上海科技大学
ShanghaiTech University

EE150 *Signals and Systems*

Lecturers: Yijie Mao and Yong Zhou
毛奕婕　　　　周勇

Network Intelligence Center
School of Information Science and Technology
ShanghaiTech University

Outline

- Course overview
- Signals and systems introduction
- Classification of signals
- Operation on signals
- Summary

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Course Overview

- Course Title: EE 150 Signals and Systems
- Course Level: Undergraduate
- Credit/Contact Hour: 4/64
- Instructor (Week 1-8)

  ☺ Yijie (Lina) Mao（毛奕婕） ✉ maoyj@shanghaitech.edu.cn
- Office Hour

  14:00-16:00 Tuesday ⌖ SIST-2 Room 302I
- Instructor (Week 9-16)

  ☺ Yong Zhou（周勇） ✉ zhouyong@shanghaitech.edu.cn
- Office Hour

  14:00-16:00 Wednesday ⌖ SIST-2 Room 302E

Course Overview

- Teaching Assistants (TAs):
  - ☺ Xiaopeng Yu（余肖鹏） ✉ yuxp2022@shanghaitech.edu.cn
  - ☺ Jinhao Qiu（邱锦灏） ✉ qiujh2023@shanghaitech.edu.cn
  - ☺ Guorui Qui（崔国锐） ✉ cuigr@shanghaitech.edu.cn
  - ☺ Tianyuan Shi（施天远） ✉ shity@shanghaitech.edu.cn

- Tutorial:

  TBD   教学中心301

- Blackboard:
  https://elearning.shanghaitech.edu.cn:8443
  (Slides and text book)

- QQ group: 866273449

Syllabus (Week 1-8, Instructor: Yijie Mao)

Week	Timeline	Chapters	Teaching Contents
1-2	**Feb. 27, 29, Mar. 5, 7**	Chapter 1: Overview	1.1 Continuous-time and Discrete-time Signals 1.2 Transformation of Independent Variables 1.3 Exponential and Sinusoidal Signals 1.4 The Unit Impulse and Unit Step Functions 1.5 Continuous-Time and Discrete-Time Systems 1.6 Basic System Properties
3-4	**Mar. 12, 14, 19, 21**	Chapter 2: Linear Time-Invariant Systems	2.1 Discrete-Time LTI Systems 2.2 Continuous-Time LTI Systems 2.3 Properties of Linear Time-Invariant Systems 2.4 Differential and Difference Equations
5-6	**Mar. 26, 28, Apr. 2, 4**	Chapter 3: Fourier Series Representation of Periodic Signals	3.1 The Response of LTI Systems to Complex Exponentials 3.2 Fourier Series Representation of Continuous-Time Periodic Signals 3.3 Convergence of the Fourier Series 3.4 Properties of Continuous-Time Fourier Series 3.5 Fourier Series Representation of Discrete-Time Periodic Signals 3.6 Properties of Discrete-Time Fourier Series 3.7 Fourier Series and LTI Systems
7-8	**Apr. 9, 11, 16, 18**	Chapter 4: The Continuous-Time Fourier Transform	4.1 The Continuous-Time Fourier Transform 4.2 The Fourier Transform for Periodic Signals 4.3 Properties of the Continuous-Time Fourier Transform 4.4 The Convolution Property 4.5 The Multiplication Property 4.6 Linear Constant-Coefficient Differential Equations

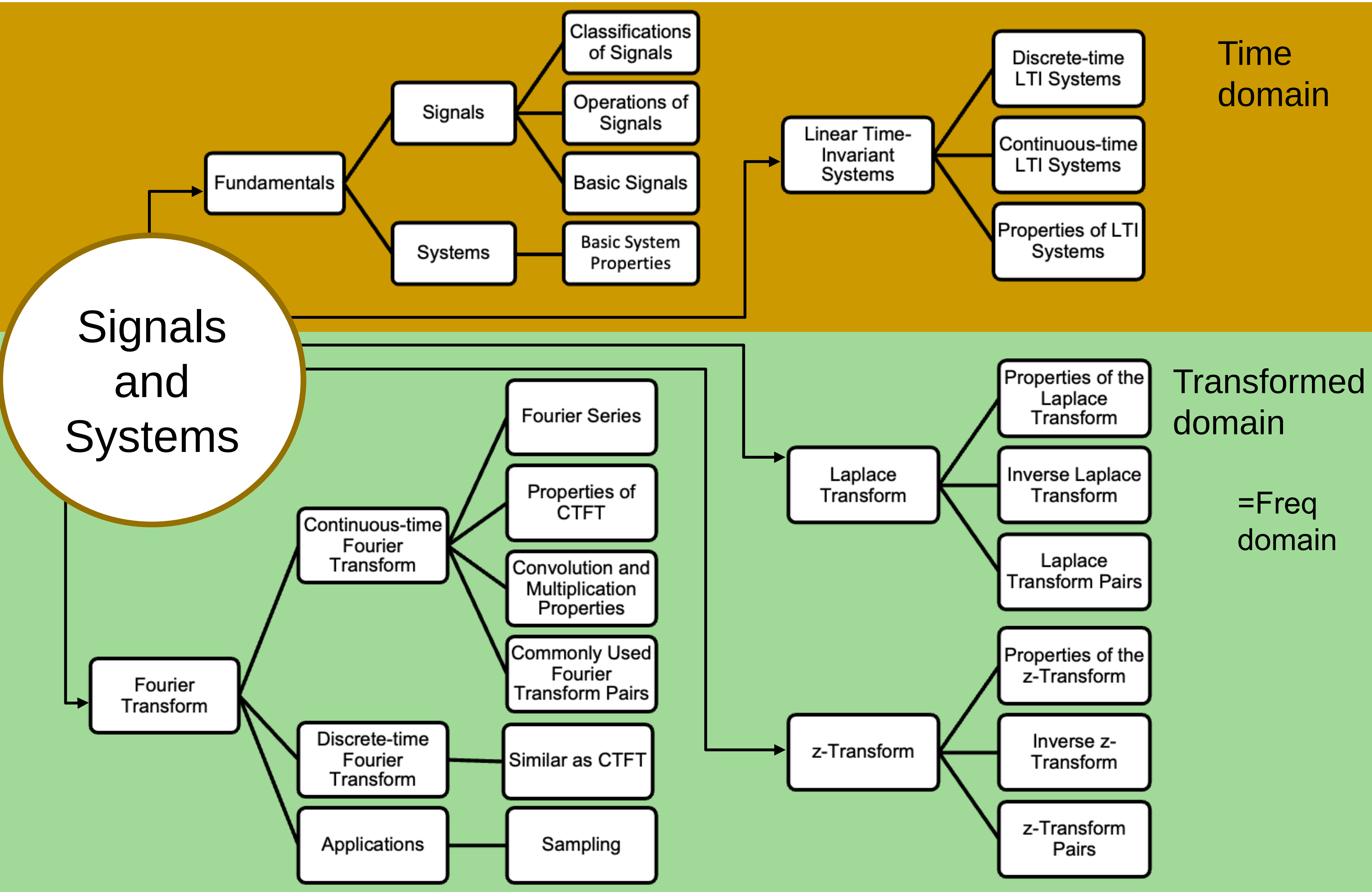
Syllabus (Week 9-16, Instructor: Yong Zhou)

Week	Timeline	Chapters	Teaching Contents
9-10	Apr. 23, 25, 30, May 2	Chapter 5: The Discrete-Time Fourier Transform	5.1 The Discrete-Time Fourier Transform 5.2 The Fourier Transform for Periodic Signals 5.3 Properties of the Disorete-Time Fourier Transform 5.4 The Convolution Property 5.5 The Multiplication Property 5.6 Duality 5.7 Linear Constant-Coefficient Difference Equations
11	May 7	Chapter 6: Time and Frequency Characterization of Signals and Systems	6.1 The Magnitude-Phase Representation of the Frequency Response of LTI Systems 6.2 Time-Domain Properties of Ideal Frequency-Selective Filters 6.3 Time-Domain and Frequency-Domain Aspects of Nonideal Filters
11-12	May 9, 14, 16	Chapter 7: Sampling	7.1 The Sampling Theorem 7.2 Reconstruction of a Signal from Its Samples 7.3 The Effect of Undersampling: Aliasing 7.4 Discrete-Time Processing of Continuous-Time Signals 7.5 Sampling of Discrete-Time Signals
13-14	May 21, 23, 28, 30	Chapter 8: The Laplace Transform	8.1 The Laplace Transform 8.2 The Region of Convergence for Laplace Transforms 8.3 The Inverse Laplace Transform 8.4 Properties of the Laplace Transform 8.5 Some Laplace Transform Pairs 8.6 Analysis and Characterization of LTI Systems Using the Laplace Transform 8.7 System Function Algebra and Block Diagram Representations

