100
Not Out

ISSN 1748-9253

Functional Safety
By Keith Armstrong
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EMCUK 2012
9 & 10 October
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Functional Safety - A warning on the risks of using inappropriate EMC standards-especially EN/IEC 61326-3-1 and -2
By Keith Armstrong, Cherry Clough Consultants

EMC design of high-frequency power “switchers” and “choppers” - Shielding (screening) the power converter’s output cable
By Keith Armstrong, Cherry Clough Consultants

Advertisers Index
Verifying EMC performance is one thing. Diagnosing the cause of EMI is quite another.

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www.agilent.com/find/EMIreceiver
MILMEGA Ltd wins Queen’s Award for Innovation 2012

MILMEGA Ltd, the designer and manufacturer of high power RF and microwave amplifiers is proud to announce that it has been awarded a Queen’s Award for Enterprise in Innovation for developing amplifiers, based on a novel design methodology, using gallium nitride-based transistors, for use in Electromagnetic Compatibility (EMC) test equipment, which has brought the Company significant, global, commercial success.

The prestigious Queen’s Award for Innovation is awarded to businesses in the UK to recognise outstanding innovative achievements relative to their operational size. To win the Award, MILMEGA Ltd was required to demonstrate continuous innovation and development over a period of five years resulting in substantial improvement in the performance of the Company. In addition the Award is only made to organisations that can demonstrate a high level of corporate responsibility.

Pat Moore, MD said “One of our key differentiators in our target markets is daring to be different while maintaining a reputation for exceptional quality and customer service. A Queen’s Award is a benchmark aspired to by many and our customers will share the pride and joy in having been selected to receive this internationally prestigious mark of excellence.”

A Queen’s Award is a benchmark aspired to by organisations that can demonstrate a high level of corporate responsibility.

Graeme Goodall, FD said “The Company and staff are very proud and honoured to have received this Award which recognises our sustained success in designing and manufacturing highly innovative, market leading, quality amplifier products for the EMC industry. We export over 90% of our sales and this globally recognised Award for achievement provides MILMEGA Ltd with tremendous additional credibility in our overseas markets.”

MILMEGA’s products cover frequency ranges from 80MHz to 8GHz with powers up to 1KW and are used throughout the world in EMC testing, defence, communications and high-energy physics. The innovative, modular amplifier design, which uses the latest GaN transistor technology, provides MILMEGA amplifiers with a number of advantages including, high power density, ease of maintenance and repair, superior reliability and the ability to upgrade in both power and frequency. These features make MILMEGA amplifiers particularly attractive to the replacement market as well as emerging markets in India, South America and the Far East.

Established in 1987, MILMEGA Ltd employs 30 design, manufacturing and support staff at its factory in Ryde, Isle of Wight. Following a MBO in 2004 the Company has grown significantly by investing heavily in new product design and by expanding its overseas markets most notably in the Far East.

The Company was acquired in January 2012 by Teseq Ltd, a UK subsidiary of Teseq Holding AG a large global EMC group based in Switzerland. Teseq has established MILMEGA Ltd as an amplifier competency centre on the Isle of Wight with responsibility for amplifier design and manufacture within the group. www.milmega.co.uk

100 Not Out

You may have noticed this is our 100th Issue. The first Issue was published March 1995. At that time frequency was four times per year, later increased due to demand, to six issues per year which is how it has remained. When The EMC journal was first launched there were another 5 or 6 titles covering EMC but all have fallen by the wayside, so why have we succeeded? Simple really… Single Target Market. Others tried to add in other directives and associated products to bump up their revenue which was a big mistake. We concentrated solely on EMC, which enabled us to cover the subject in-depth and has led to Nutwood UK publishing not only the Journal but an EMC Yearbook, Filters Directory, Test Directory and organising the highly acclaimed EMCUK Exhibition & Conference now in its 9th year. We are also Secretariat for the EMC Industry Association (EMCIA). So we penetrate what is a truly niche market. When will the innings end…who knows?
AR Executive In Training For 2012 Olympics

Dr. Tom Cantle, Managing Director of AR Europe Selected as an Operations Team Manager and Organizer for 2012 Summer Games

Dr. Tom Cantle manages the European operations of a company that creates and distributes the most advanced and innovative power amplifiers, antennas, and modules for EMC testing, wireless, medical, industrial and military applications. That, in itself, is more than a full time job. But when Cantle heard that the Olympic games would take place in London during the summer of 2012, he wanted to be a part of it. So he offered his services as a volunteer, along with countless other people, and much to his delight he was selected to be an Operations Team Member and Organizer.

Cantle will work at the male and female beach volleyball competitions, which will take place at the prestigious Horse Guards Parade ground. Located in Whitehall in central London near 10 Downing Street, the Horse Guards Parade was formerly the site where jousting was held in the time of Henry VIII. It was also once the headquarters of the British army. The annual Trooping of The Colour, where troops are presented to the Queen, takes place there currently.

Dr. Cantle is now in training, which includes not only learning the basics of beach volley ball, but also becoming conversant in British sign language, mastering all the venue information, and a wide variety of other tasks that will help him deliver a perfect experience of the London games for spectators and competitors. During the games, Cantle will be at the Horse Guards Parade site every morning at 6 a.m. helping to keep things organized and to provide information for both athletes and members of the public.

Cantle is excited to have been selected, he’s enjoying his training, and he says. “I’m proud to be British, and honored to help deliver the goals of the 2012 Summer Olympic Games.”

Blackwood Thriving as part of the Kiwa Group

Kiwa Blackwood Compliance Laboratories has celebrated a strong first year as part of the Kiwa Group of Companies. Not only has it grown in terms of turnover, but it has actively expanded into new areas and added over 50 standards to its schedule of accreditation. “The integration of Blackwood Laboratories has gone excellently, with many advantages seen at Blackwood and throughout the Group; importantly, although we may have a new look, we still offer the same excellent service as we have always done,” says James Verlaque, Business Manager.

Paul Gwilliam, the Kiwa Blackwood Laboratory Manager adds, “It has been a very busy year with the addition of many new standards and working closely with the other Kiwa Group #laboratories. Extending the range of products we test is continuing and the coming year promises to be exciting. We would also like to thank our loyal customers for their continuing business – we are committed to looking after all of our customers and will work flexibly to meet their needs.”

In addition to providing pre-compliance and compliance testing services, Kiwa Blackwood offer value added services to their customers. “A fundamental part of our role is to keep up to date with the latest legislation, regulation and standards,” says Alan Powell, Technical Sales Manager. “As part of our focus on supporting our client’s business needs, we offer a wide range of technical support in this area, free of charge, as part of our commitment to customer service – if anyone has a wide ranging compliance question please call me!”

Optical Filters appointed by 3M as Official Specialist Partner to work with Optical Films Division

Optical Filters are delighted to announce that they have become the official Specialist Partner to work with 3M Optical Films Division.

From 1st April 2012 Optical Filters will be providing the full range of 3M optical films to customers requiring specific volumes and conversion services.

If you have any questions or would like further information & pricing please do not hesitate to contact us on 01844 260377 or visit our website www.opticalfilters.co.uk.

York EMCS appoints Nick Wainwright as Chief Operating Officer

York EMCS (YES) Ltd, the leading independent supplier of EMC, safety and telecoms regulatory services has appointed Nick Wainwright as Chief Operating Officer. Nick, previously Operations Director, now leads YES’s management team and is responsible for the affairs of the company on a day to day basis as well as implementing YES’s company strategy.

Nick joined YES’s predecessor, York Electronics Centre, in 1990 as an EMC Test Engineer when its only laboratory was located on the University of York campus.

YES now has 3 UKAS accredited laboratories serving the whole of the UK; from Dalgety Bay near Edinburgh, Castleford near Leeds and Yate near Bristol. YES’s newest laboratory opened in Yate in late 2010 and has proved a tremendous success, providing customers in the South West with state of the art test facilities and unrivalled customer service.

YES also boasts an expert team of consultants, a range of market leading products such as the Comparison Noise Emitter (CNE) and Comb Generator Emitter (CGE) and a comprehensive range of CPD workshops and courses.

Nick says “Our business continues to perform extremely strongly in all of our core areas and we are now very much focussed on the future. We have devised an ambitious strategy to take YES into the next phase of its development which will see the company continue to grow but without compromising the quality of our services.”

Chris Marshman, who founded YES in 1996, steps down as Managing Director to take up the role of Development Director with specific responsibility for developing key aspects of the YES strategy.
MILMEGA
The difference between ordinary and extraordinary

- Best in class for Guaranteed power
- Removable sub sections enhance product utilisation
- 5 Year fully expensed warranty
- Exceptional compactness (half the size of the competition)
- Upgradeable, modular architecture

The new 80 to 1000MHz amplifier range from MILMEGA is everything you would expect from a Company that delivers exceptional products and service and sets standards competitors aspire to.

We promise only what we can deliver... then deliver more than we promise

Designers and Manufacturers of High Power Microwave and RF Amplifiers

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Companies who have already Booked for 2012

Agilent Technologies UK Ltd
ANSYS UK
AQL-EMC Ltd
AR UK
BAE SYSTEMS (Rochester)
BAE SYSTEMS (Warton)
Blackwood Compliance Laboratories
Castle Microwave Ltd
Cove Industrial Enterprises Ltd
CST - Computer Simulation Technology AG
Dexter Magnetic Technologies Europe Ltd
DM Systems & Test Ltd
Easby Electronics Ltd
Electronic Test & Calibration Ltd
EMC Hire Ltd
EMC Industry Association
EMC Partner UK Ltd
ETS-Lindgren Ltd
F. C. Lane Electronics Ltd
Frequensys Ltd
Global EMC UK Ltd
HTT (UK) Ltd
Hursley EMC Services Ltd
Hypertac Ltd
Kemtron Ltd
Laplace Instruments Ltd
MBDA UK Ltd
MDL Technologies Ltd
Midas Components Ltd
MILEMEGA Ltd
MIRA Ltd
MPE Ltd
MS Testing
Panashield (UK) Ltd
PPM Pulse Power & Measurement Ltd
Q Par Angus Ltd
Rainford EMC Systems Ltd
Rohde & Schwarz UK Ltd
Roxburgh EMC
Syfer Technology Ltd
Telonic Instruments Ltd
Teseq Ltd
TMD Technologies Ltd
TRaC
UKRF Ltd
Ultra Electronics
Uvvox Ltd
Wurth Electronics UK Ltd

There are just a few stands left - Don’t Miss Out!
Contact Lynne Rowland on +44 (0)1208 851530 or email: lynne@theemcjournal.co.uk

Technical Forum and Training Programme
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EMC Training Programme

Tuesday 9th October 2012

08.30 Registration

09.30–11.00 **John Davies**
EMC Goggles Ltd
*Presentation*

Visual training with practical demonstrations of:
- Understanding EMC. A sample of the EMC Goggles training course.
- The components are everywhere! See the invisible components and use them to your advantage.
- EMC design - emissions from PCBs. Live demonstration of Good versus Bad.
- After discovering an EMC failure in the lab, some tips and tricks on how to quickly diagnose the cause and also how to implement the solution.

