Improving Sound Systems by Electrical Means

The availability and flexibility of audio services on various digital platforms have created a high demand for a large range of sound systems. The fundamental components of sound systems such as docking stations, sound bars and wireless mobile speakers consist of a power supply, amplifiers and transducers. Due to historical reasons the design of each of these components are commonly handled separately which are indeed limiting the full performance potential of such systems. To state some examples the requirements of the amplifier distortion could be relaxed if the distortion of the transducer was considered, the power requirement of the power supply could be relaxed if the acoustical power requirement was known, the total sound system efficiency could be optimized which would properly require a radical design change for all the components, communication between the components could lead to intelligent control and protection functionality and so on. In this work different strategies towards improvements of sound systems by electrical means was investigated considering the interfaces between each component and the performance of the full system. The strategies can be categorized by improvements of sound quality, efficiency, size and cost as well as production. The transducer is considered the weakest component when it comes to sound quality which is especially apparent for micro-speakers. Historically the common voltage drive of a transducer has been challenged by the alternative current drive in relation to sound quality. Prior research points out that current drive provides a more direct control of the force applied to the moving parts of a transducer resulting in less distortion and thus improved sound quality but the information is quite sparse. In this work multi-tone distortion related to voltage and current drive of transducers with different characteristics were investigated using a non-linear transducer model. The goal was to predict if and when current drive is advantageous. Current drive was found to be most effective at higher audio frequencies where the non-linear voice coil inductance has a major effect on distortion. At lower audio frequencies transducer related distortions are more pronounced and an old motional feedback technique was revisited. An accelerometer is mounted on the moving parts of the transducer enabling motional control which lead to a 14 dB distortion reduction in the best case. This technology is very promising since it compensates for most distortion mechanisms of the transducer such as non-linearities, production variation, wear-n-tear, temperature changes and so on. Furthermore the accelerometer output can be used for protection purposes. The only disadvantages are challenges in terms of cost and system complexity. The noise floor of the accelerometer prevents iii/xi motional control at very low displacements. The main advantage of Class-D audio amplifiers is high efficiency which is often stated to be more than 90 %. This is only true at high power levels but at low power levels the efficiency unfortunately drops due to severe switching losses in the semiconductors. This efficiency characteristic is an environmental concern since the amplifier is operating at low power levels for background music in more than 89 % of the time and thus a lot of energy is wasted considering the amount of sound systems around the world. Even when the music is played at higher levels the average power is still quite low due to the dynamic behavior of music. In this work energy consumption and sound quality for Class-D audio amplifiers using a peak-tracking power supply scheme was investigated as a means to reduce these losses. It was proven that the efficiency of a class-d amplifier could be increased from approximately 55 % to 90 % at 1 W output power without sacrificing the distortion. A full tracking power supply scheme would further improve these numbers but the efficiency of the power supply also needs to be taken into account which should be addressed in future work. Power requirements of a sound system have been a large part of this project. There is a surprisingly big lack of scientific information regarding this topic and the goal has thus been to develop an intelligent approach to estimate the power requirements to obtain a size and cost reduction. The greatest challenge was to develop an analyzing tool to estimate the worst case power scenario versus time for a given loudspeaker application. Models including the influence of the enclosure and the most critical non-linearities were derived and experimental verified. Since the power requirement is related to the music material more than 400 music tracks were analyzed and it was proven that full power capability is only needed for a few milliseconds which inspire radical design changes and large reduction of size and cost for the power supply, the amplifiers and the transducers. The work on a power supply based on this research was performed showing a 5 times size reduction compared to a commercial power supply. Future work should expand this analysis to a range of different sound system applications and audio material. An alternative production method for the Class-D amplifier output inductor has been proposed and investigated. A hybrid winding concept for toroids were proposed where the traces in a printed circuit board completes the winding of bended copper foil cut-outs placed in a handy former. The main potential is expected to be production related and faster time to market since the former including the foil cut-outs can be pre-fabricated and pre-shipped to different suppliers around the world. A dynamic 3D model made in matlab and finite element analyses were used to optimize the shape of the bended copper foils to optimize the DC resistance. The DC resistance was reduced by 30 % compared to the starting point for a 10 turn toroidal inductor using this method. The combined work indicate that large sound system improvements are in reach by use of electrical means. Innovative solutions have been investigated and improvements of sound quality, efficiency, size and cost as well as production have been demonstrated.

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