Loudspeaker Limits and Protection Systems **AN 28**

Application Note to the KLIPPEL R&D SYSTEM

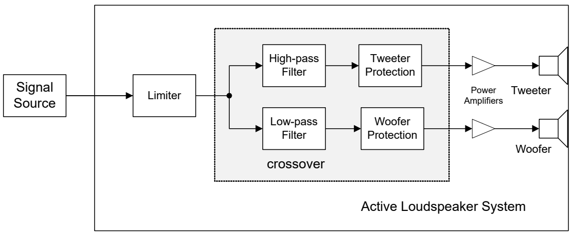
Fast and accurate measurement of the instantaneous voice coil temperature and peak displacement is one of the most important requirements for assessing the limits loudspeaker performance and the operation of electronic components protecting the loudspeaker against mechanical and thermal overload while reproducing test signal or ordinary audio signals music by multi-way and multi-channel systems.

That Application Note gives step-by-step instructions how to perform a power test on loudspeaker system using the PWT and DIS 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.

CONTENTS:

Scope of the test

Device under test



The power test is applied to loudspeaker systems comprising multiple loudspeaker transducers (e.g. woofer, tweeter) and additional electronic components such as limiter, passive or active crossover, equalizer, dedicated protection systems 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 the voice coil peak displacement versus time
- fast measurement of the voice coil temperature versus time
- measurement of voltage and current at the transducers
- monitoring of voice coil resistance R_e versus 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

Voice coil Temperature

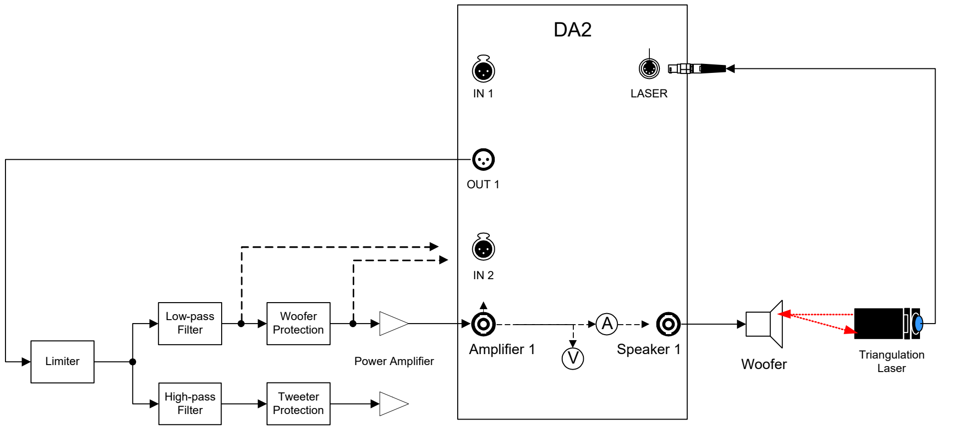
The variation of the voice coil temperature can be calculated from the dc voice coil resistance monitored from the electrical signals (voltage and current) at the transducer terminals. The dc resistance can be derived from the minimum of the electrical input impedance at a particular measurement frequency f_p. For a woofer excited by a low-pass filtered signal the measurement frequency should be as low as possible (e.g. f_p = 2Hz) to avoid any bias of the motional impedance. A tweeter excited by a high-pass filtered stimulus requires a measurement frequency which is usually above the resonance frequency of the tweeter (e.g. f_p= 3kHz) to supply sufficient energy and to avoid a bias from the motional impedance and inductance.

In order 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 may use either an internal generator or an external source providing the pilot tone with the frequency expected in the measurement of the impedance minimum.

