# Car Audio / Thiele-Small Parameters

This group of parameters outlined by A.N. Thiele, and later by R.H. Small, describe the electrical and mechanical characteristics of mid and low frequency loudspeakers operating in their pistonic region. These parameters are crucial for designing quality enclosures for sound quality or loudness.

"In the early seventies, several technical papers were presented to the AES (Audio Engineering Society) that resulted in the development of what we know today as 'Thiele-Small Parameters'. These papers were authored by A.N.Thiele and Richard H. Small. Thiele was the senior engineer of design and development for the Australian Broadcasting Commission and was responsible at the time for the Federal Engineering Laboratory, as well as for analyzing the design of equipment and systems for sound and vision broadcasting. Small was, at the time, a Commonwealth Post-graduate Research Student in the School of Electrical Engineering at the University of Sydney.

"Thiele and Small devoted considerable effort to show how the following parameters define the relationship between a speaker and a particular enclosure. However, they can be invaluable in making choices because they tell you far more about the transducer's real performance than the basic benchmarks of size, maximum power rating or average sensitivity."

| **Thiele-Small Parameters** | |
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| **B** | Magnetic flux density in gap, in Tesla-meters (TM) |
| **BL** | The magnetic strength of the motor structure. "Expressed in Tesla meters, this is a measurement of the motor strength of a speaker. Think of this as how good a weightlifter the transducer is. A measured mass is applied to the cone forcing it back while the current required for the motor to force the mass back is measured. The formula is mass in grams divided by the current in amperes. A high BL figure indicates a very strong transducer that moves the cone with authority!" |
| **C** | Propagation velocity of sound at STP, approx. 342 m/s |
| **Cas** | Acoustical equivalent of Cms |
| **Cmes** | The electrical capacitive equivalent of Mms, in farads |
| **Cms** | The driver's mechanical compliance (reciprocal of stiffness), in m/N |
| **D** | Effective diameter of driver, in meters |
| **F3** | -3 dB cutoff frequency, in Hz |
| **Fb** | Enclosure resonance (usually for bass reflex systems), in Hz |
| **Fc** | System resonance (usually for sealed box systems), in Hz |
| **Fs** | Driver free air resonance, in Hz. This is the point at which driver impedance is maximum. "This parameter is the free-air resonant frequency of a speaker. Simply stated, it is the point at which the weight of the moving parts of the speaker becomes balanced with the force of the speaker suspension when in motion. If you've ever seen a piece of string start humming uncontrollably in the wind, you have seen the effect of reaching a resonant frequency. It is important to know this information so that you can prevent your enclosure from 'ringing'. With a loudspeaker, the mass of the moving parts, and the stiffness of the suspension (surround and spider) are the key elements that affect the resonant frequency. As a general rule of thumb, a lower Fs indicates a woofer that would be better for low-frequency reproduction than a woofer with a higher Fs. This is not always the case though, because |

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| | other parameters affect the ultimate performance as well." |
| **L** | Length of wire immersed in magnetic field, in meters |
| **Lces** | The electrical inductive equivalent of Cms, in henries |
| **Le** | "This is the voice coil inductance measured in millihenries (mH). The industry standard is to measure inductance at 1,000 Hz. As frequencies get higher there will be a rise in impedance above Re. This is because the voice coil is acting as an inductor. Consequently, the impedance of a speaker is not a fixed resistance, but can be represented as a curve that changes as the input frequency changes. Maximum impedance (Zmax) occurs at Fs. " |
| **Ms** | The total moving mass of the loudspeaker cone. |
| **Mmd** | Diaphram mass, in grams |
| **Mms** | The driver's effective mechanical mass (including air load), in kg. "This parameter is the combination of the weight of the cone assembly plus the 'driver radiation mass load'. The weight of the cone assembly is easy: it's just the sum of the weight of the cone assembly components. The driver radiation mass load is the confusing part. In simple terminology, it is the weight of the air (the amount calculated in Vd) that the cone will have to push." |
| **n0** | The reference efficiency of the system (eta sub 0) dimensionless, usually expressed as % |
| **p** | (rho) Density of air at STP 1.18 kg/m^3 |
| **Pa** | Acoustical power |
| **Pe** | Electrical power |
| **Q** | The relative damping of a loudspeaker |
| **Q Parameters** | "Qms, Qes, and Qts are measurements related to the control of a transducer's suspension when it reaches the resonant frequency (Fs). The suspension must prevent any lateral motion that might allow the voice coil and pole to touch (this would destroy the loudspeaker). The suspension must also act like a shock absorber. Qms is a measurement of the control coming from the speaker's mechanical suspension system (the surround and spider). View these components like springs. Qes is a measurement of the control coming from the speaker's electrical suspension system (the voice coil and magnet). Opposing forces from the mechanical and electrical suspensions act to absorb shock. Qts is called the 'Total Q' of the driver and is derived from an equation where Qes is multiplied by Qms and the result is divided by the sum of the same.<br><br>As a general guideline, Qts of 0.4 or below indicates a transducer well suited to a vented enclosure. Qts between 0.4 and 0.7 indicates suitability for a sealed enclosure. Qts of 0.7 or above indicates suitability for free-air or infinite baffle applications. However, there are exceptions! The Eminence Kilomax 18 has a Qts of 0.56. This suggests a sealed enclosure, but in reality it works extremely well in a ported enclosure. Please consider all the parameters when selecting loudspeakers. If you are in any doubt, contact your Eminence representative for technical assistance." |
| **Qa** | The system's Q at Fb, due to absorption losses; dimensionless |
| **Qec** | The system's Q at resonance (Fc), due to electrical losses; dimensionless |
| **Qes** | The driver's Q at resonance (Fs), due to electrical losses; dimensionless. "A measurement of the control coming from the speaker's electrical suspension system (the voice coil and magnet). Opposing forces from the mechanical and electrical suspensions act to absorb shock." |
| **Ql** | The system's Q at Fb, due to leakage losses; dimensionless |
| **Qmc** | The system's Q at resonance (Fc), due to mechanical losses; dimensionless |
| **Qms** | The driver's Q at resonance (Fs), due to mechanical losses; dimensionless. "A measurement of the control coming from the speaker's mechanical suspension system (the surround and spider). View these components like springs." |
| **Qp** | The system's Q at Fb, due to port losses (turbulence, viscousity, etc.); dimensionless |
| **Qtc** | The system's Q at resonance (Fc), due to all losses; dimensionless |

