JBL Studio 590

LOUDSPEAKERS

The appearance of JBL's newest floor-stander, the Studio 590, is sure to polarise opinion. After unpacking them (no mean task, as they're imposingly tall and impressively heavy) I stood back to survey them. The first thing that sprung to mind was a vision of some kind of space creature, the second a sarcophagus and the third a vision of a mediaeval Druid. What all these three visions shared, despite being dramatically displaced in time, is that they're living things—human in the case of the sarcophagus and the Druid, and alien in the case of the space creature. But here's the thing: the Studio 590s just seemed 'friendly' somehow, and I really liked the 'look'… and I still do.

THE EQUIPMENT

JBL's entire new 'Studio 5' line-up, which comprises not only the Studio 590 model I am reviewing here, but also five other models (See the break-out titled 'Studio 5 Series Family') was designed by none other than Greg Timbers, whose most famous recent gig was designing JBL's flagship loudspeaker model, the Everest.

I was interested that JBL includes the word 'Studio' in the product name, because I have always taken this to mean 'Studio Monitor'… which in turn leads me to understand that the speaker was designed to be used in a recording studio, usually for reasons of being highly accurate (in terms of having a flat frequency response) and highly dynamic (able to withstand the very high volume levels often employed in recording studios). I can't vouch for JBL's intentions in using the word, but I also thought it instructive that, just as most of JBL's professional studio monitors use compression drivers to deliver the high-frequencies, rather than the dome tweeters used by most manufacturers of home hi-fi systems, the JBL Studio 590 also has a compression driver to deliver the high frequencies.

Because it has a compression driver, it has to incorporate horn-loading, and in this case, JBL has employed its familiar 'bi-radial' horn geometry. A compression driver is almost unique amongst loudspeakers. Almost all conventional speakers—cones, domes or ribbons—operate directly into the airspace in the room in which the speaker cabinet is placed. (One of the exceptions is the Heil Air Motion Transformer, variants of which are now used by a number of manufacturers, who jumped on it when the German patents expired.) When an ordinary loudspeaker cone (or dome) moves, for example, it actually attempts to move all the air in front of it, which is in effect, the entire volume of air in the room. A compression driver, on the other hand, only has to compress the air in a small cavity directly in front of the driver diaphragm… hence the word 'compression driver.' Obviously the air it compresses eventually has to go somewhere, so at the other end of the compression cavity (usually known as a 'throat' for the obvious reason) it has to be connected to a horn of some type.

The operating concept behind the compression driver is that when the

diaphragm area is larger than that of the area of the air in front of it, there is a significant increase in the radiation resistance, and this loading mismatch increases the efficiency, by correcting the loading mismatch between the vibrating transducer surface and the volume of air in the room. In effect, there's a far better energy transfer. The nearest analogy I can think of (admittedly not a good one, so readers are encouraged to suggest their own) is that old science trick of using your own breath to blow over an ordinary house brick that's standing on its end. You can huff and puff away all day, but you won't move it. However, if you put a paper bag under the brick and then puff into the bag, the brick will topple over immediately.

However, although the compression driver is great for delivering high efficiency, it is a nightmare when it comes to frequency response and dispersion unless it's perfectly designed and engineered. To ensure the frequency response is flat and extended, for example, there needs to be a specially designed 'phase plug' placed between the diaphragm and the throat of the horn. And to ensure correct wave dispersion (both vertical and horizontal), the horn has to be precisely designed to suit the driver diaphragm *and* the phase plug, as well as built very exactly to precise dimensions. It's because of these factors that designing a compression driver is exceedingly difficult. And if that weren't enough to discourage even the most dedicated loudspeaker designer, another problem is that because the end result will always be a defined physical shape, it is very easily patented. And whereas it's fairly easy to get around an electrical patent by designing a circuit that does the same thing a different way, it is impossible to get around a patent that's been granted on a shape.