11.00–11.30 Coffee & Visit to Exhibition Stands

11.30–12.30 **John Davies**
EMC Goggles Ltd
*Live Demo*

12.30–14.00 Lunch & Visit to Exhibition Stands

14.00–15.30 **Keith Armstrong**
Cherry Clough Consultants
*Presentation and Live Demo*

A live demonstration of how easy it is to use a home-made loop probe – perhaps made from a paper clip – with a spectrum analyser costing less than £1000, to quickly and easily diagnose common EMC problems, such as:
- slots and seams in enclosures causing problems for shielding
- inappropriate types of cables and connectors
- assembly details that can cause problems for filtering
- inadequate filtering causing radiated emission problems above 30MHz
- inadequate shielding causing conducted emission problems below 30MHz

15.30–16.00 Tea & Visit to Exhibition Stands

16.00–17.00 **Tim Williams**
ELMAC Services Ltd
*Presentation and Live Demo*

Theory and live demonstration of:
- Coupling between wires, showing common impedance, mutual inductance, mutual capacitance and the effect of shielding
- The horror of heatsinks: why it is that where and how you connect your processor or switchmode supply’s heatsink is so important

Wednesday 10th October 2012

08.30 Registration

09.30–11.00 **Tim Williams**
ELMAC Services Ltd
*Presentation and Live Demo*

Theory and live demonstration of:
- Cable shielding and the effect of a pigtail versus a proper connection
- Self-resonance of components: the effect of parasitic inductance and capacitance, ferrite materials, and terminating impedance of filters, from SM to mains components
- Inductive coupling to a small loop: why scope probes don’t always tell the truth

11.00–11.30 Coffee & Visit to Exhibition Stands

11.30–12.30 **Keith Armstrong**
Cherry Clough Consultants
*Presentation*

Using quick, easy, low-cost close-field probing techniques to reduce financial risks in every stage of a new product’s project:
- Proof of design principle
- Design, and component selection
- Development
- Fixing problems during compliance tests
- QA of EMC performance in serial manufacture
- Checking EMC effects of proposed design changes, component substitutions and software upgrades
- Helping ensure EMC of systems and installations
- Maintaining EMC despite maintenance, repair, upgrades, modifications, etc.

12.30–14.00 Lunch & Visit to Exhibition Stands

14.00–16.00 **Keith Armstrong, Tim Williams & John Davies**
The Three For All: Panel session with the audience, discussing any questions on EMC design, testing and compliance.

The presenters:
- Tim Williams is with Elmac Services, offering advice and training in all aspects of EMC design and test. He is the author of EMC for Product Designers, now in its fourth edition.
- Keith Armstrong is with Cherry Clough Consultants, and has been fixing EMC problems, providing special assistance with EMC management and design, and teaching EMC and safety training courses worldwide, on everything from cellphone PCBs to complete synchrotrons and tokamaks, since 1990. He has recently written some books on EMC design techniques.
- John Davies has over 20 years of EMC testing experience, the last 7 years as Managing Director of Blackwood Labs. He has now formed EMC Goggles, a training and consultancy company.

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The EMC Journal May 2012
Editor’s note: The volume of potential Banana Skins that I receive is much greater than can possibly be published in the Journal, and no doubt they are just the topmost tip of the EMI iceberg. Keep them coming! But please don’t be disappointed if your contribution doesn’t appear for a while, or at all. Even using four pages in every EMC Journal I can’t keep up!

LORAN saved, provides backup when GPS interfered with
The Long Range Aid to Navigation (LORAN) system (originally LRN for Loomis Radio Navigation, after it’s inventor, Alfred Lee Loomis) has been around for decades, with roots that go back to World War II and that era’s naval warfare. Simply put, it is a terrestrial, radio-based navigation system that uses the time intervals between the reception of signals to triangulate a user’s position. The venerable system has modern value: the greater capabilities of the new enhanced Loran (eLoran) make it a much-needed independent, redundant backup to GPS, and one less susceptible to interference than GPS is. (Taken from: GPS World, 8 Feb 2008. http://www.gpsworld.com/wireless/news/loran-saved-money-questions-remain-3849.)

Avoiding motor drive interference with TV filming and transmission
The fan itself sits in a plant room and is powered by a large ABB motor and a 160kW ABB low harmonic drive. This low harmonic specification is necessary to minimise interference with TV filming and transmission equipment used at all matches at the ground. (Taken from an article about the engineering used in Arsenal’s Emirates Stadium, in: The Engineer, 11-24 Feb 2008. http://www.theengineer.co.uk/news/gunning-for-perfection/304509.article)

Quantum Consciousness and Energy Medicine
Energy-related practices have been around for many thousands of years within indigenous tribes and various cultures. ‘Life as Energy’ has even been a construct in our Western minds for millennia, but in the last century it has congealed as science through quantum physics. This advanced physics model reveals that we are electromagnetic fields. In the 21st century, quantum medicine is being applied for self-healing, and the possibilities are limitless.

We have yet to utilize these constructs fully, but we are slowly catching on. We know, for example, that there are energy frequencies which are harmful to us, like living under high power wires and being too close to TVs, computers and cell phones. We also know that some energy frequencies are helpful. Energy frequencies can be quite powerful tools for healing.

E = mc²

‘Ninety-nine percent of who you are is invisible and untouchable.’ (R. Buckminster Fuller)

Einstein’s physics presented us with the knowledge that everything in the universe is the energy of light. Matter is simply frozen light. We are not bodies with an energy field surrounding us, but expansive electromagnetic fields of light within which a small part of us vibrates at a visible frequency.

Within this vast field, there is a blueprint that holds the “tensility” or tensile structure of our Being together - from cells to cosmos. This set of interacting mathematical and geometric shapes is called our sacred geometry. Quantum age energy medicine affects all levels of our electromagnetic fields - subatomic, cellular, physical, subtle, and spatial, including our geometric blueprint, the life force itself and beyond. It is able to do that merely by holding an expanded awareness. (Taken from a webpage by Virginia Leslie, MA: http://home.mindspring.com/~kiva4/id4.html)

(We always celebrate each 100th Banana Skin with something a little humorous – but perhaps we should be more sensitive, and say: something from outside the world of Electromagnetic Compatibility engineering!)

Snooping through the power socket
Power sockets can be used to eavesdrop on what people type on a computer. Security researchers found that poor shielding on some keyboard cables means useful data can be leaked about each character typed. By analysing the information leaking onto power circuits, the researchers could see what a target was typing. The attack has been demonstrated to work at a distance of up to 15m, but refinement may mean it could work over much longer distances.

Hotel attack: ‘Our goal is to show that information leaks in the most unexpected ways and can be retrieved,’ wrote Andrea Barisani and Daniele Bianco, of security firm Inverse Path, in a paper describing their work.

The research focused on the cables used to connect PS/2 keyboards to desktop PCs. Usefully, said the pair, the six wires inside a PS/2 cable are typically “close to each other and poorly shielded”. This means that information travelling along the data wire, when a key is pressed, leaks onto the earth wire in the same cable. The earth wire, via the PC’s power unit, ultimately connects to the plug in the power socket, and from there information leaks out onto the circuit supplying electricity to a room.

Even better, said the researchers, data travels along PS/2 cables one bit at a time and uses a clock speed far lower than any other PC component. Both these qualities make it easy to pick out voltage changes caused by key presses.

A digital oscilloscope was used to gather data about voltage changes on a power line and filters were used to remove those caused by anything other than the keyboard.

“The PS/2 square signal wave is preserved with good quality... and can be decoded back to the original keystroke information,” wrote the pair in a paper describing their work. They demonstrated it working over distances of 1, 5, 10 and 15m from a target, far enough to suggest it could work in a hotel or office.

“The tests performed in the laboratory represent a worst case scenario for this type of measurement, which along with acceptable results emphasizes the feasibility of the attack on normal conditions,” they added. The pair said their research was “work in progress” and expect the equipment to get more sensitive as it is refined. The attack is due to be demonstrated at the Black Hat conference that takes place in Las Vegas from 25-30 July.

The EMC Journal May 2012
1.5GHz SPECTRUM ANALYSER

Rigol DSA815

9kHz to 1.5GHz
Typical -135 dBm (DANL)
Pre-amp as standard
USB, LAN

Optional.
1.5GHz Tacking Generator
VSWR Measurement Kit
EMI Filter & Quasi-Peak Kit

Sets a new industry standard for performance and price. From £895
+VAT
In-flight calls still on hold
As the summer holiday season begins, the UK Civil Aviation Authority (CAA) is reminding air passengers that using mobile phones is still forbidden on nearly all flights.

Although some airlines have introduced ‘mobile phone systems’ on a number of their aircraft, the use of mobile phones generally remains prohibited on the majority of aircraft.

Passengers who find themselves on board an aircraft modified to allow mobile phone use will be informed by the cabin crew and given instructions on how and where their phone can be used.

Any passenger who disobeys a cabin crew instruction to turn off a mobile phone is committing an offence, which could result in prosecution.

Research carried out by the CAA found that the use of mobile telephones can adversely affect navigation and communication functions, producing significant errors on instrument displays and background noise on pilot radios. The research endorses evidence from pilots, who have complained that interference from mobiles has caused:

- False notification of unsafe conditions, e.g. false baggage compartment smoke alarm warnings;
- Malfunction of aircraft systems;
- Interrupted communications due to noise in the flight crew headphones; and
- Distraction of crews from their normal duties due to increased work levels and the possibility of having to invoke emergency drills.

Bob Jones, Head of Flight Operations at the CAA, said: “The safety risks of using a mobile on board an aircraft are well-established. Yes, some airlines are currently testing various systems, but this does not weaken in any way the ban on phones being used on board the vast majority of UK aircraft.”

“Unless specifically told otherwise, passengers must not text or phone while the cabin doors of an aircraft are closed.

Safety is the number one concern of the aviation industry, therefore mobile phones will remain banned until the technology that allows their safe use is installed.”

Notes to Editors:
- BMI, Ryanair, Air France, TAP Portugal, Qantas, Emirates and British Airways are among the airlines currently using or planning to trial on-board mobile phone systems on some aircraft. These trials are being closely monitored by the relevant aviation safety regulators.
- Some other airlines allow the use of mobile phones on-board if they can be put in ‘flight mode’, which disables any calls and texts. However, like any electronic device, these should still be turned off for take-off and landing and when instructed.
- Detailed research on the effects of mobile phones on aircraft electronic systems carried out by the CAA can be found at http://www.caa.co.uk/docs/33/capap2003_03.pdf
- The CAA is the UK’s specialist aviation regulator. Its activities include: making sure that the aviation industry meets the highest technical and operational safety standards; preventing holidaymakers from being stranded abroad or losing money because of tour operator insolvency; planning and regulating all UK airspace; and regulating airports, air traffic services and airlines and providing advice on aviation policy from an economic standpoint.

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Diagram 1) Shielding at target-receiver. Typically Silver and Copper Hybrid RFI Shield.

Diagram 2) Shielding at source-emitter. Typically Nickel and Copper RFI Shield.
information about the train’s compatibility or otherwise with EE&CS limits. Some examples are given here where there were incompatibilities identified from train testing for a variety of track circuit types operating at various frequencies. These examples are all from outside of the UK.

