LB-957

A DEVELOPMENTAL POCKET-SIZE BROADCAST RECEIVER EMPLOYING TRANSISTORS

RADIO CORPORATION OF AMERICA
RCA LABORATORIES DIVISION
INDUSTRY SERVICE LABORATORY

RADIO CORPORATION OF AMERICA

RCA LABORATORIES DIVISION

INDUSTRY SERVICE LABORATORY

LB-957

A Developmental Pocket-Size Broadcast Receiver Employing Transistors

Approved

Stuart Wm Seeley.

A Developmental Pocket-Size Broadcast Receiver Employing Transistors

Introduction

This bulletin describes a pocket-size developmental AM broadcast receiver which utilizes eight junction transistors. Its performance is comparable to that of conventional personal receivers. Emphasis has been given to developments which contribute to stability with respect to temperature, battery voltage, and variations among transistors. The superheterodyne circuit employed uses a single-transistor frequency converter to perform the functions of both mixer and oscillator. Refined detector and automatic-gain-control circuits and an audio amplifier embodying further development of the principle of complementary symmetry are incorporated. Reduction in physical size and battery requirement, as compared to conventional receivers, is substantial.

The circuits are described in detail and certain aspects of components and of physical arrangement, which contribute to the small size, are discussed. Detailed performance data are also included.

General Description

The receiver is shown in Fig. 1 in approximately full scale. Operation of tuning and volume-on-off controls is accomplished by means of rim-drive wheels which protrude through slots at the end of the receiver case. The tuning indication is marked on the tuning wheel and is viewed through the window at the lower right. A 2x3 inch speaker is located behind the lower portion of the decorative grille, and the back of the case is vented to improve acoustical performance. The 4-cell battery is contained in a compartment which is located at the rounded end of the receiver and provided with a snap-on cover.

The overall dimensions of the receiver are: height 2-3/4 inches, length 5-1/8 inches, thickness 1-1/4 inches. The total weight of this unit is 17 ounces. The dimensions of the receiver are determined principally by the speaker, tuning condenser, antenna core and battery, i.e., the transistors and small components occupy only a fraction of the total volume of the receiver. For pocket use, the thickness is an important dimension. In this receiver the desired minimum thickness was achieved by employing shallow (approximately 1 inch) versions of a conventional speaker and a conventional tuning condenser. The magnet structure of the speaker was rearranged to minimize the overall depth. Approximately the same volumes of magnet and iron are employed in both the original and modified units; no degradation in performance is introduced by the modification. The tuning condenser was modified by removing some of the plates and shortening the shaft and frame.

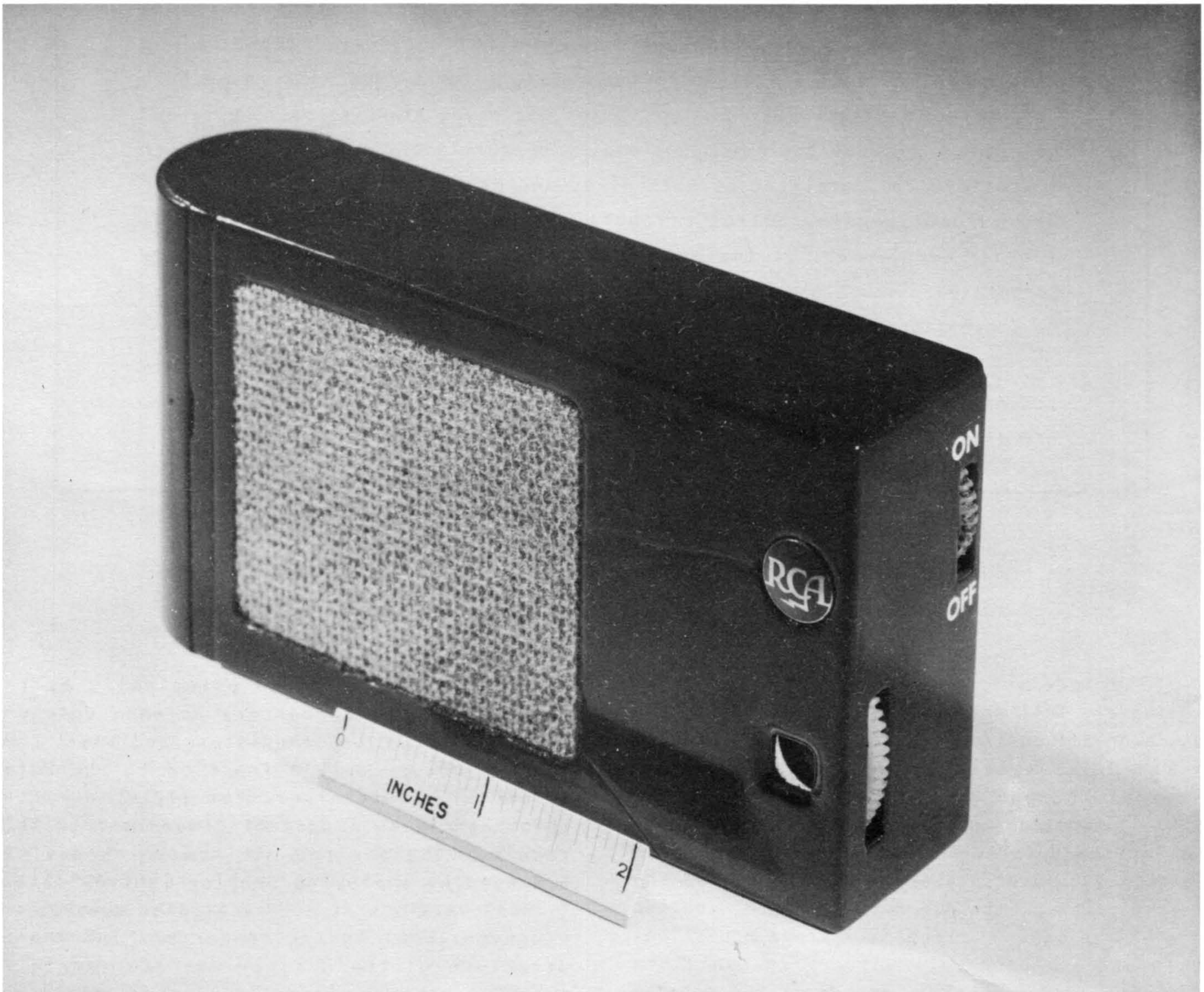


Fig. 1 - Developmental pocket-size broadcast receiver.

