A 40th Anniversary for Transistors*

Where were you on July 1, 1988—the 40th anniversary of Bell Telephone Laboratories' first demonstration of the newly invented transistor?

The July 1, 1948 edition of the *New York Times* wrote: "A device called a transistor, which has several applications in radio where a vacuum tube ordinarily is employed... was demonstrated in a radio receiver, which contained none of the conventional tubes. It was also shown in a telephone system and in a television unit controlled by a receiver on a lower floor. In each case the transistor was employed as an amplifier, although it is claimed that it can also be used as an oscillator in that it will create and send radio waves.

"In the shape of a small metal cylinder about a half inch long, the transistor contains no vacuum, grid, plate or glass envelope to keep the air away. Its action is instantaneous, there being no warm-up delay since no heat is developed, as in a vacuum tube...."

As part of the demonstrations, Bell Labs created as giant model of a transistor—eight feet long, and on wheels!

Two weeks after the public relations demonstrations, *Physical Review* (July 15, 1948) published the first scientific paper about the transistor, written by John Bardeen and Walter Brattain, the co-inventors of the transistor. Bardeen and Brattain, along with William Shockley—who developed the "junction transistor" that dominated the field of microelectronics—shared the 1956 Nobel Prize in physics for their work.

Where were you on December 23, 1987—the 40th anniversary of the transistor's actual discovery? Since it was invented in late December, the transistor has been called AT&T Bell Laboratories' "Christmas gift to the world."

The governor of Illinois recently issued a proclamation stating:

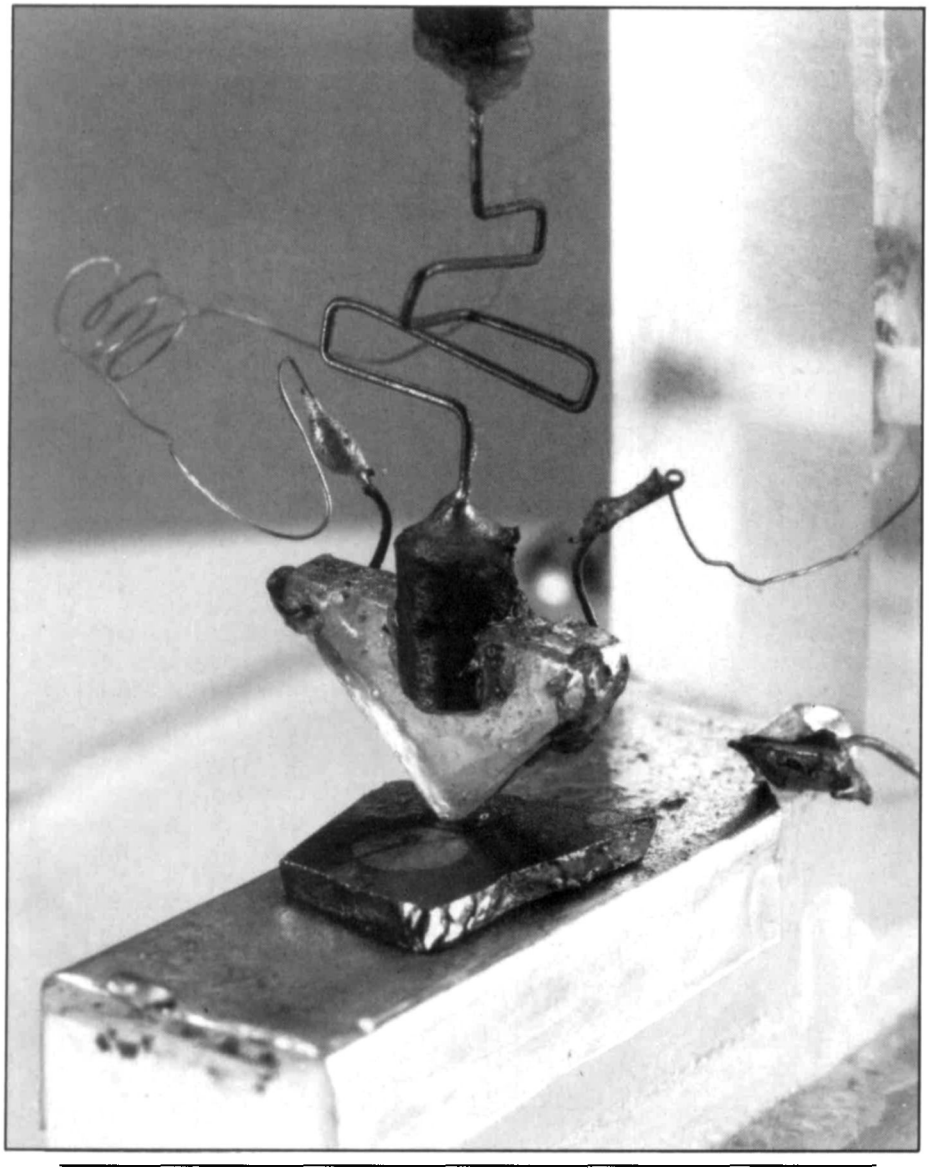
"....WHEREAS, the transistor spawned today's worldwide semiconductor electronics industry and made possible dramatic changes in communications, computing, entertainment, medicine, space exploration, and a host of other fields; and

"WHEREAS, the most far-reaching impact of the transistor's invention has been in communications. Modern communications networks wouldn't be possible without the transistor, as transistors underlie every aspect of worldwide communications today...

