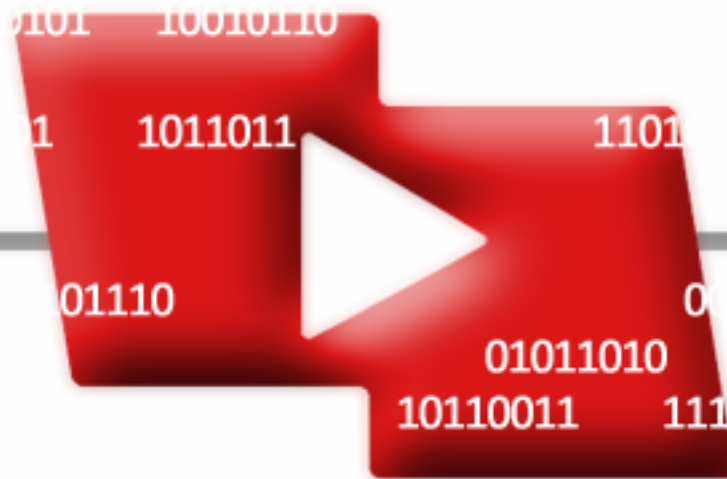


Class D Audio Amplification

37th International AES Conference 2009



August 28-30 2009 - Hillerød, Denmark

Program - Revised



Friday 14.00 – 14.10 Opening of Conference by Conference Chairman Jan Abildgaard Pedersen

Friday 14.10 – 15.00 Keynote Address

Listening with Two Ears

Lars Risbo
Texas Instruments Denmark, Lyngby, Denmark

Friday 15.00 – 18.00 Session 1 – Integration Perspectives

15.00

1-1 A Scalable Class D Audio Amplifier for Low Power Applications

Tony Forzley, Ralph Mason
Carleton University, Ottawa, Ontario, Canada

This paper describes a class D amplifier topology with digital input and a digital compensation loop filter to improve linearity. The core of the system is a high resolution hybrid multi-bit SigmaDelta-Pulse Width Modulation (PWM) modulator without the need for Dynamic Element Matching (DEM). Furthermore, high frequency DSP algorithms to correct for PWM distortion are not required. A system prototype based on a FPGA and commercial 16b analog to digital converter (ADC) validate the system design before implementation in 0.13um CMOS. Measurement results at 1 kHz yield a Total Harmonic Distortion (THD) better than 0.03% and greater than 30 dB of noise rejection. The system is inherently scalable to deep submicron processes due to its predominately digital architecture. To reduce power consumption a low power ADC design is presented.

15.30

1-2 Fully Integrated 600 W Class-D Amplifier with Feedback

Søren Poulsen
Texas Instruments Denmark, Lyngby, Denmark

Systems concept and design issues of the development of a fully integrated high performance 600 W stereo class d amplifier with feedback is presented. The hybrid feedback loop topology used accepts either an analog or a PWM input signal is described from basic concept to silicon implementation along with different function blocks of the systems design. Experimental evaluation results from actual silicon are presented.

16.00

Coffee Break



16.30

1-3 Precision Interleaved Triangle Generation ASIC

Gerald Stanley
Crown International Inc., Elkhart, IN, USA

Accurate interleaved double-sided natural pulse width modulation requires a cost and complexity of modulators that has prevented the wide-scale adoption of the one form of modulation that minimizes switching frequency while suppressing undesired switching spectra. A modular design approach using both analog and digital technology has enabled the creation of a mixed-signal ASIC that allows for flexible carrier amplitude and phase control over a wide range of operating frequency.

17.00

1-4 Dynamic Time Offset of Interleaved Modulators

Gerald Stanley
Crown International Inc., Elkhart, IN, USA

The time offsetting of interleaved modulators results in large errors in spectrum suppression at high values of modulation index. The automatically managed control of time offset can transparently allow the adaptive use of offset at low modulation index while removing it at high modulation. Such features are implemented in an ASIC modulator designed for interleave.

