WHAT'S NEXT

Analog Over Digital? For a Better Ear Implant, Yes

By ANNE EISENBERG

COCHLEAR implants that restore some hearing to the profoundly deaf have improved steadily over the past two decades. Although they are called implants, however, these systems still lie mainly outside the ear.

Most of the apparatus — including the microphone, processor and batteries that transform speech into electrical signals passed on to electrodes embedded in the cochlea — is still typically worn behind the ear or in a shirt pocket.

Researchers hope that one day the entire apparatus, which is designed to stimulate the auditory nerves of people who have lost or damaged cells in the cochlea, can be implanted in the body. But before that goal can be reached, cochlear implants will need to use far less power. Currently the batteries must be changed as often as every four hours.

Now a researcher at the Massachusetts Institute of Technology has devised a processor for cochlear implants that he says consumes only about half a milliwatt, one-tenth of the processing power of current devices. Such an acoustic processing chip, if proven to be effective, might be suitable for next-generation cochlear devices that are fully implanted.

"There might be a small bump behind the head," said Rahul Sarpeshkar, an associate professor of electrical engineering and computer science at M.I.T., who with his group created the low-power processor. "But otherwise you won't know from appearance that the person is deaf."

To save power, the new processor reverses the traditional pattern for chips used in cochlear implants: it does most of the work with analog circuits, not digital ones.

"Most people digitize the signal immediately as it comes from the microphone," turning the information into bits that a digital signal processor then handles, Dr. Sarpeshkar said. "We did the opposite." The signal remains in analog form for most of the processing, including filtering the sound, and is digitized only at the last interface to drive the control circuitry of the electrodes.

In the digital age, it turns out, there are still jobs at which a well-designed analog circuit can excel. Yannis Tsividis, a professor of electrical engineering at Columbia University who specializes in merging precision analog and digital circuits on single chips, said that Dr. Sarpeshkar had alighted on such an opportunity.

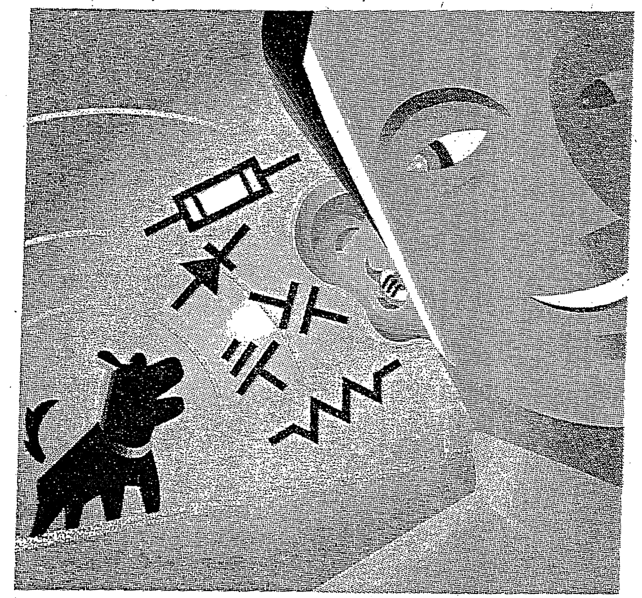
"The ear does impressive things," Dr. Tsividis said, "but not at high speed." It processes information not in the gigahertz range of say, a typical Intel chip, but in the far more leisurely kilohertz range.

"Analog circuits can be profitably operated here," he said, because the design does not demand the high current needed for digital operation.

The physical world is basically analog, he said, but at some point chip designers must convert those analog processes to the zeroes and ones of digital design. "The larger question is, when do you do this?" he asked. "There is a lot you can gain from doing much of the initial work in analog," avoiding the dissipation of power that occurs in digital number crunching, where each of millions of elements handles part of the computation. That process can quickly empty a battery.

Dr. Sarpeshkar and his group have been working on the processor project for three years and have written papers that document the circuits built for each block in the new design. The analog circuits make unusual use of complementary metal-oxide silicon, or CMOS, transistors, which are usually thought of as digital components but are in this case wired into analog circuits in a way that draws little power.

The project was underwritten by industry sponsors, and Dr. Sarpeshkar expects the chip to be available commercially within two years.



Bob Scott

For the deaf, a potential end to 'Hold on, I have to change my batteries.'

Reducing the power that cochlear devices draw is a crucial issue today as well as for the next generation of devices, said Philip Loizou, an associate professor of electrical engineering at the University of Texas at Dallas who does research in cochlear implants. "You could be in the middle of a meeting, and you have to say, 'Hold on, I have to change my batteries,' " he said.

In the digital part of the process, Dr. Loizou said, a lot of computing is required quickly. "The more complicated the algorithm, the more power it consumes," he said.

While Dr. Sarpeshkar's processor is based on analog circuits, it includes digital outputs so that it can be used with other parts of the system like the programming interface. Being able to reprogram the processor is crucial because each patient has different auditory needs that are translated into instructions to each electrode that stimulates a nerve ending in the cochlea.

Andreas Andreou, a professor of electrical and computer engineering at Johns Hopkins University, said that Dr. Sarpeshkar's circuits were unusual examples of precision engineering. "Analog does not necessarily mean low power; it's the careful engineering that does it," he said.

Dr. Andreou expects low-power analog circuitry like Dr. Sarpeshkar's to have other applications besides cochlear implants. "Some day with circuits like these, people will have a whole MP3 player in an earbud," he said, or an entire translation or speech recognition system.

Dr. Sarpeshkar's interest in imitating natural systems with analog circuits is not new. As a doctoral student at the California Institute of Technology a decade ago, he worked with the microelectronics pioneer Carver Mead, creating analog circuit models of the cochlea.

"Rahul did even better circuit models than we did," said Richard Lyon, who also worked with Dr. Mead on cochlear circuits and is now vice president for research at Foveon, a company founded by Dr. Mead that has used analog circuits for computer modeling of another natural process, vision.

"Rahul could always analyze the heck out of everything," Mr. Lyon said. "He took those circuits and came up with real innovations."