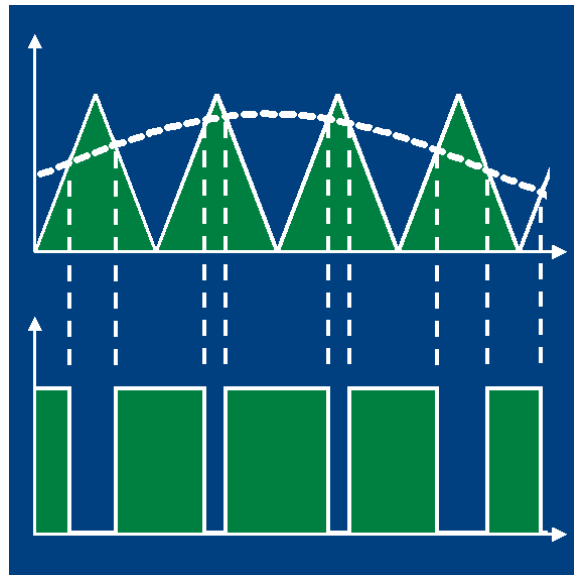


Preliminary Programme incl. general information



Industrial/PhD Course in **Switch-mode audio power amplifiers (class-D)**

August 15-19, 2011

Background and aim of the course

Linear (Class A/AB/B) amplification has been the standard for power amplification for many decades. During the last decade, 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, e.g. 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, cars, professional, mobile and/or portable audio fields. A paradigm shift seems to be on its way.

This course will present an overview and in-depth study of the current state-of-the-art in a broad perspective and address many of the new scientific disciplines involved in this emerging field.

Switch-mode audio power amplifiers are in more ways a combination of mixing otherwise complementary scientific fields as power electronics, analogue and digital signal processing, advanced analogue design, EMC and more.

The aim of the course is thus to address a new, complex and challenging era at an early stage.

Place

DTU Electrical Engineering
Technical University of Denmark
Ørsteds Plads - Building 349 - room 025
DK-2800 Kgs. Lyngby
DENMARK
<http://www.dtu.dk/centre/ele/English.aspx>

Language

English.

Literature

Electronic copies only of slides (PDF-files) will be available on-site. Please bring your own laptop PC.

Course Fee

The course fee is EUR1265 (approx. DKK 9,300) which also includes coffee, lunch and course material. For EU Ph.D. students the course fee will be EUR275 (approx. DKK 2,300). Registration is binding and no refund is possible.

Laptop PC's

Please bring your own laptop PC (preferably with PSpice evaluation version and Matlab/Simulink rel. 14 installed).

Credits

5 ECTS - upon passing this course (incl. the homework assignment). The Technical University of Denmark (DTU) will send out diplomas. To get a diploma you must register as a guest student, there are links for this when you go [on to the course registration](#).

Registration

Preferably now and not later than July 15 2011 by [link to course 31359 registration](#). Please note we have only a limited number of seats.

Organizer and further information:

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Programme

(There will be lunch at approximately 12.00 in the canteen/restaurant in building 101A - tables have been reserved for this course 31359. Coffee breaks approx. 08.45, 10.30 and 14.30 outside **room 025 in building 349** - all lectures and laboratory exercises will take place in this building).

Monday August 15 2011 (09.00-16.00):

Welcome and introduction (Andersen)

System overview (Andersen, Knott)

- System, analogue/digital input, modulators, power stages, output filters, feedback (with/without), power supply
- Exercises

Power stages (To be decided)

- Non-linearity in the output stage (dead time etc.)
 - Exercises
-

Tuesday August 16 2011 (09.00-16.00):

Digital signal processing (Bjørn-Josefsen)

- UPWM models
- Noise shaping basics
- Simulation of digital PWM, new continuous time orthogonal state-space method
- Exercises

Jitter and PWM (Risbo)

- Clock quality requirements
 - Sampling artifacts at feedback
 - THD, noise, and stability
 - Exercises
-

Wednesday August 17 2011 (09.00-16.00):

Self-oscillating control systems for switch-mode amplifiers (Høyerby)

- Oscillators in general
- Self-oscillating control systems for switch-mode applications
- Small-signal analysis in phase-shift and hysteretic self-oscillating control systems
- Key differences between clocked and self-oscillating control systems
- Linearity issues in switch-mode audio applications
- Exercises/demonstration

Self-oscillating control systems for switch-mode amplifiers (continued) (Høyerby)

- Example of linearity optimization in hysteretic switch-mode power amplifier
 - Exotic/experimental techniques for controlling self-oscillation frequency
 - Exercises/demonstration
-

Thursday August 18 2011 (09.00-16.00):

Hands-on measurement on switching audio power amplifiers (Knott, Høyerby, Hofer, Schiffner)

- Hands-on lab measurements on a class-D audio amplifier prototype board
-

Friday August 19 2011 (09.00-12.00):

Power supplies for audio (Petersen)

- Power supply pumping with single-ended audio power amplifiers
- Power supply specifications and ratings in audio, capacitor size, trade-offs
- EMI-filter design consideration for Class D dedicated switch mode power supplies
- Exercises

Homework assignment (Andersen)

- Report to be handed-in 2 weeks after this course

Lecturers



Anker Bjørn-Josefsen received the MSc EE degree from the Technical University of Denmark in 1991.