17.30

1-5 A Fully Differential Digital Input Class D with EMI Spreading Method for Mobile Application

Remy Cellier(1,3), Emmanuel Allier(1), Carlo Crippa(2), Rossella Bassoli(2), Gael Pillonnet(3), Angelo Nagari(1), Nacer Abouchi(3)

(1) ST Ericsson, Grenoble, France. (2) ST Ericsson, Agrate, Italy. (3) Institut des Nanotechnologie de Lyon (INL) – CPE Lyon, Lyon, France.

Class D audio amplifiers are widely used in embedded systems to achieve high efficiency. Digital class D accepts bit stream as input signal to drive loudspeakers. Major drawbacks of such systems are the nonlinearity due to the switched behavior and EMI radiations issued from the output low pass filter. This paper presents a digital class D amplifier with a local analog feedback loop to improve performances of the power stage and digital method to spread output spectrum in order to reduce EMI radiation. The amplifier, including digital modulator and analog power stage, was integrated in a single chip in 0.13 μm CMOS technology. The silicon results confirm the validity of the theoretical analysis.

Friday 19.30 – 21.30 Demos

AudioGraph – Demo Room

Catch the exciting demonstration of The Active Load Box integrated with an Audio Precision analyzer. This latest addition in the AudioGraph line-up for amplifier stability measurements, offer the same performance, high speed and ease of use, as our previous unit, the PowerCube.



Also, an option to use water cooled load for very high power measurements according to CEA2006 will also be on display. The system uses the concept of electronic loads to simulate reactive loads and can thus measure very large amplifiers.

Danish Sound Technology Network – Demo Room

The network was founded by the leading Danish manufactures of sound, equipmemnt, services and software: Oticon, Widex, Bang & Olufsen, TC Electronic, Brüel & Kjaer, AM3D Lyd, DPA Microphones, Steinway Lyngdorf Audio, Moto Audio, Sun Studios, Danish Badio and 3 universities: University of South Denmark SDU, Aalborg University AAU and Technical University of Denmark, DTU.

The network promote innovation, knowledge sharing, matchmaking and market development for both small, medium and large sized enterprises. For the first time ever, a national Danish booth will be organized at AES in New York October 2009. Come and meet the facilitators.

Oxford Digital Limited – Table Top Demo

Oxford Digital is a centre of excellence for Audio Processing and our team has spent more that 20 years building integrated hardware and software DSP solutions for audio across both consumer and professional applications.

At the AES 37th International Conference we will be demonstrating a complete end-to-end DSP solution for Semiconductor and Consumer Equipment Manufacturers including:

- Highly efficient, low power, low gate count **TinyCore** for both FPGA and ASIC implementation which is fully parameterisable from 1 to 32 audio channels, 16 to 48 bit-width and 128 to 8192 instructions per audio sample
- **Tiny Core** Evaluation systems
- **Graphical Programming** front-end tools that provide extremely fast workflow, maintenance and automatic software re-use
- **Audio Effects** that enhance the sonic performance of consumer equipment
- **EasyTune** back-end “tuning” tool that provides an easy-to-use integrated solution for optimising the sonic performance of consumer equipment

Pulsus – Demo Room

No preview text

SenseLab – Table Top Demo

SenseLab provides listening test, perceptual evaluation and consulting services to the industry. At the AES 37th International Conference, a new product will be announced and demonstrated for the first time. SenseLabOnline is a new rapid response web based listening test service which is being made available to you. This enables clients to quickly and easily build a listening test and then SenseLab will do the rest. The system will be demonstrated live during the conference, to illustrate how easy it can be to obtain perceptual sound quality evaluations.



