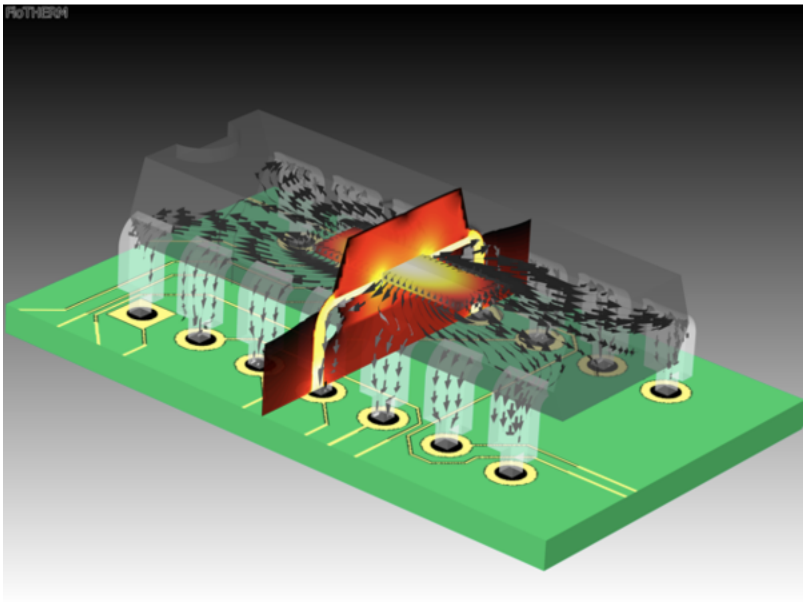
Integrating power electronics design technologies

Tony Christian, Director, Cambashi

The field of power electronics, the application of electronics for the control and conversion of electric power, is underpinned by basic electrical principles that were established in the distant past by the pioneers of electrical science. But today, the need to supply, modify and control the voltage, current or frequency of electric power arises in a vast number of applications and products spanning a huge range in terms of power handling capability. The industry has generated numerous technological advances to address the ever growing spectrum of requirements; in its 30th anniversary edition, Power Electronics Technology described some of the most important developments of the past three decades.

In the limit, the requirements for power electronics systems range from those designed to handle a few milliwatts such as the DC/DC converters designed to maintain constant voltage as the battery power declines in mobile phones and portable hand held devices, to those handling many megawatts in the large power converters used in the electrical generation and distribution industry. Naturally, the challenges for power electronics designers vary considerably according to application and scale. Those challenges now cover not only electrical function (particularly the drive to maximize efficiency for the power and frequency range in question), but a host of practical and, especially in consumer products, even aesthetic design constraints. For example, the developers of devices like mobile phones or PCs seek to pack ever more functionality into smaller spaces and their power supplies must not consume a disproportionate amount of that space. At the same time, the ever-closer proximity of the components imposes increasing constraints on electromagnetic radiation and limits the ability to dissipate heat. But that kind of challenge is not limited to what is usually regarded as the high tech sector – it seems that even purchasers of auto battery chargers want them to be small and attractive!



For applications of larger scale involving supplying power to electromechanical devices, the design of the power electronics must take into account and adapt to the behavior of the load (usually a motor or drive system) across its operating range. Considerations will include factors such as power factor optimization and minimizing losses, dealing with harmonic currents and eliminating any electromagnetic torque oscillation that might give rise to electromechanical vibrations. In many applications, including at the high end the power generation and distribution industry, achieving the electrical functionality often requires the design effort to extend to customizing the characteristics of individual system components. There is then the challenge of balancing optimization of the performance of individual elements with the behavior of the overall system.

