



Software : by Martin J. King  
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### Unit and Constant Definition

$$\text{cycle} := 2 \cdot \pi \cdot \text{rad}$$

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

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

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



### Part 1 : Thiele-Small Consistent Calculation

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

$$\text{Power} := 1 \cdot \text{watt}$$

$$(\text{Input Power}) \text{ Applied Voltage Reference} \rightarrow R_{\text{ref}} := 8 \cdot \Omega$$

Series Resistance

$$R_{\text{add}} := 0.8 \cdot \Omega$$

Front Driver Thiele / Small Parameters : Lowther DX2 Average Driver Properties

$$f_d := 43 \cdot \text{Hz}$$

$$V_{\text{ad}} := 25.7 \cdot \text{liter}$$

Adjustments

$$R_e := 6.5 \cdot \Omega$$

$$Q_{\text{ed}} := 0.415$$

$$R_e := R_e + R_{\text{add}}$$

$$L_{\text{vc}} := 0.6 \cdot \text{mH}$$

$$Q_{\text{md}} := 3.94$$

$$Q_{\text{ed}} := Q_{\text{ed}} \cdot R_e \cdot (R_e - R_{\text{ad}})$$

$$Bl := 12.8 \cdot \frac{\text{newton}}{\text{amp}}$$

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

$$S_d := 220 \cdot \text{cm}^2$$

$$Q_{\text{td}} = 0.417$$



Series Resistance

$$R_{\text{add}} := 0.8 \cdot \Omega$$

Rear Driver Thiele / Small Parameters : Lowther DX2 Average Driver Properties

$$f_d := 43 \cdot \text{Hz}$$

$$V_{\text{ad}} := 25.7 \cdot \text{liter}$$

Adjustments

$$R_e := 6.5 \cdot \Omega$$

$$Q_{\text{ed}} := 0.415$$

$$R_e := R_e + R_{\text{add}}$$

$$L_{\text{vc}} := 0.6 \cdot \text{mH}$$

$$Q_{\text{md}} := 3.94$$

$$Q_{\text{ed}} := Q_{\text{ed}} \cdot R_e \cdot (R_e - R_{\text{ad}})$$

$$Bl := 12.8 \cdot \frac{\text{newton}}{\text{amp}}$$

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

$$S_d := 220 \cdot \text{cm}^2$$

$$Q_{\text{td}} = 0.417$$



## Crossover Definition for Rear Driver

For Even Order Crossovers :      Type 1 = Linkwitz-Riley  
   Type 2 = Bessel  
   Type 3 = BEC  
   Type 4 = Butterworth

### Low Pass Filter

$f_{LP} := 2000 \cdot \text{Hz}$       (Filter Frequency)  
 $LP_{order} := 4$       (Filter Order : 0, 1, 2, 3, or 4)  
 $LP_{type} := 1$       (Filter Type : 1, 2, 3, or 4 for even order only,  
   for odd order this entry is ignored)

### Crossover Phase Connection

$LP_{phase} := 1$       (Phase : 1 = in phase, -1 = out of phase)

### Rear Driver Frequency Boost

$LP_{boost} := 0.0 \text{ dB}$



## Enclosure Geometry Definition : Model of Internal Air Volume

$L := 92 \cdot \text{cm}$       (Internal Height)  
 $z_{driver} := 20 \cdot \text{cm}$       (Driver Internal Distance From Top < Height)  
 $z_{port} := 88 \cdot \text{cm}$       (Port Internal Distance From Top < Height)  
 $S_0 := 36 \cdot \text{cm} \cdot 21 \cdot \text{cm}$       (Internal Area of the Top End,  $z = 0$ )  
 $S_L := 36 \cdot \text{cm} \cdot 21 \cdot \text{cm}$       (Internal Area of the Bottom End,  $z = L$ )  
 $Density := 0.45 \cdot \text{lb} \cdot \text{ft}^{-3}$       (Stuffing density :  $0 \text{ lb/ft}^3 < D < 1 \text{ lb/ft}^3$ )  
 $r_{port} := 4.7 \cdot \text{cm}$       (Inside Radius of the Port)  
 $L_{port} := 25 \cdot \text{cm}$       (Length of the Port)

## End of Abbreviated User Input

**Pre Formated Geometry and Stuffing Location Input (Only Edit Details Below to Change Defaults)**

**ML TL Definition**

(0 lb/ft<sup>3</sup> < D < 1 lb/ft<sup>3</sup>)

|              |                |                              |
|--------------|----------------|------------------------------|
| n_top :=4    | (n_top > 1)    | x_top :=z_driver             |
| n_open :=4   | (n_open > 1)   | x_open :=z_port - z_driver   |
| n_bottom :=4 | (n_bottom > 1) | x_bottom :=L - z_port        |
| n_port :=4   | (n_port > 1)   | x_port :=L_port + 0.6·r_port |

**Geometry Definition**

|  |                                       |
|--|---------------------------------------|
| TR := (S <sub>L</sub> - S <sub>0</sub> ) · L <sup>-1</sup> | TR = 0 m                              |
| S <sub>D</sub> := S <sub>0</sub> + TR · z_driver           | S <sub>D</sub> = 0.076 m <sup>2</sup> |
| S <sub>P</sub> := S <sub>0</sub> + TR · z_port             | S <sub>P</sub> = 0.076 m <sup>2</sup> |

**Top Section of Enclosure**

(Driver ---> Top of Enclosure)

| Section Length  | Initial Area   | Final Area   | Stuffing Density                      |
|---|--|--|---------------------------------------|
| L <sub>c<sub>0</sub></sub> := x_top · (n_top + 1) <sup>-1</sup> | S <sub>c<sub>0,0</sub></sub> := S <sub>D</sub>               | S <sub>c<sub>0,1</sub></sub> := S <sub>c<sub>0,0</sub></sub> - TR · L <sub>c<sub>0</sub></sub> | D <sub>c<sub>0</sub></sub> := Density |
| L <sub>c<sub>1</sub></sub> := x_top · (n_top + 1) <sup>-1</sup> | S <sub>c<sub>1,0</sub></sub> := S <sub>c<sub>0,1</sub></sub> | S <sub>c<sub>1,1</sub></sub> := S <sub>c<sub>1,0</sub></sub> - TR · L <sub>c<sub>1</sub></sub> | D <sub>c<sub>1</sub></sub> := Density |
| L <sub>c<sub>2</sub></sub> := x_top · (n_top + 1) <sup>-1</sup> | S <sub>c<sub>2,0</sub></sub> := S <sub>c<sub>1,1</sub></sub> | S <sub>c<sub>2,1</sub></sub> := S <sub>c<sub>2,0</sub></sub> - TR · L <sub>c<sub>2</sub></sub> | D <sub>c<sub>2</sub></sub> := Density |
| L <sub>c<sub>3</sub></sub> := x_top · (n_top + 1) <sup>-1</sup> | S <sub>c<sub>3,0</sub></sub> := S <sub>c<sub>2,1</sub></sub> | S <sub>c<sub>3,1</sub></sub> := S <sub>c<sub>3,0</sub></sub> - TR · L <sub>c<sub>3</sub></sub> | D <sub>c<sub>3</sub></sub> := Density |
| L <sub>c<sub>4</sub></sub> := x_top · (n_top + 1) <sup>-1</sup> | S <sub>c<sub>4,0</sub></sub> := S <sub>c<sub>3,1</sub></sub> | S <sub>c<sub>4,1</sub></sub> := S <sub>0</sub>   | D <sub>c<sub>4</sub></sub> := Density |

