GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL of ELECTRICAL and COMPUTER ENGINEERING

ECE 2026 Spring 2018
Lab #1: Waveform Plotting, and Reading, Recording and Writing Signals

Date: 16 – 18 Jan. 2018

The labs will be held in room 2440 of the Klaus building. Your GT login will work, if you specify the "Windows domain" to be AD.

If you have difficulty logging in, visit the web site: `www.ece-help.gatech.edu`. If you have MATLAB installed on your laptop, you are *encouraged* to use your laptop in lab instead of the lab computers.

Pre-Lab: You should read the Pre-Lab section of the lab and do all the exercises in the Pre-Lab section ***before your assigned lab time.***

Verification: The Exercise 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**. One of the laboratory instructors must verify the appropriate steps by signing on the **Instructor Verification** line. When you have completed a step that requires verification, simply raise your hand and demonstrate the step to the TA or instructor. Turn in the completed verification sheet to your TA when you leave the lab.

Lab Homework Questions: The Lab-Homework Sheet has a few lab related questions that can be answered at your own pace. The completed Lab-HW sheet is due at the beginning of the next lab.[1]

Forgeries and plagiarism are a violation of the honor code and will be referred to the Dean of Students for disciplinary action. You are allowed to discuss lab exercises with other students, but you cannot give or receive any written material or electronic files. In addition, you are not allowed to use or copy material from old lab reports from previous semesters. Your submitted work must be your own original work.

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1 Pre-Lab

Please read through the information below prior to attending your lab.

Objective: The objective of this lab is to learn to acquire signals into MATLAB and to display them for visualization. Waveform visualization is an important tool as well as a skill in signal analysis. Signals we learn to process in this course may be generated or recorder internally as a data array within MATLAB, or acquired from external sources such as a `wav` file. Furthermore, with a proper format converter, you may also record your own voice or music with your own computer and then load the recorded results, after converting them to the supported formats, into MATLAB for processing to produce interesting effects.

1.1 Intelligent Tutoring System (ITS)

During this first lab you should run ITS and answer a few questions during the warmup. In general, ITS will be used throughout the semester to provide practice on the various concepts covered in ECE-2026.

[1] The predecessor to the three-credit-hour class ECE2026, which was a four-credit-hour class called ECE2025, consisted of labs that require a substantial amount of work to be done outside of lab and an elaborate lab report. To change the workload commensurate with losing one credit hour, we have reworked the labs such that they can be completed in individual lab sessions, without requiring a separate lab report. The in-Lab sessions will be busy, so you will need to come into lab prepared.

1.2 Overview

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

1. Learn basic MATLAB commands and syntax, including the `help` system.
2. 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.
4. Plot two sinusoids, add them and demonstrate the application of the *Phasor Addition Theorem.*

In Lab #0, you have gained or regained familiarity with MATLAB particularly in terms of arithmetic operations. Using simple examples, we learned to assign data values to a variable such as:

```
x = 10;  y = [1 2 3 4 5];   yy = [1 2 3; 4 5 6];
```

A slightly more sophisticated example in Lab #0 was:

```
xx = -0.2:0.01:0.3 ;
```

which will create a row vector of dimension 51, with values that span between -0.2 and 0.3 at an increment of 0.01. The indices of a vector `zz` can be manipulated to perform simple operations such as reversal, e.g.,

```
zz = exp(-0.1*(0:20)); zzReversed = zz(length(zz):-1:1)
```

In this lab, you will learn to use these expressions to generate some interesting *signals.*

Once a signal is generated, an immediate tool we use very often is a plot for visualization and inspection. You will learn to use common plot routines to show, in a number of ways, the signal you have generated or acquired (see below).

Often times, we need to process a signal that is obtained by some other means, instead of being generated internally with MATLAB commands. For example, you may have digital music on your computer, stored as files. Or, you may use your own computer to record a sound or your own speech, which can then be stored as an electronic file. In this lab, you will also learn to read or load external data into MATLAB for processing, and to *write* the processed data or signal into a file for future consumption.

