Sprague Germanium Transistors: Sprague Electric was founded in 1926 as Sprague Specialties by Robert C. Sprague as a startup company manufacturing electrical parts, including a "Midget" radio capacitor, which was the foundation of what would become one of the world's most successful electronic component suppliers. Sprague was a major industrial supplier to the WWII effort, including crucial components for the proximity fuzes that helped win the war. Sprague also supplied special energy storage capacitors that were an essential part for the nuclear weapons program after the war. To build on its leadership position as a component manufacturer (primarily capacitors), Sprague was one of the first 26 U.S. companies that purchased a license from Western Electric to manufacture transistors. The Sprague semiconductor research effort began in 1952, and the first commercialized semiconductor product was a ruggedized germanium point contact transistor. This device was identified internally as Type 5A and was later listed with JEDEC as the 2N159 (See above left for an early Type 5A and the next page for details of the 1956 JEDEC listing). The key factor influencing Sprague’s emergence as a major supplier of germanium transistors was the mid-1950s licensing agreement that authorized Sprague to manufacture the high speed line of transistors that had been developed by Philco, including the original Surface Barrier Transistor and the later MAT and MADT technologies. Shown above, to the right of the Type 5A, are various Sprague transistors from the 1950s/1960s manufactured under the Philco license. The most recognizable of these devices are the "bullet-shaped" proprietary case style types originally developed by Philco as well as the more industry standard TO-18 and TO-5 cases at far right. Sprague produced millions of these Philco-licensed transistors and became the primary supplier when Philco exited the high performance germanium transistor business in 1963. Sprague continued to manufacture a comprehensive line of the original Philco licensed transistors well into the 1970s, and, in addition, developed its own line of silicon transistors and integrated circuits. All Sprague transistors are easily identifiable either by the "Sprague" name or the "Circled 2" graphic stamped on the transistor case.
The First Sprague Transistors: Shown above are excerpted sections from the first JEDEC transistor listing filed by Sprague. The type 5A/2N159 was a ruggedized point contact device, constructed using advanced mechanical design. This device was commercialized by Sprague but very few units were sold - by the mid-1950s, point contact transistor technology had been obsoleted by better performing types including grown junction, alloy junction and surface barrier. The Sprague 5A/2N159 is a truly unique and historic device that represents a well-engineered design approach to the first transistor type available.
1956 began with a note of long term optimism for the Sprague Electric Company as it was announced that an agreement had been reached between Sprague and the Philco Corporation under which Sprague is licensed to produce the Philco Surface-Barrier transistor, the only transistor currently available for use in high speed computers. Such computers are in continually increasing demand for industrial and military use. In the latter field, particularly, they are essential for improvement of navigation, missile-guidance and weapons-control assemblies.

Importance of the Sprague-Philco agreement in the electronic world lies in the fact that it will provide for the first time two independent manufacturing sources for an identical high-frequency transistor. Under the agreement, both firms are privileged to exchange research and development data as well as production and testing techniques, on devices in the entire field of semi-conductors.

"For our company," Mr. Robert C. Sprague, Chairman of the Board, said, "the agreement makes possible valuable additions to our already extensive line of components for the entertainment and communications industries and for the military."

Mr. Sprague pointed out that Sprague Electric, under licenses from the Western Electric Company, has carried on during the past three years a well-established development program in the semi-conductor field.

He explained: "We began activity in this field early in 1952 and have had under way an active research and engineering program. We have developed several semi-conductor devices which are already through the pilot-plant stage."

"In this program we have emphasized development of a germanium junction transistor capable of efficient operation at frequencies up to three megacycles. We also plan to start manufacturing these units during 1956."

We will begin the production of these units by the middle of this year and it is significant that it will mean employment for approximately 250 people by the end of the first 12 months of operation. At the time of this writing, no decision had been made as to where the transistor plant will be located.

Transistors are fast becoming the component wonder of this electronic age. Our own research, coupled with our license to produce the Philco transistors, will assure our Company of an important place in this expanding market.

Along with the plans for the production of these units, the announcement was made that John M. Puppolo will assume production responsibility for this operation.

Mr. Puppolo was born in North Adams and is a graduate of Drury High School and Wentworth Institute. He joined Sprague Electric in 1934 and has held positions as Foreman and Superintendent until his recent assignment. Mr. Puppolo is a past president of the Sprague Electric Management Club.

Mr. Puppolo has always been active in civic affairs having been a member and chairman of the city Recreation Board and an active participant in the activities of St. Anthony's Church. Mr. Puppolo is married to the former Lena A. DeDebbio of North Adams and they have one child, John Michael, 13 years old.

