ACOUSTICS

Q SUB SERIES

WHITE PAPER

Introduction

There is a common understanding that the deep bass sound from a subwoofer is omni-directional, giving complete freedom of placement for a subwoofer in a listening room. To an extent this is true as, in isolation, the sound from a subwoofer is not directional.

However, in real audio systems the subwoofer is not the only speaker in the room and the integration of sound between the subwoofer and partnering speakers, particularly at their critical crossover point, is not just dependant on the level, phase and crossover filter settings provided on a traditional subwoofer design, it is also very much dependent on the relative positions of the subwoofer with these other speakers and on other electrical phase shifts that may occur in the main system and its speakers.

The problems are two-fold.

- If a subwoofer is placed closer to a listener than other system speakers, the sound from the subwoofer will arrive before the other speakers.

- The phase alignment between a subwoofer and other system speakers is not always true (in phase), even for a subwoofer placed alongside those speakers.

These two problems can cause poor integration between the main speakers and subwoofer, particularly at the critical crossover point, resulting in disturbance in the system frequency response.

The brief for the Q SUB range of subwoofers was to create a no-compromise, best-in-class range of subwoofers that address both these issues of system integration using the power of Digital Signal Processing (DSP), and in addition, to create an alignment process that would empower all owners to fully optimise these relatively complex settings and achieve the very best in performance in their own leisure rooms without enlisting the help of a skilled installer.

The range

The range comprises three subwoofers, the Q SUB80, Q SUB100 and Q SUB120.

The three models are constructed in the same format and with the same DSP equipped amplifier, but the drive unit and cabinet dimensions scale with model to suit individual applications. The DSP is optimised according to the performance requirement of each individual model.

In general terms:

The Q SUB80 is the perfect partner for active speakers such as the Q Acoustics M20 and M40, also the 3020c, and 5020 passive speakers.

The Q SUB100 is intended to partner all the above speakers plus Concept 30 and other mid-size stand mounted or passive speakers in stereo systems.

The Q SUB120 is ideal for the infra-bass Low Frequency Effect (LFE) sound effects of home-cinema systems or to partner any stereo speakers, including towers, in bigger rooms.

DSP features

DSP system integration controls

Digital signal processing in the Q SUB enables the adjustment of signal delay parameters unable to be realised with an analogue subwoofer amplifier design. Fine adjustment for signal delay coupled with a signal inversion phase switch are included, together with level and frequency alignments. This comprehensive set of alignments provides complete flexibility to integrate the subwoofer with the main speakers at the critical crossover point and minimise any peaks or troughs that may otherwise unbalance the system frequency response.

The Q SUB alignment control set is shown in Figure 1.

Alignment accuracy

The Q SUB range addresses a common issue with subwoofers which is accuracy of alignment. Traditionally, subwoofer setup is either:

- Easy to set up with minimal alignment controls, but unable to fully integrate with the room and system speakers.
- Fully integrates with more complex, but confusing alignment controls, and therefore difficult to set up accurately for an untrained owner.

The solution for Q SUB is achieved through a comprehensive set of alignment settings and a step by step alignment sequence to configure the subwoofer for best integration with the main speakers.

The first step in the sequence sets all controls to starting positions. Then, using music content with good bass strength, adjusting each control in a particular sequence while listening for described changes in the audio performance. For most audio systems, repeating this sequence once will often complete the process for all alignment settings.

Figure 1

DSP features (continued)

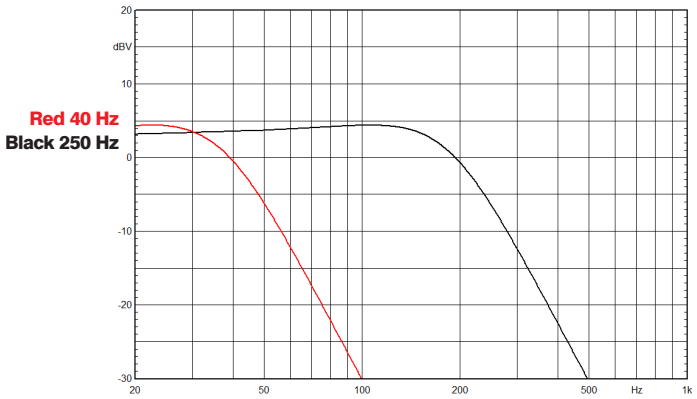
Frequency response adjustment

A necessary feature of all subwoofers is an adjustable low pass filter to enable the upper frequency response of the subwoofer to be tailored to best reinforce the diminishing bass response of the other system speakers.