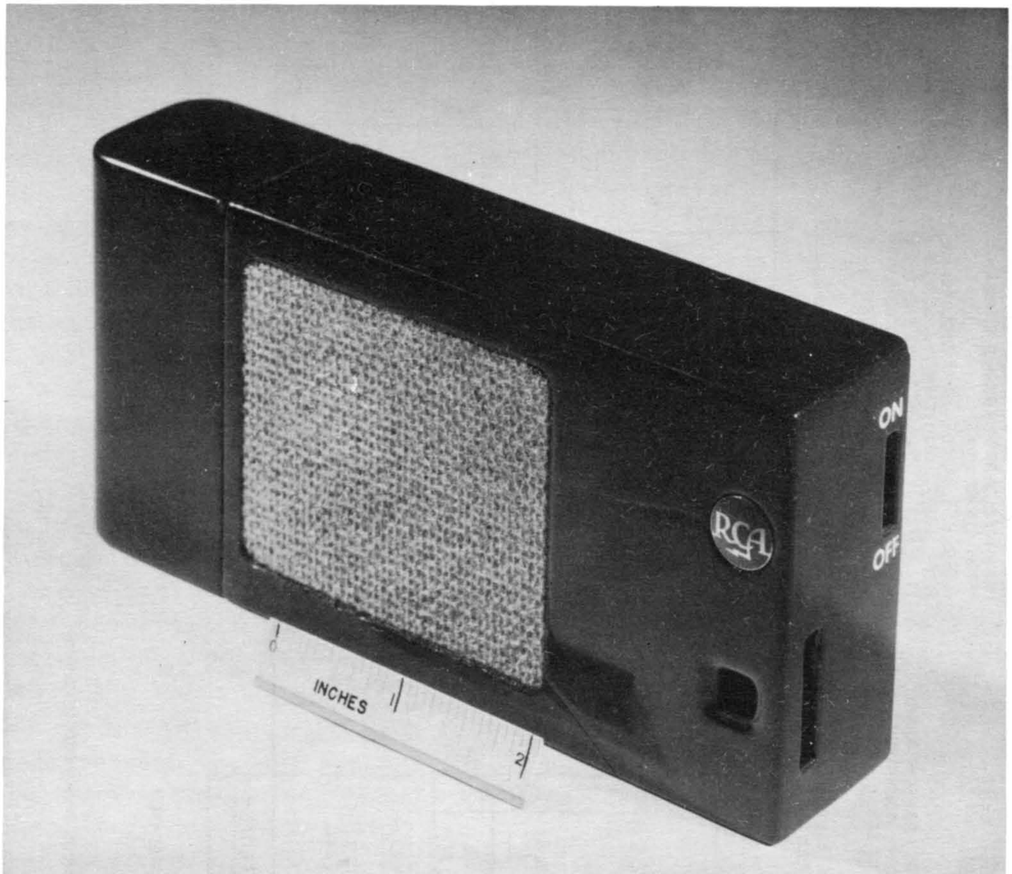


Fig. 2 - Receiver case with alternative battery case attached.

The salient performance characteristics of the receiver are as follows:*

Sensitivity	100 µv/m
Noise performance	
ENSI	15 µv/m
Input for 20 db S/N	1300 µv/m
Power output	125 mw
Selectivity (ACA)	28 db
AGC (figure of merit)	37 db

The battery life of the receiver shown in Fig. 1, employing RM-1 cells, is approximately 50 hours. Alternative battery cases housing battery complements representing different design compromises among battery life, size, weight, cost, etc., may readily be substituted. For example, the battery case shown in Fig. 2 accommodates either RM-502 cells, providing a battery life of 120 hours, or conventional "pen-lite" cells, providing a 36-hour life. This battery case increases the receiver length by ½ inch.

*These data reflect the characteristics of the experimental transistors used; units of exceptionally high and exceptionally low performance were avoided.

Circuit Description

A schematic diagram of the complete receiver is shown in Fig. 3.

Transistors V1 through V4 are of the experimental radio-frequency kind described in *LB-915, A P-N-P Triode Alloy Junction Transistor for Radio-Frequency Amplification*, and serve as converter, first and second i-f and second detector stages respectively. The intermediate frequency is 455 kc. Transistors V5 through V8 are the audio-amplifier complement. Transistors V5 and V6 are identified by the type numbers 2N34 and 2N35 respectively. Transistors V7 and V8 are experimental high-current p-n-p and n-p-n junction units, respectively, connected as a class B complementary symmetry output pair working directly into the voice coil of the speaker.*

The 5-volt battery consists of four RM-1 Mallory Mercury cells. The positive side of the battery is set at +1 volt with respect to ground by the bleeder combination of R7 and R8. The battery is centertapped to provide the

*Long-term life performance of the transistors was not evaluated.

PRIM. 90T-7/41 LITZ
CLOSE WOUND SINGLE-LAYER
CENTERED ON CORE

SEC.—5T #36 FORMEX
CLOSE WOUND OVER "R" END
OF PRIMARY

ANTENNA CORE—4-4" SECTIONS
CROWLEY NO. 20, 0.25" D. FERRITE ROD
CEMENTED TOGETHER, SIDE-BY-SIDE

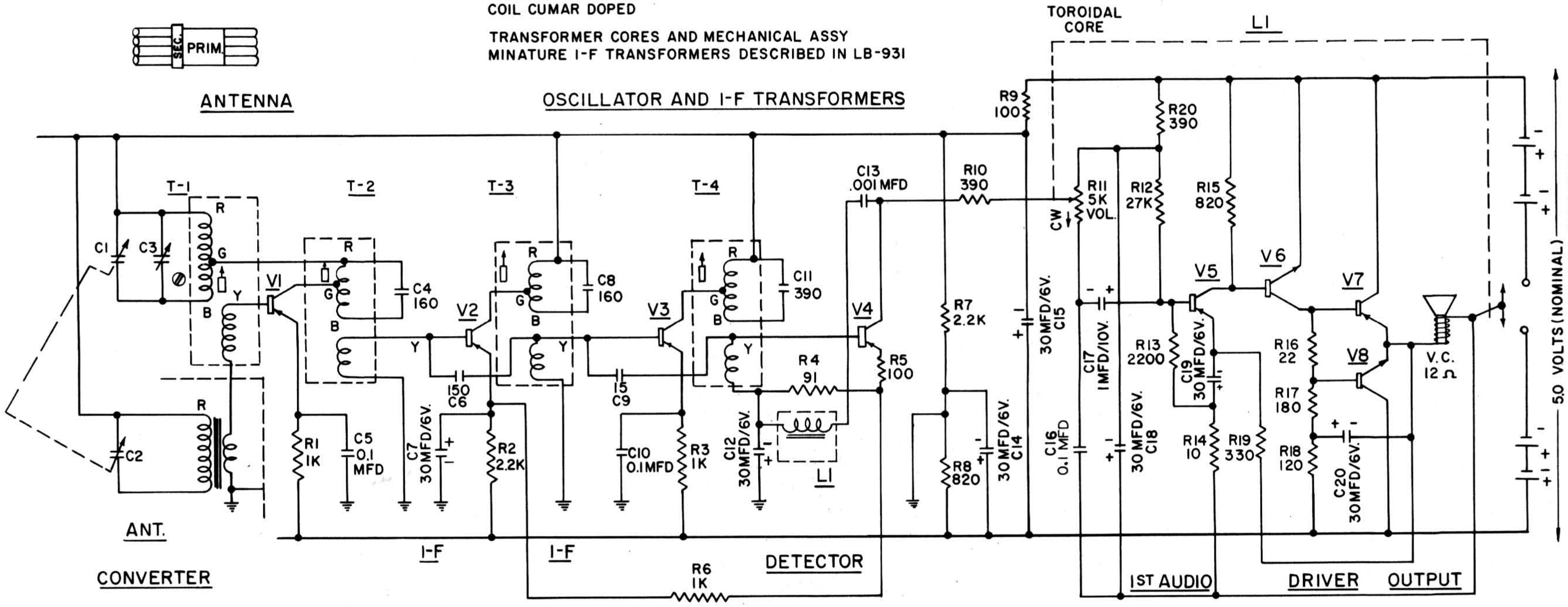
UNIT	SEC.	PRIM. R	PRIM. G	PRIM. B
T1	1T	0T	5T	65T
T2	4T	0T	55T	110T
T3	4T	0T	44T	110T
T4	47T	0T	44T	70T

#36 SSE ON 0.125 I.D. x 0.145 O.D. FIBRE FORM RANDOM WOUND ON 0.230 WIDE x 0.125 D. ARBOR. SECONDARY WOUND UNDER PRIMARY—DISTRIBUTED OVER LENGTH OF COIL. FINISHED COIL CUMAR DOPED

TRANSFORMER CORES AND MECHANICAL ASSY MINATURE I-F TRANSFORMERS DESCRIBED IN LB-931

#36 SSE SINGLE-LAYER ON FERRITE TOROID SLICED FROM MINATURE I-F TRANSFORMER CORE. NUMBER OF TURNS ADJUSTED TO OBTAIN SERIES RESONANCE WITH C13 AT 910 KC.

