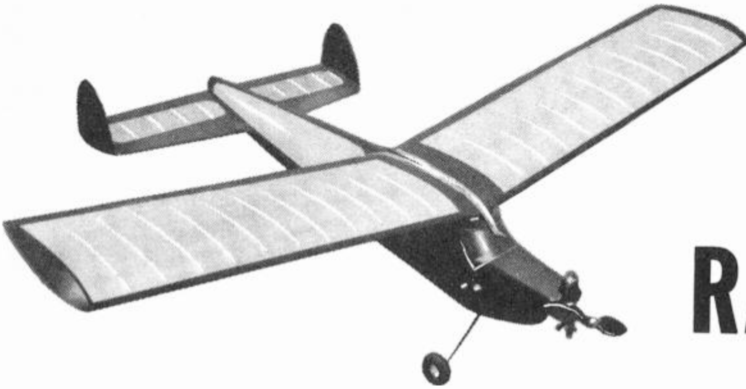
Radio Control handbook

by HOWARD G. McENTEE

Gernsback Library
No. 93

~~$4.95~~
~~(In the U.S.)~~

2.00



RADIO CONTROL HANDBOOK

by HOWARD G. McENTEE, W2SI

Radio-Control Editor, American Modeler
Formerly Editor, Model Airplane News

Published By

Gernsback Library, Inc.

New York, N.Y.

First Printing — May, 1956
Second Printing — March 1959
Third Printing — April, 1962
Fourth Printing — April, 1964

Library of Congress Catalog Card No. 61-15636

CONTENTS

(Continued)

CONTENTS *(Continued)*

Introduction

PROOF of the continuous growth of radio control is that it has been necessary to go through eight printings of the original *Radio-Control Handbook,* first published in 1954. The original intention was simply to update the old book for this revised edition, but it became apparent that more than that was necessary. As a result, this book, while it carries the same title as the original, is practically a brand-new volume. Much material from book No. 53 was dropped, not because it was of no further interest, but because so much new material just had to be included.

Since 1954 R/C has made huge advances, in number of modelers active in the field, in number of manufacturers catering to them, in the number of controls carried in the average model, in the quality of results obtained. Since by far the largest number of modelers are most active in the field of miniature airplanes, the advances, as might be expected, are most spectacular here, though boating, cars and other forms of R/C have all raced ahead at a rapid clip. As in the original *Radio-Control Handbook,* we slant most of the information in this new volume toward planes, but much of it is equally adaptable to any form of R/C in which the reader is interested.

We have again taken the approach that the majority of readers will have a modest knowledge of electronics, elementary shop work and model building; therefore, little or no "theory" will be found in the following pages. Instead, we devote as much space as possible to ideas, circuits and construction that the reader can copy directly, or which he can incorporate into equipment of his own design. Rather complete building data will be found on receivers, transmitters, servos, pulsers and other radio-control essentials, all of which have been well proven in the field. While the book is devoted more to the *parts* that go to make up complete control systems, several systems will be found in Chapter 14. They may be used as shown or expanded by addition of equipment described in earlier chapters.

We have not gone into really complex control equipment in this book; for those interested in such equipment, we recommend Gernsback Library book No. 74 – *Model Radio-Control.*

We have included considerable material in this book on proportional control, or "pulse" as it is often termed. There is relatively little pulse equipment on the market at present, and many who wish to try it have to build their own. They will find the facts and figures in these pages. The drawings are not necessarily to scale.

Since 1958 the FCC has made many changes in the R/C rules and has tightened up the specs for transmitters considerably. All the transmitters described in this book will operate legally if made with the proper parts and tuned properly. Readers should study Chapter 6 carefully before attempting to put an R/C transmitter on the air, either one they have made or a manufactured unit.

In addition to many pieces of equipment developed and well tested by the author, we include circuits, equipment and ideas from countless experimenters in the field of radio control. Without these experimenters a book of this scope would be impossible. We wish to thank *American Modeler* for the use of many illustrations which originally appeared in that magazine, and *Popular Science* for illustrations showing our R/C tractor. And without much encouragement from our very "R/C-minded" wife, Elinor, this book could never have been completed.

HOWARD G. MCENTEE

chapter ONE

simple control systems

IN electronic model control, the simplest of all steering devices is the electromagnet. This may be linked to the rudder of the model as shown in Fig. 101. It is set up so that with no incoming signal the rudder is at one extreme of its range of movement. When a signal is transmitted, the magnet armature – and with it, the rudder – takes the opposite extreme.

Assume that, with no signal coming in, the receiver relay cuts off the current flow through the electromagnet. The armature is pulled away from the electromagnet by the spring. This spring action also pulls the extension arm until it reaches the left stop. The motion of the push rod (connected to the extension arm) pulls the rudder over to one side. If, now, a signal is picked up by the receiver in the plane, the relay will put the electromagnet into operation, the iron armature will be attracted, and the push rod (now going toward the right stop) will force the rudder to assume the opposite position.

The push rod is not fastened directly to the rudder. Attached to the rudder (fastened at right angles) is the rudder horn. The end of the push rod is free to turn in the rudder horn. The motion of the push rod is such that it moves the rudder horn front or back. Since the horn is fastened to the rudder, this results in rudder motion.

When rudder horns are used, they normally have several holes in them to allow adjustment of the control surface movement. Let's assume the horn in Fig. 101 has three holes; as it is shown, the push rod will give the smallest movement. If it is placed in the holes nearer the face of the rudder, the movement will be greater – though the power will be less.

We can thus make the model turn right or left. To get neutral, or straight flight, the operator pushes the transmitter button at short intervals, the idea being to send right and left impulses rapidly enough so that the model will follow a straight line. If the pulses are fast enough, the path will be quite direct and not a wavy line as might be expected, since the reaction of the plane to the rudder is not instantaneous. Some models react rapidly; some much more sluggishly. Therefore, this sort of control should not

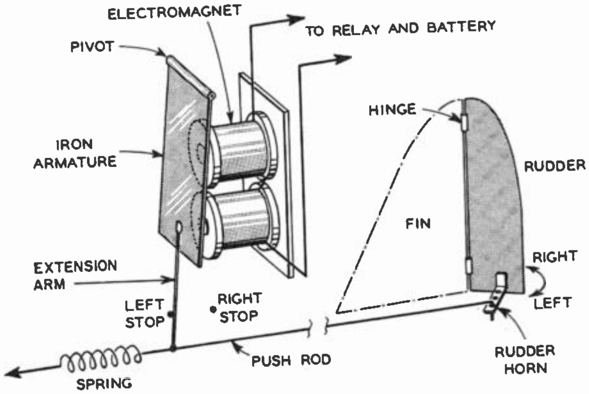


Fig. 101. *The simplest possible system for moving the rudder is just an electromagnet. A spring holds the rudder to full limit in one direction; the magnet moves it in the other. Note extra holes in the rudder horn.*

be employed on a fast and highly maneuverable model plane, though it is quite adequate for a slow plane or an electrically-driven boat.

Simple motor rudder drive

A tiny electric motor may be used to control the steering surfaces and, since it must be geared way down, there is plenty of turning power available. In the most elementary arrangement, the motor and gear train are connected directly to the sensitive relay of the model, as in Fig. 102. When the transmitter is kept on, the receiver in the plane operates the sensitive relay. The armature moves down, closing the motor circuit. The gears in the gear box are turned through a flexible coupling connected to the motor. The transmitter is kept turned on until the rudder assumes the desired angle. This means that the operator must watch carefully, and cut the signal when the turn is at the required angle. To get back to neutral, it is necessary to allow the motor-driven arm to go to the extreme position, then turn back the other way. This is certainly a rough sort of control, but a lot of fun can be had with this simple system, though it is suited only to slow-moving models, such as electrically-driven boats. However, a very similar rudder driven system may be used with a different relay and battery setup and more complex switching at the transmitter, to get quite precise rudder movement. Chapter 2 will explain how this is done.

For simplicity, the rudder in Fig. 102 is indicated as adjacent to the controlling units. For such an installation, the units would have to be located right in the tail of the model; for practical reasons, this is seldom the case. Both the escapements and motor-driven control devices are usually mounted much farther forward

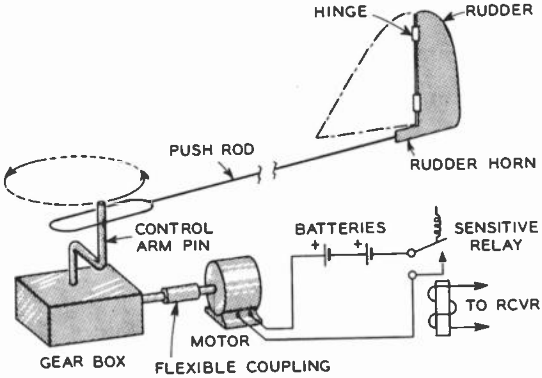


Fig. 102. *A geared-down electric motor has lots of power but gives relatively slow rudder movement.*

in the plane, often at the rear of the cabin or cockpit area. This allows easy access for maintenance, and moves the weight to a more desirable position. The control units are linked to the rudder by either torque rods or push rods.

Escapements

A very simple device for moving the rudder is the escapement, by far the most widely used control mechanism today. It can be made to give neutral, or right and left, and some types even can give right and left in two degrees, if desired. Escapements are generally classified according to the number of *arms* or the number of tips or points on the rotating wheel. The simplest is the two-arm style in Fig. 103. In Fig. 103-a, no current flows through the electromagnet, and the spring keeps the armature in the position shown. The armature fits into the bottom tip of the rotating wheel and keeps the wheel in a vertical position. When a signal is received, the electromagnet is energized and pulls down the armature, releasing the tip of the rotating wheel.

The rubber band forces counterclockwise rotation. The tip spins a quarter turn and catches into the upper part of the armature. The armature will remain in this position as long as the signal is transmitted and received. Thus, the rotating wheel will turn 90° when the transmitting key is pressed down, and another 90° when the key is released. Fig. 103-b shows a side view.

Rudder operation with a two-arm escapement is illustrated in the four-part sketch of Fig. 104. The wheel can be made to take and hold any of four positions, though the rudder itself has only three positions. At (a), we start out in one of the neutrals, and the

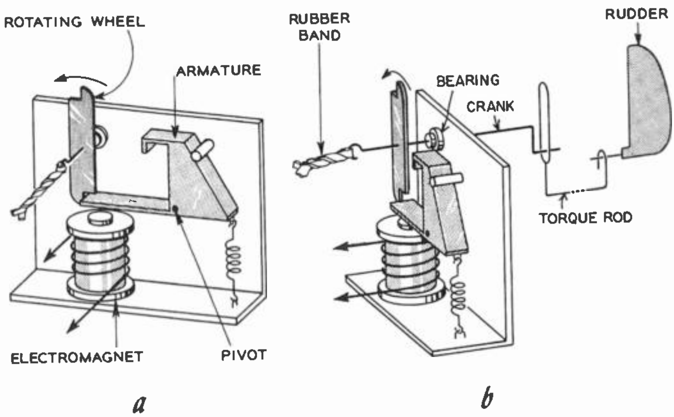


Fig. 103. *The front view (a) of a two-arm escapement, and (b) a side view. The crank on wheel shaft moves the torque rod.*

rudder is centered. At this point, there is no current going through the escapement electromagnet. If a steady signal is transmitted, the coil becomes energized and pulls the armature down, the wheel turning 90° clockwise (b). The action of this mechanism is such that the rudder is then turned to the full right position, and will stay there as long as the signal comes in. With the signal cut off, the wheel (sometimes called a bar or rotor) rotates another 90° in the same clockwise direction, getting the rudder back to neutral (c). Another signal gives a further 90° rotation for left rudder (d) and, when this signal is cut off, the wheel returns to its first neutral shown at the left in position (a). The rudder is in the turn position whenever the signal is on (b and d), and is in neutral when it is off (a and c). This is a big advantage in many ways, as the operator can always get neutral by simply releasing the transmitter button.

The two-arm style has the disadvantage of requiring power all the time the rudder is in a turn position. Current savers, to be described later, overcome this objection.

You will note in Fig. 104 that right rudder actually shows the rudder moved over to the left. The term right rudder does not refer to the positioning of the rudder, but rather to the motion of the plane. Thus, left rudder means that the plane is turning to the left, and right rudder indicates a right-hand movement of the plane.

Three-arm escapement

Such units have been rarely used, probably because there has never been a commercial three-arm unit, and they have a rather tricky sequence of operation.

Four-arm escapement

While they once enjoyed wide popularity, four-arm units are not used much anymore. However, it is still possible to buy them. They do have some advantages: they take no power to hold in the full-turn positions; and they afford half positions for shallow

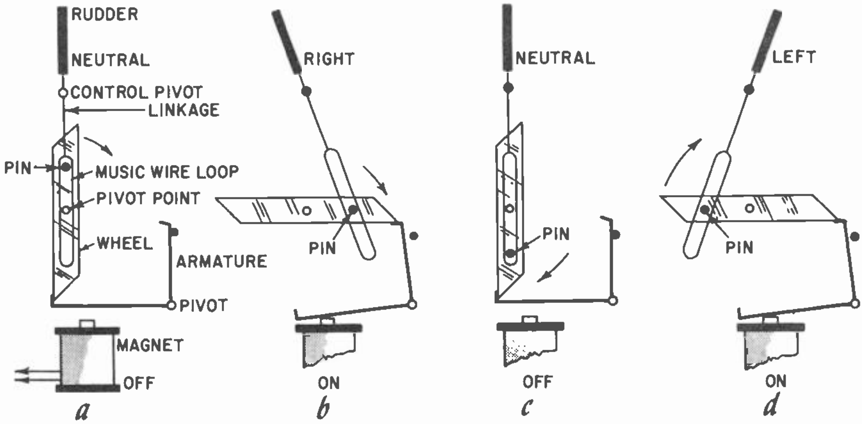


Fig. 104. *Successive stages of rudder operation using a two-arm escapement. Drawing (a) shows rudder in neutral or straight position, current off. In (b), current is on, "wheel" has turned 90°, rudder is now in full-right-turn position. When current ceases, wheel goes to opposite off position as in (c), and rudder is back to neutral. Left is had with next on signal (d).*

turns or to close contacts for other control purposes. They must be pulsed back to neutral from the turn position. This has been found confusing to beginners. Fig. 105 shows some of the different rudder positions.

Briefly, then, the two-arm escapement is the simplest to operate (and the simplest to make, if you wish to build your own equipment), but requires that current be drawn to hold a turn. If control is lost during a turn, the rudder will be returned to neutral position; this prevents a spin-in, but may result in a lost plane. Three- and four-arm units must be pulsed back to neutral after each turn. Both allow turns without current drain, and both afford intermediate or half-control positions with signal on.

Lengthy (shallow) turns would normally require the use of the

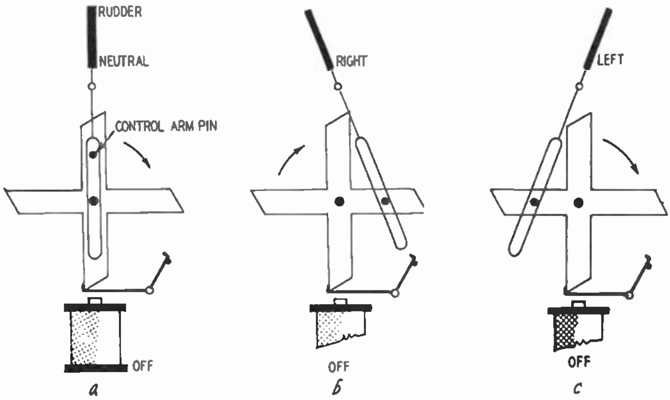


Fig. 105. *The four-arm escapement shown in off (a), right (b) and left (c) positions. Note that, in all three, no current is going through the coil. There is also a second neutral position, with the wheel rotated 180° from (a). Between every one of these no-current positions, the wheel gives a half-turn position, about 45° from positions shown here, current on.*

rudder in the half or intermediate position. Thus, to fly in a large circle, the control would have to be put half-right or half-left. Both of these positions require power to maintain the turn.

It should be understood that while we speak of two-, three- and four-arm escapements, the units available today may act as we have described yet actually have a different number of arms. Thus, a unit which gives the same control action as seen in Fig. 104 may actually have four "arms". It is probably better to think of how many *positions* the escapement can afford; one that has two control positions (not to be confused with neutral positions) is equivalent to the units sketched in Figs. 103 and 104.

The compound escapement

This unit is a comparatively recent development. It is unusual in that the rudder always returns to the same neutral after any turn. There is only one neutral, and as seen in Fig. 106-a; the neutral point or arm (1) engages only on armature stop B, while the other three arms (2, 3, and 4) engage only on stop A. With this escapement (as we show it in Fig. 106), one pulse always gives right rudder and two give left. Another arm (5) operates on three pulses, and is used to close a set of contacts for a supplementary control such as motor or elevator. Arm 5 is the shortest and the only one to engage the electrical contacts. The contacts are not operated by the longer arms. Arm 5 has a steplike bend so it alone

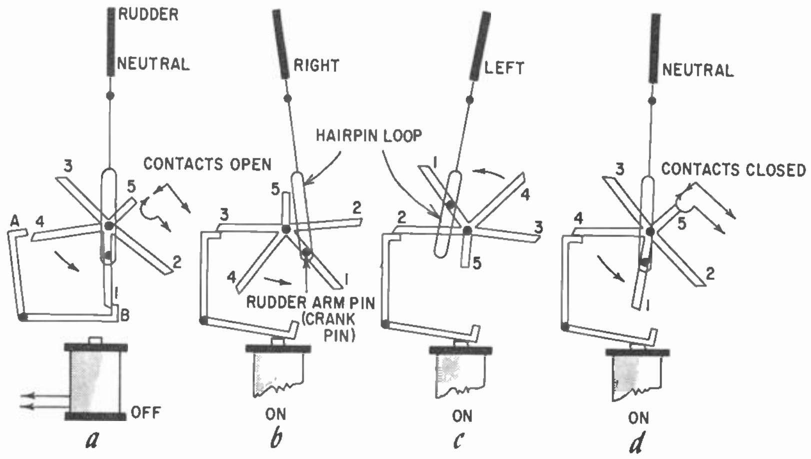


Fig. 106. *Compound escapement looks complex, but action is quite simple. There is only a single neutral position, and wheel always returns to this when current is off. For clarity we show a fifth arm, but contacts are operated in other ways in present compound escapements.*

pushes the electrical contacts, the longer arms passing either over or under them. The drawing shows that when the fourth arm is engaged on the armature stop (Fig. 106-d), the control linkage is just about in neutral, so that if you are using this position to change motor speed, for example, the rudder is essentially in neutral while the change is being made.

Since the operator couldn't possibly pulse fast enough to catch the wheel at the arm he desired, this escapement must be fitted with a governor to slow the wheel. The commercial version shown in Fig. 107 has a vibrating arm and toothed wheel for this purpose. While it is not apparent from the photo, this unit does have exactly the same stops and positions as seen in Fig. 106. The toothed wheel has tiny projections on the under side, which are caught by the armature.

The first compounds made had a single set of contacts corresponding to those operated by arm 5 in Fig. 106, but the unit in Fig. 106 has a more complex switching system which can be connected for various forms of multi-controls. It is possible to operate the rudder directly with this unit, while the contacts on it can give selective elevator action through another escapement. Motor control can also be had through an appropriate escapement. The connections for such control setups are fully covered in the instructions packed with each unit.

All the other escapements we have shown require that the operator follow a fixed sequence when moving the rudder; you have to go through unwanted positions in a set sequence. Furthermore, the number of pulses will vary, according to the direction of

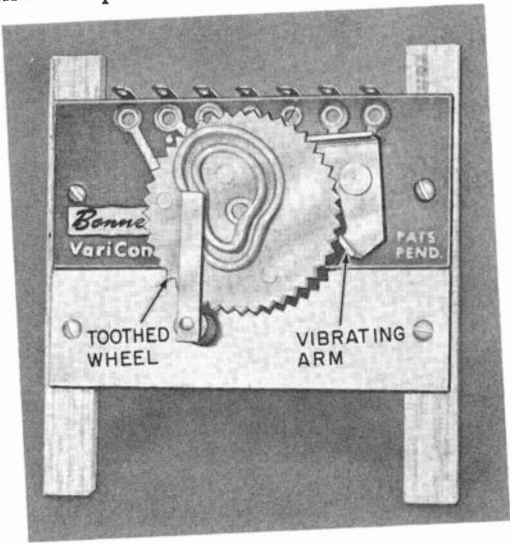


Fig. 107. *This Bonner Vari-Comp is a compound type escapement. Lower plate is only to hold bearing for torque rod. Cam on face of wheel guides pin on torque rod, replaces crank pin and "hairpin" of Fig. 106.*

the turn you wish, and which neutral the wheel happens to be in when you start the series. Thus, you have to keep in mind at all times which direction of turn you made last, so that you will know what direction is coming up next. If you wish to give three left turns in a row with a simple escapement, you still have to signal for right and neutral every time in order to get your lefts. The compound escapement is the only one that does not require this adherence to sequence – hence it is by far the easiest to fly with. One pulse will *always* give one direction of turn and two pulses will *always* give the opposite position. While the rudder does go through the undesired position, it has no effect on plane direction (since the pulses come so rapidly) and, most important of all you do not have to try to remember what rudder position is coming up next. Current must be held on for the duration of a turn; the wheel always goes into neutral when the signal goes off.

Escapement drive power and linkages

All the escapements we have covered utilize the electric power sent to them by the sensitive relay of the receiver only to *control* their rotation. The mechanical energy for such rotation, and for

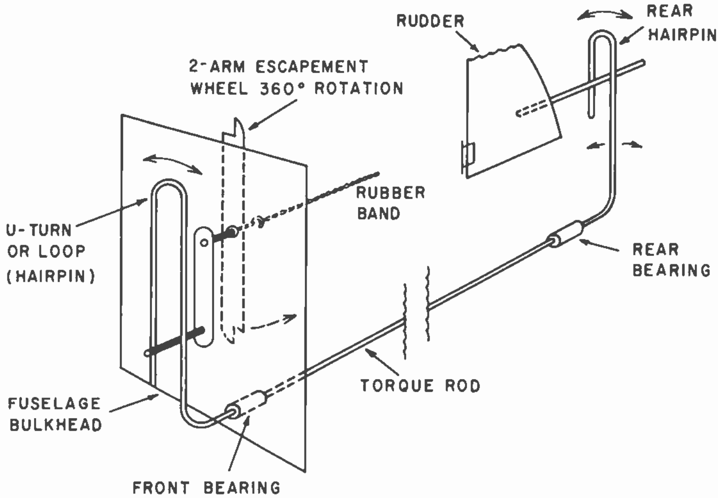


Fig. 108. *In actual escapement mounting, rubber band almost always runs to rear of fuselage, where there are a hook and an access hole, so it may be wound from outside fuselage. Hairpins are made wide for clarity here; in practice they are just wide enough to clear the pins that ride in them so there will be as little "slop" as possible in linkage, but no binding.*

moving the rudder, must come from another source. In practically all escapement operation, a twisted rubber band supplies this auxiliary power. Most commercial escapements are designed to operate on two strands of 1/8-inch flat rubber, and some will handle a loop of 1/4 inch or wider rubber. The lighter rubber is used on small models, especially for rudder operation, while heavier rubber is normally employed for elevator operation. The loop thus formed is run through the fuselage to a hook, and the far end must be fastened in such a spot that it may be easily reached, so that the rubber can be wound as the turns are used up. The rubber loop must supply torque, or twisting effort, but as little tension as possible. Because of this, it is common practice to make the loop much longer than the distance from fixed hook to escapement –

some fliers use a loop 1½ times as long. Of course, this must be wound considerably before it contracts enough to hold securely on the hooks.

Though most escapements are made without them, some experts insert tiny ball-bearing washers between the wheel and the frame to attain as close to frictionless rotation as possible. Anything that will contribute toward this end is worth while, as it is an assurance that the escapement will still move the rudder reliably, even though the rubber loop may be almost unwound.

The entire linkage to the rudder must be worked over until it is entirely free of binding. The *rocking* type of linkage is easiest to set up for free operation. As illustrated in Fig. 108, the wire that runs to the rudder rocks back and forth; there are loops (U-turns) at each end to engage the pin on the escapement, and another pin on the rudder. If several holes are made in the rudder for the pin, the amount of rudder movement may be controlled as required.

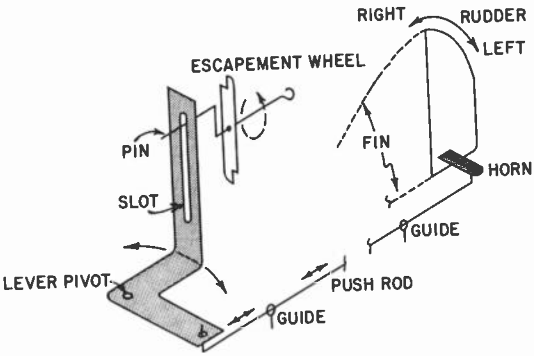


Fig. 109. *Rotary movements of escapement wheel and crank are transformed to fore and aft push-pull movements by a pivoted lever. Pivot and all parts must move very freely to avoid any binding in the linkage.*

For simplicity, the electromagnet and the armature are not shown. When the escapement wheel turns, the crank pin will turn, both parts eventually going through a complete 360° rotation. The rod, ending in the form of an inverted U, will move to the left or the right, depending on the position of the crank arm In this way, circular rotation is changed into lateral (side-to-side) motion. At the rudder end, the rod terminates in another inverted U. A rudder-control rod passes through this U but is not fastened to it. As the U moves left or right, it also pushes the rudder-control rod (or pin) left or right. Since the rudder-control rod is fastened to the rudder, this gives left or right rudder motion.

Some builders prefer the push rod arrangement shown in Fig. 109. Since the escapement must be placed in the fuselage so that the rubber band can run lengthwise, the arm must be pivoted to secure the desired fore and aft motion of the rod. A horn is then used on the rudder. The horn can be drilled with several holes so that the rudder movement can be set as required. Use care to eliminate drag and binding, for in this setup there are many more points where friction can develop and hinder the control surface action.

Since many turns are required to wind up the rubber loop, it is usual to employ some sort of winder for the purpose, such as a heavy wire hook in the chuck of a small hand drill. The rubber should be stretched to at least twice its normal length at the start of the winding, then gradually brought in to normal

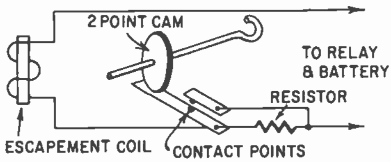


Fig. 110. *Cam is arranged to short resistor in the escapement's off positions, but to cut it into the circuit when the escapement is held in a turn position.*

length as the end of the winding is approached. This allows many more turns to be put in the rubber without fatiguing it. If the model is to be stored for a considerable time, the turns should be taken out of the rubber.

Current savers

Some escapements are fitted with means to cut the current they require, so that lengthy turns may be held without running the battery down. There are two main ways to do this: both require that the full power be fed to the escapement to initiate the movement of the armature. When the latter is close to the pole piece, it can be held there with much less power. A set of contacts is needed to shift from high to low current drain. These may be worked by a cam on the shaft, by a projection from one of the arms, or the contact may be closed through the arm itself. Some escapements have two windings on the core, one being used for full power and the other for hold. Others simply put a resistor in series with the single winding, to get a lower current drain for hold purposes. The latter is simplest and of more interest, in that the arrangement may be added to escapements that have only the usual single magnetic winding. Fig. 110 shows the details.

The average escapement requires around 500 ma at 3 volts to operate. This current can be cut in half or even further, and still retain sufficient power in the coil to hold the armature reliably. Since the coil will have a resistance of about 6 ohms to operate at these values, it will be necessary to use a resistance of the same ohmage, or higher, for the current saver. Depending upon the size of the control surface to be moved (and held), it might be found

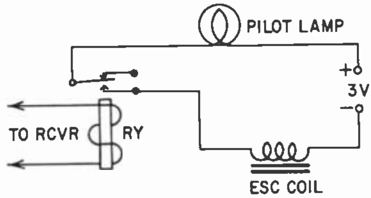


Fig. 111. *Pilot lamp gives automatic current-saving action. Resistance is low when lamp is cold, but rises when it lights.*

that a considerably larger resistance value would do, thus saving even more battery power.

A current saver that can be added to any escapement is shown in Fig. 111. It requires simply the addition of a series lamp bulb, and no contacts of any sort are needed. Bulbs have much less resistance when cold than when hot; when the relay closes, battery current is not greatly impeded by the low cold resistance of the bulb and the escapement operates reliably. By the time the armature has pulled in, however, the bulb heats and its resistance is raised, thus cutting total battery current drain. In one test, two penlight cells were used to supply 3 volts to an escapement at about 0.34 amp. Addition of the No. 13 pilot lamp (rated at 3.8 volts and 300 ma) cut the hold-in current to 180 ma, yet escapement operation was perfectly reliable. Make tests with various pilot and flashlight lamps to see how much the current to the escapement can be cut, while still retaining completely reliable action. Such tests should include trials with a fully wound rubber and also with lowered battery voltage.

Another current saver useful in certain instances is seen in Fig. 112. With the relay in the normally closed position as shown, and the switch closed, the battery simply charges the electrolytic capacitor and, once it is charged, very little current flows from the battery.

When the relay armature moves to the normally open contacts, the charged capacitor is thrown across the escapement coil and discharges almost instantly. The heavy current flow is sufficient to pull the armature in, even against a fully wound and heavy rubber motor. Also, this arrangement will operate the escapement reliably even though the 3-volt battery is quite run down — provided

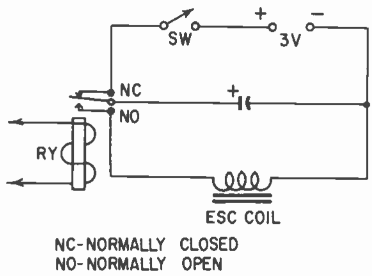


Fig. 112. *This arrangement will not hold an escapement operating, but just gives it a fast and heavy pulse of current to kick the armature. Good for motor control uses.*

that you don't key the relay too rapidly to allow full capacitor charging between pulses.

With most escapements, a capacitance of 1,000 µf will do a good job. The capacitor need only have a 3-volt rating; it will be around 1 x 2 inches in size and quite light.

This circuit will not allow you to *hold* an escapement armature in an operated position, of course; if you want to hold a position, a four-arm escapement will have to be used.

Adding contacts to escapements

Many escapements are made without electrical contacts, but these are easy to add. If the unit is a sturdy one, with a good fit between shaft and bearings, you can solder a little cam to the shaft and use this to work the contacts. The cam can have one or more points, depending upon what you wish to work with the added circuit. In the two-arm escapement, it is useful to have the added contacts close in only one of the two neutral positions. Thus, you have one plain neutral left over for straight flight. If you have a four-arm escapement, the contacts may be placed to close in one or more of the half positions; you can skip through this position quickly, if you don't want the extra circuit to operate. For either of these cases, however, it will usually be necessary to include a slight delay action in the added circuit, so that the added circuit isn't actuated every time the wheel makes one rotation. If the circuit is an escapement or other magnetic device (as is most often the case), the delay may be obtained by use of the simple arrangement in Fig. 113 where a low-voltage, very-high-capacitance electrolytic capacitor and a low-value resistor are used.

Suppose, for example, that the relay closes the escapement-coil circuit. Without the 5-ohm resistor and electrolytic capacitor,

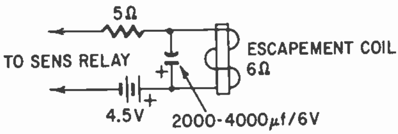


Fig. 113. *Some escapement setups require delay action, and this is one way to get it. Escapement won't operate on a quick pulse of current. The 5-ohm resistor is actually a 5.6-ohm unit, wirewound. It is similar in appearance to insulated composition resistors, is readily identified by the double width of the first color code band.*

current flowing through the escapement coil would magnetize the coil and the armature would be attracted. Now let us see what happens when the resistor and capacitor are added, as shown in Fig. 113. When the circuit is closed, a large current flows as the uncharged electrolytic capacitor acts almost like a short circuit; little current passes through the escapement coil. Since the current also goes through the 5-ohm resistor, a voltage drop is established which limits the voltage reaching the capacitor (and the escapement coil), thus slowing the charging of the former. However, the capacitor gradually becomes charged. As the charging current becomes less, several things take place. The voltage across the resistor becomes less and that across the capacitor becomes larger. Eventually, the voltage across the capacitor becomes sufficient to operate the escapement coil.

The amount of delay depends upon the values of resistance and capacitance you use. The larger the amount of resistance and capacitance, the more delay you will get.

Other simple delay arrangements are shown in Chapter 3. They may be worked from contacts on the escapement or by other means.

When a motor control escapement is operated by contacts in the third position of a rudder compound, it is desirable to have it change position when the third compound position is reached *(if the operator desires this)* – not when the rudder unit is simply passing through on its way to neutral after having been used for a turn. If the motor control escapement upper lead in Fig. 114-a had been run directly back to battery minus, the motor control escapement would receive a pulse every revolution of the compound rotor, and you would have continual undesired engine speed changes. For this reason, the escapement lead is run back to battery minus through the relay NO contacts as shown; thus engine speed change will occur only if the compound is *stopped* on position 3. Or you can use the arrangement in Fig. 114-b.

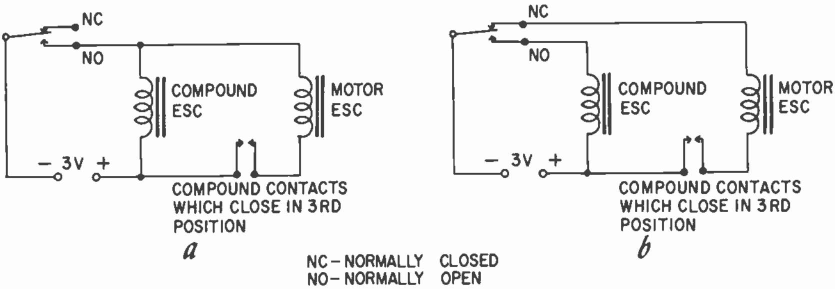


Fig. 114. *Circuit at (a) will allow motor control (or other) escapement to be held operating as long as compound is in the third position. Arrangement at (b) just gives the right-hand escapement a quick pulse of current, but won't hold it operated.*

The extra escapement will not operate when the compound reaches and stops at the third position since its circuit back to the battery is opened by the NC relay contact. As soon as the relay is released, however, the NC contact circuit is closed. This occurs before the compound can open its third-position contacts, so the motor control escapement gets a momentary pulse to step it to the next position. The pulse is only momentary, because the compound rotor soon turns to neutral and opens the contacts.

This action is fine for motor control but, if the extra escapement is used for elevator operation, it will normally need to be held on for a time in the third compound position. Fig. 114-a will do this, of course. Note that in this arrangement both escapement coils are energized all the time while position three is being held, so that heavier batteries are required. As an alternative, you can use a motor-driven servo for the elevator, since this type of unit will hold a control position without requiring any power. The modern compound seen in Fig. 107 has built-in switching circuits and will give reliable rudder and elevator operation when teamed with another unit of the same type.

Use of a compound for rudder, any other escapement for elevator, and a third escapement for motor control, operated by the so-called "quick blip" system (see Fig. 307 in Chapter 3) gives a lightweight control system making it possible to enjoy rudder, engine and elevator operation from a simple, single-channel receiver and transmitter. Admittedly, the pushbutton operation at the transmitter is a bit complex, but many modelers are flying this way.

Multiple controls with a single escapement

All sorts of ingenious schemes have been used to obtain rudder and elevator operation from a *single* escapement – either a compound or two-arm type (also called self-neutralizing or SN units). Because it does not require remembering any set sequence as does the SN unit, the compound is preferred for such use. The simplest idea is to link the escapement to the rudder in the normal manner, then have a second link running to the elevator, to give *up* when the escapement is in or near position of neutral rudder. Fig. 115 shows the general idea. Up elevator is considered much more useful than down; the elevator is lightly spring-loaded and has a

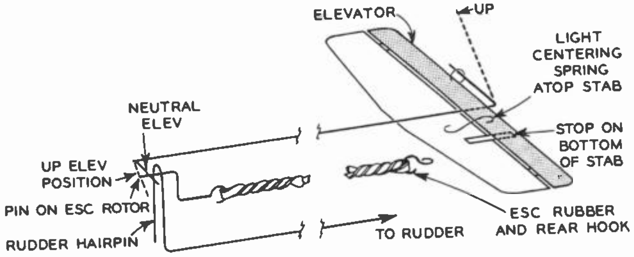


Fig. 115. *So-called "kick elevator" setup. Escapement works the rudder in the usual manner (rudder and linkage not shown for clarity) but the pin on escapement rotor hits the end of elevator torque rod in one position of the rotor – usually near one rudder neutral. As shown, elevator would be driven up. This can also be used for down (will go only one way).*

stop to prevent it from going past neutral toward down. Some makes of compounds come with extra links for this purpose.

Experimenters have altered the rotor of a compound (the type with a metal rotor) so that it has four stop positions, about equally spaced, plus the usual single neutral; with suitable linkage this can be used to give right, left, up and down! To "catch" the rotor at the desired positions, it can be slowed a bit by adding a drop of solder to the vibrating arm that acts as a governor.

Needless to say, in any control system in which the escapement does double duty (by having to move two control surfaces, plus the additional linkage), extra care is needed to see that there is no binding whatever in the entire installation. It is usual to employ 1/4-inch rubber for such setups. Normally used only on the smaller models, they are well suited to these, since the overall weight is low.

Eliminating the sensitive relay

Before leaving the subject of simple control systems, we should mention that it is quite practical to put a high-resistance winding on the escapement and work it directly from the plate circuit of the relay tube in the receiver. This arrangement is not too

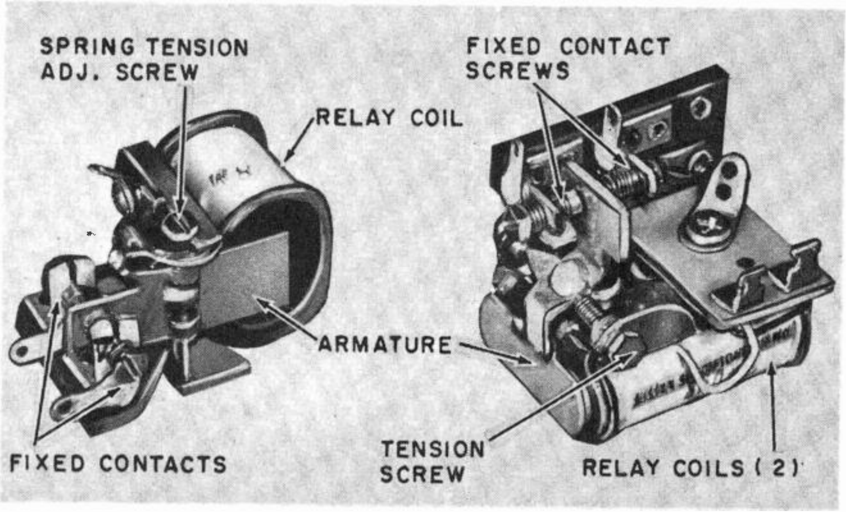


Fig. 116. *Sigma 4F (left) and 5F relays are relatively large and heavy but have lots of power. They can be made into high-resistance escapements which will move controls directly, without use of sensitive normal receiver relay. escapement and low-voltage battery circuit.*

successful, however, with simple one-tube receivers, as the plate-current change generally is not great enough to assure reliable operation. Good results may be had from a receiver in which the plate current swings from near zero to around 3 ma, or has a total change of at least 2–3 ma. Such receivers are usually of the multi-tube or transistor type, some of which are described in Chapter 5.

A powerful relay is required for this sort of operation and, if weight is no object, the Sigma 5F shown at the right in Fig. 116 is ideal. The 5F and the 4F have been used in radio control in the past, but are now considered to be rather heavy for receiver purposes. When modified to act as escapements, though, they eliminate the sensitive relay normally required and also the escapement wiring, battery and switch. Care is required in the construction of a high-resistance escapement, but if the job is well done, it will pay off in simplicity of installation and maintenance. There are no relay contacts to get dirty, and you don't have to worry about the escapement battery running down. In such an installation, it is usual to employ slightly larger B batteries; thus, overall weight saving is not a factor.

Such high-resistance escapements are not generally suited for large planes (they are best for those up to perhaps 4½-foot wing

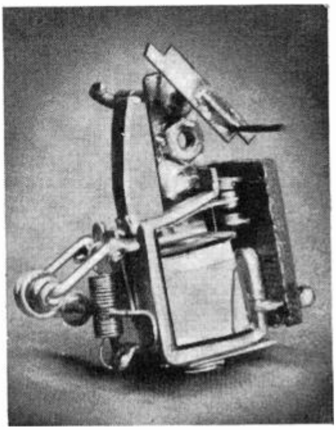


Fig. 117. *Tiny escapement was made from Gem 5K relay. Not very potent, but has enough power to move rudder of a 2-foot-span model. Very light.*

spread). They are also useful in considerably larger model gliders as these generally travel more slowly than powered planes and do not have the strong blast of the propeller on the rudder surface. At the lower end of the size scale, ultra-lightweight high-resistance escapements can be made from some of the tiniest relays. Fig. 117 shows one built from a Gem and used successfully in a 2-foot span powered model. Construction details are in Fig. 118. Weighing only a tiny bit more than the relay from which it was made—about 0.6 oz.—this escapement made possible a weight reduction in the little plane of about an ounce, a considerable saving since the overall weight was only about 8½ oz. The escapement was driven by a single strand of rubber of about 1/16 x 1/32-inch cross-section, and a fair amount of aerodynamic balance was used on the rudder to lessen the power required to move it. Such balance puts part of the rudder area ahead of the hinge line and is very helpful. It should not be overdone, though, or you might

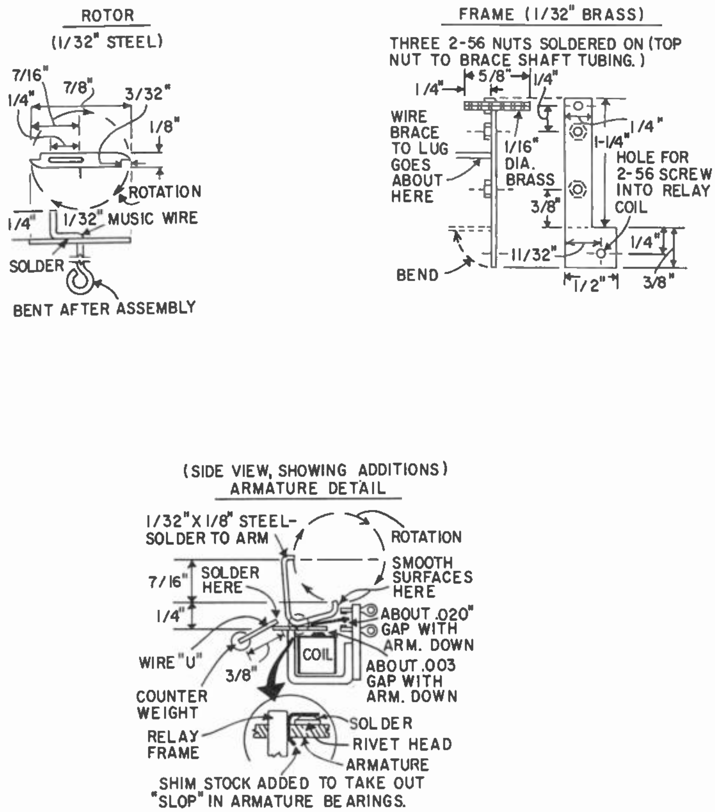


Fig. 118. *Details of the parts used in the little escapement shown in Fig. 117. Real care and accuracy are important, as clearances and power are small.*

find the rudder jamming in hard over when your plane is in a dive; 30% balance is about as far as it is safe to go in most cases, meaning that 30% of the area is ahead of the pivot point, as in Fig. 119.

The two fixed contacts were retained to act as stops for armature movement. Before assembly, the top of the core was given a couple of coats of model cement to prevent the armature from sticking to it by residual magnetism when the current ceases. The lower contact was bent to give only a few-thousandths of an inch clearance between armature and core; then the upper contact was bent to allow a total movement of perhaps 0.020-inch. These adjustments must be made *before* final touches are given to the stops, the latter being filed and bent to match the rotor. If you are in doubt as to how the rotor and stops should match, take a good look at a commercial SN escapement.

Note that a counterweight (in Fig. 118) is attached to the armature, soldered to small holes drilled in the latter and with small wire solder wrapped on for weight. After all mechanical work is completed, adjust the spring so that the armature pulls in at about 2 ma and releases near 0.8 ma. These values will differ somewhat from the escapement installed in the model and

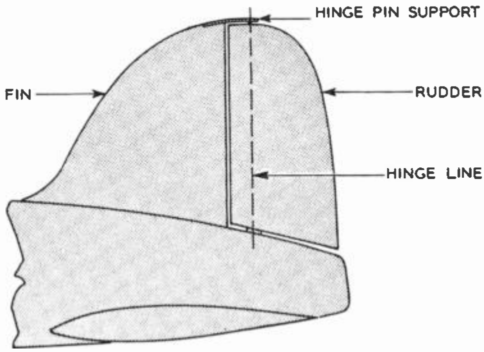


Fig. 119. *Aerodynamic balance is used on this rudder. Area forward (to left) of hinge line aids escapement in moving rudder against airstream, when in flight.*

the rubber fully wound. The rotor tips and mating stop-ends should be *polished* very carefully – remember, we don't have much power to waste here! This escapement was used with a receiver that afforded a current change of about 0.2 to 3.5 ma through it, and gave very positive rudder action. The unit had a 5,000-ohm coil, as did the relay it replaced.

Motor-driven escapements

Widely used today are a line of commercial units that function exactly like escapements but derive their operating power from electric motors instead of rubber bands. Normally a bit heavier than escapements but having considerably more power, they can be used to move control surfaces in the largest planes.

A representative unit is seen in Fig. 120. The motor turns a disc through a gear train; the disc has contact-operating rods on it and a means of linking the unit to the control surfaces through a push rod. Depending upon its purpose, the unit may have one or several sets of contacts, and operation can be had similar to an SN escapement, four-arm type, compound and so on. On the compound type, an extra set of contacts is provided to operate a second unit, either of the motor-driven type or a regular escapement. Since the motor tends to coast after power is removed, a brake is fitted to control it. Like compound escapements, Multi-Servos, as these units are called, produce a characteristic buzzing

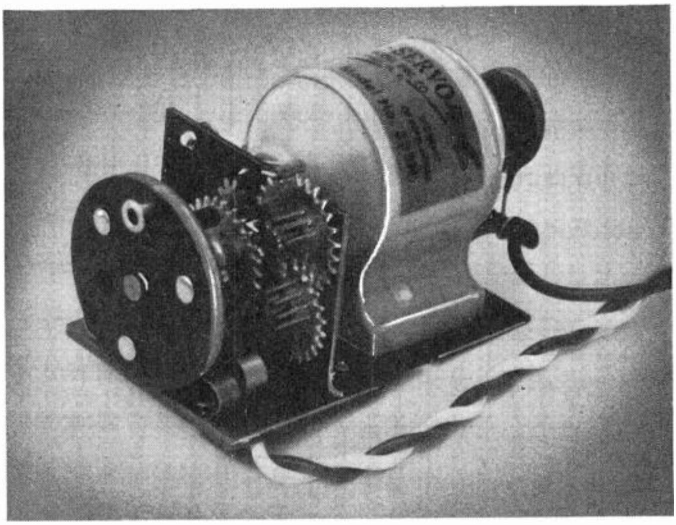


Fig. 120. *This Dmeco Multi-Servo is representative of a large line of similar units designed for single-channel and multi-control. The single-channel units give the same type of operation as various types of escapements (two-arm, four-arm, compound etc.) but have more power, do not require rubber motor. Also, these units hold a control position without any current drain. Most of them require use of both relay contacts; escapements normally use only one side of relay.*

sound when they operate. (Incidentally, this noise has been used to advantage by modelers searching for planes that have landed in thick underbrush, woods etc. If the control equipment is still functioning, keying the transmitter periodically produces a buzzing sound which can very often be heard for considerable distances in areas that are quiet).

