R&D SYSTEM USER’S GUIDE 分析仪系统用户指南

Linear Parameter Measurement

线性参数测量

By KLIPPEL GmbH

November 11，2007

Mendelssohnallee 30, 01309 Dresden, Germany

www.klippel.de

LPM – Tutorial　LPM – 指南

Overview 概述

The LPM module determines the electrical and mechanical parameters (Thiele-Small parameters) of electro-dynamical transducers. In contrast to the LSI (that identifies the large signal parameters) it focuses on the precise measurement of the small signal domain parameters.

LPM 模块测定电动式换能器的电参数和力学参数(Thiele-small 参数)。相比于 LSI (识别大信号参数)，它侧重于小信号域参数的精确测量。

What is the goal of this tutorial? 指南的目的是什么？

This tutorial makes you familiar with the LPM module.

该指南将引导您熟悉 LPM 模块。

The tutorial is divided into three parts.

指南分为三个部分。

1. In the first *Viewing LPM Results* we will show you how to view LPM results already stored in the example database.
   在第一部分 *Viewing LPM Results (查看 LPM 结果)*中，我们将会给您展示，怎样查看已保存在例样数据库中的 LPM 结果。

2. The next part of the tutorial *Performing a new LPM* provides a step-by-step recipe to measure the electrical and mechanical driver parameters.
   指南的第二部分 *Performing a new LPM (执行一个新的 LPM)* 给出了测量扬声器单体电学和力学参数的详细步骤。

3. In the final section *Customizing LPM* we discuss modifications of the setup parameters to use more powerful features and improve the performance of the measurement.

   在最后一部分 *Customizing LPM (定制 LPM)*中，我们将会讨论，怎样进行设置参数的修改，以至于使用更多的有用特性，并改善测量性能。

In the chapter *LPM-Reference* you will find more information on the basics of the linear model used as well as a detailed description of the result windows and the configuration of the property pages.

在章节 *LPM-Reference* 中，您可以找到有关线性模型基础使用以及结果窗口细节描述和属性页面配置的更多相关信息。

In the last section you will find information on possible problems, malfunctions and troubleshooting.

在最后的章节中，您可以找到有关可能出现的问题，故障和故障排除的相关信息。

Viewing LPM Results (part 1)

查看 LPM 结果 (部分 1)

Open the object **First Example Driver** in the folder **Example Drivers** in the **example database** (installed as default database after the first installation). Please refer to the dB-Lab manual section for navigating within or selecting databases.

在 **example database** (例样数据库) 中的文件夹 **Example Drivers** 里打开对象 **First Example Driver** (首次安装后作为默认数据库) 。请参阅 dB-Lab 手册中有关使用或选择数据库的章节。

After double clicking on the operation **LPM linear parameters** the default result windows will be opened.

双击操作 **LPM linear parameters** 来打开默认结果窗口。

Table Linear Parameters

线性参数表格

The result window shows the electrical and mechanical parameters of the linear driver model, the derived parameters (resonance frequency, loss factors etc.) and the parameter of the suspension creep factor that are determined by the LPM module (if measured with laser method).

结果窗口显示了通过 LPM 模块 (如果由激光法测得) 测定的线性驱动模型的电学和力学参数，衍生参数 (如谐振频率，损耗因子等) 和悬挂系统蠕变系数参数。

The most important results are: 最重要的结果如下

R_e	Electrical voice coil resistance at DC 直流音圈电阻
L_e	Frequency independent part of the voice coil inductance 独立频率部分的音圈电感
f_s	Driver resonance frequency 扬声器单体的谐振频率
M_{ms}	Mechanical mass of driver diaphragm assembly including air load and voice coil 扬声器单体膜片包括振动空气质量和音圈的力学质量
Bl	Effective force factor (Bl product) 有效力因数 (Bl 乘积)

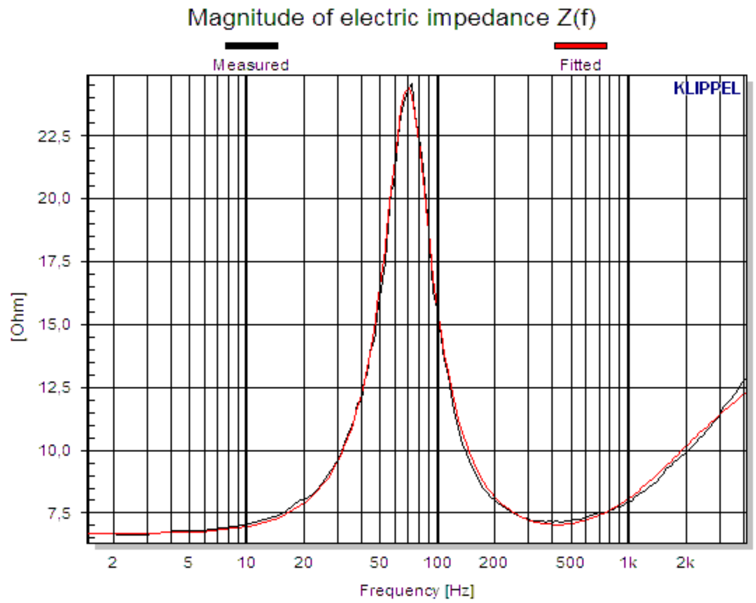
Impedance Magnitude

阻抗幅值

The result window shows the magnitude of the measured and estimated impedance $Z(f)=U(f)/I(f)$ where $U(f)$ is the terminal voltage and $I(f)$ is the current. The **measured** curve is the ratio of the measured spectra $U(f), I(f)$ while the **fitted** curve is the impedance calculated with the linear driver model using the identified parameters shown above. You can clearly detect the resonance and the increase of impedance at higher frequencies due to the voice coil inductance.

结果窗口显示了实测的和估算的阻抗 $Z(f)=U(f)/I(f)$ 的幅值，$U(f)$ 为端电压，$I(f)$ 为电流。实测曲线是实测频谱 $U(f), I(f)$间的比值，而拟合曲线是通

过以上鉴定出的参数构建的线性驱动模型计算出来的阻抗。您可以清楚地检测到，由于音圈电感导致的在高频处的谐振以及阻抗的增加。



Hx (f) Magnitude
Hx (f) 幅值

The result window shows the magnitude of the measured and estimated transfer function *Hx(f)= X(f)/U(f)* between the voice coil displacement *X(f)* and the terminal voltage *U(f)*. The **measured** curve is the ratio of the acquired spectra *X(f), U(f)* while the **fitted** curve is the transfer function based on the linear model using the identified electrical and mechanical parameters as well as the creep parameter.

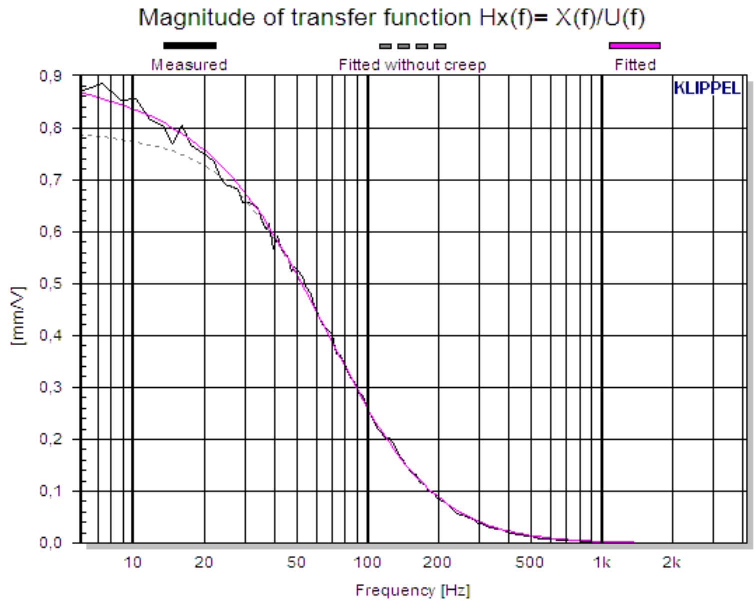
结果窗口显示了音圈位移 *X(f)*和端电压 *U(f)*之间实测的和估算的传递函数的幅值。实测的曲线是 *X(f)*和 *U(f)*频谱间的比值，拟合曲线是基于使用识别的电学和力学参数以及蠕变参数的线性模型上的传递函数。

The creep effect models the low frequency behavior of the suspension system of a loudspeaker. The stiffness is not constant over frequency but decreases for very low frequencies. For more information see the reference / Linear modeling of LPM.

蠕变效应模拟了扬声器悬挂系统的低频特性。劲度在频率上不是恒定的，但在低频处减少。更多信息，请参见 reference / Linear modeling of LPM。

The **dashed gray** curve is based on the conventional model without considering the creep factor.