Hardware Setup

Measurement by using synthetic stimuli

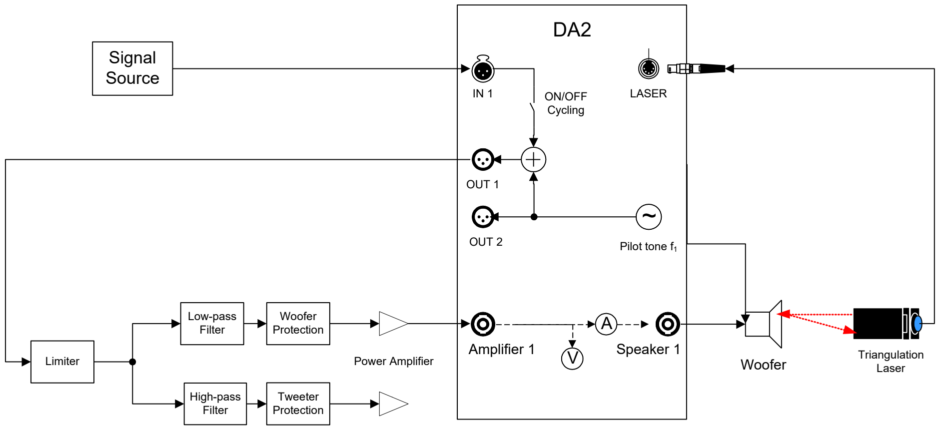


The 3D distortion measurement module DIS, the transfer function measurement module TRF and the linear parameter measurement module LPM are optimal tools for testing the loudspeaker system by using artificial test stimuli (single tone or two-tone stimulus) generated by the internal generator. Both modules measure the voltage and current at the speaker terminals, the voice coil displacement measured by the triangulation laser and any signal of the external electronics supplied to the empty XLR input IN2. The hardware setup is compatible with the following power test PWT using an external signal (e.g. music) at input IN1.

This DIS/TRF/LPM measurement require

- Distortion Analyzer DA2
- 1 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)
- 1 XLR microphone cable for providing the stimulus at output OUT1 to the input of the loudspeaker system
- KLIPPEL Triangulation Laser
- Power amplifier (mono for passive system, stereo for active system if not provided by the active loudspeaker system)

Measurement by using an external audio signal



The power test module PWT is the optimal tool for on-line monitoring of loudspeaker systems using minimal equipment

- Distortion Analyzer DA2
- 1 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)
- 2 XLR microphone cables for feeding the stimulus via input IN 1 and output OUT1 through KLIPPEL hardware
- Signal Source (CD player, generator)
- KLIPPEL Triangulation Laser
- Power amplifier (mono for passive system, stereo for active system if not provided by the active loudspeaker system)

The external signal (music or test signals) is supplied to the XLR terminal IN1. A pilot tone (e.g. 2 Hz for monitoring monitoring the dc resistance of a woofer or 3kHz for a tweeter) is added to the external signal and supplied via the total ouput signal at OUT1 to the input of the active system comprising for example a limitier, crossover, protection system or amplifiers). The amplified signal is supplied via the voltage and current sensors in the DA2 to the speaker terminals using the Speakon connectors Amplifier1 and Speaker 1.

Step-by-Step Instructions

1. **TRF Measurement** To determine the optimal frequencies of the pilot tone it is recommended to perform a TRF measurement before performing the power test

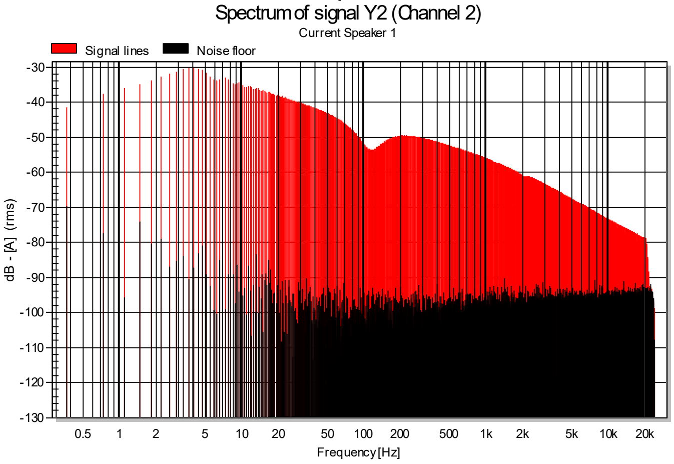
   Create an empty object in dB-Lab and Insert a TRF operation based on the template *TRF Electr. Impedance (Sp1).*

