My current 1x8 and 1x12 bass speaker designs

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Created: Long ago

Updated: Dec. 18, 2023

This notebook boils all of my design formulas down to a single Python function. It documents two of my designs. It's where I do my thinking.

- 12 inch ported system using Eminence 2512-ii driver. I've been quite happy with this design, it's a work horse, and I've been using it for well over a decade, both for electric and upright bass.
- **NEW!** 8 inch ported system using Faital Pro 8PR200, a high performance driver.

I decided to document and analyze both of my designs to serve as an example of using my formulas, plus to check the results carefully with the well known WinISD software.

New instructions for use

- Download this notebook onto your hard drive.
- You can run Jupyter Lab in your browser with no software installation on your PC. Just surf to this link:

  https://jupyter.org/try-jupyter/lab/
- Click on "Upload Files"
- Upload this notebook. It will appear in the list of files. Double-click on it. Now you're ready to go!

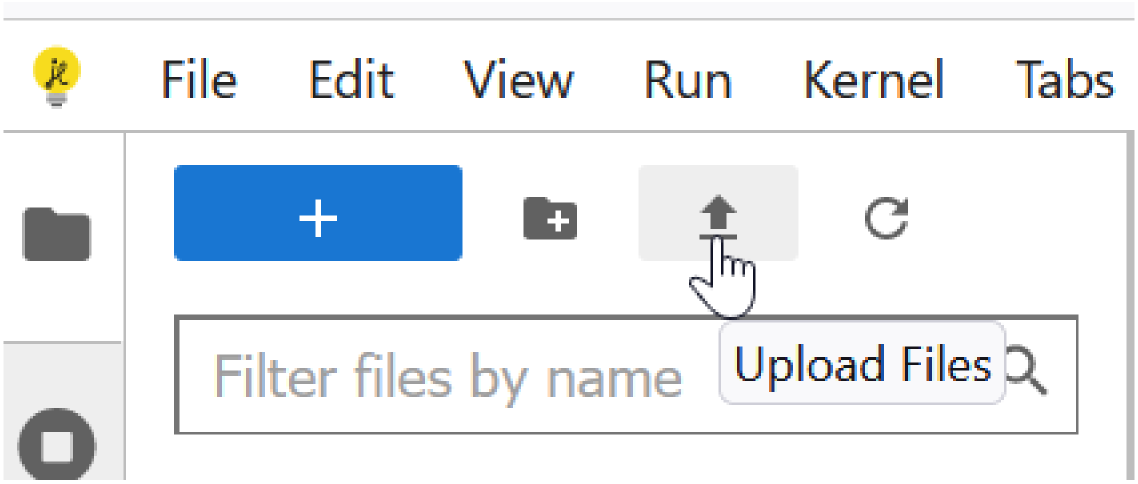

Figure 1: image.png

License information


```python
from numpy import *
%matplotlib inline
from matplotlib.pyplot import *
import pandas as pd
```

```
# Physical constants

gamma = 1.4 # adiabatic constant, dimensionless
P_atm = 101325 # atmospheric pressure, Pa
rho = 1.18 # density of air, kg/m^3
c = sqrt(gamma*P_atm/rho) # https://en.wikipedia.org/wiki/Speed_of_sound
R = 1 # listening distance in meters

# TODO review whether this is the best set of parameters
f_min = 10
f_max = 1000
f = logspace(np.log10(f_min), np.log10(f_max), 300) # a range of frequencies from 10 to 10
style = 'Francis' # preferred style is 'Francis', use 'WinISD to compare results with the
airspeed_units = 'm/s' # should be 'mach' or 'm/s'

def xCone(w = 2*pi*f,
          F_s = 37, # free air resonance in Hz
          R_e= 5.04, # series resistance of voice coil in Ohms
          L_e = 0.46*0.001, # inductance of voice coil converted from mH to H
          Q_ms = 3.13, # mechanical contribution to Q factor
          Q_es = 0.44, # electromagnetic contribution to Q factor
          Vas = 147*0.001, # equivalent box volume, liters converted to m^3
          Xmax = 4.90*0.001, # maximum excursion, converted from mm to m
          S_d = 519.5/1e4, # cone area converted from cm^2 to m^2

          Znom = 8,
          Pin = 100, # input power used for calculations like cone excursion and port air
          V_box = 32*1e-3, # box volume, 32 l converted to m^3
          ported = True,
          f_port = 40, # port tuning frequency in Hz
          Q_port = 50,
          portShape = 'rectangular', # circular or rectangular
          d_port = 100*0.01, # diameter of port if circular in cm converted to m
          a_port = 3.5*0.01, # width of port if rectangular
          b_port = 21.5*0.01, # height of port if rectangular
          endCorrect = 0.732, # port end correction factor
          initReport = {},
          design = '',
         ):

    '''
```

```
Compute cone excursion and other performance measures

Parameters are self explanatory, all are in SI units
'''

w_0 = 2*pi*F_s # resonant frequency in radians/s
m = gamma*P_atm*S_d**2/w_0**2/Vas # cone mass in kg