1.3 Microphone and Headset/Loudspeaker

For this lab and many future labs, you will need a microphone and headset. Many laptops already come with these devices. If you need to acquire these devices, there are many inexpensive selections available from Internet vendors. For the work in these labs, you do not need to become an audiophile and buy expensive headphones. (Of course, if you have a passion towards audio and music, you may already have high-quality headphones and microphones. Use them.)

1.4 Getting Prepared

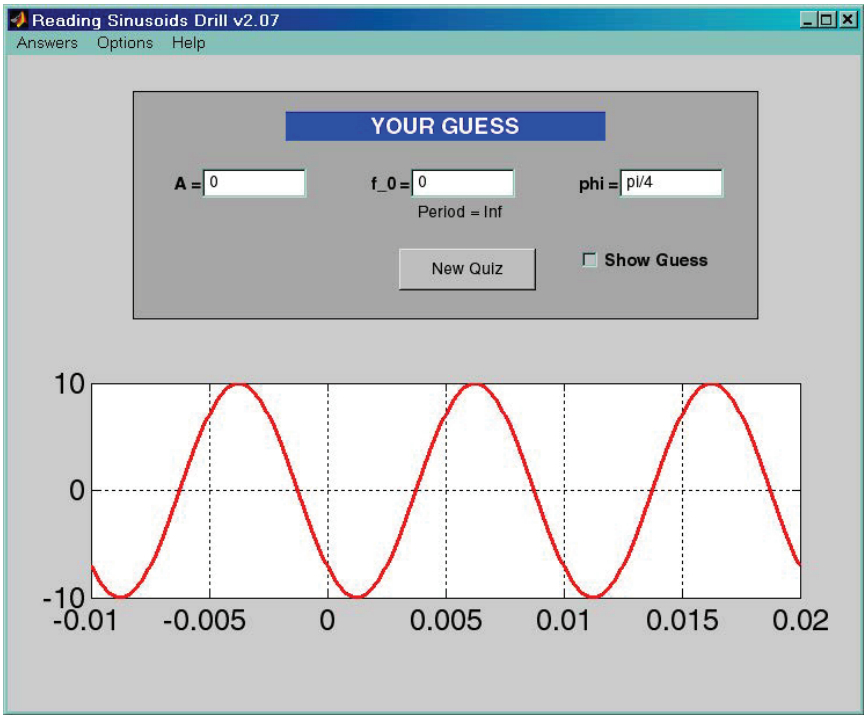
The following list of commands will be used in this lab. Before you come to the lab, read the MATLAB documentation (and use MATLAB's `help` command) to learn about these commands.

```
plot; subplot; figure; hold; input; audioread; audiowrite;
audiorecorder; record; play; getaudiodata
```

In case you have an early version of MATLAB that does not support `audiorecorder` and related commands, search MATLAB and/or the web for the appropriate command.

1.5 GUI for `sindrill`

Demonstrate that you can use the `sindrill` GUI. Set the Level to "Pro" under the `Options` menu. Work a few problems; you can check your answers with the drop-down menu `Answers`.



2 Exercise

For the instructor verification, you will have to demonstrate that you understand things in a given subsection by answering questions from your lab instructor (or TA). It is not necessary to do everything in the subsections, i.e., skip parts that you already know. The Instructor Verification is usually placed close to the most important item, i.e., the one most likely to generate questions from the TAs.

2.1 Interactive Input in MATLAB

MATLAB allows the user to provide input through interactive commands. This may be handy, particularly when you want the user to be able to specify some data values or strings in a function (.m file) during the so- called run-time. Here is a function example (take the cube root of) that involves a user input:

```
function a = crootof
x = input('what: ');
if x >= 0
a=(x)^(1/3);
else
'non-negative number only'
end
```

Then, in MATLAB, the following shows one application of the command crootof:

```
>> crootof
what: 287318
ans =
65.9864
```

where the number 287318 was given by the user. A user can use the input command to provide text strings to MATLAB as well. This is done by specifying a 's' argument in the command line:

```
>> ss= input('Text input: ','s')
Text input: once upon a time
ss =
once upon a time
```

Now, write a MATLAB code that asks the user to input a string, say `Mary had a little lamb`, and then prints out the characters in *reverse order,*, i.e., `bmal elttil a dah yraM`. Demonstrate your working function to the instructor; input your full name as the test case.

