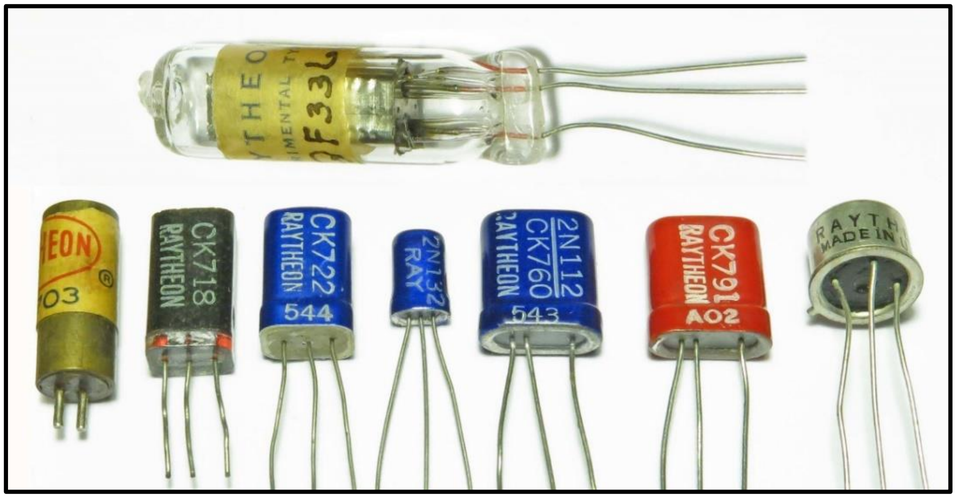
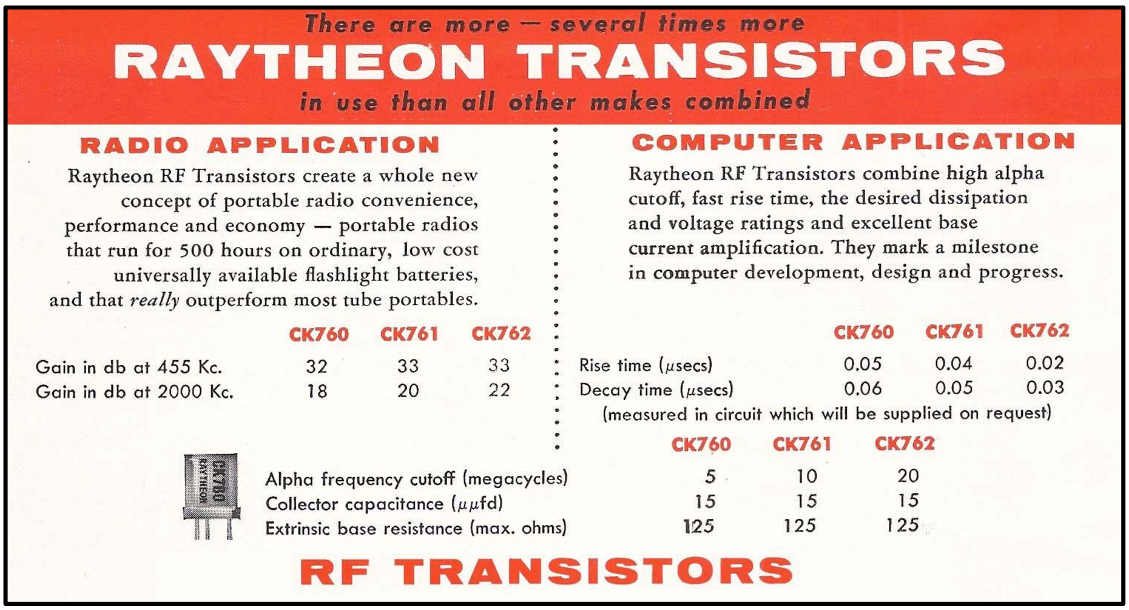
HISTORIC GERMANIUM COMPUTER TRANSISTORS

RAYTHEON





There are more — several times more

RAYTHEON TRANSISTORS

in use than all other makes combined

RADIO APPLICATION

Raytheon RF Transistors create a whole new concept of portable radio convenience, performance and economy — portable radios that run for 500 hours on ordinary, low cost universally available flashlight batteries, and that *really* outperform most tube portables.

	CK760	CK761	CK762
Gain in db at 455 Kc.	32	33	33
Gain in db at 2000 Kc.	18	20	22

COMPUTER APPLICATION

Raytheon RF Transistors combine high alpha cutoff, fast rise time, the desired dissipation and voltage ratings and excellent base current amplification. They mark a milestone in computer development, design and progress.

	CK760	CK761	CK762
Rise time (μsecs)	0.05	0.04	0.02
Decay time (μsecs)	0.06	0.05	0.03

(measured in circuit which will be supplied on request)

	CK760	CK761	CK762
Alpha frequency cutoff (megacycles)	5	10	20
Collector capacitance (μμfd)	15	15	15
Extrinsic base resistance (max. ohms)	125	125	125

RF TRANSISTORS

Early Raytheon Transistors: Raytheon was the early leader in commercial germanium transistor technology. Beginning in the late 1940s and continuing throughout the 1950s, Raytheon accomplished a number of historic "firsts" with pioneering germanium devices. For example, the CK703 point contact type in the photo at top left dates from 1948 and was the first transistor sold commercially by any company. The CK718 junction type was the first commercial transistor in volume production, with thousands of units manufactured by Raytheon in 1952 for use in the first transistorized hearing aids. Raytheon had been a leader in subminiature vacuum tubes used in hearing aids in the 1940s (an example of an experimental Raytheon submini tube shown in top photo) and moved quickly to expand this market with the CK718. The blue-cased hermetically sealed transistors are from the mid-1950s: the CK722 was the first "hobbyist" transistor, the 2N132 was an early miniature transistor and the CK760 was an early computer transistor. The red-cased CK791 was an early silicon transistor from the 1950s, and the TO-5 device at far right represents mature 1960s Raytheon germanium transistor technology. The illustration above is excerpted from a March 1955 IRE ad which described Raytheon's progress with high speed computer transistors.

