EE/TE 4385 DSP-Based Design Project I

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TA: TBA

http://www.utdallas.edu/~torlak/courses/DSProject

Why Senior Design Project?

Ideal World	Real World
supposes that there is one right answer a given question.	supposes that there are many workable solutions but that, among workable solutions, some are much better than others.
involves only one disciplinary perspective or discrete body of knowledge.	is broadly multidisciplinary.
is bounded more than it is constrained, largely because it is abstracted from context.	is unbounded and fully embedded in context.
deals with components rather than with systems.	deals with systems rather than components.
typically requires great powers of imagination to develop an understanding of the social and ethical context of the work in question.	provides direct experience of the social and ethical impacts of technology and of the human and organizational dynamics that characterize the context of engineering practice.

- Thus, the major design experience needs to introduce students to the **messiness** of “the real world,” .

From Meeting ABET Criterion 4: From Specific Examples to General Guidelines, with Heinz Luegenbiehl and Kay Neeley. *2004 ASEE Annual Conference Proceedings*, June 2004.

How?

- Overview of EE/TE 4385
  - Objectives
    - Learn real-time signal processing concepts and build a digital radio on a digital signal processor
  - Course components
    - **Lectures** (includes a Midterm and homework assignments)
    - **Laboratory** experiments (**groups of two**)
      - Labs are conducted by Teaching Assistant
      - Overview of hardware and software tools in ECSN 3.114
      - Sinusoidal generation: sinusoidal modulation
      - Finite impulse response filter
      - Pseudo-noise sequence generation
      - Pulse amplitude modulation and demodulation
    - **Project**: Digital Radio (or Software-Defined Radio)
      - Designed and built by each group on TI TMS320C6711DSK

Student Responsibilities

- "*Students must be able to integrate previous coursework and exhibit technical competence, apply the design process and project management skills to a realistic problem, and demonstrate teamwork and communication skills.*"

From "Processes For Ensuring Quality Capstone Design Projects", Ralph M. Ford and William C. Lasher

Prerequisites

- EE 2310 Computer Organization and Design
  - Assembly
- EE 3350 Communications Systems, or
  - Modulation and demodulation
- EE 4350 Digital Communications, or
  - Digital transmission
- EE 4361 Intro. To Digital Signal Processing
  - Sampling, filters, quantization, etc

Course Materials

- Course Web Site: http://www.utdallas.edu/~torlak/course/DSProject
- Textboooks (Optional)
  - Textbook: Johnson and Sethares, Telecommunication Breakdown, Prentice Hall, ISBN 0-13-143047-5, 2004.
  - Lab Manual: Kehtarnavaz and Kim, Digital Signal Processing System-Level Design Using LabVIEW, Elsevier/Newnes, 2005
  - Labview Tutorial: Labview interactive tutorial at http://zone.ni.com

Supplemental Texts

- S. A. Tretter, *Comm. system design using DSP algorithms: with lab experiments for the TMS320C601 and TMS320C6711,*
  - Assumes DSP theory, algorithm, and processor knowledge
- J. H. McClellan, R. W. Schafer, and M. A. Yoder, *Signal Processing First, 2003*
  - DSP theory and algorithms at sophomore level
- R. Chassaing, *Digital Signal Processing: Lab. Experiments Using C and the TMS320C31DSK*
  - DSP processor tutorial with source code examples

Grading

- **Calculation of numeric grades**
  - 10% homework (four assignments)
  - 10% Midterm
  - 30% Laboratory (five lab reports)
  - 50% Project: Demonstration, Implementation, and report
- **No late homework assignments/lab reports accepted**
- **Laboratory**
  - Lab team members assigned same lab report grade
  - Can drop lowest HW or Lab grade
- **Deliverable: Project Demo and Report**
- **No final exam**

Lectures

- Review of Complex Numbers
- Digital signal processing
  - Signals, sampling, filtering, and quantization
  - Oversampling and data converters
- Digital signal processor (DSP) architectures
  - Harvard architecture, special addressing modes
  - Parallel instructions, pipelining, real-time programming
- Digital communications
  - Analog/digital, modulation/demodulation
  - Pulse shaping and pseudo-noise sequences

Laboratory Experiments

- Laboratory
  - Ends at the half of the semester with lectures
  - Groups of two
- Labs are conducted by Teaching Assistant
  - TA: TBA
  - Wendesday and additional day labs
- Five experiments
  1. Overview of hardware and software tools in EC 3.120
  2. Sinusoidal generation: sinusoidal modulation
  3. Finite impulse response (FIR) filter
  4. Pseudo-noise (PN) sequence generation
  5. Pulse amplitude modulation (PAM) and demodulation

