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When the going gets tough - smarter design wins

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When the going gets tough – smarter design wins

If you think EMC is about complying with the Directive or FCC
– *think again!*

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A perennial joke told against experts, is that if you ask two of them the same question, you will get three contradictory answers.

However, if you ask any number of EMC experts what is the most cost-effective way to deal with EMC, they all give the *same* answer – *right from the start of the design process*. They all agree that leaving EMC to the end of a project is a huge mistake.

Such unanimity would be scary, if it were not so easy to show why it is true.

I suppose we could make a comparison with health experts, who always seem to be giving contradictory advice about how we should go about our lives.

But if you were to ask them the equivalent question: can you be a total couch potato, eat nothing but junk food, drink nothing but colas and booze, smoke unfiltered cigarettes like a chimney, and only start to think about your health when you are grown up and ready to face the world on your own – they would all give a similar answer: *do it right from the start!*

It is, as they say, a 'no-brainer'.

But, in my nearly 20 years as an EMC consultant, one thing has been constant – most manufacturers of products, systems or installations ignore EMC during design. Then (if they feel they cannot avoid it) they test the 'final' design for EMC, usually to find that it fails miserably and substantial design iteration is required to make it pass – at huge cost.

All the other EMC consultants I meet tell the same story of wasted opportunity. One reason, of course, is that EMC is rarely mentioned at all at undergraduate level, so people only find out about it 'the hard way'. But that doesn't explain why managers with experience of the delays and costs caused by this 'traditional' approach to EMC, don't ensure that it is designed-in from the start. It is certainly not because of a lack of available training courses!

The third paragraph in Banana Skin No. 535 (in this issue) shows that this problem has always existed in the electronics industry.

For at least three decades, until the third quarter of 2008, everyone said that design and manufacture was a tough world, unforgiving of the slightest financial slip. This is why most designers were brow-beaten into thinking it was vital to cut every last penny from the Bill of Materials, or BOM. (This was never true, for rather obvious reasons that I hope to explain in a future article.)

But now, in these days of global recession, we look fondly back on those years as a huge luxurious gravy train of excess, where delaying a product's launch by a few months while all the design drawings were ripped up and redrawn, production tooling scrapped and remanufactured, etc., was not at all unusual.

If you think my analysis is over-severe, here's a little anecdote for you. In 1996 I was visiting the design offices of one of the largest global automotive manufacturers (you know their name) where they were discussing the delayed launch of one of their new vehicles due to interference from its new-fangled electrically-power-assisted steering. The designers had routed cables carrying over 100A (with chassis return, of course – a big no-no for EMC, but one that the auto industry seems peculiarly wedded to), too close to the accelerator pedal's sensor, the one that sends the signals to the engine management unit that makes the car go faster or slower.

Unable to resist, I asked why, with a new high-power electrical system like this, they had not anticipated interference problems during design, and routed the cables (and their returns) more sensibly in the first place. The immediate answer came back, rather hotly, that in the auto industry timescales and costs were *very* tight indeed, and such luxuries as I might be used to could simply not be afforded.

Then, a senior design manager, who had been through this same scenario many times, said thoughtfully: "You know, the company always says it can't afford to do design thoroughly, but when a model is delayed through design errors there is always an infinite amount of money available to put it right."

This is a story that I have found to be all too common, across all industries. It is as if managers are trying to save money, whatever the cost.

The reason why all EMC experts agree that it is financially irresponsible to ignore EMC during design, leaving it to the end to fix any problems that arise, is because the cost of a design change rises exponentially during a project.

So solving EMC problems earlier costs much less, as shown in Figure 1, and since it is quicker to change a drawing or computer model than hardware – the time-to-market delays are also very much less.