Saturday 9.00 – 12.00

Session 2 – Power Stage Topologies and Implementation

9.00

2-1 Double-Boost DC-AC Converter with Sliding-Mode Control for Portable Audio

Gert B. Maizonave(1), Michael A. E. Andersen(1), Claus Kjærgaard(1), Kristian L. Lund(2), Lars B. R. Hansen(2)

(1) Dept. of Electrical Engineering, Technical University of Denmark, Kongens Lyngby, Denmark. (2) Bang & Olufsen ICEpower a/s, Kongens Lyngby, Denmark

The double-boost topology is studied for operation as a dc-ac converter and single stage audio amplifier. A sliding mode controller is designed in order to achieve fast enough response for the whole audio frequency range. Symmetric, asymmetric, and interleaved operation modes are analyzed, as well as the advantages and disadvantages of achieving ZCS at all modes.

9.30

2-3 Improve PSRR and Output Power Capability by Using a Boosted Class D Amplifier

Dominique Romeo
ON Semiconductor France

In mobile phone applications, Power Supply Rejection Ratio (PSRR) and Output Power capability are key parameters. In that kind of portable application, class D amplifiers (CDA), thanks to a high efficiency and a large output capability, are more and more popular. However, compared to a class AB amplifier, the PSRR is still one of the class D drawbacks. When a state of the art class AB amplifier can achieve a PSRR as high as -100 dB at 217 Hz and fully reject supply noise like GSM burst, classical class D amplifier difficultly go under -80 dB. Moreover, even if the CDA Output Power capability is larger than class AB, this output power is still dependent upon the battery voltage level. This paper depicts the concept of Boosted Class D Amplifiers (BCDA), which could be an alternative to solve these two limitations: PSRR and output power variation.

10.00 Coffee Break

10.30

2-4 Accurate Characterization of Pulse Timing Errors in Class D Audio Amplifier Output Stages

Francois Koeslag, Toit Mouton
University of Stellenbosch, Western Cape, South Africa

This paper contains 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 analysis is based on a novel simulation strategy that makes use of Newton's numerical method. The separate effect of each pulse timing error on harmonic distortion is established, after which a combination model is introduced describing the interaction between these timing errors.

11.00

2-5 Output Filter Solutions for Class D Power Amplifiers: Analysis, Characterization, and Recent Developments

Carlos Ferreira(1,3,4), Beatriz Borges(2,4), Luís De Sá(3,4).

(1) Instituto Politécnico de Tomar, Portugal. (2) Universidade Técnica de Lisboa, Portugal. (3) Universidade de Coimbra, Portugal. (4) Instituto de Telecomunicações (IT), Portugal.

This paper focus class D amplifiers output filter topology's and characterizes the tradeoffs in its design: output ripple, negative feedback loop gain, bandwidth, attenuation of differential/common components, and minimization of the system gain variation in face of load impedance changes. Recent developments in filter topologies are also discussed.

Saturday 11.30 – 12.00 Invited Speaker

Future of Class-D Amplification Technology for IP Audio Systems

John Oh
Pulsus, Korea

This paper presents near-future perspective of class- D audio technology and SoC (system-on-chip) solutions that are needed for IP audio systems and other home entertainment devices. Music listening environments are evolving fast. Handheld music players, Hi-Fi home systems, TV, and mobile phones are now networked with each other. Wired and wireless network connectivity, real-time operating system, graphical user interface, embedded DSP software, multiroom speakers, and docking capability will be common features of audio systems. We discuss what is needed for amplification components of future SoC solutions and which are missing in the current class-D amplifier technology.

Saturday 13.30 – 13.45

Go to Busses



Saturday 13.45 – 16.45 Visit to Louisiana Museum of Modern Art

At this point we break our busy schedule and invite you to sample one of Scandinavia's finest museums of modern art.



In addition to a collection of 3000 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, Louisiana this summer features **Green Architecture for the Future**, focusing on new departures in architecture that meet the need for sustainable development. New inventions, materials, processes and complex architectural methods in the built-up environment is presented in the three exhibition themes The City, Climate & Comfort and Metabolism. Four different architectural 'future laboratories' show that sustainable architecture is a far more complex matter than rainwater collection and solar cells.