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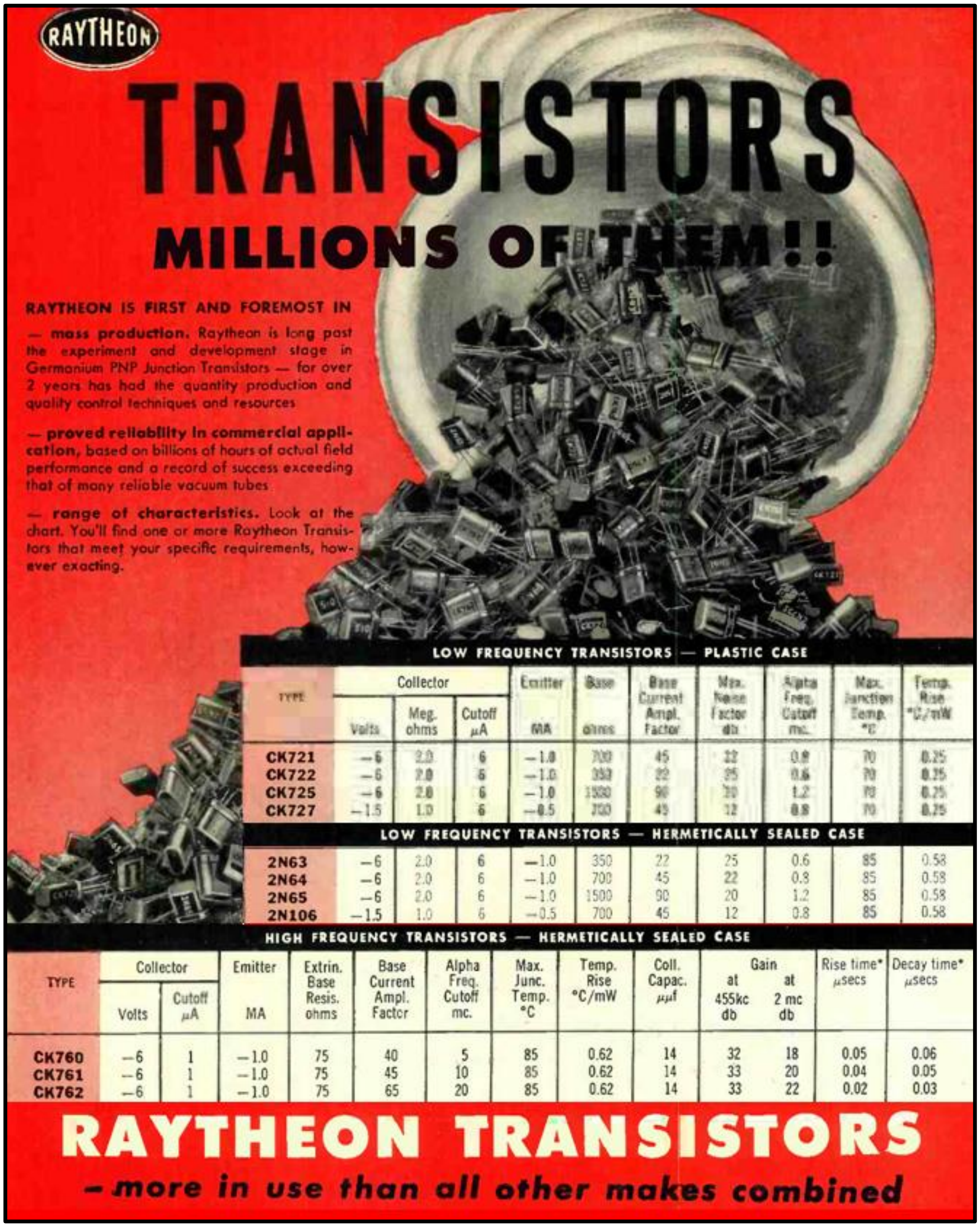
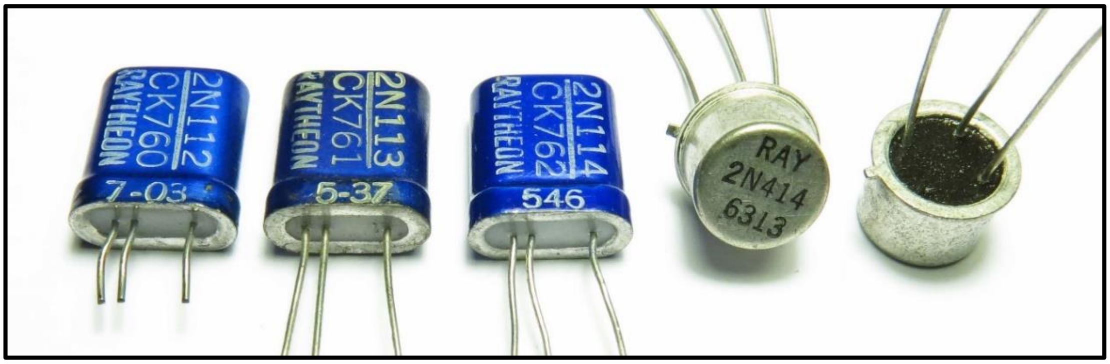


TeleTech June 1955: Above is a section of a Raytheon ad that appeared in the June 1955 TeleTech magazine. At that time, Raytheon had begun to manufacture metal-cased hermetically sealed transistors, including the low frequency 2N6X series and the higher frequency CK760 series which were designed for use in RF radio circuits and computer switching applications. By 1955 Raytheon had manufactured over 1,000,000 transistors and was the industry volume leader. Raytheon had started transistor production in 1952 using the proprietary "CK" identification sequence and then began to transition to the more standard "2N" numbering sequence by the mid-1950s.

