Can an instrument compete with a human ear at end-of-line testing ?
线上测试应用中仪器和人耳可以相比吗?

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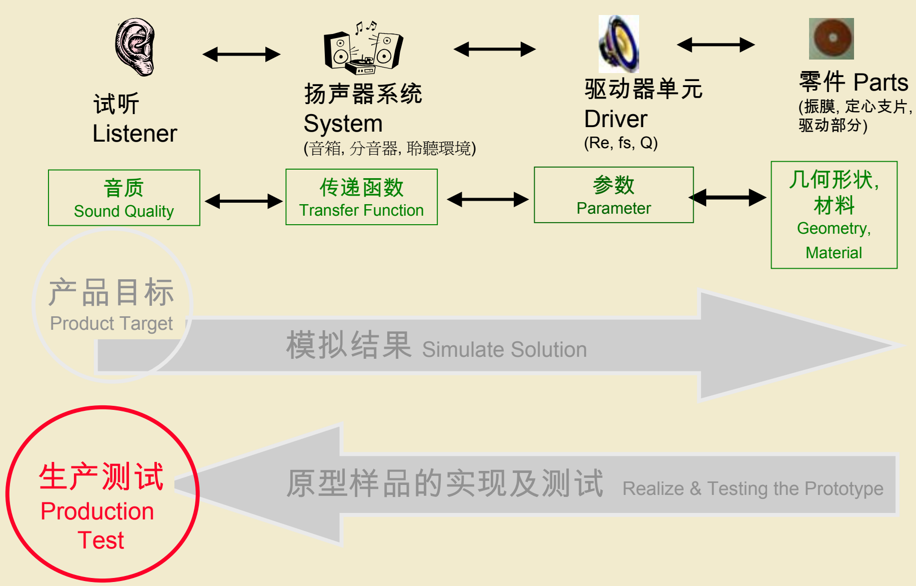
TECHNISCHE UNIVERSITÄT DRESDEN

KLIPPEL

研发 – 品管的循环 The R&D – QC life cycle



由测试工作引出的问题

Questions addressed in this workshop:

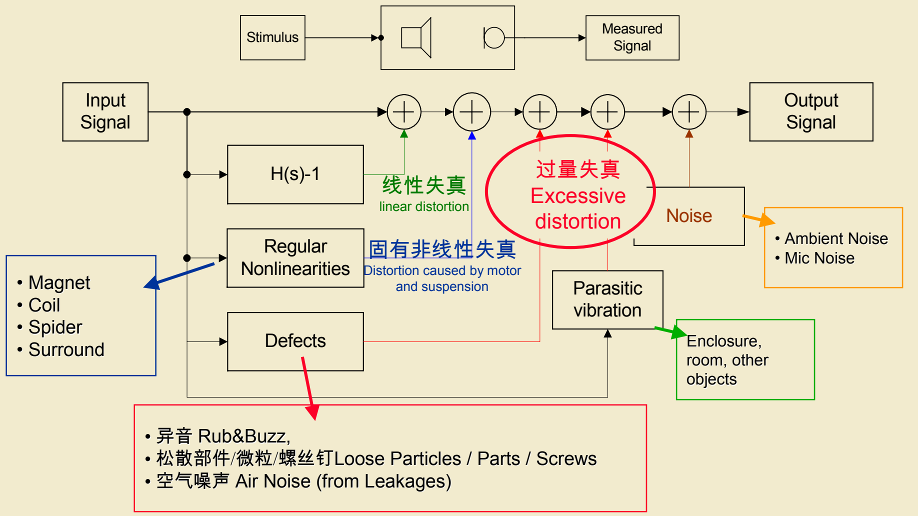
- Which kind of measurements are meaningful ? 哪种测量是有意义的?
- How to shorten the measurement time ? 如何缩短测试时间?
- How to do reliable and reproducible measurements ? 如何做到可靠的,可重复的测量?
- How to get maximal sensitivity for loudspeaker defects ?
  如何对扬声器的缺陷采用最大的灵敏度?
- How to cope with ambient noise ? 如何应对环境噪声?
- How to compare results measured in the R&D lab and at the end-of-line ?
- 如何比较R&D实验室和线上测试的结果?
- How to set the limits for PASS/Fail decision ? 如何设置PASS/FAIL判定的限制文件?
- How to mount the device under test ? 如何连接被测设备?
- Do we need a measurement box and other acoustical shielding ?
  我们需要测量箱子和其他声学屏蔽条件吗?
- How to distinguish voice coil rubbing, from buzzing, loose particles and other defects ?
- 如何辨别音圈碰撞,摩擦,松散微粒和其它缺陷?
- How to measure active systems with a digital interface ?
  如何用数字接口来测量一个主动系统?
- How to do statistics effectively and beneficially ? 如何有效地统计?
- How to test a multi-channel system ? 如何测量多通道系统?

线上100%测试要求

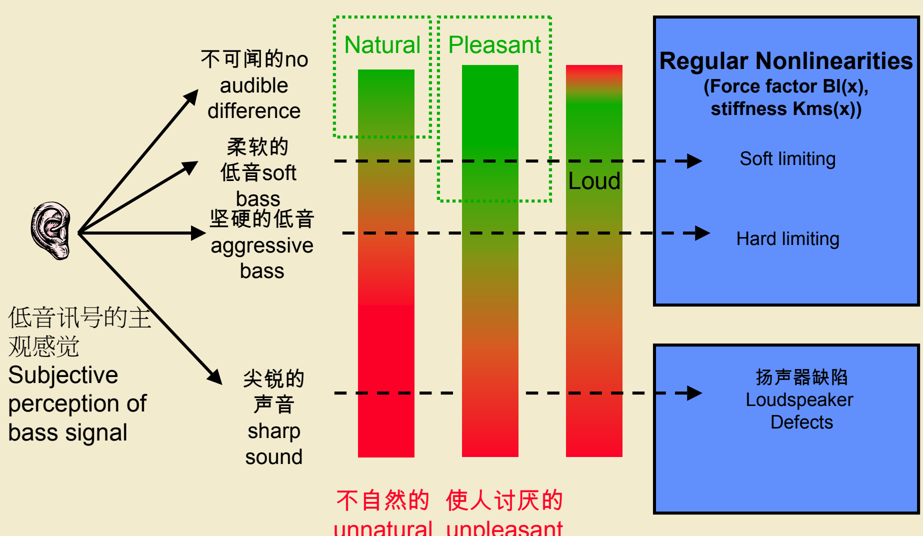
Requirements for 100 % end-of-line testing

1. 可信赖的不良品检测 reliable detection of defect units
2. 自动环境噪声修正 robustness against ambient noise
3. 快速执行 high speed
4. 灵活的客制化设计 flexibility for customer‘s needs
5. 操作简易 simple use
6. 经济实惠 cost effective solutions
7. *未来可作线上诊断 In future → on line diagnostics ?*

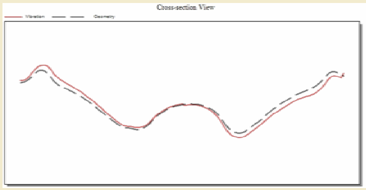
扬声器信号失真的产生
Generation of Signal Distortion in Loudspeakers



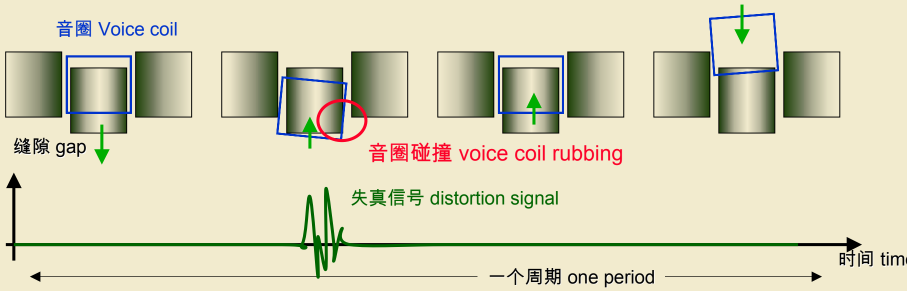
聆听测试的说明 Interpretation of Listening Test
低频下最大输出 in maximal output at low frequencies



扬声器缺陷:音圈碰撞
Loudspeaker Defect: *voice coil rubbing*

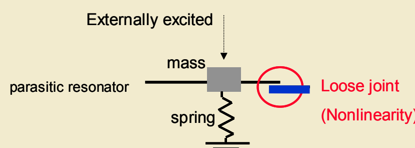


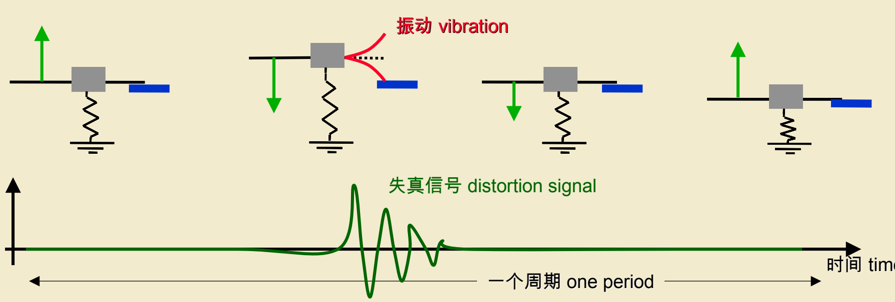
在328 Hz 处可能产生摇摆
Rocking mode may cause at 328 Hz



扬声器缺陷: 嗡嗡声问题
Loudspeaker Defect: *Buzz problem*

大多数缺陷表现为非线性振荡器
Most defects behave as a **nonlinear oscillator**
- 在一定的幅度以上起效用
  active above a critical amplitude
- 新的振动模式
  new mode of vibration
- 由激励信号驱动并同步
  powered and synchronized by stimulus
- 恒定的输出功率
  constant output power

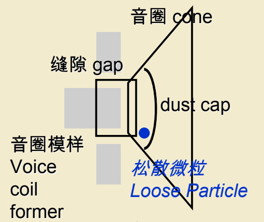


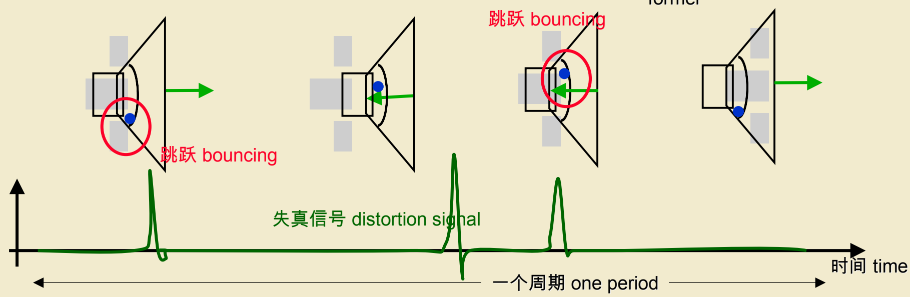


扬声器缺陷: 松散微粒

Loudspeaker Defect: *Loose Particles*

- 随机过程 stochastic process
- 微粒由音圈的位移控制加速 particles are accelerated by cone displacement
- 与激励信号不同步 not synchronized with stimulus
- 恒定的输出功率 constant output power





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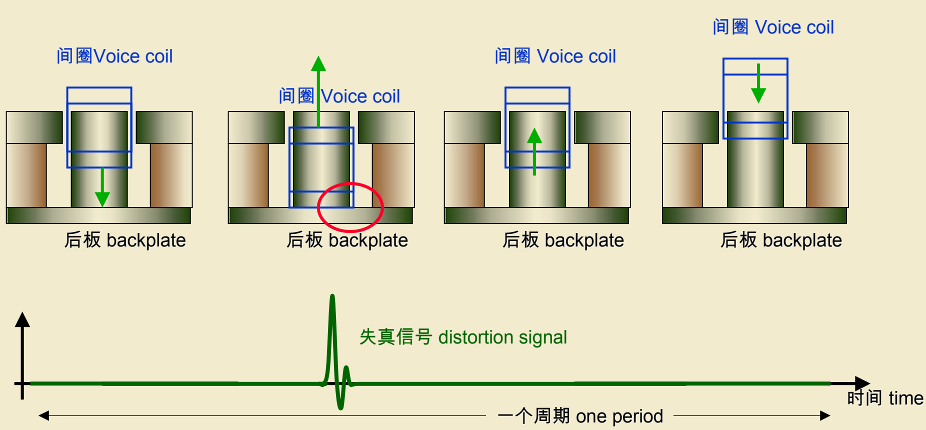
扬声器缺陷: 音圈撞击后板

Loudspeaker Defect: *voice coil hits the backplate*



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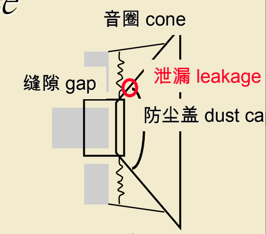
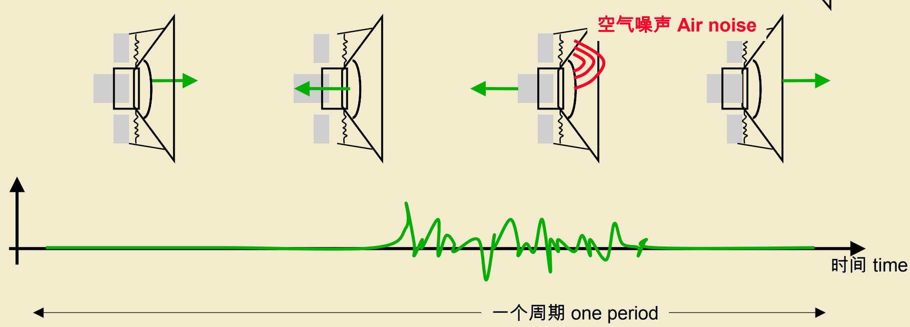
扬声器缺陷:空气泄漏和嘈杂噪声
Loudspeaker Defect: *Air Noise*



- 随机过程 stochastic process
- 气压随间圈位移改变 air pressure is changed by coil displacement
- 与激励信号同步 synchronized with stimulus



寻找一个最佳的激励信号

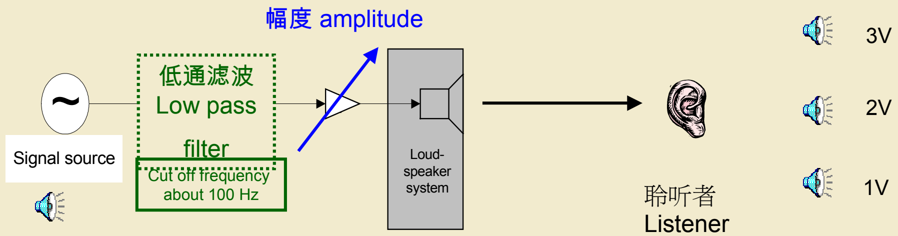
Searching for an optimal Stimulus

可闻的音圈撞击声

Audibility of Voice Coil Rubbing

Signal	Stimulus	Output 1V	Output 2V	Output 3V
Music				
Multi-Tone 20 Hz – 20 kHz				
Multi-Tone 20 Hz – 1 kHz				
Sinussoidal Sweep 1 s Most sensitive Stimulus				

聆听测试的设置 Set-up of Listening Test
低频下最大的输出 on maximal output at low frequencies



最佳激励: Optimal Stimulus:
- 具有足够低音的音乐
Music with sufficient bass
(drum, guitar, organ, double bass)
- 单音信号 Single tone

测试标准 Test Criteria:
- 低音的最大响度？Maximal loudness of bass ?
- 低音的软度和硬度? Softness and hardness of bass ?
- 声音的尖锐度? Sharpness of sound ?
- 自然度,愉悦度? Naturalness, pleasantness ?

