

60TH ANNIVERSARY EDITION
560GTi/660GTi
COMPETITION SPEAKER SYSTEMS



OWNER'S GUIDE



FOR MORE THAN 60 YEARS, JBL® HAS

DELIVERED PRODUCTS THAT EXEMPLIFY THE TECHNOLOGY AND EXPERTISE GAINED THROUGH A LEADERSHIP ROLE IN PROFESSIONAL SOUND REPRODUCTION. THE JBL NAME HAS BEEN SYNONYMOUS WITH THE PRECISE, NATURALLY ARTICULATED SOUND FOUND IN MANY OF THE WORLD'S MOST PRESTIGIOUS LOCATIONS, INCLUDING CLUBS, CINEMAS AND RECORDING STUDIOS, AND LIVE-MUSIC REINFORCEMENT IN VENUES RANGING FROM CONCERT HALLS TO OUTDOOR STADIUMS. JBL LOUDSPEAKERS ARE FOR THOSE WHO WON'T COMPROMISE - IN THE STUDIO, AT HOME OR ON THE ROAD.

MORE THAN ANY OTHER COMPONENT, SPEAKERS DEFINE THE SOUND OF AN AUDIO SYSTEM. THEY ARE THE CRITICAL CHOICE THAT DETERMINES ULTIMATE PERFORMANCE. HOW DOES A MARKET-LEADING BRAND LIKE JBL BUILD LOUDSPEAKERS THAT SATISFY SO MANY PEOPLE? WE USE THE INDUSTRY'S MOST ADVANCED TESTING METHODS AND EQUIPMENT, WITH A PANEL OF TRAINED LISTENERS TO SCIENTIFICALLY QUANTIFY AND QUALIFY THE PERFORMANCE OF EVERY JBL SPEAKER TO ENSURE THAT IT EXCEEDS EVEN THE MOST DEMANDING EXPECTATIONS. THE INTRODUCTION OF THE 560GTi AND 660GTi COMPETITION SPEAKER SYSTEMS SETS YET A NEW STANDARD IN AUTOMOTIVE SOUND.



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Real-Time FFT Laser Vibrometry: This breakthrough technology uses scanning infrared-laser impulses that are reflected off a speaker's diaphragm and analyzed by a computer. The analysis creates a three-dimensional graphic representation of the cone's movement so that cone distortion, which contributes to frequency-response aberrations, can be observed. Improvements to the cone's shape and composition can be implemented to ensure that the diaphragm operates as a rigid piston throughout its usable frequency range, resulting in flat response.

AT JBL, SPEAKER DESIGN IS ALL SCIENCE.

THERE ARE THREE STAGES IN ENGINEERING LOUDSPEAKERS AT JBL:

Computer-aided design and modeling, prototyping and testing. JBL speakers are thoroughly tested and qualified at each stage to ensure that the finished product performs flawlessly.

Every speaker design starts with physical dimensions that facilitate installation in factory locations, along with a complete set of performance targets. Performance targets include maximum SPL, or how loud the speaker must play at its limits. From the maximum SPL target, we determine the amount of power required to drive the speaker to its output limit and set a power-handling target. Sensitivity, another important performance target, indicates how efficiently the speaker converts electrical input into acoustic output. A frequency-response target is also included. This target describes not only the shape of the speaker's response but also the maximum allowable magnitude of narrow peaks and dips in its response. Finally, target Thiele/Small parameters are defined to describe the speaker's behavior at low-frequency cut-off in its intended application, whether that application is a custom-built enclosure or the interior of a car's door. A careful analysis of all these targets determines the excursion and heat dissipation required for the speaker to produce the necessary frequency response at maximum SPL and maximum input power. With that information, engineers design the motor, choosing voice coil and magnet dimensions.

COMPUTER-AIDED DESIGN AND MODELING

During this phase of development, the engineers draw intricate diagrams of the proposed speaker's construction. Once the computerized drawing is complete, it is imported into an analysis program. At JBL, we use extensive Finite Element Analysis (FEA) to model the performance of the speaker's motor and moving parts. FEA divides the device being modeled into thousands of small parts or elements, and predicts performance based on the shape of the design and the materials that will be used in construction. The motor is analyzed using magnetic and thermal FEA. This analysis helps to ensure magnetic-field symmetry for low distortion, proper motor force required to drive the speaker's moving assembly, and the heat dissipation needed for high power handling. The moving assembly – composed of the cone, voice coil and former, spider and surround – is analyzed using structural FEA, which enables the engineers to observe the movement of the assembly to guarantee symmetry for low distortion. This analysis also permits the engineers to determine the proper elasticity of the spider and surround to provide the appropriate restoring force and perfect performance at the speaker's excursion limits.

PROTOTYPING

Once the computer-modeling phase is complete, technicians hand-build prototypes, machining metal parts and attaching them to prototype frames which are built using a stereo lithography machine. The stereo lithography, or SLA, machine uses a computer-guided laser to form a speaker basket out of a bath of plastic resin. Once the basket fit and finish are perfected, off-tool parts are built and then fully working, production-grade samples are assembled.

TESTING

At JBL, we spare no expense in testing loudspeakers. Prototype and production samples are first tested for frequency-response range and uniformity in one of our anechoic chambers using MLS and swept sine-wave analyzers. Sine-wave analysis measures harmonic distortion, which is a critical element in determining the sonic accuracy of the speaker. MLS, or maximum length sequence, analysis compares the noise output from the analyzer to the output of the speaker to determine the speaker's impulse response, a measure of transient response accuracy. The speaker's impulse response measurement is then converted into a high-resolution frequency-response measurement using a mathematical operation called Fast Fourier Transform, or FFT. Real-Time Laser Vibrometry is used to measure the structural behavior of the moving assembly. The Klippel analyzer measures magnetic field symmetry during the speaker's operation. Careful analysis of all these measurements determines the location and causes of unwanted resonance and distortion in the speaker's output, enabling the engineers to refine the speaker's design to eliminate them.

Once the design is perfected, power handling is verified for production-grade samples by subjecting them to filtered octaves of pink noise at rated power for 100 hours. That's right, 100 hours. Finally, samples are tested for longevity in our environmental test lab, according to the rigorous standards set by the automotive industry. The last phase in our extensive testing involves the most critical instruments in our possession – our ears. We listen...and listen...and listen.



Klippel Analyzer: This revolutionary analyzer developed by Klippel GmbH separates the distortion generated by transducers into two categories: distortions caused by the speaker's motor and those caused by the speaker's suspension. By analyzing the symmetrical and linear nature of the measured results, JBL engineers can formulate a cure for almost any distortion caused by motor or suspension nonlinearity. Klippel analysis provides accurate Thiele/Small parameter verification at virtually any input power level.



Anechoic Chambers: JBL's anechoic chambers are expensive... but worth the investment. The baffles on the walls of the chamber absorb sound at all audible frequencies. In this setting, JBL engineers can assess critical details of the speaker's performance without the effects of extraneous noise or reflected sound.

Environmental Test Lab: JBL's environmental test lab includes machines that subject speakers to hot and cold temperatures, humidity, ultraviolet light and vibration. These tests are designed to simulate a lifetime of abuse in the most adverse environmental conditions.

