How thermal design is tackled

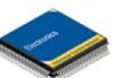
Slide	Notes
The need for thermal management ▪ How big is the problem? ▪ What heat does to the circuit ▪ What happens if we ignore the challenge? ▪ How thermal design is tackled Electronics KTN – Knowledge For Growth	By now you have seen the scale of the problem, and hopefully been encouraged not to ignore the challenge! So how do we do something about it? This is what this short section is all about …

Managing thermal design
▪ Place of thermal analysis in electronic design
  ▪ managing thermal risk
  ▪ thermal design strategies
Electronics KTN – Knowledge For Growth
	… but it is a very light touch, because we will be returning to the topic in the very last presentation.
	Thermal analysis in electronic design is all about managing thermal risk, and having strategies to deal with thermal challenges. We are putting in this effort because we want our product to have a better chance of life, and to do this we need to quantify the thermal aspects of our design.

Managing thermal design
▪ Place of thermal analysis in electronic design
  ▪ managing thermal risk
  ▪ thermal design strategies
▪ Implementing thermal analysis in product development
  ▪ a thermal design methodology
  ▪ concept development phase
  ▪ detailed design phase
  ▪ hardware test phase
  ▪ risk management
Electronics KTN – Knowledge For Growth
	Typically the process of implementing thermal analysis in product development is going to be a management-driven process that starts right at the very earliest stages of concept development. In fact, it needs to start even before that, with agreement as to how thermal design in general should be tackled!
	Having considered thermal challenges from the beginning of concept development, this needs to be followed through the detailed design phase, taking care to keep thermal design synchronised with electronic design. And finally, thermal analysis needs to be tested against reality when the product is actually built. Overall, we can't remove every element of risk, but we can ensure that the product is designed for correct function both during normal life and during life events that we might reasonably anticipate.

©2009 EKTN

How thermal design is tackled



How thermal design is tackled

- New design concept
  - package changes
  - material improvements
- Start early during the design
  - assess the extent of the problem
  - model thermally as well as build electrical prototype

Electronics KTN – Knowledge For Growth

As soon as we get our first glimpse of the latest design, we should be evaluating it thermally and assessing the options for changes to the way in which the product is made and the materials used.

The first task is to assess the extent of the problem – how big is it? – and we are going to model the product rather than build a prototype, because it is considerably cheaper to model something on a computer than to cut metal, which used to be the only way of doing it.

How thermal design is tackled

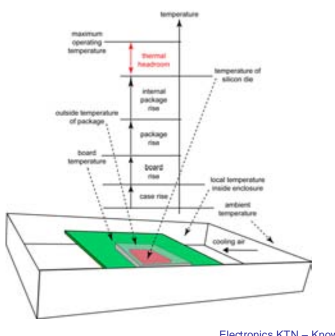
- New design concept
  - package changes
  - material improvements
- Start early during the design
  - assess the extent of the problem
  - model thermally as well as build electrical prototype
- Role of intuition
  - dangers of intuition
  - levels of modelling

Electronics KTN – Knowledge For Growth

We will be using the intuition borne of experience and knowledge of good practice to inform our evaluation of the results of modelling, so that practice and theory stack up, because things aren’t always what we expect.

You can gain a lot from talking to people who have been there before. They tend to be a bit on the conservative side, and might even say “Been there, done that, shouldn’t do that if I were you”! But you should at least ask yourself: “Well, why are they saying that?” There might just be some helpful content in the experience of others!

Aim to increase “thermal head-room”



Electronics KTN – Knowledge For Growth

Many designers will use prior experience to suggest best practice, or to indicate, by means of “rules of thumb”, shortcuts to conservative design such as the maximum dissipation for a particular enclosure type. However, there are dangers in this approach, particularly when working towards the upper limits of dissipation for a design. For this we may need to carry out at least some calculations, and probably perform some finite element modelling of the product, in order to be certain that there is enough “thermal headroom”, a concept which is illustrated here.

