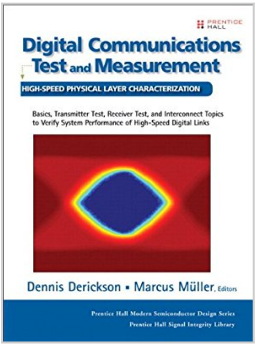

Digital Communications Test and Measurement: High-Speed Physical Layer Characterization (paperback) (Prentice Hall Modern Semiconductor Design Series: Prentice Hall Signal Integrity Library)

By Dennis Derickson, Marcus Müller

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A Comprehensive Guide to Physical Layer Test and Measurement of Digital Communication Links

Today's new data communication and computer interconnection systems run at unprecedented speeds, presenting new challenges not only in the design, but also in troubleshooting, test, and measurement. This book assembles contributions from practitioners at top test and measurement companies, component manufacturers,and universities. It brings together information that has never been broadly accessible before—information that was previously buried in application notes, seminar and conference presentations, short courses, and unpublished works.

Readers will gain a thorough understanding of the inner workings of digital high-speed systems, and learn how the different aspects of such systems can be tested. The editors and contributors cover key areas in test and measurement of transmitters (digital waveform and jitter analysis and bit error ratio), receivers (sensitivity, jitter tolerance, and PLL/CDR characterization), and high-speed channel characterization (in time and frequency domain). Extensive illustrations are provided throughout.

Coverage includes

- Signal integrity from a measurement point of view
- Digital waveform analysis using high bandwidth real-time and sampling (equivalent time) oscilloscopes

- Bit error ratio measurements for both electrical and optical links
- Extensive coverage on the topic of jitter in high-speed networks
- State-of-the-art optical sampling techniques for analysis of 100 Gbit/s + signals
- Receiver characterization: clock recovery, phase locked loops, jitter tolerance and transfer functions, sensitivity testing, and stressed-waveform receiver testing
- Channel and system characterization: TDR/T and frequency domain-based alternatives
- Testing and measuring PC architecture communication links: PCIexpress, SATA, and FB DIMM

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- Rank: #1795855 in Books
- Published on: 2007-12-20
- Original language: English
- Number of items: 1
- Dimensions: 9.10" h x 1.50" w x 7.10" l, 3.35 pounds
- Binding: Paperback
- 976 pages

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Editorial Review

About the Author

Dennis Derickson is an assistant professor at California Polytechnic State University. He spent eighteen years as member of technical staff and project manager at Hewlett-Packard and Agilent Technologies before serving as applications engineering manager for Cierra Photonics. He has authored or coauthored fifty publications in high-speed communications and is the editor of Fiber Optic Test and Measurement (Prentice Hall, 1998). Dennis has a Ph.D. from the University of California, Santa Barbara.

Marcus Müller is an R&D lead engineer with Agilent Technologies' High-Speed Digital Test segment in Boeblingen, Germany. He specializes in bit error ratio and jitter analysis of high-speed links, and has contributed to new methods for total jitter measurement at low bit error ratios, and jitter tolerance test. Marcus received his M.Sc. degree from Stuttgart University, Germany, in 1999.

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Purpose of the Book

An example of a digital communications link is an integrated circuit (IC) sending binary-level data to another receiving IC through a microstrip transmission line trace in an FR4 printed circuit board environment. At low data rates that do not challenge the performance edge of communication components, designs are robust. At data rates of 10 Gbit/s (now common in the industry), interrelated design issues in the transmitter, the communication channel, and the receiver become more pronounced.

The engineering design effort in the area of high-speed digital links has been extensive. A field called signal integrity has been identified to help high-speed digital designers understand high-frequency design issues. The ultimate goal is to require fewer design cycles during product development. There are many excellent books in the area of signal integrity for digital communications systems (see the References section in Chapter 1 for a listing of recommended books). This book tackles one important subset of this broad signal integrity field: test and measurement techniques, especially for very high speed systems. It focuses on descriptions of test instrumentation hardware, theory of operation, and applications to digital communications links. The topic of jitter in digital systems is covered extensively.

The primary topics for high-speed physical layer characterization are the following:

- Bit error ratio measurement
- High-speed digital waveform analysis
- Jitter in digital data streams
- Receiver testing
- Characterization of the physical interconnection structures

It became clear to the authors of this book that there was not a good single source of reference information on the topic of digital communications test and measurement for the physical layer, and thus this book came into existence. The work combines the collective experience of authors from leading test and measurement organizations (Agilent, Circadiant, and Tektronix), component manufacturers, and university settings. The material in this book has been developed from application notes, seminars, conference presentations, short courses, and unpublished works from the last ten years. Test and measurement equipment companies as well as semiconductor manufacturers and even standards committees are producing a steady stream of application notes on selected high-speed digital test and measurement topics. These notes are often product oriented, and one must draw from a large number of sources to piece together a cohesive coverage of the topic. Much of the material has not had wide circulation to date. A trusted reference has been missing, and this work intends to fill this gap. This book takes the expertise gathered by test and measurement authors that was previously scattered in many places and puts it under a single cover.

