Bipole Drivers in a ML TL - Acoustic and Electrical Response

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Unit and Constant Definition

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

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

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

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

Part 1 : Thiele-Small Consistent Calculation

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

$Power := 1\cdot watt$ (Input Power) Applied Voltage Reference ---> $R_{ref} := 8\cdot\Omega$

Series Resistance

$R_{add} := 4.0\cdot\Omega$

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

$f_d := 55.6\cdot Hz$

$V_{ad} := 45.1\cdot liter$

$R_e := 7.1\cdot\Omega$

$Q_{ed} := 0.33$

$L_{vc} := 0\cdot mH$

$Q_{md} := 4.02$

$Bl := 9.08\cdot\frac{newton}{amp}$

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

$S_d := 206\cdot cm^2$

$Q_{td} = 0.457$

Adjustments

$R_e := R_e + R_{add}$

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

Series Resistance

$R_{add} := 4.0\cdot\Omega$

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

$f_d := 55.6\cdot Hz$

$V_{ad} := 45.1\cdot liter$

$R_e := 7.1\cdot\Omega$

$Q_{ed} := 0.33$

$L_{vc} := 0\cdot mH$

$Q_{md} := 4.02$

$Bl := 9.08\cdot\frac{newton}{amp}$

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

$S_d := 206\cdot cm^2$

$Q_{td} = 0.457$

Adjustments

$R_e := R_e + R_{add}$

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

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

$f_{LP} := 200 \cdot Hz$ (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

$LP_{boost} := 0.0$ dB

Enclosure Geometry Definition : Model of Internal Air Volume

$L := 42 \cdot in$ (Internal Height)

$z_{driver} := 6 \cdot in$ (Driver Internal Distance From Top < Height)

$z_{port} := 38 \cdot in$ (Port Internal Distance From Top < Height)

$S_0 := 2 \cdot 9.5 \cdot in \cdot 11 \cdot in$ (Internal Area of the Top End, z = 0)

$S_L := 2 \cdot 9.5 \cdot in \cdot 11 \cdot in$ (Internal Area of the Bottom End, z = L)

$Density := 0.25 \cdot lb \cdot ft^{-3}$ (Stuffing density : 0 lb/ft^3 < D < 1 lb/ft^3)

$r_{port} := \sqrt{2} \cdot 2.0 \cdot in$ (Inside Radius of the Port)

$L_{port} := 2.0 \cdot in$ (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 ($0\ \mathrm{lb/ft^3} < D < 1\ \mathrm{lb/ft^3}$)

$n\_top := 4$	(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)	$x_{port} := L_{port} + 0.6 \cdot r_{port}$

Geometry Definition

$TR := \left(S_L - S_0\right) \cdot L^{-1}$	$TR = 0\,m$
$S_D := S_0 + TR \cdot z_{driver}$	$S_D = 0.135\,m^2$
$S_P := S_0 + TR \cdot z_{port}$	$S_P = 0.135\,m^2$

Top Section of Enclosure (Driver ---> Top of Enclosure)

Section Length	Initial Area	Final Area	Stuffing Density
$L_{c_0} := x_{top} \cdot (n\_top + 1)^{-1}$	$S_{c_{0,0}} := S_D$	$S_{c_{0,1}} := S_{c_{0,0}} - TR \cdot L_{c_0}$	$D_{c_0} := Density$
$L_{c_1} := x_{top} \cdot (n\_top + 1)^{-1}$	$S_{c_{1,0}} := S_{c_{0,1}}$	$S_{c_{1,1}} := S_{c_{1,0}} - TR \cdot L_{c_1}$	$D_{c_1} := Density$
$L_{c_2} := x_{top} \cdot (n\_top + 1)^{-1}$	$S_{c_{2,0}} := S_{c_{1,1}}$	$S_{c_{2,1}} := S_{c_{2,0}} - TR \cdot L_{c_2}$	$D_{c_2} := Density$
$L_{c_3} := x_{top} \cdot (n\_top + 1)^{-1}$	$S_{c_{3,0}} := S_{c_{2,1}}$	$S_{c_{3,1}} := S_{c_{3,0}} - TR \cdot L_{c_3}$	$D_{c_3} := Density$
$L_{c_4} := x_{top} \cdot (n\_top + 1)^{-1}$	$S_{c_{4,0}} := S_{c_{3,1}}$	$S_{c_{4,1}} := S_0$	$D_{c_4} := Density$

Open Section of Enclosure (Driver ---> Port Position)

Section Length	Initial Area	Final Area	Stuffing Density
$L_{o_0} := x_{open} \cdot (n\_open + 1)^{-1}$	$S_{o_{0,0}} := S_D$	$S_{o_{0,1}} := S_{o_{0,0}} + TR \cdot L_{o_0}$	$D_{o_0} := Density$
$L_{o_1} := x_{open} \cdot (n\_open + 1)^{-1}$	$S_{o_{1,0}} := S_{o_{0,1}}$	$S_{o_{1,1}} := S_{o_{1,0}} + TR \cdot L_{o_1}$	$D_{o_1} := Density$
$L_{o_2} := x_{open} \cdot (n\_open + 1)^{-1}$	$S_{o_{2,0}} := S_{o_{1,1}}$	$S_{o_{2,1}} := S_{o_{2,0}} + TR \cdot L_{o_2}$	$D_{o_2} := Density$
$L_{o_3} := x_{open} \cdot (n\_open + 1)^{-1}$	$S_{o_{3,0}} := S_{o_{2,1}}$	$S_{o_{3,1}} := S_{o_{3,0}} + TR \cdot L_{o_3}$	$D_{o_3} := 0.0 \cdot lb \cdot ft^{-3}$
$L_{o_4} := x_{open} \cdot (n\_open + 1)^{-1}$	$S_{o_{4,0}} := S_{o_{3,1}}$	$S_{o_{4,1}} := S_P$	$D_{o_4} := 0.0 \cdot lb \cdot ft^{-3}$

Bottom Section of Enclosure (Port Position ---> Bottom of Enclosure)

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

Port Section of Enclosure (Port Inside ---> Port Outside)