GTi COMPETITION SPEAKER SYSTEM TECHNOLOGY:

LOW-DISTORTION WOOFER

Distortion – sound produced erroneously – is the enemy of great speaker performance. At its worst, distortion makes speakers sound broken. At more moderate levels, distortion clouds the midrange, making vocals sound muddy and obscuring the music's detail. At JBL, we've had more practice than any other speaker company at eliminating distortion, and it shows. GTi competition speaker systems include the lowest-distortion woofers we've ever built.

In a loudspeaker, distortion can be produced by the cone, the motor, the suspension and even the movement of air through the speaker's assembly. In designing the 560GTi and 660GTi woofers, JBL engineers have left no stone unturned. The basket, polepiece and voice coil former all include vents to eliminate any potential distortion caused by the movement of air trapped within these parts. The ultrarigid Kevlar® cone eliminates unwanted cone flexing (also called modal distortion), which can cause big peaks and dips in the midrange response. The spider and surround are designed to ensure linear forward and rearward motion, minimizing distortion caused by the speaker's suspension. The motor includes a copper polepiece cap and a flux stabilization ring that work together to produce a linear voice coil inductance that minimizes intermodulation distortion. Finally, an extralong voice coil ensures that the coil remains in the magnetic gap to minimize distortion at low frequencies and their harmonics, and during high-output transients. The result is crystal-clear midrange, snappy mid-bass without any audible ringing or hang-over, and a smooth frequency response that needs no compensation circuitry in the crossover (see Figure 1).

- 1. Spider-Landing Vents:** Minimize distortion from mechanical noise.
- 2. Nomex® Spider:** Provides linear force in both movement directions.
- 3. Nitrile-Butylene Surround:** Ensures superior longevity.
- 4. Copper Polepiece Cap:** Provides linear inductance over the full range of forward voice-coil travel for reduced intermodulation distortion. Provides crystal-clear vocals and midrange, even during heavy bass signals.
- 5. Polished and Flared Polepiece Vent:** Provides a low-velocity inlet and outlet for the movement of air in and out of the motor structure. Minimizes distortion from mechanical noise.
- 6. Neodymium Magnet:** Provides high flux density. Also allows more room for larger steel motor components to provide critical heatsink mass for the voice coil.
- 7. Vented Gap Cooling™ Ports:** Provide movement of air over the voice coil for superior power handling.
- 8. Flux Stabilization Ring:** Provides global stabilization of the static magnetic field and works with the copper cap to minimize coil inductance during inward movement of the voice coil.
- 9. Voice Coil:** Long, over-hung 2" diameter, aluminum edge-wound voice coil provides high excursion for improved low-frequency capability. Reduces distortion at low frequencies and high input power.
- 10. Vented Voice Coil Former:** Minimizes distortion from mechanical noise.
- 11. Screw-Down Terminals:** Ensures reliable high-quality connections.
- 12. Kevlar® Dustcap and Cone Body:** Ultrarigid Kevlar dustcap and cone body minimize unwanted cone flexing for smooth frequency response.
- 13. Cast-Aluminum Basket:** Provides a rigid support for motor and moving assembly.

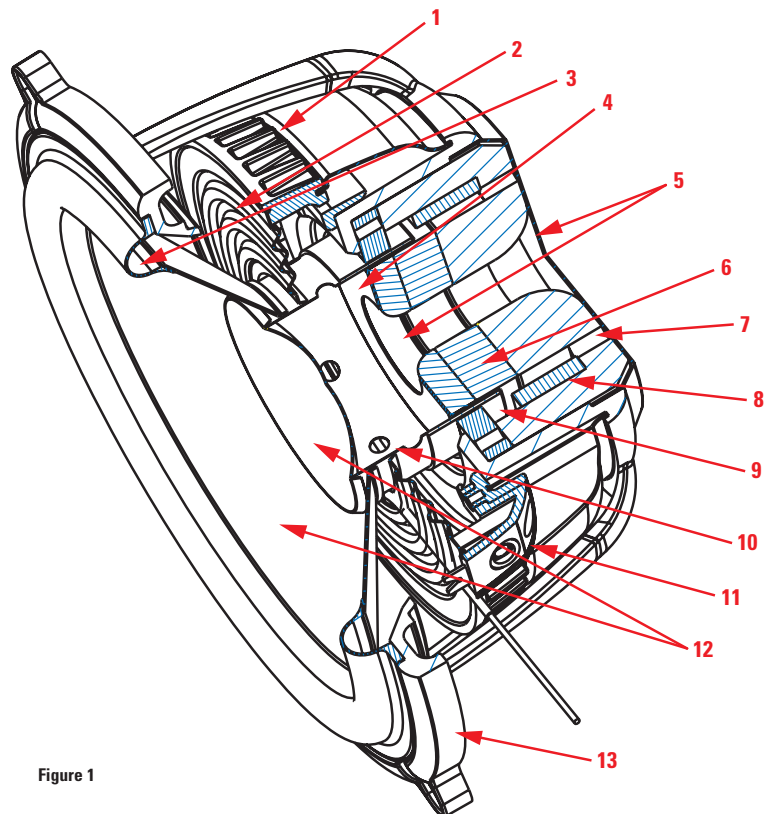


Figure 1

TWEETERS, WAVEGUIDES AND OPTIMAL FREQUENCY RESPONSE

The dispersion pattern of the sound produced by a speaker is different at low frequencies than at high frequencies. At frequencies with wavelengths greater than the circumference of the speaker's cone – the speaker's piston range – the sound is radiated in all directions. At higher frequencies, the dispersion pattern narrows. At frequencies for which the circumference of the speaker is about five times the sound's wavelength, the coverage area narrows sharply and the off-axis sound contains far less high-frequency content. This phenomenon occurs for every speaker. For multi-way speaker systems, designers have to contend with this condition for each driver in the system. What makes matters more difficult is that in the crossover region between a large low-frequency driver and a small high-frequency driver, the speakers' behaviors are opposite – the dispersion pattern of the woofer is narrow and the dispersion pattern of the tweeter is wide (see Figures 2 and 3). A multi-way speaker that is designed using only measurements of the on-axis response can sound terrible. An analysis of the frequency response of many speakers designed this way reveals a big hole in the off-axis response at the crossover frequency, where the woofer's output is focused into the forward angles (see Figure 4).

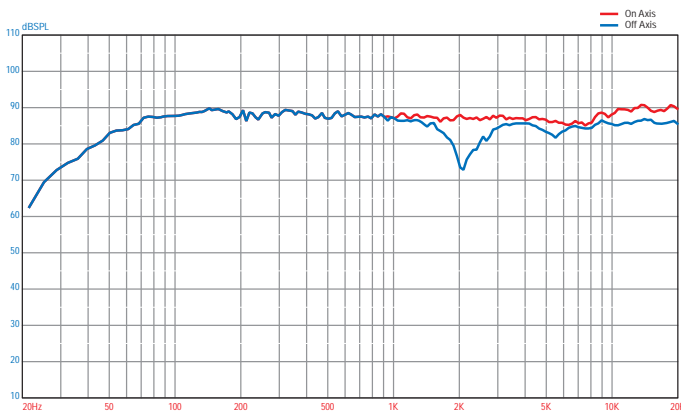


Figure 4. On- and off-axis frequency response of a conventional component system.

