Ch. 1 Fundamental Concepts

Kamen and Heck

And

T.L. Harman

Good Links

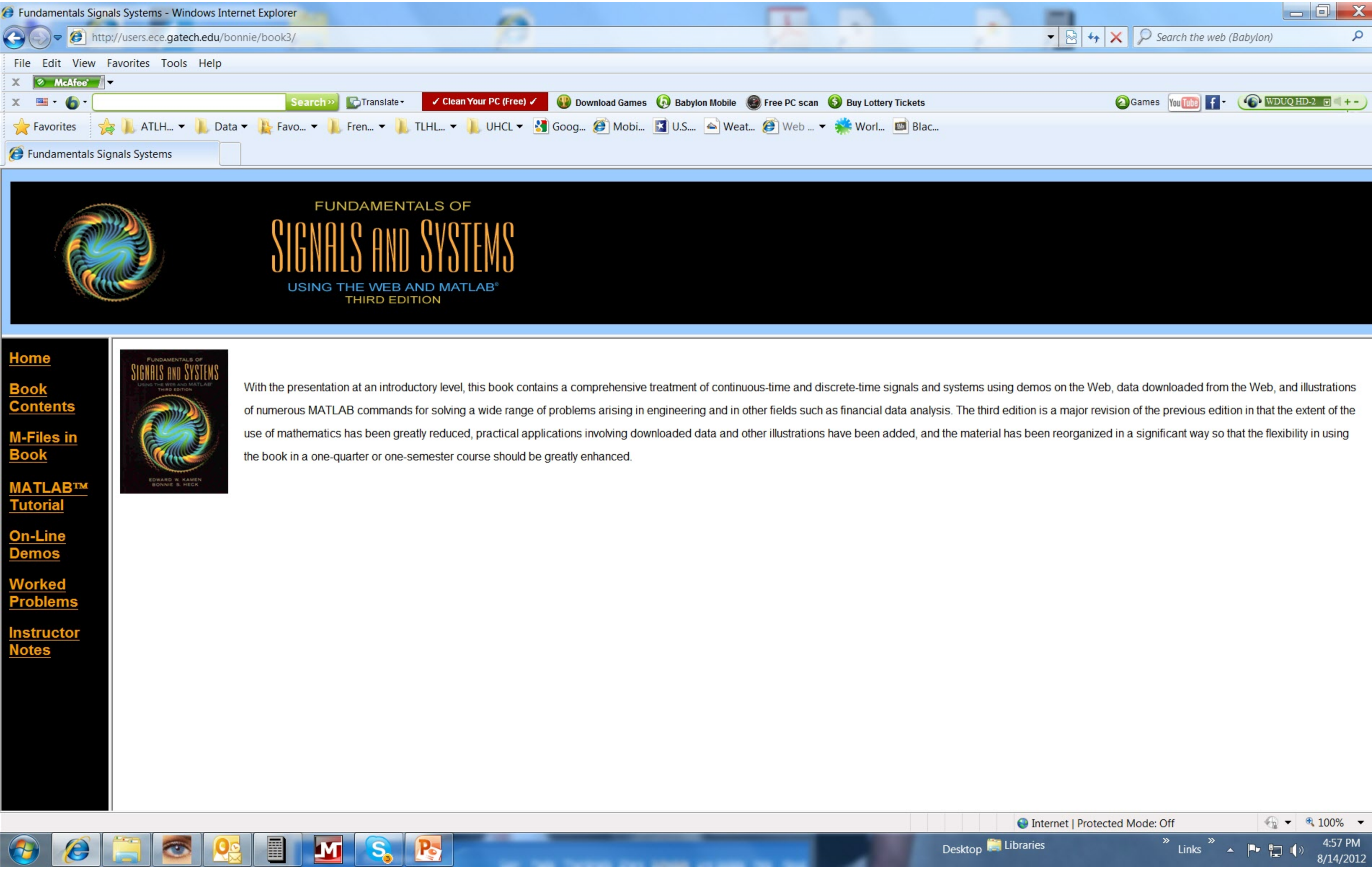
Good MATLAB Information and Help

http://sceweb.sce.uhcl.edu/harman/ MY WEB SITE

http://www.mathworks.com/access/helpdesk/help/techdoc/matlab.shtml

Kamen and Heck Website

http://users.ece.gatech.edu/bonnie/book3/



Fundamentals Signals Systems - Windows Internet Explorer

http://users.ece.gatech.edu/bonnie/book3/

FUNDAMENTALS OF

SIGNALS AND SYSTEMS

USING THE WEB AND MATLAB®

THIRD EDITION

Home

Book Contents

M-Files in Book

MATLAB™ Tutorial

On-Line Demos

Worked Problems

Instructor Notes

With the presentation at an introductory level, this book contains a comprehensive treatment of continuous-time and discrete-time signals and systems using demos on the Web, data downloaded from the Web, and illustrations of numerous MATLAB commands for solving a wide range of problems arising in engineering and in other fields such as financial data analysis. The third edition is a major revision of the previous edition in that the extent of the use of mathematics has been greatly reduced, practical applications involving downloaded data and other illustrations have been added, and the material has been reorganized in a significant way so that the flexibility in using the book in a one-quarter or one-semester course should be greatly enhanced.

1.1 Continuous Time Signals

- x(t) –a signal that is **real-valued** or scalar-valued function of the time variable t.
- When t takes on the values from the set of real numbers, t is said to be a continuous-time variable and the signal x(t) is said to be a **continuous-time signal** or an analog signal.

Examples of Continuous Signals

- Figure 1.1 Speech Signal P2
- Figure 1.2 Unit step and Unit ramp P2-3
- Figure 1.3 Pulse Interpretation P3-4
- Figure 1.4 Unit Impulse $\delta(t)$

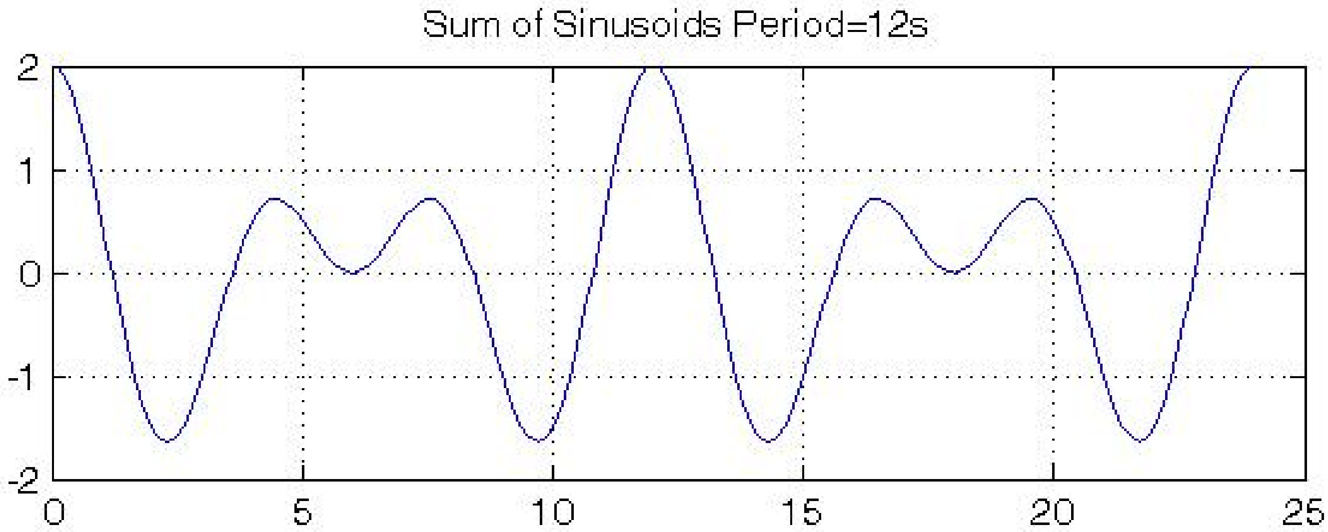
- The step, ramp, pulse and unit impulse are the most important signals for testing a system.

