

Transistor Museum™ Photo Essay

Computer History Museum - Paul Sullivan Collection



Curating the Historic Paul Sullivan Transistor Collection - The above photo collage documents just a few of the many truly historic transistors that were recently donated to the Computer History Museum. The CHM, located in Mountain View Ca, is dedicated to the preservation and celebration of computer history and is home to the largest international collection of computing artifacts in the world, encompassing computer hardware, software, documentation, ephemera, photographs, oral histories, and moving images. This Photo Essay has been published as part of an ongoing collaboration between the CHM and the Transistor Museum - this joint work has been an exciting opportunity for the Transistor Museum to provide information and technical assessment of historically important donations of semiconductor devices to the CHM. This current Photo Essay documents the Sullivan Collection, which was donated to the CHM in late 2016. The Transistor Museum wishes to thank the Computer History Museum, and especially [Dag Spicer](#), who is the CHM "Chief Content Officer", and [David Laws](#), the "CHM Semiconductor Curator", for the opportunity to be involved in the curation of this truly historic lot of semiconductors. The [CHM website](#) is an unparalleled resource for further information on computer history.

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This is an excerpt of a brief announcement by CHM's Dag Spicer to highlight the importance of this unique semiconductor collection.

Title Paul Sullivan Semiconductor Collection

CHM #: X7957.2017

Date: ca. 1948 - 1955

Donor: Gift of Pat Belotti

The history of the transistor, from which today's integrated circuits are made, begins in earnest in the 1950s. It is a story of many failed experiments, struggles to grasp the fundamental physics of these new devices, and of trying to make working transistors in large quantities. Transistors from this era are extremely rare, having been long ago consigned to the landfill or recycle bin. It was a big surprise then when the Museum received a unique collection of such transistors from former Raytheon engineer Paul Sullivan, via his family. Sullivan's collection is what transistor historian Jack Ward has called "an instant world-class collection of early and important semiconductor devices." The collection includes laboratory prototypes from the dawn of the transistor age to early commercial devices from Raytheon, Sylvania, RCA, Philco, and others.

Transistor Museum Comments - Importance of the Sullivan Collection

The transistor was invented at Bell Labs in late 1947, with the first public announcement of this new technology occurring at a June 1948 Western Electric press conference. Over the next few years, into the mid-1950s, many well-known vacuum tube manufacturers implemented transistor research programs and developed a variety of unique and innovative devices. This Sullivan Collection contains many historic semiconductors from this early timeframe in semiconductor history, including devices from pioneering transistor companies including Western Electric, Raytheon, RCA, Philco, Sylvania, Transitron, and Germanium Products Corporation. Also included are a diverse group of historically important experimental devices with no documented company origin. In total, there are more than **30 different device types and over 100 individual items** in this collection - these devices all date from the early to mid-1950s (with the single exception of the historically important Raytheon 2N3019 transistor from the 1970s) and well represent the broad range of companies and technologies that are historically significant for the first transistors. Note that more than half the device types in this collection were produced by Raytheon, the early leader in commercial germanium transistor technology. It is a real tribute to Paul Sullivan, the Raytheon engineer responsible for originally assembling this collection, and to his daughter Pat Belotti, the donor of the collection to CHM, for preserving this truly historic group of semiconductors.

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Comparing the devices in this collection with other known historic semiconductors:

A key element of the curation of the Sullivan Collection is the identification of the relative scarcity of the devices. This Photo Essay has documented the following categories for each semiconductor type in the Sullivan Collection:

Extremely Rare - Defined as (1) Previously undocumented type and (2) There are no other known examples of the type.

The Sullivan Collection contains 6 Extremely Rare semiconductor types.

Very Rare - Defined as (1) May be documented in historical literature and (2) A small number of similar devices are known to exist or were produced.

The Sullivan Collection contains 4 Very Rare semiconductor types.

Rare - Defined as (1) Produced in limited quantities, up to a few thousand at most, and often used for pre-production and developmental types. (2) These types are typically documented in historical literature.

The Sullivan Collection contains 17 Rare semiconductor types.

Common - Defined as (1) Manufactured in production quantities with units currently available in volume. (2) Product documentation available for performance characteristics and product use in current or historical literature.

The Sullivan Collection contains 6 Common semiconductor types.

Notes on this Transistor Museum Photo Essay: The following pages of this Transistor Museum Photo Essay provide photos, technical analysis and historical commentary on all the devices in the Sullivan Collection. Some helpful notes on different approaches for accessing this material:

Use this link for the [complete inventory](#) of all devices in the Sullivan Collection.

You can also access the Photo Essay material based on company of origin for the devices in the collection with these links: [Raytheon](#), [RCA](#), [Sylvania](#), [Western Electric](#), [GPC](#), [Philco](#), [Transitron](#) and [Unknown](#).

Scroll down all 39 pages for the complete Photo Essay.

Enjoy your tour of the Transistor Museum/Computer History Museum Sullivan Collection of historic semiconductors. We welcome your comments and thoughts on this material and especially if you are able to help us identify any of the "unknowns" in this collection. Send your comments to Jack Ward at transistormuseum@aol.com and Dag Spicer at dspicer@computerhistory.org.

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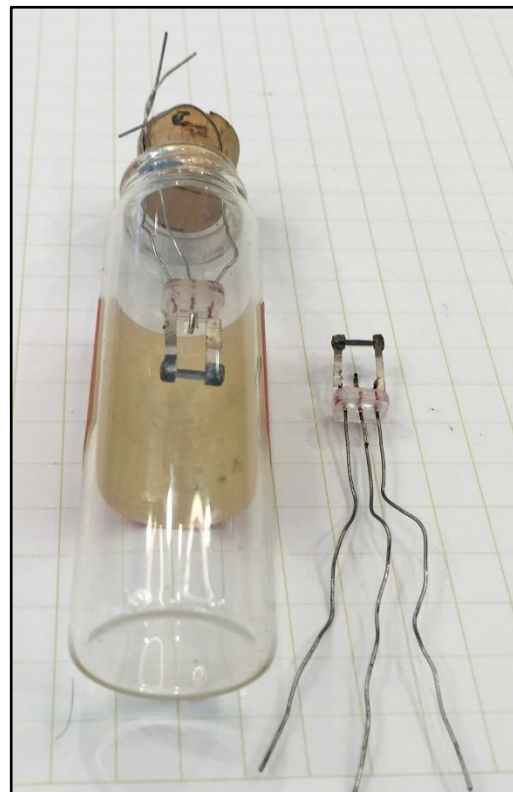
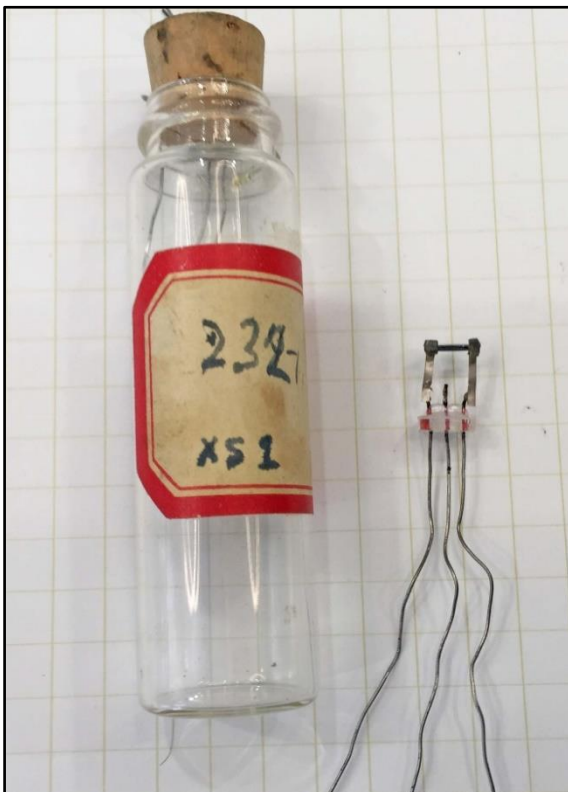
(ID-1) **Raytheon CK703/CK716** (8 pieces), developmental germanium PNP point contact transistors. 1948-1951. The Raytheon CK703 has the memorable distinction of being the first transistor sold commercially, announced late in 1948. This is very early in the transistor history timeline - note that the first public announcement of the invention of the transistor was at a June 1948 Western Electric/Bell Labs press conference held in New York City. This first transistor technology was known as point contact, which consisted of two sharpened metallic points held under pressure onto a small germanium block. Severe performance and manufacturing difficulties limited the commercial use of point contact transistors, but these types represent the first transistor technology and are very historic. The Raytheon CK716 was an improved version of the CK703 and became available in 1951. The units in this lot are not labeled by type, and may be either CK703 or CK716. Note the formal labeling identifying these units with a number id. This methodology suggests that these units were used in an engineering study to document performance characteristics, which varied widely in point contact transistors. **Very rare** (CK703), likely only a few hundred sold. **Rare** (CK716), likely only a few thousand sold.



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(ID-2) **Raytheon Grown Junction Prototypes** (2 pieces), experimental grown junction transistors. Early to mid-1950s. Raytheon did not produce commercial grown junction transistors, and instead was the high volume leader in germanium alloy junction types. Other early transistor manufacturers, such as Western Electric and Texas Instruments, did successfully manufacture grown junction types, but this technology was technically challenging, and was soon dropped for germanium devices. However, Texas Instruments did use grown junction technology for the first commercial silicon transistors, which were announced by TI in 1954. Raytheon and other germanium transistor companies rushed to reproduce TI's success with silicon technology and experimented with both grown junction and alloy junction silicon transistor types. The two units in this lot appear to be examples of Raytheon's experiments with grown junction technology, possibly to determine feasibility for commercial production. Determination that these two units are grown junction devices is based on a visual inspection the actual structure of the transistor junctions and on a handwritten label "Grown Junction" on the box containing these specimens. These units may be either germanium or silicon, but no measurements have been made to positively identify the device type. It is possible that the handwritten label "XS1" designates Experimental Silicon 1", but further research is required to confirm. **Extremely rare** - these are the only known examples.



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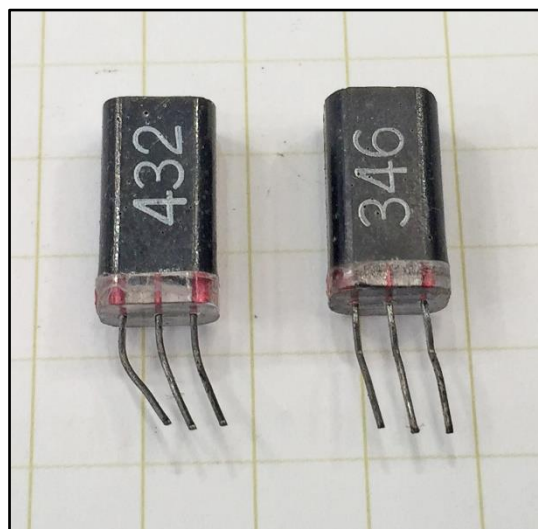
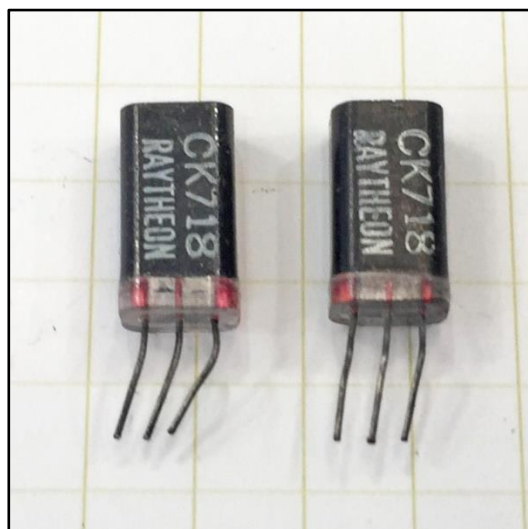
(ID-3) **Raytheon Power Transistor Prototypes** (3 pieces), developmental germanium PNP alloy junction power transistors. Mid-1950s. The first commercial transistors, beginning with the Raytheon CK718/721/722 series introduced in late 1952 were suitable only for low power applications. Substantial research was undertaken by many transistor companies at that time to develop higher power devices, which started to appear commercially in the mid to late 1950s. The three units in this lot are examples of developmental power transistors manufactured by Raytheon using the existing CK718 style epoxy resin case construction, but with added copper strips or bolts to provide better heat dissipation and resultant higher power capability. Raytheon developmental transistors typically used white resin (as below) cases. The leftmost case style was commercialized by Raytheon in 1955 as the CK750-1 series of power transistors, and used a striking iridescent blue colored resin. **Rare** - 1950s developmental power transistors from any company are uncommon, and especially from Raytheon which never became a major manufacturer of power devices. Likely only a very few of these Raytheon power prototypes were developed.



