VOLUME II

RAYTHEON

transistor applications

ALL NEW CIRCUITS

WITH COMPLETE HOW-TO-DO-IT INSTRUCTIONS

Application sections on RECEIVERS ★ AMPLIFIERS
HAM GEAR ★ SERVICE EQUIPMENT ★ GADGETS

PRICE **50¢**

Preface

Some time ago the RAYTHEON MANUFACTURING COMPANY published a booklet covering more than fifty practical applications of their popular PNP junction transistors. Including many circuits by top technical writers, this first booklet has proven extremely popular with practical engineers, Hams, experimenters, students, and electronics hobbyists, and has reached the amazing distribution of well over 100,000 copies!!

But along with the increasing popularity of RAYTHEON's *TRANSISTOR APPLICATIONS* has come a need for a broader volume . . . a booklet covering transistor applications from a general, rather than a specific, viewpoint . . . a booklet covering practical laboratory techniques and shop practice as well as circuit applications . . . in short, a booklet which would equip the experimenter to branch out "on his own" instead of rigorously following published circuits.

It was to fill this need that the present booklet was written. It is neither the author's nor the publisher's intention that this volume replace the earlier TRANSISTOR APPLICATIONS but, rather, that it serve to supplement and to reinforce the first volume. By so doing, it is hoped that the reader's interests, as well as his practical knowledge, will be broadened, and that his technical knowledge will be strengthened with increased practical "know-how".

In keeping with the booklet's intended goal as an outline of practical methods, a special effort has been made to cover data of value to the experimenter and hobbyist. Thus, theory has been minimized and laboratory and shop practice emphasized. In addition, general information on etched circuit techniques has been included, for these techniques are of especial interest to transistor experimenters. Not only is there an historical relationship between "printed (etched) circuits" and transistors, but etched circuit methods provide a convenient, almost natural, way of assembling many transistor circuits.

The reader desiring additional theoretical background will find it worthwhile to refer to one or more of the books, booklets, and magazines listed in the reference data section of this book. All of these are currently published and available through regular sources.

When using the circuits shown or described in this volume, the reader should remember that the inclusion of any circuit does not constitute a license to use that circuit or to manufacture equipment employing that circuit, in whole or in part, where the circuit is covered by an existing Letters Patent. Such license can be issued only by the legal owner of the covering Patent or by his assignee or agent.

— THE AUTHOR.

April, 1957.

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Introduction

THE TRANSISTOR is young . . . but a mere baby as electronic components go, yet the blinding blast and thundering roar of an atomic explosion seems almost mild compared to the potential effects of the transistor on electronic technology and, through electronics, on modern Industry and Communications as a whole.

To the beginner or newcomer in electronics, a transistor may seem to be just another component, like a transformer, vacuum tube, resistor or capacitor. And, although it is physically different from a vacuum tube, it is similar in application in that both are amplifying devices. But the beginner will often prefer the transistor for his experimental work because of its low cost, ready availability, and special properties which suit it to simple circuitry.

On the other hand, the *Old-Timer* in electronics, even though he may be comparatively young in years, can seldom get over his astonishment at the, to him, almost amazing characteristics of these tiny devices. But a fraction of the size and weight of his familiar "stand-by", the vacuum tube, these minute units can not only tackle virtually all the jobs of the earlier device, but can do their work while requiring but an infinitesimal amount of power. Power-wise, transistors may be said to "eat like birds".

No one characteristic of the transistor, whether it be its small physical size, minute power requirements, low noise, reliability, almost fantastic resistance to vibration and shock, moderate cost, light weight, or great versatility, can be credited with its tremendous impact on electronics. Rather, it is the combination of all of these characteristics in a single device, coupled with the ability to amplify signals and a long, almost infinite, potential service life.

The schematic symbol for a PNP junction transistor is shown in Fig. 1–1(a). The three electrodes are *emitter*, *base*, and *collector*, with these roughly, but not exactly, analogous to the three electrodes of a triode vacuum tube . . . *cathode*, *grid*, and *plate*, respectively.

Compared to a vacuum tube, the construction of a transistor is, physically, rather simple. A vacuum tube
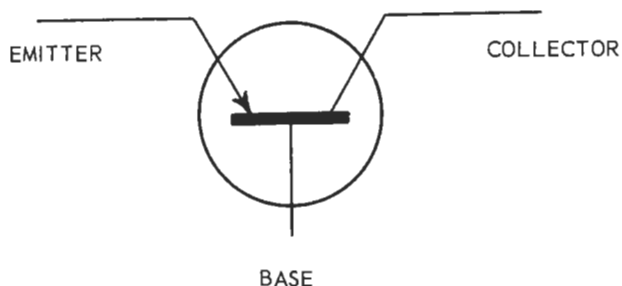
EMITTER   COLLECTOR

BASE

FIG. 1-1(a)

is made up from many, many separate components . . . insulated filament wire, coated cathode cylinder, one or more grid assemblies, a carefully shaped plate assembly, shield pieces, getter, spacers, support rods, insulators, connecting strips and leads, and other parts, with each component manufactured to precise tolerances from different materials, and all assembled with extreme care.

By contrast, a triode junction transistor is a single crystal of material which, internally, is essentially a three-layered "sandwich" . . . the "layers" are not separate, however, but simply areas within the crystal which have slightly different electrical characteristics. This *classical* "sandwich" construction of the junction transistor is shown schematically in Fig. 1–1(b).
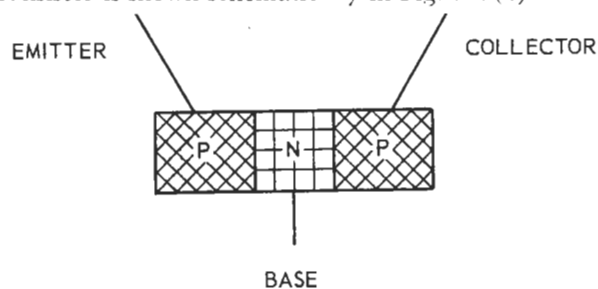
EMITTER   COLLECTOR

P   N   P

BASE

FIG. 1-1(b)

Transistors are made from a class of materials known as *semiconductors*. These are substances with properties intermediate between that of a *conductor*, such as silver, and an *insulator*, such as porcelain. A semiconductor may act either as a conductor, allowing an easy flow of electric current, or as an insulator, virtually blocking current flow, depending on various physical influences, such as electric fields, heat, or light.

In a conductor, an electric current flow is a movement of free *electrons* through the substance. In a semiconductor, a current flow may also be made up of free electrons. However, in contrast to the current flow in a conductor, the electric current in a semiconductor may include a movement of *holes*. A *hole* is a deficiency in the molecular structure of the semiconductor and represents the *absence* of an electron. Since an electron has a *negative* charge, a hole, representing the absence of an electron, acts like a *positive* charge and, in fact, the transfer of holes from one molecule to another is nearly equivalent to a movement of positively charged particles through the material.

If the "particle" concentration in a given semiconductor consists of both electrons and holes in about equal numbers, the material is called an *intrinsic* semiconductor. If the holes predominate, the material is called a *positive* or *P-type* semiconductor. And if the electrons predominate, the substance is called a *negative*

or *N-type* semiconductor. An intrinsic semiconductor may be given either P or N characteristics by adding various substances, called *impurities*, to the basic material. A *donor* impurity results in B characteristics; an *acceptor* impurity in P characteristics.

In a triode transistor, the three "layers" making up the device are alternately P-type and N-type materials, as indicated in Fig. 1–1(b). The area in which the two types of semiconductors meet (or the area where one type changes to another) is called the *junction*, hence the name "junction transistor". If the outer layers are P-type materials, then the device is called a *PNP* transistor; on the other hand, if the outer layers are N-type materials, the device is an *NPN* transistor. Thus, triode junction transistors have two junctions and three electrodes.

Electrically, a semiconductor junction is a unilateral device . . . that is, it will pass current easily in one direction, but will offer considerable resistance to current flow in the reversed direction, much like a rectifier or diode vacuum tube. Hence, a single semiconductor junction may be used as a *diode*. A semiconductor diode, like a vacuum tube diode, has two electrodes . . . a *cathode* and an anode. Generally, only the cathode is identified.

In practical circuits, D.C. voltages are applied to the three electrodes of the transistor. In operation, an electric current flow through the base and one of the other electrodes will affect the current through any other pair of electrodes. For example, the base-emitter current flow may be used to control the emitter-collector current. With a different circuit arrangement, the base-collector current might be used to control the collector-emitter current. The D.C. polarities used depend on the type of transistor.

The steady (D.C.) current through an electrode is commonly called the *bias* current. A varying current, whether external or internal, may be called the *signal* current. Often, the word "current" is dropped off . . . , thus, we may speak of "base bias", "collector bias". "input signal", or "output signal".
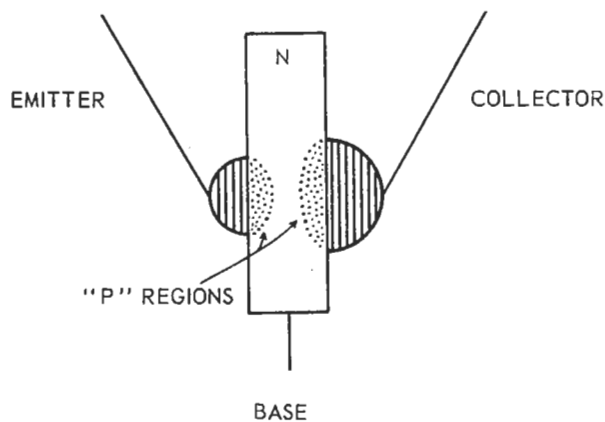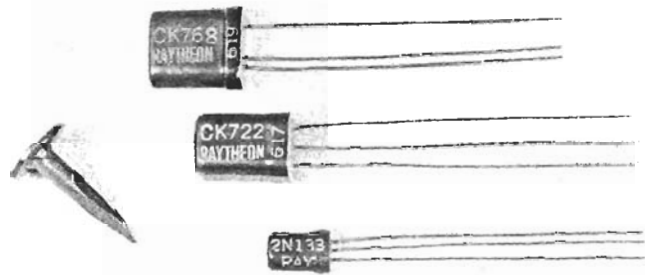

FIG. 1-1(c)

FIG. 1-2

RAYTHEON TRANSISTORS

The actual construction of a RAYTHEON transistor differs from the classical "sandwich" arrangement shown in Fig. 1–1(b). Rather, it more nearly approaches the construction shown schematically in Fig. 1–1(c). Acceptor materials are alloyed to either side of a thin slab of N-type semiconductor material. The acceptor diffuses into the N-type semiconductor, converting small regions into a P-type material. The resultant is a PNP transistor.

During manufacture, RAYTHEON transistors are encapsulated in a special plastic, then hermetically sealed in small metal cases. Any of several case sizes and shapes may be used, depending on the particular transistor type and its intended application. The three most popular cases in current use are on the three transistors shown in Fig. 1–2. The small carpet tack shown in the photo is included simply to indicate relative sizes.

The electrode lead connections used in RAYTHEON semiconductor devices are diagrammed in Fig. 1–3. Two types of transistor lead arrangements are employed. An unequal spacing of leads, as in Fig. 1–3(a), indicates that the transistor is designed to fit into a standard 5-pin "in-line" subminiature tube socket when the full length leads are cut down to approximately one-quarter inch. Typical units using this arrangement include types 2N63, 2N64, 2N65, 2N106, 2N111 (CK759), 2N112 (CK760), 2N113 (CK761), CK766, CK768, CK790, CK791, and CK793. With this arrangement, electrodes are identified by the spacing of the leads.

With the second arrangement used, leads are equally spaced and the collector electrode is identified by a small red dot on the case, as in Fig. 1–3(b). The center lead is the base. This lead arrangement is encountered in three different cases. The larger case is used on types CK721 and CK722. The smaller (subminiature) case, with a closer, but still equal, spacing of leads, is used on such types as 2N130, 2N131, 2N132, 2N133, and 2N138. Finally, a small case, with "heat sink" attached, is used on type CK751.

RAYTHEON semiconductor diode lead connections are identified in Figs. 1–3(c) and 1–3(d).
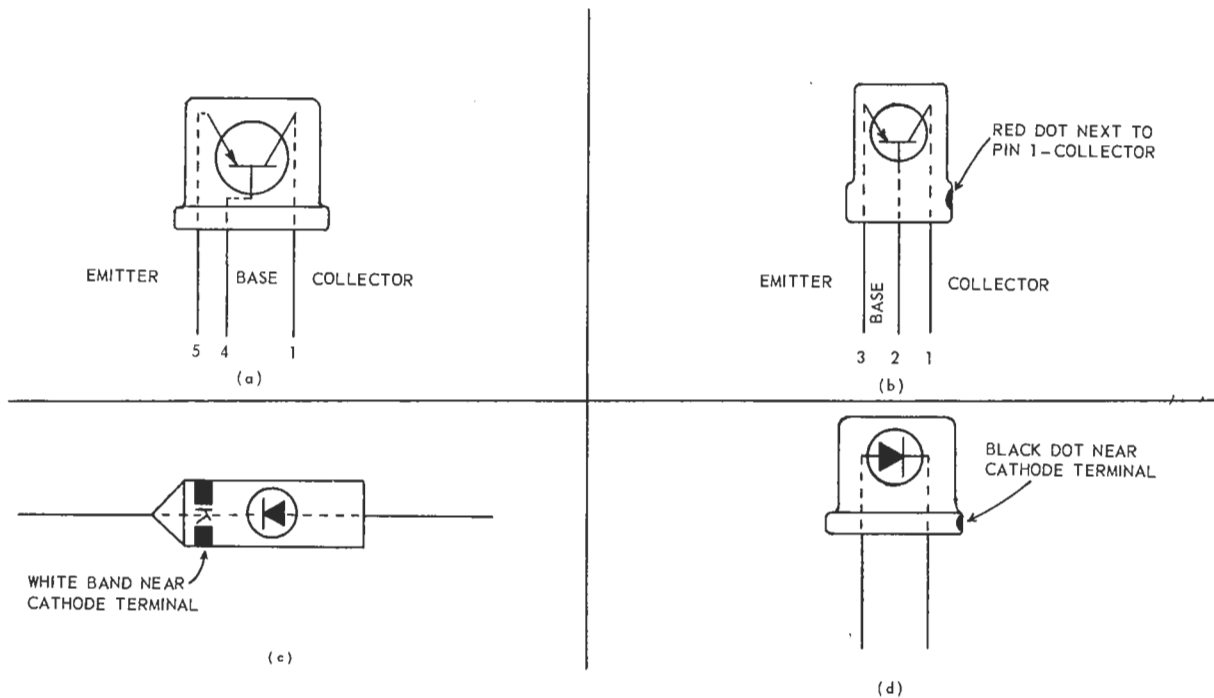
EMITTER   BASE   COLLECTOR

5 4   1

(a)

RED DOT NEXT TO
PIN 1 – COLLECTOR

EMITTER   BASE COLLECTOR

3 2 1

(b)

WHITE BAND NEAR
CATHODE TERMINAL

(c)

BLACK DOT NEAR
CATHODE TERMINAL

(d)

FIG. 1-3

Selecting Transistor Types

RAYTHEON transistors are manufactured in a wide variety of types, to meet virtually every need of the experimenter, circuit designer, or equipment manufacturer. The final choice of a type for a particular application is the responsibility of the Circuit Design Engineer, and should be made only after a detailed study of circuit requirements and a careful comparison of basic type specifications. A chart of condensed RAYTHEON transistor specifications is included in the Reference Data Section to aid the designer in this work.

Generally speaking, RAYTHEON types CK721, CK722, and CK768 are intended primarily for experimental applications. Types CK721 and CK722 are designed for use in audio and low frequency R.F. circuits. Type CK768 is a low-cost R.F. transistor.

Commercial low frequency types include the 2N63, 2N64, 2N65, 2N106, 2N130, 2N131, 2N132, and 2N133. Of these, the first four units are supplied in a larger case size, the last four in subminiature cases. Except for the 2N106 and 2N133, the specifications of all low frequency types are similar, with the major difference being in their gain and base resistance ratings. Types 2N106 and 2N133 are low noise types. The 2N133, particularly, has an unusually low noise level and is especially suited for applications in high gain audio circuits.

While almost any RAYTHEON transistor can deliver a small amount of power, if needed, types 2N138 and CK751 are designed primarily for audio power output applications. A pair of type 2N138, operated in push-pull, can deliver as much as 100 milliwatts. A pair of type CK751, strapped to a metal chassis, can deliver approximately a half-watt of audio power (500 milliwatts).

RAYTHEON transistors designed for R.F. applications in radio receivers include types 2N111, 2N112, CK766, 2N111A, 2N112A and CK766A. These units are suitable for use as front-end converters and as intermediate frequency (I.F.) amplifiers at 455 KC. In a typical circuit, the type 2N111A will supply approximately 28 db gain at 455 KC.

Special purpose RAYTHEON transistors include types 2N113 and 2N114, especially suitable for high frequency switching applications in computers, and *symmetrical* types CK870 and CK871. The *symmetrical* transistor is a comparatively new type and is designed with interchangeable collector and emitter electrodes.

The transistor types mentioned above are all manufactured using *germanium* as the basic semiconductor element and are suitable for all normal applications where the junction temperature will not exceed 85°C. Where high temperatures are likely to be encountered, RAYTHEON's *silicon* transistor types should be chosen. These include types CK790, CK791, and CK793. The maximum junction temperature for these types is 135°C. Like RAYTHEON's germanium transistors, the silicon types are PNP units.

RAYTHEON is carrying out a continuing program of semiconductor product research and development and will introduce new transistor types from time to time, as well as improved versions of older types. Because of this, equipment designers will find it worthwhile to check with RAYTHEON before "freezing" any new transistorized circuit design.

(3)

PRACTICAL CIRCUIT DESIGN

Without question, the average experimenter and home-builder enjoys assembling a new receiver, amplifier or gadget just as much as he enjoys working with it after construction is finished. There is a real thrill in putting together a new piece of electronic equipment . . . a thrill that is shared both by the Professional Technician who assembles a complex instrument and by the Boy Scout who puts together his first crystal receiver. It is a thrill like that which every creative individual feels as he works on a new project, whether he be an artist, a poet, a writer, a sculptor, or an electronics hobbyist.

But there is a much greater thrill in designing and assembling a new circuit, or in redesigning an existing circuit to meet special needs, than there is in slavishly following a published diagram. Unfortunately, advanced circuit design requires considerable technical training and experience. A full discussion of such design methods would be beyond the intended scope of this booklet. However, if certain fundamental techniques are learned, there is no reason why the average experienced experimenter can't undertake *and solve* many practical circuit design problems.

Of course, quite aside from the original design of new circuits, the experimenter will find that a knowledge of such techniques is an invaluable aid to his understanding of circuit operation and, in addition, quite useful in "troubleshooting" experimental circuits he may assemble.

The application of Practical Circuit Design methods requires, first of all, a general understanding of transistor operation . . . a knowledge of the different types of basic circuits and their characteristics, an idea of how variations in circuit values will affect transistor operation, and a fair amount of laboratory or bench "know-how". Here, then, are a few tips on *Practical Circuit Design* . . .

Circuit Configurations

The transistor is basically an amplifying device. As such, it has a "pair" of *Input* and a pair of *Output* terminals. But since it has only three electrodes, one of these electrodes must be common to both the input and output

circuits. And this gives us the three *basic* transistor circuit configurations . . . *common-emitter*, *common-base*, and *common-collector*. These three circuits are shown in Figs. 2–1(a), 2–1(b), and 2–1(c), respectively.

In actual practice, the common electrode, whether it be the emitter, base, or collector, is often connected to circuit "ground". Hence these circuits are often called . . . *grounded-emitter*, *grounded-base*, and *grounded-collector* configurations. In some texts and magazine articles, the expressions "common" and "grounded" are used interchangeably, *even if the common electrode is not connected to ground.*

The common-emitter circuit, shown in Fig. 2–1(a), provides the highest gain (amplification) of the three circuits. In operation, an input signal is coupled through capacitor C_1 to the base-emitter circuit, appearing across input load resistor R_1. The amplified output signal, appearing across collector load resistor R_2, is taken off through D.C. blocking capacitor C_2. Base bias current is supplied through R_1 by power supply battery B1. This battery also supplies collector current. In some instances, separate base bias and collector bias batteries may be used.

A signal phase reversal takes place in the common-emitter circuit, with the signal across collector load R_2 180° out-of-phase with the input signal. As far as circuit impedances are concerned, the common-emitter circuit has a moderate *input* impedance . . . from about 100 to 2000 ohms, and a high *output* impedance, from 5,000 to 50,000 ohms in most cases. The maximum circuit gain possible, with a given transistor, depends on the *beta* (β) of the transistor . . . the higher the beta, the higher the gain.

The common-base circuit, shown in Fig. 2–1(b), can provide considerable gain, although its maximum gain is less than that of the common-emitter circuit. In operation, the input signal is coupled through capacitor C_1 to the emitter-base circuit, appearing across emitter resistor R_1. The amplified output signal appears across collector load impedance R_2. Capacitor C_2 serves as a D.C. blocking capacitor for the output. Base bias current
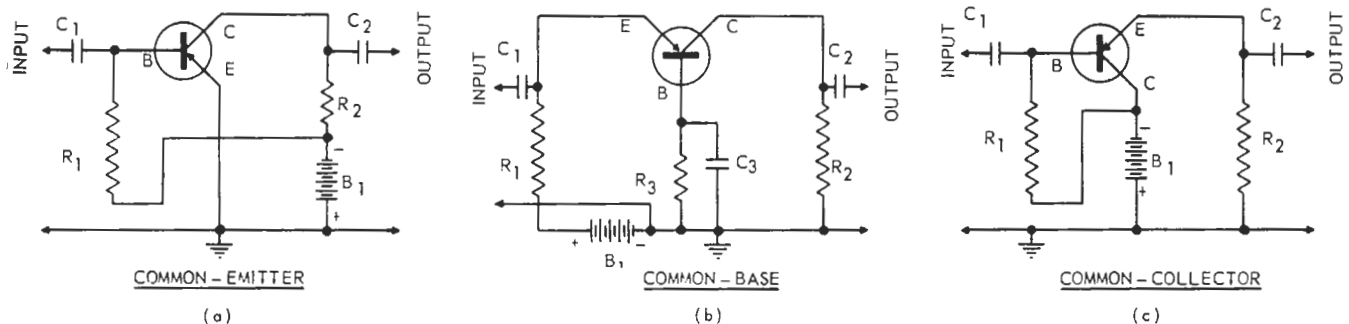

COMMON – EMITTER
(a)

COMMON – BASE
(b)

COMMON – COLLECTOR
(c)

FIG. 2-1

is supplied through R_3, by-passed by C_3. Although all operating power is supplied by a single battery, B1, many designers prefer to use separate batteries in the emitter-base and base-collector circuits.

There is no phase reversal in this circuit . . . the output signal is *in phase* with the input signal. The common-base circuit features a low input impedance, generally from 10 to 200 ohms, and a high output impedance . . . from about 10,000 to 100,000 ohms.

Finally, the common-collector configuration, shown in Fig. 2–1(c), provides a voltage "gain" *of less than 1.0*. In operation, the input signal is coupled through C_1 to the base-collector circuit, appearing across base resistor R_1. The output signal appears across emitter load resistor R_2. As in the first two circuits, C_2 serves as a D.C. blocking capacitor for the output. With the single-battery (B1) power supply shown, base bias is supplied through R_1.

The common-collector circuit, like the common-base configuration, does not introduce a phase reversal . . . the output signal is in phase with the input. Unlike the first two circuit configurations, the common-collector arrangement features a *high* input impedance, generally from 10,000 to 100,000 ohms, depending on the size of the emitter load impedance (R_2). The larger R_2, the higher the input impedance. The common-collector's output impedance, on the other hand, is moderate to low . . . typical circuits may have output impedances ranging from 50 to 5,000 ohms.

While both the common-emitter and common-base circuits are generally used as *amplifiers*, the "step-down" impedance characteristic of the common-collector circuit, plus the fact that its voltage gain is less than one, makes it attractive as an *impedance matching* circuit. It is in this application that the common-collector finds its greatest utility.

For convenience, resistive output load impedances (R_2) were used in each of the three basic circuit configurations shown in Fig. 2–1. In actual practice, the output load might be some other impedance. In the case of an R.F. or I.F. amplifier, R_2 might be replaced with a tuned circuit; in an audio amplifier, R_2 might be replaced by an inductance choke or the primary of an interstage transformer.

In all three of the circuit configurations illustrated in Fig. 2–1, the D.C. polarities shown are for PNP transistors.

Amplifier Classes

One of the most important characteristics of any amplifier circuit, whether a vacuum tube or a transistor serves as the actual amplifying device, is its *Class* of operation. Amplifiers can be arbitrarily grouped into one of four general Classes.

In a *Class A* amplifier, the operating conditions are such that every part of the input signal affects the output signal. Thus, the output signal becomes simply an enlarged "copy" of the input signal waveshape. Class A amplifiers are used in the majority of experimental and commercial circuit applications.

In a *Class AB* amplifier, the output is controlled *by more than half, but less than the whole* input signal. In a typical example, a portion of the positive peak of an amplified signal may have no control on the amplitude and/or waveshape of the output of the amplifier.

In a *Class B* amplifier, the output is controlled by essentially half of the input signal. For example, if a sine-wave signal is applied to a Class B amplifier, only the negative-going (or positive-going) half of the signal will control the output.

Finally, in a *Class C* amplifier, the output is controlled by less than half of the applied signal. In general, only the negative (or positive) peak of the input signal will determine output.

From an application viewpoint, most audio or R.F. amplifiers are operated Class A, while push-pull (to be discussed later) *power* amplifiers are often operated either Class AB or Class B. Class C amplifiers are used in oscillators and, on occasion, in R.F. power amplifiers. Where a resistive output load is used, the output of a Class B or Class C amplifier is essentially a series of pulses, regardless of the input signal characteristics.

In transistor circuits, the Class of operation is generally determined by the base bias current. A small bias current can provide Class A operation. A very small or essentially "zero" bias establishes the conditions for Class AB or Class B operation. And, finally, a "reversed" bias is required for Class C amplifiers.

From a circuit efficiency viewpoint, the Class A amplifier is the least efficient in terms of D.C. input versus A.C. output power. The "ideal" figure for a Class A amplifier is 50% efficiency, but this figure cannot be reached in practice. A well-designed Class C amplifier, on the other hand, may approach 98% efficiency.

D.C. Amplifiers

The simplest circuit application for a transistor is as a direct-coupled direct current (D.C.) amplifier. A basic D.C. amplifier, using the common-emitter circuit configuration, is illustrated in Fig. 2–2(a).

In operation, a steady D.C. voltage is applied between the emitter and collector electrodes (through the LOAD) by power supply battery B1. With the base-emitter circuit open, very little collector current can flow. Now, when an external voltage is applied to the base-emitter circuit (base negative), a small base current flow can take place. This permits a *much larger* collector current to flow through the collector LOAD. Thus, the transis-
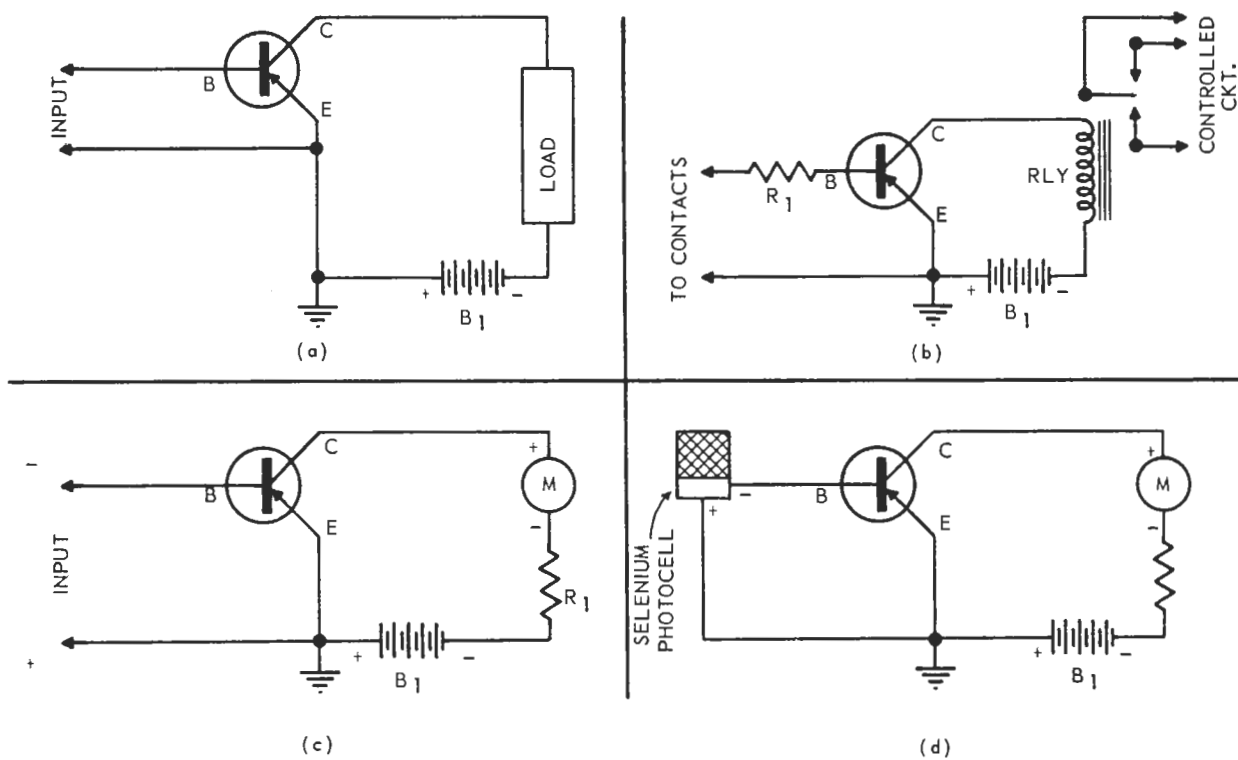
(a)   (b)   (c)   (d)

FIG. 2-2

tor serves to "amplify" the input current. The amount of amplification that takes place is directly proportional to the *beta* of the transistor used. With typical RAYTHEON transistors, the collector current may be from 10 to 50 times the base current.

In practical circuits, the LOAD may be any D.C. actuated device . . . a solenoid, relay, or meter. Typical applications are shown in Figs. 2-2(b), 2-2(c) and 2-2(d).

A sensitive electronic relay is shown in Fig. 2-2(b). In this case, the LOAD is a moderately sensitive electromagnetic relay (RLY) and the single power supply battery (B1) also serves as a source of base bias current. In operation, when the control "contacts" are closed, base bias current can flow, with its value determined by B1 and series resistor R_1. A much larger collector current flow results and operates the relay. Since the collector current flow may be from 10 to 50 times the base current, the effective "sensitivity" of the relay is increased by a similar factor.

For example, let us say that the relay requires a current of 1.5 *milliamperes* for operation and, further, that the RAYTHEON transistor used provides a gain of fifteen with the particular circuit values employed. In this case, the base current (established by R_1) need be only 100 *microamperes*.

The basic circuit for a transistorized Meter Amplifier is given in Fig. 2-2(c). In this case, a small external current is measured by passing it through the transistor's base-emitter circuit and noting the much larger reading of collector current on the meter (M). The meter may be recalibrated to take the transistor's gain into account . . . or, if preferred, a Multiplying Factor used. Series resistor R_1 is included to protect the meter from accidental overloads.

Adding a "self-generating" selenium photocell to the basic Meter Amplifier converts the instrument into a sensitive Light Meter. This circuit is given in Fig. 2-2(d). The negative lead of the photocell connects to the base of the PNP transistor, the positive lead to the emitter. In operation, light falling on the photocell develops a small current which, in turn, serves as the base bias for the transistor. With the transistor's gain as a multiplying factor, the meter (M) indicates a much larger current.

Breadboarding & Bias Measurements

One of the first, and most important, steps in the practical design of a new transistor circuit is the assembly and bench test of a *breadboard* model. The "breadboard" is a quickly wired and rough assembled circuit which is an electrical, though not mechanical, duplicate of the tentative design. Often, adjustable or variable resistors and other components are used in assembling the model. These are varied until desired circuit performance is obtained and then are replaced with standard fixed value parts.

While the circuit is in the breadboard stage, bias currents and interelectrode voltages may be checked to
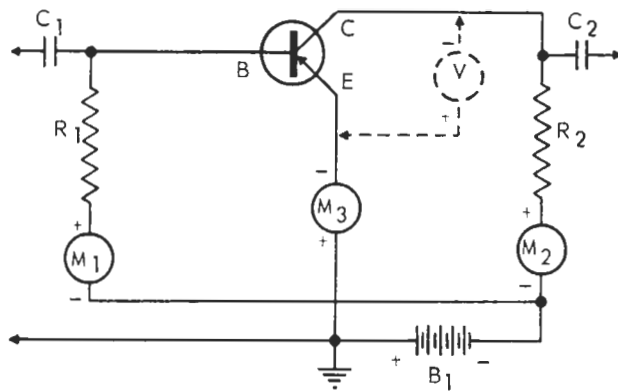
(6)

FIG. 2-3

FIG. 2-4

insure that the transistor's maximum ratings are not exceeded. In addition, several transistors of a given type may be tried in the circuit as a check on transistor interchangeability. Power supply voltages may be varied to see if any component values are especially critical.

Basic measurements in a common-emitter amplifier stage are diagrammed in Fig. 2–3 while a breadboard model of a special transistor circuit is shown in Fig. 2–4.

Referring to Fig. 2–3, M_1 is used to check base bias current, M_2 to measure collector current, and M_3 to check emitter current. A Voltmeter (V), shown dotted, is used for checking interelectrode voltages. The battery and meter D.C. polarities shown are for a PNP transistor. Depending on the transistor and its intended operation, M_1 may be an 0-100 or 0-500 Microammeter, and M_2 and M_3 may be 0-5 or 0-25 Milliammeters. Voltmeter range will depend on the battery (B1) used. In typical transistor circuits, B1 may supply from 1.5 to 30 volts.

