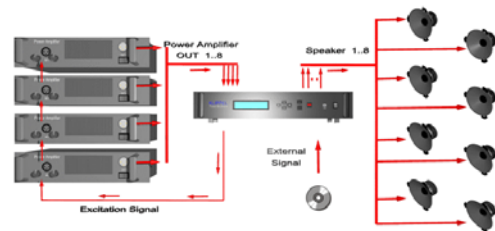


Features

- Long term driver testing without sensor
- High-speed temperature monitoring
- Ideal for thermal parameter measurement
- Full mechanical identification of woofers
- Mechanical and thermal load versus time
- Monitors destruction process
- User defined failure limits
- Measures up to 8 DUTs simultaneously
- Stand-alone operation
- Driver status displayed on hardware
- Simple PC connection via USB
- Analysis of recorded measurement



- Internal signal generator
- Stimulus shaping/filtering
- Any external signal (music)
- Control of amplitude at terminals
- Stepping amplitude
- Cycle scheme (ON/OFF)

The software module "Power Test" and the hardware platform Distortion Analyzer (2 channels) or Power Monitor 8 (8 channels) allow to perform destructive testing of transducers with permanent monitoring of electrical, mechanical and thermal state variables and parameter variations. An external or internal generated excitation stimulus may be controlled in amplitude, spectral bandwidth or crest factor and may be supplied to the transducer permanently. To apply a pre-defined time scheme (on/off cycle) gives additional flexibility. The increase of the voice coil temperature can be measured by monitoring the electrical impedance of the speaker using a conventional AC-coupled amplifier. The mechanical parameters and instantaneous displacement of a woofer can be monitored by impedance measurements dispensing with acoustical, mechanical or thermal sensors. The speaker parameters and state variables are sampled periodically and stored in a buffer in the hardware unit. Connecting a computer via USB to the hardware platform allows to view and investigate the destruction process in detail. This information is crucial for finding the physical cause of the failure and to understand the temporal order of the destructive events. This enables to assess the maximal limits of the transducer more precisely.

Article Number: 1000-700, 1000-710, 1000-711

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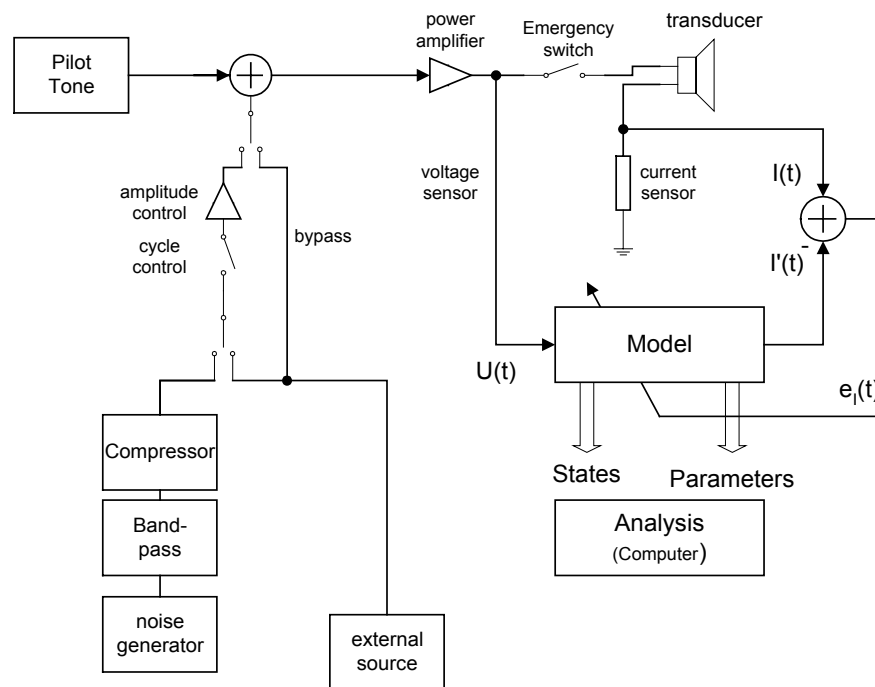
updated 23 March 2006

Measurement Technique

Principle

During the Power Test the transducer is excited by an external signal source or by the internal generator within the measurement hardware. A pilot tone required for temperature monitoring is added to the stimulus and supplied via an AC-coupled amplifier to the device under test. This allows to measure the electrical resistance and variation of the voice coil temperature. The amplitude of the stimulus may be controlled by the hardware according to user-defined values and cycles.

