Think EMC Ltd

Customised training for EMC, Electrical Safety, and Regulatory Compliance

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Course Outline: "Electronic Product Design for EMC"

Duration: 3 days (0900-1700)

Delivery: In person.

Location: On site for your company or via one of our Open Courses

Trainer: James Pawson (LinkedIn)

Each attendee receives:

- Course notes in booklet form and PDF for later reference
- One of our free EMC near field probe kit (some assembly required, may contain nuts)
- For company specific on-site courses only: a complementary 2-hour follow-up meeting (virtual) to cover any questions about your designs. This is usually held two weeks after the training session to give things chance to sink in, or for other questions to develop.

Who is this course for?

This course has been designed for electronics engineers who are interested either in their products passing Electro-Magnetic Compatibility (EMC) tests or reducing the amount of electrical noise observed in their system.

The principles and concepts taught are universal. Whilst the specific examples are primarily from the commercial sphere, they are just as applicable to the industrial, automotive, aerospace, or military sectors.

Junior or graduate engineers with 0-3 years of experience will receive an excellent introduction to the subject, preferably before having chance to pick up too many bad habits.

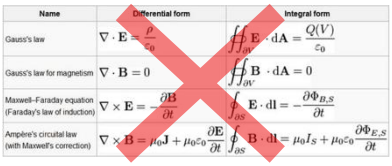
Engineers with 3+ years of experience will get answers to a lot of the questions that they have been pondering whilst taking products through compliance testing, or wrestling with internal noise issues.

More experienced engineers will no doubt be nodding their heads at much of it, and perhaps clarifying their understanding of some concepts, or being exposed to new ways of thinking about these problems.

The only pre-requisites to the course are a basic understanding of electronics principles, and the awareness of the field of EMC.

What makes this course different?

Higher Education Courses:



Name	Differential form	Integral form
Gauss's law	$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$	$\oiint_{\partial V} \mathbf{E} \cdot \mathrm{d}\mathbf{A} = \frac{Q(V)}{\varepsilon_0}$
Gauss's law for magnetism	$\nabla \cdot \mathbf{B} = 0$	$\oiint_{\partial V} \mathbf{B} \cdot \mathrm{d}\mathbf{A} = 0$
Maxwell–Faraday equation (Faraday's law of induction)	$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\oint_{\partial S} \mathbf{E} \cdot \mathrm{d}\mathbf{l} = -\frac{\partial \Phi_{B,S}}{\partial t}$
Ampère's circuital law (with Maxwell's correction)	$\nabla \times \mathbf{B} = \mu_0\mathbf{J} + \mu_0\varepsilon_0\frac{\partial \mathbf{E}}{\partial t}$	$\oint_{\partial S} \mathbf{B} \cdot \mathrm{d}\mathbf{l} = \mu_0 I_S + \mu_0\varepsilon_0\frac{\partial \Phi_{E,S}}{\partial t}$

EMC does not get adequately taught through most higher education outlets. The ones that do are often a couple of modules, mainly focused on measurable academic targets like electromagnetic theory, memorizing and applying equations, etc. This is fine on paper but there is a gap between the theory (e.g. Maxwell’s equations) and practice (e.g. how do I choose an ESD suppressor for this input?)

As such, most people learn on the job (by making mistakes and fixing them), from more experienced engineers (danger of out of date or incorrect advice), from textbooks (you can’t ask a textbook questions or for interpretation), or from the internet (everything on the internet is correct, right?)

Things that other EMC courses do:

- Focus primarily on the Regulatory side, with a significant portion of the course devoted to legal frameworks, Technical Documentation, global market access, etc. If you are a design engineer struggling with an EMC problem then this bit of the course might not be as relevant to you.
  (*The regulations and compliance side is still an important subject and we have a other courses that summarise the requirements for EMC, Safety, Radio, RoHS, and WEEE. I find the regulatory side of things quite interesting, but then I am odd)*

- Take the form of “PowerPoint Karaoke” i.e. “here is the slide, I have read you the words on the slide, you have now received the training”. If you wanted to learn about a subject just by reading and understanding words then buy a book, you don’t need a course. (I’ve sat through these and vowed never to subject anyone else to this experience)

- Lack of interactivity. Some people can focus in a classroom / lecture format of slide after slide after slide after slide. Other people can start to get overwhelmed after an hour of slides. I can focus for long periods of time on technical material but even I have my limits

- Too many equations. The beauty of Maxwells equations is undeniable to those that can intuitively grasp mathematics. If this is your preferred style of learning, then there are courses and textbooks out there for you. I’m not ashamed to say that I struggled at school with maths, and I sometimes get a mental block with numbers.

