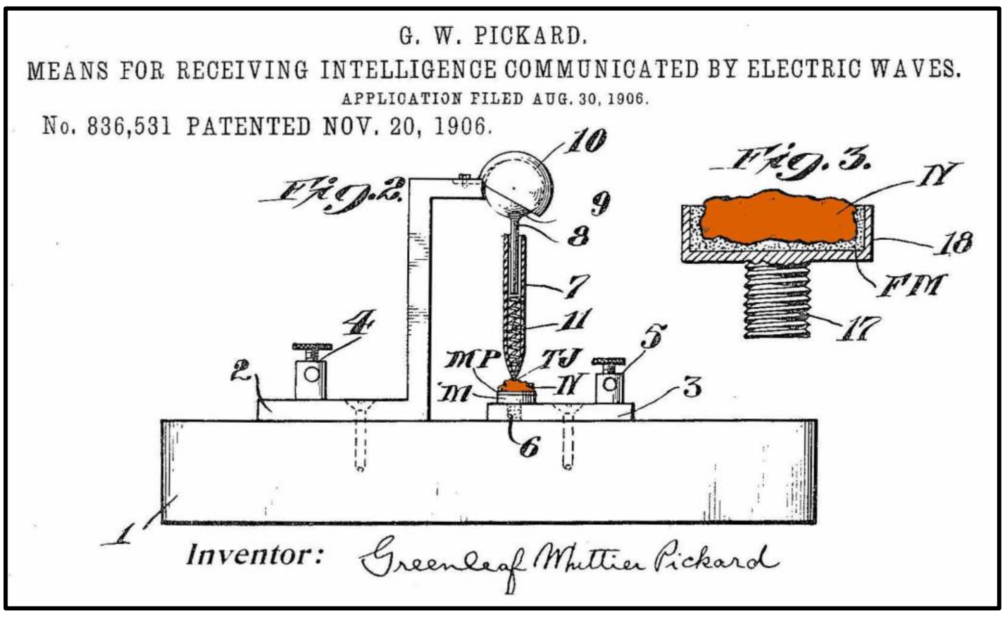
TRANSISTOR MUSEUM™

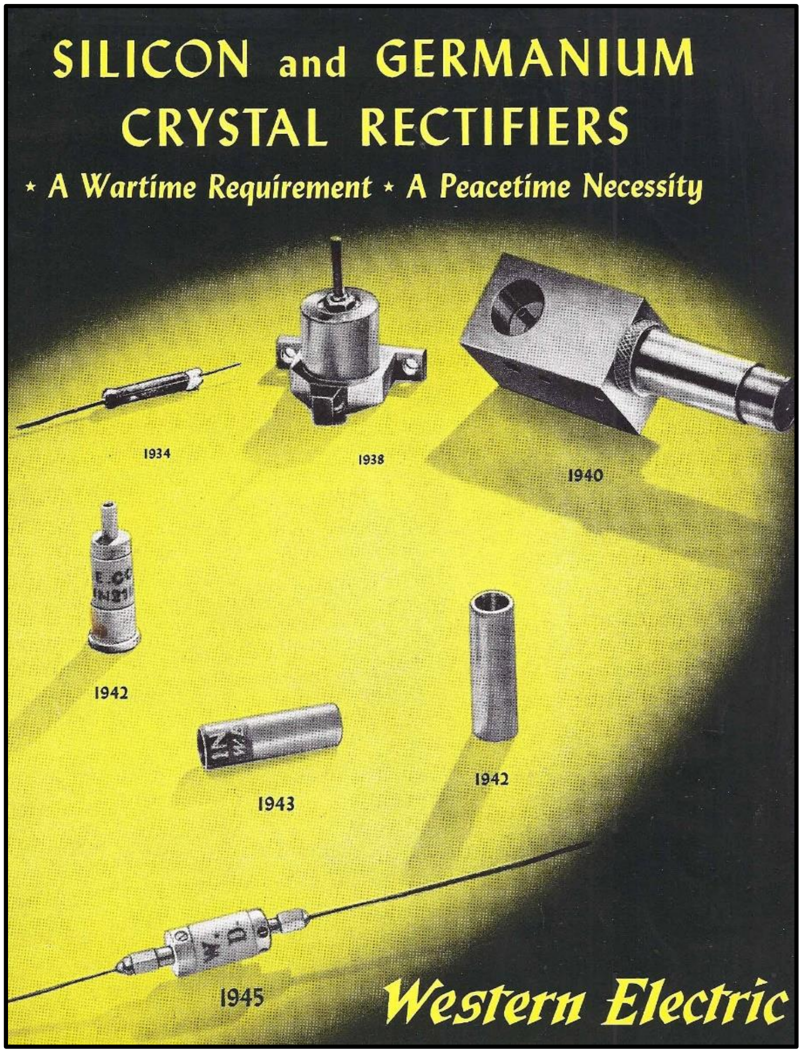
HISTORIC SEMICONDUCTORS RESEARCH AND COLLECTING KIT

A BRIEF HISTORY OF EARLY SEMICONDUCTORS

One of the earliest patents for semiconductor technology that was the basis for large scale commercial, military and research activity was granted in 1906 to Mr. G.W. Pickard of Amesbury, Massachusetts. A section of this patent (#836531) is shown below. As stated in this patent, "The invention relates to means for receiving intelligence communicated by electric waves". Further explanation by Mr. Pickard provides a clear description of the construction and operation of what would soon be known as the "cat whisker" crystal detector. This type of semiconductor device found immediate application in radio receiving sets, which were just becoming available. Marconi's famous first trans-atlantic radio transmission had occurred only five years earlier in 1901 and there was no available technology at that time for reliable and sensitive radio detectors. Pickard's patent refers to the use of the mineral silicon as the detecting material. Other minerals were also used as early crystal detectors, including carborundum, galena, copper pyrites and zincite. (See 1906 Dunwoody patent #857616). These types of "cat whisker" crystal detectors were widely used in the first commercial and amateur radio sets, up until the early 1920s when vacuum tube diodes (Fleming's Valve and De Forest's Audion) became available.

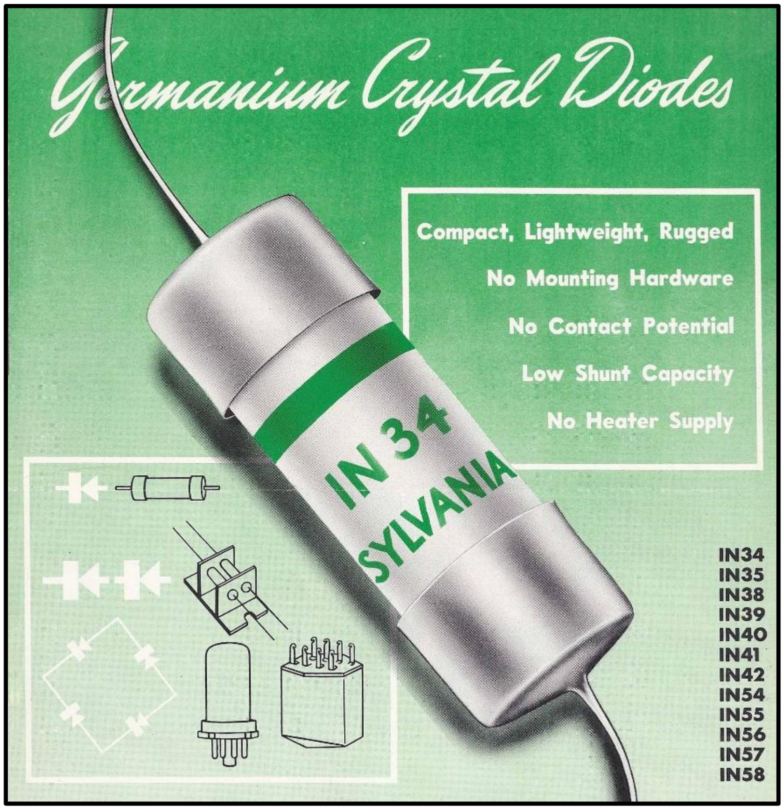


As described in the Pickard patent, the crystal detector required manual adjustment of a mechanical wire point ("cat whisker") that was pressed down to contact the crystal, and then was adjusted to find a "hot spot" on the crystal that provided the best radio wave detection.



WESTERN ELECTRIC – 1930s/1940s

From the 1920s until the early 1940s, semiconductor use appears to have been quite limited and the crystal detector (also known as crystal diode or crystal rectifier) was largely relegated to laboratory research or hobby radios. The Bell System conducted research in the 1930s which confirmed that silicon crystals performed well at high frequencies. Shown above is the cover of a 1946 Western Electric publication highlighting point contact diodes, beginning with experimental units in 1934. When the U.S. entered WWII in 1941, there was an immediate need for large quantities of reliable silicon crystal diodes for use in high frequency radar systems. Production of these devices started in early 1942 and was ramped up to produce over 1,000,000 units by August 1945. The cartridge unit shown above in the cover photo (middle row, far left - 1942) depicts this device type. These were labeled 1N21 or similar.



SYLVANIA – 1940s

The Bell System (including Bell Labs and Western Electric) was the primary research and manufacturing organization responsible for most of the silicon crystal diode activities in the 1930s and early 1940s. Several other U.S. companies were involved too, including Sylvania and General Electric, for conducting research as well as production of devices. Also, research into the properties of another semiconductor material, germanium, began in earnest in the early 1940s. Shown above is the cover of a late 1940s advertising brochure from Sylvania which presented the performance characteristics of a complete line of point contact germanium crystal diodes. Sylvania is credited with introducing the first commercial germanium diode, the 1N34, in 1946. The other model numbers (listed above) followed in rapid succession. The 1N34 has the distinction of being the germanium semiconductor device type with the longest continuous production history – that is to say, this popular device has been copied and manufactured by numerous other companies and is still in production today (although in different case styles). By the early 1950s, other U.S. companies were actively engaged in the manufacture of germanium diodes, including CBS, Hughes, National Union, Radio Receptor, Raytheon, RCA and Transitron.

PRESS RELEASE from BELL TELEPHONE LABORATORIES
463 West Street, New York 14 - CHelsea 3-1000

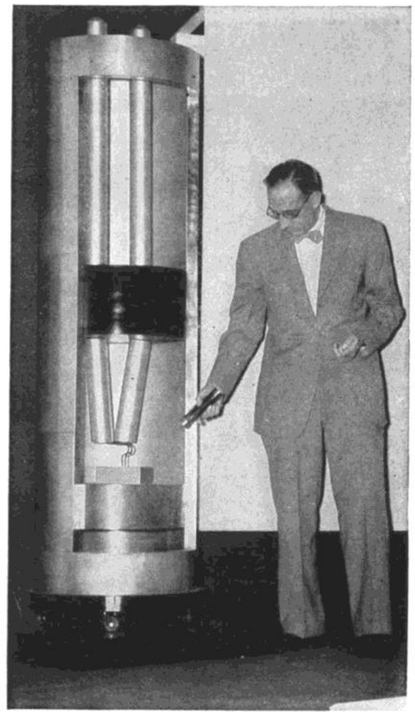
Release: A.M. Papers of Thursday, July 1, 1948.