COIL ASSY ENCLOSED IN CLOSE-FITTING COPPER BOX WITH ONE END OPEN FOR LEAD ACCESSIBILITY



ALL CAPACITANCE VALUES MMFD UNLESS OTHERWISE SPECIFIED
ALL RESISTORS 1/3 WATT—10% TOLERANCE

TRANSISTORS

V1—V4 (p-n-p) EXPERIMENTAL R-F ALLOY JUNCTION TRIODE (DESCRIBED IN LB-915)
V5-(p-n-p) — TYPE 2N34
V6-(n-p-n) — TYPE 2N35
V7-(p-n-p), V8 (n-p-n) EXPERIMENTAL HIGH CURRENT ALLOY JUNCTION TRIODE (SEE LB-905)

Fig. 3 - Schematic of pocket-size broadcast receiver.

symmetrical supply required by the output stage.

Antenna

The receiver antenna consists of a ferrite-cored loop. The core is made up of four 4-inch sections of one-quarter inch diameter ferrite rod placed side-by-side to form a flat structure. This arrangement provides a large antenna volume in a shape which is compatible with the remainder of the receiver. As large a volume as was considered practicable was utilized since the power extracted from a given radiated field by such an antenna is proportional to the volume of the ferrite core.

The antenna loop and secondary winding serve as an impedance transformer; the turns ratio is designed to match the high tuned impedance of the antenna to the low input impedance of the converter at approximately midband. This entails no appreciable sacrifice in performance at the extremes of the band.

A grounded copper shield is located beneath the antenna between the antenna and the remainder of the receiver to reduce feedback of i.f. and its harmonics from the detector circuit to the antenna.

Converter

Oscillator and mixer functions are performed by V1, the converter transistor. The oscillator transformer, T1, provides tickler feedback from collector to base. The i-f take-off transformer, T2, is located in the collector circuit in series with the oscillator transformer primary. Signal is applied to the converter base via the antenna secondary winding in series with the oscillator feedback winding. The input circuit is returned to chassis ground; the collector voltage is -4 volts. The converter is constant-emitter-current biased at approximately 1 ma by means of the 1K emitter resistor, R1, which returns to the +1 volt bus. The 1-volt bias supply is several times the emitter-to-base operating potential of the transistor. Thus, variations in emitter-to-base operating potential among transistors, or with temperature for a given transistor, have a negligible effect upon emitter current. The bleeder which fixes ground potential is relatively stiff (2 ma) so that base current variation with temperature and among transistors does not shift the operating point. Constant-emitter-current bias provides stability of operating point over a wide temperature range and affords transistor interchangeability.

The converter emitter is by-passed to ground by C5. By-passing to ground in this manner (rather than to the +1-volt bus) provides effective r-f isolation of the input circuit from the positive side of the battery.

The turns ratios of the oscillator transformer have been determined experimentally to provide high operating Q and near-optimum oscillator injection over the band. A representative value of optimum injection is 0.1 volt rms at the converter base. The oscillator frequency is substantially unaffected by a 50 per cent reduction in battery voltage or a variation in ambient temperature from 0 degrees C to 50 degrees C.

The input impedance of the converter varies approximately 2 to 1 over the broadcast band. An average value is 300 ohms. The converter output impedance at i.f. is approximately twice that of the same transistor as an i-f amplifier, or about 40,000 ohms. A typical value for conversion gain is 22 db.

IF Amplifier

The three i-f transformers, T2, T3 and T4 comprise three single-tuned circuits which serve as interstage coupling networks, having essentially unity coupling between primary and secondary windings. The mechanical arrangement of these transformers is described in *LB-931, Miniature IF Transformers*. For any given operating Q, minimum insertion loss is incurred by choosing the transformer turns ratios so that the reflected load impedance is equal to the transistor driving impedance. In this receiver, each transformer is designed for an operating Q of 35; the resulting insertion loss is 2.5 db per transformer. The different operating conditions of the various stages give rise to differences in input and output impedances among stages; the various transformer turns ratios are chosen accordingly.

The first i-f transformer, T2, feeds the base of the first i-f transistor, V2, the input impedance of which is 150 ohms. A neutralized common-emitter connection is employed. The operation of the neutralizing circuit may be visualized by referring to the single-generator common-emitter π-equivalent circuit of the transistor, shown in Fig. 4. Feedback from the output to point b′ occurs via the parallel combination of $C_{b'c}$ and $r_{b'c}$. The transistor feedback capacitance and resistance are in the order of 15 μμf and 0.1 megohms respectively. This feedback may be neutralized by deriving a reverse-phase voltage from the output which is then fed back through a suitable parallel RC circuit to the base connection, point b. The presence of $r_{bb'}$ renders the neutralization slightly dependent upon driving impedance and frequency, and influences the requisite parameters in the neutralizing circuit. This effect is second order at 455 kc, however, and can be neglected.

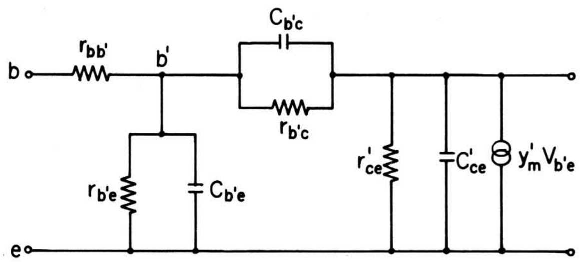


Fig. 4 – Single-generator common-emitter π-equivalent circuit of experimental radio-frequency alloy-junction transistor.

The first i-f transistor is provided with an initial constant-emitter-current bias of 0.5 ma; choice of bias for this stage is dictated in part by a-g-c considerations. The operation of the a-g-c circuit is described in conjunction with the second detector.

Neutralization is accomplished by utilizing feedback from the secondary of the second i-f transformer, T3, through the 150-μμf neutralizing capacitor, C6, to the base. The proper primary-to-secondary polarity is as indicated on the schematic. Because the resistive component of transistor feedback is relatively small, resistor neutralization need not be employed. Since the primary-to-secondary turns ratio of T3 is approximately 10 to 1, a neutralizing capacitor which is ten times the effective transistor feedback capacitance is used. T3 provides interstage coupling between the 20,000-ohm output impedance of the first i-f stage and the 150-ohm input impedance of the second i-f stage. An i-f stage gain of approximately 28 db is realized.*

The second i-f transistor, V3, is constant-emitter-current biased at 1.0 ma. The third i-f transformer, T4, operates between the 20,000-ohm output impedance of the second i-f stage and the 20,000-ohm input impedance of the second detector. This value of detector input impedance applies at receiver-sensitivity level; the detector input impedance decreases with increasing signal level. The primary-to-secondary turns ratio of this transformer is approximately 1 to 1 so that a 15-μμf neutralizing capacitor, C9, is required.

