



# **27<sup>th</sup> AES International Conference**

**Hillerød, Copenhagen, Denmark  
September 2-4, 2005**

**Efficient Audio Power  
Amplification**







**Jan Abildgaard Pedersen**  
conference chair



**Theresa Leonard**  
AES president



**Thomas Frederiksen**  
papers cochair



**Michael Andersen**  
papers cochair



27th Committee: from left, Robert Ehmsen, Preben Kvist, Subir Pramanik, Michael Andersen, Thomas Frederiksen, Knud Bank Christensen, Thomas Jensen, Eddy Boegh Brixen, and Jan Abildgaard Pedersen.



**T**he Pharmakon Conference Center in the quaint town of Hillerød near Frederiksborg Slot (see photo on previous page), one of Denmark's magnificent castles, was the locale of the AES 27th International Conference, *Efficient Audio Power Amplification*, held on September 2–4. Over 100 engineers from around the world traveled to this lovely area of North Zealand, a short train ride northwest of Copenhagen, for three days of technical papers, demonstrations, workshops, and informal discussions devoted to this important emerging area of audio engineering.

Linear (Class A/AB/B) amplification has been the standard for power amplification for many decades. During the last ten years, interest in higher efficiency power amplification has increased, particularly in the audio industry. The major driving force has been the need to provide fresh opportunities in audio design with the advantages that higher efficiency potentially offers: higher power with increased power density, savings in energy and battery life, potential cost savings, and even potential performance improvement in audio reproduction. The interest in this new field is global and includes all major industrial segments, such as consumer electronics, automotive audio, pro audio, and mobile devices. A paradigm shift in power amplification seems to be underway.



Flemming Nyboe

Ryan Lind



Lars Risbo



Jens Christensen

Victor Antunes



Conference Chair Jan Abildgaard Pedersen and his committee assembled a conference program that presented an overview of the current state-of-the-art in a broad perspective and addressed many of the new scientific disciplines involved in this emerging field. Michael Andersen and Thomas Frederiksen, papers cochairs, coordinated the technical program of 17 papers in 6 sessions.

Friday afternoon Jan Abildgaard Pedersen opened the AES 27th Conference by welcoming the attendees to Denmark, and he thanked them for their participation in the conference. AES President Theresa Leonard attended the conference, and she thanked the organizing committee for all of the hard work that went into preparing such an excellent event.

The keynote address was given by Michael Andersen, professor of power electronics at the Technical University of Denmark. His program at the university has been an incubator for much of the advanced research and development of switch-mode audio power amplification. His students have gone on to work for the leading companies in the field, a number of which are based in Denmark, making Denmark the logical site for the location of this conference. Andersen discussed the technologies and challenges facing the companies and individuals developing efficient audio power amplification.

Following the keynote address was an invited paper, "The Industrial Dynamics of Open Innovation: Evidence from the Transformation of Sound Amplification from Linear Solid-State to Class D Technology," presented by Jens Christensen of the Copenhagen Business School. He discussed how the concept of open innovation, a term coined by Henry Chesbrough in his book *Open Innovation: The New Imperative for Creating and Profiting from Technology*, can





Paul Mathews



Thomas Mørch



Bruce Hofer



Victor-Hugo Lopez de Nava



John Oh

be applied to the audio power amplification industry. The main proposition of the paper is that the specific modes in which different companies (including companies participating in the conference) manage open innovation in this emerging technology reflect their differential position within the innovation system in question and the stage of maturity of the technology. The proposition was analyzed and described through an in-depth study of the current transformation of sound amplification from linear solid-state technology to switched or digital technology within the consumer electronics system of innovation. This paper, written in a nontechnical style when compared to the other papers presented at the conference, tells the evolutionary story of switch-mode audio power amplification in the manner of a business-school case study. It gives a very interesting perspective to this emerging technology.

In the first paper of the next session, on power stage topologies, René Lambruschi and Frédéric Dezé, from the French company CL3, discussed a very high-efficiency switching power stage design. The presentation stimulated many questions about how this high-efficiency was obtained. The second paper of the session, presented by Victor Antunes of the Polytechnic Institute of Setubal, Portugal, discussed the concepts and design aspects of a digitally controlled multilevel audio power converter. The third paper of the session, presented by Petar Ljusev of the Technical University of Denmark, discussed a new self-oscillating high-frequency link inverter intended for consumer applications.

Throughout the three-day conference attendees posed questions that probed the methods and conclusions of the authors and offered additional insights and comments, all of

which stimulated many fruitful discussions that began during the technical sessions and continued during coffee breaks and meals.

After dinner on Friday evening there were table-top demo sessions by Pulsus and Texas Instruments, at which attendees were able to view some of the innovative technologies being developed. In addition Texas Instruments, Bang & Olufsen's ICEPower, CL3, and Hypex had demo rooms displaying their switch-mode audio power amplifier solutions.