"THEREFORE, I, James R. Thompson, Governor of the State of Illinois, proclaim December 23, 1987, as a day to pay tribute to AT&T Bell Laboratories on the occasion of the 40TH ANNIVERSARY OF THE INVENTION OF THE TRANSISTOR."

The tiny transistor superseded the outdated vacuum-tube amplifier with an inexpensive and reliable substitute for the relays in electromechanical telephone exchanges. But none of this happened overnight, of course.

Other researchers had been working for years to develop useful properties from semiconducting materials. At Bell Labs two metallurgists, Jack Scaff and Henry Theurer, and a chemist, Russel Ohl,



The first transistors assembled by their inventors at Bell Laboratories were primitive by today's standards. This first transistor, a "point-contact" type, amplified electrical signals by passing them through a solid semiconductor material, basically the same operation performed by present "junction" transistors. Photo courtesy of AT&T Archives.

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had been testing silicon ingots for their electrical resistance. In September 1939 they unintentionally created a silicon ingot with regions that rectified electric current in opposite directions. Scaff and Ohl decided to call the regions "p-type" (for positive) and "n-type" for negative. By good fortune the names they arbitrarily chose for those regions are also physically correct, relating to the absence or surplus of electrons in the silicon lattice.

The other member of the team, Henry Theurer, found that if he added a tiny amount of boron to molten silicon, the resulting ingot would have enhanced p-type conductivity. Adding phosphorus to the melt enhanced the n-type conductivity. When Scaff later reported this "doping" technique to Walter Brattain (who would become one of the actual inventors of the transistor), Brattain reportedly thought it was a crazy idea.

The management of Bell Labs had stated that future semiconductor progress would come about through new solid-state physics research. William Shockley, Walter Brattain, and John Bardeen were assigned to focus their efforts in this area. By 1944, when Shockley and his group were working together, fairly detailed theories had been worked out about the p-type and n-type semiconductors, how they work and why they rectified electric currents.

In April 1945 Shockley proposed a design for a solid-state device to amplify electric currents—in effect, the first transistor. Brattain tried the circuit, which sent a strong electric field perpendicular to a thin slice of semiconductor material. If successful, the circuit should have modulated the current along the semiconductor—but it didn't work. Not until seven years later, in 1952, did Shockley publish the theory that led to this (more complex) type of transistor, called the "field-effect transistor."

But in December 1947 Bardeen and Brattain continued to work on a variation of Shockley's idea, this time using germanium as the semiconducting material because they could obtain pure samples of the element with relatively little effort. They got a sample of n-type doped germanium onto which one of the group's physical chemists had evaporated a circle of gold. The gold circle had a small hole in its center for a tungsten point to be added as the electrical contact.

But, as has been the case in so many important scientific and technological discoveries, an accident happened when Brattain attempted the experiment. A spark jumped between the tungsten point and the gold, which spoiled the hole carefully left in the gold circle. Instead, Brattain tried touching the tungsten point *beside* the gold circle, separated by only a tiny distance. When he attached a power source, he immediately found a strong current modulation—and he found that the current was traveling the opposite direction from what he had expected.

Bardeen and Brattain decided that the gold circle acted to draw electrons away from the semiconductor, rather than donate them, as they had anticipated. It took them several more days to apply this principle to make an amplifier. On their first attempt they achieved an amplification factor of about 15.

A few days later, on December 23, 1947, the group demonstrated their discovery to others at Bell Laboratories. "The circuit was actually spoken over," Brattain wrote, "and by switching the device in and out a distinct gain in speed level could be heard and seen... with no noticeable change in the quality."

Bardeen and Brattain would not publish a description of their invention for seven months, however. Until that time, Bell Telephone Laboratories kept the existence of the transistor a closely watched secret. Even the editor of *Physical Review* could not speak of it, though the paper was being published in the July issue.

Bell Labs felt it important to keep the discovery confidential because they had some inkling of how substantially it would change electronics and communications. Apparently, they did not want the United States military to get wind of the transistor's invention for fear the military would attach strict security procedures on future research.

Also, another group of researchers at Purdue University seemed to be very close to making the same discovery themselves. They had proposed some of the same experiments and had worked along the same theoretical lines. Brattain and Bardeen wanted their patent negotiations to go off without any conflicts of competing research.

Finally, Bell Labs wanted to have some time to sit back and think about the best ways to apply and commercially exploit the new invention.

Ironically, when the transistor was demonstrated in July 1948, all the fanfare and public relations efforts came to almost nothing. The public took virtually no notice of the invention; even the electronics journals viewed it as just a laboratory curiosity.

Western Electric, the first manufacturer of transistors, did not release its first one until October 1951. Transistors appeared in telephone systems a year later. By 1953 transistors began to be used in hearing aids—encouraged, in part, by Alexander Graham Bell's (and hence Bell Laboratories') interest in helping the deaf. Transistor-based hearing aids were smaller, but initially much more expensive than vacuum-tube-based hearing aids.

Six years after the announcement, the first transistor radio appeared on the market. It was manufactured by Texas Instruments and the IDEA Corporation, and sold for $49.95. It was a commercial failure.

Success with transistors, however, came more and more quickly until it could finally be seen as an electronics revolution—as the transistor's inventors had envisioned it. The transistor, and specifically the MOSFET (metal-oxide semiconductor field-effect transistor), were the first steps in forming the tiny but important integrated circuits used so extensively today.

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*Much of the information in this article is courtesy of AT&T archives. □

In the next issue...

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