

Experiment 0

Introduction, Instrument Basics and Software

Systems and Signals Laboratory

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1. Introduction: Syllabus and laboratory policy

Your lab instructor will explain the course syllabus and laboratory policy at the beginning of the first lab session of the first week of classes.

2. Lab structure: Pre-lab work, lab activities and post-lab work

A student's work in this laboratory course is divided into pre-lab work, lab activities and post-lab work.

- **Pre-lab work:** Students are expected to complete a reading assignment and other preparatory work, before coming to the lab. The reading assignment can be a brief tutorial on using a lab instrument, a brief tutorial on using software and/or review of fundamental concepts and theory. The pre-lab work will also include simulations and, in some cases, analytical solutions of problems directly related to the upcoming lab experiment. At the beginning of the lab session, each student is expected to turn in his/her own solutions to pre-lab problems, a written summary of their reading assignment and/or the results of a simulation. There could also be an unannounced brief (10-15 min) quiz on the pre-lab assignment at the beginning of the associated lab session.
- **Laboratory activities:** In the lab, students work in teams of two individuals. The students will use available instruments and electronic components to build basic systems and make measurements. **Each student is required to obtain a spiral bound notebook (or a laptop).** The notebook (or laptop) will be used to keep a laboratory journal. The contents of the lab journal must not be shared among the two team members, or any other student. Students enter data, sketches and notes during each lab exercise into their notebook or laptop. When a scope (and/or a spectrum/network analyzer) is used to display signals

during an experiment, the student must save an image of the displayed scope's traces and/or waveform data on a flash memory stick. The student team photo must be taken (by the lab instructor using, say, the student's smartphone camera) with the experimental system that they built showing in the background. These scope screen captures and team photograph are to be incorporated in the lab report. At the end of each lab activity, the lab instructor will examine the student journal.

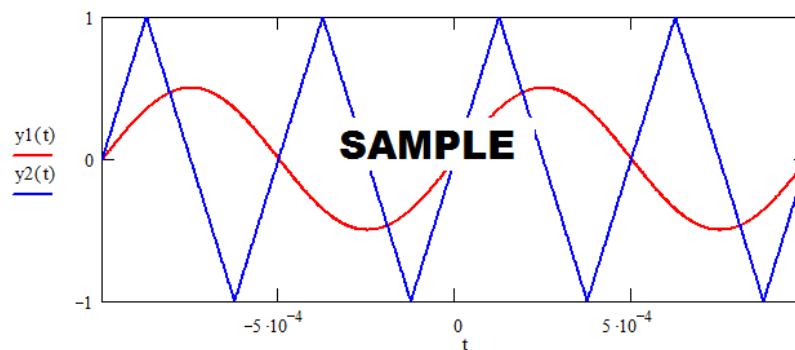
- **Post-lab work:** Students are expected to write reports to analyze, discuss and report their results. The post-lab work is essentially designed to analyze the experimental data, compare it to the pre-lab theoretical results and simulations and to generate the lab report. The lab report (submitted by each student independently) must be entirely his/her own work. Only the results of the lab experiments (data, plots, etc.) can be shared among the two lab partners. Each report must include a title page, introduction, experimental results, theoretical analysis and derivations, simulation results, discussion and conclusion. A student's lab report must be based on his/her pre-lab assignment, lab journal entries, saved scope trace images and data captures and post-lab work. The report must be typed and submitted electronically (in pdf format) to the lab instructor **before 5:00 pm one day before the next lab session**. The file name must be as follows: "YourName_ExperimentX. Also, any software-package-generated files must be placed inside a zipped folder that carries the student name and emailed to the lab instructor along with the lab report. Late reports will not be accepted and a score of zero will be assigned. Refer to Appendix 1 for more details on the lab report format.

