



AES 37th INTERNATIONAL CONFERENCE

The 37th AES International Conference, *Class D Audio Amplification*, was held in Denmark in late August. This conference was a follow-up to the AES 27th, *Efficient Audio Power Amplification*, in 2005. The scientific level of AES 37th proved that this technology has now matured and reached a very high level, with a large group of true experts and researchers in the field. The conference offered 18 high-level scientific papers, 20 scientific presentations, 5 demo rooms with technology demonstrations, a workshop, and high-level professional networking and social events. The 3-day conference was held at the Pharmakon Conference Center, which has all the necessary facilities to host the delegates—68 engineers from 16 countries around the world who traveled to this lovely area of North Zealand, a short train ride northwest of Copenhagen.

During the last ten years, switched-mode power amplifiers, very often called digital power amplifiers, have become the technology of choice in all of the global audio industry. The high efficiency and compact design inherent in digital power amplifier technology has inspired many engineers to design new and interesting products in existing and new market areas. Digital amplification technology is used in everything from the ever-expanding mobile phone and media player market in the milliwatt range to the most powerful public address systems operating at thousands of watts.

Conference Chair Jan Abildgaard Pedersen of Lyngdorf Audio 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 scientific disciplines involved in this important technology field. Thomas Mørch of Novo Nordisk, papers chair, coordinated the technical program of 18 paper presentations in 6 sessions. The technical sessions were chaired by Thomas Mørch, Knud Bank Christensen, and Jan Abildgaard Pedersen.

The conference was opened on Friday by Jan Abildgaard Pedersen, who welcomed everyone to Denmark and expressed his happiness at seeing so many people at the conference—representing no less than 16 different countries. He pointed out that it takes approximately two years of planning and preparation to organize an AES international conference. He introduced his organizing committee:

Class D Audio Amplification

Hillerød, Copenhagen, Denmark

August 28–30, 2009



Thomas Mørch (papers chair), Knud Bank Christensen (secretary), Eddy Bøgh Brixen (facilities), Subir K. Pramanik (treasurer), Preben Kvist (webmaster), and Ole Juhl Pedersen (assistant). Pedersen then introduced everyone to the conference program by showing details of all the main elements of the conference.

The keynote address was given by Lars Risbo of Texas Instruments. Risbo is one of the true pioneers and major forces in the development of Class D audio amplification. He talked about the difference between linear and nonlinear time-domain assessment of transients in a negative-feedback system. He reviewed analog-versus-digital scaling and ADC/digital logic ratio. He talked about the trend of digital logic gate density and DAC+A-in Class D followed by ADC feedback. Lars finished his keynote by talking about PWM Hybrid.

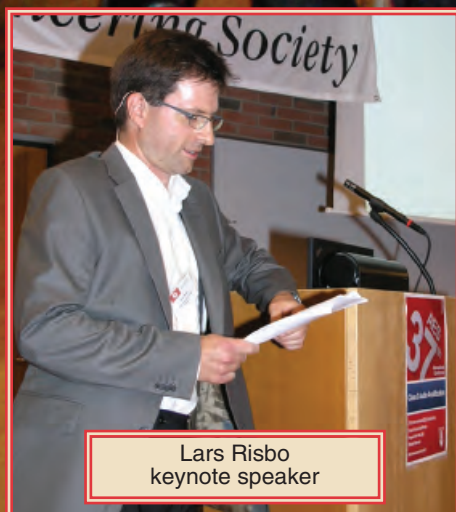
The first paper session was entitled “Integration Perspectives,” and the first paper in the session, “A Scalable Class D Audio Amplifier for Low Power Applications,” was given by Tony Forzley of Carleton University. This paper describes a Class D amplifier topology with direct digital input and a digital loop filter for low-power applications.

Then Søren Poulsen of Texas Instruments continued with a paper entitled “Fully Integrated 600 W Class-D Amplifier with Feedback.” This paper describes how a hybrid feedback loop topology can be used in a system that accepts either an analog or a PWM input signal.