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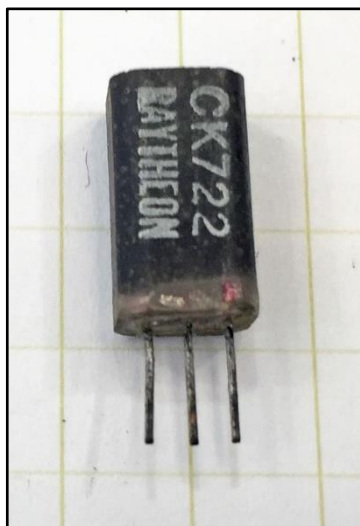
(ID-4) **Raytheon CK718** (2 pieces), germanium PNP alloy junction transistors. 1952 - 1955. The Raytheon CK718 was the first commercial transistor produced in large quantities and was developed exclusively for use in hearing aids. Throughout the 1940s and early 50s, Raytheon was the leading supplier of subminiature vacuum tubes to hearing aid manufacturers. In order to protect this market, Raytheon moved quickly to transistor technology - this was in anticipation that the features provided by the transistor (low power consumption, small size, ruggedness) would revolutionize hearing aid design. As early as 1948, Raytheon experimented with point contact transistors, but found these to be too noisy and not robust enough for hearing aids. Shortly after junction transistor technology became available in 1951/52, Raytheon established large scale production of alloy junction transistors, building on the research of this technology done at GE and RCA. By late 1952, Raytheon was making thousands of the CK718s every week and began to supply these immediately to the major hearing aid manufacturers. The CK718 was sold only to hearing aid companies, and was produced into 1955, when newer hearing aid transistor technology was introduced by Raytheon. Date codes: 346 (1953, week 46); 432 (1954, week 32). **Common**, with many thousands installed in hearing aids through the mid-1950s.



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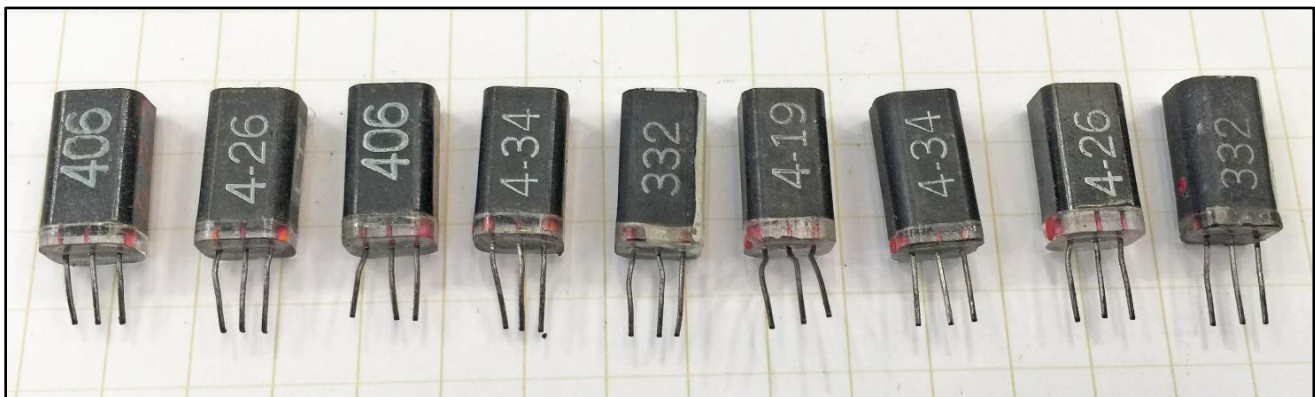
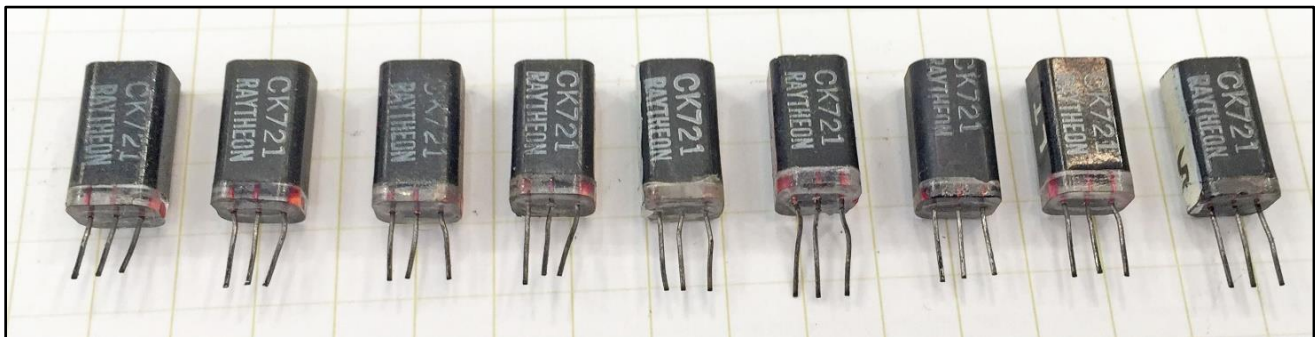
(ID-5) **Raytheon CK722** (1 piece), germanium PNP alloy junction transistor. The Raytheon CK722 is one of the best known and well-remembered transistors from the 1950s/1960s. This device was introduced by Raytheon in early 1953 through a series of ads in magazines designed for the electronics hobbyist, such as Radio Television News and Radio Electronics. Throughout the 1950s and into the 1960s, hundreds of CK722-powered construction project articles appeared in similar magazines. Many of the electronics and computer professionals of the past five decades remember the CK722 as their first transistor. The first units had cases of black epoxy, while later units were made with blue or silver metal cases. These latter two case types actually consisted of a smaller hearing aid transistor encapsulated inside the metal case. The Raytheon CK718 was the first mass produced germanium alloy junction transistor, and was manufactured in large quantities for use in hearing aids - yields from these early transistor manufacturing lines were quite poor, so Raytheon developed a successful marketing strategy to "repurpose" those CK718s which weren't quite good enough for the demanding hearing aid market (not enough gain or too noisy) - these production fallouts were labeled as CK722 and sold as affordable and readily available hobbyist transistors. Date code: 313 (1953, week 13). **Common** - with tens of thousands sold to hobbyists and experimenters, first as black epoxy units as shown, and later replaced by iridescent blue case units, beginning in mid-1950s, and later silver case units in the early 1960s.



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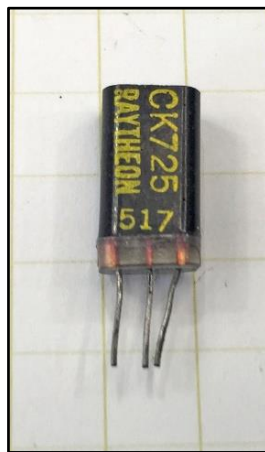
(ID-6) **Raytheon CK721** (9 pieces), germanium PNP alloy junction transistors. Better performing and more expensive version of the CK722, intended for low cost audio and general purpose applications, beginning in early 1953. As with the CK722, these early CK721 units were fallouts from the CK718 hearing aid production lines. Date codes: 406 (1954, week 6); 426 (1954, week 26); 406 (1954, week 6); 434 (1954, week 34); 332 (1953, week 32); 419 (1954, week 19); 434 (1954, week 34); 426 (1954, week 26); 332 (1953, week 32). **Common** - with tens of thousands sold to hobbyists and experimenters as general purpose, affordable and readily available transistors - first as black epoxy units as shown below, and later replaced by iridescent blue case units, beginning in mid-1950s, and later silver case units in early 1960s. The early date code units (332) are not common, as these are from very early production lots.



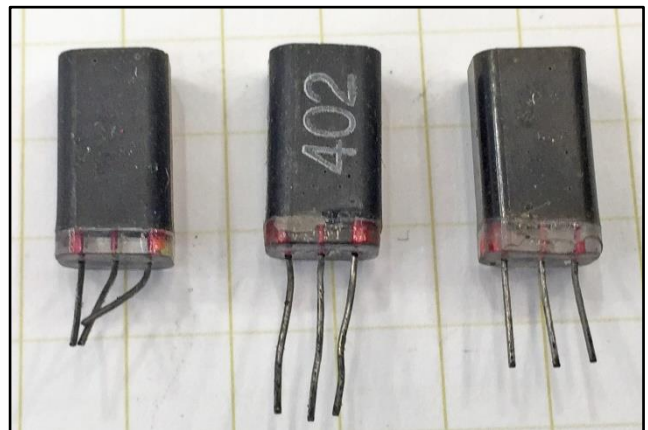
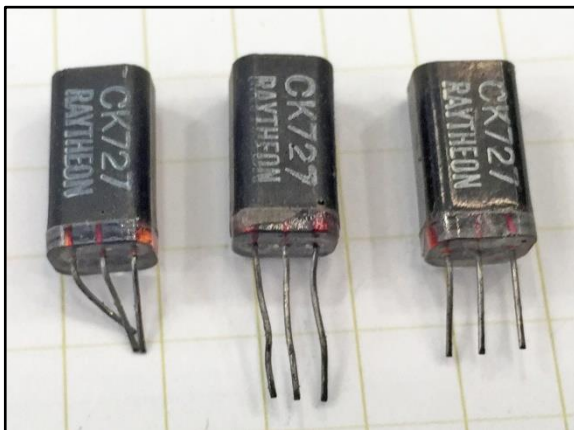
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(ID-7) **Raytheon CK725** (1 piece), germanium PNP alloy junction transistor. Highest gain performing version of the early CK7XX product line. Raytheon continued to improve the manufacturing processes for these early 1950s germanium transistors, and this resulted in high gain performance characteristics for some types, such as the CK725, which was introduced in 1954 - the more robust metal case version of this transistor type was released by Raytheon as the 2N65. Date code: 517 (1955, week 17). **Rare** - especially with the unusual yellow stamped labeling and the 1955 date code; black epoxy cases were abandoned by Raytheon in this timeframe to the more robust metal case styles.



ID-8) Raytheon CK727 (3 pieces), germanium PNP alloy junction transistors. Low noise version of the CK721. Raytheon continued to improve the manufacturing processes for these early 1950s germanium transistors, and this resulted in low noise performance characteristics for some types, such as the CK727, which was introduced in 1954. Date code: 402 (1954, week 2). **Rare** - These units represent a very early production run of the CK727, from the second week of 1954.