Nomenclature

The names of actuating units for models tend to lead to some confusion. *In general,* "servos" have been considered to be the actuating units in multi-channel installations. Escapements are *always* rubber-operated units, such as we have discussed in this chapter. Compounds are a form of escapement, of course, but are known by various trade names as well; the unit in Fig. 107 is called a VariComp. Actuators originally were considered to be the operating units in proportional control systems (described in Chapter 2, beginning on the following page), but this is no longer strictly true. The radio-control modeler no longer can visualize what a given control unit might be simply by hearing its name!

chapter TWO

complex control systems

MOST of the control arrangements described in Chapter 1 are the step-by-step type; they will give right or left, and neutral, as you desire, but only in one degree. If you want to make a long shallow turn to the right, you have to signal for a whole series of *rights*, interspersed with *neutrals*. This is true because it is usual to set the rudder to give fairly sharp turns when it is held over to either side. Much smoother action in the turns could be achieved if there were a method whereby the rudder could be moved just a little bit to one side when a shallow turn is required. Actually, there is a way, and it is not too complicated at that. It is called semiproportional control. Most of the added complexity involves the transmitter, and little extra is needed in the model for some of the systems to be described. Because you do require an added attachment to the transmitter, we have included these systems in this chapter rather than in the previous one.

Semiproportional control

Let's see just what is required to get this semiproportional control action. It's more easily understood if you will try a simple experiment. Hook up an spdt switch, two batteries and a permanent-magnet motor geared down to a ratio such that, if the switch is held closed, the output shaft of the gear box will turn steadily at a speed of about 30 rpm. The circuit is shown in Fig. 201. With the switch in one position, the motor turns steadily in one direction, and reverses when the switch arm is pressed to the other contact. Now try tapping the arm rapidly, so the motor receives reverse polarity in even pulses. What does it do? It wiggles energetically, but can't get anywhere — the output arm stands still — and that's the neutral of our semiproportional system.

It's a simple matter to transfer this system to your model for rudder operation. In the plane, instead of the spdt switch, we will have the contacts of a sensitive relay, and the gear-box shaft connected to the rudder. To control the rudder, push the button or key of the transmitter. If you push to get evenly-spaced pulses, the rudder will not move; if you hold the key down, or else let it up completely, the rudder will go to either extreme position. To hold the rudder at any point of its travel either right or left, you would have to send even pulses again. This can be a nuisance (and tough on the thumb, too), so a simple keying pulser can be rigged up similar to Fig. 202. Here we have a small geared-down

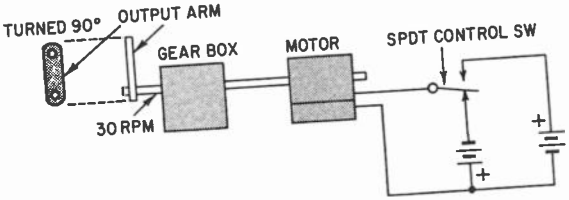


Fig. 201. *This simple arrangement may be used to demonstrate semiproportional control. Gear-box arm controls rudder.*

motor which turns a cam at steady speed. The contacts are arranged to turn the transmitter on and off, giving even on and off pulses. The actual control switch operated by you is the lever at the left; as set up here, the right position closes contact A, to give a steady signal. Left is had when contact B is opened; this cuts the transmitter signal entirely. In the center or neutral position, with contact B closed and A open as shown in the drawing, the transmitter sends out the steady series of pulses that signify neutral to the plane.

This setup can give good results, but it is possible to do a lot better with a little further complication. The next step is to go back to Fig. 201, and try another experiment. Suppose you tap the switch arm so that the pulses are *not* even; in other words, the lever is on one side longer than on the other. The gearbox arm will turn in one direction. Though the motor reverses each time you hit the lever, it turns more and longer in one direction than it does the other, so the net motion at the output arm of the gear box is in one direction only. You can reverse this direction by allowing the lever to rest against the *opposite* contact for a longer period of time.

Now, we can take the geared motor and cam arrangement of Fig. 202 and add an adjusting system to the contacts moved by the cam. (Fig. 203). If the control lever is shifted from the center position, the motor-actuated contacts can be made to close for varying periods of time. Suppose the lever is shifted halfway to left; the contact strip that engages cam A will drop downward,

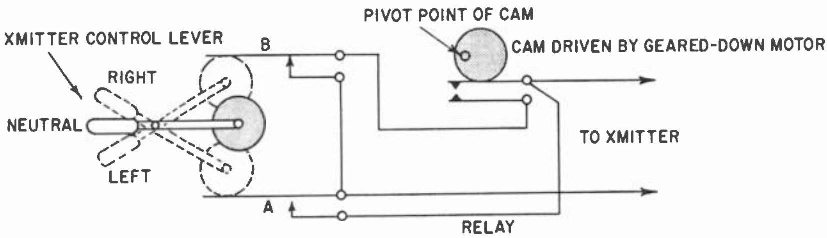


Fig. 202. *This control system replaces a thumb on button at transmitter, for better action from the rudder-moving arrangement of Fig. 201.*

and the cam will be able to hold the contacts closed only for a small part of its rotation. In the center or neutral (N) position, on the other hand, the contacts were held closed for half of each revolution of cam A. Thus, at half left, the transmitter will be sending out pulses something like those shown in Fig. 204 (½ L).

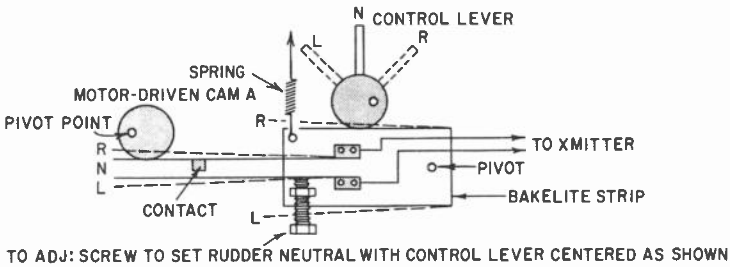


Fig. 203. *A little more complex box or "pulser" gives true proportional control, when appropriate equipment is used at receiving end of system. Note that cam on control lever moves the entire assembly of contacts and their pivoted mounting strip so contact closure intervals may be varied.*

If the lever is moved full left, the signal will be cut off. Similarly, full right will be a continuous signal, and half right will be long pulses with short intervals.

If you used this system at the transmitter and had the same motor-driven rudder of Fig. 102, what sort of control could you get? Assuming that the whole layout were adjusted so that, with the stick in the neutral position, the rudder would not move – just wiggle slightly – if the stick were shoved half left the rudder would move slowly to the left. To hold the rudder at any posigive a deflection of the rudder one way or the other. In terms of rudder-moving equipment, you can't get much simpler than this.

Fig. 207 shows a linkage that was used in a tiny radio-controlled plane based on this same sort of arrangement. Actually, a 5,000-ohm relay supplied the coil, armature and return spring. The armature was fitted with a wire extension to magnify the available movement, the wire engaging a torque-rod hairpin. This

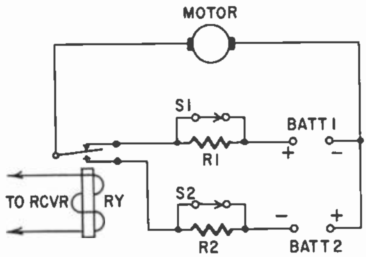


Fig. 206. *Circuit for electrical centering. In neutral, S1 and S2 are closed to short R1 and R2. As motor moves off center in one direction, a cam opens switch that puts resistor in* that side *of circuit. Light rubberband centering usually also employed with this system.*

relay is an exceptionally efficient type for its size and weight and, with a current range of from about 0.2 ma to 3.5 ma through it, gave very good control action in the tiny plane (only 24-inch wingspan and fitted with an .02 engine). For planes a little bigger than this, a low resistance relay could be used, supplied with power from a 3-or 4.5-volt battery and controlled by the receiver sensitive relay, to get a lot more rudder power than might be had from the high-resistance relay worked directly from the receiver output. The relay mounted in the plane's fuselage is seen in Fig. 208.

To get more movement of the rudder, some experimenters have used the little plastic low-voltage motors of which there are many on the market. The motor is fitted with stops so that it can turn no more than, say, one-half a revolution (Fig. 209). As the pulses come in, the motor flips back and forth between the stops, and the push-rod works the rudder. The motor has lots of torque and can move a large rudder or elevator, but it takes a lot of current. An electric motor draws the greatest amount of

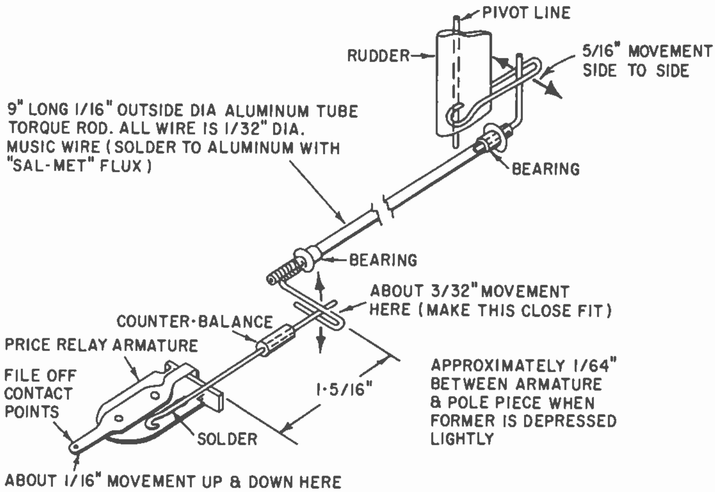


Fig. 207. *Linkage used to drive rudder on a tiny plane, direct from the armature of a sensitive relay. Price relay is very potent, quite light and compact for its size. Weight is put on wire lever soldered to relay armature, slid until entire system is roughly in balance with no tension on relay armature spring. This helps relay do its work, since power available is naturally rather feeble. System good only for very small planes.*

current when it is not turning; this system, requires that the motor be stalled at the stops part of the time and moving relatively slowly the rest.

To let the motor turn at a higher speed and to get more torque at the rudder while still holding current drain to a reasonable value, the Mighty Midget motor is widely used; it has a built-in gear train with a 7:1 reduction ratio. It is usual to add a centering rubber band (Fig. 205) sufficiently strong to limit movement of the torque rod to 180° or less; many modelers do not use stops in such an installation. Operated on 1½ volts, the motor will draw about 100 – 150 ma, depending upon pulse rate (higher current is drawn with higher pulse rates), and 250 – 350 ma on 3 volts.

To obviate the need for two sets of batteries for such proportional circuits, the motor can be driven by a dpdt relay; the circuit is seen in Fig. 210. Such an arrangement is not too highly favored, however, because double-pole relays are harder to adjust than the almost-universal spdt types, and take more current to operate reliably. They are also more costly and not widely available.

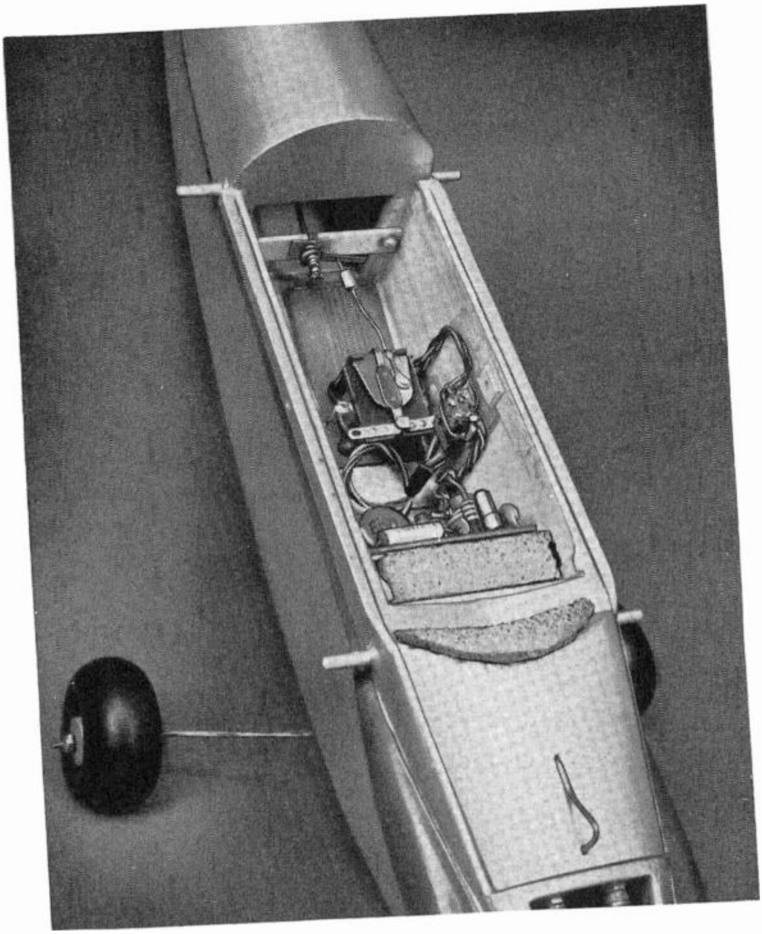


Fig. 208. *This shows the relay and linkage installed in plane. Receiver is mounted on foam-rubber pad at near end of plane cockpit. Unit on fuselage side just to right of relay is a connector for receiver, made from pair of subminiature tube sockets. Receiver battery is in holder under hatch in foreground.*

Actuators

A neat way to reduce the current drain, while still obtaining plenty of torque is with the actuator illustrated in Fig. 211. (The completed unit is shown at the upper right.) This gadget is generally termed a proportional actuator (or just actuator for short). But remember the confusion among such radio-control terms – not all actuators work like this one nor are they intended for the same job. It might be compared to a permanent-magnet

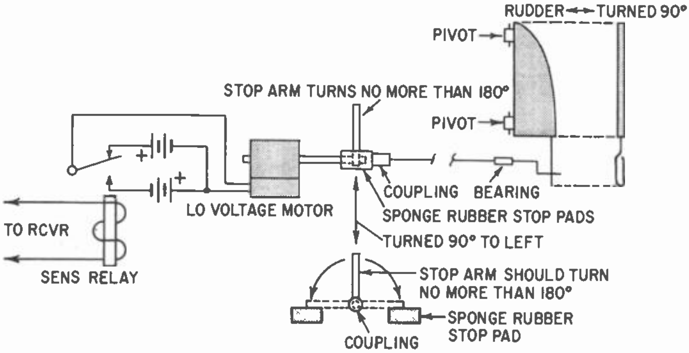


Fig. 209. *Low-voltage motor can be connected directly to rudder torque rod, but at least one stage of gearing is generally used. Mighty Midget with its built-in 7:1 gear reduction is most popular. In any case, some sort of stop to keep motor from completely rotating the rod is advisable.*

motor without a commutator. It gives a shaft rotation of up to about 100°, depending upon the power put into it and whether it is used with single or dual windings. With a single winding, it may be connected to two sets of batteries as was the motor in

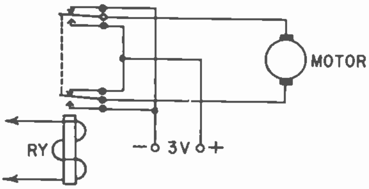


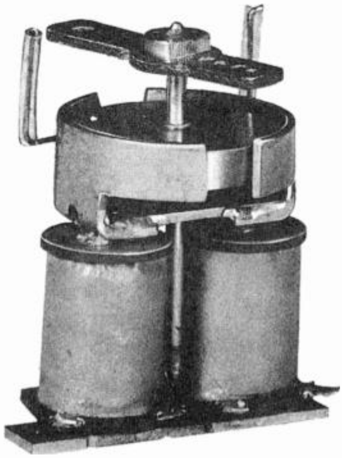
Fig. 210. *Motor can be operated from a single low-voltage battery by using a dpdt relay. Not widely used, due to scarcity of such relays and to trickier adjustment.*

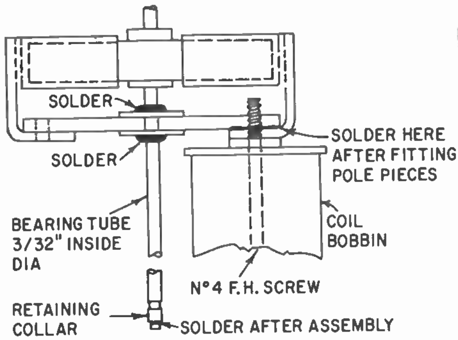
Fig. 201. The preferred connection, however, is with a single winding, using each coil separately as in Fig. 212.

The rotor of the unit is a disc permanent magnet which has its two poles, a North and a South, on *opposite edges* of the disc. Suppliers carry such magnets in several sizes. The actuator in Fig. 211 utilizes a 1 x 3/16-inch thick disc, but a 1 x 1/4 is also usable. If the thicker one is used, the pole pieces should be 1/16-inch higher than shown. Semicircular poles surrounding the disc are bent down for bolting to the tops of the coil bobbins, which have iron cores. Dimensions depend upon the size of the disc and the coil bobbins, of course, so don't cut any pieces until you are sure they match.

Despite the fact that Alnico has a reputation for resisting hard knocks, heat, etc. treat the disc with gentle care! Rough treat-

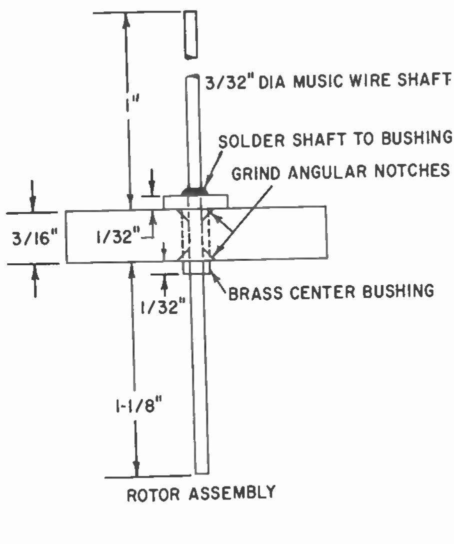
The completed actuator assembly is shown in the photo at the right.





MAIN ASSEMBLY

Main assembly (left). For the sake of clarity, only one coil bobbin is shown.



ROTOR ASSEMBLY

The rotor assembly (right) is mounted on a wire shaft.

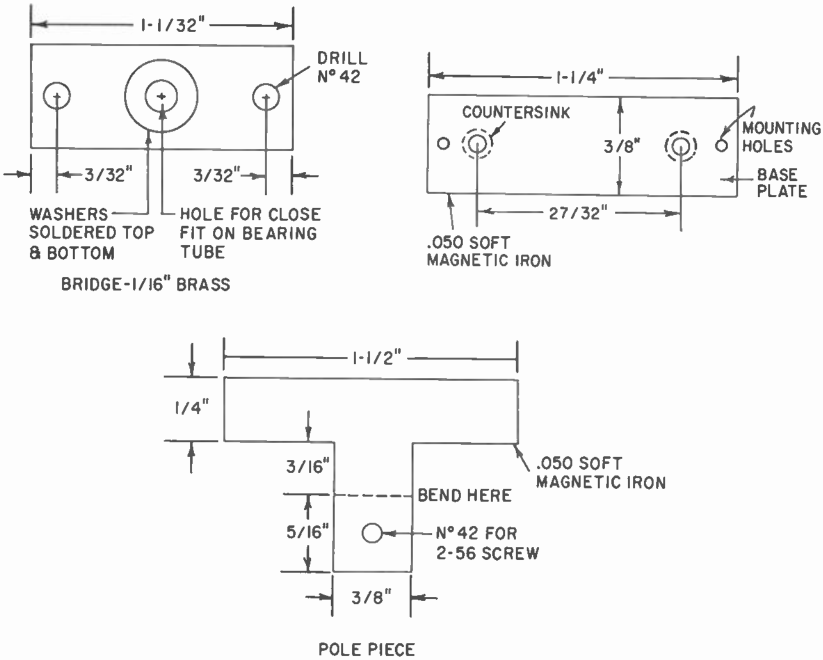


Fig. 211. *Proportional actuator useful in larger planes. Sketches give details of the parts needed and their assembly. As main assembly shows, entire rotor and pole-piece assembly is built as a unit, including long tube bearing for the rotor shaft. If holes through center of electromagnet poles are not desired, screws may be run into tapped holes in pole ends by removing the rotor. This makes it a little trickier to solder collar on end of rotor shaft, however. Shouldered bushing is soldered to rotor shaft before it is put in the magnet disc. One of the epoxy cements can be used to fasten the disc–shaft assembly permanently.*

ment will definitely weaken it. For this reason, the shaft was not soldered directly to the disc; rather, a brass bushing was turned as seen in the rotor assembly, and drilled for a close fit over the shaft. If you don't have lathe facilities, cut the bushing down with files, holding the piece of metal in a hand drill. Make the shaft hole first, then solder the 3/32-inch music wire shaft in place. Turn the bushing until it fits snugly in the magnet.

With a hand grinder, cut three equally spaced notches around the magnet hole, both top and bottom; then coat the bushing with model cement and press it in the hole. Place the assembly through a hole in a block of wood and use a small-ended (about 1/32-inch diameter) nailset or a filed-off nail to depress the brass slightly into the disc notches. If you do a good job, the disc will run true and will be amply tight on the bushing.

The main frame assembly is started by cutting the brass (*not* *iron!*) bridge and soldering to it the bearing tube of 3/32-inch inside diameter brass tubing. Make this tube as long as possible, depending upon the length of the magnet coils used. A washer at the top and bottom of the bridge strengthens the joint. Place the tube at exact right angles with the bridge.

The pole pieces and base plate are made of 0.050 soft (magnetic) iron. Plain cold-rolled steel can be used, but iron is better if you can get it (hobby stores usually can supply it). You can go up to 1/16-inch in thickness, but don't use thinner than 0.050. The poles on the actuator shown were cut from the armatures of discarded large-size relays.

If you treat it with care, the magnet itself can be used as a form around which to bend the poles, but a piece of 1-inch rod may be handier. Clamp the flat pole-piece blank centered over the rod in a vise and bend the pole ends around. If you are using a rod, you can tap the ends with a hammer and piece of scrap brass to make them conform (*don't* do this if you are using the disc as a form). The metal will spring out slightly, which is all right, as you want a gap of 1/64 to 1/32-inch all around between the disc and the poles.

With the pole-piece legs bent as in the main-assembly sketch, fasten them to the bridge with 2-56 screws. File and adjust the holes to get the desired gap between disc and each pole right, over the pole legs. (You can bend and shape the pole tips more easily after the main assembly is soldered together). Next, solder the poles and bridge together – clamp a pair of pliers or other "heat sink" at the bridge center, so the bearing-tube joint doesn't become unstuck. With the poles firmly in place, clean the assembly, open the holes and tap to fit a 4-40 screw.

The electromagnets were wound on bobbins taken from old relays (again, you can get suitable bobbins from radio-control suppliers). Because none had the desired windings, the original wire was stripped and the bobbins rewound. Since the actuator in Fig. 211 was to operate on 1½ volts, a winding of 950 turns of No. 30 enameled wire was wound on each, keeping the layers as even and smooth as possible. The winding was done by clamping the empty bobbin in the chuck of a hand drill, which in turn was clamped in a vise. These bobbins measured about ¾-inch long inside the fiber end pieces, which are ⅝-inch in diameter and the winding just about filled this space. Before winding, the iron core was drilled all the way through to pass the No. 4 filister head screw.

It takes 950 turns of No. 30 wire to produce a winding with a resistance of about 11 ohms and a current drain of about 120 ma on 1½ volts. The actuator gave sufficient power for reasonable stunting with a fast 56-inch-span plane. Later for still more power, a potent Alnico disc 1 inch in diameter by ¼ inch wide was installed. With the original magnet, the unit weighed 2½ oz.

Torque produced by such actuators is directly proportional to the number of turns of wire and the current through the coils. The actuator shown will produce lots more torque on 3 volts, of course, when the current drain will be about 240 ma. With this much torque it should handle the rudder of a 5- or 5½-foot span plane with no trouble. Fig. 212 shows the actuator circuit.

As shown in Fig. 211 the unit was fitted with a cross arm

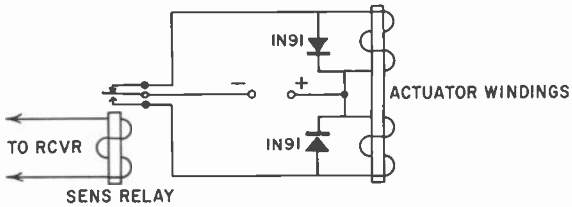


Fig. 212. *Magnetic actuator with two coils is connected to single battery this way. Coils must be polarized properly. If disc turns wrong way when you apply current, just reverse connections to the battery. Always use 1N91 suppressor diodes on such actuators, one for each coil.*

which operated the rudder through a push-pull rod. The upright arms are stops to prevent the rotor from turning too far; they are bent so that the arm does not hit them during normal pulsing. It is preferable to link the actuator to the rudder via a torque rod. The actuator is mounted with its shaft running fore and aft and, if real care is used in alignment, the torque rod could be fastened directly to the actuator shaft. It is probably more desirable to use a front bearing for the torque rod, Fig. 213, and link the rod to the actuator with a crank and hairpin. This allows a reasonable amount of misalignment and also takes the added weight of the torque rod off the actuator bearing. In any case, the whole assembly should turn absolutely free.

An actuator such as that shown in Fig. 211 has a slight centering action, but more is desirable. It can be achieved by using a rubber band on the torque rod, but this isn't recommended. Magnetic centering is preferable, and can be accomplished as shown in Fig. 214. You will need a magnet with a hole in the center (it can be a disc or bar type; plain small flat bars without holes could also be adapted). A holder of thin brass is drilled to clear the shaft, and bent to solder onto the pole pieces. The magnet is cemented and bound to the holder, with the poles turned so that the actuator disc magnet is attracted to center or neutral position. The closer the two magnets, the more the centering, however, use only enough to bring the rudder back near center. Too much centering simply eats up torque you could better use in turning the magnet.

Another type of actuator design is seen in Fig. 215. Weighing about 3¼ oz. this one has a 1⅛ x ¼-inch magnet, and the coil has 630 turns of No. 30 wire on each side of the center divider. The

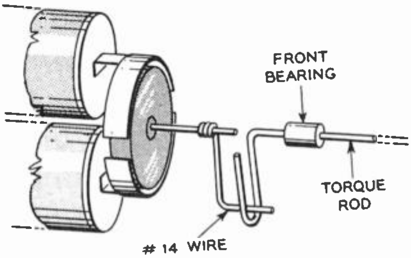


Fig. 213. *Rather than put whole weight of torque rod on actuator shaft, attach a forward bearing to fuselage or bulkhead, and link rod to actuator shaft with a hairpin.*

unit was used successfully in several planes but is not as efficient as the one in Fig. 211, whose long and more slender coils allow more efficient use to be made of the wire.

Still another unit of this sort is seen in Fig. 216, and was built for use in a very small plane. It has a ⅛ x ¾-inch disc magnet, and each half of the coil has 750 turns of No. 34 wire. Although not very strong it is ample for the tiny plane it was intended for. Dimensions are given in Fig. 217. The unit weighs ¾ oz. The current drain of each coil is 75 ma at 1½ volts.

Actuator power

The torque available from any of these magnetic devices – and this covers the escapements described in Chapter 1 as well – depends upon the number of ampere-turns in the winding. This means simply the number of turns times the current you put through them. Thus, you can get more torque by increasing the number of turns, by putting more current through an existing coil, or both. If you have a big plane and can carry plenty of batteries, you don't have to strive so hard for top efficiency. But if you want to get the most pull for the least current, it will pay to try several different coils.

As an example, the first coil used on the actuator of Fig. 215 had 780 turns of No. 32 enameled wire (on each coil), drew about 80 ma on 1½ volts and had quite a strong pull.

Another winding with 700 turns of No. 30 wire was tried. This gave considerably more pull, and a drain of 116 ma. But further coils with 600 and 500 turns of the same wire gave no increase in

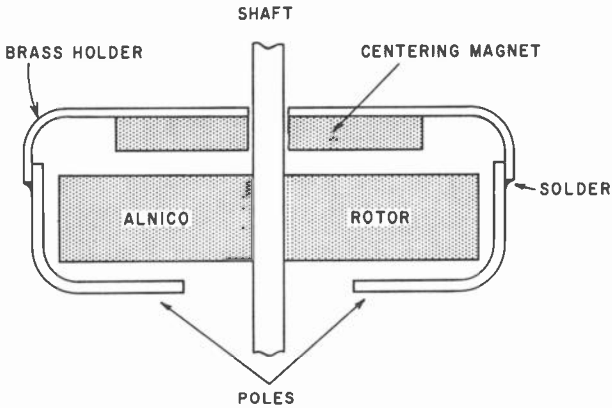


Fig. 214. *Small permanent magnet affords ideal way to obtain better centering from magnetic actuator. Should be mounted just close enough to disc to bring latter reliably back to center when current is off. Excessive centering is wasteful of power.*

pull, although the drain went up to 170 ma in the last case. Also, cutting the size of the core through the winding from 5/16 down to ¼ inch in diameter reduced the pull very noticeably in every case.

In any of these magnetic gadgets, the inner turns are the most efficient, since they give just as much magnetic field as the outer turns but do so with much less resistance, due to their shorter length. The best shape for such a coil is long and thin, hence the design in Fig. 211. Final torque available thus becomes a compromise between coil shape and size, number of turns, wire size, and the current you can afford to use.

Simplified actuator

Another type of actuator, developed by George Trammell, is shown in Fig. 218. Extremely simple, it has surprising pull. It can be made much lighter and more compact than the one in Fig. 211. Details of the actuator parts and assembly are shown in

Fig. 219 Actuator coil-winding information and a cross-section through the assembled actuator unit are given in Fig. 220.

For the simplified actuator, it seems quite possible that bar or square magnets could be used, provided they are correctly poled, if you don't require the maximum pull. This actuator has absolutely no centering action when the current is turned off.

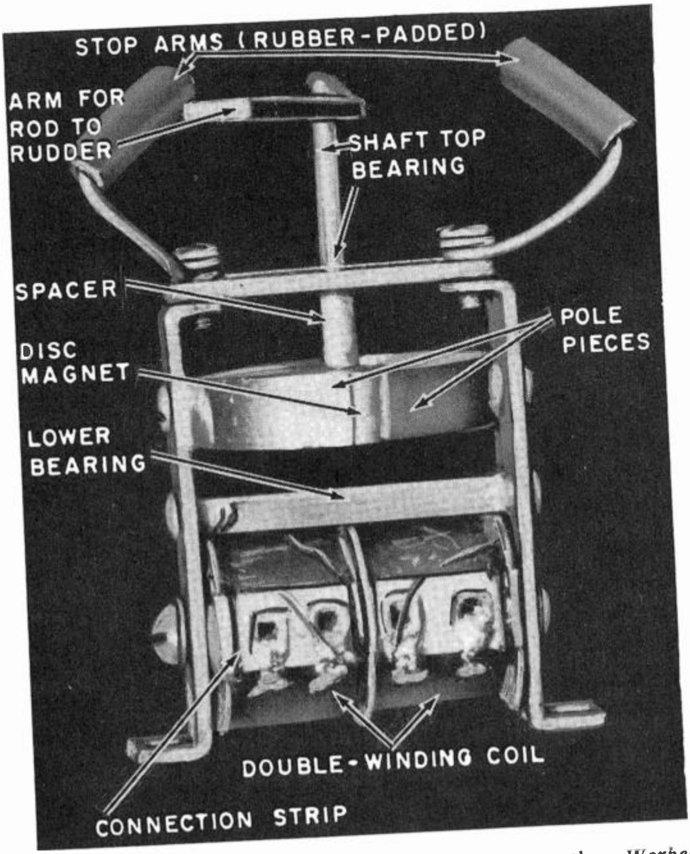


Fig. 215. *An earlier type of actuator used by the author. Worked well but, due to short fat coils, not as efficient as the one shown in Fig. 211. Weight about same.*

Simple magnetic centering can be added by placing a small piece of iron under the magnet outside the case; by moving the iron around, you can turn the actuator rotor to any position. The same effect can be had with a tiny bar magnet, and this will be lighter in weight. Magnetic centering of this sort (and also as described for the unit in Fig. 211) is much more practical than any sort of spring or rubber-band centering, simply because the centering action is strongest at neutral and grows weaker as the actuator moves to either side. Air pressure on the control surface grows greater as it moves away from neutral and will always tend to force the surface — and its actuator — back toward center. So the magnetic centering gives exactly the action we want, while spring centering is just the reverse.

We have covered actuators quite thoroughly because there are not many available on the market and hobbyists must generally make their own. On the other hand, dozens of escapements and

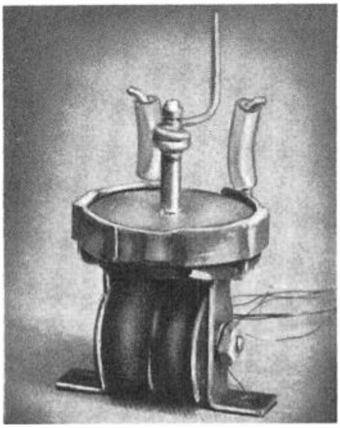


Fig. 216. *Tiny actuator for ½A size plane. Not much power but enough for the job it had to do.*

servos are obtainable, and most radio modelers do not make these units because they can obtain such a wide variety at reasonable prices.

Incidentally, it is quite practical to make an actuator with a high-resistance winding, to be operated directly from the last tube of the receiver without the need for a sensitive relay. Tests with the actuator of Fig. 215 showed that a very nice pull could be had when 8 milliamperes was put through a 5,000-ohm relay coil substituted for the normal low-resistance winding. In this instance, the coil pulled only one way, against a return spring. If it were possible to use the same push-pull coil arrangement that is shown in Fig. 212, but with the high-resistance windings, the 8 milliamperes could probably be reduced to only a few milliamperes in each coil. Such an arrangement would probably necessitate double output tubes in the receiver, and thus might add more complications than it is worth.

Motor-driven actuators

PM motors are widely used in proportional systems, with the Mighty Midget probably the most popular because it has a built-in 7:1 reduction gear train. For more torque, needed especially to move elevators on the larger planes, an even higher reduction is desirable. This is usually obtained by adding a second set of Mighty Midget gears to the motor, producing a 49:1 reduction.

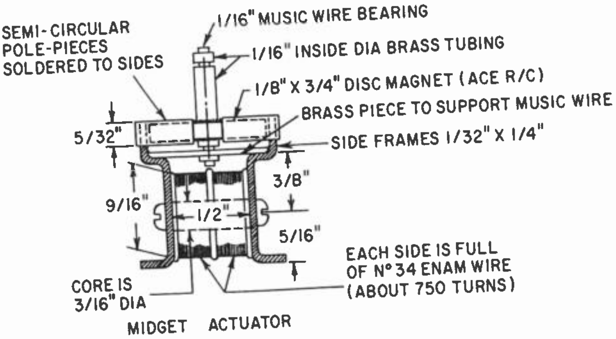


Fig. 217. *Wire driver for torque rod of this tiny unit was soldered to the 1/16-inch ID tube which holds the disc magnet. Frame was bent to accommodate magnet bobbin on hand.*

This has been found ample to move rudder or elevator of 6-foot-span stunt planes, when driven by 3 volts (or even by 2.4 volts as produced by series connection of the widely used nickel-cadmium storage cells). Some radio-control fliers feel it might be an advantage to go as high as 75 or 100 to 1 with this same motor and voltage, but too high a gear ratio is undesirable as it produces too much lag in control-surface movement.

A commercially made actuator based upon the M-M motor, and with 49-to-1 gearing is seen in Fig. 221. Although not intended for such use it can be made into a fine proportional actuator. The hole in the case through which the motor shaft protrudes should be enlarged and a small wire hook soldered on, to take a lightweight centering rubber band. The output arm may be used for push-rod or torque-rod applications, as desired. This unit can be had with any of several contact discs that are interchangeable and serve to adapt it to various sorts of single and multi-channel control systems. These contacts are normally not required for proportional work but may be left in place since they produce very little drag.

Fig. 222 shows how the Mighty Midget is fitted with an extra set of gears for an overall gear reduction of 49:1. The normal gears are at the left; added gears of the same size are at the right end of the motor. A metal plate holding a stub shaft for the added large gear is attached to the motor case with small screws. The torque rod is fastened to, or driven, by this gear.

Another useful centering scheme is shown in this illustration. An enlarged hub is pressed on over the left hand large gear, which also has a pin added to take a hook for the vertical rubber band

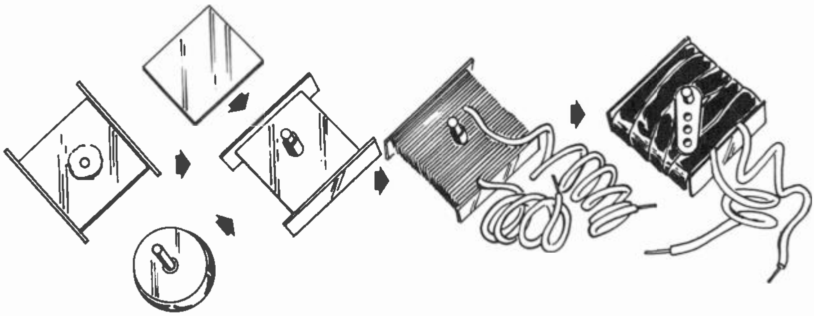


Fig. 218. *Simplified type of magnetic actuator has no iron in it except for the magnet disc itself and music-wire shaft. Frame must be made of brass or other nonmagnetic material. Inside of frame should be close fit around disc, but with enough clearance so latter can turn freely.*

or spring attachment. This band gives strongest centering effect up to about 100 degrees or so on each side of center (depending upon the diameter of the enlarged hub), but thereafter, it wraps around the hub and the centering action is greatly reduced — as is the power required for the motor to stretch this band. A light band may be attached to the motor armature as in Fig. 205 to help get the actuator back to neutral. Balance between the two centering devices may be shifted to suit the builder.

Preventing proportional-control failure

Proportional control systems all have one drawback: if you lose control for any reason, the ship goes into a hard turn to one side or the other. With a boat, this is not too dangerous, but with a plane it could — and usually does — lead to disaster. Even so, most modelers (especially those who lost an escapement-equipped plane that flew off in a straight line when the radio system failed) would much rather take home the remains of a plane that had spun to the ground when control was lost, than lose the plane through a straight-line flyaway.

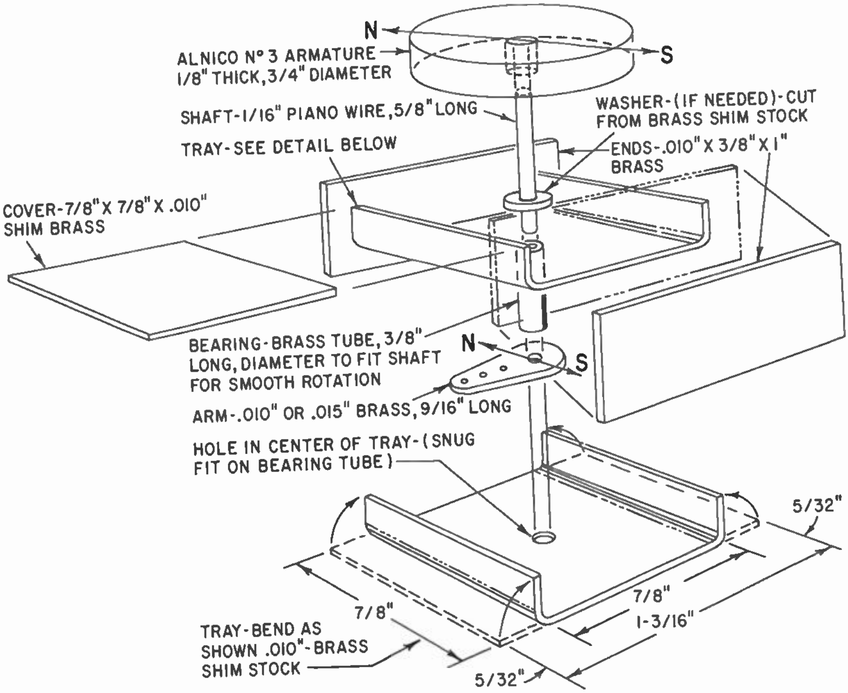


Fig. 219. *Thin washer keeps magnet from touching case on one side. Shaft protrudes through center of disc a tiny amount, is rounded on this end, keeps disc from rubbing on other side. Frame may be made of nonmetallic material such as fiber, if desired, but make sure shaft is fastened firmly in place.*

There are ways to prevent proportional-control systems from going into hard-over rudder if any part of the apparatus fails. It is usual to employ what is termed a "fail-safe" circuit for this, and the same circuit can also be put to use to operate a motor control. As the term implies, a failure produces a "safe" condition in the model, usually by returning the rudder (and other controls, if used) to or near neutral. In a proportional system, this is done by adding a circuit that will operate a relay if the pulsing from the transmitter fails to reach the plane. Some such circuits work only on loss of signal, as would occur if the transmitter were to go out of commission or the model to fly out of range. The safest arrangement is one that works either with lack of signal or with steady signal. Circuits for this purpose are shown in Chapter 3. For safety, place your fail-safe circuit as far along the control "train" toward the rudder as you can get it. If placed right in the receiver circuitry, as it sometimes is, it will work all right if the

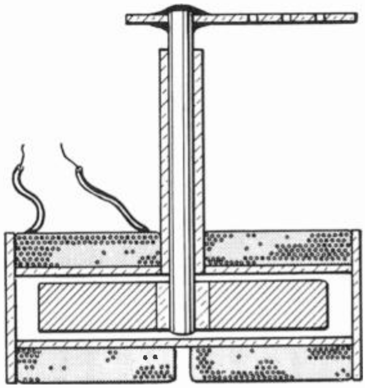


Fig. 220. *Cross-section shows winding in place; it can be either single- or double-coil type. After it is in place, apply several coats of varnish. Insulate form with tissue paper before winding. This unit took about 120 feet of No. 32 enameled wire.*

transmitter, receiver, or receiver batteries go bad. But if it is connected in the actuator circuit, the receiver relay and also the actuator battery can often be included in the parts whose failure will activate the fail-safe circuit. It is also possible to arrange things so that a failure will automatically cut the engine to low speed

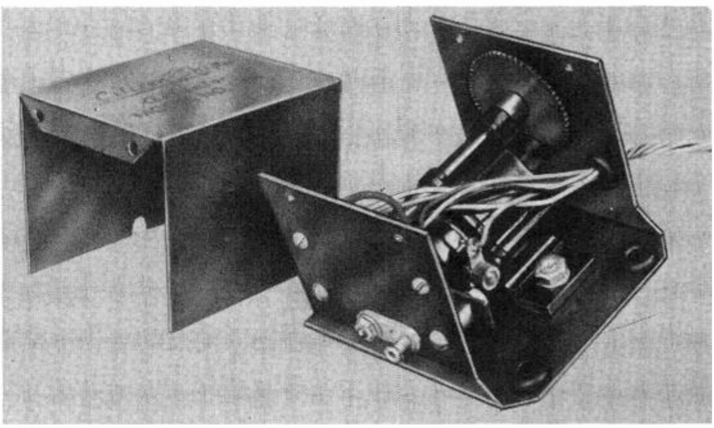


Fig. 221. *This Citizen-Ship servo can be bought finished or in kit form. It makes a good proportional actuator, due to use of Mighty Midget motor and double gearing. Intended for single- or multi-channel use.*

where it will remain unless control is regained, whereupon the engine may again be speeded up. This is also covered in Chapter 3.

Motor-driven servos

A few words on the use of geared-down motors was included in Chapter 1, since such units are widely used for the same jobs that various types of escapements perform. When used as escapement replacements, these units normally afford more power for control movement, but they are heavier and often take more current to work them. Because they do their work by electrical power and do not need the long, twisted rubber band, they can be fitted in some installations where there is simply no room for the rubber.

Motor servos are used almost exclusively to move control surfaces of multi-channel reed and audio-filter receivers. It is normal to employ one reed (or filter) channel to move a surface each way. In the popular five-reed outfits, it is customary to assign two reeds to rudder, two to elevator and the fifth to motor control. Eight-channel outfits add two more for ailerons, sometimes use two for motor control, or possibly one for this and one for such added controls as flaps. With 10 channels you can get elevator trim.

Reed servos usually have higher gear ratios than those used for proportional purposes, and are fitted with several sets of contacts for limiting movement at each extreme and for bringing the servo back to true center. The limit contacts open when the control arm reaches the desired maximum movement to either side; the servo will stay in that postion without any further current drain until the relay controlling movement in that direction is de-energized, whereupon the centering contacts act to bring the arm back to neutral.

A representative circuit is shown in Fig. 223. If the centering contacts are set to bring the arm (and its control surface) back to *exact* neutral, the servo is said to be self-centering or full-centering. Some fliers set these contacts so that the servo does not go to exact center, leaving a small "trim" range. This allows for slight control changes (usually used only on the elevator) to compensate for varied flying conditions, such as windy weather or lack of it. A few fliers prefer to fly with no centering on the elevator at all – it simply goes to the position signaled and stops there until the flier calls for some other position. This method of flying produces very smooth results, but it is more difficult to learn. In this case, limit contacts are usually fitted but no centering contacts are used.

Except with full-trimmable operation, reed servos go from neutral to extreme position when the transmitter control stick is

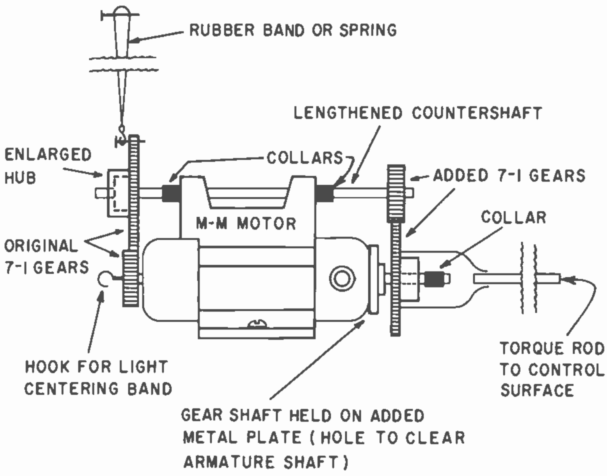


Fig. 222. *Most Mighty Midgets used as servos in multi-proportional planes have double gearing (one added set of gears like those on the motor — hobby shops stock these extra gears), various centering systems. Some users center solely by rubberband on armature shaft (Fig. 205). Other users add a band or spring to large gear as seen here. Both types can be used.*

moved, and the flier must learn to "tap" the stick a number of times in the direction he wants to go. This will tend to hold the servo in a partially operated position. If this is not done, the plane will make very abrupt movements, especially in response to the elevator (most planes are more responsive to elevator control than to rudder).

In most proportional systems, the rudder (and elevator if used) is continually moving from side to side, to some degree. The idea is to adjust the pulse rate high enough so that the plane cannot follow it and thus travels in a straight line. The higher the gear reduction of the proportional actuator (of the motor-driven type), the less the surfaces will flap. With proper pulse rates, such flapping does no harm at all — but does offend some modelers. There are systems that give full proportional operation without any control-surface wiggle at all — the control just moves to the position you signal by moving the transmitter control stick and stays there until you call for another movement. The surface thus duplicates exactly the movement of the stick. Generally called "feedback servo" arrangements, they are rather complex, and although they have been known and used for years in missiles etc., they have only recently been simplified and lightened for use in model planes.

Galloping Ghost control

We can't leave this chapter without a brief coverage of a proportional system that gives the very most in control action for least amount of equipment. Variously called Galloping Ghost, Simpl-Simul, Crank System, etc., it allows full proportional control of rudder and elevator with just a single motor in the model. The most widely used motor is again the Mighty Midget, whose 7-1 gear reduction is just right for this use.