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

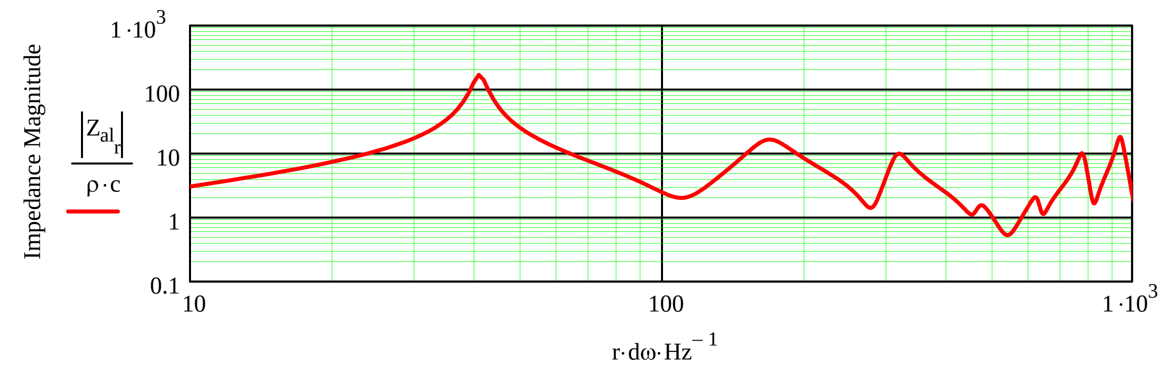
Total Amount of Stuffing

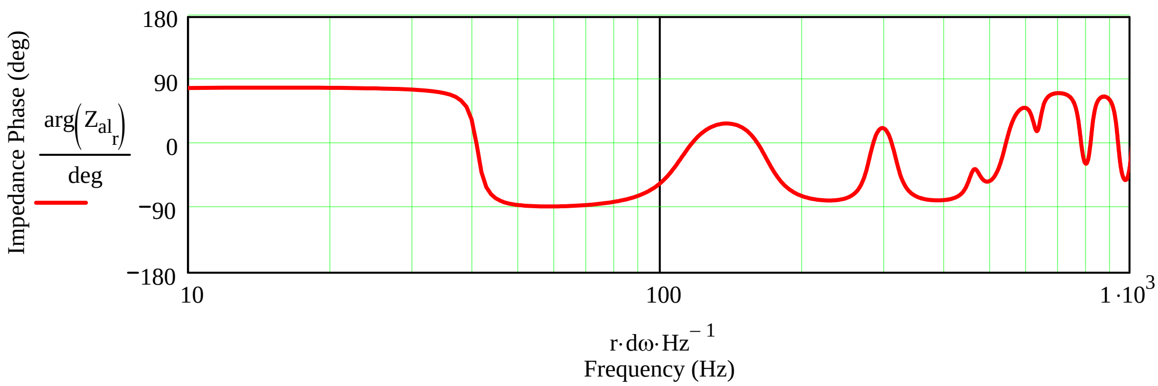
$$\sum_{r=0}^{n\_top} \left[\frac{\left(S_{c_{r,0}} + S_{c_{r,1}}\right)}{2} \cdot L_{c_r} \cdot D_{c_r}\right] + \sum_{r=0}^{n\_open} \left[\frac{\left(S_{o_{r,0}} + S_{o_{r,1}}\right)}{2} \cdot L_{o_r} \cdot D_{o_r}\right] \ldots + \sum_{r=0}^{n\_bottom} \left[\frac{\left(S_{b_{r,0}} + S_{b_{r,1}}\right)}{2} \cdot L_{b_r} \cdot D_{b_r}\right] + \sum_{r=0}^{n\_port} \left[\frac{\left(S_{p_{r,0}} + S_{p_{r,1}}\right)}{2} \cdot L_{p_r} \cdot D_{p_r}\right] = 0.762\ lb$$

End of Pre Formatted Default Input

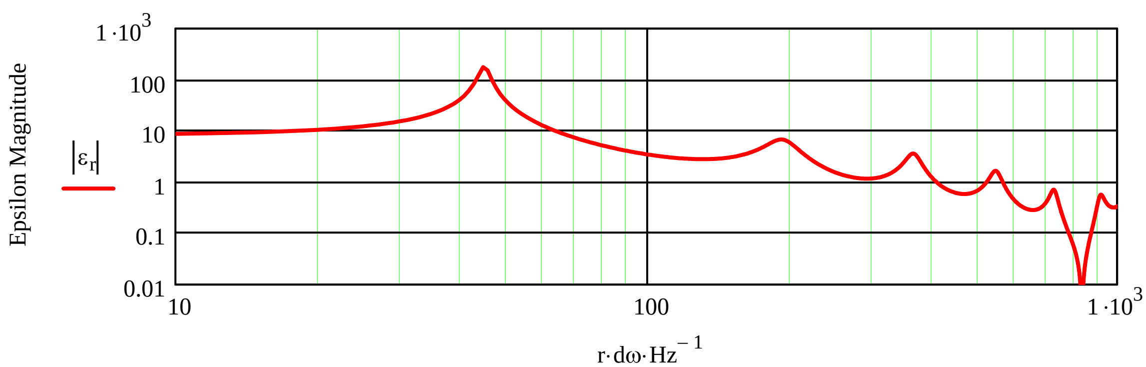
End of Part 1 Input

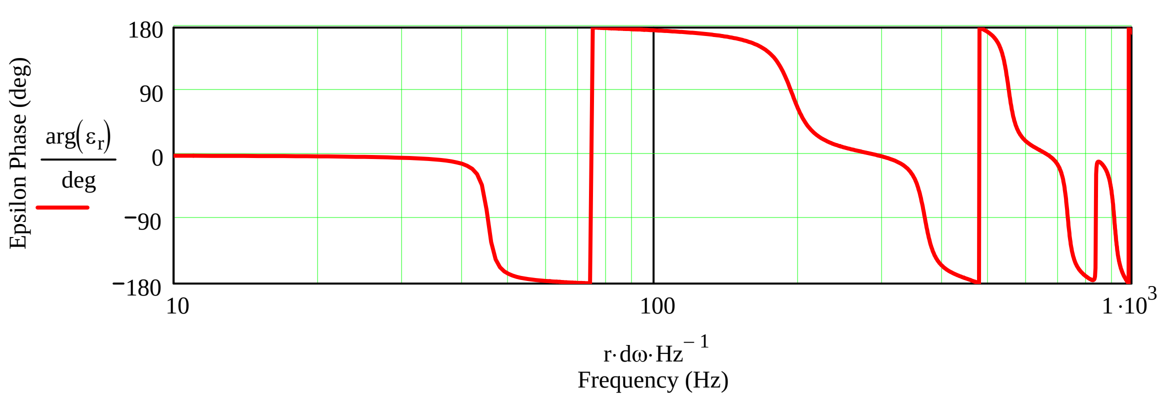
Resulting Acoustic Impedance for the Enclosure



