Lab Final

Procedure

Deliverables: Fully graded lab notebook, plot and script submitted to lab instructors via email

Exam Rules

This is an in-lab final exam designed to test your *individual* laboratory skills. You have one hour to perform the procedure and make the deliverables outlined below *by yourself*. You are to make an entry into your lab notebook as you have been doing through out the semester. Your lab notebook entry *must* follow the lab notebook guidelines posted on the resources page of the course website (https://www3.nd.edu/~prumbach/AME20216/resources/notebook_guidelines.pdf).

When you have collected the data and finished the deliverables, please email your plot and Matlab script to the TA and turn in your lab notebook for grading. (See Data Analysis and Deliverables section for details).

Measuring the Speed of Sound in Air

For this in-lab exam, you will use the ultrasonic transducers (UTs) to measure the speed of sound in air. In short, the transmitter will send out an ultrasonic pulse, and the receiver will record the echo. You will measure the time lag Δt between the pulse and echo as function of distance Δx and use this data to determine the speed of sound c in air.

Procedure

1. Sketch a schematic of the experimental set-up, and write a few sentences describing it.
2. Connect the UTs to the oscilloscope and function generator as you did in lab A10:
    a. Put the BNC T-adapter on the output of the Tektronix function generator and connect one of the terminals to Channel 1 on the oscilloscope.
    b. Connect the other end of the BNC adapter to the ultrasonic transducer (UT) that has a “T” engraved on the back. (The “T” stands for transmitter.) The cable has black heat shrink tubing. The receiver has white heat shrink tubing.
    c. Connect the other UT (the receiver) to Channel 2 on the oscilloscope.
3. Turn on the function generator reset it to the factor default by pressing the “default” button.
4. On the output menu, select “Load Impedance”, and then select “High Z”.
5. Position the UTs 10 cm away from the reflection plate. Using a 40 KHz continuous sine, turn up the amplitude on the function generator to 10 Vpp and press the “On” button above the output. Vary the frequency on the function generator until you find the resonance frequency. Record the resonance frequency in your lab notebook.
6. Press the button that says “Burst” near the top of the function generator.

7. On the burst menu select "more" in the bottom right of the screen. Choose 10 cycles and a "trigger interval" of 10 ms.
8. Set the frequency to the resonance frequency that you measured earlier and amplitude to 10 V_{PP}.
9. Turn on the output of the function generator. Adjust the vertical and horizontal scale and position until you see a nice, clean periodic burst on the transmitter (CH1). The echo shows up on the receiver (CH2) as a periodic blob.
10. Move the UTs along the rail, and see how the time lag Δt between the burst and echo changes. Convince yourself that this makes sense.
11. Use the cursors on the scope to measure Δt between the burst and echo. Cursor (a) should be placed at the very beginning of the burst on CH1 and cursor (b) on the very beginning of the blob on CH2, as shown in Fig. 1.
12. Measure Δt as a function of the distance from the UTs to reflection plate. Start at a distance of 10 cm and collect data in 10 cm increments all the way up to 100 cm. (You should end up with 10 data points total recorded in a table in your notebook.) Be sure to adjust the horizontal scale on the scope such that only a single burst and a single blob is visible on the screen at any given position Δx.

Pro-tip: Make sure there are no cables hanging in the way between the UTs and the aluminum plate. They will produce a spurious echo.

