# A Guide to Reading Transducer Specification Sheets

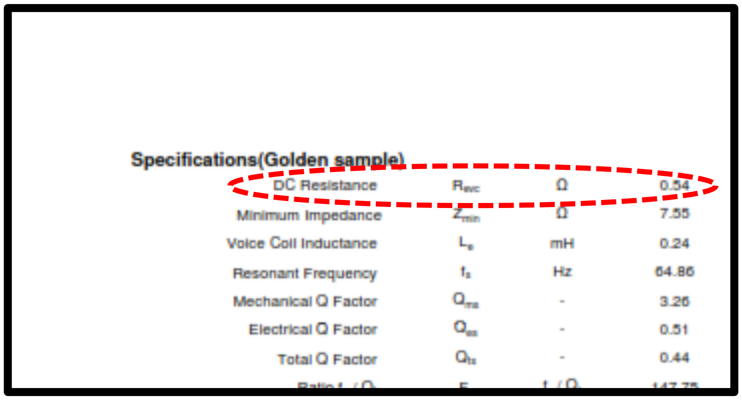
There are many numbers and figures appearing on a transducer specification sheet. This document serves as a guide to understanding the key parameters, which are:

- DCR
- Sd
- fs
- Qts
- Sensitivity
- Bandwidth
- Xmax
- Power handling
- Mounting dimensions

These parameters define how transducer may differ in implementation into audio systems

Let's tackle each of these, in order, with some elementary explanations which will allow the reader a basis for understanding specification sheets, and a basis for learning more.

## DCR



**Specifications(Golden sample)**

| | | | |
|---|---|---|---|
| DC Resistance | $R_{evc}$ | Ω | 0.54 |
| Minimum Impedance | $Z_{min}$ | Ω | 7.55 |
| Voice Coil Inductance | $L_e$ | mH | 0.24 |
| Resonant Frequency | $f_s$ | Hz | 64.86 |
| Mechanical Q Factor | $Q_{ms}$ | - | 3.26 |
| Electrical Q Factor | $Q_{es}$ | - | 0.51 |
| Total Q Factor | $Q_{ts}$ | - | 0.44 |

**DCR** (sometimes labeled "Re") refers to DC resistance of the voice coil. The importance of this parameter relates to how a loudspeaker is designed to interact with its amplifier. Typically, amplifiers are designed to optimally driver an electrical impedance of roughly 8 ohms. Loudspeakers are therefore designed to typically have this level of impedance. Now, a loudspeaker may be designed with a tweeter plus a woofer, wired in series; the typical impedance split between these two components would be for each to have a DC resistance of a little less than 4 ohms. If a tweeter is wired in series with two woofers which are wired in parallel, then the tweeter will have an impedance of 4 ohms, and the two woofers would have impedance of 8 ohms each.

The difference between DC resistance and impedance is that the transducer's voice coil includes both DC resistance and coil inductance. These two factors are summed together to form the overall impedance level.  This is one reason why DC resistance values often slightly undershoot the impedance value target of 4 or 8 ohms.  The other reason that loudspeaker designs undershoot the impedance value target is that they can produce more SPL with a lower impedance, for a given input voltage signal…so long as the amplifier driving the loudspeaker can handle the lowered impedance.

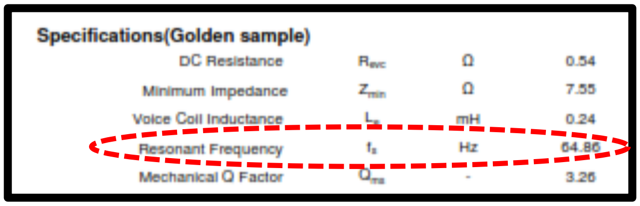
## Sd

| | | | |
|---|---|---|---|
| Suspension Compliance | $C_{ms}$ | um/N | 943.69 |
| Effective Cone Diameter | D | cm | 0.00 |
| Effective Piston Area | $S_D$ | cm$^2$ | 47.78 |
| Equivalent Volume | $V_{as}$ | L | 3.35 |
| Motor Force Factor | BL | T·m | 5.38 |

**Sd** refers to the radiating area (the effective piston area) of the diaphragm of the transducer.  A transducer functions by converting an electrical signal input to the voice coil, into a magnetic force driving the coil along the central axis of the transducer.  The diaphragm, being attached to the voice coil, experiences the same motion as the voice coil, and through its motion pushes on the air in front of it, to create the outgoing pressure wave.  The larger the radiating area, the more air can be displaced by the motion of the diaphragm, and the more sound pressure is generated.