An amazingly simple device, capable of performing efficiently nearly all the functions of an ordinary vacuum tube, was demonstrated for the first time yesterday at Bell Telephone Laboratories where it was invented.

The whole apparatus is housed in a tiny cylinder less than an inch long. It will serve as an amplifier or an oscillator -- yet it bears almost no resemblance to the vacuum tube now used to do these basic jobs. It has no vacuum, no glass envelope, no grid, no plate, no cathode and therefore no warm-up delay.

While many scientists and engineers have been associated with the work during the project, key investigations which brought the Transistor to reality were carried out by Dr. John Bardeen and Dr. Walter H. Brattain. The general research program leading to the Transistor was initiated and directed by Dr. William Shockley. All three are members of the Bell Telephone Laboratories technical staff.

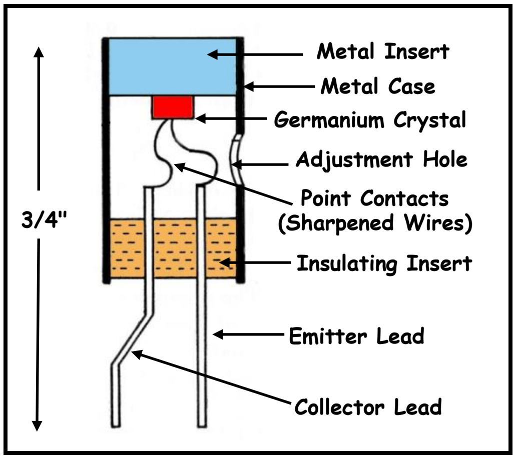
Edited Sections of the First Transistor Press Announcement



At the press demonstration in 1948 at which the invention of the transistor was announced, Dr. Bown explained its characteristics and operation by means of a greatly enlarged cut-away model of the point contact transistor.

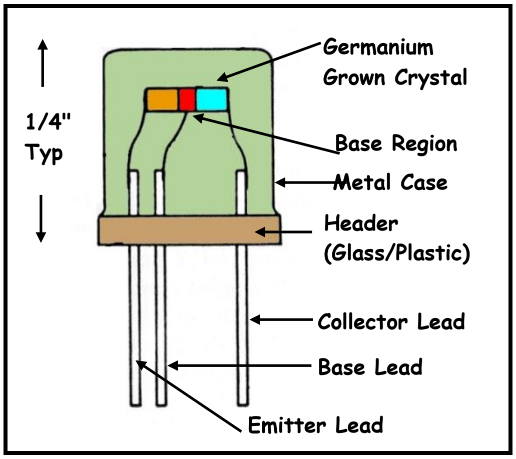
THE FIRST TRANSISTORS – 1940s

The invention of the transistor occurred in December 1947, and is credited to the Bell Labs semiconductor group of Walter Brattain, John Bardeen and William Shockley (see the references section for additional information). The first public announcement of the invention of the transistor was conducted at a press conference held by Bell Labs on June 30, 1948 in New York. Dr. Ralph Bown, the Bell Labs Director of Research, was one of the speakers at the announcement and demonstrated several applications of the new technology to the reporters in attendance. Dr. Bown also described the internal structure of this first transistor type (known as point contact) by referring to an eight-foot cutaway model of device – see the photo at upper right. The scan at above left illustrates edited sections of the Bell Labs press release describing the conference and the new Transistor. Western Electric began early production of point contact cartridge transistors in the late 1940s. The Bell System conducted public seminars for electronics companies interested in gaining transistor expertise, and by the mid-1950s many companies were producing large quantities of different germanium transistor types.



Cartridge Type Point Contact Transistor

Shown at left is a block diagram of one of the first types of point contact transistor - this cartridge type was first developed at Bell Labs in the late 1940s. A metal cartridge-style shell was used as the case for these early devices, which required very complex mechanical assembly and adjustment processes. Yields were low and there was little uniformity. Best performance was obtained when the two metal wire point contacts were physically adjusted through a hole in the side of the case. Other case styles, including plastic epoxy, were also used for early point contact transistors.

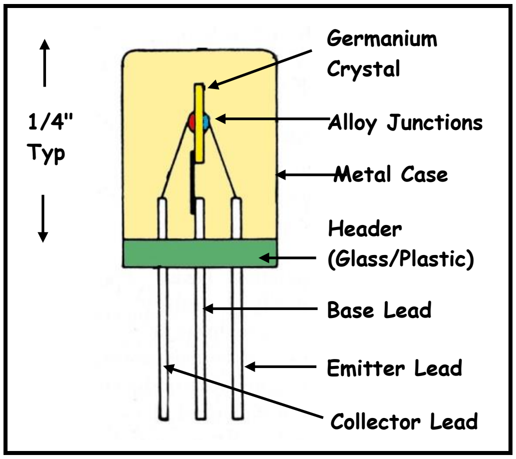


Grown Junction Transistor

Shown at left is a block diagram of the first style of grown junction transistor. The small germanium crystal was usually N-type, with a P-type impurity added for the base junction region; this results in an NPN transistor, which represents the primary form of this device type. The initial manufacturing processes were difficult to control (variable thickness of the impurity layer), and performance of the early devices was poor at high frequencies. GE developed an improved process, known as rate-grown, which overcame many of the early device limitations.

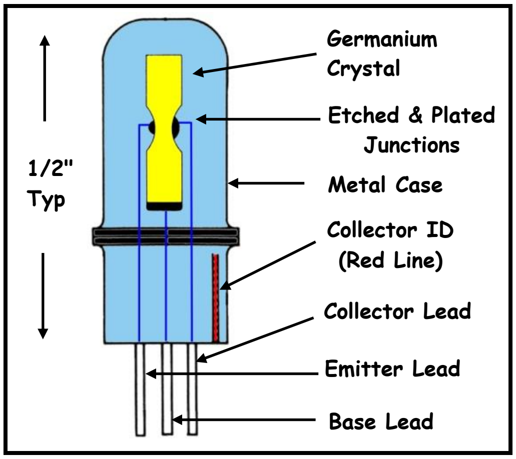
EARLY TRANSISTOR TYPES – 1940s/1950s

In 1953, over 1,000,000 transistors were manufactured; in 1955, 3,500,000 transistors were manufactured, and by 1957, annual production had increased to 29,000,000 units. During this first decade of transistor history, a variety of different device types were developed and this diversity of technologies has led to a rich historical backdrop of early transistor shapes, sizes, specifications and circuits. Shown above are details of the first transistor type (point contact) and the second transistor type (grown junction), both types initially developed at Bell Labs. Example model numbers of the point contact transistor include the 2N21, 2N32, and 2N110, and of the grown junction type include the 2N27, 2N29, 2N167/2N169 and the 900 series (silicon).



Alloy Junction Transistor

Shown at left is a block diagram of a typical alloy junction transistor, as developed in the 1950s. The transistor junctions were formed by alloying two small pellets onto either side of the germanium crystal. The collector pellet or "dot" was usually larger than the emitter, in order to accommodate higher power output. Both PNP and NPN transistors could be made using this process, although PNP was more common. The alloy manufacturing process continued to be used into the 1960s, and became the most widespread germanium transistor technology.



Surface Barrier Transistor

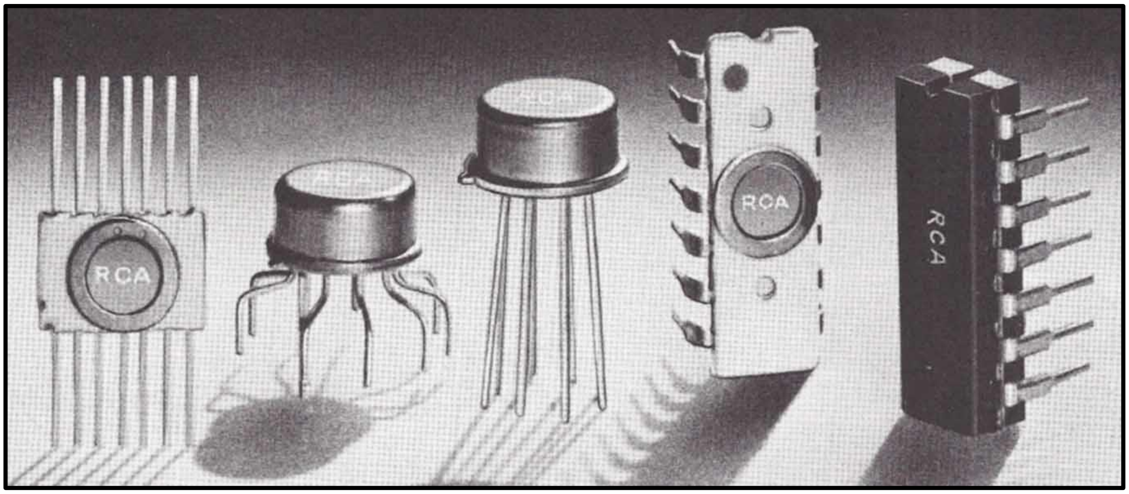
Shown at left is a block diagram for the SBT transistor type. Note the relatively thin base region of the germanium crystal, located between the collector and emitter junctions. The electro-mechanical etching process used to manufacture the SBT could be precisely controlled to produce a very thin base region, resulting in devices with excellent high frequency performance. Philco invented the SBT type and was the prime supplier – Sprague became a major second source supplier in the late 1950s. SBTs found widespread use in digital computers and radios.

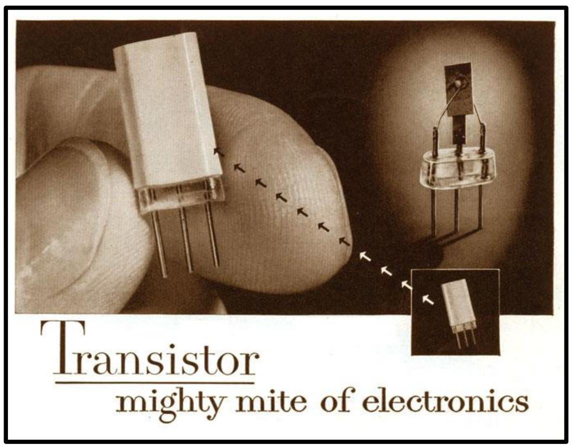
EARLY TRANSISTOR TYPES – 1950s/1960s

The alloy junction transistor technology was developed by GE/RCA in the early 1950s, and provided a number of advantages over either the point contact or the grown junction transistor, including consistency of manufacturing processes and resultant performance. Example model numbers include the CK718, 2N35, 2N107, 2N109 and 2N404. The surface barrier transistor type was developed in the early 1950s and offered the best consistent high frequency performance of the early transistor types. Example model numbers of this type (and the related MADT type) include the 2N128, 2N240, and 2N1500. Shown above are details of alloy junction and surface barrier types. Silicon transistors became commercially available in the mid-1950s, and additional new technologies were developed into the early 1960s including drift, mesa, and planar. These later transistor types are discussed in the following pages, and this kit contains examples of all these historic transistor technologies.

