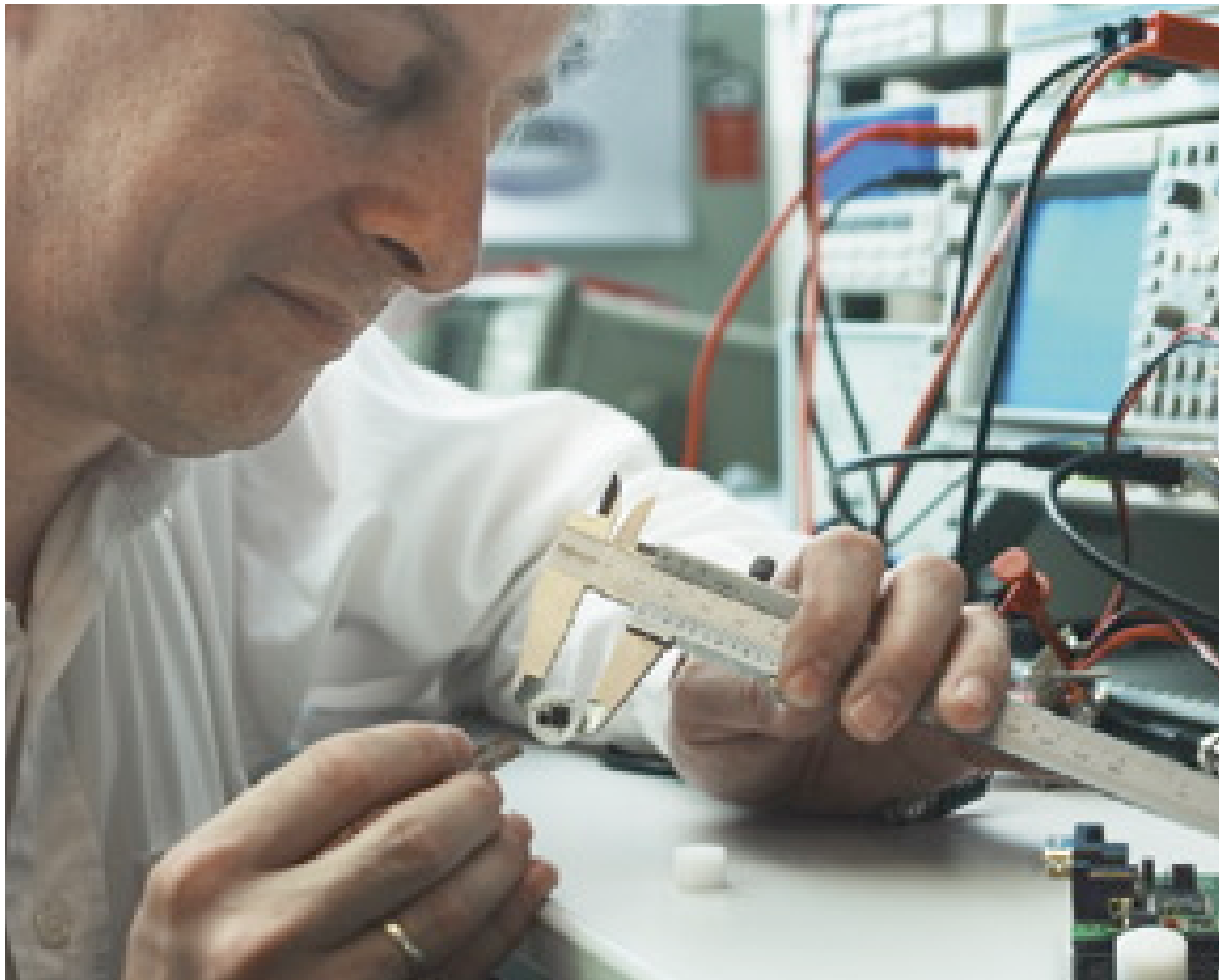


# The key to Ambient Intelligence lies in the packaging



Small System-in-Package modules, each containing specific functionality, allow a building block approach to prototyping Small Autonomous Network Devices (see sidebar on page 20).

