Anechoic Sound Box Operation Kaizen

Background:

To improve understanding of sound attenuation, the UICSC team manufactured an anechoic sound box testing apparatus, referred to as the UI sound box (UISB). The initial design of the UISB was based on an existing design, which was used to test the acoustic effectiveness of quarter-wave and Helmholtz resonator (Dr. Santora's Design – See MAQR paper). The anechoic sound box was designed to emit pure frequencies through a waveguide (pipe) without interference. The final UISB specifications are given in Table 1.

Table 1: UI Sound Box Specifications

Infinity Prius Speakers	15.88 cm (6.25 in)
Infinity Prius Tweeters	4.60 cm (1.81 in)
UI Sound Box	.23 m^3 (8.00 ft^3)
Waveguide Diameter (PVC Pipe)	5.08 cm (2.00 in)
Waveguide Length	4.06 m (13.33 ft)
Auralex 4 " Pyramid Studio-foam	10.16 cm (4 .00in)
Pyle Audio Amplifier	1100 W
Knowles Microphone Locations	45.72 cm (18 .00 in), 137.16 cm (54.00 in), 289.56 cm (114.00 in), 381.00 cm (150.00 in)

The box contains amplified speakers and tweeters acting as a sound source directed into the UISB. The housing was built using 1.91 cm (0.75 in) high density fiber board internally lined with the studio-foam. Attached to the sound box is the waveguide, which extends to the environment with a removable center section. This section in the center of the pipe is removable for the purpose of testing individual acoustic components. The component length was held constant so the waveguide spanned the same distance for each test. Four microphones were placed along the pipe at the specified locations from the outlet of the UISB. The microphone's signals were analyzed using a Digilent electronics explorer board. Figure 1 represents the final configuration of the UISB.

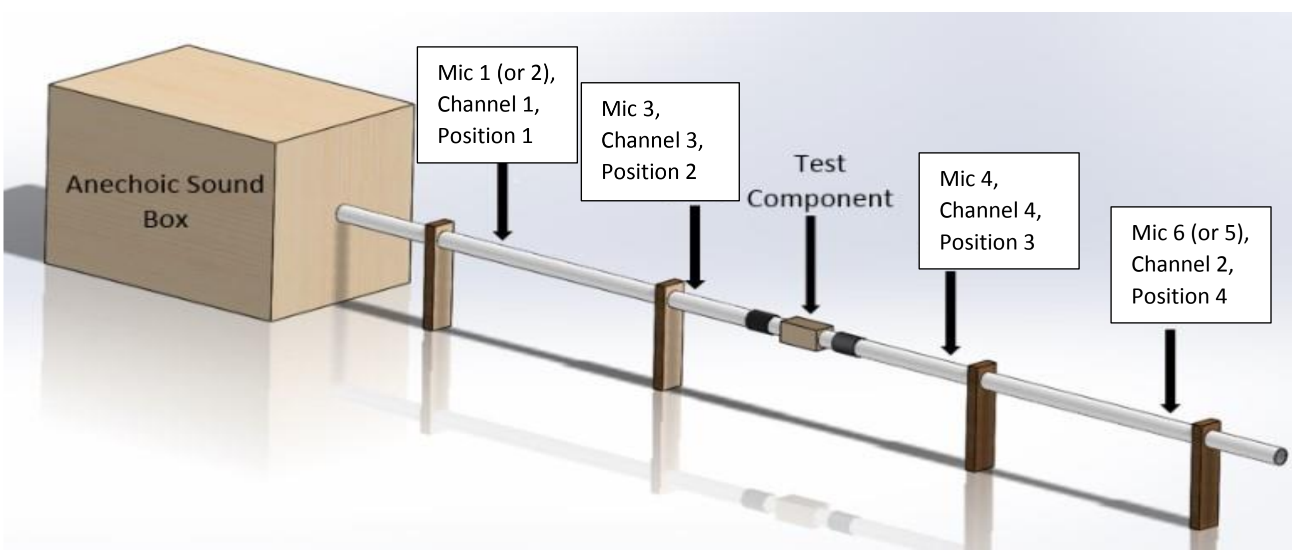


Figure 1: UICSC Sound Box Configuration

The minimum testable frequency was calculated to be 80 Hz using equation 1 while the maximum, 4000 Hz, was found using equation 2. These equations are the wavelength and narrow pipe assumption, respectively. Wavelength is the distance between two peaks of a sound wave and constrains testing due to waveguide length.

$$\lambda = \frac{c}{f} \quad (1)$$

$$\lambda > 1.71 * D \quad (2)$$

When acoustic impedance is added to the travel path of the sound wave, there is a chance for a reflected wave to occur. In this case, acoustic impedance represents barriers, sound absorption materials, or geometric changes. Two microphones were placed before and after the test component to account for the reflected wave. Under ideal testing the distance between each microphone would be equivalent to the wavelength of the tested frequency. Measuring sound phase makes moving the microphones extraneous.