But in order to patent anything, you have to be the first to do it, and this is where JBL has a decided advantage, because it has been building and patenting compression drivers—and horns!—for more than half a century. So not only has JBL amassed an impressive array of patents, it also has amassed extensive in-house engineering knowledge of what works—and what doesn't—when it comes to compression drivers and horns. Even better, JBL can 'refresh' the patents on its existing designs, which is something no other company can do. (That is, only the company granted a patent in the first place is permitted by the patent office to extend it by adding some new twist. If another company finds a way to improve a product already patented by some other company, they can't patent that improvement.)

The bi-radial horn design used in the Studio 590 is an evolution of an original design by Altec (which became Altec-Lansing and retained this name even after James B. Lansing left the company in order to establish JBL). The bi-radial horn gets its name because it extends a 'radial' horn (itself derived from an exponential horn) into both the horizontal and the vertical expansions. Joining two distinct planar flange sections in this way would normally introduce diffraction and reflection issues, and it's these that JBL's patented design solved by substituting the radial curve for the primary and secondary flares of the bell. One of the people responsible for this was the late, great John Eargle, who died in 2007 after working for JBL for more than 31 years. It was Eargle who championed the concept of flat power response in sound reinforcement applications, and conceived the application of JBL's bi-radial constant-coverage horns to both studio monitors and cinema systems. (At the time of his death he had just completed the book '*The JBL Story: 60 Years of Audio Innovation*' which is a wonderful read.) The compression driver used in the Studio 590 is a direct descendant of Eargle's designs and uses a 25mm high-frequency compression driver with a one-piece Teonex diaphragm that's powered by a neodymium magnet. It's terminated by a glass-filled ABS bi-radial horn.

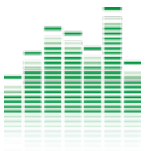
The Studio 590 has a pair of 203mm bass/midrange drivers that handle the frequencies below the crossover point (1.5kHz). Although the nominal diameter of each bass/midrange driver is 203mm, the driver frame is actually square (with rounded corners, so it measures 221mm across the corners and 200mm across the flats). However the important dimension is the Thiele/Small diameter, which is what is used to determine the driver's effective cone area (Sd) which gives an indication of the driver's ability to move air (though this must be considered in conjunction with the cone excursion). I measured the T/S diameter at 165mm, which puts the Sd at 214cm^2. However, because JBL runs these drivers in parallel at low frequencies, the total cone area available to move air is twice this, or 428cm^2. Greg Timbers has elected to use two drivers in order to increase power handling, decrease the width of the front baffle and for other reasons, but if he had elected to use a single bass/midrange driver and wanted the equivalent cone area of both these cones, that single driver would have needed a 'nominal' diameter of 253mm, so it would have had to have been at least 50mm wider.

Although I am referring to these two drivers as 'bass/midrange' drivers for grammatical simplicity, and although the two drivers are physically identical, only one of them is actually a *true* bass/midrange driver: the other one is just a straight 'bass' driver, because JBL's Studio 590 is actually a 2½-way system, despite the fact that the company lists only a single 'crossover' point in the speaker's specification. What happens in a 2½-way system is that at very low frequencies, both the cone drivers deliver bass, but at higher, midrange frequencies, only the upper-most of the two delivers the midrange frequencies.

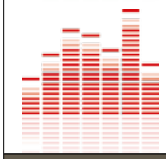
The bass/midrange drivers' cones are manufactured from something JBL calls 'PolyPlas', which it has registered as a trademark, and the particular type of 'Polyplas' used is said to be proprietary to JBL, but the cone construction is essentially one where two thin layers of plastic (or polymer) are sandwiched either side of a thicker layer of cellulose fibre (in essence, paper). I like this

JBL STUDIO 590
LOUDSPEAKERS

Brand: JBL
Model: Studio 590
Category: Floorstanding Loudspeakers
RRP: $2,499
Warranty: Five Years
Distributor: Convoy International Pty Ltd
Address: Unit 7, 1801 Botany Road
Botany NSW 2019
☎ **1800 817 787**
☎ **(02) 9700 0111**
✉ **info@convoy.com.au**
🖳 **www.e-hifi.com.au**



- Superb dispersion
- Incredible imaging
- 'You are there' bass



- Forwards stability
- Potential bung loss

LAB REPORT

Readers interested in a full technical appraisal of the performance of the JBL Studio 590 Loudspeakers should continue on and read the LABORATORY REPORT published on page 26. Readers should note that the results mentioned in the report, tabulated in performance charts and/or displayed using graphs and/or photographs should be construed as applying only to the specific sample tested.