Also employed by Sprague are two brothers of Mr. Puppolo—David, who is in the Specifications Engineering department and Henry in the Wire Coating Lab on Brown Street.

Sprague Becomes Philco Licensee: The Sprague in-house newsletter from January 1956 announced the agreement with Philco Corporation under which Sprague was licensed to manufacture the Philco Surface-Barrier transistor. This agreement established Sprague as a major producer of high performance high speed germanium transistors well into the next decade.
Sprague Produces Philco Computer Transistors: This September 1957 ad documents the early results of Sprague's 1956 commitment to manufacture surface barrier transistors under license from Philco. This impressive result in achieving volume production of multiple surface barrier transistor types in such a short timeframe highlights Sprague's corporate commitment to this effort and substantial manufacturing resources and competence (note the reference to the "completely new, scrupulously clean plant, built from the ground up"). In the next few years, Sprague expanded this volume production to include new improved transistor types from Philco such as MAT and MADT.
2N128: Developed by Philco under contract with U.S. Army Signal Corps in 1954, the 2N128 was the first surface barrier transistor to meet rigid military specifications. In 1956, Philco began to offer this device in large volume shipments for field use in military electronics equipment. Advertised features of the 2N128 included high frequency performance, extreme reliability, uniformity of characteristics, minimum battery drain, low leakage current and operating voltage, and absolute hermetic seal. The military needs for this unique device represented a potentially large and profitable market and Sprague was able to ramp up their production of the 2N128 very soon after entering the 1956 Philco second source licensing agreement. As shown above, the Sprague 2N128 transistor included in this kit is from an early 1959 production lot and was designated JAN (Joint Army Navy) to indicate conformance to military standards. The U.S. Army ORDVAC computer was an early application of the 2N128 transistor.

2N240: The 2N240 was another high performing surface barrier transistor and was introduced by Philco in 1957. As with the 2N128, Sprague followed shortly with their own version of this device, announcing availability in late 1957. The 2N240 was intended specifically for use in computers, with a fast response time in the millisecond range to give reliable operation up to 20 MC in switching circuits. Because of excellent switching characteristics, the 2N240 (and its in-house numbered equivalent devices, the L5122 and L5129) saw widespread use in a number of early transistorized computers, including the Burroughs D-204 and the Lincoln TX-2. The 1959 Allied Radio catalog listed the 2N240 for $7.35. The Sprague 2N240 devices in this kit are dated from the 1960s.
The Sprague Transimulator: In 1957 Sprague developed and sold a unique type of transistor test equipment, shown above and marketed as the “Transimulator”, which was intended to be used by circuit developers interested in characterizing transistor performance. At this time in transistor history, there was still much to be learned by circuit designers who were familiar with vacuum tube circuit design but who had little or no transistor experience. According to the Transimulator Operating Manual, The Model LF-1 Transimulator is an instrument designed basically to eliminate the breadboard stage in the design of low and medium power transistor circuitry. With it, one may simulate all types of amplifier stages short of high power audio output as well as multivibrator, switching, phasing, Class A and B push-pull and many others when using cross-coupled Transimulators. The Transimulator may also be used to permit the selection of individual transistors for best performance with established circuit parameters or for “incoming inspection” tests of transistors in a particular circuit as well as for general demonstrations of the effect of varying parameters when used as a classroom aid in teaching. The range of possible circuit configurations includes those utilizing PNP, NPN and Surface Barrier Transistors. Sprague must have expended considerable resources in the development and marketing of this test equipment, and further supported this effort with U.S. patent 3,005,953, which was filed in September 1957 by the company. The patent provides a detailed description of the design and use of the transistor tester and includes construction details and front panel graphics that closely parallel the commercialized tester. The Sprague Transimulator undoubtedly deserves a place in the annals of transistor history - this is an unusual commercialized device that allowed the performance characterization of individual transistors, at a time when semiconductor manufacturing processes were not well understood or controlled and it was often necessary to test each transistor to determine operating characteristics.
Sprague 2N393 MAT Transistor: After the introduction of surface barrier transistors, Philco continued to make improvements to the types of high speed devices that could be manufactured using the precision etch/electrochemical etching technology. In 1957, Philco announced a new transistor type, the Micro-Alloy Transistor (MAT), which offered higher speed and higher current handling capabilities than the SBT. The 2N393 was the most widely used MAT transistor and was a big seller for Philco. As with the earlier SBT types, Sprague soon followed with its own 2N393 MAT, and promoted this high performing device as shown in the late 1950s ad above.
2N393 Transistors for Computer Use: The 2N393 Micro-Alloy Transistors manufactured by Philco and Sprague were widely used in late 1950s and 1960s computers and related digital circuitry. For example, the 1963 ATACC computer, developed by Sylvania for the U.S. Army, was constructed with over 10,000 2N393 transistors. The ATACC Systems Manual provides a detailed technical discussion regarding the suitability of the MAT transistor for this application, including costs, susceptibility to nuclear radiation damage, and proven performance in computers of similar design including the MOBIDIC models A, B, C, D and 7A, the Sylvania 9400, the BASICPAC, the TX-0 and the TX-2. The 2N393 was manufactured in large quantities by both Philco and Sprague, and because of the widespread use in military data processing equipment, Sprague continued to provide this device well into the 1970s, long after Philco had ceased production of precision etch transistors. The circuit board shown at upper right is a DEC System Building Block, Type 1201, which is a Flip Flop computer module. This circuit uses six Sprague 2N393 transistors all of which have 1959 date codes. The System Building Blocks were the first commercial products from Digital Equipment Corp (DEC) and consisted of a coordinated set of transistorized circuit boards used for building and testing computer systems. Typical modules were the Flip-Flop, Logic Gate, Clock and Pulse Amplifier. The early 1960s DEC PDP minicomputers were constructed using these digital modules. The 2N393 and other Philco/Sprague MAT and MADT transistors were used extensively in these modules.
In 1958 Philco announced another improved transistor type developed with the precision etch process - this very high speed type was identified as Micro Alloy Diffused-base Transistor (MADT). Using the semiconductor diffusion techniques originally developed at Bell Labs, MADT transistors extended the range of high gain, high frequency amplifiers, suitable for high speed computers and other critical high frequency circuitry. Philco MADT transistors were the dominant "high speed" transistors until the early 1960s, when diffused base mesa transistors from Motorola, Texas Instruments and Fairchild became available. Philco developed a broad range of performance specifications and resulting "2N" transistor types using MADT technology. The Philco 2N501 was one of the first MADTs available and was widely used in the computer industry. Sprague soon developed a comprehensive set of second sourced MADTs. The above April 1959 ad highlights one of Sprague’s first MADT offerings, the 2N501, and summarizes the high frequency performance attributes of this transistor.
**SPRAGUE**