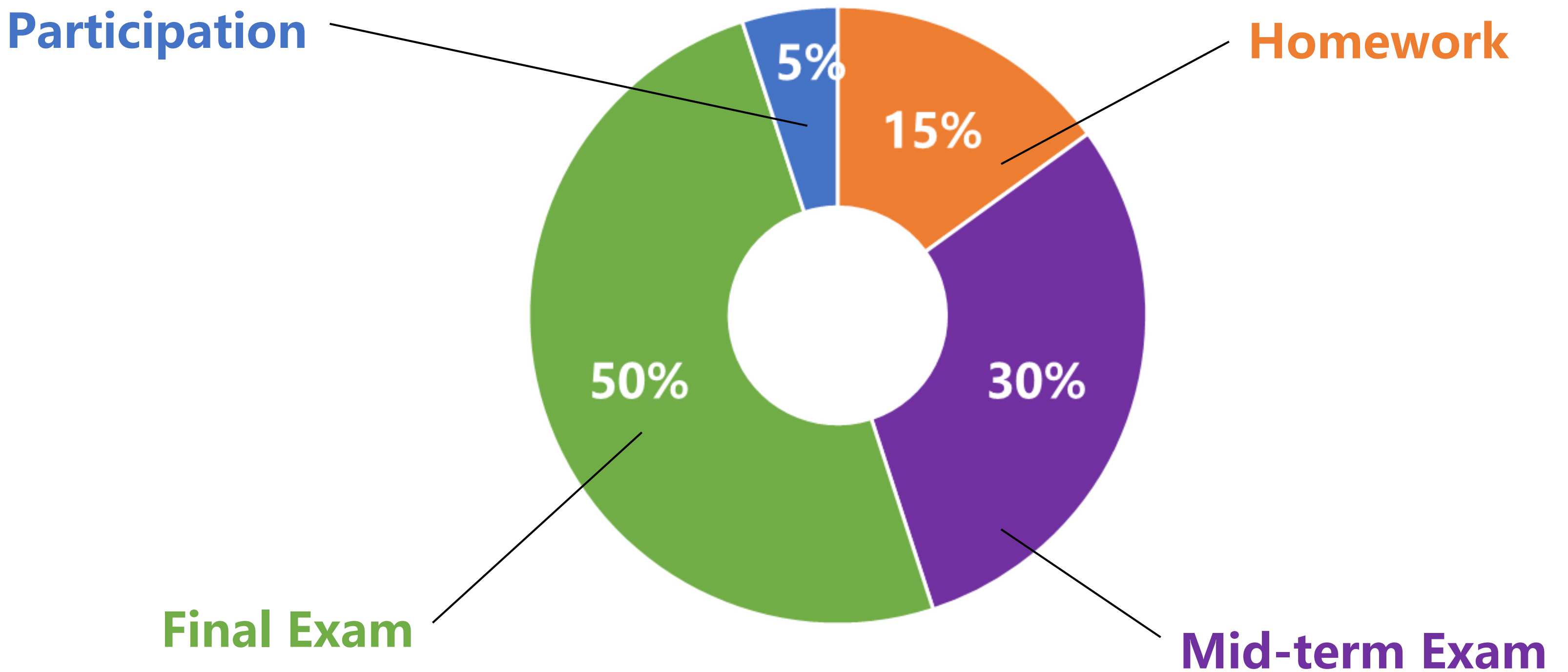
Syllabus (Week 9-16, Instructor: Yong Zhou)

Week	Timeline	Chapters	Teaching Contents
15-16	**Jun. 4, 6, 11, 13**	Chapter 9: The z-Transform	9.1 The z-Transform 9.2 The Region of Convergence for the z-Transform 9.3 The Inverse z-Transform 9.4 Properties of the z-Transform 9.5 Some Common z-Transform Pairs 9.6 Analysis and Characterization of LTI Systems Using z-Transforms 9.7 System Function Algebra and Block Diagram Representations 9.8 The Unilateral z-Transform

Knowledge Framework 复习用

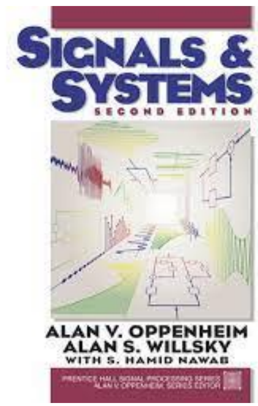


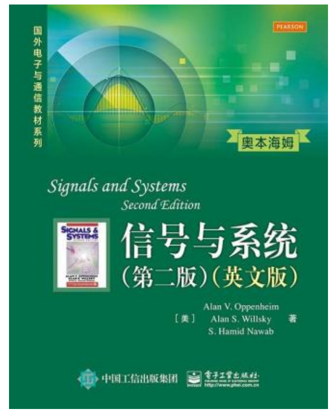
Grading

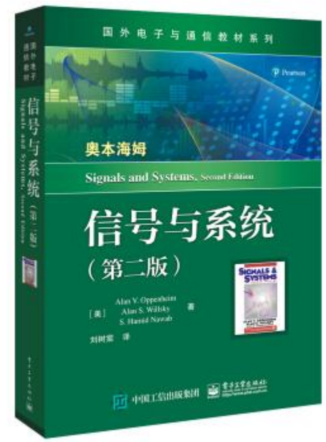


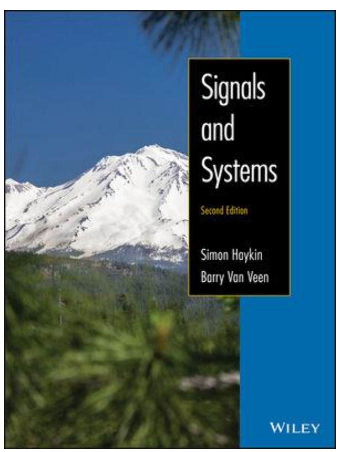
References

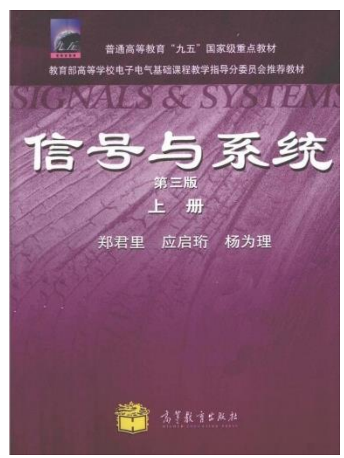
- Textbook

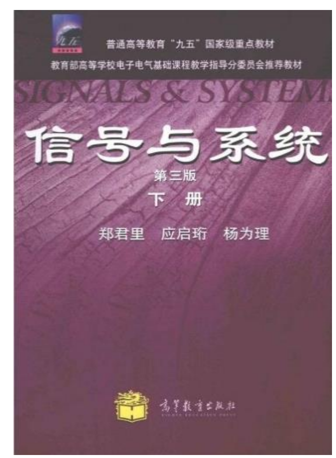












Ch.1 *Overview*

Part I *Introduction to Signals and Systems*

Outline

- Course overview
- Signals and systems introduction
- Classification of signals
- Operation on signals
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Introduction to Signals

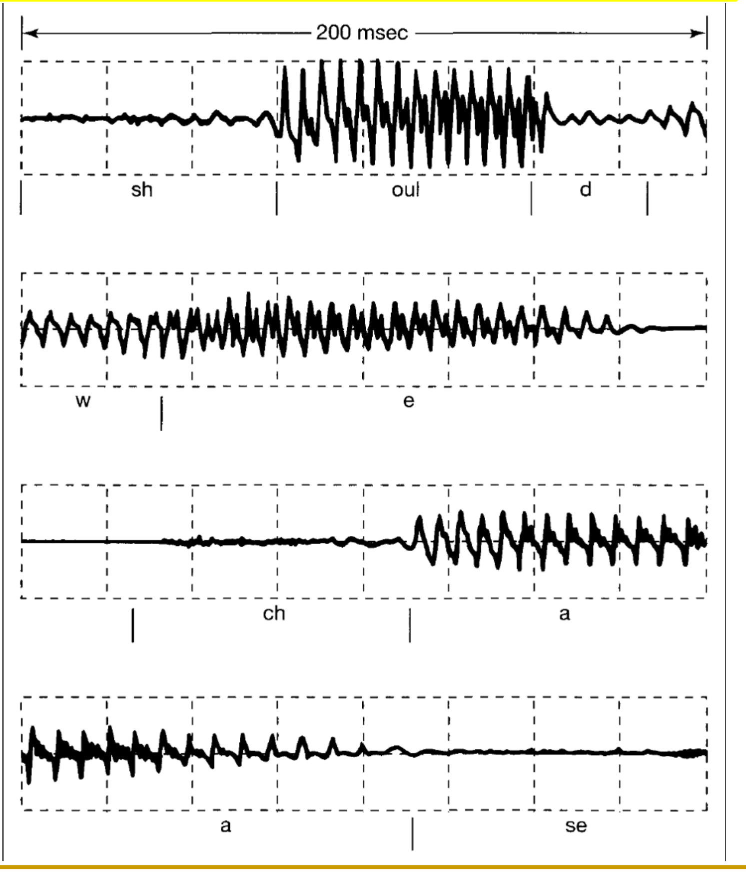
- What are Signals?
  - a function of one or more independent variables (e.g., time and spatial variables);
  - typically contains information about the behaviour or nature of some physical phenomena.
  - Our world is full of signals, both natural and man-made.
    - Voltage waveform in a circuit.
    - The periodic electrical signals generated by the heart.
    - Stock prices 变量是time
    - Variation in air pressure when we speak. 因变量是pressure

Examples to Signals

自变量是时间
因变量是intensity?

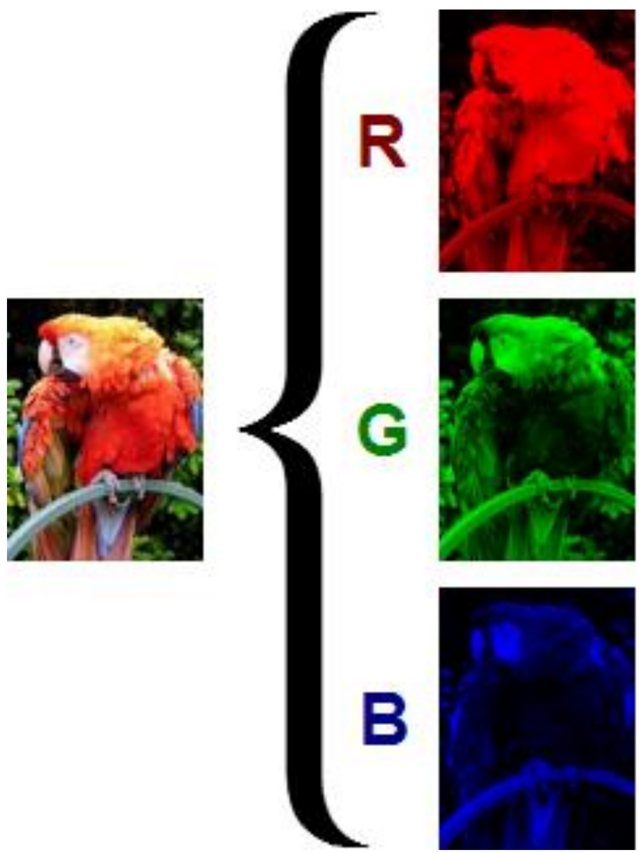
- Audio (intensity vs. time)
  - characteristics: volume, tone, timbre

音量 音高 音色



Examples to Signals

- Picture (brightness)



自变量是RGB的brightness

RGB三个二维信号组成彩色图片 (3 channels)

Examples to Signals

- TV signal (voltage vs. time)
  - modulated picture signal + audio signal

Examples to Signals

- Stock price (index vs. time; $ vs. time)

- This course focuses on signals involving a single independent variable, i.e., time.