As experience is acquired, the experimenter may find that he can estimate basic component values without too much difficulty. For example, referring to Fig. 2–3, for a typical transistor, R_1's value will generally fall between 100K and 1 Megohm, R_2's value will be from 3.3K to 47K, and B1 will supply from 1.5 to 9 volts.

Interstage Coupling

If more gain is needed for a particular application than can be obtained from a single transistor stage, two or more stages may be *cascaded*. Two popular interstage coupling techniques are shown in Fig. 2–5(a) and 2–5(b).

The simplest method, shown in Fig. 2–5(a), uses a capacitor (C_1) to connect the "output" of one stage to the "input" of the succeeding stage. In addition to its simplicity, this method offers the advantages of low cost and ease of application. But *capacity-coupling* has one serious drawback. Where the coupled stages have unequal input and output impedances, a severe loss of signal may occur due to the resulting impedance mis-
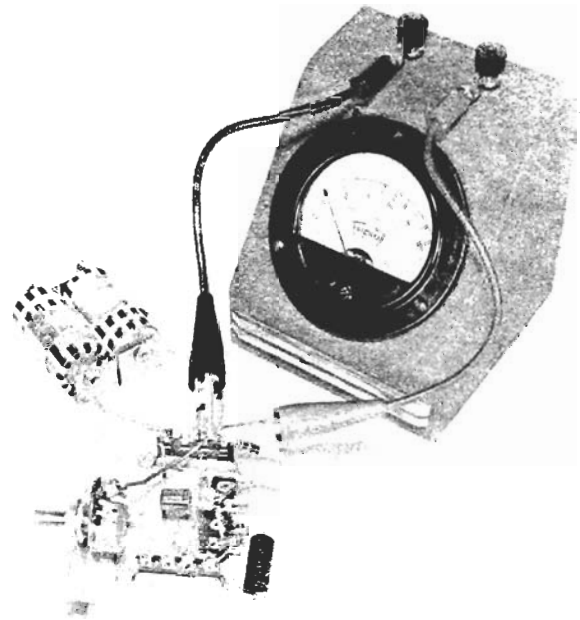
match. Maximum signal transfer occurs where the *source* impedance (driving stage) equals the *load* impedance (input of driven stage).

As may be recalled, the input impedance of a common-emitter stage is around 1,000 ohms . . . its output impedance is about 10,000 ohms. Thus, the use of capacity-coupling between common-emitter stages will result in a considerable signal loss.

One alternative is to alternate common-emitter and common-collector stages. The common-emitter has a moderate input and high output impedance; the common-collector amplifier, on the other hand, has a high input and moderate output impedance. For practical purposes, the output of a common-emitter stage matches the input of a common-collector stage . . . and vice-versa. With such an arrangement, capacity-coupling may be used between stages with little, if any, signal loss.

Another alternative is shown in Fig. 2–5(b). A step-down transformer is used to match circuit impedances.
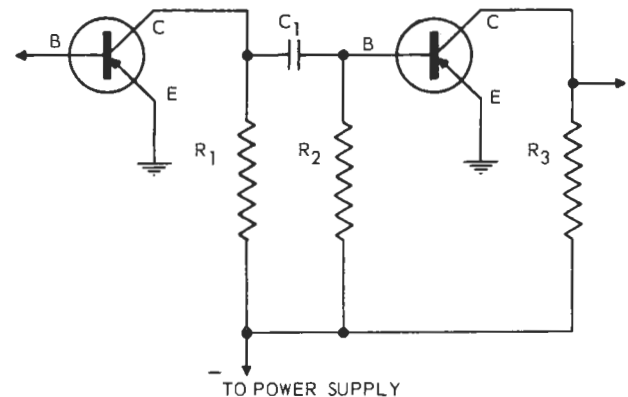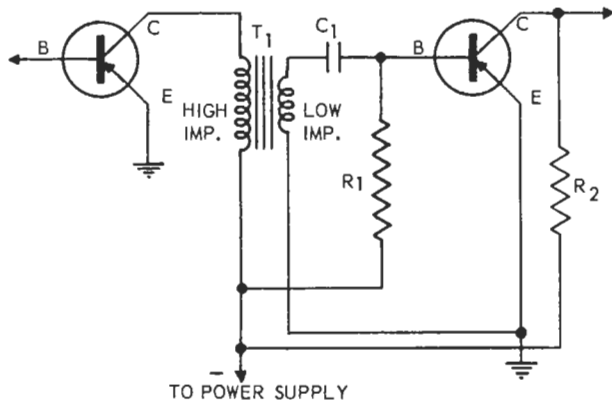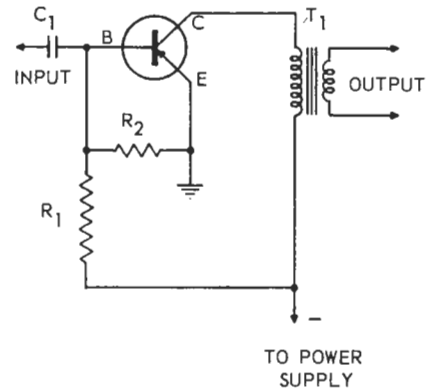

TO POWER SUPPLY

FIG. 2-5(a)

FIG. 2-5(b)

FIG. 2-6(a)

With *transformer-coupling*, it is possible to use all common-emitter stages in a multi-stage amplifier without appreciable interstage signal loss.

In practice, T_1 has a high impedance primary, a low to moderate impedance secondary. Capacitor C_1 is used as a D.C. blocking capacitor and prevents a short of the base bias current through the secondary of T_1. Base bias for the second stage is supplied through R_1. In typical circuits, T_1's primary impedance will fall between 5,000 and 25,000 ohms; its secondary impedance will be in the range of 500 to 2,000 ohms.

In most transistor circuits, D.C. blocking, interstage coupling, and signal by-pass capacitors will have moderately large values. In audio circuits, values may range as high as several microfarads. In R.F. and I.F. circuits, as high as 0.1 Mfd.

Power Amplifiers

In terms of strictest definition, all transistor amplifiers are power amplifiers. In most cases, however, the amount of power handled is negligible and the term *Power Amplifier* is reserved for stages which drive electromechanical devices, such as loudspeakers or solenoids, or which furnish a moderate to substantial amount of power for radio broadcast or similar applications.

Except for actual component values and the type of load, a transistor Power Amplifier circuit is almost identical to other amplifiers, and any of the three basic circuit configurations may be used. Two popular common-emitter Power Amplifier circuits are illustrated in Figs. 2–6(a) and 2–6(b).

A *single-ended* amplifier is shown in Fig. 2–6(a). A single transistor is used as a Class A amplifier and is transformer-coupled to the load . . . a loudspeaker, for example. Base bias current is supplied by voltage divider R_1–R_2. Where music or voice signals are handled, single-ended amplifiers are *always* operated in Class A.

A *push-pull* amplifier is shown in Fig. 2–6(b). For a given transistor type, a push-pull circuit will deliver considerably more power than a single-ended circuit, but

requires two input (drive) signals which are 180° out-of-phase with each other. In Fig. 2–6(b), these two signals are supplied by the center-tapped secondary winding of transformer T_1. Base bias for both transistors is supplied by voltage divider R_1–R_2.

In contrast to a single-ended amplifier, a push-pull circuit may be operated either Class A, Class AB, or Class B. Of the three classes of operation, Class A is the least efficient and will deliver the least power, but it introduces the least distortion. Class B is the most efficient, will deliver the maximum power output (for a given transistor), but requires the most signal drive and introduces the greatest distortion. As a result, Class AB operation is frequently chosen as the best compromise between the high efficiency of Class B operation and the distortion-free characteristics of Class A. To obtain Class AB operation, the base bias current is adjusted (by varying the ratio of R_1 to R_2) so that a small collector current flows under "no signal" conditions.

In general, a Power Amplifier has a lower output impedance than other amplifiers and requires larger operating voltages and currents. And, of course, it can handle greater signal levels without danger of overload.
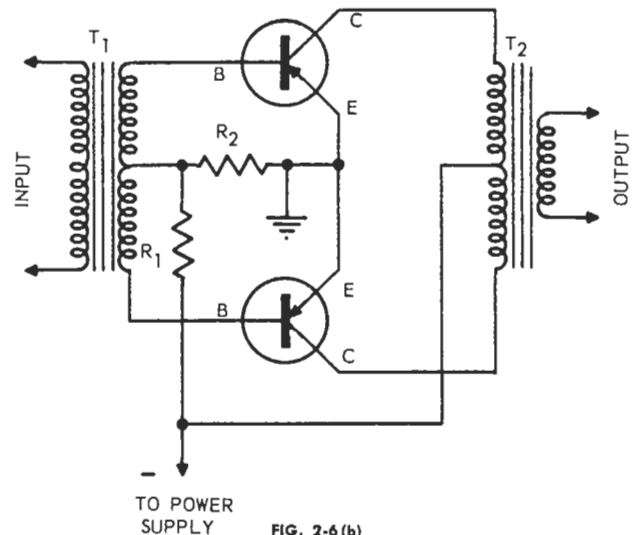

TO POWER SUPPLY   FIG. 2-6(b)

(8)

Almost any transistor can deliver some power, but when a power level in excess of, say, 30 milliwatts is required, it is best to use an especially designed Power Transistor such as RAYTHEON type CK751.

Since moderate power levels are handled, internal heat generation is a characteristic of all Power Amplifiers, regardless of their Class of operation and efficiency. If the transistor's junction temperature rises too rapidly, or to too high a level, circuit operation will suffer. In extreme cases, the transistor itself may be damaged. To avoid this, power transistors may be clamped to a metal chassis or "heat sink" which serves to conduct heat away from the transistor's body. A small metal cable clamp may be used to hold the transistor. The RAY-THEON type CK751 has an integral metal clamp for this application.

D.C. Stabilization

The electrical resistance of a semiconductor junction may vary considerably with its temperature. Therefore, it is logical to expect that the interelectrode resistances of transistors, which depend for their operation on the characteristics of semiconductors, may also vary with temperature.

From this, we can see that if the basic operating conditions of a transistor stage are determined primarily by its interelectrode D.C. resistances, then the performance of that stage will vary with temperature *unless the circuit is especially compensated for temperature variations.* In general, the technique for doing this is to minimize the effects of temperature on operating bias currents and thus to stabilize the D.C. operating conditions of the transistor. Doing this also provides a highly desirable secondary result . . . it makes the final circuit design much less susceptible to differences in individual transistors and improves transistor interchangeability.

Basic circuits for adding D.C. Stabilization to common-emitter amplifiers are illustrated in Figs. 2–7(b) and 2–7(c). For comparison purposes, an "unstabilized" circuit is shown in Fig. 2–7(a).

In order to see how temperature can affect circuit operation, let us refer first to Fig. 2–7(a). Here, we have a simple common-emitter amplifier with a resistive output load (R_2). In operation, signals are coupled to the base-emitter circuit through input capacitor C_1, and the amplified output signal, appearing across load resistor R_2, is obtained through D.C. blocking capacitor C_2. Operating power is supplied by battery B1.

The base bias current for this stage is determined by B1 and the *combined* resistance of base resistor R_1 *and* the *base-emitter resistance* of the transistor. Tracing through the circuit, we find that R_1 and the base-emitter circuit are in series across power supply battery B1. Thus, any changes in the base-emitter resistance, as may occur with temperature variations, may result in appreciable changes in base bias current, and, of course, a shift in the operating characteristics of the stage.

The effect of the base-emitter resistance on bias current may be reduced by shunting these electrodes with a fixed resistor, as shown in Fig. 2–7(b). R_3 is connected between the base and emitter electrodes of the transistor. With this arrangement, a moderate degree of stabilization is obtained and base bias current is determined by a resistive voltage divider (R_1–R_3) instead of by a series resistor alone.

Even better D.C. Stabilization may be obtained by adding a by-passed emitter resistor (R_4), as shown in Fig. 2–7(c). With this arrangement, a steady increase in emitter-collector current will develop a voltage (across R_4) with a polarity which tends to oppose, and to reduce, the base bias current, thus restoring the emitter-collector current to near its "normal" value.

In practical versions of all three circuits (Fig. 2–7), R_2 may have values of 4,700 to 25,000 ohms, C_1 and C_2 may have values of 1 to 10 Mfd., and B1 may supply from 1.5 to 12 volts. In the "unstabilized" circuit given in Fig. 2–7(a), R_1 may have a value ranging from 150K to 470K, depending on the voltage of B1 and the transistor used. With the partially stabilized circuit of Fig. 2–7(b), R_1 may have values from 10K to 100K, R_3 values from 500 to 2500 ohms. Finally, in the circuit given in Fig. 2–7(c), R_1 may have values from 10K to 47K, R_3 values from 100 to 1,000 ohms, and R_4 values from 47 to 470 ohms, with C_3 values from 6 to 80 Mfd., depending on the size of R_4 and the desired low frequency response of the circuit. The smaller R_4, the larger the value of C_3. These values are for audio circuits. Re-
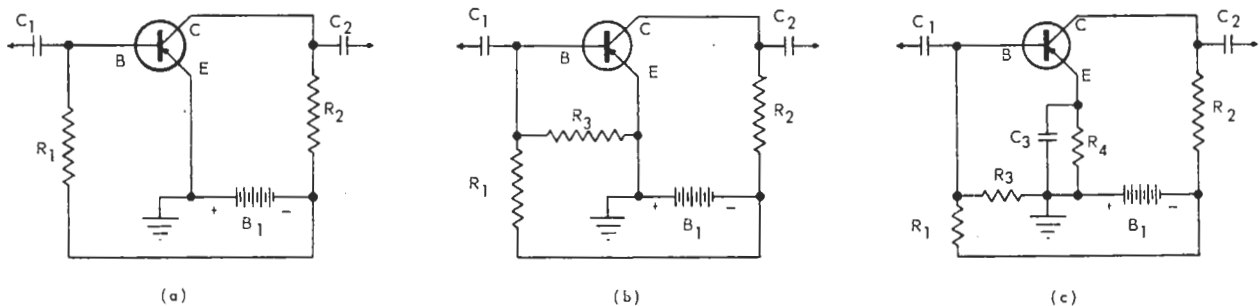

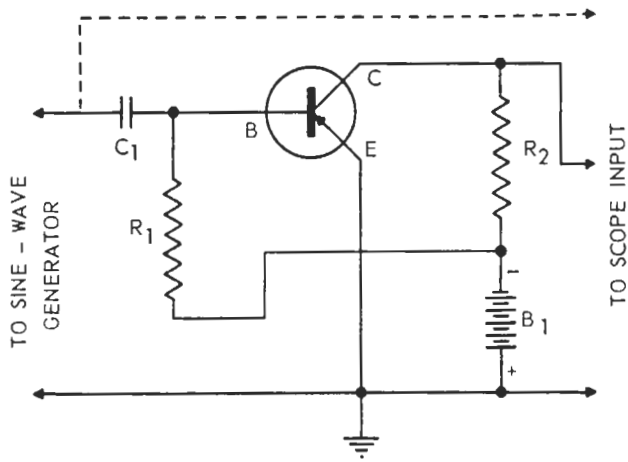(a)   (b)   (c)

FIG. 2-7

FIG. 2-8

sistance values would be similar in R.F. and I.F. circuits, but capacitor values would range from 0.01 to 0.05 Mfd.

D.C. Stabilization is more important in commercial and industrial applications than in experimental circuits and gadgets. Because of this, the average experimenter may prefer to use the simple biasing system illustrated in Fig. 2-7(a) for most of his work, even though it does not provide full circuit stabilization.

Distortion

In an "ideal" amplifier, the waveshape of the output signal should be *identical* to the waveshape of the input signal, except for amplitude. If the amplifier, whether it is a single stage or several cascaded stages, is non-linear, there will be a change, or *distortion*, in the output signal
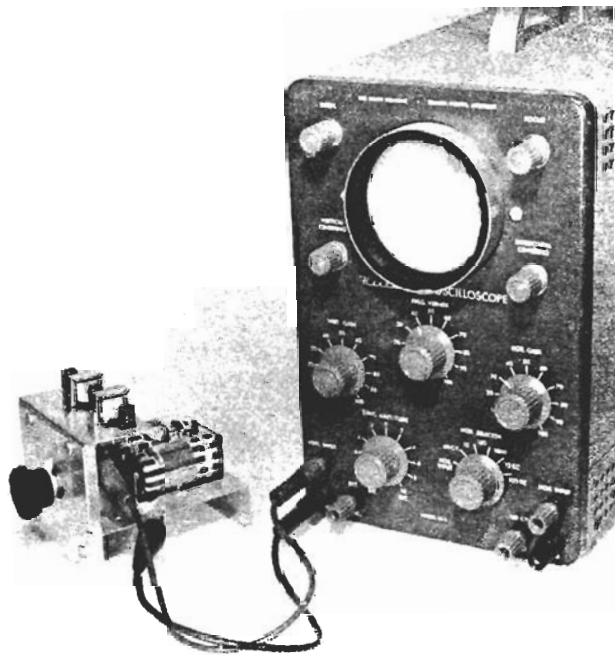

FIG. 2-9. Using oscilloscope to check distortion

waveshape. In a transistor amplifier, distortion may be caused by improper D.C. operating bias currents, incorrect circuit values, and an excessively strong input signal as well as by defective components.

One technique for checking a transistor amplifier for distortion is diagrammed in Fig. 2-8, while typical signal waveshapes (waveforms) are illustrated in Fig. 2-10.

A *Sine-Wave Generator* is connected to the input of the amplifier. A cathode ray *Oscilloscope* is used to observe the input (dotted line, Fig. 2-8) and output signal waveshapes. If the amplifier is operating properly, the output signal should be an enlarged duplicate of the input signal and should approximate the sine-wave shown in Fig. 2-10(a).

If one side of the output signal's waveshape is flattened, as shown in Fig. 2-10(b), it indicates that the base bias current is incorrect for the power supply voltage and other circuit values used. With a PNP transistor, too *low* a bias current will cause a flattening of the output waveshape when the *input* signal swings in a *positive* direction. The positive-going input signal quickly reduces the base signal current (and hence collector current) to zero and the peak is "clipped" off, leaving a flattened output waveshape.

On the other hand, too *high* a bias current may cause a flattening of the output waveshape when the *input* signal swings in a *negative* direction. A negative-going input signal increases the base and collector currents. If the increase is sufficient to drop the available supply voltage across the collector load resistor, there can be no further increase in collector current, and the signal peak is "clipped" off. For example, referring to Fig. 2-8, if the bias current is high, and a strong signal is applied to the input, B1's entire voltage may be dropped across collector load R_2 *before* the signal peak is reached . . . and the signal waveshape is flattened at this point.

Since there is a 180° phase reversal in a common-emitter amplifier, the output signal will exhibit its flattening on the *opposite* side when compared to the input signal. Thus, summing up, too *low* a base bias current will cause a flattening (or "clipping") of the *negative* side of the *output* signal, while too *high* a base bias will cause clipping on the *positive* side of the *output* waveform. In either case, the base bias current should be readjusted . . . and, in some cases, it may be necessary to change other circuit values as well. With the circuit shown in Fig. 2-8, the base bias current can be increased by lowering the value of base resistor R_1 . . . decreased by using a larger resistor here.

There is another basic type of distortion that may be encountered . . . this is shown in Fig. 2-10(c). *Both* peaks of the signal waveshape are flattened (or clipped). This indicates that the amplifier is overloaded . . . is being driven with too large a signal. The solution here is to reduce the maximum input signal, or to change to a
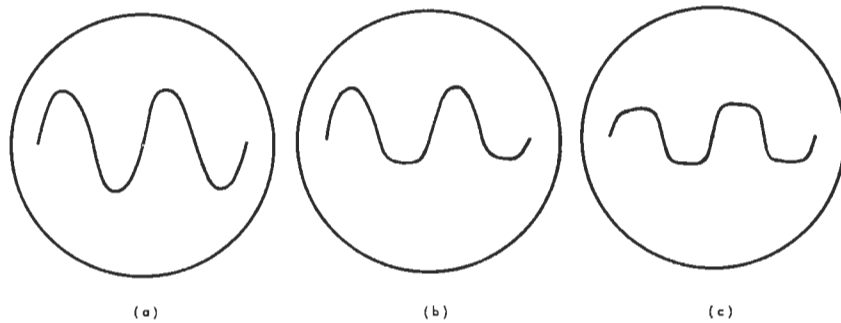
(10)

FIG. 2-10

different transistor or circuit arrangement which can handle the larger signal without overloading. If only minor overloading is encountered, the condition often may be minimized by using a higher voltage battery (B1) and readjusting base bias currents and the load resistor (R₂, Fig. 2-8).

Oscillators

An Oscillator is basically an amplifier with an in-phase signal coupled from its "output" back to its "input" circuit. Either capacity-coupling or transformer-coupling may be used provided an in-phase signal is obtained and provided that the fed back signal is of sufficient amplitude to overcome possible circuit losses.

A resistance-capacity coupled oscillator is shown in Fig. 2-11(a). The common-emitter circuit configuration is used, and, since there is a 180° phase-shift in a common-emitter amplifier, two stages are required to obtain the in-phase feedback signal necessary for oscillation. Either C_1 or C_2 may be taken as the interstage coupling capacitor . . . in which case, the other capacitor serves to provide feedback. R_1 and R_3 are the base bias resistors and R_2 and R_4 the collector load resistors for the first and second stages, respectively. Power is supplied by a single battery, B1.

The operating frequency is determined by R–C *time constants* rather than by an L–C tuned circuit. The signal obtained is basically a series of sharp-sided pulses which are rich in harmonics. Thus, the circuit is roughly analogous to a vacuum tube *multivibrator*.

Another basic oscillator circuit is shown in Fig. 2-11(b). Again, the common-emitter circuit configuration is used, but a small transformer, consisting of coupled coils L_1 and L_2, provides an additional 180° signal phase-shift, and the feedback signal, obtained from L_2, has the in-phase relationship necessary to insure oscillation. The ratio of L_1 and L_2 may be adjusted to match the different impedances of the collector and base circuits.

In this circuit, the operating frequency is established by using a tuned circuit as the transistor's collector load. Primary coil L_1 is tuned by shunt capacitor C_1. Base bias current is supplied through resistor R_1, by-passed by C_3. The power supply battery, B1, is by-passed by capacitor C_2

Since the feedback coil, L_2, serves to "tickle" the circuit into oscillation, this particular arrangement is often called a *Tickler Feedback Oscillator*. If proper component values are chosen, this circuit . . . Fig. 2-11(b) . . . may be used as an oscillator at either audio or radio frequencies.
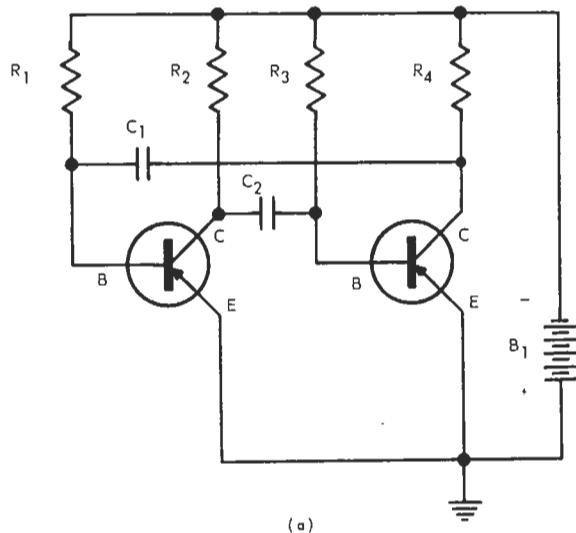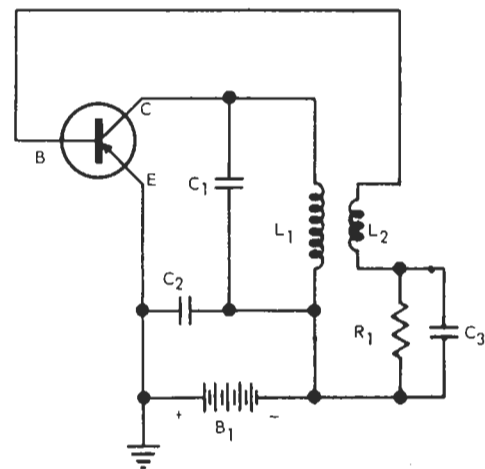
FIG. 2-11

(11)

INSTALLATION & WIRING

From a strictly mechanical viewpoint, the transistor is one of the most rugged of electronic components. Standard production units can safely withstand shocks comparable to that of being fired from a mortar. Unfortunately, transistors, by their very nature, are not as rugged electrically as they are mechanically, and may be permanently damaged by high voltages, current overloads, and excessive heat. The maximum voltage and current ratings vary with different transistor types . . . see the Reference Data Section of this booklet.

Transistors, in common with all semiconductor devices, are especially susceptible to heat damage, whether the heat is generated internally by excessive power dissipation, or applied externally, as by a soldering iron. The *maximum* junction temperature for RAYTHEON germanium transistors is 85°C (185°F), while for RAYTHEON silicon transistors it is 135°C.

In order to minimize the loss of transistors due to accidental damage, the experimenter will find it worthwhile to adopt a few "rules of good wiring practice". These should be observed scrupulously in all experimental, circuit assembly, and bench work until their use becomes almost automatic . . . a sort of "second nature".

To avoid electrical damage, the worker should always double-check power supply polarities *before* installing transistors or switching power "on". And when working with new experimental circuits, he should use meters to keep a steady check as work progresses and to insure that maximum current and interelectrode voltage ratings are not exceeded. If possible, he should check out untried circuits with low voltages before applying final operating voltages. He should take care to avoid circuits which might develop unusual surge voltages or high transient currents. And, finally, he should check other electrical components, such as capacitors, transformers, etc., prior to installation, especially where breakdowns in those components could apply excessive voltages to the transistors used.

To avoid heat damage, the experimenter should not install transistors near hot vacuum tubes, power resistors, lamp bulbs, or similar components which operate at high temperatures. Portable transistorized equipment should not be placed on or close to hot radiators or space heaters, nor exposed to excessive heat from photoflood lamps or the Sun. Special precautions are necessary when soldering transistors into circuits . . . and when soldering other components close to installed transistors. Finally, transistors should *not* be operated at or near maximum ratings under high ambient temperature conditions.

Transistor Installation

All RAYTHEON transistors are designed to provide the individual user with a choice of installation methods.
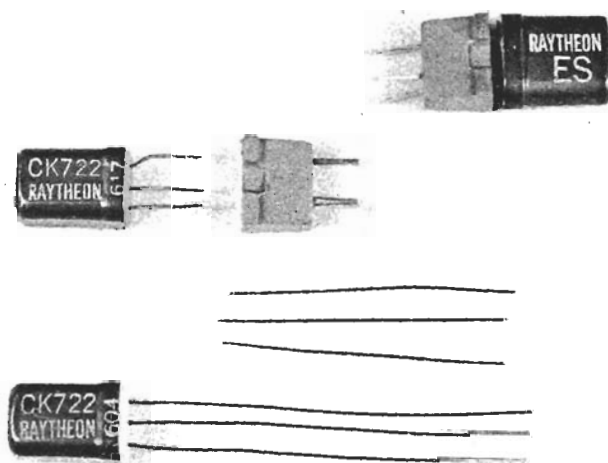

FIG. 3-1

The moderately long leads normally supplied may be clipped to approximately one-quarter inch with diagonal cutters and the transistors inserted in standard "in-line" type transistor or subminiature tube sockets. With some types, such as the CK722, CK721 and 2N138, the leads may have to be bent slightly to insure a snug fit. Long-nose pliers may be used for this job. See Fig. 3-1.

On the other hand, if the experimenter prefers, he can solder his RAYTHEON transistors in place as a permanent part of a circuit. In this case, the leads may be cut to any convenient length but, normally, should be left as long as is practicable without interfering with other wiring or circuit performance. Sharp bends in the leads close to the transistor's body should be avoided. And special care must be taken to avoid overheating the transistor as it is soldered in position.
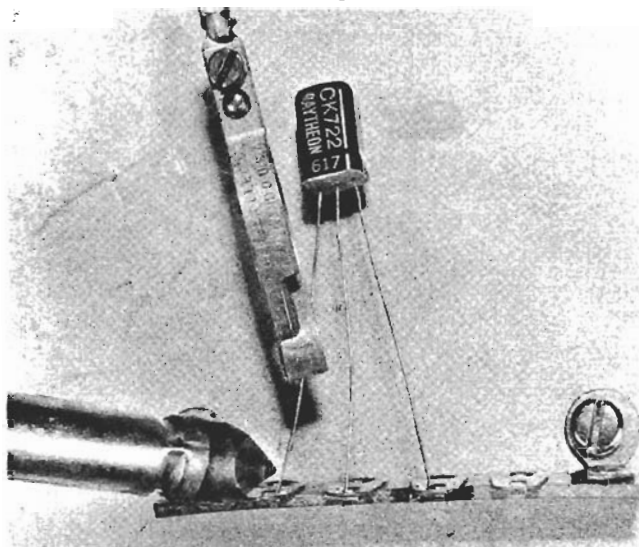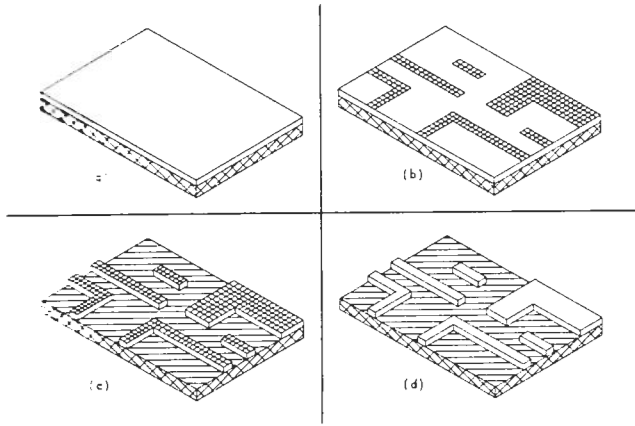

FIG. 3-2

FIG. 3-3

One technique is to grasp the lead being soldered with a pair of long-nose pliers at a point between the body of the transistor and the connection terminal. An alternative method is shown in Fig. 3-2; here, a metal clip is attached to the lead. With either method, the extra mass of metal (pliers or clip) serves as a "heat sink" to conduct excess heat away from the transistor proper and thus to prevent damage. The actual soldering is completed as quickly as possible using a hot, clean, well-tinned soldering iron.

PRINTED CIRCUITS

In recent years, many Radio and Television equipment manufacturers have adopted a relatively new wiring technique. The older "conventional" point-to-point wiring, used since the early days of electronics, is being replaced by flat *circuit boards* on which the inter-circuit wiring becomes a two-dimensional pattern of conductors. The use of these boards speeds circuit wiring, lowers manufacturing costs, often improves circuit performance, insures accuracy in wiring (since all wiring is identical), and simplifies the use of automatic assembly methods.

Several methods are used for preparing the individual circuit boards, depending on the requirements of the individual manufacturer. These include the use of dies to cut out metal foil conducting patterns, which are then mounted on an insulated base material, the use of stencils through which conducting patterns of liquid metal may be sprayed on the base, the use of conventional printing equipment and metallic inks, and the use of etching techniques. Since the final result, regardless of actual production method, is a nearly two-dimensional conducting pattern which is analogous to a printed pattern, the completed boards are generally called *Printed Circuits*.

Transistors and Printed Circuits found widespread industrial use at about the same time, so there is a definite historical, if not technical, relationship between these two items. And Printed Circuits are especially well-suited to the manufacture of transistorized products. First, of course, they fit well into the miniaturized equipment in which transistors are frequently used. In addition, the transistors themselves, because of their small size, ruggedness, light weight, and long life, fit well into the permanent installation techniques used in assembling components to Printed Circuit boards.

While the use of Printed Circuits offers many technical and financial advantages to the large manufacturer, these new methods need not be confined just to the mass producer. Experimenters and electronics hobbyists can apply these techniques to the construction of their home-built equipment and, in some cases, can lay out and prepare a circuit board, then assemble the final equipment in less time than is required for more "conventional" construction. To this end, several manufacturers have designed and made up special *Printed Circuit Kits* for experimenters and home-builders. These kits are available through most local and Mail Order RAYTHEON transistor distributors.

Etched Circuits

Of the various types of Printed Circuit boards, the most popular with manufacturers is also the simplest to produce from the experimenter's viewpoint . . . the *etched circuit*. The basic steps in the production of an etched circuit board are illustrated in Fig. 3-3.

The "raw material" used is shown schematically in Fig. 3-3(a), with the vertical scale rather exaggerated for illustration purposes. It consists of a base of insulating material, such as laminated phenolic or fiber, with a thin metal foil (usually copper) bonded to one or both sides. *Single-clad* board (foil on one side only) is shown.

The metal-clad board is coated with an acid-resistant material, called the *resist*, in the desired circuit pattern, as shown in Fig. 3-3(b). Next, the board is placed in a special chemical solution which etches (eats) away all the unprotected metal, leaving only the desired circuit pattern as a thin layer of foil covered by resist. The board, at this stage, is shown in Fig. 3-3(c). Where copper-clad boards are used, the etching chemical, called the *etchant*, is generally a solution of ferric chloride in water. The final step is to remove the resist, leaving the shiny metal foil bonded to the board, as shown in Fig. 3-3(d). This board may be machined (drilled, etc.) and used in assembling the final equipment.