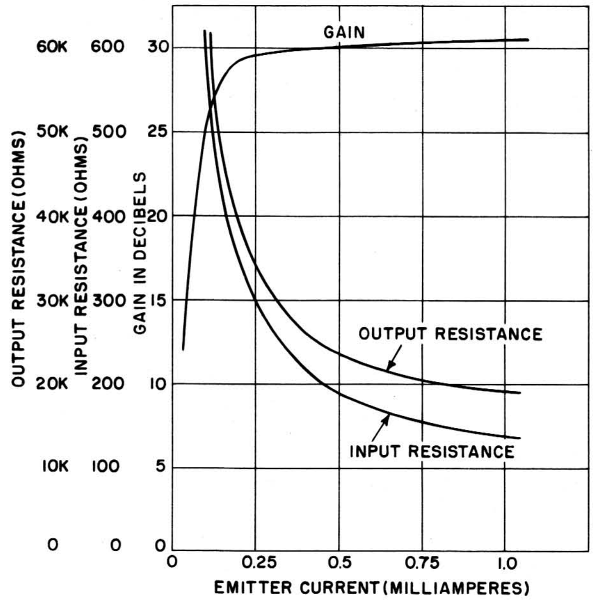


Fig. 5 – Typical variation of r-f transistor characteristics with variation of emitter current.

Automatic gain control of the first i-f stage is accomplished by varying its d-c emitter current as a function of the signal level at the detector. The manner in which 455-kc gain, input impedance, and output impedance vary with emitter current is shown in Fig. 5. The transistor gain decreases rapidly as the d-c emitter current is reduced below 0.5 ma. The input and output impedances increase with decreasing emitter current so that the stage gain is further decreased by input and output circuit mismatches. A single-stage control range of approximately 45 db is obtained. It is evident that automatic gain control will result in a change in operating Q; the effect of this change on overall bandwidth is discussed below.

Second Detector and AGC

The second detector transistor, V4, is driven by the third i-f transformer secondary. This stage operates with the base and emitter

*By way of example, i-f transistors having $r_{bb'}$ = 75 ohms, α_{cb} = 20, $C_{b'c}$ = 11 μμf, and $C_{b'e}$ = 0.001 μf ("alpha cutoff" of 6 Mc) would give typical performance.

at the same d-c potential for the zero-signal condition. As signal is applied to the detector, substantially three components of collector current are developed; these components increase with signal. Included are a high-frequency component (i-f and its harmonics), an audio-frequency component, and a d-c component. The return path for the high-frequency component is from the collector through the 910-kc series resonant circuit formed by C13 and L1, and thence through the series combination of R4 and R5 to the emitter. The 910-kc series-resonant circuit confines the i-f second harmonic current to one return path; reduction of i-f second harmonic feedback to the antenna is simplified since the inductive field of the resulting single loop may then be readily shielded from the antenna. Resistor R10 blocks high-frequency components of collector current from the volume control and associated wiring. Audio-frequency components of collector current return via C12 through the series combination of R4 and R5 to the emitter. The degeneration provided by R4 and R5 serves to reduce detector distortion.

The detector audio output is developed across the upper portion of the 5K volume control, R11. The collector is returned to the volume control slider to provide a detector-circuit output impedance which is substantially independent of volume control setting; the collector impedance is high compared to the volume control resistance. The desirability of a constant audio driving impedance for the particular audio amplifier utilized is discussed later.

Curves of detector distortion and output voltage vs detector input are shown in Fig. 6. Distortion at approximately receiver-sensitivity level is 11 per cent at 80 per cent modulation, and falls to less than 2 per cent at a signal level corresponding to the knee of the a-g-c characteristic.

The d-c component of detector emitter current is employed for a-g-c purposes. The d-c emitter current return path is from the positive side of the battery through the resistor, R2, in the emitter circuit of the first i-f stage, thence through R6 and R5 to the detector emitter. Negative feedback for d.c. in the detector circuit is provided by R5, introducing an effective delay in the a-g-c action of the detector. The 30-μf emitter by-pass capacitor of the first i-f stage, C7, in combination with R6, serves to filter out audio-frequency components of detector emitter current.

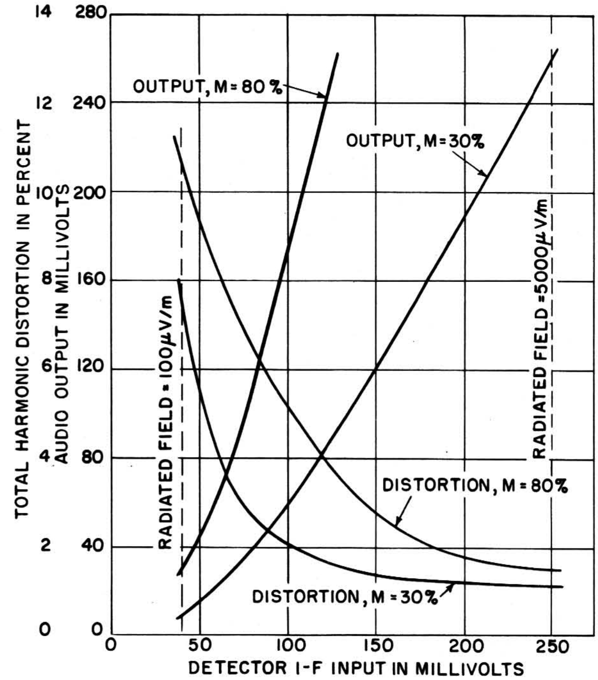


Fig. 6 - Detector characteristics.

The operation of the a-g-c circuit is as follows. For the zero-signal condition, the first i-f stage is constant-emitter-current biased at 0.5 ma, and substantially no d-c emitter current flows in the detector circuit. As signal is increased, detector d-c emitter current is developed, and flows through the resistor R2, in the emitter circuit of the first i-f stage. Since the bias arrangement of the first i-f stage holds the current in R2 essentially constant, the detector may be considered to "rob" the i-f stage of emitter current, i.e., the d-c emitter current shifts from the i-f stage to the detector. As the detector emitter current approaches 0.5 ma, the i-f stage emitter current (and stage gain) approaches zero. Thus, the detector d-c emitter current at the flat portion of the a-g-c characteristic is equal to the first i-f stage d-c emitter current at zero signal. The value of 0.5 ma is chosen as being high enough to insure operation of the first i-f stage near maximum gain for the zero-signal condition and low enough to prevent detector overload at maximum volume control setting under strong signal conditions.

The detector circuit input impedance varies with signal level, being about 20,000 ohms at receiver sensitivity level, and dropping to about 5,000 ohms at the knee of the a-g-c characteristic. This produces a lowering of the operating Q of the last i-f transformer with increasing signal level. At the same time, however, a-g-c action increases the input and output impedances of the first i-f stage; the operating Q's of the first and second i-f transformers are increased so that a negligible change in overall bandwidth occurs.

The first four stages of the receiver are decoupled from the battery by R9 and C15 which prevent audio-frequency components developed across the battery impedance from affecting the oscillator and a-g-c circuits. The +1-volt bus is by-passed to ground for audio and radio frequencies by C14.