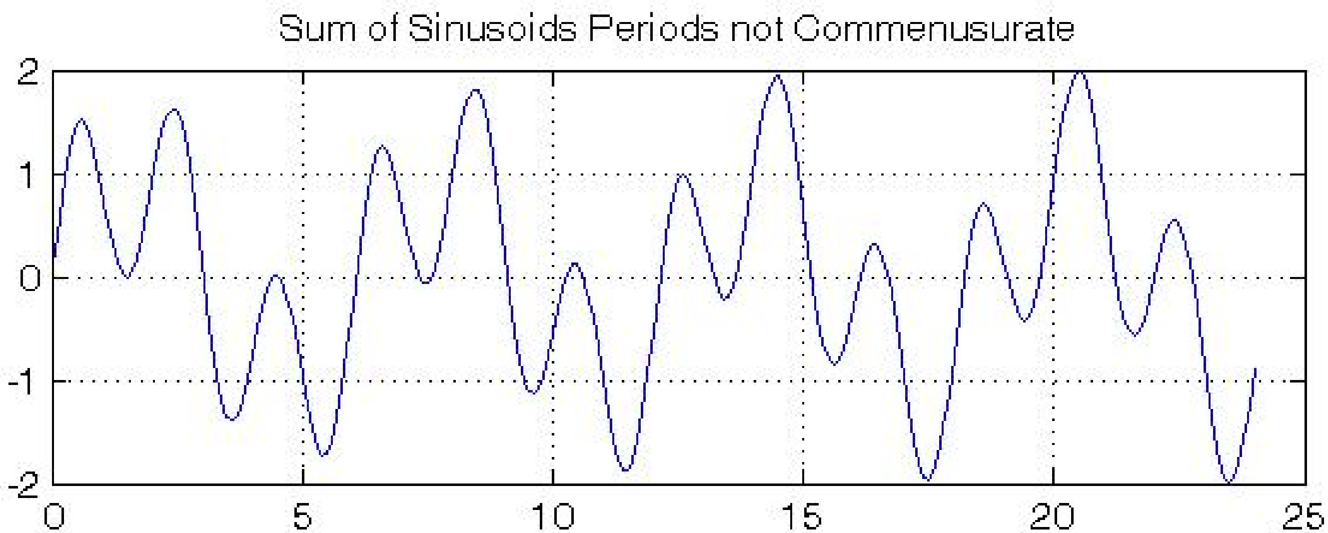
- Example 1.1 Sum of Periodic Signals is periodic if "the two non-zero periods T1=*a* and T2=*b* are ***commensurate"***

  (if *a*/*b* is a rational number.)

- Figure 1.5 Periodic Signal P5
- A $\sin(\omega t + \varphi)$ $is\ the\ most\ important\ signal$
- ω= 2 π f $\frac{radians}{second}$ $f = \frac{cycles}{second}$ $(Hertz)$
- The period T=1/f seconds or T= 2 π /ω seconds

```
% K&H Chapter 1
% Periodic Ex 1.1
t=0:0.1:24;
y=cos(pi*t/2)+cos(pi*t/3);
% T1=4s, T2=6s; LCM=12; GCD(1/4,1/6)=1/12 Hz
%
figure(1)
subplot(2,1,1), plot(t,y)
grid
title('Sum of Sinusoids Period=12s')
y1=sin(t)+sin(pi*t);
subplot(2,1,2),plot(t,y1)
grid
title('Sum of Sinusoids Periods not Commenusurate')
```


