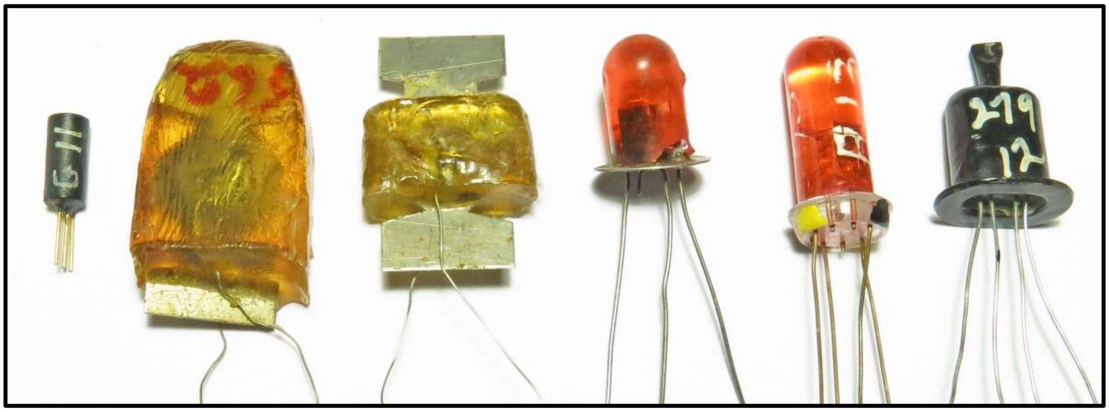
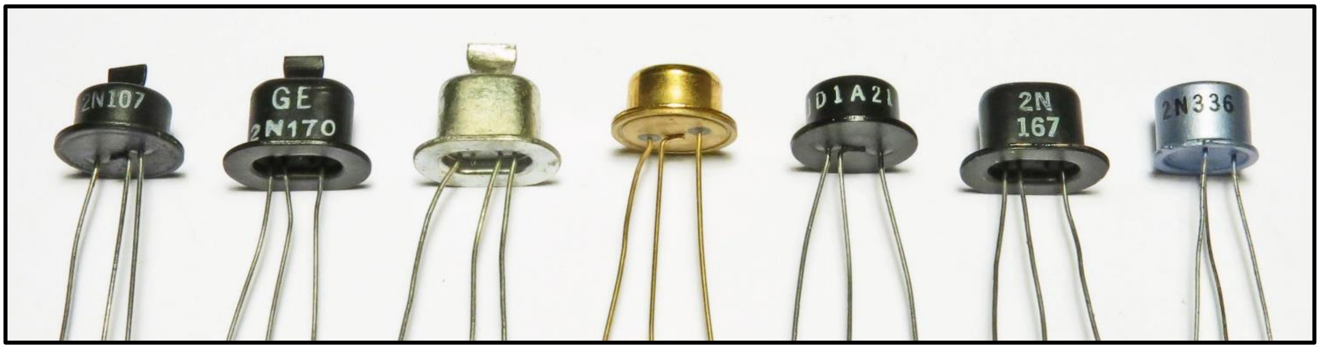
TRANSISTOR MUSEUM™

HISTORIC GERMANIUM COMPUTER TRANSISTORS

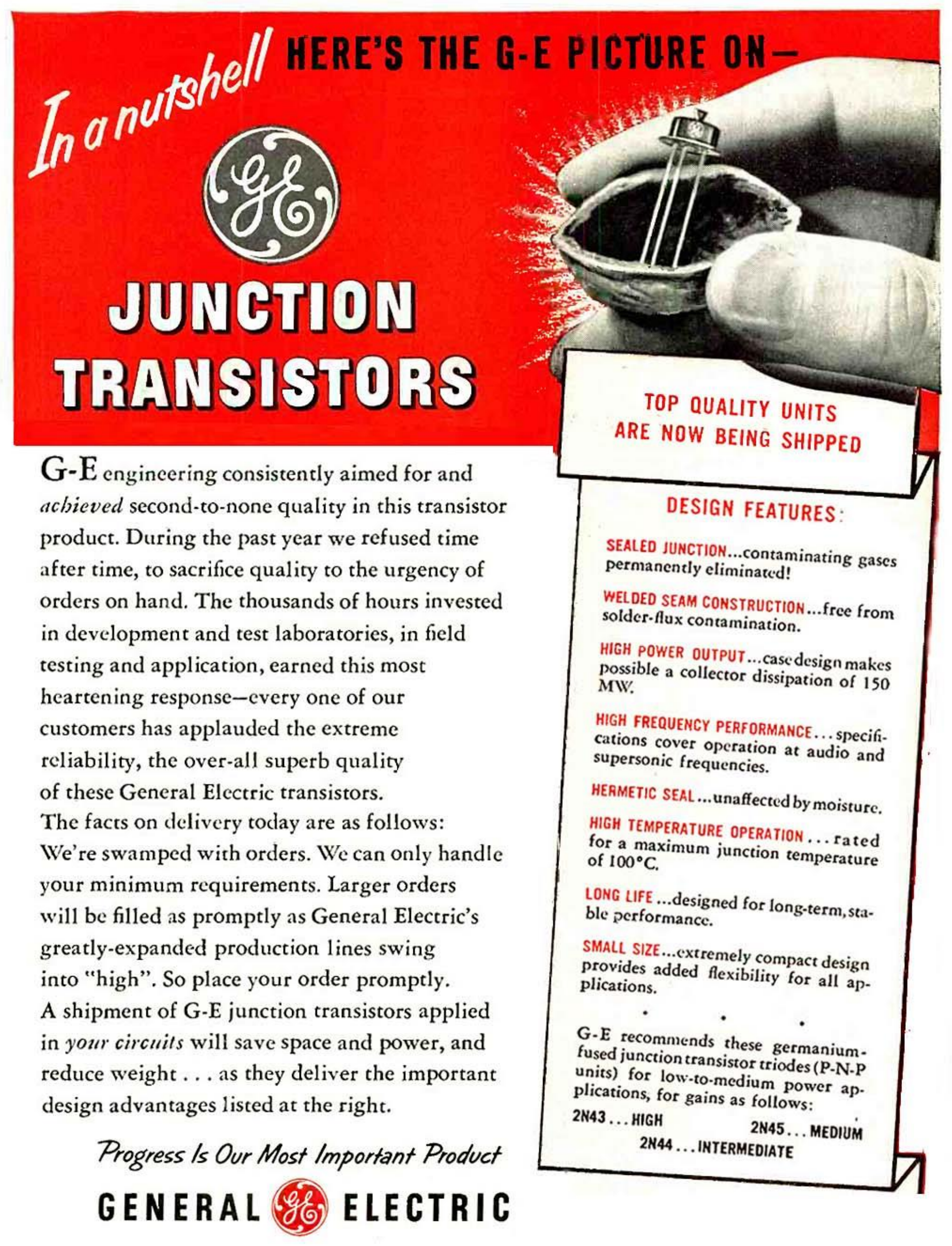
GENERAL ELECTRIC





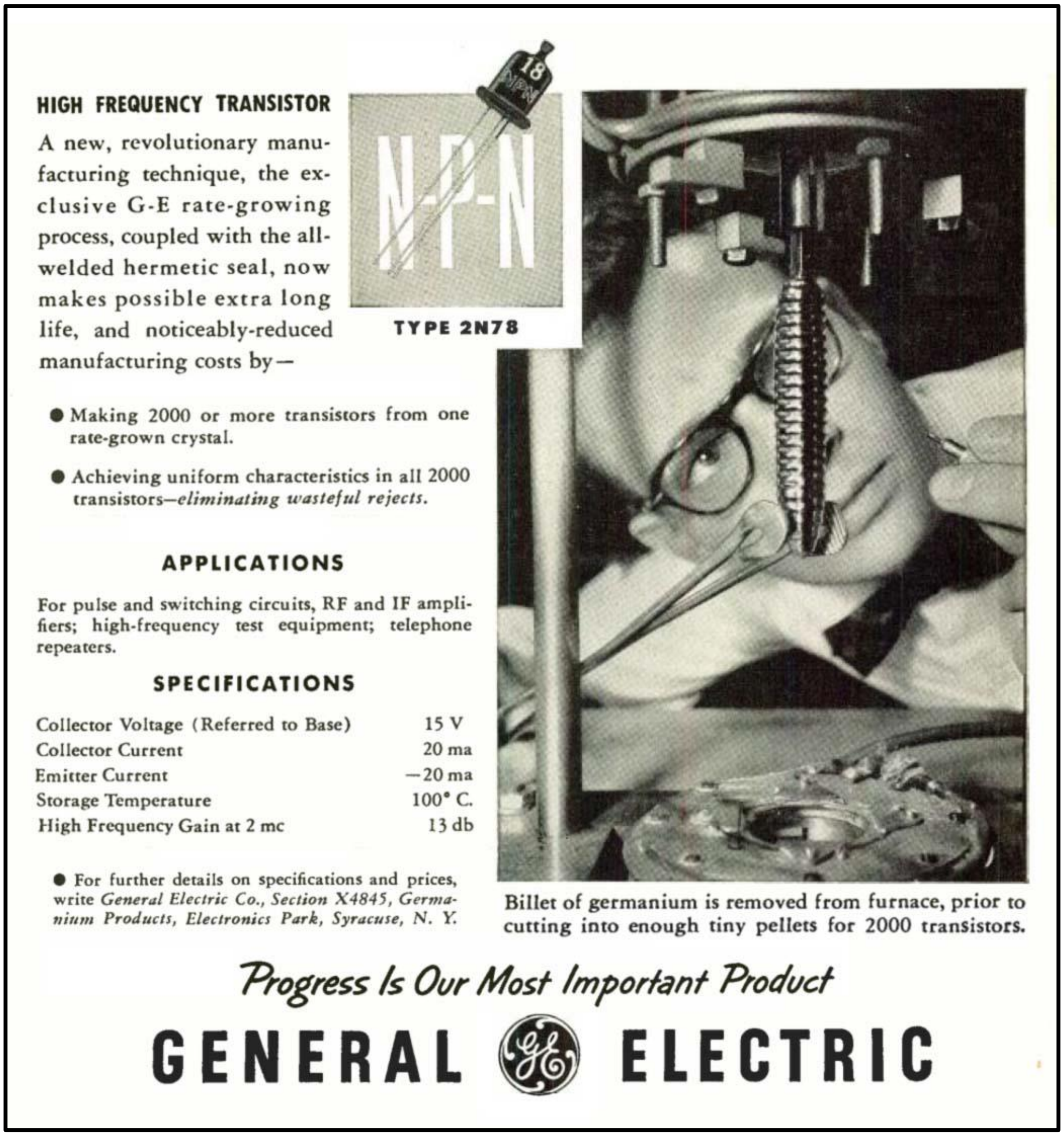
The First General Electric Transistors: General Electric Company was a major manufacturer of electronic equipment and electronic components, including vacuum tubes, at the time of the introduction of the transistor in the late 1940s and was very quick in establishing research and development programs for this new technology. The transistors shown across the top row are all early 1950s GE devices: the G11 point contact transistor at upper left was developed in 1950 and was one of the first commercial transistors available from any company. The four handmade plastic cased units at top center are examples of the industry's very first alloy junction transistors, all of which were made in 1951 at the GE Syracuse facility by John Saby. The invention of this PNP alloy junction technology was a major milestone in semiconductor history and was the basis for millions of production transistors over the next two decades. The black metal prototype unit at upper right is from 1952 and is an early example of another major transistor type (NPN grown junction) commercialized by GE and used as the technological basis for large scale production in the 1950s and 1960s. The transistors shown in the lower photo are all General Electric production units from the mid-1950s, and illustrate the broad range of transistor types manufactured by GE. The leftmost units, 2N107 and 2N170, were marketed successfully to hobbyists and were relabeled "fallouts" that didn't meet production specifications. High volume customers of 1950s GE transistors often specified unique type id numbers, such as the 4JD1A21, or purchased unlabeled and unpainted cases types – above center. Building on its success with germanium transistors, GE was also very active in developing some of the industry's first silicon transistors, such as the 1958 2N336 at lower right - early GE silicon devices are easily identifiable because of the striking silver/blue paint case paint. General Electric was a 1950s germanium transistor powerhouse and was the leading registrant of new JEDEC types through 1957. GE developed transistors for most all industry applications including consumer electronics, computers, industrial and military.