灰色虚线是基于传统模型并不考虑蠕变系数得到的。

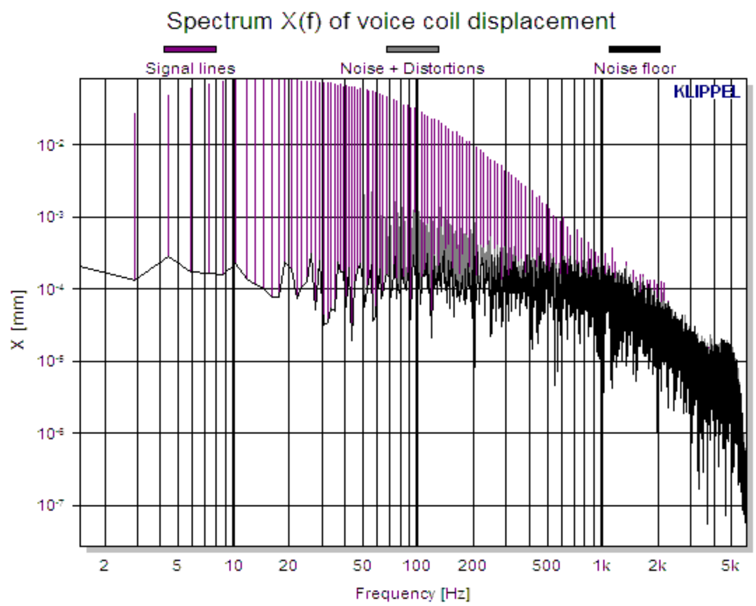


Spectra of state variables

状态变量的频谱

A multi-tone signal used for loudspeaker excitation has some advantages over conventional excitation signals such as MLS. Since we are working with a sparse spectrum we excite the speaker with a logarithmically spaced frequencies and are able to measure the distortion and noise at the unexcited frequencies in the spectrum. The spectra of the measured signals can be viewed in the result windows **Voltage (f) Spectrum**, **Current (f) Spectrum**, **X (f) Spectrum** and **p (f) Spectrum**.

用来激励扬声器的多频信号比起像 MLS 一样的传统激励信号更具有一定的优势。因为我们分析较稀少的频谱，因此通过使用带对数形式间隔的频率的激励信号来激励扬声器，并可在频谱中没被激励的频率段上测量失真和噪声。被测信号的相关频谱可在结果窗口 **Voltage (f) Spectrum**, **Current (f) Spectrum**, **X (f) Spectrum** 和 **p (f) Spectrum** 中查看到。



Measured waveforms 实测波形

The terminal voltage, terminal current, voice coil displacement (laser sensor) and sound pressure (microphone) waveforms can be viewed in the result windows **Voltage (t)**, **Current (t)**, **X (t)** and **p (t)**. These are not open by default. Please open the result windows by checking the corresponding box in the result window.

端电压，端电流，音圈位移(激光传感器) 和声压 (麦克风) 的波形都可在结果窗口 **Voltage (t)**, **Current (t)**, **X (t)** 和 **p (t)** 中查看。这些窗口没有设置为默认开启。请在结果窗口(result window) 中通过查看相应的工具箱来开启所需的结果窗口。

Performing a new LPM (part 2) 执行一个新的 LPM (部分 2)

In the second part of the tutorial a step-by-step recipe is provided to measure the electrical and mechanical driver parameters. We assume that the following standard hardware configuration is available:

- Distortion Analyzer (Power Monitor 8 Hardware does not support LPM Measurements)
- Laser displacement sensor
- Driver mounted in laser stand
- Power Amplifier

指南的第 2 部分提供了测量电学和力学扬声器参数的分步介绍。假定以下标准硬件配置可用:

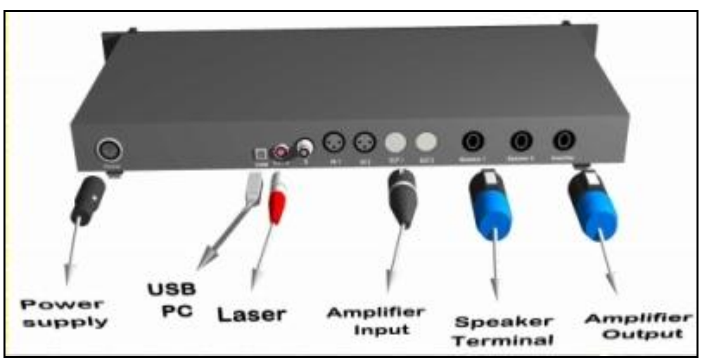
- 失真分析仪 (硬件 Power Monitor 8 不支持 LPM 测量)
- 激光位移传感器
- 扬声器单体固定在有激光头的支架上
- 功放

If you have not got a laser sensor you may consult the third part of the tutorial. The section **working without laser** will give you detailed description.

如果您没有激光传感器，请查询指南的第 3 部分。**working without laser** 将给出相关的细节描述。

Setting up the Hardware

设置硬件



Note: Relevant connectors are at the back side of the device (except USB).

注: 相关的接头都在设备的背面 (USB 除外)。

1. Connect the Distortion Analyzer with the power supply delivered by Klippel.
   将失真分析仪与 Klippel 自带的电源连接起来。

2. Connect OUTPUT 1 (XLR, symmetric signal) to the input of your power amplifier. This cable is not distributed by Klippel since there are to many Amplifier input connectors available on the market. Please use you own specific cable. You find more information on requirements for the amplifier and connections in the chapter *Hardware* within this manual.

   连接 OUTPUT1(XLR, 对称信号) 到您的功放输入端。这跟线不由 Klippel 配备，因为市场上有太多可用的功放输入接头。请使用您自己的专有接线。在本指南章节 *Hardware* 中，您可以按要求查看到更多有关功放和连接的相关信息。

3. Connect the Amplifier output to the Speakon connector AMPLIFIER of the Distortion Analyzer.

   连接功放输出端至失真分析仪的 Speakon 接头 AMPLIFIER。

4. Mount the driver in the driver stand or in a baffle.

   将扬声器单体安装在立架或挡板上。

5. Connect the Speakon connector SPEAKER to the terminals of the driver or loudspeaker using the SPEAKER cable (having a Speakon at one end, and clips at the other) coming with the system. If you have a hardware version 1.2 or higher, the second speaker channel is equipped with a high sensitive current sensor by default. Older versions may be modified on request. In this case, prefer **Speaker 2** channel for all small signal measurements, where the maximal current (peak) is below 5A.

   用系统自带的 SPEAKER 线，连接 Speakon 接头 SPEAKER 至扬声器单体或音箱端口 (一端带 Speakon，另一端带夹钳)。如果您使用的是硬件版本 1.2 或更高级别版本，第 2 个扬声器通道默认与一高灵敏的电流传感器配备在一起。旧版本可根据要求进行改进。这种情况下，对所有小信号测量尽可能使用通道 **Speaker 2**，此处的最大电流值(峰值)小于 5A。

6. A Laser Displacement Sensor can be connected to the LASER input to enable the identification of the mechanical parameters.

   激光位移传感器可连接到 LASER 输入端，以实现力学参数的鉴定。

7. Connect the Analyzer via USB to a Computer .

   通过 USB 线连接分析仪至计算机。

Note: Make a dot with white ink (correction fluid) on the diaphragm and adjust the laser to this point. Alternatively to the ink you can use white adhesive tape that can be removed easily after the measurement. See also section *Using the Laser Sensor* in chapter *Hardware* of the manual for more information.

注: 用白色墨水(涂改液) 在膜片上标记出一个点，并调整激光位置到该点。您也可以使用白色胶带替代墨水，这样在测量完成后，可以轻易得将胶带去除。更多信息，请参见章节 *Hardware* / *Using the Laser Sensor*。

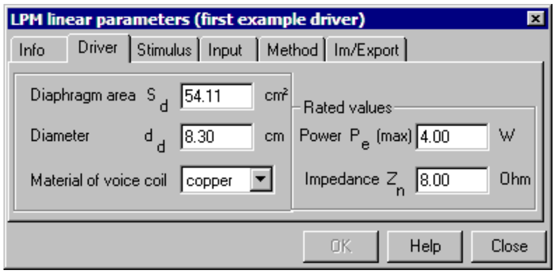
Select setup parameters

选择设置参数

1. Create a new operation and / or object for your own measurements. You should not overwrite the examples in the example database. You find more information in the dB-Lab section of the manual.

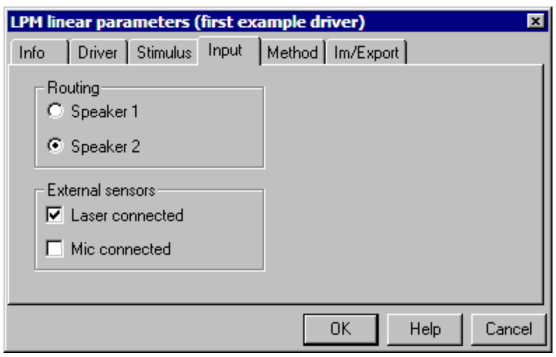
对于您自己的测量，创建一个新的操作和/ 或对象。您不必覆盖在例样数据库中的例子。手册 dB-Lab 将给出更多相关信息。

2. Select the LPM measurement and open the Property Page **Driver**
选择 LPM 测量，并打开属性页 **Driver**。

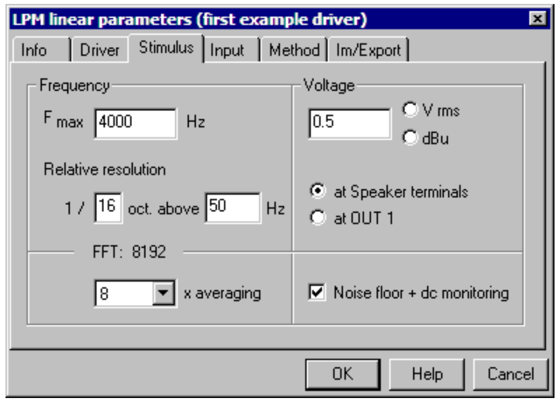


3. Enter the driver diaphragm area S_d and the nominal impedance Z_n. You find how to measure diaphragm in *dB-Lab Reference / Property Pages.*
输入扬声器单体膜片面积 S_d 和额定阻抗 Z_n。您可在章节 *dB-Lab Reference / Property Pages* 中找到如何测量膜片的相关信息。

4. Open the Property Page **Input** and specify the connected external devices as well as the used speaker channel. Using the Laser the measurement identifies all of the linear parameters in one step. It is also possible to connect a microphone to measure SPL in the near field.
打开属性页 **Input**，指定需连接的外部设备以及需用的扬声器通道。若使用激光，测量只需一步就可鉴定所有的线性参数。同样也可在近场处连接麦克风来测量声压级(SPL)。



5. Open Property Page **Stimulus** shown below
打开属性页 **Stimulus**，如下图所示。



Specify F_{max} (upper bound of frequency range), relative resolution, reference frequency and voltage of the excitation signal. The specified voltage is either referred to the speaker terminals (**at Speaker terminals**) or to the amplifier input (**at OUT 1**). Select **at Speaker terminals.** In this case the amplifier gain is measured prior to the parameter measurement and the excitation signal is adjusted to the measured gain. Deselect **Noise floor monitoring**.

