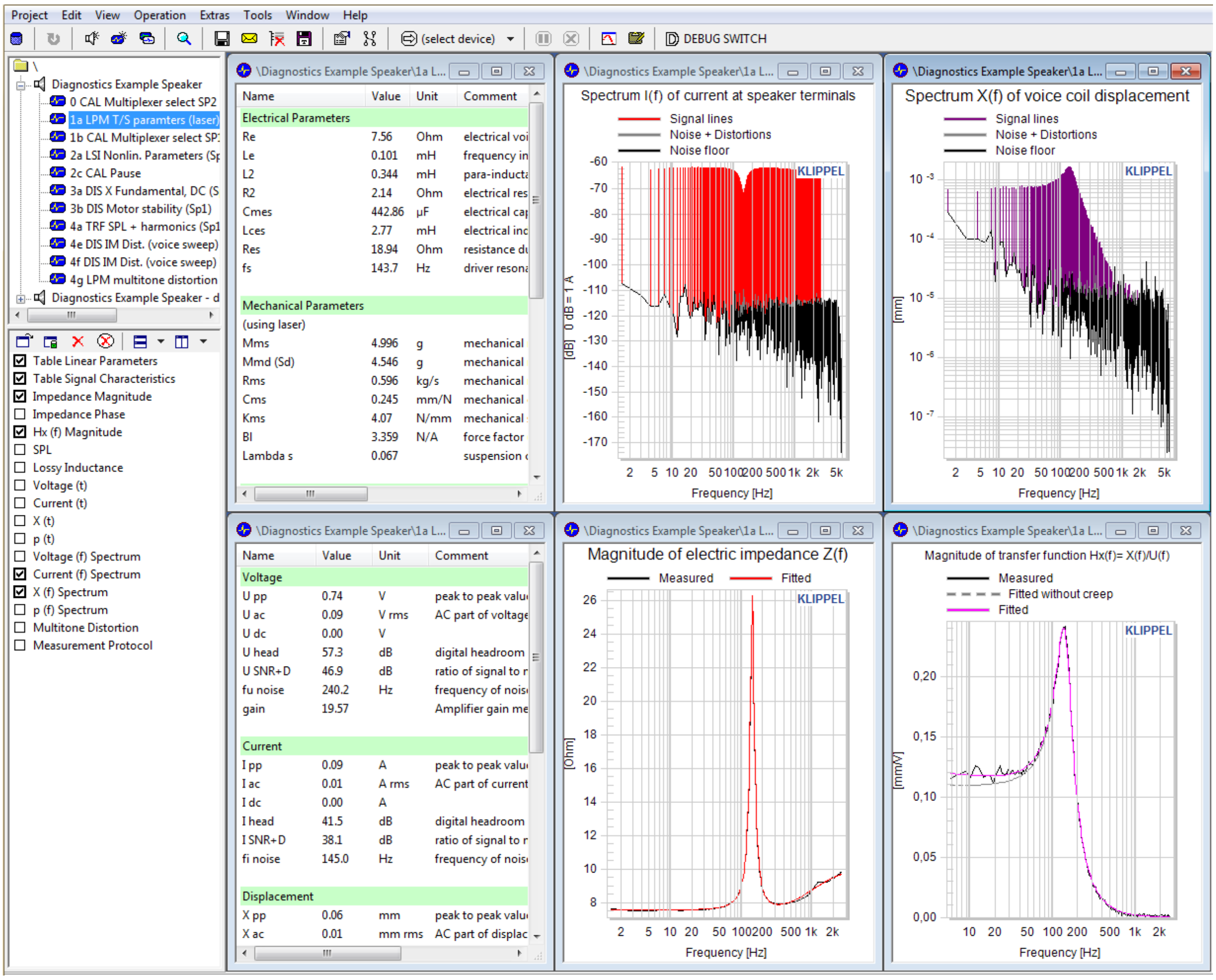
Maximizing LPM Accuracy **AN 25**

Application Note to the KLIPPEL R&D SYSTEM

This application note provides a step by step procedure that maximizes the accuracy of the linear parameters measured with the LPM Module. Factors that deteriorate the accuracy are identified and suggestions are made for improvements.