Instructor Verification (separate page)

2.2 Generating Sinusoids and Decaying Sinusoids

An example for generating a sinusoid was included in Lab #0. Here, we will again use the built-in MATLAB editor to create a script file called `mySinusoid.m` containing the following lines for future use:

```
function xs = mySinusoid(amp, freq, pha, fs, tsta, tend)
% amp = amplitude
% freq = frequency in cycle per second
% pha = phase, time offset for the first peak
% fs = number of sample values per second
% tsta = starting time in sec
% tend = ending time in sec
tt = tsta : 1/fs : tend; % time indices for all the values
xs = amp * cos( freq*2*pi*tt + pha );
end
```

This function `mySinusoid` can be called once the argument values are specified. For example,

```
amp = 6;
freq = 80;
pha = pi/6;
fs = 8000;
tsta = 0;
tend = 3; %a 3-sec long signal
xs = mySinusoid(amp, freq, pha, fs, tsta, tend);
%<--- plot first three cycles of the generated sinusoid
ts = tsta:1/fs:tsta+3/freq;
Lt = length(ts);
plot( ts, xs(1:Lt), 'b-', ts, 2*xs(1:Lt), 'r--' ), grid on
title('TEST PLOT of TWO SINUSOIDS  (scaling by 2)')
xlabel('TIME (sec)')
```

You may want to try other numbers to appreciate the use of the function. In lecture, the three parameters of a sinusoid have been studied, along with many properties of sinusoids. Here we are most interested in the

plotting tool which has many options (so you may want to read its documentation carefully).

Now, extend the previous example to make a decaying sinusoid, i.e.,

$$x(t) = Ae^{-bt}\cos(\omega t + \varphi) \tag{1}$$

Write a function called `myDecayingSinusoid(A, b, omega, phi, fs, tStart, tEnd)`

Then pick the correct numbers to generate and plot a decaying sinusoid `xDecay` that is 2 seconds long, with a frequency of 40 Hz, an amplitude of 10, a phase of $\pi/4$ rads, and a decay parameter $b = 0.8$. What happens to the plot if we increase the decaying rate to $b = 3$. Show the plotting result to the lab instructor.

Instructor Verification (separate page)

2.3 Reading WAV File into MATLAB and Playing an Array

Many sound files are stored in `.wav` format; see `http://en.wikipedia.org/wiki/WAV` for more information about this particular format. Other formats are available, such as `mp3`; we will focus on `.wav` in this lab. The MATLAB command `audioread` is the one to use to read data in `wav` files into MATLAB data arrays. For example:

```
xx = audioread('myvoice.wav');
```

will load the data in the file `myvoice.wav` into the array `xx`. Another command `length(xx)` will tell you how many values have been read into `xx`. In many applications, you may need to know what is called the sampling rate, which is the number of sample values per second at which the data was acquired into the file. These parameters can be retrieved as part of the `audioread` result:

```
[xx, fs] = audioread('myvoice.wav');
```

For this exercise, you need to access some `wav` files. If you have your own inventory of `wav` files, you are welcome to use them here. (Make sure the file is long enough for the exercise; see below). If not, a file called `ece2026Lab01voice.wav` can be downloaded from `t-square` for your use. Learn to use the `audioread` command to read the data into an array, say `xx`. You can find out how long the signal is in seconds by reading the length of the array via `length(xx)` which gives you the total number of samples and then divide it by `fs`, the sampling rate in samples per second. Then, plot the sound wave `xx`, from $t = 0.25$ to $t = 0.5$. You need to know how to translate time into the index of the array; an example has already been shown above. Show the plotted result to the instructor.

Instructor Verification (separate page)

In MATLAB, an array of data can be played to produce audible sound, using:

```
soundsc(xx, fs);
% what is xx and fs??? Make sure you know what these are
```

Try the command yourself and listen to the data you just read in from the file `ece2026lab01voice.wav`.

