Xi'an Jiaotong-Liverpool University 西交利物浦大学

# EEE204 Continuous and Discrete Time Signals and Systems II

2018–2019 Semester 2

Electrical and Electronic Engineering

Xi'an Jiaotong-Liverpool University

Feb. 18, 2019

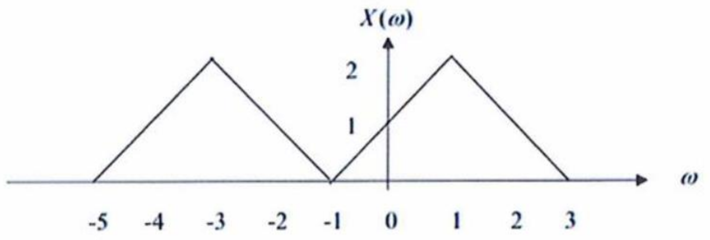
# Something in EEE203 Final Exam

**Q2.** Determine if the following Continuous Time signals are energy or power signals or neither. Calculate the energy and power of the signals in each case. (**10'**)

a) $x_1(t) = \cos(\pi t)\sin(3\pi t)$ (**5'**)

b) $x_2(t) = \exp(-2t)u(t)$ (**5'**)

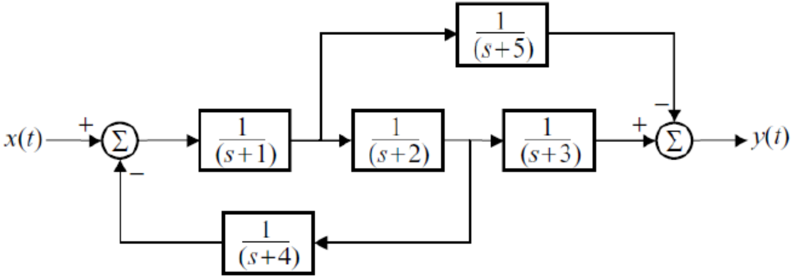
**Q7.** The Fourier transform of $x(t)$ is shown in the figure as $X(\omega)$. Compute the following items without explicitly computing $x(t)$. **(10')**




a) Compute quantities of $\int_{-\infty}^{\infty} |x(t)|^2 dt$ **(5')**

b) Computer quantities of $x(0)$ **(5')**

**Q8.** Simplify the block diagram to find the transfer function $H(s)$. **(15')**



# Module Information

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- Classes
  - ✓ Lectures: Monday 14:00–16:00, SD114 (Week 1–6, 8–14).
  - ✓ Lab: Thursday 11:00–13:00, 14:00–18:00, HS102, HS103 (Week 12).
- Instructor: Dr. Jimin Xiao
  - ✓ Office: EB312.
  - ✓ Office hours: Thursday 15:00–17:00.
  - ✓ Office landline: 0512-81883209.
  - ✓ Email: Jimin.Xiao@xjtlu.edu.cn

Home page: http://mmtlab.com/JiminXiao.ashx

# Assessments



## Grading

- Mid-term Exam: (10%)
  - ✓ Closed book exam in week 7.
- Lab: (10%)
  - ✓ Individual work (discussion allowed, plagiarism strictly prohibited).
  - ✓ Writing report, and submit the e-copy to ICE.
  - ✓ Due date TBD.
- Final Exam: (80%)
  - ✓ Closed book exam during examination days (June, TBD).

Revision class will be provided.

# Module Overview

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- Pre-requisites:
  - ✓ MTH013 Calculus (Science and Engineering).
  - ✓ MTH008 Multivariable Calculus (Science and Engineering).
  - ✓ EEE203 Continuous and Discrete Time Signals and Systems I.
  - ✓ Basic programming skills (Matlab, C, C++, Python, JAVA etc)
- Aims: Present the concepts involved with discrete-time or discrete-space signal and systems:
  - ✓ Discrete time signals and systems (p.1).
  - ✓ Sampling of continuous signals (p.514).
  - ✓ Time-domain analysis of discrete time signals and systems (p.74).
  - ✓ Discrete time Fourier transform (DTFT) (p.358).
  - ✓ Discrete Fourier transform (DFT) (Supplementary material).
  - ✓ z-transform (p.741).

