Prof. Brian L. Evans, The University of Texas at Austin, bevans@ece.utexas.edu, Jan. 2021

Course Descriptions

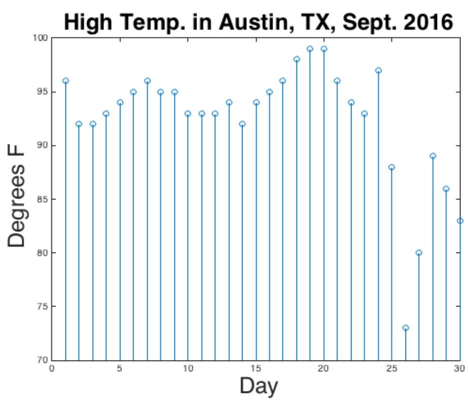
Note: Underlined text is a link to a Web resource, site or page

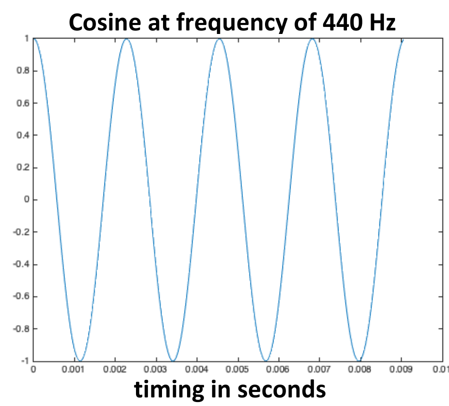
Introduction

Signals and systems have many meanings in different disciplines. In personal interactions, signals can be a non-verbal cue like a hand wave to say hello. A system could be the human eye that converts light (input) to neural impulses (output). The neural impulses are then passed along to the brain that determines that someone is waving a hand to say hello.

In the classes that I teach, students develop mathematical models for signals and systems to help them analyze their behavior and design signals and systems to achieve a certain goal. Goals could include making a music clip sound better when played back and improving the quality of photos and video when taking them on a smart phone.

