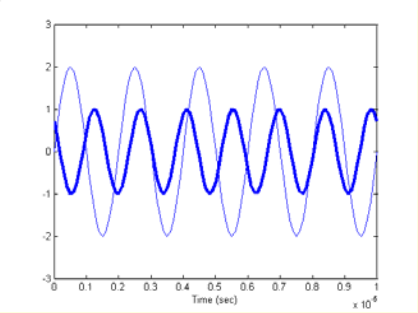
ECE 2704
Signals and Systems
Spring 2006

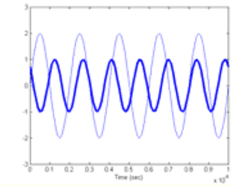
Instructor: Dr. R. Michael Buehrer

Lecture #1: Course Overview

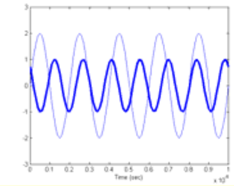
Review of Mathematics Basics



Announcements



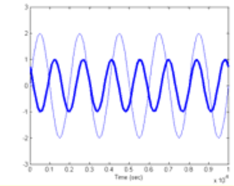
- **Today’s Handouts:**
  - Course Syllabus
  - Course Notes for Lecture #1
    - Course Notes for futures classes will be posted on the class web site.
- First Homework:
  - Available on the website
  - Due Wednesday 1/25/2005



Course Mechanics

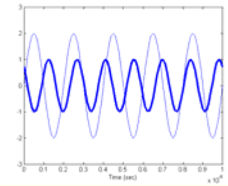
- Meeting Times and Location:
  - CRN 11752 MW 2:30-3:45pm
  - Room Whit 349
- Instructor:
  - Dr. R. Michael Buehrer, Assistant Professor
- Contact Information:
  - Office: 433 Durham Hall
  - Phone: 231-1898
  - e-mail: buehrer@vt.edu

Office Hours



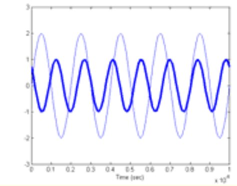
- Instructor Office Hours:
  - MW 9-10 am, T 10-12pm
- If you need to see me outside regular office hours, please make an appointment via e-mail
- I check my e-mail several times a day, so e-mail may be the best way to answer many *quick* questions
- GTA for the course
  - Jaime Torres   jatorres@vt.edu
    - Whit. 266
  - Office Hours   MW 11-2, TR 2-3, F 9-12

About Your Instructor



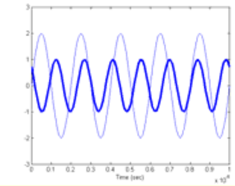
- Education:
  - Undergraduate: University of Toledo, 1991
  - Ph.D.: Virginia Tech, 1996
- Research Experience
  - Dissertation: *The application of Multiuser Detection to CDMA Cellular Systems* (1996)
  - Bell Labs – Lucent Technologies: Distinguished Member of Technical Staff in the Wireless Communications Lab (1996-2001)
  - Asst. Prof. with MPRG Laboratory (since 2001)
- Personal
  - Five kids (Faith – 10yrs. old, JoHannah - 8, Noah - 5, Gabrielle 3 yrs., Ruth Anna - 4mo. old)
  - Hobbies: sports, hiking, star gazing, gardening
  - Deacon at Blacksburg Christian Fellowship
    - Teach Old Testament Survey, New Testament Survey, Church History
    - Currently co-teaching a course titled “Introduction to Critical Thinking”

Research Interests



- Ultra-Wideband sensor and communication systems
- Position-Location Networks
- Advanced Signal Processing Techniques to improve communications
  - Space-Time Coding (MIMO systems)
  - Multiuser Detection
  - Adaptive Antennas
- Interaction between Physical Layer Algorithms and Radio Resource Control Algorithms
  - Multi-antenna scheduling
- Adaptive Modulation and Coding
- Software Radio

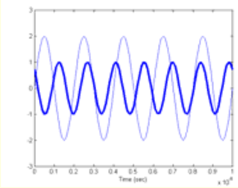
Course Web Site



- http://www.mprg.org/people/buehrer/2704/ece_2704.htm
- What will be available:
  - Lecture Notes (.pdf)
  - Homework Assignments & Solutions (.pdf)
  - Course Syllabus
  - Exam solutions
- In order to read .pdf files you will need Adobe Acrobat Reader (available free - instructions on website)
- If you know of good links for inclusion in the course web site, e-mail me and I will add them

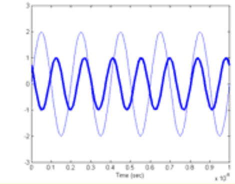
User: Signal07
Psswd: JoHannah06

Required Course Materials



- **Textbook:**
  - M.J. Roberts, Signals and Systems, McGraw-Hill, 2004.

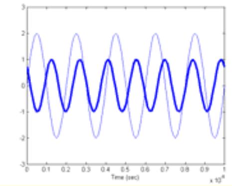
- **Access to Networked PC or Workstation**
- **Software:**
  - *Matlab* for Windows
  - I have versions 6.0 (R12), 6.5 (R13) and 7.0. Other versions of *Matlab* are acceptable, but may not be 100% compatible with *.m files which we distribute. It is your decision whether you want to purchase a new version or use an old version. I can provide some (but not exhaustive) support.
  - Version 6.5 is available at the bookstore, Version 7.0 is available through student software (www.computing.vt.edu)



Course Components

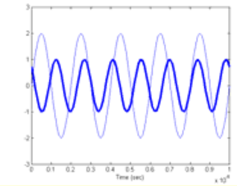
- The course has five main components:
  - *Lectures* – These are meant to introduce the key concepts in the course and provide you with fundamental understanding. This is the primary source of information in the class. I will provide you with lecture notes on the website typically the weekend before class (no guarantees though).
  - *Book* –This is meant to supplement the lectures and provide more detail that cannot be covered in a 50 minute lecture. (section numbers given in the syllabus).
  - *Homework* – This is meant to (a) test your understanding of the class material and (b) provide a means for you to obtain a "deeper" understanding. Not every homework problem is a repetition of in-class examples. They are meant to help you learn, not just to see if you can reproduce an in-class example.
  - Quizzes – These are meant to simply motivate you to keep up with the material. They will consist of one simple, fundamental question.
  - *Exams* – These are meant to show me how well you have grasped the material .

