Power Test of Loudspeakers with Crossover **AN 27**

Application Note to the KLIPPEL R&D SYSTEM

The accurate measurement of the voice coil temperature, input power and other state variables is one of the most important requirements accelerated life testing and on-line monitoring of loudspeakers using synthetic or ordinary audio signals. This application note considers the particularities of loudspeaker systems using a passive or active crossover which impairs the measurement of the dc voice coil resistance which is the basis for an accurate estimation of the voice coil temperature.

That Application Note gives step-by-step instructions how to perform a power test on loudspeaker system using the PWT Module of the KLIPPEL R&D System. It shows the hardware setup and gives valuable hints how to find a good setup in order to obtain optimal result.

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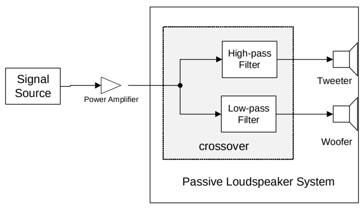
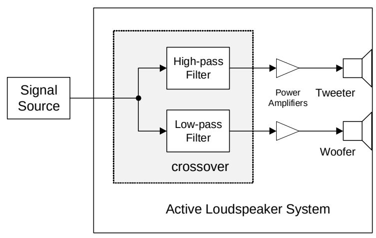
Scope of the power test

Device under test





The power test is applied to loudspeaker systems comprising multiple loudspeaker transducers (e.g. woofer, tweeter) excited by a passive or active crossover and power amplifiers. Any artificial test or ordinary audio signal (e.g. music) can be used as stimulus.

Objectives

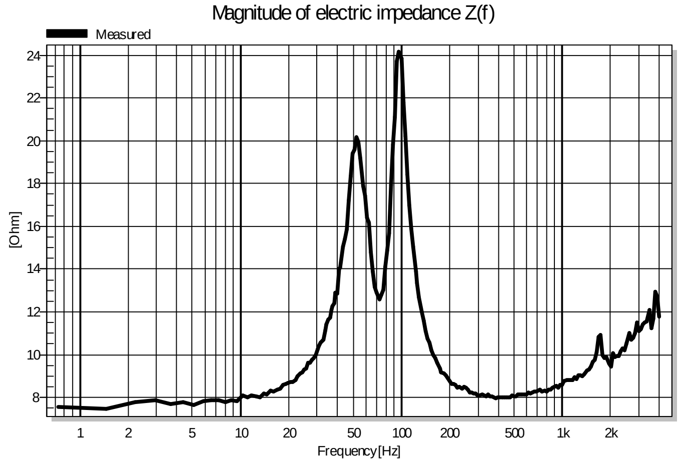
The main purpose and targets of the power test are

- measurement of voltage and current at the transducers
- monitoring of voice coil resistance R_e versus time
- calculation of the increase of voice coil temperature versus measurment time
- calculation of real input power P_{real} and power P_{Re} dissipated in the voice coil dc resistance R_e
- manual controlling the amplitude of the stimulus at the signal source

Additional targets of the power tests are

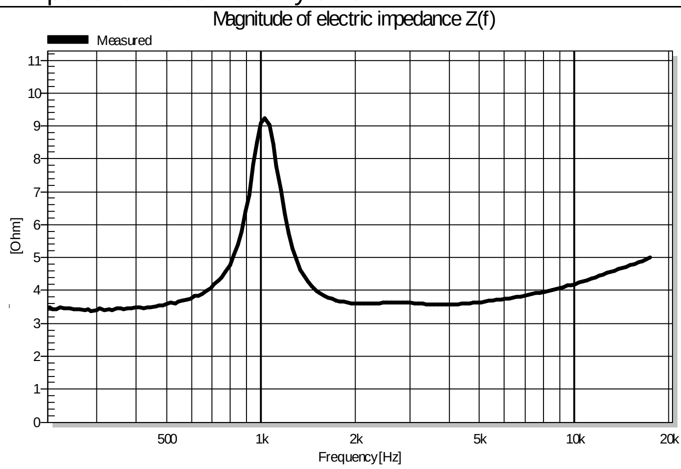
- thermal protection of the transducer
- On-Off cycling to measure the cooling curves