# Recommended Texts and References

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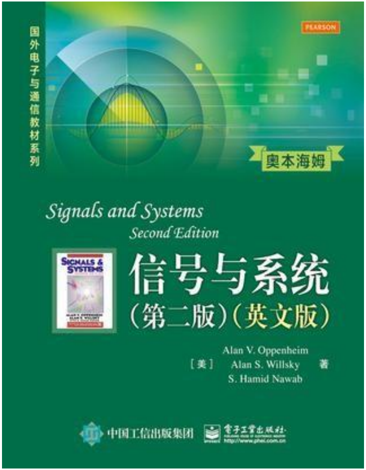
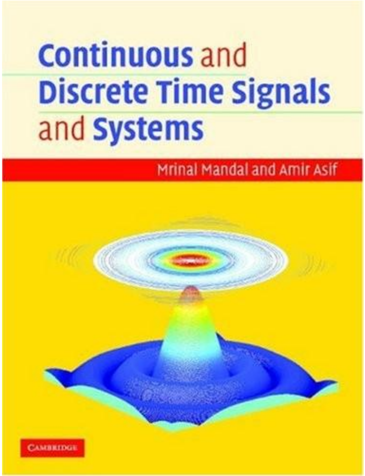
## Text Book:

Oppenheim, Alan V., Willsky, Alan S. and Hamid, S. *Signals and systems*. Publishing House of Electronics Industry, 2015.



## Previous Text Book:

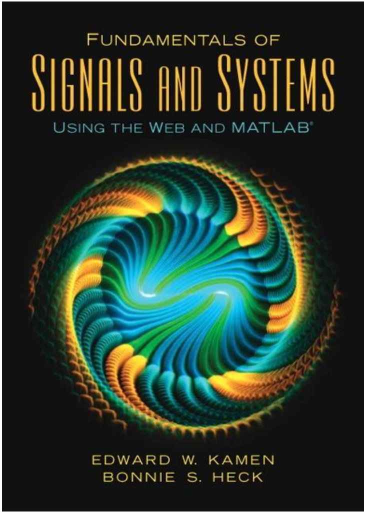
Mandal, Mrinal Kr, and Asif, Amir *Continuous and discrete time signals and systems*. Cambridge University Press, 2007.



# Recommended Texts and References

## Additional Reference 1:

Kamen, Edward W. and Heck, Bonnie S. *Fundamentals of signals and systems using the web and matlab*. 3rd Edtion. Prentice-Hall, 2006.



# Learning Outcome



- After successful completion of the module, you should have
  - ✓ an understanding of the sampling process to generate a discrete version of the signals.
  - ✓ an understanding of linear time-invariant systems in the discrete-time domain.
  - ✓ an understanding of the use of discrete-time Fourier transform (DTFT) to represent discrete-time signals.
  - ✓ an understanding of the use of discrete Fourier transform (DFT) and the differences with DTFT and CT-Fourier transform.
  - ✓ an understanding of the use of *z*-transform in circuit and system analysis.

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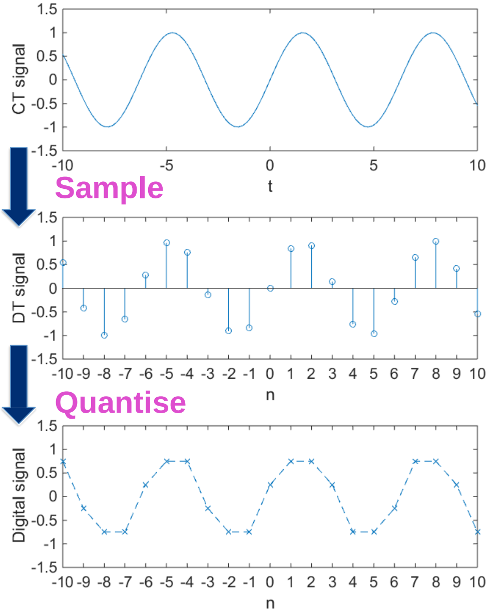
## Signal