Of course, diaphragms do add mass to the moving mass of this transducer, and this is a downwards “pressure” on the sensitivity.  Additionally, the diaphragm also exerts pressure onto the air inside the loudspeaker cabinet, and the effective stiffness of the air inside of the cabinet varies with the square of Sd; this exerts a “pressure” upwards on f0.  The result of this is that the Sd value for woofers tends to be dependent on the size of the internal air volume in the cabinet; large cabinets have large woofers, and small cabinets have small woofers.

## fs



**Specifications(Golden sample)**

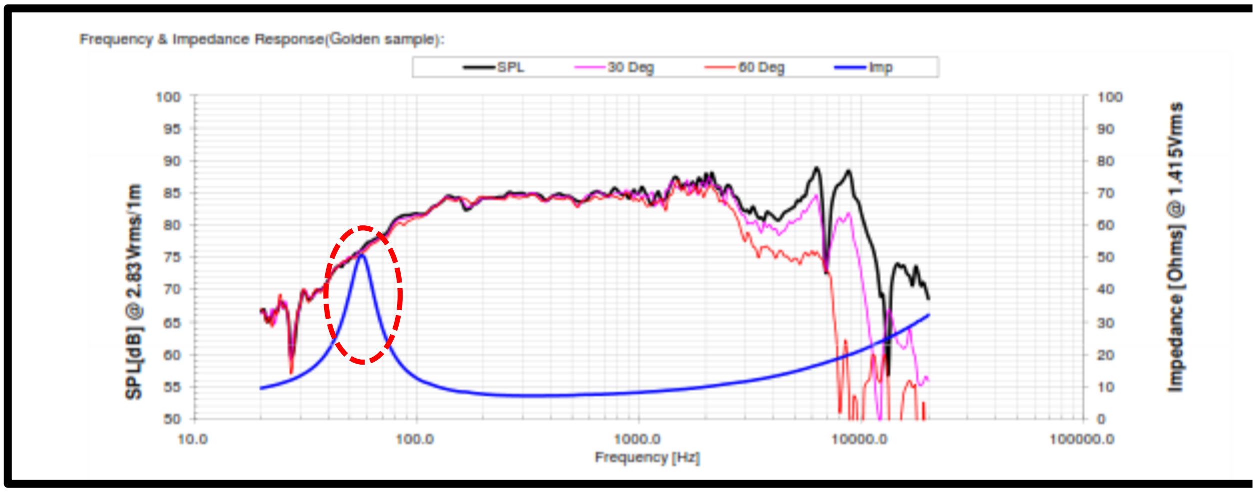
| | | | |
|---|---|---|---|
| DC Resistance | $R_{evc}$ | Ω | 0.54 |
| Minimum Impedance | $Z_{min}$ | Ω | 7.55 |
| Voice Coil Inductance | $L_e$ | mH | 0.24 |
| Resonant Frequency | $f_s$ | Hz | 64.86 |
| Mechanical Q Factor | $Q_{ms}$ | - | 3.26 |

**fs** (sometimes labelled f0) refers to the resonant frequency of the transducer.  This is the frequency at which the motion of the soft parts of the transducer are going through their primary resonance, which is pistonic diaphragm motion.  On an impedance curve, this frequency is identified as the impedance peak.