RAYTHEON



CK760/761/762 - 2N112/113/114: By the mid-1950s, as Raytheon had achieved high volume production leadership with hearing aid and low frequency germanium transistor types, improvements in the design and manufacturing of these devices were implemented. A major improvement was the introduction of hermetically sealed metal cases, which was intended to prevent the degradation of performance due to moisture penetration through the plastic/epoxy case material used in the early Raytheon transistors. Another important improvement was the use of manufacturing techniques that would allow operation at a higher frequency and broaden the range of applications to include RF radio circuits and computer switching circuits. Tentative data sheets from April 1955 document the development of these new metal-cased high frequency transistors from Raytheon, identified with both the proprietary "CK" numbers and the "2N" numbers. These devices became available commercially later in 1955 and the improved performance resulted in more expensive transistors. For example, the CK760/2N112 sold for $6.35, the CK761/2N113 for $7.50 and the CK762/2N114 for $16.00, which is equivalent to $140 today. A striking blue iridescent case color was used by Raytheon for these improved devices for only a few years in the mid-1950s. Due to the higher frequency performance of these transistors, radio manufacturers and computer companies used them in substantial quantities – for example, the first Raytheon commercial transistor radio, the 8RT1 released in 1955, used these transistors for RF/IF circuits. Documented use in digital computers include the CK761/2N113 in the Bell Labs Tradic Leprechaun research computer.

2N414: Raytheon continued to expand its high frequency transistor line throughout the late 1950s and into the early 1960s. By the late 1950s these devices used the more standard unpainted TO-5 case style and the standard "2N" numbering system. For example, the 2N414 shown above right, dated 1963, was intended for use as a general purpose high frequency transistor with performance up to 8MC. Improvements in the manufacturing processes and standardization in case styles resulted in lower prices for these transistors. In 1959 the 2N414 cost $2.28 and this same device cost less than a dollar by 1962. The 2N414 was used extensively in commercial digital computers, including the GE Erma 210 computer.

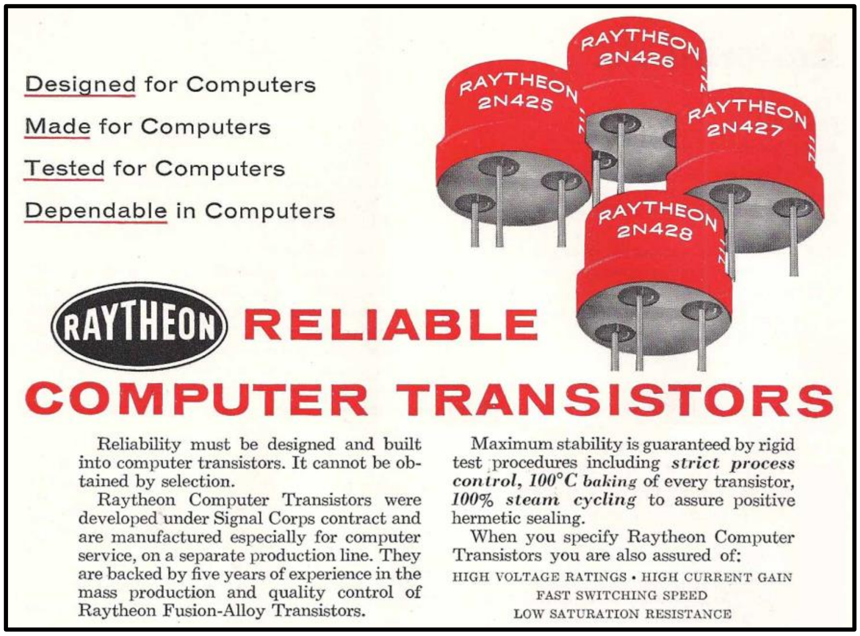
TRANSISTOR MUSEUM
Historic Semiconductor Data

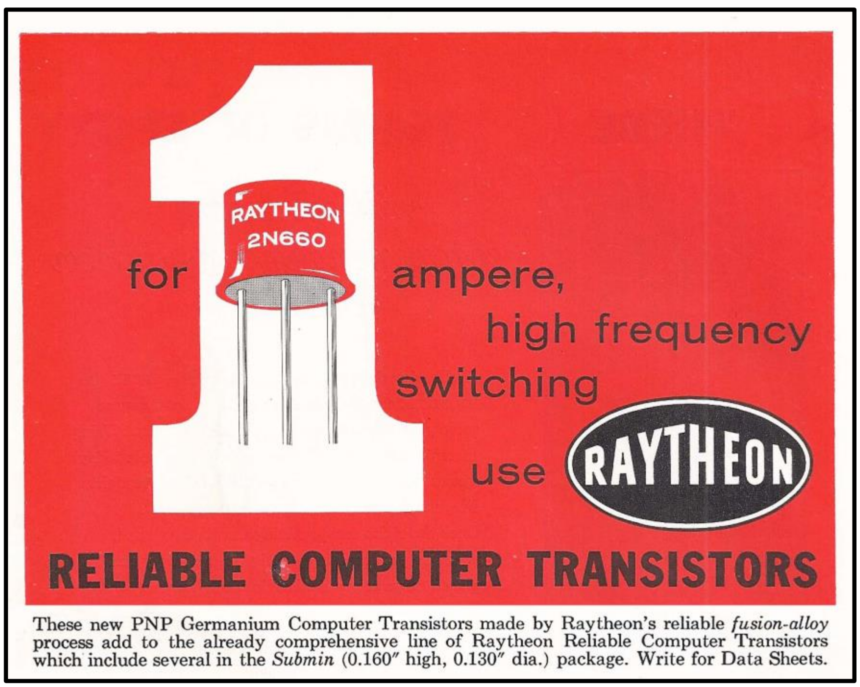
Device ID: Raytheon CK760-762 transistor
Type: Germanium PNP fusion alloy
Case Color/Style: Iridescent blue metal
Vintage/Date Code: Mid-1950s
Use: High frequency radio and computer
Notes: One of the first 1950s high freq PNP devices. Used in Bell Labs Tradic computer.

