

Part 2: Examples

Dayton 18" An incredible driver at a good price.

The Impedance plot shows 6Ω impedance, the correction factor is $10 \cdot \log(4 \div 6) = -1.76\text{dB}$. The sensitivity is $88.6 - 1.76 - 6 = 80.84\text{dB}/1\text{W}$.

A 4000W into 4Ω amplifier will only deliver 2600W into 6Ω. The SPL will rise +34.14dB to **115dB**.

The deepest fc is reached with a **big enclosure** of $Q_{tc}=0.66$. This value will rise to 0.71 when the voice-coil has warmed up with an average RMS power of 100W. That is the case with cinemas or discotheques.

For HiFi or home cinema $Q_{tc}=0.71$ is better at low SPL. **279L**

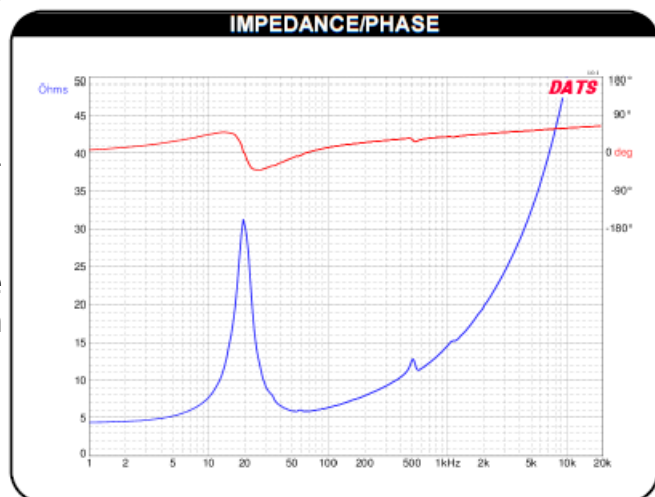
Using an Equalizer allows us to compensate for higher Q_{tc} of the **small box**. Easy to adjust with a DSP powered cross-over. For PA and transportable use.

In all cases 80-125Hz crossover, no damping needed because the cabinet resonances lie higher.

More important is to suppress vibration of the walls by bracing and doubling up the baffle and using multiplex plywood of at least 25mm.

Bigger surface areas can be covered with Hawaphon, steel **surface damping** mats invented for sound insulation in submarines. Very efficient but really heavy and expensive. The surface vibration can also be tackled with 4mm bitumen mats, cheaper.

PARAMETERS	
Impedance	4 ohms
Re	4.4 ohms
Le	2.22 mH @ 1 kHz
Fs	19.5 Hz
Qms	3.82
Qes	0.62
Qts	0.53
Mms	655g
Cms	0.1 mm/N
Sd	1,219 cm ²
Vd	2,681.8 cm ³
BL	23.8 Tm
Vas	212 liters
Xmax	22 mm
VC Diameter	75 mm
SPL	88.6 dB @ 2.83V/1m
RMS Power Handling	1000 watts
Usable Frequency Range (Hz)	19 - 500 Hz