   Open the property page *Stimulus* and select the mode Single measurement and a voltage of 5... 50 mV at output OUT1. It is not recommended to activate the automatic voltage control at the speaker terminal 1 (the crossover might attenuate the test tone at 750 Hz). Set the minimal Frequency F_{min}=1 Hz and the maximal frequency F_{max} =10 kHz with a resolution < 2.93 Hz. Activate the *Noise floor + dc monitoring.*

   Select on property page *Input* the radio buttons to Voltage *Speaker 1 Us and Is (Current Speaker 1).*

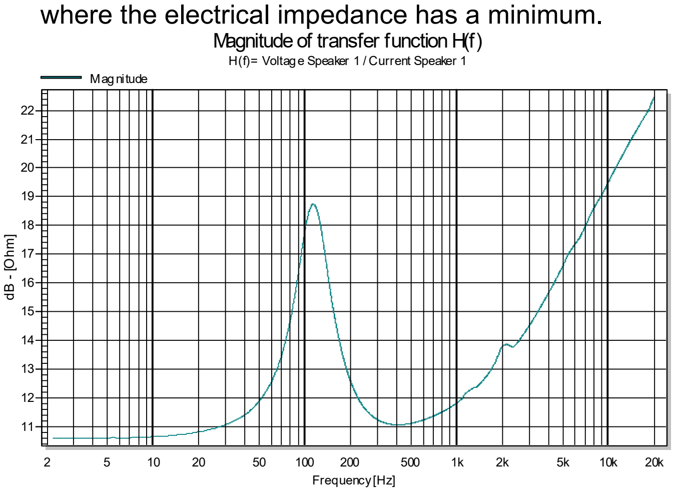
Start the TRF measurement.

Select on the property page *Processing* the transfer function *Us/Is* to measure the electrical impedance and activate *No window*.



Open the windows *Y1(f) Spectrum and Y2(f) Spectrum* to check the signal to noise ratio of the measured voltage and current signal.

Open the window *H(f) Magnitude* to read the frequency of the pilot tone where the electrical impedance has a minimum.



For example the electrical impedance shown for the woofer above becomes minimal below 5 Hz.

2. DIS Measurement

The 3D distortion measurement is ideal for the measurement of the frequency response (fundamental or distortion components) at various voltage levels.

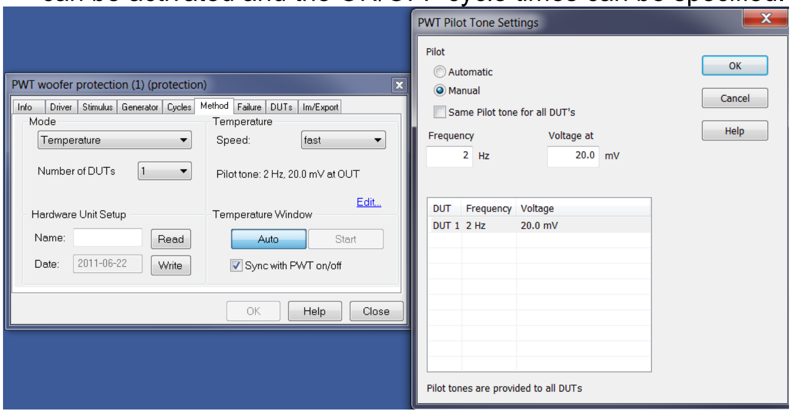
- Create an empty object in dB-Lab and Insert a DIS operation.
- Open the property page *Stimulus* and select the mode Harmonics, starting voltage U_{start} = 5 mV and a end voltage U_{end}= 50mV at output OUT1 while activating the voltage sweep and 4 points linearly spaced. It is not recommended to activate the automatic voltage control at the speaker terminal 1 (the crossover might attenuate the test tone at 750 Hz). Set the starting frequency f_{start}=20 Hz and the end frequency f_{end} =10 kHz using a logarithmic frequency sweep versus 20 points. Disable any additonal excitation before measurement .
- Select on property page *Input* the radio buttons either to Voltage *Speaker 1 Us* or *Is (Current Speaker 1)* or *X Displacement* using the laser sensor or *IN2 (Mic)* for measuring any analogue voltage in the electronic circuit.
- Disable any protection on property page *Protection*.
- Start the DIS measurement.