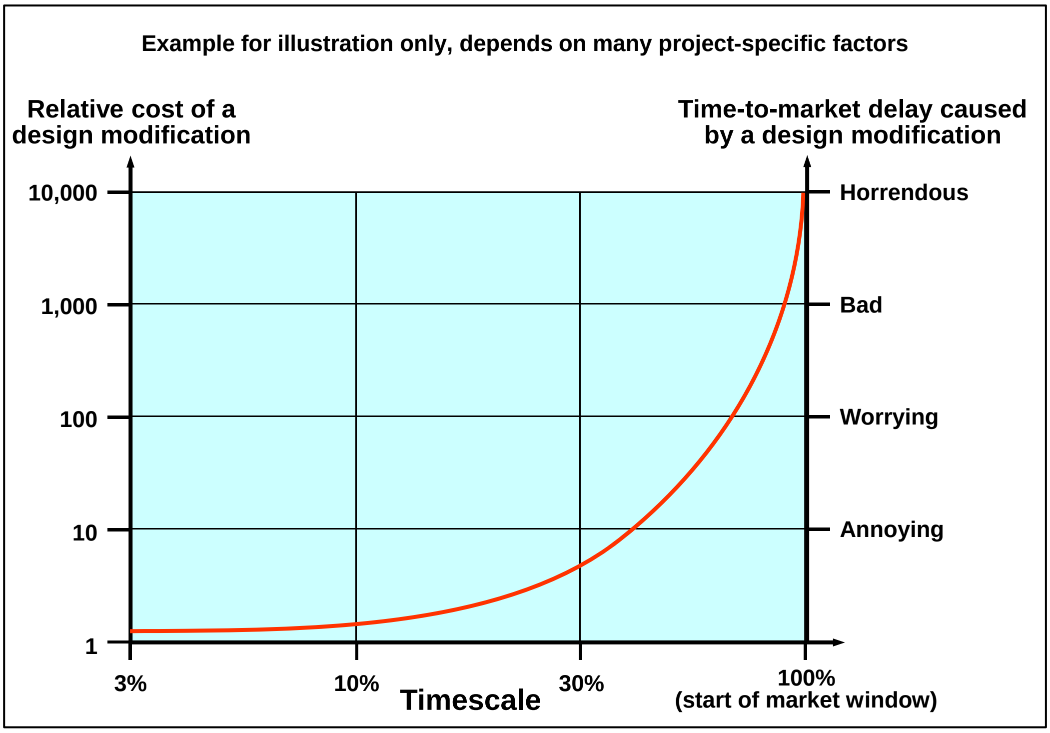

Figure 1 Cost of a design change versus project timescale

Some students of economics will be reading this, in their heads already sketching out their Letter to the Editor, in which they will point out that like most *mere engineers* I have forgotten about the cost of money, and the necessity of using discounted cash-flow analyses. Well, I'll spoil it for them by pointing out right now, that – even with interest rates of 20% or more, solving EMC problems during early design phases still proves much more cost-effective *overall*, than fixing them at the end of a project.

Another reason why this is so, is that design freedom reduces at an exponential rate as a project proceeds, as shown by Figure 2. So when problems are found at the end, it is almost always impossible to – for example – choose a different microprocessor, layout a new PCB and write new software for it, which of course would have little/no effect on the BOM cost and assembly time.

