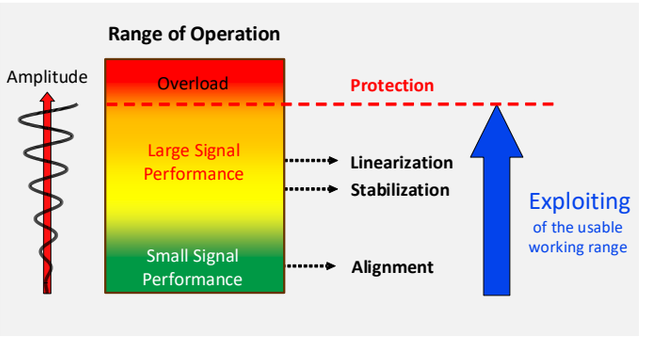
Klippel Controlled Sound (KCS)

- More sound pressure output
- Active protection against overload
- Cancellation of nonlinear distortion
- Desired linear target performance
- Coping with aging, climate, production variance
- Lower cost, weight and size

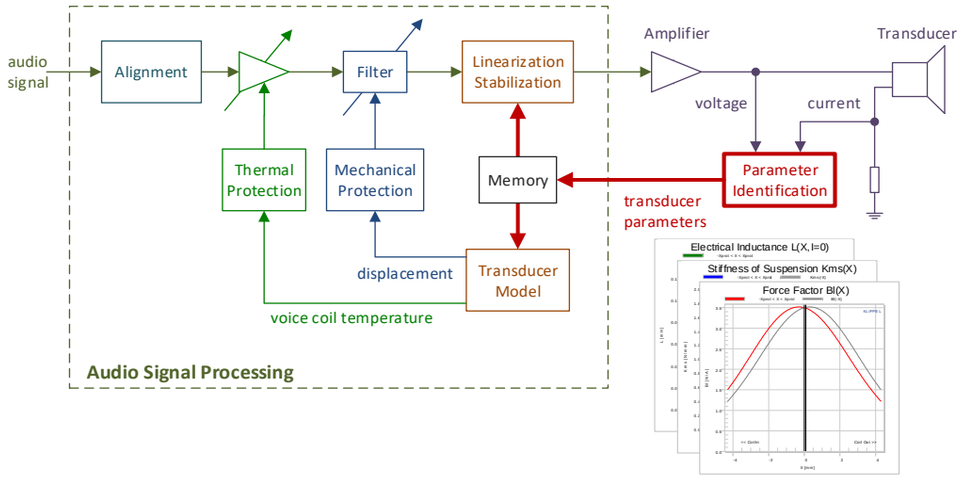


Loudspeakers are highly nonlinear and time-variant systems. Signal distortion, heating, aging, climate and other external influences limit the maximum level and the quality of the reproduced sound. The adaptive nonlinear control system KCS can cope with these undesired effects and generate the desired linear behavior over the entire working range.
The adaptive control structure is based on electro-acoustical modeling and combines real-time monitoring of the transducer parameters with active protection against thermal and mechanical overload, nonlinear distortion cancellation, system alignment and stabilization of the voice coil position.
These features lead to an extension of the usable working range to increase bass and sound pressure level or allow transducers to be made smaller, lighter and more cost effective. Additionally, transducer design can focus on increased efficiency by reducing parameter linearity to create a new generation of *Green Speakers* producing more acoustical output and less heat by requiring less energy.

Self-learning System

- Adaptive software solution
- Based on a nonlinear physical model
- Automatic parameter identification
- On-line learning with any audio signal
- Using the transducer itself as sensor

KCS uses the transducer itself as the sensor to identify the instantaneous transducer parameters by monitoring voltage and current at the speaker terminals. The nonlinearities indicate the usable working range of the transducer, eliminating time-consuming tuning by a human expert.



While playing music in on-line mode, KCS constantly monitors voltage and current at the speaker terminals to continuously adapt the internal model with time varying transducer properties, such as variances of mechanical stiffness, voice coil temperature and voice coil position. Based on the identified parameters, the nonlinear transducer model estimates precise state information such as voice coil displacement, which is required by the protection systems.