2N393: Philco registered the 2N393 with JEDEC on December 2, 1957. This device was one of the first of the Micro-Alloy Transistors (MAT) which were developed with improvements to the original SBT electrochemical manufacturing process. As described in Philco literature: “A special short-alloying cycle, combined with precise electro-chemical production techniques (pioneered and developed at Philco Transistor Center for production of SBTs), results in the micro-alloy contact for exceptionally high injection efficiency. To combine high gain at high currents with high frequency response, the new MAT transistor employs a gallium doped alloy junction for the emitter electrode”. The 2N393 was especially designed for switching applications up to 50 MC. The design was particularly well adapted to direct coupled computer logic circuits. Sprague introduced their version of the 2N393 in 1958. This was a very popular high speed switching transistor and was used in many computers of the time, including MOBIDIC. The 2N393 was produced for many years by Sprague, well into the 1970s. The 2N393 transistors in this kit (see above left) are JAN devices from the 1960s.

2N501: Philco registered the 2N501 with JEDEC on May 4, 1959. This device was one of the first of the Micro-Alloy Diffused-base Transistor (MADT) types, which were developed following the original SBT and MAT electro-chemical transistor types. The 2N501 was specifically designed for very high speed switching applications. Philco noted that reliable operation of the 2N501 in switching circuits was achieved at speeds in excess of 20 MC. Sprague introduced their version of the 2N501 in 1959 and promoted this high speed device as “The fastest mass-produced transistors available anywhere” and “They are unexcelled for high-speed computer applications”. The 2N501 was used in many historic computers, including the MIT TX-2 and the Univac LARC. The 2N501 transistors in this kit (see above right) are from the 1960s.