RAYTHEON – 1950s/1960s

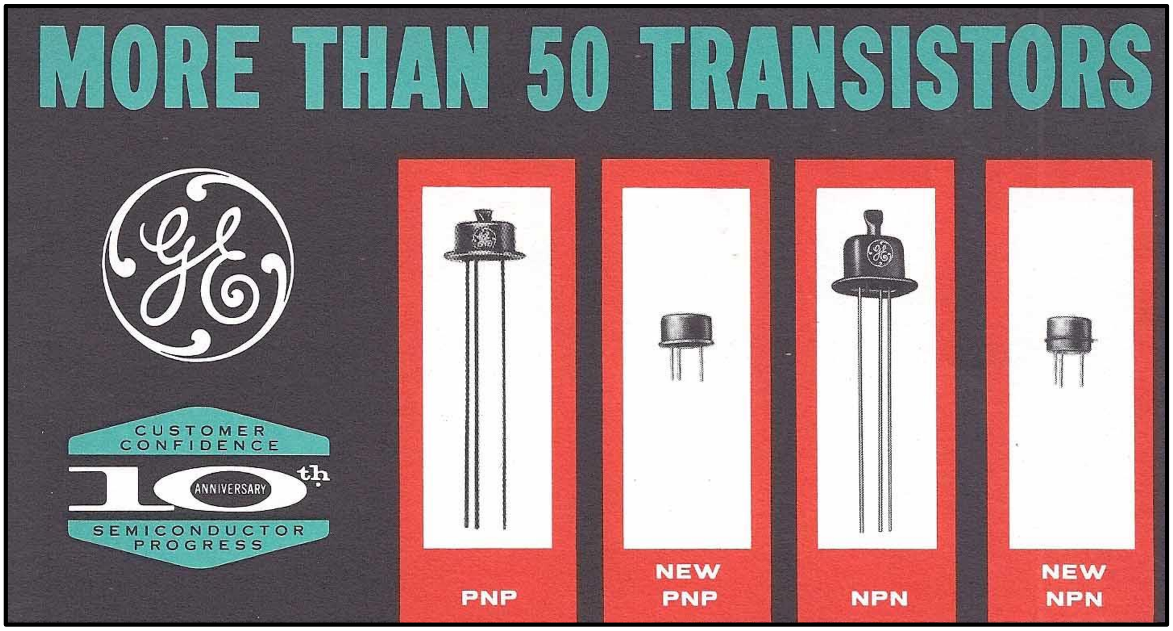
Raytheon was the first large scale manufacturer of commercial germanium transistors, beginning in 1952 with the famous CK718. Raytheon had been the 1940s/1950s leader in miniature vacuum tube production designed for hearing aids, and moved quickly to protect this market during the transition from tubes to transistors. The CK718 was sold only to hearing aid manufacturers, such as Acousticon, Beltone, Sonotone and Zenith. This was a very large market and Raytheon ramped up production to thousands of CK718 units a month by late 1952. As shown in the advertising paperweight above left, Raytheon had produced over 1,000,000 germanium transistors by 1954, which was more than all other transistor companies combined at the time. The production yield was poor for these early transistors, and Raytheon implemented a major program to market the production "fallouts" from the CK718 line as CK721/CK722 hobbyist transistors. The scan above right illustrates sections of a February 1953 ad from the Radio and Television News magazine stating "For the first time in history, Germanium Junction Transistors are commercially available...". The CK722, dropping in price from over $20 in early 1953 to $1 in 1955, is likely the best remembered commercial germanium transistor. Thousands of young hobbyists and engineers from the 1950s bought the Raytheon CK722 as their first transistor and spent many happy hours learning about this new technology and listening to their first home built transistor radio. The Raytheon CK722 continued to be available into the mid-1960s. Raytheon did not maintain its industry leadership position when silicon transistors became widely available in the 1960s.



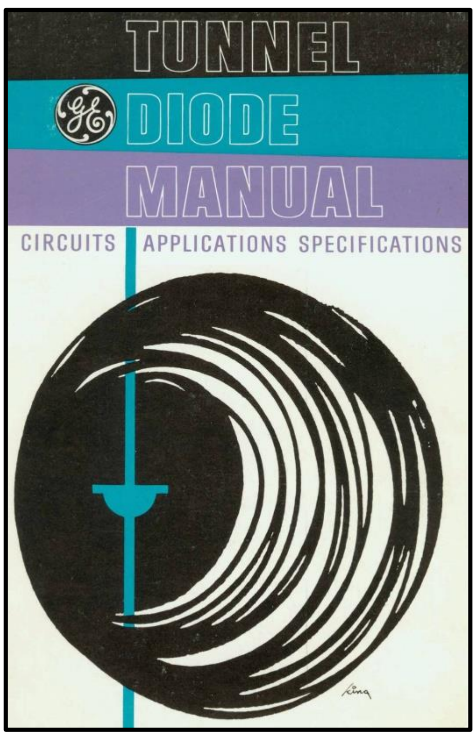


RCA – 1950s/1970s

Second only to Western Electric in the number of early 1950s transistor patents, RCA was an industry leader for two decades in the development and manufacture of semiconductors. Shown at lower left is a 1953 RCA photo of a giant classroom model of a point contact transistor used to train new employees in construction details of newly developed devices such as the 2N32 and 2N33. RCA was credited with the development of alloy junction transistor technology and the 1953 ad at left provides an interior view of this technology used for early junction transistors such as the 2N34 and 2N35. RCA was the leader in 1960s and 1970s CMOS integrated circuits, and the various case styles used for these devices is illustrated above in a mid-1960s RCA catalog photo. Unlike most other 1950s germanium transistor companies, RCA successfully transitioned to silicon technology for transistors, integrated circuits and microprocessors in the 1960s and 1970s.



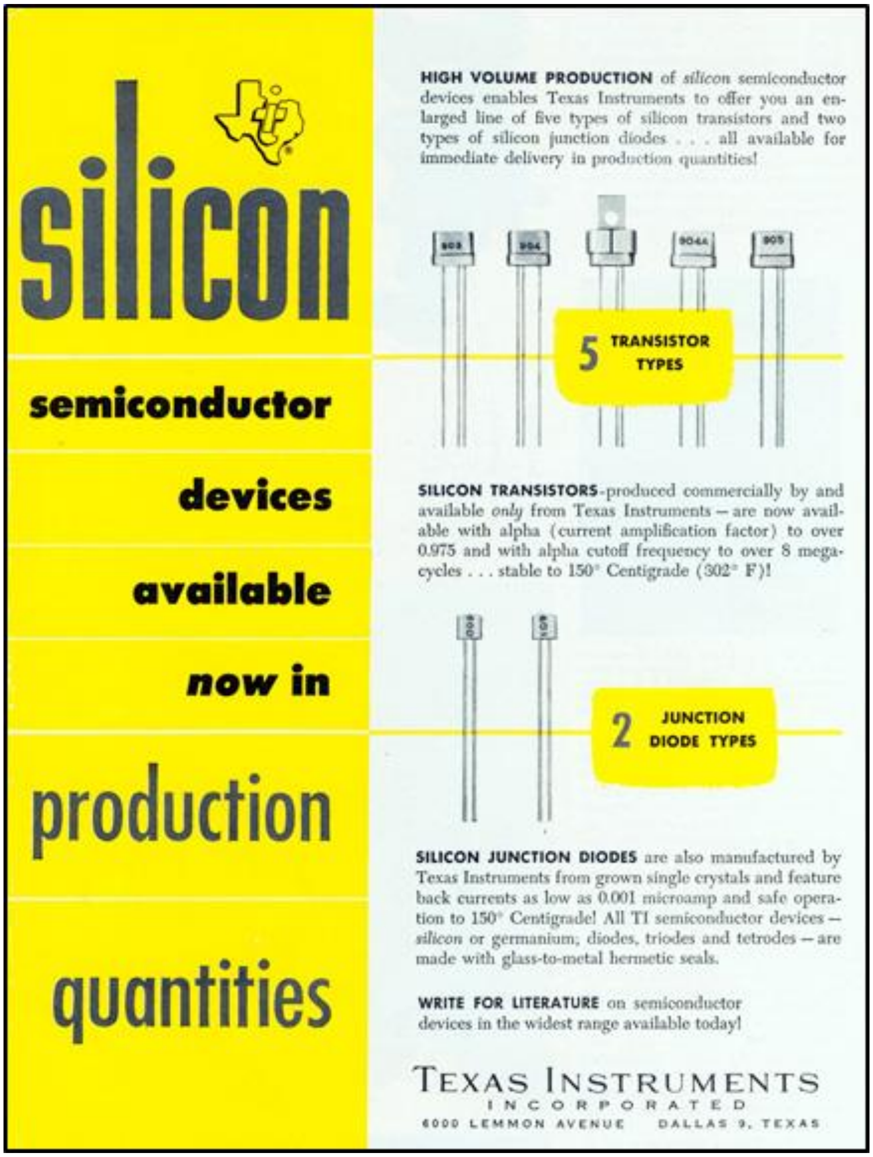
GENERAL ELECTRIC – 1950s/1960s



GE began the large scale commercial production of germanium transistors in the mid-1950s, and was a major manufacturer of alloy and grown junction devices throughout the 1960s, when these types were largely obsoleted. Shown above is a section of a mid 1950s ad illustrating various GE transistor types. GE maintained an active research and development organization, and was the leading manufacturer during this timeframe of several unique semiconductor device types, including unijunction transistors, SCRs and tunnel diodes. Shown at left is the cover of the 1961 GE Tunnel Diode Manual, which contains device specifications, theory of operation and suggested circuits. GE did make a successful transition from germanium transistor technology to silicon types and was a major supplier of commercial silicon transistors into the 1970s, including low cost plastic/epoxy general purpose small signal and medium power devices.

