

Preface

This textbook is intended for students and engineers who are engaged in the development of power electronic equipment as well as power amplifiers for radio frequency applications using integrated circuits. It covers relevant technological aspects along the value chain from device physics to power electronic and radio frequency applications.

Reading the corresponding chapters, students will get in touch with device, circuit, and application-specific knowledge to get started on projects in power electronics and radio frequency circuits. The citations throughout this textbook will guide the reader to further literature which provides in-depth description of novel technologies, future applications, and relevant device physics. This textbook thus represents a quick way of getting to the core of device-related topics by following its trails to the technologically relevant literature.

For application engineers, the aim of this textbook is to foster the understanding of device physics and gain insights into new developments of integrated power devices. This understanding is fundamental to properly comparing and choosing fabrication technologies suitable for the respective task at hand, decreasing non-conformity costs in new projects and products and reducing time-to-market.

Process and device engineers will find a decent introduction concerning the requirements of power electronic applications. Moreover, it addresses the needs of process and device engineers that are developing new power electronic devices by motivation of relevant circuit considerations and by reviewing important reliability issues. Its aim is to assist in feasibility considerations when designing these devices and circuits by providing insight into the state of the art of integrated circuit solutions and in presenting current trends and developments that may result in emerging technologies over the next decade. Among the wide range of emerging technologies, those presented in this textbook have high potential to be implemented in future integrated circuit technologies.

The textbook describes power electronic applications using integrated circuits from an academic point of view: Given that a full-fledged overview of applications using integrated circuits is beyond the scope of this book, application examples are

selected to provide a conclusive understanding of fundamental requirements inherent to this market.

In summary, the textbook presents a top-down approach from application examples over typical energy conversion and power amplifier circuits down to the lateral power devices, and an in-depth discussion of their ongoing development is given. By review of the present technology on the one hand and of emerging device concepts on the other hand, this textbook is logically divided into two sections: Chaps. 2 through 5 present the current state of the art of applications, circuits and power transistors employed therein. Chapters 6 through 9 explore ongoing developments for lateral power transistors in integrated circuits. Chapter 10 synthesizes the status quo and the emerging technologies to provide insights into potential future applications and solutions.

The introduction presents a brief rundown on the evolution of power electronics and RF applications from an economic perspective. The prospects of these applications in future innovations are discussed, and further demand for the development of the underlying technologies is identified.

In Chap. 2, an introduction to power conversion and RF amplifier applications is presented. After discussion of the impact of these solutions on energy conversion and information technologies, examples of both power electronic and RF amplifier applications are introduced. In order to provide a wide basis for discussion in the subsequent chapters, applications found in a wide range of systems are discussed. Then, the typical requirements for these types of applications are deduced. These requirements form the foundation for the discussion of emerging technologies in the final chapter of this textbook.

Chapter 3 describes circuits for power conversion which are regularly encountered in the aforementioned power electronic applications that can be realized by incorporation of integrated circuits. Moreover, relevant classes of power amplifiers for RF applications are presented here. Discussion of these circuits provides the understanding of requirements that device engineers are typically faced with, when developing new power electronic devices. By combination of the power electronic systems described in Chap. 2 and the circuits used in these applications, important requirements for power semiconductor devices are finally discussed. In order to decide on a suitable fabrication technology, the developer has to understand the benefits and limitations of power devices in integrated circuits in general. Therefore, the requirements are differentiated by considering several applications.

Chapter 4 on power semiconductor devices starts with a summary of so-called “Figures-of-Merit” that are derived from the requirements for systems and circuits listed in Chaps. 2 and 3. These Figures-of-Merit are routinely used to compare different device technologies regarding their applicability for power electronic applications at hand. Next, a rundown of different device topologies that are available for these kinds of applications is provided: The comparison of vertical power MOSFETs, stand-alone RF MOSFETs, and lateral power MOSFETs is used as a basis for the discussion of advantages and limitations when using lateral power MOSFETs in integrated circuits (so-called “smart-power ICs” and “monolithic microwave integrated circuits”).

The history of lateral power transistor development presents the first part of Chap. 5 which deals with modern power device technologies in integrated circuits. In particular, the transition from bipolar junction transistors to MOSFETs is described. In this chapter, the operation principle and design considerations of state-of-the-art lateral power MOSFETs and lateral RF MOSFETs are discussed. Moreover, important device concepts like field and ground plates as well as the “RESURF” principle are explained. Finally, the Figures-of-Merit derived in Chap. 4 are evaluated with respect to the implications arising in these lateral power transistors. Device and circuit designers are provided with a toolset to judge capabilities and limitations of different power transistors. Moreover, this state of the art acts as reference for discussions provided in Chaps. 6 through 10.

In Chap. 6, the progress for incorporation of charge compensation patterns is described. In particular, different device designs employing charge compensation and their respective electrical properties are reviewed. Additionally, integration aspects for implementation in smart-power ICs are considered.

Chapter 7 introduced the implementation of trench gates into lateral power transistors. It considers processing technology for trench gate formation, novel device designs, and electrical properties of lateral trench gate power and RF transistors. Again, feasibility of this approach with respect to implementation in integrated circuits is discussed.

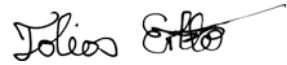
The combination of planar and trench gate topologies is considered as an example of “More-than-Moore” integration in Chap. 8 of this textbook. Integration considerations leading to this development are presented and electrical properties of these devices are discussed. The application of this concept for high output power and high frequency operation are reviewed in particular.

Device concepts based on two wide-bandgap semiconductors are described in the Chap. 9 of this textbook. Firstly, the progress on the development of lateral power transistors in silicon carbide is reviewed with respect to power electronics and RF applications. The current state of the art toward the realization of logic circuitry is discussed. Secondly, the integration of gallium nitride high electron mobility transistors on silicon substrates for radio frequency operation represents a promising yet immature development. To judge its potential for application in integrated circuits, the performance of GaN transistors and the requirements for epitaxial layers are reviewed. Moreover, the status on device reliability of GaN transistors is presented.

The final chapter summarizes the aforementioned device concepts considering Figures-of-Merit and integration density. Additionally, process complexity and costs are investigated. To conclude, these developments are rated regarding the application-specific requirements defined in Chap. 2.

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A handwritten signature in black ink, appearing to read 'Tobias Erlbacher', with a long horizontal stroke extending from the end.

Erlangen, June

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