Woofer



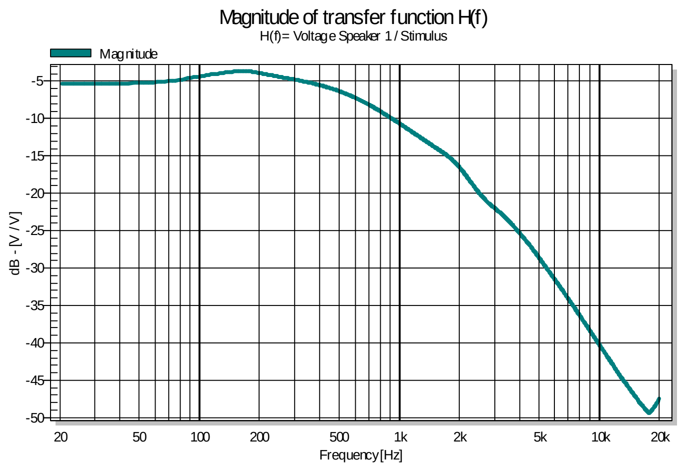
The electrical input impedance shown above is typical for a woofer operated in a vented-box enclosure. The voice coil resistance R_e can be measured at very low frequencies (f< 10 Hz) where the motional impedance is sufficiently small.

Tweeter



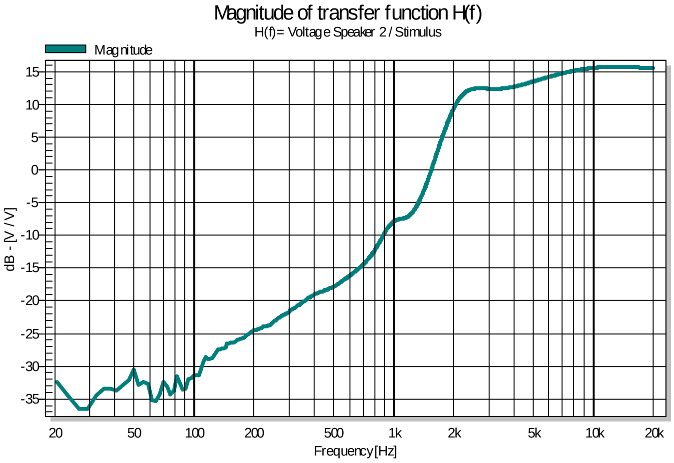
The electrical impedance shown above is typical for a tweeter having a resonance frequency at 1kHz. The electrical voice coil resistance can be measured below and above the resonance where the motional impedance and the effect of the voice coil inductance is negligible.

Low-pass Transfer Function



The magnitude response shown above is typical for the transfer function of a low-pass filter in the crossover to generate the signal supplied to the woofer.

High-pass Transfer Function



The magnitude response shown above is typical for the transfer function of a high-pass filter in the crossover to generate the signal supplied to the tweeter. Note that the signal components below the tweeter resonance frequency are attenuated by more than 20 dB.

Voice coil Temperature

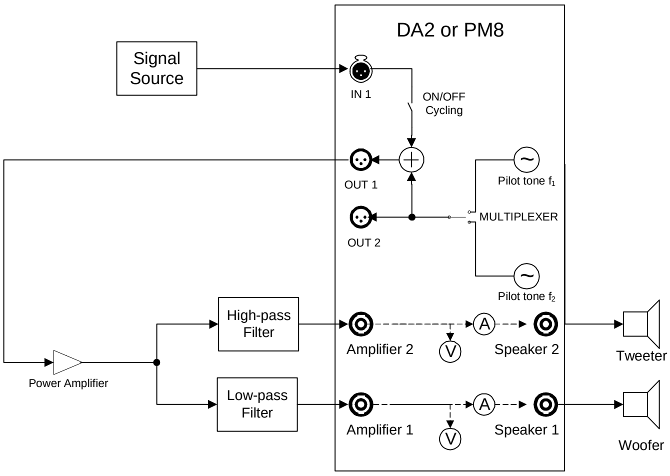
The variation of the voice coil temperature can be calculated from the dc voice coil resistance monitored from the electrical signals (voltage and current) at the transducer terminals. The dc resistance can be derived from the minimum of the electrical input impedance at a particular measurement frequency f_p. For the particular woofer excited by the low-pass filter in example here this measurement frequency f_p = 2Hz. The tweeter driven via the high-pass filter of the crossover requires a measurement frequency of f_p= 3kHz to supply sufficient energy and to avoid a bias from the motional impedance and inductance.