Voltage and current sensors measure the electrical signals at the DUTs terminals. Both signals are supplied to the signal processor (DSP) where a digital model of the transducer is implemented. The parameters and states of the model are identified by adaptive system identification. The sampled data are stored in a history buffer within the stand-alone hardware. Connecting a computer via USB to the hardware device enables viewing the history of the measurement and failure diagnostics.



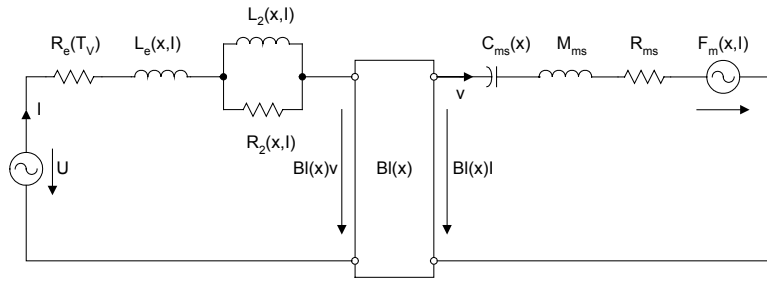
System Identification

There are two modes of system identification:

1. In the mode **Temperature** the voice coil temperature T_v and the electrical quantities (peak and rms voltage and current, real input power) at the speaker's terminals are permanently monitored. This mode can be applied to woofers, tweeters, and loudspeaker systems.
2. In the mode **Woofers Identification** the electrical, mechanical and thermal elements of a woofer in free air or in a sealed enclosure are identified on-line. The driver should correspond with the large signal model presented below.

Large Signal Modeling

The transducers considered here have a moving-coil assembly performing an electro-dynamical conversion of the electrical quantities (current and voltage) into mechanical quantities (velocity and force) and vice versa.



The lumped-parameter model shown above is used to describe the large signal behavior of electro-dynamical drivers at high amplitudes. In contrast to the well known linear model the elements

- Electro-dynamical force factor $BI(x)$
- Compliance of mechanical suspension $C_{ms}(x)$
- Voice coil inductance represented by $L_e(x, I)$, $L_2(x, I)$ and $R_2(x, I)$ versus displacement x and current I
- Resistance of voice coil at DC represented by $R_e(T_v)$

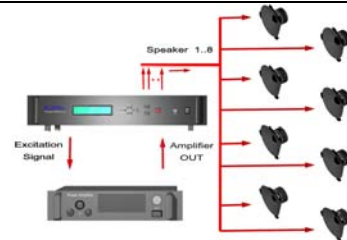
are not constant parameters but depend rather on one or more speaker states (displacement x , voice coil temperature T_v).

Hardware Setup

Minimal Configuration

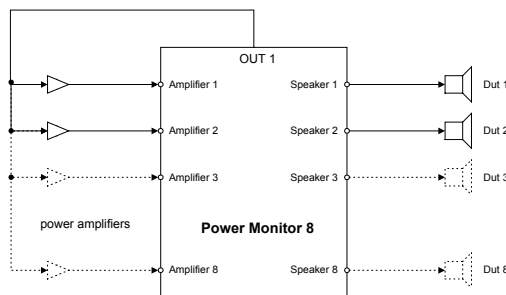
The minimal components required for running a Power Test are:

- Power Monitor 8 (or Distortion Analyzer)
- Power amplifier
- Amplifier cables
- Speaker cables



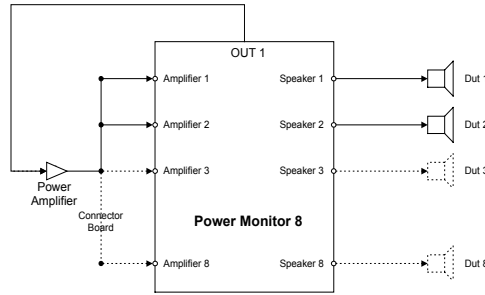
The minimal setup works without computer as a stand-alone system and dispenses with any acoustical or mechanical sensor. The USB interface allows a permanent or temporary connection to a portable or stationary computer to investigate the results in detail.