Most important is the careful adjustment of the excitation level. If the excitation level is too high distortions are generated and the driver is not longer operated in the small signal domain. Very low excitation levels lead to a poor signal to noise ratio. The LPM visualizes both noise floor and distortion. Using this information an optimal excitation level can be found.



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updated December 19, 2022

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Physical Limitations

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

Step by step procedure for maximal accuracy

Precise Calibration	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*. The calibration of the laser head should be checked more frequently but, in any case, if the head is changed or replaced (see *Laser Handling* 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 M_{ms}!
Amplifier	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.
Check hardware with reference driver	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.

Adjust laser	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. **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 (if possible) and check that the working range is not left. **To increase reflection, you may apply 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, depending on the used laser head. **Make sure that the laser is pointed to an approximate perpendicular surface** (e.g. center of the dust cap or joint). The target may be up to 20° out of the perpendicular position without degrading the performance significantly.
Check mounting of the driver	**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.
Use "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.
Use speaker channel 2	**If available use the high sensitivity sensor** for all linear parameter measurements. Depending on the device you are using, there are some special configurations of channel 2. Refer to the hardware manual for your device, to check for more information.
Adjust frequency range	**Select a meaningful template for your application and selected type of DUT**. Adjust the frequency range in property page STIMULUS if this is required by the application or type of DUT. The maximal frequency F_{max} of the excitation signal should be between 20*f_s and 100*f_s. This will shift the impedance resonance peak to the middle of the logarithmic frequency range which is optimal for curve fitting. A spectral resolution of 30 lines per octave is required at 0.5f_s or lower as the separation of noise and distortion components starts at the selected Reference Frequency. Analyzing the distortion components around resonance frequency f_s is recommended for ensuring meaningful small signal conditions. Reducing the spectral resolution down to 16 lines per octave could help reducing the distortion as less low frequency content reduces the displacement which activates the distortion. But a lower spectral density also reduces the resonance frequency f_s fitting accuracy.

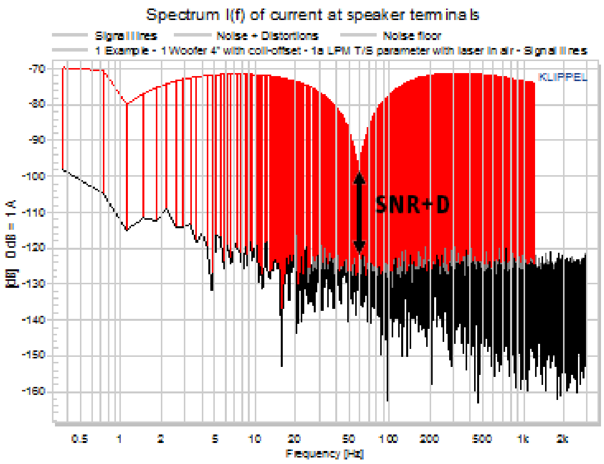
Adjust excitation level

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.

The main measurement uses a multi-tone stimulus. Only certain (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.

The result window *Current(f) Spectrum* shows the spectrum of the measured current signal.



The exited lines are plotted red. As the excitation voltage is almost constant over frequency (voltage driven measurement) the shape formed by 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 no longer operated in the small signal domain. Very low excitation levels lead to a poor signal to noise ratio.

Therefore the ratio

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

needs to be maximized for optimal results. Start with a small excitation voltage, e.g. 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 at least 20 dB. 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.

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.

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

Excitation level adjustment:

1. **If no distortion lines are visible, try to increase the excitation level** till the distortion lines exceed the noise floor slightly.
2. **In case of considerable distortion decrease the excitation level** till the distortion lines exceed the noise floor slightly. Don't hesitate to apply very small voltages. Values as small as 0.025 V (combined with a high number of averaging) are an optimal choice for some drivers.
3. **If SNR+D is still poor, increase the number of averaging**. This will reduce the noise floor. Note, that the distortion will not be decreased by more averaging. Adjust the excitation level again till the distortion exceeds the noise floor slightly.
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.
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 manual section *Increase of signal to noise ratio for high Q drivers* in part 3 of the LPM Tutorial. Please follow the outlined procedure exactly to ensure maximal accuracy of the results.

