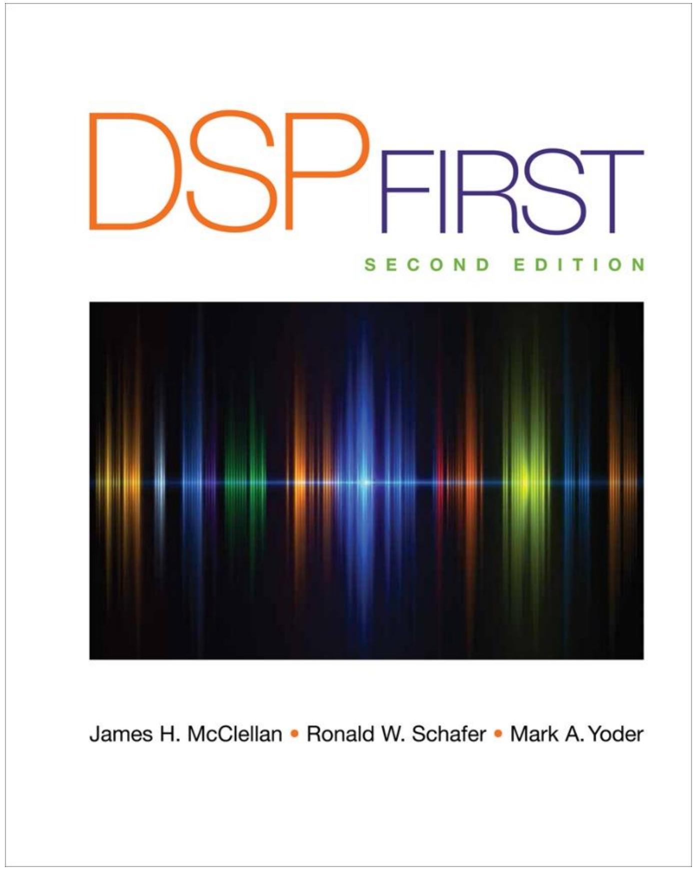
Review of Jan 19 Lecture



ENG 3315 Spring 2022

DSP First

Second Edition

Modified by TL Harman Spring 2021
For CENG 3315

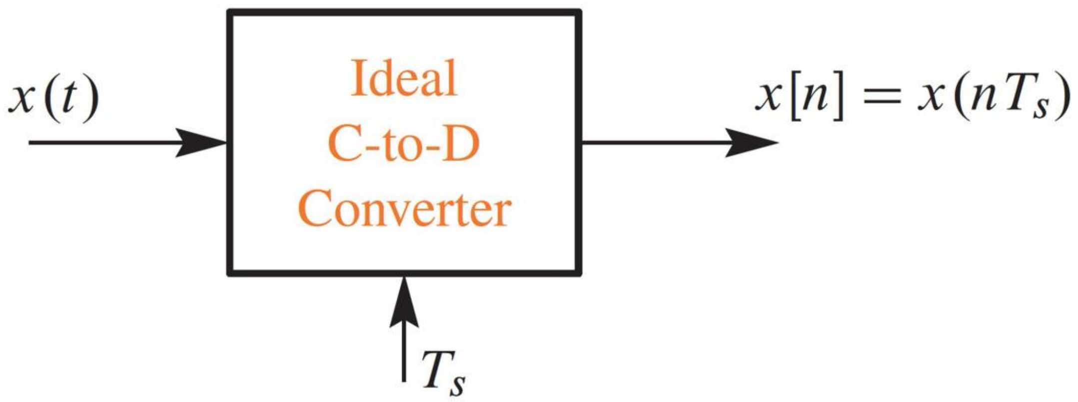
Chapter 1

Introduction

Pearson

Mathematical Representation of Systems (3 of 3)

Figure 1-6: Block Diagram Representation of a Sampler.



Ideal means NO Numerical or Electronic Errors

CD vs Record - Characteristics

Characteristic	CD	Vinyl Record*
Low frequency	20 Hz	10 Hz
High frequency	22.05 kHz	50kHz
Frequency response ripple	+- 0.5 dB	+- 3 dB
Dynamic Range	90 dB	70 dB
Signal to Noise Ratio	90 dB	60 dB
Harmonic Distortion	0.01 %	1-2 %
Stereo separation	90 dB	30 dB
Lossy	Yes	No
Damage – Scratch, dust, etc.	Relatively unaffected	Definitely

Technically – CD "sounds better on paper" But for Sound to your ears??