The third paper in the session “Precision Interleaved Triangle Generation ASIC,” was written by Gerald Stanley from Crown International. He was unable to attend the conference, so he had asked Lars Risbo to present his paper. ➔

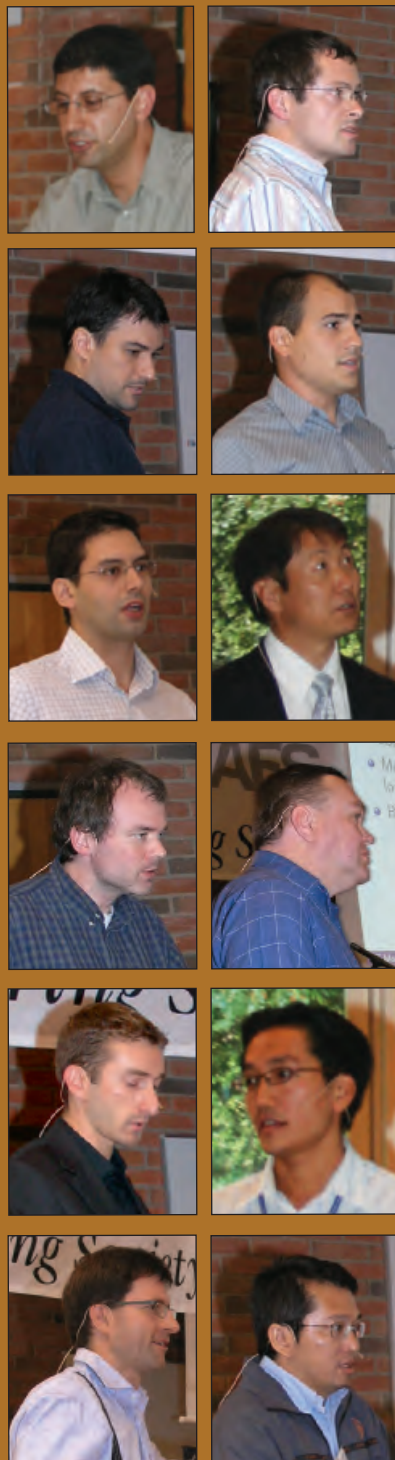


Jan Abildgaard Pedersen
conference chair



Lars Risbo
keynote speaker

Authors



Some of the authors who presented papers: from left, top row, Tony Forzley and Søren Poulsen; 2nd row, Remy Cellier, Gert Maizonave, and Dominique Romeo; 3rd row, Francois Koeslag, Carlos Ferreira, and John Oh (invited speaker); 4th row, Charles Lehmann, Bruno Putzeys, and Toit Mouton; 5th row, Toke Andersen, Alexandre Huffenus, and Yang Boon Quek; bottom row, Lars Risbo and D. Sookcharoenphol.

This paper describes an accurate interleaved double-sided natural pulse-width-modulation system based on a modular design approach using both analog and digital technology in a mixed-signal ASIC. Risbo then presented another paper written by Stanley, “Dynamic Time Offset of Interleaved Modulators.” This paper describes an automatically managed control of time offset to reduce large errors in spectrum suppression at high values of modulation index.

“A Fully Differential Digital Input Class D with EMI Spreading Method for Mobile Application,” by Remy Cellier from ST Ericsson, concluded the first session. Remy presented a digital Class D amplifier with a local analog feedback loop to improve performance of the power stage. Remy also presented a digital method to spread output spectrum in order to reduce EMI radiation.

The first day of the conference was concluded by an evening with five companies showing their products in open demo rooms. AudioGraph demonstrated the Active Load Box integrated with an Audio Precision analyzer. This latest addition in the AudioGraph line-up for amplifier stability measurements offers the same performance, high speed, and ease of use, as the company’s previous unit, the PowerCube.

A representative of the Danish Sound Technology Network discussed the group’s efforts to promote innovation, knowledge sharing, strategic matchmaking, and market development for both small, medium, and large sized enterprises. The network was founded by the leading Danish manufactures of sound equipment, services, and software.

Oxford Digital, a center of excellence for audio processing, demonstrated their products TinyCore, Graphical Programming, Audio Effects, and EasyTune.

