Design Proposal

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Functional Description

These loudspeakers will be suitable for mixing, mastering, and casual listening. They will be used within small to medium sized rooms, most likely a bedroom. For this application, the speakers should have a flat frequency response and be capable of accurately representing the low end of the audible frequency spectrum that humans are capable of hearing. The transient response should be clear and distinct. The speakers likely will be used in rooms of different sizes and types with little to no acoustic treatment. Therefore, flexibility must be incorporated into the design.

The speakers should be able to be placed on stands that will sit on either side of a desk holding two 22 inch LCD computer screens. The desk will most likely be against a wall, and thus make the placement and depth of the speaker cabinet somewhat limited.

Portability of the speakers is a desirable trait, and should be taken into consideration; however, the goal of good sound quality should not be compromised too strongly. Ideally they should be able to be moved by a single person. The weight should be within reason, so that an average man could carry the speaker to a new location. They should be durable, and have a nice wood finish.

DESIGN GOALS

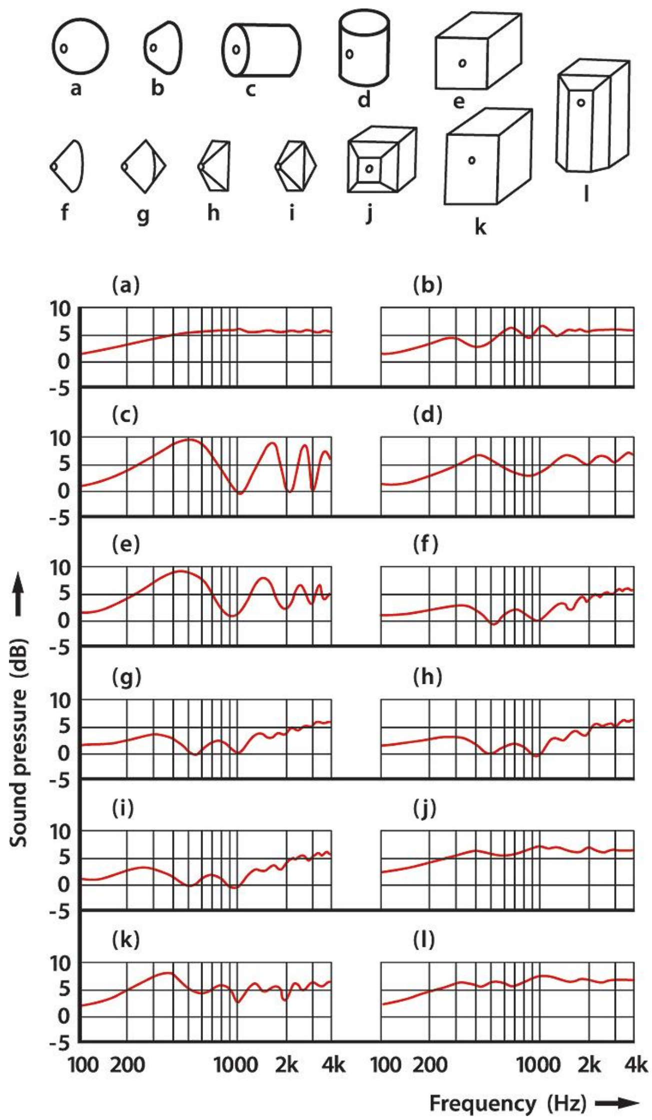
The speaker should be built to accomplish the following goals. They will serve as the guide for what decisions should be made in order to fulfill the above criteria.

SIZE & SHAPE

The size and shape of the speaker are going to play a substantial role in deciding how this speaker should be built. As stated previously, the speaker needs to be able to sit securely on an appropriately sized speaker stand. The dimensions of the box should be approximately 12” X 20” X 35”, that is, length, width, height. The top of the speaker needs to be removable to adjust stuffing densities and placement.

The box should be of rectangular shape. The rationale behind this is as follows: a transmission line is easier to build into a rectangular shaped box given the amount of time that I have, and this reason outweighs the inherent effects that the rectangular shape will have on the overall performance. Figure 1 shows various shapes of speaker cabinets and how the shape affects the frequency response. As shown, the ideal shape is “a”, but it is rather impractical for this situation. If, with future research and design, figure “l” can be achieved then that will be desirable, but for the reason mentioned previously, regarding simplicity and time constraints, shape “k” will be used.

FIGURE 1: SPEAKER SHAPE[1]



The speaker should have a nice wood finish. I would like a nice dark red or brown stain for the cabinet and the speaker to be either black and or have silver accents. The speaker should be pleasing to look at and the edges should flow well.

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[1] William Martens, Kim Sungyoung, and Marui Atsushi, *Discrimination of Auditory Source Focus for Musical Instrument Sounds with Varying Low-Frequency Cross Correlation in Multichannel Loudspeaker Reproduction,* AES 119th Convention, Paper 6544, (October 2005), Accessed February 2nd, 2013.

The speaker drivers should be flush mounted into the box to eliminate any early reflections from the box. Early reflections can also be caused by any protrusions on the front baffle, and thus screws and hardware should be counter sunk.[2] In order to achieve a better off axis response the front may be routed, and shaped around the tweeter.

An approximate drawing of what the speaker will look like is shown in Figure 2 except for the stand on the bottom. Figure 3 shows some preliminary sketches of the line design. The length A will be a fixed value corresponding proportionally to the driver. B and C can be adjusted as desired.

Figure 3: Preliminary Design Shape

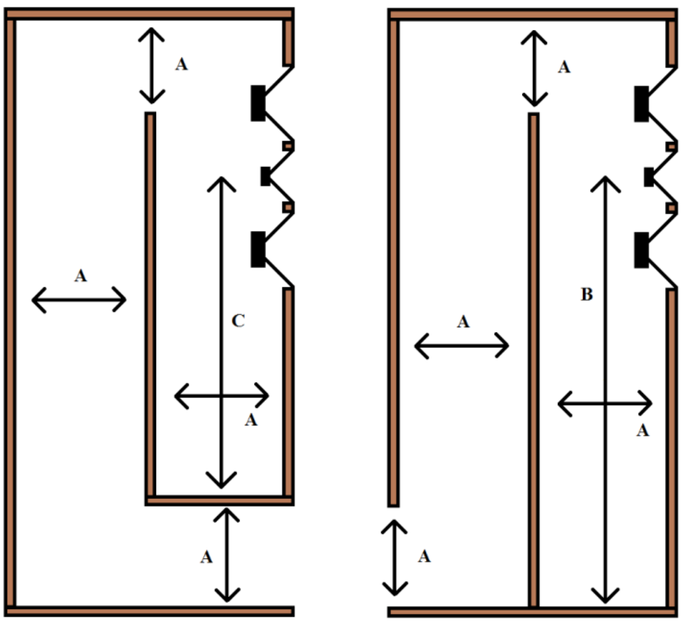

FIGURE 2: SPEAKER SHAPE[3]

SPL OUTPUT

In order to determine the maximum SPL output that the speaker should have for casual listening, I measured the volumes at which I listen to music and mix. In order to do this, I first acquired a meter that was capable of reading sound pressure levels of dB(A) accurately enough that I could use it to calibrate the application that was on my cell phone. The calibration was done using a meter and my phone while playing pink noise over a system at approximately 65 dB(A). This was done so that I could then take the phone into the room in which the speakers will be used and sit at the approximate location where I will listen to the speakers. I sat approximately one meter away from my current speakers and from there measured the output with my

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[2] *Cabinet Handbook.* New York: North Creek Music Systems, 1992

[3] Courtesy of www.seas.no/index.php?option=com_content&view=article&id=27:thor&catid=15:products &Itemid=40

phone. I proceeded to play several different songs and a video, all the while recording what the decibel meter read. I started with the speakers at absolute minimal volume, thus giving me a reference level of 41 dB(A). I then slowly started to increase the volume until I was able to perceive what I was listening to, but still wasn't quite loud enough for my taste. I labeled this as "quiet." I then proceeded to turn the volume up until it was within a comfortable range for listening. This was deemed "comfortable" and is approximately the volume level at which I listen to audio on a normal basis. Past this level was "loud", which was bearable, but too loud to listen to regularly. Past the "loud" level I proceeded to measure the volume that I deemed as "uncomfortable", which for me was exactly as it states, uncomfortable. I then chose a level that I enjoyed listening to the music at and recorded that as "Casual." The songs chosen varied in styles in order to ensure that the data was not biased to a certain genre of music. The music varied from dance music, to classical music, to an action film. All this data, along with the chosen songs, are listed on the next page in Figure 4.

Figure 4

Song Name	Quiet (dB(A))	Comfortable (dB(A))	Loud (dB(A))	Uncomfortable (dB(A))	Casual Listening (dB(A))
DOTA- Basshunter[4]	41-55	55-66	66-78	79+	61
Funk 4 - Activision[5]	41-52	53-65	66-70	71+	61
Forget Me - BT[6]	41-53	54-67	66-77	78+	60
Seal of the Wind- Noriko Matsueda[7]	41-48	49-65	66-77	78+	61
Sunshine and Celery Stalks- Pinkiepieswear[8]	41-53	54-65	66-73	74+	58
All Around Me (Acoustic) - Flyleaf[9]	41-53	54-62	63-70	71+	60
Symphony No. 92 in G Major, first movement – Joseph Haydn[10]	41-45	46-61	62-76	77+	65
Iron Man (film)[11]	41-55	55-66	66-78	78+	68

The scale that was used for this test was dB(A) as this is the scale that is usually used when the safety of hearing is of concern. The A weighting of the decibel scale takes into account the human ears increased sensitivity to mid and high frequencies. This means

[4] Basshunter. *DOTA.* Cond. Unknown. Comp. Unknown. 2006
[5] Unknown. *Funk* . Cond. Unknown. Comp. Unknown. 1996.
[6] BT. "Forget Me." *These Hopeful Machines.* Cond. Unknown. Comp. BT. 2010
[7] Unknown. *Seal of the Wind.* Comps. Noriko Matsueda, Takahito Eguchi and Kazuhiro Hara. 2003.
[8] Pinkiepieswear. *Sunshine and Celery Stalks.* Cond. Pinkipieswear. Comp. Pinkipieswear. 2011.
[9] Flyleaf. "All Around Me (Acoustic)." *flyleaf.* Comp. Flyleaf. 2007.
[10] Joseph Haydn. *Symphony No. 92 in G Major.*
[11] *Iron Man,* directed by Jon Favreau (2008: Hollywood CA: Paramount Pictures, 2008).

that higher sound pressure levels are more acceptable at lower frequencies.[12] According to the Occupational Safety & Health Administration (OSHA), the longest that someone can be listening to 90 dB(A) without suffering any hearing loss or damage is 8 hours per day.[13] Based upon my initial design conditions of designing the speaker to be rather small and having a good bass response, getting a high enough SPL may provide a bit of a challenge. Based upon the experiment that was explained above and also due to OSHA's regulations, I have decided that the speaker should be capable of a target SPL of 85 dB at one meter.

Film is usually mixed at 85 dB(C) with 20 dB of headroom.[14] These speakers are intended for mixing, and thus should have enough headroom for mixing at volume levels with which I am comfortable. I was unable to measure any dB(C) measurements to compare with the previously stated standard, so I will be using my own measurements shown in Figure 3. I will most likely be mixing at levels lower than 85 dB(A) and thus, in order to keep cost down, have decided to lower that to 80 dB(A) with 20 dB of crest factor. Thus the speaker should be capable of 80 dB SPL with peak of 100 dB SPL.

Power Response and Amplification

In order to achieve the 80 dB(A) with 20 dB of headroom, the drivers selected will need to have a sensitivity of at least 85 dB. The extra headroom will be achievable by choosing an appropriately rated amp that will provide enough power needed for the system, and matching that with the appropriate amount of wattage that the speaker can handle. Figure 5 shows the amount of decibels per watt that can be achieved for various wattages.

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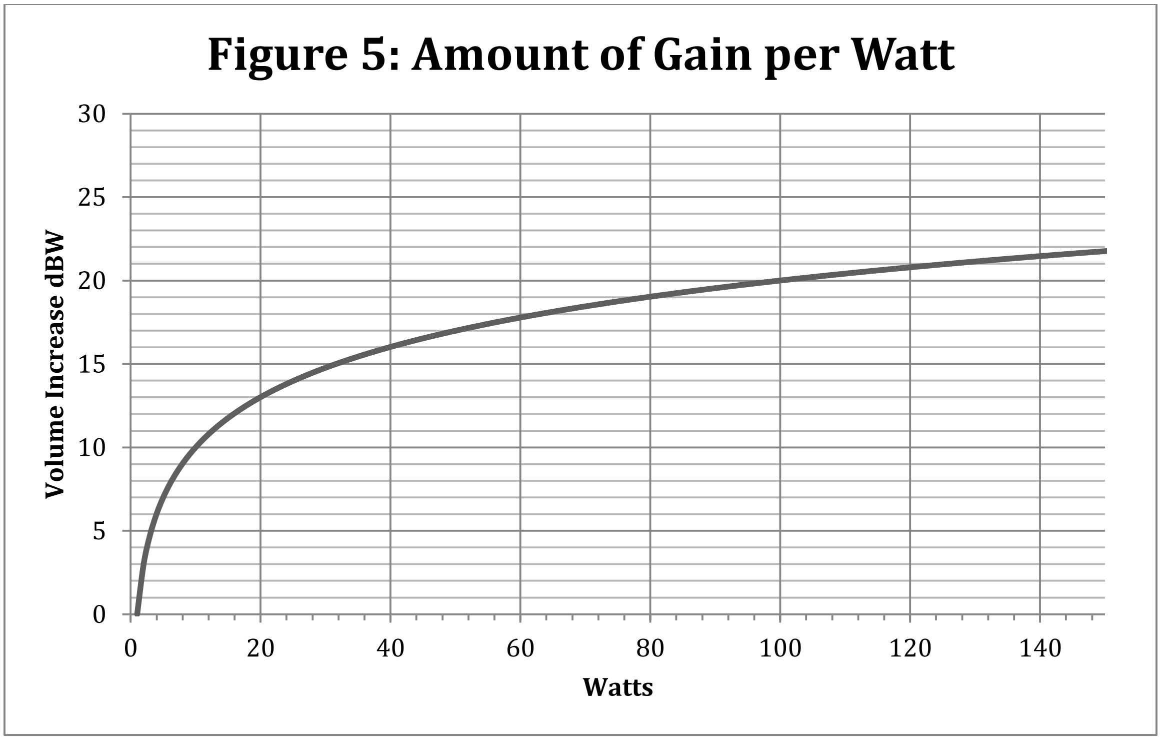
[12] *Decibel A, B and C.* 2011. http://www.engineeringtoolbox.com/decibel-d_59.html (accessed January 26, 2013).

[13] Occupational Safety and Health Administration Regulations." *United States Department of Labor.* 2012.http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735&p_text_version=FALSE#1910.95%28b%29%282%29.(accessed January 26, 2013)

[14] Phillip Newell, and Keith Holland. *Loudspeakers for Music Recording and Reproduction.* Burlington: Elsevier Ltd., 2007. Page 358



Using the chart it is easy to tell that in order to get the desired 20 decibels of headroom the amp will need to be able to deliver, at max, 100 watts of power per channel. This will be a 2 way passive speaker system, and thus the amplifier need only have 2 channels.

BANDWIDTH

I did a bit of experimentation in order to calculate the desired frequency response. The experiment was suggested by Christopher Plummer during a class lecture on January 16, 2013.[15] I went into a classroom that had equipment that was capable of producing a substantial amount of bass, and listened to a few songs with which I am quite familiar. As I was listening I started cutting off the bass frequency using an equalizer filter with a fairly steep cutoff curve. I slowly cutoff the bass frequencies while listening to the music and recorded when I noticed a change in the quality of music. I created a scale with which to judge the quality of the music. I started with deeming “excellent” as being the lowest amount of low frequency that could be removed before I started to feel that the song was lacking in bass. One step below that in terms of quality was “good.” Following after that were “bad” and “poor.” Figure 6 on the next page shows the collected data.

[15] Christopher Plummer, “Functional Design”. Michigan Technological University. Houghton, MI. January 16, 2013.

Figure 6				
Song Name	Excellent (Hz)	Good (Hz)	Poor (Hz)	Bad
DOTA - Basshunter[1]	0-60	61-80	81-110	111+
Funk 4 – Activision[2]	0-50	51-73	74-90	90+
Forget Me – BT[3]	0-55	56-72	73-92	93+
Seal of the Wind - Noriko Matsueda[4]	0-48	48-60	61-76	77+
Sunshine and Celery Stalks – Pinkiepieswear[5]	0-59	60-78	79-90	91+

After looking at the information, I have decided to aim for a response that fits within the excellent range. I will design the speaker to have a flat response from 45 Hz to 20 kHz with a flat response of ± 2 dB.

DIRECTIVITY

The directivity, or how well the speaker sounds off axis is of high importance and should be taken into consideration when designing the speaker. The speakers will mostly be listened to while sitting down at the desk within the sweet spot; however, I would like it to be relatively decent sounding when listening off-axis. This would allow me to still be able to be moving around the room or playing something for a group in the room to hear, and still have the audience feel like they aren't missing a large part of the audio. The speakers will most likely be within an untreated room and the directivity and dispersion of the sound should be as uniform as possible for the reflections in the room will have a large impact on how the overall response will sound. I would also like to have acceptable off axis response so that if I was playing a MIDI keyboard and facing away from the speakers, I would still be able to hear good musical clarity.

DESIGN PRIORITIES

One of the top priorities of this design is that it needs to stay within my budget. I would like to keep the cost of the speakers to a maximum of $950. Flat response is the top priority for me.

Bass response, SPL and size are three priorities that interact with each other in a complementary manner. Essentially, pick which two are wanted as a priority and then the third one will be what is going to be limited in the design. If a large amount of bass response and SPL are desired, then the size of the cabinet is going to have a very limited range. For my particular application I am willing to part with very high SPL in order to acquire a speaker that has good bass response and is small in size. Figure 7 shows the approximate priorities with which I will design my speaker.

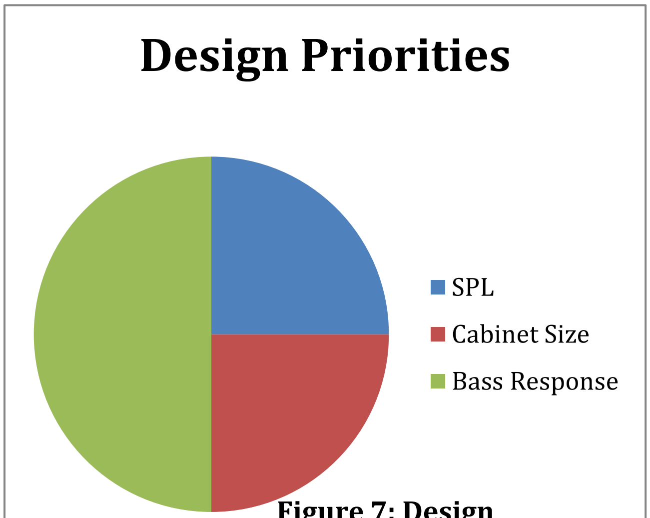


Figure 7: Design Priorities Pie Chart

In order to re-iterate and to express the design priorities in a clear and concise manner, the list below is in order of highest priority to lowest.

1. Within Budget
2. Flat, Accurate Response
3. Bass Response
4. Size
5. Sensitivity (SPL)
6. Extended Listening Time
7. Off Axis Response
8. Aesthetics

Design Consequences

This section is devoted to exploring design consequences and how the usage of the speaker will have an effect on the design.

This speaker will incorporate a 2.5 way system. This system makes use of 3 drivers per speaker, two identical woofers and a tweeter. It is a 2.5 way because one speaker will be used exclusively for mid and low bass response and act similar to a subwoofer. The cabinet will be incorporated with a transmission line that will act as a low frequency emitter and add further bass extension. The transmission line should be dimensioned such that it has a -3 dB point at 45Hz, with a roll off of 12dB per octave below 45Hz.

Due to the speaker being in a small room it is rather important that it the cabinet be able to fit within the room and not take up too much space. Due to the desk being against the wall, there may have to be a bit of attenuation in the lower frequencies in order to address this issue. This can perhaps be done by a pad within the crossover itself.

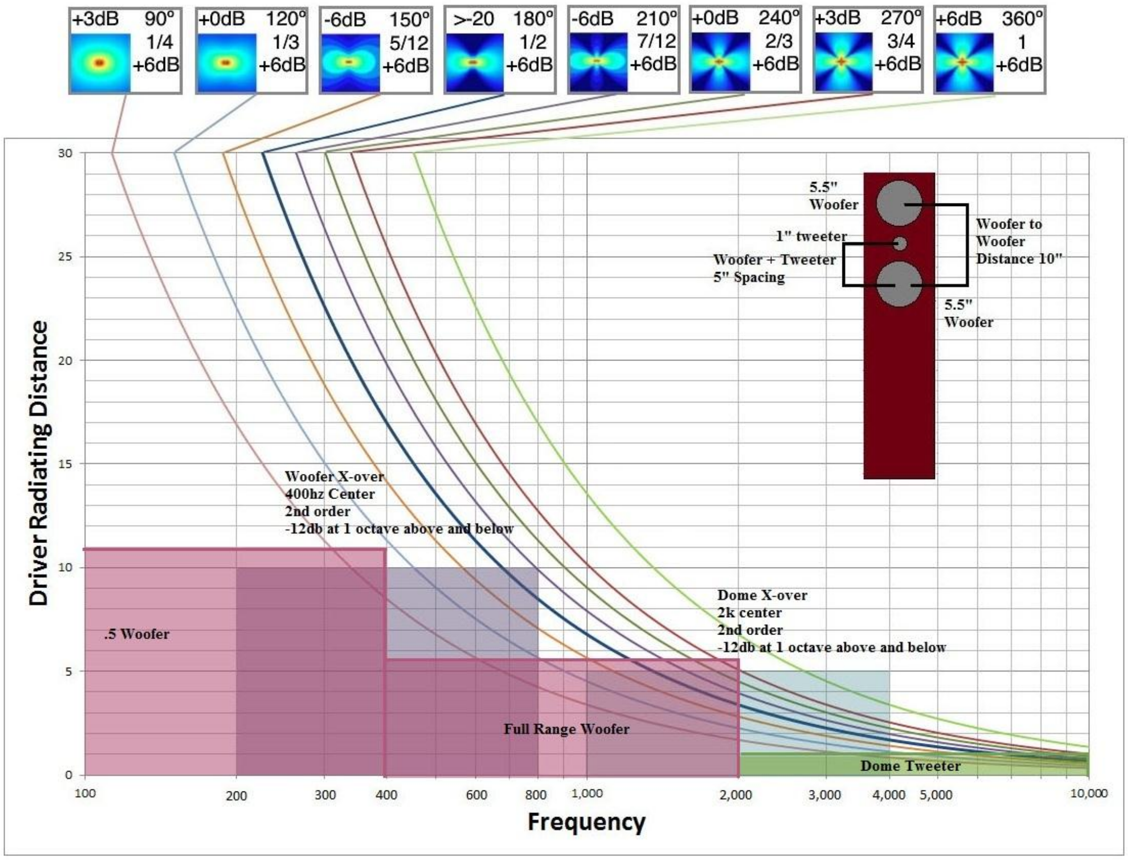
Technical Details

Driver Size and Spacing

The driver size and spacing between them can have a large impact on the sound of the speaker. More importantly the spacing between the drivers can cause lobing, which will make the off axis response rather poor. Lobing is caused when physically displaced drivers radiate at a common frequency whose wavelength is close to, or smaller than, the distance between the drivers. Cancelation occurs whenever the distance to the two drive units varies by half a wavelength. In order to minimize this, similarly radiating drivers should be close to each other.[16] Figure 8, on the following page, displays how lobing varies with frequency. The dark blue, slightly thicker line is the point at which the frequency would match the half wave and would begin to cause lobing. Ideally with this design, the distance of the drivers will be set to minimize this as much as possible. In the current setup the distance between the tweeter and full range woofer will be 5" apart. The woofer to woofer distance will be approximately 10".

[16] Phillip Newell, and Keith Holland. *Loudspeakers for Music Recording and Reproduction.* Burlington: Elsevier Ltd., 2007. Page 130

Figure 8: Mid-Hi Wavelength Analysis



The drivers for this speaker will be two 5-5.5” drivers and a 1” tweeter. This is to accommodate the small box and to also allow a minimal distance between the drivers in order to minimize lobing effects.

BAFFLE STEP

Baffle step comes into play when the frequency of the signal being produced starts to radiate into 4π space instead of 2π. Since drivers are most efficient in 2π space, there will be an approximate -6 dB point in efficiency when the waves start to radiate into 4π space. The frequency at which the phenomenon starts can be calculated using the following formula:

$$f_3 = 4560/W_B$$

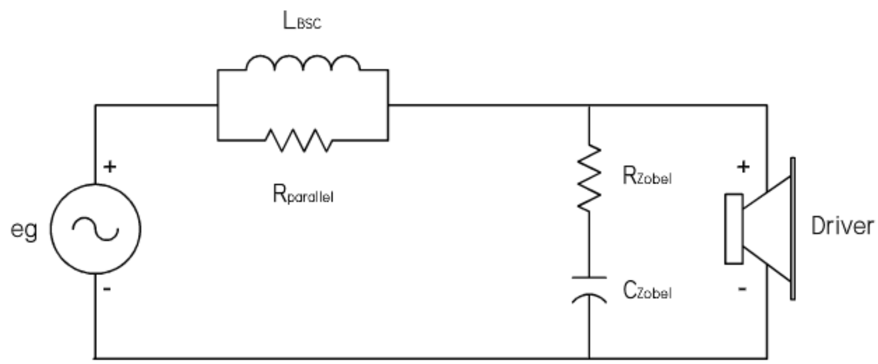
where

$$W_{B=width\ of\ the\ baffle\ in\ inches}$$

Applying this formula to my previous design dimensions, the frequency at which the speaker will start radiated into 4π space is at 506 Hz, reducing the dB level below this frequency by -6. This can be corrected a couple of different ways, but for this particular application a simple baffle step correction circuit can be incorporated into the cross over circuit.

Figure 9 shows a sample circuit that can be used to fix the baffle step problem.

Figure 9: Schematic of a Baffle Step Correction Circuit[17]



The equations to calculate the needed values are below.

$$R_{Zobel} = 1.25 * R_e = \ \Omega$$

$$C_{Zobel} = \frac{L_{VC}}{(1.25 * R_e)^2} = farads$$

$$f_3 = \frac{4560}{W_B} = Hz$$

$$R_{Parallel} = R_e * \left(10^{\frac{dB}{20}} - 1\right) = \ \Omega$$

$$L_{BSC} = \frac{R_{Parallel}}{2\pi * f_3} = henrys$$

where

$$R_e = driver's\ DC\ resistance\ in\ ohms$$

$$L_{VC} = driver's\ voice\ coil\ impedence\ in\ henries$$

[17]Martin J. King "Simple Sizing of the Components in a Baffle Step Correction Circuit." (Martin J. King) February 2004. Page 4.

$$dB = amount\ of\ attenuation\ required$$

The following driver and enclosure parameters are used to estimate what will be needed to correct the attenuation.

$$R_e = 8\ ohms$$

$$L_{VC} = 0.4\ mH$$

$$W_B = 8.5\ inches$$

Calculate the Zobel Circuit Elements:

$$R_{Zobel} = 1.25 * 8 = 10\ \Omega$$

$$C_{Zobel} = \frac{0.0004}{(1.25 * 8)^2} = 4\ \mu F$$

Calculate the Baffle Step Correction Circuit Elements:

$$f_3 = \frac{4560}{8.5} = 536.47$$

$$dB = 6\ dB = theoretical\ value\ for\ free\ s$$

$$R_{Parallel} = 8 * \left(10^{\frac{6}{20}} - 1\right) = 8\ \Omega$$

$$L_{BSC} = \frac{8}{2\pi * 506.667} = 2.513\ mH$$

These measurements are included as a reference should baffle step correction be needed. With a 2.5 way system, the additional .5 speaker adds an additional gain to the lower frequencies, and thus balances with the additional baffle step gain.[18]

Low Frequency Alignment

The transmission line enclosure was chosen as such due to its inherent properties. I wanted to create a speaker that has good frequency extension and is relatively small in size, all the while having a flat frequency response and accurate transient response. This was only achievable by means of building a box with a transmission line.

[18] Christopher Plummer, Michigan Technological University. Houghton, MI. February 15, 2013.

DIFFRACTION EFFECTS

Diffraction effects can be rather detrimental to the sound of a speaker. In order to reduce any diffraction around the edges of a speaker, various designs and solutions can be implemented. As shown in Figure 1 on page 4, different shaped cabinets can have an effect on the way waves diffract around the edges of the cabinet. As previously mentioned figure “k” is the aim for this project but if the front of the baffle can be shaped to be more like “l” then that should be done. This would help to smooth out the diffraction effects. Another simple way to reduce this is to recess the drivers and have a nice, smooth front with no odd protrusions. The corners can also be beveled to make the transition smooth. There may also be some smoothing around the tweeter to help with diffraction.

Placing the speakers near a wall can help to combat diffraction; however the speakers will exhibit an increase in bass.[19] The speakers for my application will most likely be relatively close to a wall which will help with diffraction, but will have an increase in bass. The bass increase is much more easily equalized than the diffraction irregularities.[20]

WALL CONSTRUCTION & BRACING

The speaker will be constructed using 1 to 3 types of wood. MDF is among the first choices for wood when constructing speaker cabinets due to it being readily available and easy to use. Oak or maple may be used to strengthen the box, along with birch plywood. The oak and maple would make an excellent shell for the box and would allow multiple stain color choices. The plywood would be rather sturdy and only require bracing in key areas, thus being a bit more cost effective.

The transmission line will need stuffing. Since the damping material inside the line will be responsible for attenuating all but the bass frequencies its density and placement can have a large impact on the overall sound. For this reason the top of the box will be removable, thus allowing for easy changing and manipulation of damping material. Some of the most common suggested materials for damping are Dacron fiber mat, Acousta-Stuf polyfill, and also fiberglass insulation. Further research and experimentation will be needed to determine the required amount and also which material will be best suited for the application. I am, however, going to begin using Acousta-Stuf as that has been the preferred material for transmission line speakers.

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[19] Phillip Newell, and Keith Holland. *Loudspeakers for Music Recording and Reproduction.* Burlington: Elsevier Ltd., 2007. Page 91

[20] Phillip Newell, and Keith Holland. *Loudspeakers for Music Recording and Reproduction.* Burlington: Elsevier Ltd., 2007. Page 92

DRIVER SELECTION

This section highlights what drivers were deemed usable for this project and how they compare to each other. The drivers should be placed far enough apart to avoid any unwanted interference, but also close enough that the entire speaker is perceived as a single audio source, so that the sound from the tweeter and the woofer will not be distinctly separate to the listener.

WOOFER ANALYSIS & SELECTION

The woofer of the speaker will be responsible for generating all the low frequencies of the system. For this purpose the woofer needs to be of an adequate size in order to reach the lower frequencies that are desired, as was stated in the design goals. The drivers should be approximately 5.5" - 7" in size. Since the design required the use of 4 total woofers, the cost will have to be at a maximum of $100 each. It should have a low Q and have a sensitivity of at least 85 dB 1W/1m. It should be capable of handling enough watts RMS to reach the desired output.

In order to analyze what drivers would be suitable for a transmission line design, software was needed in order to simulate the responses of the drivers. I chose to use Martin J. King's Mathcad spreadsheets in order to analyze the drivers. All of the following plots and data were done through Martin J. King's spreadsheets and should not be used for commercial use.[21]

The initial simulation made use of a simple, straight, offset transmission line with stuffing along the entire length. This version of simulation was used due to its simplification and fewer input parameters, making it more convenient when analyzing many different drivers. Further analysis of two drivers will be done in order to determine the final driver.

The dimensions are not necessarily all the same because the length of the line should be tuned to the F_s of the driver. Determining the optimum length was done using Martins' lookup tables that were implemented into an Excel spreadsheet.

The length of the transmission line should be set to be close to the resonant frequency of the driver used. As a rule of thumb, when first designing an enclosure, it may be helpful to set the length to the quarter wavelength 5-10 Hz above the resonant frequency for drivers with low Q_{ts} or to set the length to be 5-10 Hz below for high Q_{ts} drivers.[22] For the

[21] King, Martin J. *Quarter-Wave: MatCad Computer Models: Upgraded Versions.* December 27, 2012. http://www.quarter-wave.com/Back_Room/index.html (accessed January 21, 2013).

[22] Bjron Johannesen. "Pearls from Martin J. King Quarter Wave Design." *Transmission line Speakers.* December 11, 2005. (accessed February 16, 2013)

initial design, I decided to just use the Excel spreadsheet that was based on Martin's look up tables.[23] The spreadsheet combines several different parameters in order to determine the proper length for the transmission line.

Several woofers were compared using both Martin's MathCad spreadsheet in conjunction with Webb's lookup table spreadsheet. Each driver was modeled to be placed within a straight transmission line. The placement of the driver was to be offset by a factor of .12 from the closed end of the transmission line. Stuffing was also kept at the same density for the initial comparison.

The drivers that were tested are as follows:

- 6-7" Woofers
  - SB Acoustics SB17NRXC35-8
  - SEAS Prestige CA18RNX (H1215)
  - SEAS Prestige CA18RLY (H1217)
  - SEAS Prestige ER18RNX (H1456)
- 5-5.5" Woofers
  - SEAS Prestige CA15RLY (H1216)
  - SEAS Prestige L15RLY/P (H1141)
  - SB Acoustics SB15MFC30-8
  - SB Acoustics SB15NRXC30-8

Below, in Figure 10 and Figure 11, are some of the key parameters that were looked at when initially choosing drivers to test within the simulation software.

Figure 10: 6-7" Woofers

Speaker	SB17NRXC35-8	CA18RNX	CA18RLY	ER18RNX
F_s	32 Hz	35 Hz	42 Hz	37 Hz
V_{as}	44.5 L	33 L	32 L	32 L
Power Handling	60 W	80 W	80 W	80 W
Price	$62.40	$89.10	$81.80	$94.50
Sensitivity	89 dB	88.5 dB	90 dB	88.5 dB
Size	6.5"	7"	7"	7"
X-max	5.5 mm	6 mm	5 mm	6 mm
Q_{ts}	.34	.31	.47	.32

[23] Keith Webb. *Alignment Tables Spreadsheet*. March 3, 2009. (accessed January 30, 2013)

Figure 11: 5-5.5" Woofers

Speaker	CA15RLY	L15RLY/P	SB15MFC30-8	SB15NRXC30-8
F_s	44 Hz	44 Hz	39 Hz	38 Hz
V_{as}	14 L	12 L	17 L	21 L
Power Handling	60 W	80 W	50 W	50 W
Price	$59.00	$88.40	$57.65	$55.50
Sensitivity	87.5 dB	86 dB	87 dB	88.6 dB
Size	5.5"	5.5"	5"	5"
X-max	5 mm	5 mm	5 mm	5 mm
Q_{ts}	.34	.35	.36	.32

Preliminary Woofer Simulations

The following info was done through use of the Excel spreadsheet files that Keith Webb designed

Figure 12: Excel Data for 6-7" Woofers

Speaker	SB17NRXC35-8	CA18RNX	CA18RLY	ER18RNX
Transmission Line Length	101.53 in	92.33 in	75.89 in	87.13 in
Area of Open End	105.25 in^2	117.49 in^2	147.76 in^2	118.49 in^2
Area of Closed End	105.25 in^2	117.49 in^2	147.76 in^2	118.49 in^2

Figure 13: Excel Data for 5-5.5" Woofers

Speaker	CA15RLY	L15RLY/P	SB15MFC30-8	SB15NRXC30-8
Transmission Line Length	73.45 in	73.80 in	83.46	85.58
Area of Open End	73.94 in^2	57.47 in^2	63.30 in^2	70.65 in^2
Area of Closed End	73.94 in^2	57.47 in^2	63.30 in^2	70.65 in^2

When the woofer simulations were compared, it was determined that, although the larger woofers exhibited a better bass response, they required a cabinet that was simply too large. Although the simulations are not shown in here, it is obvious from Figure 11 and Figure 12 that the area and volume needed for the speakers are significantly different. This conflicted with my design goals as the speakers would be rather hard to move and occupy too much space. The smaller 5-5.5" woofers were then the ones that were to be analyzed more thoroughly.

The four smaller drivers were simulated using King's MathCad spreadsheet and adjusted to get the best performance out of the drivers. The placement of stuffing, its density, the offset of the driver all factor into how the driver can be optimized. A key concern with the optimization was making sure that the driver did not exceed Xmax before reaching the desired output SPL. The Mathcad spreadsheets output a chart that measured RMS displacement of the driver, of which a taken point can be multiplied by the square root of 2 and then that value would be comparable to Xmax of the driver.

The figures below are the corresponding simulations to each of the drivers. For the sake of maintaining space the plots are rather small.

Figure 14: SB15MFC30-8 Simulation at 15watt input

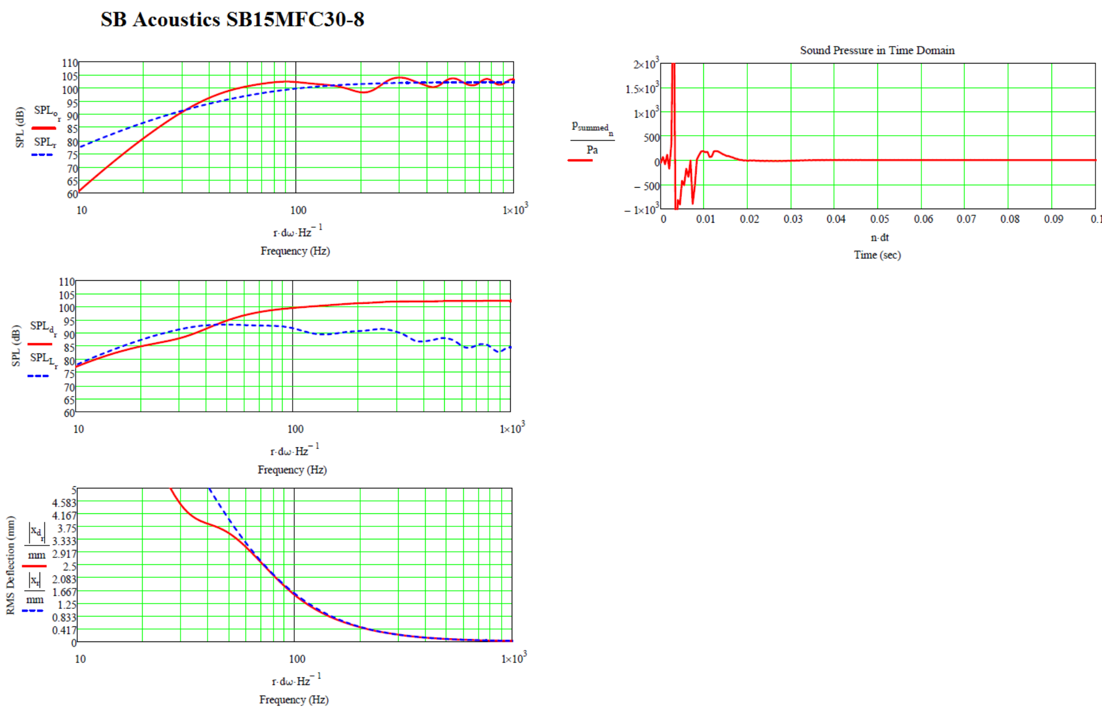


Figure 15: SB15RNXC30-8 Simulation at 15 watt input

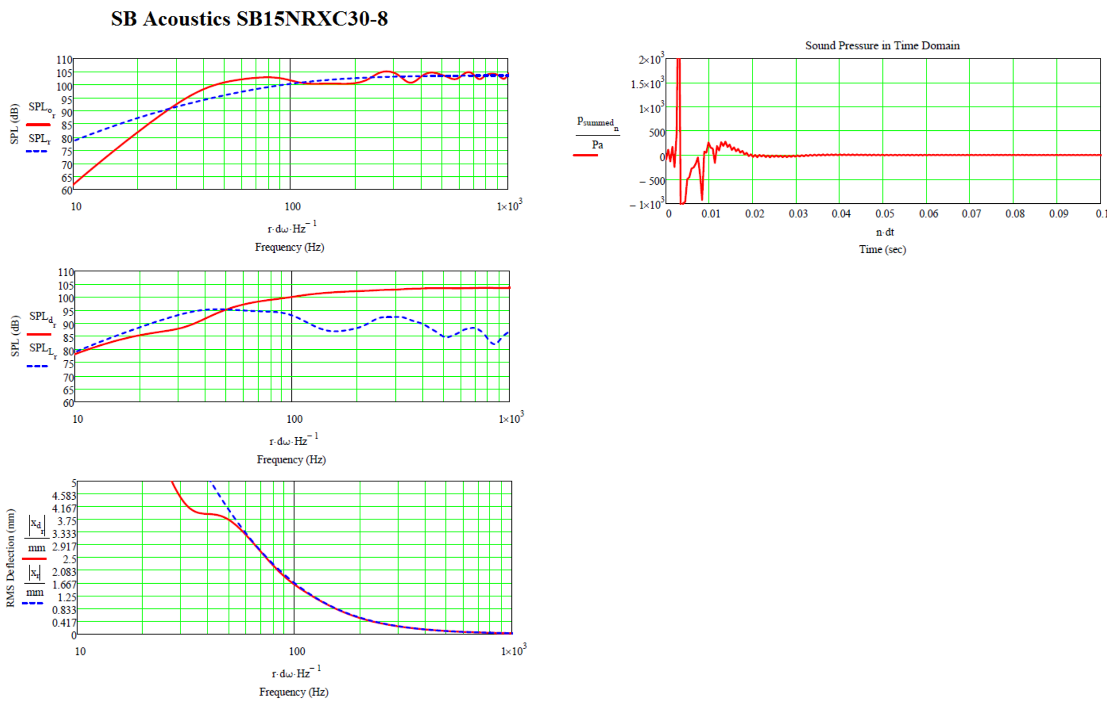


Figure 16: SEAS CA15RLY Simulation at 20 watt input

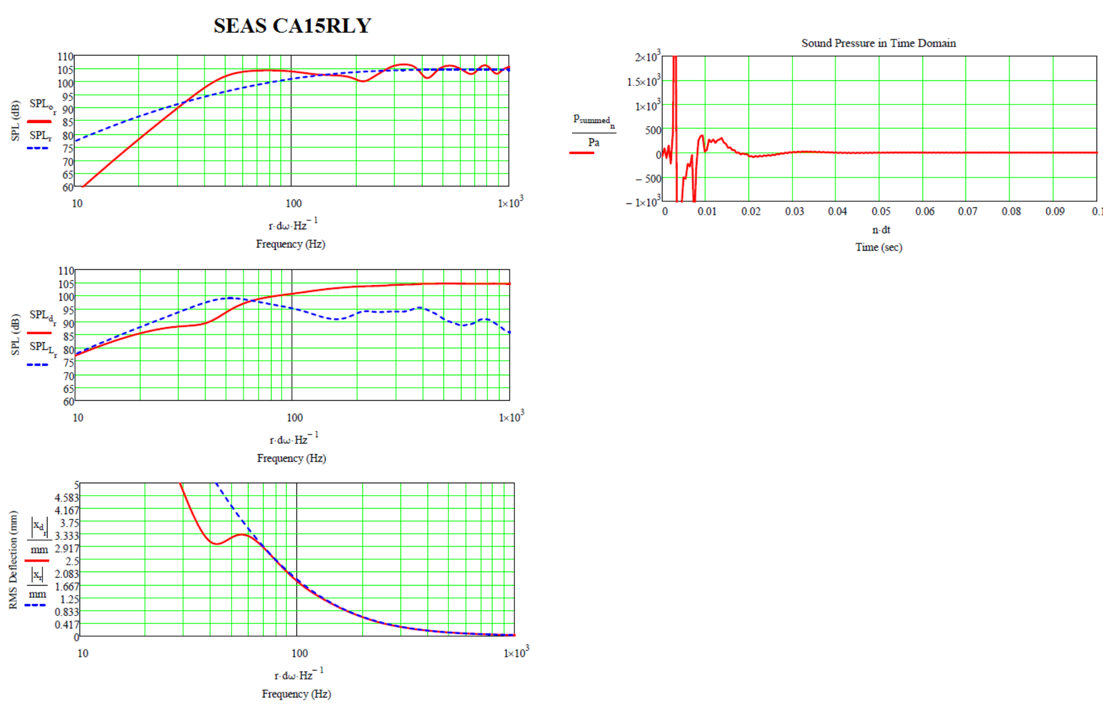
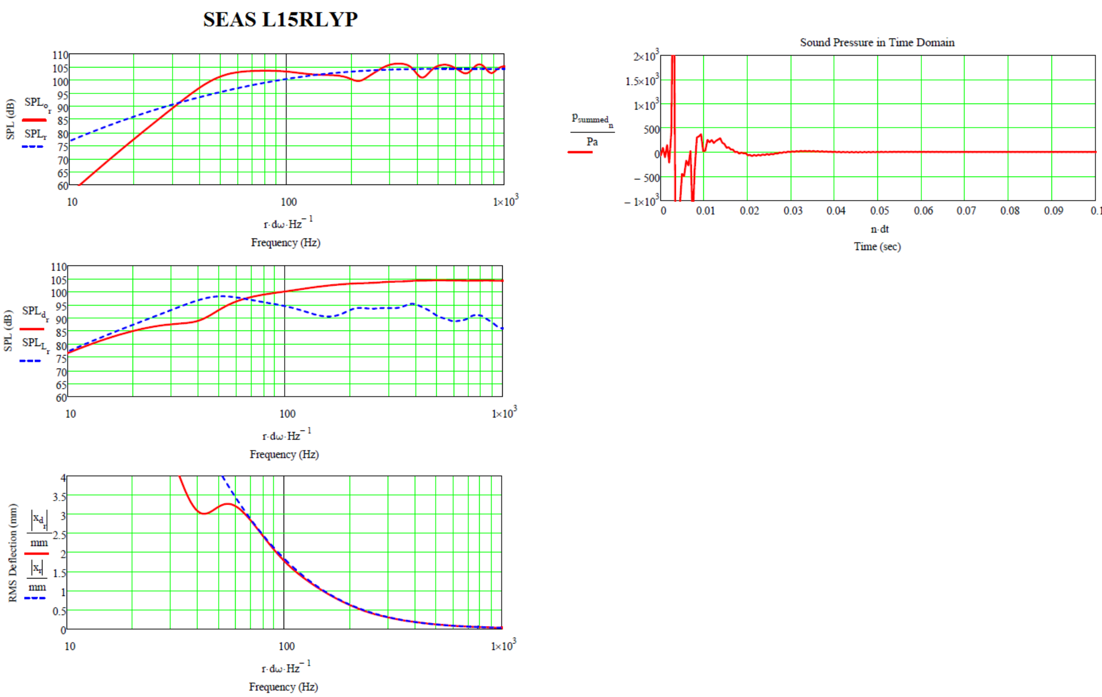


Figure 17: SEAS L15RLY/P at 20 watt input



Based upon the data shown above in conjuncture with the Excel Spreadsheet data, it is clear that the smaller drivers are capable of outputting the desired SPL while within a smaller cabinet. The SEAS CA15RLY and the SEAS L15RLY/P perform similarly in output and Xmax, able to achieve an additional 13 dB of SPL to their initial sensitivities, while keeping the driver excursion below the Xmax. The L15RLY is capable of 99 dB SPL while remaining below the Xmax. This, coupled with its previous Excel spreadsheets, shows that this driver meets the capabilities to generate the desired SPL, in a small cabinet, all the while still generating a fair amount of bass. Additionally it is an aluminum cone woofer, which is supposedly more linear throughout its excursion. For these reasons this driver will be my first choice for further analysis.

