EMC AND THE PRINTED CIRCUIT BOARD

IEEE Press
445 Hoes Lane, P.O. Box 1331
Piscataway, NJ 08855-1331

IEEE Electromagnetic Compatibility Society, *Sponsor*
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Design, Theory, and Layout Made Simple

Mark I. Montrose
Montrose Compliance Services, Inc.

IEEE Electromagnetic Compatibility Society, *Sponsor*

IEEE Press Series on Electronics Technology
Robert Herrick, *Series Editor*

IEEE
The Institute of Electrical and Electronics Engineers, Inc., New York

WILEY-INTERSCIENCE
A JOHN WILEY & SONS, INC., PUBLICATION
New York • Chichester • Weinheim • Brisbane • Singapore • Toronto

For ordering and customer service, call 1-800-CALL-WILEY.
Wiley-Interscience-IEEE **ISBN 0-7803-4703-X**

Printed in the United States of America.
10 9 8 7 6

Library of Congress Cataloging-in-Publication Data

Montrose, Mark I.
EMC and the printed circuit board : design, theory, and layout made simple / Mark I. Montrose.
p. cm. — (IEEE Press series on electronics technology)
"IEEE Electromagnetic Compatibility Society, sponsor."
Includes bibliographical references and index.
ISBN 0-7803-4703-X (alk. paper)
1. Printed circuits—Design and construction. 2. Electromagnetic compatibility. I. IEEE Electromagnetic Compatibility Society. II. Title. III. Series.
TK7868.P7M65 1998
621.3815'31—dc21 98-35408
CIP

To my family

Margaret,

Maralena,

and Matthew

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Preface

EMC and the Printed Circuit Board: Design, Theory, and Layout Made Simple is a companion book to *Printed Circuit Board Design Techniques for EMC Compliance.* When used together, these two books cover all aspects of a PCB design as it relates to both time and frequency domain issues. One must be cognizant that if a PCB does not work as intended in the time domain, frequency domain concerns become irrelevant, especially compliance to international EMC requirements. Time and frequency domain aspects must be considered together.

The intended audience for this book is the same as that for *Printed Circuit Board Design Techniques for EMC Compliance:* those involved in logic design and PCB layout; test engineers and technicians; those working in the areas of mechanical, manufacturing, production, and regulatory compliance; EMC consultants; and management responsible for overseeing a hardware engineering design team.

Regardless of the engineer's specialty, a design team must come up with a product that not only can be manufactured in a reasonable time period, but will also minimize cost during design, test, integration, and production. Frequently, more emphasis is placed on functionality to meet a marketing specification than on the need to meet legally mandated EMC and product safety requirements. If a product fails to meet compliance tests, redesign or rework may be required. This redesign significantly increases costs, which include, but are not limited to engineering manpower (along with administrative overhead), new PCB layout and artwork, prototyping material, system integration and testing, purchase of new components for quick delivery (very expensive), new in-circuit test fixtures, and documentation. These costs are in addition to loss of market share, delayed shipment, loss of customer faith in the company (goodwill), drop in stock price, anxiety attacks, and many other issues. Personal experience as a consultant has allowed me the opportunity to witness these events several times with small startup companies.

My main focus as a consultant is to assist and advise in the design of high-technology products at minimal cost. Implementing suppression techniques into the PCB design saves money, enhances performance, increases reliability, and achieves first-time compliance with emissions and immunity requirements, in addition to having the product function as desired.

Working in this industry has allowed me to participate in state-of-the-art designs as we move into the future. Although my focus is on technology of the future, one cannot forget that simple, low-technology products are being produced in ever increasing numbers. Although the thrust of this book is toward high-end products, an understanding of the fundamental concept of EMC suppression techniques will allow *any* PCB being designed to pass EMC tests. The key words here are "fundamental concepts." When one does not understand fundamental concepts, compliance and functional disaster may await.

When management decides to bring in a consultant after production has started, having failed an EMI test, causing a stop-ship situation, it is too late for efficiency. Generally, nothing can be done without major expenses being incurred. I have watched small companies go bankrupt because they invested all their capital in a product for quick shipment and then had to redesign everything from scratch. Those who control the finances of a company by mandating cost over compliance have frequently been spotted working at a different company every year. Accountants who do not understand what it takes to be a hardware or PCB designer engineer can doom a company to failure.

Sometimes, use of a single component (filter) costing $0.50 is too much for management to accept on a $1000 product. Engineers may be able to implement a redesign to prevent use of this inexpensive filter. This redesign may cost the company tens of thousands of dollars (including new compliance tests) for a production build of a few hundred units. Although the accountant may receive bonus pay for keeping the cost of the PCB down, the Return-On-Investment (ROI) will never be achieved. I do not advocate adding cost to a design unless it is mandatory. High-technology products now require use of additional power and ground planes, filter components, and the like, all at a cost for both functionality and compliance.

