	•	•						
NETHERLANDS												
Diluvite	•		•	•	•	•						
PHILIPPINES												
Dai-ichi Electronics Manufacturing Corp.	•	•	•	•	•	•						
SWEDEN												
Audio Pro, AB	•	•	•	•	•	•	•	•		•		•

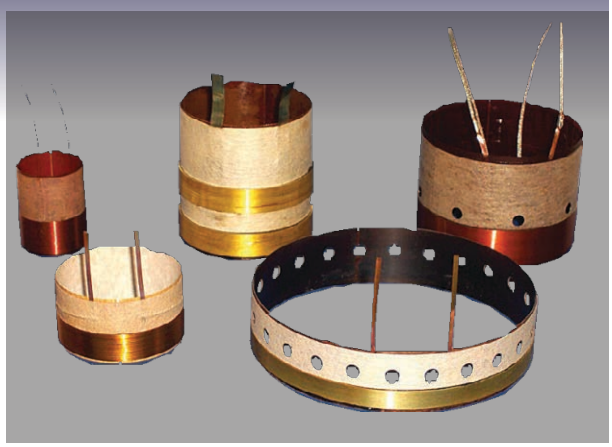
	Frames & Baskets						Lead Out Wire					
	Frame Gaskets		Stamped Steel				Flat Strip			Termination/Crimps		Lead Out Wire
	Cast Alloy		Bumped	Damped Metal	Double Bumped	Range of Diameters	Braided	Beryllium Copper	Phosphor Bronze	Litz	Stranded	
TAIWAN												
Huey Tung International Co., Ltd.	•	•	•	•	•	•	•	•			•	
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	•	•	•	•	•	•	•	•	•	•	•	•
AMS Audio Enterprises	•	•				•						•
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: Alnico	Magnets: Ferrite	Magnetic Fluids: Neodymium	Pole Pieces	T-Yokes Top Plates	Bobbins/Formers	Collars	Magnet Wire	Polyimide Tape for Collars	Voice Coil Assemblies	Amplifiers: Flat Wire	Amplifiers: Round Wire	Amplifiers: Voice Coil Stacks	Amplifiers: 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 Telecommunication Component								•	•	•	•	•	•	•	•	•
OBE Pro Audio Co., Ltd.															•	•
One Magnet Electronic Co., Ltd.		•	•	•												
Pana Sound, Ltd.															•	•
Shenzhen Guangn Nan Electronic Co., Ltd.								•	•	•	•	•	•	•	•	•
Sound Technology Development, Ltd.	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sun Technique Electric Co., Ltd.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Tianyi Electronic Co., Ltd.		•	•	•	•		•									
Tonly Electronics Holdings																•
Trueanalog Strictly OEM	•					•	•									

SPEAKER PARTS M–Z

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

Specializing in high-temperature edge-wound and multiple layer flat-wound coils for the pro audio, home theater, and automotive aftermarket



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  - Multi-layer wire configurations
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	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		
Lakshmi Metal Coils												•				
Power Electronics & Technologies														•	•	
TurboSonic Pro Speakers				•							•	•	•			
Vidyut Teletronics, Ltd.										•	•	•				
Wizard India Private, Ltd.				•			•									
INDONESIA																
SB Acoustics	•			•	•		•	•				•	•	•		
ISRAEL																
R H Sound Technology, Ltd.								•	•	•	•	•	•	•	•	•
ITALY																
ABM Bobine, SRL								•	•	•	•	•	•	•	•	•
Axiomedia, SRL				•											•	•
Boxal, SRL								•	•	•	•	•	•	•	•	•
FaitalPRO	•			•	•		•	•					•			
OEB, SRL												•	•			
Powersoft, SpA															•	
Professional Audio, Snc.	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•

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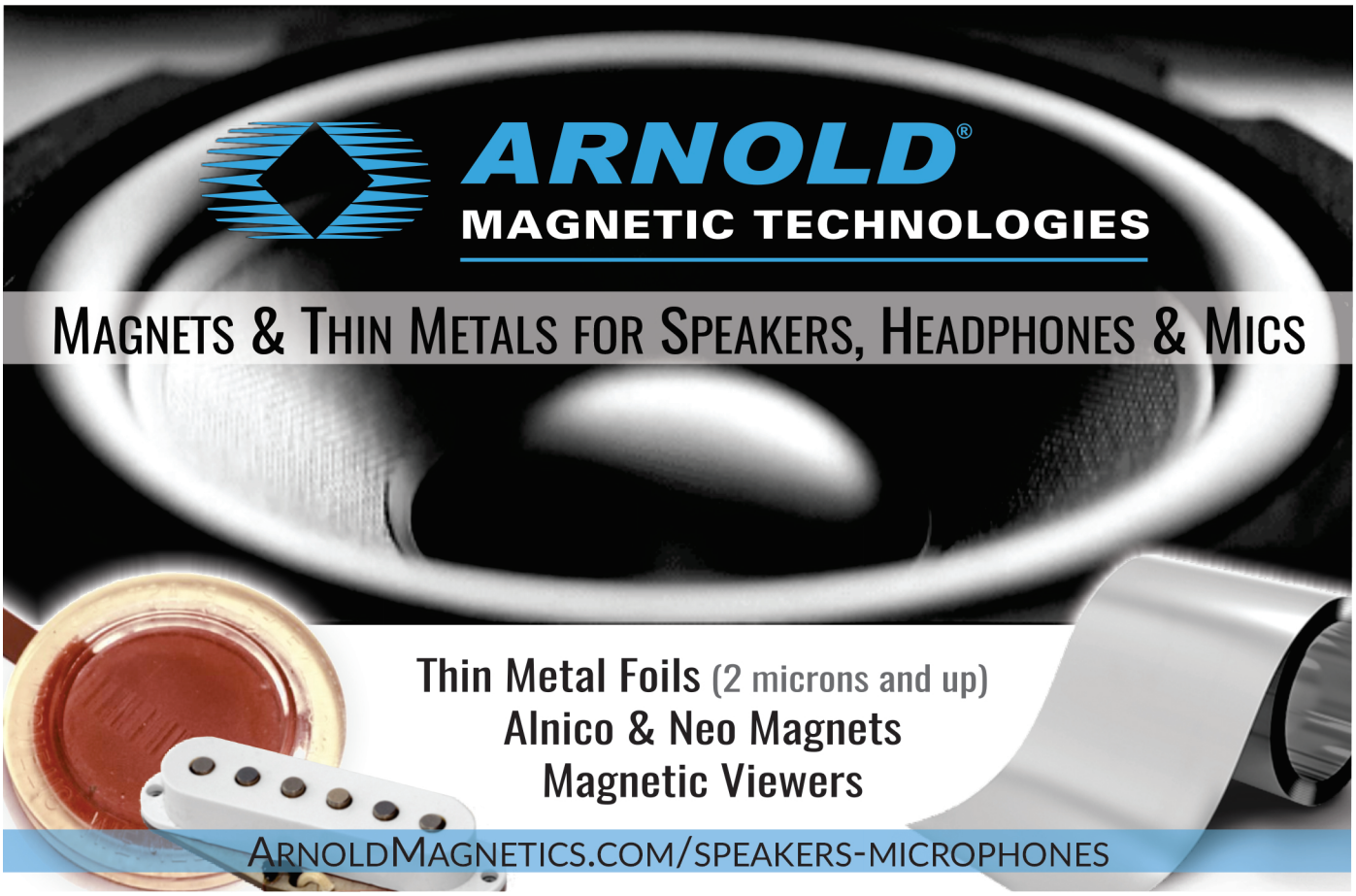
Email: onemagnet@one-magnet.com
Website: www.one-magnet.com

	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	
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 Collars	Voice Coil Assemblies			Amplifiers		
		Alnico	Ferrite	Neodymium								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	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
AMS Audio Enterprises	•	•	•		•	•	•						•		•	•

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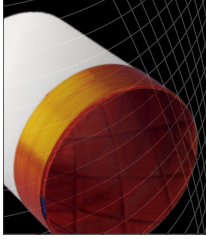

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	Magnetic Assemblies							Voice Coil Components									
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		Alnico	Ferrite	Neodymium							Flat Wire	Round Wire	Voice Coil Stacks	Powered Speakers	Amplifier for	Subwoofer Plate Amplifier	
Area 52 R&D	•			•	•		•	•								•	•
Arnold Magnetic Technologies/ Precision Thin Metals		•		•	•												
Cadillac Audio	•				•		•	•								•	•
CE Distribution																	•
CommonSense Audio																•	
Dayton Audio																•	•
DMSI																•	
Dragonfire Acoustics												•	•	•		•	•
Dynavox Electronics, Inc.	•	•		•		•		•	•	•			•			•	•
Elektrisola								•	•	•	•	•	•	•		•	•
Etal Group, AB/Anaview																•	•
FerroTec (USA) Corp.					•												
Gold Line	•	•		•	•	•	•	•	•	•	•	•	•	•		•	•
HISCO - Precision Converting											•	•	•	•			
Lamart Corp.											•						
Marchand Electronics, Inc.																•	•
Materion								•									
MISCO																•	
NedLab								•									

	Magnetic Assemblies							Voice Coil Components								
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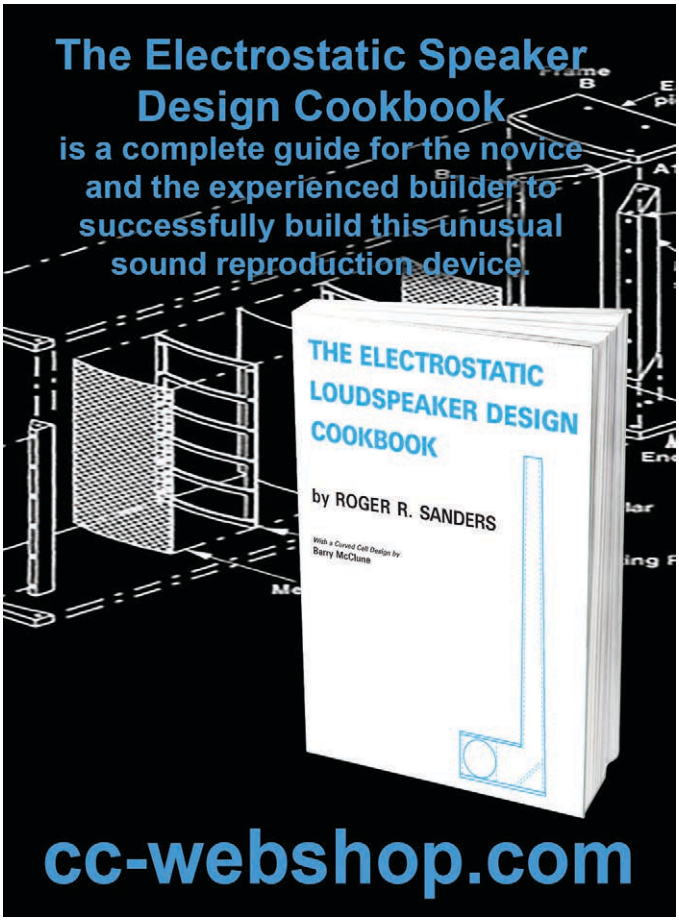
Pierce Audio Products	•			•	•		•	•					•	•		
Precision Econowind, LLC								•	•	•	•	•	•	•		
PRV Audio Brazil				•	•										•	
Radian Audio Engineering, Inc.	•	•		•	•	•	•	•								
Radio Design Labs (RDL)															•	•
RBH Sound																•
RCF USA, Inc.															•	
Simply Speakers					•											
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.		•		•				•	•		•	•				•	•	•	•		•	

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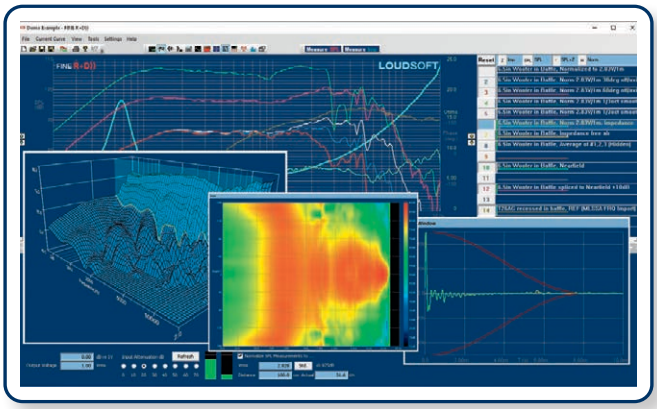
- Crossover Measurements 10 ~ 100kHz
- Auto-save Time= Change window +smooth
- Bluetooth measure w Delay compensation
- FINE Hardware3: 25W amp + GRAS mics



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- Bluetooth measure w Delay compensation
- FINE Hardware3: 25W amp +GRAS mics

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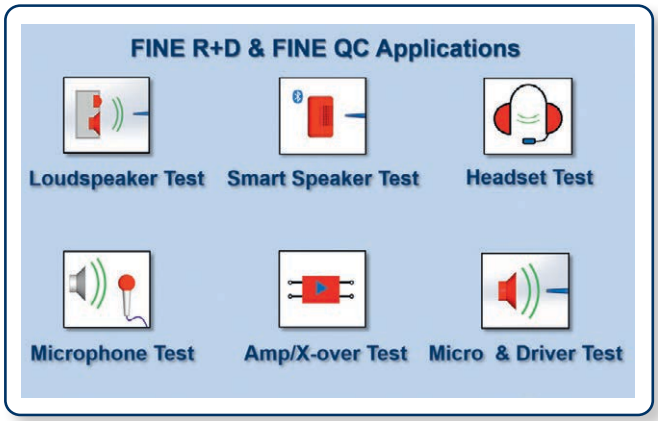

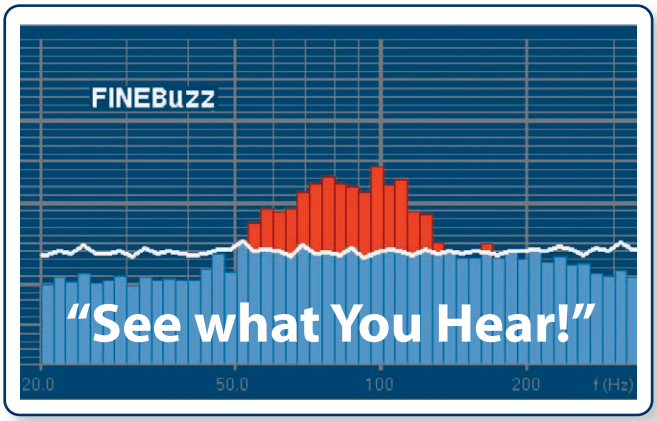

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	Accelerometers	Anechoic Chambers	Audio Analyzers	Gaussmeters	LCR Bridges	MLS	Multimeters	Oscilloscopes	Resistance Bridges	Signal Generators	Sine/Square Wave Oscillators	Speaker Parts	Speaker Turntables	Spectrum Analyzers: 1/3 Octave	Spectrum Analyzers: FFT	Spectrum Analyzers: Heterodyne	Spectrum Analyzers: TDS	Stroboscopes	Test Mics	Testing Cabinets	Turns Counters
MicW Audio																			•		
Pana Sound, Ltd.		•		•									•							•	
Shenzhen Tekzone Loudspeaker Co., 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	•	•		•																•		
Rohde & Schwarz				•					•	•					•	•	•	•				•
ISRAEL																						
R H Sound Technology, Ltd.						•			•	•	•	•		•								
ITALY																						
Audiomatica, SRL	•			•		•	•	•			•	•			•	•				•		
Axiomedia, SRL						•																
SpeakerLAB				•																		
JAPAN																						
Etani Electronics Co., Ltd.		•		•			•	•			•			•	•					•	•	
Zumi Systems				•																•	•	
LATVIA																						
Sonarworks																				•		
NETHERLANDS																						
Audio Components, BV				•											•	•						
SINGAPORE																						
Virtins Technology	•			•		•	•	•	•		•	•		•	•	•	•			•		
SWEDEN																						
Audio Pro, AB	•			•		•									•	•			•			
Bohmer Audio				•			•					•	•		•	•			•			
SWITZERLAND																						
Megatec AG					•																	
SoundChip				•																		

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UNITED KINGDOM																						
EuroTec International, PLC			•	•			•	•	•		•	•	•			•	•				•	•
GRAS Sound & Vibration UK			•																		•	•
Hill Acoustics			•																			•
UNITED STATES																						
ACO Pacific, Inc.													•								•	
Adafruit Industries	•								•	•												
Alliance, LLC					•																	
Allied Electronics, Inc.				•					•	•		•										
Amplitrex Audio Products				•																		
Audio Advisor, Inc.															•							
Audio Precision, Inc.				•								•									•	
Audix																					•	
Beach Dynamics			•																			
Behringer																					•	
Bruel & Kjaer Sound & Vibration North America, Inc.	•		•	•								•			•		•		•		•	•
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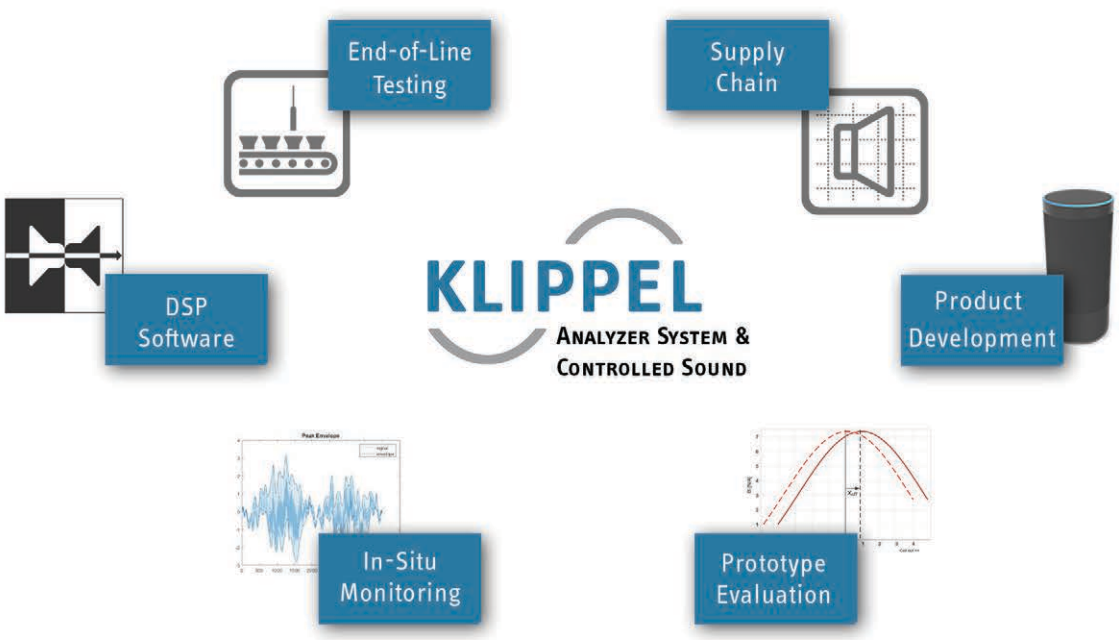

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Dayton Audio				•									•								•	
ETS-Lindgren			•									•				•	•	•	•			
Fotronic Corp.	•			•		•		•	•			•				•	•	•	•	•		
Geometric Designs, LLC & Geometric Consulting				•																		
GL Communications, Inc.				•								•									•	
Gold Line				•		•				•		•	•								•	
GRAS Sound & Vibration																					•	•
HEAD acoustics, Inc.				•																		
Herman Pro, AV		•		•								•										
HX Audio Lab																						•
IK Multimedia																					•	
Kramer Electronics												•										
Listen, Inc.				•		•		•	•	•		•				•	•	•	•		•	
Marchand Electronics, Inc.				•								•	•									
Mark Lierly																					•	
Markertek Video Supply	•			•					•	•		•			•							
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Meyer Sound Laboratories, Inc.					•																	
NedLab	•			•				•			•		•			•						
Neobits, Inc.						•		•	•		•									•		
NTi Audio					•						•	•		•	•	•		•			•	
Open Tip					•			•	•		•											
Parts Express					•			•													•	
PCB Piezotronics, Inc.	•	•			•																•	
Performance Audio, LLC					•						•										•	
Phoenix Engineering, LLC												•										
Prism Sound					•						•	•			•	•		•				
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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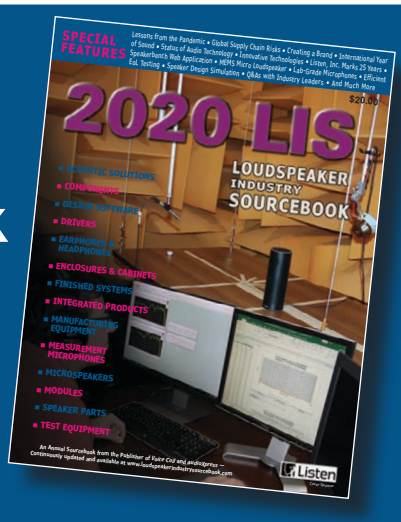

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25 Years of Audio Measurement: A Retrospective

By
Steve Temme
(President, Listen, Inc.)

As Listen, Inc. celebrates its 25th anniversary, Steve Temme outlines the changing landscape of the industry over the past quarter century, and discusses how test and measurement companies such as Listen, Inc. have evolved to keep pace with these trends.

Listen, Inc. is 25 years old this year. When I think back over the past quarter century, I am in awe at the rapid pace of change in the audio industry, and how it has driven those of us in the test and measurement business to continuously refine and expand our product offerings. Twenty-five years ago, and indeed for the first few years of our existence, we tested basic transducers—loudspeakers, microphones and headphones. Today, we test smart speakers, hearables, automotive audio, smartphones, Bluetooth headsets, MEMS microphones, and more, and the market takes a new twist or turn every couple of years.

The Beginning: 1995

In 1995, I had recently returned to the US from a four-year stint in Denmark working for Brüel and Kjær as a Telecom/Audio applications engineer. While working with the renowned 2012 Audio Analyzer at Brüel and Kjær, I had an idea for creating a software-based test system. I thought this would be faster, more flexible, and more powerful than the conventional hardware-based audio analyzers, and I knew it would be considerably less expensive. Back then, the R&D labs mostly used expensive hardware-based systems, and automated production line testing was in its infancy—most production lines relied on human listeners, if indeed they measured their products at all.

At that time, I was consulting to Sonetronics (now a division of Whitney Blake), a military headset manufacturer, and its president, Gary

Kuskin, shared my belief that a software-based system could produce a more cost-effective solution to his production test requirements. In fact, he had enough confidence in the idea that he agreed to buy several sets of such a system if I could develop it in the tight timeframe that he needed. Although the SoundCheck system was not much more than a concept at that point, I quickly set about building a product.

I aimed to simplify measurements by removing the need for the operator to understand programming in order to configure tests, so I opted to build SoundCheck on the National Instruments LabVIEW platform. This enabled tests to be built using a point-and-click interface, which hugely simplified test setup as no programming knowledge was required. This was unique at the time, although others have now emulated this style of interface.

In just six months, I had a prototype ready for evaluation. For the most part, the system performed as expected, showing the same results as the Brüel and Kjær 2012, and the customer was happy. Some minor tweaking and refining ensued, and I made my first sale! The product was named SoundCheck, and I was convinced this product could be a success, so I formed Listen and began to refine the product.

The Early Years (1995-2000)

Although the initial version of SoundCheck was designed specifically for testing military headsets, I wanted to test all audio devices, so I added functionality to make it more useful for other applications and offered it for sale more widely. A key foundation of the product was that it would work with any professional audio interface and hardware from any manufacturer, enabling people to use existing equipment. This meant that from its inception back in 1995, it could be used with anything from a $300 professional sound card to a $5,000+ NI interface. It is interesting that other test and measurement companies, after years of trying to convince customers that this was an inferior solution, are now promoting sound cards as a cost-effective alternative! This proved to be a sound business decision as it set the foundation for the versatility that would later be needed as the audio market evolved.

Steve Temme started Listen, Inc. with his vision for a software-based test system, that is now SoundCheck

My early sales efforts targeted production line users, as I had a system that was sufficiently fast and accurate, yet inexpensive enough to be a viable replacement for the subjective listening that was commonplace, even in large consumer audio companies. In today's world of software and industrial automation, it seems strange to recall that less than 25 years ago, I was trying to convince people that software could be cheaper and more reliable than human labor!

Early product development focused on the needs of the production market, with algorithms for background noise immunity and fast throughput. My focus was on catching production line faults, and I developed a unique algorithm for Rub & Buzz detection using higher order harmonics that is still in use today. I was also determined to minimize the hardware cost of the system, and introduced a low-cost microphone power supply and measurement microphone to further reduce the overall cost of the system.

As Listen began to grow slowly but steadily, we focused on expanding the capabilities of the product with additional measurements and algorithms, for example, loose particle detection for improved detection of manufacturing faults. Measurement using a time windowed, logarithmically swept sine wave was added in 2000, just weeks after Angelo Farina's landmark paper on the subject. (It was actually already being implemented, but Farina's endorsement of this technique certainly gave it instant credibility!) This technique rapidly became extensively used for making fast measurements on the production line, and is still widely used today.

The addition of functionality such as normalized distortion measurements and post-processing capability allowed Thiele-Small (T-S) measurements to be made and established SoundCheck as a viable R&D tool. The inclusion of "virtual instruments," software versions of benchtop equipment such as oscilloscopes,

multimeters, and RTAs, enabled a complete suite of laboratory equipment on a laptop and quickly grabbed the attention of audio R&D teams who saw this as a great asset when traveling to their rapidly growing China manufacturing facilities and fabricators.

As our customer base grew and diversified, we took full advantage of the modular nature of software to offer simple production systems and complex R&D systems at different price-points. Being software based also offered the advantage that it was simple to transfer tests from the R&D lab to the production line. A test sequence could simply be emailed and used in a remote location, and it could even be adapted (e.g., to show a pass/fail output rather than display full results). This also worked in reverse. Production line operators who were having problems understanding their test results could email the response signal back to the R&D lab, which could carry out its own more extensive evaluation of the raw data.

The early 2000s was when it really began to get exciting. The consumer audio landscape started to rapidly change, with a series of device and technology introductions that completely altered the way we store, share, and listen to audio. Each innovation has caused us (and others in the audio test marketplace) to continuously evolve our product lines and develop new products and test methodologies to offer a way to measure these new products.

Cellphones and MP3 Players

The rapid change began with the advent of mobile phones. In the 2000s, people began to eschew traditional landlines in favor of cellphones and VoIP phones, and conference phones (often VoIP) started to replace frequent business travel. It was a challenge to achieve similar sound quality to conventional landlines, and manufacturers needed to measure this. The telecoms industry is heavily driven by standards, and in conjunction with telephone test guru John Bareham, we developed an off-the-shelf suite of test sequences for SoundCheck.

These use a "virtual" audio cable to transmit the audio signal via Windows audio into SoundCheck, and enabled cellphones and VoIP phones to be tested to the same TIA standards as conventional phones. SoundCheck's ability to work with any hardware was particularly advantageous for the telecoms industry as it was used with head-and-torso simulators (along with associated power supplies and amplifiers for microphone, ear, and mouth simulators), handset positioners, and more. Features such as conditioning signals (needed for speech activity detection), standard and custom time domain waveform filters (used in telephony standards), active speech level, Zwicker loudness (to measure ringtone volume) and RTA analysis algorithms for comparison of speech stimulus and response signals were developed, thus expanding SoundCheck's R&D toolkit. Many of these would later prove useful for other applications. The option to use any WAV file as a test signal was added, since phone codecs do not pass sine waves (the typical test signal at the time) well, making SoundCheck the first test system to offer testing with speech and music stimuli.

