HiFi World: How we measure loudspeakers.
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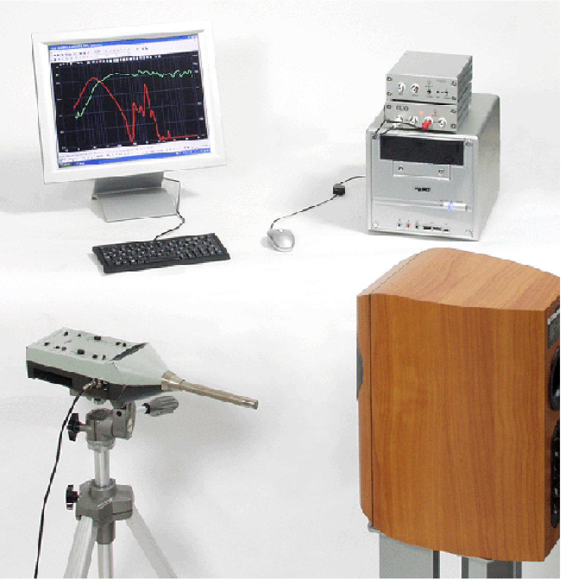
TESTING LOUDSPEAKERS

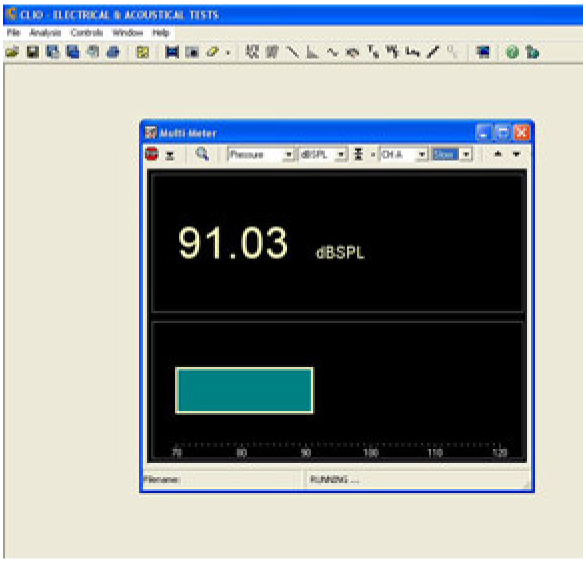


We measure the performance of loudspeakers comprehensively using, as far as possible, conventional industry methods. Our aim is to produce data that is accepted by large, well equipped manufacturers as representative of their product's performance, and also not be misleading to our readers.

We discuss testing and design with engineers from around the world, when we visit them and they visit us. There is wide understanding of our measurements as a result, and confidence in their efficacy. Many senior design engineers have visited our facilities and watched testing carried out first hand (and looked in awe at all the data our measurement computer carries on hundreds of their competitors products!).

Tests are carried out in a 28ft square concrete room, with a basic mode at 24Hz. Most tests are made using the popular Clio measurement system, from Audiomatica of Italy, housed in a dedicated, transportable Shuttle computer. Measuring microphones are Bruel and Kjaer 2230 Precision Integrating SPL meter with Type 4189 capsule, and Clio measuring microphone.

Sensitività (sensibilità)



WHAT IT TELLS US

Sensitivity tells us how loud a loudspeaker will go, given a certain amount of power (i.e. at a particular volume setting). So, set the volume control to 4, let's say, and a 90dB loudspeaker will go very loud, whilst an 82dB loudspeaker will be appreciably quieter.

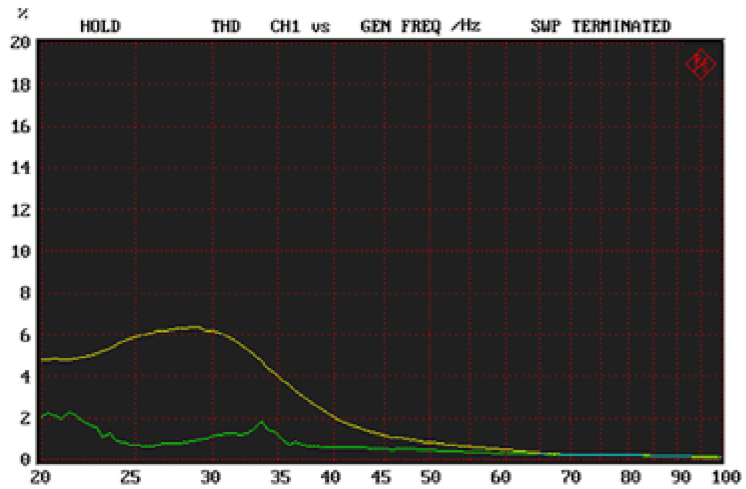
High **sensitivity** is a good thing. Sensitive loudspeakers need little amplifier power and usually sound fast and clean (there are good reasons for this).

