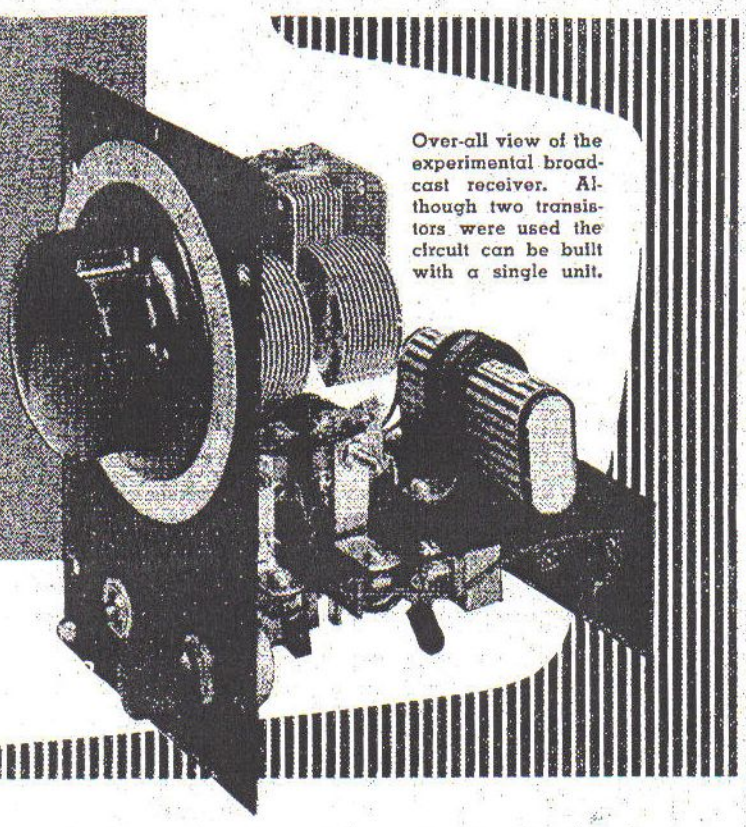
BUILD THIS TRANSISTOR RECEIVER



Over-all view of the experimental broadcast receiver. Although two transistors were used the circuit can be built with a single unit.

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Transistors are now within the reach of all. Here is a simple receiver you can build—other types of equipment using transistors will be covered in subsequent issues.

ABOUT four years ago, the transistor was first announced. Since that time, a considerable amount of effort has gone into the design and production of transistors and much has been written about them.

Transistors are semiconductor devices capable of acting as amplifiers, oscillators, and performing other functions now performed by vacuum tubes and with greater efficiency. The basic material in most transistors today is germanium and the devices are made in two different types: the point contact, which was the original, and the junction.

A semiconductor is any material which is neither a good conductor nor a good insulator, thus its name. Germanium has a simple atomic structure with the inter-atomic spacings in the crystals forming relatively straight corridors or paths. The basic lattice of the crystal has eight atoms per cell, four of which form the corners of a small cube while the other four are wholly within the cube. There are relatively large spaces between the atoms. In this pure form germanium is basically a stable material and does not exhibit a surplus or deficiency of electrons.

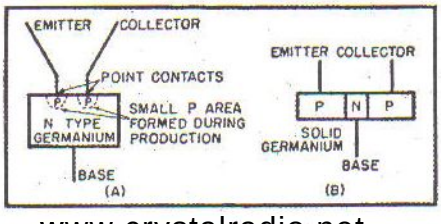
By the introduction of certain selected elements, the germanium can be made to exhibit an excess of electrons and thus become a negative or "*n*" type material, or by the introduction of other impurities or chemical elements there may be a deficiency of electrons and the material will be considered a positive or "*p*" type material.

If electrical pressure is applied to a piece of "*n*" type germanium material, current flow will exist by virtue of the free electrons existing therein. Similarly, if electrical force is applied to the positive type material, conduction appears by virtue of the phenomenon called hole conduction. The application of electrical potential causes electrons to move from the negative and toward the positive end, the presence of holes facilitating the electron flow.

