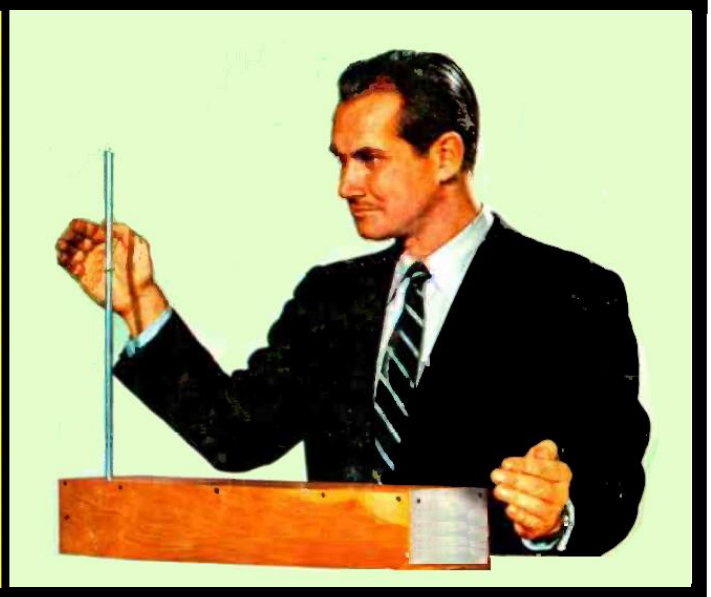
TRANSISTOR MUSEUM™

HISTORY OF TRANSISTORS PRESERVATION COLLECTION

1960s MOOG MELODIA THEREMIN TRANSISTORS & DIODES

Special Collection of Historic Mid-Century PNP and NPN Germanium Transistors and Classic Diodes for Restoration or New Build



INCLUDED ARE TWO COMPLETE SETS OF HISTORIC GERMANIUM TRANSISTORS AND DIODES FOR THE MOOG MELODIA THEREMIN - 1961 NPN VERSION SHOWN ABOVE RIGHT AND 1961 PNP VERSION SHOWN ABOVE LEFT. ALSO INCLUDED ARE PHOTOS, TECHNICAL DESCRIPTIONS AND RESEARCH LINKS ABOUT THESE FIRST "TRANSISTORIZED" MOOG THEREMINS.

A Transistor Museum Preservation Collection

ABOUT THIS TRANSISTOR MUSEUM PRESERVATION COLLECTION

1960s Moog Melodia Theremin Transistors and Diodes is dedicated to the electronic hobbyists and experimenters who still remember their first exciting work with circuits and especially those historic devices, circuits and components from the first days of transistor technology. This current Preservation Collection documents the first transistorized theremins designed and built by Robert Moog in 1950s/1960s. We have provided 17 historic 1950s/60s germanium transistor/diode types that were used or could have been used by Moog when he published the first transistor theremin construction article in 1961 and soon after sold the first commercial transistor theremins. Also included in this collection are extensive links to important online documentation, technical and historical commentary, circuits, and photographs of these famous semiconductors and theremins.

17 HISTORIC SEMICONDUCTORS INCLUDED IN THIS PRESERVATION COLLECTION

DEVICE TYPE	HISTORICAL SIGNIFICANCE
2N169A GE NPN Grown Junction Transistors (4 Included)	**General Electric Germanium NPN Transistors** Mid-1950s high performance transistors using unique grown junction germanium technology. The 2N168/169 family of devices was designed and selected for robust RF/IF circuit operation in commercial transistor radios. Selected by Moog based on cost, performance and availability.
1N34 Kemtron Classic Point Contact Diodes (2 Included)	**Kemtron "Federal Grade" 1960s Germanium PCT Diodes** These two 1960s 1N34 germanium diodes match well with the diode types specified by Robert Moog for the design and construction of the original 1961 NPN Melodia DIY construction project. These are historic devices.
2N414 PNP Alloy Junction Transistors (4 Included)	**Raytheon & Tungsol Hi-Performance Germanium PNP Transistors** The first transistor theremin offered by the Moog company was the 1961 Melodia, which was based on the original 1961 DIY project. The Melodia used four 2N414 PNP transistors – this collection includes two Raytheon and two Tungsol 1960s original and historic robust 2N414s.
1N34A Classic 1950s Point Contact Diode (2 Included)	**Sylvania 1950s Ruggedized 1N34A Germanium PCT Diodes** The Melodia theremin used the "new and improved" 1N34A glass-cased germanium diodes instead of the original 1N34 type. This collection includes two original and historic 1950s Sylvania 1N34A diodes.
DESIGN PACK Two PNPs/NPNs plus an original first 1N34 diode type (5 Included)	**Design Pack of Historic Germanium Semiconductors** Robert Moog started his famous company in 1954, building circuits in his parent's basement. In honor of his very important contributions to electronic musical instruments, this Transistor Museum Design Kit includes historic 1950s/60s semiconductors that modern day experimenters might find useful in designing their own "theremins".
TOTAL TRANSISTORS INCLUDED = 12 / TOTAL DIODES = 5	

The Transistor Museum is dedicated to preserving the Greatest Invention of the 20th Century. Each historic semiconductor included in this Preservation Collection has been inspected to best ensure legibility of labelling and acceptable cosmetic condition. Informative and protective display envelopes and packaging are used to protect and archive the included transistors. Thank you for your interest and your support of our efforts to preserve these important historical artifacts.

The First Moog Transistor Theremin was a DIY Kit Detailed in the January 1961 Electronics World

Above is an excerpted view of the cover of the January 1961 Electronics World magazine. Robert Moog was the author of this article and describes the project as: "*The instrument to be described is a transistorized Theremin, powered by a small battery, and designed to be connected to any external amplifier. Although it is quite simple and inexpensive to build, it is a true musical instrument.*" In fact, this was Moog's first transistor theremin and set the stage for the famous follow-on Moog theremins and synthesizers. The Moog Foundation and the Moog Archives websites are both excellent sources of historical information detailing the outstanding contributions to electronic musical instrument technology by Robert Moog. This Transistor Museum Preservation Collection is intended to support this legacy by making available historic semiconductors to those interested in restoring or new builds of these first transistorized Moog theremins.

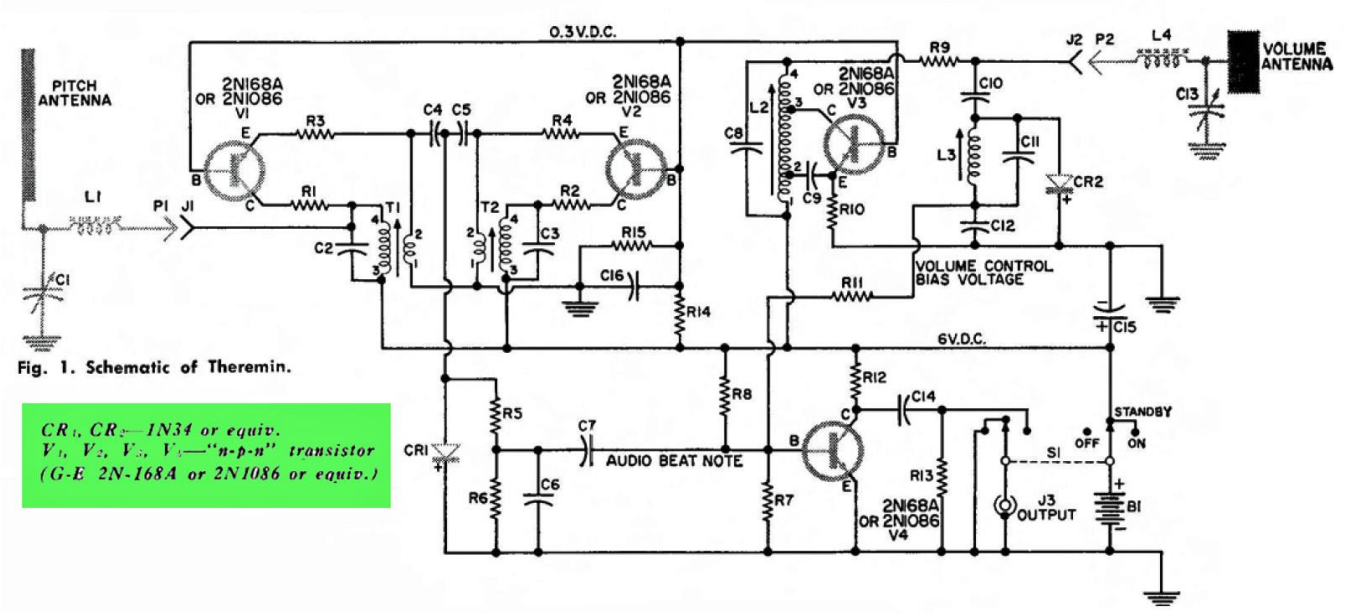


Fig. 1. Schematic of Theremin.