For my second choice the SEAS CA15RLY is also a very viable candidate. It is nearly identical in its output and response to my first choice driver, except that it can achieve a little more SPL. Additionally it is cheaper than the first choice, however it is a paper coned driver, which is the only reason it is second to the SEAS L15RLY.

FINAL WOOFER SIMULATIONS

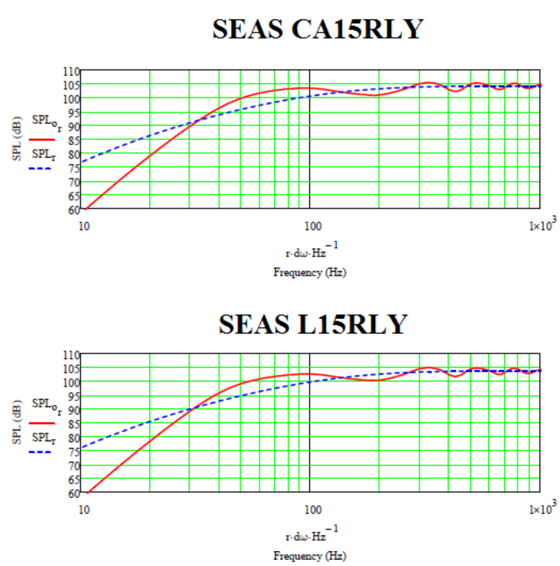
For the final woofer simulations, a more precise spreadsheet was used. This spreadsheet takes into account variance in the dimensions of a transmission line with corners in it. This allowed me to create a more accurate representation of the internal geometry of the enclosure.

As was mentioned in the previous section, the two drivers to be simulated in this manner were the SEAS L15RLY and the SEA CA15RLY.

For the simulation it was determine that the left drawing in Figure 3 would be the most desirable configuration. This shape was chosen because it gave the most ideal offset of the drivers to help in mitigating the ripple in the drivers while also keeping the same general shape and dimensions.

The speakers were both simulated using Martin King's "Section TL Worksheet" and the entire output of the spreadsheet can be found in the appendix.[24] The simulation resulted in nearly the same output from both of the drivers, however the SEAS CA15RLY was able to achieve 100 dB SPL while the SEAS L15RLY was 2-3 dB below that. This, coupled with the cheaper cost, made the SEAS CA15RLY my driver of choice. Figure 17 shows the similar frequency output of the two drivers.

Figure 17: Frequency Output of Both Final Drivers



[24] King, Martin J. *Quarter-Wave: MatCad Computer Models: Upgraded Versions.* December 27, 2012. http://www.quarter-wave.com/Back_Room/index.html (accessed January 21, 2013).

TWEETER ANALYSIS & SELECTION

The tweeter for the speaker should be sized and spaced accordingly. For this purpose I believe that a 1" soft domed tweeter should be an adequate size for the box. With this size I can get the drivers close enough to minimize lobing. In order to narrow down what drivers can be used, I applied criteria can to lower the number of potential drivers. First of all the driver needs to be within my budget, and for this particular application I believe that I can only afford a tweeter that would be in the $50-$80 dollar price range. The tweeter should be capable of being crossed over at 2000 Hz or lower. Ideally it should have higher sensitivity than the woofer, and be capable of outputting at least 100 dB peak SPL. Listed below are five drivers that were deemed suitable for the application.

- SB Acoustics SB26ADC
- Morel MDT29
- SEAS Prestige 27TDFC(H1189)
- SEAS Prestige 27TBFC/G (H1212)
- ScanSpeak Discovery D2608/9130

Figure 18 shows 5 different drivers that were deemed suitable for the application with several criteria to aid in selection

Figure 18: Tweeters

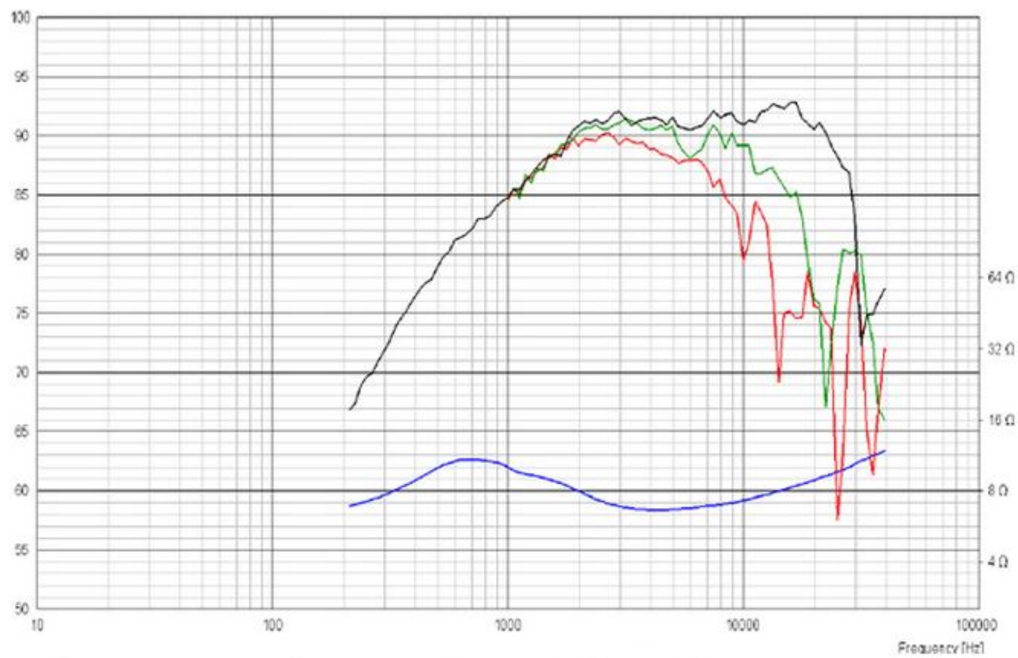
Speaker	SB26ADC	MDT29	27TBFC	27TBFC/G	D2608/9130
Frequency Range	--	1800Hz -20kHz	1500Hz-25khz	1500Hz-20kHz	--
F_s	680 Hz	900 Hz	550 Hz	550 Hz	700 Hz
Power Handling	120 W	80 W	90 W	90 W	80 W
Price	$52.90	$53.10	$50.70	$51.50	$81.40
Sensitivity	90 dB	89 dB	90 dB	91.5 dB	91.3 dB
Type	Aluminum Dome	Textile Dome	Textile Dome	Alum/Mag Dome	Textile Dome

When comparing the tweeters I focused on finding a tweeter that worked well with the woofer and also simplified cross over design. Metal dome tweeters tend to have a lot of high frequency breakup and thus I decided against them. The remaining choice was Textile/Soft Dome tweeters. A textile dome has a much softer breakup and usually exhibits clean and pleasant sounding roll-offs. For this reason I looked at the remaining 3 tweeters.

TWEETER #1 - FIRST CHOICE

The ScanSpeak Discovery D2608/9130 1” Textile Dome HDS tweeter comes highly recommended. It exhibits very smooth roll-offs around 2kHz and 20kHz. It is also recommended for systems with low crossover points. Figure 19 shows the frequency response of the driver

Figure 19: ScanSpeak Discovery Tweeter Frequency Response

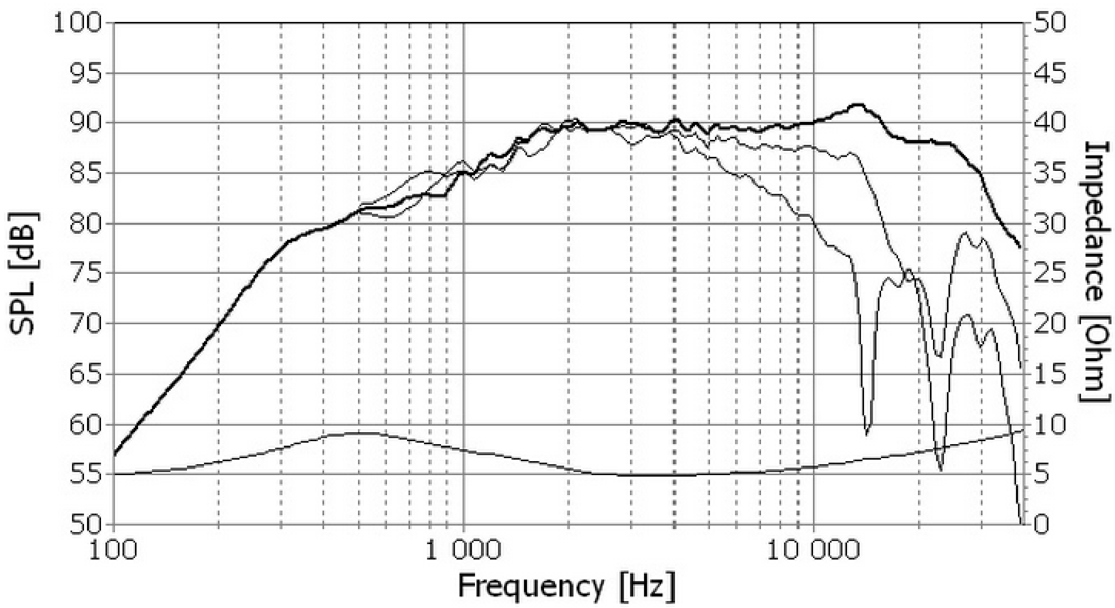


The off axis response isn’t not as superb as I had hoped, but I will rarely be listening off axis. The tweeter exhibits high sensitivity and 80W of power. This and previously mentioned traits, coupled with its ability to be replaced relatively easily make this my first choice.

TWEETER #2 – SECOND CHOICE

The Seas Prestige 27TDFC (H1189) Textile Dome Tweeter is my second choice for a tweeter. It has a very smooth frequency response between 2 kHz and 10 kHz. It exhibits a nice roll off after 2 kHz, however it does not have as nice a roll off on the high end. The off axis response is acceptable. It has a very low F_s and the manufacturer states that it can handle crossover points as low as 1.5 kHz. It is not nearly as sensitive as my first choice and it is also not replaceable making it my second choice. Figure 20 on the next page shows this drivers’ frequency response.

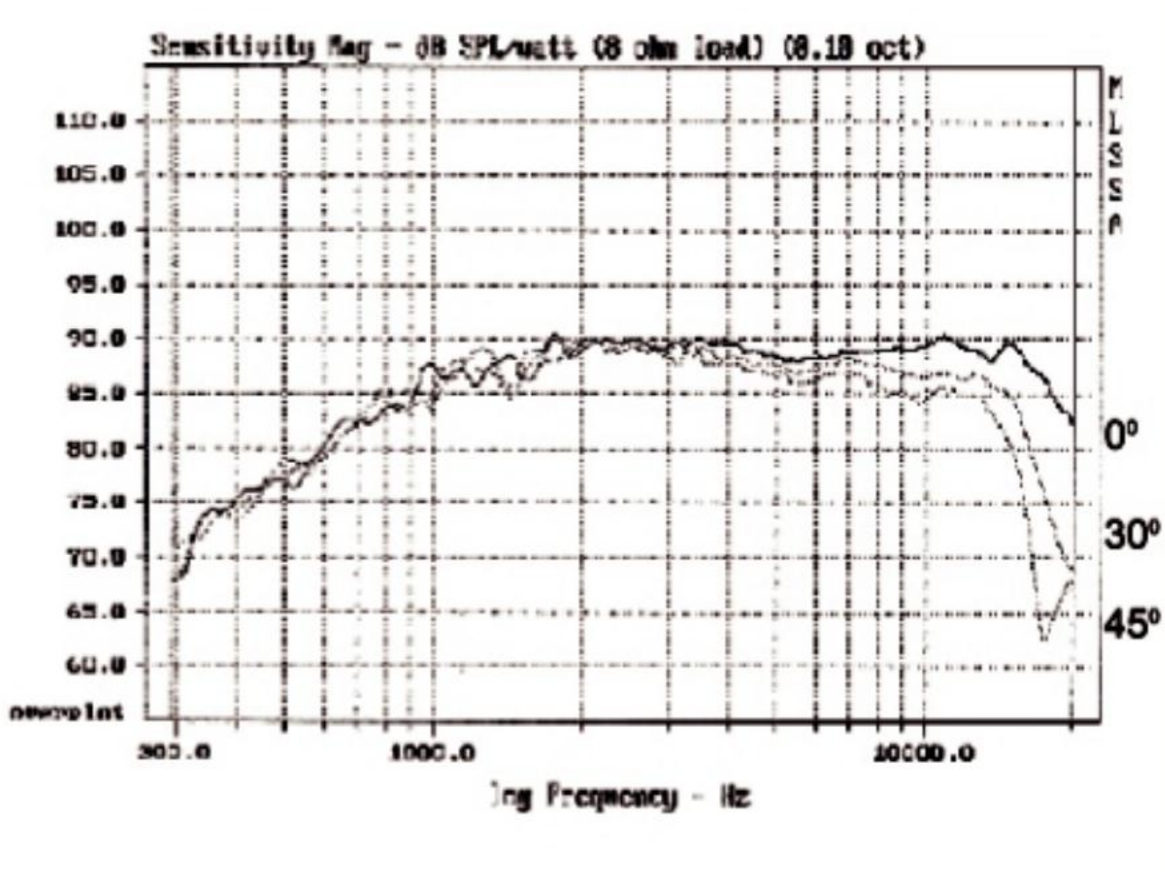
Figure 20: SEAS Prestige H1189 Frequency Response



TWEETER #3 – THIRD CHOICE

My third choice is the Morel MDT29 1” Textile Dome Tweeter. This tweeter exhibited a both a higher resonant frequency and a lower sensitivity than the two previous choices. This tweeter, however, appears to have very consistent off axis response all the way up to 10kHz. This tweeter is capable of a low frequency roll off, but it is not as good as the others. Figure 21 shown on the next page is the frequency response of this tweeter.

Figure 21: Morel MDT29 Frequency Response



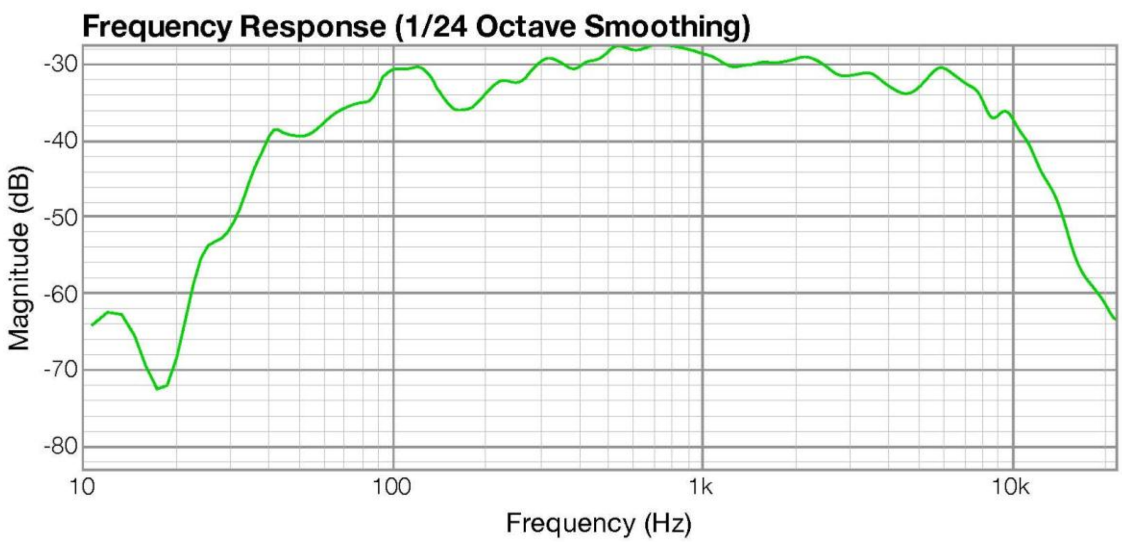
Testing and Tuning

Testing was conducted in a large black box theatre, Michigan Tech's McArdle Theatre. Due to its area being approximately 4646 square feet, it is a large enough room that any unwanted interference can be mitigated when the speaker is on a tall enough stand. Fuzzmeasure was used for all testing in with a calibrated speaker testing microphone.

Driver Performance

The woofers that were chosen operated a little bit differently when placed in the cabinet. The woofers exhibited a more prominent peak between 400 – 1 kHz, but despite many tests the cause of this could not be explicitly determined. It was just assumed that this was an inherent trait of the drivers interacting with the cabinet and that it could not be changed except by adjusting the crossover. Figure 22 is the graph of both woofers acting in parallel with no crossover connected.

Figure 22: Parallel Woofer Peak



The tweeter operated just as had been described by the data sheet. The rounded edges of the speaker worked very well to combat the effects of diffraction. The only concern that the tweeter caused was a small shelf right around the crossover frequency when the crossover was connected. The rolling off of the tweeter caused the peak at 2 kHz to flatten out to match with the dip at around 3 kHz resulting in a flat line between the two frequencies. Figure 23 shows the tweeter without a crossover connected and Figure 24 shows the tweeter's frequency response with the initial crossover added in.

Figure 23: Tweeter with No Crossover

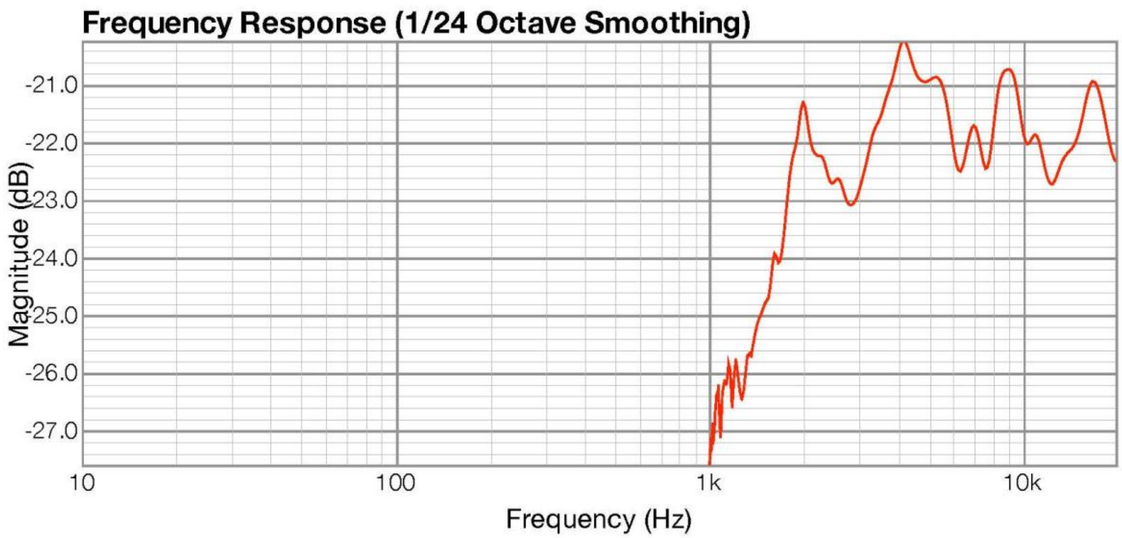
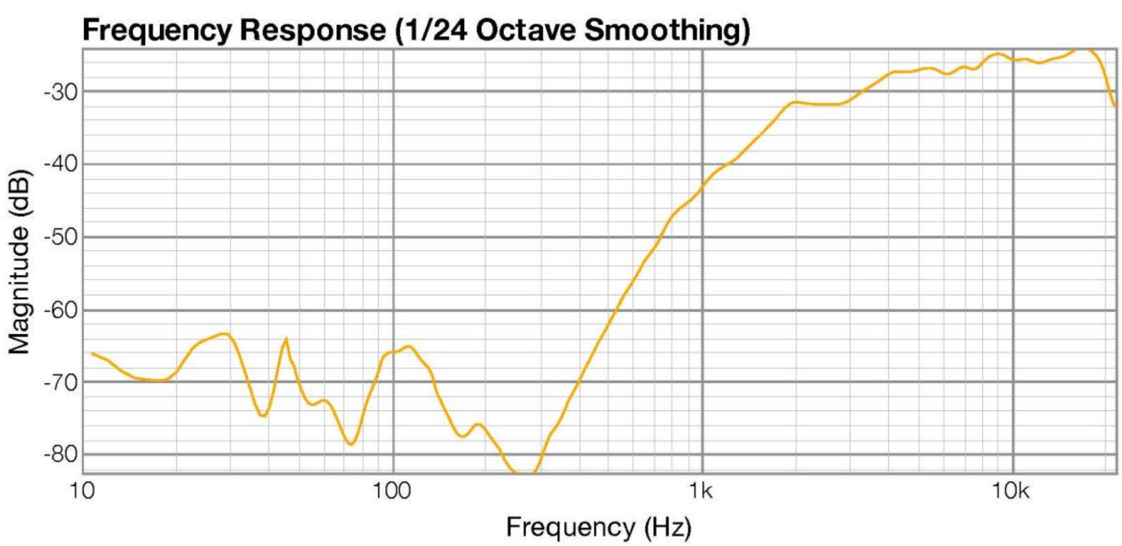


Figure 24: Tweeter with Crossover

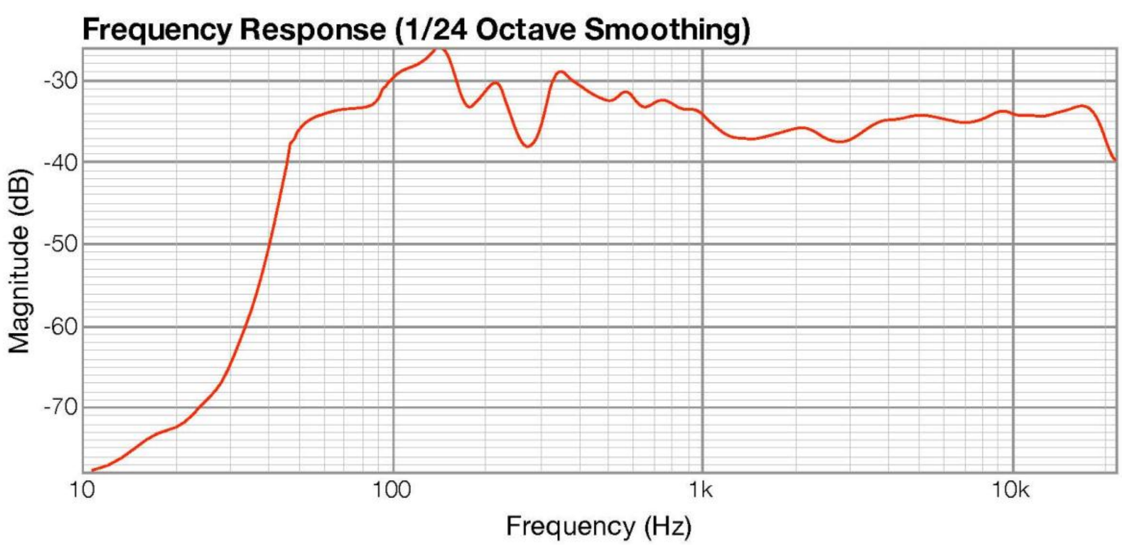


ENCLOSURE OPTIMIZATION

The enclosure required tuning due to the design choice of it having a transmission line. Transmission lines require enough stuffing to be added to the line in order to absorb all mid and high frequencies, yet still allow the low frequencies to travel through. I decided that I would add the initial amount of stuffing that the simulation suggested. This would remain in there until nearly the final tests where more would be added or removed as needed.

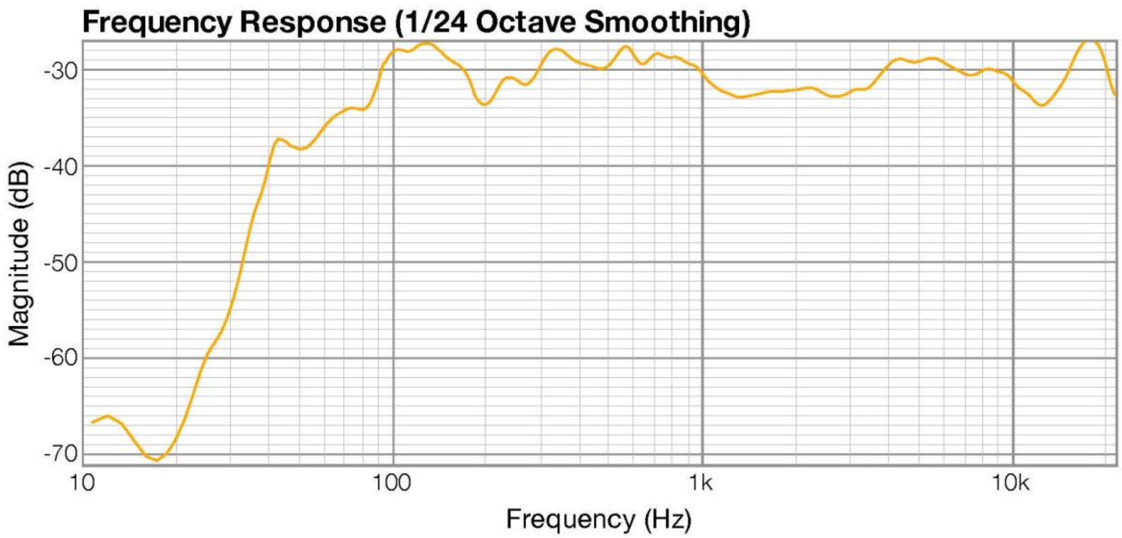
The first step when I was tuning the enclosure was to take a measurement of just the speaker with no stuffing in it. For all testing purposes the microphone was placed in direct line with the tweeter. Figure 25 shows the frequency response of the speaker with no stuffing.

Figure 25: Initial Cabinet with No Stuffing



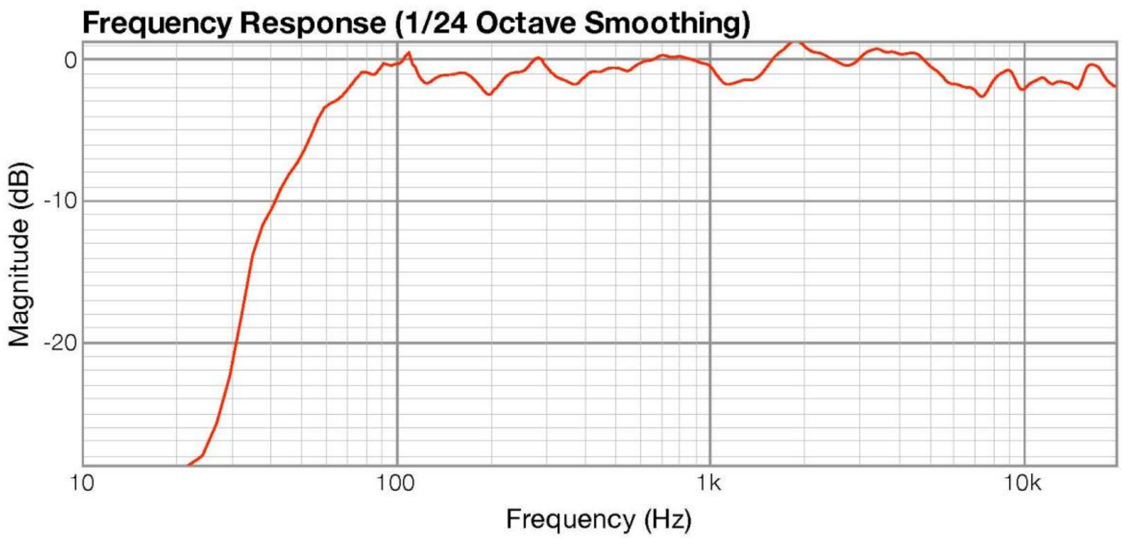
The plot shows that the bass responded similarly to the simulation; however the peaks and dips seemed to be more pronounced then was predicted. I proceeded to add the simulated amount of stuffing and that resulted in the response in Figure 26 on the following page.

Figure 26: Initial Cabinet with Stuffing



This appeared to smooth out the largest of peaks and dips but the response was far from ideal. It was then decided that the stuffing amount that was suggested from the simulation was going to be inefficient. I did not have any more Acousta-Stuf, so instead fiberglass insulation was used, which yielded a much more desirable result. Figure 27 shows the result of replacing the Acousta-Stuf with fiberglass insulation. It is worth noting that the fiberglass was used much later in the process so many other issues in the higher frequencies had already been addressed.

Figure 27: Cabinet with Fiberglass Stuffing



CROSS-OVER TUNING

For the cross-over of the circuit I will be utilizing a 2nd order Linkwitz- Riley crossover, which sums to a flat magnitude. This circuit does not require a baffle step correction circuit due to the .5 woofer.

Looking at Figure 28, one can see that the tweeter rolls off very nicely right around 2 kHz. This will therefore be the crossover point for the full range woofer and tweeter. The low frequency woofer will be crossed over at the baffle step frequency which is 536 Hz. This was calculated using the formula on page 14.

Figure 28: ScanSpeak Discovery Tweeter

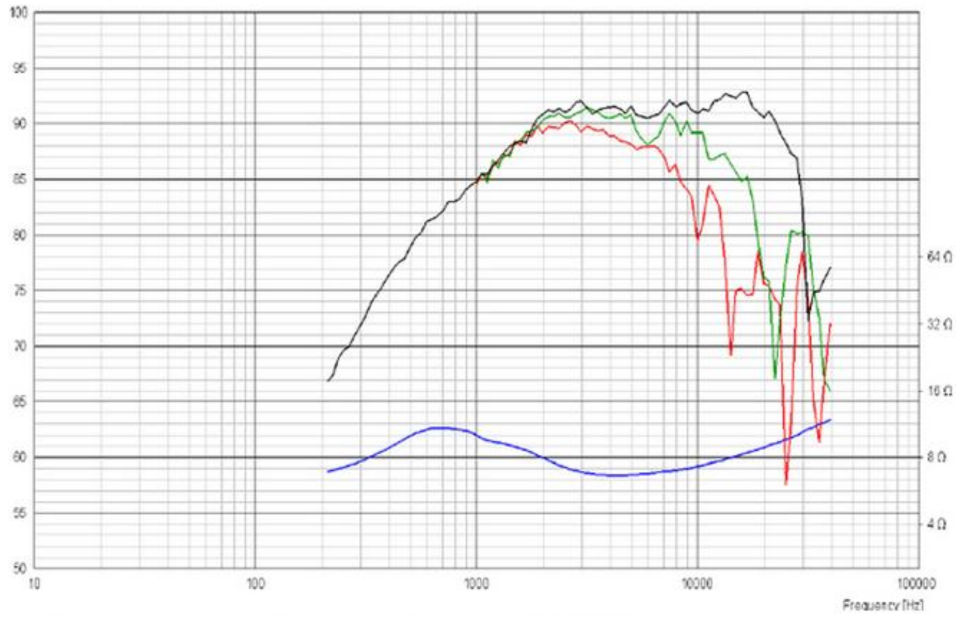


Figure 29 shows the frequency response of the woofer. There is a small peak in the response right at 1 kHz which may need to be addressed when fine tuning the crossover. The woofer and tweeter also have a rising impendence with rising frequency, so a Zobel circuit will be implemented to counteract that.

Figure 29: SEAS CA15RLY Frequency Response

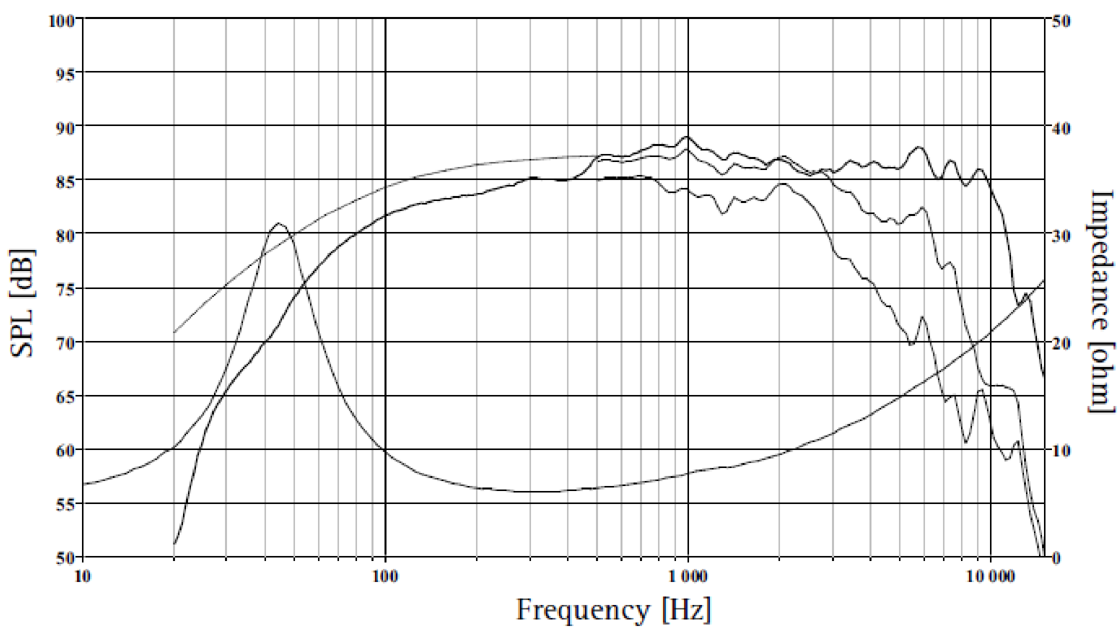
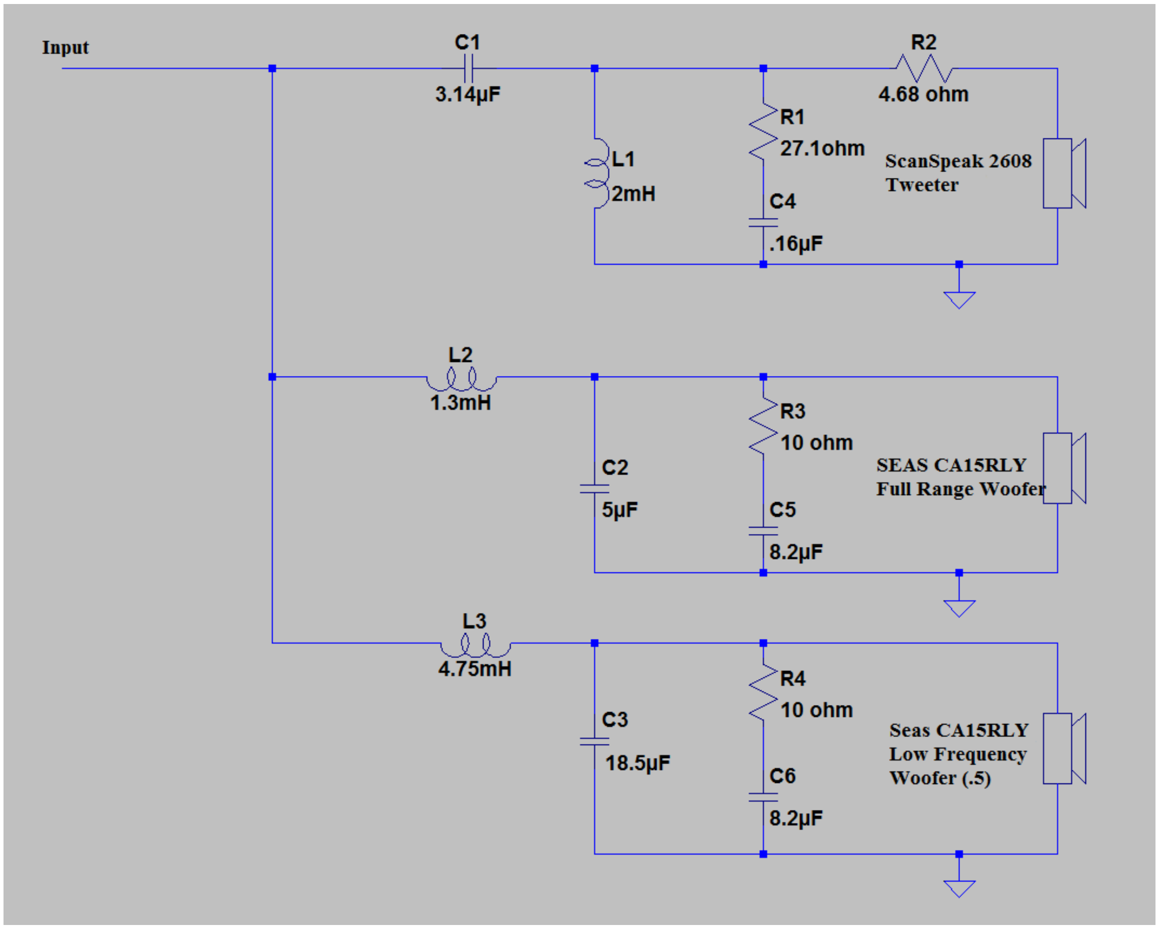


Figure 30, on the following page, is the initial design for the crossover of this system. It incorporates -4db of attenuation on the tweeter to account for the increased sensitivity and each crossover has a Zobel circuit

Figure 30: Initial Crossover Design



The above circuit was then built and placed into the speaker. The Zobel circuit was omitted on the tweeter due to the tweeter having magnetic cooling. Some values were approximated as close as possible due to the parts library not containing the exact values that were calculated. The initial design was lacking in a few areas. The calculations for the initial design for the crossover point being at 2 kHz were incorrect. As was evident in Figure 22 there was a broad peak in the response between 400 Hz and 1 kHz. A simple notch filter worked quite well to mitigate the bump, but the low end exhibited bump where the .5 woofer started combining with the full range woofer. Figure 31 on the next page shows the result of adding the notch filter. Figure 32 shows the result of L-padding the .5 woofer and the tweeter.

Figure 31: Notch Filter without Pad Correction

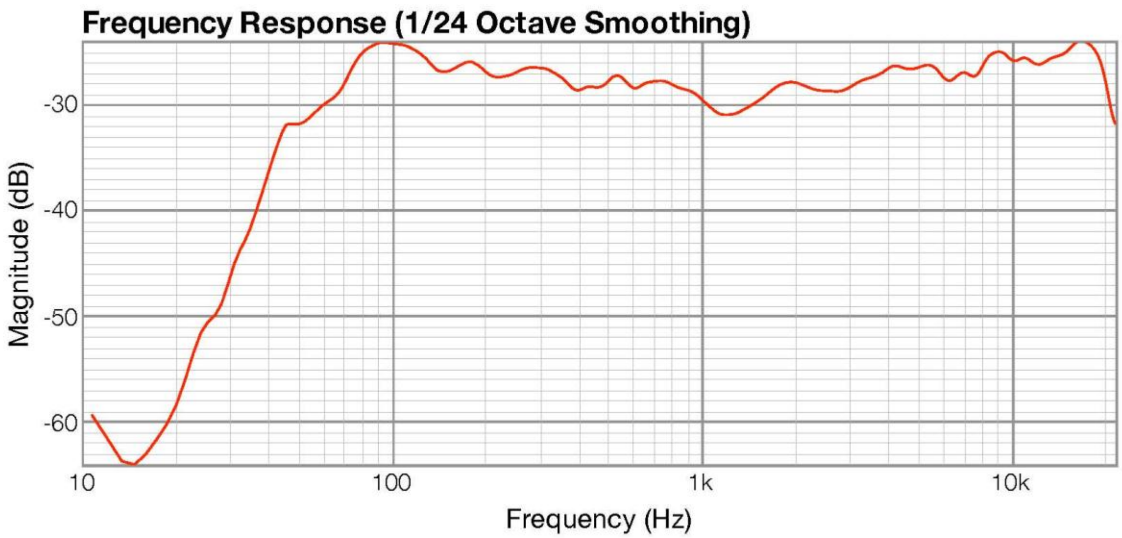
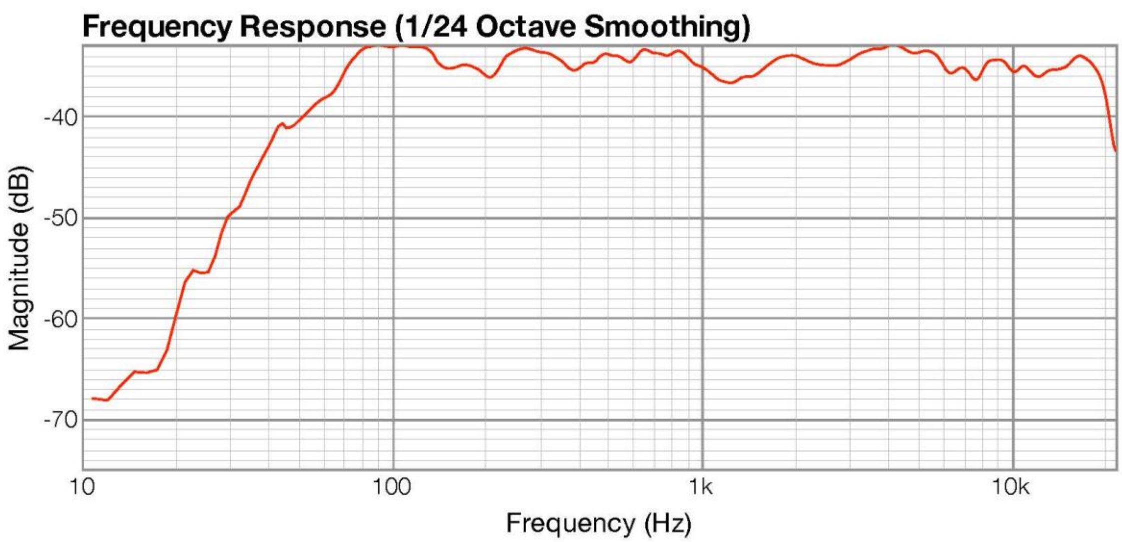


Figure 32: Notch Filter with Pad Correction



Further testing was then done with the speaker up on an 8 foot tall stand. This ensured that the surrounding room boundaries and floor would not interfere with accurate data. At this point it was discovered that adding denser stuffing to the line helped to flatten out the response without having any degenerative affects, such as loss of bass. Also there was a bit of mid frequency bleed that was coming through, but filling the spot right behind the full range woofer with a bit of Acousta-Stuf fixed the problem.

Final System Documentation

Final testing was done with the microphone at a distance of 11.25" away from the center of the tweeter. The speaker was placed on a stand of a height of 8 feet and was centered in McArdle theatre. The speaker was swept from 10 Hz to 30 kHz at a bit rate of 88.2 kHz. The system was testing to make sure that the audio interface exhibited a very flat response within the testing band. One speaker was extensively tested, checking the horizontal and vertical off axis response, and the response of each individual driver. The other speaker was tested so as to compare the response with the other speaker.