The point-contact transistor consists of a block or crystal of material such as germanium with two properly spaced pointed electrodes making contact with the surface of the germanium. In many respects, it resembles the well-known crystal diode with the exception of the additional electrode. During manufacturing, the position of the two point contact electrodes (including the relative spacing of these elements) is adjusted for proper operation of the transistor as an amplifying device.

EDITOR'S NOTE: *Obviously no attempt has been made to "miniaturize" this unit. It is more important to familiarize oneself with the design and limitations of transistors. Miniaturization is then not too difficult a task. These transistors are new items; however, they are available at a suggested retail price of $7.60.*

Fig. 1. Internal construction of the (A) point contact and (B) junction transistor.



The basic block of germanium is normally "*n*" type in the point-contact device. Small areas of the germanium adjacent to the pointed electrodes are converted to "*p*" type material during production. (See Fig. 1A.)

Junction transistors consist of a block of material in which "*n*" and "*p*" type materials are arranged in alternate layers. The end sections can be either "*n*" or "*p*" material with the center zone being the opposite type. (See Fig. 1B.)

The point-contact transistor finds wide application in switching circuits and oscillator circuits at frequencies normally not possible with the junction type units. The point-contact transistor has inherently higher noise output than the junction units.

The junction transistor, on the other hand, is a more efficient amplifier while operating at low voltages. They are extremely rugged and have exceptionally long life. The normal noise voltage generated in a junction type is lower than that of the point-contact type transistor. Since the electrons travel somewhat slower through the germanium material in transistors than in a vacuum and due to the high internal capacities of junction transistors as we know them today, operation is normally limited to the lower frequencies.

This article deals with a "*p-n-p*" junction transistor recently announced by the *Raytheon Manufacturing Com-*

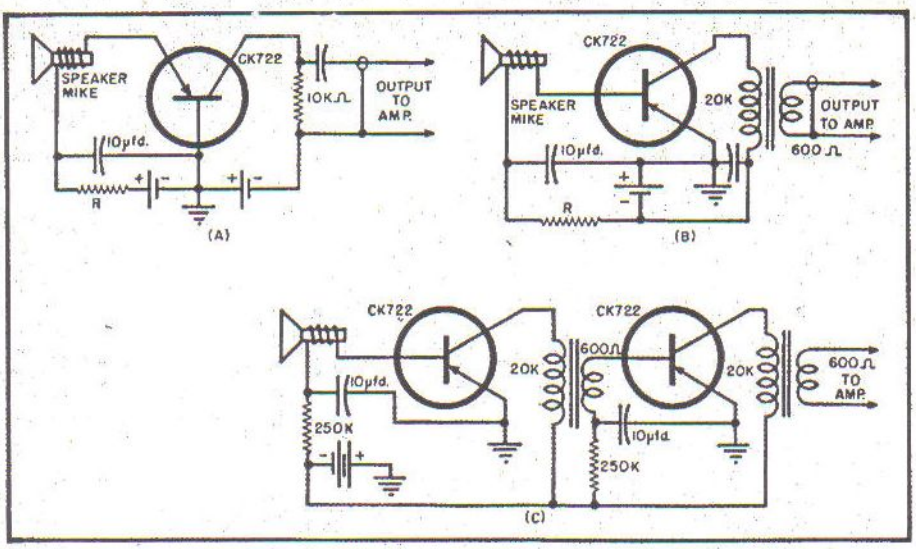


Fig. 2. Microphone preamplifiers using transistors. (A) grounded base, (B) grounded emitter, and (C) a two-stage, transformer-coupled amplifier. See text for details.