3. Pre-lab

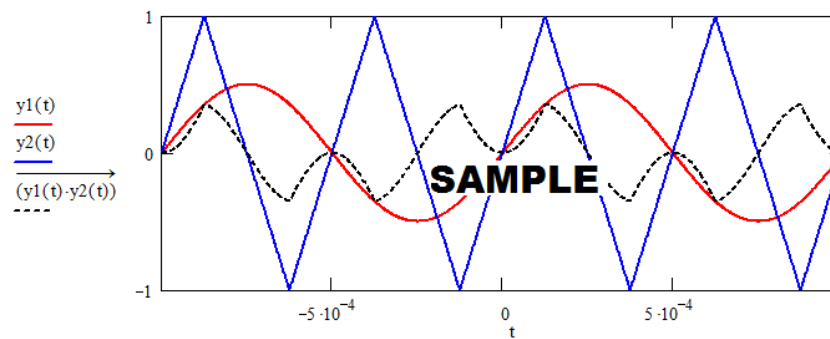
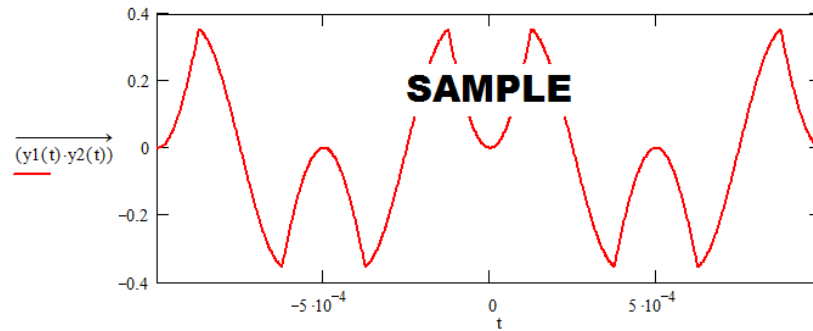
For Experiment 0 only, the pre-lab work is to be completed after this lab session. You may now skip to the lab activity.

In the following, you are to employ Matlab or (preferably) Mathcad to generate the indicated plots.

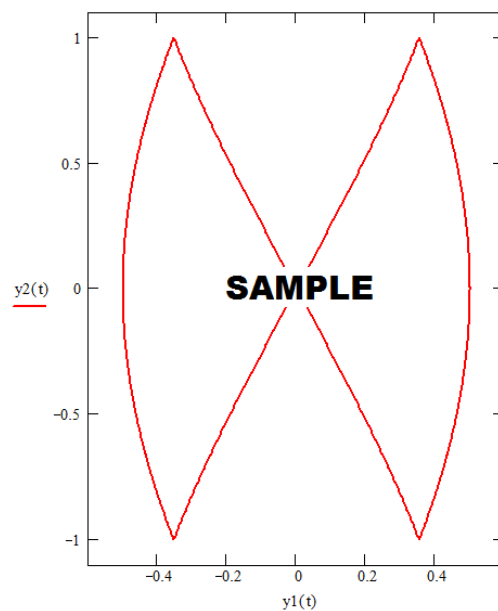
- Plot the following two signals: $y_1(t)$ a sine wave of amplitude 0.5Volt and 1kHz frequency, and $y_2(t)$ a triangular wave with 2 Volt peak-to-peak and 2kHz frequency. The triangular wave must pass through the origin, as to be phase aligned with the sine wave. Your answer should be similar to the sample plot shown below.



