Not me, guv

Ivor Catt discusses the interference when an electronic module is switched on, every second half cycle

The DC power supply market tends to be very competitive, so that there is minimal surplus and minimal margin of safety in the performance of any component. It will follow that nearly all the area in the BH curve in the input transformer will be used. Also, competition and pride will drive the material choice towards magnetic material as shown in **Figure 1**, with the smallest, narrowest area to minimise the heating from hysteresis. The area inside the closed curve represents the amount of power lost. This power has to be expensively removed as heat. Avoidance of this heating leads to high Remanent Magnetism, indicated by the point where the graph cuts the vertical axis. Minimal area within the closed curve indicates maximum remanent magnetism.

Let us assume that when switched off, the transformer core will retain its remanent magnetism, see **Figure 1**. On the next switch on, the first half cycle of the 50Hz may be positive or negative. If negative, it will take the transformer's magnetic core through its normal cycle. However, should it be positive, it will take it upwards by the vertical distance, resulting in a massive value for H, which means a massive electric current. In other words, this puts the core hard into saturation. When saturated, the transformer core behaves like air, so that the secondary loses linkage with the primary, which degrades into an air-cored choke. Such an inductor places only a small restraint on the rapidly rising input current.

In 1970, Guido Watson did the difficult experiment for me. This involved keeping the oscilloscope calm. He found mains current of some 100A in every second half cycle.

The best estimate we can make of the source impedance of the 50Hz mains is half an ohm. Thus, 100 amps will cause the mains to drop through 50 volts for the half second or so that it takes the input transformer to gradually recover towards normal working within the BH curve, and stop saturating.

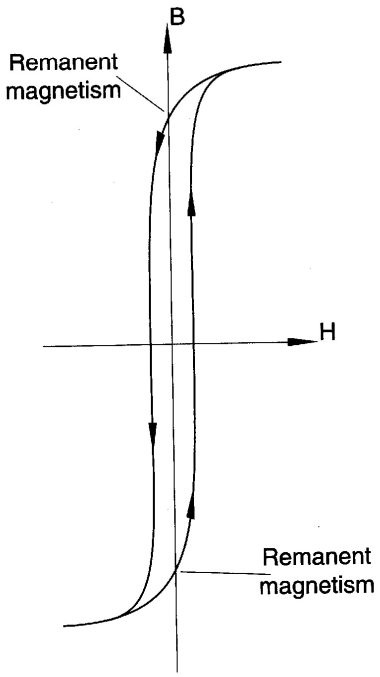

Figure 1.

The designer of an identical piece of equipment plugged in nearby has demanded in his specification that the mains should not drop by more than 6%, or 14V. The customer, or user, has agreed to this. Thus, when our equipment is switched on, the loss of logic bits in the other equipment will be the fault of the 50Hz power supplier, not of the equipment. The customer will have read the small print of the equipment, and agree that the mains voltage must not drop by more than 6%. The only blameless party will be the manufacturer who supplied the saturating transformer. Nobody has ever suggested that power switch on should or should not depress the 50Hz supply. The EMC community have slept through these problems.

Every half cycle

When a classical DC power supply is switched on, the first raw decoupling capacitor is uncharged. Let us follow the path of the initial charging current, **Figure 2**. The input voltage builds up according to the transformer's turns ratio, perhaps to 7V RMS or 10V peak. This confronts a negligible resistance in the transformer primary and then a source impedance in the secondary of perhaps 250mΩ. The impedance of the full bridge rectifier can be more or less ignored, each diode presenting less than one volt drop but no resistive drop. Thus, perhaps 8V proceeds to the uncharged capacitor, which presents no significant impedance. This means that the resulting electric current into the capacitor is defined by the resistance of the transformer secondary.

Again, the measured current pulses are 100A, in this case every half cycle, lasting for a fraction of a second.

Since another piece of digital equipment will crash when the mains voltage sags by 50V for half a second, its manufacturer will increase the capacity of his first raw capacitor. However, should he also manufacture the rogue equipment, it will drag down the mains voltage for twice as long. The manufacturer will chase his own tail.