Testing Method

Each test was performed by sweeping frequencies from 80 Hz – 4000 Hz scaled logarithmically. The pressure and phase were recorded allowing the UICSC team to calculate the power transmission coefficient. Due to the complexity of the derivation, this equation is not shown (See Matlab Code). The power transmission coefficient is interpreted as a percentage of the sound power that is reduced due to a material or geometric change. A positive value represents a reduction in sound and a negative value an increase. These increases may come from a natural resonance of the sound chamber, waveguide, or test component [16]. For example, a transmission power coefficient of .8 indicates that 80% of the sound power is reduced while 20% passes through the component.

UISB Info

Figure 2: UICSC Sound Box Cavity

The sound generation box is 0.6096 m × 0.6096 m × 0.9144 m (24 inch × 24 inch × 36 inch). The internal sound chamber is 0.6096 m × 0.6096 m × 0.6096 m (24 inch × 24 inch × 24 inch), containing an Infinity Prius PR6500cs 320 W peak set of speakers, and 0.0762 m (3 inch) pyramid foam. The speakers are driven by a Pyle PQA4100 amplifier capable of 4100 W peak (A little over powered).

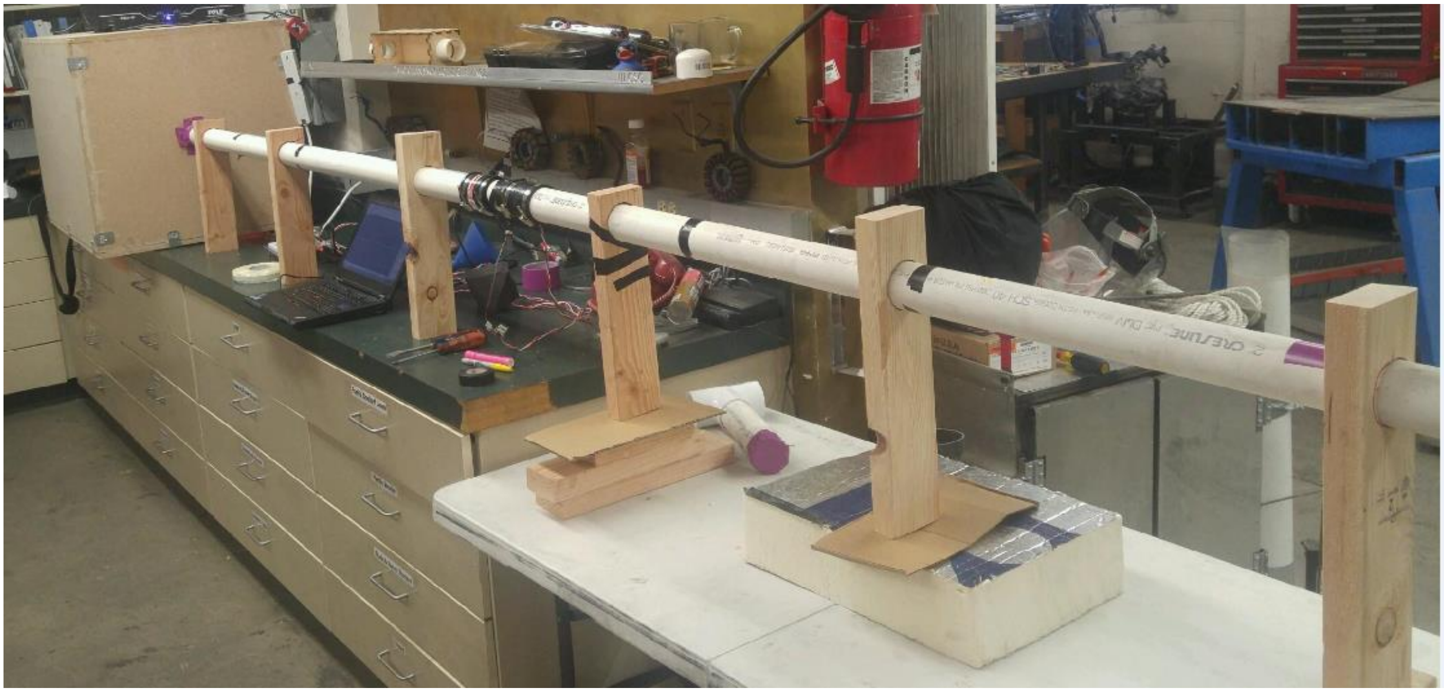


Figure 3: UICSC UISB Indoor Set-up