Lab Report on page 26

type of 'sandwich' driver cone construction because it delivers the extremely light weight and high strength that are the best physical properties of a paper cone, but gives immunity from dampness and variations in stiffness that are usually the most desirable physical properties of a polypropylene (pp) or metal cone. (Interestingly, despite the preponderance of advertising, all other things being equal, a paper cone is still stronger, lighter, and less resonant than either a polypropylene or a metal cone… but it's easier to write sexy advertising copy about polypropylene or metal cones than it is about paper cones.)

The cones themselves are connected to their cast alloy frames by a rubber suspension, which I far prefer to the more common-used foam suspension material, due to foam's propensity to disintegrate under Australian environmental conditions. The drivers also use JBL's symmetrical field geometry (SFG) magnetic design. JBL developed Symmetrical Field Geometry in 1978 primarily as a means of eliminating d.c. flux modulation caused by signal current in the voice coil. This suddenly became a problem for JBL because it had always used Alnico V for its magnets, which didn't exhibit the problem because it was such a powerful magnetic material. As Alnico V became too expensive for many of its models, JBL had to transition to using ferrite as its magnetic material, but it knew that before it could, it would have to eliminate this d.c. flux modulation, because ferrite was a far less powerful magnetic material than ferrite. (A ferrite magnet's B-H curve—essentially its magnetisation characteristics—is such that strong program [music] currents in the voice-coil generate a magnetic field that alternately adds to and subtracts from the static permanent field of the ferrite, varying the operating point along the B-H curve.) What JBL did to solve the problem is put an aluminium flux shorting ring at the base of the pole piece. Because this ring has a resistance of only a few thousandths of an ohm, considerable current is induced by transformer action involving the voice coil and the magnetic return path. The counter-current set up in the flux ring opposes the shift in operating point in the magnet structure itself, thus reducing harmonic distortion—primarily the second-order component. (Many other manufacturers now use the same technique—but only after they'd waited patiently—or impatiently—for JBL's patents to expire.

Around the rear of the Studio 590 you'll find twin pairs of gold-plated speaker terminals, so you can bi-wire or bi-amplify these speakers as you prefer. You'll also find two bass reflex ports per cabinet, each one fitted with a removable mesh 'bung' that can be used to 'tune' the level of the bass to suit your own ears, and also to best-suit the bass response to the room in which the speakers are placed. JBL's manual gives excellent instructions as to how you can establish the optimum 'bung placement' for your room, but fails to warn about one thing, which is that due to the shallow depth of the ports (each one is 65mm in diameter and only 80mm long), it is very easy to accidentally push a bung right through the port (as I did) upon which it will drop inside the speakers, where some minor speaker surgery becomes necessary to remove it. (That is, you'll have to remove the rear terminal plate to retrieve it… though the speakers will not be harmed if you simply leave a pushed-in bung inside.)

The cabinet finish is very basic black veneer, and a cherry veneer is also available. The cabinet walls are non-parallel to help constrain standing waves, and internally there's bracing to prevent cabinet resonances. You can remove the front grilles to expose the drivers if you want, but I would not recommend it. First, the grilles are very difficult to remove and you might accidentally break one of the plastic grille pegs (as I did) and secondly, I think the speakers look 'way better with the grilles on than they do with the grilles off… not to mention that the grilles also protect the bass/midrange drivers from damage. Also, because the grilles do not cover the tweeter, you will gain no acoustic advantage at all from listening without the grilles, as you can with some loudspeakers whose grilles cover the tweeters.

