

## EELE 477

# Lab 1: Introduction to MATLAB

Pre-Lab and Warm-Up: You should read the Pre-Lab and Warm-up sections of this lab assignment and go over all exercises in the Pre-Lab section before attending your lab session.

Verification: The Warm-up section of each lab must be completed during your assigned Lab time and the steps marked Instructor Verification must also be signed off during the lab time. When you have completed a step that requires verification, simply demonstrate the step to the instructor. Turn in the completed verification sheet with your lab report next week.

Lab Report: See the EELE 477 Lab Report Guidelines document.

Provide a written description of your work from Section 3. Paste in graphs, and include complete explanations. Graphs MUST be fully labeled. Axes labeled and a title for every plot. The Lab Report is due at the START of the lab section next week.

## 1-- Pre-Lab

The Pre-Lab this first week is short and straightforward. Make sure that you read through the information below prior to coming to lab.

### 1.1 Overview

MATLAB will be used extensively in all the labs. The primary goal of this lab is to familiarize yourself with using MATLAB. Please refer to Appendix B: Programming in MATLAB in the textbook for an overview. Here are three specific goals for this lab:

1. Use basic MATLAB commands and syntax, including the help system.
2. Learn to write and edit your own script files in MATLAB, and run them as commands.
3. Learn a little about advanced programming techniques for MATLAB, i.e., vectorization.

### 1.2 Getting Started

After logging in, you can start MATLAB by double-clicking on a MATLAB icon or by selecting MATLAB from the START menu.

(a) View the MATLAB introduction by typing `demo` at the MATLAB prompt. This short introduction will demonstrate some of the basics of using MATLAB.

(b) Run the MATLAB help desk by typing `doc`. The help documents provides a hypertext interface to the MATLAB documentation.

(c) Explore the MATLAB help capability available at the command line. Try the following:

```
help
help plot
help colon %<--- a VERY IMPORTANT notation
help ops
help zeros
help ones
lookfor filter %<--- keyword search
```

NOTE: it is possible to force MATLAB to display only one screen-full of information at once by issuing the command `more on`).

(d) Use MATLAB as a calculator. Try the following:

```
pi*pi - 10
sin(pi/4)
ans ^ 2 %<--- "ans" holds the last result
```

(e) Do variable name assignment in MATLAB. Try the following:

```
x = sin( pi/5 );
cos( pi/5 ) %<--- assigned to what?
y = sqrt( 1 - x*x )
ans
```

(f) Complex numbers are natural in MATLAB. The basic operations are supported. Try the following:

```
z = 3 + 4i, w = -3 + 4j
real(z), imag(z)
abs([z,w]) %<-- Vector constructor
conj(z+w)
angle(z)
exp( j*pi )
exp(j*[ pi/4, 0, -pi/4 ])
```

## 2-- Warm-Up

### 2.1 MATLAB Array Indexing

(a) Make sure that you understand the *colon* notation. In particular, explain in words what the following MATLAB code will produce

```
jkl = 0 : 6
jkl = 2 : 4 : 17
jkl = 99 : -1 : 88
ttt = 2 : (1/9) : 4
tpi = pi * [ 0:0.1:2 ];
```

(b) Extracting and/or inserting numbers into a vector is very easy to do. Consider the following definition of *xx*:

```
xx = [ zeros(1,3), linspace(0,1,5), ones(1,4) ]
xx(4:6)
size(xx)
length(xx)
xx(2:2:length(xx))
```

Explain the results echoed from the last four lines of the above code.

(c) Observe the result of the following assignments:

```
yy = xx; yy(4:6) = pi*(1:3)
```

Now write a statement that will take the vector `xx` defined in part (b) and replace the even indexed elements (i.e., `xx(2)`, `xx(4)`, etc) with the constant `pi/3`. Use a vector replacement, not a loop.

<b>Instructor Verification (separate page)</b>
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## 2.2 MATLAB Script Files

(a) Experiment with vectors in MATLAB. Think of the vector as a set of numbers. Try the following:

```
xk = cos( pi*(0:11)/4 ) %<---comment: compute cosines
```

NOTES: a *semicolon* (;) at the end of a statement will suppress the echo to the screen. The text following the % is a comment; it may be omitted.

Explain how the different values of cosine are stored in the vector `xk`. What is `xk(1)`? Is `xk(0)` defined?

(b) (A taste of vectorization) Loops can be written in MATLAB, but they are NOT the most efficient way to get things done. Before writing an expression with a loop construction, always think carefully: often there is a more efficient way to avoid loops by using the colon notation instead. The following code has a loop that computes values of the cosine function. (Remember that the index of `yy( )` must start at 1.) Rewrite this computation without using the loop (follow the style in the previous part).

```
yy = [ ]; %<--- initialize the yy vector to be empty
for k=-5:5
    yy(k+6) = cos( k*pi/3 )
end
yy
```

Explain why it is necessary to write `yy(k+6)`. What happens if you use `yy(k)` instead?

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(c) Plotting is easy in MATLAB for both real and complex numbers. The basic plot command will plot a vector `y` versus a vector `x` connecting successive points by straight lines. Try the following:

```
x = [-3 -1 0 1 3 ];
y = x.*x - 3*x;
plot( x, y )
z = x + y*sqrt(-1)
plot( z ) %<----- complex values: plot imag vs. real
```

Use `help arith` to learn how the operation “dot multiply” `xx.*xx` works when `xx` is a vector; compare with a “matrix multiply.”