Sum of Sinusoids Period=12s
2
1
0
-1
-2
0
5
10
15
20
25


Sum of Sinusoids Periods not Commenusurate
2
1
0
-1
-2
0
5
10
15
20
25

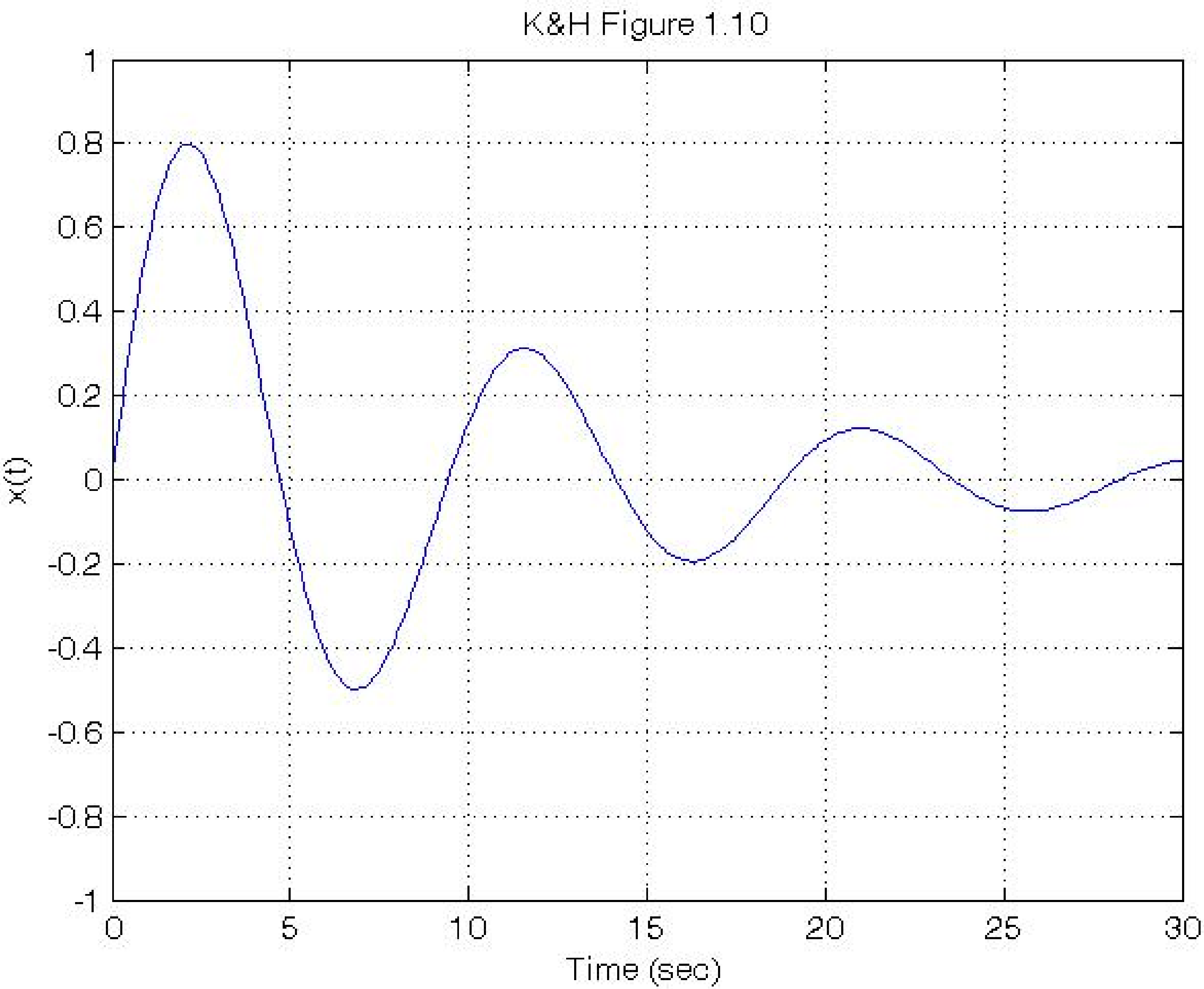
More Continuous Time Signals

- Figure 1.6 Time-Shifted Signals P6
- (A transmitted signal is time shifted at the receiver- and probably attenuated!)
- Figure 1.7 Triangular Pulse Function
- Figure 1.8 Rectangular Pulse Function P8
- Figure 1.9 Pulse train – approximate a computer clock signal
- These are all test signals for systems or approximations to useful signals!

1.1.6 Derivative of a Continuous-Time Signal

- A continuous time signal is said to be **differentiable** at a fixed point t1 if as t→0 the limit from above is the same as the limit from below. P9-10
- $\frac{dx}{dt} = \lim_{h \to 0} \frac{x(t+h) - x(t)}{h}$
- Piecewise-continuous signals may have a derivative in the **generalized** sense. $\delta(t)$

```
% PLOT  K&H Figure 1.10 decaying sinusoid

%

t = 0:0.1:30;                   % Plot from 0 to 30 seconds

x = exp(-0.1*t).*sin((2/3)*t);

%

figure(1)                       % Figure number if multiple figures

plot(t,x)

axis([0 30 -1 1 ])              % Set appropriate axis limits

grid

title('K&H Figure 1.10')

xlabel('Time (sec)')

ylabel('x(t)')
```


K&H Figure 1.10
x(t)
Time (sec)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
5
10
15
20
25
30

```
% Use MATLAB to plot using STEM Figure 1.11 K&H
n = -2:6;        %Index -2, -1, 0, ... 6 (9 values)
% x[0] =1, x[1]=2,x[2]=1, x[3]=0, x[4]= -1; others are zero
%
x= [0 0 1 2 1 0 -1 0 0] ;
figure(1)
stem (n,x,'filled');    % Plot Discrete with filled circles
title('Figure 1.11 K&H')
xlabel ('n')
ylabel ('x[n]')
```

The result using STEM is Figure 1.12 Page 13.

This could represent a digital signal since the amplitude and index values are quantized.

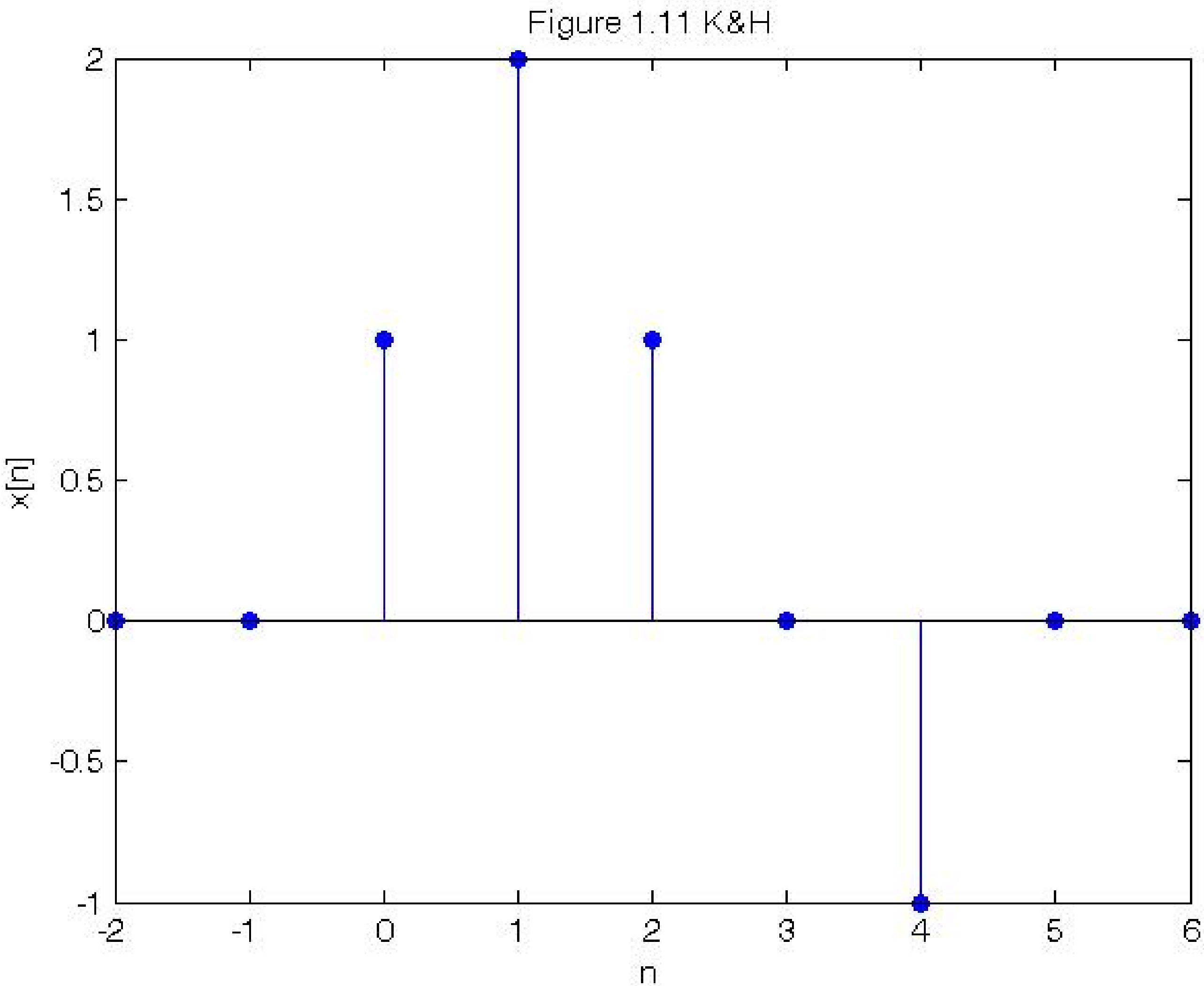


Figure 1.11 K&H
x[n]
n
2
1.5
1
0.5
0
-0.5
-1
-2
-1
0
1
2
3
4
5
6

>>help stem   % Use the help often!

stem   Discrete sequence or "stem" plot.

stem(Y) plots the data sequence Y as stems from the x axis terminated with circles for the data value. If Y is a matrix then each column is plotted as a separate series.

stem(X,Y) plots the data sequence Y at the values specified in X.

stem(...,'filled') produces a stem plot with filled markers.

stem(...,'LINESPEC') uses the linetype specified for the stems and markers. See PLOT for possibilities.