Knowles microphones are used to measure the sound pressure. The Knowles microphones used are a BL-21785 that has a jFET output and frequency range 100-10000Hz. The circuit to condition the microphone is shown in Figure 4. The jFET amplifier is created using values from the Knowles datasheet. This amplifier is conditioned with a Texas Instrument instrumentation amplifier, INA129[10]. The instrumentation amplifier is chosen because it has a large input impedance, 1 TΩ, and simplicity of implementation. The conditioned microphone signals are measured using the Network Analyzer tool in the Digilent Electronic Explorer Board. Figure 2. Microphone circuitry.

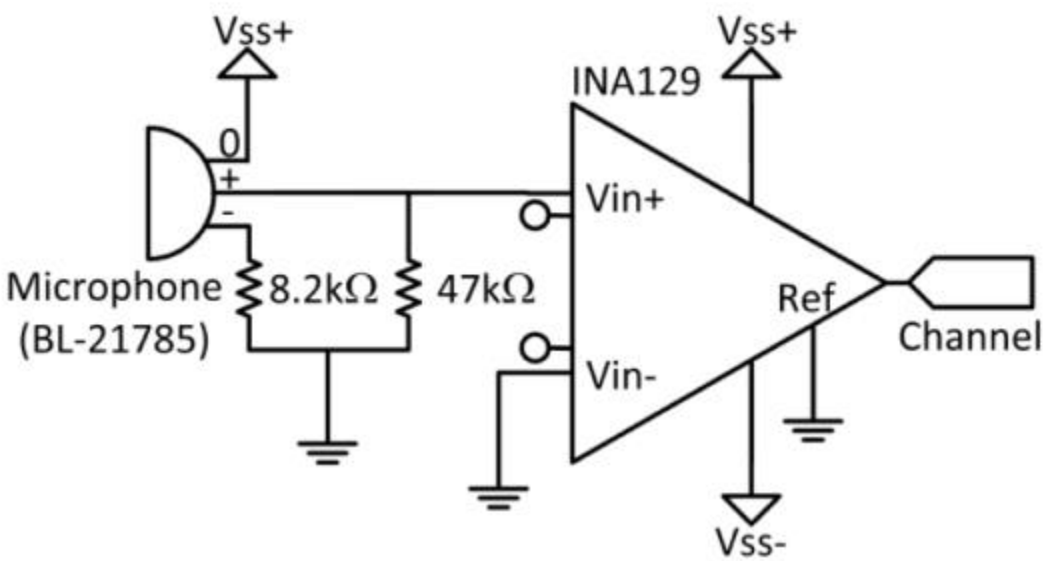


Figure 4: Microphone Circuit

How to Conduct UISB Experiments:

UISB Placement and Initial Set-up:

1. Place the UISB where the 2" pipe ending will face outside, open to the environment. (Box can be placed on the floor, ground, or on tables)
2. Place a table next the UISB to hold the computer, Digilent board, and circuit.
3. Take the inlet 2" PVC pipe and place it just inside the opening to the UISB. Ensure a good seal between pipe and box opening through the use of sticky tape and tape or other means.
   Three to four 2x4s are used to keep pipe at the correct height (**Warning**: it's very easy to tip the PVC pipe over).