TRANSISTOR MUSEUM
Historic Semiconductor Data

Device ID: Raytheon 2N414 transistor
Type: Germanium PNP fusion alloy
Case Color/Style: Silver metal TO-5
Vintage/Date Code: 1950s/1960s
Use: General purpose high frequency
Notes: Low cost switching device used in 1960s computers, including GE Erma 210.

RAYTHEON





Reliable Raytheon Computer Transistors: The above scans are sections of Raytheon advertisements from late 1958/early 1959 announcing newly available and highly reliable germanium computer transistors. The 2N42X series was registered with JEDEC by Raytheon in 1957 and the 2N660 soon followed in 1958. For all high speed transistors from this timeframe, Raytheon used the proprietary "fusion-alloy" manufacturing process, which allowed for the precise placement of the collector and emitter areas on the internal germanium pellet, as well as for very thin base regions. These device structural characteristics resulted in reliable and consistent high frequency performance.

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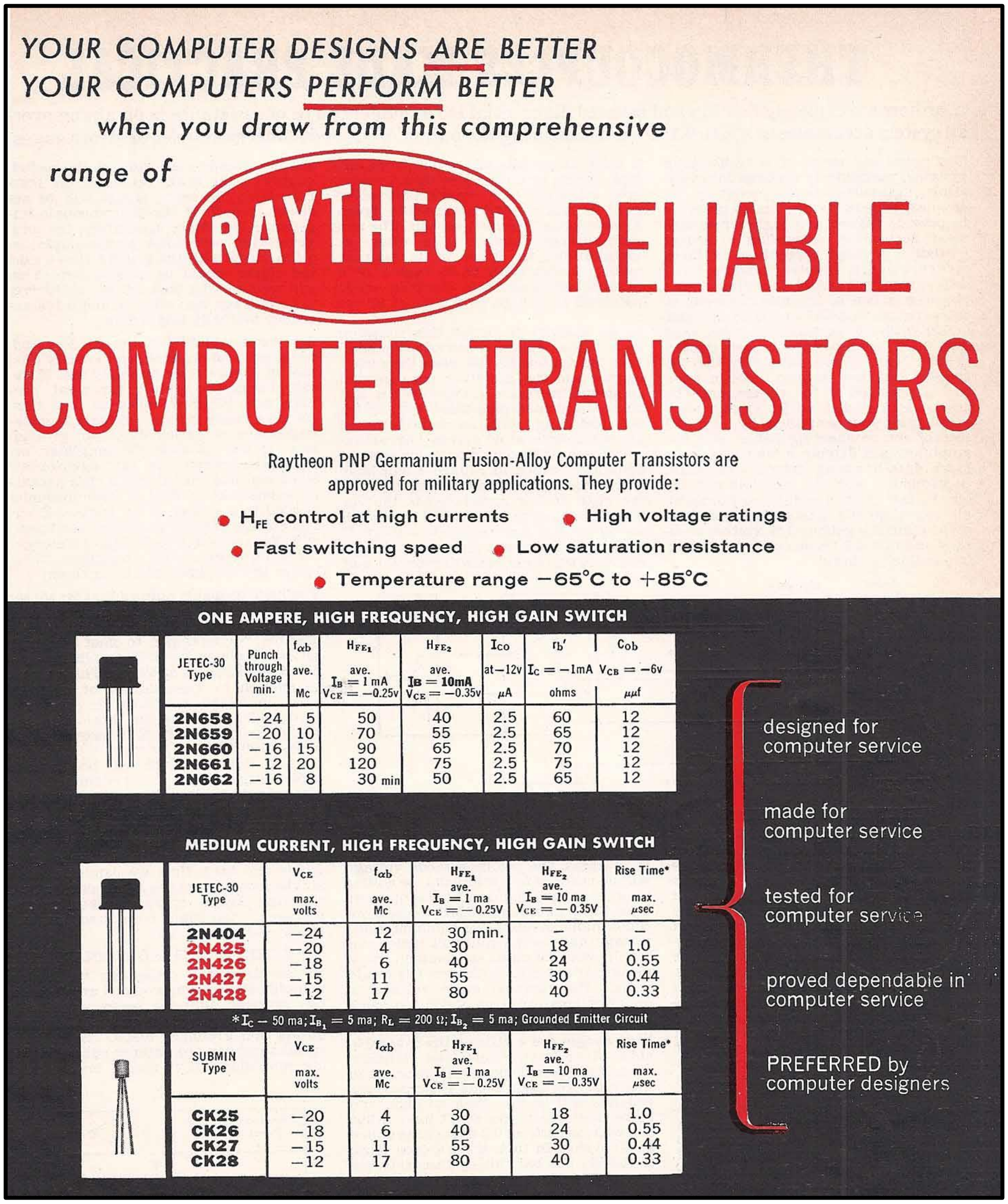

ONE AMPERE, HIGH FREQUENCY, HIGH GAIN SWITCH

JETEC-30 Type	Punch through Voltage min.	$f_{\alpha b}$ ave. Mc	H_{FE_1} ave. $I_B = 1$ mA $V_{CE} = -0.25$v	H_{FE_2} ave. $I_B = 10$mA $V_{CE} = -0.35$v	I_{CO} at −12v μA	r_b' $I_C = -1$mA ohms	C_{ob} $V_{CB} = -6$v μμf
2N658	−24	5	50	40	2.5	60	12
2N659	−20	10	70	55	2.5	65	12
2N660	−16	15	90	65	2.5	70	12
2N661	−12	20	120	75	2.5	75	12
2N662	−16	8	30 min	50	2.5	65	12

