









# Thermal modelling at NXP Semiconductors, Stockport

<p><b>Thermal modelling at NXP Semiconductors, Stockport</b></p>  <p>Martin Tarr</p>  <p>Chris Hill</p> <p>Chris is a Product Concept Engineer who has been active in thermal modelling for five years</p>  <p>Electronics KTN – Knowledge For Growth</p>	<p>For this interview, we're at NXP Semiconductors in Stockport, talking to Chris Hill, who is a Product Concept Engineer and has been active in thermal modelling for five years.</p>
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MT: First of all, Chris, perhaps you could say something about NXP: what does the company do?

<p><b>The company</b></p>   <ul style="list-style-type: none"><li>▪ NXP Semiconductors is a global semiconductor manufacturer</li><li>▪ Hazel Grove primarily manufactures power MOSFETs</li><li>▪ Other parts of the company make ICs for many different applications</li><li>▪ Diverse, broad-based company with many different interests</li></ul>  <p>Electronics KTN – Knowledge For Growth</p>	<p>CH: NXP Semiconductors, as the name suggests, is a semiconductor manufacturer. The particular part of NXP that I work for in Hazel Grove primarily manufactures power MOSFETs, although other parts of NXP located around the globe are involved in other semiconductor manufacture, such as ICs of various different types for a vast range of different applications, RFID, lighting, automotive, various different consumer applications. So it's a very diverse, very broad-based company with a lot of different interests.</p>
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MT: What are the thermal challenges that surround NXP products?

<p><b>The thermal challenges at NXP</b></p>  <ul style="list-style-type: none"><li>▪ Trend to increasing power density in power MOSFET applications<ul style="list-style-type: none"><li>▪ manufacturers trying to do more in smaller and smaller spaces</li></ul></li><li>▪ 15/20 years ago the thermal environment could be ignored<ul style="list-style-type: none"><li>▪ thermal aspects now need to be considered from product inception</li></ul></li><li>▪ Not something that can be left to chance<ul style="list-style-type: none"><li>▪ numerous cases where thermal design was not done properly</li><li>▪ result that the products ran into problems</li></ul></li><li>▪ Doing thermal design is extremely important!</li></ul>  <p>Electronics KTN – Knowledge For Growth</p>	<p>CH: Particularly for power MOSFETs, which is the area that I work in, over the past perhaps a decade or so, there has been an increasing trend in a lot of our end applications towards increased power density or, to put that another way, manufacturers are increasingly trying to do more in smaller and smaller spaces. So whereas perhaps say 15 or 20 years ago the thermal implication or the thermal environment could be ignored or perhaps wasn't so critical, now the thermal aspects of a product are something that have to be considered right from the very inception. It's not something that can be left to chance, and there are numerous examples from industry of cases where the thermal design has not been done properly and the result has been that the products have run into problems, so obviously designing or doing thermal design is extremely important.</p>
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## Thermal modelling at NXP Semiconductors, Stockport

MT: How typical are the challenges at NXP of the challenges elsewhere in the electronics industry?

### Are these challenges typical?



- NXP challenges are very typical of the challenges elsewhere in the electronics industry
  - similar concerns with other manufacturers supplying parts for similar applications
  - not a problem unique to NXP!
- In the trade press
  - more and more articles on thermal issues, thermal design
  - tend to indicate that this is something that is very much in everybody's consciousness



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CH: I think they're very typical. Certainly we see similar concerns with other manufacturers who are supplying parts into the applications that we're interested in, it's by no means a problem that's unique to NXP. You only have to read the trade press to see this, in that increasingly there are more and more articles on thermal issues, thermal design, which would tend to indicate that this is something that is very much in everybody's consciousness, not just NXP's but the industry as a whole.

MT: So how is thermal modelling and simulation used within NXP?

### Use of thermal modelling and simulation



- Two broad categories of use for thermal simulation and modelling
- *Internally*, used to investigate device performance
  - new device or a variation on a device
  - new package type
- Previously performance could only be determined by building/testing
- Benefits of modelling are enormous
  - an awful lot quicker than waiting several months for a new lead-frame type to be developed!
  - also cheaper . . . software soon pays for itself
  - an invaluable resource



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CH: There are perhaps two broad categories of use for thermal simulation and modelling. The first is internal, in that we use thermal modelling to investigate the performance of our devices, particularly when we are considering releasing a new device or a variation on a device, or maybe contemplating the use of a new package type. The thermal performance of any device that we release is important, and whereas previously the only way we could determine the thermal performance of something was actually to build it and test it, now we can use modelling, and the benefits that brings to the situation are enormous, not the least of which being the fact that modelling is an awful lot quicker than waiting several months, for instance, for a new lead-frame type to be developed, and it's also cheaper. Although the initial cost of the software is not insignificant, it soon pays itself back when you consider the number of actual physical prototypes that you no longer have to build. So internally, that's how we tend to use modelling and it's certainly an invaluable resource.