Audio

The detector is followed by a three-stage audio amplifier, employing cascade complementary symmetry in the first two stages, which operate class A, and push-pull complementary symmetry in the output stage, which operates class B. The generic principles of complementary symmetry are described in *LB-906, Symmetrical Properties of Transistors and Their Application.* The voice coil is driven directly from the emitters of the output stage. Signal feedback from the voice coil to the first audio transistor reduces distortion, relaxes the degree of match required in the output transistors, and enhances interchangeability of transistors. Stabilization of operating biases over a wide temperature range is achieved by overall d-c feedback.

The signal feedback from the voice coil to the emitter of the first stage, V5, attenuated by the R19 to C19-R14 voltage divider, increases the input impedance of the audio section to about 10,000 ohms. For this type of feedback, the degree of degeneration is a function of the relative magnitudes of this input-impedance and the signal source-impedance. The particular arrangement of detector and volume control used here was chosen to provide constant source-impedance so that the degeneration (10 db) would be independent of volume control setting. The increasing impedance of C19 at decreasing frequencies determines the low frequency roll-off of the amplifier. High frequency roll-off is controlled at the input to the audio section by the shunt 0.1-μf capacitor, C16.

The collector of the first audio transistor feeds the base of the second, or driver transistor, V6. Effectively, the collector of the driver works directly into the bases of both output transistors. Actually these bases are separated only by a 22-ohm resistor, R16, which develops a small initial bias. The major portion of the signal current of the driver is made to flow into the output stage bases by returning the coupling resistor, R17, to the common output stage emitters, via C20. Relatively little signal current flows through R17, since only the output stage base-to-emitter voltage need be developed across this resistor, rather than the full output voltage. The d-c return path for the driver collector current is R17 and R18 (no appreciable direct current flows into the output bases). The quiescent driver current is made sufficiently large to permit the output bases to be driven to a peak-to-peak voltage equal to the battery supply voltage. The total resistance of resistors R16, R17, and R18 is chosen so that the quiescent voltage developed at the driver collector by this current is approximately battery centertap voltage.

The common emitters of the output stage directly drive the 12-ohm voice coil, which returns to the battery centertap. When the bases of the output stage are driven negative with respect to the battery centertap, the p-n-p transistor, V7, conducts, current being fed from the upper half of the battery to the voice coil. The n-p-n transistor, V8, and the lower half of the battery function similarly for positive excursions. The peak-to-peak voltage available across the voice coil is less than the battery voltage by the required peak base-to-emitter voltages in the output transistors and by signal voltage developed in the dynamic battery impedance. The experimental output transistors employed are electrically similar to those described in *LB-905, Power Junction Transistors by the Alloy Process*, requiring approximately 0.5 volt between base and emitter for 145 ma collector current. Thus, with a nominal supply voltage of 5 volts, a maximum peak-to-peak voltage across the voice coil of about 3.5 volts is realized, corresponding to a power output of about 125 mw.

The three audio stages are d-c coupled to permit the use of overall d-c feedback for stabilization purposes. Bias for the base of the first transistor is developed by a bleeder, R12 and R13, between the negative side of the battery and the battery centertap. The emitter of this transistor is returned to the battery centertap through R19 and the voice coil. Thus, any d-c voltage developed across the voice coil by unbalanced currents in the output transistors is subtracted from this bias, constituting d-c feedback. The collector current of the p-n-p first stage develops a voltage from base to emitter of the n-p-n driver stage, controlling the driver collector current. The magnitude of the driver collector current determines the voltages applied to the output stage bases. When these voltages bracket the battery centertap voltage, balanced currents flow in the output transistors. Any departure from this balance, due to variations in characteristics among transistors or ambient temperature variation, is of the proper polarity to be self-correcting, through the previously mentioned d-c feedback to the first stage. The unbalance is held within ±10 ma from 0 degrees C to 50 degrees C. For example, the replacement of a normal driver transistor by one having three times the current gain results in an unbalance of only 3 ma. The maintenance of this balance avoids excessive quiescent current drain on either half of the battery supply, and prevents loss of dynamic range due to asymmetrical overload.

The collector current of the first stage is shared by the base of the driver and the shunting resistor, R15. The d-c feedback functions to adjust this current to that value which will bias the driver stage to 8 ma collector current. The component of current flowing into the base of the driver stage (for 8 ma collector current) diminishes with increasing temperature, ultimately reversing. The component flowing into R15 remains relatively unchanged. This latter component constitutes essentially the total operating collector current of the first stage near the upper temperature limit of the amplifier. The value of R15 has been chosen sufficiently low to insure adequate operating current for the first stage to at least 50 degrees C.

Threshold bias for the output transistors, which operate class B, is developed across R16. The choice of the magnitude of this bias represents a compromise between (a) the appearance of "cross-over" distortion (insufficient bias), and (b) excessive quiescent battery drain (more than sufficient bias). The compromise chosen, good at room temperature, tends toward (a) at temperatures below 10 degrees C, and toward (b) at temperatures above 40 degrees C.

The volume control and the bleeder for the first audio stage are returned to the junction of R20 and C18, decoupling them from the negative supply with respect to the battery centertap, to which the emitter of the input stage ultimately returns. The base and emitter of the driver are both returned to the negative supply, and so require no decoupling. Voltage developed across the internal impedance of the lower half of the battery, appearing at the positive battery terminal and at ground with respect to the centertap, is not directly applied to the audio section. Paths for current do exist, however, through the 910-kc filter in the detector, and through the dynamic detector collector resistance. The audio impedance of these paths is sufficiently high (more than 50,000 ohms) that negligible distortion is introduced.

Power Supply

The battery consists of four separate cells, grouped into two pairs of two cells each to provide a centertapped supply for the output stage. The three-point power switch is located at the battery centertap, where it simultaneously connects the two halves of the battery to each other and to the centertap lead. The use of a three-point switch, instead of a double-pole switch, facilitated the modification of a conventional hearing-aid volume-control-and-*single-pole-switch* combination.

The average battery drain on program material at typical listening level is about 20 ma. The first four stages require 5 ma; the first audio and driver require 8 ma; the output stage draws about 7 ma. The zero-signal current of the output stage is a few ma; the current increases with signal to as much as 50 ma (average) for maximum output on a continuous tone. By the use of the class B output stage

Table I

BATTERY LIFE CHARACTERISTICS			
Cell Type	RM-1	RM-502	"Pen-Lite"
Initial maximum undistorted output power	125 mw	135 mw	160 mw
Life to 75 mw maximum undistorted output power	50 hours	120 hours	20 hours
Life to 50 mw maximum undistorted output power	50 hours	120 hours	36 hours

rather than a conventional class A output stage the overall battery requirement has been reduced by a factor of more than three.

As the battery voltage decreases and battery internal impedance increases with operating life, the maximum power output capability of the receiver decreases, ultimately determining the useful battery life. Appreciable degradation of receiver performance in other respects does not occur within this life. The battery life for different types of cells and various maximum undistorted output-power end points is shown in Table I.

Performance

The major receiver performance characteristics are shown in Fig. 7. These characteristics are generally comparable to those of conventional personal receivers employing vacuum tubes.