In the case of the Q SUB range, the low pass filter includes frequency adjustment that sets the -6 dB point of the filter to a value between approximately 40 Hz and 250 Hz. This relatively wide range ensures that the Q SUB will always have enough bandwidth to match the low frequency response of the partnering speaker system.

The amplifier frequency response at the extremes of adjustment is shown in Figure 2.

Figure 2



Amplifier frequency response

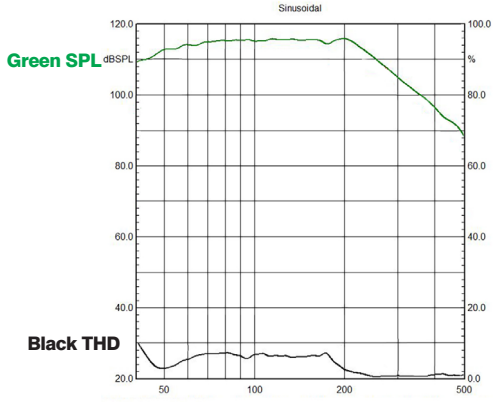
Limiter profiles

Limiter profiles are implemented in subwoofers to protect the drive unit, ensuring that the subwoofer can be driven close to the envelope of its mechanical limits, but without over-stressing the drive unit.

The DSP configuration of each Q SUB model includes a limiter profile designed to meet the requirements for that particular model, with the Q SUB80 featuring a dual limiter.

Figure 3 shows the maximum sound pressure level (SPL) at limiter threshold, measured at a distance of 1m, resulting in <10% total harmonic distortion (THD) from 40Hz.

Figure 3



Sound Pressure Level and Distortion

Channel detection

Subwoofers are unique in the field of speakers, with the need to match a broad range of different sound input sources. For example, the two channel left and right preamplifier outputs of a stereo system or the single channel feed from an active speaker or LFE channel of a home cinema system. The Q SUB range employs the DSP to read the incoming input signal(s) and determine if the signal feed is from a two channel stereo or single channel mono source. The system gain is then automatically adjusted to compensate for the presence or absence of a second audio channel. This optimises signal levels within the DSP, achieving the best dynamic range for any connected source.

Amplifier design

Power amplifier topology

The Q SUB amplifier is a bespoke Q Acoustics design including the stand-alone DSP, power amplifier and power supply.

The amplifier features four digital power amplifier stages in a parallel bridge-tied load (PBTL) configuration. A basic bridge-tied load (BTL) arrangement uses dual amplifiers driving the two terminals of the speaker as a 'balanced' load. Amongst other benefits this removes the requirement for a large coupling capacitor between the amplifier and speaker. PBTL adds two more amplifier stages in parallel with those from the basic BTL configuration, reducing output impedance which will improve the control that the amplifier has over the speaker and improve efficiency by dissipating less heat.

Figure 4 shows block diagrams of BTL and PBTL amplifier configurations.