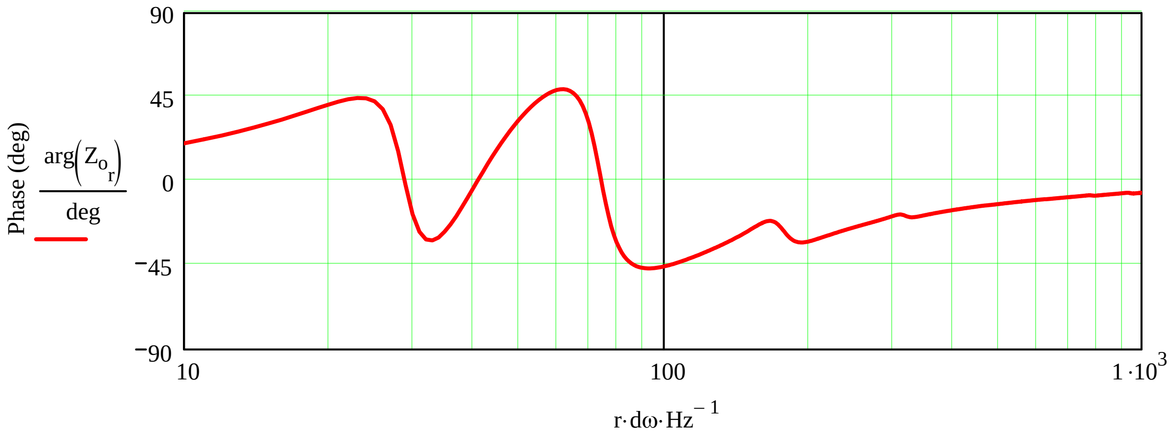


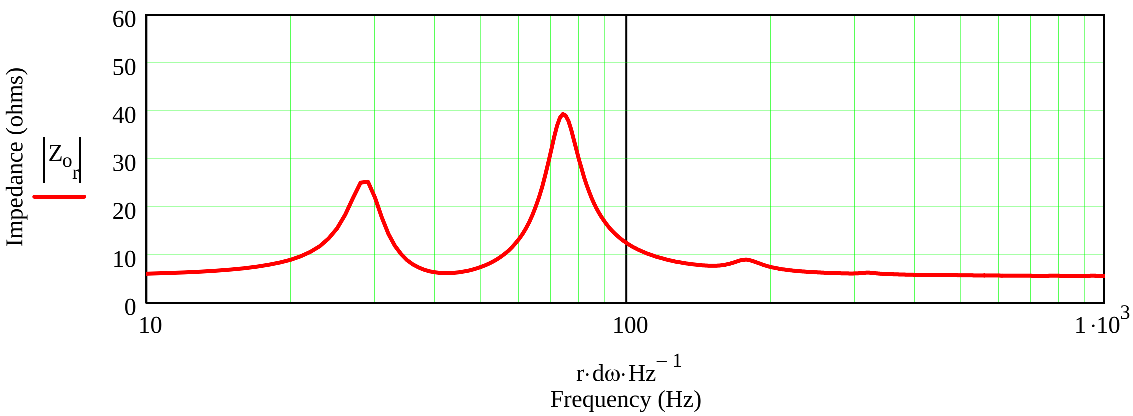
Velocity at the Terminus of the ML TL for a 1 m/sec Excitation at the Driver Position



