EMC Engineering
Printed Circuit Board Design, Grounding and Shielding
(Three Day Seminar)

Introduction
This course is a one day extension of the popular “Signal Integrity & EMC Considerations In Printed Circuit Board Design” by including system level aspects to achieve electromagnetic compatibility (EMC). One must know and understand many aspects that are not easily visualized or known. An EMC engineer must consider the signal integrity quality within all transmission lines, preventing development of common-mode EMI, ground loop control, grounding and shielding, filtering, and regulatory compliance. This course was developed for both experienced and junior level engineers who are responsible for EMC compliance at both the printed circuit board and system level.

The participant, upon completion, should be able to oversee or perform the design of a system that meets or exceeds marketing requirements. Design practices of years past is now insufficient to address today’s high speed, high technology requirement for both signal integrity and EMC.

In an informal atmosphere, design concepts and applications are introduced in an easy to follow step-by-step presentation that allows plenty of opportunities to address specific questions. Major instructional emphasis is placed on real-life examples that demonstrate enhanced engineering practices that can be incorporated immediately.

Course Objective
Both simplified EMC theory and "rules-driven, hands-on techniques" for enhancement of signal integrity along with suppression of RF energy (EMI) created within the printed circuit board is presented. The focus is at the *fundamental* level. Rigorous mathematical analysis and theory will *not* be presented. The course is geared toward multi-layer, high-density designs. Requirements for single- and double-sided designs are examined based upon fundamental concepts for multi-layer boards. Where applicable, simulations are performed to highlight design requirements for optimal performance.

For many applications, it is impossible to incorporate suppression techniques to a level required for optimal operation. Shielding and filtering is a secondary means to ensure emission and immunity requirements are met. Failure to incorporate shielding using sound engineering knowledge can result in additional problems for the designer to deal with, beyond that of functionality.

The course allows engineers to understand how a PCB functions using transmission line theory, how RF energy is created, creating an optimal power distribution network, maintaining the RF return path, and to provide insight into concepts and tools during the layout and prototype period for both commercial and military applications.

Who Should Attend
This course is intended for *practicing* design engineers of all disciplines that include system or product design, regulatory compliance engineers, EMC consultants and PCB designers. No formal training in electronic theory is required. Concepts, theory and layout techniques are presented in an easy to understand format, *without math*, using practical and real world examples. Engineers, technicians, supervisors and managers can also gain valuable insights into PCB and system design for today’s high technology products, along with obstacles that exist for the designer.

Benefits of Attending
1. Increased job knowledge
2. Enhanced signal integrity
3. Highlights EMC suppression and containment concepts
4. Allows first-time compliance to EMC requirements
5. Reduce design time and manufacturing costs
6. State-of-the-art design and layout techniques presented

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 the following best-selling text/reference books published by Wiley/IEEE Press.

- *Printed Circuit Board Design Techniques for EMC Compliance*, 1996-1st ed / 2000-2nd ed.
- *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).

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Fundamentals of EMC Engineering
Printed Circuit Board Design, Grounding and Shielding
(Three Day Seminar)

Day 1

Fundamentals of Signal Integrity
- What is Signal Integrity
- Lossless and Lossy Transmission Line Theory
- Relative Permittivity (Dielectric Constant)
- Propagation Delay Within Various Materials
- Reflections and Poor Signal Integrity
- Typical Transmission Line System
- Signal Distortion Characteristics
- Crosstalk and Design Techniques to Prevent Problems
- Power and/or Return Plane Bounce

Fundamentals of EMC - How EMI is Developed
- Definition of EMC Termonology
- The Decibel, Variations and Pitfalls
- Path of Least Resistance, Inductance and Impedance
- Current Flow in Transmission Lines
- Basic Aspects and Elements of EMC
- Component Characteristics at RF Frequencies
- How Printed Circuit Boards Create EMI
- Right Hand Rule and Maxwell's Equations
- Electric and Magnetic Field Impedance/Representation
- Closed Loop Circuit Requirements
- Radiated Emissions from a Closed Loop Circuit
- Return Current Path of Travel-Multilayer Assembly
- Loop Area Between Components
- What are Common-Mode and Differential-Mode Currents