The experimenter wishing to prepare his own etched circuit boards will find it advisable to obtain one of the standard "kits" mentioned previously. These are available in various sizes and, as a minimum, include pieces
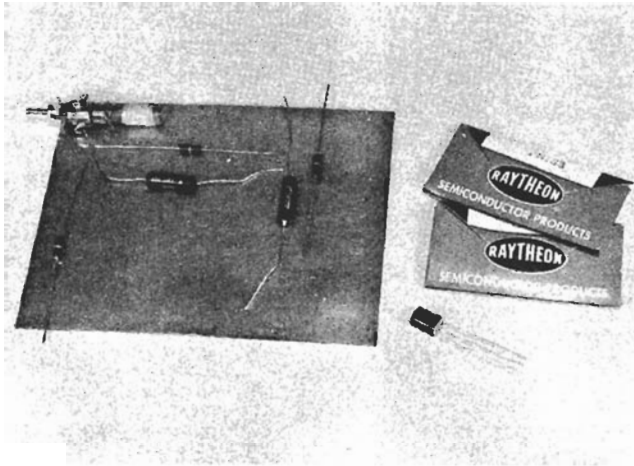
FIG. 3-4

FIG. 3-6

of copperclad board, some type of resist, and a supply of etchant, together with detailed step-by-step instructions. Larger kits may include both single-clad and double-clad boards, several types of resist, etchant materials, and an assortment of special Printed Circuit components, such as sockets and connectors.

One of the first steps to preparing an etched circuit is to design the circuit pattern *layout* needed. This may be done by referring to the schematic diagram for the intended project and working up an actual wiring arrangement, using the actual parts and electrical components to be used in final construction. This technique is illustrated in Fig. 3-4.

With the layout designed, the board should be vigorously scrubbed with powdered pumice or abrasive cleanser. This will remove grease, dirt and corrosion and will slightly roughen the metal surface, preparing the board for final etching.

The resist is applied to the prepared board in the desired circuit pattern. Any of several resists may be used, as shown in Fig. 3-5. *Scotch* electrical tape, cut to strips with a sharp knife, scapel, or razor blade, makes
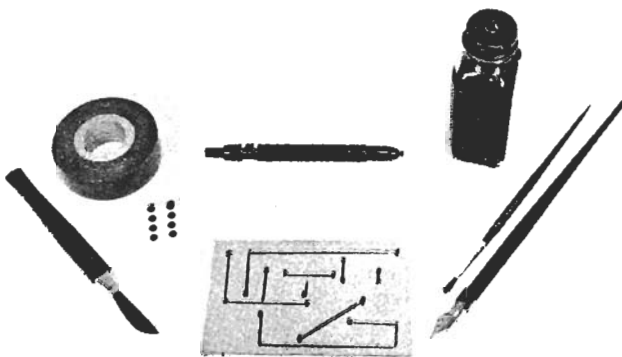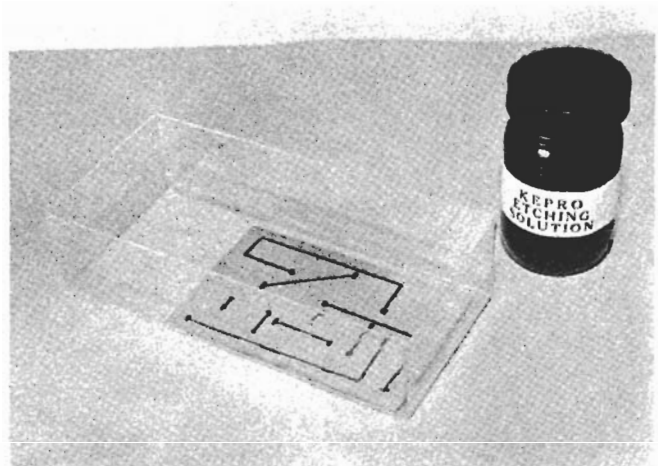
an excellent resist, but it must be bonded tightly to the metal foil. Asphalt based ink, applied with a *Speedball* pen or fine brush, is another popular resist. Finally, some manufacturers have introduced ball-point pens filled with a special acid resistant ink . . . these may be used, if available.

When applying the resist, the original layout must be followed closely, but the worker can exercise some choice in selecting conductor widths and spacing. However, individual conductors *should be not less* than 1/32″ wide, with *at least* 1/32″ spacing between separate conductors. Cross-overs may be minimized by using a layout which permits the components to serve this purpose. Where needed, they can be added later during final wiring . . . short pieces of hook-up wire may be used for this. Use round dots for connection points.

With the resist applied, and the pattern double-checked for errors, the board can be etched. This step is shown in Fig. 3-6. A plastic, *Pyrex* glass, or enameled tray may be used for this operation. The board is covered with about a half-inch of etchant and the tray rocked gently until the exposed copper is eaten away. Afterwards, the board is rinsed in clear water, and the resist removed. Tape resist is peeled off, while ink resists may be removed by buffing with steel wool.

After etching and cleaning, mounting holes are drilled for components and connecting wires, then the parts are mounted and soldered in position, completing the circuit. Special care must be exercised when soldering to avoid damage to the thin copper foil. Excessive heat will cause the foil to "peel". A clean, hot, small tip soldering iron should be used, with the actual soldering completed as quickly as possible. For best results, the experimenter will find it advisable to practice on a damaged or discarded circuit board until the proper "knack" is acquired.
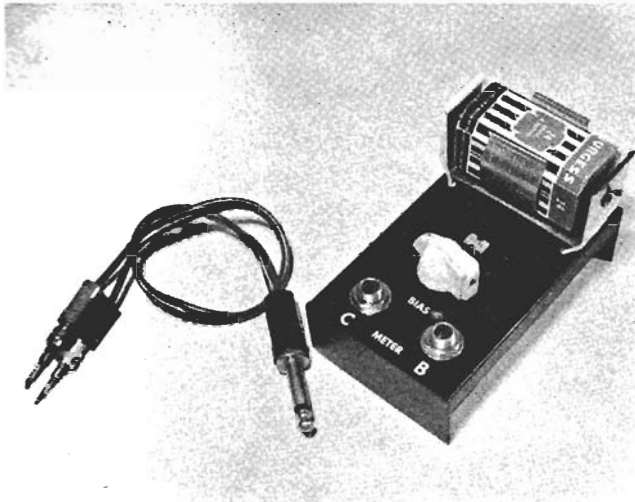

FIG. 3-5

FIG. 3-7

FIG. 3-8

TESTING TRANSISTORS

With a long, nearly infinite, potential service life, transistors should seldom "go bad" in properly designed circuits. In fact, there's a good chance that the transistors will outlast every other electronic component used in the average piece of transistorized electronic equipment. But transistors used in experimental work may be subjected to accidental overloads or, on occasion, used at levels past their maximum ratings. Under such conditions, it is inevitable that a transistor will be damaged from time to time. Therefore, the experimenter needs some simple and reliable system for checking his transistors.

Today, there are a good many Transistor Testers available to the laboratory worker. These range from simple, low-cost "build-it-yourself" kit type instruments to large, complex, and very expensive *Transistor Analyzers* which can check virtually every transistor parameter with a high degree of accuracy. However, as far as the average experimenter is concerned, it is enough to know whether his transistors are *Open* or *Shorted* ("leaky"), and their relative *Gain*. For these tests, the easily-built *Transistor Checker* shown in Fig. 3-7 is satisfactory; the schematic diagram of the instrument is given in Fig. 3-8.

Referring to Fig. 3-8, J_1 and J_2 are closed circuit jacks, Sw_1 a SPST switch mounted on R_1, a 2 Megohm potentiometer having a linear taper, and B1 is a six volt battery (*Burgess* type Z4). Resistors R_2 and R_3 are half-watt units. A standard in-line type socket is provided for the transistor.

Construction of the *Transistor Checker* is simple and straightforward. The layout of the model should be clear from the above and below chassis views given in Figs. 3-7
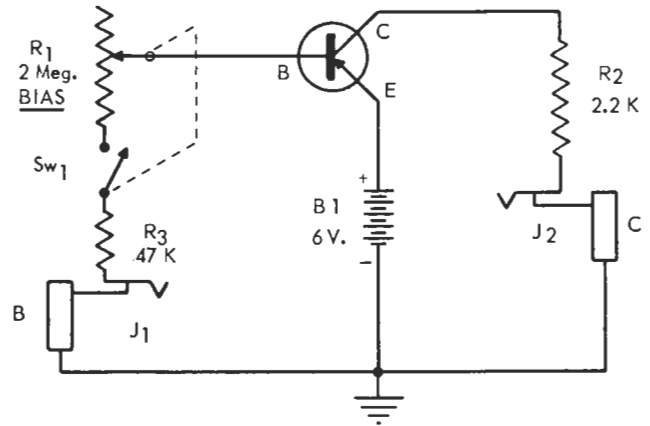
and 3-9, respectively. Neither layout nor lead dress are critical, however, and the individual builder should feel free to follow his own inclinations on these matters. The model was assembled on a small aluminum chassis, with the top surface painted black, and standard white "Decals" used to label the jacks (J_1, J_2) and BIAS control (R_1). The connections to R_1 should be such that this potentiometer is in its *maximum* resistance position when Sw_1 is *open*. An *Austincraft* battery box is provided for B1.

In operation, a standard Milliammeter with a full-scale range of at least 2 milliamperes is connected to the "C" (*Collector*) jack, J_2. See Fig. 3-10. The PNP transistor to be checked is inserted in its socket. With Sw_1 open, the meter will indicate the *collector current with an open base circuit*. Normally, this reading should be very low but, under some conditions, may range up to several
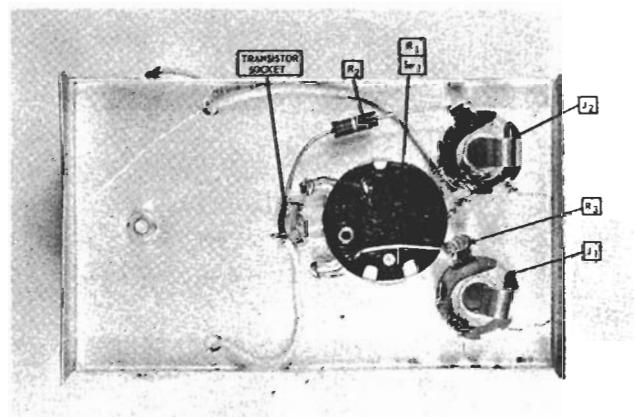

FIG. 3-9

hundred microamperes, even with "Good" transistors. If a very large reading is obtained . . . over a milliampere, for example, the transistor is "leaky" and should be discarded. If a full-scale reading is obtained, the transistor is *Shorted*, and, therefore, valueless.

With the first test completed, Sw_1 should be closed and R_1 advanced slightly up-scale. With this, the meter reading of collector current should also increase. If there is no change in the meter reading, or if the reading remains at "zero" for both tests, the transistor is *Open*, and may be discarded.

The transistor's *Gain* in the common emitter circuit configuration (*Beta*) may be approximated with the *Transistor Checker*. Transfer the meter plug to the "B" (*Base*) jack, J_1. With this arrangement, the meter will indicate the transistor's base bias current. The *Bias* control, R_1, is adjusted for a nominal current reading . . . for example, in the range from 20 to 50 microamperes. Next, the meter plug is transferred back to the "C" jack, J_2, and the meter's reading noted. This is the transistor's *collector current with a known base bias current*. The ratio of collector current to bias current will give the approximate *Beta*, or current *Gain*, of the transistor.
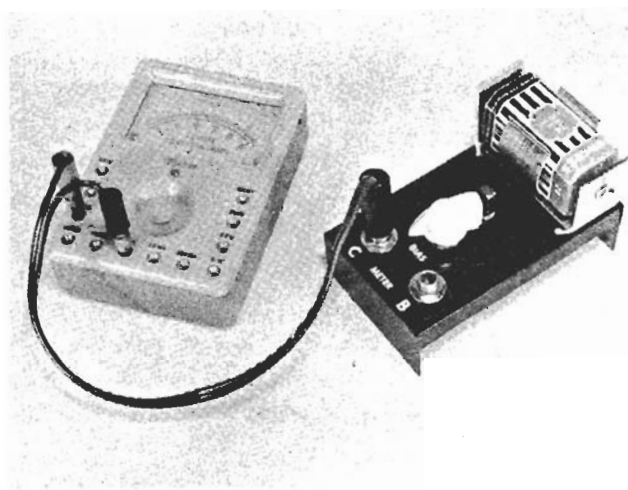

FIG. 3-10

Note that the *Transistor Checker* is designed to check PNP transistors only, with the battery polarity shown in Fig. 3-8. This is quite adequate for all RAYTHEON transistors, which are PNP units.

If desired, NPN transistors may be checked by reversing the battery in its holder and thus reversing D.C. polarities in the test circuit. In addition, the meter test leads will have to be interchanged to insure an up-scale reading. However, the test procedure is the same for PNP and NPN units.
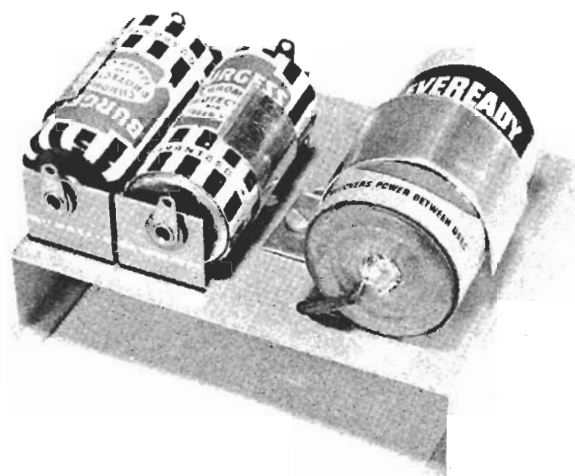

FIG. 3-11

POWER SUPPLIES

Since their voltage and current requirements are low, transistors may be powered quite economically with standard dry batteries. Either conventional zinc-carbon or the newer mercury batteries may be used. Of the two, the zinc-carbon type batteries are the least expensive, but have the shortest life. Mercury batteries, on the other hand, are much more costly, but have a considerably longer service life under semi-continuous operating conditions. Therefore, zinc-carbon units probably are best for general experimental use and average applications, but mercury units are preferred for use in Hearing Aids and similar equipment requiring long-life batteries.

Transistor operating voltages in typical circuit applications will range from 1.5 volts to as high as 30 volts, but the majority of circuits will require power supplies in the 6 to 12 volt range. Where low voltages are required . . . up to about nine volts . . . it is quite practical to "build up" the necessary power pack by connecting standard *penlight* or *flashlight* cells in series, except where space is a factor. If only limited space is available for a power supply in a particular piece of equipment, the newer "transistor batteries" may be employed. Typical units are *Burgess* types P6 (9 volts), 2N6 (9 volts), and 2U6 (9 volts). For higher voltages, small "Hearing Aid B Batteries" may be used . . . typical units are *Burgess* types U10 (15 volts), U20 (30 volts), and Y10 (15 volts).

Battery mounting procedures will depend on the mechanical requirements of the project. Two typical methods are illustrated in Fig. 3-11. On the left, two

Burgess No. 1 flashlight batteries are mounted on an Aircraft No. 144 Battery Box. This type of mounting is preferred for ease in battery replacement. Battery Boxes are manufactured in sizes to fit almost every commercial battery and are available through Radio Parts Distributors and Model Supply Shops.

An alternate battery mounting method is shown to the right (Fig. 3-11). The battery is held in place with a large metal strap, with connections made by soldering leads directly to the battery terminals. Although less costly than Battery Boxes, this method has some disadvantages . . . first, battery replacement becomes a minor servicing job. In addition, special care must be exercised when soldering leads to the battery terminals. Excessive heat will shorten a battery's life, so the soldering must be completed as quickly as possible.

Finally, some types of battery are equipped with snap connectors or small jacks. Where this type of battery is used, it may be clamped in place, with final connections made through a snap or plug.

SUN BATTERIES

It has been known for many years that the Sun is mankind's primary source of energy. Animals derive their ultimate energy from plants, which, in turn, store up Sun power in their living tissues. Wood, a common fuel in remote areas, represents Sun power stored up by a once living plant. Even the fossil fuels, peat, coal, and oil, represent Sun power stored up in prehistoric plants and animals. And hydroelectric power is derived from water raised to great heights as vapor by the Sun's rays. But it is only in comparatively recent years that Man has learned to convert the Sun's energy directly into electrical power. This is accomplished with a semiconductor device called, variously, a *Sun Battery*, *Solar Battery*, or *Solar Cell*.
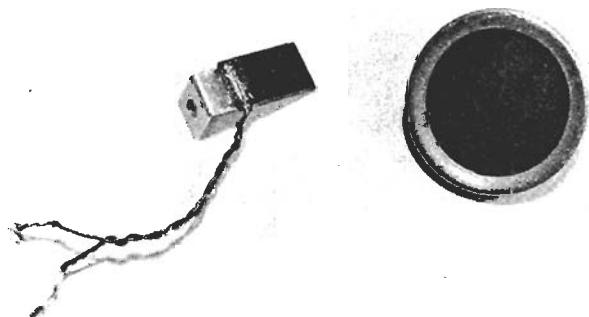
Most commercially available Sun Batteries have a comparatively low power output even when exposed to full noon sunlight. Often, the available power is measured in microwatts or, at the most, in milliwatts. Still, this is ample power to operate many types of transistor circuits.

While good results can be obtained from a single cell, you'll find that a "battery" made up of a number of cells connected in a series-parallel arrangement will give you the best results with most transistor circuits. Such a *Sun Battery* is diagrammed in Fig. 3-13. Four B2M cells are used, made up as two parallel strings, each of which consists of two cells in series. This unit is suitable for powering some of the simpler receiver and amplifier circuits. For higher powers, additional cells may be used to make up even larger batteries.

Low power transistor circuits, such as one and two transistor receivers, amplifiers, and oscillators, sometimes may be operated with the power obtained from "self-generating" photocells which, in turn, are exposed to a strong source of light . . . such as the light from a photoflood lamp or from the Sun. The two types of *Sun cells* readily available to experimenters are shown in Fig. 3-12. Both are made from semiconductor materials. A *selenium* unit is shown to the left, a *silicon* unit to the right.

Of the two, selenium Sun cells are the least expensive and the least efficient. However, they are sufficiently efficient for most experimental applications and are often preferred by experimenters because of their low cost. Silicon units, on the other hand, are frequently preferred for military and industrial applications because of their high efficiency.
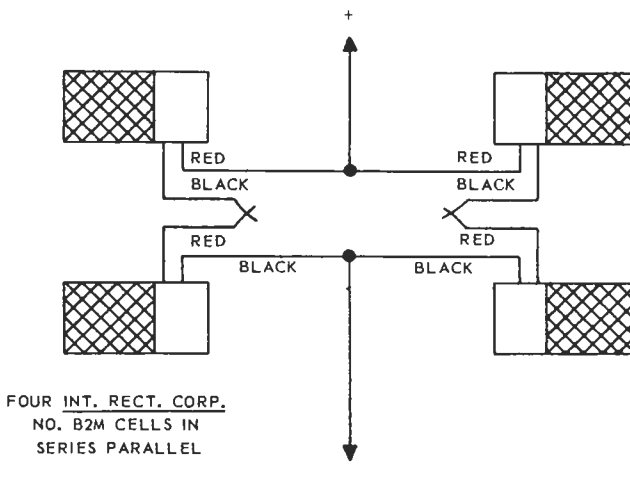
FIG. 3-12

FOUR INT. RECT. CORP. NO. B2M CELLS IN SERIES PARALLEL

FIG 3-13

TRANSISTOR CIRCUIT APPLICATIONS

When RAYTHEON first introduced the CK722 several years ago, it filled a long-felt need for a low-cost experimenter's transistor. Naturally, there was an immediate demand from experimenters and hobbyists for practical circuit data on using this new semiconductor device. And practical information was not long in coming! The leading technical electronics magazines, quick to recognize potential reader interest, assigned several of the nation's top technical writers to the job of turning out informative articles describing typical circuit applications for the CK722. Many other writers, also recognizing the advantages of the CK722, turned their talents to working up new circuits for this semiconductor triode. As a result of these efforts, RAYTHEON's CK722 has been featured in more magazine articles than any other transistor.

A few years later, a number of the more interesting circuit applications featuring the CK722 were brought together in RAYTHEON's now famous *TRANSISTOR APPLICATIONS* Volume I booklet, thus providing the experimenter with a compact and easily used source of practical circuit data. But as the use of the CK722 continued to expand, there developed an increasing interest among experimenters in *all* RAYTHEON transistor types. Many hobbyists, enthusiastic about their results with the CK722 and its higher gain "brother", the type CK721, turned their thoughts towards working with such other units as audio types 2N132 and 2N133, medium power amplifiers such as the 2N138, and RAYTHEON'S R.F. transistors, such as the 2N112 (CK760) and 2N113 (CK761). To help fill the need for additional circuit

data, the following pages are devoted to practical construction projects featuring a variety of RAYTHEON transistors in addition to the popular types CK722 and CK721.

These projects have been chosen to represent a "cross-section" of typical RAYTHEON transistor applications, and thus to appeal to all hobbyists and experimenters, regardless of their fields of special interest. While all of the projects described on the following pages have been "bench-tested" and are non-critical, not all are intended for beginners.

But whether the reader is a beginner or an advanced technician, he will find it worthwhile to review the practical material given in the sections dealing with Practical Circuit Design and Installation and Wiring before tackling the projects themselves. Special attention should be given to the detailed discussion of transistor installation and wiring techniques.

In the event that trouble is encountered with any of the projects, the first step is to recheck all wiring for possible errors and accidental shorts or opens. All electronic parts, especially any used components, should be checked. Battery and electrolytic capacitors should be checked for correct lead polarities. And any batteries used should be tested under load. In a few instances, optimum performance with particular transistors and other components may be obtained by making minor changes in circuit values. The best values to use in a particular case may be determined experimentally, but they should be reasonably close to the values given in the schematic diagrams.

RECEIVER CIRCUITS

There is little doubt that the most popular general type of electronic construction project with the Home-builder is the *Radio Receiver*. In fact, many hobbyists devote their full attention to such projects and seldom, if ever, assemble other types of equipment. It is a little difficult to "pin down" the reasons for this overwhelming popularity, but perhaps the best explanation lies in the fact that the home receiver is basically an entertainment device . . . and, after all, the real motivating forces

behind most hobbies are relaxation and entertainment. In addition, most receivers are complete within themselves . . . no additional equipment, such as turntables and pick-up arms, test equipment, or special accessories, are needed for their operation. Finally, even in the present age of such technical marvels as jets, rockets and atomic energy, there is still some flavor of romance and excitement in assembling a piece of apparatus which picks up music and news "out of thin air".

CRYSTAL RECEIVER
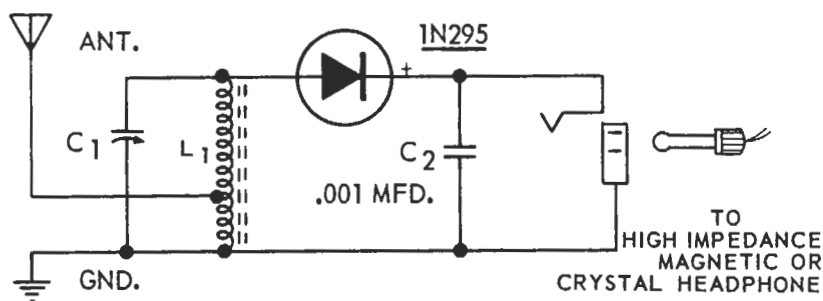
PARTS LIST

C_1 — 365 Mmf. tuning capacitor.
C_2 — .001 Mfd., disc ceramic capacitor.

L_1 — Tapped antenna coil (*Miller* No. 2000 or 2004 or *Meissner* No. 14-9003).
DIODE — (1) *Raytheon* 1N295.

MISC. —High impedance magnetic Headphones; tuning knob; small metal chassis or wooden board; Hardware . . . wire, solder, screws, nuts, terminal strips, etc.

FIG. 4-1

The simplest of vacuum tube receivers is one using a tuned circuit and a diode detector. In an analogous manner, the simplest of semiconductor receivers is one using a tuned circuit and a semiconductor diode. The circuit for such a receiver is given in Fig. 4–1. Historically, the semiconductor diode detector or *Crystal Receiver* is one of the earliest types. Home-made receivers using a small galena (lead sulfide) crystal and a "cat's whisker" contact (fine sharp-pointed wire) served as boyhood projects for many of today's outstanding engineers, scientists and technicians.

Early *Crystal Receivers* were somewhat bothersome to use. The sensitivity of individual crystals varied widely and, even with a "good" crystal, one had to carefully and tediously adjust and readjust the "cat's whisker" contact on the crystal until a point of maximum sensitivity could be found. But modern crystal receivers, using quality-controlled and precision manufactured fixed diodes, have no such disadvantage. They are inexpensive to build, yet reliable and fairly sensitive.

Referring to Fig. 4–1, the basic *Crystal Receiver* consists of a good antenna-ground system (ANT.-GND.), a tuned circuit (C_1-L_1), a semiconductor diode (1N295), an R.F. by-pass capacitor (C_2), and a pair of magnetic headphones. In operation, AM modulated R.F. signals are picked up by the antenna-ground system and selected by the C_1-L_1 resonant circuit. An antenna tap is provided on L_1 to prevent undue loading of the tuned circuit by
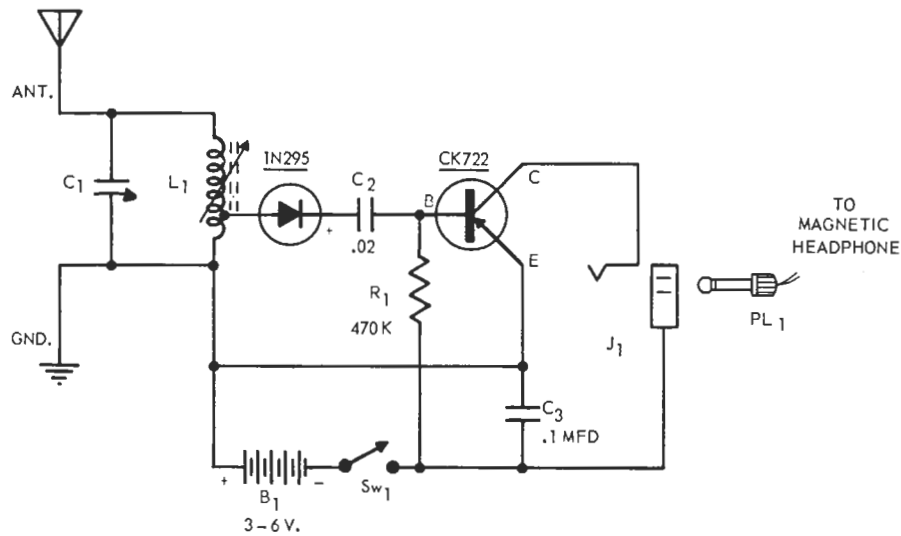
the long antenna needed for this type of receiver. After selection by the tuned circuit, the R.F. signal is demodulated (detected) by the semiconductor diode and the resulting audio signal used to drive the headphones.

Construction Hints

The *Crystal Receiver* makes an excellent "first project" for the student or beginning hobbyist, not only because of its low-cost and simple circuitry, but because it is the most basic of radio receivers and, in addition, has real historical significance in the development of present-day radio. The actual assembly and wiring of the receiver is quite straightforward, with neither parts layout nor lead dress critical. Either a small metal chassis or a wooden board will serve equally well as a mounting base for the circuit components. The only precaution which you'll need to observe is in soldering the diode in position . . . care must be taken to avoid overheating this device (see section on Installation and Wiring).

For maximum sensitivity, a *good* antenna and ground system must be used with the *Crystal Receiver*. The antenna (ANT.) may be a 50 to 100 foot (or more) lead strung as high as practicable. A ground connection (GND.) may be made to a cold water pipe or to a long metal spike driven into moist earth. For best results, high impedance headphones must be used . . . in general, the higher the impedance of the headset used, the better the sensitivity and selectivity of the receiver.

SIMPLE RECEIVER

PARTS LIST

FIG. 4-2

Although the *Crystal Receiver* is inexpensive and reliable, it has fairly limited sensitivity. Its ability to "pull in" stations depends primarily on the quality of the antenna-ground system with which it is used. The set acts simply to *select* and *detect* the R.F. signal picked up by the antenna, but it does not *amplify* that signal. Therefore, the next logical step is to add a stage of audio amplification to the basic crystal circuit . . . the wiring diagram for such a *Simple Receiver* is given in Fig. 4-2.

Referring to the schematic diagram, we see that a common-emitter transistor audio amplifier has been added to the basic detector circuit. In operation, R.F. signals picked up by the antenna-ground system are selected by tuned circuit C₁-L₁. The tap on L₁ is used to match to the low input impedance of the detector-amplifier circuit and thus to minimize loading on the tuned circuit. After detection by the 1N295 diode, the audio portion of the demodulated signal is coupled through D.C. blocking capacitor C₂ to the base of the transistor amplifier stage. Base bias current for the transistor is supplied through resistor R₁. The amplified audio signal appearing in the collector circuit of the transistor drives the magnetic headphones connected to output jack J₁. Operating power is supplied by a single battery, B1, controlled by SPST switch Sw₁, and by-passed by C₃.

Construction Hints

The *Simple Receiver* can be assembled on a small metal chassis or in a pocket-sized plastic case. With neither components arrangement nor wiring location critical, you can follow your own inclinations in these matters. The transistor may be soldered permanently in position or installed in a subminiature "in-line" transistor socket. If soldered in place, the usual precautions to avoid heat damage should be observed.

The battery voltage is not especially critical. Battery combinations supplying anywhere from three to six volts will give satisfactory results. You can use two or more penlight (or flashlight) cells in series . . . two cells will supply 3.0 volts, three give 4.5 volts, and four give 6.0 volts . . . or compact medium voltage batteries, as you prefer. A suitable choice is a *Burgess* No. Z4 (6.0 volts) or a *Mallory* type TR-113R (4.0 volts) mercury battery.

You may wish to experiment somewhat with the connections to the diode (1N295). Depending on local conditions and the tolerances of other components, you may notice some improvment in sensitivity if you reverse the diode's connections (interchange cathode and anode leads). Try both arrangements and use the one that gives the best results in your particular receiver.

(20)

With the wiring completed and double-checked for errors and possible shorts, install the battery, checking its polarity as you do so, and connect the antenna (ANT.) and ground (GND.) leads. Plug high impedance head-phones (1,000 ohms, or more) into output jack J_1 and switch the set "ON" by closing Sw_1. Adjust C_1 to tune

in local stations. Since this receiver has greater sensitivity than the *Crystal Receiver*, it does not require as elaborate an antenna and ground set-up for comparable results. If you find it difficult to separate strong local stations, it may indicate you are using too long an antenna.

REGENERATIVE RECEIVER
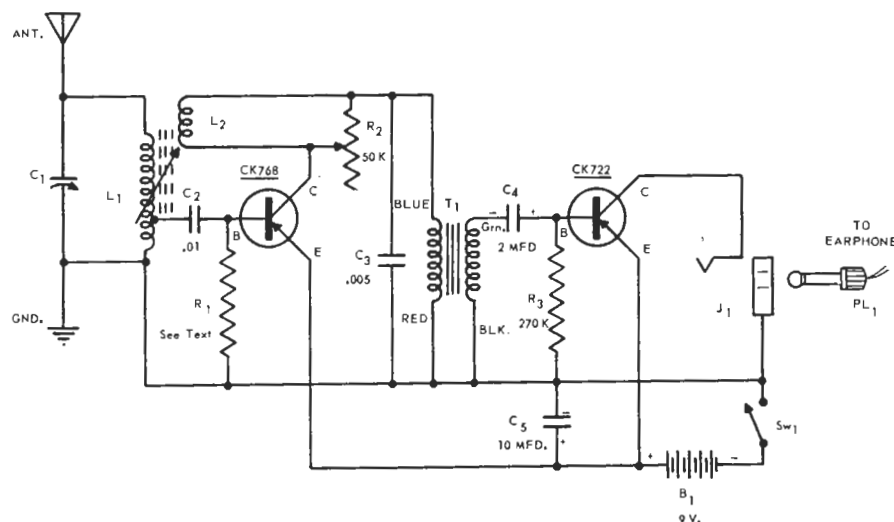
PARTS LIST

R_1 — ½ watt carbon resistor (see text).
R_2 — 50K potentiometer, with switch.
R_3 — 270K, ½ watt carbon resistor.
C_1 — 365 Mmf. tuning capacitor.
C_2 — .01 Mfd., disc ceramic capacitor.
C_3 — .005 Mfd., disc ceramic capacitor.
C_4 — 2 Mfd., 8 volt electrolytic capacitator.
C_5 — 10 Mfd., 10 volt electrolytic capacitor.

L_1 — Tapped antenna coil (*Meissner* No. 14-9015 or *Argonne* No. AR70).
L_2 — Feedback coil (see text).
T_1 — Interstage transistor transformer (*Argonne* No. AR-109 or *Thordarson* No. TR-7.
Sw_1 — SPST switch (on R_2).
J_1 — Subminiature open circuit jack.

B_1 — 9 volt transistor battery.
TRANSISTORS — (1) *Raytheon* CK768; (1) *Raytheon* CK722.
MISC. — High impedance magnetic earphone; small plastic case; (2) control knobs; (2) transistor rockets; *bakelite* mounting board; battery clip; Hardware . . . screws, nuts, wire, solder, etc.

FIG. 4-3

In general, where it is necessary to obtain greater sensitivity or to increase the gain of a radio receiver, the usual practice is to add additional stages of amplification. These need not be audio amplifiers, however; more often the greater gain is obtained at radio frequencies. But there is one other technique that may be used, at least in simple receiver circuits . . . that of adding *regeneration* to a basic detector circuit. In a regenerative detector, part of the amplified signal is coupled back to the input of the stage and re-amplified. This results in a considerable increase in sensitivity, but has one drawback . . . if the "feedback" signal is too large, the stage may oscillate. To avoid oscillation, a special "regeneration" control must be provided. Since the adjustment of the regeneration control for maximum sensitivity, while avoiding oscillation, may be somewhat ticklish, *Regenerative Receivers* have not proven too popular with the general

public. But the assembly and use of such a receiver is an excellent project for the experimenter. A suitable circuit is given in Fig. 4-3, while an assembled pocket-sized model is shown in Fig. 4-4.

Referring to the schematic diagram, we see that the *Regenerative Receiver* consists of two stages. The first stage is a regenerative detector-amplifier using a CK768 R.F. transistor in the common-emitter configuration. Transformer-coupling is used between stages, and the second stage is a CK722 transistor connected as a common-emitter audio amplifier.

