Seminar 32

SIGNAL INTEGRITY

TUTORIAL ON ECHO AND CROSSTALK IN PRINTED CIRCUIT ASSEMBLIES AND MULTI-CHIP MODULES

Tutorial presentation: This tutorial explains many different techniques for controlling crosstalk and echo in printed circuit assemblies and multi-chip modules. The first part of the tutorial presents propagation models based on transmission line (TL) theory and multiconductor transmission line (MTL) theory. In a second part, this theoretical framework is used to describe and analyze most known techniques for reducing crosstalk and echo in a uniform multiconductor interconnection. The following schemes are considered: multiple single-ended links, multiple differential links, links implementing modal transmission schemes and multichannel pseudo-differential links.
Who should attend: R&D and signal integrity engineers and researchers concerned by the reduction of echo and crosstalk in dense interconnections for wide-band signals. We assume that the participants are familiar with basic signal integrity concepts and results.
Observations: The course uses basic matrix algebra. Our Seminar 33 is an advanced sequel to this course. The lecture slides are available on line, as a free electronic book (see below).
Duration: 1 day.

SEMINAR OUTLINE

Part A — Propagation models

1. **Introduction and definitions**
   Discussion of interconnection models.
   Assumptions and definitions used throughout this course.

2. **The 2-conductor transmission line in the frequency domain**
   The telegrapher's equations for two conductors.
   Description of propagation in the frequency domain.

3. **Problems involving a TL and linear terminations**
   Voltage reflection coefficients.
   Matched terminations.
   Frequency domain analysis of lossless or lossy transmission lines.
   Time domain analysis and eye diagram.

4. **Telegrapher's equations of a uniform MTL and modal decomposition**
   The telegrapher's equations of a uniform MTL.
   Modal decomposition.

5. **The characteristic impedance matrix**
   The modal characteristic impedance matrix.
   The characteristic impedance matrix.
   The special case of the lossless MTL.

6. **Biorthonormal eigenvectors and associated eigenvectors**
   Biorthonormal eigenvectors.
   Associated eigenvectors.

7. **The choice of eigenvectors and total decoupling**
   Total decoupling.
   Common misconceptions on eigenvectors.
   Examples.

8. **Propagation in the frequency domain**
   Description of propagation using modal voltages and currents.
   Description of propagation using natural voltages and currents.

9. **Matched termination circuit and pseudo-matched terminations**
   Matrix of the voltage reflection coefficients.
   Matched terminations.
   Pseudo-matched impedances.

10. **Problems involving an MTL and linear terminations**
    Possible approaches.
    A general solution.
    Example of frequency domain and time domain analysis.

Part B — Techniques for reducing crosstalk and echo

11. **The degradation of transmitted signals**
    Echo, internal crosstalk, NEXT and FEXT.
    External crosstalk.
    Model for ground shift or noisy ground.
    Other causes of external crosstalk.
    Ground bounce, power bounce and simultaneous switching noise.

12. **Single-ended parallel links**
    Single-ended transmission and the underlying model.
    Possible models for a preliminary link design.
    The weak coupling approximation.
    Crosstalk mitigation approaches.
    Discussion.

13. **Multichannel differential links**
    Balanced pair and perfectly balanced pair.
    Modal analysis of a single pair.
    Differential-mode and common-mode characteristic impedances.
    Perfectly balanced interconnection.
    Differential transmission and the underlying model.
    Modes of a perfectly balanced interconnection.
    Possible models for a preliminary link design.
    Discussion.

14. Modal signaling

Principle of modal signaling.
Simplified definition of the ZXtalk method.
Consequences and limitations of the simplified definition..
A general definition of the general ZXtalk method.
Terminations for the ZXtalk method.
The 8 possible designs and the propagation of signals.
Applicability to non-uniform interconnections.

15. Modal signaling in a decoupled interconnection

Completely degenerate interconnections.
Decoupled interconnections.
The special ZXtalk method.
The 8 possible designs and the propagation of signals.
Using a MIMO series-series feedback amplifier.
Discussion.

16. Pseudo-differential links

The reduction of external crosstalk in a pseudo-differential link.
The four possible pseudo-differential link architectures.
Termination circuits and compatible interconnection-ground structures.
The telegrapher's equations for pseudo-differential transmission.
The ZXnoise method.
The 12 pseudo-differential transmission schemes.

Download the lecture slides

Contact us: eclavelier@eurexcem.com