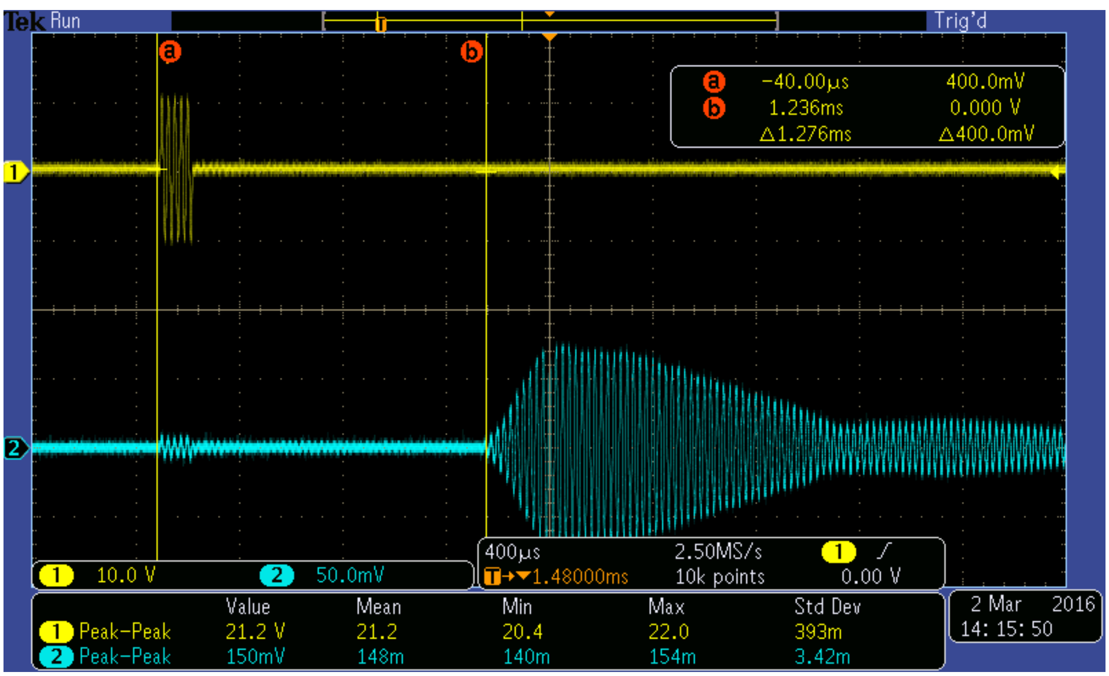

Figure 1. A screen shot of the oscilloscope demonstrating how to use the cursors to measure Δt.

Determining the Speed of Sound

The time it takes for the sound wave to travel from the transmitter, echo off the plate, and return to the receiver is $\Delta t = 2\Delta x/c$. This equation can be rearranged to obtain

$$\Delta x = \frac{c}{2}\Delta t \quad . \tag{1}$$

Plot your data and use the fit() command in Matlab to obtain the best fit slope and its uncertainty. Use these values to extrapolate the speed of sound c and its uncertainty U_c. Similar to A2 - Galileo's inclined plane, the uncertainty in the speed of sound can be determined from the relationship

$$\frac{U_c}{c} = \frac{U_{SLOPE}}{SLOPE}, \tag{2}$$

where $SLOPE$ is the slope and U_{SLOPE} is the uncertainty in the slope, both of which are determined from the output of the fit() command. **Perform all of these calculations in your lab notebook. 2.**

In your lab notebook, report the speed of sound c and its uncertainty that you extrapolated from the plot of distance vs. time for the ultrasonic transducer. It should take the form $c \pm Uc$ with the correct units significant figures. **Draw a box around it, so the grader can easily find it.**

Data Analysis and Deliverables

Please email the following deliverables to your lab section TA with the subject line "LAB FINAL – AME20216" (C.C. Prof. Rumbach on the email.) A list of the TA email addresses can be found on the "Lab Resources" page of the course website under the link "TA Contact Info.".

1. Make a plot of **distance Δx as a function of time Δt** for the ultrasonic transducer **with a linear curve fit**. Save it as a PDF with a file name that uniquely identifies it as yours, and attach it to the email.

2. Attach the Matlab script you used to make the plot and linear curve fit.

3. In the body of the email, write a caption describing the plot. Be sure to include the extrapolated speed of sound and its uncertainty with correct units.

Appendix A

Equipment Required

Speed of Sound
- Tek AFG3021 function generator
- Tek DPO3012
- BNC-BNC cable
- BNC T adapter
- 80/20 rail with 12” aluminum square plate
- Ultrasonic transmitter/receiver mounted in carriage in 80/20 slot
- Meter stick
- 3/15” allen wrench