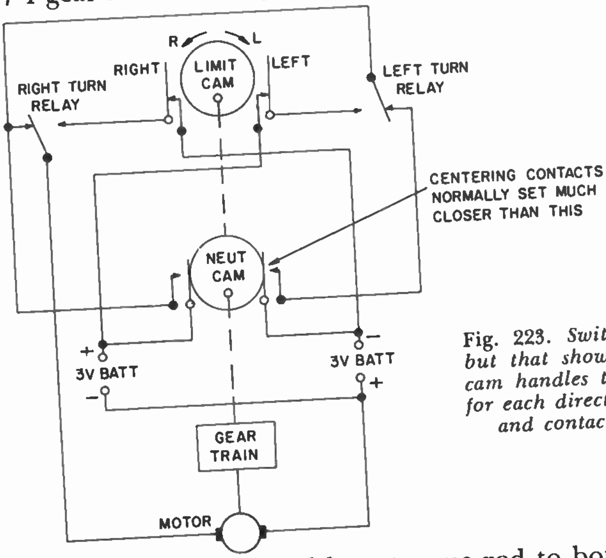
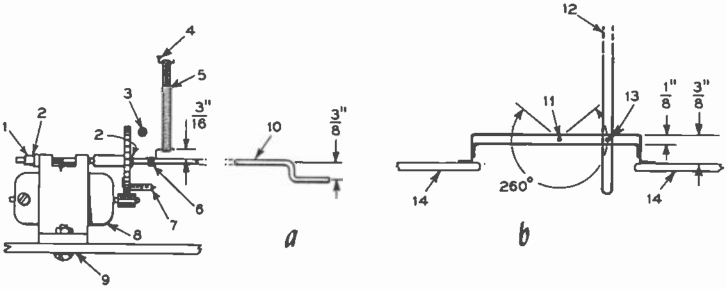


Fig. 223. *Switching on servos varies, but that shown here is typical. Each cam handles two sets of contacts, one for each direction of operation. (Relay and contacts shown in no-signal position.)*

The motor is linked by a torque rod to both elevator and rudder (Fig. 224). A stop on the large gear of the motor hits a dowel run from side to side of the fuselage; rubber or fuel line tubing on the stop pin eases the operation slightly. The crank which engages loops on the rudder and elevator can vary in size, depending upon the plane size and tail surface arrangements. However, things should be arranged so that: (1) The crank turns a total of about 260°, with the "open part" of the arc up (Fig. 225-a). (2) The rudder should be centered when the crank is straight down — this also gives fullest amount of down elevator. (3) With the crank almost horizontal, you have full rudder movement to one side, but the elevator will be about neutral or slightly up (Fig. 224-b). There must be no binding in any part of the linkage.

The rudder wiggles from side to side as in normal proportional practice, this movement being controlled by a change of pulse *length*. The elevator action is varied by a change in pulse *rate*, however. Slow pulse rates (about 4 – 5 pulses per second) will allow the motor time to drive the rear crank from practically one extreme to the other as in Fig. 225-a, and you will have effective neutral rudder (if the pulse on – off ratio is equal) plus full up elevator. A high pulse rate — perhaps 8 — 9 pulses per second — will squeeze the crank arc way down (Fig. 225-b), and give you full down elevator, again with neutral rudder (equal on – off).



1. EYELET 2. SOLDER 3. 3/16" DOWEL STOP BAR 4. PIN AT TOP OF CABIN
5. RUBBER BAND 6. BIND AND SOLDER 7. MUSIC WIRE STOP WITH FUEL TUBING OVER IT
8. M-M MOTOR 9. MOTOR MOUNTED SOLIDLY 10. 1/16" MUSIC WIRE 11. TORQUE ROD END
12. WIRE "U" ATTACHED TO RUDDER 13. CRANKPIN 14. ELEVATORS

Fig. 224. *Another use for ubiquitous Mighty Midget — as servo is Galloping Ghost control system. Single crank on rear end of torque rod drives both rudder and elevator through wire linkages. Dowel stop bar (3) runs from side to side in fuselage, should be firmly cemented. As seen from rear, (b) shows rudder at full-right-turn position, and elevator about neutral. Controls cannot hold this exact position, but give this effect by averaging.*

At some intermediate pulse rate, the crank will whip back and forth at a certain speed to produce neutral elevator (the elevator actually goes up and down past neutral, but the *effect* is neutral). Now if you vary the pulse length, while maintaining this same rate, the crank arc will swing to one side, giving rudder turn action but still holding approximately neutral elevator (Fig. 225-c). There are countless variations of pulse and length — and correspondingly countless combinations of controls!

Like many things that look extremely simple, this system has a few drawbacks. First, it takes a reliable pulser (see Chapter 8). Second, it takes quite a lot of time to get a model trimmed out *right*, so that it will fly as you wish. At the lower pulse rates, practically all models will wag their tails, not only sideways but up and down — hence the name, Galloping Ghost! Still, we know of no control system that gives so much for such simple equipment in the model.

Galloping Ghost systems have been found best for mediumsized planes, and it is usual to employ a very narrow elevator (rudder may be of conventional size), no more than a third as wide as used for most multi-control systems. Some experimenta-

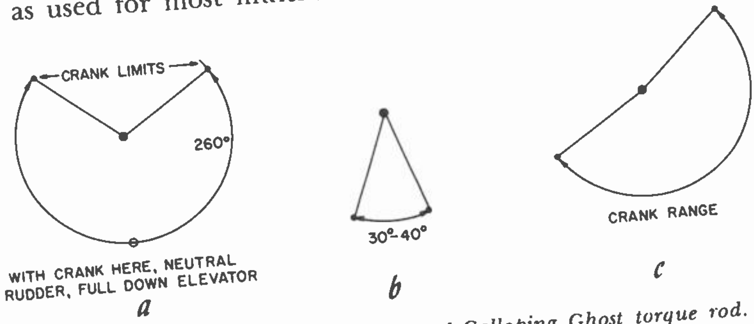


Fig. 225. *Movement of crank pin on rear of Galloping Ghost torque rod. Slow pulsing allows full range of rotation, limited only by stop bar. Highest pulse rate limits movement to very short arc to give full down effect.*

tion will be needed with centering rubber tension; many users make the top rubber holding pin adjustable so the tension can be set as needed. A good flier with a well-adjusted plane can do just about all stunts with a G – G plane.

chapter THREE

motor and auxiliary controls

MOST radio-control enthusiasts, after they have licked the problems of steering their model, develop an immediate urge to add other control actions. Some want elevator control; others prefer means to vary the engine speed. There are both simple and complex ways to effect these and other added functions. Let's see how some of the more practical systems operate.

Engine control

How, for example, can you vary the speed of your engine by radio? If you use spark ignition, it is a simple matter. The most common way is to use what are called *two-speed* points on the timing cam. One set of points runs the engine at top speed, the other slows it down, and the change between the two may be made by a simple switch. Connections are shown in Fig. 301.

Only a spst switch is required. The reason for this rests in the arrangement of the points on the timer. As the cam turns, it opens the high-speed points before the low-speed points. Thus, when the high-speed points are connected in the circuit, they fire the charge before the low-speed points get a chance to operate. The latter do no work, but they do no harm either, and are always left connected. In operation, a relay would be substituted for the spst switch. The relay, worked by the receiver in the plane, could then be set into action by the operator on the ground. When the relay is open, only the low-speed points are effective.

The speed of spark-ignition engines may also be changed by actually moving the timing points with a geared-down electric motor, but this system is seldom used due to its complexity and added weight. While spark ignition isn't too popular, some modelers stick to it, since the fuel used doesn't harm dope, and it does offer such a simple and sure way to vary speed. Also, you get much longer engine runs for a given amount of gas and oil fuel (which is used with spark ignition) than with the alcohol glow-fuel mixtures.

Twin-needle system

Glow-plug engines are a bit more of a problem when it comes to speed variation, since it is necessary to alter the fuel–air mixture in some manner. Twin needle valves are sometimes employed on the engine, both being connected to the fuel tank and both having "bleed lines" run to a special motor control escapement. The bleed lines are selectively opened by the escapement and, by

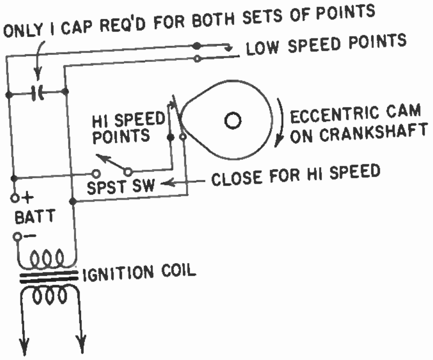


Fig. 301. *Dual contact points in ignition engine can be operated by simple spst switch or relay contacts. Only single coil and capacitor are needed for two-speed operation.*

allowing air to enter one fuel line, the needle valve connected to that particular line from the tank can no longer draw fuel. Normally, the high-speed needle valve is set for top engine performance as usual (the bleed line to it being closed by the escapement). The low-speed valve is set very rich, so that when the escapement puts it into use (by closing its bleed tube), the engine slows drastically. If the escapement is held in an operated position, both bleed lines are open and kill all fuel feed to the engine. As seen in Fig. 302, the low-speed bleed line is connected to a tee in its fuel line right at the needle valve, while the tee in the high speed line is within a few inches of the tank. This is done so that the engine will not quit once the high-speed bleed is opened, as there is a small amount of fuel in the line from tee to needle valve.

Flap-valve arrangement

A simpler system is a flap valve fitted over the air intake as in

Fig. 303. The flap must have a small hole in it to allow entrance of sufficient air to promote slow-speed running. The engine is, of course, adjusted to the desired high speed first, then the clapper is closed and the hole varied by moving the air gate until the desired slow speed is obtained. The top of the intake must be

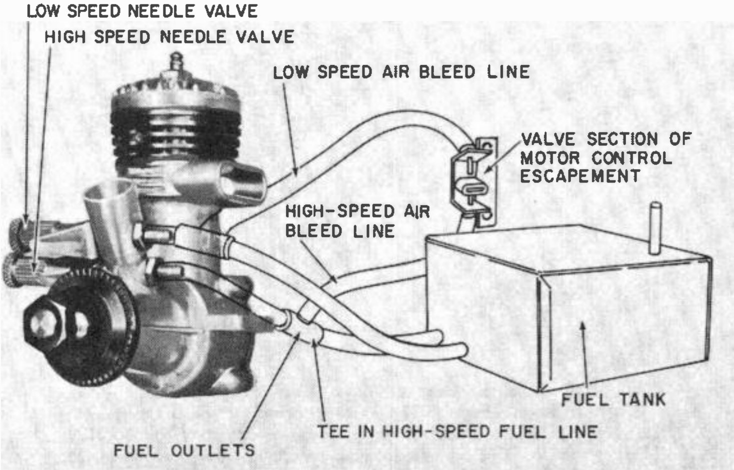


Fig. 302. *Not too widely used now, dual needle-valve speed-control setup looks like this, shown with K&B .19 engine. Valve unit is normally operated by a two-arm self-neutralizing escapement. This arrangement can give high speed, and low speed. Engine can also be stopped at will by opening both valves by holding current on.*

filed flat and smooth since air leaking in under the clapper will make it difficult to adjust the hole correctly.

While the clapper system does work, much better speed variation can be had by closing off the intake tube both above and below the needle valve. It is possible to arrange two linked butterfly valves to do this, but a more desirable way is the so-called "barrel throttle". Commercial versions are seen in Figs. 304-a and b; the cross-section of Fig. 305 shows how the parts are arranged. In this version, the needle valve rotates with the throttle barrel, as does the fuel tube nipple (other makes allow speed change with rotation of the barrel only). Such throttles normally give the same opening above and below the needle; they invariably lead to an overrich mixture in low speed when the needle valve has been set for top speed with the throttle fully open. To get around this, simply nick the top lip of the rotor barrel so that the opening on top of the needle will be greater than below it. This reduces

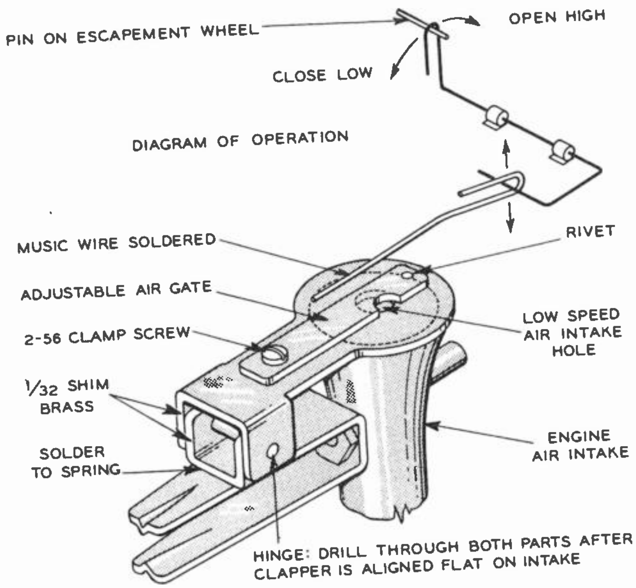


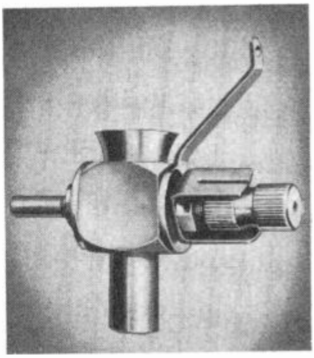
Fig. 303. *Modeler can add simple throttle to his engine. Support for clapper is soldered to spring that locks needle valve. Clapper should be a snug fit on intake (it might be necessary to file intake edges smooth). Air gate should have slot so that it may be moved sideways to regulate low speed, then clamped with 2-56 screw. Clapper does not have to be opened very widely for full speed.*

the excessive fuel draw and thins the mixture at slow speeds. Cut a little at a time, so you won't overdo it.

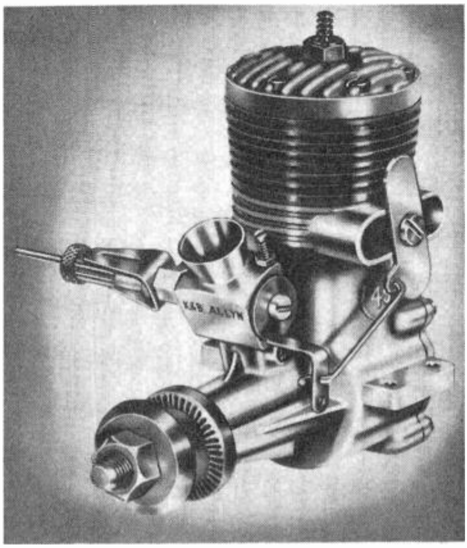
Exhaust throttles

Another widely-used throttle operates by reducing the exhaust opening of the engine. To be effective, the exhaust has to be closed down until you would scarcely think the engine capable of running at all. The closed exhaust retains part of the hot gases in the cylinder and thus tends to keep the glow plug hot (most intake throttle systems cannot drop the speed of the engine too low or the glow plug will cool excessively and stop the engine). An odd byproduct of this throttling system is that it also acts as an effective muffler; with the throttle closed, you can hardly hear the engine running at low speed!

The exhaust can be closed by sliding plates or rotating plugs of various types; one that can be made at home is shown in Fig. 306. The basis of this is a steel taper pin (large hardware stores carry them) a bit larger in diameter than the height of the exhaust stack on your engine. You will also need a taper-pin reamer of



a



b

Fig. 304. *Bramco throttle (a) comes in two sizes, can be adapted to most engines. K&B .45 engine (b) comes fitted with linked intake throttle and exhaust shutter. Their intake throttle also sold separately in two sizes.*

the same number as the pin. (Exhaust throttles can be bought, for many engines including those with radial or 360° exhaust, but the latter are very difficult to make at home. The arrangement to be described requires that the engine have an exhaust "stack").

Drill a hole on each side of the stack near the outlet, and open the holes out so that the tip of the reamer will go in each. Make sure the holes are exactly centered vertically in the stack. Now use the reamer, turning it through till you can see a noticeable cut in the top and bottom of the stack, but don't go too far to weaken the metal seriously.

Put the pin into the reamed hole and mark it at each side on the outside. Collars with setscrews will hold the pin in place; otherwise, simply drill holes for retaining pins. The last job is to file the pin in the center area, leaving a center section about 1/16 to 1/8 inch thick. The wider this is, the better the seal in the stack will be when the value is closed. If it is too wide, however, you will impede the exhaust gases enough to cut engine power.

Adjust the pin fore and aft to turn easily but snugly. If you have done a good job, the pin — which is now a valve — can be operated satisfactorily by a small escapement. As with all throttling systems, you may have to experiment with different glow plugs and fuels to get the desired range of speed change. For the ultimate in throttling, link an intake (either clapper- or barrel-type) and an exhaust throttle. With such an arrangement, a well-adjusted engine can be made to idle at a true tickover — you can practically count the rpm's.

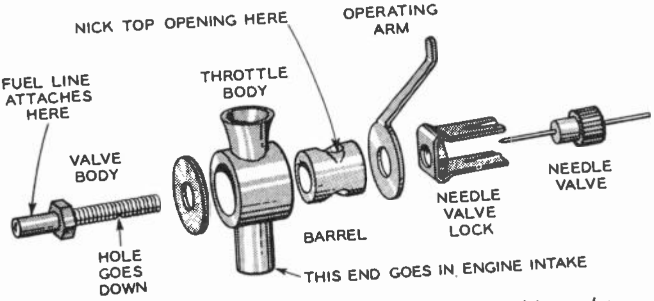


Fig. 305. *Exploded view of Bramco throttle. In this make, entire assembly of needle valve and barrel turns; soft fuel tubing is needed, especially if an escapement is used. Upper edge of barrel (on all throttles of this general style) must be nicked or notched slightly, to eliminate very rich running at low speed. Depth of notching must be matched to each engine.*

Working the throttle

Now that we've seen how to change the speed of the engine, how can the various throttle schemes be operated by radio? If you use a compound escapement, built-in contacts are ideal for controlling a second escapement linked to your throttle. Utilize the compound's third position to shift the motor-control escapement. Another way in wide use today that leaves the compound third position for other purposes is called "quick-blip" control, simply because the throttle (or other auxiliary control) is operated by giving the control button at the transmitter a very rapid "punch". The arrangement is shown in Fig. 307.

The rudder escapement, (which must be one fitted with a speed governor as are all compounds), has contacts so arranged that they close *just after* the rotor is released from neutral, and open again *before* the normal first position is reached. A punch on the button serves only to "unlatch" the compound rotor and start it on a full revolution. The receiver relay armature gets back to its normally closed (NC) position as the escapement rotor is going from neutral to the first stop position. In doing so, the relay closes the circuit through its NC contacts and the auxiliary contacts on the escapement, to give the motor-control unit a quick pulse of current too — sufficient to move it from one neutral to the other

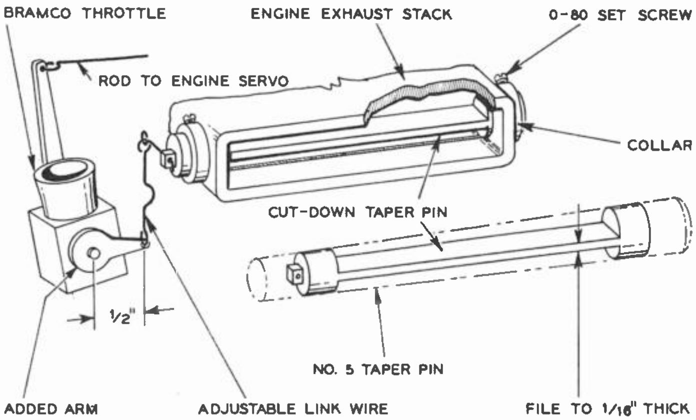


Fig. 306. *If engine has exhaust stack, a very smooth-working exhaust throttle can be made from a taper pin; you'll need a matching reamer to make a hole in the stack. Ream until there is slight cut full length of upper and lower inside stack surfaces. Must be very good fit to act efficiently as a throttle. Intake and exhaust throttles are shown linked, for widest speed change.*

and so change the motor speed. The transmitter button has to be punched fast. If you hold it too long, the relay will not get back to NC while the auxiliary contacts are closed; thus, you will not get the desired speed change and you might catch the compound in a rudder position as well.

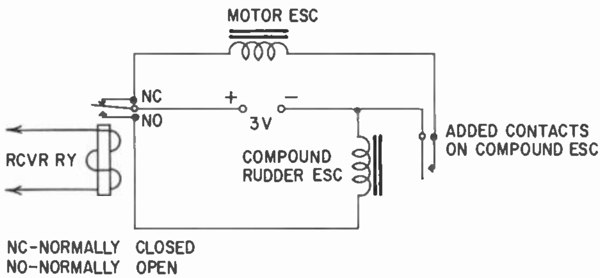


Fig. 307. *Circuit for "quick-blip" engine control. While this looks like circuit of Fig. 114-b, difference is that in latter, normal third-position contacts of escapement were used. Here, contacts must close momentarily between neutral and first position of the compound.*

Some compounds come equipped with quick-blip contacts (the unit in Fig. 107 has them); they are available as an accessory on others. You *must* use a compound for this purpose, since an SN or other escapement with no speed governor moves much too fast for even the quickest blip to catch. Multi-Servos also have contacts for working motor and other auxiliary equipment.

For proportional systems, an extra circuit must be added to the receiver or to the actuator. A circuit similar to Fig. 308 can be attached to the actuator coils. It is designed to operate with a change in pulse rate. The rudder would normally be operated at a moderate rate – perhaps 3 or 4 pulses per second – and if this is doubled, the auxiliary circuit closes its relay. This circuit can be

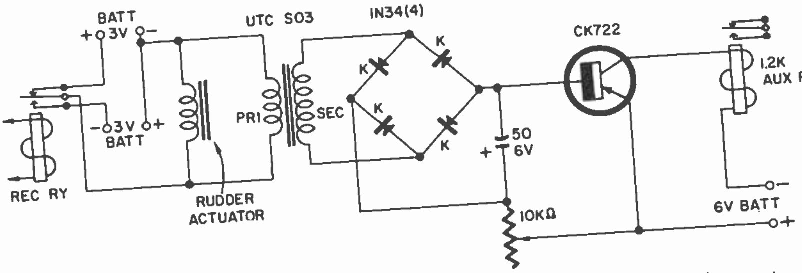


Fig. 308. Circuit for getting added control from proportional rudder system. Works by change of pulse rate. Can be used without transistor but then a very sensitive relay would be needed and speed change must be greater.

used without the transistor and added battery, if a really sensitive relay such as the Sigma 4F, 5F or 22, the Price or equivalent, is employed. In this case, it may be necessary to triple the pulse rate – a difficulty since some receivers will not follow such a high rate. If used without the transistor, a high-resistance relay would be needed – at least 5,000 ohms and preferably higher. The same capacitance and adjusting resistor as in Fig. 308 could still be used.

The transistor gives you more leeway in relay-current change, however, and also allows use of cheaper and lighter relays. A transistor circuit that will allow operation of a motor control or other added circuit and that works on *either* solid or no signal (it does not require an actual change in pulse rate) is shown in Fig. 309. This is an ideal arrangement to use for a proportional fail-safe escapement, since about 80% or more of the possible types of failure in your entire radio-control system will trip the relay. If the latter is wired to neutralize the rudder and also put the engine into low speed, you will indeed have a foolproof setup. Let's see how it can be done.

This circuit works on what is called an "inductive kick"– the kick in this case coming from the transformer windings. When power is applied to a circuit with an inductance in it (like an escapement coil, actuator or motor), or when the power is interrupted, a short pulse or "kick" of high voltage is produced. It's this kick that causes most of the trouble with dirty and arcing relay contacts and makes arc suppression necessary.

But we can put the kick to good use! In the circuit of Fig. 309, the diode cuts off most of the kick in one direction (the kicks produced when a circuit is closed and when it opens are of opposite polarity), while the kicks of desired polarity are used to charge the electrolytic capacitor to such a voltage that it prevents the tran-

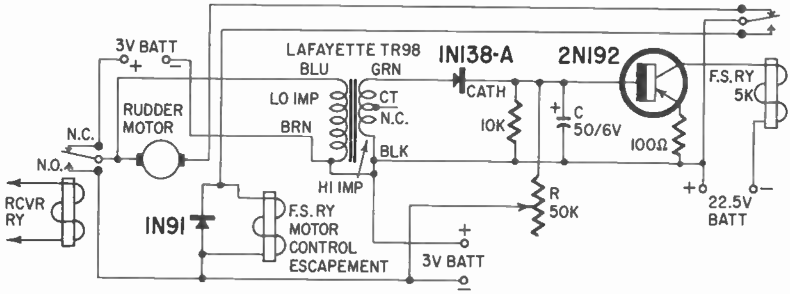


Fig. 309. *Circuit of pulse-omission detector, known among modelers as "POD." Works right-hand relay if pulsing ceases either due to lack of signal or a solid signal. Normally used as a failsafe for proportional systems (centers rudder if equipment fails), same relay can be used to shift motor control escapement at same time.*

sistor from conducting. As a result, there is little or no current through the 5,000-ohm transistor relay. If pulsing stops for any reason, the capacitor charge leaks off rapidly; the transistor then draws current through the relay of a value depending upon the resistance of R. As soon as pulsing starts, the transistor is again cut off and the relay opens.

Transistors used in this circuit should be of fairly high gain and low leakage; the 2N192 has been used very successfully, and equivalent types should be equally good. With the transformer indicated, reliable results have been obtained from the 2N192 with 2.4 volts on each side of the motor circuit; with 3 volts, as obtained from dry cells or Silvercels, a lower-gain transistor would be adequate.

The circuit shows a motor connected to the receiver relay, for driving the rudder. When pulsing is normal, the fail-safe relay keeps the rudder motor circuit closed and the engine control escapement circuit open, so that you have normal steering and steady engine speed. With an interruption of pulsing (either intentionally or from a system failure), the rudder motor loses its power (a centering system would then bring it back to near neutral rudder) and the escapement is stepped to the next position.

With a 2-position or SN escapement used to control motor speed, you would get a shift to the next speed in sequence, whatever it might be. If the motor was on low speed at the time of a system failure, it would immediately jump to a higher speed, possibly leading to a flyaway. To prevent this, a compound may be altered so that if it is held operated, it *always* goes to low speed.

The escapement shown in Fig. 310 affords three motor-speed positions, plus the fail-safe low, which is followed by the normal low. Next comes high, then medium. This is a normal Babcock Mark II compound, with the armature stop points reversed so that you

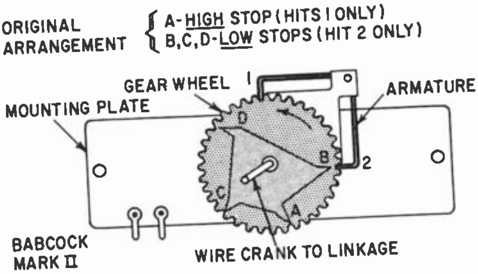


Fig. 310. *This modified Babcock Mark II escapement is intended especially for use with fail-safe proportional control setup. If system fails, escapement always throttles engine to low speed. Otherwise, three-speed operation may be had.*

get three positions of the rotor with no power through the coil and one with power (the latter is the fail-safe position).

Other compounds can be altered in this manner, but the Mark II is very easy to work on. Just clip off the tips of the armature stops and solder on new tips, so that the tip labeled 1 will now catch rotor points B, C and D, while tip 2 will catch only A. The drawing shows the escapement with the aluminum plate removed. The escapement-to-throttle linkage will depend upon your own installation. In one plane, it was found that very good three-speed operation could be accomplished with the escapement shaft linked to a throttle similar to those in Fig. 304. Point B stopped at 1 is low; point C produces high speed; point D caught on 1 gives a good intermediate.

It takes a bit of practice to learn how long to hold down the no-pulse button at the transmitter to work the MC circuit (which must have a slight lag so it will not work on very short pulse lengths) and yet step the revamped escapement to the desired stop. The amount of lag in the control circuit can be varied by different values of C in Fig. 309, while maximum relay current is set by adjustment of R.

Other auxiliary circuits

Fig. 311 shows an auxiliary circuit that can be hooked across the sensitive relay of many types of receivers. Intended for pulsing use, the auxiliary relay closes when pulsing stops for any reason.

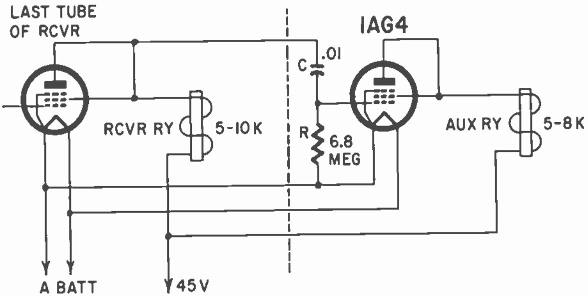


Fig. 311. *This circuit is intended principally for use with CW receivers. Pulse "kicks" from receiver relay are used to hold the 1AG4 tube cutoff. If pulsing stops, this relay conducts and operates the auxiliary relay.*

The delay may be varied by changing the value of C, of R, or both.

Another arrangement (Fig. 312) is intended for connection across the winding of an actuator such as the one in Fig. 211. At low pulse rates, the 2E36 tube conducts, closes the relay in its plate circuit and keeps it closed. When the pulse rate is raised, more voltage is developed across the 100-μf capacitor, because of rectification in the 1N48 diode rectifier. This voltage is applied to the grid as a negative bias and the tube cuts off, releasing the relay. The 2E36 uses the same A and B batteries as the receiver. It is advisable to include rf chokes in the filament leads. At low pulse rates, the plate current is around 1 ma, dropping to zero as the pulses are increased. The 25,000-ohm grid resistor is varied to shift the operating point of the tube as desired.

A neat way to drop a bomb or perform any other one-shot function in your plane is shown in Fig. 313. The wire catch is pulled to the right by the spring, but is restrained from moving in that direction by the nylon anchor thread. When an auxiliary circuit closes the relay, the hot wire burns through the thread — and bombs away!

One last auxiliary circuit is intended especially for use on proportional rudders operated by small electric motors. Fig. 314

shows it to be quite similar to that in Fig. 309. This simpler circuit works only when pulsing is interrupted. Then the transistor conducts and pulls in the relay. The capacitor value can be changed to allow operation on different pulse rates as required.

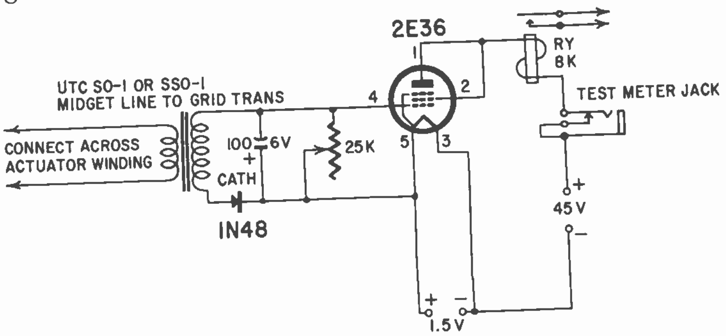


Fig. 312. *Another "kick" circuit working on pulse-rate change, could be used with either magnetic actuator or electric motor. 2E36 tube does not give much current change, requires very sensitive relay. 1AG4 would probably be better choice here.*

"Non-electronic" auxiliary circuits

We call the arrangement in Fig. 315 non-electronic because the additional circuits are operated by relays rather than through use of tubes or transistors. As shown, it is intended for addition of motor control to a pulse rudder setup (RY3 could be used for an elevator escapement just as well). With a bit more complexity, a third control could be added. The components are shown in the no-signal or open position. After S1 has been closed, the first pulse that comes in closes RY1 and moves the actuator to the right side; RY2 also closes. RY2 then closes RY3, which remains closed for ½ second due to the capacitor across the winding. With RY3 operated, the left actuator coil circuit is closed, so that normal left and right rudder action may he had. The system has been set up so that pulses at the rate of 2½ or more per second will assure that the circuit remains in this normal working condition. The pulsing unit at the transmitter is adjusted so that in the no-signal direction (which gives left rudder) the pulses never are cut off entirely, though they get very short. This makes certain that relays RY2 and RY3 remain operated in normal use. When motor-speed change is required, the transmitter is cut off for a little over ½ second, which allows RY2 to open, followed by RY3. The latter opens the rudder circuit (so the rudder won't swing hard over during this period) and closes the motor escapement circuit.

The receiver used with this hookup is of a type that puts RY1 in the position shown in Fig. 315, for a transmitter failure, and for most receiver failures as well. Thus, the same sequence of operations occurs if any of these elements of the entire control system fail. In addition, since the motor escapement is of the type which

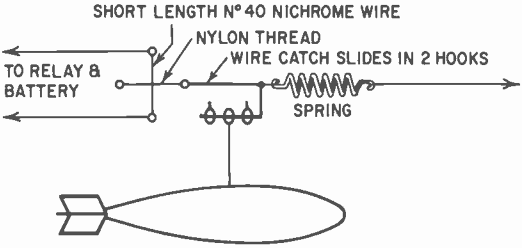


Fig. 313. *Simple bomb-drop arrangement for use with any of the auxiliary circuits shown earlier. Could also be used to drop parachutes, light fuse on smoke bomb, etc.*

cuts off the engine if allowed to remain in the operated position for any length of time, a system failure not only centers the rudder but stops the engine. Should the fault be at the transmitter, and be quickly repairable, the first pulse restores normal rudder action—though of course the engine cannot be restarted. When cutting the signal purposely to change engine speed, care must be taken not to hold the signal off too long or the engine will stop.

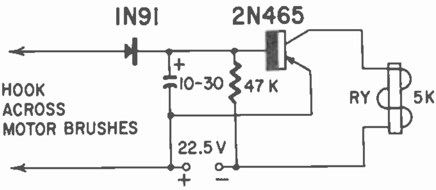


Fig. 314. *Very simple auxiliary circuit works on dc taken across rudder motor. Will operate its relay with signal of* either *off or on, but* not both. *Reverse leads to motor brushes, if action is wrong way. Usually set up to work relay with no signal.*

The system may be simplified somewhat by using battery Batt 2 to operate the motor escapement as well (now worked by Batt 3). Or with the proper resistance windings in the actuator and in RY3, Batt 1 could be used in these two circuits.

Resistor R should have the same resistance as RY2. This resistor simply balances the actuator circuit so that the rudder pull is the same both right and left. Still another auxiliary circuit could be operated by replacing R with an added pair of relays similar to RY2 and RY3. In this side of the circuit, the two relays would have to work with full-on signal, so the added relay similar to RY3 should be set to remain closed, except when the transmitter sends a steady or solid signal. Then the pulser would be limited to go only as far as 75% full signal (approximately), and the operating button for this additional operation would shift

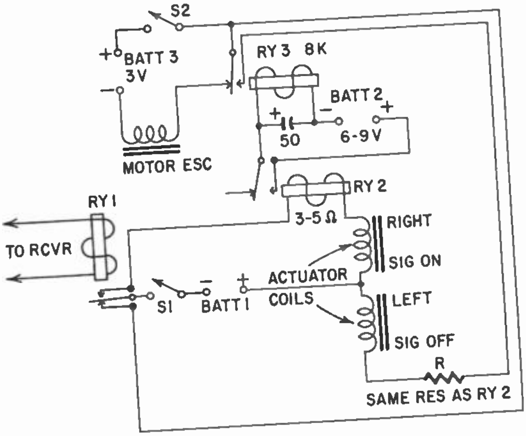


Fig. 315. *Control system to get proportional rudder plus motor control and fail-safe. Another control action could be had with added circuit, as discussed in text.*

the transmitter to 100%, or full on. This particular circuit would not have the fail-safe feature of the other, however.

Lightweight low-cost relays can be used for RY2 and RY3. RY3 can be of much lower resistance too but, if so, the capacitance across it will have to be raised and, naturally, the current drain on Batt 2 will be correspondingly higher (though the voltage could be lower).

A well-tested control system, based upon the use of a compound control escapement (which also works the rudder) and another compound used simply as a switch to operate a motor-driven elevator servo, is shown in Fig. 316. This gives lots of elevator power for violent stunting, and the setup can be used in large size planes.

The rudder escapement (a VariComp) operates the rudder in the normal way, and its contacts operate the engine escapement in the normal quick-blip manner. In the original installation, No.

2 compound was a Citizen – Ship unit fastened to a bulkhead, with two microswitches so arranged that they were tripped as the rotor was put into the two control positions the unit allows. These switches are labeled B and C in Fig. 316 and may be considered to operate exactly the same as sensitive relay contacts, for purposes of connecting the elevator servo. The latter has the usual limit and neutral switches fitted. Escapement 2 also has contacts A (another microswitch) added to it, but these are operated by a cam attached to the main shaft. The cam is cut so that A is in the position shown when the escapement is in its single neutral

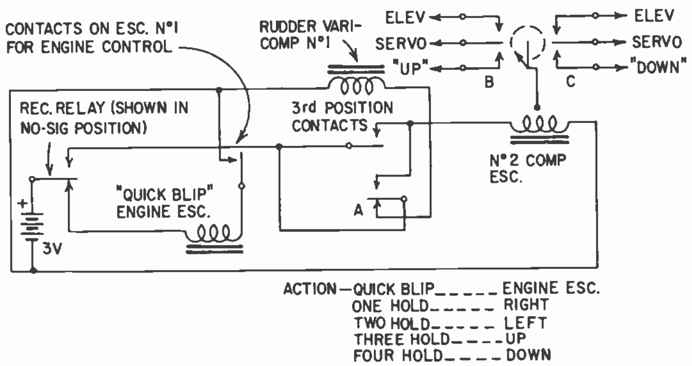


Fig. 316. *Rudder, elevator and motor control over single radio channel are had with this escapement arrangement. As shown, No. 2 compound escapement is used as a switcher to control action of motor-driven servo for the elevator. In smaller planes, this escapement could drive elevator direct.*

position, but shifts to the upper contact shortly after the rotor of compound 2 starts to rotate. Control sequence is shown. It isn't difficult to learn but, if you would prefer a control box you can get one that will do the job automatically as you move the control lever.

Circuit operation

Circuit operation is really quite simple; the VariComp works in the quick-blip and first and second positions as normal. When it comes to position three and is held there, No. 2 compound moves to its first operated position, bringing the elevator servo into action via microswitch B. As soon as compound 2 moves off neutral, the VariComp is released by switch A and returns to neutral, but the contacts of A hold escapement 2 in an operative position. Since A stays in the same position (upper contact making) as long as the elevator compound is off neutral, if you give another pulse for down (making four all together), escapement 2 simply shifts from one operate position to the other and the VariComp is not brought into use again until No. 2 gets back to neutral.

If the system is used in a smaller plane or if you don't want such violent elevator action, No. 2 can operate the elevator directly, dispensing with contacts B and C and the motor-driven servo. The latter does, however, allow you to have some trim between the neutrals, if the centering switches are set for this. Incidentally, use of another VariComp at position No. 2 will obviate the need for added contacts A, since they are built right into the escapement.

The control systems of Figs. 315 and 316 are shown and described in detail since they offer many ideas the experimenter may be able to adapt to his own uses. Another such system, described in Chapter 12, also has been well tested in extensive flying.

chapter FOUR

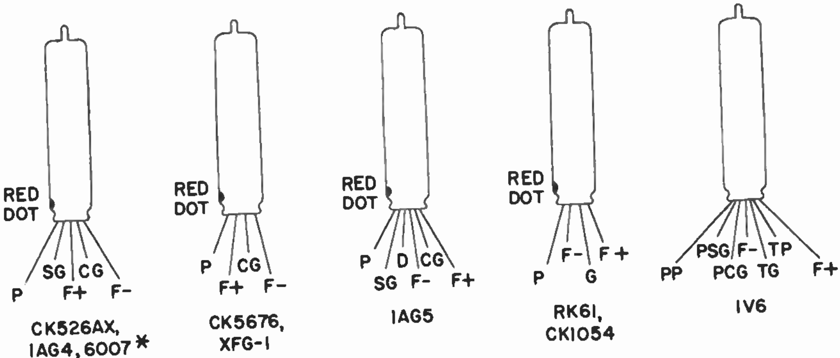
simple receivers

BEFORE getting into receivers, a few facts concerning their most important components (tubes and transistors) should be clearly understood. First, since radio-control receivers are used where small size and light weight are mandatory, we try to select the smallest components that will do the job, and also the ones that will work on the lowest possible battery power. This means that practically all receivers are fitted with either seven-pin miniature or with subminiature types — with the subminiatures more widely utilized.

Unfortunately, almost all subminiature tubes used in radio-control work were designed for audio-frequency purposes; most of them are hearing-aid types and practically none were intended for radio-frequency use. Fortunately, many of the available types do very nicely as oscillators and detectors. However, since they were not intended for such use, the makers apply no rf tests to them, and we find more variation than we would if we used subminiatures solely for audio. Even so it is unusual to get one that just won't work; however, keep these facts in mind when working with such tubes.

Since transistors have just about pushed subminiature tubes out of hearing-aid use, manufacturers are dropping more and more of the tiny tubes from their stocks. Fortunately, some are still used in various scientific and military applications. A few of the hearing-aid subminiatures we have used have been renumbered, and Fig. 401 shows some of those from the largest makers of such tubes — Raytheon; some are exact duplicates, others close enough so that they can be used with no difficulties.

Some imported types have become quite popular in radio-con-



* MOST SUB-MIN TUBES INCLUDING 1AH4, CK5854, 502, 512, 533, 539, 549.

Exact Duplicate Sub-Min Tubes		*Closely Similar Tubes*	
CK503AX	CK5854	CK506AX	CK5672
CK546	CK6519	CK522AX	CK6088
CK648AX	CK6418	CK536AX*	CK533AX
CK549DX	CK6419	CK537AX*	CK526AX
CK573AX	CK6029	1AG4	2E41, 2E42
CK574AX*	CK6281*	CK512AX	CK574AX*
		CK5854	CK518AX*

* Denotes sprayed on shield, not normally required for R/C uses. Can be removed with lacquer thinner. The letters AX and DX of the three numeral tube types refer to lead length and size of the glass bulb. "A" tubes are a bit longer and fatter than "D" types, and the "X" indicates long leads that are normally cut short when the tube is put to R/C uses. Most R/Cers ignore these letter suffixes when referring to such tubes, as we will in most cases.

Fig. 401. *Lead connections of sub-min tubes referred to in this book are illustrated at top. The table below them gives listing of Raytheon sub-min tubes which have been renumbered; also shown are some close equivalents.*

trol, among them the English DL-66 and the Dutch 6007. The 6007 is especially useful, as it is a good oscillator on 27 and 50 mc and has high gain in af stages. However, it has only a 12-ma filament, and cannot be used as a relay tube. The 1AG4 is one of the most widely used types and will do just about any job in a control receiver. It is supplied by several makers, and all makes will work quite well in af circuits, but the Raytheon 1AG4 seems best for rf. The price of this old favorite has gone up quite a bit, but because of its good performance it will doubtless be popular for a long time.

As prices come down and quality and reliability go up, transistors are destined for a more and more important part in radio-control work. Their biggest advantages are that they work well

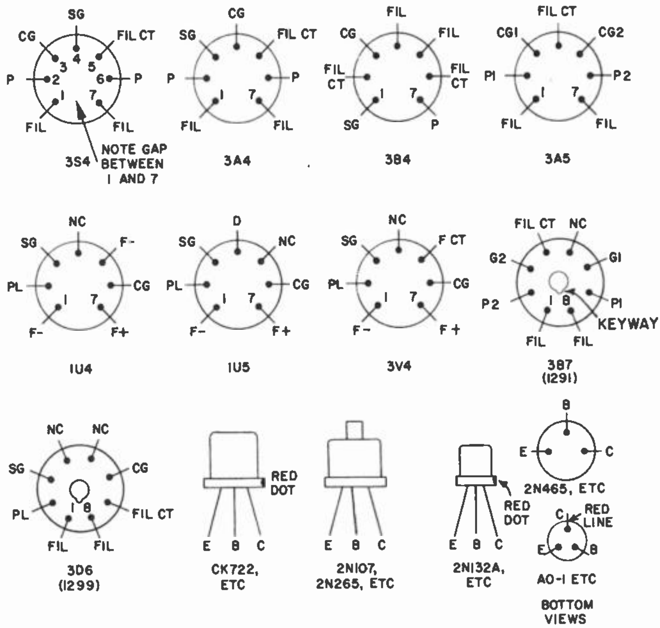


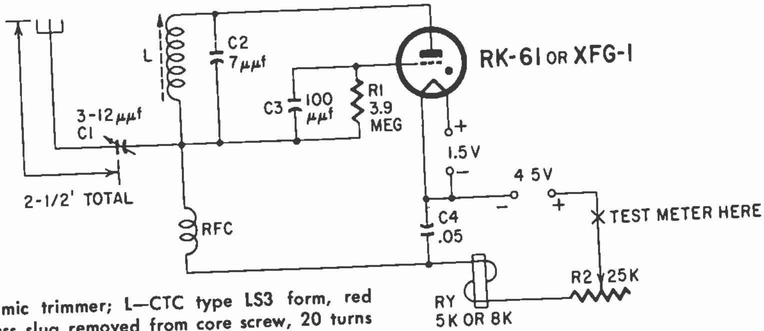
Fig. 402. *Pin connections of widely used miniature and loctal tubes, seen from* bottom *of tube. A few transistor types are also included; those at right also as seen from bottom or lead end.*

on very low voltages (eliminating the need for B-batteries) and their tiny size. Quite a few all-transistor control receivers are now on the market, and many more use transistors in the af and relay stages, with a subminiature tube as the detector. Rf transistors are still considered a bit fussy, especially for the home builder who does not have too much technical know-how; they cost considerably more than af types and are generally more easily damaged. If their limitations and special "tricks" are kept firmly in mind, transistors have a great deal to offer for the serious builder.

Fig. 402 shows lead connections for the most widely used tubes and transistors. All the seven-pin tubes are shown in bottom views, looking at the pins. Practically all subminiatures used in radio control have five wires coming from the bottom, with internal connections as in Fig. 402; this includes most imported types such as the DL-66 and 6007. Transistor cases come in various sizes and shapes, but the lead arrangements shown cover the common types normally met in radio control and mentioned in this book. Subminiature tube filament leads are labeled plus and minus by the makers, but for most control uses this polarity can be ignored. Wherever possible, we have indicated tube pin or lead numbers in circuits, except in a few cases where several types may be used, as the builder chooses. Needless to say you must be very careful, in tube circuits, to keep the B-voltage off the filaments; transistors do not require this precaution but they have other points that can't be ignored. They can be ruined instantly by incorrect polarity (which will not damage tubes in the least), and the maximum voltage limits specified by the makers should be strictly followed.

Simplest receivers

Until only a few years ago, the large majority of radio-control receivers utilized only a single tube, and most of the rest had only



C1—ceramic trimmer; L—CTC type LS3 form, red core, brass slug removed from core screw, 20 turns No. 24 enameled wire; RFC—¼-inch diameter x 1 inch L phenolic form wound full of No. 34 enameled wire.

Fig. 403. *Single gas-tube receiver circuit for 27-mc operation.*

two. Nowadays it is quite normal to consider those with two tubes, or one tube plus a transistor, "simple"; such receivers have now pushed the single-tube types into the background. About the easiest circuit that can be used for radio-control work is that based upon a special type of tube – one which is not only evacuated as are other tubes, but which then has a small amount of gas introduced. As seen in Fig. 403, there are very few elements to this receiver, which operates – as do practically all those used in control work – on the superregenerative principle.

Superregens are rather complex circuits in operation and allow extremely high sensitivity to be obtained from only one or two tubes. The single-tubers require that the tube act as an oscillator (at two frequencies) and as a detector, as well as to provide a large enough current change to work a relay reliably.