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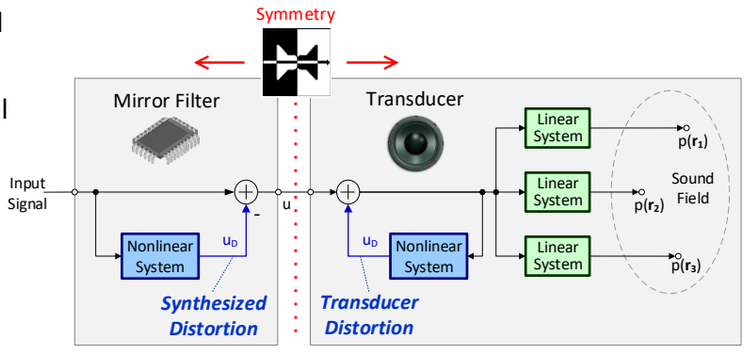
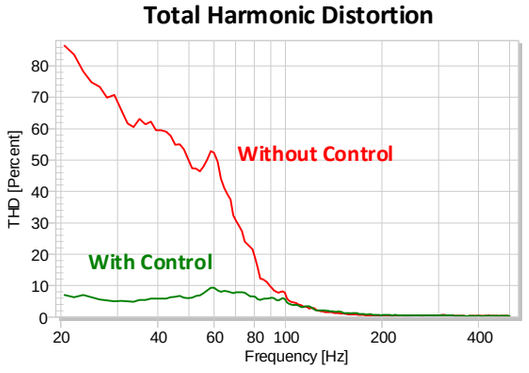
Distortion Compensation

- Linear and nonlinear distortions are reduced
- Constant transducer behavior over lifetime
- Based on a nonlinear physical speaker model
- Always stable

Nonlinear and time-variant transducer parameters will cause nonlinear and linear distortion in the transducer's output signal. KCS uses a nonlinear filter structure, which is a mirror image of the determined transducer model, to eliminate these undesired effects.



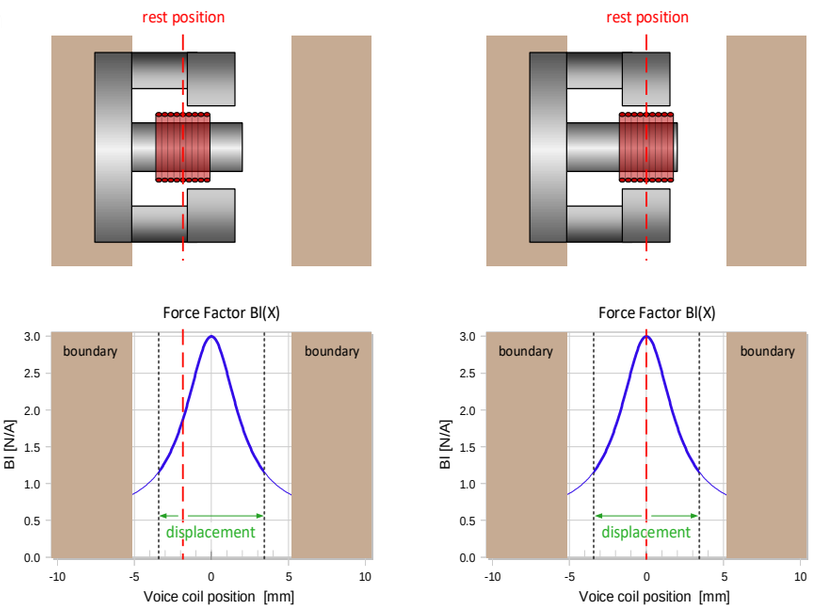


The harmonic and intermodulation distortions synthesized in the mirror filter are subtracted from the input signal before it is fed to the transducer. Thus, the distortions generated by the transducer are compensated, and a linear relationship between the input signal and sound pressure output at any point in the sound field is established.
Due to the continuous identification of transducer variances, the behavior is kept constant over the speaker lifetime because the time-variant parameters are compensated.

Active Stabilization of Voice Coil Position

- Voice Coil shift to the optimal position
- Maximum peak-to-peak displacement
- No additional sensor required

For achieving maximum bass level, the peak-to-peak displacement must be maximized. This requires the voice coil being centered between the boundaries.
However, the voice coil position is not stable because it depends on soft parts, which show high production variances and will change over time due to temperature, aging and other external influences like air pressure. In addition, transducer nonlinearities can cause dynamic voice coil position shifts due to instable behavior.