**Open Section of Enclosure**

(Driver ---> Port Position)

| Section Length  | Initial Area   | Final Area   | Stuffing Density                                      |
|---|--|--|---|
| L <sub>o<sub>0</sub></sub> := x_open · (n_open + 1) <sup>-1</sup> | S <sub>o<sub>0,0</sub></sub> := S <sub>D</sub>               | S <sub>o<sub>0,1</sub></sub> := S <sub>o<sub>0,0</sub></sub> + TR · L <sub>o<sub>0</sub></sub> | D <sub>o<sub>0</sub></sub> := Density                 |
| L <sub>o<sub>1</sub></sub> := x_open · (n_open + 1) <sup>-1</sup> | S <sub>o<sub>1,0</sub></sub> := S <sub>o<sub>0,1</sub></sub> | S <sub>o<sub>1,1</sub></sub> := S <sub>o<sub>1,0</sub></sub> + TR · L <sub>o<sub>1</sub></sub> | D <sub>o<sub>1</sub></sub> := Density                 |
| L <sub>o<sub>2</sub></sub> := x_open · (n_open + 1) <sup>-1</sup> | S <sub>o<sub>2,0</sub></sub> := S <sub>o<sub>1,1</sub></sub> | S <sub>o<sub>2,1</sub></sub> := S <sub>o<sub>2,0</sub></sub> + TR · L <sub>o<sub>2</sub></sub> | D <sub>o<sub>2</sub></sub> := Density                 |
| L <sub>o<sub>3</sub></sub> := x_open · (n_open + 1) <sup>-1</sup> | S <sub>o<sub>3,0</sub></sub> := S <sub>o<sub>2,1</sub></sub> | S <sub>o<sub>3,1</sub></sub> := S <sub>o<sub>3,0</sub></sub> + TR · L <sub>o<sub>3</sub></sub> | D <sub>o<sub>3</sub></sub> := 0.0·lb·ft <sup>-3</sup> |
| L <sub>o<sub>4</sub></sub> := x_open · (n_open + 1) <sup>-1</sup> | S <sub>o<sub>4,0</sub></sub> := S <sub>o<sub>3,1</sub></sub> | S <sub>o<sub>4,1</sub></sub> := S <sub>P</sub>   | D <sub>o<sub>4</sub></sub> := 0.0·lb·ft <sup>-3</sup> |

**Bottom Section of Enclosure**

(Port Position ---> Bottom of Enclosure)

| Section Length  | Initial Area                 | Final Area                                      | Stuffing Density                                      |
|---|------------------------------|---|---|
| $L_{b_0} := x_{\text{bottom}} \cdot (n_{\text{bottom}} + 1)^{-1}$ | $S_{b_{0,0}} := S_P$         | $S_{b_{0,1}} := S_{b_{0,0}} + TR \cdot L_{b_0}$ | $D_{b_0} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |
| $L_{b_1} := x_{\text{bottom}} \cdot (n_{\text{bottom}} + 1)^{-1}$ | $S_{b_{1,0}} := S_{b_{0,1}}$ | $S_{b_{1,1}} := S_{b_{1,0}} + TR \cdot L_{b_1}$ | $D_{b_1} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |
| $L_{b_2} := x_{\text{bottom}} \cdot (n_{\text{bottom}} + 1)^{-1}$ | $S_{b_{2,0}} := S_{b_{1,1}}$ | $S_{b_{2,1}} := S_{b_{2,0}} + TR \cdot L_{b_2}$ | $D_{b_2} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |
| $L_{b_3} := x_{\text{bottom}} \cdot (n_{\text{bottom}} + 1)^{-1}$ | $S_{b_{3,0}} := S_{b_{2,1}}$ | $S_{b_{3,1}} := S_{b_{3,0}} + TR \cdot L_{b_3}$ | $D_{b_3} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |
| $L_{b_4} := x_{\text{bottom}} \cdot (n_{\text{bottom}} + 1)^{-1}$ | $S_{b_{4,0}} := S_{b_{3,1}}$ | $S_{b_{4,1}} := S_L$                            | $D_{b_4} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |

**Port Section of Enclosure**

(Port Inside ---> Port Outside)

| Section Length  | Initial Area                                 | Final Area                                   | Stuffing Density                                      |
|---|--|--|---|
| $L_{p_0} := x_{\text{port}} \cdot (n_{\text{port}} + 1)^{-1}$ | $S_{p_{0,0}} := \pi \cdot r_{\text{port}}^2$ | $S_{p_{0,1}} := \pi \cdot r_{\text{port}}^2$ | $D_{p_0} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |
| $L_{p_1} := x_{\text{port}} \cdot (n_{\text{port}} + 1)^{-1}$ | $S_{p_{1,0}} := S_{p_{0,1}}$                 | $S_{p_{1,1}} := \pi \cdot r_{\text{port}}^2$ | $D_{p_1} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |
| $L_{p_2} := x_{\text{port}} \cdot (n_{\text{port}} + 1)^{-1}$ | $S_{p_{2,0}} := S_{p_{1,1}}$                 | $S_{p_{2,1}} := \pi \cdot r_{\text{port}}^2$ | $D_{p_2} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |
| $L_{p_3} := x_{\text{port}} \cdot (n_{\text{port}} + 1)^{-1}$ | $S_{p_{3,0}} := S_{p_{2,1}}$                 | $S_{p_{3,1}} := \pi \cdot r_{\text{port}}^2$ | $D_{p_3} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |
| $L_{p_4} := x_{\text{port}} \cdot (n_{\text{port}} + 1)^{-1}$ | $S_{p_{4,0}} := S_{p_{3,1}}$                 | $S_{p_{4,1}} := \pi \cdot r_{\text{port}}^2$ | $D_{p_4} := 0.0 \cdot \text{lb} \cdot \text{ft}^{-2}$ |

**Total Amount of Stuffing**

$$\left[ \sum_{r=0}^{n_{\text{top}}} \left[ \frac{(S_{c_{r,0}} + S_{c_{r,1}})}{2} \cdot L_{c_r} \cdot D_{c_r} \right] \right] + \left[ \sum_{r=0}^{n_{\text{open}}} \left[ \frac{(S_{o_{r,0}} + S_{o_{r,1}})}{2} \cdot L_{o_r} \cdot D_{o_r} \right] \right] \dots = 0.73 \cdot \text{lb}$$

