Honoring the Trailblazing Transistor

BY ANNA BOGDANOWICZ

T'S HARD TO IMAGINE what life would be like without the transistor, which was invented a little more than six decades ago. Considered by researchers and historians to be the most important invention of the 20th century, the transistor has led to groundbreaking advances in computing, communications, transportation, medicine, and virtually every technically related field. Without it, such developments as the personal computer, the cellphone, the GPS, and the pacemaker would not exist. IEEE is honoring the breakthrough this month with an IEEE Milestone in Electrical Engineering and Computing.

The transistor was invented by researchers John Bardeen and Walter Brattain, under physicist William Shockley's leadership, in December 1947 at Bell Telephone Laboratories in Murray Hill, N.J. 

TUBES TO TRANSISTORS

Transistors are solid-state devices used to amplify or switch electronic signals. They're made of layers of semiconductor materials and three terminals that connect to an external circuit.

Before transistors, computers and other electronics relied on vacuum tubes, which consist of electrodes in an evacuated bulb through which an electric current can be passed and manipulated, allowing the tubes to function as amplifiers and switches. John Fleming invented a two-element vacuum tube, or diode, in 1904. Fleming's invention, which was used as a rectifier in early radio work, was honored with an IEEE Milestone in 2004. In 1966 Lee De Forest—who in 1930 became president of the Institute of Radio Engineers, one of IEEE's predecessors societies—invented the three-element tube, or triode. The device became the model for most later vacuum tubes. It was one of the most important breakthroughs in electronics history, making possible amplification, modulation, and switching and thereby laying the groundwork for commercial radio and television, high-fidelity audio, and the development of the first, primitive computers.

Vacuum tubes, also known as valves, were far from ideal, however. They were large, and the heated metal that emitted electrons would eventually burn out. Their glass envelope made them relatively fragile. The tubes also required a lot of power, so they ran hot. The few computers built with tubes were huge and slow.

For years, researchers had sought to replace tubes with solid-state devices. In 1926, physicist Julius Lilienfeld patented the concept of a field-effect transistor, a type that relies on changes in an electric field to control the shape and conductivity of a channel in a semiconductor material. It is the principle behind today's field-effect transistor, the most common type of transistor. But it's not clear whether Lilienfeld ever produced such a device or if it could even be built from this patent description. Another development came in 1934, when physicist Oskar Heil patented another type of field-effect transistor.

Two years later, Mervin Kelly, research director at Bell Labs, established a department there to research solid-state physics in the hope of investigating ways to reduce the effects of surface states so as to make a viable solid-state device. They decided to make one based on the point-contact principle, rather than the field effect. In a point-contact device, the electrical capacitance, beforehand a problem, can be reduced by making the junction area of connection as small as possible.

By late November 1947, Bardeen and Brattain had created the first functioning transistor, a crude little unit made of a plastic triangle with strips of gold foil pushed down into contact with a chunk of germanium [see photo]. They spent the next few weeks improving their device and by 16 December had succeeded in producing the first solid-state transistor.

The two connected the transistor to a simple circuit with a battery and a meter and showed that the transistor amplified current. They also put their invention in a circuit containing a microphone and a speaker so they could hear how the transistor amplified the electrical signal from a microphone.

On 23 December, they showed it to Bell Labs executives, who immediately realized the potential of the new technology. Envious of his colleagues' success, Shockley went on to invent another type of transistor—the junction transistor—which was built on thin slices of different types of semiconductor materials pressed together. The junction transistor could be manufactured more easily, and it was more rugged and reliable than the point-contact transistor.

The transistor is acknowledged today as one of the greatest inventions in history. It established the vast field of solid-state electronics and thereby set the stage for today's US $250 billion global semiconductor industry. Bardeen, Brattain, and Shockley received the 1956 Nobel Prize in physics for their research on semiconductors and their discovery of the transistor effect.

A ceremony recognizing the milestone is scheduled for 8 December at Bell Labs in Murray Hill. A plaque is to be mounted in the labs' Hall of Innovations, near the room where the researchers worked. The hall houses various awards, including Nobel Prizes, and replicas of devices that trace the history of inventions developed at Bell Labs.

The Milestone plaque reads: "At this site, in Building 1, Room 1E455, from Nov 17th to Dec 23rd, 1947, under the direction of William B. Shockley, Walter H. Brattain and John A. Bardeen discovered the transistor effect and developed and demonstrated to their colleagues a point contact germanium transistor. This led directly to subsequent developments in solid-state devices that revolutionized the electronics industry and changed the way people around the world live, learn, work, and play."

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