Mattia Rossi • Nicola Toscani
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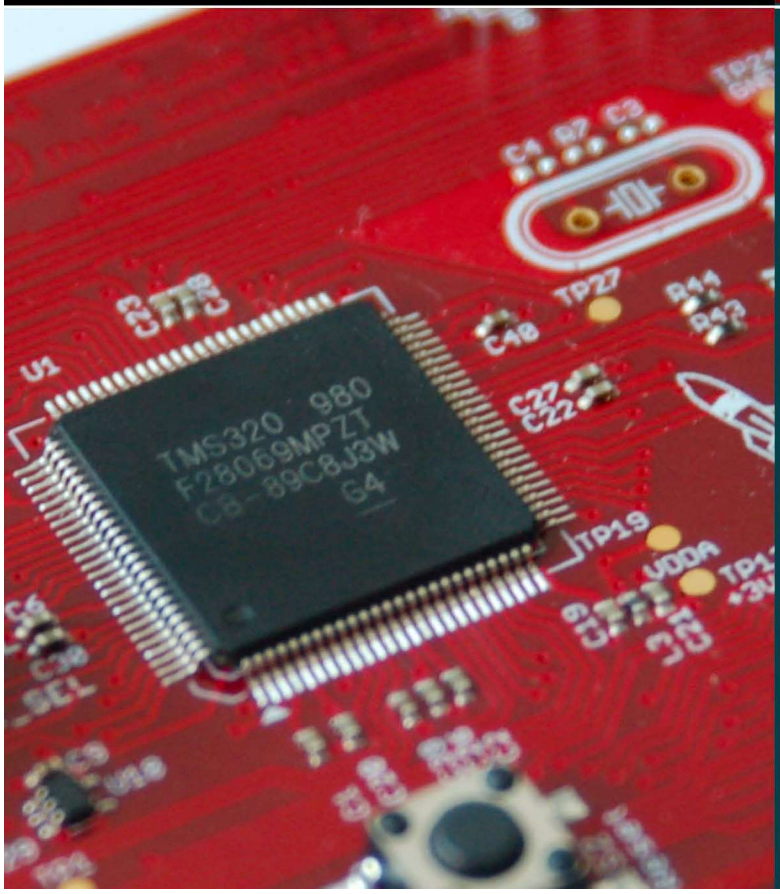
Introduction to Microcontroller Programming for Power Electronics Control Applications

Coding with MATLAB® and Simulink®



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Foreword

The new book *Introduction to Microcontroller Programming for Power Electronics Control Applications* contains the fundamental subjects of the interdisciplinary field of power electronic based systems, which draws knowledge from circuit and control theory, (digital) signal processing for embedded implementation, electrical machines/drives, and power semiconductor devices. Written for students and practicing engineers, this book introduces the analysis and design of motor control systems and their implementation on microcontrollers. The requirements and capabilities of the latter influence the structure and design choice of the closed-loop control scheme, a subject particularly relevant for laboratory activities both at university and industry level. This book presents state-of-the-art techniques to implement modulation schemes and control algorithms in a commercial microcontroller (MCU) suitable for rapid prototyping approach, and hint for designing analog circuits, such as low-voltage converter, output filters/load. MATLAB/Simulink® is introduced and used to solve example problems.

The book presents a concise workflow for the reader by using a specific embedded target, which is not a limiting factor for the validity of the suggested approach. The latter can be extended even to different boards. It is valuable to every graduate student, serving as a textbook for classes (looking to create teamwork) and as a starting point for more advanced studies, for industry professionals, researchers, and academics willing to study the broad field of power electronics. The contents of the book are easy to read and presented in an interesting way with good illustrations and solid background on the underlying theory. Solved problems (built-in files) are presented to help the readers.

Introduction to Microcontroller Programming for Power Electronics Control Applications is unique in the synthesis of the main characteristics of electrical drive behavior and in their link to the main implementation aspect into modern MCU, trying to fill the gap between system/circuit design, control techniques, and digital signal processing. The authors are power electronics and drives specialists from the Electrical Machines, Drives and Power Electronics Research Group of Politecnico di Milano, Italy. They collected in the book the several years of teaching and subjects of the laboratory activities for

the M.Sc. in Automation and Control Engineering and Electrical Engineering at the same university, with the collaboration and contribution of industrial partner. As industrial partners, we retain this book a great achievement of the last four years collaboration with the authors.

