Fundamentals of Data Converters – A short course
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Summary:
Data converters are one of the most fundamental building blocks in mixed-signal systems. This course will introduce the fundamental principles of Analog to Digital Converters (ADC) including the most common Nyquist-rate and oversampling (Delta-Sigma) architectures. The course will cover basic system and circuit architectures, performance metrics, data converter characterization, performance limitations and tradeoffs, spectral analysis, practical implementations, and design procedures. ADC topologies including Flash, two-step, pipelined, SAR, integrating, and delta-sigma.

Learning Objectives:
Upon completing the course, the participant will be able to:

- Understand data converters system specifications, performance metrics and data sheets, data converters characterization, and spectral analysis.
- Understand performance tradeoffs (power, area, sampling rate, resolution, etc...).
- Understand basic circuit topologies and circuit design procedure of the most common Nyquist-rate and oversampling (Delta-Sigma) data converters.

Target Audience:
Analog and mixed-signal IC design engineers, researchers and graduate students who are interested in data converter design, and mixed-signal SoC designers. In addition, product, test, and application engineers will learn about testing and characterization of data converters and their limitation.

Outline:
Day One – System level concepts, performance metrics and limitations, and spectral analysis
Basic definitions, data Converters tasks, performance metrics of data converters: Resolution, SNR, SNDR, THD, Dynamic Range, ENOB, and SFDR. Performance limitations: Tripping Points, Offset Errors, Gain Errors, INL Errors, DNL Errors, Absolute and Relative Accuracy, Monotonicity Errors, and Timing Errors. Fast Fourier Transform (FFT) and spectral characterization and simulations of data converters.

Day Two – Nyquist-rate ADCs
The Flash ADC topology: basic concepts, design procedure and circuit implementation, practical performance limitations and non-idealities, sub-ranging and two-step ADCs, Pipelined ADCs, SAR ADCs.

Day Three – Nyquist-rate ADCs and Oversampling (Delta-Sigma) ADCs
The integrating ADC topology, oversampling ADC Architectures (Sigma-Delta): One-bit Converters, Noise Shaping, higher order noise-shaping, circuit implementation examples of 2nd-order multi-level sigma-delta ADCs, applications to wireless transceivers.
Ayman Fayed received his B.Sc. degree in Electronics & Communications Engineering from Cairo University in 1998, and his M.Sc. and Ph.D. degrees in Electrical & Computer Engineering from The Ohio State University in 2000 and 2004 respectively. From 2000 to 2009, he held several technical positions in the area of analog and mixed-signal design at Texas Instruments Inc., where he contributed to many product lines for wire-line, wireless, and multi-media devices. From 2000 to 2005, he was with the Connectivity Solutions Dept. at TI, where he worked on the analog frontend design of high-speed wire-line transceivers such as USB, IEEE1394b, and HDMI, and on fully integrated switching/linear regulators and battery chargers for portable media players. From 2005 to 2009, he was a member of the technical staff with the wireless analog technology center at TI, where he worked on delta-sigma data converters for various wireless standards, and on the development of fully-integrated power management solutions for mixed-signal SoCs with multi-RF cores in nanometer CMOS. Dr. Fayed joined the Dept. of Electrical & Computer Engineering at Iowa State University in 2009, where he held the Northrop Grumman Assistant Professorship. He then joined the Dept. of Electrical & Computer Engineering at The Ohio State University in 2015 as an associate professor. He is the founder and director of the Power Management Research Lab (PMRL) and his current research interests include on-chip power grids for dynamic energy distribution in highly-integrated systems, high-frequency switching regulators with on-chip and on-package passives for SoCs, low-noise power supply modulators for RF transmitters, energy-harvesting platforms for power-restricted & remotely-deployed systems, and power conversion in emerging technologies. Dr. Fayed is a senior member of IEEE, an associate editor for IEEE TCAS-I and previously for TCAS-II, and serves in the technical program committee of RFIC, ISCAS, and the steering committee of MWSCAS. He is the author/co-author of many publications in the field and holds 10 US patents. Dr. Fayed is a recipient of NSF CAREER Award in 2013, and the 2015 Darlington Best Transactions Paper Award from the IEEE Circuits and System Society.