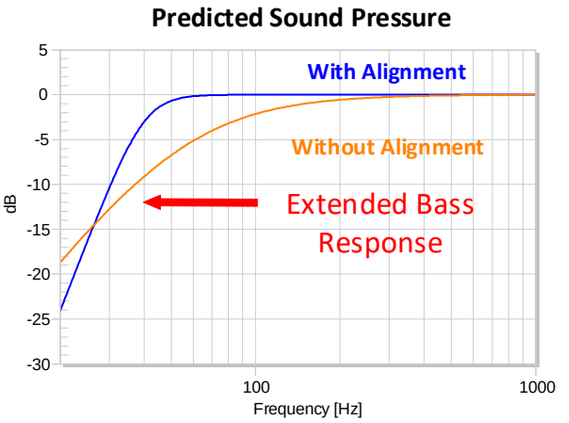


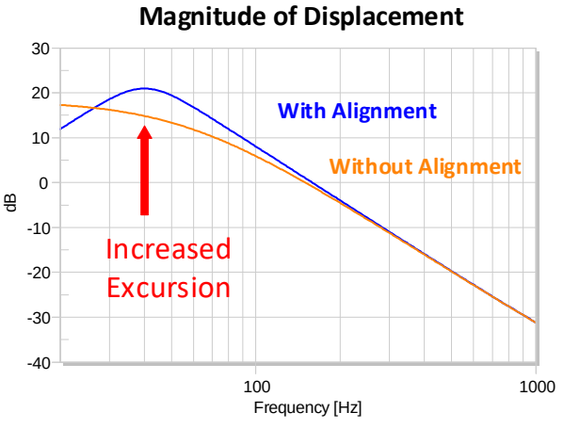
KCS detects the absolute position of the coil without a mechanical sensor by monitoring the input current and identifying an offset in the nonlinear curves. The detected offset can be actively compensated by supplying an appropriate DC voltage to the transducer via a DC-coupled amplifier. This ensures maximum positive and negative voice coil swing, giving maximum bass generated at high efficiency over the lifetime of the speaker.

System Alignment

- Extended bass response
- Optimal transducer-enclosure alignment
- Decoupled enclosure and transducer design

KCS ensures a constant linear transfer behavior between audio input and sound pressure output. By exploiting the information about the transducer and the coupled mechanical and acoustical system (box, vent, passive radiator), the KCS automatically equalizes the overall transfer function to a desired alignment (e.g. *Butterworth*) by applying a pre-filter to the input signal.
Matching the transducer to a given enclosure is no longer required as cut-off frequency, Q-factors and other alignment parameters can be adjusted in the software.

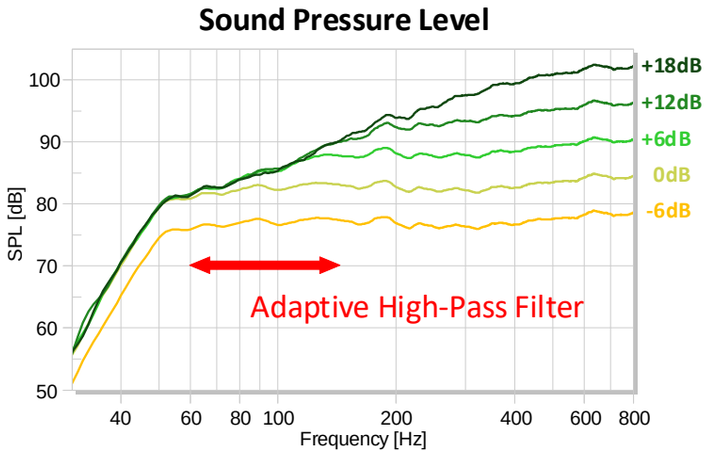


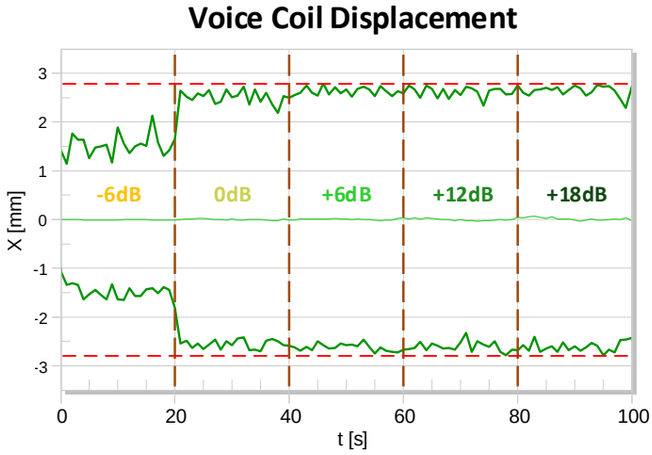


Reliable Protection

- Reliable mechanical and thermal protection
- Exploiting the entire voice coil swing
- Minimum artifacts
- Zero delay possible

Electro-mechanical transducers need active protection against mechanical overload at high excursion and against thermal overload at high input power to avoid excessive audible distortion or even destruction. The nonlinear and thermal modeling combined with the permanent parameter identification of KCS provide a very accurate displacement and voice coil temperature estimation. Thus, the protection system can anticipate critical situations and attenuate signal components to prevent the overload.
While the thermal protection reduces the level of the entire input signal to reduce the electrical power, the mechanical protection system only attenuates low frequencies where the voice coil excursion is high. Hence the maximum allowed excursion is fully utilized because the audio level can still be increased while only the excursion is restrained. This technique allows the transducer to be reliably protected without latency and avoids artifacts generated by compressors and limiters that impair the perceived sound quality.