Deliverable: Project

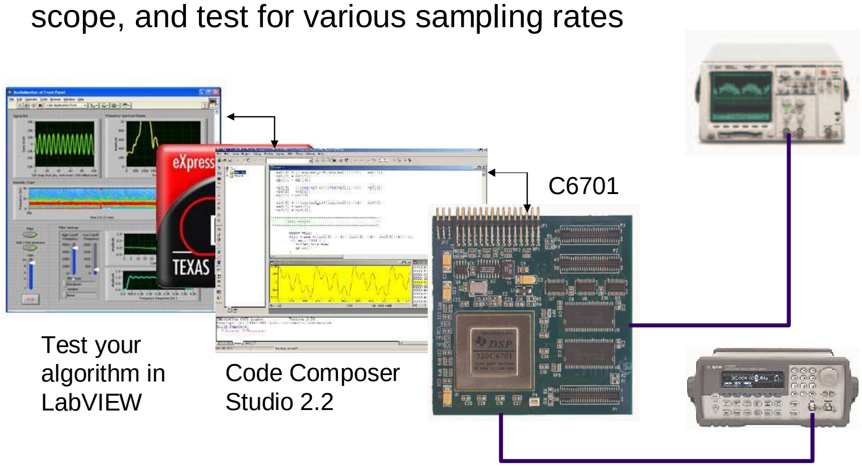
- After completing five laboratory experiments,
  - Each lab group will build a complete digital radio (or a software-defined radio) that includes each part of a typical digital communication system.
  - You will build your digital radio based on QAM digital modem within voiceband (remember dialup modems?) using TI TMS320C6711 DSK.
- You will have to complete
  - Labview simulation of digital radio based on QAM modulation and demodulation and a 4-page description of your simulation (due: Wendesday lab, 10/25/06)
  - Project demonstration based on TMS320C6711 DSK (Labview, C, and Assembly) and presentations are scheduled for Monday 11/27/06.
- A project report will be due at 5PM, Friday, 12/1/06.

TMS320C67 Manuals

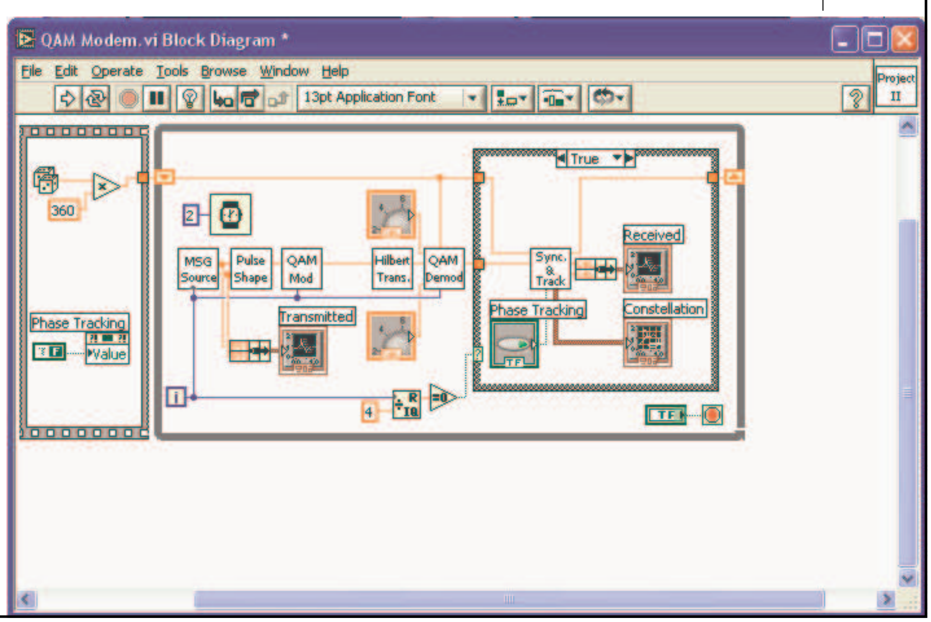
- You need to refer to various TMS320C6000 manuals, which are only available electronically:
- *Code Composer User's Guide* (328B)
  - http://focus.ti.com/lit/ug/spru301c/spru301c.pdf
- *Optimizing C Compiler* (187K)
  - http://www-s.ti.com/sc/psheets/spru187k/spru187k.pdf
- *Programmer's Guide* (198G)
  - http://www-s.ti.com/sc/psheets/spru198g/spru198g.pdf
- *CPU and Instruction Set Reference Guide* (189F)
  - http://www-s.ti.com/sc/psheets/spru189f/spru189f.pdf