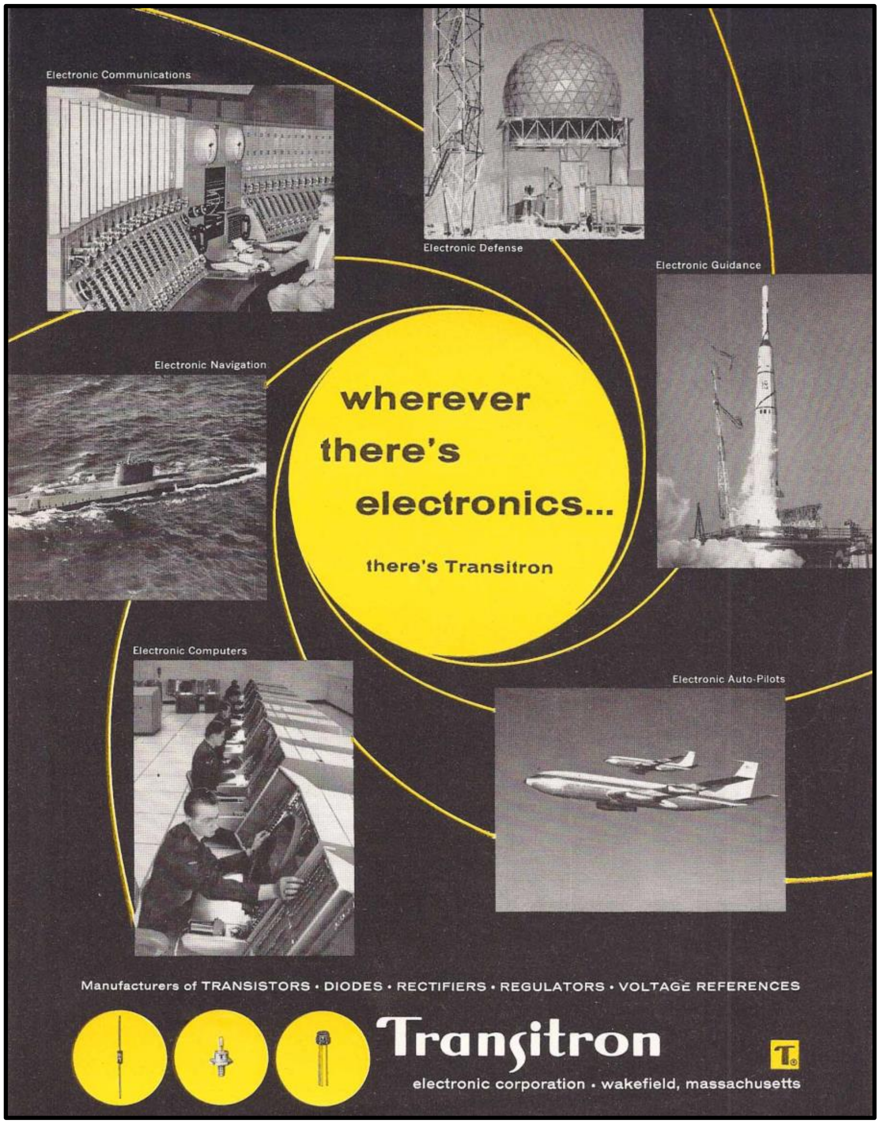
PHILCO – 1950s/1960s

Philco was an early manufacturer of transistors, starting in 1953/54 with the famous Surface Barrier Transistor (SBT). This type used a unique electrochemical etching manufacturing process that produced an extremely thin germanium base layer, which in turn allowed the transistor to operate at very high frequencies (20 to 30 MHZ). These early high frequency devices were sold in large quantities and a FY-1954 US Army Signal Corps contract was awarded to Philco to help fund SBT development for the military (see above 1956 Philco ad). SBTs were used in radios, digital computers and early satellites. Further SBT improvements led to the development of germanium MAT/MADT transistor types and silicon SAT/SADT/SPAT transistor types.



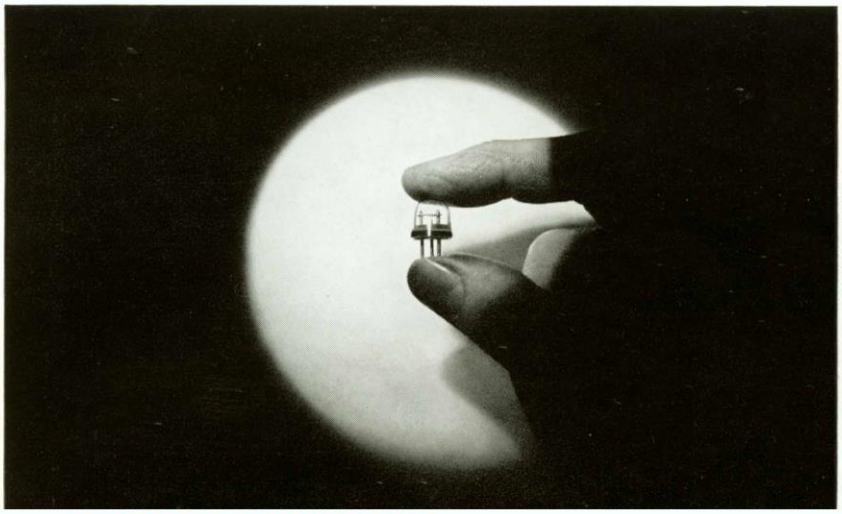
TEXAS INSTRUMENTS – 1950s/1960s

The above Nov 1954 ad for the TI 900 series of grown junction silicon transistors documents an important milestone in semiconductor history – the first commercially available silicon transistors. Silicon devices function at much higher temperatures than germanium devices, and the military was willing to pay premium prices (over $100 each) for early silicon transistors. Texas Instruments became an industry leader in silicon technology with these devices, and manufactured these first silicon transistor types in very large quantities into the 1960s, when more modern silicon technologies (most notably mesa and planar) were developed.



TRANSITRON – 1950s/1960s

In 1957, Transitron began the commercial production of silicon transistors. This was a natural fit for the existing Transitron product lines, which included successful product types such as silicon rectifiers and germanium diodes. Building on the highly profitable military and industrial market for early silicon transistors, Transitron was one of the first companies to produce "second source" device types initially developed by TI. Transitron devices were used extensively for military applications, including missiles, submarines, computers, navigation systems, radar and aircraft. The early 1960s ad shown above illustrates the broad range of military applications for Transitron transistors, diodes, rectifiers, regulators, and voltage references.



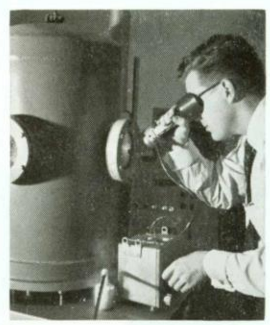
THE TRANSISTOR
that smashed a frequency barrier

A new transistor invented at Bell Telephone Laboratories can provide broadband, high-frequency amplification never before possible with transistors. The big leap in frequency is made possible by a diffusion process that earlier enabled Laboratories scientists to create the Bell Solar Battery.

This transistor is a three-layer semiconductor "sandwich." High-frequency operation is obtained by making the central layer exceedingly thin. This had previously been difficult to do economically.

The new diffusion process, however, easily produces microscopic layers of controllable thickness. Thus it opens the way to the broad application of high-frequency transistors for use in telephony, FM, TV, guided missiles, electronic brains and computers.

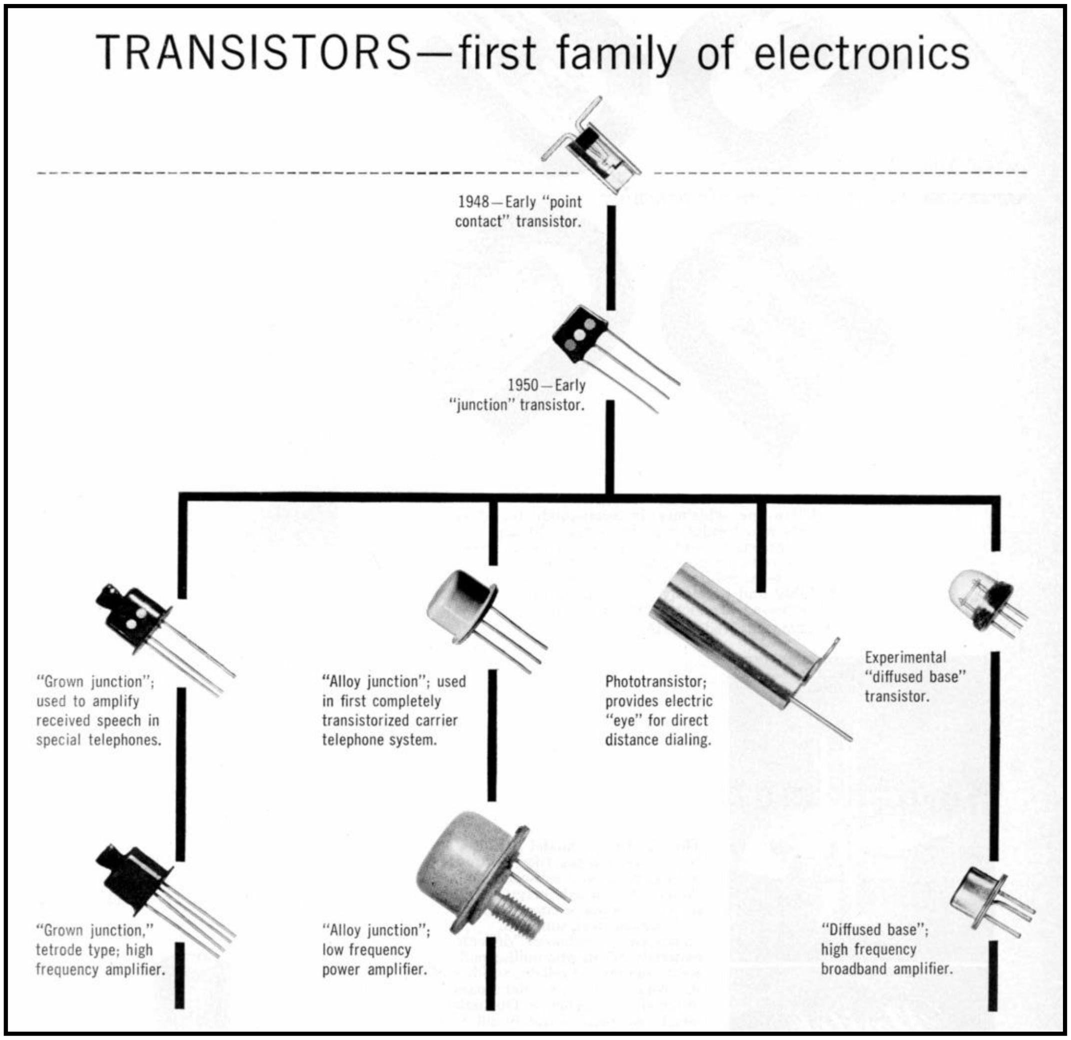
The new transistor shows once again how Bell Laboratories creates significant advances and then develops them into ever more useful tools for telephony and the nation.



Scientist checks temperature as arsenic vapor diffuses into germanium, creating 4/100,000-in. layer.