BL = sqrt(w_0*m*R_e/Q_es) # BL product in T*m
C = w_0*m/Q_ms # Mechanical damping constant of cone
K = w_0**2*m # Spring constant of cone
r = sqrt(S_d/pi) # Radius
z = R_e + 1j*w*L_e # Electrical impedance
if style == 'WinISD':
    Vin = sqrt(2*Pin*R_e) # Input voltage peak amplitude
elif style == 'Francis':
    Vin = sqrt(2*Pin*Znom) # Input voltage peak amplitude
else:
    print('style must be winISD or Francis')
K_box = gamma*P_atm*S_d**2/V_box # Spring constant of box

if ported:
    w_port = 2*pi*f_port # port resonant frequency in radians/s
    kappa = w**2/(w**2 - 1j*w*w_port/Q_port - w_port**2) # correction factor for box s
else:
    kappa = 1 # i.e., no port therefore no port correction

Keff = K + kappa*K_box # total spring constant, from driver suspension plus port-corre

x = BL*Vin/m/z/(Keff/m + 1j*w*(BL**2/m/z + C/m) - w**2) # cone excursion amplitude in

Z = z/(1 - 1j*w*BL*x/Vin) # cone impedance, complex valued, in Ohms

p = rho*r**2*w**2*kappa*x/R/2 # sound pressure amplitude in Pascal
p_rms = p/sqrt(2)

p_ref = 20e-6 # reference value for sound pressure, in Pascal
spl = 20*log10(abs(p_rms)/p_ref) # sound pressure level in dB SPL

phaseRot = 180*pi/180 # phase rotation for phase graph, to make it agree with WinISD
phase = angle(p*(cos(phaseRot) + 1j*sin(phaseRot)))*180/pi # phase of acoustic wavefro
```

```python
# More ported behavior

if ported:
    kappa2 = w_port**2/(w**2 - 1j*w*w_port/Q_port - w_port**2)

    if portShape == 'circular':
        S_port = pi*d_port**2/4
        Rport = d_port/2
    elif portShape == 'rectangular':
        S_port = a_port*b_port
        Rport = min(a_port, b_port)/2 # assume effective radius is the smaller of the
        initReport['d_port'] = sqrt(4*S_port/pi)
    else:
        print('portShape needs to be circular or rectangular')

    if airspeed_units == 'mach':
        v_port = 1j*w*kappa2*x*S_d/S_port/c # speed of port air plug
    elif airspeed_units == 'm/s':
        v_port = 1j*w*kappa2*x*S_d/S_port # speed of port air plug
    else:
        print('Airspeed units must be mach or m/s')

    lport = S_port*gamma*P_atm/rho/V_box/w_port**2 - Rport*2*endCorrect # length of po

else:
    v_port = None

report = dict(initReport)
report['resonant angular frequency w_0 (1/s)'] = w_0
report['cone mass m (kg)'] = m
report['magnetic field length product BL (T m)'] = BL
report['mechanical damping factor (N/(m/s))'] = C
report['mechanical spring constant (N/m)'] = K
report['mechanical compliance (m/N)'] = 1/K
report['input power (W)'] = Pin
report['peak input voltage (V)'] = Vin
report['cone radius (m)'] = r
report['box spring constant (N/m)'] = K_box
report['Port angular frequency (1/s)'] = w_port
report['Port area (m^2)'] = S_port
report['Port effective radius (m)'] = Rport
```

```
    report['Length of port (m)'] = lport
    report['Length of port (in)'] = lport*39.3
    report['Volume of port (l)'] = lport*S_port*1000

    return x, Z, spl, phase, v_port, p, pd.DataFrame([[tag, report[tag]] for tag in report

def graphs(f, x, Z, spl, phase, v_port, label):
    ax[0].semilogx(f, abs(x)*1000, label = label)
    ax[0].set_ylabel('cone excursion amplitude (mm)')

    ax[1].semilogx(f, abs(Z), label = label)
    ax[1].set_ylabel('impedance ($\Omega$)')