Figure 3 is an interesting example of the noise measured across an FS2500 track circuit intermediate receiver when three different forms of traction technology trains passed over the receiver. The FS2500 track circuit is an FSK coded track circuit operating at one of four centre frequencies, 1700Hz, 2000Hz, 2300Hz and 2600Hz. Lock up of the receivers were experienced, due to passage of 3 phase drive traction trains over the receiver. Due to the coding of this type of track circuit, WSF is unlikely and the problem in this case was RSF of the track circuits. This did however cause serious service disruption requiring technician call out to reset the receivers in the event of the lock ups occurring.

The first trace was for a conventional camshaft technology train. This type of train was the mainstay of traction control before the advent power electronics technologies. In essence the DC traction motor voltage is controlled by switching in and out resistors. There are no characteristic operating frequencies. The DC supply voltage is connected across the motors and the resistors which are progressively switched out to increase the voltage across the motors themselves. The control is actually more complex than this - with parallel series reconnection of the motors and weak field operation; however it is the switching events that are the most significant in terms of harmonic emissions. Their interference waveform is characterised by low level broadband noise associated with switching transients. This noise was picked up by the 1700Hz receiver and seen as voltage peaking at 1.5mV.

The second trace was for a chopper controlled train. This technology still utilises DC traction motors but Gate Turn Off (GTO) thyristor power semiconductors are used to switch (or chop) the DC voltage on and off, thus varying the net DC voltage applied to the motors. A fixed chopping frequency is used (or a number of fixed frequencies) and this results in a characteristic high level emission at the chopping frequency. Their interference waveform is similar to conventional camshaft traction (low level broadband noise) with the addition of specific harmonics related to the fixed chopping frequency, seen in the second trace as a peak of 11mV at approximately 1570Hz. Whilst the peak is relatively high at 1570Hz, this characteristic is known and it is possible to choose the chopping frequency to specifically avoid any known signalling frequencies.

The third trace was for a 3 phase drive technology train utilising IGBT (Insulated Gate Bipolar Transistor) inverters to control AC traction motors. In contrast to DC traction motors whose speed are controlled by the voltage applied to them, AC traction motor speed is controlled by varying the frequency and the voltage applied to them. The inverter fundamental frequencies vary between about 50Hz to 594Hz and at harmonics of these frequencies, therefore sweeping right through the FS2500 frequency band. The level measured was up to 10mV right through the 1700Hz receiver band and was the cause of the periodic lock ups of the receiver.

The solution to the problem was either to reduce the train emissions, which is always difficult if the train is already in service, or to reduce the susceptibility of the receivers. It is pointed out at this point that it is perfectly possible to design a 3 phase drive train to meet susceptibility requirements for FS2500 track circuits. The problem was a combination of the IGBT switching pattern not optimised to minimise harmonics in the 1700Hz band combined with poor bonding arrangements. In addition to this the FS2500 intermediate receivers were of a poor design being susceptible to common mode rail currents whereas the parent receiver is not.

This demonstrates the importance of good design from the earliest point in the project to avoid problems only being discovered on the track. In this particular case modifications were made to the infrastructure (the intermediate receivers) this being simpler and less costly than train modifications.

(Taken from: ‘Traction Compatibility with EE & CS Infrastructure’ by Adrian Hines of Railway Technology Consultants Ltd, a paper he presented at EMC-UK 2008, Newbury.)

**RFID can interfere with medical systems**

**Context.** Health care applications of autoidentification technologies, such as radio frequency identification (RFID), have been proposed to improve patient safety and also the tracking and tracing of medical equipment. However, electromagnetic interference (EMI) by RFID on medical devices has never been reported.

**Objective.** To assess and classify incidents of EMI by RFID on critical care equipment.

Design and Setting Without a patient being connected, EMI by 2 RFID systems (active 125 kHz and passive 868 MHz) was assessed under controlled conditions during May 2006, in the proximity of 41 medical devices (in 17 categories, 22 different manufacturers) at the Academic Medical Centre, University of Amsterdam, Amsterdam, the Netherlands. Assessment took place according to an international test protocol. Incidents of EMI were classified according to a critical care adverse events scale as hazardous, significant, or light.

**Results.** In 123 EMI tests (3 per medical device), RFID induced 34 EMI incidents: 22 were classified as hazardous, 2 as significant, and 10 as light. The passive 868-MHz RFID signal induced a higher number of incidents (26 incidents in 41 EMI tests; 63%) compared with the active 125-kHz RFID signal (8 incidents in 41 EMI tests; 20%); difference 44% (95% confidence interval, 27%-53%; P<.001). The passive 868-MHz RFID signal induced EMI in 26 medical devices, including 8 that were also affected by the active 125-kHz RFID signal (26 in 41 devices; 63%). The median distance between the RFID reader and the medical device in all EMI incidents was 30 cm (range, 0.1-600 cm).

**Conclusions.** In a controlled nonclinical setting, RFID induced potentially hazardous incidents in medical devices. Implementation of RFID in the critical care environment should require on-site EMI tests and updates of international standards.


**706** It’s the hardware. No, the software. No, it’s ESD!

The author’s experiences that have connected fab problems with ESD events:
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• Track system lockups
• Stepper alignment errors and lockups

A manufacturer of microprocessors was experiencing random equipment problems with one of nine steppers, which commanded the attention of in-house engineers and the equipment manufacturer’s field service engineers for almost six months. Software upgrades and major components were replaced without finding a solution. Measurements with a 500MHz digitising oscilloscope finally detected a spurious signal on the power supply line of the stepper that had not been seen with lower-bandwidth test equipment. The random nature of the signal finally pointed to EMI as the possible cause of the problem.

Using an electrostatic measurement tool to determine the presence of static charge located the cause of the problem in less than an hour. The factory static control program specified using static dissipative wall panels to avoid the presence of charged insulators, but one of the wall panels above the stepper was not connected to ground. When charged, this large isolated conductor discharged to the nearby grounded wall framing. The conducted EMI from the ESD event was causing the equipment interrupts.

Our experiences have revealed other scenarios where EMI was causing process equipment problems (other examples are listed in the table):

• In several facilities, tool problems were related to discharges from ungrounded ceiling panels that were supported by a grounded ceiling grid. Signals were radiating from ESD events at the corners of the panels and were conducted through power lines to overhead lighting to the circuit breaker box and then out to the tool being affected. This conduction path was a serious problem because the signal could be transmitted over a large distance without the 1/2 attenuation that is characteristic of transmitted EMI. In one case, the tool was a wafer prober and it was reporting calibration failures. The problem was located with a DSO and a wideband antenna test set. Grounding the ceiling panels eliminated the tool problem.
• In a 2000 ft² photolithography area, four steppers were experiencing unexplained lockups, one a number of times each day, the others randomly. Measurements with an EMI locator indicated signals throughout the room, particularly near the ceiling channels. Not surprisingly, the highest-level signals were found in the vicinity of the stepper experiencing the most frequent lockups. Checking the equipment grounding revealed a top cover panel that was not attached, but rather rested on the top of the equipment, and was very close to one of the ceiling-mounted air ionizers. When this panel was removed, all the EMI signals in the room disappeared and there were no further lockups in any of the steppers. It was apparent that the ungrounded panel was being charged by the nearby ionizer, and was then discharging to the grounded frame of the stepper near the ceiling. This ESD event signal was picked up and conducted around the room by the ceiling channel (Fig. 2).
• There are many instances where conductive parts of wet benches are isolated from ground by attaching them to insulating materials. Inevitably these conductors become charged triboelectrically due to contact with other materials. Once charged, they will discharge the next time another conductor contacts them. The result is random lockups of the wet bench control electronics.
• A reticle inspection unit was locking up approximately five times per week. It was theorized that when reticles or reticle pods come into the tool highly charged, ESD events are inevitable. Under the assumption that the unexplained lockups were ESD-related, an ionizing bar was installed in the load/unload station of the tool. Since the reticles and pods are both composed of excellent insulators (plastic and quartz), grounding them will not eliminate charge. Charge neutralization with ionizers is the only option. When the rate of lockup with and without the addition of ionization was analyzed, it revealed a 50% reduction with the latter (Fig. 3). To investigate the origin of the residual lockups, ionization was placed on the ceiling of the room in the vicinity of the inspection station. This resulted in a second 50% reduction in the lockup rate. This indicates that ESD events even in the adjacent area tools were also causing the tool under investigation to lock up. Owing to the large distance from the adjacent tools to the one experiencing the lockups (~4m), the EMI path was almost certainly conducted.
• A wafer-transfer tool was locking up frequently. It was determined that the wafer cassette loaded into the tool came from a spin-rinser-drier. The cleaning process in this tool resulted in wafers and Teflon cassettes charged to over 20kV. Placing the cassettes on a work-in-progress rack under an ionizing bar for 120sec before putting them into the transfer tool eliminated the lockups.

Conclusion

Equipment lockups will continue to occur despite the best efforts of the software and hardware designers to anticipate the complexity of the semiconductor-manufacturing process. With increasing frequency, however, equipment interrupts are coming from other sources, such as EMI due to ESD. Many equipment failures are the result of random ESD events and a great deal of production and engineering time is wasted pursuing phantom software problems. (Taken from the article with a similar title by Arnold Steinman and Lawrence B. Levit, of Ion Systems Inc., Berkeley, California, published in a Supplement publication to Solid State Technology, May 1999. For many more articles and papers on ESD and other issues in semiconductor manufacture by Lawrence B. Levit, visit http://www.lblscientific.com/publications.html.)

Banana Skins

Banana Skins are kindly compiled for us by Keith Armstrong.

If you have any interesting contributions that you would like included please send them, together with the source of the information to: keith.armstrong@cherryclough.com

Although we use a rather light hearted approach to draw attention to the column this in no way is intended to trivialise the subject. Malfunctions due to incorrect EMC procedures could be life threatening.
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Boob
Apologies for a typo in the first line last time. The new emission standard is **CISPR 32/EN 55032**; the immunity standard will be (one day!) **CISPR 35/EN 55035**. The draft CDV (first stage voting) of the latter is in the process of being edited at the time of writing.

The on-going story
The immediate issues that need to be addressed to put CISPR 32 right have been identified by the IEC committee. Since many countries will adopt the published standard, it is necessary to make it usable by industry as soon as possible. I have therefore proposed to BSI that UK should ask for an Interpretation Sheet (ISH) to be issued on those issues that can be dealt with that way. An ISH can clarify text or provide supplementary information, but it cannot change provisions of the standard.