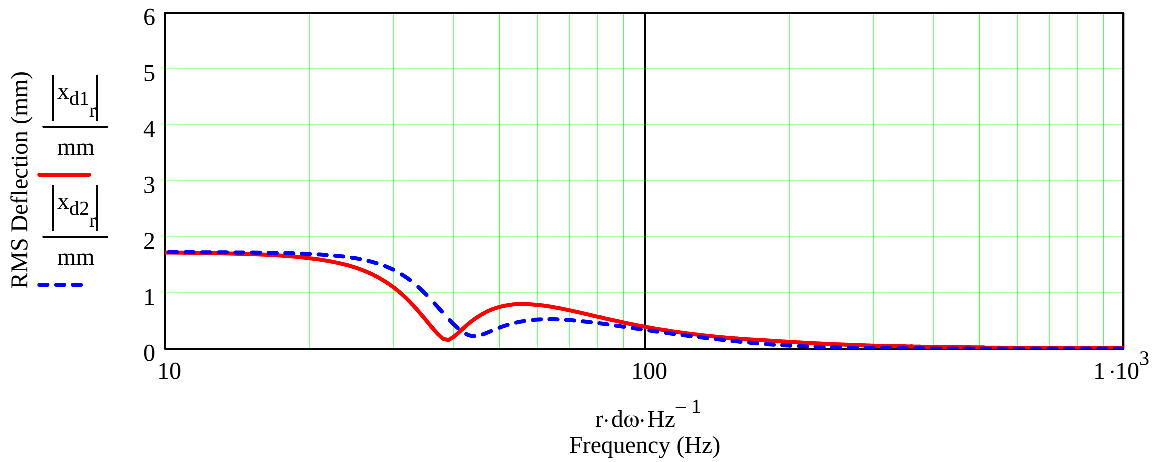


Bipole ML TL System Impedance - w/o Filter on Rear Driver

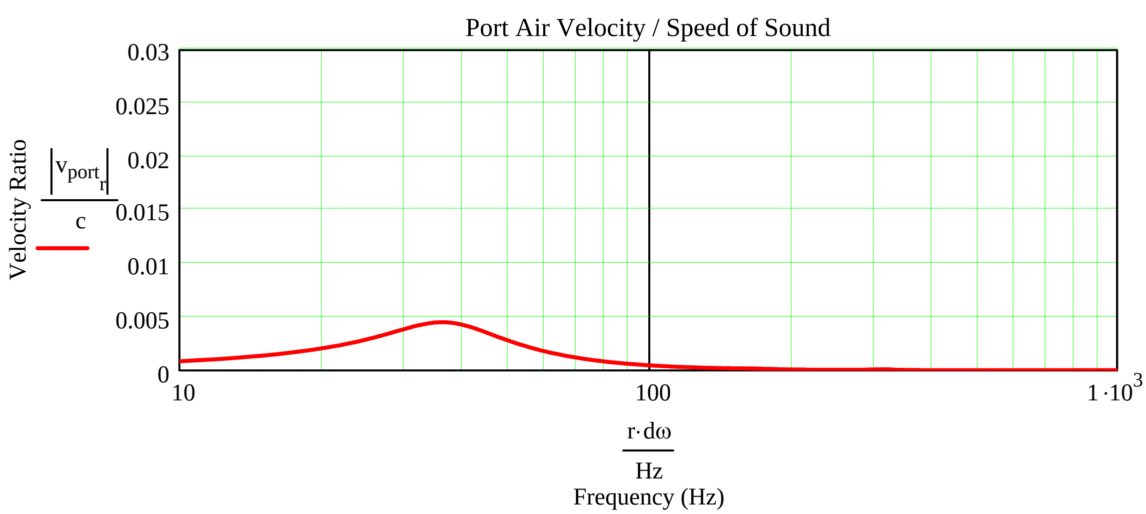




Woofer RMS Displacement (front driver - solid red curve, rear driver - blue dashed curve)



Port Air Velocity (should be < 10 m/sec / 344 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

$X_0 := 2.5 \cdot ft$	(Front Baffle Distance from Rear Wall > Depth of Enclosure)
$Y_0 := 2 \cdot ft$	(Front Baffle Distance from Side Wall)
$\theta_0 := 45 \cdot deg$	(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	
$y_{o_0} := 13.5 \cdot in$		(Bottom Right Corner)
$y_{o_1} := 13.5 \cdot in$	$z_{o_1} := 43.5 \cdot in$	(Top Right Corner)
$y_{o_2} := 0 \cdot in$	$z_{o_2} := 43.5 \cdot in$	(Top Left Corner)
$y_{o_3} := 0 \cdot in$		(Bottom Left Corner)
$depth := 17.5 \cdot in$		(Depth of Enclosure)

Driver Geometry Input

$y_{dc} := 6.75 \cdot in$ (Driver Center y Coordinate)

$z_{dc} := 36.75 \cdot in$ (Driver Center z Coordinate)

n_dvr := 8 (Number of Points Across Diameter)

Port Geometry Input

$y_{mc} := 6.75 \cdot in$ (Port Center y Coordinate)

$z_{mc} := 4.75 \cdot in$ (Port Center z Coordinate)

n_mth := 7 (Number of Points Across Diameter)

Locate := 0 (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)

$radius := 1 \cdot m$ (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)

$z_p := z_{dc} + stand$ (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)

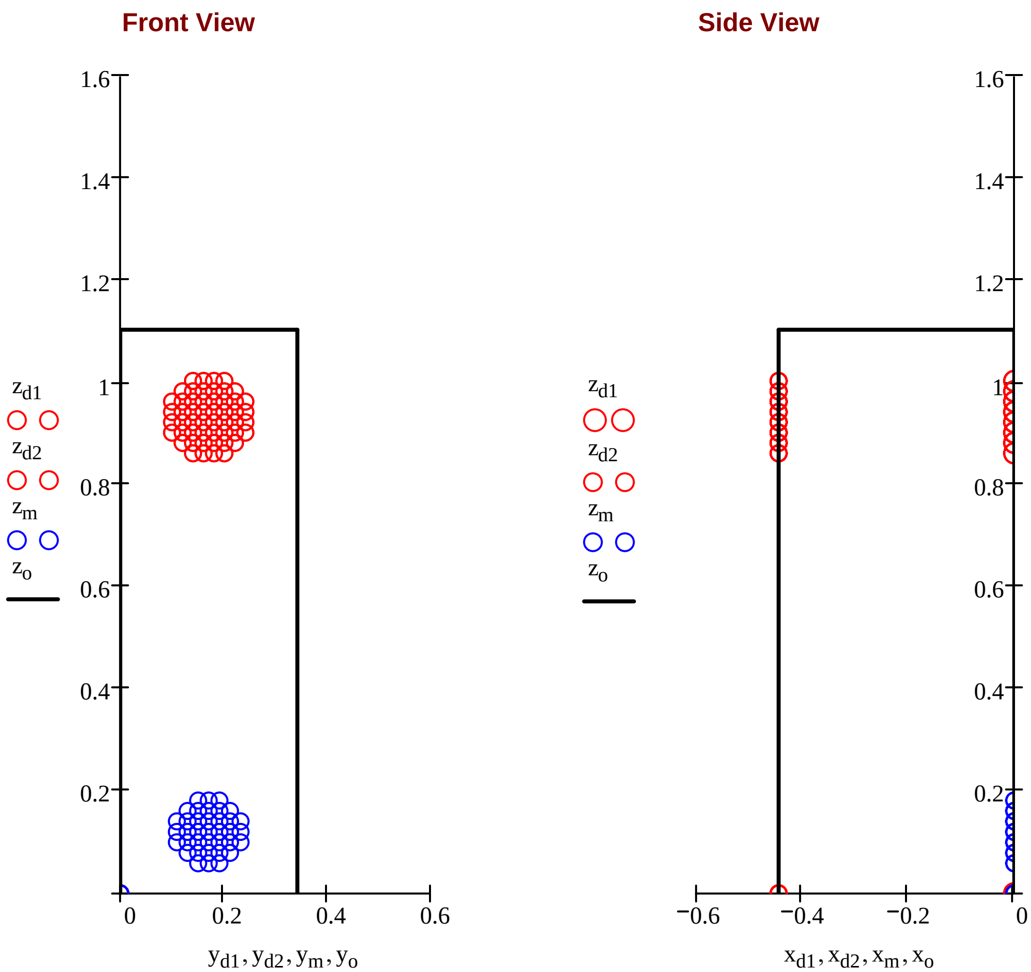
Inc_floor := 1 (Floor, Z = 0)

