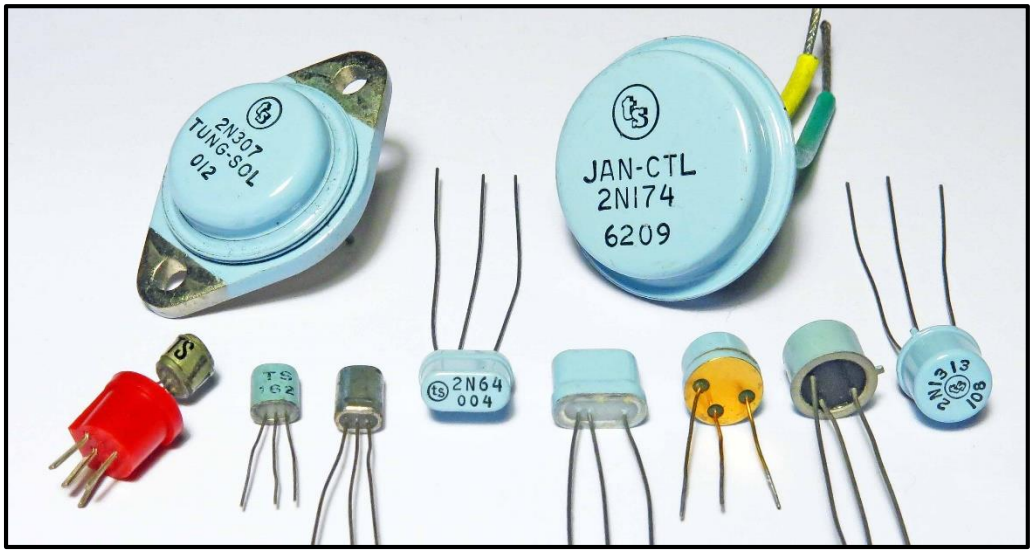
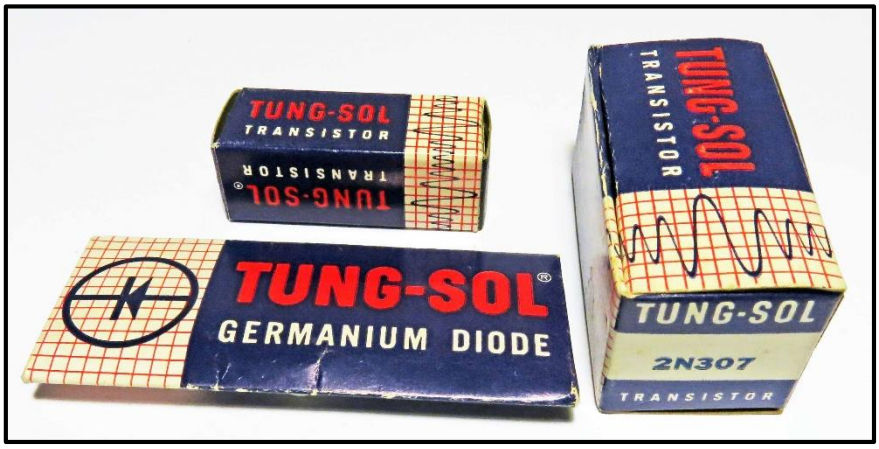
HISTORIC GERMANIUM COMPUTER TRANSISTORS