CR_1, CR_2—1N34 or equiv.
V_1, V_2, V_3, V_4—"n-p-n" transistor (G-E 2N-168A or 2N1086 or equiv.)

The 1961 NPN Moog Melodia Theremin - How It Works

Above is the Melodia schematic scanned from the January 1961 Electronics World DIY construction article written by Robert Moog. The descriptive text provided by Mr. Moog in the article provides a comprehensive and readable narrative explaining circuit operation. In summary, the Theremin utilizes "hand" capacitance to control the pitch (frequency) or loudness of a tone? The pitch-generator consists of two stable RF oscillators, transistors V1 and V2, both of which operate at about 150 kc. The signals from these two oscillators are mixed and rectified by CR1 (1N34), resulting in an "Audio Beat Note" that can be adjusted into the audio range. Hand movements in proximity to the Pitch Antenna alter the frequencies of the V1 and V2 oscillators and thus the audio beat frequency. For hand capacitance control of the theremin audio volume, transistor V3 oscillator output is rectified by CR2 (1N34), and a volume control bias voltage is applied to the base of amplifier transistor V4 – hand movements in proximity of the Volume Antenna vary this bias voltage and resultant output volume level. Note that this is a very simplified description of the actual circuit operation – Robert Moog's actual design is quite impressive and deserves a good read of the article to best understand. Also of interest is the unique design and construction of the hand-wound coils which provide much of the sensitivity and "magic" of this theremin. There are interesting comments about "right-handed" and "left-handed" operation of the theremin which are very clever and thought provoking. Finally, there are some "learning to play your theremin" instructions and exercises provided by Mr. Moog. Some concluding comments from the article: "Once you become a proficient Thereminist, you will find many opportunities to display your talents. Theremin music is ideal for providing backgrounds for amateur plays, for melodic classical and religious music, or for adding a novel touch to dance bands and vaudeville acts. Even if you never take the time to become an accomplished Thereminist, the instrument will provide you and your friends with hours of entertainment. In short, you will be able to produce "Music from the Ether." Use these links for YouTube examples of Melodia operation and music and a stunning classical performance.

GERMANIUM TRANSISTORS — GE

Type	Max Col Mw	Max Col V	Max Col Ma	DC* Cur Gain	Cut off Mc*	Use	NET‡ 1-99
2N43	240	-30	-300	53	1.3	PNP-AF	4.15
2N43A ♦	155	-25	—	53	1.3	PNP-AF	4.15
2N44 ♦	240	-30	-300	31	1.0	PNP-AF	2.90
2N78	65	16	20	70	9.0	NPN-Co	3.75
2N107	50	- 6	- 10	20	1.0	PNP-AF	1.00
2N123	150	-15	-125	30†	8.0	PNP-Co	5.40
2N135	100	-12	- 50	20	4.5	PNP-IF	2.15
2N136	100	-12	- 50	40	6.5	PNP-RF	2.55
2N137	100	- 6	- 20	60	10.0	PNP-RF	6.20
2N167	75	30	75	30	9.0	NPN-Co	6.45
2N168A	65	15	20	40	8.0	NPN	2.06
2N169	65	15	20	72	9.0	NPN-IF	2.06
2N169A	65	25	20	72	9.0	NPN-IF	2.50
2N170	55	6	20	20	4.0	NPN-RF	1.30
2N186	100	-25	-200	24	0.8	PNP-AF	1.80
2N186A	200	-25	-200	24	0.8	PNP-AF	1.95
2N187	100	-25	-200	36	1.0	PNP-AF	1.85
2N187A	200	-25	-200	36	1.0	NPN-AF	1.66
2N188	100	-25	-200	54	1.2	PNP-AF	1.90
2N188A	200	-25	-200	54	1.2	PNP-AF	1.82
2N189	75	-25	- 50	24	0.8	PNP-AF	1.75
2N190	75	-25	- 50	36	1.0	PNP-AF	1.57
2N191	75	-25	- 50	54	1.2	PNP-AF	1.80
2N192	75	-25	- 50	75	1.5	PNP-AF	1.96
2N241	100	-25	-200	73	1.3	PNP-AF	2.00
2N241A	200	-25	-200	73	1.3	PNP-AF	2.00
2N265	75	-25	- 50	110	1.5	PNP-AF	2.06
2N292	65	15	20	25	6.0	NPN-IF	1.61
2N293	65	15	20	25	7.0	NPN-IF	2.06

GENERAL ELECTRIC

GERMANIUM TRANSISTORS

Type	Max Col Mw	Max Col V	Max Col Ma	DC Cur Gain	Cut-Off Mc	Use	Net
USAF 2N43A	155	—25	—	53	1.3	PNP AF	3.75
USAF 2N44A	240	—30	—300	31	1.0	PNP AF	5.25
2N123A	150	—20	—125	30	8.0	PNP Sw	7.05
USAF 2N167	75	30	75	30	9.0	NPN Co	8.13
2N168	55	15	20	20	6.0	NPN IF	2.05
2N388	150	20	200	60	8.0	NPN Sw	5.80
2N396A	150	—20	—200	—	8.0	PNP Sw	5.00
2N448	65	15	20	8	5	NPN IF	1.37
2N449	65	15	20	34	8	NPN IF	1.90
2N1086	65	9	20	17	8	NPN Os	1.86
2N1086A	65	9	20	17	8	NPN Os	2.00
2N1087	65	9	20	17	8	NPN Os	2.06
2N1097	140	—16	—100	55	—	PNP AF	1.48
2N1098	140	—16	—100	45	—	PNP AF	1.32
2N1115	150	—15	—125	—	5	PNP Sw	14.80
2N1121	65	15	20	34	.008	NPN IF	2.10
2N1144	140	—16	—120	55	—	PNP AF	1.48
2N1145	140	—16	—100	45	—	PNP AF	1.32
2N1198	65	25	75	17	5	NPN Sw	5.80
2N1413	200	—35	—200 ma	42	2.0	PNP AF	2.06
2N1414	200	—35	—200 mc	65	2.5	PNP AF	2.30
2N1415	200	—35	—200 ma	90	2.8	PNP AF	2.65

