Lab Final
Procedure

Deliverables: Checked lab notebook; plot, Matlab script, and oscilloscope screenshot submitted to lab instructors and TA via email

Exam Rules

This is an in-lab final exam designed to test your *individual* laboratory skills. Sharing results with other students will be considered a violation of the academics honor code.

You have 50 minutes to perform the procedure, make the deliverables, and email them to your TA and lab instructors. You are to make an entry into your lab notebook as you have been doing throughout 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).

You must demonstrate your working system to the lab instructor, have them sign your lab notebook, then email the deliverables to the TA and lab instructors before the 50 minutes is up. (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. Write down which lab station you are working at.
3. 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 T-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.
4. Turn on the function generator, and reset it to the factor default by pressing the "default" button.
5. On the output menu, select "Load Impedance", and then select "High Z".
6. Position the UTs 10 cm away from the reflection plate.

7. Set up the function generator to output a 10 V peak-to-peak sine wave with a frequency near the resonance that you measured in the A10 lab. Make sure you press the Output “On” button to enable the output of the function generator.
8. Vary the frequency on the function generator until you find the resonance frequency. Record the resonance frequency in your lab notebook.
9. Press the button that says “Burst” near the top of the function generator.
10. On the burst menu, set the number of cycles to be 10. Then, select “more” in the bottom right of the screen, and set the “trigger interval” to be 10 ms.
11. Set the frequency to the resonance frequency that you measured earlier and amplitude to 10 V_{PP}.
12. Adjust the vertical and horizontal scale and position on the oscilloscope until you see a nice, clean periodic burst on the transmitter (CH1). The echo shows up on the receiver (CH2) as a periodic blob.
13. 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.
14. 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.

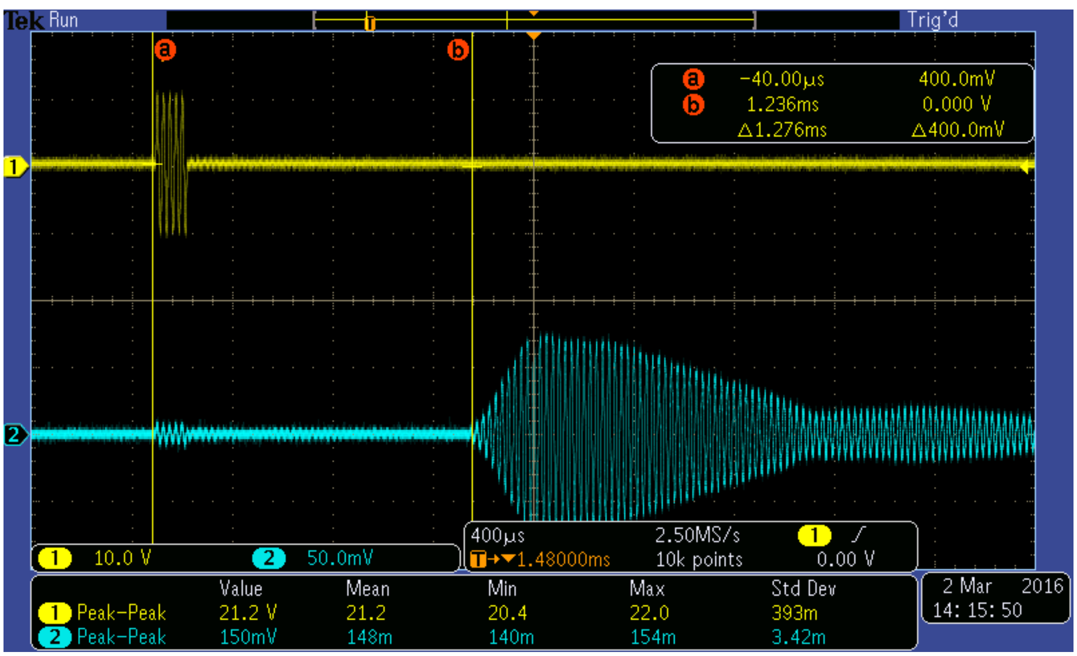

Figure 1. A screen shot of the oscilloscope demonstrating how to use the cursors to measure Δt.

15. Insert the thumb drive into the oscilloscope.
16. Press the “menu” button below the screen, and press “Save screen image” then “OK” to save a screenshot to the thumb drive. Transfer the screenshot to your laptop or the lab computer. (The oscilloscope screenshot has a timestamp on it, so no funny business!)

17. **Delete the screen shot from the thumb drive** after you have transferred it to your computer.
18. The lab instructor has written 6 values of distance Δx (cm) on the white board. Write down these values in a table in your lab notebook.
19. Measure Δt as a function of the distance x from the UTs to reflection plate. (Use the values of Δx (cm) that are written on the whiteboard.) 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.

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 A1 - 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.

In your lab notebook, report the speed of sound c and its uncertainty (units of m/s) 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 and significant figures. **You will then write a caption including the speed of sound and its uncertainty and email it to the TA along with your Matlab script, plot, and screenshot of the oscilloscope. (See the deliverables listed below.)**

Clean-up

- Leave the oscilloscope and function generator turned on.
- Disconnect the cable.
- Return the flash drive to the TA.

Data Analysis and Deliverables

Please email the following deliverables to your lab section TA with the subject line "LAB FINAL – AME20216". You must C.C. Prof. Rumbach and Prof. Ott on the email. A list of the TA email addresses can be found in Appendix B.

1. Attach the screen shot of the oscilloscope.

2. Make a plot of distance Δx (m) as a function of time Δt (s) 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.

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

4. In the body of the email, write a caption describing the plot. Be sure to include the extrapolated speed of sound and its uncertainty in units of m/s. Also note which lab station you used.

Appendix A

Equipment Required

Speed of Sound
- Tek AFG3021 function generator
- Tek DPO3012 Oscilloscope
- 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
- 3/16” allen wrench
- Flash drives

Appendix B

TA Contact Info

Lab TAs

Mon. 12:45 – 2:45 – Will Jordan, wjordan2@nd.edu

Mon. 3:00 – 5:00 – Nicholas Adrian, nadrian@nd.edu

Tues. 3:30 – 5:30 – Alin Stoica, astoica@nd.edu

Weds. 12:45 – 2:45 – Haley Marco, hmarco@nd.edu

Weds. 3:00 – 5:00 – Thomas DeFoor, tdefoor@nd.edu

Lab Instructors

John Ott – jott@nd.edu.

Paul Rumbach – prumbach@nd.edu