**Project Initialisation Document**

**Abstract**

**Project Description**

The requirements of a loudspeaker as stated by E. R. Hanson [3] are: to be as small as possible, respond as linearly and across as much of the frequency spectrum as possible, to distort minimally, and to consume and emit power efficiently. These aims are almost never completely realised due to nearly all loudspeakers outside of experimental settings not exhibiting any form of feedback mechanisms. The aim of this project is to explore methods of collecting one or many feedback signals from one or many outputs or parameters of a voice coil loudspeaker and feed them into the input to the voice coil to try and achieve the requirements stated above.

**Literature Review (for me only)**

The work laid out in [1] describes the derivation of a feedback loop from approximations of the first-order approximations of a loudspeaker. At the resonant frequency of the system, the system’s behaviour is determined only by the unchangeable electrical characteristics of the voice coil, and thus cannot be controlled. At frequencies below resonance, the system has a first-order response, and one proportional-integral (PI) controller is used. At frequencies above resonance, the system has a second order response and two real poles, therefore two PI controllers are used. The controllers take the velocity of the loudspeaker’s cone as an input – there are several ways of deriving this value, since it cannot be done directly. After mentioning the possibility of using an accelerometer or measuring the induced voltage on the voice coil to detect velocity, [1] details a method using a variable capacitance as part of a Clapp oscillator to encode the displacement of the cone using frequency modulation, then using a phase-locked-loop circuit to demodulate this value and finally integrating to obtain velocity. The results of the methods used in [1] showcase markedly more linear performance in the sub-500Hz range, with a less substantial roll-off towards the lower extremes of the loudspeaker. Performance above 500Hz remains unchanged. The feasibility of implementing all of the above digitally is also mentioned in [1].

The work laid out in [2] describes a control solution using an accelerometer attached to the cone of a loudspeaker to detect acceleration, and thereby obtaining velocity. The effect of the sensing apparatus is considered on the resulting sound pressure level of the loudspeaker, and was found to be negligible until 1kHz, which is outside the normal operating frequency of a subwoofer, which is the type of loudspeaker being tested upon. The results presented in [2] show that when injecting a 20Hz 8Vrms sinusoid, the total harmonic distortion (THD) is reduced noticeably, by a factor of 2. The acceleration of the cone against time is noticeably less distorted in a time-domain measurement. Results were improved further by the addition of an integrator into the control circuit, which caused a 5-time reduction in THD, and a better open-loop gain.

The work laid out in [4] describes in detail the control mathematics behind the proposed method of deriving an estimate of the cone velocity from the voice coil current, as originally explored by [5].

All of [1,2,4] derive, from the same initial first-order approximation of a loudspeaker, relevant control circuits. [1] describes how a total of 3 proportional-integral (PI) controllers are used to control the first-order response of the loudspeaker below its resonant frequency, and the second-order response of it above its resonant frequency. At resonance, the only parameters that describes the system are the inherent electrical properties of the voice coil, which are fixed. [2] does something.

**Background Theory**

1. **Loudspeaker Equivalent Circuit and Block Diagram**

The equations that approximate the first-order action of the lumped loudspeaker model [5] are used by both [1] and [4] to derive a system block diagram for a loudspeaker, as shown by Fig. 1(a). The system analyses conducted by [1] and [4] models the loudspeaker as two impedances:

Electrical impedance = 1/R=sL where R, L are the resistance, inductance of the voice coil

Mechanical impedance = s/(k+sb+s^2(m)) where k, m, b are the stiffness, mass, and damping coefficient of the loudspeaker. b = Kf + Zrad where Kf, Zrad are the friction and radiation impedance.

Fig. 1(a) shows that an input signal Vin(s) induces a current I(s) through the impedance of the coil, which enacts an equivalent force F(s) upon the mechanical impedance due to the existence of a permanent magnet. I(s) α F(s) through the force/back-emf constant Bl. The action of F(s) on the mechanical impedance drives the loudspeaker cone with some velocity v(s), which in turn causes a back-emf E(s) to be induced through Bl. E(s) acts against Vin(s).

Fig. 1(b) shows ??

Theile-Small parameters

Different ways to get velocity

Talk about the design of housing

**Project Specification**

* Theorise, predict, and simulate open-loop loudspeaker behaviour and frequency responses

**Project Schedule**

**Risk Register**

**Bibliography**

1. On the Design of Some Feedback Circuits for Loudspeakers
2. Design and Evaluation of Accelerometer based Motional Feedback
3. E. R. Hanson, “A motional feedback loudspeaker system," in *Audio Engineering Society Convention 46,* Audio Engineering Society, 1973.
4. Control of Loudspeakers Using Disturbance-Observer-Type Velocity Estimation
5. S. A. Lane and R. L. Clark, “Improving loudspeaker performance for active noise control applications,” *J. Audio Eng. Soc.*, vol. 46, pp. 508–519, 1998.
6. ~~W. Klippel, “Direct feedback linearization of nonlinear loudspeaker systems,”~~ *~~Journal of the Audio Engineering Society,~~* ~~vol. 46, no. 6, pp. 499-507, 1998.~~