MEDIUM CURRENT, HIGH FREQUENCY, HIGH GAIN SWITCH

JETEC-30 Type	V_{CE} max. volts	$f_{\alpha b}$ ave. Mc	H_{FE_1} ave. $I_B = 1$ ma $V_{CE} = -0.25$V	H_{FE_2} ave. $I_B = 10$ ma $V_{CE} = -0.35$V	Rise Time* max. μsec
2N404	−24	12	30 min.	–	–
2N425	−20	4	30	18	1.0
2N426	−18	6	40	24	0.55
2N427	−15	11	55	30	0.44
2N428	−12	17	80	40	0.33

*I_C – 50 ma; $I_{B_1} = 5$ ma; $R_L = 200\ \Omega$; $I_{B_2} = 5$ ma; Grounded Emitter Circuit

SUBMIN Type	V_{CE} max. volts	$f_{\alpha b}$ ave. Mc	H_{FE_1} ave. $I_B = 1$ ma $V_{CE} = -0.25$V	H_{FE_2} ave. $I_B = 10$ ma $V_{CE} = -0.35$V	Rise Time* max. μsec
CK25	−20	4	30	18	1.0
CK26	−18	6	40	24	0.55
CK27	−15	11	55	30	0.44
CK28	−12	17	80	40	0.33

Expanding the Raytheon Germanium Computer Transistor Product Line: The above ad appeared in the March 20, 1959 issue of Electronics magazine and well documents the continued active development and commercialization by Raytheon of an expanding line of germanium computer transistors. Of particular note is the 2N6XX line of high current, high frequency devices, which were useful for core memory drivers. Note also that Raytheon continued to use the "CK" identification method for select devices – in this case, the CK25 through CK28 transistors were classified as "submini", which was a unique Raytheon case style not consistent with the more standard "2N" types.

RAYTHEON

EQUIPMENT MANUFACTURERS' NET PRICE SCHEDULE

RAYTHEON

TRANSISTORS SEMICONDUCTOR DIVISION

TYPE	DESCRIPTION	1–99	PRICE 100–999
2N327A	Silicon PNP Audio Switch	14.87	9.00
2N328A	Silicon PNP Audio Switch	26.43	16.00
2N329A	Silicon PNP Audio Switch	39.65	24.00
2N404	Germanium PNP Computer Switch–Hi Frequency	~~3.13~~	~~1.95~~
USAF2N404	Specification No. MIL–T–19500/20	4.15	~~2.50~~
2N413	Germanium PNP General Purpose R.F. Amplifier	2.07	1.25
2N414	Germanium PNP General Purpose R.F. Amplifier	2.28	1.38
2N416	Germanium PNP General Purpose R.F. Amplifier	5.77	3.50
SigC2N416	Specification No. MIL–T–19500/56A	9.13	5.50
2N417	Germanium PNP General Purpose R.F. Amplifier	7.42	4.50
SigC2N417	Specification No. MIL–T–19500/57A	11.79	7.10
2N425	Germanium PNP Computer Switch–Hi Frequency	4.29	2.60
SigC2N425	Specification No. MIL–T–19500/41	6.80	4.10
2N426	Germanium PNP Computer Switch–Hi Frequency	4.45	2.70
SigC2N426	Specification No. MIL–T–19500/42	7.05	4.26
2N427	Germanium PNP Computer Switch–Hi Frequency	6.68	4.05
SigC2N427	Specification No. MIL–T–19500/43	10.60	6.40
2N428	Germanium PNP Computer Switch–Hi Frequency	8.26	5.00
SigC2N428	Specification No. MIL–T–19500/44	13.00	7.90
2N619	Silicon NPN General Purpose Amplifier	14.87	9.00
2N620	Silicon NPN General Purpose Amplifier	26.43	16.00
2N621	Silicon NPN General Purpose Amplifier	39.65	24.00
2N658	Germanium PNP Hi Current RF Computer Switch	6.20	3.75
2N659	Germanium PNP Hi Current RF Computer Switch	9.09	5.50
2N660	Germanium PNP Hi Current RF Computer Switch	12.39	7.50
2N661	Germanium PNP Hi Current RF Computer Switch	16.11	9.75
2N662	Germanium PNP Hi Current RF Computer Switch	5.17	3.10
2N1017	Germanium PNP Computer Switch–Hi Frequency	9.24	5.60
2N1034	Silicon PNP Audio Amplifier	12.78	7.74
2N1035	Silicon PNP Audio Amplifier	23.25	14.08
2N1036	Silicon PNP Audio Amplifier	35.69	21.60
2N1037	Silicon PNP Low Noise Amplifier	26.77	16.20
CK25	Germanium PNP Submin Computer Switch Hi Frequency	5.29	3.20
CK26	Germanium PNP Submin Computer Switch Hi Frequency	5.45	3.30
CK27	Germanium PNP Submin Computer Switch Hi Frequency	8.02	4.85
CK28	Germanium PNP Submin Computer Switch Hi Frequency	11.16	6.75

Raytheon 1959 Transistor Price List: By the late 1950s, Raytheon was manufacturing a broad range of semiconductor devices. The scan above is just a partial listing of a multipage 1959 price list, showing many of the germanium computer and high frequency transistors (indicated with blue marking) as well as some of the first silicon transistors sold by Raytheon (indicated with red marking). The Raytheon germanium computer line was quite extensive, and matched the lineup from other leading transistor companies from the late 1950s such as Texas Instruments and Sylvania. Note the extraordinary prices for the few silicon transistors available – for example, the 2N329A was listed for $39.65, which is equivalent to over $320 in 2015. Silicon transistor technology was not mature at this time and even poorly performing devices could be sold to the military and industry for very high prices.