What may surprise you is that small loudspeakers are insensitive whilst large ones are very sensitive. A small bookshelf loudspeaker will typically produce 82dB from one watt, for example, whilst a giant Tannoy will produce 95dB sound pressure level from one watt.

HOW WE MEASURE IT

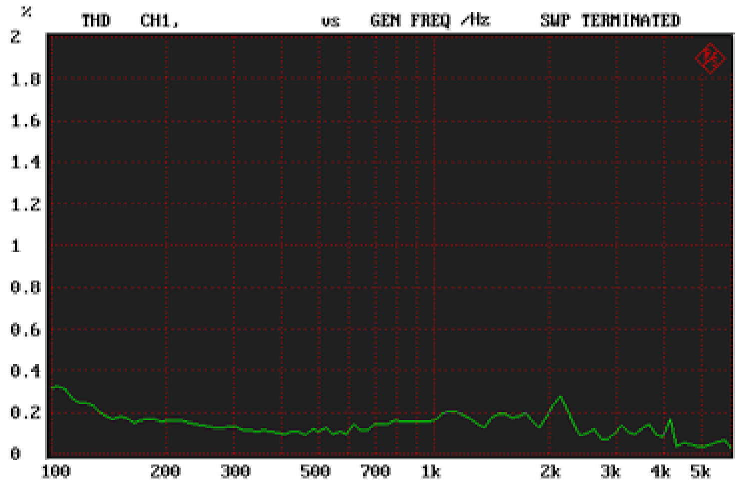
We measure the sound pressure level (SPL) at one metre from the loudspeaker, whilst injecting one nominal watt (2.8V) of pink noise into it, measured using an rms meter. This is a voltage **sensitivity** value (across a nominal 8 Ohms), not a true efficiency measurement, where a true watt would be injected (but that can be re-calculated from the figures using 2.8V and our measured impedance value). It provides a useful guide to how much 'power' (voltage) will be needed by a loudspeaker. An 82dB sensitive loudspeaker will need a powerful amplifier (at least 60W) for decent volume levels; a 92dB sensitive loudspeaker will need around 20W or less.

Distortion



Close

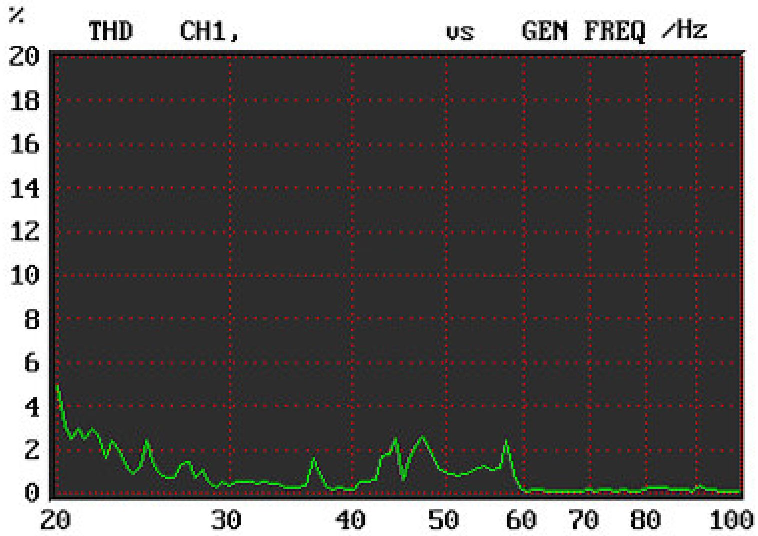
Bass distortion (Epos Encore 50 loudspeaker)
Green - bass unit. Yellow - port.