Grading



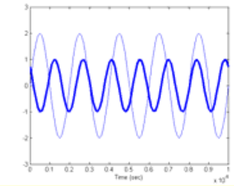
- Homework 10%
- Quizzes 10%
- Three In-class midterms 50%
  - Best grade 25%
  - Middle grade 15%
  - Lowest grade 10%
- Final Exam 30%

Homework



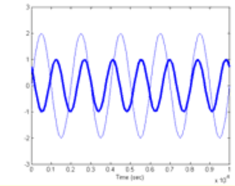
- 8 homework assignments
  - Schedule is posted on the web
  - Assignments will be posted *at least* one week in advance of the due date
  - It is your responsibility to check the website!
- Will consist of short problems which let you practice basic concepts, as well as more complicated problems to help you learn the material.
- Problems will be graded on a simple scale to allow quick feedback. Each *part of a problem* will be worth 2 points:
  - 2/2 - correct answer (solutions will be posted)
  - 1/2 - wrong answer but meaningful attempt
  - 0/2 - no meaningful attempt of problem

Homework (cont.)



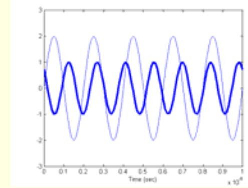
- Note: Homework and projects are due by the end of class on the due date. No late assignments will be accepted. If you will be out of town, you must make arrangements to get me your assignment by the due date.
- Lowest homework grade will be dropped.
  - This allows you some margin for error in the above policy.
- We will have homework assignments that are a blend of book problems (intended for deeper understanding) and my own homework problems that will be similar to the lectures (intended to reinforce concepts from class).

Tests and Exams



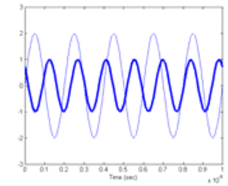
- Three In-Class Midterm Exams - 50% total
  - Dates listed on the syllabus
  - Weighted to emphasize best grade
- Final Exam - 30%
  - Tuesday, May 9   3:25pm – 5:25pm
    - Please double check time/date of final
- Closed book and notes
- We will have a help session to work sample problems before the final exam

Quizzes



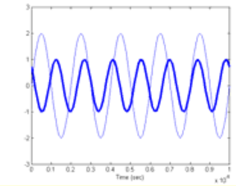
- We will have weekly quizzes
  - Every Wednesday at the end of class unless an exam is scheduled
- Quiz will consist of single, simple question (5-10 minutes)
- No studying necessary provided that you review your class notes for the week
- Purpose is to keep you engaged with the material on a regular basis
- Lowest quiz grade will be dropped
  - Allows you to miss one quiz without penalty

Travel



- An unfortunate part of my job is travel. Every semester I must travel a least a little. I do everything in my power to insure that it doesn't impact class. However, it is inevitable that I will miss some class.
- When I miss class, we will still meet with a graduate student presenting my notes/material.
- Currently I know that I will miss the following dates:
  - April 11-12
  - April 19-21

Official Course Objectives



Having successfully completed this course, the student will be able to:

a. Describe a physical process in terms of signals and systems and describe the properties of the system

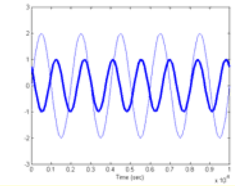
b. Calculate the Fourier series of a periodic signal

c. Calculate the spectrum of a signal using the Fourier transform

d. Solve a differential equation using the Laplace transform.

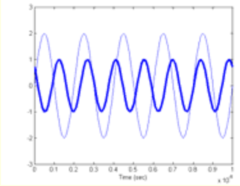
e. Calculate the steady state output of a system from the frequency response plots.

My Course Objectives



- After successfully completing this course the student will be able to
  - Describe a system mathematically including the input, the system transfer function and the resulting output
  - Determine the Fourier Series of a periodic signal
  - Determine the Fourier Transform of a periodic or non-periodic signal
  - Explain the “Frequency Domain”
  - Determine the Laplace Transform of a signal
  - Apply the Fourier Transform to determine the output of a system
  - Apply the Laplace Transform to solve differential equations and analyze a control system

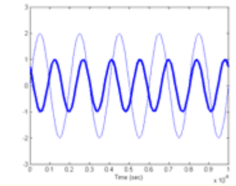
Prerequisites



- Coming into this class you should already have a knowledge of
  - Basic circuit theory
  - Complex numbers
  - Linear algebra
  - Linear differential equations