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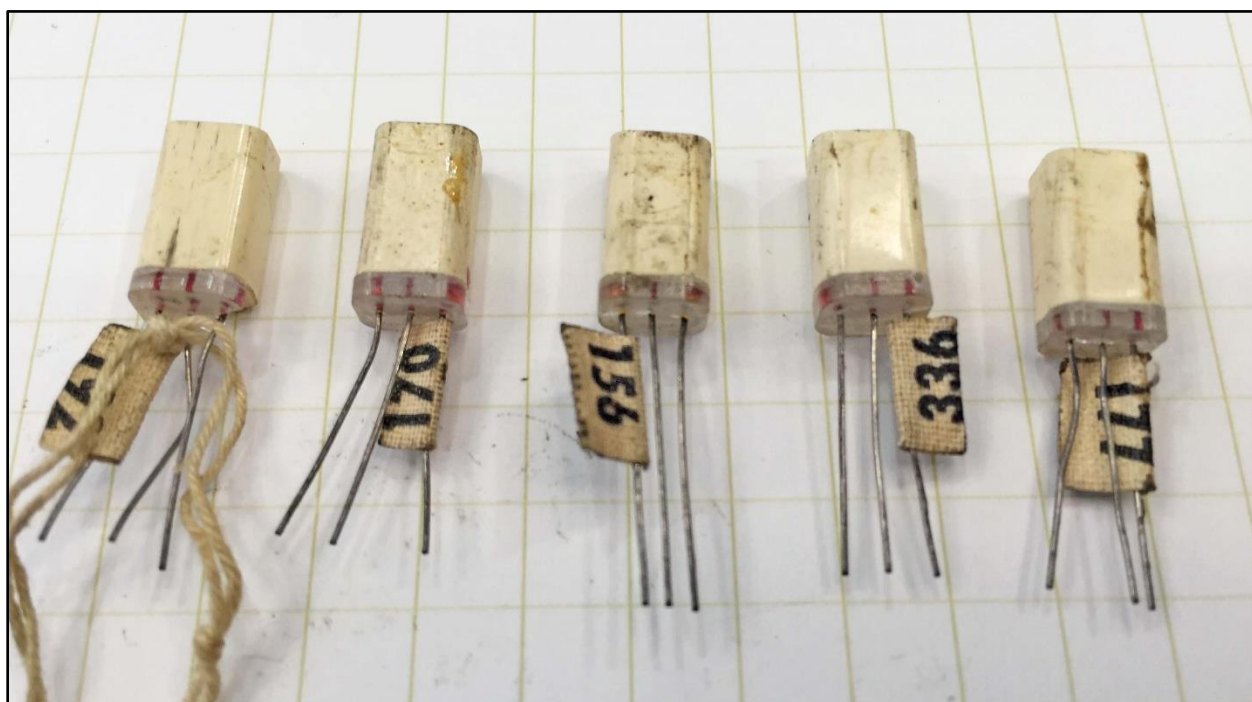
ID-9) Raytheon CK718, Hand Labeled as "HF", (3 pieces) germanium PNP alloy junction transistors. The early production runs from the CK718 production lines resulted in batches of transistors with a very wide range of performance characteristics. As manufacturing techniques were better understood and improved, it became possible to manufacture transistors with specific characteristics. Two of these units appear to have been identified as "HF" and individually identified. "HF" might be a reference to High Frequency, which was a performance characteristic in great demand for these early devices. Note that the leftmost unit is unmarked - many of these transistors from 1952-1955 failed to meet even the minimal specs for the CK722 and so were unlabeled. **Rare** (HF test units), **Common** (Unmarked black epoxy case units).



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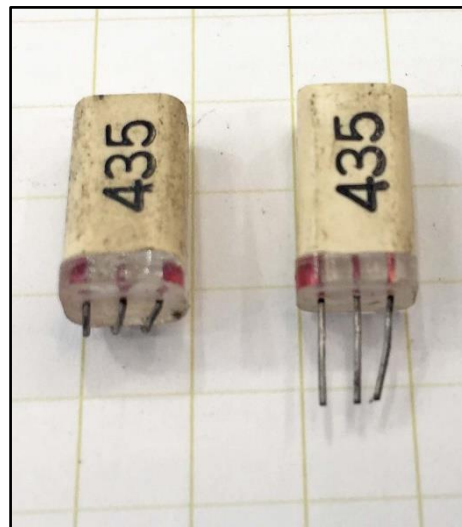
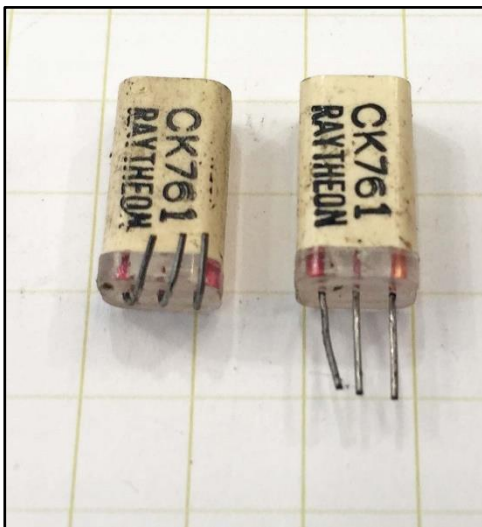
(ID-10) **Raytheon White Epoxy CK718 Prototypes** (5 pieces), developmental germanium PNP alloy junction transistors. Early to mid-1950s. Raytheon was the first to market readily available germanium alloy transistors, with the CK718/721/722 devices, beginning in late 1952. Commercial versions of these transistors used black epoxy resin cases, with the type id and date codes stamped on the case. Raytheon used white resin devices for experimental studies and prototypes. Often these prototypes were hand labeled or otherwise identified with tags. The transistors in this lot are tagged with formal printed number identification, and so were likely used in an engineering study. The leftmost transistor also is tagged with handwritten voltage measurement data. **Rare** - white epoxy resin Raytheon 1950s prototypes were not produced in large numbers, and very few have likely survived over the past 60+ years.



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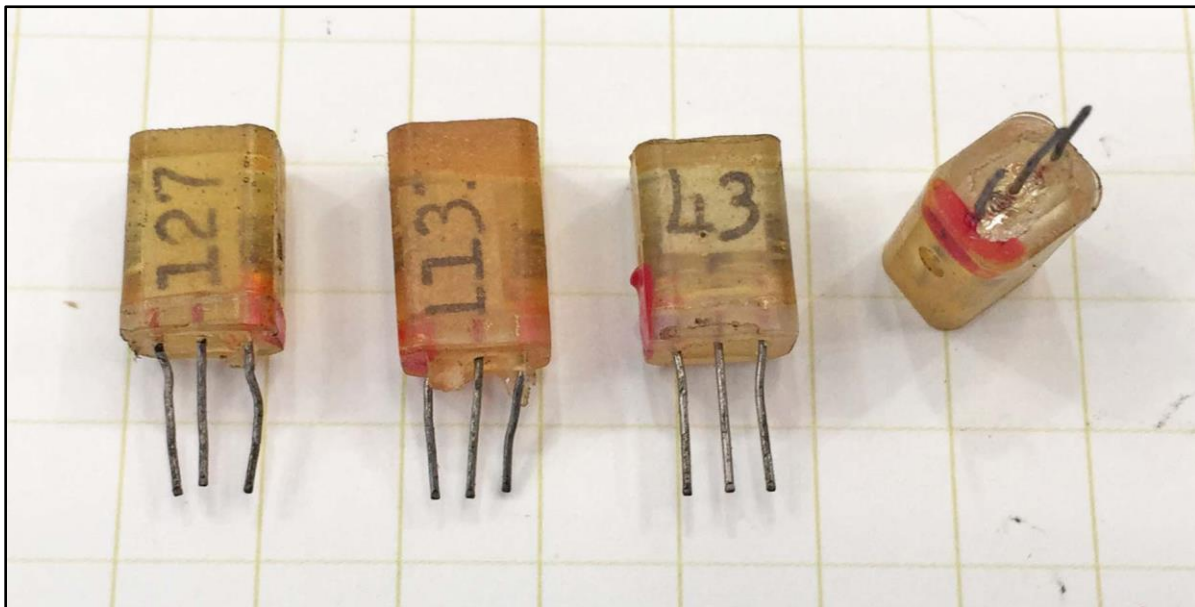
ID-11) Raytheon White Epoxy Pre-production CK761 (2 pieces), germanium PNP alloy junction transistors. By the mid-1950s, as Raytheon had achieved high volume production leadership with hearing aid and low frequency germanium transistor types, improvements in the design of these devices were implemented. An important improvement was the use of manufacturing techniques that would allow operation at higher frequencies and broaden the range of applications to include RF radio circuits and computer switching circuits. Introduced in early 1955, the Raytheon CK760/61/62 transistors were among the first high speed transistors sold commercially. Another major improvement was the introduction of hermetically sealed metal cases, which were intended to prevent the degradation of performance due to moisture penetration through the plastic/epoxy case material used in the early Raytheon transistors. The white epoxy resin case for the units in this lot represent very early pre-production/pilot build devices. Date code: 435 (1954, week 35). **Rare** - These two units represent a pilot build using the older style epoxy case, with a date code several months prior to the 1955 introduction of the more robust iridescent blue metal case commercial types. These are the only known examples of a pilot build of this very successful product line, likely developed because Raytheon was eager to provide pilot samples to radio and computer companies for engineering studies.



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(ID-12) **Raytheon Clear Epoxy CK718 Prototypes** (4 pieces), experimental germanium PNP alloy junction transistors. Early to mid-1950s. Raytheon was the first to market readily available germanium alloy transistors, with the CK718/721/722 devices, beginning in late 1952. Commercial versions of these transistors used black epoxy resin cases, with the type id and date codes stamped on the case. Raytheon used white resin devices for experimental studies and prototypes. Often these prototypes were hand labeled or otherwise identified with tags. The transistors in this lot are unique in that the case material is a translucent epoxy/plastic which allows visual inspection of the internal elements of the transistors. In addition, embedded inside the case are id tags with formal printed number identification for each transistor; these devices were likely used in an engineering study. The engineering studies may have focused on case material suitability for protecting the transistor junctions from degradation due to moisture penetration through the plastic case, which was a known problem with early transistor types. Note that the case shape and size of the transistors in this lot are the same shape and size as the standard Raytheon CK718 type, and the red paint dots used to mark the "collector" connection are a similar technique used for the CK718. **Rare** - the translucent plastic case material used for these Raytheon transistors is very unique, since all other known examples of 1950s Raytheon plastic experimental transistors use either white or black resin. Likely only a very few of these Raytheon experimental transistor types were developed.



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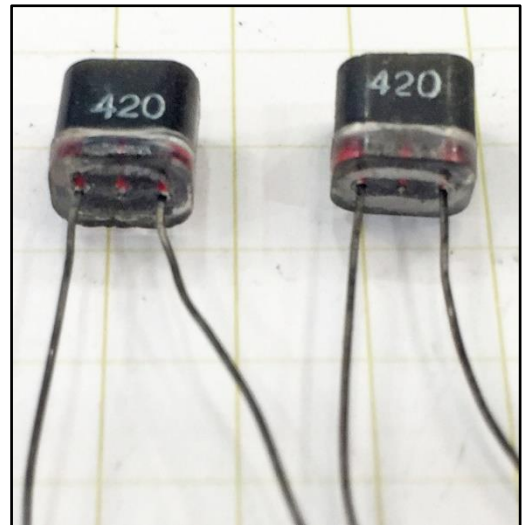
(ID-13) **Raytheon CK66A** (10 pieces), germanium PNP alloy junction subminiature transistors, in original bulk packaging. Raytheon's initial success with germanium transistors was based on the large scale production of hearing aid transistors. In this application, miniaturization was an important requirement, since smaller components would result in smaller finished device hearing aids. As early as 1956, Raytheon was manufacturing miniature transistors which were sold in large quantities to hearing aid companies. Raytheon continued to reduce the size of specific transistor types, and introduced the "subminiature" case style in 1958. These submini transistor types did not have a long term impact on the electronics industry, including computer circuits, since integrated circuits began to appear by the early 1960s and were the primary technology driving the miniaturization of semiconductor devices. Date code: 352 (1963, week 52). **Rare to Common** - although many tens of thousands of Raytheon subminiature transistors were produced in the late 1950s/early 1960s, it is rare to find these in original packaging.