Introduction to Systems

系统==信号生成器/变换器

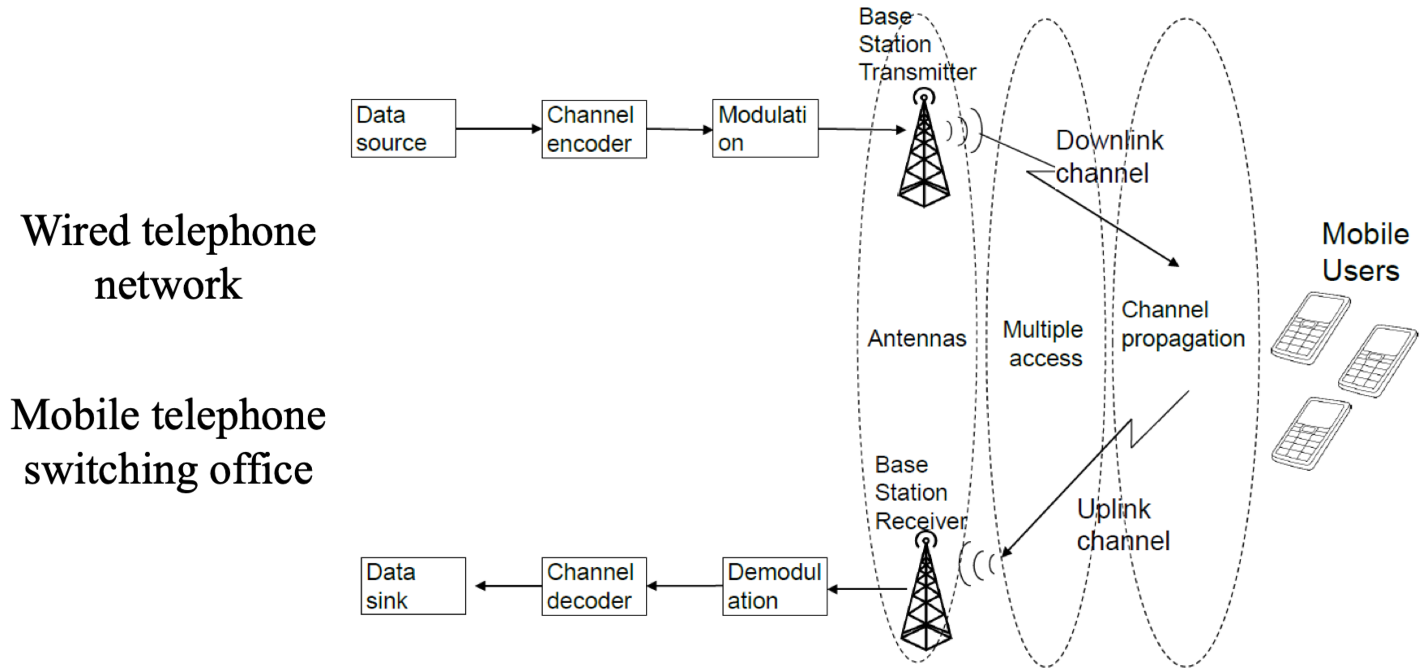
- What are Systems?
  - A system is a generator of signals or a transformer of signals.
  - A system is formally defined as an entity that manipulates one or more signals to accomplish a function, thereby yielding new signals. E.g.,
    - Mobile phone
    - Electronic circuits

=excitation
x(t) or x[n]

=response
y(t) or y[n]

Examples to Systems

- Cellular Communication Systems



Signals and systems introduction

- Typical systems in electrical and electronic engineering
  - Communication systems
  - Control systems 汽车速度控制系统：脚踩踏板的压力 <-> 加速度
  - Computer systems

Signals and systems introduction

- Why study Signals and Systems?
  - Signals and systems are fundamental to all of engineering!
  - Steps involved in engineering are:
    - **Model system:** Involves writing a mathematical description of input and output signals.
    - **Analyze system:** Study of the various signals associated with the system.
    - **Design system:** Requires deciding on a suitable system architecture, as well as finding suitable system parameters.
    - **Implement system/test system:** Check system, and the input and output signals, to see that the performance is satisfactory.

Overview of our course

- This course is about **signals** and their **processing by systems**. It involves:
  - Modelling of signals by mathematical functions
  - Modelling of systems by mathematical equations
  - Solution of the equations when excited by the functions
  - Stability of the systems

Objectives of our course

- After the course, you will know:
  - System characterization

    how it responds to input signal

    (e.g. human auditory system)
  - System design

    to process signal in a particular way

    (e.g. signal restoration, signal identification, image processing)
- The course will serve as the prerequisites for additional coursework in the study of communications, signal processing and control.

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Classification of Signals

知识要点
信号的分类

oppenheimer的书没有做具体的总结，但是这里有

- Methods used for processing a signal or analysing the response of a system to a signal significantly depend on the characteristic attributes of the signal.
- Certain techniques apply to only specific types of signals – hence the need for classification：
  - continuous-time & discrete-time signals
  - even and odd signals

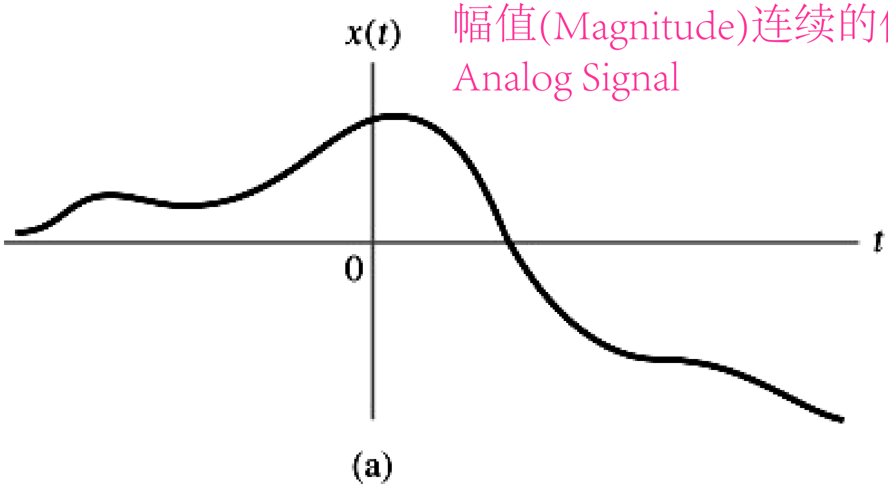
    还有非奇非偶信号
  - periodic and aperiodic signals
  - deterministic and random signals
  - energy and power signals

Continuous-time and discrete-time signals

- A continuous-time signal if it is defined for all time t, except at some discontinuous point.
- A discrete-time signal is defined only at discrete instants of time.

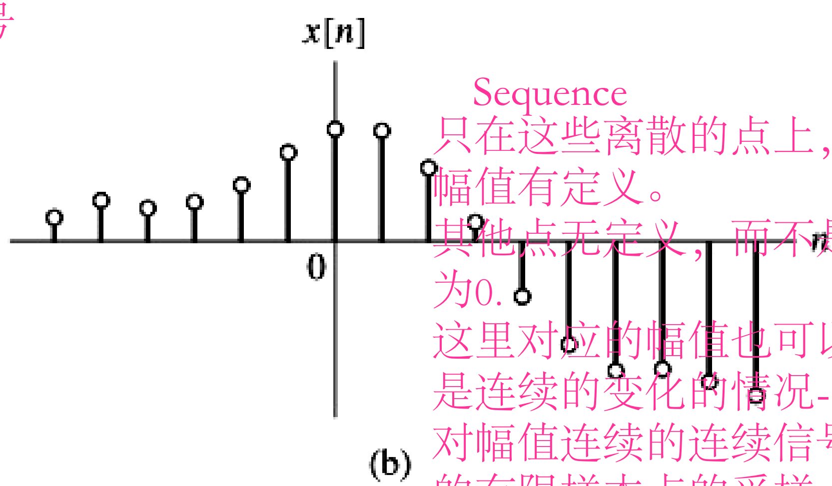
(a) Continuous-time signal $x(t)$.

幅值(Magnitude)连续的信号
Analog Signal



也有幅值不连续的:
方波，...

(b) Representation of $x(t)$ as a discrete-time signal $x[n]$.