Silicon chips have been highly successful in providing the 'brains' for intelligent digital systems. However, Ambient Intelligence, an environment that is aware of our presence and responsive to our needs, needs more than brains. It needs the equivalent of eyes, ears, arms and legs so that it can interact with real people in the real world. As intelligent interactive systems become small enough to hide away in everyday objects around us, their eyes, ears, arms and legs are increasingly becoming part of the physical package that surrounds their silicon brain – heralding a new generation of System-in-Package (SiP) solutions.

By Peter Harold

Photography: Korff & van Mierlo, Philips Design, Philips Semiconductors, Philips Applied Technologies

## From 'More Moore' to 'More than Moore'

Ever since 1965, when Gordon Moore, co-founder of Intel Corporation, predicted that the number of transistors that could be put on a given area of silicon would double every year (subsequently revised to every two years), the semiconductor industry has delivered on his promise. Moore's Law, as it came to be known, gives us the prospect of putting phenomenal computing power into everyday consumer products at extremely low cost. And there is considerably 'More Moore' to come.

**“Device packages will contain optical, mechanical and biological functions as well as silicon chips.”**

Thijs Vieggers, Philips Applied Technologies

The problem, however, is that Ambient Intelligence systems of the sort needed to improve the lives of ordinary people in areas such as healthcare and lifestyle need more than computing power. They need sensors to detect what is going on around them, and actuators to deliver an appropriate response. Ambient Intelligence will therefore require 'More than Moore' in addition to 'More Moore'.

To make the technology so unobtrusive that it disappears into the fabric of our surroundings, these sensors and actuators will need to become part of ultra-small System-in-Package (SiP) solutions, very different from those of today in which the package still largely performs traditional roles of electrical contact and sealing.

“In future you will see far more functionality built into the package, giving it more added value in terms of cost and functionality than the silicon system inside it,” says Thijs Vieggers, Chief Technology Officer at Philips Applied Technologies, whose organization helps to ensure that new SiP technologies are manufacturable as well as technologically feasible.

To illustrate his point he cites a few examples. The first is a flexible smart-card with an integrated LCD display that was built to demonstrate Philips Research's plastic substrate LCD technology. Creating the card required the integration of display drivers, a microprocessor, embedded memory and an ultra-thin battery into the plastic laminate.

A second example is a hand-held micro-beamer that projects video images onto an ordinary sheet of paper. It comprises a highly miniaturized light engine with red, green and blue lasers, plus an optical system to modulate, combine and steer their beams, all integrated into a single package with electrical and optical ports.

“The important thing is that you either develop these highly functional SiP solutions using established manufacturing methods, or you develop generic solutions that can be applied to other products,” says Thijs Vieggers. “It is the only way to get the cost down when you move into volume production.”

Philips solves the problem in a number of ways. Engineers with practical manufacturing experience from Philips Applied [➔](#)

## Intelligent Rings – a modular approach to SAND development

Just 14 mm in diameter and 1.5 mm thick, the Intelligent Rings developed by Martin Ouwerkerk's group at Philips Research allow a building block approach to prototyping Small Autonomous Network Devices (SANDs).

Each ring contains specific functionality, such as a sensor, a DSP processor or a low-power wireless link, and the rings are simply clicked together on top of each other to create the required system. The periphery of each ring carries vertical connectors to transfer signals and power up and down the stack, and a single 14-mm diameter button cell at one end supplies the power. The addition of a slide-on sleeve and end-caps provides a hermetic seal to the finished system.

Supplied in the form of a development kit, Philips Research's Intelligent Rings include a range of sensors, DSPs and wireless links, together with comprehensive software development support. Interesting applications for SANDs devices include the sensors needed in body-area networks for in-home patient monitoring. Containing several inter-communicating sensors, these body-area networks will monitor vital functions such as heart rate, blood pressure and blood oxygen levels, make intelligent decisions about the patient's state of health and pass on relevant data to local medical or emergency services.

Technologies work alongside scientists at Philips Research to provide input on the manufacturability of new technology solutions. They also act as bridges between different research groups to promote re-use. For example, moldable ceramic materials developed to cope with 200 °C junction temperatures in solid-state lighting products are also utilized to deal with the hot spots in other applications such as power ICs and medical ultrasound heads. And techniques developed to mount the lens on solid-state image sensors are used to assemble the optics in devices such as the micro-beamer.

The real challenge in SiP technology, however, remains one of reliability.