See also plot, bar, stairs.

Reference page in Help browser **Use this for more information!**

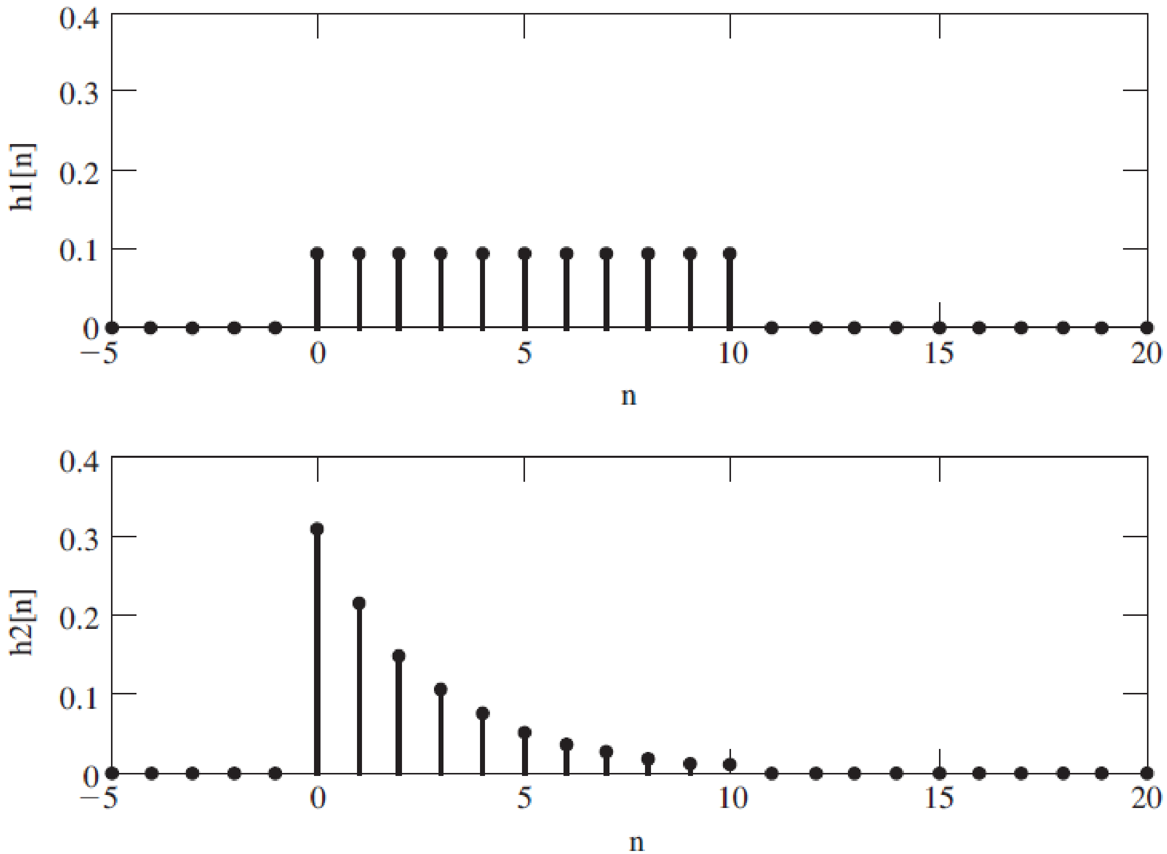
doc stem   (Active Link from help stem screen)

More Discrete Time Signals

- Sampling
  - $x[n] = x(t)|_{t= nT} = x(nT)$
  - Example—a switch is closed every T seconds
  - Using "T seconds" brings in the "real world".
- Unit pulse– $\delta(0)$—Figure 1.17
- Periodic Discrete Time Signals—Figure 1.18a,b
- F1.18a repeats every 6 cycles
- Discrete Time Rectangular Pulse Figure 1.19

More Discrete Time Signals (2)

- **Digital Signals**
  - Let {a1,a2,…,aN} be a set of N real numbers.
  - A **digital signal** x[n] is a discrete-time signal whose values belong to the finite set above.
  - A **sampled continuous time signal** (ideal case) is not necessarily a “digital signal”. Digital is quantized in time AND amplitude – i.e a computer value.
  - A **binary signal** is restricted to values of 0 and 1.


0.4
0.3
0.2
0.1
0
h1[n]
−5
0
5
10
15
20
n
0.4
0.3
0.2
0.1
0
h2[n]
−5
0
5
10
15
20
n

```
% K&H Figure 1.14   Compare this to Figure 1.10
%
n=0:30;
x = exp(-.1*n).*sin(2/3*n);
stem(n,x,'filled')
axis([0 30 -1 1]);
ylabel('x[n]')
xlabel('n')
title('Figure 1.14-Compare Figure 1.10')
gtext('Sampled Signal x(t)=exp(-0.1*t)*Sin(2/3*t)')
```