TUNG-SOL



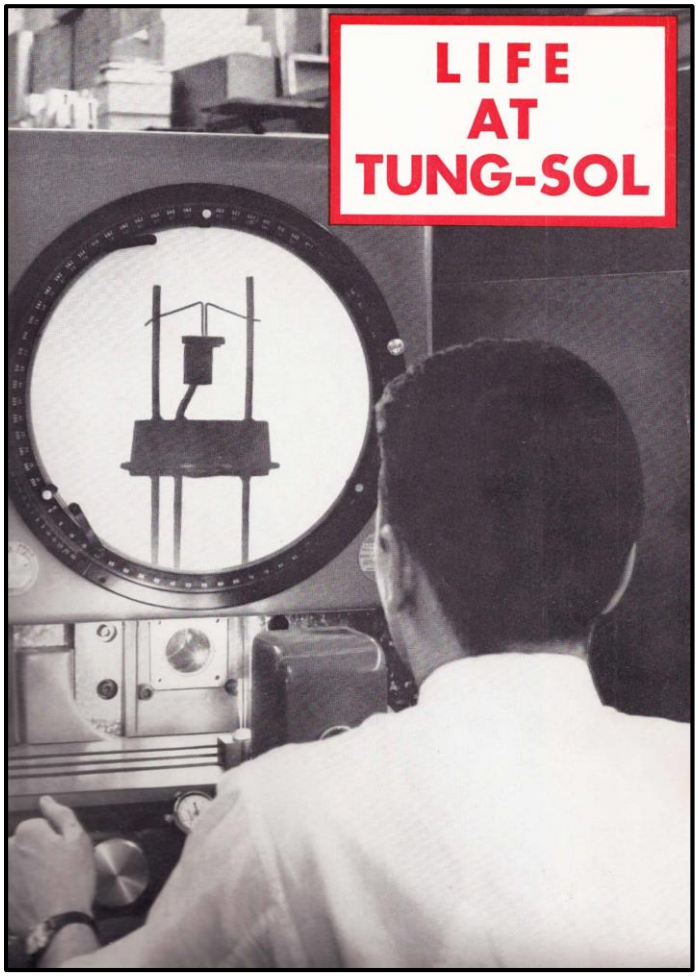


Early Tung-Sol Transistors: Primarily known as a manufacturer of rugged electron tubes and automotive lighting products, Tung-Sol entered the germanium semiconductor business in the mid-1950s. The photo at top above illustrates the range of germanium transistors manufactured by Tung-Sol until the mid-1960s when the company exited the semiconductor business. The three small transistors in the lower left of the photo were marketed as "miniatures", intended for hearing aid use. The 2N64 is from the late 1950s/early 1960s, and was second sourced by Tung-Sol for the Raytheon 2N63-65 series of audio transistors. The three rightmost transistors are typical of Tung-Sol transistors from the late 1950s. The power transistor types shown at top were major product lines for Tung-Sol. With very few exceptions, all Tung-Sol transistors were germanium PNP alloy types, and the cases were painted a unique and easily recognizable "Robin's egg blue". Consistent with the striking blue case color, Tung-Sol also developed unique and colorful graphics for the cardboard packaging used for their devices. Shown above are examples of packages for power transistors (2N307), germanium diode (1N34A) and TO-5 transistor (2N425). Tung-Sol continued to manufacture electron tubes during this timeframe and used similar packages for these devices as well.

TUNG-SOL

Tung-Sol Transistors and Tubes: This July 1956 ad from Electronics magazine highlights some of the products available from Tung-Sol during the early days of transistor technology. Tung-Sol had a long history as a manufacturer of electric/electronic devices, beginning in the 1900s as a pioneer in the design and high volume production of electric lamps, headlights and turn signal flashers for automobiles. The product line was expanded in the 1920s with electron tubes for radios, and then later in the 1940s and 1950s to include a variety of specialty tubes such as TV picture tubes, proximity fuse tubes for military ordinance, computer and data processing tubes, and Hi-Fi audio tunes. Following the lead of other electron tube manufacturers such as CBS, Raytheon, RCA and Sylvania to produce semiconductors, Tung-Sol began marketing germanium transistors and diodes in the mid-1950s. As illustrated in the ad above, miniature and small signal audio transistors as well as larger TO-3 power transistors were offered. During this timeframe, Tung-Sol continued to be a major supplier of automotive lighting products.

TUNG-SOL



The First Tung-Sol Transistors: The first transistor technology was known as point contact – this was the type of the first transistor invented at Bell Labs in late 1947 and announced to the public in June 1948. As the name implies, the point contact transistor was created by placing two tiny sharpened points in contact with a germanium semiconductor block. The spacing, mounting pressure and geometry of the points are key factors determining the characteristics of a point contact transistor. Most early transistor companies experimented with point contact technology, but manufacturing difficulties and lack of device consistency caused these companies to soon adopt junction transistor technology, which was developed at Bell Labs in 1951. Shown above is a section of the cover of the Tung-Sol in-house publication *Life at Tung-Sol*, Vol 6, No 1 dated 1953. The magnified image is of an experimental Tung-Sol point contact transistor, with two wire points shown in contact with a germanium block. The cover is captioned: "A Tung-Sol engineer examines the giant magnified image of a Tung-Sol transistor mount on the screen of a contour projector. Spacing between the two tiny parallel upright wires must be precise to a tolerance of one ten-thousandth inch. The mount when imbedded in its solid setting will form a complete transistor scarcely bigger than a baked bean." Tung-Sol did not commercialize its point contact transistors but did use similar technology for large scale germanium diode production. The first commercial Tung-Sol transistors appeared in 1954/1955 and were alloy junction types.

TUNG-SOL

These new Tung-Sol Transistors, now available in production, meet a wide range of applications where miniaturization of equipment is essential.

The Tung-Sol semiconductor design and development program is characterized by laboratory-control processing and 100% testing—including rigid life, mechanical and electrical tests. It is your assurance of uniformity, long life and reliability *in excess of design specifications.*

High production standards for Tung-Sol Transistors are consistent with the manufacturing policy which safeguards Tung-Sol's *second-to-none* reputation for quality in all its products.

For engineering assistance in adapting Tung-Sol Transistors to your product, write to Commercial Engineering Department.