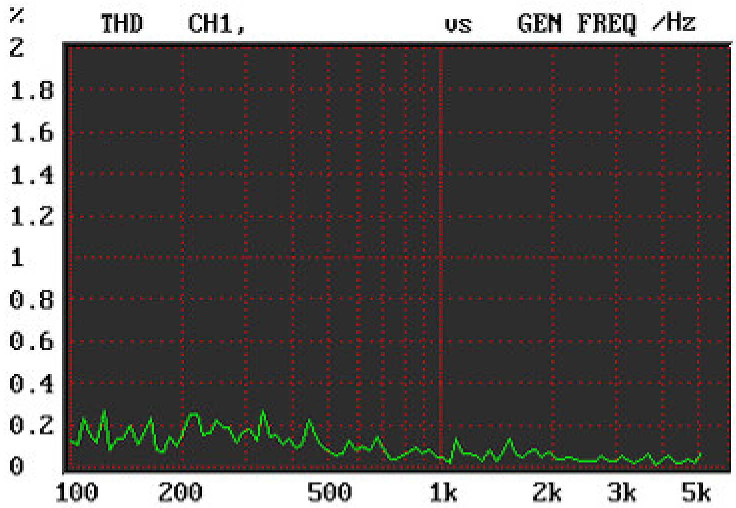
Mid-band distortion (Epos Encore 50 loudspeaker).

WHAT IT TELLS US

Superficially, a **distortion** measurement tells us how clean and free of the 'coarseness' of **distortion** a loudspeaker will be. However, with loudspeakers the picture is a little complicated. Generally, except at bass frequencies below 100Hz, **distortion** hovers around 0.3% (see the analysis above) and comprises second and third harmonics. This is a subjectively benign characteristic, meaning**distortion** is, seemingly, not a major issue in loudspeaker sound quality. Except that electrostatics typically give less than 0.1% **distortion** and measure better in this area our results show, suggesting **distortion** even at these levels may be of consequence. It is not a major factor in sound quality though.



Bass distortion (Kingsound Prince II electrostatic).



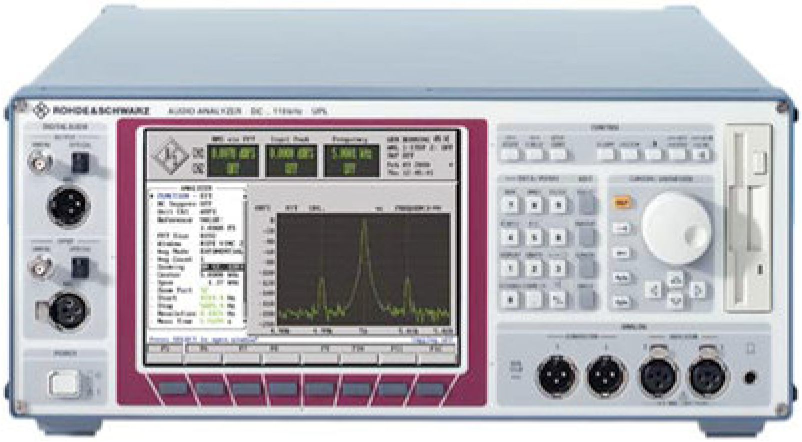
Mid-band distortion (Kingsound Prince II electrostatic).

The Epos Encore 50, whose **distortion** performance we show at top is a modern floorstander that works well and gives representative result against which other loudspeakers can be judged when reading our reviews. Just bear in mind the Encore 50 is large, expensive and has plenty of cone area. A small budget loudspeaker will inevitably produce more bass **distortion**, around 4% at least.

It is common for peaks of a few percent to exist here and there across the frequency band of our swept **distortion** measurements, usually due to mechanical effects, loosely termed “rub & buzz” (there is a proper measurement for this). Correlating peaks with perceived sound quality, in the absence of obvious buzz for example, has proved difficult in our listening tests, unless the **distortion** is severe.

Distortion rises at bass frequencies, often to 10% or so, and even to 20%. Ports commonly distort more than drive units. Much of this is what is known as ‘bass doubling’ and comprises second harmonic that, when severe (10% or more), subjectively lightens timbre slightly by transferring energy from the fundamental and into the second harmonic. However, large cone loudspeakers (12in and 15in bass drivers) consistently produce less bass **distortion**, often below 1%, than normal size domestic loudspeakers (3%), so this may well be a measure of that “relaxed” bass quality attributed to large loudspeakers. Certainly, low bass**distortion** is no bad thing and around 3% or less from the bass unit and 5% or less from the port, at 40Hz, is to be hoped for.