Final Testing Results

Figure 33: Overall Loudspeaker Frequency Response

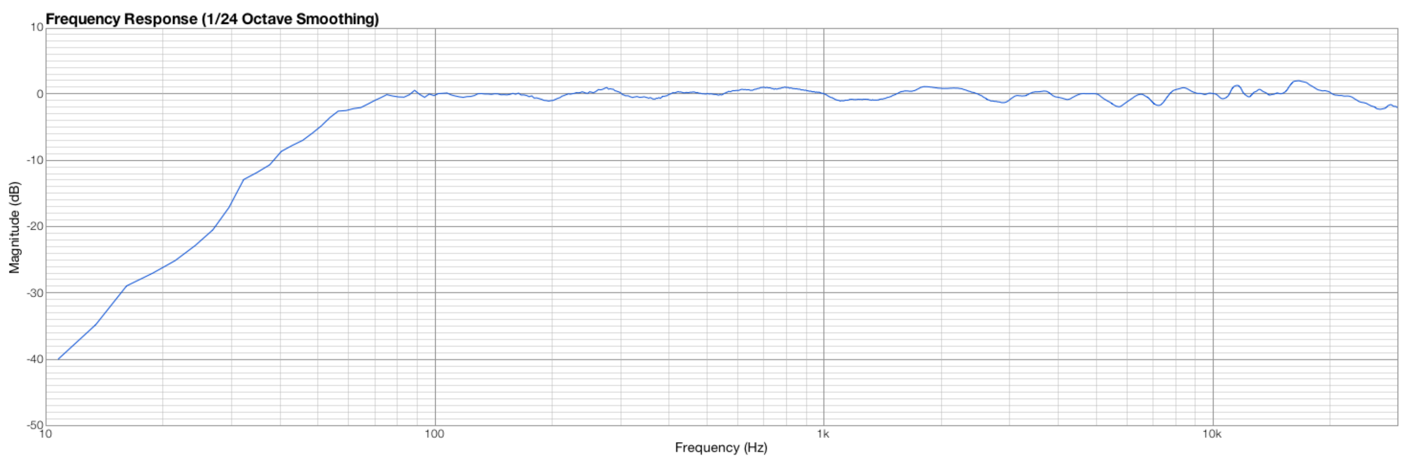
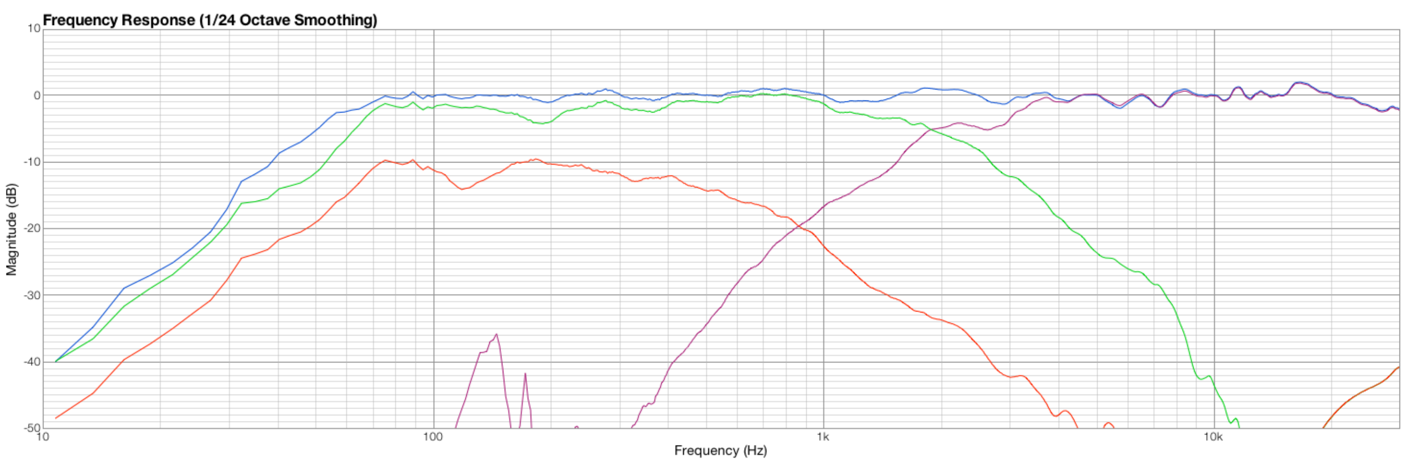


Figure 34: Overall Loudspeaker Integrated Frequency Response



Red is .5 woofer, Green is the woofer, Purple is the tweeter, Blue is overall

Figure 35: Harmonic Distortion Percentage

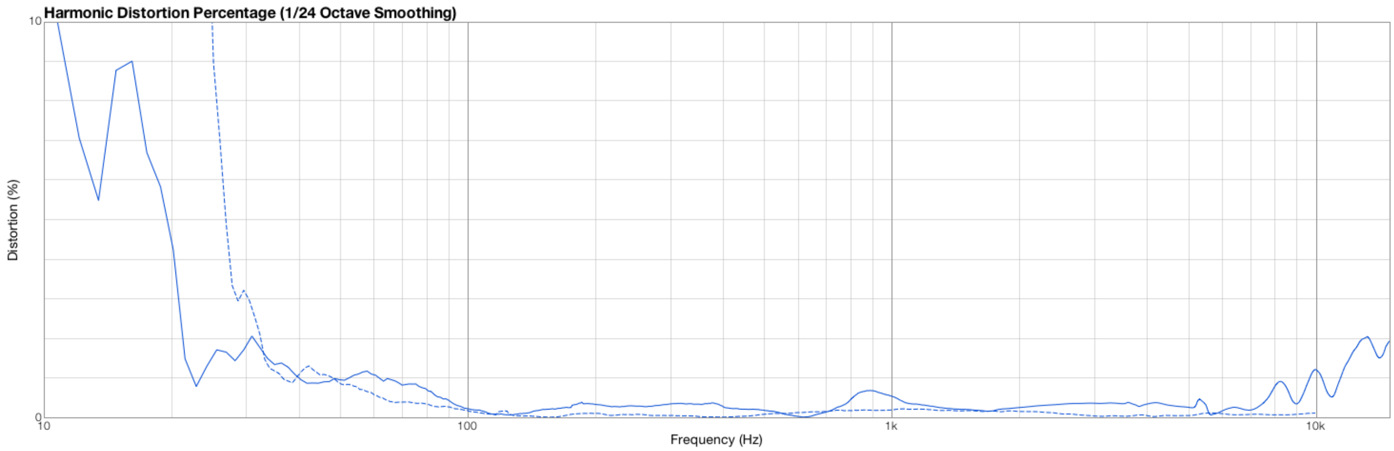


Figure 36: Loudspeaker Minimum Phase

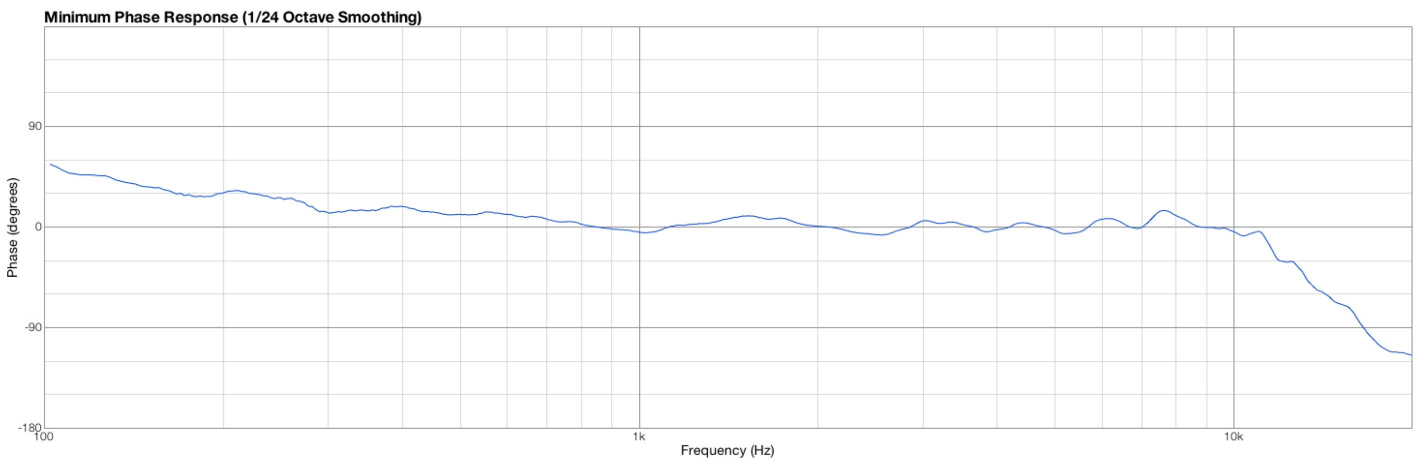
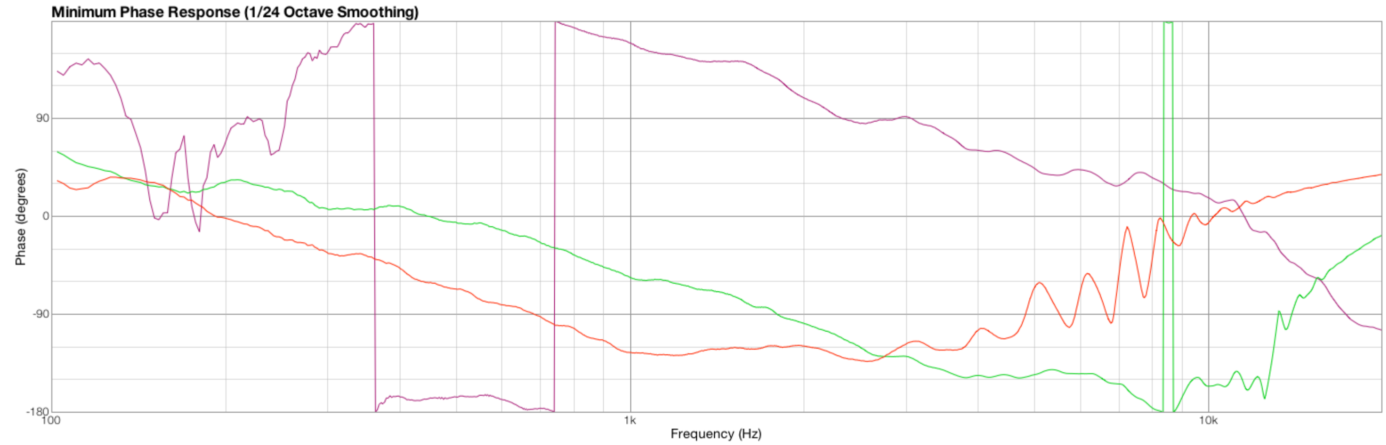
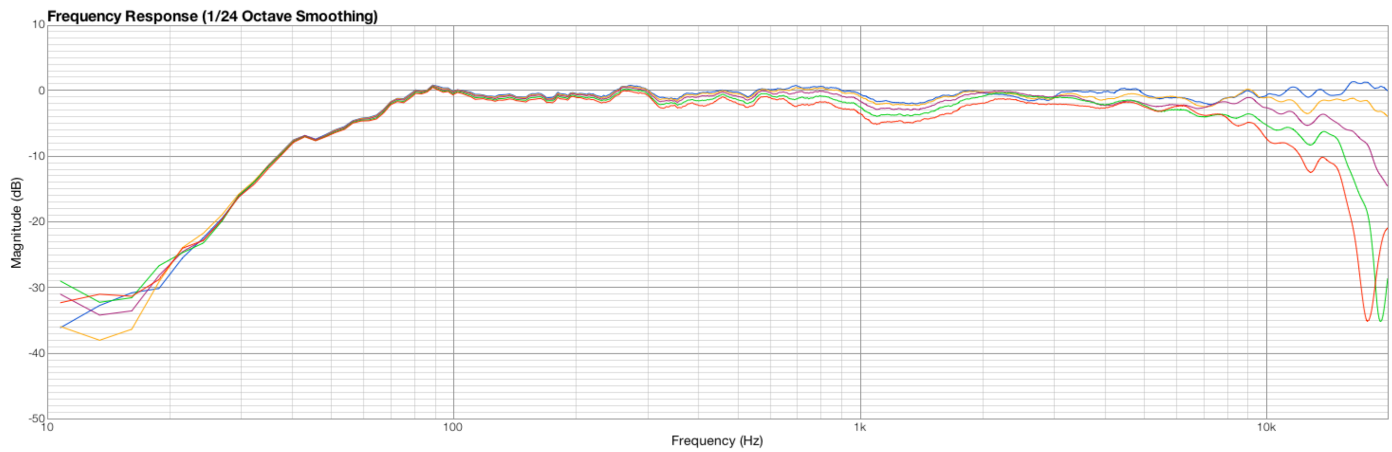


Figure 37: Loudspeaker Integrated Minimum Phase



Red/Orange is the .5 woofer, Green is the woofer, Purple is the tweeter

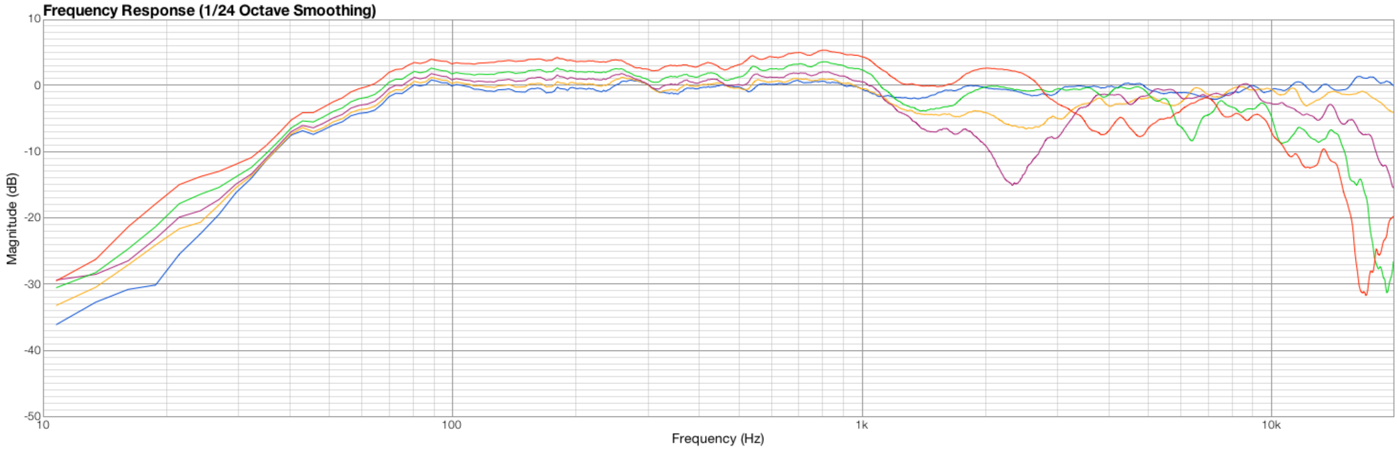
Figure 38: Horizontal Off-Axis Response



Blue 0°, Yellow 15°, Purple 30°, Green 45°, Red 60°

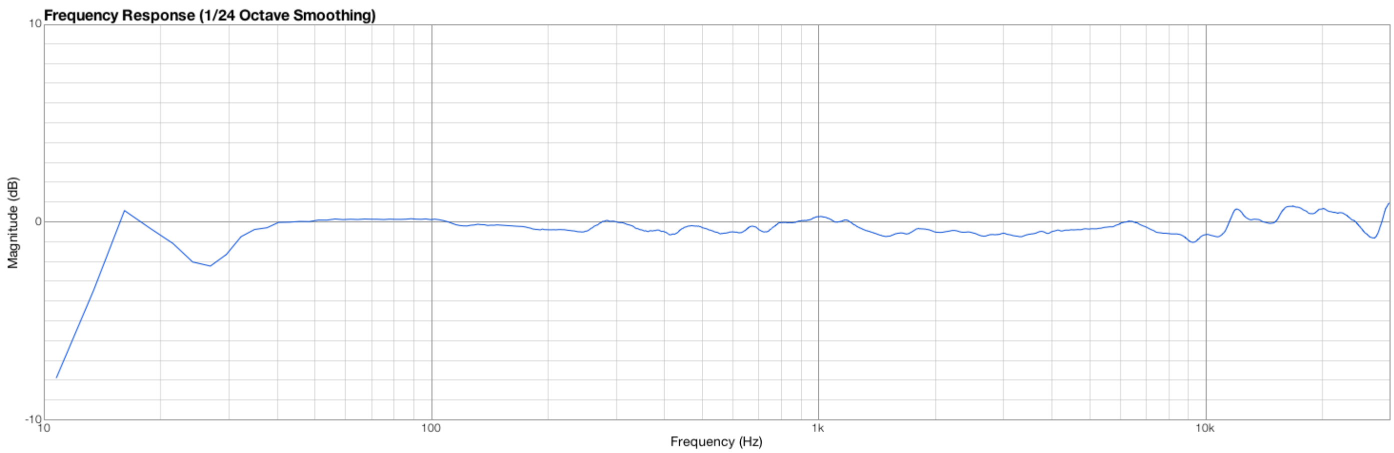
Figure 38 shows the horizontal off-axis response of the speaker. This was done using a protractor and string and making sure that the microphone was the same distance from the center tweeter throughout the span of angles. Figure 39 shows the vertical off-axis response of the loudspeaker. Due to the length of the string being 11.25” the boost in lower frequencies is most likely due to the microphone being in close proximity to the full range woofer that is on the top of the speaker.

Figure 39: Horizontal Off-Axis Response Upwards



Blue 0°, Yellow 15°, Purple 30°, Green 45°, Red 60°

Figure 40: Difference Plot between Both Speakers



The low frequency problems are not very significant. The difference between the two is most likely due to the room or slightly different microphone placements. The volume of the sound at that point is 20 dB below the rest making the difference rather miniscule.

Figure 41: Loudspeaker Step Response

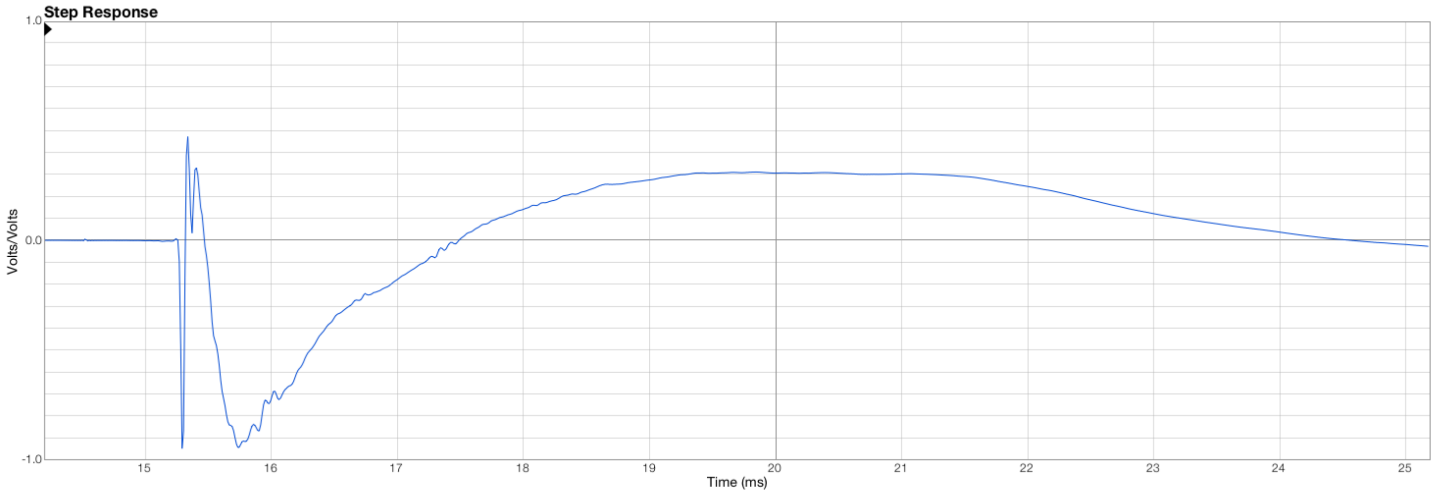
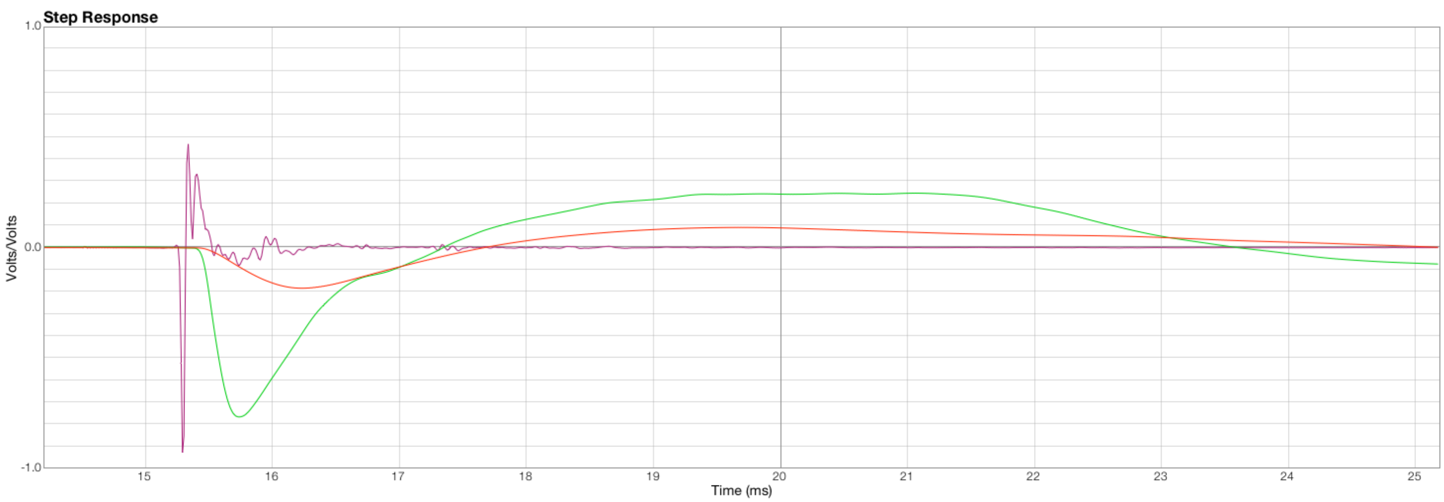


Figure 42: Loudspeaker Integrated Step Response



Red/Orange is the .5 woofer, Green is the woofer, Purple is the tweeter

Figure 43: Loudspeaker Impulse Response

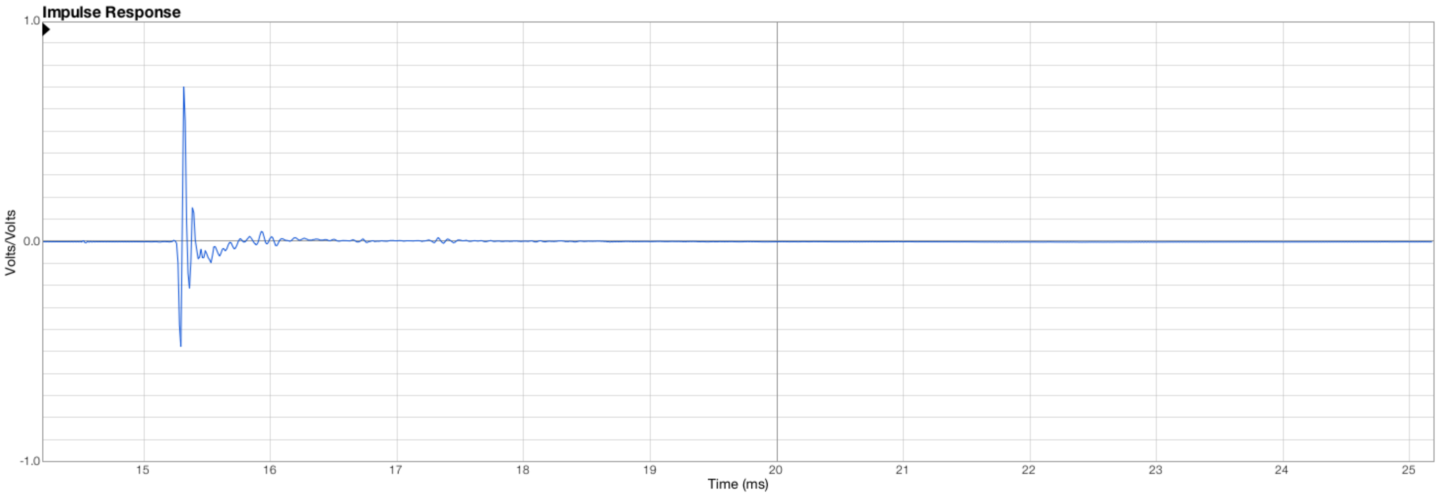


Figure 44: Loudspeaker Waterfall Plot 1

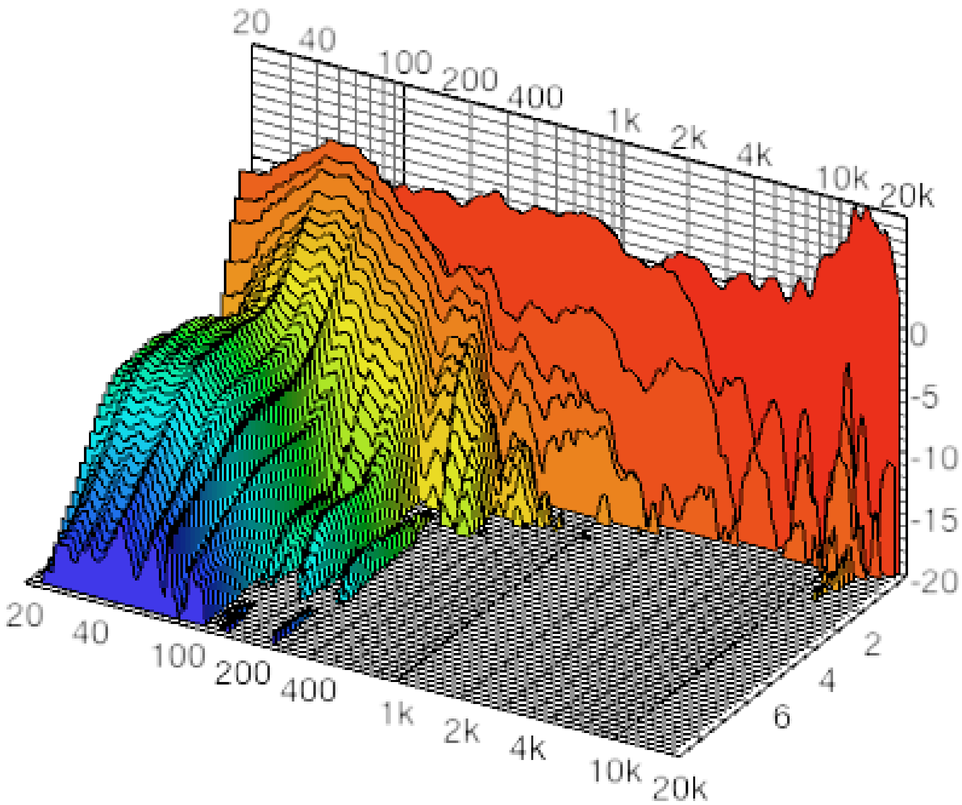
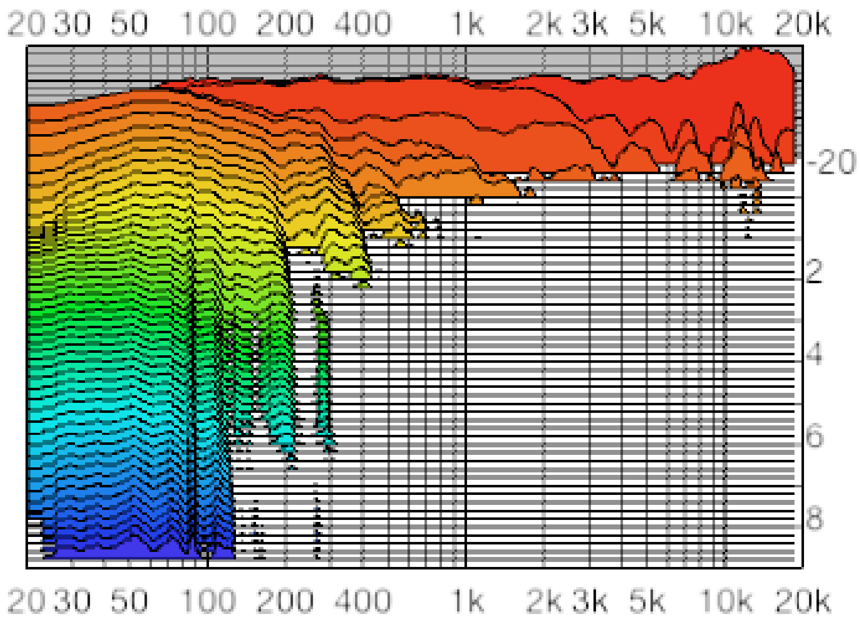


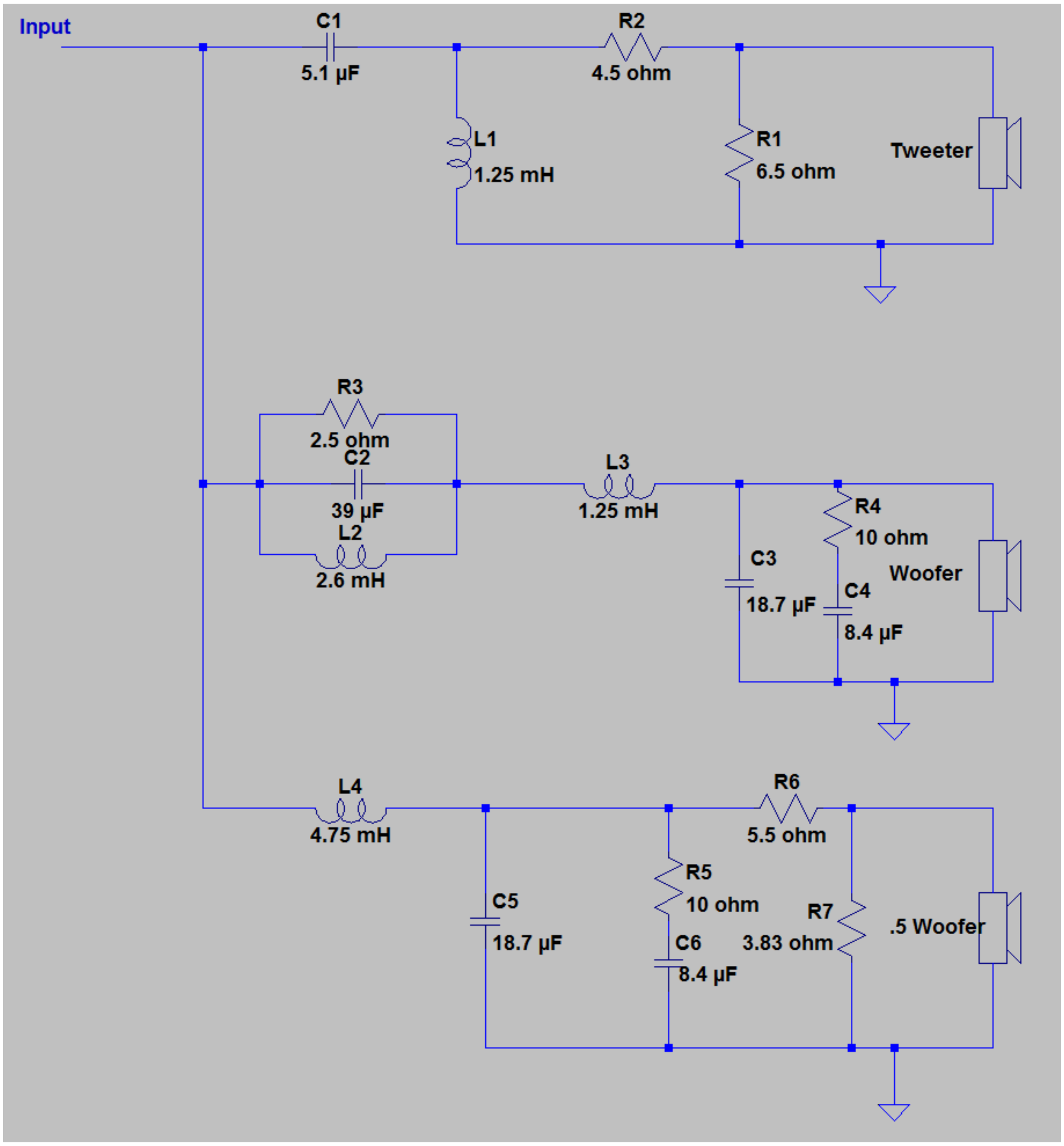
Figure 45: Loudspeaker Waterfall Plot 2



CROSS-OVER SCHEMATIC

Figure 46 on the following page is the final crossover schematic for the speakers.

Figure 46: Final Crossover Schematic



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L15RLY/P H1141

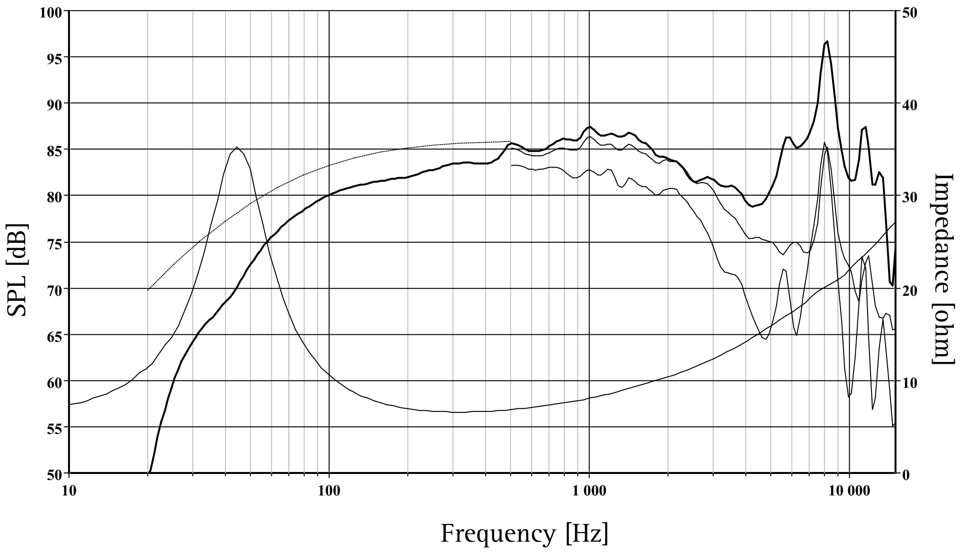
SEAS PRESTIGE

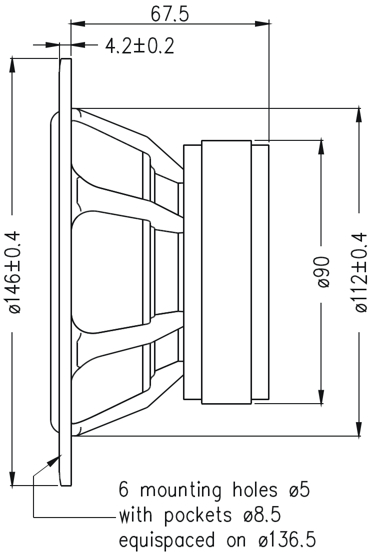
L15RLY/P is a 15 cm (5'') cone driver, developed for use as a long throw high fidelity woofer or woofer/midrange unit.

Stiff, yet light aluminium cone and low loss rubber surround show no sign of the familiar 500-1500 Hz cone edge resonance and distortion associated with soft cones.

Large magnet system , together with very long, and light weight copper clad aluminium voice coil allow for extreme coil excursion with low distortion and good transient response.

Extremely stiff and stable injection moulded metal basket, keeps the critical components in perfect alignment. Large windows in the basket both above and below the spider reduce sound reflection, air flow noise and cavity resonances to a minimum.





The frequency responses above show measured free field sound pressure in 0, 30, and 60 degrees angle using a 7L closed box. Input 2.83 VRMS, microphone distance 0.5m, normalized to SPL 1m.The dotted line is a calculated response in infinite baffle based on the parameters given for this specific driver. The impedance is measured in free air without baffle using a 2V sine signal.

Nominal Impedance	8 Ohms	Voice Coil Resistance	5.5 Ohms
Recommended Frequency Range	45 - 3000 Hz	Voice Coil Inductance	0.84 mH
Short Term Power Handling *	200 W	Force Factor	5.7 N/A
Long Term Power Handling *	80 W	Free Air Resonance	44 Hz
Characteristic Sensitivity (2,83V, 1m)	86 dB	Moving Mass	8.1 g
Voice Coil Diameter	26 mm	Air Load Mass In IEC Baffle	0.38 g
Voice Coil Height	16 mm	Suspension Compliance	1.6 mm/N
Air Gap Height	6 mm	Suspension Mechanical Resistance	1.12 Ns/m
Linear Coil Travel (p-p)	10 mm	Effective Piston Area	75 cm^2
Maximum Coil Travel (p-p)	20 mm	VAS	12 Litres
Magnetic Gap Flux Density	1.1 T	QMS	2.10
Magnet Weight	0.42 kg	QES	0.43
Total Weight	1.28 kg	QTS	0.35

CA15RLY
H1216

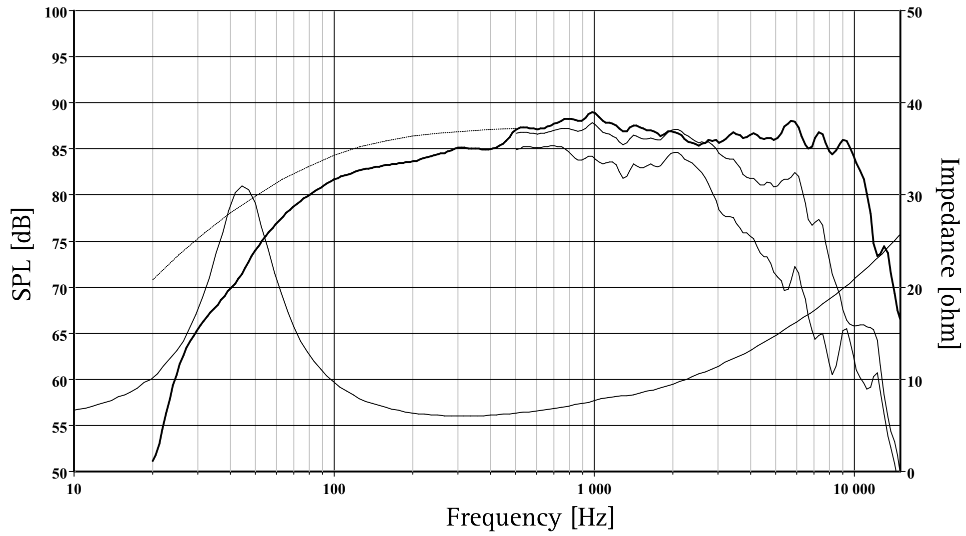
15 cm (5'') cone driver, developed for use as a long throw high fidelity woofer or woofer/midrange unit.

Classical coated paper cone that gives a smooth extended frequency response with a controlled roll off.

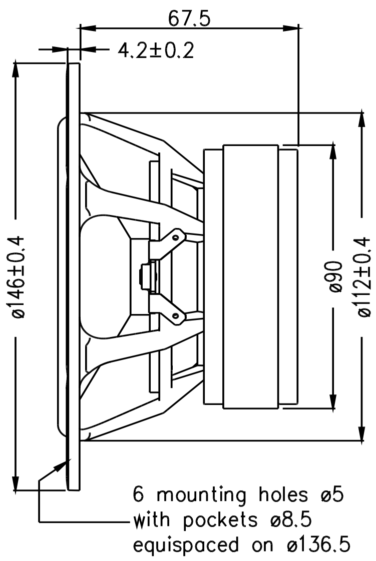
This driver uses SEAS SpiderRing® technology.

Large magnet system together with a very long and light weight CCAW voice coil allow good coil excursion with low distortion and good transient response.

Extremely stiff and stable injection moulded metal basket, that keeps the critical components in perfect alignment. Large windows in the basket both above and below the spider reduce sound reflection, air flow noise and cavity resonance to a minimum.



The frequency responses above show measured free field sound pressure in 0, 30, and 60 degrees angle using a 7L closed box. Input 2.83 VRMS, microphone distance 0.5m, normalized to SPL 1m.The dotted line is a calculated response in infinite baffle based on the parameters given for this specific driver. The impedance is measured in free air without baffle using a 2V sine signal.



Nominal Impedance	8 Ohms	Voice Coil Resistance	5.6 Ohms
Recommended Frequency Range	50 - 4000 Hz	Voice Coil Inductance	0.82 mH
Short Term Power Handling *	250 W	Force Factor	5.5 N/A
Long Term Power Handling *	60 W	Free Air Resonance	44 Hz
Characteristic Sensitivity (2,83V, 1m)	87.5 dB	Moving Mass	7.7 g
Voice Coil Diameter	26 mm	Air Load Mass In IEC Baffle	0.42 g
Voice Coil Height	16 mm	Suspension Compliance	1.7 mm/N
Air Gap Height	6 mm	Suspension Mechanical Resistance	1.19 Ns/m
Linear Coil Travel (p-p)	10 mm	Effective Piston Area	80 cm^2
Maximum Coil Travel (p-p)	20 mm	VAS	14 Litres
Magnetic Gap Flux Density	1.1 T	QMS	1.88
Magnet Weight	0.42 kg	QES	0.42
Total Weight	1.29 kg	QTS	0.34

Dec 2011

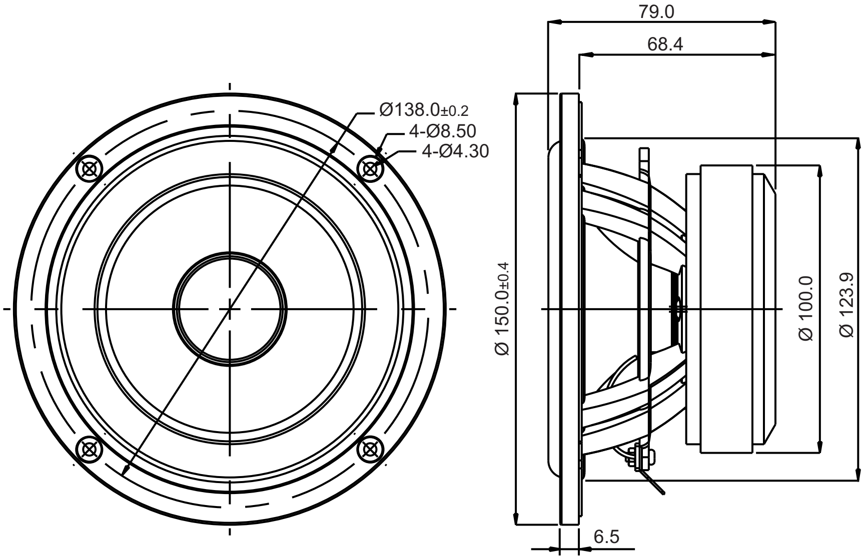
*IEC 268-5

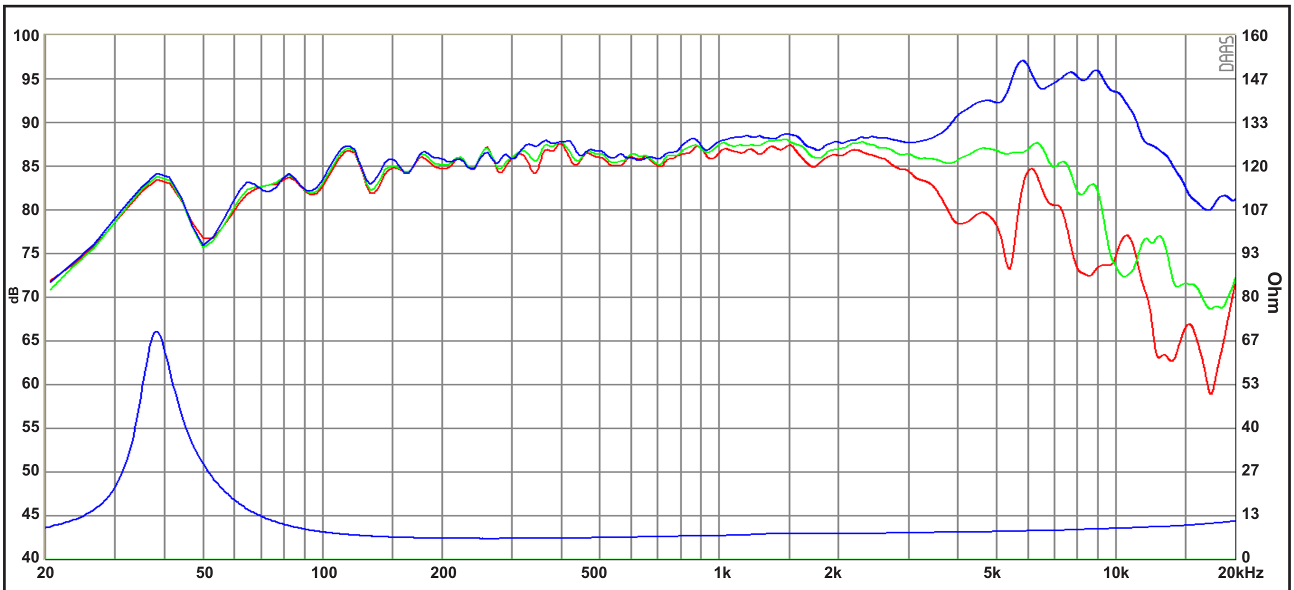
SEAS reserves the right to change technical data

SB ACOUSTICS

5” SB15MFC30-8

Preliminary data





(IEC baffle, mic. distance 31.6 cm, SPL shown for 2.83 V / 1 m)

Response Curve :

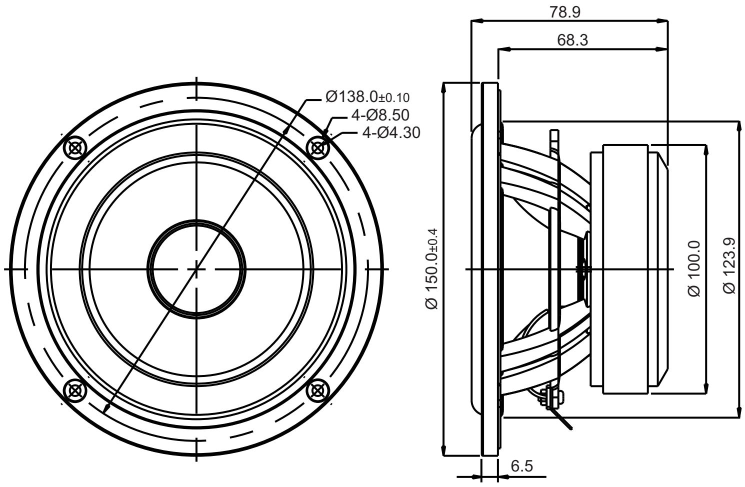
(Blue) : on axis — (Green) : 30° off-axis — (Red) : 60° off-axis

Specs :

Nominal Impedance	8 Ω	Free air resonance, Fs	39 Hz
DC resistance, Re	5.7 Ω	Sensitivity (2.83 V / 1 m)	87 dB
Voice coil inductance, Le	0.14 mH	Mechanical Q-factor, Qms	4.4
Effective piston area, Sd	82 cm^2	Electrical Q-factor, Qes	0.4
Voice coil diameter	30.5 mm	Total Q-factor, Qts	0.37
Voice coil height	15 mm	Moving mass incl.air, Mms	9.0 g
Air gap height	5 mm	Force factor, Bl	5.6 Tm
Linear coil travel (p-p)	10 mm	Equivalent volume, Vas	17.7 liters
Magnetic flux density	1.0 T	Compliance, Cms	1.85 mm/N
Magnet weight	0.54 kg	Mechanical loss, Rms	0.5 kg/s
Net weight	1.48 kg	Rated power handling*	50 W

* IEC 268-5, T/S parameters measured on drive units that are broken in.