GENERAL ELECTRIC



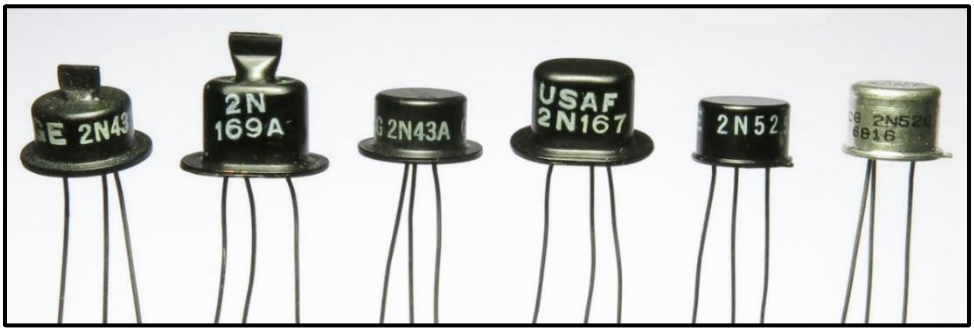
1954 GE Transistors in Production Quantities: In late 1953, GE introduced its first commercial PNP alloy junction transistors, the 2N43/44/45 – this was a robust and high performing product line, and was immediately in high demand. Note in the November 1954 ad above, that GE was "swamped with orders" and could only handle "your minimum requirements". GE was working hard to bring greatly expanded production lines on line. Many of these first GE transistors found their way to computer companies (such as Univac) and soon were incorporated in new designs.

GENERAL ELECTRIC



Commercial NPN Transistors in 1955: As shown in the April 1955 ad above, GE introduced its NPN line of germanium transistors shortly after the earlier 1953 PNP introduction. GE had developed a unique "rate grown" manufacturing process for these NPN devices that resulted in good high frequency performance and consistency across larger production lots. These characteristics were in high demand by computer engineers, and GE NPN transistors were used in large numbers in 1950s computers. A unique aspect of these GE NPN transistors was the proprietary "bath-tub oval" shape of the cases (see the 2N78 in the ad above). This case style was in contrast with the round "top hat" format used for the early GE PNP transistors, such as the 2N43/44/45. Note also that these proprietary GE cases also used the "pinched top" vacuum exhaust tube on the case top. These General Electric case types and manufacturing techniques resulted in very robust devices, which were ideal for many industrial and military applications, including computers.

GENERAL ELECTRIC



SILICON

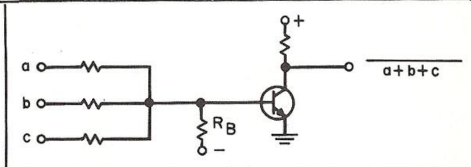
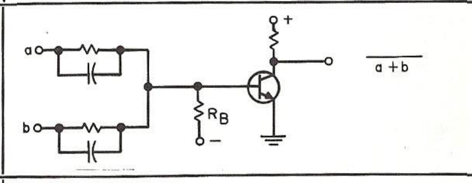
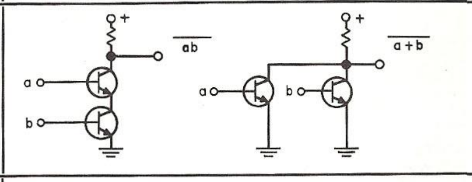
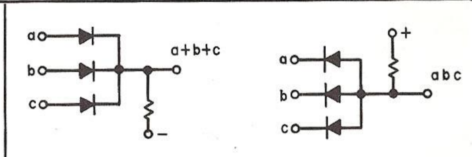
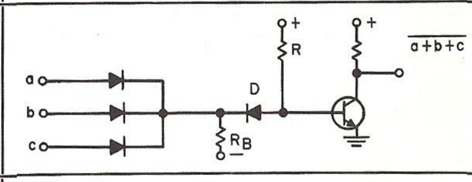
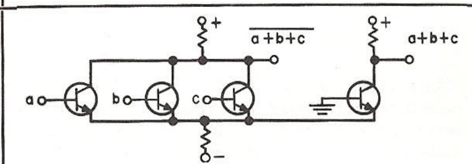
USE	TYPE NO.
AMPLIFIER AND COMPUTER NPN (Ceramic Fixed-Bed Construction)	2N332 (Per MIL-T-19500/37A) (NAVY) 2N333 (Per MIL-T-19500/37A) (NAVY) 2N334 (Per MIL-T-19500/37A) (NAVY) 2N335 (Per MIL-T-19500/37A) (NAVY) 2N336
	2N332A 2N333A 2N334A 2N335A 2N336A
	2N335B 2N337 (Per MIL-T-19500/69C) (NAVY) 2N338 (Per MIL-T-19500/69C) (NAVY) 2N1277 2N1278 2N1279
UNIJUNCTION PN (Ceramic Fixed-Bed Construction)	2N489 (Per MIL-T-19500/75) (USAF) 2N490 (Per MIL-T-19500/75) (USAF) 2N491 (Per MIL-T-19500/75) (USAF) 2N492 (Per MIL-T-19500/75) (USAF) 2N493 (Per MIL-T-19500/75) (USAF)
	2N494 (Per MIL-T-19500/75) (USAF) 2N1671 2N1671A 2N1671B
AUDIO NPN Mesa	2N497 2N498 2N656 2N657 2N497A
	2N498A 2N656A 2N657A

GERMANIUM

AUDIO PNP	2N43 2N43A (Per MIL-T-19500/18) (USAF) 2N44 2N44A (Per MIL-T-19500/6) (USAF) 2N524
	2N525 2N526 (Per MIL-T-19500/60C) (JAN) 2N527 2N1175 2N1175A
	2N1413 2N1414 2N1415
COMPUTER PNP	2N123 (Per MIL-T-19500/30) (USAF) 2N394A 2N395 2N396 2N396A (Per MIL-S-19500/64A) (NAVY)
	2N397 2N404 (Per MIL-T-19500/20A) (USAF) 2N404A 2N413 2N414
	2N450 2N1057 2N1614
COMPUTER NPN	2N167 2N167A (Per MIL-S-19500/11A) (USAF) 2N377 2N385 2N388 (Per MIL-T-19500/65) (NAVY)
	2N634A 2N635A 2N636A 2N1198 2N1217
	2N1288 2N1289 2N1304 2N1306 2N1308
	2N1510 2N1694

Early GE Computer Transistors: Shown at top are a series of 1950s and 1960s General Electric germanium transistors. GE was one of the best known and most successful manufacturers of transistors during this timeframe and produced a broad range of types, including computer transistors. A unique aspect of early GE transistors was the "pinched top" case style, shown on the two devices at top far left. This early case structure was the result of a pinched-off exhaust tube on the top of the case that was used to create a vacuum inside the case in order to protect the transistor junction from contamination. These GE devices were indeed highly reliable. By the late 1950s, the "pinched top" case style was obsoleted as more modern manufacturing processes achieved high reliability without the use of vacuum. The two middle transistors above are examples of the late 1950s GE case style. In the 1960s, GE adopted the industry standard TO-5 case style for most germanium transistors, as shown at far right above. The 1961 sales brochure excerpt above provides a listing of the many GE transistors available at this time, including early silicon devices.