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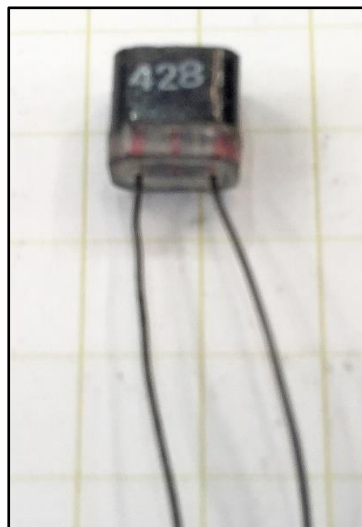
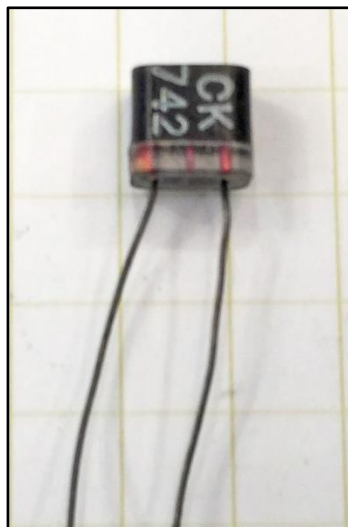
ID-14) Raytheon CK739 (2 pieces), germanium gold bonded diodes. Mid-1950s. Raytheon was a major manufacturer of germanium diodes, starting in the early 1950s. Mastering this technology allowed Raytheon to quickly move into mass production of germanium junction transistors, as the manufacturing processes were similar. Many of these 1950s Raytheon devices used the proprietary "CK" numbering system. The devices in this lot were sold as computer switching diodes, and use the unique black epoxy case characteristic of Raytheon early 1950s semiconductors. By 1955, Raytheon relabeled this diode type with the industry standard "1N305" equivalent id and a more robust metal case style. Date code: 420 (1954, week 20). **Rare to Common** - early black epoxy case style and proprietary "CK" numbering approach was used for Raytheon diodes for a short time only, with low volume production.



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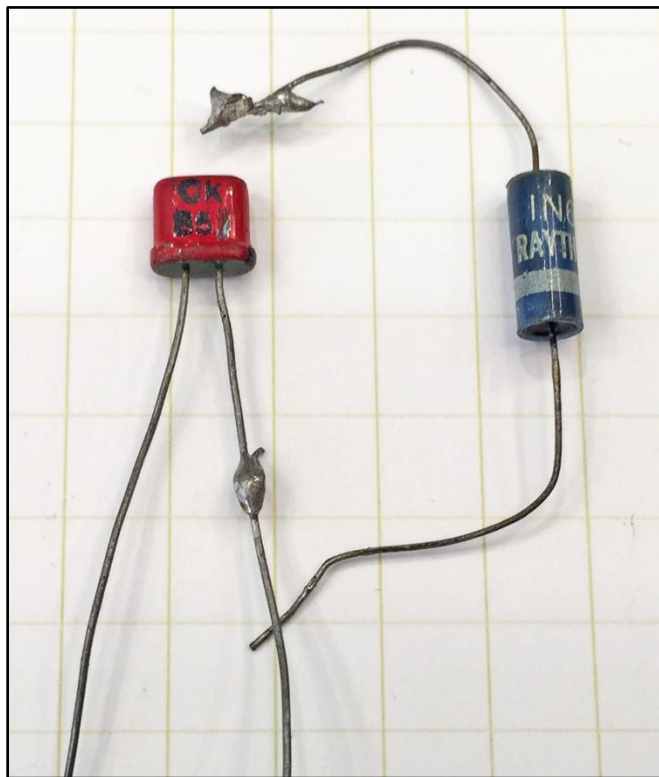
ID-15) Raytheon CK742 (2 pieces), germanium gold bonded contact diodes. Mid-1950s. Raytheon was a major manufacturer of germanium diodes, starting in the early 1950s. Mastering this technology allowed Raytheon to quickly move into mass production of germanium junction transistors, as the manufacturing processes were similar. Many of these 1950s Raytheon devices used the proprietary "CK" numbering system. The devices in this lot were sold as computer switching diodes, and use the unique black epoxy case characteristic of Raytheon early 1950s semiconductors. By 1955, Raytheon relabeled this diode type with the industry standard "1N307" equivalent id and a more robust metal case style. Date code: 420 (1954, week 20). **Rare to Common** - early black epoxy case style and proprietary "CK" numbering approach for Raytheon diodes was used for a short time only, with low volume production.



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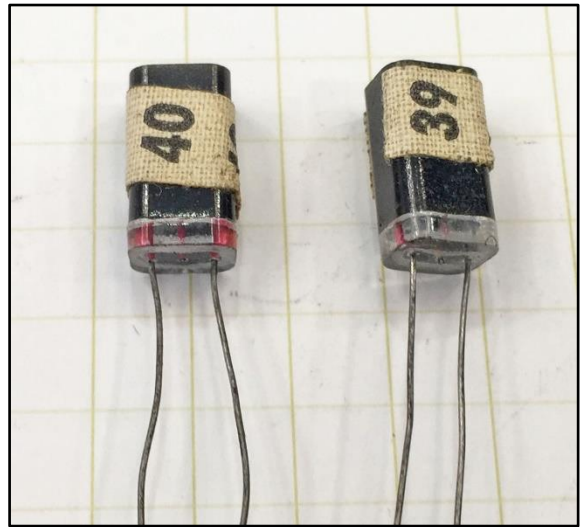
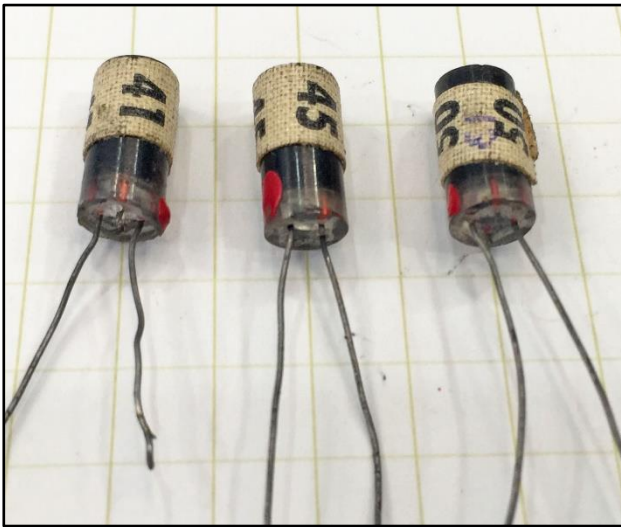
ID-16) Raytheon CK851 and 1N66 (1 piece each), silicon diffused junction rectifier (CK851) and germanium gold bonded diode (1N66). Mid-1950s. These units represent additional examples of the variety of case styles and colors used by Raytheon for mid-1950s semiconductors. Typically, Raytheon used Red case color to indicate silicon device and Blue case color to indicate germanium device, and that approach is demonstrated by the two devices in this lot. **Common** - although in production for only a few years, these types of Raytheon semiconductors were manufactured in substantial quantities.



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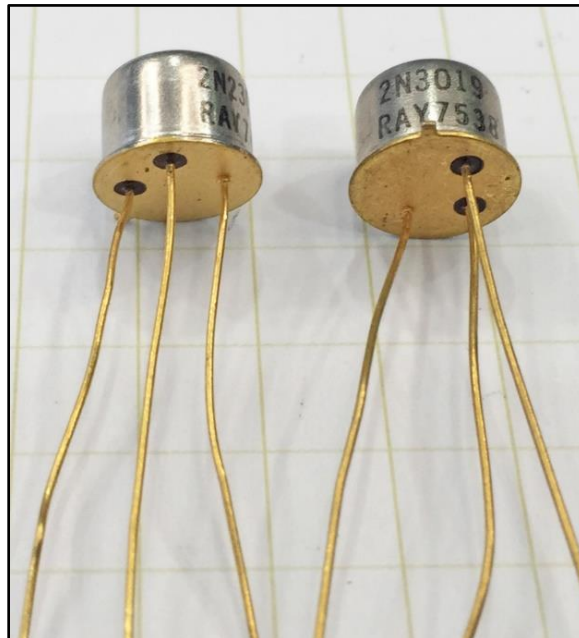
ID-17) Raytheon Unmarked Diodes (5 pieces), germanium diodes. Mid-1950s. The Raytheon diodes in this lot are likely pre-production prototypes, and are not labeled by type, but instead there is a formal printed label on each, identifying these units with a number id. This methodology suggests that these units were used in an engineering study to document performance. Although there are no date codes on these units, the black epoxy case material is typical of the earliest Raytheon transistors, dated from late 1952. **Rare** - these prototypes represent Raytheon diode case styles that never entered volume production. Only a few units like these are known to exist.



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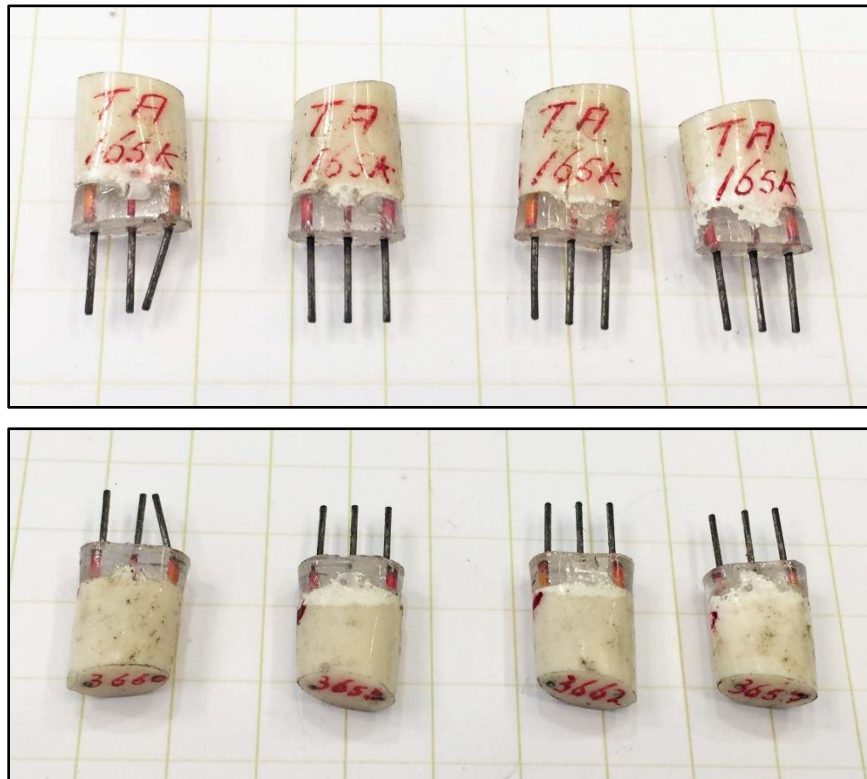
ID-18) Raytheon 2N3019 (2 pieces), silicon NPN transistors. 1960s-1970s. These devices are an unusual addition to this overall collection, since the dates for all other devices are from the early to mid-1950s, and these 2N3019 transistors are dated week 38, 1975. That's 20 years more modern than all other historic devices in this Sullivan Collection! There are several unique historical factors regarding these 1970s Raytheon semiconductors that should be noted: (1) The 2N3019/2N3020 transistors were registered by Raytheon with the JEDEC industry organization in Oct 1963, which is fairly early for silicon transistor technology, and the listed address for Raytheon in this registration is Mountain View, Ca., which confirms that the Raytheon acquisition of Rheem Semiconductor, one of the famous early transistor startups in Silicon Valley, was complete at this time. (See this link for comments at the CHM about [Rheem Semiconductors](#)). (2) This specific device (2N3019/2N3020) is a rare transistor type known as "avalanche" transistor, and Raytheon was one of the few early manufacturers that produced this specific transistor type. (3) Finally, since this collection was initially assembled by Mr. Paul Sullivan, who had been a Raytheon engineer, it seems very appropriate that historically important 1950s Raytheon germanium transistors from the first days of this technology can be compared with unique Raytheon silicon transistors from the 1970s. Very few companies maintained such an impressive leadership position in this competitive and rapidly evolving technical arena for so long. **Rare to Common** - Raytheon labelled versions of these devices are rare, but other companies produced large quantities of these transistors over the past 50 years and modern versions can still be purchased.