To keep the resistance measurement operative even if the audio signal provides not sufficient spectral power at frequency f_p it is recommend to add an additional pilot tone at all measurement frequencies f_p. This also keeps the temperature measurement operative if the external audio signal is switched off.

The KLIPPEL hardware supports the generation of a series of pilot tones where the instantaneous frequency is synchronized to transducers monitored sequentially. The pilot tone is generated by the KLIPPEL hardware and either added internally to the stimulus or is provided at the output OUT1 for external mixing.

Hardware Setup

Recommended Setup

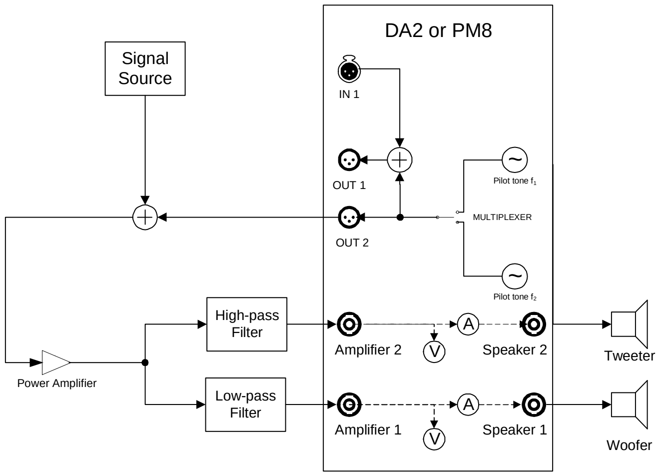


This is the most convenient setup which requires minimal equipment

- Distortion Analyzer DA2 (for monitoring 2 transducers) or Power Monitor PM8 (for monitoring up to 8 transducers)
- 2 Speaker Cables (wires 1+ and 1- for forcing and wires 2+ and 2- for sensing – always keep both 1+, 2+ to the first terminal and 1- and 2- to the second terminal)
- 1 Amplifier Cable (wires 1+ 1- for speaker channel 1 and wires 2+ and 2- for speaker channel 2)
- 2 XLR microphone cables for feeding the stimulus via input IN 1 and output OUT1 through KLIPPEL hardware
- Signal Source (CD player, generator)
- Power amplifier (mono for passive system, stereo for active system)

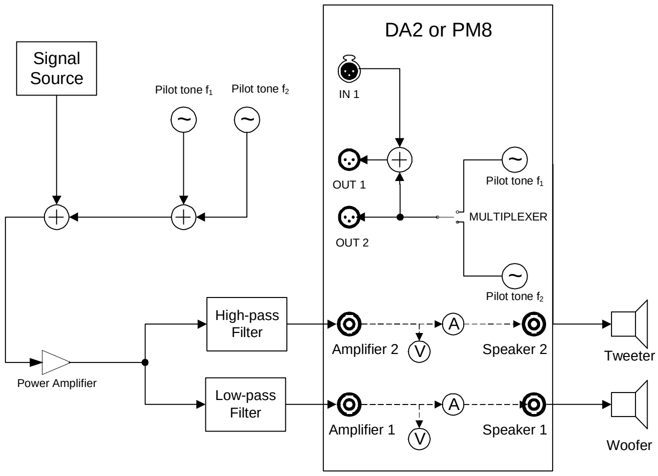
The pilot tone f_1=2 Hz used for monitoring the woofer and the second pilot tone at f_2=3kHz are added sequentially to the external signal provided at input IN1. The total ouput signal at OUT1 is supplied via crossover and amplifiers to the voltage and current sensors at the Speakon connectors Amplifier1 and Amplifier 2. The current sensors have a very low resistance (10 micro Ohms) and are supplied via four-wired Speaker cables to the transducers.

1st Alternative Setup



Feeding the stimulus through the KLIPPEL hardware can be avoided by performing an external mixing of the pilot tone provided at OUT2 to the stimulus by using for example a computer soundcard and Microsoft audio mixer. This configuration has the advantage that the amplitude of the pilot tone can be attenuated manually during the power test. Using the pilot tone at OUT2 ensures that the generator frequency of the pilot tone is always synchronized with the expected frequency of the analyzer.

