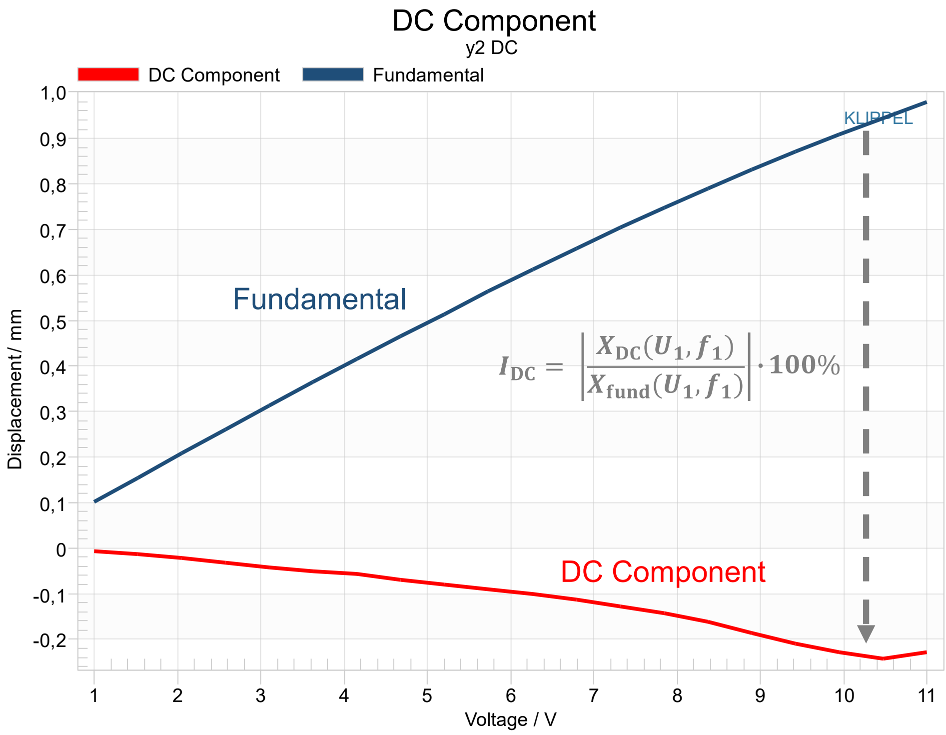
Motor Stability

AN14

Application Note to the KLIPPEL R&D system (Document Revision 1.3)

DESCRIPTION

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 3D Distortion (DIS) module of the Klippel Analyzer System, the most critical excitation frequency is determined to measure the corresponding dynamically generated DC displacement. Various ways for improving the stability of the driver are discussed.



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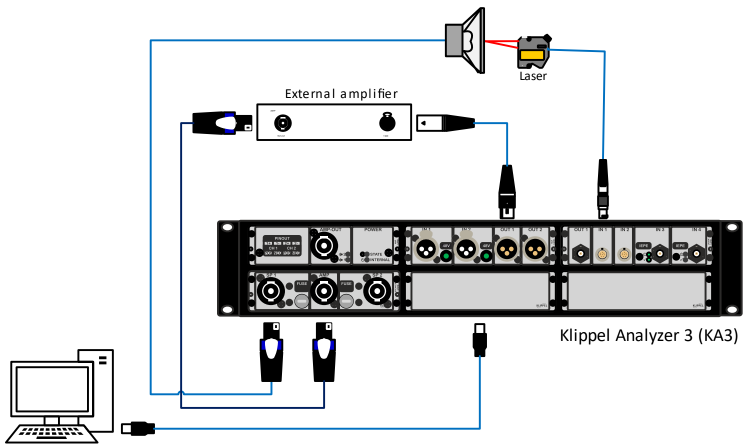
1 Instability of the Motor