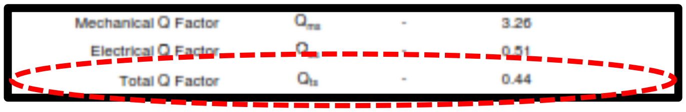
If you know the moving mass and the stiffness (or compliance) of your suspension system, you can calculate the resonant frequency from the standard mass-spring equation:

$$f_s = \frac{1}{2\pi\sqrt{C_{MS}M_{MS}}}$$

It should be noted that it is common that the value shown on the graph vs. in the table are often slightly different.  This is because the measurement conditions are different, resulting in different diaphragm excursion levels. Transducer suspension system behavior is known to be complex, and the stiffness of the suspension system changes with excursion.



## Qts



| | | | |
|---|---|---|---|
| Mechanical Q Factor | $Q_{ms}$ | - | 3.26 |
| Electrical Q Factor | $Q_{es}$ | - | 0.51 |
| Total Q Factor | $Q_{ts}$ | - | 0.44 |

**Qts** is the total quality factor for the transducer. Quality factors are a measure of the "strength" of a resonance (for the lack of a better phrase), so for the transducer the Qts relates to the primary, pistonic resonance. A few points to keep in mind:

- The lower the Qts, the more damping there is in the system (mechanical or otherwise).
- A Qts value of 0.7 for a transducer means that the transducer which has a "maximally flat" frequency response. Such a transducer is well suited to an infinite baffle type system (like in-wall applications, or "very large cabinets").
- A Qts value between 0.4 and 0.6 for a transducer means that the transducer can be well suited for ported enclosures.
- A Qts value of 0.4 or less for a transducer means that the transducer can be well suited for use in sealed enclosures.

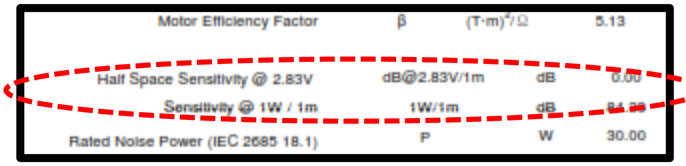
Qts can be calculated from other parameters, using the following equations:

$$Q_{MS} = \frac{\sqrt{C_{MS}M_{MS}}}{C_{MS}R_{MS}} = \frac{\sqrt{M_{MS}}}{R_{MS}\sqrt{C_{MS}}}$$

$$Q_{ES} = \frac{R_E M_{MS}}{(Bl)^2\sqrt{C_{MS}M_{MS}}} = \frac{R_E\sqrt{M_{MS}}}{(Bl)^2\sqrt{C_{MS}}}$$

$$Q_{TS} = \left(\frac{1}{Q_{ES}} + \frac{1}{Q_{MS}}\right)^{-1}$$

# Sensitivity



| | | | |
|---|---|---|---|
| Motor Efficiency Factor | β | $(T\cdot m)^2/\Omega$ | 5.13 |
| Half Space Sensitivity @ 2.83V | dB@2.83V/1m | dB | 0.00 |
| Sensitivity @ 1W / 1m | 1W/1m | dB | 84.38 |
| Rated Noise Power (IEC 2685 18.1) | P | W | 30.00 |

**Sensitivity** relates to the frequency response to the transducer. Specifically, as per the picture below, it gives an indication as to the frequency response level (dB SPL) at a frequency which corresponds to the minimum in the impedance curve, at a frequency above fs.