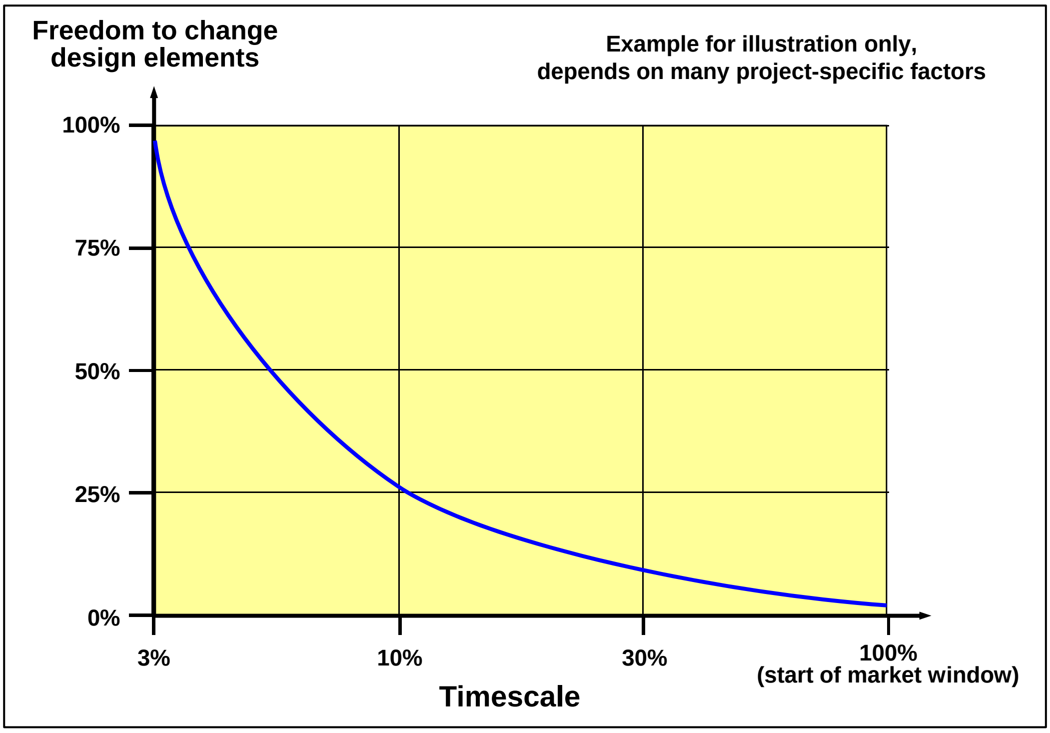

Figure 2 Design freedom versus project timescale

Instead, the same result is achieved by getting busy with copper shielding tape, screened cables and connectors, large lumps of ferrite, filters, etc., and it can often be a problem to squeeze the resulting mess into the available space. The BOM cost increases dramatically, as does the assembly time, which of course all comes directly off the bottom line of each product sold. And of course the time-to-market suffers dreadfully.

Yet another reason, is that the true cost of being late to market is so very much greater than most people realise. In fact, those who study these things professionally tell me that – for most products – time-to-market is now much more important than cost of manufacture, for the financial health of a manufacturer.

Of course, the very significant financial benefits of solving problems early in design, rather than fixing them at the end, applies to everything, not just EMC. Analysis based on real-world numbers often shows that it is very cost-effective to equip all designers with computer simulators costing as much as £50,000 (maybe more) per seat, plus training to use them properly, plus changing new product procedures to require all designs to be proven with *validated* simulation models before any hardware tooling is ordered.

I mentioned earlier that not all manufacturers are as fiscally irresponsible as the black picture I have painted above. Many of those who believe in solving problems early are based in Japan, where (according to a major study in 2000) the direct result is that most of their electronic manufacturers take about half the time of 'western' manufacturers, to turn financial investment into world-beating products.

My point is: *now that times really are tough*, the inefficiency and waste created by leaving EMC considerations to the end of a project, is no longer affordable. Companies that continue to use such traditional approaches in the present economic climate, risk failure like never before.

Just continuing to exist until the recession is over and the good, lazy times return, never mind increasing market share, requires *working smarter* – taking EMC fully into account right from the start of any project.

But the above is not the whole story, by any means!

If you thought EMC was only about meeting specifications – whether to comply with the EMC Directive or FCC, or customer specifications such as rail, military or aerospace – you should think again!

There are many electronics trade magazines, with design articles all about signal integrity, eye closure, jitter, noise margin, power integrity, overshoot/undershoot, ringing, double-clocking, crosstalk, noise, signal-to-noise ratio, distortion, etc. – all the things that electronics designers have to wrestle with to make their increasingly complex designs work.

And once they have finally managed to control all of these issues, and finally got their PCB or module to work to specification, along comes the system integration phase. All of the various designers' items are connected together – and found not to work because of signal integrity, eye closure, jitter, noise margin, power integrity, etc., etc., as before.

At this point, when a Director asks how long it will take to fix the problems so that the product can be launched without *too* much slippage from its market window – all the engineering team leader can say, is that it might be day or three, or it might be a month or two, please ask again later in the week when he more of an idea just what the problems are. This is not the answer any Director wants to hear!

Reading the trade magazines, attending classes at university, and reading textbooks about all these difficult electronic design issues – which, by the way, are getting more difficult year by year as silicon technology advances, marketing demands increase and timescales reduce – one could be forgiven for not realising that their common underlying physical basis is electromagnetic compatibility, EMC.

We often call this 'internal EMC', see Figure 3 – to differentiate it from the world of EMC test laboratories and operational EM environments – but it is EMC nevertheless. The key realisation, is that *cost-effective EMC engineering from the start of a project automatically deals with internal EMC issues*.