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如何从不规则的扬声器缺陷中获得征兆
How to get Symptoms from Irregular Loudspeaker Defects

- 缺陷仅产生声学的征兆→需要有灵敏的麦克风
  Defects produce only acoustical symptoms
  → Sensitive microphone required
- 缺陷产生高频成分→使用低通滤波的激励和对麦克风信号使用高通滤波
  Defects produce high frequency components
  → Excite with low-pass filtered stimulus and apply high-pass filtering to microphone signal
- 缺陷和环境噪声相似→ 麦克风放置在靠近音源的地方(近场测量)
  Defects are similar to Ambient noise
  → Microphone is located close to the source (near field measurement)

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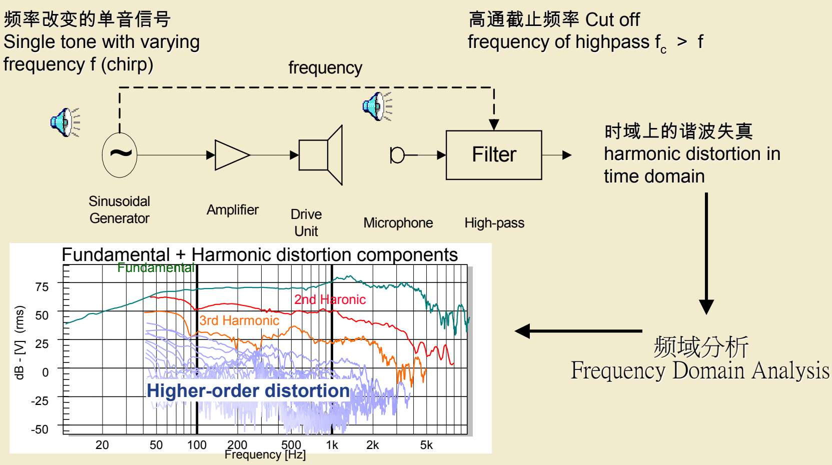
高次谐波的测试设置

Measurement Setup for Higher-order Harmonics

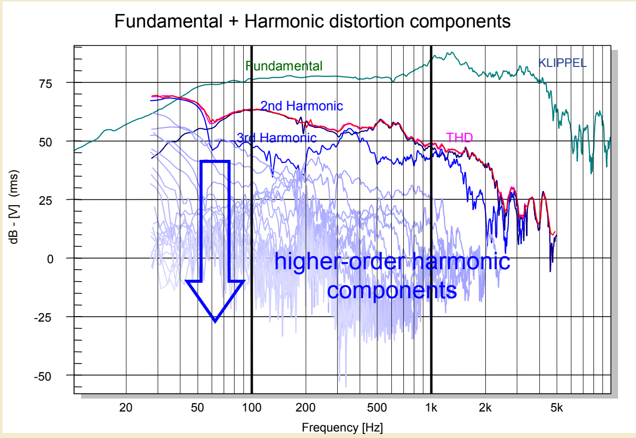


DEMO

Introduction to Klippel QC

利用高次谐波的信息
Using information from Higher-order Harmonics

Example:
woofer
near-field

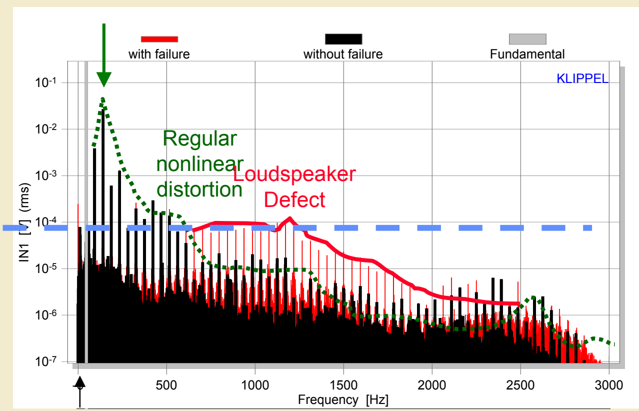


高次谐波成分(n>10)幅度非常低,通常会被环境哭声干扰
magnitude of higher-order Harmonic components (n > 10) is extremely low
are usually corrupted by ambient noise

扬声器缺陷的征兆
Symptoms of a Loudspeaker Defect
扬声器音圈碰撞和没有碰撞的情形
loudspeaker with and without rubbing coil

- 80 dB

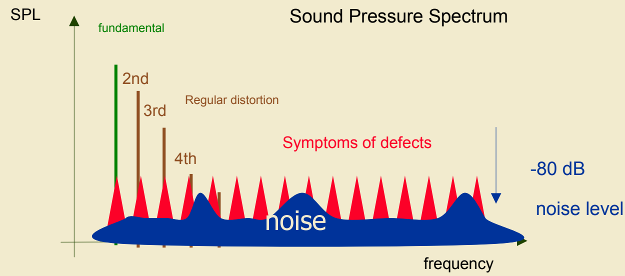
被噪声和常规的失真掩蔽
Masked by noise and regular distortion



基频50Hz Fundamental 50 Hz

频域分析 Frequency Domain Analysis

扬声器由单音信号激励 loudspeaker excited by a single tone stimulus

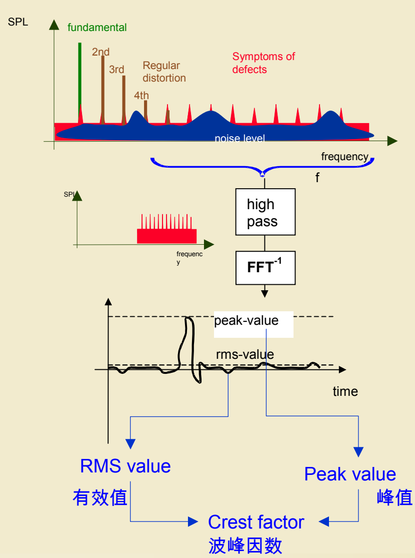


问题 PROBLEMS:

- 遍布在整个频率范围内 spread over a wide frequency range
- 在基频成分整数倍的地方会出现周期性的最大值 periodic maxima at multiples of the fundamental
- 在低频处被常规失真和基频成分掩盖 at low frequencies masked by regular distortion and fundamental
- 非常接近噪声电平 close to the noise level

时域分析

Time Domain Analysis



解决方法:返回到时域

Solution: back to the time domain

→ 高次谐波的峰值振幅和相位 Peak exploits amplitude and phase of higher-harmonics

→ 峰值揭示短暂的瞬间 peak value reveals small transients (clicks)

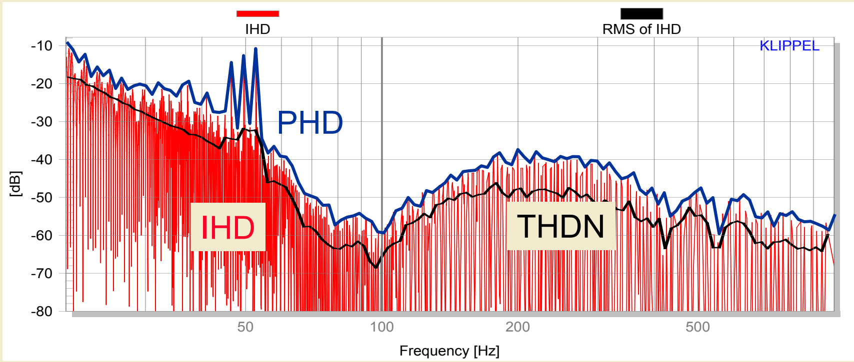
→ 峰值和有效值的比值给出失真的波峰因数 Ratio between peak and rms value gives crest factor of distortion

→ 常规失真产生很低的波峰因数 regular distortion generates low crest factor

→ 大多数缺陷产生很高波峰因数的征兆 most defects generate symptoms with high crest factor

谐波失真
Harmonic Distortion

驱动信号: 正弦扫频 Stimulus: Sinusoidal sweep



瞬时谐波失真 Instantaneous harmonic distortion

谐波失真的平均值 Mean value of harmonic distortion

峰值谐波失真 Peak harmonic distortion

谐波失真的峰值因子
Crest factor of harmonic distortion (CHD)

驱动信号: 正弦扫频 Stimulus: Sinusoidal sweep

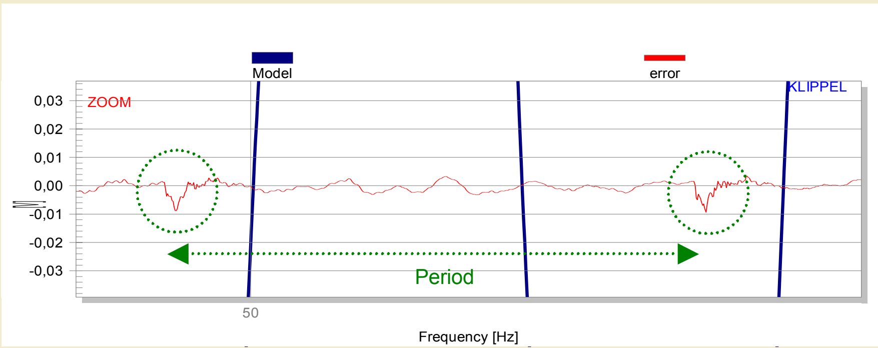
谐波失真峰值因子可以在绝对标度上被解释！

CHD can be interpreted on an absolute scale ！

时域信号失真的细节

Detail of the distortion time signal

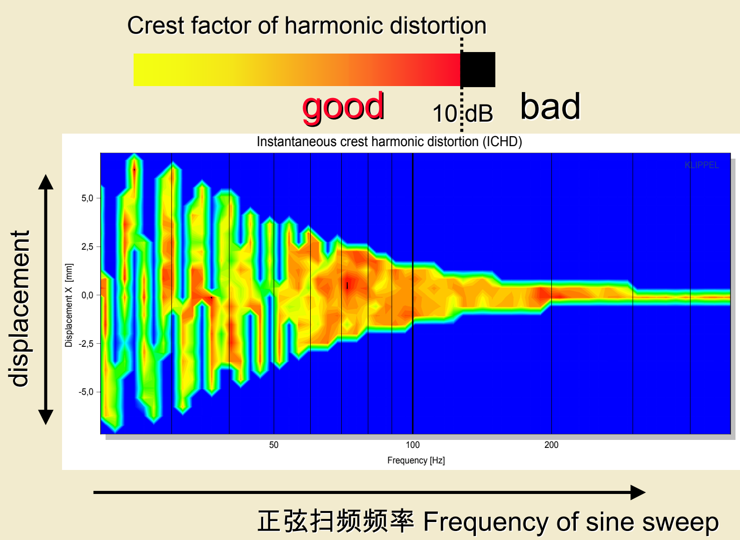
案例 A:Case A: „beating wire of a defect driver “



• 固有失真具有高能级 Regular distortion have high energy
• 异声具有低能级 Disturbances have low energy
• 异声是集中在一小部分周期里的 Disturbances are concentrated at a fraction of a period
→ 峰值失真 (大峰值因子) peaky distortion (high crest factor)
→ 有源补偿是有益的 Active compensation is useful

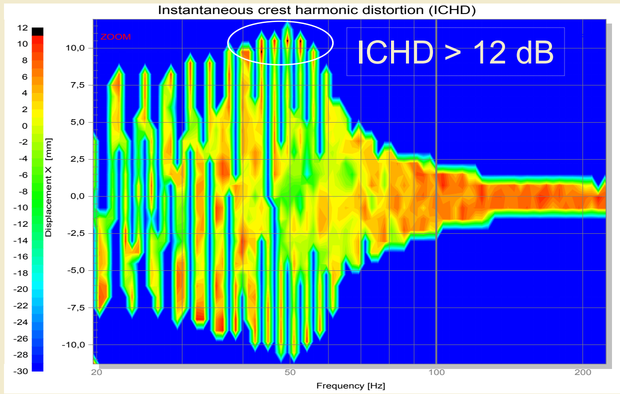
检查: 谐波失真的峰值因子

Check: crest factor of harmonic distortion



瞬时峰值谐波失真
Instantaneous crest harmonic distortion ICHD(f,x)

案例A: 毁损单体接线敲打 Case A: „beating wire of a defect driver "

