

The Transistor: A True Innovation

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I really never gave thought to appreciating the technology we have at our fingertips and take for granted. We have our own computers – sometimes both a desktop and a laptop; iPods, iPhones, and now iPads; computers run our cars, guide our driving (GPS) – even run our toothbrushes! We truly are surrounded by it, and take it all in stride.

If you take a trip back to the year 1973, students were saving their summer job earnings to purchase an incredible machine – a Texas Instruments SR-10 calculator (complete with features to add, subtract, divide, multiply, and even calculate square roots), which cost \$179. Today, we can go to the nearest drugstore and buy a smaller and more powerful machine for no more than a dollar. When I learned that the transistor was the reason behind this leap in technology in a relatively short time, I was fascinated. I wanted to learn more about it, and chose it as the subject of my research project.

I started my research on the internet – both to learn a bit of background, as well as the online catalog for the local public library system. The company who drove the innovation of the transistor – AT&T Labs, published prolifically. Many books were available, as well as newspaper and periodical resources. Following references in many of the books I was able to find many primary sources, including advertisements, press releases, newspaper articles, and even a song written by the workers in the AT&T lab that were responsible for the development of the transistor.

The many different primary sources, my desire to include the sound file of “Hell’s Bell’s Laboratory,” as well as my interest in technology made easy the decision to present the data in documentary form. I created the project using Ulead Video Studio. I scanned documents as needed, collecting them into folders. I recorded the voice over, and created the final product using the Ulead Video Studio program. I presented the data

in a timeline fashion, starting with the development of other solid-state technological devices that lead to the development of the transistor, and following its impact on society and technology through the decades.

This project fits perfectly to the 2010 theme of National History Day– Innovation in History. The transistor is considered the most innovative development in electronics and technology of the twentieth century. The transistor started as an invention. Bell Labs discovered a way to more efficiently convert sound waves into voice in order to strengthen their position in the telecommunications industry, but were legally limited in their ability to pursue other markets. When they offered open licenses to all interested – the transistor quickly became an amazing innovation. Electronic technology, which, thanks to transistors, has evolved from microtechnology to the nanotechnology we experience today.

ANNOTATED BIBLIOGRAPHY

Primary Sources

AT&T Bell Laboratories. "The Transistor." *A History of Engineering and Science in the Bell System: Electronics Technology (1925-1975)*. Indianapolis: AT&T Bell Laboratories, 1985. 1-100. Print.

Bell Laboratories had the policies of early and full publication and selling nonexclusive patent licenses to all comers at a reasonable price. These policies contributed to the widespread interest and application of transistor technology. This book, published by Bell Laboratories, provides an in-depth look at their role in making the transistor a device used in common household appliances.

Bardeen, John, and Walter H Brattain. Three-Electrode Circuit Element Utilizing Semiconductive Materials. Patent 2,524,035. Oct. 1950. *United States Patent and Trademark Office*. N.p., n.d. Web. 7 June 2010. <<http://www.uspto.gov>>.

William Shockley was determined to have his be the only name on the transistor's patent. In the end, the patents filed for work done on Shockley's field effect transistor was too similar to another invention twenty years prior--the only way Shockley could put his name on any patent would be to use Walter Brattain's and John Bardeen's point-contact transistor. This patent is a useful primary source in its documentation of the dispute between the inventors of the transistor.

Bell Telephone Laboratories. *An Amazingly Simple Device*. New York: n.p., 1 July 1948. Print.

The transistor was a tiny, simple device that functioned very similarly to the vacuum tube, amplifying electrical signals about one hundred times to about twenty decibels. The device was revealed to the public on July 1, 1948. Bell Laboratories' press release about the transistor provides a concise description of the functions and benefits of the transistor; it also allows comparison between itself and the initial articles published in major periodicals.

Dr. E.F.W. Alexanderson and R.D. Kell inspecting experimental home television set. *The History of Television*. By Norm Goldstein. New York: Portland, n.d. N. pag. Print.

Dr. E.F.W. Alexanderson was the first chief engineer for the Radio Corporation of America and was photographed as he studied a primitive television set. This picture shows the hardware of the first television sets and the development of communications technology after the invention of the transistor.