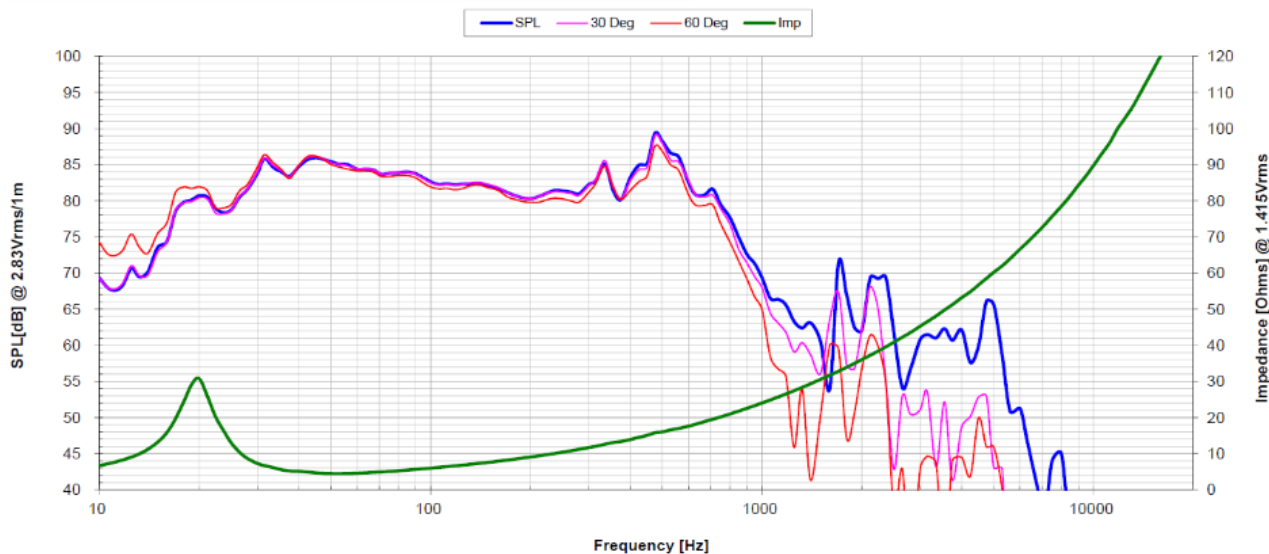


Net	Qtc	fc	Amp	Max SPL	Stroke	X-over	Power	Gain/Power
371L	0.67	24.44Hz	2600W	115dB	±20.9mm	80Hz	760.6W	- / -
279L	0.71	25.87Hz	2600W	115dB	±18.6mm	80Hz	755.7W	- / -
114L	0.9	33.0Hz	2600W	115dB	±11.4mm	80Hz	744.7W	- / -

When fully driven, the speaker will dissipate in the small box 744.7W when cold, warm(123°) 539.5W with 2.8dB compression. This keeps it always on the safe side, even if the temperature inside the cabinet rises. Suitable for professional use with 2600W amp.

Peerless 15" another Monster: 25kg, 5000W peak, 188mm Voice-coil.

DC Resistance	Revc	Ohms	3.09	5.0%	Energy Bandwidth Product	EBP	(1/Qes)*fs	47.28
Minimum Impedance	Zmin	Ohms	4.46	7.5%	Moving Mass	Mms	g	537.99
Voice Coil Inductance	Le	mH	1.25		Suspension Compliance	Cms	um/N	84.22
Resonant Frequency	Fs	Hz	23.64	15%	Effective Cone diameter	D	cm	31.42
Mechanical Q Factor	Qms		6.26		Effective Piston Area	Sd	cm^2	775.4
Electrical Q Factor	Qes		0.5		Effective Volume	Vas	L	71.12
Total Q Factor	Qts		0.46		Motor Force Factor	BL	Tm	22.19
Ratio Fs/Qts	F	Fs/Qts	51.39		Motor Efficiency Factor	β	(T*M^2)/Ohms	159.35
Half Space Sensitivity @2.83V	db@2.83V/1M	dB	85.4	+/- 1.0db	Voice coil former Material	VCfm		GSV
Half Space Sensitivity @1W/1M	db@1W/1M	dB	82.86	+/- 1.0db	Voice coil inner diameter	VCd	mm	188
Gap Height	Gh	mm	36		Rated Noise Power	P	W	2200
Maximum Linear Excursion	Xmax	mm	10.5		Test Spectrum Bandwidth	20Hz-200Hz		
Ferrofluid Type	FF				Transducer Size	Inch	15	
Transducer Mass	Kg	25						



This speaker is optimized for very small enclosures. Sensitivity is very low (76.9dB/1W) and a powerful amplifier is needed for higher levels.

Net	Qtc	fc	Amp	Max SPL	Stroke	X-over	Power	Gain/Power
64.1L	0.67	34.33Hz	2600W	111.0dB	±10.5mm	80Hz	648.6W	2.8dB/1235W
52.2L	0.71	36.33Hz	3100W	111.8dB	±10.2mm	80Hz	755.7W	2.8dB/1440W
38.6L	0.78	40.0Hz	5000W	113.8dB	±10.7mm	80Hz	1112W	1.7dB/1650W

The Impedance is **4.46Ω**, a 4Ω amp will deliver 10% less power.

Crossover frequency 80Hz (impedance is rising).

This driver is ideal for Home Cinema or HiFi, but the extreme weight and low efficiency make it unsuitable for the road.