Separate Amplifier



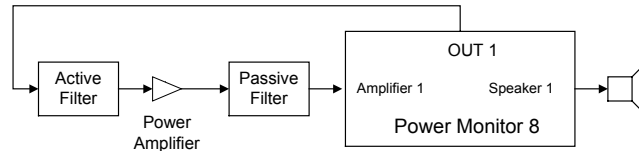
Use a separate amplifier for each DUT if the impedance of the transducers is relatively low and the power amplifier may not provide the current for multiple DUTs connected in parallel.

Common Amplifier



A powerful amplifier may be used for driving multiple DUTs connected in parallel. The inputs Amplifier 1, Amplifier 2, ... Amplifier 8 may be linked internally in the PM 8 on request.

Crossover, Filter, Limiter



Active and passive crossovers and any other kinds of filter may be used to shape the spectral characteristic of the excitation signal.

Note: The pilot tone (1 ... 4 Hz) should pass the filters and power amplifier with sufficient amplitude (damping < 40 dB)

Stimulus

Excitation Source

The stimulus used during Power Test may be provided by an external source (CD-player) or from the internal noise generator.

Noise Generator

The measurement hardware hosts an internal generator producing a noise signal with pink or white spectral characteristic.

Stimulus Shaping

The internal excitation signal may be preconditioned to have user-defined signal properties (crest factor and bandwidth).

Cycle Control

The stimulus may be switched on and off during Power Test to simulate variations of the voice coil temperature. The user may define the cycles or the time scheme.

Amplitude Control

The voltage $U(t)$ at the terminals may be set to a user-defined RMS-value while considering the amplitude gain of the power amplifier and the amplitude of the stimulus. This value may be constant during the measurement or increased automatically by user-defined steps.

Bypass

The user may use external equipment for generating, shaping and controlling the stimulus and may provide the stimulus directly to the input of the power amplifier. The output of the power amplifier has to be fed through the power path of the used hardware device to measure electric signals at the terminals.

Measurement

Initial Identification

Before starting with the regular power testing an initial identification of driver parameters is performed. The number steps depends on the identification mode:

In the mode **Temperature** the electrical resistance of the voice coil is measured and stored as a reference value for monitoring the increase of the voice coil temperature. If a Distortion Analyzer is used as hardware platform the peak and bottom displacement may be monitored for 1 DUT.

In the mode **Woofers Identification** the following steps are processed sequentially:

	<ol style="list-style-type: none"> 1. Amplifier check (cables, gain control) 2. Measurement of the cold voice coil resistance 3. Identification of small signal parameters 4. Identification of the nonlinear parameters
Voice Coil Temperature	<p>The voice coil temperature is estimated by measuring the electrical impedance close to DC. An adjustable small pilot tone at very low frequency (about 1 ... 4 Hz) is added to the stimulus to measure the temperature while the stimulus is switched off (OFF-Phase). This technique dispenses with a DC signal required in traditional temperature monitoring causing a voice coil offset and can be realized with conventional ac-coupled amplifiers.</p> <p>The user may select different amplitude levels (small or high) of the pilot tone. In both cases the amplitude depends on the level of the stimulus used.</p> <p>The time constants affecting the temperature measurement are also adjustable during measurement. The mode Fast is recommended for monitoring of fast thermal transients produced by tweeter systems. The mode Slow recommended for woofer application.</p>
Detailed Temperature Response	<p>If Number of DUTs is equal 1 then the results window Temperature Detail shows the voice coil temperature at high temporal resolution (sampled at 200 ms). For multiple DUTs, the detailed temperature measurement may be started automatically or manually and synchronized with the cycling (at the OFF/ON and ON/OFF slope).</p>
Regular Sampling	<p>During the Power Test all of the parameter estimates and important characteristics of the state variables (peak and RMS values) are sampled periodically and stored in a history buffer within the hardware. Connecting a computer via USB interface makes it possible to upload, view and save the history of the measurement and to investigate temporal variations of the parameters due to thermal, reversible and irreversible processes. The user may define the time elapsing between taking samples (regular sample period).</p>
Death Report	<p>In addition to the regular sampling all values are measured internally at a much higher rate and stored in a ring buffer of the hardware. In case of an identified malfunction this high sampled data of the particular DUT are copied into the history data buffer. This allows a detailed analysis of the time just before destruction. This information are important to find the cause of the failure.</p>
Malfunction Detection	<p>Several malfunctions of the driver will be detected during Power Test. In the case of a electrical shortcut between the driver terminals the Power Test will disconnect the driver from the power amplifier automatically.</p>
Status Information	<p>During the Power Test the status of the DUT may be viewed in detail by the software module Power Test hosted by the dB-Lab frame software. Additionally, the most important information are directly shown on the display at the hardware device:</p> <ul style="list-style-type: none"> • Number of DUTs connected • Status of the DUTs (alive, malfunction) • Malfunction of the amplifier <p>state variables (peak displacement, temperature, input power, RMS voltage)</p>

PC based Operation

USB connection	<p>The universal serial bus (USB) makes it easy to connect or disconnect a computer with a processor units (PM 8 or DA 1) without interference with a running measurement. Using hubs multiple units may be connected to one PC. The software tool SPY shows the display of each hardware on the PC.</p>
Customizing Setup	<p>The property pages of PWT give access to a variety of setup parameters which may be used to customize the Power Test. The setup parameters may be stored in the hardware device and may be activated by starting the hardware in stand-alone operation.</p>
Import Parameter	<p>The system identification is based on an impedance measurement providing electrical parameters and states in absolute quantities (Volt, Ampere, Watt) but the mechanical system as relative quantities only. Importing one mechanical parameter (moving mass</p>

	M_{ms} or $Bl(x=0)$ at the rest position) allows to calibrate all state variables (e.g. displacement in mm) and all of the mechanical parameters (e.g. compliance in mm/N).
Database	Connecting a PC via USB to the monitoring hardware (Distortion Analyzer 1 or Power Monitor 8) all of the sampled data will be stored in a database for detailed analysis and diagnostics.
Log-File	A summary of the most important information (name of DUTs, date, life time, failure, resonance frequency, ...) are stored in a separate file in csv-format. This file is a convenient interface to other software tools (Access , Excel, ...) to browse or summarize the results and to perform a query or statistical investigations.

Limits

Transducer

Parameter	Symbol	Min	Typ	Max	Unit
Voice coil resistance	R_e	0.1	4 - 32		Ω
Resonance frequency	f_s	15		900	Hz
Total loss factor	Q_t	0.3		6	
Voice coil inductance	L_e	0.05		5	mH

External Excitation

Input Voltage for external excitation (peak)	U_{max}	-3.5		3.5	V
Input Impedance	R_{in}		10k		Ω

Power Amplifier

Maximal input level,				15	dBu
Input sensitivity at rated output power			0 (775)		dBu (mV)
High pass characteristic (damping at 4 Hz)				30	dB

Pilot Tone for Temperature Measurement

Amplitude at loudspeaker terminals	U_p	0.050			V
Frequency (automatically selected according amplifier highpass characteristic)	f_D	1	1	4	Hz
Amplitude Ratio (pilot tone referred to total voltage)	U_p/U_{total}	0.025		0.1	

Input Parameters (Setup)

Parameter	Symbol	Min	Typ	Max	Unit
Stimulus					
Source	<ul style="list-style-type: none"> external (hardware controls external signal) internal (hardware controls internal generated signal) bypass (external signal directly supplied to DUT) 				
Starting value of voltage at terminals (rms)	U_{Start}	0.2		500	V
Amplitude amplification (stepping)	on / off				
Step size of amplitude amplification	G_U	0	1	6	dB
Maximal amplitude amplification (6 dB steps)	G_{max}	0		30	dB
Noise Generator (internal source)					
Spectral characteristic	pink, white or shaped noise according IEC 60268, EIA 426 B				
Lowpass cut-off frequency (- 3dB)	f_{low}	20		23040	Hz

