ECE3340

Review of Numerical Methods for Fourier Transform Applications

PROF. HAN Q. LE

Segment 2

(cont. from Segment 1)

Note: PPT file is the main outline of the chapter topic – associated Mathematica file(s) contain details and assignments

Outline

1. Introduction: concept of spectrum and periodic phenomena
2. Review of Fourier transform
3. Review of Fourier analysis
4. Numerical method: FFT
5. Applications in linear time-invariant system and signal processing

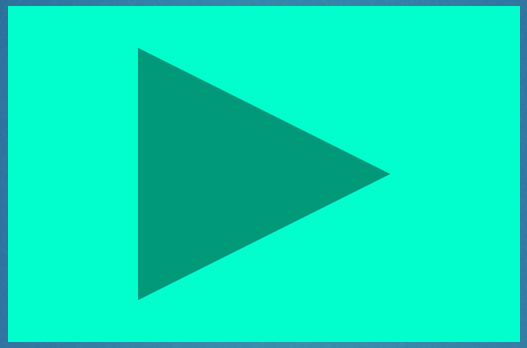
Overview (or the "big" perspective)

- We have learned Fourier transform, Laplace transform, and their applications in scientific/engineering problem – specifically for ECE, circuit and signal analysis. (Math 3321)
- Fourier transform is most applicable for harmonic, steady state phenomena (or when a starting time is not important).
- Laplace transform is most applicable when the initial condition is essential.
- In computation and digital applications, we use numerical methods such as FFT for Fourier analysis, or Z-transform for Laplace application to digital control of physical systems.

Learning objectives: review and practice numerical computation of these methods with specific examples of circuits and signal processing.

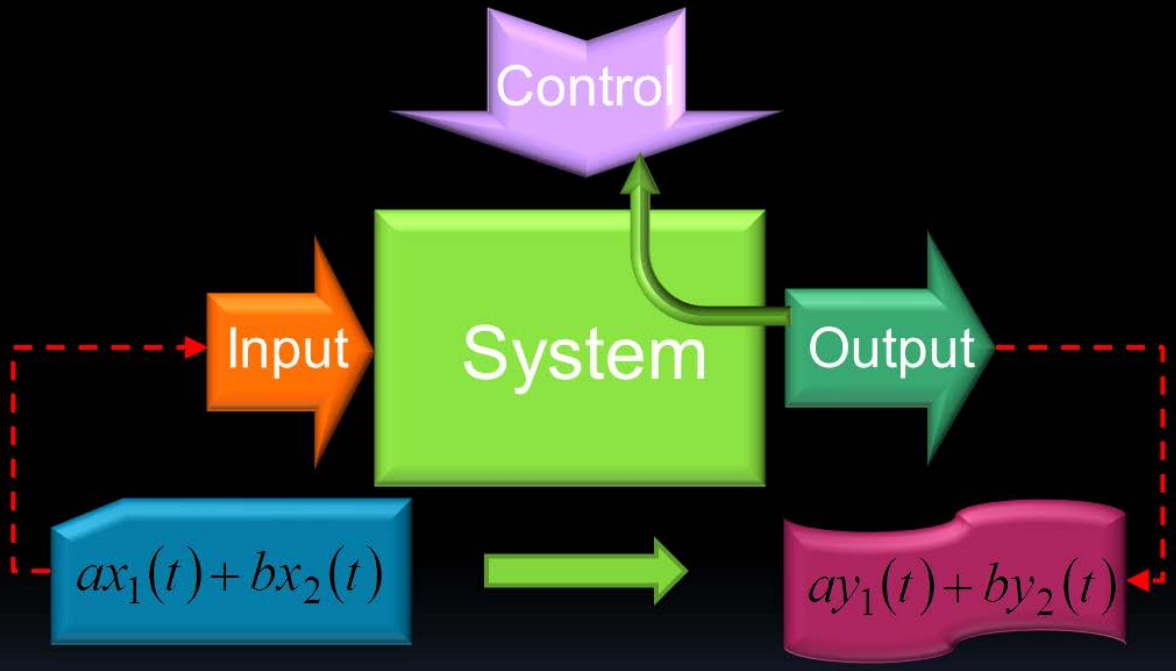
Review: Fourier theorem and Fourier transform

