Another EMC resource
from EMC Standards

Five day course for cost-effective EMC design for electronic products in 2023

Helping you solve your EMC problems

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Practical Electronic Design Techniques for Cost-Effective SI, PI, and EMC, in 2023 (3 days)

— *plus* —

Basic and Advanced PCB Design and Layout Techniques for SI, PI, and EMC, in 2023 (2 days)

A five-day training course

by

Keith Armstrong, Cherry Clough Consultants, U.K.

Synopsis

Training for electronic, mechanical and PCB design engineers, and their managers, in the use of good EMC design and manufacturing practices for modern products and equipment.

This 5-day course covers all the issues that most electronic designers need for cost-effective SI, PI and EMC. More specialist course modules are available to customise this course.

Objective

The aim of the course is to help companies quickly improve their commercial and financial performance by using design techniques that have been proven in real-life for many years to:

- Bring advanced products to market / deliver custom projects more quickly
- Meeting delivery deadlines to help avoid penalty charges
- Reduce unit manufacturing costs
- Reducing warranty costs and improving customer perception of the brand
- Reducing overall financial risks
- Improving Return On Investment

This course is highly recommended for those involved in any aspect of the design, manufacture or testing of electrical/electronic products.

It is based upon the EMC course module that Keith taught to post-graduate students as part of an IET-accredited M.Sc. course at the University of Manchester (formerly UMIST, University of Manchester Institute of Science and Technology), UK.

Who Should Attend

All electronic, mechanical and PCB designers and their managers, in all industry areas, including:

Automotive	Medical & healthcare	
Consumer	Household (domestic) appliances	
Information Technology (IT)	Industrial instrumentation or control	
Railway	Marine	
Aerospace	Military	
Telecommunications	Radiocommunications	Datacommunications

Prerequisites

Familiarity with circuit (hardware) design, PCBs/PWBs and electronic and mechanical assembly and interconnection techniques.

Plain English is used, with a small amount of very easy mathematics.

Course Methodology

This course is presented classroom style using a PowerPoint slideshow containing practical illustrations of the techniques to aid understanding.

Case studies that are relevant to the trainees will be included verbally.

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Each attendee will be presented with a colour-PDF copy of the PowerPoint slides used during the training, printed at both 2 slides per page, and 6 slides per page. The spaces around the slides suffice for taking extra notes. Copies of relevant textbooks can be provided, at extra cost.

Course Duration

Five (5) full days, for example 9:00am – 5:00pm, but other timings may be used.

This is a very intensive course with a very large amount of practical detail.

If presented as an in-house course it can be very usefully combined with individual consultancy for each engineer or manager, to help him or her apply the material to his or her current projects.

In countries where English is not the first language, a longer duration may be preferred.

Venue and Date

To be decided. The course could be provided as a public course, or as an in-house course, either 'in person' (face-to-face), or on-line with a maximum of 1,000 attendees.

As an in-house course, it has the added value of allowing confidential discussions on how best to apply the material to particular projects or products.

Reviews of this course

For over 25 years, delegates world-wide have always awarded this course an overall score of *at least* 80%.

COURSE OUTLINE

Day 1

A. Introduction to EM phenomena, EMI and EMC 2 hrs

All electronic designers and their managers should attend, at least.
Preferably cabling, mechanical/packaging, and PCB designers, too.

1. What are EMI and EMC?
2. Four types of EM energy coupling
3. The EM environment and EM phenomena
   (conducted, radiated, continuous, transient, ESD, power quality, etc.)
4. How devices can be interfered with
5. EMC and the law
6. EMC standards
7. EMC and reliability
8. Managing the functional safety risks that can be caused by EMI
9. Data security
10. Financial benefits of designing EMC in, from the start
11. Some useful references

B. EMC and Interconnections 2 hrs

All electronic, cabling, and mechanical/packaging designers should attend, at least

1. 'Accidental antenna' behaviour of all conductors
2. Using fibre-optics, and other alternatives to conductors
3. The "RF Reference"
4. Cable classification and 'EM Zoning' (segregation)
5. Good practices for both shielded and unshielded interconnections: DM & CM return paths
6. Shielding techniques for cables
7. Terminating cable shields
8. Interconnecting shielded enclosures
9. Dealing with 'ground loops'
10. Transmission-line interconnections
11. Some useful references