指定 F_{max} (频率范围上限)，相对解析度，参照频率和激励信号的电压。指定的电压，要么就参照扬声器端口(**at Speaker terminals**)，要么就参照功放输入端(**at OUT 1**)。选择 **at Speaker terminals**，这种情况下，功放增益将在参数测量前进行测量，并要求针对实测增益调整激励信号。取消选择 **Noise floor monitoring**。

Note: Make sure that the chosen voltage will not destroy the driver. Performing identifications of the linear parameters at higher amplitudes will cause additional parameter variations since the linear model is no longer adequate for the large signal domain.

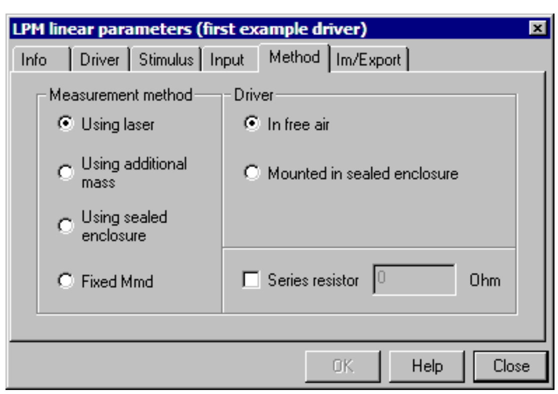
注: 确保被选电压不会损坏扬声器单体。在较高振幅处执行线性参数识别会引起额外的参数变化，因为此时线性模型已不再能够胜任对大信号域进行测量。

Select measurement method

选择测量方法

Open Property Page **Method**.

打开属性页 **Method**。



Select Using laser and In free air.
选择 Using laser (使用激光) 和 In free air (在自由场中)。

Start measurement
开始测量

1. Start measurement by pressing
   Run
   按 **Run** 键，开始测量。

   After testing the amplifier you will hear the multitone excitation. In the case that the measured signals are too low in amplitude or considerably distorted you will get one of the **warning messages** discussed in the Tutorial part 3. To optimize your measurements you should open the result table **Signal Characteristics**. In the first line you find useful hints to improve the accuracy of the measurement. Refer also to the section **Reduce noise level** in the tutorial part 3 for further help.

   测试完功放后，您将听到多频激励信号。如果被测信号在振幅处过低或很大程度上已失真，您将得到一个在指南部分 3 中讨论到的 **warning messages** (告警消息)。要优化您的测量，应打开成果表 **Signal Characteristics**。您将在第一行中找到改善测量准确性的有用提示。指南部分 3 中的 **Reduce noise level** 将提供更多帮助。

Name	Value	Unit	Comment
HINT :			Reduce Fmax to 20* fs to improve impedance fitting
U pp	9.61	V	peak to peak value of voltage at terminals
U ac	1.30	V rms	AC part of voltage signal
U head	34.6	dB	digital headroom of voltage signal
U SNR+D	48.0	dB	ratio of signal to noise+distortion in voltage signal
fu noise	1.5	Hz	frequency of noise+distortion maximum in voltage signal

2. View all result windows and tables by setting the checkboxes in the result window list. You may also define your own window arrangement and your own setting of default windows (Default windows are opend automatically if double clicked on the operation). For customizing result presentation, refer to the dB-Lab manual section.

   在结果窗口列表 (result window list) 中设定检查箱 (checkbox)，以查看所有结果窗口和成果表。您也可以自定义窗口布置和默认窗口设定 (如果双击操作，默认窗口会自动打开)。定制结果展示的相关信息，请参阅 dB-Lab 手册章节。

3. Repeat the measurement if necessary by pressing
   Run
   如有必要，按 **Run** 键，重复测量。

Ensuring accuracy
确保准确性

To become even more familiar with the LPM we <u>strongly recommend</u> to perform at least once a pair of laser based and added mass based measurements with the same driver. This test not only gives you the practical training, it also ensures that the hardware is properly calibrated and connected. By performing both methods of determining the small signal parameters you should obtain an agreement of the *Bl* and M_{ms} parameter of at least 5%. By optimizing the measurement a typical deviation of 2-3% is standard and should be aimed. Please find detailed information on performing and optimizing these measurements in the tutorial part 3.

要想更熟悉 LPM，我们强烈建议您对同一扬声器单体进行至少一组基于激光和基于附加质量的测量。该测试不仅仅是提供了实际练习，它同时也确保了硬件已正确地校准和连接。通过执行测定小信号参数的两个方法所得的 *Bl* 和 M_{ms} 值之间的不一致性应小于 5%。通过优化测量，2-3%的典型偏差被规范出，并作为目标。指南第 3 部分将提供有关执行和优化这些测量的细节信息。

Furthermore we recommend to use a reference driver. This is the quickest way to check the proper operation of the LPM. You keep one driver that you are familiar with in the shelf. To check the LPM you measure the parameters of this driver and compare them with the known ones.

此外，我们还建议使用一参照扬声器单体，这是检查 LPM 正确操作最快捷的途径。选择一个您熟知的扬声器单体。要检查 LPM，请测量现有扬声器单体的参数并与你熟知的扬声器单体参数进行比较。

The calibration and the proper operation of the hardware can be checked easily with a reference driver. We strongly recommend to keep one driver as reference in the shelf and to measure its parameters once in a while. Any deviation of the parameters indicates a hardware or calibration problem.

使用一参照扬声器单体可以方便地检查硬件的校准和其正确的操作。我们强烈建议保留一扬声器单体作为参照单元，并测量其参数。任何参数的偏差都会引起硬件或校准方面的问题。

Customizing LPM (part 3) 定制 LPM (部分 3)

In this part of the tutorial we discuss modifications of the setup parameters to use more powerful features and improve the performance of the measurement.

我们将在指南的这一部分中讨论如何修改设置参数，以使用更多强大的特性和改善测试的性能。

Physical Limitations 物理限制

Influence of measurement conditions

测量条件的影响

The most important results of the linear parameter measurement are the moving mass M_{ms}, the force factor Bl and the DC voice coil resistance R_e. These parameters are almost independent on the amplitude of the excitation signal.

线性参数测量最重要的结果有，振动质量 M_{ms}，力因数 Bl 和直流音圈电阻 R_e。这些参数几乎都独立于激励信号的振幅。

The properties of the suspension depend on many factors (excitation level, time, ambient temperature, humidity). The compliance C_{ms} and all derived parameters such as the resonance frequency f_s and the loss factors Q_{ts} and Q_{es} vary even in the small signal domain. C_{ms} and f_s may easily vary by 10-20% with (small signal) excitation level [1]. Furthermore C_{ms} and f_s can change by 50 % (!) if the temperature is increased from normal ambient temperature to 40 °C [2]. However, the parameters R_e, Bl and M_{ms} should not vary with measurement conditions.

悬挂系统的特性取决于很多因素 (如激励级，时间，环境温度，环境湿度)。顺性 C_{ms} 和所有衍生参数，如谐振频率 f_s 和损耗系数 Q_{ts} 和 Q_{es} 甚至可在小信号域内变化[1]。C_{ms} 和 f_s 可随 (小信号) 激励级轻易地变化 10-20%。甚至 C_{ms} 和 f_s 可以改变多达 50 % (!)，如果温度由室温升高到 40 °C [2]。然而，参数 R_e, Bl 和 M_{ms} 不应随测量条件而发生改变。

Adequate Modeling

充分的建模

The measurement of the linear parameters fails if the model is not adequate for the particular driver. For example additional electrical components, mechanical sub-resonance and acoustical guides may cause substantial deviations between the measured and expected behavior.

如果模型对特定的扬声器单体不合用，线性参数测量将失败。例如，额外的电器元件，力的次谐振和声导都可能引起实测和预期特性之间的重大偏差。

The creep of the suspension can only be measured by a mechanical sensor. This effect may cause substantial errors in the traditional two-step measurements using an additional mass or test enclosure. Both perturbation methods assume that the stiffness is independent on frequency. However, some drivers "forget" 50% stiffness at frequencies one decade below f_s.

悬挂系统的蠕变只能由力学传感器测得。该影响可能在使用附加质量或测试箱体的传统 2 步骤测量中引起重大误差。两个摄动法假定，刚性独立于频率。然而，一些扬声器单体"忘记"了，在低于谐振频率 1 个倍频程处，刚性减少 50%。

Reference 参考文献:

[1] Klippel, W. and Seidel, U. *Fast and accurate measurement of linear transducer parameters.* Presented at the 110th Convention of the Audio Engineering Society, Amsterdam, Mai 2001

[2] Hutt, S. *Ambient temperatures influences on OEM automotive loudspeakers.* Presented at the 112th Convention of the Audio Engineering Society, Munich, Mai 2002, preprint 5507

How to get the best Performance ?