TUNG-SOL ELECTRIC INC. Newark 4, New Jersey

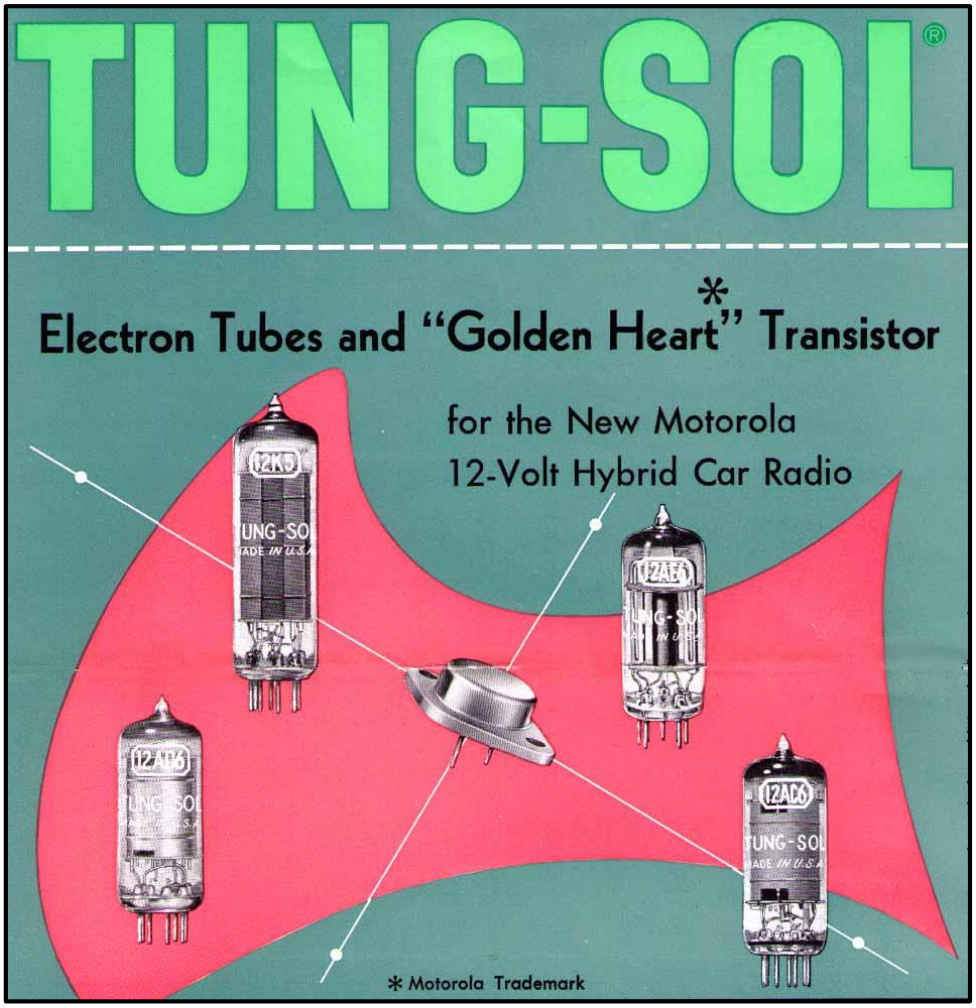
CHARACTERISTICS OF TUNG-SOL TRANSISTORS

RATINGS (Abs. Max.)	TS-162	TS-163	TS-164	TS-165	TS-166
Collector Volts	−10	−25	−25	−25	−10
Collector MA	10	10	10	10	10
Dissipation at 25°C (MW)	50	50	50	50	50
Junction Temp. (°C)	85	85	85	85	85
AVERAGE CHARACTERISTICS (Common Base, I_e = 1.0MA, E_c = −6v)					
Cutoff μA (Max.)	15@-10v	25@-25v	25@-25v	25@-25v	15@-10v
Current Gain	.93	.96	.98	.99	.97
Noise Figure	20	20	20	20	15
Frequency Cutoff (MC)	0.5	0.7	0.9	1.1	—
Power Gain (DB)	37	39	41	42	36

The Tung-Sol semiconductor development program also includes a line of high frequency and high power transistors.

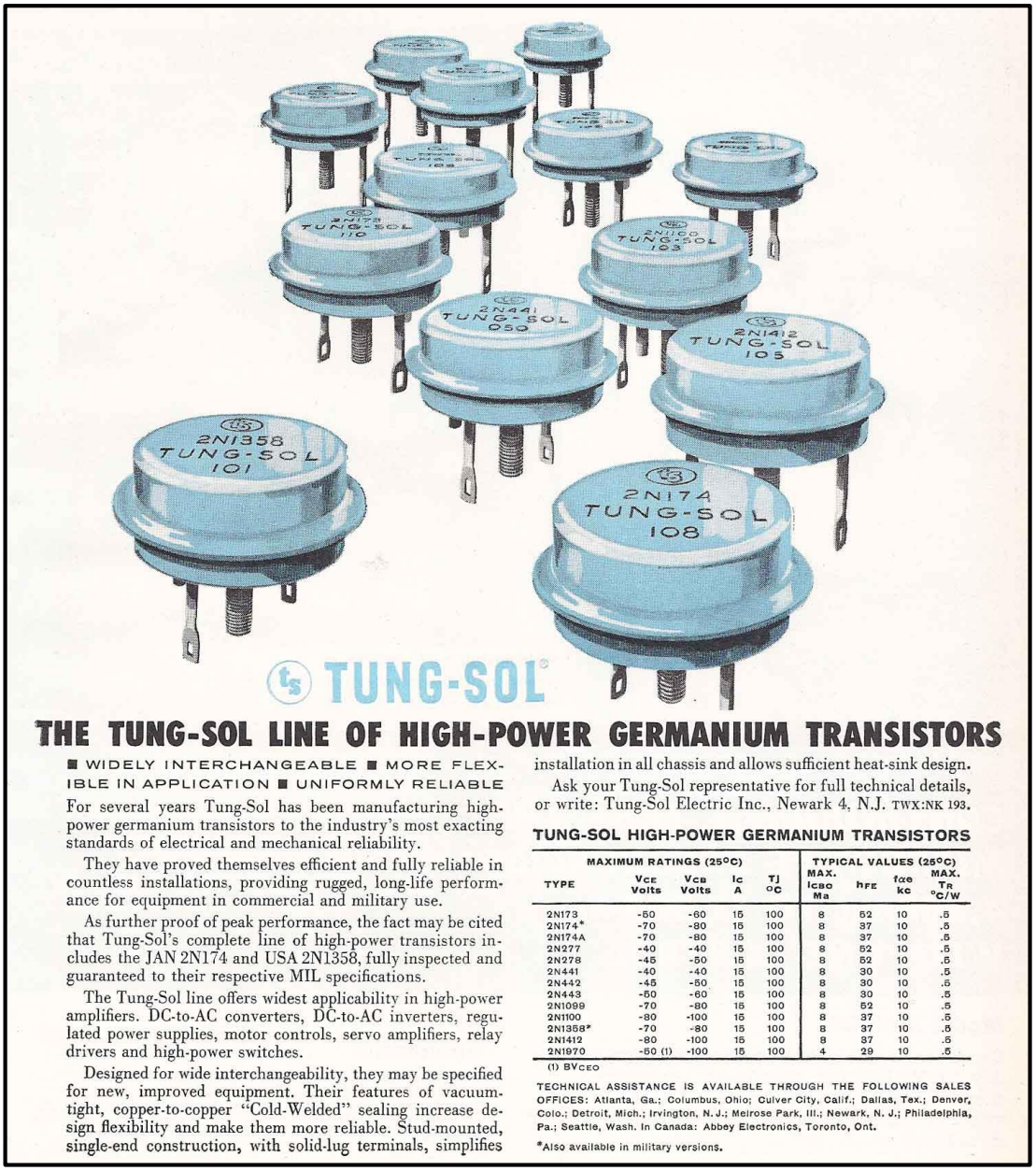
Tung-Sol Miniature Transistors: Above are sections of an ad that appeared in the January 1956 issue of Teletech magazine that announced the commercial availability of miniature germanium PNP alloy junction transistors from Tung-Sol. The small size of these transistors was intended to encourage hearing aid manufacturers such as Zenith, Sonotone and Acousticon to incorporate these devices into their products. Hearing aids were the first large scale consumer application for transistors, and leading semiconductor manufacturers developed miniature transistors to meet the limited space requirements of hearing aids. In addition to the production of miniature transistors, note that the ad states: "The Tung-Sol semiconductor development program also includes a line of high frequency and high power transistors." By 1956 Tung-Sol had developed a comprehensive line of germanium alloy transistors and was advertising availability in production quantities.