*** Depends heavily on Record Player.**

LectureCh2_1 **VanVeen Video, Tuning Fork, Rotating Vector Video, Review of Trig, Phase = Time Shift**

https://sce.uhcl.edu/harman/CENG3315_DSP_Spring2020/Lectures2020/2_1_TLH_SlidesLecture1_Ch2_1to2_3_D%20S%20P%20First.pdf

1. Barry VanVeen Introduction to DSP
Introductory overview of the field of signal processing: signals, signal processing and applications, philosophy of signal processing, and language of signal processing. 12:58

https://www.youtube.com/watch?v=YmSvQe2FDKs

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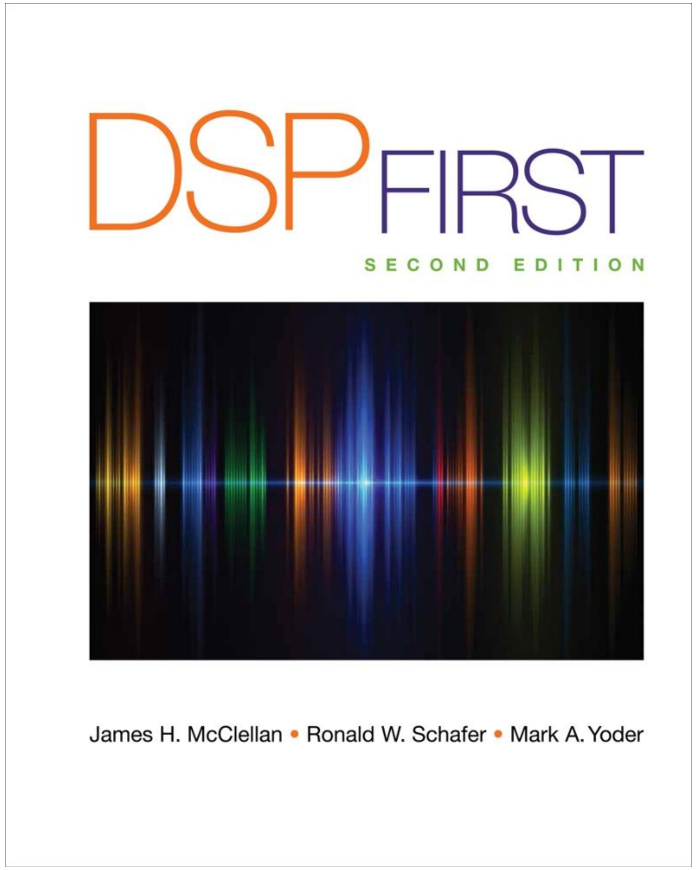
- Let’s Master Sinusoids

TLH Modified CENG 3315
CHAPTER 2 2-1 TO 2-3



Chapter 2

Sinusoids

LET'S VIEW A FEW VIDEOS - SINUSOIDAL REVIEW

1. Dr. Van Veen and Sinusoids 11 Minutes

Introduction to Signal Processing
137,979 views
https://www.youtube.com/watch?v=YmSvQe2FDKs&feature=youtu.be

2. Why Study Sinusoids?
https://www.youtube.com/watch?v=yXjXJ5OlNyQ&feature=youtu.be

3. Example Finding Parameters of a Sinusoid from a Graph **6:19**
https://www.youtube.com/watch?v=h72Eax1jQkw&feature=youtu.be

SEE OUR REFERENCES FOR OTHER VIDEOS BY VAN VEEN

Table 2-1: Basic Properties of the Sine and Cosine Functions

Property	Equation
Equivalence	$\sin\theta = \cos(\theta - \pi/2)$ or $\cos(\theta) = \sin(\theta + \pi/2)$
Periodicity	$\cos(\theta + 2\pi k) = \cos\theta$, when k is an integer
Evenness of cosine	$\cos(-\theta) = \cos\theta$
Oddness of sine	$\sin(-\theta) = -\sin\theta$
Zeros of sine	$\sin(\pi k) = 0$, when k is an integer
Ones of cosine	$\cos(2\pi k) = 1$, when k is an integer
Minus ones of cosine	$\cos[2\pi(k + \frac{1}{2})] = -1$, when k is an integer

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Table 2-2: Some Basic Trigonometric Identities