- Virtual only. Interruptions on the laptop from Teams / Slack / email notifications. Having another window open so that you can work during the ‘boring’ bits. Other distractions from our environment. Interrupting with questions becomes more difficult.

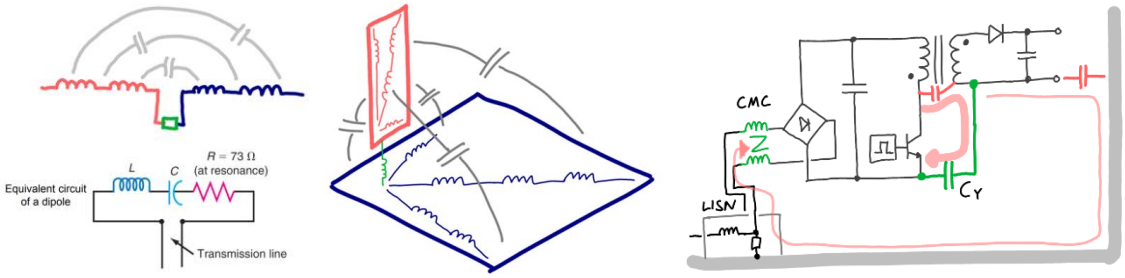
This course:

This course is designed for a regular engineer with regular EMC problems. We tackle the normal shortcomings of other courses by:

- **Electronics Design focused**. All concepts are related to the task at hand: understanding EMC as much as possible. Approximately 12.48% of the course is about the ‘why’ of EMC, the rest is technical.

- **Live Demonstrations.** A very popular part of the course are the real life demonstrations of EMC concepts and fixes. These simple yet effective tools really drive home the concepts. With the output of the spectrum analyser on the screen this is a powerful learning tool.

- **Visual Learning**. All concepts are presented through simple, friendly diagrams and drawings in our unique style. The format of the course is “here is a picture, lets talk about the picture”. If there is a question or concept that needs further explanation or exploration, we draw a new diagram on the screen live to illustrate the concept.



- **Mental Models.** We want to develop a few simple concepts that enable us to think about EMC. Where do emissions come from? How are antennas created? Where does high frequency current flow? Where is this impedance and how can I get rid of it? In many cases, we break down the teaching into simple, relatable circuit diagrams.

- **Minimal equations and mathematics.** Any equations more complicated than Ohms law are presented in support of the diagrams, graphs, and concepts. The maths is not the main focus. We want to develop an intuitive, visual understanding.

- **In-person.** Dedicated time for you and your learning, (relatively) free of interruptions, pop-ups, notifications, meetings, and other work. Our goal is for you to receive quality learning. Other engineers working from home are welcome to dial in remotely but they will not be receiving the full benefit of the training.

- **Your products discussed**. If you are coming to the course with specific problems or questions then let me know beforehand if there are specific subjects you want to cover or emphasise and we can work this into the training. If you have anything you want to talk about after the training, maybe seeking clarification of a point or to discuss something privately then we are available after the course each day to chat.

- **Real Examples**. The course contains many examples of products and problems straight from the Unit 3 Compliance laboratory. These are not abstract case studies, these are real products with real problems that we have worked on and fixed. Mistakes are the best teachers, so learn from other peoples instead of your own.

- **Fun and interesting**. Demonstrations, exercises, terrible jokes, stories from the lab, quizzes, even colouring in (no, really). EMC has an unjustified reputation of being difficult and boring. This training is as fun as it can be 😊

Course Structure

Opening (0.25 days)

An introduction to the course, set the stage about why we should care about EMC. Briefly cover key regulations and market specific EMC considerations

- General course introduction, housekeeping, timings, etc
- Introduction to EMC
- EMC Regulations Overview

EMC Toolkit (1.25d days)

The basic principles of EMC, but without the scary maths. Seeking to answer questions like: Where does it comes from? How does noise get from one place to another? What we can do about it?

