CSE 3451
Signals and Systems

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Agenda

- Course Overview and Mechanics:
  - Syllabus
  - Marking
  - Schedule
  - Labs
  - Etc
- Intro to Signals (Chapter 1)
- Assignment 1

Course Content, Format

- Continuous (CT) and sampled or discrete (DT) signals
- Theory
  - Behaviour of linear differential equations with constant coefficients
  - Signal analysis/synthesis using transforms (Fourier, Laplace, Z) and convolution
- Applications
  - filtering
  - signal/image processing
  - feedback controls
- Two 90-minute lectures, 3-hour lab each week

Textbook, Tools

- M. Mandal and A. Asif, *Continuous-time and Discrete-time Signals and Systems*, Cambridge University Press, 2007, ISBN-13: 978-0-521-85455-9
- Lab handouts extracted from Stonick, V., Bradley, K., “Labs for Signals and Systems Using MatLab”, PWS Publishing Co., 1996, ISBN 0-534-93808-6
- MatLab available on 3rd floor lab, most engineering lab computers (student version ~$100)
- Open source – GNU Octave also can be used – obtained here:

  http://www.gnu.org/software/octave/

Course Grading

Assignments, Quizzes (10% each)	20%
Lab Projects	25%
Mid-term	15%
Exam	40%
TOTAL	100%

Rough Lecture/Assignment/Quiz/Lab Schedule

Week	Lab	Day	Date	Assignment/Quiz	Lecture Topic (Reading)
1		R	4-Sep		**Introduction to Signals (Chapter 1):** 1. Transformations: Shifting and Scaling, 2. Types: Periodic vs. Aperiodic; Even vs. odd; Energy vs. Power, 3. Examples: Exponential; Sinusoidal; Ramp; Gate; Impulse; Step
2	Lab 1 (1-Matlab)	T	9-Sep		
		R	11-Sep		**CT and DT Systems (Chapter 2):** 1. System Connections and Properties
3		T	16-Sep	Assignment 1 due	**Time Domain Analysis, LTIC Systems (Chapter 3):** 1. Constant Coefficient Differential Equations 2. Solution of Differential Equation 3. Convolution
	Lab 1 due	R	18-Sep		
4	Lab 2 (2-Audio)	T	23-Sep		
		R	25-Sep	Quiz 1	
5		T	30-Sep	No Class	Rosh Hashanah
	Lab 2 due	R	2-Oct		**Integral Transforms (4.1, 4.2, 4.3, Chapter 6):** 1. Transformation of LTICs 2. Solution of LTICs using Laplace Transforms 3. Transfer functions from Constant Coefficient Differential Equations 4. Convolution Property, Multiplication Property
6	Lab 3 (3-B 5th)	T	7-Oct		
		R	9-Oct	No Class	(Yom Kippur)
7		T	14-Oct		**Fourier Transform - CT Systems (Chapter 4, 5):** 1. CT Fourier Transform for CT Periodic Signal 2. CT Non-periodic Signals: CT Fourier Transform 3. Properties of CT Fourier Transform
	Lab 3 due	R	16-Oct	Mid-term Test	

Rough Lecture/Assignment/Quiz Schedule (Cont'd)

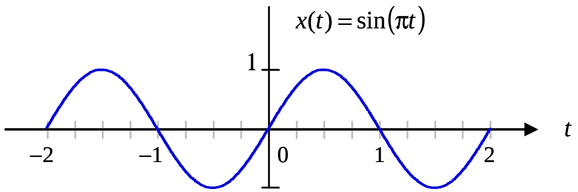
Week	Lab	Day	Date	Assignment/Quiz	Topic/Exercises
8	Lab 4 (4-Sound Synth)	T	21-Oct		**Design of Frequency Selective Filters (Chapter 7)** 1. Design of CT (analogue) filters 2. Butterworth filters **Sampling and Quantization (Chapter 9)** **Time Domain Analysis of DT Systems (Chapter 10)** **z Transform for DT Signals and Systems (Chapter 13)** 1. z Transform: Definition 2. DTFT for DT Periodic Signal 3. Properties of DT Fourier Transform 4. Convolution Property, Multiplication Property: Circular Convolution. Digital Signal Processing
		R	23-Oct	Assignment 2 due	
9	Lab 4 due	T	28-Oct		
		R	30-Oct		
10	Lab 5 (6 – Speech)	T	4-Nov		
		R	6-Nov	Assignment 3 due	
11	Lab 5 due	T	11-Nov		
		R	13-Nov		
12	Lab 6 (12 – AM radio)	T	18-Nov		
		R	20-Nov	Quiz 2	
13	Lab 6 due	T	25-Nov		**CT and DT Control Systems** 1. Transfer functions from Constant Coefficient Difference Equations
		R	27-Nov		
14		T	2-Dec	Assignment 4 due	
		R	4-Dec	No Class	