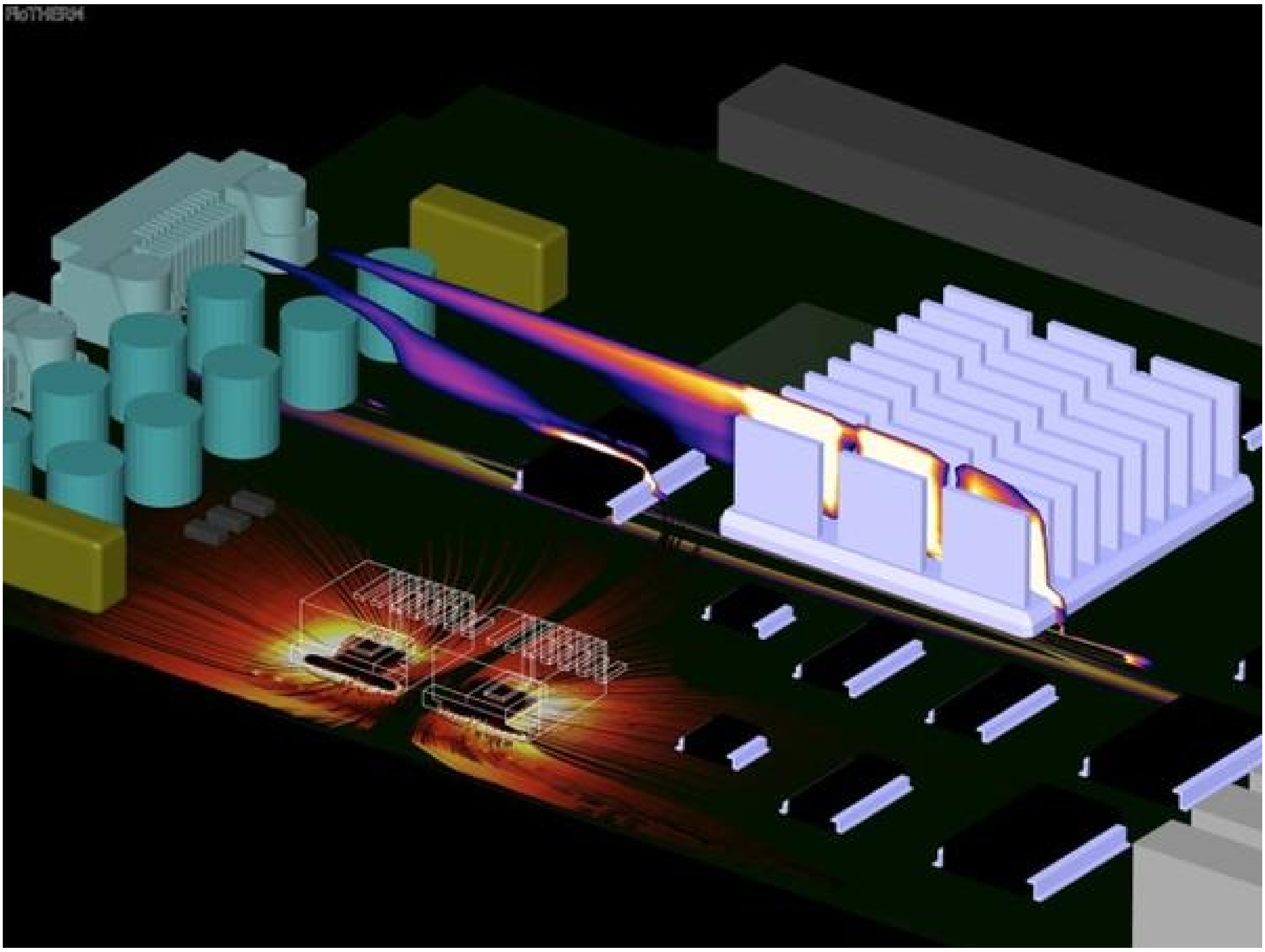
Power electronics is therefore one of the most multi-disciplinary design problems in the modern industrial landscape. The sheer range of considerations and the differing emphasis between them according to application has led to the development of numerous design tools, each targeted at specific aspects of the design problem. The design of a power electronics solution will involve using some combination of:

• ‘Whole system’ simulation technologies based on setting up the circuit logic using component manufacturers’ data for off the shelf components and sub-systems. Here the goal is to understand the system current and voltage levels and frequency components under the range of operating conditions. The analysis is often rendered more complex by the need to incorporate the behaviors of any electromagnetic and /or electromechanical elements. The goal will be to optimize the characteristics of the power electronic system (in terms of the balance of efficiency and cost, size and/or weight) for the application.
• Systems to analyze individual component or sub-system performance for device types in given applications. For example, since inductors and transformers have a significant impact on power losses and the volume and weight of the system, in many applications optimizing their individual characteristics and performance will be a focus of the design effort.

• Systems that analyze electro-magnetic emissions. In the majority of applications the power electronics system is in close proximity to other electronic equipment or there are stringent EMC limits such as in defense applications. It is necessary to understand the electro-magnetic signature of the system in order to develop mitigation strategies in terms of electrical filters and/or physical shielding.

• Thermal analysis technologies. Since the electrical performance of power system components varies with temperature and the function of the system by its nature will involve the need to dissipate waste power in the form of heat, temperature control is a central aspect of power electronics design. Indeed, studies have shown that temperature issues are a major source of failure in electronic systems and avoiding excessive temperatures is therefore a vital aspect of achieving high reliability and extending operating life. Accurate simulation of not only the heat generated by the system but the heat dissipation performance of the options for cooling requires both heat transfer and fluid dynamics capabilities to support the development of the optimum approach to temperature control.

• Structural analysis technologies. Many power electronics systems operate in hostile environments, for example in aerospace and automotive applications they may be subjected to extremely high levels of vibration, requiring that the structural strength of the system is assured under the target operating conditions.



While adequate technologies for each of these aspects of power electronics design have been around for ten years and in some areas longer, there remain a number of significant challenges in terms of achieving maximum exploitation of the capabilities. The first is ensuring that the design technologies can accurately model the characteristics of the more recent (and continuing) semiconductor and ancillary component advances – we have already noted that recent decades have seen substantial progress. This requires a combination of high flexibility in the system modelling logic and continuous software development.