Note: this portion is in a Mathematica file



Introduction to Fourier analysis for linear time-invariant systems

Linear Time-Invariant (LTI) System



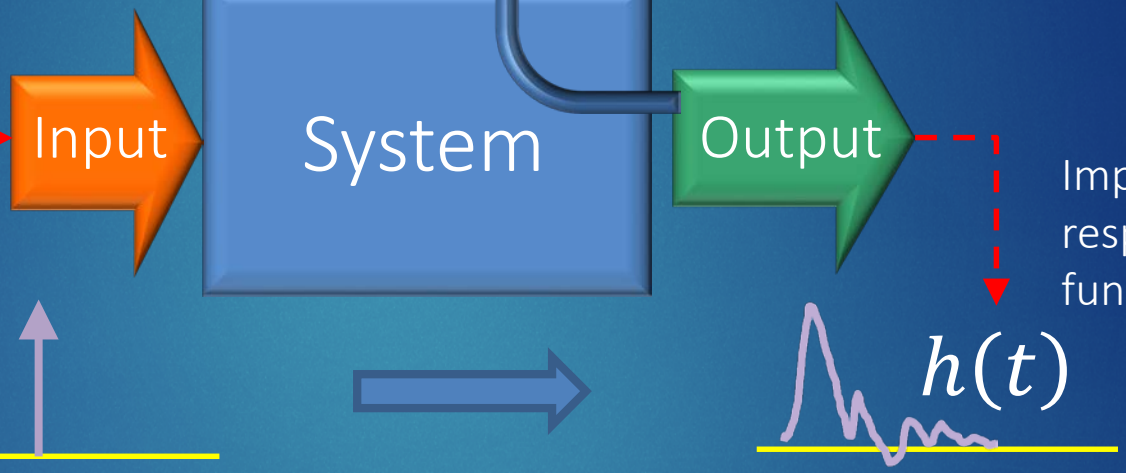
This is called "linear"

Time-invariant DOES NOT mean time-constant. It means that it does not matter when you input the signals (today or 1,000,000 yr BC), you'll get the same output

Linear Time-Invariant (LTI) System

Time domain

Link to Mathematica file



$$x_i(t) = \int x_i(t')\delta(t-t')dt' \qquad x_o(t) = \int x_i(t')h(t-t')dt'$$

in previous Segment, we discussed this:

Conceptual relationship between spectrum and spectral response:

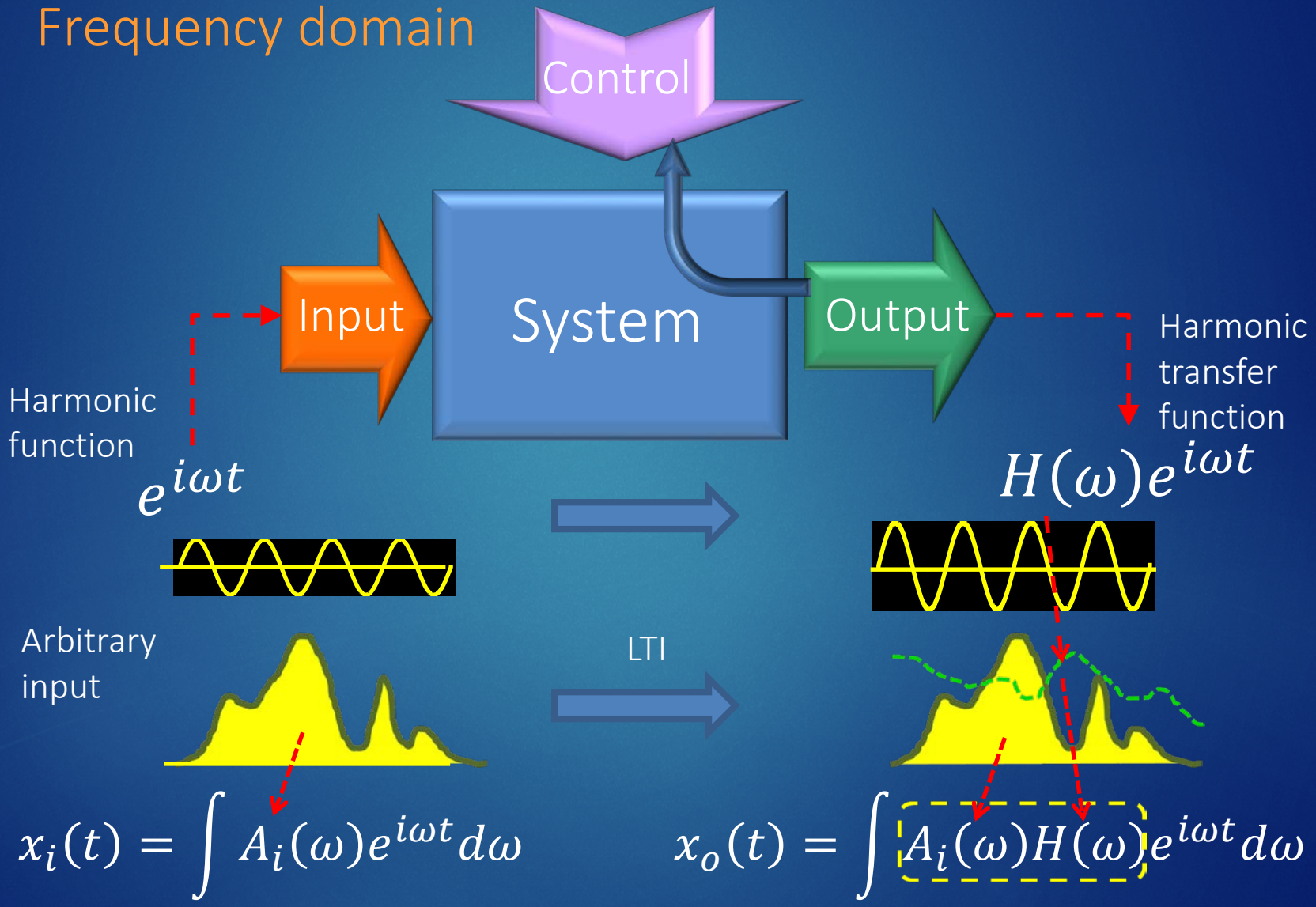
- spectrum of a signal coming from a source
- spectral response of an object given a stimulus