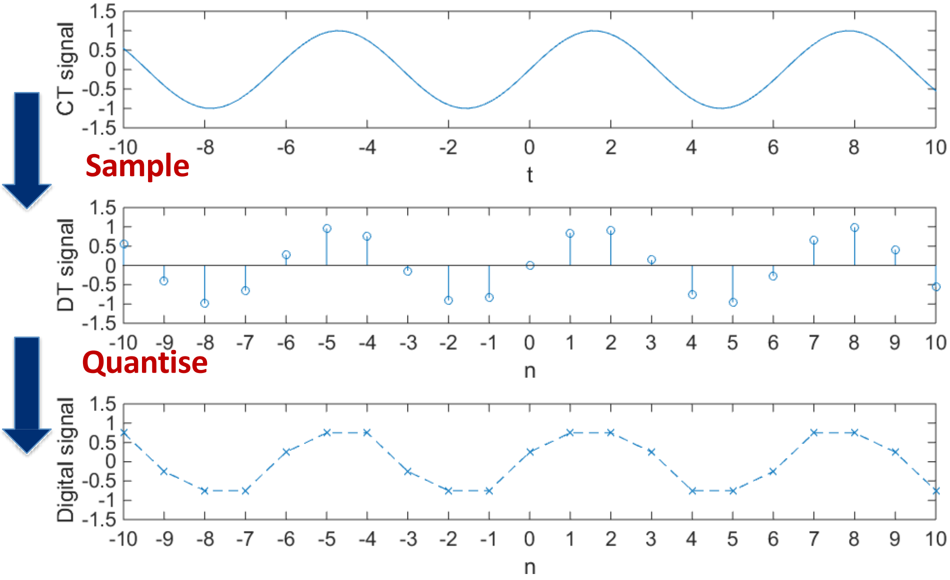
A signal can be broadly defined as any quantity that varies as a function of time and/or space and has the ability to convey information about a certain physical phenomenon.

# CT vs. DT Signals

- Continuous signal: $t \in \mathbb{R} \to x(t) \in \mathbb{R}$ or $\mathbb{C}$
- Discrete signal: $n \in \mathbb{Z} \to x[n] \in \mathbb{R}$ or $\mathbb{C}$
- Digital signal: $n \in \mathbb{Z} \to x[n] \in \mathbb{A}$ where $\mathbb{A} = \{a_1, \cdots, a_L\}$ is a finite set of $L$ signal levels.

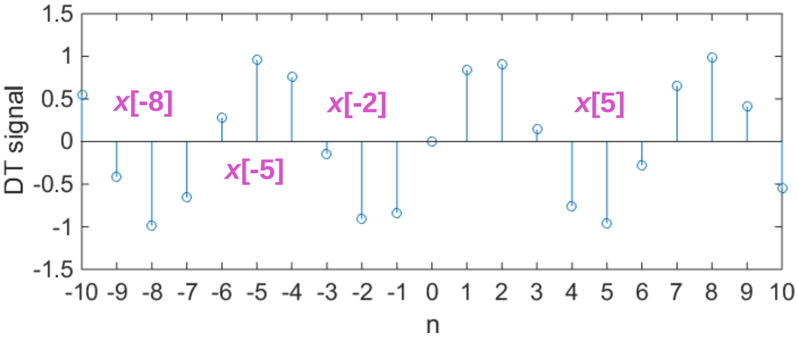


# CT vs. DT Signals



# Discrete-time Signals

- ✓ A discrete-time signal is represented by a series of values, each of which has an index indicating the corresponding time ordering of the values: $x[n] = \{x[0], x[1], x[2], \cdots\}$.
- ✓ Note that the square brackets represent the index of the independent variable.



