

Cross-PC 5.0

Loudspeaker simulation

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and

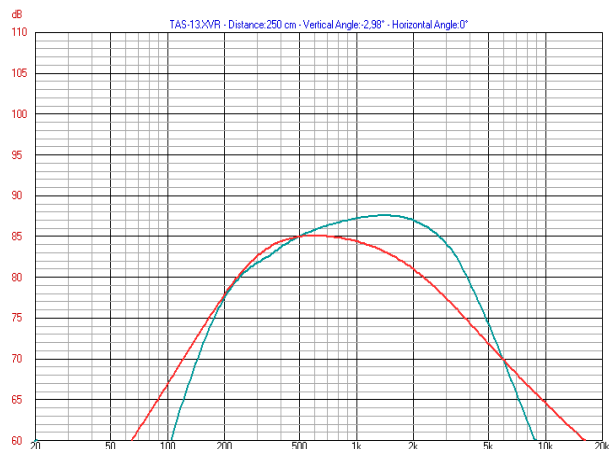
Pierfrancesco Fravolini

A crossover calculated using the formulas of the classical theory of the filters can provide accurate results only if terminated on purely resistive loads.

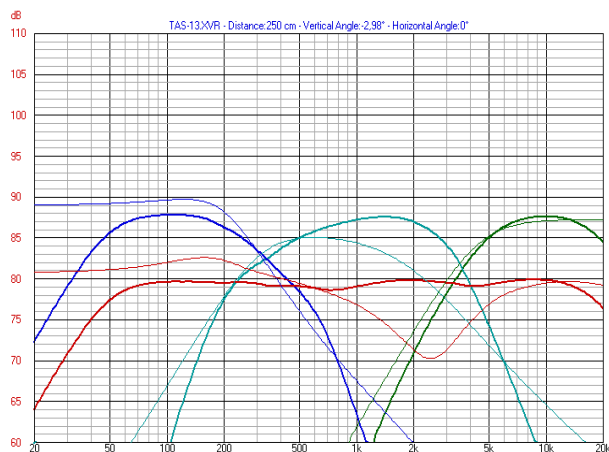
In order to predict the real acoustic response of a system, you must consider both the electrical response of the filter loaded by impedance of your speakers, both the real acoustic responses of the various components, as well as the respective mounting conditions.

Frequency response of a real speaker.

The light blue curve shows the response of a real midrange filtered by a band-pass filter cell. The red curve shows the same midrange not considering the frequency response of the transducer and its impedance curve.

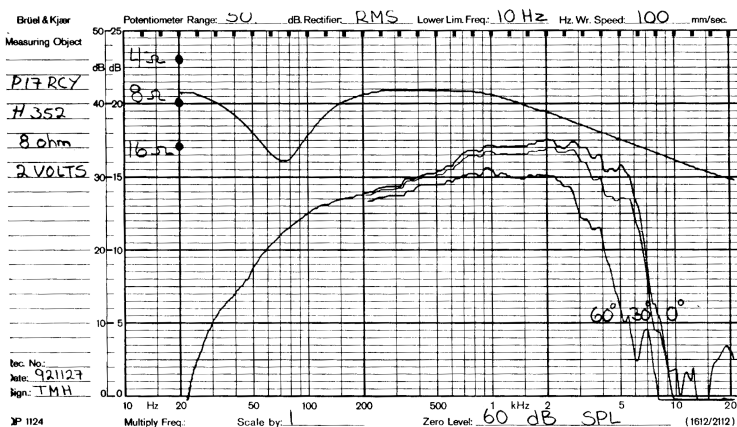


Frequency responses of the various ways of a system of real loudspeakers, together with the overall response. The thinner curves are drawn up not considering the response and impedance of transducers.



The calculation routines included in the Cross-PC software are able to simulate the effects on the acoustic response of the final resulting from the termination of a network of passive crossover on real speakers. Of course, both the impedance and the response of the components and their geometry assembly must be available and must somehow be communicated to the computer to allow it to perform all necessary calculations.

Frequency response and impedance of the mid-woofer Seas RCY p17. In this case the graph of the impedance is even backwards. Fortunately values are easily obtainable through the linear scale shown on the left.