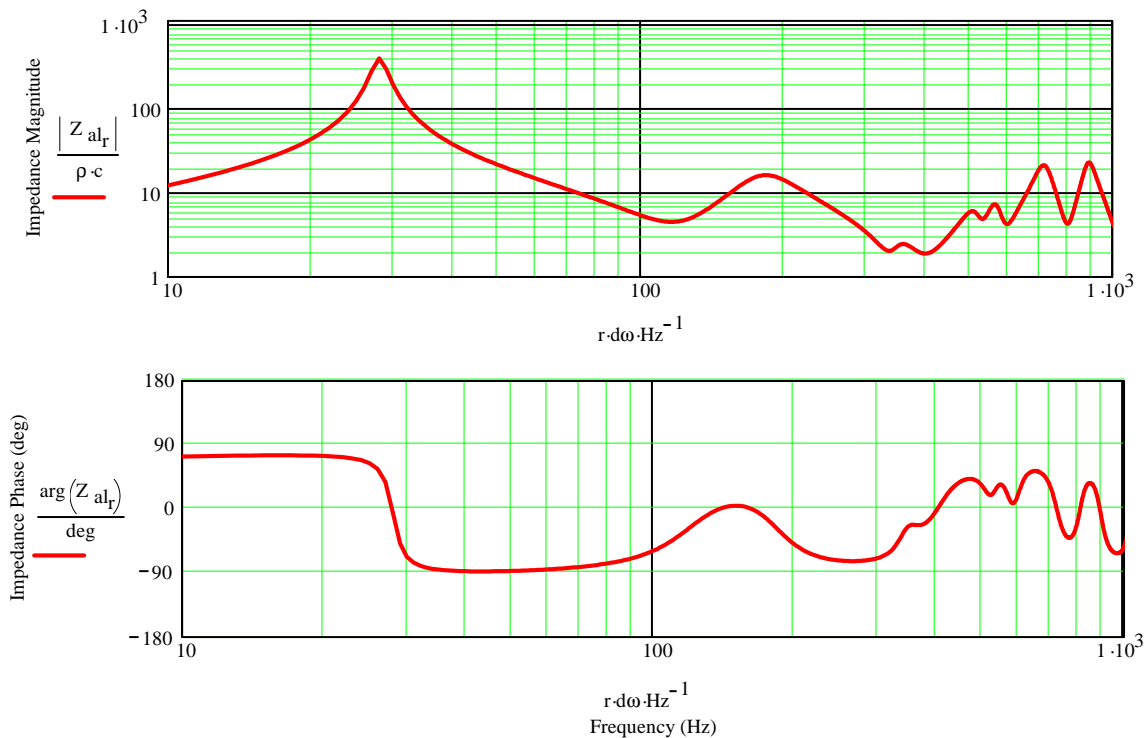
$$+ \left[ \sum_{r=0}^{n_{\text{bottom}}} \left[ \frac{(S_{b_{r,0}} + S_{b_{r,1}})}{2} \cdot L_{b_r} \cdot D_{b_r} \right] \right] + \left[ \sum_{r=0}^{n_{\text{port}}} \left[ \frac{(S_{p_{r,0}} + S_{p_{r,1}})}{2} \cdot L_{p_r} \cdot D_{p_r} \right] \right]$$

**End of Pre Formatted Default Input**

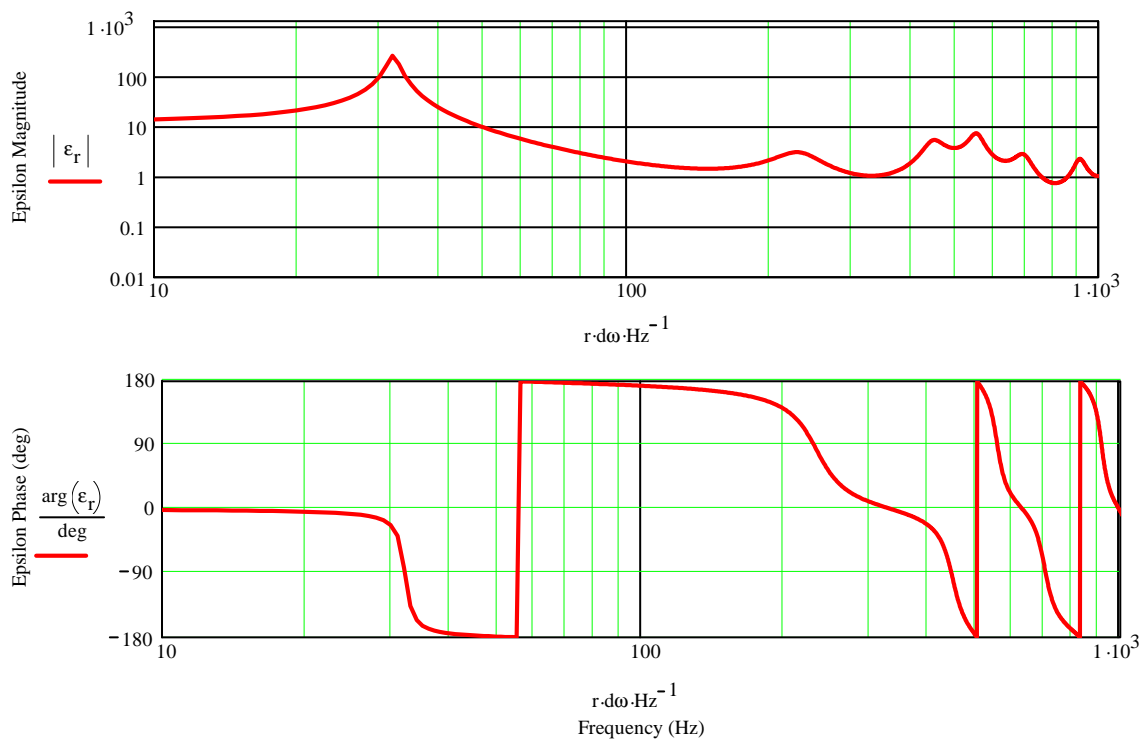
**End of Part 1 Input**



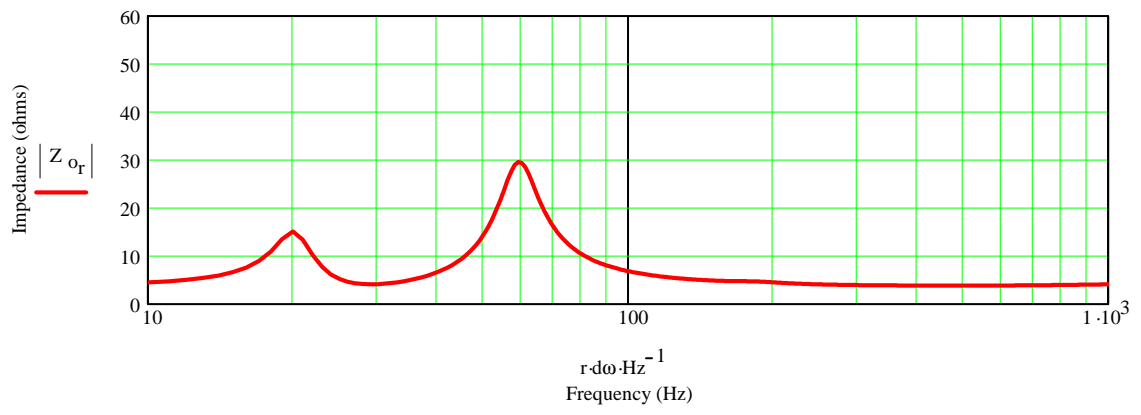
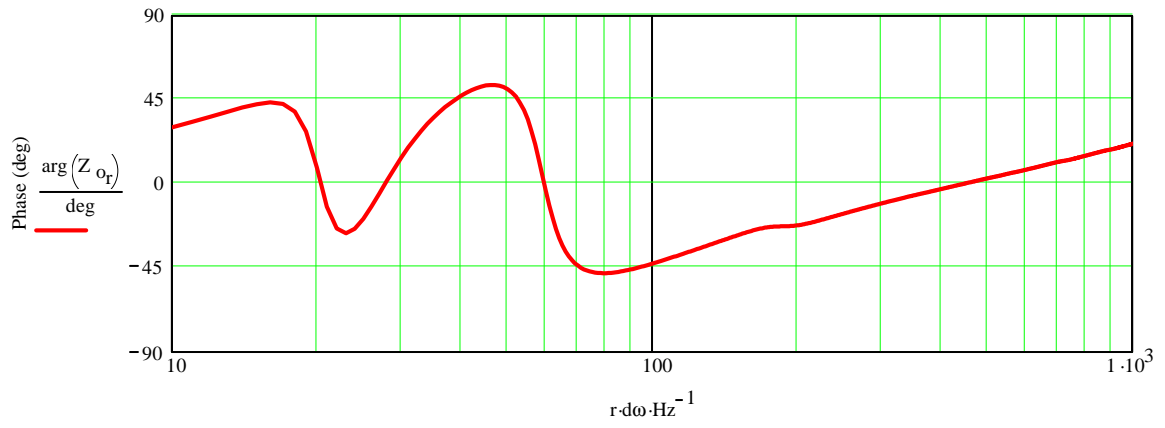
### Resulting Acoustic Impedance for the Enclosure