Lots of practical, intuitive demonstrations, pictures, and analogies to allow us to build mental models allowing us to begin to understand EMC, and to help us think about problems that are not covered by common design guidelines.

We break down common EMC problems into simple, relatable circuit diagrams to explain what is going on. This part of the course allows us to build our future knowledge on sound foundations.

- Radiated Emissions
- Antenna Structures
- High Frequency Current Flow
- Improving Emissions
- Radiated Immunity
- Coupling
- Conducted Emissions
- Conducted Immunity

- Shielding
- High Frequency Current in PCBs

EMC Design (1.5d)

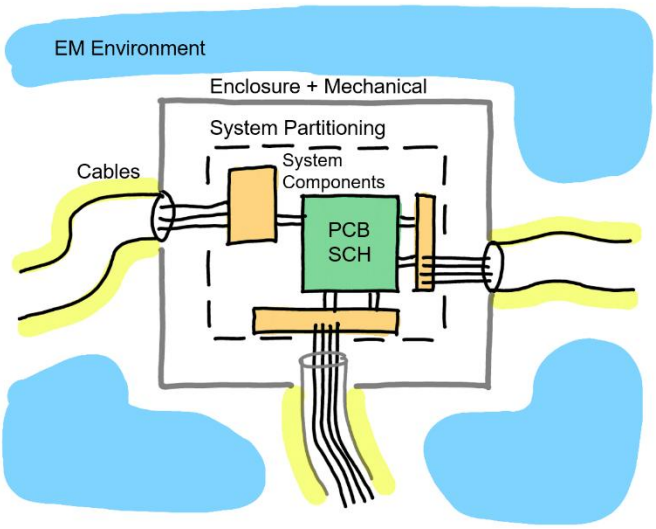
You may be exposed to a multitude of designs in the course of your career. These modules take the most common mistakes seen in the test laboratory, demonstrate the errors, and show best practice.

We learn from our mistakes, so why not learn from other people's instead?

This module builds on the ideas established in the **EMC Toolkit** allowing us to see these in practice.

We take an “outside in” system approach to design for EMC. The EM environment in which our product must operate first interacts with the cables and the enclosure of the product. Without knowing what their characteristics are (how much if any EM attenuation they provide) we can’t design our subsystems and circuit boards correctly.

Topics in this section



- Mechanical Design + Shielding Considerations
- Cables and Cable Shielding
- Modules + 3rd Party Components
- Radio Modules
- Design Partitioning
- PCB Ground Plane
- PCB Stackup
- DC/DC Converters, power supplies, invertors, variable frequency drives
- Decoupling
- Single Ended Digital Signals
- Differential Digital Signals
- Analogue Circuits
- Filtering
- Transient Suppression (Surge, ESD)
- Software

Concluding Thoughts

- Considerations for how to manage the product design cycle to serve EMC and regulatory compliance.
- A look at market surveillance figures from the EU to see how well other manufacturers are performing.

Case Studies

A chance for you to bring your problems to the table. At the end of the course, taking what we have already discussed, how do we go about applying what we have learned to your products? Let’s look at products and problems that you are working on at the moment. This is like free consultancy!

References

The slides have links and references to summarise the guidelines discussed. This is no substitute for a textbook or in-depth technical reference, rather they serve as a reminder of the key concepts covered.

Feedback from previous course attendees

“The course went very well and James was excellent all throughout the week. Extremely knowledgeable and passionate about EMC. Everyone learnt a lot during the training and truly enjoyed it.”

“The obvious passion that James has for the subject of EMC came across strongly in the training. He presented ways of looking at situations that help you understand what’s going on without getting bogged down in too much theory…along with the excellent demonstrations this really brought what can be a dry subject to life. I definitely left the training with a much better understanding of the pitfalls that await a product design that has been undertaken with little consideration of the potential EMC issues.”