In a similar timeframe, Apple launched its iPod and, although this was not the first MP3 player, it rapidly drove market adoption, and MP3 players became the new "must-have" consumer electronics item. This brought with it new measurement challenges: synchronization of the input and output signal (both time delay and sampling rate), and accounting for jitter. New algorithms were created for this, resulting in what we now call "open loop testing"—measuring a device where the input and output are not synchronous and must be accounted for in the measurement. We also developed a multitone test signal that made it extremely fast for measuring frequency response and crosstalk between left and right channels.

Smartphones and Large-Scale Production

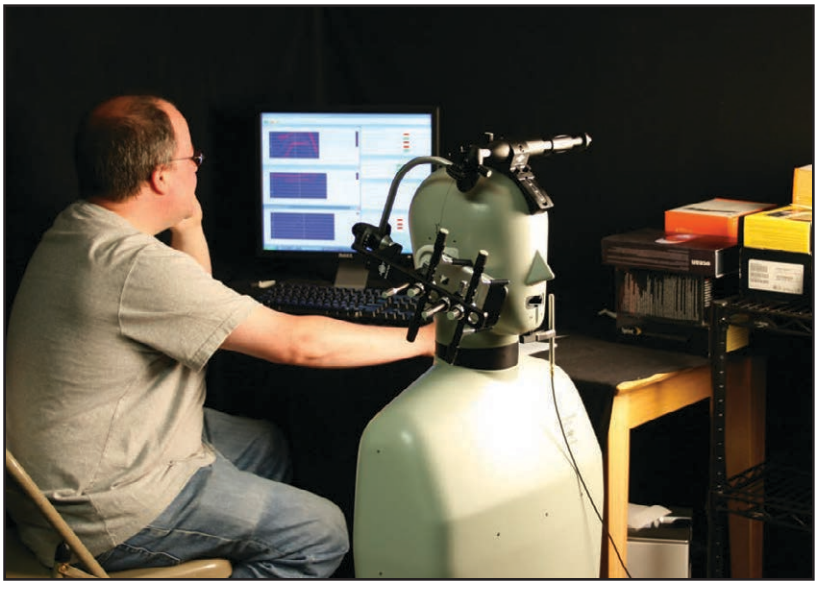
As one might expect, it wasn't long before MP3 players, phones, video recorders, and more became one device, to create the smartphone—

This is the first edition SoundCheck as it was used at Sonetronics, circa 1996.

SoundCheck is pictured on a driver production line in China, circa 2005.

arguably the biggest change so far this century in the way people use consumer electronics. Although Blackberry instigated the smartphone revolution with email functionality and other basic tasks in 2002, it wasn't until the iPhone was introduced in 2007 with its strong emphasis on music, photos, and video that the market exploded, spawning a whole new class of consumer electronics from industry giants such as Apple, Google, Samsung, and others.

Initially, we saw a huge demand for testing smartphone components (e.g., microspeakers and microphones), and we introduced new algorithms, such as loose particle detection and perceptual Rub & Buzz testing, which were popular with microspeaker manufacturers looking to reject faulty speakers while retaining maximum yield. Smartphone business models drove the lifespan of a smartphone down to a couple of years, creating a very high volume market.



This is a telephone test conducted at Boston-based Reviewed.com in 1997.

With microspeakers being manufactured by the millions for this marketplace, high volume throughput and high yields became important for the factories producing them. By 2010, the production landscape had completely changed. Automated, objective measurement had replaced human listeners on the production line, and the use of large-scale contract manufacturers rather than owned factories became the norm. This, however, brought its own set of challenges.

Under the new business models, vast factories made high volume products for many customers, each with their own specified end of line test protocols. Factories installed and commissioned production lines faster than ever before to meet regular product launch cycles, and employees migrated from rural areas to work in these massive facilities. With such rapid expansion, we had to account for the fact that the production line operators using SoundCheck frequently had minimal experience or knowledge of audio testing.

Although we had always had the ability to lock down a test sequence against unauthorized changes, there were still many variables that allowed measurement errors to creep in. When we considered how to simplify production line setups, there was one answer: hardware. The flexibility that was so useful for the R&D lab sometimes caused challenges in the hands of less experienced and well-trained operators.

We responded to this marketplace need by launching AmpConnect, the first in our new line of audio measurement hardware products. AmpConnect was designed as a one box, one cable solution to work with the SoundCheck software. It is simply connected to the computer with a single USB cable and incorporates the audio interface, microphone power supply, amplifier, digital I/O and all internal signal routing. This reduced a production line speaker or microphone test setup to a microphone and speaker connected to the AmpConnect, connected via USB cable to the computer. Naturally, SoundCheck could still be used with any device, but this one-box solution was embraced by production customers. It has also become widely accepted as a simple and cost-effective R&D lab solution, although there are also many more complex configurations in this environment.

Over the next few years, other hardware products such as microphone power supplies and amplifiers were launched. Though off-the-shelf products had served us well for many years (and still work well with SoundCheck), the new Listen-designed hardware was conceived specifically for audio test with full USB control, minimal front-panel buttons to avoid operator error, and fully integrated with the SoundCheck software. Hardware items also contained advanced features for audio testing not usually found in off-the shelf hardware, such as the SC Amp amplifier's patented method of high accuracy single channel impedance measurement.

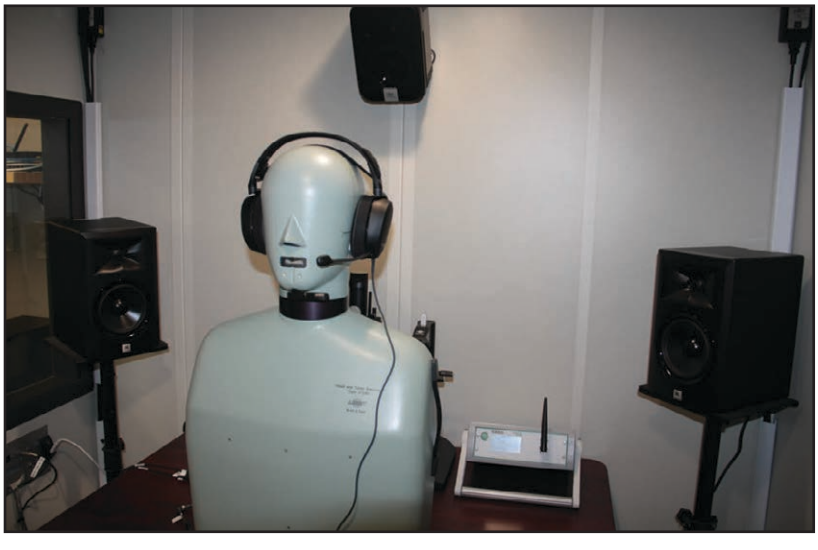
As the smartphone market matured and sound quality became a differentiating factor, audio tests moved upstream to finished products, and this presented new challenges to overcome. With conventional audio tests, a wired connection provided an input to the speaker, and it was simply a case of playing the test signal and recording the response. With a smartphone, there was no simple analog input; in playback mode, the test signal had to be manually transferred to the device for playback, and in record mode, the recorded waveform had to be manually transferred to the computer for analysis. SoundCheck had always been able to use any WAV file as a test signal, and this proved to be a significant advantage when it came to testing smartphones since sine sweeps are not passed well by phone codecs. As early as 2006, we had algorithms to measure, for example, non-coherent distortion with speech and music.

Headphones

Hot on the heels of the smartphone revolution (and largely as a result of it), came the headphone revolution. Consumers soon realized that as much as they loved the convenience of Steve Jobs' "1000 songs in your pocket," the earbuds provided with the phones did not offer much listening pleasure to a true audiophile (or even just the average listener). It wasn't long before established headphone companies (e.g., Bose and Sony) saw their business boom, and the market was full of both established speaker and headphone companies, and numerous headphone startups trying to build a better headphone. Some of these, such as Beats, are now household names; others faded into obscurity or were snapped up by larger companies. Naturally this renewed interest in headphones, particularly for music "on the go," spurred much innovation, such as active noise cancellation, sports headphones (bone conduction and earbuds) as well as high-end audiophile headphones for in-home listening.

Headphone tests are conducted at Maximum PC in 2016.

In recent years, specialist gaming headphones—in fact not only headphones but chairs, shoes and other sound-producing accessories have also been a growth area. Signal paths became more complex with lightning connectors, USB-C connectors, and the ultimate challenge: Bluetooth testing connectivity to eliminate wires. For some of these innovations, the test capability was already there—we just had to teach people how to use it. For example, active noise cancellation (ANC) simply took advantage of the pink noise stimulus and RTA functionality that already existed in the software, as did the ability



Headphone tests (Bluetooth with background noise) are done at Indy Acoustics in 2017.

This smart speaker test is conducted in an anechoic chamber at Indy Acoustics in 2017.

to import a target curve and set limits based on it. However, Bluetooth connectivity presented greater challenges to solve.

In the mid-2000s, we launched Soundmap, a time-frequency analysis module that allowed transient artifacts such as Bluetooth dropouts to be measured using Windows native Bluetooth control. This was followed in 2013 by a partnership with Portland Tool and Die to offer professional-grade Bluetooth interfaces. These offer the user full control over the Bluetooth protocols and can be set and controlled directly within SoundCheck, enabling them to be used within a test sequence. With both an R&D grade instrument and a simplified, lower cost, production line version, Bluetooth tests were easily translated to the production line.

About the Author

Steve Temme is founder and President of Listen, Inc., manufacturer of the SoundCheck audio test system. Temme founded the company in 1995, and for the past 25 years the company has remained on the cutting edge of research into audio measurement, regularly introducing new measurement techniques, algorithms, and hardware to enable testing of all kinds of devices ranging from basic transducers to complex audio systems. In recent years, Listen's product development focus has been on creating the algorithms, interfaces, and test methods to measure today's many and varied wireless and cloud-communicating devices. Prior to founding Listen, Temme worked for many years as an acoustic test and measurement applications engineer at Brüel & Kjær, and also as a loudspeaker design engineer at Apogee Acoustics. He holds a BSME from Tufts University, has authored numerous papers on acoustic testing, and has lectured extensively throughout the world.

MEMS Microphones and Multichannel Testing

Around the same time, the micro-electromechanical systems (MEMS) revolution was slowly gaining momentum. MEMS microphones are used in cellphones, and more recently voice-activated devices due to their small size, low cost, array capability, and digital output. Testing a MEMS microphone is similar in principle to testing a regular microphone—the main difference being the interface. Since a MEMS microphone has the pre-amp and A-D converter integrated, the interface is needed to convert the 1-bit PDM output of a Digital MEMS microphone to the 24-bit, 48 kHz PCM signal accepted by audio test systems. Through our partnership with Portland Tool and Die, we launched both R&D grade and lower-cost production interfaces, fully integrated into SoundCheck for use in test sequences.

MEMS microphones are often used in an array, which means several need to be tested at once. In fact, by the early 2010s we were seeing a multitude of multichannel test applications. SoundCheck has offered up to 32 channels of analysis since 2007, and in 2015 expanded this to 64 channels. Since the channel expansion is software based (provided you have a multichannel audio interface), it is easy to upgrade an older two-channel system for multichannel analysis.

Voice Recognition

In 2014 the audio test landscape took another dramatic turn with the advent of Amazon Alexa. Testing voice-activated devices is the convergence of many of the measurement techniques that are used in other markets. Like the smartphone, the Amazon Echo, and similar devices from other brands, are true multi-function devices. They are used for playing music (driver test), listening (microphone test—often multi-channel), voice recognition (often in the presence of varying background noise), operating as a hands-free communication device (telephone test) and more. All of these require open-loop testing techniques.

Interestingly, pretty much all the aspects of testing, with the exception of voice recognition, were things that we had the capability and experience to measure from the other markets in which we were active, although we did have to figure out how to store test signals in the cloud.

To facilitate voice recognition studies, we created a software sequence to generate ETSI-standard background noise via SoundCheck—an extremely low-cost alternative to a dedicated background noise system that has the added

advantage that it can be controlled from within a test sequence.

Now, in 2020, voice-activated testing is still moving full steam ahead, and though it seemed like a complex device just 5 years ago, a smart speaker is one of the simpler voice activated devices that we are testing! Voice activation has moved into not only smart speakers, but smart hearables, smart homes, and smart cars.

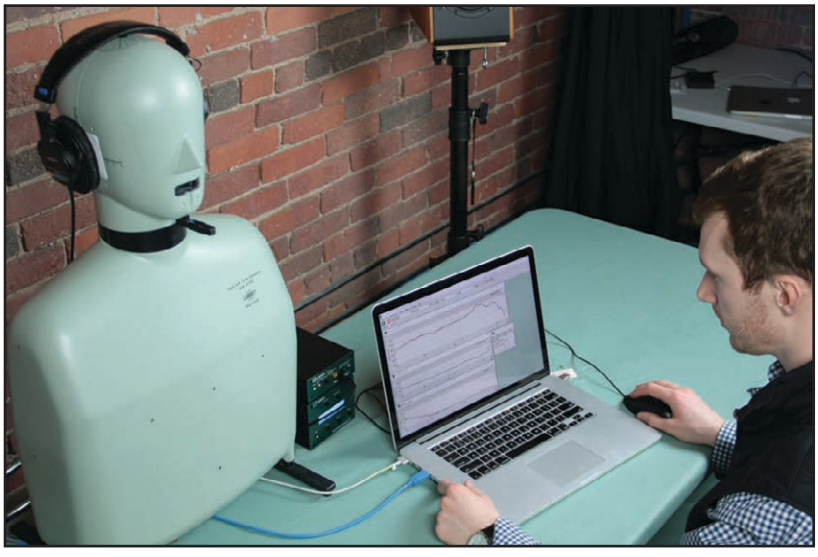
Tests include speech recognition, voice quality and noise cancellation in addition to microphone, MEMS microphone and driver test, and these generally need to be done via the cloud and/or Bluetooth—and sometimes an A2B car audio bus, often with the presence of added and varying background noise. Such tests require the flexibility of a software-based system with a virtually unlimited number of channels that can communicate with a wide range of interfaces and the right stimulus signals and analysis algorithms to turn the measured signals into meaningful data.

Production applications still require simpler tests than the R&D lab, but the way in which these are done is changing. In 25 years, we have moved from human listeners, through manually operated automated tests to large-scale tests where the audio test system is automatically operated as part of a larger test scheme with vast volumes of data being written to cloud-based databases for big data analysis and full component and device traceability. Recent production developments have focused both on enabling this with functionality such as TEDS integration, multi-channel interfaces, better external control functionality and improved database capabilities, as well as functionality which increases the speed of large-scale set-up. I anticipate this trend will continue for the next few years at least!

The Future

It's been an amazing journey this past quarter century! Although my retrospective here has focused on the technological innovations in the industry and how we have evolved with it, there is so much more that has gone unmentioned.

For example, I have been fortunate enough to present many of our innovations at the Audio Engineering Society (AES) conventions, at several Association of Loudspeaker Manufacturing & Acoustics (ALMA) International Symposium & Expo (AISE) events—the organization is now known as Audio & Loudspeaker Technologies International (ALTI)—and ISEAT, and other symposia, as well as sharing a stage for panel discussions, and authoring and presenting papers with such industry leaders as Sean Olive, Laurie Fincham, Don Keele, Floyd Toole, Mike Klasco, Patrick Dennis, and more.



SoundCheck version 18 was released in March 2020.

It has truly been a privilege to work with so many knowledgeable people over the past 25 years. Of course, the dedicated Listen team, several of whom have been with the company for many years, have played a huge part in our success, as well as our many customers who have made us what we are today by needing solutions to demanding audio test challenges!

So, what's next? I don't think anyone can say for sure. Voice control is here to stay, and that will continue to present new and exciting challenges. I suspect that the recent huge increase in working from home will drive innovation in the teleconferencing, communications and accessories marketplace, and we will see innovation here with more on-board DSP in the quest for better sound quality, which will lead to more complex test requirements. One thing that is certain though, is that no matter what the device, correlation to human perception will be important, whether for voice control or listening pleasure. This means that we need to invest in new and improved algorithms with stronger correlation to human listeners.

No doubt we will also see whole new classes of devices that haven't been conceived yet, which will present new testing challenges. We have seen so much audio innovation in the past 25 years, and the pace of change has been quite incredible. I look forward to seeing what the next 25 years brings! ***LIS***

Speakerbench

Photo 1: Three impedance measurements are performed in free air, with the driver secured tightly in a suitable jig/ workbench.

By
Claus Futtrup and Jeff Candy

Our previous article for the *Loudspeaker Industry Sourcebook* (LIS) was published in 2017. That article focused on the benchmarking of various viscoelastic models for the loudspeaker motional impedance. Now, three years later, it seems like a good opportunity to pick up where we left off—by introducing our Speakerbench web application.

The 2017 LIS article was published after a January presentation of some preliminary data at the Association of Loudspeaker Manufacturing & Acoustics (ALMA) International's AISE 2017 (ALMA is now known as Audio & Loudspeaker Technologies International or ALTI). During the presentation, we benchmarked a number of speaker units with several viscoelastic lumped-parameter models. At that ALMA International's Symposium & Expo (AISE) presentation, we also premiered the dual-added-mass technique for determining small-signal parameters, including the (new) viscoelastic parameter.

Our research, shown at AISE and presented in LIS 2017, indicates a preference for the Knudsen LOG-model of viscoelasticity, extended with the Retardation Spectra function by Tobias Ritter and Finn Agerkvist, named the three-parameter creep (3PC) model. The 3PC model gave promising results across a wide range of loudspeaker units, and didn't fail for any of the tested drivers. In the name of both accuracy and robustness, this model was our favorite.

One could imagine that we had spent a lot of our time measuring other loudspeakers and comparing, but I'm afraid that's not the case. Instead our next step was an Audio Engineering Society (AES) paper, published in December 2017, which explained a novel dual-added-mass method to determine small-signal parameters from three impedance measurements and adding different masses to the cone.

Added-mass measurements were the standard for determining loudspeaker Thiele-Small (T-S) parameters when I (Claus Futtrup) started to work in the loudspeaker industry, but they have since been replaced by Klippel measurements, which means measurements with a "Distortion Analyzer" by Klippel GmbH, at least on the professional side. The vast majority of DIY and professionals who cannot (or will not) afford the expensive equipment still rely on added-mass measurements today.

Added-Mass, Twice

By performing three impedance measurements instead of two (see **Photo 1**), you gain much higher precision because you can isolate the pure motional impedance, and also gain insight into the quality of the measurement. This is an improvement over the old-fashioned way of manually dialing in f_L, f_S and f_H. Furthermore, with the three measurements, one can accurately compute a new model parameter that measures the level of driver viscoelasticity. The underlying technique was explained at the ALMA presentation in 2017. The AES paper goes into greater detail and further verifies the dual-added-mass method with a Gage R&R analysis, which shows that you can expect to accurately determine Bl (the motor force factor strength) with tolerances of ±1%. Generally speaking, the Gage R&R verifies the quality of our proposed method.

The dual-added-mass method completely separates the electrical part and the mechanical part of the impedance from each other, facilitating determination of a high-quality electrical model (resistance, inductance, etc.). In a relatively simple yet powerful computation, the mechanical and electrical contributions are separated, without any assumption of the underlying models. It's a model-free extraction entirely based on the measurement data.

The electrical model that we prefer is the five-parameter one by Thorborg-Futtrup, which includes motor semi-inductance. This model is versatile—it can describe a wide variety of transducer designs accurately over the full audible frequency range. We would say the model is valid within the speaker's usable range plus one or more octaves beyond. Although the quality of the results from the dual-added-mass method is high, we are well aware of the fact that some people might find the mathematics to be difficult to approach. Therefore, we decided to create a web-application, which serves the underlying routines to anyone who can measure impedance—something not so hard to do. This application is named Speakerbench (http://speakerbench.com).

This is a web-application, which runs directly in your browser (see **Figure 1**). Almost any browser is supported, on a wide variety of platforms, including your smartphone.

Everyone is invited to try the software. It's free as in no-cost, not even financed through advertisements, and the results are yours! The additional effort of measuring a third impedance curve is well worth it, because you get a lot more information as well as a quality assessment of the measurement data and model fit.

Comparison with Klippel Analyzers

Although the dual-added-mass method has many virtues, it is not a competitor to the Klippel analyzers that occupy various laboratories around the world. The most significant distinction is that our method is valid only for small-signal analysis, whereas the Klippel analyzers offer large signal identification (LSI) with the LSI module. Speakerbench doesn't offer this. That aside, I would say that the parameters identified with our method are every bit as good as what you can achieve with a setup from the Klippel analyzers and their Linear Parameter Measurement (LPM) module. It just takes a bit more effort.

On the other hand, small businesses and DIYers alike do not need to invest in expensive laser measurement equipment and are now able to evaluate the quality of their added-mass measurements, while with prior added-mass methods one would simply rely on experience and intuition (one's gut feeling) for judging if it was good or bad.

The key requirements for a good result with Speakerbench are that you have a decent setup for impedance measurements, and a quality scale for measuring the added masses. Obviously, if you're using your kitchen scale with a ±1 gram resolution, then you cannot expect to identify your moving mass (M_{MS}) with adequate precision. Measuring with 1/10 gram precision is mandatory if you wish to achieve M_{MS} with somewhere around 2% to 5% error, and we recommend scales with 1/100 gram resolution, because then the mass measurement doesn't play a role in the overall accuracy anymore. These recommendations are based on the assumption that we are measuring normal speaker units with M_{MS} in the 10 to 25 gram range.

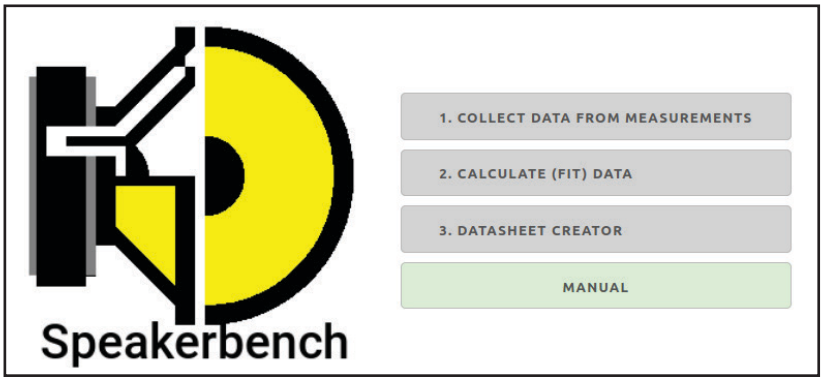


Figure 1: Speakerbench is a web application designed for anyone who can measure impedance.

Advanced models for the driver compliance contain a parameter (beyond static compliance and resistance) that describes the viscoelastic (memory) effect. The viscoelastic parameter that we have specified with the dual-added-mass method is called beta (β). This is conceptually similar to the original Knudsen-Jensen LOG-model lambda (λ) value, but different model functional forms mean that lambda and beta are not directly comparable. When it comes to the results from the Klippel analyzer, they specified yet another λ value, which is subtly different than the Knudsen-Jensen definition. In Speakerbench, we provide an estimate of the λ_K (Klippel) value for the user, as well as equivalent values for the simpler traditional T-S parameters.

The λ_K from the Klippel analyzer and the β from Speakerbench deviate in one important way. Whereas Speakerbench measures and identifies the parameter by fitting around the resonance frequency of the driver, the Klippel analyzer uses a very-low-frequency effect that stems from creep and relaxation in viscoelastic materials.

The Klippel output is essentially there to predict the excursion and voice coil position of the driver (for distortion analysis purposes) and therefore the λ_K value out of the Klippel software will differ from Speakerbench. Our model parameters are identified for box simulation purposes and β describes the frequency-dependent damping around the resonance frequency. In other words, the two methods are valid for two different frequency ranges and for different purposes.

Viscoelastic Models

The models available for low-frequency simulation are relatively simple, in the sense that they are linear, and represent a first-iteration of modeling. This is in spite of the fact that we're essentially simulating effects from relatively complex processes, like losses in roll surrounds of rubber and corrugated cloth spiders, with glue joints and edge coating near the cone/surround interface. Anything that creates damping mechanically which isn't constant with frequency is lumped into the parameter β of the 3PC model described in the first section.

Recall that in traditional transducer models there is only a simple (constant) friction loss (often represented by R_{MS}), whereas in reality the materials are viscoelastic. The viscoelastic property implies a memory effect, which with further scrutiny, might show to be level dependent as well. When we measure drivers with the dual-added-mass method, and keep the signal low (below 100 mV) we can see a drop in the β value when compared to results measured at higher voltage. At this point we can only guess, but for viscoelasticity to show up, the components need to bend and/or stretch, such that the materials experience stress and strain. So, at very low signal levels, low excursion suggests that large parts of the surround and/or spider are not being exercised. This further implies that the driver's mechanical properties are fundamentally level (voltage) dependent and we strongly suggest that the user record the measurement voltage in the voltage input cell.

The Electrical Model

A number of different models for describing the inductance exist (e.g., a mathematical four-parameter model by J. R. Wright) to a classical ladder-circuit model (e.g., the L2R2 model).

In an AES article from 1989, John Vanderkooy shows that the voice coil will exhibit what he coins as semi-inductive behavior when located around a steel rod (like what you find in all classical transducer magnet systems). The person who first took this semi-inductive component, named K_E, and plugged it into an electrical equivalent circuit was Knud Thorborg.

Thorborg developed his model successively in several AES papers, the last one together with me (Claus Futtrup) defining a five-parameter model of the voice coil inductance and resistance (five parameters including R_{DC}), which works remarkably well for a broad selection of different driver designs, including the ones with underhung magnet systems and the ones with lots of copper shorting rings and caps in the magnet system.

If you expand the L2R2 model with one further term, it becomes a six-parameter model (perhaps called L3R3) that still doesn't work as well as the five-parameter Thorborg-Futtrup model in various general (more or less extreme) cases. Expanding the model this way is also undesirable because it creates ambiguity as to exactly what each component in the model is representing in the real (physical) world. Too many parameters can lead to overfitting.

The Thorborg-Futtrup model seems to be the simplest way to describe the voice coil inductance and resistance accurately, for a broad frequency range, including the semi-inductive effect which stems from eddy currents in the surrounding materials (think aluminum voice coil formers, shorting rings and caps, and steel parts in the magnet system).

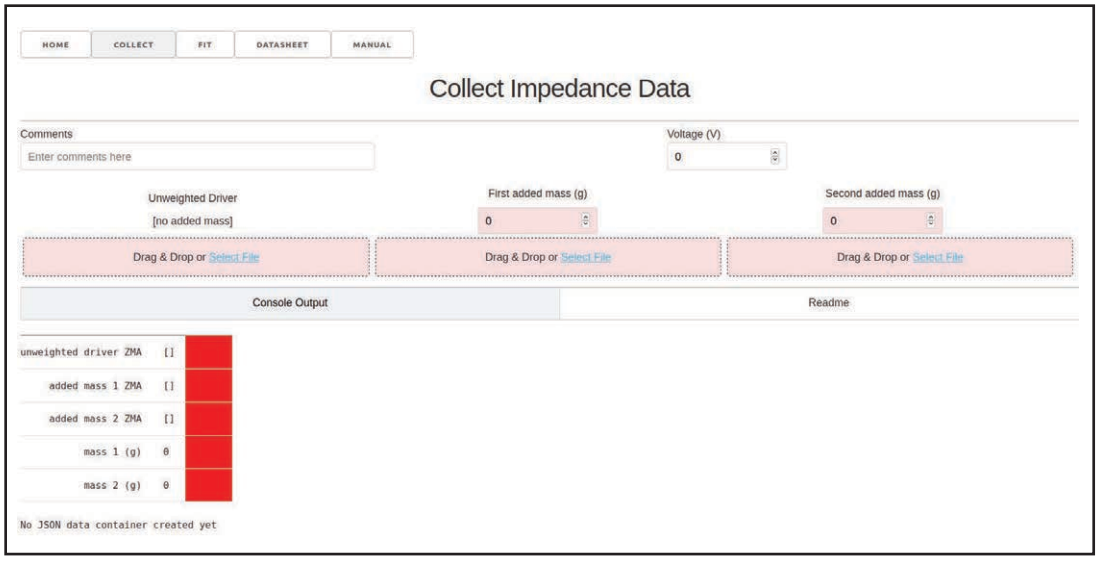


Figure 2: The first step is to collect data from the measurements.