如何获得最好的性能？

In this section a step by step procedure is outlined that maximizes the accuracy of the results. Factors that deteriorate the performance are identified and suggestions are made for improvements.

这一节中的分步介绍描述了如何使结果准确性最大化，识别恶化性能的因素，并制定改进建议。

Precise Calibration

精确校准

High accuracy of the results requires that the sensors for voltage, current and displacement (if a laser is used) are calibrated carefully. The current and voltage sensors are already factory calibrated and may be checked with a *Hardware Check module* which is included in the *Service package*.

测量结果的高准确性要求非常小心得校准电压传感器，电流传感器和位移传感器 (如果使用激光)。电流传感器和电压传感器已进行过工厂校准，且可通过使用 *Service package* 里的 *Hardware Check module* 进行检查。

The calibration of the laser head should be checked more frequently but in any case if the head is changed or replaced (see *Using Laser Sensor* and *Laser Calibration Check* in the *Hardware* manual). Any laser calibration error will deteriorate the accuracy of the mechanical parameters. For instance a 3 % calibration error causes an error of 3 % for *Bl* and 6 % for *Mms*!

应频繁地检查激光头的校准，但在任何情况下，一旦改变或更换激光头，请进行校准检查(参见手册 *Hardware*/*Using Laser Sensor* 和 *Hardware*/*Laser Calibration Check*)。任何激光校准误差都会恶化力学参数的准确性。比如，一个 3%的校准误差会导致 Bl 产生 3 %，Mms 产生 6 %的误差。

Amplifier

功放

Do not use DC-coupled amplifiers. Neither use amplifiers with a very steep low frequency roll-off (roll-off > 40 dB at 1Hz) . The DC voice coil resistance *Re* is measured at the two lowest frequency lines (about 0.5 Hz –2 Hz). In case of a steep roll-off the signal to noise ratio will be insufficient for this measurement. Note, that the LPM can measure and compensate (to a certain degree) the roll-off.

不要使用直流耦合的功放，也不要使用带急剧低频滚降的功放(在 1 赫兹处，频率响应下降(滚降) > 40 dB)。直流音圈电阻将在两个最低频率线处测得 (大约 0.5 Hz –2 Hz)。当存在急剧滚降的时候，测量得不到足够的信噪比。注意，LPM 可测量并补偿(到一定程度) 滚降。

Check hardware with reference driver

通过参照扬声器单体检查硬件

The calibration and the proper operation of the hardware can be checked easily with a reference driver. We strongly recommend to keep one driver as reference in the shelf and to measure its parameters once in a while. Any deviation of the parameters indicates a hardware or calibration problem. Please keep the remarks made in section *Physical Limitation* (see above) in mind.

硬件的校准和正确操作可轻易地通过使用一参照扬声器单元来进行检查。我们强烈建议保留一扬声器单体作为参照单元，并测量其相应参数。任何参数的偏差都会引起硬件问题或校准问题。请牢记 *Physical Limitation* (见上) 中的备注。

Adjust laser

调整激光

Adjust the distance between the laser head and the diaphragm carefully. The adjustment is described in section *Using Laser Sensor* in the *Hardware* manual. Please refer for basic considerations on using and installing the laser to this chapter.

请小心地调整激光头和膜片之间的距离。调整说明，请参见 *Hardware*/*Using Laser Sensor*。请参阅章节中有关激光使用及安装的基本考虑。

Make sure that the rest position of the diaphragm is in the middle of the lasers working range. Move the diaphragm slightly with your fingers and check that the working range is not left.

确保膜片的静止位置在激光工作范围的中间位置。用手指轻微地移动膜片，并检查其有没有离开激光工作范围。

To increase reflection make a **white dot** (white correction fluid or adhesive tape) on the diaphragm and adjust the laser to this point. The white dot increases the signal to noise ratio of the laser signal considerably; never measure without it ! Make sure that the laser is pointed to an approximate perpendicular surface (e.g. center of dust cap or joint). The target may be up to 20° out of perpendicular position without degrading the performance significantly.

在膜片上标记一白点 (用白色涂改液或胶带) 以增加反射，并将激光调整到该点位置。白点显著地增加了激光信号的信噪比; 永远不要在没有白点的情况下进行测量! 确保激光指向一近似垂直的表面 (例如，防尘帽的中心或接头处)。在不显著降低性能的情况下，目标可偏离垂直位置最多达 20°处。

Check mounting of the driver

检查扬声器单体的安装

Check that the driver is tightly mounted in the laser stand. If the driver is improperly mounted it will vibrate or even change position. Both will falsify the laser measurement. Make sure that no cable, etc. touches the driver or the laser head. It might vibrate slightly during the test and disturb the laser signal.

检查扬声器单体是否已牢固地安装在激光立架上。如果扬声器单体安装得不合适，它将会振动，甚至改变位置。这两种情况都会歪曲激光测量。确保没有接线等物体触碰到扬声器单体或激光头，它可能会在测试中轻微地振动，并干扰激光信号。

Use "at Speaker terminals"
使用 "at Speaker terminals"

Select **Voltage: at Speaker terminals** in property page STIMULUS. In this mode the amplifier low frequency roll-off is measured and compensated (by increasing the excitation level for the attenuated lines). Without roll-off compensation the measurement of the voice coil resistance R_e may be corrupted due to poor SNR. This will deteriorate the accuracy the other small signal parameters as well.

在属性页 STIMULUS 中选择 **Voltage: at Speaker terminals**。在该模式下，可测量并补偿功放低频滚降 (通过对衰减频谱线增加激励级)。在不带滚降补偿的情况下，由于过小的信噪比，音圈电阻 R_e 的测量可能会中断。这将恶化测量准确性及其它小信号参数。

Use speaker channel 2
使用扬声器通道 2

Starting with hardware version 1.2 the second speaker channel is equipped with a high sensitivity current sensor. Older versions may be modified on request. If available use the high sensitivity sensor for all linear parameter measurements. The speaker channel is selected in property page INPUT.

从硬件版本 1.2 开始，第 2 个扬声器通道配备了高灵敏度电流传感器。旧版本可根据要求进行修改。如果可行，使用高灵敏度传感器进行所有线性参数测量。在属性页 INPUT 中选择扬声器通道。

Adjust frequency range
调整频率范围

Adjust the spectral resolution in property page STIMULUS to your particular driver. A spectral resolution of at least 16 lines (better 24) per octave is required at the resonance f_s. Providing higher resolution at frequencies below the resonance f_s won't result in any additional benefit because the increased displacement will activate more distortion. The bandwidth F_{max} of the excitation signal should be about $20 \cdot f_s$. This will shift the impedance resonance peak to the middle of the logarithmic frequency range which is optimal for curve fitting.

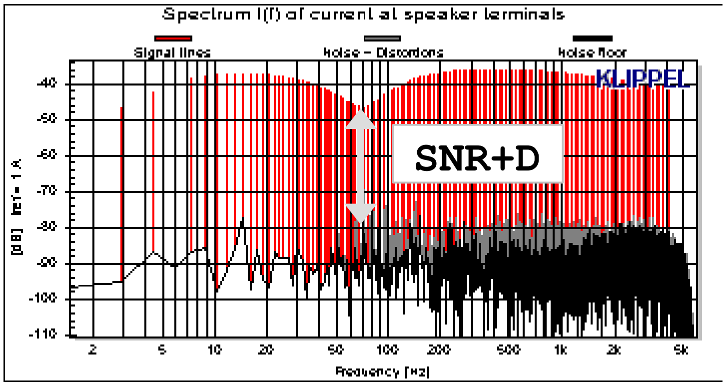
根据您的具体的扬声器单体，在属性页 STIMULUS 中调整频谱分辨率。在谐振频率 f_s 处，要求每个倍频程至少 16 根 (24 根更好) 频率线的频谱分辨率。在低于谐振频率 f_s 的频率段上提供更高的分辨率不会带来任何额外的好处，因为增加的位移会激励更多的失真。激励信号的带宽 F_{max} 应为 $20 \cdot f_s$，这将谐振峰值移动至对数频率范围的中间位置，使得曲线拟合达到最优。

Adjust excitation level
调整激励级

The excitation voltage needs to be adjusted carefully. Select **Noise floor monitoring** in property page STIMULUS. This will invoke an additional (zero stimulus) noise floor measurement before the main measurement.

激励电压需很小心地进行调整。在属性页 STIMULUS 中选择 **Noise floor monitoring**，这将在主测量前，调用附加的(激励为零) 本底噪声测量。

The main measurement uses a multi-tone stimulus. Only some few (logarithmically spaced) frequency lines are excited. The output signal of a purely linear system will show only those lines. In case of a nonlinear system (like a driver operated in the large signal domain) additional lines (distortion) are present in the output signal. In the result window **Current(f) Spectrum**



Current spectrum with noise floor and distortion lines
电流频谱带本底噪声和失真频率线

the exited lines are plotted red. As the excitation voltage is almost constant over frequency (voltage driven measurement) the shape formed by the red lines is the inverse of the impedance curve. The additional distortion lines are plotted gray while the noise floor spectrum is depicted as black line. This is very important for adjusting the excitation level. If the level is too high the distortion lines exceed the noise floor indicating that the driver is not longer operated in the small signal domain. Very low excitation levels lead to a poor signal to noise ratio.