"Huge Growth Seen for Electronics." *New York Times* 5 Jan. 1952: 18. *ProQuest Historical Newspapers*. Web. 19 Jan. 2010. <<http://www.proquestk12.com>>.

The transistor began an entirely new electronics industry, in which physics and chemistry had contributed to a new era of communications. Dr. Robert M. Burns, chemical director of Bell Laboratories, warned that the booming industry required a greater number of industrially trained chemists and physicists. This article provides insight into the excitement and sense of looming felt as the electronics revolution approached in the 1950s.

Jones, Stacy V. "New Use Is Found for Spectacles with Adaptation as Hearing Aid." *New York Times* 11 Oct. 1952: 28. *ProQuest Historical Newspapers*. Web. 19 Jan. 2010. <<http://www.proquestk12.com>>.

The invention of the transistor allowed new, smaller hearing devices to be developed, such as the hearing aid spectacles. Transistors are located in the bows of the glasses, with the microphone over the bridge and the sound reproducer pressed against one ear. The article provides insight into the technological developments possible using the transistor.

Kennedy, T. R. "TV Set Functions with Transistors." *New York Times* 18 Nov. 1952: 33. *ProQuest Historical Newspapers*. Web. 19 Jan. 2010. <<http://www.proquestk12.com>>.

Transistors, also known as "laboratory magic" in the article, had demonstrated their worth through cutting the size and cost of older, tube-based television sets. The researchers interviewed expressed great hope for the future of the television. "TV Set Functions with Transistors" truly shows the development from vacuum-tube televisions to those in homes in modern day America.

Kikuchi, Makoto. *Japanese Electronics: A Worm's Eye View of Its Evolution*. Tokyo: Simul, 1983. Print.

When the transistor was invented, most major newspapers dedicated less than a page to the revolutionary device. The transistor was based on an entirely new physical phenomenon, so everyone was a newcomer to the field, which provided for fresh and innovative ideas. *Japanese Electronics* provides not only a first-hand glimpse into the age of the transistor, but also primary documents, such as the *Newsweek* article announcing the birth of the device.

"Long Distance Dial System in Installed in 20th City." *Chicago Daily Tribune* 26 May 1953: C7. *ProQuest Historical Newspapers*. Web. 3 Jan. 2010. <<http://www.proquestk12.com>>.

On May 25, 1953, Scranton, Pennsylvania became the twentieth city to be equipped with long distance telephone equipment, technology fueled by the transistor. This article demonstrates the marvel of American citizens as transistor technology efficiently transformed their society.

Mackintosh, Ian. "The Hell's Bells Laboratory." Institute of Electrical and Electronics Engineering, 2009. Web. 23 Jan. 2010. <<http://www.ieee.org>>.

The song "Hell's Bells Laboratory" was written by the engineers of Bell Laboratories. It includes verses about the transistor and its three inventors, and shows the camaraderie and mutual respect of the scientists working there.

Manchester, Harland. "Fabulous Midget - the Transistor." *Reader's Digest* May 1953: n. pag. Web. 9 Mar. 2010. <<http://www.transistorhistory.50webs.com>>.

The transistor is a revolutionary new device designed to replace the bulky, cost-inefficient vacuum tube. This article shows how the transistor was becoming a household, common item instead of a technical device.

"New Hearing Aid Uses Transistor." *New York Times* 30 Dec. 1952: 29. *ProQuest Historical Newspapers*. Web. 3 Jan. 2010. <<http://www.proquestk12.com>>.

The Sonotone hearing aid was the first consumer product that made use of transistors. The development of smaller hearing aids using transistors opened the doors to an almost unlimited future in miniaturization. "New Hearing Aid Uses Transistor" demonstrates the hope of consumers and professionals alike as to the dawning new age of electronics.

"New Phone Device Halves Call Time." *New York Times* 2 Aug. 1953: 61. *ProQuest Historical Newspapers*. Web. 3 Jan. 2010. <<http://www.proquestk12.com>>.