TUNG-SOL



Tung-Sol and Automotive Transistors: The design of automobile radios was undergoing rapid change in the mid-1950s with the increasing availability of commercial transistors. With decades of automotive lighting and vacuum tube experience, Tung-Sol was uniquely positioned to provide new technologies for car radios. Shown above in a May 1956 ad are two major technological breakthroughs from Tung-Sol which had a substantial impact in auto radio design: (1) Tung-Sol developed a complete set of electron tubes for radio circuitry that could operate with only 12 volts of plate potential (as supplied by the car battery) and (2) Tung-Sol developed the TS-176 audio power transistor as a second sourced equivalent to the Motorola 2N176. With the Tung-Sol low voltage tubes and the audio power transistor, car radios would be built with many fewer parts and better performance compared with the existing high voltage tube radios on the market. These hybrid radios were very popular with car manufacturers for several years into the mid-1960s, when all-transistor designs were introduced. During this transition period, Tung-Sol sold large quantities of the low plate voltage tubes (known as Space Charge tubes) as well as power transistors. Into the 1960s, Tung-sol continued to supply transistors for the automotive radio market.

TUNG-SOL



THE TUNG-SOL LINE OF HIGH-POWER GERMANIUM TRANSISTORS

■ WIDELY INTERCHANGEABLE ■ MORE FLEXIBLE IN APPLICATION ■ UNIFORMLY RELIABLE

For several years Tung-Sol has been manufacturing high-power germanium transistors to the industry's most exacting standards of electrical and mechanical reliability.

They have proved themselves efficient and fully reliable in countless installations, providing rugged, long-life performance for equipment in commercial and military use.

As further proof of peak performance, the fact may be cited that Tung-Sol's complete line of high-power transistors includes the JAN 2N174 and USA 2N1358, fully inspected and guaranteed to their respective MIL specifications.

The Tung-Sol line offers widest applicability in high-power amplifiers. DC-to-AC converters, DC-to-AC inverters, regulated power supplies, motor controls, servo amplifiers, relay drivers and high-power switches.

Designed for wide interchangeability, they may be specified for new, improved equipment. Their features of vacuum-tight, copper-to-copper "Cold-Welded" sealing increase design flexibility and make them more reliable. Stud-mounted, single-end construction, with solid-lug terminals, simplifies installation in all chassis and allows sufficient heat-sink design.

Ask your Tung-Sol representative for full technical details, or write: Tung-Sol Electric Inc., Newark 4, N.J. TWX:NK 193.

TUNG-SOL HIGH-POWER GERMANIUM TRANSISTORS

TYPE	MAXIMUM RATINGS (25°C) V_{CE} Volts	V_{CB} Volts	I_C A	T_J °C	TYPICAL VALUES (25°C) MAX. I_{CBO} Ma	h_{FE}	$f_{\alpha e}$ kc	MAX. T_R °C/W
2N173	-50	-60	15	100	8	52	10	.5
2N174*	-70	-80	15	100	8	37	10	.5
2N174A	-70	-80	15	100	8	37	10	.5
2N277	-40	-40	15	100	8	52	10	.5
2N278	-45	-50	15	100	8	52	10	.5
2N441	-40	-40	15	100	8	30	10	.5
2N442	-45	-50	15	100	8	30	10	.5
2N443	-50	-60	15	100	8	30	10	.5
2N1099	-70	-80	15	100	8	52	10	.5
2N1100	-80	-100	15	100	8	37	10	.5
2N1358*	-70	-80	15	100	8	37	10	.5
2N1412	-80	-100	15	100	8	37	10	.5
2N1970	-50 (1)	-100	15	100	4	29	10	.5