In operation, R.F. signals picked up by the antenna-ground (ANT.-GND.) system are selected by resonant circuit C_1-L_1. A tap on L_1 permits a good impedance match between the high impedance of the tuned circuit and the low input impedance of the first stage, and thus minimizes loading on the tuned circuit. The selected
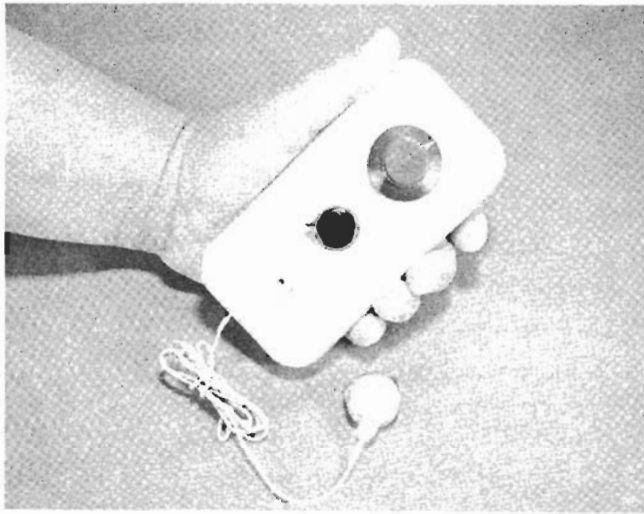
(21)

FIG. 4-4

R.F. signal is coupled to the base of the CK768 transistor through D.C. blocking capacitor C_2. Since the CK768 serves as a detector, very little base bias current is required, and this is supplied through R_1.

The amplified signal appearing in the collector circuit of the CK768 includes both R.F. and A.F. (audio) components. The R.F. component is coupled back to the input circuit through feedback coil L_2, thus serving to strengthen the original signal. L_2, in turn, is shunted by rheostat R_2. As this control is adjusted, it serves to bypass a larger or smaller portion of the available R.F. signal around L_2 and thus acts to control the *feedback*, becoming the REGENERATION CONTROL. The audio component of the detected and amplified signal is coupled through impedance matching transformer T_1 to the second stage. T_1's primary winding is by-passed for R.F. by capacitor C_3.

The audio signal appearing across T_1's secondary winding is coupled through D.C. blocking capacitor C_4 to the input of the second stage. Base bias current for this stage is supplied through resistor R_3. After additional amplification by the second stage, the audio signal in the collector circuit of the CK722 drives the magnetic earphones connected to output jack J_1.

Operating power for the entire receiver is supplied by a single 9-volt battery, B1, controlled by SPST switch Sw_1, and by-passed by capacitor C_5.

Construction Hints

Like the two receivers described earlier in this *Section*, the *Regenerative Receiver* is designed to cover the AM Broadcast Band (550 to 1600 KC). However, unlike the earlier receivers, this set requires a relatively simple antenna-ground system. In fact, when operated reasonably close to strong local stations, satisfactory results may

be obtained with *either* an antenna *or* ground (not both).

Although the circuit's layout and lead dress are not critical, good wiring practice should be observed . . . that is, signal leads should be kept reasonably short and direct, especially in the first (R.F.) stage, and battery and electrolytic capacitor polarities should be observed. And you'll find it best to use transistor sockets instead of soldering these components in place. A small piece of *bakelite* or fiber board may be used as a "chassis".

Feedback winding L_2 consists of 12 to 15 turns of No. 26 or 28 enameled copper wire around the middle of antenna coil L_1. Temporary "lap" soldered joints should be used for connecting this coil as it may be necessary to reverse its connections later.

The value of base bias resistor R_1 is not specified. Its value will vary somewhat from set to set, depending on the tolerances of other components used. Therefore, for best results, its value should be determined experimentally for your particular receiver. If R_1 is made too *small*, detection (demodulation) will be inefficient . . . and may not even take place. If R_1 is made too *large*, the receiver's gain (sensitivity) may suffer. In general, R_1's value should fall between 1 Megohm and 10 Megohms. Try different resistors between these limits and install the one giving the best results.

With the wiring completed and double-checked for errors, install the battery (B1) and transistors. Plug in a pair of high impedance (2,000 to 8,000 ohm) earphones. Connect a 12 to 15 foot antenna wire and connect the "GND." terminal to a good external ground . . . such as a cold water pipe. With the set turned "ON" and REGENERATION CONTROL R_2 turned to its maximum resistance position, try adjusting C_1 over its range to pick up various local stations. In some cases, the receiver may oscillate, causing a "whistling" or, sometimes, a "putt-putt" sound in the earphones. If this happens, readjust R_2 until the sound disappears and continue to tune C_1.

If oscillation does not occur, tune in a station and try interchanging the connections to feedback coil L_2. With one arrangement, the feedback signal is *degenerative* and actually reduces the receiver's sensitivity. With a reversed arrangement, the signal is *regenerative* and, in some cases, may result in oscillation. Use the final connections to L_2 which give the maximum signal (or cause oscillation). Once L_2's connections have been finalized, you can try different values for R_1.

After completing the final circuit adjustments, as outlined above, the receiver may be installed in a small plastic case. A typical assembly is shown in Fig. 4-4. When using the *Regenerative Receiver*, adjust the REGENERATION CONTROL for maximum sensitivity or just below the point where oscillation takes place . . . and use the shortest antenna lead that will give satisfactory reception of local stations in your particular location.
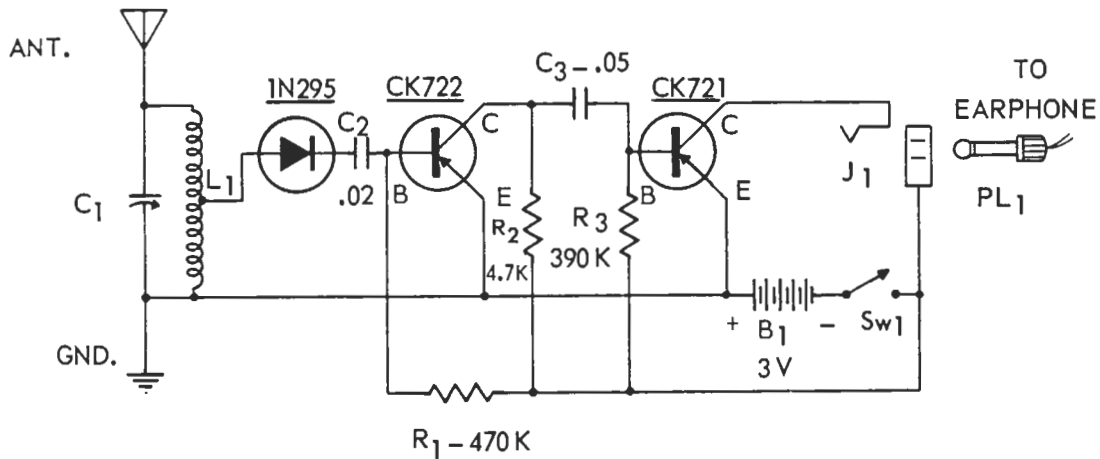
(22)

TWO TRANSISTOR RECEIVER

FIG. 4-5

The circuit diagram for an easily-built two-transistor AM Broadcast Band *Receiver* is given in Fig. 4–5. Although the circuit requires relatively few low-cost parts, the set's performance is good. With a moderate length external antenna and a good earth ground, this radio *Receiver* will deliver good headphone volume on most local stations.

In operation, R.F. signals are picked up by the ANT.-GND. system and the desired station is selected by tuned circuit C_1-L_1. A tap on L_1 provides a good match to the relatively low input impedance of the detector-amplifier circuit and minimizes loading on the tuned circuit, thus insuring good selectivity and gain.

After detection (demodulation) by the 1N295 diode, the resulting audio signal is amplified by the CK722 transistor, with the amplified audio signal appearing across collector load resistor R_2 coupled through interstage coupling capacitor C_3 to the base of the second stage. Base bias current for the first stage is supplied through base resistor R_1. Additional amplification takes place in the second stage, with the CK721 transistor driving the magnetic earphones serving as its collector load. Base bias for the second stage is supplied through R_3. The common-emitter circuit configuration is used in both stages, while operating power for the entire receiver is supplied by a three volt battery, B1, controlled by SPST switch SW_1.

Construction Hints

The construction of the two-transistor *Receiver* is relatively simple and, therefore, it is suitable for newcomers as well as more advanced workers. It makes an excellent project for the beginner who has "cut his teeth"

on a crystal receiver. With neither parts layout nor lead dress critical, the individual builder may follow his own inclinations in these matters, as well as in the type of housing (cabinet) used. For educational work or experimental tests, the *Receiver* may be "breadboarded". However, if a more permanent construction is preferred, the set may be assembled in a small plastic or wooden box.

Several circuit changes are permissible. For example, battery voltage is not too critical, and B1 may deliver from 1.5 to 6.0 volts, or more. A type CK722 transistor may be substituted for the type CK721, but with some loss of gain in the second stage. In some instances, better results are obtained if the diode's leads are reversed . . . the best connection to use will vary with local conditions and is best determined by experiment. Finally, although the circuit is designed for use with high impedance *magnetic* earphones, a crystal earphone may be used if a 12K, ½ watt resistor is connected across the output jack's (J_1) terminals.

SUPERHET RECEIVER

FIG. 4-7
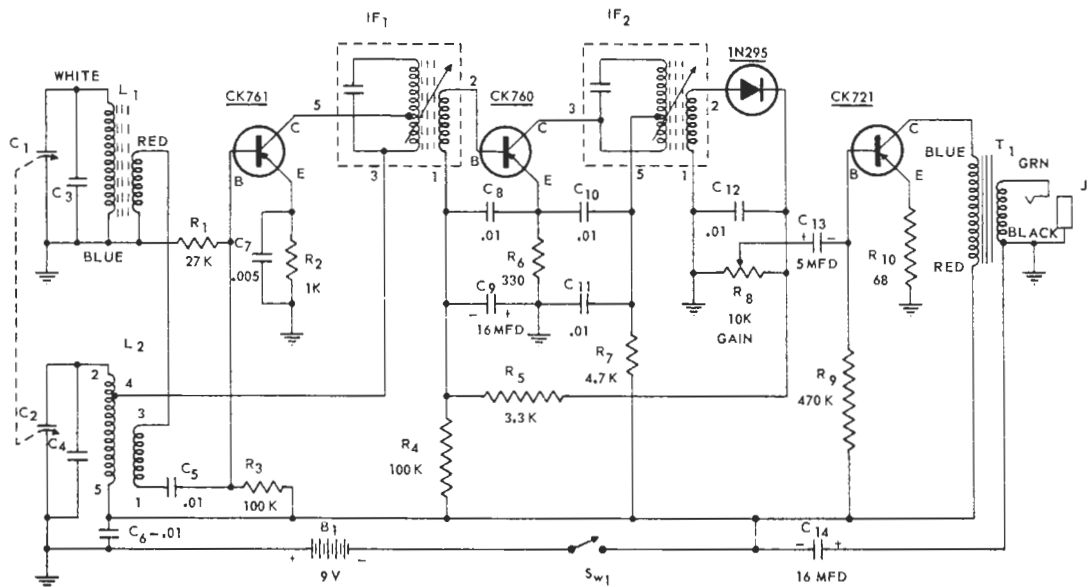
PARTS LIST

C_1, C_2, C_3, C_4 — Two-gang variable capacitor (*Argonne* No. AR-93).
C_5, C_6, C_8, C_{10}, C_{11}, C_{12} — .01 Mfd. disc ceramics
C_7 — .005 Mfd. disc ceramic
C_9, C_{14} — 16 Mfd., 12 volt electrolytics
C_{13} — 5 Mfd., 12 volt electrolytic
R_1 — 27K, ½ W. carbon resistor
R_2 — 1K, ½ W. carbon resistor
R_3, R_4 — 100K, ½W. carbon resistor
R_5 — 3.3K, ½ W. carbon resistor
R_6 — 330 ohm, ½ W. carbon resistor
R_7 — 4.7K, ½ W. carbon resistor

R_8 — 10K potentiometer, audio taper, with On-Off switch.
R_9 — 470K, ½ W. carbon resistor
R_{10} — 68 ohm, ½ W. carbon resistor
L_1 — Antenna coil (*Argonne* No. AR-97)
L_2 — Oscillator coil (*Argonne* No. AR-98)
IF_1 — Input I.F. transformer (*Miller* No. 2041 or *Meissner* No. 16-9002)
IF_2 — Output I.F. transformer (*Miller* No. 2042 or *Meissner* No. 16-9014)
T_1 — Transistor interstage transformer (*Argonne* No. AR-109 or *UTC* No. DOT-11 or *Thordarson* No. TR-7)

J_1 — Open circuit jack
Sw_1 — SPST switch, on R_8
B_1 — 9 volt transistor battery
DIODE — *Raytheon* 1N295 diode
TRANSISTORS — (1) *Raytheon* 2N113;
(1) *Raytheon* 2N112;
(1) *Raytheon* CK721
MISC. — Plastic case; (2) Knobs; (3) transistor sockets; battery; clips; small metal or fiber chassis; terminal strips; High impedance magnetic earphone, with plug to fit J_1; assorted hardware ... screws, nuts, solder lugs, wire, solder, etc.

Today, the superheterodyne receiver is, by far, the most popular type. Virtually all FM and TV receivers as well as the vast majority of home, portable, and auto radio receivers employ the basic "superhet" circuit, whether transistors or vacuum tubes are used in their design. In general, the superhet offers better selectivity and greater sensitivity than other receiver circuits. The home-built *Pocket Receiver* shown in Fig. 4-6 is typical of the personal-sized AM Broadcast Band radios that may be assembled around a transistorized superheterodyne circuit.

The schematic diagram for a simple, but reliable, three-transistor *Superhet Receiver* is given in Fig. 4-7. Although it requires but one more transistor than the circuit shown earlier (Fig. 4-3), this set has considerably more gain and much better selectivity. In fact, in most localities this receiver will give good earphone volume on stronger local stations *without* requiring an external antenna or ground connection.

Referring to Fig. 4-7, R.F. signals are picked up by *antenna* coil L_1 and selected by the tuned circuit made up of variable capacitor C_1, trimmer capacitor C_3 and the coil. A step-down winding on L_1 matches the comparatively low input impedance of the converter stage, with the selected R.F. signal fed through one of the windings of *oscillator* coil L_2 and blocking capacitor C_5 to the base of the converter (oscillator-mixer) stage. A type 2N113/CK761 transistor is used here. The *oscillator* coil, L_2, is tuned by variable capacitor C_2 and its trimmer C_4. Capacitors C_1 and C_2 are ganged mechani-

FIG. 4-6

(24)

cally so that both antenna tuning and oscillator frequency are varied simultaneously, maintaining a frequency difference of 455 KC . . . the *intermediate frequency* (I.F.) for the receiver.

Base bias current for the 2N113 is furnished by voltage divider R_1-R_3 in conjunction with emitter resistor R_2, by-passed by C_7. This biasing arrangement insures D.C. stabilization of the circuit.

The locally generated signal and the picked up R.F. signal are combined in the 2N113, with their difference frequency of 455 KC selected by I.F. transformer IF_1. The primary of IF_1 is tapped to insure a good impedance match to the collector circuit of the transistor, while maintaining a reasonably high "Q" tuned circuit. The common-emitter circuit configuration is used in the converter stage.

The selected I.F. signal appearing across the secondary winding of IF_1 is applied to the base of the common-emitter I.F. amplifier stage. The I.F. transformer also serves to match the interstage impedances by virtue of a step-down turns ratio between primary and secondary windings, thus insuring efficient coupling between stages and minimum loading of the tuned circuit. A 2N112/CK760 R.F. transistor serves as the I.F. amplifier, with base bias current for this stage supplied both through R_4 and R_5, working in conjunction with emitter resistor R_6. In operation, the bias current supplied through R_5, which returns to the second detector stage, serves to reduce current supplied through R_4. Since the current supplied through R_5 varies with relative signal level, the final bias of the I.F. amplifier stage, and hence its gain, also varies with signal level, providing a form of *automatic volume control* (AVC) action. C_8 and C_9 serve as by-pass capacitors in the bias circuit.

The second I.F. transformer, IF_2, like IF_1, also has a tapped primary winding to insure a good match to the transistor's collector circuit. Collector current for the IF stage is supplied through decoupling resistor R_7, by-passed by capacitors C_{10} and C_{11}.

After amplification by the 2N112, the I.F. signal appearing across the secondary of IF_2 is applied to the 1N295 diode detector, with the resulting demodulated signal appearing across diode load resistor R_8. A potentiometer here serves as the receiver's GAIN control. C_{12} serves as an R.F. by-pass across R_8. The D.C. component of the demodulated signal is coupled back through R_5 to control the gain of the I.F. amplifier. The audio component is coupled through C_{13} to the base of the CK721 audio amplifier stage. The common-emitter configuration is used here also. Bias for the audio amplifier is supplied through base resistor R_9, operating in conjunction with unby-passed emitter resistor R_{10}.

A step-down audio transformer, T_1, insures a good match between the high output impedance of the CK721 stage and the moderate impedance of the magnetic earphones connected to output jack J_1. Operating power for the entire receiver is supplied by a single battery, B1, controlled by SPST switch Sw_1, ganged with the GAIN control, and by-passed by capacitor C_{14}.

Construction Hints

The assembly and wiring of the *Superhet Receiver* should be a fairly routine operation for the more advanced worker, and the basic circuit is sufficiently simple and non-critical that its construction should not be beyond the skills of the less experienced hobbyist who has successfully completed a number of simpler projects. While components layout and lead dress are not too critical, good wiring practice should be observed . . . the "input" and "output" circuits should be kept well separated, and short, direct connections should be used in all signal circuits. Coil and transformer connections are shown in Fig. 4–8.

Since standard miniature parts are specified, the receiver is well-suited to construction in a pocket-sized case, as shown in Fig. 4–6, or in a larger cabinet, for table or bed-side use, depending on the interests of the individual builder. A plastic or wooden case is mandatory, however, for a metal cabinet will shield the built-in antenna coil (L_1). Either a metal or a plastic (fiber) "chassis" may be used. More advanced workers may wish to work up a printed circuit layout for the receiver and to assemble the unit on an etched circuit board.

A number of parts substitutions may be made if desired. For example, the 2N112/CK760 transistor may be replaced with a type CK768. The CK721 audio transistor may be replaced with a type CK722. The output transformer (T_1) may be left out, and the magnetic earphone connected directly into the collector circuit of the audio stage. Almost any general purpose diode, such as the 1N66 or the CK705, may be used in place of the 1N295 specified. However, except for the use of a different type of diode, the other substitutions men-
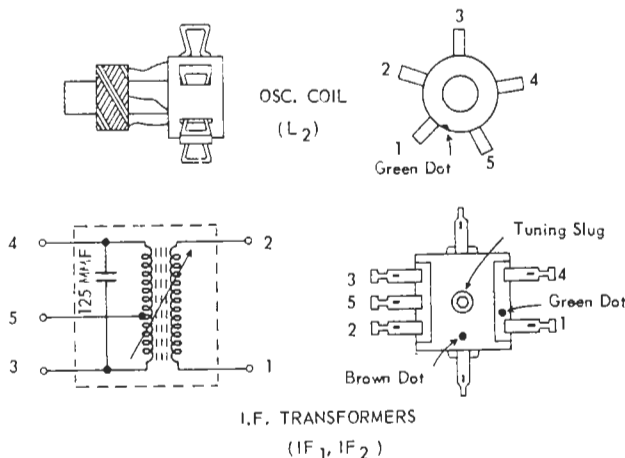

OSC. COIL
(L_2)

Green Dot

Tuning Slug

Green Dot

Brown Dot

I.F. TRANSFORMERS
(IF_1, IF_2)

FIG. 4-8

tioned will result in a slight loss of overall gain, but they may be feasible if strong local signals are available.

Alignment

With the wiring completed and checked, the receiver must be aligned. An *R.F. Signal Generator* and an insulated *Alignment Tool* are required for this operation. Magnetic earphones are connected to output jack J_1, the set is turned "ON" and the GAIN control is turned full up. The tuning capacitor (C_1-C_2) is set to its lowest frequency position (plates fully meshed). The coaxial cable from the *Signal Generator* is connected to the receiver's "ground" and to the "hot" side of coil L_1 (white lead). A small (10-25 Mmf) capacitor is connected in series with the generator's R.F. lead.

The *Signal Generator* is set to deliver a modulated R.F. signal at 455 KC and at an output level which produces a barely heard tone in the earphone. Next, transformers IF_1 and IF_2 are adjusted until the tone peaks in volume. As the peak is reached, the generator's output is reduced. The level, at all times, should be such that the tone barely can be heard.

After the I.F. transformers are peaked, the tuning capacitor plates are fully opened and the *Signal Generator* set to 1600 KC. The oscillator's trimmer capacitor (C_4) is adjusted for peak output. The test frequency is shifted to 1500 KC and the receiver's dial set at this value; next, the R.F. trimmer (C_3) is adjusted for peak output.

With a preliminary adjustment of the trimmer capacitors (C_3 and C_4), the *Signal Generator* is set to 600 KC. Next, the receiver's dial is "rocked" back and forth near the 600 KC setting and L_2's iron "slug" is adjusted for peak output. Finally, the 1600, 1500 and 600 KC adjustments are repeated, but with a "gimmick" (1 to 5 MMf) coupling capacitor in series with the *Signal Generator's* lead.

After alignment, the *Superhet Receiver* is ready for use, and may be mounted in its case. When using the set near strong local stations, no external antenna (or ground) is needed. In outlying areas, however, somewhat better results can be obtained if a short antenna is connected to the *white* lead of coil L_1 . . . length can be from 18″ to 3 feet.

BEAT FREQUENCY OSCILLATOR

Thus far, only radio receiver circuits have been described in this *Section* of your manual. However, RAYTHEON transistors may be used in the design and construction of *receiver accessories* as well as in the receivers themselves. The circuit for an interesting and valuable transistorized receiver accessory is given in Fig. 4–9, while a home assembled model of the device is shown in Fig. 4–11. This unit is a *Beat Frequency Oscillator* (abbreviated *B.F.O.*).

A standard superheterodyne Short-Wave Receiver may be able to pick up Radiotelegraph Code (CW) signals, but these cannot be heard over the set's loudspeaker unless converted into an audible tone. The *B.F.O.* does this job by providing a fixed signal at a frequency close to the receiver's intermediate frequency (I.F.). The *B.F.O.*'s signal is combined with the receiver's I.F. signal and the resulting difference, or "beat", frequency falls within the audio range, providing the audible tone in the loudspeaker. All commercial and amateur *Communications Receivers* have built-in *B.F.O.*s, but not all *Short-Wave Receivers* have this feature. However, the transistorized *B.F.O.* can be added to virtually any portable superhetrodyne Short-Wave Receiver, thus permitting its use as a Communications Set.

Referring to the schematic diagram (Fig. 4–9), we see that a RAYTHEON CK768 R.F. transistor is used as a common-emitter oscillator. In operation, the oscillator's
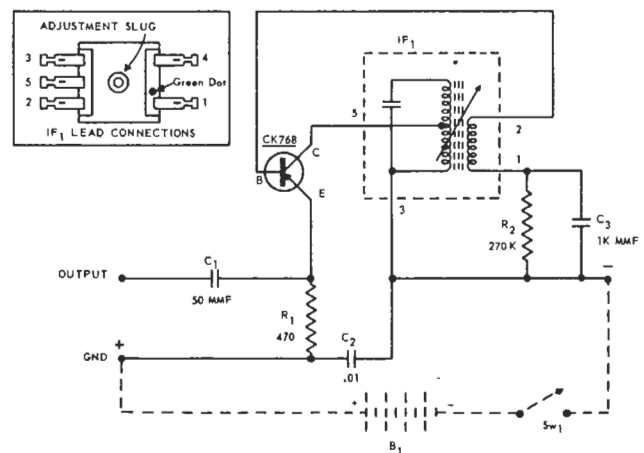
PARTS LIST

R_1 — 470 ohm, ½ watt carbon resistor.
R_2 — 270K, ½ watt carbon resistor.
C_1 — 50 Mmf., tubular ceramic capacitor.
C_2 — .01 Mfd., disc ceramic capacitor.
C_3 — 1K Mmf., disc ceramic capacitor.
IF_1 — 455 KC transistor interstage I.F. transformer (*Argonne* AR-60 or *Meissner* No. 16-9008).
Sw_1 — SPST toggle or slide switch.
TRANSISTOR — (1) *Raytheon* CK768.

MISC. — Transistor socket; small piece of perforated *bakelite*; small "L" bracket; (3) ground lugs; Hardware . . . screws, nuts, wire, solder, etc.

FIG. 4-9

frequency is determined by the tuned primary winding of I.F. transformer IF$_1$, with the feedback necessary to start and sustain oscillation obtained from the secondary winding. Proper impedance matching between the collector and base circuits is assured by the tap on the primary winding and the step-down turns ratio between IF$_1$'s primary and secondary windings. Base bias current is supplied through R$_2$, by-passed by C$_3$. The output signal is obtained across the unby-passed emitter resistor R$_1$ through coupling capacitor C$_1$. Operating power is obtained from the receiver's "A" or filament battery B1), and is controlled by SPST Sw$_1$, with the power supply by-passed by C$_2$.

Construction Hints

The construction of the model is apparent from the above and below "chassis" views given in Figs. 4-11 and 4-10, respectively. A small piece of perforated *bakelite* serves as a "chassis", and the I.F. transformer (IF$_1$), transistor socket, terminal lugs, and "L" bracket are mounted on it. You can follow the model's layout if you wish, but since neither parts arrangement nor lead dress are critical, you may also work up your own design. The transformer's lead connections are shown in the insert in Fig. 4-9.

With the wiring completed and checked, identify the *positive* battery terminal . . . you can use a dab of red
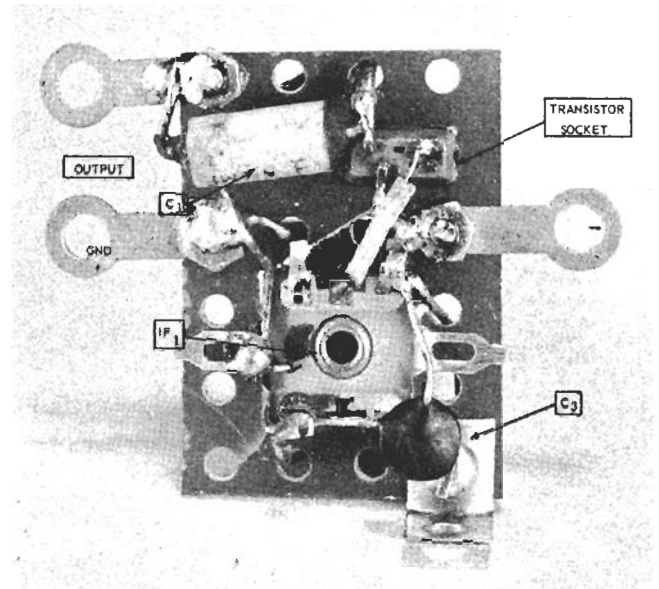

FIG. 4-10

fingernail polish or enamel for identification. *Either* the positive or the negative power supply terminal may be connected to the receiver's "ground" circuit, depending on the receiver's battery wiring. The positive terminal is shown as "GND." in Fig. 4-9.
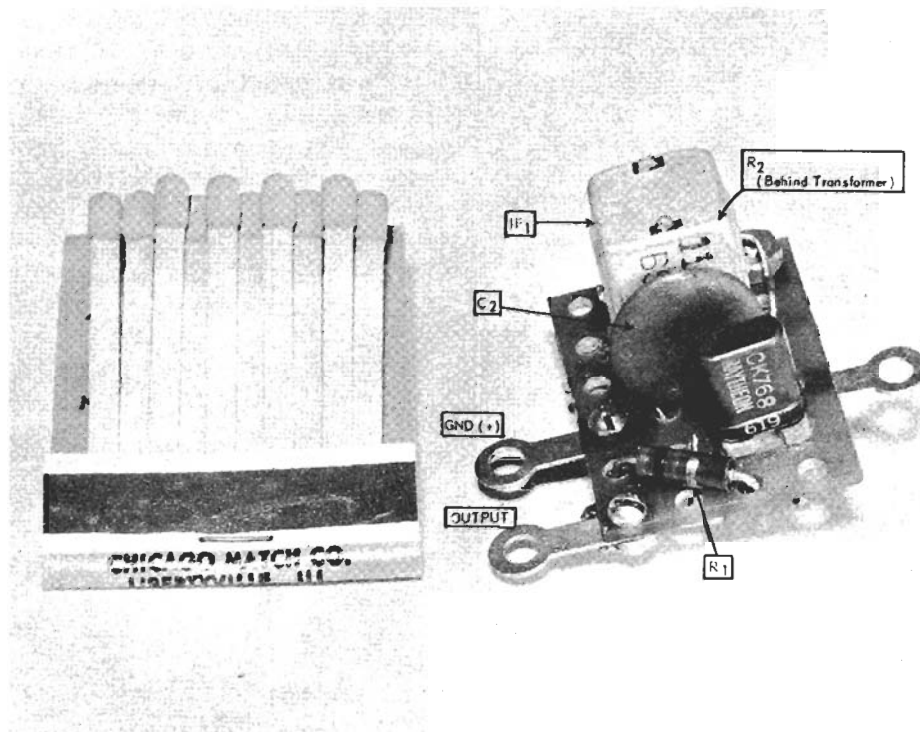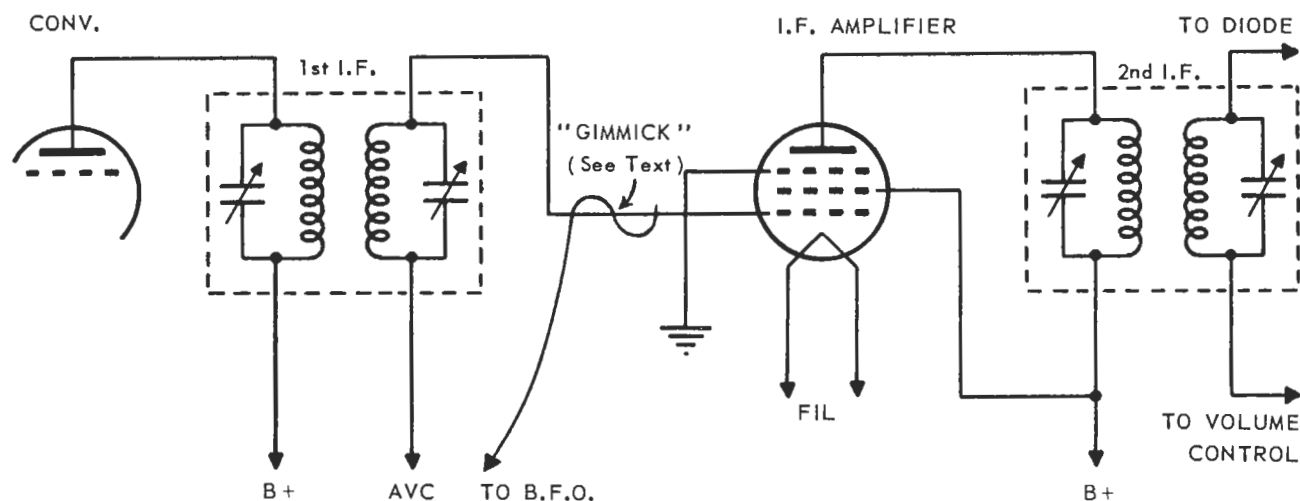

FIG. 4-11

FIG. 4-12

Installation and Adjustment

To install the completed *B.F.O.* in a receiver, mount it on the receiver's chassis with a screw through its "L" bracket. Run power supply leads from the receiver's "A" or filament battery to the appropriate terminals on the *B.F.O.* and to Sw₁. The *B.F.O.* Switch, Sw₁, is a SPST slide or toggle switch and should be mounted on the receiver's front panel to permit ready access to the operator. Another lead is run from the *B.F.O.*'s OUT-PUT terminal (Fig. 4-9) to the last I.F. stage in the receiver and wrapped tightly around the last I.F. amplifier's grid lead, forming a "gimmick" capacitor, as shown in Fig. 4-12. All coupling is through the interlead capacity, as *no direct connection to the receiver's I.F. stage is used.* A typical mounting of the *B.F.O.* in a portable receiver is shown in Fig. 4-13.

The component values specified in Fig. 4-9 are based on the use of the *B.F.O.* in receivers having a 455 KC I.F. and a 6-volt "A" battery. If a higher (or lower) voltage "A" battery is used, some readjustment of the bias resistor's value (R₂) may be necessary for optimum performance. In general, if a lower supply voltage is used, R₂ will be smaller . . . and vice versa. If you wish to install the *B.F.O.* in an A.C. or A.C.-D.C. line-operated receiver, you should provide a separate 6-volt battery for its operation. A suitable choice is a *Burgess* type Z4 battery.

