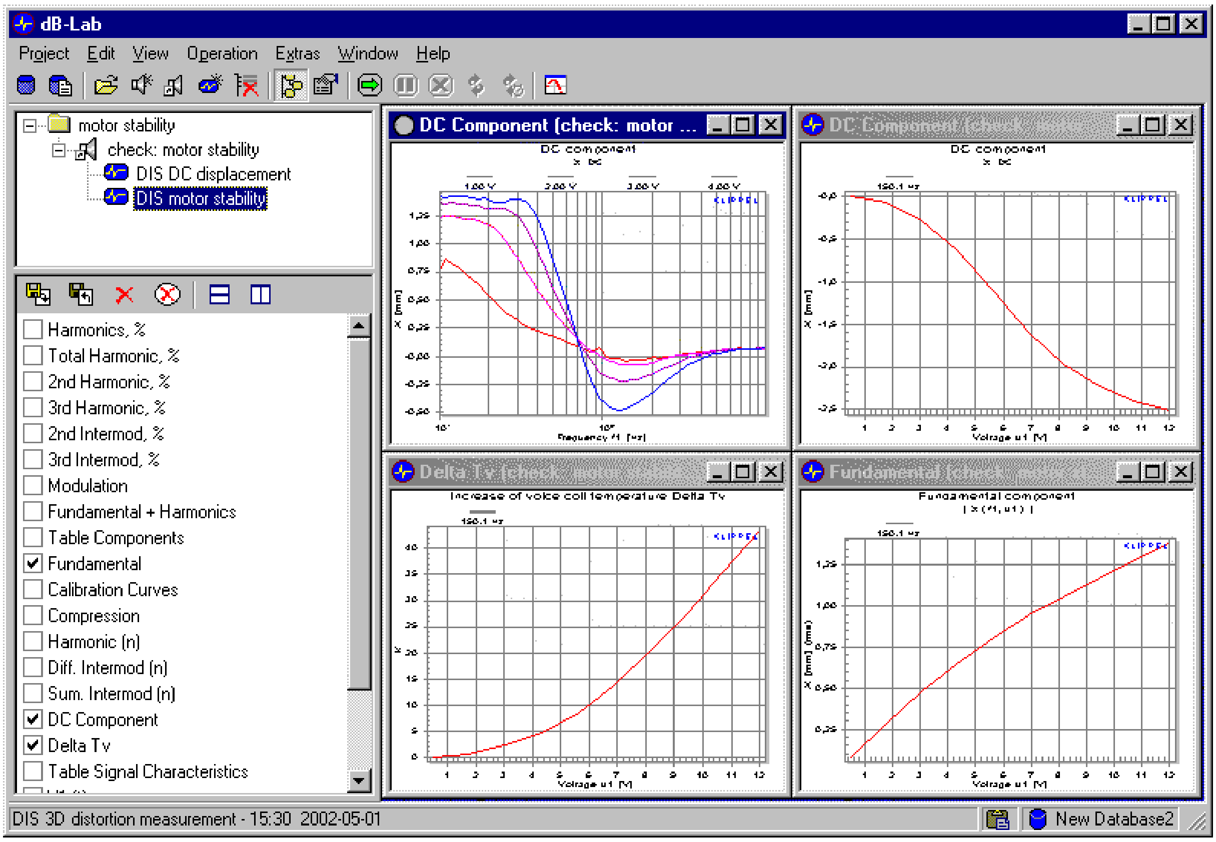
Motor Stability **AN 14**

Application Note to the KLIPPEL R&D SYSTEM

The movement of the voice coil in a magnetic field can become unstable for excitation tones above the resonance frequency. The instability has the tendency to push the coil out of the gap. Using the DIS software module (3D distortion measurement) of the Klippel R&D System the most critical excitation frequency is determined in order to measure the corresponding dynamically generated DC displacement. Various ways for improving the stability of the driver are discussed.