GENERAL ELECTRIC

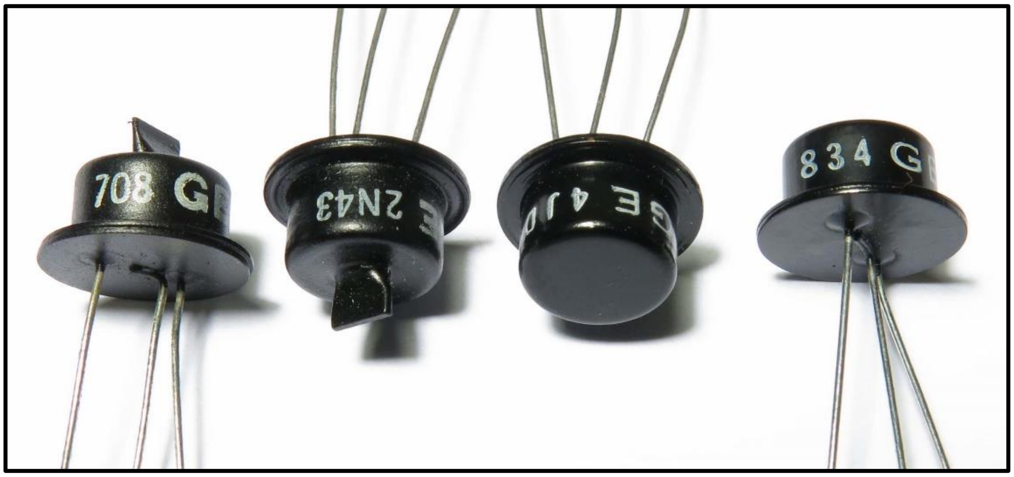
NAME	TYPICAL CIRCUIT (Positive signals are defined as 1)	DESCRIPTION	FEATURES	SUITABLE TRANSISTORS	
				GERMANIUM	SILICON
RTL Resistor transistor logic (NOR)		Logic is performed by resistors. Any positive input produces an inverted output irrespective of the other inputs. Resistor R_B gives temperature stability. (See p. 131)	The circuit design is straightforward. All logical operations can be performed with only this circuit. Many transistors readily meet the steady state requirements.	2N43A* 2N78* 2N167* 2N169A 2N396* 2N525 2N526* 2N635 2N1057	2N335*
RCTL Resistor capacitor transistor logic		Same as RTL except that capacitors are used to enhance switching speed. The capacitors increase the base current for fast collector current turn on and minimize storage time by supplying a charge equal to the stored base charge.	Faster than RTL at the expense of additional components and stringent stored charge requirements.	No standard types are characterized specifically for this logic 2N404* 2N525 2N634 2N1115	
DCTL Direct coupled transistor logic		Logic is performed by transistors. V_{CE} and V_{BE}, measured with the transistor in saturation, define the two logic levels. V_{CE} must be much less than V_{BE} to ensure stability and circuit flexibility. (See p. 130)	Very low supply voltages may be used to achieve high power efficiency and miniaturization. Relatively fast switching speeds are practical.	4JD1A68 (PNP Alloy) Surface barrier types	
DL Diode logic		Logic is performed by diodes. The output is not inverted. Amplifiers are required to maintain the correct logic levels through several gates in series.	Several gates may be used between amplifiers. High speeds can be attained. Non - inversion simplifies circuit design problems. Relatively inexpensive components are used.	2N43A* 2N78* 2N123* 2N167* 2N396* 2N525 2N635	2N333* 2N337*
LLL Low level logic		Logic is performed by diodes. The output is inverted. The diode D isolates the transistor from the gate permitting R to turn on the collector current. By proper choice of components only small voltage changes occur.	The number of inputs to the diode gate does not affect the transistor base current thus giving predictable performance. The small voltage excursions minimize the effects of stray capacitance and enhance switching speed.	2N123* 2N396* 2N525 2N526* 2N635 2N1115	2N335* 2N338*
CML Current mode logic		Logic is performed by transistors which are biased from constant current sources to keep them far out of saturation. Both inverted and non-inverted outputs are available.	Very high switching speeds are possible because the transistors are operated at optimum operating conditions. Although the voltage excursion is small the circuitry is relatively unaffected by noise.	2N1289 Mesa Types	2N337* 2N338*

1960s Transistor Logic Systems: General Electric actively promoted the use of its transistors in a variety of applications throughout the 1950s and 1960s, including use in computer logic circuits. Shown above is a section of a table excerpted from the Fifth Edition of the GE Transistor Manual, published in 1960, which documents the specific transistor logic circuits that were typical for 2nd generation digital computers. This timeframe coincides with the brief period in the late 1950s and early 1960s, just prior to the commercialization of integrated circuits, when discrete transistor circuits were used in large scale digital computers. RTL (Resistor Transistor Logic), for example, was used extensively in many 2nd generation computers, such as the RCA 501. The above table provides an excellent summary of the primary transistor logic circuits that were the basis for most commercial transistorized digital computers. Note that GE manufactured an extensive variety of germanium transistors that were suitable for all the different logic systems shown above and that silicon transistors were just beginning to become available.

TRANSISTOR MUSEUM™

HISTORIC GERMANIUM COMPUTER TRANSISTORS

GENERAL ELECTRIC



2N43: In mid-1953, General Electric (GE) made an early commercial entry into the new field of junction transistors with the 2N43/44/45 line of germanium alloy junction devices. These were rugged, reliable transistors enclosed in the now classic "pinched top" metal case. These first GE commercial germanium junction transistors were quite expensive, costing as much as $23.75 (for the 2N43) in the 1954 Radio Shack catalog. All these devices were made on the same manufacturing lines, with a gain test process used to sort the transistors into the appropriate 2N4X categories. "Leftovers" from the 2N4X line, which failed to meet minimum specs, were sold as the famous 2N107 hobbyist transistor. The 2N45 was obsoleted by GE in the late 1950s, but the 2N43 and the 2N44 remained in production for many years, into the 1960s. These devices were "second-sourced" by both ETCO and General Instruments (GI). The 2N43A was the first USAF qualified transistor, and was tested to ensure high reliability. The GE 2N4X line of germanium PNP alloy junction transistors were versatile, rugged devices that found widespread use in military, commercial and audio applications. Early digital computers that used the 2N43 transistor included the ORDVAC and EDVAC.

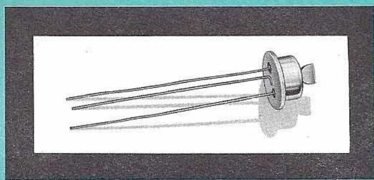
4JDA121: In the 1950s, the industry standards for transistor typing and part number assignment were rapidly evolving, and many early semiconductor companies identified new devices with proprietary or "house-numbered" designations instead of the more standard "2N" sequence. GE, for example, used the "ZJ" designation for early prototypes and the "4JD" prefix for preproduction types or those types which did not meet specific "2N" requirements or were developed specifically to meet individual customer requirements. The 4JDA121 transistor had performance similar to the 2N43 and was sold throughout the 1950s. It was used in the MIT TX-2 computer.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE 2N43 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black metal top hat
Vintage/Date Code: 1950s/1960s
Use: General purpose computer-industrial
Notes: First GE junction transistor type. Widespread use in early computers.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE 4JDA121 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black metal top hat
Vintage/Date Code: 1950s/1960s
Use: General purpose computer-industrial
Notes: House-numbered and selected 2N43. Rare type. Used in MIT TX-2 computer.

GENERAL ELECTRIC

TRANSISTOR SPECIFICATIONS (Computer-Industrial) Page 1, Feb. 1, 1958



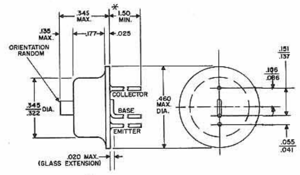
Computer-Industrial
TRANSISTORS

PNP
GERMANIUM TYPES
2N43
2N44

The General Electric Types 2N43 and 2N44 alloy junction triode transistors are PNP units particularly recommended for low to medium power applications. A hermetic enclosure is provided by the use of glass-to-metal seals and welded seams.

absolute maximum ratings (25°C)

Voltages			
Collector to Base	V_{CB}	—45	volts
Collector to Emitter	V_{CE}	—30	volts
Emitter to Base	V_{EB}	—5	volts
Collector Current	I_C	—300	ma
Temperatures			
Storage	T_{STG}	Max. +100°C Min. —65°C	
Operating Junction	T_J	Max. +85°C	
Total Transistor Dissipation	P_{AV}	(See note 1)	



* CUT TO 0.200" FOR USE IN SOCKETS.
LEADS TINNED DIA. .018
MOUNTING POSITION – ANY
WEIGHT: .05 OZ.
BASE CONNECTED TO TRANSISTOR SHELL.
DIMENSIONS IN INCHES.

electrical characteristics (25°C)

SMALL SIGNAL CHARACTERISTICS

(Unless otherwise specified; V_C = —5v common base; I_E = 1ma; f = 270 cps.)

		2N43 Min.	2N43 Max.	2N43 Design Center	2N44 Min.	2N44 Max.	2N44 Design Center	
Output Admittance (Input A-C open circuited)	h_{ob}	0.1	1.5	0.8	0.1	1.5	0.9	μmhos
Forward Current Transfer Ratio (Common Emitter; Output A-C short circuited)	h_{fe}	30	66	42			25	
Input Impedance (Output A-C short circuited)	h_{ib}	25	35	29	27	38	31	ohms
Reverse Voltage Transfer Ratio (Input A-C open circuited)	h_{rb}	1	15	5	1	13	4	$\times 10^{-4}$
Output Capacity (f = 1mc; input A-C open circuited)	C_{ob}	20	60	40	20	60	40	μμf
Noise Figure (f = 1kc; BW = 1 cycle)	NF		20	6		15	6	db
Frequency Cut-off	f_{ab}	0.5	3.5	1.3	0.5	3	1.0	mc

D-C CHARACTERISTICS

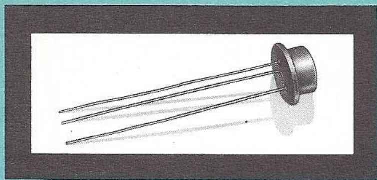
		2N43 Min.	2N43 Max.	2N43 Design Center	2N44 Min.	2N44 Max.	2N44 Design Center	
Forward Current Gain, Common Emitter I_C/I_B (V_{CE} = —1v; I_C = —20ma)	h_{FE}	34	65	53	18	43	31	
(V_{CE} = —1v; I_C = —100ma)	h_{FE}	30		48	13		25	
Base Input Voltage, Common Emitter (V_{CE} = —1v; I_C = —20ma)	V_{BE}			—.23			—.25	volts
Collector Cutoff Current (V_{CBO} = —45v)	I_{CO}		—16	—8		—16	—8	μamps
Emitter Cutoff Current (V_{EBO} = —5v)	I_{EO}		—10	—4		—10	—4	μamps
Collector to Emitter Voltage (R_{BE} = 10K ohms; I_C = —0.6ma)	V_{CER}	—30			—30			volts
Punch-through Voltage	V_{PT}	—30			—30			volts

THERMAL RESISTANCE (k)

	2N43	2N44	
Junction Temperature Rise/Total Transistor Dissipation;			
Free Air (Note 2)	.25	.25	°C/mw
Infinite Heat Sink	.11	.11	°C/mw
Clip-on Heat Sink in Free Air (Note 2) (.95 sq. in. radiating surface)	.20	.20	°C/mw

Introduced by GE in 1953, the 2N43/44/45 line of transistors was very successful and sold in the millions of units over the next 20 years. By 1958, the lower performing 2N45 had been obsoleted, as can be seen by the spec sheet for these devices above. Note also that in 1958, the case style for these transistors continued to use the "pinched top" exhaust tube as introduced in 1953. The early GE PNP transistors were also notable for the "top hat" case style, which was continued throughout the 1950s.