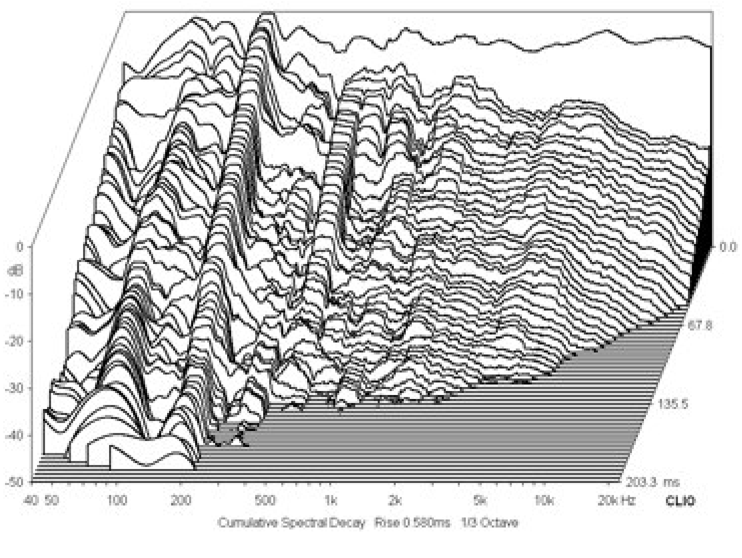
HOW WE MEASURE IT

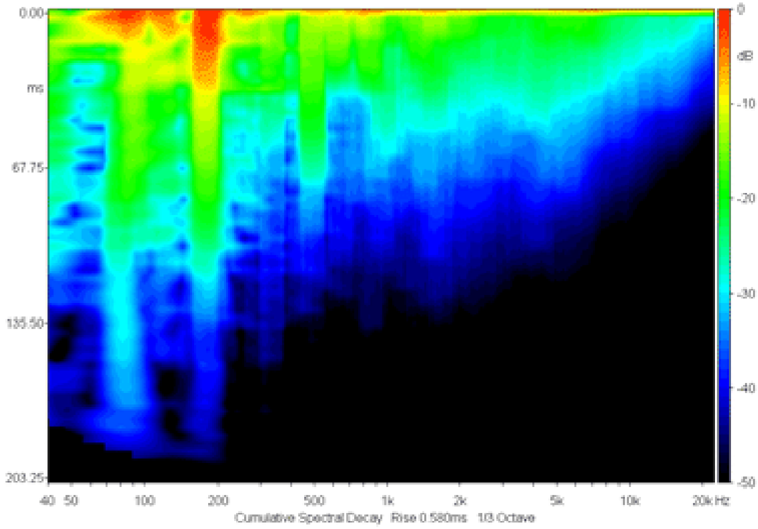


Rohde & Schwarz UPL distortion analyser.

In a room **distortion** must be measured ‘near field’, the mic positioned within millimetres of the cone, to avoid standing waves which severely disrupt results. This methodology relates **distortion** to specific drive units; for system response an anechoic chamber must be used. We measure at a modest sound pressure level of 90dB at 1m, which translates to 110dB at the cone. Our Rohde & Schwarz UPL analyser is stepped over 100 points from 20Hz to 100Hz, measuring bass unit then port, and from 100Hz to 6kHz, measuring bass/mid unit or midrange unit. As most bass/mids and mids cut off progressively above 3kHz, little is to be expected above this frequency. Our plots show true relative **distortion** in percent, rather than showing harmonic level relative to the frequency response curve (as in Clio, etc), and thus give a very clear picture of **distortion** trends and loudspeaker behaviour in this area.

Waterfall





Decay spectrum and colour contoured map of Waterfall 'Victoria Evo' glass cabinet loudspeaker.

WHAT IT TELLS US

The idea behind this measurement is to fire a short signal at a loudspeaker and see what emerges when it stops. Ideally, there should be nothing. In practice, energy bouncing around inside the cabinet and stored in mechanical reactance within resonant systems dissipates, out through the cone(s) and cabinet walls and port, producing a decaying signal. This isn’t wanted, as it muddies the sound and colours it.