2nd Alternative Setup



Steady-states pilot tones generated by external generators can also mixed with the signal used in power testing. Here the frequencies of the external pilot tones have to correspond with frequency of the internal pilot tones used in the asynchronous analyzer. The pilot tone may be stored in a wavefile and mixed with the stimulus (2nd wavefile) in the audiostream.

Step-by-Step Instructions

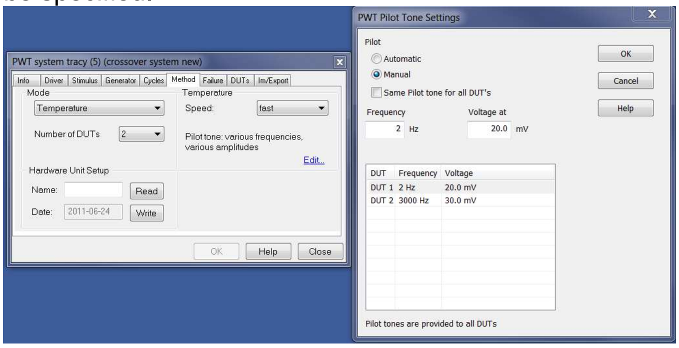
1. Hardware	Setup the hardware as discussed in the previous chapter.

2. Pre-measurement	To determine the optimal frequencies of the pilot tone it is recommended to perform an LPM measurement of the hardware configuration before performing the power test 1. Create an empty object in dB-Lab and Insert an LPM operation. Open the property page Stimulus and select a voltage of 10 mV at output OUT1. It is not recommended to activate the automatic voltage control at the speaker terminals due to the crossover limiting the band. Set the maximal frequency F_{max} to 10 kHz. 2. Select on property page Input speaker 1 on Routing and start the first measurement. 3. Open the window Voltage (f) Spectrum and see the passband of the crossover on speaker channel 1. Open the window Impedance Magnitude and search for the frequency of the first pilot tone where the electrical impedance is minimal and the SNR of the voltage signal is high (this frequency is usually below fs for a woofer and above fs for a tweeter). 4. Duplicate the LPM operation by using the Duplicate button. Open the on property page Input speaker 2 on Routing and start the second measurement. 5. Open the window Voltage (f) Spectrum and see the passband of the crossover on speaker channel 2. Open the window Impedance Magnitude and search for the frequency of the second pilot tone where the electrical impedance is minimal and the SNR of the voltage signal is high.

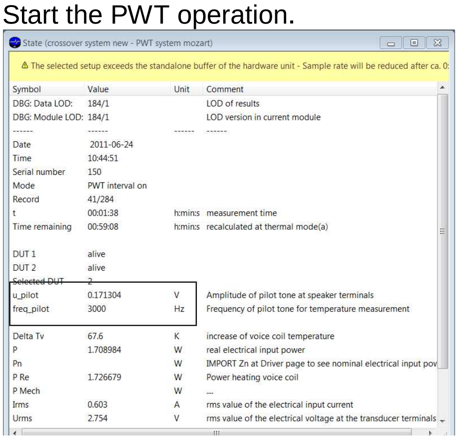
3. Software Setup of PWT

Create an empty object and insert a PWT operation.

1. Select the property page *Stimulus* and select as source *bypass.*
2. Select the property page *Cycles* and specify the total length T_{tot} of the power test and the sample rate T_{upd} under *Duration.* If the recommended hardware setup is used the intermittent excitation can be activated and the ON/OFF cycle times can be specified.



3. Select the property page *Method* and select *Temperature* as preferred measurement mode and specify the number of *DUTs* (2 for monitoring a woofer and tweeter). Select the *Speed* of the temperature measurement (*fast* gives the highest temporal resolution). Press *EDIT* to activate the manual pilot tone adjustment. Specify the frequency and amplitude (at output OUT1 or OUT2 before amplification !!) of each DUT.
4. Select the property page *Failure* and specify the permissible variation of the voice coil resistance and voice coil resistance to remove the transducer from the power amplifier in case of thermal overload or electrical defect. It is possible but not recommended to disable this functionality.
5. Start the PWT operation.