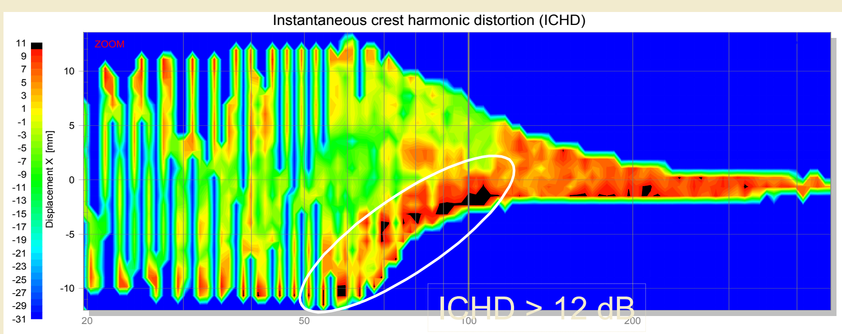


毁损出现在50赫兹 + 10 mm 位移处

Defect occurs at + 10 mm displacement at 50 Hz

瞬时峰值谐波失真
Instantaneous crest harmonic distortion ICHD(f,x)

案例B: 毁损单体音圈摩擦 Case B: „rubbing voice coil of a defect driver "



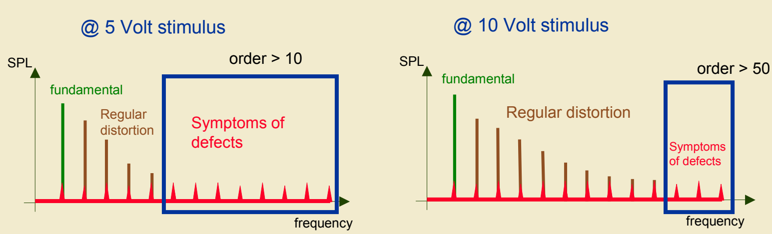
初始摩擦条件 Conditions initiating rubbing:

- 负转折点的音圈偏移
  Negative turning point of voice coil excursion
- 共振频率之上 (质量主导) → 音圈倾斜
  Above resonance frequency (mass dominant) → Tilting of voice coil former

描述谐波失真的特性
Characteristics describing Harmonic Distortion

- 总谐波失真的有效值 RMS value of the total harmonic distortion (THD)
- 将失真成分与基频成分或总信号成分相比较(失真百分比) Referring distortion components to the fundamental component or total signal (distortion in percent)
- 独立阶次失真的评估(2次,3次谐波) Assessment of individual order of distortion (2nd, 3rd-order)
- 总谐波失真的峰值(PHD→Rub and Buzz检测) Peak value of Total Harmonic distortion (PHD →Rub and Buzz detection)
- 高次谐波失真的峰值因子(将缺陷和马达产生的失真分离) Crest Factor of higher-Order Harmonics distortion (Separation of Defects and Motor Distortion)

目标: 可靠的检测 Target: Reliable Testing
问题: 掩蔽影响 Problem: Masking effects

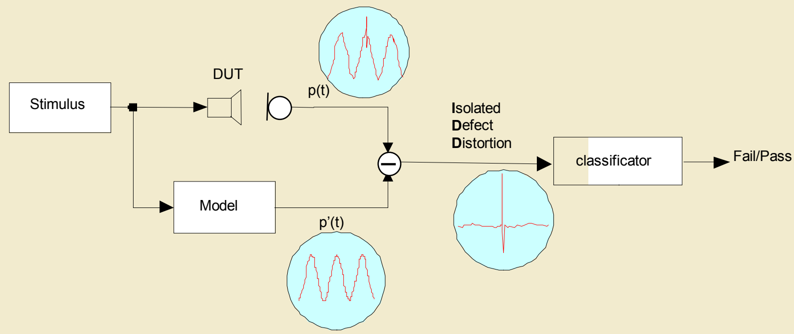


人耳测试的限制 Where are the limits of a human tester ?

- 一些缺陷的征兆通常具有恒定的能量 Symptoms of some defects have almost constant energy
- 常规非线性失真随幅度升高而升高 Distortion of regular nonlinearities rise with amplitude
- 缺陷被掩盖(幅度高的情况下变成不可闻)Defects are masked (become inaudible at higher amplitudes)
- 增加的高通频率 → 能量少→ 噪声问题 Increasing high-pass frequency → less energy → noise problems

可检测人耳难分辨得缺陷

Detecting Defect Units with inaudible symptoms

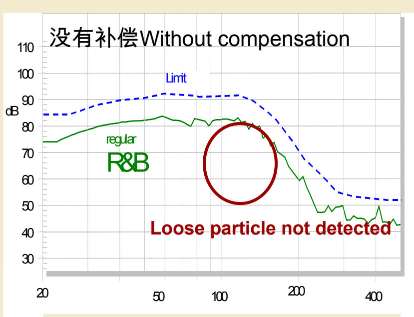


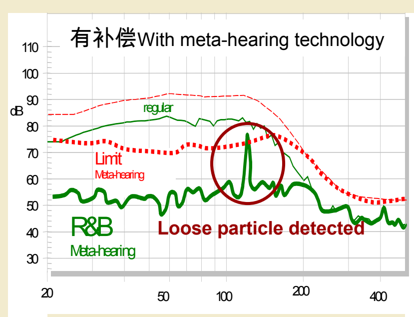
Meta-Hearing Technology

- 固有失真可预测 Regular distortion are predictable
- 模拟固有失真 Modeling of regular distortion (adaptive learning)
- 遮掩固有失真可主动滤除 Masking by regular distortion can be removed actively

目标: 可靠的测量 Target: Reliable Measurement

超听力技术的好处 Benefits of Meta-hearing Technology:





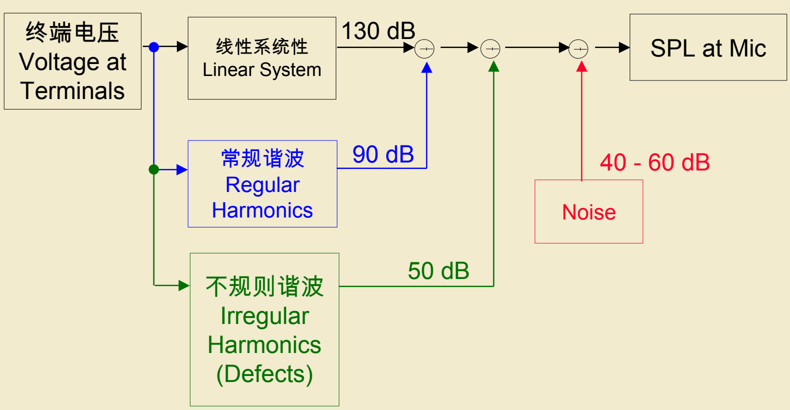
→ 简单地定义PASS/FAIL极限 Simple definition of PASS / FAIL thresholds

→在听力极限下测量 Measurement below the hearing threshold

DEMO

Meta Hearing Technology

信号成分的电平
Level of the Signal Components



问题 Problems:

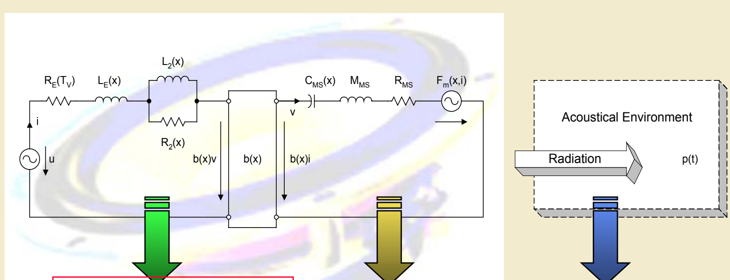
- 缺陷的征兆非常小(但仍可闻) symptoms of defects are very small (but still audible)
- 生产线的环境噪声 (强大的,宽带的) ambient noise in a production environment (impulsive, wideband)
- 影响是什么?→缺陷(R&B),谐波,没有基频成分!! What is affected? → Defects (Rub&Buzz), Harmonics, no fundamental!

如何处理环境噪声
How to cope with Ambient Noise

问题 Questions:

- 我们一定要进行声学测量吗?
  Can we avoid acoustical measurements ?
- 我们可以衰减多大的环境噪声?
  Can we attenuate ambient noise ?
- 我们可以检测到被环境噪声干扰的成分吗?
  Can we detect an invalid measurement corrupted by ambient noise ?
- 我们可以补偿环境噪声带来的影响吗?
  Can we compensate for ambient noise ?
- 我们如何利用每次测量的有效部分?
  Can we use the good parts of each measurement ?

我们一定要进行声学测量吗?
Can we avoid acoustical measurements ?



传感器类型 Sensor Type	电流,电压传感器Current & voltage sensor	光学镭射传感器Optical Laser Sensor	麦克风 Microphone
优点 Advantages	强大的,可靠的,便宜的传感器 Robust, reliable, inexpensive sensor	绝对的测量X,V Absolute measurement x, v	对声学的问题非常灵敏,高信噪比 Sensitive to acoustical problems, high SNR
缺点 Disadvantages	直接影响机械和声学系统 Reflects mechanical and acoustical system indirectly	价格高,低信噪比,线性度,处理 Price, low SNR, Linearity, Handling	声学干扰,时间延迟 Acoustical disturbances Time delay

电子的测试强有力地抵抗环境噪声

Electrical tests are robust against ambient noise !

电子测量可以测量什么?

What can be measured with electrical tests?

阻抗(线性失真): Impedance (Linear Distortion):

- T/S参数 T/S Parameter: RDC, fs (Moving Mass, Stiffness), Q
- 感应系数 Inductance (turns, shortcut ring position)
- 灵敏度 Sensitivity (before break up, given Bl, Sd)

常规失真 Regular Distortion:

- 音圈偏移 Coil offset
- 劲度不对称度 Stiffness Asymmetry
- (Xmax, X_{Bl}, X_C)(limited by motor and suspension)
- 感应系数(极性) Inductance (polarity)

不规则失真 Irregular Distortion:

- 松动连接 Loose connections

声学测试中可以测量什么?

What can only be measured with acoustical tests?

线性失真 Linear Distortion:

- 频率响应(辐射问题) Frequency Response (radiation problems)

Not affected

常规失真 Regular Distortion:

- 多普勒失真 Doppler Distortion (R&D)
- 音圈振动引发的失真 Distortion generated by Cone Vibration (R&D)

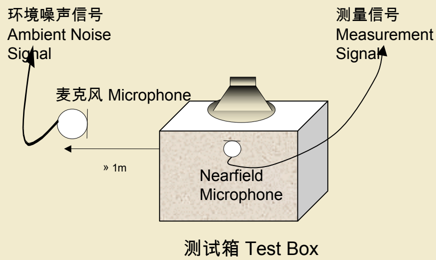
Partly affected

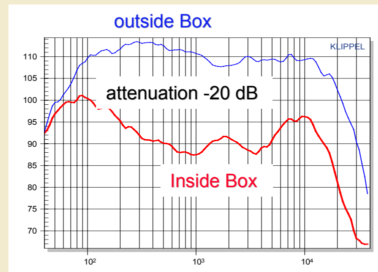
不规则失真 Irregular Defects:

- 异音测试 Rub&Buzz test
- 松散微粒/部件 Loose Particles / Parts
- 空气漏 Air Leakage

Most Sensitive against Ambient Noise

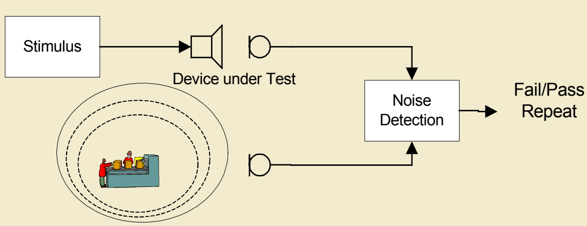
最佳的SPL测试 Optimizing SPL tests
环境噪声检测 Ambient Noise Detection





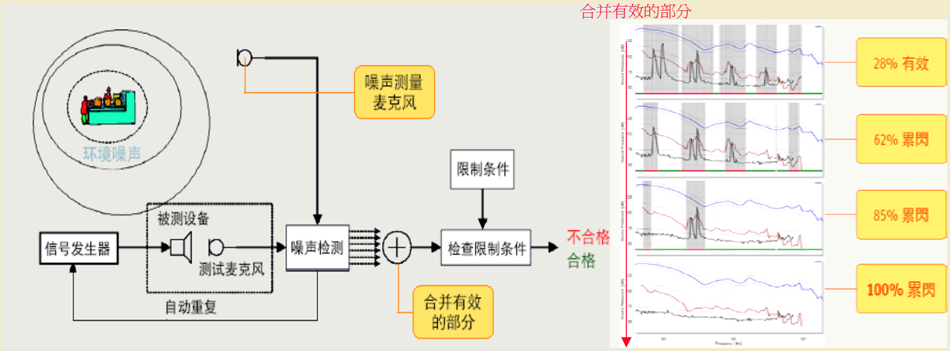
- Use test box
- 每个箱都是独立的 each box is indivudual
- 测试箱体的衰减系数 measure test box attenuation.