### Use of thermal modelling and simulation



- *Externally*, thermal modelling capability made available to customers
- Detailed models of most power semiconductors freely downloadable for Flotherm users
- NXP able to answer specific questions for customers without access to thermal modelling software
  - by using simulation, customers with a thermal problem can be given at least a steer in the right direction, usually very quickly



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CH: Externally, the thermal modelling capability is something that we make available to our customers. We have available detailed models of the majority of our power semiconductor devices and these are freely downloadable for anybody who is using the simulation package that we use, which is Flotherm. We make the models available to whoever would like to use them. Also we are able to answer specific questions for customers who maybe don't have access to thermal modelling software themselves but are trying to solve a particular thermal problem that they're having, we can give them at least a steer in the right direction, usually very quickly, by the use of simulation. So in summary, as I say, there are two uses, internal and external.

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MT: That's fine. How are projects like this initiated?

### How projects are initiated



- Internal projects are initiated as the result of a plan to release a new product or a new range of products
- External projects are normally a response to a specific customer request for help received by email or during a site visit



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CH: Again, it comes back to whether it's a internal use or an external use of the software. If we're talking about an internal project, then this will come about as the result of a plan to release a new product or a new range of products, so it will be internally initiated. Externally, normally we would be working in response to a specific request from a customer. Sometimes this can be just a request that comes in by email, or maybe it could be somebody that we've actually seen in person at their particular site who will then need some help. So it can be initiated internally within NXP or alternatively it can be initiated by a customer or potential customer who's asking for help.

MT: Thanks. What's involved in a project? What is actually done, and who does what?

### What is involved in a project



- A simulation project generally involves
  - gathering all the relevant data
    - you can never have too much information!
  - for example, for simulating a board assembly
    - physical makeup/size of board; copper layers/thickness
    - devices intended to be uses
- The results are only as good as the input data
  - incomplete or inaccurate data = inaccurate results
- Getting all relevant information at start is extremely important
  - can take longer to do than setting up/running the simulation



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CH: A simulation project generally involves, well, in the first instance gathering all the relevant data, so if we're building a simulation, we need to know as much information as possible, in fact you can never really have too much information, and that can be things like -- let's say for instance we're simulating a customer's PCB with some devices mounted on it, we would need to know things like the physical makeup of the PCB, the size, the copper layers, how thick the copper is, the shapes of the layers, and so forth, and also what devices they're intending to use in that application. As with any simulation software of any kind, the results that you get out of it are only as good as the data that you put into it and if the data is incomplete or inaccurate, then the results that come out of the other side will, obviously, not be very accurate either, so getting all the relevant information to begin with is extremely important and in my experience, that can actually be the most time-consuming element of the project, it can take longer to do that than actually to set up and run the simulation.

### What is involved in a project



- After all the relevant information to hand the process is
  - building the three-dimensional model in software
    - very much like a CAD package
    - complex models built up from simple shapes
    - thermal and physical properties attached
  - gridding and running the simulation
- After building the simulation, probably only a couple of hours to get first-pass answers
  - used to take many hours, even days
  - now faster with the sort of computing power available cheaply



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CH: Once you have all the relevant information to hand, it's then simply a matter of building the three-dimensional model in software. The software package that we use has a front end which is very much like a CAD package, so you build up complex models from relatively simple cuboids, primitive shapes, to which can be attached various properties, thermal properties or the physical properties. Once that's done it's then simply a matter of gridding and running the simulation, and typically, once the simulation is built, to actually get some answers out of it, now, I would say is probably only a matter of a couple of hours. Perhaps once upon a time to run these sort of simulations might have taken many hours or perhaps even days, but with the sort of computing power that's available now, cheaply, we can usually get first-pass answers out very quickly, within a matter of hours. Those are the steps that are involved with creating and running a simulation.

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MT: You've implied that you need to check that the results of simulation are accurate. How do you set about verifying your predictions?

### Verifying your predictions



- Verification generally approached *before* speculative simulation
  - verify individual component models
  - calibrated against real empirical data
- This involves
  - building real test cases
  - measuring the performance of the devices in the lab
  - trying to reproduce those test cases in the software
  - tweaking and calibrating the models in the software until the results match up with a reasonable degree of accuracy



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CH: The way that we approach this generally is, before we start to do speculative simulation work, in other words, simulating scenarios which haven't actually been built in reality, what we would do prior to that is verify that the individual component models that we have actually when they're running a simulation reflect reality, in other words that they're calibrated against real empirical data. This involves typically building real test cases and measuring the performance of the devices in the lab, and then trying to reproduce those test cases in the software and tweaking and calibrating the models in the software until the results match up with a reasonable degree of accuracy.

### Verifying your predictions



- Also a very good way of learning in any simulation
  - which parts are important
  - which parts aren't important
  - sometimes this can be a surprise . . .
- Thermal simulation results sometimes non-intuitive
  - what you expect to have the most influence may be wrong!
- To verify the results, make sure that the models are properly calibrated before running the simulations



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CH: This is also a very good way of learning in any simulation which parts are important and which parts aren't important, and sometimes this can be a surprise. It seems to me that the thermal world, and simulation in particular, the results that you get sometimes are non-intuitive, so you might look at a particular scenario and think that you know which bits are going to be the most important or have the most influence on the operating temperatures in that scenario but, when you actually come to analyse what's going on, it can be that your expectations are wrong, so there's always an element of learning, as well. But getting back to your original question, which is how do we verify the results, it's by making sure that the models, prior to running the simulations, are properly calibrated.