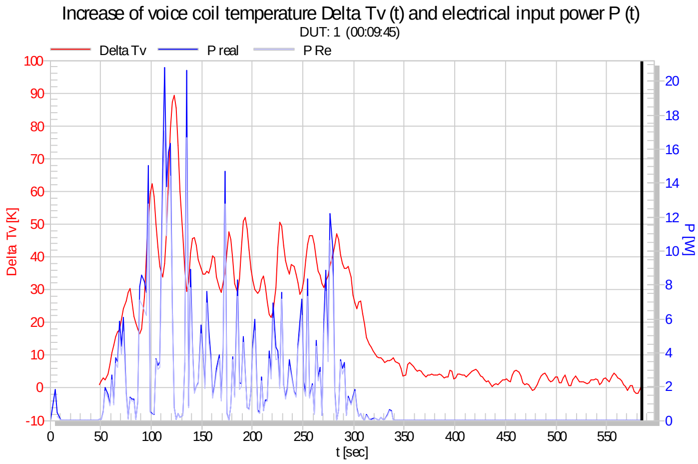


6. After finishing *Initialization* and entering the normal PWT-*Mode Interval ON* the PWT open the result window *State* and check the amplitude of the pilot tone at the speaker terminals. Open the property page DUT and select the other DUTs and check the amplitude of the pilot tones at the other transducers. It is recommended to keep the amplitude of the pilot tone 20 - 40 dB below the total voltage. Fast measurement speed requires a higher voltage than using the slow mode. If the measure amplitude is too high or too low stop the measurement and change the gain in the property page METHOD (PWT Pilot tone setting) accordingly before starting the measurement again. After finding the optimal setup it is recommended to save the PWT operation as a template.

4. Power Test	Start the PWT measurement with the optimal setup parameters. After entering the normal PWT-*Mode Interval ON* apply the external audio signal and adjust the level of the stimulus. You may disconnect the dB-lab software from the power test and operate the DSP hardware in stand-alone mode. You can duplicate the PWT operation and reconnect this operation to the running stand-alone measurement at any time.

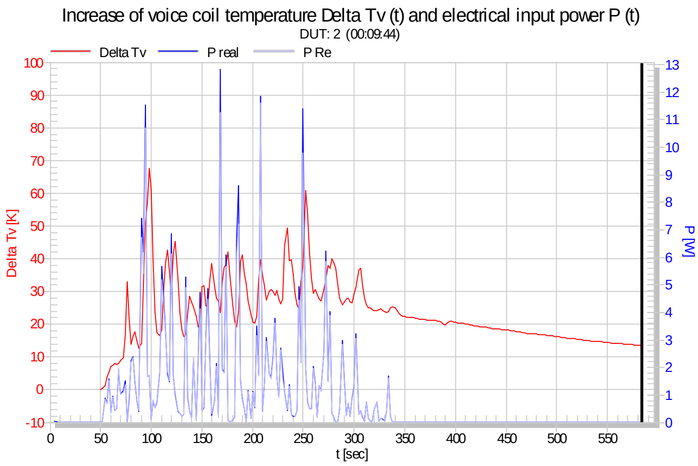
Viewing and Interpreting Results (Diagnostics)

Electrical Input Power at Woofer



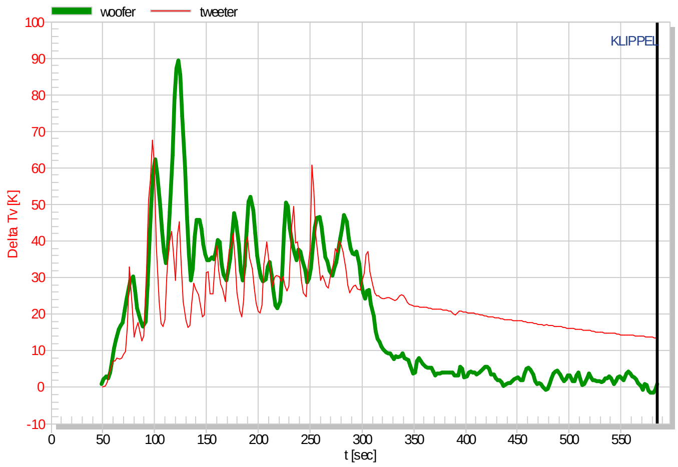
Open the property page DUTS and select the desired device under test (e.g. DUT 1 for the woofer). Open the result window Temperature, Power and see the increase in voice coil temperature in Kelvin (comparable to Celsius) and the real electrical input power P_{real} and the power dissipated in the voice coil dc resistance R_e. Note that a high instantaneous input power of the stimulus generates a corresponding increase of the voice coil temperature. After switching off the external stimulus at t=300 s the cooling curve is monitored automatically.