The Saturday morning session featured four papers delving into the topic of modulation and control. Bert Wank of Cirrus Logic led off this session, presenting a paper on real-time power supply feedback for digital class-D amplifiers. He discussed and evaluated the system performance of a the real-time PSR feedback for a half-bridge and full-bridge amplifier output stage powered from a low-cost unregulated linear power supply. Michael Page of Texas Tech University followed with the presentation of a paper on feedback for distortion and error reduction on PWM-signals in class-D power stages to be made on-chip. Mikkel Høyerby of the Technical University of Denmark presented the third paper of the session. He discussed an analog input bandpass current-mode self-oscillating control scheme featuring low cost and high performance. The final paper of this session was by Lars Risbo of Texas Instruments. He presented a

methodology for discrete-time linearized small-signal modeling of PWM loops having continuous-time loop filters. This paper was judged to be a real step forward in explaining loop stability and other important characteristics.

The first afternoon session on Saturday addressed errors and distortion. Gael Pillonnet, representing two French companies, CPE Lyon and STMicroelectronics, gave a presentation on the reduction of output stage THD by adding output capacitance. The second paper of the session, presented by Flemming Nyboe of Texas Instruments, was on time domain analysis of open-loop

distortion in output stages. He showed how large-signal transfer characteristic ➡



John Melanson offers a comment during technical session. Extensive audience participation in the form of questions and comments added significantly to the value of the conference.

analysis can be applied to individual parts of a PWM output signal to help identify problems and optimize a design for minimum THD.

The final Saturday session was on integrated circuits and integration. Ryan Lind of Texas Instruments presented the first paper in this session. He discussed an integrated 40-W analog input class-D amplifier, reviewing the design tradeoffs and the silicon results, respectively. The next paper was presented by Paul Mathews of the Rane Corporation. He described how careful integration of power-factor-corrected switch-mode power supplies, class D power amplifiers, and digital signal processors can yield high power density and especially reliable and electromagnetically quiet products at a reasonable cost. Thomas Mørch of Texas Instruments presented the final paper in this session, looking at a high-performance 8x150-W digital audio system.

After a full day of technical sessions, the early autumn day in Denmark provided ample sunlight for a late-afternoon excursion to the spectacular Frederiksborg Castle (see photo on page 1166). Attendees received a full tour of the beautifully restored castle, which has been home to the Denmark's Museum of National History since 1878. The museum contains Denmark's most important collection of historical paintings and some of its most distinguished examples of decorative art. After touring the castle the group returned to the Pharmakon Center for an excellent banquet followed by some live jazz provided by the Katrine Madsen Quartet.

Sunday morning began with a three-paper session on measurements and tests. Bruce Hofer of Audio Precision presented the first paper. He discussed how to measure distortion in switching amplifiers and what to be aware of. The second paper in the session, by Victor Lopez de Nava of

Texas Instruments, was on IDDQ measurement techniques. This was followed by the paper of Tomas Sørensen of Texas Instruments on click and pop measuring techniques. He pointed out that the audibility of a click is very dependent on the system, amplifier, and speaker and that the perception of the click is subjective. This paper specified a measurement technique that can be used for all systems and can make results comparable, giving limits to what is acceptable in an end application.

The rest of the technical program on Sunday was comprised of a workshop on measurement and instrumentation and a workshop/tutorial on EMI/EMC. The measurements and instrumentation workshop featured four brief presentations followed by discussions with the audience. Bruce Hofer of Audio Precision discussed on-line measurements on a no-name class-D amplifier. Lars Ohlen of Audiograph pre-



Texas Instruments' table-top demo.





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In addition to a strong technical program, the conference committee did not forget about food and social activities: clockwise from above, Pharmakon Center provided excellent meals; outside courtyard supplied sun and fresh air; Katrine Madsen Quartet played soulful jazz Saturday evening; one of the magnificent paintings seen during tour of Frederiksborg Castle; coffee breaks offered an opportunity for networking.



sented the company's PowerCube measurements, showing good, bad, and poor power-supply behavior in test objects. Kristian Lund presented information on ICEPower's filterless topology for mobile/portable applications, stressing how important a proper PCB layout is. Thomas Mørch presented Texas Instruments' modular test platform for fast "new-IC" development, highlighting an example of 5320 tests on an IC. These tests took 4 to 6 weeks when done manually; done automatically the completion time can be reduced to 47 hours while also generating a complete 190-page test report.

The EMI/EMC Tutorial and Workshop featured three presentations. First a general introduction to EMC by Viggo Brøndegaard Nielsen of Delta, a Danish consulting firm. Next John Oh gave an introduction to full-digital amplifier

solutions of Pulsus Technologies. Lars Petersen of ICEPower talked about EMI problems and issues about using power-factor-corrections power supplies for switch-mode audio power amplifiers.

Conference Chair Jan Abildgaard Pedersen closed the conference by thanking the authors for their papers and presentations, his conference committee for working to produce an outstanding conference, the AES for its support and encouragement, and the attendees for their participation. He also encouraged everyone to visit the beautiful, vibrant city of Copenhagen before returning home.

Editor's note: The conference proceedings and CD-ROM can be purchased online at <http://www.aes.org/publications/conf.cfm>.