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

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

Inc_ceiling := 0 (Ceiling)

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

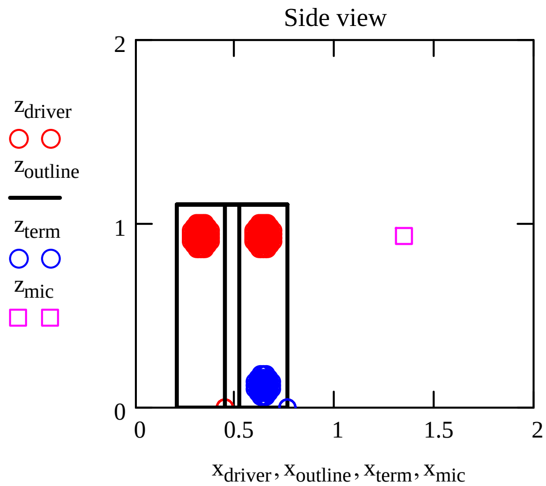


Red sources represent the driver.
Blue sources represent the port.
Black outline represents the baffle edge.
Origin is at the bottom front left corner of the enclosure.

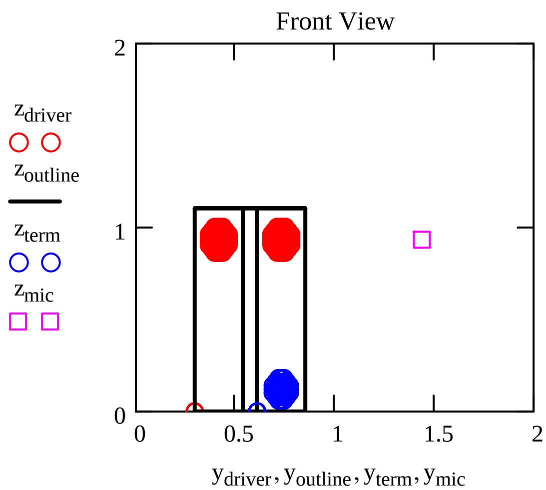
Three Dimensional View

