BUSINESS

Silicon down to the wire

Microchip-makers are starting to look beyond silicon, and what they see, reports Colin Macilwain, is a semiconductor industry of a very different complexion — but not for some time yet.

Jack Kilby, the Texas Instruments engineer who invented the integrated circuit in 1958 and won the Nobel Prize in Physics for it in 2000, died of cancer last month. But the silicon-chip technology his idea gave birth to will be ubiquitous for a long time yet. That's the emphatic message of the latest roadmap for the semiconductor industry, which will be released in San Francisco on 13 July.

But the authors of the 2005 International Semiconductor Technology Roadmap, which will be previewed at the Semicon West 2005 trade show, have added extensive treatments of 'emerging technologies' that could work with, or even rival, the silicon-based CMOS (complementary metal-oxide semiconductor) technology that's got the industry where it is today.

The roadmap — a venture involving about 1,000 semiconductor specialists worldwide — is revised every two years, and the latest version reflects the chip-makers' expectation that CMOS will reach absolute limits on its performance by around 2020.

"The roadmap is giving a good deal of attention to alternatives," explains Ralph Cavin, an engineer with Semiconductor Research Corporation (SRC) at Research Triangle Park in North Carolina and a member of the roadmap steering committee. "But you should not be misled — CMOS is going to be around for a long time." For the logic circuits that form the heart of computers and other electronic devices "we haven't found anything that's superior to CMOS," he says. But in memory devices, he believes, there may be viable alternatives.

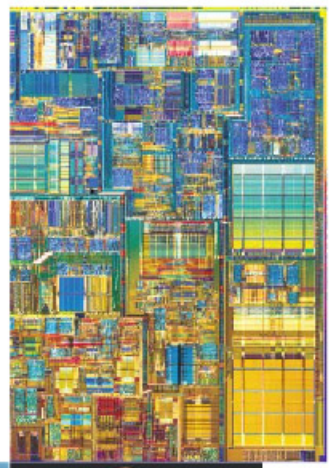
Memory chips sit at the worthy but dull end of electronics, however. And the roadmap doesn't dodge the question of which new technologies could find their way into the computer's brain — the logic circuit. But its exhaustive examination of the issues raises as many questions as it answers.

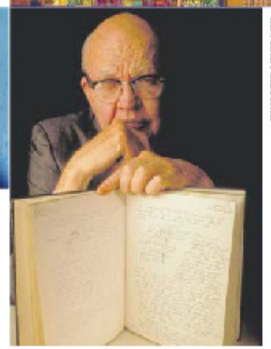
The "emerging research architecture" section of the document, which deals with technologies that could be used in logic circuits, looks in detail at several approaches, most notably quantum computing, biology-based approaches and cellular arrays.

The quantum computer is probably the alternative that the public hears most about. But Victor Zhirnov, a physicist-turned-electrical engineer at SRC and member of the roadmap's working group on emerging devices, takes a dim view of its realistic prospects.

Over the past five years, there have been vastly more research papers published on quantum computing than on the other alternatives. "Ninety per cent of these papers are theoretical," says Zhirnov. "And their assumptions are questionable — for example, that the device will be 'isolated from its environment'." They might as well, Zhirnov caustically observes, assume movement faster than light.

The last roadmap, in 2003, was equally scathing about the prospects for quantum computers. They depend on wave functions that "would easily decohere when interacting with an external environment", it said. "Although enormously capable for a few selected algorithms, such as encryption or deep database searching, quantum computing is not seen yet as being of more general interest." This time, the approach will get less play, says Jim Hutchby, another physicist-turned-engineer at SRC, who chairs the group that is writing the roadmap.





TEXAS INSTRUMENTS/INTEL

Then: the first integrated circuit (above), invented by Jack Kilby (right), and now: Intel's Pentium 4 microprocessor (top right).

The other options all have their own flaws, however. Zhirnov puts most faith in approaches inspired by biology, marvelling at the phenomenal processing power — and thrifty fuel consumption — of the human brain. "I personally believe we need to focus on how the brain works," he says, "but our understanding of its architecture is very embryonic."

He points to work suggesting that each neuron works not as a binary switch, but as a server in its own right (see C. Koch, *Nature* **385**, 207; 1997). Zhirnov hopes the roadmap will help emphasize the need for an interdisciplinary effort. "There's a lack of communication between engineers and neuroscientists", he says.

Another approach for some computer functions would be cellular arrays, which involve interactions between a large grid of nanoscale elements — electrostatically coupled quantum dots, perhaps, or coupled magnets. The roadmap authors see potential for this approach in some specialized applications such as character recognition.