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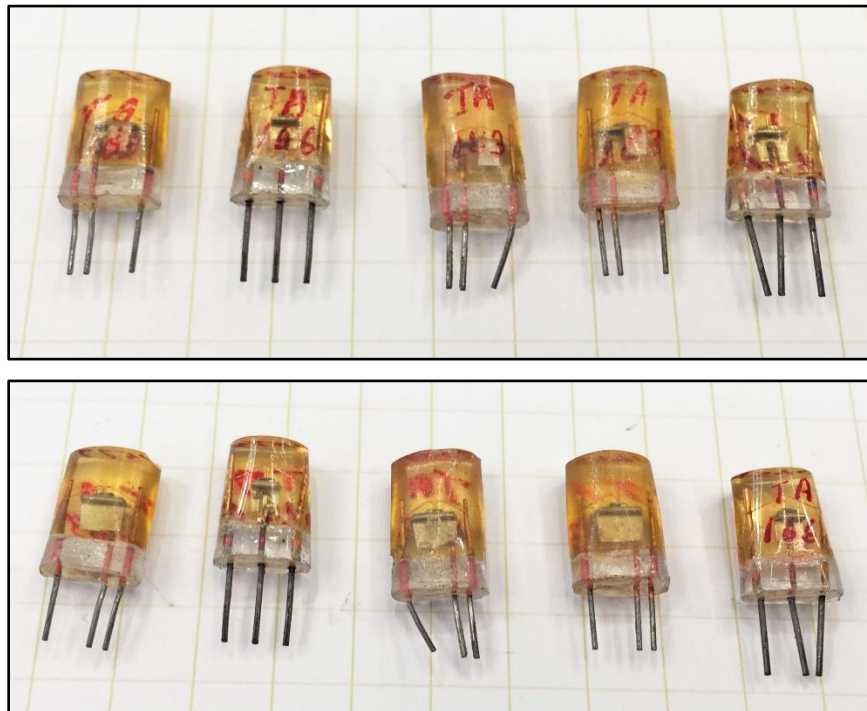
(ID-19) **RCA TA165K** (4 pieces), developmental germanium PNP point contact transistors. Early 1950s. The TA165 was the first RCA developmental point contact transistor with initial units built by Bob Slade's transistor group established at the Harrison NJ RCA Tube Division. Mr. Slade documented the development of this transistor in the article "A method for Improving the Electrical and Mechanical Stability of Point Contact Transistors", by B.N. Slade, RCA Review, December, 1951. The first units were encased in an amber epoxy, while later units contained a white pigment. Several thousand of this type were built and the main purpose was to supply functioning transistors to RCA circuit engineers for developing applications such as radios and digital circuits. It is likely that the TA165 was the prototype for the commercialized 2N32. No date codes are indicated on these transistors, but each is hand-serialized: S/Ns: 3657, 3662, 3653, 3660. **Rare** - These are unique developmental devices from the first days of the RCA transistor program, established in the early 1950s. Likely only a few thousand of these transistors were made, with later devices identified with the more standard "2N" labeling.



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(ID-20) **RCA TA163** (3 pieces), and **RCA TA166** (2 pieces), developmental germanium PNP point contact transistors. Early 1950s. The first RCA developmental point contact transistors were built by Bob Slade's transistor group established at the Harrison NJ RCA Tube Division, beginning in 1951. The earliest units, such as the devices in this collection, were encased in an amber epoxy, while later units contained a white pigment. Several thousand of this type were built and the main purpose was to supply functioning transistors to RCA circuit engineers for developing applications such as radios and digital circuits. The TA166 was designated a "high frequency RF amplifier" and performed with sufficient stability to be used in the front-end circuitry of the first documented transistor television receiver, constructed at RCA Labs in 1953. As of 2001, a TA166 was displayed at the Smithsonian Museum Information Age Exhibit as an example of important early transistor technology. No date codes are indicated on these transistors, but each is hand-serialized. **Very rare** (TA163), this type is not referenced in existing RCA historical records, and likely only a very few units were made. **Rare** (TA166), these are unique developmental devices from the first days of the RCA transistor program, established in the early 1950s. Likely only a few thousand were made.

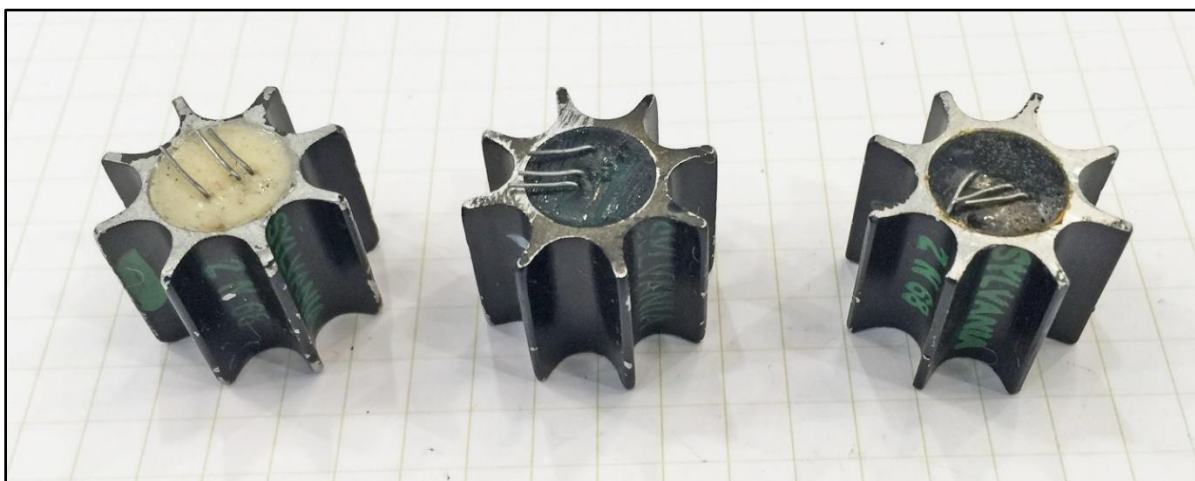


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ID-21) Sylvania 2N68 (3 pieces), germanium PNP alloy junction power transistors. Mid-1950s. The Sylvania 2N68 and 2N95 were among the industry's first commercially available germanium power transistors. These were made with an integral finned heatsink to allow increased power output. Sylvania supplied both PNP (2N68) and NPN (2N95) transistors with similar characteristics, and this allowed substantial flexibility in circuit design, especially for audio circuits that did not require expensive or bulky transformers. The characteristics and suggested circuits for these transistors is well documented in the 1955 Sylvania booklet "28 Uses for Junction Transistors". The Sylvania type 2N101 (supplied without a finned heatsink) is electrically equivalent to the 2N68. The 1955 Lafayette catalogue lists these transistors for \$6.50 each.

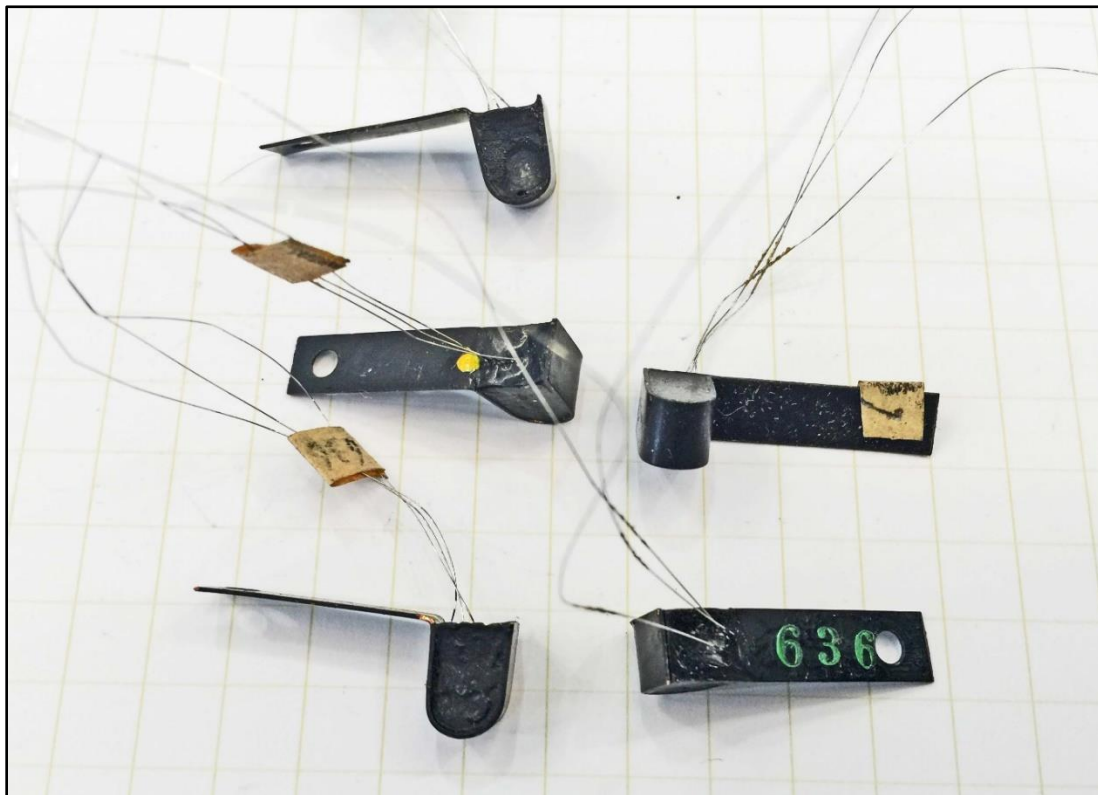
Common - Sylvania was a major supplier of germanium power transistor technology throughout the 1950s and 1960s. Devices such as the 2N68 saw widespread use in many applications and were manufactured in substantial quantities.



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ID-22) Sylvania Power Transistor Prototypes (5 pieces), developmental germanium PNP alloy junction power transistors. Early to mid-1950s. Sylvania was one of several large 1940s/1950s vacuum tube manufacturers that invested heavily in early germanium transistor technology and later entered volume production of germanium transistors. Sylvania began experimentation with transistors in the late 1940s, starting with point contact technology and low power alloy junction types, but it was the successful development of germanium power transistors that became a major technology focus for Sylvania, with types such as the 2N68 and 2N95 produced in large quantities. The units in this lot are examples of very unique developmental prototypes of germanium power transistor technology from Sylvania - of special interest is the use of heat dissipating metal strips bonded to a plastic case. This approach was never commercialized by Sylvania (although Raytheon did commercialize a similar case type) and represents a previously undocumented Sylvania transistor technology. **Very rare** - 1950s prototype power transistors from any company are uncommon, and the unique devices in this lot have not been previously documented. These units may be the only remaining examples of this historic Sylvania device type.