Page 14

Number	Equation
1	$\sin^2\theta + \cos^2\theta = 1$
2	$\cos 2\theta = \cos^2\theta - \sin^2\theta$
3	$\sin 2\theta = 2\sin\theta\cos\theta$
4	$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$
5	$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$

SINUSOIDAL SIGNAL

$$A\cos(\omega t + \varphi)$$

- **FREQUENCY** $\boxed{\omega}$
  - Radians/sec
  - Hertz (cycles/sec)

$$\omega = (2\pi) f$$

- **PERIOD** (in sec)

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

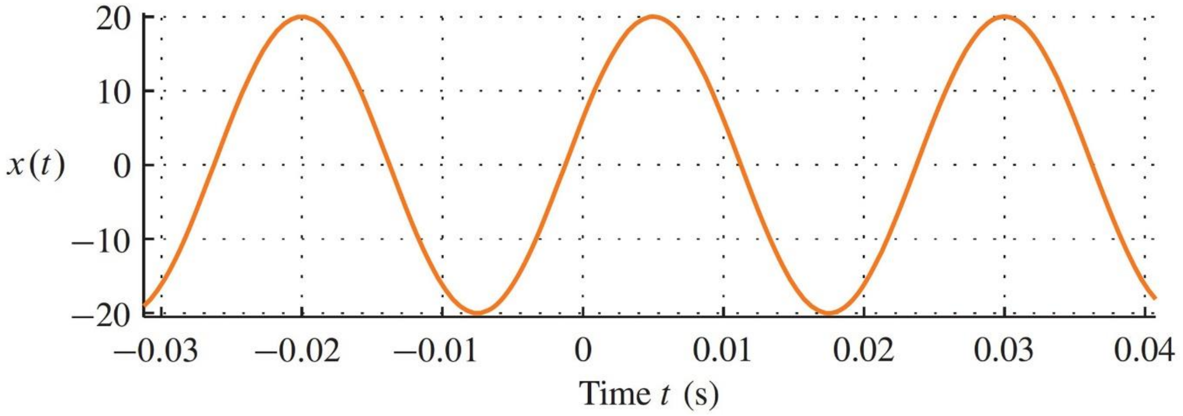
- **AMPLITUDE** $\boxed{A}$
  - Magnitude

- **PHASE** $\boxed{\varphi}$

Relation of Frequency to Period (1 of 2)

Time-Domain versus Frequency-Domain

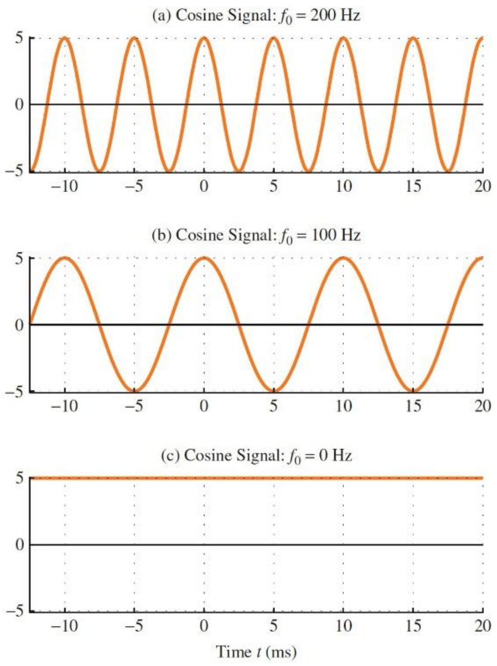
Figure 2-6: Sinusoidal signal with parameters *A* = 20, $\Omega_0 = 2\pi(40), F_0 = 40\ \text{Hz, and}$ $\phi = -0.4\pi rad.$



Relation of Frequency to Period (2 of 2)

Figure 2-7: Cosine Signals $X(t) = 5Cos(2\pi f_0 t)$ for Several Values of $F_0 : (A) F_0 = 200 \text{ Hz};$ $(B) F_0 = 100 \text{ Hz}; (C) F_0 = 0$

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$



$$\omega = 2\pi f$$

1. Why Study Sinusoids? VanVeen

https://www.youtube.com/watch?v=yXjXJ5OlNyQ

Fundamental reasons why sinusoids are **so** important in signal processing:

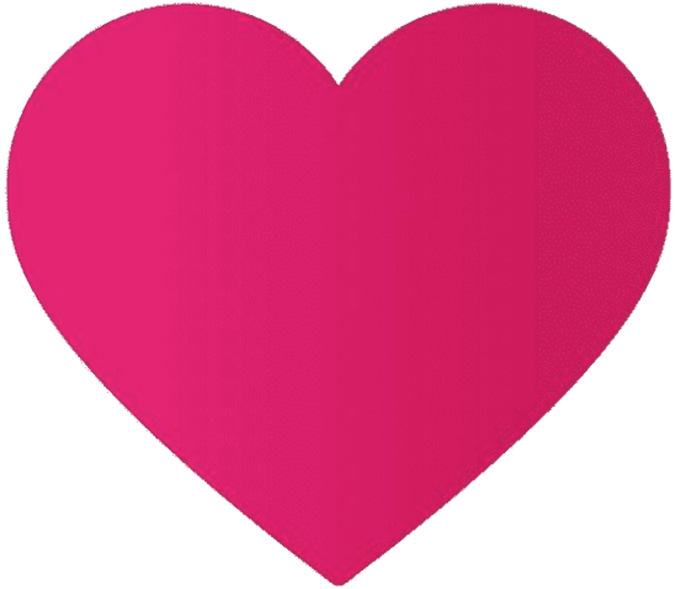
1. They occur in nature (physics)
   - electromagnetic waves (e.g. light)
   - pendulum
   - crystal oscillator
   - tuning fork

2. They are used in communication systems

- radio WIBA 1310 KHz
  AM, FM
- television
- cellular
- etc

3. Any signal can be represented as a "sum" of sinusoids

- music, speech
- images
- fMRI
- stock prices
- EEG
- etc



THIS IS THE BIG ONE!

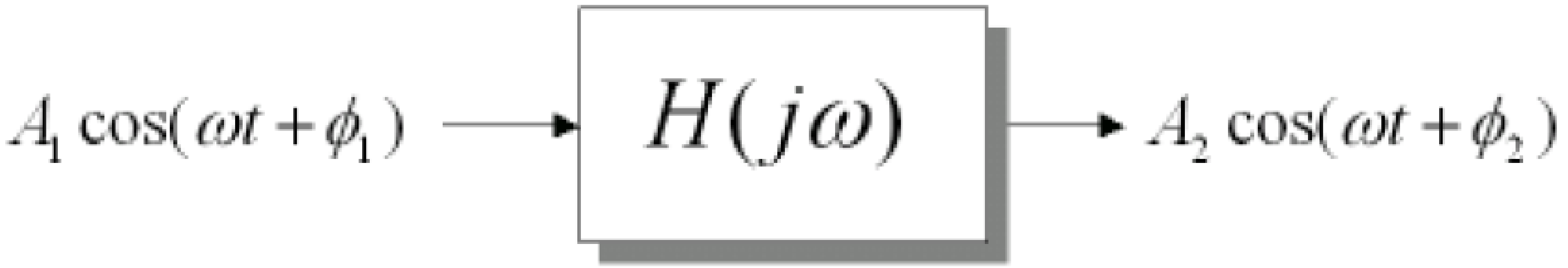


Figure 1: LTI system

LTI SYSTEMS CAN CHANGED AMPLITUDE AND PHASE BUT NOT FREQUENCY!

LINEAR TIME INVARIANT SYSTEM

DIFFERENCE OR DIFFERENTIAL EQUATION WITH CONSTANT COEFFICIENTS.

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TLH LECTURE 2_2
Section 2-3.2, 2-4

Chapter 2

Sinusoids

PLOTTING COSINE SIGNAL from the FORMULA

$$5\cos(\underline{0.3\pi}t + 1.2\pi)$$

- Determine **period**:

$$T = 2\pi/\omega = 2\pi/0.3\pi = 20/3$$

- Determine a **peak** location by solving

$$(\omega t + \varphi) = 0$$

$$0.3\pi t + 1.2\pi = 0$$

- **Peak at t=-4**

```
% Lecture Ch2_2
%
% 5*cos(0.3*pi*t +1.2*pi)
% Find the radian frequency, the frequency, and period
omega = 0.3*pi              %   0.9425 rad/sec
omega_deg = 0.3*180         %   54 degrees per second
f = omega/(2*pi)            %   0.1500 Hertz (cycles/sec)
T = 1/f                     %   6.6667 seconds in a period
```

```
%
% Find phase shift and time shift 0.3*pi*t+1.2*pi =0
%
phi_shift = 1.2*pi       %  3.7699 rad
tpeak= -1.2*pi/(0.3*pi)  % -4 seconds (shift to LEFT)
% CHECK 1.2*pi/2*pi  and -4/T
rad_shift_ratio = -1.2*pi/(2*pi)  %  0.6000  (60%)
t_shift_ratio  = -4/T             %  0.6000  Same ratio
```