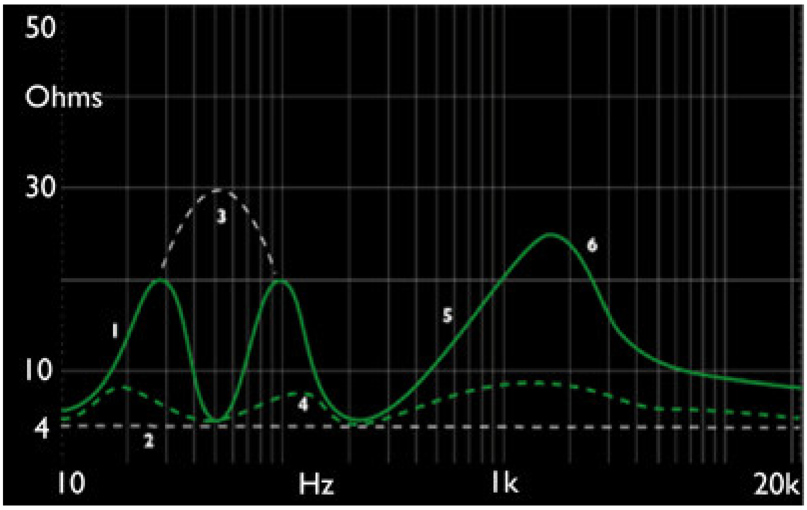
Measurement of spectral decay (waterfall plot) produces a large amount of complex data in a pretty picture that looks impressive but is difficult to interpret. Unlike frequency response there is no agreed and commonly used methodology behind this measurement. We use this test to look at perceptibly obvious colouration, such as box ‘boof’, rather than the intrinsic character of a drive unit, for example. Consequently we use a decay time outside the 20-30mS boundary between intrinsic colour and a divorced echo or colouration, such as box 'boof’. At present, after experiment across a large sample of loudspeakers under test for review, we use 200mS for a useful picture. For similar reasons International Audio Group (Quad, Mission, Wharfedale, Castle and Leak brands) use 500mS (half a second) decay time. Many published waterfall decay plots, however, show a short time window of 20mS or less, inside the Intrinsic / Divorced boundary. These attempt to reveal intrinsic drive unit colouration and are not comparable to our data.

Ideally, there will be no time delayed information but in practice long decays, seen as ranges of descending hills, exist and are evidence of colouration. The undamped glass cabinet of Waterfall's Victoria Evo loudspeaker (above) clearly illustrates this. Often, a colouration seen in this plot can be linked to a small perturbation in our green frequency response plot, and greater disturbance in our red port plot,indicating a strong internal box mode exists. This not uncommon phenomenon, revealed by a spectral decay plot, can be heard as slight chestiness and boxy colour to deep male speech on the radio, where live talk direct to the microphone provides a stringent real life test signal. So spectral decay analysis can be useful, especially when it helps identify a problem seen less obviously within other measurements.

HOW WE MEASURE IT

We fire a test signal known as a ‘log chirp’ (short, fast gliding sine wave burst) through the loudspeaker, as this gives strong low frequency excitation and good signal-to-noise ratio (unlike mls noise). Decay over 200mS (0.2sec) afterward is analysed, depicted as a waterfall plot and as a contour-coloured map. The latter looks at the waterfall from above and uses colour to identify different levels, much like an Ordnance Survey map. Correlation between the two display methods is shown clearly, where the 'hills' in the waterfall are seen as streaks of colour in the contoured map. Highest levels are Red (hot) and Lowest are Blue (cold), running through the colour spectrum between. This is visually easily assimilated and quite powerful once understood. The data is referred to, but not published in the magazine, to save space.

Impedance



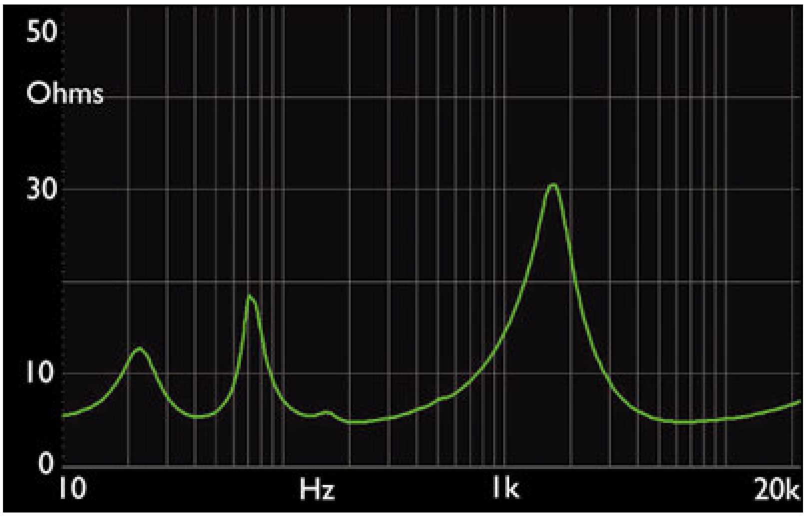
Impedance graph of reflex (ported) loudspeaker - solid green line (1).