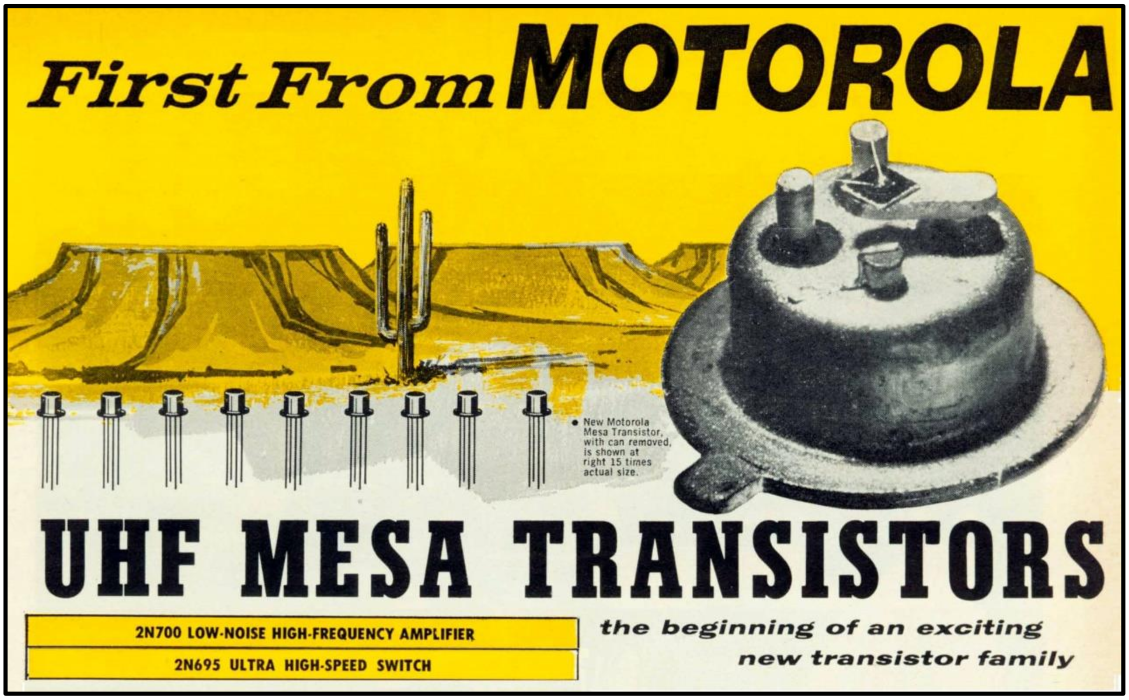
DIFFUSION TECHNOLOGY DEVELOPED AT BELL LABS - 1950s

A major breakthrough in early transistor technology was accomplished at Bell Labs in 1954/55 with the development of diffused base transistors. Using chemical diffusion to fabricate a very thin transistor base layer (50 millionths of an inch), high operating frequencies could be achieved reliably. High frequency capability, low power requirements and the enhanced reliability of diffused transistors meant that these devices were better suited than existing mid-1950s transistor technologies for critical applications such as the Nike Zeus missile system and Vanguard/Explorer satellites. Diffusion technology was applied to both silicon and germanium devices and was a major contribution leading to the development of integrated circuits. The above ad highlighting the development of diffusion technology appeared in the Feb 1956 issue of the Bells Labs Record magazine.



BELL SYSTEM TRANSISTOR FAMILY TREE – 1940s/1950s

This August 1956 Bell Labs ad reads in part: "In 1948, Bell scientists announced their invention of the transistor – a tiny device able to amplify signals a hundred thousand times using a small fraction of the power of an electron tube. From the original "point contact" transistor has grown a distinguished family of immense usefulness to electronics. Some of its leading members are shown here, in approximate actual size, with their scientific names." In fact, by 1956, Western Electric was manufacturing many of these types in large quantities for use in Bell System equipment, and was also supplying experimental and early production prototypes of the more advanced types for military and satellite use. Western Electric was known for manufacturing excellence, and remaining devices from this timeframe are often fully functional.



The Motorola Mesa Transistor

We believe the Motorola Mesa units are the most advanced transistor devices in the semiconductor art. Their adaptability to miniaturization of complete electronic systems helps answer the need for reduction in size and weight of electronic devices for aircraft, missiles, and rockets.

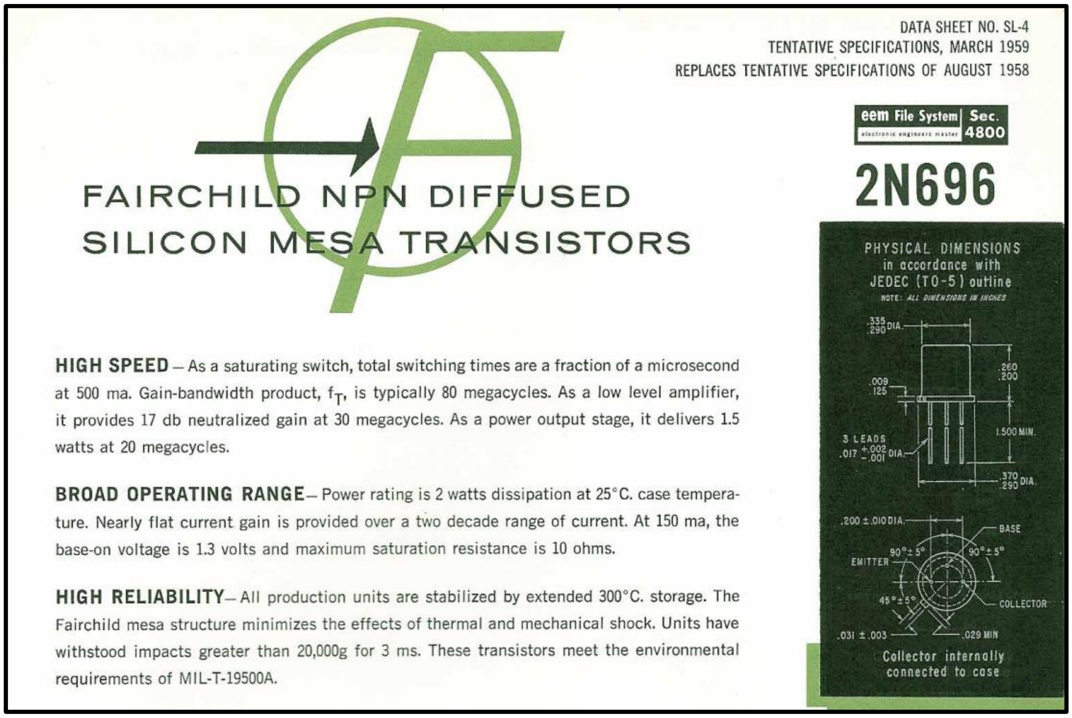
We also believe the Motorola Mesa is the most precise semiconductor available today, and the smallest, mass-produced transistor manufactured.

The active region of Mesa transistors can be covered by an area less than the cross-sectional area of a human hair, yet they are manufactured by methods so precise that they are turned out on a production line basis to meet rigid standards of reliability. Mesa transistors are produced in meticulously clean laboratories having closely regulated temperature and humidity. Production personnel wear special uniforms to minimize dust contamination.

Extension of the Mesa design to higher powers and higher frequencies will be introduced in the near future. Soon there will be an entire family of the highly-precisioned Mesa transistors, devices that will open whole new areas of transistor application.

MOTOROLA MESA – 1950s/1960s

Motorola's first large scale commercial success in transistor production was the 2N176 germanium power transistor, which, beginning in 1957, was used as the audio output amplifier in millions of 1950s/1960s automobile radios. Motorola followed this success by becoming the volume leader in commercial germanium mesa transistors – the 1958 announcement shown above introduced the first Motorola mesa types, with the commitment: "the beginning of an exciting new transistor family". The 1959 Motorola Annual Report (section at left) emphasizes the company's intention for continued development and mass production of mesa transistors. Motorola produced millions of these germanium devices into the 1960s and simultaneously transitioned to the large scale production of new silicon types and ICs.



DATA SHEET NO. SL-4
TENTATIVE SPECIFICATIONS, MARCH 1959
REPLACES TENTATIVE SPECIFICATIONS OF AUGUST 1958

eem File System Sec. 4800

2N696

FAIRCHILD NPN DIFFUSED SILICON MESA TRANSISTORS

HIGH SPEED – As a saturating switch, total switching times are a fraction of a microsecond at 500 ma. Gain-bandwidth product, f_T, is typically 80 megacycles. As a low level amplifier, it provides 17 db neutralized gain at 30 megacycles. As a power output stage, it delivers 1.5 watts at 20 megacycles.

BROAD OPERATING RANGE – Power rating is 2 watts dissipation at 25°C. case temperature. Nearly flat current gain is provided over a two decade range of current. At 150 ma, the base-on voltage is 1.3 volts and maximum saturation resistance is 10 ohms.

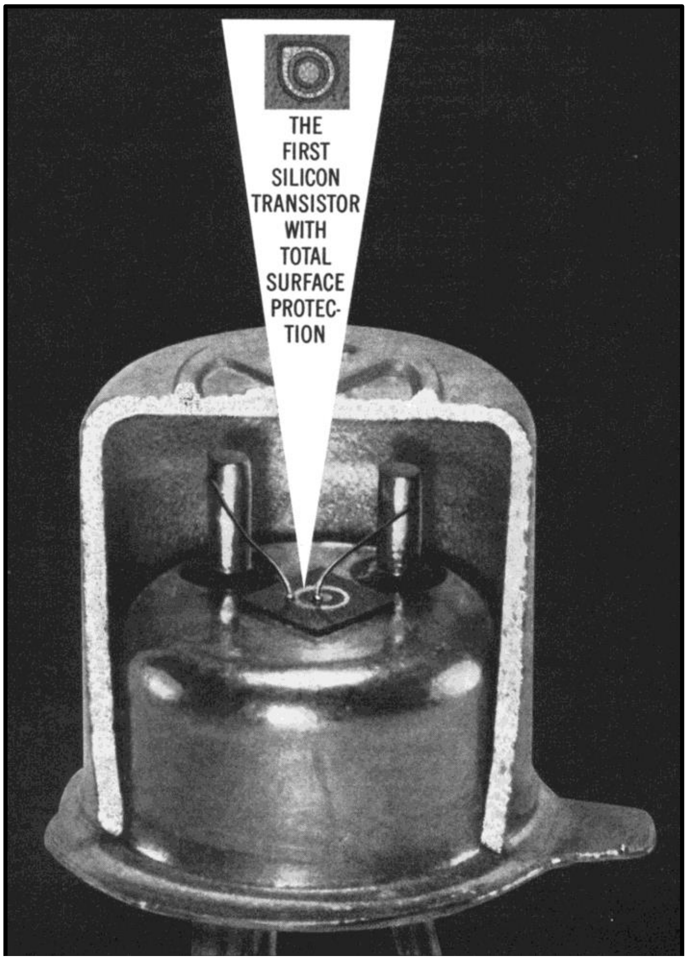
HIGH RELIABILITY – All production units are stabilized by extended 300°C. storage. The Fairchild mesa structure minimizes the effects of thermal and mechanical shock. Units have withstood impacts greater than 20,000g for 3 ms. These transistors meet the environmental requirements of MIL-T-19500A.

