# ECE423 - DSP for Communication

## Department of Electrical and Computer Engineering
## Colorado State University
## Spring 2014

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## COURSE OBJECTIVES:

Digital signal processing can be found almost everywhere in the realm of electronic systems: motor controllers, patient monitoring and medical imaging systems, cell phones, mechanical vibration analyzers used to study airplane wing characteristics, and so forth. Recently, DSP has become even more prevalent due to the availability of cheap but powerful DSP processors, one of which we will study and use in this class.

In this course, we will learn some of the underlying DSP techniques used in these systems through study and hands-on lab experience. We will program DSP algorithms in C and assembly, download the programs to a DSP development board (provided), and observe signals being processed in real-time.

Ultimately, students will learn (1) how interesting communications and signal processing algorithms are implemented using a modern, industry-standard programming environment, (2) how high-level and assembly programs are translated into hardware operations, and (3) how modern DSP processors are architected and why. The knowledge and skills acquired in this class are applicable not only to a wide range of DSP applications but also to broader areas such as embedded processor system development, chip-to-chip high speed link system design, and system firmware development.

## PREREQUISITES:

ECE 312 covers the basic theory needed in this class; lectures will review and extend this material as needed. As far as programming: the emphasis will be on specific instructions to make the DSP chip perform the required operations. This will be covered in the lectures and lab notes, so if you have had some exposure to C or other programming language, you should be fine.

## SCHEDULE:

- Lecture Tuesday 4:00-5:15pm
- Lab Recitation Thursday 4:00-5:15pm (optional). The instructor will be available to answer questions regarding the labs.

## CLASS ORGANIZATION:

- Students work ideally in teams of two. In odd number enrollment cases, a team of three is discouraged.
- Lab hours are at the team's discretion – the lab is open 7AM to 11PM M-Sat – but attendance during the recitation session is encouraged.

## TEXTBOOK and CLASS MATERIALS:

- **Optional** R. Chassaing, *Digital Signal Processing and Applications with the C6713 and C6416 DSK*, John Wiley and Sons, Inc., New York, 2005
- On-line TI materials for the TI C6713 DSK board: http://www.ti.com
- ECE 423 Lab Write-ups
- Code Composer Studio (CCS) help tutorials

## COURSE OUTLINE:

1. Introduction to programming the TMS320 C6000 series of DSP chips in the C programming language.
2. Review of basic signals and systems concepts and implementation on the TMS320C6713 floating-point DSP Starter Kit (DSK).
3. Introduction to assembly language coding and code optimization using the C6713 DSP assembly language.
4. Design, analysis, and implementation of finite impulse response (FIR) filters on the DSK. Design will include windowing methods, pole-zero placement design, and software methods using MATLAB's SPTOOL toolbox/GUI). Filter designs will include linear phase lowpass, highpass, bandpass, bandstop filters, linear phase approximation to a Hilbert transformer, linear-phase discrete-time differentiator, and notch filters. Implementation will be done in both C and assembly. Circular buffers on the C6713 will also be implemented.
5. Design, analysis, and implementation of infinite impulse response (IIR) filters on the DSK. Design will include impulse invariance and bilinear Z-transform methods, pole-zero placement design, and software packages, specifically MATLAB's SPTOOL toolbox/GUI). Filter designs will include lowpass, highpass, bandpass, and bandstop filters, comb filters, and enhanced notch filter. Implementation will be Direct Forms I and II, and cascaded second order systems (biquads) coded in C.
6. Design, implementation, and application of fast Fourier Transform (FFT) Algorithms. Implementation will be a floating-point C coded decimation-in-time FFT and inverse FFT (IFFT) algorithms. Application will be real-time block convolution FIR filtering using FFT algorithms.
7. Analog modulation using DSP techniques. Quadrature amplitude modulation (QAM) and demodulation basics. Implementation of AM, DSB-SC, SSB, QAM, and FM radios using DSP techniques.
8. Student project, chosen from a list of suggested projects or proposed by the group (subject to approval by the instructor). A final report and short oral presentation is required.

## LANGUAGES OF INSTRUCTION:

English, Mathematics, MATLAB, C code, and TMS320 C6000 series assembly. As far as reports: although not required, it is suggested that they be typed, but please submit a paper copy for grading. Cellphone cameras are fine to make images of the oscilloscope. Other data plots can be created in MATLAB or another plotting program and included in the report as image files.

## GRADING BREAKDOWN:

The course grade is determined entirely by the labs and Final Project. Total points for the course is 200, allocated as follows:

- Seven Labs, five of two weeks duration and two of one week, points weighted by scheduled length of lab - (total 70%/140 points). See http://www.engr.colostate.edu/ECE423/grading/grading_policy.pdf for information on how lab reports are graded.
- Final Project, three weeks duration - (30%/60 points).
- Grading scale (%):

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|---|---|---|
| A+:100-97 | A:96-93 | A-:92-89 |
| B+:88-85 | B:84-81 | B-:80-77 |
| C+:76-73 | C:72-66 | |
| D+:65-62 | D:61-55 | |
| F: $<$ 55 | | |

## ACADEMIC INTEGRITY:

As practicing engineers, we design systems that affect people's lives, and it is critical that any work we produce and sign off on has been done with integrity: all the work in a design or report is our own work or the sources are cited, and all calculations, simulations, and other analyses have actually been done even if only the results are summarized. These requirements also apply to engineering students.

In this class, you will generally be a member of a team and jointly working on and producing reports that will form the basis of your grade. Team members of course can freely share information with each other but NOT with other teams. Any data presented in the report, whether in tabular or graphical form, must be backed up with a description of the methods which were used, specifically the program code and measurement procedures. **The instructor reserves the right to require demonstration of these procedures**.

Violation of academic integrity will be dealt with full compliance with CSU policies
(web site: http://tilt.colostate.edu/integrity/guides/what_to_do.cfm).
For further information on academic integrity, see http://learning.colostate.edu/integrity/index.cfm.
Information on the CSU Honor Pledge can be found at http://tilt.colostate.edu/integrity/honorpledge/

## REFERENCES:


1. S.A. Tretter, *Communication System Design Using DSP Algorithms: With Laboratory Experiments for the TMS320C6701 and TMS320C6711*, Kluwer Academic Publishers, New York, 2003

2. R. Chassaing, *DSP Applications Using C and the TMS320C6x DSK*, John Wiley and Sons, Inc., New York, 2002

3. L.B. Jackson, *Signals, Systems, and Transforms*, Addison-Wesley, Reading, MA, 1991

4. L.B. Jackson, *Digital Filters and Signal Processing: With MATLAB Exercises*, Third Edition, Kluwer Academic Publishers, Boston, 1996

5. A.V. Oppenheim and R.W. Schafer, *Discrete-Time Signal Processing*, Second edition, Prentice-Hall,Upper Saddle River, NJ, 1989

6. J.G. Proakis and D.G. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications*, Third edition, Prentice-Hall,Upper Saddle River, NJ, 1989
7. S. Haykin, *Communication Systems*, Fourth Edition, John Wiley and Sons, Inc., New York, 2002