RCA

LB-898

PROGRESS REPORT ON TRANSISTOR RESEARCH AND CIRCUIT APPLICATIONS

RADIO CORPORATION OF AMERICA
RCA LABORATORIES DIVISION
INDUSTRY SERVICE LABORATORY

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Progress Report on Transistor Research and Circuit Applications

Approved

Stuart Wm. Seeley

FRONTISPIECE

Dr. E. W. Engstrom, Vice President in Charge of RCA Laboratories Division, examines the ten types of transistors employed in demonstration equipment at the transistor symposium. The four transistors in the front row are developmental types, a junction transistor, TA-153, at the left, the other three point-contact varieties, TA-165, TA-166 and TA-172. The middle and rear rows are made up of experimental junction transistor types. The larger transistors are for handling higher power in electronic circuits.

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Progress Report on Transistor Research and Circuit Applications

Introduction

RCA's tube and electronic equipment licensees were invited to visit the David Sarnoff Research Center of the RCA Laboratories Division at Princeton, N. J., to attend a Symposium constituting an engineering progress report on the status of transistor research. The program continued for a week, beginning November 18th, 1952.

The broad objective of the Symposium was to describe the experimental work which has been carried on, to show the state to which transistor research and circuit applications have advanced, and to indicate future possibilities in the use of transistors in electronics. Preliminary and experimental equipment was demonstrated which included transistors operating in radio and television receivers, miniature radio transmitters, audio amplifiers, and sections of electronic computers and musical devices. Many of the devices demonstrated partial or complete transistorizing of standard equipment while others were essentially new approaches to such equipment made possible by research and development based on the unique characteristics of the transistor.

Lectures and demonstrations were given describing the processes by which germanium is prepared and purified, and the technique used in growing germanium crystals. The doping, testing, and cutting of the crystals was discussed and illustrated. The making and testing of junction and point-contact transistors was also demonstrated. Detailed technical information on these subjects is contained in the twenty-four Industry Service Laboratory Bulletins already issued on this general subject. The numbers and titles of these bulletins may be found in the Appendix.

In the demonstrated apparatus, three types of point-contact transistor and seven types of junction transistors were used. Four of these types, the three point-contact type and one of the junction types, will be available in small sample quantities from the RCA Tube Department. In this bulletin these will be referred to by their developmental numbers, TA-165, TA-166, TA-172 or TA-153. The other six types are still in the experimental stage. Bulletins on them will be issued as soon as the information is sufficiently crystallized to permit a useful technical description.

It is the purpose of this bulletin to present a brief description of each apparatus embodying experimental applications of transistors shown at the Symposium. It should be remembered, however, that the items described are experimental applications and are not intended to exemplify commercial designs.

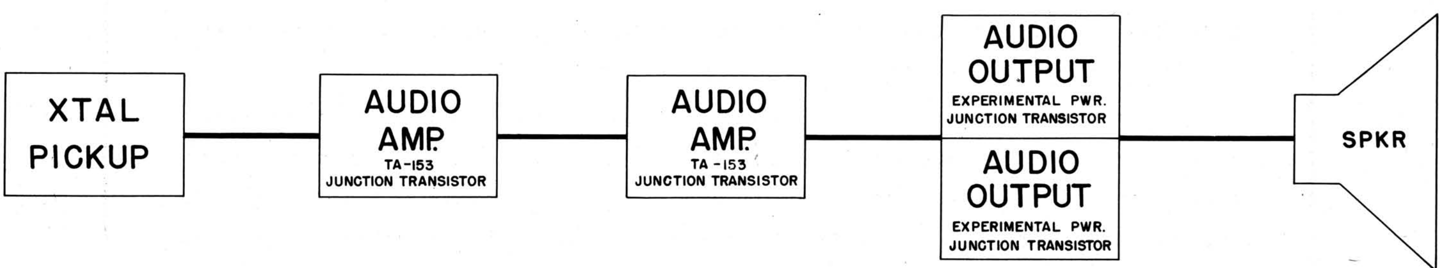
Experimental Audio Equipment Applications

In addition to such characteristics as small size and weight, low current drain, and instant starting, junction transistors appear to have attractive potentialities in audio amplifiers because efficient high-gain cascade stages can be designed using resistance coupling. Amplification of low level audio signals is possible because of the inherently low internal noise of junction transistors. Several audio apparatus applications are described below.

Portable Battery-Operated Transistor Phonograph

In one investigation of transistor utility in audio amplifiers, a light-weight, spring-motor-driven 45-rpm portable phonograph, shown in Fig. 1, was constructed. Two TA-153 junction transistors in the two-stage audio amplifier and two experimental power junction transistors in the power-output stage draw a current of 18 ma from the $22\frac{1}{2}$-volt battery which provides power for approximately 75 hours of operation. To help preserve battery life, an internal switch automatically disconnects the battery when the motor stops, which is permissible because of the instant starting characteristic of the transistors. Fig. 2 is a block diagram of the circuit used in this instrument.

Fig. 1 - Photo of portable battery-operated transistor phonograph.



Data:

TRANSISTORS — 4
POWER SUPPLY — 22.5 VOLTS
CURRENT — 18 MA
BATTERY LIFE — 75 HOURS
AUDIO OUT — 80 MW

Fig. 2 - Block diagram of portable battery-operated transistor phonograph.

AC-Operated Transistor Phonograph

This unit utilizes two TA-153 junction transistors and one experimental junction power transistor in a standard a-c operated 45-rpm record player. Unlike its tube counterpart, this experimental transistor-amplifier phonograph plays instantly when turned on. Power is derived from the a-c line by means of a selenium diode and a suitable RC filter. A block diagram of the circuit used in this player is given in Fig. 3.

Transformerless Audio System (Complementary Symmetry Principle)

This apparatus demonstrates a new amplifier principle termed the "complementary symmetry" system first made possible with transistors. Although shown for audio use, it is applicable to other amplifiers such as those for television deflection and the like.

P-n-p and n-p-n junction transistors conduct current in opposite directions, and the magnitude of the current flow is controlled in the opposite manner by the same impulse. Thus, if two of these units are connected in parallel, a single-ended input signal is given push-pull amplification to a single-ended output load without any direct current flowing through that load. Consequently, this type of push-pull transistor amplifier requires neither a phase inverter nor a push-pull input transformer. Perhaps of even greater significance, it provides a direct drive to the output load, be it a voice coil, a deflection yoke or the like, without an output transformer.

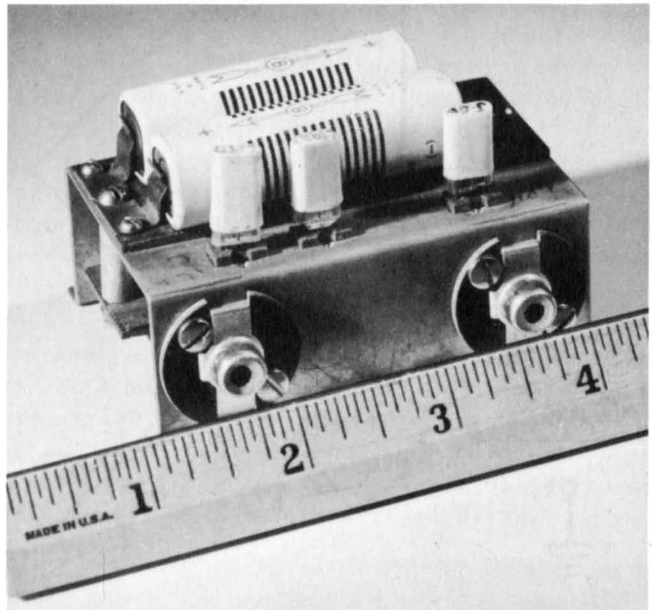
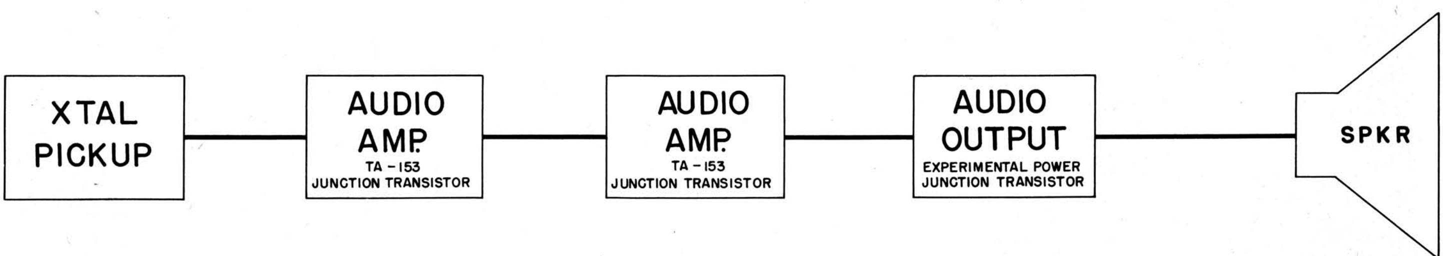


Fig. 4 – Junction transistor amplifier for complementary symmetry operation.

In one embodiment, Fig. 4, a TA-153 junction transistor was paralleled with an experimental n-p-n transistor and operated from a miniature 22½-volt battery directly into a 500-ohm speaker voice coil, to give about 150 milliwatts of audio output. A second arrangement consisted of two TA-153 and two n-p-n



Data:

TRANSISTORS — 3
POWER SUPPLY — A.C. LINE
AUDIO OUT — 165 MW

Fig. 3 – Block diagram of AC-operated transistor phonograph.

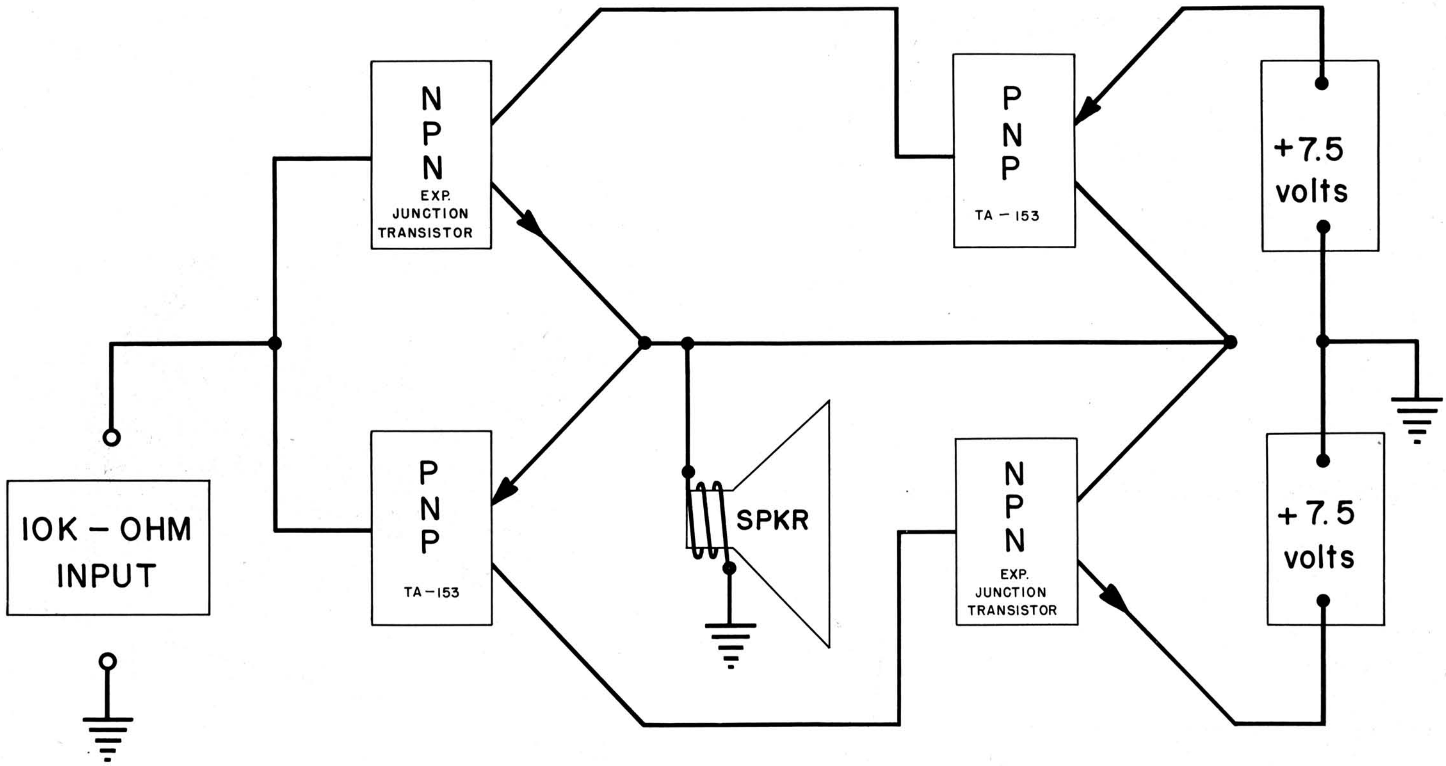
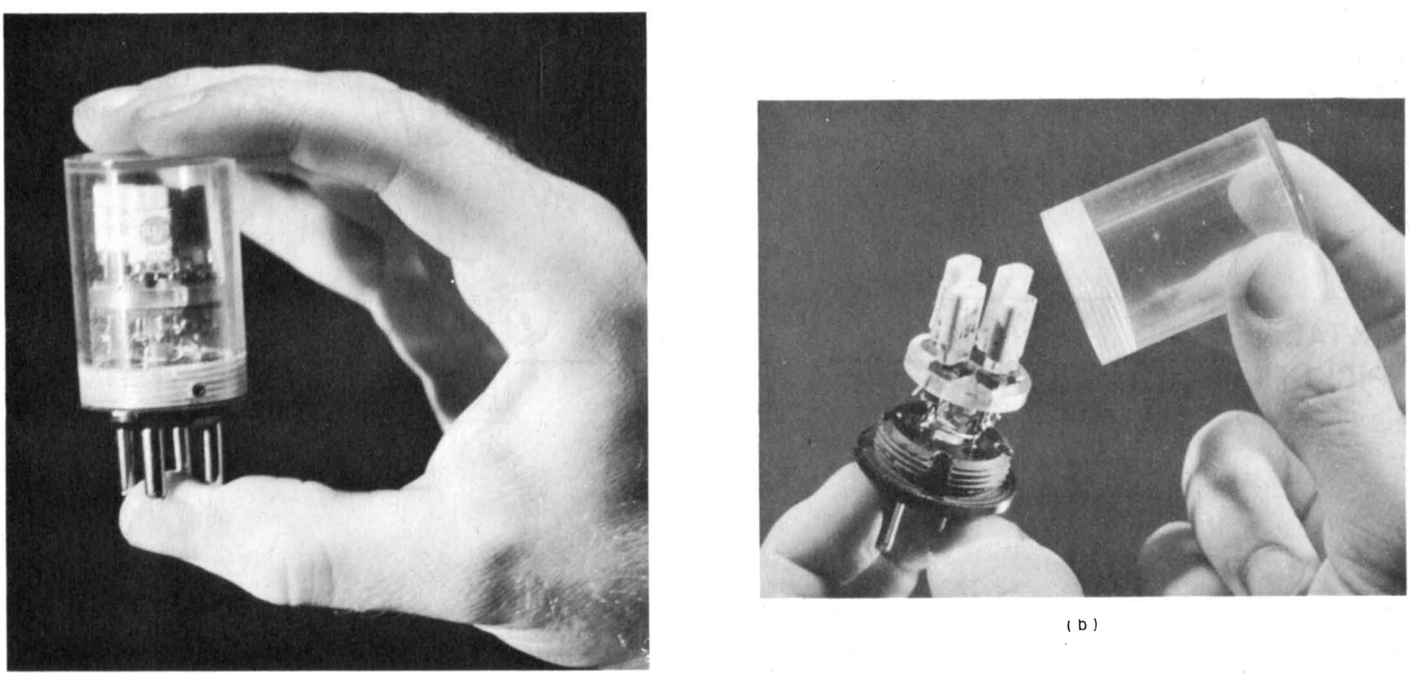


Fig. 5 - Circuit diagram of class-B transistor amplifier for complementary symmetry operation.



(a) (b)

Fig. 6 - Photographs of class-B transistor amplifier unit.

experimental transistors in a novel class-B inverse feedback circuit, shown in the circuit diagram of Fig. 5. Two photographs of this unit, housed in a compact lucite container, appear in Figs. 6a and 6b. It delivers about one-half watt directly into a 16-ohm voice coil and uses no transformers, no capacitors, no resistors and no components other than the four transistors, the battery for power, and the loudspeaker.