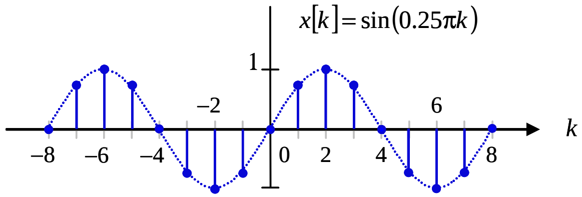
Use of Wiki Pages

- Course resources available online through the department's Wiki pages
- http://wiki.cse.yorku.ca – may have to follow Course Archive Link
- You can check site to
  - Review lecture material
  - Check schedule, due dates, marks
  - Submit assignments, labs – setting up a drop box for paper submissions as well
  - Ask course-related questions via the forum

Intro to Signals (Chapter 1)

- Typically we are talking about:
  - Time-varying – continuously (CT) OR sampled (DT)
  - Electrical (voltage/current) output…
    - …from a transducer which is monitoring some ongoing process (sending analog information), OR
    - …from a processor or ADC which is sending digital information
  - Main idea is that there is a “sender” and “receiver” that exchange information via the signal

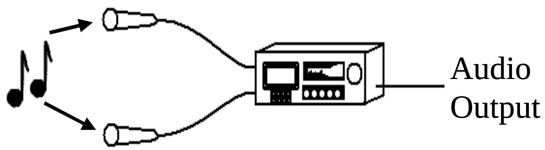


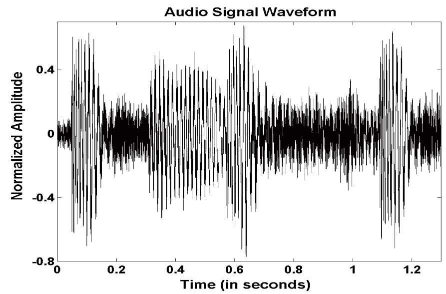


$T_s = 0.25$

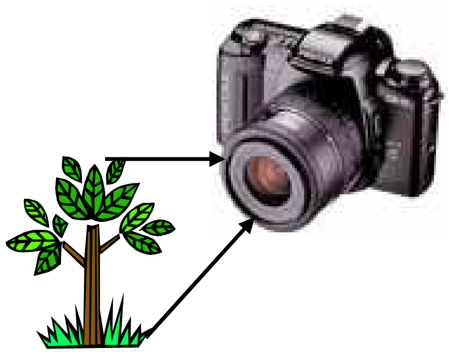
Signal Examples

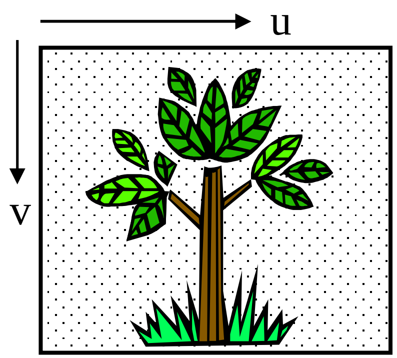
- Sound (pressure) - CT





- Light - DT





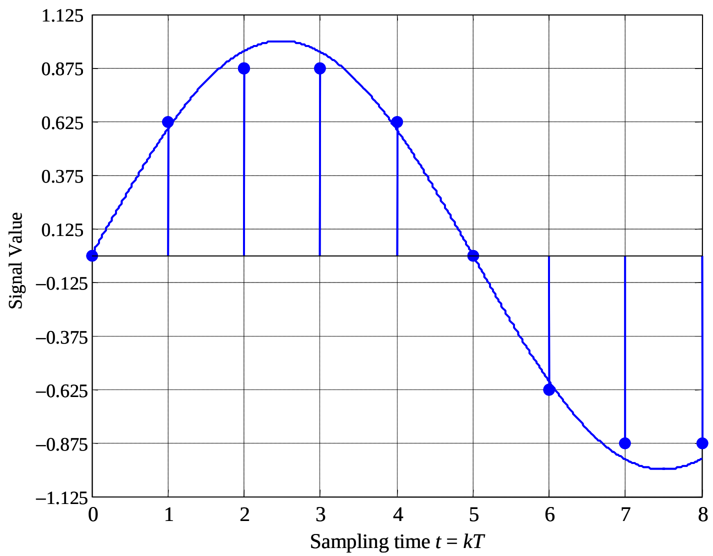
Analog vs. Digital Signals

- CT and DT classification is a mathematical one

$$x(t) = \sin(0.25\pi t)$$

$$x[k] = \sin(0.25\pi k)$$

- Analog/Digital classification is based on hardware and how it operates on signals