在吵杂的生产环境作可靠性高的测试
Reliable Measurement in a noisy production environment



Solution:
→ 第二支麦克风测远场噪音 Second microphone in the far field
→ 预测在待测物的噪音 Predict noise at DUT
→ 有效得知测量是否被环境噪声干扰 Detects corrupted measurements reliably
→ 自动重复测试 Repeats measurement automatically

环境噪声免疫 - Noise Immunity

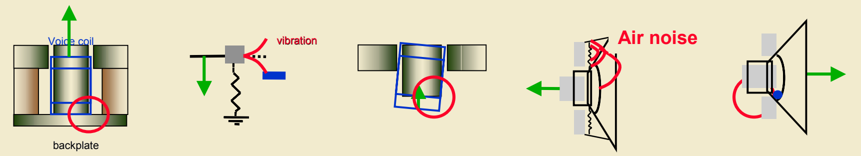


生产线上的环境噪声可以由置于远场的第二个麦克风来监测。被环境噪声干扰的测量结果会自动重复测量，每个测量结果都会保存并整合，最后提供有效的测量结果。尽管每个单一的测量都被环境噪声干扰，也确保了完全的生产线环境噪声免疫

DEMO

Auto repeat - Noise Immunity

扬声器缺陷的模型
Modeling of Loudspeaker Defects



hitting backplate *Buzzing* *Coil rubbing* *Air leakage* *Loose particles*

确定的过程
Deterministic Process

半随机过程
Semi-Random Process

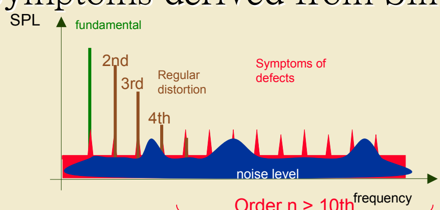
随机过程
Random Process

可重现的
reproducible

确定性和随机过程的调制
Deterministic Modulation of a random process

不可预知的
Not predictable

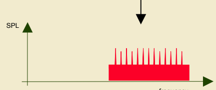
正弦激励下征兆
Symptoms derived from Sinusoidal Stimulus

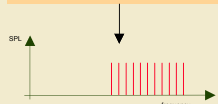


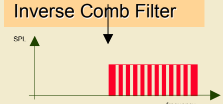
高通滤波器 High-pass Filter

梳状滤波器 Comb Filter

倒转梳状滤波器
Inverse Comb Filter







复杂的频谱(幅度+相位)
Complex Spectrum (Amplitude + Phase)

失真时间信号
Distortion Time signal

总谐波失真
Total harmonic Distortion (n > 10)

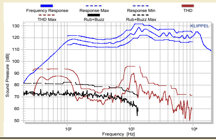
总的非谐波失真
Total non-harmonic distortion (n > 10)

确定的信号
Deterministic signal

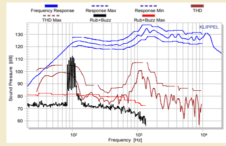
随机信号
Random signal

音圈撞击　Voice Coil Rubbing

正弦扫描信号激励 Stimulus: sinusoidal sweep

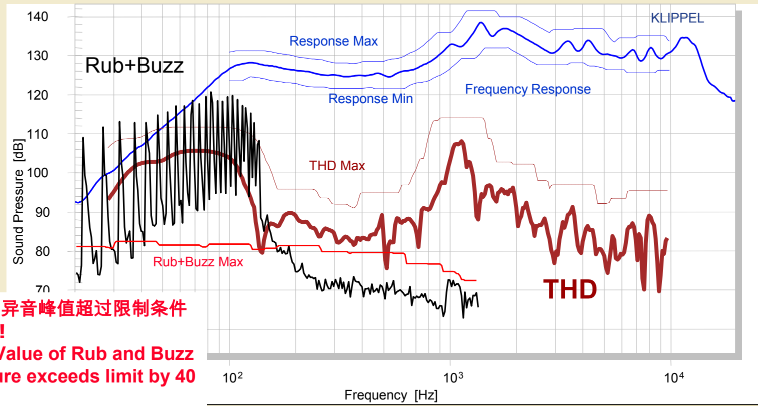


1V



2V

3V

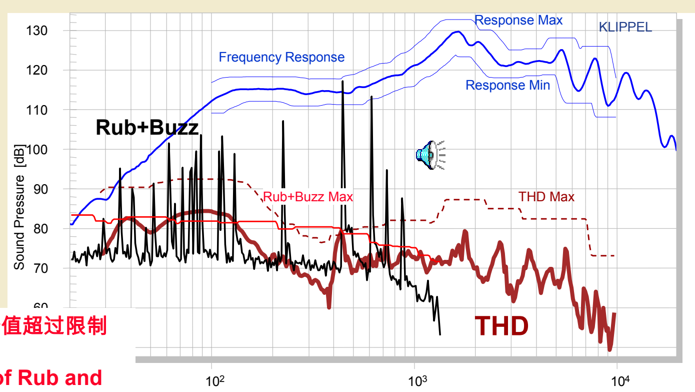


测量的异音峰值超过限制条件40dB!!
Peak Value of Rub and Buzz measure exceeds limit by 40 dB !!

缺陷:大的松散微粒
Defect: Large Loose Particle

small washer

正弦激励
Sinusoidal Stimulus

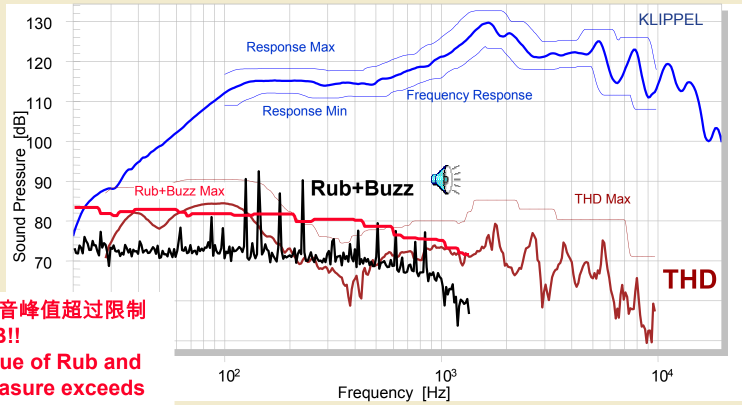


测量的异音峰值超过限制条件40dB!!
Peak Value of Rub and Buzz measure exceeds limit by 40 dB !!

非常小的松散微粒
Very Small Loose Particle

些许细盐 one grain of fine salt

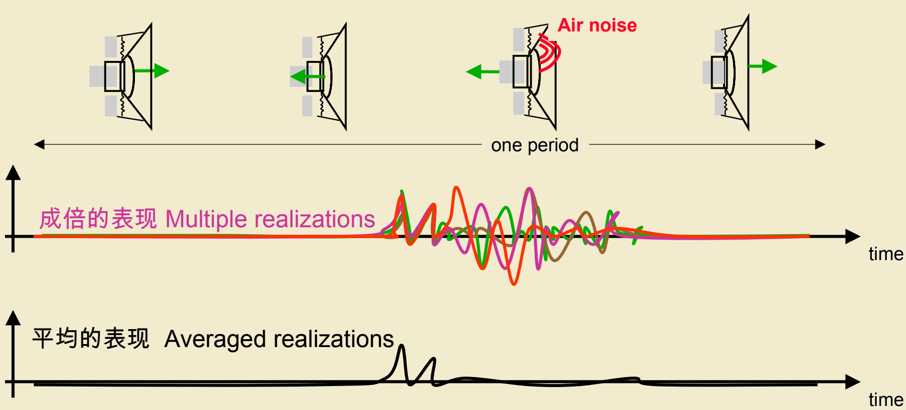
正弦激励
Sinusoidal
Stimulus



测量的异音峰值超过限制条件10dB!!
Peak Value of Rub and Buzz measure exceeds limit by 10 dB !!

AP Technology

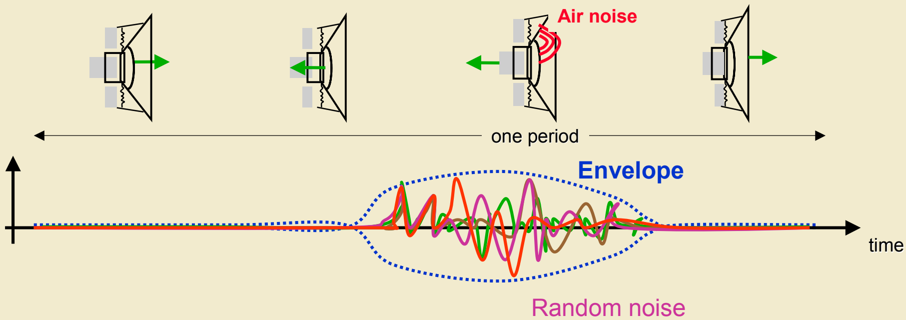
随机噪声是个有价值的征兆
Random Noise is a valuable Symptom



→ 平均方法来抑制随机成分 Averaging suppresses the random component

AP Technology

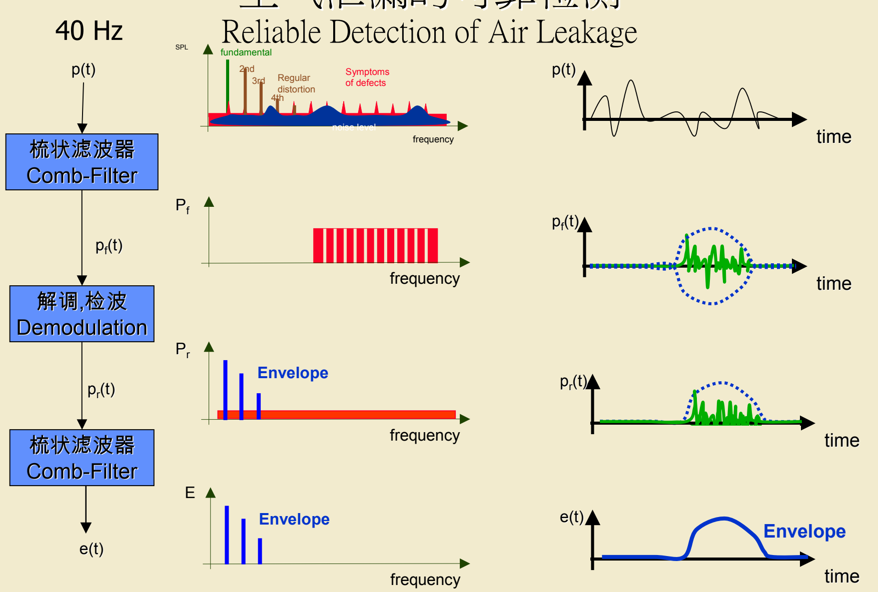
空气泄漏产生调制的信号
Air Leakage generates a modulated signal



- 封装是具有确定性的 Envelope is deterministic
- 封装跟空气压力和音圈位置相符合 Envelope corresponds with air pressure and coil displacement
- 混乱产生随机的噪声信号 Turbulences generate a random noise signal

→ 空气泄漏产生调制的噪声信号 A air leakage generate a modulated noise signal

空气泄漏的可靠检测
Reliable Detection of Air Leakage



→可以使用大功率的调制噪声信号 Full power of the modulated noise can be used

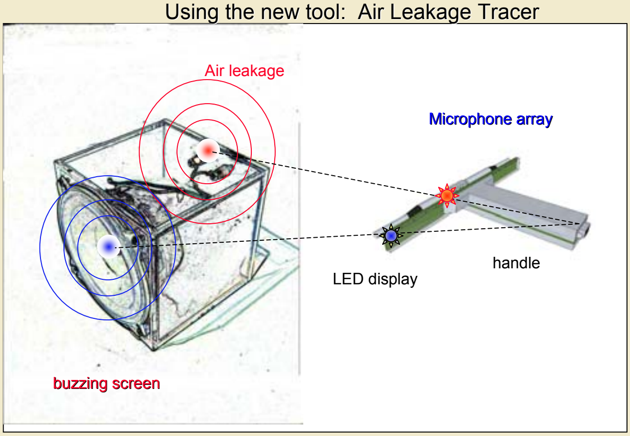
DEMO

Vented box system with air leakage

空气泄漏的定位

Localization of Air Leakage

使用新的工具: 空气泄漏跟踪器
Using the new tool: Air Leakage Tracer



- 两通道解调技术来估算麦克风信号之间的时间延迟

  Time delay between the microphone signal is estimaten by Two-Channel demodulation technique

- LED显示空气泄漏的角落

  LED display shows the angle of the incident sound

- 少数测量显示确定的和随机的声源

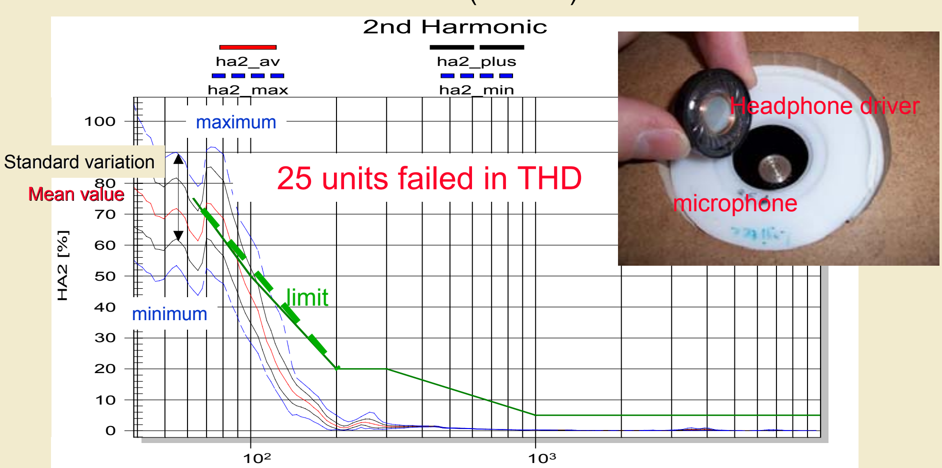
  A few measurements shows the source of deterministic and random sound

在线测试的目标
Objectives in end-line-testing:

1. 基本目标:将有缺陷的单元从交货的产品中分离出来.
   Basic Goal: Separate defect units from delivered goods
   → 使用限制文件简单进行PASS/FAIL判定 simple PASS/FAIL decision using limits

2. 最终目标 :避免制造出不良的产品
   Ultimate Goal: Avoid manufacturing of defect units
   → 使用诊断来获取有意义的特性反馈来控制生产过程 use diagnostics to get meaningful characteristics used as feedback in controlling the production process

二次諧波失真
2nd-order Harmonic Distortion
batch A (30 Duts)



如何來減小不良率?

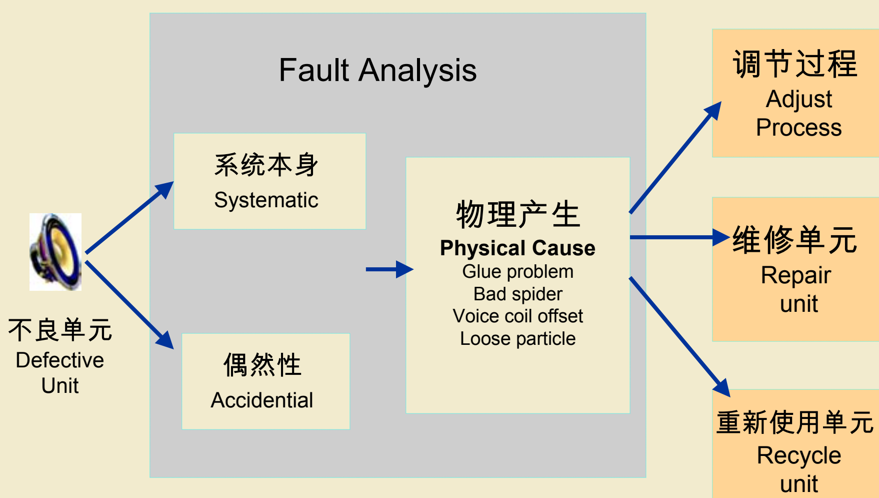
How to reduce the rejection rate ?