How thermal design is tackled

- Holistic
  - reliability
  - components
  - materials
  - testing
- Focuses sequentially on
  - packaging
  - interconnect method
  - enclosure

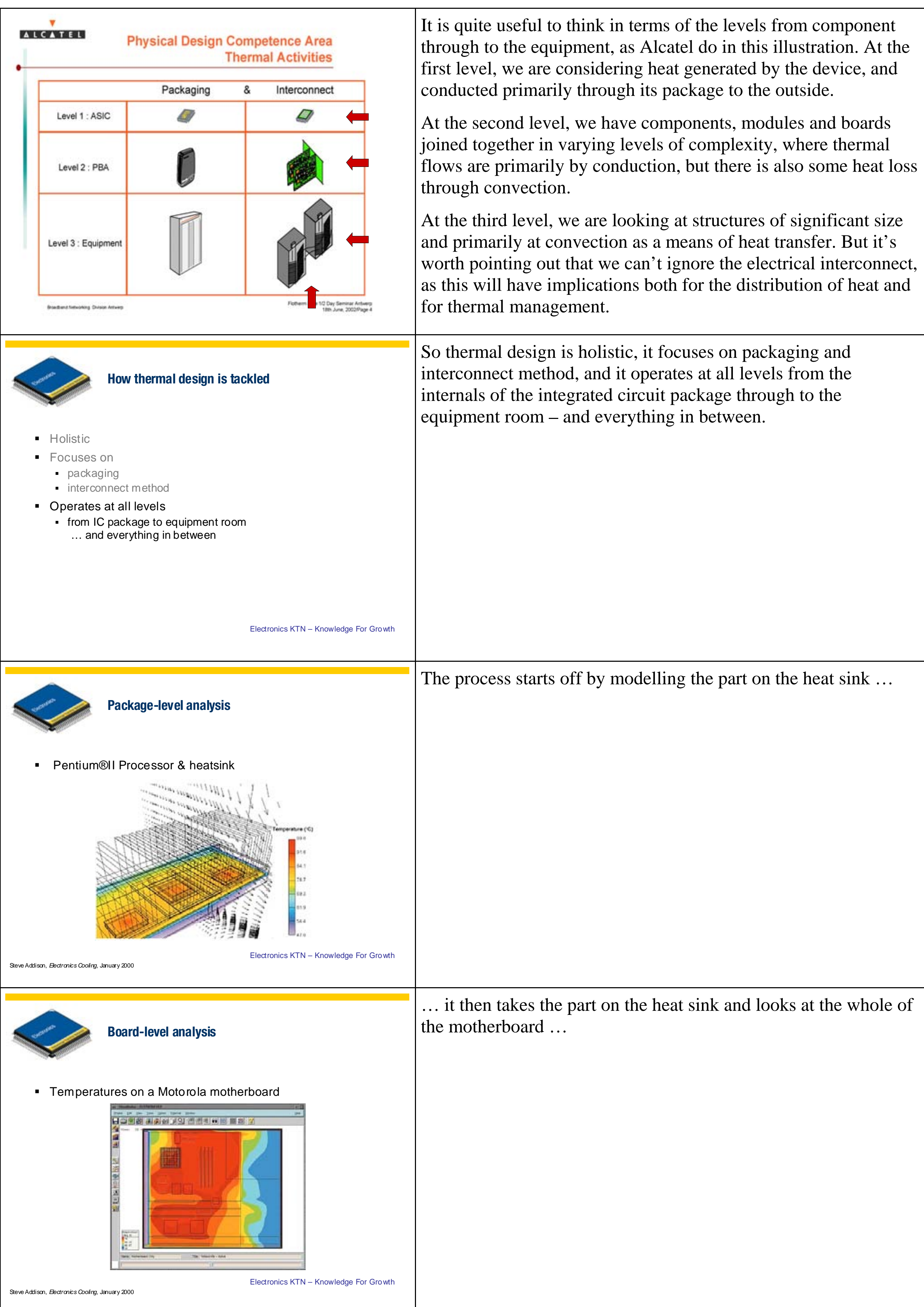
Electronics KTN – Knowledge For Growth

Thermal design has to be holistic. We need to look at the components, at the way that they interconnect, at the materials that we’re using. In fact, at every aspect of the design, which in some cases might include the room in which the product is sited. In other cases we may need to look in very great detail at the silicon device that is generating the heat.