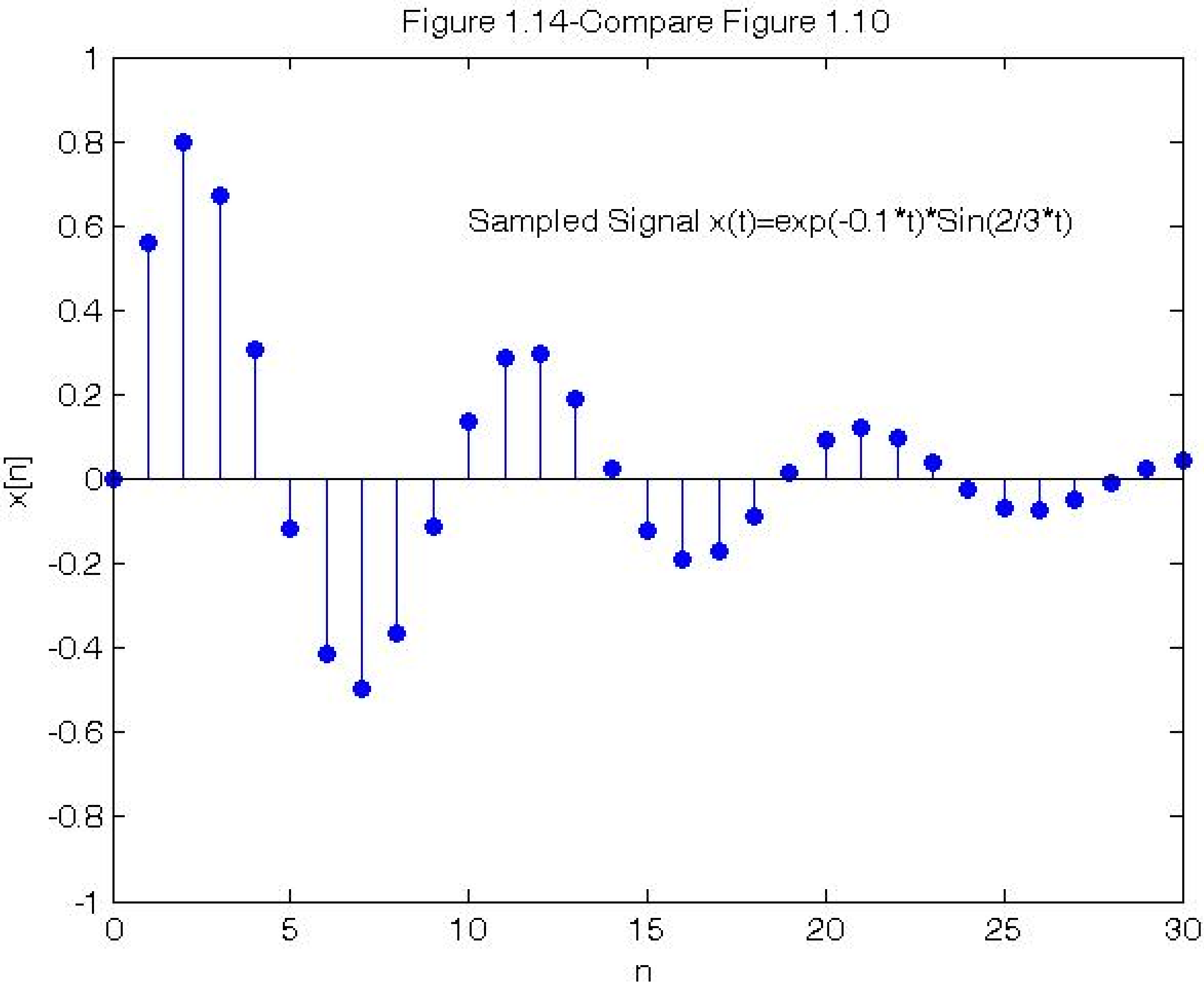


Figure 1.14-Compare Figure 1.10
Sampled Signal x(t)=exp(-0.1*t)*Sin(2/3*t)
x[n]
n
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
5
10
15
20
25
30

Downloading Discrete-Time Data from the Web P18

- Discrete-time data = a **time series**
- Time series data on websites can often be loaded into spreadsheets.
- If the spreadsheet data can be saved in csv (comma-separated value) formatted files, MATLAB will be able to read the file.

- OPTIONAL FOR US

Price Data for QQQ

- QQQ data is the historical data for an index fund, whose value tracks the stock price of 100 companies.
- Go to http://finance.yahoo.com
- Near the top of the page enter QQQQ and click “GO”.
- In the left hand column click on “historical prices”.
- Click on “Download to Spreadsheet”.
- Example 1.2.
- (NOTE: Some things have changed a little since the book was printed but this still works.)

1.3 Systems

- A system is a collection of one or more devices, processes, or computer-implemented algorithms that operates on an input signal x to produce an output signal y.
- When the inputs and outputs are continuous-time signals, the system is said to be a continuous-time system or an analog system.
- When inputs are discrete-time signals, the system is said to be a discrete-time system.

READ PAGES 21 -24 CAREFULLY!

SYSTEM EXAMPLES-MECHANICAL, ELECTRICAL, BIOLOGICAL

SIGNAL ANALYSIS–In the time domain or frequency domain
rise time, amplitude, power, etc. in Time.
Frequency spectrum in frequency. (Fourier)

MATHEMATICAL MODELS of SYSTEMS – IDEAL
differential equations or difference equations (Time)
Transfer function representations (Fourier, Laplace, z)

INPUT/OUTPUT - Time or Frequency
STATE-SPACE - Input, state, and output

1.4 Examples of Systems

- RC Circuit P24

  This is a model for input stages of many analog electronic systems.

  The RC acts as a low-pass filter and attenuates high frequencies in the input signal.

- Mass-Spring-Damper System P26

  Why is the world a 2nd Order system (almost)?

- Moving Average Filter (Discrete) P 27
  - This is also a low-pass filter that acts to “smooth” the data.
  - See Example 1.4

1.5 Basic System Properties

- Systems are classified as follows
  - Analog or Discrete (Digital)
  - Linear or Nonlinear
  - Time Invariant (shift invariant) or not
  - All analog physical systems are causal (as far as we know!)
- Signals can be Analog or discrete (digital) and
  - continuous or discontinuous
  - Periodic or not
  - Even or Odd

Linearity

- A system is **additive** if for x1(t) and x2(t) (inputs), the response to the **sum** of the inputs is the **sum** of the individual outputs.
- A system is **homogeneous** if the output for input ax(t) , where a is a scalar, is ay(t).
- A system is **linear** if it is **additive and homogenous**.
- That is, if $x_1(t) \rightarrow y_1(t)$, and $x_2(t) \rightarrow y_2(t)$, and a_1 and a_2 are scalars, then a system is linear if the input