now, we have a specific statement:

The spectral response of a LTI is the spectrum of its output under an impulse input (Dirac delta-function input).

Linear Time-Invariant (LTI) System

Frequency domain



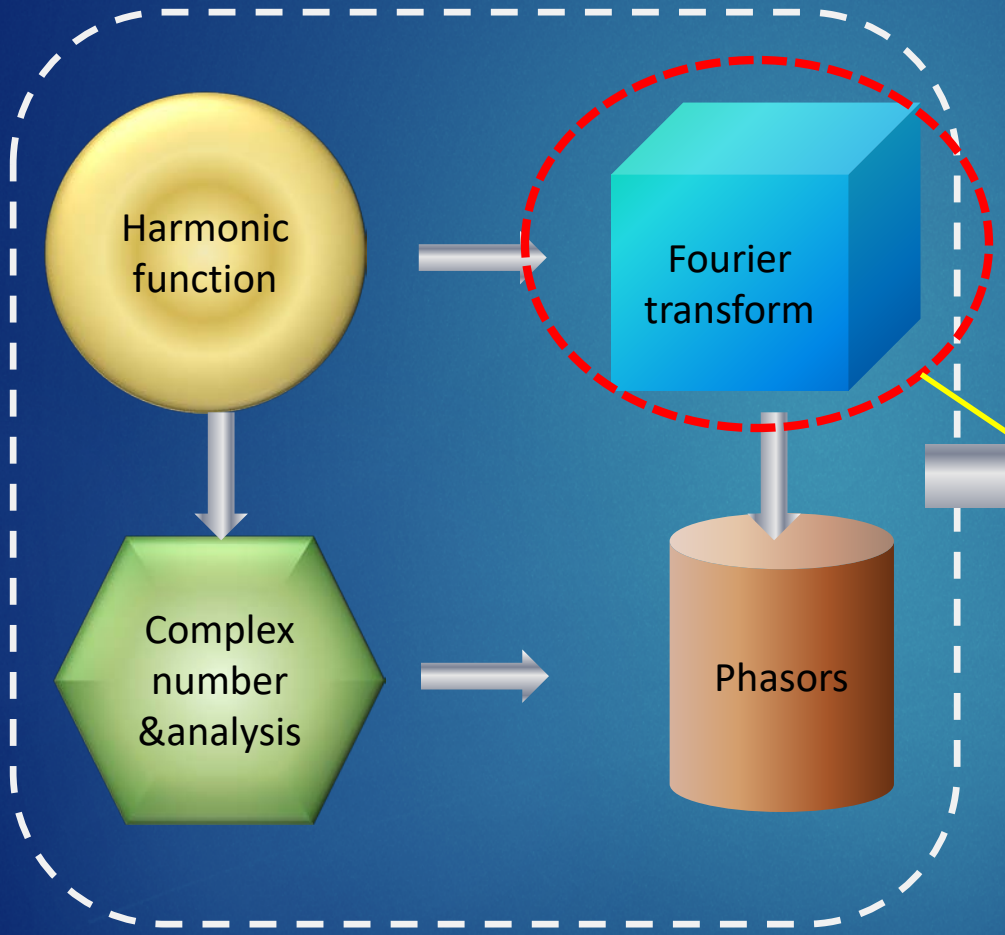
Concept Review: Signal Processing

- All electronics around us involve signal processing.
- Signal represents information. That information can be something we generate. The APP is an example of sound signal. Other common types: texts, images, all sensors (as discussed previously)
- Electronics deal with signals: preprocessing, post-acquisition, analog, digital.