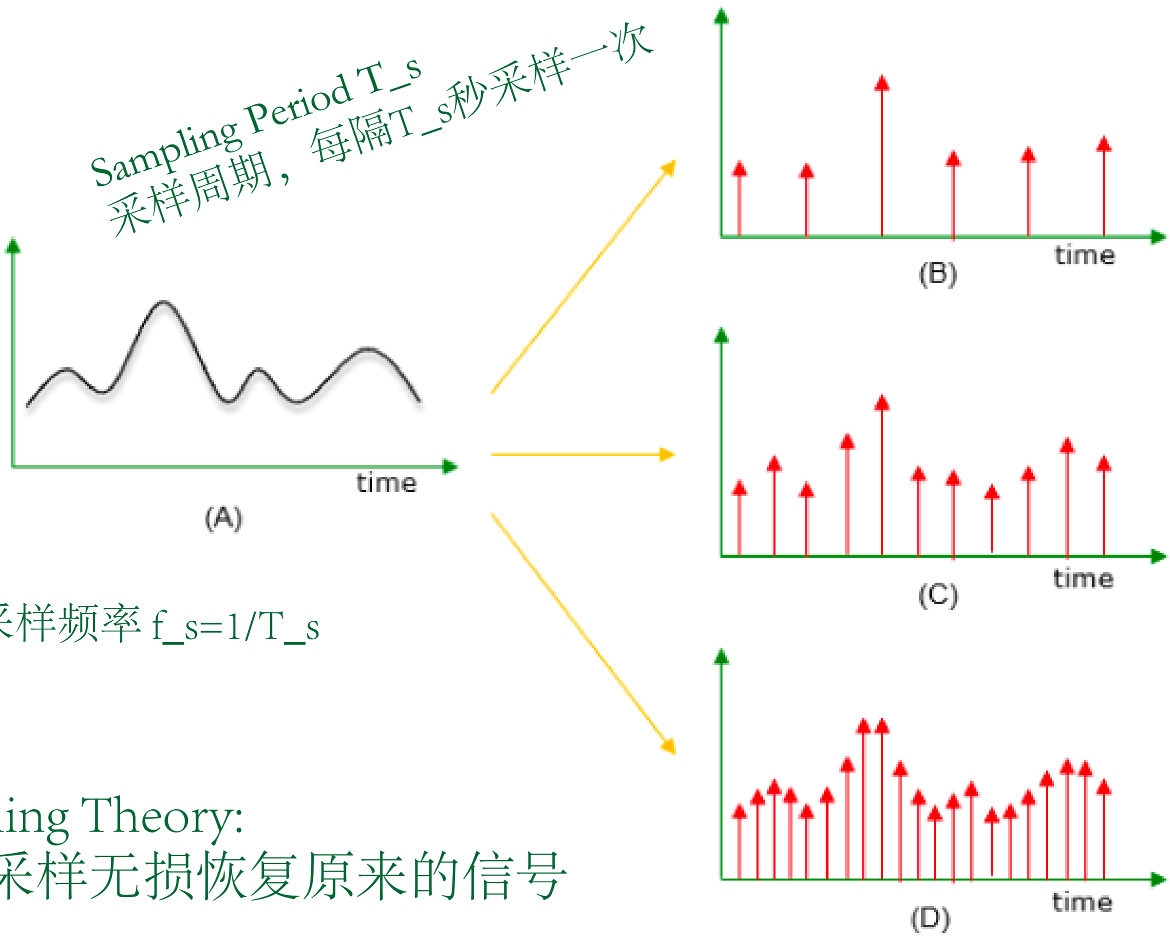


Sequence
只在这些离散的点上，幅值有定义。
其他点无定义，而不是为0.
这里对应的幅值也可以是连续的变化的情况->对幅值连续的连续信号的有限样本点的采样，幅值连续的离散信号。
(Digital Signal)

Continuous-time and discrete-time signals

- Sampling $x[n] = x(t)|_{t=nTs} = x(nT_s)$

Sampling Period T_s
采样周期，每隔T_s秒采样一次



采样频率 f_s=1/T_s

Sampling Theory:
通过采样无损恢复原来的信号

Continuous-time and discrete-time signals

- A discrete-time signal is often derived from a continuous-time signal by sampling it at a uniform rate.

$$x[n]=x(t)|_{t=nTs}=x(nT_s)$$ n = 0,1,2,.....,-1,-2,...... can be less than zero

T_s: *sampling period;* n *denote an integer*

In this lecture, we use ***t*** to denote time for a continuous- time signal, and ***n*** to denote time for a discrete-time signal.

Continuous-time signals: $x(t)$

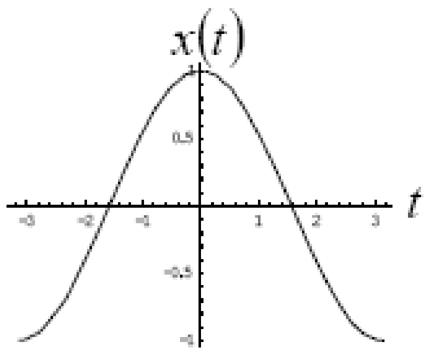
Parentheses (·)

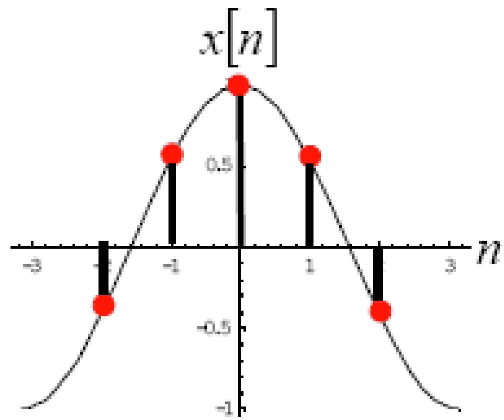
Discrete-time signals: $x[n]=x(nT_s), \quad n=0, \ \pm 1, \ \pm 2, \ ....$ **where *t* = *nT*$_s$**

Brackets [·]

Even and odd signals ==奇偶函数

- Even signals: $x(-t)=x(t), \quad x[-n]=x[n] \quad \text{for} \quad \text{all} \quad t$

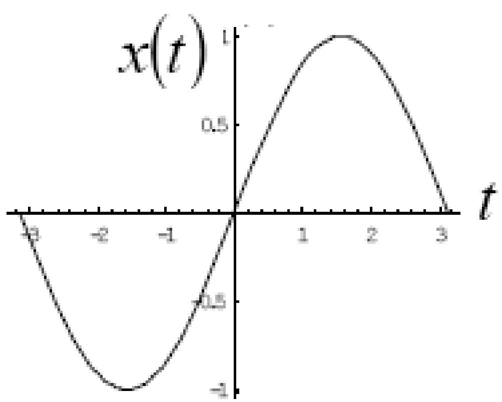


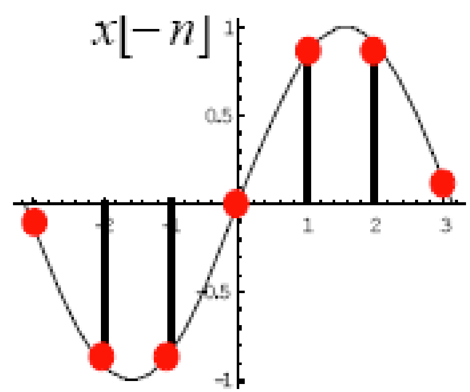


轴对称

Symmetric **about vertical axis**

- odd signals: $x(-t)=-x(t), \quad x[-n]=-x[n] \quad \text{for} \quad \text{all} \quad t$





原点中心对称
旋转180度不变

Antisymmetric **about origin**

Even and odd signals

Problem: **Consider the signal**

$$x(t)=\begin{cases}\sin\left(\dfrac{\pi t}{T}\right), & -T\le t\le T\\ 0, & \text{otherwise}\end{cases}$$

Is the signal $x(t)$ an even or an odd function of time?

sin(omega*t), 基波周期 T=2pi/omega

Even and odd signals

- **Even-odd decomposition of $x(t)$:** *Any signal can be broken into a sum of two signalsone even and one odd.*

$$x(t) = x_e(t) + x_o(t)$$

奇偶分解
每个函数都可以分成一个奇函数和偶函数的加和。

两个分解结果如左下。

where

$$x_e(t) = E_v\{x(t)\} = \frac{1}{2}[x(t) + x(-t)]$$

$$x_o(t) = O_d\{x(t)\} = \frac{1}{2}[x(t) - x(-t)]$$

Even and odd signals

- **Even-odd decomposition of $x(t)$:** *Any signal can be broken into a sum of two signalsone even and one odd.*

$$x_e(t) = E_v\{x(t)\} = \frac{1}{2}[x(t) + x(-t)]$$

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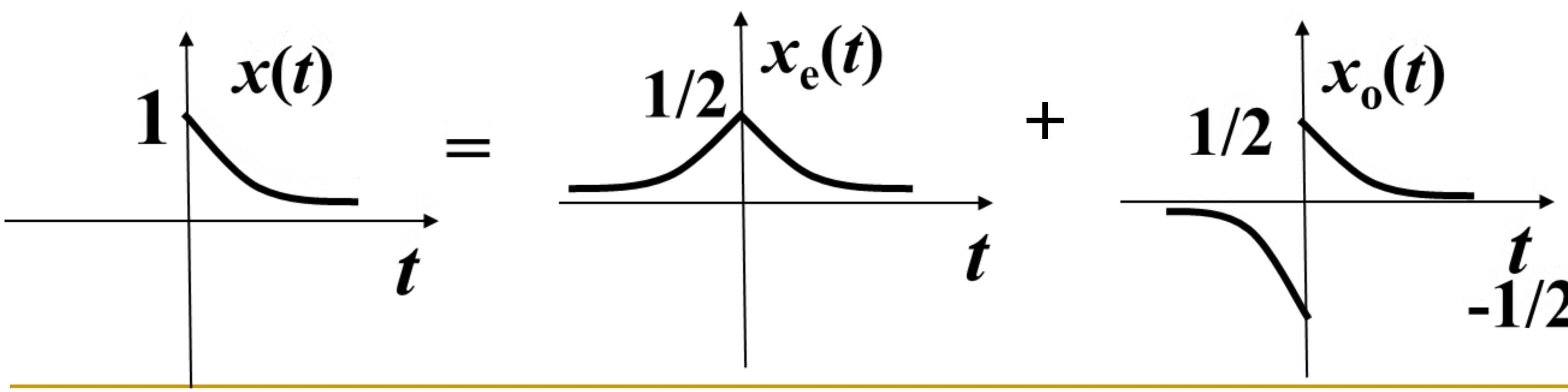