GENERAL ELECTRIC



Computer-Industrial TRANSISTORS

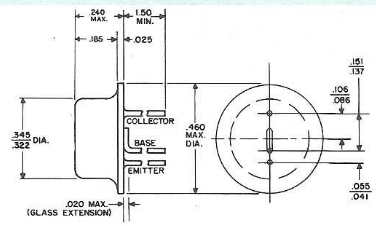
PNP GERMANIUM TYPES

2N43 2N43A 2N44

The General Electric Types 2N43, 2N43A and 2N44 alloy junction triode transistors are PNP units particularly recommended for low to medium power applications. A hermetic enclosure is provided by the use of glass-to-metal seals and welded seams.

absolute maximum ratings (25°C)

Voltages		
Collector to Base ($I_E = 0$)	V_{CB}	−45 volts
Collector to Emitter ($R_{BE} = 10K$)	V_{CE}	−30 volts
Emitter to Base ($I_C = 0$)	V_{EB}	−5 volts
Collector Current	I_C	−300 ma
Temperatures		
Storage	T_{STG}	Max. +100°C Min. −65°C
Operating Junction	T_J	Max. +85°C
Total Transistor Dissipation	P_{AV}	(See note 1)



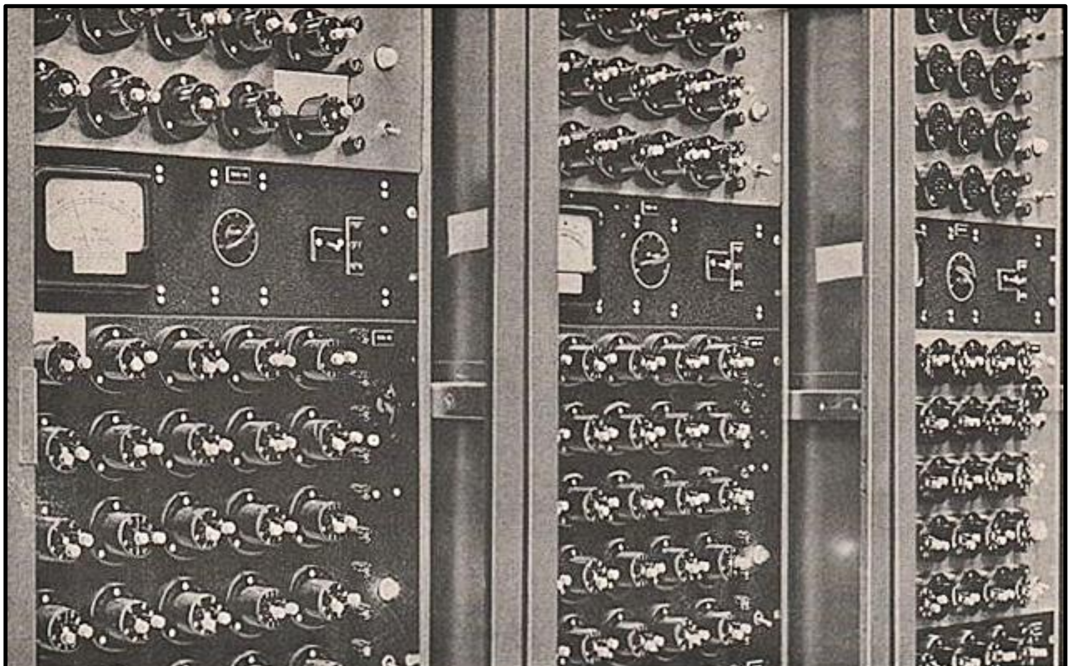
electrical characteristics (25°C)

SMALL SIGNAL CHARACTERISTICS (Unless otherwise specified; $V_C = -5v$ common base; $I_E = 1ma$; f = 270 cps.)		2N43 Min.	2N43 Design Center	2N43 Max.	2N43A* Min.	2N43A* Design Center	2N43A* Max.	2N44** Min.	2N44** Design Center	2N44** Max.	
Output Admittance (Input A-C open circuited)	h_{ob}	0.1	0.8	1.5	0.1	0.8	1.5	0.1	0.9	1.5	μmhos
Forward Current Transfer Ratio (Common Emitter; Output A-C short circuited)	h_{fe}	30	42		30	42	66		25		
Input Impedance (Output A-C short circuited)	h_{ib}	25	29	35	25	29	35	27	31	38	ohms
Reverse Voltage Transfer Ratio (Input A-C open circuited)	h_{rb}	1	5	15	1	5	15	1	4	13	$\times 10^{-4}$
Output Capacity (f = 1mc; input A-C open circuited)	C_{ob}	20	40	60	20	40	60	20	40	60	μμf
Noise Figure (f = 1kc; BW = 1 cycle)	NF		6	20		6	20		6	15	db
Frequency Cut-off	f_{ab}	0.5	1.3	3.5	0.5	1.3	3.5	0.5	1.0	3	mc
D-C CHARACTERISTICS											
Forward Current Gain, Common Emitter I_C/I_B ($V_{CE} = -1v$; $I_C = -20ma$)	h_{FE}	34	53	65	34	53	65	18	31	43	
($V_{CE} = -1v$; $I_C = -100$ ma)	h_{FE}	30	48		30	48		13	25		
Collector Saturation Voltage ($I_C = -20$ ma; I_B as indicated)	V_{CE} (SAT)	65	90	130	65	90	130	55	90	130	mv
	@ I_B =	1.3	1.3	1.3	1.3	1.3	1.3	2	2	2	ma
Base Input Voltage, Common Emitter ($V_{CE} = -1v$; $I_C = -20ma$)	V_{BE}	−180	−230	−280	−180	−230	−280	−200	−250	−300	mv
Collector Cutoff Current ($V_{CBO} = -45v$)	I_{CO}		−8	−16		−8	−16		−8	−16	μamps
Emitter Cutoff Current ($V_{EBO} = -5v$)	I_{EO}		−4	−10		−4	−10		−4	−10	μamps
Collector to Emitter Voltage ($R_{BE} = 10K$ ohms; $I_C = -0.6ma$)	V_{CER}	−30			−30			−30			volts
Punch-through Voltage	V_{PT}	−30			−30			−30			volts
THERMAL RESISTANCE (k)											
Junction Temperature Rise/Total Transistor Dissipation; Free Air (Note 2)				.25			.25			.25	°C/mw
Infinite Heat Sink				.11			.11			.11	°C/mw
Clip-on Heat Sink in Free Air (Note 2) (.95 sq. in. radiating surface)				.20			.20			.20	°C/mw

*Per Mil-T-19500/18 **Per Mil-T-19500/6

By 1959, GE germanium transistors no longer used the "pinched-top" case style, as illustrated by the spec sheet above. The 2N43A transistor was similar to the 2N43, except that the gain for the 2N43A was guaranteed to be between 30 and 66, which was electrically identical to the USAF 2N43A.

GENERAL ELECTRIC



At this moment, 30,000 transistors are on test at General Electric

Among the more than 30,000 transistors you will find right now on General Electric's cycled life-test racks are Series 2N43 PNP germanium devices dating back to 1952.

Each of these 2N43's has clocked at least 40,000 hours of operating life. This represents five years of "power-on" operation without failure. And the "old" 43's still live on!

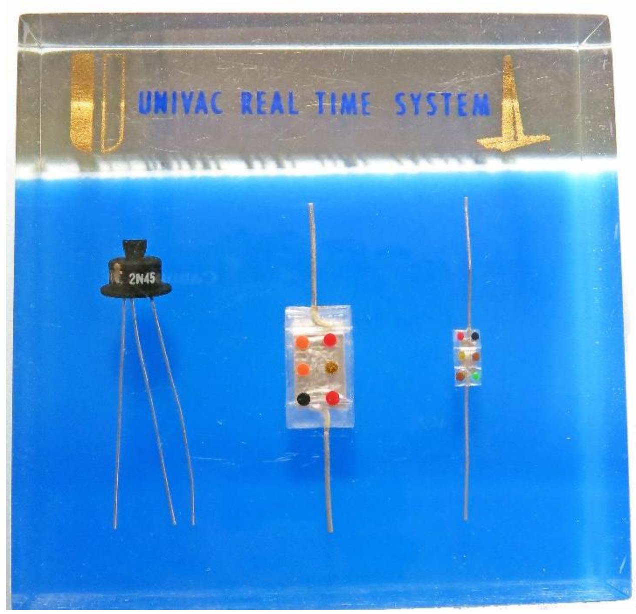
Since 1952, General Electric Company has produced and thoroughly tested well over 20-million transistors. A quarter-million of these devices have been subjected to from 1000 to 10,000 hours of maximum-rated-power.