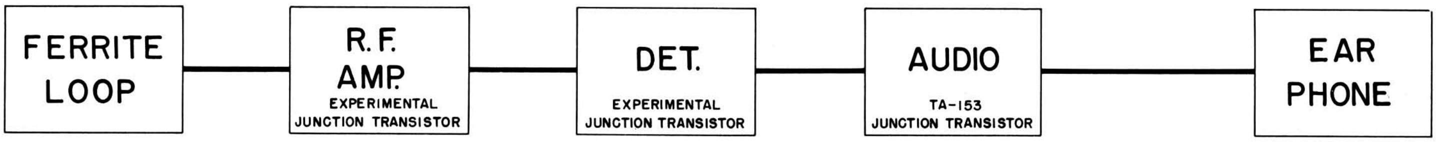
Personal Paging System

The experimental personal paging receiver, illustrated in Fig. 7, is housed in a plastic container. It feeds a hearing-aid earphone held in the ear of the listener, as in Fig. 8. As shown in Fig. 9, one TA-153 and two experimental junction transistors are used in the three-stage circuit made up of an r-f amplifier, a detector and an audio amplifier powered by a single 1.35-volt mercury cell whose life is about 500 hours. AGC is applied to the r-f stage. The receiver utilizes a ferrite antenna which works on the induction field of a 100-kc voice-modulated signal, picked up from a wire located near the ceiling of the demonstration room. In one demonstration, a single voice channel was used, with a wire recorder modulating a signal generator which fed a signal of approximately 1/10 watt to the overhead wire. To test the possibility of greater coverage, a larger loop, installed on the second floor of a three-story wing of the laboratory, was fed a 7-watt signal. Satisfactory reception of the signal was obtained on any floor of this wing. The steel of the building provides some shielding, with consequent reduction in field strength outside the building. Measurements showed that the outdoor field strength in this case was well below 15 microvolts per meter at a distance equal to the wave length divided by 2π.

Fig. 7 – Receiver unit of personal paging system.

Fig. 8 – Personal paging unit in use by listener.

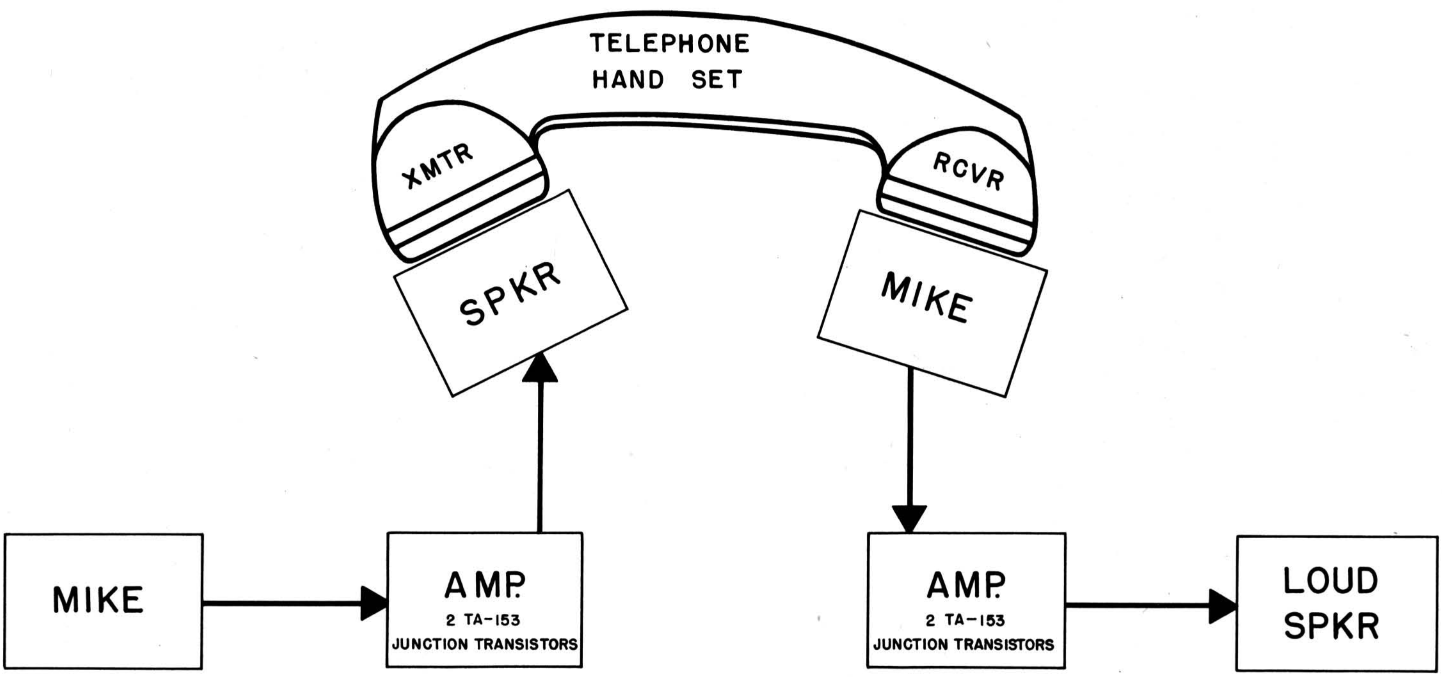
Although not demonstrated with this apparatus, several possibilities for selective calling might be used, such as frequency division or tone coding.



Data:

TRANSISTORS — 3
POWER SUPPLY — 1.35 VOLTS (MERCURY CELL)
BATTERY LIFE — 500 HRS
FREQUENCY — 100 KC INDUCTION FIELD

Fig. 9 - Block diagram of personal paging unit.



Data:

TRANSISTORS — 4
BATTERY — 22.5 V
CURRENT — 18 MA

Fig. 10 - Block diagram of conference telephone unit.

Conference Telephone

In this experimental telephone attachment or accessory, illustrated diagrammatically in Fig. 10, means are provided both for speaking to and listening to the telephone from a short distance. A microphone, amplifier and loudspeaker serve to pick up the user's voice and introduce it to the handset transmitter. Within the same unit another microphone, amplifier and loudspeaker pick up the opposite voice from the handset receiver and deliver it with sufficient loudness to be heard throughout the room. A photograph of the unit is given in Fig. 11.

Each amplifier is of the two-stage single-ended type and uses two TA-153 junction transistors. Two transformers are required to couple the output stages to the respective loudspeakers. At a 19-ma current drain the life of the $22\frac{1}{2}$-volt battery is approximately 75 hours. This corresponds to approximately 1500 3-minute phone calls.

Dynamic Transistor Microphone

In present-day mobile transmitting equipment the carbon-button microphone is used widely because of its high sensitivity. It has a number of disadvantages, however, including high noise and distortion levels and wide variations of output. Dynamic microphones have not usually been used in such applications because, even though they have none of the disadvantages of the carbon-button microphone, their sensitivity is too low without the introduction of an additional audio stage. This often introduces excess microphonism and extraneous noise.

By placing one TA-153 junction transistor in an experimental dynamic microphone it has been possible to achieve a unit which combines the advantages of both types. With this arrangement distortion is low, noise is considerably reduced, sensitivity is on a par with the carbon-button microphone and no transformer

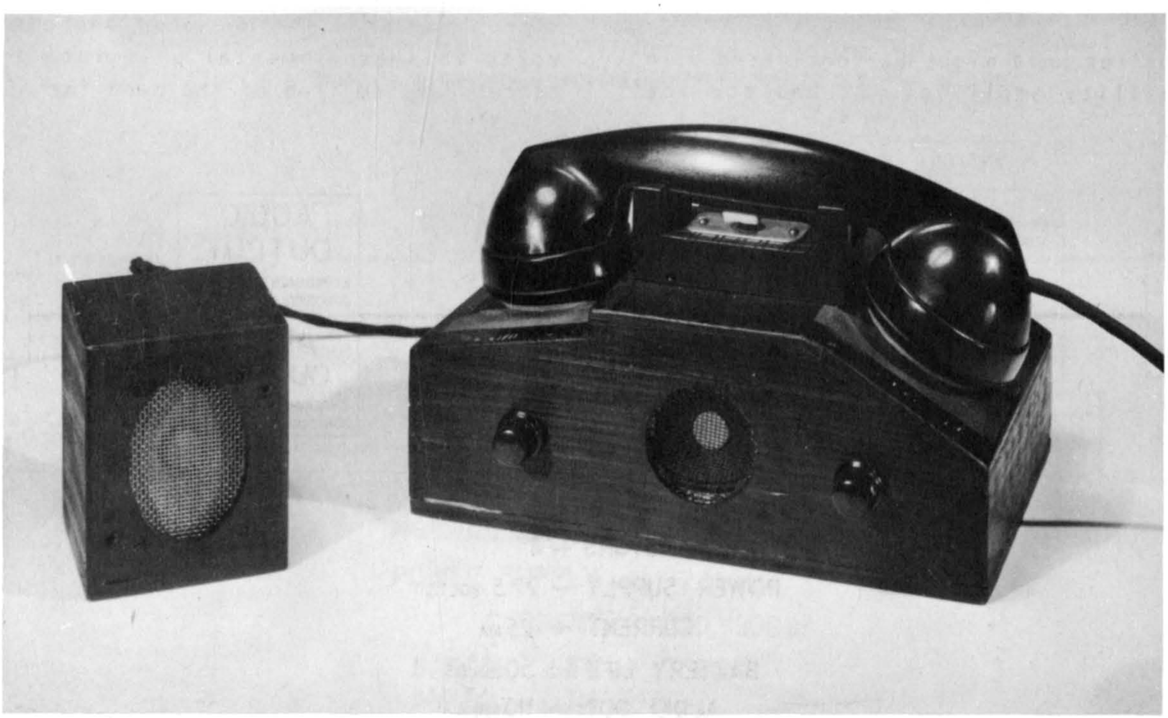
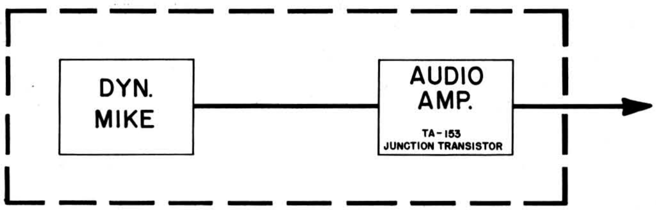


Fig. 11 - Photograph of conference telephone unit in use.



Data:

TRANSISTOR — 1
POWER SUPPLY — 180 VOLTS
CURRENT — 2 MA
AUDIO OUTPUT — 0.18 V / DYNE (APPROX.)

Fig. 12 - Block diagram of dynamic transistor microphone.

is necessary. The transistor is rugged and free from microphonic noise, and uses even less power than the carbon microphone. The junction transistor, four resistors and two capacitors used are enclosed within the microphone case. Fig. 12 is a block diagram of the instrument.

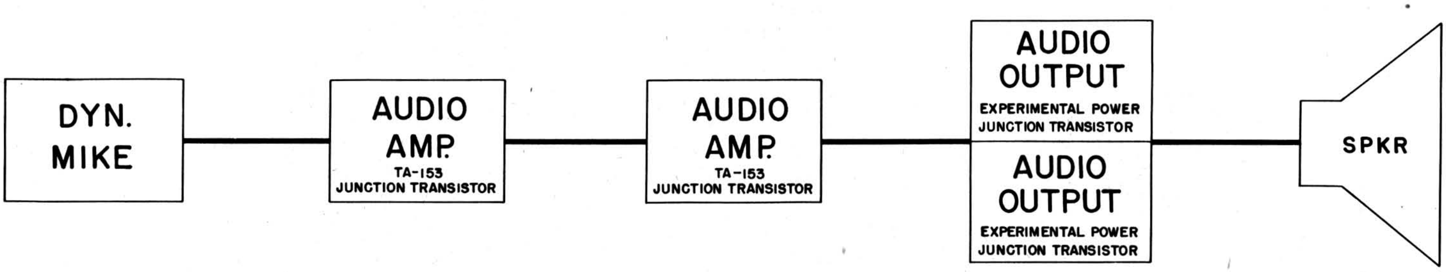
Small Battery-Operated Public Address System

In exploring the capabilities of transistors in audio amplifiers, two units of different size and power output were constructed for use as public address systems.

The smaller unit might be considered as a portable utility amplifier. It has the low battery drain characteristic common to transistor circuits. This amplifier, therefore, could serve well for an item such as stand-by service or intercom station. The addition of a microphone or a record player converts the amplifier into a portable public address system or record-reproducing system. Two TA-153 and two experimental power-type junction transistors which draw 25 ma from a $22\frac{1}{2}$-volt battery are used in the circuit shown in block form in Fig. 13.

Large Battery-Operated Public Address System

A larger battery-operated unit was built for installations requiring more audio output than that given by the small PA system. This experimental class-A amplifier delivers 1.25 watts to a self-contained 12-inch speaker and draws approximately 260 ma from a large $22\frac{1}{2}$-volt battery supply with an estimated battery life of 25-50 hours. Two TA-153 junction transistors, in cascade, and four experimental power junction-type transistors, in push-pull, parallel, are utilized in this circuit. These can be seen in the photograph of Fig. 14, and are indicated in the block diagram of Fig. 15. As with the smaller amplifier, the addition of a microphone or a spring-wound phonograph converts this experimental unit into a public-address system free of the need for a-c power.



Data:

TRANSISTORS — 4
POWER SUPPLY — 22.5 VOLTS
CURRENT — 25 MA
BATTERY LIFE — 50 HOURS
AUDIO OUT — 110 MW

Fig. 13 - Block diagram of utility amplifier.

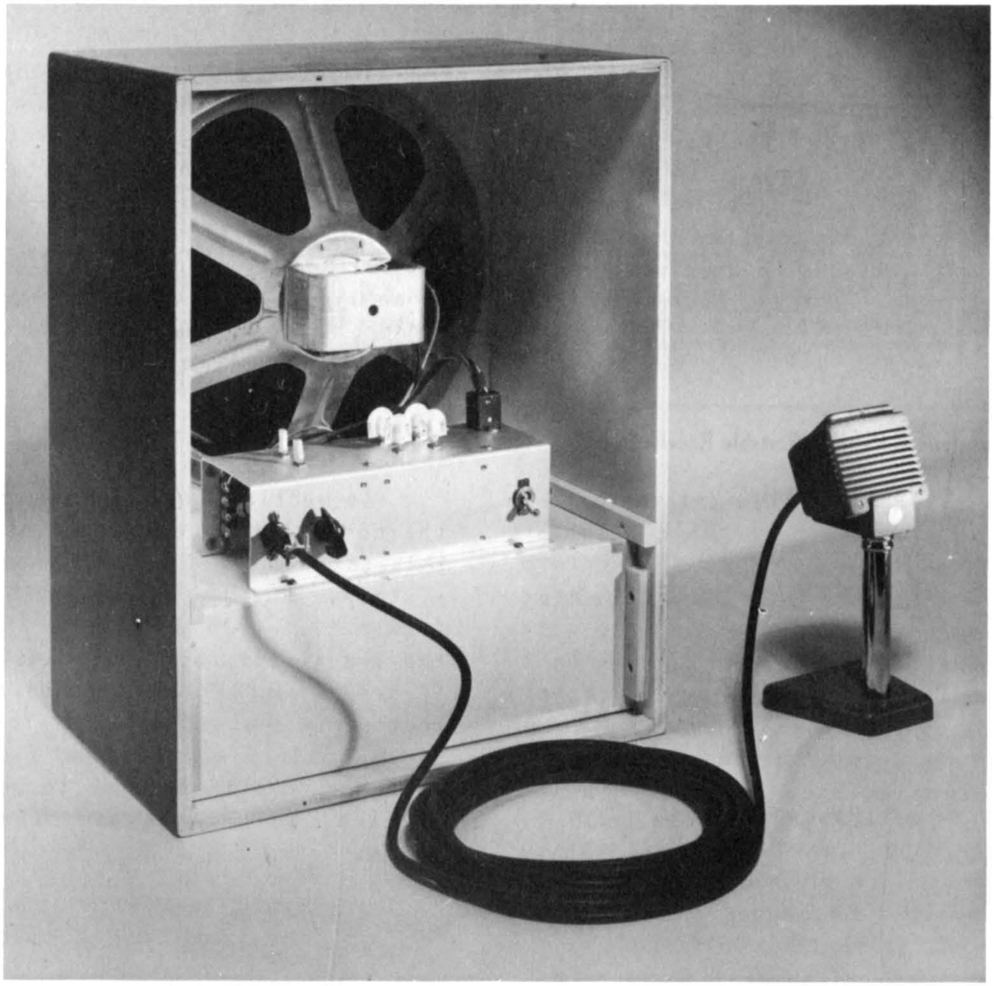
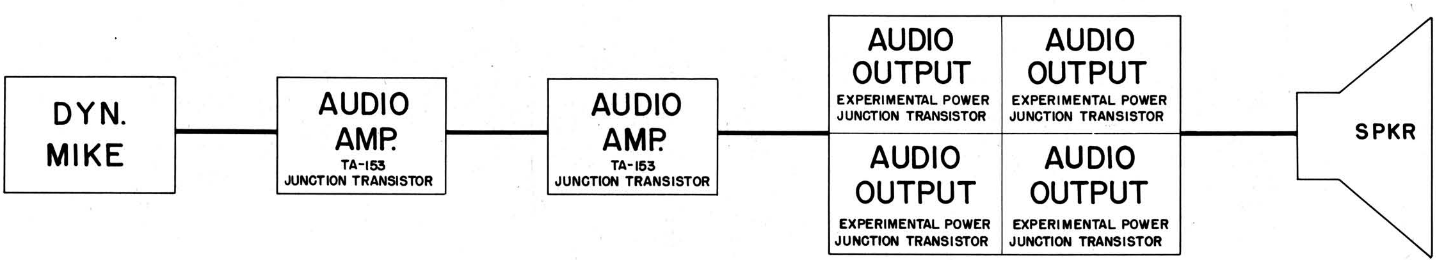


Fig. 14 - Photograph of large battery-operated public address system.