FAIRCHILD SEMICONDUCTOR was organized as a corporation in October 1957 by a group of scientists and engineers with the financial backing of Fairchild Camera and Instrument Corporation, Syosset, Long Island, New York. The initial objective of the Mountain View, California company was to develop a new process in solid state diffusion and adapt it to volume production of advanced silicon semiconductor devices.

At WESCON, in August of 1958, the new company introduced the industry's first commercially available NPN double-diffused silicon "mesa" transistor. Within a short time the "mesa" transistor became the standard among the semiconductor manufacturers and Fairchild was recognized as the "state-of-the-art" leader in the industry.

FAIRCHILD MESA - 1950s/1960s

Mesa transistor technology was the best available in the late 1950s, and Fairchild Semiconductor, founded by a group of scientists and engineers who resigned as a group from the Shockley Transistor Corporation, soon was established as the leader in producing silicon mesa transistors. These first Fairchild types were designated 2N696 and 2N697, and were introduced at the 1958 WESCON show. The text at left is a section of a late 1950s Fairchild brochure and the above scan is a section of a 1959 Fairchild spec sheet for the 2N696. The reliability and switching speed of Fairchild mesa transistors were major factors in the company's early success.



FAIRCHILD PLANAR - 1960s

According to an early 1960s Fairchild brochure: "With the introduction of the Planar transistor at I.R.E. in March of 1960, Fairchild Semiconductor achieved what has been called the single most important development in semiconductor technology since the invention of the transistor". Shown at left and below left are sections of a Fairchild January 1961 ad describing the technical aspects and benefits of the "PLANAR STRUCTURE". This technology was rapidly adopted by most other transistor manufacturers and has become the standard structure for modern semiconductor devices. The planar process was also an important technology for the commercial development of ICs, which appeared on the market in this same timeframe.

A MAJOR CAUSE OF FAILURE ELIMINATED BY BUILDING A TRANSISTOR INSIDE ITS OWN SHELL

Most transistor failure is not abrupt. It consists of surface changes causing a gradual shift in parameters. While the whole industry has sought answers, Fairchild has followed a research and development course of its own. We can now reveal a unique solution.

Called "PLANAR STRUCTURE," this Fairchild answer uses a passivated surface — a hard, passive coating of silicon oxide — not new in theory, but new in the way it is done. Fairchild oxidizes the surface first. Then the transistor's junctions are diffused **under the oxide.** Contaminants cannot reach them during process or after. Result: performance is unchanged by time, use, environment or even exposure to foreign matter.

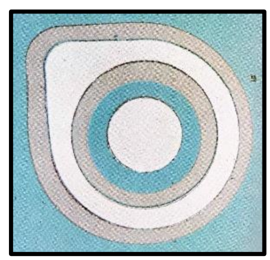
Planar is the answer: for system reliability where thousands of transistors must all be operative at an instant — for fast, simple circuits tightly packed in minimum space — for carefully matched pairs, triplets or quads that must stay exactly in balance — and for leakage reduction by a factor of one hundred. And planar is the answer even for simpler circuit requirements where high assurance has a value.

These advantages apply to planar diodes,too. Of course, Fairchild planar silicon transistors and diodes are available in production quantities. A new 12-page brochure explains the process and results more fully. May we send you a copy?

A wholly owned subsidiary of Fairchild Camera and Instrument Corp.

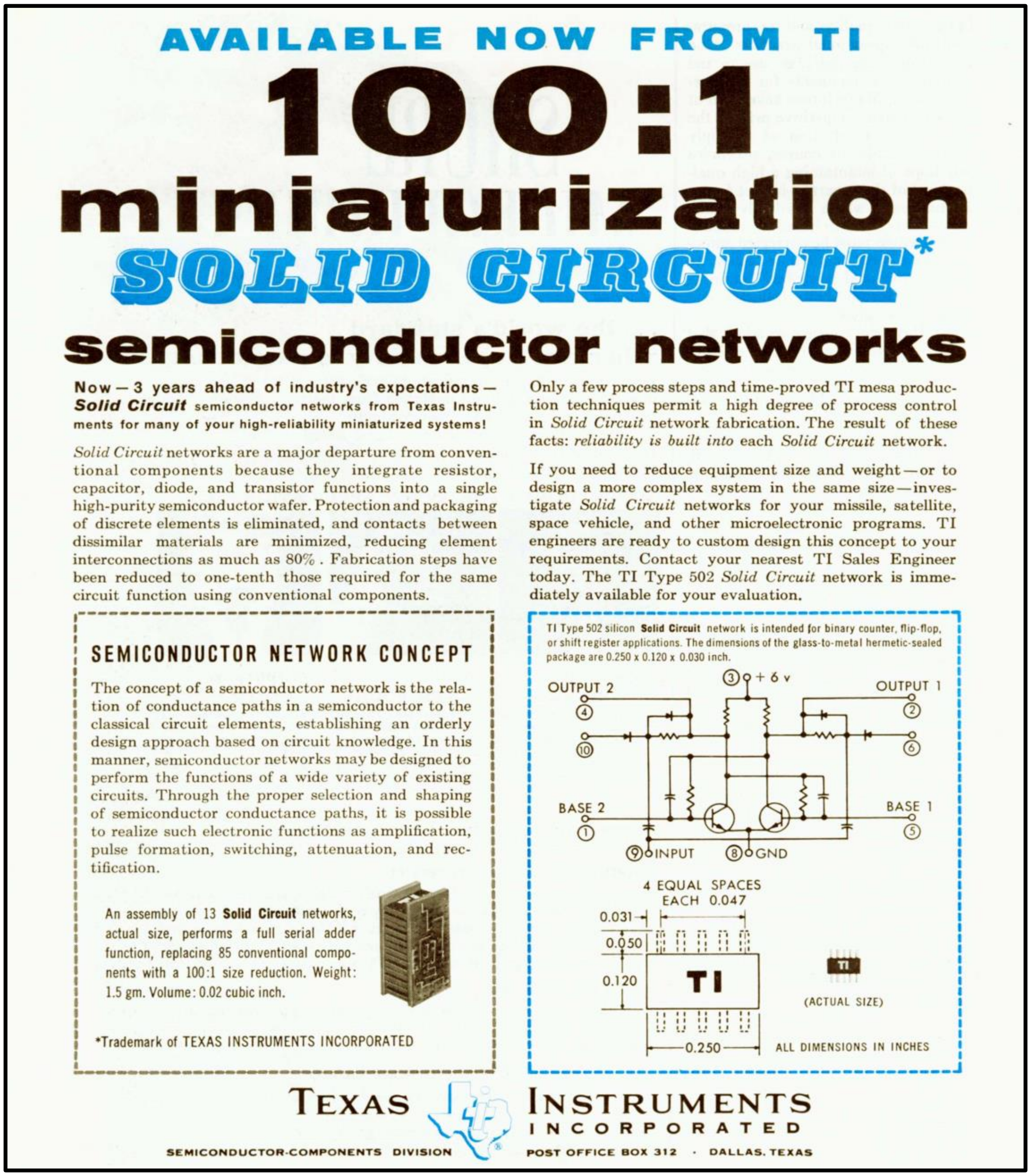
FAIRCHILD SEMICONDUCTOR CORPORATION

545 WHISMAN RD. • MOUNTAIN VIEW, CALIF. • YOrkshire 8-8161



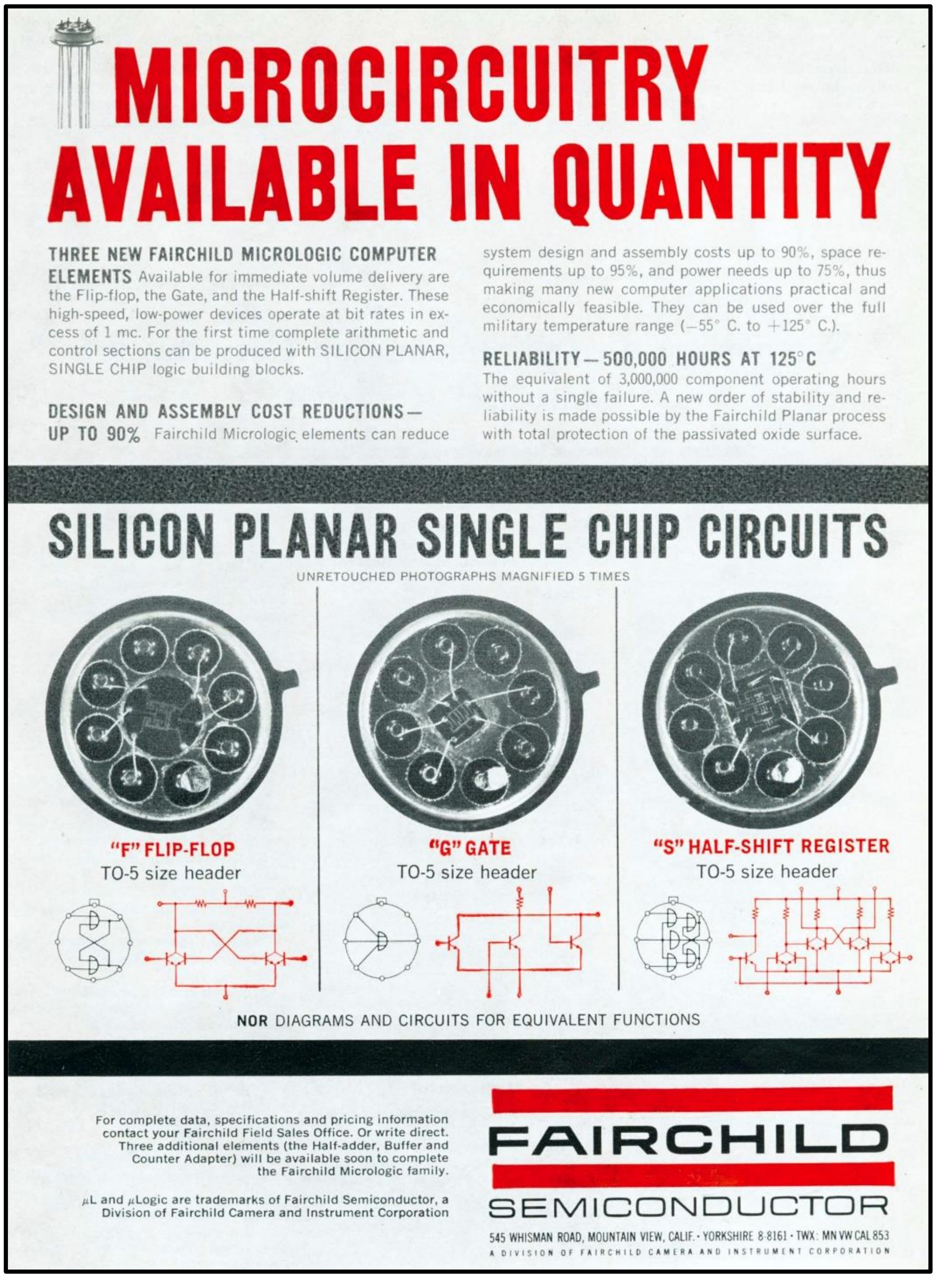
PLANAR STRUCTURE

The above 1959 photo is from a Fairchild publication with the text: "The first planar transistor - A teardrop device which marked the beginning of an industry revolution."