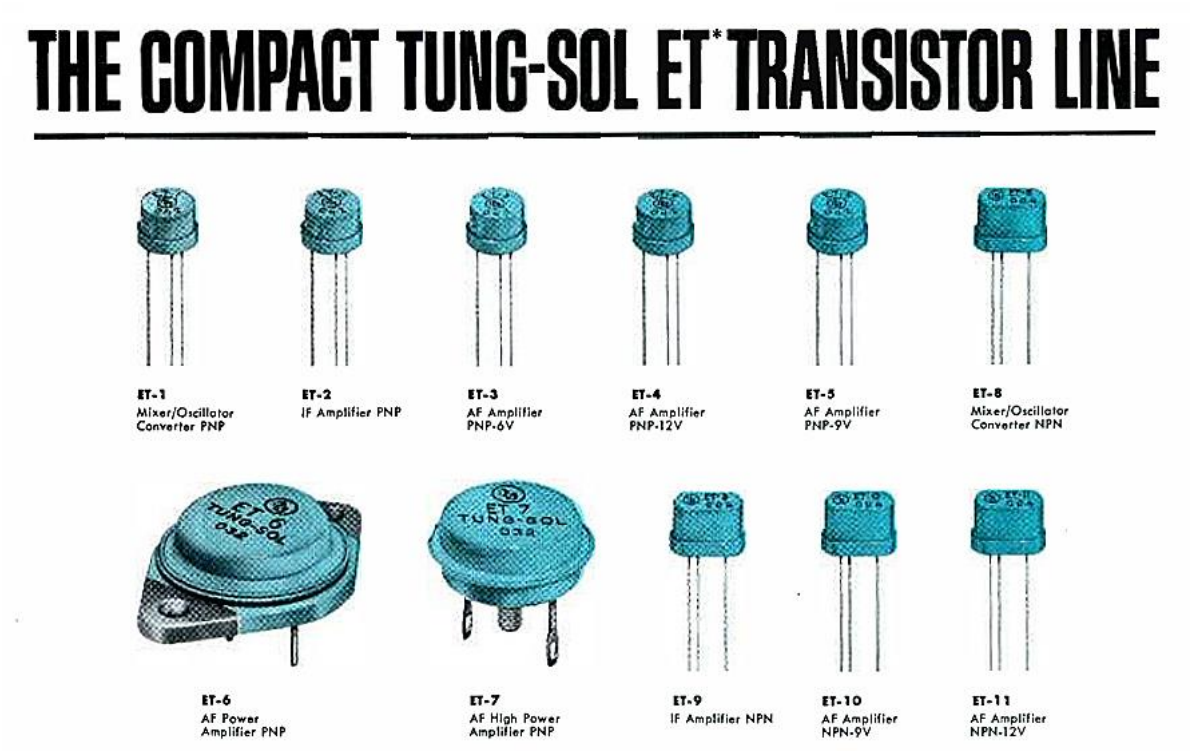
(1) BV_{CEO}

TECHNICAL ASSISTANCE IS AVAILABLE THROUGH THE FOLLOWING SALES OFFICES: Atlanta, Ga.; Columbus, Ohio; Culver City, Calif.; Dallas, Tex.; Denver, Colo.; Detroit, Mich.; Irvington, N. J.; Melrose Park, Ill.; Newark, N. J.; Philadelphia, Pa.; Seattle, Wash. In Canada: Abbey Electronics, Toronto, Ont.

*Also available in military versions.

Tung-Sol High Power Germanium Transistors: There was a ready market for high power transistors in the 1950s and 1960s for military, industrial and data processing applications. Several early semiconductor companies specialized in these types of devices, including Delco, Motorola, and Tung-Sol. One of the first successful high power transistors was the 2N174, which was registered with JEDEC in 1956 by Delco. The unique "door-nob" shape of the massive metal case for this transistor provided a very effective heat sink which in turn allowed for very high ampere current handling capabilities for the transistor. Following Delco's lead, Tung-Sol second sourced the 2N174 and soon was marketing a range of these high power transistors - the above ad for the August 11, 1961 Electronics publication illustrates the types available from Tung-Sol. This was a successful product line until the mid-1960s.

TUNG-SOL



Tung-Sol ET Replacement Transistors: With the increasing use of transistors in consumer products in the 1950s and 1060s, there was a growing market for replacement transistors that were intended to be used by technicians and service personnel to repair electronic devices. Many germanium transistor manufacturers developed replacement transistor product lines to capitalize on this market. Notable examples include the following semiconductor replacement product lines: Sylvania "ECG", RCA "SK", GE "GE" and Tung-Sol "ET". The top scan above is from the October 1961 issue of PF Reporter magazine and illustrates the complete set of Tung-Sol "ET" (Entertainment Transistor) transistors. The lower scan is from the December 1962 issue of the same publication and provides more detail on these devices. Its likely that Tung-Sol and the other major suppliers of replacement transistors were able to make a profit with these products by relabeling and marketing surplus devices or devices that didn't quite meet published specs. The Tung-sol "ET" products were heavily marketed and sold well.

TUNG-SOL

2N425: The 2N425/6/7/8 line of computer transistors was developed by Raytheon in the mid-1950s under contract with the U.S. Army Signal Corps and was registered with JEDEC by Raytheon in 1957. This line of devices was very widely used into the late 1960s in military and industrial computer systems, and many semiconductor manufacturers second sourced these popular transistors. For example, the *Transistor Substitution Handbook*, Third Edition, published by Howard W. Sams in 1962, lists the following companies as suppliers of the 2N425: C.P. Clare, ETCO, General Instrument, General Transistor, Industro, Kearfott, Motorola, Raytheon, Sylvania, Transitron, Tung-Sol and U.S. Transistor. Prices remained high for these transistors, at over $4 in 1959 and over $1 in 1962. Your Tung-Sol 2N425 is supplied NIB in the original and unique cardboard packaging developed by Tung-Sol.