The PDF shows how to build an enclosure with braces and a basket holder from the back.

The **Audio-Wizard** can boost the low end to 15.9Hz when using the smallest box, reproducing even the Pipe-Organ.



Eminence LAB12 This driver reaches a low resonance with a very soft suspension (Cms) and not with a heavy cone (Mms) like the models before. This increases sensitivity.

89.2dB - 0.38dB - 6dB = 82.8dB/1W

800W Δ +29.0dB; max SPL= 111.8dB
 1200W Δ +30.8dB; max SPL= 113.6dB
 1600W Δ +32.0dB; max SPL= 114.8dB

The required cabinet is of medium size for a 12" woofer. Total dissipation to be kept **below 300W**, because of increased temperature in the enclosure.

THIELE & SMALL PARAMETERS*

Fs	22 Hz
Re	4.29 Ω
Le	1.48 mH
Qms	13.32
Qes	0.39
Qts	0.38
Vas	4.42 cu.ft., 125.2 liters
Vd	659 cc
Cms	0.35 mm/N
BL	15 T-M
Mms	146 grams
EBP	56
Xmax	13 mm
Sd	506.7 cm ²
Xlim	22 mm

Net	Qtc	fc	Amp	Max SPL	Stroke	X-over	Power	Gain/Power
50.9L	0.71	40.93Hz	800W	111.8dB	± 12.4 mm	80Hz	171.6W	+2dB 271.4W
36.5L	0.78	46.32Hz	1200W	113.6dB	± 11.9 mm	100Hz	253.0W	+0.5dB 296W
30.0L	0.86	50.0Hz	1600W	114.8dB	± 11.7 mm	125Hz	303.1W	/

SPL is limited by **excursion** or dissipation (<300W because of closed box).

Nominal Basket Diameter	12", 305 mm
Nominal Impedance*	6 Ω
Power Rating**	
Watts	400 W
Music Program	800 W
Resonance	22 Hz
Usable Frequency Range	25 Hz – 0.1 kHz
Sensitivity***	89.2 dB
Magnet Weight	160 oz.
Gap Height	0.375", 9.5 mm
Voice Coil Diameter	2.5", 64 mm

The **biggest case** is useful for PA, since 4-string Bass can be reproduced at full power. With our test-track Peak Amplitude 80Hz x-over is -2.87dB so we can add 2.0dB of channel gain increasing Total RMS Power from 171.6W to 271.4W max SPL to **113.8dB**.

The **medium cabinet** with 1200W amp will need some equalization for the higher Qtc, which can be combined with a fixed bass boost of 3dB to reach 39Hz. **113.6dB** max, PA capable, 1200W.

The **smallest enclosure** is ideal for Home Cinema in combination with the Audio-Wizard or DSP Crossover.

With -9dB of channel gain and 11dB of fixed bass-boost we reach 26.6Hz at 105.8dB SPL. The Wizard extends this to 20Hz at lower levels.



EQ-Assisted Sub-Woofer:

Another possibility is to take a high efficiency driver like 18" Feital [18XL1600](#) reaching **125.5dB** with 3200W. 373€

Attenuating channel gain by -12.5dB it still delivers 113dB and the additional power serves to boost the bass from 75Hz to 37Hz(f-3dB). Using +12.5dB SL12dB filter. Excursion limit is ±8mm at 36.6Hz 113dB.

The required enclosure net **40.8L** is tiny for an 18". It just fits around the speaker (inside 48x48x21cm).



TECHNICAL PARAMETERS

Nominal Impedance	8 Ω
Minimum Impedance	7.4 Ω
AES Power Handling (1)	1600 W
Maximum Power Handling (4)	3200 W
Sensitivity (1W/1m)	98 dB
Frequency Range	30÷1500 Hz
Voice Coil Diameter	100 mm (4 in)
Winding Material	Cu
Former Material	Glass Fiber
Winding Depth	31 mm (1.22 in)
Magnetic Gap Depth	15.5 mm (0.61 in)
Flux Density	1.05 T
Magnet	Neodymium Slug Crown
Basket Material	Aluminum
Demodulation	Triple Al Dem. Ring
Cone Surround (5)	Triple Roll
NET Air Volume filled by Loudspeaker	7.3 dm³ (0.258 ft³)
Spider Profile	2x non-adjacent symmetrical constant height waves