Verifying Results

In physics and engineering, it is common practice to benchmark alternative methods against one other in order to assess the most accurate and robust approaches. The added-mass method is well-established and has been in use for more than 50 years. The dual-added-mass method adds additional power to this method.

On the other hand I have a lively imagination when it comes to the introduction of the Klippel analyzers many years ago. I can easily understand that when attempting to sell this new system, customers would benchmark it against the added-mass method, and deviations had to be explained. Remember, although the added-mass method relies on gut feeling, some loudspeaker designs had been measured many times, sometimes verified by cutting the speaker into pieces and measuring the flux in the gap directly, as well as the moving masses directly.

In light of this, the Klippel analyzers were expected to comply with an added-mass method, which was the proven method at the time, yet I also expect that many discussions must have occurred, when things didn't add up. Presumably some aspects of the results from the Klippel analyzer had to be "tuned" to provide the results that engineers expected.

We do not consider our dual-added-mass method as a competitor to the Klippel analyzer, but it does offer a completely different way to obtain loudspeaker parameters, and as such it could be a strong tool for verifying the linear parameter results from the Klippel analyzer, and vice versa. Therefore, we hope that Klippel GmbH and others will receive this method, supported by Speakerbench, with open arms.

Speakerbench

We think of Speakerbench as a workbench where you can import speaker data and, in addition, perform calculations in a workflow organized in separate programs in a so-called application suite. Today, we have:

- Collect Data From Measurements
- Calculate (Fit) Data
- Datasheet Creator
- Manual (which is just a link to a separate HTML webpage)

This way we can easily modify the structure of Speakerbench, add new functionality, and so forth. We have started with the listed applications, because it gives people access to the dual-added-mass method without first doing the

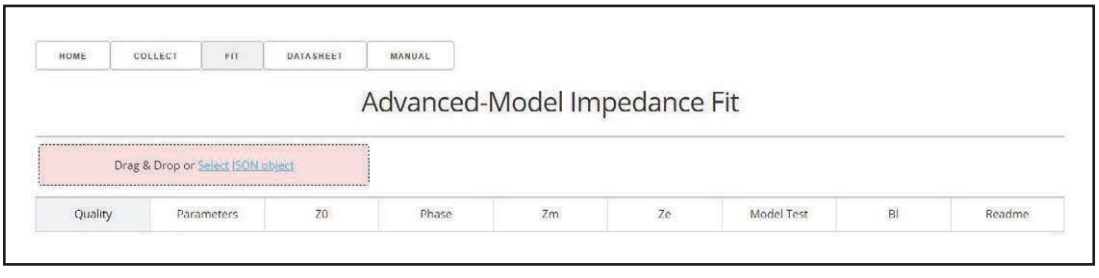


Figure 3: Fit Data can be uploaded via a file browser or a simple Drag & Drop into the red box.

Quality | Parameters | Z0

```
Fit quality      : EXCELLENT
Zero-mass error  : 0.11
Full-mass error  : 0.29
Electrical error : 0.58
Error (fail > 1) : 0.42

Datafile (JSON)  : ADV20200309_013154.json
```

Quality | Parameters | Z0

Parameter	Value	Unit
Re	5.72125	Ohms
Leb	0.125781	mH
L3	0.525458	mH
Le	1.17742	mH
Rss	562.405	Ohms
Ke	0.0386331	SH
Bl	7.00892	Tm
Mms	14.8959	g
R0	1.71396	kg/s
Rms	2.11006	kg/s
C0	0.784866	mm/N
Cms	0.840309	mm/N
beta	0.10336	
f0	45.7839	Hz
fs	44.985	Hz

Figure 4: Fit results. The first tab with "Quality" assessment is shown in a text console. You download the resulting file by clicking on the hyperlink, but you can also view the results directly in the Parameters table (the second tab).

programming by themselves, and because it lays out the foundation. We expect the capabilities to expand over time (to include, for example, a box simulation module).

Step 1: Collect Data. Since the input measurement data and additional information about the added masses all adds up to a handful of different information, we found it practical to collect all that information into a single file (see **Figure 2**). That's what we do in "Collect Data"—collect the following information:

- ZMA file containing impedance measurement of unweighted driver
- ZMA file containing impedance measurement of driver with added mass m_1
- ZMA file containing impedance measurement of driver with added mass m_2
- The value of m_1 in grams
- The value of m_2 in grams

The output from the first app is a single JSON container of all the data, which in our opinion is a nice and handy (elegant) way to collect all the information in a single file. The output file is generated as a hyperlink when the necessary input data is available (see the red boxes in Figure 2).

Step 2: Fit Data. The second application takes the previous JSON container with all your measurement data (including three impedance measurements and two added-mass values). This can be uploaded via file browser or a simple Drag & Drop into the red area in the image shown in **Figure 3**.

Once the file has been uploaded, the extraction of motional impedance and subsequent fit to our chosen small-signal model is immediately carried out (the server code executes on your computer). The first two output tabs show the fit quality and fit parameters (**see Figure 4**).

In the first tab you can read messages from the fit routine. We are trying to establish a good set of quality parameters such that we can give a simple thumbs up or down for the quality of the input data or the fit. This means you don't have to be an expert in analyzing the output from the fitter, because Speakerbench does it for you. This part is something we are still improving. The quality groups are: (1) EXCELLENT, (2) GOOD, (3) FAIR, and (4) FAIL.

The console also shows error metrics, which gives you (or at least us) an indication of what part of the fit was successful and (potentially) what part wasn't. Additional tabs contain information about the calculated advanced parameters and equivalent traditional T-S parameters. This collection of computed parameters (shown in Figure 4) is served as a JSON file for download.

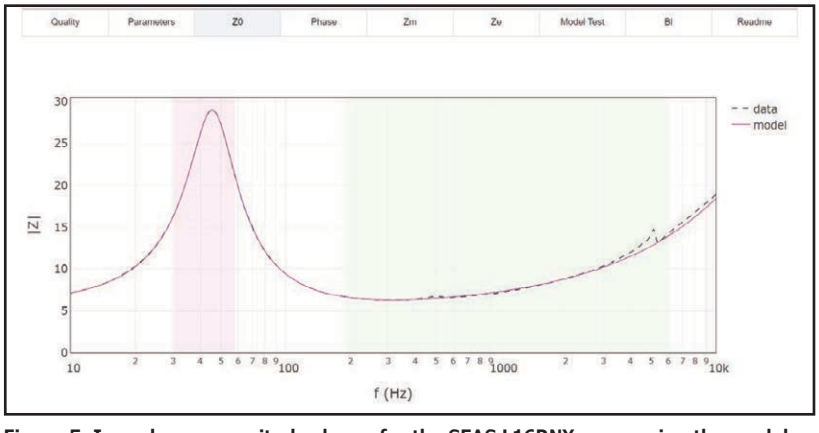


Figure 5: Impedance magnitude shown for the SEAS L16RNX, comparing the model (magenta curve) against the original data (dashed line).

Beyond the computed parameters, we provide numerous function plots for diagnostic purposes: total impedance, phase, motional impedance, electrical impedance, and more. Next, we discuss some of these plots.

Unweighted impedance and phase: These plots present the most basic model-versus-data comparisons for the unweighted measurements; namely the complex impedance magnitude (see **Figure 5**) and phase (see **Figure 6**). In these plots, the magenta shaded region indicates the motional fit range and the green shaded area the electrical fit range. It is readily apparent that the fit quality for the advanced driver model is far beyond that achievable from the traditional T-S approach.

Motional and electrical impedances: Extracting the motional and blocked-electrical impedances is a multiple-step process since neither can be measured directly. Untangling these two functions is highly problematic and the dual-added-mass approach was introduced to simplify this procedure.

By using three separate impedance measurements, it is possible to algebraically extract the motional impedance without any assumption about the creep compliance. For this reason, the motional impedance computed this way is referred to as the "model-free" motional impedance, Z_M*. The 3PC compliance model is then fit to the model-free motional impedance over a narrow region around the driver resonance. A comparison of these two curves for the SEAS L16RNX is shown in **Figure 7**, with excellent agreement over a wide frequency range (25 Hz to 100 Hz). Furthermore, the associated electrical impedance is shown in **Figure 8**.

The Bl force factor (motor strength): The model-free motional impedance extraction process allows us to algebraically compute a diagnostic Bl-curve. This is not to be interpreted as a Bl-versus-frequency dependence that exists in real life, as the force factor (Bl) should be a single value. Given the three impedance curves, we calculate a Bl estimate for each frequency

Resources

J. Candy and C. Futtrup, "An Added-Mass Measurement Technique for Transducer Parameter Estimation," *Journal of the Audio Engineering Society (JAES)*, Volume 65, Issue 12, December 2017.

C. Futtrup, "Benchmarking Viscoeleastic Models for Loudspeakers," *Loudspeaker Industry Sourcebook*, 2017, www.cfuttrup.com/LIS2017.pdf.

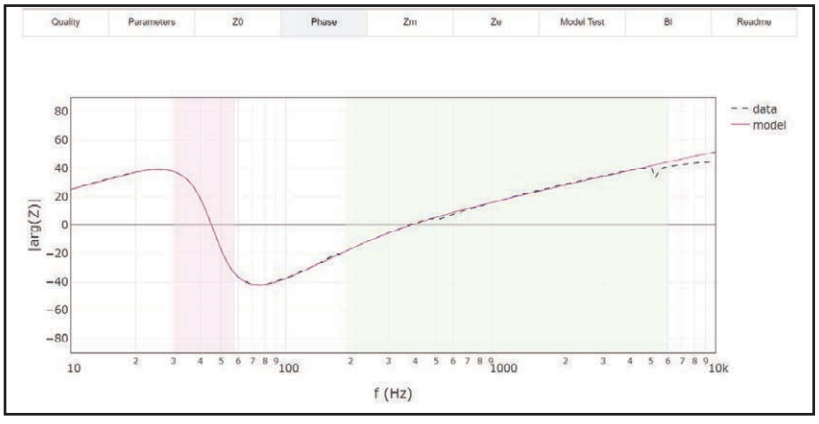


Figure 6: Impedance phase is shown for the SEAS L16RNX, comparing the model (magenta curve) against the original data (dashed line).

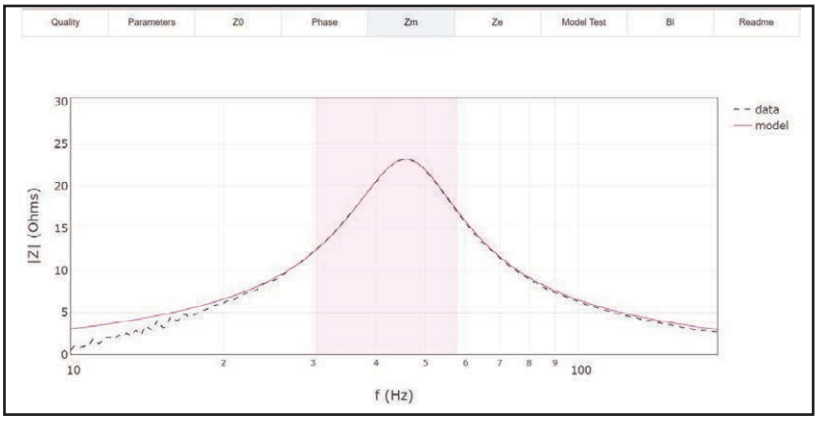


Figure 7: Motional impedance is shown for the SEAS L16RNX, comparing the model (magenta curve) against the (extracted) data. Even though the motional impedance cannot be measured directly, the dual-added-mass method can extract the motional impedance (Z_M*) from the total using the entire three-measurement dataset.

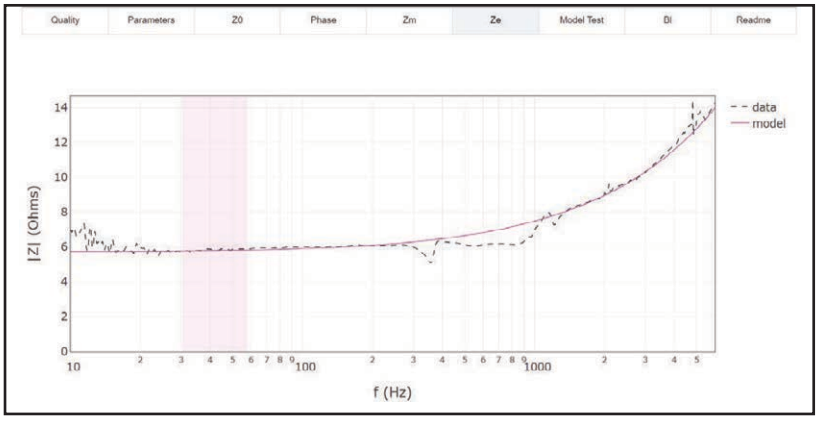


Figure 8: Electrical impedance curves for the SEAS L16RNX compare the model (magenta curve) against the (extracted) electrical impedance data $Z_E = Z\text{-}Z_M$. The data curve indicates the presence of driver resonances outside the scope of the model, as well as measurement artifacts.

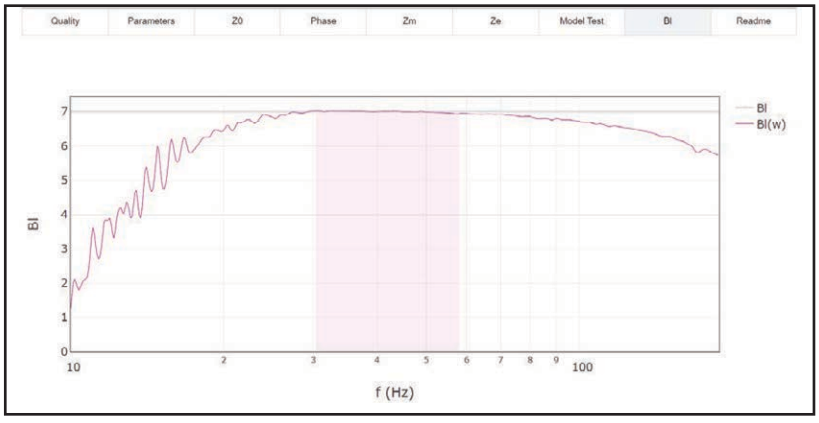


Figure 9: Diagnostic Bl-versus-frequency curve for the SEAS L16RNX. The constancy of this curve over the shaded region gives an indication of overall quality of the input data used for the subsequent fit. The grey horizontal line indicates the best estimate of Bl = 7.01 Tm based on simple average over the fit region.

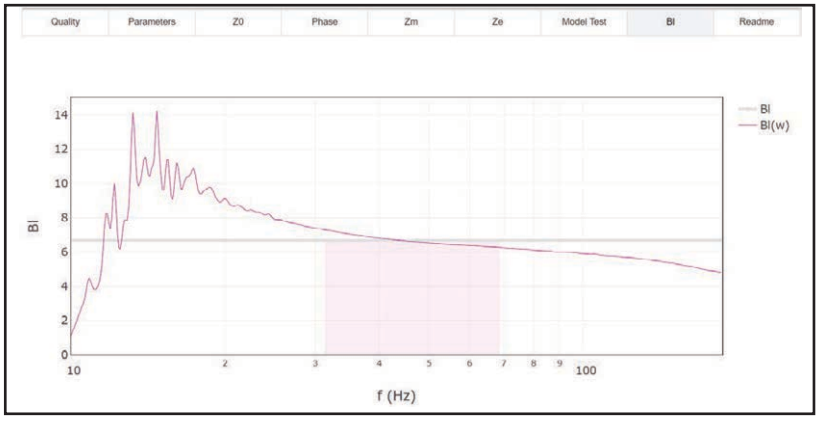


Figure 10: Bl-versus-frequency curve for one of the discarded cases from our Gage R&R analysis. Within the focus area, the Bl variation of 6.2-7.3 Tm is too big a window (±8%) to guarantee that Bl is determined with acceptable precision.

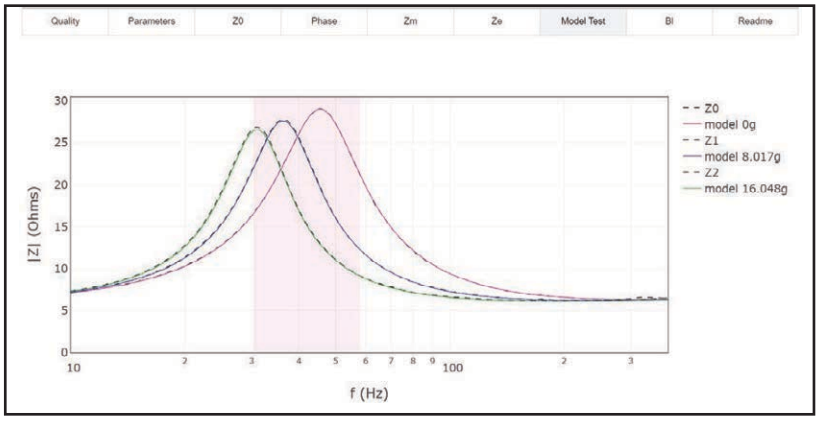


Figure 11: The model performance test compares model prediction of all three impedance measurements against original data. Shown are the unweighted case (magenta), the case with added mass m_1 (blue) and the case with added mass m_2 (green). The difference in peak height between the three measurements is due to frequency-dependent damping and is a consequence of viscoelasticity.

separately. Ideally, this curve should be flat through the focus area around the resonance frequency in free air, and if that's fulfilled, and the overall fit looks good too, then the average value will represent a very precise identification of the true Bl-value (see **Figure 9**).

However, if the curve has a slope, as illustrated in **Figure 10**, then something in your measurements isn't exactly right. Bear in mind that with these calculations we assume that the moving mass is a constant. This implies that radiation impedance (air load) is assumed to be constant in the frequency range of interest. So, constant mass means you cannot push your driver too hard, and if a driver has a stiff suspension and soft cone, such that the cone is bending and essentially is just as much part of the suspension, then these conditions are not met.

If the anomaly is of fairly mild character, you can still get a good measure of the Bl-value, but depending on the anomaly, then additional tolerances are implied. If the Bl-curve has a strangely nonlinear character and doesn't pass through the estimated average Bl-value at the resonance frequency, but seems off, then it's a clear sign of a faulty measurement. Please check that your added masses are securely attached and their movement essentially follows the voice coil's movement.

Model test: Speakerbench also generates a key performance test, in which model predictions of impedance are plotted for (1) the computed value of M_{MS}, (2) $M_{MS}+m_1$, and (3) $M_{MS}+m_2$. These three model curves are then overlayed with the raw data. If you see three curves neatly on top of three dashed lines, then the fit (solid lines) agree nicely with your measurements (dashed lines), as shown in **Figure 11**. We focus on the free-air measurement without added mass, so most likely the first deviations you'll see are for the measurement with the highest amount of added mass. Here measurement and simulation might deviate by the peak of the impedance, or alternatively one of the slopes.

If the peak impedance for the curve with the highest amount of added mass is measured lower than simulated (as shown in **Figure 12**), the reason could be that you're not entirely in the small-signal domain. What might cause this is if the speaker is moving at a fairly high excursion and some increase in stiffness at the extremes causes the driver to brake, which causes a higher draw of current from the amplifier, which is then reflected as lower impedance in your measurement. The solution may be to reduce the input voltage

(perhaps try half the voltage, equal to one quarter the input power).

If there's a gap between measurement and fit down the sides of the peak above the individual resonance frequencies as shown in **Figure 13**, then this could be another alarming observation which could disqualify the measurement or the fit. We're not so worried if the deviation is below the lowest resonance frequency and we can expect sometimes to see some deviations "creep" in here. The desire for a good fit at higher frequencies is due to our focus on box simulations and this means the fit should look good here, which again means the data and fit is suitable for extrapolation into the higher frequency range (because the resonance of the speaker in the box is normally higher than the free-air resonance frequency).

Datasheet Creator

After all that effort with measuring one additional impedance curve and finding the parameters, not just classic T-S, but the advanced parameters from the advanced model, you stand sort of empty-handed at the moment. What do you do with it?

Well, for now we are focusing on doing the parameter identification as consistently and robustly as possible. You can download a finished datasheet by putting the results from the data fitting into our Datasheet "Creator;" nothing more than just a way to specify additional information about the driver. The relevant parts being the area of the cone, and the properties of air, such that V_{AS} can be calculated, but also some description of the measured object, etc.

In the near future, a box calculation module that implements our proposed transducer model will be added to Speakerbench. One will be able to drop the object prepared from the Datasheet Creator directly into the box module. The usual calculations (SPL, excursions, vent velocities, etc.) will be done automatically. ***LIS***

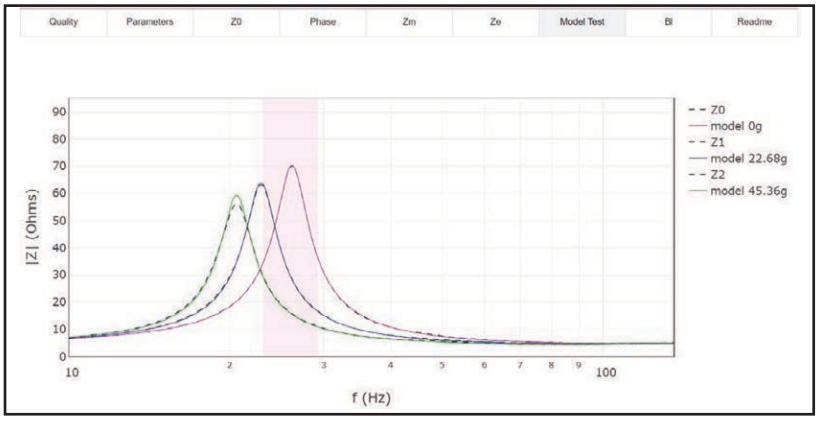


Figure 12: In this example of a 10" woofer, driven with an additional 45.4 grams of added-mass at 500 mV, we see that the dashed curve peaks a bit less than what was predicted by the linear model (green solid curve). The deviation is not significant and this particular fit is still qualified as GOOD, but not excellent.

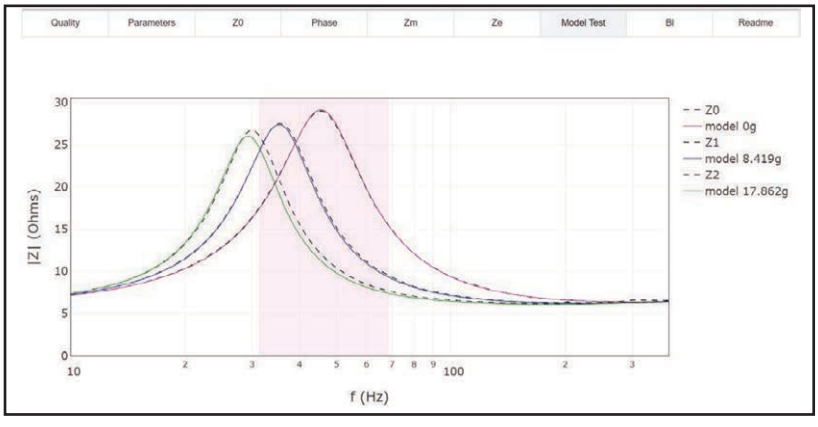


Figure 13: This example of the SEAS L16RNX is one of the discarded measurements from the Gage R&R analysis of our Audio Engineering Society (AES) paper. We suspect the m_2 added-mass was not properly attached. The large difference between measurement and simulation inside the focus area (purple rectangle) is a clear indication of a bad fit or a bad set of input data.

Authors' Note: We welcome other developers of software to implement the dual-added-mass technique or to import our fit results into their measurement or box simulation, such as Room EQ Wizard (REW) or Vituix CAD.

About the Authors

Claus Futtrup was born in Herning, Denmark, in 1971. He received his M.Sc. in mechanical engineering in 1997 from Aalborg University. His special field is material science; steel and other metals, ceramics, rubber, plastics, and composites in regard to design parameters, process engineering, and chemical and environment issues. During his career, he has worked for several loudspeaker companies. From 1997 to 2006, he worked at Dynaudio A/S first as an R&D Engineer, designing loudspeaker boxes and later as a System Engineer for automotive. From 2006 through 2007, he was employed as a Transducer Design Engineer at Tymphany Denmark and, in 2008-2013 he was R&D Manager at Scan-Speak. In 2013, he started working as Technical Sales Manager for SEAS, Norway, and in 2015 he was promoted to Chief Technical Officer.

Jeff Candy was born in Edmonton, Canada in 1966. He received his Ph.D. in Physics from the University of California, San Diego in 1994, and is currently manager of the Turbulence and Transport Group at General Atomics in San Diego, CA. At General Atomics, he works on various topics in theoretical and computational plasma physics, with specific focus on plasma kinetic theory and turbulence. In the field of audio, he is interested in the application of methods in theoretical acoustics to practical situations. Candy is a member of the Audio Engineering Society and a fellow of the American Physical Society (APS).

The MEMS Micro Loudspeaker

Concept, Technology, and Applications

In this article, USound's co-founder/managing director details a concept that uses piezoelectric benders to generate the force necessary to move an acoustic membrane.

By
Andrea Rusconi Clerici
(Managing Director and CTO, USound GmbH)

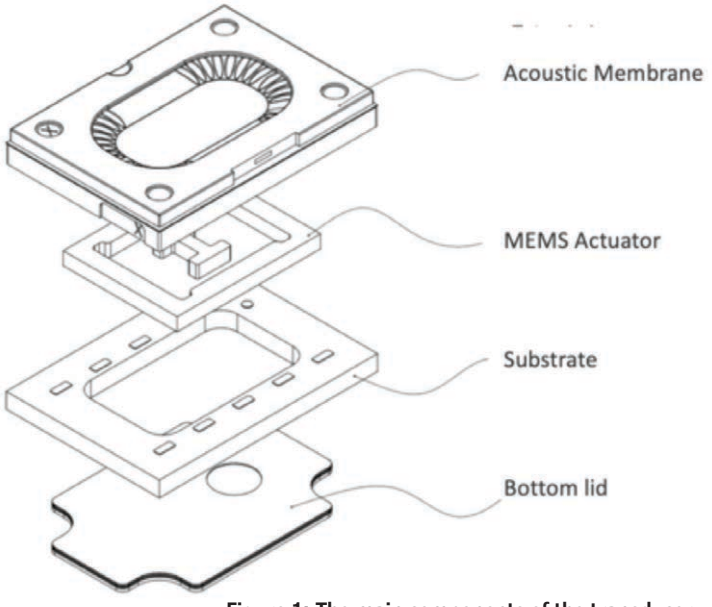


Figure 1: The main components of the transducer include: the MEMS chip, the membrane, the substrate, and the bottom lid.

In the past three decades, microelectronics R&D progress has been focused on Integrated Circuit (IC) miniaturization down to nanometer dimension and System on Chip (SoC) integration, which has led to outstanding results in products and services for users. The best way to summarize this roadmap is with the Moore's Law, which is the observation that the number of transistors in a dense IC doubles about every 18 months, driving up computing power and driving down costs.