<table>
<thead>
<tr>
<th>Items taken from the CISPR committee summary</th>
<th>My comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The need for maximisation</td>
<td>If it is a 'clarification', it can be in an ISH.</td>
</tr>
<tr>
<td>2. Clarification of definition 3.1.28</td>
<td>OK for ISH</td>
</tr>
<tr>
<td>3. Full applicability of measurement uncertainty as given in CISPR 16-4-2</td>
<td>Not for ISH</td>
</tr>
<tr>
<td>4. Options to simplify the standard</td>
<td>Not for ISH</td>
</tr>
<tr>
<td>5. Clarify that compliance includes emissions at a level equal to the limit</td>
<td>OK for ISH</td>
</tr>
<tr>
<td>6. The use of 'may' in requirements</td>
<td>If it is a 'clarification', it can be in an ISH.</td>
</tr>
<tr>
<td>7. The definition of AE (especially local/remote)</td>
<td>If it is a 'clarification', it can be in an ISH.</td>
</tr>
<tr>
<td>8. Clarify the coupling devices to be used</td>
<td>OK for ISH</td>
</tr>
<tr>
<td>9. Clarify which channels to test on for broadcast receivers</td>
<td>OK for ISH</td>
</tr>
<tr>
<td>10. The use of scrolling H's for exercising displays during testing</td>
<td>If it is a 'clarification', it can be in an ISH.</td>
</tr>
<tr>
<td>11. The meaning of 'two loops' in the measurement method for impedance</td>
<td>OK for ISH if no new requirement is involved</td>
</tr>
<tr>
<td>12. The use of Horizontal/Vertical ground reference planes for mains emission testing</td>
<td>If it is a 'clarification', it can be in an ISH.</td>
</tr>
<tr>
<td>13. Clarify the need to use an ISN for telecomm ports with less than 4 ports</td>
<td>OK for ISH</td>
</tr>
<tr>
<td>14. Emissions indicated in report *indicate in the report if <em>more</em> than 6 emissions are within six dB of the limit.</td>
<td>If it is a 'clarification', it can be in an ISH.</td>
</tr>
<tr>
<td>15. Clarify conflict of Note 8 in table A.12 with Table B.3</td>
<td>OK for ISH</td>
</tr>
<tr>
<td>From CISPR 13</td>
<td></td>
</tr>
<tr>
<td>1. Use of RMS/average detector</td>
<td>Not for ISH</td>
</tr>
<tr>
<td>2. LNB requirements (see CD on home satellite receivers)</td>
<td>Not for ISH</td>
</tr>
<tr>
<td>From CISPR 22</td>
<td></td>
</tr>
<tr>
<td>1. Clarify that non-invasive methods shall be used only when ISN cannot be used. (see CISPR 32 Table C.1 and clause C.4.1.2)</td>
<td>OK for ISH</td>
</tr>
</tbody>
</table>

It remains to be seen whether this proposal is considered to have merit.

Meanwhile, what is to happen about the implementation of EN 55032 under the EMC Directive and the withdrawal of EN 55013, EN 55022 and EN 55103-1 remains unclear. CENELEC set a withdrawal date in mid 2015, but did not specify which standards it considered it applies to. If the uncertainty continues for some time, it will erode the transition time that industry needs in order to comply with the new standard. I propose that a three-year period should run from the date at which the decision about withdrawal is made for each standard concerned.

**EN55024**
The previous edition of EN 55024 had a Common Modification in respect of surge testing, to use the 1.25/50 µs pulse instead of the 10/700 µs pulse, a much more stringent test. The German National Committee wants this modification carried over into the forthcoming new edition of EN 55024, but this has just be voted unanimously positive, so it can’t be changed. In addition, the more stringent test seems now to be considered justified.
EMC and functional safety

The key publication, IEC 61000-1-2, on this subject is a Technical Specification (TS), but is referenced normatively in several other standards, so it should be upgraded to a standard. However, at present it isn’t written as a standard, and it would be very confusing if only its designation were changed. It needs editing to turn it into more definitive ‘standards’ language. Keith Armstrong, the prolific contributor to this august journal, is the main UK expert on this publication. There is concern about the way the IEC committee is operating, as one country has a large number of experts appointed.

Generic standards

IEC 61000-6-5 on immunity requirements in power station environments is also a TS at present, but it should be converted to a standard.

It is proposed to review all the Generic immunity standards, but it seems that few experts are willing to undertake this work.

Faster, faster!

IEC now allows comment periods (not voting periods) on document circulated to national committees to be set at 2, 3 or 4 months. A proposal to establish a norm of 4 months was modified to allow each case to be judged individually, with readiness to object to an inappropriate time being set. It was also recognized that BSI committees can use electronic communication to make actual decisions, apart from just discussing possibilities or the reverse. (I might mention that BSI committee EPL100 runs with very few meetings indeed, through the wide use of electronic communication, but its deliberations are usually less controversial or complex than those of the EMC committees.)

New revisions

IEC 61000-2-2 on compatibility levels for emissions into the low-voltage mains supply system is to be revised, as is the advisory IEC 61000-2-12, which deals with the same subject for the MV power system. IEC 61000-3-3 is also under revision at the CDV stage.

Class A and Class B emission limits

This perennial subject surfaced again a while back. CISPR is trying to achieve consistency across all standards, but there is a big stumbling block. The Generic standards hold that Class B limits apply, without exception, in commercial and light industrial locations as well as to residential, but CISPR 22 and some other standards allow Class A limits to apply, and do not even exclude the use of Class A limits in residential locations provided any resulting interference is mitigated. Considering the low level of interest on the part of the spectrum management authorities in complaints of interference (that don’t affect the emergency or air transport services), it seems unjustified to maintain the stricter limits.

CISPR 16/EN 55016

The Parts and Sections of this monster standard are continually changing. CISPR 16-1-1 is to deal with the use of a preamplifier with a measuring receiver. CISPR 16-1-5 on antenna calibration test sites is to be amended. CISPR 16-2-3 will have additional material on the application of ferrite-clamp common-mode absorption devices (CMAD). CISPR 16-4-5 will have additional material on measurement uncertainty in the context of alternative test methods.

It has been agreed to strengthen the UK representation on CISPR/A working groups.

Technical corrigenda

IEC management is complaining about the number of corrigenda that have to be issued, but it’s a direct consequence of the pressure to produce standards in very short times. However, some committees have been using ‘corrigenda’ to make updates, e.g. of the effective editions of normative references, and this has never been officially permitted.

Main meetings

CENELEC TC210 met in mid-May, after this article was written. CISPR and its sub-committees will meet in Bangkok in November 2012.

PLT (can’t get away from it!)

The European Commission’s EMC consultant is not happy about the proposed EN 50561 standard. How this can be resolved is far from clear, since it’s the Commission that wants the standard. (At any price? You might think that, I couldn’t possibly comment.)

J. M. Woodgate B.Sc.(Eng.), C.Eng. MIET MIEEE FAES HonFInstSCE
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The story continues...
Are we ready for a second helping of premium immunity standard? Last time, we looked at IEC 61000-4-1 to -10, so now we have to enter the second decade.

IEC 61000-4-11
This is a standard about tests for immunity to power-frequency phenomena, specifically voltage dips, short interruptions and voltage variations. These low-frequency standards are produced by IEC SC77A, while the high-frequency standards (above 9 kHz, with some exceptions) are produced by SC77B. Not all product standards call up IEC 61000-3-11, because the products concerned, such as heaters, are not seriously affected by these disturbances.

IEC 61000-4-12
The ring wave immunity test is not well known; indeed, what is a ‘ring wave’? The standard says it’s a damped oscillatory transient, so it should really be called a ‘ringing wave’, because a tuned circuit is said to ‘ring’ like a bell, as it produces such a decaying transient when prodded with a suitable pulse. Indeed, the basic test signal generator uses this technique. The tuned circuit resonates at 100 kHz, and is prodded by the voltage on a charged capacitor. This voltage may be as low as 250 V or as high as 4 kV, depending on the conditions set in the product standard. The test generator Is a powerful beast; it can deliver up to 333 A.

IEC 61000-4-13
This is about immunity to harmonics and interharmonics, including mains signalling, at a.c. power ports for products rated at 16 A per phase or less. The ‘mains signalling’ concerned is ‘ripple control’ which is not used in Britain, but is used in many countries. An on-off modulated signal at a frequency in the range 105 Hz to 1995 Hz (125 Hz to 2395 Hz in 60 Hz systems), unrelated to the mains frequency, is used to control remote equipment in the distribution system. Most, but not all, of the recommended voltage test levels are well below 10 % of the supply voltage.

IEC 61000-4-14
IEC 61000-4-11 is about immunity to, amongst other things, voltage dips and variations. IEC 61000-3-14 is about immunity to voltage fluctuations. So, what’s the difference? We have to look at the definitions in the standards.

In Section 11 (i.e. IEC 61000-4-11), we have:

**voltage dip**
*a sudden reduction of the voltage at a particular point of an electricity supply system below a specified dip threshold followed by its recovery after a brief interval*

Curiously, ‘voltage variation’ is not formally defined and we have to look at the test conditions to find out what it is:

**Voltage variations (optional)**
*This test considers a defined transition between rated voltage $U_r$ and the changed voltage.*

NOTE The voltage change takes place over a short period, and may occur due to change of load.

The preferred duration of the voltage changes and the time for which the reduced voltages are to be maintained are given in Table 3. The rate of change should be constant; however, the voltage may be stepped. The steps should be positioned at zero crossings, and should be no larger than 10 % of $U_r$. Steps under 1 % of $U_r$ are considered as constant rates of change of voltage.

The description ‘optional’ is curious; it should really be for product standards to specify which tests should be done.

**Table 3 – Timing of short-term supply voltage variations**

<table>
<thead>
<tr>
<th>Voltage test level</th>
<th>Time for decreasing voltage (td)</th>
<th>Time at reduced voltage(ts)</th>
<th>Time for increasing voltage (ti) (50 Hz/60 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 %</td>
<td>Abrupt</td>
<td>1 cycle</td>
<td>25/30° cycles</td>
</tr>
<tr>
<td>$X^a$</td>
<td>$X^a$</td>
<td>$X^a$</td>
<td>$X^a$</td>
</tr>
</tbody>
</table>

* To be defined by product committee.

$25/30$ cycles” means “25 cycles for 50 Hz test” and “30 cycles for 60 Hz test”.

In Section 14, we have:

**voltage fluctuations**
*series of voltage changes or a cyclic variation of the voltage envelope [IEV 161-08-05]*

So, we see that variations are assumed non-repetitive, whereas fluctuations are repetitive. Well, maybe.

IEC 61000-4-15
Like IEC 61000-4-7, this is not a Basic standard but the specification of a measuring instrument – in this case, the Flickermeter. The instrument is designed to output numerical values consistent with the subjective effects of rapid voltage variations on the light output of a 60 W coiled-coil incandescent lamp, which is, of course, now nominally an extinct species. However, it was agreed not to revise the standard to change the reference device to a compact fluorescent lamp, because these products will quite soon be superseded by affordable LED lamps. At the same time, lamp manufacturers are being encouraged to make lamps which are no more sensitive to flicker than the 60 W lamp.

Flicker can be very disturbing to people of an anxious disposition – they fear that the power will go off or even that a fire or explosion might occur. Unfortunately, on rare occasions, they might be right.
IEC 61000-4-16
This is one of the few Basic standards about low-frequency phenomena; in this case it’s immunity to conducted, common-mode disturbances in the frequency range 0 Hz to 150 kHz. So it’s also one of the few standards that crosses the ‘great divide’ at 9 kHz, between ‘low’ and ‘high’ frequencies. The Scope clause admits that it is of limited applicability - to equipment including cables more than 20 m long, mostly in industrial plants. The disturbances are launched on the power system cables, in common-mode, i.e. line and neutral voltage fluctuate together with the same polarity. However, they may couple to other cables, especially in the case of the higher-frequency disturbances produced by power electronic equipment using switching techniques.