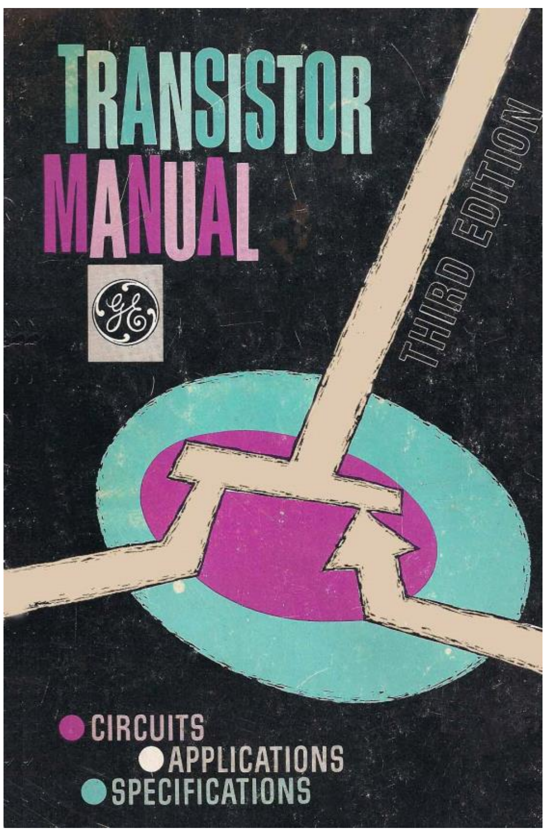
Life testing is but one of many exacting product quality-assurance criteria *all* General Electric semiconductor products must meet. For example, on an average, 16 separate quality-level tests . . . electrical, mechanical, environmental, as well as life . . . are given every General Electric transistor.

Through its system of stringent quality control, General Electric strives to continuously raise the stability/long-life reliability goals for semiconductor products—to the ultimate benefit of the user, the industry and the country at large.

Reliable GE Transistors: Above is a section of a 1960 electronics industry ad from GE, publicizing the high reliability characteristics of the GE germanium transistor product line. GE metal-cased transistors, beginning in 1952 with the 2N43/44/45 product line, were very rugged devices, and were used extensively in military and industrial applications such as computers where long life and continued reliable performance were required. Note some interesting facts from the above ad: (1) GE manufactured over 20-million transistors from 1952 to 1960, which is an impressive number and confirms GE's early and continued commercial success with germanium transistors and (2) The life-cycle tests discussed above confirm an actual minimum of 40,000 hours of operating life for these transistors, which is also an impressive result for devices manufactured in the very early days of transistor technology.

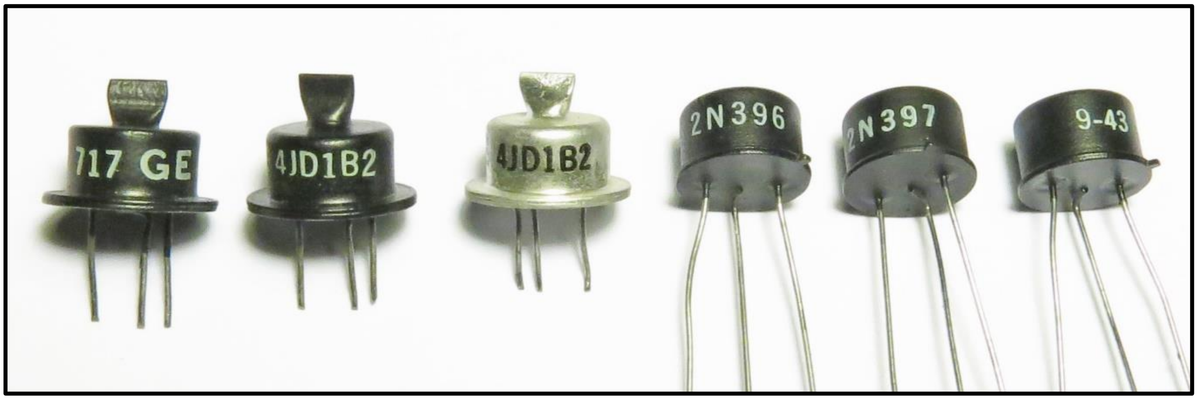
GENERAL ELECTRIC





GE Transistors in Univac Computers: Shown above is a paperweight highlighting the use of GE transistors in Univac Real Time Systems. The actual transistor shown is a PNP germanium GE 2N45, with a 1956 date code. GE was a leader in supplying rugged transistors to the computer industry during this timeframe, and Univac was a leader in the computer industry. Real time systems were designed for the high speed processing requirements of military and scientific computing applications. At upper left is a Univac type 495-53A2 circuit board loaded with 11 GE transistors, all of type 4JD1B2 with date codes of 1956. As noted earlier, the "4JD" numbering approach was used by GE to identify non-standard or performance specific device types. The "495" circuit board series was used for the Univac File System Computer, which was originally introduced in the early 1950s. At left is the cover of the Third Edition of the GE Transistor Manual, published in 1958. GE published a series of Transistor Manuals, beginning with the First Edition in 1956 and concluding with the Seventh Edition published in 1964. These publications were highly regarded and contained substantial technical information on the design and use of early transistors, including extensive information on the use of transistors in computers.

GENERAL ELECTRIC



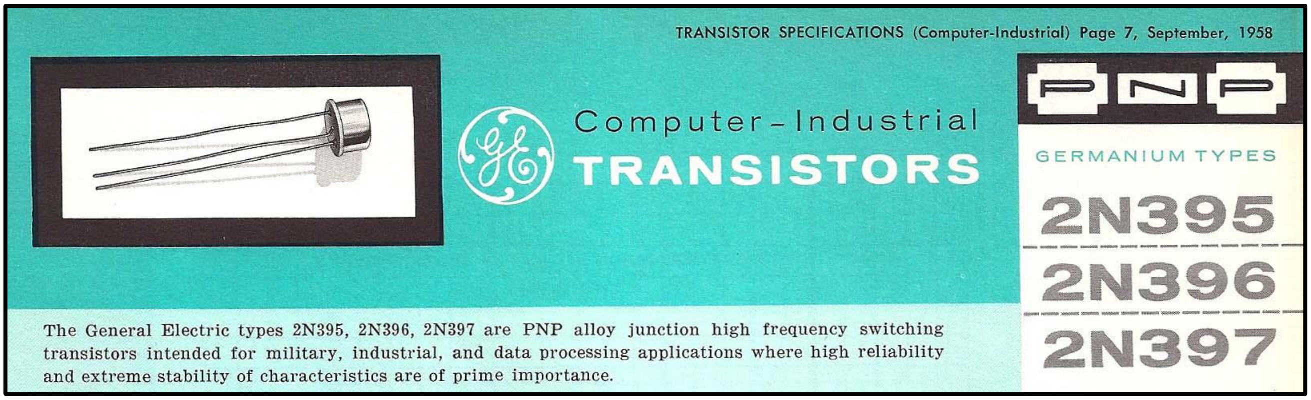
4JD1B2: The 4JD1B2 transistors shown above left are dated 1957 (black units) and 1958 (silver units). As noted earlier the "4JD" numbering sequence was used by GE to identify non-standard or performance specific device types. The 4JD1B2 type was developed as the initial entry in the sequence of transistors "4JD1B3 and 4JD1B4". These types were identified as symmetrical or bi-lateral transistors, which were designed specifically by GE for computer switching applications. The 4JD1B2 was rated at the highest voltage of these three types, all of which were rated to perform up to .8 MC. GE sold this device type to Univac for use in the Univac File Computer. These transistors were available commercially, with the 4JD1B3 and 4JD1B4 listed for over $6 each in the 1959 Allied Radio catalog. Symmetrical transistor types were developed by several computers in the 1950s, including General Electric and General Transistor. This technology was short-lived and remaining examples of germanium symmetrical transistors are rare.

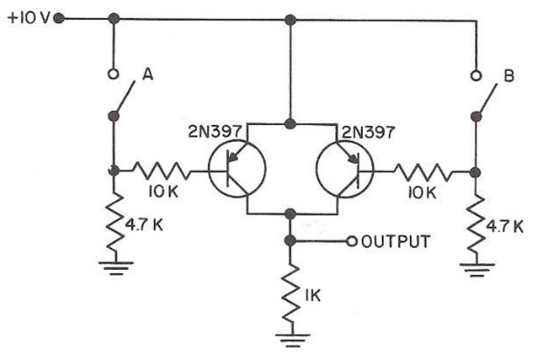
2N395/2N396/2N397: This line of transistors was registered by General Electric with JEDEC in December 1957, with the following statement of functionality: "The General Electric types 2N395, 2N396, 2N397 are PNP alloy junction high frequency switching transistors intended for military, industrial, and data processing applications where high reliability and extreme stability of characteristics are of prime importance." These three types offered similar performance, with the primary exception of high frequency response – the 2N395 offered the lowest cutoff frequency of 4.5 MC, the 2N396 was 8 MC and the 2N397 was 12 MC. The 2N397 was the most expensive, at almost $8 in 1959. These types were highly reliable and the documented switching speeds were adequate for most computer requirements of the time. This product line was used in several historic computers, including the 1959 Autonetics RECOMP II Transistorized Computer, the MIT TX-2, and the BASICPAC U.S. Army tactical field data computer.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE 4JD1B2 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black/silver pinched top
Vintage/Date Code: 1957/1958
Use: Symmetrical switching logic - 800KC
Notes: Unique "bi-lateral" junction type used in Univac File Computer circuits.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE 2N395/396/397 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black metal TO-5
Vintage/Date Code: 1950s/1960s
Use: High reliability data processing
Notes: Late 1950s advanced germanium transistors for reliable/stable computer use.