Broken lines show -
2 - D.C. resistance, commonly 4 Ohms. This is also the minimum **impedance**, and an ideal **impedance** characteristic.
3 - bass resonance of closed box (no port) loudspeaker.
4 - almost ideal **impedance**, with low peaks.
5 - midband **impedance** rise caused by bass inductor in crossover.
6 - fall in **impedance** above 2kHz due to high pass section in crossover and tweeter.

WHAT IT TELLS US
This graph shows change of **impedance** with frequency, and is a more detailed look at how the loudspeaker behaves as a load on an amplifier. Because a loudspeaker's acoustic behaviour reflects back into the load it also shows how the loudspeaker is behaving, especially at low frequencies where the acoustic load is high. This is why we publish the **impedance** graph, it says a lot, but it does need interpretation.

Ideally, the green trace should be smooth and horizontal, and at 4 Ohm on the left vertical scale for a 4 Ohm loudspeaker (see broken line 2), 6 Ohms for a 6 Ohm loudspeaker, etc. If **impedance** were flat like this the loudspeaker would be 'ideal' as far as an amplifier is concerned, so flatness is what we are looking for.

In practice most **impedance** plots look like a series of hills and dales, our solid green trace showing a typical two way reflex design. Compare this with a real two-way like the Q Acoustics 2050 below. The hills and dales can be explained, at least in basic outline. Bass resonance (3) is opposed by the anti-resonant system of the port, which introduces a dip at either side of which lie residual peaks. These sudden and steep changes of **impedance** indicate high values of reactance (energy storage) and are unwanted. The common rise in **impedance** above 200Hz is due to the bass inductor and low pass network to the bass unit, not the voice coil, Spice analysis shows The sudden drop in **impedance** above 2kHz is caused by the high pass section feeding the tweeter.



Q Acoustics 2050 impedance graph.

It is possible to flatten the **impedance** curve of a loudspeaker by using equalising Zobel networks across drive units and cleverly adapted bass loading techniques, like stagger tuned chambers, resistive ports etc, but at present loudspeaker designers don't appreciate the importance of this, so ignore it. Amplifier feedback networks can be affected by excessive reactance and the V/I phase shift it produces at high frequencies. At low frequencies excessive reactance can upset the sensing systems of protection circuits, causing them to 'chatter'. So what the**impedance** graph has to say about the loudspeaker's design sophistication and efficacy as a load is far ranging.

HOW WE MEASURE IT
Our measurement system is calibrated with an 8 Ohm resistor first and a gated sine wave measurement signal is stepped downward in frequency to slowly but accurately capture sharp **impedance** changes. The result is checked with a slow gliding tone test and, where high rates of change exist, with mls noise.

IMPEDANCE VALUE
(modulus of **impedance**; we call it 'overall **impedance**'.)

WHAT IT TELLS US
The **impedance** of a loudspeaker is its rating as a load. Traditionally, the U.K. has used 8 Ohm loudspeakers, the USA 4 Ohms. Nowadays, manufacturers are settling on 6 Ohms. A 4 Ohm loudspeaker draws twice as much power from an amplifier as an 8 Ohm, at any given volume setting, so it will sound appreciably (3dB) louder. Modern transistor amplifiers can drive 4 Ohms with ease, although distortion rises a little in most cases. However, **impedance** varies with frequency and 6 Ohm loudspeakers actually use 4 Ohm bass units. Since most power is delivered at bass frequencies this is the load the amplifier sees (our **impedance**graph tells more about this).

Loudspeakers with a 4 Ohm **impedance** value are fine providing their minimum value does not sink much lower. If it does current limiting protection circuits may trigger, causing relay chatter, as volume is turned up. Loudspeakers with an**impedance** higher than 8 Ohms need a powerful amplifier to go loud. They do not utilise the power available from an amplifier and waste its potential.