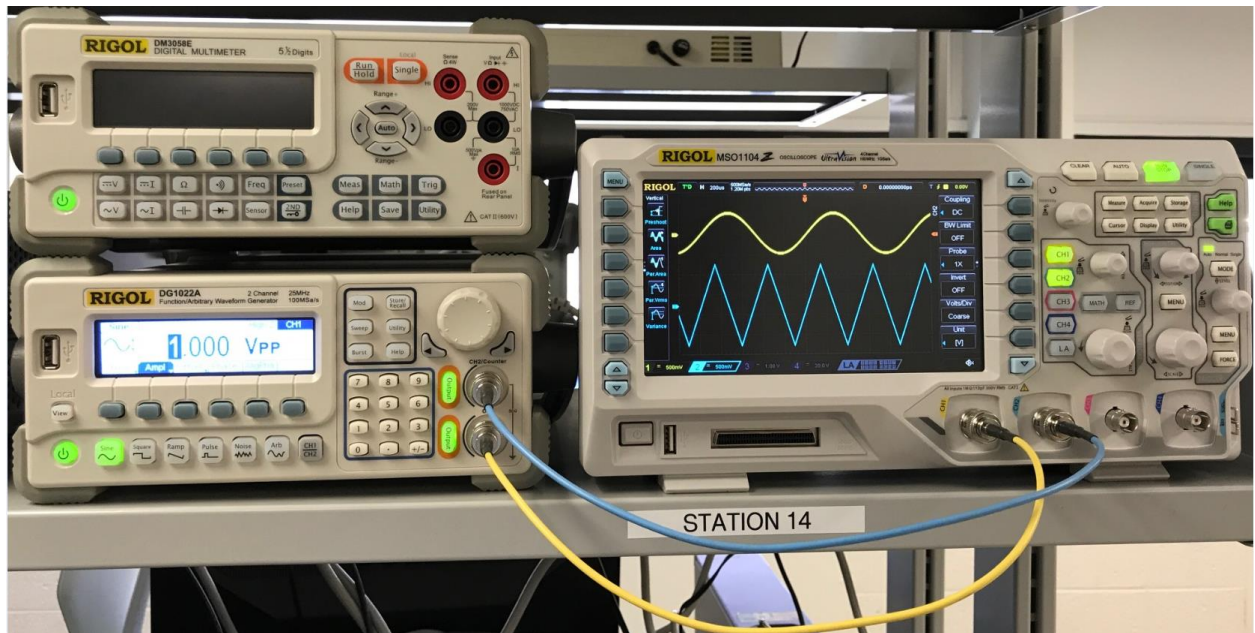
- b. Plot the product of the two signals. Recall that Matlab employs the operation “ $y1.*y2$ ” for component-wise multiplication of two arrays. Similarly, Mathcad employs the notation $\overrightarrow{y1(t) \cdot y2(t)}$ for component-wise multiplication of the two signals (functions) $y1(t)$ and $y2(t)$. The following are sample plots using Mathcad.



- c. Generate a parametric plot of $y2(t)$ versus $y1(t)$. Your plot should look as follows.



4. Lab activity

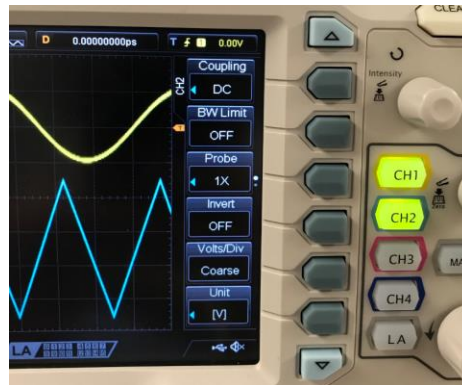


You have already used various laboratory instruments in earlier ECE laboratory courses including a waveform generator and a scope. In this lab activity, the student performs some preliminary experiments that will familiarize her/him with the RIGOL instruments. Mastering the use of the waveform generator and the oscilloscope are of fundamental importance for all future experimental work in this course.

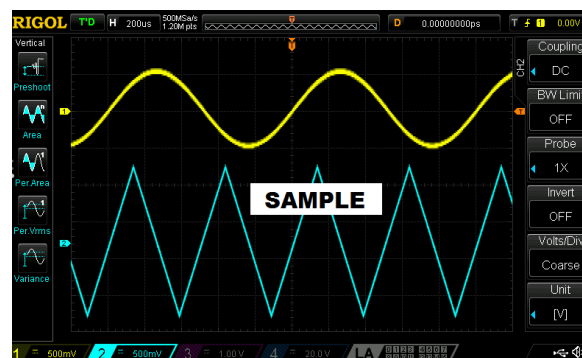
- a. Generate a 1 kHz, 1Vpp (i.e., 1 Volt peak-to-peak) sine wave on channel 1 of the waveform generator. Also, generate a 2 kHz, 2Vpp triangular wave on channel 2 of the waveform generator. Both signals are to have zero offset. The waveform generator will only output the waveforms (through the BNC connectors labelled CH1 and CH2) if the “Output” button/indicators are lit. For example, in the following figure, only the signal on CH1 is active.



- b. Press the “AligPha” button on the waveform generator in order for the generated signals to be aligned.
- c. Use two short BNC to BNC cables to connect the outputs CH1 and CH2 of the waveform generator to CH1 and CH2 of the scope, respectively.
- d. Configure CH1 and CH2 of the scope to allow for DC coupling, 1X probe and no inversion, as shown below.