When we listen to speakers, we hear a combination of the sound that comes directly from the speaker (the on-axis response) and the off-axis response, which arrives at our ears after being reflected by boundaries and other objects in the room. In large rooms, the walls and other objects are often located several feet from the speaker enclosure, so the intensity of the reflected sound is lower than that of the direct sound. In rooms, the direct sound in the "listening window" dominates the sound we hear. The off-axis sound is a secondary but important part of the overall sound of the speaker (see Figure 5).

In cars, the boundaries are much closer to the speaker and to the listener, so the intensity of the reflections is more similar to the intensity of the direct sound. Additionally, the reflective surfaces in a car are so close that our brains can't distinguish between the direct sound and much of the reflected sound. Reflections contribute greatly to the quality of the audio experience in cars. Since it isn't practical to change the overall shape or size of the car to minimize the effects of the reflections, closely matching the on- and off-axis responses of the speaker system can help to ensure a smooth and balanced sound (see Figure 6).

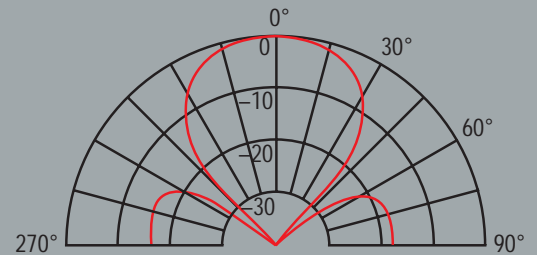


Figure 2. Woofer dispersion pattern in the crossover region.

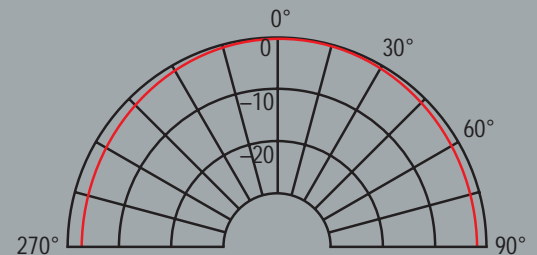


Figure 3. Tweeter dispersion pattern in the crossover region.

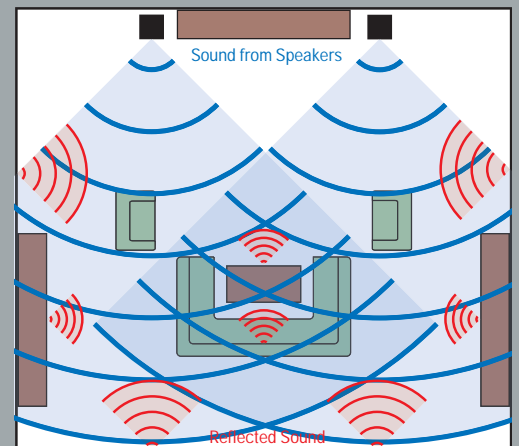


Figure 5. Reflected sounds are attenuated at the listening position because the boundaries are far from the speakers and the listener.

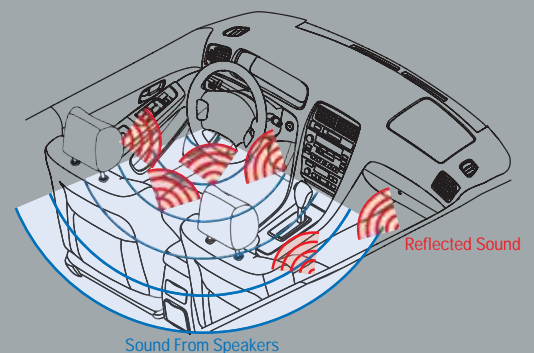


Figure 6. The intensity of reflected sounds in a car closely match that of the direct sound, because the boundaries are close to the speakers and the listeners.

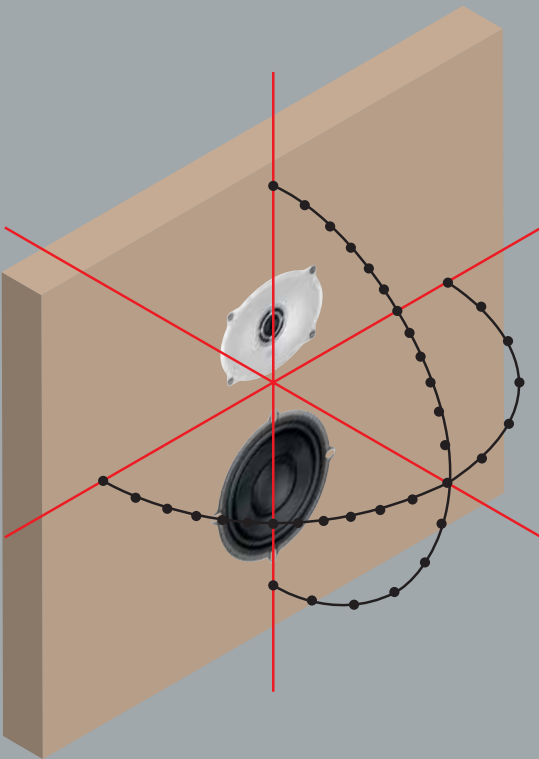


Figure 7. Measurements are made at 10° intervals along the horizontal and vertical axes.

THE DIRECTIVITY INDEX (DI): HOW WE MEASURE THE RELATIONSHIP BETWEEN ON-AXIS RESPONSE AND OFF-AXIS RESPONSE

The Directivity Index (DI) is the ratio of the intensity of the sound in the listening window to the average of the intensity of the sound radiated at all angles (sound power). We make measurements of the speakers in two semicircular patterns along the horizontal and vertical axes of the speaker (Figure 7). With those measurements, we determine the size of the optimal listening window and calculate the sound power of the speaker. We then compare the sound power to the response in the listening window and plot the directivity index for the speaker system's frequency response.

The blue curve at the top in Figure 8 is the Window Response and the curve at the bottom is the Directivity Index. The Directivity graph indicates the difference in level of the response in the window and off-axis (sound power, represented by the green line in the graph). Low-directivity values indicate that the sound is radiated at all angles and higher directivity values indicate that the sound is more focused into the listening window. The practical ideal is constant directivity (a flat line) in the woofer region and a smooth and gradual upward slope in the crossover region and above.