主测量使用多频激励信号。只有少量频率线(对数间隔的)被激励。纯线性系统的输出信号将只显示这些被激励的频率线。若是非线性系统 (像作用在大信号域的扬声器单体)，在输出信号中会表现额外的频率线(失真)。在结果窗口 **Current(f) Spectrum** 中， 激励的频率线图示为红色。因为激励电压在频率上趋近恒定(电压驱动的测量)，因此由红线构成的波形是逆的阻抗曲线。额外的失真频率线图示为灰色，本底噪声频谱以黑线描绘出。这对调整激励级是非常重要的。如果激励级过高，失真频线将超过本底噪声频线，这导致扬声器单体不再在小信号域内运作。过低的激励级引起过小的信噪比。

Therefore the ratio

$$SNR + D = \frac{Signal}{Distortion + Noise}$$

needs to be maximized for optimal results. Start with a small excitation voltage, say 0.3 V. After the measurement has finished check the result window **Current(f) Spectrum**. The signal lines should exceed the noise floor and the distortion by <u>at least 20 dB</u>. If not, you have probably noticed a warning, saying that the current signal is not properly conditioned. The minimal distance **I SNR+D** between signal and noise + distortion lines is given numerically in **Table Signal Characteristics**. Normally it occurs around the resonance frequency (70 Hz in the above figure) due to the resonance notch formed by the signal lines.

因此比值

$$SNR + D = \frac{Signal}{Distortion + Noise}$$

需最大化，以得到最优的结果。随着小的激励电压 0.3 V 开始进行测量。测量结束后，查看结果窗口 **Current(f) Spectrum**。信号频率线应超过本底噪声和失真频线至少 20 dB，如果没有，您可能已经注意到一条警告信息，告知该电流信号是不适合的条件。在 **Table Signal Characteristics** 中，信号和噪声+失真之间频线的最小距离 **I SNR+D** 以数字形式给出，由于信号频线所形成的谐振缺口，通常，它都发生在谐振频率(上图 70Hz 处)周围。

Note: The accuracy of the electrical and mechanical parameters is directly related to the SNR+D value. The right hand table gives the required SNR+D to obtain *Bl* with a certain accuracy.

注: 电参数和力学参数的准确性直接与 SNR+D 值相关。右手边的表格给出了对得到带一定的准确性的 *Bl* 值所要求的 SNR+D 值。

SNR+D	Accuracy
20 dB	10 %
30 dB	3 %
40 dB	1 %

<u>Excitation level adjustment 激励级调整</u>

1. If no distortion lines are visible try to increase the excitation level till the distortion lines exceed the noise floor slightly.
   如果无失真频线可见，试着增加激励级，直到失真频线略微地超过本底噪声频谱。

2. In case of considerable distortion decrease the excitation level till the distortion lines exceed the noise floor slightly. Don’t be afraid of very small levels. Levels as small as 0.025 V (combined with a high number of averaging) are an optimal choice for some drivers.
   若失真过于明显，减少激励级，直到失真频线略微地超过本底噪声频谱。不要对过小的激励级感到害怕，对于一些扬声器单体来说，激励级小到 0.025 V(与大数目的 averaging 相结合) 是其最佳选择。

3. If SNR+D is still poor increase the number of averaging. This will reduce the noise floor. Note, that the distortion will <u>not</u> be decreased by more averaging. Adjust the excitation level again till the distortion exceed the noise floor slightly.
   如果 SNR+D 值依然很小，增加 averaging 数目，这会减少本底噪声。注意，失真将不会因更多的 averaging 数目而减小。再次调整激励级，直到失真略微地超过本底噪声。

4. If steps 1-3 lead to no improvement check the result window **Current(f) Spectrum** for humming components (caused by ground loops). You may also check **fi noise** (frequency of the minimal SNR+D) in **Table Signal Characteristics**. In case of ground loops check your setup carefully.

如果步骤 1 到 3 对测量都没有改善，对于嗡嗡声成分(由地线环路引起)，检查结果窗口 **Current(f) Spectrum**。您同样可检查 **Table Signal Characteristics** 中的 **fi noise** (最小 SNR+D 值处频率)。如果是由于地线环路引起的问题，请仔细检查您的设置。

5. The above procedure may fail to increase SNR+D above 20 dB if the current spectrum shows a very deep decay (notch) at resonance frequency. This is normally the case if the driver has a high Q_{ms}/Q_{es} ratio. The decay can be flattened considerably if a resistor of 10-20 Ohm is connected in series to the driver. Proceed as described in section *Use a series resistor to increase signal to noise ratio* in part 3 of the Tutorial. Please follow the outlined procedure <u>exactly</u> to ensure maximal accuracy of the results.

   如果电流频谱在谐振频率处显示一非常深的衰减(缺口)，上述步骤所提到的增加 SNR+D 值到 20dB 以上可能会失败。如果扬声器单体具有高 Q_{ms}/Q_{es} 比值，这是一通常发生的情况。如果将一阻值为 10-20 Ohm 的电阻器与扬声器单体串联，可以很大程度地抚平该衰减。更进一步的描述，请参见手册部分 3，*Use a series resistor to increase signal to noise ratio*。请跟随所描述的程序准确地确保测量结果的最大准确性。

   Use the series resistor only if steps 1-3 definitely fail to produce a proper SNR+D !

   只有在步骤 1-3 不能产生合适的 SNR+D 值的情况下，才使用串联电阻器！

Check laser spectrum 检查激光频谱

Open result window **X(f) Spectrum**. The displacement spectrum is normally quite constant below resonance frequency f_s and decreases by 12 dB/octave above f_s. Check the following:

打开结果窗口 **X(f) Spectrum**。位移频谱通常在谐振频率 f_s 以下都相当恒定，高于谐振频率 f_s，每倍频程下降 12 dB。查看以下内容:

1. Most important is the ratio

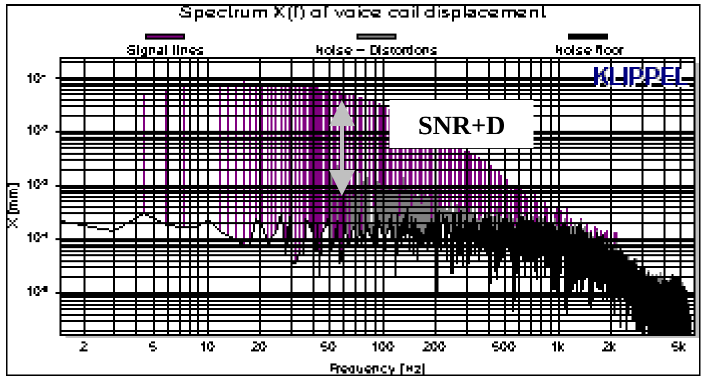
$$SNR + D = \frac{Signal}{Distortion + Noise}.$$

   As the displacement signal naturally vanishes in the noise at higher frequencies SNR+D is evaluated around and below the resonance frequency only.

   最重要的是该比值

$$SNR + D = \frac{Signal}{Distortion + Noise}$$

   因为位移信号自然地在高频处消失在噪声中，因此 SNR+D 值只在谐振频率周围或低于谐振频率范围内进行计算。



Displacement spectrum with noise floor and distortion lines
位移频谱带本底噪声和失真频率线

SNR+D of the displacement should be <u>at least 20 dB</u>. If it is too low try to increase averaging and/or the excitation level. Check the impact of the changes to the current spectrum. Readjust the excitation level if necessary.
位移的 SNR+D 值应<u>至少为 20 dB</u>。如果该值太小，试着增加 averaging 数目和/或激励级。查看此改变对电流频谱的影响。如有必要，重新调整激励级。

<u>**Note**</u>: that maximizing SNR+D for the current is more important than maximizing SNR+D for the displacement.
<u>注</u>: 电流 SNR+D 值最大化比位移 SNR+D 值最大化更重要。

2. The minimal distance **X SNR+D** between signal and noise + distortion lines is given numerically in **Table Signal Characteristics**. The calculatíon ignores signal lines with a level less than 3 dB below the maximum level of the spectrum.
   在 **Table Signal Characteristics** 中，信号和噪声+失真频线间的最小距离 **X SNR+D** 以数字形式给出。低于频谱最大级，校准将忽略小于 3dB 的信号频线。

3. Check the distortion present in the displacement spectrum. Normally there are no distortion in the displacement if there are none in the current. There might be something wrong with the laser if the displacement signal is considerably distorted while the current signal is not.
   检查位移频谱中表现出的失真。一般来说，如果电流中无失真，位移中也不会有。当电流信号无失真，而位移信号却显著失真，那么激光可能存在一定问题。

Check impedance fitting

检查阻抗拟合

1. Open result window **Impedance Magnitude**. Is the measured curve (black) smooth (not noise corrupted) ?
   打开结果窗口 **Impedance Magnitude**。实测曲线 (黑色) 是平滑的 (无噪声干扰) 吗？

2. Check the overall agreement between measured and fitted curve. Check the agreement at low frequencies (< 5 Hz). This region is most important for fitting the DC voice coil impedance *Re*. If the fitting is poor you can specify the Re value manually in property page IM/EXPORT.

检查实测曲线和拟合曲线之间的总体一致性。检查低频段 (<5Hz) 的一致性。该区域段对于拟合直流音圈阻抗 *Re* 是非常重要的。如果拟合不够，您可以在属性页 IM/EXPORT 中手动指定 Re 值。

Open **Table Linear Parameters** and check the fitting error **rmse Z**. Values between 2 % and 4 % indicate a good fitting.

