Signal Integrity

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Applied Electromagnetics and Professional
Practice

Springer

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Introduction

Why Study This Subject?

It is my hope that this book will help the reader understand *applied electromagnetics*. The book will be getting into some fairly complicated and very abstract topics, but remember – the emphasis will be on the practical or “applied” aspects of the subject.

Have you ever wondered why the flight attendant tells you to turn off your cell phone at takeoff? Have you ever wondered how your hard drive talks to your computer at 3 gigabits per second over a very thin cable? How did the company that makes your computer’s processor get it to work at 3 GHz?

All of these daily examples are part of the world of *signal integrity*. Signal integrity is the science (and art) of designing systems that carry signals intact over distance and that do not interfere with each other. The subject lies at the intersection of electromagnetics and computer engineering, and so understanding it is vital for computer engineers in the gigahertz era.

Why This Book?

One may wonder whether a textbook like this is worth the cost. In the case of this book, it turns out there are two good reasons. First, this subject is extremely important and rarely taught in college. So this book is not only what students will use to take this class, it can also become a permanent part of a technical bookshelf and might even bail you out if you get stuck on a signal integrity issue. This book is designed specifically for that purpose – the technical bailout. Second, the book has plenty of examples and some real-world testimonials based on my own experiences.

Why Are We Here, and Where Is “Here”?

The twin revolutions of computing and communications have achieved the dream of a world with nearly instantaneous access to all corners of the globe and with a seemingly limitless body of knowledge at our fingertips. All of this was brought about through the hard work of roughly three generations of electrical and computer engineers who developed the computer chips, interconnections, and communications systems that made it all possible.

As the twin revolutions were unfolding in the 1995 time frame (right about the time the World Wide Web was launched), clock frequencies and data rates nudged up into hundreds of megahertz. (I still remember my whopping 90 MHz Pentium computer.)

At this point, a very crucial change occurred.

It turns out that there are two ways of thinking about a wire. One can use a “lumped” approximation and assume the wire is a zero ohm resistor with the same voltage at every point, or one can use a “distributed” approximation and assume the wire has inductance and can have different voltages at different points.

When the 100 MHz barrier was crossed, wires on computer motherboards stopped being wires (in the lumped sense) and started becoming transmission lines (i.e., distributed wires).

The only way to design systems today that work correctly is to use distributed analysis. This is the traditional domain of electromagnetics experts. Computer engineers literally need to know most of the methods that were used to design microwave systems back in the 1960s. This is where we are today – in a world that must be modeled using distributed analysis.

This book will teach how to convert fluently between frequency, time, and distance. This book will then teach how signals propagate, how they interfere, what can go wrong, and how to fix it. The focus in this book is on the design of real-world systems using physical principles and in cultivating an engineering intuition based on physics and measurements. Along the way, the book also looks at the design of digital systems from a manager’s perspective so you can both be a better informed engineer and become a successful manager one day (if you want to).

What makes digital design challenging? I think the challenge lies in three very common ingredients. First, digital designs are almost always cost-constrained, especially consumer items like MP3 players. Second, the increasing clock speeds (more accurately, the faster rise and fall times) make the design more complicated because everything has to work up to higher frequencies. Third, there is a considerable time-to-market pressure in the fast-changing world of computer engineering. (Did you know that Motorola lost to Intel when IBM designed the first PC because the Motorola processor was 6 months late? A 6-month slip in schedule forever changed the microprocessor landscape!) You have to get the design working and into mass production quickly, without much time to make or fix mistakes.

So, armed with this book, students and professionals can embark on successful digital designs.