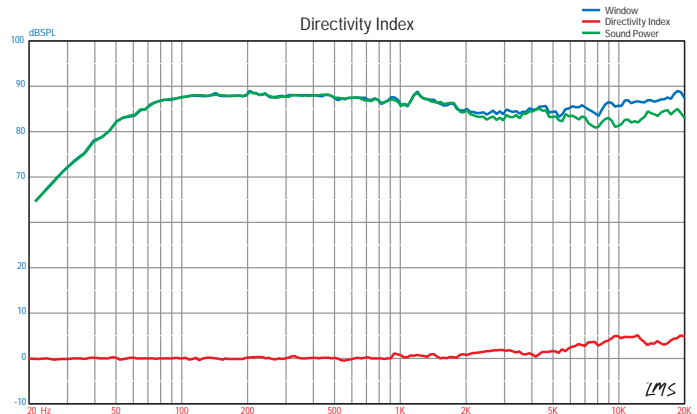


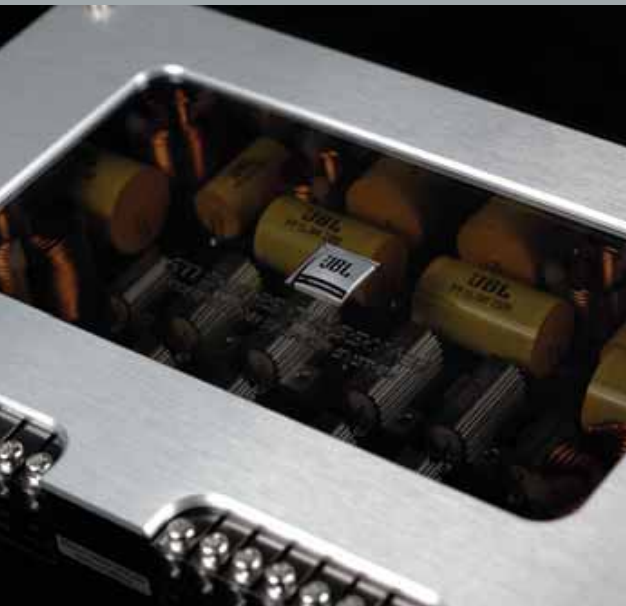
Figure 8. The directivity index is equal to the window response minus the sound power response.

CONTROLLING THE DIRECTIVITY OF THE TWEETER: WAVEGUIDES CONTRIBUTE TWO SIGNIFICANT IMPROVEMENTS TO THE PERFORMANCE OF THE GTi COMPETITION SPEAKER SYSTEMS

- Waveguides match the directivity of the tweeter to that of the woofer at the crossover by focusing the tweeter's output into the listening window.
- Waveguides decrease the directivity of the tweeter at high frequencies through controlled diffraction along the gentle transition from the waveguide's conical center section to the waveguide's outside edge.

Both of these contributions ensure that the off-axis response reflected by nearby surfaces more closely resembles the response in the optimal listening window. That makes speakers sound better in any environment.

In understanding how a waveguide works, it's useful to think of its shape as a passageway for sound between the listening window and radiation into full space; the waveguide can focus the sound into the listening window or allow it to be spread out over all the angles. At the lowest frequencies the tweeter plays, the tweeter operates in its piston range and radiates in a spherical pattern. The conical section in the center of the waveguide (indicated in green in Figure 9) directs some of the off-axis output back into the listening window. That increases



the tweeter's output at low frequencies in the listening window and decreases its output in the off-axis response. That's a much closer match to the directivity of the woofer, which is focused into the listening window in the crossover region. The crossover region is also indicated in dark green in the frequency response plot in Figure 9.

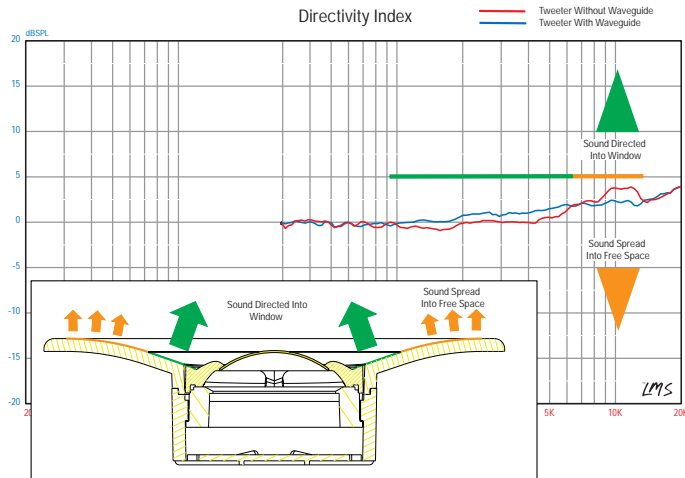


Figure 9. The waveguide provides a smooth and gradual increase in tweeter directivity in the crossover region and a reduction in tweeter directivity at higher frequencies.

At higher frequencies, the waveguide's gentle curve (indicated in orange in Figure 9) spreads the sound over all the angles, increasing the high-frequency content of the off-axis response and decreasing it in the listening window. This region is also indicated in light green in the frequency response plot in Figure 9. Essentially, the directivity of the waveguide is the inverse of the tweeter's directivity, and the combination of the two provides nearly constant directivity over the tweeter's range above the crossover. At the highest frequencies (to the right of the orange region), the waveguide has no effect because the dispersion pattern is narrower than the waveguide.

THE CROSSOVER: MORE THAN A DIVIDING NETWORK

The crossover included in GTi competition speaker systems is more than a set of simple filters. The filter frequencies, slopes and Q values are carefully chosen to provide a phase-aligned transition between woofer and tweeter with optimally flat frequency response at the design axis and throughout the listening window. Additionally, the tweeter's high-pass filter circuit includes a level control and frequency contour to optimize the system's response when the waveguide is used or when the tweeter is conventionally mounted.

Capacitor, inductor and resistor types have been selected to minimize distortion and maximize power handling. Air-core coils minimize saturation, which can cause distortion at high input power. Low-loss, low-ESR polypropylene capacitors provide crystal-clear high frequencies, while wire-wound precision resistors with integral heatsink ensure filter stability at high input power.

Finally, for systems that will include a separate amplifier channel for each speaker, the GTi competition system crossover includes bi-amp capability. For instructions in setting up the crossover for bi-amp systems, see "Adjusting the Crossover" on page 11.



Figure 11. Bi-Amp Capable

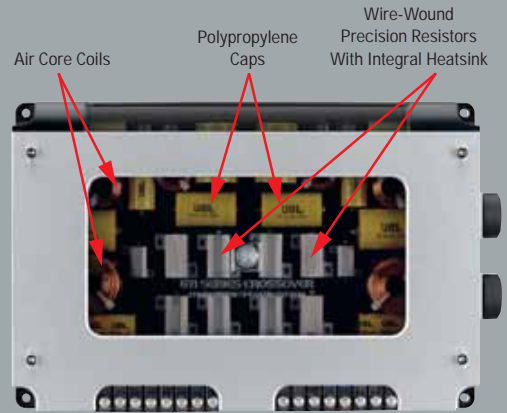


Figure 10.

Tweeter Level Adjustment

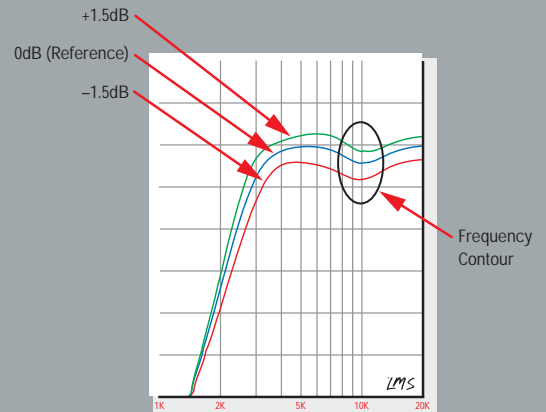


Figure 12.