To adjust the *B.F.O.*, connect a standard *R.F. Signal Generator* to the Receiver and turn both the Receiver and

the Signal Generator "ON" . . . but leave the *B.F.O.* "OFF". Adjusting the Signal Generator to supply a *modulated* R.F. signal, carefully tune in this signal on the receiver. Next switch the "modulation" *off*, and the *B.F.O. on.* Adjust the *B.F.O.*'s operating frequency until a tone can be heard in the Receiver's loudspeaker. Do this by using an insulated alignment tool to adjust IF₁'s powdered iron "slug" (see Fig. 4-9). After this preliminary adjustment, the *B.F.O* may be readjusted whenever desired on actual code stations. Use the final adjustment which gives the tone (audio frequency) you prefer.
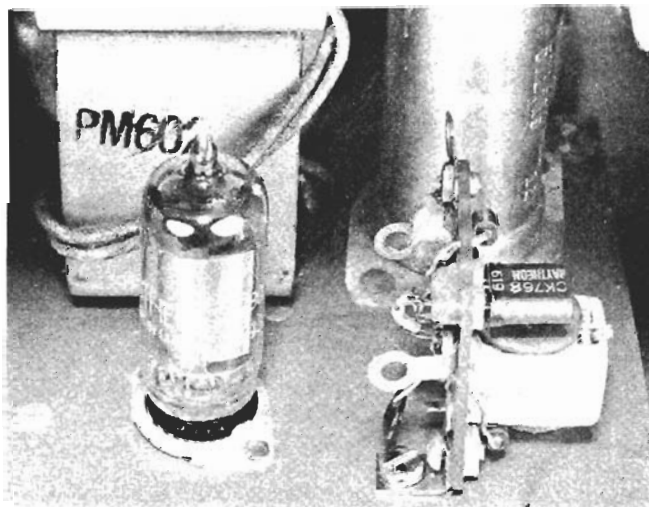

FIG. 4-13

(28)

AMPLIFIER CIRCUITS

Historically, the first large-scale commercial use of transistors was as audio amplifiers, and it was in a branch of this field that the transistor first completely displaced the vacuum tube . . . that is, in the manufacture of sub-miniature audio amplifiers — *Hearing Aids*. For the experimenter, the construction and test of transistorized audio amplifiers serves as an excellent introduction to the use of transistors. Since most audio circuits are fairly non-critical, especially as far as layout and wiring are concerned, the assembly of such circuits provides the experimenter with the opportunity to become familiar with transistor operation without the need of worrying about exact parts placement, lead dress, and similar mechanical details. In this *Section* we shall discuss several practical devices using RAYTHEON transistors as audio amplifiers.

HI FI PREAMPLIFIER
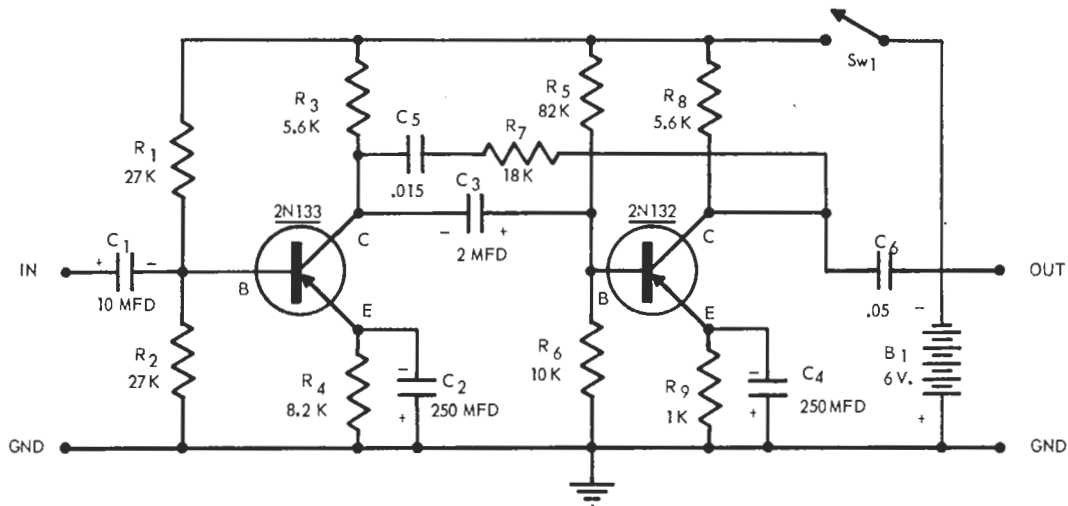
PARTS LIST

C_1 — 10 Mfd., 25 volt electrolytic
C_2, C_4 — 250 Mfd., 6 volt electroytics
C_3 — 2 Mfd., 25 volt electrolytic
C_5 — .015 Mfd., 200 volt paper or ceramic capacitor
C_6 — .05 Mfd., 200 volt paper or ceramic capacitor

R_1, R_2 — 27K, ½ W. carbon resistors
R_3, R_8 — 5.6K, ½ W. carbon resistors
R_4 — 8.2K, ½ W. carbon resistor
R_5 — 82K, ½ W. carbon resistor
R_6 — 10K, ½ W. carbon resistor
R_7 — 18K, ½ W. carbon resistor
R_9 — 1K, ½ W. carbon resistor

TRANSISTORS — (1) *Raytheon* 2N133;
(1) *Raytheon* 2N132
Sw_1 — SPST Toggle or Slide switch
B_1 — 6 volt battery (four penlight cells in series)
MISC. — Etched circuit wiring board (see text); Assorted hardware . . . screws, nuts, wire, solder, etc.

FIG. 5-1

For the Audiophile, a logical application of transistors to his hobby would be their use in low level audio pre-amplifiers. In this type of application, extremely low hum and noise levels are of paramount importance . . . and, on these two counts, especially designed RAYTHEON transistors can provide superior performance to conventional vacuum tubes. In the first place, the low power requirements of transistors makes battery operation entirely feasible, thus eliminating several primary sources of hum . . . A.C. power supplies, stray A.C. leads, and A.C. powered filaments. Secondly, the inherent random noise level of a well-designed transistor is lower than that of a comparable vacuum tube.

The schematic diagram for a high gain, low hum, high fidelity preamplifier is given in Fig. 5-1. Requiring but two RAYTHEON transistors, and with a noise level lower than similar vacuum tube amplifiers, this circuit is designed specifically for use with *variable reluctance* type pick-up cartridges.

Referring to Fig. 5-1, the *Hi Fi Preamp* consists of two cascaded common-emitter amplifier stages. Resistance-capacity coupling is used between stages. In operation, audio signals from the pick-up are applied through input capacitor C_1 to the base of the first stage, a type 2N133 low noise transistor. Base bias for the 2N133 is supplied by voltage divider R_1-R_2 in combination with emitter resistor R_4, by-passed by C_2, thus providing D.C. stabilization of the stage.

The amplified audio signal appearing across collector load resistor R_3 is coupled through interstage capacitor
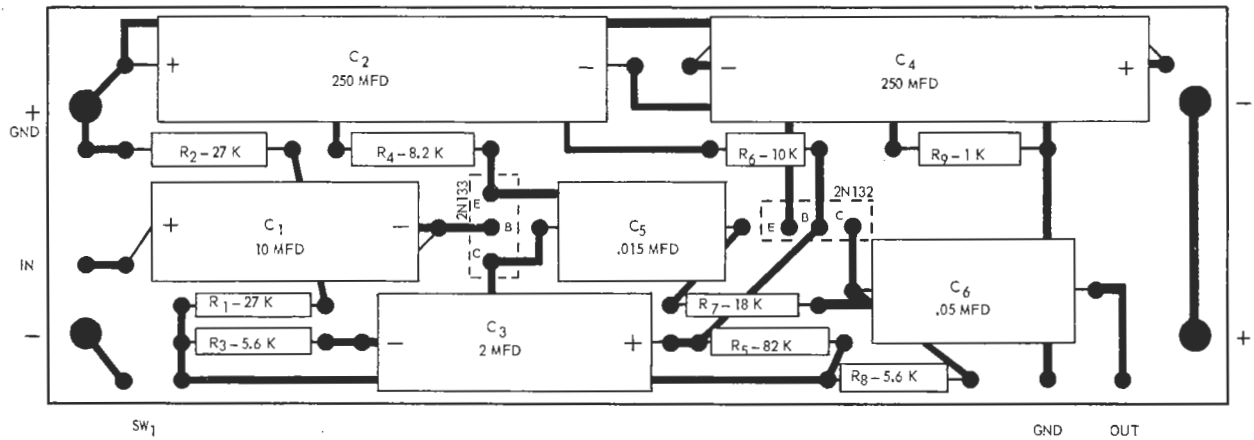
FIG. 5-3

C_3 to the second stage. The second stage, like the first, is also D.C. stabilized, with base bias supplied by a combination of voltage divider R_5-R_6 and emitter resistor R_9, by-passed by C_4.

After additional amplification by the second stage, the audio output signal appearing across collector load R_8 is coupled through D.C. blocking capacitor C_6 to the high impedance input of a power amplifier. The desired response characteristic is obtained partially by the choice of component values and partially by means of feedback circuit C_5-R_7, between the collector circuits of the two stages. Operating power is supplied by a six volt battery, B1, controlled by SPST switch Sw'.

Construction Hints

While conventional construction and wiring may be used, the *Hi Fi Preamp* fits especially well into Printed
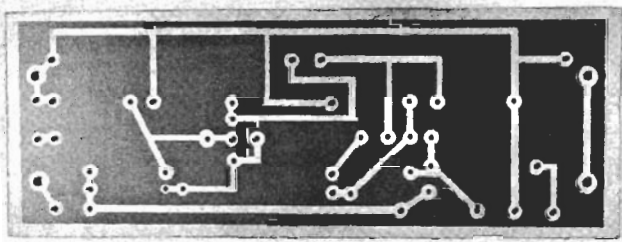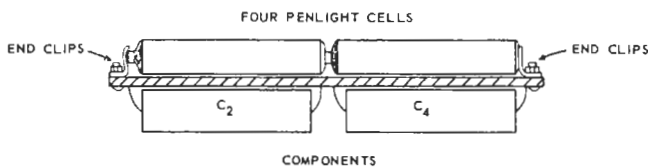

FIG. 5-2

FOUR PENLIGHT CELLS

FIG. 5-4

Circuit construction, using the etched circuit techniques discussed in the Installation and Wiring Section of this booklet. A typical etched circuit board for the instrument is shown in Fig. 5-2. Overall dimensions are not indicated since these will vary considerably with the physical size of the final components used. The pictorial layout of parts, based on the use of the board shown in Fig. 5-2, is given in Fig. 5-3 . . . relative sizes are shown, but the drawing is *not* to scale. The circuit board illustrated was made up from a *KEPRO* Printed Circuit Kit (*Keil Engineering Products*, 4356 Duncan, St. Louis 10, Missouri).

Regardless of whether conventional or etched circuit construction is followed, the builder should observe the general rules of good wiring practice. Signal leads should be kept short and direct. The "input" and "output" circuits should be kept well separated. Electrolytic capacitor polarities should be scrupulously observed. And the usual precautions against accidental heat damage should be taken when the transistors are soldered in position . . . of course, if preferred, transistor sockets may be used. As is customary, the wiring should be double-checked for possible errors *before* the battery is connected.

Power for the *Hi Fi Preamp* may be supplied by a special six volt battery, such as the *Burgess* type Z4, or by four flashlight or penlight cells connected in series. If penlight cells are used, they may be mounted on the back of the etched circuit board, as shown in Fig. 5-4, or in a separate battery holder, such as an *Austincraft* type 123 Battery Box.

Because of its light weight, small size, and freedom from microphonics, the completed *Hi Fi Preamp* may be mounted in the record player or changer's base. In order to keep stray hum pick up to a minimum, the preamp should be physically located as far away from the motor and A.C. wiring as is practicable in the available space.
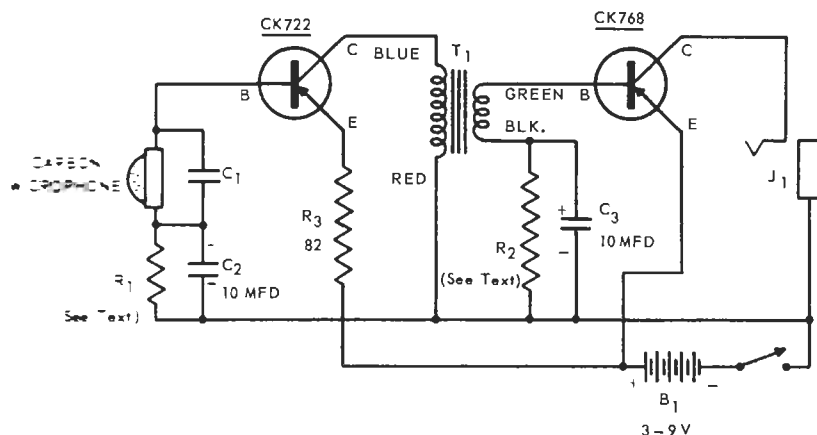
DETECTOPHONE

FIG. 5-5

The schematic diagram for a two-transistor *Detectophone* is given in Fig. 5–5. If you have an adventuresome spirit, you can have fun with your friends by using the completed instrument as a hidden "detectophone"; simply use a long microphone lead and hide the "mike" in the room where you want to overheard conversations.

Referring to Fig. 5–5, we see that the instrument is basically a two-stage transformer-coupled amplifier, with the common-emitter circuit used in each stage. In operation, the *carbon microphone* converts sound into audio electrical signals. These are applied to the CK722 stage and, after amplification, to the CK768 stage through interstage coupling transformer T_1. This transformer serves to match the high output impedance of the first stage to the moderate input impedance of the second stage, assuring an efficient transfer of the amplified signal. After additional amplification by the second stage, the final output signal drives the magnetic earphones connected to output jack J_1. Base bias current for the first stage is supplied through R_1, by-passed by C_2 . . . for the second stage, through R_2, by-passed by C_3. An unbypassed emitter resistor, R_3, is used in the first stage to raise its effective input impedance, providing a better impedance match to the microphone.

Construction Hints

The *Detectophnoe* may be assembled in a pocket-sized metal or plastic case. Although exact components placement is not critical, you should use care in making your layout to insure the most compact arrangement. If you prefer a very thin instrument, you can arrange the circuit in a pattern around the microphone cartridge. A small piece of fiber or *bakelite* may be used as a chassis. The transistors may be mounted in sockets or soldered permanently into the circuit . . . the latter method will result in the most compact construction — but be sure to observe the precautions against heat damage.

If unwanted noise is to be minimized, special care must be used in mounting the microphone cartridge. The cartridge should be cushioned in a rubber or felt ring and *recessed* into the case . . . so that the front surface of the microphone is protected by the case. Be sure to provide small holes so sound can reach the microphone proper.

Battery voltage is not especially critical, and from 3 to 9 volts may be used. The higher voltages will provide somewhat greater output volume. A small battery may be obtained by cutting a two-cell to seven-cell section from a VS087 "Separable Cell" Transistor Battery. For somewhat longer battery life, multi-cell Mercury batteries may be used. Suitable units are *Mallory's* types TR-113R (4.0 volts), TR-114R (5.0 volts) and TR-115R (6.5 volts).

The values of base bias resistors R_1 and R_2 will vary with the battery voltage used and, to a lesser extent, with the individual transistors. Choose these two resistors experimentally to give the best compromise between gain and distortion. Typical values should fall between 100,000 and 560,000 ohms.

With the wiring completed, double check all connections for possible shorts or opens and for wiring errors *before* connecting the battery ($B1$) or turning the instrument ON. Pay particular attention to electrolytic capacitor (C_2 and C_3) and battery polarities.

MICROPHONE PREAMPLIFIER

A permanent magnet (PM) electrodynamic loud-speaker makes an excellent low-cost Dynamic Micro-phone, but has the disadvantages of low signal level and low output impedance. By adding a single-stage transistor amplifier to a standard PM loudspeaker, you can assemble a good quality, high output microphone. A suitable circuit is shown in Fig. 5-6. This instrument may be used with recorders or P.A. systems, or in Ham Radiotelephone work.

Referring to the schematic diagram (Fig. 5-6), a RAYTHEON type CK722 transistor is connected as a common-base amplifier. In operation, the input signal to the emitter-base circuit is supplied by the PM loud-speaker and the amplified output signal is obtained from a small impedance matching transformer (T_1). Base bias current is supplied through base resistor R_1, by-passed by C_1, with operating power for the entire circuit supplied by a single 6-volt battery (B1), controlled by a SPST push-button switch, Sw_1.

The common-base circuit configuration used in the *Microphone Preamplifier* has a low input impedance and a high output impedance and thus is ideal for this general type of application. Transformer output is provided where the instrument is used with another transistorized instrument. However, if the device is to be connected to a high input impedance vacuum tube instrument, the matching transformer (T_1) may be replaced by a collector resistor (R_2) and D.C. blocking capacitor (C_2), as shown in the *Alternate Output Circuit* (Fig. 5-6).

Construction Hints

You can follow your own inclinations about layout and wiring when assembling the *Microphone Preamplifier*, for the circuit is completely non-critical. Any small plastic or metal box may be used as a housing; however, for an attractive desk instrument, the unit can be
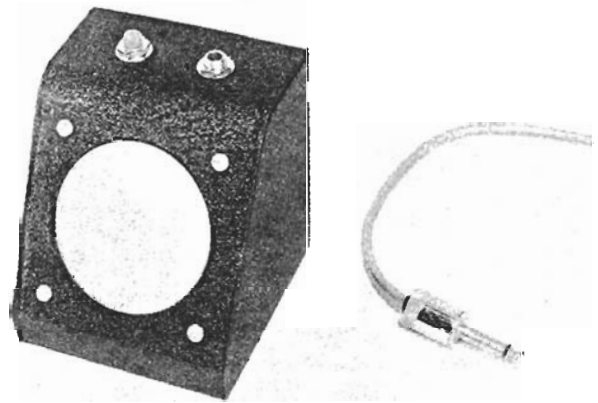
FIG. 5-7

mounted in a standard sloping front meter case, as shown in Fig. 5-7. The speaker's paper cone should be protected against accidental damage by a piece of perforated metal or flocked metal screening.

Two output circuit arrangements are shown in Fig. 5-6. The one to use will depend on the intended application of the completed instrument. If it is to be used with another piece of transistorized equipment having, say, a moderate input impedance, then best results will be obtained with the transformer-coupled arrangement. On the other hand, if the *Microphone Preamplifier* is to be connected to equipment having a high input impedance (50,000 ohms, or higher), then the price of the transformer can be saved and the alternate, resistance-coupled, output circuit used. In either case, a shielded cable is used to connect the instrument to the equipment with which it is employed to minimize noise and hum pickup.
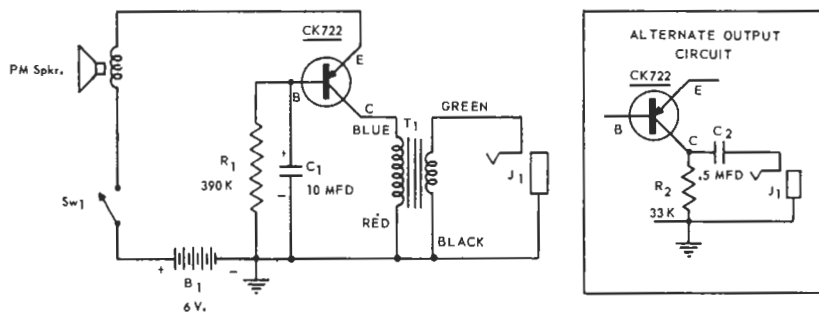
FIG. 5-6

PARTS LIST

R_1 — 390K, ½ watt carbon resistor.
R_2 — 33K, ½ watt carbon resistor (optional — see text).
C_1 — 10 Mfd., 6 volt electrolytic.
C_2 — 0.5 Mfd., 200 volt metallized paper capacitor.
T_1 — Transistor interstage transformer (*Argonne* No. AR-104 or *Thordarson* No. TR-14).
J_1 — Open circuit output jack.
Sw_1 — SPST Push-button switch.
B_1 — 6 volt transistor battery (*Burgess* No. Z4).
SPKR — 2½″ PM Loudspeaker, 10 to 16 ohm voice coil.
TRANSISTOR — (1) *Raytheon* CK722.
MISC. — Small chassis; transistor socket; battery box; flocked metal screening; meter case; Assorted Hardware . . . wire, solder, screws, nuts, etc.

(32)

PARTS LIST

R_1 — 20K potentiometer, with SPST switch.
R_2 — 470K, ½ watt carbon resistor.
R_3 — 82 ohm, ½ watt carbon resistor.
C_1 — 0.5 Mfd., 200 volt metallized paper capacitor.
C_2 — 2 Mfd., 20 volt electrolytic capacitor.
Sw_1 — SPST switch, on R_1.
B_1 — 15 volt battery (*Burgess* No. Y10).
J_1, J_2, J_3, J_4 — 'Phone tip jack.
TRANSISTOR — (1) *Raytheon* CK722.
MISC. — Battery box; control knob; small metal case; decals; Hardware . . . wire, solder, machine screws, nuts, soldering lugs, etc.

FIG. 5-8

While test instrument and shop facilities may vary considerably from one electronics laboratory to another, there is one piece of equipment that is sure to be found in virtually every lab., whether operated by a large corporation or by a Hobbyist in the basement of his home

a Magnetic Headset! And here is a piece of transistorized equipment which will greatly increase the utility of a Magnetic Headset . . . an easy-to-build *Headphone Amplifier*. The schematic wiring diagram for this instrument is given in Fig. 5-8, while an assembled model is shown in Fig. 5-9.

With a built-in long-life power supply and a self-contained GAIN control, the *Headphone Amplifier* provides an appreciable increase in Headset sensitivity and output volume. The instrument is equally valuable whether used with a piece of test equipment, such as an Impedance Bridge or Frequency Meter, or with more commonplace gear, such as a Communications Receiver.

Referring to Fig. 5-8, a CK722 transistor is used as a single-stage common-emitter amplifier. In operation, the input signal is coupled through D.C. blocking capacitor C_1 to GAIN control R_1. A portion of the available signal, depending on the setting of R_1, is coupled through capacitor C_2 to the base of the transistor. The magnetic Headphone, itself, serves as the collector load impedance, with the amplified signal driving the 'phone directly. Base bias current is supplied through base resistor R_2. Unby-passed emitter resistor R_3 serves the dual function of raising the transistor's input impedance and of providing a degree of degeneration, thus improving the amplifier's overall stability. Power is supplied by a single 15-volt battery, B1, controlled by SPST switch Sw_1, ganged with the GAIN control.
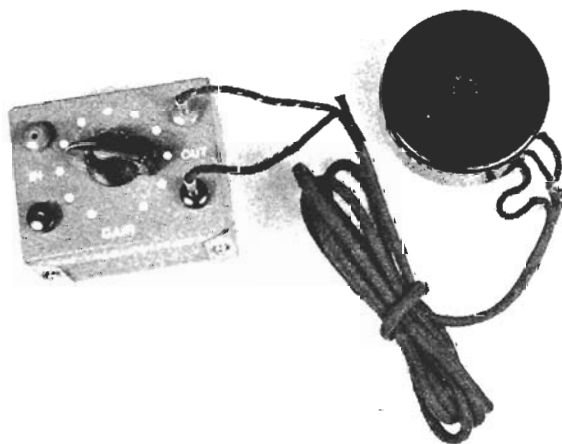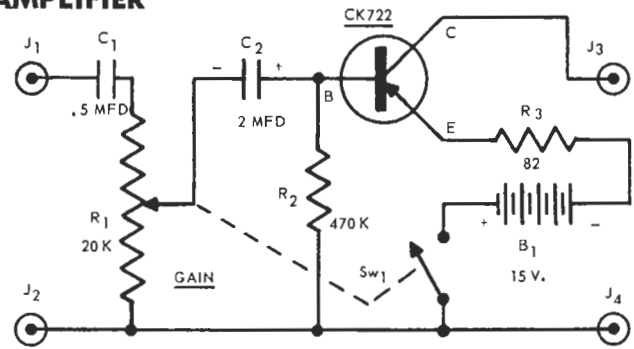

FIG. 5-9

Construction Hints

The model shown in Fig. 5-9 was assembled in a small, commercially available aluminum box; however, a plastic box will do as well, for shielding is not especially important. Neither layout nor lead dress are critical, so you can follow your own desires on these matters.

A professional "factory-built" appearance was obtained in the home-built model by using standard decals for labeling the controls and IN and OUT terminal jacks. These decals are applied *after* all mechanical work (drilling, etc.) is finished but *before* any parts are mounted. For maximum service life, the decals should be protected, after application, by spraying on two or three light coats of transparent acrylic plastic.

To use the *Headphone Amplifier*, connect your Magnetic Headset to the "output" terminals J_3 and J_4. The higher the impedance of your Headset, the better the results . . . satisfactory results can be obtained with 1,000 or 2,000 ohm 'phones, but much better gain with 4,000 or 8,000 ohm sets. A *crystal* Headphone can be used if a 27K, ½ watt resistor is connected between the output terminals. With the "input" terminals J_1 and J_2 connected to the equipment with which the amplifier is to be used, the GAIN control is turned until the switch clicks "on", then set to the desired volume level.

Several mechanical modifications may be made to meet individual requirements. If you wish, you can use a separate toggle or slide switch for Sw_1. For many applications, input capacitor C_1 can be omitted, with R_1 connected directly to the "IN" terminals. Finally, the 'phone tip jacks (J_1, J_2 and J_3, J_4) may be replaced with conventional 'phone jacks or coaxial connectors.

SPEAKER AMPLIFIER

FIG. 5-11

FIG. 5-10
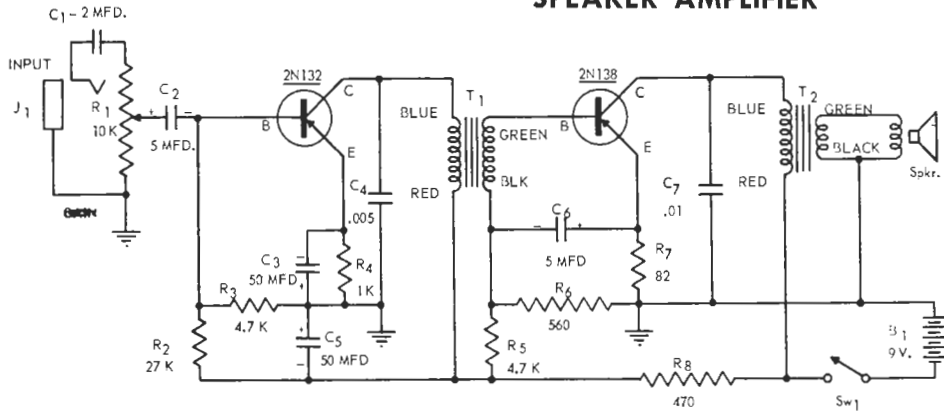
PARTS LIST

C_1 — 2 Mfd., 400 volt metallized paper capacitor.
C_2, C_6 — 5 Mfd., 12 volt electrolytics.
C_3, C_5 — 50 Mfd., 12 volt electrolytics.
C_4 — .005 Mfd., disc ceramic capacitor.
C_7 — .01 Mfd., disc ceramic capacitor.
R_1 — 10K, carbon potentiometer, audio taper, with switch.
R_2 — 27K, ½ W. carbon resistor.

R_3, R_5 — 4.7K, ½ W. carbon resistor.
R_4 — 1K, ½ W. carbon resistor.
R_6 — 560 ohm, ½ W. carbon resistor.
R_7 — 82 ohm, ½ W. carbon resistor.
R_8 — 470 ohm, ½ W. carbon resistor.
T_1 — Interstage transistor transformer (*Argonne* No. AR-109 or *Thordarson* No. TR-7).

T_2 — Output transistor transformer (*Argonne* No. AR-119 or *Thordaison* No. TR-27).
B_1 — Nine volt battery (*Burgess* No. 2N6).
Sw_1 — SPST switch, on R_1.
SPKR — 3″ PM Loudspeaker, 3.2 ohm voice coil.
TRANSISTORS — (1) *Raytheon* type 2N132; (1) *Raytheon* type 2N138.
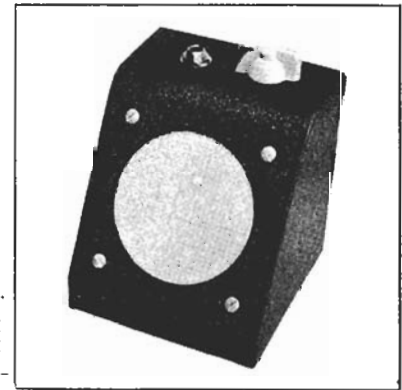
A self-contained and portable audio amplifier with loudspeaker output has many potential applications in the electronic experimenter's workshop. It may be used to check the operation of preamplifiers, audio oscillators, Radio Tuners, or similar instruments. Alone, it can be used as an *Audio Signal Tracer* for trouble-shooting P.A. amplifiers, Hi Fi Systems or Intercoms. And, of course, it might be used to provide loudspeaker operation when connected to equipment which is normally designed for earphone operation only.

The circuit for a relatively low cost and easy-to-assemble *Speaker Amplifier* is given in Fig. 5-10, while an assembled model is shown in Fig. 5-11. Assembled from standard components, the instrument has a "factory-built" appearance, and, although it operates from a single battery, its output volume is more than ample for most shop and lab. applications.

As can be seen by reference to Fig. 5-10, PNP transistors are used in a two-stage transformer-coupled amplifier, with the common-emitter circuit configuration employed in both stages. In operation, audio signals applied through INPUT jack J_1 and D.C. blocking capacitor C_1 appear across GAIN control R_1. A portion of the available signal, depending on the setting of R_1, is coupled through C_2 to the base of the first stage. Base bias current for this stage is obtained through a combination of voltage divider R_2-R_3 working in conjunction with emitter resistor R_4, by-passed by C_3. This type of bias arrangement insures D.C. stabilization of the circuit.

Interstage coupling transformer T_1 serves to match the high output impedance of the first stage to the low input impedance of the second stage, insuring an efficient transfer of the amplified audio signal. D.C. stabilization of the output (second) stage is assured by the base bias arrangement, consisting of voltage divider R_5-R_6, by-passed by C_6, and emitter resistor R_7. After additional amplification by the second stage, the audio signal is coupled to the PM loudspeaker through output transformer T_2.

The effects of harmonic distortion are minimized by high-frequency by-pass capacitors C_4 and C_7. Possible interstage coupling is eliminated by a filter network consisting of resistor R_8 and by-pass capacitor C_5. Operating power is obtained from a single 9 volt battery, B1, controlled by SPST switch Sw_1, ganged with the GAIN control (R_1).

Construction Hints

The "professionally-built" appearance of the model, shown in Fig. 5-11, is obtained by mounting the amplifier and speaker in a commercially available sloping front "Meter Case". The loudspeaker is protected by a small piece of flocked metal screening. The amplifier itself is assembled on a small sub-chassis which is wired as a separate unit *prior* to mounting in the case. Although neither parts layout nor lead dress are critical, good wiring practice should be observed . . . that is, the "input" and "output" circuits should be kept well separated and all signal leads should be as short and direct as is practicable. Special care must be taken to observe electrolytic capacitor and battery polarities.

(34)

HAM GEAR

The amateur radio operator, or *Ham*, always has been a pioneer in trying and working with new radio and electronic techniques. He did much of the early work with Ultra-High-Frequencies which, later, were used so successfully in Radar. He reduced the techniques of Single Side Band Communication to a fine art. And he was using directional high frequency antenna arrays long before their use became popular in Television. With this pioneering spirit, it is only natural that the Ham have an interest in transistor applications, for the transistor, along with related semiconductor devices, represents one of the frontiers in modern-day electronics. It is to the interests of the Ham, then, that the following *Section* of this Manual is dedicated. In discussing several applications of RAYTHEON transistors to Ham Radio, we will try to represent a cross-sectional sampling of typical uses, rather than to show the ultimate application of these marvelous devices to any particular branch of the field.
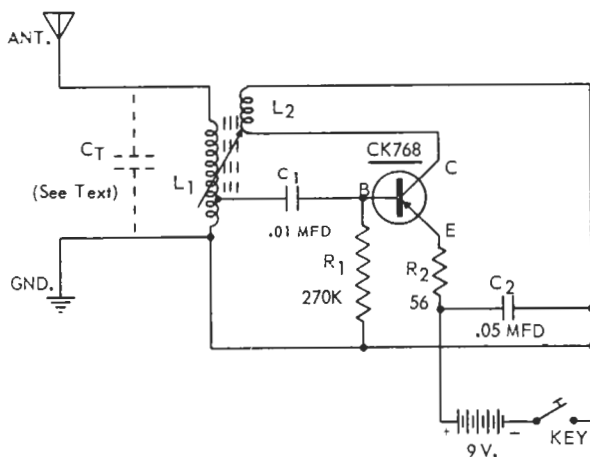
WIRELESS TRANSMITTER

FIG. 6-1

PARTS LIST

R_1 — 270K, $\frac{1}{2}$ watt carbon resistor.
R_2 — 56 ohm, $\frac{1}{2}$ watt carbon resistor.
C_1 — .01 Mfd., disc ceramic capacitor.
C_2 — .05 Mfd., 200 volt tubular paper capacitor.
C_t — Fixed ceramic capacitor (see text).
L_1 — Tapped Broadcast Band antenna coil (*Argonne* No. AR-65 or *Meissner* No. 14-9015).
L_2 — Feedback coil (see text).
B_1 — 9-volt transistor battery (*Burgess* No. 2N6).
KEY — Standard Handkey.
TRANSISTOR — (1) *Raytheon* CK768.
MISC. — Transistor socket; battery clips; small mounting board or metal chassis; Hardware . . . wire, solder, machine screws, nuts, fahnestock clips, etc.

Just as the construction of Broadcast Band Radio Receivers is the most popular project with electronic Hobbyists, the assembly and wiring of Transmitters leads the "popularity parade" with those Hams who have a yen to build their own equipment. In its simplest form, a radio transmitter need be little more than an R.F. Oscillator which is connected to an antenna. Such a transmitter emits a steady R.F. signal or *continuous wave* CW). A message may be sent by interrupting this CW signal and converting it into a series of short ("dots") and longer ("dashes") bursts of transmission, arranged according to the *Radiotelegraph Code*.

The schematic diagram for a simple transistorized *Wireless Transmitter* is given in Fig. 6–1. This transmitter is intended for experimental and demonstration use only, and while it is quite capable of sending code signals for short distances, it lacks the power and frequency stability needed for serious communications work. However, because of its limited power, it will not radiate a signal which exceeds the limits established by the FCC for unlicensed equipment and, therefore, can be used by beginners as well as licensed operators.

Referring to the schematic diagram, we see that a single R.F. transistor is used as a common-emitter R.F. oscillator. In operation, the frequency of oscillation is determined by the L_1-C_t tuned circuit. The antenna-ground (ANT., GND.) system is connected to this tuned circuit. The transistor's base is connected to a tap on L_1 through D.C. blocking capacitor C_1. Base bias current is supplied through R_1. The feedback necessary to start and sustain oscillation is furnished by collector coil L_2, coupled to L_t. An unby-passed emitter resistor, R_2, helps to stabilize the circuit, while operating power is supplied by a single 9-volt battery, B1, controlled by the Handkey (KEY), and by-passed by capacitor C_2.