Lab Ex: Sine Wave Generation

- Make your sine wave in DSP
- Evaluation procedure: Validate sine wave frequency on scope, and test for various sampling rates



LabView QAM Modem

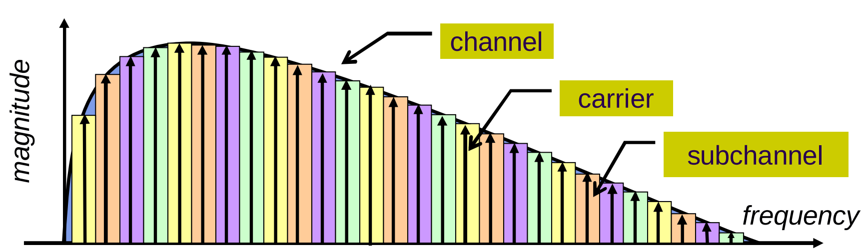


Communication Systems

- Transmitter
  - Signal processing conditions the message signal
  - Lowpass filtering to make sure that the message signal occupies a specific bandwidth, e.g. in AM and FM radio
  - Add redundancy to the message bit stream $m[n]$ to assist in error detection (and possibly correction) in the receiver
- Receiver
  - Carrier circuits undo effects of carrier circuits in transmitter, e.g. demodulation
  - Signal processing subsystem extracts and enhances the baseband signal

Example: Faster Than Dial-Up?

- Multicarrier modulation divides broadband (wideband) channel into narrowband subchannels
  - Uses Fourier series computed by fast Fourier transform (FFT)
  - Standardized for Digital Audio Broadcast (1995)
  - Standardized for ADSL (1995) & VDSL (2003) wired modems
  - Standardized for IEEE 802.11a/g wireless LAN & 802.16a



Each ADSL/VDSL subchannel is 4.3 kHz wide (about a voice channel) and carries a QAM signal

Slide by Prof. Evans

Signal Processing Systems

- Speech synthesis and speech recognition
- Audio CD players
- Audio compression (MP3, AC3)
- Image compression (JPEG, JPEG 2000)
- Optical character recognition
- Video CDs (MPEG 1)
- DVD, digital cable, and HDTV (MPEG 2)
- Wireless video (MPEG 4/H.263)

Audio Compact Discs

- Human hearing is from about 20 Hz to 20 kHz
- Sampling theorem: sample analog signal at rate of more than twice highest analog frequency
  - Apply a lowpass filter to pass frequencies up to 20 kHz; e.g. a coffee filter passes water (small particles) through but not coffee grounds (large particles)
  - Lowpass filter needs 10% of maximum passband frequency to roll off to zero (2 kHz rolloff in this case)
  - Sampling at 44.1 kHz captures analog frequencies that are less than 22.05 kHz
- *Other examples of signal processing systems?*

Communication Systems

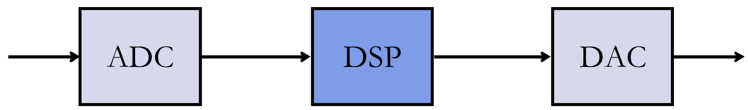
- Voiceband Dialup/Fax modems
- Digital subscriber line (DSL) modems
  - ISDN: 144 kilobits per second (kbps)
  - Business/symmetric: HDSL and HDSL2
  - Home/asymmetric: ADSL and VDSL
- Cable modems
- Cell phones
  - First generation (1G): AMPS
  - Second generation (2G): GSM, IS-95 (CDMA)
  - Third generation (3G): cdma2000, WCDMA

What is a DSP?

- Digital Signal Processor (DSP) process digital signals
- An alternative method to process analog world signals
- Digital technology offers tremendous processing power

  - Convert analog signals into electrical signals
  - Digitize these signals using an analog-to-digital converter (ADC)
- Once the signal is in digital form, digital signal processor (DSP) can easily process it.
- The DSP specializes in processing these signals, thus, it is slightly different from microprocessors and microcontrollers.
- After the DSP has processed the signal, the output signal must be converted back to analog so that we can sense it

Why Digital Signal Processing?