MT: You say "properly calibrated". Do you actually make measurements on the real product?

### "Properly calibrated"?



- Measurements made on the real product
- Capability to measure device temperature very accurately
  - most interested in silicon temperature in a given application
  - different techniques, some described in JEDEC standards
  - custom test equipment able to carry out these tests with a high degree of accuracy



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CH: Yes, absolutely. We have the capability here to measure device temperature very accurately, that's one of the most important thermal phenomena for us, we're most interested in the temperature that the silicon actually runs at, in a given application. We have various techniques for doing this, some of these techniques are described in the relevant JEDEC standards, and we have custom test equipment here in the labs at NXP which enable us to carry out these tests with a high degree of accuracy.

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MT: It's clear that modelling is a very useful tool? So why isn't it used everywhere? What are the barriers to its adoption?

### Barriers to the adoption of modelling



- Several barriers to adoption of modelling
- Software not cheap
  - have to balance purchase price against prototyping savings
  - on cost analysis, not as expensive as it first appears
- Users don't realise the nature or extent of their thermal problems
  - no realisation that thermal simulation is needed
- Inertia?



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CH: I think there may be several. Possibly potential users are initially put off by the price of the software, and it's fair to say that the software is not cheap. However, you have to balance the purchase price against the savings that can be made through eliminating one or more prototyping cycles when developing a new product. So when you do a proper cost analysis of how much it would cost to employ modelling, it's not as expensive as it might first appear. Possibly a second reason is perhaps that users don't realise the nature or the extent of the thermal problems that they're facing and therefore there is not the realisation that something like thermal simulation is actually needed in the first place. Other than that, I don't know, perhaps inertia?

MT: My impression is that there is also a significant learning curve. Is this true?

### The learning curve



- Significant learning curve
  - particularly for electronics engineers rather than material scientists
  - the thermal world is different – you have to learn about and appreciate new physical phenomena
- Usability of software has improved enormously in recent years
  - no command line data entry!
  - user-friendly CAD-style front end



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CH: There is a significant learning curve, yes, I think particularly for somebody who is primarily an electronics engineer rather than, say, a material scientist or something like that, somebody who's used to dealing with volts and amps and ohms. The thermal world is different, with different phenomena, so not only is the aspect of having to learn how to use an unfamiliar software package, which is always a challenge, there is also the fact that you are having to learn about and appreciate new physical phenomena which you may perhaps not have been so aware of before, or perhaps only aware of on the fringes. So there are perhaps two reasons why the learning curve is steep, although it should be said that the usability of the software has improved enormously in the past few years, certainly the package that we use here has made significant leaps and bounds in its usability, so it's not as if you're having to enter all this data on a command line or something like that, there is quite a user-friendly CAD style, front end, so that's perhaps not as bad as it could be.

MT: How important is it to have a thermal guru, or at least a thermal champion within the company?

### Importance of a thermal champion



- How important is it to have a thermal guru, or at least a thermal champion within the company?
- If manufacturing products where thermal concerns are important
  - need understanding of thermal aspects/questions in general
  - could reside with one person or a group of people
    - probably down to the individual organisation to decide
- But thermal knowledge should reside somewhere and should be freely available to anybody who needs to access it



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CH: I think that if you're manufacturing products where the thermal concerns are important, then it's necessary to have an understanding of the thermal aspects and thermal questions in general. Whether that resides with one person or a group of people is probably down to the individual organisation to decide but certainly that knowledge should reside somewhere and should be freely available to anybody who needs to access it.

## Thermal modelling at NXP Semiconductors, Stockport

MT: What does modelling do that other approaches can't? Are there any alternatives to building a full thermal model?

### Simpler approaches?



- Are there any alternatives to building a full thermal model?
- More simplistic system-level approaches may be sufficient to give
  - an initial feel of thermal behaviour
  - an idea of how a system will respond
- Proper modelling tool needed if you
  - need to start looking in detail at the thermal behaviour
  - have a system which is marginal
  - are pushing the limits of what can be done
- Insufficient degree of accuracy with other methods



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CH: There are more simplistic system-level approaches that can be taken, and in the first instance these sort of approaches may even be sufficient to get an initial feel for how something is going to behave thermally. There are various papers written on the subject of 2R models, DELPHI models, flow networks, that sort of thing, and they can give an idea of how a system will respond, but I think if you really need to start looking in detail at the thermal behaviour of a system, or you have a system which is marginal -- in other words it's pushing the limits of what can be done -- then really you need to be employing a proper modelling tool, because the degree of accuracy that you may get with other methods simply might not be good enough for what you're trying to do.

### Conclusion



- Thanks to Chris for his very helpful insights
- Elsewhere in this material, Chris will explain step-by-step how he carries out a simulation . . .



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MT: Well, thank you Chris for your very helpful insights. You'll hear from Chris elsewhere in this material as he explains step-by-step how he carries out a simulation.