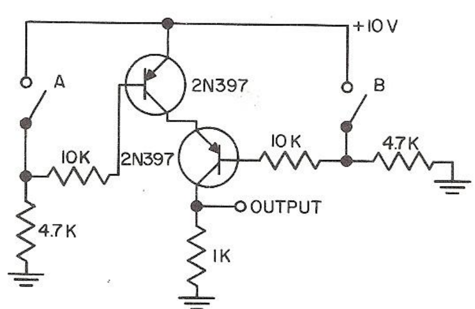
GENERAL ELECTRIC





GATE USING PNP TRANSISTORS
IF CLOSING A SWITCH IS AN INPUT THIS IS AN "AND" GATE
IF OPENING A SWITCH IS AN INPUT THIS IS AN "OR" GATE
NOTE: PHASE INVERSION OF INPUT

BASIC LOGIC CIRCUITS USING PARALLEL TRANSISTORS



GATE USING PNP TRANSISTORS
IF CLOSING A SWITCH IS AN INPUT THIS IS AN "OR" GATE
IF OPENING A SWITCH IS AN INPUT THIS IS AN "AND" GATE
NOTE: PHASE INVERSION OF INPUT

BASIC LOGIC CIRCUITS USING SERIES TRANSISTORS

The Popular 2N395/396/397
Series of GE Computer Transistors:

By 1958, General Electric had developed advanced germanium transistor design and manufacturing processes and was able to supply highly reliable switching transistors for the computer market. The 2N395/96/97 product line of transistors was well received by computer designers and saw widespread use across the industry. The scan above is a partial view of the September 1958 data sheet for these transistors, and note the claim of "high reliability and extreme stability" for data processing applications. These transistors offered similar performance to the earlier GE 2N123 computer transistor and were also identified by the internal GE type numbers as 4JD1D2 (2N395), 4JD1D1 (2N396) and 4JD1D3 (2N397). Due to the broad suitability of this product line for computer circuits, GE highlighted the use of these transistors in the reference section "Basic Computer Circuits" of the 1960 Fifth Edition of the General Electric Transistor Manual. Shown at left are excerpted circuits for both parallel and series configurations of logic circuits using 2N397 transistors. Other 2N397 circuits are also shown including non-saturating flip-flop, Schmitt triggers, astable multivibrator, and monostable multivibrator.

GENERAL ELECTRIC

2N123: The 2N123 was an early entry by General Electric in the industrial/military/computer market for reliable and reasonably high performance (for the time) germanium transistors. This device was rated at 8MHz switching frequency, which made it suitable for computer and RF applications. For reliability, it used the unique hermetically sealed and evacuated metal case design common to early GE transistors. The high purchase price of this device limited its use in commercial applications, but the military used it in large numbers. The 2N123 sold for approximately $5.50 throughout the late 1950s, which is equivalent to approximately $50 per transistor in 2015. The 2N123 was used in many military and commercial computers in the 1950s and 1960s, including the EDVAC which was a largely vacuum tube based successor to the original ENIAC computer. The 2N123 was also used extensively in military digital applications.

4JDA70/ZJ11-501: General Electric, and other early transistor manufacturers, often used unique device identifiers for experimental, preproduction or customer-specific devices that did not meet the requirements of the more standard "2N" numbering scheme. GE, for example, used both the "ZJ" and the "4JD" prefixes for these types of transistors. The 4JDA70 transistors shown above right are devices that are samples from the actual lot of these transistors that were evaluated in the late 1950s by Battelle Institute under contract to Remington Rand Univac. The technical aspects of this device evaluation program are detailed in the September 1959 issue of IEEE/AIEE Transactions in the paper entitled: "Effects of Operation of Germanium Alloy Junction Transistors Above Rated Conditions" by B. C. Spradlin. (See next page for more information). As discussed in the paper, the GE 4JDA70 transistors, also identified as type ZJ11-501, were special types of the standard 2N123. Note that each transistor is individually serialized. These are extremely rare and historic devices.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE 2N123 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black metal top hat
Vintage/Date Code: 1950s/1960s
Use: High frequency switching
Notes: First GE PNP high speed switch. High performance early computer transistor.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE 4JDA70/ZJ11-501 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black metal top hat
Vintage/Date Code: 1950s/1960s
Use: High frequency switching
Notes: Special type 2N123 device used in 1959 life test for Univac. Very rare.

GENERAL ELECTRIC

Effects of Operation of Germanium Alloy Junction Transistors Above Rated Conditions

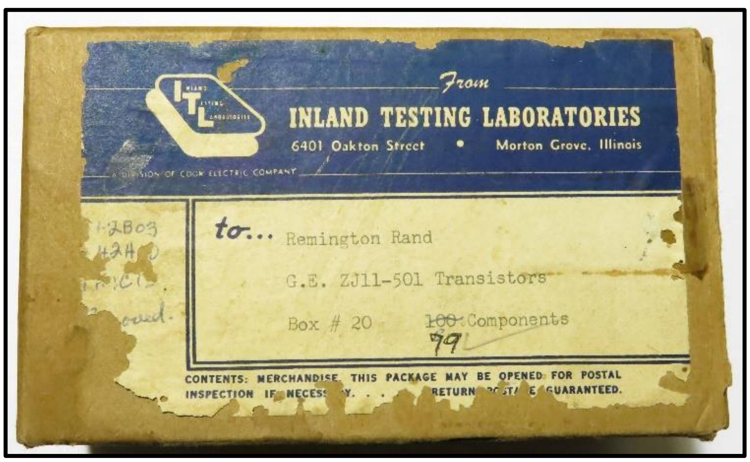
AS A PART of the investigations and analyses performed at Battelle Memorial Institute for Remington Rand Univac, some exploratory experiments were performed at various operating conditions with type *ZJ1-501(4JD1A-62)* and *ZJ11-501(4JD1A-70)* transistors. Both of these transistors are special type *2N123* p-n-p alloy junction high-frequency switching transistors. (The primary physical difference between the *ZJ1-501* and *ZJ11-501* transistors is the thicker base region of the *ZJ1-501*.) These exploratory experiments were performed as a portion of a program directed toward the development of accelerated life test procedures for transistors.

(degrees centigrade), all the operating conditions of the experiment are above the transistors' ratings.

Table I. Factorial Representation of the Operating Conditions of the Exploratory Experiments

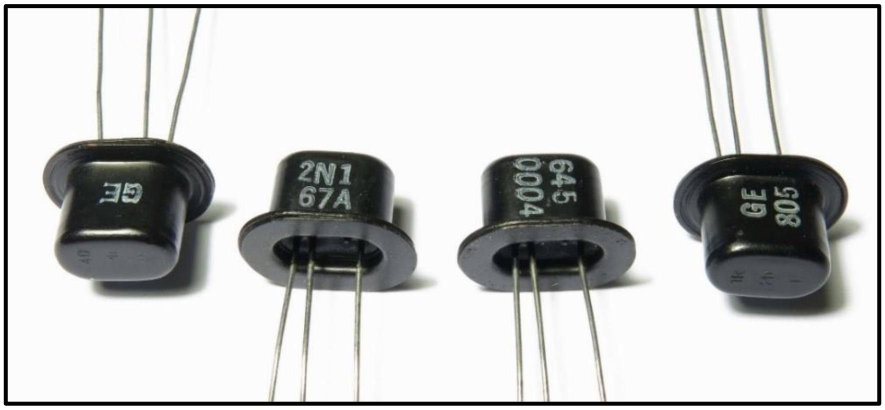
Ambient Temperature, C	Power Dissipation, Milliwatts 100	150	200
Type ZJ11-501(4JD1A-62) Transistors			
100	20	20	20
120	20	20	20
Type ZJ11-501(4JD1A-70) Transistors			
80	20	20	20
90	20	20	20
100	20	20	20

Note: The number 20 is the number of transistors operated at each combination of temperature and power dissipation.



Historic GE Transistors: The 4JDA70/ZJ11-501 transistors shown here were used in the late 1950s life test study documented by Spradlin in the paper noted above. Each transistor is identified with a serial number label, and the transistors are packaged in a GE carton identifying the devices as type ZJ11-501 and 4JDA70. These transistors were developed by GE as a special type of the 2N123 p-n-p alloy junction high-frequency switching transistors. In addition to use in this life test study, this transistor type was also used in the commercially available Autonetics RECOMP II digital computer.

GENERAL ELECTRIC



2N167/2N167A: The first GE junction transistors were introduced in 1953 (PNP alloy junction devices, labeled as 2N43/44/45). Within the next couple of years, GE developed a variety of additional types, including the NPN grown junction 2N167, introduced in 1955. This was a high reliability switching transistor and was used in many digital computers and by the military in high reliability switching applications. The 2N167 was one of the first NPN germanium computer transistors available to the computer industry and found wide spread acceptance for many years. The 2N167A was introduced in 1960 as a mechanically "ruggedized" version of the 2N167 (same electrical specs). GE also developed USAF versions of the 2N167 and 2N167A. The 2N167/167A was produced well into the 1960s with likely millions of units sold. The early GE NPN transistors were also notable for the "bath tub oval" case style, which was continued throughout the 1960s. The high reliability aspects of this device allowed GE to charge a premium price for these transistors; $6.45 each in the 1960 Lafayette Radio Semiconductor catalog - that's over $50 in 2015 prices. An example of a computer using the 2N167A transistor was the Philco BASICPAC artillery computer developed for the Army in the early 1960s.

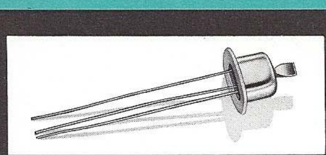
CDC 6450004: The two rightmost units above are "house numbered" versions of the 2N167 – this device uses the CDC company proprietary transistor numbering system, and was recovered from a surplus lot of transistors manufactured by GE for use in CDC computers from the 1960s, prior to the large scale use of silicon transistors or integrated circuits in commercial computers. It was not uncommon for computer companies to use proprietary part numbers to identify devices purchased from the major semiconductor manufacturers such as GE, General Transistor, Sylvania, TI, RCA and Motorola, and then use these devices for circuit board production. The "645xxxx" transistor numbering system also appears in the Federal Supply Code "FSC" listings for transistors approved for military use. These particular transistors have a 1968 date code and were likely manufactured by GE as replacement parts for computers and digital equipment originally designed and manufactured in the late 1950s or early 1960s.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE 2N167/2N167A transistor
Type: Germanium NPN rate grown junction
Case Color/Style: Black metal bath tub oval
Vintage/Date Code: 1950s/1960s
Use: High reliability switching
Notes: Early "ruggedized" NPN device.
Widespread industrial/military applications.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE 6450004 transistor
Type: Germanium NPN rate grown junction
Case Color/Style: Black metal bath tub oval
Vintage/Date Code: 1950s/1960s
Use: High reliability switching
Notes: Early "ruggedized" NPN device.
Federal Supply Code - military approved.