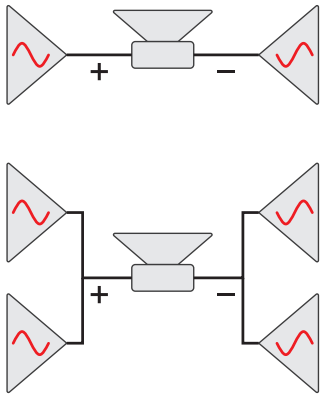


Figure 4

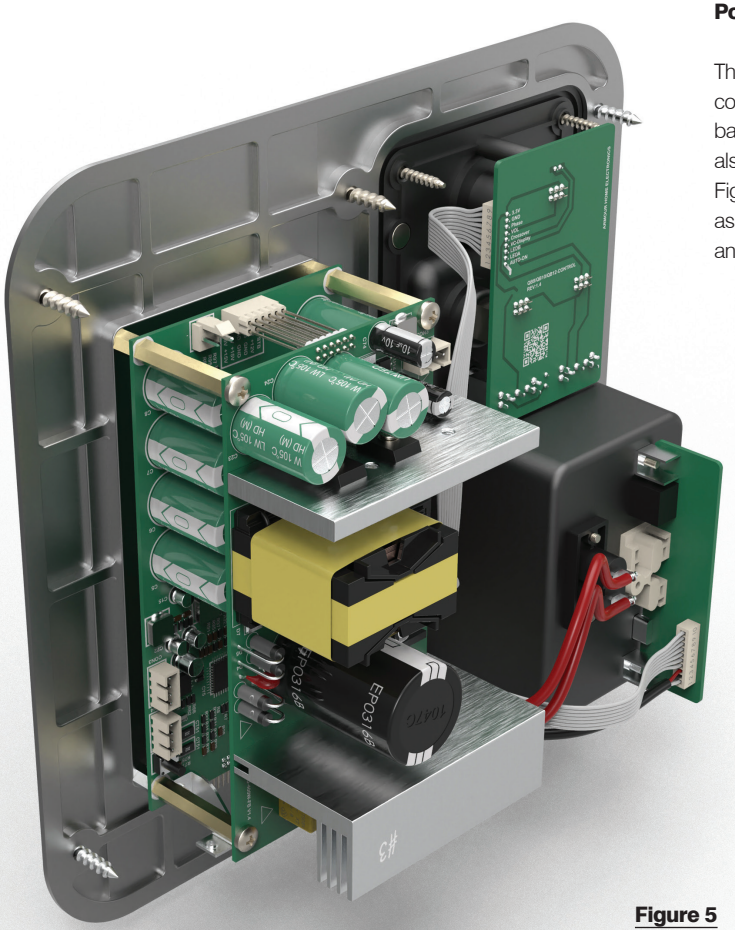


Figure 5

Power amplifier construction

The power amplifier chassis is a robust die-cast component which provides a rigid, low resonance base for the amplifier electronics and control panel and also essential heatsinking for the power amplifier. Figure 5 shows an inside view of this chassis, assembled with the amplifier and power supply PCBs and the control panel.

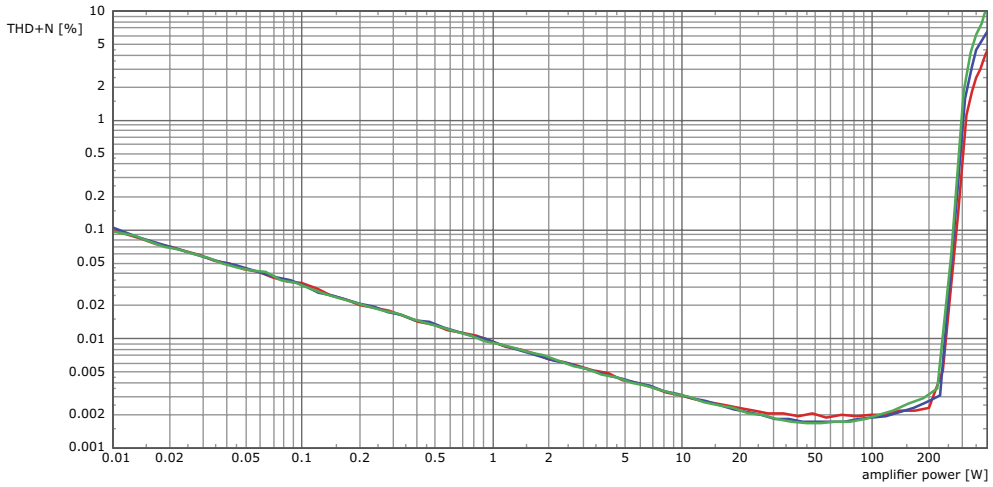
Amplifier design (continued)

Power output and distortion

The amplifier can effortlessly deliver up to 300W continuously and 600 W peak into the speaker load.

THD performance is exceptional for a digital design at <0.1% up to 300 W. Figure 6 shows THD+N performance vs power output (4 ohm resistive load) at frequencies of 50 Hz, 100 Hz and 150 Hz.

Figure 6



Red 40 Hz
Blue 100 Hz
Green 150 Hz

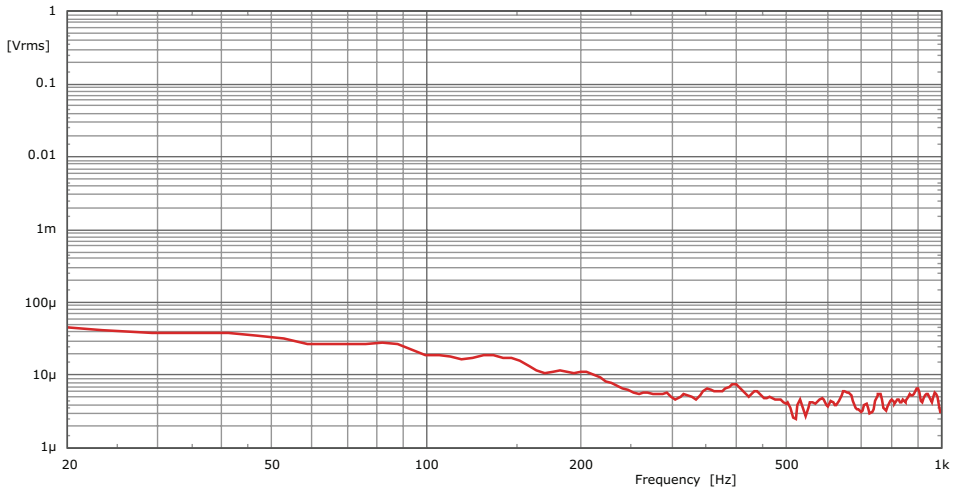
Amplifier Power Output vs THD+N

Noise floor

Internal signal routing from the DSP, through the power amplifier, to the speaker is balanced at all times to minimise any ground or power supply interaction with the signal. This contributes to a particularly low noise floor of 50 μV.