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ID-23) Sylvania 3N21 (1 piece), germanium tetrode transistor. Mid-1950s. The earliest junction transistors performed better than the original point contact transistors in all respects except one - frequency response. Whether grown junction or alloy, the first junction transistors were very limited in terms in effective operating frequency. This limitation was overcome in a number of ways, including the use of a fourth electrode attached to the base of the transistor. By proper use of bias voltages on this additional base lead, the transistor could be made to effectively operate up to 15MHz, which was fairly impressive for this timeframe. Several companies offered these four lead (tetrode) transistors, including Western Electric (3N22), Texas Instruments (3N34/35) and GE (3N36/37), and the Sylvania 3N21 included in this collection. The "3N" designation for the tetrode transistors represents the general approach of: "N" number + 1 = the actual number of leads, so $3N + 1 = 4$; four leads on a tetrode. **Rare** - these four lead (tetrode) transistors were in production for only a few years, with low volume production. This device represents a unique and short-lived transistor technology from the mid-1950s.



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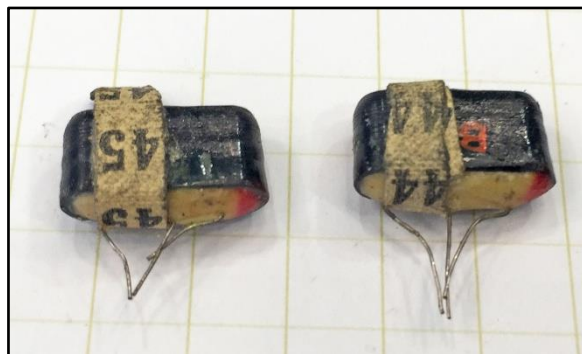
ID-24) Western Electric Pre-Production Type 1729 (9 pieces), developmental germanium PNP point contact transistors. 1951-1953. Shortly after the June 1948 public announcement of the invention of the transistor by Western Electric, this legendary company began development of initial pre-production devices, more robust than the first experimental units, that could be used by device engineers and circuit designers to better understand the performance characteristics of this new technology. One of the first of these pre-production types was the 1729, with exploratory data sheets dated as early as 1951. These 9 units in this lot are very early examples of the metal cartridge case style developed by Western Electric for the first production point contact transistors. The 1729 was used extensively for circuit application development purposes and was later released as the more standard 2N25 type. One of the units in this lot is hand labeled as "1729" - the other units have more formal paper labels identifying these units with a number "id". This methodology suggests that these units were used in an engineering study. **Rare** - these types of pre-production point contact transistors were produced only in the early 1950s and the few remaining units provide a "hands-on" look at the first transistors.



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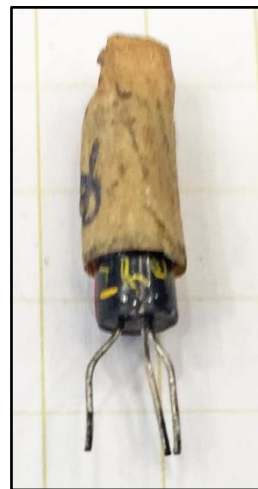
ID-25) Germanium Products Corporation RD2525 (2 pieces), germanium NPN grown junction transistors. Early to mid-1950s. The first commercial product using transistor technology was the Sonotone 1010 hearing aid, introduced in late 1952. This product used a hybrid circuit, with two traditional subminiature vacuum tubes and a single germanium transistor. Because of the low current requirements of transistor circuits, this hybrid approach resulted in enhanced battery life for the hearing aid, and also maintained the good sound quality provided by the tubes. These first Sonotone transistorized hearing aids employed transistors manufactured by the little known Germanium Products Corporation (GPC), which was a subsidiary of RDR, or Radio Development & Research Corp, a New Jersey company which had been one of the original transistor licensees from Western Electric. The GPC RD2517 transistor, used in the Sonotone 1010 hearing aid, had been advertised as early as June 1952, with the higher performing RD2520 and RD2525 released in 1953. GPC & RDR were not successful transistor companies and exited the market in the mid-1950s. Raytheon became the dominant supplier of germanium hearing aid transistors and sold thousands of devices, such as the CK718, to hearing aid manufacturers throughout the 1950s. **Very rare** - these GPC transistors were not produced in large quantities, and most of these devices were installed in hearing aids. The GPC RD2525 transistor, documented in this collection, was the highest performing early GPC type and remaining units are very scarce.



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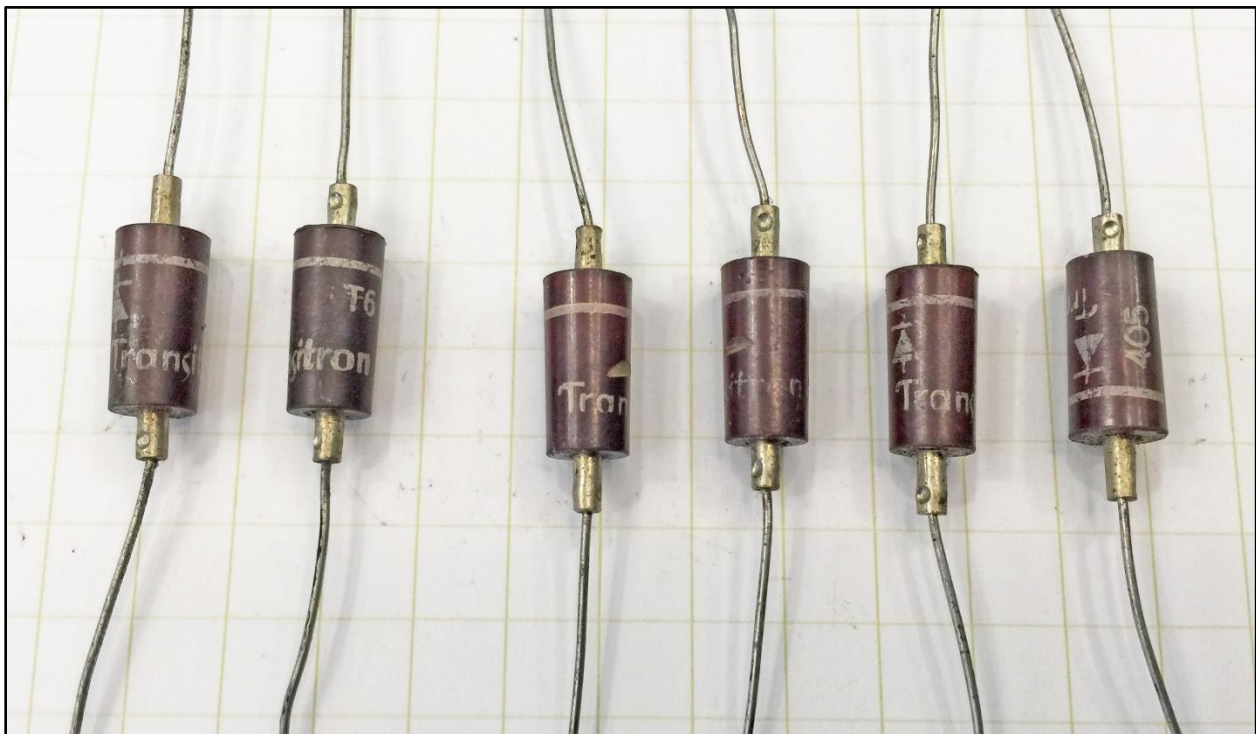
ID-26) Philco Surface Barrier Transistor (3 pieces), germanium PNP surface barrier transistors. Early 1950s. Philco was one of several large mid-century electronics firms that moved quickly into the newly evolving world of germanium transistor technology - other successful companies of similar market presence included GE, Raytheon, RCA, and Sylvania. Philco's major and most successful transistor product line began with the SBT (Surface Barrier Transistor) which used a unique precision etch manufacturing process to produce very high frequency switching and RF devices. These first SBTs were developed by Philco in the early 1950s under a U.S. Army Signal Corps contract. A unique aspect of these Philco early SBTs was the use of a proprietary "bullet-shaped" metal case, later defined as JEDEC TO-24, which was a successful Philco implementation of a hermetically sealed case. Continued improvements to the precision etch process by Philco supported the rapid development of new higher performance types, including the MAT (Micro Alloy Transistor) and the MADT (Micro Alloy Diffused-base Transistor). These high speed devices were ideally suited for military and commercial applications, including computers, satellites and RF equipment, and were sold in the millions throughout the 1950s. **Rare** - the SBTs in this lot are hand serialized and not stamped with production type numbers. These are early production devices, likely from 1952/53, and represent some of the earliest SBTs available.



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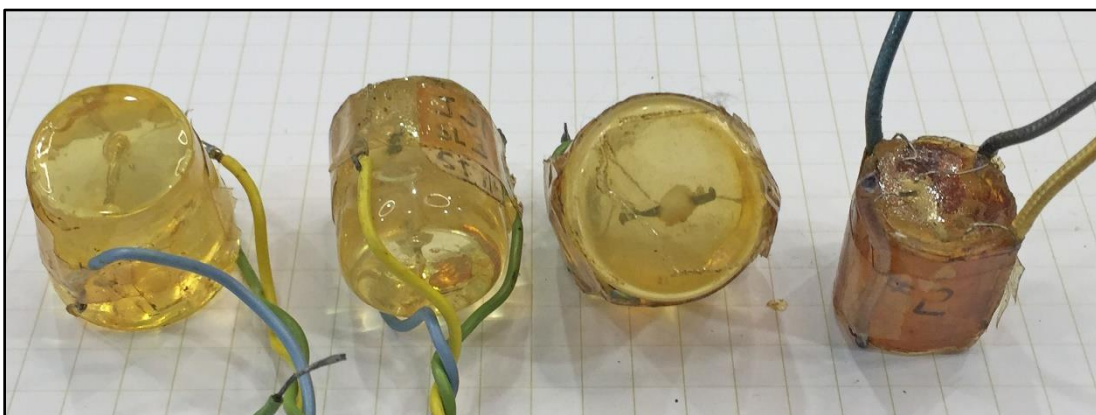
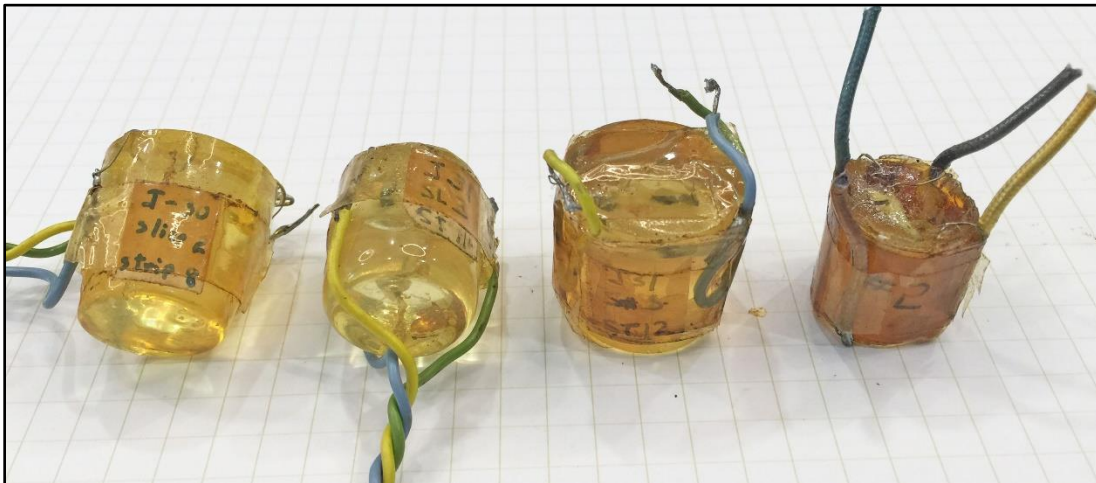
ID-27) Transitron T6 Diodes (6 pieces), germanium gold bonded diodes. Mid-1950s. Founded in 1952 by David and Leo Bakalar in an old mill in Wakefield Massachusetts, Transitron Electronic Corporation became one of the most successful semiconductor manufacturing companies in the world within a few short years. By the mid to late 1950s, Transitron was in the top two or three U.S. producers of diodes, rectifiers and transistors, challenging such long established electronic companies as General Electric, RCA and Raytheon. David Bakalar was the president of Transitron from 1952 to 1984 and his substantial technical achievements with the development of such breakthrough semiconductor devices as gold bonded germanium diodes and silicon rectifiers were the primary basis for Transitron's success. The units in this lot are gold bonded diodes, a type of semiconductor structure patented by Bakalar which resulted in high reliability and high performance devices - the high switching speeds suited these diodes for 1950s computer use. The "T6" is a proprietary number which was cross-referenced to the more standard 1N144 type. The brown phenolic case material used for these diodes is typical for early commercial diodes, and was replaced in the mid-1950s by more reliable plastic hermetically sealed case types. **Rare to Common** - likely tens of thousands of these early types of Transitron diodes were manufactured, but not many of the phenolic cased units remain.