TIME-SHIFT

- In a mathematical formula we can replace t with $t\text{-}t_m$

$$x(t - t_m) = A\cos(\omega(t - t_m))$$

- Thus the $t=0$ point moves to $t=t_m$

- Peak value of $\cos(\omega(t\text{-}t_m))$ is now at $t=t_m$

PHASE ←→ TIME-SHIFT

- Equate the formulas:

$$A\cos(\omega(t - t_m)) = A\cos(\omega t + \varphi)$$

- and we obtain:

$$-\omega t_m = \varphi$$

- or,

$$t_m = -\frac{\varphi}{\omega}$$

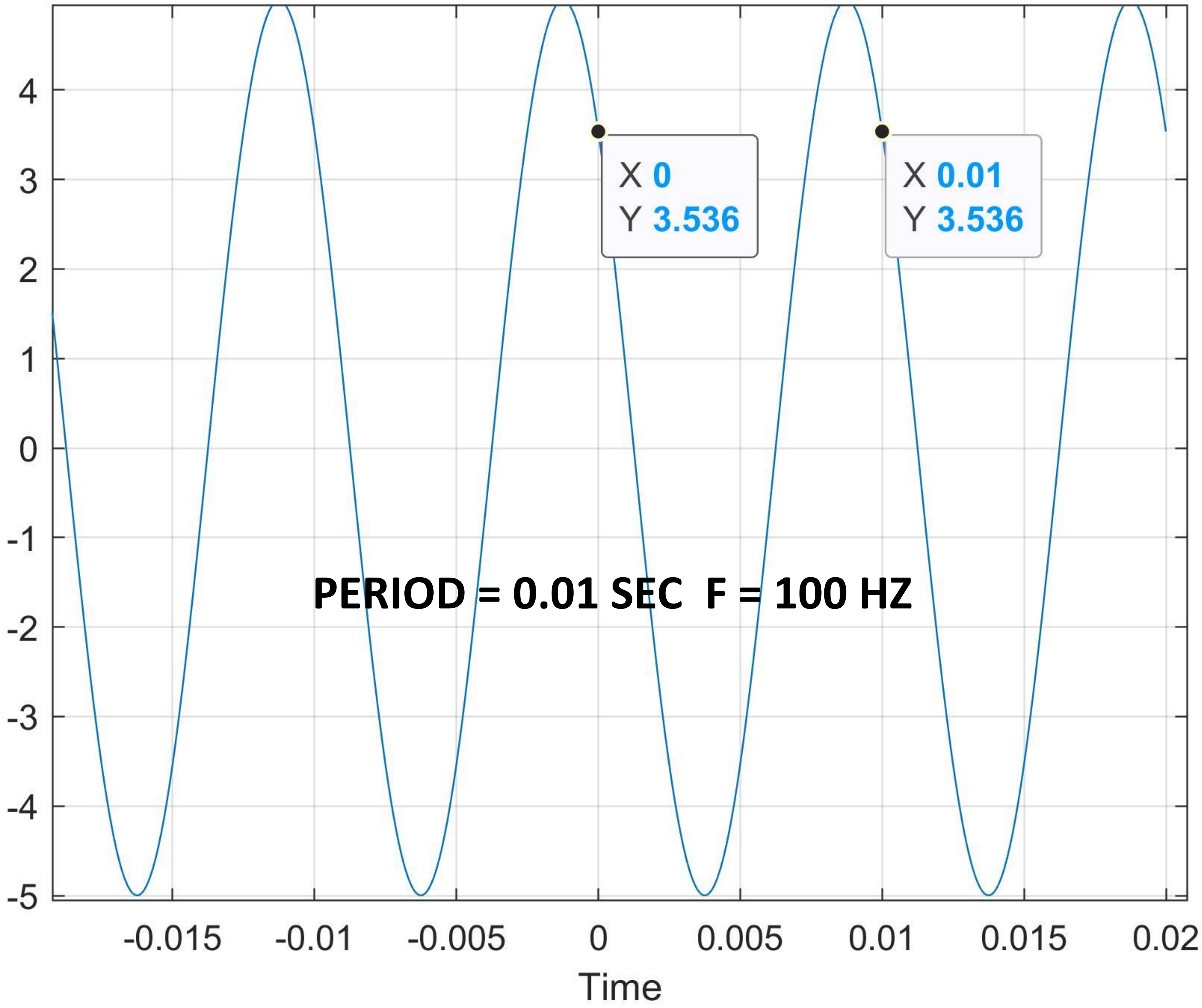
```
%
format long    % Get full precision
figure(1)
t=-0.02:.0001:.02;
y=5*cos(200*pi*t + 0.25*pi);

plot(t,y),grid,xlabel('Time')


t_shift = -.25*pi/(2*pi)*(1/100)  % -0.00125000000000 s

sprintf('%0.5f', t_shift)    %  ans = '-0.00125'
```