The tests are divided into three categories:

- mains frequencies (16.67 Hz, 50 Hz and 60 Hz) short-term;
- mains frequencies long term;
- other frequencies (15 Hz to 150 kHz).

No tests are specified below 15 Hz, except at d.c. (0 Hz). A d.c test signal generator is specified, with an output voltage adjustable between 1 V and 30 V and an output source impedance of 50 ohms.

A very significant consideration is that the means for injecting the disturbance to balanced communication ports may seriously degrade the common-mode rejection by applying unequal source impedances to the two inputs. This is acknowledged, but the relevant Note has an unfortunate omission of the word ‘not’:

NOTE It may [NOT] be possible to produce T networks suitable for use with common mode rejection ratios greater than 80 dB, in which case the product standard should define an alternative coupling method.

IEC 61000-4-17
This Section defines test methods for immunity to ripple at the d.c. input power port of electrical or electronic equipment, and applies to low-voltage d.c. power ports of equipment supplied by external rectifier systems, or batteries which are being charged. The disturbance level is specified as the ratio of the peak-to-peak ripple voltage to the d.c. voltage, and test levels are from 2 % to 15 %. The waveform is the ‘sine cap and linear decay’ typically produced by a rectifier.

IEC 61000-4-18
This deals with another rare phenomenon – the damped oscillatory wave, to be carefully distinguished, of course, from the ‘ring wave’, which is a damped oscillatory wave! So, what’s the difference? IEC 61000-4-12 specifies only a damped 100 kHz signal, where as IEC 61000-4-18 specifies signals at 100 kHz and 1 MHz, described as ‘slow’ signals, and 3 MHz, 10 MHz and 30 MHz, described as ‘fast’ signals. The whole standard is oriented to these disturbances being produced by switching and other operations in power stations, or caused by a high-level electromagnetic pulse (HEMP) (which we hope is of natural origin!). However, text in the Scope (which it appears should have been deleted in favour of other, similar text), refers to ‘electrical and electronic equipment intended for residential, commercial and industrial applications’. The skeleton test signal generator circuit is more complex than that specified in IEC 61000-4-12.

IEC 61000-4-19
This has not yet been published, being still at the CD stage ((but is available as BSI Draft for Public Comment 12/30258875). It is about immunity to conducted, differential mode disturbances in the frequency range 2 kHz to 150 kHz. (IEC 61000-4-16 is about immunity to conducted, common-mode disturbances.) Test signals are either 60 second ‘tone bursts’ of sine-wave signals, the frequency incrementing by 2% for each burst, or tone bursts, in the same frequency range, of increasing duration from 1.6 ms to 330 ms (for 50 Hz mains). The switching instants are not synchronized to the mains frequency.

IEC 61000-4-20
This Section is about emission and immunity testing in transverse electromagnetic (TEM) waveguides. Unlike most standards, it includes a lot of mathematics. It may be better to follow the instructions of the TEM test device rather than the more generalized treatment in the standard. There are at present thirteen more Sections of IEC 61000-4 to look at, before we go on to other delights later this year.

J. M. Woodgate B.Sc.(Eng.), C.Eng. MIET MIEEE FAES HonFInstSCE
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AR Introduces Multi-Tone RF Test System

The Multi-tone software includes amplifiers.

The signal generator bandwidth number of tones that can be tested products to market quicker. The reduces costs and helps get previously possible. Faster testing testing 10 times faster than possible to conduct RF immunity immunity testing per IEC 61000-43 except the required amplifiers, antennas and directional couplers.

Amplifiers are selected and sized based on your required field levels and testing needs.

The system mimics real world threats with the ability to expose EUT’s to more than one frequency at a time. By testing multiple frequencies simultaneously, a user is able to maximize their efforts during dwell time to increase testing speed. The AR Multi-Star Multi-tone RF Test System is capable of testing up to 10 frequencies at once, making it possible to conduct RF immunity testing 10 times faster than previously possible. Faster testing reduces costs and helps get products to market quicker. The number of tones that can be tested simultaneously is limited only by the signal generator bandwidth (150 MHz) and the size of the amplifier.

The multi-tone software includes automated routines for field calibration and maximizing the test speed, while still maintaining the linearity and harmonic requirements of the standard. In the event of an EUT failure, thresholding or margin investigation and traditional signal tone testing can be performed.

The MT06000 is available as a self-contained system or can be integrated with amplifiers and accessories into an automated test system.

To learn more about AR’s approach to multi-tone testing, visit AR’s website (www.arworld.us) and read Application Note #61 “Multi-tone Testing Can Save Both Time and Money.”

Tel: +44 (0)1908 282766
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emcia Member

Narda Safety Test Solutions now offers low-frequency electromagnetic field measuring devices with evaluation conforming to ICNIRP 2010. PC software is available free of charge for the Electric and Magnetic Field Analyzer EFA-300, which enables uploading of the new limit values to the instrument. A separate “ICNIRP 2010” version of the Exposure Level Tester ELT-400 is available. All previous and existing probes can also be used with the new instrument.

Background: In 1998, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published its “Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)”. The limit values in these guidelines were mandatory for more than a decade. However, recent findings have necessitated a revision of the limit values in the low frequency range. These have been taken into account in the ICNIRP “Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz – 100 kHz)”, published in 2010. The new limit values applying to the workplace (occupational) as well as to the general public allow considerably higher magnetic field strengths in some low frequency ranges. In contrast, the limit values for electric field strength have been tightened up to some extent. Although the new limit values are only slowly being incorporated into national regulations, measuring equipment from Narda now includes evaluation according to the new standard. Clients wishing to invest right now in test equipment can therefore be already prepared for exposure measurements complying with future standards. Tel: +49 (0) 7121/97 32 - 0 support@narda-sts.de
www.narda-sts.de

Telonic goes beyond measure... with RIGOL’s New DSA800 Spectrum Analyser & Tracking Generator

Telonic Instruments has news of affordable RF / pre-compliance measurements with the new DSA800 series spectrum analyser, the latest development in the RIGOL family of fast, easy-to-use, reliable test instruments. The newly available DSA800 series from RIGOL has outstanding price/performance and high resolution display for the most demanding of needs.

Designed to speed RF measurement tasks, RIGOL’s powerful wide-screen, yet compact, DSA800 series helps engineers to accomplish a range of testing by combining many functions into one easy-to-use instrument. Model DSA815 comes with pre-amplifier as standard, and 1MHz typ.) and a total amplitude uncertainty of less than 1.5dB, this spectrum analyser has more measuring power as standard including AM/FM-demod and built-in pre-amplifier. Plus there are additional options for built-in EMI filter and a quasi-peak detector kit.

Rigol DSA815 is the baby in a series of high-performing spectrum analysers.

RIGOL DSA815-TG Extensive connectivity including LAN, USB host and USB device makes it easy to integrate the instrument into complete T&M solutions with software control and data capture for recordings and results. There’s no compromise on low-noise, with 135dBm (DANL f/
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Agilent Technologies introduces Fast, Accurate LCR Meter for Testing High-Frequency Passive Components

Agilent Technologies Inc. (NYSE: A) today introduced the E4982A LCR meter, the newest addition to its LCR family of meters. The Agilent E4982A delivers the best performance for manufacturing passive components such as SMD inductors and EMI filters, where impedance testing at frequencies of 1 MHz to 3 GHz is required. The E4982A’s powerful list measurements make it suitable for R&D and quality assurance.

Makers of chip inductor/EMI filters and integrators of chip inductor/EMI filter test systems are driven by the need for accurate and repeatable inductance, quality factor and impedance measurements. They are also under continual pressure to improve throughput and test yield while keeping test costs low. The Agilent E4982A offers 0.8 percent basic impedance measurement accuracy and repeatable measurements with small measurement variation. It also delivers measurement speeds of 0.9 ms, 2.1ms or 3.7 ms. The meter’s accuracy improves test quality, while its measurement speed translates into fast test throughput.

The E4982A is compatible with the current industry-standard Agilent 4287A LCR meter, while offering greater performance. SCPI commands and handler interface function for the E4982A are compatible with the Agilent 4287A LCR meter as well, allowing customers to leverage their earlier investments and expertise in the software.

“The new E4982A LCR meter is really set apart from other commercially available solutions,” said Akira Nukiyama, vice president and general manager of Agilent’s Component Test Division, Japan. “Its features ensure manufacturers and system integrators fast, accurate impedance measurements while realizing improved test efficiency and a lower overall cost of test.”

The E4982A LCR meter offers PC connectivity via GPIB, LAN and USB; an easy-to-use, intuitive user interface; a 10.4-inch display; and a compact design with 277-mm depth.

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www.agilent.co.uk

Syfer’s ProtectiCaps save on production stage

The latest innovation in multilayer capacitor (mlccs) from Syfer Technology is a range of compact devices suitable for high voltage applications, supplied with a built-in protective coating. Typically, with standard high voltage capacitors, a special coating is applied after the devices are soldered onto the board in order to minimise the risk of flashover from one termination on the chip to another.

Syfer’s ProtectiCap™ process applied to its high voltage range of mlccs has been developed specifically to address this issue. The integral coating, a matte tin layer over the nickel FlexiCap base termination, minimises the risk of flashover and avoids the need for the customer to apply conformal coating after soldering.

Aimed at applications such as power supplies, lighting ballasts, inverters/DC link, and general high voltage circuits, the X7R dielectric ProtectiCap range of mlccs combines high voltage capability with small package size. The capacitance range of devices in this series is 100pF to 33nF, package sizes range from 1206 to 2220, and voltages available include 2KV, 2.5KV, 3KV, 4KV and 5KV. Typical devices include a 2KV mlcc in 1206 package with capacitance range of 100pF to 3.3nF, 2KV mlcc in 2220 package with capacitance range of 220pF to 35nF, 3KV device in 1880 package with 100pF to 3.3nF capacitance range, and 5kV mlcc in 2220 package with 220pF to 4.7nF capacitance range.

Additional specifications include operational temperature range of -55 to 125°C, temperature coefficient of capacitance typically at +/-15%, and insulation resistance of 100Gohms or 1000s, whichever is the least.

This range is fully compliant with the RoHS and WEEE directives and parts are compatible with lead free solders. The devices, manufactured at Syfer’s Norwich, UK facility, are available immediately in sample packs or on standard 6 week delivery for production volumes. Pricing, on application, depends on value and volume.

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www.syfer.com

New RF radiation monitor features field-replaceable sensor module

Link Microtek, the largest UK supplier of RF radiation safety equipment, is now stocking the new Nardalert S3 RF radiation monitor from Narda Safety Test Solutions. Featuring an innovative design with removable sensor module, the S3 unit allows rapid support in the field, simplifies calibration logistics and offers a simple means of implementing future upgrades. These are significant benefits for organisations such as broadcast and telecoms companies, which typically operate a large number of monitors to protect personnel working in the vicinity of high-power transmitters.

The frequency response of the sensor module is shaped to match the requirements of the ICNIRP international standard. Should the monitor detect electric field strengths that approach or exceed the specified exposure limit, it will generate visual, audible and vibration alarms to alert the user.

The unit’s two alarm thresholds are preset to 50% and 200% of exposure limit but can be altered to other values if required.