<table>
<thead>
<tr>
<th>Transistor Museum</th>
<th>Historic Semiconductor Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Device ID:</strong> Sprague 2N393 transistor</td>
<td></td>
</tr>
<tr>
<td><strong>Type:</strong> Germanium PNP Micro-Alloy</td>
<td></td>
</tr>
<tr>
<td><strong>Case Color/Style:</strong> Silver “bullet” TO-24</td>
<td></td>
</tr>
<tr>
<td><strong>Vintage/Date Code:</strong> 1950s/1960s</td>
<td></td>
</tr>
<tr>
<td><strong>Use:</strong> High speed 50 MC computer switch</td>
<td></td>
</tr>
<tr>
<td><strong>Notes:</strong> Best known and most popular MAT. Produced for two decades, into the 1970s.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transistor Museum</th>
<th>Historic Semiconductor Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Device ID:</strong> Sprague 2N501 transistor</td>
<td></td>
</tr>
<tr>
<td><strong>Type:</strong> Germanium PNP MADT</td>
<td></td>
</tr>
<tr>
<td><strong>Case Color/Style:</strong> Silver “bullet” TO-1</td>
<td></td>
</tr>
<tr>
<td><strong>Vintage/Date Code:</strong> 1950s/1960s</td>
<td></td>
</tr>
<tr>
<td><strong>Use:</strong> Very high speed computer switch</td>
<td></td>
</tr>
<tr>
<td><strong>Notes:</strong> 1959 high speed “leader”. Special slim-line TO-1 case. Very widely used.</td>
<td></td>
</tr>
</tbody>
</table>

Continued Rollout of 2nd Sourced Philco Transistors: When introduced by Philco in 1960, the MADT 2N1500 was likely the highest switching speed computer transistor generally available, with advertised performance up to 20 MC. The 2N501A was electrically identical but was packaged in the more familiar slim-line case. With this exceptional high speed performance, and greater reliability achieved with the use of cadmium transistor junctions, these transistors were well received by computer designers. Sprague quickly followed Philco with a 1961 release of both these transistors, and promoted the advantages of these types with ads as shown above.
2N976: Philco continued to develop additional MADT transistors throughout the late 1950s and into the early 1960s. Philco announced the 2N976/2N977 MADT series in 1961, and Sprague followed with their version of these devices by 1964. The Philco July 1961 tentative data sheet states the following: “The 2N976 is a hermetically sealed, germanium Micro Alloy Diffused-base Transistor (MADT) designed for extremely high speed switching applications. Reliable operation of the 2N976 has been achieved at speeds in excess of 100 MC”. Device characteristics make the 2N976 suitable for all low-level, high-frequency logic circuits. Note that the 2N976 uses an industry standard TO-18 metal case, and Sprague units, as shown above, are typically painted black and stamped with the “Circled 2” Sprague logo. Pre-commercial prototypes of the 2N976 were used in the MIT FX-1 computer.

2N2401: The 2N2400/2N2401/2N2402 series of Philco MADT transistors followed a similar history as the 2N976, except that the release date was slightly later (March 1962 Philco release date and 1964 Sprague release date) and the performance exhibited lower switching speed, but greater radiation resistance. The Philco March 1962 tentative data sheet states the following: “The 2N2400, 2N2401 and 2N2402 are hermetically sealed, germanium Micro Alloy Diffused-base Transistors (MADT) specifically designed for high speed switching applications. Operation of the 2N2402 can be achieved at speeds up to 20 MC. The very thin base width of the 2N2400 series make them exceptionally radiation resistant. This latter feature, radiation resistance, was a key factor in the use of the 2N2400 series of transistors in military computer applications. As with the 2N976 types, the Sprague 2N2401, shown above right, was supplied in a black painted TO-18 case.
2N1499A:  In May 1960, Philco registered several new high frequency transistors with JEDEC. This was a very active time for Philco, which was rapidly expanding its lead in commercial switching transistors with new MADT types. The Philco tentative data sheet for the 2N1499 reads in part: "The 2N1499 is a hermetically sealed, germanium Micro Alloy Diffused-base Transistor (MADT) designed for use in saturated switching circuits. The 2N1499 is capable of switching at frequencies in excess of 5 megacycles. It is intended to be used in high-speed commercial computers, data processing and automation equipment. The very thin base width of the 2N1499 makes it exceptionally radiation resistant. The TO-9 package is cold welded for high reliability". Philco soon offered an improved version of this transistor, designated 2N1499A, which doubled the original switching speed, from 5MC to 10 MC. The 2N1499A was marketed as a "high-speed, low-cost switch". The Sprague version of the 2N1499A included in this kit is dated from the late 1960s and uses a TO-5 case (see above left).