Figure 7 shows an FFT plot of the amplifier noise floor. Here it can be seen that all noise artefacts are below the 50μV level.

Figure 7



Amplifier Noise FFT

Amplifier design (continued)

Power supply

A substantial power supply feeds the power amplifier via a huge bank of reservoir capacitors, placed close to the amplifier. A secondary, low-consumption power supply drives only the system management circuitry to keep power consumption during standby mode to an absolute minimum.

Standby modes

The Q SUB amplifier includes a comprehensive range of operational modes, selectable to cover all system requirements.

- Auto-detection
  For most systems, auto detection will be the preferred option, quickly powering the Q SUB into action when an input signal is detected. In this mode the Q SUB will revert to standby to save power if no signal is detected within a 20 minute period.
- 12V trigger
  A 12V trigger input is included via the industry standard 3.5 mm mini-jack connector. For systems that include a 12V trigger feed, the Q SUB will power up when the trigger signal is detected.
- Always powered
  If preferred, the Q SUB can be manually set to a permanently powered state.

Protection

An intelligent protection system constantly monitors the electronics to ensure that the amplifier and power supply are fully protected in the unlikely event of excesses of temperature.

Control cover and cable management

A cover can be fitted to conceal all alignment controls and cable connections with the exception of the level control. This ensures that in use there will be no accidental change to room alignment settings.

Cable connections to the Q SUB are also hidden beneath the cover for a cleaner appearance in locations where the control panel is visible.

Drive unit

Drive unit construction

The drive units are constructed on a heavy-duty steel chassis, with a paper cone and rubber edge surround.

Bass unit diameters are:
203 mm (Q SUB80)
254 mm (Q SUB100)
305 mm (Q SUB120)

The powerful motors utilise substantial ferrite magnets:
110 mm x 24 mm (Q SUB80)
120 mm x 24 mm (Q SUB100)
140 mm x 30 mm (Q SUB120)

and voice coils of 39 mm diameter for Q SUB80 and Q SUB100, and 50 mm diameter for the Q SUB120.

To complete the design, an aluminium demodulation ring is mounted underneath the pole-plate for reduced inductance-induced modulation distortion.

Figure 8 shows a section view of the Q SUB100 drive unit.