In parallel to this trend, there is ever-increasing awareness, R&D efforts, and business drivers to push the development and the application of "More than Moore" (MtM) concepts that are derived from silicon technologies but do not scale with Moore's law.

This emerging trend is trigged by the increasing need to pair computing power with analog sensory functionalities able to interact with the environment but still fully integrated into a digital system. The goal is to realize systems that are sensitive and responsive to the environment and to the presence and needs of people. A key enabler for such applications is the ability to integrate diverse microfabrication technologies with complementary functions in a system up to a direct interface to the human body or environment.

Microelectromechanical systems (MEMS) play a fundamental role in this trend with a number of successful applications in consumer, automotive, medical, and industrial fields. This is the environment in which audio MEMS have been developed. With MEMS microphones now widely adopted in many fields of application—looking at smartphones and hearables—they are enabling advanced system functionalities and have been successfully integrated thanks to their small form factors and for being reflow solderable thus compliant with surface-mount technology

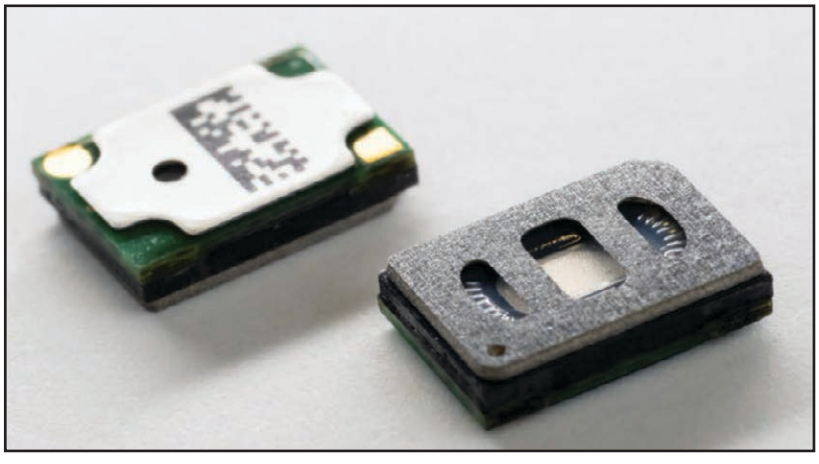


Photo 1: This is a MEMS speaker, using a MEMS die as a driving element.

(SMT) manufacturing processes. Very similar key advantages are true for MEMS microspeakers, with the goal to enable new product roadmaps outperforming traditional voice coil transducers.

MEMS Speaker Architecture and Performances

There are different ways to generate sound waves based on silicon transducers, including analog and digital approaches. Here we will describe the concept developed by USound GmbH, which uses piezoelectric benders to generate the force necessary to move an acoustic membrane.

There are four main MEMS technology developments and roadmaps that make a new generation of speakers and ultrasound transducers possible. Those technology and design innovations are:

- Microfabrication technology: piezoelectric materials thin film deposition on silicon; maximized material properties and performances; high deposition rates at low costs; availability at silicon foundries
- Assembly techniques: enable heterogeneous technology integration into modules
- Device design: advanced design and F.E.M. tools; design for manufacturing and testing.
- System design: efficient driving of piezo actuators; enable new integration concepts and applications

The convergence of these innovations makes MEMS devices able to produce high acoustic pressure levels and sensitivity per unit area; enables precise manufacturing of miniaturized transducers; makes possible radical innovation in smart system designs by integrating electronics circuits (ASIC), transducers, and passives in very small and thin form factors; leverages a low-cost, scalable manufacturing infrastructure; enables roadmaps in both device performances and cost reduction.

The biggest challenge for generating high sound pressure levels (SPLs) in a tiny form factor is to be able to generate large forces and elongations in a linear way. This has always been too much of a problem for MEMS technologies and one of the reasons why silicon transducers have been mostly limited to sensing. This has changed in the last couple of years with the advent of new materials, in particular thin film piezo ceramics with high piezo coefficients.

The MEMS microspeaker is based upon three building blocks: a MEMS linear motor realized on silicon with piezo actuation; an integrated package with acoustic emitting surface (a membrane and a stiffening plate); and an ASIC power amplifier for efficient driving.

PZT (Lead-Zirconate-Titanate) is the material among piezo ceramics that can generate enough energy per unit area—thus mechanical force and elongation—to compete with standard voice coil

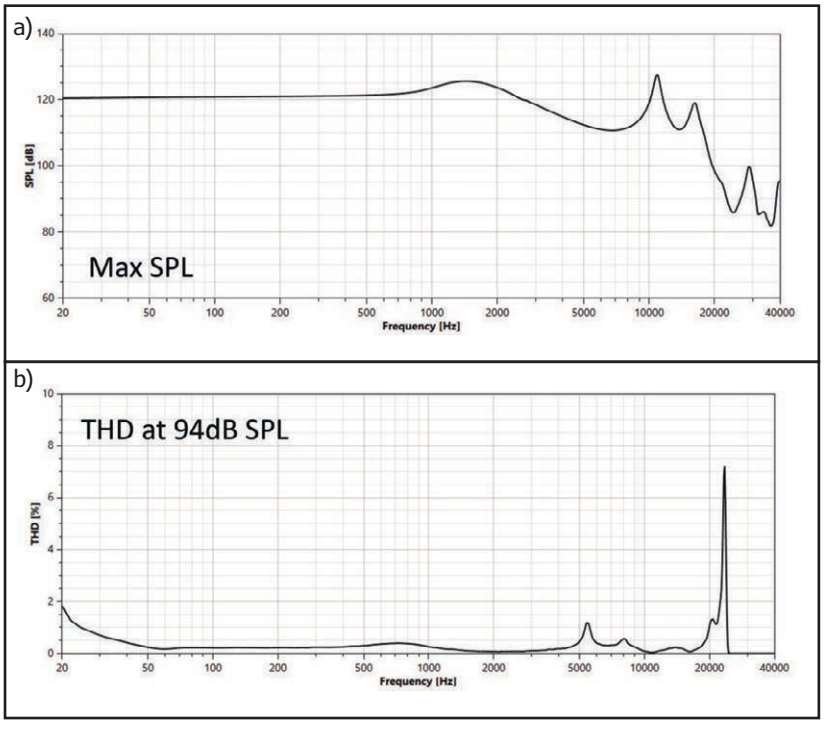


Figure 2: The maximum SPL of a MEMS speaker up to 40 kHz (a) and THD at 94 dB SPL (b).

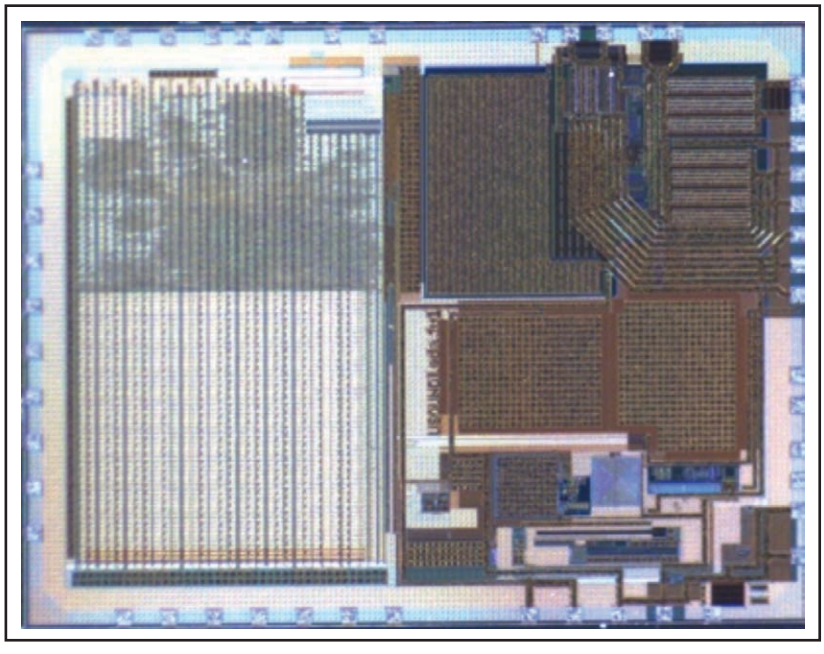


Photo 2: Here is an image of a mixed signal silicon audio amplifier.

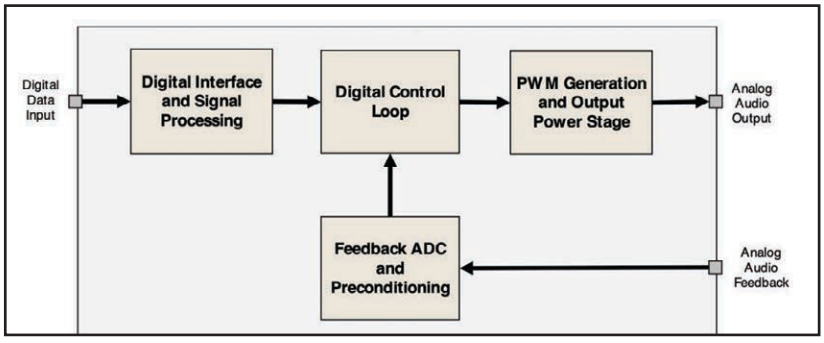


Figure 3: This is the basic block diagram for a MEMS speaker's audio amplifier.

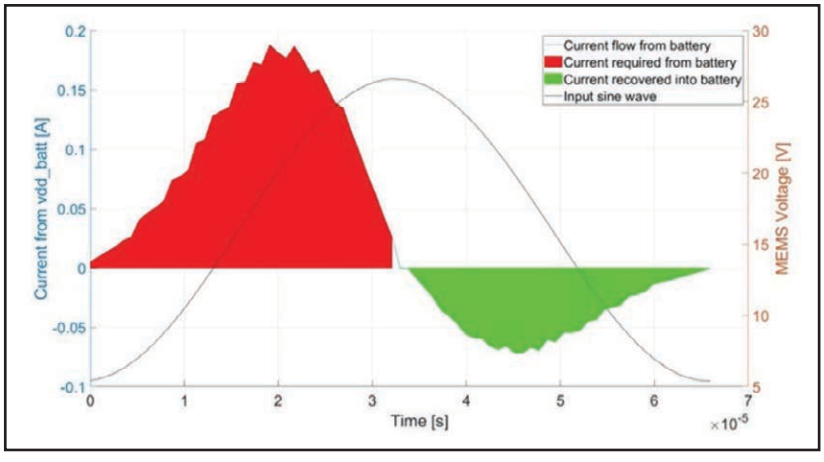


Figure 4: Current flow during one sine wave period shows the energy recovery functionality.

transducers. The MEMS motor is realized on silicon using multiple piezoelectric actuators connected together to realize a precise vertical out-of-plane movement. These trends are clearly pushed by technology development and expressed in more than a decade research on thin film deposition of piezoelectric materials, in particular PZT and ScAlN (Scandium-Aluminum-Nitride). But the technological breakthrough alone is not enough to produce a radical innovation, it is necessary to marry it with new concepts of device design and application.

A key technical innovation is to integrate the MEMS actuator chip with an acoustic membrane at package level. The main reason is that the emitting surface must be as large as possible for maximizing SPLs, which is in contrast with the cost structure of MEMS manufacturing where the area used on wafer is the main driver.

To the contrary, typical polymeric membranes used in acoustics are inexpensive with costs barely sensitive to their surface area. Also, by decoupling MEMS and membrane one can optimize the design characteristics of both without a trade-off on performance. In particular, the MEMS have to have an open structure to generate large forces and elongations with high linearity performances. **Figure 1** shows the exploded view of the concept, highlighting the main components: the MEMS, membrane, the substrate, and the bottom lid. **Photo 1** shows the actual component.

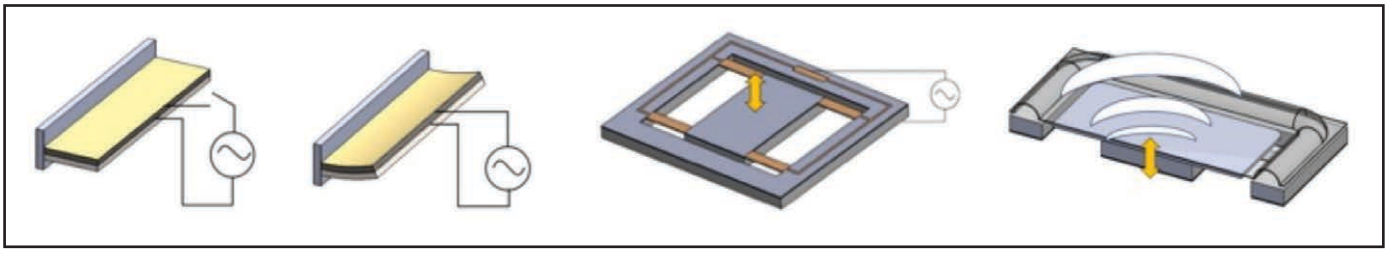


Figure 5: The schematic concept of a MEMS speaker uses a cantilever principle for driving an acoustic membrane.

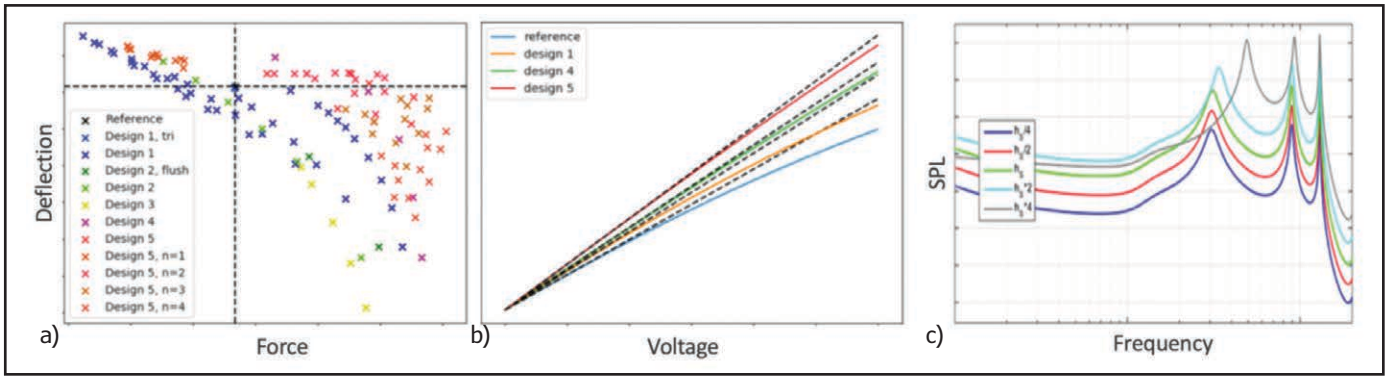


Figure 6: Design iterations for optimizing key transducer parameters include: force (a), voltage (b) and frequency (c).

In **Figure 2**, the main acoustic performances of a MEMS loudspeaker is measured in a 711 Coupler (2 cm^2 hear simulator).

The amplifier is a closed-loop system with digital loop control. The input for the loop control is the digital audio input signal and the digital value of the current output voltage, provided by the feedback ADC. The digital control loop sends the input signal to a pulse width modulation (PWM) stage. The required output voltage is defined by changing the pulse width. The output power stage provides the high voltage required at the speaker (up to 30 V_{PP}).

For typical audio applications, there is the ability to configure all the important settings such as digital filter settings, predistortion coefficients, DC offset voltages, and gain settings. A hybrid can also be implemented (e.g., one where the configuration is stored outside the audio module and is transferred to the module during startup). **Photo 2** shows the mixed signal silicon chip. **Figure 3** provides the basic block diagram of the audio amplifier.

A key feature of the amplifier is the energy recovery functionality to reduce overall power consumption, especially at high amplitudes. A novel energy recovery architecture is included inside the output driving stage. **Figure 4** shows the current flow based on a schematic-based system simulation during one sine wave period. During the rising phase of the sine wave, energy is transferred to the MEMS speaker; during the falling edge, the energy is recovered and brought back to the system. The maximum peak efficiency during charging is up to 80% and close to 70% during discharging.

PZT Thin-Film MEMS Speaker Modeling and Design

By definition, a piezoelectric material will show a change in physical volume when an electrical field is applied and generates a charge when deformed. PZT is the most widely used piezoelectric material in MEMS actuator (e.g., it is used in inkjet head printers, micromirror scanners, and autofocus lenses for smartphones). Its adoption is thanks to high piezoelectric coefficients, which enable designs with large actuating forces and displacements.

An electric field is applied to a piezoelectric cantilever that consists of two layers: an active layer and a passive layer. One side of the structure is fixed, which results in a displacement of the opposite side. There is an even number of cantilevers (2, 4, or 6) arranged in a symmetric way and connected in the middle to a central structure via spring elements. The resulting mechanical movement is perfectly vertical ("piston mode") and is used to move a membrane and to generate the acoustic output of the speaker. The magnitude of the movement depends on the polarization of the material as well as the applied voltage (see **Figure 5**).

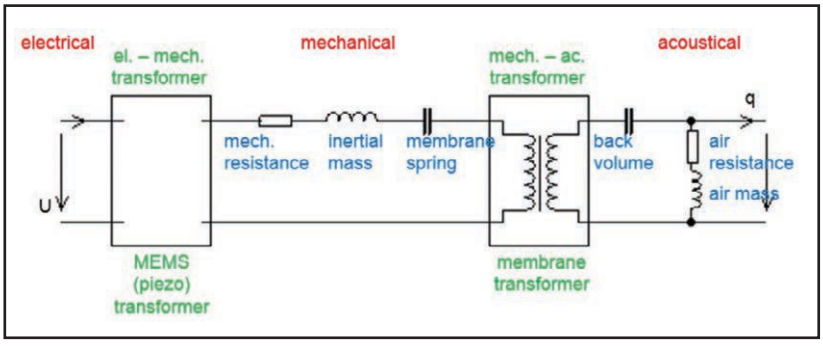


Figure 7: Here is a simplified equivalent circuit of a piezo electric loudspeaker with FU and pF analogy.

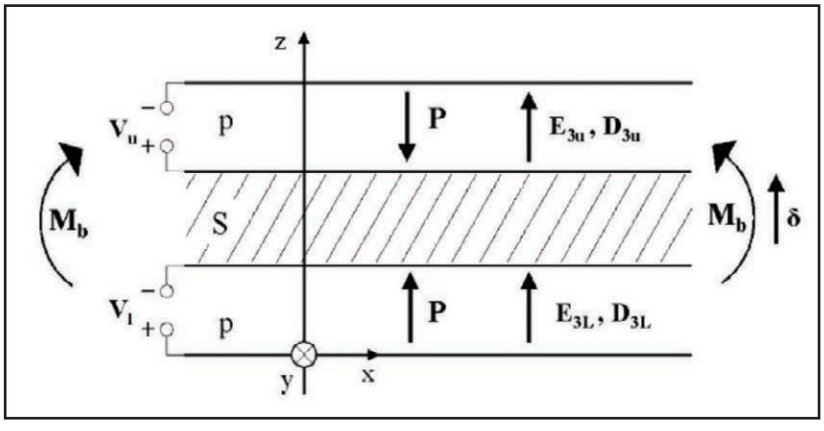


Figure 8: The crosscut of the actuator beam defines the directions of the variables and parameters. Note that in the following derivations the lower piezo layer is not existent; realized by setting its thickness to 0.

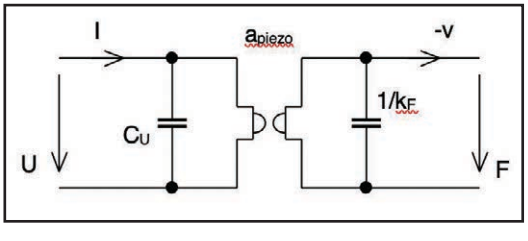


Figure 9: An intuitive way to put the transition matrix into a model is by use of a gyrator.

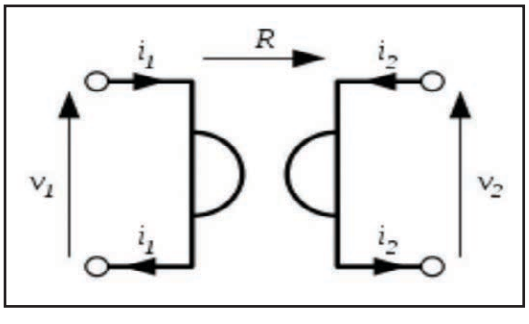


Figure 10: The symbol and the circuit of a gyrator is shown with the gyrator constant R.

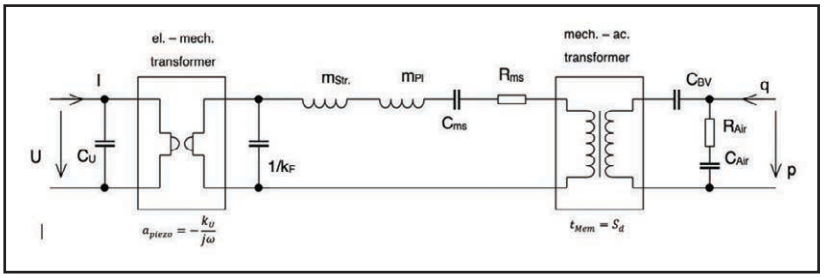


Figure 11: The drawing shows the model of a speaker radiating in free field.

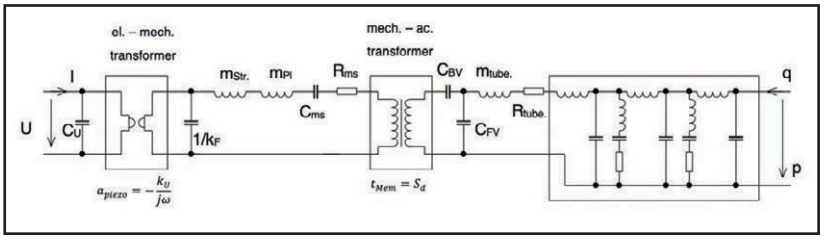


Figure 12: Here is the model of a speaker radiating in coupler (ear simulator).

Parameter	Coefficients [units]
Relative Permittivity	ε_{33}
Length of the piezo layer	l_{PZT} [mm]
Width of the piezo layer	w_{PZT} [mm]
Thickness of the piezo layer	h_p [µm]
Thickness of the passive layer	h_s [µm]
Piezo electric coefficient / constant	d_{31} [C/N]
Elastic constant (with short circuited) piezo	s^p_{11} [m²/N]
Elastic constant of the Poly-Si layer	s^s_{11} [m²/N]
Volume of the MEMS Structure in the middle	V_{Str} [mm³]
Mass of Plate	m_{Pl} [kg]
Compliance of the membrane	C_{ms} [mm/N]
Friction of the mechanical system	R_{ms} [Ns/m]
Membrane size	S_d [mm²]
Back volume	V_{BV} [mm³]
Front volume	V_{FV} [mm³]
Length of the tube	l_{tube} [mm]
Diameter of the tube	d_{tube} [mm]
Permittivity of vacuum	ε_0
Density of the Structure (silicon)	ρ_{Str} [kg/m³]
Velocity of sound in air	c [m/s]
Density of air	ρ_{air} [kg/m³]

Table 1: The table provides a description of model parameters.

To design the speaker the engineering task is to maximize three main performance parameters: elongation, force, and linearity. **Figure 6** shows examples of how design iterations are aiming for improving the force/elongation trade-off (left), how to evaluate and improve linearity (center) and parameters variations to optimize the SPL audio output.

The lack of tools for modeling large-signal piezoelectric MEMS devices have been an important early stage challenge for the development. Now the devices can be modeled and simulated in the acoustical, mechanical, and electrical domains, both analytically and numerically. Input are electrical parameters, material properties, geometry, and design; output are excursion, force, velocity, SPL, and impedance.

The schematics in **Figure 7** show the building blocks of a lumped parameter model of the piezo MEMS transducer for generating sound pressure radiating into free air.

For a loudspeaker, the input is given at the left side in the electrical domain. Most of this model is well known and used in the industry for electrodynamic speakers, the innovative part of our work in this field has been to develop a proper piezo transformer applied to MEMS bending actuators to translate the electrical signals into mechanical movement.

Two-Port Linear Model for Piezo Benders

In the piezoelectric effect the mechanical strain *S* and the dielectric displacement *D* are described by the constitutive piezoelectric linear equations, which can be written using the Voigt notation, as:

$$S_1 = s_{11}^E \times T_1 - d_{31} \times E_3 \quad \textbf{(2.1)}$$

$$D_3 = -d_{31} \times T_1 - \varepsilon_{33}^T \times E_3$$

The index 1 means x and 3 means z. This nomenclature is typical in this field.

S_1 Strain in x direction [-]
S_{11}^E Compliance of the piezo in x direction with no electrical field (E3=0, U=0) [m²/N]
T_1 Tension in x direction [N/m²]
d_{31} Piezoelectric constant, piezoelectric charge constant [m/V]
E_3 Electric field in z direction [V/m]
D_3 Electric displacement in z direction [C/m² = N/(v x m)]
E_{33}^T Dielectric constant in z direction with no tension(T_1=0, F=0) [F/m = N/V]

The direction of each component is defined using the following convention for a bending plate composed by a structural layer and two piezoelectric layers, one on each side of the structural layer (see **Figure 8**). The goal is to derive formulas based on (2.1) in the form of:

$$\Delta z = \frac{1}{k_F} \times F + \frac{1}{k_U} \times U \quad \textbf{(2.2)}$$

$$Q = c_F \times F + c_U \times U$$

Δz Deflection of the piezo in z direction relative to the idle position [m]
F Force acting on the piezo [N]
U Voltage through the piezo [V]
Q Charge going into the piezo [C=As]

With that we can easily derive the typical two-port model:

$$\Delta z = \frac{v}{j\omega} \text{ and } Q = \frac{I}{j\omega}$$

$$v = \frac{j\omega}{k_F} \times F + \frac{j\omega}{k_U} \times U$$

$$I = j\omega \times c_F \times F + j\omega \times c_U \times U$$

This results in:

$$\begin{bmatrix} I \\ v \end{bmatrix} = Y \times \begin{bmatrix} U \\ F \end{bmatrix}$$

$$\begin{bmatrix} U \\ I \end{bmatrix} = A \times \begin{bmatrix} F \\ -v \end{bmatrix}$$

$$Y = \begin{bmatrix} j\omega \times c_U & j\omega \times c_F \\ \frac{j\omega}{k_U} & \frac{j\omega}{k_F} \end{bmatrix}$$

$$A = \begin{bmatrix} -\frac{k_U}{k_F} & -\frac{k_U}{j\omega} \\ -j\omega \times \left(\frac{k_U \times c_U}{k_F} - c_F \right) & -k_U \times c_U \end{bmatrix}$$

The system is solved for a MEMS cantilever with one piezo layer and one passive layer. The following general assumptions are applied:

- The bender behaves like the Euler-Bernoulli-beam-theory says
- There is no slip between the layers
- The beam is in a static equilibrium. This just holds for the pure piezo model and not for dynamic movement but can be extended to dynamic behavior.