    ax[2].semilogx(f, spl, label = label)
    ax[2].set_ylabel('Sound pressure (dB SPL)')

    ax[3].semilogx(f, phase, label = label)
    ax[3].set_ylabel('Phase')

    ax[4].semilogx(f, abs(v_port), label = label)
    ax[4].set_xlabel('frequency (Hz)')
    ax[4].set_ylabel('port air speed (' + airspeed_units + ')')


    for a in ax:
        a.set_xticks([10, 20, 40, 60, 100, 200, 400, 600])
        a.get_xaxis().set_major_formatter(matplotlib.ticker.ScalarFormatter())
        a.legend()

def runGraph(name, driver, box):
    x, Z, spl, phase, v_port, p1, df = xCone(**(name | driver | box), initReport = name |
    label = name['design']
    graphs(f, x, Z, spl, phase, v_port, label)
    return df
```

```
# Driver library.

emi2512ii = { # Eminence DeltaLite 2512-ii
    'F_s': 37, # resonant frequency in Hz
    'R_e': 5.04, # series resistance of voice coil in Ohms
    'L_e': 0.46*0.001, # inductance of voice coil converted from mH to H
```

```python
    'Q_ms': 3.13, # mechanical contribution to Q factor
    'Q_es': 0.44, # electromagnetic contribution to Q factor
    'Vas': 147*0.001, # equivalent box volume, liters converted to m^3
    'Xmax': 4.90*0.001, # maximum excursion, converted from mm to m
    'S_d': 519.5/1e4, # cone area converted from cm^2 to m^2
}

fp8pr200 = { # Faital Pro 8PR200
    'F_s': 58, # resonant frequency in Hz
    'R_e': 5.1, # series resistance of voice coil in Ohms
    'L_e': 0.55*0.001, # inductance of voice coil converted from mH to H
    'Q_ms': 9.4, # mechanical contribution to Q factor
    'Q_es': 0.38, # electromagnetic contribution to Q factor
    'Vas': 16.9*0.001, # equivalent box volume, liters converted to m^3
    'Xmax': 8.15*0.001, # maximum excursion, converted from mm to m
    'S_d': 209/1e4, # cone area converted from cm^2 to m^2
}

# Box database

box1 = { # My little 12" box
    'Znom': 8,
    'Pin': 100,
    'V_box': 32*1e-3, # box volume, 32 l converted to m^3
    'ported': True,
    'f_port': 40, # port tuning frequency in Hz
    'Q_port': 50, # value borrowed from WinISD
    'portShape': 'rectangular', # circular or rectangular
    'd_port': None, # diameter of port if circular in cm converted to m
    'a_port': 3.5*0.01, # width of port if rectangular
    'b_port': 21.5*0.01, # height of port if rectangular
    'endCorrect': 0.732, # port end correction factor
}

box2 = { # My little 8" box as designed
    'Znom': 8,
    'Pin': 100,
    'V_box': 15*1e-3, # box volume, 32 l converted to m^3
    'ported': True,
    'f_port': 40, # port tuning frequency in Hz
    'Q_port': 20, # value borrowed from WinISD
```

```
    'portShape': 'rectangular', # circular or rectangular
    'd_port': None, # diameter of port if circular in cm converted to m
    'a_port': 5.5*0.01, # width of port if rectangular
    'b_port': 5.5*0.01, # height of port if rectangular
    'endCorrect': 0.732, # port end correction factor
}

box3 = {
    'Znom': 8,
    'Pin': 100,
    'V_box': 15*1e-3, # box volume, 32 l converted to m^3
    'ported': True,
    'f_port': 45, # port tuning frequency in Hz
    'Q_port': 20, # value borrowed from WinISD
    'portShape': 'rectangular', # circular or rectangular
    'd_port': None, # diameter of port if circular in cm converted to m
    'a_port': 5.5*0.01, # width of port if rectangular
