Preface

Brain–machine interfaces (BMIs) create an artificial pathway between the brain and the external world. BMIs have broad applications in fundamental neuroscience research, neuroprosthetics development, neural disease treatment, and may eventually change the way that humans interact with the world. In the past decade, the research and application of BMIs have received enormous attention from the scientific community as well as the public. However, conventional medical instrumentation used in existing BMI research is not capable of studying the complex and dynamically changing behavior of the brain. Moreover, many neuroscience experiments need to be conducted on freely behaving animals during locomotion and social interaction. The key goal of this book is to address these challenges by the design of next-generation BMIs with innovative solutions from the neuron-electronics interface level up to the system architecture level.

This book provides an introduction to the emerging area of BMIs, with an emphasis on the electrical circuit and system design. This book can help electrical engineers, bioengineers, as well as neuroscience investigators to understand the next-generation bidirectional closed-loop BMIs. Background information, comprehensive surveys and reviews, and design specifications are presented, which will be beneficial for researchers who are new to this area or readers with general interests in this research. In addition, the in-depth discussion of circuit and system design methods, trade-offs, practical issues, and animal experiments will also be valuable for experienced researchers.

Design innovations have been proposed in neural recording front-end (Chap. 2), neural feature extraction module (Chap. 3), and neural stimulator (Chap. 4). Practical design issues of bidirectional closed-loop neural interface (Chap. 5) and overall system integration (Chap. 6) have been carefully studied and discussed. To the best of our knowledge, this work presents the first reported portable system to provide all required hardware for a closed-loop sensorimotor neural interface, the first wireless sensory encoding experiment conducted in freely swimming animals, and the first bidirectional study of the hippocampal field potentials in freely behaving animals. The circuit and system design details are presented with bench testing and animal experimental results. The methods, circuit techniques, system topology, and experimental paradigms proposed in this work can be used in a wide range of relevant neurophysiology research and neuroprosthetics development, especially in experiments with freely behaving animals.

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