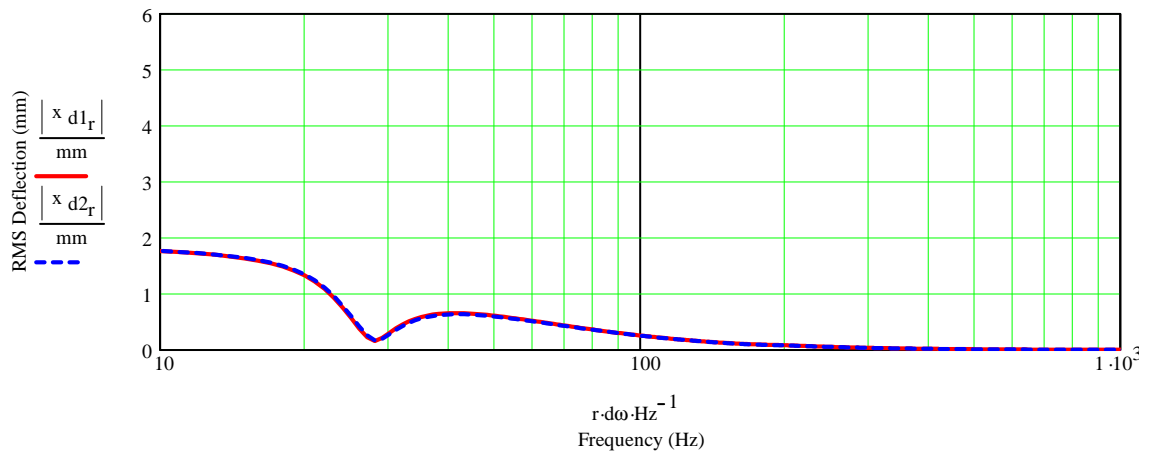
### Velocity at the Terminus of the ML TL for a 1 m/sec Excitation at the Driver Position



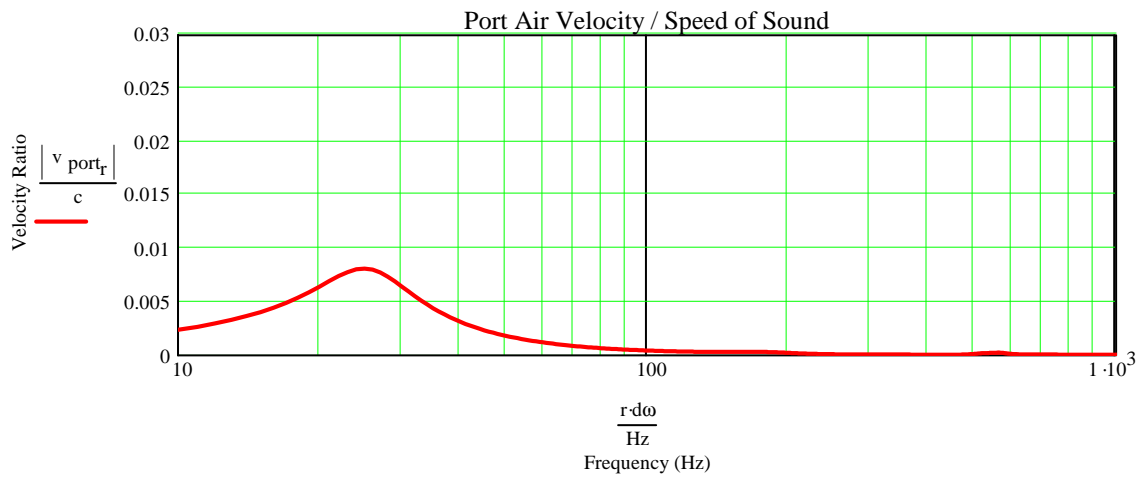
# Bipole ML TL System Impedance - w/o Filter on Rear Driver



**Woofer RMS Displacement** (front driver - solid red curve, rear driver - blue dashed curve)



**Port Air Velocity** (should be  $< 10 \text{ m/sec} / 344 \text{ m/sec} = 0.03$ )



## Part 2 : Detailed SPL Response Calculation

Calculation Includes :

Position of Driver and Port on the Baffle.

Baffle Step Defraction for the Driver and the Port.

Floor and Rear Wall Reflection for the Driver and the Port.

### Geometry

Coordinate System :

Origin is the lower left corner of the front baffle

x = horizontal direction

y = vertical direction

The variables num\_r, n\_drv, and n\_mth control the number of simple sources used in the calculations. Increasing each will improve accuracy at the expense of longer calculation times. Increase each variable until final plotted SPL stops changing at which point the solution has converged.

### Enclosure Geometry Input

|                                      |   |
|--------------------------------------|---|
| $X_0 := 60 \cdot \text{cm}$          | (Front Baffle Distance from Rear Wall > Depth of Enclosure) |
| $Y_0 := 75 \cdot \text{cm}$          | (Front Baffle Distance from Side Wall)                      |
| $\theta_0 := 125 \cdot \text{deg}$   | (Rotation Towards Room Center)                              |
| $Z_0 := 8 \cdot \text{ft}$           | (Floor to Ceiling Distance)                                 |
| $\text{stand} := 0.1 \cdot \text{m}$ | (Height from Floor to Bottom Edge of Front Baffle)          |
| $\text{num}_r := 10$                 | (Number of Points per Unit Length of Baffle Edge)           |

### Corner Coordinates

| Y coordinate                         | Z coordinate                    |                       |
|--------------------------------------|---------------------------------|-----------------------|
| $y_{o_0} := 40 \cdot \text{cm}$      |                                 | (Bottom Right Corner) |
| $y_{o_1} := 40 \cdot \text{cm}$      | $z_{o_1} := 96 \cdot \text{cm}$ | (Top Right Corner)    |
| $y_{o_2} := 0 \cdot \text{in}$       | $z_{o_2} := 96 \cdot \text{cm}$ | (Top Left Corner)     |
| $y_{o_3} := 0 \cdot \text{in}$       |                                 | (Bottom Left Corner)  |
| $\text{depth} := 25 \cdot \text{cm}$ |                                 | (Depth of Enclosure)  |