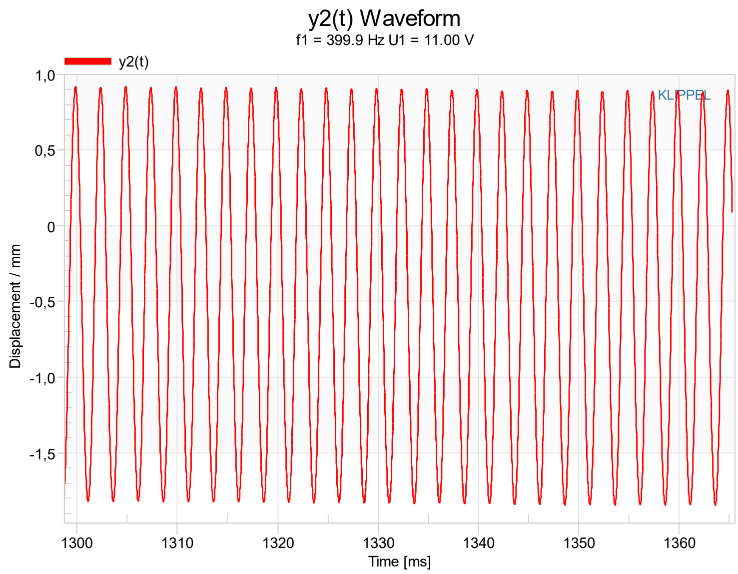
Causes	The 'Achilles' heel of the electro-dynamical transducer is the stability of the coil above the resonance frequency. This problem is typical for drivers using a short coil and a soft suspension. The natural decay of the force factor begins already at small positive and negative displacements if the overhang of the coil is low. A small coil offset or even some small disturbances produce a substantial asymmetry of the force factor curve $Bl(x)$. Due to the phase relationship between current i and displacement x a new DC component will be produced by the driving force $F=Bl(x)\cdot i$. It increases the asymmetry of $Bl(x)$ and pushes the coil 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 above resonance frequency f_s at $f_c \approx 1.5\cdot f_s$. High current and displacement magnitudes are observed, while the displacement phase lags the current by more than 90°. Note: 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 $f_c \approx 1.5\cdot f_s$ may be done.
Critical ration	The ratio between DC displacement and magnitude of fundamental displacement is a critical measure for the stability of the driver: $$I_{\mathrm{DC}} = \left\|\frac{X_{\mathrm{DC}}(U_1, f_1)}{X_{\mathrm{fund}}(U_1, f_1)}\right\| \cdot 100\%$$ A value of $I_{\mathrm{DC}} < 10$ % indicates that the driver is sufficiently stable.
Remedy	There are some ways to improve the stability of the driver: 1) Any voice coil offset should be avoided and an asymmetrical geometry of the induction field in the gap should be minimized. The measurement of the large signal parameters combined with accurate FEM-based modeling of the motor structure are key for understanding the behavior. 2) When the generation of a DC force is unavoidable, the associated DC displacement may be reduced by using a high-stiffness suspension. However, this remedy does not solve the root cause of the problem. The increase of stiffness will also shift the resonance frequency to higher values, which is not acceptable in many cases. 3) By reducing the creep factor of the suspension, stiffness can be selectively increased at low frequencies while remaining unchanged at higher frequencies. This leads to a reduction in DC displacement while maintaining an almost constant resonance frequency