Highpass cut-off frequency (- 3dB)	f_{high}	20		23040	Hz
Crest factor	C_r	6		18	dB
Sweep Generator (internal source)					
Start frequency	f_1	1		20000	Hz
End frequency	f_2	1		20000	Hz
sweep time	t	1		100	s
Harmonic Distortion	THD		1		%
Two-tone Generator (internal source)					
Frequency of first tone	f_1	1		20000	Hz
Frequency of second tone	f_2	1		20000	Hz
Amplitude ratio between both tones	U2/U1	-100		0	dB
Harmonic Distortion	THD		1		%
Cycles					
ON-Interval ²	t_{on}	1			s
Off-Interval ²	t_{off}	2			s
Duration of total measurement	t_{tot}	0,1			h
Update cycle period	T_{upd}	1			s
Intermittent cycle mode	on / off				
Methods					
Modes	Temperature (PWT Pro and Lite) , Woofer Identification (PWT Pro only)				
Hardware settings (name, date, read and write function)	The Input Parameters (Setup) may be stored in the hardware unit (DA1)				
Number of DUTs	DUT	1		8	
Frequency of pilot tone	automatic adjustment (1...4 Hz) depending on high pass frequency of power amplifier used				
Speed of temperature measurement (depending on selected speed fast and slow)	τ	0.375		6	s
Material, Geometry Parameters					
Effective area of the driver diaphragm.	S_d	0		10000	cm ²
Material of voice coil	copper or aluminum				
Failure (permissible variation of R_e)					
Min. resistance ref. to cold state	R_{MIN}	10		80	%
Max. resistance referred to cold state	R_{Max}	120		500	%
Max decrease voice coil temperature	ΔT_{TV}	-273		-53	Kelvin
Max. increase voice coil temperature	ΔT_{TV}	53		1053	Kelvin
Import Parameters					
Voice coil resistance at DC (required)	$R_e(T_v=T_a)$				Ω
Force factor at rest position	$Bl(x=0)$				N/A
Moving mass	M_{ms}				g

Measurement Results

Parameters at the Rest Position ($x=0$) ¹			PWT LITE	PWT PRO
	Electrical voice coil resistance	$R_e(t)$	✓	✓
	Electrical parameters $x \ll x_{max}$	$L_e, L_2, R_2, C_{mes}, L_{ces}, R_{es}$		✓

	Mechanical parameters $x \ll x_{max}^1$	$M_{ms}, R_{ms}, C_{ms}(t), BI$		✓
	Derived parameters $x \ll x_{max}$	$Q_{eps}, Q_{tp}, Q_{ms}, T_v, Q_{es}(t), Q_t, f_s(t)$		✓
Transducer States				
	Electrical signals	$U_{rms}(t), I_{rms}(t), U_{peak}(t), I_{peak}(t), P(t), pdf(U)$	✓	✓
	Displacement (predicted by using imported $BI(x=0)^1$)	$x_{peak}(t), x_{bottom}(t), x_{dc}(t), x_{max}(t)$		✓
	Displacement (measured by using a Laser)	$x_{peak}(t), x_{bottom}(t), x_{dc}(t)$	✓	✓
	Analyzed distortion components	$d_C(t), d_L(t), d_{BI}(t)$		✓
	Temperature (regular and fast ² sampling)	$\Delta T_v(t)$	✓	✓
Nonlinear Parameters				
	Voice coil Inductance	$L_e(x), L_e(x_{rel}),$		✓
	Force factor (effective BI-product) ¹	$BI(x), BI(x_{rel})/BI(0),$		✓
	Suspension characteristic ¹	$K_{ms}(x), K_{ms}(x_{rel})/K_{ms}(0)$		✓

¹ absolute identification of the mechanical parameters and states requires import of $BI(x=0)$ and/or M_{ms}