Transistors were used to create devices called Translators in long distance telephone connections. The translator selected the most direct calling route; if that route was busy, it would choose a free, alternate route. The advent of common long distance telephoning brought about what we know today as the area code. "New Phone Device Halves Call Time" documents the results of the innovation of the transistor, including the increase of telephone call speed.

"The News of Radio." *New York Times* 1 July 1948: 46. *ProQuest Historical Newspapers*. Web. 19 Jan. 2010. <<http://www.proquestk12.com>>.

This was the first mention of the transistor in a major publication. The innovation received only three paragraphs in a small section on page 46 of the *New York Times*. This article shows the mixed feelings towards the transistor when it was first revealed to the American public, and contrasts with the later electronics revolution.

"Radio Bouncing Back from 'Dead.'" *New York Times* 16 June 1957: F1. *ProQuest Historical Newspapers*. Web. 1 Jan. 2010. <<http://www.proquestk12.com>>.

Sales of portable transistor radios, records, phonographs, and sound equipment rapidly increased after the invention of the transistor. While radio sales had been decreasing in years prior, as of June 1957, portable radios greatly outsold both home radios and

television. This article demonstrates the great influence the transistor had over the commercial communications industry.

Shockley, William. Circuit Element Utilizing Semiconductive Material. Patent 2,569,347. Sept. 1951. *United States Patent and Trademark Office*. N.p., n.d. Web. 7 June 2010. <<http://www.uspto.gov>>.

After William Shockley discovered that the only way he could put his name on a transistor patent would be to use Walter Brattain's and John Bardeen's point-contact transistor, he applied for a patent with his improved version of the transistor, known as the junction transistor. This patent is a useful primary source in its documentation of the dispute between Shockley, Bardeen, and Brattain.

"The Silicon Engine." *Computer History Museum*. Computer History Museum, 2007. Web. 24 Jan. 2010. <<http://www.computerhistory.org>>.

The transistor was a part of a continuum of technological advances, documented on this website. The pictures found on this website help to explain the details and events of the invention of the transistor.

"Small Device Gives Radio - TV Industry Push." *Chicago Daily Tribune* 29 Dec. 1952: B7. *ProQuest Historical Newspapers*. Web. 19 Jan. 2010. <<http://www.proquestk12.com>>.

The board chairman of the Radio Corporation of America (RCA) predicted that further technological development with transistors would bring electronics into many new career fields. The article expresses the potential of the transistor to create an electronics revolution that would affect all fields.

"S. R. O. Meeting Held by A. T. & T." *New York Times* 16 Apr. 1953: 45. *ProQuest Historical Newspapers*. Web. 3 Jan. 2010. <<http://www.proquestk12.com>>.

In 1953, the annual meeting of American Telephone and Telegraph Company (AT&T) was attended by more than 1,200 stockholders, due to the invention of the transistor. The meeting was televised for the first time and projected on screens in adjoining rooms because of the crowd's size. This article demonstrates America's fascination with the new technology and their knowledge that the transistor was something that would change their lives forever.

"Tiny Electric Unit Promises Wonders." *New York Times* 25 Feb. 1952: 23. *ProQuest Historical Newspapers*. Web. 19 Jan. 2010. <<http://www.proquestk12.com>>.

In February, 1954, the Radio Corporation of America (RCA) demonstrated the new transistor technology. This revealed to the American public the potential of the device to overtake vacuum tubes. The author speculates that the new technology will most likely be used in radio, television, and computing machines. "Tiny Electric Unit Promises Wonders," shows the uncertainty and hope with which the American public and scientific community alike looked forward to the age of the transistor.

"Tiny New Transistor Undergoing Tests in Dial Phone System." *Chicago Daily Tribune* 21 Oct. 1952: B6. *ProQuest Historical Newspapers*. Web. 19 Jan. 2010. <<http://www.proquestk12.com>>.

In 1952, the transistor was undergoing tests to be incorporated into long distance telephone equipment. This short article documents the skeptical hopes for the transistor's ability to replace the vacuum tube in electronic devices.

"Transistor Boom Hardly Begun." *New York Times* 24 June 1956: F1. *ProQuest Historical Newspapers*. Web. 1 Jan. 2010. <<http://www.proquestk12.com>>.