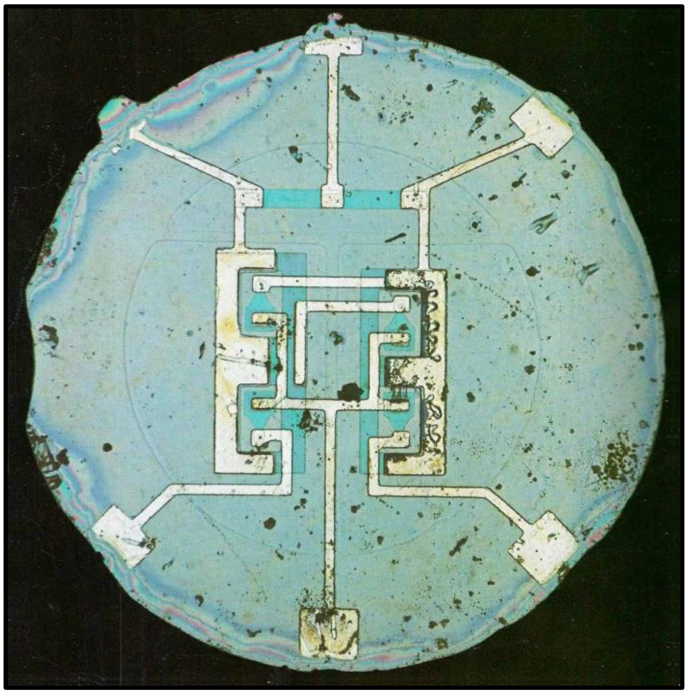
TEXAS INSTRUMENTS SOLID CIRCUIT IC – 1960s

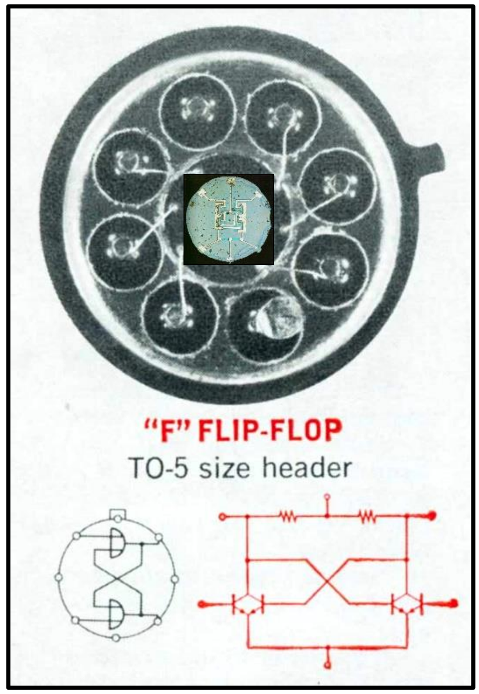
Texas Instruments and Fairchild are credited with the developing the first commercial integrated circuits. The above May 1960 ad documents early TI ICs, which consisted of multiple transistors, resistors, capacitors and interconnections formed on a single silicon chip. TI designated this line of ICs as ***Solid Circuit*** semiconductor networks and implemented various digital logic functions with these devices. Shown above is the schematic for the digital circuit implemented with the TI type 502 ***Solid Circuit.***



FAIRCHILD uLOGIC RTL IC – 1960s

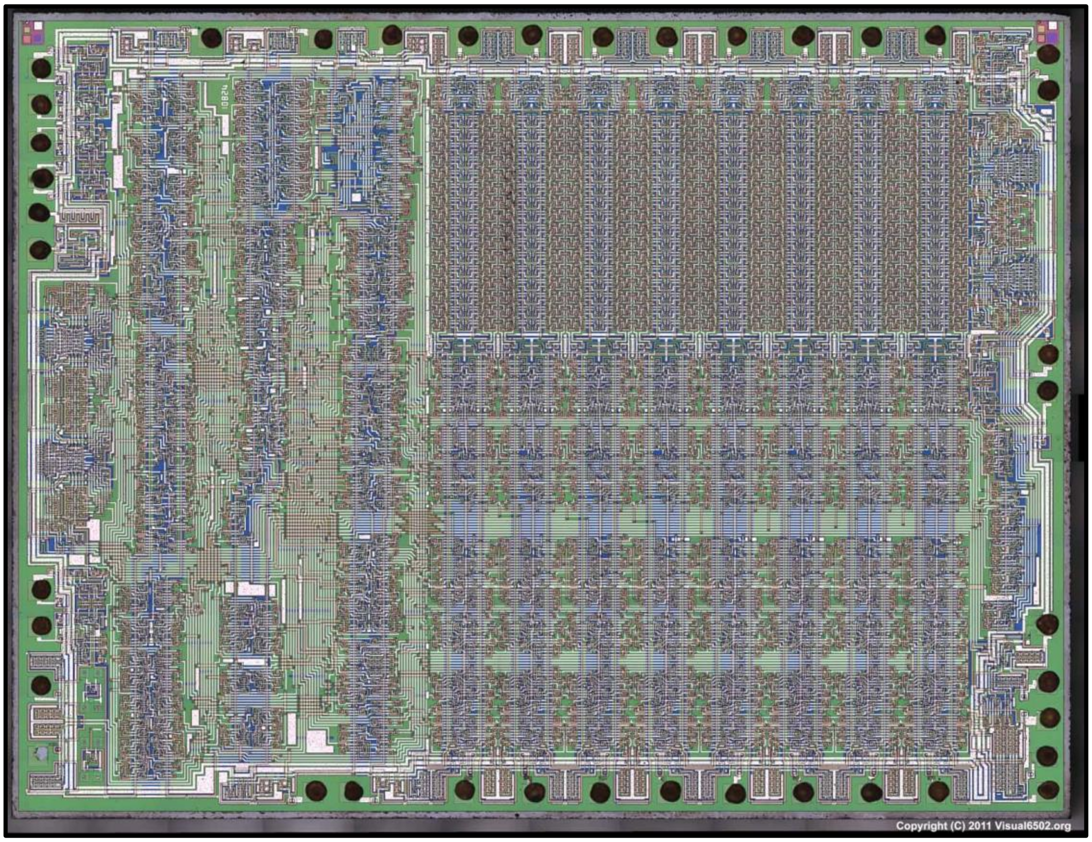
The above I.R.E. ad from October 1961 documents the first commercially available Fairchild ICs. These first ICs were an important milestone in semiconductor development, and implemented basic digital logic circuits using RTL or Resistor-Transistor-Logic, which had been developed for digital computers in the 1950s using discrete components connected together on a printed circuit board. Fairchild designated this first line of ICs as the Micrologic family (also known as uL and uLogic).





FAIRCHILD uLOGIC RTL IC – 1960s

Shown above left is an enlarged view of the silicon chip for the 1961 Fairchild RTL Flip-Flop integrated circuit (this photo is from a Fairchild marketing brochure "A Solid State of Progress"). At right is a section of the 1961 Fairchild ad shown on the previous page, with the image of the chip overlaid to show approximate size and location of the chip in the TO-5 package. These first ICs contained only a few transistors - the RTL IC above uses a total of four transistors to implement a basic digital Flip-Flop function. (See the schematic in the ad above right). The four transistor elements, the two resistors and the interconnections can be seen quite clearly in the enlarged view of the chip. For example, the two resistors shown in the schematic can be seen in the enlarged chip view as light blue bars across the upper center of the chip, with the interconnections clearly visible. This first IC technology, developed in the early to mid-1960s, is often classified as "small scale integration", which refers to the relatively small number of transistors contained in the IC. Following the lead of TI and Fairchild, other semiconductor manufacturers soon began commercial production of integrated circuits, including established transistor companies such as Sylvania, Motorola, GE, RCA, and Transitron, as well as newly formed companies such as Signetics and Siliconix. The 1960s saw widespread use of the new IC technology in military, industrial and consumer electronics – both digital and analog IC types were produced in very large quantities.



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RCA 1802 MICROPROCESSOR – 1970s

By the mid-1970s, the level of integration possible with IC technology had progressed by several orders of magnitude beyond the early 1960s ICs, and chips with thousands of transistors were commercially available. This level of integration supported the development of the first microprocessor ICs, including the Intel 4004, 8008 and 8080, the TI TMS 1000 and the RCA 1802, all introduced in the 1970s. An enlarged image of the RCA 1802 chip is shown above, and the level of complexity required to produce a device with approximately 2500 transistors is striking. Just as the first transistors from the 1950s provided the advanced technology that enabled the early U.S. satellite program, these first microprocessors from the 1970s provided the advanced technology that enabled more ambitious space programs – for example, the Galileo spacecraft, which travelled successfully to Jupiter and transmitted back spectacular color photographs and other valuable scientific data, was instrumented with 17 RCA 1802 microprocessors. This unique microprocessor also saw widespread use in early home/hobbyist computers such as the RCA Cosmac VIP.

SUMMARY TIMELINE OF SEMICONDUCTOR HISTORY THROUGH THE 1970s

The preceding material has provided a brief history of early semiconductors, and specifically those types of diodes, transistors and ICs from the 1940s through the 1970s that are the primary interest of this kit. The timeline shown below and on the next pages is intended to highlight the tremendous technological advances made in the semiconductor industry over just a few decades.

1906	Patents by Pickard and Dunwoody for cat whisker crysta1 detectors.
1930s	The Bell System conducted research in the 1930s which confirmed that silicon crystals performed well as radio wave detectors at high frequencies.
1945	When the U.S. entered WWII in 1941, there was an immediate need for large quantities of reliable silicon crystal diodes for use in high frequency radar systems. Production of these devices started at Western Electric in early 1942 and was ramped up to produce over 1,000,000 units by August 1945. These were labeled 1N21 or similar.
1946	Sylvania is credited with introducing the first commercial germanium diode, the 1N34, in 1946. The 1N34 has the distinction of being the germanium semiconductor device type with the longest continuous production history.
1947	The invention of the transistor occurred in December 1947, and is credited to the Bell Labs semiconductor group of Walter Brattain, John Bardeen and William Shockley, all of whom were jointly awarded the 1956 Nobel Prize in Physics "for their researches on semiconductors and their discovery of the transistor effect". (Quote from Nobel.org)
1948	The first public announcement of the invention of the transistor was conducted at a Bell Labs press conference on June 30, 1948 in New York.
1949	Raytheon was the first company to commercially market a transistor, the CK703 point contact device.