² for 1 DUT only

Example: Analysis of the Destruction Process

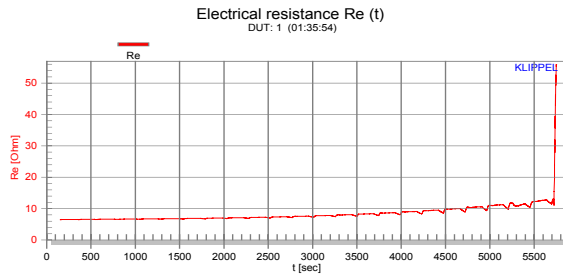
History

The Power Test monitors the parameter and state variables of each DUT and stores this data in the history buffer automatically. Connecting a PC to the measurement hardware the user may view the test conditions (supplied voltage and power) and the behavior of the DUT during the whole measurement. If a driver is damaged during the test a death report shows the period just before destruction in greater details. It is most important not only to find all of the defects such as

- Mechanical suspension damaged due to high displacement
- Voice coil damaged due to high displacement
- Voice coil damaged due to thermal overload

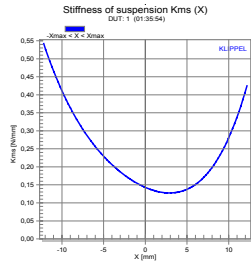
but also the sequence of the destructive events and the initial failure.

Voice Coil Resistance



The electrical resistance R_e of the voice coil increases with the instantaneous voice coil temperature. A sudden increase indicates a loose connection or a broken coil. A sudden decrease is caused by a shortcut of the windings in the gap.

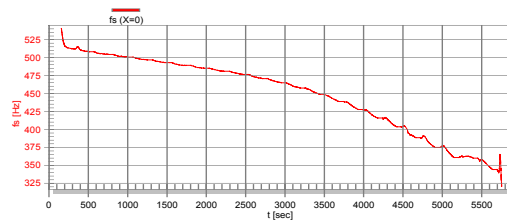
Suspension



The properties of the mechanical suspension are represented by the nonlinear stiffness $K_{ms}(x)$ versus displacement x and the stiffness $K_{ms}(t, x=0)$ at the rest position versus measurement time.

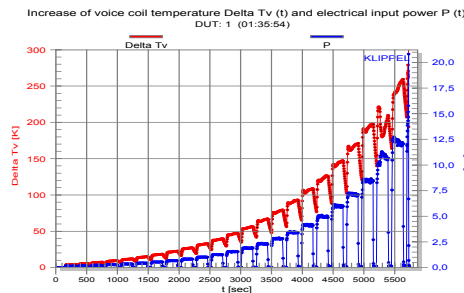
A high increase of the stiffness at maximal displacement $x=x_{max}$ in the nonlinear characteristic indicates high mechanical load which may cause a destruction of the suspension.

resonance frequency $f_s(t)$ at rest position $X=0$



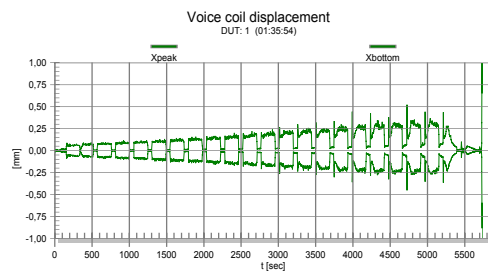
Reversible and nonreversible processes such as creep or ageing cause a decrease of the stiffness and resonance frequency during the measurement time which is normal for most drivers (figure below). A sudden decrease of $f_s(x=0)$ indicates a broken suspension or a lost joint.

Temperature, Input Power



The voice coil temperature (upper curve) is closely related to the real input power (lower curve) supplied to the transducer. Both state variables plotted versus measurement time give important information for defining admissible maximal input power.

Displacement



The instantaneous displacement is the most important mechanical state variable. The maximal displacement x_{max} determines the maximal acoustical output possible at low frequencies. If the driver is damaged during Power Test the peak and bottom value of the displacement may show the mechanical condition.

Find explanations for symbols at <http://www.docs.klippel.de/symbols.pdf>

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