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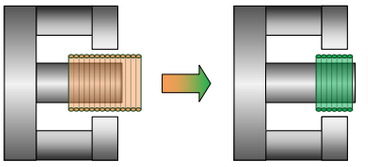
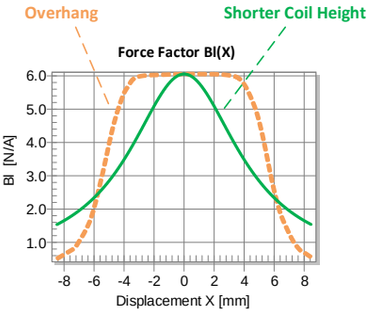
Green Speaker Design

- Increased efficiency and voltage sensitivity
- More bass from smaller speakers
- More SPL output with less heat
- Longer battery life





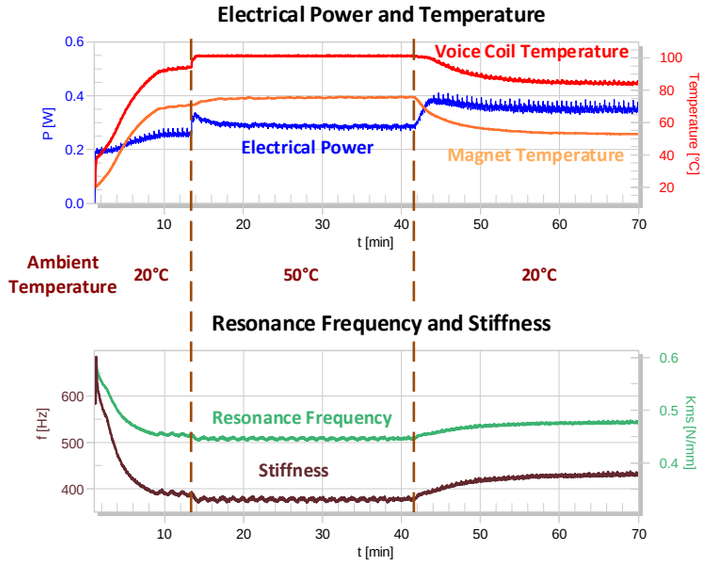
The unique features provided by KCS allow a change of paradigm in passive transducer and system design. Increasing efficiency and voltage sensitivity of the transducer has the highest priority for using available resources such as energy, size, weight, material, manufacturing effort and cost. This leads to *Green Speaker Design* aiming at more output while needing less energy.
Many design choices dedicated to improving efficiency, such as using very soft suspensions or very nonlinear motors, were not applicable in the past due to the high risk of destruction and increased distortion.
These issues can be solved with adaptive nonlinear control as the increased signal distortion is compensated and the protection system prevents any overload.
For instance, the voice coil height can be reduced significantly while the same pole plate, magnet and other transducer parts are kept. This significantly increases the efficiency and voltage sensitivity because the resistance R_e and the moving mass M_{ms} are reduced.

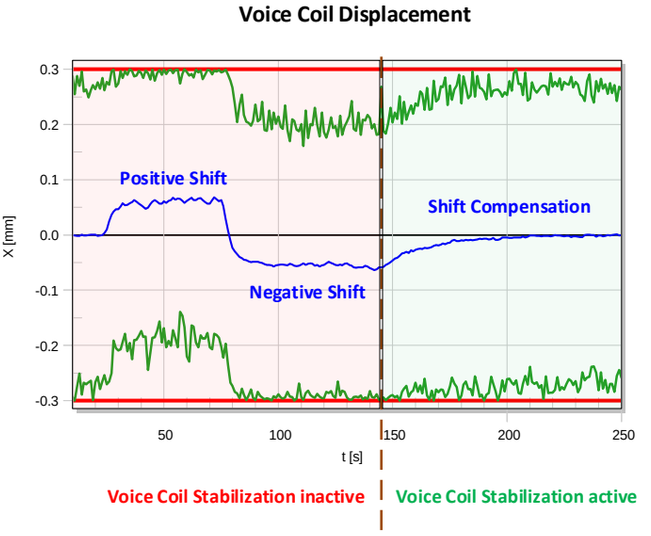
Pass-band efficiency:

$$\eta_0 = \frac{P_a}{P_e} = \frac{(Bl)^2}{R_e M_{ms}^2} \frac{\rho_0 S_d^2}{2\pi c}$$

On-Line Diagnostics

- Measurement with any audio signal
- In-situ monitoring over lifetime
- Comprehensive information
- Feedback to the design process





KCS extracts valuable information about the instantaneous properties of the transducer in the target application from the voltage and current signals. The parameter and state information reveal the influence of climate, acoustical load and the progress of the natural aging process. Furthermore, the parameters can give early indications of defects which may eventually lead to a complete breakdown. The diagnostic information provided by KCS can be used to operate the transducer safely at reduced amplitudes until the defective transducer is replaced.