2.4 Processing the Data and Writing the Result into a wav File

2.4.1 Time reversal

Following Section 2.2, you have an array `xx` that contains a signal or a sound. There are many simple operations that can be performed on `xx`. For example, scaling where we reduce the signal's amplitude by a half (called attenuation),

```
xh = xx * 0.5;
```

A more complicated operation would be to reverse the time axis of the signal and then plot it.

```
Lx = length(xDecay);
xDecayReversed = xDecay(??:??:??);  % figure out how to fill in those ??s
plot( ... xDecayReversed ... ??? )
```

In the plot of `xDecayReversed`, it should be easy to see the time reversal. Show the plot to the instructor for verification.

Instructor Verification (separate page)

If the signal were a sound file, then the output of the time-reversal could be written out to a new `wav` file:

```
Lxh = length(xh);
xhReversed = xh(??:??:??);  % figure out how to fill in those ??s
audiowrite( 'ECE2026lab01outRev.wav' , xhReversed , fs );
```

If we listen to `xhReversed`, the sound will be played backwards. Note that the argument `fs` can be copied from the `audioread` result. But you can experiment with your own number, such as reducing it to half or doubling it to twice the original value. Using `soundsc`, play the output `wav` file `ECE2026lab01outRev.wav`. You can even combine two operations to have the sound file be played backwards with every other samples skipped.

2.5 Recording and Playing Sounds in MATLAB (For Homework)

You can also record your own sound with MATLAB. To record data from an audio input device (such as a microphone connected to your system) for processing in MATLAB, follow the sequence below:

- Create an audiorecorder object:

```
>> audiobject = audiorecorder(8000, 16, 1);
% an object here is like a device or channel
% fs = 8000; use 8000 values for each second of sound
% nbit = 16; use 2 bytes to represent a value
% nchannel = 1; use 2 for stereo recording...
% (need stereo microphone)
% you may try other numbers
```

- Call record or recordblocking:

```
>> record(audiobject)
>> stop(audiobject)
% record opens a channel that links to audiobject
% stop closes the channel; if you do not close the channel..
% recording continues and audiobject cannot be accessed
```

or

```
>> recordblocking(audiobject, 5);
% record a fixed duration of 5 seconds into audiobject
```

- Create a numeric array corresponding to the signal data using the getaudiodata:

```
>> xx = getaudiodata(audiobject);
```

For example, connect a microphone to your system and record your voice for 5 seconds. Capture the numeric signal data and create a plot (from Mathworks):

```
% Record your voice for 5 seconds.
recObj = audiorecorder(8000, 16, 1);
disp('Start speaking.')
recordblocking(recObj, 5);
disp('End of Recording.');
% Play back the recording.
play(recObj);
% Store data in double-precision array.
myRecording = getaudiodata(recObj);
% Plot the samples.
plot(myRecording);
```

In the above, the array `myRecording` contains the voice data, which can be processed. The recording (or processed results) can be written into a `wav` file using the aforementioned `audiowrite` command.

$\Longrightarrow$ For homework, you should record a vowel sound and measure the pitch period of your voice.

Lab #1
ECE-2026 Spring-2018
INSTRUCTOR VERIFICATION SHEET

Turn this page in to your lab grading TA.

Name: _____ Date of Lab: _____

Part 2.1 Write the string reversal output below and show it to the instructor.

Verified:_____ Date/Time:_____

Part 2.2 Show the plot of a decaying sinusoid.

Verified:_____ Date/Time:_____

Part 2.3 Read in a sound file and plot a section.

Verified:_____ Date/Time:_____

Part 2.4.1 Show the plot of a time-reversed decaying sinusoid.

Verified:_____ Date/Time:_____

Lab #1
ECE-2026 Spring-2018
LAB REPORT QUESTIONS

Name: _____ Date: _____

1. Make a recording of your own voice saying the vowel "AAAHH." Make sure to turn in your code segment.
2. Plot a section of the recording where the signal is quasi-periodic. Include 5 periods. This should look something like the "bat signal" shown in lecture. Make sure to turn in your code segment.
3. Measure the period. In fact, measure the period five times and take an average. Annotate the plot to show where/how the measurements were made.
4. Turn in the plot at the beginning of Lab #2. Write your estimated average pitch period in the title of the plot.