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

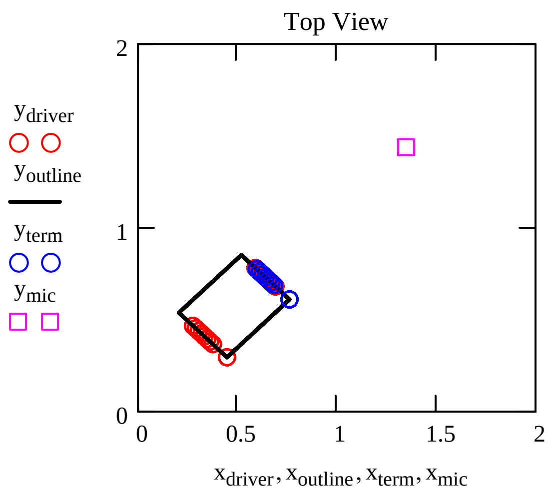
Room Corner is the Origin



Side View - looking out from side wall

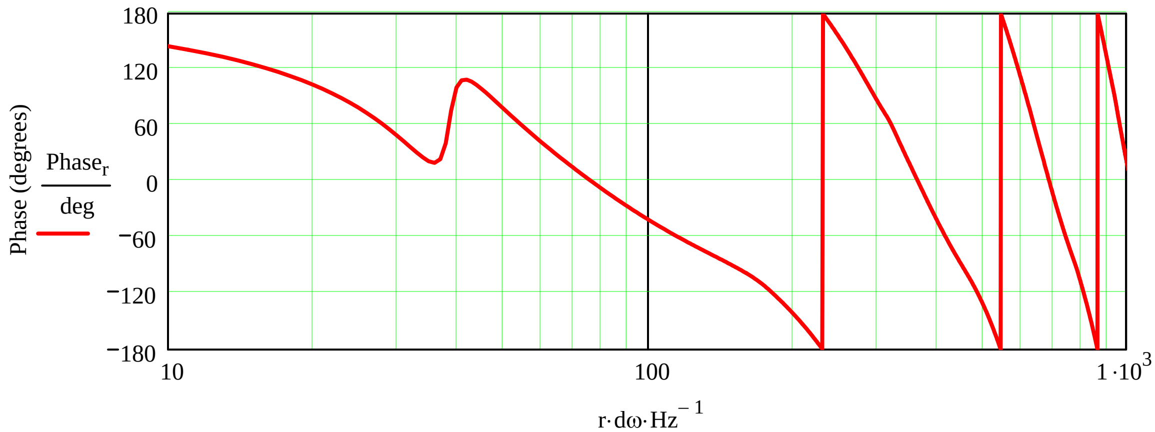


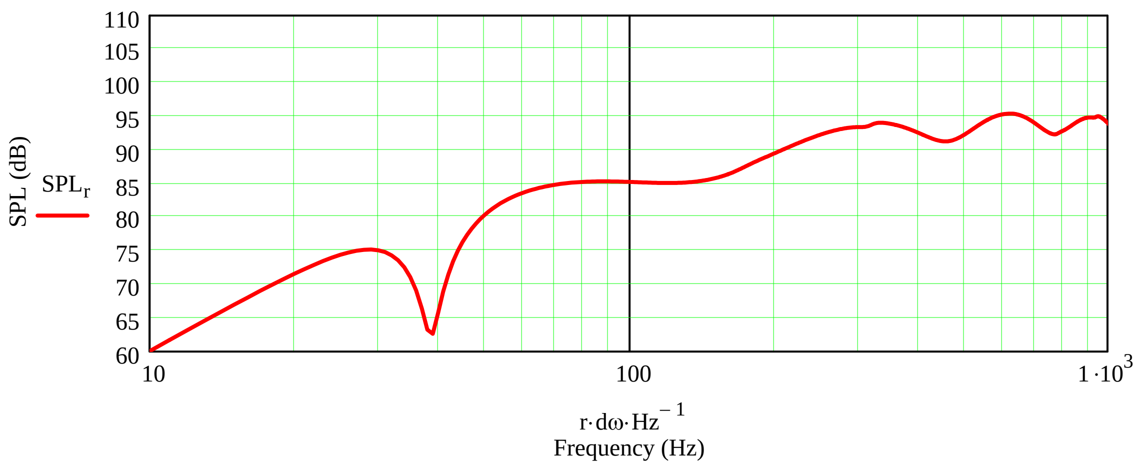
Front View - looking towards rear wall



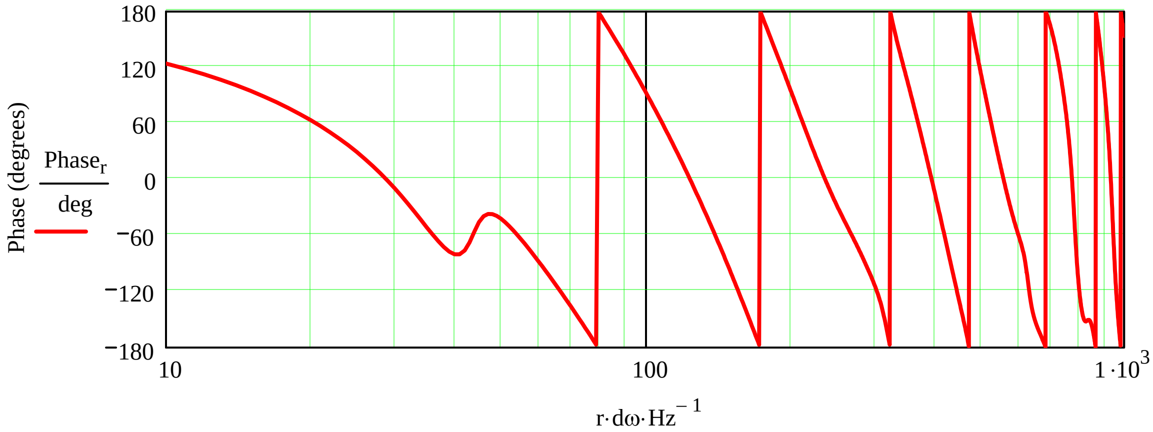
Top View - looking down from ceiling

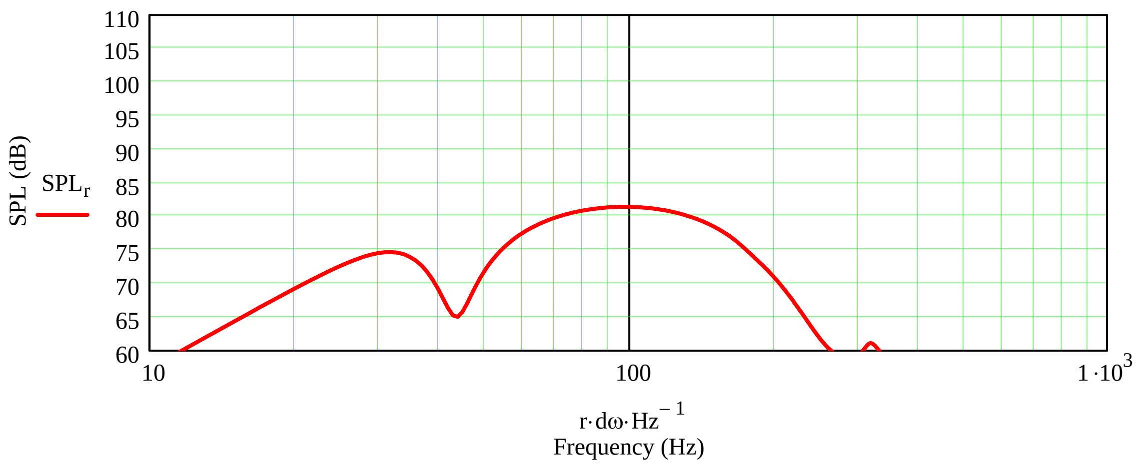
Plotted Baffle Step and Reflection SPL Response for the Front Circular Driver Source