3. PWT Measurement

Create an empty object and insert a PWT operation.

1. Select the property page *Stimulus* and select as source *bypass.*

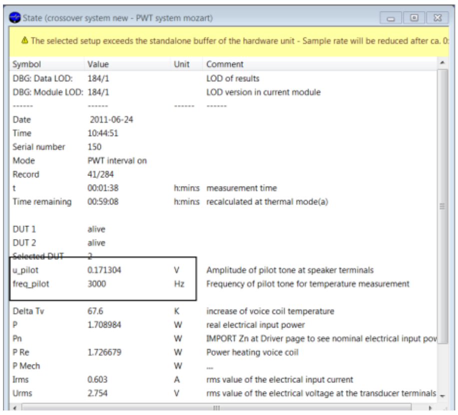
Select the property page *Cycles* and specify the total length T_{tot} of the power test and the sample rate T_{upd} under *Duration.* If the recommended hardware setup is used the intermittent excitation can be activated and the ON/OFF cycle times can be specified.



Select the property page *Method* and select *Temperature* as preferred measurement mode and specify the 1 for the number of *DUTs* (for monitoring either a woofer or tweeter). Select the Fast as the preferred *Speed* of the temperature measurement. Press *EDIT* to activate the manual pilot tone adjustment. Specify the frequency and amplitude at output OUT1 (before amplification !!).

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.

Start the PWT operation.



State (crossover system new - PWT system mozart)

The selected setup exceeds the standalone buffer of the hardware unit - Sample rate will be reduced after ca. 0:

Symbol	Value	Unit	Comment
DBG: Data LOD:	184/1		LOD of results
DBG: Module LOD:	184/1		LOD version in current module
------	------	------	------
Date	2011-06-24		
Time	10:44:51		
Serial number	150		
Mode	PWT interval on		
Record	41/284		
t	00:01:38	h:min:s	measurement time
Time remaining	00:59:08	h:min:s	recalculated at thermal mode(a)
DUT 1	alive		
DUT 2	alive		
Selected DUT	2		
u_pilot	0.171304	V	Amplitude of pilot tone at speaker terminals
freq_pilot	3000	Hz	Frequency of pilot tone for temperature measurement
Delta Tv	67.6	K	increase of voice coil temperature
P	1.708984	W	real electrical input power
Pn		W	IMPORT Zn at Driver page to see nominal electrical input pow
P Re	1.726679	W	Power heating voice coil
P Mech		W	...
Irms	0.603	A	rms value of the electrical input current
Urms	2.754	V	rms value of the electrical voltage at the transducer terminals

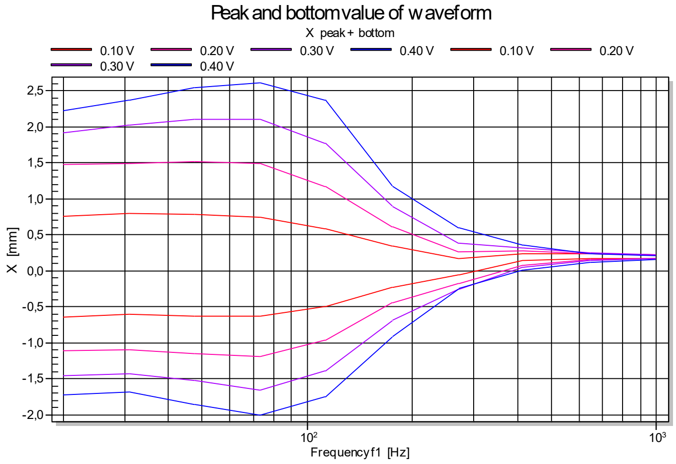
After finishing *Initialization* and entering the normal PWT-*Mode Interval ON* open the result window *State* and check the amplitude of the pilot tone at the speaker terminals. It is recommended to keep the amplitude of the pilot tone 20 - 40 dB below the total voltage. The *fast* measurement speed 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.