IN USE AND LISTENING SESSIONS

The Studio 590s weigh 31kg each and I'd guess that a lot of that weight must come from that compression driver and bi-radial horn assembly because this, combined with the height of the cabinets (1,270mm) meant that I found it was fairly easy to tip the speakers forwards (but much more difficult to tip them sideways or backwards). Because of this, I would recommend positioning the speakers with their rears fairly close to a wall, so no-one can get behind them to destabilise them. To its credit, JBL has attached a sticker alerting owners to this to the rear of each speaker. If stability is a serious concern for you, the fact that the design uses outrigger feet means that you could very easily use a tether (or screw) to anchor the two rear-most outrigger feet to the floor. (And if you wanted to avoid fasteners entirely, you could also use a removable glue-like material such as Blu-tac or Earthquake putty.)

If you thought the Studio 590s were visually imposing, just wait until you fire them up! These are JBLs through and through, with a very exciting and highly dynamic sound, powerful bass and crisp

The Studio 590s are JBLs through and through, with a very exciting and highly dynamic sound, with powerful bass and crisp treble

treble. And, as you'd expect from the most famous name in professional audio, if you feel like raising the rafters by winding up the wick, the Studio 590s can be played LOUD, to say the least. But the beautiful thing about the Studio 590s is that even if you choose not to play them at high volume, they still deliver a sound that is immediately and totally realistic. I find that many speakers, although they produce sound that's technically 'accurate' in that it's very well-balanced, can also be rather dull. I don't mean that in the sense of the sound being audibly dull, but in the sense that the music played through them, no matter how good, is reproduced in such a way that it sounds uninspiring and uninteresting. Music played through the JBL 590s, on the other hand, is involving and interesting, making you want to listen to more and more music, and the clarity of their sound lets you appreciate the finer details of the music, the tiny touches that musicians inject to lift their performances to the highest level. I heard an excellent example of what I'm talking about when using The Angels' 'Take it to the Streets' to audition the JBL Studio 590s. After skipping the title track (which I always do… boring!), I was able to start the auditioning session with the sound of Brewster's guitar screaming out the intro to *Wounded Healer* before the solid skins of Nick Norton thwacked into the mix. Then about one minute in, the guitar solo literally leaps from the JBLs, just as I imagine it did in the studio (which, incidentally, very likely used JBL speakers as control room monitors!). Vocal presentation of the Studio 590s is excellent and heard to good effect on *There Comes a Time* where the harmonies are balanced nicely, and despite the harmonising and the harmonics, the individual voices are still easily identifiable. *Small Price*, the boogie on the next track, gave the Studio 590s woofers a work-out, with Charlie Bailey working the bottom string of his bass to death, but the JBLs were more than up to the task, even when I wound the volume up to 'stun'.

But if the JBLs could rock, they could also be astoundingly delicate, which I proved to my entire satisfaction with an extraordinary disc from Stuart & Sons, recorded to demonstrate the capabilities of two of their unique concert grand pianos using Earthworks' PianoMic system. In seven short tracks, pianists Bill Risby and Kevin Hunt explore the possibilities of the Stuart & Sons piano's extra pedal and wider-than-usual keyboard, not to mention their piano's possibilities as a percussion instrument.

Mostly Risby and Hunt play their own original compositions, which are good, but I confess my favourite on the disc is Hunt's interpretation of Keith Jarrett's *Country*. One thing the clarity of the recording did permit—and which I hadn't noticed with any of the music I'd previously played—was that the JBLs sounded to me just a tiny bit bright in the highest final full octave of the piano, which starts at C7 (2.093kHz) and finishes at 4.186kHz. (Most piano keyboards finish at C8, but the Stuart & Sons models top out at the F above C8, which is at 5.587kHz).