Construction Hints

With neither components layout nor wiring arrangement critical, you can follow your own inclinations in assembling and wiring the *Wireless Transmitter*. For experimental work, "breadboard" construction may be followed, with all parts mounted on a wooden, *Masonite*, fiber, or *bakelite* board, or, if you prefer, more conventional construction may be used, with a metal chassis serving as a mounting base. Fahnestock clips, binding posts, or other connectors may be provided for the ANT.,

GND., and KEY terminals. The 9-volt power supply may be a single battery, as specified in the *Parts List*, or six (6) penlight or flashlight cells connected in series.

Feedback coil L_2 consists of ten to fifteen turns of No. 26 or 28 enameled wire, wound directly on top of L_1. During initial wiring, temporary "lap" soldered joints should be used for connecting L_2 into the circuit. Later, it may be necessary to reverse L_2's leads to obtain oscillation.

Tuning capacitor C_T, across L_1, determines the basic operating frequency. The exact operating frequency may be shifted somewhat by adjusting L_1's iron "slug" core. Operation is within the AM Broadcast Band, and C_T is chosen for operation near the low frequency end, middle, or high frequency end of the band, as you prefer. For operation near the high frequency end, C_T should have a value of from 25 to 100 Mmf.; for operation near the middle of the band, from 100 to 220 Mmf.; and, finally, for operation near the low frequency end, from 240 to 370 Mmf. In general, it is best to operate near the low frequency end of the band.

If you are unable to pick up the signal after tuning through the band at least twice, reverse the connections to coil L_2 and repeat the initial tests. Once you can pick up the signal, readjust L_1's "slug" (shifting frequency) until the transmitter is picked up at a "dead" spot on the receiver's dial . . . that is, at a point between local broadcast stations. When this final adjustment is made, the transmitter and receiver may be separated to maximum range . . . this will vary with the length of antenna used and the receiver's sensitivity but, in general, will be under 60 feet.

When the wiring is completed, double-check all connections before connecting the battery or installing the transistor. Connect the GND. terminal to a cold-water pipe or other external ground; connect the ANT. terminal to a six to twelve foot long antenna.

Operation and Use

Since the *Wireless Transmitter* radiates an unmodulated (CW) signal, just like larger code transmitters, it is used with a *Communications Receiver* or similar receiver having a *B.F.O.* For initial tests, the Communications Receiver should be located about ten to twelve feet from the transmitter's antenna. The transmitter's KEY is depressed and the receiver turned ON and tuned *slowly* through the AM Broadcast Band (550 to 1600 Kc); its *B.F.O.* should be "on". The transmitter will be heard as a steady tone, which can be controlled by operating the KEY. L_1's "slug" should be in its mid position.

If you are unable to pick up the signal after tuning through the band at least twice, reverse the connections to coil L_2 and repeat the initial tests. Once you can pick up the signal, readjust L_1's "slug" (shifting frequency) until the transmitter is picked up at a "dead spot" on the receiver's dial . . . that is, at a point between local broadcast stations. When this final adjustment is made, the transmitter and receiver may be separated to maximum range . . . this will vary with the length of antenna used and the receiver's sensitivity but, in general, will be under 60 feet.

CRYSTAL CALIBRATOR

The facilities and ability to measure Radio frequency signals with reasonable accuracy is extremely important to the practicing Ham. First and foremost, of course, he must make sure he operates his transmitter on the assigned Amateur Bands and within the frequency limits established by the FCC. In addition, his ability to check frequencies will help him to locate and to identify other stations which he may contact.

One of the most useful tools for quick frequency measurements is an *accurately calibrated* Communications Receiver. With such a receiver, he need simply tune in the desired signal and read its frequency on the set's calibrated dial. Such a measurement, while approximate only, is satisfactory for many types of work. Unfortunately, the dial calibration of a receiver may not be accurate . . . or, under some conditions, its accuracy may change. Factors which may affect a receiver's calibration include extreme temperature and humidity, excessive vibration or shock, as may occur in mobile
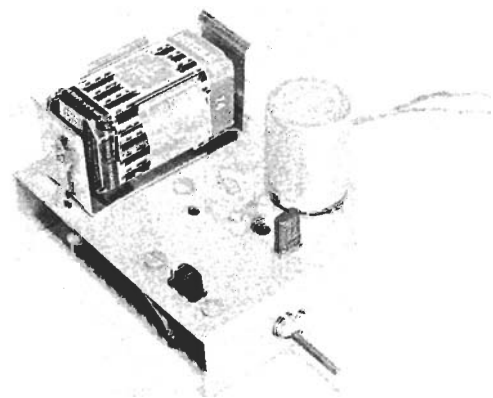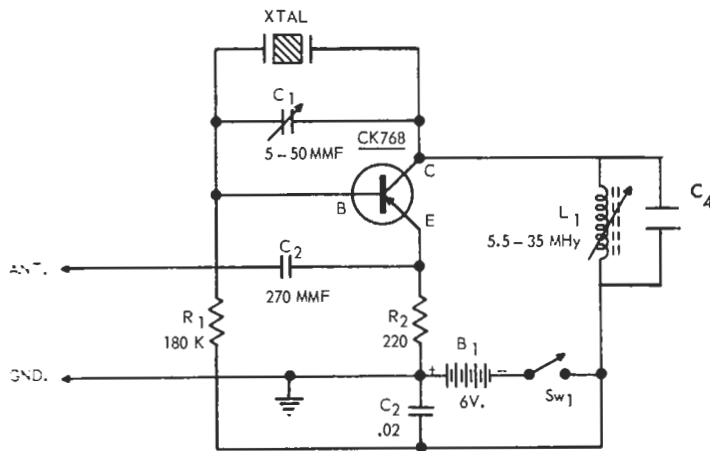

FIG. 6-2

(36)

FIG. 6-3

work, or a change in tubes in the set's "front-end" without appropriate realignment checks.

However, if you have the valuable transistorized instrument shown in Fig. 6–2 (schematic diagram given in Fig. 6–3), you can check the dial calibration of your receiver whenever you wish. This instrument provides a crystal-controlled 100 KC R.F. signal, with harmonics at 100 KC intervals, thus giving you many, many "check points" across a receiver's dial. The *Crystal Calibrator* is a worthwhile addition to any "Ham Shack".

Referring to Fig. 6–3, we see that a CK768 R.F. transistor is used as a common-emitter crystal-controlled oscillator. In operation, an adjustable R.F. choke, L_1, serves as the collector load impedance, while the feedback necessary to start and sustain oscillation is provided through the quartz crystal (XTAL) with its adjustable trimmer capacitor C_1. Base bias current is supplied through R_1. Unby-passed emitter resistor R_2 provides sufficient degeneration to insure stable operation while, at the same time, serving the second function of acting as an output resistor, providing a low-impedance resistive output and minimizing circuit loading. The output signal is obtained through D.C. blocking capacitor C_2. Operating power is obtained from a single six volt battery, B1, controlled by SPST switch Sw_1, and by-passed by C_3.

Construction Hints

Since the circuit is not at all critical, you can vary the type of construction with the intended use of the completed instrument. If you plan to use the *Crystal Calibrator* as a general purpose test instrument in field work as well as in the lab., you might assemble it in a small plastic or metal case. For bench use only, simple chassis construction might be employed. If your primary interests are

circuit investigation and experimental tests, you may wish to "breadboard" the circuit on a flat wooden or fiber mounting board. And, finally, you might wish to assemble the unit as an integral part of a Communications Receiver.

Above and below chassis views of the author's home-built model are given in Figs. 6–2 and 6–4, respectively. A top view of the completed model is shown in Fig. 6–2, while a partially assembled view is given in Fig. 6–4. Since the author's model was intended for bench use only, "chassis" type construction was employed. The parts layout and general arrangement are evident from the photographs, but this layout need not be followed exactly in your model.

Operation and Adjustment

When the wiring is completed and double-checked for accuracy, the battery, crystal, and transistor may be installed. The ground (GND.) lead is connected to the *GROUND* terminal of the receiver with which the *Crystal Calibrator* is to be used. The output (ANT.) lead is loosely coupled to the receiver's *antenna lead-in* by giving it several twists around this wire.

With the receiver turned "ON" and warmed up, turn on the receiver's Beat Frequency Oscillator (*B.F.O.*) and the *Crystal Calibrator*. Tune to some even multiple of 100 KC near the low frequency end of the receiver's range . . . say near 600 or 700 KC in the AM Broadcast Band . . . listening for the "beat note" from the *Crystal Calibrator*. You can tell when you have it by switching the calibrator "off". If you are unable to pick up the signal, try readjusting L_1 until the circuit oscillates easily.

Finally, tune to a known station (such as WWV at 2.5 MC or 5 MC) whose frequency is an even multiple of 100 KC. Switch the receiver's *B.F.O.* "off", and the

Crystal Calibrator "on". Adjust the calibrator to "zero beat" with the station by adjusting C_1 and L_1. In general, C_1's adjustment will cause a *slight* shift of frequency. L_1's adjustment has relatively little effect on frequency and is important only to insure that the circuit oscillates easily.

Once the *Crystal Calibrator* is set to *exactly* 100 KC by using a known station as a "standard", you should be able to pick up "beats" at 100 KC intervals across the receiver's dial, using the set's *B.F.O.* Since the higher frequency harmonics are weaker, you may have to connect the calibrator's output (ANT.) lead *directly* to the receiver's *Antenna* terminal to get beats on the higher frequency bands.
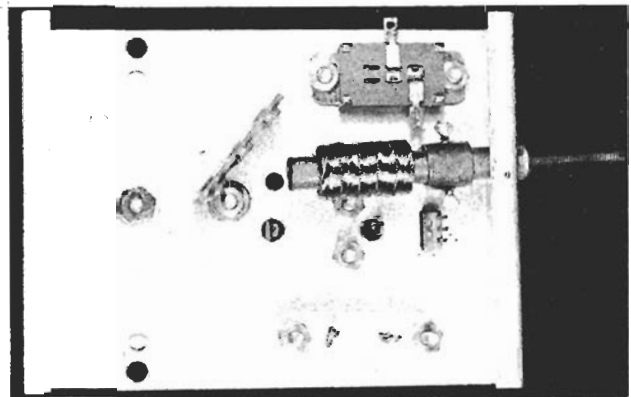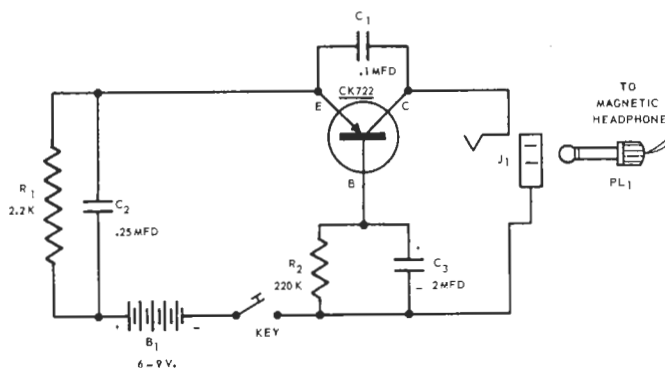

FIG. 6-4

CODE PRACTICE OSCILLATOR

FIG 6-5

PARTS LIST

R_1 — 2.2K, ½ watt carbon resistor.
R_2 — 220K, ½ watt carbon resistor.
C_1 — 0.1 Mfd., 200 volt tubular paper capacitor.
C_2 — 0.25 Mfd., 200 volt tubular paper capacitor.
C_3 — 2 Mfd., 12 volt electrolytic capacitor.
B_1 — 6 to 9 volt battery.
J_1 — Open circuit 'phone jack.
PL_1 — Standard 'phone plug.
KEY — Standard Handkey.
TRANSISTOR — (1) *Raytheon* CK722.
MISC. — Magnetic headphones (1,000 to 2,000 ohms); transistor socket; small metal box; binding posts or tip jacks; battery clip; Hardware . . . wire, solder, machine screws, nuts, etc.

The *Radiotelegraph Code* is the "universal" language of radio communications. Because of this, a prospective Ham must demonstrate a useable knowledge of this code before he can be issued an operator's license by the Federal Communications Commission (FCC) . . . he must be able to *send* and to *receive* code messages accurately with reasonable speed. The ability to do this is acquired by both study and practice, with the major emphasis on *practice*.

Practice in receiving code messages may be obtained by listening to CW stations over a Communications Receiver. Practice in sending code is obtained by using a *Code Practice Oscillator* and standard Handkey. Such an instrument is also useful for practicing code reception if you have a skilled friend who can "send" to you . . . with the added advantage that you can start "receiving" at a slow rate, then gradually work up to greater speeds as your skill increases. The schematic wiring diagram for a low-cost *Code Practice Oscillator* is given in Fig. 6–5.

Referring to the schematic diagram, we see that a single CK722 transistor is used as a common-base audio oscillator. In operation, base bias current is supplied through R_2, by-passed by C_3. A pair of magnetic Headphones, plugged into output jack J_1, serves as the collector load, while the feedback necessary to start and sustain oscillation is obtained through voltage-divider C_1-C_2. A

small resistor, R_1, serves as the emitter "load". Operating power is supplied by a single battery, B1, controlled by the Handkey (KEY).

Construction Hints

As with most simple transistor projects, the layout and wiring of the *Code Practice Oscillator* are completely non-critical. You can assemble the instrument in a small metal or plastic box . . . or you can use an open "breadboard" wiring, as you prefer. An open circuit jack (J_1) is provided for the magnetic headphones with which the instrument is used, and either 'phone tip jacks, binding posts, Fahnestock clips, or similar connections may be provided for the Handkey terminals.

The battery voltage is not especially critical and you should obtain acceptable results with either a 6 volt battery (such as a *Burgess* No. Z4) or a 9 volt unit (such as a *Burgess* No. 2N6). If you prefer, you can obtain the necessary operating voltages by connecting penlight or flashlight cells in series. Four cells will supply 6 volts . . . six will supply 9 volts.

For proper operation the *Code Practice Oscillator* must be used with a pair of moderate impedance Magnetic Headphones. Impedance values of 1,000 to 2,000 ohms will give the best results.

HAM STATION MONITOR

FIG. 6-6
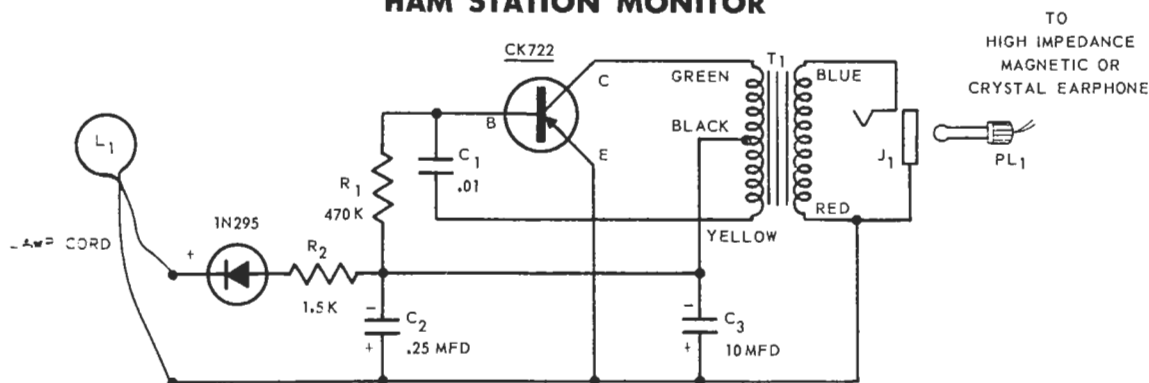
PARTS LIST

R_1 — 470K, ½ watt carbon resistor.
R_2 — 1.5K, ½ watt carbon resistor.
C_1 — .01 Mfd., disc ceramic capacitor.
C_2 — .25 Mfd., 200 volt tubular paper capacitor.

C_3 — 10 Mfd., 6 volt electrolytic capacitor.
L_1 — Pick-up loop, 3 to 4 turns No. 16 wire (see text).
T_1 — Interstage transistor transformer (*Argonne* No. AR-109 or *Thordarson* No. TR-7).
J_1 — Open circuit 'phone jack.
PL_1 — Standard 'phone plug.

DIODE — (1) *Raytheon* 1N295.
TRANSISTOR — (1) *Raytheon* CK722.
MISC. — High impedance crystal or magnetic earphone; small plastic case; transistor socket; lamp cord; Hardware . . . wire, solder, machine screws, nuts, soldering lugs, etc.

The radio Ham who operates a CW station can improve his "fist" if he monitors his own signals. He can do this without keeping his Communications Receiver tuned to his station frequency if he assembles and uses a simple *Ham Station Monitor*. The schematic circuit diagram for a transistorized version of such an instrument is given in Fig. 6–6. Basically, the instrument shown is an audio oscillator which is powered by R.F. energy picked up from the Ham's own transmitter. When a signal (dot or dash) is sent, an audio tone is heard in the earphones. The instrument uses no "stand-by" power and, because of the minute power requirements of the transistor, uses only an infinitesimal amount of the R.F. energy available from the Ham's transmitter, and has virtually no effect on the station's effective radiated power.

Referring to Fig. 6–6, a CK722 transistor is connected as a common-emitter audio oscillator, transformer-coupled to a high impedance magnetic or crystal earphone. The feedback necessary to start and sustain oscillation is obtained from the center-tapped winding of transformer T_1; one side of this winding connects directly to the transistor's collector; the other side of the winding is coupled through D.C. blocking capacitor C_1 to the transistor's base. Base bias current is supplied through R_1.

In operation, D.C. operating power is obtained from an R.F.-powered half-wave rectifier circuit. R.F. energy is picked up from the final stage of a transmitter by means of coil L_1 and rectified by a 1N295 diode. The rectified signal is filtered by R_2 and capacitors C_2 and C_3.

Construction Hints

The assembly and wiring of the *Ham Station Monitor*

is straightforward and simple. A small piece of *bakelite* or fiber board may be used as a "chassis" and the completed instrument may be mounted in a small plastic or metal case. The only special care that should be exercised in wiring the unit is in soldering the diode in place (a socket is used for the transistor) and in observing diode and electrolytic capacitor (C_3) polarities.

After the wiring is completed and checked for errors, the pick-up coil (L_1) may be assembled. This consists of from three to six turns of No. 16 or 18 wire on a form two to four inches in diameter . . . for best results, L_1 should be wound on a form slightly larger than the "final" tank coil in your transmitter. Enameled, cotton-covered, silk-covered, or plastic insulated hook-up wire may be used for L_1. This coil is connected to the "monitor" with a length of twisted pair *lamp cord*.

To use the completed instrument, plug a high impedance magnetic or crystal earphone into output jack J_1. Listening to the earphone, close the key of your transmitter and couple L_1 *loosely* to the plate tank coil of your "final". Use the *minimum* coupling needed to produce a tone in the earphones and arrange a permanent mounting for L_1 in this position. The coupling needed will vary with the output power of your "final".

If the output tone is not to your liking, you can vary its frequency and tonal quality somewhat by experimenting with the values of C_1 and R_1. In addition, a small capacitor (.001 to .01 Mfd.) across T_1's primary will change the audio frequency. Finally, electrolytic filter capacitor C_3 may not be necessary in all cases. Try your own unit with C_3 disconnected, leaving it out if you are satisfied with the results.

TEST EQUIPMENT

Every electronics laboratory worker, be he an experimenter, hobbyist, student engineer, factory technician, or Radio-TV serviceman, uses test instruments in his work or avocation. But the actual application of the test instruments vary widely, depending on the interests of the individual user. Experimenters, hobbyists, and students use their test gear to check out circuits and to eliminate "bugs" in newly assembled equipment. Servicemen, on the other hand, are more interested in finding the defective part or connection in a piece of factory-built equipment.

Because of their small physical size, light weight, reliability, and minute power requirements, transistors are ideally suited to the design and construction of workbench and portable test equipment. In this *Section* we will discuss several transistorized test instruments you can build and use.

But before trying to operate any piece of test apparatus, whether transistorized or not, you should remember that a test instrument is only a tool . . . it is not a panacea or "cure-all". Its effectiveness in trouble-shooting or circuit investigation work depends more upon the skill of the operator than upon its built-in characteristics. So to obtain the most from your test instruments, you'll find it best to obtain considerable practice using them before tackling serious jobs.
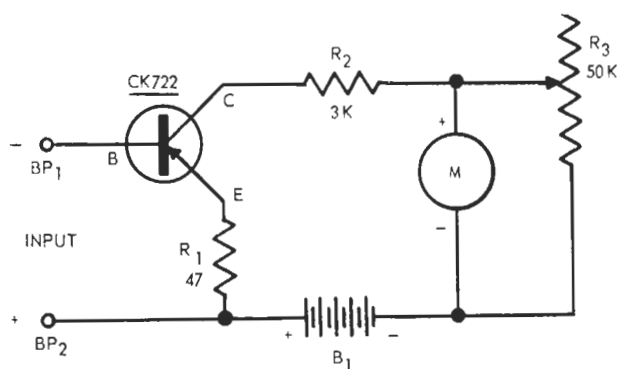
METER AMPLIFIER

FIG. 7-1

PARTS LIST

R_1 — 47 ohm, ½ watt carbon resistor.
R_2 — 3K, ½ watt carbon resistor (see text).
R_3 — 50K, carbon potentiometer.
M — 0-1 MA D.C. milliammeter.
B_1 — 3 to 9 volt battery (see text).
TRANSISTOR — (1) *Raytheon* CK722.
MISC. — Transistor socket; battery box; (2) binding posts (BP₁, BP₂); meter case; Hardware . . . wire, solder, small chassis, machine screws, nuts, soldering lugs, etc.

When connected in the common-emitter configuration, a junction transistor is essentially a *current* amplifier. A comparatively small base current can control a much larger collector current. What more natural, then, to use the transistor as a D.C. amplifier to increase the effective sensitivity of a meter? A basic circuit for accomplishing this is given in Fig. 7-1.

Referring to the schematic diagram, a CK722 transistor is used as a single-stage D.C. amplifier. The collector load consists of a series current limiting resistor (R_2) and a meter, M, shunted by an adjustable calibration rheostat, R_3. Unby-passed emitter resistor R_1 has a dual function . . . it increases the effective input impedance of the circuit while, at the same time, improving circuit stability by virtue of its degenerative action. Power is supplied by a single battery, B1.

In operation, the instrument is used as a D.C. current meter with a sensitivity many times greater than that of the basic meter movement (M) used. *Input* terminals

BP₁ and BP₂ are connected in series with the circuit whose current is to be measured, as with any current meter. Thus, the D.C. circuit current becomes the base-emitter current of the transistor. The collector current, measured by meter M, is much larger than the base current due to the gain of the transistor. However, the collector current is directly proportional to base current. Hence M's scale may be calibrated to indicate *Input* (or base) current flow.

Calibration

The gain obtained will depend on parts tolerances. In general, you should be able to obtain a current gain of at least ten . . . thus, an 0-1 MA meter (M) will have a full scale sensitivity of 100 microamperes. Calibration potentiometer R_3 is used to adjust the full-scale sensitivity of the meter (M) to the value you require. To adjust R_3, apply the maximum current you wish to measure to the instrument's *Input* terminals (for example, 100 microamperes), and adjust R_3 for a full-scale reading.

The meter's (M) original scale may be used for *approximate* readings, with an appropriate "Multiplying Factor". For example, if you use an 0-1 MA meter and have a gain of ten, then your multiplying factor become 0.1 ... that is, the new full-scale reading is 0.1 MA (100 Microamperes). For more accurate readings, you'll need to make up a new scale or a Calibration Chart. Make a series of test readings to obtain the necessary calibration points.

Construction Hints

Since the *Meter Amplifier* is a D.C. instrument, neither lead dress nor parts layout are critical. Almost any type of construction and housing may be used, but for a "factory-built" appearance, the basic amplifier circuit may be assembled on a small metal sub-chassis, with the entire instrument housed in a standard sloping front Meter Case, as specified in the *Parts List*. The calibration resistor (R₃) should be equipped with a slotted shaft for screwdriver adjustment and should be readily accessible with the instrument mounted in its case.

Series resistor R₂ is included to protect the meter (M) in the event that the transistor is accidentally damaged or shorted. Its value will depend on the D.C. resistance of the meter and on the type of meter used. If a delicate D'Arsonval meter movement is used, R₂ should be chosen to permit not more than a 100% overload in the event that the emitter-collector circuit is shorted. The value

listed (3K) is satisfactory for an 0-1 MA meter and a 4.5 or 6 volt battery (B1), but a larger resistor should be used here for higher battery voltages . . . and vice versa. If a high resistance "moving vane" meter movement is used, R₂ may be omitted.

The battery may supply from 3 to 9 volts, depending on the basic meter movement used. It may be made up from penlight cells connected in series or a single medium voltage battery may be used. A suitable choice is a *Burgess* type Z4 (6 volt) if an 0-1 MA meter is used, and if other component values are as specified in Fig. 7-1.

After the wiring is completed and checked, the battery and transistor may be installed and the instrument's operation checked. In some instances, a small up-scale reading will be obtained even with the *Input* terminals BP₁ and BP₂ "open". The value of this reading will depend on the transistor's inherent "leakage" current and will vary with different units due to normal tolerances. In any case, the meter's reading (M) with BP₁ and BP₂ "open" is the nominal "zero" reading of the instruent.

Apply a small current to the *Input* terminals and note ihe meter (M) reading obtained. As the *Input* current is tncreased, the meter's pointer should swing further and further up-scale. A test current may be obtained by connecting a 1 megohm potentiometer in *series* with a 1.5 volt dry cell. Set the pot. to its maximum resistance *before* connecting to the *Meter Amplifier's Input* terminals.

SIGNAL TRACER

Of the various trouble-shooting or diagnostic techniques available to the Radio-TV Serviceman, by far the most effective are those which use a known signal for checking the operation of the defective equipment. Such techniques fall into two general classes . . . *Signal Tracing* and *Signal Injection*. Where a Signal Tracing method is used, a known signal is followed through the equipment. Where a Signal Injection method is used, a known signal is inserted (injected) into various stages of the equipment. Both techniques are suitable for troubleshooting various defects, including *noise, weak operation,* or *no operation* ("dead set").

Transistorized test instruments may be used to advantage in applying either of these valuable servicing methods. An easily-built pocket-sized *Signal Tracer* is shown in Fig. 7-2. This instrument is designed especially for checking AM Broadcast Band receivers, including auto sets, portables, and Home Receivers. A simple *Signal Injector* will be discussed later.

The schematic wiring diagram for the *Signal Tracer* is given in Fig. 7-3. Referring to this diagram, we see that the complete instrument consists of a diode detector and a two-stage resistance-capacity coupled audio ampli-
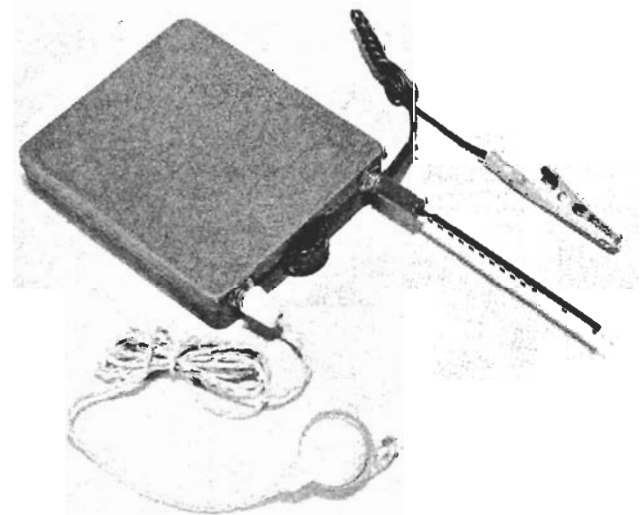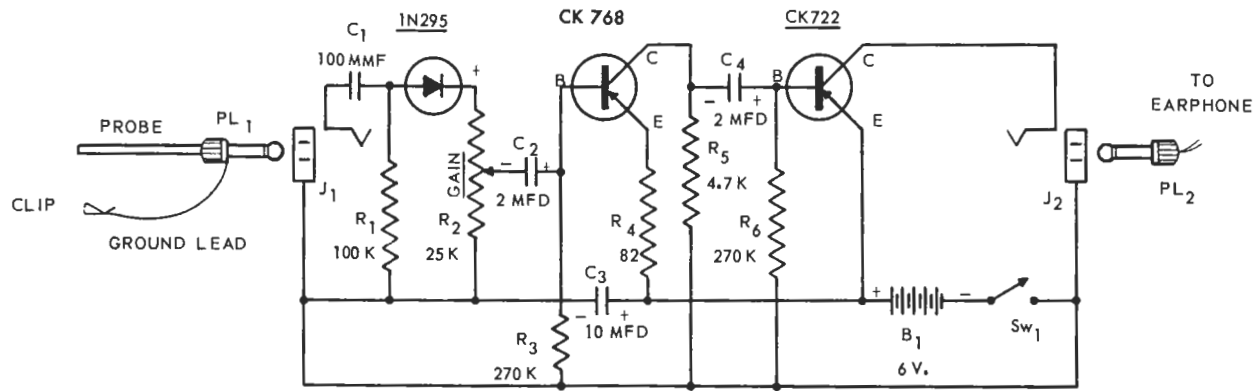

FIG. 7-2

fier. The common-emitter circuit configuration is used in both stages. An earphone serves as an output indicator and operating power is supplied by a 6 volt battery (B1), controlled by a SPST switch (Sw₁) and by-passed by an electrolytic capacitor (C₃).

CK 768   CK722

1N295

PROBE   PL₁

CLIP

GROUND LEAD

TO EARPHONE

PARTS LIST

R₁ — 100K, ½ watt resistor.
R₂ — 25K, subminiature gain control, with switch and knob.
R₃, R₆— 270K, ½ watt carbon resistors.
R₄ — 82 ohm, ½ watt carbon resistor.
R₅ — 4.7K, ½ watt carbon resistor.
C₁ — 100 Mmf., tubular ceramic capacitors.

C₂, C₄ — 2 Mfd., 6 volt electrolytic capacitors.
C₃ — 10 Mfd., 6 volt electrolytic capacitor.
Sw₁ — SPST switch, on R₂.
J₁, J₂ — Subminiature open circuit jacks.
PL₁, PL₂, — Subminiature plugs.
B₁ — 6 volt battery (see text).
DIODE — (1) *Raytheon* 1N295..
TRANSISTORS — (1) *Raytheon* CK768;
                  (1) *Raytheon* CK722

EARPHONE — High impedance magnetic earphone.

MISC. — Small metal case; *bakelite* or fiber mounting board; miniature alligator clip; (2) transistor sockets; Hardware . . . wire, solder, machine screws, ground lugs, nuts, etc.

FIG. 7-3

In operation, the R.F. signal picked up by the PROBE is coupled through capacitor C₁, appearing across input resistor R₁. This signal is demodulated (detected) by the 1N295 diode, and the resulting audio signal appears across GAIN control R₂. A portion of this audio signal, depending on the setting of R₂, is coupled through D.C blocking capacitor C₂ to the base of the first stage.

The amplified audio signal appearing across collector load resistor R₅ is fed through interstage coupling capacitor C₄ to the second stage, where additional amplification

occurs, with the final output signal driving the magnetic earphone connected to output jack J₂. The earphone serves as the collector load for the second stage.

Base bias current for the first stage is supplied through R₃ . . . for the second stage through R₆. An unby-passed emitter resistor (R₁) in the first stage serves the dual purpose of increasing the effective input impedance of the stage and of improving circuit stability, by virtue of its degenerative action.
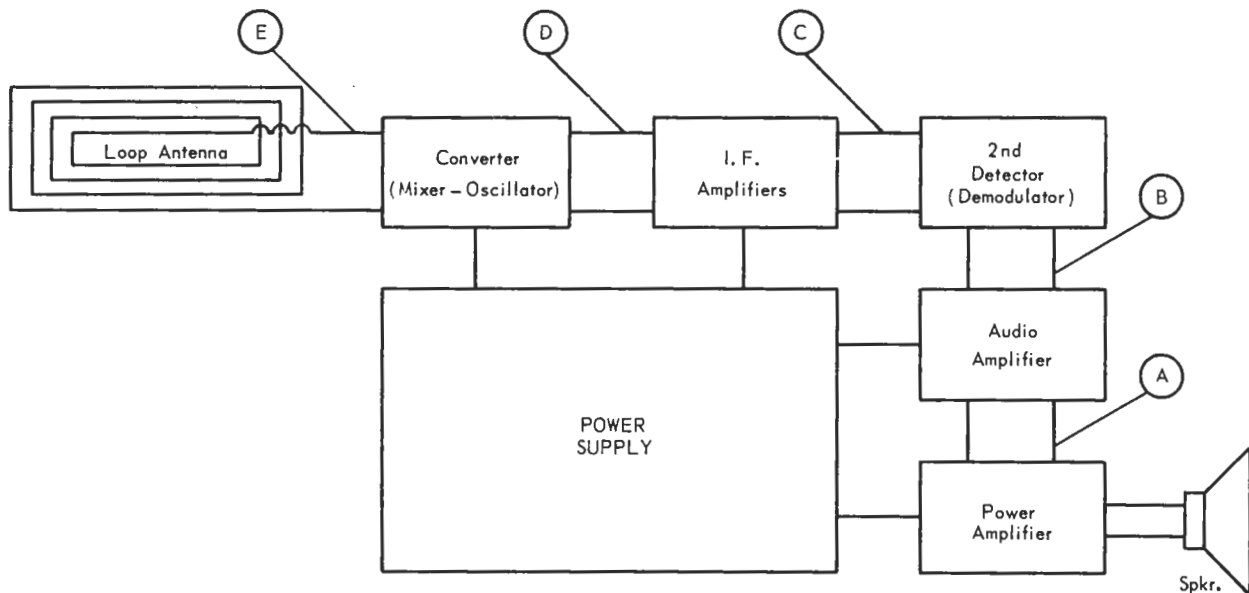

FIG. 7-4

(42)

Construction Hints

Although the *Signal Tracer's* layout and wiring are not especially critical, you'll find it best to follow good wiring practice when assembling your own instrument. The detector circuit should be kept as close to the input PROBE as is practicable, and the "input" and "output" circuits of the amplifier stages should be kept well separated. All signal leads should be kept as short and direct as is possible. And be sure to observe all electrolytic capacitor and battery polarities.