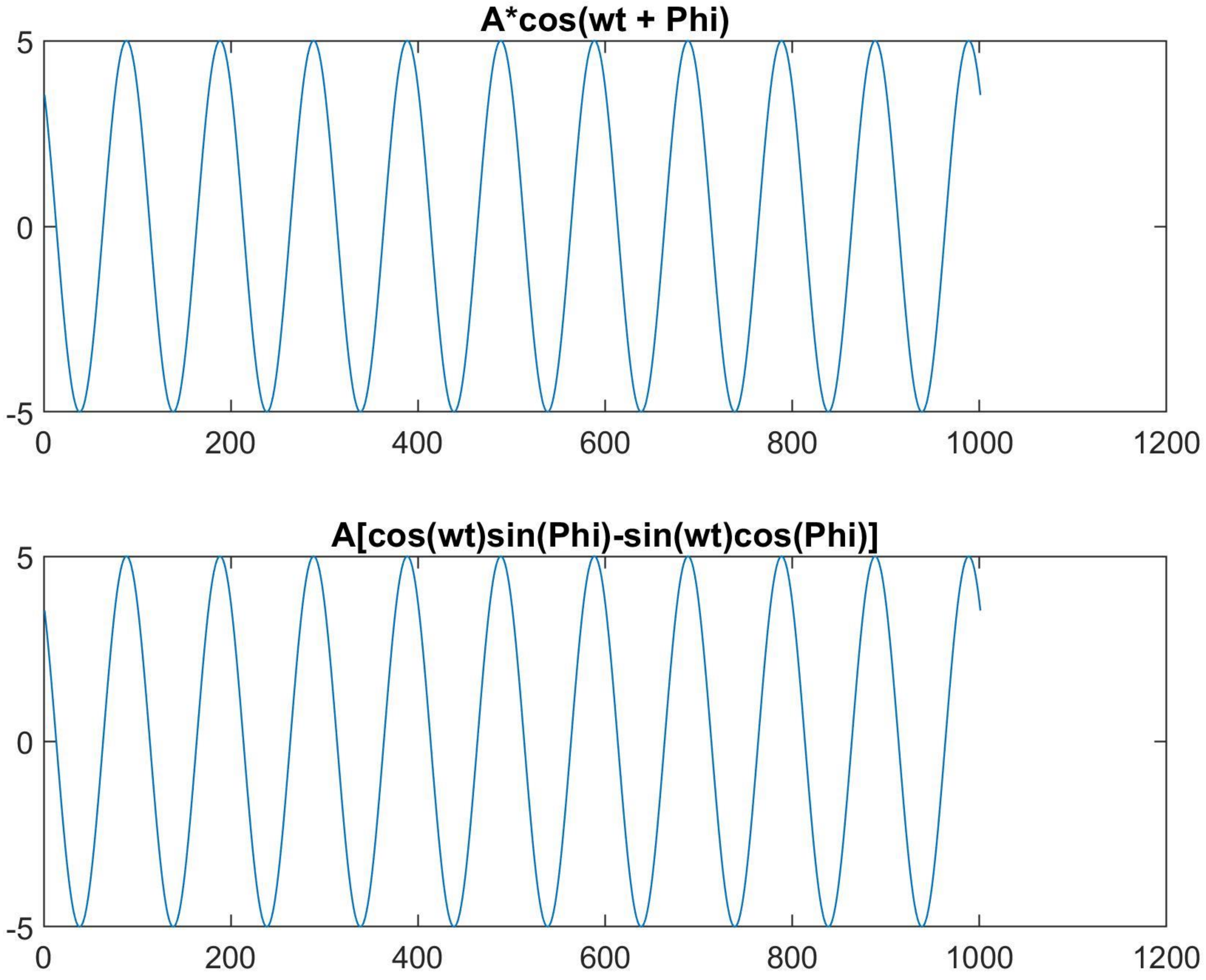
F= 100 Hz Shift is 0.25*pi or 45 degrees. Shift is to left in figure.


