Design of an Analog VLSI Cochlea

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Abstract

The cochlea is an organ which extracts frequency information from the input sound wave. It also produces nerve signals, which are further analysed by the brain and ultimately lead to perception of the sound.

An existing model of the cochlea by Fragnière is first analysed by simulation. This passive model is found to have the properties that the living cochlea does in terms of the frequency response.

An analog VLSI circuit implementation of this cochlear model in CMOS weak inversion is proposed, using log-domain filters in current domain. It is fabricated on a chip and a measurement of a basilar membrane section is performed. The measurement shows a reasonable agreement to the model. However, the circuit is found to have a problem related to transistor mismatch, causing different behaviour in identical circuit blocks.

An active cochlear model is proposed to overcome this problem. The model incorporates the effect of the outer hair cells in the living cochlea, which controls the quality factor of the basilar membrane filters. The outer hair cells are incorporated as an extra voltage source in series with the basilar membrane resonator. Its value saturates as the input signal becomes larger, making the behaviour rather closer to that of a passive model. The simulation results show this nonlinear phenomenon, which is also seen in the living cochlea.

The contribution of this thesis is summarised as follows: a) the first CMOS weak inversion current domain basilar membrane resonator is designed and fabricated, and b) the first active two-dimensional cochlear model for analog VLSI implementation is developed.

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