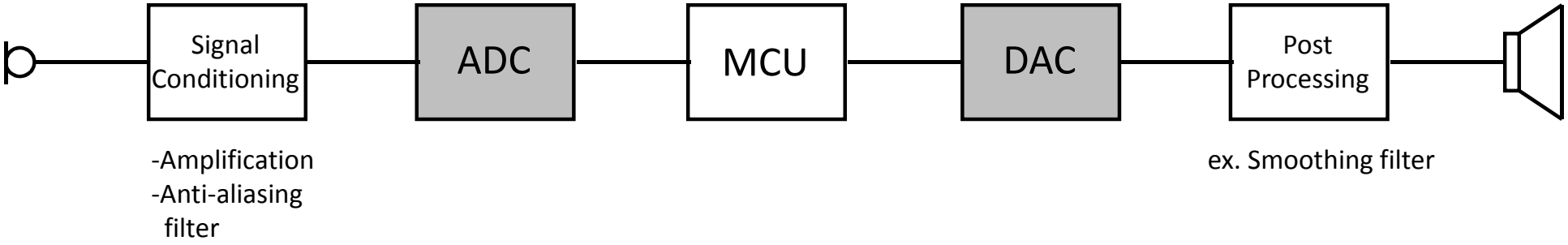
EE 691W
Data Converter Design

Introduction

Data Converters



- Analog-to-Digital Converters (ADCs) provide an interface from the outside world to a computing system
- Digital-to-Analog Converters (DACs) provide an interface from a computing system to the outside world

Why This Course on Data Converters?

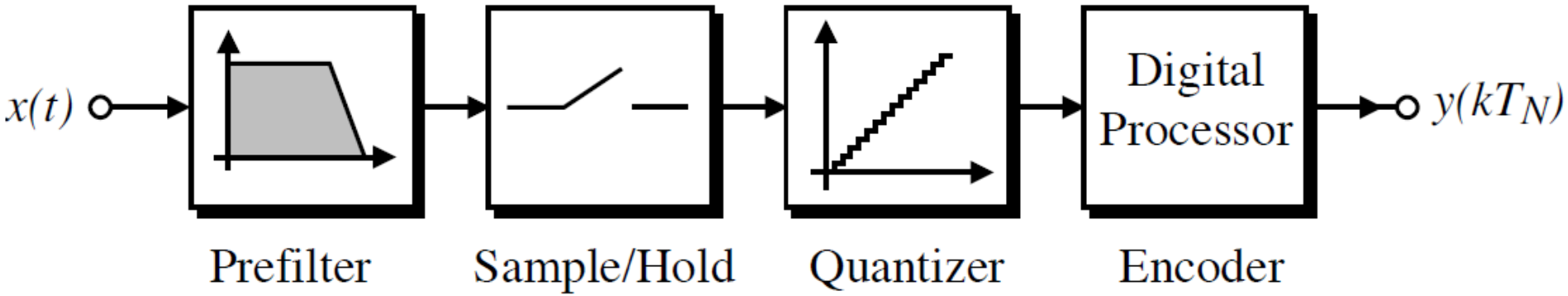
- Needed to interface with the physical world
- Data converters are everywhere – huge market
- Demand for increasing data converter performance keeps growing
- System-on-a-chip applications mean that data converters are in truly mixed-signal applications
- Data converters are typically the bleeding edge of analog/mixed-signal design
- Data converters are notoriously difficult to design

Why is data converter design difficult?

- Need high precision from imprecise parts
- Very large, complicated systems, so simulation is difficult (and sometimes impossible)
  - Many, many transistors – simulations can last hours/days
  - Convergence problems
- These are mixed-signal systems
  - Noise
  - Coupling
- Often require advanced processing and/or post-fabrication correction
  - Laser trimming
  - Fuses
  - Interaction with DSPs
  - These techniques complicate design/simulation
- Different from other analog systems
  - Deal with large signals (not small-signal modeling)