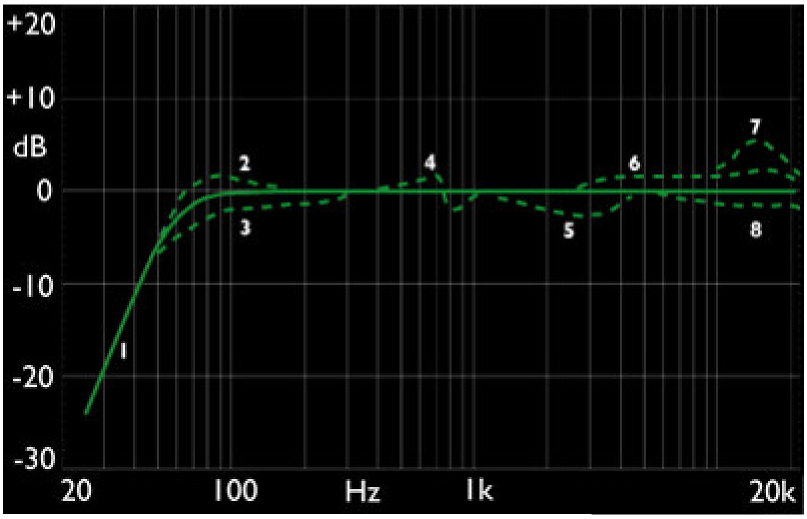
HOW WE MEASURE IT
We inject 2.8V rms of pink noise applied for sensitivity measurement and measure true rms a.c. current flowing into the loudspeaker, calculating an**impedance** value from the two. This should - and does - compare sensibly with the graph of **impedance** we also publish.

DC RESISTANCE

WHAT IT TELLS US
This is the minimum **impedance** of most loudspeakers, at d.c. and is in most cases the minimum value of the **impedance** graph. This does not hold true with loudspeakers using an input capacitor, as some KEFs in the past, or the few with parallel reactive networks in their crossovers. These apart, d.c. resistance is in most cases a measure of bass unit voice coil resistance, including that of the internal wiring and series low pass inductor. This measurement is a useful cross check and also allows reactance to be calculated at any frequency.

HOW WE MEASURE IT
Resistance is measured with a normal Fluke hand held voltmeter / ohmeter.

Frquency Response



Ideal frequency response - solid green line (1).

Common response errors are shown by dashed lines.
2 - under damped bass peak gives lively, 'obvious' bass.
3 - over damped bass gives 'tight' bass and suits near wall placement.
4 - a small up / down blip suggests a strong internal reflection and resultant colouration.
5 - a dip around 3kHz is due to driver mismatch in the crossover and softens the sound.
6 - raised output from the tweeter, above 3kHz, results in a bright sound with strong detail.
7 - treble peak at 15kHz produces sharp treble.
8 - falling output from the tweeter, above 3kHz, results in warm sound.

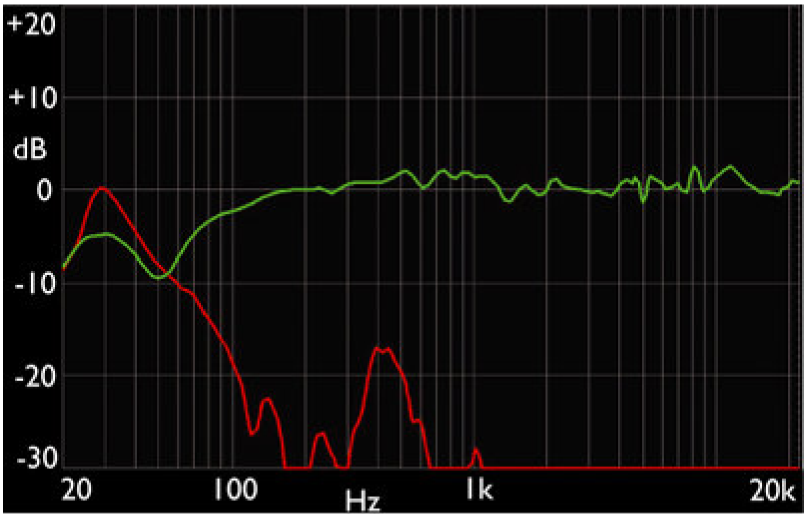
WHAT IT TELLS US
Frequency response is a guide to tonal balance, or whether cymbals will burn your ears out whilst kick drum lacks kick. Ideally, the green trace of our**frequency response** graph should be horizontal within a few dB (decibels) from 100Hz to 20kHz, as in the solid green line above. It should also be flat and smooth, as this indicates a lack of resonances. Dome tweeters in particular, which typically work from 3kHz up to 20kHz, can look ragged and uneven in their response (see 7 above) and sound coarse and coloured as a result, whilst better quality ribbon tweeters (and others such as magneto planars and ring domes) measure almost ruler flat and sound commensurately smoother, less coloured and more natural. **Frequency response** tells quite a big story and, with loudspeakers, the bumpier it is the more colour there will be.

To make loudspeakers sound detailed and clear in showroom demonstration against rivals, a majority have raised output above 3kHz (as in 6 above). Taken too far, this results in a fatiguingly sharp sound in the home, especially when a poor metal dome tweeter dome is used. Our graphs warn of this common ‘enhancement’, that’s really a blight.