打开 **Table Linear Parameters**，查看拟合误差 **rmse Z**。误差值在 2 %到 4 %之间将生成好的拟合。

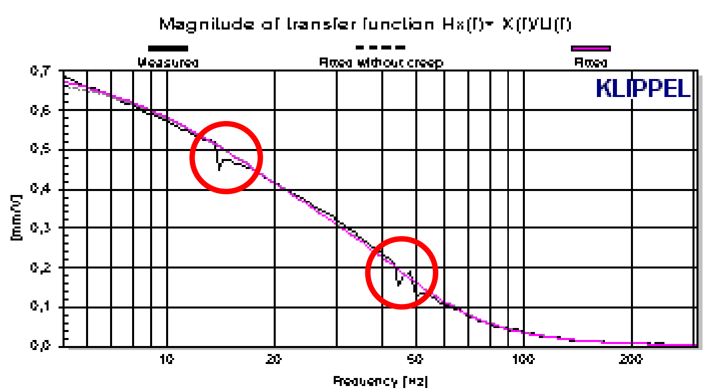
Check Hx(f) fitting

检查 Hx(f)拟合

1. Open result window **H_x(f) Magnitude**. Is the measured curve (black) smooth (not noise corrupted) ?
   打开结果窗口 **H_x(f) Magnitude**。实测曲线(黑色)是平滑的(无噪声干扰) 吗？

2. Check the agreement between measured and fitted (purple) curve. Open **Table Linear Parameters** and check the fitting error **rmse Hx**. Values between 2 % and 4 % indicate a good fitting. Check the measured curve for mechanical resonances which may be caused by the mounting of the driver (see figure below).

   检查实测曲线和拟合曲线(紫色)之间的一致性。打开窗口 **Table Linear Parameters**，查看拟合误差 **rmse Hx**。误差值在 2 % 到 4 % 之间将生成好的拟合。查看可能由扬声器单体安装引起的实测曲线上的力谐振(见下图)。



Transfer function Hx(f) with two additional mechanical resonances
带 2 个额外的力谐振的传递函数 Hx(f)

Try to damp the resonances if they are significant. Make sure that your clamping mechanism is appropriate for the drivers size. Klippel currently offers two different driver stands: a small portable stand and a bigger (more rigid) professional stand.

如果谐振过于明显，试着阻抑它们。确保您的夹紧机构适合扬声器单体尺寸。Klippel 公司目前提供 2 款不同的扬声器立架: 小型便携式立架和大型(更具有刚性)专业立架。

Select inductance model

选择电感模型

Open property page IM/EXPORT and switch between the different models in the combobox **Inductance model.** If you are free to choose the inductance model select the one that gives the lowest fitting errors **rmse Z** and **rmse Hx**.

打开属性页 IM/EXPORT，在组合框 **Inductance model** 中转换不同的模型。如果您可以自由选择电感模型，请选择使用给出最小拟合误差 **rmse Z** 和 **rmse Hx** 的模型。

Cross check with loaded mass method

带加载质量法的交叉检查

If you doubt the laser based linear parameters , perform a second measurement with the loaded mass method (see section *Working without laser | Using an additional mass* in part 3 of the Tutorial). The results for *Bl* and M_{ms} should deviate no more than 2-3% between the two methods.

如果您加倍基于线性参数上的激光，执行带加载质量法的第 2 次测量(参见指南第 3 部分，*Working without laser | Using an additional mass*)。2 种测量办法所得的 *Bl* 和 M_{ms} 值不应偏差超过 2-3%。

Speed up Measurement

加速测量

The duration of the measurement depends on a variety of factors. You may expedite your measurement significantly by considering the following things:

测量的持续时间取决于各种因素。通过考虑以下条件，您可以显著加快测量进程。

- Disable the checkbox **Noise floor monitoring** in the property page **Stimulus**.
  禁用属性页 **Stimulus** 中的检查框 **Noise floor monitoring**。

- Decrease the number of averaging in the property page **Stimulus**
  减少属性页 **Stimulus** 中的 averaging 数目。

- Disable the checkbox **Mic connected** and/or **Laser connected** in the property page **Input** if one or both sensors are not used
  如果一个或二个传感器都不使用，禁用属性页 **Input** 中的检查框 **Mic connected** 和/或 **Laser connected**。

- Open the property page **Stimulus**. Reduce the value of spectral **Relative resolution** and/or increase the reference frequency.
  打开属性页 **Stimulus**。减少频谱 **Relative resolution** 的值和/或增加参考频率。

- Decrease the upper frequency $\mathbf{F_{max}}$ of the excitation components in the property page **Stimulus**.
  在属性页 **Stimulus** 中，减少激励分量的上限频率 $\mathbf{F_{max}}$。

Reduce noise level

减少噪声级

All the sensors used for measuring sound pressure, displacement, voltage and current add noise to the measured signal. You may reduce any noise component, which is uncorrelated to the stimulus by activating the averaging in the property page **Stimulus**. We recommend to average over at least 16 measurements.

所有用于测量声压，位移，电压以及电流的传感器都会给被测信号加载噪声。您可以减少任何与在属性页中激活 averaging 的激励信号无关的噪声成分。我们建议，至少平均 16 次测量。

Importing M_{ms}, Bl, R_e

导入 M_{ms}, Bl, R_e

The fitting algorithm fits all parameters automatically to the measured impedance data by default. However, it might be desirable to define fixed values since they are measured or known by other methods. At the **Import** page fixed values for M_{ms}, *Bl* and R_e can be specified. If the user sets or modifies these values the fitting algorithm tries to fit all other parameters but the fixed ones. Please note that all parameters are refitted if one of the fixed parameters are changed.

默认设置下，拟合算法自动地拟合所有参数和实测阻抗数据。然而，定义通过其他方法测得的或已知的固定值是可取的。在页面 **Import** 中，可以指定 M_{ms}, *Bl* 和 R_e 的固定值。如果用户设定或修改这些值，拟合算法将试着拟合除固定值以外的所有其它参数。请注意，如果任何一个固定参数发生改变，所有其他参数将重新拟合。

How to set a fixed Re

怎样设定固定 Re 值

If the DC resistance is precisely known the parameter R_e can be fixed to this value at the **Import** property page. If measuring high impedance drivers this method may increase the parameter accuracy. The lowest two frequency lines are used for R_e measurement. Due to the high pass at the lower band limit of the power amplifier these lines can be noisier than the lines in the pass band.

如果精确告知直流电阻值，那么在属性页 **Import** 中可将参数 R_e 固定设为该值。如果测量高阻抗的扬声器单体，该方法可增加参数准确性。使用两跟最低频率线用进行 R_e 测量。由于在功放频段范围下限的高通，这些频率线将比在通带中更容易被噪声干扰。

Use a series resistor to increase signal to noise ratio

使用串联电阻器增加信噪比

Due to the dip in the current spectrum the signal to noise ratio sometimes decreases rapidly at the resonance frequency. This dip can be flattened considerably if a resistor of 10-20 Ohm is connected in series to the driver under test. Furthermore the shunt will decrease the overall displacement leading to a more linear operation of the driver. However care must be taken as the increased resistance $R_e + R_{Series}$ will be measured with less absolute accuracy than R_e only. This problem can be circumvented if the accurate value of R_e value is imported for the measurement with the shunt. The method described below is perfect for measuring *Bl* and M_{ms} very precisely for drivers that have a high Q_{ms}/Q_{es} ratio (causing a deep current decay at f_s). In order to use the shunt do the following:

由于电流频谱中的谷值，信噪比有时在谐振频率处急速下降。如果一阻值为 10-20 欧的电阻器与被测设备串联，该谷值可被大幅削平。此外，分流器将减少整体位移，引发扬声器单体更多的线性运作。然而必须注意的是，测量增加的电阻 $R_e + R_{Series}$ 要比只测量 R_e 具有更少的绝对准确性。该问题可以规避，如果测量中的 R_e 值的准确值是与分流器一起引进的。下面所描述的方法对于带高 Q_{ms}/Q_{es} 比值的扬声器单体的 *Bl* 和 M_{ms} 可可达到非常精确的完美测量。为了使用分流器，请进行以下步骤:

1. Adjust the setup parameters for the measurement
   对测量调整设置参数

2. Connect the Speaker cable to driver
   连接 Speaker 线到扬声器单体

3. Start measurement and wait until the result windows are updated
   开始测量，并等到所有测量窗口更新完毕

4. Open **Table Linear Parameters** and read the value of $\mathbf{R_e}$. Open property page **Im/Export** and enter the value into the edit field $\mathbf{R_e}$. Uncheck **Voice coil resistance** in order to deactivate the imported R_e for the following measurement of the shunt resistance.
   打开 **Table Linear Parameters**，读出 $\mathbf{R_e}$ 值。打开属性页 **Im/Export**，在编辑框 $\mathbf{R_e}$ 中输入该值。对分流电阻的以下测量，为了关闭引进 R_e，不检查 **Voice coil resistance**。

5. Connect the shunt to the Speaker cable (instead of the driver)
   连接分流器到 Speaker 接线(替代扬声器单体)

6. Start measurement and wait till the result windows are updated
   开始测量，并等到所有结果窗口更新完毕

7. Open **Table Linear Parameters** and read the value of **Re**
   打开 **Table Linear Parameters**，读出 **Re** 值

8. Open property page **Method**. Select **Series resistor** and enter the measured value.
   打开属性页 **Method**。选择 **Series resistor**，输入实测数值。

9. Connect the speaker cable to the series connection of the resistor and the driver.
   连接 speaker 接线到串联的电阻器和扬声器单体。

10. Restart measurement and wait till the result windows are updated. Open property page **Im/Export** and activate the imported R_e by checking **Voice coil resistance**. Now you should get most accurate *Bl* and M_{ms} results.
    重新开始测量，并等到所有结果窗口全部更新完毕。打开属性页 **Im/Export**，并通过查看 **Voice coil resistance** 激活引进的 R_e。现在您应该得到更准确的 *Bl* 和 M_{ms} 结果值。

Use an additional Microphone

使用额外的麦克风

Select **Mic connected** in property page **Input** to measure the sound pressure signal in the near or far field of the driver. Whereas the low frequency response of the driver can be measured by the laser or predicted by the model at high accuracy the microphone preferably shows the properties at higher frequencies.