步驟Steps:

1. 物理原因是什麼？ What is the physical cause ?
2. 如何能快速地檢測出物理原因？ How can the cause quickly be detected ?
3. 如何使用這些信息來進行過程控制？ How to use this information for process control ?

目标: 减小不良率 Target: Reduce Rate of Rejection

解决方案: 在线诊断 Solution: On-line Diagnostics



從諧波成分中獲取訊息

Exploiting Information from Components

Harmonic Distortion

- 2次諧波失真 / 2nd-order harmonic distortion → 非線性曲線不對稱 / Asymmetry of nonlinear curve shape
- 3次諧波失真 / 3rd-order harmonic distortion → 非線性曲線對稱度 / Symmetry of nonlinear curve shape
- 高次諧波失真 / higher-order harmonic distortion → 限制，雜音，線撞擊 / Limiting, rub&buzz Wire beat

存在問題

Open Questions:

非線性的種類

What kind of nonlinearity ?

自身缺陷還是裝配問題？

A defective part or an assembling problem ?

如何修理問題

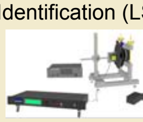
How to fix the problem ?

基於非線性參數的診斷

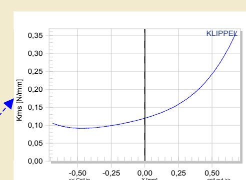
Diagnostics based on Nonlinear Parameters

大信號識別

Large Signal Identification (LSI)



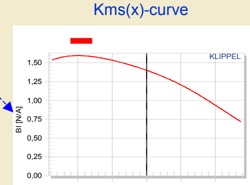
But the measurement time > 10 minutes



勁度係數曲線

Stiffness

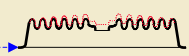
Kms(x)-curve



耦合係數曲線

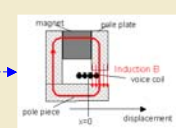
Force Factor

Bl(x)-curve



悬吊结构

Suspension Geometry

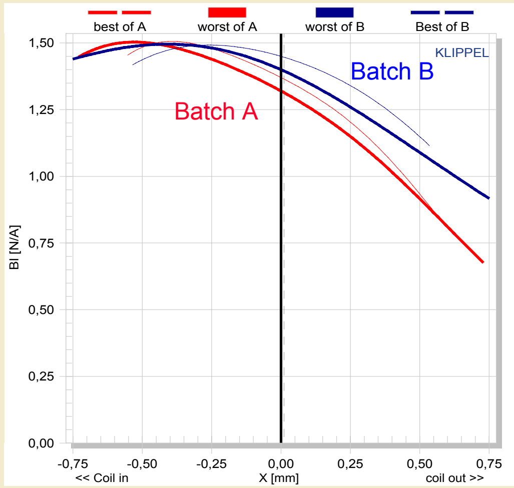


线圈偏移

Coil Offset

耦合系数曲线

Force Factor Curve Bl(x)

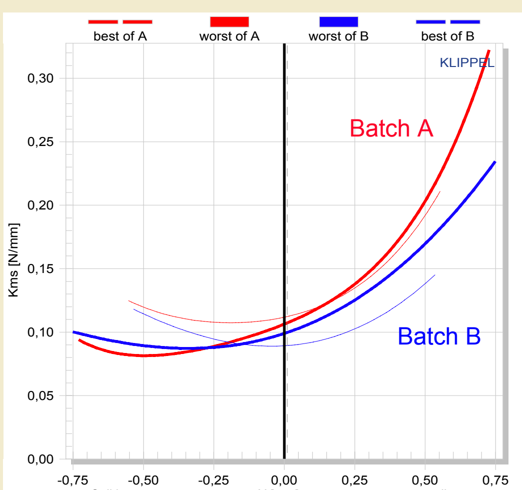


大信号识别技术
测量的曲线
Curve measured by using Large signal Identification (LSI)

测量时间：10min
Measurement time: 10 min

劲度系数曲线

Stiffness Curve Kms(x)



大信号识别技术
测量的曲线
Curve measured by using Large signal Identification (LSI)

测量时间：10min
Measurement time: 10 min

非線性曲線對在線測試有用嗎？

Are nonlinear curves good for end-of-line testing ?

Good point:

- 曲線提供所有相關的訊息 Curves provide all relevant information

Bad points:

- 全部識別需要更多的時間 Full identification requires more time
- 複雜的狀態導致解釋困難 Complexity makes interpretation difficult
- 曲線表徵多種多樣的物理原因 Curves reveals multiple physical causes
- 不可以運用Cpk, Ppk Cpk and Ppk can not be applied

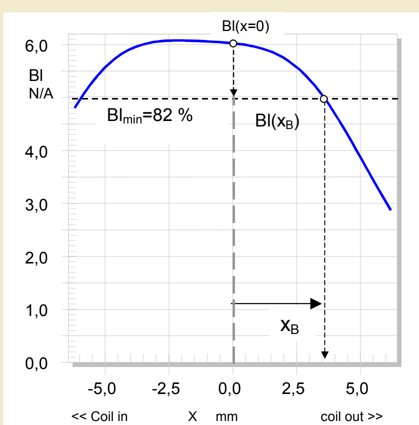
→ 單值數據的規格參數顯示更適合於QC

single-value characteristics are preferable for QC

耦合係數限制的偏移X_B

Force Factor Limited Displacement x_B defined according IEC standard 62458

根據IEC 62458 標準規定



Criterium:

最大峰值偏移Xb產生10% 的互調失真

Maximal Peak Displacement x_B generating 10 % intermodulation distortion

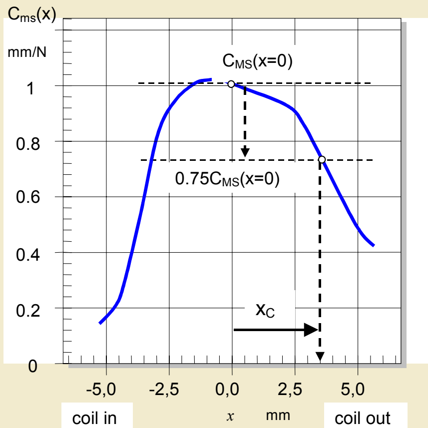
Steps:

1. 在大訊號模式下激勵換能器Operate transducer in large signal domain
2. 在耦合係數下降到靜態位置 Bl(x=0) 的82%的地方讀取偏移數值X_B
   Read displacement X_B where force factor Bl(x_{ac}) decreases to 82 % of the value Bl(x=0) at rest position

順性係數限制的偏移x_C

Compliance Limited Displacement x_C defined according IEC standard 62458

根據IEC 62458標準規定



Criterium:

最大的峰值偏移產生10%的諧波失真

Maximal Peak Displacement x_C generating 10 % harmonic distortion

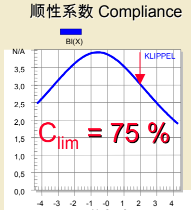
Steps:

1. 在大訊號模式下激勵換能器
   Operate transducer in large signal domain
2. 在順性係數下降到靜態位置的75%的地方讀取偏移值Xc
   Read displacement X_C where compliance value $C_{ms}(x_{ac})$ decreases to 75 % of the value $C_{ms}(x=0)$ at rest position

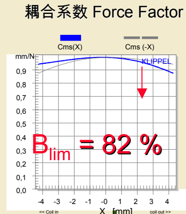
Xmax和其他位移限制

Xmax and other Displacement Limits

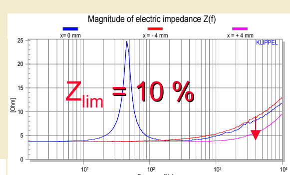
顺性系数 Compliance



耦合系数 Force Factor



自感 Inductance



Doppler

X_c	X_{Bl}	X_L	X_D
X limited by Cms(x)	X limited by Bl(x)	X limited by Le(x)	X limited by Doppler
10 % THD	10 % IMD	10 % IMD	10 % IMD

minimum

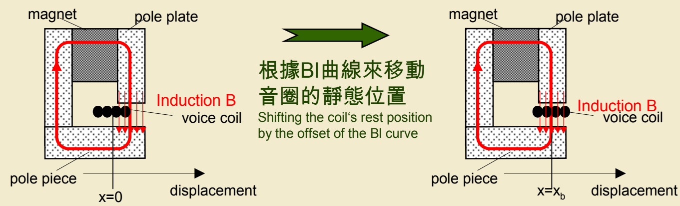
X_{max}

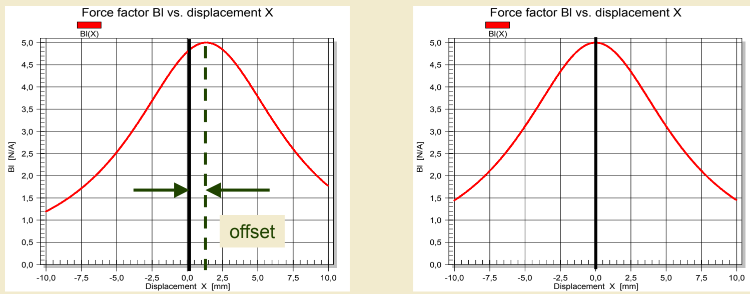
產生不超過10%的THD或10%的IMD

Generating not more than 10 % THD or 10 % IMD

校正音圈的靜態位置

Adjusting Coil's Rest Position



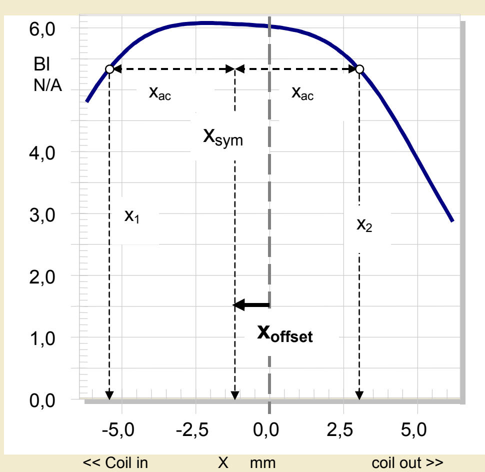


AP Technology

音圈偏移X_{offset}

Voice Coil Offset x_{offset} defined according IEC standard 62458

根据IEC 62458标准定义



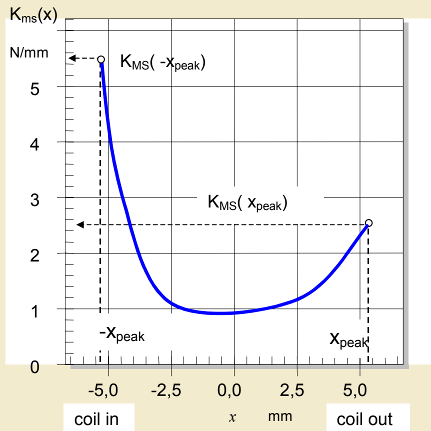
步骤 Steps:

1. 在大信号模式下激励换能器 Operate transducer in large signal domain
2. 在最大峰值位移xac处读取对称点Xsym Read symmetry point X_{sym} at maximal peak displacement x_{ac}
3. $X_{offset}=x_{sym}$ if $X_{ac} > X_{Bl}$

AP Technology

劲度不对称度 A_k

Stiffness Asymmetry A_K defined according IEC standard 62458
根据IEC62458标准定义



步骤 Steps:

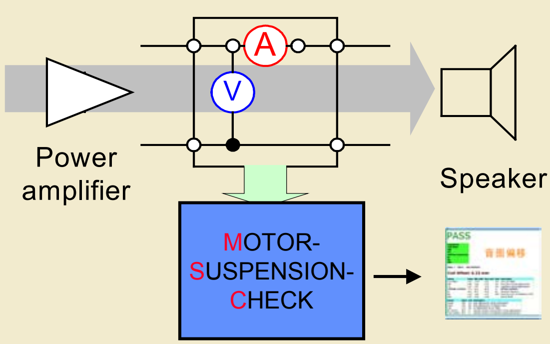
1. 在大信号模式下激励换能器
   Operate transducer in large signal domain
2. 在最大峰值偏移处读取劲度值
   Read stiffness values $X_{ms}(X_{peak})$ and $X_{ms}(-X_{peak})$ at maximal peak displacement
3. 根据公式计算劲度不对称度
   Calculate stiffness asymmetry according

$$A_K(x_{peak}) = \frac{2\left(K_{MS}(-x_{peak}) - K_{MS}(x_{peak})\right)}{K_{MS}(-x_{peak}) + K_{MS}(x_{peak})}100\%,$$

驱动和悬吊系统检查

Motor & Suspension Check (MSC)
用于品质控制的特别的LSI
Special LSI dedicated to Quality Control (e.g. end-of-line testing)

电压和电流 Voltage & current



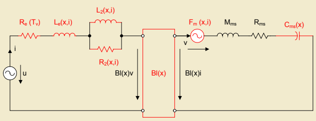
结果 Results:

- 音圈偏移 Voice coil offset
- 悬吊不对称度 Suspension asymmetry
- 测量过程中的峰值位移 peak displacement
- 10%失真时的位移 Displacement (Xmax) producing 10 % distortion
- X=0处的T/S参数 T/S parameters at x=0
- 箱体参数 Box parameters fb,Qb
- x=0处的阻抗 Impedance at x=0

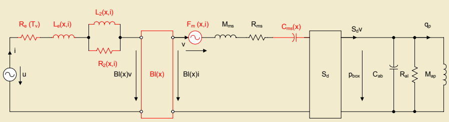
0.2 –2 s 测量时间 0.2-2s measurement time

MSC中使用的模型

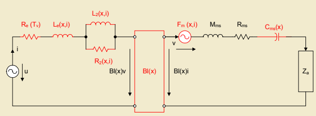
Models used in MSC



- •超低音 Subwoofer
- •低音 Woofer
- •耳机 Headphone
- •小型喇叭 Microspeaker
- •麦克风 Microphone
- •混合器 Shaker