$$x(t) = a_1 x_1(t) + a_2 x_2(t)$$

produces the output

$$y(t) = a_1 y_1(t) + a_2 y_2(t).$$

Linear Systems Theory
Professor David Heeger

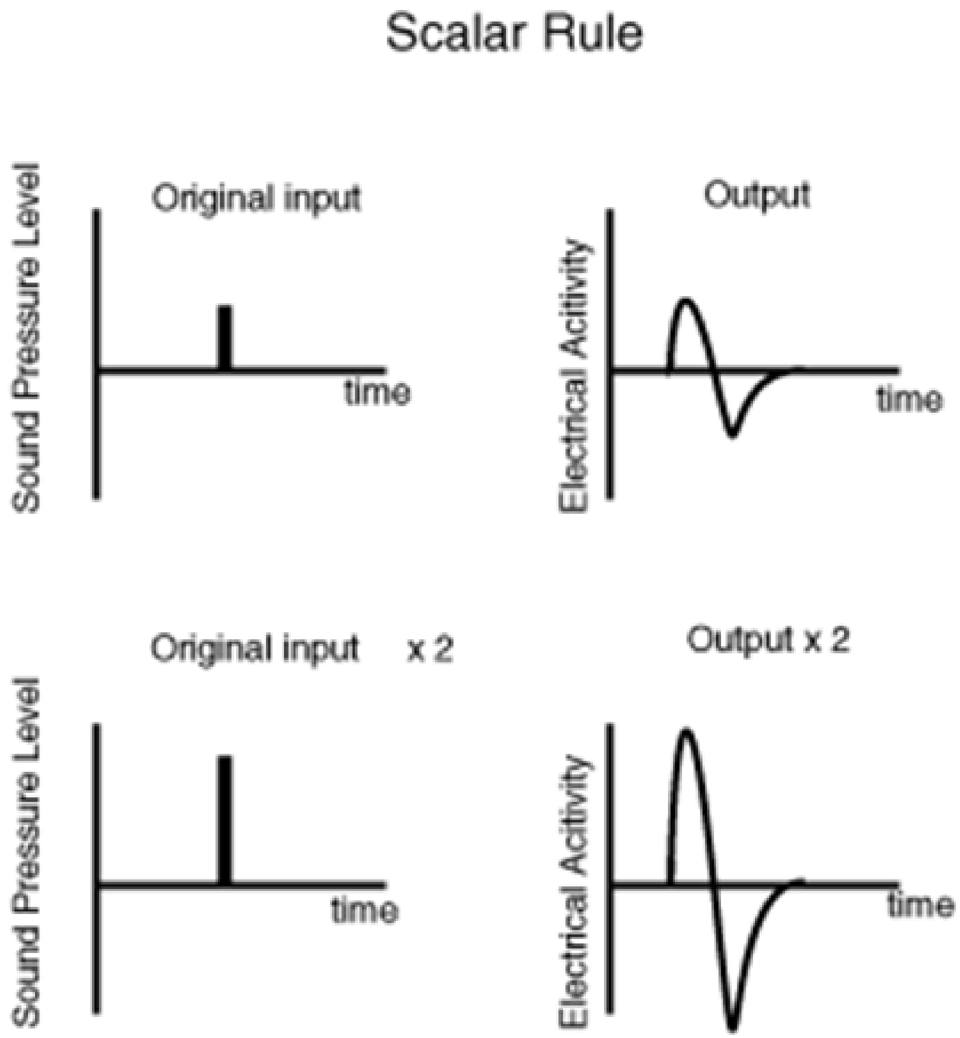
Characterizing the complete input-output properties of a system by exhaustive measurement is usually impossible. When a system qualifies as a *linear system*, it is possible to use the responses to a small set of inputs to predict the response to any possible input. This can save the scientist enormous amounts of work, and makes it possible to characterize the system completely.

- The challenge of characterizing a complex systems
- Simple linear systems

    - Homogeneity - Double Input- Double Output

    - Additivity - Sum of Outputs for Sum of Inputs

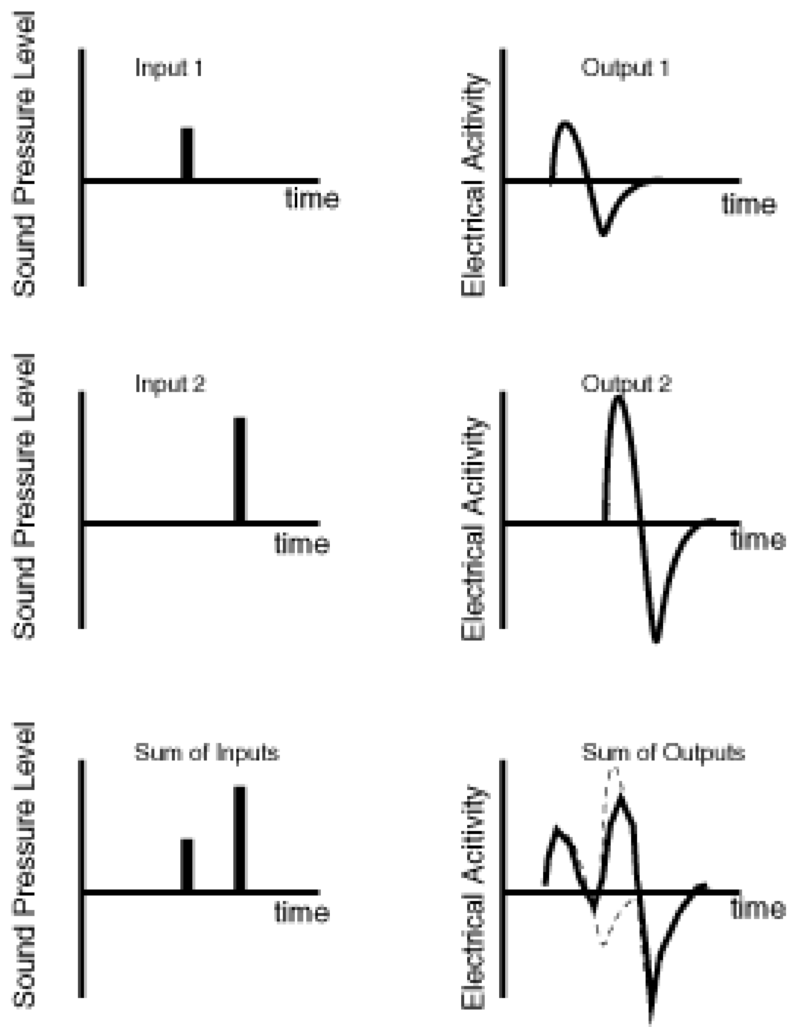
    - Superposition - THE BIG ONE
    - homogeneity and additivity = LINEAR