The most important condition so the program can calculate the performance of the complete system

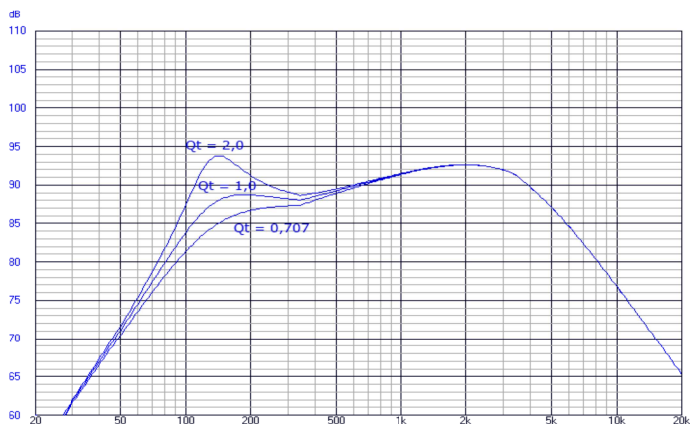
with adequate approximation, is that the impedance and frequency response of each speaker are simulated accurately.

To do this, the user must obtain a number of values, to be attributed to the same number of parameters, from the data declared by the manufacturers or by measures carried out directly on the components. These values can be easily obtained from the datasheet provided by speaker manufacturers, but sometimes have to be modified or extrapolated to make sure that the curves simulated by the software are as similar as possible to those of the transducer.

In summary, the data that the user of Cross-PC needs to know to perform an accurate simulation of a three-way system are the following:

- **F_c , - Q_{tc}** - Resonance frequency and quality factor of the woofer in order (not necessary);
- **R_e** - Voice coil resistance of each speaker (essential);
- **F_s , Q_{ts}** - Resonance frequency and quality factor of the tweeter and midrange (not necessary);

Effect of the variation of Q_{ts} parameter on frequency response. Similarly, F_s change the lower cutoff frequency of the curve.

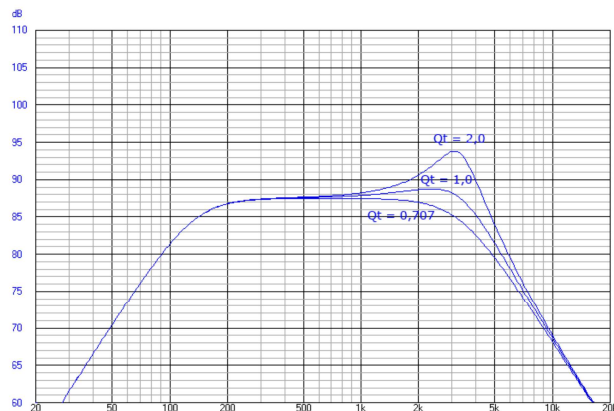


- ***Qms*** - Mechanical quality factor of tweeter and midrange (not necessary);
- **Graphs of frequency response of the three speakers**, measured in an anechoic chamber to the distance meter, for a sinusoidal voltage of 2.83 volts (essential);
- **Graphs of impedance of the three speakers** (essential).

The graphs of frequency response must be used to decide the values to be attributed to the following parameters:

- ***Fa, Qa*** - Resonance frequency and quality factor of the low-pass filter that simulates the natural trend of woofer, midrange and tweeter response to upper limit of their response, without filter.

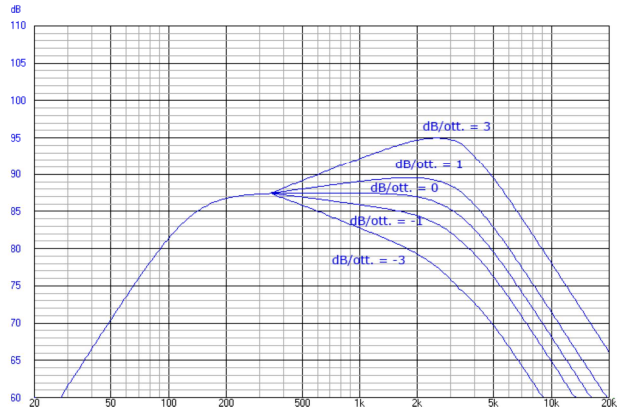
Effect of changing the parameter Qa on frequency response, Similarly, the parameter Fa changes the upper cutoff frequency of the curve.