Even and odd signals

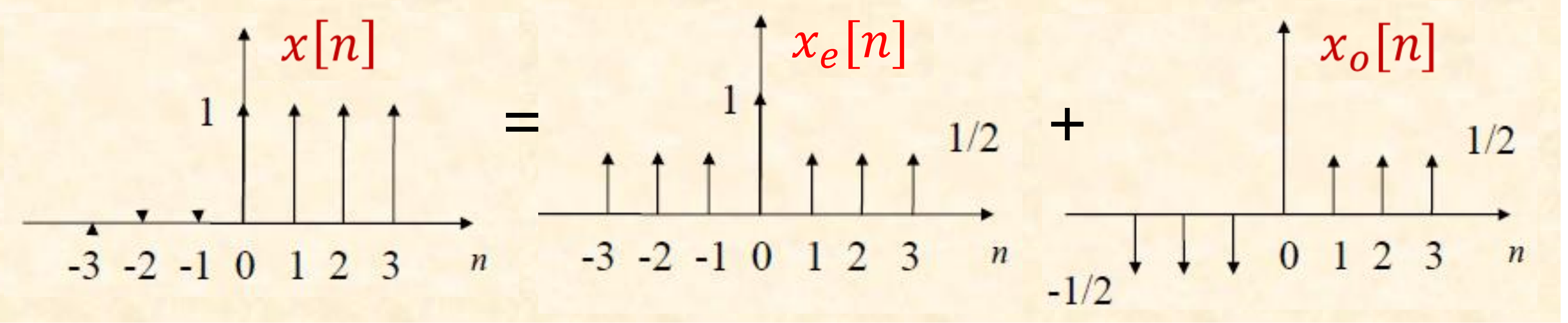
- **Even-odd decomposition of $x[n]$:** *Any signal can be broken into a sum of two signalsone even and one odd.*

$$x[n] = x_e[n] + x_o[n]$$

$$x_e[n] = (x[n] + x[-n])/2$$

$$x_o[n] = (x[n] - x[-n])/2$$

step function 阶跃函数
n=0,1,2... -> f = 1
otherwise, f=0
非整数点没有定义(离散情况下)



Even and odd signals

- **Even-odd decomposition of $x(t)$:**

Problem: **Find the even and odd components of the signal**

$$x(t) = e^{-2t}\cos t$$

$$x(t) = e^{-2t}\cos t$$

$$x(-t) = e^{2t}\cos t$$

$$x_o(t) = \frac{1}{2}(e^{-2t} - e^{2t})\cos t$$

sinh(2t)cos(t)

$$x_e(t) = \frac{1}{2}(e^{-2t} + e^{2t})\cos t$$

cosh(2t)cos(t)

Even and odd signals

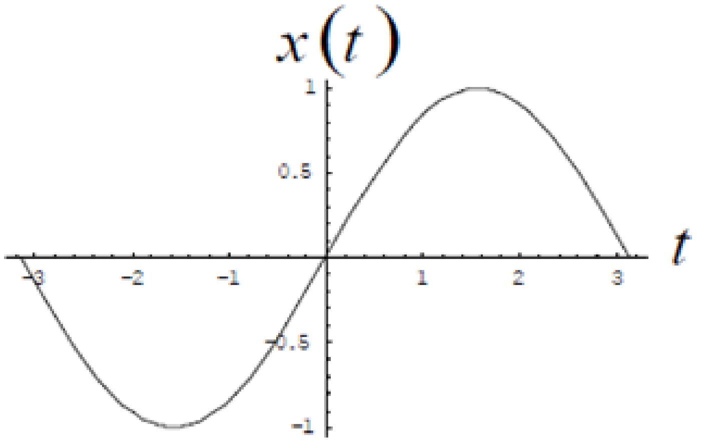
- **PRODUCT rule**

ODD × ODD = EVEN

EVEV × EVEN = EVEN

EVEN × ODD = ODD

ODD × EVEN = ODD



$$s = \int_{-T}^{T} x(t)dt = 0, \quad \text{always if } x(t) \text{ is odd.}$$

$$s = \int_{-T}^{T} x(t)dt = 2\int_{0}^{T} x(t)dt, \quad \text{for } x(t) \text{ is even.}$$

Periodic and Aperiodic Signals

- **Continuous-Time Case**
  - **Periodic signals:**

$$x(t) = x(t+T) \quad \forall t, \quad \text{where T is a positive constant.}$$

$$T = T_0, \quad 2T_0, \quad 3T_0, \quad \ldots\ldots$$

- Fundamental period （smallest positive value of T): $T = T_0$

- Fundamental frequency: $\omega_0 = \dfrac{2\pi}{T_0}$ measured in radians per second.

  - **Aperiodic signals:** $\boldsymbol{x(t)}$ where $\boldsymbol{T_0}$ does not exist.

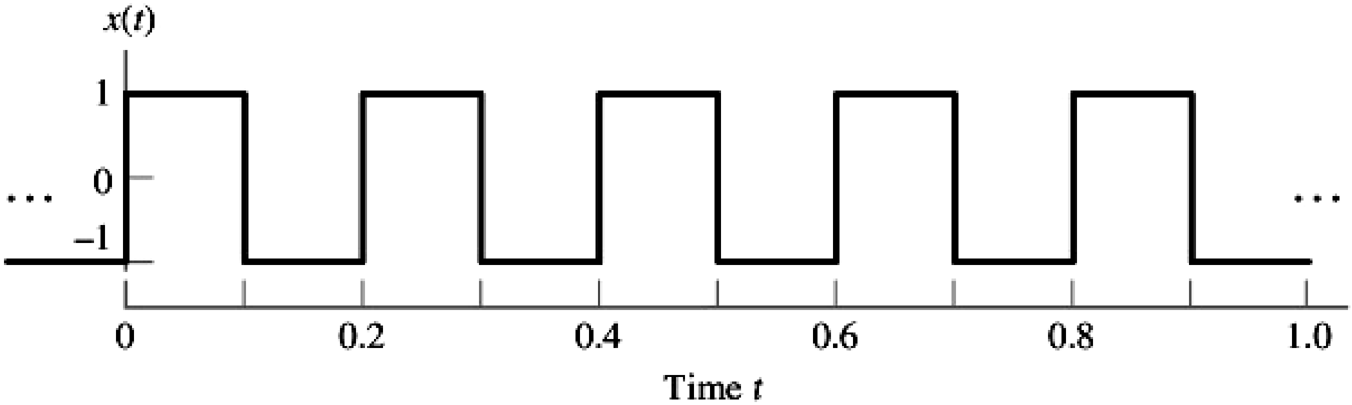
Periodic and Aperiodic Signals

- **Continuous-Time Case**

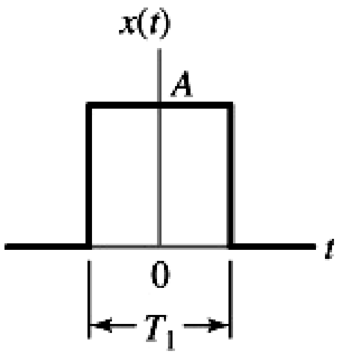
Example of periodic and nonperiodic signals.

(a) Square wave with amplitude $A = 1$ and period $T = 0.2$s.

(b) Rectangular pulse of amplitude A and duration T_1.



(a)



(b)

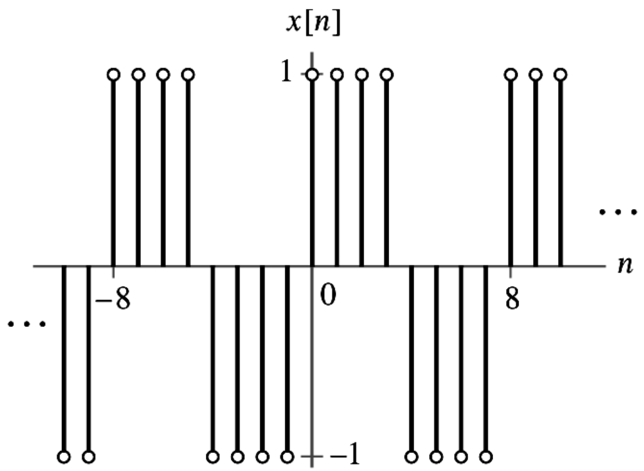
$T = 0.2$s ⇒ $f = \dfrac{1}{T} = 5Hz, \quad \omega = \dfrac{2\pi}{T} = 10\pi \text{ rad/s}$

Periodic and Aperiodic Signals

- **Discrete-Time Case**
  - **Periodic signals:** $x[n] = x[n+N] \quad \text{for} \quad \text{integer} \quad n$
    - Fundamental period: The smallest positive integer value of *N* for which the periodicity holds
    - Fundamental angular frequency: $\Omega = \dfrac{2\pi}{N}$, measured in radians, or radians/cycle.

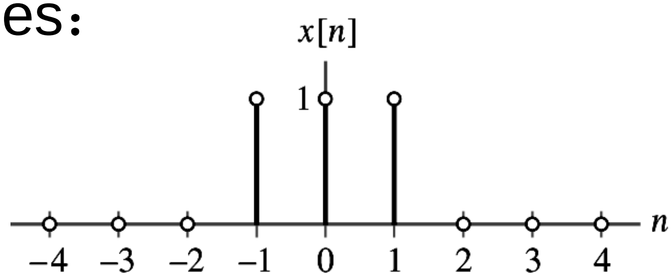
Discrete-time square wave alternative between –1 and +1：

$N = 8$ ⇒ $\Omega = \dfrac{2\pi}{8} = \dfrac{\pi}{4}$ radians.



Periodic and Aperiodic Signals

- **Discrete-Time Case**
  - Aperiodic discrete-time signal consisting of three nonzero samples：

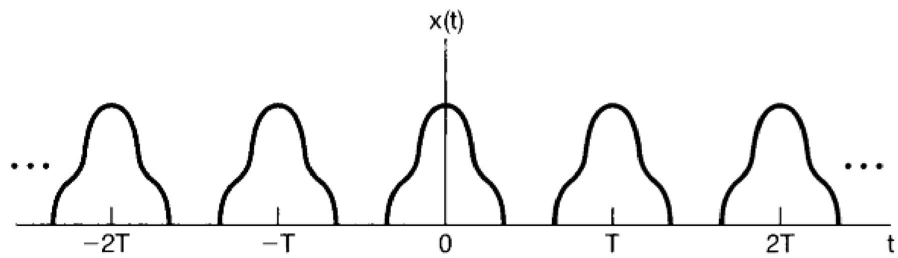


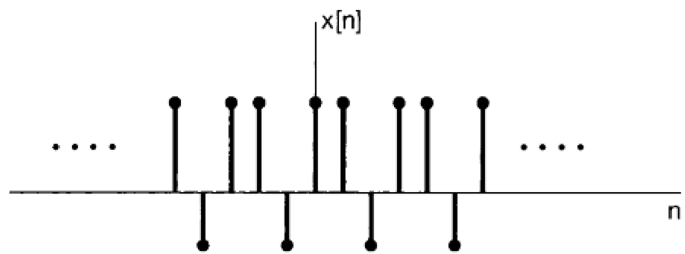
- **Notes**
  - A sequence obtained by uniform sampling of a periodic continuous-time signal may not be periodic.
  - The sum of two continuous-time periodic signals may not be periodic.
  - The sum of two periodic sequences is always periodic.