C. Filtering for EMC 2 hrs

All electronic, cabling, and mechanical / packaging designers should attend, at least

1. Filtering is not 'black magic', 'EM Zoning'
2. How filters work
3. The advantages of soft ferrites
4. CM filtering
5. Specifying filters
6. Real-life problems with resonances, inductors, and capacitors
7. Earth leakage currents and safety
8. Filter construction, mounting, and cabling
9. The synergy of filtering and shielding
10. Some useful references

Day 2

D. Shielding 2 hrs

All electronic, and mechanical / packaging designers should attend, at least

1 Economic issues for shielding
2 Shielding with metal plates (image planes)
3 How shielded enclosures work
4 DC and low frequency shielding
5 The problems caused by apertures
6 The problems caused by box resonances
7 The problems caused by conductor penetrations
8 Shields in the near field of a source
9 RF-bonding with multiple low-Z bonds or conductive gaskets
10 Waveguides-below-cutoff
11 Shielding of displays
12 Shielding of ventilation
13 Shielding of plastic enclosures
14 Preventing corrosion at shielding joints
15 D-I-Y testing SE before hardware or software is ready
16 Shielding with 'clamshell' enclosures
17 Some free SE calculators and useful references

E. EMC techniques for heatsinks 1 hr

All electronic, and mechanical / packaging designers should attend, at least

1 Importance of controlling stray heatsink currents
2 Ceramic and plastic heatsinks have no stray currents
3 Returning stray heatsink currents to their sources
4 Using the PCB's Reference Plane as a heatsink
5 Practical RF-bonding issues
6 Heat sink RF resonances
7 Resonance effects of heat sink shapes, fins, pins, and semiconductor's locations
8 Heat pipes could help improve EMC
9 Some other techniques that could help improve EMC
10 Low-inductance bonding to control resonances to GHz
11 Combining shielding with heatsinking
12 Some useful references

F. Circuit design for EMC 2 hrs

All electronic designers should attend, at least

Digital circuits

1 Rise/fall times and emissions spectra
2 Numerous digital circuit design techniques
3 Watchdogs and brownout monitors
4 Data scrambling and spread-spectrum clocking
5 Design of firmware and software

Analogue circuits

5 Linearity, bandwidth and stability of feedback circuits
6 Numerous analogue circuit design techniques; using hysteresis in comparators

Switching power converters

7 Cleaning up switching waveforms; using ‘spread-spectrum’
8 Snubbers; and reducing output ripple
9 Heatsinks
10 Use SiC Schottky or soft-switching rectifiers, SiC or GaN switching devices
11 The isolating transformer’s interwinding capacitance
12 Don’t over-use galvanic isolation!

Communications circuits

13 Better alternatives to copper cabling
14 How to use copper cabling
15 Common-mode noise reduction techniques
16 Optoisolators and optocouplers
17 Gigabit laser diodes
18 Terminating transmission lines
19 Some useful references

G. Component selection for EMC 1 hr

All electronic designers should attend, at least

1 Active devices
2 Passive components
3 Problems with second sources, counterfeits, and controlling purchasing
4 Some useful references

Day 3

H. Suppressing electrostatic discharge (ESD) 2hrs

All electronic, PCB, and mechanical / packaging designers should attend, at least

1 ESD threats
2 Insulation techniques
3 Shielding techniques
4 Suppressing signal, data and power connector pins and conductors
5 PCB layout for ESD suppressors
6 Earth lift problems in systems
7 Protecting control, data and signals from errors
8 Some useful references, including “software techniques for ESD suppression”

I. Suppressing spikes, transients, surges, ripple on AC power supplies, signals, controls, and data 3hrs

All electronic designers should attend, at least

1 Surges, spikes, transients and ripple, and how they cause damage
2 Galvanic isolation for signals / data (and isolating power converters)
3 Suppression using filters
4 Types of surge protection component (SPC)
5 Choosing SPCs and designing their circuits
6 Protecting and maintaining SPCs
7 Not used anymore
8 Avoiding the effects of SPC capacitance on signals
9 Types of surge protection device (SPD)
10 Active electronic transient protection for DC power busses
11 “Earth/ground lift” problems in systems
12 Data needs error correction
13 Dealing with long-duration overvoltages
14 Some useful references

