CpE 144 DSP Architecture Design **Elective Course**

2000-2002 Catalog Description: Fundamental principles of Digital Signal Processing (DSP): sampling theory, aliasing effects, frequency response, Finite Impulse Response filters, Infinite Impulse Response filters, spectrum analysis, Z transforms, Discrete Fourier Transform and Fast Fourier Transform. Emphasis on hardware design to achieve high-speed real and complex multiplications and additions. Pipelining, Harvard, and modified Harvard architectures are included. Concludes with architectural overviews of modern DSP applications: modems, speech processing, audio and video compression and expansion, and cellular. Prerequisite CpE 142, 3 units.

Prerequisites: Knowledge of logic design, experience with HDLs, and computer architecture design

Text: McClellan, Schafer, & Yoder, **DSP FIRST: A multimedia approach**, Prentice Hall, 1998, ISBN 0-13-243171-8

Additional Support Material: Xilinx ISE, Xilinx Core-Generator, Xilinx Intellectual Property, Xilinx Corporation; Model Sim XE (starter), Model Technology Corporation; MATLAB, DSP Filter Design tool, The Mathworks Inc.

Course Objectives:

1. To cover the fundamental theory of sampling and processing of discrete signals
2. To present design process for digital filters and expose students to commercial DSP design tools
3. To develop knowledge of frequency/time relationship including z-transforms and the Discrete Fourier Transform
4. To analyze commercial DSP devices with respect to their architectures

Topics Covered:

1. Signal models: sinusoids, complex exponentials, phasors.
2. Signals: additive linear combination, periodic, non-periodic, amplitude modulation
3. Sampling: Nyquist limit, effects of over/under sampling, interpolation
4. FIR filters: impulse response, convolution, filter structure, LTI systems
5. Frequency Response: superposition, steady state, spectrum plots
6. Z-Transforms: system function, n-domain – z-domain relationship
7. IIR filters: filter structures, poles, zeros, phase response
8. Spectrum Analysis: DFT/FFT derivations, application and analysis

Class Schedule:

Week	Topic	Text Pages
1	Intro Systems & Signals: Signal Models	1-23, 23-36
2	Sum of sinusoids, periodic, non-periodic, beat notes	46-77
3	Sampling: sampling (aliasing, folding), Nyquist, interpolation	83-111
4	FIR Filters: convolution, implementation	119-138
5	Review adders, multipliers types, fixed point arithmetic	handouts
6	Frequency Response of FIR filters:	157-169
7	Filter types: Lowpass, Bandpass, Matlab Examples	170-194
8	Review, Midterm Exam	
9	Xilinx ISE 4.2i software, Core-generator software	Lab, handouts
10	Z-Transforms	202-220, 221-242
11	IIR Filters: impulse response, system function	249-263
12	IIR Filters: structure, poles, zeros, second-order systems	263-310
13	DFT derivation, and analysis	handout 320-355
14	FFT derivation, applications, and analysis	handout 356-370
15	DSP Processors, Project Demonstrations	handouts
16	Final Exam	

Laboratory Schedule:

There is no scheduled laboratory for this course. However, students are assigned two types of design problems that use software design tools: MATLAB and Xilinx's DSP design tools. Students use open labs that support these two tools. Student versions of both software applications exist and are used also.

Contribution of Course to Meeting the Professional Component:

1. ABET category content as estimated by faculty member who prepared this course description:
   Engineering science: 1.5 units or 50 %, Engineering design: 1.5 units or 50 %
2. This course is an overview of DSP theory and a strong component of implementation of DSP elements/architecture in hardware.

Course Outcomes:

CpE 144 CO_1 Students will solve discrete time system problems and use the sampling theorem
CpE 144 CO_2 Students will know how z-transforms are used to describe discrete system
CpE 144 CO_3 Students will use the MATLAB DSP toolbox to simulate designs
CpE 144 CO_4 Students will design DSP hardware and architecture systems using industry tools
CpE 144 CO_5 Students will understand the Discrete Fourier Transform and it's implementations

Relationship of Course Outcomes to Program Outcomes: ABET designations, "a" through "k"

a. ability to apply knowledge of mathematics, science, and engineering – **CpE 144 CO_1, CO_2, CO_5 Sampling theory, frequency response, DFT and z-transforms are based in mathematics.**
b. an ability to design and conduct experiments, as well as to analyze and interpret data – **CpE 144 CO_3 MATLAB assignments will simulate complex discrete systems and provide results for students to study.**
c. an ability to design a system, a component, or process to meet desired needs – **CpE 144 CO_4 The assigned semester project involves the design of an FIR filter into an FPGA.**
d. an ability to function on multi-disciplinary teams – **Not applicable.**
e. an ability to identify, formulate, and solve engineering problems – **CpE 144 CO_3, CO_4 The assigned semester project begins with problem definition, possible solutions via MATLAB and implementation via a commercial DSP design tool.**
f. an understanding of professional and ethical responsibility - **Not applicable.**
g. an ability to communicate effectively – **Not applicable.**
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context – **CpE 144 CO_4 Students are informed of the many practical applications of DSP that has changed much of the world's society: cell phones, MP3 players, CD and DVD players, hard disk drives.**
i. a recognition of the need for, and an ability to engage in life long learning – **CpE 144 CO_4 Students are informed of the fast changing technology in the DSP area; DSP devices, once the domain of special purpose ASIC devices are now commonly done in custom designs and in FPGAs.**
j. a knowledge of contemporary issues - **Not applicable.**
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice – **CpE 144 CO_4 The usage of MATLAB and a DSP design tool from an FPGA vendor is the same process as used in industry.**

Course Coordinator and Preparer of this Course Description:

Professor Ronald W. Becker, December 2, 2002; contributions by Prof. Dan Corlette