Interestingly, when armed with what I'd heard on the Stuart & Sons disc, I went back and listened again to what I'd heard previously, and tried so see if I could hear this slight brightness, I couldn't. Indeed further auditioning showed that I could detect it only when listening to extremely well-recorded and clean captures of solo piano. So unless you listen to solo piano, I doubt you will be able to hear it either. For those who can, I can advise that one of the several amplifiers I used had tone controls and I found that if I turned its treble tone control back from the 12 o'clock position to the 11 o'clock position, the slight brightness disappeared entirely and I couldn't hear it even when re-auditioning the Stuart & Sons recording.

Another sonic area where the JBLs stand out from the crowd is their incredibly wide dispersion and their uncanny ability to image. Whereas most speakers have a very defined 'sweet spot' which means that only one person—or two at most—will ever enjoy a perfect high-frequency response and perfect imaging at the same time, the JBL Studio 590s will deliver exactly the same high-frequency level in a broad sweep that encompasses all listeners in a room, simultaneously delivering perfect stereo imaging. The bi-radial horn is obviously the reason for the dispersion, but JBL's quality control on the compression driver is no doubt the reason for the imaging. I found I didn't have to angle the speakers towards the listening position as I usually do with large floorstanding designs—I just pointed the JBLs straight up the room and those huge bi-radial horns did the rest.

The very high efficiency of the JBL Studio 590 design should not be under-estimated. Using efficient speakers means you make the most of the amplifier power at your disposal. The JBL speakers are a full 3dB more efficient than most speakers, which means that you need only *half* the amplifier power to make them sound equally loud. So, for example, if you pair the JBLs with a 50-watt amplifier, to get a pair of speakers of average efficiency to sound equally loud as the JBLs, you'd have to use them with an amplifier rated at 100-watts per channel.

CONCLUSION

For my money, JBL has done it yet again. I loved the look, I loved the sound, and I loved the fact that they're not only great stereo speakers when used on their own, they're even-better front-channel speakers when used in a multi-channel home theatre system. (In a multi-channel system, adding a subwoofer and therefore relieving the two cone drivers from having to reproduce the deepest bass lifts their performance level across the upper bass and midrange even higher.)

I was so impressed by them that I have already asked if I can borrow a pair of JBL Studio 530s for review and publication in an upcoming issue. So, as they say, watch this space for that review and, in the meantime, check out a pair of JBL Studio 590s for yourself. I can guarantee that you will be as impressed as I was! ***Lesley Swan***

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STUDIO 5 SERIES FAMILY

In addition to the JBL Studio 590s reviewed here, other models in the Studio 5 Series include the Studio 580s, which are also floorstanders and use the same high-frequency array as the Studio 590, but have smaller (165mm) bass/midrange drivers. They retail for $1,999 per pair. The Studio 570s ($1,499 per pair) are floorstanders and again use the same high-frequency array, but have 130mm-diameter bass/midrange drivers. There's also a bookshelf/standmount Studio 530 ($999 per pair) that again uses the same h.f. array in combination with a single 130mm-diameter bass/midrange driver. The Studio 520C centre-channel ($599) has dual 100mm bass/midrange drivers and the same h.f. array. There's also a Studio 550P ($1,199) subwoofer.

The Studio 5 has been designed so consumers can use any pair from the series as right- and left-channels in a stereo system, or mix 'n match all of the models to create a full 5.1-channel system to suit any-sized room (or budget). For a multi-channel system, I would ideally have liked a JBL to include a second centre-channel model in this series, one with twin 130mm drivers, but perhaps this model is still to come. Also on my wish-list would be an even-larger three-way floorstanding model using twin 203mm drivers for the bass, a 130mm driver for the midrange, and the same compression driver/bi-radial horn for the high-frequencies. Again, maybe this model is still to come too. L.S.