The transistor was about the size of a grasshopper's head and was far more reliable than the vacuum tube. The transistor had a failure rate of 5% for every 10,000 hours of use, while the vacuum tube had a failure rate of 15% for every 1,000 hours of use. "Transistor Boom Hardly Begun" shows the greater reliability and hope for miniaturization found in transistors.

"Transistor Device in 1st Public Test." *New York Times* 4 Mar. 1952: 35. *ProQuest Historical Newspapers*. Web. 19 Jan. 2010. <<http://www.proquestk12.com>>.

A transistor-based device, used for long-distance teletype military communications, was publicly revealed in March of 1952. The device weighed ten pounds and needed only one and a half watts of power to operate, while its predecessor (which employed vacuum tubes) weighed 100 pounds and required 175 watts of power. This article demonstrates both military and nonmilitary benefits of transistor technology.

Transistorized! 1999. Public Broadcasting Station. Videocassette.

The three inventors of the transistor, though they were often deemed one of the best teams in science, did not get along very well due to Shockley's inflated ego. After Brattain and Bardeen invented the point-contact transistor without Shockley's presence, Shockley was determined to outshine them. He moved to Palo Alto, where he founded Silicon Valley with his company "Shockley Semiconductors." Unfortunately, his company failed miserably due to his ambition and overwhelming desire for glory. *Transistorized!* provides an excellent context in which the transistor was invented.

"Transistor Radios Available." *New York Times* 8 Dec. 1956: 22. *ProQuest Historical Newspapers*. Web. 2 Jan. 2010. <<http://www.proquestk12.com>>.

Two new transistor radios by General Electric were for sale; one cost \$49.95 (with gold finish and a leather trim), and the other cost \$59.95 (complete with a leather case). This article shows how well published the phenomenon of transistor radios was.

"Transistors Set for Hearing Aids." *New York Times* 26 Jan. 1953: n. pag. *ProQuest Historical Newspapers*. Web. 3 Jan. 2010. <<http://www.proquestk12.com>>.

Transistor use in hearing aids was expected to lower cost 80 to 97 percent; people were expected to be able to own and maintain some aids for less than \$2 a year. "Transistors Set for Hearing Aids" shows the great benefits received through the new transistor technology.

"Vacuum Tube Hearing Aid Now Obsolete." *Washington Post and Times Herald* 23 Aug. 1954: 5. *ProQuest Historical Newspapers*. Web. 2 Jan. 2010. <<http://www.proquestk12.com>>.

The newspaper for which this article was written offered a booklet summarizing how the transistor-based hearing aid helped them in their daily lives. This article shows the improvements of the transistor-based hearing aid and how these improvements have helped the population.

"Vast Power of the Sun in Tapped by Battery Using Sand Ingredient." *New York Times* 26 Apr. 1954: 1. *ProQuest Historical Newspapers*. Web. 24 Jan. 2010. <<http://www.proquestk12.com>>.

In 1954, the first solar battery was constructed at Bell Laboratories. The battery used solid-state technology and operated similar to the transistor. This article shows the new transistor applications that were found very soon after the invention and the promise for more to come.

Secondary Sources

Amos, Stan, and Mike James. *Principles of Transistor Circuits*. Boston: Newnes Butterworth-Heinemann, 2000. Print.

The transistor could switch, amplify, and oscillate but only needed a few microwatts of power. The device paved the way for the development of the integrated circuit (i.c.); nowadays, several million transistors can operate on an i.c. less than one square centimeter large. This book provides a brief summary of the benefits and applications of the transistor.

Bray, John. "The Inventors of the Transistor and the Microchip: A World-Wide Revolution in Electronics." *Innovation and the Communications Revolution*. London: Institution of Electrical Engineers, 2002. N. pag. Print.

The primary feats of the transistor are its reduced size and power requirements, economy, and versatility. Transistor technology led to many devices, including telephone circuit submarine cables (the first laid between the United States and Spain in 1970), low noise microwave amplifiers, and solar cells. This book provides the immediate impact of the transistor on familiar devices and its accomplishments in various areas of technology.