Periodic and Aperiodic Signals

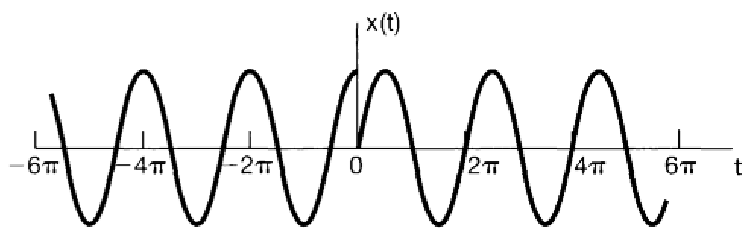
- **Even-odd decomposition of $x(t)$:**

Problem: **What is the fundamental period of a constant function?**





$$x(t) = \begin{cases} \cos(t) & \text{if } t < 0 \\ \sin(t) & \text{if } t \geq 0 \end{cases}$$



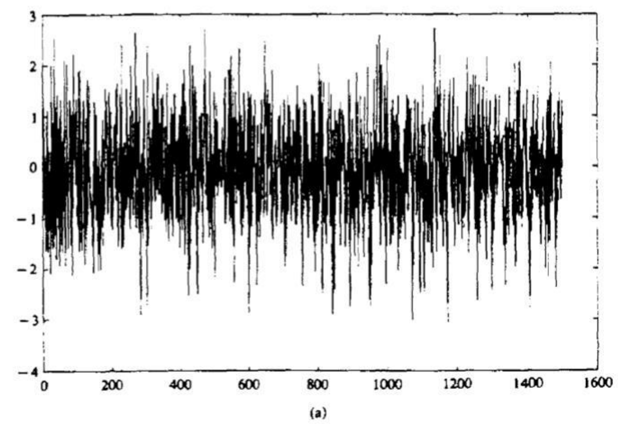
Deterministic signals and random signals

- *Deterministic signals* are those signals whose values are completely specified for any given time. Thus, a deterministic signal can be modeled by a known function of time.

- *Random signals* are those signals that take random values at any given time and must be characterized statistically.

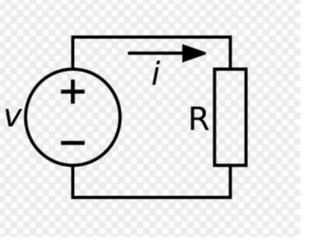
- Random signals will not be discussed in this course.

Random signals



Energy and Power Signals

- $v(t)$ and $i(t)$ are voltage and current across a resistor R, the instantaneous power is



$$p(t) = v(t)i(t) = \frac{1}{R}v^2(t) = Ri^2(t)$$

- The total energy over the time interval $t_1 \leq t \leq t_2$ is

$$E_R = \int_{t_1}^{t_2} p(t)\,dt = \int_{t_1}^{t_2} \frac{1}{R} v^2(t)\ dt$$

- The average power over the time interval $t_1 \leq t \leq t_2$ is

$$P_R = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} p(t)\,dt = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \frac{1}{R} v^2(t)\ dt$$

- If R = 1 Ω and $x(t)$ represents a current or a voltage, then

$$p(t) = x^2(t)$$

Energy and Power Signals

- **Over finite time interval** $t_1 \leq t \leq t_2$ or $n_1 \leq n \leq n_2$

- **Continuous-time signal** $x(t)$
  - **Total energy:**

$$E = \int_{t_1}^{t_2} |x(t)|^2 \, dt,$$

  - **Time-averaged/average power**

$$P = \frac{E}{t_2 - t_1}$$

- **Discrete-time signal** $x[n]$
  - **Total energy:**

$$E = \sum_{n=n_1}^{n_2} |x[n]|^2,$$

  - **Average power**

$$P = \frac{E}{n_2 - n_1 + 1}$$

Energy and Power Signals

- Over infinite time interval $-\infty \leq t \leq \infty$ or $-\infty \leq n \leq \infty$

- Continuous-time signal $x(t)$
  - Total energy:

$$E_\infty \triangleq \lim_{T\to\infty} \int_{-T}^{T} |x(t)|^2\, dt$$
$$= \int_{-\infty}^{\infty} |x(t)|^2\, dt$$

  - Time-averaged/average power

$$P_\infty \triangleq \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} |x(t)|^2\, dt$$

- Discrete-time signal $x[n]$
  - Total energy:

$$E_\infty \triangleq \lim_{N\to\infty} \sum_{n=-N}^{N} |x[n]|^2$$
$$= \sum_{n=-\infty}^{\infty} |x[n]|^2$$

  - average power

$$P_\infty \triangleq \lim_{N\to\infty} \frac{1}{2N+1} \sum_{n=-N}^{N} |x[n]|^2$$

Energy and Power Signals

- **Finite-energy signal**

  If and only if the total energy of the signal satisfies the condition

$$E_\infty < \infty$$

$$P_\infty \triangleq \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} |x(t)|^2 \, dt = 0$$

$$P_\infty \triangleq \lim_{N\to\infty} \frac{1}{2N+1} \sum_{n=-N}^{N} |x[n]|^2 = 0$$

- **Finite-power signal** $P_\infty < \infty, E_\infty = \infty$

- **Infinite energy & power signal** $P_\infty \to \infty, E_\infty \to \infty$

Energy and Power Signals

- **Finite-energy signal**

$$(1)\ x(t) = \begin{cases} 0, & t < 0 \\ 1, & 0 \le t \le 1 \\ 0, & t > 1 \end{cases} \qquad E_\infty < \infty, P_\infty = 0$$

- **Finite-power signal**

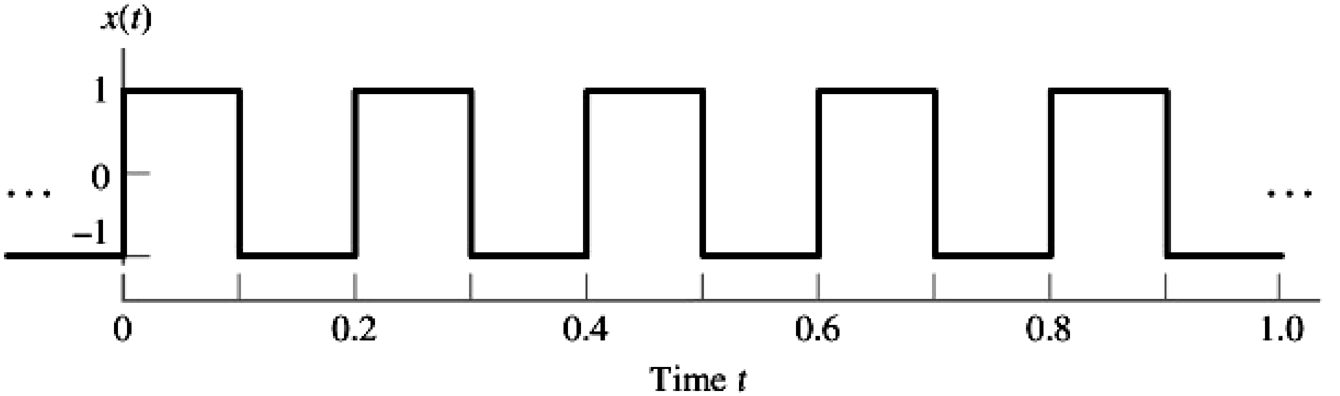
$$(2)\ x[n] = 4 \qquad P_\infty < \infty, E_\infty = \infty$$

- **Infinite energy & power signal**

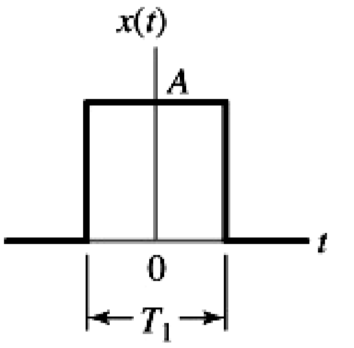
$$(3)\ x(t) = t \qquad P_\infty \to \infty, E_\infty \to \infty$$

Energy and Power Signals

Problem:



(a)



(b)

Outline

- Course overview
- Signals and systems introduction
- Classification of signals
- Operation on signals
- Summary

Operation on Signals

- An issue of fundamental importance in the signals and systems is the use of systems to process or manipulate signals. This issue usually involves a combination of some basic operations in signals.
  - Three transformation in amplitude
    - ***Amplitude scaling***
    - ***Addition***
    - ***Multiplication***
  - Three transformations in time domain
    - ***Time Scaling***
    - ***Time Reversal***
    - ***Time Shifting***