Periodic vs. Aperiodic

- Signal (CT, DT) is periodic if

$$x(t) = x(t + T_0)$$

$$x[k] = x[k + K_0]$$

- CT, sinusoidal signals are periodic by definition

$$x(t) = A\sin(2\pi ft + \theta) = x(t + T_0) = A\sin(2\pi ft + 2\pi fT_0 + \theta)$$

$$fT_0 = m$$

$$T_0 = 1/f \quad (m = 1)$$

- Sampled sinusoidal signals may NOT be periodic

$$x[k] = A\sin(2\pi fT_s k + \theta) = x[k + K_0] = A\sin(2\pi fT_s k + 2\pi fT_s K_0 + \theta)$$

$$fT_s K_0 = m$$

$$K_0 = m / fT_s = mT / T_s$$

To be periodic, the sampling period and sinusoidal frequency (period) MUST be expressible as a rational fraction (n/m).

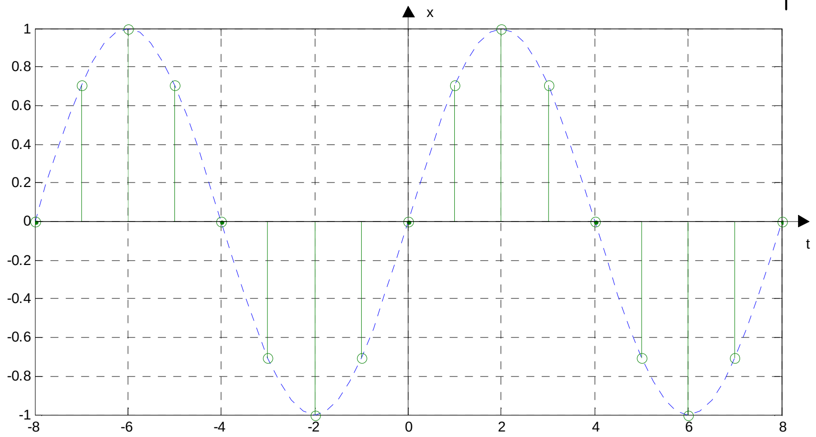
Example Problems

(1) CT signal is $x(t) = \sin(0.25\pi t)$

What is period?

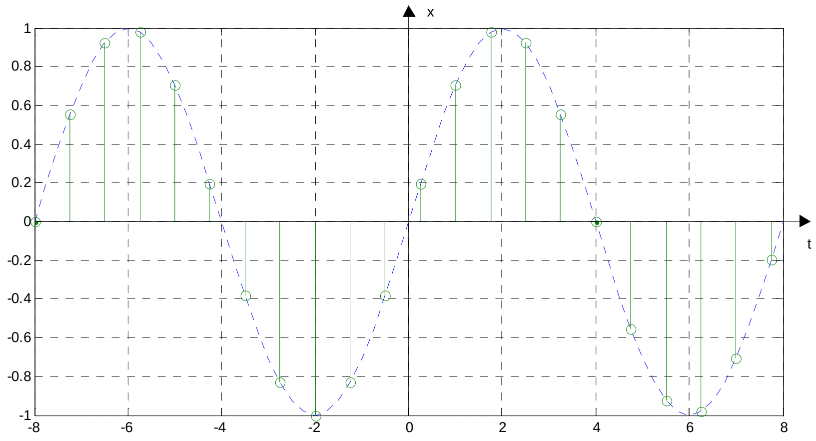
Top plot also shows the sampled DT signal for T_s = 1 s

Is $x[k]$ periodic? If so, what is K_0?



(2) Bottom is the DT sampled signal for T_s = 0.75 s.

Is $x[k]$ periodic? If so, what is K_0?



Harmonics, Superposition

- Sinusoidal components of a signal which have frequencies (periods) which are integer multiples of some fundamental component