But, however holistic, thermal design tends to focus first on the packaging and the interconnect, before looking at the enclosure.

©2009 EKTN

How thermal design is tackled



It is quite useful to think in terms of the levels from component through to the equipment, as Alcatel do in this illustration. At the first level, we are considering heat generated by the device, and conducted primarily through its package to the outside.

At the second level, we have components, modules and boards joined together in varying levels of complexity, where thermal flows are primarily by conduction, but there is also some heat loss through convection.

At the third level, we are looking at structures of significant size and primarily at convection as a means of heat transfer. But it's worth pointing out that we can't ignore the electrical interconnect, as this will have implications both for the distribution of heat and for thermal management.

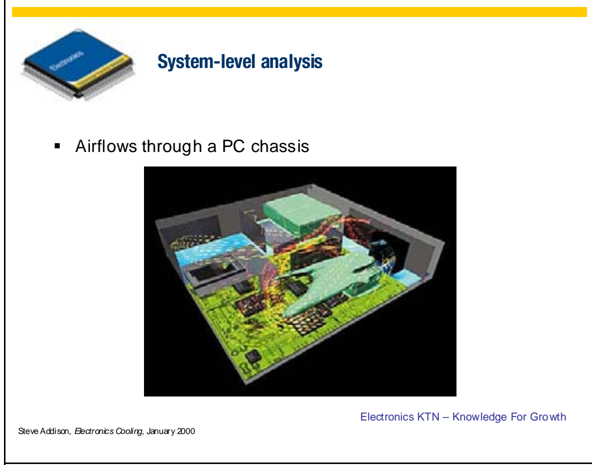
So thermal design is holistic, it focuses on packaging and interconnect method, and it operates at all levels from the internals of the integrated circuit package through to the equipment room – and everything in between.

The process starts off by modelling the part on the heat sink …

… it then takes the part on the heat sink and looks at the whole of the motherboard …

©2009 EKTN

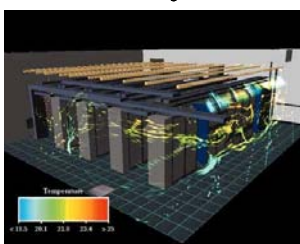
How thermal design is tackled



… it then looks at the motherboard in the context of the complete computer chassis in this case. At this stage we are looking in more detail at convection, so this view includes the air flow.

When you examine models of this sort, it becomes clear where the hot spots are likely to be. Intuition will perhaps have told you some of that, but intuition on its own is by no means a substitute for doing things properly.