带孔的箱体系统 Vented-box system



$$Z_a(s)=\frac{(s-a_1)(s-a_2)}{(s-b_1)(s-b_2)}$$

具有复杂的机构或声学负载的系统 System with complex mechanical or acoustical load (panel, horn, transmission line)

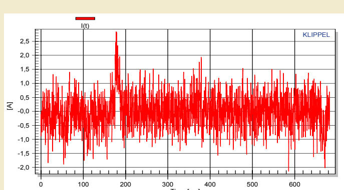
MSC中使用的特殊的激励信号

Special Stimulus used in MSC

- 需要对换能器设备进行持续的激励
  Persistant excitation of the transducer is required !
- 少量的，综合不同的长度的多音信号是最佳的激励
  Sparse multi-tone complex of length T is the best stimulus
- 需要预激励来达到稳定状态
  Pre-excitation (fraction of T) is required for steady state

测量所得电流的波形

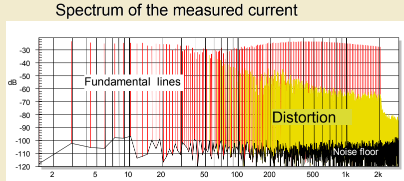
Waveform of the measured current



T= 170 ms ... 2.7 s

测量所得电流的频谱

Spectrum of the measured current



失真是鉴别非线性的基础

Distortion are the basis for the identification of the nonlinearities

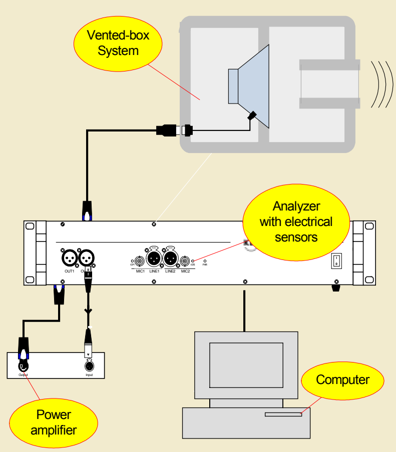
MSC的高速测量

High Measurement Speed of MSC

喇叭类型 Speaker Type	典型的共振频率 Typical resonance frequency	典型的激励长度 Typical stimulus length	最小激励长度 Minimal stimulus length
Subwoofer	30 Hz	2.73 s	**1,3 s**
Woofer	60 Hz	1.3 s	**0.68 s**
Midrange	300 Hz	0.68 s	**0.34 s**
Tweeter	2000 Hz	0.17 s	**0.17 s**
Headphone	100 Hz	0.68 s	**0.34 s**
Microspeaker	500 Hz	0.34 s	**0.17 s**
Exciter (shaker)	100 Hz	0.68 s	**0.34 s**
Closed-box System	60 Hz	1.3 s	**0.68 s**
Vented-box System	50 Hz	1.3 s	**0.68 s**

不需要额外的感应器

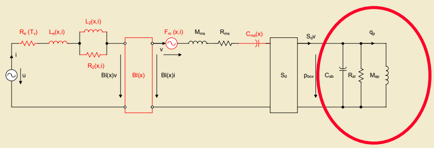
No Additional Sensor Required



- 在连接端仅仅测量电压和电流 Only voltage and current is monitored at the terminals
- 换能器安装好了也能够检测出驱动和悬边Motor and suspension can be checked when the transducer is mounted in enclosure
- 可以通过长线材测量Measurement via long cables possible
- 对环境噪声的免疫 Full immunity against ambient noise

测试密闭体

Testing the Enclosure

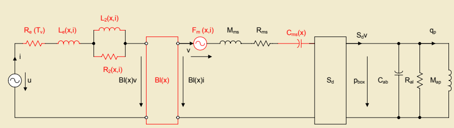


- •传统的测量表征扬声器系统的总体表现 Conventional measurements show total behavior of the loudspeaker system
- •MSC将驱动单元的缺陷与密闭体的缺陷区别开来 MSC separates defects in the drive unit from defects of the enclosure (port, sealing, damping)
- •不必将驱动单元拿到密闭体外面来 No need for taking the drive unit out of the enclosure
- •对租赁的客户来讲，是防止由于老化、疲累、气候的影响的检测扬声器系统品质的最佳选择 Perfect for checking the quality of loudspeaker systems in rental companies due to ageing, fatigue, climate influences

单一数値参数总览

Overview on Single-Valued Parameters representing loudspeaker nonlinearities in MSC

MSC中表征扬声器非线性



Parameters at x=0

Thiele-Small Parameters

Electrical Parameters R_e, L_e

Relative Parameters $f_s, Q_{ts}, Q_{ms}, Q_{es}, f_b, Q_b$

Mechanical Parameters $Bl, M_{ms}, R_{ms}, C_{ms}, K_{ms}$

Nonlinear Parameters at $x=x_{peak}$

Stiffness asymmetry A_K

Voice Coil Offset x_{offset}

Xmax for 10 % distortion in IMD or THD

Compliance limited displacement x_C

Force factor limited displacement x_B

MSC的灵敏度

Sensitivity of MSC, Example showing Influence of Gravity on Voice Coil Position
重力对音圈位置的影响的样例

X_{offset} = 0.060 mm	X_{offset}= 0.072 mm	X_{offset}= 0.084 mm

$$\Delta X_{offset} = -12\,\mu m \qquad \Delta X_{offset} = 12\,\mu m$$

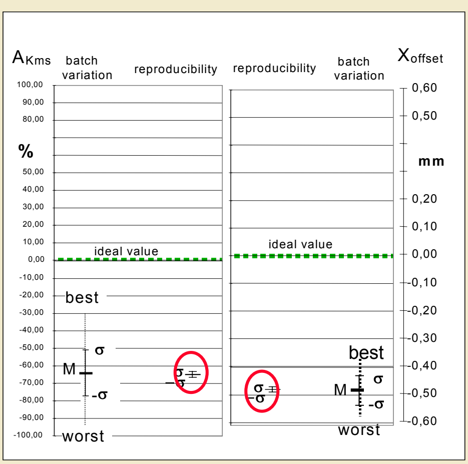
Prediction using
gravity constant g=9.81 ms^{-2}
Moving mass Mms= 4.94 gram
Compliance Cms(x=0)= 0.4 mm/N
Compliance Cms(x=3mm)= 0.2 mm/N

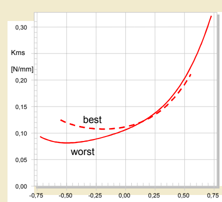
$$\Delta X_{offset} = M_{ms} g C_{ms} \approx 10 \ldots 20\ \mu m$$

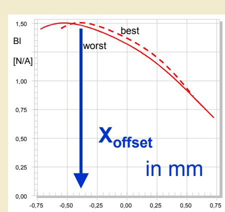
MSC的可重现性

Reproducibility of the MSC

在许多换能器上进行的R&R测量结果
Result of an R&R test performed on various transducers



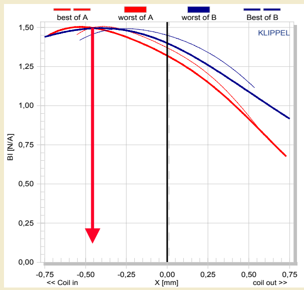




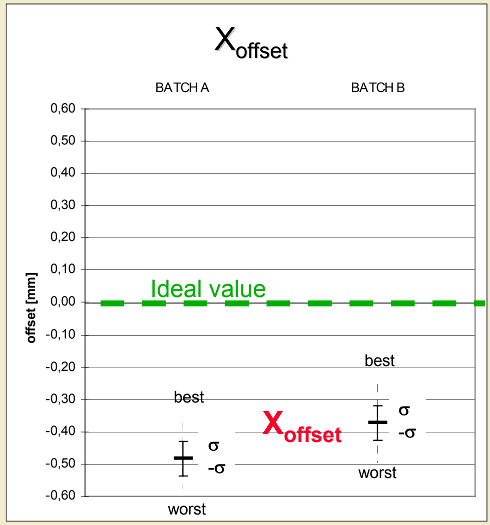
耳机的音圈位移X_{offset}

Voice coil offset X_{offset} of the headphone

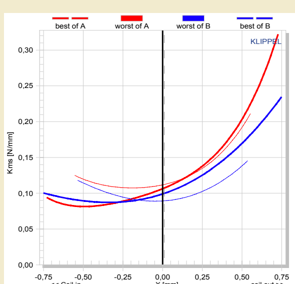
Bl curve measured with R&D

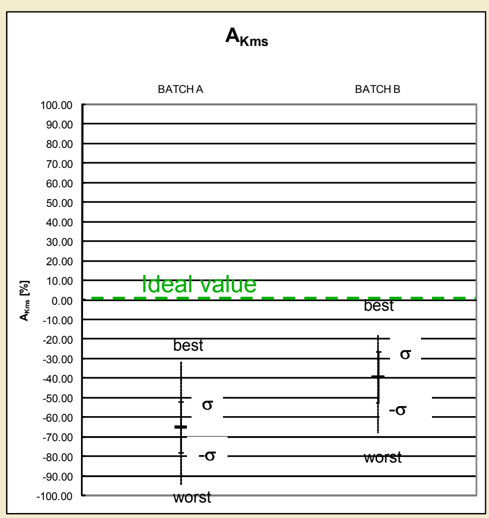


X_{offset} in mm

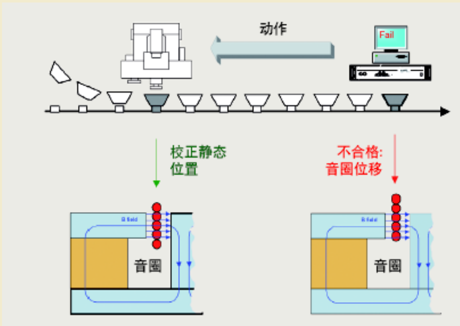


劲度不对称度 Stiffness Asymmetry A_{Kms}





在线诊断
On-Line Diagnostics



如果新的支架系统导致音圈静态位置发生改变时，当第一个产品被KLIPPEL QC 检测到时，音圈的位移量可以马上测量出来；这一信息可以用来校准音圈的静态位置，以及用来补偿悬吊系统改变的部分，有音圈位移问题的扬声器单元就不会输送出来。

KLIPPEL QC系统集成了先进的诊断技术，用于生产线终端测试，简化了测试结果的说明，指示出扬声器缺陷产生的根源。不仅是提供维修的依据，而且还可以发现参数变化的趋势，调节制造过程，及时减少产品不良率，确保产品的高品质和一致性。

→ mimimal rate of rejection　最小化不良率

结论
Conclusion

MSC是一种新的测量技术,提供 MSC is a new kind of measurement providing:

- 全面的驱动和悬吊系统的诊断　full motor and suspension diagnostics
- 单一数值的简单阐述说明　simple interpretation of single-valued parameters
- 指明失真的物理原因　shows physical cause of distortion
- 密闭体的缺陷(泄露,风口,阻尼)　defects of the enclosure (leakage, port, damping)
- 对所有的驱动单元适用　applicable to all kinds of drive units
- 小信号和大信号领域　small and large signal domain
- 极短的测量时间　short measurement time (< 1s)
- 强大的, 环境噪声免疫　robust, immune against ambient noise
- 过程控制的基础 basis for process control

->最大限度减小不良率　→ minimal rate of rejection

在线测试的目标

Objectives in end-line-testing:

1. 基本目标:将有缺陷的单元从交货的产品中分离出来.
   Basic Goal: Separate defect units from delivered goods
   → 使用限制文件简单进行PASS/FAIL判定 simple PASS/FAIL decision using limits

2. 最终目标 :避免制造出不良的产品
   Ultimate Goal: Avoid manufacturing of defect units
   → 使用诊断来获取有意义的特性反馈来控制生产过程 use diagnostics to get meaningful characteristics used as feedback in controlling the production process

DEMO

Motor Suspension Check

目标:可信赖的测试 Target: Reliable Testing

问题: 测量环境 Problem: Measurement Condition

声学环境 Acoustical environment
- 空气 Free air, panel
- 箱子 box
- 平面波管 plane wave tube
- 人造耳 artificial ear

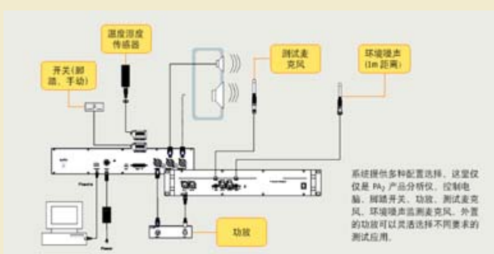
激励 Excitation
- 功放的输出电阻
  Output impedance of amplifier
- 分流或不分流 Shunt or not

天气条件 Climate conditions
- 温度 temperature
- 湿度 humidity

扬声器位置 Speaker position
- 垂直/水平
  vertical/horizontal
- 到麦克风的距离
  Distance to microphone

测量结果应该 Measurements results should be
- 可再生和可重复 reproducible and repeatable
- 对定义条件有效 valid for defined condition

目标: 可信赖的测试
Target: Reliable Testing



解决方法: 致力于QC的硬件
Solution: Hardware dedicated for QC

- 可靠的硬件用于在线测试
- 100 dB 信噪比
- 4 个输入模块(2 XLR 线输入+ 2 BNC 输入)可选
- 通過先置放大器控制步进1 dB，保证了最大的信噪比
- 使用ICP供电模式的麦克风、加速计和其它
- 2个扬声器连接端可保证同时测量高音和低音喇叭
- 伽伐尼式去耦电流传感器高达60 A
- 电压传感器高达300 V
- 温度和湿度传感器用来监测大气条件
- 通用的数字输入输出引脚(GPIO)

目标: 高速性能表现
Target: High Speed Measurements

物理条件限制下测量
Measurements at physical limits:

1. 没有时间进行稳态响应 No time for steady-state response
2. 稳定时间和共鸣 Settling time and ringing of resonances
3. 大信号模式下测量 Test in large signal domain
4. 具有很低的能量 Rub and buzz defects have low energy
5. 环境噪声电平很高 High ambient noise level
6. 没有时间进行后续处理 No time for post-processing

目标: 高速性能表现 Target: High Speed Performance
解决方案: 并行信号处理 Solution: Parallel Signal Processing

- 多重任务交互进行 Interlacing of multiple tasks

→ 测量过程中同时分析 Analysis during measurement

- 最小化数据产生和采集的数据包 Minimal block size in data generation and acquisition

→ 减少了延迟 Latency is reduced

- 时域分析是首选 time domain analysis is preferred

→ 最小限度的后续处理 minimal post processing

目标: 高速性能表现 Target: High Speed Performance
解决方案: 使用最佳的激励信号 Solution: Using Optimal Stimulus

激励 Stimulus	敏感参数Sensitive for	优点Advantages	缺点 Disadvantages
连续正弦扫描 Continuous sine sweep	声压级,谐波,阻抗,异音 SPL fund, Harmonics, Impedance, Rub & Buzz	快速,测量异音最佳 Fast, best for Rub & buzz	没有互调成分 no intermodulation
多音激励 Multi-tone complex	声压级,失真,阻抗.SPL fund, Distortion, Impedance	快速,测量阻抗,常规失真最佳 Fast, best for impedance, best for regular distortion	对异音不敏感 Insensitive for rub & buzz
音乐,语音,噪声 Music, Speech, noise	声压级,失真. SPL fund, Distortion	音频信号应用 audio signal applicable	对异音不敏感,很慢 Insensitive for rub & buzz, slow

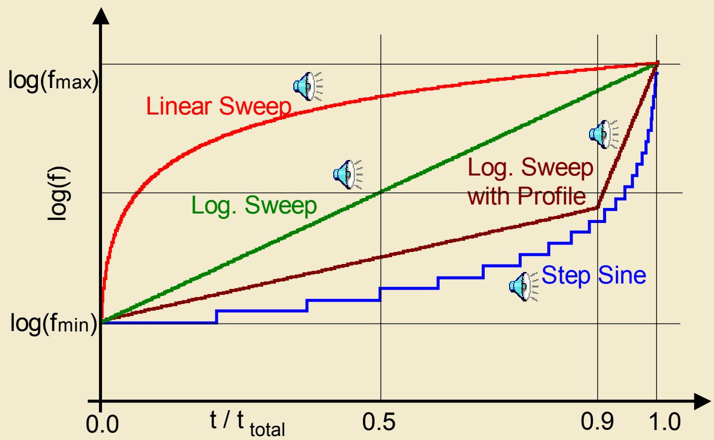
谐波失真测量
Harmonic Distortion Measurement

一次一个单音信号产生: Single tone at one time generates:
- 没有掩蔽的影响 No masking effects
- 揭示所有阶次的谐波 Reveals all order of harmonics

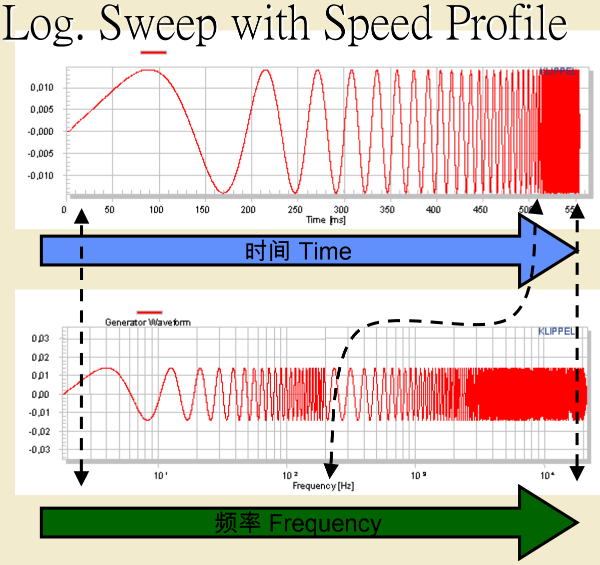
	Step Sine	Sine Sweep
Isolation from Fundamental	- FFT - Fixed Filter	- Tracking Filter - Windowed Impulse Resp.
Exciting all frequencies ?	No	Yes
Steady State	Yes	No
Duration	Long	Short

多种激励产生谐波
Various Stimuli for Harmonics

不同的时间频率映射with different Time Frequency Mapping



具有速度模式的倍频扫描仪
Log. Sweep with Speed Profile

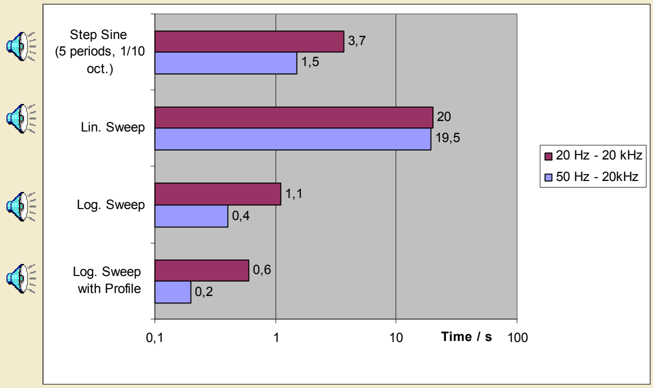


测试信号的持续时间

Duration of Test Signals

Requirements:
Fundamental: 20Hz - 20kHz
Harmonics: 20Hz - 20kHz
Rub&Buzz: 20Hz - 5kHz

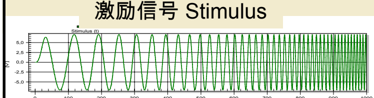
Requirements:
Fundamental: 20Hz - 20kHz
Harmonics: 50Hz - 20kHz
Rub&Buzz: 20Hz - 5kHz



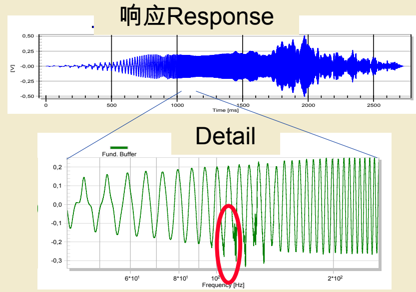
目标: 对Rub and Buzz 可靠的测量 解决方案: 所有频率都激励

Target: Reliable Testing of Rub and Buz
Solution: Excite ALL Frequencies !

激励信号 Stimulus



响应Response



缺陷 Defect

为什么使用连续扫描?

Why using continuous sweep?

- 缺陷: 高品质因数 Defects: high Q resonators
- 避免没有正确激励而错失信息 Missed, if not excited exactly

→ 不要使用低精度的步进正弦信号去激励 Do not use stepped sine excitation with low resolution

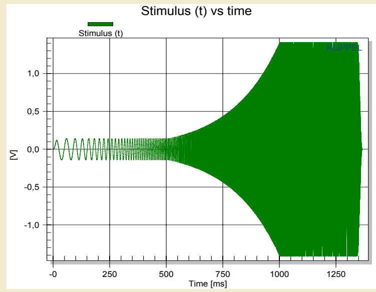
目标: 高速的表现能力

Target: High Speed Performance ?

解决方案: 使用条件幅度扫描模式

Solution: Sweep with variable amplitude profile

水平剖面 Level profile



Benefits:

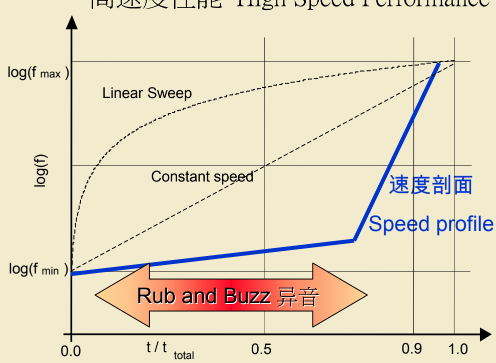
- 提供足够的能量进入临界带 Provide sufficient energy into critical bands
- 在低频处保护单体 Protect driver at low frequencies
- 在高频处保护操作者 Protect operator at high frequencies

AP Technology

使用非常短的测试信号 (<0.5s)

Using very short test signals (<0.5s)

高速度性能 High Speed Performance



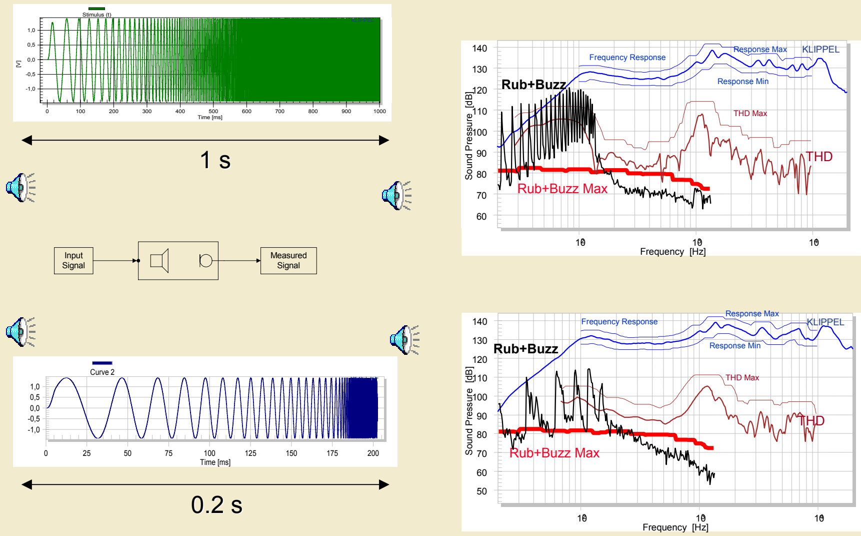
优点 Benefits:

- 节约时间 Save time
- 提供足够的能量进入临界带 Provide sufficient energy into critical bands
- 给予足够的时间来建立临界振动 Give sufficient time to establish critical vibration

AP Technology

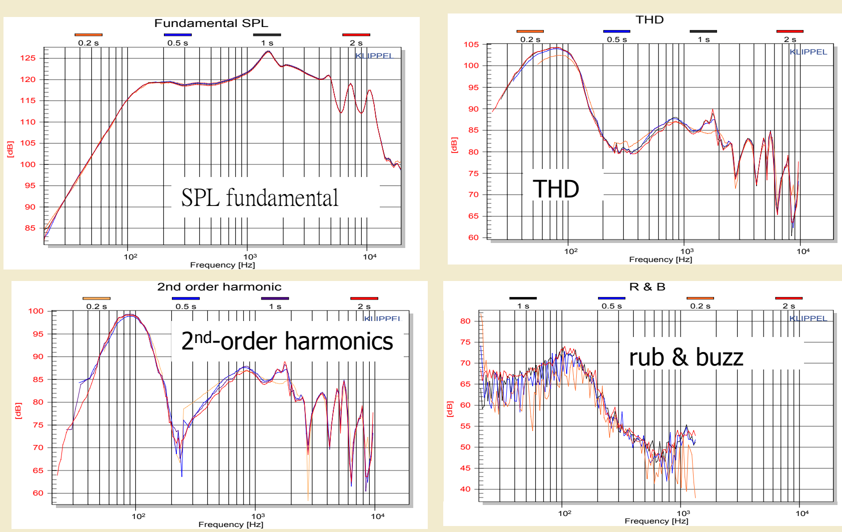
非常快速的异音测量

Ultra-fast testing of Rub & Buzz

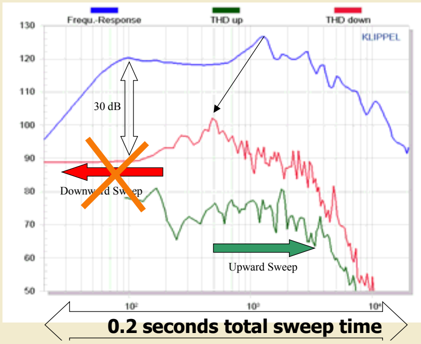


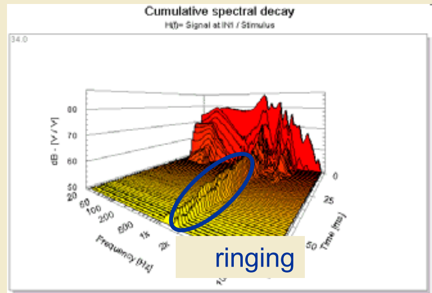
测量时间的影响 Influence of measurement time

扫描时间 2s,1s,500ms,200ms sweep time 2s, 1s, 500ms and 200ms



向上还是向下扫描 Sweeping up or down ?
异常短的测量< 0.5s Ultra short testing < 0.5 s



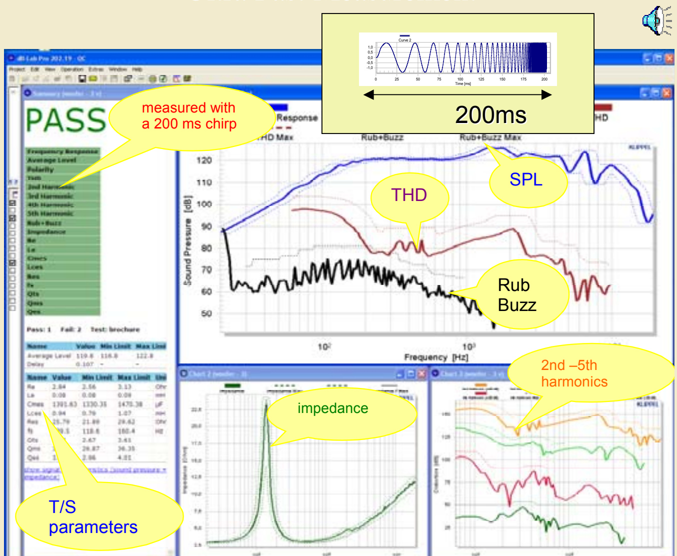


响声的问题 Problems of ringing:

- 高品质因数需要衰减时间>50 ms High Q resonances need decay time of >50ms
- 基频成分被误认为是谐波 fundamental interpreted as Harmonics

→使用向上扫描来达到非常快速的测量 Use UPWARDS SWEEP for extremely fast testing

异常快速的测量
Ultra Fast Measurement



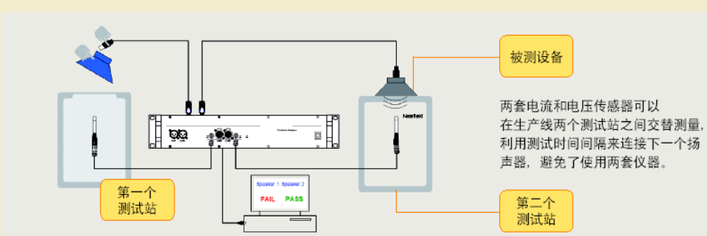
DEMO

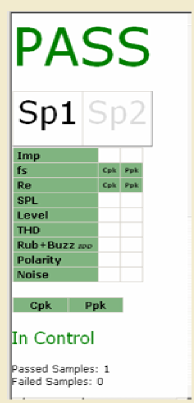
Ultra Fast Measurement

目标: 高速性能表现 Target: High Speed Performance ?
解决方案: 交互式测量 Solution: Alternating Measurement

硬件拥有支持两个被测设备的传感器

Hardware has sensors for 2 Duts





测量一个DUT的同时可以连接下一个DUT

while measuring a first DUT the next DUT can be connected

结论 Conclusion

- 特别快速的测量可以实现
  Extremely fast measurement technique can be realized

但是 but

- 扬声器并不是永恒不变的 Loudspeaker is NOT in steady-state
- 速度被摩擦共振限制了 Speed is limited by buzzing resonances

→调节扫描速度来给驱动单元足够的激励达到共振
adjust sweep speed to give sufficient excitation to resonances

目标: 灵活+简易

Target: Flexibility + Simplicity

问题: 每个制造商需要不同的QC工具

Problem: Each manufacturer wants a different QC-tool !