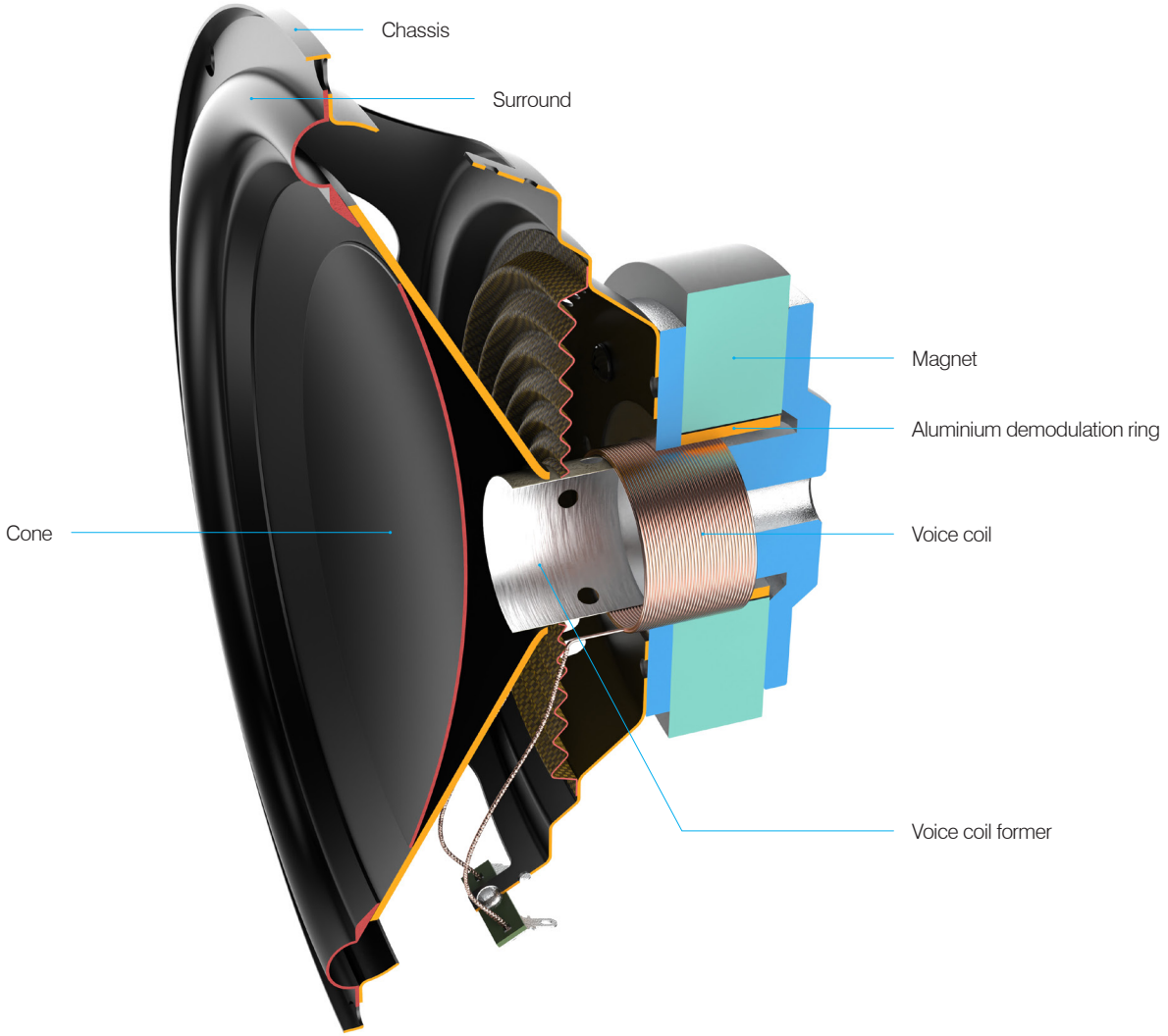


Figure 8

Drive unit (continued)

Drive unit performance

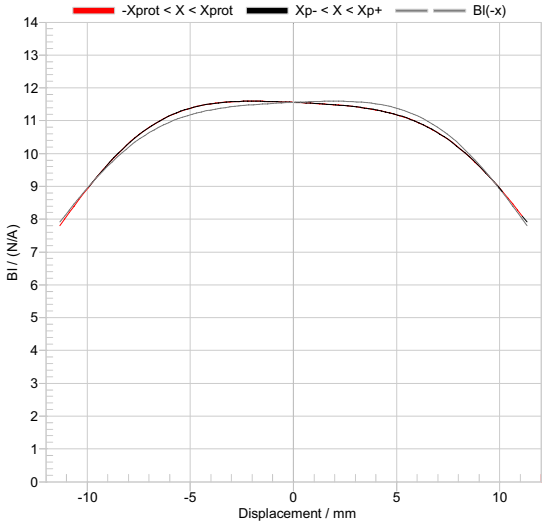
The symmetric shape of the measured Bl(x) and Kms(x) graphs for the drive unit (254 mm driver from the Q SUB100 in this example) are shown in Figures 9 and 10 The symmetry of these curves assures: low harmonic distortion at low frequencies and high excursions and a well defined rest-position for the voice-coil.

Linearising the inductance variation with voice coil displacement will also bring benefits in the distortion performance of the drive unit.

To achieve this, an aluminium demodulation ring was added underneath the pole-plate and its height and thickness optimised for best linearity. This measure reduces eddy-current related modulation distortion induced by the current in the voice-coil.

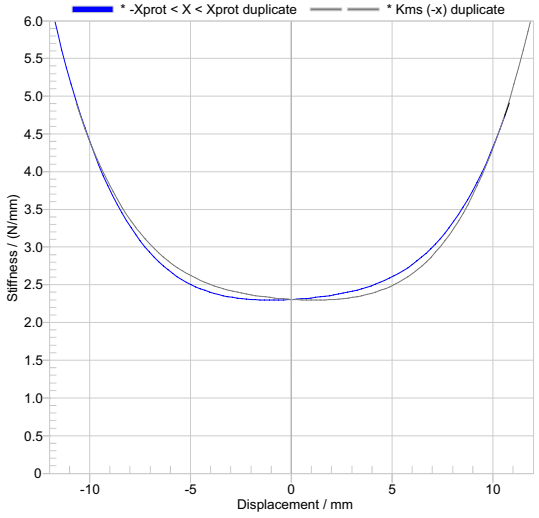
In Figure 11 a comparison is shown of the performance of an un-compensated drive unit with a drive unit that includes the above measures to improve linearity.