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Most people go about their day blissfully unaware of the electric motors that are spinning the world around us. We wake up staring upwards at a ceiling fan, silently rotating in a circle. We jump into our car and rely on up to 40 motors—pumps, fans, locks, and lifts—to get us to our destination. We power up our laptop computers and hear the soft whine of fans working to keep the electronics cool. Motors are everywhere because they are one of the main ways that an electronic circuit can interact with the real world, i.e. a power electronic-based system. They are "lectromechanical, turning analog and digital signals into real and visible mechanical motion. It is estimated that electric motors consume 45 percent of the total worldwide electricity—this is a stunning statistic! As we look to reducing energy consumption and enabling a greener future, electric motors present a huge potential for efficiency improvements.

Few engineering students are aware of the impact of electric motors on the world around them, and even less are versed in the design and control of motor systems. This is a problem! We need engineers growing in competency in this field to create better and more efficient motor drive systems.

Motor drive and control is an incredibly multidisciplinary field. Real-time digital processing is implemented in microcontrollers to be the "brain" behind the motor system; controlling speed, power, and efficiency from the digital domain. A wealth of analog components from power management (voltage regulators & gate drivers) and signal chain (amplifiers & sensors) interface the microcontroller to the motor through a power converter while providing sensing, safe operation, and support for the system. Texas Instruments has over 25 years of experience in the field of real-time control and also provides

Texas Instruments Incorporated (Nasdaq: TXN) is a global semiconductor company that designs, manufactures, tests and sells analog and embedded processing chips for markets such as industrial, automotive, personal electronics, communications equipment and enterprise systems. Our passion to create a better world by making electronics more affordable through semiconductors is alive today, as each generation of innovation builds upon the last to make our technology smaller, more efficient, more reliable and more affordable—making it possible for semiconductors to go into electronics everywhere. We think of this as Engineering Progress. It is what we do and have been doing for decades. Learn more at www.ti.com.

a comprehensive analog portfolio covering every block of the motor drive and control system.

This book presents very practical and important lessons to engineers and engineering students alike on the topics of motor drive and control, covering not only general concepts but details on how to create a motor drive system. It provides an excellent resource to encourage the next generation of engineers to grow and develop skills in the area of electric motors and power electronics, introducing them the tools they need to make an impact on the world.

Politecnico di Milano is an outstanding academic partner, and the focus of the *Electrical Machines, Drives and Power Electronics Research Group* on cutting-edge power electronic-based technologies helps shape quality engineering minds. We wish the best of success to this publication and to the continued collaboration between industry and academia.

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Can you write the 100 million lines of code that are needed to build an average modern car? The answer is pretty obvious: of course you can, it's just a matter of time. And how would you compare the complexity of this problem to writing the 4501 lines of assembly code needed to build the first version of UNIX in 1971? While both tasks appear to be at a similar level of dauntlessness, the half century separating them has witnessed the emergence of high-level languages that enable programmers to address highly complex problems on their own while reusing the legacy of their peers.

At MathWorks Inc., we relentlessly work on providing the best high-level programming tools to automate the implementation of your ideas into embedded systems. Simulink allows you to design and simulate complex algorithms that you can translate into thousands of lines of embedded code with a click of a button via our code generation technology.

The book *Introduction to Microcontroller Programming for Power Electronics Control Applications* will teach you how to use these modern techniques to create control algorithms for systems involving complex physics. The remarkable work of *Mattia Rossi, Nicola Toscani, Marco Mauri* and *Francesco Castelli Dezza* from Politecnico di Milano, Italy, clearly explains deep concepts to the reader in the field of embedded programming for power electronics applications using Model-Based Design.

While the shift to digital is now largely dominating the industry of motor control, this revolution is just starting for power conversion applications. The material in this book provides state of art techniques to train the many engineers that the world needs tomorrow in a field that is at the core of the indispensable transition to clean energy.

In recent conversations with *Mattia* and *Nicola*, while they politely thanked us for our help, it was clear to us that the quality and the amount of effort in this book deserved much more thanking from our side. With this foreword, we extend all our gratitude to this outstanding contribution to accelerating the pace of engineering and science, our core mission.

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