The Nardalert S3 also features a top-mounted colour display, which shows battery status, sensor information and the frequency band of any detected fields. For more advanced applications, an S3 ‘Optioned’ model provides additional functionality such as storage and display of exposure history and transfer of recorded data via USB or fibre-optic links.

Designed to be worn on the body or used as a fixed area monitor, the Nardalert S3 is housed in a rugged plastic casing measuring just 117.1 x 82.6 x 31.8mm and weighing only 230g with sensor attached. It is powered by an RCR123A rechargeable lithium-ion battery, which provides approximately 25 hours of operation and can be charged either via a computer’s USB port or using the universal charger supplied.

Each monitor also comes with belt clip, lanyard clip, silicone rubber skin for additional shock protection, USB cable, software, operating manual, calibration certificate and carrying case. Optional accessories include fibre-optic cables and converters, as well as a mounting bracket to facilitate area monitoring.

For further information, visit www.linkmicrotek.com and www.radhazonline.com.

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Narda Safety Test Solutions S.r.l. (Italy) have announced the PMM EP-602 isotropic probe for electromagnetic fields from 5 kHz to 9.25 GHz, designed for applications in EMC immunity tests up to 1500 V/m.

The PMM EP-602 is an isotropic probe designed for measuring electromagnetic fields in a wide dynamic range of amplitude (from 1.5 to 1500 V/m) and frequency (from 5 kHz to 9.25 GHz) with an outstanding overloading capability of 3000 V/m and resolution of 0.01 V/m.

Besides these unique characteristics, the probe PMM EP-602 features innovative design solutions that overcome the common limits of conventional field probes. A nearly perfect isotropy is achieved thanks to the spherical symmetrical design of the six monopoles around a central body of only 17 mm of diameter which contains all the electronics, the rechargeable battery and the two-way fiber optic interface for data communication.

In addition to the excellent isotropic characteristics, this configuration allows for minimizing the probe influence to the field to measure. The overall size of only 53 mm and the extremely light weight of only 25 g give the PMM EP-602 an unsurpassed installation flexibility, e.g. in GTEM cells, vehicles, chambers.

The button-type Li-Mn rechargeable battery is characterized by excellent performances, e.g. very long life, negligible self-discharge and no memory effects. Charged by means of the supplied charging pod, it provides the probe for up to 80 hours of operation. If required, the battery can be easily replaced by removing an accessible cap. Sending the probe to factory and recalibration is unnecessary, thus saving user’s time and money.

The probe communicates with a PC by means of a fiber optic cable, available for lengths up to 40 m, and an optical/RS232-USB adapter. The user-friendly software supplied with the probe allows for setting the measurement parameters and displaying the measurements.

The measurements are simultaneous on the X-Y-Z axis, in a range of up to 22 Samples/s for very fast feedback response e.g. to the power amplifiers drivers in an EMC immunity system.

Other settings are: rejection filters, averaging, reading rate and frequency compensation (when the source is known). The software displays the three single axis values, the total value and the probe temperature. Readings can be held and logged as text files for further processing. For the integration in existing systems, drivers and communication protocol are available.

These peculiar characteristics make the new field probe PMM EP-602 particularly suited for the immunity systems in the automotive, aerospace and military applications, and wherever the field values can be quite high.

The family of PMM field probes is completed by the models EP-600 (0.14 - 140 V/m) and EP-601 (0.5 - 500 V/m). Narda’s Accredited Calibration Centre in Cisano s/Neva (Italy) can provide the accredited calibration certificates, if required.

Tel: +39 02 2699871 support@narda-sts.it www.narda-sts.it

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**New Range of Low Cost High Performance Digital Oscilloscopes**

Telonic Instruments have introduced new high performance low cost benchtop digital oscilloscopes manufactured by China based RIGOL. Designated DS1000E there are two models in the range that have dual channels, alternate timebase, external trigger channel and FFT function.

These simple to use oscilloscopes have two channels with either 50 or 100MHz bandwidth, depending on the model. The large 142mm and 64 TFT LCD screen enables easy viewing of the waveform displays. Multiple trigger types include edge, pulse width, video, slope, alternate and duration with a unique adjustable trigger sensitivity to meet different requirements. The DS1000E range is able to measure 20 types of wave parameters and track measurements via the cursor automatically with waveform record and replay. They also feature a pass / fail detection function to enable output testing results and standard configuration interface like USB device and host, RS-232 and support U disk storage with support for remote command control.

Utilising the latest state of the art electronics they measure 303 x 154 x 133mm and weigh 2.3kg making them easily transportable. Ideal for Education, Research and training with their ability for electronic circuit and circuit functional testing with logical relation evaluation between signals. This innovative Oscilloscopes combines high performance with an economic starting cost of £260-00 plus VAT and carriage for the 50MHz DS1052E.

For further information contact Bob or Doug Lovell on 0118 9786911 or please visit www.rigol-uk.co.uk. Tel: +44 (0)118 978 6911 info@telonic.co.uk www.telonic.co.uk www.rigol-uk.co.uk

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Equipment and systems for which errors, malfunctions or failures in electronics (whether in their hardware, software or firmware) can increase safety risks, should comply with Functional Safety requirements [1][2], for example by applying:

- IEC 61511 (Safety instrumented systems for the process industry sector, also ANSI/ISA S84)
- IEC 62061 (Safety of machinery)
- EN 50128 (Railway applications - Software for railway control and protection)
- EN 50129 (Railway applications - Safety related electronic systems for signalling)
- IEC 61513 (Nuclear power plant control systems)
- EUROCAE ED-12B (European Airborne Flight Safety Systems)
- RTCA DO-178B (North American Avionics Software)
- RTCA DO-254 (North American Avionics Hardware)
- IEC 62304 (Medical Device Software)
- EN 50402 (Fixed gas detection systems)
- MISRA (various guidelines for safety analysis, modelling, and programming in automotive applications)
- Defence Standard 00-56 Issue 2 (Accident consequence)
- ISO 26262 (Automobile functional safety)
- EN/ANSI/IEC 60601-1 Edition 3 (Safety of medical equipment and systems, note that this uses the term Safety Risk Management instead of Functional Safety)

Functional Safety is quite a new area of engineering, and a rapidly growing concern because we are increasingly controlling everything with ever-more-complex electronics.

Where equipment or systems that need to comply with Functional Safety can’t use one of the product standards listed above (or published since this article was written, in May 2012), they should apply the IEC’s Basic Standard on Functional Safety, IEC 61508 [3], from which all the above list of product standards were developed. That is, all except for medical equipment and systems, which should apply ISO 14971).

Because all electronics suffer from electromagnetic interference (EMI) and so should be designed to have adequate electromagnetic compatibility (EMC), since 2000 [3] has required that EMC be done in a way that helps ensure the achievement of acceptable levels of functional safety risks. But it has never said how to actually do EMC for functional safety.

Unfortunately, the usual approach to EMC – testing to EMC emissions and immunity standards – is inadequate for functional safety engineering. It can’t even provide sufficient confidence (that EMI won’t cause a dangerous error, malfunction or failure) to reach the lowest rung of compliance to 61508 – Safety Integrity Level 1 (SIL 1 for short, see [1] and [2]), and the author discusses this in [4][5] and [6].

However, since 2000 we have had IEC TS 61000-1-2 [7], the IEC’s Basic Publication on EMC for Functional Safety, which will be converted to a full International Standard sometime in 2012 (possibly 2013).

Despite being only a TS (Technical Specification), [7] is a mandatory requirement under 61508 Ed.2:2010, and this mandatory requirement should eventually ‘flow down’ into all of the Functional Safety Product Standards, which are based on 61508, as they in turn are up-issued to keep up with technical progress.

[7] employs a variety of design verification and validation techniques – including (but not limited to) enhanced immunity testing – to help achieve the appropriate level of confidence in systematic safety risks when demonstrating compliance with a SIL.

IEC TS 61000-1-2 [7] is the IEC’s basic publication on what we generally call ‘EMC for Functional Safety’, which will be published as a full IS (International Standard) during 2012 (possibly 2013).

The IET has published a comprehensive guide on this publication, which can be purchased as a colour-printed book from Nutwood UK (the publishers of the EMC Journal you are currently reading) at www.emcacademy.org/books.asp, or downloaded via www.theiet.org/factfiles/emc.

At the time of writing, there are no published Basic or Product standards published as International Standards on EMC for Functional Safety, so [7] is all that can be used. (The author is the UK’s representative on all the IEC standards teams writing [7] and the generic and product standards based upon it, including Edition 4 of the medical equipment/system EMC standard: IEC 60601-1-2.)
Excellent EMC Books

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This book is about good-practice EMC design techniques for printed circuit board (PCB) design and layout. It is intended for the designers of any electronic circuits that are to be constructed on PCBs, and of course for the PCB designers themselves. All applications areas are covered, from household appliances, commercial and industrial equipment, through automotive to aerospace and military.

This is a book for electronic and PCB engineers who need to employ good EMC and SI techniques to save time and money when designing with the latest technologies, to make reliable and compliant products.

The book uses very little maths and does not go into great detail about why these techniques work. But they are well-proven in practice by successful designers world-wide, and the reasons they work are understood by academics, so they can be used with confidence. Numerous references lead to detailed explanations and mathematical foundations.

It is difficult for textbooks to keep up to date with fast-changing PCB technology and EMC techniques, which is why most of the references are recent conference papers and articles available via the Internet.

EMC for Product Designers
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The Physical Basis of EMC
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Coupling of EM energy;
An overview of emissions;
Immunity issues;
Crosstalk and “internal EMC” issues inside a product;
Types of EM phenomena and how they can interfere.

EMC for Product Designers
Fourth Edition
Author: Tim Williams

Cost £45 plus p&p. ISBN 978-0-75-068170-4
Faced with this lack of published international standards on EMC for Functional Safety, many engineers wishing to comply with Functional Safety requirements, especially in the industrial and process control industries, apply the EMC test standards EN/IEC 61326-3-1 [8] or 61326-3-2 [9] for this. As you can see from their full titles (see references [8] and [9] below), they give the appearance of being EMC for Functional Safety standards, but unfortunately these titles are misleading.

61326-3-1 [8] and -2 [9] are merely immunity test standards, and as such are intended to be used only within a functional safety process controlled by both IEC 61508 and IEC TS 61000-1-2.

But I keep on meeting people who incorrectly assume that all they need to do on EMC for functional safety is test to 61326-3-x.

Such errors can be very serious ones indeed, because they concern safety-related and safety-critical systems so the safety and financial risks can be huge.

The main problem with using IEC 61326-3-1 [8] and -2 [9], is that they do not say anything about being part of a functional safety risk-control process under both [3] and [7]. A lesser problem is that they do not require immunity testing at the maximum levels that can reasonably foreseeably occur in the operational environments within their scopes, which is a requirement in [7] (although not a sufficient one).

Many years ago, the convenor of the IEC team that produced [8] and [9] made clear to the author that they were intended to be used as just a part of a process controlled by [3] and [7], and this is confirmed in the presentation that Dr Bernd Jaekel and Diethard Moehr (who is the Secretary of IEC TC77, the committee responsible for all IEC EMC test standards) gave jointly to the 100th Anniversary meeting of the IEC in Berlin on the 27th September 2006, as shown in the figure, which is taken from their presentation.

