Another EMC resource
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2-day Good EMC Engineering Practices for Equipment, Systems and Installations without legal requirements

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

Good EMC Engineering Practices for Equipment, Systems, and Installations

— *without* considering issues of legal compliance

A 2-day Training Course

by **Keith Armstrong** C.Eng, FIEE/IET, Senior MIEEE, EurIng(Gp1), ACGI, Cherry Clough Consultants Ltd, U.K.

In 2018, Keith was the first recipient of the IEEE EMC Society's "**Excellence in Continuing EMC Education Award**", presented for "Continuous education in EMC, signal integrity and power integrity from a practically based point of view"

Synopsis

Practical EMC engineering techniques described in sufficient detail to be used right away for helping achieve reliable operation of equipment, systems and installations, and pass EMC tests (where required), in any sectors (commercial, medical, industrial, military, aerospace, etc.).

Most of the descriptions use examples of industrial equipment cabinets, systems and sites, but the techniques are equally effective for any assemblies of electrical/electronic units in enclosures, systems, or installations, of any kind, any size, fixed or mobile, in any applications, for e.g.:

- Avionics and aircraft, airports, control towers, etc.
- Domestic appliances, point-of-sale terminals, etc.
- Entertainment (recording/broadcasting studios, theatres, cinemas, sports facilities, etc.)
- Extraction and refining (oil, gas, metals, minerals, mines, refineries, etc.)
- Hospitality (restaurants, hotels, spas, gymnasiums, resorts, etc.)
- Industrial plants (manufacturing, processing, all types)
- Machines, cranes, etc., (including those using hydraulics or pneumatics)
- Medical and healthcare (hospitals, diagnostics, treatment, care homes, dentistry, etc.)
- Offices or commercial buildings or sites (e.g. their lighting, HVAC, computer systems)
- Power generation (photovoltaic, wind, wave, gas-fired, fission, fusion, etc.)
- Public utilities (electricity and gas power grids, water, telecoms, etc.)
- Railway rolling stock, signaling, stations and other railway infrastructures
- Road vehicles, and road infrastructures
- Robots and robotic systems of all types
- Science facilities (accelerators, synchrotrons, electron microscopes, etc.)
- Server rooms, data centers, etc.
- Ships, submarines, and their ports, harbors, docks, etc.
- Spacecraft, their launch vehicles and launch facilities

– and *anything else* where two or more electrical or electronic units, without limit, are interconnected with cables, fiber-optics or wireless datalinks, on any scale.

This course does not cover any legal compliance issues, for example complying with the requirements for 'fixed installations' and equipment/systems used to construct them, under the EU's EMC Directive or UK's EMC Regulations. We have a different course Agenda that covers these.

Objective

To provide practical grounding in the EMC techniques that developments in electronic technology have made important for reliability, and for the compliance of systems and installations with EMC standards (where applied).

The practical techniques described here will help reduce project and financial risks when constructing equipment, systems and installations that involve electronics.

They will also be of great value to electronic and mechanical product designers, to help them design sub-assemblies and products that can be assembled and installed without suffering from problems and unreliability. This will also help to reduce warranty costs, which can be a huge drain on profits.

Who Should Attend

All mechanical, electrical, or electronic designers – and their managers – in all of the areas listed on the first page, but not limited to those areas.

Prerequisites

Familiarity with the design of electrical and/or electronic equipment, systems, or installations. 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 people attending each course will be included verbally.

Each attendee will be presented with a colour PDF of the PowerPoint slides used during the training, printed at both 2 slides per page (for viewing on a device) and 6 slides per page (to reduce the cost of colour-printing).

Copies of the textbook "*EMC for Systems and Installations*" (Newnes, 2000, ISBN 0-7506-4167-3) co-authored by Keith Armstrong and Tim Williams, can be provided at extra cost.

Course Duration

Two (2) full days, for example: 9:00am – 5:00pm each day.

This is a very intensive course with a very large amount of practical detail. In countries where English is not the first language, a longer duration may be preferred.

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.