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LABORATORY TEST RESULTS

Graph 1 shows the JBL Studio 590's in-room frequency response both unsmoothed (red trace) and smoothed to one-third octave via post-processing, but because both traces are actually averaged from nine individual traces, some additional averaging is inevitable. However, the end result is that the JBL's frequency response was measured as extending from 40Hz to 20kHz ±3dB, which is an excellent result. As you can see—and equally important—within the ±3dB variation, the frequency response is not 'skewed' to favour one section of the audio spectrum over another. (A loudspeaker with a badly skewed response, so that the low frequencies were at –3dB and the high frequencies were at +3dB, for example, would sound bass-shy and bright, despite having a response that is 'technically' within ±3dB). As you can see from this graph, the frequency response of the JBL Studio 590 is almost ruler-flat from around 60Hz up to 3kHz, after which there's a slow and minor rise in response that reaches +2.5dB at 9kHz before rolling off to 'reference' at 14kHz then rolling off gently to be 2.5dB down at 20Hz. This response was obtained without the port plugs in place, and with the speakers a metre from a rear wall. Moved back closer to the wall, I'd expect some additional low-frequency extension and a slight lift in the response in the 100–200Hz region. Although the bass response is 3dB down at 40Hz, you can see the roll-off below 40Hz is shallow, so you could expect significant bass output to 29Hz.

The high-frequency response of the JBL Studio 590, as measured by *Newport Test Labs*, is shown in Graph 2. The gating technique used to acquire this trace simulates the result that would be obtained when measuring the speaker in an anechoic chamber and you can see that the result is very close to that of Graph 1, with a very linear response below 3kHz and a gradual rise above this frequency. The 'jagged' appearance of the trace above 16kHz is measurement error that's to be expected when measuring a horn-loaded compression driver due to path-length differences from different parts of the horn to the measuring microphone. Therefore you should ignore the 'jaggedness' and instead concentrate on the overall trend of the response. You can see the Studio 590's response rolls off to 20kHz, then picks up again to be only around 5dB down at 25–30kHz, then rolls off to 40kHz.

Newport Test Labs measured the low-frequency response of the JBL Studio 590 using a nearfield measurement technique, and without the port bungs in place. You can see that the bass and bass/midrange drivers hold up very flat down to 69Hz, after which the response rolls off quite sharply to a minimum at 42Hz that's slightly different for each driver due to their different positions on the front baffle relative to the rear-firing ports. The port output picks up where the bass and bass/midrange drivers roll off, producing significant output between 28Hz and 65Hz. It's also a very 'low-Q' response, without a peak, so the bass from the Studio 590 won't 'boom' like some bass reflex designs. The ports are well-behaved at higher frequencies and there's not a lot of unwanted leakage through them, though you can see some significant leakage from the upper port at 280Hz. So if you prefer the sound of the JBL Studio 590 with one of the bungs fitted, I'd suggest placing the bung in the upper port, rather than the lower one. In fact the leakage is not significant, because it's more than 15dB below the main output of the front-firing drivers, (the level of this trace was not compensated for differences in radiating areas, nor for the fact that the port is rear-firing, which would reduce its level even further.) On this trace you can see that Greg Timbers has started rolling off the response of the lower (bass) driver at 200Hz, but it looks to be at a rate of only at 6dB/octave, which is quite shallow. (Note that I am only considering the way the traces diverge: the fact that both traces appear to be rolling off early is just a function of the limitations of the near-field measuring technique used by *Newport Test Labs* for this measurement: the technique gives correct results only at low frequencies.)

There's quite a lot going on in *Newport Test Labs'* measurement of the JBL Studio 590's impedance modulus. The tiny differences in the impedance between the speakers show the pair matching is not perfect, but it's very, very, good nonetheless, showing excellent quality control by JBL.