In the author's model, shown in Fig. 7-2, a small masonite board was used as a "chassis", and a flat metal cigarette box used as an outer case. The "factory-built" appearance of the model was achieved by applying a coat of *wrinkle* varnish to the case. The finish should be applied *after* all machine work is finished, with plenty of drying time allowed before parts are mounted and wiring started.

A detachable PROBE is provided. It is made up by mounting a straightened piece of heavy bus bar in a sub-miniature plug (PL$_1$). A flexible ground lead and clip are attached to the plug's barrel. The PROBE's assembly is completed by slipping a piece of insulating tubing over the bus bar, leaving only the tip exposed.

The battery voltage is not too critical. A suitable power supply may be made up by using a 4-cell or 5-cell section cut from a type VS087 "separable cell" transistor battery. The battery (B1) may be held in place by a small "C" type cable clamp or by a hand-made bracket.

Signal Tracing

A detailed discussion of servicing techniques would be out-of-place in this booklet. However, we can discuss the basic use of the completed *Signal Tracer*. Refer to the simplified block diagram of a superheterodyne AM Broadcast Band receiver given in Fig. 7-4. To use the *Signal Tracer* for checking such a receiver, first make sure that the set is "on" and tuned to a strong local station. Connect the instrument's GROUND LEAD to the receiver's chassis or "ground". Insert the earphone plug and turn the *Signal Tracer* "on", adjusting GAIN control R$_2$ for full volume. Starting at the receiver's antenna, the PROBE may be touched to the "input" and "output" of each stage to check individual stage operation.

For example, referring to Fig. 7-4, the probe might be touched to points "E", "D" and "C". At each point, the GAIN control can be readjusted for normal earphone volume. If we find that the radio station's program is heard at points "E" and "D", but not at point "C", we have isolated the defective stage . . . the I.F. amplifier!

As designed, the *Signal Tracer* is intended for use in checking R.F.-I.F. stages only. The instrument may be converted for use as an *Audio Signal Tracer* by replacing C$_1$ (Fig. 7-3) with a 0.05 Mfd. capacitor and shorting out the diode detector (1N295).

One word of caution . . . when using the *Signal Tracer* to service or to check A.C.-D.C. receivers, use an *isolation transformer* between the receiver and line receptacle to avoid accidental shocks. No isolation transformer is needed when checking A.C.-only sets (those with a power transformer) or self-contained (portable) receivers.

SIGNAL INJECTOR
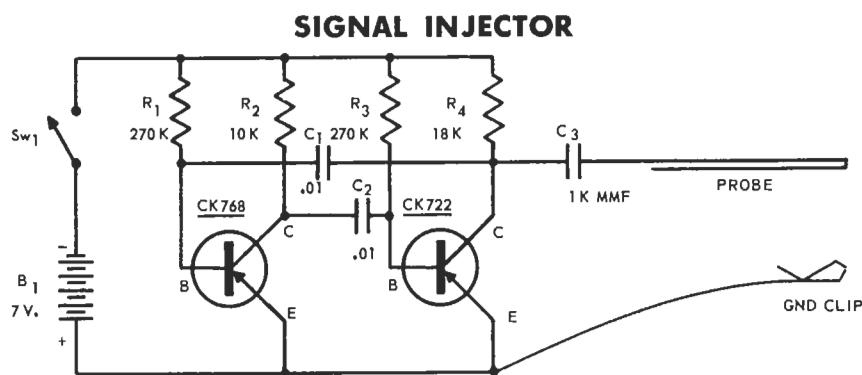
PARTS LIST

R$_1$, R$_3$ — 270K, ½ watt carbon resistors.
R$_2$ — 10K, ½ watt carbon resistor.
R$_4$ — 18K, ½ watt carbon resistor.
C$_1$, C$_2$ — .01 Mfd., disc ceramic capacitors.

C$_3$ — 1K Mmf. (.001 Mfd.) disc ceramic capacitor.
Sw$_1$ — SPST slide switch.
B$_1$ — 7 volt battery (see text).
TRANSISTORS — (1) *Raytheon* CK768
(1) *Raytheon* CK722

MISC. — Small plastic case; subminiature clip; piece of perforated *bakelite;* (2) transistor sockets; Hardware . . . wire, solder, machine screws, nuts, soldering lugs, etc.

FIG. 7-5

The basic servicing "philosophy" is the same whether *Signal Tracing* or *Signal Injection* diagnostic techniques are employed. That is, each stage of the defective equipment is checked under typical operating conditions. However, in actual applications these two techniques are almost exact opposites. In *Signal Tracing*, a signal ap-

plied to the "input" of the equipment is followed ("traced") through the circuit stage by stage. For example, in a receiver the signal is followed from the *antenna* towards the output (loudspeaker) stage. With *Signal Injection*, on the other hand, a signal is deliberately injected into each stage *starting at the output and working back towards the input stage.*

The schematic wiring diagram for a simple transistorized *Signal Injector* is given in Fig. 7-5, with top and rear views of a completed model given in Figs. 7-6 and 7-7, respectively. The instrument is shown in use in Fig. 7-8.

Referring to Fig. 7-5, we see that two RAYTHEON PNP transistors are connected as a simple collector-coupled multivibrator. The common-emitter circuit configuration is used in both stages. Base bias currents are furnished through base resistors R_1 and R_3; R_2 and R_4 serve as collector load resistors; interstage coupling is provided by capacitors C_1 and C_2. The output signal is obtained through D.C. blocking capacitor C_3. Operating power is supplied by a single 7-volt battery, B1, controlled by SPST switch Sw_1.

In operation, the multivibrator circuit used in the *Signal Injector* furnishes a complex signal rich in harmonics. Although the basic repetition rate (frequency) falls within the audio range, signal harmonics extend through the AM Broadcast Band, thus permitting the instrument to be used to inject a test signal in I.F. and R.F. as well as in audio stages.

Construction Hints

The construction of the author's model is shown clearly in Figs. 7-6 and 7-7. You should have little or no difficulty assembling your own *Signal Injector* using these illustrations as a guide. Of course, if you prefer, you can work up an original layout, for neither components arrangement nor lead dress are critical.

In the author's model, a small plastic box was used as a case. A piece of perforated *bakelite* serves as a chassis, and the 7-volt battery, a five-cell section cut from a type VS087 "separable cell" transistor battery, is held in place by two ground lugs wedged on either end of the unit. These soldering lugs also serve to make electrical contact to the battery. The PROBE is a short length of straightened #12 tinned bus bar. A hand-made clip is used to hold the PROBE in place, making it easily removable for packing. The PROBE is shown in place in Fig. 7-6 and removed in Fig. 7-7.

Operation and Use

The basic use of the transistorized *Signal Injector* is illustrated in Fig. 7-8. The GND CLIP is clipped to the defective equipment's chassis or "ground" circuit. Both the *Signal Injector* and the equipment being serviced (receiver in this case) are turned "on". Finally, the in-
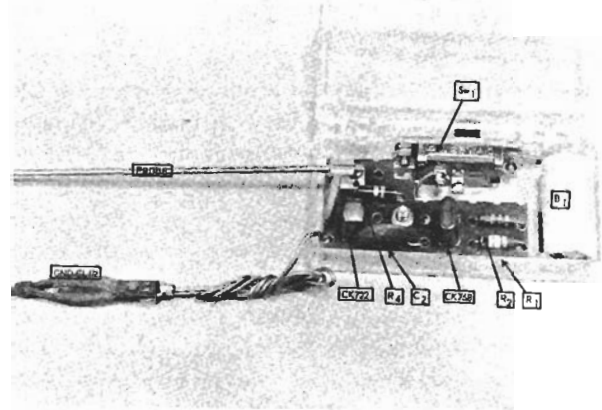
FIG. 7-6
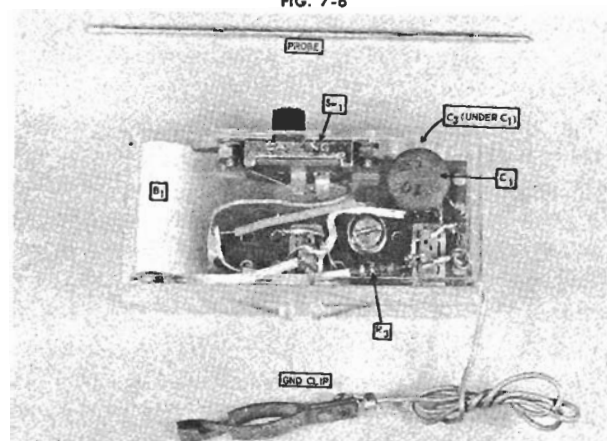
FIG. 7-7
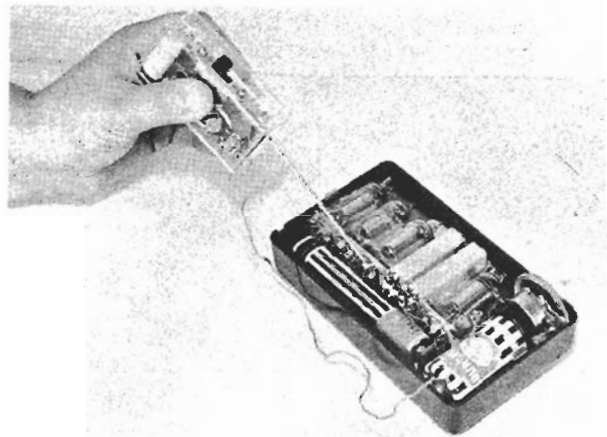
FIG. 7-8

strument's PROBE is touched to the "input" of the equipment's *output* stage and transferred back, stage-by-stage, to the input. Whenever the signal is lost, the defective stage has been isolated.

Referring to Fig. 7-4, the *Signal Injector's* would be touched first to point "A", then to points "B", "C", "D" and "E", in that order. In each case, an audio tone should be heard in the loudspeaker unless the following stage is defective.

(44)

CONTROLS & GADGETS

Aside from Communications and Entertainment equipment applications, the greatest Industrial use of electronic circuitry, whether transistorized or not, is in Control Equipment. Electronic control applications cover an area limited only by the imagination of Design Engineers. Such controls handle jobs ranging from automatically switching on lights at night to operating complex production and processing machinery in block-sized Manufacturing plants . . . from opening doors for Department Store customers to guarding Military In-

stallations against spies and saboteurs . . . from counting the number of autos crossing a bridge to automatically directing the guided missile batteries that guard our cities against sneak attacks. Because of their overall importance, we will discuss a few simple transistorized controls in the following pages. In addition, you'll find circuits and construction data for a couple of intriguing "Gadgets" . . . transistorized devices which are interesting to build and fascinating to use, but which cannot be classified to fit into earlier *Sections* of this Manual.

HOME BROADCASTER

FIG. 8-1

PARTS LIST

R₁ — 47K, ½ watt carbon resistor.
R₂ — 100 ohm, ½ watt carbon resistor.
R₃ — 470K, ½ watt carbon resistor.
C₁ — Small ceramic or mica capacitor (see text).
C₂ — .005 Mfd., disc ceramic capacitor.

C₃ — .01 Mfd., disc ceramic capacitor.
C₄, C₅ — 10 Mfd., 10 volt electrolytics.
L₁ — Tapped antenna coil (*Argonne* No. AR-65 or *Meissner* No. 14-9015).
L₂ — Tickler feedback coil, 10-15 turns on L₁ (see text).

T₁ — Interstage transistor transformer (*Argonne* No. AR-109, *Thordarson* No. TR-7).
T₂ — Crystal input transformer (*Argonne* No. AR-102 or *Thordarson* No. TR-24).

Crystal Microphone — Microphone cartridge (*Argonne* No. AR-52 or *Shure Bros.* No. R7).
Sw₁ — SPST slide or push-button switch.
B₁ — 6-volt or 9-volt battery.
TRANSISTORS —
(1) *Raytheon* CK768;
(1) *Raytheon* CK722.

Few electronic gadgets have the universal appeal of a "wireless microphone" or *Home Broadcaster*. Basically a miniature, but self-contained, radio station of limited range, such a device can be used to "broadcast" announcements and programs through a nearby radio receiver. Employed in this fashion, it can be used to play practical jokes on party guests or to enable potential announcers or actors to have their fling "on the air". The circuit for a simple transistorized *Home Broadcaster* is given in Fig. 8-1.

Referring to the schematic diagram, we see that a RAYTHEON CK768 R.F. transistor is used as a "tickler feedback" R.F. oscillator which, in turn, is modulated

by a CK722 transistor serving as an audio amplifier. The common-emitter circuit configuration is used in both stages.

In operation, the oscillator's frequency is determined by tuned circuit L_1-C_1. Inductance coil L_1 is tapped to provide a match to the moderate output impedance of the transistor and thus to avoid excessive loading on the tuned circuit, with a resulting loss of "Q". The feedback necessary to start and sustain oscillation is provided by "tickler" coil L_2. Base bias current for the R.F. oscillator is supplied through R_1, while D.C. blocking capacitor C_2 keeps L_2 from acting as a D.C. short across this resistor.

(45)

The R.F. oscillator is modulated by an audio signal introduced in its emitter circuit by impedance matching transformer T_1. Capacitor C_3 serves as an R.F. by-pass across the transformer's secondary. The transformer, in turn, is driven by the CK722 audio stage.

A *crystal microphone* drives the CK722 audio amplifier through coupling capacitor C_5. Base bias current for this stage is supplied through R_3. The audio amplifier's unby-passed emitter resistor, R_2, serves a dual function . . . It helps to raise the circuit's input impedance and improves circuit stability and operation.

Operating power for the circuit is supplied by a single battery, B1, controlled by SPST switch Sw_1, and by-passed by C_4. The modulated R.F. signal obtained from the R.F. oscillator is radiated by a simple antenna-ground (ANT.-GND.) system.

Construction Hints

With neither components layout not lead dress critical you can follow your own inclinations when assembling and wiring the *Home Broadcaster*. However, you'll find that time spent in designing a "clean" and compact layout will be richly repaid in ease of construction and in the professional appearance of the completed device. A small piece of *bakelite* or fiber board makes an excellent "chassis" for mounting the transistor sockets, transformer, and other components. The completed instrument may be fitted into a small plastic box. When wiring the unit, be sure to observe all electrolytic capacitor and battery polarities.

Feedback coil L_2 consists of 10 to 15 turns of No. 24 or 26 wire, wound directly on top of L_1. The initial connections to this coil should be temporary or "lap" soldered joints, as it may be necessary later to reverse these connections to obtain oscillation.

The value of capacitor C_1 is not specified in the *Parts List*. This capacitor determines the nominal operating frequency of the *Home Broadcaster*, with a final adjustment of frequency made by adjusting L_1's iron core. The instrument operates in the AM Broadcast Band (550 to 1600 KC). For operation near the high frequency end of the band, C_1 should have a value of from 50 to 150 MMF; for operation near the middle of the band, from 180 to 240 MMF; and, finally, for operation near the low frequency end of the band, from 280 to 360 MMF.

Generally it is best to operate near the *low frequency* end of the band unless these frequencies are "crowded" with broadcast stations in your particular locality.

Operating power is supplied by a 6 or 9 volt battery. Suitable units are the *Burgess* No. Z4 (6 volt) or No. 2N6 (9 volt). If you prefer, you can obtain the necessary voltages by connecting penlight or flashlight cells in series. Four cells will provide six volts; six cells, in series, will supply nine volts.

A crystal microphone has a *high* output impedance; a common-emitter amplifier has a moderate input impedance. As a result, there is a power loss in the audio input circuit due to mismatched impedances. Regardless of this loss, there is still ample signal to modulate the R.F. oscillator due to the gain of the audio amplifier. However, if you wish to minimize audio signal losses, you can employ the *Alternate Input* circuit given in Fig. 8–1. A small transformer (T_2) is used to match the high output impedance of the microphone cartridge to the moderate input impedance of the transistor.

Operation and Use

With the wiring completed and double-checked for possible errors or accidental shorts, you can install the transistors and the battery, and attach the antenna (ANT.) and ground (GND.) leads. The antenna may be a six to ten foot length of flexible wire. The ground is a short length of wire fitted with an alligator clip, and clipped to a radiator, cold water pipe, or other suitable external "ground". It is needed to reduce body capacity effects as the *Home Broadcaster* is used.

To check out the completed instrument, spread out the antenna lead and adjust L_1's core about $\frac{1}{3}$ "out". Turn the unit on and, counting or speaking into the microphone, try tuning in the signal on a nearby AM Broadcast Band receiver. The receiver should be four to eight feet away. Tune *slowly* over the band. If you are unable to pick up the *Home Broadcaster's* signal, reverse the connections to L_2.

After this preliminary test, adjust L_1's core until the *Home Broadcaster* is picked up at a "dead" spot on your receiver's dial (between stations). The instrument is then ready for use. Its maximum range will vary with the length of antenna used and the sensitivity of your receiver but, normally, will be under 50 feet.

ELECTRONIC RELAY

In the last *Section*, we discussed the use of a transistorized amplifier to increase the sensitivity of a D.C. Meter (see Fig. 7–1). A similar amplifier may be used to increase the sensitivity of an electromagnetic relay. A practical version of such a circuit is given in Fig. 8–2, while an assembled model is shown in Fig. 8–3. Essentially a transistorized *Electronic Relay*, this device can

serve as the basis for a variety of electronic alarm and control instruments.

Referring to the schematic diagram, a CK722 transistor is used as a direct-coupled common-emitter amplifier. In operation, both base and collector currents are supplied from a single battery, B1, controlled by SPST switch Sw_1. Normally, with terminals "4" and "5"
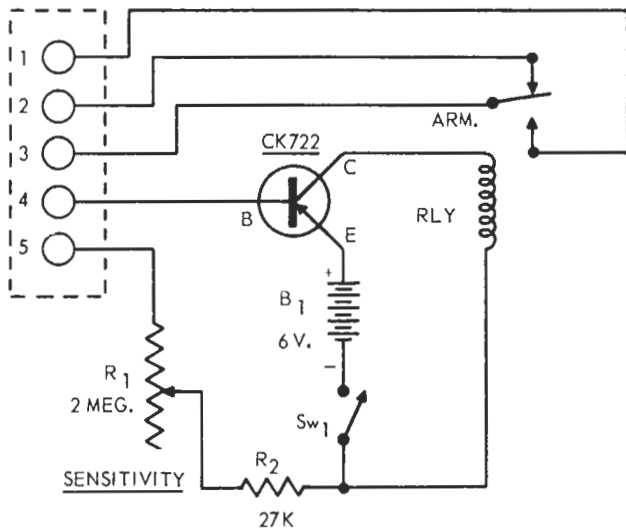
PARTS LIST

R_1 — 2 Megohm potentiometer, with switch (SENSITIVITY control).
R_2 — 27K, ½ watt carbon resistor.
Sw_1 — SPST switch, on R_1.
RLY — Sensitive relay, 3500 ohm coil (*Advance* type SV/1C).
B_1 — 6 volt battery (*Burgess* No. Z4).
TRANSISTOR — (1) *Raytheon* CK722.
MISC. — Small Chassis; transistor socket; 5-position screw-type terminal strip; battery box; Hardware . . . machine screws, nuts, wire, solder, etc.
ACCESSORIES: (see text).
    Fine wire or metal tape; door, window contacts; selenium photocells (*International Rectifier* type B2M); sensor plate; alarm bell or buzzer; heavy duty battery or bell transformer; etc.

FIG. 8-2

open, there is insufficient collector current to close the relay (RLY). When these two terminals are closed by an external switch or "sensor", base current is supplied through SENSITIVITY control R_1 and series limiting resistor R_2. The base current, though small, controls a much larger collector current which "pulls in" the relay. The relay contacts, in turn, serve as a switch to control an external device, such as an alarm bell, a motor, a solenoid, or a light.

Construction Hints

The layout and construction of the author's model is shown clearly in Fig. 8-3. You can use this photograph as a guide when assembling your own unit. The relay (RLY), battery box, SENSITIVITY control (R_1), and other components making up the *Electronic Relay* are assembled on a small aluminum chassis.

Several changes in construction details are possible, depending on individual requirements. First, the screwdriver adjusted SENSITIVITY control (R_1) may be replaced by a conventional shaft-type control, fitted with a small knob. The control-type switch (Sw_1) may

be replaced by a separate slide, toggle, or lock-type switch. The screw-type terminal strip may be replaced with a multi-contact connector and plug. The transistor may be soldered permanently into the circuit instead of installed in a small socket (be sure to observe the usual precautions to avoid heat damage). And, finally, the entire circuit might be assembled in a small closed box or case rather than on an open chassis.

With the wiring completed and checked for errors, you can install the battery and transistor and give the unit an operational test. Connect a short piece of hook-up wire between terminals "4" and "5" (Fig. 8-2). Close switch Sw_1 and adjust the SENSITIVITY control until the relay closes. Cut the wire connecting terminals "4" and "5" . . . the relay should open.

The *Electronic Relay* is seldom used alone. Rather, it is used as the basic control of a more complex alarm or control system. In such applications, a "sensing" element of some type is connected to terminals "4" and "5", with an accessory device, such as alarm bell, switched by the relay contacts connected to terminals "1", "2", and "3" (Fig. 8-2). Typical sensing elements are shown in Fig. 8-4. The actual installation of the *Electronic Relay* will vary with its intended application. Typical applications are listed below:

Burglar Alarm

To use the *Electronic Relay* as a *Burglar Alarm*, you'll need to install a closed electrical circuit around the protected area. All openings should be covered. Doors and windows may be protected by simple contacts or *Microswitches*, arranged to open when the respective door or window is opened. Large glass areas, such as picture windows, may be protected by cementing fine wire or
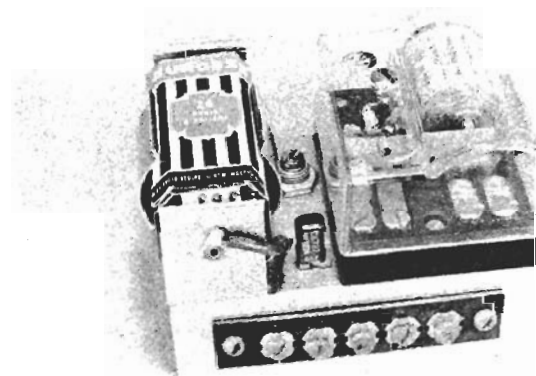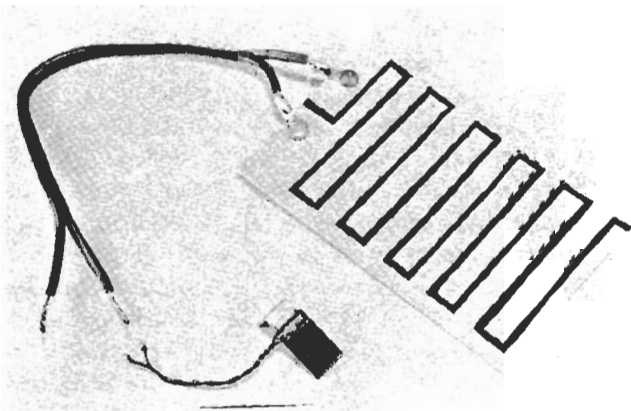

FIG. 8-3

FIG. 8-4

flat metallic tape around them, so arranged that the wire or tape is broken if the window is broken. All contacts, switches, or protective wires are connected in *series* so that a break anywhere will open the circuit. The two "free" ends of this closed circuit are connected to terminals "4" and "5" and the SENSITIVITY control adjusted until the relay (RLY) closes.

The alarm bell or buzzer is operated from a separate power source, such as a storage battery or bell transformer. The alarm circuit is controlled by terminals "3" and "2", connected as a simple switch. Install a SPST "SILENCE" switch in series with the alarm. This switch is used to silence the alarm bell during the day, when the *Burglar Alarm* is switched "off".

Note that the relay is held *closed* in normal operation, hence the armature (ARM.) and "normally closed" (NC) relay contacts are used for switching the alarm. This type of operation is called *Fail Safe* operation, since an open in the relay's coil, a failure of the transistor, or a weak battery (B1), as well as an open in the closed "protective" circuit, will cause the relay to "drop out", switching on the alarm.

Fire Alarm

If you wish, you can use the *Electronic Relay* as a control for a simple, but effective *Fire Alarm* system. The basic installation and wiring is the same as for the *Burglar Alarm*, described above, but the closed "protective" wiring is replaced by a number of fusible-link contacts connected *in series*. These contacts are placed in attics, at the top of stair wells, or in similar locations where heat from a fire is likely to concentrate. The heat melts the fusible link, opening the circuit and operating the *Electronic Relay*. The *Fail Safe* provisions of the *Burglar Alarm* are retained.

Electric Eye

If a self-generating selenium photocell is connected to the *Electronic Relay's* control terminals ("4" and "5"), the device may be used as a light-controlled relay or *Electric Eye*. A suitable unit is an *International Rectifier Corporation* type B2M photocell. One of these cells is shown in the foreground in Fig. 8-4.

For best results and maximum sensitivity, the photocell should be mounted in a closed housing of some sort, with a lens installed to concentrate light on the sensitive surface of the cell. A typical installation is diagrammed in Fig. 8-5. Note that the "negative" (black) lead of the photocell connects to terminal "4" of the *Electronic Relay*, the "positive" (red) lead to terminal "5".

With this type of installation, the relay *closes* when sufficient light falls on the photocell and the SENSITIVITY control is properly adjusted. The circuit to be controlled by the *Electric Eye* is connected either to terminals "1" and "3" or to terminals "2" and "3" (Fig. 8-2), depending on the action desired. If you want the controlled circuit to be switched "on" when light shines on the photocell, use terminals "1" and "3"; if you want the external circuit to be switched "on" when the light is interrupted, use terminals "2" and "3".

Rain Alarm

For this application, you'll need a small "moisture sensor". A typical sensor is shown in Fig. 8-4. It consists of two conductors arranged in a grid-like pattern with a narrow strip of insulation between them. A drop of rain (or dew) or a film of condensed moisture bridges the insulating gap and closes the circuit. You can make up your own sensor by cementing pieces of aluminum foil to a *bakelite* or plastic panel (arranged in a pattern similar to that shown in Fig. 8-4) or by etching an insulating path through a piece of copper-clad phenolic (you can get the materials for this from an *Etched Circuit Kit*).
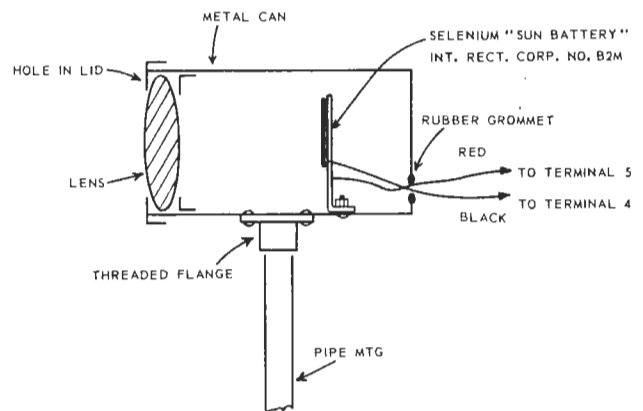

FIG. 8-5

To install the *Rain Alarm*, place the sensor outside (where rain can fall on it) and connect its two terminals to terminals "4" and "5" of the *Electronic Relay*. Ordinary lamp cord may be used for this job. The alarm circuit, including its separate power supply, is switched by contacts "1" and "3". The SENSITIVITY control is set so that the relay *closes* when a drop of moisture bridges the insulating gap on the sensor.

ELECTRONIC SQUEALER
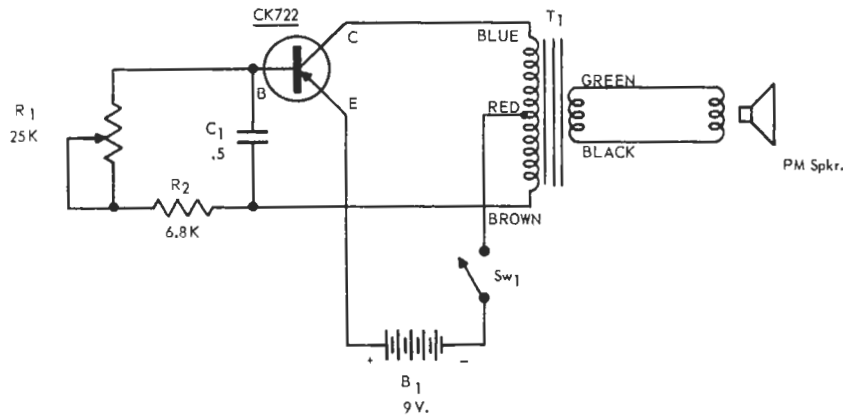
FIG. 8-6

PARTS LIST

R₁ — 25K carbon potentiometer.
R₂ — 6.8K, ½ watt carbon resistor.
C₁ — 0.5 Mfd., 200 volt tubular paper capacitor.
T₁ — Transistor output transformer (*Argonne* No. AR-119 or *Thordarson* No. TR-27).
B₁ — 9-volt transistor battery (*Burgess* No. 2N6).
Sw₁ — SPST push-button switch.
PM SPKR — Permanent magnet loudspeaker, 2½″ diameter, 3.2 ohm V.C.
TRANSISTOR — (1) *Raytheon* CK722.
MISC. — Small metal chassis; transistor socket; battery clip; lever type control knob; sloping panel Meter Case (ICA No. 3995) small piece of flocked metal screening; Hardware . . . machine screws, nuts, wire, solder, terminal strips, etc.

Electronic toys are fascinating to adults and children alike. An interesting electronic "musical" toy can be assembled around a self-contained transistorized variable frequency audio oscillator. A suitable circuit for such an instrument is given in Fig. 8-6, while a hand-assembled model is shown in Fig. 8-7. Named an *Electronic Squealer* because of its tone quality, this simple instrument can be assembled in a single evening, yet will provide many hours of fun for the lucky owner. It can be used to make unusual sound effects or, with practice, to play simple tunes.

Refer to the schematic diagram. A CK722 transistor is connected as a common-emitter audio oscillator.

Transformer T₁ serves a dual function . . . it provides the feedback necessary to start and sustain oscillation by virtue of its center-tapped winding while, at the same time, serving to match the high impedance of the transistor to the low impedance of the PM loudspeaker's voice coil. The oscillator's operating frequency is varied by changing its base bias current and the R-C time constant in the base circuit. This is accomplished by rheostat R₁, in series with fixed base resistor R₂. The two resistors are partially by-passed by C₁. Operating power is supplied by a 9-volt battery, B1, controlled by a SPST push-button switch Sw₁.
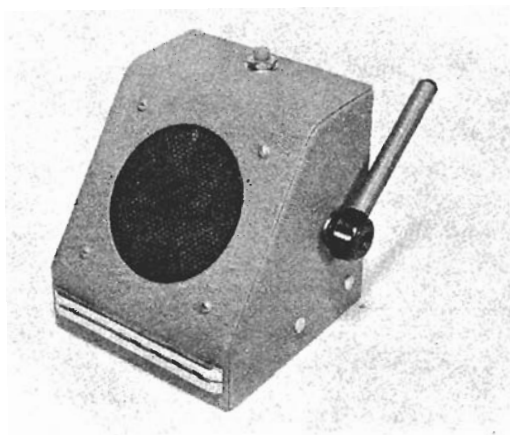
FIG. 8-7
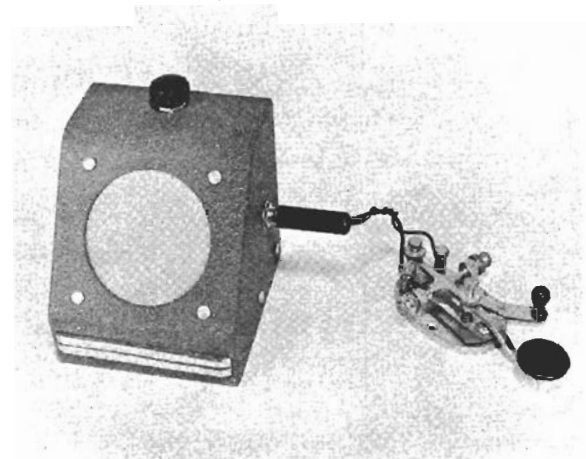
FIG. 8-8

Construction Hints

The *Electronic Squealer* is assembled on a small metal chassis. Neither layout nor lead dress are critical. The professionally built appearance of the author's model, shown in Fig. 8–7, was obtained by mounting the completed instrument in a sloping panel Meter Case. The TONE CONTROL (R_1) was mounted on the side of the case, the CONTROL SWITCH (Sw_1) on top. Don't install the battery or transistor until all wiring is completed and double-checked for possible errors and accidental shorts, and be sure to protect the loudspeaker by installing a piece of flocked metal screening (or plain screening if you don't have the flocked type (in front of its paper cone.

To use the completed *Electronic Squealer*, simply depress the CONTROL SWITCH (Sw_1). Different tones may be sounded by adjusting R_1's long control lever. If you wish to shift rapidly from one tone to another to create unusual sound effects, simply keep Sw_1 depressed while manipulating the TONE CONTROL. If you want to sound individual notes, preset the TONE CONTROL lever, then quickly depress and release the CONTROL SWITCH. The length of time you hold the CONTROL SWITCH depressed will determine whether you sound an eighth, quarter, half, or full note.

Code Practice Oscillator

The basic *Electronic Squealer* circuit may be used for a loudspeaker operated *Code Practice Oscillator*. Such an instrument will provide ample volume for practice in a small class. A typical set-up is shown in Fig. 8-8. The push-button switch (Sw_1) has been replaced with an open-circuit jack into which the Handkey is plugged. The control rheostat (R_1) has been shifted to the top of the case, with the long control lever replaced by a conventional knob.

