An Introduction for Speaker Engineers to Smart Speakers

By Mike Klasco (Menlo Scientific, Ltd.)

The cliché everything old is new again is from the lyrics from *All That Jazz*, a musical from the mid-1970s. Even further back, when I was a kid in the 1950s, we had table radios that often included a clock. Clock radios were truly a classic early example of a consumer electronics multi-tool pocket knife. Jump forward a half a century and the digital personal assistant, MP3 player, and flip-phone merged into the smartphone. Today, if you ask nicely, the smart speaker will tell you the time, and play your requested music. Perhaps even inadvertently order a pizza for you when you tell your voice command TV to change the channel or pass along your conversations back to "big brother's" cloud data bank.

Good, bad, or ugly, product designers must go with the flow and learn new tricks. Meanwhile the guys with the grey hair in your engineering team may wistfully remember when a speaker designer only had to worry about the woofer, put a cap in series with the tweeter, and stick it all in a fake walnut vinyl-wrap particle board box. Of course, there always were the pricey and more critical higher-end audio components, but most products on the market consisted of a receiver, a turntable, and a cassette deck along with the passive speakers. Each product design group could focus on their own turf.

Yet even the transition from designing soundbars to smart speakers has challenges. From the hardware side, the voice assistant smart speaker must be compact, yet be packed with a power supply, all sorts of signal processing and memory, an amplifier, an Internet interface, mic(s) and a loudspeaker—all stuffed in an enclosure the size of a thermos. Smart speaker technology is all over the place (and therefore so is this article!).

The software/firmware side that performs the tasks or services for an individual, based on commands or questions is provided in the form of the Intelligent Virtual Assistant (IVA). Amazon Alexa, Alphabet Google Assistant, Apple Siri, and Microsoft's Cortina. For Asian markets, there is DuerOS, Ali Genie, and Dingdong used by Chinese players such as Baidu, Alibaba, Anker, and Xiaomi with local language support in the main software. Regardless of the smart eco-system, voice-enabled smart speakers are the primary interface to the smart home. With the wake word and a simple sentence, you have the power to interact with the Internet.

To prime the pump, the early market leaders such as Amazon and Google saw voice assistants as a pathway for long-term future revenue and a funnel for acquisition of "big data." These devices were positioned at intensely competitive pricing, especially the entry-level models. The smart speaker market is estimated in the range of $7 billion and expected to grow at a compound annual growth rate (CAGR) of 17% or more through 2025. North America absorbs a major share with Asia growing at an even higher CAGR. Smart speakers strive to understand the natural connected speech. Even without voice command, the ability to use your smartphone to remotely take care of stuff you forgot to do (e.g., turn off the lights or lock the front door) even if you are not home is invaluable.

The IVA voice command industry became real when Amazon launched the Alexa Echo in 2014 and the platform is used by many companies. In 2016, Google followed with Google Assistant IVA for Google Home speakers. Google Assistant is supported by the data generated from its web search engine. Typically, IVAs gather usage data from their associated eco-system devices, a process that has created some controversy regarding privacy. The user's inquiry, whether for a delivery order from the local pizza joint or whatever, might not have all the meta-data passed to the intended recipient, but even more disconcerting are the security failures from "bad actors"—the cyber-creeps who hack electronic door locks and security systems.

When Amazon Echo was launched in 2014, fidelity was an afterthought. The inflection point toward quality audio in smart speakers came when Sonos entered the market in 2017. Also that year Apple introduced the HomePod as a self-contained quality sound system as well as the gateway to Apple's Music service through Siri and a hub for controlling lights and the rest of the automated home. I thought the HomePod was quite decent but the market did not. More recently, the Amazon Echo Studio was the first smart speaker to attempt to deliver Dolby Atmos, and from what I hear sound is back in the spotlight.

Speakers, Speakers and More Speakers

At the core of *Voice Coil* magazine is the knowledge that the world revolves around speakers. Let's focus on a number of speakers that have some advantages for smart speaker appliances. Drivers for smart speakers are not inherently unique, but a single full-range driver, very shallow, high efficiency, and wide dispersion would be a good fit and we will discuss a half-dozen innovative designs.

Dinaburg Technology

The defining characteristic is a concentric passive ring radiator compliantly held in place by surrounds on both the inner and outer periphery. There are a number of positive aspects beyond the obvious benefits of a conventional vent-substitute design. The design techniques enable compactness, lower distortion, extended frequency range, higher efficiency, and more consistent beam width (dispersion). The passive radiator's diaphragm (compared to a simple vent) blocks midrange sound energy that is otherwise emitted from a port and the passive ring configuration also provides for tighter constructive coupling to the active speaker (and to the room) compared to an open bass reflex port or a non-concentric passive radiator.