THIELE & SMALL PARAMETERS

Fs	32 Hz
Re	5.4 Ω
Qes	0.37
Qms	9.3
Qts	0.36
Vas	184.7 dm³ (6.52 ft³)
Sd	1124 cm² (174.2 in²)
Xmax (2)	12.9 mm
Xdamage (3)	28 mm
Mms	240 g
Bl	26.7 N/A
Le	1.45 mH
Mmd	217 g
Cms	0.1 mm/N
Rms	5.20 kg/s
η _L (Eta Zero)	1.61 %
EBP	86 Hz

With the before mentioned 12000W amp only 1834W can be pushed into the speaker (7.4Ω) and 123.64dB can be reached, channel gain=-10.6dB and bass boost 12.5dB: 36.6Hz 113dB.

The additional headroom for higher frequencies allows compensation for inductive loss and a x-over frequency of 500Hz and more.

Even lower frequency with the new [18XL2000](#).

There are many suitable woofers not as pricey as the models above but requiring larger cabinets.

Name	Dia	SPL @P	fu Q	Box	Gain	Stroke	Boost fu	fo
18XL2000 Feital	18"	127dB 4000W	67Hz 0.645	42.9L	-14dB 113dB	±12mm 4000W	+16dB 26.7Hz	700Hz 439€
18PWB1000 Beyma	18"	122.3dB 2000W	55.8Hz 0.78	97L	-9.3dB 113dB	±9mm 2000W	+11dB 29.6Hz	700Hz 345€
18LX60 Beyma	18"	123.5dB 1400W	66.1Hz 0.91	100L	-10.5dB 113dB	±7mm 1400W	+12dB 33Hz	400Hz 199€
LF21N451 RCF	21"	126.5dB 3000W	60Hz 0.52	125L	-13.5dB 113dB	±9.3mm 3000W	+15dB 25.3Hz	250Hz 469€

High Power Amplifiers:

With the advent of digital technology amps have become more powerful and affordable.

Important points to observe:

- The driver might have a lower value than the rated minimum impedance. This will cause instability or mute mode when operated at full power. To prevent this we can use a **Limiter** set at a lower level. If the driver has 6.4Ω and the amp 8Ω minimum load, threshold is set 2dB below +4dBu. This will for example reduce the maximal power from 4000W to 2560W. When the driver warms up and R_e increases we can gradually turn up the threshold accordingly.
- The music signal is dynamic and the Total RMS Power usually less than half of the peak value. If there is a continuous sine at maximum level caused by feedback or faulty operation the amp will eventually overheat and hopefully shut down.
- Cheap amps eventually create a lot of distortion(>1%) at peak levels. This is more relevant with treble speakers, since the sub-woofer has a higher distortion itself and our ears are not that sensitive for it in the bass.
- Set the input sensitivity and do not move the pots any more, better use an amp with fixed -4dBu input.

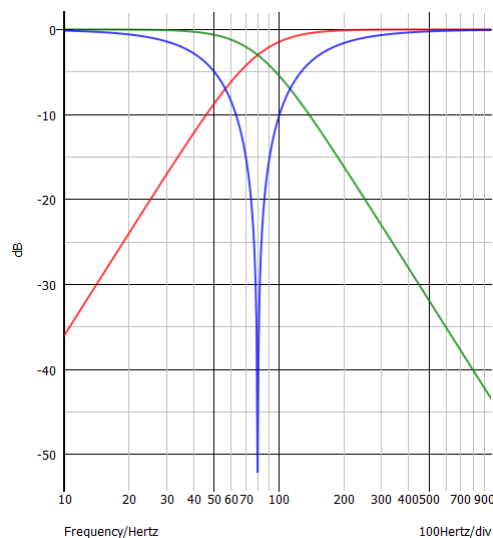
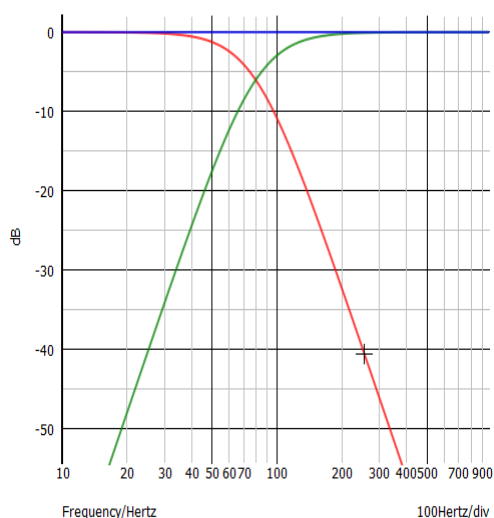
Name	2 Ω /peak	4 Ω /peak	8 Ω	Br 4 Ω	Br 8 Ω	~Price
EP4000 Behringer	2x1250W 2x2000W	2x950W 2x1400W	2x550W 2x750W	1x2400W 1x4000W	1x1750W 1x2800W	499\$
NX 4-6000 Behringer	4x1600W	4x840W	4x480W	2x3000W	2x1600W	549€
TSA 4-700 Thomann	4x930W	4x810W	4x490W	2x1800W	2x1600W	388€
NU12000 Behringer	2x6000W	2x3400W	2x1700W	-	-	569€
TSA 4-1300 Thomann	-	4x1670W	4x1220W	-	2x4000W	488€



