System Design to Achieve EMC – PCB and System Level

(Two and Three Day Seminar Options)

Introduction

This course is an inclusive tutorial that covers the fundamentals of designing a product to meet EMC. There are many areas of concern not just at the printed circuit board level, but also mechanical packaging and external interconnects. In order to be compatible within its intended operating environment, we must design systems to stringent requirements without generally understanding how and whys things work since electromagnetic theory is complex and the math unbearable for many.

In order to be a successful, one must design and manufacture a product in a short period of time. Performing experiments using trail and error or locating and reading technical papers takes valuable time. Engineers need to understand fundamental concepts and be able to implement design requirements quickly. Once the designing is completed, simulation analysis can then be performed.

For the two day version, topics include:
A review of electromagnetic fundamentals; electrical noise concepts, transmission line theory (signal integrity); EMC suppression concepts for printed circuit boards; clocks, impedance control and trace routing; terminations (signal integrity); layer stackup assignments, interconnects and I/O; grounding concepts, grounding methodologies, ground loops/common impedance coupling; and grounding implementations.

The three day version has the following additional subjects added:
Filtering, shielding, gasketing and an approach toward testing, troubleshooting and certification.

Course Objective

This course presents simplified knowledge on how RF energy is generated within a system and the manner of propagation. Implementing suppression techniques along with simulation analysis is required to ensure functionality for signal integrity as well as complying with EMC requirements. No matter how well one designs a printed circuit board, common-mode RF currents will still propagate from digital components. To mitigate undesired RF fields, shielding, gasketing and filtering must occur. Secondary topics are also presented which allows one to understand other aspects of design engineering, with grounding being a primary topic of concern.

Upon completion, one should be able to design and test a system to meet both time domain (signal integrity) and EMC (frequency domain) quickly and at minimal cost.

Who Should Attend

The course targets engineers and technicians that are tasked to design a system without formal training in multiple disciplines of engineering, either the time and/or frequency domain. The course is presented at the "fundamental level." Experienced engineers may find benefit as a refresher course. In addition, this seminar is especially useful for practicing designers of all disciplines, regulatory compliance engineers and EMC specialists.

Benefits of Attending

- Increased job knowledge
- Allows first-time compliance to international EMC requirements
- Reduce design time and manufacturing costs
- State-of-the-art design techniques presented
- Allows one to perform testing and troubleshooting in an efficient manner

About the Instructor

Mark Montrose is principle consultant of Montrose Compliance Services, Inc., a full service regulatory compliance firm specializing in Electromagnetic Compatibility with 30 years of applied EMC experience. Prior to becoming a consultant, Mark was responsible for regulatory compliance for several high-technology companies in Silicon Valley, California. His work experience includes design, test and certification of both Information Technology (ITE) as well as Industrial, Scientific and Medical products (ISM). He is assessed by a European Competent Body to perform CE compliance approval and in situ testing and certification of industrial products.

Mark is a Senior Member of the IEEE and a past member of the *Board of Directors* of the IEEE as Division VI Director (2009-2010). He is also a long-term past Board member of the IEEE EMC Society plus Champion and First President of the IEEE Product Safety Engineering Society. He was a popular distinguished lecturer for the IEEE EMC Society and is considered an expert in printed circuit board design and system level applications for EMC compliance. He has presented numerous papers based on sophisticated research related to printed circuit boards and the field of EMC at International EMC Symposiums and Colloquiums worldwide. Mark also provides personalized in-house seminars and consulting services to corporate clients worldwide in addition to the University of California, Santa Cruz extension program.

Mark has authored best selling text/reference books published by Wiley/IEEE Press.

- *Printed Circuit Board Design Techniques for EMC Compliance*, 1996-1st edition / 2000-2nd edition
- *EMC and the Printed Circuit Board - Design, Theory and Layout Made Simple*, 1999.
- *Testing for EMC Compliance – Approaches and Techniques*. 2004.
- Contributing author to the *Electronics Packaging Handbook*. Chapter 6, 2000. (CRC/IEEE Press).

Montrose Compliance Services, Inc.
Electromagnetic Compatibility and Product Safety

2353 Mission Glen Drive
Santa Clara, CA 95051-1214
☎ and FAX (408) 247-5715
mark@montrosecompliance.com

Design for EMC – PCB and System Level
(Two Day Version)

REVIEW-ELECTROMAGNETIC FUNDAMENTALS
- Definition of EMC Terms
- Signal Spectra (Fourier Analysis)
- How RF Energy is Created - Simplified
- Right Hand Rule and Maxwell's Equations
- Electric and Magnetic Fields
- Component Characteristics at RF Frequencies

ELECTRICAL NOISE CONCEPTS
- Basic Concepts Related to Reducing Electrical Noise
- Digital Components as a Source of EMI
- Basic Aspects of EMC and the Environment
- How Does Current Travel–What Path Does It Take?
- Path of Least Impedance / Typical Wire Configuration
- Concept of Self Inductance
- What are Common-Mode and Differential-Mode Currents