Data:

TRANSISTORS — 6
POWER SUPPLY — 22.5 VOLTS
CURRENT — 220 - 300 MA
BATTERY LIFE — 25 HOURS
AUDIO OUT — 1.25 WATTS

Fig. 15 - Block diagram of large public-address system.

Experimental Transistor Radio Receivers

Several approaches were taken in applying transistors to broadcast receiver circuits. In personal portable receivers the use of transistors appears attractive because of their small size, low-power drain, instant starting characteristics, and their ability to operate at low power-supply voltages. Four experimental broadcast receivers, all battery operated, were described.

Partly-Transistorized Personal Portable Receiver

In the construction of this set, a current production model 2B-400 RCA portable receiver was so modified that transistors now perform all functions except those of the converter stage. Both receivers appear in Fig. 16, with the partly-transistorized unit on the left side. This receiver contains one converter tube, one TA-153 and five experimental junction transistors, and one crystal diode. The original ferrite-cored loop antenna is used, and the mixer is unchanged except that its supply voltage has been reduced to 22½ volts. Three i-f stages are employed, coupled by single-tuned circuits giving the same number of tuned circuits as in the original receiver. These are followed by a detector and two audio stages, the last of which utilizes an experimental junction power transistor as the output stage. AGC voltage is supplied by a crystal diode and is applied to the converter tube in the usual manner. A block diagram of the circuit is given in Fig. 17. Performance is essentially the same as in the original all-tube counterpart as regards sensitivity, noise, audio output, and battery life.

As mentioned previously, the B voltage on the converter tube was reduced to 22½ volts; this same voltage is used to operate the transistors. Thus the B battery has been reduced from a 67.5-volt unit to a 22½-volt unit for the transistor receiver. Similarly, a smaller filament supply battery has been used. This represents a substantial difference in battery size, battery weight, and battery cost. The ratio is more than three to one. Battery life in each instance is nominally rated as 100 hours.

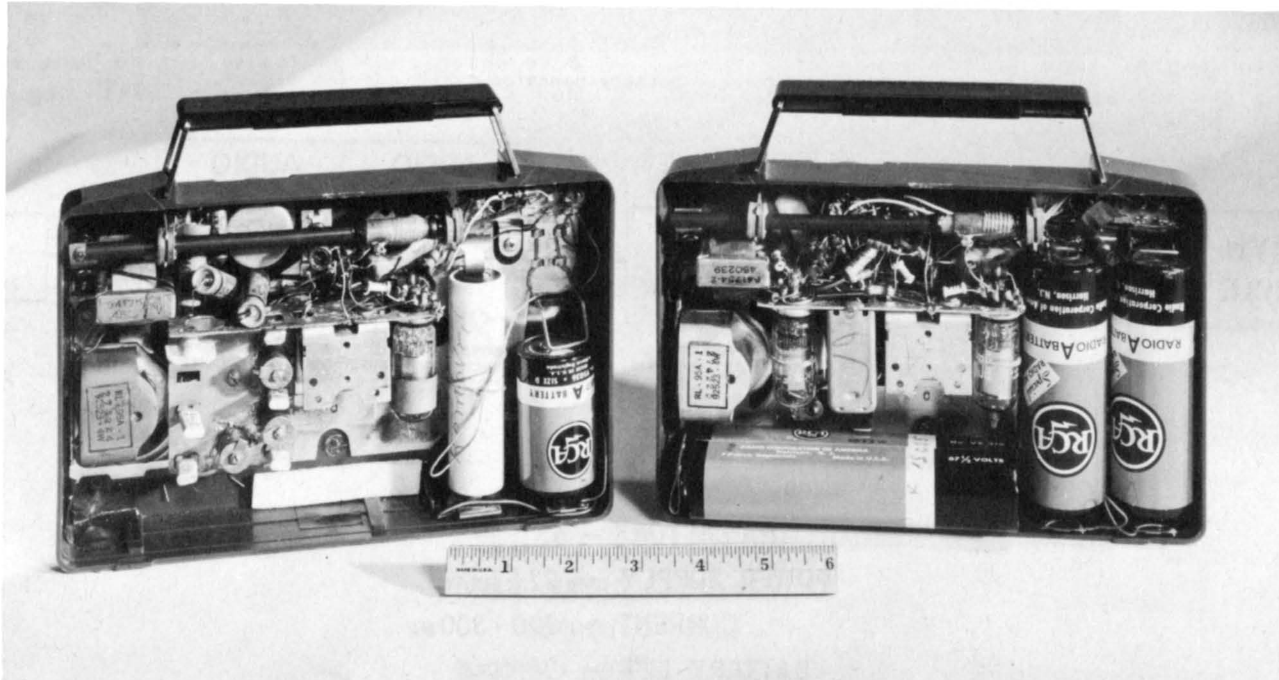


Fig. 16 - Photograph of all-tube and partly-transistorized portable receivers; original all-tube receiver on right, transistor-modified receiver on left.

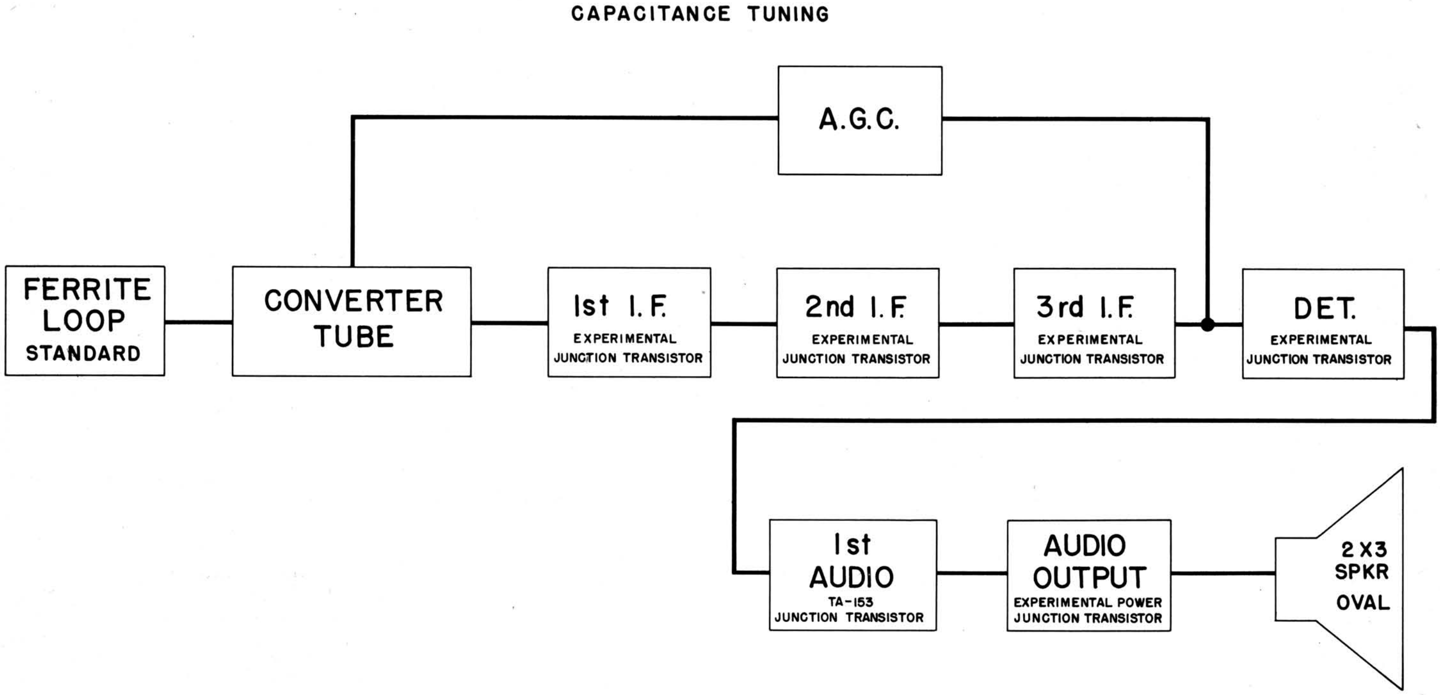


Fig. 17 - Block diagram of partly-transistorized portable receiver.

All-Transistor Personal Portable Receiver

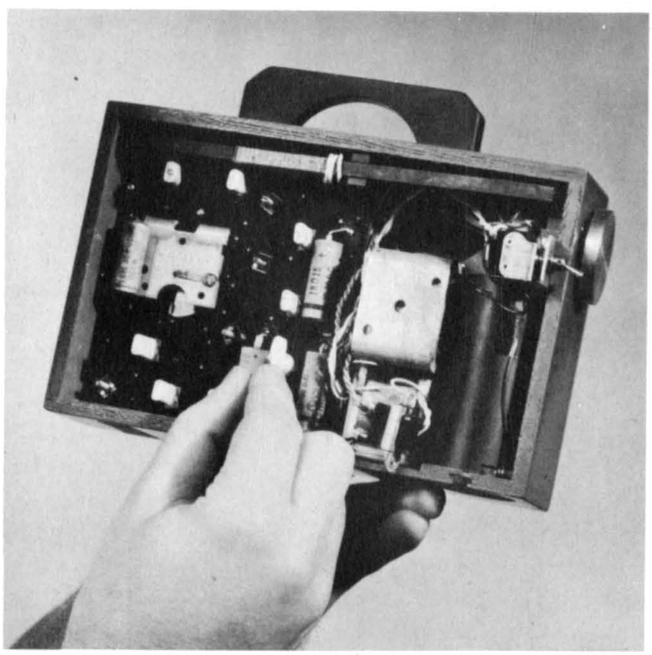


Fig. 18 - Backview photograph of all-transistor personal portable receiver.

Whereas the preceding receiver retained one tube, this experimental receiver is completely transistorized, as shown in Fig. 18. A somewhat larger antenna core was used to aid in maintaining sensitivity and minimizing noise. In other respects the receiver resembles the the preceding one, with the exception of an additional audio stage, again to help maintain sensitivity. Thus, as illustrated in the block diagram of Fig. 19, there are two TA-153 and seven experimental junction transistors, plus a crystal diode for generating a.g.c. which is applied to the first i-f stage to prevent overload on strong signals. Five small 1.35-volt Mallory mercury cells, giving an estimated battery life of 100 hours, are used for power. Fig. 20, a front view of the receiver, gives a comparison of the size of the mercury cells and transistors with the tubes and batteries whose functions they perform. In the present state of development the sensitivity of the all-transistor receiver is about four times less, and the noise about two times higher than the all-tube set. Battery size and weight are less than in the all-tube set. Although not evident in the photograph, the space saved by the smaller battery was used to incorporate a 4-inch speaker, which improves sound quality over the 2" x 3" elliptical speaker often used in personal portable sets.

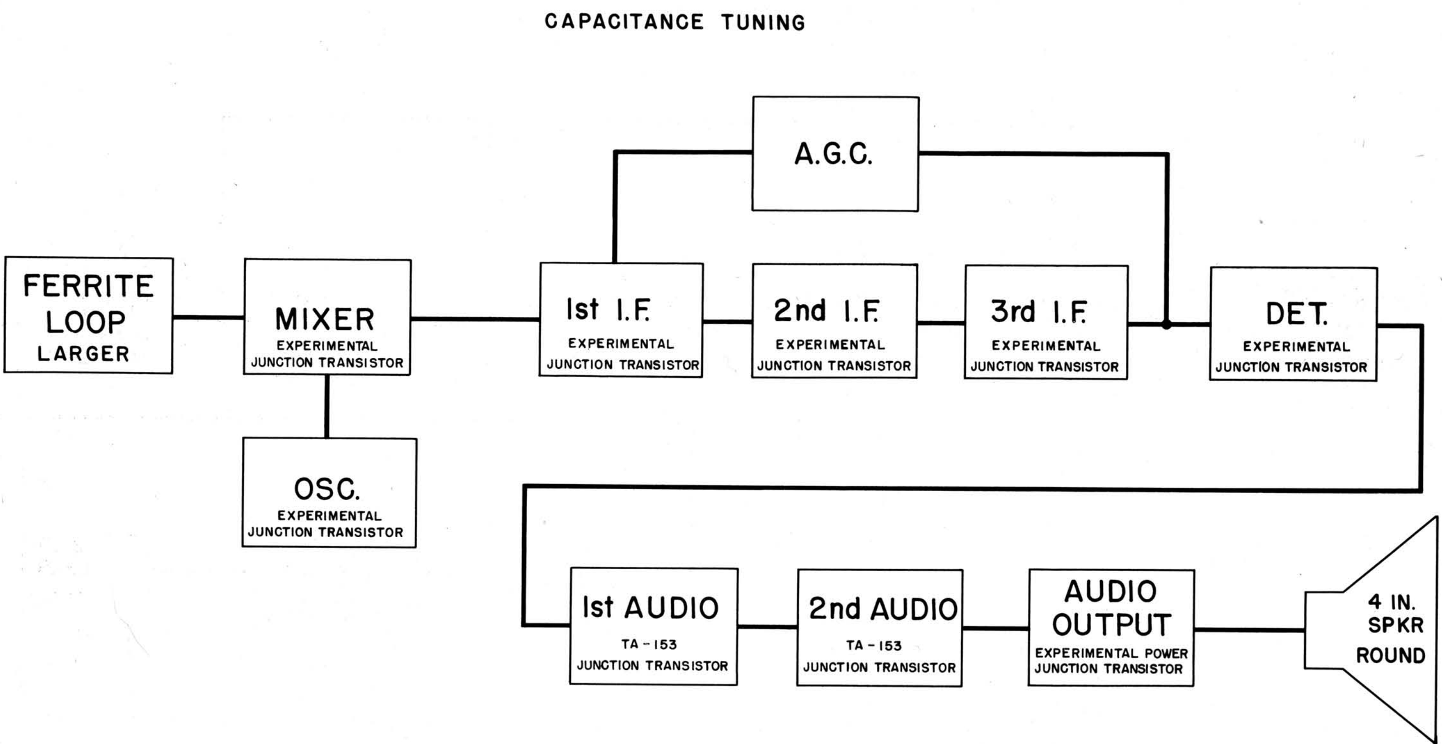


Fig. 19 - Block diagram of all-transistor personal portable receiver.

Fig. 20 - All-transistor portable receiver. Its batteries and transistors are compared with the tubes and batteries which would be required in an all-tube receiver of similar performance.

All-Transistor Automobile Radio

This experimental automobile receiver, depicted in Figs. 21 and 22, employs two TA-153 and nine experimental junction transistors in a circuit similar to that of the all-transistor portable just described except that the input circuit was changed from a condenser-tuned loop antenna to a permeability-tuned rod antenna. Consequently, the oscillator was also changed from condenser tuning to permeability tuning. At the output end a push-pull class B output stage using two experimental power junction transistors was added for greater power output. AGC voltage is applied to the first two i-f stages. Fig. 23 is a block diagram of the receiver.

Fig. 21 – Front view of all-transistor automobile radio.

An important feature is the elimination of the high-voltage power supply common to auto receivers with tubes. This power supply, comprising a vibrator, transformer, rectifier and filter, is not necessary in this transistor receiver since the transistors operate directly from the 6-volt automobile storage battery. Audio output of the receiver is one watt, and the current drain is 150 ma for zero signal condition. This rises to 450 ma at maximum audio output on a continuous tone. If two 150-ma dial lights are added, the total current drain is about 0.6 ampere as contrasted to six or eight amperes for the conventional commercial instrument.

When operating this particular kind of experimental output-stage power transistor from a supply voltage as low as six volts the maximum power output is not limited by dissipation but by the peak current which is over ½ ampere in each transistor. This means that these same transistors are capable of a little more than twice the power output, say 2½ watts, when operated from a 12-volt supply. This is mentioned because of the contemplated change to 12-volt electrical systems by several automobile manufacturers, and also because of the obvious applicability to commercial communication apparatus and to military equipments which frequently are designed to operate from 12 or 24-volt batteries.