Time	Barbie Tootle	Hayes Cape	Cartoon Room I	Cartoon Room II	Suzanne M. Scharer	Rosa M. Ailabouni
Monday Aug 5th, 2013 10:10-11:50	A1L-A Analog Circuits I Chr: Ming Gu, Shantanu Chakrabartty Track: Analog and Mixed Signal Integrated Circuits	A1L-B Low Power Digital Circuit Design Techniques Chr: Joanne Degroat Track: Digital Integrated Circuits, SoC and NoC	A1L-C Student Contest I Chr: Mohammed Ismail Track: INVITED ONLY	A1L-D Design and Analysis for Power Systems and Power Electronics Chr: Hoi Lee, Ayman Fayed Track: Power Systems and Power Electronics	A1L-E Design and Analysis of Linear and Non-Linear Systems Chr: Samuel Palermo Track: Linear and Non-linear Circuits and Systems	A1L-F Emerging Technologues Chr: Khaled Salama Track: Emerging Technologies
Monday Aug 5th, 2013 13:10-14:50	A2L-A Analog Circuits II Chr: Ming Gu, Shantanu Chakrabartty Track: Analog and Mixed Signal Integrated Circuits	A2L-B Low Power VLSI Design Methodology Chr: Genevieve Sapijaszko Track: Digital Integrated Circuits, SoC and NoC	A2L-C Student Contest II Chr: Sleiman Bou-Sleiman Track: INVITED ONLY	A2L-D Power Management and Energy Harvesting Chr: Ayman Fayed, Hoi Lee Track: Power Management and Energy Harvesting	A2L-E Oscillators and Chaotic Systems Chr: Samuel Palermo, Warsame Ali Track: Linear and Non-linear Circuits and Systems	A2L-F Bioengineering Systems Chr: Khaled Salama Track: Bioengineering Systems and Bio Chips
Monday Aug 5th, 2013 16:00-17:40	A4L-A Analog Design Techniques I Chr: Dong Ha Track: Analog and Mixed Signal Integrated Circuits	A4L-B Imaging and Wireless Sensors Chr: Igor Filanovsky Track: Analog and Mixed Signal Integrated Circuits	A4L-C Special Session: Characterization of Nano Materials and Circuits Chr: Nayla El-Kork Track: SPECIAL SESSION	A4L-D Special Session: Power Management and Energy Harvesting Chr: Paul Furth Track: SPECIAL SESSION	A4L-E Communication and Signal Processing Circuits Chr: Samuel Palermo Track: Linear and Non-linear Circuits and Systems	A4L-F Sensing and Measurement of Biological Signals Chr: Hoda Abdel-Aty-Zohdy Track: Bioengineering Systems and Bio Chips
Tuesday Aug 6th, 2013 10:10-11:50	B2L-A Analog Design Techniques II Chr: Valencia Koomson Track: Analog and Mixed Signal Integrated Circuits	B2L-B VLSI Design Reliability Chr: Shantanu Chakrabartty, Gursharan Reehal Track: Digital Integrated Circuits, SoC and NoC	B2L-C Delta-Sigma Modulators Chr: Vishal Saxena Track: Analog and Mixed Signal Integrated Circuits	B2L-D Special Session: University and Industry Training in the Art of Electronics Chr: Steven Bibyk Track: SPECIAL SESSION	B2L-E Radio Frequency Integrated Circuits Chr: Nathan Neihart, Mona Hella Track: RFICs, Microwave, and Optical Systems	B2L-F Bio-inspired Green Technologies Chr: Hoda Abdel-Aty-Zohdy Track: Bio-inspired Green Technologies
Tuesday Aug 6th, 2013 13:10-14:50	B3L-A Analog Design Techniques III Chr: Valencia Koomson Track: Analog and Mixed Signal Integrated Circuits	B3L-B VLSI Design, Routing, and Testing Chr: Nader Rafla Track: Programmable Logic, VLSI, CAD and Layout	B3L-C Special Session: High-Precision and High-Speed Data Converters I Chr: Samuel Palermo Track: SPECIAL SESSION	B3L-D Special Session: Advancing the Frontiers of Solar Energy Chr: Michael Soderstrand Track: SPECIAL SESSION	B3L-E RF/Optical Devices and Circuits Chr: Mona Hella, Nathan Neihart Track: RFICs, Microwave, and Optical Systems	B3L-F Carbon Nanotube-based Sensors and Beyond Chr: Nayla El-Kork Track: Nanoelectronics and Nanotechnology
Tuesday Aug 6th, 2013 16:00-17:40	B5L-A Nyquist-Rate Data Converters Chr: Vishal Saxena Track: Analog and Mixed Signal Integrated Circuits	B5L-B Digital Circuits Chr: Nader Rafla Track: Programmable Logic, VLSI, CAD and Layout	B5L-C Special Session: High-Precision and High-Speed Data Converters II Chr: Samuel Palermo Track: SPECIAL SESSION	B5L-D Special Session: RF-FPGA Circuits and Systems for Enhancing Access to Radio Spectrum (CAS-EARS) Chr: Arjuna Madanayake, Vijay Devabhaktuni Track: SPECIAL SESSION	B5L-E Analog and RF Circuit Techniques Chr: Igor Filanovsky Track: Analog and Mixed Signal Integrated Circuits	B5L-F Memristors, DG-MOSFETS and Graphine FETs Chr: Reyad El-Khazali Track: Nanoelectronics and Nanotechnology
Wednesday Aug 7th, 2013 10:10-11:50	C2L-A Phase Locked Loops Chr: Chung-Chih Hung Track: Analog and Mixed Signal Integrated Circuits	C2L-B Computer Arithmetic and Cryptography Chr: George Purdy Track: Programmable Logic, VLSI, CAD and Layout	C2L-C Special Session: Reversible Computing Chr: Himanshu Thapliyal Track: SPECIAL SESSION	C2L-D Special Session: Self-healing and Self-Adaptive Circuits and Systems Chr: Abhilash Goyal, Abhijit Chatterjee Track: SPECIAL SESSION	C2L-E Digital Signal Processing-Media and Control Chr: Wasfy Mikhael, Steven Bibyk Track: Digital Signal Processing	C2L-F Advances in Communications and Wireless Systems Chr: Sami Muhaidat Track: Communication and Wireless Systems
Wednesday Aug 7th, 2013 13:10-14:50	C3L-A SAR Analog-to-Digital Converters Chr: Vishal Saxena Track: Analog and Mixed Signal Integrated Circuits	C3L-B Real Time Systems Chr: Brian Dupaix, Abhilash Goyal Track: System Architectures	C3L-C Image Processing and Interpretation Chr: Annajirao Garimella Track: Image Processing and Multimedia Systems	C3L-D Special Session: Verification and Trusted Mixed Signal Electronics Development Chr: Greg Creech, Steven Bibyk Track: SPECIAL SESSION	C3L-E Digital Signal Processing I Chr: Ying Liu Track: Digital Signal Processing	C3L-F Wireless Systems I Chr: Sami Muhaidat Track: Communication and Wireless Systems
Wednesday Aug 7th, 2013 16:00-17:40	C5L-A Wireless Systems II Chr: Sami Muhaidat Track: Communication and Wireless Systems	C5L-B System Architectures Chr: Swarup Bhunia, Abhilash Goyal Track: System Architectures	C5L-C Image Embedding Compression and Analysis Chr: Annajirao Garimella Track: Image Processing and Multimedia Systems	C5L-D Low Power Datapath Design Chr: Wasfy Mikhael Track: Digital Integrated Circuits, SoC and NoC	C5L-E Digital Signal Processing II Chr: Moataz AbdelWahab Track: Digital Signal Processing	C5L-F Advances in Control Systems, Mechatronics, and Robotics Chr: Charna Parkey, Genevieve Sapijaszko Track: Control Systems, Mechatronics, and Robotics