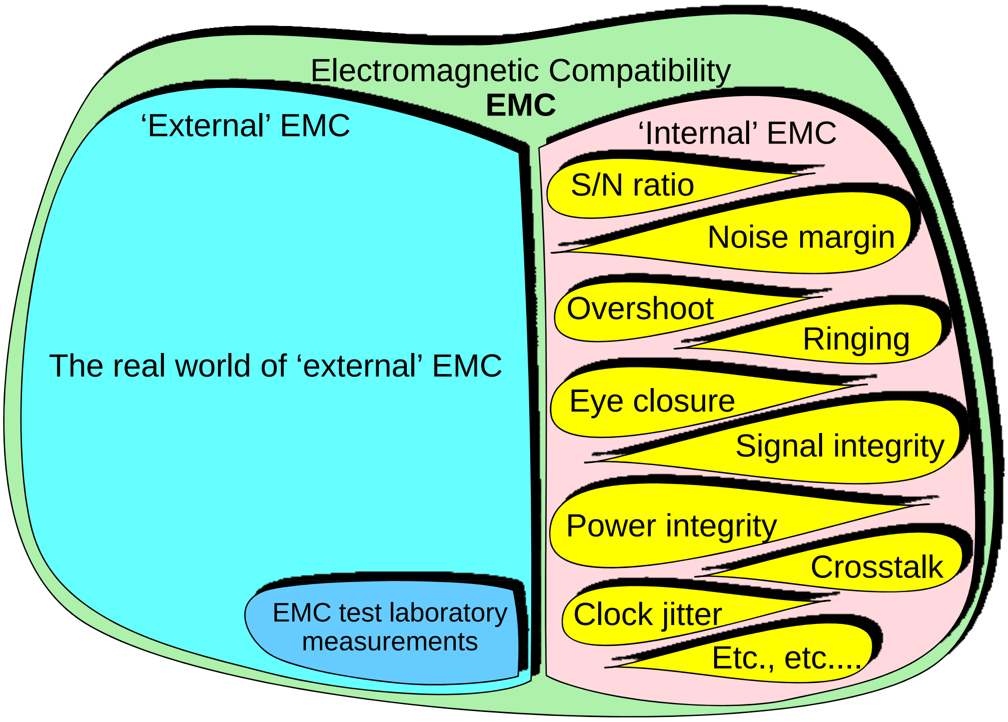

Figure 3 The world of EMC – 'External' and 'Internal'

Internal EMC problems cause major delays in almost all new product design and development, and they are at their worst when a product uses two or more technologies chosen from the following list: digital; analogue; switch-mode power conversion; wireless; high-power electrical, and electromechanical.

The 1980s was the decade when almost everything 'went digital' (as the marketing guys described it). I started that decade as an experienced analogue designer, and throughout it worked for a number of companies whose products were famous for their state-of-the-art functional performance, based solely on how good they were at analogue design. But the instant they added a microprocessor or two, or a switch-mode power converter, their functional performance (e.g. S/N ratio) degraded by between 40 and 60dB.

At the start of the 80s, it would often take me and my colleagues at least 6 iterations of the PCBs, and then of the system design, to get close enough to the original specifications, at 2 to 4 weeks for each. 16 iterations was not unheard of. That's a time-to-market delay of between 36 weeks and 96 weeks (nearly 2 years), but it was the best we could possibly achieve at the time, and many families went without sight of their too-rapidly-ageing breadwinners during that period.

It was a steep learning curve, and my education cost my employers millions at 1980s prices, but I comfort myself against my obvious shortcomings and ignorance by noting that at least I learnt the basics of what was going on when no-one else seemed able to. By the middle of the 80s, I was able to give a group of graduate engineers with no previous design experience at all, a list of instructions on how to do circuit design, system design, and PCB layout, and have them meet all the product's functional specifications *on the first design iteration*.

At the time, I was working on microwave instrumentation that had to meet world-best functional specifications, whilst also breaking new ground with the power of their digital processing and efficiency of their switch-mode power conversion. The first time this happened, all of us senior designers and design managers broke out the champagne and celebrated wildly, much to the puzzlement of the new graduates, who simply couldn't understand what all the fuss was about.

They had designed the circuits, assembled the product, and – when tested – it met all its specifications. Wasn't that how things normally went? No, we explained as best as we could whilst pouring another glass of bubbly – that was <u>not</u> how things normally went, not at all!

Of course, their education had ignored such issues as current return paths, crosstalk, EMC, etc. – all the things that it turns out you have to take into account to make real designs work well-enough in the real world, even when EMC isn't a specific requirement.

Unfortunately, electronic design undergraduates these days are mostly taught in the same way as they were in the 1980s. Unless quickly brought up to speed by in-house training, they inevitably learn the same lessons the hard way, usually over a period of years, at great expense to their employers. We are talking about millions of Pounds, Euros, Dollars, whatever, totally wasted, *for no good reason*.

In 1990, when I set up to offer independent services in EMC, I soon found that when a product had been designed using my techniques to avoid delay in time-to-market – was tested for compliance with FCC Regulations or EMC Directive standards – it generally passed on the first go.

However, products designed using the traditional techniques I had started off with in 1980 – that had required multiple design iterations just to meet their functional specifications – almost always also required multiple design iterations to pass their EMC tests, piling delay on top of delay.

Looking into why this should be, I realised that my design techniques were actually dealing with electromagnetic emissions, susceptibility, and coupling paths – but at the level of individual devices, PCB traces, wires and cables. As I said earlier, all these issues of signal integrity, eye closure, jitter, noise margin, power integrity, etc., are actually 'internal EMC' issues – and controlling *internal* EMC to get good functional performance in mixed-technology products – also results in good '*external*' EMC when measured in an EMC laboratory.