MECHANICAL DATA

CASE: Plastic and Glass
BASE: None (0.016" tinned flexible leads.** Length: 1.5" min. Spacing: 0.08" center-to-center)
TERMINAL CONNECTIONS: (Red dot is adjacent to lead 1)
Lead 1 Collector
Lead 2 Base
Lead 3 Emitter
WEIGHT: 0.025 ounce
MOUNTING POSITION: Any

ELECTRICAL DATA

RATINGS—ABSOLUTE MAXIMUM VALUES:

Collector Voltage	−20	volts
Collector Current	−5	ma.
Collector Dissipation (at 30°C)	30	mw.
Emitter Current	5	ma.
Ambient Temperature	50	°C

AVERAGE GAIN CHARACTERISTICS—GROUNDED EMITTER: (at 30°C)

Collector Voltage	−1.5	volts
Collector Current	−0.5	ma.
Base Current	−20	μa.
Current Amplification Factor	12	
Power Gain*	30	db
Noise Factor # (1000 cycles)	22	db

* Source: 1000 ohms; Load: 20,000 ohms
# At −1.5 volts (−1.0 ma.) to the collector.
** Socket types: Cinch Nos. 14148 & 14273 or equivalent.

Table 1. Tentative data on the Raytheon CK722 germanium junction transistor.

pany, identified as the CK722. The characteristics and ratings of the CK722 are shown in Table 1. It is extremely rugged and when operated at normal ratings has exceptionally long life.

Basically, the *"p-n-p"* junction transistor may be compared to the vacuum tube with the emitter resembling the cathode, the base resembling the grid, and the collector resembling the plate. There are several basic differences, however, which are outstanding.

In the *"p-n-p"* junction transistor, conduction is accomplished in a solid instead of in a vacuum. The collector is operated with a negative bias instead of the customary positive voltage applied to the plate. Another outstanding difference lies in the input impedance. The vacuum tube has almost infinite input impedance over a considerable range of frequencies. The transistor, on the other hand, is a current-operated device and has a rather low input impedance in the grounded base or grounded emitter connection which is analogous to the grounded grid and grounded cathode type amplifiers.

The graphic symbol for the *"p-n-p"* junction transistor is shown in Fig. 3. Since the transistor is a three-terminal device, several combinations of connections may be used, namely, the grounded emitter, the grounded base, and the grounded collector.

Fig. 5 is a typical set of characteristic collector curves for the CK722. These curves may be compared to the plate characteristics of a pentode amplifier except that instead of grid voltage we use various values of base current. A load line of 1000 ohms has been drawn in and examination of the curve will show that operation is linear over almost the full range from zero to maximum collector current. The slow increase in collector current with increasing collector voltage at any fixed value of base current is typical of junction transistors and is indicative of the high collector resistance.

An additional characteristic which is little known but of considerable importance is the "Zener" effect. If the transistor is operated with positive base current so that normally there is no collector current, the collector voltage can be increased to a point where conduction will occur. This is the "Zener" point and may be an important consideration in operation of transistors. "Zener" current flowing during the peak a.c. voltage cycle could cause excessive limiting and consequent high distortion in an amplifier.

Many applications for the CK722 junction transistor will become apparent to the experimenter. Since junction transistors had up to now been available on only a limited basis, very little application and circuit work has been done.

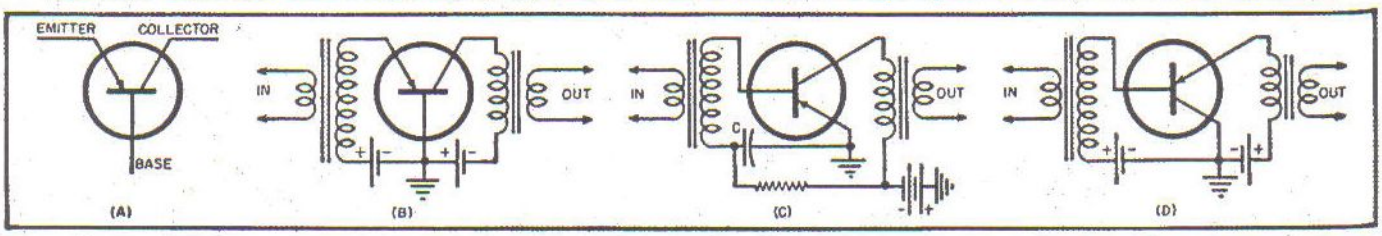
Three basic type circuits immediately suggest themselves. These are: switching circuits, oscillator circuits, and amplifier circuits.