With all the coefficients known, the two-port matrix is fully defined as:

$$k_F = \frac{(K \times w)}{2 \times s_{11}^p \times s_{11}^s \times (h_s \times s_{11}^p + h_p \times s_{11}^s) \times l^3};$$

$$k_U = -\frac{K}{3 \times d_{31} \times s_{11}^s \times s_{11}^p \times h_s \times \left(h_s + h_p\right) \times l^2}$$

$$c_U = \frac{\left(K \times \varepsilon_{33} \times \varepsilon_0 - d_{31}^2 \times h_s \times \left(h_s^3 \times s_{11}^p + h_p^3 \times s_{11}^s\right)\right) \times w \times l}{h_p \times K};$$

$$c_F = -\frac{1}{k_U}$$

$$K = h_s^4 \times s_{11}^{p\,2} + h_p^4 \times s_{11}^{s\,2} + 2 \times h_s \times h_p \times s_{11}^s \times s_{11}^p \times \left(2 \times h_s^2 + 3 \times h_s \times h_p + 2 \times h_p^2\right)$$

This results in:

$$\begin{bmatrix} U \\ I \end{bmatrix} = A \times \begin{bmatrix} F \\ -v \end{bmatrix}$$

$$A = \begin{bmatrix} -\frac{k_U}{k_F} & -\frac{k_U}{j\omega} \\ -j\omega \times \left(\frac{k_U \times c_U}{k_F} + \frac{1}{k_U} \right) & -k_U \times c_U \end{bmatrix}$$

$$U = -\frac{k_U}{k_F} \times F + \frac{k_U}{j\omega} \times v$$

$$I = -j\omega \times \left(\frac{k_U \times c_U}{k_F} + \frac{1}{k_U} \right) \times F + k_U \times c_U \times v$$

For visualization it helps to not just have a transition matrix but to also have a lumped parameter model representation as with all other parts of the system chain. There is more than one way to put the transition matrix from before into a model. A quite intuitive version is the one shown in **Figure 9** by use of a gyrator.

With:

$$a_{piezo} = \frac{-k_U}{j\omega}$$

as the gyrator constant and CU = cU and the mechanical compliance $\frac{1}{k_F}$.
Note: A gyrator transforms voltage in current and vice versa (directions according to **Figure 10**– with the gyrator constant "R", in this document "a" will be used):

$U_1 = -a \times I_2$
$U_2 = a \times I_1$

In **Figure 11**, the assembled system model is drawn with the speaker radiating into free air. Starting left with the electrical domain going through the piezo transformer into the mechanical domain, via the MEMS actuator connected to the membrane into the acoustical domain. In **Figure 12**, the assembled system model is drawn with the speaker directly connected to the coupler (ear simulator).

Table 1 provides a description of model parameters. Linear models are valid only in first approximation as ferroelectric piezo materials like PZT display nonlinear behaviors in polarization and strain. If the driving signal is

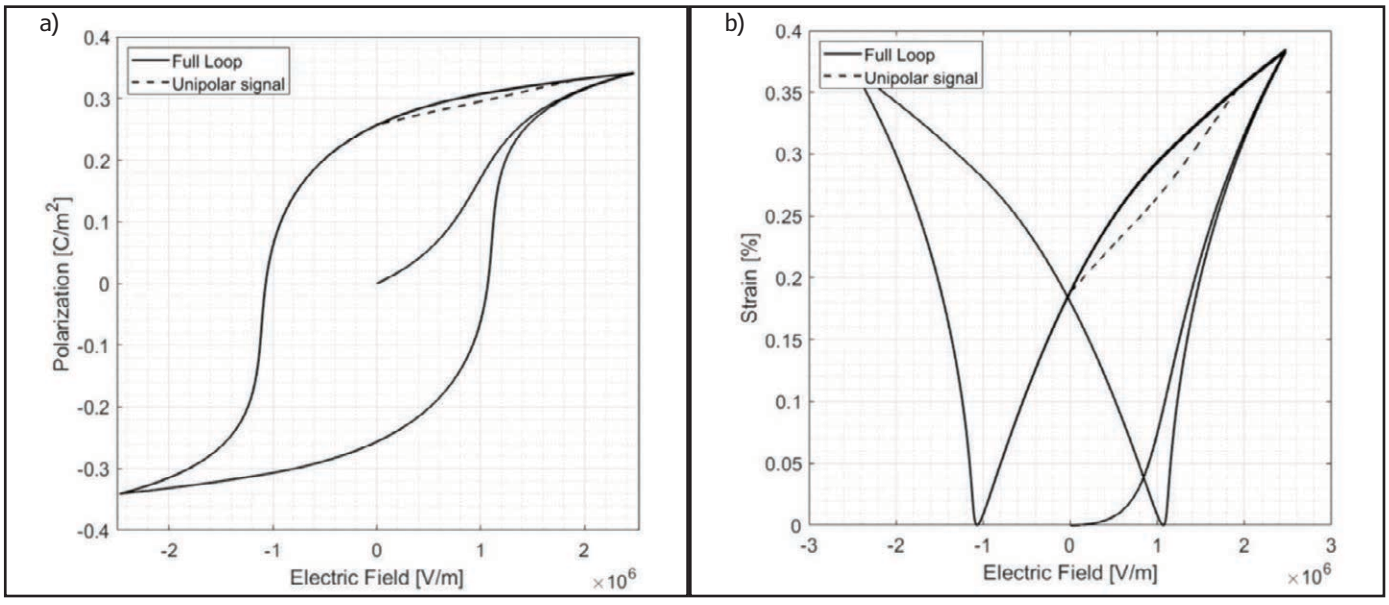


Figure 13: These drawings show the polarization loop (a) and strain loop (b) for a typical PZT thin film.

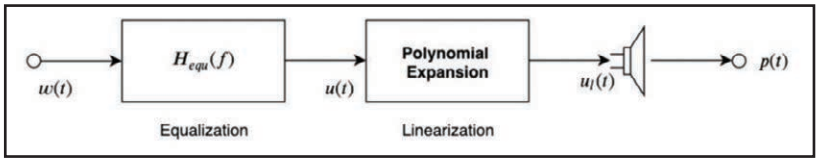


Figure 14: The system's signal flow chart is shown with polynomial pre-distortion.

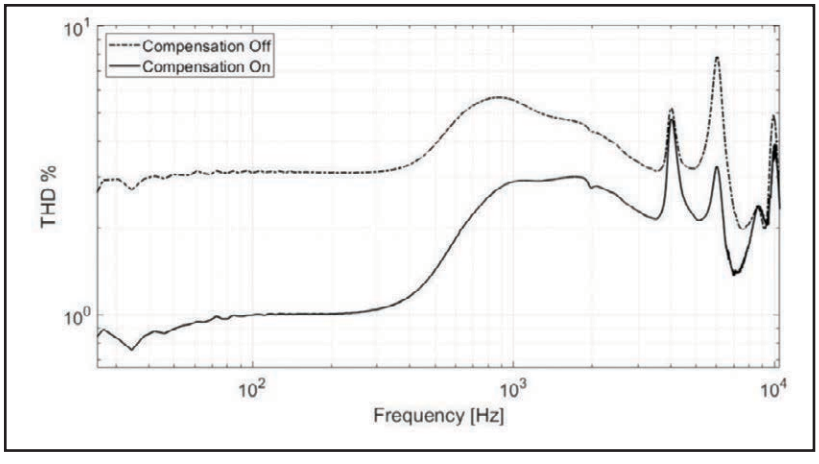


Figure 15: The acoustic THD in a 711 Coupler is shown with and without polynomial pre-distortion at 118.5 dB SPL.

About the Author

Andrea Rusconi Clerici has 20 years experience in the MEMS industry being involved in technology R&D, product design, manufacturing, engineering, and operations, ranging from new technology IP development to mass production. He has experience in research (Fraunhofer Institute), large companies (STMicroelectronics and Maxim Integrated) and start-ups (Sensordynamics and USound). He co-founded USound with the mission of bringing MEMS-based microspeakers to the market, he now serves as USound's Managing Director and CTO.

bipolar and, therefore, the electric field between electrodes changes its sign, the material exhibits a polarization switch. The electric field needed for the PZT to switch its polarization when the signal is increasing is different from the electric field needed when the signal is decreasing. This means that the polarization behavior is hysteretic. The consequence on the strain, which is to a first approximation proportional to the square of the polarization, is shown in **Figure 13**, with a cycle that, because of its peculiar shape, is often referred to as a butterfly loop. However, by applying a DC offset to the signal, it is possible to avoid the polarization switch. In this case, as can be seen from the small loops in Figure 13, the system presents only small hysteretic behavior and the nonlinearities are greatly reduced. Therefore, PZT loudspeakers are always driven with a DC offset combined with the desired acoustic signal.

Still, the piezoelectric coefficients are proportional to the state of polarization of the material, therefore, the polarization directly influences the electro-mechanical coupling and the remaining nonlinearities in the material will cause a nonlinear response of the transducer. Such nonlinearities are acoustically measurable in terms of THD and have to be added to other mechanical nonlinearities inherent of the MEMS actuator design and membrane. For reference, in traditional voice coil loudspeakers the main causes of harmonic distortion are the nonlinear Bl factor (force factor), the non-linear inductance of the coil, and the nonlinear stiffening of the membrane.

To link the electrical and mechanical nonlinearities can make the approximation that the elongation of the transducer is proportional to the tensor of the piezoelectric module, which is nonlinear with respect to the applied electric field and inversely proportional to the stiffness of the device, which is nonlinear with respect to the elongation itself. This can be written as:

$$x\alpha - \frac{e_{31}(V)}{K_x}V$$

This relation can be used to model, within a good approximation, the nonlinear behavior of the speaker and to compute a linearization of the system. The nonlinear factors are modelled approximating the real behavior with polynomial fits and the compensation can be fitted into a polynomial expansion. This method is convenient because it is easily implementable in the digital signal processing (DSP) block. **Figure 14** shows the system's signal flow charts with the main blocks being the equalization filters and the polynomial pre-distortion.

The effect of the compensation can be seen in **Figure 15**, which details the acoustic measurements of the speaker in an ear simulator (GRAS 43 AC Coupler), at a sound pressure level of 118.5 dB SPL at 1000 Hz. The efficiency of the compensation is particularly good below resonance frequency where the mechanical behavior is dominated by stiffness.

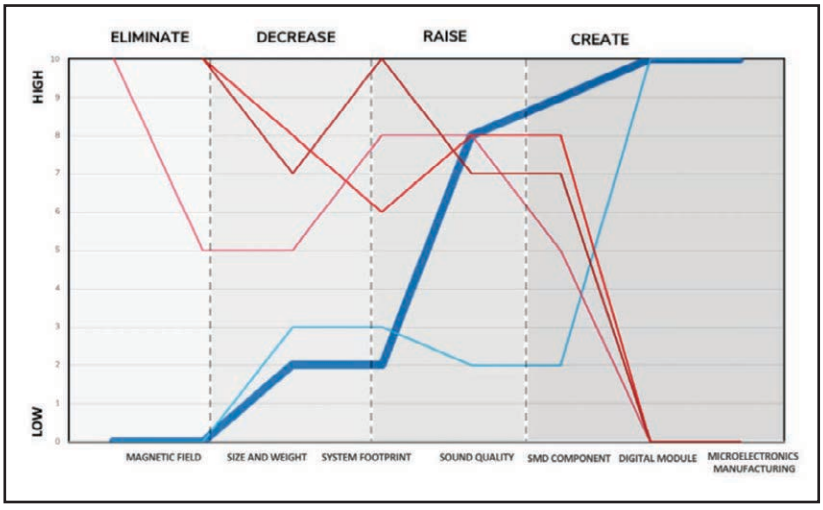


Figure 16: This ERRC Grid explains the value proposition of MEMS speakers. USound's technology value proposition is shown in dark blue and the voice coil speaker solutions are shown in red.

MEMS Speakers Compared to Electrodynamic Microspeakers

Compared to microspeakers based on voice coils, piezo MEMS are superior in three categories: sound quality, form factor, and system integration.

Sound quality: The piezo linear motor is faster and more precise than a voice coil, for in-ear

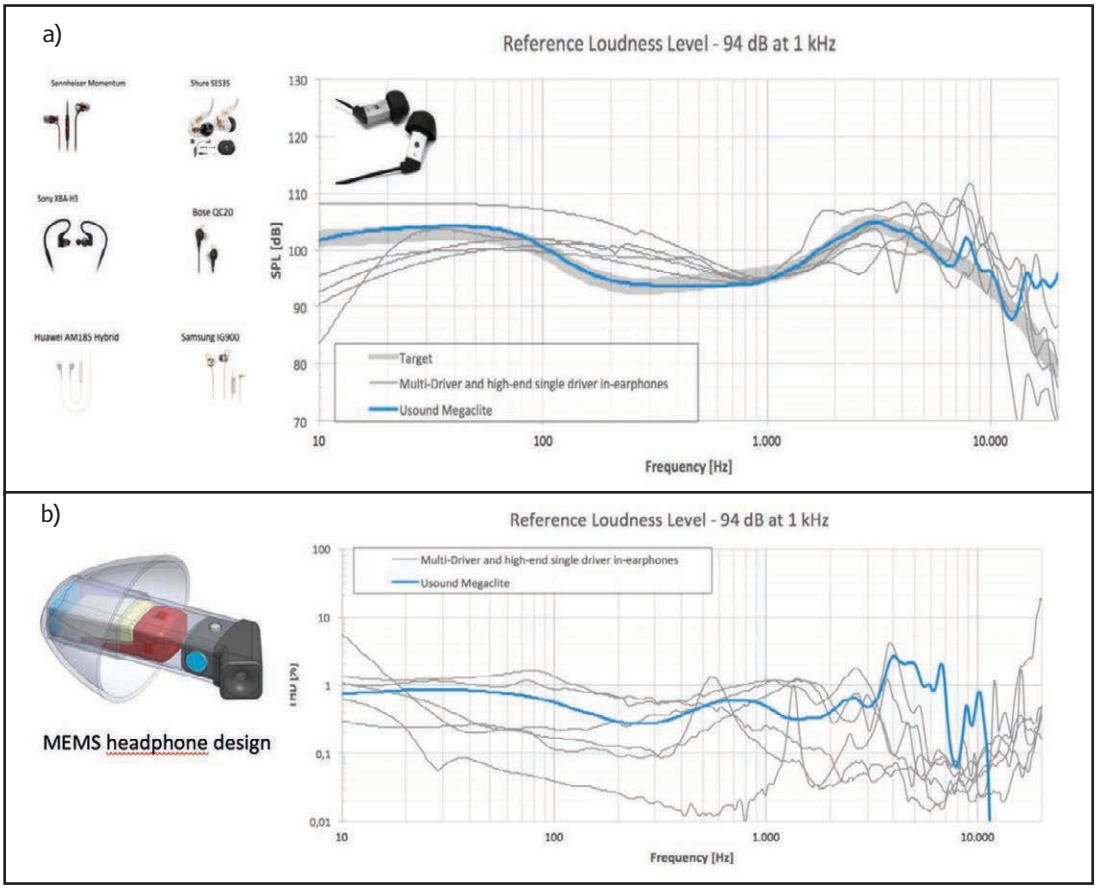


Figure 17: The benchmark between the ED/BA occluded hear earphones (a) and the MEMS (b) is illustrated in this diagram.

headphones, which means precise bass and crisp and clear treble. Covering both aspects within one transducer results in wider bandwidth and using on single element instead of multiple drivers. THD distortions are determined by the linearity of the MEMS design, with the adoption of a closed loop control THD have the potential to go down to virtually zero.

Mechanical integration: MEMS and microelectronics are planar technologies, the MEMS microspeakers achieve a thickness of 1 mm compared to 2 mm to 5 mm voice coil transducers; the lack of heavy metals and use of low density materials enable a 10× lighter design; contrary to a voice coil, piezo do not generate any heat thus improving reliability and durability; devices can be connected directly to PCB as SMD components.

System integration: PZT consumes 95% of reactive power, an energy recovery loop can transfer more than a half back to the system making these devices very efficient. The ASIC driver works purely with digital inputs eliminating the need of a DAC. Thanks to the system architecture, electro-mechanical overdrive is impossible. This eliminates the need of smart power amplifiers, and tight specs coming out of the lab avoid the need of calibration and enable array configurations.

In particular, the goal is to realize a fully digital speaker module, which only needs a power supply and a digital audio stream to function.

In **Figure 16**, we summarize the comparison to standard electrodynamic speaker technology: elimination of magnetic components and magnetic fields; reduction of system footprint and volume; and creation of a digital component manufactured with microelectronics production equipment.

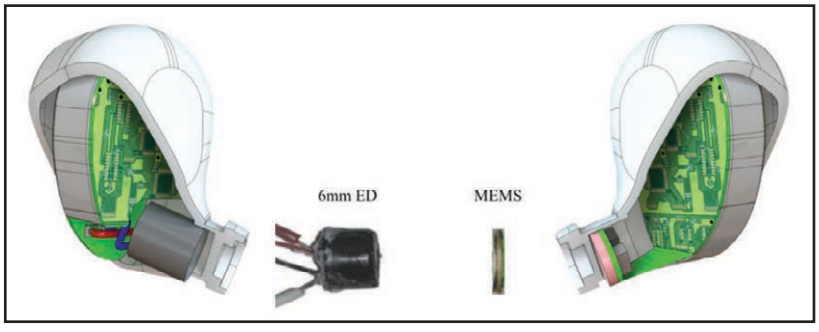


Figure 18: A study for integrating a MEMS speaker into TWS earphones shows the MEMS speaker uses much less volume than a voice coil speaker.

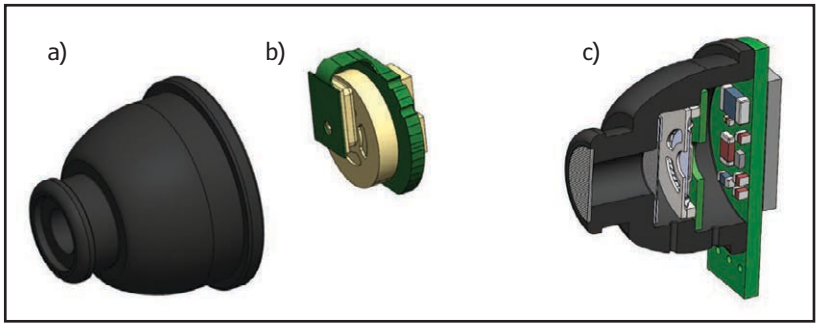


Figure 19: The audio module elements include the audio module shell (a); the rigid-flex PCB containing MEMS speaker, amplifier, and ANC feedback microphone (b); and the module integration with Bluetooth connectivity (c).

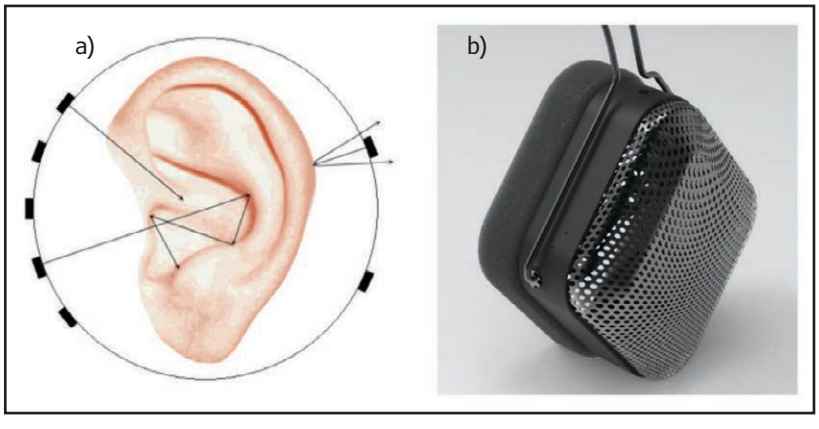


Figure 20: Configuration of MEMS speakers placed around an ear (a) and the design of an open headphone for 3D audio (b).

MEMS Speaker Applications

MEMS speakers can be integrated in a variety of audio products, in particular, we describe here the most relevant for demonstrating the impact of MEMS technology into audio products.

In-Ear Headphones: USB-C and Audio Module for TWS

A MEMS driver fits very well for in-ear headphones as it is the smallest transducer available to effectively cover the whole hearable bandwidth form 20 Hz to 20 kHz. The acoustic design including volumes and channels can be optimized for its characteristic performances to produce a crisp and clear sound signature. In **Figure 17**, the benchmark of a MEMS speaker headphone reference design is compared to several commercially available products based on voice coil speakers.

The audio signal chain is purely digital, from the Bluetooth or USB-C digital interface to DSP up until the power stages of the amplifier, this makes the system very easily integrable into modern systems as with, for example, True Wireless Stereo (TWS).

The typical TWS uses a 6 mm voice coil driver, which is 4 mm to 5 mm thick. The MEMS component needs five times less volume (140 mm^3 vs. 30 mm^3), is 10 times lighter (500 mg vs. 50 mg), produces five times less vibrations (0.1 mg/s^2Pa vs. 0.05mg/s^2Pa) and generate no heat.

Figure 18 compares the standard technology with the MEMS solution, the additional free space made available can be used for designing a more compact product with more advanced digital and sensors integration.

The MEMS speaker enables an audio module that sits directly in the ear canal, leading to an ideal electronics integration and fitting standardized headphone ear tips. **Figure 19** shows the audio module elements.

The module includes all the electronics required for the audio signal chain including Bluetooth Low Energy (BLE) connectivity. The microphone and speaker are integrated as a sub-assembly connected via Rigid-Flex PCB, a digital bottom-port MEMS microphone is used to keep the electronics package as small as possible. The shell creates a closed front volume for the speaker and microphone. This is ideal for rich, full-bodied sound reproduction and for high quality ANC capability. The module incorporates front venting to allow for pressure adjustment of the TWS in the ear canal and includes a mesh for dust protection, along with a waterproof membrane.

This concept greatly improves the manufacturing processes of TWS headphones, with MEMS loudspeakers all components are assembled using fully automated SMT manufacturing lines, this is a key aspect for mass manufacturing TWS at low costs.

Virtual Reality and Gaming

MEMS enable multi-driver headphones that can bring virtual reality (VR) and gaming headphones to the next level. The system comprise an electrodynamic woofer and several MEMS tweeters positioned around the ear. By placing the speakers in specific positions, it is possible to improve the sound source localization in space, the reason is the listener actually uses its own ear pinna to localize the source. The hardware configuration is supported with HRTF and room model algorithms; compared to standard HRTF Headphones, the MEMS cue-preserving headphone significantly increases the externalization perceived sound and doesn't need an individualized configuration procedure. **Figure 20** shows a configuration of seven MEMS speakers placed around the ear and the product design of an open headphone for 3D audio.

Smart Glasses and Augmented Reality

MEMS speakers are used in an audio system for smart glasses and augmented reality applications. The speakers are mounted in the temples delivering great audio quality with the smallest form factor. A two-way system combines a woofer and a tweeter to get the maximum out of the acoustic performances of both transducers: the tweeter is MEMS with crisp and clear treble, the woofer is electrodynamic with best-in-class bass performances.

Photo 3: These are the Fauna audio glasses, with integrated MEMS speakers.

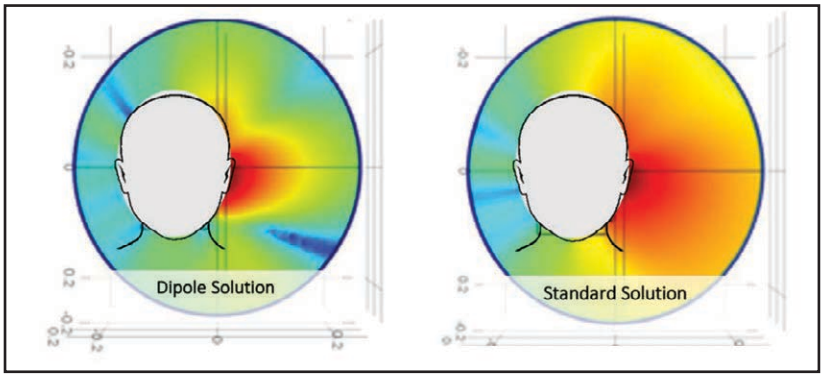


Figure 21: This graph shows the effect on SPL when using acoustic dipoles for improving audio privacy.

The system has a specific architecture in order to damp and reduce the noise radiated to the ambient and maximize privacy. **Photo 3** shows the final product. **Figure 21** shows the effect on SPL of using acoustic dipoles for improving audio privacy.

In this article, we have covered several key aspects of silicon-based MEMS speakers, showing that the technology has reached the performances and the maturity level to compete with the established voice coil transducers. In particular, it enables those who are looking for unique industrial designs and are driving the development of next-generation wearable devices. In the era of audio-centric wearables, virtual assistants, and technology is becoming a fashion statement, re-designing the essential blocks of audio systems is necessary to match the market requirements, of more light-weight and ergonomics hearables and wearables. ***LIS***

Advantages of Lab-Grade Microphones vs. Electret Microphones for Audio Applications

Learn more about the advantages of using lab-grade microphones and test and measurement microphones to improve audio products.

By
Mark Valentino
(PCB Piezotronics)

Photo 1: This is an example of a lab-grade test and measurement microphone made by PCB Piezotronics shown with the grid cap and without it.

The Audio market is constantly changing, resulting in constant product evolution. Audio design engineers are searching for sensors with improved accuracy over a wider amplitude and frequency range to test their equipment. They want sensors with sensitivities that are extremely stable over time and perform consistently under varying environmental conditions, with the ability to have close relative phase responses. This is why more audio design engineers recognize the advantages of using lab-grade microphones in their tests (see **Photo 1**). This means audio design engineers are shifting toward utilizing more test and measurement sensors in the design, and end-of-line (EoL) testing of products. The introduction of lab-grade test and measurement microphones allows them to improve their products and gain a distinct competitive advantage.

Many audio microphones use low-cost electret elements with Mylar or other plastic/polyester diaphragms, whereas test and measurement microphones use a stainless alloy or titanium diaphragms (see **Figure 1** and **Figure 2**). These lab-grade microphones go through a strenuous aging process in environmental chambers for temperature and humidity testing to stress relieve the materials and ensure long-term stability.

Noise Reduction

During speaker development, multiple tests are performed (e.g., Rub and Buzz), which is required to determine the noise/hiss or other imperfections of the product under test, especially at low volumes. By being armed with this information for the new product design, the research and development engineers can use the data to improve the product and minimize the noise, resulting in improved clarity and enhanced sound quality.

With the proper tools (or sensors) to test the speaker or product under development, the engineer can determine where the noise or imperfections to the sound are coming from. They can trust that the noise is not from the sensor they are using to test the product. When used in the proper environment, such as anechoic chambers or noise free rooms, these IEC-compliant lab-grade

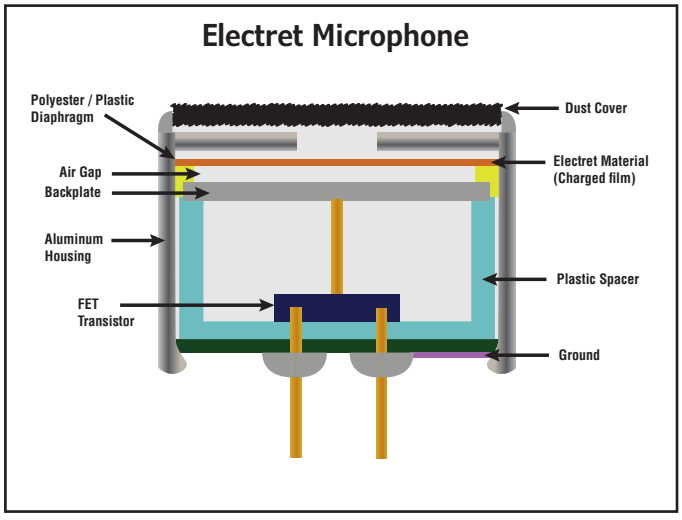


Figure 1: This is the design for an electret microphone.