▪ A telecommunications switching room

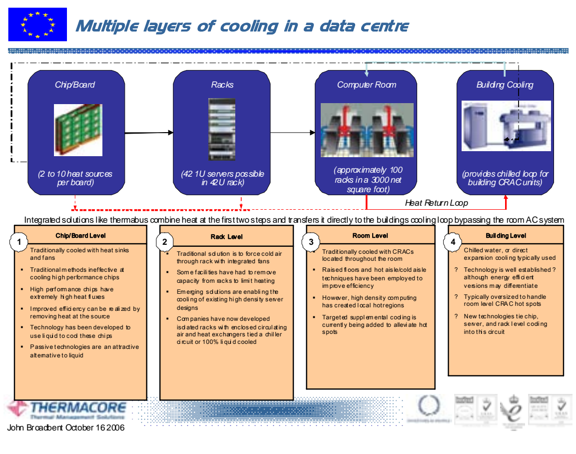


Electronics KTN – Knowledge For Growth

Steve Addison, Electronics Cooling, January 2000

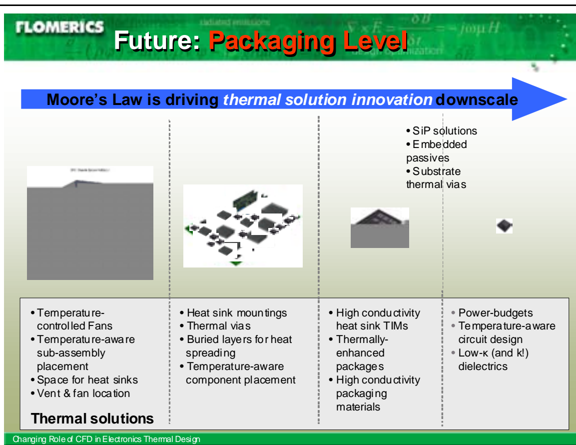
Finally, we view the whole environment, in this case a telecoms switching room. Here our model can be useful in examining the effect of the different strategies for supplying the room with air. For example, for reasons of dust control, you might want to have the input air coming downwards.

The picture is also a reminder that this isn't really a closed box, but what is happening outside will have an impact on our system. There are many air-conditioning systems that function well during temperate weather, but struggle during the summer months.



This slide reinforces the point that one needs to consider cooling at all levels, from the chip right through to the building. It is a reminder too that there are different solutions for different tasks.

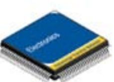
But the original point of this picture is also worth bearing in mind, that there are innovative solutions that allow direct heat transfer, in this case, direct from board level to building cooling by using heat pipe technology.



So far we've taken a bottom-up approach to the challenge, but it's equally valid to start with the larger problem and work downwards, finally focusing on chip-level problems, like graphic chips that use more energy than they should!

Such an approach is useful, at least to use in parallel, because it sets the context for the overall solution, and then looks at ways in which design, materials and components can work together for optimal effect.

©2009 EKTN

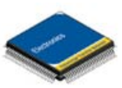


How thermal design is tackled

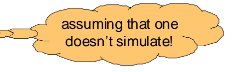
- Holistic
- Focuses on
  - packaging
  - interconnect method
- Operates at all levels
  - from IC package to equipment room
    ... and everything in between
- Manages
  - excess heat
  - risk

Electronics KTN – Knowledge For Growth

So our holistic thermal design has considered solutions at all levels, and used a simulation approach to manage excess heat and the associated risk.



Hidden hot spots!

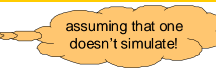


- Unknown until prototypes tested
- Engineers forced to over-design
  - "safe" guidelines
  - more fans, heat sinks, vents
  - experience is needed

Electronics KTN – Knowledge For Growth

If you aren't going to simulate, then the situation is going to be unknown until the prototypes have been tested, so typically you are going to have to play safe, adopt conservative guidelines, use more fans, heat sinks and vents, and you will need to draw on experience, either your own or from a colleague who has been there before.

Hidden hot spots!



- Unknown until prototypes tested
- Engineers forced to over-design
  - "safe" guidelines
  - more fans, heat sinks, vents
  - experience is needed
- Results
  - lower *average* operating temperatures
  - no insurance against lurking hot spots
  - unnecessary cost and weight
  - greater noise and reduced reliability (fans)

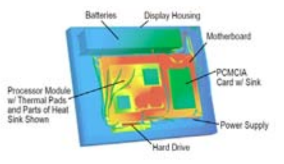
Electronics KTN – Knowledge For Growth

The probable result of doing things without simulation is that you will be operating circuits rather cooler than you need to. However, that's still no insurance that every part of the circuit is going to be cool enough. On average, the whole enclosure might be nice and cool, but that's no good if you have a hot spot next to a sensitive component.