“Really enjoyed the demos, the slides about PCB stack up and coupling were very good, radiated emissions topic was presented very well. Overall enjoyed it a lot.”

“The real world examples, especially before and after data, really underlined the differences that the discussed changes make.”

“Good morning James, I would just like to say a big thank you for your efforts with the Product Design for EMC Course. I think that you have found a brilliant way of conveying the subject matter in a really easily digestible format that highlights the pitfalls that any electronics design engineer can fall into as well as practical methods to rectify issues should a design turn out to be "less than optimal"! I will certainly recommend this course to all of my team members, so hopefully we will authorise another training course in the not-too-distant future. I am really glad that the course didn't focus on trying to work out the "divergence of this" or the "curl of that" (I personally find the integral forms of Maxwell's more intuitive) - especially because real world applications with noise or other non-sinusoidal waveforms, parasitic capacitances and induction loops etc. are next to impossible to calculate anyway. I used to have a work colleague who had a PhD but also had good practical electronics engineering experience and he always used to joke about the physics equations stating that they were only really applicable to "spherical chickens in a vacuum" !”

Customisation Options

This course has been designed to cover the majority of EMC theory and design strategies in a three day period. Even then it is a tight squeeze to fit everything in. The compromises are that there are many topics that don’t receive as good a coverage as I would like.

If you are working in a particular field (automotive, aerospace, military, marine) then the presentation can be delivered in a way that emphasises specific EMC characteristics of these environments. All of the principles within are broadly applicable to nearly all fields of electronics

If you want to discuss a specific topic in more depth, then we can have a chat about tweaking the course to suit your requirements.

For example, I’ve given a course recently where we discussed regulations, EMC principles and problem solving, and Electrical Safety all in one go.

Prices & Availability

We come to your location:

This course can be run in-house with an approximately 4 week lead time (depending on existing commitments)

The cost is **£8955** including travel and accommodation expenses for the trainer.

There is a limit of 12 people per course to ensure everyone gets the learning experience they deserve, the attention they need and their questions answered whilst keeping the course to 3 days.

If your site is daily commutable from Bradford, West Yorkshire then a discount will be applied to account for the reduced requirement for accommodation for the trainer.

If the travel time to your site is outside of the UK or hard to get to (e.g. Cornwall, Orkney) then there may be a slight cost increase.

If you want to have your course customised to fit your particular requirements, standards, or industry then please get in touch to discuss.

You come to our location:

We run Open Courses twice a year (April and October) in the well-connected city of Leeds, UK. You can find the list of upcoming courses on the Think EMC website.

The price for the course is **£1450 per person.**

If you would like to have an open EMC course local to where you are based, and there are other companies or engineers nearby who are interested, then please let me know and I’ll be happy to investigate running a course near you all.

Our payment terms are any fees to be received in full 30 days before the course date.

Return on Investment

The headline benefits of the training

- Fewer EMC testing induced delays
- Better quality, more resilient, cheaper products that are quicker to market
- Lower field return rates
- Happier customers
- Lower stress, lower blood pressure, more time for family, cycling, walking, golf, etc.

A typical worst case

Let’s make some quick estimates on the cost of EMC problems on a typical product, based on a typical scenario. These are conservative estimates as EMC problems and costs have a tendency to spiral out of control.

Your company takes a product to your local laboratory and it fails one or more of the tests. This means that a three to four day slot at the lab has been wasted. Hopefully, you do a bit of tinkering around at the lab and find what you think is the problem.

4 days @ £1500 / day (lab fees, engineer time, transport, expenses) = £6000

You need to assess the product back at your lab to see if you understand the issue. If you are lucky and you have some basic EMC test equipment, you re-design the product with the features that you think / hope / pray will make the difference to the test. Also consider the knock on effect of the engineer working on this and not other things.

1 week of engineer time @ salary of £45kpa plus 20% overheads and £250 materials = £1300
Total delay + 1 week

New PCBs ordered, parts sourced, allocated to manufacturing (hopefully no parts shortages) with a short turnaround time. Laboratory re-booked for the next set of tests with a 4 week lead time (again, if lucky).