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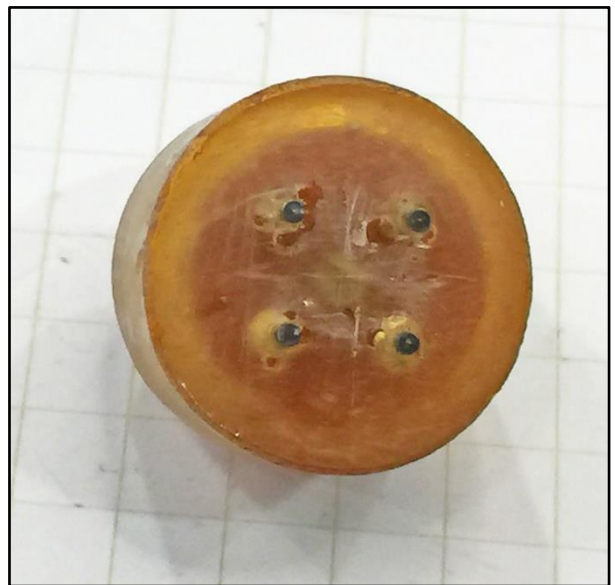
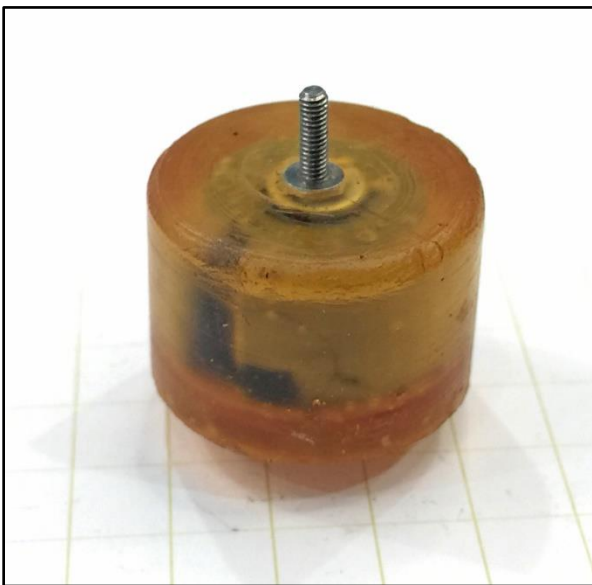
(ID-28) **Unknown Amber Epoxy Case Experimental Transistors** (4 pieces), junction or point contact experimental transistors. Early 1950s. There was substantial experimentation with the first transistor types to determine how best to encapsulate the active transistor structure in a protective case. It was found early on that moisture penetration through an ineffective case would degrade the electrical characteristics of a transistor. Various types of plastic and metal cases were used in the early to mid-1950s and there was little standardization across the industry. The four devices in this lot are very unusual amber epoxy cased units, enclosing experimental transistor structures typical of the first transistors from the early 1950s. Several early transistor manufacturers used this type of epoxy material for experimental transistors, including Bell Labs/Western Electric, RCA, and General Electric. Further electrical tests would be required to positively identify the transistor structures of these encased devices, but a visual inspection of the transistor structure seen through the top of the case in the lower image, second from right, suggests that these experimental transistors were made in the early 1950s by BTL/Western Electric. **Extremely rare** - these are the only known examples.



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ID-29) Unknown Amber Epoxy Semiconductor Cylinder Device (1 piece), unknown type. Early to mid-1950s. The case material for this unique semiconductor is typical of experimental devices from the early 1950s, produced by such pioneering transistor companies as Bell Labs/Western Electric, RCA and GE. The structure of the device suggests that this might be a multi-diode, with a common screw-type lead shown at lower left, and four individual diode leads shown at lower right. Further electrical tests would be required to positively identify the actual semiconductor type. **Extremely rare** - this is the only known example.



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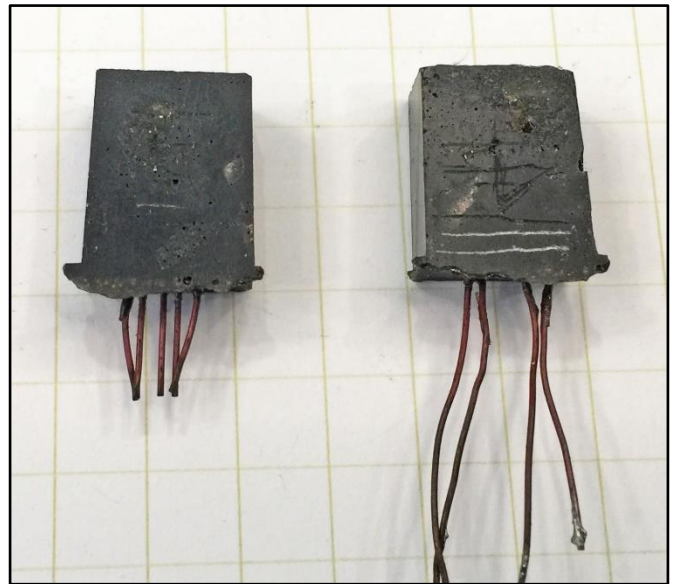
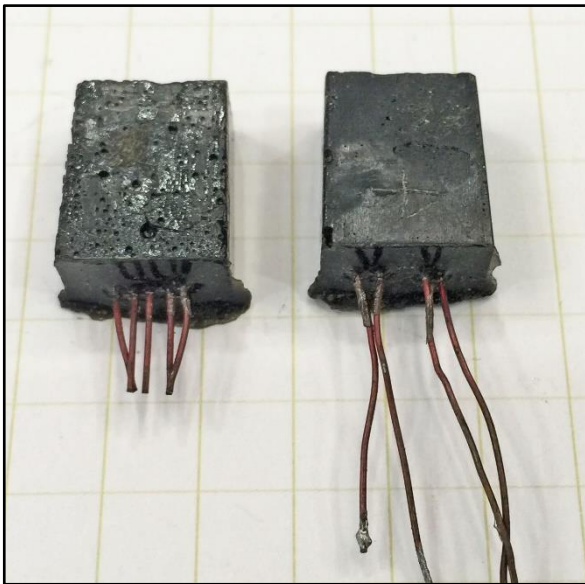
ID-30) Unknown Metal Cube Case Semiconductor (1 piece). Early to mid-1950s. This mysterious device was contained in the Sullivan historic semiconductor donation. The black metal cube case is approximately .75" in each dimension. There is a formal red stamp identification logo on the front of the case, but the text and graphics are not completely legible and do not resemble any known semiconductor manufacturer from this early timeframe. A preliminary assessment identifies this device as a transistor, either point contact or junction, from the early to mid-1950s. Further electrical measurements would be required to confirm the actual semiconductor structure of this device. **Extremely rare** - this manufacturer and type of this device is not currently known. A preliminary assessment suggests that this device is a prototype or very early production semiconductor from a little known or possibly foreign manufacturer. This is the only known example.



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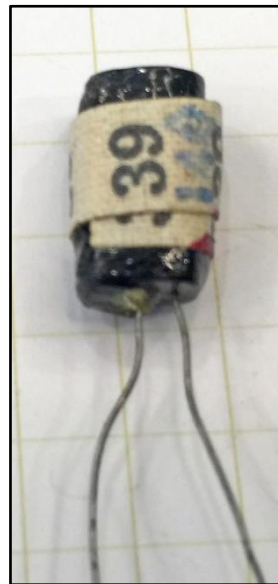
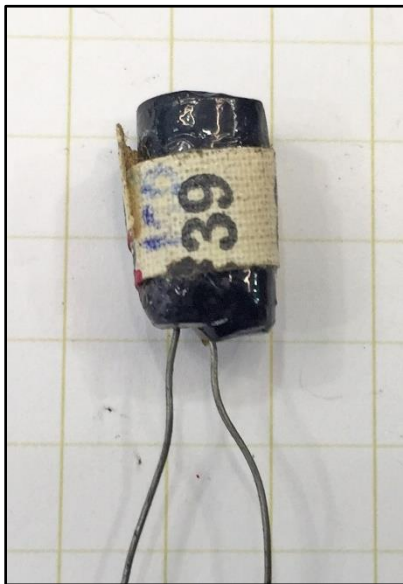
ID-31) Unknown Black Molded Plastic Experimental Semiconductors (2 pieces). Early to mid-1950s. These two devices are not yet identified. The construction appears to be experimental roughly molded plastic. There are no labels or other type of identification. One device has four leads and the other has five. It is possible that these are multiple diode structures, but further electrical measurements would be required to confirm the actual semiconductor structure of these unique devices. **Extremely rare** - the manufacturer or structure of these devices is not currently known. A preliminary assessment suggests that these devices are experimental units, and possibly multiple diode structures. These are the only known examples.