BURGLAR ALARM
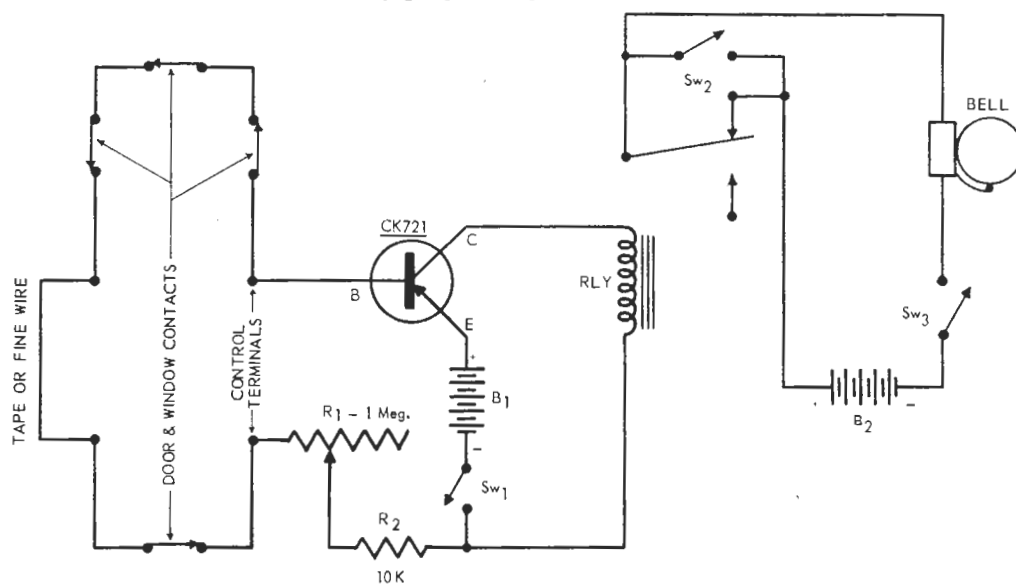
FIG. 8–9

PARTS LIST

R_1	— 1 Megohm potentiometer (SENSITIVITY control)	RLY	— 3500 ohm coil sensitive relay (*Advance* type SV/1C)
R_2	— 10K, $\frac{1}{2}$ W. carbon resistor	B1	— 6 volt Heavy Duty battery (*Burgess* No. TW1)
Sw_1	— SPST lock-type switch (CONTROL SWITCH)	B2	— 6 volt "Hot Shot" battery (*Burgess* No. 4F4H)
Sw_2	— SPST push-button switch (BELL TEST switch)	BELL	— Six volt D.C. Alarm Bell
Sw_3	— SPST lock-type switch (BELL SILENCE switch)	TRANSISTOR	—(1) *Raytheon* type CK721

MISC. — Small chassis; Heavy metal box or case with lock-type cover; Door and window contacts; transistor socket; terminal strips; Fusible-link sensors (for *Fire Alarm*); foil tape, and cement; Assorted Hardware . . . wire, solder, soldering lugs, machine screws.

Most commercially available protection equipment is much too expensive to justify its use in any but the most costly homes. But the simple transistorized *Burglar Alarm* circuit shown in Fig. 8–9 can form the basis of a system which not only provides good protection against illegal intruders, but is inexpensive, as well as easy to assemble and to install. The average householder with a "do-it-yourself" flair should have little or no difficulty in assembling his own unit and installing it in his home in a single week-end. What's more, the basic circuit arrangement may also be used as a basis for a reliable home *Fire Alarm*.

Referring to the schematic diagram (Fig. 8–9), a CK721 transistor is used as a common-emitter D.C. amplifier. In operation, when control switch Sw_1 is closed, power supply battery B1 supplies the transistor with both base and collector bias currents. Base bias is supplied over the path consisting of series limiting resistor R_2, SENSITIVITY adjustment R_1, and the external *alarm* circuit. The *alarm* circuit is a closed electrical circuit including contacts (or switches) on doors and window openings and, if desired, thin tape cemented to larger window panes.

As long as the *alarm* circuit remains intact, sufficient base bias current is supplied to the transistor to keep the electromagnetic relay in its collector circuit *closed*, and thus to open the *BELL* circuit. In normal operation, BELL SILENCE switch Sw_3 is closed, BELL TEST switch Sw_2 is open.

Should an intruder attempt illegal entry of the protected premises, the alarm circuit will be opened. This removes base bias current from the transistor and allows the collector current to drop to too low a value to hold the relay closed, thus allowing the armature to "drop out", closing the BELL circuit and sounding the alarm. The BELL will continue to sound as long as the alarm circuit is open, unless deliberately silenced by switch Sw_3, or until the bell battery (B2) is exhausted.

This *Burglar Alarm*, unlike many inexpensive systems, incorporates a reliable "Fail-Safe" provision. Since the relay is held *closed* in normal operation, any failure of the control circuit, such as exhaustion of the control battery (B1), failure of the transistor, or an open in the relay's coil, will result in an immediate alarm. Further safety is assured by using *separate* batteries (B1 and B2) for the control and BELL circuits. The BELL battery is used only when the system goes into alarm. Further, since the alarm circuit is a closed loop, it cannot be defeated by cutting one of its leads . . . an open anywhere in the circuit will result in an alarm.

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Construction Hints

The assembly and wiring of the *Burglar Alarm* is simple and straightforward. The transistor and relay (RLY) and the associated control circuit may be wired on a small metal sub-chassis, with the entire instrument, including all switches and *both batteries* (B1 and B2) mounted in a metal box or cabinet having a key-locked cover. Neither component layout nor lead dress are critical, but, from an operational viewpoint, the mechanical design should permit ready access to the batteries for occasional test and replacement.

Installation and Operation

The metal "control box", containing the transistor and relay circuitry, control switches and batteries, should be wall-mounted in a convenient and reasonably accessible location. Although the exact location is not too important, for maximum battery life and to protect the transistor, the "control box" should not be placed near or over a radiator, furnace, water heater, or similar source of concentrated heat, nor should it be mounted in a damp or moist area. A *dry* basement or utility room is the customary location.

The ALARM BELL may be mounted near the "control box" or at some other location, depending on individual choice. It should be mounted fairly high on the wall and the leads between the "control box" and BELL should be protected to prevent deliberate cutting. This may be done by running the wires through conduit or metal pipes or by using BX cable for the installation.

Careful wiring of the *alarm* circuit is extremely important. This is connected to the *Control Terminals* (Fig. 8–9) and consists of a closed series loop which includes contacts on all doors, windows and other exterior openings, and thin metal tape cemented around larger panes and picture windows. If standard door and window contacts are not available, small push-button or *micro*-switches may be used instead, so mounted that opening the door or window will *break* the *alarm* circuit.

If the system is to be used as a *Fire Alarm*, the door and window contacts may be replaced by *fusible link sensors*. Again, a closed series loop is used, with the individual sensors mounted at the tops of stair wells, in the furnace room, in attics, and in other locations where heat from a fire is likely to accumulate.

To set up the system, whether used as a *Burglar* or *Fire Alarm*, a standard operating procedure should be followed. First, the closed loop *alarm* circuit is checked to make sure all contacts are closed. Next, the BELL SILENCE switch (Sw$_3$) is opened and the CONTROL SWITCH (Sw$_1$) closed. The SENSITIVITY control (R$_1$) is adjusted until the relay (RLY) "pulls-in". The BELL SILENCE switch (Sw$_3$) is closed next and the ALARM BELL circuit checked by momentarily depressing and releasing the BELL TEST switch (Sw$_2$). Finally, the "control box" is closed and locked.

ELECTRIC EYE RELAY

Of all electronic control circuits, few are as widely used as light-controlled "electric eyes". Commercial and industrial uses include such widely divergent applications as automatically opening Department Store doors as a customer approaches, counting auto or pedestrian traffic, operating manufacturing equipment, inspecting cleaned bottles for foreign matter, measuring tank and bin levels, detecting smoke, and controlling packaging machinery. In the home and office, light-controlled relays may be used as automatic light switches, as a visitor annunciator, or as a simple intruder alarm.

The transistor, as an excellent D.C. amplifier, is well-suited to the design and construction of a reliable *Electric Eye Relay*. A typical circuit is shown in Fig. 8–10, while exterior and interior views of a working model are given in Figs. 8–11 and 8–12, respectively.

Referring to the schematic diagram, a single CK722 is used as a common-emitter D.C. amplifier to control an electromagnetic relay (RLY). In operation, the transistor's base bias current is supplied by a "self-generating" selenium photocell, itself a type of semiconductor device. When light falls on the photocell, or "Sun Battery", the base current increases, allowing a similar, but much larger, increase in collector current, and closing the relay. When the light source is interrupted, the base current, and hence the collector current, drops, and the relay opens. Collector current is supplied by a 9 volt battery, B1, controlled by a SPST "On-Off" switch, Sw$_1$.
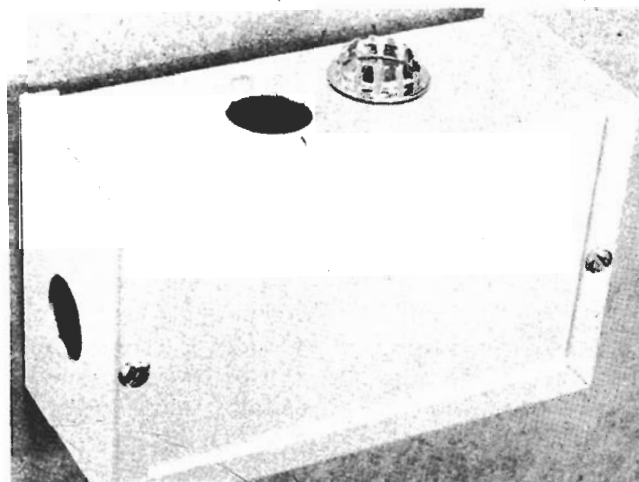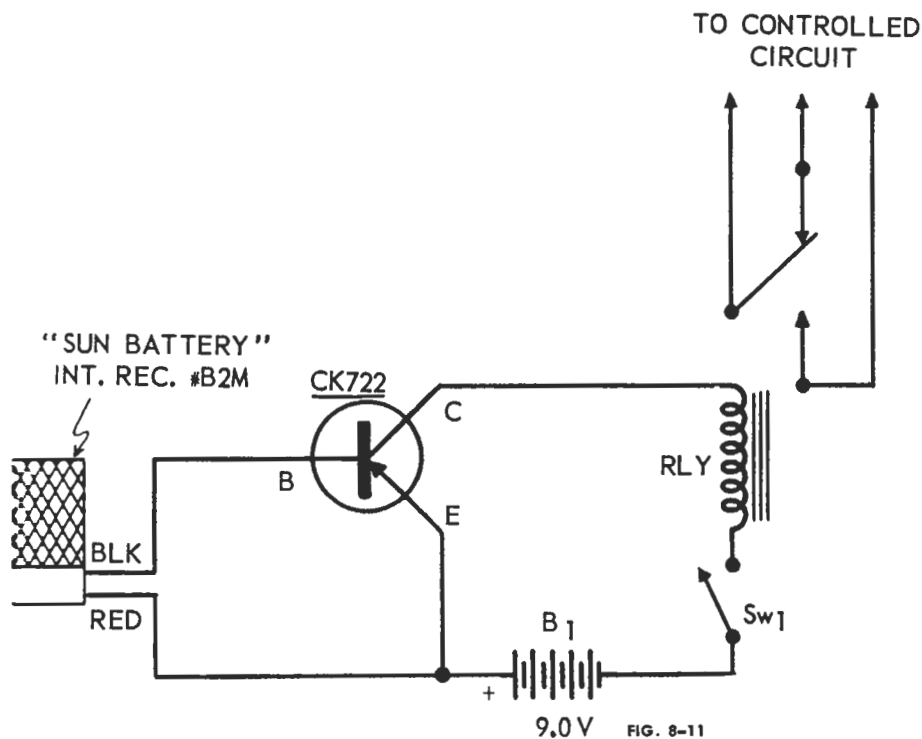

FIG. 8-10

TO CONTROLLED
CIRCUIT

"SUN BATTERY"
INT. REC. #B2M   CK722

BLK

RED

RLY

B₁

Sw₁

9.0 V   FIG. 8-11

Construction Hints

Since only direct currents are involved in the operation of the *Electric Eye Relay*, components layout and wiring arrangement are completely non-critical. In the model, shown in Figs. 8-11 and 8-12, the transistor, relay, and photocell were mounted on a small perforated *bakelite sub-chassis"* which, in turn, was mounted inside a standard aluminum box, along with the battery (B1) and control switch (Sw₁). In order to prevent unauthorized operation of the device, the switch (Sw₁) was mounted in a recessed position in the top of the box, then covered with a Snap Hole Plug . . . this is shown removed in Fig. 8-11. A hole is provided in one side of the box to permit the control light to fall on the sensitive surface of the photocell.

No lens was used in constructing the model, nor is one needed for fairly short light beam "throws" where a moderately strong light source is used. However, the *Electric Eye Relay's* overall sensitivity may be increased considerably by mounting a good-sized lens in front of the photocell, so arranged as to concentrate light on the cell's sensitive surface.

Two different types of relays are specified in the PARTS LIST to permit a choice by the individual builder. Either will give satisfactory results, but if the *Potter & Brumfield* relay is used, its coils must be connected in *parallel*. As supplied by the factory, the two coils are connected in series.

Installation and Use

A moderately strong, well-focused *light source* must be used with the *Electric Eye Relay*. In a typical installation, the *light source* is mounted on one side of a doorway or similar opening, and the relay control box is placed directly across from it, so mounted that the light beam falls directly on the photocell. The relay contacts are used as a simple switch to control an external circuit, which is equipped with its own power source. The mounting height is generally between 18 and 24 inches . . . high enough so that the average person won't step over the beam, and low enough to be interrupted by a small child. As a person passes through the doorway, the light beam is interrupted, the relay closes, and the external circuit is actuated.

The device controlled by the *Electric Eye Relay* will depend on its intended application. If used as an *Annunciator*, a simple buzzer or electric gong might be operated. If used as an *Automatic Door Opener*, the relay will control the door opening motor. For *Burglar Alarm* applications, the relay might switch on a loud bell. And, if used as an *Automatic Light Switch*, the relay could serve to turn on one or more electric lamps.
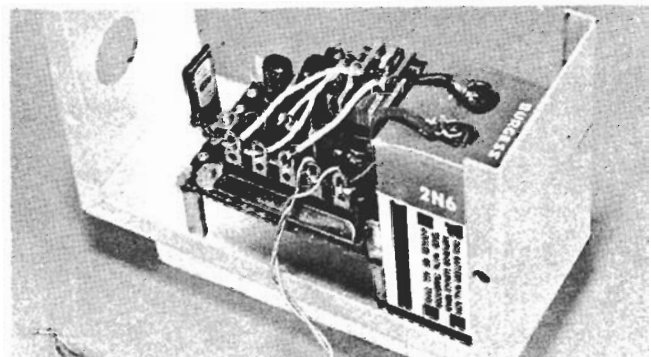
FIG. 8-12

(53)

REFERENCE DATA

Unlike earlier Parts of this booklet, the following material is not intended to be read or studied in detail but, rather, to be used as needed. For this section is devoted to general Reference material which should be of value to every reader, whether he is an experimenter, student, practical engineer, Ham, serviceman, hobbyist, or "gadgeteer". Included is a selection of basic *Definitions*, a collection of *Useful Formula*, a listing of additional *Reference Books & Magazines*, and condensed *Charts* giving specifications of RAYTHEON transistors and semiconductor products. A useful *Transistor Interchangeability Chart* is included for the benefit of readers who may refer to circuits in magazines and books in which other types of transistors are encountered.

To obtain the maximum value from this section of the booklet, the reader will find it worthwhile to review the entire section briefly. In this way, he can become familiar with the general content and physical arrangement. Later, as he needs specific data in his work, he can refer directly to the necessary material.

DEFINITIONS

The following *Definitions* have been abstracted from the *TRANSISTOR CIRCUIT HANDBOOK* and are reprinted here with the permission of the Author and Publisher. Only a few of the more than eighty definitions appearing in the *Handbook* are reproduced here. The *TRANSISTOR CIRCUIT HANDBOOK* is published by the *Coyne Electrical School*, is distributed by the *Howard W. Sams* organization (2201 E. 46th Street, Indianapolis 5, Indiana) and is available through all Electronics Parts Distributors. This book contains approximately two hundred practical transistor circuits, many of which feature RAYTHEON transistors.

Acceptor: A substance (impurity) which, when added to a pure semiconductor material, results in an increase in the number of *holes* so that major conduction through the material takes place as a transfer of the hole structure from molecule to molecule. Since this is equivalent to the transfer of a positive charge, the resulting alloy is called a P-type semiconductor.

Alpha (α): The current amplification factor of a transistor when connected in a *common-base* configuration.

Beta (β): The current amplification factor of a transistor when connected in a *common-emitter* configuration.

Bias: The steady (D.C.) operating voltage or current applied to an electrode to establish the basic operating conditions of a device.

Cutoff Frequency: Generally taken as the frequency at which the gain of a device is 3 db below its low frequency value. Used when referring to a variation of *alpha* or *beta* with respect to frequency.

Donor: A substance (impurity) which, when added to a pure semiconductor material, results in an increase in the number of free electrons so that major conduction through the material takes place as a movement of electrons. Since this is equivalent to the transfer of a negative charge, the resulting alloy is called an N-type semiconductor.

Heat Sink: As applied to semiconductor work, a mass of metal or other good heat conductor which serves to quickly absorb and to dissipate quantities of heat energy.

Hole: In semiconductor work, the absence of an electron in the atomic or molecular structure of a material resulting in a net positive charge which can be transferred through the material by the exchange of valence bonds. In effect, the hole acts more or less like a particle with the mass and size of an electron, but with a positive charge.

Impurity: In transistor work, a substance which, when added to a pure semiconductor, gives it specific electrical properties. See *acceptor* and *donor*.

Saturation Current: The collector current flowing with zero emitter current. Sometimes called *leakage current* or *collector cutoff current*. Abbreviated I_{co}. An excessively high saturation current indicates a defective transistor.

Semiconductor: In general, a material with electrical resistivities intermediate between those of a conductor and an insulator. Semiconductors may be grouped into three general classes: An *intrinsic* semiconductor is one in which the concentration of acceptors and donors is zero, so that current flow is by means of both holes and free electrons in equal quantities. A *P-type* semiconductor is one with a majority of acceptors, so that current flow is primarily by means of hole migration. An *N-type* semiconductor is one with a majority of donors, so that current flow is primarily by means of free electrons.

Transistor: A device which depends for its essential action on the movement and control of charges in a semiconductor material. In general, a semiconductor device having several electrodes in which the resistance between two electrodes is controlled by the current supplied to another electrode. The name is coined from the expression *TRANSfer resISTOR*.

USEFUL FORMULAE

I. *Alpha* and *Beta* relationships are as follows:
$$\alpha = \frac{\beta}{(1 + \beta)} \quad \text{or} \quad \beta = \frac{\alpha}{(1 - \alpha)}$$

II. *Ohm's law* is used for determining resistance:
$$R = E/I,$$
where R is the resistance in *ohms*, E is the voltage in *volts*, and I is the current in *amperes*.

III. *Power* used or dissipated in a circuit is determined as follows:
$$W = EI, \quad \text{or} \quad W = E^2/R, \quad \text{or} \quad W = I^2R$$
where W is the power in *watts*, E is the voltage in *volts*, I is the current in *amperes*, and R is resistance in *ohms*.

IV. *Efficiency* of a circuit is proportional to the ratio of output to input power:
$$\text{Eff.} = (P_{\text{out}}/P_{\text{in}}) \times 100,$$
where Eff. is the efficiency in *percent*, P_{out} is the output power in *watts*, and P_{in} is the input power in *watts*.

V. *Decibels* are used to express the gain or loss of an amplifier and are proportional to the logarithm of the power ratios:
$$\text{db} = 10 \log. P_2/P_1,$$
where db is an arbitrary number, the logarithm (log.) is to the base 10, and P_1 and P_2 are the power levels in question.

VI. *Resonant frequency* of a tuned circuit depends on its inductance and capacity:
$$f = \frac{1}{2\pi}\sqrt{LC},$$
where f is the frequency in *cycles* per second, π is a constant (3.1416), L is the inductance in *Henries*, and C is the capacity in *farads*.

VII. *Q* of a tuned circuit is the ratio of reactance to resistance:
$$Q = X/R,$$
where Q is a pure number, X is reactance in ohms, R is resistance in ohms.

VIII. *Wavelength* of a radio signal depends on frequency:
$$\lambda = 300/f$$
where lambda (λ) is the wavelength in *meters*, and f is the frequency in *megacycles* (MC).

IX. *Impedance* of a complex circuit depends on both reactance and resistance:
$$Z = \sqrt{R^2 + X^2},$$
where Z is the impedance in *ohms*, R is the circuit's resistance in *ohms*, and X is the circuit's reactance in *ohms*.

X. *Time constant* of a RC circuit is the time, in seconds, required for a capacitor to reach a charge equal to 63 percent of an applied voltage:
$$T = CR,$$
where T is the time in *seconds*, C is the capacity in *farads*, and R is the resistance in *ohms*. If preferred, C may be in *microfarads* and R in *megohms*.

XI. *Impedance ratio* of a transformer is proportional to the square of the turns ratio:
$$Z_p = Z_s N^2,$$
where Z_p is the primary impedance in *ohms*, Z_s is the secondary impedance in *ohms*, and N is the *turns ratio*, primary to secondary.

XII. *Voltage ratio* of a transformer is directly proportional to the turns ratio:
$$E_s = E_p N,$$
where E_s is the secondary voltage in *volts*, E_p is the primary voltage in *volts*, and N is the *turns ratio*, secondary to primary.

REFERENCE BOOKS

Of necessity, the discussion of semiconductor and transistor theory has been touched on only briefly in this booklet. And space limitations have prevented our including the larger percentage of the many, many possible transistor circuits. The serious reader will find it worthwhile to obtain and to study one or more of the *Reference Books* listed below. In addition, to keep current on latest circuits and transistor types, he will find it advisable to subscribe to one or more of the more popular technical magazines . . .

ELEMENTARY BOOKS

TRANSISTORS AND THEIR APPLICATIONS, by Louis E. Garner, Jr. 100 Pages, covering elementary theory, basic applications, typical circuits. Published by *Coyne Electrical School*, distributed by *Howard W. Sams, Inc.*, 2201 E. 46th St., Indianapolis 5, Indiana.

TRANSISTORS — THEORY & PRACTICE, by Rufus P. Turner. 144 Pages, discusses semiconductor theory, equivalent circuits, transistor characteristics. Published by *Gernsback Library*, 154 West 14th Street, New York 11, N. Y.

INTERMEDIATE BOOKS

FUNDAMENTALS OF TRANSISTORS, by Leonard Krugman. 140 Pages, discusses semiconductor and transistor theory, equivalent circuits, moderate amount of mathematics. Published by *John F. Rider*, 480 Canal Street, N. Y. 13, N. Y.

TRANSISTORS IN RADIO AND TELEVISION, by Milton S. Kiver. 324 Pages, discusses semiconductor structures, transistor construction, circuits. Published by *McGraw-Hill Book Company, Inc.*, 330 W. 42nd Street, New York 36, N. Y.

ADVANCED BOOKS

PRINCIPLES OF TRANSISTOR CIRCUITS, by Richard F. Shea, et al. 535 Pages, published by *John Wiley & Sons, Inc.*, New York, N. Y.

TRANSISTOR AUDIO AMPLIFIERS, by Richard F. Shea. 219 Pages, published by *John Wiley & Sons, Inc.*, New York, N. Y.

TRANSISTORS HANDBOOK, by William D. Bevitt. 410 Pages, published by *Prentice-Hall, Inc.*, Englewood Cliffs, N. J.

TRANSISTORS: THEORY AND APPLICATIONS, by Abraham Coblenz and Harry L. Owens. 313 Pages, published by *McGraw-Hill Book Co., Inc.*, New York, N. Y.

TRANSISTOR ELECTRONICS, by Lo, Endres, Zawels, Waldhauer & Cheng. 521 Pages, published by *Prentice-Hall, Inc.*, Englewood Cliffs, N. J.

TRANSISTORS I, a selection of papers by various engineers and scientists. 676 Pages, published by *RCA Laboratories*, Princeton, N. J.

ELECTRONS AND HOLES IN SEMICONDUCTORS, by William Shockley. 558 Pages, published by *D. Van Nostrand Co., Inc.*, New York, N. Y.

CIRCUIT BOOKS

TRANSISTOR CIRCUIT HANDBOOK, by Louis E. Garner, Jr. 430 Pages, covers approximately 200 practical transistor circuits, with parts values included, practical techniques, considerable reference material. Published by *Coyne Electrical School*, distributed by *Howard W. Sams Co., Inc.*, 2201 E. 46th Street, Indianapolis 5, Indiana.

TRANSISTOR APPLICATIONS, by several authors. 116 Pages, covering more than 50 practical applications for RAYTHEON transistors. Published by *Raytheon Manufacturing Company*, 55 Chapel Street, Newton 58, Mass.

GERMANIUM PNP JUNCTION TRANSISTORS

AVERAGE CHARACTERISTICS MEASURED AT 27°C
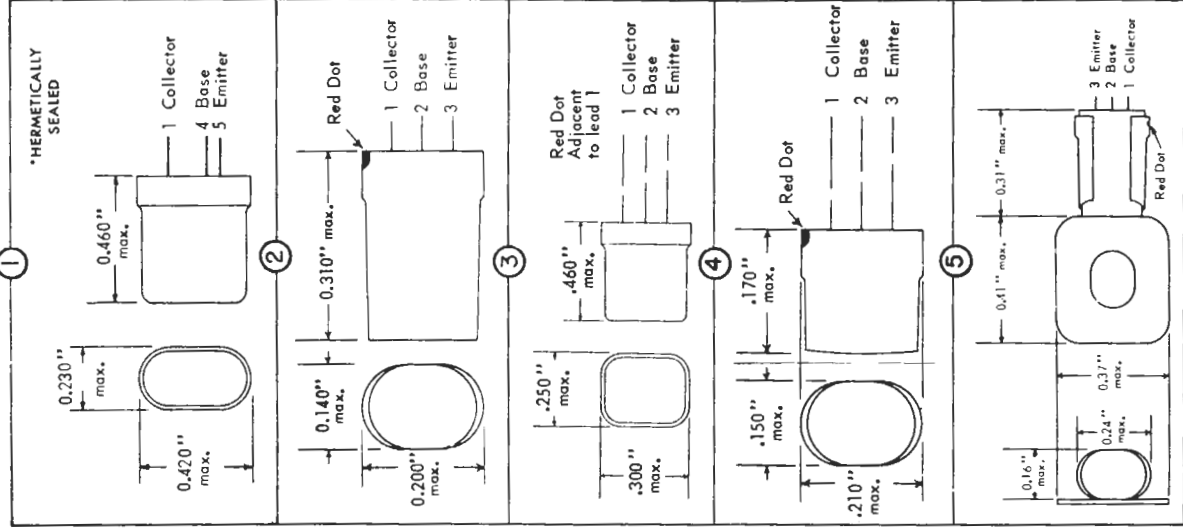
TYPE	Typical Application	Dwg. No.	Collector Voltage (volts)	Emitter Current (ma)	Average Collector Resist. (megohms)	Average Base Resist. (ohms)	Average Emitter Resist. (ohms)	Average Base Current Ampl. Factor	Average Cut-off Current (Approx.) (µa)	Max. Noise Factor (db)†	Alpha Cut-off (mc)	TYPE
2N63	AF-RF AMPLIFIER	1	—6	1.0	2.0	350	25	22	6	25	0.6	2N63
2N64	AF-RF AMPLIFIER	1	—6	1.0	2.0	700	25	45	6	22	0.8	2N64
2N65	AF-RF AMPLIFIER	1	—6	1.0	2.0	1500	25	90	6	20	1.2	2N65
2N106	LOW NOISE AF AMPLIFIER	1	—2.5	0.5	1.0	700	50	25	6	6	0.8	2N106
2N111	IF-RF AMPLIFIER	1	—6	1.0	1.7	‡50	25	25	1		3	2N111
2N111A	MED. GAIN IF AMPLIFIER	1	—6	1.0	1.7	‡50	25	25	1		3	2N111A
2N112	HIGH FREQ. AMPLIFIER	1	—6	1.0		‡55	25	40	1		5	2N112
2N112A*	HI GAIN IF AMPLIFIER	1	—6	1.0	1.5	‡55	25	30	1		5	2N112A*
2N113	HIGH FREQ AMPLIFIER	1	—6	1.0		‡60	25	45	1		10	2N113
2N114	HIGH FREQ. AMPLIFIER	1	—6	1.0		‡75	25	65	1		20	2N114
2N130	AF-RF AMPLIFIER	2	—6	1.0	2.0	350	25	22	6	25	0.6	2N130
2N130A	AF-RF AMPLIFIER	4	—6	1.0	2.0	350	25	22	6	25	0.6	2N130A
2N131	AF-RF AMPLIFIER	2	—6	1.0	2.0	700	25	45	6	22	0.8	2N131
2N131A	AF-RF AMPLIFIER	4	—6	1.0	2.0	700	25	45	6	22	0.8	2N131A
2N132	AF-RF AMPLIFIER	2	—6	1.0	2.0	1500	25	90	6	20	1.2	2N132
2N132A	AF-RF AMPLIFIER	4	—6	1.0	2.0	1500	25	90	6	20	1.2	2N132A
2N133	LOW NOISE AF AMPLIFIER	2	—2.5	0.5	1.0	700	50	25	6	6	0.8	2N133
2N133A	LOW NOISE AF AMPLIFIER	4	—2.5	0.5	1.0	700	50	25	6	6	0.8	2N133A
2N138	HI GAIN AF OUTPUT	2	—6	1.0	2.0	1800	25	140	6		1.4	2N138
2N138A	LOW DISTORTION AF OUTPUT	2	—6	1.0	2.0	1600	25	120	6		1.4	2N138A
CK721	AF-RF AMPLIFIER	3	—6	1.0	2.0	700	25	45	6	22	0.8	CK721
CK722	AF-RF AMPLIFIER	3	—6	1.0	2.0	350	25	22	6	25	0.6	CK722
CK725	AF-RF AMPLIFIER	3	—6	1.0	2.0	1500	25	90	6	20	1.2	CK725
CK751	HI GAIN AF OUTPUT	5	—6	1.0	2.0	1500	25	14	6		1.2	CK751
CK766	RF AMPLIFIER	1	—6	1.0	1.0	‡60	25	45	1		10	CK766
CK766A*	HI GAIN IF AMPLIFIER	1	—6	1.0	1.0	‡60	25	45	1		10	CK766A*
CK768	IF-RF AMPLIFIER	1	—6	1.0	2.0	‡50	25	2	6		3.5	CK768
CK870	SYMMETRICAL AMPLIFIER	2	—6	1.0	2.0	150	25	10	6		0.5	CK870
CK871	SYMMETRICAL AMPLIFIER	2	—6	1.0	2.0	250	25	15	6		0.6	CK871
CK882	AF-RF AMPLIFIER	1	—6	1.0	2.0	1500	25	90	6	25	1.2	CK882
CK888	LOW DISTORTION AF OUTPUT	1	—6	1.0	2.0	1600	25	120	6		1.4	CK888

SILICON PNP JUNCTION TRANSISTORS

TYPE	Typical Application	Dwg. No.	Collector Voltage (volts)	Emitter Current (ma)	Average Collector Resist. (megohms)	Average Base Resist. (ohms)	Average Emitter Resist. (ohms)	Average Base Current Ampl. Factor	Average Cut-off Current (Approx.) (µa)	Max. Noise Factor (db)†	Alpha Cut-off (mc)	TYPE
CK790	AF AMPLIFIER	1	—6	1.0	0.5	1200	25	14	0.001	30	0.4	CK790
CK791	AF AMPLIFIER	1	—6	1.0	0.5	1300	25	24	0.001	30	0.6	CK791
CK793	LOW NOISE AF AMPLIFIER	1	—6	1.0	0.5	1400	25	16	0.001	15	0.8	CK793

† MEASURED UNDER CONDITIONS FOR GROUNDED EMITTER OPERATION AT $V_{cb} = -2.5$ VOLTS FOR A 1 CYCLE BANDWIDTH AT 1000 CYCLES.
‡ EXTRINSIC BASE RESISTANCE.
* COLLECTOR CAPACITY 12±2 µµF

RAYTHEON TRANSISTOR REPLACEMENT GUIDE RAYTHEON

Following is a listing of suggested Raytheon replacements for various transistor types encountered in servicing transistor radios. Although not all suggested replacements have the exact characteristics of the original types, the similarity should be sufficient to give comparable performance.

TYPE	REPLACE WITH RAYTHEON TYPE	TYPE	REPLACE WITH RAYTHEON TYPE
2N34	2N131	2N218	2N111A
2N35	None	2N219	2N112
2N44	2N63	2N220	2N133
2N78	None		
2N94	None	2T12	2N130
2N104	2N132	2T51	None
2N107	CK722	2T52	None
2N109	2N138A	2T53	None
2N112	2N112		
2N112A	2N112A	R 26-2	None
2N132	2N132	R 35	2N132
2N135	2N111		
2N136	2N112	210	None
2N137	2N113	222	None
2N138	2N138	223	None
2N138A	2N138A	234	None
2N139	2N111A	235	2N111
2N140	2N112	310	2N132
2N145	None	353	2N138A
2N146	None	354	2N138
2N147	None		
2N172	None	CK 721	CK 721
2N173	None	CK 722	CK 722
2N174	None	GT 760	2N112
2N175	2N133	GT 761	2N113
2N185	2N131		
2N189	2N138	L 5021	2N131
2N192	None	L 5021 L	2N131
2N215	2N132	L 5022	2N132
2N217	2N138A	L 5028	2N138

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