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Instability of the motor

Causes	The 'Achilles' heel of the electro-dynamical transducer is the stability of the coil above the resonance frequency. We face this problem on many drivers using a short coil and a soft suspension. The natural decay of the force factor begins already at small positive and negative displacements if the overhang of the coil is low. A small coil offset or even some small disturbance produces a substantial asymmetry of the *Bl(x)* curve for the coil. Due to the phase relationship between current *i* and displacement *x* a new DC component will produced by the driving force $F=Bl(x)*i$. It increases the asymmetry of *Bl(x)* and pushes the coil more and more out of the gap. This unstable process continues until the suspension has produced a restoring force large enough to stop it.
Critical frequency	The most critical excitation frequency is at $f \approx 1.5*f_s$ there f_s the resonance frequency. Here both the magnitude of current and displacement is high and the phase of the displacement is lagging by more than 90 degree behind the current.
Critical ratio	The ratio between DC displacement and magnitude of the fundamental displacement $$I_{DC} = \frac{X_{DC}(U_1, f_1)}{X_{fund}(U_1, f_1)} * 100\%$$ is a critical measure for the stability of the driver. If the value of I_{DC} < 10 % the driver is sufficient stable. Please note that in the DIS module X_{fund} is presented in mm rms and X_{DC} in mm peak.
Remedy	There are some ways to improve the stability of the driver 1) First of all we have to avoid any voice coil offset and have to reduce an asymmetrical geometry of the induction field B in the gap. The measurement of the large signal parameters in connection with a good FEM program for modeling the motor structure will lead to success eventually. 2) If we cannot avoid the generation of a DC force we may reduce the generated DC displacement by using a suspension with a high stiffness. However, this remedy does not solve the root of the problem. The increase of the stiffness will also shift the resonance frequency to higher values. In many applications this is not acceptable. 3) Reducing the creep factor of the suspension is a good way to increase the stiffness at low frequencies and DC while leaving the stiffness at higher frequencies unchanged. This reduces the DC force while leaving the resonance frequency nearly unchanged.

Method of measurement

Loudspeaker setup	The driver is mounted in the driver stand and the laser sensor is adjusted to the diaphragm. A dot of white ink should be used to increase the signal to noise ratio of the measured displacement signal.
Resonance frequency	If the resonance frequency f_s of the driver is not known the fundamental response of the current can be measured with the DIS module. The minimum of the current response shows the resonance frequency of the driver.
Measurement	At the frequency f_c a series of measurement with varied amplitude is performed to determine the DC and the fundamental component of the displacement and to provide the ratio I_{DC}.

Using the DIS module

Requirements

The following hardware and software is required for assessing Xmax

- Distortion Analyzer + PC
- DIS software module + dB-Lab
- Laser sensor head and laser controller

Setup

Connect the laser to the input **X** at the rear side of the DA. Mount the speaker in the Laser Stand and connect the terminals with output **Speaker 1**. Switch the power amplifier between the connectors **OUT1** and **Amplifier**.

Preparation

- Create a new object.
- Assign a new DIS operation based on the template *DIS Motor Stability AN14*.

Measurement

1. Start the measurement
2. If the measurement is interrupted with the warning *Total harmonic distortion in displacement X exceeds limit* cancel the measurement and reduce voltage U_{end} on the property page *Stimulus.* Restart the measurement.
3. Open result window *Total harmonics*. If the total harmonic distortion in displacement are less than 10 % you may increase the voltage U_{end} on property page *Stimulus* and restart the measurement.
4. Open result window *Fundamental* and *DC displacement*. Calculate the critical ratio I_{DC}.
5. Print the results or create a report

Setup parameters for the DIS module

Template

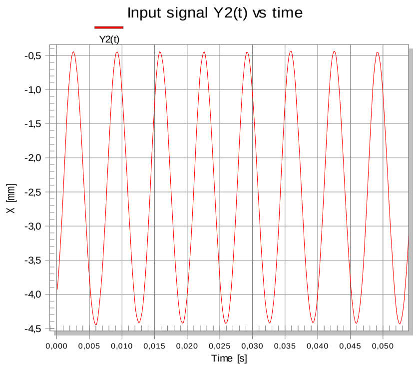
Create a new Object, using the operation template *DIS Motor Stability AN14* in dB-Lab. If this database is not available you may adjust the default DIS setup as described below. You may also modify the setup parameters according to your needs.

