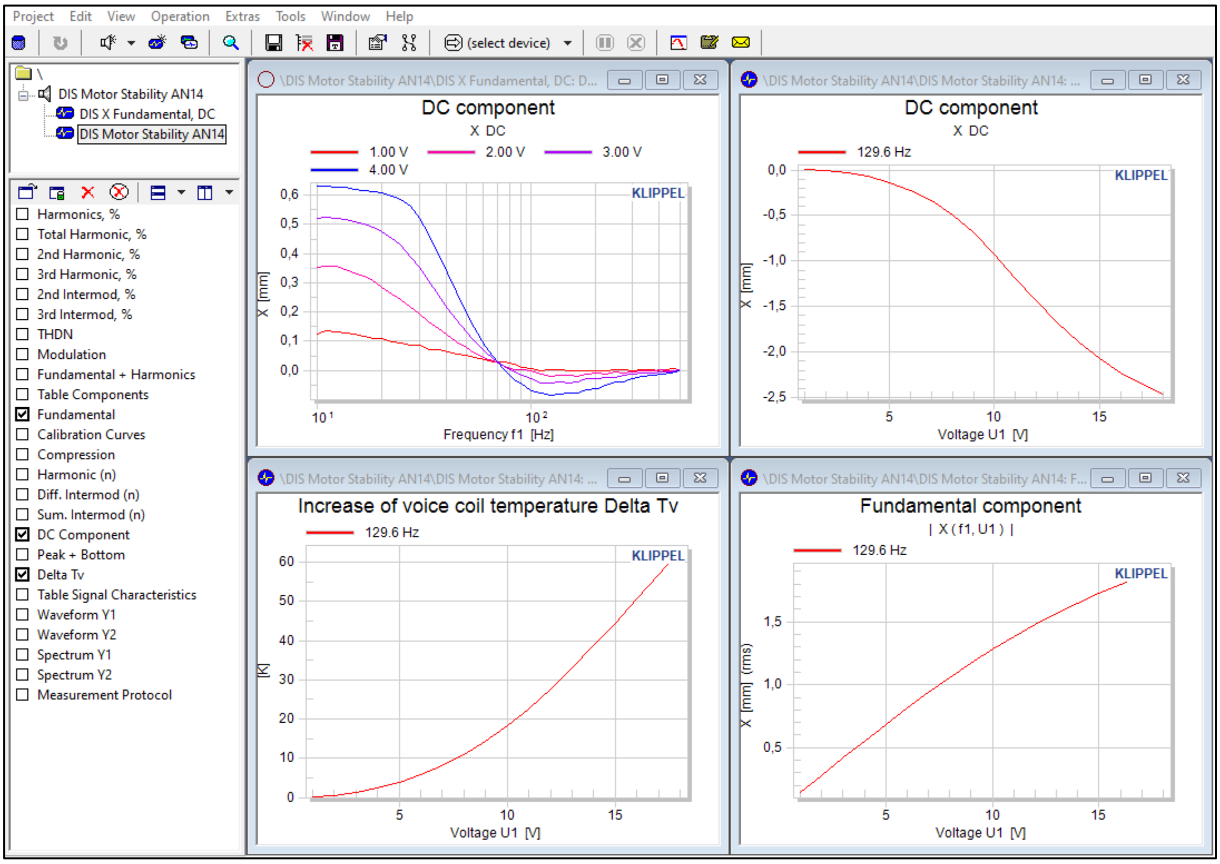
Motor Stability AN14

Application Note to the KLIPPEL ANALYZER SYSTEM (Document Revision 1.2)

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 Analyzer 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.



CONTENT

1 Instability of the motor

Causes	The 'Achilles' heel of the electro-dynamical transducer is the stability of the coil above the resonance frequency. This problem is typical for 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 disturbances produce a substantial asymmetry of the *Bl(x)* curve. Due to the phase relationship between current *i* and displacement *x* a new DC component will be 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 (for woofers) is at $f_c \approx 1.5 * f_s$ where f_s the resonance frequency. At this frequency 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. This frequency might be a little different for other types of speakers (e.g. micro-speakers). In this case, several measurements at different frequencies around $1{,}5 * f_s$ may be done.
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. A value of $I_{DC} < 10\ \%$ indicates that the driver is sufficiently stable.
Remedy	There are some ways to improve the stability of the driver: 1) First of all, any voice coil offset should be avoided and an asymmetrical geometry of the induction field *B* in the gap should be reduced. 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 the generation of a DC force cannot be avoided, the generated DC displacement may be reduced by using a suspension with a high stiffness. However, this remedy does not solve the root cause 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 while leaving the stiffness at higher frequencies unchanged. This reduces the DC force while leaving the resonance frequency nearly unchanged.