J. Suppressing electro-mechanical devices 1hr

All electronic designers should attend, at least

1 Emissions caused by arcs and sparks
2 Suppressing electromechanical contacts
3 Suppressing the flyback from switched inductive loads
4 Suppressing commutator motors
5 Suppressing sliprings
6 Suppressing spark ignition
7 Suppressing electric bells and buzzers
8 Some useful references

DAY 4

L. Essential PCB design/layout techniques generally required for good, cost-effective SI, PI, and EMC in 2023 Full day

All electronic, PCB, and mechanical / packaging designers should attend, at least

1 Saving time and money
2 Scope and application of these design and layout techniques
3 EM Zoning (i.e. circuit segregation)
4 Interface analysis, filtering, and suppression
5 Planes for 0V(GND) and other power rails (PWR)
6 RF-bonding PCB Reference Planes at EM Zone boundaries
7 Power supply decoupling
8 Switching power converters (inc. AC-DC, DC-DC, DC-AC, AC-AC, etc.)
9 Matched transmission line techniques
10 Layer stacking and trace routing
11 Devices with BGA packages and/or multiple DC power rails
12 Some useful references, sources and webinars

DAY 5

M. Advanced PCB design/layout techniques for good, cost-effective SI, PI and EMC, in 2023 Full day

All electronic, and PCB designers should attend, at least.

1 When should we use advanced PCB techniques?
2 Future trends and their implications
3 Guidelines, approximations, simulations, and virtual design for SI, PI and EMC
4 Advanced EM Zoning techniques
5 Advanced interface filtering and suppression, inc. BLS (board-level shielding) and Metamaterials to 60+ GHz
6 Advanced RF-bonding for PCB Reference Planes at EMZ boundaries
7 Advanced RF-bonding PCB Reference Planes at EMZ boundaries
8 The totally shielded board assembly
9 Damping the resonances in parallel metal structures, including Metamaterial methods, e.g.: Virtual Ground Fence; EBG (Electromagnetic Band Gap); HIS (High Impedance Surface), Split-Ring Resonators, etc.
10 Advanced PCB power supply decoupling
11 Buried components (especially buried capacitance decoupling)
12 Not used in this version
13 Advanced transmission lines, up to at least 32Gb/s
14 Microvia (high density interconnect, HDI) board manufacturing techniques
15 3-D Moulded PCBs, Additive Manufacturing, Silicon Interconnect Fabric, etc.
16 Advanced crosstalk
17 Some final tips and tricks
18 Some useful contacts, sources, and references

A more detailed course contents list is available upon request.

Note 1: Modules recommended as additions or replacements to those in the above standard course:

- **Getting Started with EM Engineering, List of Resources** 0.5 hr
- **Cost-effective uses for near-field probing, and RF current monitoring in every project stage, for emissions, immunity, and more!** 2 hrs
- **Introduction to EMC and EMI** 2 hrs
- **The Physical Basis of EMI and EMC** (Maxwell's without maths!) 4 hrs
- **EMC Awareness – the Myths and the Realities** 2 hrs
- **Analogue design techniques for SNR and EMI immunity** Half-day
- **Switch-mode power convertors from mW to MW** Full-day
- **Good EMC practices for cabinets, systems and installations** 1.5 days
- **The Safe design of electrical equipment, and compliance with the LVD or RED – and their equivalent UK Regulations** 1, 1.5, or 2 day versions
- **Managing Functional Safety Risks that can be caused by EMI** Half-day

Many more modules are available – if you don't see what you want, please ask!

This course can be converted to ***military*** applications
by replacing Module I in the above list with:

- **Suppressing spikes, transients, surges, ripple on military vehicle DC power busses, signals, controls, and data** 3 hrs

Note 2: Versions of every module listed here are available for mechanical/electrical engineers with no electronic training

Course Instructor

Academic Qualifications

BSc (Elec.Eng), Upper 2nd Class with Honours, Imperial College of Science & Technology, London, UK, 1972

Professional Qualifications

Fellow IET (Institution of Engineering and Technology, formerly the Institution of Electrical Engineers, IEE), London, UK (Member since 1977)	2010
Senior Member IEEE (Institute of Electrical and Electronic Engineers Inc.) USA, member of its EMC, Product Safety Engineering Societies since 1998	2010
Associate of the City and Guilds Institute, London, UK	1972
UK Chartered Engineer, Engineering Council, London, UK	1978
Group 1 European Engineer (EurIng), FEANI, Paris, France	1988
Presented with the IEEE EMC Society's new "Excellence in Continuing EMC Education Award"	2018