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| **Qts** | The driver's Q at resonance (Fs), due to all losses; dimensionless. "The 'Total Q' of the driver and is derived from an equation where Qes is multiplied by Qms and the result is divided by the sum of the same." |
| **R** | Ripple, in dB |
| **Re** | "This is the DC resistance of the driver measured with an ohm meter and it is often referred to as the 'DCR'. This measurement will almost always be less than the driver's nominal impedance. Consumers sometimes get concerned the Re is less than the published impedance and fear that amplifiers will be overloaded. Due to the fact that the inductance of a speaker rises with a rise in frequency, it is unlikely that the amplifier will often see the DC resistance as its load." |
| **Ras** | Acoustical equivalent of Rms |
| **Res** | The electrical resistive equivalent of Rms, in ohms |
| **Rms** | "This parameter represents the mechanical resistance of a driver's suspension losses. It is a measurement of the absorption qualities of the speaker suspension and is stated in N*sec/m." |
| **Revc** | DC voice coil resistance, in ohms |
| **Rg** | Amplifier source resistance (includes leads, crossover, etc.), in ohms |
| **Rms** | The driver's mechanical losses, in kg/s |
| **Sd** | Effective piston radiating area of driver, in square centimeters. "This is the actual surface area of the cone, normally given in square cm." |
| **SPLo** | Sound Pressure Level, usually measured at 1 watt, at 1 meter in front of the loudspeaker |
| **Vas/Cms** | "Equivalent volume of compliance", this is a volume of air whose compliance is the same as a driver's acoustical compliance Cms (q.v.), in cubic meters. "Vas represents the volume of air that when compressed to one cubic meter exerts the same force as the compliance (Cms) of the suspension in a particular speaker. Vas is one of the trickiest parameters to measure because air pressure changes relative to humidity and temperature — a precisely controlled lab environment is essential. Cms is measured in meters per Newton. Cms is the force exerted by the mechanical suspension of the speaker. It is simply a measurement of its stiffness. Considering stiffness (Cms), in conjunction with the Q parameters gives rise to the kind of subjective decisions made by car manufacturers when tuning cars between comfort to carry the president and precision to go racing. Think of the peaks and valleys of audio signals like a road surface then consider that the ideal speaker suspension is like car suspension that can traverse the rockiest terrain with race-car precision and sensitivity at the speed of a fighter plane. It's quite a challenge because focusing on any one discipline tends to have a detrimental effect on the others. " |
| **Vd** | Maximum linear volume of displacement of the driver (product of Sd times Xmax), in cubic meters. "This parameter is the Peak Diaphragm Displacement Volume — in other words the volume of air the cone will move. It is calculated by multipying Xmax (Voice Coil Overhang of the driver) by Sd (Surface area of the cone). Vd is noted in cc. The highest Vd figure is desirable for a sub-bass transducer." |
| **Xmax/Xmech** | Maximum peak linear excursion of driver, in meters. "Short for Maximum Linear Excursion. Speaker output becomes non-linear when the voice coil begins to leave the magnetic gap. Although suspensions can create non-linearity in output, the point at which the number of turns in the gap (see BL) begins to decrease is when distortion starts to increase. Eminence has historically been very conservative with this measurement and indicated only the voice coil overhang (Xmax: Voice coil height minus top plate thickness, divided by 2). Xmech is expressed by Eminence as the lowest of four potential failure condition measurements times 2: Spider crashing on top plate; Voice coil bottoming on back plate; Voice coil coming out of gap above core; Physical limitation of cone. Take the lowest of these measurements then multiply it by two. This gives a distance that describes the maximum mechanical movement of the cone." |
| **Zmax** | "This parameter represents the speaker's impedance at resonance." |