Fürstenrieder Str. 279a, 81337 Munich, Germany

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Applying Practical EMI Design & Troubleshooting Techniques

This course gives engineering professionals the ability to successfully recognize, solve and avoid challenging EMI problems. Demonstrations using working hardware illustrate concepts such as radiated emissions, high frequency antennas, radiated and conducted immunity and crosstalk in connectors, cables and IC packages. Integrating over 30 years of hands-on troubleshooting experience and the latest EMC research, this course is appropriate for experienced circuit and system design engineers, EMC engineers, as well as those who are new to EMI problem solving.

Course Instructor

Lee Hill is Founding Partner of SILENT, an independent EMC and RF design firm established in 1992 that specializes in EMC and RF design, troubleshooting, and training. Lee received his MSEE from the Missouri University of Science & Technology EMC Laboratory, where he studied under Dr.'s Tom Van Doren, Todd Hubing, and James Drewniak He teaches a graduate course in EMC as a member of adjunct faculty at Worcester Polytechnic Institute (WPI), and is also an EMC course instructor for University of Oxford (England), US Department of Defense, and the IEEE EMC Society's Global University and Fundamentals education programs. He received the Society's IEEE EMCS Excellence in Continuing EMC Education in 2025. He is a past EMC instructor for UC Berkeley, Agilent, and Hewlett Packard.

With over 30 years of EMC design and troubleshooting experience, Lee consults and teaches worldwide, and has presented courses in Taiwan, China, Poland, Singapore, Mexico, Norway, Canada, South Korea, France, Germany, Portugal , Italy, and United Kingdom. Lee is a past member of the IEEE EMC Society's Board of Directors (2004-2007).

After Attending This Course, You Will Be Able To:

- Systematically analyze and solve noise problems by using the noise model to create and analyze a noise circuit schematic
- Minimize radiated EMI by designing low inductance signal interconnects
- Understand ground loops, how to represent them in an equivalent circuit, and how to eliminate them
- Clearly identify and manage the different types of "ground" in schematics and physical circuits
- Identify "accidental antennas" in new designs
- Understand, measure, and reduce common-mode current in emissions and immunity, and functional noise problems
- Improve the quality of sensor and instrumentation signals in the presence of noise

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Applying Practical EMI Design & Troubleshooting Techniques

Section 1: Measuring and Inducing Noise

1) The electrical noise model
2) Distinguishing the four noise paths by name, electrical driving function, necessary physical features, and impact of source to victim distance
3) Troubleshooting techniques based on the noise model
4) Far-field versus Near-field coupling + DEMONSTRATION
5) Practical antenna theory for radiated emissions and immunity + DEMONSTRATTION
6) Problems inherent in predicting radiated emissions and radiated immunity test results
7) Conducted emissions—mode separation, LISNs, troubleshooting

Section 2: Predicting and Solving Noise Problems

1) Capacitance—in ESD, PD boards, decoupling networks, filter networks, cables + DEMONSTRATION
2) Electrostatic discharge (ESD). IC and system ESD tests. Problems with test repeatability. Design techniques to improve PCB ESD immunity + DEMONSTRATION
3) Inductance—in PC boards, connectors, ICs, high speed signal paths, decoupling networks,
4) How to use connectors for improved signal quality, reduced emissions, & improved immunity
5) Behavior of current paths at low and high frequencies + DEMONSTRATION

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Section 3: The Four Noise Coupling Paths, Functions of "Ground" and "Ground" Loops

1) Common impedance - in PCB power planes, ground planes, cables
2) Capacitive - in PCB power filtering, transformers, heatsinks, connectors +DEMONSTRATION
3) Inductive - in PCB ground planes, connectors, and IC packages
4) Radiative - from small electronic products +DEMONSTRATION
5) Ground - the three distinct functions, ground loop problems, +DEMONSTRATION

Section 4: Optimum Use of EMI Control Components

1) Control components: capacitors, inductors, ferrite beads, common-mode filters +DEMONSTRATION
2) Coping with and improving non-ideal characteristics such as interconnect inductance, DC bias

Section 5: Measuring and Diagnosing Effects of Common and Differential-Mode Sources and Filters

1) Differential-mode current, voltages
2) Common-mode currents, voltages, +DEMONSTRATION
3) Understanding the common-mode current and antenna path for emissions and immunity
4) Antenna currents and relevance to filter networks and troubleshooting
5) Common and differential-mode filtering. Filter network topology and function
6) Inherent difficulties in EMC filter design. Effects of filters on intended and unintended signals
7) Where to use common-mode filters—application circuits
8) Where to use differential-mode filters—application circuits

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Advanced Printed Circuit Board Design for EMC + SI

This course provides a unique blend of theory, applications, and numerous hardware demonstrations to describe effective PCB design strategies to eliminate EMC problems such as radiated emissions & immunity, and ESD, and to improve low and high frequency signal integrity of analog and digital sensors.