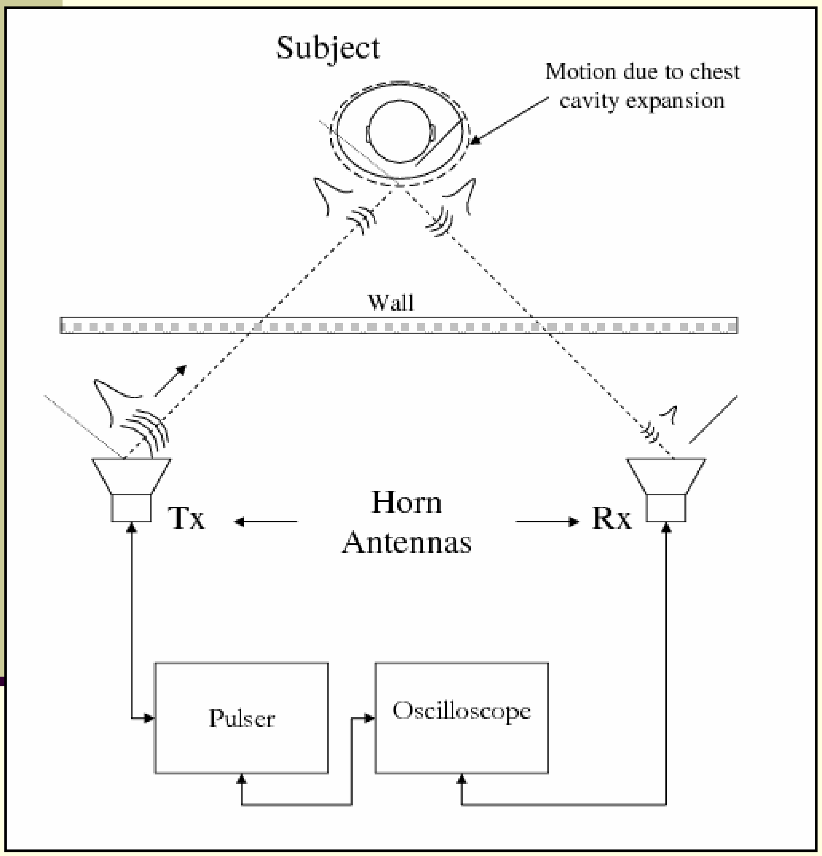
- May be satisfied by completion of
  - ECE 2004
  - MATH 1114
  - MATH 2214

Why is this course useful?



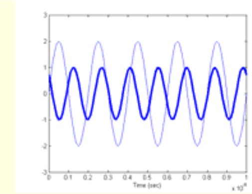
- Being able to describe signals and systems mathematically and to use those descriptions to understand and design the system are fundamental to most areas of engineering
- Understanding time domain representation and transforms (Fourier and Laplace) is absolutely critical for
  - Communications
  - Controls
  - Electronics
  - Electro-magnetics
  - Signal Processing
- To hone your ability to learn and apply complex ideas
  - Life-long learning and innovation are vital to remaining competitive in the global economy

Example Application

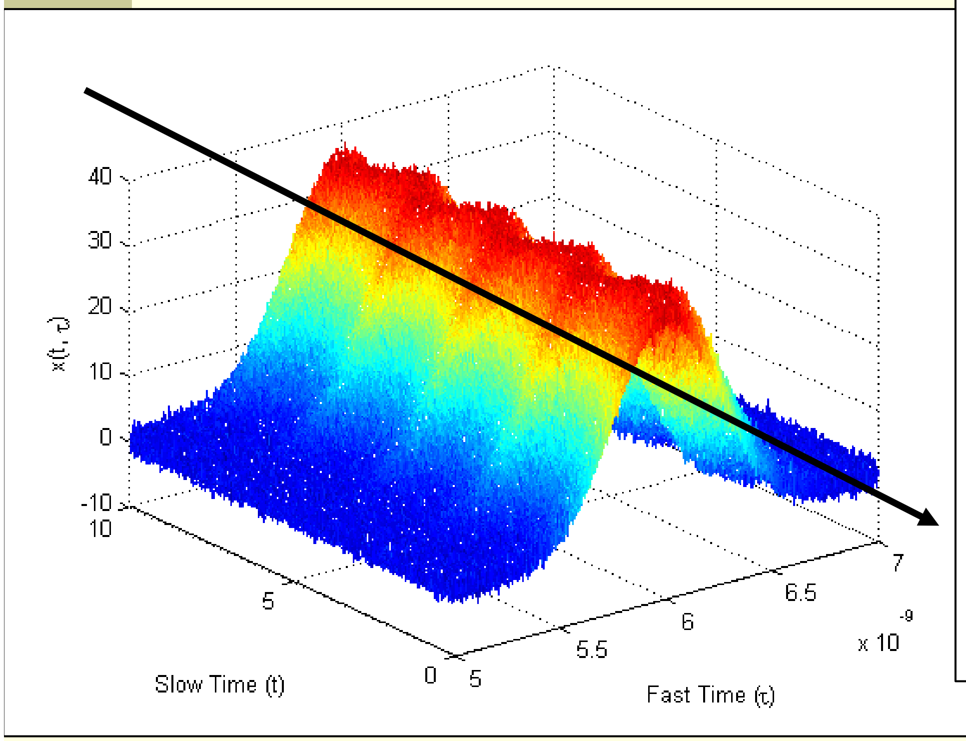


- Determining the heart and breathing rate of a person who is either behind closed doors or trapped under an object
- EM signals are transmitted at the individual and the reflections are received and processed
- We must be able to describe the transmit signal, the received signal and the changes in the signal due to breathing or the heartbeat mathematically.
- Further we must use these descriptions to develop signal processing techniques to extract breathing and heart rate data