*When unsure about a command, use help.*

(d) Use the built-in MATLAB editor to create a script file called `mylab1.m` containing the following lines:

```
tt = -1 : 0.01 : 1;
xx = cos( 5*pi*tt );
zz = 1.4*exp(j*pi/2)*exp(j*5*pi*tt);
%<--- plot a sinusoid
plot( tt, xx, 'b-', tt, real(zz), 'r--' ), grid on
title('TEST PLOT of a SINUSOID')
xlabel('TIME (sec)')
```

Explain why the plot of `real(zz)` is a sinusoid. What is its phase and amplitude? Make a calculation of the phase from a time-shift measured on the plot.

(e) Run your script from MATLAB. To run the file `mylab1` that you created previously, try

```
mylab1           %<---will run the commands in the file
type mylab1     %<---will type out the contents of
                % mylab1.m to the screen
```

**Instructor Verification (separate page)**

### 3-- Lab Exercise: Manipulating Sinusoids with MATLAB

Now you are “on your own.” **Include a short summary of this Section with plots in your Lab Report.**

Write a MATLAB script file to do steps (a) through (d) below. Include a listing of the script file WITH EMBEDDED COMMENTS with your report.

- (a) Generate a time vector (`tt`) to cover a range of  $t$  that will exhibit approximately two cycles of the 4000 Hz sinusoids defined in the next part, part (b). Use a definition for `tt` similar to part 2.2(d). If we use  $T$  to denote the period of the sinusoids, define the starting time of the vector `tt` to be equal to  $-T$ , and the ending time as  $+T$ . Then the two cycles will include  $t = 0$ . **Finally, make sure that you have at least 25 samples per period of the sinusoidal wave.** In other words, when you use the colon operator to define the time vector, make the increment small enough to generate 25 samples per period.
- (b) Generate two 4000 Hz sinusoids with arbitrary amplitude and time-shift.

$$x_1(t) = A_1 \cos(2\pi(4000)(t - t_{m1})) \quad x_2(t) = A_2 \cos(2\pi(4000)(t - t_{m2}))$$

Select the value of the amplitudes and time-shifts as follows: Let  $A_1$  be equal to your age and set  $A_2 = 1.2 A_1$ . For the time-shifts, set  $t_{m1} = (37.2/M) T$  and  $t_{m2} = -(41.3/D) T$ , where  $D$  and  $M$  are the day and month of your birthday, and  $T$  is the period.

Make a plot of both signals over the range of  $-T \leq t \leq T$ . For your final printed output in part (d) below, use `subplot(3,1,1)` and `subplot(3,1,2)` to make a three-panel figure that puts both of these plots in the same figure window. See `help subplot`.

- (c) Create a third sinusoid as the sum:  $x_3(t) = x_1(t) + x_2(t)$ . In MATLAB this amounts to summing the vectors that hold the values of each sinusoid. Make a plot of  $x_3(t)$  over the same range of time as used in the plots of part (b). Include this as the third panel in the plot by using `subplot(3,1,3)`.
- (d) Before printing the three plots, put a title on each subplot, and include your name in one of the titles. See `help title`, `help print` and `help orient`, especially `orient tall`.

### 3.1 Theoretical Calculations

Remember that the phase of a sinusoid can be calculated after measuring the time location (or in the case of a discrete-time signal, the sample index) of a positive peak, if we know the frequency.

- (a) Make measurements of the “time-location of a positive peak” and the amplitude from the plots of  $x_1(t)$  and  $x_2(t)$ , and write those values for  $A_i$  and  $t_{mi}$  directly on the plots. Then calculate (by hand) the phases of the two signals,  $x_1(t)$  and  $x_2(t)$ , by converting each time-shift  $t_{mi}$  to phase. Write the calculated phases  $\phi_i$  directly on the plots.

Note: when doing computations, express phase angles in radians, not degrees!

- (b) Measure the amplitude  $A_3$  and time-shift  $t_{m3}$  of  $x_3(t)$  directly from the plot and then calculate the phase ( $\phi_3$ ) by hand. Write these values directly on the plot to show how the amplitude and time-shift were measured, and how the phase was calculated.
- (c) Now use the phasor addition theorem. Carry out a phasor addition of complex amplitudes for  $x_1(t)$  and  $x_2(t)$  to determine the complex amplitude for  $x_3(t)$ . Use the complex amplitude for  $x_3(t)$  to verify that your previous calculations of  $A_3$  and  $\phi_3$  were correct.

### 3.2 Complex Amplitude

Write one line of MATLAB code that will generate values of the sinusoid  $x_1(t)$  above by using the complex-amplitude representation:

$$x_1(t) = \Re \{ X e^{j\omega t} \}$$

Use appropriate constants for  $X$  and  $\omega$ .

[ End of Lab 1 ]

EELE 477

## Lab 1: Introduction to MATLAB

### INSTRUCTOR VERIFICATION SHEET

For credit, you MUST attach this sheet to your Lab Report and turn it in at the start of the lab session next week.

Your Name: \_\_\_\_\_

Date of lab: \_\_\_\_\_

Part 2.1 Vector replacement using the colon operator:

Verified: \_\_\_\_\_

Part 2.2(b) Explain why it is necessary to write  $yy(k+6)$ . What happens if you use  $yy(k)$  instead?

Verified: \_\_\_\_\_

Part 2.2(d and e) Explain why the plot of  $\text{real}(zz)$  is a sinusoid. What is its amplitude and phase? In the space below, make a calculation of the phase from time-shift.

Verified: \_\_\_\_\_