- ***dBspl*** - output level of each of the three speakers, whose value have to be determined by successive approximations, together with values of ***Fs, Qts, Qa, Fa, dB/oct.***, to bring the simulated response curve at the same SPL level of the one shown on the graph measured (or declared).
- ***dB/Oct.*** - Indicate a value between -3 and +3. This

value will be used to vary the slope of the response between the zones of high-pass and low-pass without filter.

How the response curve varies changing the dB/Oct. value

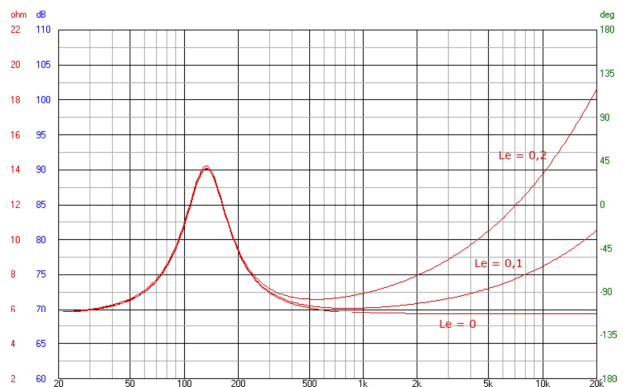


The impedance graph must be used to decide the values to be attributed to the following parameters:

- **Le** - must be calculated from the value of **Re** and impedance magnitude at the frequency **f** equal to 1 kHz (woofer) or 10 kHz (midrange and tweeter). In order to be used the following formula:

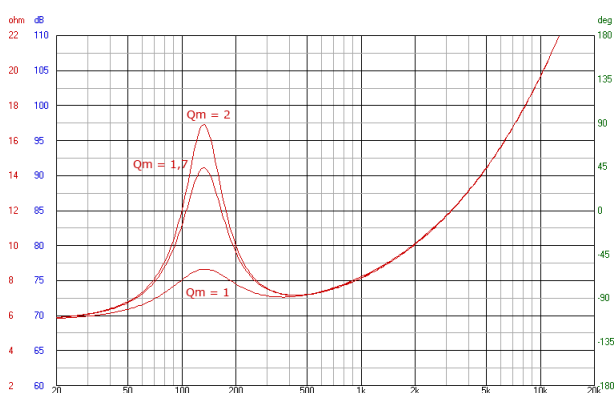
$$Le = (Z^2 - Re^2)^{1/2} / (2 \times 3.14 \times f)$$

The effect of the change in the value of Le impedance curve.



- ***Q_{ms}*** - Mechanical quality factors of tweeter and midrange must be set initially at declared value. If the maximum peak of the magnitude of the impedance calculated by Cross-PC, not match to the value that appears in the graph, you will have to vary arbitrarily ***Q_{ms}*** until the peak is at the correct value.

*Effect of change of ***Q_{ms}*** in the impedance curve*



Simulation

If the woofer is mounted in an acoustic suspension system, the data of ***F_c*** and ***Q_{tc}*** are available. In other cases the simulation of the interaction filter/speaker can not be predicted. But you have to consider however that, where the cutoff frequency of the low-pass crossover of the woofer is at least two octaves higher (ratio 4: 1) as the cutoff at -3 dB of the response at low frequencies, the sizing of the filter network and the calculation of the relative frequency response in the midrange and treble will still be correct. Since the program requires a mandatory value for ***F_c*** and ***Q_{tc}***, you can use the default data without problems

$$F_c = 50\text{Hz and } Q_{tc} = 0.8.$$

As for the values of *F_s* and *Q_{ms}* of midrange and tweeter, unless they are known, can be taken quite easily from response and impedance graphs. In particular, the resonance frequency matches that of the maximum peak of the magnitude of the impedance, while the merit factor may be derived from observation of the graph of the frequency response. The first thing to do is to evaluate the attenuation in dB of the output level at the resonance frequency compared to that of the first approximately straight line of the response (asymptotic level of emission for rigid piston work), searchable, for the cases that interest us, just above the rate of 2.5 times that of resonance frequency. The value of *Q_{ts}* it will be:

$$Q_{ts} = 10^{(-dB/20)}$$

While the value of *F_s* and *Q_{ts}* determine the trend of the low-frequency response curve, the values *F_a*, *Q_a*, and *dB/oct.* parameter, together with the given *dBspl*, determine the shape of the curve at higher frequencies. Their determination is made by examining the graph of the speaker response curve: you must ensure that this is replicated as best as possible from the curve simulated from the cross. To do this you must change the values *F_a* and *Q_a* so that the highest replicate simulation area in the best way the response of the transducer, while the figure *dB/oct.* adjusts the slope of the response in the central area of the graph. In practice the speaker response is simulated, in the cross, by a curve formed by three sections: at the bottom by a filter passes more of the second order, in the central area by a straight portion characterized by a certain slope, and in the upper part by a low-pass filter always of the second order. *F_s* and *Q_{ts}* regulate the shape of the filter high-pass (at low

frequency) *dB/oct.* adjusts the slope to the medium frequencies, *Fa* and *Qa* regulate the shape of the filter low-pass (at high frequency).