在属性页 **Input** 中选择 **Mic connected**，来测量扬声器单体近场或远场处的声压信号。扬声器单体的低频响应可在高准确性下，由激光测得或由模型预测出，麦克风则能更好地显示出高频处的特性。

The microphone must always be connected to **IN1** input channel for LPM measurements. Older hardware versions than 2.0 must use an external power supply to power the microphone. Newer versions have built in ICP and phantom power supply for input channel 1 and 2.

对 LPM 测量，麦克风必须总是与输入通道 **IN1** 相连接。比 2.0 老的硬件版本须使用一外接电源供电给麦克风。对输入频道 1 和 2，新版本已在 ICP 电源和幻像电源中建立好了。

The result window **SPL** shows the measured (laser and microphone) and predicted driver sensitivity (SPL in 1m for 1W electrical input power). The microphone can be placed anywhere in the near filed. The microphone sensitivity will be detected automatically.

结果窗口 **SPL** 显示了实测的(激光和麦克风)和预计的扬声器单体灵敏度(在 1 米距离处，输入功率为 1 瓦特的声压级)。麦克风可安装在近场处的任何位置，其灵敏度将自动被侦测。

First the driver sensitivity is calculated from the displacement signal using the relationship

$$p_{laser}(t) = \frac{dx^2(t)}{dt^2}\frac{S_d \rho}{2\pi}$$

where $p_{laser}(t)$ is the sound pressure signal in 1m and ρ is the density of air. After this the microphone spectrum $P_{mic}(f)$ is scaled by a factor α to match the spectrum $P_{laser}(f)$ in the vicinity of 2 f_s, i.e.

$$P_{laser}(2f_s) = \alpha P_{mic}(f_s)$$

首先，扬声器单体灵敏度由位移信号通过下面的关系式计算得出。

$$p_{laser}(t) = \frac{dx^2(t)}{dt^2}\frac{S_d \rho}{2\pi}$$

$p_{laser}(t)$表示在 1 米距离处的声压信号，ρ 表示空气密度。之后，麦克风频谱 $P_{mic}(f)$通过因子 α 被标度，来与 2 f_s附近的频谱 $P_{laser}(f)$ 匹配。

$$P_{laser}(2f_s) = \alpha P_{mic}(f_s).$$

This leads to a 1m far field microphone signal. The factor α accounts for the microphone sensitivity and the near field - far field conversion. Finally the ratio of P_{laser}(f), P_{mic}(f) and the input power spectrum is calculated to get the driver sensitivity.

这引出了 1 米远场麦克风信号。因子 α 解释了扬声器灵敏度和近场-远场之间的转换。最后，计算 P_{laser}(f), P_{mic}(f)和输入功率频谱之间的比值，以得到扬声器单体的灵敏度。

How to measure drivers mounted in a sealed enclosure ?

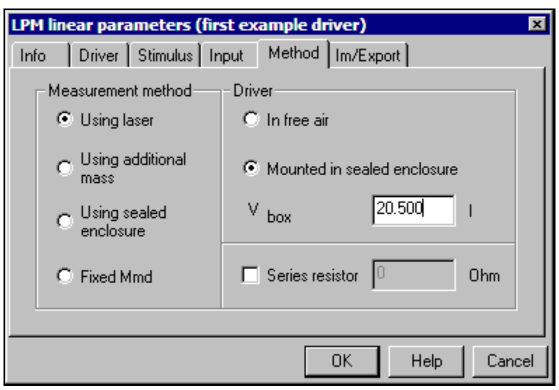
如何测量安装在密封箱体内的扬声器单体?

The electrical and mechanical parameters of drivers that are mounted in a sealed enclosure of known volume can be measured with the laser. This is useful if you don't want to remove the driver from the enclosure for the measurement. Due to the stiffness of air enclosed by the box the overall stiffness and the resonance frequency increase. As the force factor *Bl* can still be determined correctly with the laser the deviation of the parameters caused by the enclosure can be calculated and compensated if the volume of the enclosure is known. To use this feature follow these steps:

安装在已知体积的密封箱体内的扬声器单体的电参数和力学参数，可通过激光测得。如果您不想为了测量从箱体内移出扬声器单体的话，这个方法是非常有效的。由于被箱体包围的空气的劲度，整体劲度和谐振频率增加。因为力因数 *Bl* 依然可以正确地通过激光测定，因此如果箱体体积已知，那么由箱体引起的参数偏差可计算和补偿。使用该特性，请跟随下列步骤:

1. Open property page **Method** and select **Using laser** in group **Measurement method** and **Mounted in sealed enclosure** in group **Driver**. Specify the volume V_{box} of the enclosure.

   打开属性页 **Method**，在组 **Measurement method** 中选择 **Using laser**，并在组 **Driver** 中选择 **Mounted in sealed enclosure**。指定闭合箱体的体积 V_{box}。

2. Start the measurement and wait until the result windows are updated
   开始测量并等到所有结果窗口更新完毕。

3. In **Table Linear Parameters** you will find both the parameters of the system driver + box (influence of the enclosure not removed) as well as the parameters of the sole driver.
   在 **Table Linear Parameters** 中，您将找到 system driver + box (不去除箱体对测量的影响)的参数以及单独扬声器单体的参数。

How to use different inductance models

如何使用不同的电感模型

The inductance and the magnetic losses of real world drivers are strongly frequency dependent and show a very complex behavior. The LPM supports various common models. They can be selected in property page **Im/Export**.

现实的扬声器单体的电感和磁损耗强烈地取决于频率并显示出非常复杂的特性。LPM 支持各种常见模型的测量，可在属性页 **Im/Export** 中对它们进行选择。

See section *LPM-Reference | Linear Modeling | Inductance model* for detailed information. Note that the inductance model is used for post-processing only. Switching between models will not destroy any measurement data. Always use the **Shunted inductor model** if you want to export the results to the SIM module.

细节信息，请参见 *LPM-Reference | Linear Modeling | Inductance model*。注意，电感模型只用于后处理。各种模型之间的转换不会损坏任何测量数据。如果您想将数据输出到 SIM 模块，请一直使用 **Shunted inductor model**。

Measure distortion online

在线测量失真

Select **Noise floor monitoring** in the property page **Stimulus** to separate the residual noise floor (uncorrelated to the excitation) and nonlinear distortions (harmonics and intermodulation components). It is strongly recommend to use always this option despite it doubles the measurement time. With this option you may assess the distortion level produced by the driver and therefore the validity of linear measurements (where the distortion should be at least 20 dB below the fundamental components).

在属性页 **Stimulus** 中选择 **Noise floor monitoring** 来分离剩余的本底噪声(与激励级无关)和非线性失真(谐波和互调分量)。强烈建议一直使用该操作，尽管它双倍地延长了测量时间。使用该操作，您可以评估由扬声器单体产生的失真级以及线性测量的有效性 (失真应至少低于基波分量 20 dB)。

You may also use the LPM for distortion measurements produced by multitone excitations. The distortion can’t be separated into harmonic and intermodulation components but the effective distortion pattern may give you clues about the broadband distortion produced by a complex excitation signal. This requires high excitation levels. For this special application of LPM refer to the Application note **AN16 Multitone Distortion.**

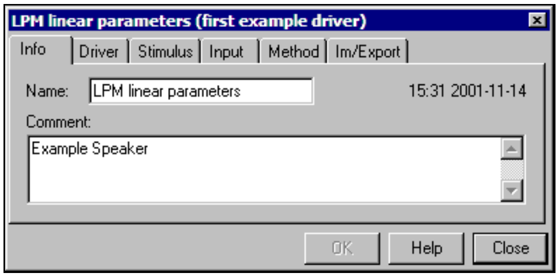
您也可使用 LPM 进行由多频激励信号产生的失真测量。失真不能分离为谐波和互调成分，但有效的失真模式会给您有关由复激励信号产生的宽带失真线索，这要求较高的激励级。LPM 的这一特殊应用，请参阅应用须知 **AN16 Multitone Distortion**。

Add comments

添加评论

The **Info** page allows the user to change the name of the measurement and to add a comment to the measurement (comments may be included in the report file). Using templates the comments are copied to each derived operation. Changing the name may also be done by a slow double click on the operation name in the object tree window.

页面 **Info** 允许用户更改测量名并对测量添加评论 (评论包括在报告文件中)。使用模块，评论将复制到每个自带的操作下。也可通过在对象树窗口中慢双击操作来改变名字。



Working without Laser

无激光测量

All electrical parameters are obtained from the impedance curve. The module identifies the electrical parameters regardless whether the laser is connected or not. The laser signal is used to identify the mechanical parameters. Although we strongly recommend to use the laser the mechanical parameters may be obtained by performing a second perturbed measurement with an additional mass attached to the driver or the driver mounted in an sealed test enclosure of known volume. Furthermore it is possible to calculate the mechanical parameters from the impedance curve if the value of Mmd is known ("Fixed Mmd method"). It is highly recommended to perform at least once a comparison between the classical perturbed method and the laser based method. The *Bl* and M_{ms} values should agree with at least 5% accuracy. This way you make sure that the parameters are identified correctly and the laser is calibrated and used right.