2N1313: Tung-Sol was an active second source supplier of germanium transistors developed by other manufacturers. The 2N1313 was one of the few transistor types developed specifically by Tung-Sol. The company registered this transistor with JEDEC on Feb 29, 1960 with the following description: "The 2N1313 PNP Germanium Alloy Junction Transistor is designed especially for premium high-speed, high-current switching applications. Featuring a precise balance of the most wanted computer transistor characteristics, the 2N1313 offers improved performance at lower cost over most popular computer types." Because this transistor was late to the market and did not offer substantial performance gains over existing types, the 2N1313 was not a major commercial success. However, this is a rare and historically important germanium computer transistor - it represents a major effort by Tung-Sol in the late 1950s to become a leading transistor supplier with a high performing germanium switching device.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: Tung-Sol 2N425 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Robin's egg blue TO-5
Vintage/Date Code: 1950s/1960s
Use: Computer switching applications
Notes: Popular line of computer transistors from Raytheon. 2nd sourced by Tung-Sol.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: Tung-Sol 2N1313 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Robin's egg blue TO-5
Vintage/Date Code: 1960s
Use: Premium switching applications
Notes: Rare device developed by Tung-Sol for early 1960s computer market.

TUNG-SOL

TUNG-SOL PRODUCT BULLETIN

GERMANIUM TRANSISTOR TYPE 2N1313

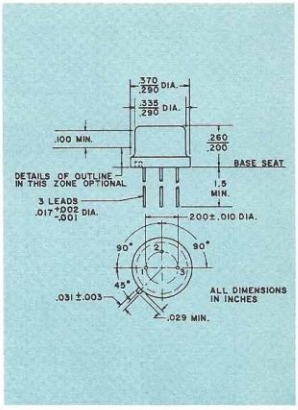
NOVEMBER 15, 1960

APPLICATIONS: Computer Switching, High Frequency Control Circuits, High Frequency Relay Drivers, Electromechanical Lead In/Out Circuits, Blocking Oscillators, Logic Circuits, Multivibrator.

DESCRIPTION:

The 2N1313 PNP Germanium Alloy Junction Transistor is designed especially for premium high-speed, high-current switching applications. Featuring Tung-Sol's exclusive "thermal bond" construction establishes a sturdy electrode-to-case bond while maintaining excellent heat dissipation capability and complete electrical isolation.

Furthermore, the 2N1313, designed to meet rigorous military environmental standards, provides greater mechanical reliability.



ABSOLUTE MAXIMUM RATINGS

Collector to Base Voltage	BV_{CBO}	−30 Volts
Emitter to Base Voltage	BV_{EBO}	−20 Volts
Collector to Emitter Voltage	BV_{CEO}	−15 Volts
Collector to Emitter Voltage (V_{BE} = +0.1 Volt)	BV_{CEV}	−20 Volts
Collector Current (Continuous)	I_C	400 mA
Base Current (Continuous)	I_B	50 mA
Device Dissipation (Free Air) T_A = 25°C	P_c	180 mW
Device Dissipation (Infinite Heat Sink) T_C = 25°C	P_c	350 mW
Junction Temperature	T_J	−65° C to +100° C
Lead Temperature (1/16" from case)		260° C For 10 Sec.

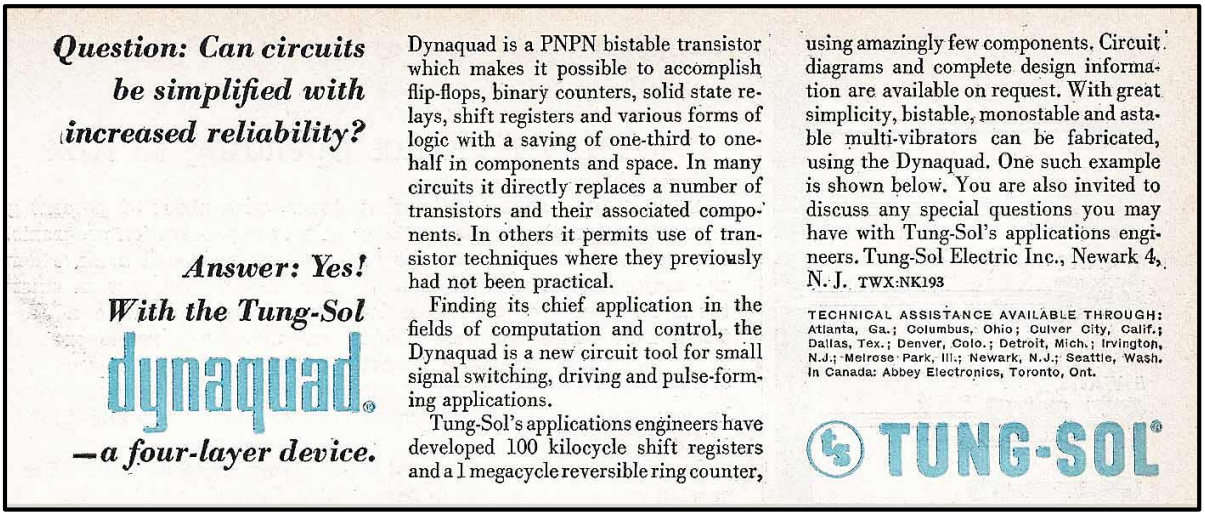
ELECTRICAL CHARACTERISTICS (25°C)