Below on the left is a signal that is all too familiar to us in Austin, Texas, which is the daily temperature in September. Daily temperature is a discrete-time signal; that is, the values are taken at discrete points in time (days). On the right is a plot of continuous-time signal that represents the principal frequency for an 'A' musical note in the fourth octave on a Western scale (440 Hz) and a short program in MATLAB to generate it.






```
f0 =   440;
fs = 44100;
Ts = 1/fs;
t = 0 : Ts : 4/f0;
x = cos(2*pi*f0*t);
plot(t, x);
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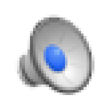

Play 440 Hz sound for 2 seconds

The 440 Hz sound (cosine wave) might sound artificial because it does not contain other frequencies that an acoustic instrument such as a trumpet, piano, or acoustic guitar would create. These other frequencies include multiples of the principal frequency, e.g. 880 Hz, 1320 Hz, etc. in this case, which are known as harmonic frequencies. The principal frequency plus its harmonic frequencies create a perceived richness of sound for the note.

Signal processing "is the enabling technology for the generation, transformation, and interpretation of information". [IEEE Signal Processing Society] Signal processing involves mathematical analysis, algorithm design, computer simulation, hardware/software implementation, and applications. Applications include speech recognition; noise reduction in videoconferencing; audio effects, recording, mixing, and mp3/mp4 compression; photo effects and JPEG compression; media streaming and videoconferencing; increasing cellular data rates and coverage for smart phones; and object tracking in radar and video data in advanced driver assistance systems and self-driving cars. Signal processing is an integral part of machine learning, and cuts across many areas of electrical and computer engineering and certain areas in computer science and other engineering disciplines.

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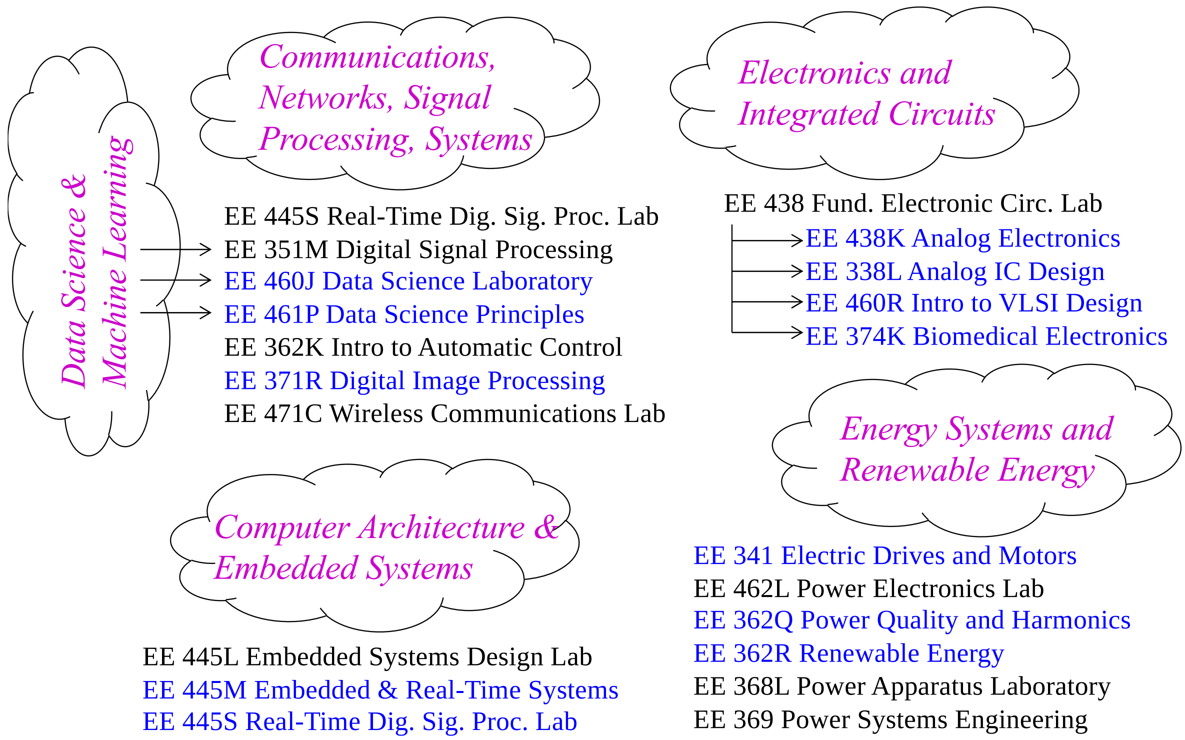
EE 313 Linear Systems & Signals

EE 313 Linear Systems & Signals has been required for both electrical and computer engineering majors since 1998. It is a foundational course that provides pre-requisite information for more than 20 upper division electrical and computer engineering (ECE) courses, which are grouped below by BS ECE specialization shown as clouds:



Both majors are required to take the same set of ten core ECE courses, including EE 313. Each student chooses a specialization, and that determines whether the student is an electrical or computer engineering major. Students can change their specialization until their graduating semester; hence, the choice of major is fluid until the graduating semester.

The graphic shows that EE 313 overlaps with two computer engineering specializations (computer architecture & embedded systems, and data science & machine learning) and three electrical engineering specializations (communications, networks, signal processing & systems; electronics & integrated circuits; and energy systems & renewable energy). The above graphic shows the pre-approved upper division courses under each specialization. The BS ECE major has a total of eight specializations, and any of the above courses can be taken as electives in the other three specializations with a faculty member's approval.

Here are the specific topics covered by EE 313:

> Representation of signals and systems; system properties; sampling; Laplace and z-transforms; transfer functions and frequency response; convolution; stability; Fourier transform; feedback; and control applications. Computer analysis using MATLAB or Python.

Instructors have wide latitude on topic order, textbook selection, assignments, teaching style, etc. They choose between two widely used simulation tools, MATLAB and Python.

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EE 445S Real-Time Digital Signal Processing Laboratory

I created the Real-Time Digital Signal Processing Laboratory course in 1997 for students to

- build intuition for applying signal processing concepts
- design algorithms with tradeoffs in signal quality vs. run-time complexity in mind

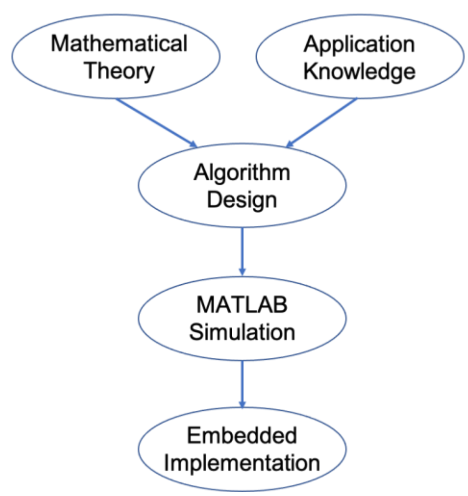
The first objective is to help students use critical thinking via inductive reasoning to put the pieces together from the pre-requisite required courses to form a big picture of the field. Signal processing concepts enable a wide variety of applications across science and engineering; the same signal processing concepts apply to speech, audio, image, video, and communication systems, as well as biomedical instrumentation and geophysical analysis.

What changes across applications in how one measures the quality of the signal. When humans are the ultimate consumer of the information, speech and audio quality is about the perceived auditory quality. Likewise, image and video quality is about the perceived visual quality. When machine interpretation of the data is ultimate consumer, the signal quality relates to improve the accuracy and precision of the machine interpretation.

The second objective relates to the critical thinking via deductive reasoning in designing signal processing algorithms. Each algorithm can achieve a certain signal quality but at a certain implementation cost. For implementation cost, this course focuses on how fast the algorithm executes or runs on the input data to produce output data, which is called run-time complexity. For a given application, students would evaluate multiple algorithms to pick the one with the best tradeoff. This is a critical thinking exercise.

The second objective is to introduce students to the design and implementation of signal processing systems. This introduction will help them in the two-semester senior design sequence, for which the Real-Time Digital Signal Processing Lab course is one of seven lab course pre-requisities. The introduction will also help them in courses across several application spaces, including EE 360K Digital Communications, EE 371Q Digital Image Processing, and EE 374K Biomedical Instrumentation, as well as courses in system design and implementation, such as EE 445M Embedded and Real-Time Systems.

As shown on the right, students will use mathematical theory to model applications. From those models, they will design algorithms, simulate them in MATLAB, and map them to embedded software in C. They will quantify tradeoffs in signal quality vs. run-time complexity in the algorithms. Students will connect the application theory from their signals and systems course (EE 313/BME 343) and the implementation skills from their courses in programming (EE 312) and embedded systems (EE 319K).



System Design Flow

The specific topics in this course follow:

> Digital signal processing algorithms; simulation and real-time implementation of audio and communication systems; filters; pulse shaping and matched filters; modulation/demodulation; adaptive filters; carrier recovery; symbol synchronization; equalization; quantization.