Default settings for checking motor stability

1. Open the property page *Stimulus*. Select *Harmonics* in the drop down box *Mode*. Select *Sweep* in group *Voltage U_1*. Set U_{start} to 1 V_{rms}, U_{end} to 8 V_{rms}, *Points* to 20 and *Spaced* to *lin*. Make sure the signal level is appropriate for loudspeaker.Unselect *Sweep* in group *Frequency f1* and set f to 2 f_s. Select *Additional excitation before measurement* and set it to 0.5 s. Set maximal order of distortion analysis to N = 4.
2. Open property page *Protection*. Select *Monitoring: Voice coil temperature and amplifier gain.* Select *Interrupt measurement if*: *increase of voice coil temperature exceeds* and set the temperature to 60 K. Select *total harmonic distortion in displacement X exceeds* and set the threshold to 10 %.
3. Open PP Input. Select X (Displacement) at the second channel (Y2). Disable the first channel (Y1).
4. Open property page *Display*. Select *Displacement X* in drop down box *State signal*.

Example

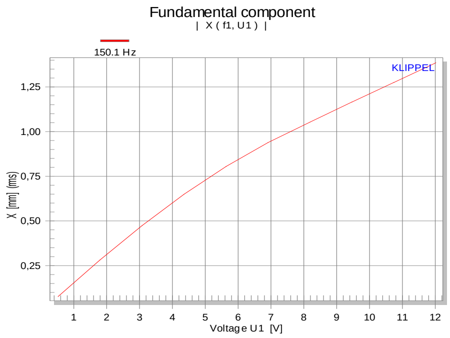
Waveform



After pausing the measurement the result window *Waveform Y2* shows the displacement versus time. The DC offset which exceeds the fundamental component shifts the coil out of the gap.

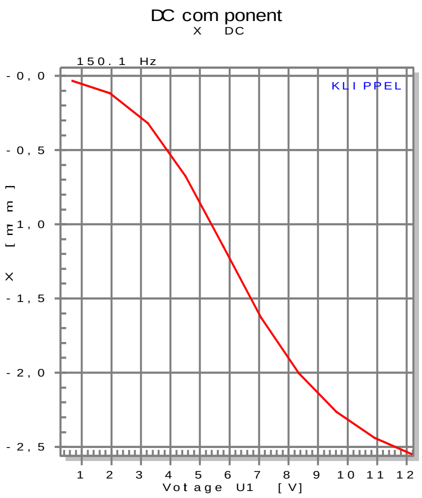
The driver in this example is a mass product used in high-quality audio equipment.

Fundamental displacement



The result window *Fundamental* shows the rms displacement versus amplitude U_1. At higher amplitudes (U_1 > 4 V rms) there is a distinct compression of the output amplitude because the coil is moves out of the gap. Please net that the fundamental is plotted in mm (rms), the DC component in mm (absolute).

DC component



The result window *DC Component* shows the DC displacement generated dynamically versus voltage U_1 for an excitation of 150 Hz.) The DC component grows slowly at low amplitudes (U_1 < 3V rms) because the asymmetry of the suspension produces a DC force in opposite direction. At medium amplitudes the DC force from the motor dominates and initiate the unstable process. At high amplitudes the progressive stiffness of the suspension limits the DC displacement. The critical ratio is very high (I_{DC} > 120 %) indicating a severe instability of the driver.

More information

Related ANs	*Dynamic Generation of DC Displacement*, Application Note 13 *Asymmetry of Compliance*, Application Note 15
Related Specs	"DIS", S4
Software	User Manual of the *Klippel R&D System*.

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