### Driver Geometry Input

$y_{dc} := 20 \cdot \text{cm}$  (Driver Center y Coordinate)  
 $z_{dc} := 78 \cdot \text{cm}$  (Driver Center z Coordinate)  
 $n_{dvr} := 8$  (Number of Points Across Diameter)

### Port Geometry Input

$y_{mc} := 20 \cdot \text{cm}$  (Port Center y Coordinate)  
 $z_{mc} := 5 \cdot \text{cm}$  (Port Center z Coordinate)  
 $n_{mth} := 7$  (Number of Points Across Diameter)  
 $\text{Locate} := 1$  (0 = Front Baffle Port, 1 = Rear Baffle Port)

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

$n_{listen} = 0$  (Listening Position Relative to Speaker)  
 $\text{radius} := 1 \cdot \text{m}$  (Calculation Radius, Effective Radius is Greater if  $y_p$  is Changed from Default)  
 $\theta := -80 \cdot \text{deg}$  (0 deg is along the Driver's Axis,  $-80 \text{ deg} < \theta < 80 \text{ deg}$ )  
 $z_p := z_{dc}$  (Default Height is Equal to Driver Height)

$n_{listen} = 1$  (Listening Position Relative to the Room Corner)  
 $X_p := 2.5 \text{ m}$   
 $Y_p := 2 \cdot \text{m}$   
 $Z_p := z_{dc} + \text{stand}$  (Default Height is Equal to Driver Height)  
 $n_{listen} := 0$  (Method Selection)

### Floor Condition

$\text{Reflect} := 1$  (0 = hardwood or concrete, 1 = carpeted)

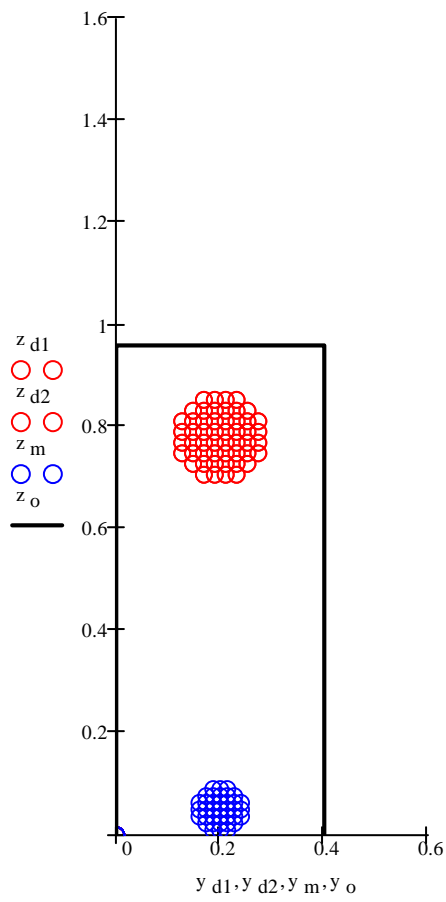
### Reflective Surface Selections (if 1 reflective surface is included, if 0 reflective surface is removed)

$\text{Inc\_floor} := 1$  (Floor,  $Z = 0$ )  
 $\text{Inc\_rear} := 1$  (Rear Wall,  $X = 0$ )  
 $\text{Inc\_side} := 1$  (Left Side Wall,  $Y = 0$ )  
 $\text{Inc\_ceiling} := 0$  (Ceiling)

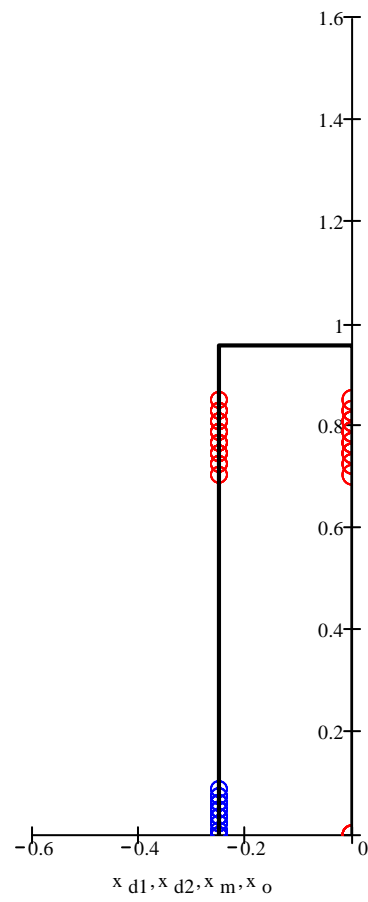


## Circular Drivers and Circular Mouth Simple Source Pattern with Baffle Edge Outline

Front View



Side View



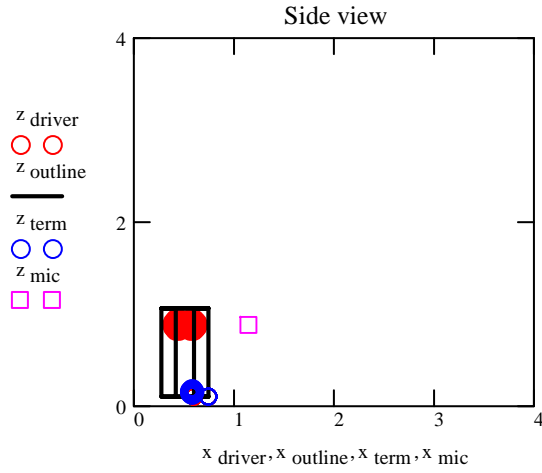
Red sources represent the driver.  
Blue sources represent the port.  
Black outline represents the baffle edge.  
Origin is at the bottom front left corner of the enclosure.