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.

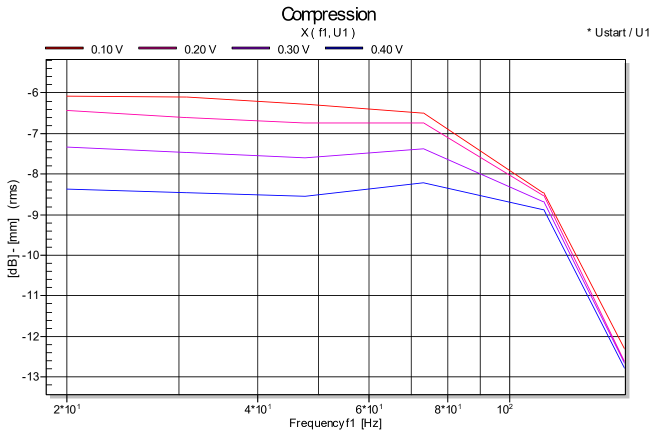
Viewing and Interpreting Results of the DIS Module

Peak and bottom displacement



Select the DIS operation in which the laser signal is activated on the property page *Input* and open the property page *Display* and select state signal *Displacement X*. Select the plot style *2D plot versus f1*. This plot shows total transfer behavior between the electrical input of the loudspeaker system and the voice coil displacement considering the natural compression of the transducer and the performance of the protection system.

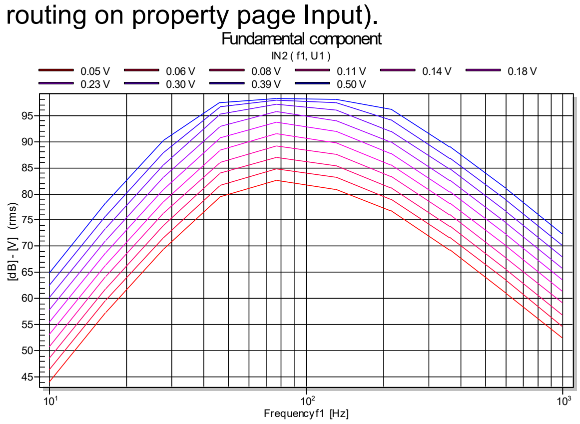
Compression of the displacement



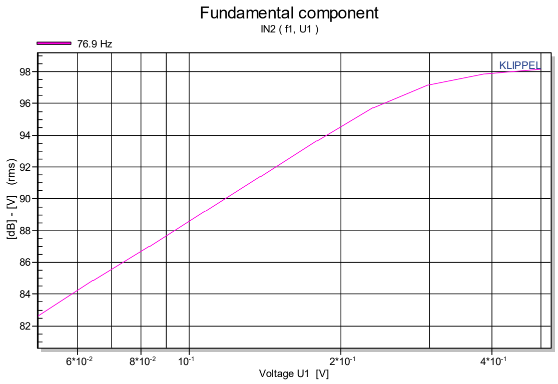
Open the result window Compression to see the relative attenuation of the voice coil displacement as a function of the input voltage. The displacement and the corresponding acoustical output decreases by 2.5 dB below 90 hz but there is almost no compression above 150 Hz.