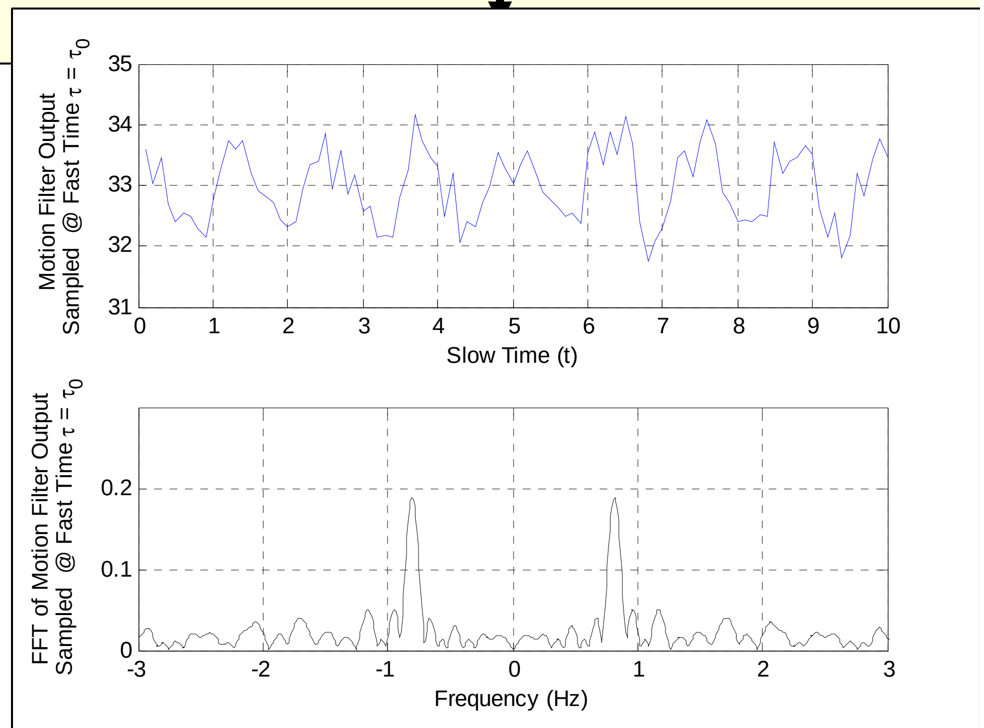
Example Continued



Signal processing allows us to extract a signal which is due to movement in the environment

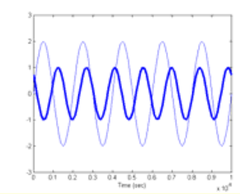


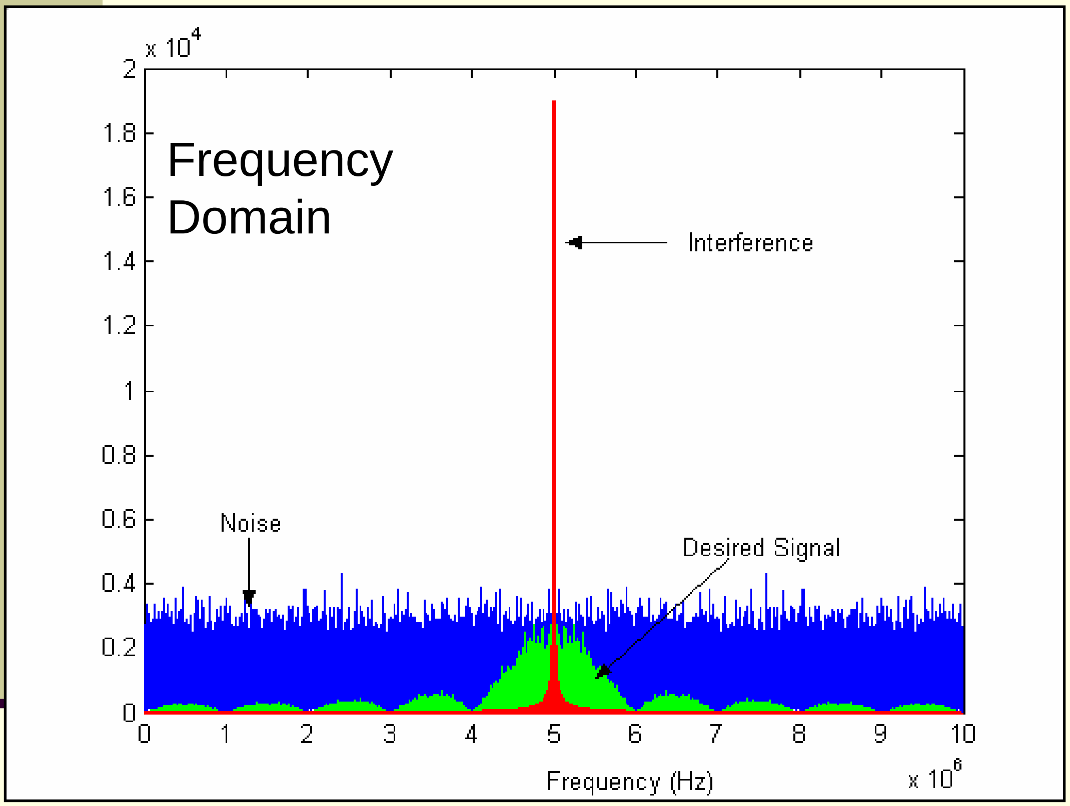
Further signal processing allows us to isolate the changes due to breathing



Determining the Fourier Transform provides a representation that has peaks at the breathing rate