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HISTORIC GERMANIUM COMPUTER TRANSISTORS

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CK25/26/27/28: Raytheon's initial success with germanium transistors was based on the large scale production of hearing aid transistors. In this application, miniaturization was an important requirement, since smaller components would result in smaller finished device hearing aids. As early as 1956, Raytheon was manufacturing miniature transistors which were sold in large quantities to hearing aid companies. Raytheon continued to reduce the size of specific transistor types, and introduced the "subminiature" case style in 1958. Although the submini case style was originally developed for the hearing aid market, Raytheon was also able to use this case style with the higher frequency transistor types that had been developed for computer use. For example, the CK26 subminiature transistor shown above left with the classic red, white and blue Raytheon cardboard packaging was electrically equivalent to the larger 2N426 computer transistor. A complete line of these CK submini computer types was introduced in early 1958, all of which were electrically equivalent to the corresponding 2N42X TO-5 devices: CK25=2N425, CK26=2N426, CK27=2N427 and CK28=2N428. These submini transistor types did not have a long term impact on the computer industry, since integrated circuits began to appear by the early 1960s and were the primary technology driving the miniaturization of computer circuits.

U.S. Army 2N426: 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. Devices which were manufactured and tested to meet specific Army specifications, as shown above right with the 2N426, were stamped with the "U.S. Army" designation. The 2N42X line of computer transistors was very successful and these devices were used in many 1950s/1960s computer applications. For example, the 2N426 was used in such historically important computers as ORDVAC and Univac LARC.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: Raytheon CK25-CK28 transistor
Type: Germanium PNP fusion alloy
Case Color/Style: Silver metal submini
Vintage/Date Code: 1950s/1960s
Use: Miniaturized computer switch
Notes: Unique Raytheon "submini" case for miniaturization of 2N425-428 product line.

TRANSISTOR MUSEUM
Historic Semiconductor Data
Device ID: Raytheon Army 2N426 transistor
Type: Germanium PNP fusion alloy
Case Color/Style: Silver metal TO-5
Vintage/Date Code: 1950s/1960s
Use: Medium frequency computer switch
Notes: Originally developed by Raytheon for Army/Sig C. Very successful product line.

RAYTHEON

2N660: The 2N660 transistor, above left, was introduced by Raytheon in the late 1950s as part of a series of germanium computer transistors designed for high switching speed and high current capabilities. This group of transistors included the JEDEC types 2N658 through 2N662, with the different types meeting various frequency and current specifications. For example, the 2N660 datasheet indicated an average alpha cutoff frequency of 15 MC, with a DC collector current capability of 1.0 Amperes. Performance levels of this range would have been appropriate for magnetic core memory driver applications – magnetic core memory technology was leading edge for digital computer systems during the late 1950s and germanium transistors that could perform at this level were just becoming available. The 2N660 was registered by Raytheon with JEDEC in 1958 and was available commercially that year. The initial price for the high performing 2N660 was quite high ($12.39 in 1959) but soon dropped ($4.62 in 1962) as improved transistor types, including the new silicon mesa and planar devices, became available.

2N1017: According to the 3/15/1960 Raytheon Tentative Data Sheet, "The 2N1017 is a high frequency PNP fusion alloy junction transistor intended for use in computer and switching applications. This transistor features close control of large signal gain and response parameters as well as rigid processing control to insure reliability and stability of electrical characteristics. Reliable hermetic sealing is assured by use of a welded package." The 2N1017 was an addition to the group of Raytheon germanium computer transistors initially released as 2N658 through 2N662. These transistors varied in performance characteristics, primarily frequency response and current handling capabilities. For example, the 2N1017 had an average cutoff frequency of 20 MC, which was higher than the 2N660 shown above, but had a current capacity of .40 Amperes, which was less than the 1.0 Amps listed for the 2N660. As noted in the text of the data sheet, Raytheon had developed controllable manufacturing processes, which allowed for the specification of a broad range of performance characteristics for these computer transistors. The 1962 price for the 2N1017 was $4.65.

TRANSISTOR MUSEUM
Historic Semiconductor Data

Device ID: Raytheon 2N660 transistor
Type: Germanium PNP fusion alloy
Case Color/Style: Silver TO-5
Vintage/Date Code: Late 50s/Early 60s
Use: 15 MC - 1 Amp computer switch
Notes: Unique fusion alloy construction for high frequency, high current switching use.

TRANSISTOR MUSEUM
Historic Semiconductor Data

Device ID: Raytheon 2N1017 transistor
Type: Germanium PNP fusion alloy
Case Color/Style: Silver TO-5
Vintage/Date Code: Late 50s/Early 60s
Use: 20 MC - .40 Amp computer switch
Notes: From a series of fusion alloy devices designed for high frequency computer use.

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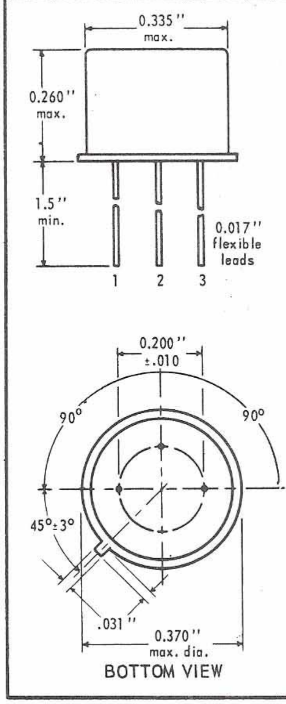
TECHNICAL INFORMATION

Excellence in Electronics

GERMANIUM TRANSISTOR

TYPE 2N1017

The 2N1017 is a high frequency PNP fusion alloy junction transistor intended for use in computer and switching applications. This transistor features close control of large signal gain and response parameters as well as rigid processing control to insure reliability and stability of electrical characteristics. Reliable hermetic sealing is assured by use of a welded package.