RT82: The production yields for 1950s/60s germanium transistor manufacturers were often low, with resulting quantities of "fallouts" of devices that did not meet specifications, but were still functional. Some companies would sell these production "fallouts", usually as specially marked hobbyist grade devices offered at a reduced price. Three companies were most active in this area - Raytheon (with the CK722), GE (with the 2N107/2N170) and Sylvania (with 2N229). Sprague also developed a line of low cost experimenter transistors, and these most likely were manufacturing "fallouts". The Sprague RT82, shown above right, sold for about 60¢ in 1965, while the comparable production quality 2N1742 MADT rf amplifier sold for almost $3.00. Sprague continued the "RT" line of low cost transistors into the 1970s.
Sprague Electric is taking immediate steps to significantly increase its production capability for electrochemical processed transistors in Concord, according to a recent announcement by Ernest L. Ward, President. The Company has taken this step in the light of recent announcements by the Philco Corporation, a subsidiary of the Ford Motor Company, that Philco will discontinue the manufacture of this type of semiconductor. Market research indicates that a substantial need will continue for these unique high-speed, high-frequency devices. The continuous process advancements which have been made in electro-chemical transistors at Sprague Electric have had universal acceptance, starting with the ECDC core driver in 1960, the ECDC logic transistor in 1961, and earlier this year, the ECDC power amplifier. At the WESCON Show in August of this year, the Company announced the availability of 71 new transistor types, which included high-performance silicon epitaxial planar transistors, a full line of communications MADT transistors, a family of ECDC power amplifiers, a line of symmetrical transistors, and a very complete line of MADT/ECDC switches.

During 1965 sales of transistors increased, especially our line of SEPT® Silicon Epitaxial Planar Transistors which was expanded by the addition of a number of new types. Good progress was made, also on increasing production of planar transistors. Production of Silicon Integrated UNICIRCUITS® for several important military and space programs will be in large-scale production when the new plant is in operation. Our Silicon Monolithic UNICIRCUIT® line has been expanded to include additional digital circuits in the medium and high speed ranges employing resistor-transistor, diode-transistor and transistor-transistor logic systems of the most advanced design. "THIRD GENERATION" COMPUTERS: The Semiconductor Division expects to become increasingly involved in supplying components for the commercial computer industry. With the introduction of the so-called "third generation" of commercial data processing systems, which are currently going into volume production, a number of new approaches to computer circuit fabrication have been developed.

Sprague Semiconductors in the 1960s: Beginning with the widely publicized 1956 licensing agreement with Philco, Sprague became a high volume manufacturer of the SBT, MAT and MADT high speed germanium transistors. These devices were used extensively by the military and industry and sold in the millions of units through the 1960s. As noted above left in an excerpted 1963 inhouse publication, Sprague became the primary supplier of these types of transistors when Philco unexpectedly announced its withdrawal from this market. Sprague’s commitment to large scale transistor production was expanding during this timeframe, with the availability of 71 new transistor types announced at the 1963 WESCON show. Sprague was also investing in silicon technology with a proprietary line of Silicon Epitaxial Planar Transistors (SEPT) and integrated circuits (UNICIRCUITS), with expected markets in space, military and Third Generation Computers. Sprague’s planned growth as a major semiconductor supplier appeared to be on track in the mid-1960s, when the 1965 Annual Report announced the construction of a new semiconductor plant in Worcester Ma and, for the first time in corporate history, sales exceeded $100,000,000 and company-wide employment passed the 10,000 mark.
Sprague Expands Production of Philco’s Germanium Transistor Types: When Philco exited the germanium transistor manufacturing business in 1963, Sprague expanded its production capabilities for these devices. Because of the millions of high performance Philco transistors sold to industry and the military, Sprague found a ready market for its Philco style transistors well into the 1970s. The February 1964 ad above from the IEEE Spectrum magazine highlights Sprague's commitment to continued volume availability of the original Philco SBT, MAT and MADT transistors, as well as newer silicon types using the Philco precision etch process.


Historic Germanium Computer Transistors Research and Collecting Kit
Sprague Enters the Silicon Era: Although Sprague’s primary transistor business was based on manufacturing SBT/MAT/MADT high speed germanium transistors under license from Philco, Sprague did establish its own silicon semiconductor product lines in the 1960s and into the 1970s, including planar transistors and integrated circuits. This effort required substantial resources, including a newly built IC plant in the mid-1960s, as well as continued R&D work in silicon technology. The May 1965 ad above highlights a major product announcement for some of Sprague’s first modern silicon transistors, based on the epitaxial planar technology, which would have been competitive with existing devices from industry leaders such as Fairchild, Texas Instruments and Motorola. Through the 1970s and 1980s, the Sprague semiconductor business was involved in multiple corporate ownership changes and evolving product lines. In 1990, this business was sold to Sanken Electric Ltd. Of Japan and renamed Allegro Microsystems. A comprehensive account of Sprague’s historical semiconductor accomplishments can be found in Sprague Electric: An Electronic Giant’s Rise, Fall and Life After Death, by John L. Sprague, 2015, CreateSpace Independent Publishing Platform, North Charleston, SC.