Another EMC resource
from EMC Standards

Mechanical and Electrical Design for Good, Cost-effective EMC

Helping you solve your EMC problems

1 Brassey Road, Old Potts Way, Shrewsbury, SY3 7FA T:+44 (0) 1785 660 247 E:info@emcstandards.co.uk

Cherry Clough Consultants Ltd
9 Bracken View, Brocton, Stafford, ST17 0TF, UK
Phone: +44 (0)1785 660 247
Cell: +44 (0)7785 726 643
Email: keith.armstrong@cherryclough.com
Web: www.cherryclough.com
www.emcstandards.co.uk

Mechanical and Electrical Design for Good, Cost-effective EMC

'Generic' Agenda

To be modified to suit specific customer requirements

This material does not contain anything on electronics or PCB layout, but it is relevant for electronic and PCB designers, and their managers.

Please choose the modules you want to fill the time you want, assuming 6 module-hours to the full working day (to allow some time for discussions)

A Demonstration of emissions and near-field probing 1.5 hrs

- Showing (amongst other things) how near-field probing can help with designing/developing the EMC aspects of a mechanical and electrical construction, e.g. the shielding effectiveness of the enclosure and screened cables, and the effectiveness of filters and their assembly methods.

B EMC and interconnections (for mechanical and electrical designers) 1.5 hrs

- Antenna effects of conductors
- Use fibre optics or alternatives, instead of conductors
- The "RF Reference"
- Cable classification and segregation
- Good practices for both shielded and unshielded interconnections: controlling the DM & CM return paths
- Shielding techniques for cables
- Terminating cable shields
- Interconnecting shielded enclosures
- Ground loops
- Transmission-line interconnections

C EMC filtering (for mechanical and electrical designers) ¾ hr

- Filtering is not 'black magic'
- How filters work
- Filter construction, mounting, and cabling
- The synergy of filtering and shielding

D EMC shielding (for mechanical and electrical designers)

Short: 1.5 hrs
Detailed: 2.5hrs

- Economic issues for shielding
- Shielding with metal plates (image planes)
- How shielded enclosures work
- Low frequency shielding
- The problems caused by apertures
- The problems caused by box resonances
- The problems caused by conductor penetrations
- Shields in the near field of a source
- EMC gasketting
- Waveguides-below-cutoff
- Shielding of displays
- Shielding of ventilation
- Shielding of plastic enclosures
- Preventing corrosion at shielding joints
- Some free shielding calculators and useful references

E Heatsinks and EMC (for mechanical and electrical designers) 1¼ hr

- Importance of controlling stray heatsink currents
- Ceramic and plastic heatsinks have no stray currents
- Returning stray heatsink currents to their sources
- Using the PCB's Reference Plane as a heatsink
- Practical RF-bonding issues
- Heat sink RF resonances
- Resonance effects of heat sink shapes, fins, pins, and the locations of the semiconductors
- Heat pipes
- Some other techniques that could be useful
- Low-inductance bonding to control resonances to GHz
- Combining shielding with heatsinking

F Good EMC engineering practices in the design and construction of electrical/electronic cubicles/cabinets
(for mechanical and electrical designers) 3 hrs

1. Good EMC practices for general use

- Buying electrical/electronic units, following the manufacturer's sensible EMC instructions, and using good EMC engineering practices
- Reducing the accidental RF-antenna efficiency of cables
- Cable classification
- Segregation (zoning) of equipment and cables

2. EM Mitigation Techniques
   - EM Zoning
   - Creating an “RF Reference”
   - Routing cables close to the RF Reference
   - Don’t confuse the RF Reference with safety earthing
   - RF bonding techniques for metalwork
   - RF bonding techniques for cable screens (shields)
   - Filtering techniques
   - Shielding techniques
3. Preventing corrosion
4. Maintaining EMC during maintenance, upgrades, repair, refurbishment
5. Providing EMC installation information in user manuals
6. Easy, low-cost EMC checking

G Good EMC engineering practices for systems and installations

(for mechanical and electrical designers) 3 hrs

1. Introduction
   - EMC Directive
   - Lightning protection for electronics
   - IEE Wiring Regulations (BS7671)
   - Overview of the overall EMC control procedure
2. Good EMC practices for general use
   - Power distribution systems and power quality for EMC
   - Galvanic isolation for EMC
   - Reducing the RF-antenna efficiency of cables
   - Segregation (zoning) of apparatus and their supplies
   - Using a bonding ring conductor (BRC)
   - Cable classification, segregation and routing
3. EM Mitigation Techniques
   - EM Zoning
   - Safety earthing/grounding for safety and EMC
   - Mesh-bonding, and creating an RF Reference
   - What to do if you can’t use mesh-bonding
   - Direct and indirect RF-bonding practices
   - Terminating cable shields at both ends is best for EMC
   - Parallel earth conductors (PECs)
   - Selecting and installing mains filters
   - Cable shielding
   - Shielding for EM Zones