MECHANICAL DATA

CASE: JEDEC TO-5
BASE: JEDEC E3-44
TERMINAL CONNECTIONS:
Lead 1 Emitter
Lead 2 Base
Lead 3 Collector

ELECTRICAL DATA

ABSOLUTE MAXIMUM RATINGS:

Collector to Base Voltage (Emitter Open)	−30	volts
Emitter to Base Voltage (Collector Open)	−20	volts
Collector to Emitter Voltage (Base Open)	−10	volts
Collector to Emitter Voltage (V_{BE}=+0.1 volts)	−12	volts
DC Collector Current	400	mA
Peak Collector Current	1	amp.
Dissipation Coefficient (in air) Ka●	0.35	°C/mW
Dissipation Coefficient (infinite sink) Ks●	0.18	°C/mW
Storage Temperature	−65 to +100	°C
Lead Temperature (at 1/16" ± 1/32" from case)	240	°C for 10 seconds
Total Power Dissipation (in air)	170	mW

CHARACTERISTICS: @ 25°C (V_{CB}=−5V, I_E=1 mA except where noted)

PARAMETER	SYM	CONDITIONS	DESIGN VALUES Min.	Avg.	Max.	Units
Collector Cutoff Current	I_{CO}	V_{CB}=−1.5V	----	2.0	4.0	µA
Emitter Cutoff Current	I_{EO}	V_{EB}=−1.5V	----	1.5	4.0	µA
Collector Cutoff Current	I_{CO1}	V_{CB}=−30V	----	−10	−25	µA
Emitter Cutoff Current	I_{EO1}	V_{EB}=−20V	----	−5	−25	µA
DC Current Gain	hFE_1	Ib= 10 mA, V_{CE}=−0.25V	70	100	----	----
DC Base Voltage	V_{BE1}	Ib= 10 mA, V_{CE}=−0.25V	----	−0.35	−0.45	volts
DC Current Gain	hFE2	IB= 10 mA, V_{CE}=−0.35V	20	30	----	----
DC Base Voltage	V_{BE2}	IB= 10 mA, V_{CE}=−0.35V	----	−0.6	−0.8	volts
Saturation Resistance	Rsat.	IC=200mA, IB= 10 mA	----	0.9	1.3	ohms
Alpha Cutoff Frequency	f∝b		15	20	----	Mc
Collector Capacitance	Cob	f=1Mc	----	12	20	µµf
Extrinsic Base Resistance	rb"	f=1Mc	----	80	----	ohms

3/15/60/T — Tentative Data — SEMICONDUCTOR DIVISION

Raytheon Computer Transistor Data Sheet: Above is an example of a typical Raytheon transistor "spec sheet" from the 1950s/1960s – this "spec sheet" documents the Tentative performance parameters of the 2N1017 germanium computer transistor. By this time, the standard TO-5 case style was used for the 2N1017, although an earlier 1958 Raytheon "spec sheet" lists the less common TO-9 case.

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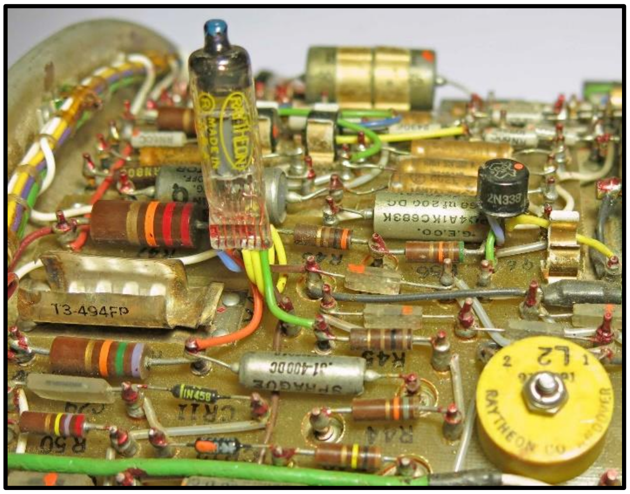