In 1938, when the gas tube was first introduced, it was found to do all these things very well – but it had and still has drawbacks.

One of the greatest is short life; another is a tendency to change operating characteristics throughout its life. Gas tubes are very difficult to produce uniformly, and production variations sometimes make it difficult to procure even a brand-new tube that will work in a given receiver.

Those who wish to try this simplest tube type set will find the circuit in Fig. 403 useful. Note that two tube types are specified. The set works well with either type — but, remember, not all specimens of either type can be counted upon to work, even though brand new. When operating properly, such a receiver will idle with no signal at around 1.5 ma (current should not be run any higher than 1.5 ma, as tube life will be drastically reduced) and will drop to perhaps 0.2 ma with a strong signal. Because of the rather limited upper current, high-grade relays should be used — the Sigma 4F, 26F, Kurman 13C44, etc. They would be set to operate at about 1 ma and release (or open) at perhaps 0.5 ma.

Gas-tube receiver operation

The filament current is about 50 ma with the specified 1½-volt supply. Turn resistor R2 to maximum and connect the B-battery. Then reduce R2 until you read about 1.3 ma on the test meter (which should have a scale of perhaps 0 – 3 ma). Turn on a 27.255-mc transmitter and rotate the core in L with an insulated screwdriver until you get a drop in plate current. Open the transmitter key, and the receiver current should jump back to maximum instantly. With no signal, you will probably hear a harsh "singing" sound from the relay, and the meter needle will wobble a bit. If this wobble is more than 0.05 ma, the set is too "hot" and the capacitance of C1 should be increased. You will then have to retune L.

A distance check is now in order. You should get about the same current change ¼ mile away as near the transmitter, though the current might not drop to quite as low a value. Gas-tube sets have lots of little tricks — one reason why the single gas-tuber has dropped in popularity. If the plate current stays low with no incoming signal, lengthen the antenna or increase the capacitance of C1 — or do both. You can't use too much antenna, of course, as it would become too cumbersome to handle. C2 can be increased to raise the plate current but, if it is made much larger than shown, turns will have to be taken off L to tune it to the desired frequency.

If the plate current won't drop when the transmitter is keyed, try connecting the metal coil end to A-minus with a short length of wire.

In most receivers, the RK-61 and XFG-1 are not considered interchangeable. The RK-61 usually works better with a lower L–C ratio — that is, less inductance (fewer turns) on L and more capacitance at C2. In any case, as the tubes age, you will have to keep changing the setting of R2 to maintain the desired maximum plate-current.

More reliable gas-tubers

Much longer tube life can be had from gas tubes if the tube is operated at considerably lower plate current and a second tube is

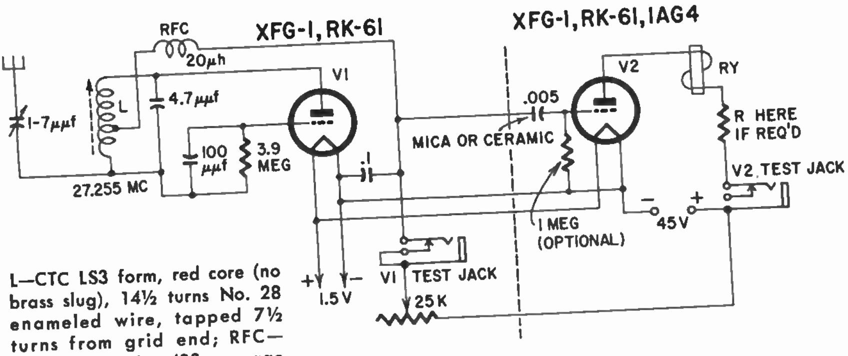


Fig. 404. *Gas-tube receiver with added relay tube. A very low leakage capacitor needed in grid circuit of V2.*

added to provide the necessary large change in current for the relay. A circuit for such use is seen in Fig. 404. V1 can be operated at a maximum of perhaps 0.5 ma, which will drop to around 0.1 ma with signal. This change in operation is sufficient to trigger V2 into a much larger current change. Both gas and hard tubes (the latter are highly evacuated, but do not have the added gas) are used as V2, with hard tubes favored due to considerably longer life, lower cost and ability to operate at higher plate current without harm. Some modelers put old gas tubes which no longer operate reliably as detectors in the V2 position, where they will usually be found to give good results for many more hours. It is normal to use no grid leak on V2; however, if the relay chatters a great deal, a 1-megohm grid-leak resistor may be run from grid to B-minus.

Depending upon tube type and relay resistance, the maximum plate current of V2 can be several milliamperes. If a pentode is used in this spot, connect the screen grid to the plate and operate the tube as a triode. A fixed resistor may be placed in series with the relay to cut the current down to a couple of ma. Types widely used for V2 include the 1AG4, CK521, CK526, CK5672, etc. Two test jacks are normally utilized, or else a switch to shift the meter from one tube to the other. Normally, once V2 has been set up to operate properly, it is not necessary to check it continually. If V1 is working correctly, V2 will almost invariably do so as well.

Because of the higher current possible, smaller relays can be used in this circuit to effect a weight saving.

A further refinement of the two-tube circuit of Fig. 404 is the

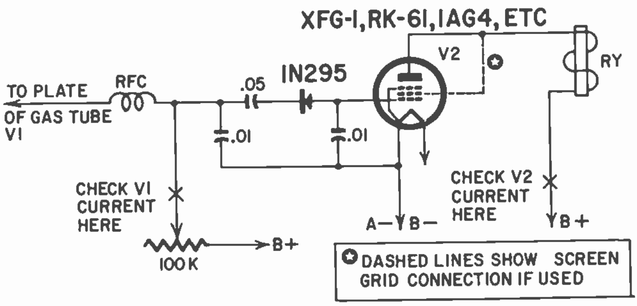


Fig. 405. *Improved relay tube operation is had with addition of a diode, to supply dc to grid of V2. Simple one-diode circuit shown here. Better results can be had with a diode voltage-multiplier circuit.*

use of a diode between the two tubes. A single diode connected as in Fig. 405 serves to rectify the "hiss" produced by the first tube, and the voltage is applied to the grid of V2. Use of one or more diodes (some circuits have used up to four in a voltage-multiplier circuit) between the tubes allows V1 to run at a lower idling current, and also makes V2 idle lower.

The next development was to add a transistor amplifier to the single gas-tube circuit; one version (the Gazistor) is shown in Figs. 406 and 407 and its circuit in Fig. 408. Both RK-61 and XFG-1 tubes were used, but for some RK-61's, it might be necessary to use more capacitance across L than the indicated 6.8 μμf, with correspondingly fewer turns on L. (A Neomatic relay is shown, but the lower-cost Gem will do as well and also fit in the same space.) Base layout of the original receiver is shown in Fig. 409. Flea clips are used for the leads of both tube and transistor.

Try out the set first with just V1 in its clips; set R1 to bring the tube plate current to about 0.5 ma, then key your transmitter. The current should drop to about 0.1 ma. If it does, you are ready to install the transistor (always open the power switch when you are plugging the transistor in or out).

Transistors vary quite a bit – especially the low-cost jobs used here. Upon turning the power on, a meter in J2 should read a minimum of about 0.8 – 1.5 ma when you adjust R1. If you can't get a reading this low, you may have to install a 470,000-ohm resistor at R2. (With one transistor tried, it was found necessary

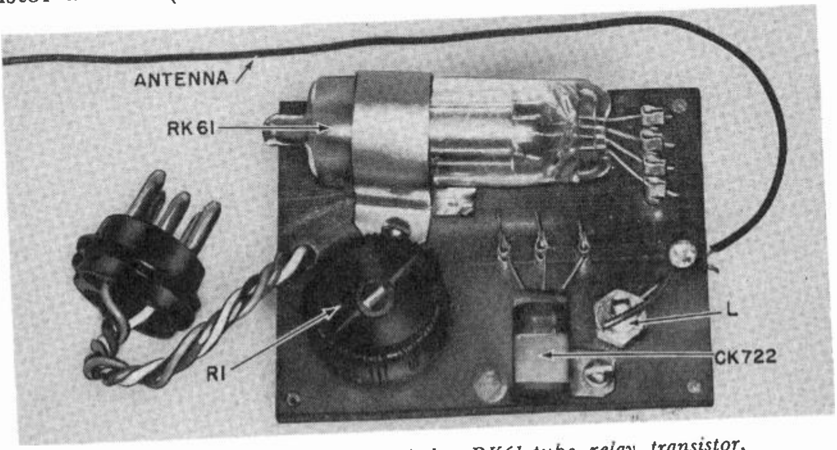


Fig. 406. *Top of Gazistor chassis has RK61 tube, relay, transistor, two variable controls. Use of transistor reduces size, provides plenty of current change for tiny relay.*

to go up to 820,000 ohms!) Many other types of transistors can be used, and here again different values of R2 may be required.

A better idea of how the test meter reacts as R1 is varied can be seen in Fig. 410. Note that an increase in resistance from the point of lowest B-current (for both tube and transistor) will give an unsteady increase in meter reading. If you decrease the resistance, however, the meter will show a steady current rise. The best potentiometer setting is just to the lower resistance side of the maximum current dip.

Since most gas tubes are now used with a following tube or transistor, and thus used at lower plate current than they had originally been designed for, Raytheon Mfg. Co., only American manufacturer of such tubes, has brought out a type especially designed for such circuits; it is called the CK1054. It is the same size as the RK-61, looks the same and has the same lead connections. However, it is intended for low current operation *only* (it should *not* be used in the circuit in Fig. 403, for example); in normal use, the plate current of the CK1054 should run no higher than 0.5 ma, and this drops when a signal is received. With proper use, this

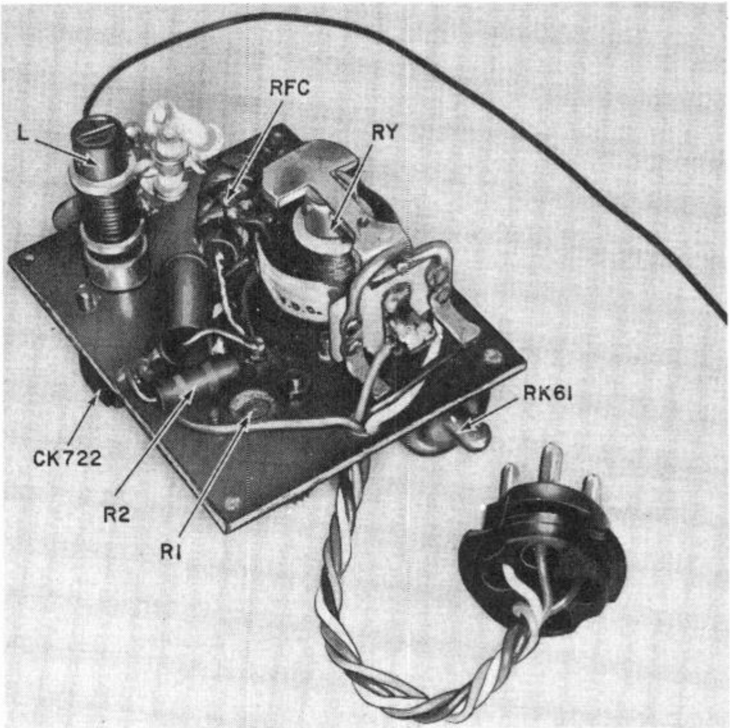


Fig. 407. *Underside of Gazistor receiver. Neomatic relay shown here, but Gem will do fine. Most 5,000 and 7,500 ohm relays are suitable.*

tube should give good results for at least 200 hours; in the single gas-tube circuit, some RK-61's will last only 6 hours or so.

Hard-tube receivers

Because their tubes have long-life, hard-tube receivers have become increasingly popular. Here, again, it is quite usual to add a relay tube or transistor to the basic single-tube receiver. In this case, it is not because the higher plate current shortens tube life, but to get other advantages such as more reliable operation, good current change with lower B-voltage and reduced filament current (using a transistor in the second position).

The basic hard-tuber with a seven-pin miniature tube seen in Fig. 411 has been highly popular. It goes under the name of Simple-Single. A look at the circuit in Fig. 412 will show a couple of parts not used in the single gas-tube circuit – L2 and C1. These are used to enable the tube to oscillate strongly at a low frequency

— but much above audibility — C1 gives a direct control of this low-frequency oscillation, and indirectly controls receiver sensitivity as well. Though the tube used is a pentode, the screen grid (pin 4) is connected to the plate (pin 2) and operates as a triode. The 3S4 tube has a dual filament and only half of it is used in the Simple-Single, thus saving some A-battery power.

All parts of the original were mounted on a 1/16-inch thick piece of linen-base phenolic measuring 2⅛ x 3 inches. A balsa protective case was made to fit over the bottom. The relay shown in

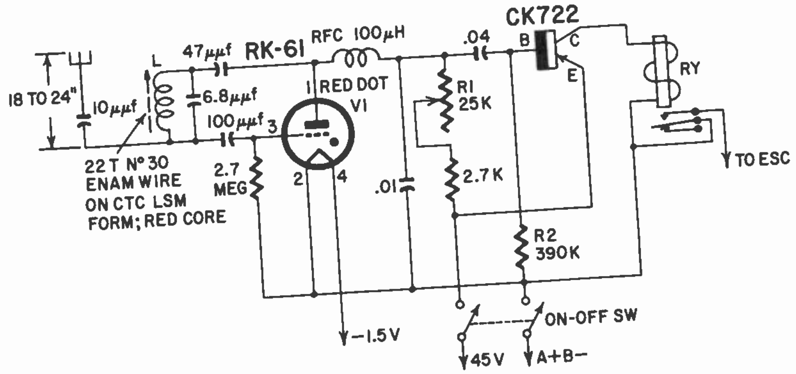


Fig. 408. *Gazistor circuit. Some arrangement should be made to check current of tube and transistor separately. After you are familiar with operation, this is not necessary. Tube current is most imporant. Transistor current gives indication of B-battery condition. Original set had CRL type B16-117 for R1. RFC is National type R-33, or equivalent.*

the photos is an English E. D. and may not be available; an American RBM of 5,000 ohms would be a good substitute. Since the range of current change of this receiver is about 2.25 to 0.75 ma, the relay should be set to pull in at about 1.6 ma and to drop out at about 1.1 ma. This type of receiver should give almost the same current change at a distance from the transmitter as it does close by.

When the set is connected to the batteries, turn the adjustment screw in sensitivity control C1 so as to compress the capacitor plates — this raises the capacitance. The plate current should be under 1 ma. Now lower C1's capacitance and you should reach a point where the plate current suddenly jumps to its highest value. The current change is very abrupt. The set is most sensitive just at the point where the current jumps, but the trimmer capacitance should be lowered at least another half-turn beyond this point. Now key a nearby transmitter and rotate the core in L1

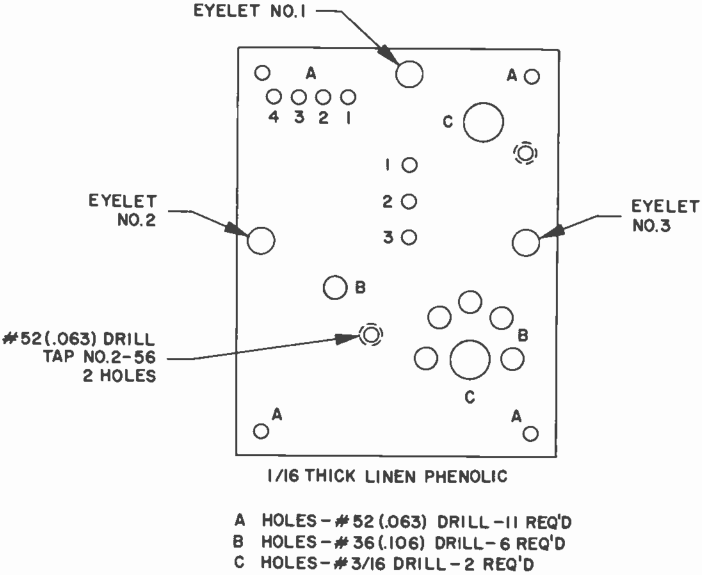


Fig. 409. *The seven numbered holes are for flea clips to take leads of tube and transistor. Most R/C suppliers carry these clips which hold in proper-sized hole by spring pressure.*

until you get a sharp drop in current. There is little interaction between the tuning and sensitivity controls — one of the biggest advantages of this circuit.

If you can't get the sudden current rise when C1 is reduced, you may have to lengthen the antenna a bit. It has also been found helpful with this sort of receiver to run a wire from B-minus along the bottom of the fuselage to the tail; the wire increases the effective antenna and stabilizes the receiver.

On the other hand, if your meter shows a high current that won't drop when C1 is turned up tightly, then the antenna needs to be shortened. If you can get a sudden current change as C1 is adjusted, it is almost a certainty that the set is working correctly.

Most 3S4 tubes work in this receiver, though some are more sensitive than others. The acid test, of course, is to make a distance check; you should be able to get reliable operation of the relay with the receiver at least a quarter of a mile from the transmitter. If the set doesn't seem quite right, try another 3S4 tube, preferably of a different make or at least from a different supplier. The set should always be operated with C1 turned as far from the sensitive point (where the plate current jumps up as C1 is reduced in capacitance) as possible, while still making sure that you get enough sensitivity for maximum-range operation.

This necèssity for working out a rather critical sensitivity adjustment is the main drawback of the single hard-tuber, but once the trick is learned you will have no trouble.

If the sensitivity is set too close when the plane is on the ground

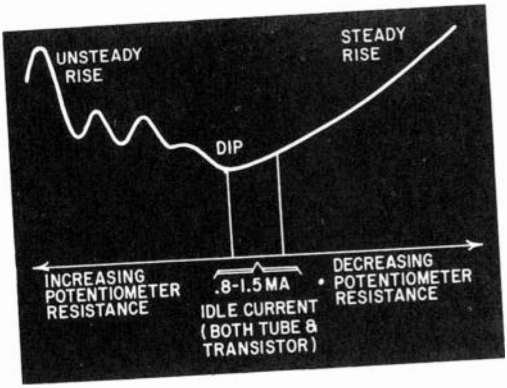
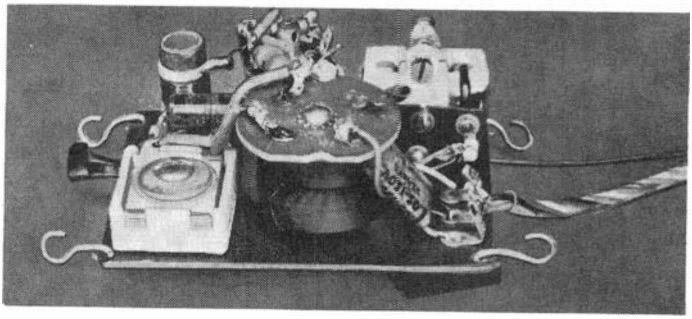


Fig. 410. *Current change of Gazistor receiver as R1 is varied. This shows total current change, as measured at B battery.*

or held in one hand, the current is apt to drop to the lower value when the model is launched and leaves the ground. It is safest to set the sensitivity with the model held by its two wingtips as far as possible off the ground. This is not very practical, of course, and you will soon get used to setting the sensitivity so that it will not be *too* acute and yet, the receiver will operate at any range within which you can still see the model.

This type of receiver thrives on high voltage and seems more sensitive if used with 52½ volts (standard 22½-and 30-volt batteries in series), or even 60 or 67½ volts. Maximum plate current naturally will be higher than with 45 volts and, while signal-on current will also be somewhat higher, it won't rise by the same percentage. Thus, the current *change* will be greater, which makes relay operation more reliable.

With the balsa-bottom case, the set weighed about 4 oz. Some quench transformers (the technical name for L2) have been found to be marked differently from the one used here. The larger of the two coils should be connected from C2 to L1, with C1 connected in parallel. The two windings must be polarized properly; to check this, try shorting the primary lugs (the smaller coil) with



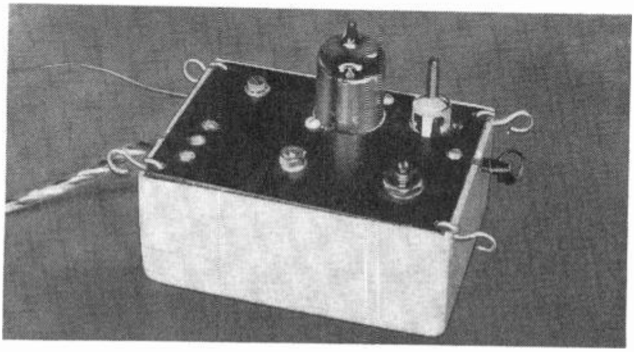


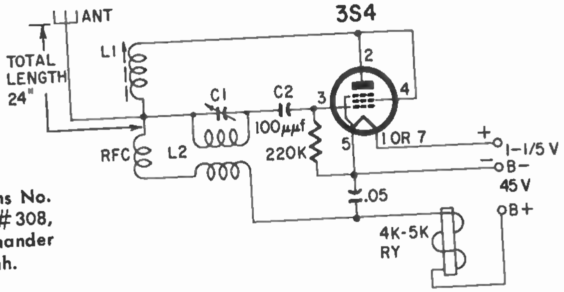
Fig. 411. *Simple Single gets name from rather simple circuitry, use of single tube. Only tube top and adjustments for L1 and C1 project above chassis. Wood cover on bottom is mainly to keep dirt out. It is not much protection in case of a crash! English polarized relay was used. Tube socket is mounted on long screws with spacers.*

a screwdriver. This should produce quite a change in plate current. If there is no such change, reverse the two primary leads.

Subminiature single hard-tubers

Since planes and equipment are steadily getting smaller, the subminiature version of the receiver just described is increasingly popular. The circuit (Fig. 413) is almost identical, but smaller parts have been used throughout. The quench transformer should be mounted by cementing a wood (or any insulating material) rod in the core and by use of a *short brass* screw, either a wood or machine screw. Don't run a metal screw all the way through the core hole. The full-sized chassis with all holes indicated is shown in Fig. 414. Fig. 415 shows how the socket is mounted, plus details of L1 and RFC. The relay shown is an E. D. nonpolarized, an English make; the widely-distributed Gem will do very nicely and is a bit lighter. Since the total current change of this set, known as the Mini-Mac (Fig. 416) is approximately 1.8 to 0.5 ma, the relay can be set to operate at around 1.3 ma and to release at 0.9 ma. The CK526AX tube draws only 20-ma filament current, and even a penlight cell will keep it lighted for quite a long time.

The lugs on the plates of C1 were clipped short (run solder over the clipped-off ends to make sure there is a good connection to all plates) and the capacitor was mounted by means of the two little

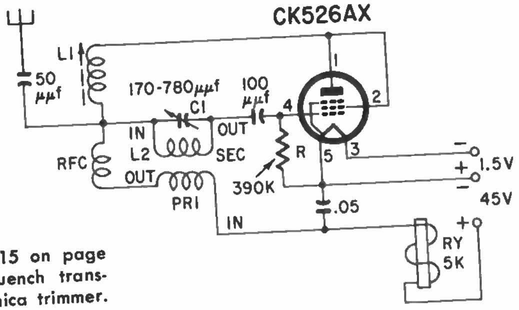


L1—CTC LS3, red core, 17 turns No. 28 enameled wire; C1—Arco #308, 450-1390 μμf; L2—Ace Commander II quench coil; RFC—22 mh.

Fig. 412. *Circuit of the Simple-Single.*

center tabs. Connections are soldered directly to the capacitor's metal ends.

A and B on the chassis drawing (Fig. 414) are small eyelets used to hold ends of wires, while the row of four holes near the tube socket are used to anchor the battery and relay leads. A



L1 and RFC—see Fig. 415 on page 85; L2—Ace sub-min quench transformer; C1—Arco 469 mica trimmer.

Fig. 413. *Mini-Mac circuit for 27 mc. Tube uses a subminiature 5-pin socket.*

small metal clamp lined with felt holds the tube down. Tube connections are as shown in Fig. 402.

Operation of this receiver is exactly the same as for the Simple-Single. You must get a sharp jump in plate current as sensitivity capacitor C1 is reduced. If C1 is set a little to the low-capacitance side of the point where the plate current suddenly jumps, then

L1 is tuned to the transmitter. The receiver will sometimes work poorly or even not at all very close to the transmitter; this is called overloading and many types of receivers are so affected. The remedy, of course, is to move them apart.

Final tuning of *any* radio-control receiver should be done at a

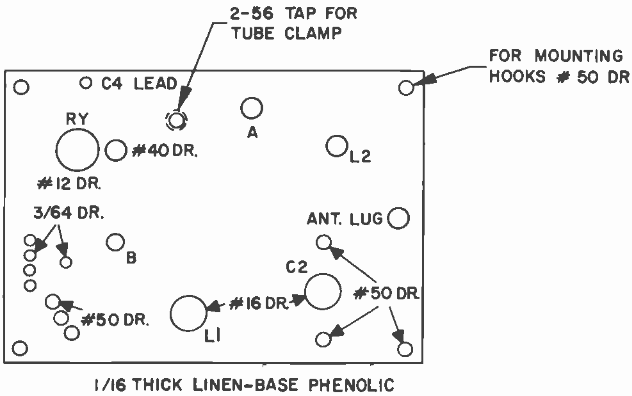


Fig. 414. *Mini-Mac chassis. Four holes in row at far left are for relay and battery leads. L2 is mounted by cementing it to base.*

considerable distance from the transmitter — at least several hundred feet and preferably much farther. It is impossible to tune most receivers accurately when they are close to a transmitter;

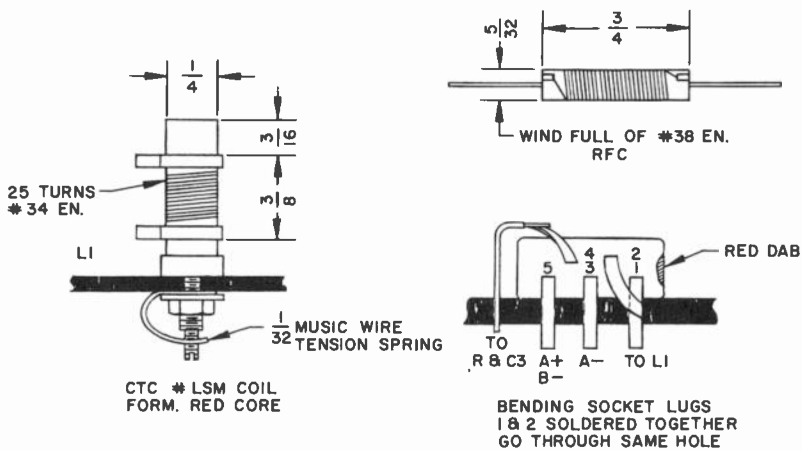
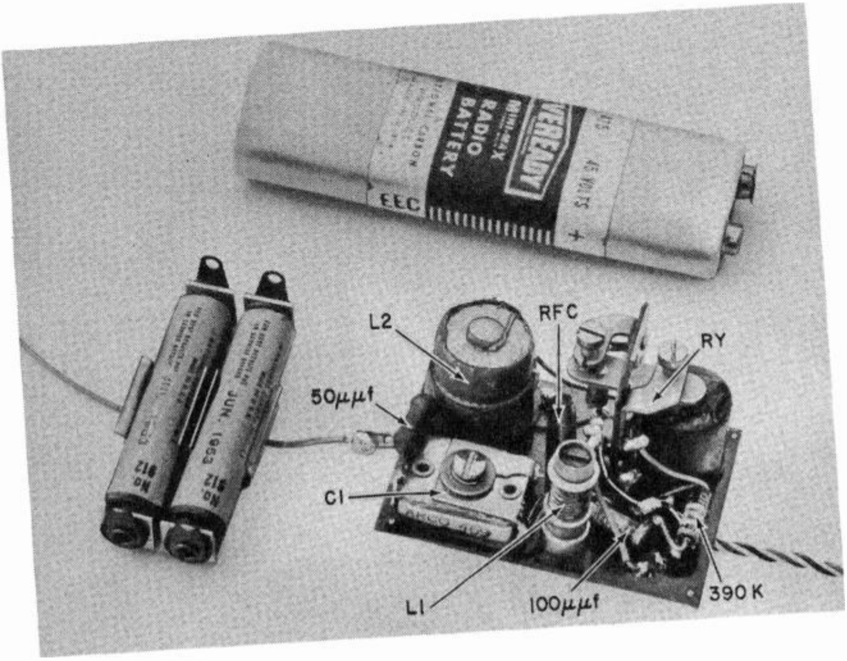


Fig. 415. *Coil and socket mounting details for Mini-Mac. Cement socket in place.*



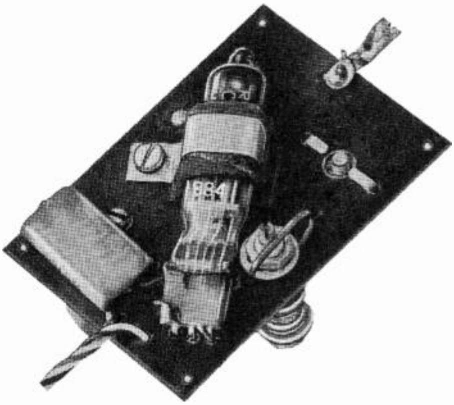
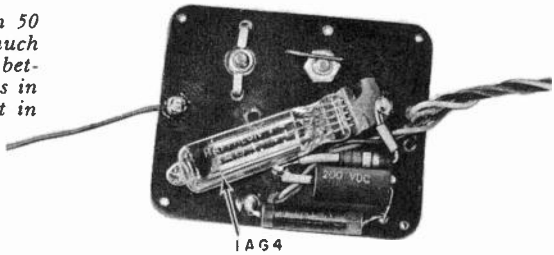


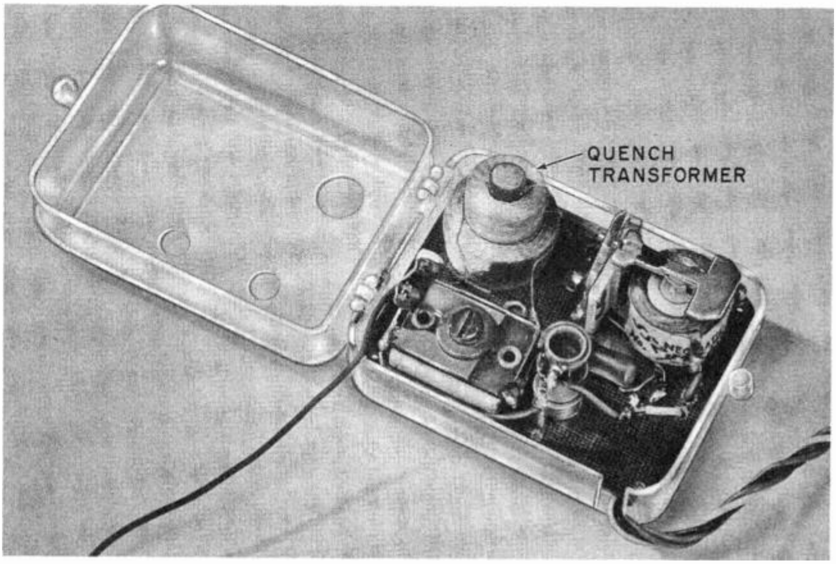
Fig. 416. *Mini-Mac with batteries. Quench coil is wrapped with tape to protect fine wire windings. E.D. relay shown; Gem will fit in same space. The two half size penlight cells in holder at left would be connected in parallel for A-supply. Tube runs diagonally, is held by small clamp.*

the tuning is far too broad there to find the true optimum point.

The plate current of the Mini-Mac should not be much higher than 1.8 ma, due to the low filament drain tube used. It is usually considered that a safe plate current for almost any of these little tubes is one-tenth of the filament current — this holds true for the subminiatures and the seven-pin types as well. If you go over this

Fig. 417. *Mini-50 for use on 50 mc ham band. Layout is much like Mini-Mac but operates better when tube is mounted as in Fig. 418. Cement tube socket in place.*





figure, the filament is apt to be ruined, even though it will still light. With fresh batteries, plate current should not be higher than 2 ma; if it is less than 1.8 ma, reduce R a bit to raise the current. As B-battery voltage drops with use, the plate current will also drop.

The Mini-Mac weighs about 2 ounces and this, plus its low A and B drain, makes it useful for very small models.

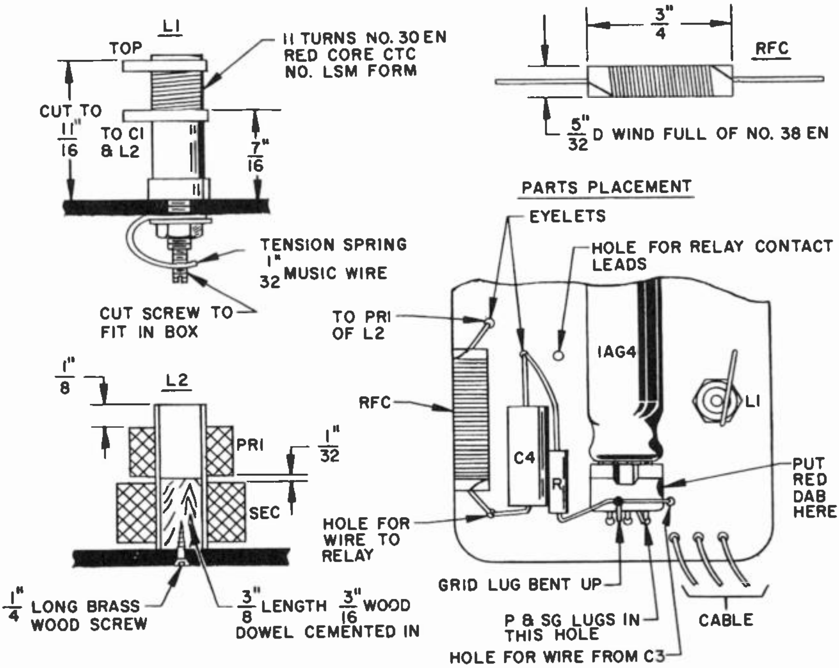


Fig. 418. *Component details of Mini-50. Use brass screw for mounting L2 or cement it to base. Note straight tube mounting, better than diagonal arrangement, though this was used in original Mini-50. Small dab of cement will hold tube but it can be removed when necessary.*

50-mc single hard-tuber

A 50-mc version of the single hard-tuber, known as the Mini-50, is illustrated in Fig. 417. This is very much like the Mini-Mac, except that operation on the higher frequency necessitated another tube and a few changes in circuit values to accommodate it. Things are a bit fussier on 50 mc than on 27.25, and it was found better to mount the tube as shown in Fig. 418 rather than diagonally, as in the bottom view. This change gets the tube away from the bottom of quench transformer L2, which is rather sensitive to metal. Using the Neomatic relay shown, the set will just go in a standard 1-inch high plastic case. A Gem relay could be used, but parts would have to be repositioned to mount it on its side (keeping all metal as far away from L2 as practical), or a hole could be cut to allow the relay to poke through the top of the box. Two ledges of hard balsa are cemented inside the case for the 3/64-inch thick linen phenolic chassis to rest on, and positioned just high enough from the bottom to squeeze the 1AG4 snugly between case and chassis underside.

The Mini-50 idles (no signal) at about 2.2 ma — this drops to around 0.75 ma on a fairly weak signal. Filament drain is about 45 ma; the set, complete with case, weighs 2¼ ounces. Tuneup and operation are just the same as for the Mini-Mac.

Let us emphasize that single hard-tubers generally are rather

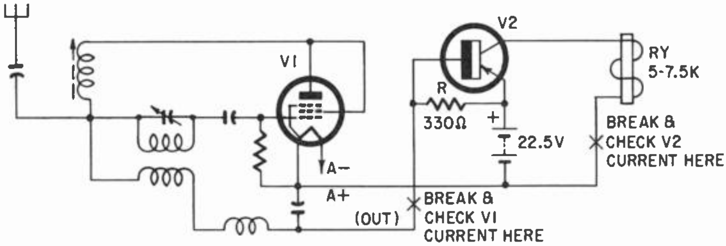
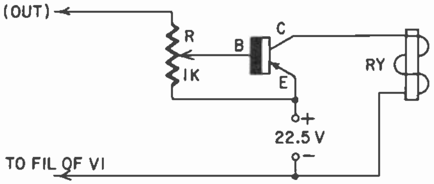


Fig. 419. *Single hard-tube circuit with added transistor. Components not marked are as shown in previous circuits. R may vary, depending on transistor used, current drawn by V1.*

broad in frequency response, especially when set up to be too sensitive. With the growing emphasis on sharper tuning receivers and transmitters, this type will doubtless gradually drop out of use. It is quite popular at present, however, both in home-made and commercial versions. For this reason, we will give two more circuits, actually additions that can be applied to most of the single hard-tubers now in use.

Fig. 420. *Use of variable resistor at R allows control of transistor current. This control could be a CRL type B16, small enough to mount in most receivers.*



The first makes use of a single transistor relay stage, and allows high relay current, while the receiver only requires 22.5 volts for operation. Fig. 419 shows the circuit, as it would be added to any single hard-tuber of the type we have described. Circuit values not indicated are just the same as those we have already shown, and the added transistor circuit does not have much effect on operation of the hard-tube circuit itself. Resistor R takes the position in the circuit of the sensitive relay, which is shifted to the collector circuit of the transistor. This circuit has given good results with low-cost transistors like the CK722. Depending upon the value of R, the transistor may idle around 2.5 ma and drop to perhaps 0.3 with signal. Since transistors vary so much, some experimenters prefer to use a tiny adjustable resistor as in Fig. 420; this can be set to give the best overall current change in the relay. Fixed resistors could be substituted for the variable to save space and weight; there would be no further need for the variable resistor unless a different transistor were to be installed.

Since maximum current is not important when the transistor is used, but rather the *change* in the current through the transistor base and emitter resistor, there is no particular need for a high-current tube. Some experimenters have had good results by replac-

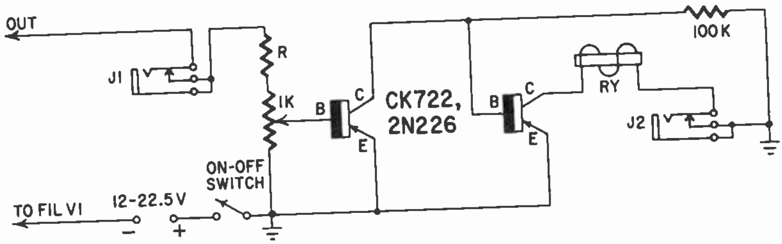


Fig. 421. *Two transistors give advantage of lower relay current with no signal. The two jacks allow check of tube current and relay current.*

ing the CK526AX in the Mini-Mac with a 10-ma filament tube such as the CK548 for example. In the circuit of Fig. 419, the 1AG4 which had been used in the single tube receiver idled (no signal) at about 1 milliampere and dropped to several tenths of a milliampere with signal; the CK548 idled at about 0.75 ma and also dropped to a few tenths of a milliampere. In addition, its filament drain was less than one quarter that of the 1AG4.

This sort of transistor addition to a single hard-tuber will give relay current in the same direction as that of the receiver alone — that is, transistor current will be high with no signal and will drop when you key the transmitter. By using two low-cost transistors (Fig. 421), you can get the opposite action; this circuit takes little or no more power than the single transistor version. The lead market OUT would connect to the lead with the same indication in Fig. 419. J1 monitors tube current, while relay current is checked via J2. This circuit has been used with only 12 - 18 volts total, as indicated, though 22½ volts could be used if desired. Resistor R is selected to produce a tube current (at J1) of 0.5 to 0.6 ma, and the 1,000-ohm variable resistor is adjusted to produce a no-signal current through the relay of about 0.1 ma.

chapter FIVE

complex receivers

ALTHOUGH the receivers of Chapter 4 can give excellent results if handled intelligently — thousands of them are doing so right now — they are all a bit tricky to handle. The gas-tubers require a frequent check of the detector to make sure it is functioning properly, and adjustment of the variable plate resistor. The single hard-tubers (with or without added transistor) require a fussy sensitivity adjustment. Practically all the sets are touchy as to antenna length and placement. Many modelers are willing to try more complex and expensive receivers for the big advantage of doing away with general fussiness — in other words, getting rid of all variable adjustments except for tuning. Most of the receivers to be described in this chapter have no sensitivity adjustment and are generally rather independent of antenna length or placement (with most of them, you can actually hold the antenna and the receiver will still pick up a signal).

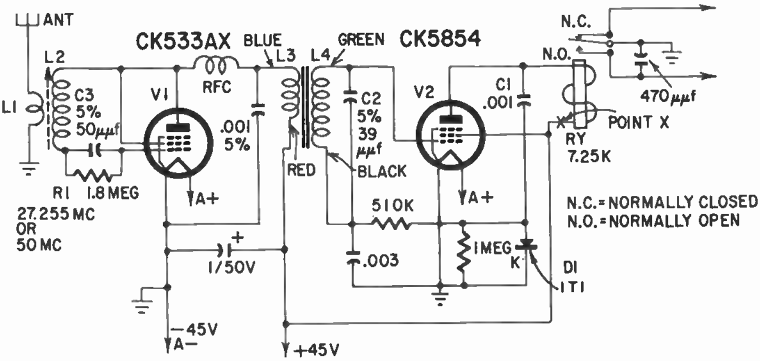
Although all the receivers described so far are intended for continuous wave (CW) operation, many in this chapter must have a modulated signal to operate. CW means that the transmitter emits an unchanging rf signal on the desired frequency — the signal has no modulation, and the receiver is operated by keying the transmitter on and off. In tone work, it is usual to leave the transmitter turned on continuously, so that it emits a steady carrier or CW signal, then to key the *audio tone* on and off.

This has several advantages, the most important being that with the strong CW signal always coming in, the receiver in the model is less likely to be triggered by an interfering signal of any sort. Also, tone receivers are generally less sensitive to rf noise in the plane for the same reason. Because af equipment is more complex and expensive than the CW type, it is possible that the majority of modelers still use the latter, and prefer it; for this reason we will describe several more CW receivers here.

Twin hard-tuber

This receiver, widely known as the Tech-Two, is used on both 27 and 50 mc. It has proven extremely reliable, has no variable adjustments aside from tuning and produces a husky relay current change. Many variations of the circuit have been seen, that in Fig. 501 being one of the most popular. Intended for 50-mc use, this set is light, compact and relatively easy on batteries. The relay current idles low and increases with a signal.

With no signal coming in, V1 produces quite a strong hiss, actually a high-frequency "tone." The hiss is stepped up a bit by



L1—18 turns No. 28 enameled wire, CTC LSM form, white core (50 mc); 32 turns No. 32 enameled wire, CTC LSM form, red core (27.255 mc); L2—1 turn around center of L1 (50 mc); 2 turns around center of L-1 (27.255 mc). Use insulated hookup wire for L2.

Fig. 501. *Tech-Two circuit for 50 mc. Point X for insertion of test meter, not needed once set has been checked out. 5% capacitors are tiny mica units (Arco) stocked by many radio suppliers.*

transformer L3 – L4 and amplified by V2. The amplified hiss is taken off the plate circuit by C1 and rectified by diode D1, then sent back to the grid of V2. Since the polarity is negative, V2 is held to a low plate current – usually from 0.2 to 0.4 ma. When a signal comes in, the hiss stops, V2 loses its negative bias and conducts heavily, pulling in the relay.

A rather special transformer must be used to couple the tubes but fortunately, a ready-made one can be obtained from radio-control suppliers. Many builders wind their own transformer coils but, since the manufactured one is entirely satisfactory (and it saves a lot of time too!), we recommend its use. For those who want to try making one, the specifications are shown in Fig. 502-a; coil forms are made of tubes of rolled paper smeared with model cement, with fiber discs cemented on for end pieces. Winding is done by holding the coil bobbin thus made on a bolt, clamped in the chuck of a hand drill. It is not necessary to put on the exact number of turns specified; several hundred turns either way will make little difference. Flexible stranded wire should be attached to each end of the No. 42 wire, and the coils given a protective wrapping of electrician's plastic tape.

The core material is a special alloy called Mu-metal; possibly, strips taken from more common transformer core metal might do

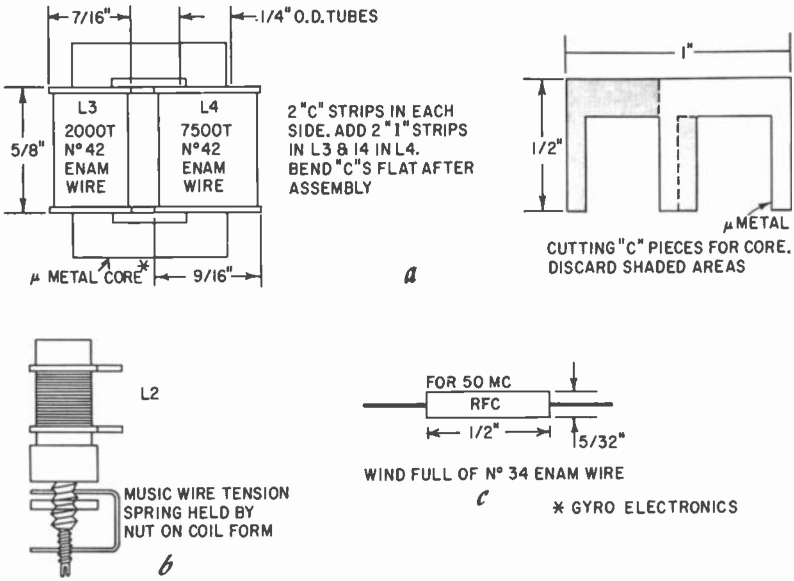


Fig. 502. *An "RCA 10 μh" rfc can be used in place of one shown (Ace or Gyro). Winding transformer is tedious job. Commercial units can be had at reasonable cost.*

as well, but the Mu-metal works. (It can be obtained from radio control suppliers). After the specified number of strips are inserted in the coils, the rest of the space is filled with balsa and smeared with model cement to hold it in place. Bend the C strips flat along the sides of the coil bobbins and give the whole transformer a coat of polystyrene coil dope (model dope will probably do as well). The set is mounted on the usual 1/16-inch thick linen base phenolic and fits into a standard plastic protective case; it measures 1-5/8 x 2-1/8 inches. The tube sockets are each held by a single 2-56 screw, plus a spot of "Goo" (a cement available in model shops) on the underside.

Construction details for the antenna transformer are given in Fig. 502-b and 503. L1 is supported by its lugs, which are soldered into small eyelets in the base plate. The transformer is seated in shallow grooves cut in the plate for the bottoms of the two coils. Before mounting, they are coated with Goo; the transformer is then bound tightly to the base with heavy thread. Several eyelets in strategic places serve to tie down the loose ends of the small parts.

The set whose circuit is shown in Fig. 501 was intended for 50 mc. It will work on 27.25 mc with the following changes: L1 is wound on the same form, but using a red core – 34 turns of No. 32 enameled wire; L1 is two turns of insulated hookup wire wound around the center of L2; RFC, a 22-µh iron-core choke (Gyro or equivalent); C2, a 75-µµf 5% mica capacitor; R1, a 1.5-megohm resistor. A 5% mica capacitor is specified for C2 and for other capacitors in the set; small ceramics will work just as well, but many of them have very wide capacitance tolerances, some as much as 100%. This wide variation can make a serious difference, so it is better to use close-tolerance parts unless you have capacitance-measuring equipment. Construction details for the radio-frequency choke (RFC) shown in Fig. 502-c, are for 50-mc operation.

The Neomatic relay was used in this set because it could be bolted to the chassis and the cover could still be closed. If a Gem relay is used, a hole will have to be cut in the case to allow the contact plate to protrude.

Wire the filament circuits first. Do not put the diode in until the very end, and use care in cutting and bending the leads. If they are loose in the tiny head, the diode should not be used. Hold the diode leads close to the case with long-nose pliers when soldering, to prevent heat from ruining the unit. Be sure to use arc-suppressor capacitors across the relay contacts; if the set is to be used for control systems that require only a single contact of the relay, you won't need the double suppressor, of course.