所有电参数和力学参数都可从阻抗曲线测量中得到。不管激光连接与否，模型都可鉴定电参数，激光信号用来鉴定力学参数。尽管我们强烈建议使用激光，但力学参数也可通过执行第 2 个带附加质量的扬声器单体测量法或扬声器单体安装在已知体积的密封测试箱体中的摄动测量法获得。如果 Mmd 值已知 ("固定 Mmd 法")，甚至可从阻抗曲线中计算力学参数。更建议进行至少一次经典摄动法和基本激光法之间的比较。两个测量方法所得出的 *Bl* 和 M_{ms} 值之间的不一致性应小于 5%。这样您可以确保，参数已正确地鉴定以及激光已校准并使用正确。

Using an additional mass

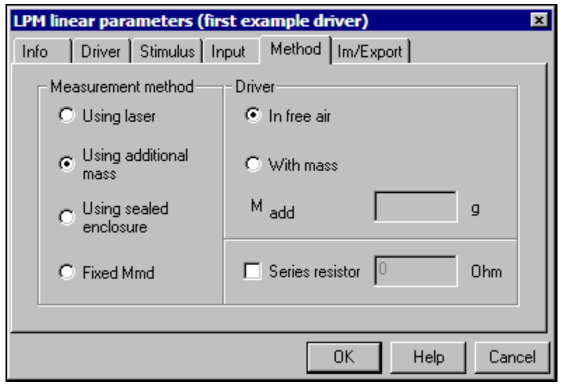
使用附加质量

To obtain the mechanical parameters with the loaded mass method you have to do the measurement in the following steps:

要使用加载质量法获得力学参数，您须遵照以下步骤进行测量:

1. Open the property page **Method** and select the **Using additional mass** in the group **Measurement method** and select **In free air** in the **Driver** group.

   打开属性页 **Method**，在组 **Measurement method** 中选择 **Using additional mass**，并在组 **Driver** 中选择 **In free air**。



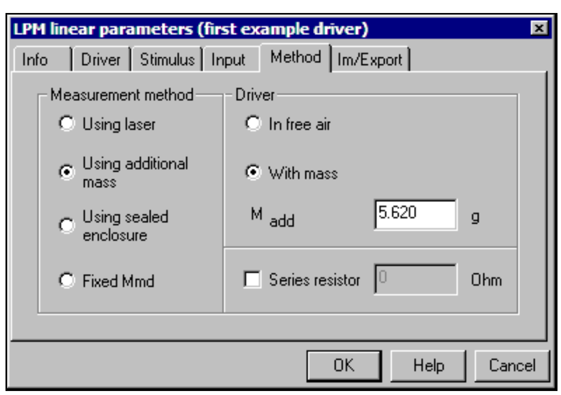
2. Connect the speaker without additional mass.
   在不带附加质量的情况下，连接扬声器。

3. After selecting the other setup parameters in the property pages **Stimulus** and **Input** start the first part of the measurement by pressing **Run**
   在属性页 **Stimulus** 和 **Input** 中选择完其它设置参数后，按 **Run** 键，开始测量的第一部分。

4. Wait until the result windows are updated.
   等到所有结果窗口更新完毕。

5. Attach the additional mass to the driver. Be careful to distribute the mass symmetrically over the cone to prevent from stagger and try to fix it tightly to avoid resonances.
   将附加质量加到扬声器单体上。请仔细地将附加质量对称得分布到纸盆上，以防止参差，并试着将其固定以避免谐振。

6. Open property page **Method,** select **With mass** in group **Driver** and specify the value $\mathbf{M_{add}}$ of the mass attached to the driver.
   打开属性页 **Method**，在组 **Driver** 中选择 **With mass**，并指定扬声器单体的附加质量值 $\mathbf{M_{add}}$。



7. Start the second part of the measurement by pressing **Run**

按 **Run** 键，开始测量的第二部分。

8. Wait until the result windows are updated. The result windows **Impedance Magnitude** and **Impedance Phase** will show the results of both measurements. Both the unloaded resonance frequency (f_s) and the perturbed resonance frequency (f_{ct}) are listed tn the **Table Linear Parameters**.
   等到所有结果窗口更新完毕。结果窗口 **Impedance Magnitude** 和 **Impedance Phase** 将显示两个测量的测量结果。空载谐振频率(f_s) 和摄动谐振频率(f_{ct}) 都将在 **Table Linear Parameters** 中列举出来。

Using a test enclosure of known volume

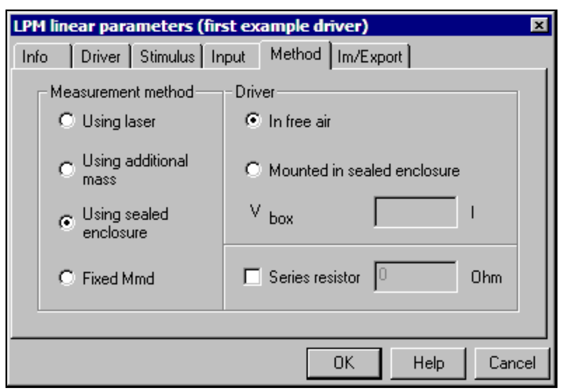
使用已知体积的测试箱

Using a test enclosure as perturbation you have to do the measurement in the following steps:

使用测试箱作为摄动，您必须遵照以下步骤进行测量:

1. Open the property page **Method** and select the **Using sealed enclosure** in the group **Measurement method** and **In free air** in **Driver** group.

   打开属性页 **Method**，在组 **Measurement method** 中选择 **Using sealed enclosure**，并在组 **Driver** 中选择 **In free air**。

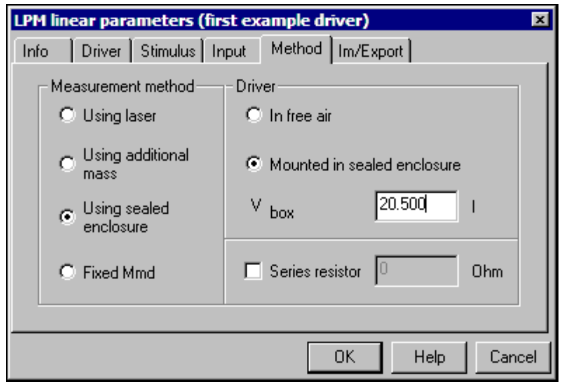
   

2. After selecting the other setup parameters in the property pages **Stimulus** and **Input** start the first part of the measurement by pressing **Run**
   在属性页 **Stimulus** 和 **Input** 中选择好其它设置参数后，按 **Run** 键，开始测量的第一部分。

3. Wait until the result windows are updated.
   等到结果窗口更新完毕。

4. Open property page **Method** and select **Mounted in sealed enclosure** in group **Driver** and specify the volume V_{box} of the test enclosure in liter.

打开属性页 **Method**，在组 **Driver** 中选择 **Mounted in sealed enclosure**，并以升为单位，指定测试箱体积 V_{box}。



5. Start the second part of the measurement by pressing **Run**
   按 **Run** 键，开始测量的第 2 部分。

6. Wait until the result windows are updated. The result windows **Impedance Magnitude** and **Impedance Phase** will show the results of both measurements. Both the free air resonance frequency (f_s) and the perturbed resonance frequency (f_{ct}) are listed in the **Table Linear Parameters**.
   等到结果窗口更新完毕。结果窗口 **Impedance Magnitude** 和 **Impedance Phase** 将显示 2 个测量的测量结果。自由场谐振频率 (f_s) 和被扰乱的谐振频率 (f_{ct}) 都将在 **Table Linear Parameters** 中列举出来。

Fixed Mmd

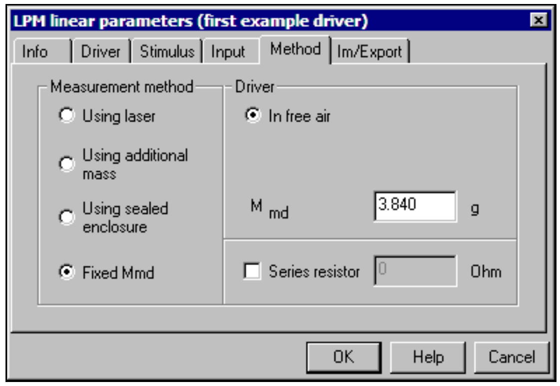
固定 Mmd

The mechanical parameters can be derived directly from the impedance measurement the mass M_{md} of the voice coil and the diaphragm (without air load) is known.

力学参数可直接由阻抗测量中获得，音圈和膜片的质量 M_{md} 已知 (不含空气载荷)。

1. Open the property page **Method** and select the **Fixed Mmd** in the group **Measurement method**.
   打开属性页 **Method**，并在组 **Measurement method** 中，选择 **Fixed Mmd**。

2. Enter *Mmd* in group **Driver**.
   在组 **Driver** 中输入 *Mmd*。



3. After selecting the other setup parameters in the property pages **Stimulus** and **Input** start the measurement by pressing

    **Run**

   在属性页 **Stimulus** 和 **Input** 中选择完其它设置参数后，按 **Run** 键，开始测量。