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Manager's Guide to AV Design and Development

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Where Is Our Industry Headed?

By Steve Mowry

Perhaps the best way to look into the future is to first take a brief look at the past. In 1877, German scientist Ernst Siemens patented the first loudspeaker. In 1898, Englishman Sir Oliver Lodge received the second patent for a loudspeaker. This was all before music was even electrified.

In 1924, two General Electric researchers, Chester W. Rice and Edward Washburn Kellogg, patented the modern, moving coil, direct radiator loudspeaker, which has become the dominant design for all loudspeakers. While working at Acoustic Research in 1952, Henry Kloss and engineer Edgar Villchur produced the first acoustic suspension loudspeaker, the AR-1. However, it was Arnie Nudell who designed and developed the Infinity Servo-Statik One back in 1968.

I will attempt to list the technology milestones in the development of the loudspeaker industry as an engineer may see them.

1. The Thiele/Small linear parameters and system theory.
2. Filters including even- and odd-order Butterworth, Linkwitz-Riley, Bessel, Chebyshev, NTM, and so on.
3. Full-range electrostatic loudspeaker.
4. Material science including advanced polymers, rare-earth magnets, composites, adhesives, elastomers, and so on.
5. Manufacturing/industrial process including CPD, SPC, DOE, QC, DFMA, FMEA, TQM, and so on.
6. The active servo-controlled low-frequency loudspeaker.
7. Klippel's nonlinear parameters, nonlinear model(s), and nonlinear system identification.
8. Hardware- and/or software-based CAE/CAD and virtual measurement/analyzing tools.
9. CD–DVD–home theater.
10. High efficiency and high power amplifier development.
11. Signal processing including DSP, state space control theory/systems, FIR (finite impulse response), and IIR (infinite impulse response) digital filters and filter banks, all-pass (phase filters) and adaptive filters, and so on.
12. The expert A/V/IT convergence systems.
13. The true digital loudspeaker.

I list only 13 loudspeaker milestones; however, I may have missed some in my attempt to generalize, and items 12 and 13 are still futuristic concepts.

Although the audio transducer is clearly the "weak link" in audio system technology, within the first nine milestones, the technology appears quite mature. Certainly, there is always room for incremental improvements and item 3 may be the exception—but with cost driving the industry, material R&D is typically prohibitive to all but the major loudspeaker companies. Having said that, I see items 10 through 12 as perhaps the "last frontiers" for loudspeaker development. With signal processing, it's always cheaper and more versatile to implement in software rather than hardware.

There are a handful of companies that currently offer low-frequency loudspeaker systems with closed loop or servo or adaptive control systems. The benefits of control systems have long been identified and subsequently implemented into systems by companies such as Velodyne, Genesis, Meridian, and Infinity.

A control system, in it simplest form, is a device in which a sensed quantity is used to modify the behavior of the system through feedback and actuation. The task of synthesizing controllers is to evaluate the observed information and to apply an appropriate control strategy to the system to achieve a desired behavior while rejecting disturbances acting on the system. In engineering and mathematics, control theory deals with the behavior of dynamic systems over time. When one or more output variables of a system need to show a certain behavior over time, a controller manipulates the inputs to a system to obtain the desired effect on the output of that system.

In control engineering, a state space representation is a mathematical model of a physical system as a set of input, output, and state variables related by differential

equations. To abstract from the number of inputs, outputs, and states, the variables are expressed as vectors and the differential and algebraic equations are written in matrix form. The state space representation (also known as the "time-domain approach") provides a convenient and compact way to model and analyze systems with multiple inputs and outputs.

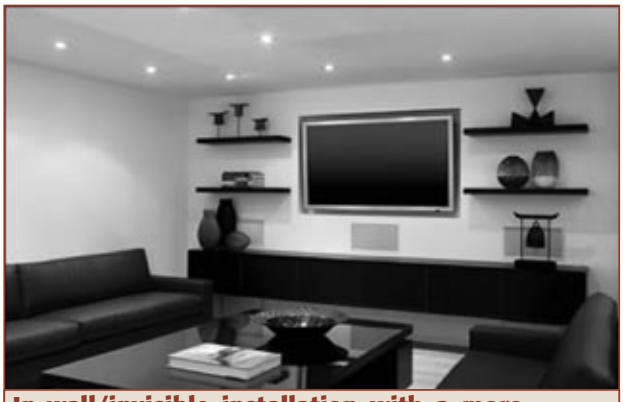
In reviewing published papers over the last few years, I believe that the scientist whose research is most concentrated and clear in the area of state space control systems for loudspeaker applications is Wolfgang Klippel. Recent research on loudspeakers has improved the understanding of the physical mechanisms and has provided a nonlinear model, which describes the behavior of the loudspeaker more precisely at large amplitudes. This lumped model illustrates the nonlinear parameters and explains their relationship to nonlinear distortions, which do not exist in the original input signal. This model comprises thermal and nonlinear parameters that can be measured by the Klippel Measurement System, http://www.klippel.de/.

On the basis of this extended modeling and the nonlinear parameters, you can predict the behavior of the loudspeaker by a numeric simulation. The controller can be taught to linearize the loudspeaker's output at low frequencies where displacement is high. A thorough discussion of control systems and loudspeakers was presented at the Technical University of Denmark in 2003. You can download the slides from that presentation at http://isp.imm.dtu.dk/nonlincomp/Klippel.pdf. The slides do a splendid job of explaining the pros and cons of various control system approaches.