"The semiconductor industry has spent thirty years and billions of dollars working out how to produce reliable transistors on silicon wafers", says Thijs Vieggers. "We can't spend another thirty years and a similar amount of money doing the same for every other technology that will end up in tomorrow's SiPs."

Philips reduces the problem to its fundamentals. Virtually all functional devices rely on interfaces between materials for their electrical and/or mechanical properties, which means that a thorough understanding of the nature of these interfaces and the way they behave under thermal, electrical and mechanical stress is the key to predicting device reliability. Working with universities and research institutes, Philips investigates the characteristics of these interfaces at molecular and atomic levels, allowing it to develop design rules that can be applied across a wide range of applications.

### From Micro to Nano

If the first step towards producing the SiP solutions needed for Ambient Intelligence is to increase their functionality, the next step is to scale down their physical size and scale up their manufacturability.



Prototype of a hand-held micro-beamer enabled by a highly miniaturized package containing all the functional elements.

**"SiP packages today are an evolution of the printed circuit board approach we had in the past. That has to change ..."**

Ronald Wolf, Philips Research

"The SiP packages we sell today, mostly for RF applications, are an evolution of the printed circuit board approach of the past," says Ronald Wolf, Department Head of the System-in-Package Devices group at Philips Research. "We are still mounting active dies and passive components onto a substrate, albeit at the micro-scale, and putting it in a package to add stability and reliability. If we want to achieve higher packaging densities coupled with greater functionality, that has to change."

Using current interconnect methods, the practical limit to bond-pad pitch (the distance between adjacent electrical contacts) is around 50 µm. To achieve higher connection densities it will be necessary to create technology platforms that allow the largely 2-dimensional designs of today to be replaced by truly 3-dimensional circuit assemblies.

It will be possible to stack multiple paper-thin dies on top of each other, incorporating cavities to accommodate MEMS structures or fluidic devices. To achieve this, Philips Research is developing new construction technologies such as through-silicon

'vias' (vertical conductors through silicon wafers) and substrate transfer processes. It is also addressing 3-D design capability in areas other than pure electronic design – for example, addressing thermodynamic and mechanical issues.

These new technologies will lie at the heart of an innovative new System-in-Package concept being developed by Philips Research in its Small Autonomous Network Devices (SANDs) project. SANDs will use multiple die stacks to integrate sensors, signal processing, data storage, power management, low bit-rate wireless communications and a power source into complete systems that could one day be little bigger than a grain of sand.

"But we also have the potential to go one better than multi-chip packages or multi-die stacks," says Ronald Wolf. "At Philips Research we are already investigating ways of integrating multiple semiconductor technologies, including a whole range of III-V materials, directly onto silicon in order to extend our System-on-Chip capabilities."

According to Ronald Wolf, however, the day that SiP solutions revert back to being SoCs could still be five to ten years away. **DW**

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## RF SiP – a commercial success

There is considerable debate at the moment about the relative benefits of System-on-Chip (SoC) and System-in-Package (SiP). It usually centers on RF solutions for consumer-product applications such as mobile telephony or wireless networking. Protagonists of SoC argue that the improved high-frequency performance of CMOS transistors and the increased digitalization of RF transceivers will make SoCs the cheapest solution. Protagonists of SiP argue that the freedom to

employ optimum RF process technologies and to quickly migrate digital circuitry to next-generation baseline CMOS processes promises the best price/performance ratios.

"There are still components in an RF transceiver, such as the antenna filter and duplexer, that you cannot integrate into a CMOS process," says Fred van Roosmalen, General Manager for Technology Partnerships at Philips Semiconductors, "which means that most RF SoCs still end up in RF SiPs."

Philips firmly believes in integrating as much of the RF

system onto silicon as possible, because this leverages the cost advantages of wafer-scale production. However, it does not believe that it should necessarily be a single piece of silicon.

"Thanks to our collaboration with Philips Research we have developed a set of RF process technologies that allow us to partition active and passive components onto the lowest cost silicon," says Fred van Roosmalen. "We may end up with more than one die to mount in the SiP but each die is cost/performance optimized to give us a highly competitive total system solution."

As a result, Philips is already delivering Bluetooth and IEEE 802.11 modules that offer antenna in, data out plug-and-play simplicity.

Bluetooth SiP