Concept Review: Signal Processing (*cont.*)

- Signal processing is a general concept, not a single specific operation. It includes:
  - signal synthesis or signal acquisition
  - signal conditioning (transforming): shaping, filtering, amplifying
  - signal transmitting (telecomm) or applying for control (robotics)
  - signal receiving and analysis: transforming the signal, converting into information, for implementing certain controls.
- Signal processing is mathematical operation; electronics are simply tools.
- Some computation are high-level signal processing: dealing directly with encode or embedded information rather than raw signal.

Concept review: numerical methods

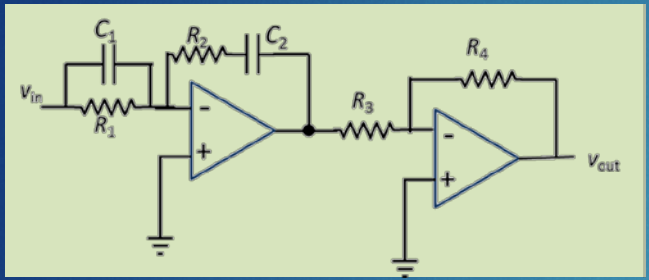


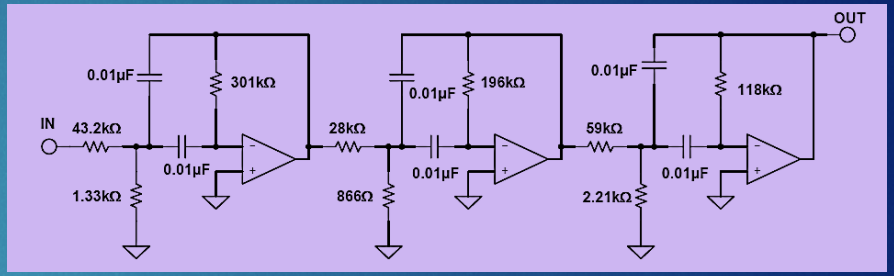
Signal and AC circuit problems

- RLC or any time-varying linear circuits. Applicable to linear portion of circuits that include nonlinear elements
- Signal processing
  - signal analysis (spectral decomposition)
  - filtering, conditioning (inc amplification)
  - synthesizing

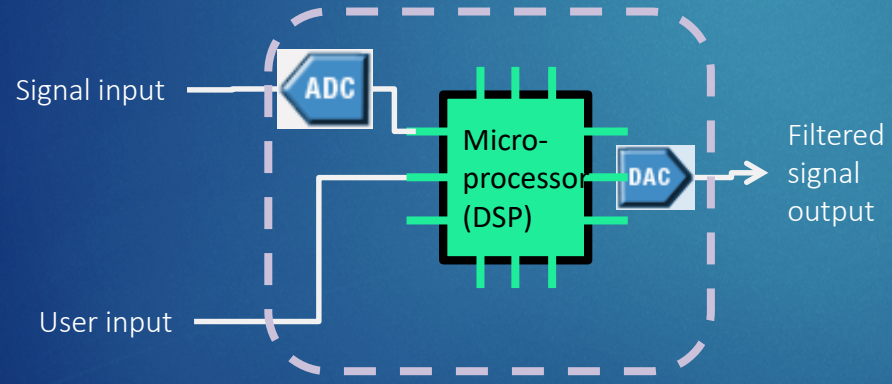
Concept: analog processing vs. digital processing

simplicity, capable of high speed and high frequency

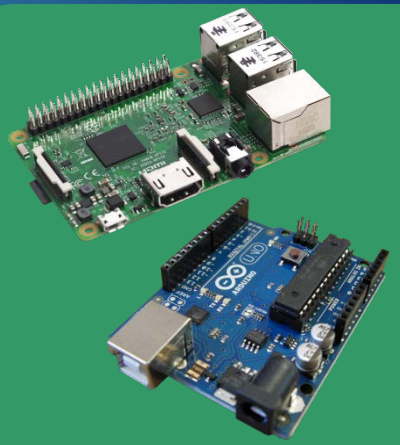




mid-range speed and frequency



hard-wired/dedicated
(use “recipes”)



software-implemented
direct compatibility with num. methods

To be continued