If all parts used are as specified, the set almost certainly should work. With batteries connected but with no signal, total drain will be about 1 ma, which should jump to about 3 ma or more when a signal is tuned in. Actual current through the relay is about 0.5 to 2 ma. The circuit values shown should give good results, with normal parts tolerances and variations in the tubes; it might be possible to get even better results from the set by selecting parts.

If you wind your own transformer, try reversing the leads of *one* winding, either L3 or L4; you will generally get several tenths of a milliampere higher current with the transformer polarized the

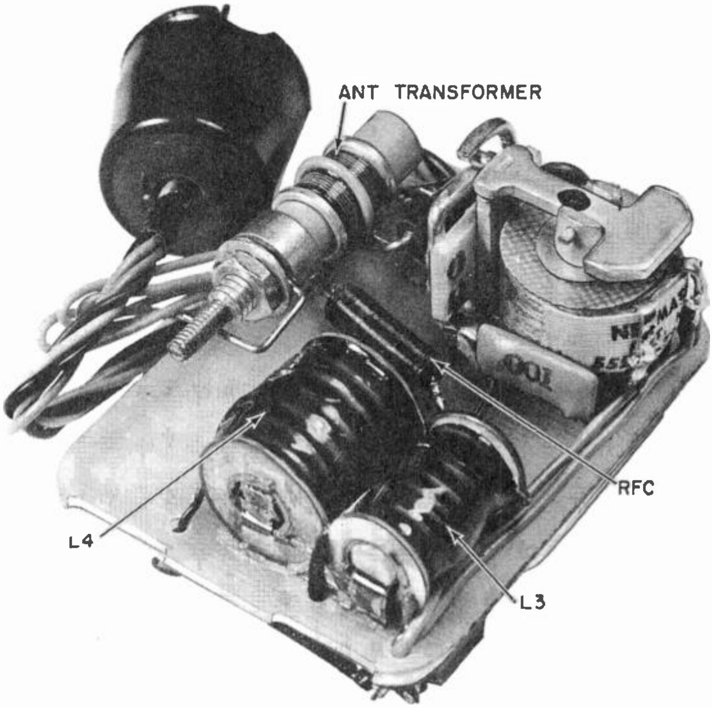


Fig. 503. *Single turn coil (L1) is seen centered on the antenna transformer. Interstage transformer L3-L4 is cemented to base. Windings are protected with tape wrapping.*

proper way (if you use a manufactured transformer, connection of wires according to colors indicated in Fig. 501 will assure proper polarization). With only V1 in the set you should have a B-current of 0.3 – 0.4 ma, and this should drop a tiny bit when the transmitter is keyed.

Best indication of set operation is to insert a meter in the plate circuit of V2 at point X (keep the meter leads *short*) ; this will read only plate current through the relay. Put your finger momentarily on the radio-frequency choke and note how high the plate current of V2 goes (it ought to be 2 – 2.2 ma); you should get about the same current when the transmitter is keyed on. With no signal, V2 plate current will be around 0.5 ma and will be seen to "wiggle" a little – possibly as much as 0.1 ma. If you don't get the maximum current rise with an incoming signal, R1 is too high in value; reduce it several tenths of a megohm and check again.

If V2 current won't go to the maximum with a *weak* signal,

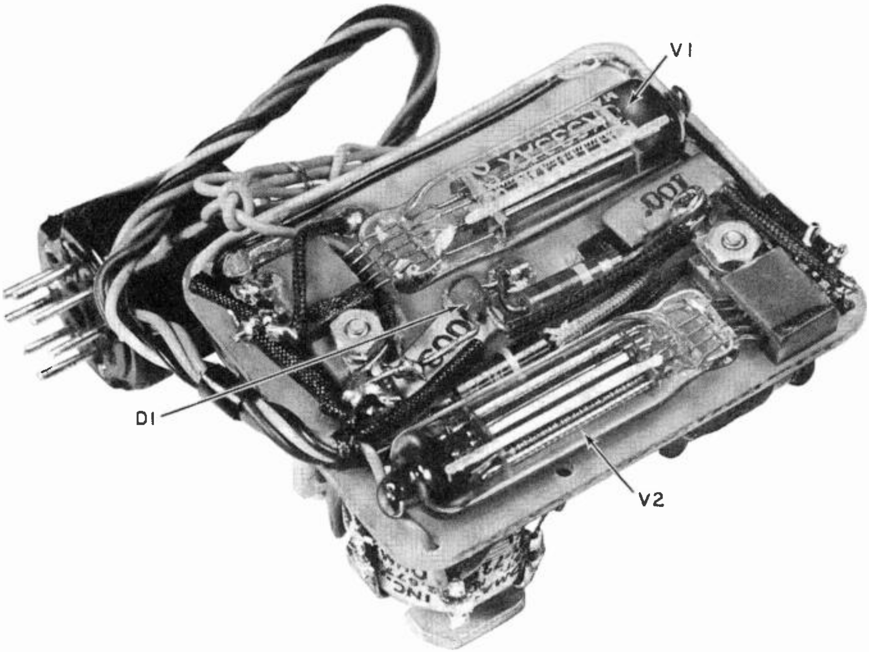


Fig. 504. *Sockets are cemented to base but are also held with single screw. Filament leads run along upper edge of base, are cemented to keep them from shifting. Lug on relay mounting screw is ground connection for various small parts.*

the capacitance of C2 may be increased a bit; however, too high a capacitance here will raise the no-signal plate current of V2.

If the parts specified are used and mounted as in Figs. 503 and 504, you should have no trouble with oscillation in V2. Separate the interstage transformer and relay as much as possible to prevent such oscillation. If V2's plate current stays at a very low value – say 0.1 – 0.2 ma, and won't change with signal, it is a sure sign that V2 is oscillating at audio frequency; this can sometimes be cured by reversing the leads to the relay coil. There have been cases of trouble of this sort when the sensitive relay has been mounted at a distance from the receiver; you can often get proper operation in such an installation by connecting a 100-μf capacitor from the plate of V2 to B-minus right at the socket.

The foregoing troubleshooting hints are given, not because the Tech Two is a difficult receiver to get going, but because so many have been built with so many variations, it is felt that these hints will help to get the most out of the receiver. Many other tubes have been tried for V1 and quite a few have been found to work fine, but most require a slightly different grid leak resistor (R1) than that specified in Fig. 501. Good detectors besides the CK-533AX are the 1AG4, DL-66 and CK502; if you use other than the CK533AX, check for optimum grid leak as outlined above.

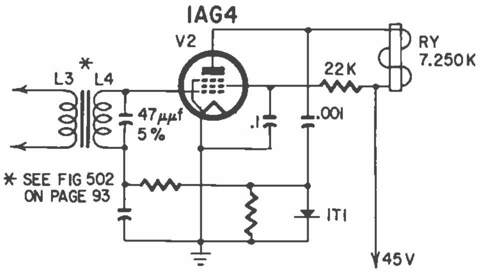


Fig. 505. *Use of 1AG4 allows much higher relay current. Capacitor across L_4 might need some experimentation.*

Generally, R1 should be as high a value as possible while still allowing V2 to go to maximum current with signal.

Higher relay current for the Tech-Two

The 2-ma current obtained from the original receiver was found quite satisfactory, but some builders like to have more current than this. Also, the CK5854 is a rather expensive tube. The 1AG4 makes an ideal relay tube, but requires the addition of two more circuit parts, as shown in Fig. 505 (a 20K resistor in the screen grid circuit and a 0.1 μf capacitor between screen grid and cathode); with these, the current through the relay will be about 0.7 – 3.0 ma. Don't use the 1AG4 without the screen-grid dropping resistor or you will ruin it.

Low-voltage Tech-Two

To save weight in smaller models, many builders prefer receivers that will work on 22½ volts instead of the more usual 45. Subminiature tubes in normal use won't draw enough relay current at this low voltage, so we must turn to the transistor. A receiver based on the Tech-Two, but featuring very low filament-current drain (about 25 ma total) and 22½-volt operation, is shown in Fig. 506-a; the layout is shown in Fig 506-b. The circuit (Fig. 507) is very similar to Fig. 501 and many of the parts are the same, but a transistor amplifier (V3) is added to supply sufficient relay current. The same transformer L3 – L4 is used, but a new component, L5, has been added. (Fig. 508 gives construction

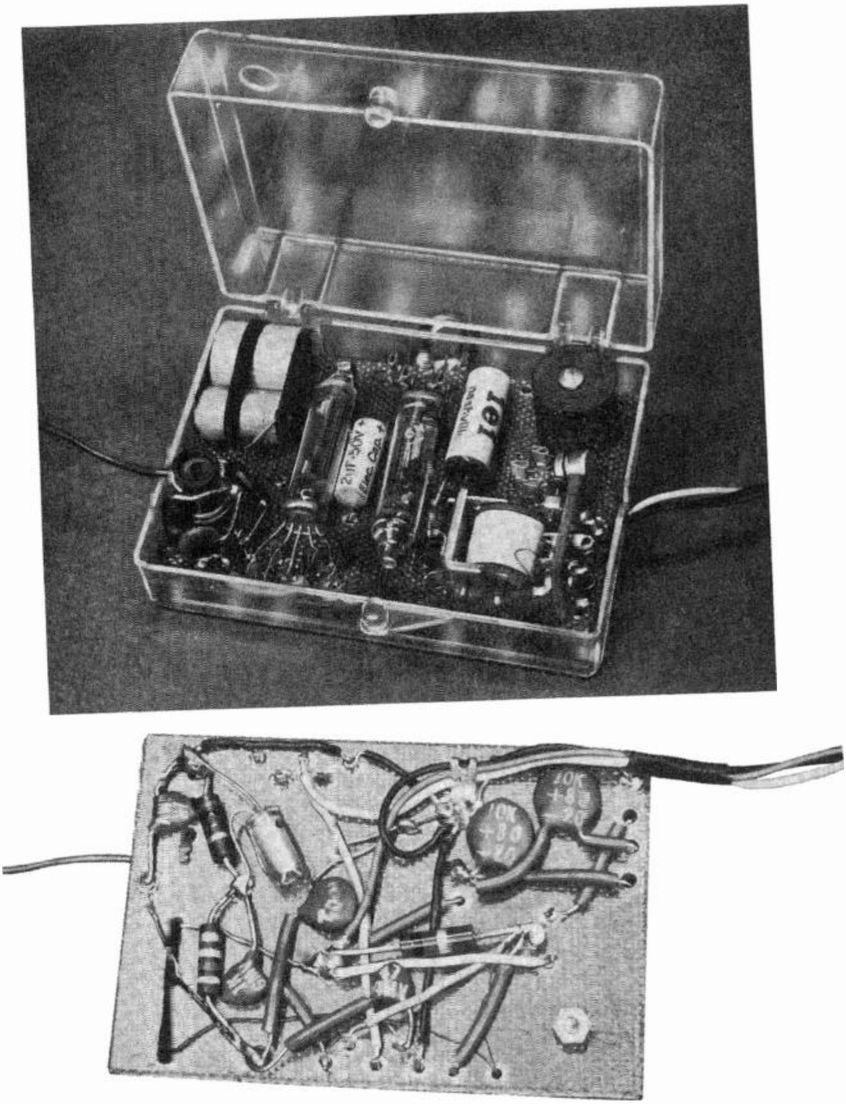


Fig. 506. *Tech-27 (see photo above) is in larger case than Tech-Two to make space for added components. Same interstage transformer is used. Note relay (lower photo) held down by four wires through eyelets at right, and by wire to lug on frame at left side.*

details of L1, L2 and L5.) This functions as an af choke and its value is not at all critical. The one shown was made from a 1,500-ohm Gem relay coil, with several core strips of the same metal as

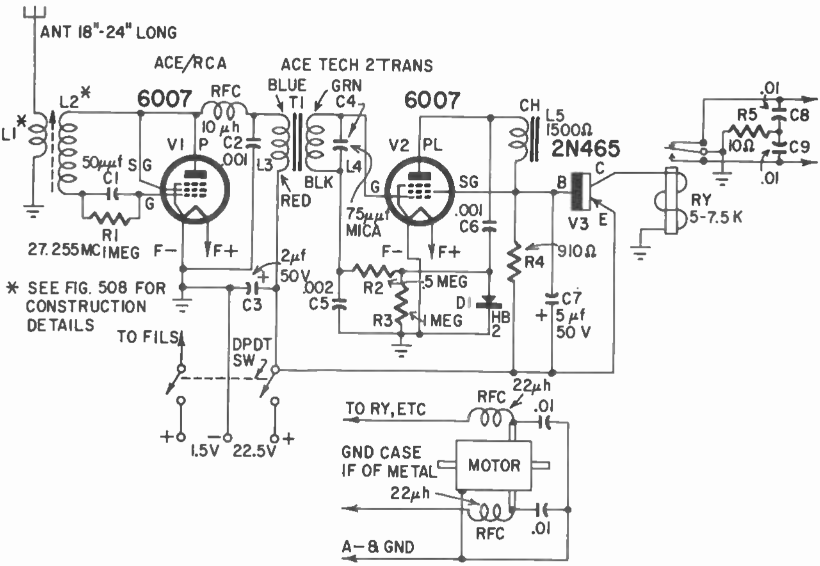


Fig. 507. *Circuit diagram of the low-voltage Tech-Two. L1, L2, T1 and L5 are available from Ace Radio Control.*

specified for the interstage transformer. (L5 can also be obtained ready to use). The transistor acts as a dc amplifier, controlled by the variation in current through R4. Since V2 does not have to work a relay, a low-filament-current tube may be used; the 6007 has been found ideal for both V1 and V2.

To make the set easier to build, a slightly larger plastic case is used; a bottom-view layout (not scaled) for the base plate is shown in Fig. 509-a. A top view of the base plate is shown in Fig. 509-b; mounting of components is in Fig. 509-c. The interstage transformer is cemented with Goo to the base and bound with heavy thread through two holes. Instead of sockets, flea clips are used for the tube and transistor leads. After the set has been completely checked out, V1, V2 and V3 are coated with Goo on the underside and stuck to the base; they can be pried off easily later, if desired, but the Goo will hold them firmly in place during use. To be able to close the case, it was necessary to mount the Gem relay on its side; it is held firmly by wire soldered to the frame lug near the tension spring, and by other wires running through eyelets in the base and attached to lugs on the relay terminal board.

At the lower voltage used here, V1 is a little more fussy on circuit components, and the exact parts specified should be used. This applies especially to the rf choke, coil form, etc.; experienced

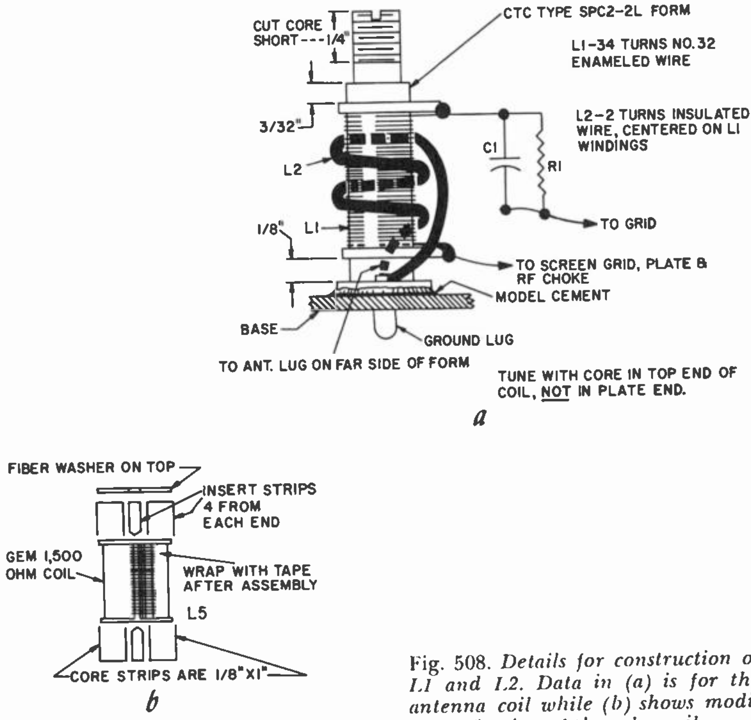


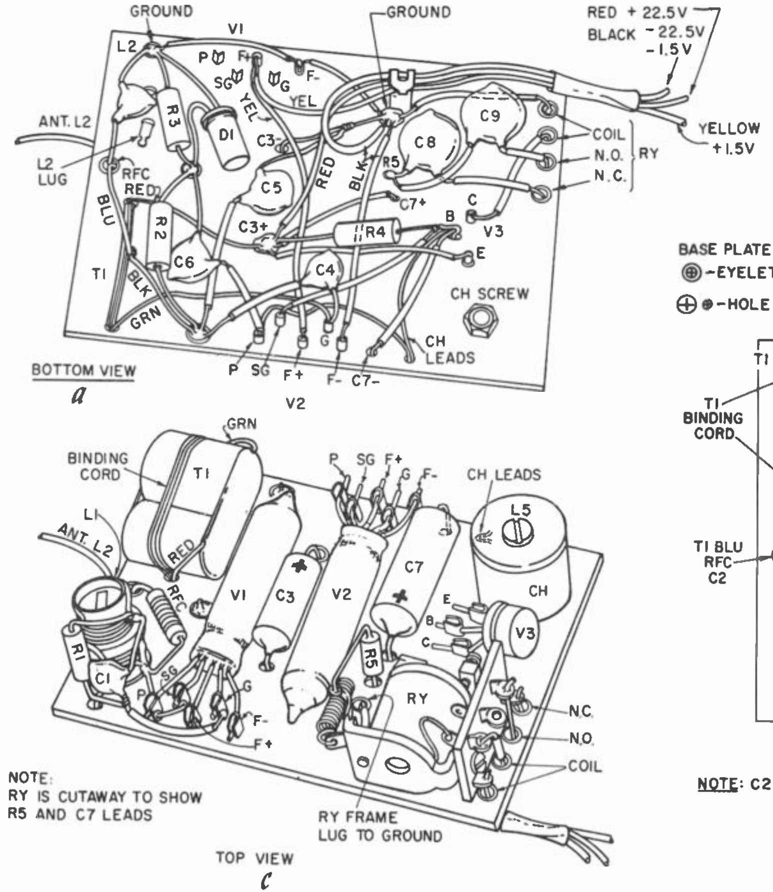
Fig. 508. *Details for construction of L1 and L2. Data in (a) is for the antenna coil while (b) shows modification of the relay coil.*

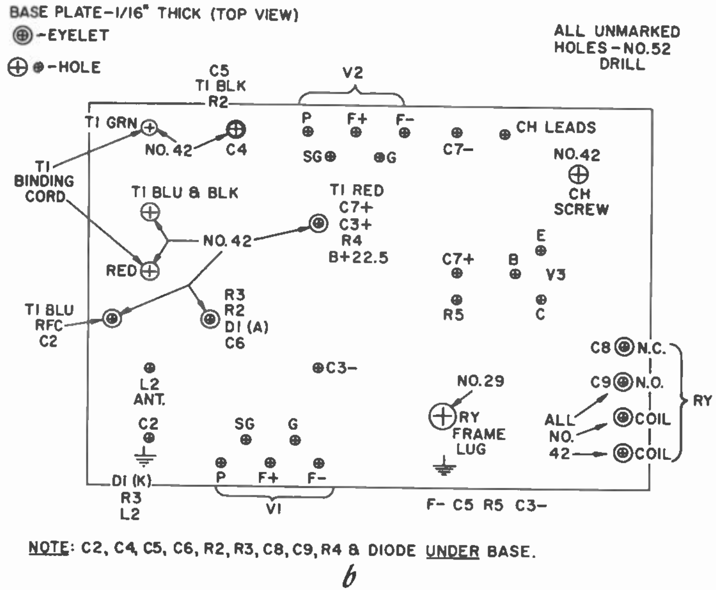
constructors can try other parts, of course, and will probably know what to do if the set does not act right.

Operation is exactly the same as for the set shown in Fig. 501, and the same troubleshooting hints apply. We strongly advise use of close-tolerance parts where specified, as the values were chosen after a great deal of experimental work to assure top-grade results. If the specified parts *are* used throughout, about the only item that might require alteration is R4; transistors may have a bit of variation in the circuit.

To tune the receiver; insert V1 only and check for proper operation. The plate current should be about 0.17 ma with no signal, and perhaps 0.15 ma with a strong signal. If you get this, install V2. This tube idels at about 0.15 ma, and its total current (plate and screen grid combined) rises to perhaps 0.3 ma with strong signal. A meter in the receiver B-lead will read about 0.3 ma idling and 0.45 ma or so with signal, for total current of V1 and V2. V3 can now be inserted (be *sure* you have it the right way!); it adds 0.1 — 0.2 ma to the total idling current and, with signal, the

Fig. 509. *Drawing (a) is a bottom view. Base plate (b) is epoxy-fiberglass for maximum strength. The set fits into a plastic box, 3 x 2⅛ x 1⅛" outside dimensions. Component mounting is shown in (c). Insulate D1 to prevent shorts. After all soldering is finished, clamp battery and relay wires lightly in end of ground lug to keep them in place. Receiver is held in box by ⅛" foam plastic on bottom, ½" on top, both cut to clear rf parts and relay.*





relay current is about 3.5 ma. Thus, the total receiver current should be about 0.7 ma idling and 4 ma with signal.

Those experimentally inclined might want to vary the value of R4 to make sure they have the best resistor here, though the 910 ohms specified was found to cover a large variety of tubes and transistors. If R4 is too large, the idling current of V3 will be higher than we have indicated; if R4 is too low, V3 might not be able to reach maximum collector current. The value can be

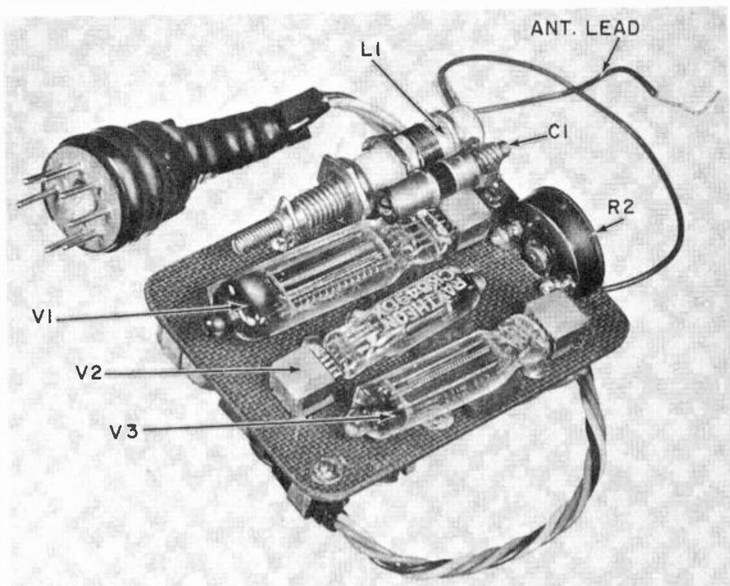


Fig. 510. *AES receiver in original form. Fits plastic case 2¼ x 1¾ x 1-3/16" high; held by ledges of plastic cemented inside case.*

checked by touching the rf choke with a finger (you will have to use a meter in the collector circuit though, since touching the choke puts V1 out of oscillation and its plate current jumps to a milliampere or more); note the relay current, which should be the same as with the set tuned to a strong signal.

Like all so-called "noise-operated" receivers this one is bothered by electrical interference in the model, caused by electric-motor brush arcing, rattling metal push rods, etc.

3-tube CW receiver

Another noise-operated receiver is seen in Figs. 510 and 511. This one has been found most reliable and easy to get going. The same general circuit has been found adaptable to other uses. Basically, V1 acts as a detector and noise generator (with no incoming signal); the noise is amplified by V2 and passed along to the grid of V3. The large grid leak for this tube allows a fairly large grid voltage to be developed that holds the plate current of V3 to a rather low value. When a signal comes in, the noise from V1 ceases and V3 puts a fairly large current through the relay in its plate circuit.

While there is a variable resistor, R2, used as a sensitivity control (Fig. 512) it has to be set only once for any given installation

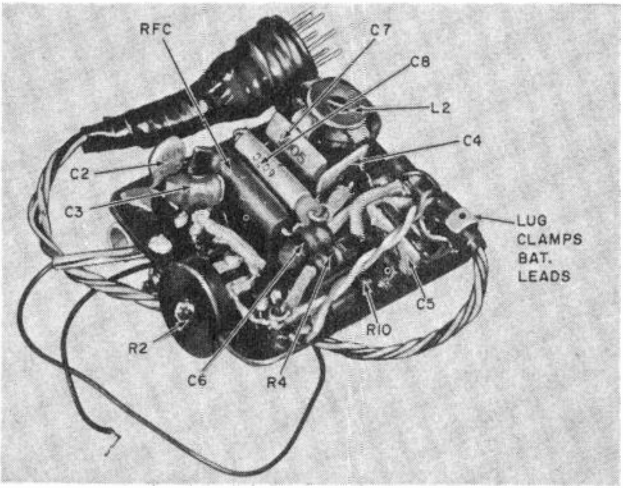


Fig. 511. *Underside of AES chassis. C8 is sub-min af choke with normal core removed, a few strips of core iron inserted and wrapped around coil form. Whole unit dipped in polystyrene cement. R2 (CRL #B16-124) is held by wires soldered to the two brass mounting screws. Base has small eyelets in which to solder leads of small parts.*

and tube at V1. The original set had a variable capacitor at C1, but a fixed 1 μμf would do for most installations.

L2 is an af choke made from a standard unit, but with the core greatly reduced primarily to reduce size and weight. The entire core was removed and replaced with four core strips (from another transformer, as the ones originally used were not long enough to be wrapped all the way around the winding). It is held by a 2-56 bolt through the center. It could be replaced with a choke such as the UTC DOT-8, used just as it comes.

This receiver fits in the usual plastic box, and has a 1-5/8 x 2-1/8-inch base plate. Tiny hearing-aid sockets were used, and each was held by running the pins through five holes in the base. L1 is held by soldering the ends of the two clips in eyelets.

Because the current in V3 is not very large, a fairly sensitive relay is advisable; the Sigma 26F, Kurman 13C44 and Price 5,000-ohm units have been used. Although it was not done in the set shown, if optimum value resistors were chosen for R5 and R6, V3 could be made to idle at a lower value.

As in other sets described, quite a few small eyelets have been used in the base plate as tie points for small parts. Everything is tied down at both ends to prevent vibration troubles.

The set shown was used mostly on 50 mc, and the coil specified is for such use; for 27.25 mc, use the same coil form but put on 18 turns of No. 28 enameled wire. Use a 20-μh rf choke, raise C1 to

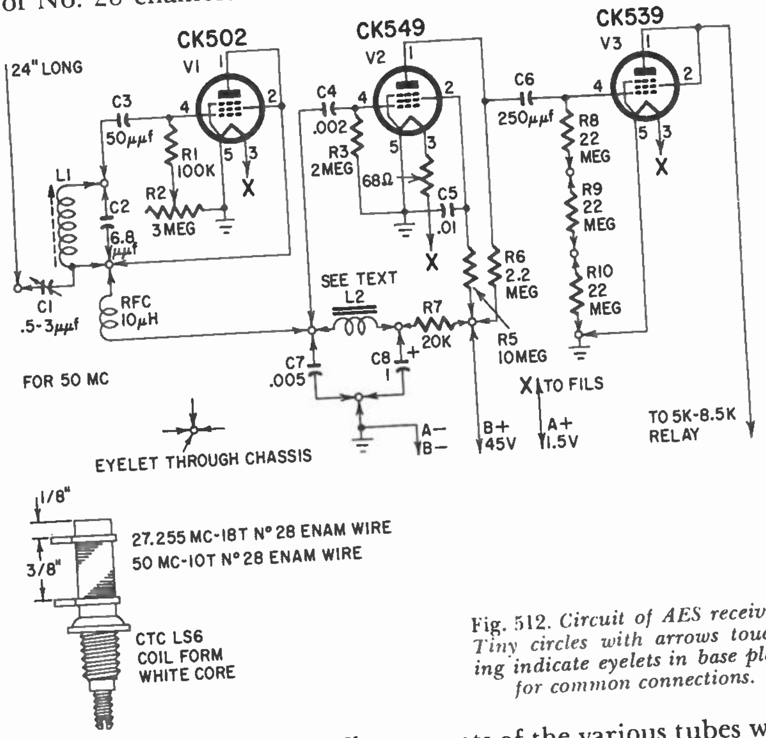


Fig. 512. *Circuit of AES receiver. Tiny circles with arrows touching indicate eyelets in base plate for common connections.*

about 3 μμf and C2 to 10 μμf. The currents of the various tubes will be about the same on either frequency. The total receiver current will be around 0.4 ma idling, with R2 set at the optimum. With signal, the total current will rise to about 1.4 ma, when using an 8,000-ohm relay. R2 should be set at the highest possible value that will still allow maximum B-current with signal on. Because of the use of L2, the set should not be placed too close to actuating units in a model; as a matter of fact, *all* receivers should be kept as far away as possible from escapements, actuators, motors etc.

Furthermore, always run the receiver antenna lead as far away from motors as possible — in fact, keep it as far away from any metal as possible.

This receiver has also been known as the AES — it was billed as an Advanced Experimenter's Special, because the general circuitry is adaptable to other uses as we will describe.

Compact 3-tube tone receiver

The circuit of a three-tuber intended for use with tone modulation is shown in Fig. 513. This is an AES receiver conversion. Externally it looks the same. The circuit values have been changed

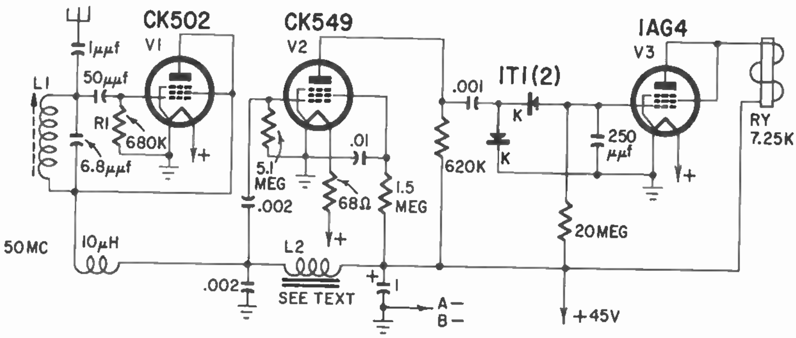


Fig. 513. *AES receiver converted for tone operation. Note that relay current is high with* no tone, *drops when tone is transmitted. Main changes from AES are in V3 circuits. L1 and L2 same as for Fig. 512. Variable grid leak and antenna capacitor not required.*

a bit to get better af operation, and a 1AG4 put in the V3 position for more current change. An odd connection will be seen at the control grid of this tube. The grid leak runs to B-plus! The set was intended for pulsing operation and this grid-leak arrangement peps up pulsing speed considerably. Used mostly on 50 mc, the same changes specified for the AES receiver will allow operation on 27.25.

Tone operation is not so fussy as that based upon CW only. The tone receiver has no need for a variable grid leak resistor, R1; a fixed value of 680,000 ohms will do just as well. This receiver peaks broadly at around 1,000 cycles, the exact value depending upon what type of choke is used for L2. A UTC DOT-8 choke peaks at about 1,100 cycles, as does a Telex type 8901 interstage transformer used as a choke (blue and green leads connected, red and black to circuit). A wide variety of other chokes (and transformers with only one winding used, or with both hooked up either bucking or aiding) will work here.

With a 5,000-ohm relay, the circuit in Fig. 513 showed the following results: total A-current – 80 ma; B-drain of V1 and V2 – 0.25 ma. Relay current with no CW carrier – 0.2 ma; with CW signal tuned in – 4.1 ma; with tone of optimum frequency (960 cycles in this case) and 100% modulation — 0.1 ma. This set

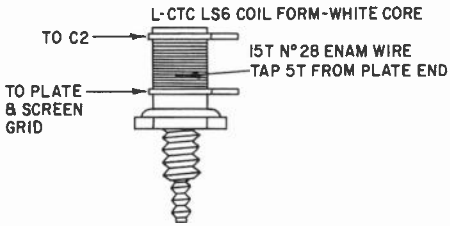
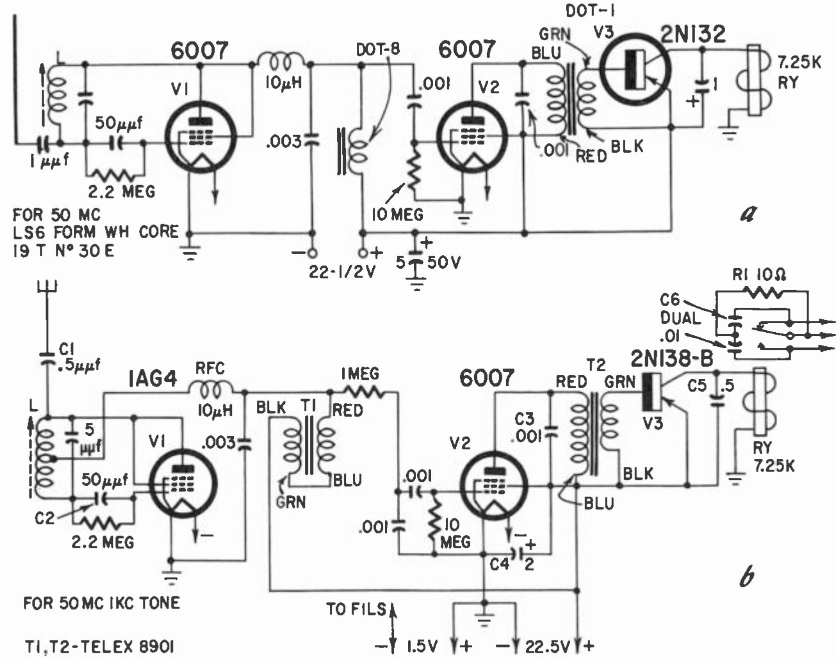


Fig. 514. *Circuit (a) worked well experimentally but was never used in a model. It could use same af transformers as in b. C3 in latter might need change—see text. Circuit (b) worked well in many flights.*



will respond to much weaker signals than will the AES, as is usually the case when tone receivers are compared with CW sets. Thus, while a transmitter with modulation facilities is required, the rf section can be of considerably lower power, and total transmitter battery drain will come out about the same.

2-tube hybrid tone receiver

This is still another modification of the AES, but this time the old three-tuber is hardly recognizable (Fig. 514). This receiver was modified to operate on 22.5 volts; this made it necessary to attach a transistor to the output to afford a reasonably high relay current. First tests were made with the relay hooked onto the three-tuber using a circuit like that of Fig. 513, but with a resistor in the V3 plate lead and the transistor base and emitter across this resistor. Results were fine, but the set looked rather complex, so a simplification program was undertaken, with the end result seen in Fig. 514. Originally, two 6007 tubes were used at V1 and V2 and the results were very good indeed. However, it was found that with a rather potent transmitter, the receiver tended to overload when

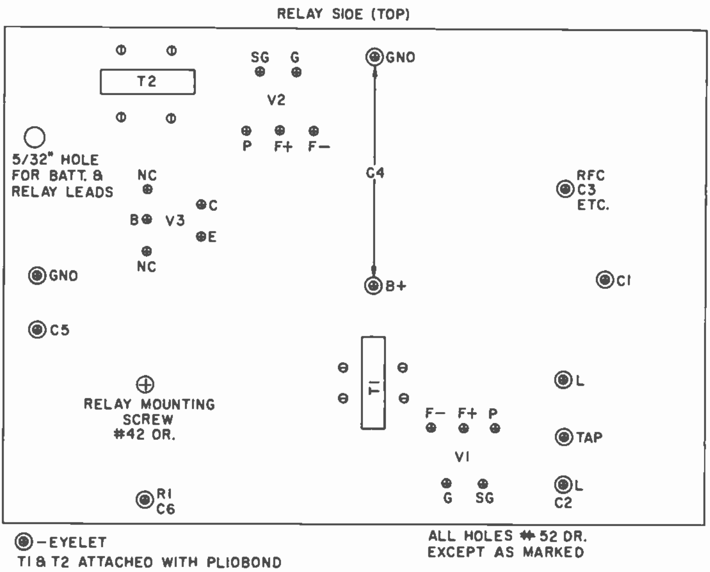


Fig. 515. Base plate layout (not to size) for hybrid tone receiver using 8901 transformers. Eyelets are used for soldering leads and parts down. All sockets are 5 pin Cinch-Jones #46A-22452 (R/C suppliers have these). Prongs project through holes, are held by wires soldered to opposite side.

the model was close to the antenna. Considerable experimentation showed that most of the overload trouble could be eliminated by using a 1AG4 at V1, and by loose antenna coupling. Only 0.5 μμf has been used at C1 and total antenna length from set to tip is only about 2 feet. This has proven ample for the transmitter used (the Mac 50 with modulator, shown in Chapter 7), but with a lower power transmitter it might be necessary to increase C1 to 1 μμf. With the two 6007's, the filament drain was only about 25 ma, but substitution of the 1AG4 raised this to 55 ma. The B-plus drain for the two tubes is about 1 ma, while the transistor runs at zero current (with carrier, but no tone) and this rises to around 3.3 ma with a 1,000-cycle tone. Due to the low B-voltage and 50 mc operating frequency, every effort was made to design the circuits of V1 for most efficient operation and results have been most satisfactory. It is suggested that *no* parts substitutions be made if this fine operation is to be retained. A template for this set is given in Fig. 515.

Overloading was reduced quite a bit by putting the set in a metal case, preventing direct signal transfer from transmitter antenna to input inductance L. Such a case is recommended for maximum freedom from this annoyance.

The receiver chassis is seen in Figs. 516 and 517. For utmost strength, the base plate is of epoxy fiberglass, which also has very

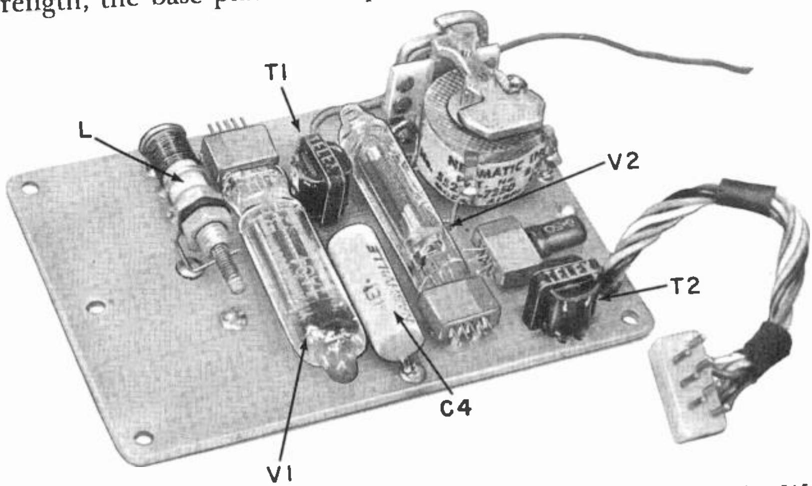


Fig. 516. *Extra space at left on base is not needed. Dimensions of Fig. 515 does not include it. Sockets have dab of red paint to show plate or collector side. Tubes and transistor have spot of cement to hold them to base.*

fine insulating properties. However, from electrical considerations, a good grade of linen phenolic would doubtless do as well. The receiver shows a rather broad peak of af response, the actual peak frequency depending to a great extent upon the value of inductance used at T1. Because of its tiny size and moderate cost, a commercial audio transformer is connected as a choke for T1; in fact, the windings are connected to oppose each other to obtain the desired inductance and af response peak. The only circuit component that might be considered at all critical is C3 across the winding of T2; this removes most of the quench frequency before it can act upon V3 and, with any one receiver, it can actually be varied several hundred percent without affecting operation too much. But it should be chosen to match T2. If too high in capacity, C3 will reduce the af signal sent along to V3 too much; if too low, it lets too much quench frequency pass through T2. Be sure to follow the color code for transformer connections as given.

For pulse operation, C5 should be no larger than specified, but for escapement use it can be raised to 1 μf. If lower than 0.5 μf, the transistor will not draw maximum possible collector current with tone on.

The simplest way to get the receiver going is to hook it up first with just V1 in place; this should show an idling current of

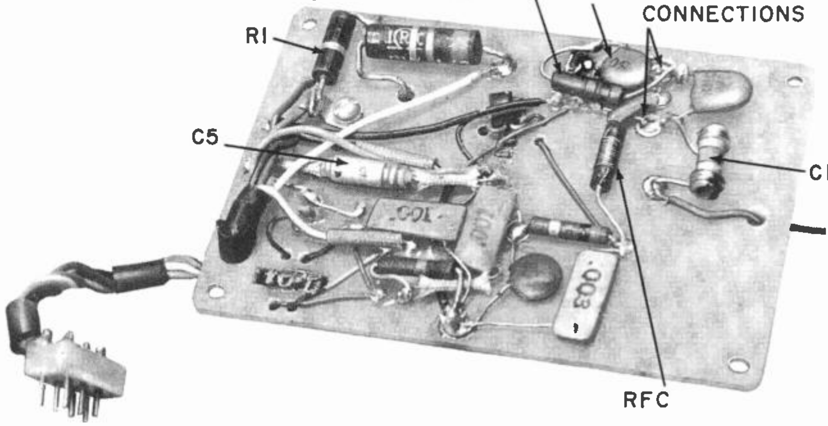


Fig. 517. *Under side of hybrid tone receiver. Large resistor next to R1 was part of control circuits, not used in receiver itself. C5, Cornell-Dubilier #TY-101 tantalum, used because of tiny size.*

about 0.17 ma, which will drop slightly when a signal is tuned in. If all is well so far, add V2; the total idling current will now be around 0.75 ma, and this will drop very slightly when a CW signal is tuned in. With tone, there should be another drop of about 0.1 ma, or a bit more. Now the transistor (V3) can be added. With no incoming signal, the transistor current should be no higher than 0.2 ma, and it will probably fluctuate a little. With CW tuned in, this current should drop to zero and, with tone of the proper audio frequency, the current will rise to a value dependent upon the relay resistance. With a 7,250-ohm relay, maximum collector current is about 2.8 ma.

A transistor of low leakage is needed to keep the idling current of V3 to a minimum. A medium-high-beta transistor is used; many p-n-p units are quite suitable in place of the one specified. If a different transistor type is used, be sure to select one with a maximum voltage rating higher than 22½ volts.

This set was intended for proportional work and will pulse at high speed without distorting the pulses. Like most tone receivers, it is not particularly bothered by electrical noise. However, it is always wise to take the usual precautions — keep the set away from motors, etc., and bond push or torque rods. Keep the antenna lead as far as possible from motors.

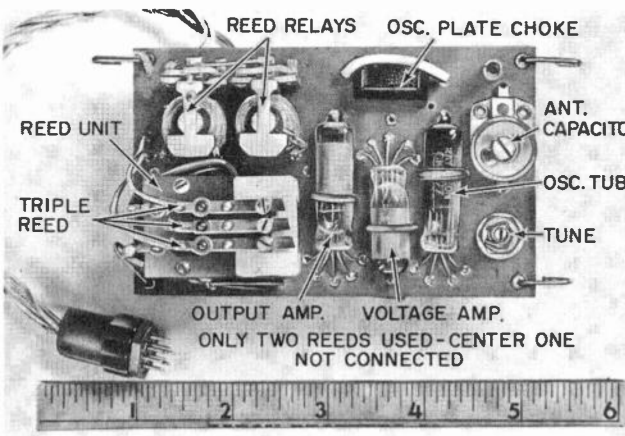


Fig. 518. *Reed receiver with E.D. triple reed unit. Most R/C modelers want more channels, so 4 to 6 (or more) reed units could be used. Variable antenna capacitor not a necessity, fixed 5 μμf should do. Oscillator plate choke was rather large type; high resistance winding of Johnson sub-min unit (Ace) should do nicely. Set could be made much smaller with latest tiny parts.*

Simple reed receiver

The set shown in Figs. 518 and 519 was based on an earlier version of the AES, and gave very good results. Tuned reeds afford the simplest and lightest way to get a variety of operations in your model, since they act as a very compact multi-channel unit. Reed units can be obtained that will differentiate between any number of tones from 1 up to 15 or more. The set in Fig. 518 has only a three-reed unit (and only two of the reeds were used), but five- and eight-reed units are commonplace today. Actually, there is little or no difference in the receiver itself no matter how many reeds you use; the only changes come in the reed unit itself and the relays required, with their associated L-C filters. The filters smooth the vibratory current the relays would receive without them. Each reed vibrates and hits its associated fixed contact when its own particular tone comes in. The reeds do not make solid contact but close the circuits only momentarily as they vibrate. Thus, the filters are needed to smooth this vibrating current so the relays will be held solidly closed, and also to reduce sparking at the reed contacts.

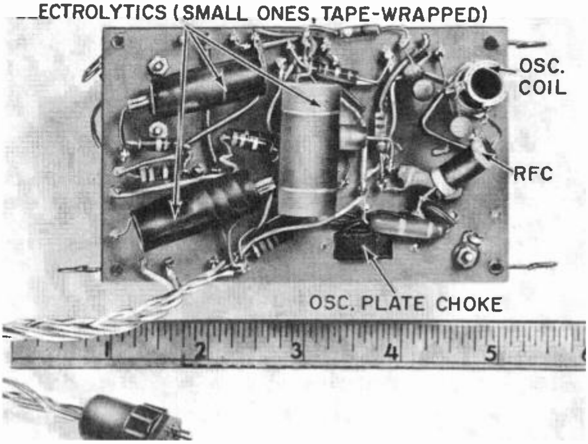


Fig. 519. *Underside of reed receiver. Large electrolytic in center is 5 μf, 50 V unit. Small ones are those in reed circuits. Much smaller units can now be had.*

In the circuit shown in Fig. 520 the reed coil takes the place of the sensitive relay. The capacitor in parallel with the coil is often built right into the reed unit, and serves to tune the coil to the approximate range of frequencies covered by the reeds. The grid leak of V3 is dropped to a comparatively low value because we do not want a *change* of current in the reed amplifier tube, but a *steady* high af output. For the same reason, the detector grid leak can be a fixed value.

Since some of the tubes originally used in the receiver in Fig. 518 may now be difficult to obtain, presently available tubes and components to suit them are shown in Fig. 520. This accounts for the fact that, although only four leads are shown on the oscillator tube in Fig. 518 (a high-frequency triode, the CK5677, was used). A triode-connected pentode is shown in Fig. 520. A better voltage amplifier is also specified. It is probably not essential to use a variable antenna capacitor although one is seen in the circuit (Fig.

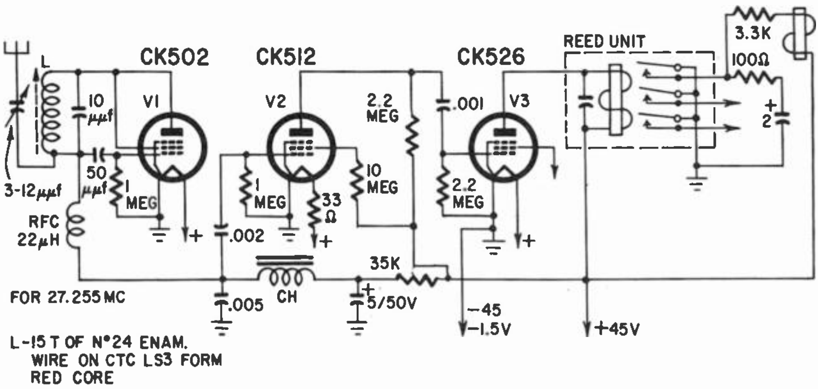


Fig. 520. *Capacitor across reed unit coil must match coil; makers always specify what value to use. CK512 is low voltage tube, requires dropping resistor, even for use on 1.5 V. 3.3K in series with relay was to lower current to conserve battery life. It may be reduced or eliminated to get greater relay current, if desired. Do not omit 100 ohm resistor in reed circuit.*

520). This receiver, which was developed quite a few years ago, is a good example of a home-built reed unit. There are not too many built today — not because such a set is so difficult to construct, but because there are many good commercial reed receivers on the market now. Such modern sets, though, may have more reeds and be more compact. The circuitry of the tube-type receivers is very similar to that in Fig. 519.