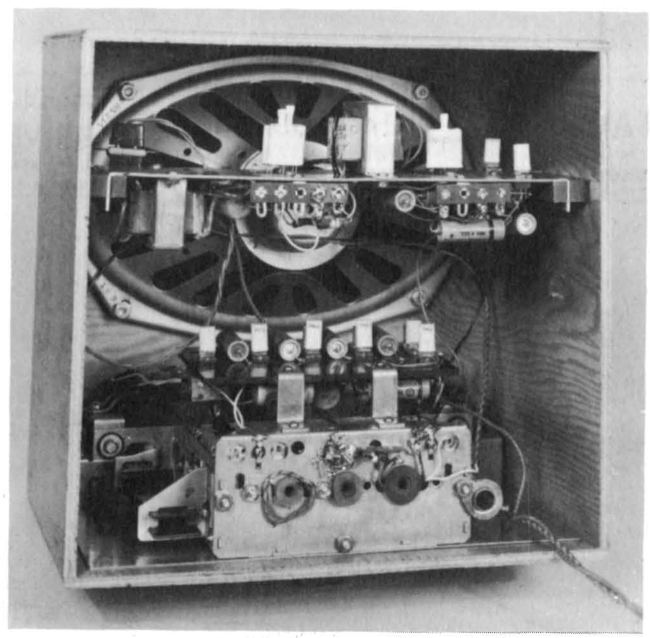


Fig. 22 – Rear view of all-transistor automobile radio showing transistors used in the circuit.

All-Transistor Portable FM Radio

In the interest of acquiring experience in the operation of transistors for v-h-f reception, an FM receiver was built to operate in the 88 to 108-Mc range.

This experimental tubeless portable FM receiver, shown in Figs. 24 and 25, has no r-f stage and uses a 5-Mc intermediate frequency. Eleven transistors and two pairs of crystal

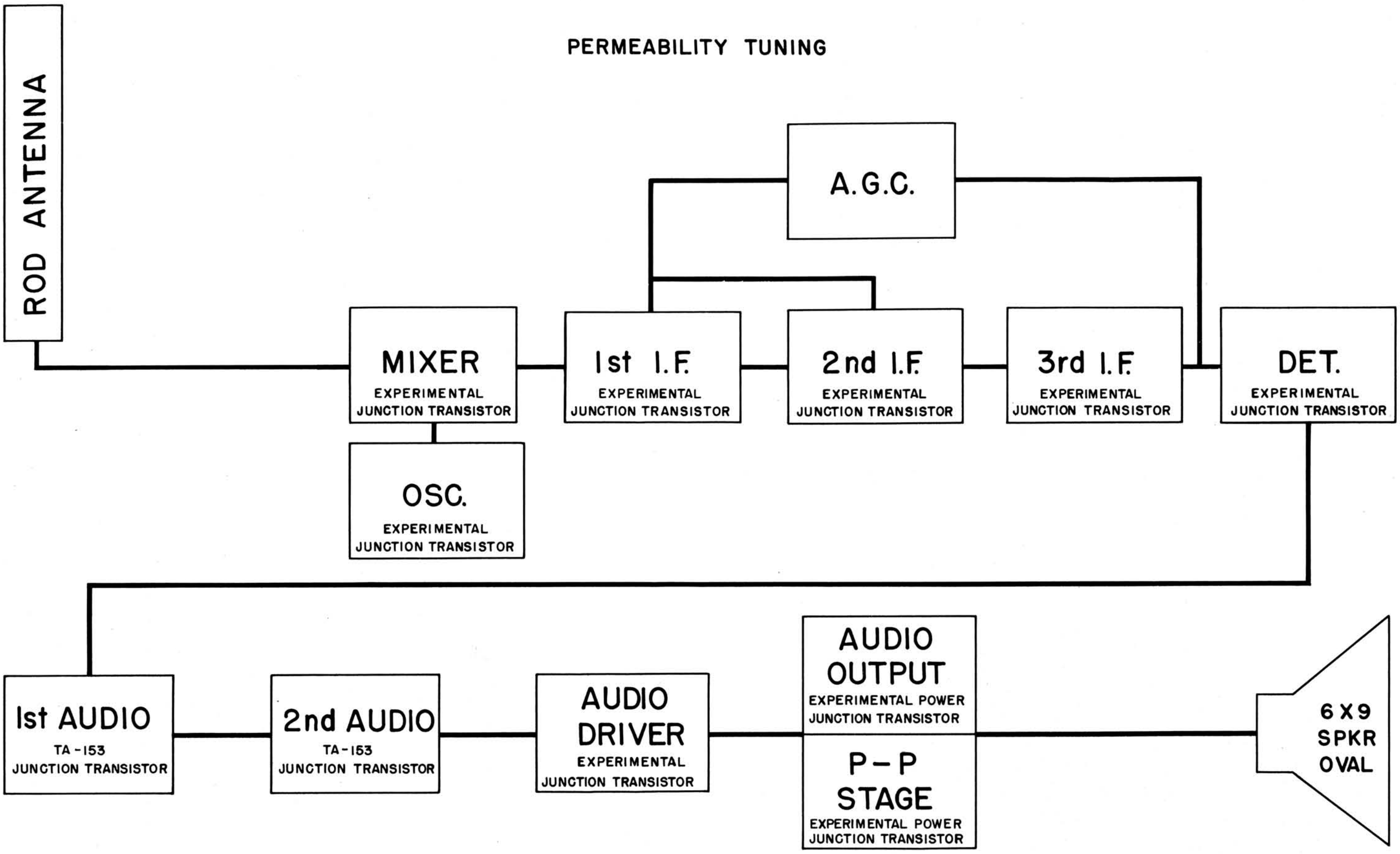


Fig. 23 - Block diagram of all-transistor automobile radio receiver.

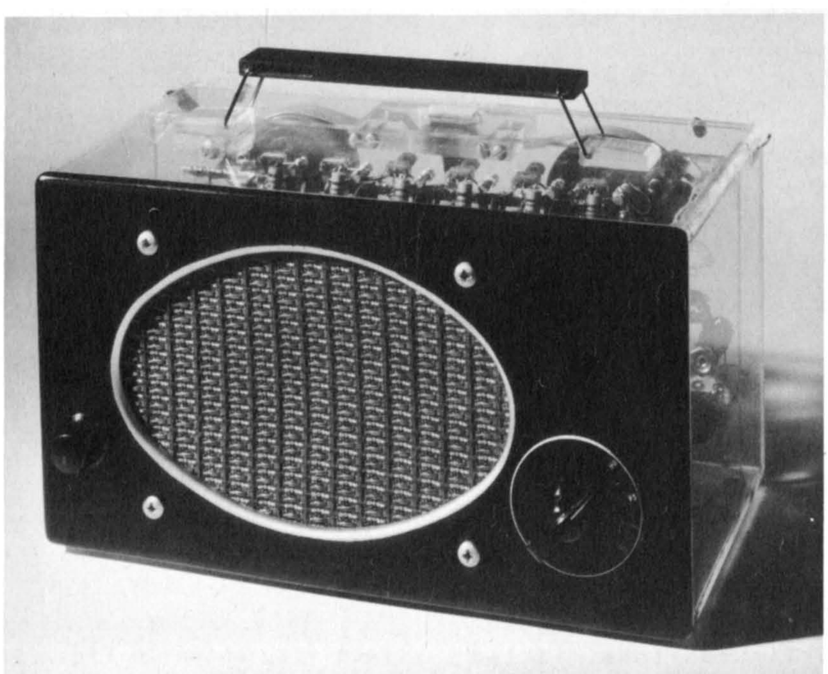


Fig. 24 - Front view of all-transistor FM portable receiver.

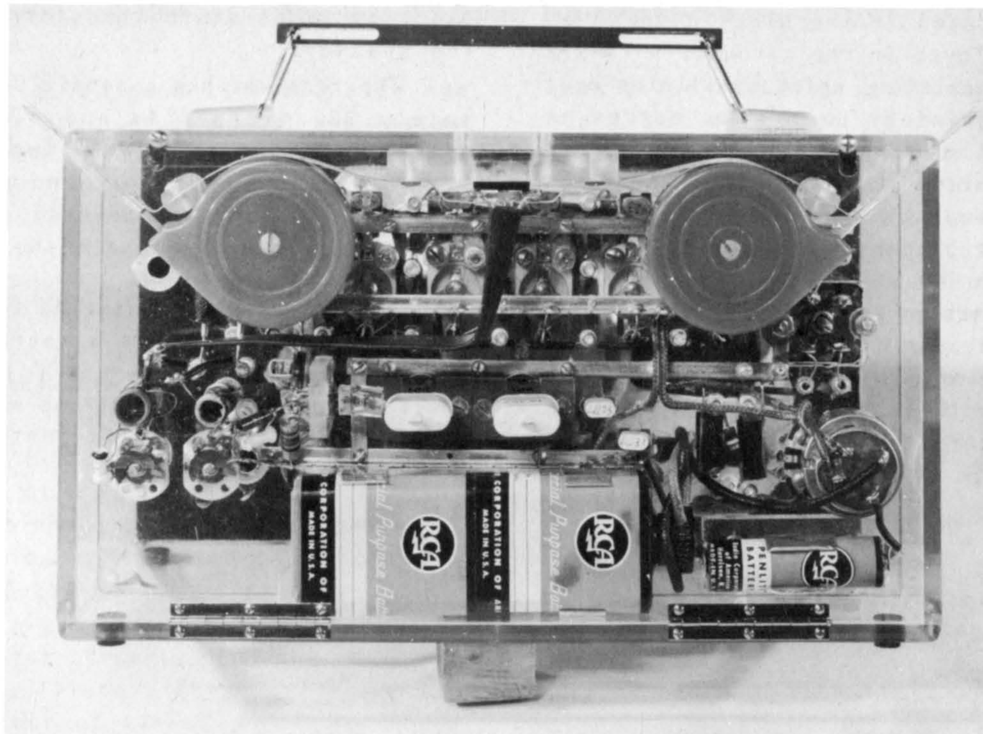
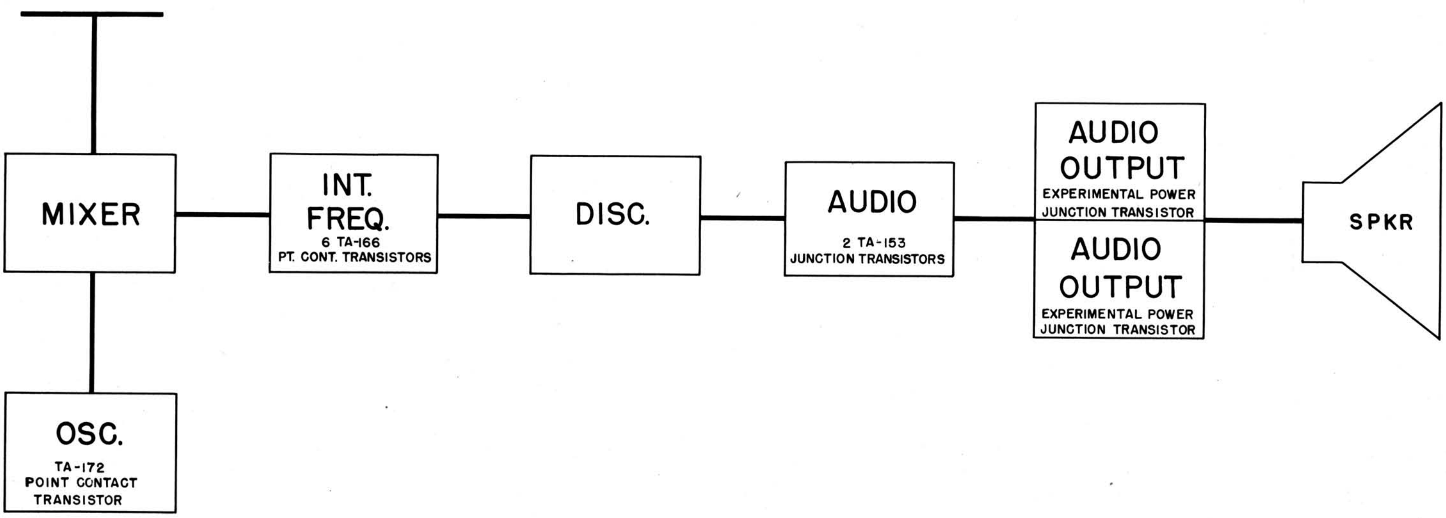


Fig. 25 - Rear view of all-transistor FM portable receiver showing retractible dipole antenna.



Data:

TRANSISTORS — 11
POWER SUPPLY — 22.5 V & 1.5 V
BATTERY DRAIN — 1 WATT
AUDIO OUT — 100 MW
FREQUENCY — 88 — 108 M.C.

Fig. 26 - Block diagram of all-transistor FM portable receiver.

diodes, as indicated in the block diagram of Fig. 26, are employed in the circuit. A TA-172 point-contact transistor, which oscillates over a frequency range of 83 to 103 Mc, serves as the local oscillator. One pair of crystal diodes act as a mixer stage generating the 5-Mc intermediate frequency which is amplified by six grounded-base stages of TA-166 point-contact transistors. Each i-f stage has a gain of about 11 db. Limiting action takes place in the final stages. A second pair of crystal diodes serve as a discriminator. In the audio system two TA-153 junction transistors comprise two grounded collector stages driving a push-pull output power stage using two experimental power junction transistors transformer-coupled to the speaker.

The receiver has a sensitivity of approximately 300 microvolts and a maximum audio output of 100 milliwatts. Two batteries, a $22\frac{1}{2}$-volt hearing-aid unit and a $1\frac{1}{2}$-volt penlight cell, provide a power of slightly over one watt, and will operate the receiver from 2 to 3 hours.

A pair of steel measuring tapes built into the cabinet are used as a retractible dipole antenna. Provision is made for attaching an external antenna for locations where the signal field strength is insufficient for the self-contained dipole.

Experimental Transistor Television Circuits

Characteristics such as small size and weight, low power drain, ruggedness, and instant operation of transistors appear attractive for many television applications. The following descriptions take up in turn four different projects relating to experimental television circuits.

Television Receiver Transistor Applications

Developmental transistors were tried in those circuits of a commercial 17-inch television receiver where transistors appeared to be most adaptable. As indicated in the chart of Fig. 27, two TA-153 junction transistors were applied to the a-g-c circuits, two TA-153's in the sync separator circuits, and one TA-153 in the vertical oscillator. These performed the functions of four of the original 22 tubes, three of which were dual tubes, thus replacing seven tube functions. Although not done in this instance, the audio stage could also have been designed for transistors.

The receiver operates superficially like its all-tube counterpart. However, it has not been given rigorous performance tests needed quantitatively to evaluate possible shortcomings. For example, it was noticed that the transistor vertical oscillator shows a warm-up effect during the first to minutes of operation, which has not been fully investigated. On the other hand, it appears that a substantial reduction in the total number of resistors, capacitors and other components in such a receiver may result from partially transistorized television circuits.

Portable Battery-Operated Transistor Television Receiver

This item represents a pioneering attempt to build a television receiver in which transistors were applied to perform all of the functions performed by vacuum tubes, other than the kinescope. It was realized that certain compromises would be necessary in applying transistors to all of the circuits since there were many problems to meet and overcome. In the course of the work on this experimental project, certain radically new circuits had to be developed.