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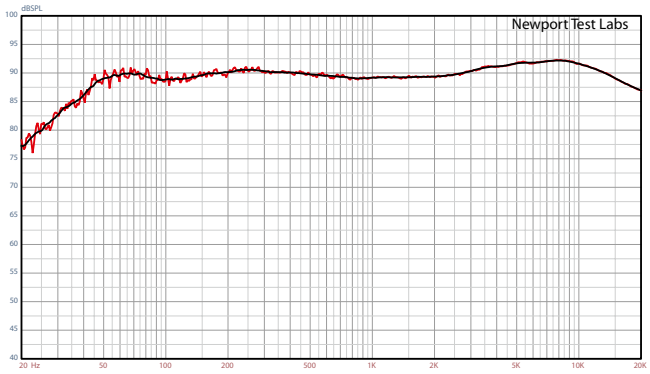
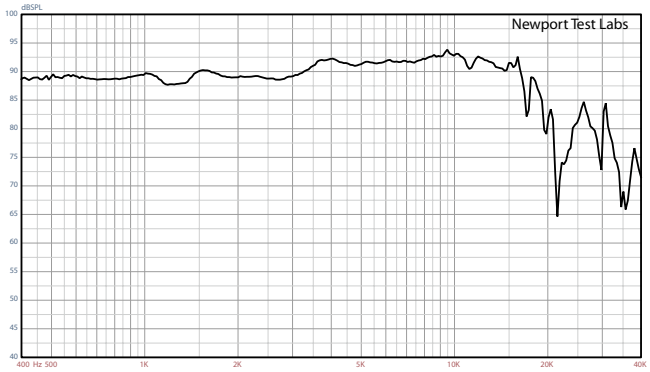
Minor cabinet resonances are visible at 190Hz and 280Hz, but considering the size of the cabinets, JBL has done a good job here too. The impedance drops to 5Ω at 138Hz and to 4.5Ω at 15kHz, so the Studio 590 is technically a 6Ω design, which is exactly as it's rated by JBL. Although the impedance is fairly low at 15kHz, it rises afterwards and is above 10Ωand rising at 40kHz, so the design should be very amplifier-friendly. The electrical crossover point seems to be at 1.4kHz rather than the 1.5kHz claimed by JBL, but this error is close enough to fall within the region of measurement error and production variations. Phase response is generally controlled, though it swings as far as 90° up at 40kHz, which is so high in frequency that it doesn't matter. Graph 5 shows the effect on impedance of using the port bungs: I'd expect to hear only very minor differences in bass level, based on these measurements.

Graph 6 is a composite one, combining several of the measurements made by *Newport Test Labs* on a single graph to give an overall picture of the Studio 590's frequency response. It's obvious from this that the JBL has been brilliantly engineered. *Newport Test Labs* measured the efficiency of the JBL Studio 590 at 90dBSPL at one metre for a 2.83Veq. input. This is an excellent result, which puts the Studio 590 into the 'high efficiency' category, meaning you can expect it to perform very well—and be able to be played very loudly—even with low-powered amplifiers and AV receivers. I wasn't concerned about the 2dB difference between the lab's measurement and JBL's own specification (92dBSPL) as NTL uses a particularly stringent measurement technique. (If NTL had measured SPL only at 8kHz, for example, it would have returned a figure that matched JBL's measurement. However, NTL averages sound pressure levels across the entire audio band, rather than using spot measurements.)

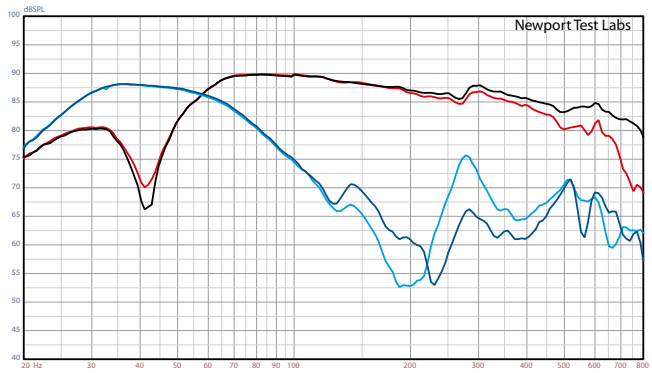
As I said, I think JBL has done a brilliant job engineering these speakers, and their excellent performance in all the tests well-rewards the obvious effort and attention to detail that's been put in. ***Steve Holding***