X 0
Y 3.536
X 0.01
Y 3.536
PERIOD = 0.01 SEC F = 100 HZ
4
3
2
1
0
-1
-2
-3
-4
-5
-0.015
-0.01
-0.005
0
0.005
0.01
0.015
0.02
Time

```
% A*cos(wt + Phi) = A(cos(wt)sin(Phi)-sin(wt)cos(Phi)
A= 5
Phi = pi/4  % 0.7854
w=200*pi    %  628.3185  rad/sec
f=200*pi/(2*pi)
t=0:.0001:.1;
y1=A*cos(w*t+Phi);
y2=A*[cos(w*t)*sin(Phi)-sin(w*t)*cos(Phi)];
figure(1)
subplot(2,1,1),plot(y1),title('A*cos(wt + Phi)')
subplot(2,1,2),plot(y2),title('A(cos(wt)sin(Phi)-
sin(wt)cos(Phi)')
```

ARE THEY THE SAME ??

YOU
BET!

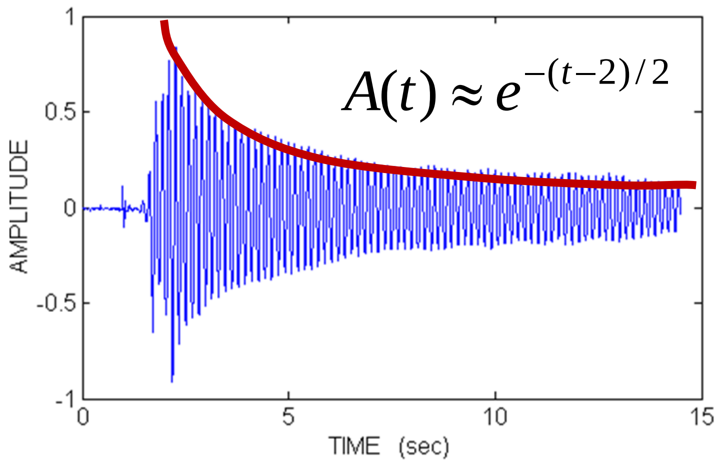

A*cos(wt + Phi)
5
0
-5
0
200
400
600
800
1000
1200
A[cos(wt)sin(Phi)-sin(wt)cos(Phi)]
5
0
-5
0
200
400
600
800
1000
1200

Attenuation

In real waves, there will always be a certain degree of attenuation, which is the reduction of the signal amplitude over time and/or over distance.

$$x(t) = A\cos(\omega t + \varphi)$$

In a sinusoid, A **is a constant.**



However, the amplitude can have exponential decay, e.g.,

$$A(t) = Ae^{-t/\alpha}$$

$$x(t) = Ae^{-t/\alpha}\cos(\omega t + \varphi)$$

MATLAB Example (I)

Generating sinusoids in MATLAB is easy:

```
% define how many values in a second
fs = 8000;
% define array tt for time
% time runs from -1s to +3.2s
% sampled at an interval of 1/fs
tt = -1 : 1/fs : 3.2;
xx = 2.1 * cos(2*pi*440*tt + 0.4*pi);
```

The array `xx` then contains a "sampled" signal of:

$$x(t) = 2.1\cos(880\pi t + 0.4\pi)$$

MATLAB Example (II)

Introducing attenuation with time

```
% fs defines how many values per second
fs = 8000;
tt = -1 : 1/fs : 3.2;
yy = exp(-abs(tt)*1.2);% exponential decay
yy = xx.*yy;
soundsc(yy,fs)
```