$$g(t) = X_1 \sin(2\pi f_1 t) + X_2 \sin(2\pi f_2 t + \theta)$$

$$f_2 = \pm m f_1$$

- The resulting function is periodic if

$$\frac{T_1}{T_2} = \frac{f_2}{f_1} = \frac{m}{n}$$

$$T_0 = nT_1 = mT_2 = 1/ f_0$$

Example – Beat Frequency

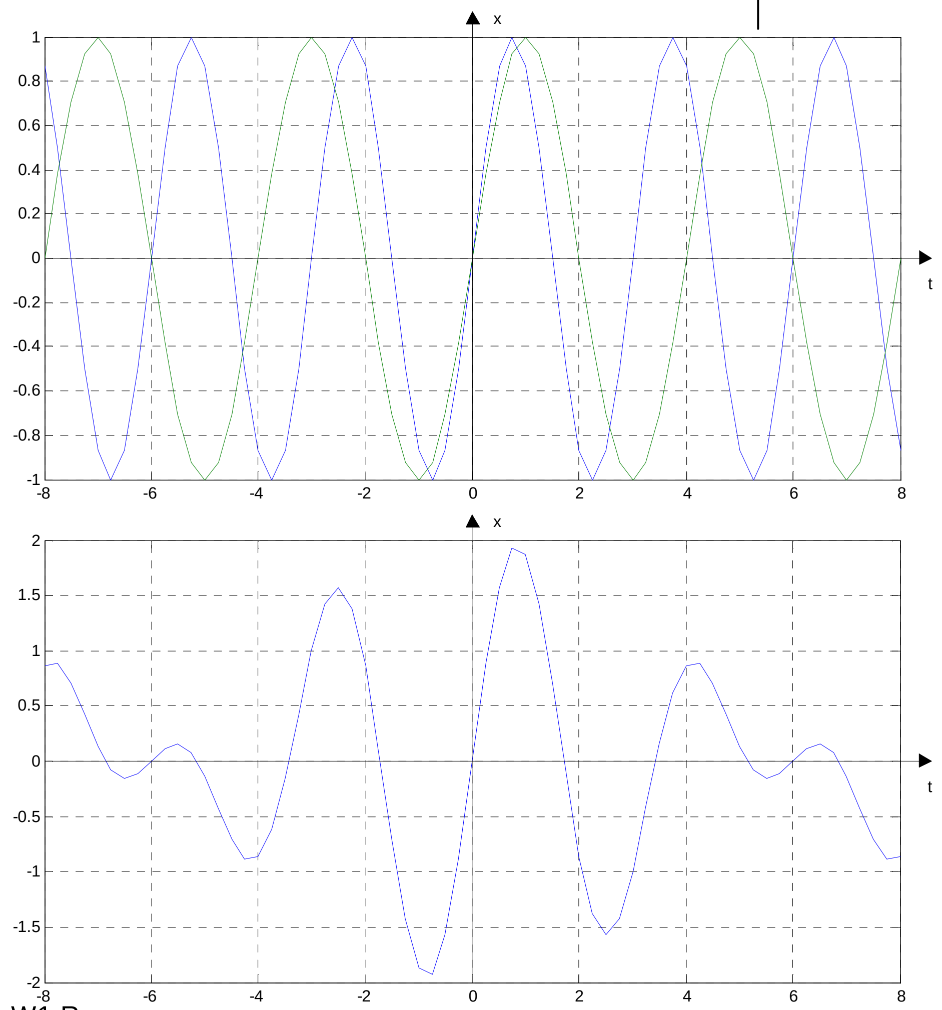
- CT signals are:

$$x_1(t) = \sin\left(\frac{2\pi}{3}t\right)$$

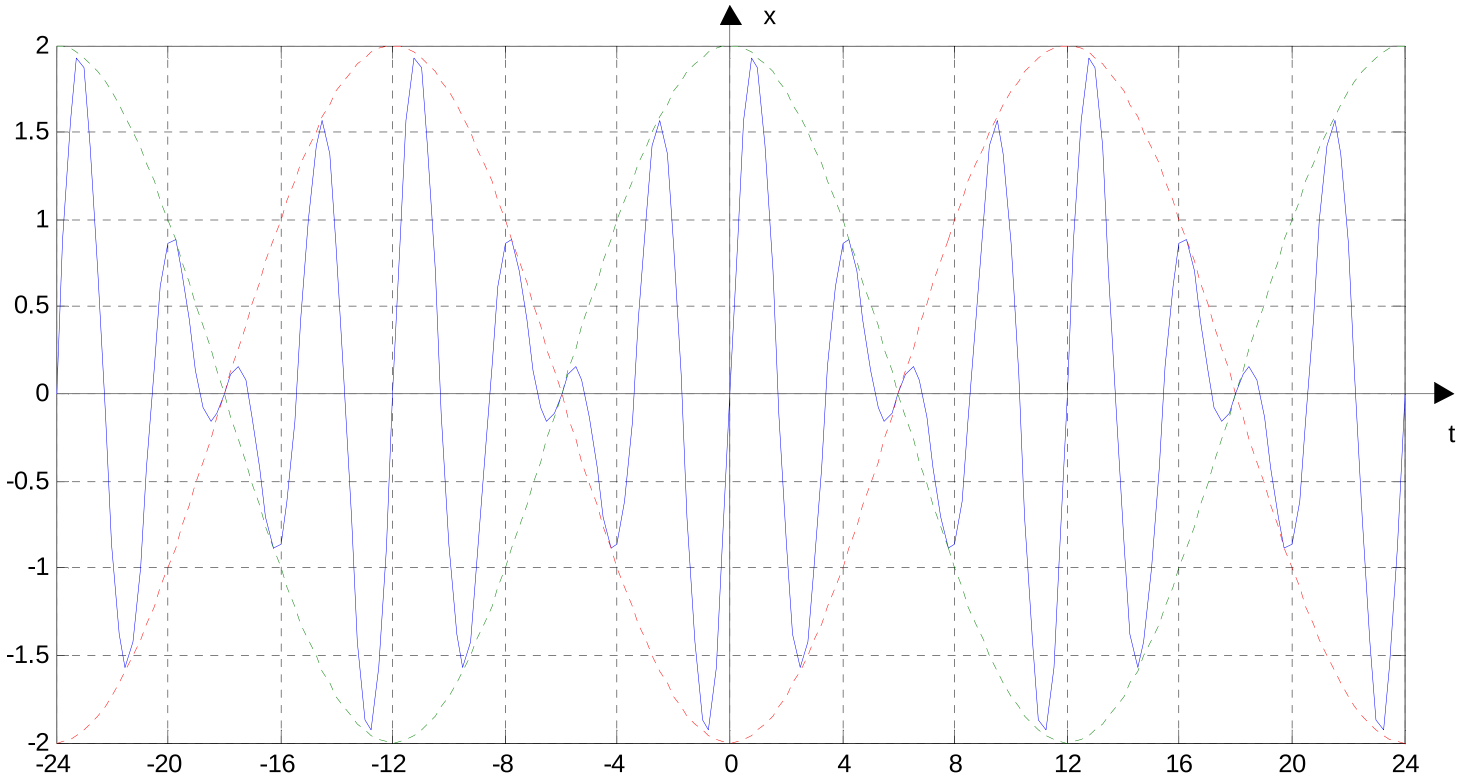
$$x_2(t) = \sin(0.5\pi t)$$

- Signal superpostion
- What is the period of this signal?
- Use trig identities to show

$$x_1(t) + x_2(t) = 2\cos\left(\frac{\pi}{12}t\right)\sin\left(\frac{7\pi}{12}t\right)$$



Beat Frequency (cont'd)



Energy and Power

- For an electrical signal, the instantaneous power is

$$P(t) = \frac{v^2(t)}{R} \qquad P[k] = \frac{v^2[k]}{R}$$

- In general, we will define the instantaneous power of a signal, *x(t)* to be

$$P(t) = x^2(t) \qquad P[k] = x^2[k]$$

- Average power and energy of a signal, *x(t)* over some time interval is

$$E(t_1 ... t_2) = \int_{t_1}^{t_2} x^2(t)dt \qquad E[k_1 ... k_2] = \sum_{k_1}^{k_2} x^2[k]$$

$$P_{avg}(t_1 ... t_2) = \frac{E(t_1 ... t_2)}{t_2 - t_1} \qquad P_{avg}[k_1 ... k_2] = \frac{E[k_1 ... k_2]}{k_2 - k_1}$$

Energy, Power – Periodic Signal

- If a signal is periodic, then the average power can be computed by considering only a single period of the signal – Why?

$$E(t_1 \ldots t_1 + T_0) = \int_{t_1}^{t_1+T_0} x^2(t)dt$$

$$E[k_1 \ldots k_1 + K_0] = \sum_{k_1}^{k_1+K_0} x^2[k]$$

$$P_{avg} = \frac{E(t_1 \ldots t_1 + T_0)}{T_0}$$

$$P_{avg}[k_1 \ldots k_1 + K_0] = \frac{E[k_1 \ldots k_1 + K_0]}{K_0}$$

Signal Power Example

- We measure the power of a 12 MHz radio carrier to be 0 dBm. What is the carrier signal's voltage amplitude as it propagates along a 50 Ω coax cable?

$$dB_m = 10\log\left(\frac{P\ mW}{1\ mW}\right)$$

Assignment 1

- Chapter 1: Signals
  - Q 1.2 (ii), (iv), (vi) use Matlab to sketch signals
  - Q1.3 (ii), (iv), (v) use Matlab to sketch signals
  - Q1.5 (i), (iv), (vii)
  - Q1.6 (ii), (iii), (vi)
  - Q1.10
  - Q1.31