5” SB15NRXC30-8



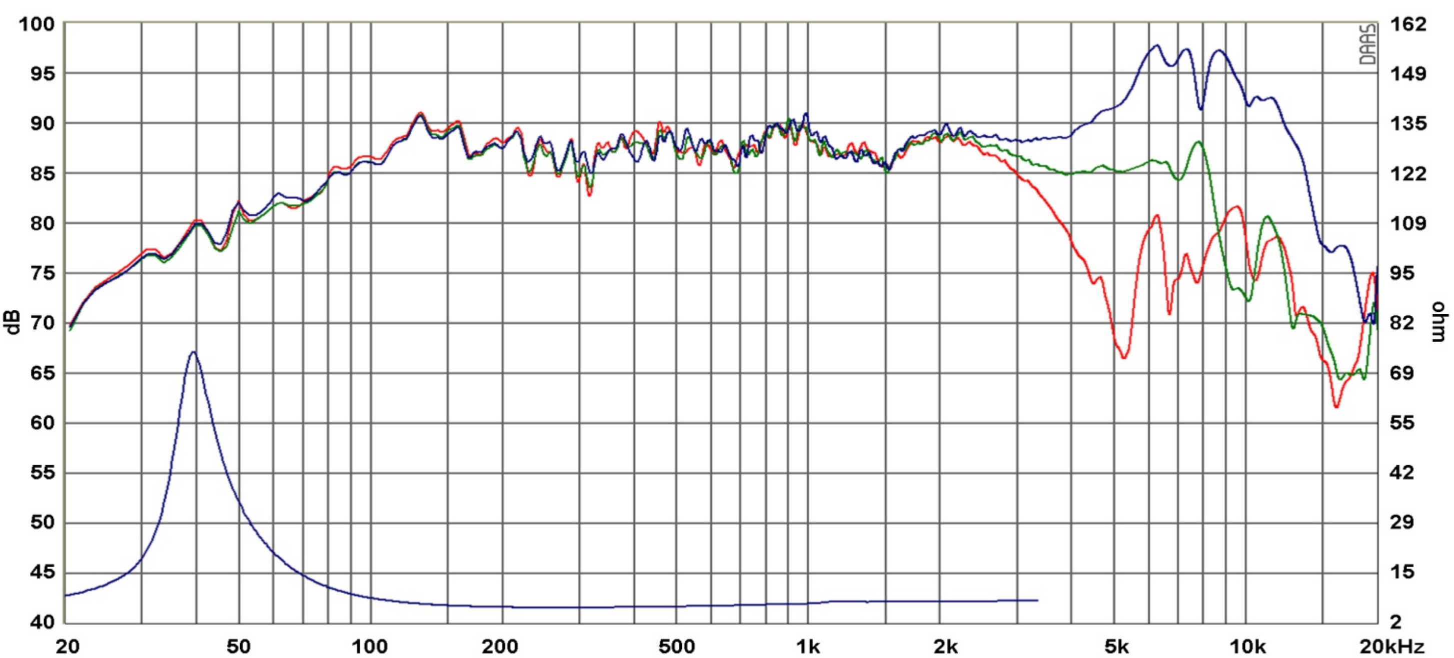
FEATURES

- Vented cast aluminum chassis for optimum strength and low compression
- Proprietary cone material with natural fibers made in-house
- Soft low damping rubber surround for transient response
- Non-conducting fiber glass voice coil former for minimum damping
- Extended copper sleeve on pole piece for low inductance and low distortion
- CCAW voice coil for reduced moving mass
- Long life silver lead wires
- Vented pole piece for reduced compression

Specs :

Nominal Impedance	8 Ω	Free air resonance, Fs	38 Hz
DC resistance, Re	5.7 Ω	Sensitivity (2.83 V / 1 m)	88 dB
Voice coil inductance, Le	0.14 mH	Mechanical Q-factor, Qms	4.8
Effective piston area, Sd	82 cm^2	Electrical Q-factor, Qes	0.35
Voice coil diameter	30.5 mm	Total Q-factor, Qts	0.33
Voice coil height	15 mm	Moving mass incl.air, Mms	8.1 g
Air gap height	5 mm	Force factor, Bl	5.6 Tm
Linear coil travel (p-p)	10 mm	Equivalent volume, Vas	20.7 liters
Magnetic flux density	1.0 T	Compliance, Cms	2.17 mm/N
Magnet weight	0.54 kg	Mechanical loss, Rms	0.4 kg/s
Net weight	1.48 kg	Rated power handling*	50 W

* IEC 268-5, T/S parameters measured on drive units that are broken in.



(IEC baffle, mic. distance 31.6 cm, SPL shown for 2.83 V / 1 m)

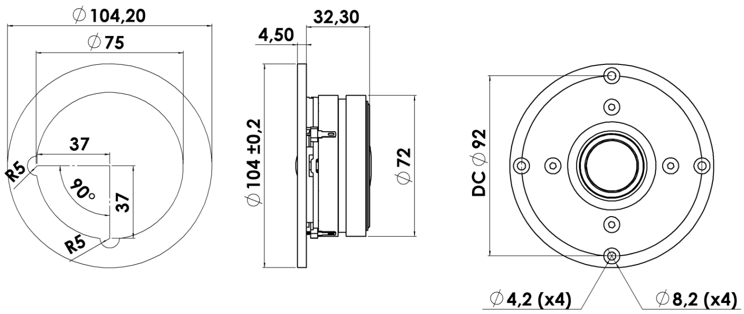
Response Curve :

------ (Blue) : on axis   ------ (Green) : 30° off-axis   ------ (Red) : 60° off-axis

DISCOVERY

TWEETER D2608/913000

The Discovery series offer traditional design, superior sound, a solid construction, and a wide range of variants. Combining these elements - plus a wealth of technical features and finesses - it gives our customers the possibility of acquiring a tailor-made Scan-Speak solution with very good performance at a reasonable low price point!



KEY FEATURES:

- Very low mass soft dome diaphragm
- Ferrofluid
- Low resonance Frequency
- Optimized Magnet System with Double magnets
- Fully Vented Motor System for Low compression
- Black Die-Cast Aluminium Face Plate

T-S Parameters

Resonance frequency [fs]	700 Hz
Mechanical Q factor [Qms]	0.51
Electrical Q factor [Qes]	0.65
Total Q factor [Qts]	0.29
Force factor [Bl]	2.6 Tm
Mechanical resistance [Rms]	1.54 kg/s
Moving mass [Mms]	0.18 g
Suspension compliance [Cms]	0.29 mm/N
Effective diaph. diameter [D]	30 mm
Effective piston area [Sd]	7 cm²
Equivalent volume [Vas]	0.02 l
Sensitivity (2.83V/1m)	91.3 dB
Ratio Bl/√Re	1.10 N/√W
Ratio fs/Qts	2434 Hz

Notes:
IEC specs. refer to IEC 60268-5 third edition.
All Scan-Speak products are RoHS compliant.
Data are subject to change without notice.
Datasheet updated: February 22, 2011.

Electrical Data

Nominal impedance [Zn]	8 Ω
Minimum impedance [Zmin]	6.6 Ω
Maximum impedance [Zo]	10.0 Ω
DC resistance [Re]	5.6 Ω
Voice coil inductance [Le]	0.04 mH

Power Handling

100h RMS noise test (IEC 17.1)*	80 W
Long-term max power (IEC 17.3)*	400 W

*Filter: 2. order HP Butterworth, 4 kHz

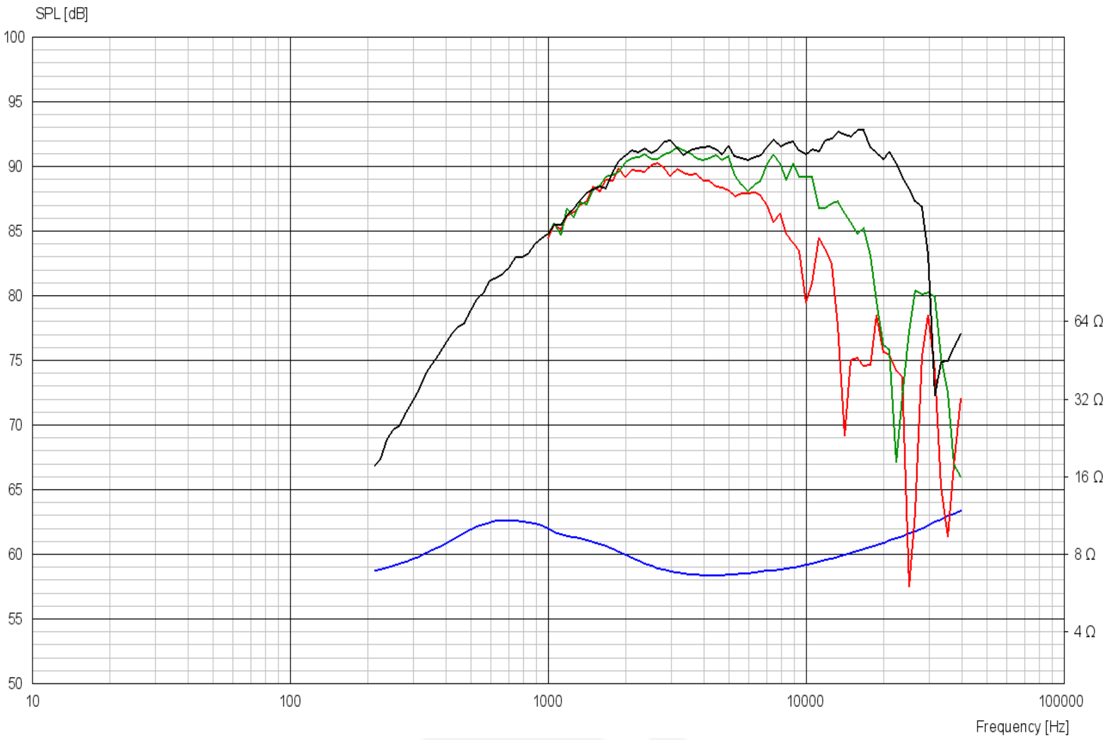
Voice Coil and Magnet Data

Voice coil diameter	26 mm
Voice coil height	1.5 mm
Voice coil layers	2
Height of gap	2.5 mm
Linear excursion	± 0.5 mm
Max mech. excursion	± - mm
Unit weight	0.7 kg

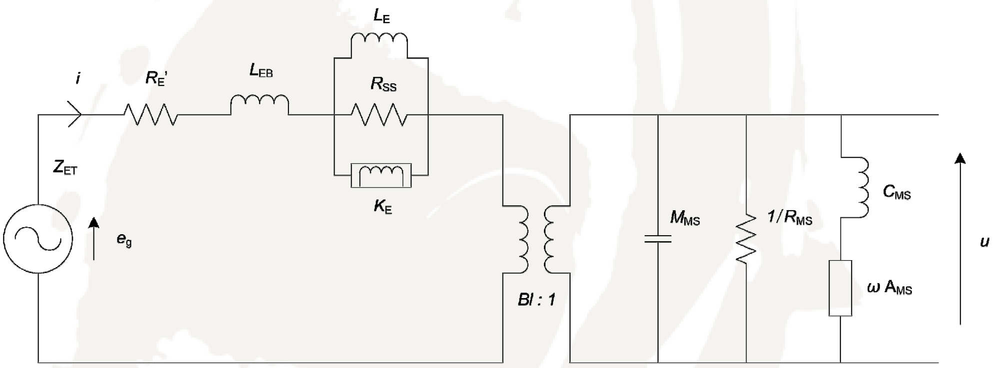
SCANSPEAK
N.C. Madsensvej 1 · 6920 Videbæk · Denmark · Phone: +45 6040 5200 · www.scan-speak.dk

DISCOVERY

TWEETER D2608/913000



Advanced Parameters (Preliminary)



Electrical data:	
Resistance [Re']	- Ω
Free inductance [Leb]	- mH
Bound inductance [Le]	- mH
Semi-inductance [Ke]	- SH
Shunt resistance [Rss]	- Ω

Mechanical Data	
Force Factor [Bl]	- Tm
Moving mass [Mms]	- g
Compliance [Cms]	- mm/N
Mechanical resistance [Rms]	- kg/s
Admittance [Ams]	- mm/N

SCANSPEAK

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SEAS PRESTIGE

27TDFC H1189

27TDFC is a High Definition precoated fabric dome tweeter with a wide, soft polymer surround and a rear chamber.

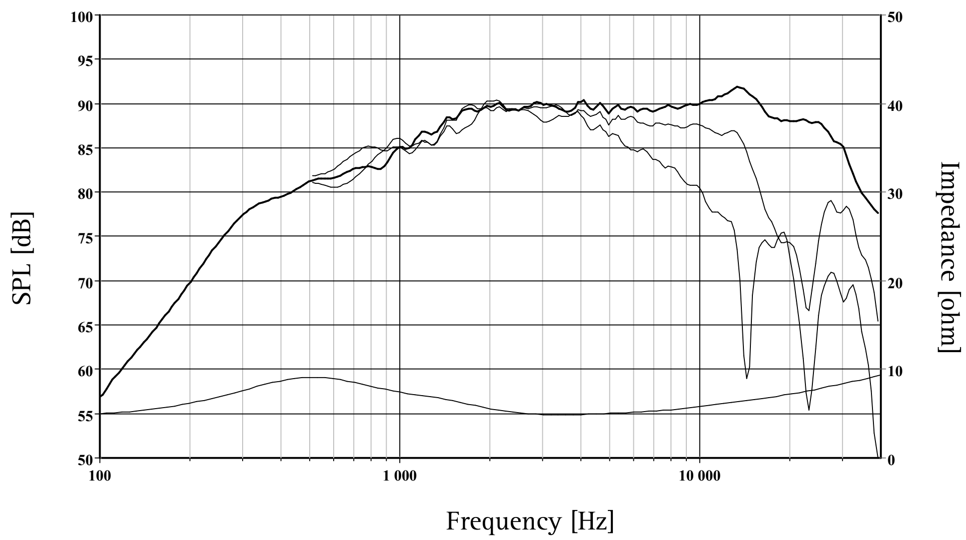
Sonotex precoated fabric diaphragm with high consistency and excellent stability against variations in air humidity

Sonomax surround for low resonance and excellent mechanical linearity.

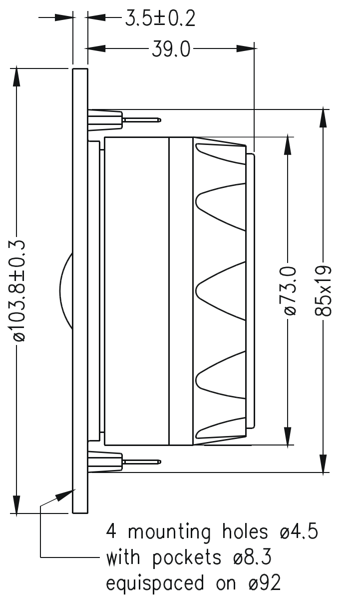
Voice coil windings immersed in magnetic fluid increase short term power handling capacity and reduce the compression at high power levels.

Stiff and stable rear chamber with optimal acoustic damping allows the tweeter to be used with moderately low crossover frequencies.

The chassis is precision moulded from glass fibre reinforced plastic, and its front design offers optimum radiation conditions.



The frequency responses above show measured free field sound pressure in 0, 30, and 60 degrees, mounted in a 0.6m by 0.8m baffle. Input 2.83 Vrms, microphone distance 0.5m, normalized to SPL 1m. The impedance is measured without baffle using a 2V sine signal.



Nominal Impedance	6 Ohms	Voice Coil Resistance	4.8 Ohms
Recommended Frequency Range	1500 - 25000 Hz	Voice Coil Inductance	0.05 mH
Short Term Power Handling *	220 W	Force Factor	3.5 N/A
Long Term Power Handling *	90 W	Free Air Resonance	550 Hz
Characteristic Sensitivity (2.83V, 1m)	90 dB	Moving Mass	0.37 g
Voice Coil Diameter	26 mm	Effective Piston Area	7.5 cm^2
Voice Coil Height	1.5 mm	Magnetic Gap Flux Density	1.8 T
Air Gap Height	2.0 mm	Magnet Weight	0.25 kg
Linear Coil Travel (p-p)	0.5 mm	Total Weight	0.50 kg

Jul 2007-1

*IEC 268-5, via High Pass Butterworth Filter 2500Hz 12 dB/oct.
SEAS reserves the right to change technical data

T27-531

27TBFC/G
H1212

27TBFC/G is a High Definition metal dome tweeter with a wide, soft polymer surround and a rear chamber.

Aluminium/magnesium alloy diaphragm with pistonic behaviour throughout the audible frequency range, resulting in a good dispersion also above 10kHz.

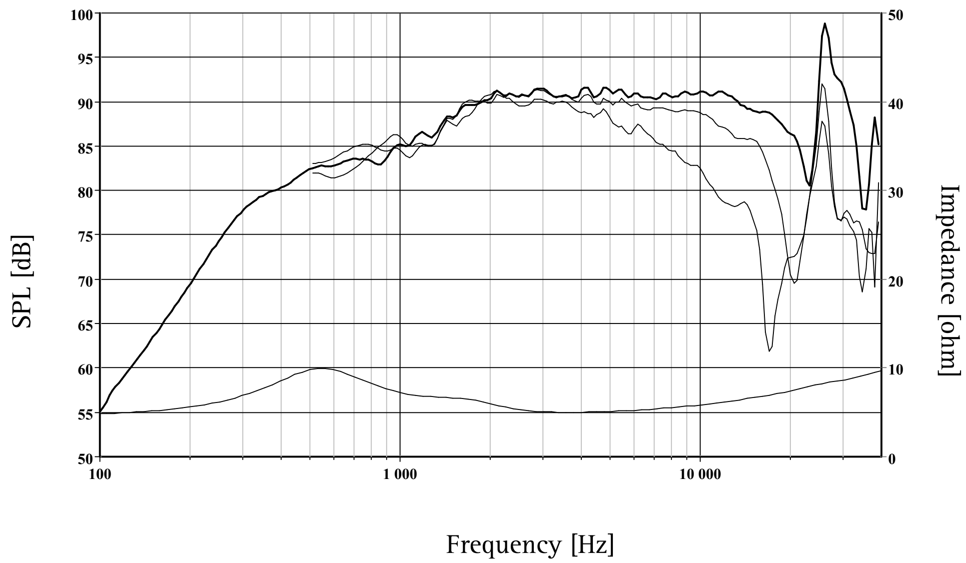
A Hexagrid protects the diaphragm, and supports a phase plate which compensates for a slight axial roll off towards 20 kHz.

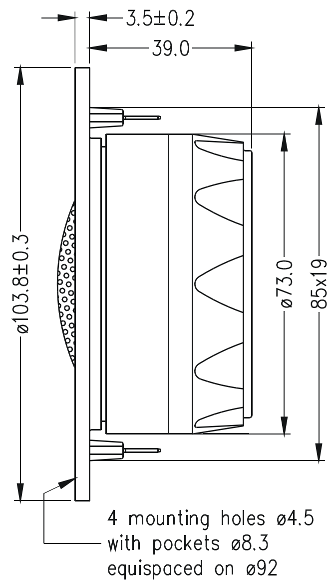
Sonomax surround for low resonance and excellent mechanical linearity.

Voice coil windings immersed in magnetic fluid increase short term power handling capacity and reduce the compression at high power levels.

Stiff and stable rear chamber with optimal acoustic damping allows the tweeter to be used with moderately low crossover frequencies.

Precision moulded chassis from glass fibre reinforced plastic, and its front design offers optimum radiation conditions.





The frequency responses above show measured free field sound pressure in 0, 30, and 60 degrees, mounted in a 0.6m by 0.8m baffle. Input 2.83 Vrms, microphone distance 0.5m, normalized to SPL 1m. The impedance is measured without baffle using a 2V sine signal.

Nominal Impedance	6 Ohms	Voice Coil Resistance	4.8 Ohms
Recommended Frequency Range	1500 - 20000 Hz	Voice Coil Inductance	0.05 mH
Short Term Power Handling *	220 W	Force Factor	3.5 N/A
Long Term Power Handling *	90 W	Free Air Resonance	550 Hz
Characteristic Sensitivity (2.83V, 1m)	91.5 dB	Moving Mass	0.34 g
Voice Coil Diameter	26 mm	Effective Piston Area	7.5 cm^2
Voice Coil Height	1.5 mm	Magnetic Gap Flux Density	1.8 T
Air Gap Height	2.0 mm	Magnet Weight	0.25 kg
Linear Coil Travel (p-p)	0.5 mm	Total Weight	0.50 kg

Jul 2007-1 — *IEC 268-5, via High Pass Butterworth Filter 2500Hz 12 dB/oct. — T27-431

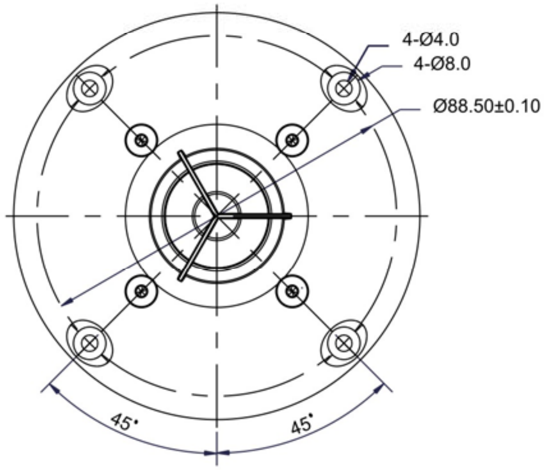
SEAS reserves the right to change technical data

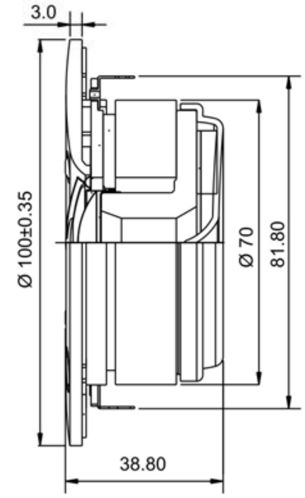
RoHS compliant product

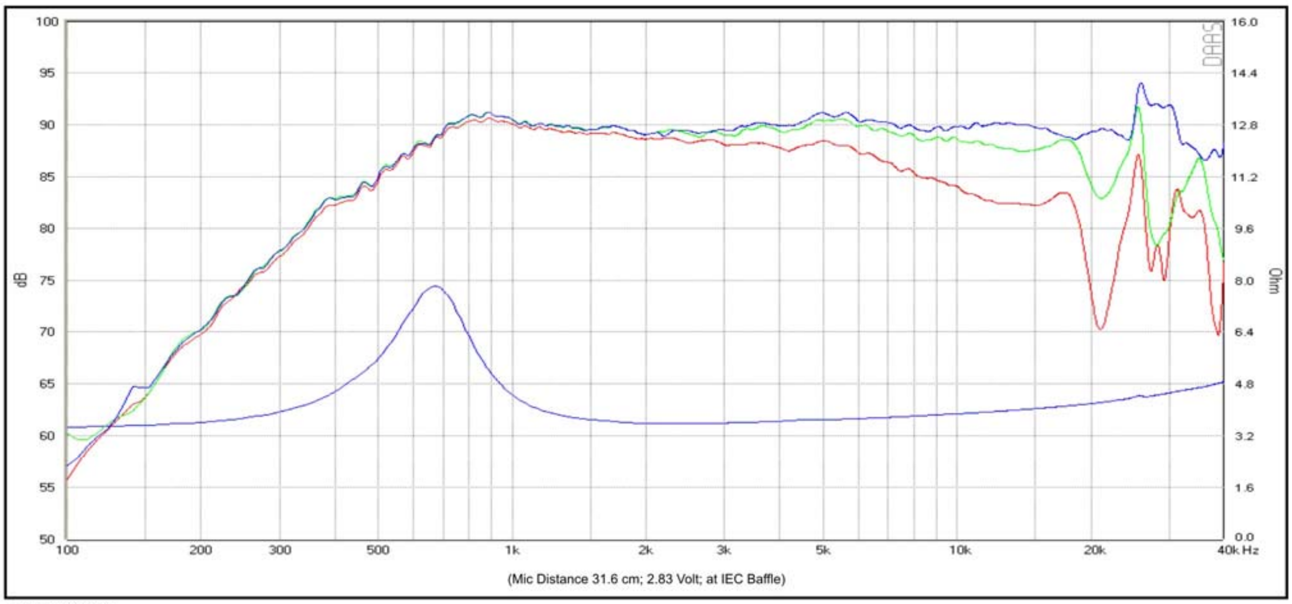
SB ACOUSTICS

SB26ADC-C000-4

Preliminary data







Response Curve :

(Blue) : on axis — (Green) : 30 off-axis — (Red) : 60 off-axis

Specs :

Nominal Impedance	4 Ω	Free air resonance, Fs	680 Hz
DC resistance, Re	3.2 Ω	Sensitivity (2.83 V/1m)	90 dB
Voice coil inductance, Le	0.04 mH	Mechanical Q-factor, Qms	2.9
Effective piston area, Sd	6.2 cm^2	Electrical Q-factor, Qes	2.0
Voice coil diameter	25.4 mm	Total Q-factor, Qts	1.2
Voice coil height	1.3 mm	Force factor, Bl	1.6 Tm
Air gap height	2.5 mm	Rated power handling*	120 watt
Linear coil travel (p-p)	1.2 mm	Magnetic flux density	1.15 T
Moving mass incl. air, Mms	0.38 g	Magnet weight	0.22 kg
		Net weight	0.5 kg

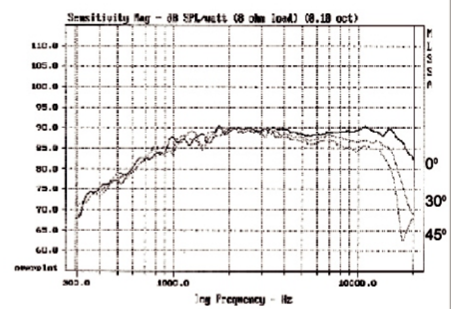
*(IEC 268-5, Via High Pass Butterworth Filter 2500Hz 12 dB/oct.

MDT 29 –SOFT DOME TWEETER, CLASSIC RANGE

Acuflex Treated Dome Ferrite Magnet

FEATURES:

- -Large diameter voice co l
- -Replaceable dome/co l assembly
  Aluminum face plate
- -Ferrofluid cooled
- -High power handling
- -Sturdy gold-plated nput tags

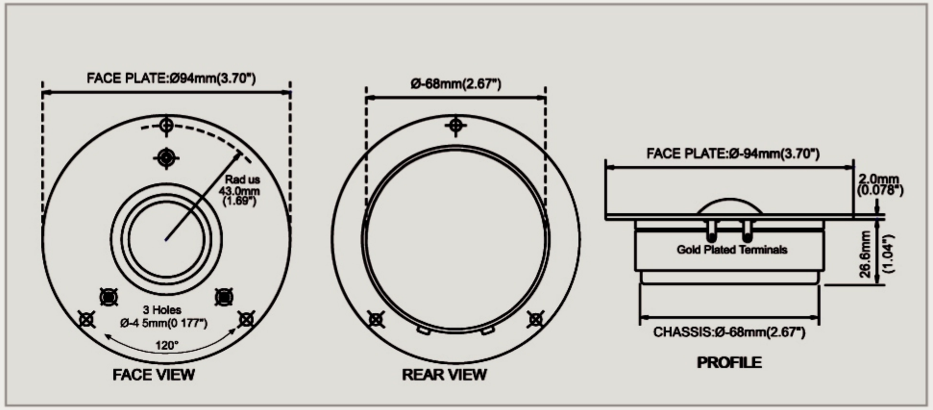


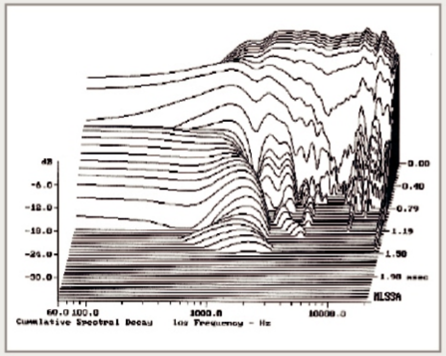
Specifications

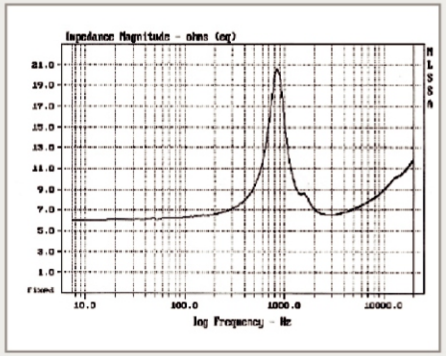
Overall Dimensions		ø94mm(3 7")x28.6mm(1.11")
Nominal Power Handl ng (D N)	P	80 W
Transient power 10ms		1000 W
Nominal Impedance	Z	8 Ohms
Sensitivity 1W/1M		89 dB
Frequency Response		1800–20000 Hz
Resonant Frequency	FS	900 Hz
Voice coil		
Voice Coil Diameter	DIA	28mm (1.125")
Voice Coil Height		2.5mm (0 098")
Voice Coil Former		Aluminum
Voice Coil W re		Copper
Number of Layers		2
DC Resistance	RE	5.2 Ohms
Voice Coil Inductance @ 1KHz	LBM	0.05 mH
Magnet System		
Magnet System Type		Ferrite
HE – Magnetic Gap He ght	HE	2.5mm (0.098")
B Flux Dens ty	B	1.45 T
BL Product	BXL	3.3 N.A
Max. Linear Excursion	X	
Operational Parameters		
Suspension Compliance	CMS	
Mechanical Q Factor	QMS	
Electrical Q Factor	QES	
Total Q Factor	Q/T	
Mechanical Resistance	RMS	
Moving Mass	MMS	0.5 gm.
Eq. Cas Air Load (liters)	VAS	
Dome Mater al	Acuflex	Hand Treated Fabric
Effective Piston Area	SD	6.0 cm²
Net Weight	Kg.	0.54 Kg.

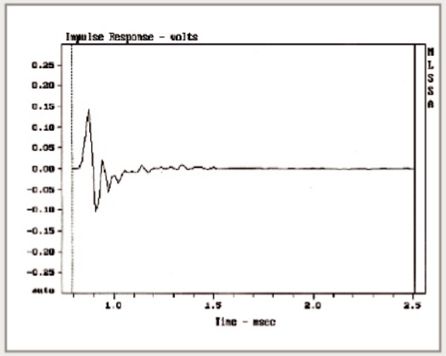
morel HIGH FIDELITY

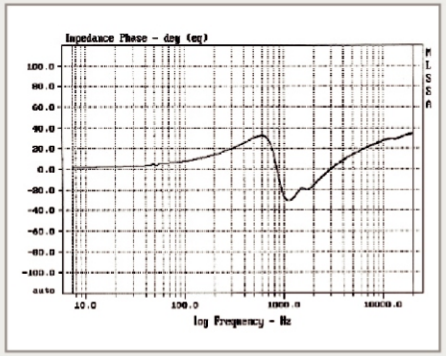
MDT 29











morel www.morelhifi.com

Offset Driver in an Open Ended Transmission Line - Acoustic and Electrical Response **7/03/09**

Software : by Martin J. King
e-mail MJKing57@aol.com

Line Configuration : Near End Closed -> Offset Driver -> Far End Open.

Unit and Constant Definition

$cycle := 2 \cdot \pi \cdot rad$

$Hz := cycle \cdot sec^{-1}$

Air Density : $\rho := 1.205 \cdot kg \cdot m^{-3}$

Speed of Sound : $c := 344 \cdot m \cdot sec^{-1}$

Part 1 : Thiele-Small Consistent Calculation

Detailed User Input (Edit This Section and Input the Parameters for the System to be Analyzed)

Series Resistance

$R_{add} := 0.0 \cdot \Omega$

Driver Thiele / Small Parameters : SEAS CA15RLY

$f_d := 44 \cdot Hz$

$V_{ad} := 28 \cdot liter$

Adjustments

$R_e := 11.2 \cdot \Omega$

$Q_{ed} := .42$

$R_e := R_e + R_{add}$

$L_{vc} := 1.64 \cdot mH$

$Q_{md} := 1.88$

$Q_{ed} := Q_{ed} \cdot R_e \cdot (R_e - R_{add})^{-1}$

$Bl := 11 \cdot \frac{newton}{amp}$

$Q_{td} := \left(\frac{1}{Q_{ed}} + \frac{1}{Q_{md}} \right)^{-1}$

$S_d := 160 \cdot cm^2$

$Q_{td} = 0.343$

$Power := 18 \cdot watt$ (Input Power) Applied Voltage Reference ---> $R_{ref} := 16 \cdot \Omega$

Enclosure Geometry Definition

Reference : Derivation and Correlation of a Viscous Damping Model Used in the Design of a Transmission Line Loudspeaker System
by Martin J. King, 3/04/01

The following dimension were derived from "Figure 18 : Cabinet Construction Details and Dimensions (inches)" of the referenced article. This is the most accurate model for the Focal 8V 4412 two-way transmission line enclosure. All of the required input data has been entered below directly into the Geometry Definition section of the worksheet. No variable definitions have been used to describe the enclosure geometry.

Transmission Line Definition

(0 lb/ft^3 < D < 1 lb/ft^3)

$n\_closed := 4$ (n_closed > 1)

$n\_open := 9$ (n_open > 1)

Geometry Definition

Closed End of Transmission Line (Driver ---> Closed End)

Section Length	Initial Area	Final Area	Stuffing
$L_{c_0} := 3.225 \cdot in$	$S_{c_{0,0}} := 7in \cdot 7.125in$	$S_{c_{0,1}} := 7in \cdot 7.125in$	$D_{c_0} := 1 \cdot lb \cdot ft^{-3}$
$L_{c_1} := 3.225 \cdot in$	$S_{c_{1,0}} := 7in \cdot 7.125in$	$S_{c_{1,1}} := 7in \cdot 7.125in$	$D_{c_1} := 1 \cdot lb \cdot ft^{-3}$
$L_{c_2} := 3.225 \cdot in$	$S_{c_{2,0}} := 7in \cdot 7.125in$	$S_{c_{2,1}} := 7in \cdot 7.125in$	$D_{c_2} := 1 \cdot lb \cdot ft^{-3}$
$L_{c_3} := 3.225 \cdot in$	$S_{c_{3,0}} := 7in \cdot 7.125in$	$S_{c_{3,1}} := 7in \cdot 7.125in$	$D_{c_3} := 1 \cdot lb \cdot ft^{-3}$
$L_{c_4} := 3.225 \cdot in$	$S_{c_{4,0}} := 7in \cdot 7.125in$	$S_{c_{4,1}} := 7in \cdot 7.125in$	$D_{c_4} := 1 \cdot lb \cdot ft^{-3}$

Open End of Transmission Line (Driver ---> Open End)

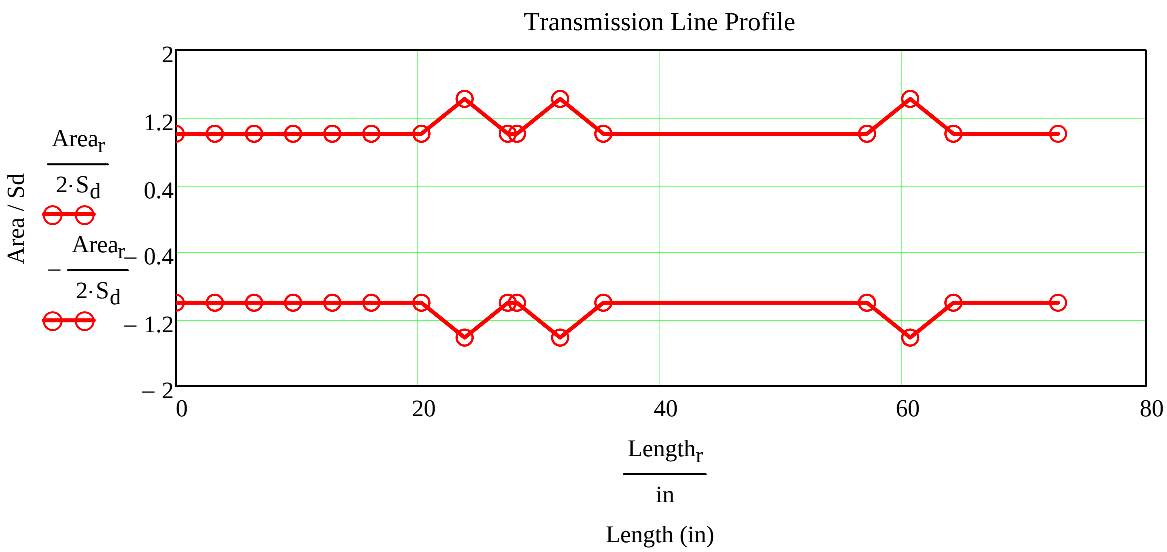
Section Length	Initial Area	Final Area	Stuffing
$L_{o_0} := 4.125 \cdot in$	$S_{o_{0,0}} := 7in \cdot 7.125in$	$S_{o_{0,1}} := 7in \cdot 7.125in$	$D_{o_0} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_1} := 3.5625 \cdot in$	$S_{o_{1,0}} := 7in \cdot 7.125in$	$S_{o_{1,1}} := 7in \cdot 10.0726i$	$D_{o_1} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_2} := 3.5625 \cdot in$	$S_{o_{2,0}} := 7in \cdot 10.0726in$	$S_{o_{2,1}} := 7in \cdot 7.125in$	$D_{o_2} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_3} := 0.75 \cdot in$	$S_{o_{3,0}} := 7in \cdot 7.125in$	$S_{o_{3,1}} := 7in \cdot 7.125in$	$D_{o_3} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_4} := 3.5625 \cdot in$	$S_{o_{4,0}} := 7in \cdot 7.125in$	$S_{o_{4,1}} := 7in \cdot 10.0726i$	$D_{o_4} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_5} := 3.5625 \cdot in$	$S_{o_{5,0}} := 7in \cdot 10.0726in$	$S_{o_{5,1}} := 7in \cdot 7.125in$	$D_{o_5} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_6} := 21.75 \cdot in$	$S_{o_{6,0}} := 7in \cdot 7.125in$	$S_{o_{6,1}} := 7in \cdot 7.125in$	$D_{o_6} := .5 \cdot lb \cdot ft^{-3}$
$L_{o_7} := 3.5625 \cdot in$	$S_{o_{7,0}} := 7in \cdot 7.125in$	$S_{o_{7,1}} := 7in \cdot 10.0726i$	$D_{o_7} := 0 \cdot lb \cdot ft^{-3}$
$L_{o_8} := 3.5625 \cdot in$	$S_{o_{8,0}} := 7in \cdot 10.0726in$	$S_{o_{8,1}} := 7in \cdot 7.125in$	$D_{o_8} := 0 \cdot lb \cdot ft^{-3}$
$L_{o_9} := 8.625 \cdot in$	$S_{o_{9,0}} := 7in \cdot 7.125in$	$S_{o_{9,1}} := 7in \cdot 7.125in$	$D_{o_9} := 0.0000 \cdot lb \cdot ft^{-3}$

Total Length of the Transmission Line

$$\sum_{i=0}^{n\_closed} L_{c_i} + \sum_{i=0}^{n\_open} L_{o_i} = 72.750 \cdot in$$

Total Amount of Stuffing

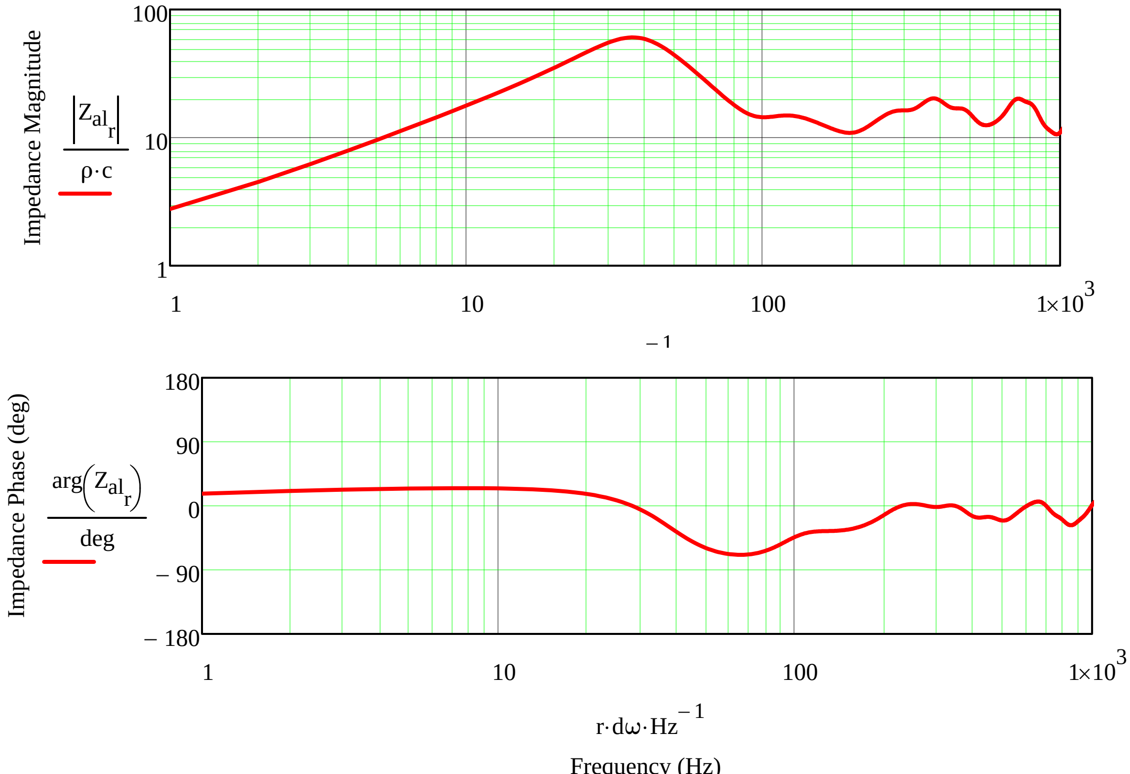
$$\sum_{r=0}^{n\_closed} \left(\frac{S_{c_{r,0}} + S_{c_{r,1}}}{2} \cdot L_{c_r} \cdot D_{c_r} \right) + \sum_{r=0}^{n\_open} \left(\frac{S_{o_{r,0}} + S_{o_{r,1}}}{2} \cdot L_{o_r} \cdot D_{o_r} \right) = 1.416 \cdot lb$$



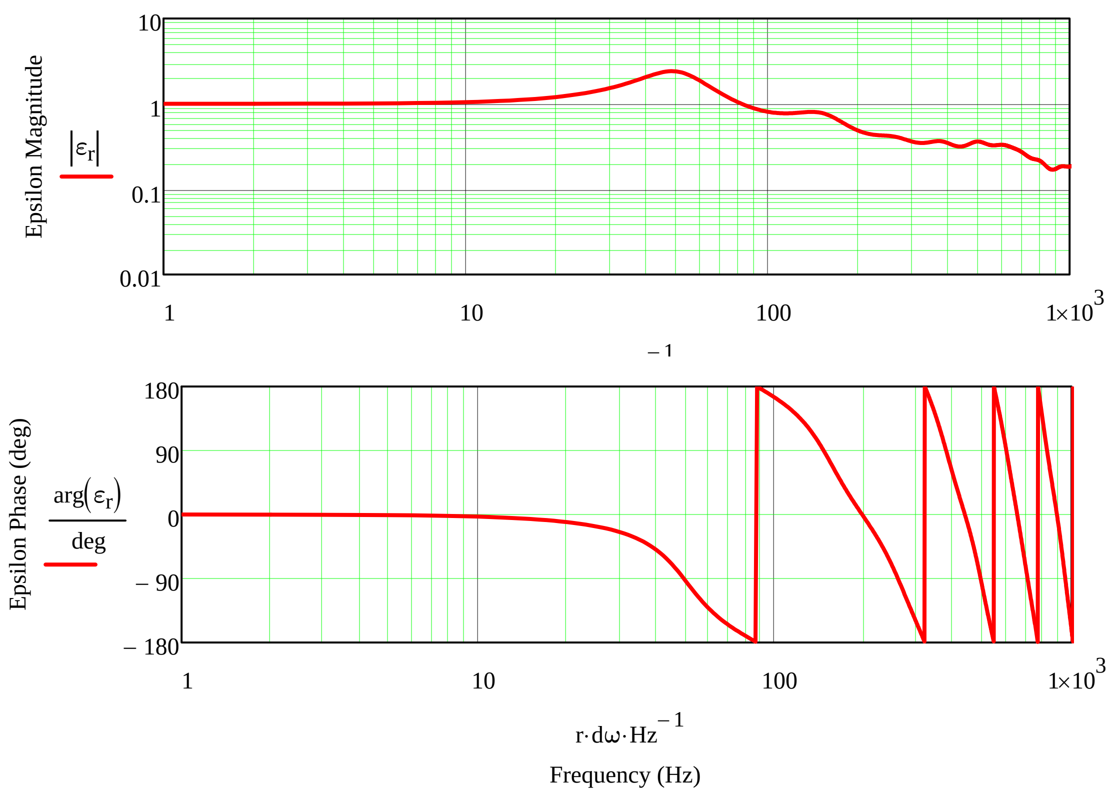
End of Detailed Input

End of Part 1 Input

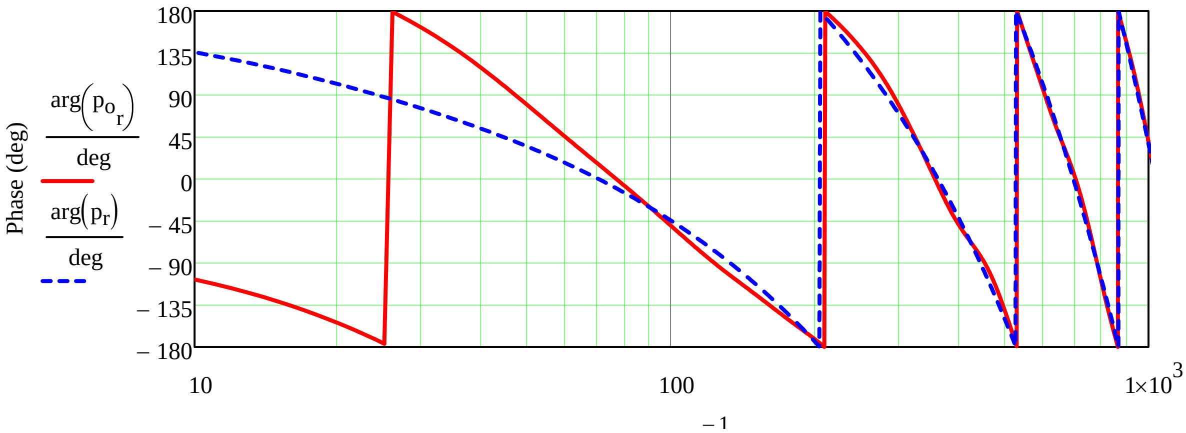
Resulting Acoustic Impedance for the Transmission Line

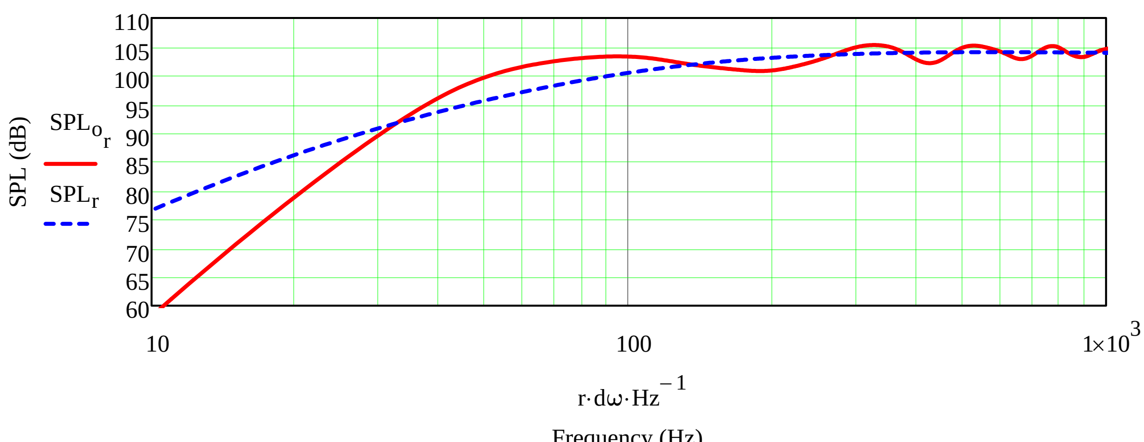


Velocity at the Terminus of the Transmission Line for a 1 m/sec Excitation at the Driver