For a more technical discussion that shows how RF emissions and immunity are simply the 'other side of the coin' to overshoot on digital waveforms – essentially the same basic physical issue, just measured in a different way, see [1].

What this shows is that the most cost-effective EMC design techniques, are those that are applied at the level of the system design, circuit design, component selection, board layout, right from the beginning of a project. They help ensure that everything goes to plan from the functional performance point of view, as well as helping ensure that EMC tests at the end are passed.

A couple of final points still remain to be made.

The first is that products designed from the first using good EMC engineering have lower warranty costs, because they tend to be more robust to real-world EM environments than products that have merely been fiddled with to just about scrape through a few tests. The second is that they often achieve better functional performance.

For example, Cadac are a manufacturer of professional sound mixing consoles, mostly for theatres and other live-performance applications, and for 30 years they had been the choice for musicals in the West End, Broadway, and equivalent areas in major cities around the world because of their high quality sound.

Then in the early 1990s they added a single microprocessor for control, and immediately suffered a degraded signal-to-noise ratio. Being a responsible manufacturer, they were in the process of finding out how to comply with the EMC Directive, newly introduced at that time, and found that their microprocessor had too-high emissions, and their analogue circuits were not immune enough. And their next product was going to have one-microprocessor per channel – a minimum of 64 in one product!

By adopting the 'internal EMC' design techniques I had developed in the 1980s, they were able to pass all EMC tests with the 64-microprocessor product. But much to their very great surprise, they also found that it had a signal-to-noise ratio in its audio channels that was nearly 10dB better than their lowest-noise all-analogue console!

Not only that, but another direct result was that assembling and testing their very complex products became much easier, allowing Cadac to increase throughput by a factor of 5 without having to increase the number of people employed in its test department. Installation of their consoles in the Albert Hall and similar venues now took less than half the normal time, with far fewer problems. In fact, installing their consoles now took so much less time that some installers made official complaints to their managements about missing the double and triple time payment they had been expecting for working nights and Sundays, as was usually the case with audio mixers – and still was for other makes.

It was also notable that a cellphone near to other consoles made the usual blippety-bip noises come out of the speakers, whereas you could place a cellphone on the Cadac console and not hear any extra noise.

If you find all the above hard to swallow – especially as some good EMC design techniques contradict pro-audio traditions such as bonding cable screens at one end only, to avoid 'ground loops' – then I have permission from Tony Waldron, Cadac Group's Technical Manager (and an EMC Journal author on this issue, see [2]), for you to email him at tony@cadac-sound.com or twaudio@btconnect.com to confirm all I have said.

I have only used a few of the many examples and anecdotes from my nearly 20 years of EMC consultancy, but many of the stories I would love to tell have to remain confidential. The Banana Skins book [2] has many stories of what poor EMC can cost, but hundreds of stories of wasted time and money, like Banana Skin No. 437 never see the light of day. After all, what company is going to admit that it doesn't do simple things that have been well known for over a decade (publicly available since my first series of articles in this Journal in 1999), and as a result wastes millions?

So I hope that you can now see the point of the subtitle to this brief article. EMC is indeed *very* much more than just complying with regulations, Directives or customer specifications.

Good EMC engineering requires designers and their managers to be *cleverer*, and for many companies over the next few years getting to be this clever could mean the difference between success, and failure.

It seems that most electronic product manufacturers (other than Japanese and a few noteworthy others) have so far managed to avoid using proven good EMC engineering techniques, because – whatever they said to the contrary – times were so good that the resulting waste and delay was acceptable. For the next year, and we pray no longer, this will not be the case.

After writing the above, I found myself on a train journey, sitting opposite an attractive, smartly-dressed American businesswoman, who from her cellphone conversations was clearly a marketing executive for a large company. I asked her what was her take, as a marketing person, on the global recession. She replied that it provided a great opportunity to get ahead of your competitors, when the markets recover.

I thought this provided an excellent, upbeat finish to this article!

[1] Keith Armstrong, "*EMC and Signal Integrity*", Compliance Engineering magazine, March-April 1999, from the archives at www.ce-mag.com.

[2] Tony Waldron, "*A Practical Interference-Free Audio System*", EMC Journal, Issues 42 and 43, September and November 2002, www.compliance-club.com/archive/Old_Archive/020918.htm, and www.compliance-club.com/archive/Old_Archive/021122.htm

[3] "*The First 500 Banana Skins*", Nutwood UK, 2007, http://www.compliance-club.com/BananaSkins.aspx or email pam@nutwood.eu.com for an order form (cost around £10)