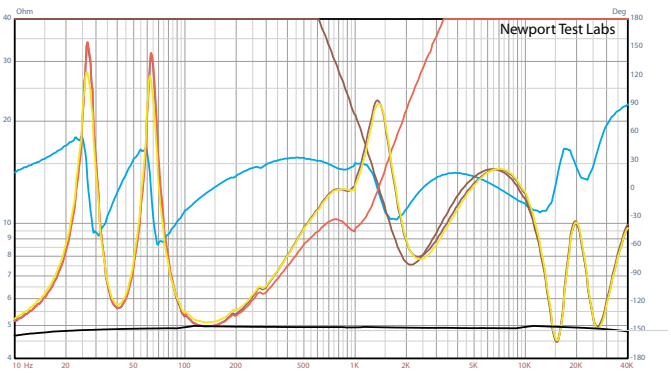
Graph 1. Averaged frequency response using pink noise test stimulus with capture unsmoothed (red trace) and smoothed to one-third octave (black trace). Both traces are the averaged results of nine individual frequency sweeps measured at three metres, with the central grid point on-axis with the compression driver. [JBL Studio 590 Loudspeaker]



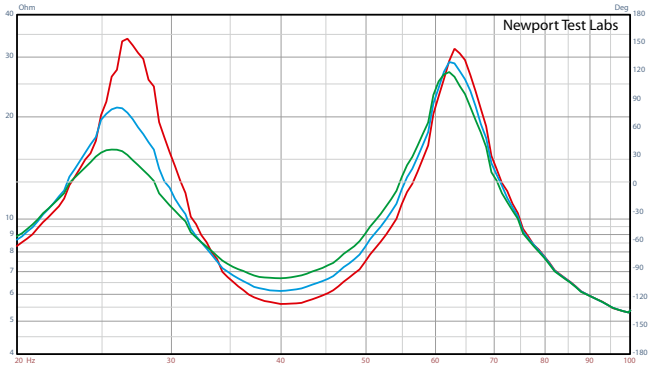
Graph 2. High-frequency response, expanded view. Test stimulus gated sine. Mic placed at three metres on-axis with compression driver. Lower measurement limit 400Hz. [JBL S590]



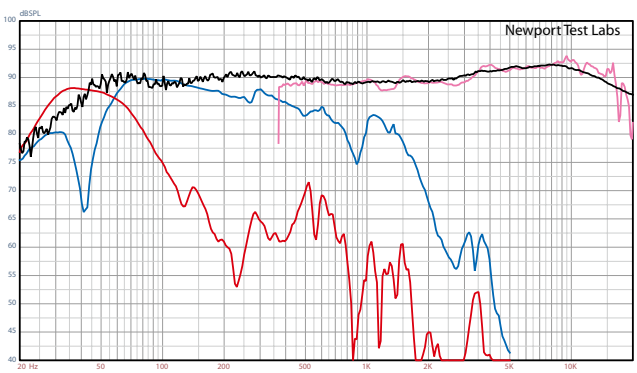
Graph 3. Low frequency response of upper (black trace) and lower (red trace) bass drivers and upper (light blue trace) and lower (dark blue trace) rear-firing bass reflex ports. Nearfield acquisition. Port/woofer levels not compensated for differences in radiating areas.



Graph 4. Impedance modulus of left (red trace) and right (yellow trace) speakers plus phase (blue trace), plus low-pass section (orange trace) and high-pass section (brown trace). Black trace under is reference 5-ohm precision calibration resistor. [JBL Studio 590]



Graph 5. Impedance modulus of left speaker showing effect of port bungs on impedance. No bung (red trace); one bung (blue trace); and two bungs (green trace). [JBL Studio 590]



Graph 6. Composite response plot. Red trace is output of bass reflex port. Dark blue trace is anechoic response of bass driver. Pink trace is gated (simulated anechoic) response above 370Hz. Black trace is averaged in-room pink noise response (from Graph 1). [J590]