    'b_port': 5.5*0.01, # height of port if rectangular
    'endCorrect': 0.732, # port end correction factor
}

box4 = {
    'Znom': 8,
    'Pin': 100,
    'V_box': 15*1e-3, # box volume, 32 l converted to m^3
    'ported': True,
    'f_port': 50, # port tuning frequency in Hz
    'Q_port': 10, # value borrowed from WinISD
    'portShape': 'circular', # circular or rectangular
    'd_port': 7.62*0.01, # diameter of port if circular in cm converted to m
    'a_port': 7*0.01, # width of port if rectangular
    'b_port': 7*0.01, # height of port if rectangular
    'endCorrect': 0.732, # port end correction factor
}
```

```
'''
Data harvested from the Javascript version of my program, to test whether it agrees with t
'''

jsData = '''f(hz), x(mm), v(mach)
20, 21.336504357769137, 0.07153718094165383
```

```
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202, 1.2900918688455116, 0.0013372155877799379
203, 1.2766976589104924, 0.0013162852826638684
204, 1.263508539060929, 0.0012957895640472845
205, 1.250520440516531, 0.0012757172587099098
206, 1.237729389847416, 0.001256057532129746
207, 1.2251315065711084, 0.0012367998768438673
208, 1.2127230008042247, 0.0012179341012462487
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210, 1.1884594015511178, 0.0011813389376857453
211, 1.1765971609176704, 0.0011635906507554742
212, 1.1649099991791114, 0.0011461964259679527
213, 1.1533945461100652, 0.0011291474970996666
214, 1.1420475091189584, 0.001112435354832045
215, 1.130865671268789, 0.0010960517381631463
216, 1.1198458893477639, 0.0010799886261362909
217, 1.10898509198895, 0.0010642382298731692
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221, 1.067072734116096, 0.0010042157256490516
222, 1.0569631779947146, 0.000989919675996335
223, 1.04699558762186, 0.0009758940717822566
224, 1.037167345818851, 0.0009621325487827549
225, 1.0274758938622792, 0.0009486289207376877
```

```
226, 1.0179187300025898, 0.0009353771736394029
227, 1.008493408022168, 0.0009223714602256125
228, 0.9991975358319737, 0.0009096060946686491
229, 0.9900287741057793, 0.0008970755474535086
230, 0.9809848349510734, 0.0008847744404373922
231, 0.9720634806157024, 0.0008726975420837477
232, 0.9632625222293363, 0.0008608397628641093
233, 0.9545798185788663, 0.0008491961508212943
234, 0.9460132749168437, 0.0008377618872877912
235, 0.9375608418020929, 0.0008265322827534018
236, 0.9292205139716467, 0.0008155027728764647
237, 0.9209903292431707, 0.0008046689146332062
238, 0.9128683674470499, 0.0007940263825999783
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249, 0.8301594029038802, 0.0006884565134946354
250, 0.8232002979923447, 0.0006798107667106299'''
fjs, xjs, sjs = array([list(map(float, s.split(','))) for s in jsData.split('\n')[1:]]).tr
```
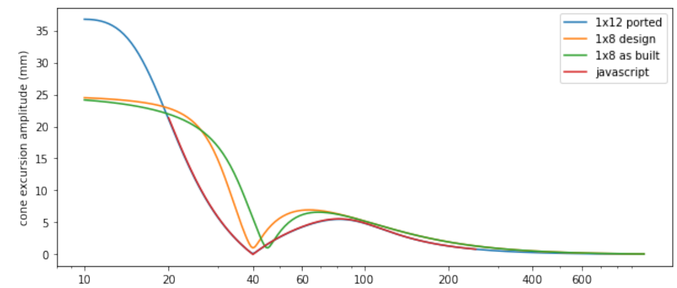
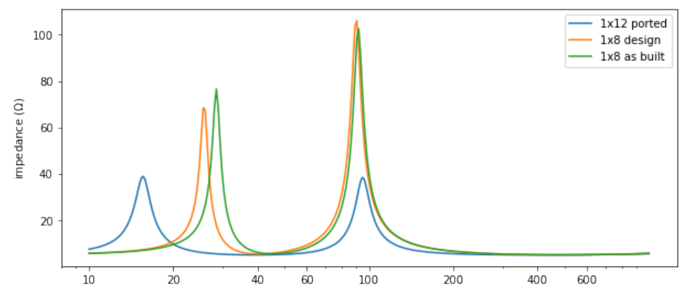

```
fig, ax = subplots(5, 1, figsize = (10, 25))

df1 = runGraph({'design': '1x12 ported'}, emi2512ii, box1)
df2 = runGraph({'design': '1x8 design'}, fp8pr200, box2)
df3 = runGraph({'design': '1x8 as built'}, fp8pr200, box3)
#df4 = runGraph({'design': 'proposed'}, fp8pr200, box4)

df1[2] = df2[1]
df1[3] = df3[1]
#df1[4] = df4[1]
display(df1)

ax[0].plot(fjs, xjs, label = 'javascript')
ax[0].legend()
```