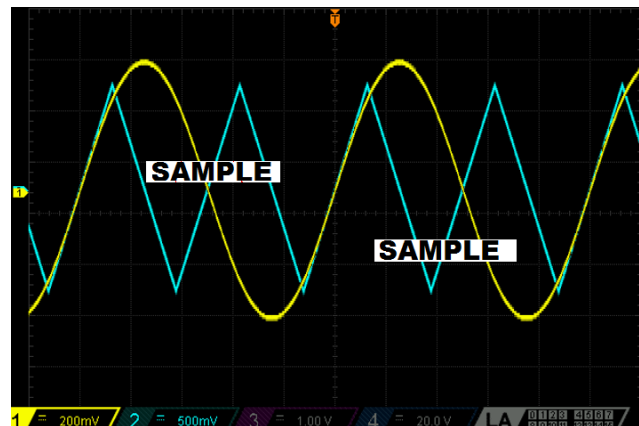
- e. Adjust the volt/div and time/division settings of CH1 and CH2 of the scope so that the displayed traces look like the ones in the following image. The scope allows you to shift the signals (up or down) so that each will have its own voltage reference level, as shown.



- f. Save the scope’s display image on your memory stick by first inserting the memory stick in the USB port of the scope (located on the lower left side of the scope’s front panel). Next, press the green colored button with the printer icon. Choose the option of saving the file to your external drive (D:). The scope will save the display image in a default file named “DS1Z_QuickPrint1.png”.



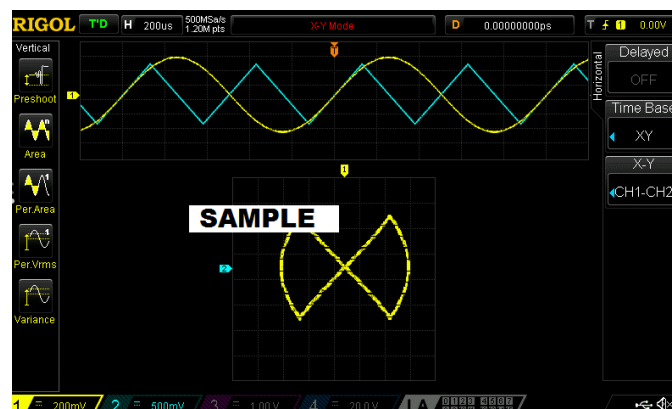
- g. Scale and shift the scope's waveforms so that they look similar to the following image. Save the scope screen image on your flash memory stick, as you did in Step f. The scope will save the image in the file "DS1Z_QuickPrint2".



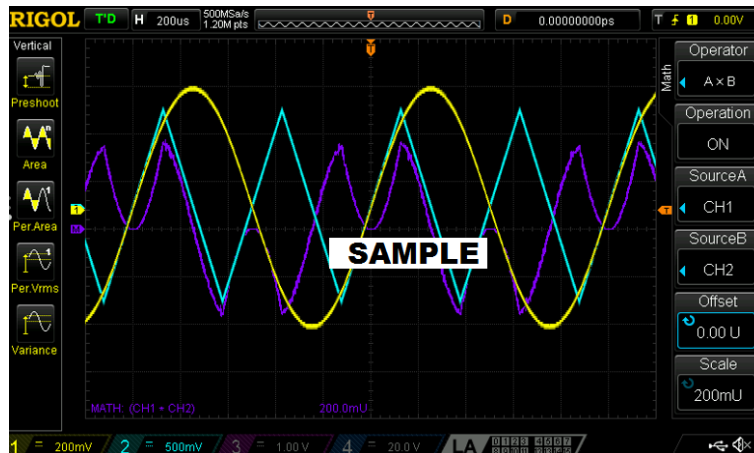
- h. Use the "Storage" button utility to save the traces data in a .csv spreadsheet compatible file. The scope will assign the default name "NewFile1". You will use this data in the post-lab to plot the signals using Mathcad/Matlab. If you are to open this saved file with Excel you should see the following data at the top part of the spreadsheet:

	A	B	C	D	E
1	X	CH1	CH2	Start	Increment
2	Sequence	Volt	Volt	-1.20E-03	2.00E-06
3	0	-4.20E-01	-1.60E-01		
4	1	-5.00E-01	-2.80E-01		
5	2	-4.80E-01	-2.00E-01		
6	3	-4.20E-01	-3.20E-01		
7	4	-4.80E-01	-2.40E-01		
8	5	-4.20E-01	-3.60E-01		
9	6	-4.20E-01	-3.60E-01		

- i. Generate an X-Y plot of the two signals and capture the scope's display image. Your plot should look like the following plot. Pressing the "Menu" button (within the HORIZONTAL section of the scope's front panel) allows you to set the scope mode to X-Y plotting and to choose the channels to be plotted.