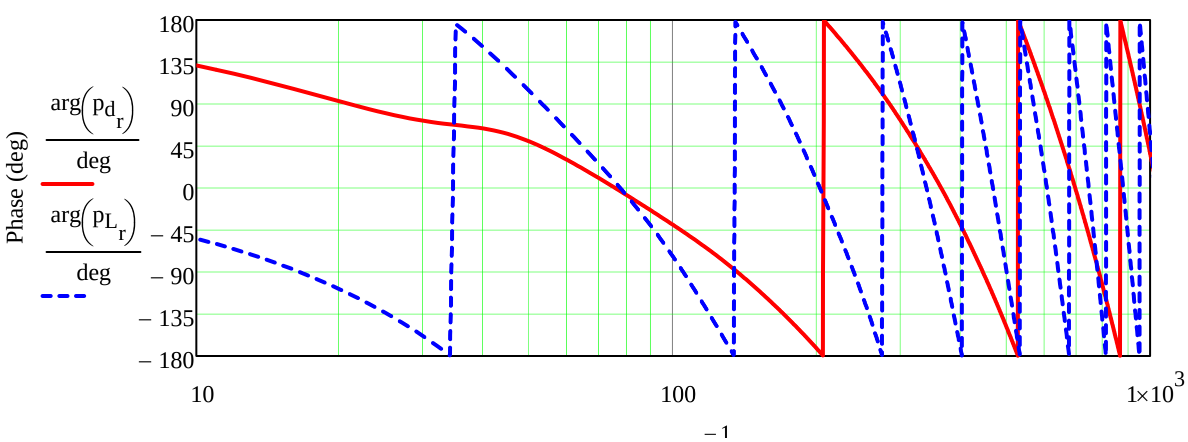


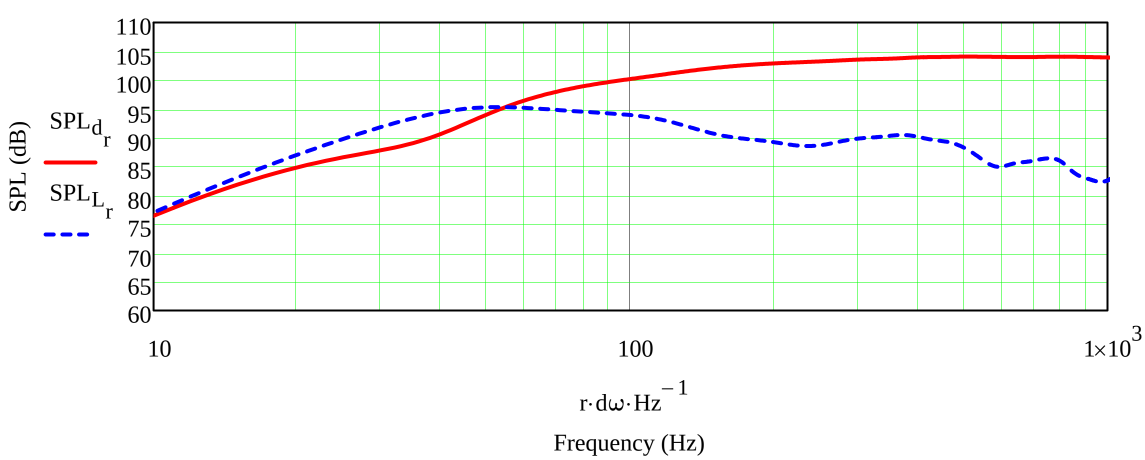
Far Field Transmission Line System and Infinite Baffle Sound Pressure Level Responses



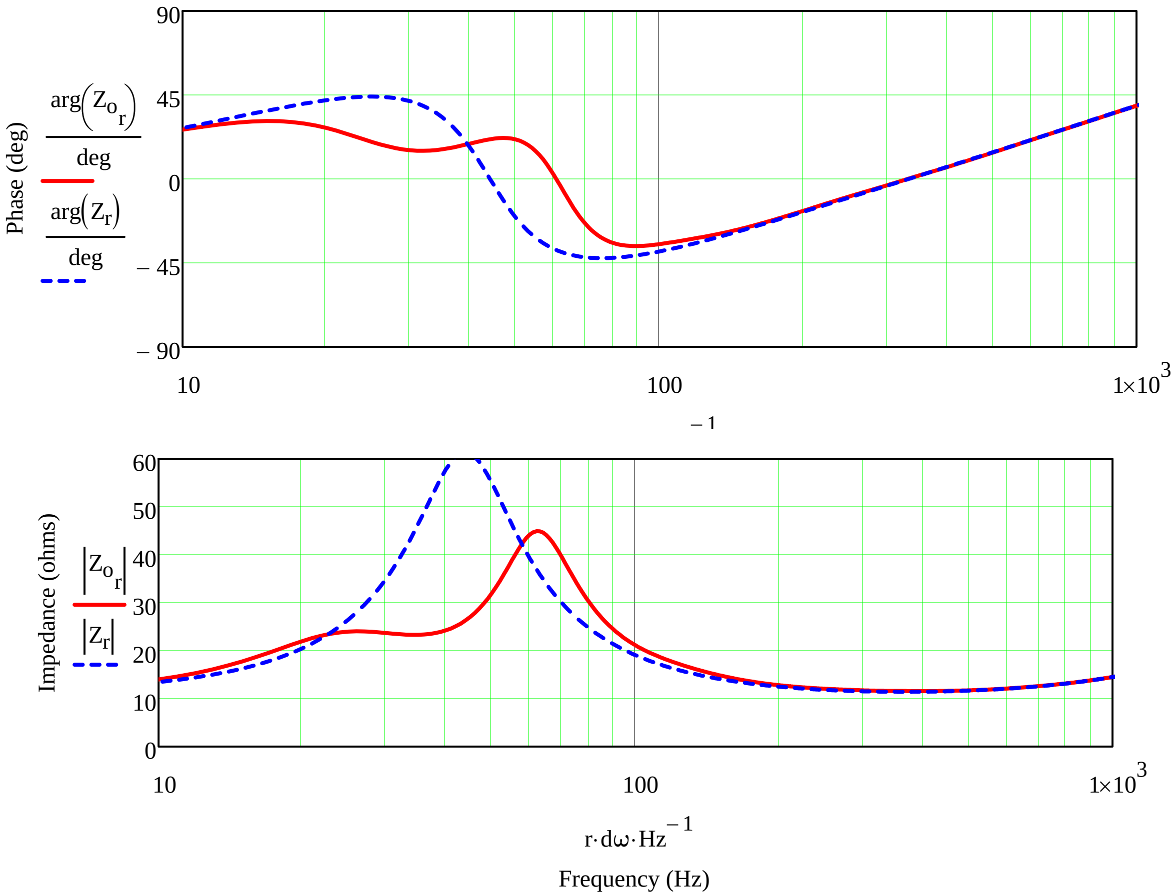


Woofer and Terminus Far Field Sound Pressure Level Responses

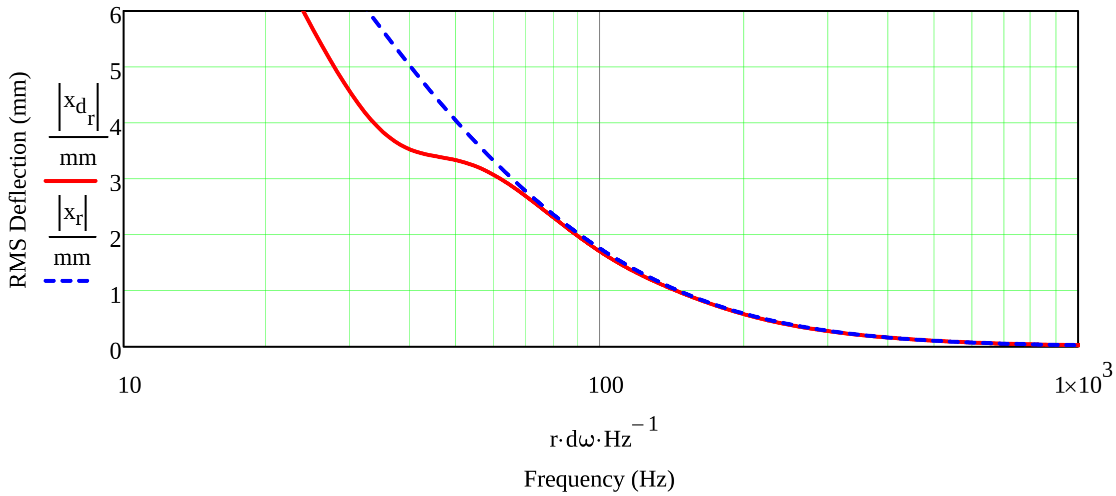




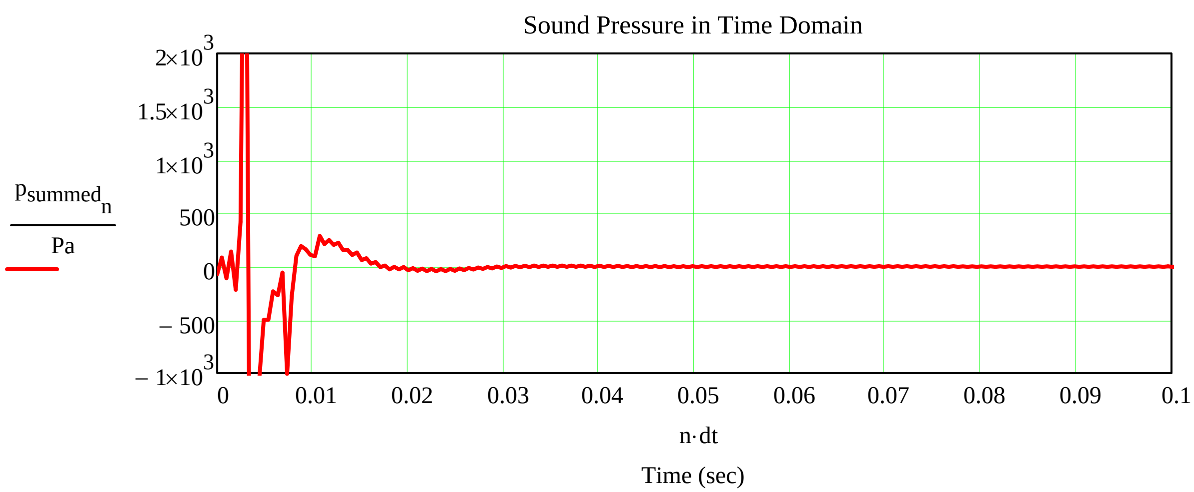
Transmission Line System and Infinite Baffle Impedance



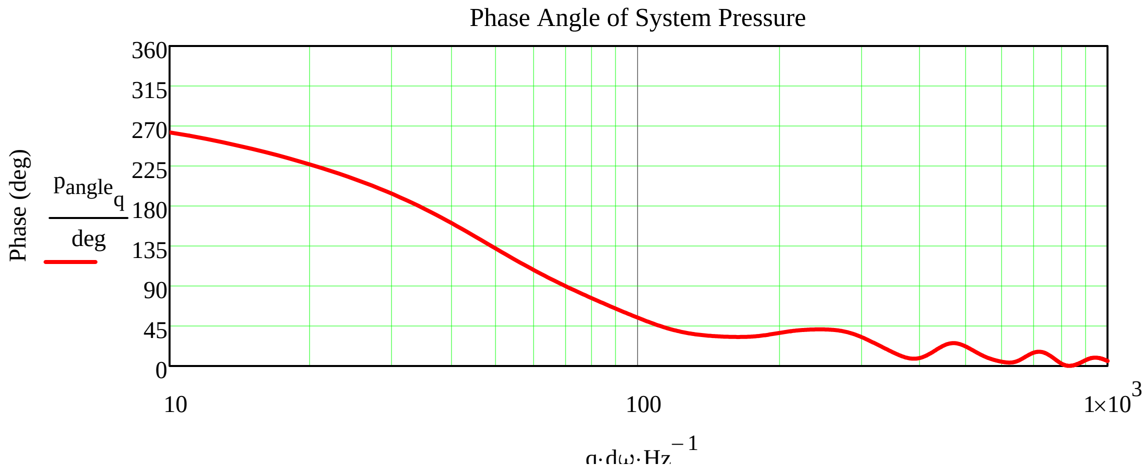
Woofer RMS Displacement

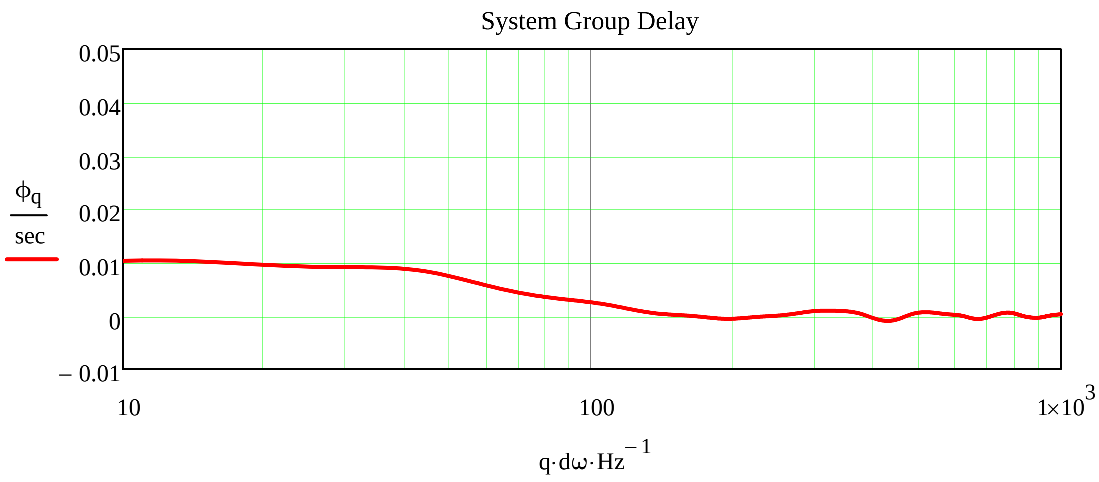


System Time Response for an Impulse Input

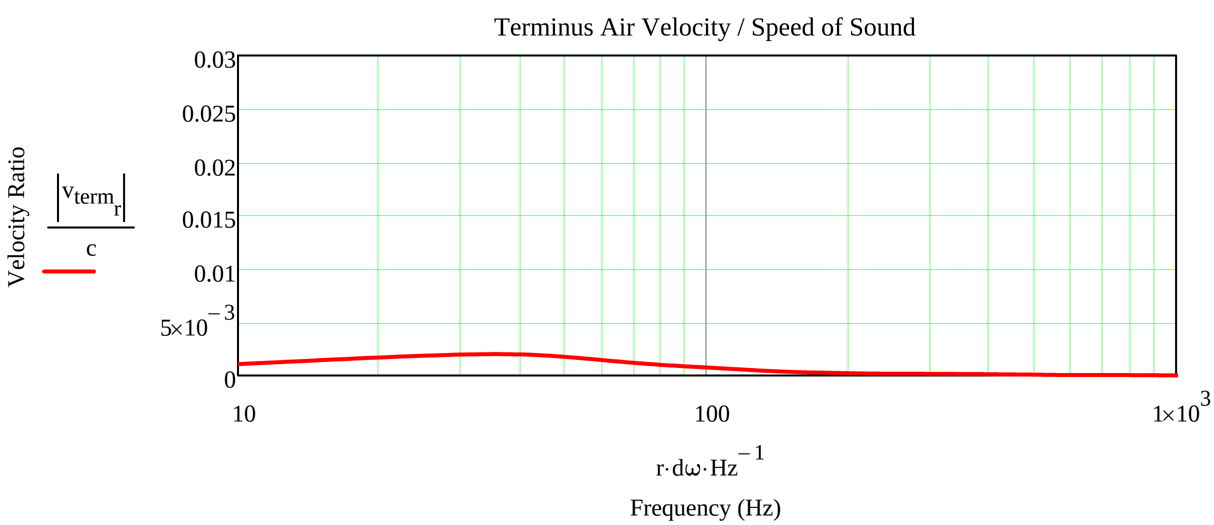


System Group Delay





Terminus Air Velocity (should be < 10 m/sec / 344 m/sec = 0.03)



Part 2 : Detailed SPL Response Calculation

Calculation Includes :
Position of Driver and Terminus on the Baffle.
Baffle Step Defraction for the Driver and the Terminus.
Room Reflections for the Driver and the Terminus.

Geometry

Baffle Coordinate System :
Origin is the lower left corner of the front baffle
y = horizontal direction
z = vertical direction

The variables num_r, n_drv, and n_mth control the number of simple sources that are used in the calculations. Increasing each will improve accuracy at the expense of longer calculation times. Increase each variable until plotted SPL stops changing at which point the solution has converged.

Enclosure Geometry Input

$X_0 := 5\cdot ft$ (Front Baffle Distance from Rear Wall > Depth of Enclosure)

$Y_0 := 2\cdot ft$ (Front Baffle Distance from Side Wall)

$\theta_0 := 90\cdot deg$ (Rotation Towards Room Center)

$Z_0 := 8\cdot ft$ (Floor to Ceiling Distance)

$stand := 0\cdot m$ (Height from Floor to Bottom Edge of Front Baffle)

$num\_r := 10$ (Number of Points per Unit Length of Baffle Edge)

Corner Coordinates

Y coordinate	Z coordinate	
$y_{o_0} := 8.5\cdot in$		(Bottom Right Corner)
$y_{o_1} := 8.5\cdot in$	$z_{o_1} := 37.5\cdot in$	(Top Right Corner)
$y_{o_2} := 0\cdot in$	$z_{o_2} := 37.5\cdot in$	(Top Left Corner)
$y_{o_3} := 0\cdot in$		(Bottom Left Corner)
$depth := 16.5\cdot in$		(Depth of Enclosure)

Driver Geometry Input

$y_{dc} := 4.25 \cdot in$ (Driver Center y Coordinate)

$z_{dc} := 24 \cdot in$ (Driver Center z Coordinate)

n_dvr := 5 (Number of Points Across Diameter)

Terminus Geometry Input

$y_{mc} := 4.25 \cdot in$ (Terminus Center y Coordinate)

$z_{mc} := 3.5625 \cdot in$ (Terminus Center z Coordinate)

$w_{mth} := 7 \cdot in$ (Terminus Width)

n_mth := 10 (Number of Points Across the Width)

Locate := 0 (0 = Front Baffle Terminus, 1 = Rear Baffle Terminus)

Listening Position (Default Location is at 1 m Distance Along the Driver's Axis)

n_listen = 0 (Listening Position Relative to Speaker)

radius := 1·m (Calculation Radius, Effective Radius is Greater if y_p is Changed from Default)

$\theta := 0 \cdot deg$ (0 deg is along the Driver's Axis, -80 deg < θ < 80 deg)

$z_p := z_{dc}$ (Default Height is Equal to Driver Height)

n_listen = 1 (Listening Position Relative to the Room Corner)

$X_p := 10ft$

$Y_p := 7 \cdot ft$

$Z_p := z_{dc} + stand$ (Default Height is Equal to Driver Height)

n_listen := 0 (Method Selection)

Floor Condition

Reflect := 1 (0 = hardwood or concrete, 1 = carpeted)

Refective Surface Selections (if 1 reflective surface is included, if 0 reflective surface is removed)

Inc_floor := 0 (Floor, Z = 0)

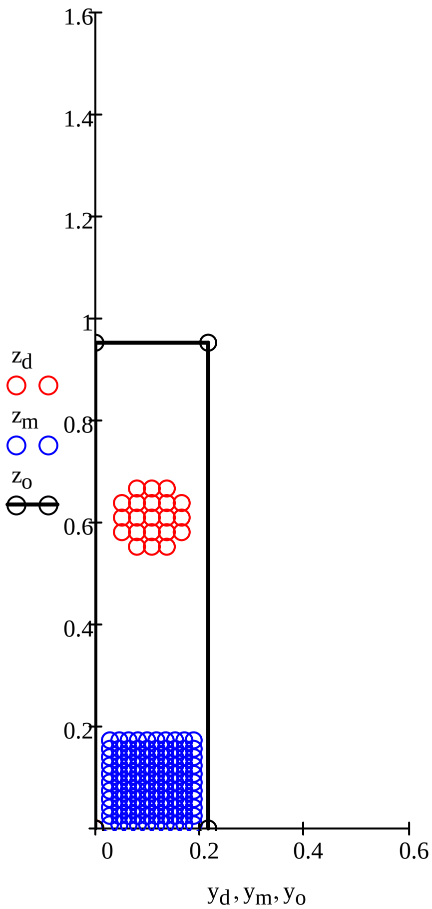
Inc_rear := 0 (Rear Wall, X = 0)

Inc_side := 0 (Left Side Wall, Y = 0)

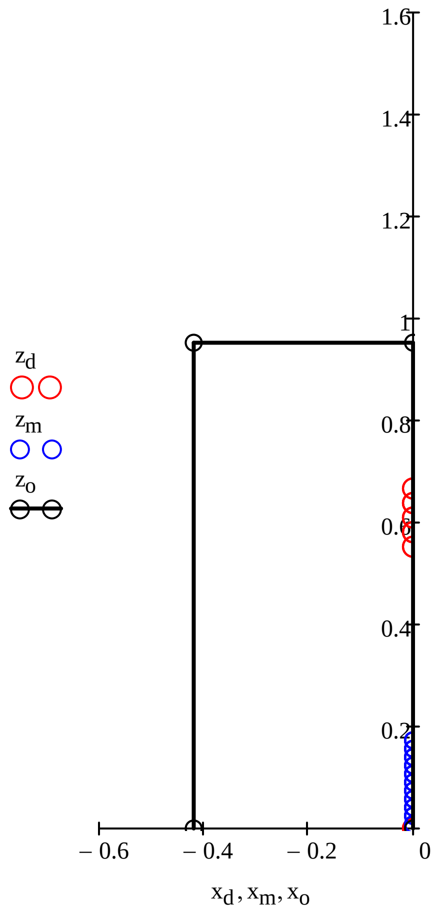
Inc_ceiling := 0 (Ceiling)

Circular Driver and TL Terminus Simple Source Pattern with Baffle Edge Outline

Front View



Side View

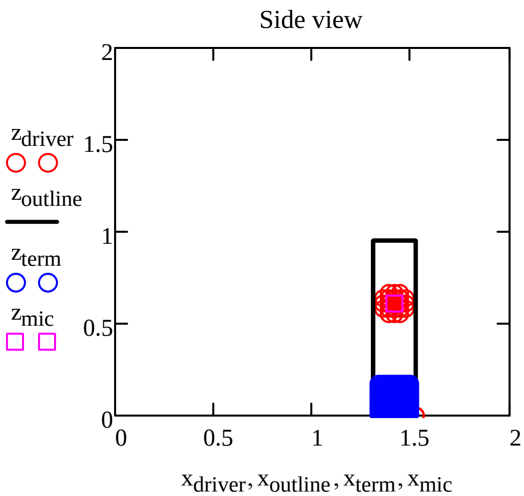


Red sources represent the driver.
Blue sources represent the terminus.
Black outline represents the baffle edge.
Origin is at the bottom front left corner of the enclosure.

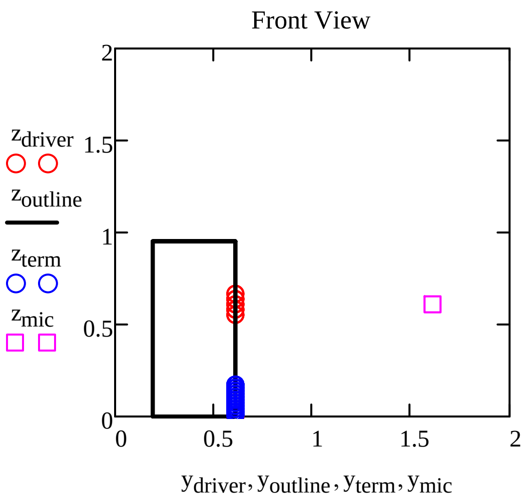
Three Dimensional View

Axis Length (m) axis := 2 <---- Change value of "axis" to rescale plots

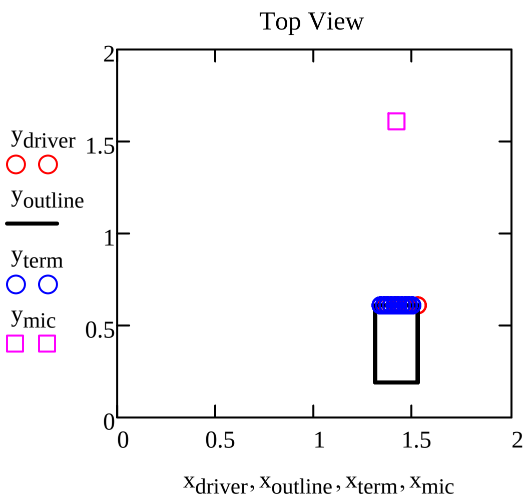
Room Corner is the Origin



Side View - looking out from side wall

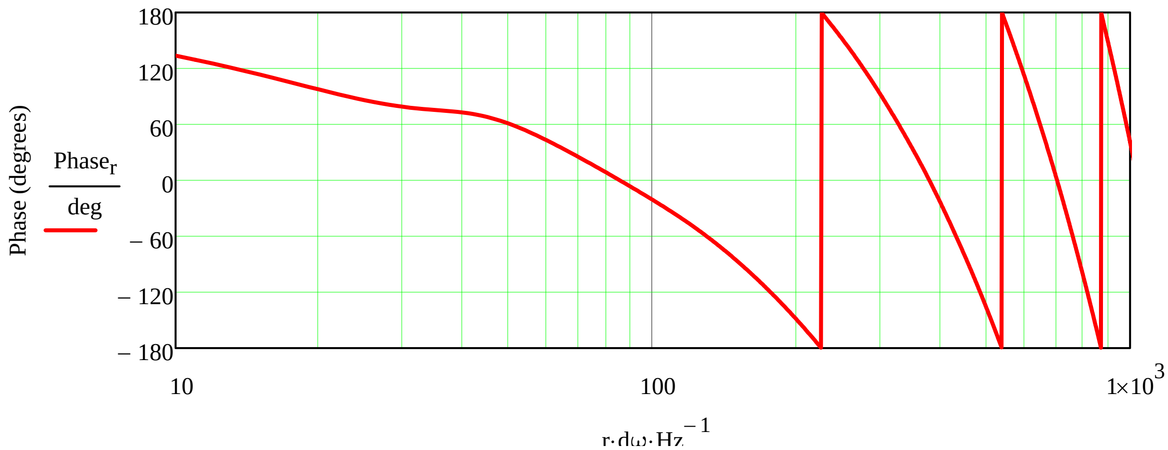


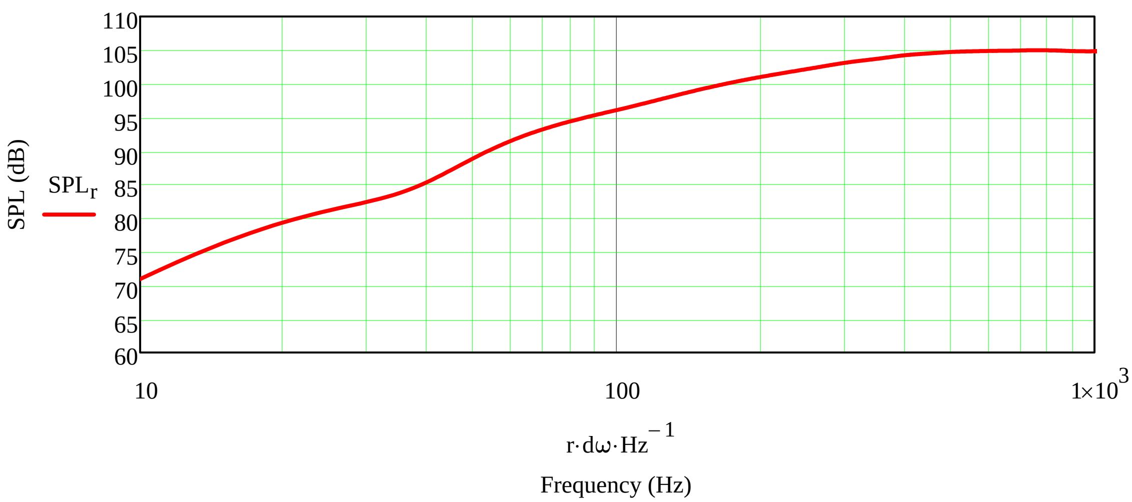
Front View - looking towards rear wall



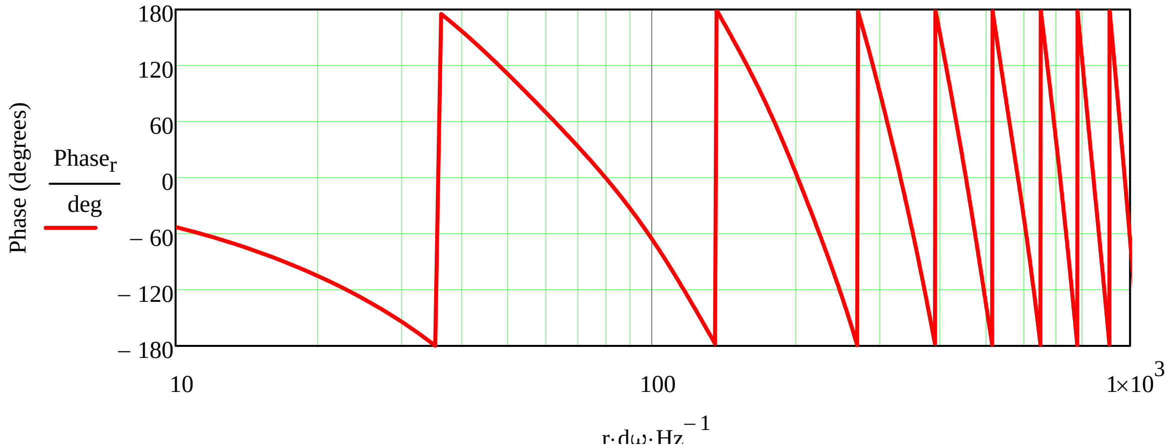
Top View - looking down from ceiling

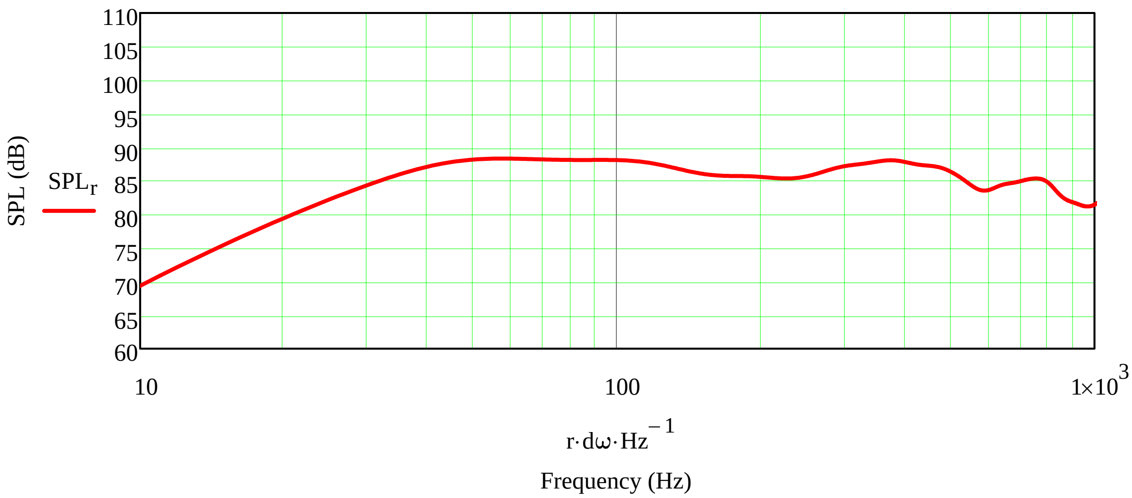
Plotted Baffle Step and Reflection SPL Response for the Circular Driver Source



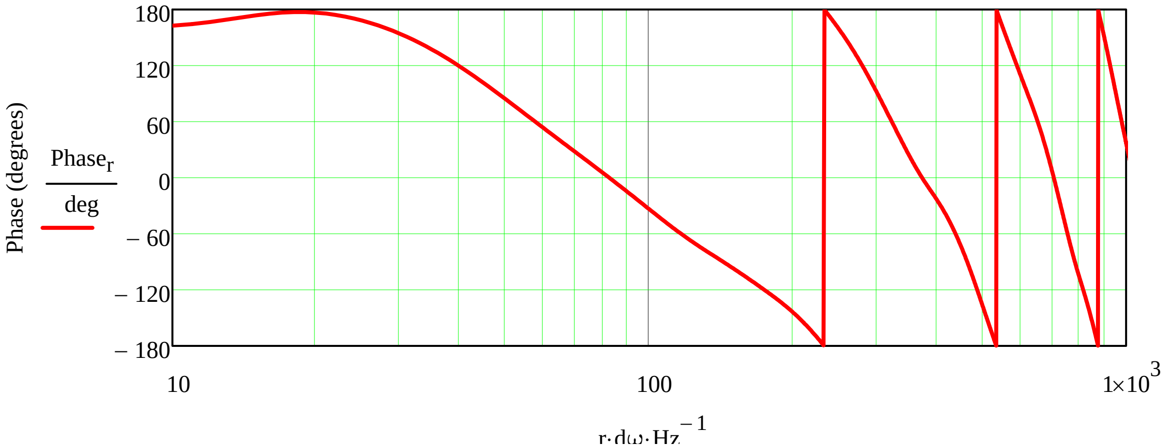


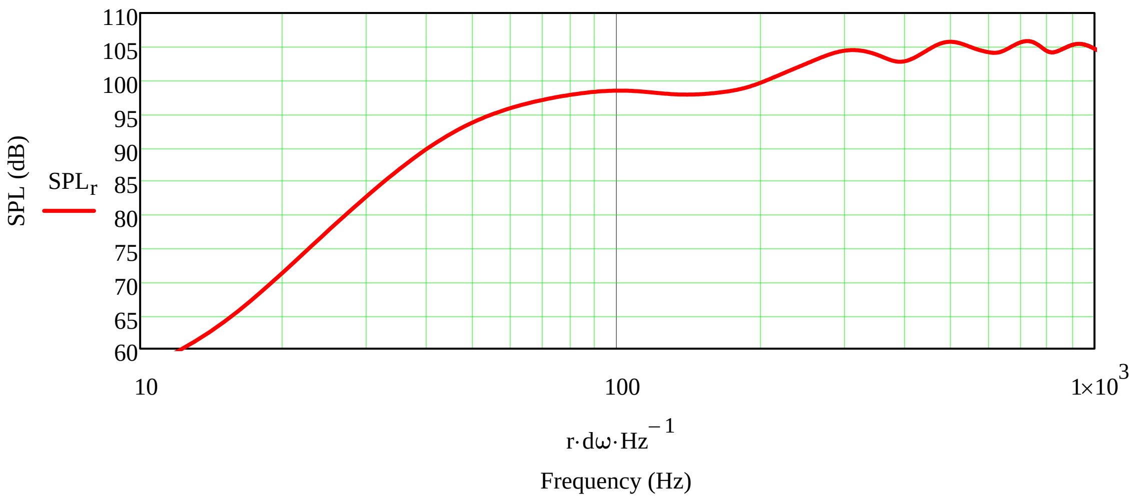
Plotted Baffle Step and Reflection SPL Response for the TL Terminus





Plotted SPL Response for the System





Part 3 : Baffle Step Correction Circuit Design

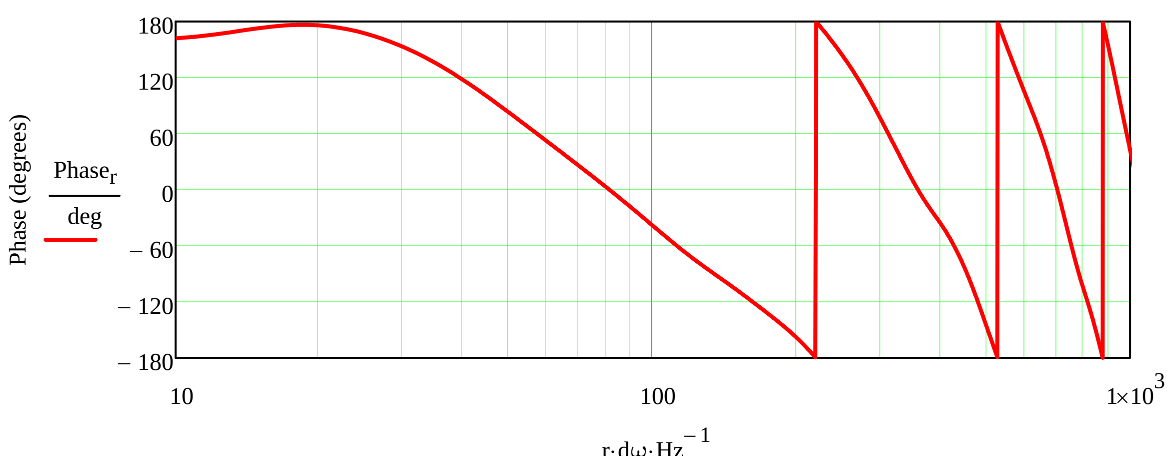
Input Center Frequency of the Baffle Step and the desired dB of Attenuation.

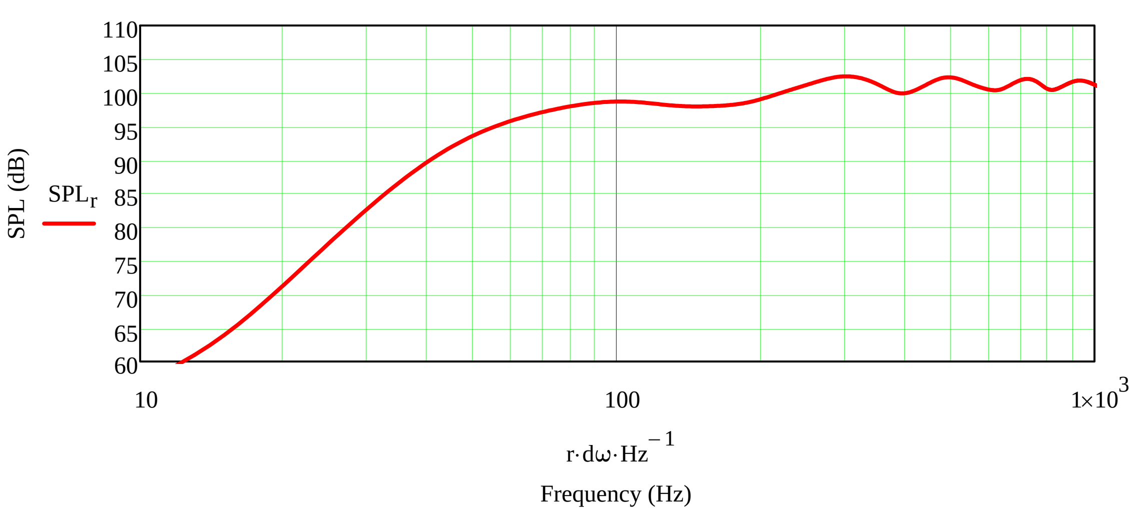
$f_{center} := 400 \cdot Hz$ <--- Input Center Frequency

$dB := 6$ <--- Input dB of Attenuation

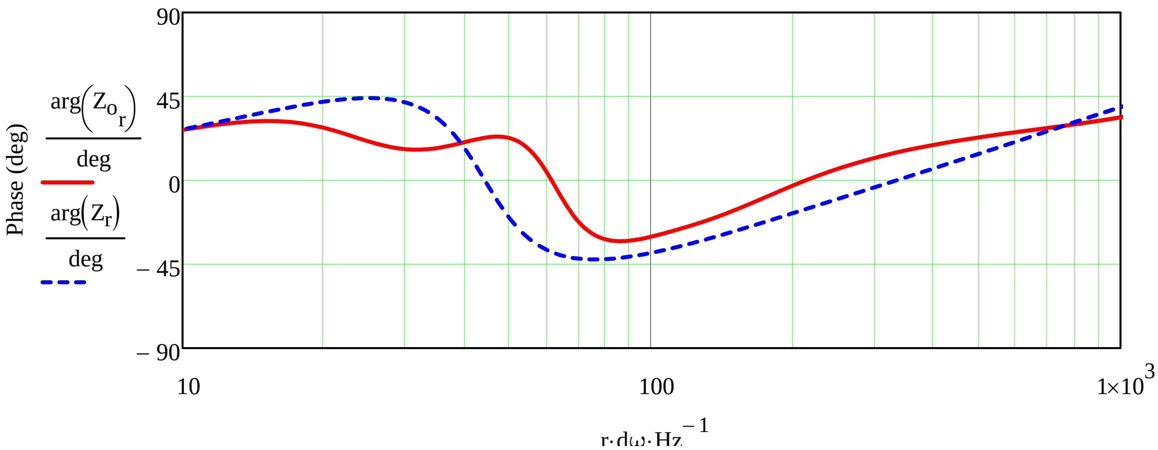
Calculated Component Values		User Assigned Component Values Based on Calculated Values at Left	
$R_e \cdot \left(10^{\frac{dB}{20}} - 1\right) = 11.147 \cdot \Omega$	Parallel Resistor	Input Value --->	$R_{parallel} := 8 \cdot \Omega$
$\frac{R_{parallel}}{f_{center}} = 3.183 \cdot mH$	BSC Inductor	Input Value --->	$L_{BSC} := 3 \cdot mH$

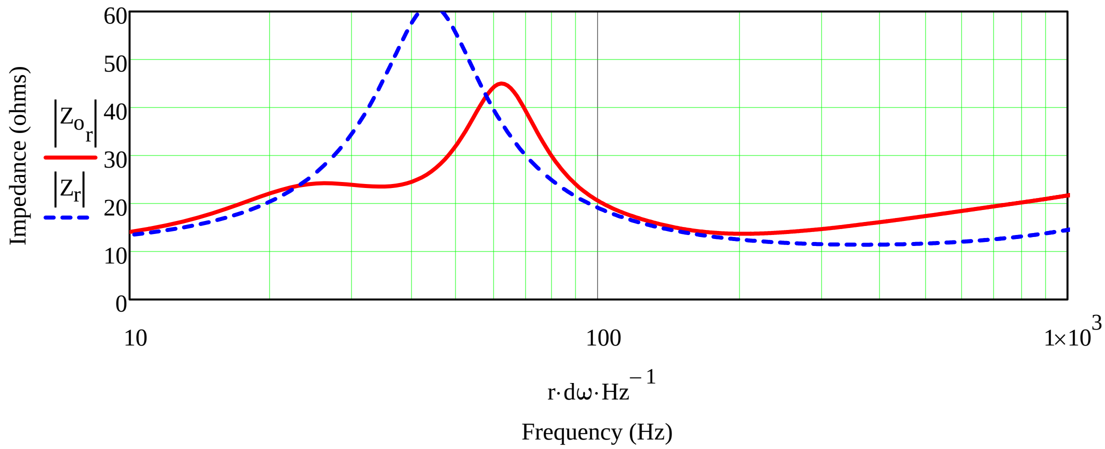
Plotted Corrected SPL Response for the System



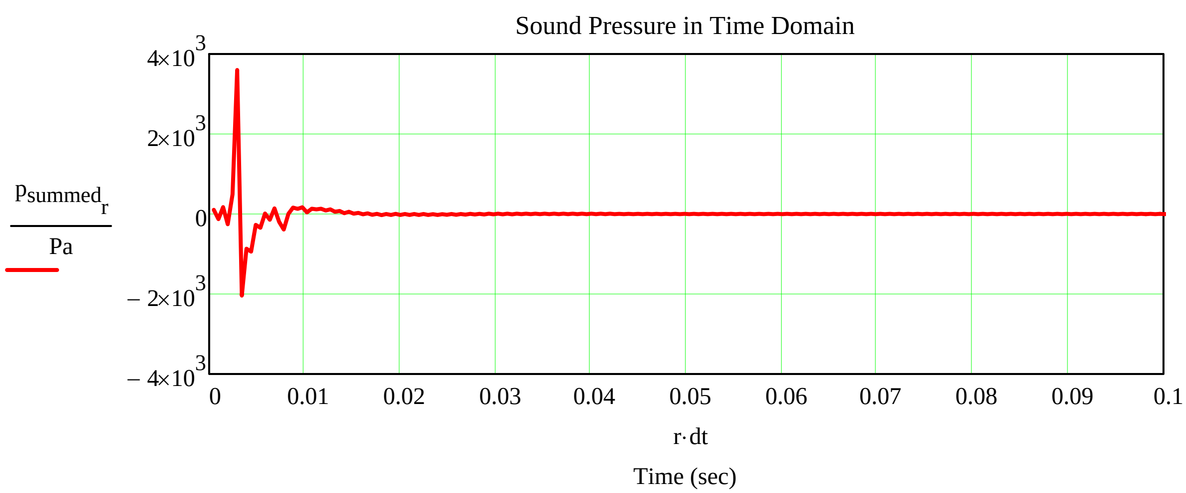


Transmission Line Corrected System and Infinite Baffle Impedance





System Time Response for an Impulse Input



Offset Driver in an Open Ended Transmission Line - Acoustic and Electrical Response **7/03/09**

Software : by Martin J. King
e-mail MJKing57@aol.com

Line Configuration : Near End Closed -> Offset Driver -> Far End Open.

Unit and Constant Definition

$cycle := 2 \cdot \pi \cdot rad$

$Hz := cycle \cdot sec^{-1}$

Air Density : $\rho := 1.205 \cdot kg \cdot m^{-3}$

Speed of Sound : $c := 344 \cdot m \cdot sec^{-1}$

Part 1 : Thiele-Small Consistent Calculation

Detailed User Input (Edit This Section and Input the Parameters for the System to be Analyzed)

Series Resistance

$R_{add} := 0.0 \cdot \Omega$

Driver Thiele / Small Parameters : SEAS L15RLY

$f_d := 44 \cdot Hz$

$V_{ad} := 24 \cdot liter$

Adjustments

$R_e := 11 \cdot \Omega$

$Q_{ed} := .43$

$R_e := R_e + R_{add}$

$L_{vc} := 1.68 \cdot mH$

$Q_{md} := 2.1$

$Q_{ed} := Q_{ed} \cdot R_e \cdot (R_e - R_{add})^{-1}$

$Bl := 11.4 \cdot \frac{newton}{amp}$

$Q_{td} := \left(\frac{1}{Q_{ed}} + \frac{1}{Q_{md}} \right)^{-1}$

$S_d := 150 \cdot cm^2$

$Q_{td} = 0.357$

$Power := 17 \cdot watt$ (Input Power) Applied Voltage Reference ---> $R_{ref} := 16 \cdot \Omega$

Enclosure Geometry Definition

Reference : Derivation and Correlation of a Viscous Damping Model Used in the Design of a Transmission Line Loudspeaker System
by Martin J. King, 3/04/01

The following dimension were derived from "Figure 18 : Cabinet Construction Details and Dimensions (inches)" of the referenced article. This is the most accurate model for the Focal 8V 4412 two-way transmission line enclosure. All of the required input data has been entered below directly into the Geometry Definition section of the worksheet. No variable definitions have been used to describe the enclosure geometry.