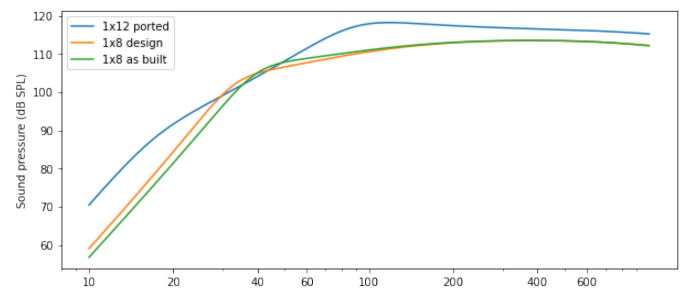
```
ax[4].plot(fjs, sjs, label = 'javascript')
ax[4].legend()
```

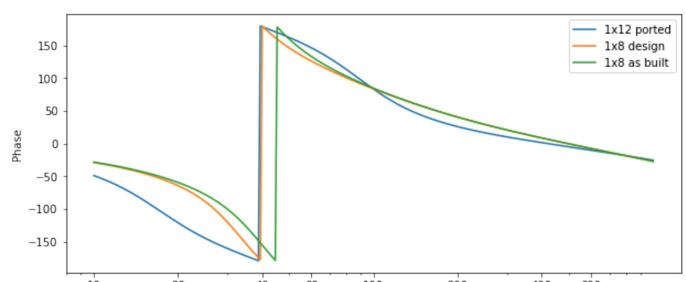
	0	1	2	3
0	design	1x12 ported	1x8 design	1x8 as built
1	F_s	37	58	58
2	R_e	5.04	5.1	5.1
3	L_e	0.00046	0.00055	0.00055
4	Q_ms	3.13	9.4	9.4
5	Q_es	0.44	0.38	0.38
6	Vas	0.147	0.0169	0.0169
7	Xmax	0.0049	0.00815	0.00815
8	S_d	0.05195	0.0209	0.0209
9	Znom	8	8	8
10	Pin	100	100	100
11	V_box	0.032	0.015	0.015
12	ported	True	True	True
13	f_port	40	40	45
14	Q_port	50	20	20
15	portShape	rectangular	rectangular	rectangular
16	d_port	0.097883	0.062061	0.062061
17	a_port	0.035	0.055	0.055
18	b_port	0.215	0.055	0.055
19	endCorrect	0.732	0.732	0.732
20	resonant angular frequency w_0 (1/s)	232.477856	364.424748	364.424748
21	cone mass m (kg)	0.048188	0.027608	0.027608
22	magnetic field length product BL (T m)	11.327846	11.620227	11.620227
23	mechanical damping factor (N/(m/s))	3.579089	1.070323	1.070323
24	mechanical spring constant (N/m)	2604.344413	3666.490092	3666.490092
25	mechanical compliance (m/N)	0.000384	0.000273	0.000273
26	input power (W)	100	100	100
27	peak input voltage (V)	40.0	40.0	40.0
28	cone radius (m)	0.128593	0.081564	0.081564