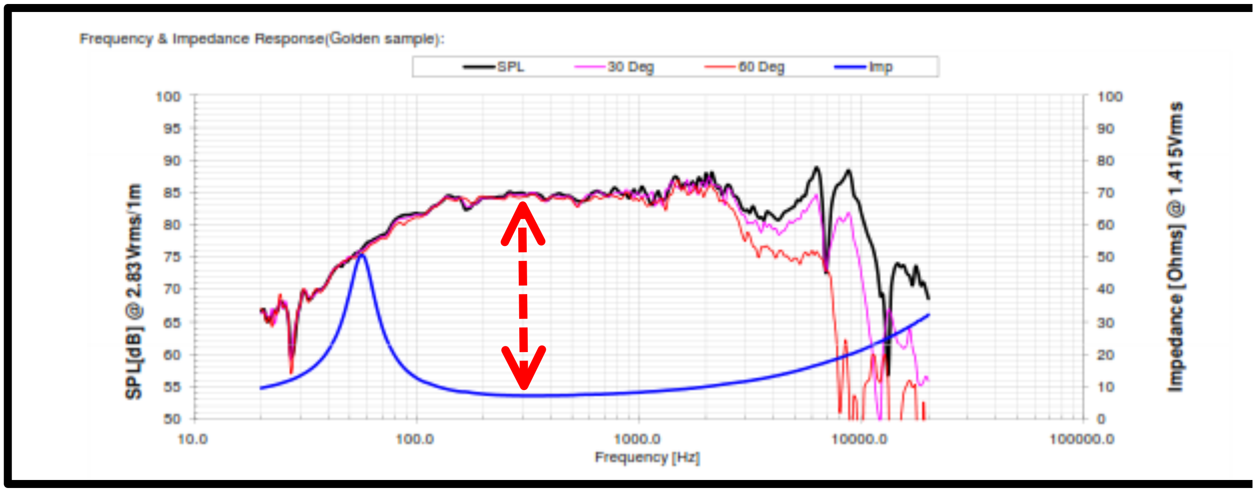
The controlling factors for sensitivity are moving mass Mms (the less Mms is, the higher the sensitivity), the motor force factor BL (more BL means higher sensitivity), coil resistance (more DCR means less sensitivity), and radiating area (more radiating area means more sensitivity).

Sensitivity is often quoted in two different ways:

- Sensitivity given a certain fixed input voltage to the transducer (usually 2.83 Vrms), measured at a 1 meter distance in a semi-anechoic chamber.
- Sensitivity given a certain fixed input power to the transducer (usually 1 W), measured at a 1 meter distance in a semi-anechoic chamber.

The second measurement nulls out the impedance factor from the sensitivity calculation (impedance changes are often easy to accommodate in transducer designs), allowing for an "apples to apples" comparison to be made between competing transducers.

The value in the sensitivity number is that it relates how easy it is for the transducer to reproduce normal sound pressure levels. Normally, speech lies in the 70-80 dB range, and we play music in the 80-90 dB range. The higher the sensitivity value, the easier it is for the audio system to play both at a normal sound level, but to accommodate SPL "spikes" associated with things like FX in movies (as an example). "Easier" in this context means "less power required".



## Power handling

| | | | |
|---|---|---|---|
| Half Space Sensitivity @ 2.83V | dB@2.83V/1m | dB | 0.00 |
| Sensitivity @ 1W / 1m | 1W/1m | dB | 84.39 |
| Rated Noise Power (IEC 2685 18.1) | P | W | 30.00 |
| Test Spectrum Bandwidth | 0 | | 12db/oct |

**Power handling** is a term which relates to reliability tests which the transducer design is successfully subjected to. These tests ensure that the product is reliable during expected applied input signals, for an extended period of time. A higher value for the power rating implies that the transducer can be played at a louder signal level than otherwise.

There are a number of different testing standards for power handling tests. One must use caution when interpreting values, therefore, as the signal bandwidth, type of test tone, and duration of the test may all be different between different testing standards.