Limiter in the woofer channel

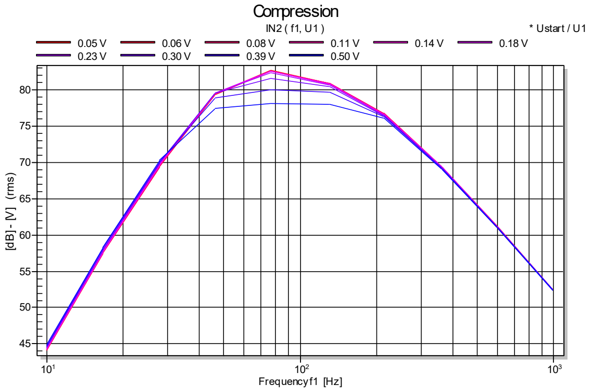
To evaluate the performance of the electronic the output of the protection system or the voltage at the speaker terminals is measured versus frequency and amplitude of the sinusoidal stimulus. Open the property page Display and select Voltage at Speaker 1 or Signal at IN2 (depending on the routing on property page Input).



Select the plotting style versus f1 to see frequency responses as shown in the diagram above measured in 1 dB increments. In the frequency range between 60 Hz and 200 Hz the limiter in the woofer channel causes a significant reduction of the gain.



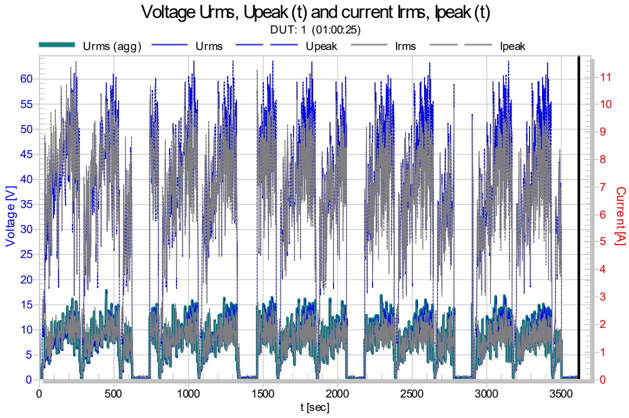
Selecting the plotting style versus voltage U1 and logarithmic Y-axis on property page Display to see the input-output characteristic of the limiter at the critcial frequency of 76 Hz as shown in the diagram above. For small input voltages (< 200 mV) there is a linear relationship between input and output but the maximal output is limited to 400 mV.



Open the result window Compression to see relative attenuation (-5 dB) of the transfer response at 80 Hz.

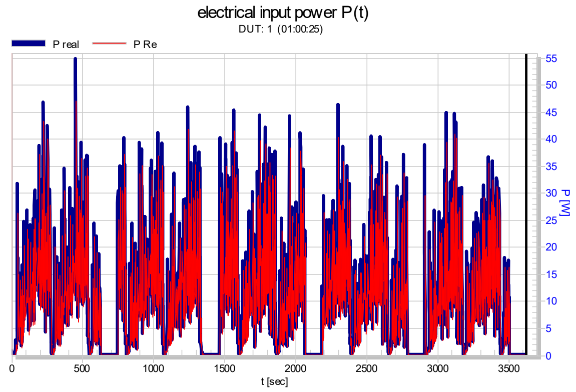
Viewing and Interpreting Results of the PWT Module

Voltage and Current at the transducer terminals



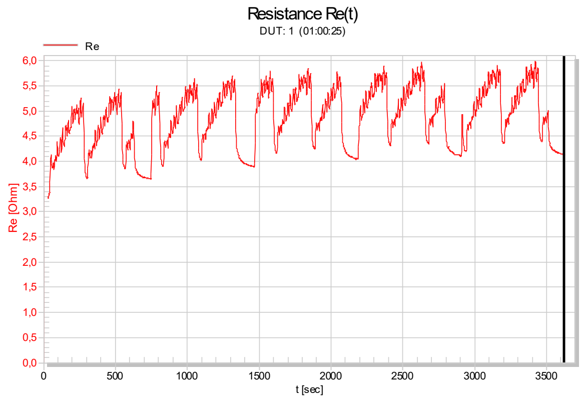
The peak and rms value of the voltage and current at the terminals of the woofer is recorded over the measurement time and reveals the crest factor of the stimulus. After 10 min of operation the stimulus was muted for 2 min to measure the cooling characteristic of the voice coil.