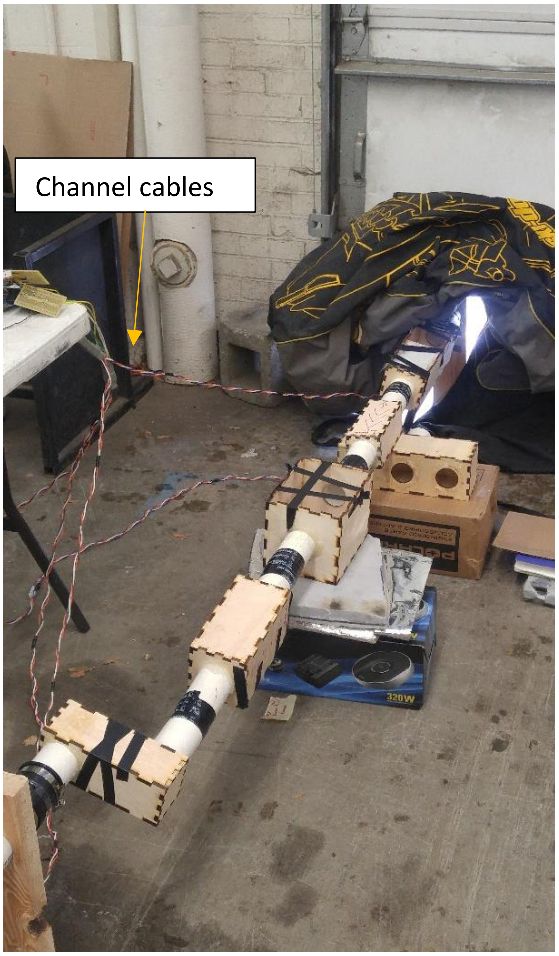


Figure 5: UISB With End in Open Environment

4. 2" ID rubber connections with hose clamps are used to connect test element to PVC pipe.
   a. Test element pipe and 2" pvc pipe should butt ends before tightening clamps.
5. Connect outlet 2" PVC pipe to test element with end facing outside as seen in Figure 5.
6. On the inlet and outlet guide tubes there are three 3/8" holes drilled into the pipe. Make sure the middle hole on each tube is covered with electrical or pipe tape.
7. If not already in place, place microphones in PVC pipe. There are 6 labeled mics (#1-6), only four are needed to complete test.
   a. Place two mics (Mic 1 and Mic 3) on inlet tube.
      Note: Microphones are already set-up to attach directly to the outside of the PVC pipe with the head of the mic facing down inside the pipe through the ¼" hole. Make sure the end of the mic is placed within the pipe to ensure proper reading.
      Use electrical tape to secure the mic to the PVC pipe. See Figure 6.

i. Based on Calibration: Place Mic 1 at Position 1. This Mic should be connected to the circuit cable labeled “Channel 1”. This Mic can be replaced with Mic 2 if needed (Will need to replace calibration #’s in spreadsheet to match replaced mic). See Figure 1.
ii. Based on Calibration: Place Mic 3 at Position 2. Connect to circuit cable labeled “Channel 3”.

b. Place two mics on outlet tube (Mic 4 and Mic 6). See Figure 1.
   i. Based on Calibration: Place Mic 4 at Position 3. Connect to circuit labeled “Channel 4”.
   ii. Based on Calibration: Place Mic 6 at Position 4. Connect to circuit labeled “Channel 2”. This Mic can be replaced with Mic 5 if needed (Will need to replace calibration #’s in spreadsheet to match replaced mic).
   Note: If other mics need replaced, the mics will need to be recalibrated with Mic 6. Be consistent with the channel cable being used during calibration and testing.
c. Place electrical tape around mic hole opening to ensure a tight seal around the mic inlet hole and the mic. See Figure 6.
d. **Note:** If Microphone housing breaks for any reason, talk with the Electrical Engineer Mike. His office is located in the basement of Gause Johnson. He also helped solder the wires to the Mic’s so if those come undone for any reason, he can help re-solder the wires to the Mics.