Figure 9



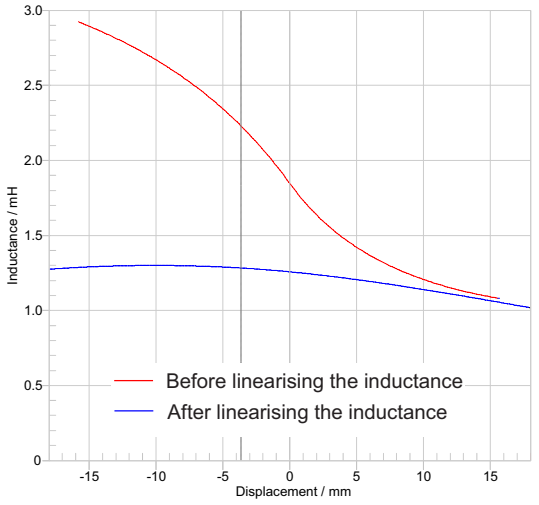
Bl(x) Force Factor

Figure 10



Kms(x) Stiffness of Suspension

Figure 11



L(x,i=0) Electrical Inductance

Cabinet

Cabinet design

An infinite baffle (sealed box) design is ideal for a subwoofer. Acoustically, this will present a tighter and more focussed bass response, and coupled with the DSP allows for very precise tuning to achieve the best acoustic response possible.

With no port to accommodate, the subwoofer is also easier to place in proximity to walls, corners and furniture than a ported design.

Cabinet volume

The cabinet volumes range from 13.9 litres for the Q SUB80 and 23.5 litres for the Q SUB100 to 44.1 litres for the Q SUB120.

Cabinet finish

The Q SUB series is available in two durable, high quality finishes - satin black with a black grille or satin white with a grey grille as shown in Figure 12.

Cabinet construction

The cabinets are constructed from heavy duty 18mm high density MDF, with a massive, double-thickness, 36mm baffle to provide extra rigidity for mounting the drive unit.

Dart bracing is employed internally in all models to create a stiff mechanical grounding structure and mounting for the drive unit.

A sealed enclosure is provided for the amplifier to eliminate the opportunity for air to leak through the amplifier mountings or controls.

Substantial grilles, constructed from 15mm MDF, are fixed securely to the front of the cabinet to eliminate any opportunity for buzzes and rattles to occur between the grille/cabinet interface.

Figure 12

Dart bracing

Dart brace purpose

The ‘dart brace’ provides high axial stiffness directly to the motor system, effectively providing a mechanical ground to the drive unit.

The load is spread to all faces of the cabinet which also rigidly constrains the enclosure walls effectively over the subwoofer’s operating bandwidth.

The ‘dart brace’ not only gives superior mechanical stability to the drive unit over unbraced systems, that can otherwise result in drive unit ‘bounce’ on the mounting fixtures and baffle, but also reduces the ‘ballooning’ effect of the cabinet, critical for subwoofers that inherently contain high internal acoustic pressure.

A section view through the bracing can be seen in Figure 13.