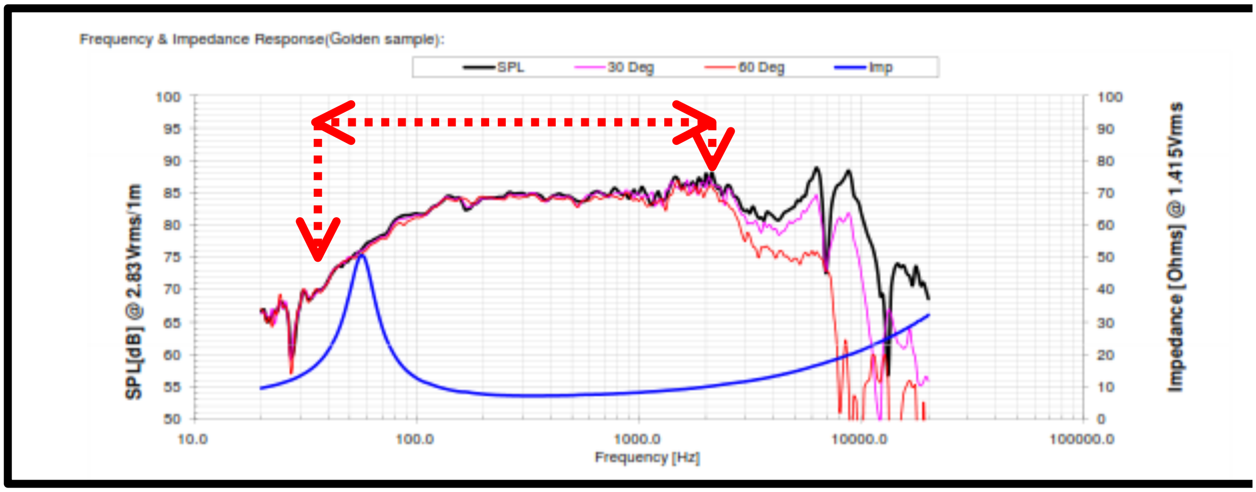
Operating transducers at power levels higher than the rated power may expose the transducer to early failure, due to audible defects, "bottoming" (moving parts coming into hard contact with non-moving parts), and general fatigue and failure of the moving components.

## Bandwidth

| | | | |
|---|---|---|---|
| Half Space Sensitivity @ 2.83V | dB@2.83V/1m | dB | 0.00 |
| Sensitivity @ 1W / 1m | 1W/1m | dB | 84.39 |
| Rated Noise Power (IEC 2685 18.1) | P | W | 30.00 |
| Test Spectrum Bandwidth | 0 | | 12db/oct |

**Bandwidth** in this context relates to the frequency range used in the power handling tests. This bandwidth is meant to relate to the frequency range expected to be used in operation of the transducer in typical audio system applications. The low frequency or "start" of the bandwidth usually corresponds to a frequency somewhat lower than fs. The high frequency or "end" of the bandwidth corresponds to the start of the roll-off in the frequency response, or a large spike in the frequency response to the break-up behavior of the diaphragm at those high frequencies, or an expected cross-over point for a woofer (a frequency at which the system stops sending signals to the woofer, instead sending them to a midrange driver or to a tweeter). Often the bandwidth is also the range used for frequency response testing, at the end of the transducer production line; during such a test, the deviation in the sound pressure level from that produced by a "golden sample" is evaluated against acceptable limits.

"Sweep test bandwidth" is a slightly different term, referring to the frequency range used for the swept sine tone listening test usually conducted at the end of a transducer production line.