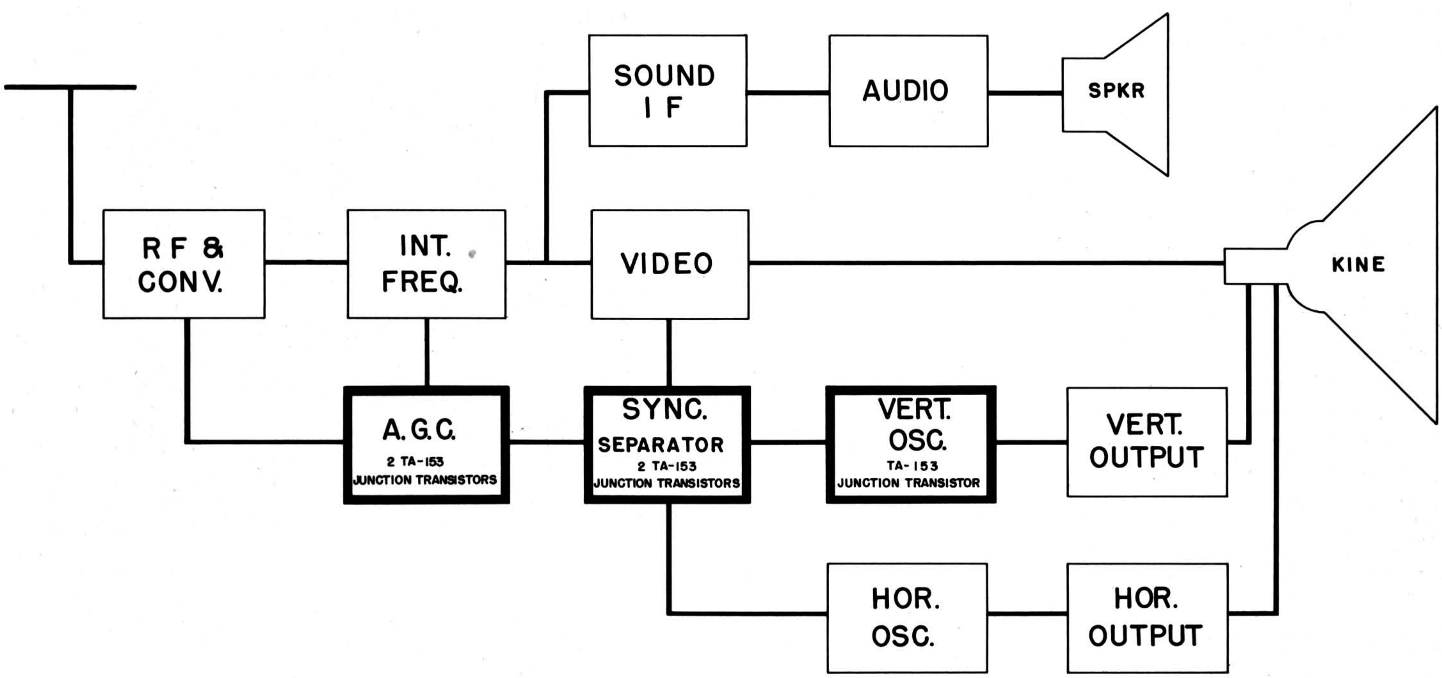


Fig. 27 - Block diagram of partial transistorization of conventional television circuit.

The preliminary result is a single-channel receiver with a 5-inch picture tube housed in a 7" x 12" x 13" cabinet, three views of which are shown in Figs. 28 and 29. It is a battery-operated portable unit containing 36 transistors of ten different types, five crystal diodes and no tubes except for the 5-FP4 type kinescope. The kinescope operates on 2000-volt second-anode voltage and provides a 3 x 4 inch picture with a brightness of 10 foot-lamberts. It has magnetic focus and deflection.

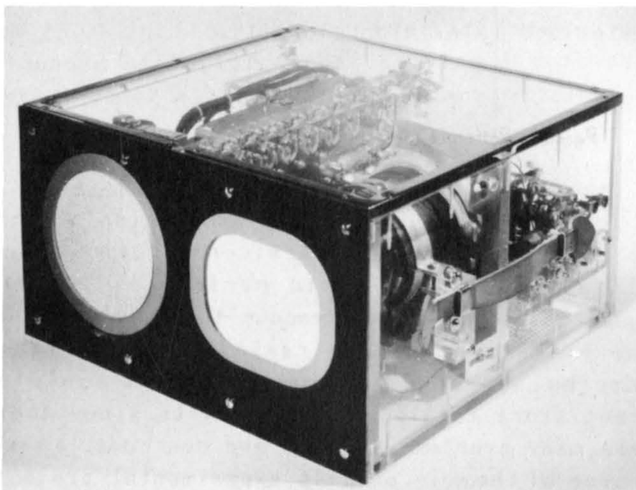
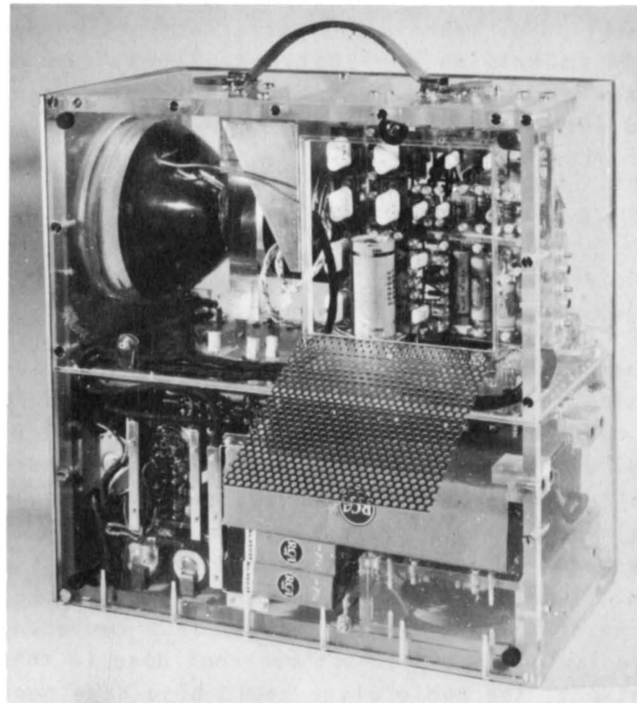


Fig. 28 - All-transistor battery-operated portable television receiver.

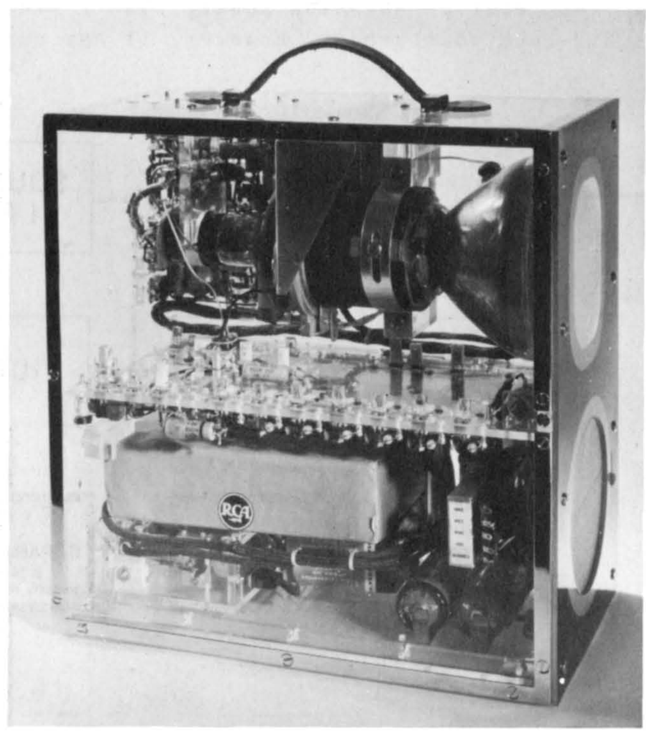
A block diagram of the circuit is given in Fig. 30, on which are indicated the types and quantities of transistors used for the various functions in the receiver. Intercarrier sound and a ratio detector are used. Both the audio amplifier and the vertical deflection circuits employ the complementary symmetry principle discussed earlier in this bulletin. The intermediate frequency is approximately 8 Mc, and the video bandwidth is 2 Mc. In the process of building the receiver some simplified deflection and a-f-c circuits were developed.

Of the 13 watts of power consumed by the receiver, 3.6 watts, or 25 per cent, are used to heat the filament of the kinescope. High voltage for the kinescope is obtained with a pulse amplifier using a special experimental junction transistor and a small 2500-volt selenium rectifier.

While the receiver has relatively low sensitivity it produced a fairly satisfactory picture when operated from its self-contained loop antenna five miles from the WNBT transmitter on the Empire State Building. With a small "rabbit-ear" antenna a similar picture was obtained 15 miles from the transmitter.



(a)



(b)

Fig. 29 - Two views of the all-transistor television receiver chassis as seen through the lucite cabinet.

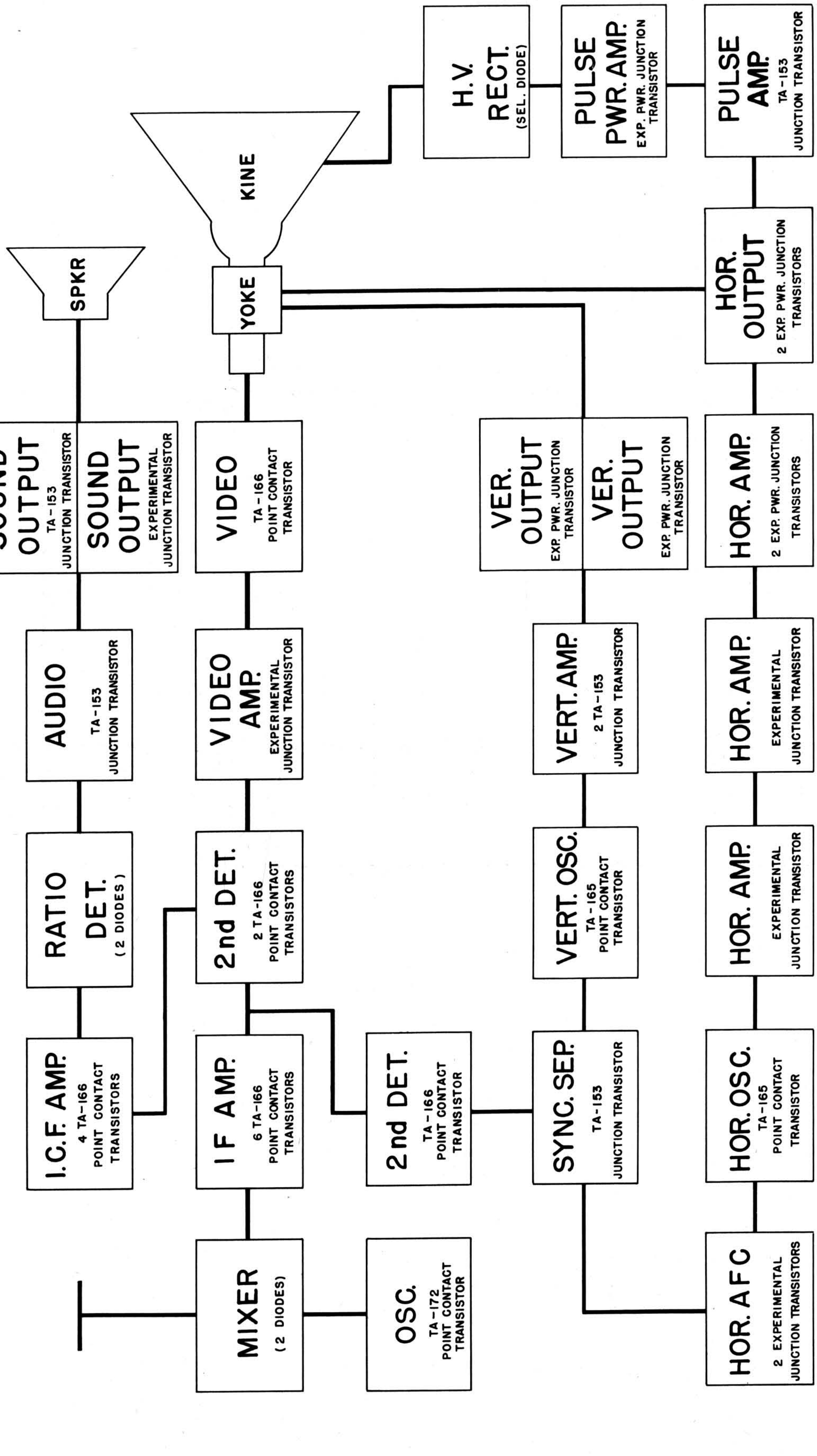


Fig. 30 – A block diagram of all-transistor television receiver.

Transistor Applications in RCA Industrial Television Equipment

LB-851, *An Industrial Television System,* released late in 1951, described a camera and monitor closed-circuit portable television equipment useful for many types of industrial and instructional application. Subsequently a program was initiated to investigate the possibilities of using transistors in some of the circuits in order to reduce its weight, size, power consumption and circuit complexity.

A typical pulse circuit used in industrial television equipment is a synchronizing generator to provide the necessary frequencies and driving pulses to present a standard 525-line 30-field interlaced picture as shown in block form in Fig. 31. This is accomplished by providing a 2H frequency of 31,500 by a blocking oscillator, and by utilizing three additional blocking oscillators as counters to obtain the field frequency of 60 cycles. Three and one-half double triodes are required in this circuit.

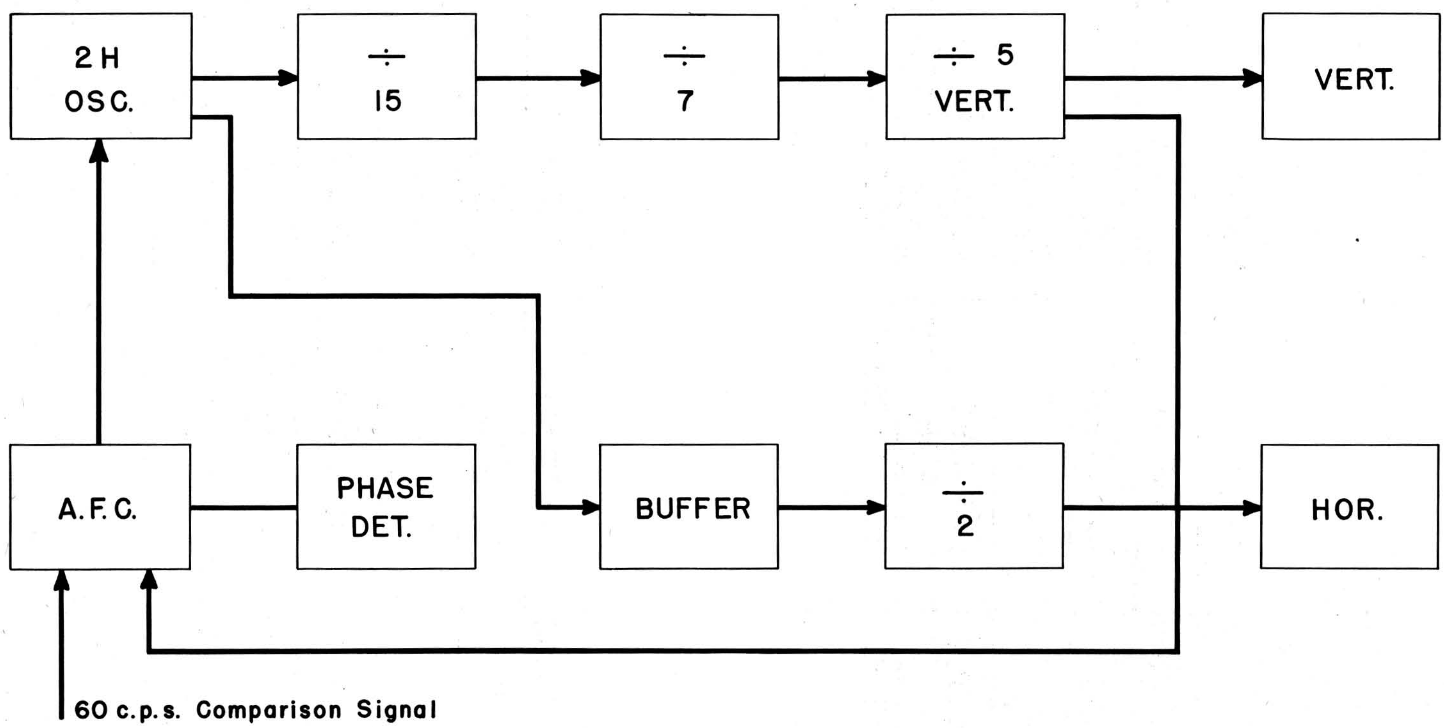


Fig. 31 – Block diagram of synchronizing generator in industrial television equipment.

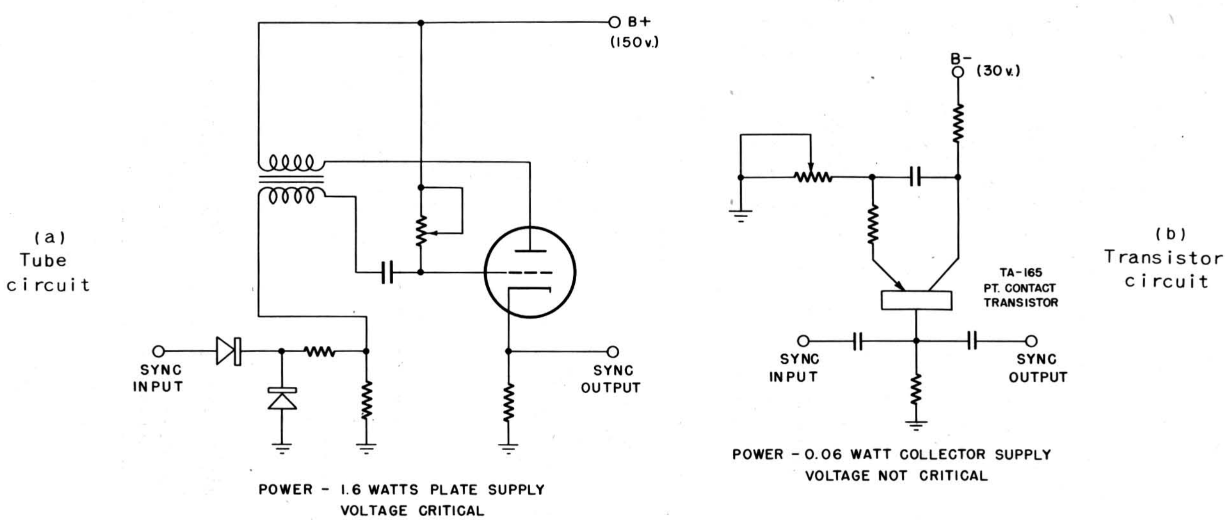


Fig. 32 – Typical blocking oscillator or divider stage.