This book will be useful for technicians, engineers, and scientists who are involved in the digital communications industry or need to learn about it. The book is designed to address the needs of people new to the field and those intimately familiar with it. Digital communications engineers and technicians spend a good fraction of their lives characterizing their system, subsystem, and component performance. This book serves as a reference that adds cohesion to the wide range of topics that must be understood to succeed in system characterization.

The coverage emphasizes an understanding of how the digital system works, how the test and measurement system is connected, and how an instrument does its job. Understanding instrument architectures and operation gives additional insight on limitations and flexibility of the measurements that can be performed. The book also provides insight into the characteristics of the devices under test. Illustrations are intentionally numerous because the authors believe that visual communication of information is how many people receive information most efficiently.

Organization of Contents

The book is organized around the architecture of a simple digital communications link consisting of a transmitter, a receiver, and a channel. Chapters 1-3 give an introduction that provides background needed to understand later chapters in the book. Chapters 4-8 cover transmitter testing, Chapters 9-12 cover receiver testing, and Chapters 13-15 address characterization of the communication channel and internal computer communications links.

Introduction Chapters

Chapters 1-3 provide a general introduction to digital communications and digital communications systems. These chapters offer a series of definitions, concept descriptions, and specific examples of digital communications link topics. They serve as a foundation for understanding the test and measurement chapters that follow.

Chapter 1 (general introduction): This chapter gives an overview of high-speed digital communications systems. The goal is to set a framework for the more detailed chapters that follow. This chapter also introduces terminology used in the rest of the book.

Chapter 2 (jitter introduction): Jitter is a pressing design problem in high-speed systems. This topic has also seen a large development effort by test and measurement companies in the last five years. Jitter is an extensive subject area and deserves its own introduction.

Chapter 3 (communications link examples): This chapter provides specific discussions on selected serial digital communications links. One often needs to understand some detail of the higher-level system definition and performance even when testing is done on the physical layer.

Transmitter Characterization Chapters

Chapters 4-8 address the characterization of the transmitter portion of a digital communications link.

Chapter 4 (bit error ratio testing): A fundamental property of a digital communications link is the bit error ratio (BER), which is the number of bit errors divided by the total number of bits sent. This chapter along with Appendix A provides a detailed description of the test hardware and test methodology for BER.

Chapter 5 (bit error ratio scanning): This chapter describes techniques to find the system bit error ratio as a function of the digital decision threshold settings in time and voltage. One can obtain information on the signal-to-noise margin that is present in a digital link by scanning the decision thresholds. This can be very time consuming, and considerable discussion is given on performing measurement scans in a reasonable time period.

Chapter 6 (real-time oscilloscopes): This chapter covers high-speed waveform measurements based on real-time oscilloscope architectures. Here very fast analog-to-digital converters (now up to 40 GSamples/s) provide time snapshots of digital waveform segments. Advanced jitter measurement capabilities are described in detail.

Chapter 7 (equivalent-time sampling oscilloscopes): Very high speed waveforms can be reconstructed by a sampling process where data points are taken less frequently compared to real-time oscilloscopes. The sampling architectures and unique instrument capabilities are discussed in detail in this chapter. Finally, applications in digital waveform analysis and jitter component decomposition are given.

Chapter 8 (all-optical sampling oscilloscopes): This chapter departs from the earlier ones in that it concentrates on forward-looking optical sampling techniques that will allow viewing of high-speed optical signals such as 40 Gbit/s data streams with high sensitivity and waveform fidelity. Test and measurement equipment with several hundred gigahertz of bandwidth is now becoming available.

Receiver Characterization Chapters

Chapters 9-12 highlight concepts and measurements for the receiver in a digital communications link.

Chapter 9 (digital clocks, clock recovery, and phase locked loops): This chapter first outlines the characteristics of oscillators used as reference clocks in digital systems. It then analyzes clock recovery circuits using phase locked loops. Finally, this chapter gives the critical measurement parameters used to characterize clock recovery circuits.

Chapter 10 (receiver jitter tolerance characterization): This chapter covers the basic hardware, test methods, and setup for characterizing the jitter tolerance performance for receivers.

Chapter 11 (digital optical receiver sensitivity testing): This chapter develops topics related to the testing of digital optical receivers. It addresses uncertainty values in the bit error ratio measurement and gives data-plotting strategies.

Chapter 12 (stressed receiver testing): Standards groups have specified that receivers be tested with controlled signal degradations. This stressed testing method allows the receiver to be characterized in a more realistic signal environment.

Channel and System Characterization Chapters

Chapters 13 and 14 highlight test techniques for the interconnecting transmission line structures for digital links. Both frequency domain and time domain characterization techniques are given. Chapter 15 covers the specific topic of link characterization for internal computer communication functions.

Chapter 13 (time domain reflectometry TDR and time domain transmission TDT): This chapter covers time domain methods for characterizing the propagation of a signal from the transmitter to the receiver. Step-by-step analysis techniques are given to interpret TDR/TDT displays. Advanced measurement software can also be used to create a discontinuity model for the channel.

Chapter 14 (frequency domain measurements): Frequency domain techniques can be used to obtain the same information as traditional TDRs/TDTs with several other modes of operation. This method is contrasted against the direct time domain measurements discussed in Chapter 13. Several examples of measurement applications are given.

Chapter 15 (communications links inside the PC computer archite...

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