Transmission Line Definition $(0\ lb/ft^3 < D < 1\ lb/ft^3)$

$n\_closed := 4$ (n_closed > 1)

$n\_open := 9$ (n_open > 1)

Geometry Definition

Closed End of Transmission Line (Driver ---> Closed End)

Section Length	Initial Area	Final Area	Stuffing
$L_{c_0} := 3.225 \cdot in$	$S_{c_{0,0}} := 7in \cdot 7.125in$	$S_{c_{0,1}} := 7in \cdot 7.125in$	$D_{c_0} := 1 \cdot lb \cdot ft^{-3}$
$L_{c_1} := 3.225 \cdot in$	$S_{c_{1,0}} := 7in \cdot 7.125in$	$S_{c_{1,1}} := 7in \cdot 7.125in$	$D_{c_1} := 1 \cdot lb \cdot ft^{-3}$
$L_{c_2} := 3.225 \cdot in$	$S_{c_{2,0}} := 7in \cdot 7.125in$	$S_{c_{2,1}} := 7in \cdot 7.125in$	$D_{c_2} := 1 \cdot lb \cdot ft^{-3}$
$L_{c_3} := 3.225 \cdot in$	$S_{c_{3,0}} := 7in \cdot 7.125in$	$S_{c_{3,1}} := 7in \cdot 7.125in$	$D_{c_3} := 1 \cdot lb \cdot ft^{-3}$
$L_{c_4} := 3.225 \cdot in$	$S_{c_{4,0}} := 7in \cdot 7.125in$	$S_{c_{4,1}} := 7in \cdot 7.125in$	$D_{c_4} := 1 \cdot lb \cdot ft^{-3}$

Open End of Transmission Line (Driver ---> Open End)

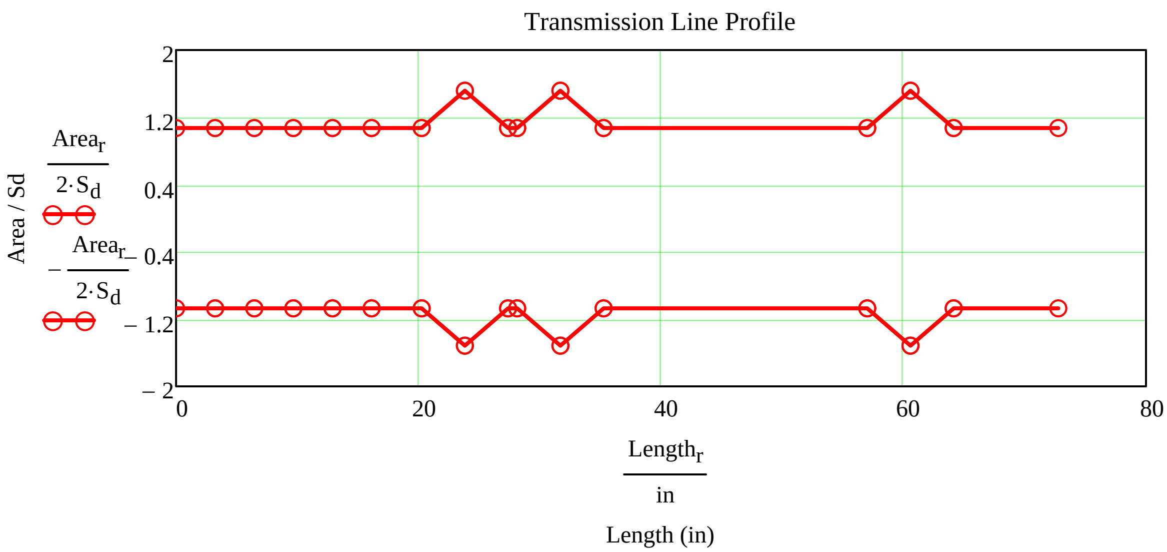
Section Length	Initial Area	Final Area	Stuffing Density
$L_{o_0} := 4.125 \cdot in$	$S_{o_{0,0}} := 7in \cdot 7.125in$	$S_{o_{0,1}} := 7in \cdot 7.125in$	$D_{o_0} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_1} := 3.5625 \cdot in$	$S_{o_{1,0}} := 7in \cdot 7.125in$	$S_{o_{1,1}} := 7in \cdot 10.0726i$	$D_{o_1} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_2} := 3.5625 \cdot in$	$S_{o_{2,0}} := 7in \cdot 10.0726in$	$S_{o_{2,1}} := 7in \cdot 7.125in$	$D_{o_2} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_3} := 0.75 \cdot in$	$S_{o_{3,0}} := 7in \cdot 7.125in$	$S_{o_{3,1}} := 7in \cdot 7.125in$	$D_{o_3} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_4} := 3.5625 \cdot in$	$S_{o_{4,0}} := 7in \cdot 7.125in$	$S_{o_{4,1}} := 7in \cdot 10.0726i$	$D_{o_4} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_5} := 3.5625 \cdot in$	$S_{o_{5,0}} := 7in \cdot 10.0726in$	$S_{o_{5,1}} := 7in \cdot 7.125in$	$D_{o_5} := 1 \cdot lb \cdot ft^{-3}$
$L_{o_6} := 21.75 \cdot in$	$S_{o_{6,0}} := 7in \cdot 7.125in$	$S_{o_{6,1}} := 7in \cdot 7.125in$	$D_{o_6} := .5 \cdot lb \cdot ft^{-3}$
$L_{o_7} := 3.5625 \cdot in$	$S_{o_{7,0}} := 7in \cdot 7.125in$	$S_{o_{7,1}} := 7in \cdot 10.0726i$	$D_{o_7} := 0 \cdot lb \cdot ft^{-3}$
$L_{o_8} := 3.5625 \cdot in$	$S_{o_{8,0}} := 7in \cdot 10.0726in$	$S_{o_{8,1}} := 7in \cdot 7.125in$	$D_{o_8} := 0 \cdot lb \cdot ft^{-3}$
$L_{o_9} := 8.625 \cdot in$	$S_{o_{9,0}} := 7in \cdot 7.125in$	$S_{o_{9,1}} := 7in \cdot 7.125in$	$D_{o_9} := 0.0000 \cdot lb \cdot ft^{-3}$

Total Length of the Transmission Line

$$\sum_{i=0}^{n\_closed} L_{c_i} + \sum_{i=0}^{n\_open} L_{o_i} = 72.750 \cdot in$$

Total Amount of Stuffing

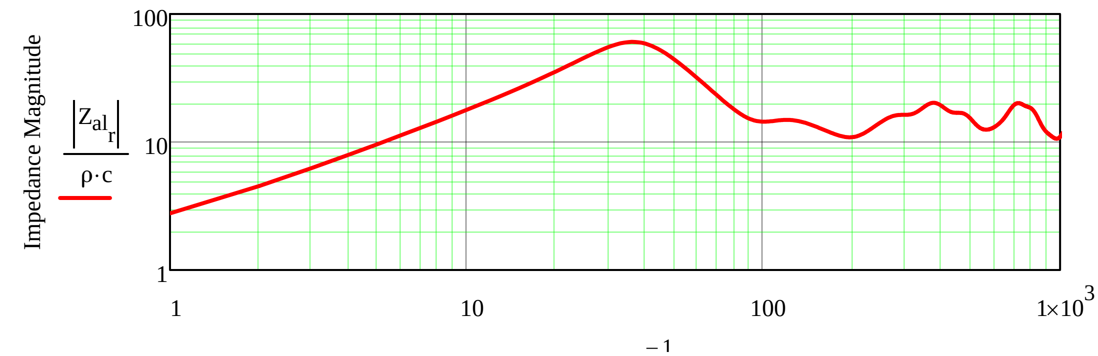
$$\sum_{r=0}^{n\_closed} \left(\frac{S_{c_{r,0}} + S_{c_{r,1}}}{2} \cdot L_{c_r} \cdot D_{c_r} \right) + \sum_{r=0}^{n\_open} \left(\frac{S_{o_{r,0}} + S_{o_{r,1}}}{2} \cdot L_{o_r} \cdot D_{o_r} \right) = 1.416 \cdot lb$$

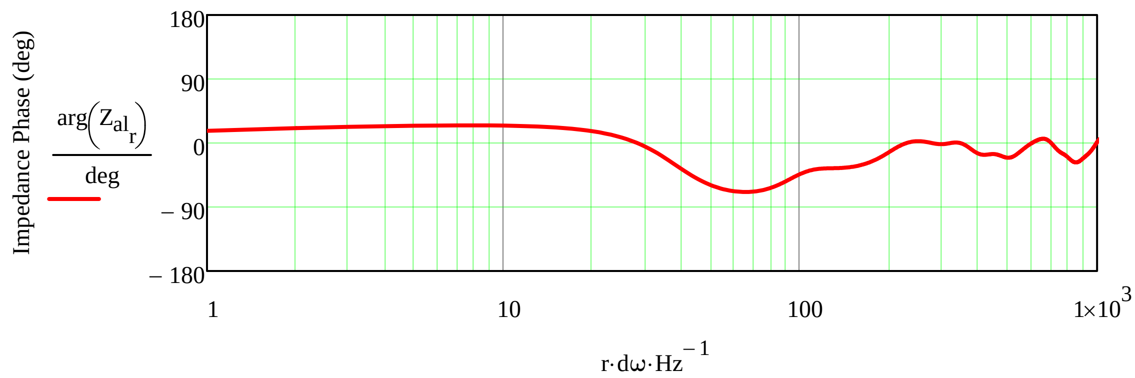


End of Detailed Input

End of Part 1 Input

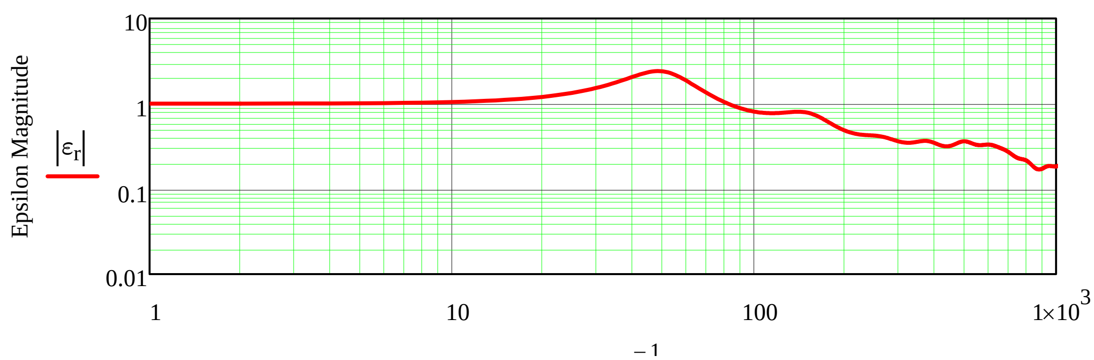
Resulting Acoustic Impedance for the Transmission Line

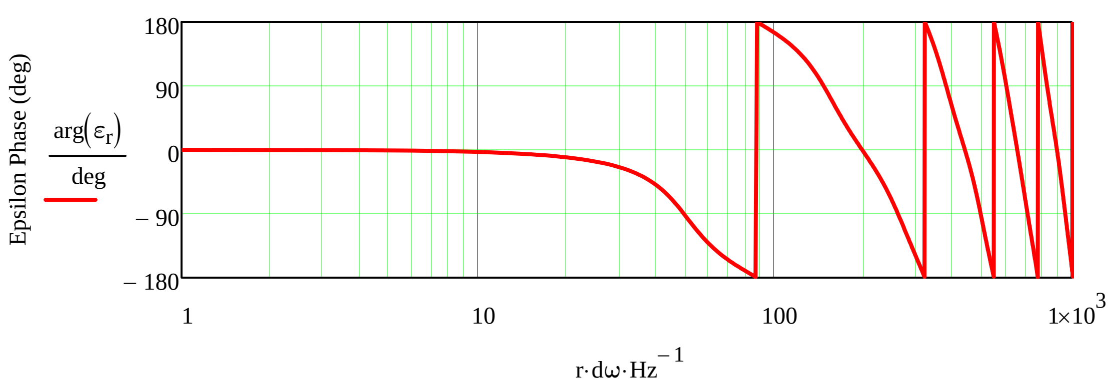




Frequency (Hz)

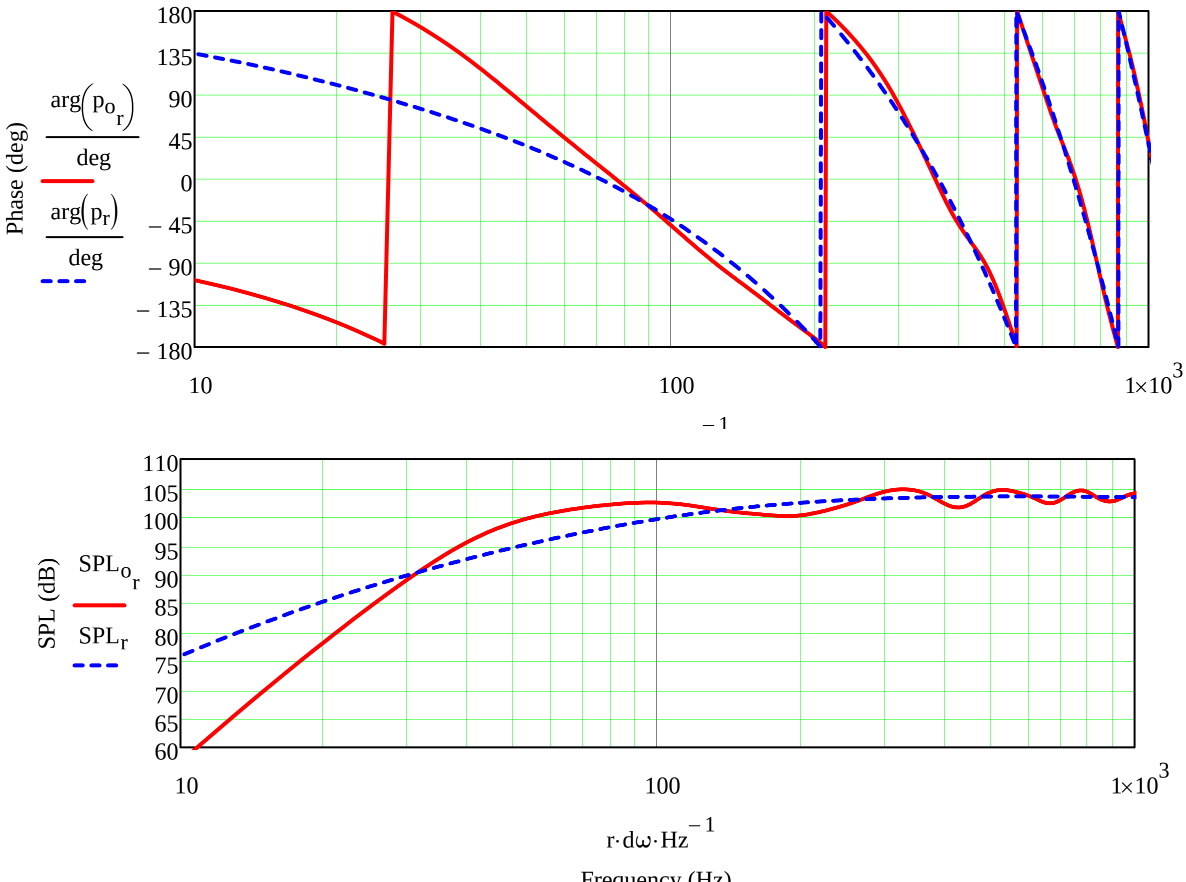
Velocity at the Terminus of the Transmission Line for a 1 m/sec Excitation at the Driver



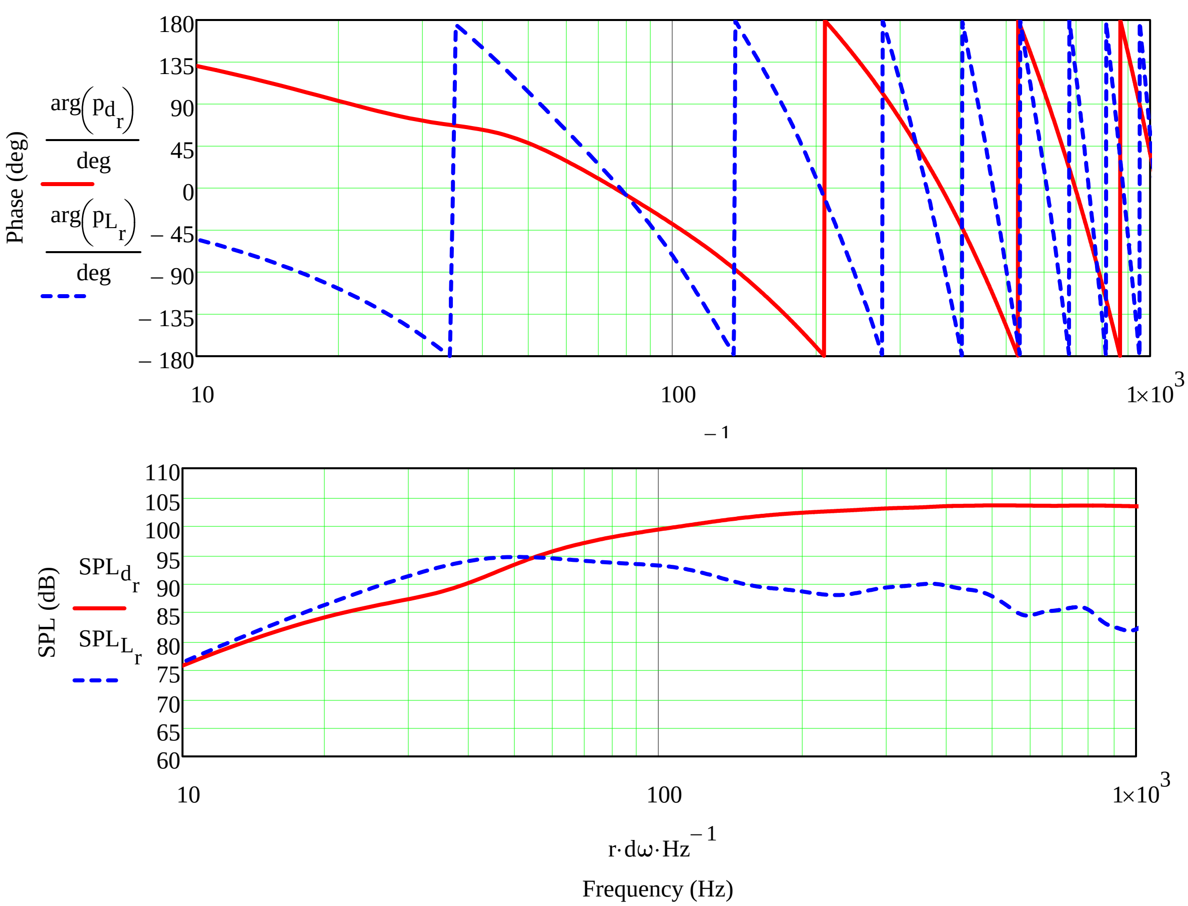


Frequency (Hz)

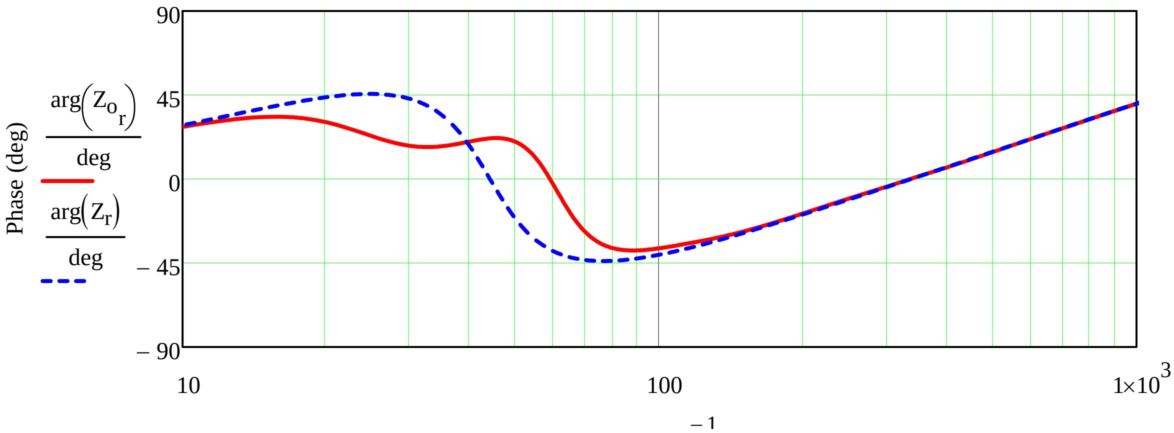
Far Field Transmission Line System and Infinite Baffle Sound Pressure Level Responses

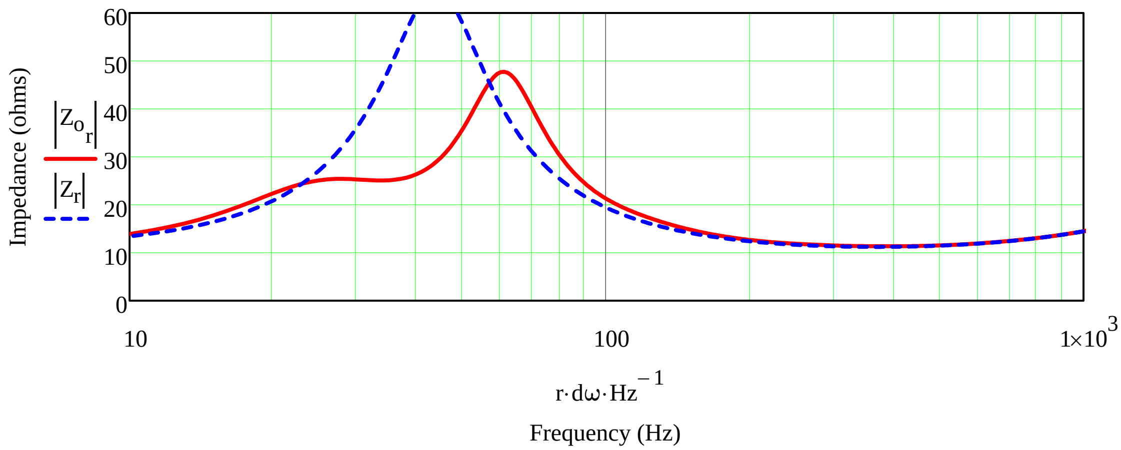


Woofer and Terminus Far Field Sound Pressure Level Responses

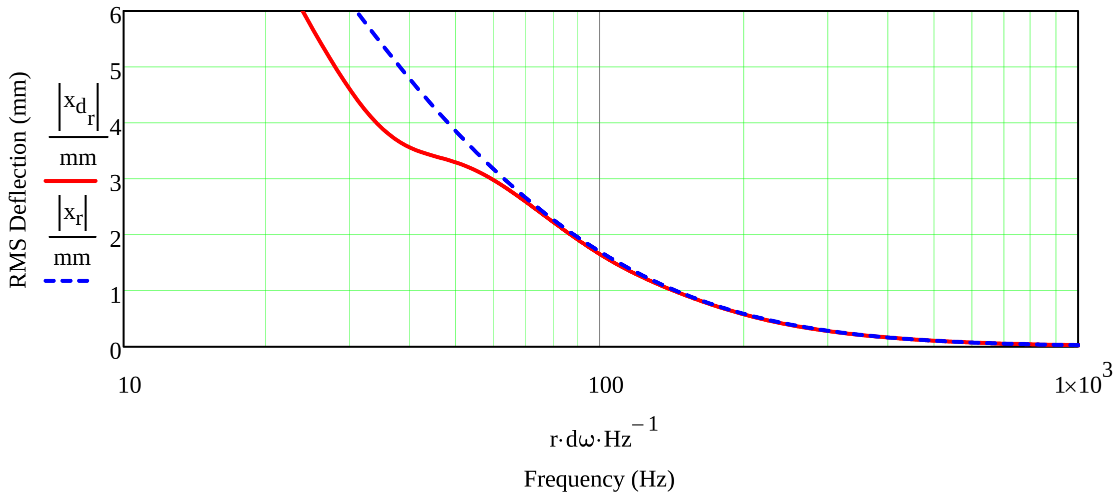


Transmission Line System and Infinite Baffle Impedance

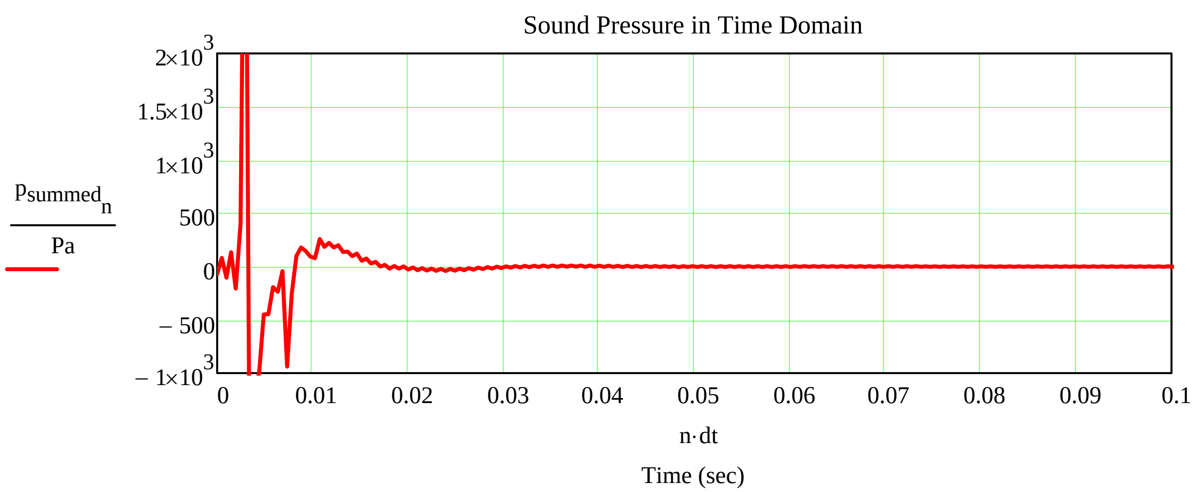




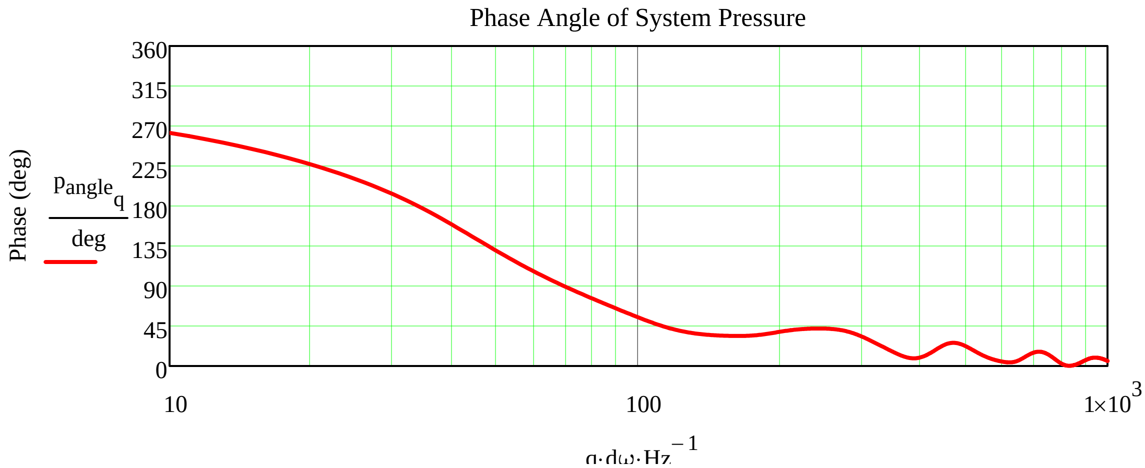
Woofer RMS Displacement

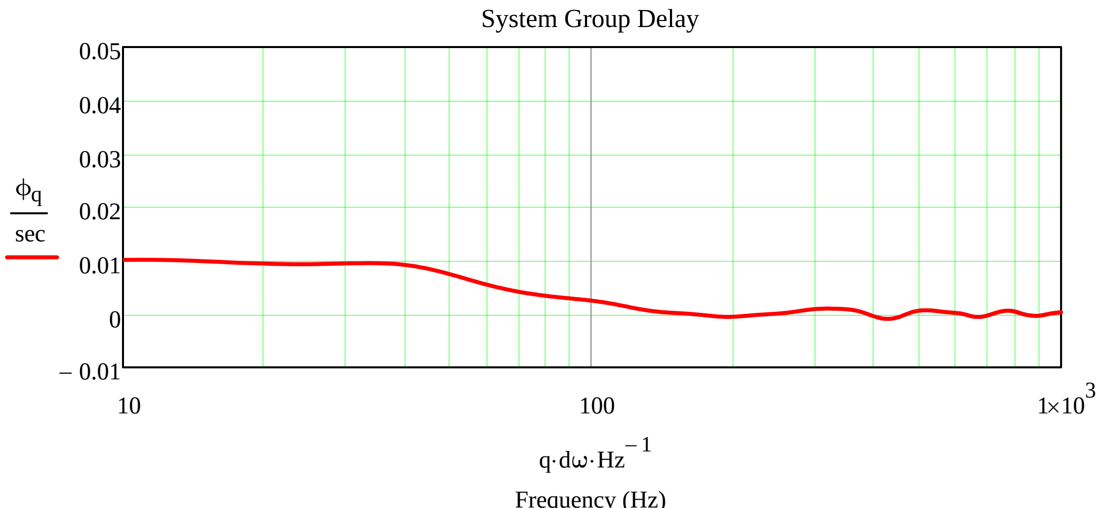


System Time Response for an Impulse Input

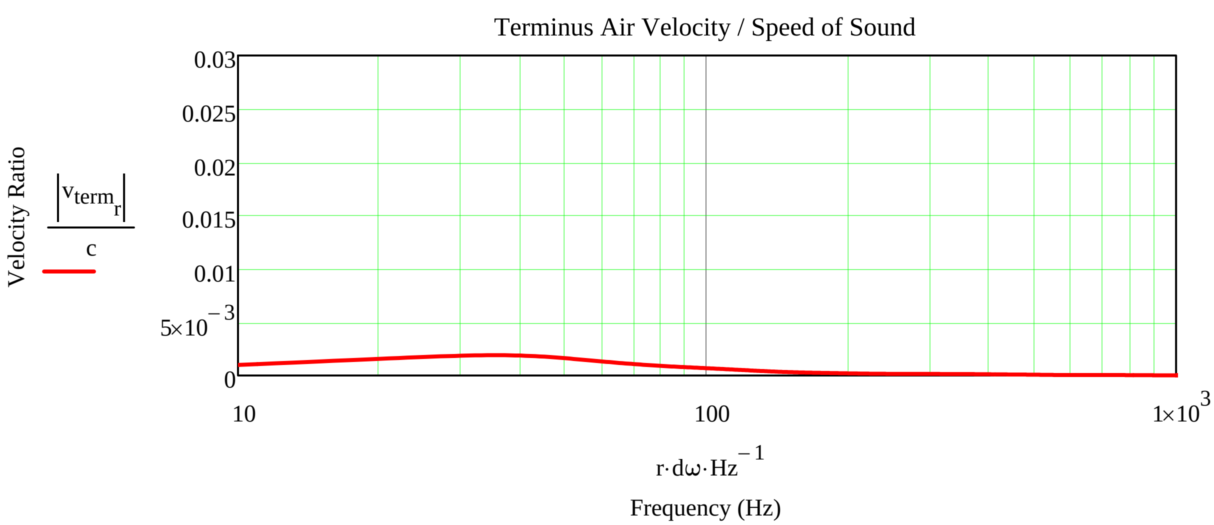


System Group Delay





Terminus Air Velocity (should be < 10 m/sec / 344 m/sec = 0.03)



Part 2 : Detailed SPL Response Calculation

Calculation Includes :
Position of Driver and Terminus on the Baffle.
Baffle Step Defraction for the Driver and the Terminus.
Room Reflections for the Driver and the Terminus.

Geometry

Baffle Coordinate System :
Origin is the lower left corner of the front baffle
y = horizontal direction
z = vertical direction

The variables num_r, n_drv, and n_mth control the number of simple sources that are used in the calculations. Increasing each will improve accuracy at the expense of longer calculation times. Increase each variable until plotted SPL stops changing at which point the solution has converged.

Enclosure Geometry Input

$X_0 := 5 \cdot ft$ (Front Baffle Distance from Rear Wall > Depth of Enclosure)

$Y_0 := 2 \cdot ft$ (Front Baffle Distance from Side Wall)

$\theta_0 := 90 \cdot deg$ (Rotation Towards Room Center)

$Z_0 := 8 \cdot ft$ (Floor to Ceiling Distance)

$stand := 0 \cdot m$ (Height from Floor to Bottom Edge of Front Baffle)

$num\_r := 10$ (Number of Points per Unit Length of Baffle Edge)

Corner Coordinates

Y coordinate	Z coordinate	
$y_{o_0} := 8.5 \cdot in$		(Bottom Right Corner)
$y_{o_1} := 8.5 \cdot in$	$z_{o_1} := 37.5 \cdot in$	(Top Right Corner)
$y_{o_2} := 0 \cdot in$	$z_{o_2} := 37.5 \cdot in$	(Top Left Corner)
$y_{o_3} := 0 \cdot in$		(Bottom Left Corner)
$depth := 16.5 \cdot in$		(Depth of Enclosure)

Driver Geometry Input

$y_{dc} := 4.25 \cdot in$ (Driver Center y Coordinate)

$z_{dc} := 24 \cdot in$ (Driver Center z Coordinate)

$n\_dvr := 5$ (Number of Points Across Diameter)

Terminus Geometry Input

$y_{mc} := 4.25 \cdot in$ (Terminus Center y Coordinate)

$z_{mc} := 3.5625 \cdot in$ (Terminus Center z Coordinate)

$w_{mth} := 7 \cdot in$ (Terminus Width)

$n\_mth := 10$ (Number of Points Across the Width)

$Locate := 0$ (0 = Front Baffle Terminus, 1 = Rear Baffle Terminus)

Listening Position (Default Location is at 1 m Distance Along the Driver's Axis)

n_listen = 0 (Listening Position Relative to Speaker)

$radius := 1 \cdot m$ (Calculation Radius, Effective Radius is Greater if y_p is Changed from Default)

$\theta := 0 \cdot deg$ (0 deg is along the Driver's Axis, -80 deg < θ < 80 deg)

$z_p := z_{dc}$ (Default Height is Equal to Driver Height)

n_listen = 1 (Listening Position Relative to the Room Corner)

$X_p := 10ft$

$Y_p := 7 \cdot ft$

$Z_p := z_{dc} + stand$ (Default Height is Equal to Driver Height)

$n\_listen := 0$ (Method Selection)

Floor Condition

$Reflect := 1$ (0 = hardwood or concrete, 1 = carpeted)

Refective Surface Selections (if 1 reflective surface is included, if 0 reflective surface is removed)

$Inc\_floor := 0$ (Floor, Z = 0)

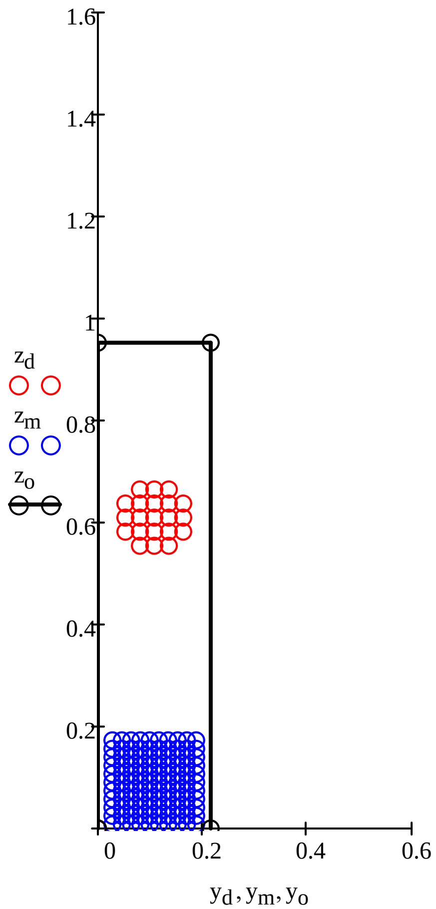
$Inc\_rear := 0$ (Rear Wall, X = 0)

$Inc\_side := 0$ (Left Side Wall, Y = 0)

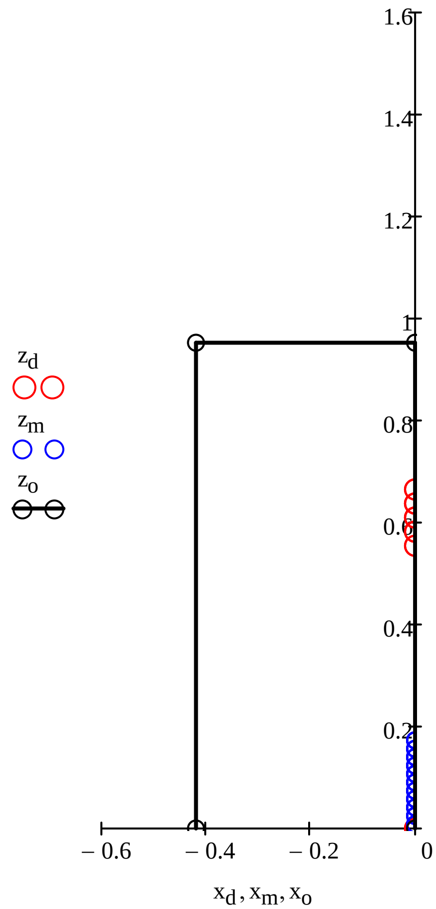
$Inc\_ceiling := 0$ (Ceiling)

Circular Driver and TL Terminus Simple Source Pattern with Baffle Edge Outline

Front View



Side View

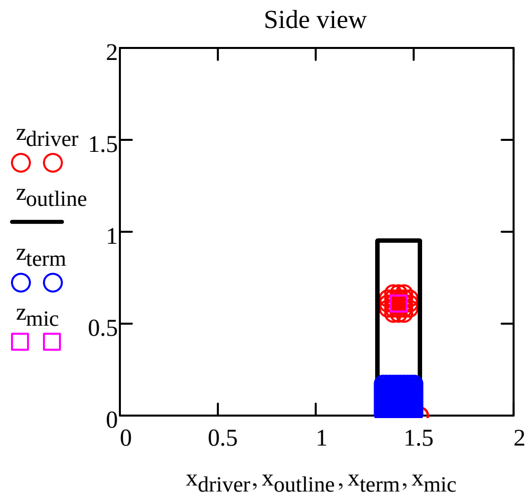


Red sources represent the driver.
Blue sources represent the terminus.
Black outline represents the baffle edge.
Origin is at the bottom front left corner of the enclosure.

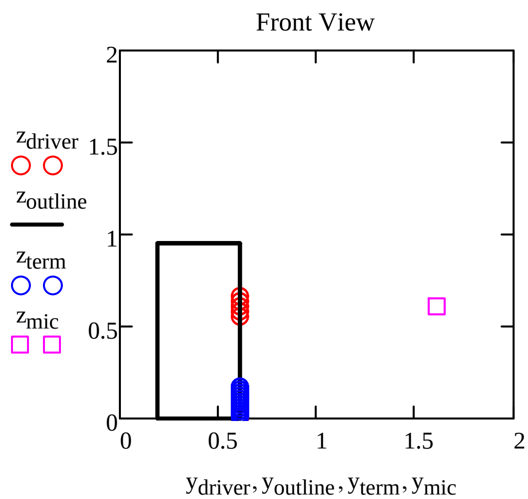
Three Dimensional View

Axis Length (m) axis := 2 <---- Change value of "axis" to rescale plots

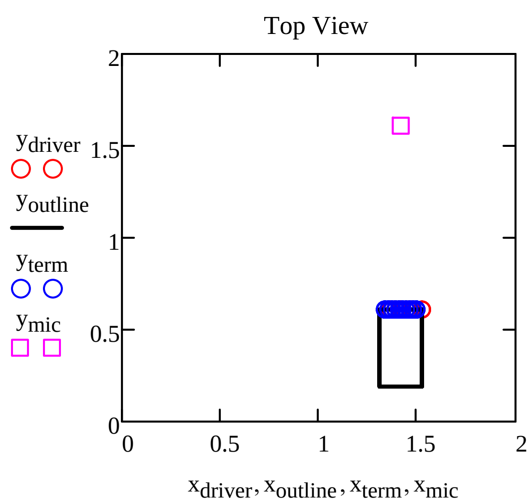
Room Corner is the Origin



Side View - looking out from side wall

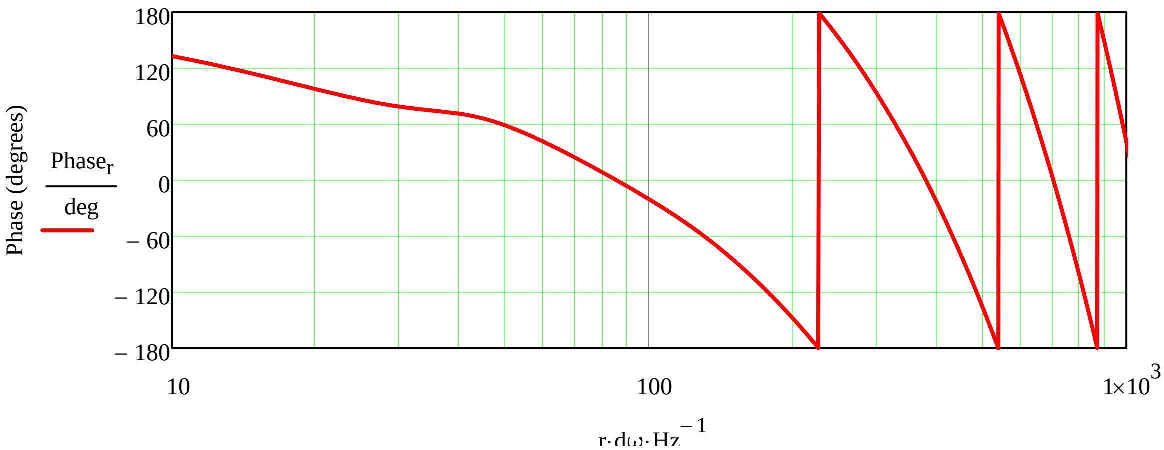


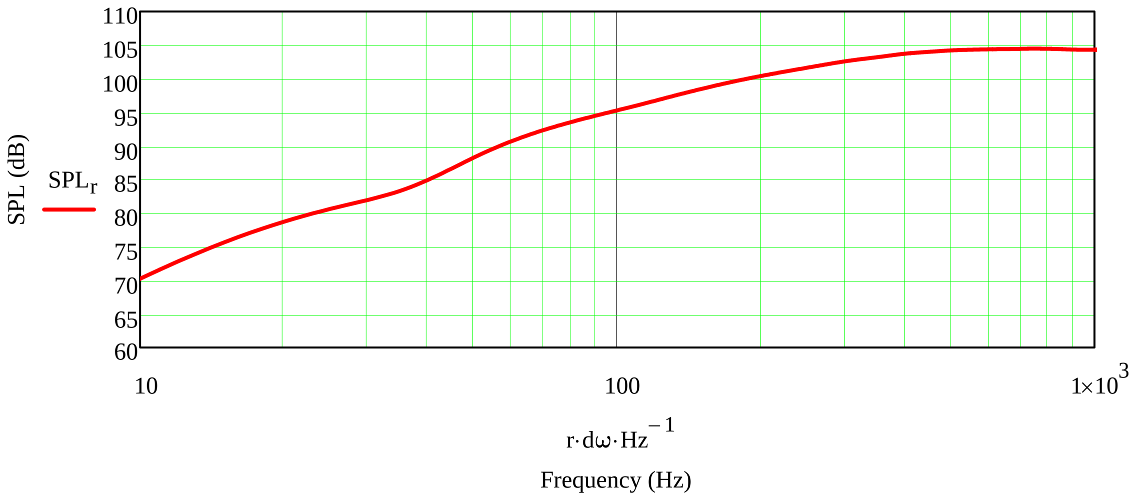
Front View - looking towards rear wall



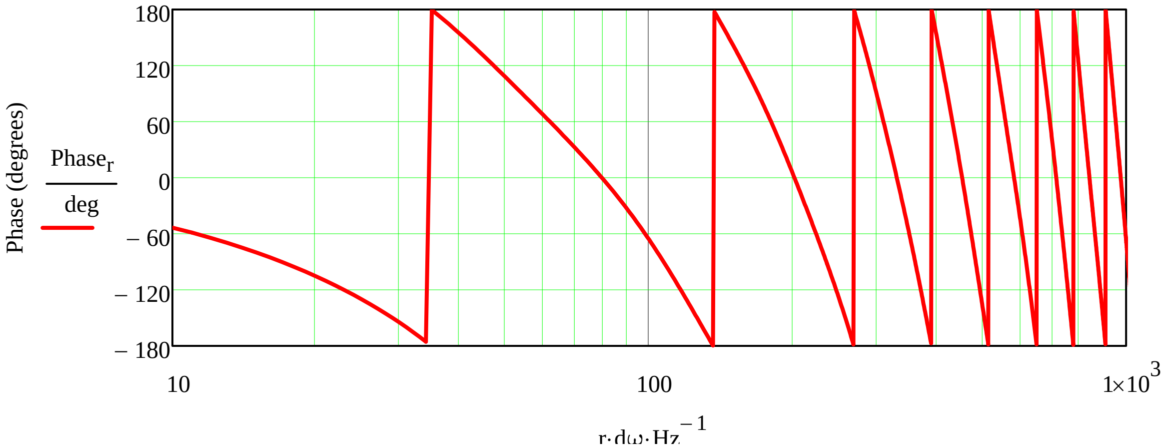
Top View - looking down from ceiling

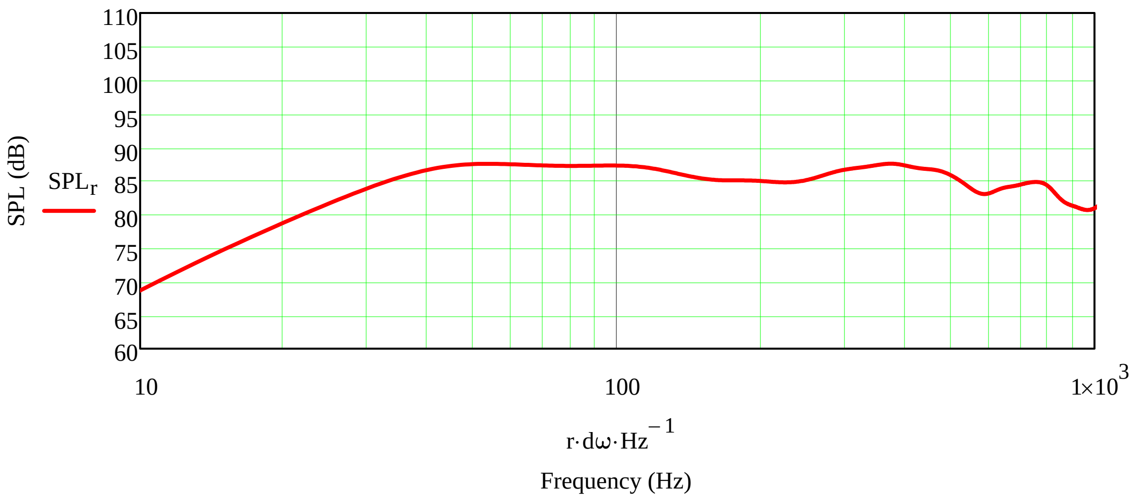
Plotted Baffle Step and Reflection SPL Response for the Circular Driver Source



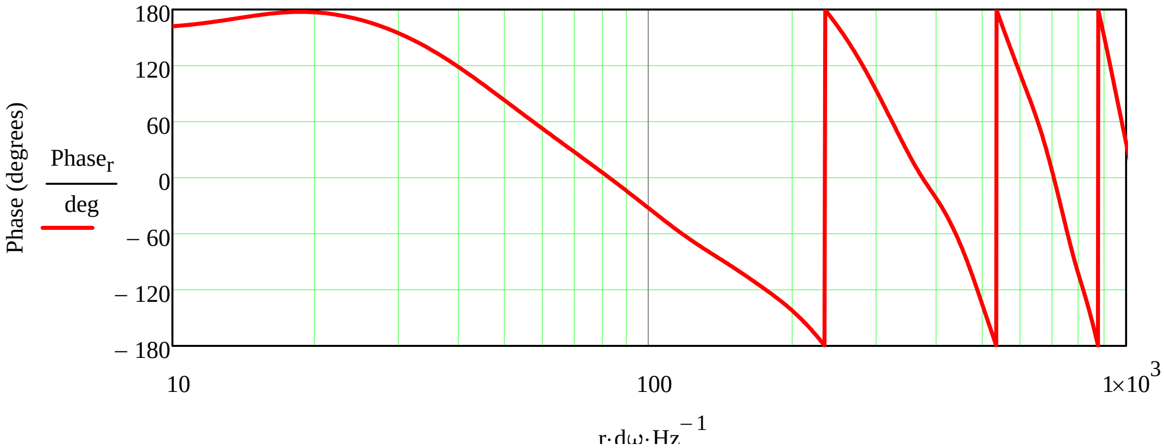


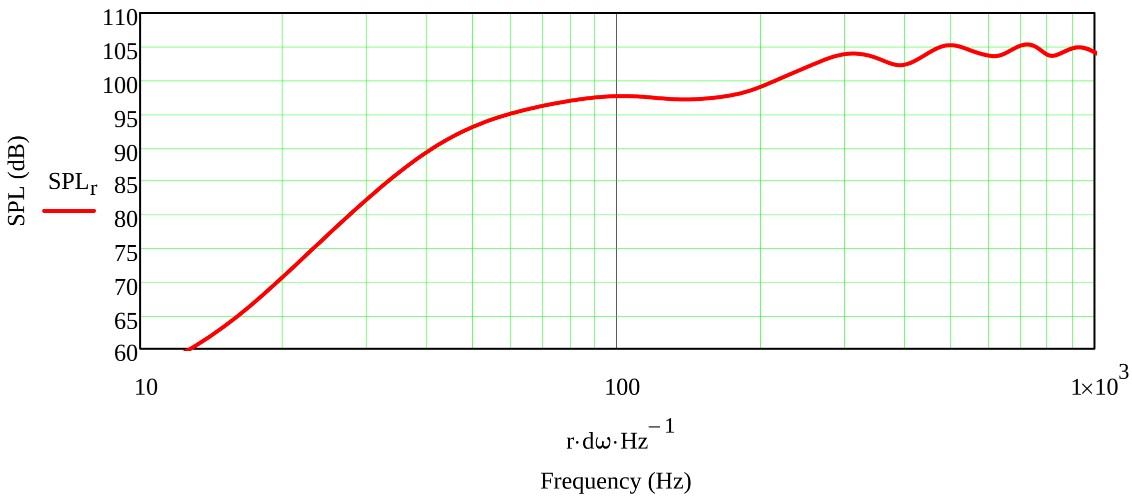
Plotted Baffle Step and Reflection SPL Response for the TL Terminus





Plotted SPL Response for the System





Part 3 : Baffle Step Correction Circuit Design

Input Center Frequency of the Baffle Step and the desired dB of Attenuation.

