POWER ELECTRONICS



ABOUT THE AUTHORS

Ned Mohan is a professor in the Department of Electrical Engineering at the University of Minnesota, where he holds the Oscar A. Schott Chair in Power Electronics. He has worked on several power electronics projects sponsored by the industry and the electric power utilities, including the Electric Power Research Institute. He has numerous publications and patents in this field.

Tore M. Undeland is a Professor in Power Electronics in the Faculty of Electrical Engineering and Computer Science at the Norwegian Institute of Technology. He is also Scientific Advisor to the Norwegian Electric Power Research Institute of Electricity Supply. He has been a visiting scientific worker in the Power Electronics Converter Department of ASEA in Vaasteras, Sweden, and at Siemens in Trondheim, Norway, and a visiting professor in the Department of Electrical Engineering at the University of Minnesota. He has worked on many industrial research and development projects in the power electronics field and has numerous publications.

William P. Robbins is a professor in the Department of Electrical Engineering at the University of Minnesota. Prior to joining the University of Minnesota, he was a research engineer at the Boeing Company. He has taught numerous courses in electronics and semiconductor device fabrication. His research interests are in ultrasonics, pest insect detection via ultrasonics, and micromechanical devices, and he has numerous publications in this field.



POWER ELECTRONICS

Converters, Applications, and Design

SECOND EDITION

NED MOHAN

Department of Electrical Engineering University of Minnesota Minneapolis, Minnesota

TORE M. UNDELAND

Faculty of Electrical Engineering and Computer Science Norwegian Institute of Technology Trondheim, Norway

WILLIAM P. ROBBINS

Department of Electrical Engineering University of Minnesota Minneapolis, Minnesota



JOHN WILEY & SONS, INC. New York Chichester Brisbane Toronto Singapore



Acquisitions Editor Steven M. Elliot Developmental Editor Sean M. Culhane Marketing Manager Susan Elbe Senior Production Editor Savoula Amanatidis Text Designer Lynn Rogan Cover Designer David Levy Manufacturing Manager Lori Bulwin Illustration Coordinator Jaime Perea

This book was typeset in Times Roman by The Clarinda Company, and printed and bound by Hamilton Printing Company. The cover was printed by NEBC.

Recognizing the importance of preserving what has been written, it is a policy of John Wiley & Sons, Inc. to have books of enduring value published in the United States printed on acid-free paper, and we exert our best efforts to that end.

PSpice is a registered trademark of MicroSim Corporation. MATLAB is a registered trademark of The MathWorks, Inc.

Copyright © 1989, 1995 by John Wiley & Sons, Inc.

All rights reserved. Published simultaneously in Canada.

Reproduction or translation of any part of this work beyond that permitted by Sections 107 and 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons, Inc.

Library of Congress Cataloging in Publication Data:

Mohan, Ned.

Power electronics: converters, applications, and design / Ned Mohan, Tore M. Undeland, William P. Robbins.—2nd ed. p. cm.
Includes bibliographical references and indexes.
ISBN 0-471-58408-8 (cloth)
1. Power electronics. 2. Electric current converters. 3. Power semiconductors. I. Undeland, Tore M. II. Robbins, William P. III. Title.
TK7881.15.M64 1995

621.317—dc20 94-21158 CIP

Printed in the United States of America.



To Our Families . . .

Mary, Michael, and Tara

Mona, Hilde, and Arne

Joanne and Jon



DOCKET

Explore Litigation Insights



Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time** alerts and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