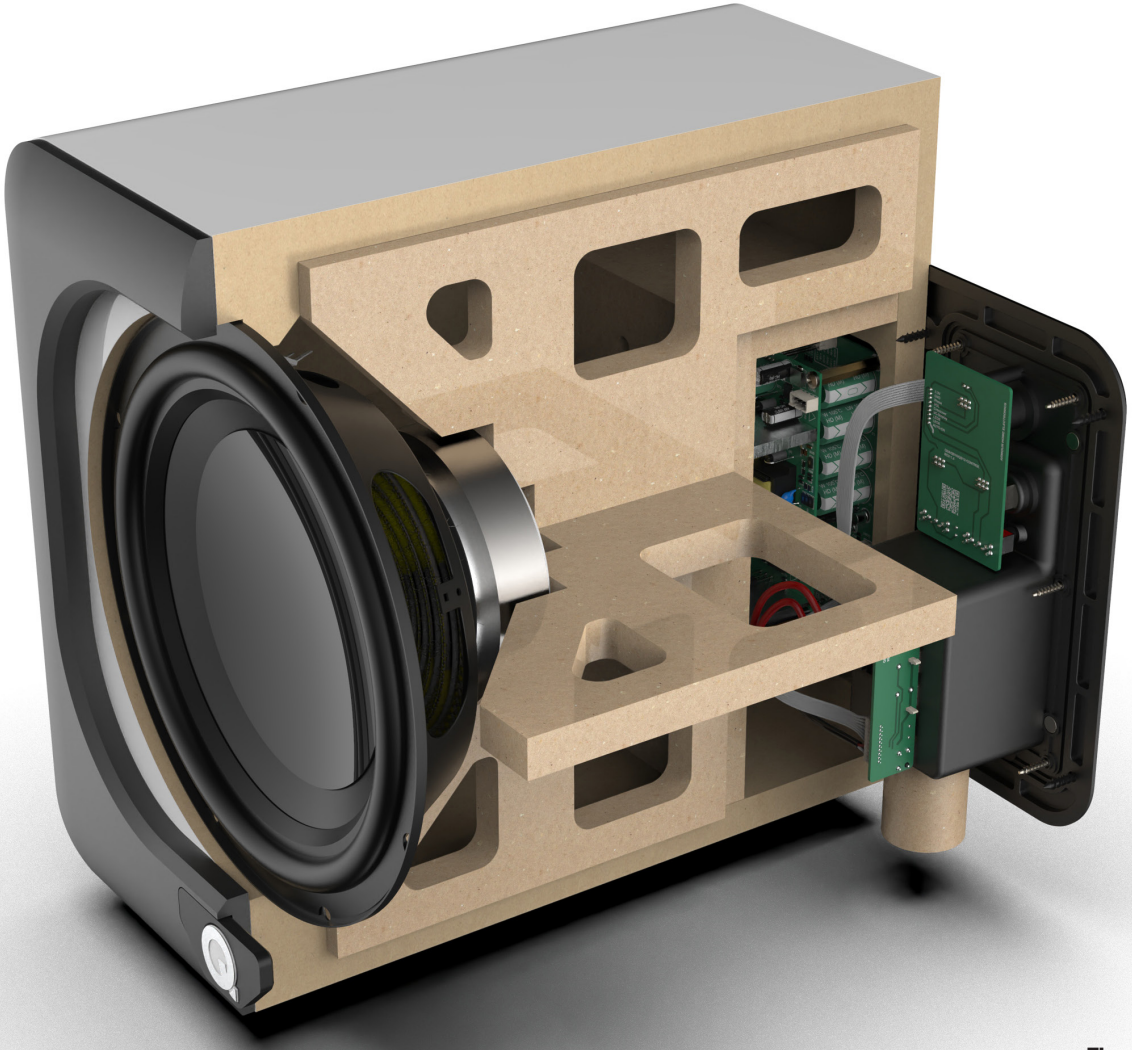


Figure 13

Dart bracing (continued)

Dart brace 'colour-map' simulation

The benefits of the dart brace can be clearly seen in the simulation in Figure 14 which shows the deformation of a Q SUB100 cabinet without dart bracing. Where displacement is greatest the area is coloured towards the red end of the spectrum and where it is least it is coloured towards the blue end.

When the simulation is repeated on an enclosure with dart bracing, shown in Figure 15, the deformation maps show how effectively the cabinet resonances have been reduced.

Dart brace displacement magnitude analysis

The benefits of the dart brace can also be analysed as a displacement magnitude plot where the displacements of all cabinet surfaces are integrated and plotted against frequency.

Figure 16 shows the plot of an un-braced Q SUB100 cabinet at approximately 190Hz. An out of band structural resonance at 250Hz can also be seen.

Figure 17 shows the same analysis of a cabinet that includes dart bracing. Note that the in-band 190Hz mode has been suppressed.