Bridgman, Roger. "Development of the Transistor." *Electronics*. New York: Dorling Kindersley, 1993. 38-9. Print.

Diodes, the earliest semiconductor devices, were used for one-way conduction; the triode duplicated its ability to amplify without requiring the use of vacuum tubes. This section explains the development and historical context of the transistor, showing how a transistor operates and how the standard of life would be different without it.

Bromley, D Allan. *A Century of Physics*. New York: Springer, 2002. Print.

After World War II, physicists from the Manhattan Project, the Radiation Laboratory, and other wartime facilities needed new areas of research in which they could best utilize their talents. Some of the best physicists migrated to Bell Laboratories, where the physicists' excitement and focus resulted in a replacement for the vacuum tube. *A Century of Physics* shows the impact of the war on the development of the transistor and how the post-war atmosphere was conducive to such scientific developments.

Buderi, Robert. "The Magic Month." *The Invention That Changed the World*. New York: Simon, 1996. 308-33. Print.

The invention of the transistor was largely influenced by radar usage during World War II. The fragile materials used for airborne interception radars sparked an interest into solid-state materials (such as germanium and silicon) research. Immediately following the birth of the transistor, most mainstream newspapers (such as the New York Times) claimed that the device was more technical than popular, while the trade press predicted the eventual revolution. This book places the invention of the transistor in historical context and contrasts the immediate reaction of commercial and trade periodicals to the device.

Chandler, Alfred D, Jr. *Inventing the Electronic Century*. New York: Free, 2001. 1-125. Print.

The demand for technology created by the war created companies and laboratories, producing an environment optimal for technological discovery. In April 1952, Bell Laboratories held a symposium on the transistor that sparked the electronics revolution: An international congregation of physicists and engineers were educated on the discovery and could then bring new applications of the technology to life. *Inventing the Electronic Century* provides an excellent study of the transistor's impact and discusses the development of the transistor into the multi-billion dollar industry of today.

Eckert, Michael, and Helmut Schubert. "Solid-State Electronics: A New Industry." *Crystals, Electrons, Transistors*. N.p.: American Institute of Physics, 1990. 157-97. Print.

In 1940, the United States founded laboratories, including the Massachusetts Institute of Technology's Radlab, to coordinate radar research. Two years later, Bell Laboratories developed the first radar detectors using semiconductor technology. This paved the way for the invention of the transistor using similar technology and solid-state materials. This book provides more detail regarding historical context for, the immediate impact of, and the influence of radar on the transistor.

Frisch, Aaron. *The Story of Sony*. North Mankato: Smart Apple, 2004. Print.

Sony created the world's smallest transistor radio in 1957 and the first transistor television in 1960, products that were heavily demanded in America. The company successfully changed American consumer's attitude toward Japanese products and propelled the transistor into everyday use. *The Story of Sony* chronicles the influence of the transistor in foreign markets and its development into an internationally important device.

Gerrish, Howard H, William E Dugger, Jr, and Richard M Roberts. "Transistors." *Electricity and Electronics*. Tinley Park: Goodheart-Willcox, 2009. 287-90. Print.

The transistor can amplify current, create signals at desired frequencies, and be used as switching devices, as in computer circuits. There are two types of transistors: bipolar junction transistors (a device that relies on electrical current) and field-effect transistors (a device that relies on voltage). This section discusses the benefits of the transistor over vacuum tubes, displaying its technological impact.

Haven, Kendall F. "Transistor." *100 Greatest Inventions of All Time*. Westport: Libraries, 2006. 240-242. Print.

Transistors replaced the functions of bulky vacuum tubes with condensed, lightweight solid-state material. Transistors marked the beginning of Silicon Valley, microchips, portable radios, and smaller hearing aids. This source emphasizes the innovation of the transistor and how it has revolutionized the world.

Lewis, Tom. *Empire of the Air: The Men Who Made Radio*. New York: HarperCollins, 1991. Print.