Tweeter Level Adjustment
Frequency Contour

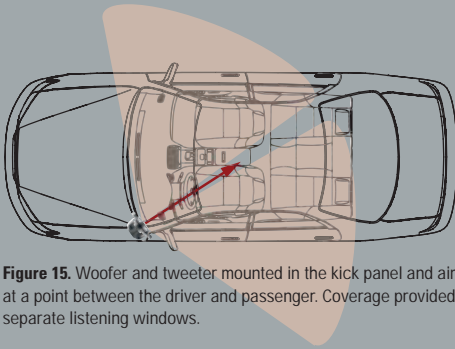


Figure 15. Woofer and tweeter mounted in the kick panel and aimed at a point between the driver and passenger. Coverage provided by separate listening windows.

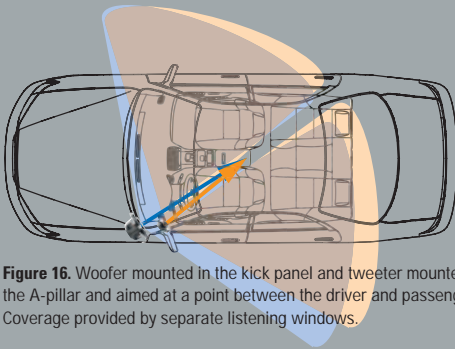


Figure 16. Woofer mounted in the kick panel and tweeter mounted in the A-pillar and aimed at a point between the driver and passenger. Coverage provided by separate listening windows.

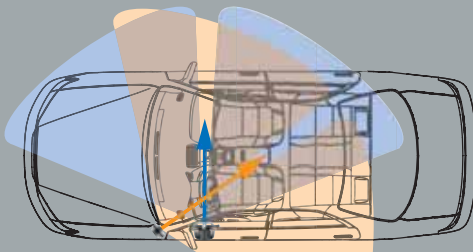


Figure 17. Woofer mounted in the door and waveguide mounted in the kick panel or A-pillar. Woofer aimed across the car, and tweeter aimed at a point between the driver and passenger. Woofer coverage provided by a single window. Tweeter coverage provided by separate listening windows.

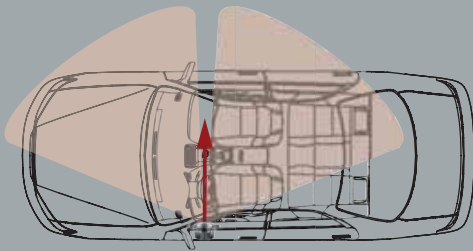


Figure 18. Woofer and tweeter mounted in the door and aimed across the car. Coverage provided by a single listening window.

SYSTEM DESIGN USING THE GTi COMPETITION SPEAKER SYSTEMS.

Many speaker systems are designed for on-axis listening and often include a listening window that's $\pm 30^\circ$ from the speaker's 0° axis. That's great for home audio or other applications where speakers can be easily pointed at a single listener. In a car, however, the possible speaker mounting locations don't always allow for on-axis placement even for a single listener. In many cases, on-axis placement for two listeners simply isn't possible because the mounting locations are too close to the listeners to allow a single 60° window to cover both listeners. GTi competition speaker systems incorporate a 35° design axis, which provides an optimal listening window for each front-seat listener.

LISTENING WINDOWS AND MOUNTING LOCATIONS: CHOOSING THE BEST MOUNTING LOCATION AND AIMING THE TWEETER

Using the waveguides and planning your installation carefully will help to provide the best performance from your GTi competition speaker system. Consider the illustrations that follow and the ones to the left, when determining the best mounting locations for your woofers and tweeters.

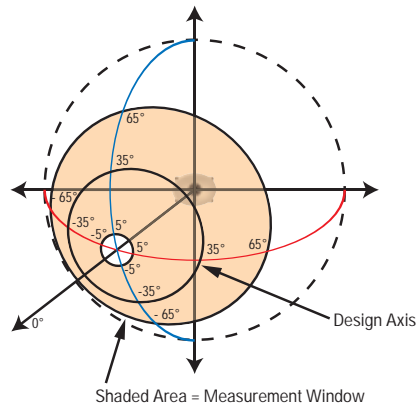


Figure 13. Listening window illustrated in three dimensions.

The shaded area in Figure 13 indicates the listening window (the area over which the waveguide is optimized).

The small circle marked 5° represents one edge of the listening window and the circle marked 65° represents the other.

The small white area inside the 5° circle in the middle indicates the area considered to be "on-axis."

The circle marked 35° indicates the design axis, or the center of the listening window.

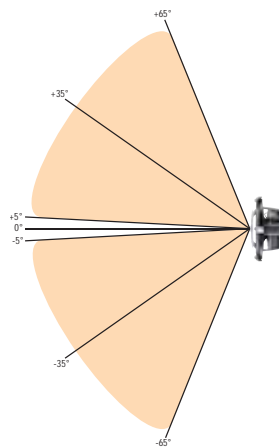


Figure 14. Listening windows viewed in two dimensions.

WOOFER MOUNTING CONSIDERATIONS

- All woofers require a rigid baffle and isolation between the front and back of the speaker for best low-frequency extension.
- The 660GTi woofer may be used in an infinite baffle or in a small sealed enclosure with a volume equal to or larger than 1/8 ft³. The 560GTi woofer may be used in an infinite baffle or in a small sealed enclosure with a volume equal to or larger than 1/12 ft³.
- The GTi competition speaker systems include a choice of grille trim. See Figure 19 to change to the carbon fiber grille trim.

TWEETER MOUNTING CONSIDERATIONS

- Use the waveguides, if possible.
- The waveguide requires a hole 4" in diameter for mounting.
- Aim the tweeters at a point in between the two front-seat positions, if the waveguides will be mounted in the A-pillars or kick panels.

ADJUSTING THE CROSSOVER

- If you are bi-amping the speakers, remove the jumpers, as illustrated in Figure 20.
- If you are using the waveguides, move the switch to the "Waveguide" position.
- If you are not using the waveguide, move the switch to the "No Waveguide" position.
- After installing the system, set the "Tweeter Level" switch according to your preference.

See pages 14–19 for dimensions, mounting and wiring diagrams, Thiele/Small parameters and performance graphs.

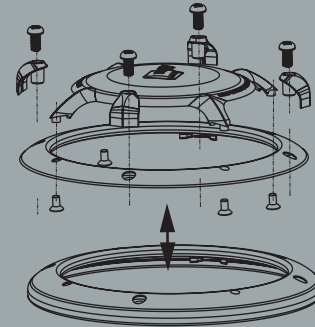


Figure 19.

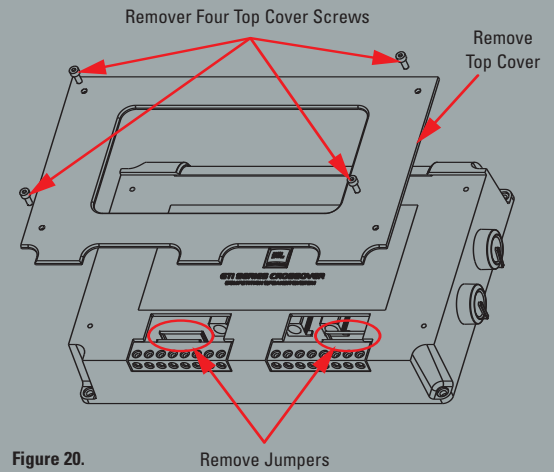


Figure 20.