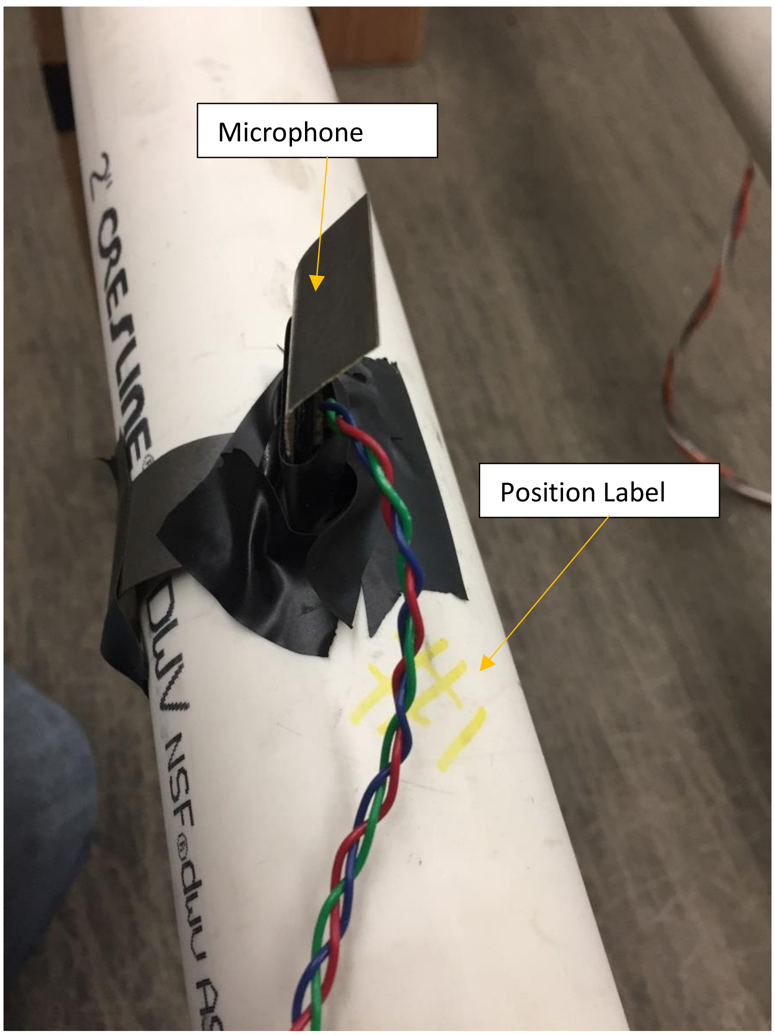


Figure 6: Mic attached to Pipe using Elec. Tape

Equipment Set-Up Procedure: Hardware/Software

1. Ensure circuit wires are connected to the Digilent Board Correctly. See Figure 7 and Figure 8 (Four Complete circuits should already be set-up and labeled).
   Warning: Improper placement of wires could fry op-amps within either circuit or could damage the Mics.