SUMMARY TIMELINE OF SEMICONDUCTOR HISTORY THROUGH THE 1970s

Early 1950s	Four different germanium technologies were used for the manufacture of transistors – point contact, grown junction, alloy junction and surface barrier.
	In 1952, Raytheon began high volume commercial production of the CK718 germanium alloy junction hearing aid transistor.
1954	Raytheon led all other manufacturers in volume production of transistors, and commemorated its "Millionth Transistor" on June 23, 1954.
	Other semiconductor companies began high volume production of commercial germanium transistors, including General Electric, Philco, RCA, and Sylvania.
	Texas Instruments announced the first commercially available silicon transistors in late 1954 – these first silicon transistors were designated as the "900" series and were constructed using the grown junction process.
1955	The first diffused based transistors were developed at Bell Labs. The diffusion technology was applied to both silicon and germanium transistors and was a major contribution leading to the development of high frequency transistors and the IC.
	The annual production of all transistors totaled 3,500,000 units, and all but a handful were germanium.
1956	Western Electric started manufacturing ramp up of diffused based transistors for use in Bell System equipment and military applications. Initial diffused types included the GF45011 and the 2N559.
1957	Leo Esaki developed the tunnel diode at Sony. GE would eventually become the largest U.S. manufacturer of this unique device into the 1960s.
1958	Motorola announced commercial availability of germanium diffused base/mesa high frequency transistors, with the intention to expand production of this type. The first Motorola mesa types were 2N695, 2N700 and 2N705.
	Fairchild Semiconductor announced commercial availability of the 2N696/2N697 silicon double-diffused mesa transistor in August 1958.
1959	The annual production of all transistors totaled 29,000,000 units, still mostly germanium but with silicon production ramping up rapidly.

SUMMARY TIMELINE OF SEMICONDUCTOR HISTORY THROUGH THE 1970s

1960	Fairchild announced the availability of the first planar transistor, the 2N1613, at the March 1960 I.R.E. convention. This technology was rapidly adopted by most transistor manufacturers and became the standard structure for modern semiconductor devices, including ICs.
	Texas Instruments announced the availability of the Solid Circuit series of integrated circuits.
1961	Fairchild announced the availability of its first integrated circuit line, the Micrologic family of RTL devices.
Mid 1960s	Silicon transistor technology continued to replace germanium transistor technology for most commercial, industrial and military uses – this trend was based primarily on the excellent performance characteristics, device consistency and manufacturability of silicon epitaxial planar transistors.
	In addition to TI and Fairchild, other companies began to manufacture silicon transistors and ICs, including Signetics, National, Siliconix, GE, RCA, Sylvania, and Motorola. These early ICs implemented basic digital logic functions using a small number of transistors (typically 10 to 20 transistors). Analog ICs also became available, including IC op amp types.
1970s	East coast electronics manufacturers had been responsible for the advances in solid state technology from the 1940s through the late 1950s. By the 1970s, leadership was largely the domain of the many emerging semiconductor companies in Silicon Valley and the more established Fairchild, Texas Instruments and Motorola.
	Advancing IC fabrication technology in the 1970s allowed for a larger scale of integration (more components per chip), and complex ICs such as microprocessors were developed. The first Intel microprocessor, the 4004, was released in Nov 1971 and contained 2300 transistors. Other more complex microprocessor types soon followed. For example, the 1979 Intel 8088, used in the first IBM PC, contained 29,000 transistors. The power of these first microprocessors also set the stage for what is likely the greatest accomplishment of the semiconductor industry, and that is the development of ever more powerful and affordable computers.
2014	Modern microprocessor chips such as the Apple A8 (used in the iPhone 6) and Intel high end processors have two billion+ transistors.

BIBLIOGRAPHY OF EARLY SEMICONDUCTOR RESEARCH AND COLLECTING MATERIAL

This bibliography provides additional information regarding the material that has been presented in your booklet. Included are links to useful websites as well as references to published material such as books, articles and magazines. Many of these publications are no longer in print, but you should be able to find most of them through online auctions or online vintage book sellers. All are highly recommended and provide a comprehensive view of the world of the early semiconductor history. In addition, these references should be very useful as you conduct your own research and begin to expand your own collection of historic semiconductors.

HISTORIC SEMICONDUCTOR WEBSITES

[1] **The Transistor Museum** This is the homepage for our museum. You'll find hundreds of pages of information about early semiconductors, including oral histories, photographs, technical descriptions and reference material. When researching historic semiconductors, be sure to visit the Photogallery for detailed information to aid in building and documenting your collection.

[2] **Transistor History** Developed by Mark PD Burgess, this website has a wealth of information on early transistors from such companies as GE, RCA, Philips, Raytheon, Texas Instruments, Western Electric and others. Mark's indepth research is an invaluable resource for semiconductor historians and collectors.

[3] **Mr. Transistor Semiconductor History** Andrew Wylie has been collecting historic semiconductors, mostly transistors for over 20 years. His website has long been the "go to" resource for excellent technical descriptions and a wonderful photogallery of the "2N" series of early transistors.

[4] **Computer History Museum – The Silicon Engine** Located in the heart of Silicon Valley, the Computer History Museum is the true mecca for all things related to the history of computers, including unmatched research material on semiconductor history. David Laws, the Museum's semiconductor curator, continues to provide otherwise unobtainable research information on historically significant semiconductors. Use the link above for the comprehensive "Silicon Engine".

HISTORIC SEMICONDUCTOR WEBSITES

[5] **RadioMuseum** This German website has developed a massive database of information about radios and related technology, including historic semiconductors. Easily translated by Google and with excellent search tools provided, use this site to further research your collection.

[6] **Vintage Transistors** Jan de Groot has created a highly informative website, loaded with great photos of many early transistors, from different countries including the US, Japan, Europe and Russia. Of special interest is a section called Brand History, illustrating packaging graphics for various companies.

[7] **PBS Transistorized** A very professionally developed website, with lots of useful research data regarding the development of the transistor and a very helpful and extensive index of people and technologies. Also included is a teacher's package of study guides and videos for middle and high school level courses.

[8] **Smithsonian Chip Collection** As you might imagine, the Smithsonian Museum has acquired an impressive collection of historically significant early semiconductor material, including photos, documents and references. You can spend hours at the website shown here and extensive use of the "search" function is recommended.

[9] **Visual6502** This is a very impressive website and organization. You'll find much information about early microprocessors, including "die shots" of the silicon chips for many of the first microprocessors. Also, much other related information, projects and links.

[10] **Intel** The corporate site includes a Historical Microprocessor Quick Reference Guide, starting with Intel's first, the 4004, introduced in November 1971.

HISTORIC SEMICONDUCTOR PUBLICATIONS

[1] Riordan, M., Hoddeson, L., ***Crystal Fire - The Birth of the Information Age.*** New York: W.W. Norton & Co. 1997. Comments: This is a modern classic, and provides a really comprehensive overview of the development of the transistor. Very readable, with much information of interest to the transistor historian and researcher.

[2] ***Proceedings of the IEEE, Special Issue: 50th Anniversary of the Transistor.*** January 1998, Vol 86 No 1. Comments: This Special Issue of the IEEE Proceedings is another "must-have" for transistor historians. There are reprints of original transistor historical articles, as well as current commentary – a wealth of information.

[3] Hunter, L.P., ***Handbook of Semiconductor Electronics***. New York: McGraw Hill, 1956. Comments: This is an excellent text for introducing the modern reader to the world of mid-1950s transistor technology. This is a classic, and although not written at the typical hobbyist level, the extensive bibliography and frequent use of diagrams and photos makes this a "must-have" for those interested in early transistor history.

[4] ***The Transistor, Selected Reference Material on Characteristics and Applications,*** Bell Telephone Laboratories, Inc. 1951. Comments: This almost 800 page classic is sometimes referred to as "Ma Bell's Cookbook". This material was used as the textbook for the first transistor symposium conducted by Western Electric in April 1952 and provides an extraordinary view of the state of semiconductor science during the very early years of transistor development.

[5] ***General Electric Transistor Manual. Volumes 1–7.*** General Electric Semiconductor Products Department. 1956 – 1964. Comments: This series of Transistor Manuals is likely the best known of all transistor publications from the 1950s and 1960s. The first volume, from 1956, was a mere 61 pages, and contained a very comprehensive discussion of the state of the art in germanium transistor technology. The final volume, 7th edition, appeared in 1964 and was an impressive 670 pages. All editions contain substantial technical information and extensive lists of available transistors, with cross-references.

[6] ***Popular Electronics, Radio & TV News, Radio Electronics.*** Comments: Electronics experimenters and hobbyists from the 1950s through the 1970s will well remember the excitement of receiving the next monthly issue of one the three leading construction project magazines listed above. These classic publications contained industry news, product reviews, numerous construction projects and countless ads from distributors offering "must have" semiconductors at affordable prices. Vintage editions of these magazines are readily available and remain the best source of classic semiconductor information.

[7] ***Lafayette Radio Electronics, Allied Radio, Olson Electronics, Burstein-Applebee, Radio Shack:*** Comments: Beginning in the 1920s, these companies sold all types of electronic products, including semiconductors. These publications are one of the most complete sources of semiconductor research information available, including device types, company material, prices, and a detailed view into the evolution of semiconductor technology over many decades.

[8] ***Semiconductor Company Catalogues:*** Comments: All the semiconductor companies documented in this book can be further researched with the use of product catalogues, which are readily available through online auctions and vintage book sites. For example, Fairchild catalogues from the 1960s are an excellent resource to learn about early IC technology, and 1950s Texas Instruments catalogues offer useful information about the first silicon transistors.

HOW TO PURCHASE THIS BOOK AND KIT

The web version of this book is available at no cost as a pdf at this url:
http://www.semiconductormuseum.com/

A hard copy version of this book is included in the Transistor Museum Historic Semiconductors Research and Collecting Kit, which also includes 50 packaged historic semiconductors and the associated presentation envelopes and data cards. You can visit the Transistor Museum Store for details on how to purchase this book and kit as well as numerous other historic semiconductors.
http://www.semiconductormuseum.com/MuseumStore/MuseumStore_Index.htm

The kit is one of a continuing series of semiconductor research and collecting kits developed by the Transistor Museum. The **Historic Semiconductors Research and Collecting Kit** provides comprehensive technical descriptions, historical commentary and timelines, and photographs of the famous diodes, transistors and integrated circuits that were first developed in the 1950s, 1960s and 1970s and which have had such a profound effect on the world of today's electronics. This wealth of research information should be of great interest and value to the modern-day historian, engineer, researcher and electronics hobbyist. Also included in this unique Transistor Museum kit are 50 vintage, historic and collectable mid-20th century semiconductors, all documented with key data and photographs. Be sure to visit the Transistor Museum often. You will find extensive historical semiconductor information as well as additional research and collecting material and supplies to further expand your kit.