SPECIFICATIONS



Model	560GTi	660GTi
Description	5" 2-Way professional-grade automotive component speaker system	6" 2-Way professional-grade automotive component speaker system
Power Handling (W peak)	500	600
Power Handling (W RMS)	125	150
Sensitivity (dB @ 2.83V)	91	92
Frequency Response (Hz)	58–30k	50–30k
Crossover Frequency (Hz)	2500	2500
Voice Coil Diameter (mm)	50	50
Voice Coil Diameter (in)	2	2
Impedance	4 ohms	4 ohms



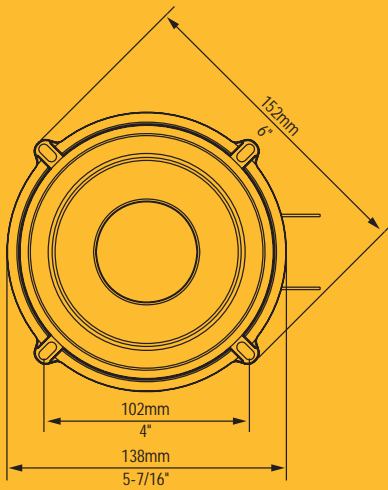


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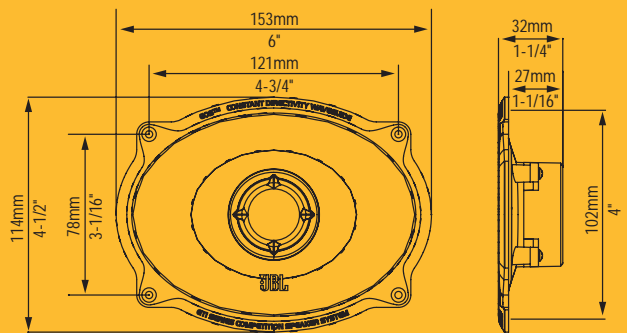
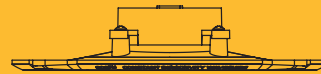
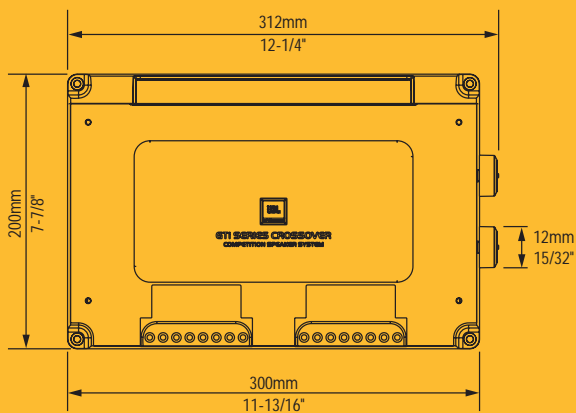
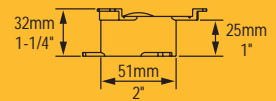
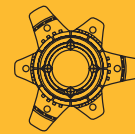
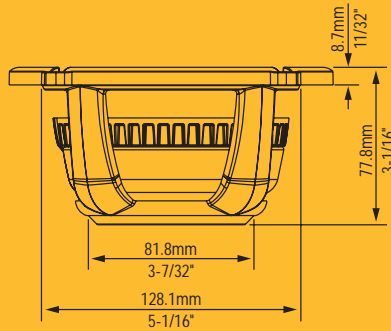
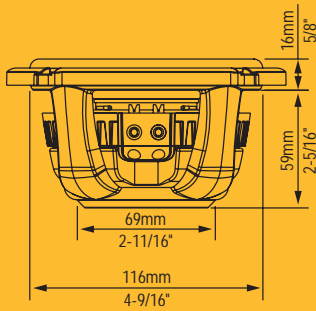
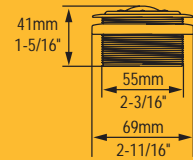
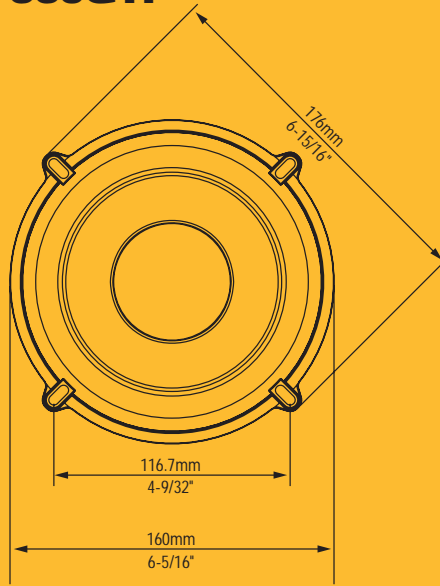