From the measured data, it can be seen that the Dinaburg topology results in more output than what would be predicted by the more basic speaker box modeling simulations. Actually, these simulations assume the on-axis response in the range of where the passive ring is, providing a larger effective radiating area and tighter coupling of the bass to the room. This is in the bottom end response with the added benefit of avoiding beaming in the midrange that would have resulted from an active speaker of the same overall size as the outer diameter of the ring radiator. On the other end, the passive ring radiator maintains the speaker's pattern control down to a bit lower inflection point than the active driver has if just mounted on a baffle, (from acoustic suspension, vented or with non-concentric passive).

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Premium Sound Solutions

Premium Sound Solutions (PSS), which was first conceived 50 years ago at Phillips, offers its patented and popular Coscone shallow speaker technology in sizes 2" and up. Essentially moving the magnet position forward and wrapping the diaphragm over the magnetic structure enables about 50% depth reduction. The shallow cone's integrity is due to the unusual contoured rib structure. The stable and linear excursion provides the extra margin from acoustic echo cancelation processing (full-duplex) and is offered in Neodymium and Ferrite.

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Mike: I added his name. Is this correct?
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Fibona Acoustics

Fibona's Enclosure Magnet Coaxial Transducer (EMCT) technology is reminiscent to many smartphone microspeakers. Fibona's speaker is a full-range shallow coaxial neodymium magnet design with an integrated enclosure. The Fibonacci spiral was the inspiration for achieving diaphragm integrity with reduced depth. The company states "Nature uses this number sequence from the blooming and structure of something as simple as a flower, to the galaxy and stars in the sky." It would be interesting to see a Comsol simulation and I suspect that may show that there is something here of value for transducer engineers.

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Resonado Labs

Another driver technology that has been receiving attention is Resonado's Flat Core Speaker™ (FCS™) technology. FCS technology was introduced to provide the form-factor advantages of racetrack drivers with the acoustic performance of conventional circular drivers. The motor structure of FCS is the key differentiator of the technology as the flat voice coil is able to run along the entire length of the diaphragm and apply uniform force. This enables a larger bandwidth of pistonic behavior for a high-aspect ratio, low-depth driver superior to that of a conventional racetrack driver. For smart speakers, Resonado has introduced FCS Dual Core adding a second motor structure underneath one flat diaphragm. This enables a larger cone and greater surface area to push more air for the reproduction of lower frequencies Resonado Labs licenses FCS technology to OEMs/ODMs and is currently licensing partners with Asian OEM/ODMs Zylux Acoustic and SoundLab.

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Trulli Thin Driver

The Trulli TD38S 2" is a combination of high thermal power handling, while maintaining a small footprint and shallow depth. This is achieved by repositioning and expanding the voice coil to the juncture of the flat square diaphragm periphery and the juncture of the surround. This 2" speaker boasts a 1.3" voice coil and the square diaphragm confers over 20% more piston area than round. This configuration enables more spider corrugations with huge gains in excursion.
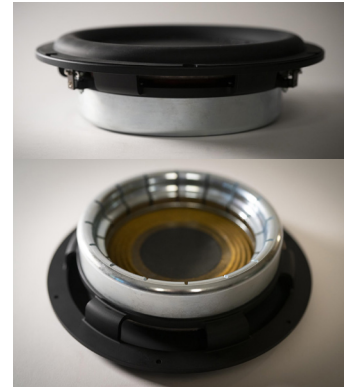
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Mayht

If you have watched the Devialet woofer do its yoga exercises Mike: I am not sure what this means. Please rephrase. , let's just say that evokes a similar perception of Mayht's operation. Highly compact and powerful, the developer promises increased bass performance. Motor, suspension, and dual membrane architecture moving in opposing directions is quite unique. Mayht feels this is the most efficient way to increase air displacement capability and prevent mechanical resonance of the enclosure, without increasing depth by having to mount two drivers back-to-back. Each driver uses "Negative Compliance," in order to avoid the effect of air pressure working against the movement of the membranes. Mayht developed a distributed suspension because at maximum excursion, the membranes almost touch each other so there is not any space for a conventional secondary suspension.

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Tectonic Audio Labs

NXT was formed 20 years ago to research and commercialize its bending wave flat panel Distributed Mode Loudspeaker (DML) concept. More recently, this has evolved to Balanced Mode Radiators (BMRs), a hybrid technology

that blends DML technology with that of traditional pistonic-action loudspeakers. BMR variants have both square and round shapes and combine the low-frequency performance of a traditional loudspeaker, but with a wider directivity and shallower profile.

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How About Smart Speaker Electronics?

There are many compelling reasons for amplifier selection, and most will funnel the designer to select the smart amp choices from Texas Instruments, NXP, Maxim, Qualcomm, and Cirrus Logic. Perhaps your team is experienced using one vendor's parameter setting software for the speaker protection, or other key component parts from a specific vendor, and we may even want to consider the sound quality. But aside from the amplifier protecting the speaker and not degrading the signal, what else could a designer hope for?