Test	Symbol	Conditions	Min.	Typ.	Max.	Unit
Collector Cut-off Current	I_{CBO}	V_{CB} = −0.5 V			2.5	μA
	I_{CBO}	V_{CB} = −30 V			25	μA
Emitter Cut-off Current	I_{EBO}	V_{EB} = −12 V			4	μA
	I_{EBO}	V_{EB} = −20 V			25	μA
Collector Emitter Current	I_{CEO}	V_{CE} = −15 V			1	mA
Collector-Emitter Current	I_{CEV}	V_{CE} = −20 V, V_{BE} = +0.1 V			10	μA
DC Current Ratio	h_{FE}	I_B = 1mA, V_{CE} = −0.25 V	40		125	—
Frequency Cut-off	f_{hfb}	V_{CB} = −6 V, I_C = 1mA	8			Mc
Sat.-Voltage Collector-Emitter	SV_{CE}	I_B = 0.5 mA, I_C = 10mA			−0.12	V
Sat.-Voltage Base-Emitter	SV_{BE}	I_B = 0.5 mA, I_C = 10mA			−0.3	V
Delay & Rise-Time	T_1	I_{B1} = 1mA, I_{B2} = 1mA, I_C = 10mA, R_L = 1K			0.65	μSec.
Storage-Time	t_s				0.70	μSec.
Fall-Time	t_f				0.40	μSec.

TUNG-SOL ELECTRIC INC.
SEMICONDUCTOR DIVISION
ONE SUMMER AVENUE
NEWARK 4, NEW JERSEY

Tung-Sol Computer Transistor Data Sheet: Shown above is the data sheet for the 2N1313. This type of documentation was typical of that supplied by transistor manufacturers to customers in large Handbooks or Data Books. This device was documented with an 8 MC cut-off frequency, or switching speed, which is quite slow compared to competing computer transistors from this timeframe, and this factor may account for the low sales volume for the product. After Tung-Sol exited the transistor business in the mid-1960s, the 2N1313 was second sourced by ETCO, General Instrument, Industro and Western Transistor Corp.

TUNG-SOL



Question: Can circuits be simplified with increased reliability?

Answer: Yes! With the Tung-Sol **dynaquad**® *—a four-layer device.*

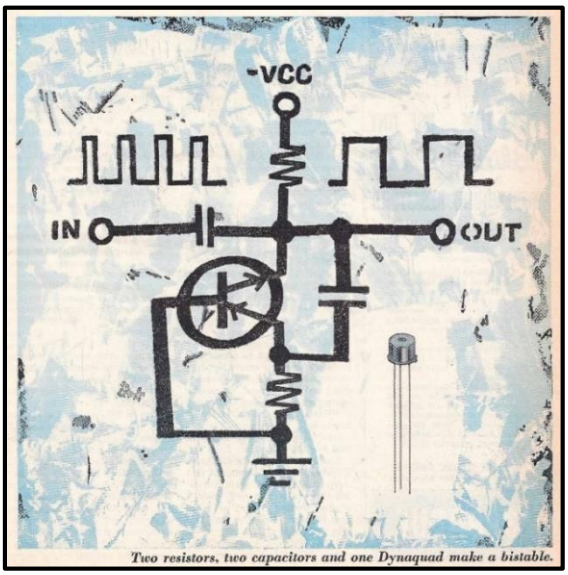
Dynaquad is a PNPN bistable transistor which makes it possible to accomplish flip-flops, binary counters, solid state relays, shift registers and various forms of logic with a saving of one-third to one-half in components and space. In many circuits it directly replaces a number of transistors and their associated components. In others it permits use of transistor techniques where they previously had not been practical.

Finding its chief application in the fields of computation and control, the Dynaquad is a new circuit tool for small signal switching, driving and pulse-forming applications.

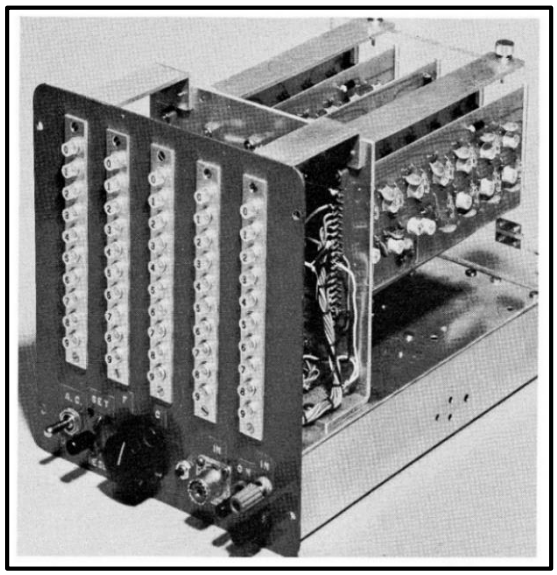
Tung-Sol's applications engineers have developed 100 kilocycle shift registers and a 1 megacycle reversible ring counter, using amazingly few components. Circuit diagrams and complete design information are available on request. With great simplicity, bistable, monostable and astable multi-vibrators can be fabricated, using the Dynaquad. One such example is shown below. You are also invited to discuss any special questions you may have with Tung-Sol's applications engineers. Tung-Sol Electric Inc., Newark 4, N. J. TWX:NK193

TECHNICAL ASSISTANCE AVAILABLE THROUGH: Atlanta, Ga.; Columbus, Ohio; Culver City, Calif.; Dallas, Tex.; Denver, Colo.; Detroit, Mich.; Irvington, N.J.; Melrose Park, Ill.; Newark, N.J.; Seattle, Wash. In Canada: Abbey Electronics, Toronto, Ont.