GENERAL ELECTRIC

TRANSISTOR SPECIFICATIONS (Computer-Industrial) Page 4, Feb. 1, 1958



Computer – Industrial TRANSISTOR

NPN

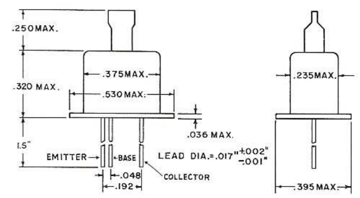
GERMANIUM TYPE **2N167**

The General Electric Type 2N167 is an NPN germanium high frequency, high speed switching transistor intended for industrial and military applications where reliability is of prime importance. In order to achieve the high degree of reliability necessary in industrial and military applications, the 2N167 is designed to pass 500G 1 millisecond drop shock, 10,000G centrifuge, 10G of vibration fatigue and 10G variable frequency vibration, as well as temperature cycling, moisture resistance, and operating and storage life tests as outlined in MIL-T-19500A.

absolute maximum ratings: (25°C)

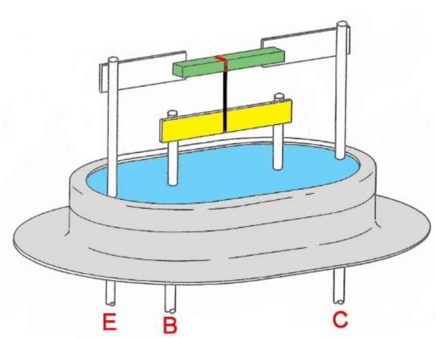
Voltages		
Collector to Emitter (base open)	V_{CEO}	30 volts
Collector to Base (emitter open)	V_{CBO}	30 volts
Emitter to Base (collector open)	V_{EBO}	5 volts
Collector Current	I_C	75 ma
Emitter Current	I_E	−75 ma
Collector Dissipation (25°C)*	P_C	65 mw
Transistor Dissipation (25°C)**	P_M	75 mw
Storage Temperature	T_{STG}	85°C

*Derate 1.1 mw/°C increase in ambient temperature.
**Derate 1.25 mw/°C increase in ambient temperature.



electrical characteristics: (25°C)

SWITCHING CHARACTERISTICS (COMMON EMITTER)		Design Center	Min.	Max.	
D-C Base Current Gain (V_{CE} = 1v; I_C = 8 ma)	h_{FE}	30	17		
Saturation Voltage (I_B = .8 ma; I_C = 8 ma)	V_{CE}(SAT)	0.35			volts
Pulse Response Time (See Below; I_C = 8 ma)					
Turn-on Time	t_o	.5			μsec
Storage Time	t_s	.3			μsec
Fall Time	t_f	.2			μsec
CUTOFF CHARACTERISTICS					
Collector Cutoff Current (V_{CB} = 15v)	I_{CO}	.7		1.5	μa
Emitter Cutoff Current (V_{EB} = 5v)	I_{EO}	.6		5	μa
Collector to Emitter Voltage (Base Open; I_C = 0.3 ma)	V_{CE}		30		volts
HIGH FREQUENCY CHARACTERISTICS (COMMON BASE) (V_{CB} = 5v; I_E = 1 ma)					
Alpha Cutoff Frequency	f_{ab}	9.0	5.0		mc
Collector Capacity (f = 1 mc)	C_{ob}	2.5		8	μμf
Voltage Feedback Ratio (f = 1 mc)	h_{rb}	7.3			$x10^{-3}$

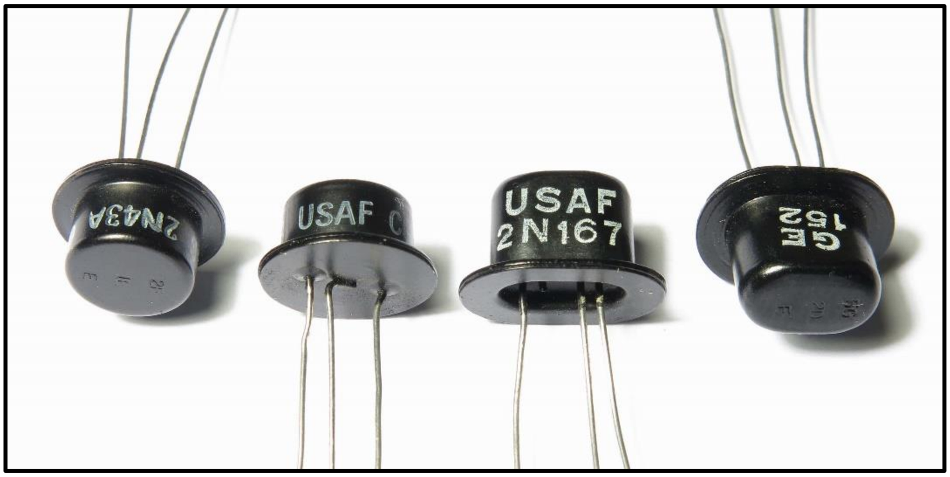


GE Rate Grown NPN Germanium Transistors: The scan above is a section of a 1958 datasheet documenting key performance specifications for the 2N167 transistor. The GE NPN germanium rate grown technology, utilized for the 2N167, as well as for other important 1950s/1960s GE transistors, was first developed at GE in the mid-1950s and resulted in high reliability, high frequency devices that saw widespread use in both commercial and military applications for many years. At left is a diagrammatic view of this transistor technology. The green highlighted area is an N-type germanium bar which was grown from a bath of molten germanium and doped with a small amount of P-type material so that the resultant bar has an NPN structure. The red highlighted area shows the P-type area. High mechanical reliability is achieved by solid physical support of the germanium bar at each end (the **E**mitter and **C**ollector connections) and also at the P-type region (shown at left by the support of the red highlighted area to the yellow highlighted **B**ase connection.)

TRANSISTOR MUSEUM™

HISTORIC GERMANIUM COMPUTER TRANSISTORS

GENERAL ELECTRIC



USAF 2N43A: The first junction transistors made commercially by General Electric were the 2N43, 2N44 and 2N45, all introduced in 1953. This product line was originally developed under a military contract, and the devices were required to meet rigorous performance requirements; GE developed a unique "top hat" style case, which allowed a hermetic seal and internal vacuum to be used to ensure transistor junction protection and high reliability. In 1955, a special version of the 2N43, labeled as the 2N43A, became the first transistor qualified for use by the U. S. Air Force. The 2N43A was the commercial version of the first military transistor, Air Force Type USAF 2N43A per MIL-T-25096. Many of the stringent mechanical and electrical requirements of MIL-T-25096 were retained in the commercial 2N43A specification. For both versions, the current amplification was held to relatively narrow limits by accurate process control rather than by selection. The USAF 2N43A was a highly reliable general purpose transistor and was developed and qualified to be used in military applications, including computers.

USAF 2N167/2N167A: Introduced in the mid-1950s, and using GE's unique grown junction process, the 2N167 was one of the first highly reliable NPN germanium transistors available to the industry. Following the military qualification process established first by the PNP 2N43A, the 2N167 and 2N167A NPN transistors were also qualified for military use as USAF versions, using MIL-S-19500/11A (USAF). The USAF 2N167 and USAF 2N167A were highly reliable NPN germanium switching transistors developed and qualified to be used in military applications, especially computers. Other GE transistors from the 1950s/1960s qualified to USAF specifications included the USAF 2N123 and the USAF 2N461.

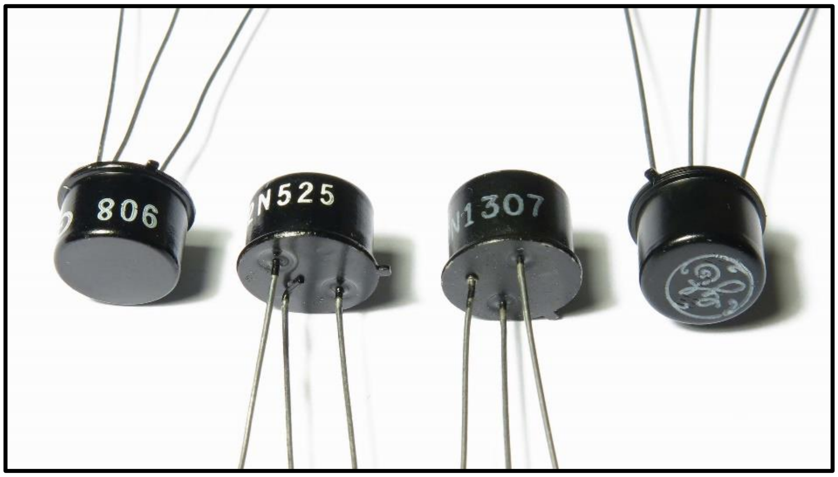
TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE USAF 2N43A transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black metal top hat
Vintage/Date Code: 1950s/1960s
Use: General purpose computer-industrial
Notes: First military approved transistor.
Widespread use in early computers.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: GE USAF 2N167/A transistor
Type: Germanium NPN rate grown junction
Case Color/Style: Black metal bath tub oval
Vintage/Date Code: 1950s/1960s
Use: High reliability switching
Notes: Early military approved transistor.
Widespread industrial/military applications.

GENERAL ELECTRIC

The First Air Force Transistor: This February 1955 ad in Teletech magazine documents GE's important achievement with the USAF 2N43A transistor, the first industry's first Air Force transistor. The 2N43/44/45 line of transistors was introduced in late 1953 and set the standard for reliability.

GENERAL ELECTRIC



2N525: GE was a major manufacturer of germanium transistors in the 1950s and 1960s, and the earliest versions of the many different GE transistor types used a range of proprietary metal case styles, referred to at the time as "pinched top", "top hat" and "bath tub oval". As the transistor industry became more standardized in the late 1950s, GE released a series of transistors using the more standardized case styles developed by the electronics industry organization "JEDEC". Shown above are examples of GE transistors using the JEDEC "TO-5" case style. The GE types 2N524, 2N525, 2N526 and 2N527 were germanium PNP alloy junction transistors particularly recommended for low to medium power amplifier and switching applications in the frequency range from audio to 100 KC. This series of transistors was intended for military, industrial, and data processing applications where high reliability and extreme stability of characteristics are of prime importance. The 2N524 and the 2N525 were equivalent to the 2N44 and 2N43 respectively and could be directly substituted in most applications. These devices were used extensively in early commercial digital computers, including the Autonetics RECOMP II.