The amplifier development that I see having the most impact on speaker design this year is not even a transducer but a processing technique that will change how most of us design not just integrated speaker systems, but the drivers themselves. This is Dr. Klippel's KCS in chip form from Nuvoton.

Nuvoton

For my recent projects, this is "just what the doctor ordered." This is essentially a dynamic predistortion circuit that is calibrated to the speaker and the enclosure.

You might consider smart amps as the caterpillar and KCS as the butterfly emerging as the complete form. A smart amp, typically designed with the smartphone as its intended home, is predominately a feed-forward protection circuit, specifically tuned for the limits of the speaker, both displacement and thermal. I have consulted for a couple of the leading smart amp chip vendors over the years and we consistently ran up against Dr. Klippel's patents.

For functionality, aside from keeping the speakers from damage, we wanted a drop distortion. For applications where there is full duplex with acoustic echo cancelers, the lower bass distortion provides significant margin before echoes—and improved wake-word barge-in function.

Another intriguing aspect is what Dr. Klippel has defined as "green speaker design." Given enough of a materials budget you can design an underhung voice coil with a huge magnetic structure and achieve high linearity—but at a cost, both in materials and weight. Or you can design a less extravagant design and use dynamic predistortion to keep your driver on its best linear behavior.

This is what Klippel's KCS promises and as I found in a recent project, it actually delivers. I cannot talk about the current product development that so impressed me (it won't be shipping until after this article is published) but let's just say I am a believer. KCS changes what a system designer can demand from smart speakers, Bluetooth speakers,

soundbars, conferencing room voice only products, and studio monitors.

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www.nuvoton.com/news/news/products-technology/TSNuvotonNews-000390

Voice Assistance—Privacy and Security

For speaker designers, Privacy and Security are something new on our plate, for sure! Not a topic for a loudspeaker article, but still it is an issue in a smart speaker product requirement document (PRD). Privacy is not just about keeping personal conversations from ending up somewhere such as "big brother's server farm, or targeted ads showing up in odd places, but even more unnerving is a bad guy hacking your electronic key and unlocking your (not-so) smart front door or turning on your security camera to look around for themselves.

Syntiant

To mitigate these issues consider the edge on-board capabilities to avoid trips to the cloud for simple voice commands (turn on the lights, turn off the hot tub, etc.). Edge (onboard) computing ICs include Syntiant's voice always-on (VAO), which enables up to 60 command words. One reason for a brand (i.e., Uber, Bose, etc.) to consider bypassing Alexa in their products is to hang onto their big data, another is that Cloud computing is not free and can add up to significant costs for device manufacturers. Google Dialog Flow pricing has just increased as you read this. Text is $0.007 per request and for audio input/output—speech recognition, speech-to-text (STT), speech synthesis, text-to-speech (TTS) telephony—is $0.06 per minute. Amazon Lex charges $0.004 per API call, which amounts to $14.60 per annum for a voice-enabled device with 10 voice interactions per day. This unbounded operating cost can be prohibitive for device builders. Edge processing can tap into freely available on-device compute resources to significantly reduce or eliminate cloud and connectivity expenses. But a few dozen commands cannot avoid the requirement of access to the Internet.

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Native Voice

The work-around from Native Voice side-steps Alexa with custom wake words that designers can integrate into their architecture to bypass Alexis and Google Assistant paths to the cloud. I perceive this as similar to a VPN personal network enabling brands direct access to the customer base. Essentially an on-demand voice services library that is using your voice. With about 50 direct connections to multiple voice services (e.g., Alexa and Siri), as well as the brands that are developing their own (e.g., "Hey Spotify" and "Hey Uber"). Native Voice is working with leading brands in fitness, retail, and smart home technology to create a large collection of voice services and partnering with audio hardware device manufacturers to integrate their SDK to minimize or by-pass the "Big Brother" toll-keepers.

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Linkplay

Another key provider is Linkplay and its integrated mobile app audio software and hardware solutions for lossless audio formats, Wi-Fi, wireless multi-room and multichannel audio streaming, and Alexa Voice Service (AVS) integration. Components include a Wi-Fi module, device cloud software, and global streaming content. A single-chip solution and customization is available giving brands the ability to build out and launch innovative and differentiating products. There are more than 200 connected products powered by Linkplay in the home audio market in various wireless soundbars, speakers, and audio receivers, which are now optimized to integrate in devices across multiple verticals, including smart home devices such as robust security to and from the device through authentication and encryption.

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On a final note, the next game-changer for smart speakers will be completely wireless operation, specifically the power cord. As we have touched upon here, there is a lot of stuff going on in a smart speaker, and all that drains battery power—but that is another story. **VC**