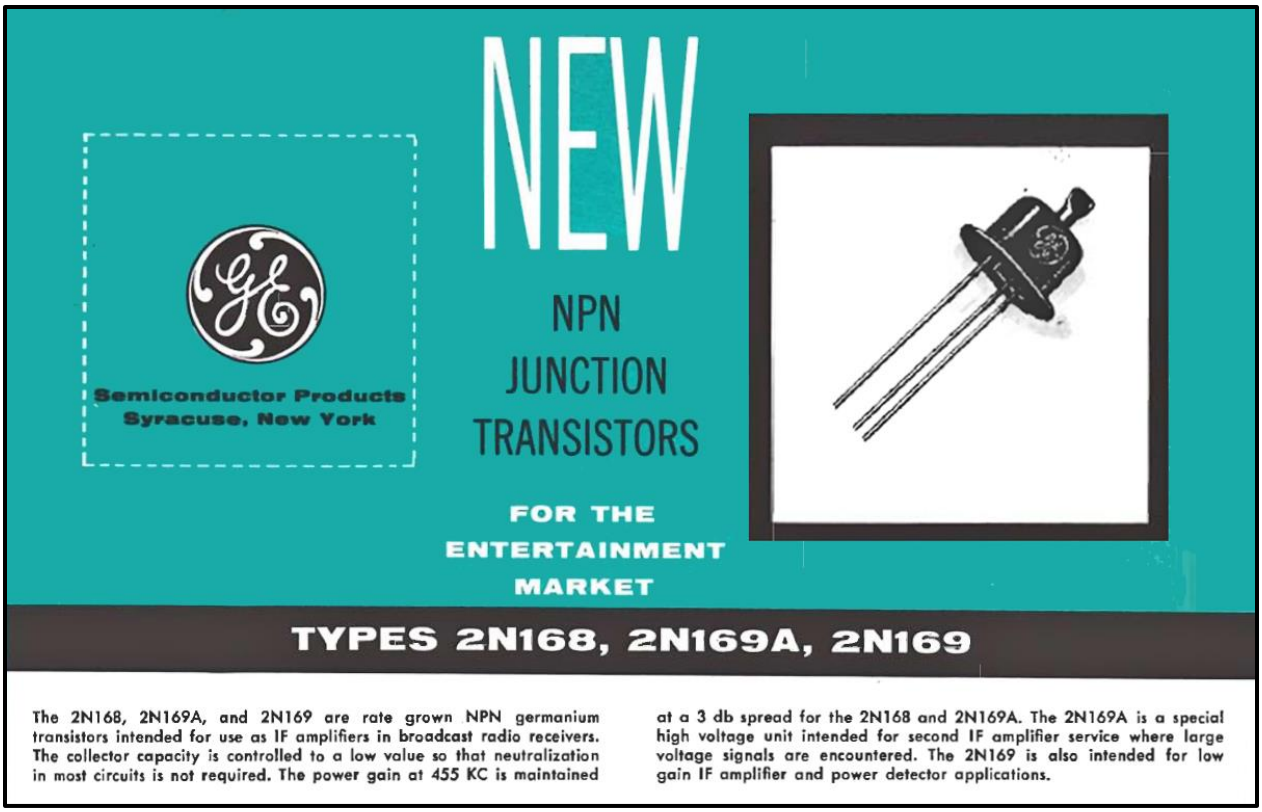
GENERAL ELECTRIC

SILICON TRANSISTORS — NPN

Type	Max Col Mw	Max Col V	Max Col Ma	Cut-Off Mc	Use	NET 1-99	NET 100 up
2N333A	500	45	25	2.5	Sw	17.60	11.75
2N334A	500	45	25	2.5	Hw	17.60	11.75
2N335A	500	45	25	2.5	Sw	23.55	1 .70
2N336A	00	45	25	2.5	Sw	23.55	15.70
2N336A	500	45	25	2.5	Sw	25.75	17.20

Reviewing the Original General Electric Transistor Types Suitable for the 1961 NPN Moog Melodia Theremin

The 1960 Lafayette Radio Semiconductor Directory provided a very complete listing of the germanium and silicon transistors and diodes available to the general public at that time. It is likely that Robert Moog used sources such as this to review and assess the suitability of transistors for his first transistorized Theremin project. Moog selected the GE 2N168A or the 2N1086 (or equivalent) as the transistor types to be used in the 1961 NPN version of the Melodia. The above scans are from the Lafayette Directory and document the performance (and prices) of the range of General Electric transistors in the same family as the 2N168A and 2N1086. At upper left in green highlight are the specs for the 2N168A/169/169A. The 2N168A is the lowest performing device in this group (gain and frequency) and was reasonably priced. Note the scan at right highlights the performance of the 2N1086, with much lower gain than the higher end 2N168/169/169A types. This large performance range suggests that the actual GE type acceptable for the Melodia could be any of the GE NPNs shown above and highlighted in green (including the 2N292/293). Also note the incredibly high prices for the early silicon transistors.



Semiconductor Products
Syracuse, New York

NEW

NPN JUNCTION TRANSISTORS

FOR THE ENTERTAINMENT MARKET

TYPES 2N168, 2N169A, 2N169

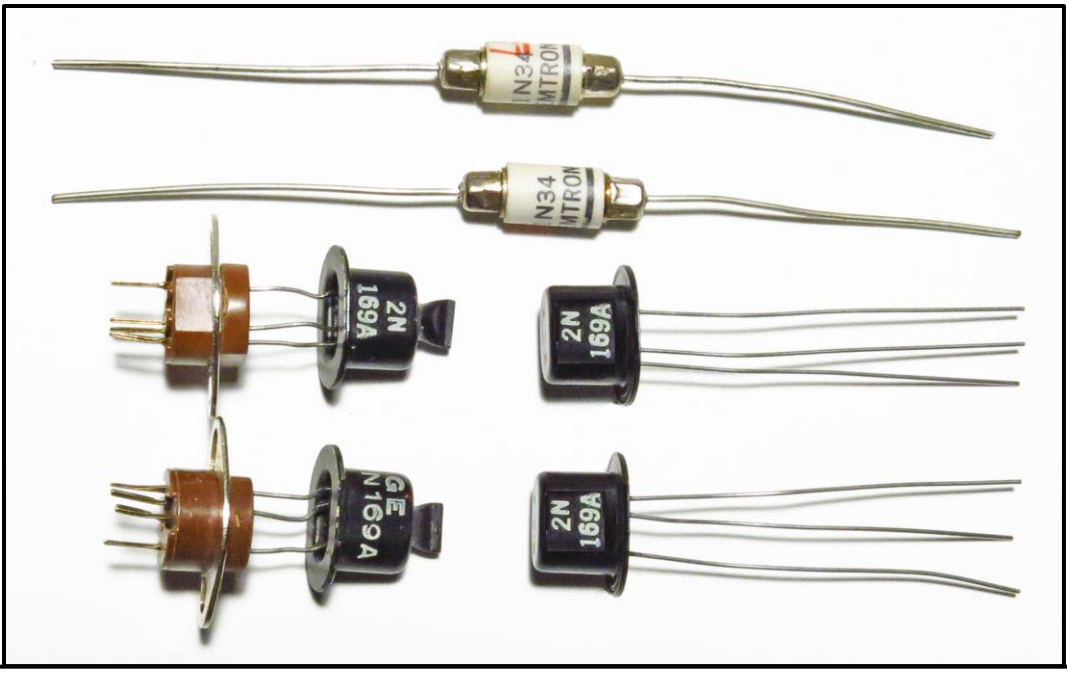
The 2N168, 2N169A, and 2N169 are rate grown NPN germanium transistors intended for use as IF amplifiers in broadcast radio receivers. The collector capacity is controlled to a low value so that neutralization in most circuits is not required. The power gain at 455 KC is maintained at a 3 db spread for the 2N168 and 2N169A. The 2N169A is a special high voltage unit intended for second IF amplifier service where large voltage signals are encountered. The 2N169 is also intended for low gain IF amplifier and power detector applications.

TYPE 2N168A

The 2N168A is a rate grown NPN germanium transistor intended for mixer/oscillator and IF amplifier applications in radio receivers. Special manufacturing techniques provide a low value and a narrow spread in collector capacity so that neutralization in many circuits is not required. The 2N168A has a frequency cutoff control to insure proper operation as an oscillator or autodyne mixer. For IF amplifier service the range in power gain is controlled to 3 db.