TUNG-SOL®

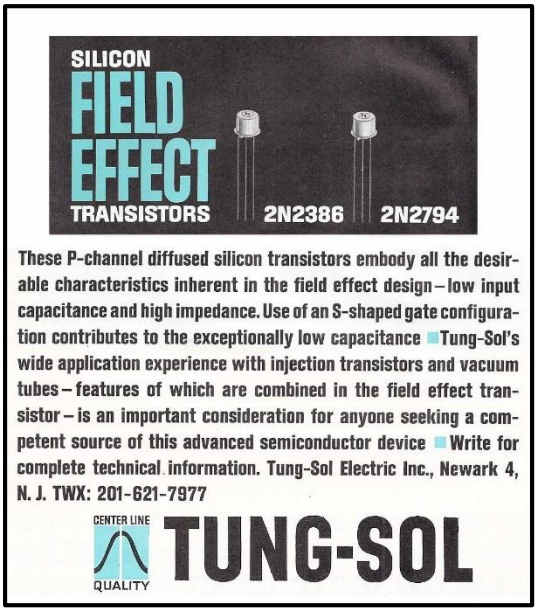


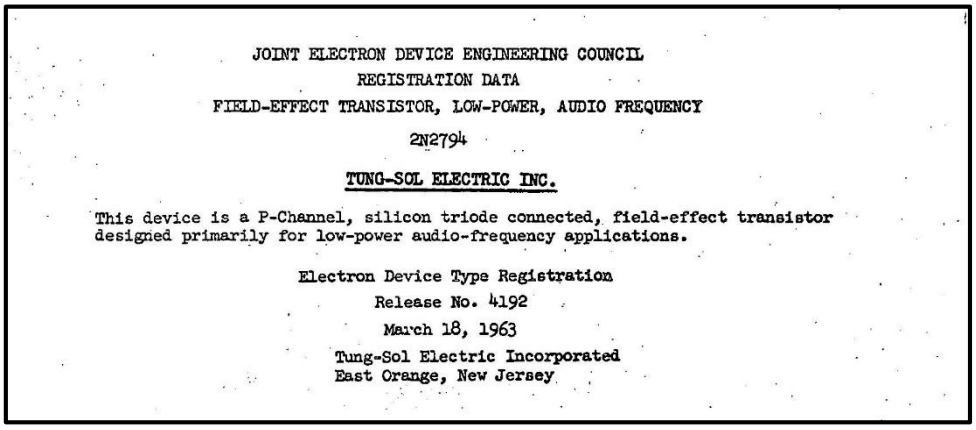
Two resistors, two capacitors and one Dynaquad make a bistable.



Tung-Sol Dynaquad: Marketed as a 4 layer bi-stable germanium transistor, the Dynaquad was the trade name used by Tung-Sol for a group of PNPN switching devices introduced in the early 1960s and targeted for use in digital switching applications. Multi-layer PNPN semiconductor devices were available from other manufacturers at this time including: (1) Trigistor from SSPI (2) Silicon Controlled Rectifier/Silicon Controlled Switch from GE and others (3) Dynistor by Westinghouse and, most famously (4) Shockley 4-layer diode from Shockley Transistor Corp. These devices were constructed with two or three leads and all had the property of performing high speed "on/off" switching analogous to the Thyratron electron tube. An advantage claimed for these devices over the standard PNP or NPN transistor structure was the reduction in the number of parts required to implement switching circuits. The scans above are from 1961 Tung-Sol material describing the advantages of the Dynaquad, including a photo of a 100KC digital counter constructed using a small number of these devices. Tung-Sol registered the Dynaquad in 1961 and 1962 with JEDEC as types 2N1966-68, and 2N2260-62. These unique Tung-Sol devices sold in low quantities as digital integrated circuits with much greater functionality became available commercially.

TUNG-SOL





JOINT ELECTRON DEVICE ENGINEERING COUNCIL
REGISTRATION DATA
FIELD-EFFECT TRANSISTOR, LOW-POWER, AUDIO FREQUENCY

2N2794

TUNG-SOL ELECTRIC INC.

This device is a P-Channel, silicon triode connected, field-effect transistor designed primarily for low-power audio-frequency applications.

Electron Device Type Registration
Release No. 4192
March 18, 1963
Tung-Sol Electric Incorporated
East Orange, New Jersey

The Last Tung-Sol Transistors: In 1963, Tung-Sol registered its first and only silicon transistor with JEDEC. This device was the 2N2794 Field Effect Transistor, as shown in the 1963 ad above and in the JEDEC listing info. The 1963 Eleventh Annual Transistor Data Chart published by *Electronic Design News* lists Tung-Sol as manufacturing only a handful of TS type germanium transistors and the two silicon FETs shown in the top scan. The 1965 Semiconductor Reference Edition of the *Electronic Design News* lists Tung-Sol as a rectifier manufacturer only, and no longer supplying transistors. During this same timeframe, Tung-Sol was involved in a business merger and in 1966 the company was acquired by the Studebaker Worthington Corporation, with a business focus on auto lighting. The brief history of Tung-Sol semiconductors spans the decade from the mid-1950s to the mid-1960s when germanium technology was initially dominant but was later superseded by silicon devices, including integrated circuits. Although the company developed some interesting devices in the early 1960s, including the Dynaquad and the 2N2794 FET, Tung-Sol never made the corporate investment required to enter the silicon era, and is best remembered for its broad range of "bright blue" PNP germanium alloy junction devices including power transistors, entertainment replacement transistors, hearing aid and audio transistors, and digital computer switching transistors.