29	box spring constant (N/m)	11963.707145	4130.91217	4130.91217
30	Port angular frequency (1/s)	251.327412	251.327412	282.743339
31	Port area (m^2)	0.007525	0.003025	0.003025
32	Port effective radius (m)	0.0175	0.0275	0.0275
33	Length of port (m)	0.421928	0.343551	0.262998
34	Length of port (in)	16.581763	13.501541	10.335814
35	Volume of port (l)	3.175007	1.039241	0.795568

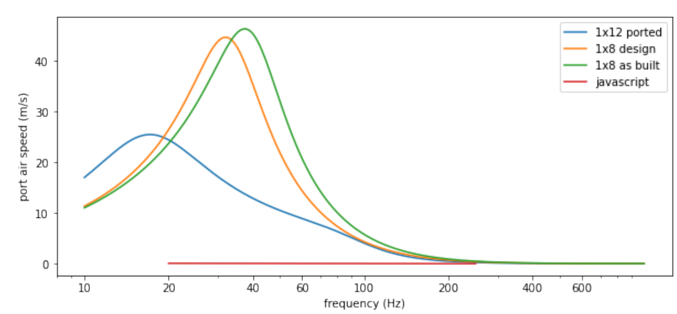
```
<matplotlib.legend.Legend at 0x1cc843c6bf0>
```


cone excursion amplitude (mm)
1x12 ported
1x8 design
1x8 as built
javascript


impedance (Ω)
1x12 ported
1x8 design
1x8 as built


Sound pressure (dB SPL)
1x12 ported
1x8 design
1x8 as built


Phase
1x12 ported
1x8 design
1x8 as built


port air speed (m/s)
frequency (Hz)
1x12 ported
1x8 design
1x8 as built
javascript

Measured curves for 12” box

Impedance

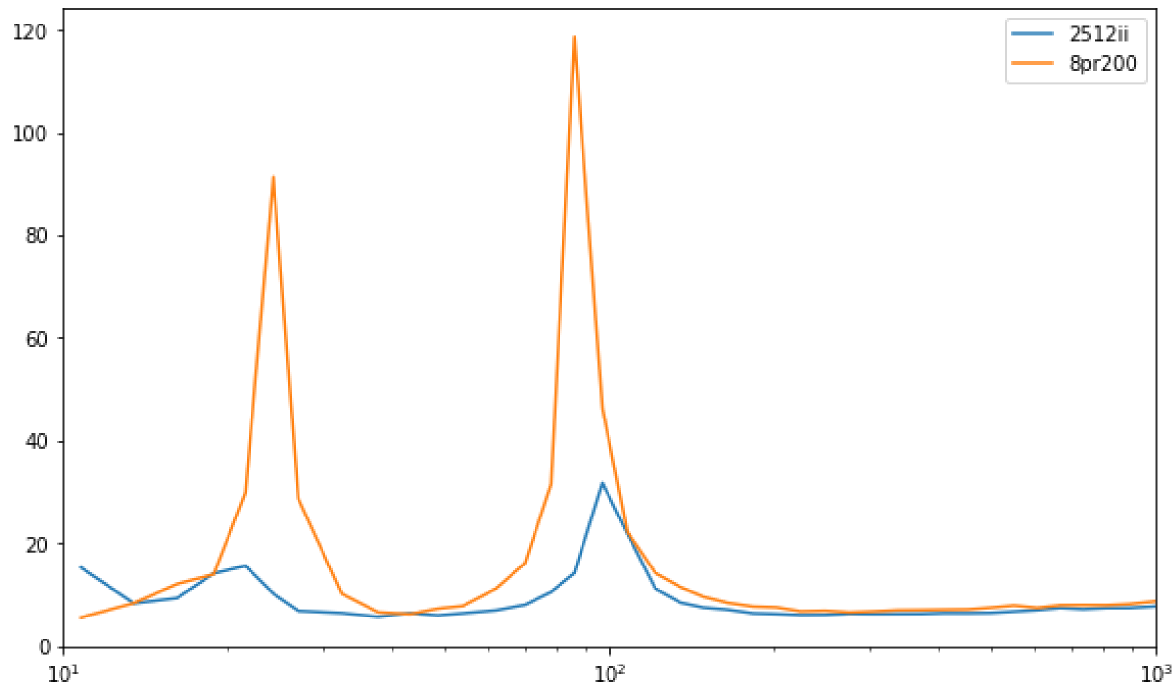


Figure 2: image.png

Nearfield cone response

Graphs for these designs from WinISD

There’s a disagreement between me and WinISD, as to how we calculate the signal in Volts feeding the speaker, see above for the “style” parameter. WinISD uses the R_e of the coil, I use the nominal impedance. I’ve set the “style” to WinISD for the purpose of comparison.