Electrical Input Power at Tweeter



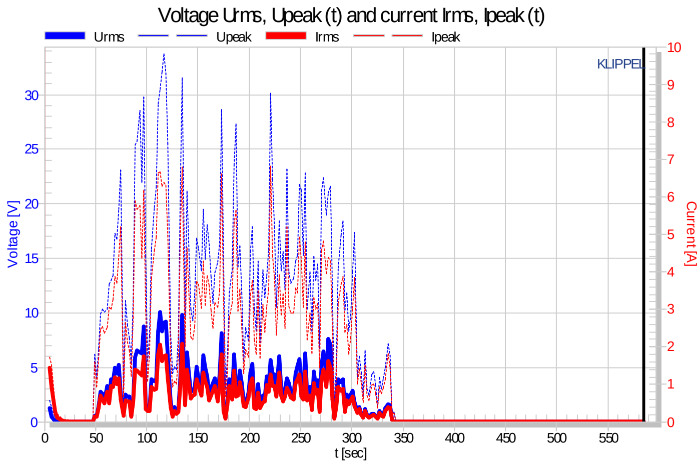
Open the property page DUTS and select the desired device under test (e.g. DUT 2 for the tweeter) and view the increase of the voice coil temperature and the electrical input power of the tweeter. The temperature of the tweeter shows much shorter fluctuation than the woofer but stronger long term variation which is caused by the heating of the small magneti, pole plates and frame which has a much smaller thermal capacity.

Comparison of Voice coil Temperature



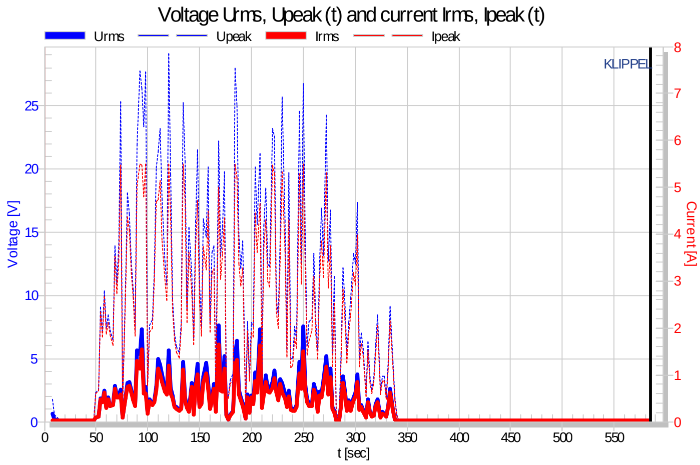
Before switching the DUT on the property page DUTS you can select the temperature curve, copy this curve into the clipboard (by using the right mouse button) and paste this curve into this window (as a passive curve) or in any other window or application by changing the style and name of the curve. Comparing the voice coil temperature of the tweeter and woofer in the example shown above shows that the tweeter produces a more peaky temperature curve than the woofer corresponding with a shorter time constant of the voice coil (lower mass). However, the cooling down curve decays at a much slower slope showing the impact of the tweeter magnet.

Voltage and Current at Woofer



The peak and rms value of the voltage and current at the terminals of the woofer is recorded over the measurement time and revels the crest factor of the stimulus.

Voltage and Current at Tweeter



The peak and rms value of the voltage and current at the terminals of the tweeter is recorded over the measurement time and revels the crest factor of the stimulus.

More Information

Software Documentation

[1] Specification of the Power Test, see www.klippel.de

[2] Manual of PWT Power Test

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KLIPPEL

Klippel GmbH
Mendelssohnallee 30
01309 Dresden, Germany

www.klippel.de
info@klippel.de

TEL: +49-351-251 35 35
FAX: +49-351-251 34 31