General Electric NPN Grown Junction Transistors

General Electric was an early leader in 1950s germanium transistor technology. This company invented several new and high functioning transistor types, including the NPN grown junction types shown above in late 1950s data sheets. GE published a series of well-known Transistor Manuals, beginning in the late 1950s, which includes substantial information about these early transistor types. The 2N168A/169/169A transistors, as shown above, were likely produced on the same manufacturing lines, with the same processes. Due to the somewhat wide variations in the germanium transistor production processes at that time, transistors from the same production line would be tested for specific performance characteristics and then labeled with the appropriate model/type number. Of the types shown above, the 2N168A had the lowest gain while the 2N169 series had higher gain. The "A" suffix indicated higher collector voltage specifications.



What's Included in this 1960s Moog Melodia Theremin Transistors and Diodes Preservation Collection (NPN Version)

This Preservation Collection includes six historic mid-century semiconductors that are provided to support restoration and new builds of the original 1961 Moog NPN Melodia Theremin. As shown above, four GE 2N169A NPN germanium grown junction transistors are included – the two leftmost 2N169A transistors are the earliest types available (from the 1950s) and are notable for the "crimped-top" exhaust tubes which were the result of vacuum sealing inside the metal transistor case during manufacture. The two 2N169A transistors at right are from the "improved" flat top case design which was used by GE beginning in 1960. We have provided plug-in sockets for the two crimped-top 2N169A transistors to facilitate interchange of the various transistors during testing of restorations and new builds. The performance characteristics of these 1950s/60s transistors could vary substantially from unit to unit, and matching transistors to specific circuit functions was common for best overall performance. As noted earlier, the 2N169A transistors are a higher gain/HFE version of the 2N168A types used in the original NPN Melodia circuit and have been provided in this collection to support reliable and consistent operation. Note also that the original 1961 NPN version of the Melodia used two 1N34 germanium diodes – we have included two classic 1960s "Kemtron" 1N34 types which best represent actual types available at that time. These diodes have been selected from a lot of "Federal Grade" diodes provided to the military in the early 1960s. Note the large ceramic case style for these 1N34 devices – Kemtron was a "second-source" supplier of the original Sylvania 1940s 1N34 to the military. Sylvania and Kemtron used the ruggedized ceramic case for the 1N34 throughout the 1950s and into the 1960s. These diodes are rare and should provide a pleasing tone quality matching the original Melodia.

CIRCUITRY OF THE MOOG THEREMIN

Every Moog Theremin is fully transistorized and designed for years of trouble-free use. The instrument utilizes hand capacitance to control both pitch and volume. The pitch control section consists of a beat frequency oscillator, whose frequency is changed by the addition of hand capacitance to the pitch antenna. The volume control section utilizes a third R. F. oscillator, whose output is rectified and used to bias a control amplifier. Addition of hand capacitance to the volume antenna varies the output of the oscillator, and hence the gain of the amplifier.

THE MELODIA

The Melodia is a Moog Theremin in kit form. Retaining all of the essential characteristics of the standard Theremin, the Melodia can be assembled with a few hand tools. Step-by step instructions, easy to follow and fully illustrated, make building your own Theremin fun. Tips on playing your Melodia are included, too. All parts are of premium grade. The chassis and panel are pre-formed and punched. The hand-crafted natural walnut cabinet is designed to mount on a microphone stand.

The Melodia has a five-octave range, extending from two octaves below to three octaves above Middle C. Build it, plug it into an audio amplifier, and enjoy the creative challenge of the Theremin.

SPECIFICATIONS:

Power requirements	6 volts at 10 milliamperes (one 6-volt battery)
Transistors	4 2N414
Useful pitch range	60—2,000 cycles
Max. R.M.S. output	0.5 volts, medium impedance
Cabinet dimensions	22¼" x 6" x 3⅛"
Weight	8 pounds

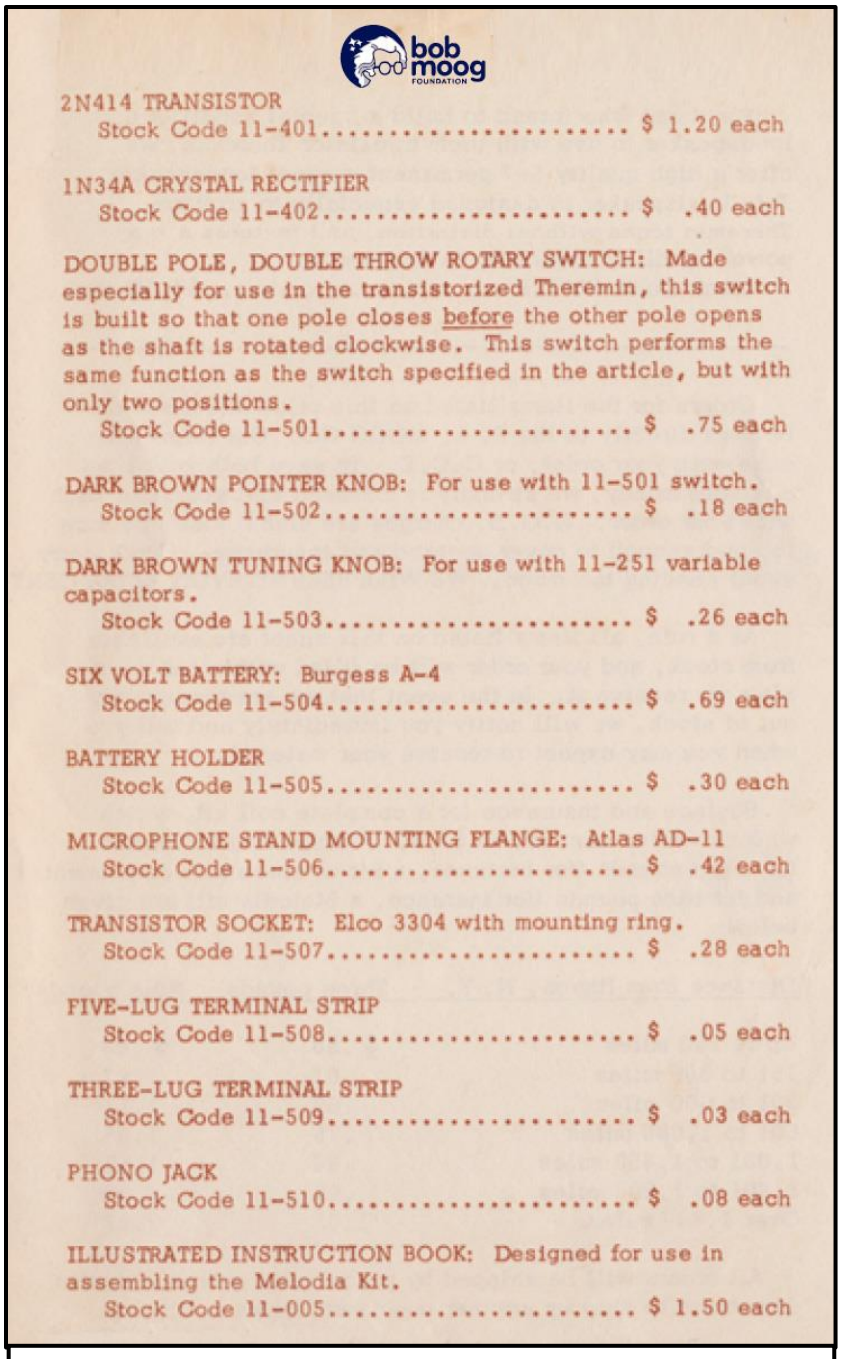
Melodia Model Theremin Kit MT. Shipping weight — 11 pounds **$49.95**

Melodia Model Theremin Assembled MA. Completely assembled and adjusted at the factory, this model needs only an amplifier, loudspeaker and microphone stand. Shipping weight — 13 pounds **$75.00**

Theremin Components Kit TC. Contains all components needed to build the Melodia Theremin, except chassis, panel and antennas. Ideal for advanced experimenters, students, Science Fair contestants. Shipping weight — 3 pounds. **$29.95**

A Classic – Moog Melodia Transistorized Theremin

Shown above is a section of the Moog 1964 catalog highlighting the Melodia "fully transistorized" theremin. The Melodia had been available from the Moog company since 1961 and was continued in this 1964 catalog along with newer models including the updated and more professional "Troubador" version. These theremins could be purchased as "factory assembled" as well as two kit versions. Note the explicit reference to the four 2N414 transistors used in the Melodia. Although the original 1961 DIY Melodia magazine circuit was designed with NPN transistors, the 1961 version made available through the Moog company used 2N414 PNP transistors. At this time in the early 1960s it was common for radio manufacturers to emphasize the transistor count in their product. Moog's amazing circuit design produced exceptional performance with only four transistors!