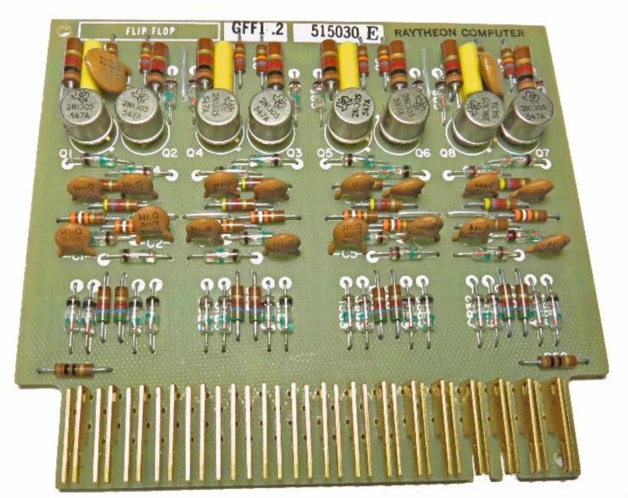

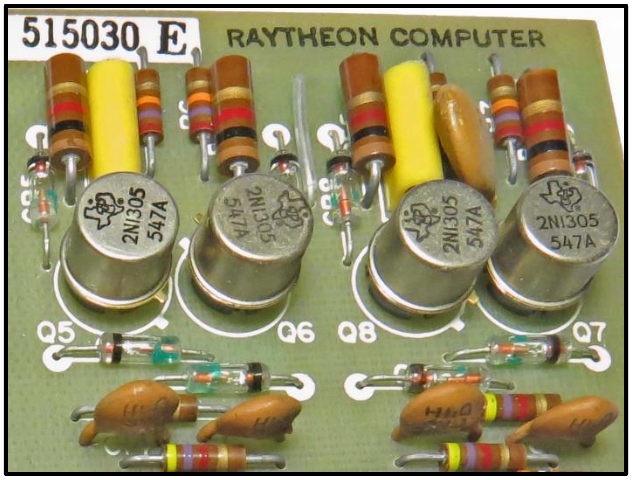

Raytheon Missiles and Computers: Shown across the top are two views of an early 1960s Hawk Missile onboard control system circuit board. Raytheon was the prime contractor for this surface to air missile system which was first deployed in 1959. It is interesting to note that Raytheon did not use Raytheon transistors in this important military application; the close-up view of a section of the circuit, at upper right, shows a Texas Instruments 2N338 silicon transistor, dated 1960, next to a Raytheon USN 5702 electron tube, dated 1958. Vacuum tubes continued to play an important role in 1960s missile electronics because of their better performance when exposed to high radiation levels. The Raytheon computer circuit card above is stamped "FLIP FLOP" and appears to contain four identical FF circuits. It is not documented which Raytheon computer used this circuit board. As with the Hawk missile, the Raytheon computer board did not use Raytheon transistors, and instead used eight Texas Instruments 2N1305 germanium computer transistors, dated 1965. In both these above instances, it seems that business organizations within corporate Raytheon were not required to use devices available from the Raytheon Semiconductor Division.

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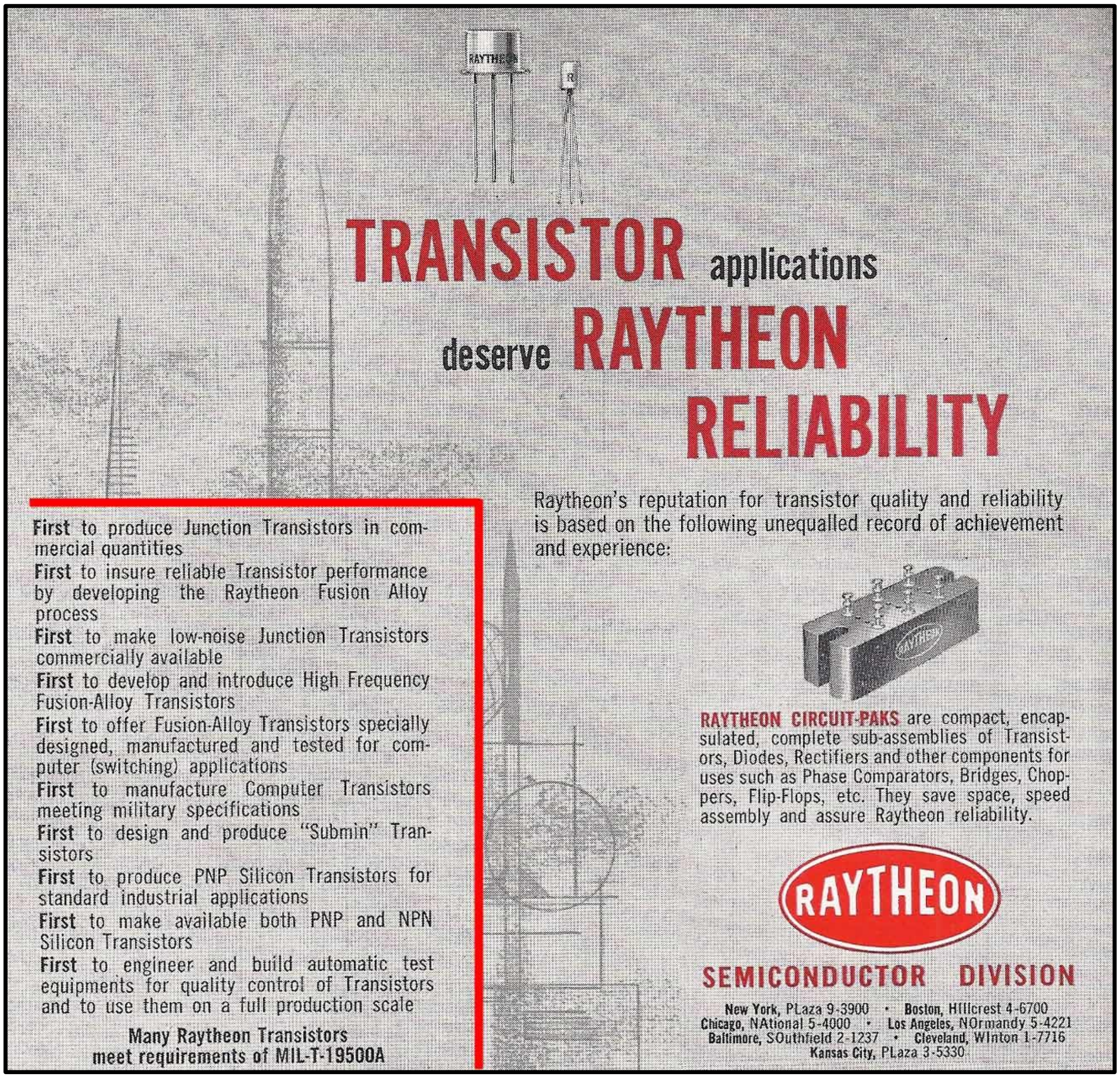

Raytheon Transistor "Firsts" from the 1950s: The above scan, excerpted from the June 1959 Electronics Industries magazine, provides an excellent summary of Raytheon's considerable contributions to 1950s transistor technology. Note the list of important "Firsts", which begins with the volume production of the CK718 junction hearing aid transistor in 1952. Other important "Firsts" highlight the development of the Fusion-Alloy process for high frequency transistors, including computer and military devices. Also mentioned is the development of the submini transistor. Primarily known as an important leader in early germanium transistor technology, Raytheon was not able to make a successful entry into large scale silicon transistor production. Raytheon did develop and manufacture relatively modest quantities of silicon transistors in the late 1950s and early 1960s using the proprietary "fusion alloy" process, but these devices were never competitive with the mesa and planar devices available from leading silicon companies such as Fairchild, Motorola and Texas Instruments. Raytheon may be best remembered as the first major commercial germanium transistor company, and many of this company's 1950s/1960s devices were used in quantity and performed well in early transistorized computers.