Transformation in Amplitude

- ***Amplitude scaling***: $y(t) = cx(t)$ **c: scaling factor**

  $$y[n] = cx[n]$$

  - Performed by amplifier or resistor

- ***Addition***: $y(t) = x_1(t) + x_2(t)$

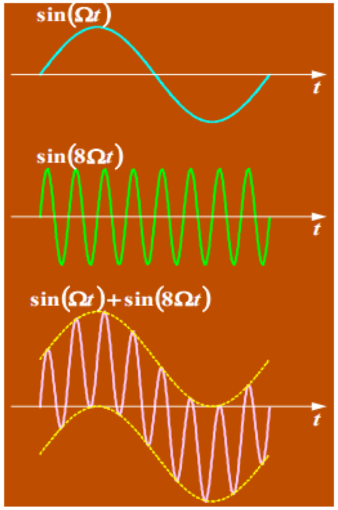
  $$y[n] = x_1[n] + x_2[n]$$

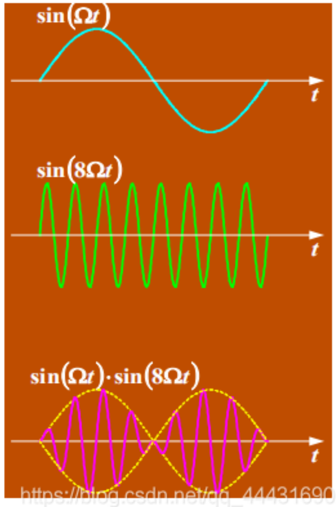
  - E.g. audio mixer

- ***Multiplication***: $y(t) = x_1(t)x_2(t)$

  $$y[n] = x_1[n]x_2[n]$$

  - E.g. AM radio signal

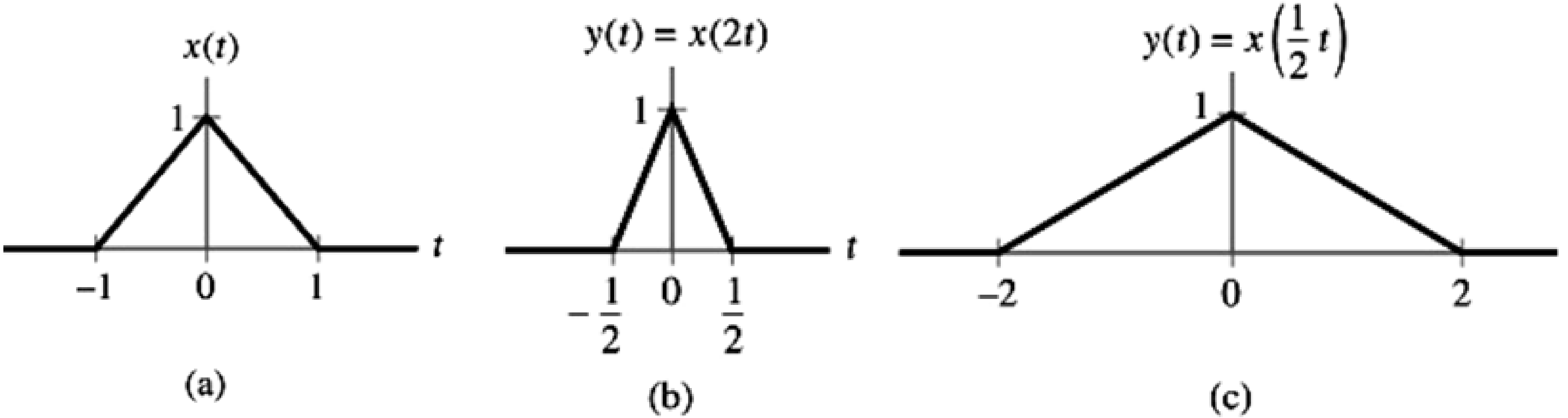




Time Scaling

- **Continuous-Time Case**

$$y(t) = x(at), \quad a > 0 \;\Rightarrow\; \begin{cases} a > 1 \Rightarrow \text{compressed} \\ 0 < a < 1 \Rightarrow \text{expanded} \end{cases}$$



(a) continuous-time signal $x(t)$

(b) version of $x(t)$ compressed by a factor of 2

(c) version of $x(t)$ expanded by a factor of 2.

Time Scaling

- **Discrete-Time Case**

$$y[n] = x[kn], \quad k > 0$$

***k* = integer** ⟹ **Some values lost!**

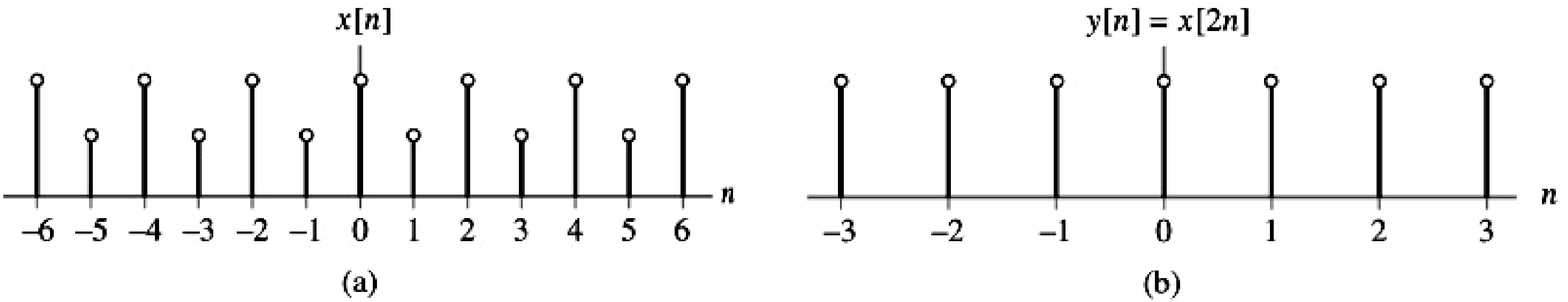


Figure 1.21

Effect of time scaling on a discrete-time signal: (a) discrete-time signal $x[n]$ and (b) version of $x[n]$ compressed by a factor of 2, with some values of the original $x[n]$ lost as a result of the compression.

Time Shifting

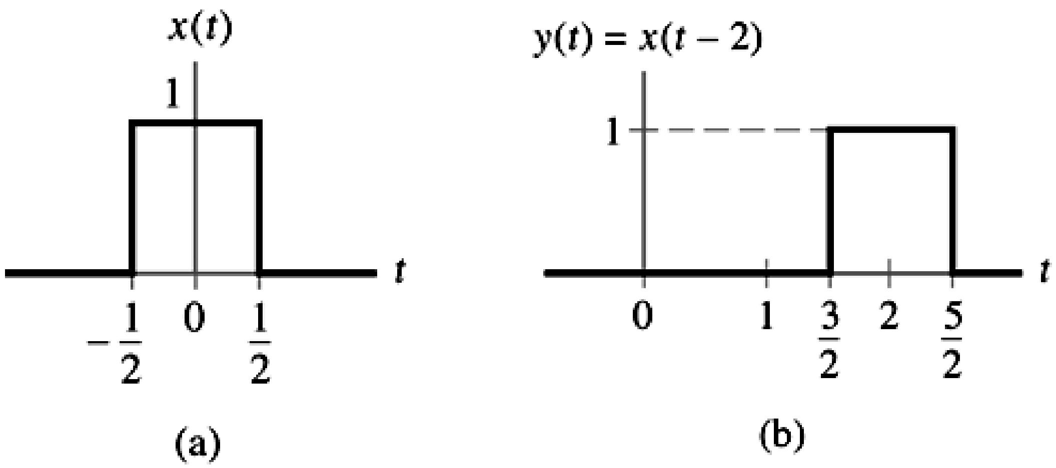
- **Continuous-Time Case**

$$y(t) = x(t - t_0)$$

$t_0 > 0 \Rightarrow$ **shift toward right**

$t_0 < 0 \Rightarrow$ **shift toward left**

Example $y(t) = x(t - 2)$



- **Discrete-Time Case**

$$y[n] = x[n - m]$$

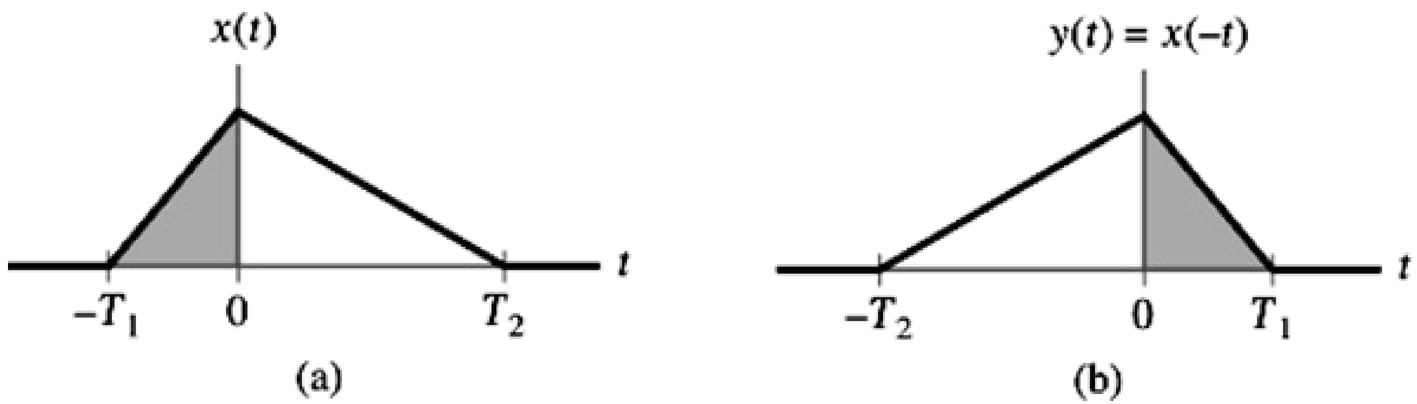
where *m* is a positive or negative integer

Time Reversal

$y(t) = x(-t)$ ⇨ **$y(t)$ represents a reversed version of $x(t)$ about $t = 0$.**

- An even signal is the same as its reversed version: $x(-t) = x(t)$
- An odd signal is the negative of its reversed version: $x(-t) = -x(t)$

Example Consider the triangular pulse x(t) shown in (a). Find the reversed version of x(t) about the amplitude axis (i.e., the origin).