An experimental sync generator utilizing transistors to accomplish the same result was designed, one unit of which is shown schematically in Fig. 32b along with its tube counterpart, Fig. 32a. By providing a capacity feedback as illustrated, a relaxation oscillator which can be triggered is obtained. Circuits of this type are used in the transistor sync generator as counters. A comparison of power consumption and components required appears on the diagram. A transistor oscillator provides the 2H frequency while four transistor counters provide the count down. An a-f-c circuit locks the generator to the 60-cycle power line. Seven TA-165 point-contact transistors and one TA-153 junction transistor were used. In Fig. 33 the entire transistor generator can be seen and compared in size with its tube counterpart.

Fig. 33 - Industrial television transistor sync generator chassis compared with its all-tube counterpart.

While the transistor counters will operate over a 2 to 1 change in voltage, the oscillator is more critical. A temperature change of 10 degrees Centigrade sometimes requires a re-adjustment of the circuits in this particular application.

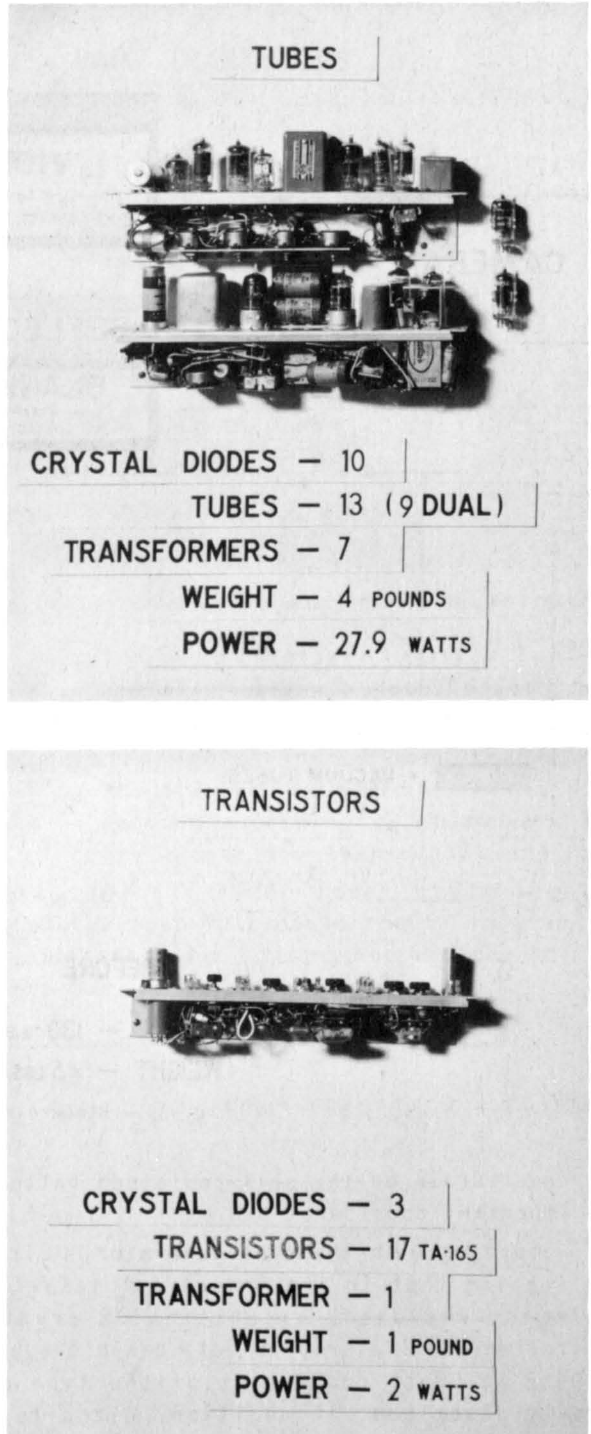


Fig. 34 - "Walkie-Lookie" sync circuits comparing the transistor chassis with the all-tube chassis.

Transistor Applications in RCA "Walkie-Lookie"

This battery-operated portable television pickup unit, commonly referred to as the "Walkie-Lookie", used by NBC for pickups from the floor at the Chicago political conventions earlier this year, was investigated for possible transistor application in many of its circuits. Since the present back-pack unit weighs 50 pounds, reduction of overall weight and size,

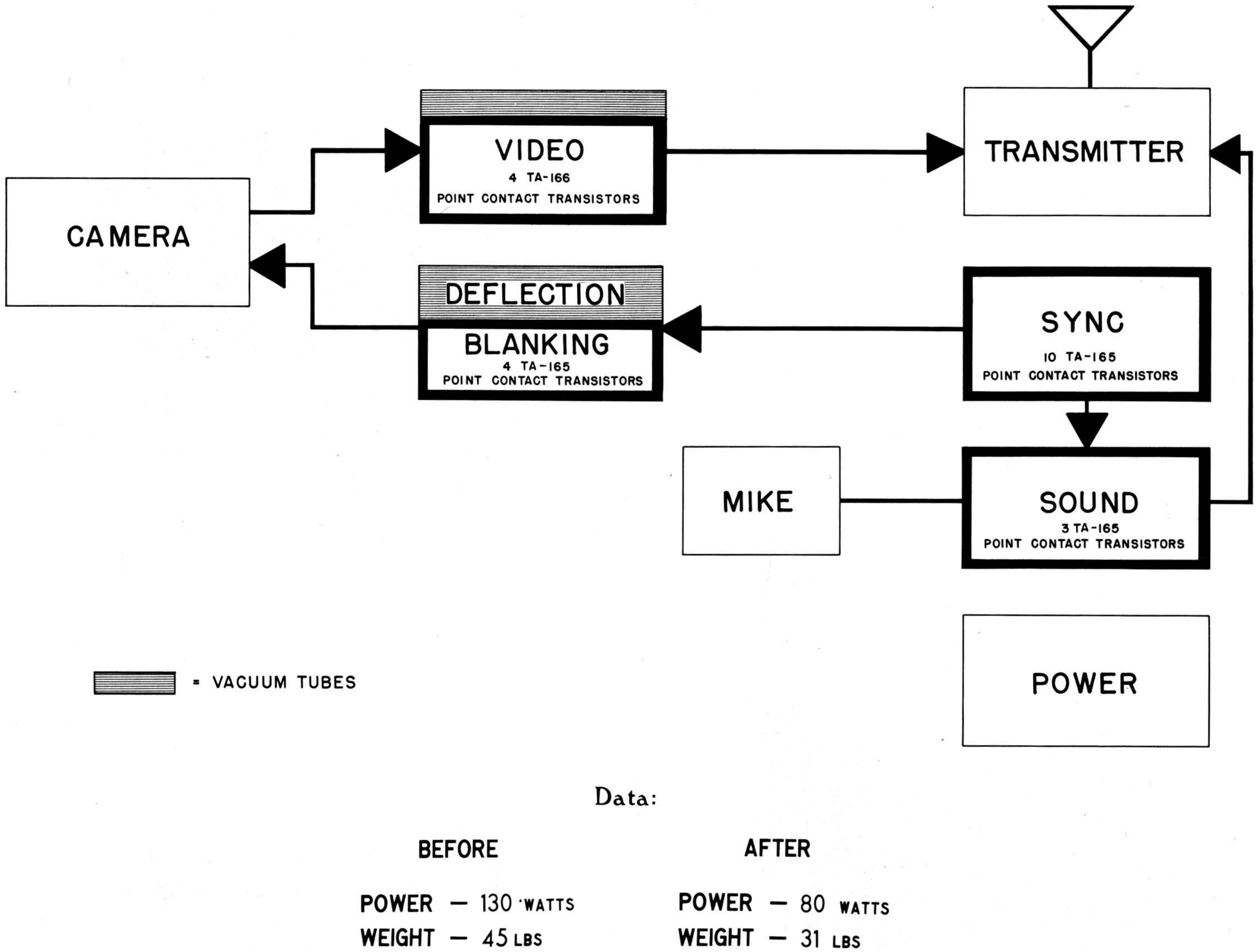


Fig. 35 – Block diagram of "Walkie-Lookie" equipment.

and power drain on the self-contained batteries are important considerations.

Starting with the sync generator, a circuit duplicating that in the industrial television equipment was used, except that a crystal-controlled oscillator provides a basic frequency of 93.5 kc. Each counter is of the type previously described. In addition, circuits for generating and mixing horizontal and vertical blanking pulses, and for generating clamping pulses of both polarities were developed using transistors.

Sound in the Walkie-Lookie is transmitted on the video carrier by modulating the position of the trailing edge of the horizontal sync pulse, the audio information at the receiving end being recovered by integration after sync separation. Circuits for generating the horizontal sync pulse and modulating its width also employ transistors. The complete transistorized chassis performing these functions is shown in Fig. 34, along with the corresponding tube chassis. Seventeen TA-165 point-contact transistors are indicated both in this figure and in the block diagram of Fig. 35. A saving of three pounds in weight and nearly 26 watts in power is noted.

A further development in this equipment involves the use of transistors in the main video amplifier. Four stages of video amplification including the high peaking stage necessary for compensation for input capacity

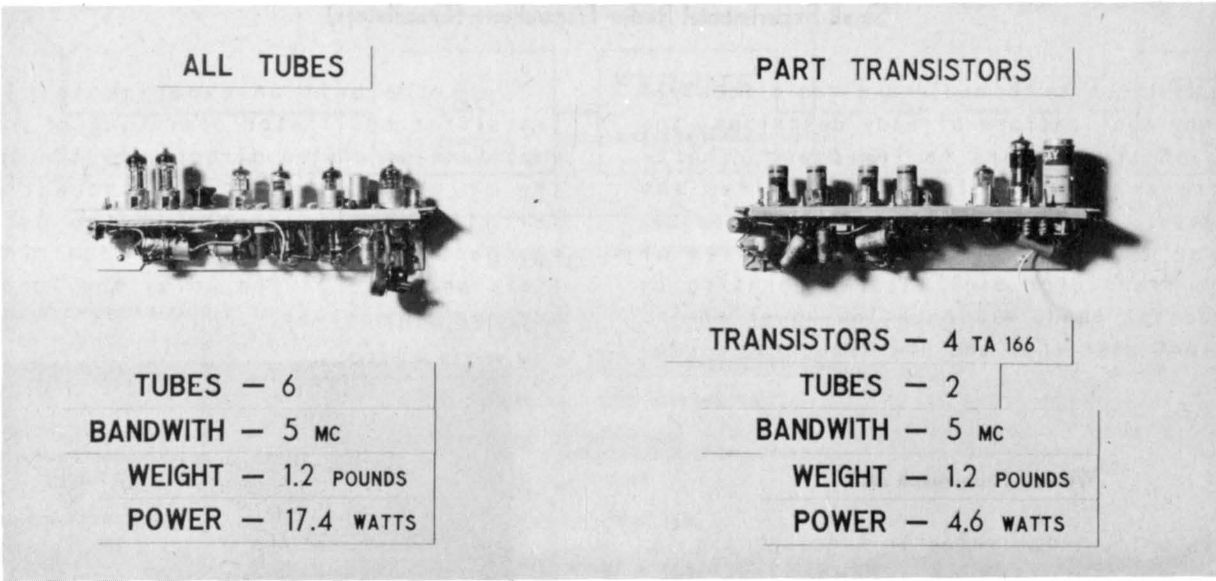


Fig. 36 - Partly transistorized video circuits of "Walkie-Lookie" compared with the all-tube video chassis.

are replaced by four TA-166 point-contact transistors. This video unit also appears in Fig. 35, and is compared in Fig. 36 with an all-tube chassis. Uniform response to 5 Mc was obtained. It was found necessary to use two tubes in the output of the amplifier to supply sufficient power to modulate the transmitter. A saving of 12.8 watts is made in this unit.

Of this total power saving in the entire equipment of 38 watts, 26 watts is in heater power alone. The plate power must be divided by the efficiency factor of 60 per cent for power supply which gives a total power saving from the battery of 50 watts. (see Fig. 35). This is a direct saving of more than 1/3 in total power. Size and weight of the equipment could be reduced accordingly. It appears that all circuits except the transmitter and modulator, and the video input stage might be transistorized. This could result in a unit of one-half the power consumption and one-half the weight for the same performance.

Small Experimental Radio Transmitters (Oscillators)

In addition to the audio and radio receiver transistor applications already described, the utility of transistors in low-power, short-range transmitting equipment or devices was investigated. These are described briefly below. The first three came about from studies of junction transistor oscillators operating in the broadcast band. All have low power drain, are instant starting, and are free from microphonics.

Wireless Phonograph Jack

This unit, illustrated in Figs. 37 and 38, performs the function of a phono-jack on a broadcast receiver without requiring any physical connection between the record player and the receiver. Operation is shown diagrammatically in Fig. 39.

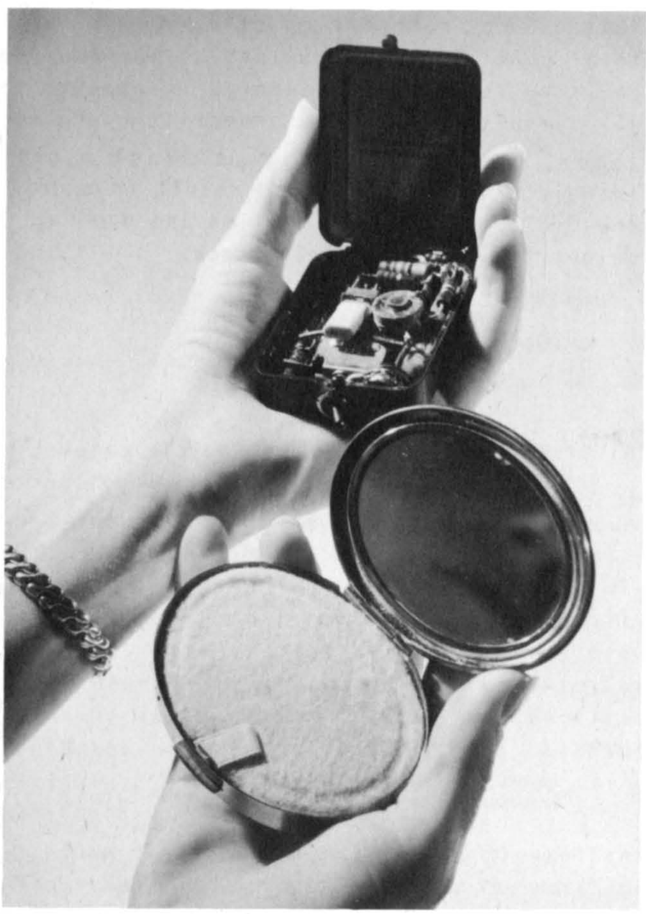


Fig. 37 - Transistor phono-jack compared in size with a lady's compact.

In the unit an experimental junction transistor oscillator operating at 540 kc is amplitude-modulated directly by the output of the crystal pickup of the phonograph. The ferrite core inductance in the oscillator resonant circuit creates a local induction field which is picked up by the loop in the broadcast receiver.