Saturday 17.00 – 19.00 Session 3 – Methods and Topologies

17.00

3-1 A Simple Post-Filter Feedback Topology for Class-D Amplifiers

Charles Lehmann
Berne, Switzerland

A feedback topology shall be proposed that allows the straightforward inclusion of the output filter into the feedback loop. It can be adapted to high- or low-Q output filters equally well. It is not restricted to either self-oscillating or carrier-based modulator topologies. One advantage is that the slew-rate requirements on the operational-amplifiers used for the proposed topology are quite relaxed since they are not forced to handle fast transients. Another advantage is that the feedback branch is based on resistors only.

17.30

3-2 Globally Modulated Self-Oscillating Amplifier with Improved Linearity

Bruno Putzeys
Hypex Electronics B.V., Groningen, The Netherlands

An exact oscillation criterion applicable to all binary self-oscillating structures and accounting for modulation index is derived. An exact expression for the averaged DC transfer from the comparator input to the output is derived, permitting precise prediction of the linearity of the modulation process. A 400-W amplifier optimized according to these insights was built and results are presented.

18.00

3-3 Digital Control of a PWM Switching Amplifier with Global Feedback

Toit Mouton(1), Bruno Putzeys(2).

(1) University of Stellenbosch, Western Cape, South Africa. (2) Hypex Electronics B.V., Groningen, The Netherlands.

A digitally-controlled class-D amplifier using global feedback is presented. The output signal of the amplifier is sampled using a sigma-delta analog-to-digital converter. A novel compensation strategy is used to minimize distortion resulting from ripple feedback of the output signal. An evaluation system, based on a Field Programmable Gate Array, was developed and an experimental evaluation was performed. State-of-the-art performance was achieved.



18.30

3-4 Multi-Carrier Modulation Audio Power Amplifier with Programmable Logic

Theis Christiansen(1), Toke Andersen(1), Arnold Knott(1), Gerhard Pfaffinger(2), Michael A. E. Andersen(1).

(1) Technical University of Denmark, Kgs. Lyngby, Denmark. (2) Harman/Becker Automotive Systems GmbH, Straubing, Germany

While switch-mode audio power amplifiers allow compact implementations and high output power levels due to their high power efficiency, they are very well known for creating electromagnetic interference (EMI) with other electronic equipment. To lower the EMI of switch-mode (class D) audio power amplifiers while keeping the performance measures to excellent levels is therefore of high interest. In this paper a class D audio amplifier utilizing Multi-Carrier Modulation (MCM) will be analyzed, and a prototype Master- Slave Multi-Carrier Modulated (MS MCM) amplifier has been constructed and measured for performance and out of band spectral amplitudes. The basic principle in MCM is to use programmable logic to combine two or more Pulse Width Modulated (PWM) audio signals at different switching frequencies. In this way the out of band spectrum will be lowered compared with conventional class D amplifiers. Analytically expressions, simulations, and measurements result in reduced switching frequency amplitudes using MCM techniques. It is also shown that the Total Harmonic Distortion (THD) tends to be compromised compared to conventional class D amplifiers due to intermodulation products of the switching frequencies entering the audio band. Still, the MS MCM topology with two carrier signals shows a 6 dB reduction of the switching frequency amplitudes as well as THD across the audio band below 1 percent at 55 W output power open loop.

Saturday 20.00 – Banquet

A 3-Course Gourmet Dinner with Selected Wines

Beer and soft drinks are available.



Sunday 9.30 – 10.00 Session 4 – Control/Protection System Design

4-1 A Speaker Protection Scheme for Class D PWM Amplifiers

Alexandre Hufenus(1), Gael Pillonnet(2), Robert Cittadini(3), Vincent Rabary(3).

(1) EASII IC, Grenoble, France. (2) Institut des Nanotechnologies de Lyon, Villeurbanne, France. (3) ST Microelectronics, Grenoble, France.