The image rejection and sensitivity characteristics are shown in Fig. 7a. The operation of the antenna circuit at approximately one-half its unloaded Q (matched condition) results in a steepening of the slope of the image rejection characteristic. Approximately 30 db rejection is provided at the upper extreme of the band; rejection increases to 60 db at the lower extreme of the band. The i-f rejection (not shown) is 30 db at 600 kc.

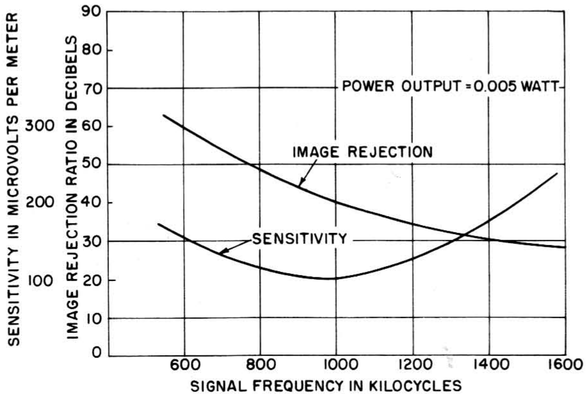
The a-g-c characteristic, and the signal-to-noise ratio as a function of signal level, are shown in Fig. 7b. The a-g-c figure of merit is 37 db. The receiver noise performance, depending upon many factors (antenna effectiveness, receiver bandwidth, converter noise, etc.), is not readily compared with a conventional receiver on the basis of any one contributing factor. The signal-to-noise ratio for a given signal level is in the order of 4 db lower than that of a conventional personal receiver.

The i-f selectivity, shown in Fig. 7c, represents a design compromise between selectivity and gain for the three single-tuned circuits employed. The adjacent channel attenuation is 20 db. A requirement of more selectivity might justify the substitution of one or more double-tuned circuits.

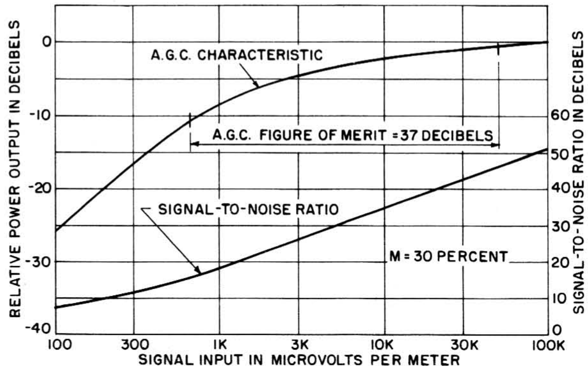
The overall selectivity characteristic is displayed in Fig. 7d. Overall selectivity curves for two typical signal levels are included, demonstrating that the selectivity change due to detector and a-g-c action is small.

The electrical fidelity of the receiver is shown in Fig. 7e. The high-frequency roll-off has been adjusted in listening tests to provide a pleasing tonal balance.

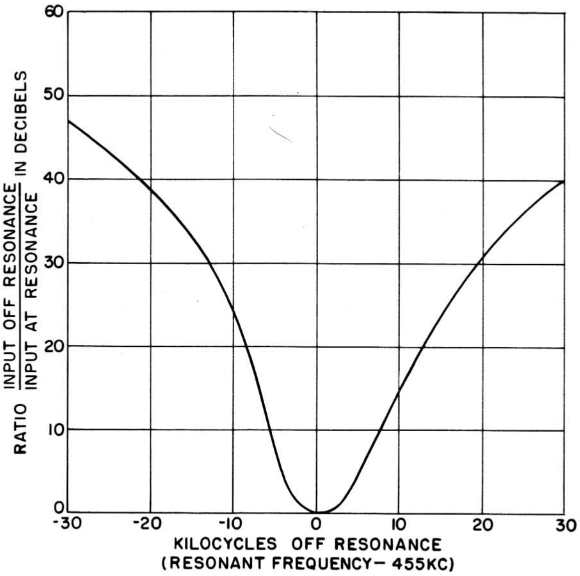
The distortion-vs-power-output characteristic is shown in Fig. 7f. This characteristic is influenced by the battery complement employed; the maximum power output obtained increases approximately as the square of the battery voltage, and decreases with increased battery internal impedance. For a battery complement of four RM-1 cells, (5.0 terminal volts under load) as illustrated, the maximum power output (10 per cent distortion) is approximately 125 mw. The maximum power output achieved with four penlite cells (5.6 terminal volts under load) for example, is approximately 160 mw.



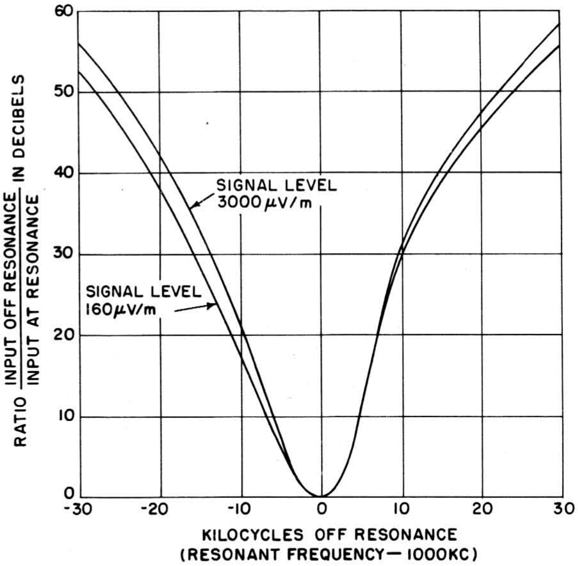
(a) Image rejection and sensitivity.



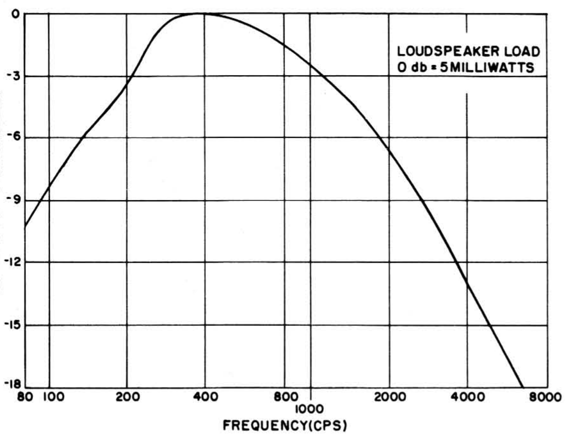
(b) Signal-to-noise ratio and agc characteristic.



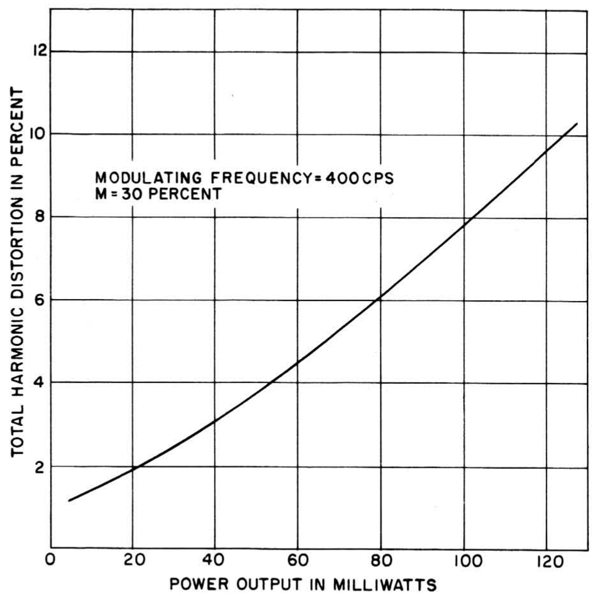
(c) I-f selectivity.



