2A Pre-Lab Assignment
(due by Mon/Tue Lab)

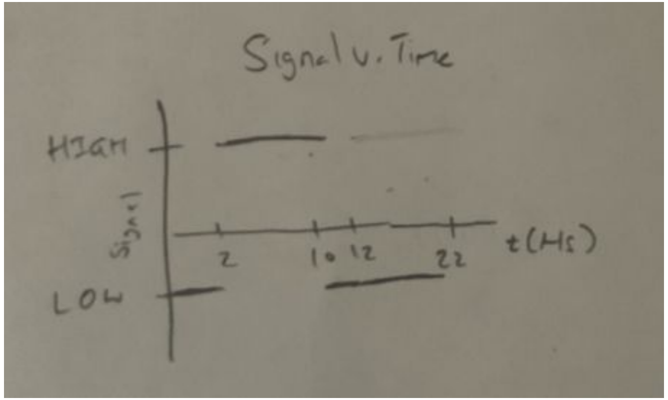
Submit answers to Slides 6 & 7 on Gradescope.

Ultrasonic sensor

- For the next lab we will be using an ultrasonic sensor. This works by emitting a sound wave from a speaker and bouncing it off an object. The delay between the sending and retrieval of this sound wave allows us to determine the distance to the object. Assuming a speed of sound of 343 m/s, answer the questions below.
  - How far in centimeters does a sound wave travel in 3000 microseconds?
    - 102.9cm
  - How long in microseconds does it take a sound wave to travel 30 cm? Truncate your answer to the first decimal place.
    - 874.6 microseconds
  - How long in microseconds does it take for a sound wave generated to bounce and get back from an object 50 cm away?
    - 2915.45 microseconds

Ultrasonic sensor code

To the right is the code you will be using to send out the sound pulse. Below, paste a plot of the signal as a function of time with the time axis in microseconds. This plot may be hand-drawn.




```
//------- UltraSound -------
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
```

Ruler/reference length

Lab 2A requires a ruler or any other distance measuring apparatus. If you do not have a ruler, please identify objects in your place of stay with known reference lengths. Lab 2A will require at least six reference lengths.

Between-Labs Assignment
(due by Wed/Thu Lab)

Submit answers to Slides 34, 35, 36 and 37 on Gradescope.

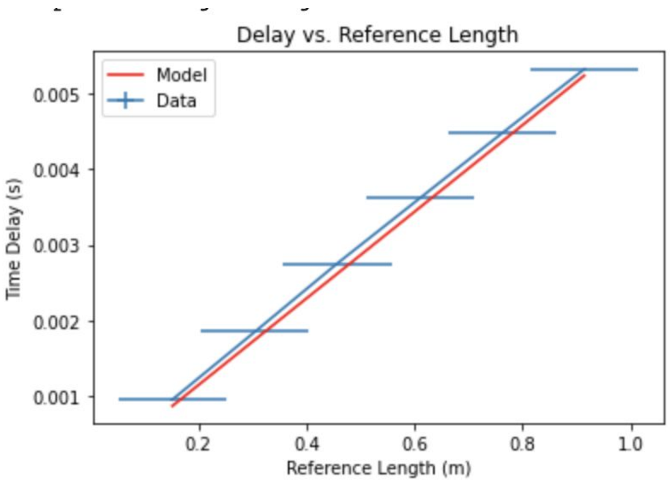
Distance vs delay

Distance (cm)	Delay (microsecond, mean ± stddev)
15.2	955 ± 12.1
30.5	1852 ± 6.2
45.7	2751.9 ± 11.3
61.0	3615 ± 9.7
76.2	4473.4 ± 16.1
91.4	5317.8 ± 12.6

Change the distance values on the left column based on the reference lengths you used. Use microsecond or seconds for time delay.

Plot of distance vs delay

- Plot time-of-flight delay (y-axis) vs reference length (x-axis). Jupyter notebook



Error: 4.27 m/s

Speed of sound

- What speed of sound did you find through your analysis?
  - 349.3 m/s
- What is the temperature in your room? 72º F
- What is a standard speed of sound from a textbook given the measured room temperature? 344.44 m/s
- What may contribute to any differences between the speed of sound you found and a textbook speed of sound?
  - Human error in measurement, extra delay generated by the devices used to record data

Acceleration

Suppose you use a numpy polyfit function to fit the position vs time of an object.

```
results = np.polyfit(time, position, 2)
```

Given the following properties of motion, fill in the elements of the "results" array (assuming velocity and acceleration are in the same direction)?

- Initial position = 1 meter
- Initial velocity = 0.5 m/s
- Acceleration = 9.8 m/s

results = [4.9, 0.5, 1]

Error propogation

- The covariance matrix from np.polyfit provides the variance in the slope and the intercept.
- If the speed of sound was 1/slope, then the error in speed of sound is obtained from error in the slope as follows.

$$\frac{\sigma(Speed\ of\ sound)}{|Speed\ of\ sound|} = \frac{\sigma(Slope)}{|Slope|}$$

σ is the standard deviation and it is the square root of variance. The standard deviation of the speed of sound is the required error. (The denominators must hold absolute values)

Reference (page 2) : http://ipl.physics.harvard.edu/wp-uploads/2013/03/PS3_Error_Propagation_sp13.pdf