We shall discuss in some detail, the CK722 as a small-signal, low-voltage amplifier.

The small size and relatively high efficiency at low operating voltage coupled with the absence of any heater voltage make the transistor ideally suited for preamplifier use. A further advantage is the fact that transistors are not microphonic, thus no special precautions in mounting need be taken.

Fig. 2 includes several suggested circuits for transistors used as microphone preamplifiers. The microphone

Fig. 3. Equivalent graphic circuits. (A) Graphic symbol of CK722 "p-n-p" junction transistor. (B) Common base amplifier, with low input impedance and high output impedance. Requires two batteries. (C) Common emitter circuit having medium input impedance and high output impedance. Permits single battery operation. (D) Common collector with high input impedance and low output impedance.



may be a small 2 or 3 inch dynamic speaker. Notice that it is directly connected to the transistor without use of an impedance matching transformer. With a voice coil impedance of 6 ohms and with R adjusted for a collector current of 100 microamperes, the sensitivity will be approximately equal to a good carbon mike with much better fidelity and less noise. The circuit of Fig. 2B may be used to eliminate the need of a tapped battery, however, the gain will be slightly less. If a long shielded cable is required, a transformer should be used instead of a resistor load in the collector of the transistor as in Fig. 2B. This can be a small plate-to-line transformer of 20,000/600 ohms impedance.

Because the operating current is low, battery life is good. The supply for the transistor can be obtained from the standard high voltage plate supply of the amplifier and, in fact, this circuit has the advantage of supplying a more constant current to the transistor. The important factors in these circuits are the low input impedance of the emitter, on the order of 100 ohms with the grounded base connection, and the high output impedance of the collector, on the order of 500,000 ohms. With grounded emitter connection, the input impedance of the base is a function of other operating parameters so no value can be given for it.

Several stages of transistor amplifiers can be cascaded and the use of coupling transformers will assure maximum gain. Plate-to-line transformers may be used as shown in Fig. 2C. Resistance coupling can be used but with some loss in gain (approximately 6 db). Large coupling condensers must be used to obtain good low frequency response because of the low impedance levels.

Push-pull operation of transistors is entirely feasible, permitting greater power dissipation with consequent greater power output. Class A operating efficiencies on the order of 50 per-cent are obtainable while class B operating efficiencies to nearly 80 per-cent are possible. Matched units should be used in this application and degeneration can be applied to improve performance.

The audio amplifier type operation lends itself admirably to a simple broadcast receiver. To investigate this application more thoroughly, such a receiver has been built. For those interested in duplicating it, a description follows:

Transistor Receiver

One or two transistors may be used in this receiver (Fig. 4.). The first unit is utilized as a detector/amplifier. The second transistor is connected as a grounded emitter amplifier.

The first unit is capable of delivering adequate earphone volume so that the second stage can be eliminated if it is desired to reduce the cost of the receiver. Although the experimental receiver shown has been built on