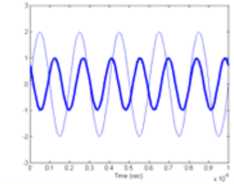
Secure Communications

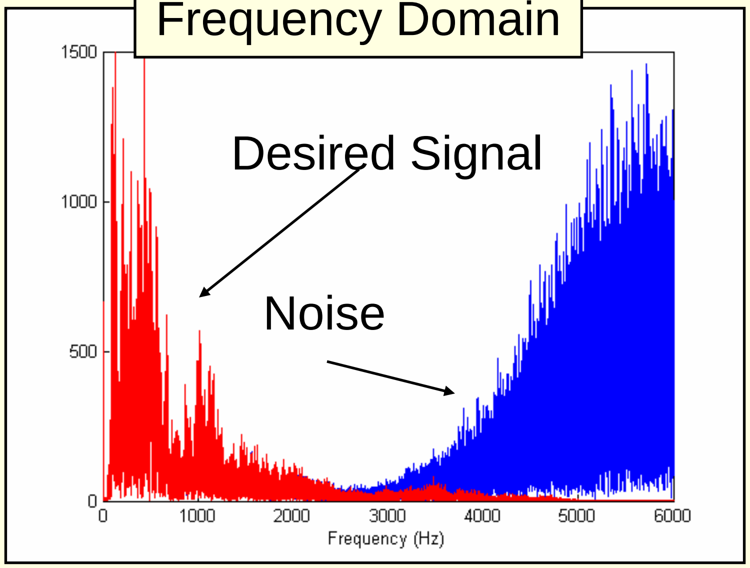


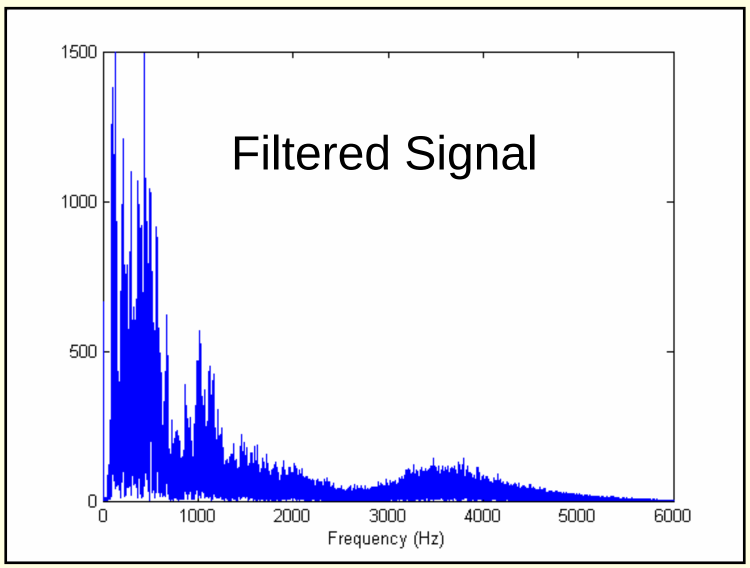


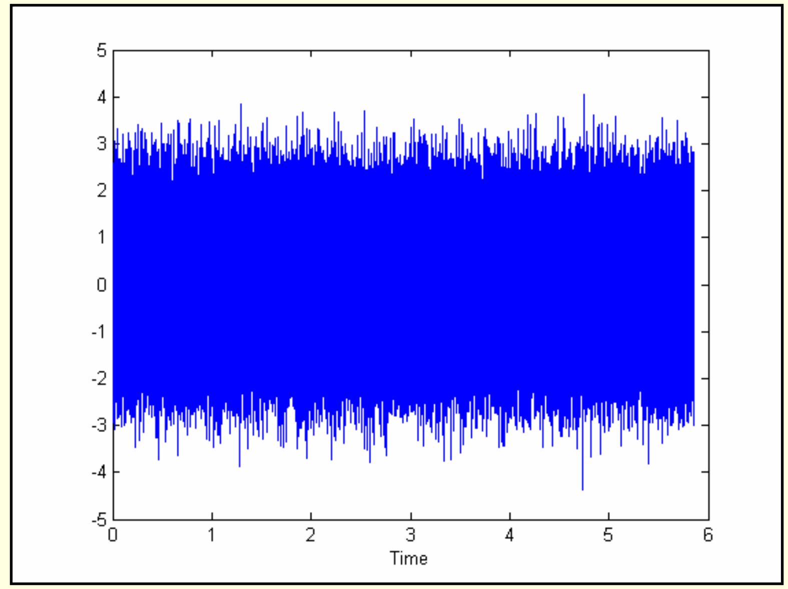
- Understanding the frequency domain allows us to hide a signal in the noise floor from unintended reception.
- Understanding the frequency domain also allows us to identify, isolate, and eliminate interference

Voice Signals





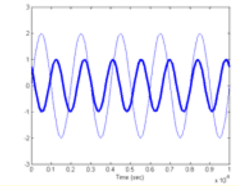




Time Domain (Signal + Noise)

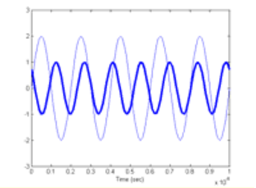
- Frequency domain representation allows us to improve the voice quality of a recording or signal by eliminating noise in unimportant frequency regions