The second issue has been how to integrate the different design technologies into a coherent and efficient design workflow. Traditionally, the electrical performance was the dominant aspect and once the circuit was confirmed as being able to do the job, the 'packaging' – not only size and weight but including the means of controlling temperature and EMC emissions - could be developed to accommodate the electronics. In the last decade, the emphasis has been on how to integrate the various areas of simulation and analysis technology into a unified design environment. For example, data should be able to be exchanged seamlessly between the thermal simulation of a power circuit and the electrical circuit simulator to enable transient junction temperatures to be calculated directly. Not only would such comprehensive integration enable a better balance between the all of the system characteristics to be achieved, but it would also provide the opportunity to reduce the design timescale dramatically.
The third challenge arises from the fact that the recent history of using the sophisticated design tools available for power electronics design has enabled the capture of all kinds of knowledge regarding power electronics performance – electrical, thermal, EMC, reliability and so on. As a result, adequate designs for the majority of applications can be developed relatively easily based on the knowledge and rules encapsulated in the modern design tools. The drive for improved designs is therefore focused on the 1% efficiency improvement or the small reduction in size or weight, making the use of leading edge simulation and analysis tools essential. For the developers of those tools, the challenge then becomes how to make them accessible to a much broader community of users than the traditional market of specialist analysts in companies with large R&D budgets.

Developments in recent years in both the electrical and mechanical design software tools, assisted by continued advances in IT hardware and infrastructures, have made substantial progress in addressing these issues. The ability to exchange data between different solutions for different disciplines from different vendors has improved enormously. Companies like Ansoft, Zuken and Gecko Research now offer integrated suites with the ability to perform complete multi-domain simulations and analyses of power electronics systems, including the full time and frequency performance of the circuit, the thermal behavior, the electromagnetic and electro¬mechanical behavior and mechanical stress analysis. The fourth challenge for both multi-discipline analyses and greater accessibility has been the computing power required – even a single-discipline analysis for a moderately complex power electronics design is a highly computing intensive problem. Typically, a simulation is run for each step in a time/frequency series so that many thousands, if not hundreds of thousands, of simulation runs can be required to fully validate all aspects of system performance. The computing requirement is heightened by the fact that many control systems now involve software control and the additional variable of the software set up introduces yet further dimensions to the analysis problem. The promise of 'infinite' computing resources in the cloud and the growth in power of dedicated processors that can be added locally mean that there is now sufficient processing power available to the engineer's desktop to run even quite complex simulations for thousands of time steps.

Give that good progress has been made in addressing the issues of multi-discipline integration and sufficient desktop computing power, the remaining challenge for broadening the user constituency for power electronics design technologies is that of being able to address a suitably wide range of applications while achieving ease of use. The spectrum of applications covers a huge range of power handling requirements (milliwatts to megawatts), frequencies (DC to GHz), temperatures (-55°C to 275°C) and physical scale (µm to m). In the past, as with almost all analysis and simulation systems, the design engineer needed strong expertise and knowledge in modelling and simulation techniques as well as in the technology being modelled in order to ensure that the results represented reality with a reasonable degree of accuracy. Now, to fully exploit the workflow benefits of an integrated suite of design tools, we need the design engineer to be confident in not only the electrical simulation at both the component and system level, but also those for the thermal and electromagnetic behaviors, as well as possibly structural aspects too. The tools therefore need to sufficiently easy to use to be handled by an engineer who is not a specialist in a particular discipline while still providing confidence in the results. There is no doubt that the leading vendors have made invested substantial effort in this aspect of integrated power electronics design and it continues to be a priority area.

For many applications, power electronics forms part of the final product and a likely significant further step in the development of power electronics design technology will be full integration with the product lifecycle management (PLM) environments in use by most large manufacturing companies. The data volumes resulting from larger numbers of design simulations by greater numbers of engineers will put pressure on the data management capabilities of existing PLM deployments, but, in parallel with the increased accessibility of multi-discipline power electronics design tools, we are seeing a similar effort to exploit cloud and web technologies to extend the reach of PLM solutions to smaller companies. As a result there is an opportunity to move the two forward to support even better management of the power electronics design workflow.

Bio:
Tony Christian has a wide-ranging experience in engineering, manufacturing, energy and IT. His early career was in technical R&D roles, after which he moved into computer-aided engineering. His subsequent roles included divisional head of the IT subsidiary of a major international engineering and construction company and leadership of teams developing and implementing state of the art manufacturing control systems at British Aerospace. More recently, Tony was a director of the UK Consulting and Systems Integration Division of Computer Sciences Corporation (CSC), leading a consulting and systems practice for

manufacturing industries, and then Services and Technology Director at AVEVA Group plc where he was responsible for all product development and the company's worldwide consulting and managed services business.

Tony has a BSc degree (Mechanical Engineering) and MSc degree (Engineering Acoustics, Noise and Vibration) from the University of Nottingham.

Source URL (retrieved on *04/28/2015 - 3:07am*):
http://www.ecnmag.com/articles/2012/10/integrating-power-electronics-design-technologies?qt-video_of_the_day=0