He joined Toccata Technology in 1999, member of the Technical Staff in Texas Instruments after TI's acquisition of Toccata in 2000.

His present assignment is as system engineer with responsibility for TI's line of PWM-DAP processors.

Inventor or co-inventor of numerous patents related to digital amplifiers.



Lars Risbo born in 1966, MSc EE 1991, PhD (1994) from the Technical University of Denmark.

Founder of Toccata Technology in 1996 later acquired by Texas Instruments (2000). Toccata designed the world's first true digital audio power amplifier Tact Millennium (according to Guinness book of records 1999).

He is currently working as manager of strategic research at Texas Instruments Denmark under the Digital Audio and Video division.

Research interests include Signal Processing, Sigma-Delta & PWM modulation, switching amplifiers.

Lars Risbo has published several papers on digital amplifiers and data converters and holds numerous patents within the field.



Mikkel C. W. Høyerby received the MSc EE degree in 2004, and the PhD degree in 2010 from the Technical University of Denmark, working in-between as a research assistant. Research includes high-bandwidth dc-dc converters, class-D audio power amplifiers, switch-mode control IC design, switch-mode controller modeling, RFPAs systems

with envelope tracking and RFPAs linearization. In 2009/2010 he was employed as a research engineer with Motorola in Copenhagen, working on RFPAs linearization and general RF/IF design. In 2010 he co-founded class-D audio startup Merus Audio where he currently functions as system architect.



Bruce Hofer co-founded Audio Precision in 1984 with a group of audio engineers from the labs of Tektronix. In addition to serving as Board Chairman, Bruce remains technically active as the company's principal analog design engineer. Bruce has received 12 patents, authored several articles and papers and in 1995 received the Fellowship Award from the international Audio Engineering Society (AES). He

earned his BSc EE degree from Oregon State University in 1970.



Klaus Schiffrer has an extended experience with audio measurements and is currently Product Manager for the Rohde & Schwarz® UPV Audio Analyzer.

Arnold Knott was born in 1979 and received his Bachelor of Honour (Dipl.-Ing.) degree from the University of Applied Sciences, Deggendorf, Germany, in 2004.



He was working at Harman/Becker Automotive Systems GmbH, Germany, designing switch-mode audio power amplifiers and power supplies from 2006 to 2009.

In 2010 Arnold got his PhD degree in corporation with Harman/Becker Automotive Systems GmbH, Germany, under the project title "Improvement of out-of-band Behaviour in Switch-Mode Amplifiers and Power Supplies by their Modulation Topology". Interests include switch-mode audio power amplifiers, power supplies, RF electronics, and modulation topologies. Currently, Arnold Knott is working as assistant professor in Power Electronics at DTU.



Lars Petersen received a PhD degree in electrical engineering from the Technical University of Denmark in 2003, working on a project dealing with switch-mode power supplies for Power Factor Correction.

From 2003 to 2007 Lars has been working for Bang & Olufsen ICEpower a/s in Kgs. Lyngby. First as a Research & Technology Engineer with focus on various new technologies and then as an Innovation Manager dealing with New Concept & Business Development as well core IPR development.

In January 2008 Lars founded Upcon Technology A/S together with a colleague. Upcon Technology is focusing on developing high efficient AC/DC converters, mainly for telecom and server applications.



Michael A. E. Andersen was born in Aalborg, Denmark. He received the MSc EE and PhD degrees from the Technical University of Denmark in 1987 and 1990, respectively, all in power electronics.

From 1990 he was assistant professor at the Technical University of Denmark, from 1994 he was associate professor, and since 2003 he has been a

Professor in Power Electronics at DTU. His research areas include switch mode power supplies, power factor correction, and switch mode audio power amplifiers. He has published more than 80 papers in his area of research.

Prof. Andersen is also a member of IEEE, AES and EPE. He received "A. R. Angelo's Grant" in 1990, the "P. Gorm-Petersen's Memorial Grant" in 1991, the "Best Poster Prize" at UPEC '91, the Danish "AEG Elektronprisen" in 2004, and the DTU Innovation Prize in 2006.



Course 31359 website:

<http://www.dtu.dk/centre/ele/English/education/courses.aspx?coursecode=31359>

General information:

Building 349 is open from approx. 07.30 to 17.00.

Get-together reception on Monday 15 August 2011 at approx. 16.00-17.00 hours in building 349 room 005.

Laboratory is in building 349 room 005.

Useful links:

[DTU Campus in Lyngby](#) with links to [public transportation to DTU](#)

[Danish Railways](#)

[Journey planner:](#)

Wireless access in building 349:

Please ask Michael A. E. Andersen or Henriette Wolff for username and password.