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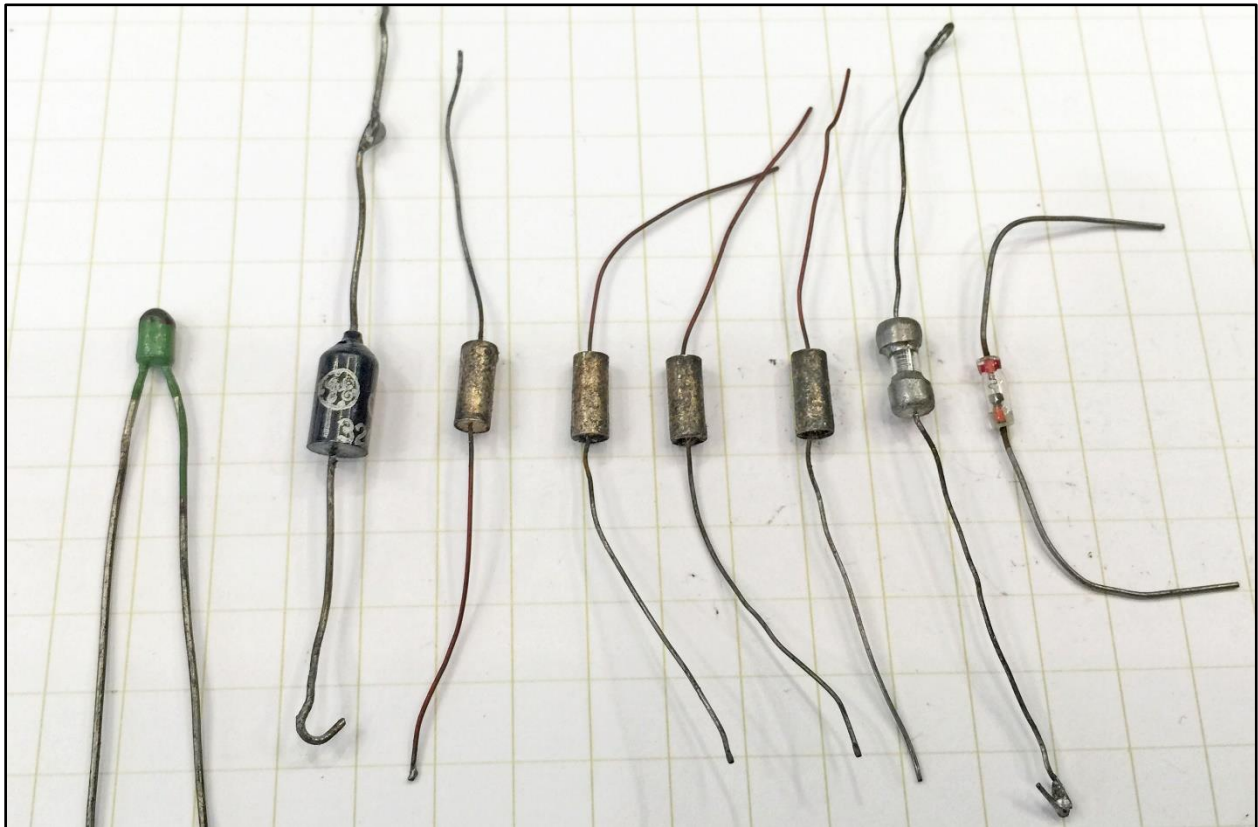
ID-32) Unknown Experimental Diodes (2 pieces), germanium diodes. Mid-1950s. These devices appear to be fabricated from a molded black plastic, which has been roughly formed with multiple surface irregularities - this is consistent with an early to mid-1950s manufacturing date. There are no visual similarities in the physical appearance of these diodes with semiconductor devices from other known manufacturers. It is likely that these are experimental, developmental or pre-production devices that were produced to allow testing of the electrical performance of devices still under development and prior to full-scale production. **Extremely rare** - the manufacturer of this device is not currently known. These are the only known examples.



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ID-33) Assorted Production Diodes (8 pieces), germanium diodes. Mid-1950s. These units represent a range of production diodes from various companies, including International Rectifier and General Electric (leftmost two devices). The other devices shown in the photo below are unmarked but use case styles typical of mid-1950s production diodes. **Common** - these are all production level devices and represent standard semiconductor technology from this timeframe.



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Inventory

Computer History Museum

Sullivan Collection of Historic Semiconductors

Note: This following inventory is a complete list of the devices curated as part of the Sullivan Collection. In each case, a link has been provided which will direct you to a more detailed description and photograph of the actual device.

RAYTHEON	
ID-1	CK703/CK716 (8 pieces), developmental germanium PNP point contact transistors. The Raytheon CK703 has the memorable distinction of being the first transistor sold commercially, announced late in 1948. <i>Rare-Very rare.</i>
ID-2	Grown Junction Prototypes (2 pieces), experimental grown junction transistors. These two units appear to be examples of Raytheon's early experiments with grown junction technology. <i>Extremely rare.</i>
ID-3	Power Transistor Prototypes (3 pieces), developmental germanium PNP junction power transistors. 1950s developmental power transistors from any company are uncommon, and especially from Raytheon which never became a major manufacturer of power devices. <i>Rare.</i>
ID-4	CK718 (2 pieces), germanium PNP alloy junction transistors. The Raytheon CK718 was the first commercial transistor produced in large quantities and was developed exclusively for hearing aids. Historically significant - commonly available in 1950s hearing aids. <i>Common.</i>
ID-5	CK722 (1 piece), germanium PNP alloy junction transistor. The Raytheon CK722 is one of the best known and well-remembered transistors from the 1950s/1960s. This device was introduced by Raytheon in early 1953 for the electronics hobbyist. <i>Common.</i>
ID-6	CK721 (9 pieces), germanium PNP alloy junction transistors. Better performing and more expensive version of the CK722, intended for low cost audio and general purpose applications, beginning in early 1953. <i>Common.</i>
ID-7	CK725 (1 piece), germanium PNP alloy junction transistor. Highest gain version of the early CK7XX product line. Raytheon continued to improve the manufacturing processes for these early 1950s germanium transistors, and this resulted in improved performance. <i>Rare.</i>
ID-8	CK727 (3 pieces), germanium PNP alloy junction transistors. Low noise version of the CK721. Introduced in 1954 as manufacturing processes for these early 1950s germanium transistors continued to improve. These units are from a very early production run. <i>Rare.</i>

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RAYTHEON	
ID-9	CK718, Hand Labeled as "HF" (3 pieces) germanium PNP alloy junction transistors. Two of these units are identified as "HF", which is likely a reference to High Frequency, a performance characteristic in great demand for these early devices. <i>Rare.</i>
ID-10	White Epoxy CK718 Prototypes (5 pieces), developmental germanium PNP alloy junction transistors. Raytheon used white resin devices for experimental studies and prototypes. Often these prototypes were hand labeled or otherwise identified with tags. <i>Rare.</i>
ID-11	White Epoxy Pre-production CK761 (2 pieces), germanium PNP alloy junction transistors. Introduced in early 1955, the Raytheon CK760/61/62 transistors were among the first high speed transistors sold commercially. These are very early pre-production units. <i>Rare.</i>
ID-12	Clear Epoxy CK718 Prototypes (4 pieces), experimental germanium PNP alloy junction transistors. The translucent plastic case material used for these transistors is unique, since all other known examples of Raytheon plastic experimental transistors use either white or black resin. Likely only a very few of these transistors types were developed. <i>Rare.</i>
ID-13	CK66A (10 pieces), germanium PNP alloy junction subminiature transistors, in original bulk packaging. As early as 1956, Raytheon was manufacturing miniature transistors for hearing aid use and in 1958 introduced the "subminiature" case style. <i>Rare to Common.</i>
ID-14	CK739 (2 pieces), germanium gold bonded diodes. Raytheon was a major manufacturer of germanium diodes, starting in the early 1950s. Mastering this technology allowed Raytheon to quickly move into mass production of germanium junction transistors. <i>Rare to Common.</i>
ID-15	CK742 (2 pieces), germanium gold bonded diodes. Raytheon was a major manufacturer of germanium diodes, starting in the early 1950s. Mastering this technology allowed Raytheon to quickly move into mass production of germanium junction transistors. <i>Rare to Common.</i>
ID-16	CK851 and 1N66 (1 piece each), silicon diffused junction rectifier (CK851) and germanium gold bonded diode (1N66). Mid-1950s. These units represent additional examples of the variety of case styles and colors used by Raytheon for 1950s semiconductors. <i>Common.</i>
ID-17	Unmarked Diodes (5 pieces), germanium diodes. The Raytheon diodes in this lot are likely pre-production prototypes, and are not labeled by type, but with a printed label. This methodology suggests that these units were used in an engineering study. <i>Rare.</i>
ID-18	2N3019 (2 pieces), silicon NPN transistors. These devices dated week 38 1975 - that's 20 years more modern than all other historic devices in this Sullivan Collection! These are unique "avalanche" transistors from the early days of silicon technology. <i>Rare to Common.</i>
RCA	
ID-19	TA165K (4 pieces), developmental germanium PNP point contact transistors. The TA165 was one of the first RCA developmental point contact transistor types. The earliest units were encased in an amber epoxy case, while later units contained a white pigment. <i>Rare.</i>
ID-20	TA163 (3 pieces), and TA166 (2 pieces), developmental germanium PNP point contact transistors. Very early developmental units. <i>Very rare</i> (TA163), this type is not referenced in existing RCA historical records, and likely only a very few units were made. <i>Rare</i> (TA166), As of 2001, a TA166 was displayed at the Smithsonian Museum Information Age Exhibit as an example of important early transistor technology.

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SYLVANIA	
ID-21	2N68 (3 pieces), germanium PNP alloy junction power transistors. Sylvania was a major supplier of power transistor technology in the 1950s, and the 2N68 was one of the first commercially available power transistors. Unique massive metal finned case. <i>Common.</i>
ID-22	Power Transistor Prototypes (5 pieces), developmental germanium PNP alloy junction power transistors. The units in this lot are of special interest because of the experimental use of heat dissipating metal strips bonded to a plastic case. <i>Very rare.</i>
ID-23	3N21 (1 piece), germanium tetrode transistor. The earliest transistors were triodes, meaning three electrical connections were required. Several companies experimented with tetrode types (four leads) to increase high frequency performance. <i>Rare</i>
WESTERN ELECTRIC	
ID-24	Pre-Production Type 1729 (9 pieces), developmental germanium PNP point contact transistors. These types of transistors were produced only in the early 1950s and the few remaining units provide a "hands-on" look at the first transistors from 1951-1953. <i>Rare.</i>
GERMANIUM PRODUCTS CORP	
ID-25	GPC RD2525 (2 pieces), germanium NPN grown junction transistors. The first commercial product using transistor technology was the Sonotone 1010 hearing aid, introduced in late 1952, and this historic product used a GPC RD type transistor. <i>Very rare.</i>
PHILCO	
ID-26	Surface Barrier Transistor (3 pieces), germanium PNP surface barrier transistors. Philco's most successful transistor product line began in the early 1950s with the SBT (Surface Barrier Transistor). The SBTs in this lot are early hand serialized units. <i>Rare.</i>
TRANSITRON	
ID-27	T6 Diodes (6 pieces), germanium gold bonded diodes. The units in this lot are early production gold bonded diodes, a type of semiconductor structure developed by Transitron for high reliability and high performance computer use. <i>Rare to Common.</i>
UNKNOWN	
ID-28	Unknown Amber Epoxy Case Experimental Transistors (4 pieces), junction or point contact transistors. The four devices in this lot are experimental transistor structures typical of very early BTL/Western Electric transistors. <i>Extremely rare.</i>
ID-29	Unknown Amber Epoxy Semiconductor Cylinder Device (1 piece), unknown type, possibly a multi-diode. The case material for this unique semiconductor is typical of experimental devices from the early 1950s produced by Bell Labs/Western Electric. <i>Extremely rare.</i>

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UNKNOWN	
ID-30	<u>Unknown Metal Cube Case Semiconductor</u> (1 piece). This black metal cube case is approximately .75" in each dimension, with an illegible red stamp logo on the front of the case which doesn't resemble any known semiconductor manufacturer. <i>Extremely rare.</i>
ID-31	<u>Unknown Black Molded Plastic Experimental Semiconductors</u> (2 pieces). These two devices are not yet identified. The construction appears to be experimental roughly molded plastic. These are no labels or other type of identification. <i>Extremely rare.</i>
ID-32	<u>Unknown Experimental Diodes</u> (2 pieces), germanium diodes. It is likely that these are experimental, developmental or pre-production devices of unknown origin produced to allow testing of devices under development and prior to full-scale production. <i>Extremely rare.</i>
ASSORTED DIODES	
ID-33	<u>Assorted Production Diodes</u> (8 pieces), germanium diodes. Mid-1950s. These units represent a range of production diodes from various companies and represent standard semiconductor technology from this timeframe. <i>Common.</i>

Final Notes:

1. The photographs of the Sullivan Collection devices were taken with a $\frac{1}{4}$ " grid paper background to aid in providing actual size information for each device.
2. All photographs were taken with a hand-held iPhone 7 Plus.
3. Thanks again to Dag Spicer at CHM for providing access to these historic devices during the photography session and the initial review of the collection.