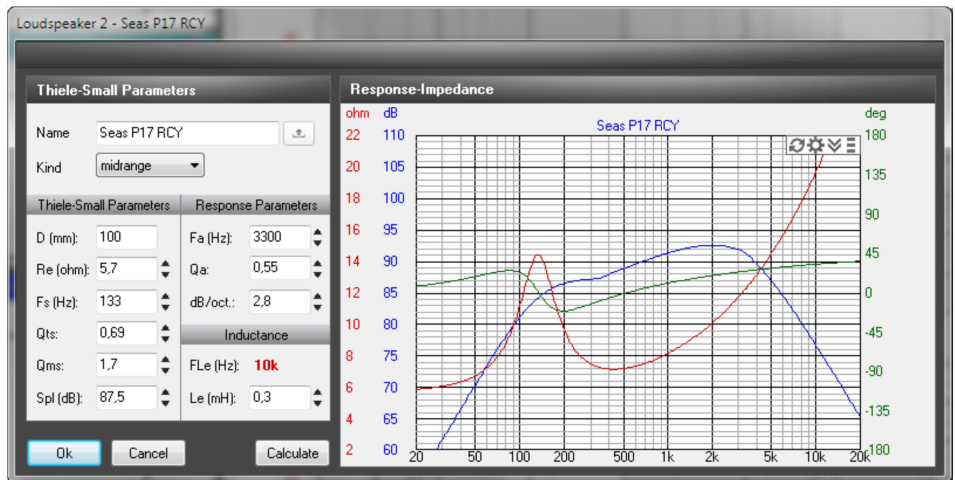
Necessary and sufficient condition for a proper simulation is that the Cross drawn from the response curve is a replica as faithful as possible of the response graph, even at the cost of using other parameters than those supplied by the manufacturer.

In each case, respected the correspondence between the graphs of real response and impedance and that simulated by the computer, even if the values chosen for the various parameters at the end will be different from those declared, your simulation will still have a good chance of being perfectly reliable.

Indeed, whereas the measurement and publication of numbers by manufacturers may be subject to different and numerous types of errors and alterations (sometimes intentional!), the measurement and publication of an acoustic response in an anechoic chamber and a impedance curve are far less critical. Since the transducers are preferred when accompanied by graphics, possibly experimental, recognizable by the characteristic irregularities similar to those of the curves published by the magazines in the tests pages.

Parameters input

Cross 5 allows you to enter the parameters of each speaker using a handy window where you also can see a graph with the response curves and the transducer impedance.



In addition to the speaker's name and type , you can enter all the data used in the program to properly simulate the response.

For some input cells , all those marked by the \updownarrow sign to the right of them, you can change rapidly and interactively the value added by the Up and Down keys on the keyboard . It ' also possible to quickly increase or decrease the values of the selected box using the mouse wheel and immediately see the effect of changes on the charts of response or impedance.

You can access to the parameters of the speakers also from " Speakers ... " item in the " Check " menu.

In this window you can view and edit the parameters for all three present speakers.

Loudspeakers

Thiele-Small Parameters

	woofer	midrange	tweeter
Name	RCF L-12 P/48 8 ohm	Seas P17 RCY	Dynaudio D28 AF
Re (ohm):	5,00	5,70	4,90
Le (mH):	1,30	0,30	0,09
Fs (Hz):	43,00	133,00	800,00
Qts:	0,75	0,69	0,45
Qms:	5,00	1,70	0,65
Fa (Hz):	650,00	3300,00	18000,00
Qa:	1,00	0,55	0,80
Spl (dB):	86,50	87,50	88,20
dB/oct.:	2,40	2,80	0,00
D (mm):	260,00	100,00	32,00

Ok Cancel

Window for entering the parameters of all speakers