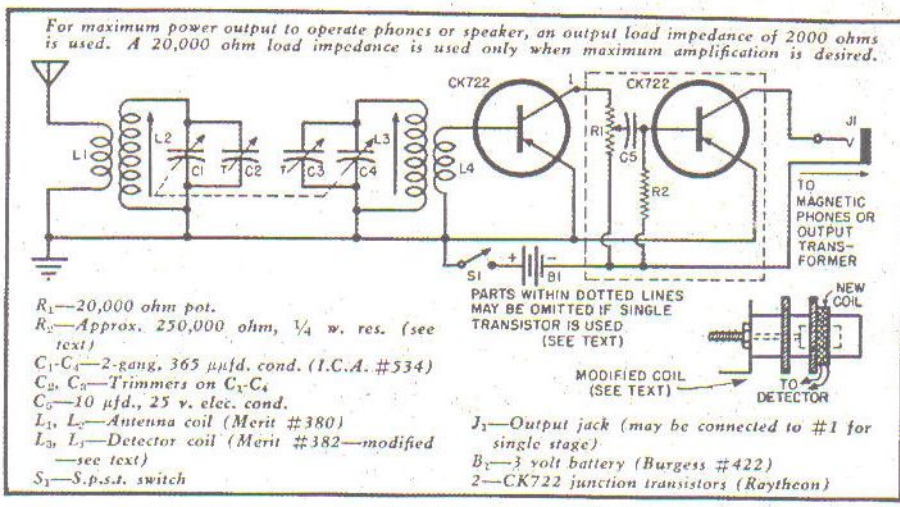


Fig. 4. Diagram of transistor receiver. A single unit may be used if desired. See text.

metal, obviously it could be built using a wooden case without affecting its performance.

In the Boston area where this receiver has been operated, the two tuned circuits have given more than adequate selectivity to separate the local stations. An antenna of 50 feet and a good ground made possible reception of stations over approximately a 15 mile radius. The importance of a good antenna and ground, particularly in an area somewhat remote from high power broadcast stations, cannot be overemphasized.

The two circuits are coupled through mutual coupling existing by physically placing the coils close together, one inch separation center-to-center is recommended. The detector coil must be modified to connect to the transistor detector/amplifier. The antenna coil portion of the *Merit* type 382 should be carefully removed. It can be slid off the end of the form without damage to the coils after unsoldering the leads. The wire from this antenna coil may be used to scramble wind 50

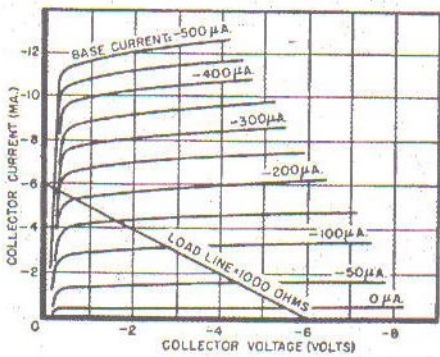


Fig. 5. $I_c/E_c/I_b$ curves for the CK722.

turns on the 382 form, tight against the first pi of the tuning coil. (See Fig. 4). This detector coil can be cemented in place with a good coil dope, such as *Amphenol* 912.

The amplifier is connected in the grounded emitter type circuit. The advantages of this circuit are that only one battery is required and that it has a higher input impedance than the

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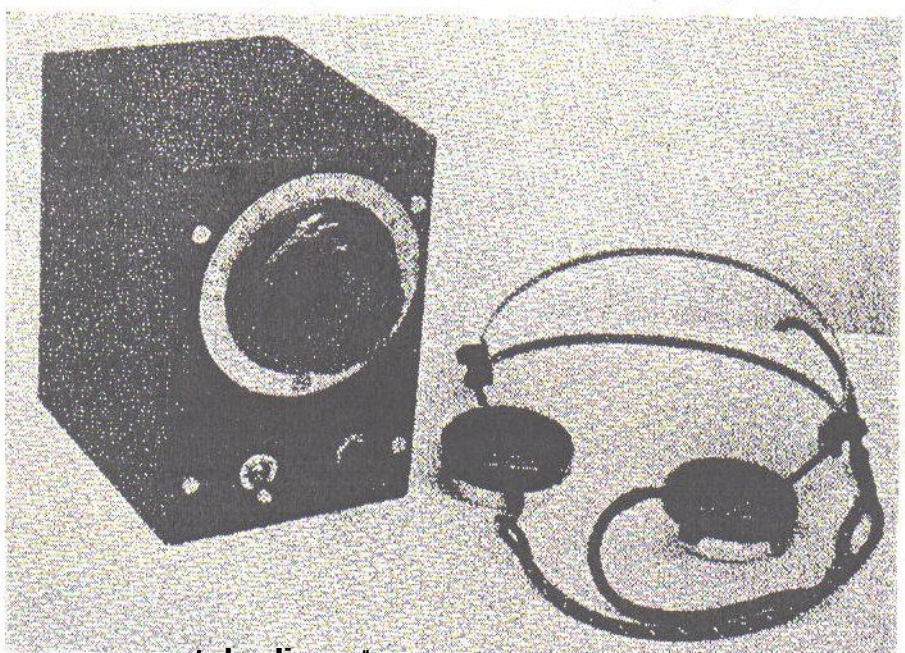
Over-all view of the experimental transistor receiver showing accessory headphones.