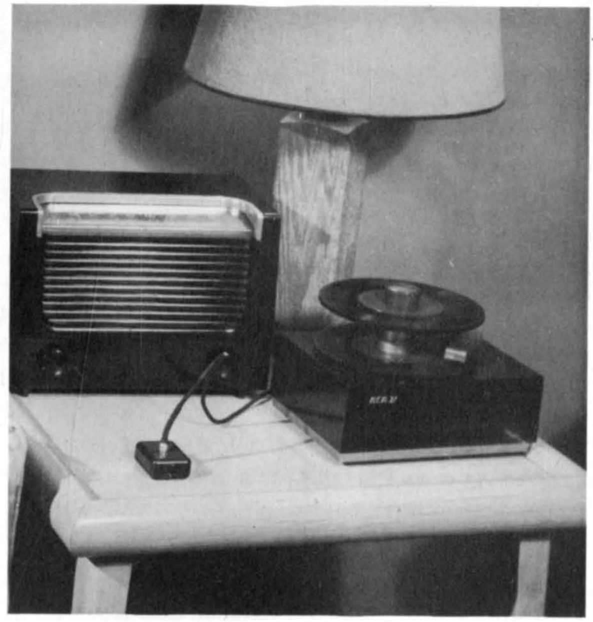


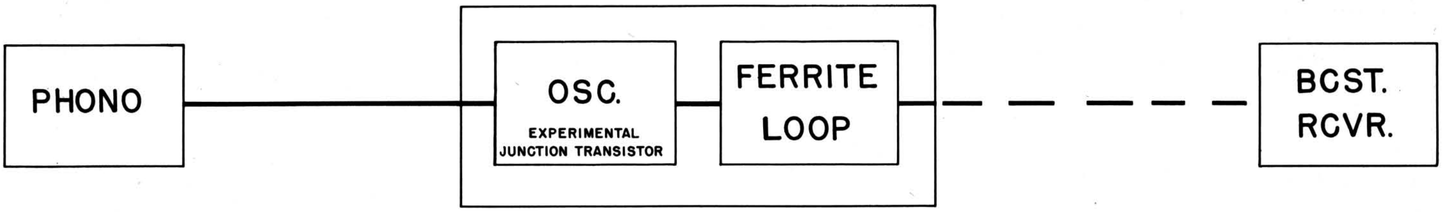
Fig. 38 - Transistor phono-jack connected to record player, transmitting signal to receiver.

A single small mercury cell provides the power for the phono-jack. At a power drain of only 100 microwatts (70 microamperes at 1.35 volts) the battery life is approximately 3000 hours, probably longer than that of the stylus in the arm of the record player.

In this developmental model the setting of the record player volume control affects the level of modulation of the r-f signal. A satisfactory setting is found and the receiver volume control is then employed to set the sound at the desired level. The range of the unit is two or three feet.

Transistor Phonograph Oscillator

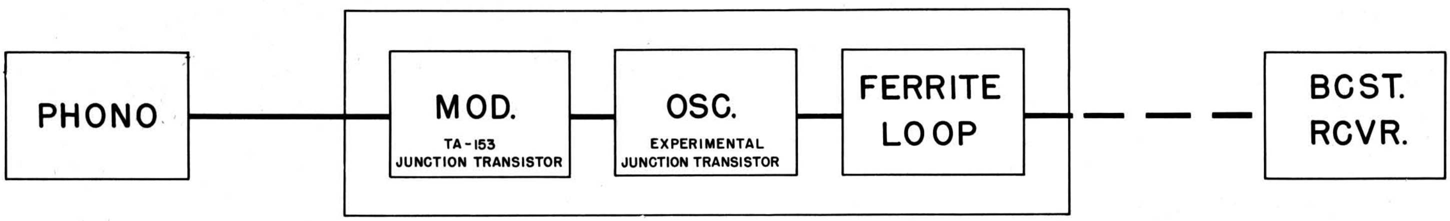
A similar function, but with somewhat greater range, is performed by this device, termed the wireless phonograph. It uses a TA-153



Data:

TRANSISTOR — 1
POWER SUPPLY — 1.35 VOLTS (MERCURY CELL)
POWER DRAIN — 100 MICROWATTS
BATTERY LIFE — 3000 HRS
RANGE — 2 FEET
FREQUENCY — 540KC (AM)

Fig. 39 - Block diagram of transistor phono-jack.



Data:

TRANSISTORS — 2
POWER SUPPLY — 22.5 VOLTS (HEARING AID BATT)
POWER DRAIN — 70 MILLIWATTS
BATTERY LIFE — 10 HOURS
FREQUENCY — 540KC (AM)
RANGE — 25 FEET

Fig. 40 - Block diagram of transistor phonograph oscillator.

junction transistor as a modulator and an experimental junction transistor as an oscillator, again amplitude modulated, operating at 540 kc. Power is supplied by a 22½-volt hearing aid battery whose life is approximately 10 hours. Such a circuit might well be built into the record player, using line power rather than batteries. Its range, contrasted with the former unit, is 25 to 30 feet, so that the player could operate from the opposite side of a living room without wire connection to the receiver. The field strength is less than 15 microvolts per meter at a distance equal to the wave length divided by 2π. The unit is illustrated in the block diagram of Fig. 40 and the photographs of Figs. 41 and 42.

Transistor Roving Microphone (Wireless PA System)

Another unit similar to that of the one just described is a roving microphone, Fig. 43 and Fig. 44, in which a hearing-aid earphone used as a dynamic microphone replaces the

Fig. 41 - Close-up view of transistor phonograph oscillator.

Fig. 42 - Transistor oscillator unit attached to record player.

phono-jack input. It was made to explore the transistor possibilities of a small portable wireless microphone-transmitter, the signal from which is picked up and amplified by any broadcast receiver. Its use is illustrated in Fig. 45. Its transmissions are effective within a radius of 25 feet with a field strength the same as in the previous item.

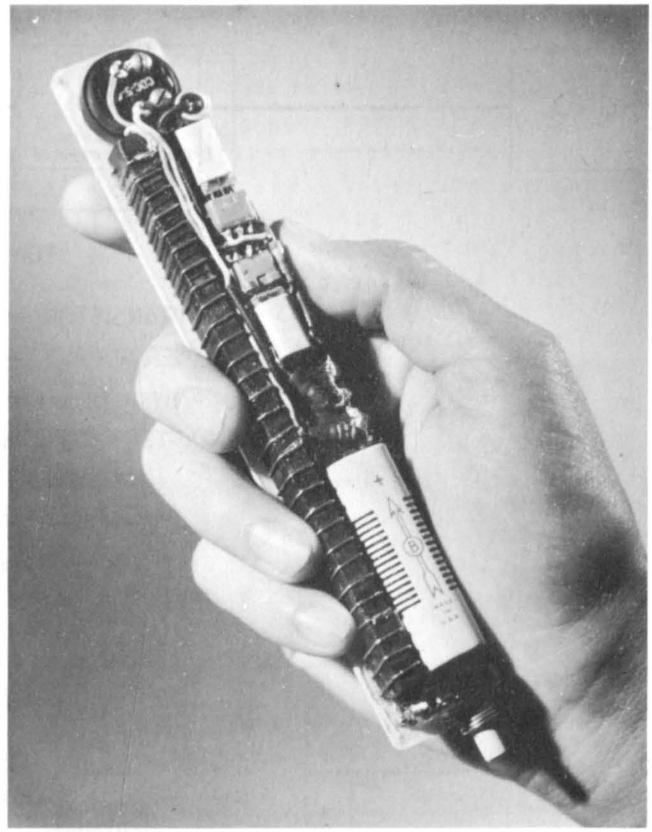
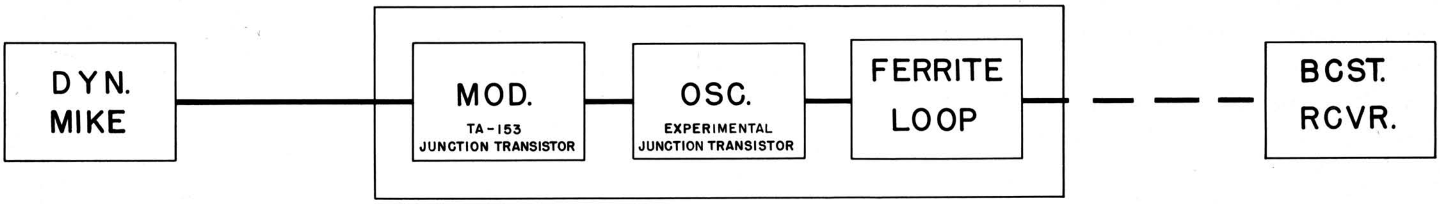


Fig. 43 - Close-up view of transistor roving microphone.

Fig. 45 - Transistor roving microphone in use.



Data:

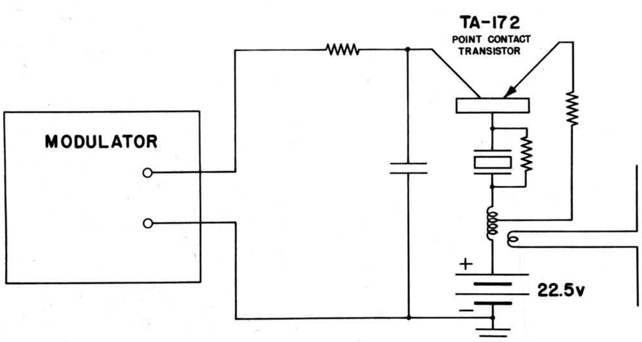
TRANSISTORS — 2
POWER SUPPLY — 22.5 VOLTS (HEARING AID BATT)
POWER DRAIN — 70 MILLIWATTS
BATTERY LIFE — 10 HOURS
FREQUENCY — 540KC (AM)
RANGE — 25 FEET

Fig. 44 - Block diagram of transistor roving microphone.

100-Mc Crystal-Controlled Oscillator

With proper control of the contact spacing and of the resistivity of the germanium point-contact transistors can be made to oscillate at very high frequencies.

Internal feedback supplied by an impedance in the base circuit of a transistor, or external feedback in a manner analogous to many of the feedback circuits used with vacuum tubes, may be used to sustain oscillations in transistor circuits. Crystal control may be effected by inserting a crystal at essentially any point in the oscillator circuit where the r-f impedance is substantially higher than the resonant impedance of the crystal.



Data:

TRANSISTOR — 1 TA — 172
INPUT POWER — 60MW

Fig. 46 - Schematic of 97-Mc crystal-controlled oscillator.

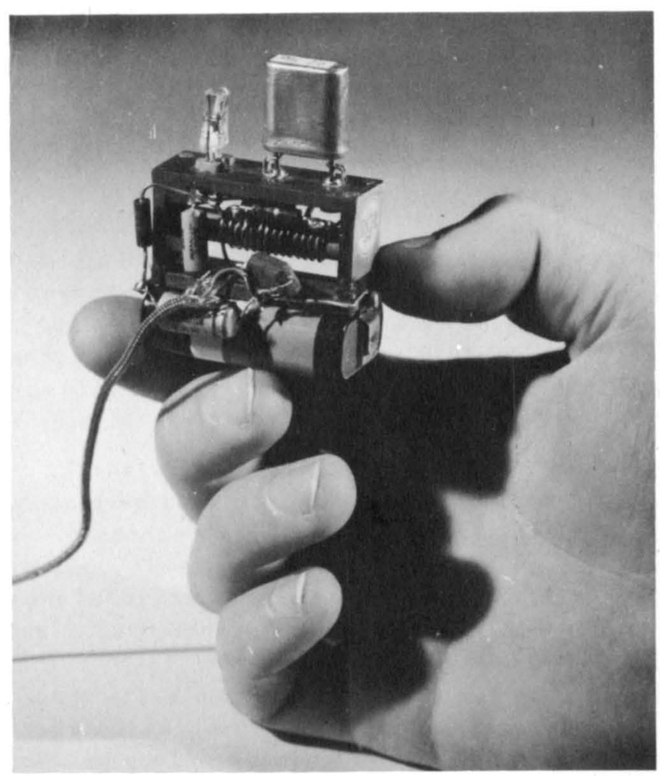


Fig. 47 - Close-up view of 97-Mc crystal-controlled oscillator.

In the demonstration oscillator, (whose circuit is analogous to the Hartley circuit) shown schematically in Fig. 46, the crystal, shunted by a resistor to provide a d-c path, operates at 97 Mc on the fifth overtone. The oscillator is amplitude modulated by applying an audio signal from a phonograph to the collector of the TA-172 point-contact transistor. For demonstration purposes the signal was picked up and amplified by an FM receiver rewired to provide AM detection. A close-up view of the unit appears in Fig. 47.

Experimental Computer Elements Using Transistors

One of the first uses visualized for transistors was in electronic computer equipment which now requires thousands of electron tubes with their attendant bulk, power drain, and heat. Two experimental units, in which transistors perform the functions of vacuum tubes, are discussed briefly.

Transistor Counter

The counter is one vital element of a computer. In the model, shown in Fig. 48, and diagrammed in the chart of Fig. 49, one decade uses 11 TA-156 point-contact transistors and 12 crystal diodes. It is designed to count electrical pulses either at random or at regular rates. Each decade of the counter makes counts from zero to nine, with each count indicated by the glow of a neon lamp in the demonstration unit. The counter is of the transfer pulse-ring type. Each decade consists of 10 bistable units

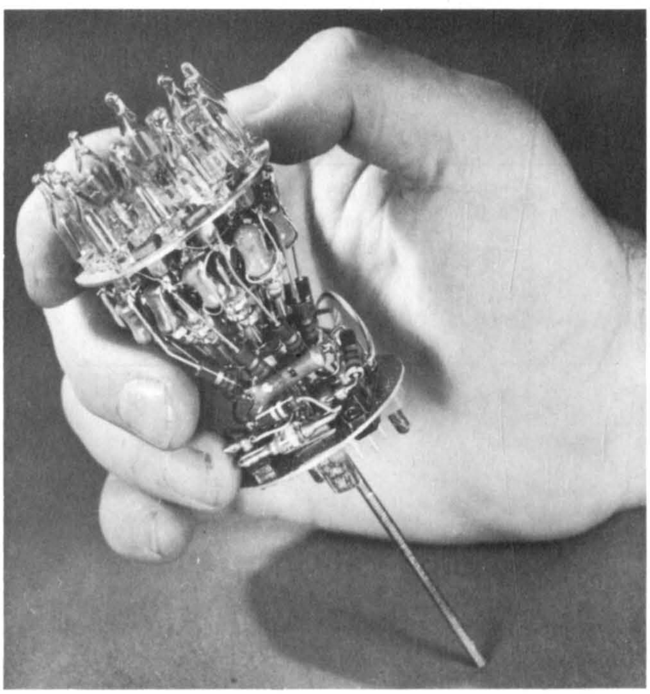


Fig. 48 - Close-up view of transistor counter unit.

interconnected to form a closed ring. Before operation a button is pressed to turn unit zero to the on-state and all of the other units to the off-state. Each input count impulse will advance the on-state one unit in the ring.

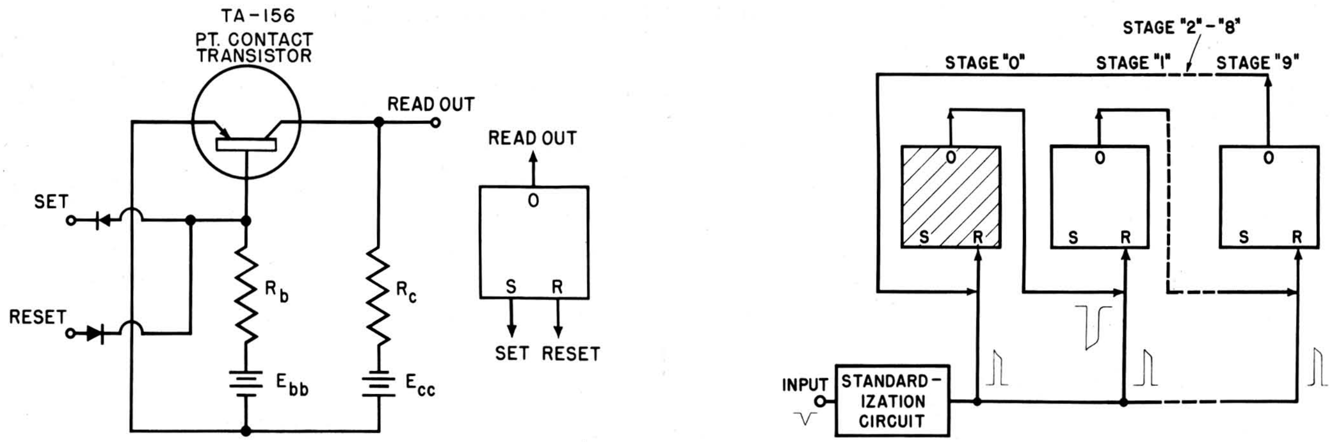
Power consumption is less than two watts per decade. Without any attempt at size reduction, the experimental model measures 6 cubic inches and weighs four ounces. A vacuum decade counter of comparable performance requires 10 twin triodes, 2 pentodes, a much larger number of passive circuit elements, and a power consumption of about 60 watts.

Transistor Adder

Another important element of a computer is an electronic adder. In the diagram of Fig. 50 is shown a transistor adder which performs in a manner similar to equipment with vacuum tube counterparts. The experimental transistor parallel adder is composed of four identical sections called three-input adders. One section appears in Fig. 51 along with its tube counterpart. Transistors are utilized in pulse circuits acting as drivers to a diode network. Fig. 52 shows the assembled adder unit.