2N414 TRANSISTOR
Stock Code 11-401..... $ 1.20 each

1N34A CRYSTAL RECTIFIER
Stock Code 11-402..... $ .40 each

DOUBLE POLE, DOUBLE THROW ROTARY SWITCH: Made especially for use in the transistorized Theremin, this switch is built so that one pole closes before the other pole opens as the shaft is rotated clockwise. This switch performs the same function as the switch specified in the article, but with only two positions.
Stock Code 11-501..... $ .75 each

DARK BROWN POINTER KNOB: For use with 11-501 switch.
Stock Code 11-502..... $ .18 each

DARK BROWN TUNING KNOB: For use with 11-251 variable capacitors.
Stock Code 11-503..... $ .26 each

SIX VOLT BATTERY: Burgess A-4
Stock Code 11-504..... $ .69 each

BATTERY HOLDER
Stock Code 11-505..... $ .30 each

MICROPHONE STAND MOUNTING FLANGE: Atlas AD-11
Stock Code 11-506..... $ .42 each

TRANSISTOR SOCKET: Elco 3304 with mounting ring.
Stock Code 11-507..... $ .28 each

FIVE-LUG TERMINAL STRIP
Stock Code 11-508..... $ .05 each

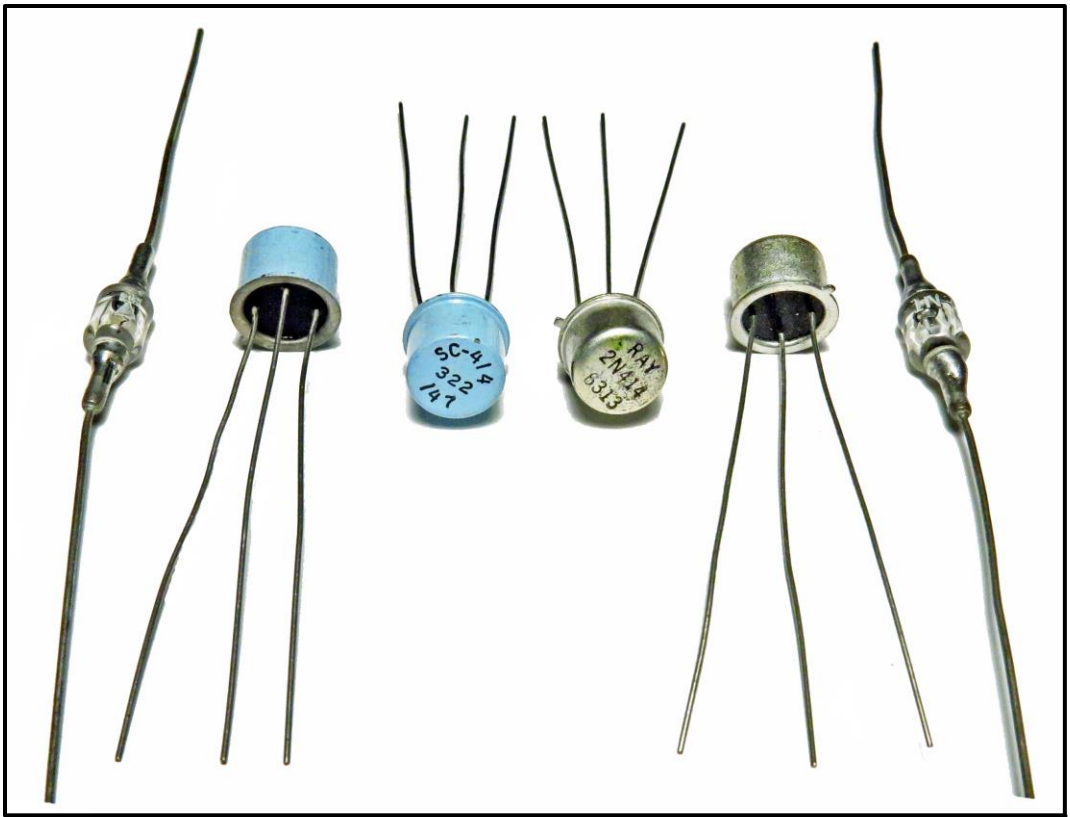
THREE-LUG TERMINAL STRIP
Stock Code 11-509..... $ .03 each

PHONO JACK
Stock Code 11-510..... $ .08 each

ILLUSTRATED INSTRUCTION BOOK: Designed for use in assembling the Melodia Kit.
Stock Code 11-005..... $ 1.50 each