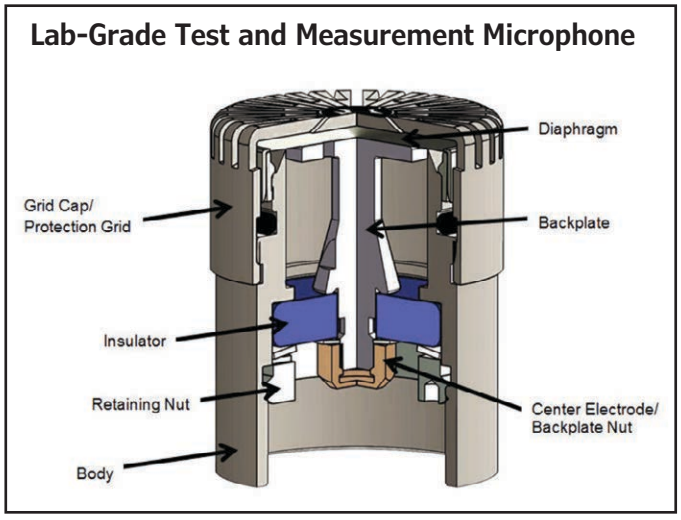


Figure 2: Here is a cut-out design of a lab-grade test and measurement microphone.

microphones have the capability of measuring down to 5.5 dBA (typical). It is important to note that all of the components in the measurement chain: microphone, preamplifier, cables, power supplies, computers, the room acoustics, all play a part and contribute to the noise that the system is capable of measuring.

Figure 3 shows a comparison of a typical audio microphone vs. the lab-grade PCB model 376A32 test and measurement microphone. Audio microphones typically have a 5 dB to 20 dB higher noise floor. It is important to note that just a 6 dB increase is a doubling of sound pressure level (SPL). Thus, audio mics have a significantly worse low noise measuring capability than that of a laboratory grade microphone, in pounds per square inch (psi).

Total Harmonic Distortion

Figure 4 shows total harmonic distortion (THD) displayed in a percentage over a specified frequency range and voltage. It represents a deviation of the output signal comprised of the fundamental frequency and its harmonic frequencies. The higher the THD, the more distortion is represented in the signal. The lower the level of THD, the more accurate the signal is displayed and more natural instruments are heard.

While some industries standardize on a 3% distortion value, the audio market standardizes on a more stringent 1% THD value. If using a microphone to test a speaker, headphone, or instrument, and the microphone has an inherently higher level of distortion, the design engineer for the speaker or instrument will not be able to accurately confirm if the high amplitude distortion stems from the product they are developing or the instrument (microphone) used to measure that specific product. Lab-grade microphones with a low inherent distortion allow high-quality studio or live recordings to have enhanced clarity and sound less muddy, especially at high amplitudes (see **Table 1**).

The ability for a microphone to go to higher SPLs without distorting, enables a film maker to, for example, capture bomb blasts more

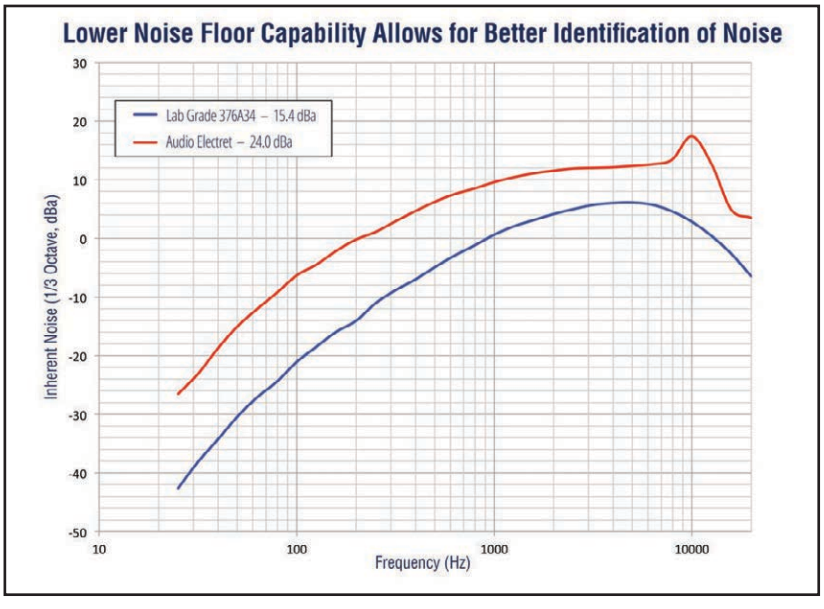


Figure 3: This graph shows a noise floor (minimum amplitude measurement capability) comparison between a typical audio microphone and a PCB lab-grade microphone.

realistically, without the output (sine wave) clipping, or the microphone overloading. The high amplitude signal of a loud snare drum or kick drum can be represented more naturally with a lab-grade measurement instrument that can accept higher amplitudes (sound pressure levels) with minimal distortion. Clarity of loudspeakers, instruments or recordings are not compromised.

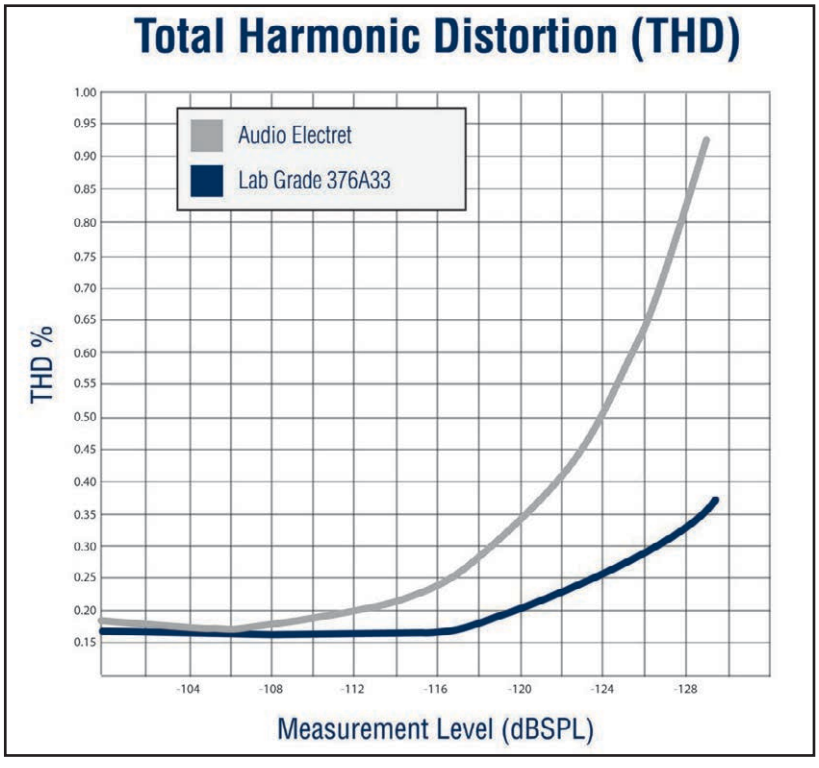


Figure 4: The maximum amplitude capability is displayed over a specified frequency and voltage.

Distortion Testing	Lab Grade	Lab Grade	Lab Grade	Audio
	376A31 (1/4″)	376A32 (1/2″)	376A33 (1/2″)	Electret
1% THD	156 dB	137 dB	150 dB	130 dB

Table 1: Distortion testing with 1% total harmonic distortion

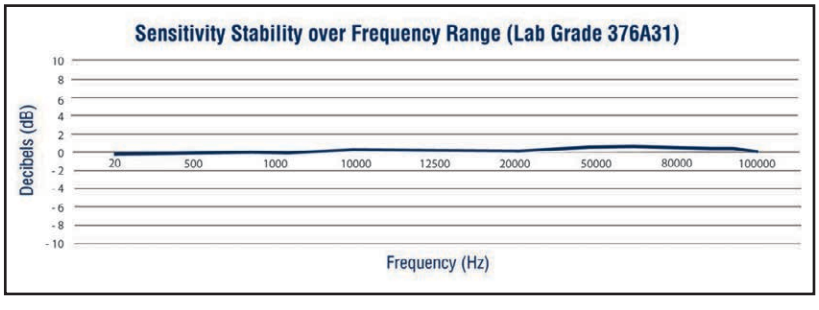


Figure 5: Lab-grade microphones offer higher accuracy measurements over wide frequencies.

Stability of Sensitivity over Varying Frequencies

Truer sound is captured with a flat sensitivity response. The sensitivity deviation over frequency for lab-grade microphones is much more stable than Audio microphones. Audio microphones can have deviations of sensitivity over frequency of over 10 dB. Lab-grade microphones are specified over a larger frequency range with resonance peaks within ±1 and 2 dB tolerances.

Modeling is also becoming extremely popular in the industry. Modeling is the ability of the sound coming from one speaker (amplifier, microphone or instrument) to accurately display the sound characteristics or signature sounds of other speakers. This is desired because the speaker is no longer manufactured, or is too expensive, or for the flexibility and convenience of having one model sound like several others with the flip of a switch. A lab-grade microphone does not have the large sensitivity peaks or attenuation imperfections/ inaccuracies that an electret audio microphone exhibits. This flat response minimizes changes of frequency response that are not present in the target instrument being tested or recorded. Engineers can obtain a closer sampling sound of the original, so they can design or model the replica more accurately.

For high-quality recordings, limiting the inaccuracy of the measuring device itself, minimizes negative impact on the output. This translates into more consistent levels for all instruments and notes played, from low frequencies to high frequencies and minimal corrections (see **Figure 5**).

High-Frequency Capability

The human audible range is 20 Hz to 20 kHz, and some technicians feel that they do not have to consider frequencies higher than the audible range because we can't hear it. Higher frequency capability not only provides wider frequency measurements, but also means faster impulse response times, enhanced recovery from an overload signal, resulting in a crisper sound, and better transients. Lab-grade microphones can measure frequencies to 100 kHz within a tight ±3 dB tolerance.

Relative Phase

Relative phase between two microphones involves the timing of the signal and sine wave from when a pressure wave approaches the diaphragm to when the output signal gets sent to the desired sound board or recording device (see **Figure 6**). If one microphone is out of relative phase with

the second microphone, the time that each signal reaches the board will vary. Stereo recording with two microphones that are very close in relative phase have the advantage of the sound seeming tighter, clearer, and crisper.

Environmental Conditions

Lab-grade microphones offer advantages of having smaller sensitivity changes over temperature, humidity, and atmospheric pressure. Electrets have an operating temperature of -10°C to +50°C, where the lab-grade microphones can typically be used in environments from -40°C to +120°C (see **Table 2**). With lower coefficients, lab-grade microphones used for high-quality live recordings will be more consistent from sea level to mountain tops, or in a hot and dry desert to a rainy or cold forest.

Calibration, Verification, and Traceability

Lab-grade test and measurement microphones are easily calibrated to reference standards. These calibrations are not just a single-point calibration test, which only tests at one frequency (typically performed at 250 Hz or 1 kHz), but are verified via a more stringent test utilizing all frequencies in the original manufacturers specification. This test is sometimes referred to as a "Sweep." This multi-frequency test is verified by a traceable reference microphone, which is sent out to a national standard laboratory periodically (typically once every six months to a year) for verification. Documentation of sensitivity is verified to the original manufacturer's specifications and to the IEC 61094-4 working-class grade of test and measurement microphones standard.

In Summary

Lab-grade microphones offer many advantages over electret audio microphones for design, EoL test verification or for high-quality recordings. When performing speaker noise (Rub and Buzz) tests, you need a microphone with a low noise floor, so you can determine that the noise you want to eliminate is truly from the speaker and not the instrument you are using to measure it.

By being able to go very high in amplitudes with less 1% THD, your microphones will not overload and you can capture bomb blasts or the snap of a snare or kick drum without added distortion. With tighter relative phase that lab-grade microphones offer, you can perform stereo recording and have a tighter more crisp sound. Modeling of other amplifiers, microphones or musical instruments requires a very accurate signature signal to be captured. Lab-grade microphones with a very flat sensitivity over a wide frequency range provide you with the capability to capture the true sound characteristics of the original instrument that you wish to duplicate, without introducing the inaccuracies of the sensor you are using. These high-accuracy sensors come with documented and verified quality, meeting stringent testing standards for microphones. Lab-grade test and measurement microphones enable users to build a better instrument, with a better instrument. ***LIS***

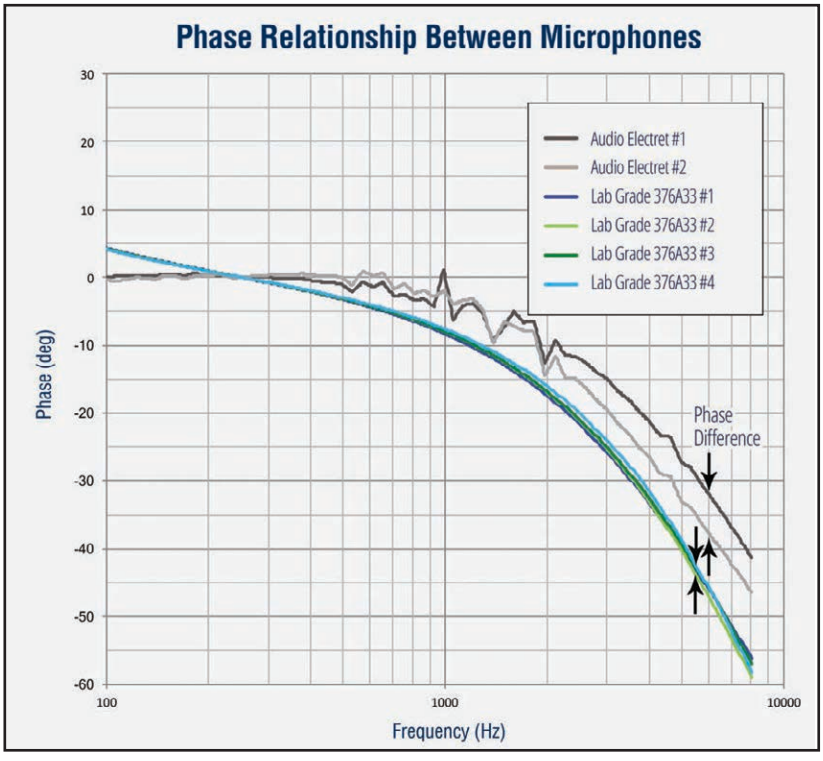


Figure 6: This is a relative phase comparison of audio vs. lab-grade microphones.

	Lab Grade	Audio
	376A33 (1/2")	Electret
Temperature Coefficient	0.006 dB/°C	0.037 dB/°C
Humidity Coefficient	0.002dB/% RH	0.003 dB/% RH
Pressure Coefficient	-0.007 dB/kPa	0.031 dB/kPa

Table 2: Here we compare the stability of lab-grade vs. electret microphones in changing environments.

About the Author

Mark Valentino has Bachelor's degrees in Mechanical Engineering and Industrial Engineering from Buffalo State College in Buffalo, NY. He has more than 17 years of product and application experience with test and measurement microphones. He is responsible for managing all phases of the acoustic portfolio life cycle. He also has more than 25 years of acoustic audio experience as a professional musician and his musical group was inducted into the Buffalo Music Hall of Fame in 2009.

Minimizing Costs through Efficient End-of-Line Testing

This article by industry expert Wolfgang Klippel details how measured characteristics and corresponding limits in end-of-line (EoL) testing are important for minimizing total costs.

By
Wolfgang Klippel
(KLIPPEL GmbH)

Producing a defective audio product has economic consequences. A defective unit detected at the end of the production line and not shipped to the customer increases manufacturing costs, denoted as C_{EOL}. Likewise, a defective unit may not be noticed in production and may fail in some way in the possession of the end user. These field rejects generate additional after-sales costs C_P, which may include technical support, shipping and replacement during the warranty period. The dissatisfaction of the end user and a damaged reputation of the brand may be also considered in C_P. This article describes the problem of balancing C_{EOL} against C_P using PASS/FAIL limits in end-of-line testing to minimize the total cost C_T.

End-of-Line (EoL) Testing

The main goal of manufacturing is to reproduce a selected prototype as cheaply, reliably, and quickly as possible. Selecting the optimal test stimulus (e.g., sinusoidal chirp) is crucial for EoL testing [1]. The production environment calls for using a test box that provides shielding from ambient noise and placing the measurement microphone in the nearfield [2]. If acoustical measurements are corrupted by accidental ambient noise, the measurement can be repeated to avoid falsely increasing the rejection rate.

Feature Extraction for PASS/FAIL Classification

Two types of defects may be present in any given devices under test (DUT):

D1. Static defects with no significant change of the properties over the remaining product life.
D2. Dynamic defects with time-varying properties, which degrade the perceptual and physical performance over time and potentially cause field rejects.

The D1 defects are present at the end of the assembly line so the impaired performance is clearly seen during the EoL test. The D2 defects are more complicated because the performance of the DUT at the EoL test might be acceptable for an end user. However, the stimulus and the effects of aging, fatigue, climate, or other external influences in the target application may degrade the performance over time and lead to a destructive process.

Physical signals measured from the DUT are analyzed to extract unique characteristics, which are the basis for any PASS/FAIL decision. **Table 1** shows a list of selected characteristics from acoustical and electrical measurements and their importance for detecting D1 and D2 failures for most common audio devices.

The most critical step during EoL testing is the separation of the faulty units from the fault-free products shipped to the customer. Typically, there is an overlapping region between the distributions of passed and failed DUTs. Therefore, either faulty DUTs will pass the test or fault-free DUTs will be rejected. Depending on the limits, the probability of a false rejection is exchanged for the probability of false acceptance, increasing either C_{EoL} or C_p. In order to reduce this overlap, the characteristics should be carefully selected by:

- Exploiting physical knowledge about the root cause of the defect and the symptoms generated
- Measuring signals that contain unique symptoms of the defect
- Minimizing measurement noise or the influence of other random variables (e.g., climate) that increases the data variance of fault-free units

Figure 1 is an example showing the probability distributions of passed and failed DUTs for two different characteristics. The impulsive distortion (ID) plot shows the distribution of passed DUTs separated from the distribution of failed DUTs, indicating an important characteristic. The Average Level plot shows distributions that are significantly overlapping, indicating a less important characteristic. The failed distribution in both cases does not appear Gaussian because of the relatively few failed units.

Acoustical Metrics

The sound pressure signal p(t) is the most important signal for checking the performance of an audio device and detecting defects in Class D1 and Class D2. **Figure 2** shows the amplitude distribution (sonograph) of a chirp stimulus versus spectral frequency and time, which reveals important characteristics from Table 1:

- The second, third, and higher-order harmonics appear at distinct lines parallel to the fundamental.
- At low frequencies, impulsive distortion is generated by a mechanical defect in the particular DUT that excites all frequencies at the particular time, appearing as a vertical pattern in the amplitude distribution.

Characteristics	Audio Quality (D1, D2)	Reliability (D2)
Sonograph SPL (f,t)	***	***
Frequency response (SPL)	**	**
Average SPL level	**	*
Polarity	**	–
Harmonic distortion (THD, second, third)	**	*
Impulsive distortion	***	***
Modulated noise	**	**
Electrical impedance	*	*
Electrical parameters (RE, fs, QTS, QMS, QES)	*	*
Maximum displacement	**	**
Stiffness asymmetry	**	**
Voice coil offset	**	***

Table 1: Importance (* low, ** medium, * high) of physical characteristics used for detecting defects in audio quality and reliability.**

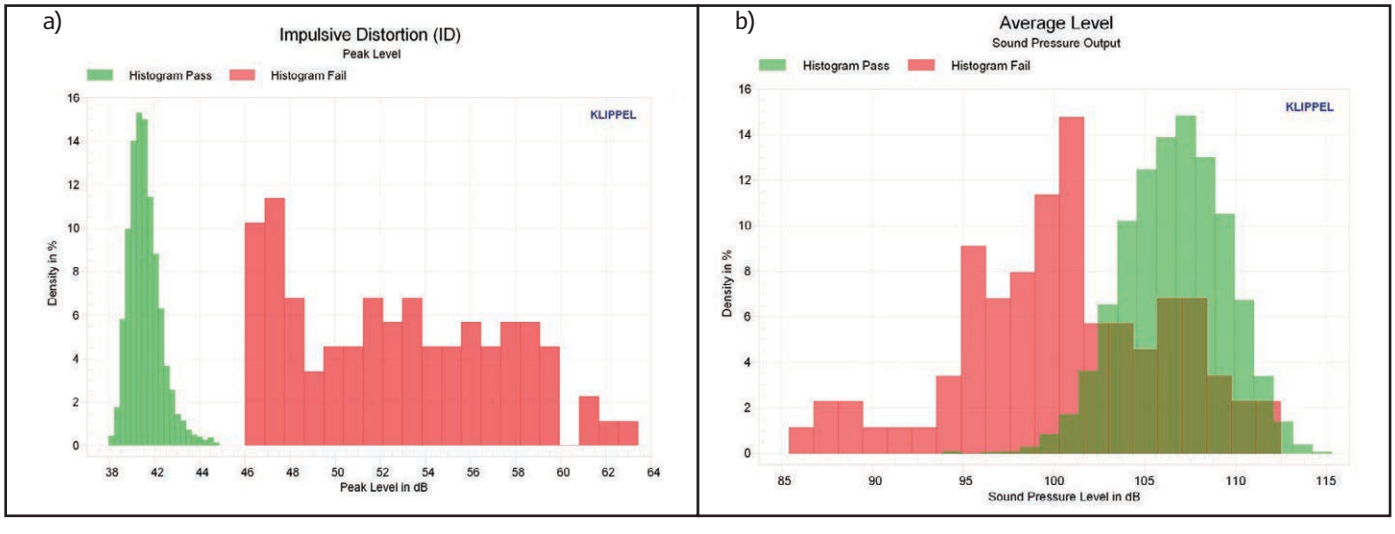


Figure 1: This example shows the probability distributions of passed and failed DUTs for peak impulsive distortion (a) and average level SPL (b).

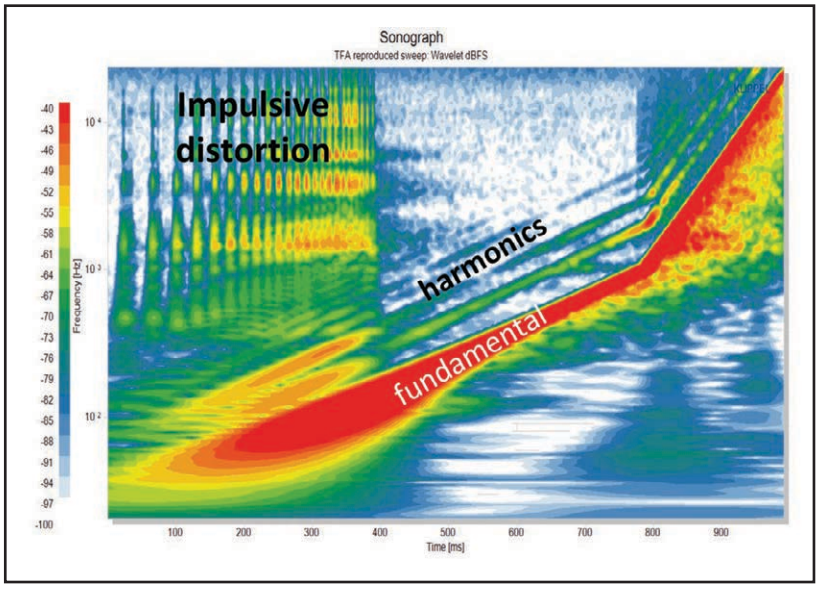


Figure 2: The sonograph shows the amplitude (color) versus frequency and time of the measured sound pressure response of the DUT excited by a chirp stimulus.

However, the original sound pressure waveform in the time domain provides further information, which the sonograph lacks. Time domain analysis can use the phase information [3] in combination with amplitude to differentiate noise from certain impulsive distortions. It is also required for detecting modulated air noise caused by leakages in loudspeaker enclosures.

Electrical and Mechanical Metrics

The electrical measurement of input current and terminal voltage provides further valuable features in Table 1, which are not affected by ambient noise. The impulsive distortion in the current signal shows any loose contact, improper soldering, or temporary shortcut generated by voice coil rubbing. Fitting the measured electrical signals to a lumped parameter model determines stimulus independent parameters:

- Electrical parameters R_E, f_s, Q_{TS}, Q_{MS}, Q_{ES}
- Offset of voice coil rest position x_{off}
- Asymmetry of the stiffness nonlinearity $K_{ms}(x)$

as well as stimulus dependent characteristics:

- Peak displacement
- DC displacement

These ensure the motor and suspension system [4] can produce maximum acoustical output without excessive distortion or mechanical overload that could shorten the product life through a D2 defect. The spider, the surround, the diaphragm, and other soft parts are the most critical components in transducers because they have a higher variance in the geometry and material properties than the coil and magnet system [5],[6],[7].

The suspension not only determines the nonlinear stiffness characteristic $K_{ms}(x)$ but also the voice coil rest position, which can generate an undesired offset x_{off} in the nonlinear force factor $Bl(x+x_{off})$. The measurement of second-harmonic distortion alone does not provide reliable information about the voice coil offset, stiffness asymmetry, or other suspension failures. Due to the complicated interaction of multiple nonlinearities, an unwanted offset from the optimum rest position might actually decrease harmonic distortion but increase intermodulation distortion at higher frequencies as well as generate dynamic DC displacement that reduces peak displacement clearance and maximum SPL output.

PASS/FAIL Production Limits

The definition of the PASS/FAIL limits is a challenging task [8] in EoL testing because those limits affect the total cost. While some production probabilities or distributions can be assumed [5],[6],[7], it is difficult to estimate probability of a false acceptance or defective DUT for the following reasons:

- These probabilities are usually small, and a larger number of samples must be manufactured and monitored in the field to get reliable statistical data.
- Field rejections are not sufficient to evaluate increased costs because the customer may not claim the fault while being dissatisfied with the product.
- The statistical information collected on one particular product cannot necessarily be used for another product.

Important statistical information about the failures is missing when the first PASS/FAIL limits are generated for a new product. However, they can be adjustment at a later time when root cause analysis of rejected DUTs provides more accurate information about the failures. This process will be illustrated in the next section.

The generation of initial PASS/FAIL limits related to D1 defects starts when the product

is initially being considered. Marketing and engineering should come to a compromise between audio performance and the total cost C_T, which affects the price of the product, in an attempt to maximize the benefit-cost ratio as seen by the end user.

From this, a clear definition of the target performance P_F in the final application with permissible tolerances ΔP can be generated. Listening tests, distortion auralization and perceptual modeling are extremely helpful in determining P_F and ΔP. Because of the difference in measurement conditions, the target performance P_F in the final application (e.g., in a car) is usually not equal to the target performance P_s under standard condition (e.g., anechoic room) or P_{EoL} in the manufacturing environment (e.g., test box). Therefore, it is good practice to transform P_F into P_s and P_{EoL} using a Golden Reference Unit [2]. However, the permissible tolerances ΔP measured in decibels first determined for P_F can be directly applied to both P_s and P_{EoL} for D1 defects.

The unknown D2 defects impairing robustness and reliability need a different approach for determining limits that uses available statistical information. The probability density function of the error free DUTs can be estimated by statistical analysis of similar audio products or determined by a pre-production run.

Optimum limits will differ between products and companies. Premium audio products will trade tighter limits and a moderate increase of C_{EoL} against a significant reduction of the risk for a field rejection. In standard consumer products with smaller profit margins, looser limits will reduce C_{EoL} in order to accommodate the price point. This approach is advantageous because the mean C_{EoL} can be estimated beforehand and used in the product's price calculation.

Learning from Field Rejects

If the number of field rejects is higher than anticipated, actions should be taken to mitigate this. An important first step is the verification of the failure in the field reject by physical measurement, listening, and visual inspection. If the failure is confirmed, an engineer tries to understand the destructive process and to identify the root cause.