Typical ADCs



Anti-aliasing filter to bandlimit the signal

Converts from continuous-time to discrete-time (switched-capacitor techniques)

- Primary active element is the comparator
- Often includes a DAC

- Creates the digital word
- Provides error correction
- Time synchrony

Nyquist-Rate vs. Oversampled

- Nyquist-Rate
  - Sample at a rate close to the Nyquist frequency
  - “Conventional” type of data converters
  - Provides the fastest sampling rates / bandwidths

- Oversampled
  - Sampling rate is much, much higher than the Nyquist rate (typically at least 20 times higher)
  - Often called “noise-shaping” circuits
  - Provides very high resolution

Schedule

Week	Topic
1	Introduction, Data Converter Fundamentals
2	Advanced Simulation, Behavioral Modeling
3	Comparators
4	Introduction to Switched Capacitor Circuits
5	Switched Capacitor Amplifiers and Filters
6	Sample-and-Hold Circuits
7	Parallel Nyquist-Rate DACS
8	Improved Parallel Nyquist-Rate DACS, Serial DACs
9	Low and Medium Speed Nyquist-Rate ADCs
10	High Speed Nyquist-Rate ADCs
11	Oversampled Converters
12	Oversampled Converters
13	Current State of the Art, Final Project Design
14	Current State of the Art, Final Project Design
15	Current State of the Art, Final Project Design

Expectations Coming into Class

- That you will participate!
- That you will actually do the reading
- Emphasis on doing, simulating, and creating
- That you remember (or can relearn) Cadence
- That we will be able to find a time to meet outside of class time for brief project updates (for the final project)
- A willingness to experiment and search for answers

Mechanics of Class

- Several short announced quizzes
  - Cover recent reading material
  - Usually 15-20 minutes
  - Focus on understanding concepts, as opposed to solving problems
- Reading synopses
  - Short write-ups on what you read
  - In-class summaries of a specific aspect/circuit (short explanatory presentation, usually just a few minutes)
  - Statement saying that you actually did the reading
- In-class discussion and problems
  - Class time is a time for discussion, sharing ideas/designs, and getting questions answered
- Design reviews and project summaries
  - Everyone participates!
  - Please provide your input, suggestions, questions