Pulsus, one of the world’s leading suppliers of Class D power amplifiers, showed a number of different modules and technologies.

SenseLab provides listening test, perceptual evaluation, and consulting services to the industry. The company’s new product was announced and demonstrated for the first time at AES 37th: SenseLabOnline is a new rapid-response web-based listening-test service.

Saturday morning started with the session “Power Stage Topologies and Implementation.” The first paper, “Double-Boost DC-AC Converter with Sliding-Mode Control for Portable Audio,” was given by Gert Maizonave from the Technical University of Denmark. Gert described how a sliding-mode controller was designed in order to achieve fast-enough response for the whole audio frequency range. Symmetric, asymmetric, and interleaved operation modes were analyzed, as well as the advantages and disadvantages of achieving ZCS at all modes.

Dominique Romeo from ON Semiconductor presented the paper “Improve PSRR and Output Power Capability by Using a Boosted Class D Amplifier.” This paper describes the concept of boosted Class D amplifiers (BCDA), an alternative approach to solve two limitations of class D amplifiers in portable applications: PSRR and output power variation.

“Accurate Characterization of Pulse Timing Errors in Class D Audio Amplifier Output Stages” was presented by Francois Koeslag from the University of Stellenbosch. Francois ➤



37th Committee: from left, Dennis Nielsen, Theis Christiansen, Preben Kvist, Jan Abildgaard Pedersen, Knud Bank Christensen, Eddy Bøgh Brixen, Toke Andersen, Subir Pramanik, Roger Furness, and Thomas Mørch.

offered a detailed investigation of three sources contributing to pulse timing errors during switching within a half-bridge or full-bridge configuration, i.e., dead time, the switching device's turn-on and turn-off delays as well as the nonlinear rise and fall switching transitions. The separate effect of each pulse timing error on harmonic distortion was established, after which a combination model is introduced describing the interaction between these timing errors.

The final paper in this session, "Output Filter Solutions for Class D Power Amplifiers: Analysis, Characterization, and Recent Developments," was presented by Carlos Ferreira from Instituto Politécnico de Tomar. The paper focuses on the output filter topology and characterizes the tradeoffs in its design.

John Oh from Pulsus presented a look forward in his invited paper, "Future of Class-D Amplification Technology for IP Audio Systems." John presented near-future perspectives of Class D audio technology and SoC (system-on-chip) solutions that are needed for IP audio systems and other home-entertainment devices.

On Saturday afternoon the delegates took a break from the technical sessions for an excursion to one of Scandinavia's finest museums of modern art, the Louisiana Museum of Modern Art. They enjoyed the museum's collection of 3,000 items by such artists as Picasso, Giacometti, Dubuffet, Yves Klein, Andy Warhol, Rauschenberg, Henry Moore, Louise Bourgeois, Philip Guston, Morris Louis, Jorn, Baselitz, Polke, Kiefer, and Per Kirkeby.

After enjoying the cultural excursion to the museum, the delegates returned to the lecture hall for the next session "Methods and Topologies." The first paper, "Simple Post-Filter Feedback Topology for Class-D Amplifiers," was given by Charles Lehmann from Berne. Charles proposed a feedback topology that allows the straightforward inclusion of the output filter into the feedback loop.

The paper "Globally Modulated Self-Oscillating Amplifier with Improved Linearity" was then presented by another

true pioneer of Class D power amplifiers, Bruno Putzeys from Hypex Electronics B.V. Bruno derived an exact oscillation criterion applicable to all binary self-oscillating structures and accounting for the modulation index.

Toit Mouton from the University of Stellenbosch presented "Digital Control of a PWM Switching Amplifier with Global Feedback," in which he presents a digitally-controlled class-D amplifier using global feedback and a novel compensation strategy to minimize distortion resulting from ripple feedback of the output signal.

The final paper on the Saturday, "Multi-Carrier Modulation Audio Power Amplifier with Programmable Logic," was given by Toke Andersen from the Technical University of Denmark. He analyzed a Class D audio amplifier utilizing multicarrier modulation (MCM), constructed a prototype master-slave multicarrier modulated (MS MCM) amplifier, and measured it for performance and out-of-band spectral amplitudes.