公司不同归因于:

Companies are different due to

- 掌握的知识 Know how
- 规定,约束 Constraints
- 不同的客户 Customers
- 使用的标准 Standards

→公司喜欢特别的测试设置

Company prefer special setups

- 测量 Measurement
- 图表曲线 Graphics
- 结果显示 Result Display

→公司开发他们自己的运算法则

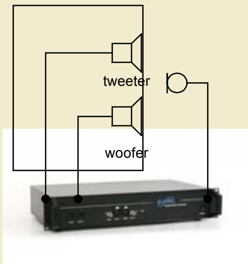
Companies develop their own algorithms

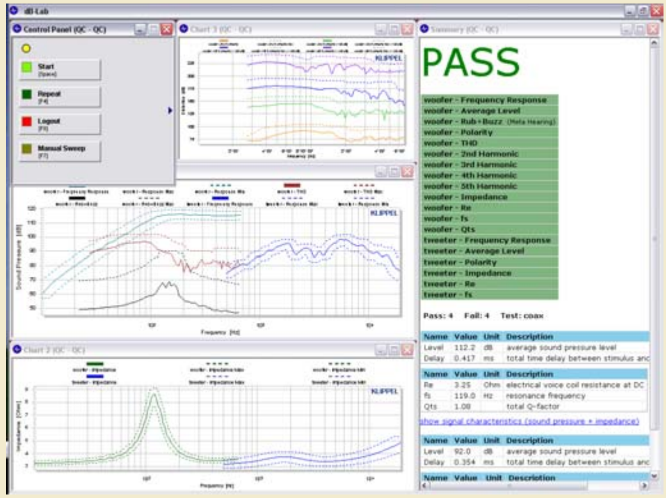
- 限制条件计算 Limit Calculation
- 黄金单元处理 Golden DUT Handling
- 报告/统计 Reports / Statistics

自主地定制但使用简单

Freedom for customization **BUT** simple to use !

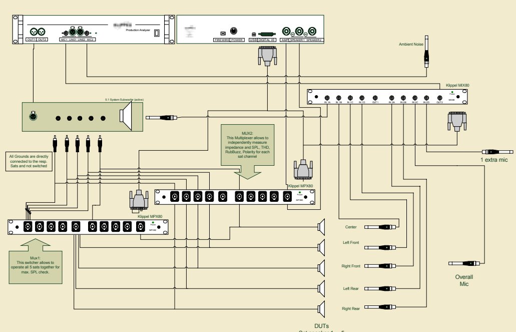
两路系统的测量
Measurement of two-way systems

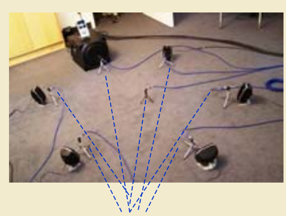




使用双扬声器通道
Using dual
Speaker channels

测量5+1系统
Measurement of 5+1 Systems





麦克风 Microphones

电压和电流多路复用器 Multiplexer for voltage and current

麦克风多路复用器 Multiplexer for microphones

KLIPPEL 分析仪(PA) KLIPPEL analyzer (PA)

目标: 灵活+简易 Target: Flexibility + Simplicity

解决方案: 使用现成的QC工具箱 Solution: Use available QC Toolbox

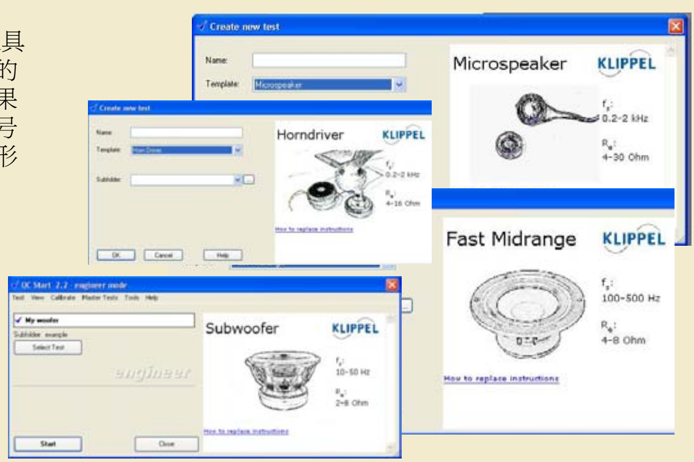
- 基于模板的测试 Template-based test
- 预置的包含最佳激励设置的任务Predefined tasks with optimal stimulus
- 基于运算法则的限制条件设置 Algorithm-based limit setting
- 自动检测黄金单元 Automatic golden unit detection
- 用数据提取工具进行统计 Statistics with Extraction Tool

对大部分测试任务不需要额外编程

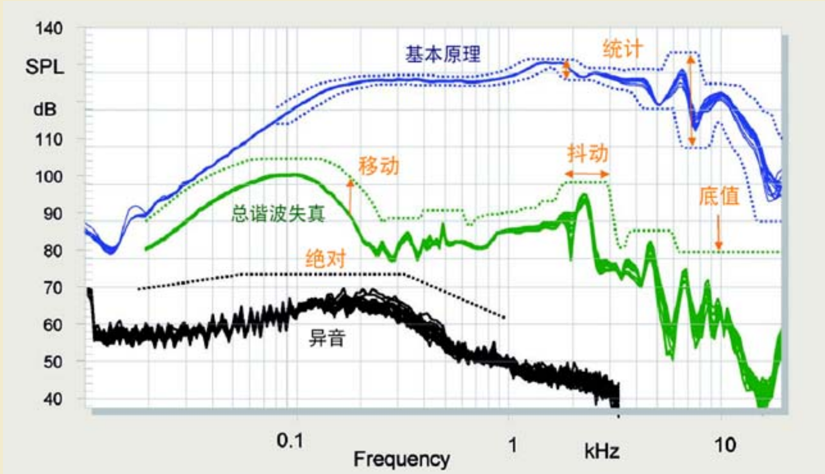
No programming required for most tasks !

预置最优的测试任务 Templates

模板管理的QC开始工具简化了对扬声器单元的测试设置和对测量结果的组织，扬声器的型号和序列号可以经由条形码阅读器获取。



智能设置限制条件 - Smart Setting of Limits



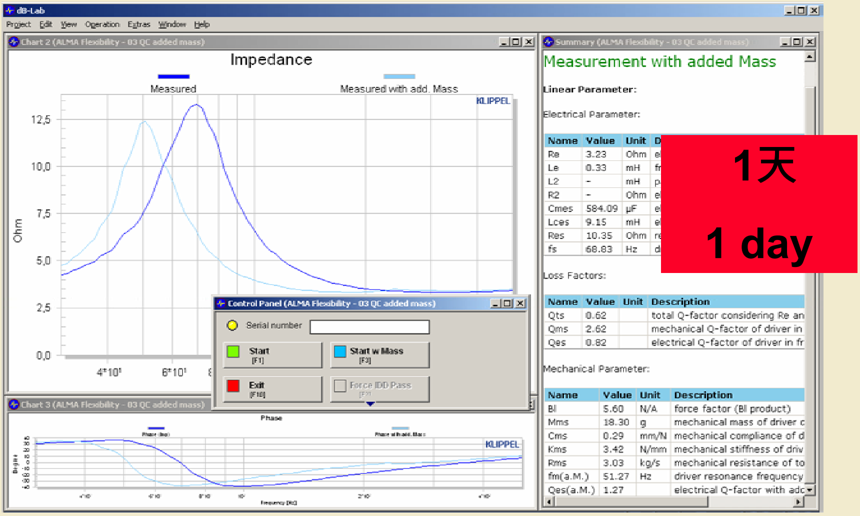
基于随机样品和统计分析计算，KLIPPEL 提供强大的手动或自动设置测试限制文件的工具。这些数据可以用来查找出所谓的"黄金参考单元"，测试参数接近平均测量值。如果测试环境温度或其他条件发生改变，测试限制条件可根据这些黄金单元数据来作校准或调节。

DEMO

Limit Calculation

实现客户特制测试程序

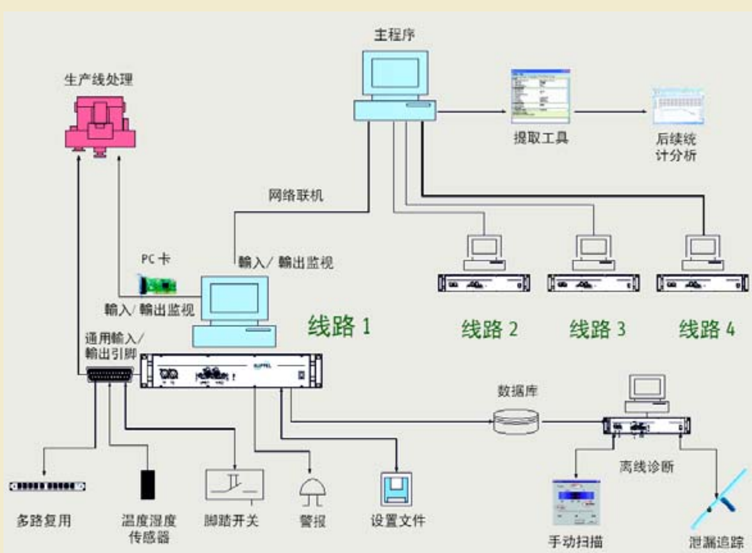
Implement specific algorithms



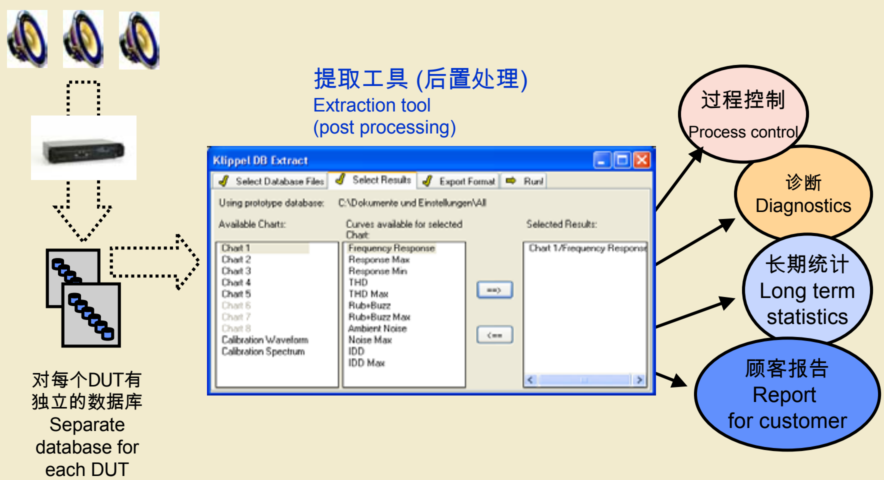
→ 密码被保护 Code can be protected

在生产过程中整合

Integration in the Production Process



目标: 灵活性 + 简易操作
Target: Flexibility + Simple Use
解决: 获取所有数据 Solution: Access to all data



概要 Summary

测试仪器优于人耳听力 An instrument is superior to the human ear

- 快速→非常快速地测试,更加全面的测量
  fast→ultra-fast testing, more comprehensive measurements
- 不会疲劳→可靠,可重复地测量
  no fatigue → reliable, reproducible results over time
- 定量地评估→ 绝对限制条件
  quantitative assessment → absolute limits
- 强有力的→ 环境噪声免疫
  robust → ambient noise immunity
- 灵敏的→ 平均,超听力技术
  sensitive → averaging, meta-hearing

人耳测试优于仪器 An human tester is superior to the instrument

- 学习能力→ 诊断,问题分析, 过程控制
  learning capabilities → diagnostics, problem analysis, process control

结论 Conclusions

操作员新的任务 New tasks for the human operator

- 根据特别的驱动单元校准测试系统 (最佳的设置)
  Adjusting the measurement system to the particular drive unit (→ optimal setup)
- 明白问题产生的根源 (扬声器诊断)
  Understanding the cause of the problem (→ loudspeaker diagnostics)
- 尽快地解决问题 (过程控制)
  Solving the problem as quick as possible (→ process control)

联系方式 Contact

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音頻技術有限公司
www.AudioAPT.com

- Download Software (free viewer) 免费數據观看软件
- Get Know-How (applications notes, papers, ...) 应用注释,论文
- Discuss Solutions (email or phone) 电邮电话联系
- Get Training (workshops) 详情请联络后方展位

非常感谢!!

Many thanks !