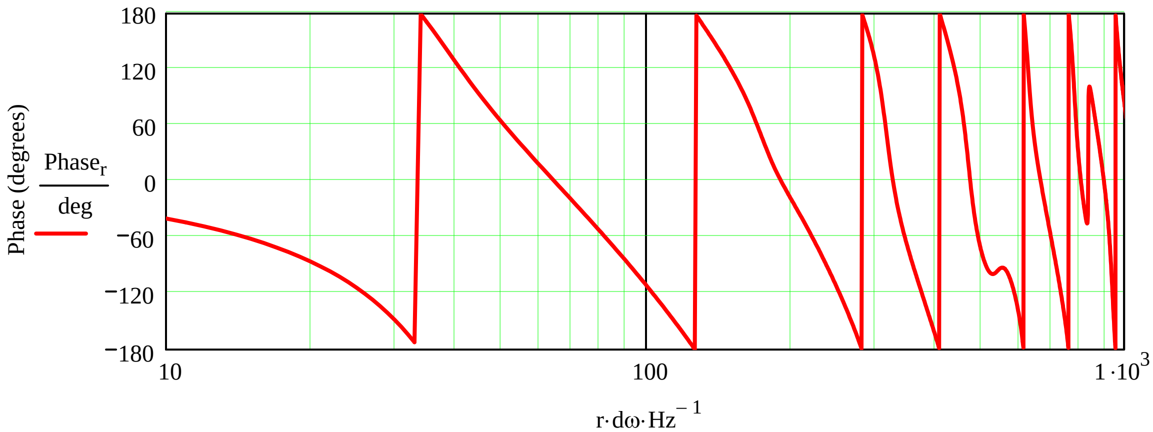


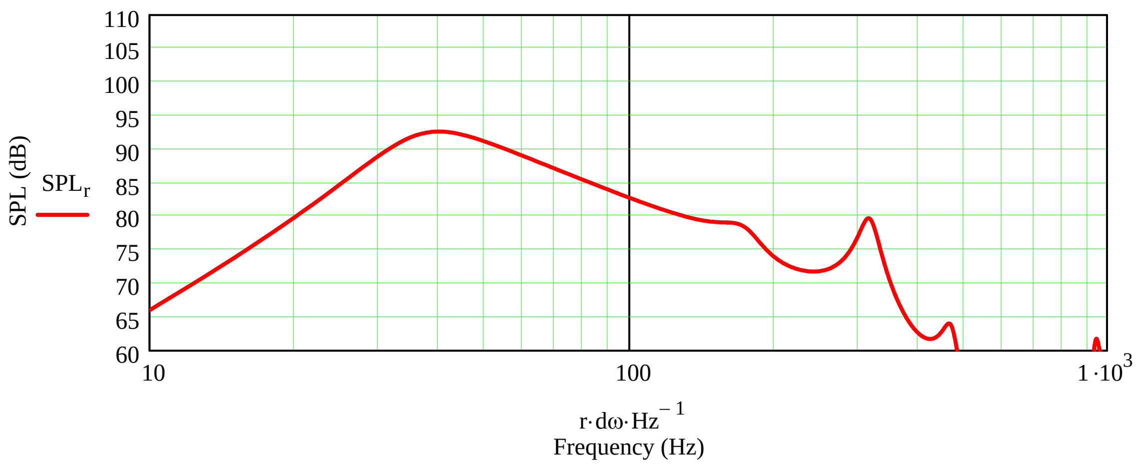
Plotted Baffle Step and Reflection SPL Response for the Rear Circular Driver Source



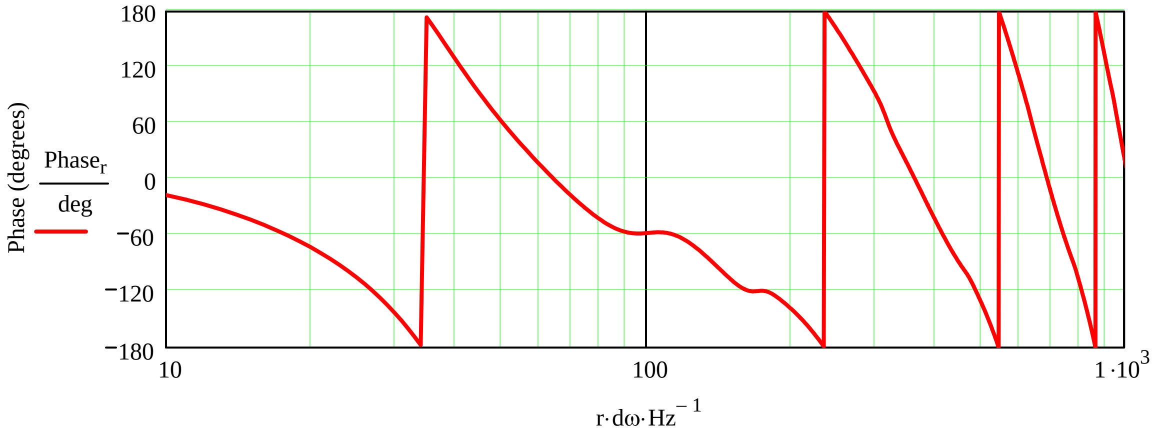


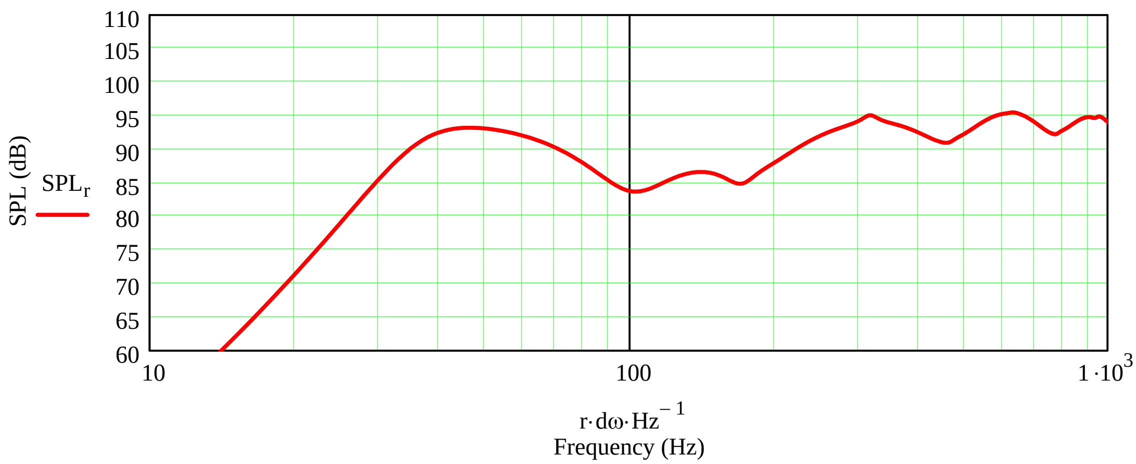
Plotted Baffle Step and Reflection SPL Response for the Circular Port Source





Plotted SPL Response for the System





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

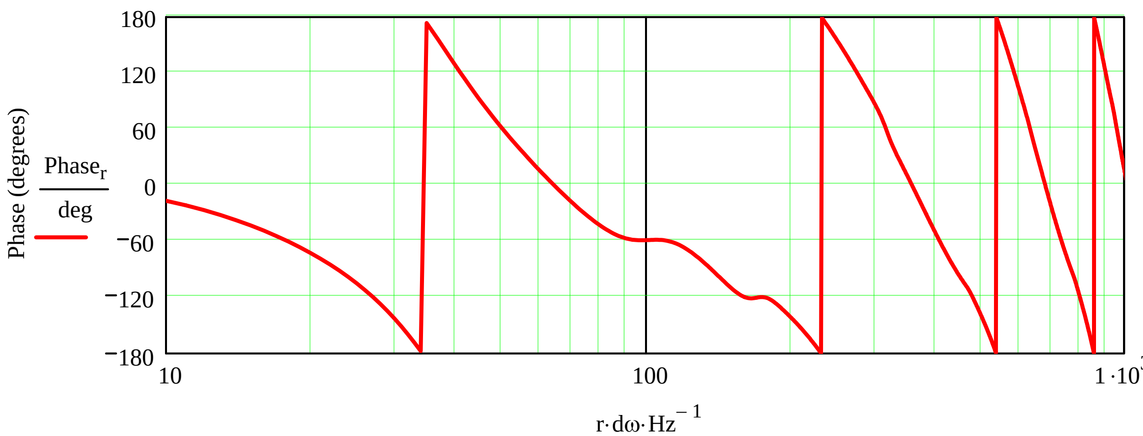
Input Center Frequency of the Baffle Step and the desired dB of Attenuation.