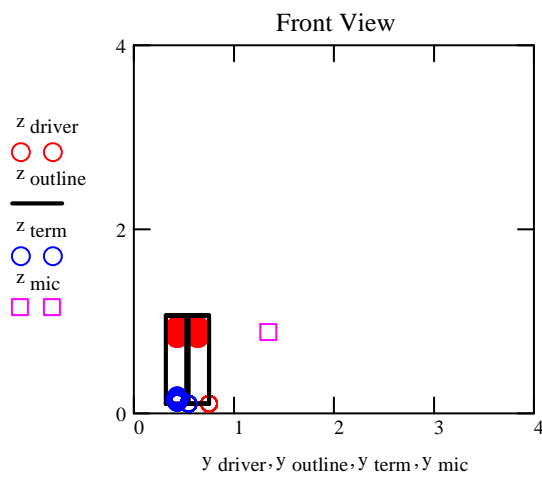
### Three Dimensional View

Axis Length (m) `axis := 4` <---- Change value of "axis" to rescale plots

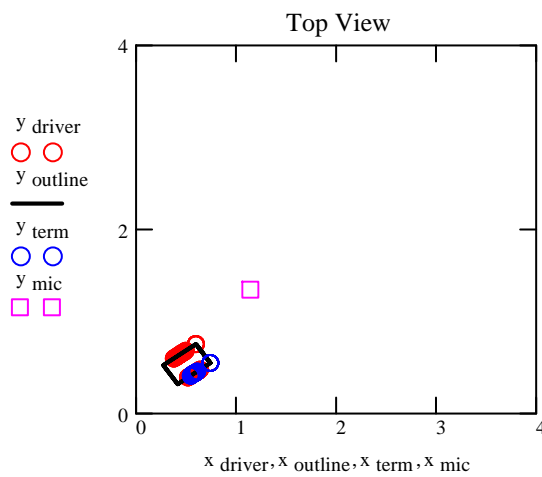
Room Corner is the Origin



Side View - looking out from side wall



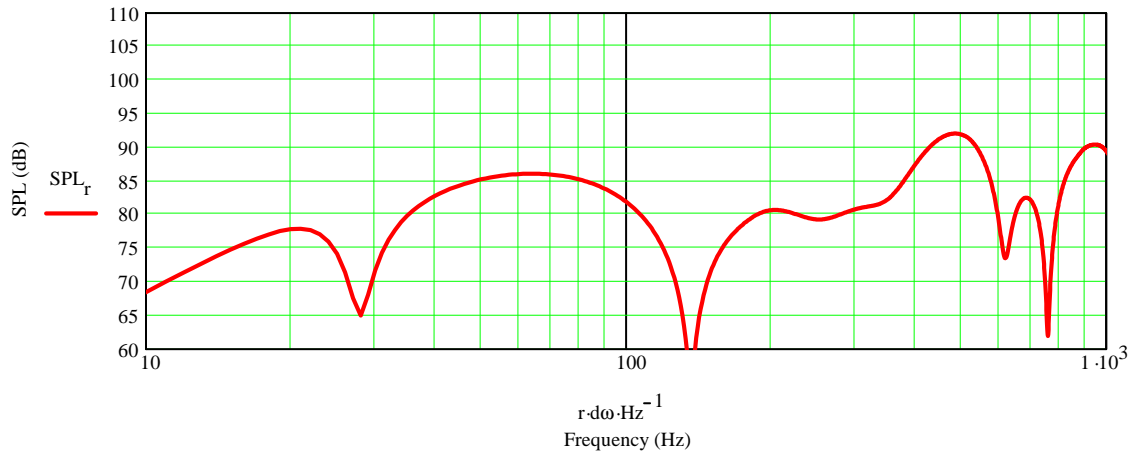
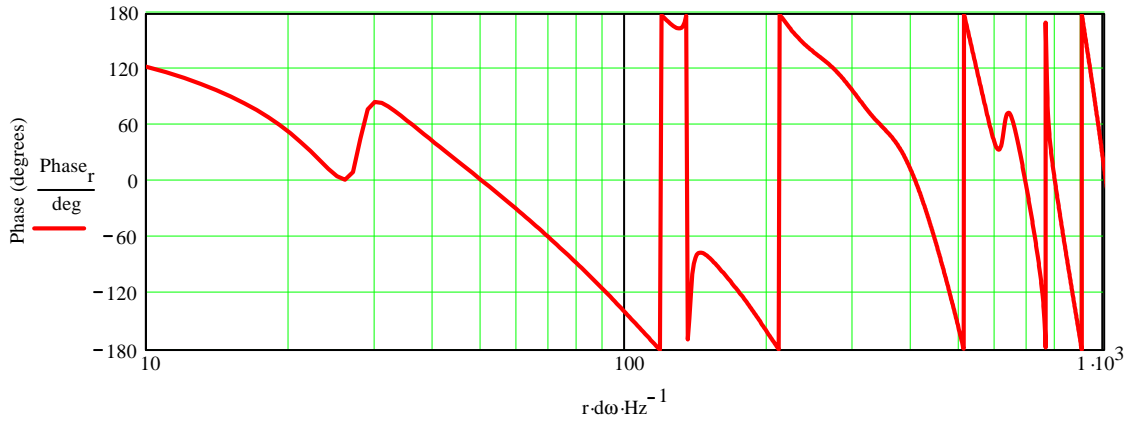
Front View - looking towards rear wall



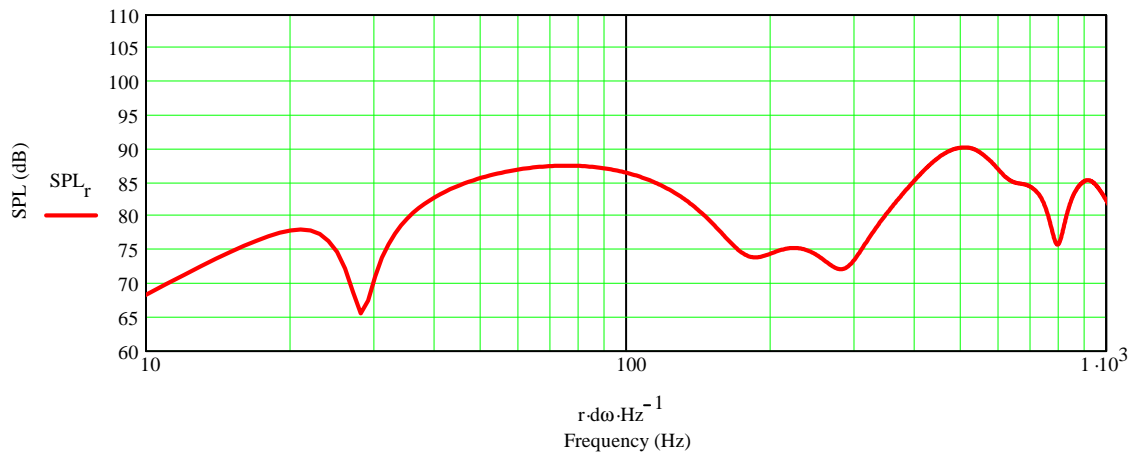
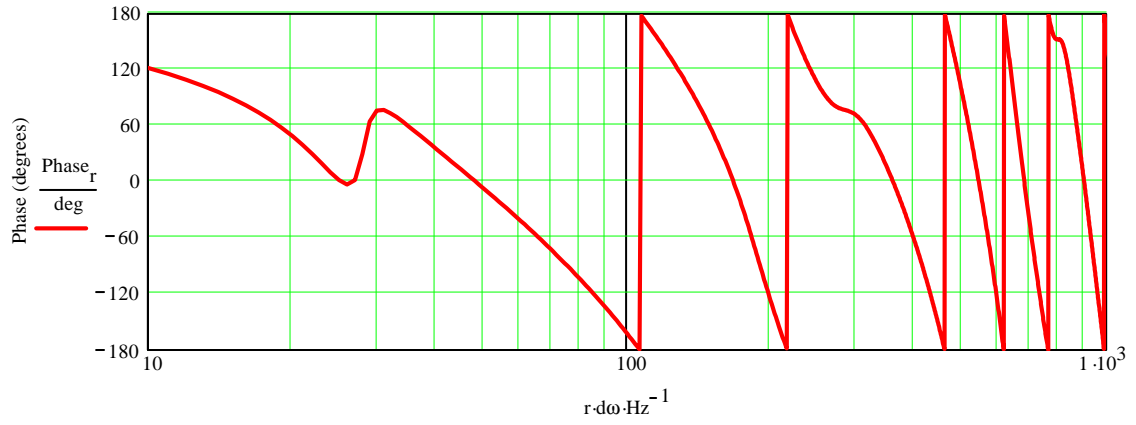
Top View - looking down from ceiling