# Example of DT Signals

- Any series of measurements of a physical quantity is a discrete signal.
- The one-dimensional hourly measurements of the temperature $x[k]$ made with an electronic thermometer.
- Although many signals in the real world are continuous, for some practical applications we can only measure and save discrete values.

# Example of Discrete-Space Signals

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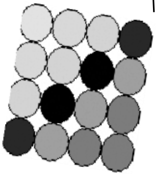
digital grey images: are 2-D discrete-space signals

- ✓ The intensity of the image at location $p[x, y]$.
- ✓ Stored images are made up of a discrete number of points → discrete-space signals.



pixel or pel



# Why DT Systems



There are many important advantages with digital signal processing such as:

- ✓ Flexibility: the system can be reprogrammed such that the same hardware can be used in a variety of different applications.

- ✓ Self-calibration: the digital hardware used to implement DT systems does not drift with age or with changes in the operating conditions and can be self-calibrated easily.

# Why DT Systems



There are many important advantages with digital signal processing such as (cont.):

- ✓ Digital signals are less sensitive to noise and interference than analog signals →are widely used in communication systems.
- ✓ Data-logging (saving): the data available from the DT systems can be stored in a digital server so that the performance of the system can be monitored over a long period of time.

# However

The primary advantage of CT signal processing is its higher speed. This is due to limits on the sampling rate of the A/D converter and the clock rate of the processor used to implement the DT systems.

# Energy and Power of Signals

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## Energy

- The energy of CT signal $x(t)$ is

$$\epsilon(x) = \int_{-\infty}^{+\infty} |x(t)|^2 \, \mathrm{d}t.$$

- The energy of DT signal $x[n]$ is.

$$\epsilon(x) = \sum_{n=-\infty}^{+\infty} |x[n]|^2.$$

## Power

Power is a time average of energy (energy per unit time)

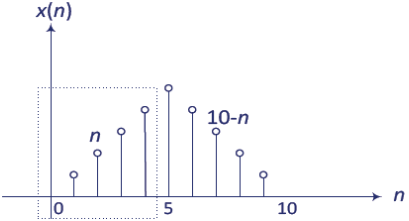
| | |
|---|---|
| CT signal $x(t)$ | $p(x) \triangleq \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} \lvert x(t)\rvert^2 \, \mathrm{d}t$ |
| DT signal $x[n]$ | $p(x) \triangleq \lim_{N\to\infty} \frac{1}{2N+1} \sum_{n=-N}^{+N} \lvert x[n]\rvert^2$ |
| DT periodic signal | $p(x) \triangleq \frac{1}{N_0} \sum_{n=n_1}^{n_1+N_0-1} \lvert x[n]\rvert^2$ |

$n_1$ is an arbitrary integer and $N_0$ is the fundamental period.

## Example:

Find the energy of:

$$x[n] = \begin{cases} n, & 0 \leqslant n < 5 \\ 10 - n, & 5 \leqslant n < 10 \\ 0, & \text{otherwise} \end{cases}$$




$$E = \sum_{n=-\infty}^{+\infty} |x[n]|^2, \left( \sum_{i=1}^{n} i^2 = \frac{1}{6} n(n+1)(2n+1). \right)$$

$$= 1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 4^2 + 3^2 + 2^2 + 1^2,$$

$$= 2 \times 5 \times 6 \times 11 \div 6 - 25 = 85.$$

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# Elementary Sequences

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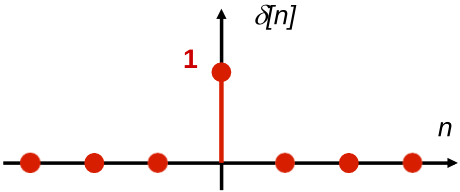
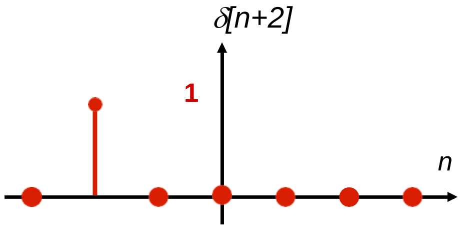
## The DT impulse function (Kronecker Impulse)