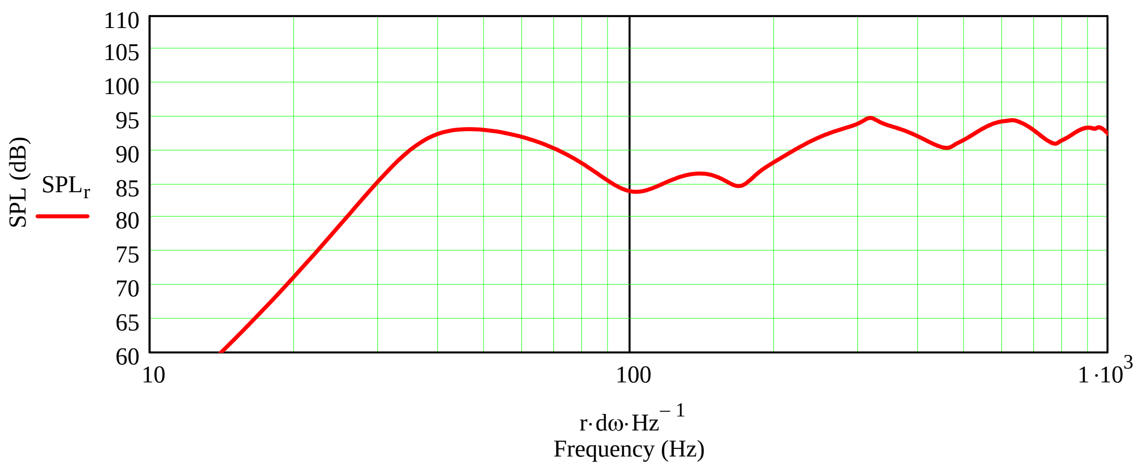
$f_{center} := 640 \cdot Hz$ <--- Input Center Frequency

$dB := 2$ <--- Input dB of Attenuation

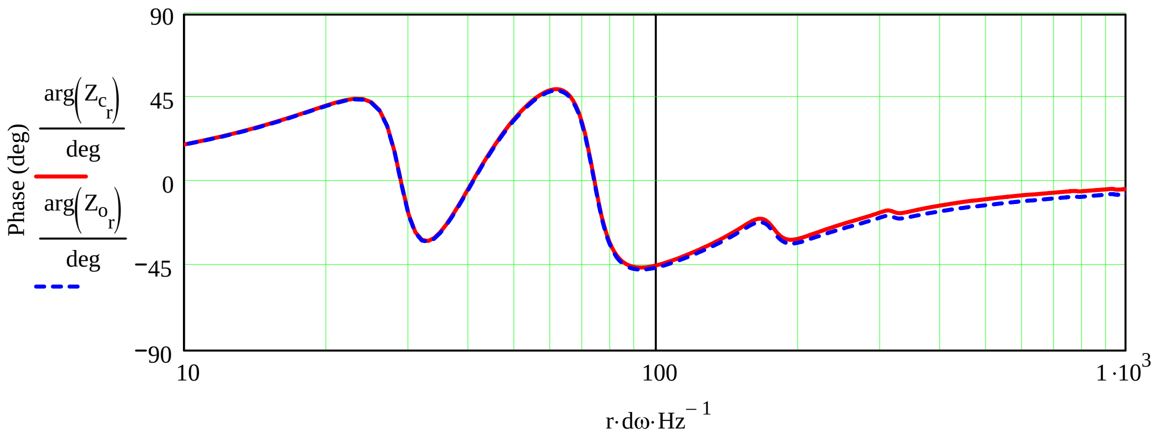
Calculated Component Values		User Assigned Component Values Based on Calculated Values at Left	
$R_e \cdot \left(10^{\frac{dB}{20}} - 1\right) = 2.874\,\Omega$	Parallel Resistor	Input Value --->	$R_{parallel} := 3 \cdot \Omega$
$\frac{R_{parallel}}{f_{center}} = 0.746\,mH$	BSC Inductor	Input Value --->	$L_{BSC} := 0.75 \cdot mH$

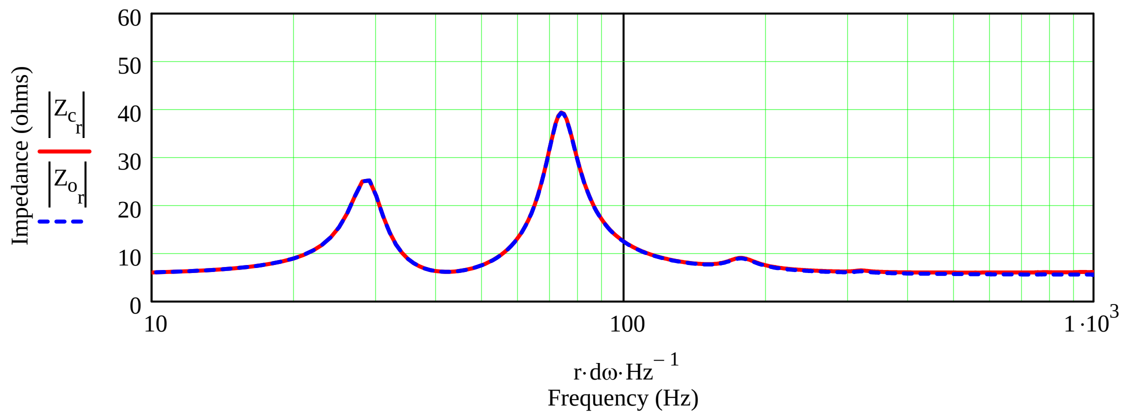
Plotted Corrected SPL Response for the System





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





System Time Response for an Impulse Input