Professional Activities

Chair of IEE/IET's Working Group on EMC and Functional Safety	1997-date
Chair of IEEE EMC Soc. Special Committee on Risk Management of EMC	2012-2016
UK expert appointed (by invitation) to IEC maintenance team MT23 for IEC 60601-1-2 (Medical Equipment/Systems EMC)	2006-date
UK expert appointed (by invitation) to IEC maintenance team MT15 for IEC 61000-1-2 (EMC & Functional Safety)	2003-date
UK expert appointed to IEC 61000-6-7 (EMC & Functional Safety, Generic)	2010-date
Member EMC Industries Association (EMCIA)	2003-date
Member EMC Test Labs Association (EMCTLA) and its Working Group B	2001-date
Editorial Advisory board member, Interference Technology magazine	2007-date
Editorial Advisory board member, In Compliance magazine	2005-date
EMCIA representative to BSI GEL 210/12 EMC committee	2009-date
President of the EMC Industries Association (EMCIA)	2008-2010
Vice-President of the EMC Industries Association (EMCIA)	2010-2012
Chair of IEE's EMC Professional Group (E2)	1997-1999

RECENT RELEVANT EXPERIENCE (1990-PRESENT)

Started Cherry Clough Consultants in 1990, Director of the Limited Company since 2010.
Started EMgineering Ltd (owns www.emcstandards.co.uk) and appointed Director, October 2017.

External lecturer, Sensors and Electronic Instrumentation MSc course, University of Manchester, teaching an IET-accredited module on practical EMC design techniques, 2002/3 – 2007/8.

The services that Keith provides for Cherry Clough Consultants include:

- Product, system, and installation EMC and safety good practices for reliability and cost-effective regulatory compliance
- Assessment of electromagnetic environments
- Control plans, test plans, etc., for effective management of EMC and safety in projects of all sizes
- Company procedures for EMC and safety, for financial benefits and/or regulatory compliance
- Production / QA procedures for maintaining regulatory compliance in volume manufacture and custom engineering
- Testing and remedial work to meet EMC and safety standards

- Creation of EMC Directive Technical Construction Files and other compliance documentation
- Assessment of EMC Directive Technical Construction Files for a number of EMC Competent / Notified Bodies
- Education and training for designers and managers on cost-effective EMC and Safety techniques; and on "EMC for Functional Safety, high-reliability and legal metrology"
- Education and training for executives in EU compliance; liability; financial benefits of using good EMC techniques; and related marketing issues

The above services have been applied in the following areas (not a complete listing):

Systems and installations:

Machinery and manufacturing/process systems and installations of all types and sizes
Robotics

Air traffic control towers	Computer and telecommunication rooms
Administration centres	Financial dealer rooms

Professional audio systems and installations (e.g. theatres, opera houses, recording studios)

Steel rolling mills	Hospitals
Hotels	Chemical and pharmaceutical processing plant
Nuclear processing plant	Bottling and canning lines
Road tunnel lighting schemes	Broadband-Over-Power-Line (BPL) systems
Railway systems	Mobile X-ray systems for shipping containers

Synchrotrons (e.g. the Diamond Light Source, Harwell, Oxfordshire, www.diamond.ac.uk)
Fusion reactors, Tokamaks, (e.g. the ITER project in southern France, www.iter.org/)

Products and items of equipment:

Industrial instrumentation, control, and machinery of all types and sizes
Variable speed AC and DC motor drives, from very small up to 10MW
Automotive engine control units (ECUs) and other electronic subassemblies (ESAs)
Battery chargers, from very small up to MW
Power converters: AC-DC, DC-DC, DC-AC, AC-AC, from very small up to MW
Information technology equipment (ITE) e.g. computers, servers, RAID arrays
Personal Digital Assistants (PDAs) and other hand-held wireless-enabled computing devices

Marine equipment	Subsea oil and gas production equipment
Photocopiers	Digital Signal Processing
Datacommunications devices	Professional audio consoles and other pro equipment
Professional video projectors	Lighting
Telephones and telecommunications	Consumer electronics (TV, Hi-Fi, etc.)