$$\delta[n] = \begin{cases} 1 & n = 0 \\ 0 & n \neq 0 \end{cases}$$

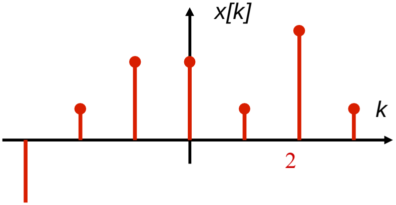


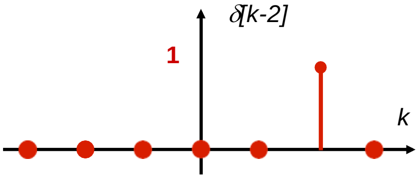

## Can you write the expression for $\delta[n + 2]$?

$$\delta[n+2] = \begin{cases} 1 & n = -2 \\ 0 & n \neq -2 \end{cases}$$



# Multiplying a DT signal with a Kronecker Impulse




$$x[k]\delta[2-k] = x[k]\delta[k-2] = \begin{cases} x[2] & k = 2 \\ 0 & k \neq 2 \end{cases}$$

Why is $\delta[2-k] = \delta[k-2]$?

Any DT signal $x[n]$ can be represented by the infinite sum of the multiplication of a sample and a Kronecker Impulse

Proof:

$$\sum_{k=-\infty}^{+\infty} x[k]\delta[n-k]$$

$$= \cdots x[-1]\delta[n+1] + x[0]\delta[n] + x[1]\delta[n-1],$$

$$+ x[2]\delta[n-2] + \cdots ,$$

$$= x[n].$$

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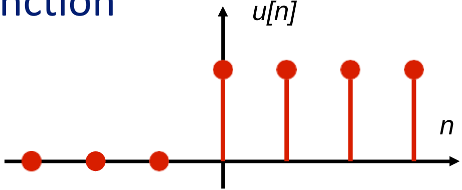
## The DT step (unit step) function

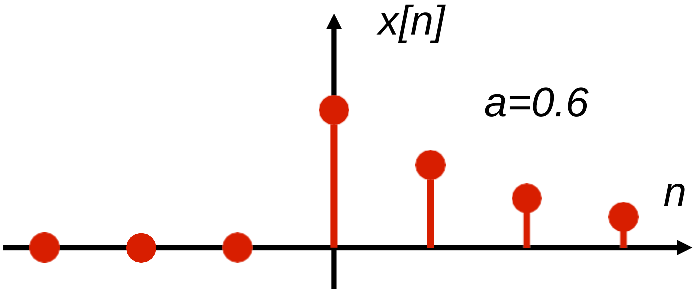
$$u[n] = \begin{cases} 1 & n \geqslant 0 \\ 0 & n < 0 \end{cases}$$




$$\begin{aligned} u[n] &= \delta[n] + \delta[n-1] + \delta[n-2] + \delta[n-3] + \cdots, \\ &= \sum_{k=0}^{+\infty} \delta[n-k], \\ &= \sum_{k=0}^{+\infty} u[k]\delta[n-k] = \sum_{k=-\infty}^{+\infty} u[k]\delta[n-k]. \end{aligned}$$

# Real-valued exponential sequence

$$x[n] = a^n u[n]$$



# Homework



- Page 6–7, read content about energy and power of discrete-time signals
- Page 21–25 read section 1.3.2
- Page 30–32, read section 1.4.1
- Page 57, Q1.4, all.
- Page 59, Q1.22, all.

# Thank you for your attention.