Basic EMC Suppression Concepts
- Image Plane Theory
- RF Current Density Distribution
- Grounding Methodologies
- Resonances in a Multi-Point Ground System
- Aspect Ratio-Minimizing Ground Loops
- Ground Slots and Through-Hole Component Effects
- Functional Partitioning
- Component Selection and their Relationship to EMC

Power Distribution (Bypassing and Decoupling)
- Power Distribution Network Overview
- Capacitor Details; Types, Dielectrics, Functional Use
- Capacitors Characteristics and Self-Resonance
- Effects of Capacitors in Parallel
- Power and Return Plane Capacitance
- Multipole Decoupling Concept
- Decoupling Radius of Operation
- The Capacitor Brigade
- Dipole Effects from Use of Decoupling Capacitors
- Placement Recommendations
- Mounting Pads and Loop Inductance
- Burried Capacitance

Day 2

Introduction to PCB Materials and Specifications
- Core Laminates for Enhanced Signal Integrity
- Significant PCB Design Specifications of Concern

Clocks, Impedance Control and Trace Routing
- Signal Spectra (Fourier Analysis)
- Microstrip and StriplineTopologies
- Impedance Control Equations
- Capacitive Loading
- Calculating Maximum Trace Length for Critical Nets
- Trace Separation and the 3-W Rule
- Trace Routing for Clocks and Signals
- Layer Jumping, Guard and Shunt Traces

Layer Stackup Assignments
- Single, Double and Multilayer Assignments
- Film and Manufacturing Concerns

Terminations (Signal Integrity Concerns)
- Fundamental Concepts
- Transmission Line Effects
- Common Termination Methodologies
- Correct Method to Implement Termination

Simulation Demonstration
- Impedance control, layer stackup, termination

Interconnects and I/O
- Partitioning, Isolation (Moating) and Bridging
- Plane Violation
- Analog/ Digital Partitioning
- Filtering and Grounding of I/O Connectors
- Common-Mode and Differential-Mode Currents on Cables
- Multi-Point Grounding for Interconnects
- Video and Audio Circuits

Electrostatic Discharge (ESD) Protection

Miscellaneous Design Techniques/Concepts
- Localized Planes
- Trace Routing for Corners
- The *20-H Rule*
- How to Select a Ferrite Device
- Grounded Heatsinks

Day 3

Basic Grounding Concepts

- Grounding Concepts and Definitions
- Different Types of Grounds Possible in a System
- Multiple Return Path Possibilities
- Grounding Misconception
- Product Safety Requirements and Signal Referencing

Grounding Methodologies (Printed Circuit Boards)

- Floating/Single/Multiple/Hybrid Grounding Systems
- Ground Trees

Ground Loops and 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-Mode Rejection
- Avoiding Ground Loops
- Isolation Techniques

Shielding Theory

- Definition and the Need to Shield
- Transmission Line Theory of Shielding Effectiveness
- Skin Depth and Absorption Loss
- Reflections and Loss in Copper and Thin Shields
- Reflection Loss Due to Plane Waves
- Reflections in Thin and Copper Shields
- Apertures and Waveguides

Shielding Applications and Implementation

- The Need to Use Gaskets
- Effects of Shield Discontinuity
- Slot Antenna Effects and Control
- Selection of Common Gasket Material
- Properties of RF Gaskets and Fingers
- Performance Characteristics
- Mechanical Problems
- Electrochemical Grouping
- Gasket Implementation
- Conductive Coatings and Metallization Techniques
- Concerns When Using Conductive Coatings
- Shielding Integrity Violations
- Shield Discontinuities
- Slot Antenna and Joint Unevenness
- Proper and Improper Shield Penetrations
- Cable Shield Grounding Requirements/Implementation
- Implementation a Cable Shield into an Assembly
- Terminating a Cable Shield
- Aspects to Consider When Specifying a Shielded Cable
- Shielded Compartments
- Measuring Shielding Effectiveness and Seam Voltages
- Summary

Open Discussion on Any Aspects of EMC