Radiocommunications, cellphones and pagers

Lifts (elevators)	Domestic (household) appliances
Gambling machines	Gas boilers
Electricity meters	Electrical power generators (small scale)
Building electrical services equipment	Digital microwave radio
Robots	Solar power converters
Military avionics	Military land vehicles
Military submarine variable-speed winch	Medical equipment (various)
Microscope manipulators	Coin mechanisms
Security equipment	Mains-borne communications
Induction heating	Laser welding
Digital microwave radio	Variable-speed winch for a military submarine
Military land vehicles (to Land Class A)	Wheeled robots for search/rescue and bomb disposal

PREVIOUS PROFESSIONAL EXPERIENCE (1982-1990)

Keith was mostly involved with the design and development of state-of-the-art capital equipment during the period 1968 to 1990. He has wide experience in electronic product design and project management in the UK, South Africa and France, after finishing graduate apprenticeship with Thorn Automation in 1973.

Technically: he started in analogue design in 1968; adding digital control of analogue circuits in 1978, and A/D and D/A conversion in 1980. Project and departmental management experience was gained from 1983 onwards, including teams of more than 20 engineers and scientists (this was for the Microwave division of Marconi Instruments Ltd, Stevenage, UK, 1983-1988).

BOOKS, PUBLICATIONS and PAPERS

EMC Design Techniques for electronic engineers
Nutwood UK November 2010, ISBN: 978-0-9555118-4-4, full colour graphics throughout.
Order from www.emcstandards.co.uk/books4. Covers all electronic applications, with a very practical approach to good design practices that will save time and cost, reduce time-to-market, and reduce warranty costs and financial risks.
(Chapter 2 of this book is the complete text of "The Physical Basis of EMC" (below), so don't buy both!)

The Physical Basis of EMC
Nutwood UK October 2010, ISBN: 978-0-9555118-3-7, full colour graphics throughout.
Order from www.emcstandards.co.uk/books4. Provides an understanding of electromagnetic phenomena, in a way that can be easily understood by practising electronic engineers.
(Chapter 2 in "EMC Design Techniques for electronic engineers" is the same text, so don't buy both!)

EMC for Printed Circuit Boards – Basic and Advanced Design and Layout Techniques
Nutwood UK December 2010, ISBN 978-0-9555118-5-1, full colour graphics throughout. (2nd Edition, identical to 1st Edition except for format.) From www.emcstandards.co.uk/books4.
Practical good-practice EMC design techniques for printed circuit board (PCB) design and layout, for designers of electronic circuits and PCB designers themselves. All application areas are covered, from household appliances, commercial and industrial equipment, through automotive to aerospace and military. This book is used by some University courses.

The First 500 'Banana Skins' **(also known as 'EMI Stories')**
Nutwood UK, 2007, 500 reports and anecdotes concerning electromagnetic interference (EMI), collected and edited by Keith Armstrong. Read them for free (and at least 300 more 'EMI Stories') at www.emcstandards.co.uk/emi-stories, or buy the book from www.emcstandards.co.uk/books4.

EMC for Systems and Installations
By Tim Williams and Keith Armstrong, Newnes, 2000, ISBN: 0-7506-4167-3, www.bh.com/newnes, RS Components part number: 377-6463, also available from www.emcstandards.co.uk/books4.

Keith has written and presented a great many papers for a wide range of symposia, conferences, colloquia, and seminars worldwide, including ERA, IEE, IET, IEEE EMC Society and IEEE Product Safety Engineering Society events. Too many to list here, please ask for further details.

He has also published a great many articles on EMC for publication in professional journals and trade magazines worldwide, including the following five annual series for the EMC Compliance Journal (now available from www.emcstandards.co.uk):

- "EMC design of Switching Power Converters" (14 parts, 2011-2013)
- "Designing for EMC" (6 parts 2006-8)
- "Advanced PCB Design for EMC" (8 parts, 2004-5)
- "EMC Testing" (7 parts, 2001-2)
- "EMC for Systems and Installations" (6 parts, 2000)

Keith has written 17 informative booklets on electromagnetic phenomena, what they are, what causes them, how they cause interference, and how to test for them using IEC and EN standard methods, plus another 5 booklets on EMC issues in systems and installations, for example: Power Quality, Good EMC Engineering Practices, Variable-Speed Drives, etc. They can all be downloaded for free from www.emcstandards.co.uk.

Please visit www.cherryclough.com and/or www.emcstandards.co.uk for more information.