Non-linear Control

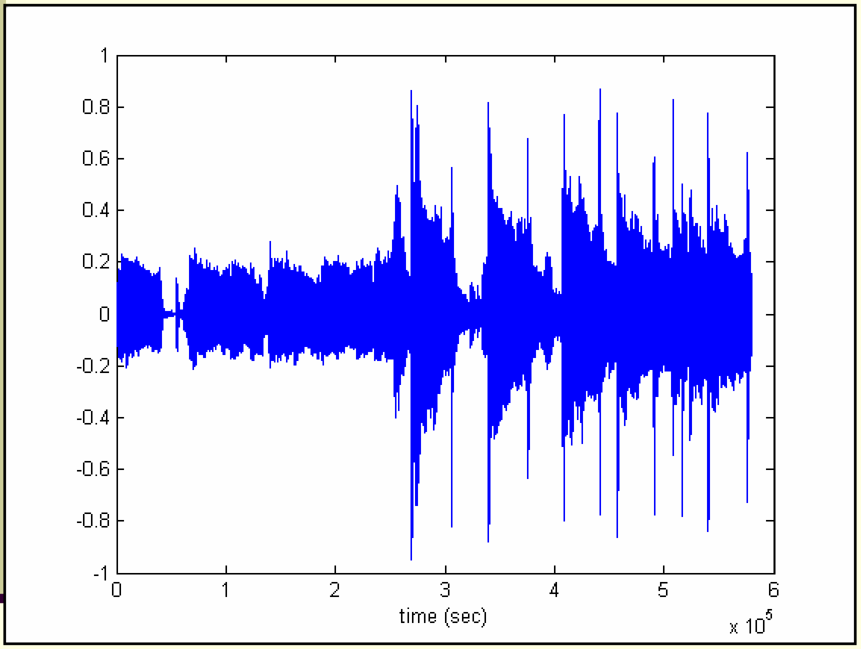


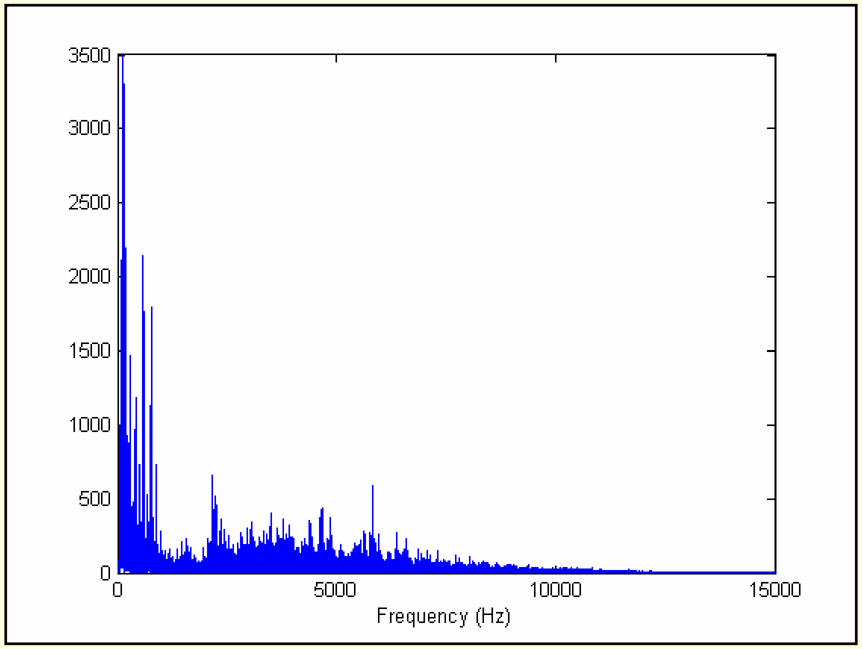
- Understanding signals and systems (particularly Laplace transforms) allows us to design adaptive control systems to automatically load a container on the deck of a ship while at high seas.

Music Equalizer

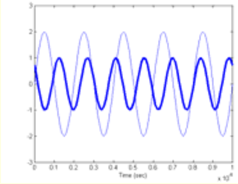


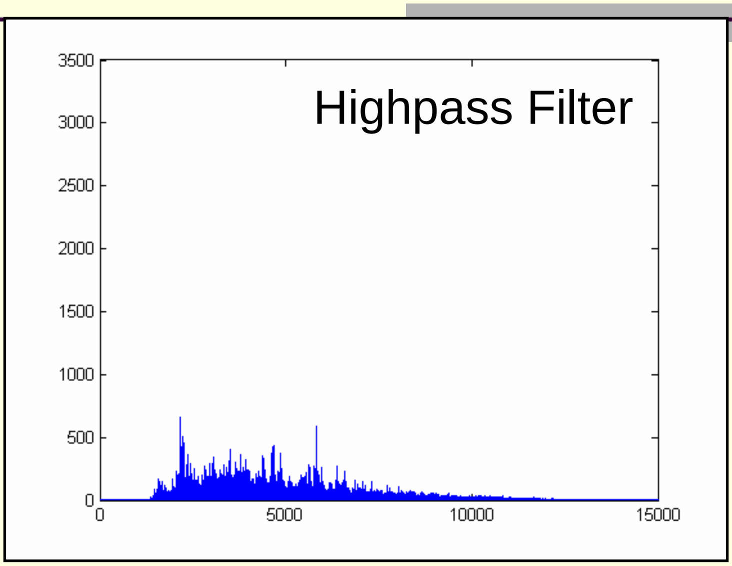
- Song in Time Domain & Frequency Domain

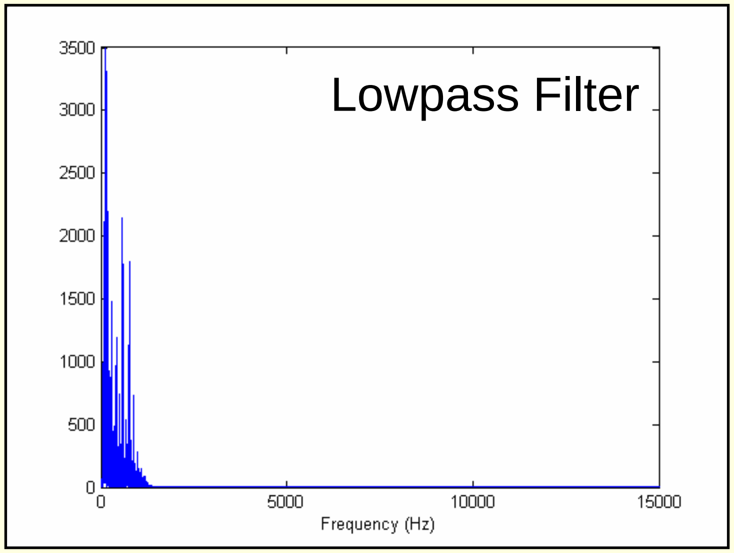


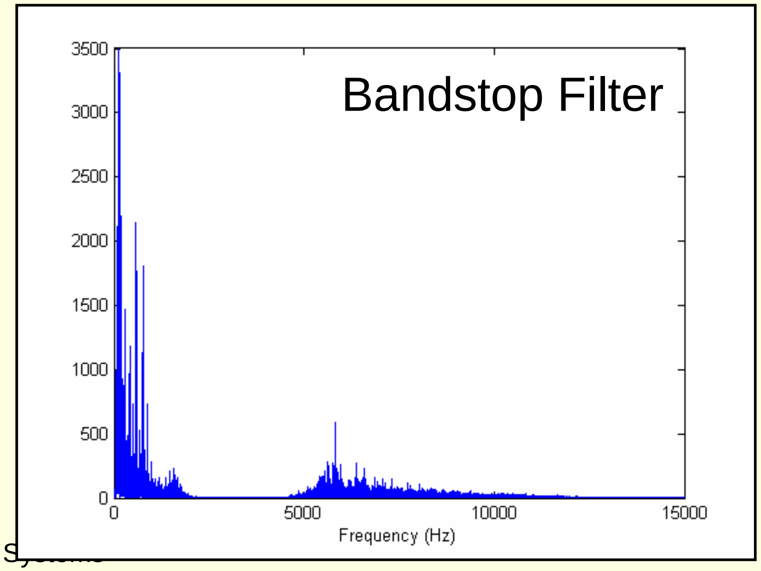


Filtered Music

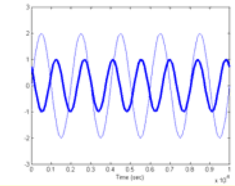






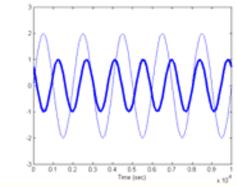


Controls



- Understanding control systems allows us to automatically control vehicles

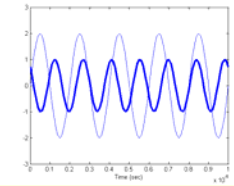
Why is this course useful?