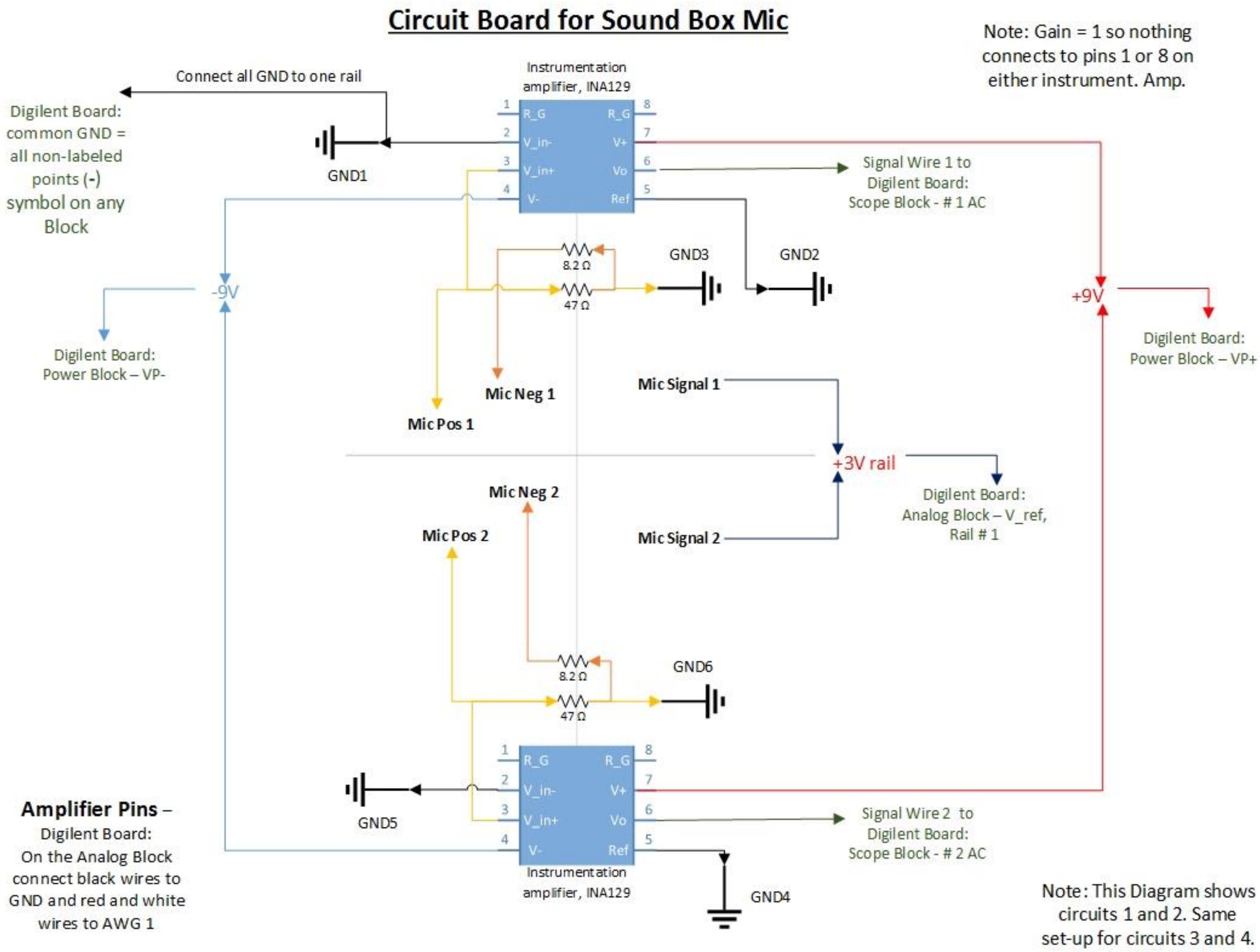


Figure 7: Circuit Connection Diagram and Digilent Board connection

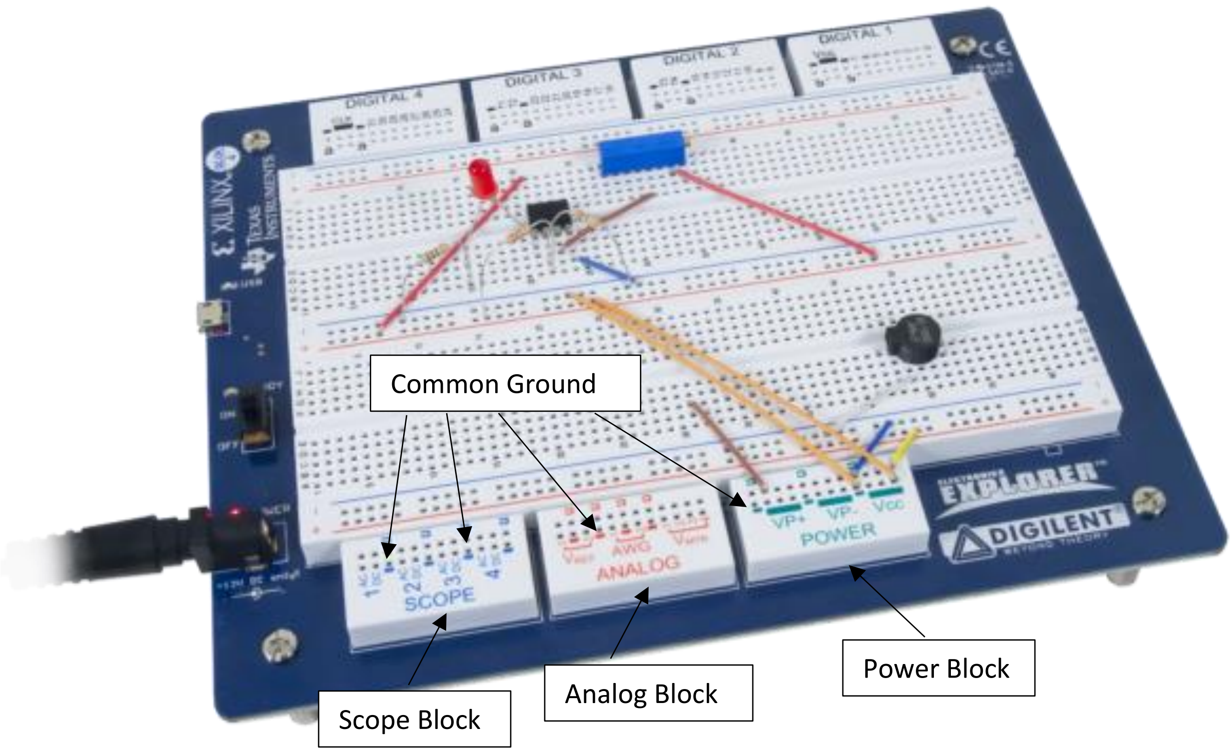


Figure 8: Digilent Explorer Board

2. Ensure that every component is plugged in and turned on.
    a. If not already done, plug in and turn on the Digilent board (to wall and computer)
    b. Plug in and turn on the Amplifier. Make sure that the knobs are **not** turned up too high!! This could blow the speakers. They should be placed in the straight up position. Both knobs should be at the same location.

Figure 9: Knob Position

i. Plug the speaker wires from the sound box into the amp. The blue wire with electrical tape goes to ground and the other wire to (+) as shown in Figure 9.