- j. Save the scope's display image on your flash memory stick, as you did in Step f. The scope will save the image in the file "DS1Z_QuickPrint3".
- k. With the aid of the "Math" utility of the scope, generate the product of the two signals. Save the scope's display image to your memory stick. Your lab instructor will show you how to use the scope's Math utility. Your plot should look as the one shown below.



Note: Ask your lab TA to give your team an Analog Discovery 2 module with its USB connector and two short BNC-to-BNC cables (refer to figure below). You will need those items to complete Step g in the Post-lab activity at home.

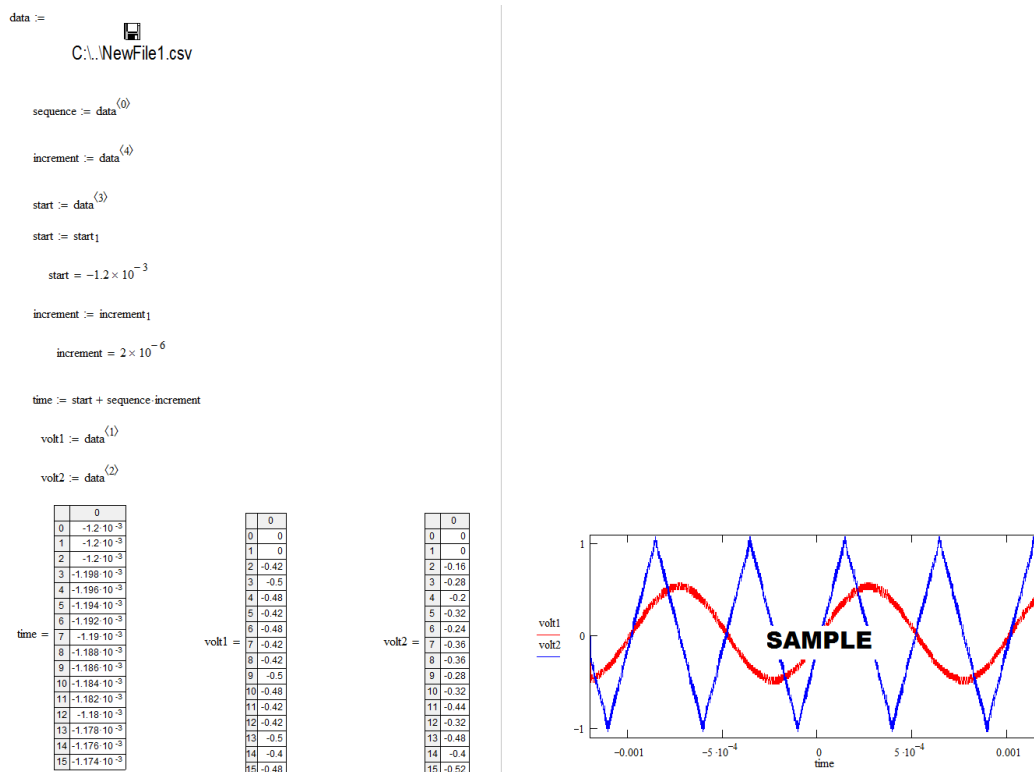


5. Post-lab

The results from the following activities along with the pre-lab work and experimental results (including scope display captures and trace data) are to be integrated together in your lab report.

Note: The lab report must not look like a solution to a set of problems as in traditional homework assignments. The lab report must have the format and structure as outlined in Appendix 1.

- Transfer the files that you have saved on your memory stick to your PC and save them in a directory named "Experiment0 lab work." You should do this for all future experiments and be prepared to provide this lab generated data and scope display captures to your lab instructor if he/she request it.
- Make sure you have installed Jing on your PC because you will be using it extensively for capturing screen images and inserting them in your lab report.
- Use Mathcad (or Matlab) to import and plot the scope waveform data (NewFile1.csv) that you have saved (refer to Part h of Section 4). You may use the following Mathcad worksheet (also available for download from the "experiments link" on the course website): http://neuron.eng.wayne.edu/auth/ece4340/plotting_imported_scope_traces.mcd After you open the Mathcad worksheet, you have to right-click on the file name in the "data" instruction and click on "Choose File" and choose the correct data file. Next, capture the Mathcad screen (refer to sample image below) and include it in your report.