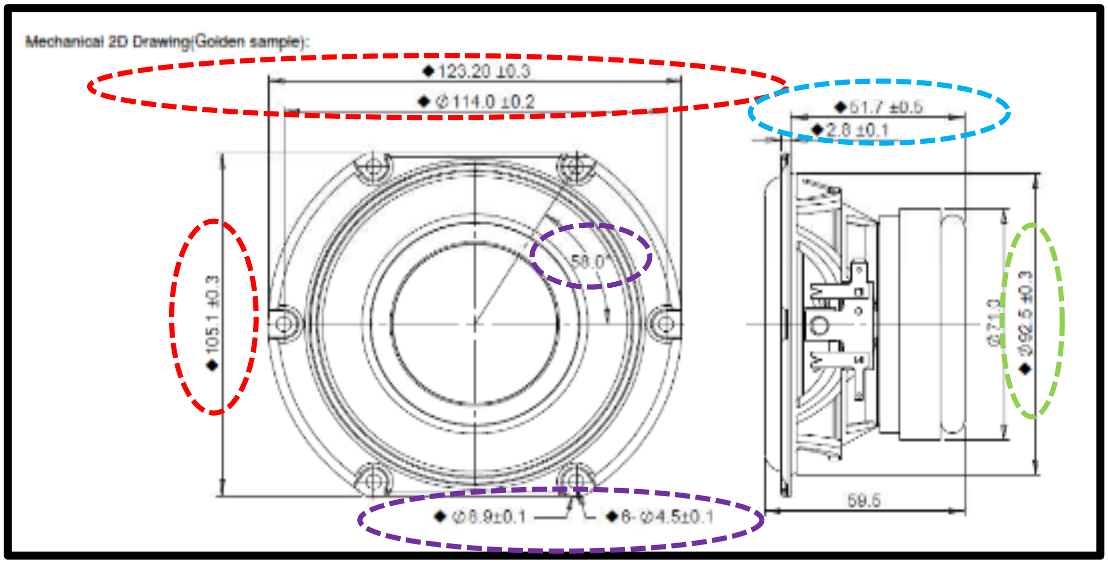


## Xmax

| | | | |
|---|---|---|---|
| Voice Coil Former Material | VCfm | - | 0.00 |
| Voice Coil Inner Diameter | VCd | mm | 25.73 |
| Gap Height | Gh | mm | 0.00 |
| Maximum Linear Excursion | Xmax | mm | 0.00 |

**Xmax** is an indication of how much excursion the diaphragm can make, before the performance of the transducer starts to become non-linear. The larger this value is, the louder the transducer can play before distortion effects become discernible in the sound quality. As woofers naturally have more excursion than tweeters, a large value for Xmax is intrinsically more valuable for woofers than for tweeters.

## Mounting Dimensions



The mechanical drawings shown on specification sheets (see picture above) will show dimensions typically relating:

- The outside envelope of the transducer (red circles)
- The mounting depth of the transducer (blue circle)
- The size of the enclosure cut-out hole needed for the transducer to fit into the enclosure (green circle)
- Positioning and size of the mounting holes (purple circles)

## Parameters Not Discussed

The fundamental parameters not discussed are:

- **BL** – this is the motor force constant, relating the conversion constant for current traveling through the voice coil, into magnetic force acting along the voice coil's axis, by way of the Lorentz force law.
- **Cms** – this is the compliance of the transducer's suspension system.
- **Mms** – this is the moving mass of the transducer (diaphragm, voice coil, dust cap, glues, etc.)
- **Rms** – this is the mechanical damping in the transducer's suspension system.

This parameters are typically derived by transducer measurement systems, from calculations and formulae relating these parameters to the parameters discussed above. Some of these equations are:

$$V_{AS} = (\rho_0 c^2)(C_{MS} S_D^2)$$

$$f_s = \frac{1}{2\pi\sqrt{C_{MS} M_{MS}}}$$

$$Q_{MS} = \frac{\sqrt{C_{MS} M_{MS}}}{C_{MS} R_{MS}} = \frac{\sqrt{M_{MS}}}{R_{MS}\sqrt{C_{MS}}}$$

$$Q_{ES} = \frac{R_E M_{MS}}{(Bl)^2\sqrt{C_{MS} M_{MS}}} = \frac{R_E\sqrt{M_{MS}}}{(Bl)^2\sqrt{C_{MS}}}$$

$$C_{MS} = \left(\frac{1}{\rho_0 c^2}\right)\left(\frac{V_{AS}}{S_D^2}\right)$$

$$M_{MS} = \left(\frac{\rho_0 c^2}{4\pi^2}\right)\left(\frac{S_D^2}{f_S^2 V_{AS}}\right)$$

$$R_{MS} = \left(\frac{\rho_0 c^2}{2\pi}\right)\left(\frac{S_D^2}{Q_{MS} f_S V_{AS}}\right)$$

$$(Bl) = \sqrt{\left(\frac{\rho_0 c^2}{2\pi}\right)\left(\frac{R_E S_D^2}{Q_{MS} f_S V_{AS}}\right)}$$

These equations, coupled with knowledge of the typical transducer equivalent circuit model, allows for the calculation of BL, Cms, Rms, and Mms from fs, Sd, Re, and Qts.