

Design of an Analog VLSI Cochlea

A thesis
submitted in partial fulfilment
of the requirements for the degree
of
Master of Engineering
at the
University of Sydney
by

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Sydney, Australia

August 2003

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.

Acknowledgements

First of all, I wish to express my gratitude to Dr André van Schaik, my supervisor, for the guidance and assistance he provided me throughout the three years of my study. He taught me everything from the basics of analog VLSI to cochlear physiology and modelling, opened my eyes to the concept of combining them, and kindly dedicated a lot of time to discussions for extending my understanding. I would also like to deeply thank Dr Craig Jin for his advice and comments, especially on building the active cochlear model.

I am grateful to Associate Professor Simon Carlile and the members of the Auditory Neuroscience Laboratory for their ongoing interest in my research. I also thank Mr Alistair McEwan, for supporting me as a member of the research group.

I would like to thank Dr Neal Williams and Mr Duncan Blair for providing me with information on cochlear cell biology and the nervous system. My thanks also go to Mr Richard Mason, Ms Virginia Best and Dr Andrew Barton for proofreading and giving me comments. I especially thank Mr Roger Butler for his passionate efforts to help me with every detail of this thesis.

I wish to extend thanks to Professor Kazuyuki Aihara for understanding and supporting my wish to study overseas, and Ms Toshie Ogawa for her help with the arrangements to start this research at the University of Sydney. My thanks also go to Dr Tomonari Furukawa for giving me advice on research as well as getting settled in Sydney. Furthermore, I thank all of my friends and my family for their encouragement and support.

Last, but far from least, I would like to thank Christopher Collier for his love, encouragement and never failing belief in me, as well as for organising the printing and binding of this thesis.

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