- d. Since the RIGOL scope employs sampling and digitization to capture an analog signal, and since analog signals are noisy by their nature, the noise exhibited in the above plotted signal is to be expected. The high-frequency noise can be suppressed by post-processing. Employ the following Mathcad-based averaging method to generate the noise-suppressed waveforms, as shown below.

Noise suppression using averaging:

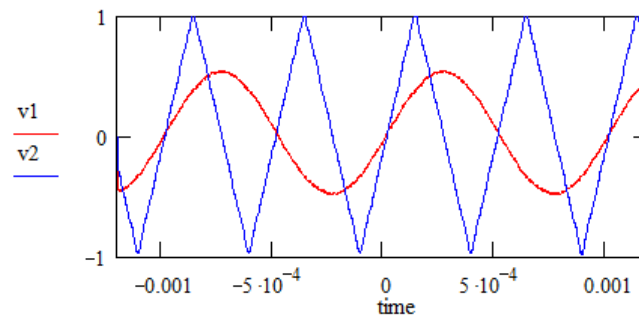
$$n := \text{rows}(\text{volt1})$$

$$n = 1.202 \times 10^3$$

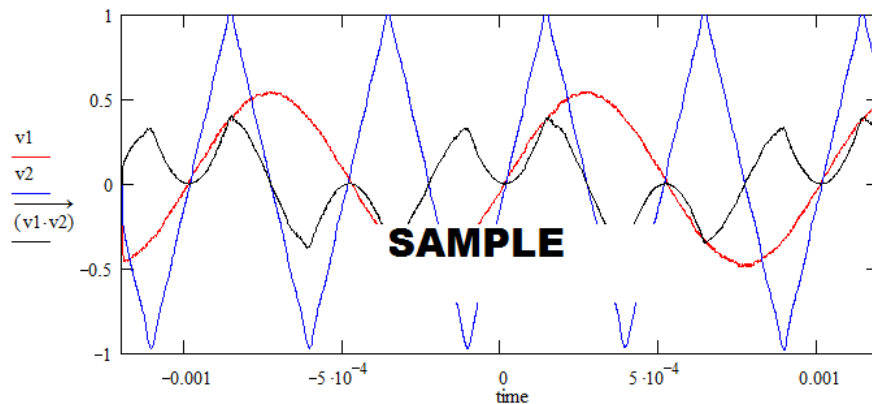
$$k := 0..n-7$$

$$v1_{k+3} := \frac{\text{volt1}_k + \text{volt1}_{k+1} + \text{volt1}_{k+2} + \text{volt1}_{k+3} + \text{volt1}_{k+4} + \text{volt1}_{k+5} + \text{volt1}_{k+6}}{7}$$

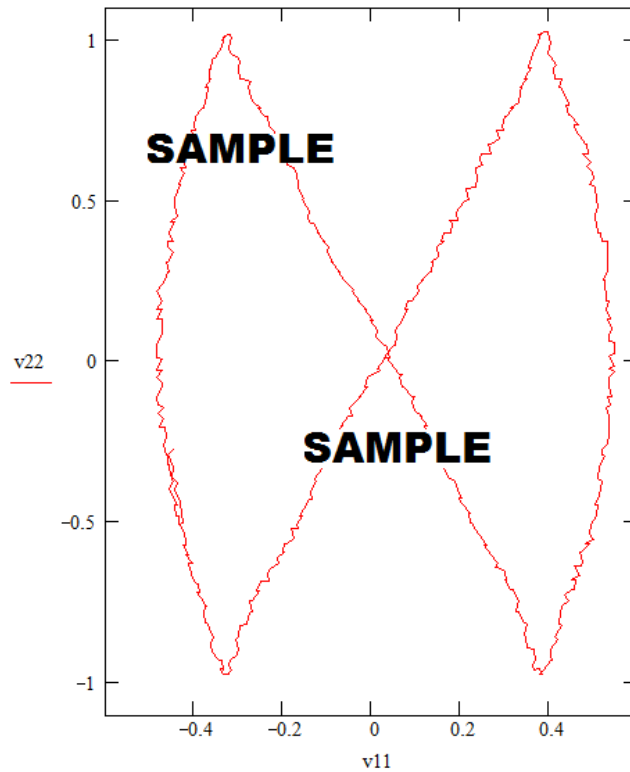
$$v2_{k+3} := \frac{\text{volt2}_k + \text{volt2}_{k+1} + \text{volt2}_{k+2} + \text{volt2}_{k+3} + \text{volt2}_{k+4} + \text{volt2}_{k+5} + \text{volt2}_{k+6}}{7}$$