Detailed definitions of various terms are presented within specific chapters of this book. Before we proceed, an important distinction is in order. EMC stands for Electromagnetic Compatibility. This means that electrical equipment must work within an intended environment. We can have EMI (Electromagnetic Interference) problems due to incompatibilities between equipment. EMC is *achieved;* EMI *occurs.* According to common usage, EMC refers to the total discipline concerned with achieving electromagnetically compatible equipment and systems. EMI refers to the event or episode indicating an incompatibility, for example, a *lack* of EMC. EMI refers to all events experienced across the frequency spectrum. Radio Frequency Interference (RFI) originally referred to those incompatibilities arising between radio sets. During the 1970s and 1980s, RFI was generally not used because it failed to indicate the problems that can arise from Electromagnetic Pulse (EMP), lightning, Electrostatic Discharge (ESD), and so on. Over the past few years, however, RFI has been creeping back into our vocabulary. Caution should be used with the acronym RFI, however, for its meaning is unclear in the field of EMC.

The main differences between my two books on EMC and PCBs are as follows.

Printed Circuit Board Design Techniques for EMC Compliance provides information for those who have to get a product designed and shipped within a reasonable time frame and within budget. It illustrates that a PCB may exhibit an EMI problem, it briefly explains why the problem occurs, and it shows how to solve the design flaw during layout. It does not go into detail on how and why EMI occurs, theoretically.

University textbooks are available (listed in the References sections) that cover all aspects of theoretical physics related to EMC. Numerous other publications present EMC concepts in a brief manner, giving just enough detail to make one aware of theory with minimal mathematical analysis. Many managers and some engineers do not care about why something happens. *Printed Circuit Board Design Techniques for EMC Compliance* has compiled a track record of successful results.

EMC and the Printed Circuit Board: Design, Theory, and Layout Made Simple is a companion book targeted at those designers who want to know how and why EMI occurs within a PCB. These designers may not be directly responsible for the actual PCB layout, but they may have to oversee the end product. Engineers generally want to understand technical concepts. This book is written for ease of understanding a subject that is generally not taught in universities or other educational environments, again using a minimal amount of math.

In the present book, we examine two sides of the coin—time domain (signal functionality and quality) and frequency domain (EMC). A signal that is present within the PCB may be viewed in both domains. No difference exists between the two; rather, only the way one examines a signal. Test instrumentation also differs. Chapter 2 illustrates using simplified physics, with minimal mathematical analysis, how these two domains exist simultaneously. Theory is presented in a format that is easy to comprehend in the limited time one has to read and study a book on EMC and PCB, especially when work needs to be done at the office.

The focus of this book is *strictly* on the PCB. Discussion of containment techniques (box shielding), internal and external cabling, power supply design, and other system-level subassemblies that use PCBs as subcomponents will not be discussed in depth. Again, excellent reference material is listed in the References on these aspects of EMC system-level design engineering.

The incentive for writing this book has come from my numerous seminar and workshop students in the United States, Europe, and Asia. These students ask, "How and why does EMI get developed within a PCB?" Recognizing a need to fill a gap that currently does not exist within the published literature in the public domain worldwide (at time of writing), I want to enlighten the reader to a field of engineering that is considered to be a *Black Magic* art. Those who do not take electromagnetic compatibility seriously provide job security for EMC engineers. EMC engineers know various tricks of the trade on how to apply rework or a quick fix to a PCB to pass a particular test. These under-the-pressure enhancements implemented during compliance testing are identified as *Band-Aid* techniques. These PCBs could have been designed properly from the start. The concept advanced is to change design habits and thinking from Band-Aids to low-cost suppression layout techniques during the design cycle.

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Acknowledgments

I want to acknowledge the following individuals who played a part in the review cycle of this book.

Bill Kimmel and Daryl Gerke, Kimmel & Gerke Associated, Ltd., both of whom performed a thorough and technical review not only of this book, but also *Printed Circuit Board Design Techniques for EMC Compliance.* As always, both gentlemen provided excellent input to ensure accuracy.

Elya B. Joffe, K.T.M. Project Engineering, Ltd., Israel, who was a technique reviewer scrutinizing everything for accuracy, in addition to providing numerous comments in the interest of enhancing the reader's ability to understand complex concepts.

Bob Herrick, Department of Electrical Engineering, Purdue University, who as editor of the IEEE Press Series on Electronic Technology, served as my direct interface with IEEE Press.

David Angst, TCAD, provided a sanity check on the time-domain portion of this book.

William Hubbard, Department of Electrical Engineering, Purdue University, for a comprehensive review on all subject matter.

Norm Violette, Violette Engineering Corporation, who performed a technical review and also provided insights into unique aspects of EMC theory with a different point of view.

Hugh Denny, Georgia Technical Research Institute, who as the IEEE EMC Society's liaison to IEEE Press, and a technical reviewer, took me to task on various issues presented to guarantee the accuracy of my discussions.

Hans Melberg, EMC Consultant, who gave me my first opportunity to document my knowledge of EMC and PCBs into written form at Wyse Technology. This document inspired me to write my first book, *Printed Circuit Board Design Techniques for EMC Compliance.*

A special acknowledgment is given to W. Michael King, my mentor in the field of EMC. Without his friendship, expertise, and the ability to teach me complex aspects of EMC, along with providing a comprehensive technical review of the material, this book could not have been written.

My most special acknowledgment is to my family. Margaret, my wife, and my two children, Maralena and Matthew. After surviving the time and effort it took me to write my first book, my family stood by me again as I spent months to write another. Their understanding and support are beyond belief.

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