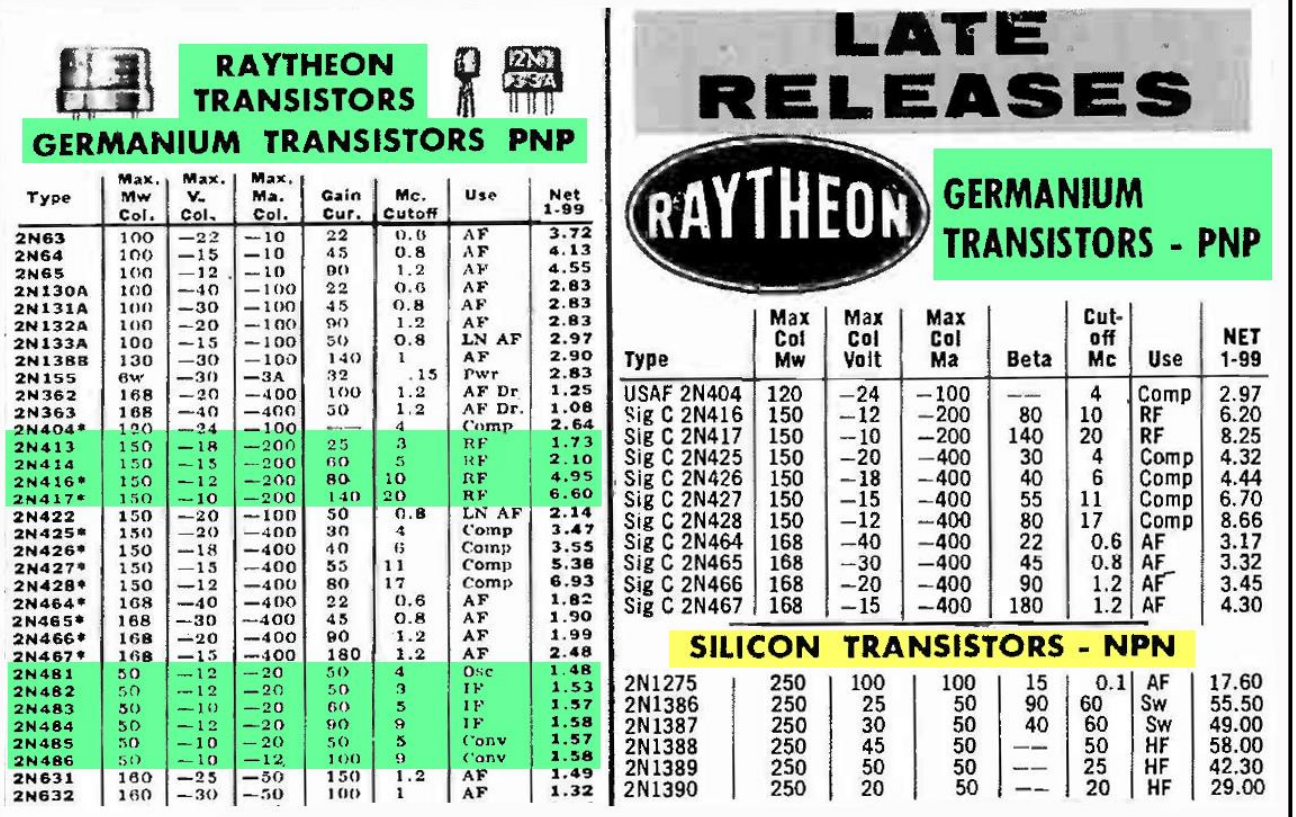
1961 Moog Melodia Component Price List

Shown above is one page from the 1961 Moog catalog listing prices for some individual Melodia components. Of special note are the explicit call-outs for the 2N414 transistors and the 1N34A diodes. These were the types in use for the completely factory-assembled Melodia as well as component kits. Would be great to come across the original "Illustrated Instruction Book" for $1.50.



What's Included in this 1960s Moog Melodia Theremin Transistors and Diodes Collection (PNP Version)

This Preservation Collection includes six historic mid-century devices that are provided to support restoration and new builds of the original 1961 Moog PNP Melodia Theremin. As shown above, four 2N414 PNP germanium alloy junction transistors are included – the two rightmost 2N414 transistors are Raytheon types with dates codes from 1963. The two 2N414 transistors at left are Tungsol types (see "322" EIA code stamped on the case tops). These are dated from 1961. Raytheon had developed the 2N414 and related types (2N413-2N417) in the 1950s under U.S. Signal Corps contract and provided both military and commercial grade versions of these devices. Military contracts frequently required a second-source supplier to ensure adequate availability. Tungsol was an identified second-source supplier of the 2N414 – note the specialized "type id" on the case: "SC-414" = Signal Corps qualified 2N414. These are robust transistors. The PNP version of the Melodia calls for "1N34A" diodes, and we have included two of these as shown above at left and right. The 1N34A type was developed by Sylvania in the late 1940s and was intended to provide a smaller glass-bodied case size than the original larger ceramic case 1N34. The two 1N34A diodes in this collection are both 1950s Sylvania types and would have been readily available to Moog during the 1961 transition from NPN to PNP versions of the Melodia. Note that all case markings for the transistors and diodes in this collection are clear and readable.



RAYTHEON TRANSISTORS

GERMANIUM TRANSISTORS PNP

Type	Max. Mw Col.	Max. V. Col.	Max. Ma. Col.	Gain Cur.	Mc. Cutoff	Use	Net 1-99
2N63	100	—22	—10	22	0.6	AF	3.72
2N64	100	—15	—10	45	0.8	AF	4.13
2N65	100	—12	—10	90	1.2	AF	4.55
2N130A	100	—40	—100	22	0.6	AF	2.83
2N131A	100	—30	—100	45	0.8	AF	2.83
2N132A	100	—20	—100	90	1.2	AF	2.83
2N133A	100	—15	—100	50	0.8	LN AF	2.97
2N138B	130	—30	—100	140	1	AF	2.90
2N155	6w	—30	—3A	32	.15	Pwr	2.83
2N362	168	—20	—400	100	1.2	AF Dr	1.25
2N363	168	—40	—400	50	1.2	AF Dr.	1.08
2N404*	120	—24	—100	——	4	Comp	2.64
2N413	150	—18	—200	25	3	RF	1.73
2N414	150	—15	—200	60	5	RF	2.10
2N416*	150	—12	—200	80	10	RF	4.95
2N417*	150	—10	—200	140	20	RF	6.60
2N422	150	—20	—100	50	0.8	LN AF	2.14
2N425*	150	—20	—400	30	4	Comp	3.47
2N426*	150	—18	—400	40	6	Comp	3.55
2N427*	150	—15	—400	55	11	Comp	5.38
2N428*	150	—12	—400	80	17	Comp	6.93
2N464*	168	—40	—400	22	0.6	AF	1.82
2N465*	168	—30	—400	45	0.8	AF	1.90
2N466*	168	—20	—400	90	1.2	AF	1.99
2N467*	168	—15	—400	180	1.2	AF	2.48
2N481	50	—12	—20	50	4	Osc	1.48
2N482	50	—12	—20	50	3	IF	1.53
2N483	50	—10	—20	60	5	IF	1.57
2N484	50	—12	—20	90	9	IF	1.58
2N485	50	—10	—20	50	5	Conv	1.57
2N486	50	—10	—12	100	9	Conv	1.58
2N631	160	—25	—50	150	1.2	AF	1.49
2N632	160	—30	—50	100	1	AF	1.32

LATE RELEASES

RAYTHEON GERMANIUM TRANSISTORS - PNP

Type	Max Col Mw	Max Col Volt	Max Col Ma	Beta	Cut-off Mc	Use	NET 1-99
USAF 2N404	120	—24	—100	——	4	Comp	2.97
Sig C 2N416	150	—12	—200	80	10	RF	6.20
Sig C 2N417	150	—10	—200	140	20	RF	8.25
Sig C 2N425	150	—20	—400	30	4	Comp	4.32
Sig C 2N426	150	—18	—400	40	6	Comp	4.44
Sig C 2N427	150	—15	—400	55	11	Comp	6.70
Sig C 2N428	150	—12	—400	80	17	Comp	8.66
Sig C 2N464	168	—40	—400	22	0.6	AF	3.17
Sig C 2N465	168	—30	—400	45	0.8	AF	3.32
Sig C 2N466	168	—20	—400	90	1.2	AF	3.45
Sig C 2N467	168	—15	—400	180	1.2	AF	4.30

SILICON TRANSISTORS - NPN

2N1275	250	100	100	15	0.1	AF	17.60
2N1386	250	25	50	90	60	Sw	55.50
2N1387	250	30	50	40	60	Sw	49.00
2N1388	250	45	50	——	50	HF	58.00
2N1389	250	50	50	——	25	HF	42.30
2N1390	250	20	50	——	20	HF	29.00

Raytheon 2N414 and 2N4XX Series-Related Transistors

As with the original selection by Moog of the 2N168A/169/169A series of GE NPN germanium transistors for the DIY theremin kit, the 1960 Lafayette Radio Semiconductor Directory would have an excellent reference for selecting the best corresponding PNP transistors for the updated 1961 factory version of the Melodia. Moog selected the 2N414 type, which fits well as a "medium gain" RF/IF/high frequency type that was readily available and at a comparable price to the NPNs ($2.10 each in quantities up to 99). The less expensive 2N413 from the same series had much poorer gain and frequency response capabilities, as seen in the green highlighted sections above. The much higher performance characteristics of the 2N416 apparently weren't required for the Melodia and also came at a much higher price ($4.95). Also note the very much higher prices for the Sig C versions of the 2N4XX series of transistors in the upper right of the above scan – U.S. Army Sig C qualification required very extensive production burn-in and testing and closer spreads on performance. And, as mentioned earlier, silicon transistors noted with yellow highlight, which would soon appear in later models of Moog theremins, were still too expensive for most commercial applications.