- Surge and Lightning protection

7. Preventing corrosion
8. Maintaining EMC during maintenance, upgrades, repair, refurbishment
9. Providing EMC installation information in user manuals
10. Easy, low-cost EMC checking

H Close-field probing techniques to find EMC problems with enclosures and assemblies before electronics are available

3 hrs

I 'Show and Tell' *ad hoc* half-day problems solving session

3 hrs

Attendees bring examples to discuss, which could be associated with old, current or future projects, or generic issues associated with certain technologies, applications or products. Examples can be described by, for example:

- going out into the manufacturing or testing facility to look at the example, and/or
- bringing actual hardware to the course room (I have sometimes had quite large machines wheeled in), and/or
- drawings, test results, other documents or simulations projected onto the screen, and/or
- oral presentations, usually accompanied by ad-hoc sketches on the whiteboard and a lot of hand-waving.

This session can be run as *ad hoc* EMC design consultancy, but if used at the end of a training course I usually encourage group discussion and try to avoid stepping in unless something significant is being overlooked or misunderstood.

Presented by: Keith Armstrong EurIng (Gp1), C.Eng, FIET, Senior MIEEE, ACGI

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, and member of its EMC and Product Safety Engineering Societies since	2010 1998
IEEE EMC Society's 'Excellence in Continuing EMC Education Award'	2018
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
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
Chair of IET Standards Code of Practice on 'Electromagnetic Resilience'	2015-2016
Chair IEEE Standards P1848: 'Techniques & measures to manage functional safety and other risks with regard to electromagnetic disturbances'	2016-date
Member EMC Industries Association (EMCIA)	2003-date
Member EMC Test Labs Association (EMCTLA) and its Working Group B	2001-date
Editorial board member, Inside Functional Safety magazine	2010-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. Good signal integrity, power integrity, and EMC can be achieved quickly and cost-effectively, without risking over-engineering, by a well-proven set of design techniques.
- Assessment of electromagnetic environments
- Control plans, test plans, etc., for effective management of EMC and safety in projects of all sizes. De-risking projects as regards EMI and EMC issues.
- Company procedures for EMC and safety, for financial benefits and 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, 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 "Functional Safety Risk Management of EMI"
- 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 plant of all sizes, including:
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

Synchrotrons (inc. the Diamond Light Source, Harwell, Oxfordshire, www.diamond.ac.uk)

Railway and tram systems	Mobile X-ray systems for shipping containers

Large nuclear fusion reactors (specifically ITER, www.iter.org)

Products and items of equipment:
Industrial instrumentation, control, and machinery of all sizes, including:
Variable speed AC and DC motor drives from very small to 10MW
Automotive engine control units (ECUs) and other electronic subassemblies (ESAs)
Information technology equipment (ITE) e.g. computers, servers, RAID arrays
Cellphones, Personal Digital Assistants (PDAs), pagers and similar hand-held wireless devices

Marine equipment	Computers
Photocopiers	Digital Signal Processing
Datacommunications devices	Professional audio consoles and other equipment
Professional video projectors	Lighting
Telephones and telecommunications	Consumer electronics (TV, Hi-Fi, etc.)
Radiocommunications	Very large video displays e.g. for Sports Stadiums
Lifts (elevators)	Domestic (household) appliances
Gambling machines	Gas boilers
Electricity meters, inc. 'smart' meters	Electrical power generators (small scale)
Building electrical services equipment	Subsea oil and gas production equipment
Robots	Solar power converters (grid-connected, bidirectional)
Military avionics	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	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.

Started in analogue design in 1968; added 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'
Nutwood UK 2007, 500 reports and anecdotes concerning electromagnetic interference (EMI), collected and edited by Keith Armstrong. Buy from www.emcstandards.co.uk/books4. Now published as 'EMI Stories' at www.emcstandards.co.uk/emi-stories, where there are currently 873 of them.

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, Asia-Pacific EMC, Euro-EMC, and 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 or www.emcstandards.co.uk for more information.