way, South Africa) *Radio Hue* can be heard in Japan very well but with some hum around 0500-0800 on 7.205; closes 0800 with identification in French. *Radio Dalat* is at fair strength, sometimes QRM'd by *Radio Moscow*, on 7.265, closes 0630 daily except Sat. when runs to 0700; has French on Sat. 0630-0700. (Wada, Japanese Short-Wave Club)

Iraq—*Radio Baghdad*, 11.724A, noted 1145 with Arabic music; at 1200 clock chimes the hour, call, then news in Arabic. (Pearce, England) Should have *English* 1415-1500A closedown.

Italy — Rome, 9.575A, noted with news to North America 1930, good level. (Niblack, Ind.) Noted on 6.010 in Russian 2215-2245. (Lubell, N.Y.)

Jamaica—Due to requests of listeners, *Radio Jamaica* has announced it no longer changes from 4.950 to 3.360 at 1515 but remains on 4.950 to 2300 closedown; opens 0600. (Levy, N.Y., others) Station officials list this one as 5 kw., using omnidirectional antenna. (Baitzel, N.J.)

Japan—AFRS, Tokyo, noted parallel over JKL, 9.605, and JKI, 11.825, at 0100. (Stein, Calif.) Good signal over JKL, 4.860, at 0825, moderate fading. (Ballou, Calif.)

Mexico—A Mexican has been noted on 9.575 identifying as "La Hora

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Transistor Receiver

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grounded base circuit. The value of R_2 should be chosen so that the collector current is about 1 milliampere. The collector current of the detector/amplifier transistor will depend on the strength of the received signal but will average about 200 microamperes with a strong signal.

Battery life with only one transistor will probably equal the shelf life of the battery. With two transistors, the life will depend on average hourly use but should be at least 100 hours for two penlight type cells.

If magnetic phones are used, they may be connected directly in the collector of either transistor. Low impedance phones or a speaker will require the use of a matching transformer. A load impedance of 2000 ohms in the output stage is correct for the voltage and current indicated.

Alignment is perfectly straightforward but should be done carefully in order to realize maximum sensitivity. Any good service oscillator or signals from broadcast stations may be used to accomplish the alignment. The collector current of the first transistor is a good indication of resonance. The parallel trimmers are used to line the set up on the high frequency end and the slugs on the low frequency end.

The output power of this receiver is about 1.5 milliwatts and is sufficient for adequate earphone volume. An efficient speaker can be connected to the output circuit and adequate volume will be obtained in a quiet location. However, the addition of a class B output stage to drive the loudspeaker is recommended.

The receiver, as originally built and as shown in the photos, included a CK705 germanium rectifier and several parts associated with this rectifier. The junction transistors were used as straight audio amplifiers. Tests proved that the diode was not essential and in fact provided no advantage, so the receiver has been modified to the circuit of Fig. 4.

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Under chassis view of the transistor receiver designed around the CK722 transistor.