$x(t) = 0 \quad \text{for} \quad t < -T_1 \quad \text{and} \quad t > T_2$ ⇨ $y(t) = 0 \quad \text{for} \quad t > T_1 \quad \text{and} \quad t < -T_2$

Transformations in Time Domain

General: Let $x(t) \rightarrow x(\alpha t + \beta)$

- if $|\alpha| > 1$, compressed
- if $|\alpha| < 1$, stretched
- if $\alpha < 0$, reversed
- if $\beta \neq 0$, shifted

- **Recommended operation order**

1st step: time shifting $x(t) \rightarrow x(t + \beta)$

2nd step: time scaling $x(t + \beta) \rightarrow x(|a|t + \beta)$

3rd step: time reverse $x(|a|t + \beta) \rightarrow x(at + \beta) \text{ if } a < 0$

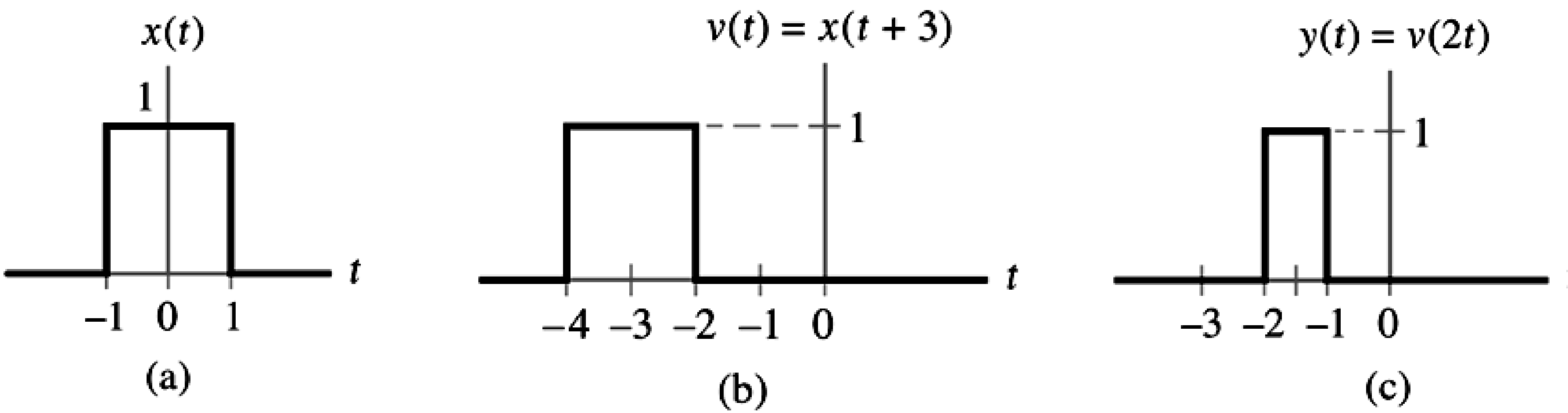
Example. **Consider the rectangular pulse $x(t)$ in (a). Find**

$$y(t) = x(2t + 3).$$

<Sol.> **Case 1: Shifting first, then scaling**

$$v(t) = x(t+3)$$

$$y(t) = v(2t) = x(2t+3)$$



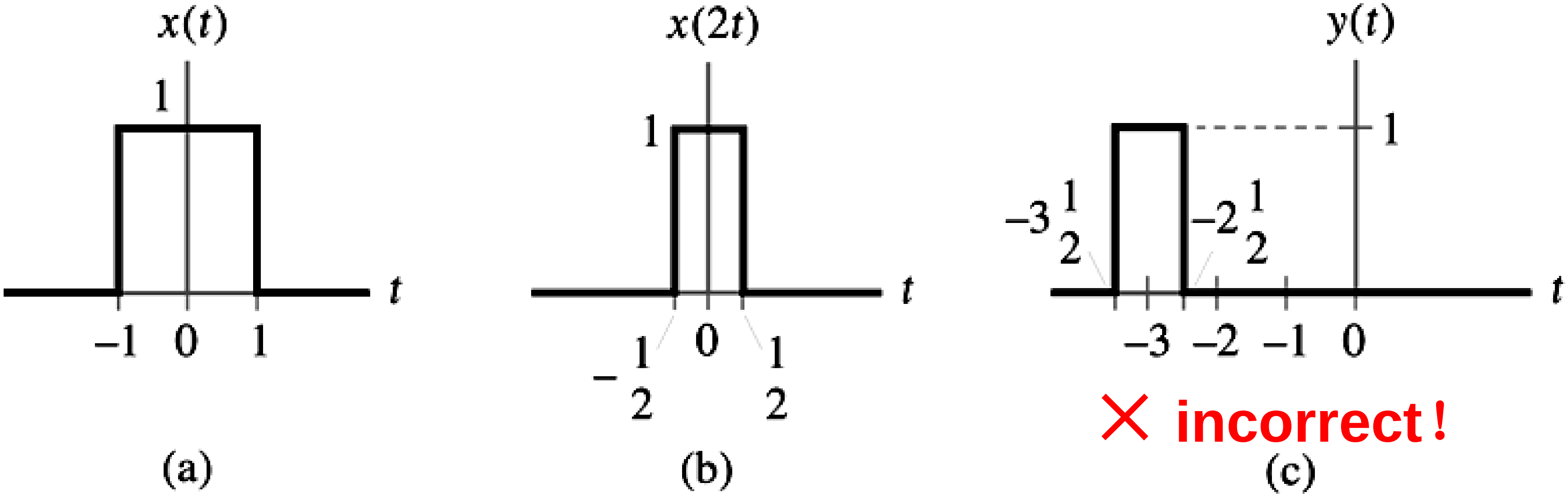
The proper order of time scaling and time shifting operations

Transformations in Time Domain

Case 2: Scaling first, then shifting

$$v(t) = x(2t)$$

$$y(t) = v(t+3) = x\left(2\left(t+3\right)\right) \neq x\left(2t+3\right)$$

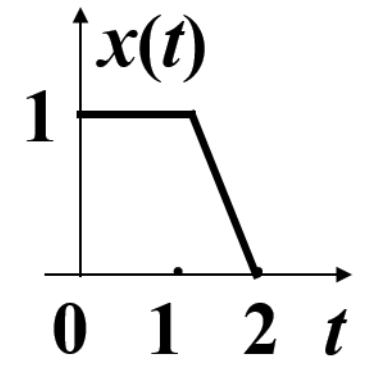


The incorrect way of applying the precedence rule.

Transformations in Time Domain

Problem. **Given the signal $x(t)$ below, determine and sketch:**

- $x(t+1)$
- $x(-t+1)$
- $x(3t/2)$
- $x(\frac{3t}{2}+1)$

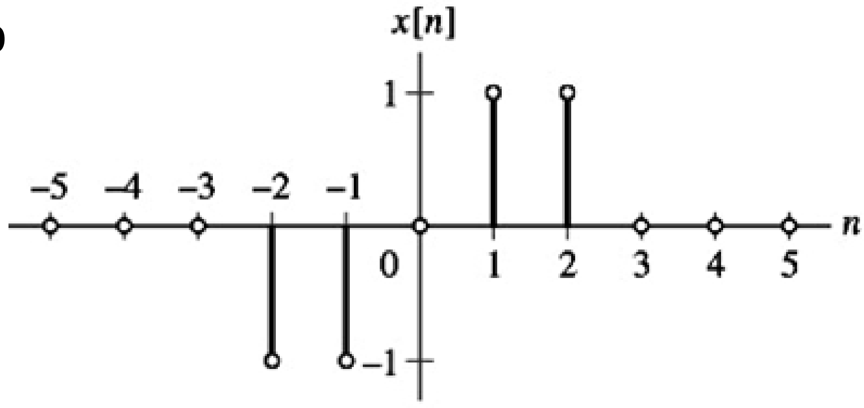


Transformations in Time Domain

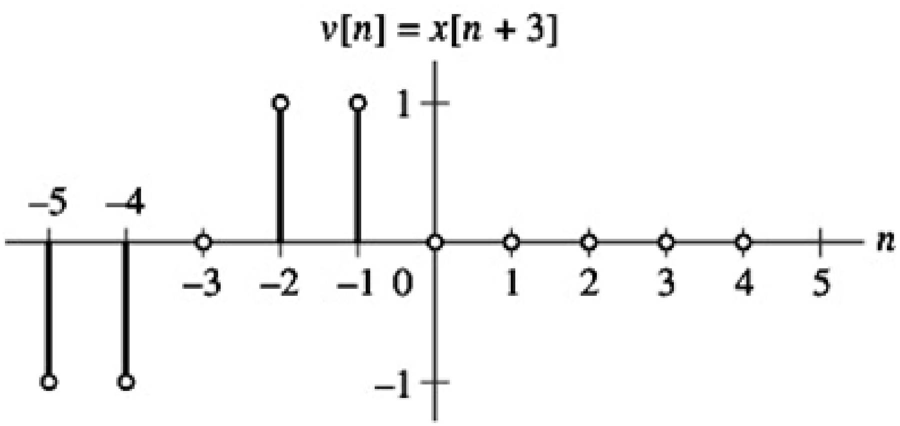
Example **A discrete-time signal is defined b**

$$x[n]=\begin{cases}1, & n=1,2\\ -1, & n=-1,-2\\ 0, & n=0 \text{ and } |n|>2\end{cases}$$

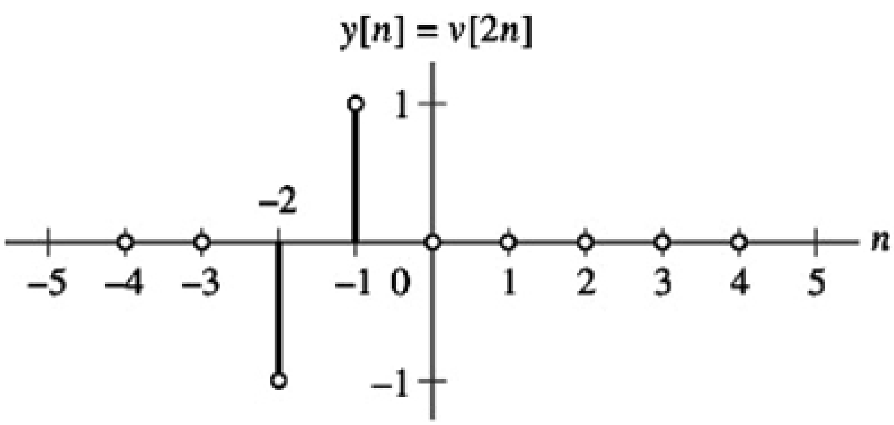
Find $y[n] = x[2n + 3]$.



(a)



(b)



(c)

Summary

- Signals and systems introduction
- Overview of our course
- Classification of signals
- Operation on signals

- Reference in textbook:
  - 1.1,1.2