2N1307: The 2N1302 to 2N1309 series of transistors was originally developed by Texas Instruments in the late 1950s to provide a complementary range of NPN/PNP high-frequency transistors for computer and switching applications. The 2N1307 is the PNP complement to the NPN 2N1306 transistor, both of which will operate up to a cutoff frequency of 10MC. This series of transistors was very successful and was used extensively throughout the 1960s and 1970s in commercial and military computer applications. Several transistor manufacturers, including GE, second-sourced this popular line of computer transistors, and the 2N1307 shown above is typical of one of these 1960s devices from GE. The 2N1307 was used in a variety of industrial applications, including, for example, the control circuitry for the HFIR Test Module for the Safety System of the Oak Ridge National Laboratory High Flux Isotope Reactor in 1968.

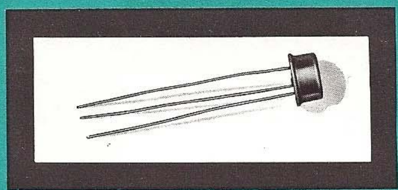
TRANSISTOR MUSEUM
Historic Semiconductor Data

Device ID: GE 2N525 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black metal TO-5
Vintage/Date Code: 1950s/1960s
Use: General purpose computer-industrial
Notes: Industry standard TO-5 version of 2N43. Common type in 1960s applications.

TRANSISTOR MUSEUM
Historic Semiconductor Data

Device ID: GE 2N1307 transistor
Type: Germanium PNP alloy junction
Case Color/Style: Black metal TO-5
Vintage/Date Code: 1950s/1960s
Use: High frequency computer switch
Notes: PNP complement to NPN 2N1306. 2nd sourced by GE of successful TI series.

GENERAL ELECTRIC



Computer-Industrial TRANSISTORS

PNP

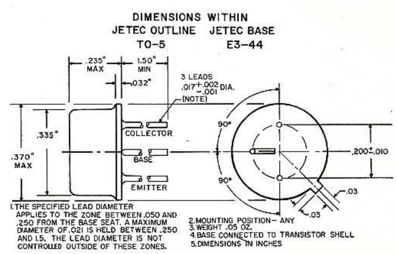
GERMANIUM TYPES

2N524
2N525
2N526
2N527

The General Electric types 2N524, 2N525, 2N526 and 2N527 are germanium PNP alloy junction transistors particularly recommended for low to medium power amplifier and switching applications in the frequency range from audio to 100 KC. This series of transistors is intended for military, industrial and data processing applications where high reliability and extreme stability of characteristics are of prime importance. The 2N524 and 2N525 are equivalent to the 2N44 and 2N43 respectively and may be directly substituted in most applications.

absolute maximum ratings (25°C)

Voltages			
Collector to Base	V_{CBO}	−45	volts
Collector to Emitter	V_{CER}	−30	volts
Emitter to Base	V_{EBO}	−15	volts
Collector Current	I_{CM}	−500	ma
Temperatures			
Storage	T_{STG}	−65°C to 100	°C
Operating	T_J	+85	°C
Total Transistor Dissipation	P_{AV}	225	mw



The transistor power dissipation is limited by the operating junction temperature. In a properly stabilized circuit, the permissable maximum operating junction temperature is 85°C. Method for computing operating junction temperature:

$$T_J = T_A + k\, P_{AV}$$

Method for computing maximum allowable transistor power dissipation:

$$P_{AV} = \frac{85°C = T_A}{k}$$

where;

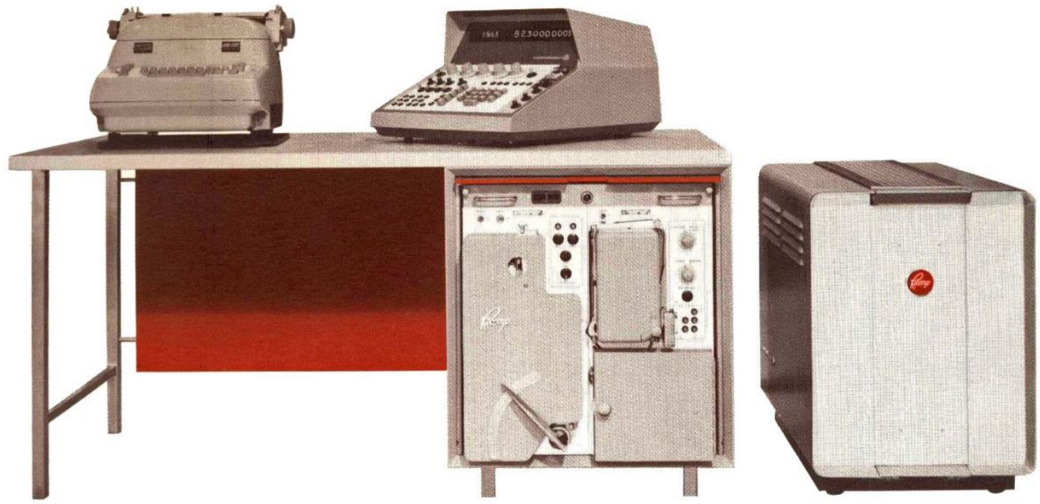
T_J = Operating junction temperature in °C
T_A = Operating ambient temperature in °C
P_{AV} = Transistor power dissipation in mw
k = Thermal resistance in °C/mw (See ratings under Electrical Characteristics)

special controls for reliability

1. All transistors are aged at a temperature of 100°C min. for 100 hrs. min.
2. All transistors are subjected to a high pressure detergent test to insure reliable hermetic seals.
3. All transistor D-C characteristics are controlled and guaranteed to be within the limits shown.

By 1959, new GE germanium transistor types became available using the industry standard JETEC/JEDEC TO-5 metal case style. The earlier GE transistor types using the proprietary case styles (top hat and bath tub oval) continued to be produced as well. Shown above is a section of the June 1958 spec sheet for the GE 2N524, 2N525, 2N526 and 2N527 series of TO-5 computer-industrial transistors, with the 2N524 representing the lowest performance (gain and frequency cutoff) and the 2N527 representing the highest performance (gain and frequency cutoff). As noted in the specification, the 2N525 was electrically equivalent to the earlier 2N43 top hat transistor. In the 1950s, General Electric had established a reputation for highly reliable and stable germanium transistors, and this new line of devices continued to emphasize these characteristics, especially for military, industrial and data processing applications. These devices sold well throughout the 1960s until commercial silicon transistor types became widely available.

GENERAL ELECTRIC



1959 Autonetics RECOMP II Transistorized Computer

GE Transistors in the RECOMP II

GE was a major supplier of germanium transistors for commercial digital computers in the late 1950s through the 1960s. As an example, the RECOMP line of computers manufactured by Autonetics used a variety of GE transistor types – the table at lower right was developed based on an analysis of the RECOMP II schematics and shows the range of GE transistor types (including non-standard "ZJ" and "4J" types) used in the RECOMP II. This table also documents other transistor manufacturers that were supplying devices for computer use. The photo above and the product description of the RECOMP II are excerpted from a 1959 Autonetics product brochure. There is substantial information about the RECOMP computers available online, with Ed Thelen's excellent BRL computer report website providing extensive material for further research.

RECOMP II—general purpose, all-transistor, single address, digital computer built by North American Aviation's Autonetics Division—solves problems of extreme complexity with split-second rapidity. Remarkably small in size, RECOMP II is extremely large in capacity—is virtually limitless in applications of science and industry.

OUT-PERFORMS BIG, HIGH-PRICED COMPUTERS—RECOMP II offers impressive advantages over computers much greater in both size and price. It comes equipped with built-in floating point arithmetic and automatic decimal conversion. Its transistor-compact construction provides mobility from one location to another, and guarantees sturdy reliability. Its simple command structure brings new ease to programming, and its huge storage capacity speeds operation for significant time-cost reductions in laboratory and field.

FAST AND EASY TO OPERATE—The five components of RECOMP II—computer and memory, photoelectric tape reader, typewriter, tape punch, and console—work together to produce problem solutions previously reserved for only the most expensive system.

A tape, coded with the problem solution plan (program), is put into the computer through the photoelectric reader. The applicable data are then fed into RECOMP II—either with the console keyboard or typewriter keyboard, or on punched tape. Rapidly and accurately, RECOMP II then solves the problem and delivers the answer via the typewriter or a punched tape.

Operation is fast and simple—can be learned by an inexperienced operator in a single day.

RECOMP II performs additions at the rate of 1,852 per second...fixed point multiplication in 10.8 milliseconds...and floating point multiplication in 12.4 milliseconds. Input-output flexibility is achieved by easy-to-learn devices including transfer switches, electric typewriter, punched paper tape, and a minimum of other controls. Data can be verified immediately, and discrepancies will stop the process and display error lights.

Transistor Type	Manufacturer	Example Use in Recomp II
4JX1D804 = 2N395	General Electric	Flip-Flop
ZJ11-509 = 2N123	General Electric	Differential Amplifier
2N43A = 2N525	General Electric	Switch
2N321	General Electric	Photo Amplifier
2N443	Delco	Power Supply
NAA358 = 2N358	General Transistor	Clock Power Amplifier
2N359A = H6	Minneapolis Honeywell	Power Supply
L5044B	Philco	Clock Power Amplifier
2N398	RCA	Neon Driver

Transistor types used in the RECOMP II computer.

GENERAL ELECTRIC

GE Vacuum Tubes vs GE Transistors: This GE ad from the June 1961 volume of Scientific American magazine well illustrates the dilemma faced by GE in the early 1960s, when sales of their vacuum tube products were still a significant part of the corporate "bottom line" and transistor sales had not yet reached the levels required to compensate for dropping tube sales. Several East Coast transistor manufacturers, including Raytheon, Sylvania, CBS, RCA and GE were also large scale vacuum tube manufacturers, and within a few years, with the rise of ICs and Silicon Valley, ads such as this one became irrelevant and these germanium transistor companies were in decline.