TRANSMISSION LINE THEORY (SIGNAL INTEGRITY)
- Transmission Line Equivalent Circuits
- Relative Permittivity (Dielectric Constant)
- Propagation Delay Within Various Materials
- Ringing – Poor Signal Integrity
- Typical Transmission Line System
- Signal Distortion Characteristics
- Crosstalk
- Design Techniques to Prevent Crosstalk
- Power and/or Return Bounce
- Typical Bounce Waveform

EMC SUPPRESSION CONCEPTS FOR PCBs
- Closed Loop Circuits
- Image Planes
- RF Current Retrun and Flux Cancellation
- RF Current Density Distribution
- Loop Area Between Circuit and Components
- Calculating RF Field Strengths
- Three Primary Grounding Methodologies
- Resonance in a Multi-Point Ground System
- Aspect Ratio
- Ground Slots with Through-Hole Components
- Partitioning
- Component Selection Related to EMC

CLOCKS, IMPEDANCE CONTROL, TRACE ROUTING
- Microstrip and StriplineTopologies
- Impedance Control Equations
- Capacitive Loading
- Calculating Maximum Trace Length for Routing
- Trace Separation and the 3-W Rule
- Routing Differential Pair Signals
- Trace Routing and Clock Networks
- Routing Layers
- Layer Jumping - Use of Vias
- Routing Over a Split Plane
- Guard and Shunt Traces

TERMINATIONS (SIGNAL INTEGRITY CONCERNS)
- Fundamental Concepts of Trace Termination
- Transmission Line Effects
- Termination Methodologies
- Correct Method to Implement Termination
- What Happens When One Cannot Terminate
- *Simulation Examples: Termination Concepts*

LAYER STACKUP ASSIGNMENTS
- Single and Double Sided Recommended Layout
- Multi-Layer Stackup Assignments
- Film and Manufacturing Concerns
- *Simulation Examples: How to Specify a Layer Stackup*

INTERCONNECTS AND I/O
- Partitioning
- Isolation (Moating), Bridging and Mat Violations
- Digital and Analog Partitioning
- Filtering and Grounding
- Common-Mode and Differential-Mode Currents
- Multi-Point Grounding (I/O Connectors)

GROUNDING CONCEPTS
- Grounding Hierarchy
- Different Types of Grounds Possible in a System
- Common Ground Symbols
- Multiple Return Path Possibilities
- Grounding Misconceptions
- Product Safety and Signal Referencing Requirements
- Dealing With Ground Currents
- Important Grounding Principles
- Single/Multiple/Hybrid Ground Systems

Montrose Compliance Services, Inc.
Electromagnetic Compatibility and Product Safety

2353 Mission Glen Drive
Santa Clara, CA 95051-1214
☎ and FAX (408) 247-5715
mark@montrosecompliance.com

Design for EMC – PCB and System Level
(Three Day Version)

The contents of the three day version contain the same material as the two day except with the following additional topics.

GROUNDING METHODOLOGIES
- Grounding Systems
- Cable Shield Grounding
- Ground Trees

GROUND LOOPS/COMMON IMPEDANCE COUPLING
- Inductance of Wire
- Minimizing Ground Inductance
- Mutual Inductance/Capacitance
- Common Impedance Coupling
- Difference in Loop Area–Square vs. Circle
- Ground Loop Control – System and Adapter Cards
- Common-Miode Rejection Ratio
- Avoiding Ground Loops
- Isolation Techniques

GROUNDING IMPLEMENTATION EXAMPLES
- Avoiding Common-Impedance Coupling
- Ground Voltage Potential Between Two References
- Connecting AC Signal Reference to Chassis
- Ground Versus Floating–Hazardous Fault Currents
- Ground Concept Summary

FILTERING
- Defining a Filter
- Signal and Power Line Filter Configurations
- Common-Mode and Differential-Mode Filtering
- Basic Filter Component Characteristics
- Capacitive and Inductive Filtering
- Filtering Guidelines

SHIELDING
- Transmission Line Theory of Shielding
- Losses Achieved with Shielding Material
- Absorption Loss and Skin Depth
- Reflection Loss - Plane Waves/Thin Shields
- Apertures in Shielded Walls
- Waveguide Below Cutoff
- Board Level Component Shielding

GASKETING
- The Need for Gaskets
- Common Gaskets Material Use
- Properties and Characteristics of RF Gaskets

APPROACH TOWARD TESTING, TROUBLESHOOTING AND CERTIFICATION
- International Requirements and Differences
- Testing Methodology and Approach
- Knowing the Test Environment
- Self-Compatibility
- Validation of Measured Data
- Pitfalls and Problems
- Process for Designing Systems to Achieve EMC
- Formal EMC Qualification Tests Requirements
- Strategy for EMI Debugging/Troubleshooting
- Testing and Troubleshooting Concerns
- Emission, Immunity and In Situ Testing
- Compliance Measurement Procedure-Emissions
- Performing Testing-Beyond Standard Procedures
- Systematic Approach for Testing and Troubleshooting
- Summary