At low frequencies it is common to acoustically under damp bass units to give them a little life and presence at low volumes and make bass content stand out (see 2 above). Again, how acceptable this is is a matter of degree. The effect can be seen as a small peak of a few dB, usually around 80Hz, in the green trace of our graphs and about +2dB is all that is acceptable. The response we publish slightly under states this effect; our unpublished pink noise analysis makes this effect clearer. Too much bass lift does mean bass will sound boomy; there is strong correlation here.

Some loudspeakers are over-damped and have progressively falling bass (see 3 above). They work well with powerful amplifiers, giving solid punchy lows, free of waffle, but only at medium to high volume. They are good for Rock played loud. This type of loudspeaker works well close to or against a rear wall. Small bookshelf and wall mounting loudspeakers and even floor standers like the KEF iQ5, designed for near wall use, commonly produce less bass to compensate for rear wall presence.

There are arguments in favour of a non-flat forward response, such as maintaining constant acoustic power and compensating for baffle effects. However, subjectively they upset the forward, direct sound to a listener in quite a strong manner and are rarely pursued.



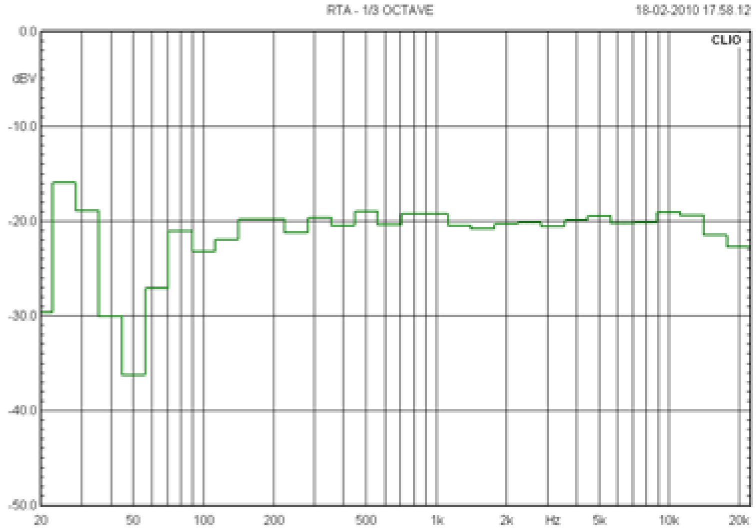
Epos Encore 50 frequency response - green trace. Port - red trace.

A majority of modern loudspeakers have ports (bass reflex). The port both damps resonance in the bass unit(s) and extends output downward. We show port output in the red trace (see above). A narrow tuned port will give extra bounce to the bass, but not “tightness”. Broad tuned ports, a recent development, apply more damping to the bass unit and this usefully reflects back into the electrical load, making the loudspeaker more amplifier friendly. Broad tuned ports do result in more controlled sounding bass.

Also, to keep the loudspeaker sounding fairly spry in its bass behaviour, companies like B&W and KEF now tune the port high, to 40Hz, the lower end of the bass range. This eliminates subsonics, or rumbly effects, but it does make for very tidy sounding bass lines. So the red port trace tells quite a big story.

HOW WE MEASURE IT

We make an initial measurement using third octave analysis of pink noise, moving the microphone to find a reasonably representative microphone position for response measurement, and also assess off axis behaviour and poor phase matching between drive units.



Epos Encore 50 third-octave analysis of pink noise.

Our published response curve is made using gated sine wave bursts, with delay compensation. Note that this system as used by Clio weights down low frequency data below 180Hz in the FFT measurement window so there is progressive loss of detail in the plots and they are lower in amplitude than the steady state data collected using pink noise; compare the two Encore 50 plots above to see this. However, they are close to more laboriously collected, spliced-in near field data, which gives a true 'anechoic' result, differences being small. Comparison of results and discussion with a large number of loudspeaker manufacturers makes us confident that our published **frequency response** data is accurate in itself and representative of a product's performance.

The red port trace is not positioned to match the green trace in terms of Sound Pressure Level, or Acoustic Power. However, we do measure SPL at the port entrance relative to that at the drive unit (nearfield) at 80Hz to provide guidance as to relative levels, and quote the figure in our Measured Performance summary. In practice ports commonly measure around +6dB above drive unit output at 80Hz. Large ports exceed this and small ones provide less output.