$f_{center} := 400 \cdot Hz$ <--- Input Center Frequency

$dB := 6$ <--- Input dB of Attenuation

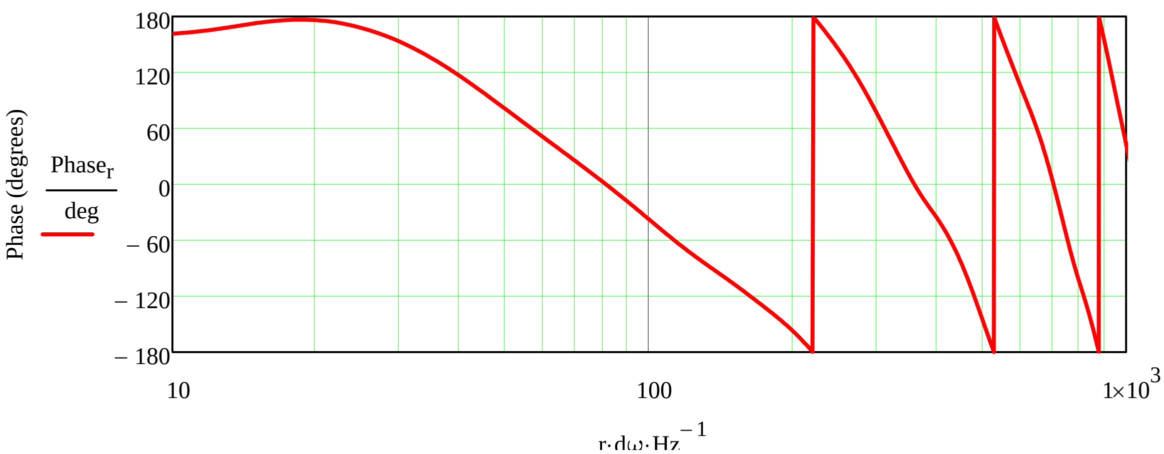
Calculated Component Values

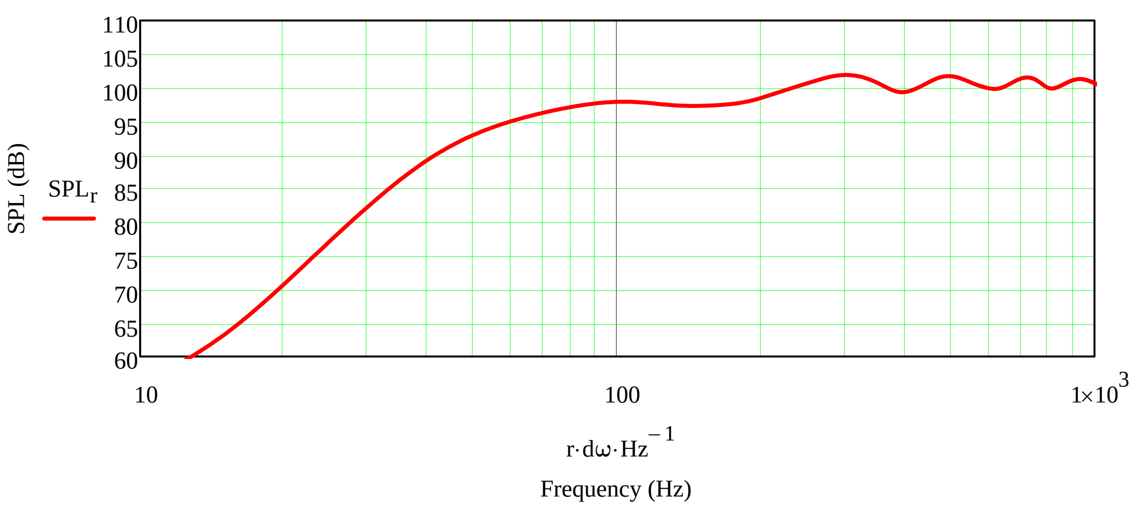
User Assigned Component Values Based on Calculated Values at Left

$R_e \cdot \left(10^{\frac{dB}{20}} - 1\right) = 10.948 \cdot \Omega$ Parallel Resistor — Input Value ---> $R_{parallel} := 8 \cdot \Omega$

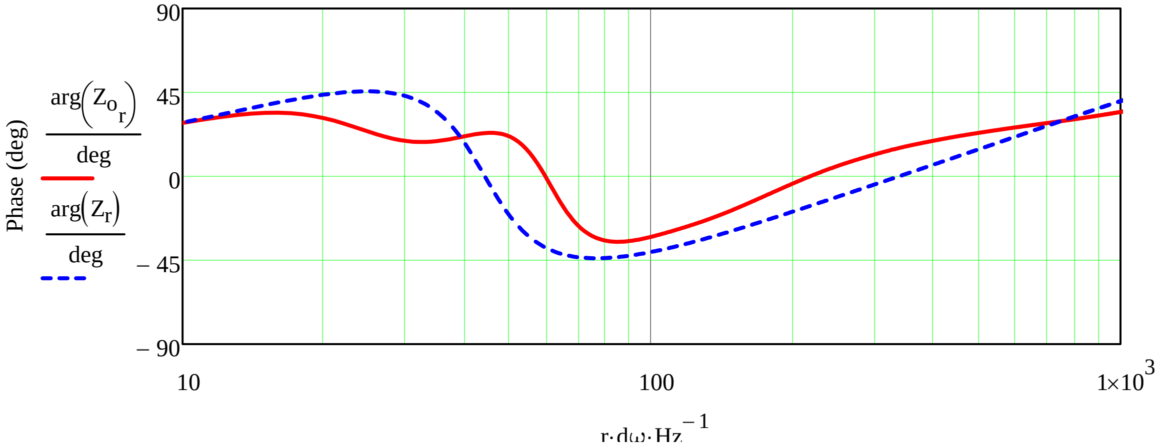
$\frac{R_{parallel}}{f_{center}} = 3.183 \cdot mH$ BSC Inductor — Input Value ---> $L_{BSC} := 3 \cdot mH$

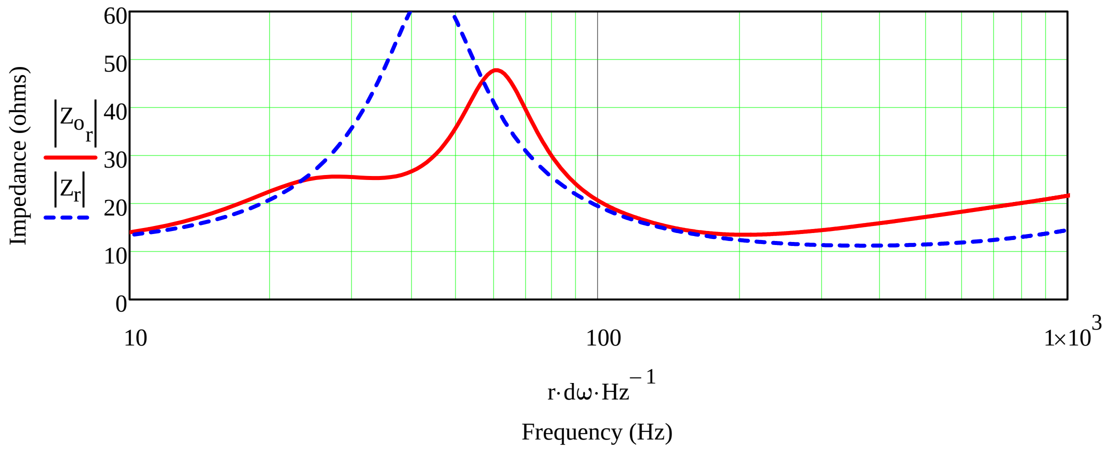
Plotted Corrected SPL Response for the System



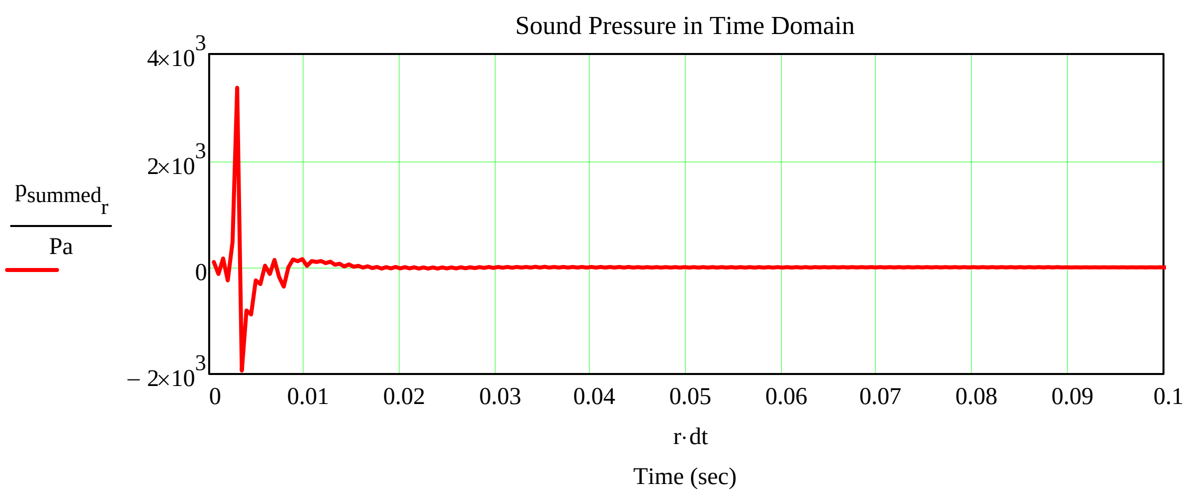


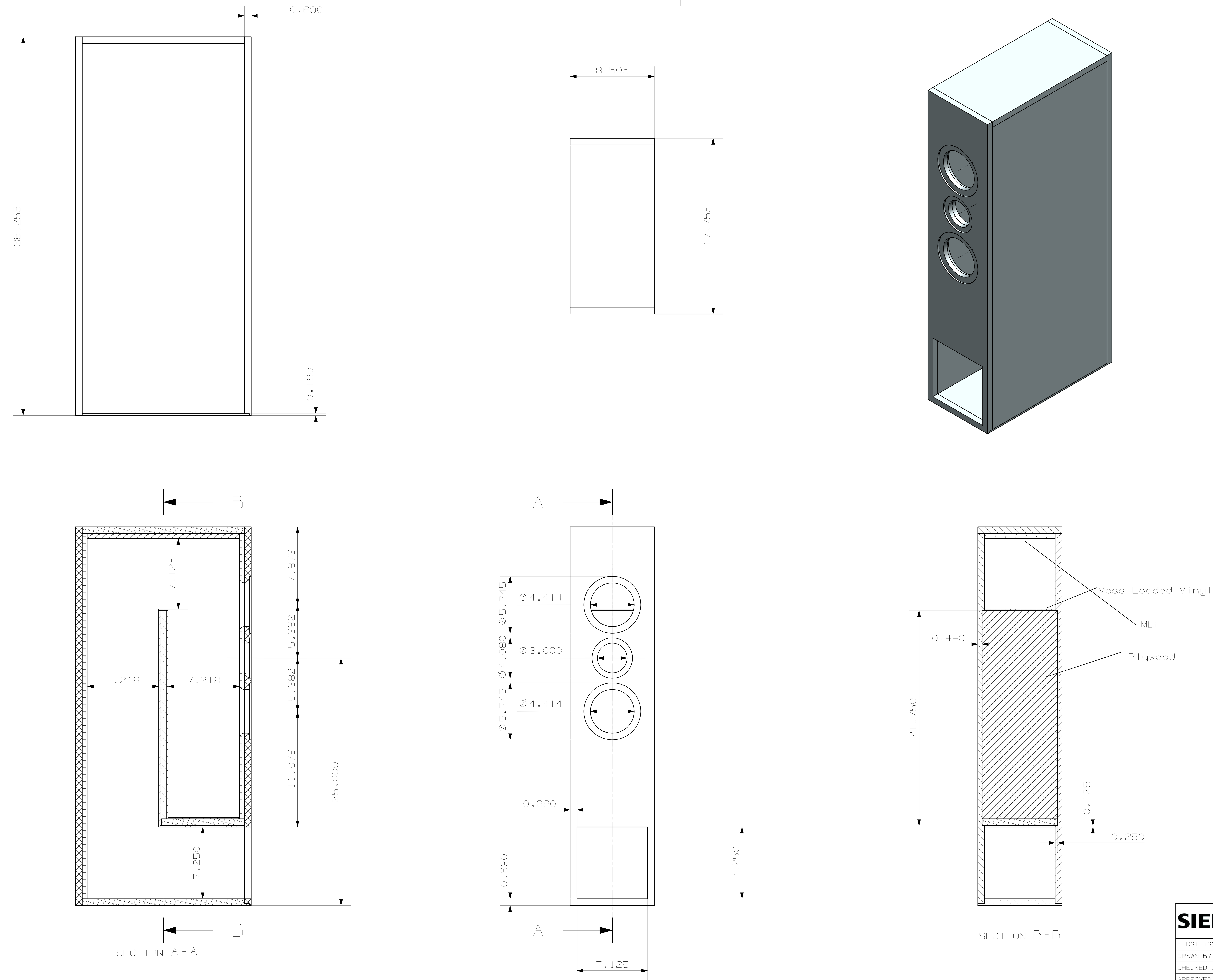
Transmission Line Corrected System and Infinite Baffle Impedance





System Time Response for an Impulse Input





3D CAD MASTER PART NAME:

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SIEMENS	Michigan Technological University
FIRST ISSUED	TITLE
DRAWN BY	Overview
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APPROVED BY	SIZE D DWG NO. Final Box 6 REV 1
Shawbitz Kevin	SCALE 1:5 SHEET 1 OF 1

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Michigan Technological University

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Shawbitz	Kevin

TITLE
4' x 8' Plywood Cutout

SIZE	DRG NO.	REV
A	Board 1 Rev 3-8-2013	4

SCALE 1:10 | SHEET 1 OF 1

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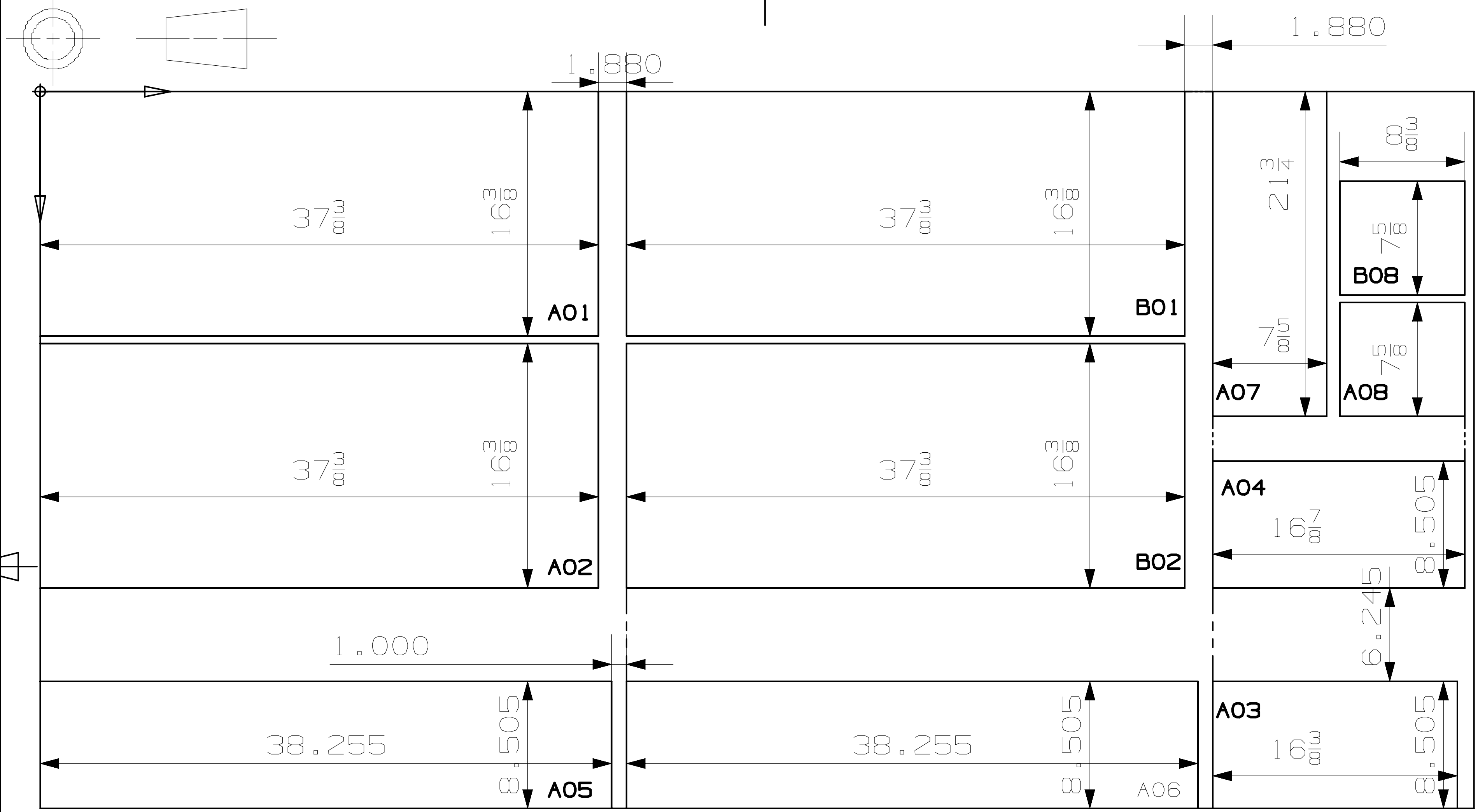
3D CAD MASTER PART NAME:



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Shawbitz	Kevin

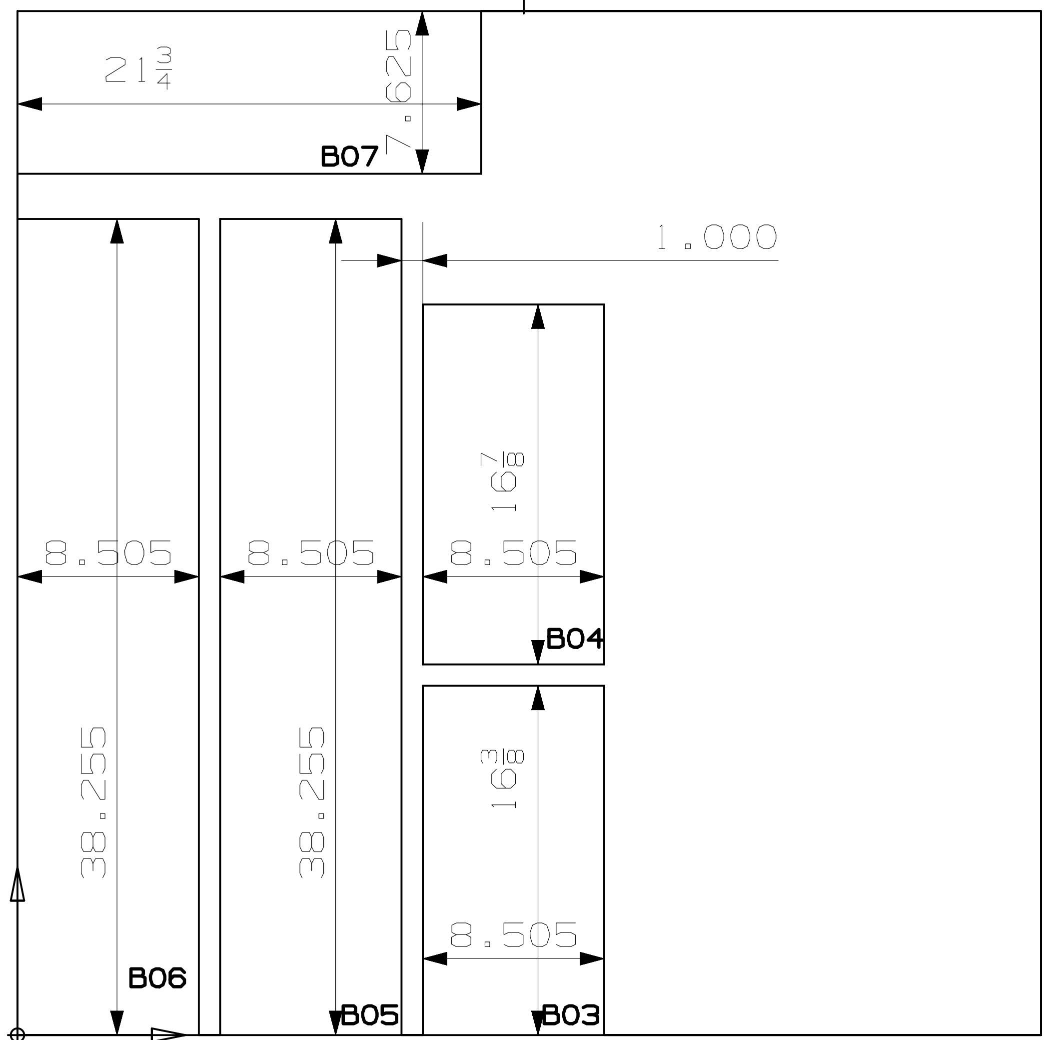
TITLE

4" x 8" Plywood Cutout

SIZE	DRG NO.	REV
A	Board 1 Rev 3-8-2013	4

SCALE 1:10

SHEET 1 OF 1



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		SCALE 1:9 / SHEET 1 OF 1

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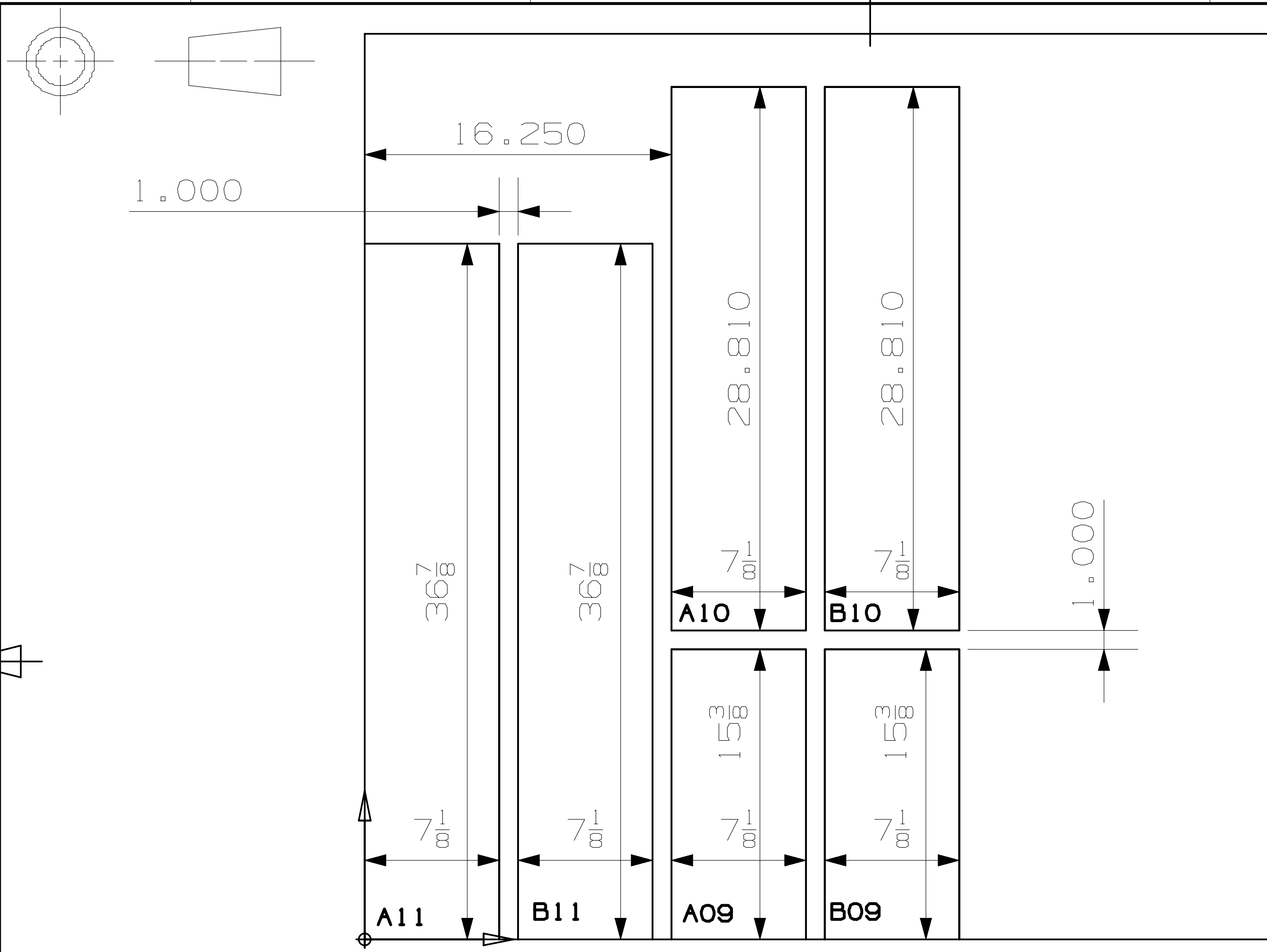

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APPROVED BY	
Shawbitz	Kevin

TITLE
4' x 4' MDF Cutout

SIZE	DRG NO.	REV
A	MDF Cutout	3

SCALE 1:9 | SHEET 1 OF 1

ALL DIMENSIONS IN INCHES

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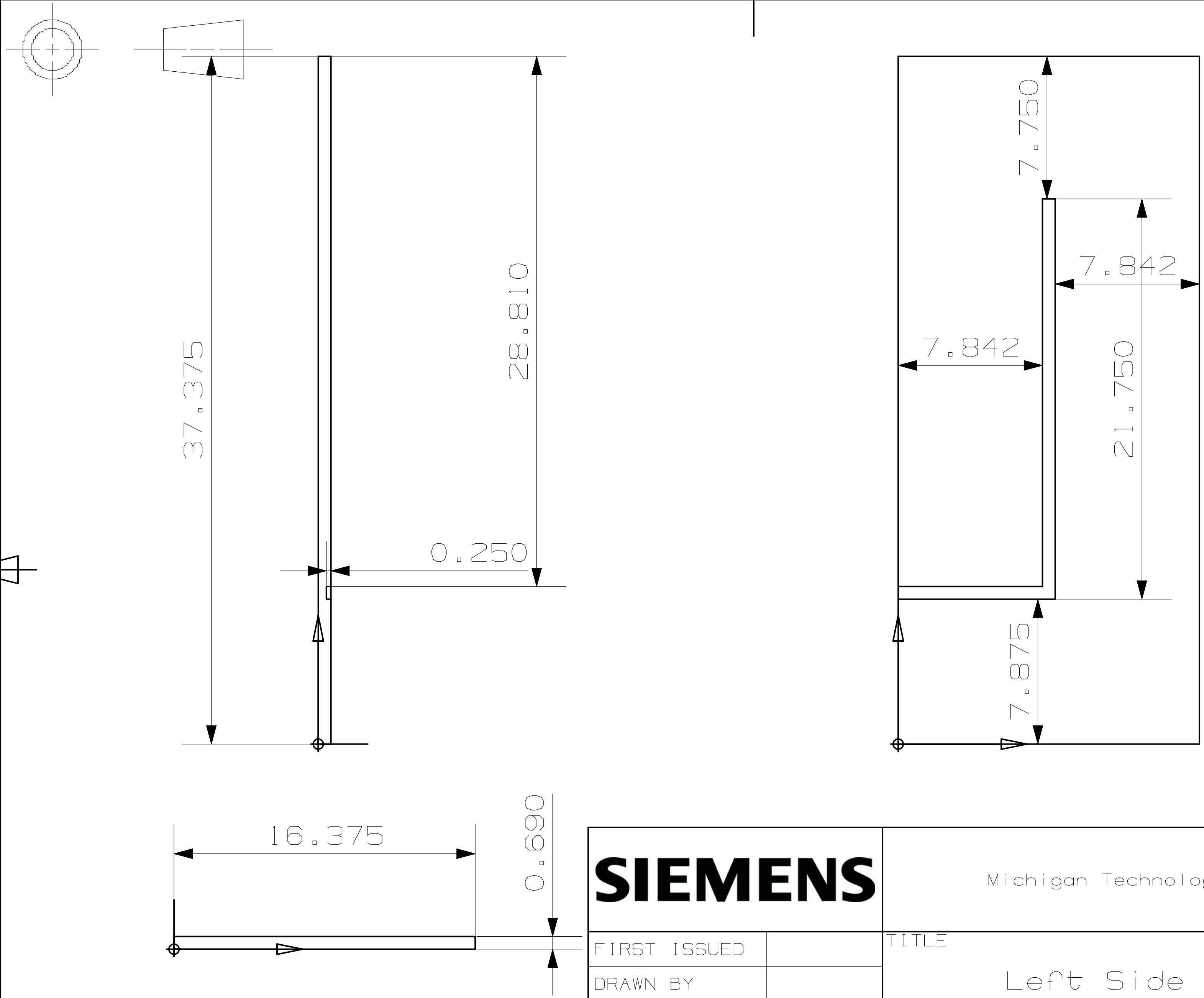

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DRAWN BY		
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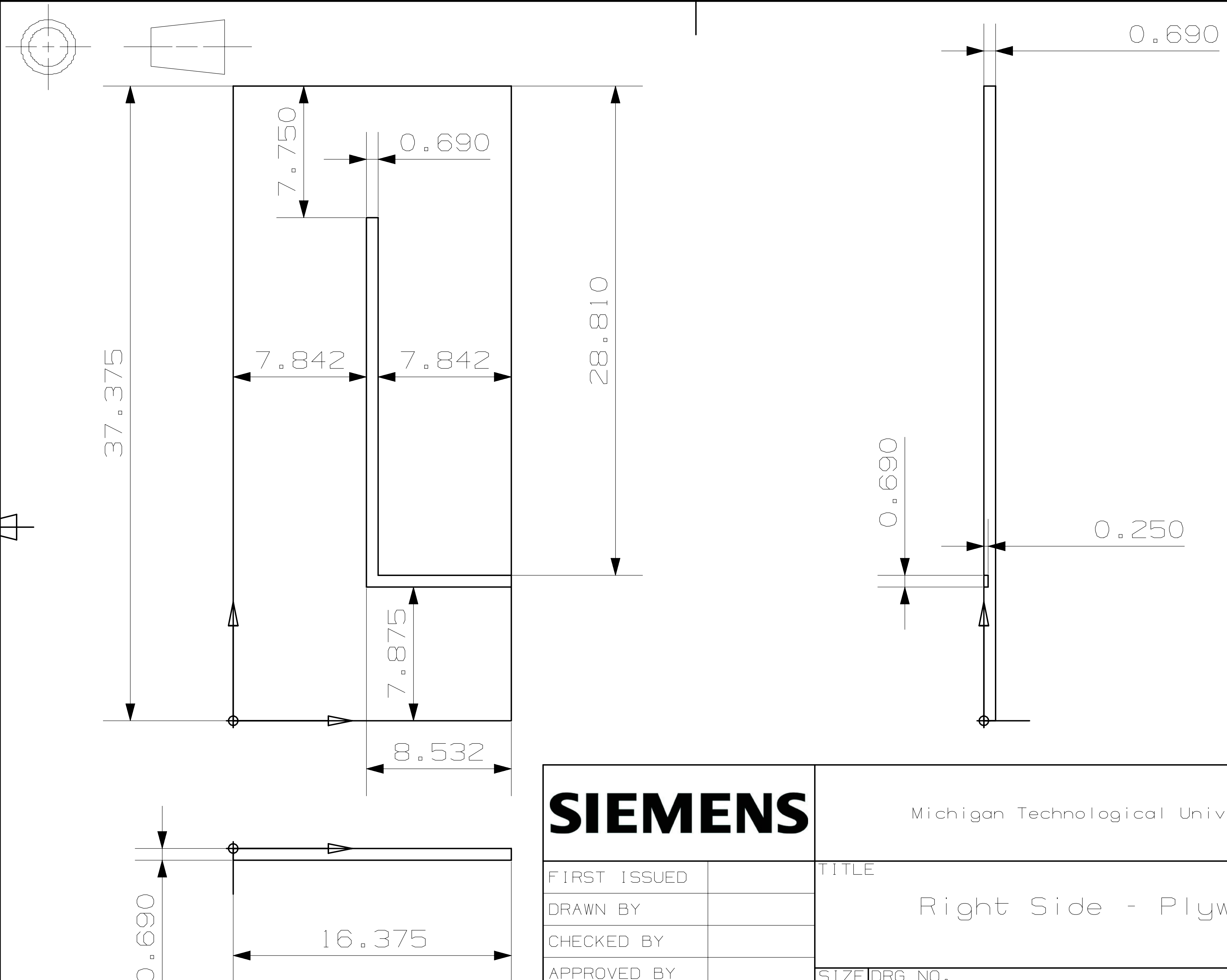
APPROVED BY		SIZE A / DRG NO. 01 / REV 3
Shawbitz	Kevin	
		SCALE 1:8 / SHEET 1 OF 1



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3D CAD MASTER PART NAME:

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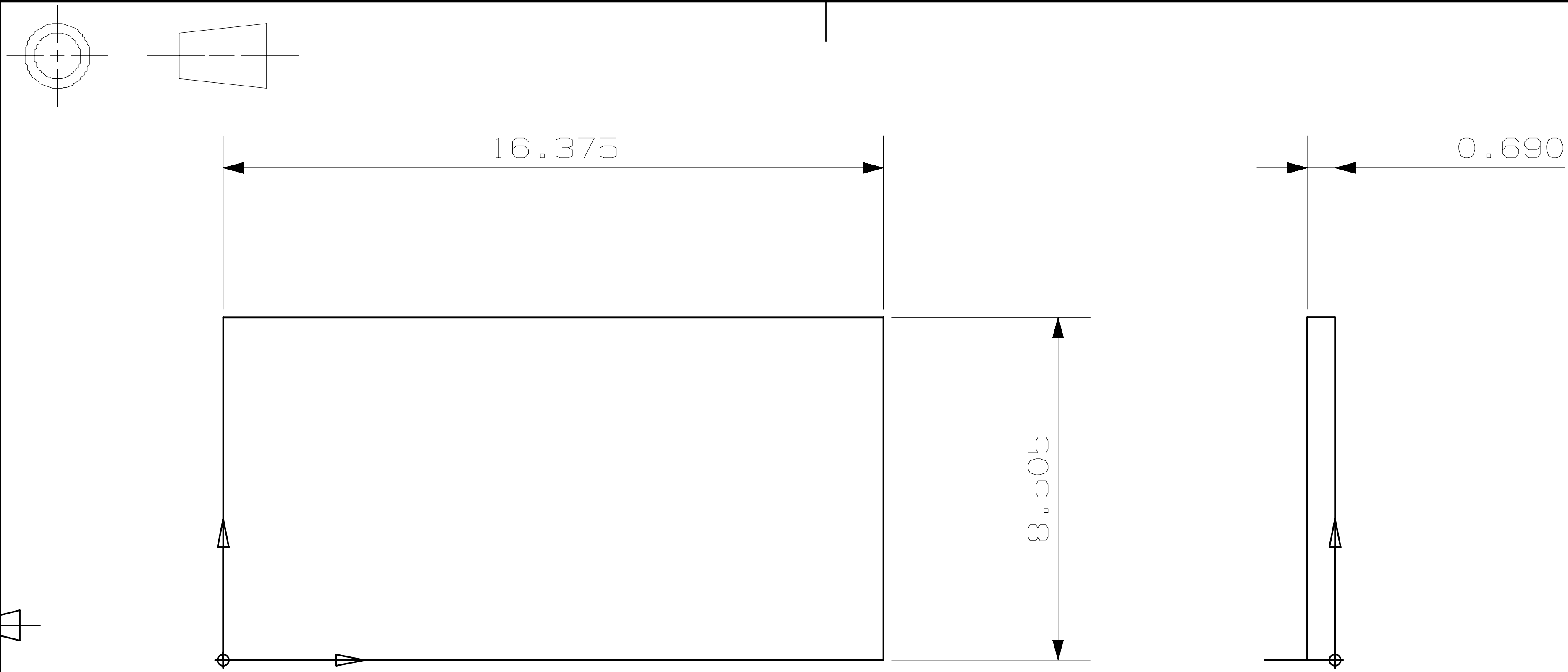
TITLE

Right Side - Plywood

SIZE	DRG NO.	REV
A	02	3

SCALE 1:8		SHEET 1 OF 1



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FIRST ISSUED		TITLE Top - Plywood
DRAWN BY		
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APPROVED BY		SIZE: A · DRG NO.: 03 · REV: 3
Shawbitz	Kevin	
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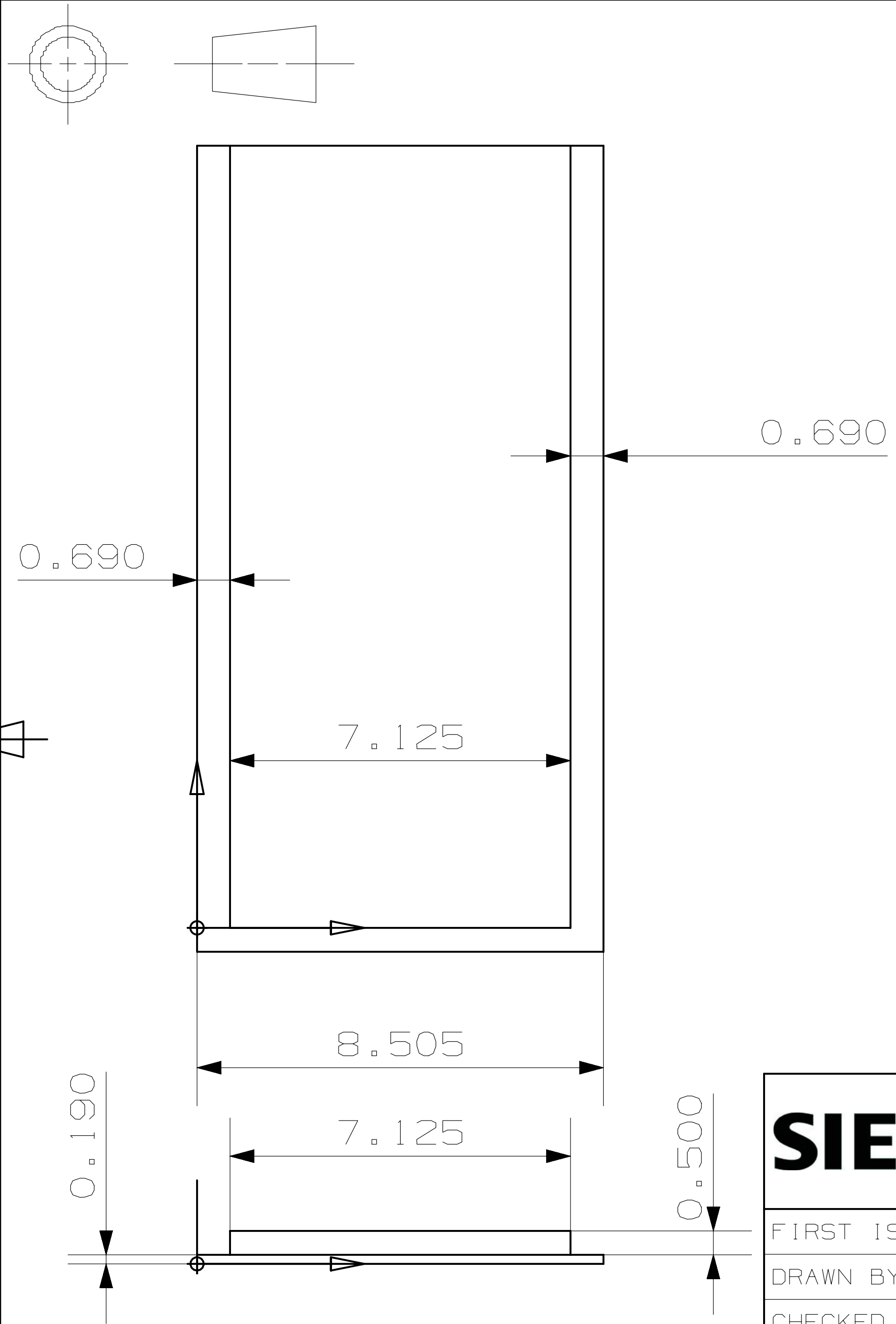

ALL DIMENSIONS IN INCHES

3D CAD MASTER PART NAME:

SIEMENS	Michigan Technological University
FIRST ISSUED	TITLE
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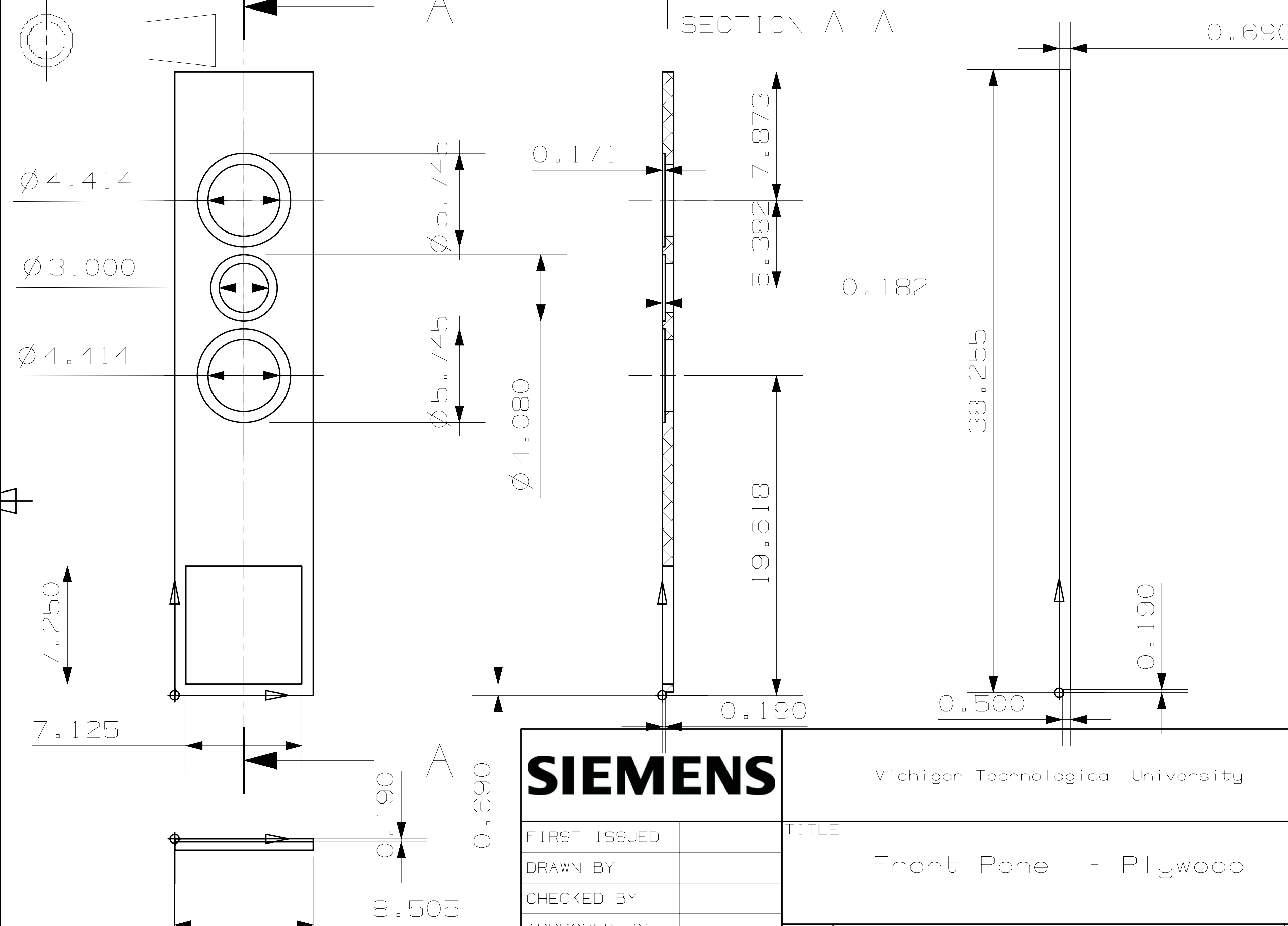
CHECKED BY	
APPROVED BY	SIZE A — DRG NO. 04 — REV 3
Shawbitz Kevin	SCALE 1:4 — SHEET 1 OF 1



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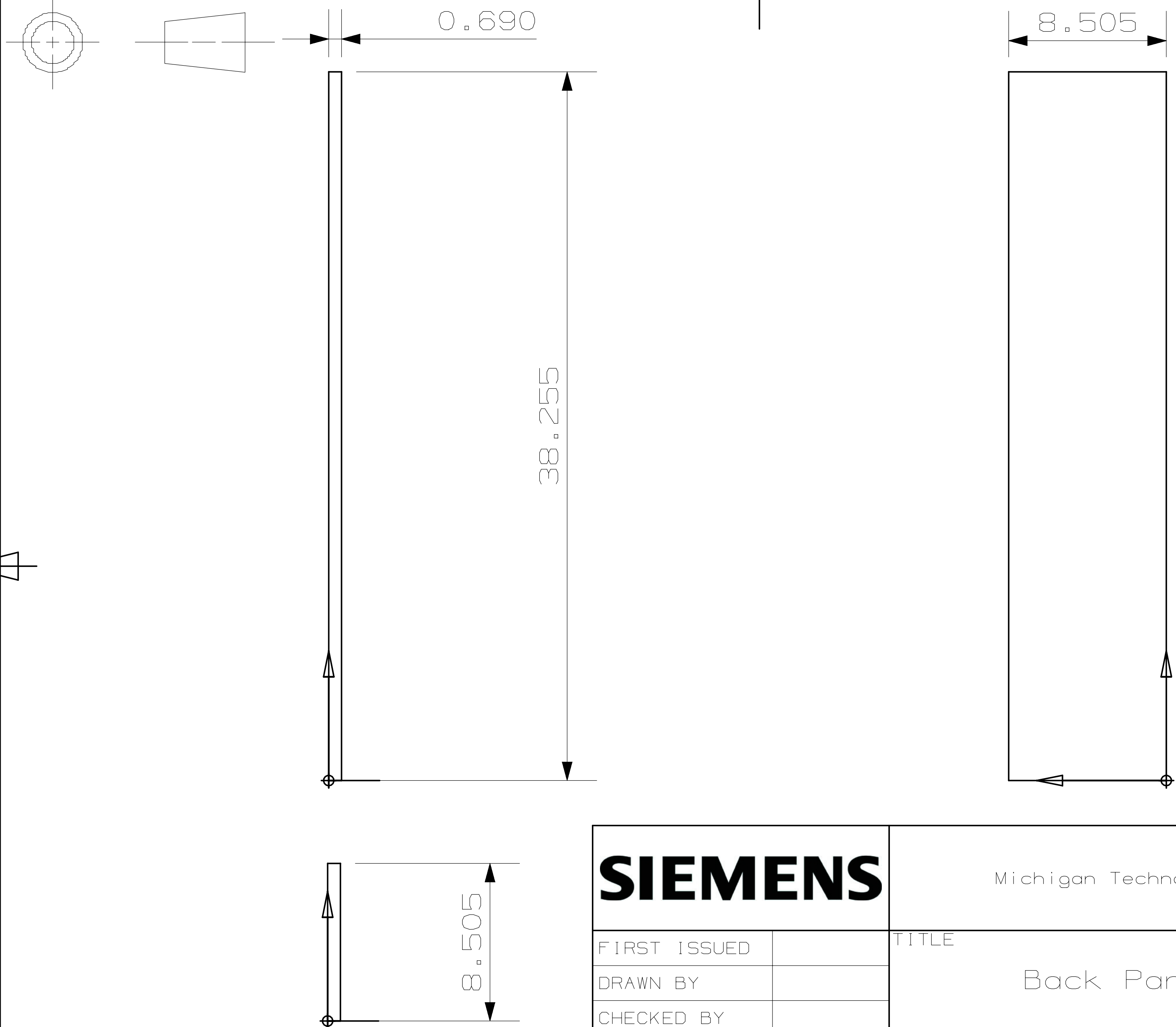
APPROVED BY	
Shawbitz	Kevin

TITLE

Front Panel - Plywood

SIZE	DRG NO.	REV
A	05	3

SCALE 1:8 | SHEET 1 OF 1



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Shawbitz	Kevin

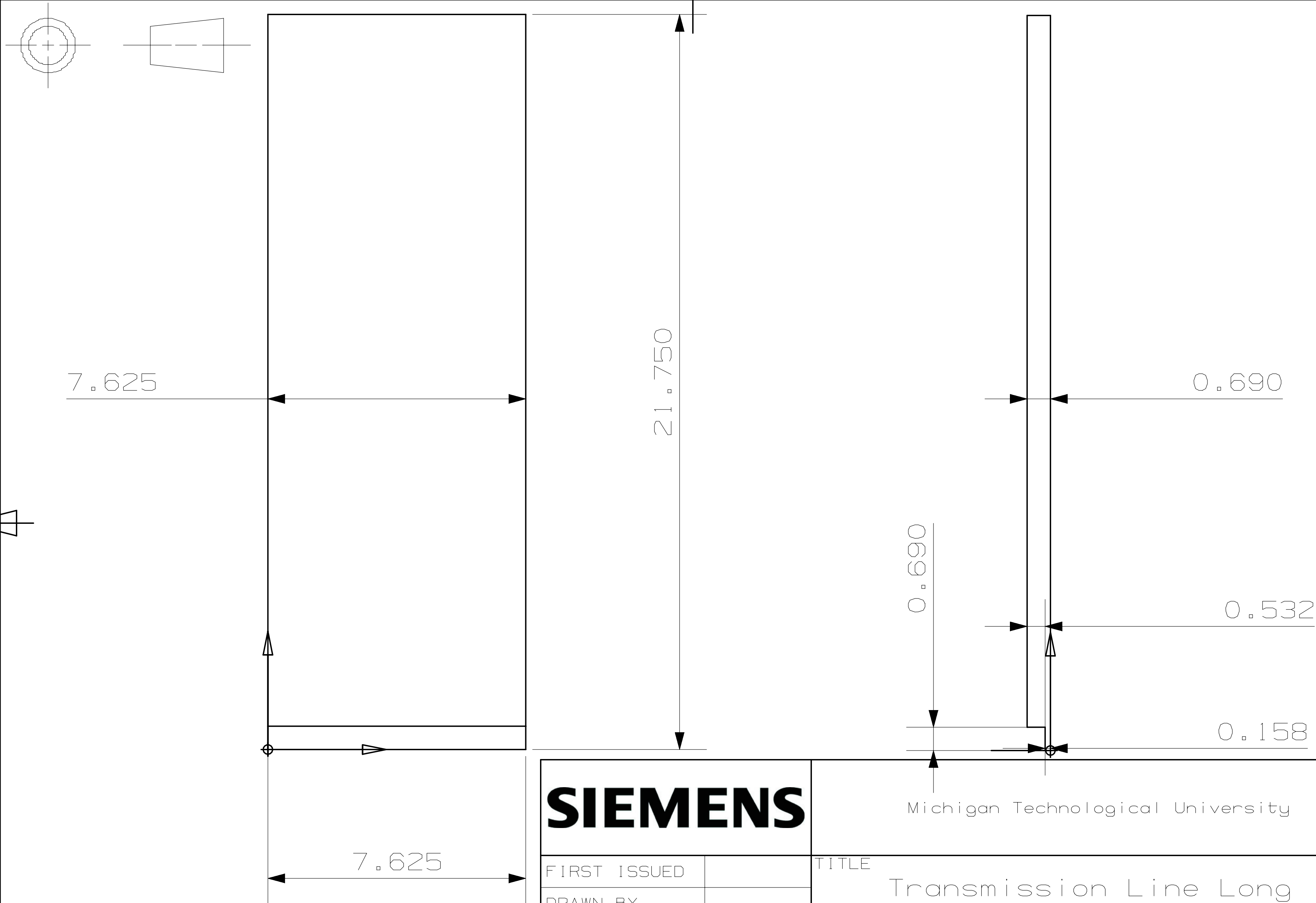
TITLE

Back Panel-Plywood

SIZE	DRG NO.	REV
A	06	3

SCALE 1:8

SHEET 1 OF 1



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Shawbitz	Kevin

TITLE
Transmission Line Long Brace - Plywood

SIZE	DRG NO.	REV
A	07	3

SCALE 1:4 | SHEET 1 OF 1

ALL DIMENSIONS IN INCHES

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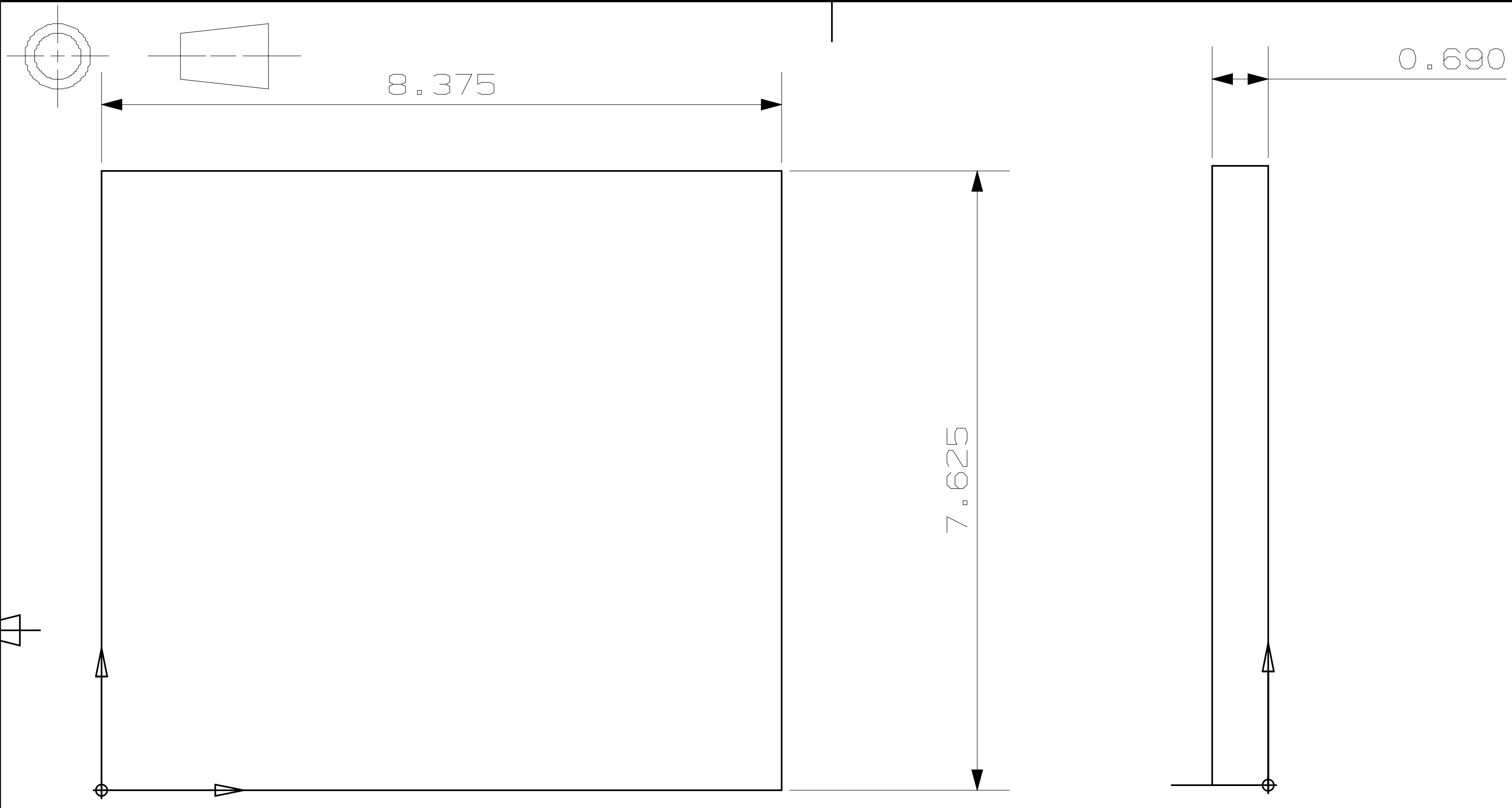

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Michigan Technological University

TITLE
Transmission Line Short
Brace - Plywood

FIRST ISSUED	
DRAWN BY	
CHECKED BY	
APPROVED BY	
Shawbitz	Kevin

SIZE	DRG NO.	REV
A	08	3

SCALE 1:2 | SHEET 1 OF 1

ALL DIMENSIONS IN INCHES

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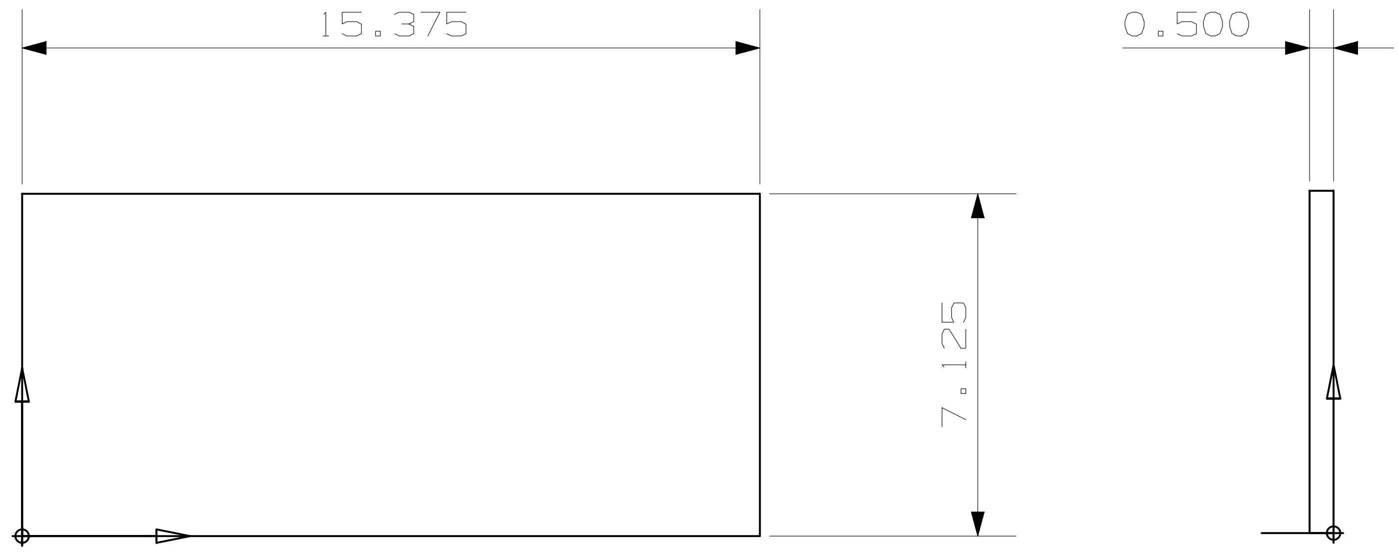

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APPROVED BY	
Shawbitz Kevin	

TITLE

Top - MDF

SIZE	DRG NO.	REV
A	09	3

SCALE 1:4

SHEET 1 OF 1

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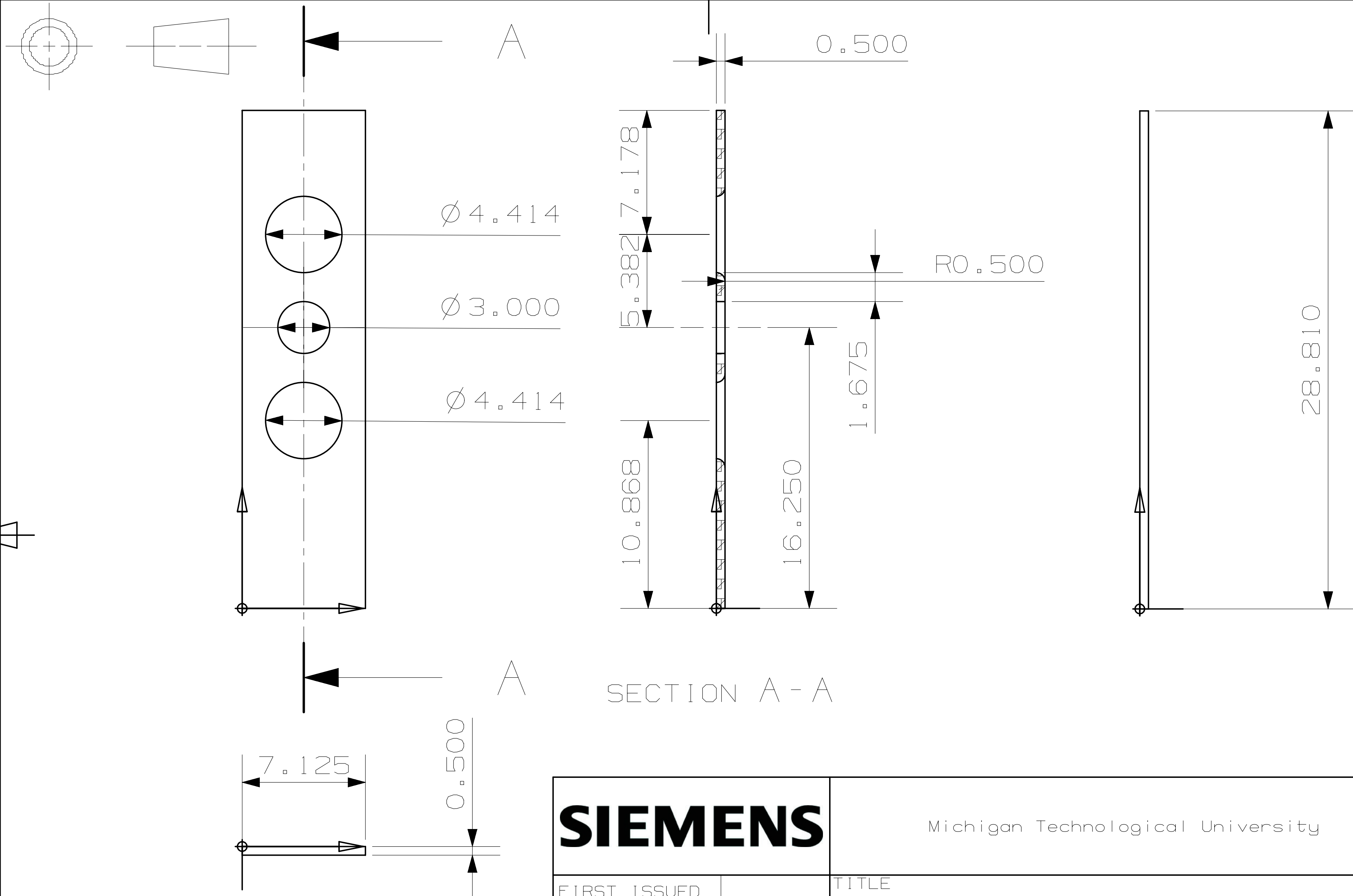

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FIRST ISSUED	TITLE
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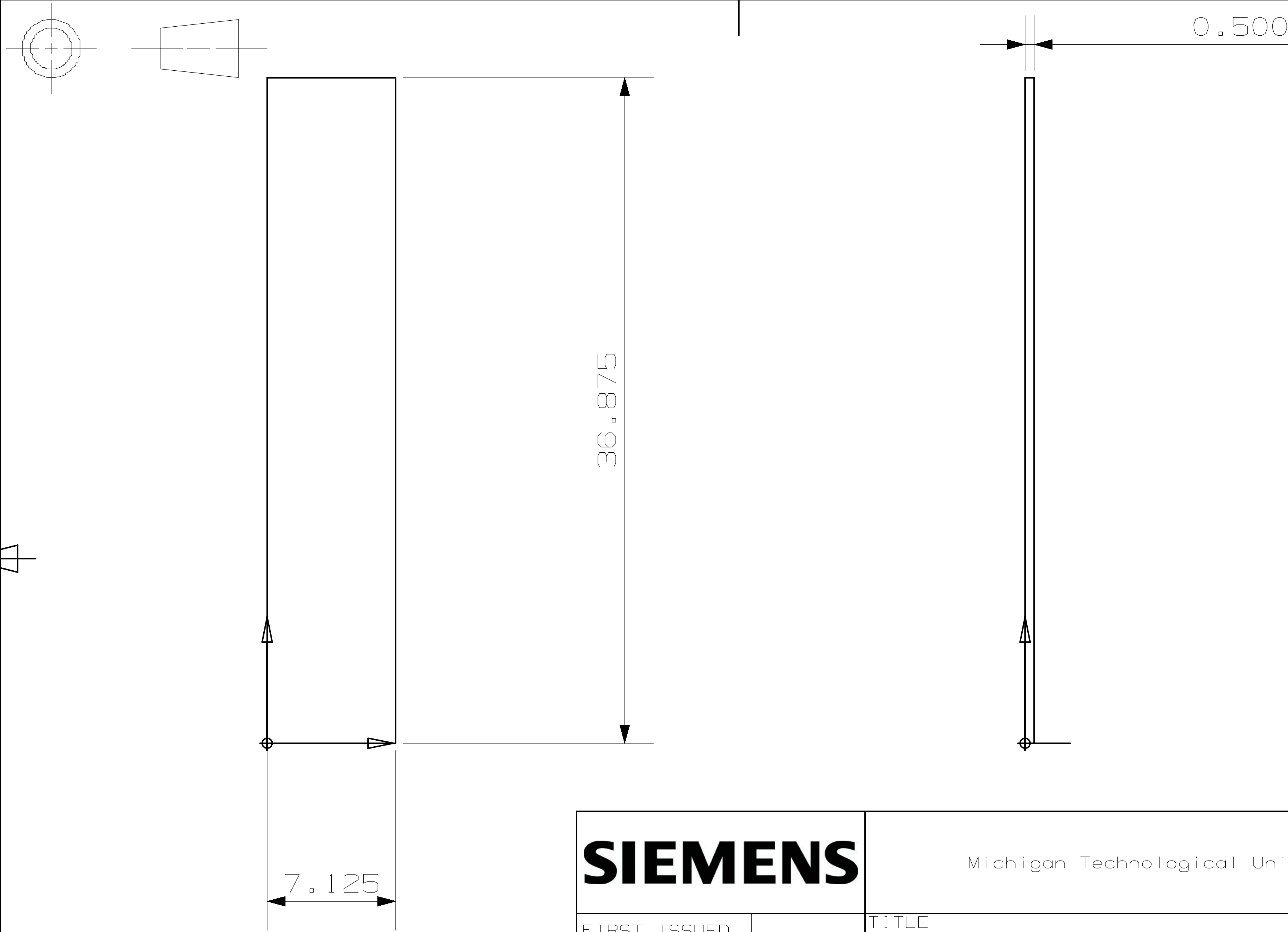
CHECKED BY	
APPROVED BY	SIZE: A / DRG NO.: 10 / REV: 3
Shawbitz Kevin	
	SCALE 1:8 / SHEET 1 OF 1



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APPROVED BY	SIZE: A — DRG NO.: 11 — REV: 3
Shawbitz Kevin	SCALE 1:8 — SHEET 1 OF 1

ALL DIMENSIONS IN INCHES

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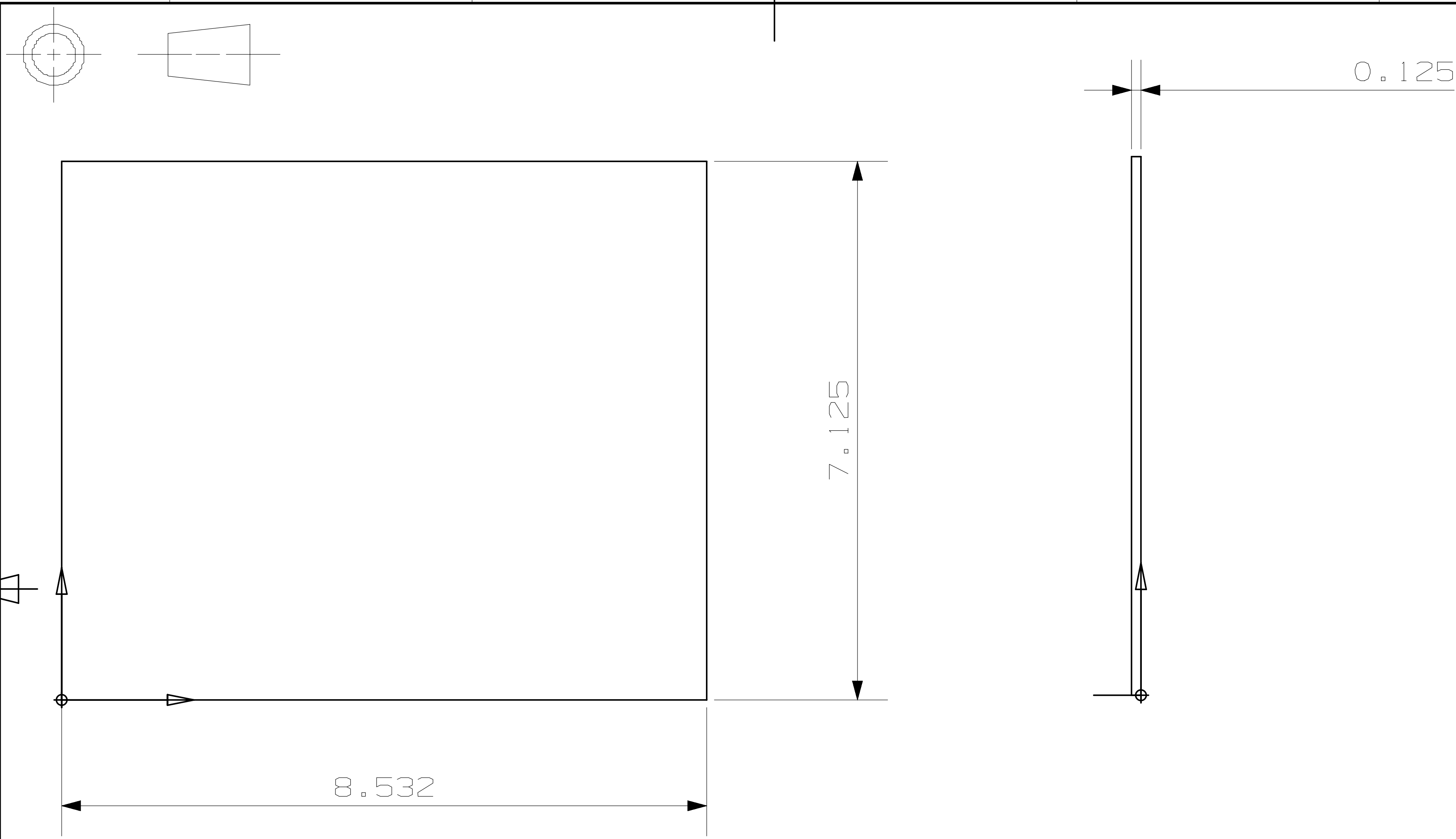

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CHECKED BY	
APPROVED BY	SIZE A / DRG NO. 12 / REV 3
Shawbitz Kevin	
	SCALE 1:2 / SHEET 1 OF 1

ALL DIMENSIONS IN INCHES

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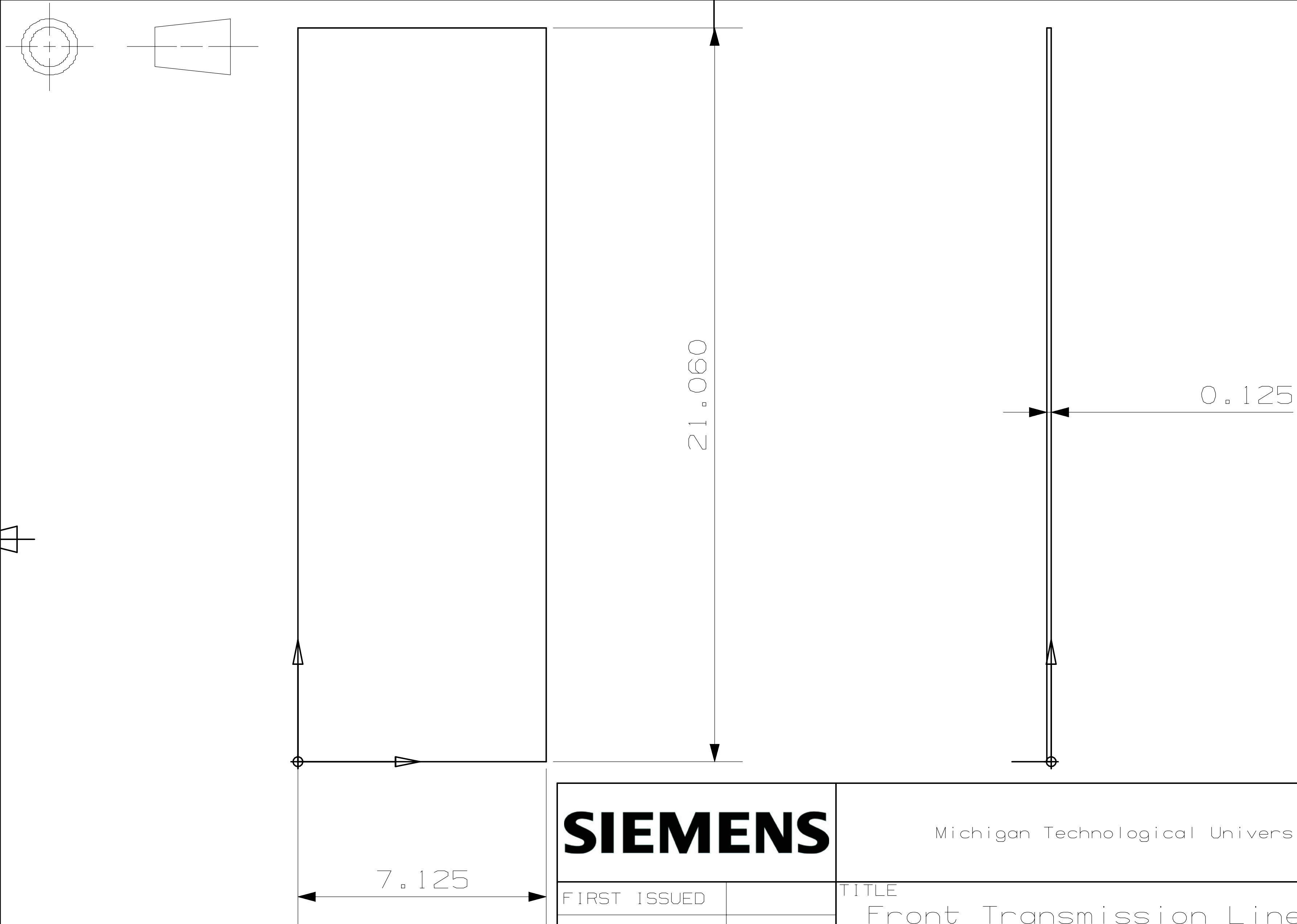

SIEMENS

Michigan Technological University

FIRST ISSUED		TITLE Front Transmission Line Long Brace - Mass Loaded Vinyl
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CHECKED BY		
APPROVED BY		SIZE A / DRG NO. 13 / REV 3
Shawbitz	Kevin	
		SCALE 1:4 / SHEET 1 OF 1

ALL DIMENSIONS IN INCHES

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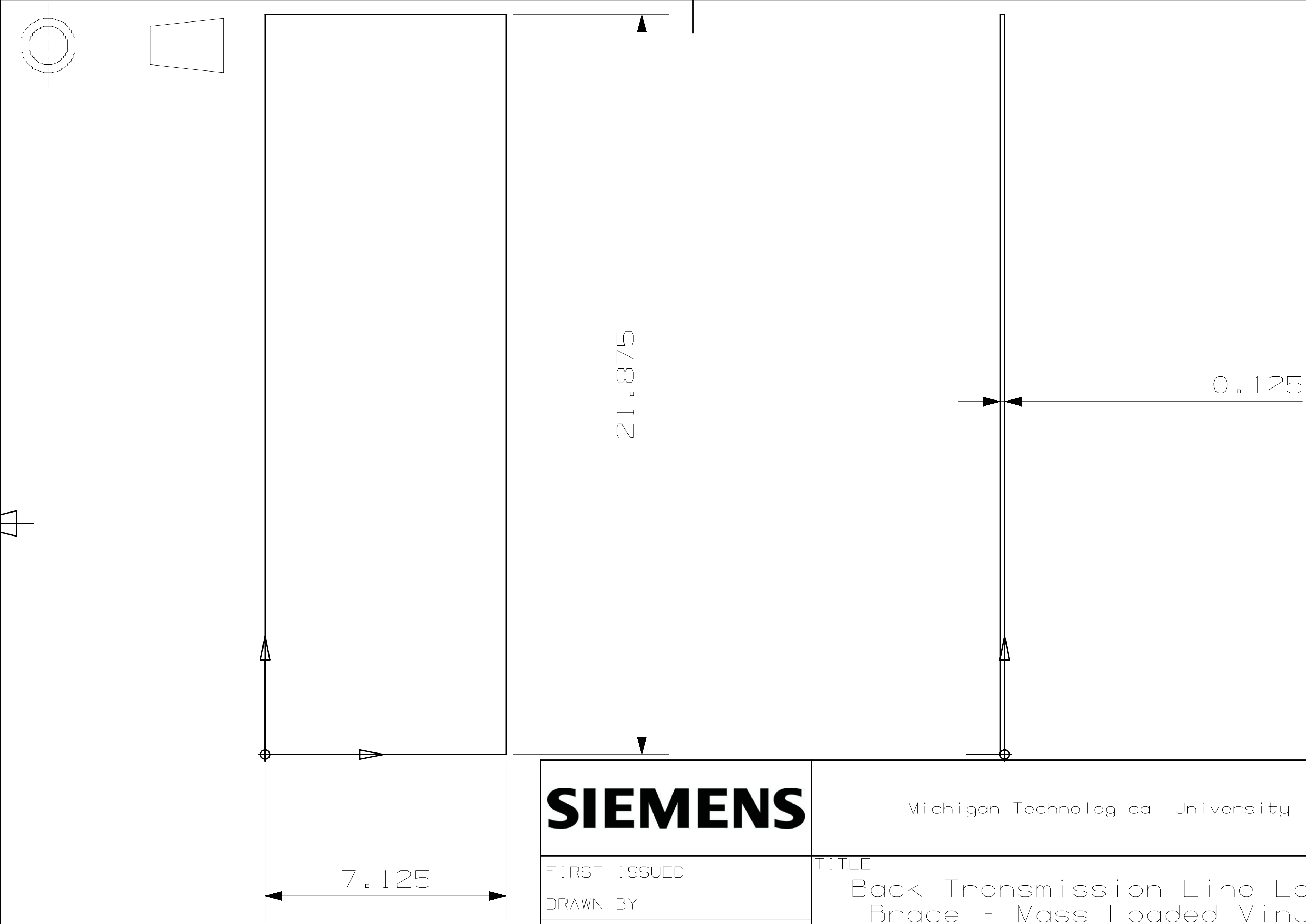

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FIRST ISSUED		TITLE Back Transmission Line Long Brace - Mass Loaded Vinyl
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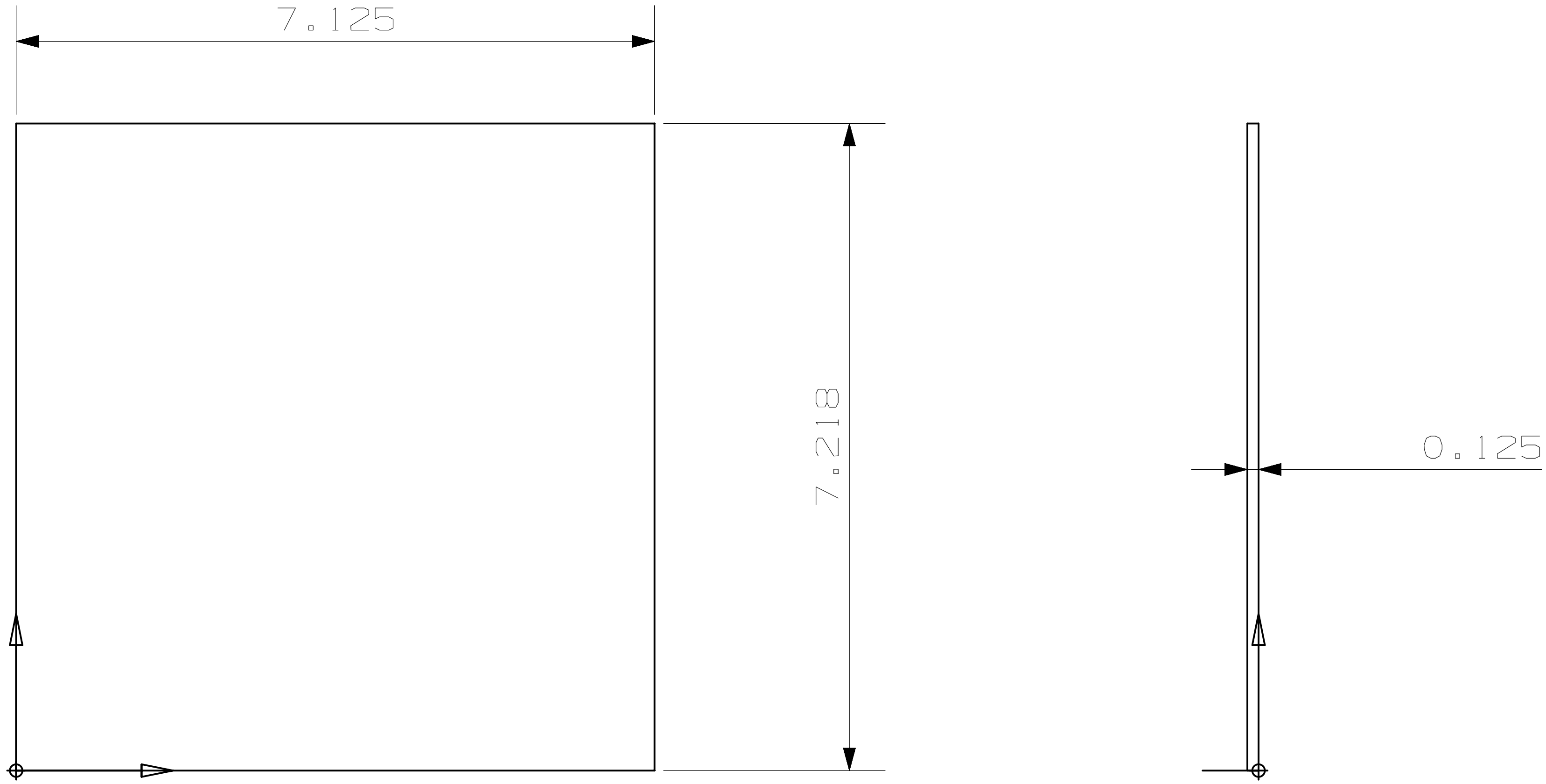
APPROVED BY		SIZE: A; DRG NO.: 14; REV: 3
Shawbitz	Kevin	SCALE 1:4; SHEET 1 OF 1

ALL DIMENSIONS IN INCHES

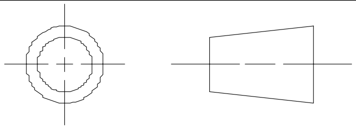
3D CAD MASTER PART NAME:

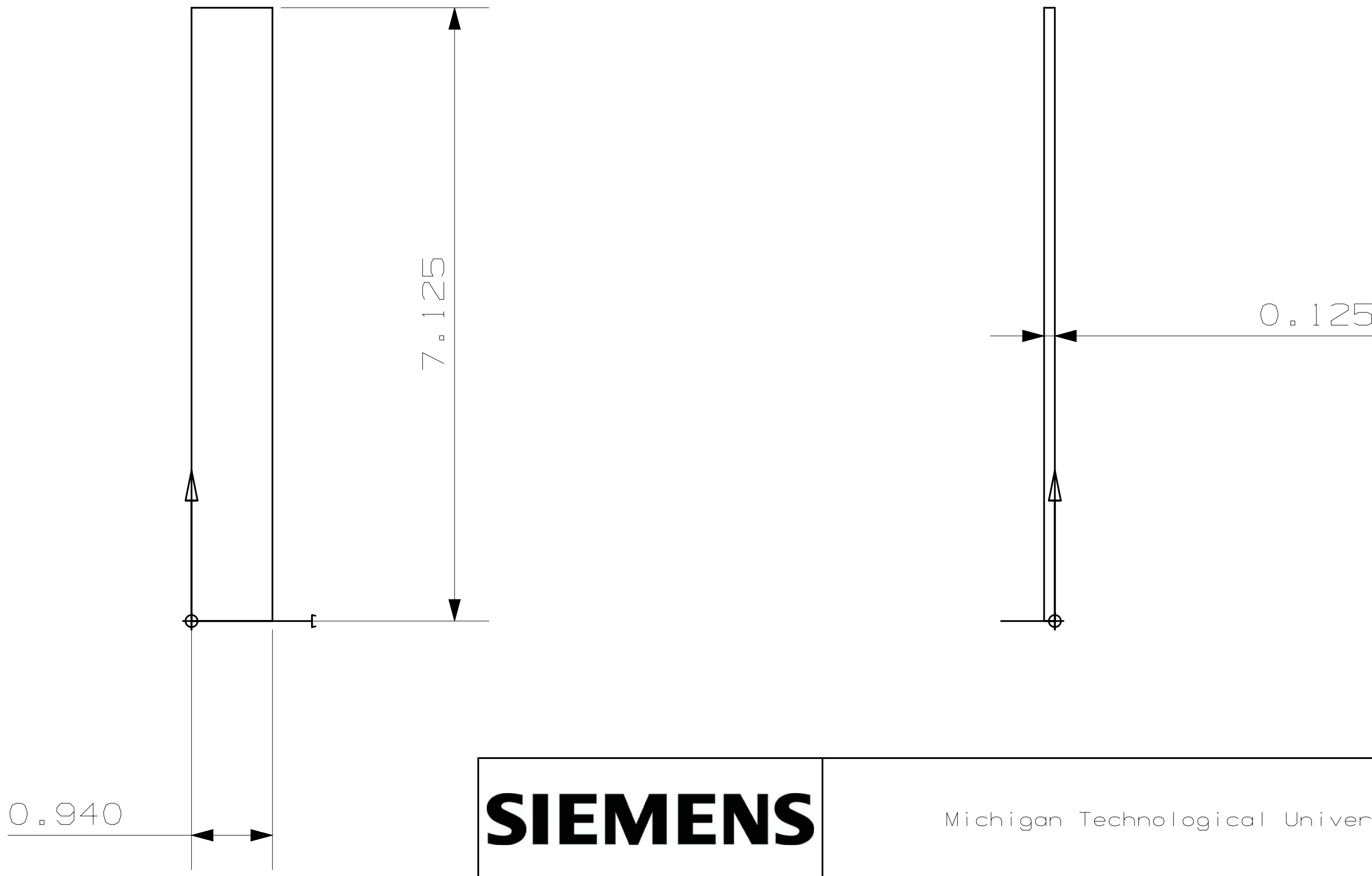


SIEMENS	Michigan Technological University	
FIRST ISSUED	TITLE Top Transmission Line Short Brace - Mass Loaded Vinyl	
DRAWN BY		
CHECKED BY		
APPROVED BY	SIZE A	DRG NO. 15 — REV 3
Shawbitz Kevin	SCALE 1:2	SHEET 1 OF 1

ALL DIMENSIONS IN INCHES

3D CAD MASTER PART NAME:





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3D CAD MASTER PART NAME:

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Shawbitz	Kevin

TITLE
Top Transmission Line Long Brace - Mass Loaded Vinyl

SIZE	DRG NO.	REV
A	16	3

SCALE 1:2		SHEET 1 OF 1