Think of
F=-kx
Spring

Heeger

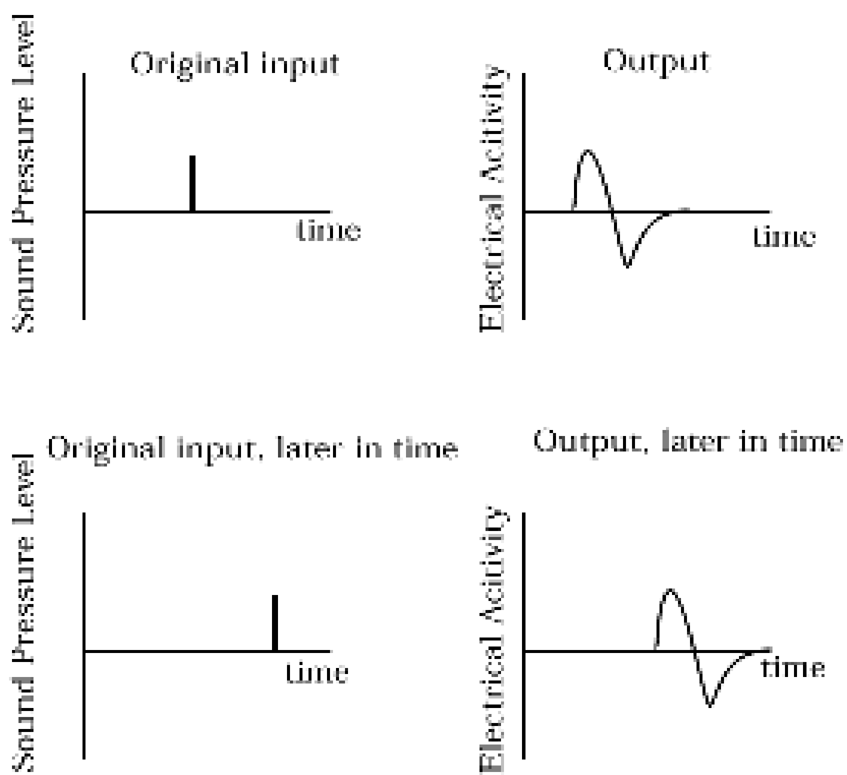
Additivity

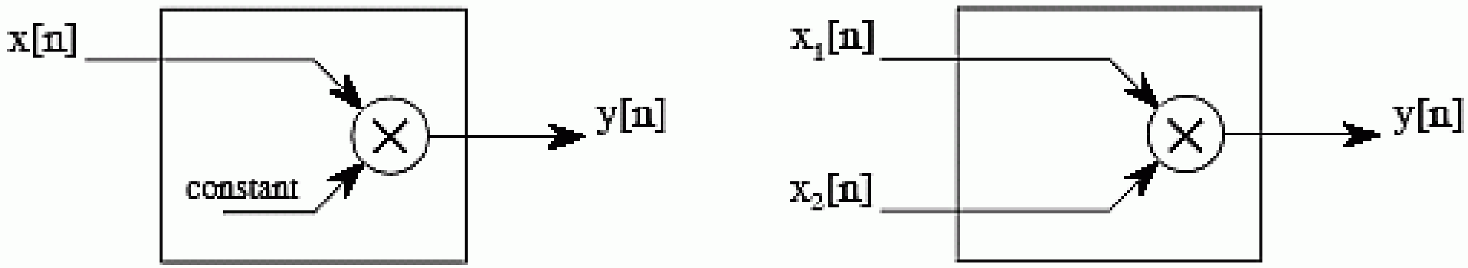


Input 1
Sound Pressure Level
time
Output 1
Electrical Acitivity
time
Input 2
Sound Pressure Level
time
Output 2
Electrical Acitivity
time
Sum of Inputs
Sound Pressure Level
time
Sum of Outputs
Electrical Acitivity
time

- Shift-invariance
    - Decomposing a signal into a set of shifted and scaled impulses
    - The impulse response function
    - Use of sinusoids in analyzing shift-invariant linear systems
    - Decomposing stimuli into sinusoids via Fourier Series
    - Characterizing a shift-invariant system using sinusoids

Shift-Invariance Rule





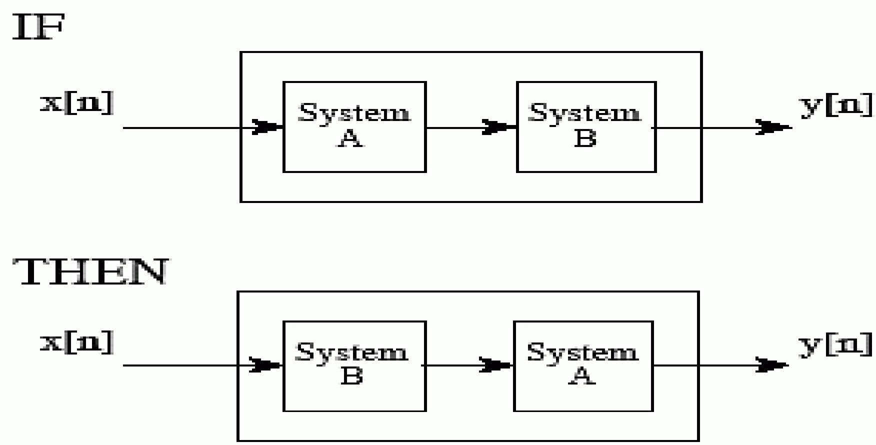
Linear
a. Multiplication by a constant

Nonlinear
b. Multiplication of two signals

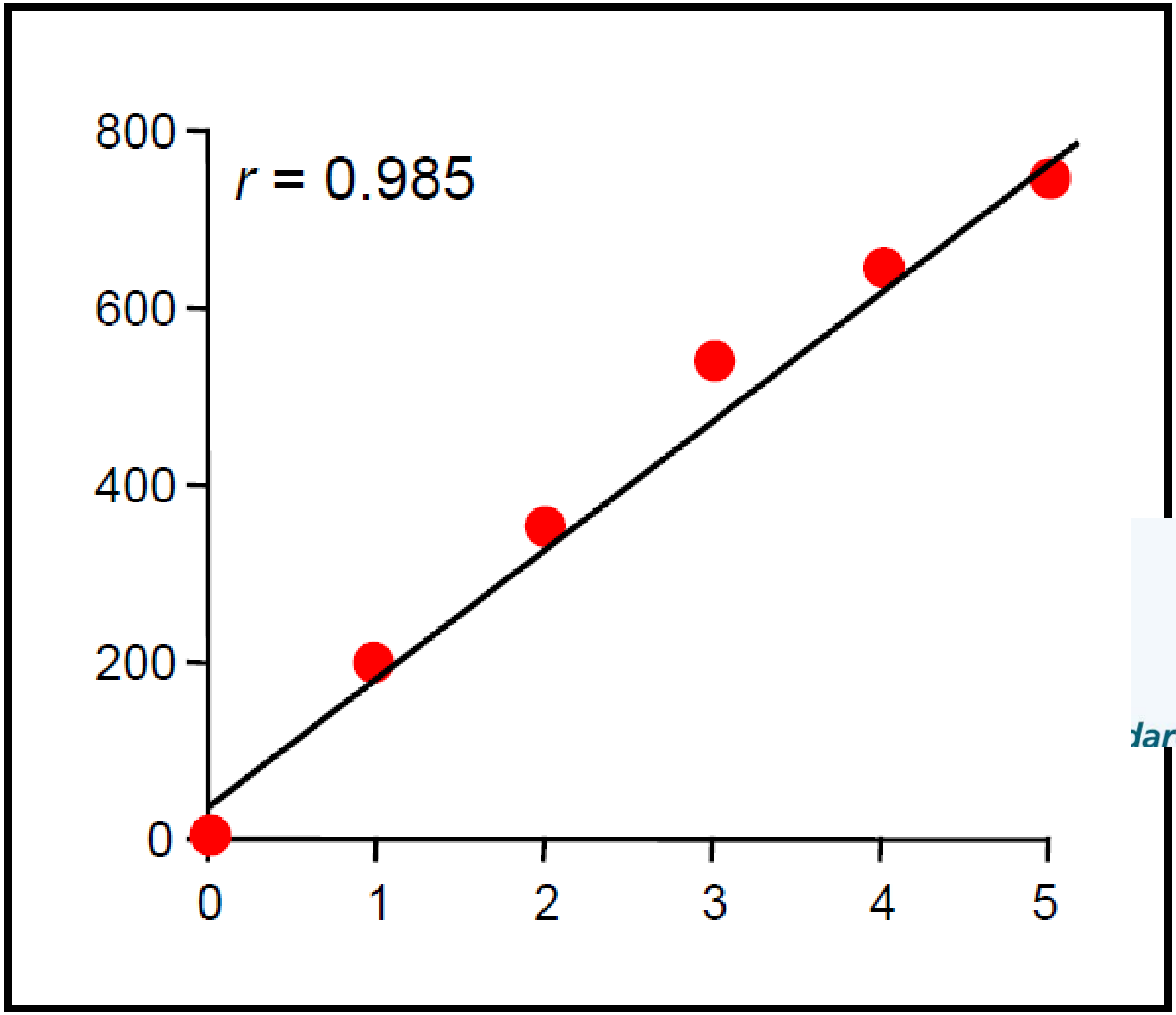
FIGURE 5-9
Linearity of multiplication. Multiplying a signal by a constant is a linear operation. In contrast, the multiplication of two signals is nonlinear.