(d) Overall selectivity.



(e) Electrical fidelity.



(f) Distortion characteristic.

Fig. 7 - Major receiver performance characteristics.

The overall acoustical performance of the receiver appears in Fig. 8. The curve shown was obtained in a free field sound room with the receiver placed on a table, as indicated in the sketch.

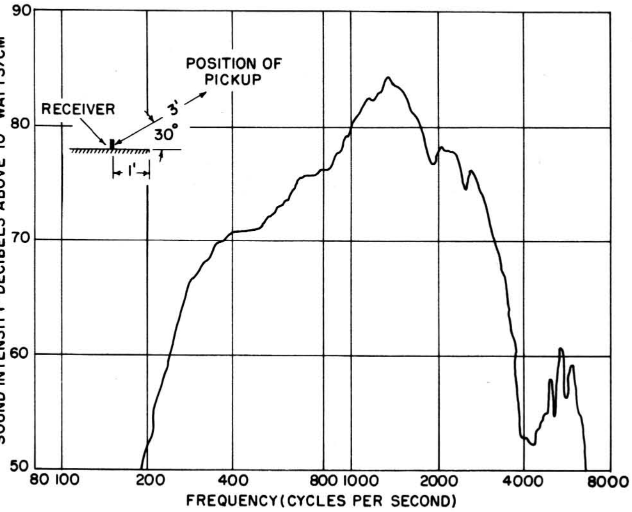


Fig. 8 - Acoustical performance.

The performance of the converter, i-f amplifier and a-g-c circuits is substantially unaffected by a variation in ambient temperature over the range from 0 degrees C to 50 degrees C. The detector (and thus the receiver) sensitivity varies approximately 2 to 1 over this range, being higher at elevated temperatures. The performance of the audio amplifier as a function of ambient temperature is shown in Fig. 9. These data were taken on an experimental "breadboard" while the receiver was under development. The unbalance current remains within limits of approximately ±10 ma over the temperature range from 0 degrees C to 50 degrees C. The distortion, for a constant output of 125 mw, is substantially unaffected over this temperature range.

Physical Details

Front and rear views of the receiver with the covers removed are shown in Fig. 10. The ferrite-cored antenna may be seen at the top of a "chassis" which is essentially vertical and to which are attached, by means of brackets, the tuning condenser, speaker, and battery compartment. The eight transistors, mounted in subminiature sockets, occupy the space immediately below the antenna. The miniature oscillator and i-f transformers are mounted on the chassis, which serves as an electrical

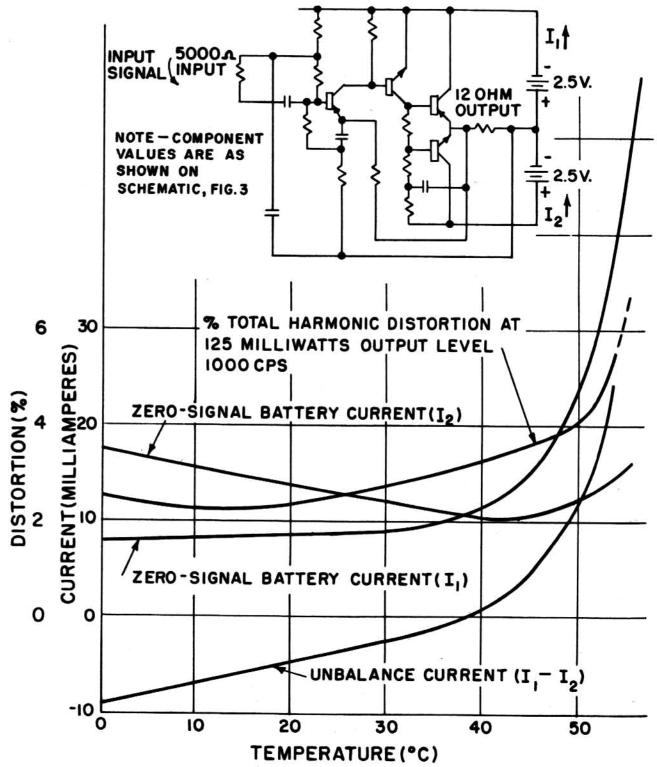


Fig. 9 - Audio amplifier performance vs ambient temperature.

ground for the r-f and i-f portions of the receiver. The top of the chassis is bent over to form a horizontal flange. This flange, the subminiature sockets, a copper shield, fibre spacers, and the antenna are cemented together to form an integral sandwich.

The tuning capacitor, supplied by Radio Condenser Corporation, Camden, N. J., is a modification of a capacitor employed in a conventional personal-portable receiver design. The oscillator and r-f sections employ four stator plates each instead of five and seven respectively, providing the requisite reduction in capacitor depth. The resultant reduction in the ratio of maximum to minimum capacitance can be tolerated because of the relatively low shunt capacitance reflected across the antenna and oscillator tuned circuits by the converter transistor. The tuning wheel is mounted on the rotor shaft, within the frame of the condenser.