The simplest way out for the EMC community is to cover the whole subject with a smokescreen of mathematics, tell us not to use our mobile phone or computer while flying in an acroplane, and so forth.

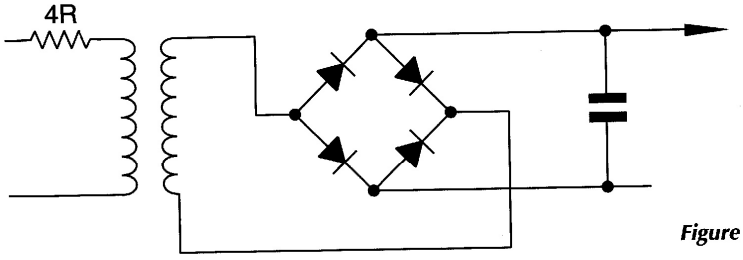

Figure 2.

That is the way the EMC community deals with its failure is to solemnly tell us not to use more than one piece of equipment at the same time. A piece of equipment which is not in use is likely to be compatible with an active piece of equipment, without the aid of half a century of EMC pontification.

Put a four ohm resistor in series with the transformer primary. That will ameliorate the problem, which is that during the critical quarter of a second after switch-on, nothing limits the primary current. The long-term solution is to include the transient behaviour of a piece of equipment along with its steady state behaviour. The people who should have been doing this, of course, are the EMC punkah-wallahs. The problem is a physical one, and mathematical high trapeze acts will not help.

Broadening out

Transformer, bridge rectifier followed by raw capacitor is not the only way in which AC is converted into DC. The circuit may use a swinging choke, which probably gets even more upset during power switch-on. My warning is that, the EMC community and the rest of us having apparently ignored the problem of switch-on for more than a half century of digital electronics, questions have to raised about the hazard to other equipment presented by switching on all other types of power supply. Looking behind this, we have to ask whether, and why, the glamorous, well funded EMC community have ignored the subject. (Probably this is because you have to know what you are doing, rather than just brew up fancy maths.) If so, I would argue that enforcement of their regulations by the EEC using criminal sanctions must end. We must not allow incompetents to control our profession and industry. In particular, they must not be allowed to take control of the necessary similar analyses needed for other DC power supply circuits. Note that my analysis above contains no mathematics. If EMC wallahs are allowed to bury such problems in fancy maths, with the support of criminal sanctions, they will create a terrible mess.

It has only just occurred to me that the reason why the necessary investigations are so difficult is that, as my colleague Guido Watson found, an oscilloscope is traumatised when something else is switched on, so that more skill and care is needed when looking at these effects than EMC hotshots could muster. Buried in the necessary experiments is the very problem being investigated!

Background

Three engineers including myself were concerned that professional engineers did not have the information and understanding that they needed to design and build digital electronic systems. Education remained in the hands of radio men who had migrated from the lab to take college jobs.

We began giving private seminars in 1977. I have found the letter acknowledging our deposit paid to Theobalds Park College towards £900 to rent the Stately Home for two days to give residential courses, 26-28 October 1977 and 14-16 December 1977. We used the umbrella of Middlesex Polytechnic, who were developing my WSI invention (see Wireless World July 1981), to give us further credibility, but took all the risk ourselves. We made the mistake of charging too little - £45, or £60 residential – but then hurriedly increased the price to reach £240, so that in future engineers would be able to attend with honour. These courses continued for ten years, and I have the 1987 brochure. Companies who sent their engineers to more than one of our courses included STL Harlow; ITT Cockfosters; Shell, Chester; Square D, Swindon; BTel Holborn; ICI Plastics, Welwyn; Redifon, Crawley; GEC, Coventry; Royal Free Hospital, Hampstead. We discussed many of the subjects ignored (and still ignored) by the EMC Community and by academia.

I find that every item on our list (www.ivorcatt.com/43.htm) is still ignored, although most of them remain important today, a quarter of a century later. All the course notes were later published privately, and most of them were republished by Macmillan in our 1979 book *Digital Hardware Design*. Macmillan quickly took the book out of print.

In sixteen hours of lecturing, we had to omit some critical problems. The one discussed in this article has never before seen the light of day.