CLICK SPEAKER

Array `yy` contains a signal with changing amplitude:

$$y(t) = 2.1e^{-1.2|t|}\cos(880\pi t + 0.4\pi)$$

`Soundsc` **lets you hear the signal** `yy`

```
% define how many values in a second
fs = 8000;
% define array tt for time
% time runs from -1s to +3.2s
% sampled at an interval of 1/fs
tt = -1 : 1/fs : 3.2;
xx = 2.1 * cos(2*pi*440*tt + 0.4*pi);
%fs defines how many values per second
fs = 8000;
tt = -1 : 1/fs : 3.2;
yy = exp(-abs(tt)*1.2);% exponential decay
yy = xx.*yy;
soundsc(yy,fs)
```

Figure 2-9: Plotting the 40-hz Sampled Cosine 2.8(b) for (A)

$$T_s = 0 \cdot 005\ S;\ \text{(B) } \mathrm{T_s} = 0 \cdot 0025\ \ \mathrm{S;(C)}\ \mathrm{T_s} = 0 \cdot 0005\ \ \mathrm{S}$$

RESOLUTION MAKES ALL THE DIFFERENCE
0.005, 0.0025, 0.0005

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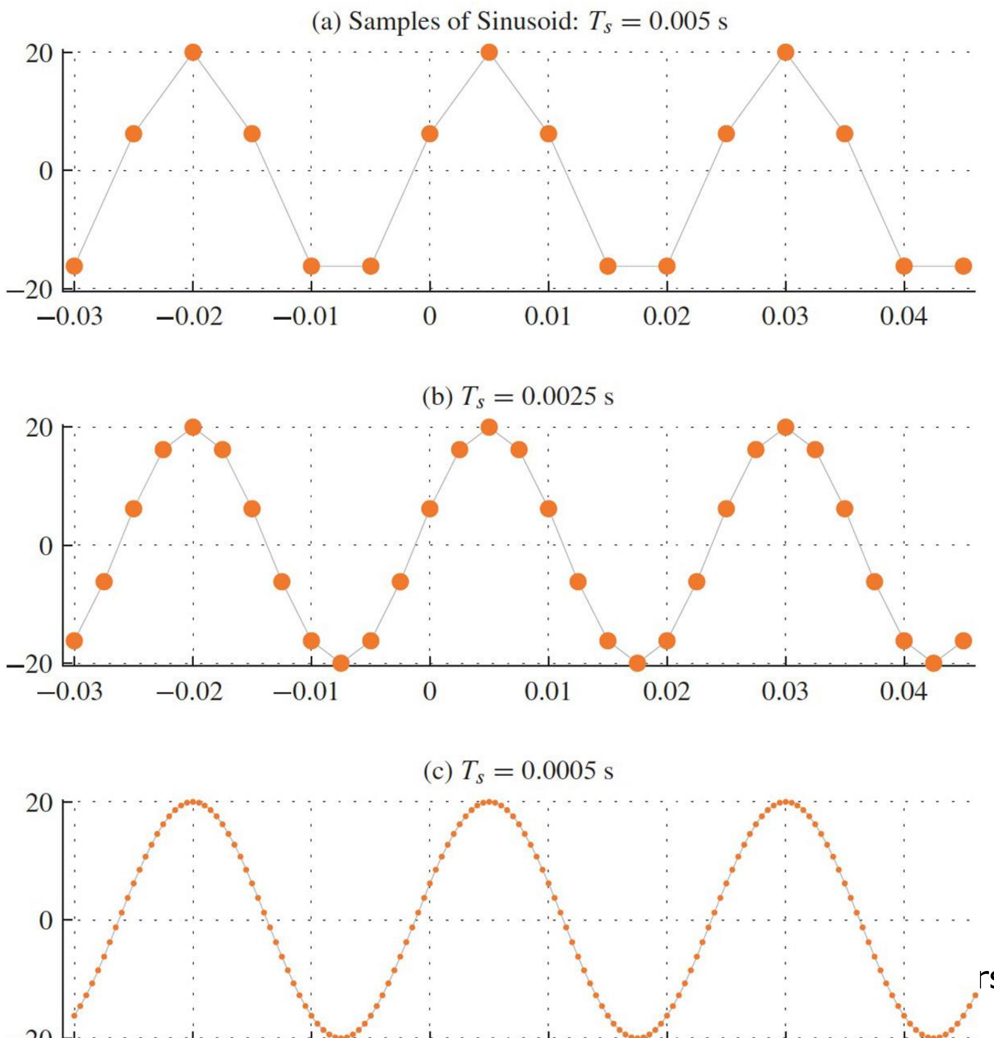

STRAIGHT LINE INTERPOLATION