The roadmap will also explore the vexed question of how alternatives to the silicon chip will tolerate defects. The stunningly high reliability of solid-state silicon circuitry is "probably the most important aspect of CMOS", says Texas Instruments' Bob Doering, co-chair of the roadmap steering group. But the reliability of alternatives is far less sure. According to the 2003 document, each working nanoscale device might need between 1,000 and 10,000 back-ups to make the whole circuit work reliably — although that point is disputed and may be toned down this year.

Then there's heat dissipation. Getting the heat out of today's CMOS microprocessors is already a huge challenge. And Cavin says that CMOS will soon operate close to the theoretical limit that could be achieved by any alternative that relies on moving electrical charge.

The roadmap is a unique global exercise, in which bitter competitors lay aside their differences to reach agreement on where the technology of their business is heading. It originated in 1994 with Sematech in Austin, Texas, a collaboration of US semiconductor manufacturers with their backs to the wall at the time. Now it is an international effort involving more than 1,000 engineers and physicists.

But the authors of the roadmap don't see it as their job to pick winners between rival approaches. Instead, Doering explains, "its main function is to raise red flags" that engineers can get working on.

The industry does, however, need to identify which technologies to support. With the 2020 deadline in mind, it is working with the US National Science Foundation (NSF) on a nanoelectronics initiative to support students and projects on the emerging approaches. Given the time it will take to get these up and running, semiconductor-makers want to know which ones to back by 2008, says Michael Roco, the NSF official behind the initiative.

But this research effort doesn't anticipate finding new technologies that will allow chips to extend the amazing run of ever-greater performance and miniaturization that CMOS has enjoyed — performance has doubled every 18 months for decades. "The focus will no longer be on miniaturization or speed," says Roco. "It will be on new functions. It will be devices that you put on your skin to monitor your health, or ways to connect between a neurological system and a machine."

To open up this brave new world, "there need to be some decisions made", says Hutchby. "What matters now is not density or clock speed," he adds. "It is new functionality that CMOS was not going to address." ■

IN BRIEF

STEM-CELL FLOAT Edinburgh-based research company Stem Cell Sciences says it will seek a listing on London's Alternative Investment Market later this month. The company wants to raise £10 million (US$18 million) by the proposed stock-market float. Stem Cell Sciences, which was founded in 1994 in Australia by biologist Peter Mountford, employs 30 people and has research interests in Japan as well as in Scotland and Australia. If the public offering succeeds, the company will join a small handful of other listed European companies with an interest in stem-cell research.

CHANGE OF PLAN Genentech, the California biotechnology company, is paying $408 million to take over a pharmaceutical factory left idle as the result of a drug suspension. Biogen Idec of Cambridge, Massachusetts, had planned to produce the multiple sclerosis drug Tysabri at its facility in Oceanside, California, but had to withdraw the drug in February because of safety concerns. The company says it is taking a $50-million loss on the sale. Genentech, which has research collaborations with Biogen Idec, says it will start making Avastin — a treatment for colon cancer — at the 430-employee plant in 2007.

BIG CARBON EXCHANGE Two of Europe's main markets for carbon emissions have announced plans to merge. The combination of Paris-based Powernext Carbon and the European Climate Exchange (ECX), which is based in Amsterdam and does most of its business in London, is expected to create the continent's largest emissions exchange. Analysts expect more consolidation between the half-a-dozen existing exchanges in Europe as trading in carbon dioxide emissions hots up.

MARKET WATCH

SOURCE: LUX RESEARCH

Stocks in companies related to nanotechnology have rebounded this spring, as investors grow a little less risk-averse.

The Lux Research Nanotechnology index, which covers a global cross-section of companies that supply nanotechnology products, build nanotech tools or rely heavily on the use of the technology, has grown by more than 9% over the past two months. And the biggest factor at work, says Peter Heberl, president of the New York-based consultancy, is investors' renewed willingness to put their money into small, technology-based companies.

But strong individual performances by some of the 25 companies in the index also played a role. Strongest of all was French company Flamel Technologies, of Lyon, a specialist in nanoparticle-based drug-delivery systems, whose stock rose from $13 to $20 on news of a management shake-up.

Another big winner was Canadian company Westaim, whose Massachusetts-based subsidiary Nucryst makes silver nanoparticles for wound dressings. Nucryst stock rose from $2.40 to more than $3 on strong sales reports.

And stock in Symyx Technologies, a specialist in nanoscale catalysts based in Santa Clara, California, went from $22 to $27 on news of deals with Exxon and Dow, who will use its products in petroleum processing and plastics production, respectively.

Hebert predicts that nanotech stocks — whose performance pipped that of the Nasdaq technology index for the two-month period — could do better yet. "The summer is looking very strong," he says, noting that nanotech companies could be exempt from adverse factors, such as weak demand for semiconductors, that could hold back the technology sector as a whole.

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