When tuning a reed receiver, there isn't a great deal to do but make sure it will cover the same radio frequency as the transmitter. It is useful to hook headphones temporarily across the reed-unit coil to make sure the transmitted tones come in properly. A crystal phone is best for this purpose, as it will not change the current through the coil. Reeds are not adjustable in frequency; the transmitter tones must be varied to match them. Basically, each tone is tuned until its associated reed vibrates. Instructions provided with the reed units will tell how to proceed from there for most reliable reed operation.

If a different layout of parts from that in Fig. 518 is used for a reed receiver, the af choke should be kept as far from the reed bank as practical, to prevent any possible audio feedback and oscillation.

Tone receiver with miniature tubes

One of the most reliable receivers to be developed for tone work is shown in Fig. 521. It has been made in many home-built and commercial versions, and is still preferred by some builders. Use of the low-cost seven-pin miniature tubes means a highly reliable set (though rather large and heavy). It is an ideal receiver for boats, where weight, size and lowest possible current drain are of little consequence.

The large and rather heavy Sigma 4F relay is used, but many of the smaller types will do very well, since the receiver gives a

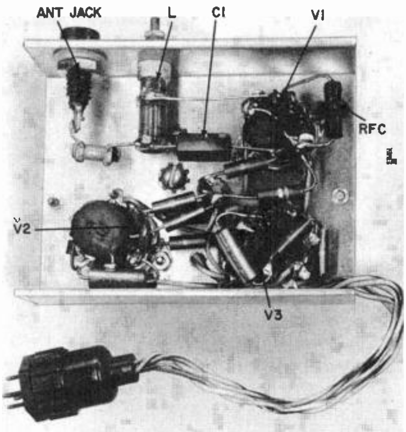


Fig. 521. *WAG tone receiver was rugged and fairly big. Heavy but sensitive Sigma 4F relay is used. Too large for modern planes, receiver is fine for boat use where large size is little drawback.*

relatively large current change through the relay. Still, if lowest possible weight is not an objective, the 4F is probably a good choice.

Known as the WAG single-channel receiver, the outfit was built on an aluminum chassis measuring 2¼ x 3 inches on top and ⅞ inches high. Practically all small parts including the rf choke are supported by their leads and grouped around the three tube sockets. In the underside view of the chassis (Fig. 521), V1 is upper right with L to its left. Note that L and the parts connected to it are kept away from other components as much as possible. At upper left is the pin jack used as an antenna connection point. Directly below V1's socket is that for V3, while V2's socket is below the antenna post.

The total current drain of the set with no incoming signal is about 2.5 ma, and this rises a few tenths when a CW signal is tuned in. Upon receiving a modulated tone of 300 – 500 cycles, the plate current drops to around 0.2 ma. Practically all the current is drawn by V3, so the relay can be set up with heavy spring tension.

The original receiver (Fig. 522) was intended for use with an escapement and hence did not have to pulse very rapidly. Other experimenters did want fast pulsing, however, and a circuit that allows this is shown in Fig. 523. This circuit also allows low idling

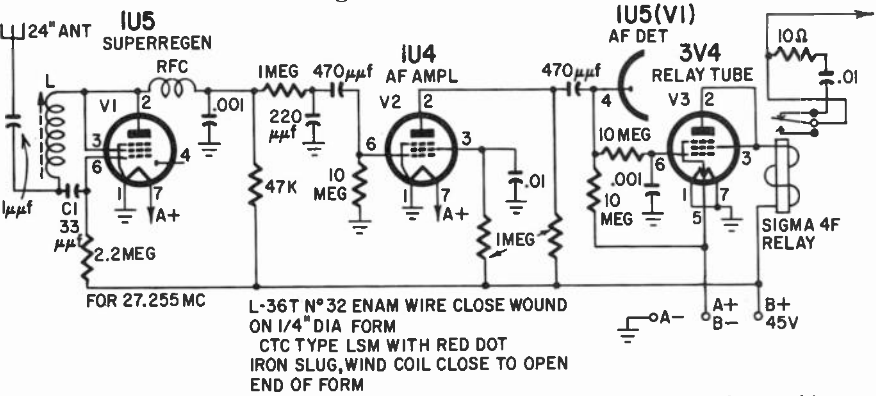


Fig. 522. *RFC is 100 μh National R33. Relay can be 5000 to 7500 ohms. This receiver has high current through relay with no tone, current dropping toward zero when tone is received.*

current in V3, which rises when an audio signal comes in, the opposite of the action in the WAG set. This circuit requires use of a bias battery on V3, but this can be composed of the tiniest

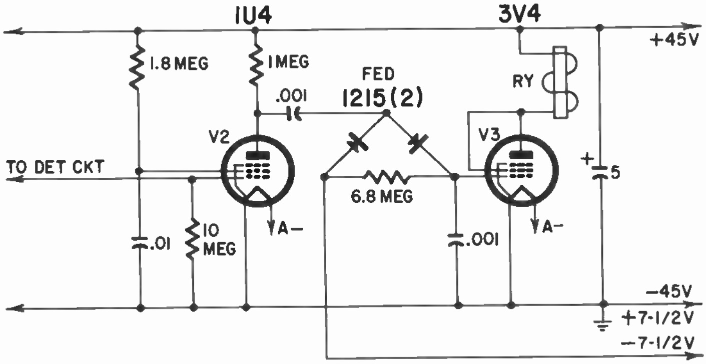


Fig. 523. *Low idle-current is the result of adding diodes and bias voltage to relay tube circuitry.*

possible cells (five cells cut from a small B-battery will do fine), as there is no current drain on them and they will last for many months.

Submin WAG receiver

A circuit very similar to that in Fig. 523 but using subminiature tubes and parts is seen in Fig. 524, while Fig. 525 shows a photo of the set. Aside from the different tubes, there is very little change in the circuit, V1 being used as both a detector and diode rectifier, as it is in the WAG. R1 might need to be changed for some tubes, but the value given is probably good for most 1AG5's. C1 has been reduced from the original WAG value so that this subminiature version will pulse at a higher rate. The photo shows a set of round subminiatures installed, but the flat types specified in Fig. 523 have been found preferable. The total A-battery drain is 110 ma, and the relay current change is from 3.5 ma to zero when an audio tone of about 400 cycles is received.

2-tube af receiver

An interesting subminiature receiver circuit is shown in Fig. 526. Only two tubes are used, since the 1V6 actually has two sets

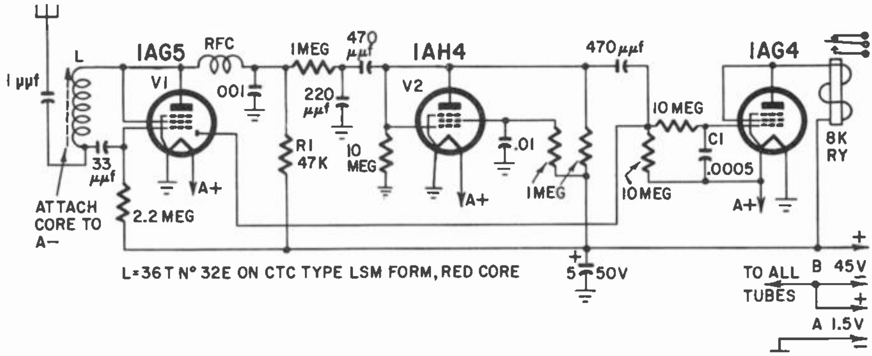


Fig. 524. *Miniaturized WAG receiver. Though entirely different tubes are used parts values are similar to those used in much larger WAG. This 27.255-mc receiver could use sub-min 22 μh rfc (Gyro, etc.).*

of elements in the one envelope. The antenna length isn't critical, but the set will not follow very high pulse rates. Either 45 or 67½ volts can be used. With 67½ volts and with a 5,000-ohm Price relay, the relay current is 2.3 ma with a signal tuned in; this drops to about 0.1 ma when a tone of around 1,000 cycles is received. The set can be used with tones in the range from 500 – 1,000 cycles, but heavy transmitter modulation is preferred. If used on 45 volts, B-minus should be connected to A-plus since this raises the relay current slightly. Also, for 45-volt use, a relay like the Sigma 26F is preferable due to the lower relay current available. On

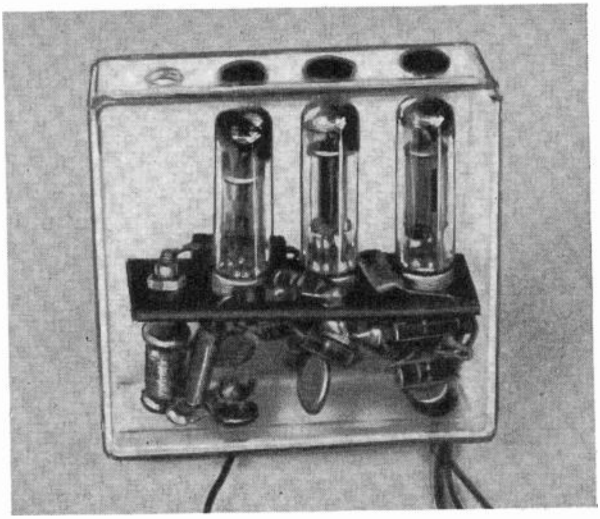


Fig. 525. *Receiver is mounted in flat plastic box. Tube tips are protected by small rubber grommets. Though round subminiatures are shown, the flat types specified in Fig. 524 gave better results and are recommended.*

67½ volts, V1 and the pentode section of V2 draw 0.3 ma. The filament drain is 80 ma. This receiver operates on 27.25 mc with coil shown.

All-transistor tone receiver

Really subminiature, this receiver (Fig. 527) uses transistors throughout and operates on low voltage, which can come from the smallest penlight cells (Eveready 904; Burgess NE or equivalent) or some of the tiny transistor receiver batteries now available. The circuit is shown in Fig. 528. Like many high-frequency all-transistor receivers (including some commercial makes), this one is somewhat sensitive to heat, which causes a slight frequency shift. A simple way was found to reduce this—simply cement a little sleeve of asbestos around V1! This is not necessary on V2 and V3, which are quite well stabilized for most temperatures the receiver will operate in.

When the set was developed, V1 was a Philco L-5108 while V2 and V3 were Raytheon 2N138A's. The transistor field is moving fast, however, and these types are no longer available. For V1, a good substitute is the Philco 2N346 (SB103), while for V2 and V3 you could use such types as Raytheon 2N138B and 2N631, GE

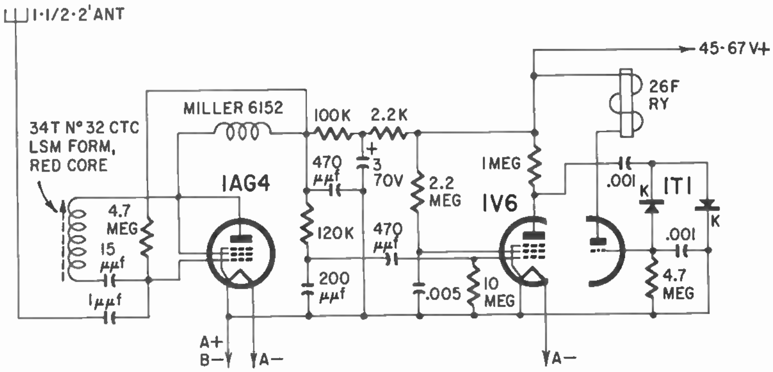


Fig. 526. *Circuit for tone receiver for 27.255 mc. 1V6 has two sections, acts as amplifier and relay tube. Since there are only two tubes and the relay is mounted separately this receiver is extremely compact.*

2N265, etc. V3 should, if possible, be selected for low leakage, since a high leakage current in this unit will mean that the current through the relay with no af coming in will be larger than desirable.

The receiver base is 2-1/8 x 1-7/16 inches and the parts are not particularly crowded. Sockets are used for all transistors, to pre-

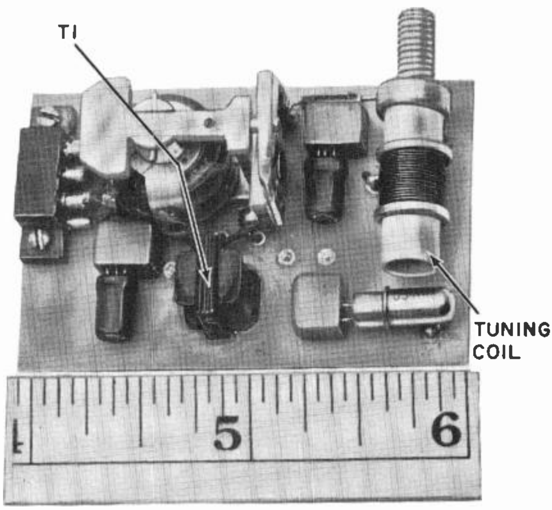


Fig. 527. *All-transistor receiver is compact. Sockets are used for all transistors. Rf transistor is at lower right. Unit at far left is socket for batery and relay cable.*

vent damage when working on the set, especially for the relatively fragile (electrically, that is) V1. The original interstage transformer (T1) was a Gramer M2, but a UTC DOT-1 or Telex 8901 will probably be easier to find in the radio supply stores.

Low-cost Philco AO-1 high-frequency transistors were tried in this set as oscillators and, while some of them worked, the sensitivity did not seem as good. If you have access to several of these low-cost jobs, you might be able to pick a "hot" one; otherwise, better stick to the higher-grade unit suggested.

This receiver follows the lines of others we have already de-

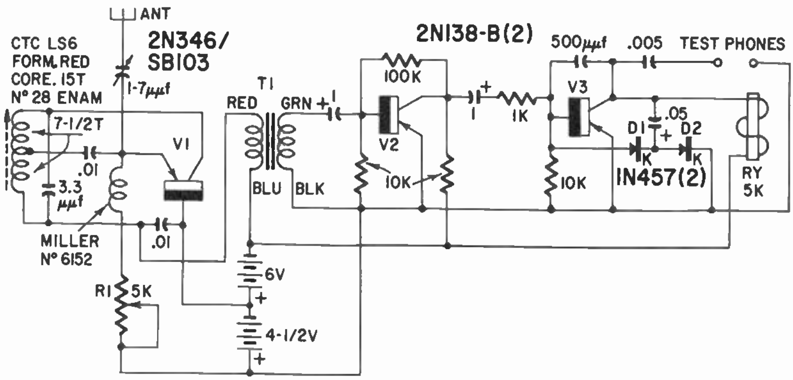


Fig. 528. *The Miller 6152 rfc is rated at 22 μh; other chokes of this value might work as well. T1 is Johnson subminiature transformer (Ace). R1 is a fixed resistor in actual receiver; see text for selection.*

scribed, as far as operation of the various stages goes. V1 is a superregenerative oscillator or detector whose operation is controlled by R1. It might be wise to make R1 a 5,000-ohm variable resistor until the best value for the particular V1 used is found, when a fixed resistor may be substituted. V2 is simply an af amplifier, while V3 is the same; the latter amplifies the audio tone, which is rectified by the two diodes, D1 and D2. The resultant dc is then fed back to the base of V3 in a direction to cause it to conduct more heavily. R1 should be set so that V1 draws about 1.3 ma and a stable hissing is heard in the phones. V2 will draw about 0.7 ma, while V3 idles at close to zero and relay current rises to about 1.8 ma with a 1,000-cycle tone.

chapter SIX

simple transmitters

BEFORE operating a radio control transmitter, it is mandatory that the owner obtain a license from the Federal Communications Commission. An application Form 505 for such a license is packed with most commercial transmitters and kits. If you make your own transmitter, you can obtain Form 505 from hobby shops, R/C suppliers or by writing to the Federal Communications Commission, Washington 25, D.C. The forms may also be had by applying in person or by mail to any local FCC office, located in most large cities in the U.S. Regardless of where you obtain them, they must be returned *only* to the main FCC office at the Washington address.

There is no charge for the forms or for the license, but the license must be notarized before you return it (the notary public usually makes a small charge – often 25¢ – for this service). Also, before you send in the forms, you must obtain a copy of the FCC rules and study Part 19 of the Citizens Radio Service carefully. You certify that you have these rules when you sign the FCC forms. The rules book costs $1.25 and may be available from some hobby shops or R/C suppliers, but you can always get it by sending $1.25 to the Government Printing Office, Washington 25, D.C.

Be sure you use only those Form 505's dated September 1958 or later. You will receive a page of instructions plus six additional sheets, five of which must be filled out and returned to the FCC. One of the six sheets you keep for your own records. Five sheets sounds like a lot of work but they are all duplicates and you can use a typewriter and carbon paper if you wish.

Briefly, here is what the license allows: You can operate a transmitter of 5 watts input or less for the radio control of models or other objects on any of six frequencies (26.995, 27.045, 27.095, 27.145, 27.195 and 27.255 mc) under the so-called class-C license. You can operate a class-B transmitter of the same power on 465 mc, but in this case only type-approved transmitters are legal, and only two such transmitters have been approved by the FCC (the type-approval number appears on such transmitters). You can, of course, make your own transmitter for 27-mc but *not* for 465 mc. Operation of your 27-mc unit is subject to preliminary checking which we will cover a little later.

The FCC license covers the "station" only – no operator's license is required. Therefore you can allow anyone to operate your transmitter on the assigned frequencies as long as you are present to supervise. Subject to general citizenship restrictions, any person 12 years or older may obtain an R/C license. Class-B and -C stations are the *only* ones allowed to engage in radio control. Class-A licenses are generally for fixed communications stations working in the vicinity of 460–470 mc, while class D covers portable voice-communication stations whose frequencies are interspersed with those set aside for R/C (class-D stations can also operate on 27.255 mc). All class-B and -C stations are considered by the FCC to be "portable" and may be operated any place in the United States.

Class-C transmitters must maintain frequency stability within $\pm .01\%$ if power input to the tube connected to the antenna is 3 watts or less, and within .005% if input is between 3 and 5 watts. With proper transmitter design and tuning, frequency stability is governed by the crystal used, and only crystals certified by the supplier to be within these limits should be purchased.

Rather sweeping changes in the R/C rules were made by the FCC in 1958, and further "interpretations" were given out late in 1959. Any transmitters in existence as of Sept. 1, 1958 can be kept in service until June 15, 1963, or until the current Citizens license of the owner (obtained before Sept. 1, 1958) expires. In either case, the transmitter must then be altered, if necessary, to conform to present rules. These dates apply to both class-B and class-C transmitters. Since 465-mc class-B units may not be constructed by the owner (or even serviced in any way, except by a first- or second-class licensed operator, other than to replace batteries) we will not cover them further in this book.

These "interpretations" went into effect on Nov. 15, 1959. The commission points out that these rules had actually been in Part 19 all along but had never been enforced; after the November date they were to be enforced. The rules state that all transmitter tests and tuning while radiating power (in other words, connected to an antenna) made either during construction or in use shall be made by or under the supervision of a person holding a first-or second-class commercial radio operator license, either radiotelephone or radiotelegraph. Such licensee must certify that the transmitter conforms to the existing FCC rules on power input, frequency, etc. This means, of course, that it is not legal to tune up either any commercial equipment you might purchase (whether in kit or finished form) or any transmitter you might construct yourself — whether from data in this book or from other sources. Thus you cannot legally change crystals to shift among the six R/C spot frequencies, or even recheck tuning to assure best power output for a ground type transmitter when used on various surfaces.

There is one slight out in this provision. If you purchase a transmitter (or a kit) which has all the frequency-determining elements sealed by the maker, and he certifies that the frequency will remain stable regardless of what tuning you might do to the output circuits of the transmitter (and that you will not exceed the 3- or 5-watt input maximum, as the case may be) you can build, tune and operate the transmitter without certification and check by a commercial operator. If you purchase a kit or finished transmitter, make *sure* a written statement covering these provisions is packed with it.

Filling out the license forms

While they look rather imposing at first glance, the forms (see pages 122 and 123) are simple. They cover all possible licenses — class A through class D in the Citizens Radio Service — and many of the questions do not apply to class B or C at all. One of the large sheets included with Form 505 is labeled "work sheet" and you should fill this one out first, to make sure you know how to do the job. Do it in pencil, as you keep this sheet. When you are sure you have everything correct, fill out in ink or with typewriter the one other large sheet and four small sheets. Briefly, the items you must include are: *Item 1* — For 27-mc operation, put "Class C" under 1a and 1b and number of transmitters you have under "Mobile." Don't put anything under "Base" or "Fixed" in Item 1. *Item 2* — Your name and full address. *Item 3* — Skip this. *Item 4* — Check "C" (for 27-mc operation). *Item 5* — Write "In vicinity of your home town or county" or "In the state of ———." *Item 6* — Skip this. *Item 7* — Check the "Indi-

CITIZENS RADIO SERVICE

(Refer to "Instructions for Completion of FCC Form 505 and FCC Rules Pertaining to Citizens Radio Service)

DETACH WORK SHEET, FILL OUT IN PENCIL, COMPLETE REMAINING SHEETS ON TYPEWRITER AND SUBMIT TO FEDERAL COMMUNICATIONS COMMISSION, WASHINGTON 25, D. C.

FCC Form 505
September 1958

Form Approved
Budget Bureau No. 52-R123.8

CITIZENS RADIO LICENSE

This authorization permits the use only of transmitters which: (1) Are listed under Special Conditions below, (2) appear in the Commission's "Radio Equipment List, Part C", or (3) in the case of Class C or Class D stations, are crystal controlled.

1(a) FREQUENCIES	1(b) EMISSION	1(c) NO. OF TRANSMITTERS BASE	MOBILE	FIXED
CLASS C	CLASS C	—	ONE	—

2(a) Name (see instructions)
JOHN DOE

(b) Mailing address (number, street, city, zone, county, state)
1200 FULTON ST.
NEW YORK 77, N.Y.

3. Location of transmitter(s) at a fixed location
Number and street (or other indication of location)

City | County | State

Latitude ° ' " | Longitude ° ' "

4. Class of station (Check one)
A ☐
B ☐
C ☒
D ☐

APPLICANT'S FILE COPY

FOR COMMISSION USE ONLY

CALL SIGN

5. If mobile units, or other class of station at temporary locations, are included in this authorization, show area of operation
STATE OF NEW YORK

6. Location of control point(s)

FOR COMMISSION USE ONLY

Special Conditions:

SHEET

Term of authorization: This authorization is effective ______
and will expire 3:00 A. M. EST. ______ and is subject to further conditions as set forth on reverse side.

By direction of the FEDERAL COMMUNICATIONS COMMISSION

SECRETARY

7. State whether applicant is (Check one)

Individual ☒ Partnership ☐ Association ☐ Corporation ☐

Governmental Entity ☐

(If applicant is a corporation or an unincorporated association, Part II on the reverse side of this form must be filled out.)

WORK

8. (a) Will applicant own the radio equipment? YES ☒ NO ☐

If answer is "No", give name of owner ______

(b) If not the owner of the radio equipment, is applicant a party to a lease or other agreement under which control will be exercised in the same manner as if the equipment were owned by the applicant? YES ☐ NO ☐

(c) Will applicant have unlimited access to the premises/station and will effective measures be taken to prevent use of the radio equipment by unauthorized persons? YES ☐ NO ☐

9. How is radio to be used in connection with applicant's business or personal activities? (Use space on the reverse of this page or attach additional sheet if necessary.)

FOR CONTROL OF MODELS

10. If you are now authorized to operate the station referred to in this application, give call sign and present frequency, and state why you are filing this application

FOR COMMISSION USE ONLY

11. If for Class C or Class D stations, are transmitters crystal controlled? YES ☒ NO ☐

12. If antenna will extend more than 20 feet above ground or more than 20 feet above an existing man-made structure on which it will be mounted, give the following:

(a) Overall height above ground of tip of antenna ______ feet.

(b) Elevation of ground above mean sea level at antenna site ______ feet.

(c) If mounted on an existing

(1) antenna structure, give call sign of user ______

(2) man-made structure, submit profile sketch showing structure height and antenna height.

13. If this application is for a fixed station, attach a diagram showing the locations of all the other stations at fixed locations (base or fixed) in the system and the area of operations of the mobile units, if any.

14. If it is proposed to use a transmitter which does not appear on the Commission's "Radio Equipment List, Part C", or a non-crystal-controlled transmitter in a Class C or D station, describe such transmitter in detail. (See Subpart C of Rules). Attach Additional Sheets.

All the statements made in the application and attached exhibits are considered material representations, and all the exhibits are a material part hereof and are incorporated herein as if set out in full in the application.

I certify that I have a current copy of Part 19 of the Commission's Rules governing the Citizens Radio Service.

If an individual or partnership applicant, I also certify that I, or each partner, is a citizen of the United States, and eighteen or more years of age (or twelve or more years of age if for Class C). I also certify that I am not (or if a partnership, corporation, or association is the applicant, that each partner, the corporation, or the association is not) the representative of any alien or any foreign government; that I waive any claim to the use of any particular frequency or of the ether as against the regulatory power of the United States because of previous use of the same, whether by license or otherwise; that I accept full responsibility for the operation of, and will retain control of any Citizens Radio Station licensed to me pursuant to this application in accordance with the law and the Rules of the Federal Communications Commission. I further certify that said station will not be used for any purpose contrary to federal, state or local law.

Subscribed and sworn to before

me this ______ day of ______, 19 ____.

Notary Public ______ SEAL
(OR NAME AND TITLE OF OTHER PERSON COMPETENT TO ADMINISTER OATHS)

My commission expires ______

John Doe
SIGNATURE OF APPLICANT (MUST AGREE WITH NAME AS SHOWN IN ITEM 2(A))

By 1200 Fulton St, New York 77, N.Y.
(DESIGNATE APPROPRIATE CLASSIFICATION BELOW)

☒ Individual Applicant

☐ Member of Applicant Partnership

☐ Officer of Applicant Corporation or Association

☐ Official of Governmental Entity

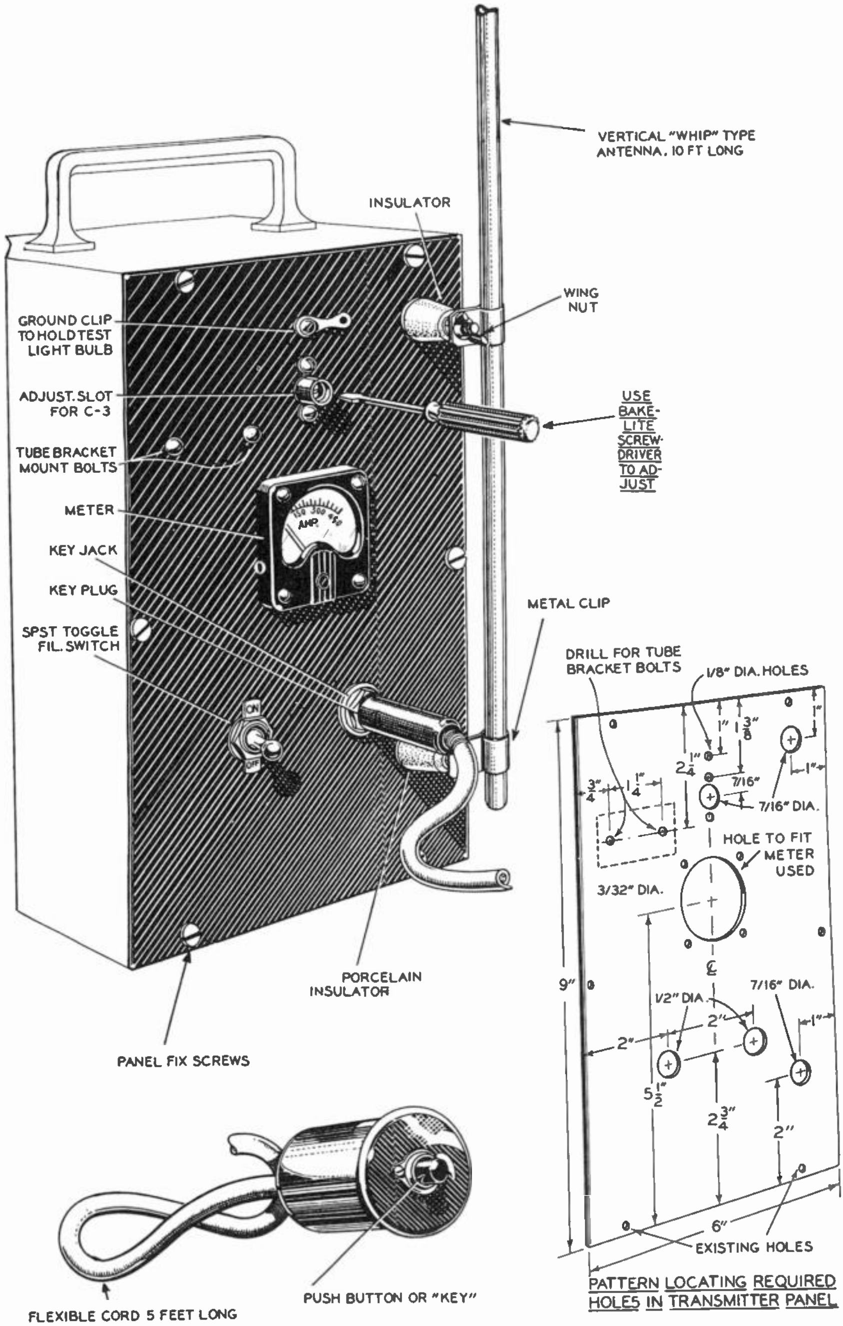


Fig. 601. *Simple crystal-control transmitter is contained in 5 x 6 x 9" black crackle finished steel case. Aluminum case would save considerable weight.*

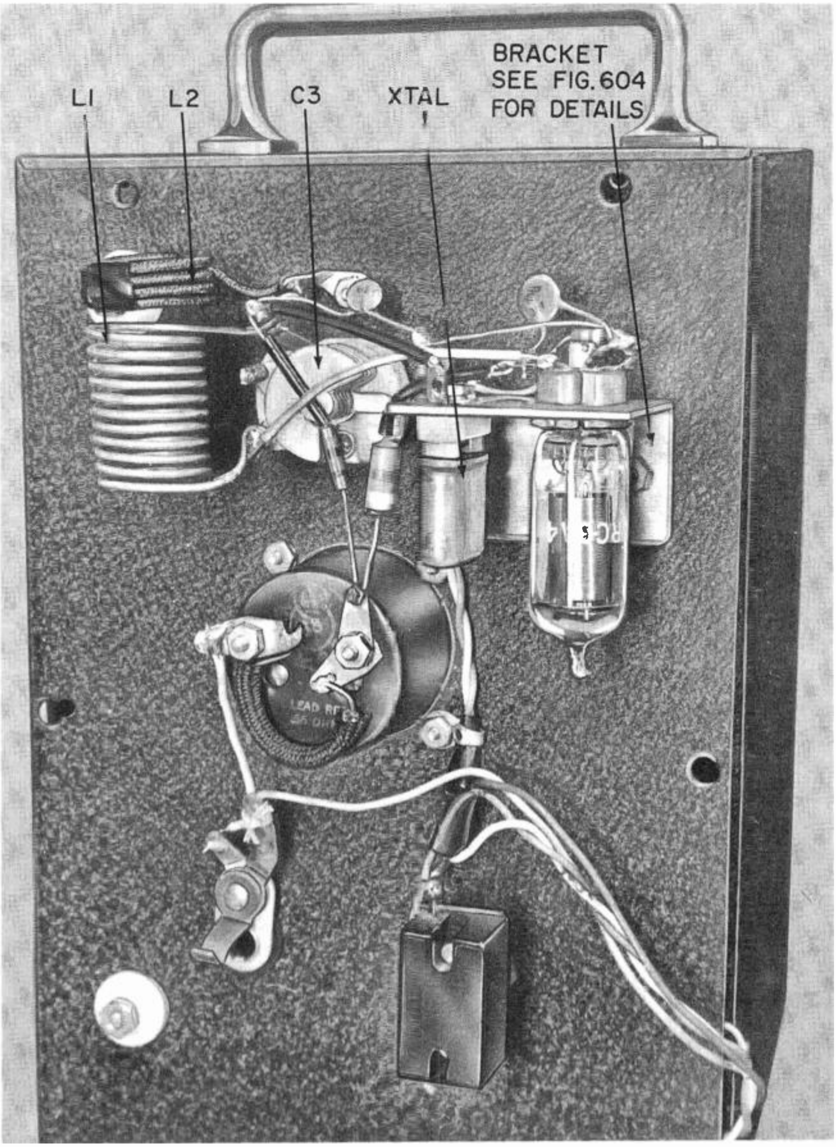


Fig. 602. *Tube and crystal are held in sockets on small bracket. They stay in sockets well, but rubber bands or adhesive tape would insure that they don't pop out during transit. Meter has external shunt.*

vidual" box (or whichever one applies). *Item 8* — If you own the equipment, check box in line with 8a; if not, ignore 8a, put name of owner on dotted line, put check in box opposite 8b. Ignore line 8c. *Item 9* — Write something like "For radio control of models" (or whatever you intend to control). *Item 10* — This is *only* used for renewal of your license (it's best to send in the renewal form several months before your present license expires, to allow for possible time lag at the FCC and in the mails) or for change of address and similar matters. If this is your first license application or your old license has already expired, ignore Item 10. *Item 11* — Answer here *must* be "yes." Ignore Items 11 and 12. Read carefully the material below the lowest heavy line on the form, and also on the reverse upper half, then go to a notary, sign the form and mail it direct to the Federal Communications Commission, Washington 25, D.C.

One often hears it stated that R/C operates on "license-free" frequencies; nothing could be further from the truth. However,

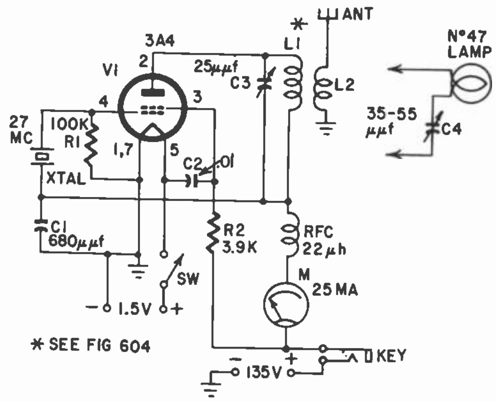


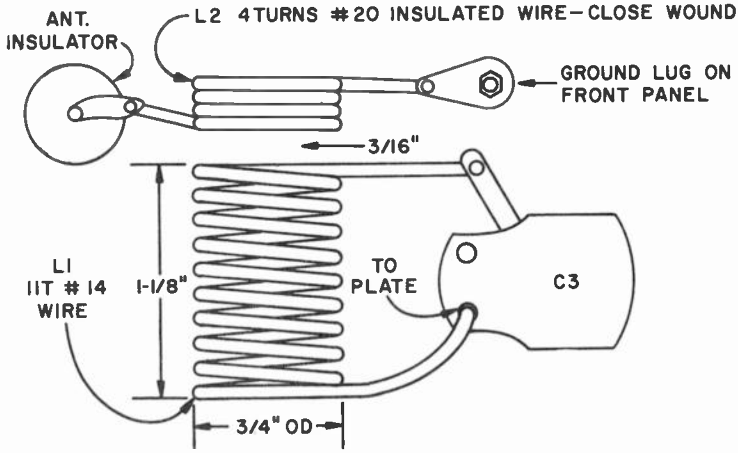
Fig. 603. *Circuit is simple, stable, puts out ample power for radio control purposes. Test lamp is connected across L2 (antenna collapsed or removed).*

the necessary license is simple to obtain and you don't have to take any kind of examination, as you do when applying for a radio amateur license. The more class-C license applications the FCC receives, the more attention they are apt to pay to our needs — so it is incumbent upon every R/C experimenter and modeler to send in his form and operate legally.

Many R/C modelers have obtained ham licenses so that they can operate on the various amateur frequencies. The 50-mc band is the most widely used, with some operators obtaining good results on 220 mc and other ham frequencies. The amateur technician license is the most popular for those R/C'ers who wish to work on the various ham bands.

A simple crystal-control transmitter

Now that the legal angles have been covered briefly, what about the actual transmitters themselves? Until quite recently, a large majority of radio-control transmitters were single-tube affairs and



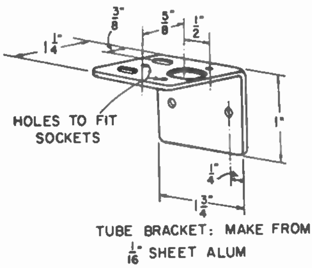


Fig. 604. *Space L1 turns to 1⅛ inches. L2 is close wound with insulated wire. A wrap or two of tape helps hold turns snug. Same bracket could be used with crystal and tube projecting to right. Most leads could then be made shorter.*

were entirely adequate. A great amount of power is simply not needed for reliable radio-control work – in fact, we don't have to have as much as the 5 watts allowed by the FCC. We do have to use crystal control. Even though a transmitter has a "legal" crystal in it, this is no guarantee that it can't operate on the wrong frequency, or that the frequency can't drift to a greater extent than the rules specify. We must use the right crystal, have a circuit designed to allow it to work at the frequency its maker intended and operate the transmitter so that these results will be assured. A simple transmitter (front view) is seen in Fig. 601; the rear view is seen in Fig. 602. The circuit is given in Fig. 603. The entire unit is housed in a 5 x 6 x 9-inch metal case that holds batteries large enough to operate for many hours before replacement. All of the circuit parts are mounted on the front panel, which can be removed for construction or service. Normally, the rear of the case is removed to test or change batteries.

A small metal bracket (Fig. 604) holds the tube and crystal sockets, these elements hanging downward; they stay in place very well, but rubber bands or adhesive tape may be used to bind them more securely. Coil L1 is supported by C3, while L2 is held by the antenna post and the ground connection to the panel (scrape any paint away at this point to assure a good connection). Make the wiring as short and direct as possible. The lug of C3 which contacts the center shaft (rotor) of the unit should go to the radio-frequency choke (and the crystal socket).

The rather odd mounting of these parts comes about because this transmitter is a revised version of one which has been widely used in the past. First known as the Air Trails Annual Transmitter, it also appeared in its original form in the older edition of this handbook. The mounting of components is not critical as long as leads are kept short. You can remount the parts and still obtain fine results. If C3 were mounted farther to the left (viewed from the rear), the tube and crystal socket bracket could be vertical with V1 and the crystal projecting toward the right, and very short connections to all parts could be achieved.

The tip of the antenna must be about 10 feet high, since the lower 6 inches or so is inactive – connection being made at the top insulator. Either a collapsible or a sectional antenna can be used; both are available from radio-control suppliers.

Be sure to use insulating washers on both sides of the panel when mounting the phone jack, and connect the frame of this jack (the threaded part) to the milliammeter. Slip a piece of insulating tubing over the projecting stub shaft of C3 to prevent shorts; most users prefer not to have a knob on this capacitor so it can't be altered by prying fingers.

The case will hold three 45-volt B-batteries and one 1½ volt cell, all of which are connected by plugs on the battery cables. Wooden spacers keep the batteries from sliding forward toward the panel, and angle brackets on the back of the case hold the A-battery from slipping sideways. The A-battery will run down first but the B's should last many months, as there is no drain on them unless the key is depressed.

Tuning the one-tube transmitter

Make your initial tuneup with a No. 47 pilot bulb connected in series with a 35 — 55 μμf ceramic trimmer capacitor. Connect these two parts between the upper antenna terminal and the lug on the front panel. Don't use a bulb socket — solder the leads directly to the base. The capacitor permits adjustment of the tuning so that the bulb will draw maximum power from the transmitter; it should be set at about mid-range for first trials. The bulb and capacitor could be attached to the case front permanently for handy access whenever desired. If this is done, place them directly below the upper antenna insulator; the antenna

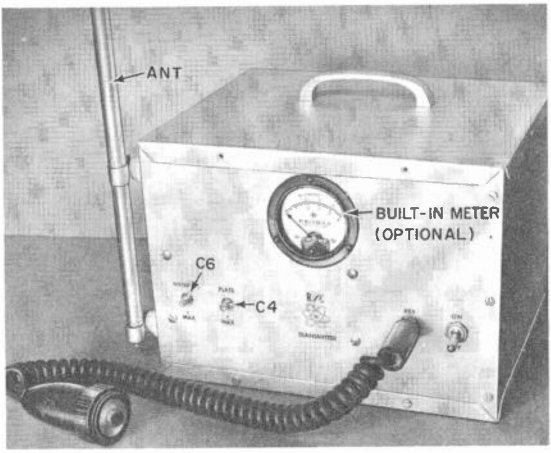


Fig. 605. *Known as the Solo-Mac, this transmitter is of MOPA type, but has only one tube, a dual-section 3B7. Meter is not absolute necessity but is strongly recommended. Handle on cover is off-center so transmitter "carries" level; battery weight is concentrated along rear of case.*

will then afford physical protection. If a collapsible antenna is used, it need not be removed when testing with the bulb circuit — just shove the sections down to make the antenna as short as possible.

It is smart to use only two B-batteries for preliminary trials. The coupling coil should be in the approximate position shown in Fig. 602. Simply turn on the filament switch and push the key button while rotating the tuning capacitor (C3). It is preferable to use an insulated screwdriver for the latter, to prevent the possibility of shock; if a metal tool is used, be sure to hold it only by the insulating handle.

At some point of rotation, the meter current should drop suddenly and the No. 47 pilot bulb may glow dimly. Notice that as you tune from high frequency (with capacitor plates fully open) to low, the meter drops smoothly to a low point (where the bulb will be brightest), then suddenly jumps up again as you turn just a little beyond this point of maximum output. In field use, the capacitor must be backed off a little toward the high-frequency side for safe operation; if this is not done, the circuit might cease operation as the key lead is moved around, or when someone comes near to the antenna.

If all seems well with the 90-volt B-supply, hook in the other battery and try again. This time the bulb should light up brightly, and the meter should indicate no higher than about 20 ma. If it does with C3 set a little to the high-frequency side of the position of brightest illumination, reduce the capacitance of the series capacitor (C4) a bit and retune C3. On the test transmitter, best output was at about 19 ma. Any attempt to load the transmitter to higher plate current resulted in lower output. The plate current will go up to 35 ma or more when the circuit is not oscillating; do not hold the key down in this position as the tube cannot stand this high current for any length of time. Just punch the key button briefly as you tune C3, until the current drops to reasonable values.

This transmitter operates at a power input of about 2½ watts, so you can use either 0.01% or 0.005% crystals in it. Power output is around 0.7 watt — sufficient for any control purposes. With the antenna installed and extended to the full 9½ to 10-foot length (a few inches longer or shorter will make little difference in operation), the set may be tuned-up for field use. It *must* be sitting on the ground or on some conducting surface to radiate properly with the antenna. Some users place the transmitter on their car hood, with a layer of cardboard under the set to prevent scratches. Metallic contact is not necessary — the capacitance of the case to the ground or car hood does the job.

Tune C3 and check the meter reading; if it is lower than 20 ma by very much, push L2 closer to L1 and try again. Touch up C3 every time the transmitter is used, as ground conductivity varies widely. If the plate current is lower than 17 ma, couple L2 more closely to L1. You will eventually find a position for L2 that will be useable in most locations. Don't forget to back off C3 a little to the high-frequency side of the point of greatest plate-current dip when you are using the transmitter.

Never tune up without either the antenna extended (and the transmitter on a conducting surface) or with the bulb-capacitor combination connected instead. The latter is very handy for receiver tests at close range, as for testing in the shop; quite a strong signal may be had close to the transmitter, but by moving away from the receiver you can simulate a weak signal. Don't leave the bulb in place when you are using the transmitter for actual model control in the field, as the power used to light the bulb will naturally be subtracted from that going out via the antenna.

Simple MOPA transmitter

MOPA means Master Oscillator, Power Amplifier and, in such a transmitter, there must be at least two tubes, one acting as the crystal oscillator and the other as an amplifier to boost the oscil-

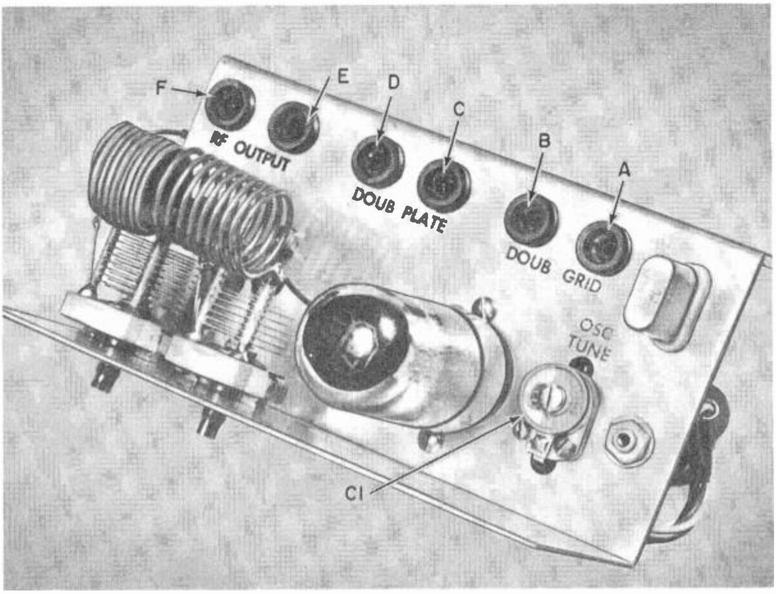


Fig. 606. *Small aluminum chassis carries working parts of Solo-Mac. Row of pin jacks along rear allows meter to be shifted to three different circuits. Nut to right of C1 holds coil form carrying L1. C6 is at lower left, C4 to right of it.*

lator power and send it along to the antenna. Though they are more complex than the transmitter of Fig. 603, such units have certain advantages. First, they are easier on crystals, and make it a simple matter to keep within the FCC regulations as to transmitter frequency stability, while still putting out a strong signal. Second, they are more stable in use: operation on grounds of varying conductivity, approaching or even grabbing the antenna, waving a long key lead around, all have little effect on frequency or ability of the transmitter to keep in operation (though they may change actual power output). Due to necessity of maintaining proper antenna loading, it is still advisable to touch up the tuning of the amplifier stage each time the transmitter is used, however.

The transmitter shown in Figs. 605, 606 and 607, known as the Solo-Mac, is a relatively simple form of MOPA in which a single tube is used; however, the tube (a type 3B7) has two separate triodes in the single bulb. V1 acts as the oscillator and V2 the amplifier, but the latter is generally called a doubler. The crystal and V1 operate at half the output frequency, while V2 doubles this to the frequency we want to radiate. While this arrangement is not as efficient as using a straight amplifier at V2, it is simpler to put into operation and more nearly foolproof, especially for the modeler who is not too versed in transmitter operation.

Triode crystal oscillators are not generally used as they often load the crystal heavily. However, the circuit shown for V1 is very good in this respect and can be highly recommended. The doubler section of the 3B7 operates at about the same input as does the 3A4 transmitter already described, but is considerably more efficient, producing an output of about 1 watt. Of course, the current "lost" in V1 is not counted here and must be considered pure waste, as far as actual power output; but by the same token, so is the power consumed by the screen grid circuit of the 3A4. Efficiency is boosted considerably by use of higher plate voltage on the 3B7, but currents in each of the two tube sections should be kept to 14 ma or lower.

The 3B7 is very similar to the 3A5 though physically larger; the 3A5 can be used in this transmitter with about the same results, but the grid leak (R3) should be of a higher value – perhaps 47,000 to 82,000 ohms. The 3B7 was found to produce a bit more output than the 3A5; the latter has a maximum voltage rating of only 135 volts, while the 3B7 is designed for 180 volts maximum.