The three-adder input is composed of four driver stages and a diode logic circuit. The function of a driver stage is to receive binary information pulses and to transmit pulses of proper polarity and magnitude to the logic circuit. Binary addition may be performed by a number of electronic circuits but practical experience favors the diode logic circuit because of its great reliability.

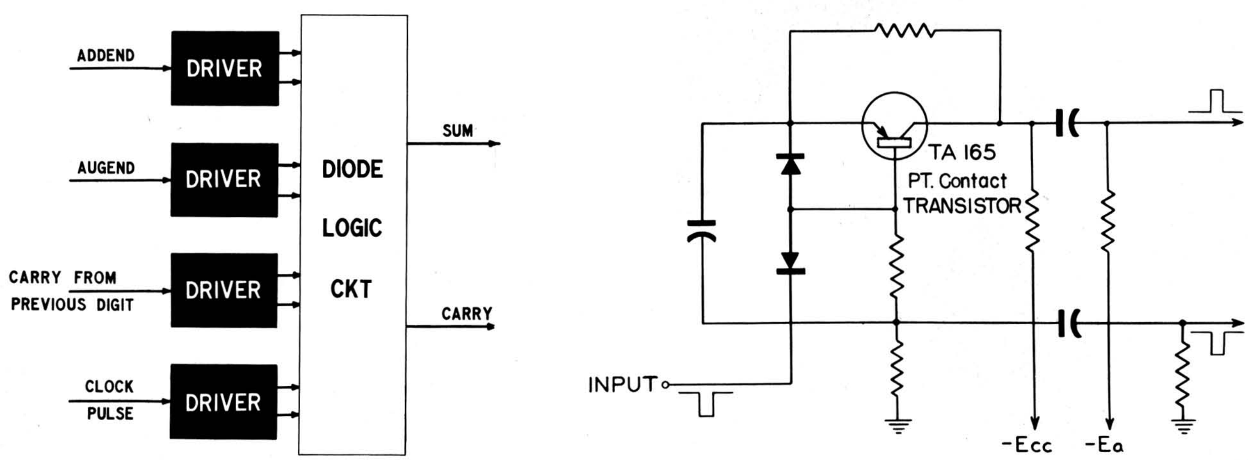
Transistors, being low-impedance devices, appeared to be a good choice as drivers for the low-impedance diode logic circuit. The chart, Fig. 50, gives a good comparison between the transistor and vacuum-tube versions of the adder. Each adder section employs five TA-165 point-contact transistors and 39 crystal diodes, 31 of which are employed in the logic circuit. A significant saving in weight and space was achieved by the elimination of the four pulse transformers used in the vacuum-tube model. Lower supply voltage and smaller current result in a considerable reduction in power consumption. In this unit a speed of 100,000 single-digit additions per second can be realized.



Data:

TRANSISTOR MODEL		VACUUM TUBE MODEL	
TRANSISTORS	11 TA-165	TUBE ENVELOPES	12
CRYSTAL DIODES	12	CRYSTAL DIODES	25
POWER	1 WATT	POWER	60 WATTS
SIZE	6 CUBIC INCHES	SIZE	200 CUBIC INCHES
WEIGHT	1/4 POUND	WEIGHT	4 POUNDS
RATE	10^6 COUNTS/SECOND	RATE	10^6 COUNTS/SECOND

Fig. 49 - Block diagram of transistor counter unit with schematic of one bistable unit.



Data:

TRANSISTOR MODEL		VACUUM TUBE MODEL	
TRANSISTORS	5 TA-165	PENTODES	4
CRYSTAL DIODES	39	CRYSTAL DIODES	31
		PULSE XFMRS	4
POWER	5 WATTS	POWER	23 WATTS
SIZE	30 CUBIC INCHES	SIZE	225 CUBIC INCHES
WEIGHT	1/4 POUND	WEIGHT	3 POUNDS
OPERATING SPEED	100 THOUSAND ADD'S/SEC.	OPERATING SPEED	100 THOUSAND ADD'S/SEC.

Fig. 50 - Block diagram of transistor adder with schematic of one driver stage.

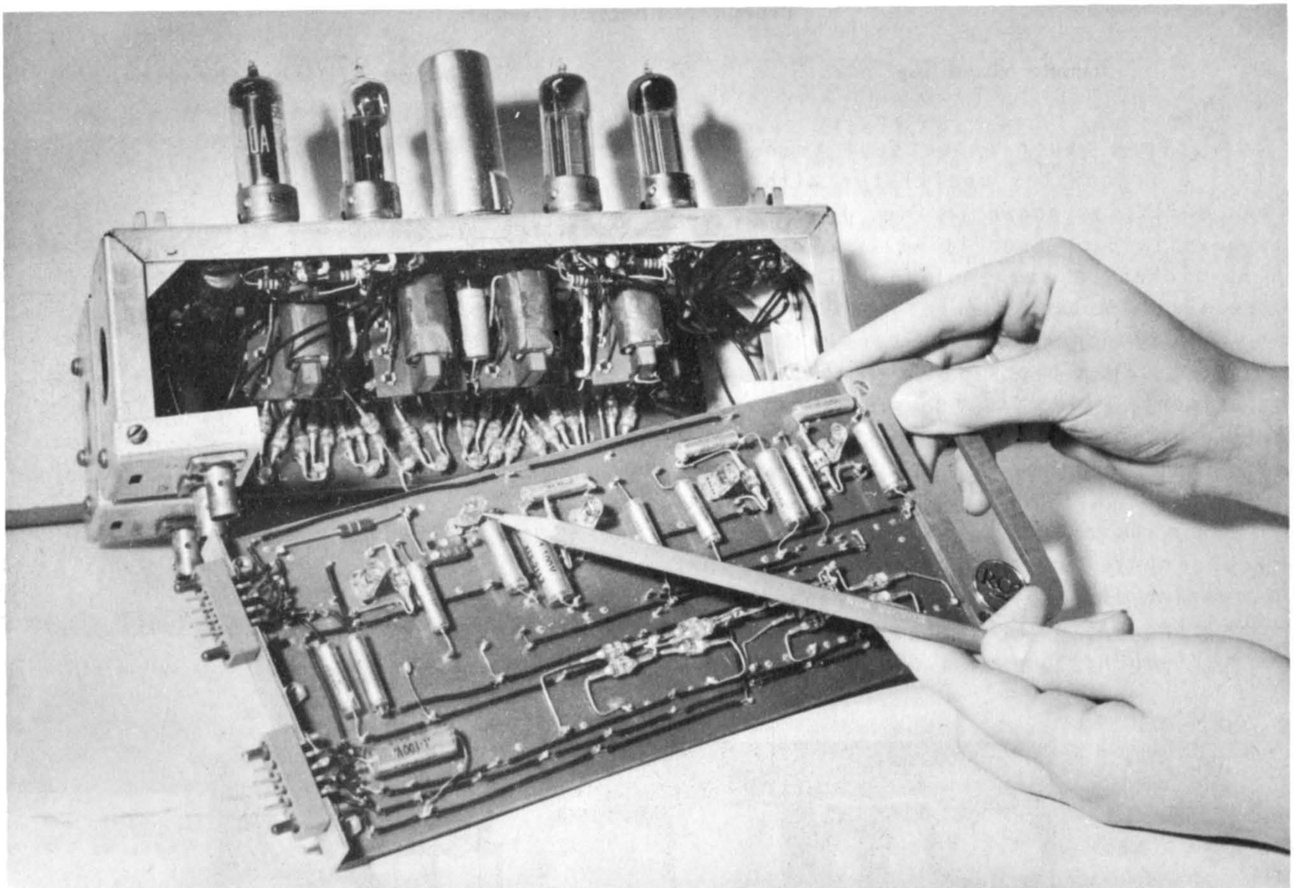


Fig. 51 – Photograph of a transistor adder section, compared with all-tube counterpart.

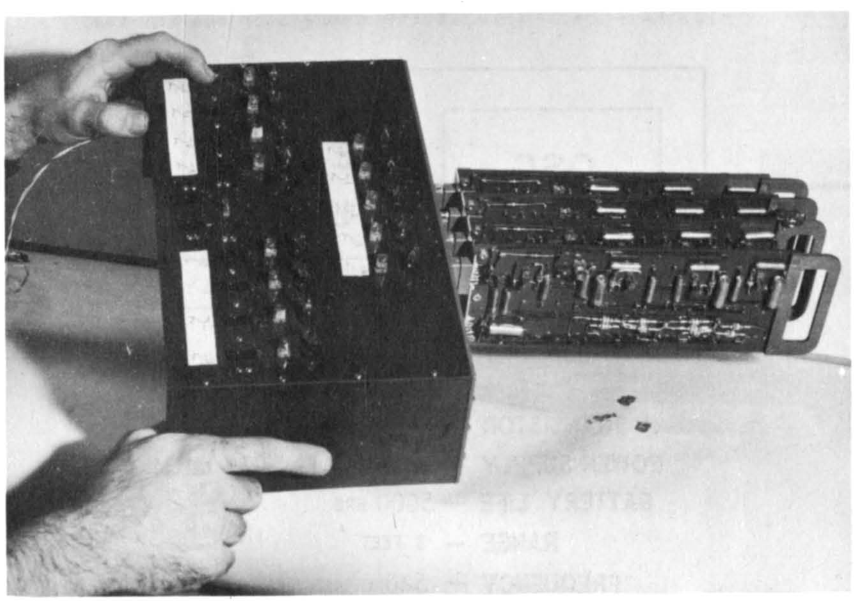


Fig. 52 – The assembled adder unit.

Experimental Musical Devices

Transistor Musical Toy

To explore other aspects of transistor circuits, a transistor oscillator with eight keys was built, as shown in Fig. 53. When one of its keys is depressed it will sound a tone which is picked up and amplified in a nearby radio receiver. A back view of the instrument, showing its components, is given in Fig. 54, while Fig. 55 is a block diagram of the unit. One experimental junction transistor serves as an oscillator, at a nominal 540 kc, controlled by the eight keys which produce a complete octave scale. When no key is depressed the oscillation is continuous, activating the the receiver AVC and quieting the receiver. The depression of a key changes a capacitor in the bias circuit, causing the oscillator to become self-quenching at a controlled audio rate, which determines the pitch of the note heard.

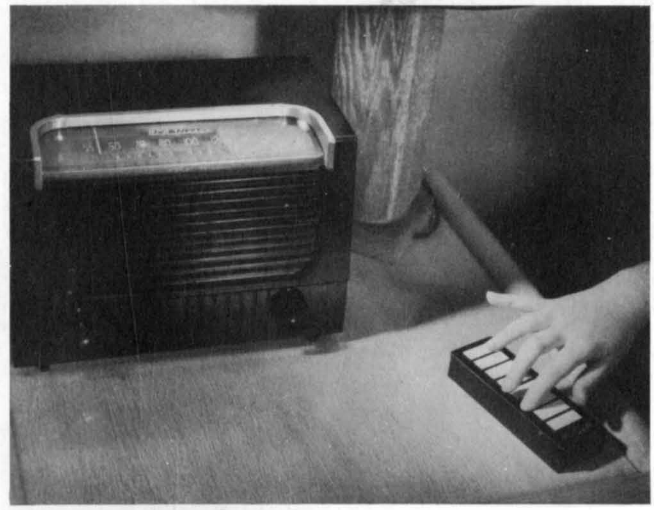


Fig. 53 - Transistor musical toy being played through a receiver.

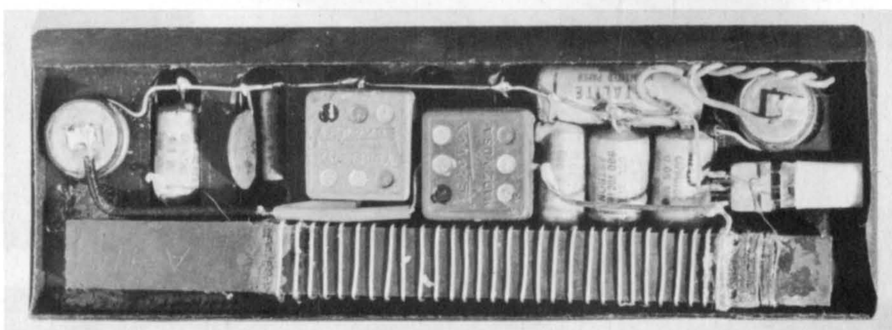
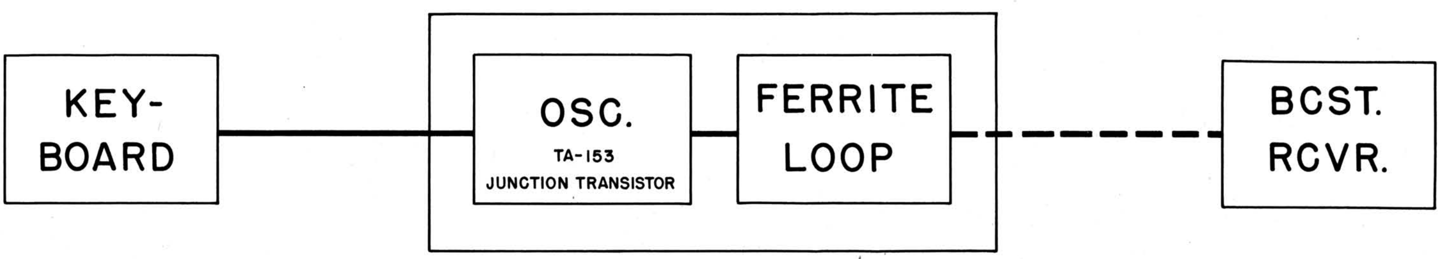


Fig. 54 - Back view of the transistor musical toy.



Data:

TRANSISTOR — 1
POWER SUPPLY — 2.7 VOLTS (2 MERCURY CELLS)
BATTERY LIFE — 5000 HRS
RANGE — 3 FEET
FREQUENCY — 540KC (AM)

Fig. 55 - Block diagram of transistor musical toy.

Transistor-Amplifier Ukelele

Fig. 56 – Back view of ukelele showing transistor amplifier and speaker housed within the body of the instrument.

This ukelele, for which any similar stringed instrument might as readily be used, resembles an electric guitar in function except that transistors enable the amplifier to be entirely self-contained within the body of the instrument itself, as shown in Fig. 56. Four junction transistors are used in the amplifier, the speaker of which is mounted in the sounding hole of theukelele. A magnetic pickup transfers the vibrations of the steel strings to the amplifier.

Of the four transistors used in the amplifier, two are TA-153 junction transistors and two are experimental junction transistors. The output stage is of the type which uses complementary symmetry, described previously in this bulletin and illustrated in Fig. 5 . Power is supplied by two $22\frac{1}{2}$-volt batteries from which the current drain is 20 ma. Conservatively, the life of the batteries should be 10 hours or more. Some three pounds of weight are added to the instrument when fitted with this amplifier system.

Long sustained tones can be obtained because of the feedback provided by the close proximity of the speaker to the strings. In addition to conventional ukelele chords, an instrument so equipped enables melodies to be played; or with a steel bar, Hawaiian guitar effects are possible.

Appendix

RCA Industry Service Laboratory Bulletins on Transistors

1. LB-770 - Some Novel Circuits for the Three-Terminal Semiconductor Amplifier.
2. LB-804 - A High-Performance Transistor With Wide Spacing Between Contacts.
3. LB-805 - Effects of Contact Pressure on Transistor Gain.
4. LB-849 - A Method of Improving the Electrical and Mechanical Stability of Point-Contact Transistors.
5. LB-858 - Licensee Patent Bulletin - Transistors.
6. LB-860 - The Preparation of Single and Multiple P-N Junctions in Single Crystals of Germanium.
7. LB-862 - A Survey of Transistor Development.
8. LB-865 - Transistor Oscillators.
9. LB-867 - The Control of Frequency Response and Stability of Point-Contact Transistors.
10. LB-868 - Germanium P-N-P Junction Transistors.
11. LB-869 - P-N Junctions by Impurity Introduction Through an Intermediate Metal Layer.
12. LB-870 - Junction Transistor Equivalent Circuits and Vacuum Tube Analogy.
13. LB-871 - Dynamic Test Set for Transistors.
14. LB-875 - Transistor Trigger Circuits.
15. LB-876 - Noise Factor Measurements of Transistors.
16. LB-881 - Determination of Orientation and Deformation of Germanium Crystals.
17. LB-882 - A Transistor Curve Tracer.
18. LB-885 - Electrical Measurements on Germanium.
19. LB-886 - Low-Temperature Electrical Measurements on Semiconductors.
20. LB-889 - Application of Linear Active Four-Terminal Networks to Transistors.
21. LB-890 - Purification of Germanium by Gradient Freezing.
22. LB-891 - Laboratory Equipment for Germanium Purification.
23. LB-892 - Preparation of Single Crystals of Germanium and Silicon.
24. LB-896 - Resistivity Striations in Single-Crystal Germanium.