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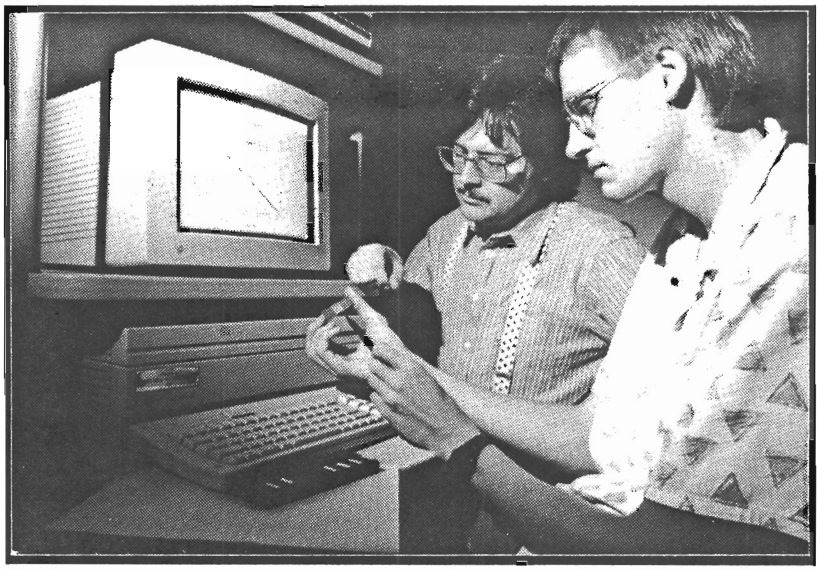
LEARNING TO IMPROVE THEMSELVES: NEURAL NETWORKS HELP DEVICES ENHANCE THEIR OWN ACCURACY & PERFORMANCE

Electrical engineers at the Georgia Institute of Technology have built a new class of high-speed analog integrated circuit (IC) amplifier which learns to accurately control its own performance through neural network technology.

Using 15 individual amplifier circuits working in parallel, the device produces accurate linear response (to within one-tenth of one percent) over a wide input range. It can also generate specific non-linear performance designed to compensate for the operation of other equipment.



Martin Brooke and Axel Thomsen examine a neural net IC amplifier they designed, as a graph charts performance before and after the device is trained. (Color/B&W Avail.)

"One of the great problems people have had with high-speed analog circuits is controlling them, since their behavior can be difficult to predict," said Dr. Martin A. Brooke, assistant professor in Georgia Tech's School of Electrical Engineering. "Instead of trying to design a circuit that is inherently linear -- which is difficult to do for high-performance systems -- we are training the circuit after it is built."

The work represents a new use for neural network technology, and could have widespread application for sensors, fiber optic communications and other equipment requiring high-speed analog IC amplifiers. The parallel nature of the circuit and its ability to be easily adjusted also could help electronic devices compensate for temperature changes and the effects of aging materials.

FOR MORE INFORMATION:

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Using the design facilities of Georgia Tech's Joseph M. Pettit Microelectronics Research Center, Brooke and graduate student Axel Thomsen built an array of 15 amplifiers on the same integrated circuit (IC) chip that work together to provide the desired performance.

"Each amplifier only works over a limited range, so each takes care of a different part of the overall transfer characteristics," Brooke explained. "They hand off like relay runners. When the input goes out of the region for one amplifier, it hands off to the next, which then takes over."

Brooke uses three different types of amplifier circuits on the IC, none of which provides rail-to-rail linear performance by itself. But by making use of the portions of their performance range where they are linear, and by combining the work of the individual amplifier circuits, the overall IC amplifier provides the desired performance, he said.

A special circuit built into the IC chip determines the voltage level at which each individual amplifier begins to operate. That voltage level is adjustable, set as part of the "training" received by the overall IC amplifier.

Like many humans, the IC amplifier learns accurate performance by doing its task and getting feedback on it. And like the human brain, neural circuits are "wired" to reflect that experience.

As part of the training, Georgia Tech engineers feed an input voltage into the IC amplifier, then measure the output. They then adjust special on-chip circuits which determine the points at which the relevant amplifiers turn on. Similar test and adjustment steps are made at increasing voltage levels until the IC amplifier has been trained over its entire performance range.

Engineers now do the training manually, but Brooke plans to automate the process through an on-chip device that would generate inputs, measure the output and make the adjustments. Once in service, the IC amplifiers could periodically re-train themselves to account for aging and other operational changes.

Brooke sees one possible application of the IC neural amplifier in the cable television industry, which faces difficulty with the non-linear response of lasers and detectors used to send signals through fiber optic cable. In that application, the IC amplifier would learn to operate in a non-linear mode to compensate for the operation of the lasers and detectors.

"The cable system gets distortion due to the non-linearity of the laser," he said. "One of the ways you could fix that would be to drive the laser with an IC amplifier that had learned to correct for the non-linearity of the laser. The overall package, laser and IC amplifier, could then be linear."

The IC amplifier developed by Brooke and Thomsen has a 3 dB bandwidth of 10 to 20 MHz when fabricated in a two-micron digital CMOS process available through the MOSIS foundry. Tests show performance of the IC amplifier should be stable over long periods of time.

Neural networks have been studied widely for applications in such areas as machine vision systems and artificial intelligence. The Georgia Tech IC amplifier grew out of an interest in those potential uses, and may be one of the first applications of the neural network concept to analog circuit design. The IC amplifier circuits use EPROM devices also implemented through the MOSIS Foundry.

The research was supported by the National Science Foundation under grant MIP-901136 and by Analog Devices, Inc. The work was presented to the International Joint Conference on Neural Nets during July 1992 in Baltimore, and a paper describing the IC amplifier has been accepted for publication in the IEEE Journal of Solid State Circuits.

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