Fast Times in Silicon Circuits

In the ultrafast world of microelectronics, the blink of an eye seems to last a century. It is a world in which time is measured in picoseconds — trillionths of a second. Recently, a team of IBM researchers generated electrical pulses so short that each one lasts only half a picosecond. In that fraction of a second, light travels a distance of less than a millimeter.

The IBM technique is one of several methods now being developed for measuring the characteristics of high-speed integrated circuits. As researchers develop electronic devices that switch on and off faster and faster, the need for measurement techniques that can keep up with such devices grows.

"The problem," says IBM's Dan Grischkowsky, "is that standard electronic measurement capability is not as fast as the fastest devices." Techniques for generating and detecting extremely short electrical pulses make it possible to time brief events and to track a pulse as it travels along microscopic transmission lines laid down on a silicon chip.

To generate ultrashort electrical pulses, scientists at IBM in Yorktown Heights, N.Y., refined a technique first developed more than a decade ago. They fabricated a transmission line consisting of a pair of parallel, micron-wide aluminum strips, 2 microns apart, on a thin piece of silicon. That transmission line, in normal operation, is maintained at a certain voltage.

When a laser pulse strikes the silicon between the two aluminum strips, the light frees electrons. The presence of that electrical charge in the gap momentarily shorts the circuit, abruptly changing the voltage that moves down the line. A similar "photoconductive" switch is used to detect an electrical pulse later in its travels.

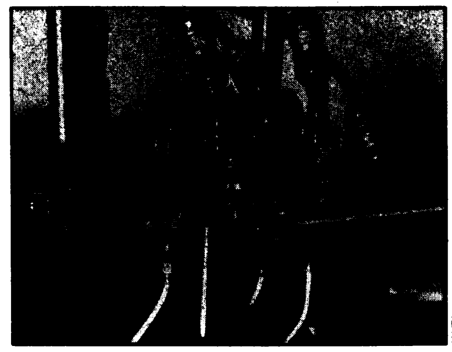
To keep the electrical pulse sharply defined so that it matches the shortness of the triggering laser pulse, IBM scientists bombard the silicon surface with atoms to create a large number of defects capable of quickly swallowing up the loose charge carriers. Thus, the short circuit is brief, and the resulting pulse starts and stops sharply.

By incorporating a set of transmission lines within experimental, high-speed integrated circuits, researchers can use ultrashort electrical pulses to test how well the devices work. The pulses can also be used for scientific studies, says Grischkowsky. IBM researchers have, for instance, watched what happens to such electrical pulses as they travel down a superconducting transmission line. "We see an enormous amount of structure and ringing," says Grischkowsky. For these and similar scientific studies, he says, "you need as short a pulse as you can get."

"The applications are very interesting, particularly the work on superconducting transmission lines," says David H. Auston of AT&T Bell Laboratories in Murray Hill, N.J. Auston and his colleagues invented the photoconductive switch subsequently refined by the IBM researchers. Using a different process, Auston's group in 1984 reported generating electromagnetic pulses lasting a quarter of a picosecond. However, these pulses travel through space inside a crystal rather than along a transmission line.

For testing integrated circuits, the IBM approach has the disadvantage of requiring the installation of suitable transmission lines on a chip. But at Stanford University, a group of researchers, led by David M. Bloom, avoids this. They inspect integrated circuits built on gallium arsenide by shining 2-picosecond bursts of infrared light directly onto the chip's surface. Gallium arsenide is transparent to infrared light and changes the transmitted light's speed, depending on the voltage applied to the material. This phenomenon is known as the electro-optic effect. By monitoring light reflected from gallium-arsenide chips, researchers can track what happens to an electrical signal as it travels through the chip's circuits.

Bloom's indirect, noninvasive approach has the advantage that no contact with or modification of the chip is necessary for making measurements. However, the use of infrared rather than visible light limits the shortness of the laser pulses needed for probing a chip. And the method doesn't work with silicon, which is not an electro-optic material.



IBM

Apparatus for generating and detecting an ultrashort electrical pulse.