Reviews of this course

Delegates have always awarded this course an overall score of at least 80%

Venue and Date

To be decided. The course could be provided as a public course, or as an in-house course. As an in-house course, it has the added value of allowing confidential discussions on how best to apply the techniques described to particular projects or products.

COURSE OUTLINE

A) EM phenomena – where they come from, how they can interfere

- Three parts to every EM interference event
- Four types of EM coupling
- EM phenomena in long cables
- EM phenomena in any conductors
- EM phenomena associated with electrical power supplies
- EM phenomena caused by electrical power use
- EM fields from intentional radiators
- EM fields from unintentional radiators
- Electric and magnetic fields from electrostatic discharges
- EM weapons (Intentional EMI)
- Comparing immunity test standards with real-life EMI
- Intermodulation and demodulation
- Interference with analogue devices and circuits
- Interference with digital devices, circuits and software
- Interference with electromechanical devices
- EMI problems are worsening all the time, because…
- Some useful references

B) CE + CE *doesn't* = CE!

Neither technically, nor legally. ***What to do instead***

Assembling equipment, whether in cabinets, or as distributed systems or installations, from electrical/electronic units which are individually declared by their manufacturers to be compliant with their relevant EMC standards, *cannot in itself provide any confidence* that the resulting equipment will comply with its relevant EMC standards.

Equipment that does not comply with its relevant EMC standards tends to annoy customers/users in real life, either by causing interference or being upset by it.

So, there are sound financial reasons for following this course module to learn how to use well-proven methods for:

- Choosing items with good EMC
- Avoiding items with bad or unknown EMC
- Helping to ensure that the final assembly of the items (whatever it is, and however large or complex it is) keeps its owners and users happy, and – if tested – compliant with the relevant EMC standards.

Continued on next page…..

C) Good EMC practices in the design and construction of electrical/electronic equipment, as cabinets, systems, or installations (using mostly industrial examples, but relevant for any/all applications)

1. **Introduction**
   - EMC Directive (2014/30/EU) and UK EMC Regulations
   - Lightning protection (e.g. EN 62305)
   - National Wiring Regulations (e.g. BS7671)
   - Overview of the overall EMC control procedure

2. **Good EMC practices for general use**
   - Planning
   - Dealing with legacy equipment, systems and installations
   - Buying equipment; and CE + CE ≠ CE
   - Power distribution systems; and power quality for EMC
   - Galvanic isolation for EMC
   - Segregation (EM Zoning)
   - Cable classification, segregation, and routing
   - Using Bonding Ring Conductors (BRCs)
   - Creating an RF Reference by RF-bonding conductors and/or metalwork
   - Reducing the 'accidental RF antenna' efficiency of cables
   - Terminating cable shields at EM Zone boundaries, at both ends
   - Using Parallel Earth Conductors (PECs)
   - Reducing EMC problems caused by metal joints (e.g. due to corrosion)
   - Some more things to take into account

3. **EM Mitigation Techniques**
   - Earthing/grounding for both Safety and EMC Zoning
   - Using Meshed Bonding Networks as RF References
   - What to do when EM Zones must be isolated
   - Controlling CM resonances in loops
   - Filtering for EM Zoning
   - Shielding for EM Zoning
   - Shielding large volumes, e.g. rooms, laboratories, buildings, etc.
   - RF-bonding filters to shielded EMZs where cables enter/exit
   - RF-bonding cable shields/screens to shielded EM Zones at entry/exit
   - Surge and Lightning protection

4. **Maintaining good EMC over the operational lifecycle**

5. **Some useful references**

6. ***Bonus:*** **Alain Charoy's presentation on EMC fixes and mistakes**

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

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'	2015-2017
Chair IEEE Standards 1848: 'Techniques & measures to manage functional safety and other risks with regard to electromagnetic disturbances'	2016-2021
Member EMC Industries Association (EMCIA)	2003-date
Member EMC Test Labs Association (EMCTLA)	2001-date
Editorial Advisory Board member, Interference Technology magazine	2007-date
Editorial Advisory Board member, In Compliance magazine	2005-date
EMCIA representative to BSI's 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 (which 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.