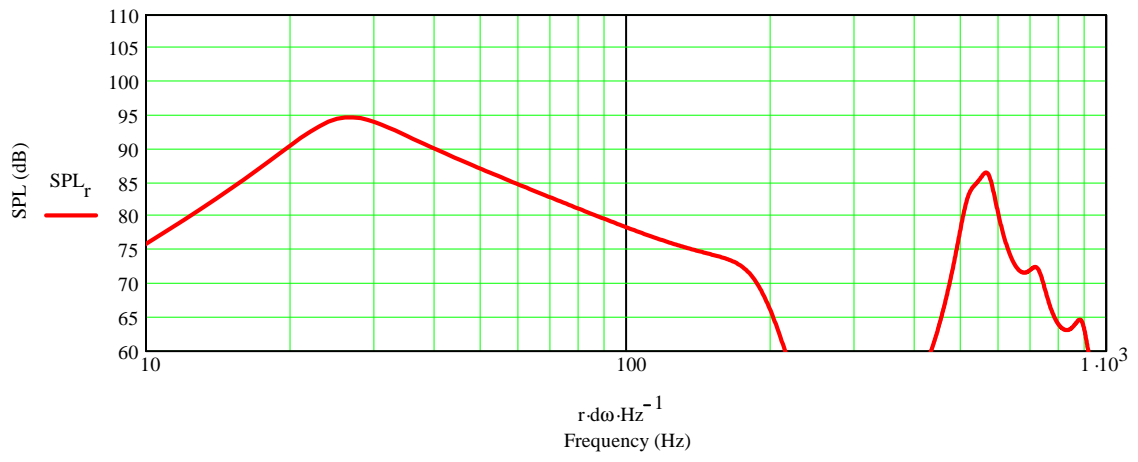
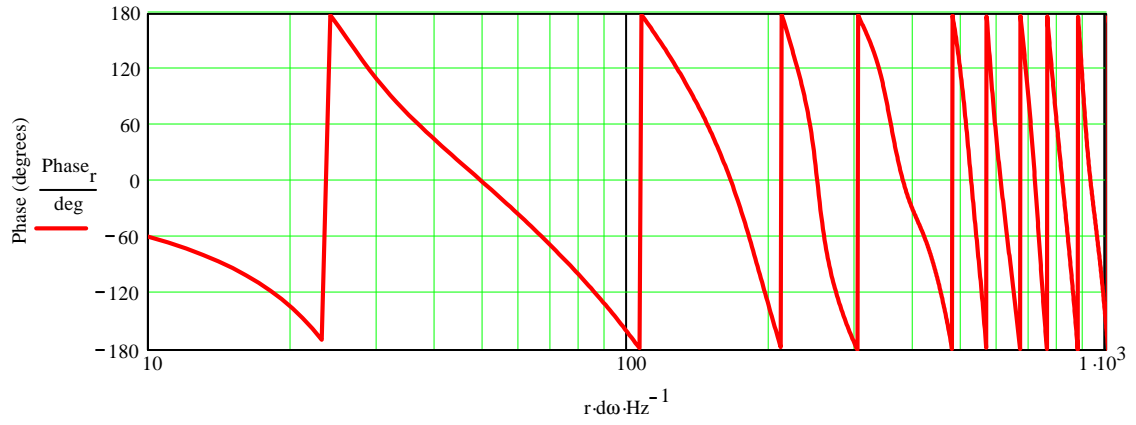
### Plotted Baffle Step and Reflection SPL Response for the Front Circular Driver Source



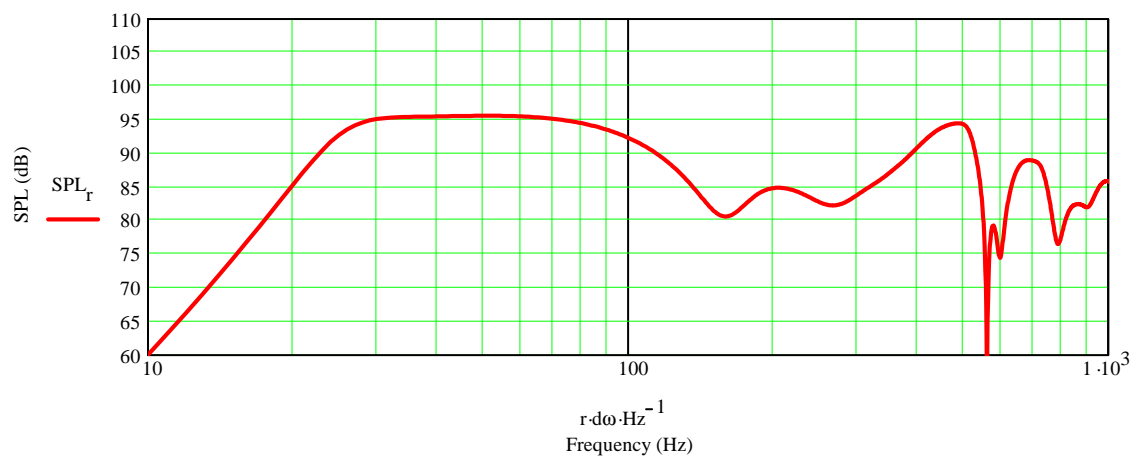
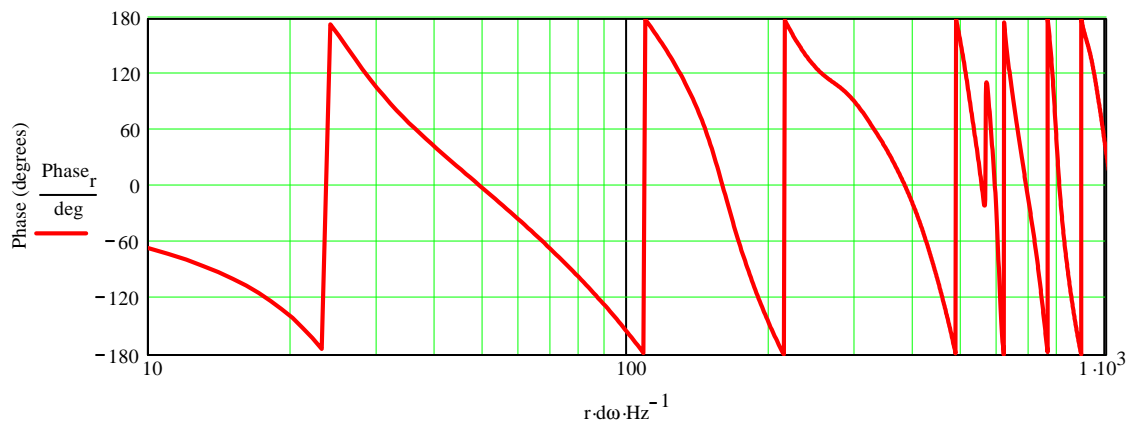
### Plotted Baffle Step and Reflection SPL Response for the Rear Circular Driver Source