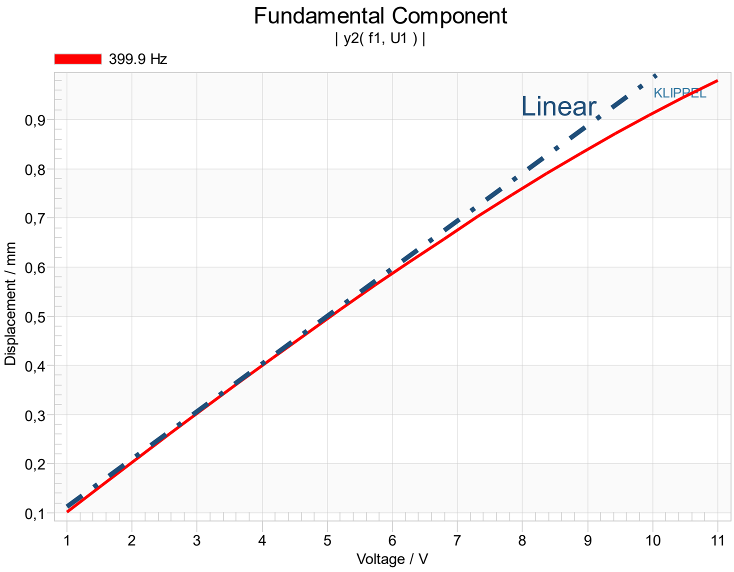
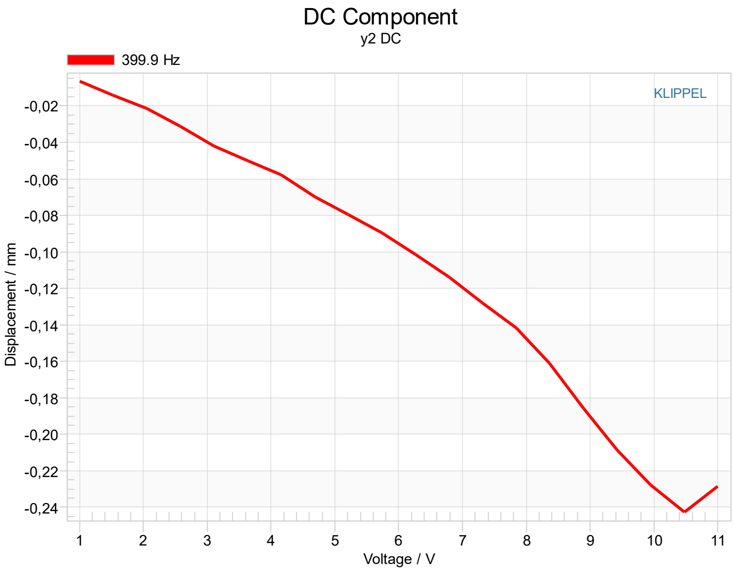
2 Using the KLIPPEL R&D System

Requirements	• Klippel Analyzer (KA3 or DA2) + PC • Laser sensor • dB-Lab Software • DIS software module
Setup	• Connect external power amplifier or use internal AMP-Card of KA3 • Mount DUT to the driver stand and connect terminals with speaker output of Klippel Analyzer • Connect laser with laser input of Klippel Analyzer and adjust beam to diaphragm of the speaker. Note: A dot of white ink shall be used to increase the signal to noise ratio of the measured displacement signal.

	
Preparation	Create a new operation based on the operation template “DIS Motor Stability AN14” provided in the dB-Lab operation template.
DIS measurement	1. Open property page of the DIS operation, make sure the stimulus level is appropriate for your DUT. 2. Set excitation frequency to $f_c \approx 1.5 \cdot f_s$. 3. Start the measurement. 4. Open the windows “Fundamental” and “DC Component”. Check the results and calculate the critical ratio l_{DC}. 5. Print the results or create a report. Note: The measurement is continuously monitored by protection parameters (THD, voice-coil heating) to ensure safe operation of the driver. If the default values are not suitable the protection limits can be adjusted on the property page “Protection”. If the measurement is interrupted due to protection limits, cancel the measurement and reduce the highest voltage U_{end} on the property page “Stimulus”. Restart the measurement after the DUT has cooled down.

3 Example

Waveform	The result window “y2(t) Input Waveform” 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. 

Fundamental displacement	The result window "Fundamental" shows the rms displacement versus amplitude U_1. At higher amplitudes ($U_1 > 6$ V rms) there is a compression of the output amplitude because the coil is moved out of the gap. 
DC component	The result window "DC Component" displays the DC Displacement generated dynamically versus voltage U_1 for an excitation frequency of f_c = 400 Hz. The DC component grows slowly for lower amplitudes (U1 < 8 Vrms) 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 I_{DC} is already 26 % indicating that the driver is instable. 

4 More Information

Application Notes	Dynamic Generation of DC Displacement, Application Note AN 13 Checking for Compliance Asymmetry, Application Note AN 15
Related Specification	3D Distortion Measurement (DIS), Specification DIS Klippel Analyzer 3 (KA3), Specification H3 Laser displacement sensor, Specification A2
Manuals	User Manual 3D Distortion Measurement

Find explanations for symbols at:

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

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