The convenor assured me that the total lack of any information about this in the 61326-3-x standards did not matter, because everyone involved with safety-related or safety-critical systems knew all about [3] and [7] and would naturally understand how to fit [8] and [9] into their functional safety compliance processes.

Sadly, he has been proved to be wrong, because even now in 2012 it is commonplace to find the 61326-3 standards [8] and [9] being used on their own, without also complying with both IEC 61508 and IEC TS 61000-1-2.

The exact same problem also seems to afflict complying with IEC 62061 and IEC 61511, which the figure also shows should be part of a process controlled by both [3] and [7].

Very similar problems arise when automotive engineers wishing to comply with ISO 26262 apply various automakers’ in-house EMC testing standards, which are also unsuitable for achieving EMC for Functional Safety, see [10][11][12] and [13], because, as [7] states, any practical amount of immunity testing is usually insufficient.

Also, I keep on meeting engineers and safety assessors who incorrectly assume that all they need to do on EMC for functional safety is to comply with immunity test standards that are listed as providing compliance with the EMC Directive – even though this Directive states perfectly clearly that it does not cover safety issues.

EMC for Functional Safety is a new field of standardisation that goes well beyond what can possibly be achieved by EMC immunity testing alone, so it will no doubt take a few years before the Independent Safety Assessment industry catches up with this new state of the art.

While waiting for the Safety Assessment industry to catch up, manufacturers and integrators of safety-related equipment and systems must still employ the state of the art in EMC and Functional Safety, which is expressed by [7].

Huge penalties can be awarded in civil lawsuits under the Product Liability Directive. We can be fined up to 70 billion Euros (more in some Member States) without it even having to be proved that it was our equipment or system that caused the injuries, deaths or financial losses!

The risk of deviating from the state of the art in EMC for Functional Safety is much greater than any Financial Director would ever accept – if anyone took the trouble to warn them about this very unsafe situation.

References:

[8] BS EN 61326-3-1:2008, “Electrical equipment for measurement, control and laboratory use. EMC requirements. Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety). General industrial applications”


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One of a number of “Stand Alone” articles on the EMC design of switch-mode and PWM power converters of all types

By Keith Armstrong, Cherry Clough Consultants Ltd, www.cherryclough.com

Issues 93-99 of The EMC Journal carried the preceding parts of this “Stand Alone” series – my attempt to cover the entire field including DC/DC and AC/DC converters, DC/AC and AC/AC inverters, from milliwatts (mW) to tens of Megawatts (MW), covering all power converter applications, including: consumer, household, commercial, computer, telecommunication, radiocommunication, aerospace, automotive, marine, medical, military, industrial, power generation and distribution, in products, systems or installations.

Hybrid & electric automobiles, electric propulsion/traction; “green power” (e.g. LED lighting); and power converters for solar (PV), wind, deep-ocean thermal, tidal, etc., are also covered.

Issues 93-95 used a different Figure numbering scheme from the rest, for which I apologise.

I generally won’t repeat material I have already published, instead providing appropriate references to the EMC Journal [14] and my recently-published books based on those articles [15], so that you don’t get bored by repetition.

I keep meeting companies that still design merely to get their circuits working to spec., then have them tested for EMC compliance and iterate the design until it passes the test (ditto, often, for safety compliance too). This approach is guaranteed to increase time-to-market and increase overall-cost-of-manufacture (much more important than the BOM cost, see [12]) when compared with using EMC (and safety) skills from the start of the design process.

7 Suppressing RF emissions from inputs and outputs

This is the section I began to write in Issue 98 [72] and continued in Issue 99 [84]. Despite my aim in this series to only publish ‘stand-alone’ articles, each covering a single topic, the issue of suppression is so large that it is impossible to publish it all in a single issue.

The topic of suppression is so large, because it is so difficult and contains so much detail. Please don’t forget that it is much better (more cost-effective, shorter time-to-market, see section 7.1 in [72], [11] and Chapter 1 of [5]) to design the power converters in such a way as to minimise their input and output emissions. These design topics were covered in the early parts of this series, [13] [42] [64] [65] and [66] because they are more important for technical and financial success.

My earlier story about suppressing the emissions from a military submarine’s winch (page 33 of [84]) was given as an example of filter resonance. But it serves equally well as a story about the cost-effectiveness and development time-savings of designing the noise out of the converter in the first place. Instead of a multi-component mains filter that used costly Y-rated capacitors, and after a day I still hadn’t developed well enough to achieve compliance, instead I used a single X-rated 470nF capacitor to adequately suppress the drive’s DC Link, and it only took me a few minutes.

Yes, I haven’t covered suppressing DC Links yet (it will be covered in the next Issue of the EMC Journal), but this example still proves the general principle that all EMC experts agree with – it is very much better (quicker, less costly, more reliable) to suppress any noise at source, than try to deal with it once it has coupled (escaped!) into other circuits in the same equipment, or any circuits in other equipment.

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7.5 Shielding the output cable

The “accidental antenna” effect of output cables should always be reduced by using techniques such as twisted pairs and routing close to a CM return path (see Chapter 4.3.3 of [5] and Chapter 4.4 of [69]). These are helpful and should generally be used, because they reduce the specification of any output filters (i.e. make it easier to pass conducted and radiated emissions tests with a lower-cost output filter).

In fact, some cable suppliers offer specially balanced cables specifically intended for motor drive outputs. These are claimed to be better than twisted pairs, because they are said to convert less of the pulse-width-modulated (PWM) output voltage into common-mode (CM) noise current flowing around the drive system (i.e. they have a lower longitudinal conversion loss, LCL).

It is the CM noise currents that cause most of the conducted and radiated emissions from a motor drive at frequencies above about 1MHz. Below about 1MHz differential-mode (DM) noise from the switching devices can be the dominant cause of emissions, and suppressing this type of noise was discussed in sections 7.1 and 7.2, see [72], and will be returned to again later when I discuss filtering the DC Link.

An alternative to filtering the RF noises from output cables – as discussed in section 7.3.13 of [84] is to shield (screen) them, which is the topic of this article.
Figure 7.5-1 shows the overall current loops when using a shielded (screened) output cable, using the style of drawing I used in [72] to show how filtering should be designed to control the DM and CM current loops.

All currents always flow in loops, including all ‘stray’ or ‘coupled’ noise currents, a vital understanding for good EMC design, discussed in detail in [32], [33] and [85], also in [4] or Chapter 2 of [5] (which use the same text).

Converters with fixed DC outputs generally have low-enough output noise (just a little RF ‘ripple’) that output filtering is easy and low-cost enough, but variable-speed DC or AC motor drives – using PWM – are very noisy indeed.

We can consider an XkW variable-speed motor drive to be the equivalent of an XkW radio transmitter. An XkW radio transmitter emits its RF power at only one frequency, and is connected via a matched transmission-line cable (so that cable emissions are very low) to a transmitting antenna. It is required to give a strong audible signal for radio receivers that may be as much as hundreds, maybe thousands of kilometres distant.

However, an XkW motor drive emits its RF power at a large number of frequencies (the chopper’s switching frequency and its first thousand harmonics (at least), and is connected via a variety of types of power cable that are all unmatched transmission lines (making them very effective ‘accidental antennas’ in their own right) to a motor (which is also an effective ‘accidental antenna’).

And the motor drive is required to create an inaudible signal on radio receivers that are only 10 metres (in domestic, commercial, light industrial applications) or 30 metres (in heavy industrial applications) distant.

It is little wonder that the introduction of variable-speed motor drives using switch-mode power conversion technology has been accompanied by so many EMI problems, the world over.

But with appropriate use of input and output inductors, filters, cable shielding and RF bonding, as shown in Figure 7.5-1, much reduced harmonics, DM and CM noises flow in the long mains cable and mains distribution network. The output CM and DM noises flow in the whole length of the output cable and the motor, and are made to behave as very ineffective ‘accidental antennas’ by good cable shielding, plus good shield-bonding (RF-bonding) assembly methods at both ends.

Figures 7.5-2, 7.5-3 and 7.5-4 show how these principles were applied to a moderately-powerful motor drive in an industrial cabinet (simply by following the manufacturers EMC Installation Instructions), but could just as well be an electric traction drive (e.g. hybrid car) instead. (Figure 7.5-2 is a copy of Figure 7.3-20 from [84], repeated here to make it easier to understand the following two figures.)
As the above figures show, if the shielded motor cable has its shield correctly RF-bonded at both ends, the CM current loops associated with the drive’s motor output ‘prefer’ to flow inside the cable’s shield. By following this path, the area enclosed by their current loop is very much less than that of all the other paths available to the CM current, making its loop impedance very much lower than the alternatives (for example the CM loop paths that exist in the earth/ground structure outside of the cable shield).

If it seems difficult to understand why an RF current should prefer to flow in a particular loop (the one with the least impedance), think of a number of resistors connected in parallel – it is the resistor with the lowest value that carries the bulk of the current.

The impedance of the CM loops at frequencies above a few kHz or so are dominated by inductive and capacitive reactances, rather than resistance, but the same principle applies – the bulk of the CM current automatically ‘prefers’ to flow in the loop that presents the least overall impedance, which is the loop with the least inductance, which is the loop that creates the smallest surrounding magnetic field, and is therefore the loop that provides the lowest emissions, see [85], also in either in [4] or Chapter 2 of [5] (which use the same text).

To achieve the low impedance necessary to ensure that the motor drive’s output CM currents ‘prefers’ to flow in paths that cause the least emissions:

- At the chopper end, the motor cable shield must be RF-bonded to the chopper’s metal enclosure, chassis or frame.
- At the motor end, the motor cable shield must be RF-bonded to the motor’s metal terminal box, which in turn must be RF-bonded to the motor’s enclosure or frame (e.g. by seam-welding or multiple spot or tack welds).

There are many good design and assembly practices associated with cable shielding, and they have all been addressed in Chapter 4.3 of [3], Chapter 4.6 of [5], Chapter 5.11 of [69], and in [61] and [70].

Notice that for a cable shield to act as a shield at RF frequencies, it must be 360° RF-bonded at both ends. Never use a pigtail, or ‘take the shield through a connector pin’. Of course, this causes potential equalising currents to flow in the shield, which have been demonised as ‘ground loops’, ‘earth loops’, ‘hum loops’ etc. ever since the first electronic systems were built to add sound to movies, which had previously been silent.

In fact, these loops are a positive advantage in improving the signal-to-noise ratio of correctly designed electronic equipment, and they also help reduce the common bonding impedance of a site and so help achieve EMC specifications.

Also, 360° RF-bonding at both ends is the only way to maintain the RF shielding performance of shielded cables that are longer than $\lambda/100$ (for example, that are up to 0.3 metres long, about a foot, at frequencies below about 10MHz). And as Figure 7.5-1 showed, not RF-bonding the motor cable’s shield at both ends would result in high levels of emissions, because the shield would not then provide the CM current loop with the path of least impedance (= the path of least external field, = the path that causes the least EM emissions).

The problem with so-called earth/ground loops arises because most electronic circuit boards and their resulting equipment are specified (and thus designed) to work well when tested on a bench, rather than in a real-life system or installation.