Figure 14

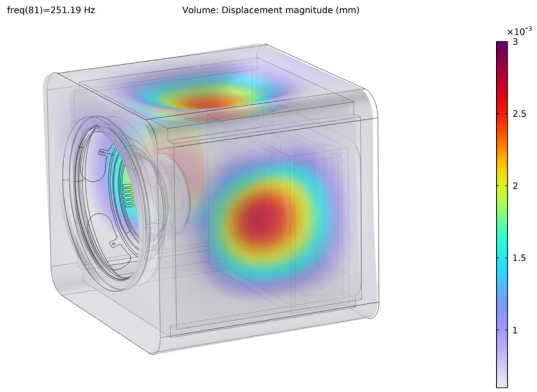


Figure 15

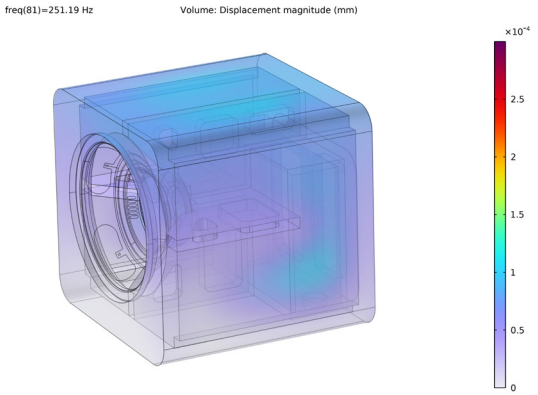


Figure 16

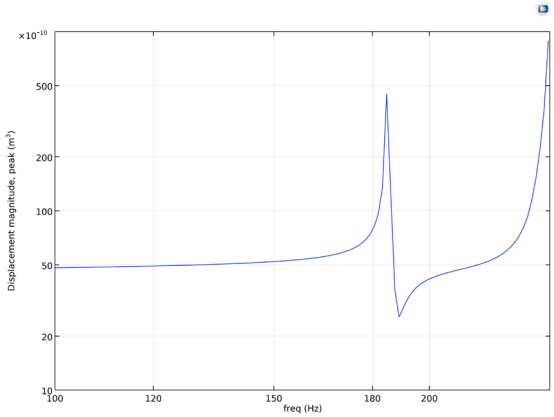
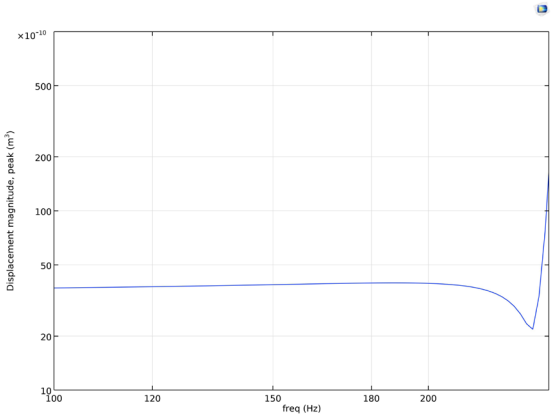


Figure 17



Accessories & cables

The Q SUB range is supplied with adjustable, locking spikes to level the cabinet and provide a good acoustic 'ground' to the floor surface. Spike cups are also supplied to use with sensitive floor covering.

Choice of interconnect cables is critical when connecting a subwoofer to ensure hum pickup is minimal, especially in longer lengths. Whilst not supplied, Q Acoustics recommend subwoofer interconnects from QED, available in a range of lengths, for the best performance in this regard.

qed.co.uk

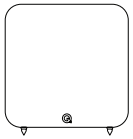
Conclusion

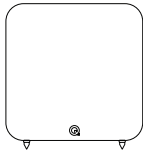
The Q Acoustics Q SUB range of active subwoofers marks a significant stride forward from the traditional concept of placing a large bass driver in a box and powering that with an amplifier.

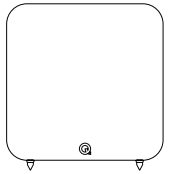
The inclusion of a DSP for this range brings the opportunity to add alignment features that enable excellent integration between the Q SUB and any speaker system. Less obviously, the advanced limiter techniques and attention to detail in the cabinet design squeeze the last ounce of acoustic performance from these subwoofers without any risk of over-driving them.

In conclusion, the original design brief for the range has been met and exceeded, with the size and performance of the different models in the range meeting the requirements of a broad range of system scenarios.

Specifications







	Q SUB80	Q SUB100	Q SUB120
Enclosure type	Infinite baffle	Infinite baffle	Infinite baffle
Bass unit diameter	203 mm (8 in)	254 mm (10 in)	305 mm (12 in)
Effective volume	13.9 litres	23.5 litres	44.1 litres
Max SPL @ 1 m	107 dB	111 dB	114 dB
Frequency response (-6dB)	36 Hz – 250 Hz	32 Hz – 250 Hz	28 Hz – 250 Hz
Low pass crossover range	50 Hz – 250 Hz	40 Hz – 250 Hz	40 Hz – 250 Hz
Peak amplifier power	400 W	500 W	600 W
Continuous amplifier power	200 W	250 W	300 W
THD @ rated power	0.09%	0.09%	0.09%
Input sensitivity (max gain)	300 mv rms	300 mv rms	300 mv rms
Maximum input level	2.1 V rms	2.1 V rms	2.1 V rms
Input impedance	20 kΩ	20 kΩ	20 kΩ
Noise floor (A wtd)	50 μV	50 μV	50 μV
Dimensions (HxWxD)	315 x 315 x 347 mm (12.4 x 12.4 13.6 in)	350 x 350 x382 mm (13.7 x 13.7 x 15 in)	400 x 400 x 432 mm (15.7 x 15.7 x 17.0 in)
Weight (per loudspeaker)	15 kg (33 lbs)	16.7 kg (36.8 lbs)	22.5 kg (49.6 lbs)