Saturday evening's conference banquet, which included a gourmet dinner with fine wine, provided the delegates time ➔



Bruno Putzeys poses a question during the question-and-answer session after a lecture. Such feedback can give authors (and the audience) new insights and suggestions for future research.



The chefs and serving staff at Pharmakon provided outstanding meals and service during coffee breaks and meals (top) and at the conference banquet (bottom).



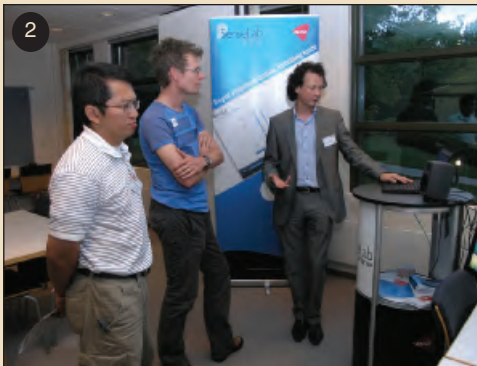
to relax, meet new friends, and expand their professional network.

The final day of the conference began with the paper session “Control/Protection System Design.” The one paper in this session, “A Speaker Protection Scheme for Class D PWM Amplifiers,” was presented by Alexandre Huffenus from EASII IC. Alexandre presented a current and area effective solution to limit the clipping from Class D power amplifiers.

The next session “Testing and Evaluation,” was com-



On Saturday afternoon the attendees went on an excursion to one of Scandinavia’s finest museums, the Louisiana Museum of Modern Art, which also features beautiful art outside on the grounds along the Øresund Strait.



Demos

- 1 Oxford Digital
- 2 SenseLab
- 3 Pulsus
- 4 AudioGraph



prised of one paper, “A Proposed Method of Characterizing Audio Distortion Induced by Power Supply Ripple in Audio Amplifier,” by Yang Boon Quek from Texas Instruments. He introduced a new term PSRDF (power supply ripple distortion factor) as a figure of merit for audio quality.

The final session in the conference was “Signal Processing,” and once again Lars Risbo from Texas Instruments took the floor to give another presentation, this time he presented his paper “Suppression of Continuous-Time and Discrete-Time Errors in Switch-Mode Control Loops.” Lars compared conventional continuous-time (CT) errors, such as hum and thermal noise, to discrete-time (DT) errors, being impulses at the pulse edges, such as distortion due to power-stage deadtime or timing jitter.

The very final paper of the conference, “A New Realiza-

tion of Linear-Phase Magnitude Complementary Network for Digital Bi-Amplifier,” was given by D. Sookcharoenphol from King’s Monkut Institute of Technology. Sookcharoenphol presented a new realization of a real-time linear-phase magnitude complementary filter pair structure based on a combination of two parallel all-pass networks.

The technical conclusion of the conference was a workshop that focused on what future developments and research is called for by the people who design end-user products based on Class D power amplifiers. To start the discussion, Jan Abildgaard Pedersen gave a presentation prepared by Lars Buur from Lyngdorf Audio. The delegates participated in a lively discussion, contributing many very good ideas. One conclusion was to try to obtain better EMI models and increased knowledge to enable better prediction of real EMI performance of products.

The conference was closed by conference chair Jan Abildgaard Pedersen, who thanked his organizing committee, the invited speakers, all the authors, the sponsors, the staff at AES headquarters in New York, the exhibitors, and all the delegates for contributing to the conference. Roger Furness, AES executive director, thanked Jan Abildgaard Pedersen and his team for preparing an outstanding and highly successful conference. He pointed out that the high scientific level of AES international conferences provide important contributions to the success and stature of the Society.



Conference Chair Jan Abildgaard Pedersen (right) and Roger Furness, AES executive director, spoke at the conference closing.

Editor’s note: The conference papers are available for purchase as a book or as a downloadable PDF at www.aes.org/publications/conferences. Individual conference papers can also be obtained from the AES Electronic Library at www.aes.org/e-lib. For a further discussion of some of the 37th papers, see Francis Rumsey’s follow-up article on p. 1087.