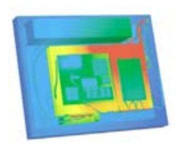
If you are being cautious, you might say: "I'll put an extra fan in here anyway". Well, that's not a good idea, because two fans are not necessarily better than one as we'll see in Section 4. Also, if you put an extra fan in, you double the cost, you use more energy, you make the whole system heavier, and you make it noisier.

Reducing the thermal challenge

- Original simulation showed four components above max. temperature



- Cured using custom heat sink — and without fans!



Electronics KTN – Knowledge For Growth

This is an interesting real example of a simulation where the original design had a number of components that were hotter than they were allowed to be. In this case, whilst there were a number of options, the designer chose not to use fans but instead to develop a custom heat sink.

This is a very good example of a solution that could be developed by simulation much more easily and at much lower cost than by developing and testing prototypes. In fact, without using simulation, it is unlikely that a passive solution would have been the outcome.

©2009 EKTN

How thermal design is tackled

Benefits of thermal modelling

- Evaluate proposed design changes
  - without cutting metal
  - fast enough to encourage "what if?"
- Can be used to see the effect of likely failure modes

Electronics KTN – Knowledge For Growth

Thermal simulation has the benefit that one can evaluate proposed design changes without cutting metal, and the process is fast enough to encourage you to play around with the simulation, and say: Well, what happens if I do this? What happens if I move things around? What effect does this have on the thermal distribution and performance? And you can also see what happens if a link in the heat management system fails.

ALCATEL

Thermal Simulation ABCE Board

- Simulation results fan failure
  - 1 half of the chimney inlet has fixed velocity = 0.5 m/s
  - Junction temperature rise above inlet
  - Inlet temperature = 63 C

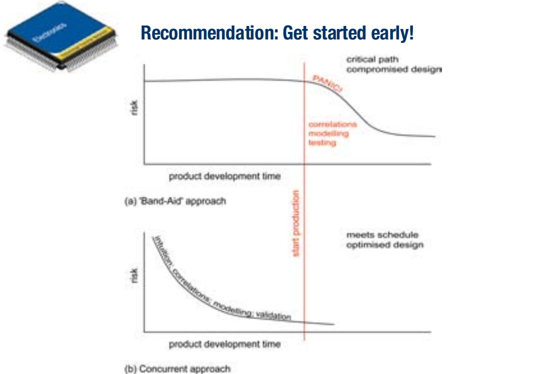
	Metal core Ended vias		Multi layer Ended vias	
Component	Fans ON	FF	Fans ON	FF
ISE OUT	35.2 C	39.9 C	39.2 C	47.6 C
ISE IN	34.5	39.7	38.3	46.6
TMC OUT	22.7	25.7	24.5	29.0
TMC IN	22.1	25.4	23.7	28.4

Broadband Networking Division Antwerp

Flotherm Free 1/2 Day Seminar Antwerp 18th June, 2002/Page 34

Such system failure was indeed what Alcatel modelled here, showing the two conditions of fans on and fans failed. In this case, you will notice that they also favoured a conduction-led solution, as a way of keeping the temperature down in the event of fan failure, but in this case they ended up substituting the multi-layer board with a metal-cored laminate.

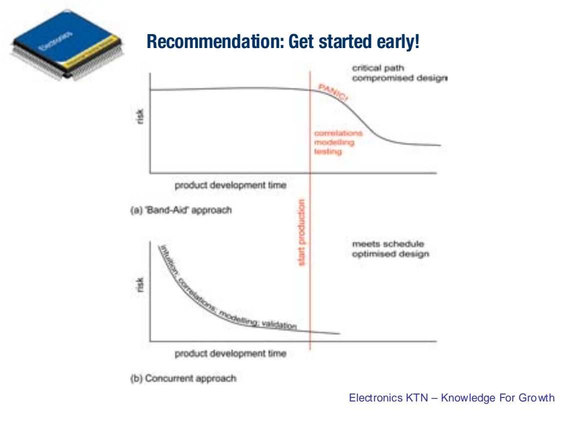
Recommendation: Get started early!