The real-time hardware demonstrations use a spectrum analyzer, oscilloscope and signal generators to illustrate inductance, common-impedance coupling, and ground loops in PCBs, cables, and systems. Specific examples of single-point, multi-point, "good", and "bad" grounds will be discussed. We will also apply the course learning by discussing and examining actual SILENT client case histories as well as examples of integrated circuit application notes

After Attending This Course, You Will Be Able To:

- Place decoupling capacitors to obtain best performance for a given layer stackup, based on the latest university research
- Explain the pros and cons of different PCB stackups, and know where to route and not to route high frequency noise sources
- Control trace inductance for signal integrity and low noise design
- Correctly identify the possible noise paths that can disrupt PCB operation and choose appropriate solutions
- Explain the problems that split ground planes cause and how to use them correctly
- Choose & place connectors and assign signals for lowest crosstalk, best signal integrity, and lowest EMI
- How to identify mutual inductance and improve the effectiveness of filter capacitors
- Identify good and bad design practices when viewing actual PCB layout screenshots

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Advanced Printed Circuit Board Design for EMC + SI

Section 1: PCB Noise Models

1. Top EMI problems in PCB designs
2. Review of the four noise coupling paths + Demonstration
3. Traces versus antennas
4. Near-field coupling

Section 2: Capacitance, Inductance and Mutual Inductance in PC Boards

1. Good and bad capacitance. Good and bad inductance
2. Mutual Inductance impact on EMI filter capacitors
3. Mutual Inductance in PCBs that causes emissions and immunity problems
4. Connectors, cables, and I/O wires connected to the PCB
5. PCB to PCB connectors and flex cables - simulation results
6. Analog to digital converters

Section 3: “Ground” and Signal Return Paths on PCBs

1. Top reasons that clients ask SILENT for help with noise problems
2. Locating the return current in low and high frequency PCB designs
3. Design example and discussion
4. Ground structure

Section 4: High Frequency PCB Decoupling Networks

1. Empirically validated research from MS&T
2. Three distinct types of PCB power distribution networks
3. Goals of high frequency PCB decoupling in time and frequency domain
4. Explanation and summary of research findings
5. Recommendations for new designs

Section 5: PCB Design Topics and Examples

1. Stackup
2. Return current
3. Design strategies with signal and return vias
3. Examining vendor applications notes that give bad EMC advice for PCB design
4. Examining past SILENT PCB design review findings

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Mechanical Topics (enclosure & cable shielding) for EMC

This course for mechanical engineers provides clear applications, theory and demonstrations for the successful design of conductive enclosures, shielded cables, and shielded connectors for good system emissions and immunity performance. Key topics include grounding at the PCB and enclosure, system ground maps, PCB component placement and control drawings, enclosure and cable shielding, PCB device "cans", resonant slots and enclosures, heat sinks, unintentional antennas, as well as connector, screw, and conductive gasket placement.

After Attending This Course, You Will Be Able To:

- Effortlessly identify unintentional antennas using pictures of past SILENT projects with EMI problems
- Easily and simply visualize common-mode current in cables and enclosures
- Explain the four noise coupling paths, & identify near-field coupling in real designs
- Understand the function of grounds in electronic product design
- Understand shielding of enclosures and cables, without electromagnetics mathematics
- Design a "good enough" high frequency shield
- Design a "good enough" low frequency shield
- Identify the most common types of grounding and shielding defects
- Apply the concepts of conductivity, transfer impedance, and skin depth to practical designs
- Estimate the resonant frequencies of enclosures, slots, and waveguides
- Specify shielded connectors and cable assemblies to ensure good system EMC

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Mechanical Topics (enclosure & cable shielding) for EMC

Section 1: Review of Key Concepts and Introduction to Shielding

1. The theoretical, perfectly shielded enclosure
2. The expensive, practical enclosure
3. Review of the four noise paths
4. Understanding & visualizing common-mode current + DEMONSTRATION
5. Accidental antennas and antenna circuits
6. Regulatory and functional emissions and immunity tests
7. The three properties of electromagnetic shields

Section 2: PCB and Mechanical Control Drawings

1. Placement and location of grounds, and connectors
2. Effects of heat sinks
3. “Ground” / reference maps
4. External shielded connector interfaces

Section 3: Shielding

1. Classical shielding and shielding for EMC
2. Problems with the prediction of shielding effectiveness
3. Practical aspects of shielding enclosures
4. Slot and cavity resonances in shielded enclosures + DEMONSTRATION
5. Review: The three properties of electromagnetic shields
6. Reflective and absorptive properties of shields + low frequency shielding
7. Magnetically conductive materials
8. Popular and incorrect ideas about shielding from vendors of shielded cable
9. Transfer impedance for base materials, connectors, cables and enclosures

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Mechanical Topics (enclosure & cable shielding) for EMC

Section 3: Shielding (continued)

10. Transfer impedance for base materials, connectors, cables and enclosures
11. Effects of apertures
12. Latest research on apertures and cavities
13. Simple tests to verify performance of enclosures and transfer impedance + DEMONSTRATION
14. Overall shielding using enclosures
15. PCB level shields + factors that affect performance
16. Prevention of "accidental antennas"
17. Troubleshooting techniques

Section 4: Shielding of Cables

1. Cable shielding and terminations
2. Applying transfer impedance concepts to cables, connectors, and system interconnect
3. Examples and discussions of common shielded connectors and their defects (ENET, d-sub, video)
4. Shield terminations + DEMONSTRATION
5. Examples of bad cable shielding designs

Section 5: System Design Review Practice

1. During class, review and recommend EMC design changes for a prototype system design.