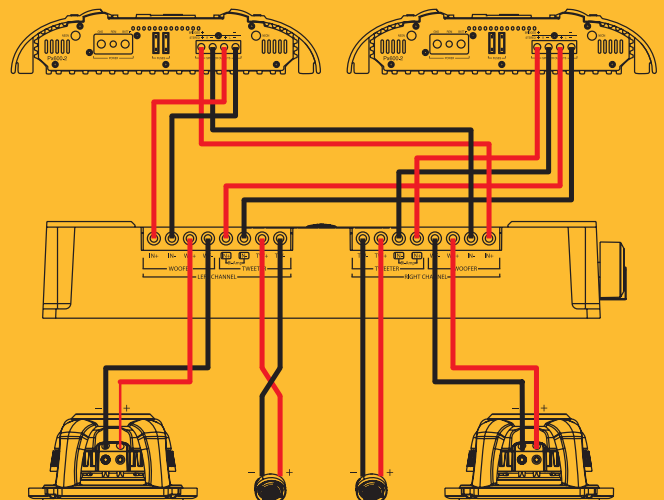
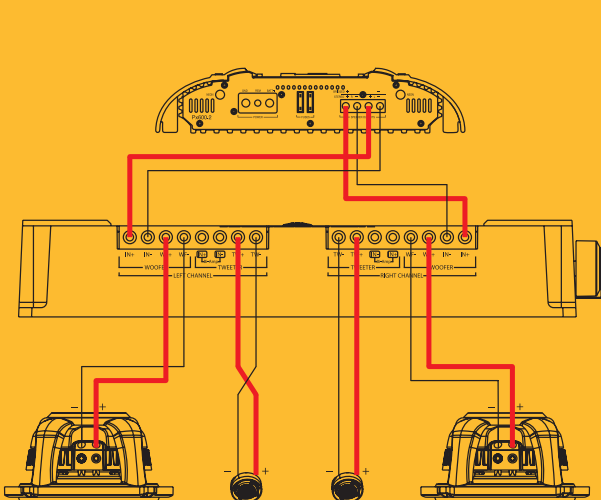
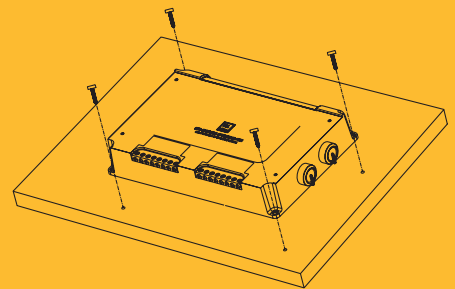
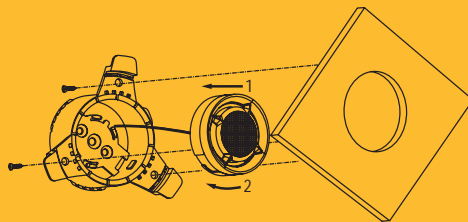
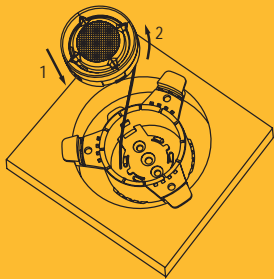
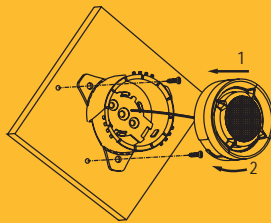
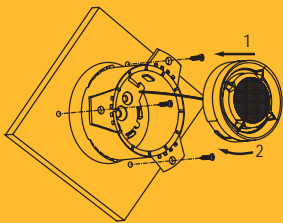
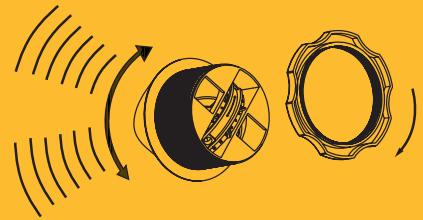
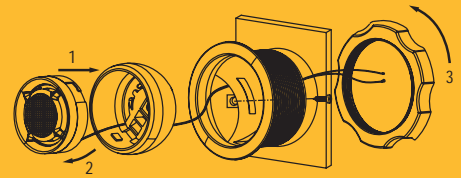
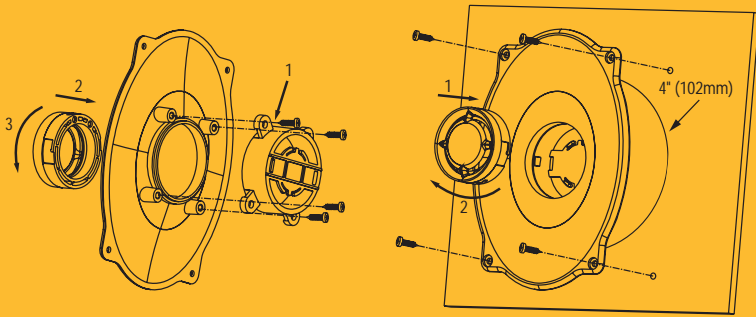


560GTi

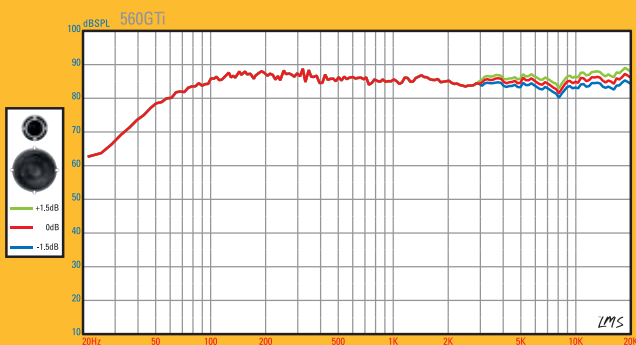
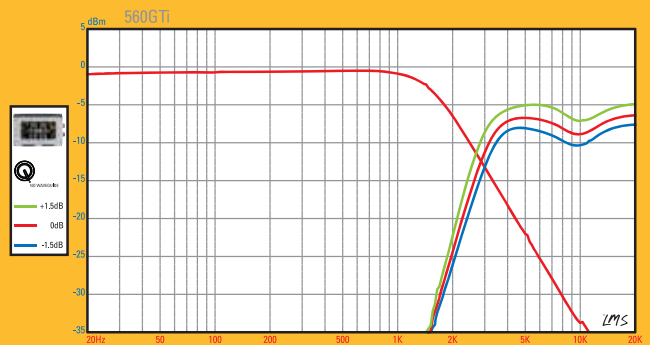
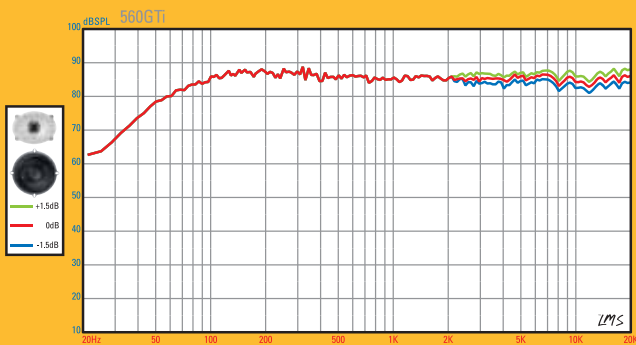
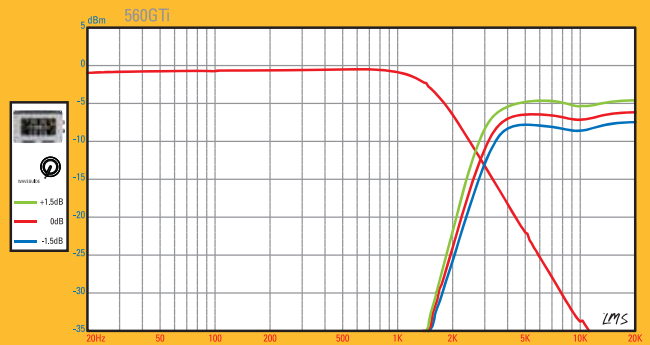
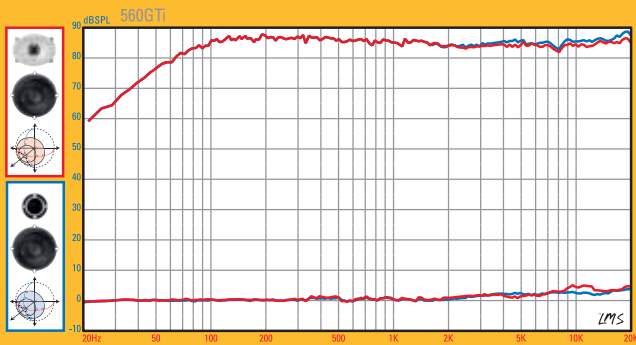
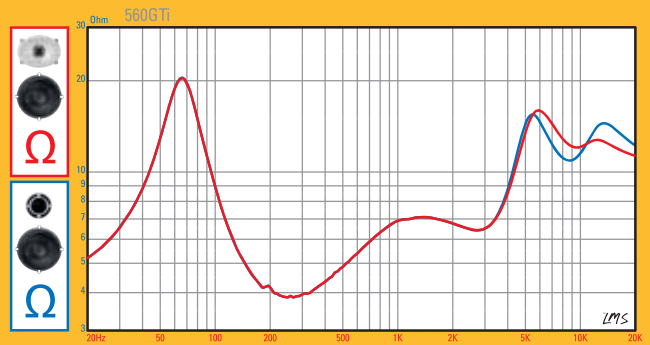
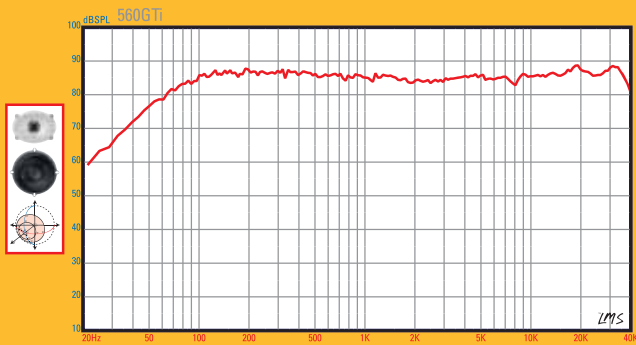