As a loudspeaker engineer, I see control systems and DSP as opportunities to improve linearity, increase displacement, and self-protect the woofer. It simply needs high and clean power to correct for a drop in Bl and an increase in the rate of reaction force, Kms, and knowing where the zero or rest position is located, without DC-offset. There are links to several additional papers and brochures on the topic of digital loudspeakers, DSP, and control theory at http://www.s-m-audio.com/resources.html.

Another approach is to take cost out of the transducer but maintain performance with DSP or a control system. Andrew Bright from Nokia Corporation presented a case study on this topic, which you can download at http://isp.imm.dtu.dk/nonlincomp/bright_hand.pdf. His results seem to be consistent with Klippel's.

DSP is also currently being used for array steering, which is a fundamental concept in sonar theory in which the signal must be very directional, almost like a laser beam. JBL Pro and Meyer Sound have implemented digital steering for use with large venue quasi-line array systems. You can view a detailed presentation of this array phenomenon at http://www.meyersound.com/support/papers/steering/.



In-wall/invisible installation with a more contemporary approach.

The challenge is to develop cost-effective, available controller and observer technology that can be implemented within the manufacturing infrastructure already in place within Asia. I recommend that you recruit the resources necessary to staff DSP and controls development teams. Ironically, these resources are typically much easier to find than classical transducer and loudspeaker engineers.

Partnerships and cooperative efforts between companies are another strategic option. The people in the loudspeaker industry should realize that circumstance could change very quickly. What happened to manufacturing in Japan, Singapore, Taiwan, or even Mexico? History tells us that capital seeks the least expensive but most capable resources.

One such company that has positioned itself for the continued shift from analog to digital technologies is a client of mine, Advanced Sound Products, http://www.asp.com.my/. They have recruited engineering support from Europe and the US and have hired several Malaysian engineers, some of whom have studied overseas. They have developed sound solutions and close working relationships with companies such as Philips, LG, and Pioneer.

The level of education in Malaysia is surpassed in Asia only by Singapore, Japan, and Taiwan; but many young Malaysians study abroad in the US, the United Kingdom, and Australia with supplemental government funding. Furthermore, English is now just about as widely spoken in Malaysia as in the US, expressed as a percentage of the population; however, many Malaysians also speak Chinese.

Advanced Sound Technologies is among the few companies that are currently searching for A/V/IT system solution development partners. Advanced Sound has positioned itself by allocating the essential competencies and hardware and software tools to develop the systems of the future. This is a company to watch closely.

I believe software-based DSP and control systems will improve audio systems in the near future. This will happen concurrently with the increase in popularity of the "Convergence System." A convergence home entertainment and productivity system will provide home theater; computer; hi-fi; multimedia from within an integrated, compatible, and interconnected platform; and true home A/V/IT of the future that includes multidiscipline electroacoustic solutions. We have gone about as far as we can with the transducer itself (hardware)—the implantation of software algorithms in the digital domain is inherently exciting. Just make sure that there is a competent DSP resource on staff.

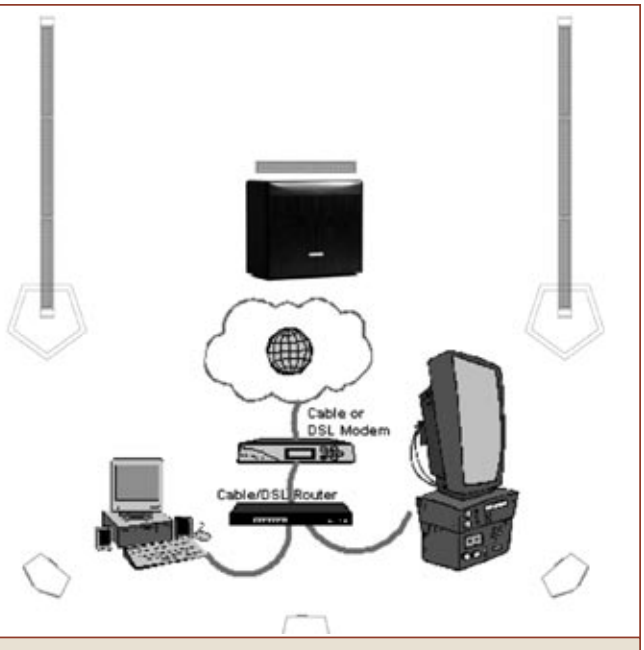
Finally, the integration of your home network and Internet connection into common consumer electronic devices has begun. Electronics manufacturers are scrambling to figure out ways to utilize your broadband Internet connection and your home network. Their first step is to further digitize your audio/video (AV) system to deliver a content-rich TV and music experience.

Digitizing your music, video, and photo collection means being able to distribute

access to these collections throughout your home or even across the Internet. Your media collection can become accessible from all of your home computers, from your stereo systems, from your televisions, anywhere. A connection to the Internet means being able to retrieve any song, photo, or video in your collection from anywhere in the world.

We are headed toward small high-powered loudspeakers and loudspeaker arrays with software-based DSP and active control that are integrated into a system that can access digital audio or video via the Internet or other digital programs. Clearly the possibilities are limitless, but the true digital loudspeaker is not on the radar screen quite yet.

Alex Salvatti, Senior Transducer R&D Engineer at JBL Pro and a colleague, gave an informative presentation to AES Convention attendees in Los Angeles a few years ago that described the 40 years of essentially fruitless efforts to develop a viable digital loudspeaker in *"Trends in Digital Loudspeakers."* The presentation is available for download at www.aes.org/sections/la/MeetingPresentations/TrendsDigitalLoudspeakers.pps. M³



An integrated A/V/IT WOW Convergence System.