RAYTHEON

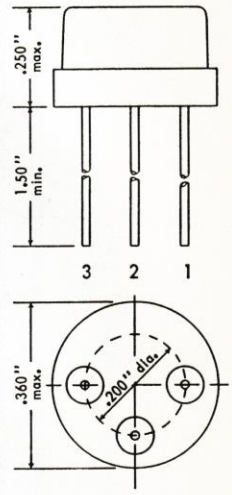
TECHNICAL INFORMATION

GERMANIUM TRANSISTOR

Excellence in Electronics

TYPE 2N414

The 2N414 is a medium gain PNP fusion alloy junction transistor especially intended for high frequency amplifier applications up to 8 megacycles. This transistor features 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: Metal

BASE: Metal with glass eyelets. 0.017" silver plated flexible leads. Length: 1.5" min. Spacing: 90° on 0.200" circle diameter.

TERMINAL CONNECTIONS:

Lead 1 Emitter
Lead 2 Base
Lead 3 Collector

MOUNTING POSITION: Any

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)	−15 volts
Collector to Emitter Voltage (V_{BE}=+0.1 volts)	−20 volts
DC Collector Current	−200 ma.
Peak Collector Current	−400 ma
Dissipation Coefficient (in air) Ka ●	0.4 °C/mw
Dissipation Coefficient (in sink) Ks ●	0.18 °C/mw
Junction Temperature (Operating or Storage)	−65 to +85 °C
Lead Temperature (at 1/16" ± 1/32" from case)	240 °C for 10 seconds

CHARACTERISTICS: @25 °C (V_{CB}=−6V, I_E=1 ma, f=1 Kc, except as noted)

PARAMETER	SYM.	CONDITIONS	DESIGN VALUES Min.	Avg.	Max.	Units
Collector Cutoff Current	I_{CO}	V_{CB}=−12V	----	−2.0	−5.0	μa.
Emitter Cutoff Current	I_{EO}	V_{EB}=−12V	----	−2.0	−5.0	μa.
Input Impedance	hib		----	25	----	ohms
Base Current Gain	hfe	V_{CE}=−6V	----	60	----	----
Voltage Feedback Ratio	hrb		----	0.5	----	X10^{-3}
Output Admittance	hob		----	0.62	----	μmhos
Alpha Cutoff Frequency	fαb		----	7	----	Mc
Collector Capacitance	Cob	f=2 Mc	----	12	----	μμf
Extrinsic Base Resistance	rb"	f=2 Mc	----	55	----	ohms
Noise Figure	N.F.	V_{CE}=−6V f=1.5 Mc	----	6	----	DB
Power Gain	Gp	V_{CE}=−6V f=1.5 Mc	----	16	----	DB

Tentative Data

RAYTHEON MANUFACTURING COMPANY

RECEIVING TUBE AND SEMICONDUCTOR OPERATIONS

December 15, 1957 NEWTON 58, MASS. Page 1 of 5

Raytheon 2N414 PNP Fusion Alloy Junction Transistors

Raytheon was the original manufacturer of the 2N414 transistor and registered this type with the industry JEDEC organization in 1958, along with the complete 2N414 series (2N413, 414, 415, 416 and 417). Raytheon data sheets supporting these transistors were published in late 1957 as shown above. These high performance transistors had been developed by Raytheon under a U.S. Army Signal Corps contract and continued to be made available for the military for several decades into the 1970s.

TUNG-SOL PRODUCT BULLETIN

GERMANIUM TRANSISTOR TYPE 2N414

NOVEMBER 15, 1960

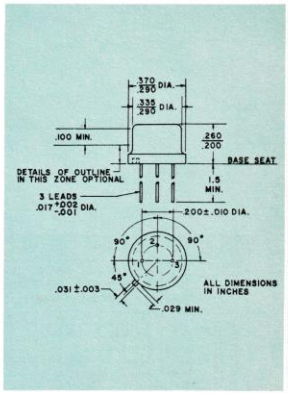
TYPE 2N414 is a PNP Alloy Junction Transistor designed and tested for use in high frequency amplifier applications up to 8 megacycles. As a result of rigid processing controls, reliability and stability of electrical characteristics is assured. The case features a welded hermetic seal and a standard basing design which facilitates automatic mounting with printed circuits.

MECHANICAL DATA

OUTLINE: JEDEC TO-5.

CASE: Metal, with glass to metal hermetic seal.

BASE: 0.017" flexible leads.
JEDEC E3-44.
1 — Emitter
2 — Base
3 — Collector



ABSOLUTE MAXIMUM RATINGS

Collector to Base Voltage (Emitter Open)	BV_{CBO}	−30 Volts
Emitter to Base Voltage (Collector Open)	BV_{EBO}	−20 Volts
Collector to Emitter Voltage (Base Open)	BV_{CEO}	−15 Volts
Collector to Emitter Voltage (V_{BE} = +0.1 Volt)	BV_{CEV}	−20 Volts
Collector Current	I_C	400 mA
Dissipation Coefficient (In Air) T_A = +25°C		0.4° C/mW
Dissipation Coefficient (In Sink) T_C = +25°C		0.18° C/mW
Junction Temperature (Operating or Storage)	T_J	−65° C to +100° C

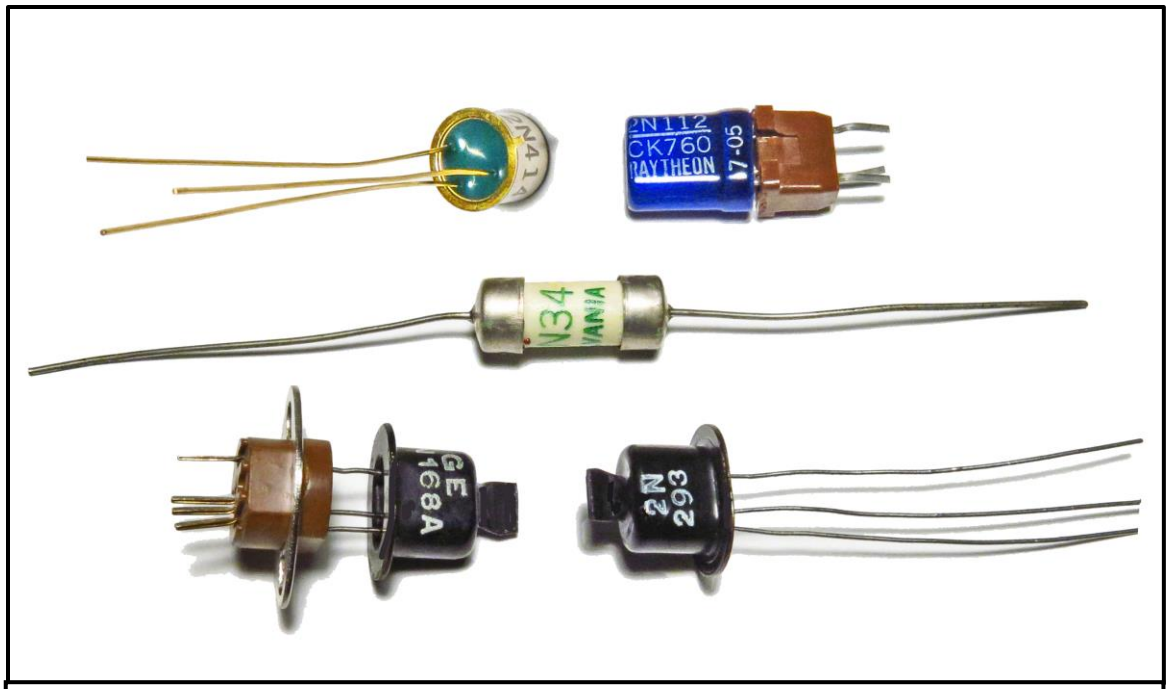
ELECTRICAL CHARACTERISTICS (25° C)