- Being able to describe signals and systems mathematically and to use those descriptions to understand and design the system are fundamental to most areas of engineering
- Understanding time domain representation and transforms (Fourier and Laplace) is absolutely critical for
  - Communications
  - Controls
  - Electronics
  - Electro-magnetics
  - Signal Processing
- To hone your ability to learn and apply complex ideas
  - Life-long learning and innovation are vital to remaining competitive in the global economy

Review

- The purpose of the rest of today's lecture is to review some basic mathematical concepts that we will use extensively in this course
- The following concepts should have been covered in the prerequisites but will be briefly reviewed
  - Derivatives and Integrals
  - Sinusoids – amplitude, phase
  - Complex numbers
  - Phasors



Derivative

- The derivative of a function is the rate of change of that function

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$$

- Example: The number of atoms of a certain radioactive isotrope is found to follow the equation of time

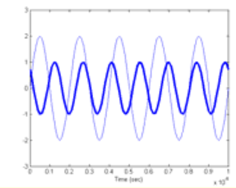
$$N(t) = 1000e^{-0.4t}$$

  - The rate of change is then

$$N'(t) = -400e^{-0.4t}$$

thus, the number of atoms is decreasing with time

The Integral



- The integral of a function is the area between the function and the x-axis.
- The integral of a function *f(x)* over the interval [a,b] is defined as

$$\int_a^b f(x)\,dx = \lim_{\Delta x \to 0} \sum_{i=1}^{n} f(x_i)\,\Delta x$$

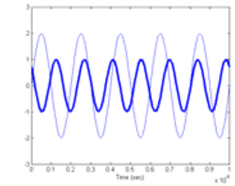
where $x_1 = a$, $x_i = x_{i-1} + \Delta x$, $n = (b-a)\Delta x$

- Example: The velocity of a train is 20m/s time 0 and begins accelerating 1.5m/s^2. What is the distance traveled in 1 minute?

$$D(t) = 20 + 1.5t$$

$$\int_0^{60} D(t)\,dt = \int_0^{60} (20 + 1.5t)\,dt = \left[20t + 0.75t^2\right]_0^{60} = 3900m$$

Sinusoids



- The most common function that we will use this semester is the sinusoid
  - sin(x)
  - cos(x)
- Sinusoid is a transcendental function where

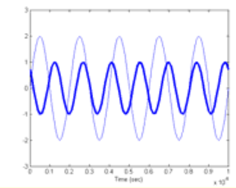
$$-1 \leq \cos\left(x\right) \leq 1$$

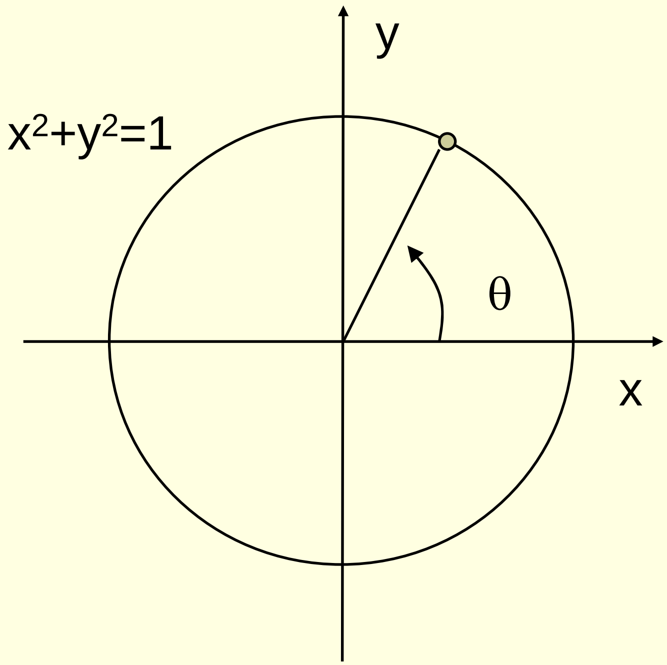
  - Both functions are periodic in 2π:

$$\cos\left(x\right) = \cos\left(x + 2\pi\right)$$

$$\sin\left(x\right) = \sin\left(x + 2\pi\right)$$

Definition

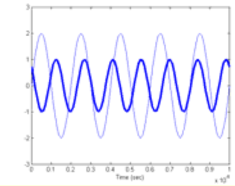




- Transcendental trigonometric functions are defined as
  - $\cos\theta = x$
  - $\sin\theta = y$
  - $\tan\theta = y/x$

- Radians – defined as the length of the arc subtended by the angle on the unit circle
  - For the full circle the circumference $= 2\pi r = 2\pi = \theta$
  - For ¼ of the circle (i.e.,a 90º angle) $\theta = 2\pi/4 = \pi/2$
  - By definition of sin(x) the argument *x* is in radians

Trigonometric Identities



- Basic Relationships

$$\cos(A) = \sin\left(A + \frac{\pi}{2}\right)$$

$$\cos(A) = \cos(-A)$$

$$\sin(A) = -\sin(-A)$$

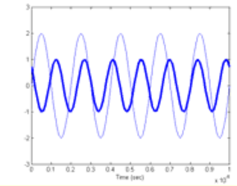
$$\cos^2(A) + \sin^2(A) = 1$$

- Addition of arguments

$$\cos(A+B) = \cos(A)\cos(B) - \sin(A)\sin(B)$$

$$\sin(A+B) = \sin(A)\cos(B) + \cos(A)\sin(B)$$

Imaginary Numbers



- The roots of the equation

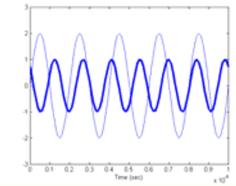
$$x^2 + 1 = 0$$

can be expressed as

$$x = \pm\sqrt{-1}$$
$$= \pm j$$

- This was the invention of the imaginary number.
- While even the term “imaginary” may seem to reflect the fact that they are abstract and artificial, it turns out that they are incredibly useful.