Electronics KTN – Knowledge For Growth

In order to get the benefits of modelling, the thermal designer should be an integral part of the design team right from the start, rather than wait until the later part of the development cycle. In other words, looking at this comparison of different ways of risk management for thermal design, the designer needs to use a concurrent approach rather than the Band-Aid approach.

Recommendation: Get started early!



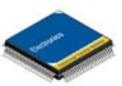
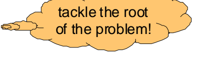
Electronics KTN – Knowledge For Growth

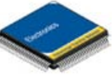
Another point that these curves reinforce is that informed intuition or simple hand calculation employed early in the design process is sometimes worth more than detailed CFD analysis at the end! We would certainly recommend anyone to get started early with thermal management, using a combination of approaches, including experience, simple calculation and modelling, and to finish the validation before production starts.

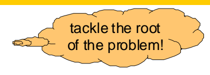
©2009 EKTN

How thermal design is tackled

Slide	Notes
   Thanks to Life in LDN's photostream at http://www.flickr.com/photos/mycreativecorner/ Electronics KTN – Knowledge For Growth	As well as making an early start to tackling a thermal management challenge, a second recommendation is to think out of the box, and as far as possible tackle the root of the problem. As we saw, the X-box problem came from trying to package a product that was consuming too much power, and considerable reduction in power was possible without extreme thermal management.

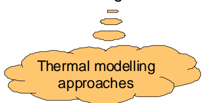
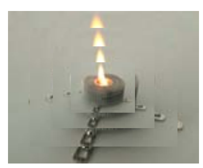
 **Thinking out of the box** 
▪ CherryPal cutting the power
  ▪ $249, paperback-sized desktop
  ▪ onboard flash memory
  ▪ boots in 20 seconds
  ▪ only 2W — 97% less than typical desktop
▪ Integration a key factor
  ▪ Freescale MPC5121e processor includes network connectivity, multimedia processing and graphics subsystem
 	
http://www.edn.com/article/CA6580041.html
Electronics KTN – Knowledge For Growth
	What CherryPal did was to create the equivalent of a desktop PC, but considerably smaller and consuming only 2W, which is 97% less than a typical desktop. Integration was a key factor in making this possible, …

 **Thinking out of the box**
▪ Small, cheap, robust, reliable, green … *but*
▪ Downsides
  ▪ external peripherals
  ▪ online processing and storage resources
  ▪ relatively slow processor
  ▪ "invisible OS" – browser manages all functions and applications
  ▪ only pre-installed software
Electronics KTN – Knowledge For Growth
	… and the product was small, cheap, robust, reliable and green. Of course there are some downsides, such as not being able to install your own software. But, for many users, 2W might be sufficiently attractive to make the compromises acceptable.

Thinking out of the box  Thanks to Life in LDN's photostream at http://www.flickr.com/photos/mycreativecorner/ Electronics KTN – Knowledge For Growth	If you get started early enough, you have the opportunity of thinking outside the box; if you wait until you have a thermal problem, then you have much more of a challenge!

©2009 EKTN

How thermal design is tackled

 The need for thermal management - How big is the problem? - What heat does to the circuit - What happens if we ignore the challenge? - How thermal design is tackled   Electronics KTN – Knowledge For Growth	We said at our introduction that thermal management is often not taken seriously, or even considered at all, and we have seen the potential magnitude of thermal problems. Hopefully by now you have decided not to ignore the challenge, but to tackle thermal design by appropriate modelling approaches, and these are the subject of our subsequent sections. If we tackle thermal design in this structured fashion, we will find that we shrink the size of the thermal problem. It doesn't go away, but it becomes more manageable, and gives us a better product at an affordable cost.

©2009 EKTN