Though the basic circuit is considered quite simple, several changes have been made to aid in tuning. The antenna circuit contains a variable capacitor to simplify the chore of tuning the antenna for use on various ground surfaces. Three sets of pin jacks on the chassis allow a single meter to be shifted to various parts of the circuit; in normal field operation the meter would be used with jacks E – F, to give an indication of power output. A 5-ma dc meter is used; in jacks A – B it is used in this range (the 1,000-ohm shunt resistor does not change the reading appreciably) to read grid current of V2, which is helpful when first tuning up. Jacks C – D show the plate current of V-2, and again we caution — don't operate the tube at higher than 15 ma. Actually, the best power output with most 3B7's is at 13 – 14 ma. Resistor R5 is supplied with the meter specified, and changes it

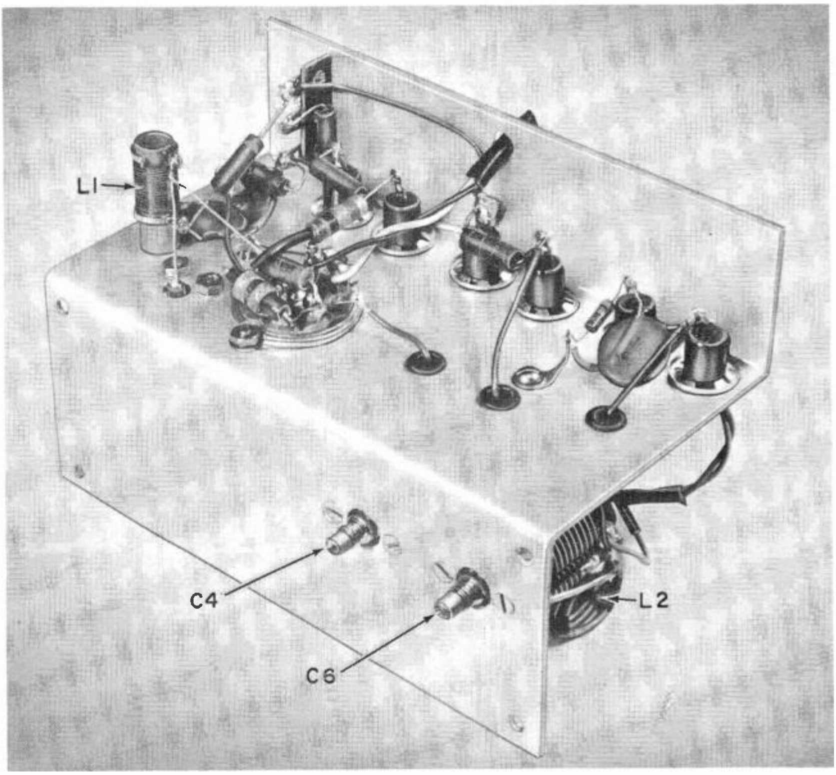


Fig. 607. *Several small circuit parts are mounted right on socket; pin 5 should not be used as a tie point since some 3B7's use it for internal part mounting. Four bolts secure entire rf assembly to front panel of case.*

to read 25 ma full scale. Jacks E – F allow M to indicate actual rf power output. This is simply a comparative reading, depending upon resistor R6, which is a single strand taken from the flexible hookup wire used in the transmitter. It is adjusted to allow M to read perhaps two-thirds full scale, when V2 is loaded to 14 ma or so. Start with the wire on the short side to protect the meter. Lengthen it until you get the desired reading and then solder it.

All parts except the jack and the switch are mounted on a small chassis (see Fig. 608) bent from sheet aluminum. Note that no core is used in L1. This circuit is tuned by C1. Variable capacitors C4 and C6 are attached to the chassis with flat-head screws, so the entire rf unit may be assembled, wired and tested before putting it in the case. Wire the rotors of C1 and C4 to the chassis so that they will not be "hot" with high voltage. Connect the threaded part of the jack to the transmitter (not to the B-battery) and use insulated washers. The circuit of the transmitter is shown in Fig. 609.

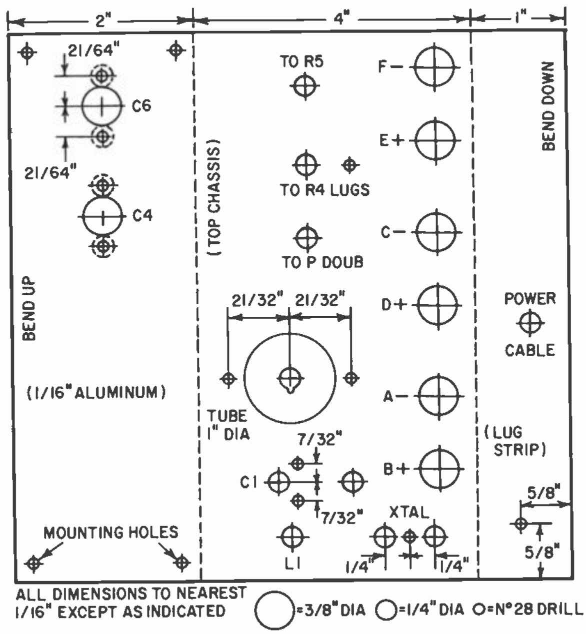


Fig. 608. *Chassis layout (not to scale). Check mounting holes for parts you use before drilling; this is a top view of the chassis before bending.*

Wiring is straightforward. Leads carrying rf should be as short and direct as possible. It is advisable to use solid wire for all rf connections in the plate circuit of V2, and for L3. Make the battery leads long enough so they won't be too tight when you are changing batteries, etc.

Preliminary tests of the MOPA

Make your first tests with only 135 volts until you are sure everything will tune all right. Connect the meter leads to jacks A and B, and rotate C1. You should get an indication of grid current with the capacitor around mid-position (with the silvered portion of the rotor toward the tube). The meter may read about

1.8 ma. Connect a No. 47 bulb from the case to the top antenna post, set C6 at about mid-position and rotate C4. At some position, again near mid-scale, the bulb should glow. With the meter leads in jacks C and D there will be a reading of perhaps 10 ma.

There is only one way you could go wrong on tuning; it is possible that you might set C4 to produce triple the crystal frequency, rather than double. The best way to check this is with a calibrated field-strength meter. If the transmitter is built exactly as specified, this triple-frequency point will occur with C4 near

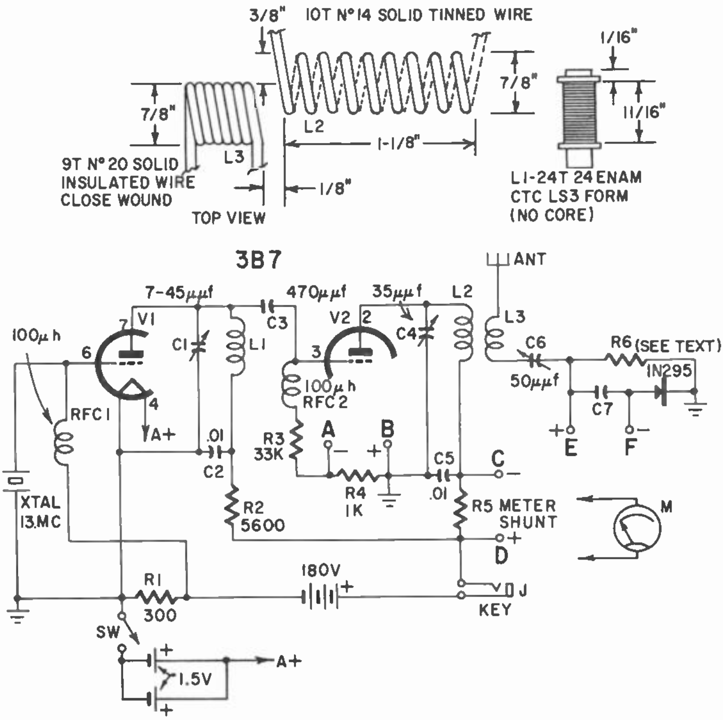


Fig. 609. *Both rf chokes are National R-33, 100 microhenry. M is basic 5 ma meter, R5 selected to shunt it to 25 ma full scale reading. If a smaller case is desired, smaller B batteries may be used, with single 1.5 V unit for A supply. Approximate spacing shown in upper drawing for L2 and L3 proved correct on test transmitter. Put several wraps of tape around L3 to hold turns tight. L1 is wound on commercial coil form, but core is removed.*

minimum capacitance (plates fully unmeshed). The proper double-frequency position will be with plates about half-meshed.

If all is well so far, you can add the other B-battery and make a final tuneup. Again shift the meter to jacks A – B; the reading here should be 2 to 2.3 ma or so. Don't forget to back off C1 toward the high-frequency side (move the silvered part of the top plate *away* from the end with mounting screws) to get stability of tuning. As a rough guide, this detuning should be enough to reduce the grid current reading about 0.1 ma. Shift the meter to C – D and retune C4, making sure the plate current is no higher than 15 ma. As you tune C4 through resonance, the current will drop sharply and the bulb should be brightest at the *lowest* dip in plate current. If the meter reads less than 14 ma at the dip, increase the capacitance of C6 a bit, then retune C4. Note that you never *tune* C6 – just shift it a little either way, then retune by moving C4 back and forth for best output and lowest plate current reading.

When you have discovered the best settings for C4 and C6 that give maximum bulb brilliance but with V2 plate current about 14 ma, you can shift the meter to jacks E – F. Tap the key and see if the meter reads near scale maximum; if it does, shorten the wire that constitutes R6 a bit and try again. The meter should read about three-fourths full scale with the lamp-bulb load. It will generally read somewhat lower with the antenna. Readings with an antenna connected are a bit difficult to interpret but, for any given set of conditions, you should always vary C4 and C6 to get maximum meter reading – while making sure not to exceed the 15-ma plate current for V2. The meter would be more useful if there were dpdt switch on the panel to shift the meter connections between jacks C – D and E – F without having to remove the cover of the case.

Tube characteristics

The 3B7 tube (and also the 3A5) has an unusual characteristic. If, after tuning up this transmitter, you were to pull the crystal out of its socket, the plate currents of the two sections of the tube would not fly up to very high values as they would with most tubes. They would go to about the same values as they do with the crystal in place and everything operating normally. This feature prevents the tube from destroying itself if the crystal stops oscillating, but makes it a bit difficult to know from looking at the plate meter if you are putting out a signal or not. This was the main reason why jacks E – F and the output monitoring circuit were added; if you see a reading on the meter when it is plugged in E – F, you can be *certain* the outfit is transmitting.

If you can't make V2 draw 14 ma no matter where you set C6, move L3 closer to L2 and try again. Remember that you tune for *lowest* reading of the meter at jacks C – D but for *highest* reading at E – F. C4 and C6 interact to a considerable extent and you should never shift C6 without retuning C4. We'll give a few more notes on how to set C6 later in this chapter.

This transmitter draws about 220 ma from the A-batteries, but by using two of these in parallel very good life may be had. However, the batteries should be replaced when they drop below 1.3 volts with the filament switch on. The B-batteries can drop to 140 volts or so before they need replacement, but power output will be reduced at this voltage. However, they will last many months with normal use. When operating normally, V1 draws about 8 – 9 ma, but there is little need to monitor this. If you get the specified grid current for V2, you can be sure V1 is doing all right. With no antenna or bulb load the plate current of V2 will drop to 5 or 6 ma at resonance. For shop test work, you can use this transmitter with V2 unloaded or loaded very lightly, without harm (unlike all other transmitters covered in this book), to save B-battery power. Just be sure C4 is tuned to resonance at all times.

A single length of 1 x 1-inch aluminum angle strip is cut to hold all the batteries snug. Make sure none of the self-tapping screws which hold the top and bottom on the case can dig into a battery and short it; relocate any that do. (See Fig. 610.)

Antennas and how to load them

Both the transmitters described so far have been designed for quarter-wave antennas, which are about 9½ feet long for 27-mc. A quarter-wave antenna *must* be operated with a good ground, for the latter takes the place of the missing quarter-wave of wire or metal (it takes a *half*-wave antenna to get good radiation from a transmitter). But 9½ feet is not a sacred length, and the antenna may be several inches longer or shorter and still work well; if there is any great variation, it is better to be on the long side. It is not necessary for the transmitter to be actually touching the ground, as the capacitance between the case and ground will assure good operation, especially with a case that has fairly large bottom area (as has the one in Fig. 605). If you raise such a transmitter even a foot away from the earth (unless it is placed on another conducting surface such as a car hood or top), the capacitance effect is reduced to the point where it will be difficult or impossible to load the transmitter properly.

Ground conductivity varies greatly, of course, depending on the amount of moisture in the soil and the nature of the surface – grass, bare dirt, concrete or other paved road, airport runway, etc. If, in Fig. 609, the antenna coupling coil is made over-large, then its effectiveness can be reduced by C6. This allows a quicker and more effective adjustment to bring antenna loading to optimum on most types of earth surface the modeler is likely to encounter. C6 will not, however, compensate when the transmitter is on extremely dry ground or when the outfit is raised above ground. If it is necessary to operate under such conditions, you can provide an artificial ground by connecting about four radial wires to the transmitter case. Make them approximately as long as the antenna is high (shorter wires will help but use more of them) and extend them along the top of the ground away from the case in four directions. These wires may be insu-

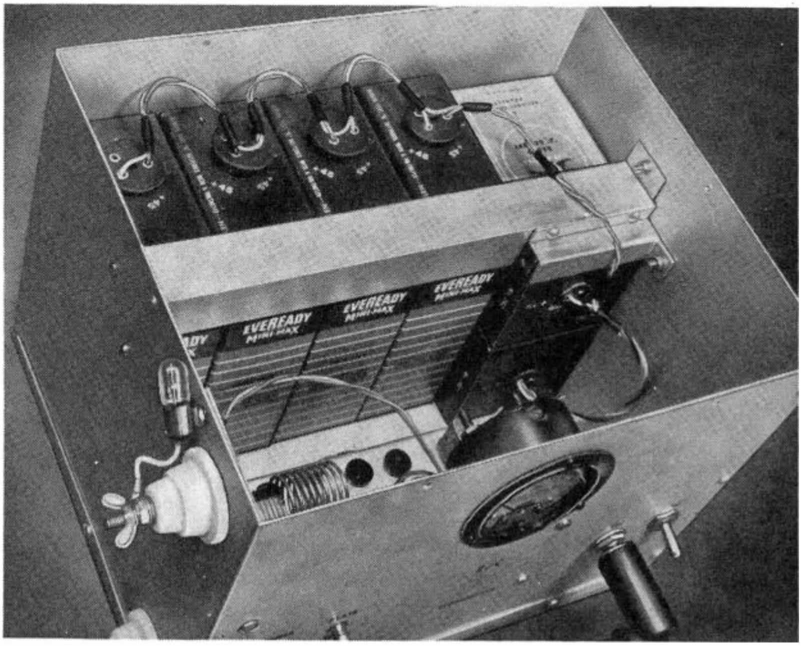


Fig. 610. *Large size batteries were chosen for extra long life. Case still has room enough at front right for addition of a pulser, modulator, etc. Test lamp is seen attached to upper antenna support at left.*

lated or bare — it makes no difference, for again it is their capacitance to earth that does the job. Ordinary flexible hookup wire is useful for such a "counterpoise."

When you place your transmitter on the ground and turn it on, the first action after closing the on – off switch should be to push the key button briefly and vary the plate tuning capacitor to obtain minimum current reading on the plate meter. If this reading is lower than specified for the particular transmitter, you will know (provided your batteries are good) that the antenna is not loading the transmitter sufficiently. If there is no antenna tuning capacitor, move the coupling coil closer to the plate inductance and again vary the plate capacitor. Repeat this until you see the plate current dip to the desired value.

In transmitters with a variable loading adjustment, (such as C6 in the Solo-Mac) simply increase the capacitance of this component a slight amount, then retune the plate capacitor again. Any change you make in the antenna system will call for retuning the coupled plate circuit, as there is considerable interaction.

Quarter-wave and half-wave

Many hand-held transmitters use a much shorter antenna, but in most cases this is acting as a shortened quarter-wave and the operator himself acts as part of the "ground quarter-wave." Such antennas are often only 3 feet long but, with a sensitive receiver and correct tuning at both ends of the control system, they allow ample range of operation.

The best antenna of all is the half-wave. It is self-contained and does not depend upon the ground or anything else to take the place of a missing half. However, such an antenna on 27 mc would be some 19 feet or so long and very impractical. It is possible to "load" such an antenna with a coil inserted in its length, so that electrically it is still a half-wave long but mechanically it is considerably shorter. Any half-wave antenna is self-sufficient and will radiate near the ground or above. Since they, too, are used under portable conditions, half-wave antennas must have some sort of adjustable loading, or tuning arrangement. A variable capacitor does the job conveniently. Because it is not dependent upon a rather nebulous "ground quarter-wave" for efficient radiation, the half-wave antenna will generally be found to put out a stronger signal than will an equivalent quarter-wave type.

The actual radiation patterns of different types of antennas vary to a certain extent, of course; some project much of their power close to the ground, others at higher angles. The vertical antenna used almost exclusively in radio-control radiates fairly uniformly in every direction at right angles to the antenna, but often, there will be a rather "dead" area directly over the transmitter. Generally, an irregular radiation pattern is not of too much consequence in radio-control, because ranges are so short and receivers sensitive enough so that, even though the model is in what would be considered a dead area of the antenna (such as high over a vertical), good control can still be achieved. Still, it is well to be aware of such effects, as dropping battery voltages in the transmitter or receiver, or both, can reduce the effectiveness of the R/C link to a point where control is lost.

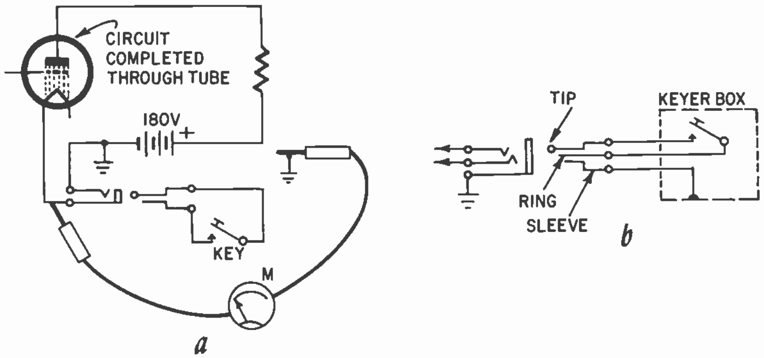


Fig. 611. *With the filament switch closed, tube conduction will allow full battery voltage to be measured to circuit ground (usually the transmitter case) as shown in the simplified circuit in (a). The three-contact jack and plug in (b) will offer some safety if the ground wire is connected through to the keyer box.*

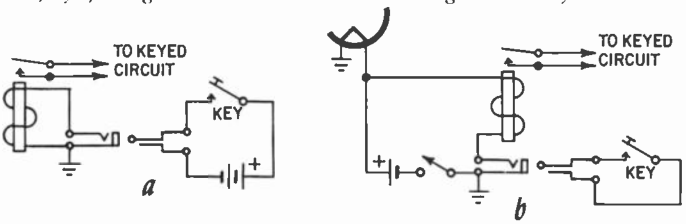


Fig. 612. *Keying relay will take little additional space in the transmitter case. Batteries can be in the keyer box (a) or the filament battery can be utilized as in (b).*

Warning — for your safety!

While the 5-watt output of these R/C transmitters is often looked on with disdain, the voltages involved can produce a bad shock. Under certain conditions of weather and an individual's health this can be fatal. Make every effort to prevent accidental contact with the B-plus voltage. If a single-circuit jack such as in the circuit in Fig. 609 is used, recess it so that it is not possible to touch the frame which is at B-plus potential when the keying device completes the circuit. Even with the frame grounded, when connected in the B-minus lead, (Fig. 611) part of the keying device will still have full battery voltage on it when open. A three contact jack will remove B-plus from the frame (which can now be grounded to the case) but the keyer will still be hot. For maximum protection use a keying relay circuit (Fig. 612).

chapter SEVEN

complex transmitters

THE transmitters described in Chapter 6 were both for the 27-mc frequencies (any of the six radio control spots) and of rather simple design. Here we will cover more complex units, some intended for tone operation, others for use on the Amateur 50-mc band.

Converted Mac II

The Mac II was, and still is, a very popular "high-powered" 27-mc transmitter. Many hundreds of them are in use. It was intended to come near the maximum 5-watt input the FCC allows for radio control purposes on 27-mc. At the time this transmitter was first described, the regulations were much more lenient than now and it has become necessary to revamp the old unit to bring it up to date. In doing so, the power input has been reduced somewhat, but the 1¼-watt or so output is ample for any radio-control purposes.

The original Mac II was based upon conversion of a surplus power supply unit (the PE157) that is no longer generally available. The case and most of the power supply parts of the transmitter seen in Fig. 701 come from this source. However, parts placement is not fussy and Mac II's have been made in a wide variety of shapes and sizes; even the rf unit (Fig. 702) can be changed around—if you know what you're doing. If not, better stick to that shown. The power supply and battery can be remounted to suit, so no chassis layout of the power supply chassis is given.

The power comes from a 2-volt storage battery (Fig. 703) that not only supplies plenty of high voltage for the transmitter, but is also used as an engine-starting voltage source. Not all glow plugs will stand 2 volts, so be sure you use only those that can. If the cable to the glow engine is fairly long, though, the drop will be sufficient to reduce the voltage to a safe level, even for 1.5-volt plugs.

Use a heavy duty switch in the 2-volt circuit, as there is some 5 amperes flowing here and a very small voltage drop will reflect a severe drop in B-voltage. For the same reason, wire the entire primary circuit with heavy-duty flexible wire; the kind sold for

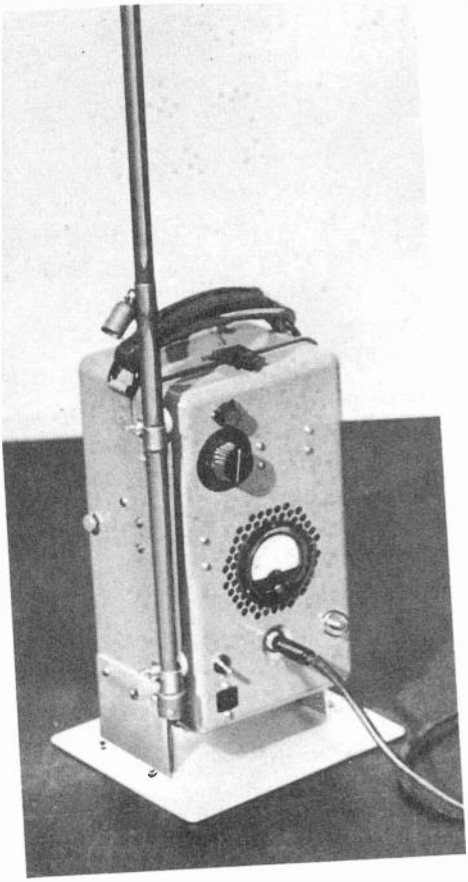


Fig. 701. *Originally called the Mac II, converted transmitter is now known as Numac II. External appearance is unchanged but rf section is now an MOPA. Same 2-volt vibrator power supply is used. Although the original outfit was built in a surplus case and used surplus parts, many Mac II's have commercial cases and use standard parts. Size and shape of case are not important, but follow rf chassis layout.*

auto primary circuit work is suitable. Several types of 2-volt cells are available, with capacity ratings from 20 up to 32 ampere-hours. Any of these will do a good job, though the highest capacity cell is preferable, of course. The cells are all the same external size. They come dry and you must add electrolyte and charge them. The charging rate varies according to capacity. Typical charging circuits are seen in Fig. 704.

In many respects, this transmitter is quite like that in Fig. 607 in that it is a MOPA, uses a 13-mc oscillator, 27-mc doubler circuit, and has a tuned antenna-coupling arrangement. Tune-up is much the same as for the Solo-Mac, and we won't go into it extensively here.

Since this transmitter (see Fig. 705) uses pentode tubes (the 3D6 is another surplus type widely used in radio-control and available from most radio control suppliers at low cost), you must be

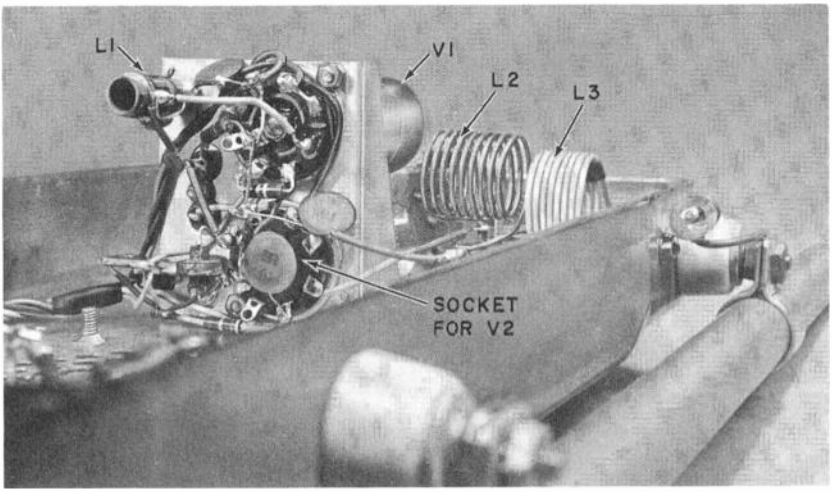


Fig. 702. *Underside of Numac II chassis shows two tube sockets at right, oscillator inductance L1 at upper left. L2 and L3 supported by C1, C2 and antenna post. Short lug strip at lower left of chassis holds ends of small parts. Projecting above chassis are the two tubes and the crystal in their sockets. Test bulb is seen near antenna post.*

careful when tuning. Unlike the 3B7, pentodes go up to very high plate-current drains when the crystal is not oscillating or the doubler circuit is not tuned to resonance. Furthermore, pentodes should always be run at about the designed plate current. If this current is allowed to drop considerably – as it might should the doubler plate circuit be tuned to resonance with no output load, the screen grid current will rise to a dangerously high level. The transmitter can be used without an antenna for shop testing by utilizing the faithful lamp bulb to load the output. In this case, use a blue bead No. 44 or 46 bulb.

The vibrator power supply is sometimes called "soft" – that is, it has poor regulation. The high voltage drops considerably as more current is drawn from it. With the key up, the voltage will rise to 230 or so but, under full load of this transmitter, you should

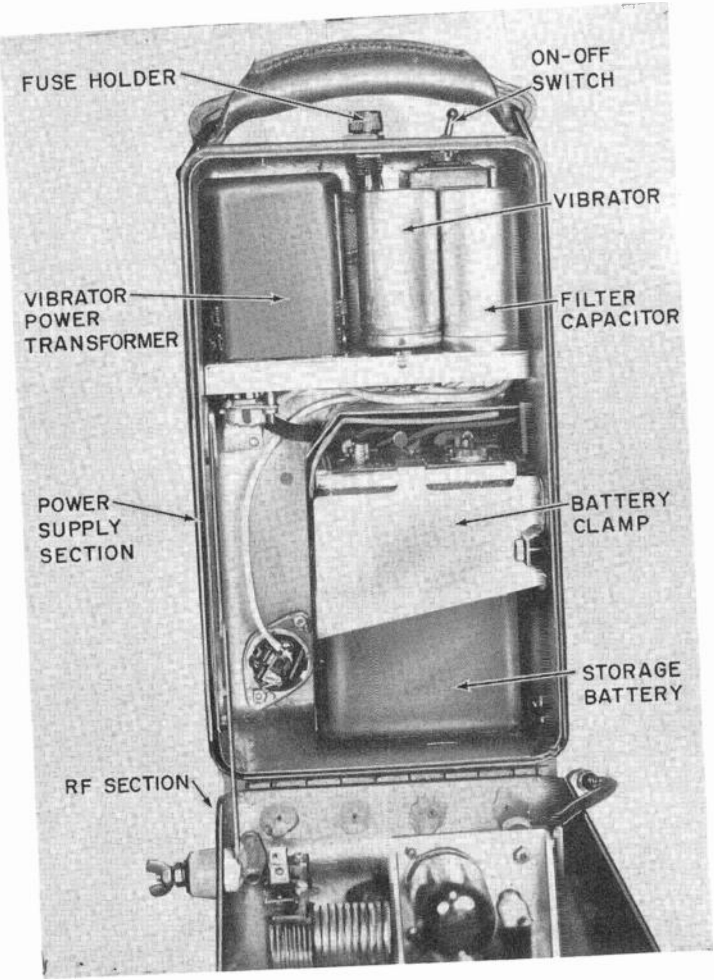


Fig. 703. *Power supply of Numac II is on upper chassis, a 2-volt storage cell at lower right. The socket seen on back of case (at lower left) is for cable used to start glow-plug engines and for battery charging. Due to voltage drop, fuse is not used — any drop in 2-volt system seriously reduces high voltage.*

measure about 175 volts with a fully-charged cell. This fluctuating voltage is a safety factor in one way. If the crystal should quit when you are tuning, the heavier current drain of both tubes will cause a voltage drop so that the tubes are protected from immediate damage — though the key should be opened until you can move the slug back for reliable oscillator operation.

Some builders have used this circuit with B-batteries. This sort of power supply is referred to as "hard." Batteries that are reasonably new have good regulation and will maintain their voltage even under much heavier than normal loads, so you must use more care in tuning.

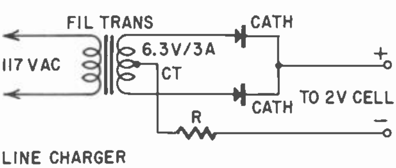
All parts of the rf unit except C1 and the antenna tuning components are mounted on a single small chassis, dimensioned as in Fig. 706. Coil information is shown in the same drawing. The parts layout can be changed considerably, but it is wise to keep L1 and L2 separated as much as possible. Terminals 4 and 5 on the loctal sockets are open on the 3D6 and are used as tie points. A three-lug tie strip also holds the ends of some of the small parts. You *must* use a 1-ohm resistor (preferably wirewound) to drop the battery voltage for the tube filaments. This resistor is R1 in Fig. 705.

To facilitate tune-up, use test points A and B to check the grid current of V2. A low-range dc milliameter having a full-scale deflection of 1 ma is fine. Use a 35- or 50-ma meter in V2's plate circuit. No provision is made for reading screen grid current, but it can be checked by plugging a meter in at the keying jack. Keying is accomplished by breaking the two screen grid circuits; this meter would read the screen grid current of both tubes. V1 should never draw more than 1 ma, and will usually run at about 0.75-ma screen grid current.

Provided you have about 175 volts under full load, here are some current readings: V1, plate current 6–7 ma; V2 grid current 0.5 – 0.6 ma; V2 screen grid, 4 – 6 ma; V2 plate current 15 – 18 ma. Total B-drain of the test transmitter was 28 ma and total drain on the 2-volt cell about 5 amperes.

Simple modulator for Mac II

For radio control purposes, the simplest form of modulation has been found to be via the grid of the output tube. A suitable modu-



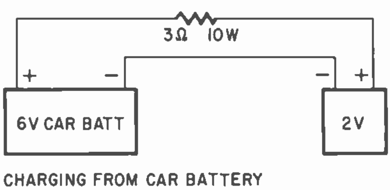


Fig. 704. *The 2-volt cells can be charged at a rate up to 3 amperes. Rectifiers must be picked to carry sufficient current. Federal 1018 will allow about 1.8-ampere charging rate. R must be picked to give the desired charging rate.*

lator used with the Numac II is seen in Fig. 707. The underside of the modulator is shown in Fig. 708. It utilizes a single 3A5 tube as a multivibrator and has ample audio output for this job. Since tone receivers vary as to the exact tone they prefer, potentiometer R1 allows a wide range of tone shift – about 350 to 1,650 cycles in this case. The modulator draws 6 – 8 ma, depending upon the tone chosen. When the modulator is keyed, the plate current of V2 in Fig. 705 will drop appreciably. Power output as checked

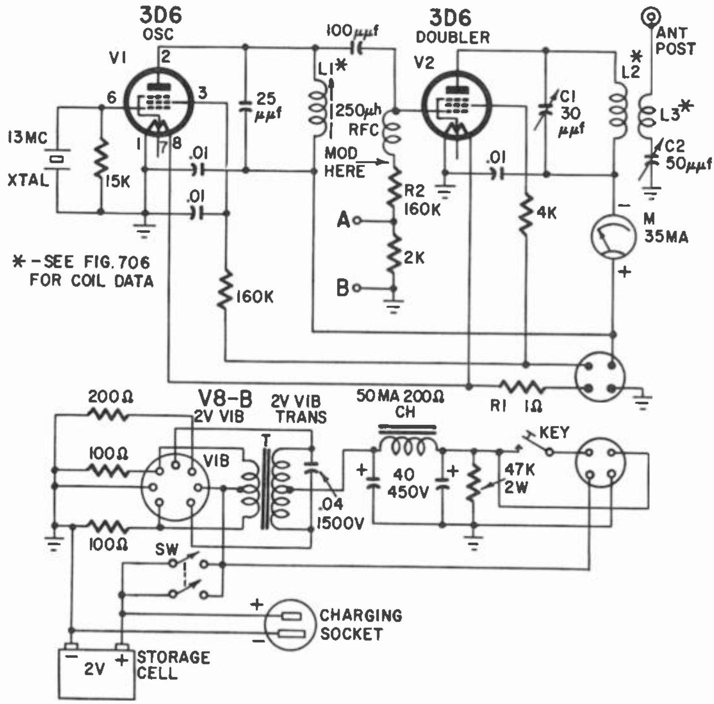


Fig. 705. *Schematic of transmitter and vibrator power supply. Power supply could be replaced by dry batteries.*

on a lamp bulb or a field-strength meter will also drop. This is quite normal, and the modulated power output of the transmitter will still be adequate.

Since there was no room on the rf "shelf" for the added tube, another small angle bracket was bent from aluminum to hold it. As seen in Fig. 709, a small transformer is also on this shelf. While the circuit of Fig. 707 requires no transformer, it was used in an effort to obtain a more stable audio tone. Most af oscillators change frequency quite a bit with changes in B-voltage, and the multivibrator is no exception. For some radio-control receivers, notably those utilizing reeds, a very high order of af stability is required. The transformer (which is actually used as an af choke of relatively

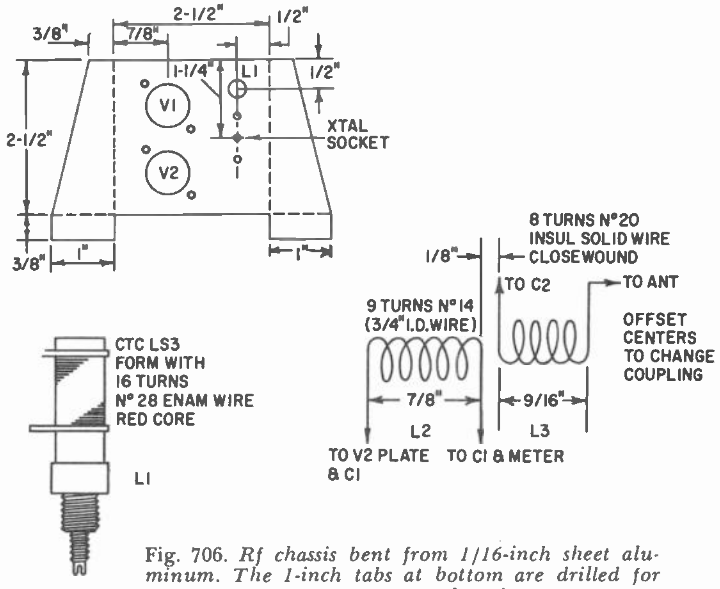


Fig. 706. *Rf chassis bent from 1/16-inch sheet aluminum. The 1-inch tabs at bottom are drilled for four mounting screws. Crystal sockets vary somewhat — drill holes to fit.*

high Q) aids in holding the multivibrator stable, despite changes in B-voltage.

A suggested circuit is shown in Fig. 710. The components

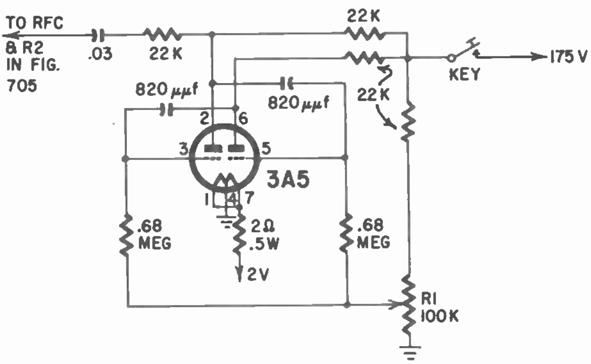


Fig. 707. *Simple modulator for Numac II. R1 varies tone to suit receiver. Lead at upper left goes to point marked "Mod Here" on Fig. 705.*

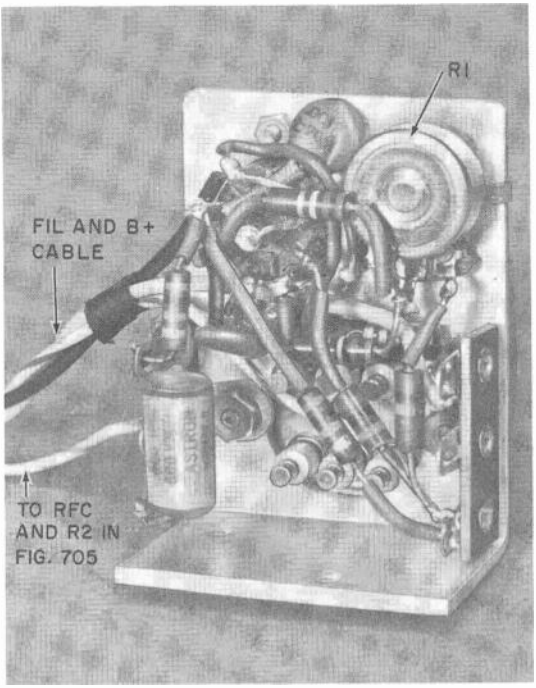


Fig. 708. *Underside of small modulator chassis. This one uses choke, circuit as in Fig. 710. Two lug strips hold ends of small parts. If circuit of Fig. 707 is used, chassis may be somewhat smaller.*

within the dashed lines would be duplicated for each af tone desired. Note that dpst keys are required, one section switching the audio tuning components and the other the B-voltage to the modulator. No great effort was made to get rocklike stability from this circuit, but it showed a change of only about 4 cycles, with a B-voltage change of 180 to 90. Better results than this could be had by running the oscillator at lower voltage and the output through an audio amplifier tube to the rf section. For even less frequency shift, a neon tube connected as in Fig. 711 would serve to keep things stable.

Note that not just any old af choke will do the job in Fig. 710; the higher the Q of this unit, the better. Some builders have used costly toroids with fine results, but the surplus transformer indicated is inexpensive and a good one with which to experiment. Additionally, the capacitor used across the choke should be high-grade, hermetically sealed oil-filled units being very good.

This modulator produces a "chopped" carrier wave, as seen in

Fig. 712. There is some question as to whether this is the best waveshape for reed use, but it does work and many radio control transmitters produce such a waveshape. The height of the rf signal is the same, with or without modulation, indicating that the strength of the signal does not drop when the tone is keyed on. The "holes" that are cut out of the rf carrier cause the plate-circuit meter reading to drop, as does that of a field-strength meter. This type of scope pattern is obtained by simply bringing a small one- or two-turn coupling loop adjacent to the output-tube plate inductance (L2). A piece of TV twin-lead couples this loop directly to the vertical plates of the scope (the vertical amplifier must be bypassed).

With the modulator of Fig. 707 in use on the converted Mac II, the plate current of the doubler stage drops from about 16 ma to 10 when the tone is keyed on.

One final note about this type of modulator. The multivibrator

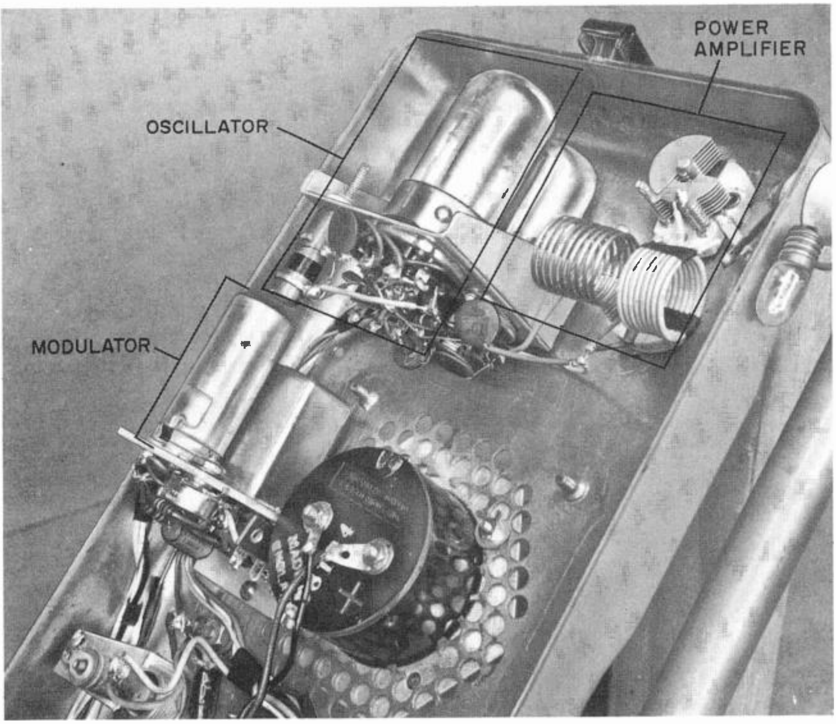


Fig. 709. *Here we see rf chassis of Numac II (top). There are two APC type capacitors C1 and C2 (C1 hidden under L3). Modulator is small chassis next to doubler plate meter. Pilot lamp at lower left. All these parts mount on cover of surplus case used in Mac II.*

is rather sensitive to rf. The af oscillator circuits should be kept isolated from the rf section as much as possible, particularly the leads in the grid circuits of the 3A5. It is normal, for reed operation, to run the leads to the tone-switch keys through an extended cable to a hand-held control box (when using a ground type

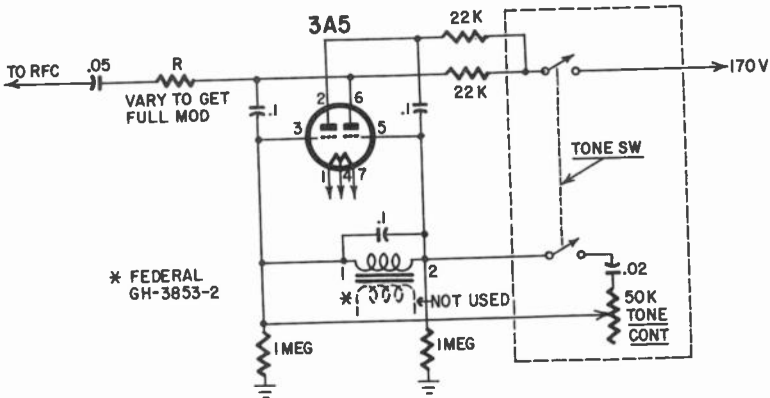


Fig. 710. *More stable modulator for reed and filter use. Choke is one winding of a fairly high-Q surplus transformer. Capacitance across choke, units in dotted box, must be tailored to receiver employed. R may run from zero to several thousand ohms.*

transmitter). The tone setting components, in the dashed enclosure in Fig. 710, are also usually in the control box. In such cases, a shielded control cable is a must.

Rf pickup bothering the multivibrator usually shows up as an increase in the af tone frequency. This can be checked by turning on the multivibrator alone, listening to the audio output, then

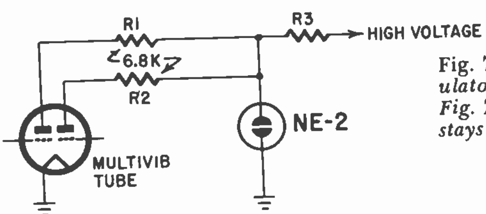


Fig. 711. *Neon bulb acts as voltage regulator tube. Other components as in Fig. 710. R3 chosen to insure that NE-2 stays lit over entire voltage range expected from power supply.*

turning on the rf section of the transmitter (but make sure any change in frequency isn't caused by a drop in B-voltage when the rf section is energized – a set of heavy-duty B-batteries will help here). Rf pickup in the keying leads can usually be minimized by use of small bypass capacitors across the key leads where they enter the transmitter case. Sometimes rf chokes are also needed.

50-mc rf unit—the Mac 50

Utilizing the same case and power supply as that seen in Fig. 703, Fig. 713 shows a 50-mc rf section that has been used extensively. The circuit is shown in Fig. 714; Figs. 715 and 716 show the chassis and Fig. 717 the chassis template of the unit. The 3A5 acts

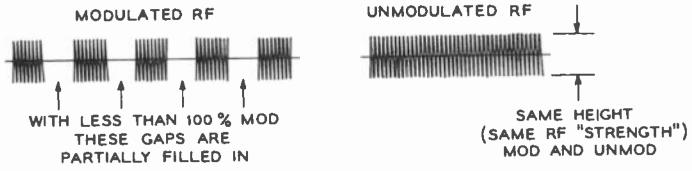


Fig. 712. *Scope pattern of grid modulation often used in R/C transmitters. Af chops holes in rf signal when 100% modulated. Field-strength meter usually shows reduced reading, with modulation.*

as a crystal oscillator and doubler, crystals in the range of 25–27 mc being utilized. The rf amplifier is a 3B4 and, while it *can* be operated without neutralization, the latter makes it much more stable and less liable to "takeoff." Because of the low drive requirements of the 3B4, the 3A5 runs at very low power, both sections to-

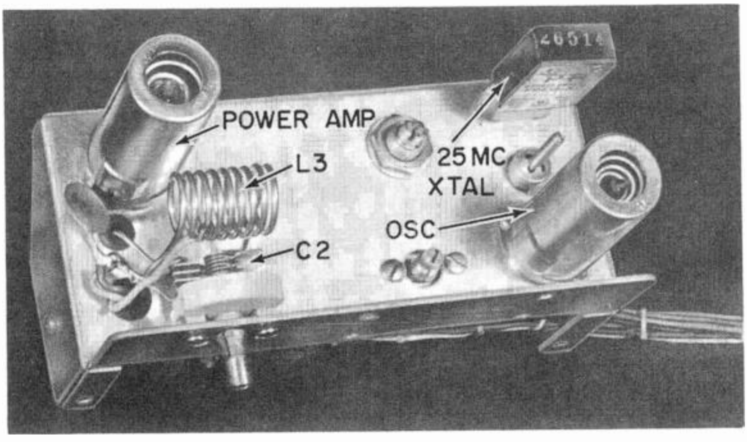


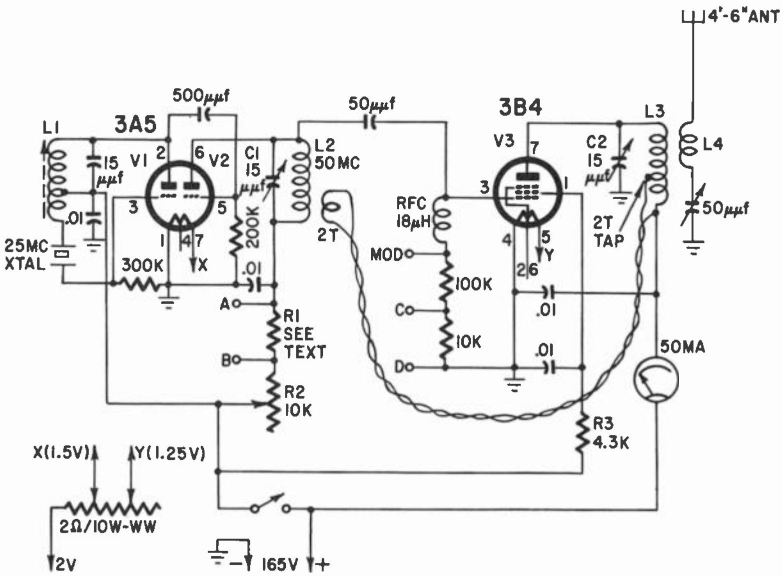
Fig. 713. *Top view of Mac 50 rf chassis. Shaft of C2 must be insulated from chassis and case, as it carries full B-plus voltage. Small capacitor at left of amplifier shield is .01-µf bypass for L3. Shaft of C1 appears to left of oscillator shield, and above it is shaft of R2.*

gether drawing an average of only about 10 ma. Variable resistor R2 allows setting the grid drive to V3 as required, and was put in mainly because a variety of crystals have been used, ranging from surplus FT243 fundamental types used here as third-overtone oscillators to "hot" sealed metal-case units.