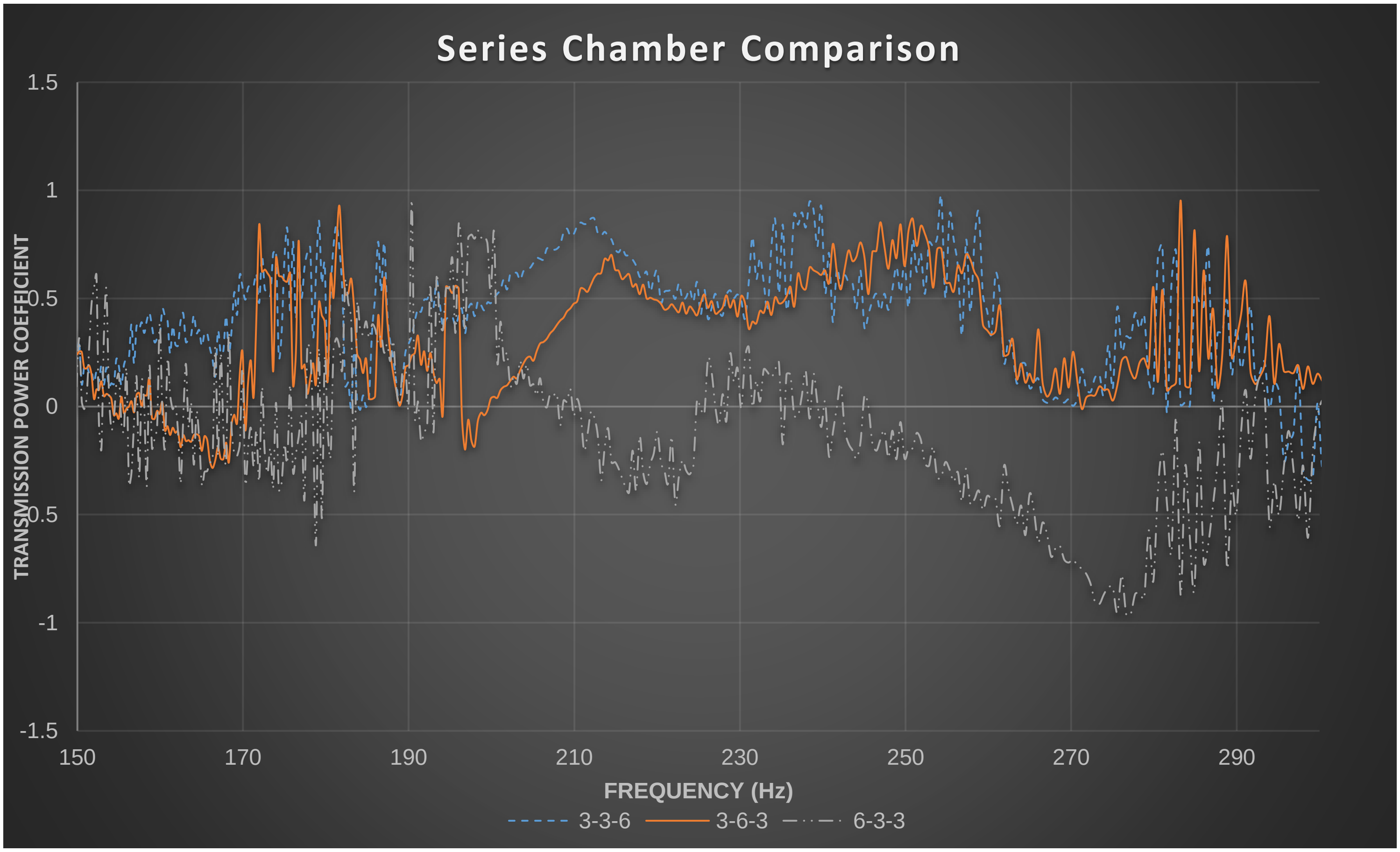
Figure 10: Speakers to Amp

3. Turn on the computer and open “Waveforms”.
4. Go into the supply window (Select “welcome” and then “Supply”)
    c. Set the Positive Supply to 9V
    d. Set the Negative Supply to -9V
    e. Fix Supply should be set to 3.3V
    f. Referene Voltage should read:
        i. 1) = 3V
        ii. 2) = 0V
5. Go back into the “Welcome” page again and select “Network”
    g. Within “Network” Select “logarithmic Scale”
    h. Range: 80 Hz to 4000 Hz
    i. Samples: 2000
    j. For using four Mic’s make sure all channels are turned on (Box next to channel name has check mark).
    k. Set voltage from amp to 100 mV. Under “Amplitude”
    l. For first test uncheck “use as reference” box in Ch.1
6. Turn on the supply on computer screen. (Click green arrow on supply tab, It will turn into a red circle when on).
7. Start test by selecting “Single” on Network tab. (this is roughly a 3 minute Test).
    a. Trouble shoot mics that aren’t workings as needed. Each mic should initially read at different dBA levels with mics ordered from Ch.1, Ch.3, Ch.4, and then Ch.2 where Ch.1 is loudest and Ch.2 is quietest. Each channel reading will change as test progresses.
8. Once test is complete, save the data by selecting “File”, then click “Export”. In the export window click “Save”
    m. Save data using the proper format “year_month_day_Test_Run#”
9. For each test component run sound test at least three times. Run three tests to gather the Decibel reading and three tests to get the phase measurements.
    n. For the phase tests. Select the box under channel 1 “Use as reference”. This will ensure phase is read in reference to mic position 1.
    o. To ensure accurate results with possible environment changes, run phase test directly after running the decibel test for each experimental test iteration.