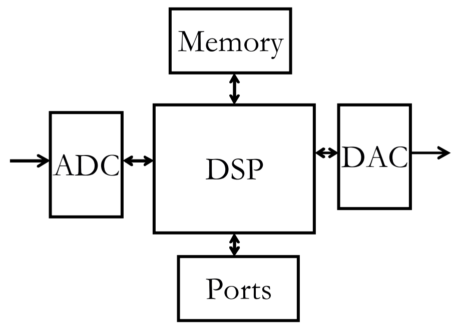
- Advantages of digital signal processing
  - Programmability – one hardware many tasks
  - Flexibility and upgradeability – develop a new code
  - Repeatability – A CD player always plays the same music quality
  - Specific functions – compression and digital filtering
- Advantages of Analog signal processing
  - low cost in some applications – attenuators, amplifiers
  - wide bandwidth (GHz)
  - Infinite resolution (no quantization error) and low signal levels

Characteristics of DSP processors

- Mostly designed with the same few basic operations in mind
- They share the same set of basic characteristics
- These characteristics fall into three categories:
  - specialized high speed arithmetic
  - data transfer to and from the real world
  - multiple access memory architectures

A DSP System

- DSP chip
  - Arithmetic logic Unit
  - TMS320C6X
- Memory
- Converters
  - Analog-to-digital
  - Digital-to-analog
- Communication Ports
  - Serial
  - Parallel

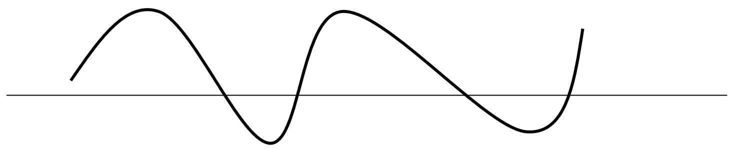


Review: Signals

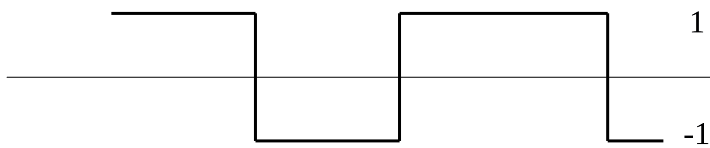
- Continuous-time signals are functions of a real argument
  - $x(t)$ where t can take any real value
  - $x(t)$ may be 0 for a given range of values of t
- Discrete-time signals are functions of an argument that takes values from a discrete set $x[n]$
  - $n \in \{...-3,-2,-1,0,1,2,3...\}$
  - Integer index n instead of time t for discrete-time systems
- Values for $\boldsymbol{x}$ may be real or complex

Analog and Digital Signals

- Amplitude of an analog signal can take any real or complex value at each time/sample



- Amplitude of a digital signal takes values from a discrete set



Review: Systems

- A system is a transformation from one signal (called the input) to another signal (called the output or the response).
- Continuous-time systems with input signal x and output signal $\boldsymbol{y}$ (a.k.a. the response):

  $y(t) = x(t) + x(t\text{-}1)$

  $y(t) = x^2(t)$

- Discrete-time system examples

  $y[n] = x[n] + x[n\text{-}1]$

  $y[n] = x^2[n]$

Review of Sinusoidal Signals

- Make the angle a function of t

$$x(t) = A\cos(w_0 t + \phi) = A\cos(2\pi f_0 t + \phi)$$

  - A: amplitude, ϕ:phase shift, ω_0:radian frequency, and f_0: cyclic frequency
- Relation to the period, $x(t)=x(t+T_0)$
- Phase shift and time shift

$$\text{if} \quad x_0 = A\cos(w_0 t), \qquad x_0(t - t_1) = ?$$

  - Express the phase shift in terms of t_1, f_0 or T_0
- Discrete time representations

Review of Complex Numbers

- Cartersian and polar representations
  - $z=x+jy$ or $z=re^{j\theta}$
  - $x=\Re\{z\}$ and $y=\Im\{z\}$
  - $e^{j\theta}=\cos(\theta)+j\sin(\theta)$
- Complex number multiplication
  - $z=r_1e^{j\theta_1}$ and $z=r_2e^{j\theta_2}$
  - $z=z_1z_2=?$
  - Phasor = complex amplitude

Review of Complex Exp. Signals

- Complex exponential signals
  - $z(t)=Ae^{j(w_0t+\phi)}$, find $|z(t)|$=? and arg $z(t)$=?
- Any sinusoid can be written

$$A\cos(w_0t+\phi) = \Re Ae^{j(w_0t+\phi)} = \Re Ae^{j\phi}e^{jw_0t}$$

- Phasor addition rule

$$x(t) = \sum_{k=1}^{N} A_k \cos(w_0t+\phi_k) = A\cos(w_0t+\phi)$$

  - Instead use the following addition of complex numbers

$$\sum_{k=1}^{N} A_k \cos(w_0t+\phi_k) = \sum_{k=1}^{N} \Re\left\{A_k e^{j(w_0t+\phi_k)}\right\}$$