Switched mode (class D) audio amplifiers gained much popularity in low power applications during the last decade thanks to their high efficiency, compactness, and increasing sound quality. They have become the technology of choice for battery operated systems such as mobile phones, PDAs, portable media players, etc. In such applications it is critical to protect the microspeakers from an excessive output power that could result from severe amplifier clipping. A current and area effective solution is presented in this paper, to limit the clipping from the Class D amplifier.

Sunday 10.00 – 10.30 Session 5 – Testing and Evaluation

5-1 A Proposed Method of Characterizing Audio Distortion Induced by Power Supply Ripple in Audio Amplifier

Yang Boon Quek

Texas Instruments Inc, Dallas, TX, USA

Digital input class-D amplifiers will be the predominant amplifier technology enabling consumer audio systems in the future. The traditional Power Supply Rejection Ratio (PSRR) measurement method cancels supply ripple in Bridge-Tied-Load (BTL) amplifiers, thus is unable to measure audio distortion induced. The proposed method employs innovative measurement of both Intermodulation Distortion (IMD) and Total Harmonic Distortion Plus Noise (THD+N) to more accurately represent audio quality. A new term known as Power Supply Ripple Distortion Factor (PSRDF) is introduced as a figure of merit for audio quality. Examples of how the proposed method effectively characterizes different levels of distortion induced by power supply ripple in closed-loop and open-loop BTL Class-D amplifiers are also presented. The proposed method is also applicable in characterizing all audio power amplifiers.

Sunday 10.30 – 11.00 Coffee Break



Sunday 11.00 – 12.00 Session 6 – Signal Processing

11.00

6-1 Suppression of Continuous-Time and Discrete-Time Errors in Switch-Mode Control Loops

Lars Risbo(1), Mikkel C. W. Høyerby(2)

(1) Texas Instruments Denmark, Lyngby, Denmark. (2) Motorola Denmark, Denmark.

This paper presents a theoretical and experimental study of the ability of common class-D switch-mode control loops to suppress various error signals. Such errors are categorized as either of conventional continuous-time (CT) nature, e.g., hum and thermal noise, or as discrete-time (DT) nature being impulses at the pulse edges, e.g., distortion due to power stage deadtime or timing jitter. It is shown both theoretically and experimentally that DT error suppression can be dramatically worse than for CT errors depending on the carrier generation/modulation mechanism used. The theoretical modeling is based on a previously presented discrete-time small signal model. An experimental measurement setup is presented along with measurement data compared to the theoretical model.

11.30

6-2 A New Realization of Linear-Phase Magnitude Complementary Network for Digital Bi-Amplifier

D. Sookcharoenphol, C. Chakreeteekapakvisi

King's Monkut Institute of Technology, Bangkok, Thailand

A new realization of real-time linear-phase magnitude complementary filter pair structure that is based on a combination of two parallel all-pass networks is proposed in this paper for dividing wide audio spectral into low and high frequency bands before passing to digital switching amplifiers. Each all-pass network consists of a cascade of a noncausal and causal IIR filter to obtain the linear-phase characteristics. The advantage of the proposed network is that it does not introduce a self-distortion and can save power consumption. Since the magnitude responses of each network have only squared of sub all-pass filters. While the power complementary network has the cross product of sub all-pass filters that degrade an efficiency of amplification. Moreover, the power complementary network gives a high sensitivity to the phase difference of two filters around the transition band. The new structure can be reduced an implementation complexity of the noncausal and causal filters compared to the conventional structures. In addition, the proposed structure provides a low sensitivity to coefficients quantization thus bit rate can reduce, example of simulations is also given.

Sunday 13.30 – 14.30 Workshop

In the latest 10 years the semiconductor industry has developed and marketed an increasing number of Class D Power Amplifier products spanning from very limited power to now more than 600W in a monolithic device and with a lot of extra features. But how are these products received in the consumer electronics industry? This workshop will try to look into this market segment and investigate the needs for - and requirements to - future integrated Class D Power Amplifier solutions.

Sunday 14.30 – 15.00 Closing of Conference

Goodbye! See you in New York City!