- e. Employ the averaged signals $v1$ and $v2$ from the previous step and generate the following plot. The signal $\overrightarrow{v1 \cdot v2}$ represents the (component-wise) product of the signals $v1$ and $v2$. This operation is equivalent to the “.” operation in Matlab.



- f. Generate the parametric plot of v_2 versus v_1 as shown below. The signals v_{11} and v_{22} in the plot are sub-signals that were generated from v_1 and v_2 by retaining the 5th through the 520th samples. This can be done employing the submatrix command in Mathcad.



- g. Repeat Step k of the Lab activity employing the Analog Discovery 2 Module that you were provided by your TA. Read the following [tutorial](#) to get started.

Appendix 1

Laboratory Report Format

The following are guidelines for preparing your laboratory report. Each student must write his/her own lab report for every experiment.

- **Title:** The cover page of your report should have the title of the lab experiment, the date the experiment was performed and your name. The photo of the team and their completed experimental setup must be inserted on the cover page. You must also include the following signed statement at the bottom of the cover page: *“I have neither received nor provided any assistance on this work.”*
- **Introduction:** State the objectives of the experiment.
- **Experimental Results:** Various measurements are typically made in a given experiment. In this section, you are to describe (using plots, diagrams and pictures) the experimental set-up and report your results. Present your data in tables or graphs. Use a spreadsheet (or graphing software: Mathcad or Matlab) to generate all graphs. You should include all scope display captures.
- **Theoretical Results:** This section must provide the analytical work (derivations) associated with the experiment including any analysis performed in the pre-lab.
- **Simulation Results:** Most experiments will require you to perform circuit analysis using Electronics Workbench (or Multisim) or computational software such as Matlab or Mathcad. You should include in your report screen captures that are generated by such software (a PC screen capture such as Jing may be used). These include circuit schematic and virtual instrument displays (e.g., scope traces), Simulink block diagrams and graphs generated using Matlab/Mathcad/Simulink. Also, include additional tables and graphs that help explain your simulation results.
- **Discussion:** In this section you are to compare experimental, theoretical and simulation results. Present those results in table and/or graph form. Most measurements will contain some error. The relative error (in percent) is to be used:

$$\varepsilon = (100) \frac{\text{Theoretical value} - \text{Measured value}}{\text{Theoretical value}}$$

Calculate the relative error and discuss its possible sources. If the error is less than 5 percent, consider the theory, simulation and measurements to coincide. If the error is greater than 5 percent, you should comment on the possible source(s) for such error (such as things that are not accounted for in the experiment or in the theoretical results, or possible set-up errors).

- **Conclusion:** In this section, you summarize all key findings and lessons learned. You also answer the following questions: Have the objectives of the experiment been met? Were there errors in the measurements that you could not account for? Etc.

Appendix 2

Software installation on student laptops: Matlab, Mathcad, Multisim (or Electronics Workbench), WaveForms, and PC screen capture

Students are expected to install software packages on their laptops. Some of these packages (Mathcad, Matlab and Multisim) were required in previous courses taken by the student in her/his ECE program at Wayne, and students should already have them installed on their laptops. The lab instructor will explain how to install the software and where to download it from.

The software packages that will be used in this course are:

- Matlab/Simulink (student version should have already been purchased by students)
- Mathcad (can be downloaded from the course website)
- Multisim (student version can be purchased on-line; see link on the course web site)
- Waveforms (software for interfacing with the Digilent AnalogDiscovery2 module; see link on the course web site)
- PC screen capture software (Jing screen capture software is free and can be downloaded from the course webpage).

Note: The student can start installing the above software on their laptops in class if time allows. Otherwise, the installation of such software is left as an assignment and must be completed before the next lab session. See your lab instructor during his/her office hours for help if you encounter installation difficulties. Bring your laptop to the lab and have your instructor verify that you have successfully installed the above listed software packages.