Test	Symbol	Conditions	Min.	Typ.	Max.	Unit
Collector Cut-off Current	I_{CBO}	(V_{CB} = −12 V)		2.0	5.0	μA
Emitter Cut-off Current	I_{EBO}	(V_{EB} = −12 V)		2.0	5.0	μA
Input Impedance	h_{ib}	(V_{CB} = −6 V, I_E = 1 mA, f = 1 Kc)		29		ohms
Forward Current Ratio	h_{fe}	(V_{CE} = −6 V, I_C = 1 mA, f = 1 Kc)	30	60	120	
Reverse Voltage Ratio	h_{rb}	(V_{CB} = −6 V, I_E = 1 mA, f = 1 Kc)		0.5		x10⁻³
Output Admittance	h_{ob}	(V_{CB} = −6 V, I_E = 1 mA, f = 1 Kc)		0.62		μmhos
Alpha Cutoff Frequency	$f_{\alpha b}$	(V_{CB} = −6 V, I_E = 1 mA,	3	7		Mc
Collector Capacity	C_{ob}	(V_{CB} = −6 V, I_E = 1 mA, f = 1 Mc)		12		μμF
Extrinsic Base Resistance	r_b'	(V_{CB} = −5 V, I_E = 1 mA, f = 2 Mc)		55		ohms
Noise Figure	NF	(V_{CE} = −6 V, I_C = 1 mA, f =1.5 Mc)		6		db

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

Tungsol 2N414 PNP Alloy Junction Transistors

Tungsol was a second-source supplier for Raytheon's Sig C 2N4XX transistor line. Shown above is a section of the 1960 Tung-Sol 2N414 transistor dada sheet, showing characteristics similar to Raytheon's 2N414. Tungsol continued germanium transistor production through the 1960s. For restoration and new builds of the Melodia, this Tungsol device should provide excellent and robust performance. Tungsol transistors could be easily identified by the unique robin's egg blue case color.



What's Included in this Classic Germanium Theremin Semiconductor Design Pack Preservation Collection

This Preservation Collection includes five historic mid-century semiconductors as shown above that are provided to support restoration and new builds of the original 1961 Moog PNP and NPN Melodia Theremins. The devices included are:

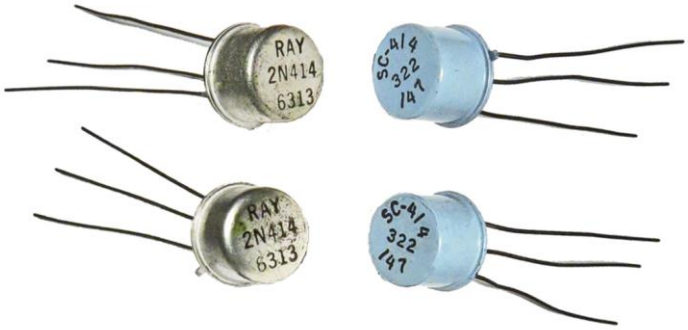
Top Row: General Instrument 1970s "Federal Grade" 2N414 PNP germanium transistor, and Raytheon 1950s CK760/2N112 PNP germanium transistor. The GI 2N414 is a high quality "Federal Grade" transistor supplied by GI to military and government agencies. The iridescent blue Raytheon CK760/2N112 was one of the first 1950s PNP types available for commercial transistor radio RF/IF use.

Middle Row: Sylvania 1940s/50s 1N34 germanium diode. Sylvania introduced the 1N34 first commercial germanium diode in 1946. These first production units are easily identifiable by the large white ceramic case and the Sylvania "green" markings. As shown above, the unit included in this Design Pack is one of these very early historic types – this device is 70+ years old!

Bottom Row: GE 1950s 2N168A NPN germanium transistor mounted in socket, and GE 1950s 2N293 NPN germanium transistor. For complete authenticity we have included one of the original GE 1950s 2N168A types referenced in the MOOG 1961 NPN DIY construction project. The 2N293 is a higher performing 1950s NPN type, equivalent to or slightly higher performing than the 2N1086.

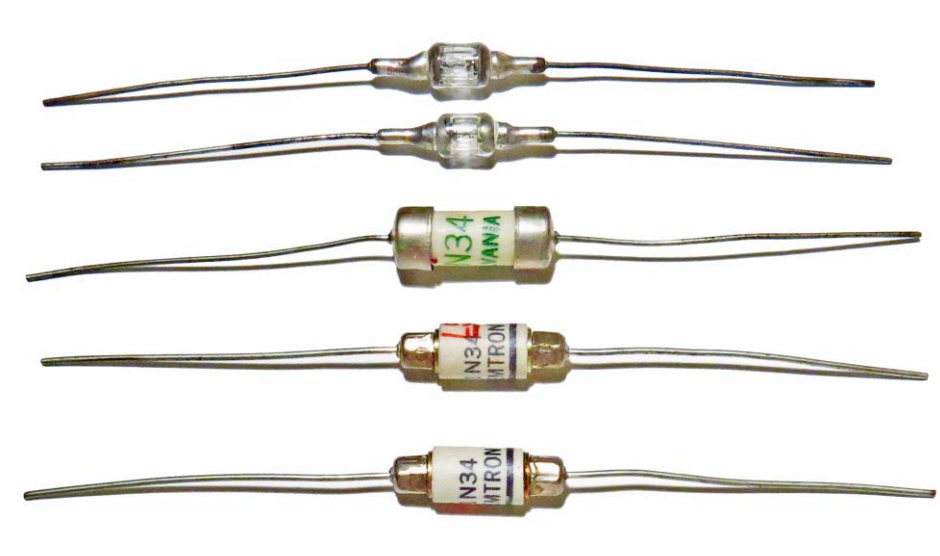
These selected and tested historic semiconductors have been provided in this Moog Germanium Theremin Design Pack to support those interested in experimenting with the early semiconductor types that may have been used by Robert Moog when he was designing and constructing his first transistor theremin.

Contents and Display Packaging for the GE 2N169A Germanium NPN Grown Junction Transistors Historic Preservation Collection



Contents and Display Packaging for the 2N414 Germanium PNP Fused and Alloy Junction Transistors Historic Preservation Collection

Contents and Display Packaging for the Design Pack Germanium PNP & NPN Theremin Transistors Historic Preservation Collection



Contents and Display Packaging for the 1N34 & 1N34A Germanium Point Contact Crystal Diodes Historic Preservation Collection

The Four Display and Storage Envelopes and Included Historic Semiconductors are Provided in a Protective Sleeve Mounted at the Back Cover of the Transistor Museum Preservation Collection Documentation Package

Concluding Remarks and Some Useful Links
"Robert Moog's Legacy and Contributions to Mid-Century Electronic Musical Instruments

1	The First Moog "Transistorized" Theremin Construction Project in Jan 1961 Electronics World. This was the formal introduction of Moog Theremin. Used GE NPN germanium grown junction transistors from the 2N168A/169/169A series of RF/IF devices.
2	The First Moog Melodia "Transistorized" Theremin sold commercially by the Moog Company. Based on the 1961 construction article, but used 2N414 PNP germanium alloy junction transistors. Many kits and assembled units were sold and introduced the amazing "Theremin" to a wider audience.
3	The Moog Archives and the Moog Foundation are both excellent resources for further exploration of Robert Moog's legacy, contributions, historical documentation and artifacts.
4	YouTube provides many instructive examples of original Melodia operation and music as well as professional classical Theremin performances. See also these Theremin Intros: Intro to Theremins (1) and Intro to Theremins (2).
5	Interesting Google Arts and Culture article on early Moog Theremins.
6	Very informative "Historical Timeline of Moog Catalogs", including the 1961 Melodia.
7	An incredibly well done modern day "Reproduction of the Moog Melodia" by Roger Hess. This is a very valuable view into craftmanship, technology and musicality. Amazing!
8	Here are some Transistor Museum writeups on early transistor technology including Raytheon, General Electric, Tungsol and Sylvania – all types used in the Melodia Theremin.