Complex Numbers



- A complex number is a number composed of two real numbers, one which represents the "real" part and one which represents the the "imaginary" part (originally created for defining roots of a polynomial)

$$z = x + jy$$

Real part: x — Imaginary part: y — $j = \sqrt{-1}$

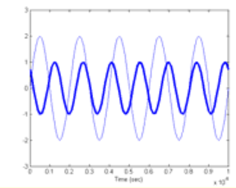
- We define addition and multiplication as

$$z = x + jy$$

$$c = a + jb$$

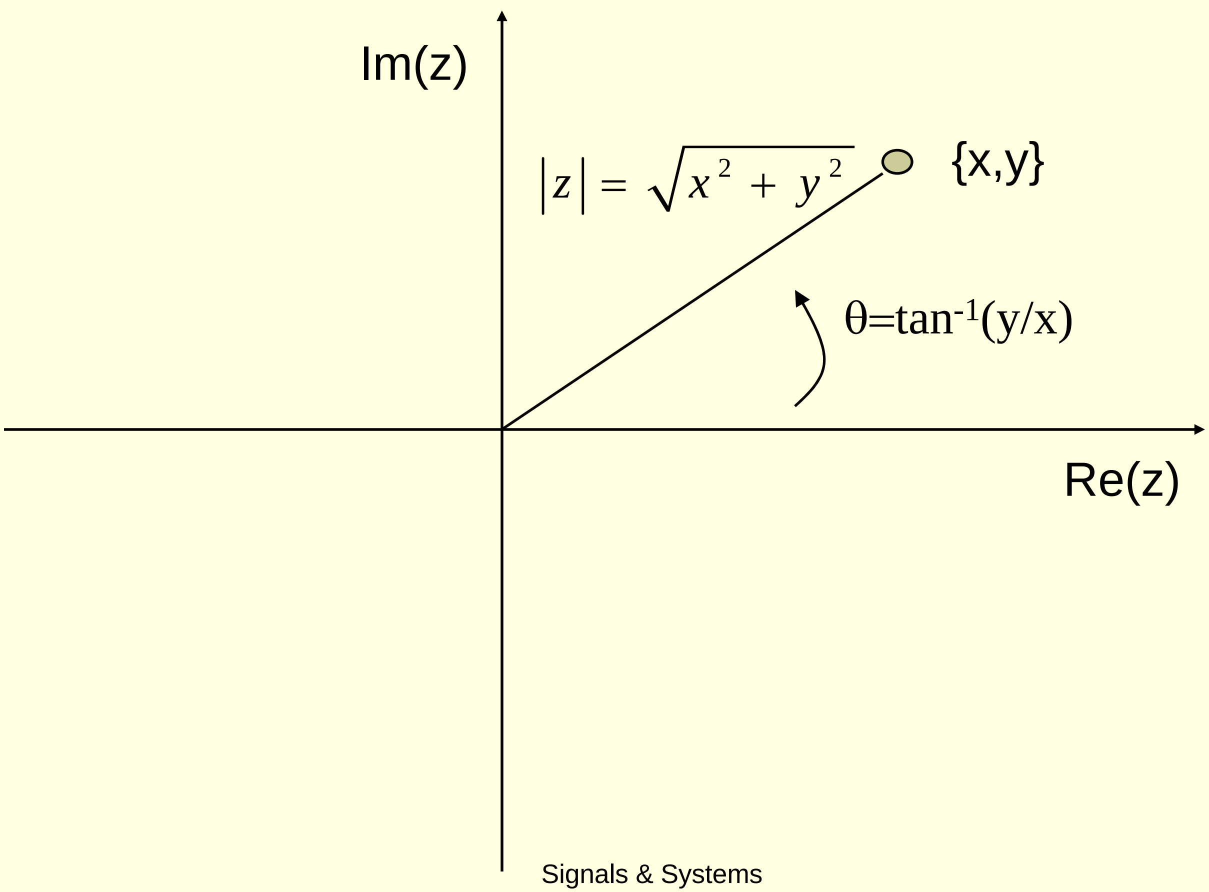
$$z + c = (x + a) + j(y + b)$$

$$z * c = (xa - yb) + j(ya + xb)$$

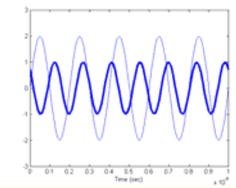


Complex Plane

- A complex number z=x+jy can be represented as a point in the complex plane



Euler’s Identities



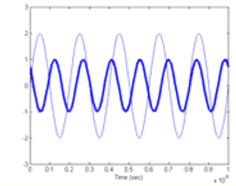
- $$e^{j\theta} = \cos(\theta) + j\sin(\theta)$$

This is termed a *phasor* representation of sinusoidal signals. We will use this representation extensively.

- $$\sin(\theta) = \frac{e^{j\theta} - e^{-j\theta}}{2j}$$
  $$\cos(\theta) = \frac{e^{j\theta} + e^{-j\theta}}{2}$$

- **Note:**
  $$\left|e^{j\theta}\right| = \sqrt{\cos^2\theta + \sin^2\theta}$$
  $$= 1$$
  $$\angle e^{j\theta} = \theta$$

Conclusions



- Being able to create and manipulate mathematical representations of signals and systems is a fundamental aspect of engineering and crucial to several disciplines
- Of primary importance is taking a signal and “transforming” it using either the Fourier Transform or the Laplace Transform
- After successfully completing this course you will be more familiar with these types of analyses and their application to different branches of engineering