### Plotted Baffle Step and Reflection SPL Response for the Circular Port Source



### Plotted SPL Response for the System



### Part 3 : Baffle Step Correction Circuit Design - Applied to Front Driver

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

$f_{center} := 640 \cdot \text{Hz}$  <--- Input Center Frequency

$\text{dB} := 2$  <--- Input dB of Attenuation

Calculated Component Values

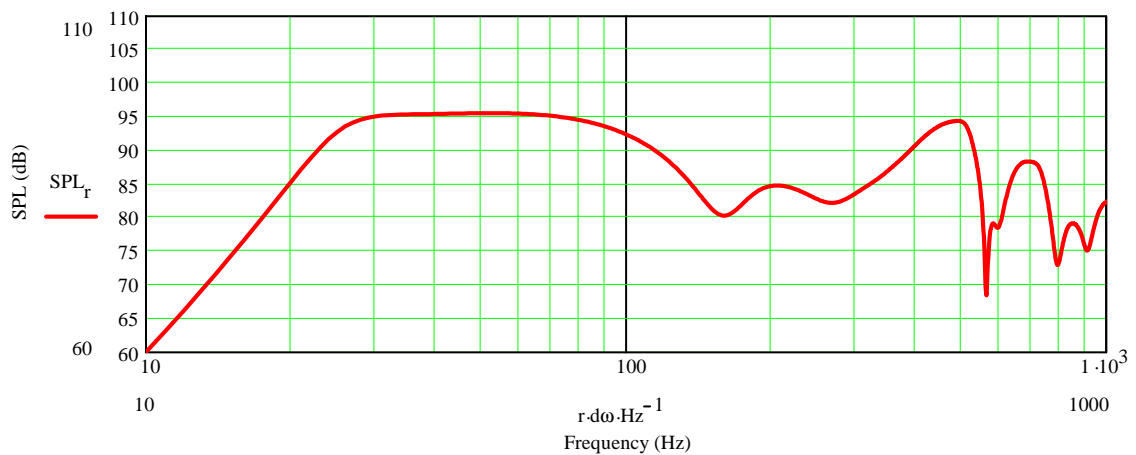
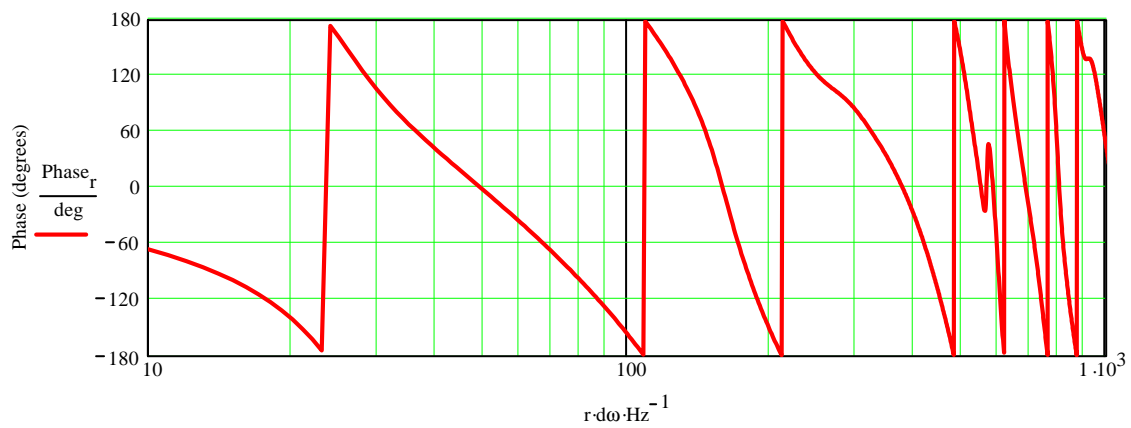
User Assigned Component Values  
Based on Calculated Values at Left

$R_e \cdot \left( 10^{\frac{\text{dB}}{20}} - 1 \right) = 1.89 \ \Omega$       Parallel Resistor      Input Value --->       $R_{parallel} := 3 \cdot \Omega$

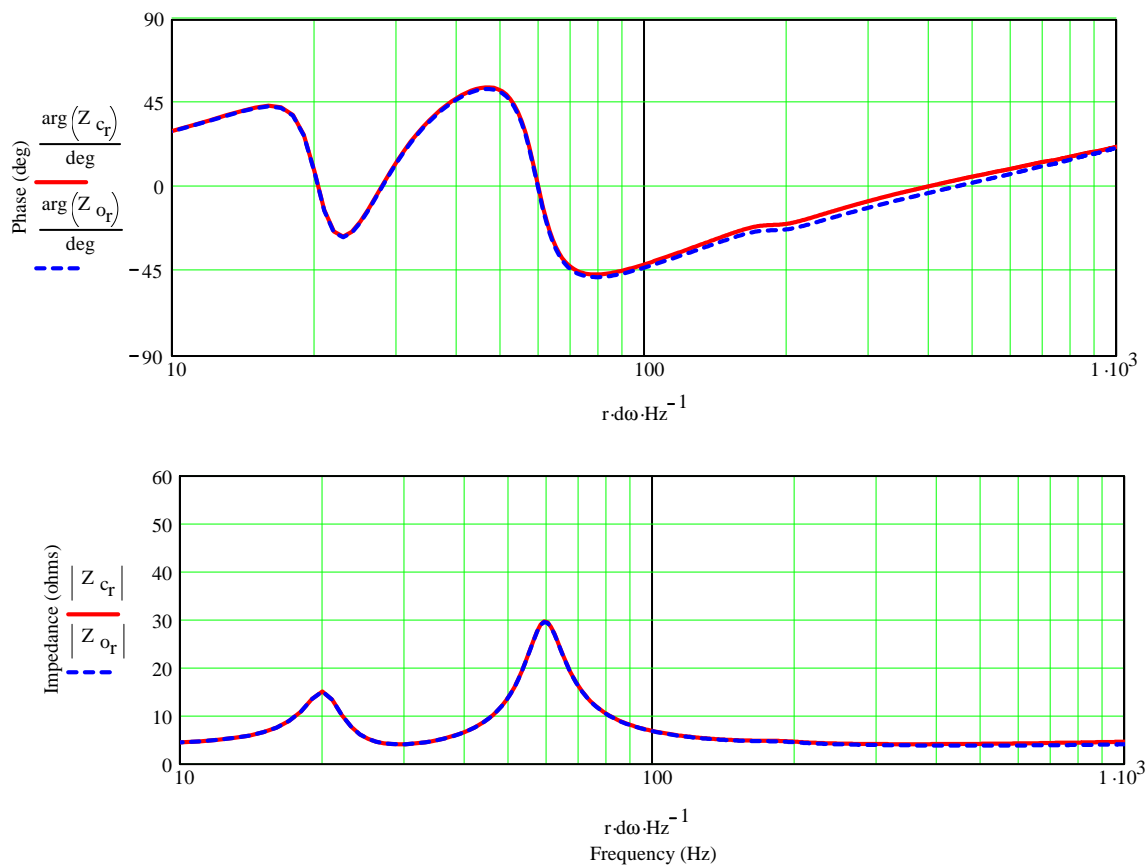
$\frac{R_{parallel}}{f_{center}} = 0.746 \cdot \text{mH}$       BSC Inductor      Input Value --->       $L_{BSC} := 0.75 \cdot \text{mH}$



#### Plotted Corrected SPL Response for the System



**Ported Box Corrected and UnCorrected System Impedance**  
 (corrected - solid red curve, uncorrected - blue dashed curve)



**System Time Response for an Impulse Input**