When circuits and equipment are designed correctly for use in real systems/installations, with their inevitable potential equalising currents, it is found that RF-bonding cable shields at both ends always provides very positive benefits, from DC to RF frequencies, well beyond what is possible with any type of system that uses single-point earthing/grounding (sometimes called star earthing/grounding), which requires cable shields to only be connected at one end. [62] and [63] have much more detail on this, as does Chapter 4.6.8 of [5].

The installation method known as meshed earthing/grounding (more correctly – meshed bonding) – which benefits from RF-bonding cable shields at both ends – has been proved conclusively over many years in numerous installations, including those as large as the Diamond Light Source at the Rutherford-Appleton Laboratory in Harwell, Oxfordshire, UK (http://en.wikipedia.org/wiki/Diamond_Light_Source), the Singapore Opera House, and the huge new Danish Radio City.

Systems and installations designed and constructed using this good installation engineering method almost always fully meet their signal-to-noise specification from the instant of switch-on, and they are safer, too.

(I am allowed to talk about ‘correct electronic design’ for real systems and installations, because 30+ years ago I used to design circuits that tested very well on a bench, but proved difficult to install and meet their specifications in real systems – though in my defence I must add that every other circuit designer in the companies I worked for were no better. Later, I learned how to design circuits so that they met their specifications when tested on a bench, and also without any fuss when installed and used in real systems and installations. No prizes for guessing that the much-preferred latter designs RF-bonded their cable shields at both ends.)

It can seem difficult to find shielded cables with the appropriate voltage and current ratings for high-power motor drives, but figure 7.5-5 shows a cable type from Belden that has excellent shielding characteristics (when RF-bonded properly at both ends, of course) and is rated for up to 2kV and is available with conductors of up to 2AWG (i.e. 6.5mm in diameter, with a current rating of 94A).
Figure 7.5-5  Example of shielded cables for variable frequency (VFD) motor drive outputs

Where higher-power output cables are required, or to save cost, unshielded cables may be used and fitted with an overbraid or shielded flexible conduit, like the examples shown in Figure 7.5-6.

Figure 7.5-6  Examples of overbraids and shielded conduits

Solid round metal conduit could of course be used instead, and if fitted with appropriate 360° RF-bonding at all joints and both ends – for example by using the RF-bonding ‘earthing nuts’ in Figure 7.5-7 – can provide the ultimate in output cable shielding performance up to a few hundred MHz. Higher frequencies would need a complete 360° electrical connection at the equipment and motor ends of the conduit, instead of the multi-point bond provided by the component shown in Figure 7.5-7.

When the switch-mode converter is in a shielded enclosure, filter and shield bonds must be to the enclosure wall, or its floor, top, or back surface, as shown in Figure 7.5-8.

In accordance with the good shielding practices described in Chapter 4.4.7 of [3], Chapter 4.6 of [5], Chapter 5.12 of [69], and [70], anything that is conductive that passes through the wall of a shielded cabinet, must be RF-bonded to that wall, using either 360° direct bonding, or filtering, at the very point where it penetrates the wall.

This is the case for any type of signal or power conductor (even for a mouse cable) and also when the conductor is not an electrical conductor, for example if it is a metal pipe for hydraulics or pneumatics. I often see costly shielded cabinets ruined despite the use of good shielding practices, because the mouse cable has not been RF-bonded as it passes through the wall of a shielded cabinet wall.

The PEC referred to in Figure 7.5-8 is the ‘Parallel Earth Conductor’ that is described in the standard on good practices in cabling and earthing: IEC 61000-5-2. This is an unfortunate term because it gives the impression that good EMC design for systems and installations has something to do with metal rods stuck into the ground (earth). Some product-specific installation standards and national wiring regulations call it a Parallel Bypass Conductor instead, which is better, although in my view the best term for it would be Parallel Bonding Conductor, PBC.
The usefulness of PECs, and how to design installations with them, is covered in Chapter 5.9 of [69], and in [70].

There are two downsides with using shielded cables for power converter outputs, which sometimes create very real problems for motor drives.

The first issue is that allowing RF currents to flow in the load can be harmful to it. In particular, the stray capacitance between a motor’s windings and its rotor encourages stray RF current to flow through the motor’s bearings. All motor bearings are insulating, even if they use steel rollers or balls they are always coated with an insulating film of oil or grease when the motor is turning, so this stray rotor current can only flow through its insulating bearings as spark discharges.

This causes two undesirable effects. The sparks inevitably erode any metal surfaces and degrade the quality of the oil or grease. Some motor bearings have been known to last for a tenth of their expected lives, due to the effect of stray RF bearing currents from variable-speed motor drives, and they are quite costly to replace.

Correct RF design and assembly of shielded motor cables provides the optimum low-impedance path for stray RF currents in the motor’s stator, but the bearings present an essentially infinite resistance – until they spark over when the voltage across them is high enough. When the voltage across the bearings is less than what is needed to break down the gap and spark over, stray rotor current will tend to flow in other paths, which is much less desirable for achieving good EMC.

Oil or grease that has been degraded by bearing currents will contain free carbon, which – when above a certain particle density, basically black sludge – will develop a resistance and thus reduce the currents flowing into whatever the rotor is coupled to. Of course, but the time this occurs the bearing is probably grinding away at the premature end of its life, so it is not a desirable situation. However, it does show us that using a conductive oil or grease in the first place, when the bearings are assembled, should reduce (possibly eliminate) the damage caused by sparking in the bearings, and also reduce the emissions by providing a more optimal current loop path for the stray RF rotor currents.

Where a suitable conductive oil or grease is not available with the specifications required for a bearing, rotary conductive gaskets are an alternative. These are metal springs or carbon-fibre brushes that are electrically bonded direct to the motor frame or stator close to the motor’s metal driven shaft, and press against it. They wear and so require maintenance, but they provide much lower resistance than conductive oils or greases and so can help reduce RF emissions.

The second problem with shielded power converter output cables, is that they are not matched transmission lines (see Chapter 4.7 of [5]), and as a result suffer from overvoltages caused by the reflection of electromagnetic waves at the load end.

It is worth reminding ourselves at this point that all electrical activities (power, signals, data, wireless communications, etc.) are really electromagnetic wave propagation rather than electrons speeding down conductors, as discussed in [32], [33], [85], and also in [4] or Chapter 2 of [5] (which use the same text).

Connect an LED to a battery and it will light up almost immediately regardless of the length of wire (although if the wire went right around the earth at the equator, it would take about an eighth of a second). But if you could somehow follow the movement of a single electron as it flowed in that wire, you would find that you could easily jog faster than it was travelling.

If we use a cable that is made to provide constant characteristic impedance (called $Z_c$) we can then ‘match’ it by providing source and load impedances that equal the cable’s $Z_c$. This is why all general-purpose RF test equipment has 50Ω outputs and inputs, provided by connectors that have 50Ω characteristic impedances, and we connect them together using cables that also have 50Ω characteristic impedances. In this way we don’t measure erroneous voltages at frequencies that depend on the cable lengths.

The same ‘impedance matching’ methods are used for radio and television broadcast antenna, where it is especially important because any mismatch at any point along the antenna cable, or at the antenna itself, reflects power back from the antenna into the transmitter, which can be damaged as a result. The overvoltages arising in such situations can also cause very dangerous and damaging arcs.

However, no motor matches the characteristic impedance of its motor cable, so the high frequencies (actually, RF) present in a converter output, especially those with PWM outputs, reflect back from the motor, causing overvoltages and ringing on the switching edges. [86], [87] and [88] provide a wealth of detail on this problem.

The peak value of these overshoots are generally considered to reach as high as double the voltage on the converter’s DC Link, but no higher, and the insulation ratings of motors and motor cables are set accordingly. However, since the mid-90’s it has been known that they can be higher still, up to three, even four times the DC Link voltage, as shown by [89] and [90].

If the insulations of the motor cable and the motor itself are not rated for continuous operation with the high voltage peaks caused by the motor-cable mismatch, they will degrade, reducing the operational life of the system. Also, the corona discharge (and even sparking) caused by inadequate insulation will increase RF emissions and help cause EMC test failure, as well as increasing the possibility of interfering with other equipment.

The height of the overvoltages that arise at a motor cable’s connection to its motor depend upon the $dV/dt$ of the power converter’s chopper output, and the length of the cable connecting it to its load.

Developments in the power switching semiconductors themselves are generally in the direction of shorter switching times, to reduce thermal losses, increase electrical efficiency, and use smaller heatsinks to pack more converter power into smaller packages that cost less. The result is that, as time progresses, new motor drives have PWM outputs with ever-
higher values of $dV/dt$ that can cause damaging levels of overvoltages with ever-shorter lengths of cable.

The switching edge rates can be reduced by $dV/dt$ filtering as mentioned in 7.3.13 and figure 7.3-38 in [84], so here we would be using output shielding and filtering together, to minimise costs and maximise performance.

Of course, using a sinewave filter at the output of a PWM filter, as described in 7.3-13, totally removes the PWM waveform, along with all its nasty RF.

In [91] Gary Skibinski proposes fitting a termination network to the motor, to match the motor’s connection to the surge impedance of the cable – a sort of transmission line matching method.

Well, that’s it for converter output cable shielding. The next issue will discuss suppressing RF noise in converter’s DC Links.

References (for this article only)
[14] Keith Armstrong’s earlier articles are available from the archives at www.theemcjournal.com
[69] “Good EMC engineering practices in the design and construction of fixed installation”, Keith Armstrong, published by REO (UK) Ltd, free download from: www.reo.co.uk/knowledgebase
[86] “Effects of AC Drives on Motor Insulation - Knocking Down the Standing Wave”, ABB Technical Guide No. 102, help-us-3
### New Harmonised Standards

On April 11 2012, the European Commission published in the Official Journal of the European Union the following updated consolidated list of harmonized standards to be used for assessing compliance:

**R&TTE Directive 1999/5/EC**


**EMC Directive 2004/108/EC**


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This incredible system cuts RF immunity testing from days down to hours by testing multiple frequencies simultaneously. It saves time & money, and helps get your product to market faster.

**1.0 to 2.5 GHz Solid State Amplifiers**
This amplifier family provides an alternative to TWTA's and offers better harmonics, less noise and superior reliability.

**Integrated Test Systems**
AR can provide an all-in-one test system for any EMC application from DC to 50 GHz. Everything you need is right at your fingertips. Our systems make testing easy, accurate, efficient and affordable.

**Dual Band Amplifiers**
For the first time you can go from 0.7 to 38 GHz with the reliability of solid state. You not only have new freedom, you've got a two-amp package that costs less, weighs less, and takes up less space than two separate amplifiers.

**Traveling Wave Tube Amplifiers**
We may not have invented TWTA's, but we definitely perfected them. Our extensive line of TWTA's provide higher power up to 40 GHz. Reliable power, compact size. We offer CW or pulse designs.

**Laser-Powered E-Field Probes**
Never needs batteries. Most continuous coverage from 5 kHz to 60 GHz and up to 1000 V/m field strength. With outstanding accuracy, linearity and bandwidth.

**Radiant Arrow Bent Element Antennas**
We bent the rules and advanced the science of log periodic antennas. Our bent element antennas are up to 75% smaller, lighter, and more compact to fit in smaller chambers.

When "good enough" isn't good enough for you,
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