Analyzing Data

1. For proper organization, each test element should have a separate folder. Keeping files organized by name of test, each folder should have at least 6 excel sheets saved. 3 for each mic dBA reading and 3 for Phase reading. Using a flash drive transfer data folders to shared drive folder
   S:\Engineering\SeniorDesign\- Group Folders\CSC\2017\Silent Nightmare\Testing\Anechoic Sound Testing Data
2. Within “Anechoic Sound Testing Data” file, go to “Final Data Averaged” file and select the excel sheet labeled “Averaged Data Template”
   a. Transfer data from each test into the excel sheet.
      i. The sheet includes Mic calibration. If mics were changed, replace mic calibration #’s with correct values. This will be found under:
         S:\Engineering\SeniorDesign\- Group Folders\CSC\2017\Silent Nightmare\Testing\Anechoic Sound Testing Data\Microphone Calibration
         Go to the “Complied” excel sheet for the mic needed and replace Mic cal. #’s in the “Averaged Data Template” with the correct values. Follow instructions within the “Complied” sheet for each Mic.
3. After saving the averaged data to a new folder, Select all the data within the sub-sheet titled “Final Data”. This will be copied directly over to the Matlab workspace.
   a. Within the Matlab workspace, create a new workspace table and name it “Data”. Take the copied data from the excel sheet and copy it directly into the table. Dimensions on table should read “2000 x 8”.
   b. Save workspace Data as name of test completed. This should be saved in:
      S:\Engineering\SeniorDesign\- Group Folders\CSC\2017\Silent Nightmare\Testing\Sound Testing Math Model
4. Open the Matlab code:
   S:\Engineering\SeniorDesign\- Group Folders\CSC\2017\Silent Nightmare\Testing\Sound Testing Math Model**Completed_Sound_Box_Model**
   a. Follow instructions in code.
5. Go to:
   S:\Engineering\SeniorDesign\- Group Folders\CSC\2017\Silent Nightmare\Testing\Anechoic Sound Testing Data\Final Data Averaged
   And select the excel sheet “Final Results”. This is where all the final data is saved.
   a. Create a new sub-sheet for testing element.
   b. Within the workspace find the data for “Frequency”, copy it, and paste it in the first column in the excel sheet. Then find the data named “T_Total” within the workspace, and paste it in the column directly to the right of the frequency.
   c. Plot the data on a “Scatter with Smooth Lines” plot.
6. Run the next test and repeat the process.

Example of results



<u>Test Points of Concern from previous tests</u>

		Frequency (Hz)				
Configuration		150	500	1250	2000	Average
Expansion Chamber Size (in x in x in)	3x3x8	0.008	0.828	0.491	-0.194	0.283
	4x4x4	0.296	-0.179	0.518	0.01	0.161
	4x4x12	0.287	0.522	-0.037	-0.372	0.100
	6x6x8	0.211	-0.31	0.055	0.381	0.084
Sound Material with Weight	F.G. Blanket (25 g)	0.062	-0.014	0.135	-0.565	-0.096
	F.G. Blanket (50 g)	0.627	0.765	0.073	-0.177	0.322
	Ceramic Blanket (25 g)	0.382	0.234	0.114	-0.343	0.097
	Ceramic Blanket (50 g)	0.367	0.236	0.121	-0.165	0.140
Perforated Hole Density	1/4 in 22%	0.256	0.299	0.227	-0.157	0.156
	1/4 in 40%	0.247	0.119	0.014	-0.13	0.063
	1/4 in 58%	0.2885	0.358	0.682	-0.207	0.280
Deflectors	Round Middle Same	0.316	0.238	0.332	0.026	0.228
	V Middle Same	0.48	0.113	0.339	-0.0003	0.233
	Round Desc. Size	0.319	0.161	0.191	-0.081	0.148
Series	3 then 3 then 6	0.265	0.157	0.041	-0.188	0.069
	3 then 6 then 3	0.243	-0.087	0.163	-0.469	-0.038
	6 then 3 then 3	0.133	0.206	-0.1	0.084	0.081