American culture was greatly influenced by its inventions. Radio broadcasts, in particular, allowed people to hear news, music, and drama immediately and through a more personal level of communication--the human voice. This book provides a great deal of historical context in which the transistor was invented and its immediate and long-term effects on America.

Making It Count: History of Computing. 1980. Videocassette.

The human race always tried to improve their methods of communication and computing to make their lives more comfortable, an attempt through which the transistor ultimately arose. "History of Computing" follows the mathematical process from cavemen to the computers of the early 1980s, allowing a collective study of technology and communications.

Milestones in Science and Engineering: The Transistor. Films for the Humanities & Sciences, 1977. Videocassette.

The development of the transistor allowed for global communications--most people could afford and carry the small, cost-efficient devices, and thus remain informed about global affairs. "The Transistor" allows one to look into the global impact of the transistor.

Naughton, John. "Origins." *A Brief History of the Future*. Woodstock: Peter Mayer, 2000. 63. Print.

One of the main purposes of the transistor was to fix the reduction in the signal-to-noise ratio of telephone lines. The transistor was a cheap, efficient, long-lasting amplifier installed at intervals along the telephone line. This book provides a brief historical context and allows one to understand the necessity of the transistor.

Queisser, Hans. "Transistors Come of Age." *The Conquest of the Microchip*. Cambridge: Harvard UP, 1988. 64-81. Print.

Both the public and large engineering companies showed resistance to the transistor at first. Because semiconductors could be off-balanced easily, engineers became paranoid about contamination and would simply continue using the vacuum tubes with which they were comfortable. This book describes the resistance the Bell scientists encountered by not only the government, but also the public and their peers.

Reid, T. R. *The Chip: How Two Americans Invented the Microchip and Launched a Revolution*. New York: Random, 2001. Print.

Before the invention of the transistor, all electronics were built around big, expensive, fragile, inefficient vacuum tubes. Had more complicated devices been made involving the tubes, the filaments would have given off such great amounts of heat that the machinery would have melted and burned (essentially halting technological progress). *The Chip* provides extensive information regarding the major technological and societal changes originating in the invention of the transistor.

Riordan, Michael, and Lillian Hoddeson. *Crystal Fire*. New York: W.W. Norton, 1997. Print.

The study of the elements germanium and silicon during World War II facilitated the development of the transistor and similar solid-state devices. The invention of the transistor brought about the information age. *Crystal Fire* provides an in-depth view of the development and effects of the transistor.

Seitz, Frederick, and Norman G Einspruch. *Electronic Genie: The Tangled History of Silicon*. Chicago: U of Illinois P, 1998. 164-96. Print.

Radar detectors were developed by Bell Laboratories using semiconductor diode technology, which gave Bell the idea to create a practical semiconductor triode (the transistor). Texas Instruments, International Business Machines (IBM), and Hewlett-Packard all became major participants in the design, fabrication, and use of new, transistor-based devices. The production of perfect single-crystal silicon eventually became a large business, involving companies such as DuPont and Siemens. *The Tangled History of Silicon* provides a clearer glimpse into the progression from radar to the transistor and the companies that utilized the new technology.

Shurkin, Joel N. *Broken Genius: The Rise and Fall of William Shockley, Creator of the Electronic Age*. New York: Macmillan, 2006. Print.

William Shockley was the co-inventor of the transistor and the founder of Silicon Valley in California. He was a key contributor to modern science through his inventions, but, later in his career, deliberately defamed himself. *Broken Genius* provides information on both the development of the transistor and its immediate impact on Shockley.

Sterling, Christopher H, ed. *Military Communications: From Ancient Times to the 21st Century*. Santa Barbara: ABC-CLIO, 2008. Print.

The invention of the transistor began the solid state of electronics revolution in communications. Transistors were first utilized in the developing U.S. missile and space program; they made the equipment far lighter and less complex to manufacture. The easily understandable *Military Communications* provides a brief summary of the development and initial utilization of the transistor.

Youtube. N.p., n.d. Web. 10 June 2010. <<http://www.youtube.com>>.

This site provided access to audio from the time period and audio that relates to the transistor. Audio clips and sound bytes from the 1940s and 1950s serve to highlight the information presented.