Researchers at Bell Labs have overcome some of these disadvantages. To get shorter pulses, they construct photoconductive switches that inject sufficiently short electrical pulses into any circuit or electronic device. To probe the interior of an integrated circuit, Janis Valdmanis of Bell Labs has shown it's possible to pick up faint traces of electrical activity by bringing a small electro-optic crystal close to a chip's surface. The advantage of his method is that it works for both silicon and gallium-arsenide chips.

Although most integrated circuits don't operate yet in the sub-picosecond range, says Auston, "it's very important to have a capability to characterize integrated circuits." The most important areas for improvement are in sensitivity and convenience, he says. At the moment, it's not the duration of the probing pulse that matters so much as the time it takes to make a measurement. — *I. Peterson*

Putting the freeze on liver tumors

For nine out of 10 people whose colon cancer has spread to the liver, there is essentially no treatment. Their tumors are either too close to major blood vessels or too numerous to allow conventional surgery. And "there is no effective treatment other than surgery," says Gary Onik, a radiologist at Allegheny General Hospital in Pittsburgh. "There is nothing we can do for them."

Now Onik and his colleagues offer a ray of hope for some of the 50,000 people diagnosed with this form of liver cancer each year in the United States. They have developed a new surgical procedure that destroys liver tumors while leaving most of the liver tissue and blood vessels intact. The technique combines two existing surgical tools: the cryoprobe, which freezes and kills tumors, and ultrasound, which images tumors and guides the cryoprobe.

Of the seven patients on whom this procedure has been tried, reports Onik, four show absolutely no evidence of having the disease today. The longest follow-up time so far is 14 months, he says. He discussed the findings in Edmonton, Alberta, at a recent meeting of the Society for Cryobiology.

Oncologist Robert J. Mayer of the Dana-Farber Cancer Institute in Boston says the procedure is "a promising technique that will probably prolong survival in patients who are unresectable [can't have their tumors cut out]. But I doubt very much that it will cure people and I don't think it will be a substitute for surgical resection."

Onik, however, points out that without

cryosurgery, the four unresectable patients now in remission would have died. Moreover, he suspects that the cryosurgery will be at least as effective as resection, which has a "cure rate" (meaning patients are living and the cancer has not spread to other parts of the body) of about 25 percent after five years. He also notes that cryosurgery involves far less blood loss, and animal studies suggest that by leaving the killed tumor in place, cryosurgery may help the body's immune system identify and destroy escaping cancer cells.

Surgeons routinely use cryoprobes — in which circulating liquid nitrogen cools tissues to −196°C — for treating skin cancers and other medical problems in easily accessible parts of the body. With ultrasound, Onik's group has extended cryosurgery's potential to solid organs in far less accessible spots.

The researchers are working to apply their technique to tumors in the kidney and brain. They've also developed, and plan to try soon, a new procedure for prostate tumors, which they believe will avoid the complications associated with conventional prostate surgery.

— S. Weisburd

Hunting Planet X: A nothing that counts

The search for "Planet X," a possible 10th planet, continues to produce nothing. But now one scientist has concluded that the latest round of nothing may in fact be a clue to the whereabouts of such a Planet X, whose gravitational influence some researchers believe is evident in measurements of the motions of Uranus and Neptune since at least the early 19th century.

The crux of the latest nondiscovery is the failure to detect, after half a decade of radio-tracking, any changes in the paths of the distant Pioneer 10 and 11 spacecraft not attributable to the pull of the known planets. The two probes, controlled from NASA's Ames Research Center at Moffett Field, Calif., are now heading out of the solar system in nearly opposite directions, following their visits to Jupiter and Saturn in the 1970s.

Neptune was discovered in 1846 after the presence of a massive object was inferred from analysis of irregularities in the orbital motion of Uranus, the next planet in toward the sun. Pluto, the ninth and most recently discovered planet, was found in 1930 when Neptune (and Uranus as well) kept showing up slightly out of its expected position. But Pluto turned out to be a case of mere serendipity, since its mass was later shown to be far too low to account for the perturbations of the other planetary orbits that had prompted the successful search for it. Thus the possibility of a still-undiscovered Planet 10, or X, has been a tantalizing one ever since.