660GTi

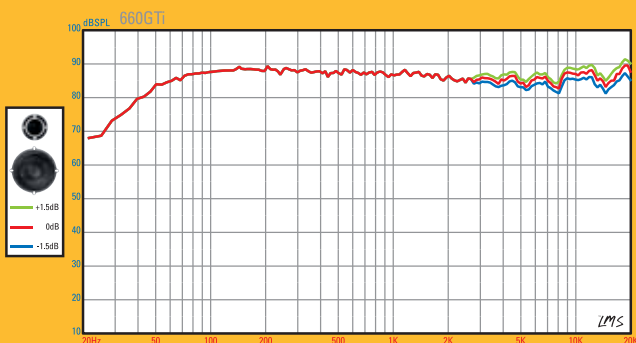
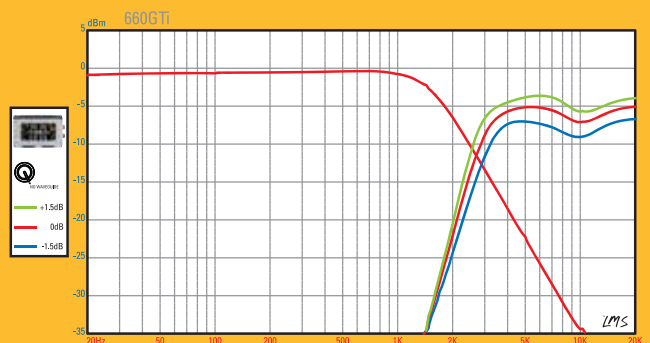
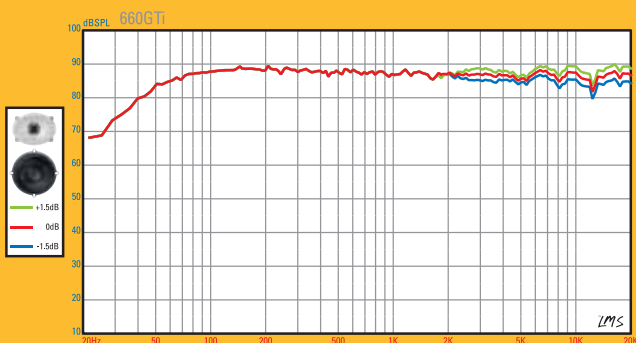
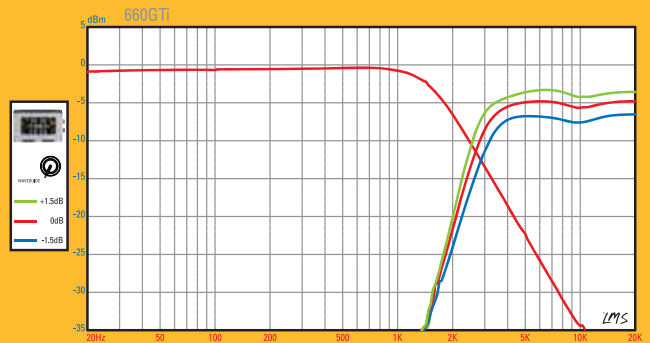
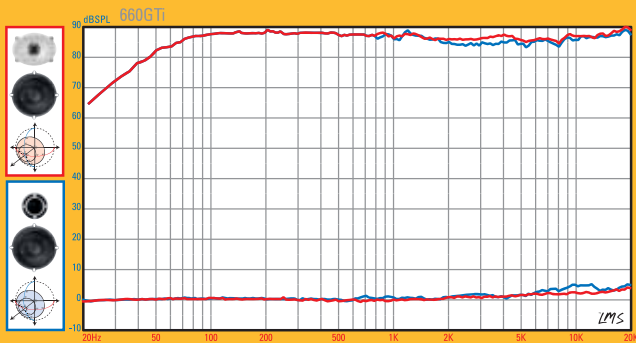
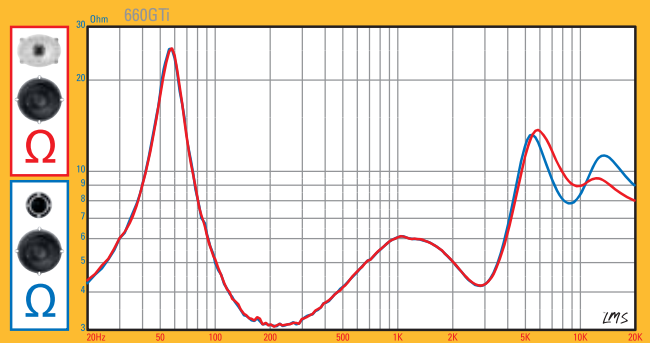
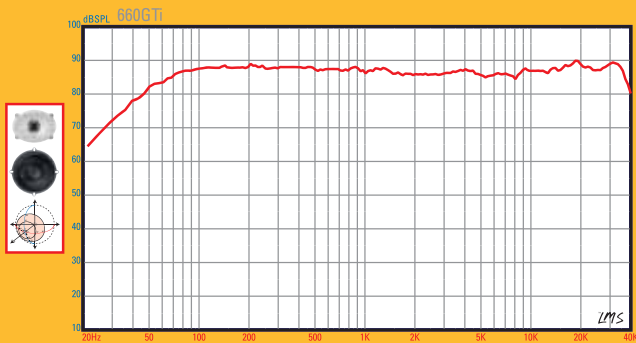




560GTi



660GTi



THIELE/SMALL

	560GTi	660GTi
BL (T _M)	7.6	7.56
DCR (ohms)	3.07	3.48
M _{MS} (g)	14.84	17.94
S _D (sq cm)	86.6	132.7
C _{MS} (μm/N)	312	382
V _{AS} (l)	3.29	9.45
F _S (Hz)	74	60.8
Q _{ES}	0.37	0.42
Q _{MS}	5.49	10.17
Q _T	0.34	0.4
1wSPL (dB0)	87.5	89
SPL 2.83V	91.7	92.6
H _{VC} (mm)	15.74	17.27
H _{AG} (mm)	6	6
X _{MAX}	4.87	5.36
V _B	196,000mm ³	288,890mm ³
L _{EVC} (mHz)	0.1	0.13





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