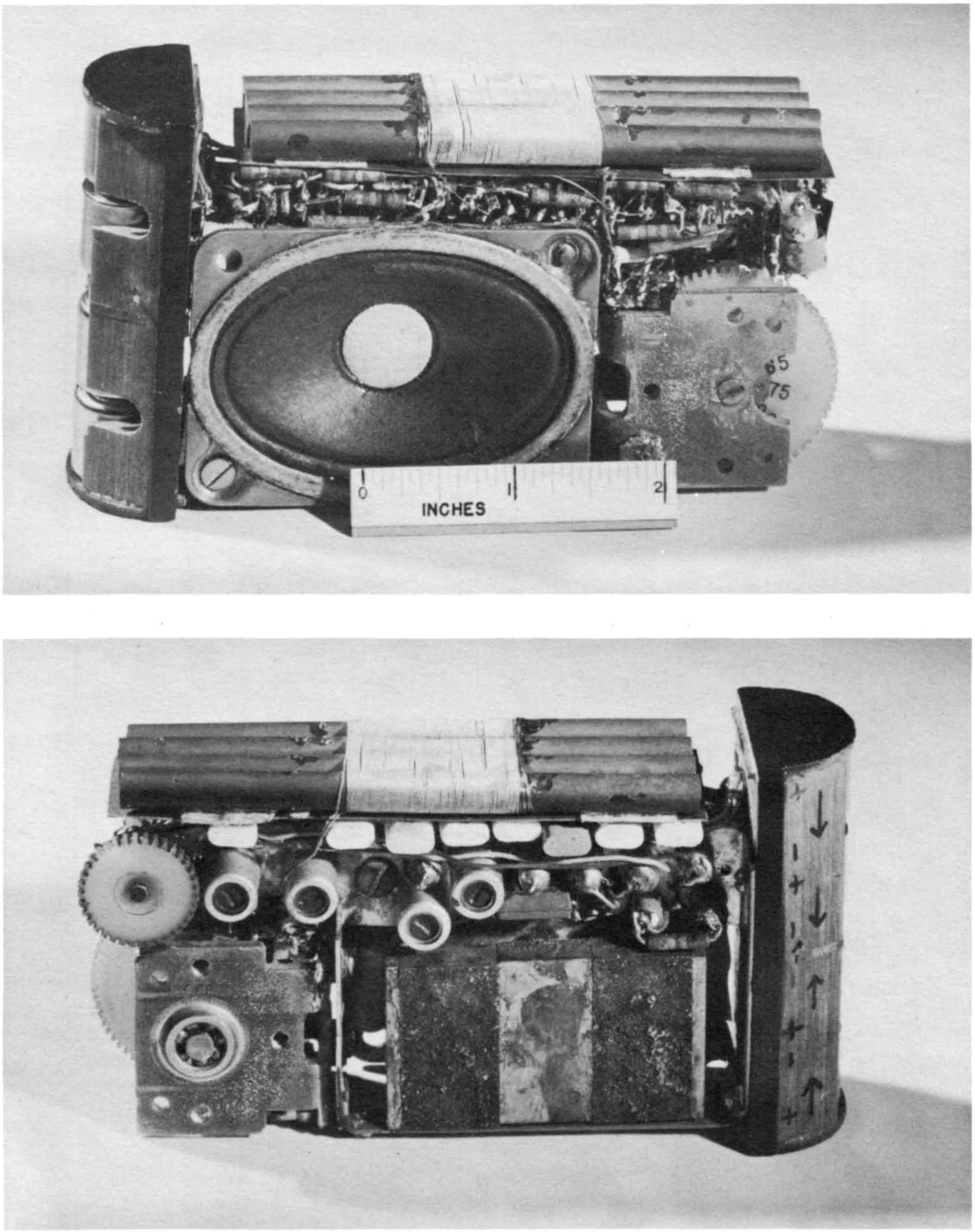


Fig. 10 - Front and rear views of the receiver with the covers removed.

The speaker is a modified version of the RCA 214S1 unit. Standard parts were used except for the field structure, which was arranged as shown in Fig. 11. The structure was magnetized, after assembly, by the impulse method, using a ten-turn coil on each magnet (series-opposing) and a 4000-ampere discharge.

The volume control as acquired (Centralab Model 1 Radiohm, with switch) is equipped with a SPST switch which was modified as shown in Fig. 12 to provide the desired three-point switch. The switch action is such that the movable contact is forced between the two stationary contacts.

Three small 0.1-μf ceramic capacitors of an experimental type are employed. The small size (0.2 x 0.50 x 0.03 inch) is achieved through the use of partially-reduced barium-strontium titanate as the dielectric.

The 30-μf electrolytic capacitors are of the sintered-tantalum type which is notable for

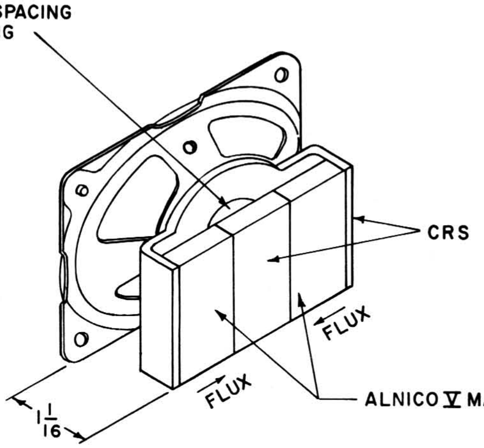


Fig. 11 - Speaker, showing modified field structure.

its high capacitance-to-volume ratio. These units were mounted by pressing them into holes in the chassis plate. In those instances where it was necessary that the outer case of the capacitor be insulated from ground, the unit was first covered with a plastic sleeve.

The battery compartment and receiver case shown here were milled from linen-base phenolic stock. For convenience, the receiver case was milled in two sections which were then cemented together to form a slide-on unit which fits flush with the battery case and is screw-fastened to a bracket on the bottom of the receiver chassis. Other experimental receiver cases have been constructed using resin-impregnated fibre-glass cloth.

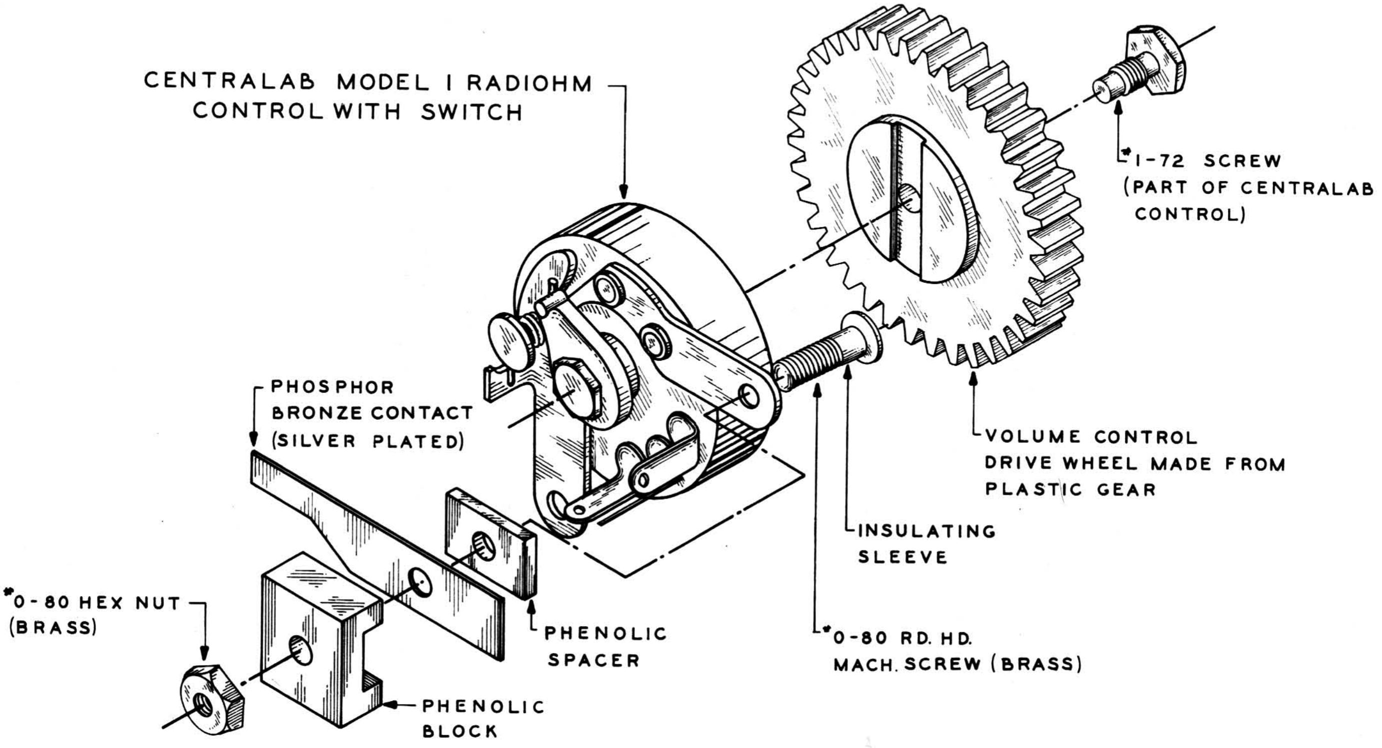


Fig. 12 - Exploded view of modified volume-control-and-switch.

Larry A. Freedman

Thomas O. Stanley

David D. Holmes