Traceability to physical characteristics measured on the same DUT during the EoL test shows the change of properties over time and might reveal distinct and early symptoms that are not found in other passed DUTs. If these symptoms are also found in other field rejects, then this correlation may be a good reason to adjust the PASS/FAIL limits in the on-going production. If a physical understanding of the root cause and the explanation of the destructive process is plausible, then the same remedies are applicable to similar products. This scenario can be illustrated in a practical example:

A woofer rejected from the field generates no output. Visual inspection of the disassembled voice coil reveals a damaged coil. The recorded EoL test data of same DUT also shows a voice coil offset and a significant increase of the stiffness asymmetry that do not appear on the other passed units, leading to the following casualty illustrated in **Figure 3** to explain the failure:

1. The spider part of the suspension system was stored under wrong conditions, causing a temporary deformation.
2. After breaking in the fully assembled speaker, the spider deformation will eventually disappear, causing an offset of the voice coil rest

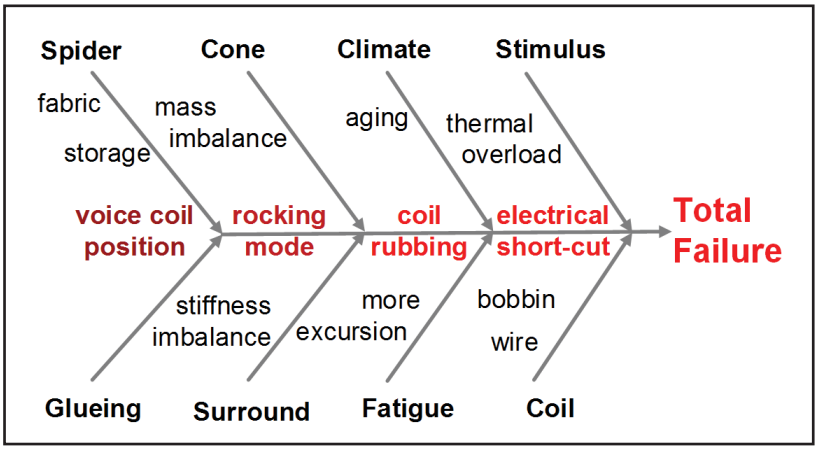


Figure 3: Here is an example of root cause analysis (fish-bone) of a total loudspeaker failure in the target application.

About the Author

Wolfgang Klippel studied electrical engineering at the University of Technology in Dresden, in the former East Germany, where his initial studies focused on speech recognition. Afterward, he joined a loudspeaker company in the eastern part of Germany where he was engaged in transducer modelling, acoustic measurement, and psychoacoustics. He later returned to his studies and received a Ph.D in Technical Acoustics in 1987.

After spending a post-doctoral year at the Audio Research Group in Waterloo, Canada and working at Harman/JBL in Northridge, CA, he returned to Dresden in 1997 and founded Klippel GmbH, a company that develops novel control and measurement systems dedicated to loudspeakers and other transducers.

Klippel has also been engaged as Professor of Electro-acoustics at the University of Technology in Dresden since 2007. His papers and tutorials on loudspeaker modeling and measurement—particulary those on large signal behavior and physical distortion mechanisms—are considered reference works in the field.

position and an increased asymmetry in the total stiffness curve $K_{ms}(x)$ that excite a rocking mode due to the stiffness imbalance.

3. This rocking mode causes a rubbing of the coil at the pole tips, damaging the wire insulation and shorting the coil wire.

4. The shorted coil experiences a dramatic increase in current and temperature, disconnecting from the voice coil former and opening the connection to the amplifier.

With this knowledge, the manufacturer then takes more care that the spider is stored under proper conditions and also tightens the limits for voice coil offset and stiffness asymmetry for upcoming production lots, thus slightly increasing C_{EoL} and dramatically reducing C_p for an overall reduction in C_T.

Conclusion

EoL testing is more than detecting production failures. It collects valuable information from all units shipped to the customer, which can be used to find optimal production limits that minimize C_T. In order to minimize the error in PASS/FAIL decisions, it is important to select sensitive physical characteristics that generate distinct distributions of the good and bad units.

The derivation of PASS/FAIL limits starts by defining the performance in the final application in an attempt to maximize the benefit-cost ratio as seen by the end user. Listening tests, auralization techniques and perceptual modeling are important for this first step. Physical characteristics and corresponding limits and tolerances can be transformed from the final application to standard lab environment and to the production environment using a Golden Reference Unit to provide clear specifications for both development engineers and manufacturers.

The time-varying defects in Class D2 need a proactive and adaptive strategy for EoL testing because the symptoms might not be audible or critical during the EoL test but could become unacceptable over time in the final application. Certain characteristics measured during the EoL (e.g., voice coil offset) can indicate insufficient robustness and reliability of the product.

Nowadays, digital signal processing can reduce D2 failures in the final application. For example, algorithms can be implemented that protect a transducer against mechanical and thermal overload, cancel signal distortion in the output and stabilize the voice coil position. Thus, the production variances of the soft parts become less critical for product reliability if the mechanical properties of the transducer are measured (e.g., monitoring transducer current) and compensated by a preprocessed input signal. This kind of adaptive control delays D2 failures and enables the collection of further diagnostic information, which can be used to optimize the design and manufacturing process and reduce the total cost. ***LIS***

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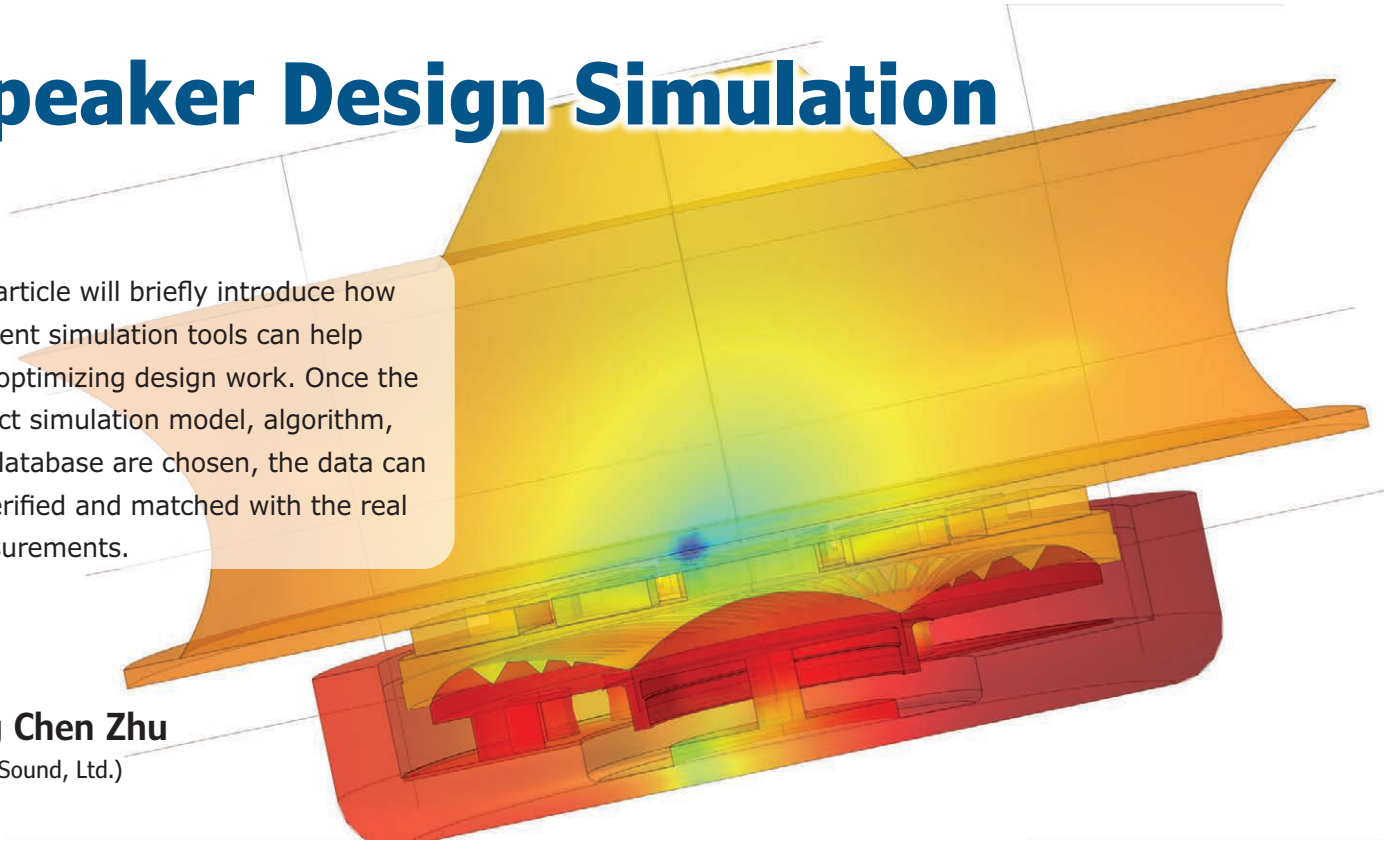
Speaker Design Simulation



This article will briefly introduce how different simulation tools can help with optimizing design work. Once the correct simulation model, algorithm, and database are chosen, the data can be verified and matched with the real measurements.

By
Ling Chen Zhu
(Pana Sound, Ltd.)

To begin, we need to decide on the classification of simulation. The Lumped Parameters (equivalent circuit) Method (LPM) is when the driver unit works at the piston area, all the movement is nearly in the same phase, and isotropic assumption can be achieved. We can use LPM to find the speaker unit's Thiele-Small (T-S) parameters, bass output, transfer function for passive/active crossover design, and heat transfer (see **Figure 1**). Some of the software systems are known as industrial standards such as the LoudSoft FINE Series, FINE Motor, FINE Box, FINE XOVER /DSP, and more, which can solve most of the problems in our daily work.

The complete Finite Element Analysis (FEA) model includes the stimuli, load, and geometry with appropriate the material properties, or physical boundaries. The whole geometry is meshed into many elements, which can be in 2D or 3D. Based on the physics, the equations or formulas are established for each node in the element, to solve the equation we will get the result. The more elements we set up, the more accurate the results. We also have to balance the accuracy and time cost.

The FEA tool can be used for all the frequency ranges from piston, breakup and the area in between. For regular design work, if FEA is used for piston area, it will only be more time consuming and provide no benefit.

Benefits of Simulation Software

Simulation software can help with your design in a number of ways. For example, Bl(x) optimization. Ideally, the current driving force should be constant. If not, the nonlinearity will

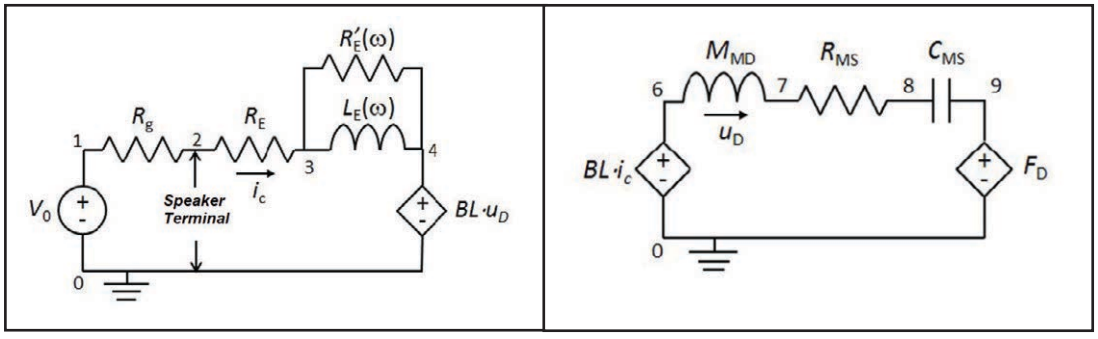


Figure 1: One of the circuit models converts electricity to movement.

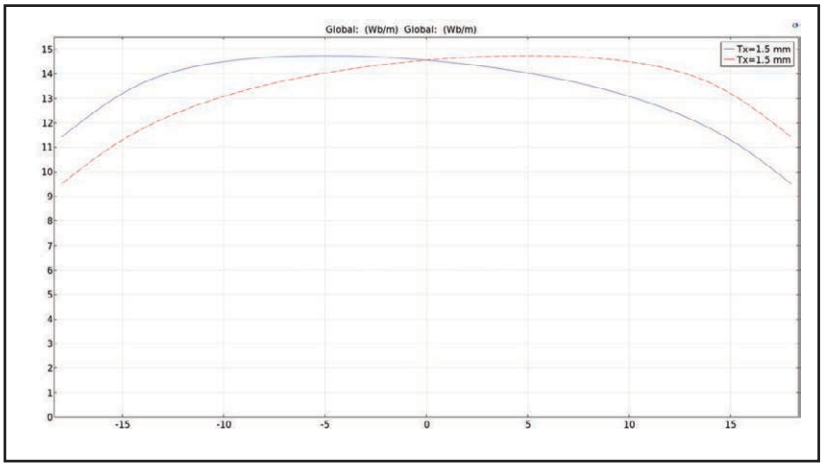


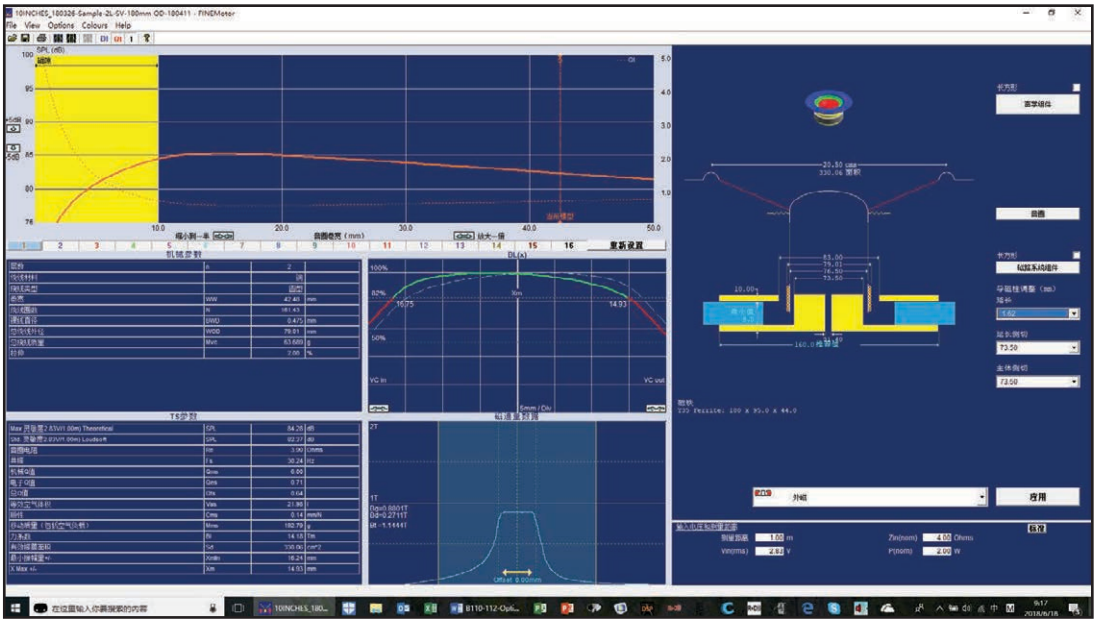
Figure 2: This is a Bl(x) Finite Element Analysis (FEA) simulation by COMSOL.

generate harmonic distortion. We can optimize the motor system to make Bl(x) curve as flat as possible and more symmetric. If we compare the simulations shown in **Figure 2** and **Figure 3**, we can see both simulations match with the real sample measurement displayed in **Figure 4**.

The restoring force is defined by Hook's law, F=-Kms(x)*x, x is displacement and Kms is the stiffness ratio, which ideally should be a constant number. Unfortunately, it is the function of x, so called Kms(x). As discussed earlier, we should make the Kms(x) curve flat and symmetric. This can also be optimized by FEA tools (see **Figure 5** and **Figure 6**). The same principle can be applied to the surround.

In nature, all the physics affect each other, until finally it gets to a certain kind of balance. So we need to couple the different physics or

Figure 3: Here, the Bl(x) Lumped Parameter method is simulated by LoudSoft's FINE MOTOR.



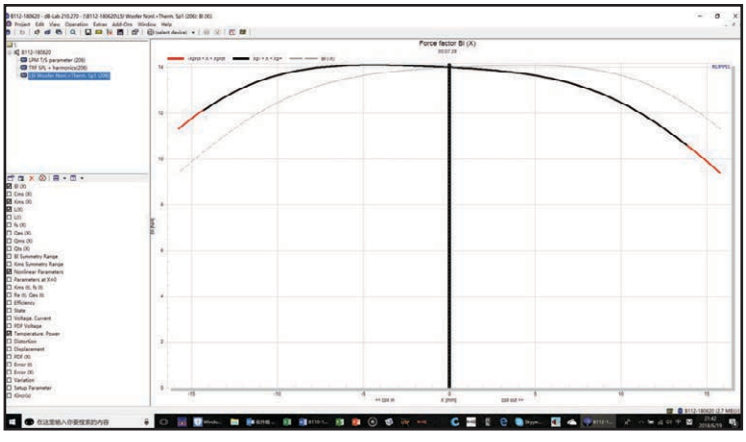


Figure 4: This Bl(X) real sample is measured by a KLIPPEL analyzer system.

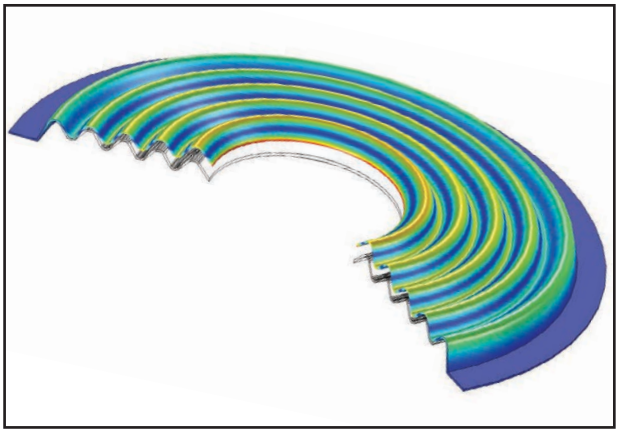


Figure 5: This shows spider geometry deformation and von Mises.

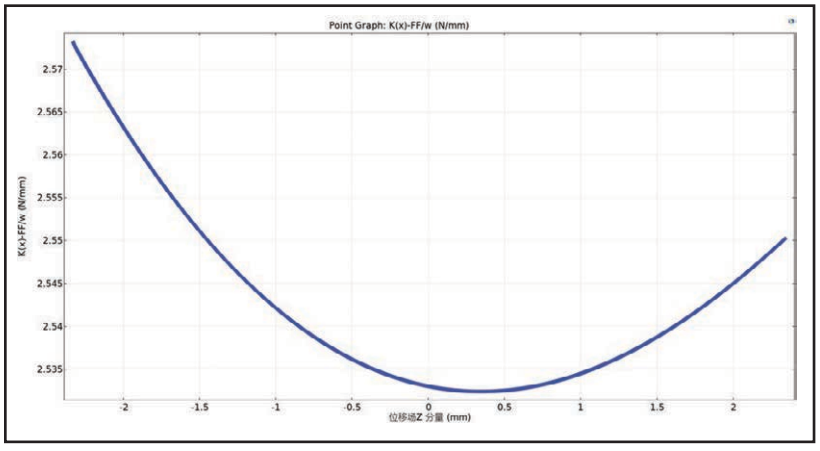


Figure 6: This simulated Kms(x) shows the asymmetry.

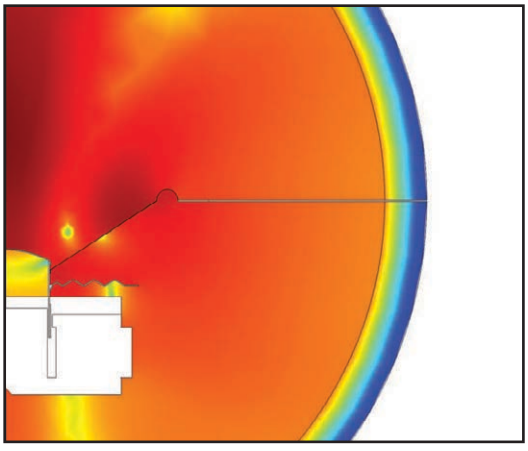


Figure 7: This is a simulated sound pressure level (SPL) and directivity plot.

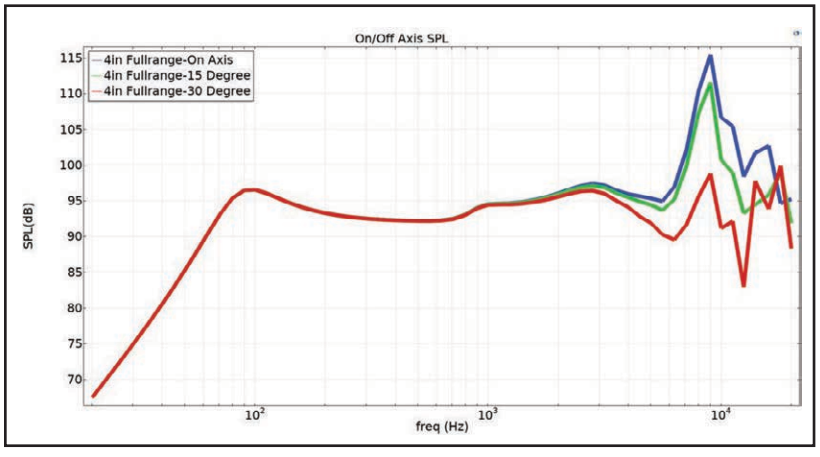


Figure 8: This is an on-axis 0°, 15°, and 30° simulated SPL plot.

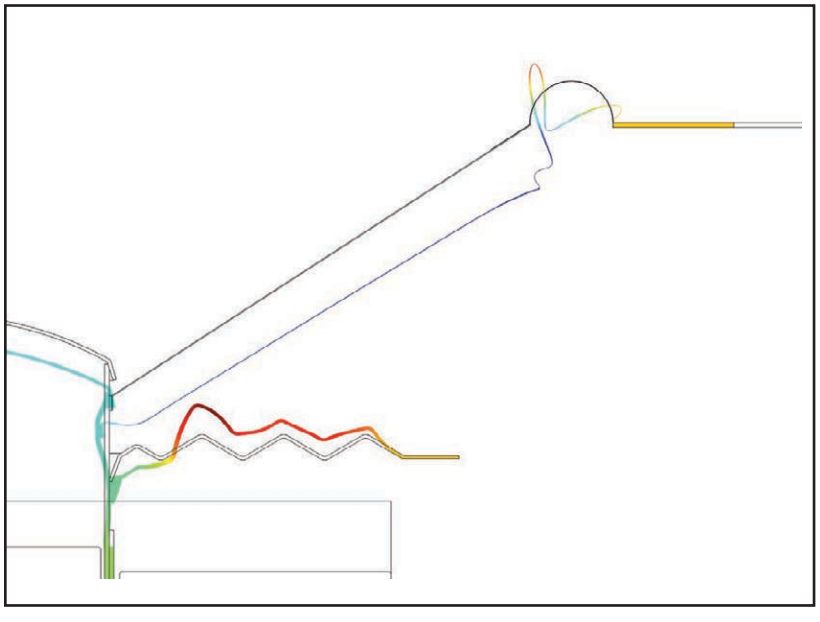


Figure 9: The cone break-up simulation

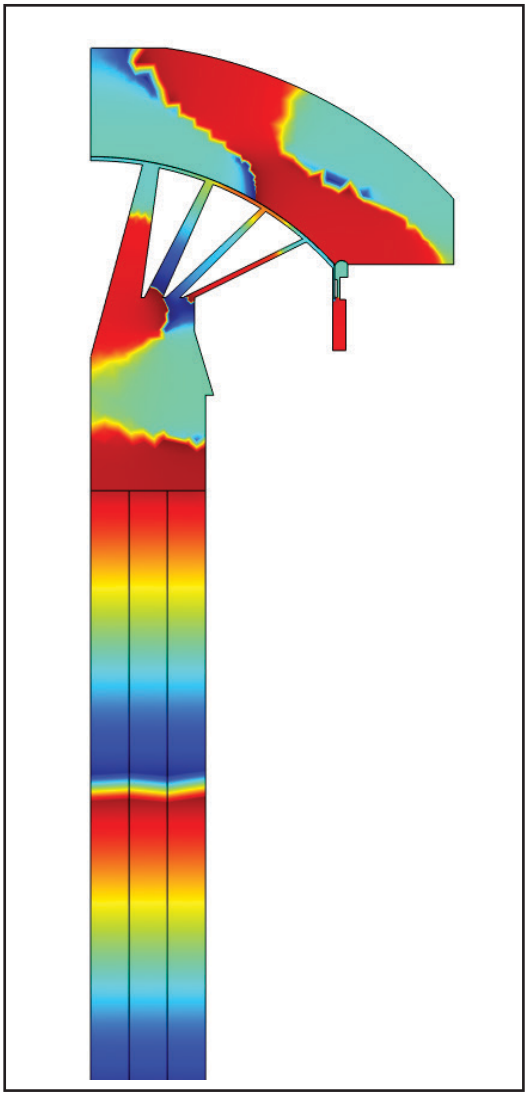


Figure 10: This is the pressure phase in the phase plug of the compression driver in the plane wave tube (PWT).

formula together. For a speaker unit, it will include magnetic, pressure acoustics, solid/shell mechanic, maybe thermo-viscous acoustics, this is quite complicated for physics coupling.

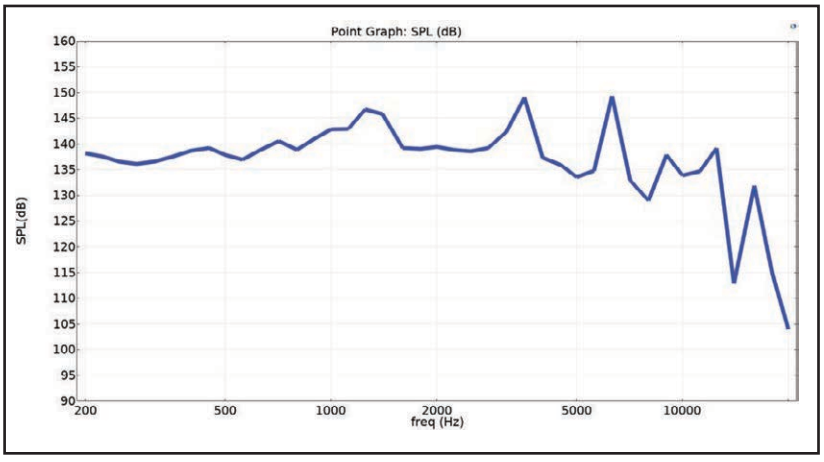


Figure 11: The SPL of the compression driver is shown in the plane wave tube (PWT).

