

Detailed Agenda – EC Essentials Course

EMC 01 - Introduction to EMC / EMC Standards & Tests

1. Introduction to EMC, EMC standards, and compliance tests
2. EMI versus EMC
3. Examples of EMI
4. Today's frequency spectrum
5. Five key EMC threats
6. Common EMC standards (can add MIL-STD-461, plus commercial tests)
7. Update on the IEC 60601-1-2 medical EMC standard
8. EMC test equipment and compliance tests
9. Common compliance test lab errors
10. Electrical dimensions and wavelength
11. Working with dB
12. EMC management

EMC 02 - Signal Spectra, Clocking & Spread Spectrum Clocks

1. Periodic square waves
2. Effect of rise/fall times on spectral content
3. Effect if duty cycle
4. Effect of ringing
5. Clock harmonic analyzer **(Demo)**
6. Spread spectrum clock generation **(Demo)**

EMC 03 - Radiated & Conducted Emissions / Resonance Measurement

1. Measuring radiated emissions **(Demo)**
2. Measuring conducted emissions
3. Differential- versus common-mode emissions
4. Calculating the E-field from DM and CM currents
5. DM emissions model
6. CM emissions model
7. Examples of CM emissions experiments
8. Current probes
9. Calculating the E-field from CM current
10. Cable emission experiments **(Demo)**
11. Why do products radiate?
12. Mitigating radiated emissions
13. Introduction to the dipole antenna

EMC 04 - Non-Ideal Behavior of Components & Filter Design

1. Non-ideal behavior of electrical components
2. Wires, resistors, capacitors, inductors, ferrites
3. Impedance plots with measured examples
4. Capacitors as diversion elements
5. Inductors as blocking elements
6. Common-mode chokes

7. Selecting ferrites
8. Ferrite impedance versus bias current
9. Common filter topologies
10. Calculating ferrite choke insertion loss
11. Proper layout of filters
12. Case study – 500 kHz filter
13. Rolling off clock edges with RC filters
14. Filtering brush motors
15. Use of snubbers on SMPS

EMC 05 - Transmission Lines & Printed Circuit Board (PCB) Design

1. Current density versus distance
2. E and H fields
3. Low frequency return paths
4. High frequency return paths
5. Experimental results
6. Wave propagation in transmission lines
7. Simulation results
8. Discontinuous return paths
9. Traces passing through planes
10. Slot in return plane **(Demo)**
11. PC board stack-up for reduced EMI
12. Stack-up examples
13. Component placement for reduced EMI
14. Clock trace routing
15. Power distribution network design
16. Decoupling capacitor selection and placement
17. Circuit board shape versus EMI experimental results

EMC 06 - Electrostatic Discharge (ESD) Design & Videos

1. Types of ESD discharge
2. Typical circuit upsets
3. The triboelectric series
4. The ESD phenomenon
5. Human body model discharge
6. ESD simulators
7. Typical and measured ESD pulse
8. Effects of the ESD event
9. ESD coupling to circuits
10. Preventing ESD problems
11. Protecting low cost (non-shielded) products
12. CPU reset issues
13. Transient suppressors
14. Aircraft and lightning
15. ESD videos and **emos**

EMC 07 - Shielding & Bonding

1. Principle of a shield
2. Penetrating the shield with a cable
3. Slot radiation
4. Calculating shielding effectiveness
5. Measuring shielding effectiveness
6. Magnetic field shields
7. Effects of slots and holes
8. SE versus frequency
9. Waveguide below cutoff principle
10. Conductive and metallic-coated plastics
11. Local PC board shields
12. EMI gaskets
13. Gasketed connectors
14. Galvanic chart for dissimilar metals

EMC 08 - System Design & Grounding

1. Invisible Antennas
2. Examining the system layout
3. Ground loops
4. Single point grounds
5. Multipoint grounding
6. Segregating grounds
7. Analog and digital grounds
8. Generation of common-mode currents
9. Use of a common-mode choke
10. Methods of decoupling systems
11. Power supply filter placement
12. Multiple boards and CM currents
13. Ribbon cable pinouts
14. Closely-coupled boards
15. Cable shield bonding and pigtails (**Demo**)
16. Locating clock oscillators
17. Component placement for best EMI control
18. I/O connector placement for best EMI control
19. Cable routing
20. Voltage versus current coupling
21. Stray coupling paths

EMC 09 - Bench Top Troubleshooting & Pre-Compliance Testing

1. EMI troubleshooting kit
2. Source – path – receptor model
3. Common issues leading to radiated emissions
4. Troubleshooting radiated emissions
5. Choosing and using spectrum analyzers
6. Use of oscilloscopes

7. DIY and commercial near field probes
8. Troubleshooting with near field probes (**Demo**)
9. Mapping EMI hot spots
10. DIY and commercial current probes (**Demo**)
11. Troubleshooting with current probes
12. Using low cost EMI antennas for troubleshooting
13. Calibrated EMI antennas for pre-compliance testing
14. Preamplifiers
15. Other troubleshooting techniques
16. Measuring cable resonance (**Demo**)
17. Identifying close-spaced harmonics
18. Use of an image plane
19. Measuring voltage differentials
20. Measuring power supply ringing
21. Troubleshooting radiated emissions
22. Radiated emissions pre-compliance testing
23. Conducted emissions pre-compliance testing
24. Power line filtering and conducted emissions
25. Pre-compliance testing with Tektronix' EMCVu (**Demo**)
26. Radiated immunity testing
27. Troubleshooting RI with low cost energy sources
28. Generating intense local radiation with near field probes
29. Troubleshooting EMI and immunity with a TEM cell
30. Troubleshooting ESD with low cost energy sources
31. DIY ESD detectors
32. Direction-finding ESD sources
33. Conducted immunity testing with simple equipment
34. Electrically fast transient (EFT) testing with simple equipment
35. Surge testing and surge protectors

EMC 10 - Philosophy in Troubleshooting Radiated Emissions

1. Troubleshooting philosophy
2. Five key threats
3. Four basic tenets of EMI troubleshooting
4. Common coupling effects
5. Source – path – receptor model
6. Assessing immunity
7. Assessing radiated emissions
8. The four coupling paths
9. Organizing the information
10. Three-step process for troubleshooting radiated emissions

EMC 11 - Other Pre-Compliance Tests

1. Measuring shielding effectiveness with a harmonic comb generator
2. Evaluating power bus noise
3. Measuring resonance with near field probes

4. The concept of the image plane
5. Measuring plated plastic shields using conductivity measurement

EMC 12 – Wireless Design Issues (NEW!)

1. Self-interference to wireless devices
2. Near field probing
3. Evaluating DC-DC converter EMI
4. Processor and clock EMI
5. Evaluating cables with a current probe
6. Testing EMI in a TEM cell **(Demo)**
7. Measuring DC-DC converter switched waveforms with a near field probe and oscilloscope **(Demo)**
8. Why do DC-DC converters “suck” for EMI
9. Examples: Buck and flyback converters
10. Use of shielded inductors
11. Local shields
12. Troubleshooting self-interference
13. Remediation checklist
14. Self-interference – typical experiments to characterize the issue

EMC 13 - Design Reviews & Case Studies

1. How to perform a design review
2. PC board viewers
3. Case study: In-house design
4. Case study: OEM design
5. Case study: Industrial controller
6. Case study: industrial alarm system
7. Case study: medical product (blood glucose meter)
8. Case study: medical product (blood analysis machine)
9. Case study: ESD resetting the CPU
10. Case study: ESD in an automated factory