Excursion amplitude

Impedance

I get the same peak frequencies as WinISD, but noticeably different peak heights

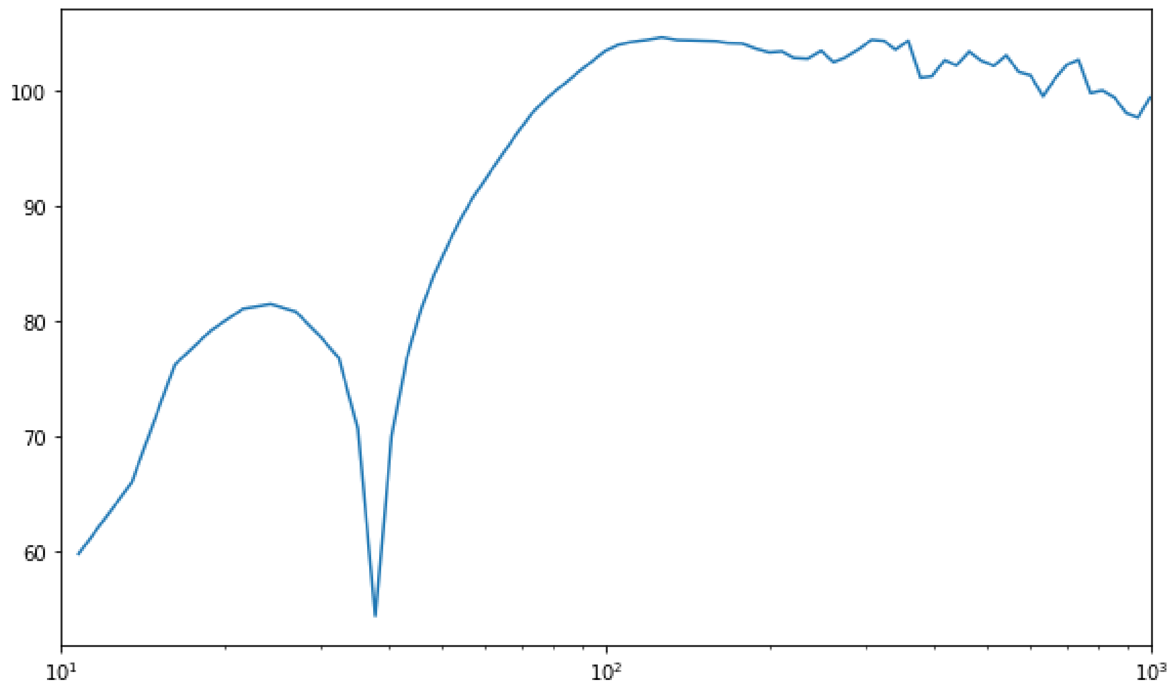


Figure 3: image.png

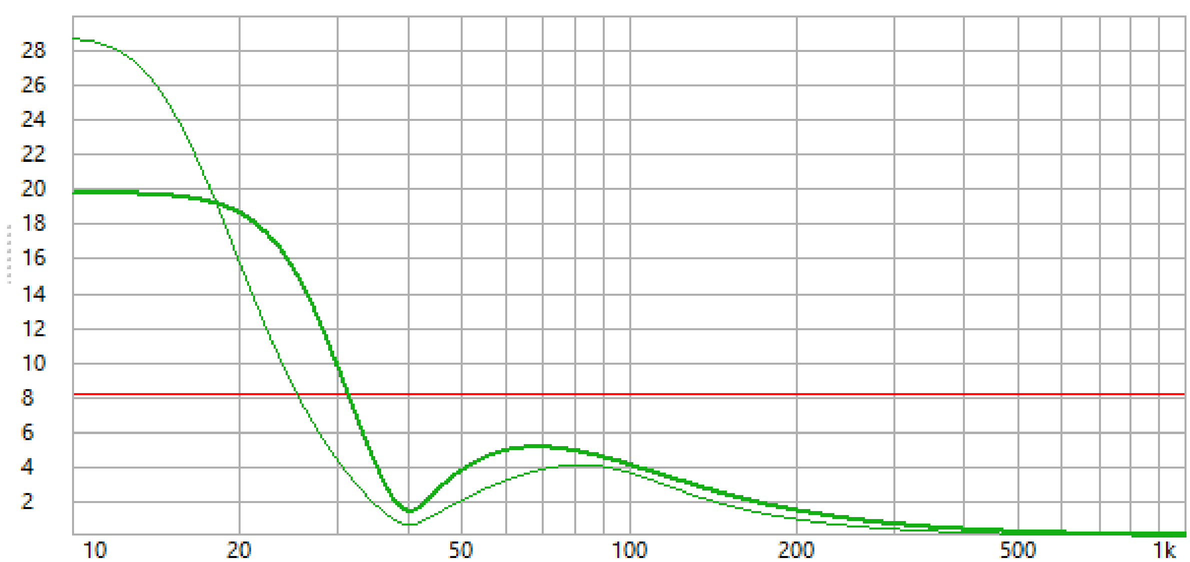


Figure 4: image.png

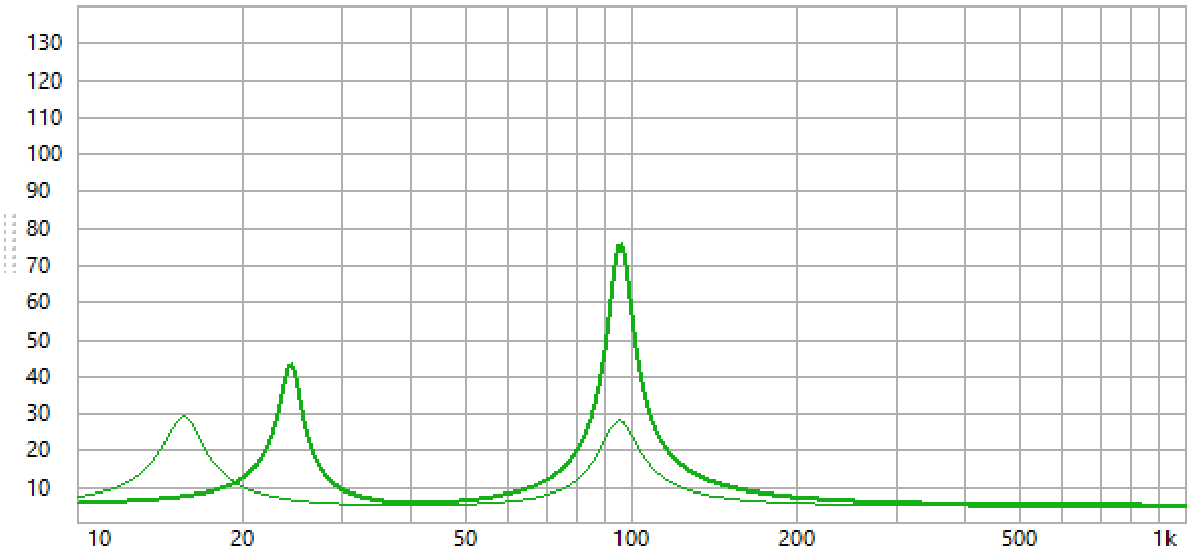


Figure 5: image.png

SPL

Phase

I added a 180° phase rotation to make my graph match WinISD. This shouldn't have an acoustic effect, but is useful for comparing the programs.

Port air speed

```
# don't forget to save before running this cell...
!jupyter nbconvert --to html "12 and 8 inch designs.ipynb"
```

```
[NbConvertApp] Converting notebook 12 and 8 inch designs.ipynb to html
[NbConvertApp] Writing 936639 bytes to 12 and 8 inch designs.html
```