Electrical Input Power



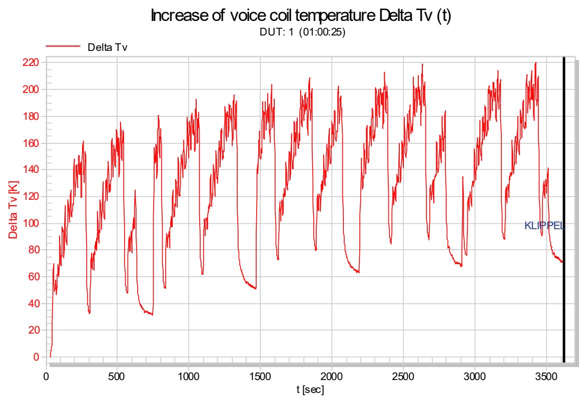
The diagram above shows the real value of the electrical input power (blue curve) and the power R_{Re} dissipated on the electrical dc resistance R_e (shown as red curve).

Voice Coil Resistance



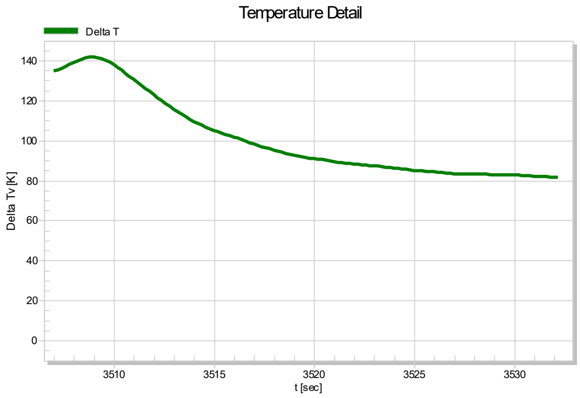
The electrical dc resistance R_e is measured at the minimum of the electrical impedance (e.g. 2 Hz) by using an additional pilot tone added to the stimulus. This technique measures stays operative also in the OFF-Cycle when the external stimulus is muted. The R_e resistance is used for calculating the increase of the voice coil temperature during the test and can also be used for calculating the absolute voice coil temperature.

Increase of Voice Coil Temperature



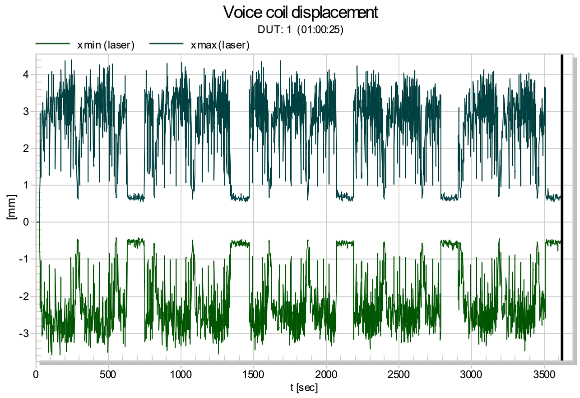
During the initial mode of the power test the resistance $R_e(t=0)$ of the cold voice coil is measured and used as a reference value for calculating the increase of the voice coil temperature during the following test. Note the temperature decays quickly in the break between the music titles which last about 5-10 seconds. The 2 minutes break caused by the ON-OFF cycling generates a characteristic cooling curve in 12 minutes intervals. The exponential decay converges against the magnet temperature which rises slowly over time.

Temperature Detail



The power test applied to 1 DUT only provides the increase of the voice coil temperature at a high sampling frequency measure the thermal dynamics at high accuracy. This is important for microspeakers, headphones, tweeters where the thermal capacity of the voice coil is small. The detailed temperature measurement can be triggered automatically at the beginning of the OFF cycle or started manually.

Voice Coil Displacement



The power test PWT performed on the Distortion Analyzer hardware DA and restricted to 1 DUT supports the measurement of the peak and bottom value of the voice coil displacement using a laser triangulation laser. This measurement is crucial for assessing the mechanical load and the performance of the protection system.

More Information

Software Documentation

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

[2] Manual of PWT Power Test

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