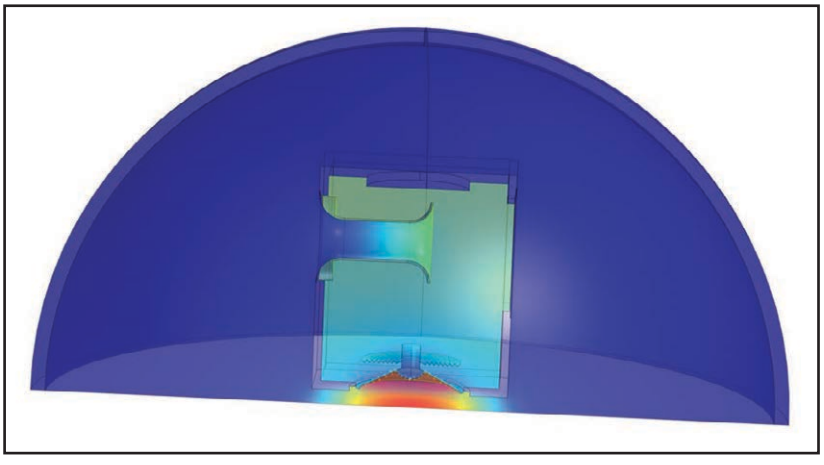


Figure 12: Here we simulate a down-fire subwoofer.

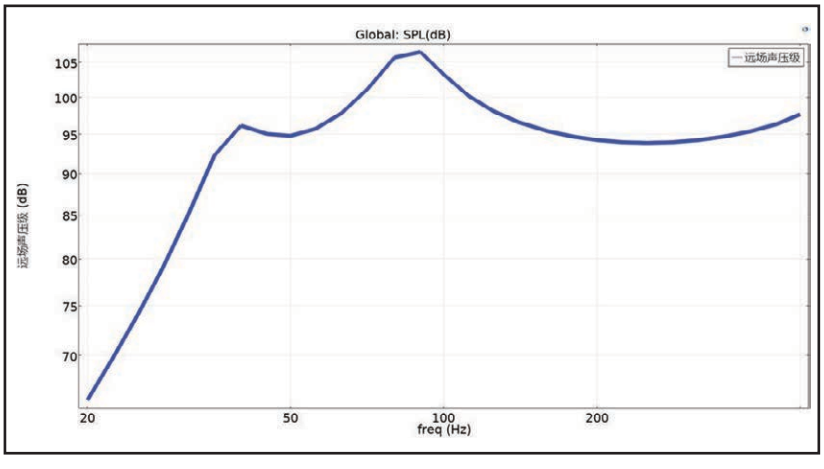


Figure 13: This graph also simulates a down-fire subwoofer.

Figure 7 shows a full-range speaker unit. **Figure 8** shows the on-axis 0°, 15°, and 30° simulated SPL plot and **Figure 9** shows the cone break-up simulation.

In the old days, we designed CD phase plug by using experimental formulas. Now, we have better tools. But before we use one of the tools, we can try to predict the performance. This is called using a virtual product development (VPD) method. This will help us to optimize our product in a more efficient way (see **Figure 10 and Figure 11**).

Special Speaker Box Design

Down fire subwoofers are often used in home AV or multimedia systems. By using FEA or boundary elements analysis (BEA), the performance can be predicted (see **Figure 12 and Figure 13**).

Earphone Design

With earphones (see **Figure 14**), we need to determine the DC pressure field (see **Figure 15**). To do so, we can simulate the test result by using 318 or 711 standard artificial ear. By performing the simulations, we can tweak the cavity performance (see **Figure 16**).

IEC Baffle Performance Simulation

An IEC 60268-5 baffle is often used for our daily speaker unit tests. The sound path has some shortcuts, which makes ripples on the curve. If we could simulate this curve, we can do normalization to get the real unit under test (UUT) performance (see **Figure 17 and Figure 18**).

Problem Solving

It is important to determine which tools to use to get the most accurate results. Our goal is to solve the engineering problems that we encounter. So our first choice is to use the lumped parameter method (LPM) since it takes almost no time to do. If the LPM works, then there is no need to use the FEA method. If you can save time, then that means you can try more options, and you will have more choices. There is also the use of a 2D/3D model. If 2D works, don't use 3D, it would just be wasting time with no benefits.

You could also use pressure acoustic or viscous acoustic testing. Normally pressure acoustics can solve most of the problems, if it is not very low frequency, or there is air flowing through a narrow slot or hole. It is not necessarily to use very time-consuming viscous acoustic tests.

As for which tool is more advanced? It is not really meaningful to discuss which is more advanced, both LPM and FEA can provide

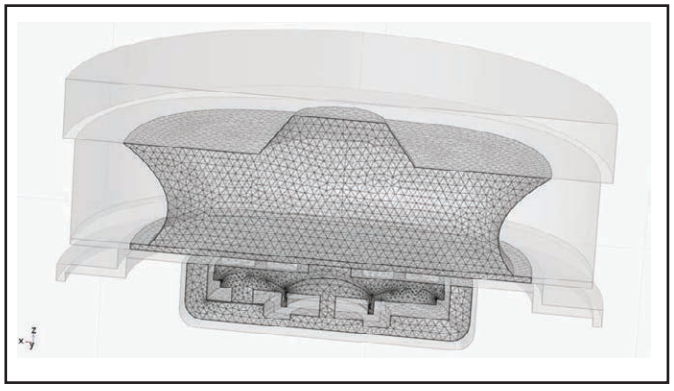


Figure 14: Here is an earphone mashed geometry.

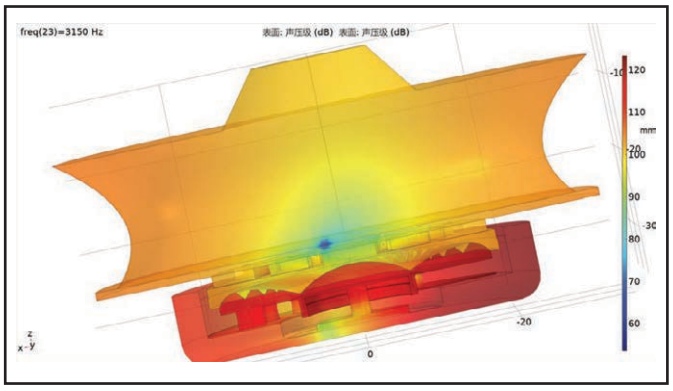


Figure 15: This diagram shows the SPL in a earphone.

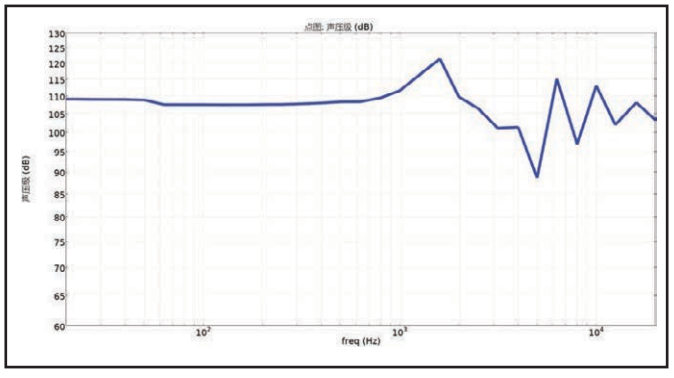


Figure 16: The simulated SPL curve was obtained using the 318 Artificial Ear.

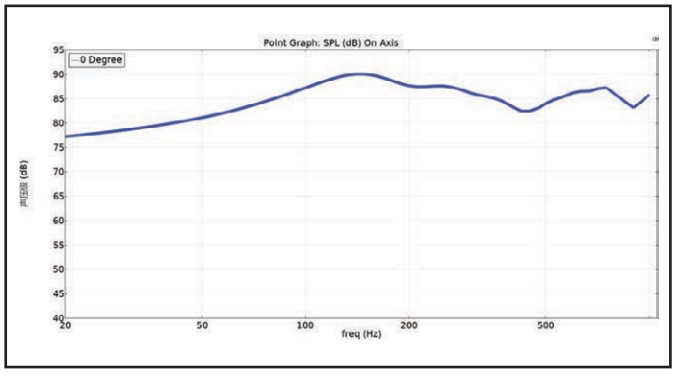


Figure 17: Here we have simulated an IEC baffle performance.

convincing results under certain conditions. As the saying goes, "All roads lead to Rome," but we should take the easiest road. As far as I can see, in the industry, lots of engineers use both methods in their daily work.

Improving Our Model and Database

The key to improving our model is that the simulation or VPD should match with the real measures. If not, we should know the reason why. The FEA method typically is as simple as the use of a calculator, so if your input is wrong, what you get will also be wrong. Sometimes, we need to experiment to modify our data or model.

In Summary

LPM and FEA tools can help us to optimize design work in many aspects, saving time and cost. Always try the easiest way first. If that doesn't work, then we have to use other methods. More importantly, the simulated results should match with the real measurements. If they do not match, there must be something wrong. And finally, take the time to experiment or make a real sample to improve your model and to build up your own database. ***LIS***

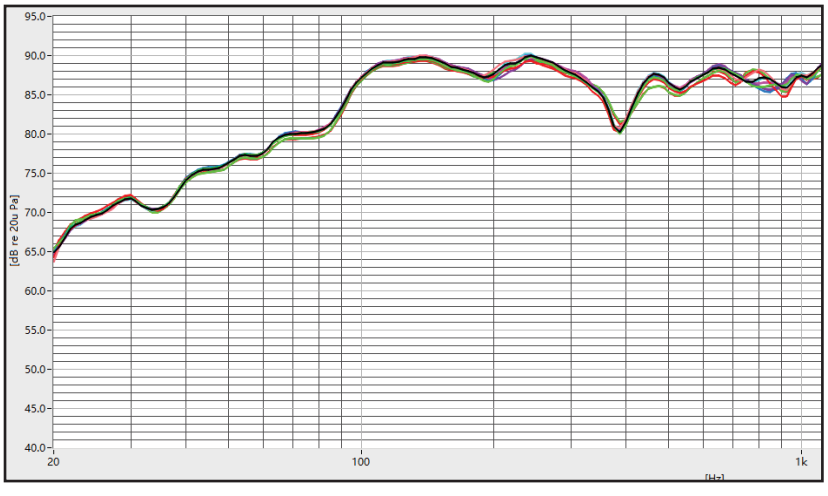


Figure 18: This is a real speaker unit installed on an IEC baffle/on-axis measuresments.

About the Author

Ling Chen Zhu is the owner of Pana Sound, Ltd. The company uses LoudSoft software, COMSOL Multiphysics software, and Klippel analyzer systems to do development work. Pana Sound also manufactures hi-fi and PA products, serving many famous brand names in audio industry. To reach Zhu via email: zlc@panasoundtech.com; via phone: +86-13926893329 or through the company website: www.panasoundtech.com.

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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.

Andrew Bellavia

Director of Market Development, Knowles

Question 1: How did your current business evolve in the past 12 months and what were the main trends and factors affecting your business?

Bellavia: The audio space was really dynamic in the last 12 months with voice-control and voice assistant access being added to any number of products. These continued to include smart speakers, of course, but also smart outlets with built-in voice, voice control in automobiles, and intelligent earphones, often referred to as "hearables." The number of Knowles microelectromechanical systems (MEMS) microphones shipped to IoT device makers rose steadily as a result. For earphones, we also saw the number of mics per unit climb. In the past, a single mic on the cable was typical. Now we see as many as six total in true wireless earphones for voice assistant access, calls, and active noise cancellation (ANC)—all features that gained greater adoption over the last 12 months.

In my main area of interest, I also saw a trend toward premium sound adoption in True Wireless Stereo (TWS) earphones. With so many models introduced last year, it makes sense that sound quality would become a differentiator. This is evidenced by the introduction of two-speaker models, such as the Samsung Galaxy Buds+ (dual dynamic speaker), Anker Soundcore Liberty 2 Pro (hybrid balanced armature + dynamic), and Amazon Echo Buds (dual balanced armature).

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

Bellavia: Apart from the disruption caused by COVID-19, I expect these same trends to accelerate, especially for in-ear devices. People are consuming mobile audio at an increasing pace including music, audiobooks, and podcasts. This will drive developments on two fronts. One is in the hardware where comfort, sound quality, and long battery life will be in increasing demand. The other is on the software side where the content will continue to improve in quality. For music this means greater adoption of hi-res streaming services. It also means more wireless earphones will use high-performance Bluetooth codecs and multiple speakers.

With people wearing their hearables for longer periods, the desire to access voice assistants will continue to increase. Voice assistant providers and third-party

developers will increasingly create voice apps specifically for the hearables case. Longer wear in varied environments will also drive greater adoption of ANC. Noise cancellation will become increasingly adaptive, intelligently filtering the ambient sound according to the circumstances at the moment.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your field of interest over the last 12 months?

Bellavia: One of the most exciting trends has been the convergence of consumer hearables and medical-grade hearing aids. On the hearables side, more products adopted "hearing personalization," a stigma-free term meaning the process of giving a hearing test, then loading an equalization profile into the headphone to compensate. Some of these models also compensate the microphones and apply programmable filtering, giving people enhanced hearing in loud environments such as noisy restaurants. This has the potential to make users more comfortable with the concept of addressing hearing loss when it is still mild, and therefore reducing the stigma around wearing hearing aids when their loss becomes more severe. This is a public health benefit.

On the hearing aid side, the biggest trend was toward Bluetooth connectivity. For those who must wear hearing aids full time, the ability to stream music or podcasts, have phone calls, or interact with voice assistants is of real value. The functionality of hearing aids is increasingly coming to match that of hearables with the added benefit of compensation for more severe hearing loss than hearables can provide.

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

Bellavia: Adoption of the new Bluetooth 5.2 will change how we use earphones and hearables in many ways. The broadcast capability of the new standard is especially interesting. Sports venues will have the capability of streaming the television broadcast directly to the attendants, in real time, and without the need for mobile phones as an interface. In restaurants and bars with multiple televisions, the audio stream from each can be broadcast on a separate Bluetooth channel. A related feature is the ability to have multiple connections to a single device. Two people can, for example, share the same audio stream while watching a movie on a tablet. All of these features will drive innovation and increasing adoption in the hearables space.

The short-range nature of Bluetooth will also allow enhanced services on location basis. A restaurant, for example, could prepare a short audio description of the menu and atmosphere. Passersby, on seeing the restaurant, could choose to listen. Museums, many of which already provide handsets for guided tours, could stream informative content directly to people's ears depending on where they are standing. Individual metro trains can announce the next stop and other information through Bluetooth, allowing people to listen to music while still hearing the announcements. The possibilities are endless.

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

Bellavia: Since becoming a connected hearing aid user in 2018, I have adopted a two-tiered strategy. I always use my hearing aids for listening to spoken words because the audio is compensated for my hearing response. I can also dynamically change the mix between real sound and streamed audio, making it possible to listen while going about daily life as if there was a radio in the background. This is also really useful for using the spoken Google Maps walking directions without risk of not hearing important street sounds.

When casually enjoying music, especially while out and about, I also listen this way. However the music quality is not what one can have from headphones. When I am sitting and really listening, I use a good set of in-ears with equalization applied. ***LIS***

Brian Youngil Cho

CEO, Resonado

Question 1: How did your current business evolve in the past 12 months and what were the main trends and factors affecting your business?

Cho: Our business has evolved to meet the direct demand of the market spurred by consumer trends toward product miniaturization and the need for products that provide aesthetic value as well as function value. Our objective this past year has been to meet this demand head on by introducing our patented Flat Core Speaker (FCS) technology as an alternative transducer-type solution that can be licensed by brands and manufacturers. After deciding to start by tackling the mobility and mid-sized consumer electronics product categories first, our engineering team went to work and delivered in time to debut the first commercially available product to meet these market trends at CES 2020. The Neo Mid 5, a 30 W midrange FCS driver with a 25 mm depth, and the Neo Sub 8, an 80 W FCS DualCore subwoofer also with a 25 mm depth, immediately caught the attention of leading multinational corporations.

These first FCS products have been successful because they were boosted by the market need to have a thinner, lighter, more versatile transducer type that doesn't compromise on sound quality. By engineering the technology to take advantage of the existing loudspeaker supply chain, costs were also kept in check in order to provide a solution that is innovative yet also accessible for mass market applications. Our engineering team also factored in other recent audio trends such as 3D-audio technology and voice-based-communication for connected devices and ensured that driver architecture was designed for optimal compatibility there as well.

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

Cho: The year began with a big buzz around 5G and its expected impact to the world, particularly within the audio industry as voice command is becoming the mainstream communication method among connected devices. So for the next 12 months we'll be keeping an eye on 5G-enabled solutions, including but not limited to autonomous vehicles and smart devices. I'll also be keeping a pulse on the intersection of smart devices and the recent efforts to achieve fully personalized sound zones, where 3D-sound technology, voice recognition, and noise reduction technology, respectively, have been actively explored and heavily invested in.

It's also difficult to talk about the next 12 months without taking COVID-19 into consideration. With a disruptive entry into the global economy in late Q1 and into Q2 this year, many industries have suffered, but audio solutions appear to be experiencing an abrupt rise thanks to increased time spent at home, leading to an increase in demand in two broad product segments: home office and home entertainment. Due to the rapid transition many had to make from traditional office settings to "work-from-home" settings, home office products

such as monitors, webcams, headphones, and virtual assistants were heavily sought after. With increased time spent at home there also came an increase in digital content consumption, which brought consumers to demand more home entertainment systems such as home theater systems, soundbars, or smart speakers.

Regardless of the overall macroeconomic impact of COVID-19, the demand for audio products will continue to rise, especially in the area of wearable technology (headphones, earbuds, and smart watches for example) and technology-compatible solutions both at home and work. With increased competition brought about by non-traditional audio companies such as Amazon and Apple, there has been and will continue to be a call for differentiated solutions from both new and incumbent market leaders.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your field of interest over the last 12 months?

Cho: The most exciting developments for Resonado have all been around our introduction of the FCS Neo series. After years of hard work, we were able to bring about the first commercially available product lines, representing our proprietary FCS technology and its potential applications. We directed our engineering team to develop two standard transducer solutions for the mobility and mid-sized consumer electronics product categories, and the result was our Neo Mid 5 and Neo Sub 8; both of which push the limits of traditional loudspeaker design while obtaining superior performances.

Our upcoming Intra series, featuring FCS Micro technology, will produce driver solutions for headphones and laptops that we're confident will set new standards for the next generation of small consumer electronics in a way that it was never before imagined possible. The Neo series was developed as a response to trends of thinner and lighter products that have an emphasis on unique industrial design, while the Intra series will be engineered to address trends of ergonomic design to produce products that provide comfort without sacrificing function.

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

Cho: The adoption of 5G will change the way we experience the world with audio. As we have already been noticing, voice command has and will become the mainstream communication method that interacts with connected devices we surround ourselves with. With an influx of data being collected and emitted with connected devices, there will come a point where we will need to rely more heavily on audio products for the consumption of contents and information.

This change has been accelerated due to the COVID-19 situation and will further 5G adoption in areas where audio already has a place, such as with podcasts, digital streaming contents and many others. Such change will only give a boost to the overall audio industry and its respective software-based technologies such as 3D audio, noise-cancellation, voice-recognition and many others.

Another trend to watch is within simulated experiences. Although virtual and augmented realities have disappointed many with a slower than expected development rate, as sensor technologies are enhanced and hardware catches up to software advancements, I think these technologies will arrive at a time when consumers will be very receptive to an experience in which they can escape from their reality with a fully immersive experience. I expect directional audio software and haptic technology to play a major role in this growing product category.

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

Cho: Headphones. Over the past 12 months, I have moved away from mostly earbuds to mostly headphones, primarily to experience the latest 3D-audio technology and comfortable noise-cancellation without causing discomfort to my eardrums, which I found to be problematic with earbuds solutions. ***LIS***

Jann U. Evers

Sales Director, ScanSpeak

SCANSPEAK

Question 1: How did your current business evolve in the past 12 months and what were the main trends and factors affecting your business?

Evers: Our business was more or less at the same level as the year before, only with the usual fluctuations caused by our individual customers' order schedulings.

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

Evers: Before the world was hit by the coronavirus pandemic, I expected a steady market without a lot of growth and where ScanSpeak—due to the recent launch of several very interesting new products—would win market share and have some growth. This is of course challenged, at least short term, as the world came to an almost complete stand-still, which will take a while to get over. When we are able to put the pandemic behind us and we will need to learn a "new way of life" with less going out, less travelling, less congregating in large groups, and less time physically at work. We will stay more in our homes; doing an increased part of our jobs from our home offices and enjoy life with friends in our homes. This will put more focus on how our homes are set up and it will shift some of our investments away from activities and things outside home into things we can enjoy at home—such as nice furniture, home automation, TVs and most important, new and better AUDIO equipment.

In the long-run—and that may not be far away—there is a good chance that the high-end audio industry will benefit from the pandemic. As people will appreciate products of higher performance and quality when they spend more time with it.

I also anticipate a shift in where our materials and products come from, as the pandemic really showed us how vulnerable most companies in the audio industry have become regarding their current supply chain. We have already seen some brands start to move their supplies away from China and some of that business has come our way. In the coming years, I expect this to continue and probably at a higher pace driven by the US-China trade war and the coronavirus pandemic.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your field of interest over the last 12 months?

Evers: In the field of loudspeaker transducers, we did not see any significant new groundbreaking technology appearing, the past year have mainly been focusing on refinements of already existing technologies and materials.

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

Evers: This is a good question that is not easy to answer. I do, of course, hope that our Ellipticor line, which is mainly recognized by its Elliptical voice coil and magnet gap, becomes the new "must have" speaker transducers for the entire high-end industry.

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

Evers: Most of my music listening time is background music from an FM radio at the office or in the car. At home and during work sessions, I used to listen mainly to CDs but the past year has pushed me over to streaming from various sources, such as Tidal and Spotify, supplemented by music from a NAS-drive where I have stored all my CDs as it got more convenient to use. ***LIS***

Mike Klasco

President, Menlo Scientific, Ltd.

Question 1: How did your current business evolve in the past 12 months and what were the main trends and factors affecting your business?

Klasco: We are audio engineering consultants and our projects with smartphones, earphones, and headphones remain strong. Even the recent pandemic has not slowed down new projects but I wonder if this confidence will evaporate in the fall. True Wireless Stereo (TWS) earphone products are ever popular and are now a must as performance continues to improve. There are also a growing number of innovative speaker topologies and materials for speakers.

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

Klasco: If I had a clue, I would not be in speaker engineering writing this, instead I would be having a drink on a yacht! Will the world pick up and get back to work when the worst is over or will we sink into a depression? On the audio side, we might finally see better response from smartphones, partly from 5G with superior protocols and the next generation of microspeakers.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your field of interest over the last 12 months?

Klasco: There were several exciting developments over the past year. Just a few of them include Graphene, microelectromechanical systems (MEMS) speaker (earphone) technology, plastics with enhanced acoustical characteristics for enclosures and speaker frames, new materials and processes for speaker cones and diaphragms, and higher performing magnets and non-steel return structures.

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

Klasco: I think the start of a number of initiatives for re-shoring speaker component manufacturing and speaker assembly would be the most promising.

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

Klasco: Well, I'm no longer listening to music from the inflight entertainment system on a plane! Otherwise, no changes.... ***LIS***

Christopher E. Rose

Eminence, President/COO

EMINENCE®
The Art and Science of Sound

Question 1: How did your current business evolve in the past 12 months and what were the main trends and factors affecting your business?

Rose: Eminence had been working for months to develop the Tour Grade series of woofers, which we began shipping last fall. Sales of those products started out extraordinarily well, and most of us in the industry thought that we had a great kickoff for 2020 with the NAMM show. Fast forward to March and we had come to the realization that the Prolight+Sound Show would ultimately be cancelled leaving a critical void for presenting our new products to our European clientele.

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

Rose: The music industry was one of the first industries to be impacted by COVID-19. Artists were forced to stop touring. Bars, nightclubs, and even small intimate music venues were mandated to close, and remain so to this day. Looking forward, the music industry will continue to be impacted, and may be one of the last industries to achieve any sense of normalcy. Loudspeakers are still in demand, but there is no denying that the need for such products will likely be stifled over the next 6-12 months.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your field of interest over the last 12 months?

Rose: Our Tour Grade series of woofers and high-frequency devices is probably one of the most exciting innovations in the loudspeaker industry. Our new NSW-6021-6 moves nearly 30% more air than any other loudspeaker of its kind. We also introduced a new 1.4" compression driver named the N314X. This product features a new thin ply carbon diaphragm from Textreme that is not only strong, and lends very unique and pleasing sound quality for professional Tour Sound applications.

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

Rose: Touring and installed sound are a huge part of the music industry. Loudspeakers, and the systems they reside within are consistently becoming stronger, lighter, and more targeted for each seat in the house. Patrons not only want to hear the music…they want to also feel it. Today's loudspeakers, the enclosures, high-power amplifiers and steering make that possible. Sound quality is only going to get more exciting in the next 5 years.

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

Rose: I have a couple of Sonos speakers at home. I find myself listening through those most of the time while grilling outside using the Play One. I also love the stock system in my vehicle, and a really cool system I put together for our basement several years ago. ***LIS***

Stephen Siegel

President and Co-Founder, Fulcrum Acoustic

Question 1: How did your current business evolve in the past 12 months and what were the main trends and factors affecting your business?

Siegel: We are primarily installation-focused. The install markets have been very competitive, with many capable products available to choose from. This forces us to look to innovate and develop unique/interesting solutions that differentiate Fulcrum Acoustic from the other brands.

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

Siegel: As I write this, we are in the ramp-up phase of the global coronavirus (COVID-19) outbreak. We are already seeing impacts on segments of the audio industry due to festival and trade show cancellations. Hopefully, this subsides before deeper damage is done to the world economies.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your field of interest over the last 12 months?

Siegel: The past year, we have seen tremendous interest in our products incorporating Passive Cardioid Technology. This patented innovation allows subwoofers and full-range products to create a sub-cardioid radiation pattern without relying on additional cancellation drivers, amplifier channels or DSP channels. We've seen applications in worship spaces, performing arts centers and large sports facilities.

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

Siegel: We are presently working on a number of new product initiatives requested by our customers and the market in general. We are also expanding our sales and distribution outside of the US to respond to growing demand for our products and technologies.

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

Siegel: I listen to music at the gym through Sennheiser Momentum wireless ear buds, or at the office through a pair of our RM28ac reference monitors. ***LIS***

Martin Turesson

Head of Thin-ply Carbon Diaphragms, Textreme

TeXtreme®

Question 1: How did your current business evolve in the past 12 months and what were the main trends and factors affecting your business?

Turesson: The past 12 months have represented the breakthrough of the Thin-ply Carbon Diaphragm (TPCD) technology, crowned with customers releasing fantastic audio products using TPCDs. TPCD is a new category of loudspeaker diaphragms. Our vision with TPCD is to engineer diaphragms to make it sound like you want it to sound. That is realized by combining pistonic motion with controlled and smooth (engineered) break up behavior. That in turn is made possible by the combination of ultralight weight, high stiffness, and the ability to engineer the behavior of the diaphragm at different frequencies, areas and directions. Much like the tone of a guitar string can be tuned by adjusting the tension, the behavior and sound of a TPCD can be tuned by adjusting its material structure and construction.

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

Turesson: We have many customer projects in the final stages, looking to be released in the coming 12 months. We will also be working on the developments of the second-generation TPCD, advancing the possibility to engineer diaphragm behavior, frequency response, and optimized sound even further.

Question 3: What were the most exciting developments, technology innovations, and trends happening in your field of interest over the last 12 months?

Turesson: We see several driver technologies being facilitated by the use of our TPCD technology, for instance, when it comes to flat diaphragm speakers for phones, laptops, and soundbars.

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

Turesson: There seems to be a growing interest among consumers for improved sound quality, not just in the audiophile type of products, but wider consumer products such as soundbars and wireless speakers. We look forward to be an important facilitator in that strive toward improved sound quality.

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

Turesson: Being a father of three small children makes it difficult to find time to listen to music at home. I, therefore, mostly listen in the car on my way to work or using my headphones when travelling. ***LIS***

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Steve Temme, President, Listen, Inc.

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