2 Method of measurement

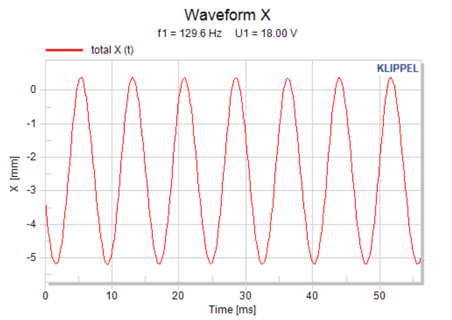
Loudspeaker setup	The driver is mounted in the Pro Driver Stand and the laser displacement sensor is adjusted to the diaphragm. A dot of white ink at the diaphragm may be used to increase the signal to noise ratio of the measured displacement signal.
Resonance frequency	If the resonance frequency f_s 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 critical frequency f_c a series of measurements with varied amplitude is performed to determine the DC and the fundamental component of the displacement and to provide the ratio I_{DC}.

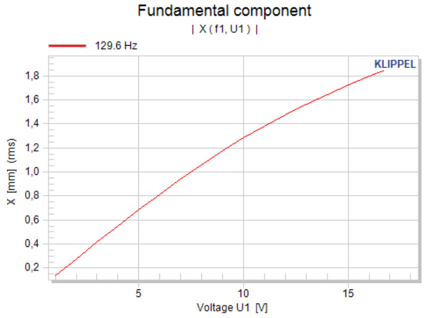
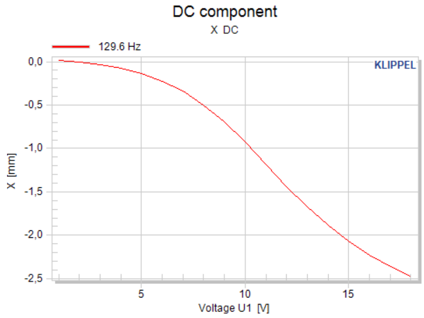
3 Using the DIS module

Requirements	The following hardware and software are required for assessing *Xmax:* • Klippel Analyzer + PC • DIS software module + dB-Lab • Laser displacement sensor
Setup 	Connect the laser to the according input at the Klippel Analyzer hardware. Mount the speaker to the Pro Driver Stand and connect its terminals with output *Speaker 1*. Switch the power amplifier between the connectors *OUT1* and *Amplifier* of the Klippel Analyzer hardware.
Preparation	• Create a new driver object in dB-Lab. • Create a new DIS operation based on the template *DIS Motor Stability AN14*[1].
Default settings for checking motor stability	1. Most of the properties of the DIS operation are already set correctly in the DIS template. You may only need to change the stimulus voltage and frequency according to the DUT. 2. Make sure the stimulus level (parameters U_{start} and U_{end}) is appropriate for the loudspeaker. 3. Set the frequency *f* to $1{,}5*f_s$. 4. You might change the temperature limit (thermal protection) on property page *Protection* if the default value does not fit to your DUT. You also might activate the protection for the *total harmonic distortion in displacement X* if needed.
Measurement	1. Start the DIS measurement 2. If the measurement is interrupted due to the protection limits (either thermal protection or THD limit exceeded), please cancel the measurement and reduce the voltage U_{end} on property page *Stimulus.* Restart the measurement after the DUT has cooled down. 3. Have a look to the result windows *Fundamental* and *DC Component*. Calculate the critical ratio l_{DC}. 4. You may create a report by using the Report Generator in dB-Lab.

[1] If you do not find this template in dB-Lab, please contact support@klippel.de for getting an older version of this application note, where the DIS operation settings are explained in more detail.

4 Example

Waveform		After pausing the measurement, the result window *Waveform Y2* shows the displacement versus time of the last measured point. 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 moved out of the gap. The fact that the fundamental component is plotted in mm (rms) while the DC component is plotted in mm (peak) is no problem for the calculation of I_{DC}.
DC component		The result window *DC Component* shows the DC displacement generated dynamically versus voltage U_1 for an excitation frequency 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 initiates the unstable process. At high amplitudes the progressive stiffness of the suspension limits the DC displacement. The critical ratio is very high in this example (I_{DC} > *120 %*) indicating a severe instability of the driver.

5 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 Analyzer System*.

Find explanations for symbols at:

http://www.klippel.de/know-how/literature.html

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