Smith

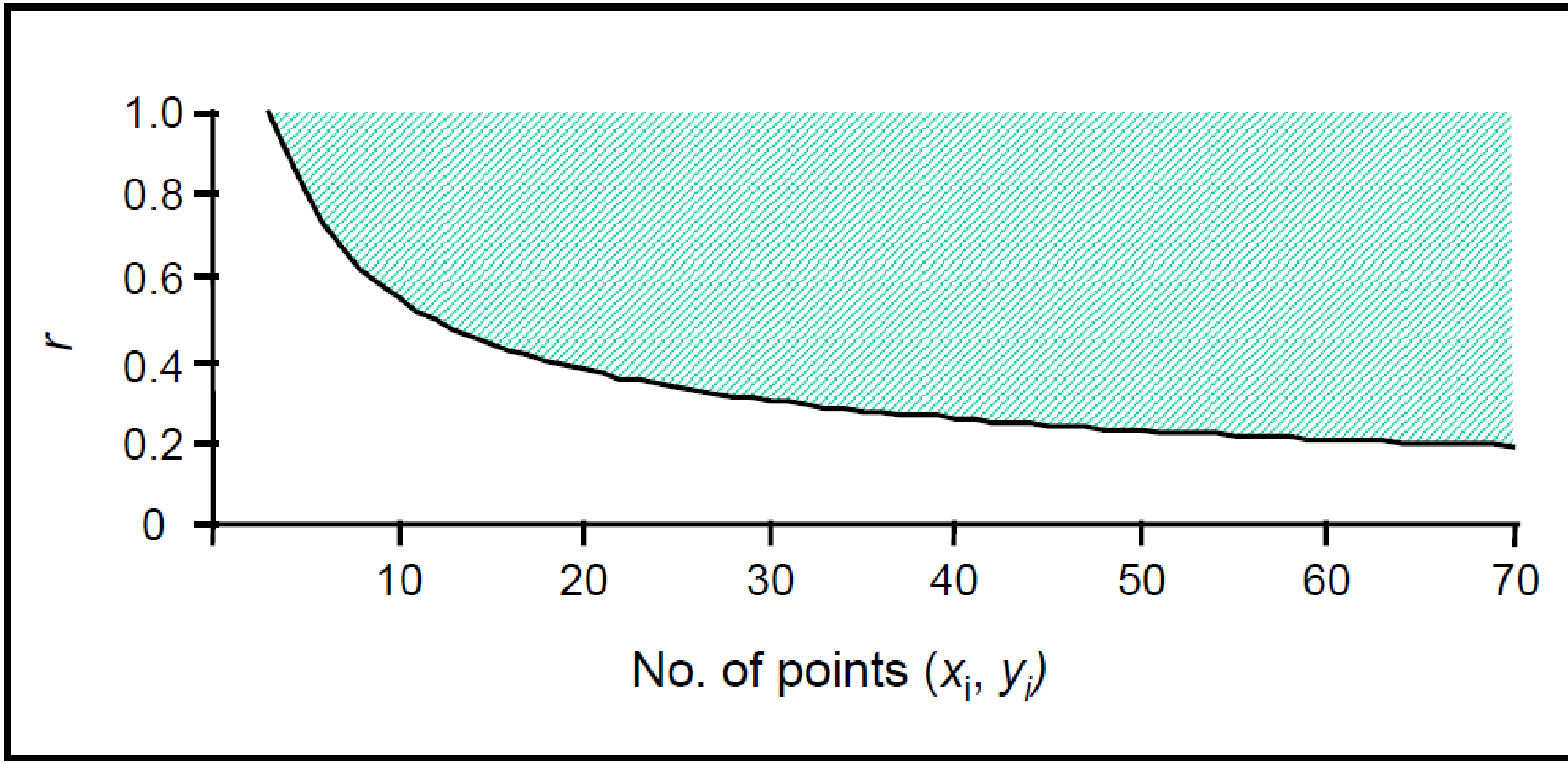
FIGURE 5-7
The commutative property for linear systems. When two or more linear systems are arranged in a cascade, the order of the systems does not affect the characteristics of the overall combination.



- LINEAR
- Systems described by Linear differential or difference equations
- Passive Circuits R, L, C and linear amplifiers and filters
- Differentiation and integration or difference or running sum
- Small perturbations in an otherwise nonlinear system



a) Non-linearity



1.0
0.8
0.6
0.4
0.2
0
r
10
20
30
40
50
60
70
No. of points (x_i, y_i)

- NON LINEAR

- NO STATIC LINEARITY I.E, NOT Y=M X such as P=v^2 R
- NO SINUSOIDAL FIDELITY – PEAK DETECTION, SQUARING, CLIPPING, FREQUENCY DOUBLING
- Systems with hysteresis, saturation, or a threshold
- DIODES FOR EXAMPLE

Shockley diode equation

$$I = I_S \left(e^{V_D/(nV_T)} - 1 \right),$$

I is the diode current,
I_S is the reverse bias saturation current,
V_D is the voltage across the diode,
V_T is the thermal voltage , and
n is the *ideality factor.*

I_s and nV_T are constants.

Let's Linearize the Diode equation using Taylor's series near V_D=0

MacLaurin series:

$$
\begin{aligned}
e^x &= f(0)\frac{x^0}{0!} + f'(0)\frac{x^1}{1!} + f''(0)\frac{x^2}{2!} + f'''(0)\frac{x^3}{3!} + f^{(4)}(0)\frac{x^4}{4!} + \cdots \\
&= \frac{x^0}{0!} + \frac{x^1}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \cdots \\
&= \sum_{n=0}^{\infty} \frac{x^n}{n!}
\end{aligned}
$$

For small x - close to the origin assume $x^2 \ll x \; so$

$$e^x \sim 1 + x \quad where\; x\; here\; is \quad \frac{V_D}{nV_T}$$

The result is

$$I \sim I_s \frac{V_D}{nV_T}$$

Linear in V_D

Other System Properties

- Time Invariance
  - A system is time invariant or constant if the response for the input x(t-t1) is y(t-t1).

- Causality
  - A system is said to be causal or nonanticipatory if the output response to input x(t) for t=t1 does not depend on values of x(t) for t>t1

    (ie, future inputs).

Important problems – whether I assign them or not !

1.2 Spacing when plotting or sampling

1.18 Linearity – Integral, derivative

1.21 Dead zone – Nonlinear

1.23 Save some work –Impulse response is the derivative of the step response