   Note: The series resistor should be used only if steps 1-3 definitely fail to produce a proper SNR+D!

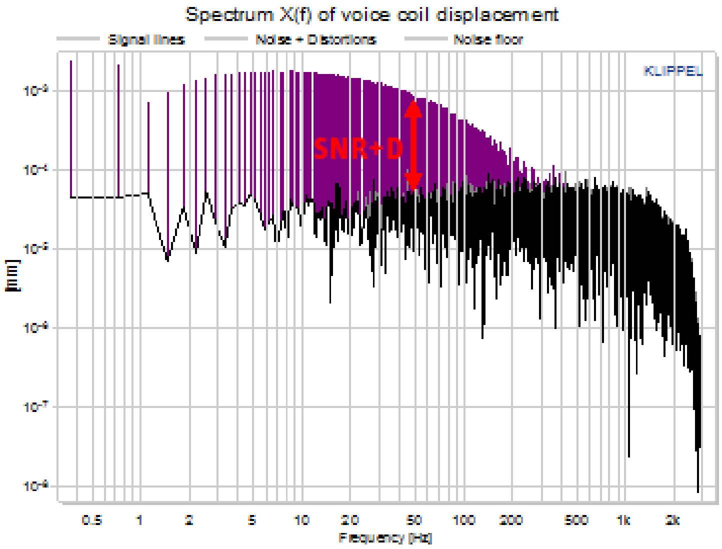
Check laser spectrum

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:

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.



   SNR+D of the displacement should be at least 20 dB. 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.

   Note: Maximizing SNR+D for the current is more important than maximizing SNR+D for the displacement.

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.

3. Check the distortion present in the displacement spectrum. Normally there are no distortions 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.

Check impedance fitting

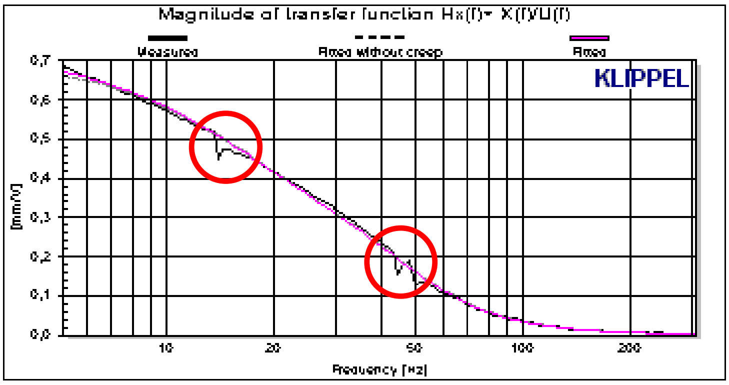
1. Open result window *Impedance Magnitude*. Is the measured curve (black) smooth (not noise corrupted)?

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 R_e. If the fitting is poor you can specify the R_e value manually in property page IM/EXPORT.

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

Check Hx(f) fitting

1. Open result window $H_x(f)$ *Magnitude*. Is the measured curve (black) smooth (not noise corrupted)?
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.
3. **Check the measured curve for mechanical resonances** which may be caused by the mounting of the driver (see figure below).



Try to damp the resonances if they are significant. Make sure that your clamping mechanism is appropriate for the driver size. See our product list for clamping and driver stand offered by us.

Select inductance model

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*.

Cross check with loaded mass method

If you doubt the laser based linear parameters, perform a second measurement with the loaded mass method (see LPM manual section *Working without a laser* in part 3 of the LPM Tutorial). The results for *Bl* and M_{ms} should not deviate more than 2-3% between the two methods.

More Information

References

[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

Documents

User manual for the KLIPPEL R&D SYSTEM

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