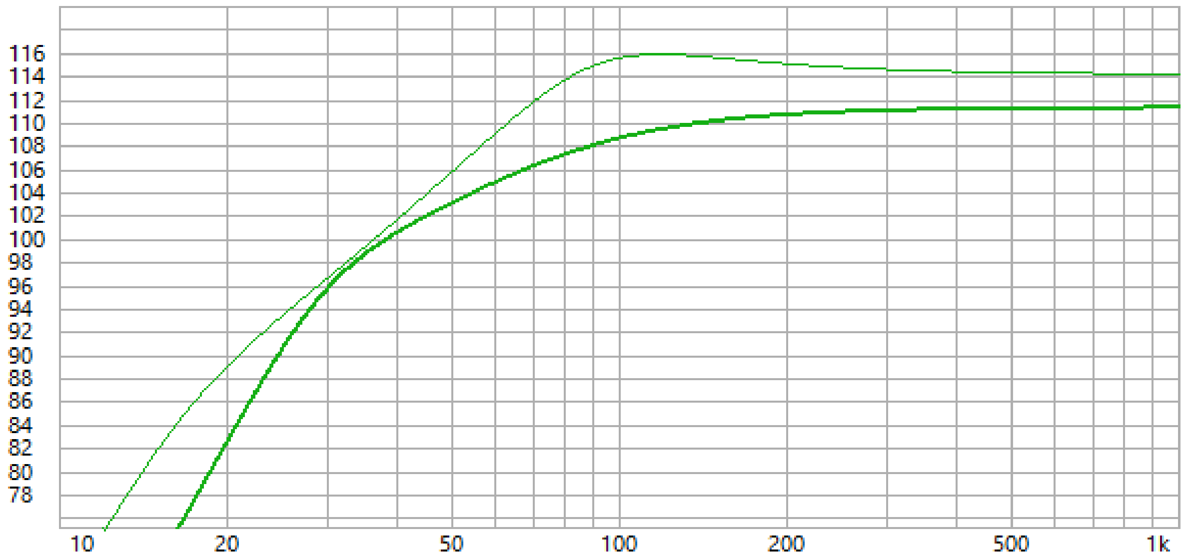


Figure 6: image.png

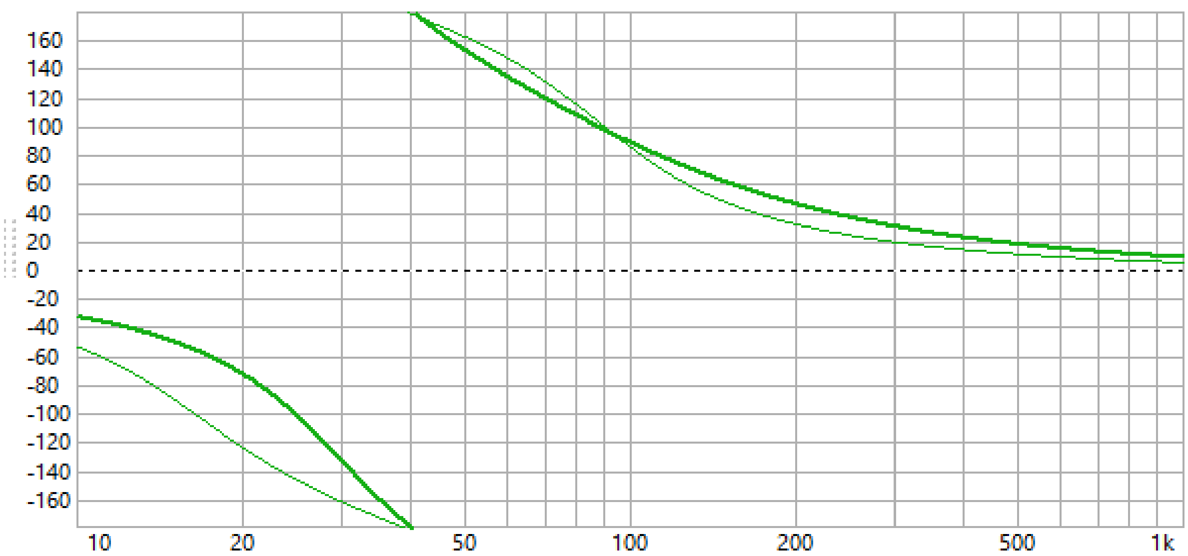


Figure 7: image.png

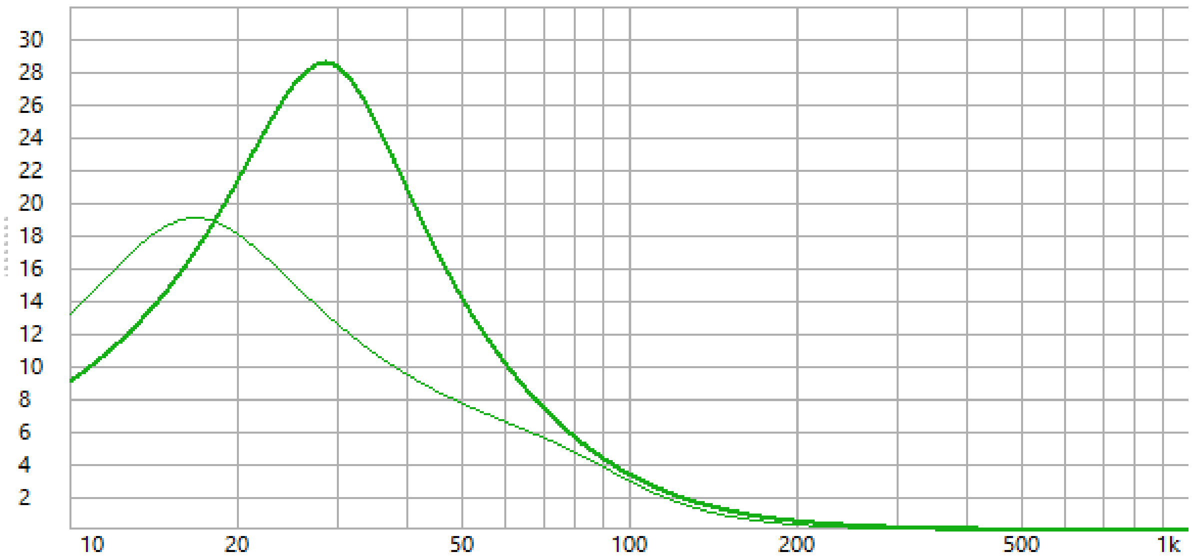


Figure 8: image.png