Cross-Over Design:

A complex matter, many hobbyists have problems to understand phase and how several sources interact.

High-Pass 2nd order 80Hz Q=0.71 combined with **Low-Pass** 80Hz Q=0.71; the **resulting** output is not what was expected, because both filters shift the phase by 90° at 80Hz but in opposite direction and cancel each other.



A very suitable design is the 4th order **Linkwitz-Riley** (LR4) configuration consisting of two cascaded low- or high-pass filters with Q=0.71.

Both filters shift $\pm 180^\circ$ and have -6dB at 80Hz. They **combine** perfectly in the frequency domain, but cause an additional delay at lower frequencies.

Since the radiation of a speaker in a closed cabinet behaves like a high-pass of 2nd order, it can be **included** in the calculation.

The **Bass/Mid-driver** combined with a single high-pass has already the required characteristic. The Qts value can be corrected with a Filter between 0.5 and 1.5 if needed. List of Mid/Bass drivers:

Prices found at [Blue Aran](#), UK. Shipping not included

Name	Diam.	SPL	fc	Qtc	Box	Amp	fo	Stroke
8LW30 Beyma	8" 116€	112.9dB	100Hz 125Hz	0.53 0.66	15.3L 7.3L	500W	2.5kHz	±5.3mm ±3.5mm
10MW/Nd Beyma	10" 199€	113.7dB	100Hz	0.65	12.9L	700W	1.5kHz	±3.7mm
PA255 Dayton	10" 72.50€	113.1dB	80Hz 100Hz	0.97 1.21	27.2L 14.1L	600W	600Hz	±5.5mm ±3.5mm
10CL51 B&C	10" 88€	110.0dB	100Hz 125Hz	0.66 0.82	18.2L 9.9L	300W	2kHz	±2.7mm ±1.7mm
SM110N Beyma	10" 62€	111.5dB	80Hz 100Hz	0.65 0.81	26.4L 14.7L	400W	2kHz	±4.5mm ±2.9mm
SM112N Beyma	12" 108€	116.9dB	80Hz 100Hz	0.6 0.75	39.0L 22.3L	800W	1.5kHz	±5.4mm ±3.4mm

Conclusion:

Most modern sub-woofer drivers are designed for reflex or horn loaded enclosures with low Qts, usually not suitable for closed cabinets.

They reach **half an octave lower** with the same excursion and power than a closed box, but require much bigger enclosures and a steep low cut.

Commercial ready made units are all reflex constructions, since the data look better. Also many manufacturers measure half-room which gives a 6dB higher SPL value. Many speakers extend their linear excursion at those levels and produce high distortion.

With a DSP-powered cross-over and a powerful amp, high efficiency drivers can be used in incredibly small enclosures.

We are awarded with a clean sound and the ability to tailor the performance with filters only.

Great design,
better cooling,
better protection

[RV4504](#)



free software:

[AJ-Horn](#) easy to use,
very precise

Closed, Vented, Bandpass enclosures (Horn, TML: not free)

[REW](#) not so easy to use
measure Impedance, SPL, Distortion etc.