PCBs and components £500, Manufacturing £1000 = £1500
Total delay +4 weeks

Resubmit product to test laboratory and it now (hopefully) passes. Otherwise you get to do this whole cycle again, probably doubling this cost and your stress levels.

Total unplanned costs = £8800
Total project delay = 5 weeks
(Multiply this across every project and the costs really start to stack up.
Now compare this cost with the cost of the training course)

Now you have to live with the following problems:

- A project that is both late and over budget. What are the commercial and reputational effects of this?
- A perhaps vague understanding of what caused and what fixed the problem located in the brain of just one of your engineers. How do you share this experience with the rest of the team? Are the conclusions even correct?
- If the problem is not entirely fixed, then maybe the product has latent problems that will only become apparent once the product is operating in its intended Electro-Magnetic environment. Lower quality products, customer returns showing No Fault Found that were actually caused by electrical noise.
- Which of the design changes you made actually fixed the problem? Do you carry these over automatically to new designs? Are you building in cost and complexity that you don’t need?
- No guarantee that another problem won’t occur on another project in future. Can your business survive this scale of delay and cost on every project?

With EMC Training Scenario

The company invests in the rather marvellous training course that you’ve just been reading about and all the engineers attend.

Cost = as above, plus the time for your engineers
Time delay = 3 days

Outcome:

- The engineers look at their designs with fresh eyes and spot several problem areas highlighted in the course.
- Designs and PCBs are changed ahead of release for manufacture and before products are taken to the test lab.
- Options are designed in and alternate components are sourced ahead of testing so that, instead of a wholesale re-design in the case of problems, planned component placements on PCBs can be populated, alternate cables or components can be used to pass the tests first time

Example: one customer had cleared all plane layers under their DC/DC converter switching nodes on their new PCB. Immediately after the course the engineering team were adding return plane fill in these holes to help control the radiated emissions from the boards. This PCB was meant for release the week before the course but they held on to it just in case there was anything that came up during the sessions. This wasn’t the only change made either.

- For existing products, the engineers may be able to change the designs to improve the EMC performance and to reduce the Bill of Materials (BoM) or assembly costs of the device.

Example: after attending the course, one engineer went back to his company and experimented with his PCB stackup and filtering of analogue circuits. The existing product utilized a metal enclosure with shielding gasket, screened cabling and a dedicated input filter. With some simple PCB changes, he was able to remove all of these EMC measures and move to a plastic enclosure and unshielded cable. They saved £35 of material and assembly costs on their biggest selling

product and (when re-tested at Unit 3 Compliance) he had actually improved its EMC performance as well.

About the Trainer



James Pawson has been an Electronic Design engineer since 2002 with a background in embedded design, AC/DC and DC/DC power supplies, high speed digital circuits, and project management (he did not like having to give up his soldering iron). He has worked on design, test, and problem solving for EMC and regulatory testing since 2008.

In 2017, after the closure of his previous employer, he bought the EMC test lab assets and set up **Unit 3 Compliance**, an independent EMC test laboratory in Bradford, West Yorkshire. This has grown from being a “man-in-a-shed” to a professional laboratory with a team of several engineers. Unit 3 Compliance provides EMC testing, Electrical Safety assessments, environmental testing, and consultancy / problem solving activities. Customers range from fellow small businesses to divisions of multinational corporations.

He specializes in quick, proportionate EMC problem solving on systems from fingernail sized implants to large factory machinery and everything in between.

To deal with the increase in requests for training, he established his training company **Think EMC** in 2023. The 500+ hours of training that he has delivered on EMC and regulatory topics have received consistently good feedback.

Inspired by the cartoons and graphic novels he loved as a child, Japanese *ukiyo-e* art, and the books and cartoons of Randall Munroe he has an ongoing project to distil complex EMC problems into simple drawings and diagrams. These unique, simple, quirky, yet intuitive diagrams form the backbone of the training.

He also has started writing EMC textbooks in his own style.

Involved with supporting training and events for companies like Eurofins, TUV SUD, Rohde & Schwarz and MDL Technologies, he will happily speak about design and test for EMC until people pay him to go away.