John Anderson, "celestial mechanics" experimenter for the two Pioneers, admits that he had originally expected the object responsible for deflecting the paths of Uranus and Neptune to reveal its location by its effects on the spacecraft trajectories. "Well," says Anderson, who works at Jet Propulsion Laboratory in Pasadena, Calif., "we've ruled that out."

Yet those early observations by ground-based astronomers have strongly persuaded some researchers at the U.S. Naval Observatory (USNO) in Washington, D.C., that something is out there. The need, then, is to reconcile past evidence that says "yes" with findings from two spacecraft that say "no." The problem, says Anderson, is that the present model of the solar system is not complete enough to predict the motions of Uranus and Neptune to the level of accuracy with which they can in fact be measured.

The USNO group's conclusion is that Planet X may be in an orbit tilted 30° or more from the paths of the known planets, so that sometimes it is too far away to affect them. Anderson adds that the suggested orbit also needs to be extremely elliptical, since if it were round, and large enough for Planet X not to be measurably affecting the Pioneers in the present, it would probably not have affected Uranus or Neptune in the past, either.

In its proposed path, Planet X would take about 700 to 1,000 years to go around the sun once, and would have about five times the mass of the earth. (With more than about 10 "earth masses," its effects would probably be far more conspicuous than they are, elliptical orbit notwithstanding.) Another possibility, though Anderson finds it unlikely, is that it was a one-time visitor, not circling the sun at all.

— J. Eberhart

On the trail of ocean bubbles

Although the atmosphere is an obvious force in weather and climate, another vital participant in global dynamics is the interior of the ocean. It has a mass that is 260 times that of the atmosphere and a significantly greater capacity to store heat. Through the uppermost layer of the ocean, these two huge reservoirs exchange heat, momentum and gases — a transference that drives the ocean currents, influences short-term weather and even affects the gradual shifts in the global climate.

While scientists know that the subsurface mixing of water provides this important link between the atmosphere and deep ocean, "the processes of mixing in the upper few meters of the ocean are poorly known and largely unquantified," say S.A. Thorpe of the University in Southampton and A.J. Hall of the Institute of Oceanographic Sciences in Surrey, England.

In the July 2 NATURE, Thorpe and Hall report on a new means of monitoring this mixing process by using sonar and thermistors (electric thermometers) to track the movement of clouds of bubbles. A trial of this technique revealed a downward movement of relatively warm near-surface water — a process that transported bubbles into colder, deeper water, which is ordinarily deficient of bubbles, say the British researchers.

As they descend and encounter increased pressure, the bubbles shrink until they disappear, transferring their gas content to the ocean. In this way, the ocean provides a sink for important gases such as carbon dioxide, which can contribute to the gradual heating of the earth via the greenhouse effect. Although the mechanism behind this downward transport is unknown, Thorpe and Hall suggest three possible mechanisms and say they will test for these in future experiments.

Until now, scientists had lacked the tools to measure these slow, vertical flows, which are easily obscured by the turbulence of ocean waves, says Robert A. Weller of the Woods Hole (Mass.) Oceanographic Institute. "This is a whole new tracking tool and way of looking at the important physical [subsurface] processes," he says. Previous, unsuccessful methods for measuring the vertical water movement near the surface had involved mechanical instruments such as propellers.

Thorpe and Hall made their observations by towing a catamaran that had sonar and thermistors hung at varied depths beneath the vessel. Because the catamaran rides the waves without disturbing the subsurface waters, the researchers could monitor the top 8½ meters of the ocean during these trials in the seas east of Iceland.

Bubble clouds, created at the ocean surface by breaking waves, proved to be a good target for the sonar, which emits and receives sound waves. These waves reflect off variations in the water, including bubbles, and are recorded when they return to the sonar.

The new method, says Weller, will contribute to a better understanding of these ocean-atmosphere interactions and will help scientists who are devising models of the global climate.

— R. Monastersky