A slug coil tunes the oscillator, but it was found necessary to use the variable-capacitor – fixed-inductance arrangement for the tank circuit of V2. The 3B4 amplifier is quite conventional except for the inductive neutralization arrangement. Although not widely used, this type of neutralization has been found advantageous. Moreover, it is easy to apply to an existing unstable amplifier. The twisted link of insulated hookup wire is tapped onto two turns of L3, and two turns of the same wire at the other end are brought adjacent to L2. Adjustment will be discussed later.

The original transmitter includes an elaborate switching system to shift the meter to various points in the circuit. It is seldom used in the field and the meter could be left permanently in the plate circuit of V3. The lettered test points can be used to check circuit operation with external meters in the shop. Resistor R1 across A – B can be chosen to give a 10-ma full-scale reading with, say, a 1-ma test meter. The same meter can be tapped in across C – D with little change in reading due to the 10,000-ohm shunt resistor.

Note that the 3B4 has a 1¼-volt filament. A dropping resistor



L1—CTC LS3, red core, 17½-turns #24 enam. tapped at 5 turns from bottom. L2—8-turns #16, 7/16-inch i.d. ⅞-inch long. L3—8½-turns #16, ½-inch i.d. ⅞-inch long. L4—7-turns insulated solid wire, close-wound; mount at ground end of L3.

Fig. 714. *Most crystals will work in this oscillator circuit. The power amplifier is neutralized with the 2-turn loop tapped across the output tank coil.*

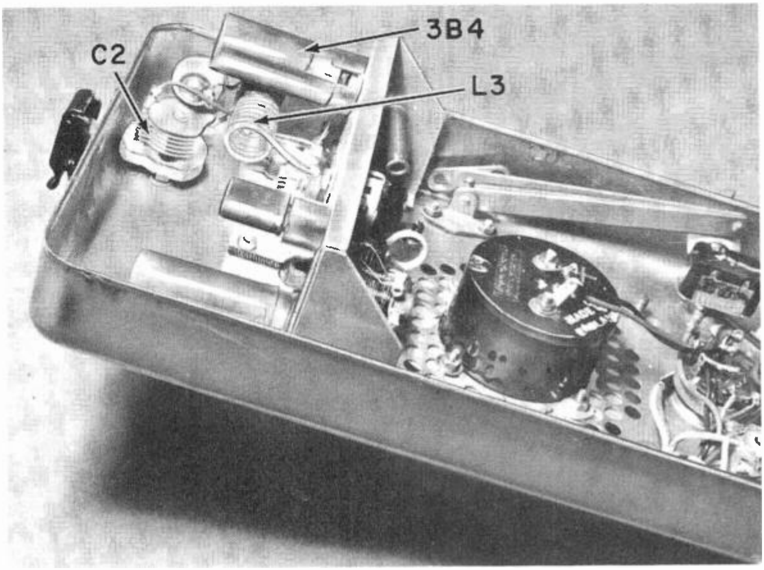


Fig. 715. *Same type of case and arrangement of parts were used for this Mac-50 as for Mac II (and more recent Numac II). Switch below meter is for shifting meter to various circuits, seldom used in field. Power supply is same as in Fig. 703.*

must be used with it, even with a dry-battery filament supply. This transmitter has a 10-watt wirewound resistor with two adjustable taps for setting the filament voltages for both tubes. Separate resistors would be even better.

To put the unit into operation, temporarily open the screen grid lead of V3 (it will then draw no plate current) and tune the oscillator with L1. Keeping an eye on the grid current meter of V3, tune C1 to resonance. With variable R2 at zero resistance, it should be possible to get about 0.6-ma grid current, and the plate current of V2 should be no more than 7 ma.

Next, the 3B4 must be neutralized roughly. This can be done by watching the grid current of V3 as the plate capacitor is tuned through resonance. If grid current jumps either up or down as C2 is varied through its range, change the position of the link coil near L2 and make another try. If no position can be found that eliminates the twitch in grid current, try rotating the coil on the end of the link 180° (if it is the wrong way around, the arrangement will produce *regeneration*) and repeat. It should be possible to get a position where the grid current doesn't change a bit when C2 is tuned.

Now close the screen grid circuit of V3 and tune the plate circuit, using a blue-bead pilot lamp from antenna post to case as a load. The best output has been found to occur at about 25-ma plate current, and with R2 set to give a little less than maximum grid current. The screen grid current of V3 should not be allowed to go over 6 ma. Monitor this with an external meter when first tuning the transmitter. After getting V3 adjusted to give good output, final close neutralization can be accomplished. This is best done with a field-strength meter coupled to L3 with a link.

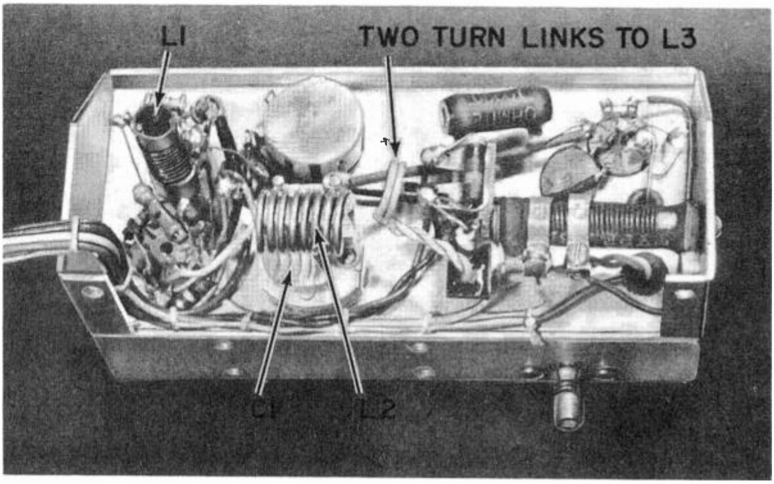


Fig. 716. *L2 is supported on lugs of APC type capacitor, C1. Fastened to right edge of chassis is 2-ohm 10-watt wirewound resistor with two sliders for individual filament-voltage adjustment. R2 (above L2) should be small wirewound unit rather than carbon. All power supply leads come out in single cable.*

Again open the screen grid lead to B-plus, turn on the power and shift the neutralizing coil near L2 carefully. You will find it possible to get neutralization so close that even a sensitive meter will give practically no reading.

With a freshly-charged storage cell this transmitter will produce a power output of about 2 watts, the high voltage being 165. Current drain from the cell is about 6.6 amperes with the key closed and 2.25 with it open.

The transmitter was used for some time with the antenna coupling arrangement shown in Fig. 714 and a quarter-wave antenna about 4½ feet long. This worked fine, but a half-wave antenna with the coupling setup in Fig. 718 is even better and makes the transmitter much less fussy as to what sort of ground it is set upon. Also, with this coupling system, the transmitter can be fully loaded with the antenna collapsed all the way or extended to a

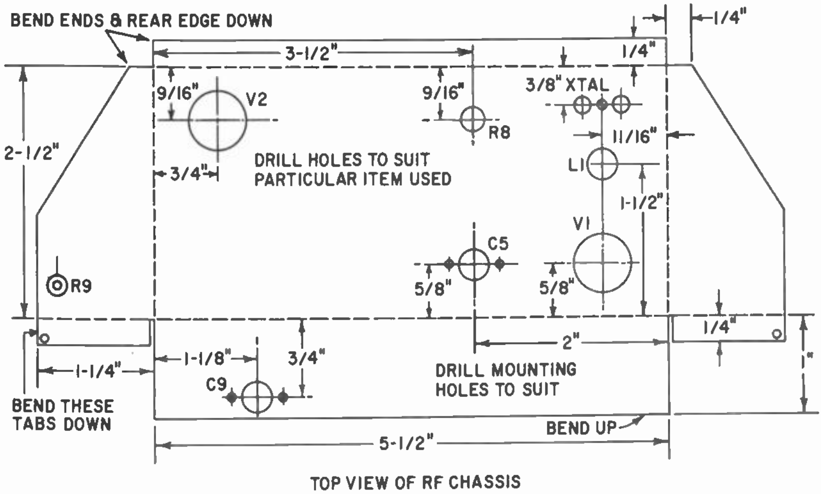


Fig. 717. *Check your parts before drilling screw holes to hold parts on chassis. Mica-filled phenolic sockets are better than black type. Chassis is 1/16-inch aluminum.*

couple of feet — very useful for shop test work. Note that a bulb load cannot be connected from antenna post to case with this coupling circuit. You can, however, insert it in the coupling tuned circuit at point X. It should be shorted for normal transmission.

Modulating the Mac 50

To use this transmitter with untuned tone receivers, the mod-

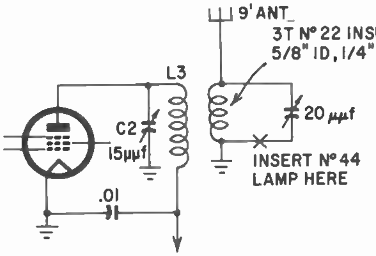


Fig. 718. *Half-wave antenna (for 50 mc) is about 9 feet long. Special output circuit is needed to tune it. If lamp is used for shop testing, insert at X; short lamp when using transmitter normally. Transmitter can be fully loaded with antenna collapsed.*

ulator shown in Fig. 707 was utilized. It works exactly as shown, with no circuit changes. However, to cut down the power drain on the storage cell during tone operation, and to permit quick shifting from cw to tone operation, the switching circuit seen in Fig. 719 was installed. R3 is the same screen grid dropping resistor seen in Fig. 714 and is in use for CW operation.

For tone work, an added resistor, R4, is put in series with R3; this cuts the plate current of V3 to about 16 ma. When the key is closed, this plate current drops to 10 ma. The changeover switch takes care of this screen resistor change, shifts the keying leads as required for the two types of operation, and closes the filament

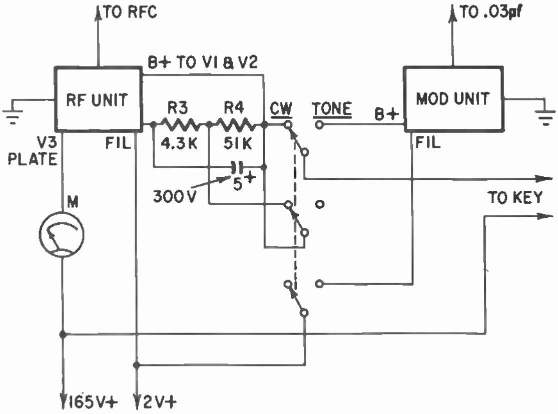
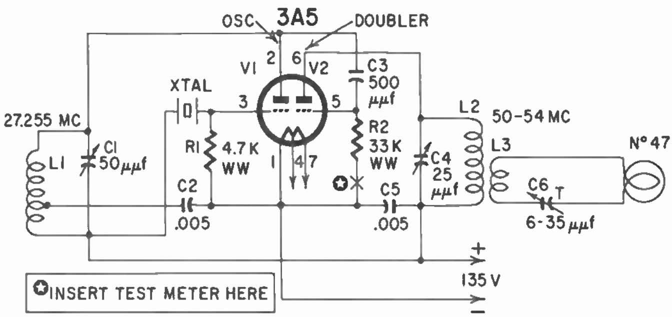


Fig. 719. *CW tone-switching circuit for Mac-50. Rf power is considerably reduced when switch is in tone position. This saves battery power and reduced output is ample for most tone receivers. Electrolytic across R3 and R4 prevents waveshape distortion caused by this large screen dropping resistor value. Switch should be nonshorting type.*

circuit of the 3A5 modulator tube. This transmitter shows the same drop in plate current and in field-strength reading when the audio is turned on as for the Mac II tone conversion.



L1—17-turns #18 enameled wire on form ½" i.d., 1⅜" long; the tap on L1 is 6-turns from the lower end of the coil. L2—9-turns #16 enameled wire on form ½" i.d., ¾" long; L3—3½-turns #16 enameled wire on form having ¾" i.d.

Fig. 720. *This simple "one-tube" transmitter gives ample power output for many uses. If modulated (with unit in Fig. 707), rf choke should be inserted between tube socket terminal 5 and R2, modulation connected to lower end of choke. Left-hand 22,000 ohms on Fig. 707 may not be needed; 135 volts should be ample for modulator.*

Simple 50-mc circuit

For those who wish to use 50 mc and are looking for a simple transmitter, the circuit of Fig. 720 will give very nice results if used with an active crystal. The output is ample for any control work within the range of sight, when the circuit is correctly tuned. The crystal oscillator must operate between 25 and 27 mc. In general, crystals in small sealed metal cases are the "hottest." An overtone type is recommended.

The second half of the 3A5 acts as a doubler, making neutralization unnecessary. Grid resistors R1 and R2 should both be wirewound types, as these act as rf chokes. If you can get only carbon resistors for these positions, insert small rf chokes in series with the resistors. The wirewound resistors may be of any wattage up to 10 watts; higher-wattage units are too bulky.

To put the circuit into operation, connect the usual bulb load

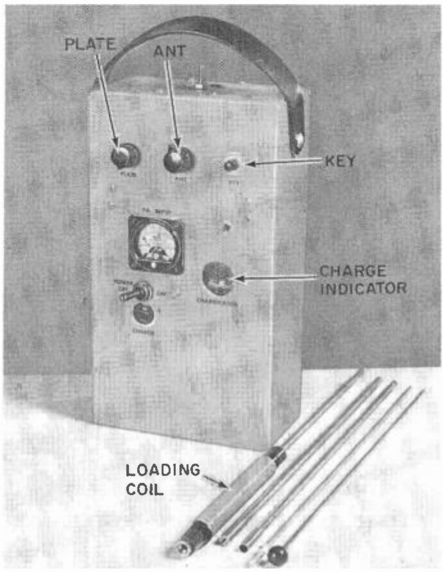


Fig. 721-a. *Known as Mac Jr., this 27-mc hand-held unit has considerable output. Units of center-loaded antenna seen disassembled. Hole in case front allows observance of storage-cell charge indicator. Socket under switch used either for charging or starting glow-plug engines via 6-foot cable. Original, built in 3 x 10 x 5½-inch chassis, was crowded. Slightly larger case is advisable.*

to L3; a milliammeter of about 0–5-ma range should be connected temporarily between the ground end of R2 and B-minus. This meter will indicate grid drive for the second section of the 3A5. Rotate the 50-μμf oscillator tuning capacitor until the meter reads maximum. It should go to at least 2 ma for good efficiency in the doubler. Then tune C4 for the best output. When working correctly, the plate current of V1 will be about 8 ma and that of V2 will be about 16 ma. A large amount of regeneration has been

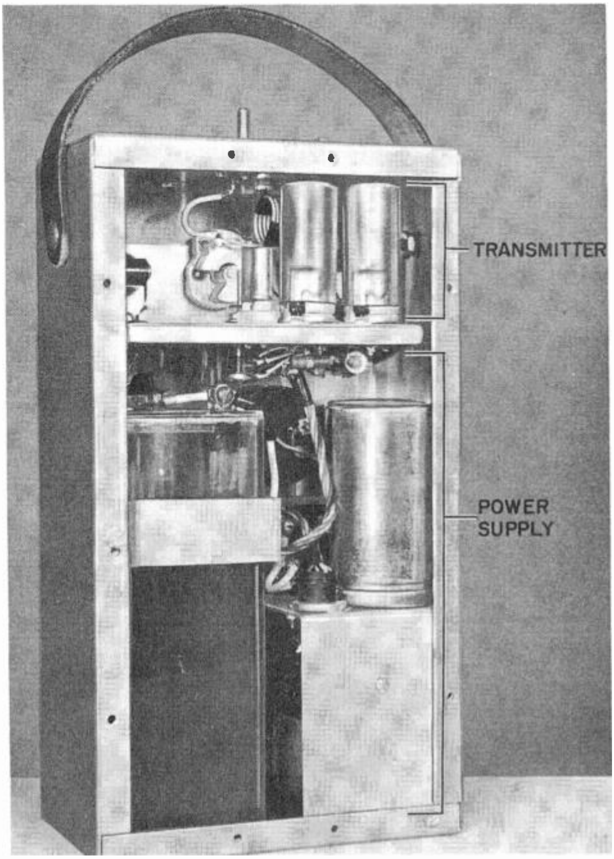


Fig. 721-b. *Surplus storage cell and power supply chassis were a glove fit in small chassis. Tube on cell vent leading to outside of case may be seen atop cell. Chassis bottom plate was used to cover back of transmitter.*

used in V1 to assure high output, so use care when tuning to be certain you are on the correct frequency.

It may be difficult to get enough coupling between L2 and L3 to load V2 properly when a bulb is being used. Hence, a tuned output circuit is shown, composed of the No. 47 bulb with L3 and C6. This circuit is tuned to the output frequency of V2, or very near it, and will then be found to take as much power out of L2 as you wish, depending upon how close L2 and L3 are coupled. With this sort of tuned-output circuit, it is easy to overload tube V2, so adjust the coupling with care. The plate current of V2 will go up to about 25 ma with L1 tuned to the point of best output, but with C4 off resonance. If C4 is tuned to resonance with no plate-circuit load, the plate current will drop to around 4 ma.

This little transmitter has the usual advantages of the MOPA; it is very stable and easy to put into operation. It can be used with any of the antenna coupling arrangements shown in this chapter for 50 mc, with the one in Fig. 718 suggested (if it is to be a ground-based transmitter). For hand-held use, a 4½-foot rod would form a quarter-wave antenna and would be used with a coupling coil of about four or five turns of insulated wire of the same diameter as L2. Power output should be around 0.7 watt.

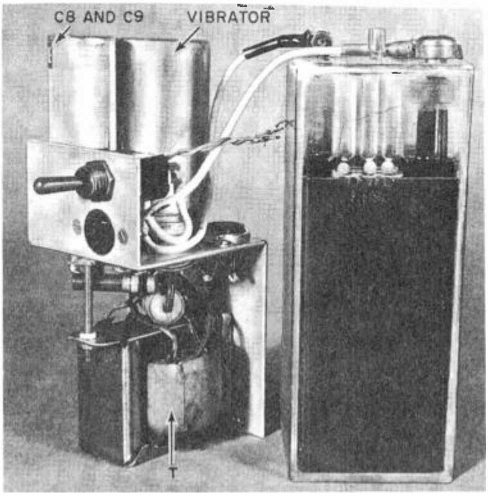


Fig. 722. *Power supply chassis carries on–off switch and charging plug. If transmitter is to be used for tone, a filter choke should replace R7 in Fig. 726. Larger case would be needed for these additions. This transmitter can use 135-volt B-battery, and usual dry A, instead of power supply shown above.*

This transmitter could be used for tone work with the modulator shown in Fig. 707. Replace grid resistor R2 (Fig. 720) with a carbon type and use an rf choke of about 100 μh, with the modulator lead connected to the junction of the two.

High-power hand-held transmitter

Intended for 27-mc operation, the Mac Jr. (Figs. 721-a and -b) was an attempt to cram a vibrator power supply into a case small and light enough for hand use. Here again an MOPA circuit has been used, but in this case the oscillator is on 27.255 mc, uses a 3V4 tube connected as a triode, and the usual 27-mc third overtone crystal. To get efficient radiation from the antenna and yet keep it to a reasonable length, an unusual loaded half-wave type is employed. Due to its circuit and this antenna, the transmitter puts out as potent a signal as many ground-type transmitters using a full 9½-foot vertical antenna. In addition, the unit is not fussy

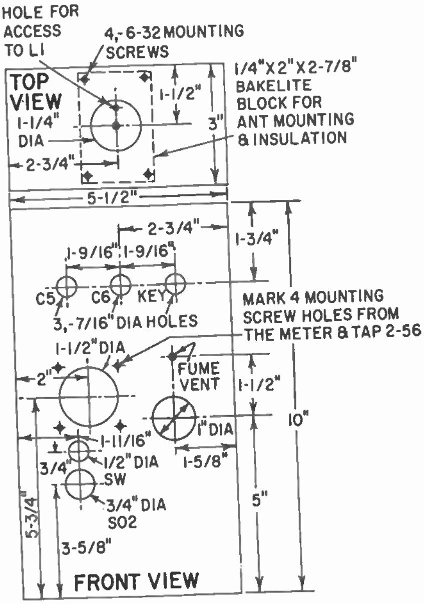
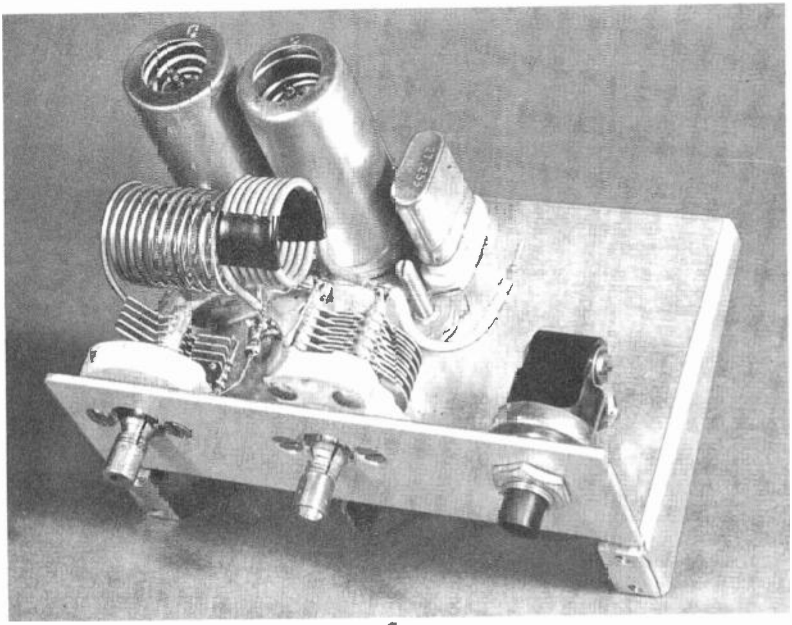


Fig. 723. *Holes to be cut in case if original size is used. As noted previously, larger size is preferable. Cut hole so that cell charge indicator can be observed.*

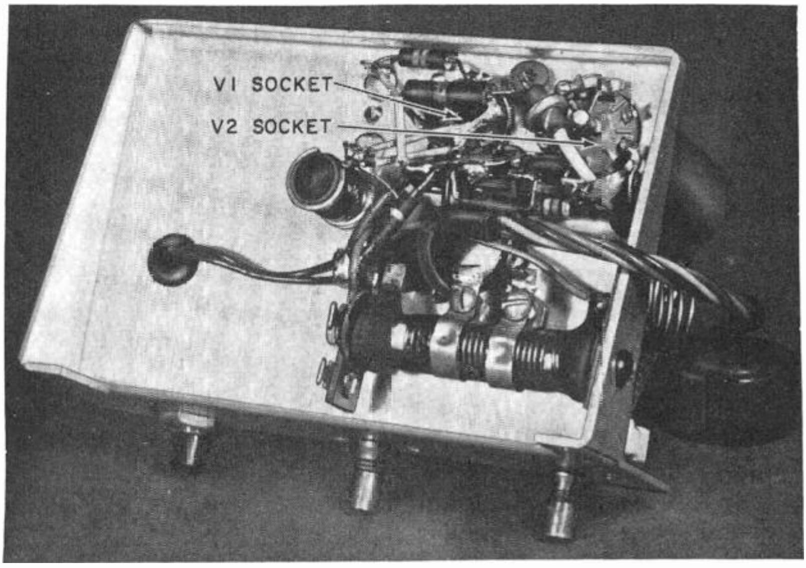
as to ground effect, and will give about the same signal strength when held in one or both hands, when set upon a wooden table, or placed on the ground.

The power supply is a vibrator type (Fig. 722) similar to that in the Mac II, but using a much smaller transformer and no af choke. The single storage cell is a surplus type of about 20-ampere hours capacity. It will last for several flying sessions before it needs recharging. It has plenty of capacity to act as a starting cell for glow-plug engines.

An aluminum chassis (Fig. 723) forms the case. The storage cell is clamped in the lower right corner (viewed from the front). As a measure of protection, the cell is completely cradled in thin foam rubber. Plastic and rubber tubing lead the fumes from the cell vent tube outside the case – a most important provision in any transmitter using such a storage cell. All power supply parts are mounted on a chassis bent out of 1/16-inch sheet aluminum, including the on–off switch and the two-prong socket used both



a

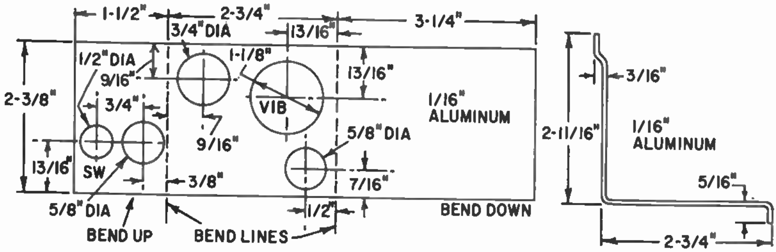


b

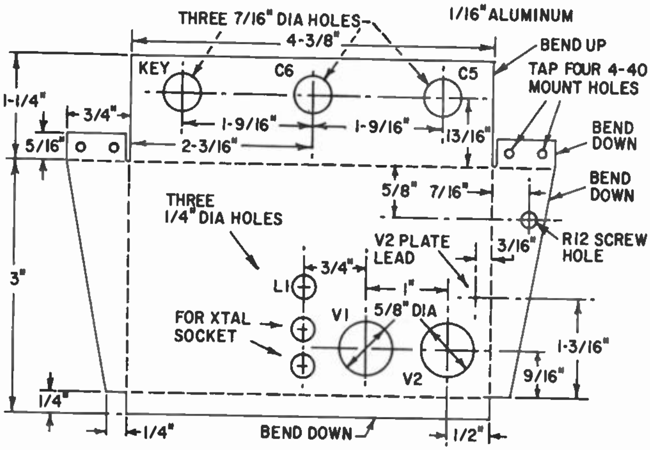
Figs. 724-a, -b. *Wire seen coming from C6 is soldered to antenna lug on top of case. Layout is compact but parts are placed for minimum interaction. Neutralization is not required. Insulate shaft of C5 (left capacitor in upper photo) from chassis and case. Underchassis view shows R12 in foreground, other parts grouped around tube sockets and four-terminal lug strip.*

for charging and for the engine starting cable. A socket on this chassis receives a plug from the rf chassis.

The storage cell was cut from a 6-volt Willard ER-25-5 battery, which has three complete cells cemented together. The same cells can also be had singly as ERH-25-2 (sometimes labeled with the military number BB-210-U). The cell is listed in some of the



a



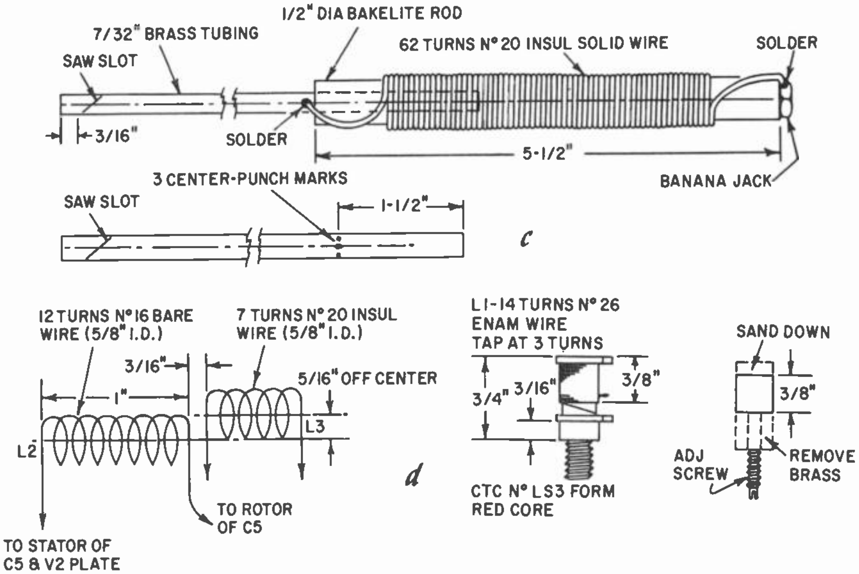
b

Figs. 725-a, -b. *Layout for rf and power supply of Mac Jr. About half the space is utilized for rf components; rest could be used for pulser or modulator.*

radio mail-order catalogs as Radio-25-2, and has been used in portable broadcast receivers. Its case measures about 2½ inches square by 6 inches high. Like many other lead – acid cells, this one has three colored balls to indicate the degree of charge, and a hole is cut in the case front so they can be checked.

The rf components of the transmitter take up only one end of its chassis, and a pulser or modulator could be mounted on the other portion (Remember to shield it from stray rf fields.) Top and bottom views of the rf chassis are shown in Figs. 724-a and -b. In this outfit a plain pushbutton is fitted to key the transmitter and, as usual, it controls both tubes. There are two sets of test points, A — B and C — D, used when tuning initially. The transmitter meter is always in the plate circuit of V2. As in the Mac 50, a single 10-watt wirewound resistor with two adjustable clips is used to set the tube filament voltages.

The tuned circuits are isolated so the 3B4 can be used without neutralization (which is also why tube shields should be employed). Unless you are experienced it is strongly suggested that no change be made in the rf chassis layout (Figs. 725-a, -b). Many of these units have been built and operated very successfully with dry batteries, housed in a larger cabinet.



Figs. 725-c, -d. *Follow dimensions of antenna and loading coil* exactly. *Spread saw slots with screwdriver for tight fit. Punch marks are made in outer tubing to keep tube that slides inside from going right through. If larger case is used for transmitter, LS3 coil form (for L1) may be used intact.*

Variable capacitors C5 and C6 can be used either with knobs as shown in Fig. 721-a (in which case ¼-inch-diameter tubular bushings are soldered to the stub shafts) or tuned with a screwdriver. Due to the type of antenna and coupling system used, there is little need to retune these capacitors at any time during use, unless the crystal is changed. L1 can be tuned from the top of the case through a small hole. The coil form and slug were cut short so they do not interfere with the storage-cell terminals.

A ¼-inch-thick phenolic plate is bolted under the hole in the

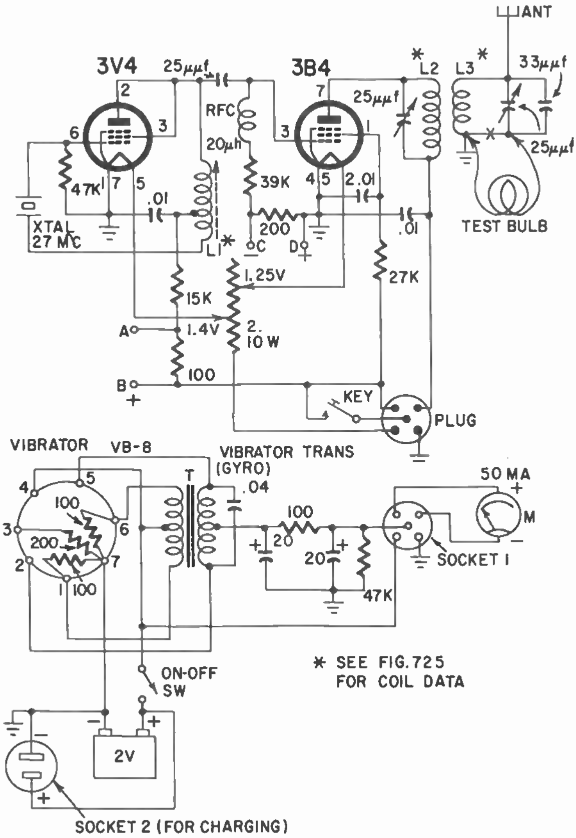


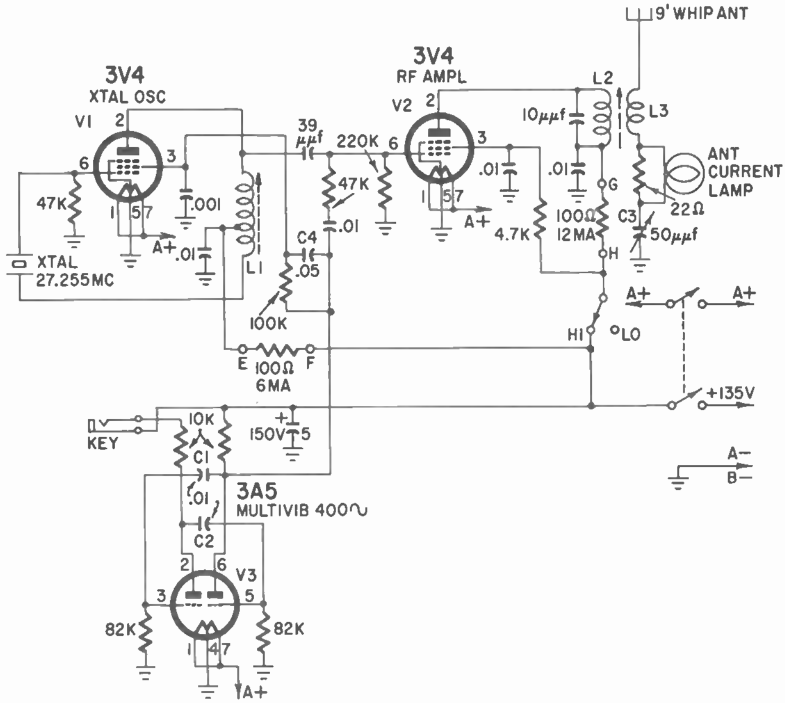
Fig. 726. *Circuit diagram of complete transmitter and power supply.*

top of the case and carries a 10-32 screw to hold the antenna. The latter is made of five 1-foot sections of telescoping brass tubing obtainable in most hobby shops. The lower piece is 9/32-inch OD and has a brass bushing soldered inside flush with the bottom and tapped for a 10-32 screw.

The 7/32-inch OD tube carries the loading coil (Fig. 725-c). Be sure to use *solid* wire for this coil. A banana jack in the top of the coil serves as support for the top three sections. Slide the various sections of tubing together, with the punch marks shown in Fig. 725-c keeping the inner tubing from sliding right on through. The saw slots are sprung open a bit with a screwdriver to provide a light force fit. (Coil winding data is given in Fig. 725-d.)

Use heavy flexible wire for all connections in the 2-volt vibrator circuit, and a heavy-duty dpst switch with the two sides paralleled to cut down voltage drop. Ordinary two-wire zip-cord is used for the engine starting cable. About 6 feet long, it has insulated spring clips at the end.

When the set is complete, pull the vibrator out and turn on the switch to make the filament resistor adjustments. Set them at 1.5 volts for the 3V4 and 1.3 for the 3B4 (they will be a bit lower



L1—18-turns of #22 enameled wire, close wound. Tap at 3 turns. L2—17-turns of #22 enameled wire, close wound. L1 & L2 are 3/8" dia. CTC (LS-3 or LS-5) form with red dot powdered iron slug, not brass. Wind coils close to open end of form. L3—8-turns of #22 enameled wire, 7/8" dia. close wound and self supporting. Couple to hot (plate) end of L2.

Fig. 727. *Pink-bead No. 48 lamp is always in circuit to show output. Power switch cuts dc to amplifier entirely in LO position; leakage through tube still allows some signal to get out for close-range tests. Both 3V4's are modulated.*

when the vibrator is working). Temporarily open the screen grid lead of V2, connect a 1-ma meter across the test points C—D and tune the oscillator. As usual, set the slug a little to the high-frequency side of the point of highest output. Grid current should be from 0.6 to 0.9 ma, with 0.75 a good average value. A 10-ma meter across points A – B should read about 5.5 ma. You can now close the screen grid circuit of V2 and tune it. A load should always be on this tube, of course. With the antenna coupling circuit used in this transmitter, you can't just connect a pilot lamp from antenna terminal to ground. Rather, open the connection between L3 and C6 and insert a temporary No. 44 or 46 bulb at this point (Fig. 726). As we've noted previously, set C6 to some position, then tune C5 to attain resonance (that is, rock it back and forth over its whole range). If you don't get a plate current reading of about 20 ma for V2, move C6 a little, then retune with C5. The plate current should be no higher than 20 ma. On the test trans-

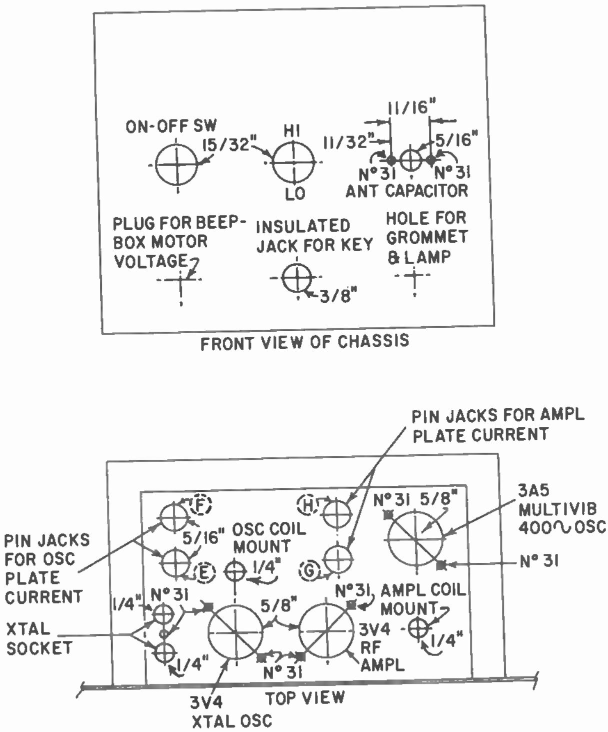


Fig. 728. *A 3 x 4 x 5-inch aluminum box (Bud CU-3005 or equivalent) holds all small parts of the transmitter, is mounted inside 10 x 10 x 8-inch case that holds antenna and batteries. Small box drilled as above.*

mitter, this current provided a power input to V2 of about 3.4 watts, and the measured power output with the bulb load was 1.8 watts. Current drain on the 2-volt cell was approximately 6 amperes.

Do all testing with the chassis out of the case. When it is completed, remove the No. 44 bulb and assemble the transmitter. As a continuous check on power output, you could install a No. 48 pilot lamp in the same position, with sufficient shunt resistance to keep the brilliancy to a low level; such an output indicator does not take too much power and is very useful. For shop testing V2 can still be loaded by the proper setting of C6 (and retuning of C5) with only a single section of antenna in use — or even with none at all.

27-mc tone transmitter

The circuit shown in Fig. 727 was designed expressly for audio tone work (with nonselective tone receivers) and has been widely popular as the WAG. It is used in many versions, both homemade and commercial. It uses a pair of 3V4 tubes in a MOPA circuit, employs a 27.255-mc crystal oscillator and has a 3A5 multivibrator for modulation. Despite the fairly low power input to V2, the tuned antenna system radiates a fairly husky signal — and of course, audio receivers do not need anywhere near as much rf power as do CW types.

To prevent leakage of rf when used with very sensitive receivers, the entire rf section is mounted in a 3 x 4 x 5-inch aluminum case, and this in turn is attached to the front of the 10 x 10 x 8-inch outer case. No meter is fitted to this transmitter, but test jacks facilitate tune-up. A permanently installed No. 48 (pink bead) pilot bulb serves to show when the transmitter is turned on and also to monitor rf output. Fig 728 shows a dimensional layout of the WAG chassis from the front and the top.

Both tubes in the circuit of Fig. 727 are tuned by slug coils which are accessible only from within the large case. However, the antenna capacitor (C3) is brought out through the front so it can be touched up to accommodate various types of grounds. Also on the front panel is a high – low switch. In the low position, all power is removed from V2, but there is enough leakage through this tube to allow operation of a receiver within a few feet of the transmitter. Some tone receivers have been troubled with what is called "swamping", an effect caused by leakage of enough unmodulated rf from the oscillator through V2, even though the latter is fully modulated, to render the receiver partially or wholly inoperative. To overcome this af is fed to V1 through the .05-µf capacitor (C4) from V3. This connection also makes it possible to work a receiver at very close range, even though V2 is disabled by the high – low switch.

To tune, put the power switch in LO and tune the slug in L1. A 10-ma meter connected to jacks E – F should show a current dip to about 6 ma when this tube is working properly (tune a little to the high-frequency side of resonance for stability). The tube will stop oscillating when you touch the coil with a finger, but it should start immediately when the finger is removed. Connect a meter with a maximum scale range of at least 20 ma to jacks G – H, turn the power switch to HI and tune L2 for the greatest current dip. A No. 47 pilot lamp could be connected from antenna insulator to case for an indication of power output. The pink-bead bulb built into the transmitter also indicates power output. The current dip of V2 will only be 1 ma or so, so tune carefully. Now tune C3 and L2 for maximum brightness of both bulbs. (You can dispense with the No. 47 bulb and connect a short from antenna post to case, if you prefer).

V2 will draw about 12-ma plate current when properly tuned, but it can go as high as 25 ma when out of resonance or if the crystal stops oscillating. This much current can be damaging. Do final testing in the field with a 9—9½-foot antenna installed. Again tune L2 and C3 for maximum brightness of the pink-bead lamp, but keep V2's plate current to 12 ma or less. When the key is closed, the bulb will dim and V2's plate current will drop to about 7 ma. V3 takes about 6 ma when it is working, so the total plate current of the transmitter runs from 16 – 19 ma. Modulation is at about 400 cycles, which is right for many nonselective tone receivers. If other tone values are required, they may be had by using different values in place of the two .01-μf capacitors, C1 and C2. Power output of the WAG transmitter is about ½ watt.

chapter EIGHT

keying the transmitter

FOR years, the accepted means of keying has been a simple pushbutton at the end of the key leads to the transmitter. Some operators favor a Microswitch, as they find the snap action that can be felt as it operates gives assurance that the command has been transmitted to the model. With the advent of higher-speed planes, more complex maneuvers and multicontrols of one sort or another, various types of automatic keyers have been developed. Such keyers are not really new. Experimenters used mechanical selector switches long before World War II. However, they did not attain wide use at that time.

Rotary selector

The simplest style of semi-automatic selector you can make is just a rotary switch. If it allows 360° of rotation and the contacts are arranged correctly, the escapement can be made to turn in sequence as you advance the switch. For this use, you must always turn the switch knob in the same direction; some users have fitted a ratchet so that the wheel cannot be turned backward, which would get you out of step with the escapement. Choose a switch that has at least four contacts at 90° intervals; any extra contacts can be ignored. With a two-arm escapement, the contacts could be arranged as in Fig. 801. There are only two live contacts in this case; from the straight-up neutral position, if the switch were stepped 90° to the left, you could have left turn, while right would be signaled if the switch arm were turned 270° from the straight-up position. The arm should always be returned to the straight-up position after either a right or left turn. While right, left and the single neutral could be marked on the face of a small box holding the switch, many users prefer to mark plain lines at all four of the 90° positions. Then, if the plane escapement is found to have gone out of step with the switch for any reason, the box is just turned in the hand till the usual rotation (say, 90° for left and 270° for right) positions are regained.

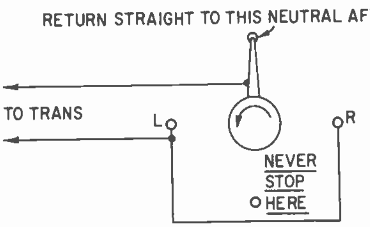
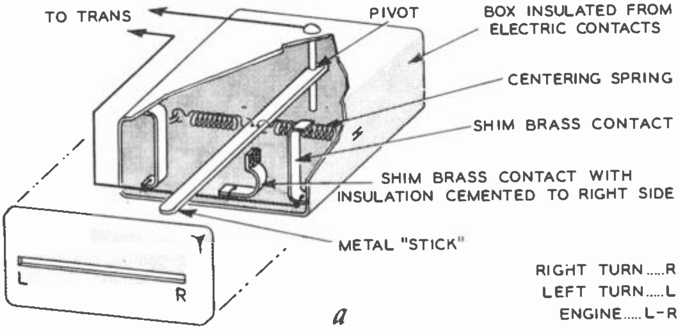


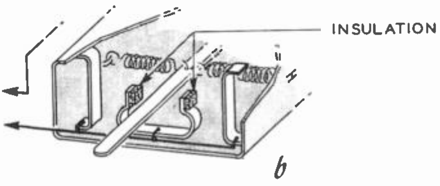
Fig. 801. *Rotary switch with two "live" contacts helps in keying an escapement. Always return arm to position shown, after giving a control command. Bottom position is never used.*

The same sort of switch box can be rigged for any type of escapement, whether it be two, three, four or any other number of arms.

Control-stick escapement keyer

While the compound escapement has no sequence of operation and most users prefer to key it with a plain pushbutton, some modelers feel that control-stick action is more realistic and thus





Figs. 802-a, -b. *Simple lever switch allows more natural keying action. Can be arranged to give right and left with corresponding movement of lever, with center neutral. Arrangement at (a) for compound escapements, and at (b) for self neutralizing style. Deliberate, complete stick moves are essential.*

more easy to fly with. Fig. 802-a shows a simple keyer box that has proved successful. Solder the stick to a piece of brass tubing that is as wide as the inside of the box, with a snug fitting screw used as a pivot. This prevents unwanted fore and aft movement of the stick, which might allow it to skip the fixed center contact.

The center contact is of springy material such as brass shim stock, and has a small piece of insulation cemented to the right side. Thus, the metal stick will make contact when moved from center to right, but not when returning again to center from the right side. Metal contacts at the limit of stick movement allow the user to hold rudder positions as desired. Be sure to insulate the stick (put a plastic ball on the end, too) and all protruding screws that are hot.

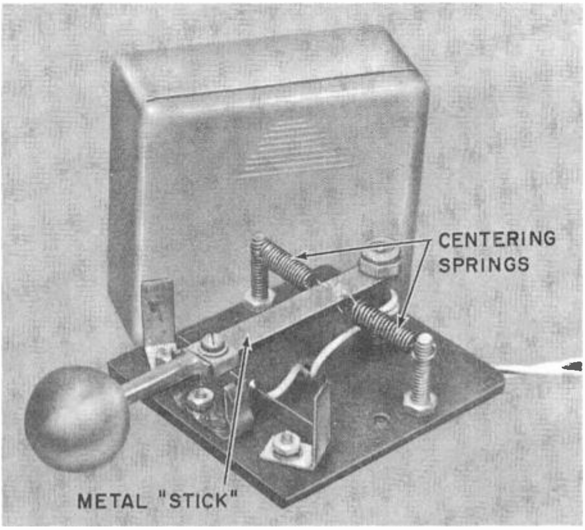


Fig. 803. *Construction of control box with contact arrangement of Fig. 802-b. Both center contacts close circuit in one direction of stick movement but not in the other. Cover in background cut from a plastic cigarette case with slot in cover to clear control lever.*

A similar box which was used with a two-arm or self-neutralizing escapement is shown in Fig. 803. It works just as does that diagrammed in Fig. 802-a except that two center contacts are needed to keep the escapement rotor in the proper sequence. Fig. 802-b shows how the contacts are arranged for two-arm operation.

These units work very well, provided the operator learns to make all control movements deliberate and not too rapid, and to *complete* each movement of the stick. If you start to move it to the right, go all the way until you hit the end contact. This is not too important with the compound, of course, since no matter what you've done with the stick, when you let it snap back to center, the escapement will also neutralize. With the unit in Fig. 802-b you have to make a controlled *return* movement of the stick to center, too. Sounds complicated, but it's easy once you get used to it.

Beep box

Some escapement users have had fine results from what has been named a "beep box," one version of which is illustrated in Fig. 804. The internal view (Fig. 805) shows a small electric

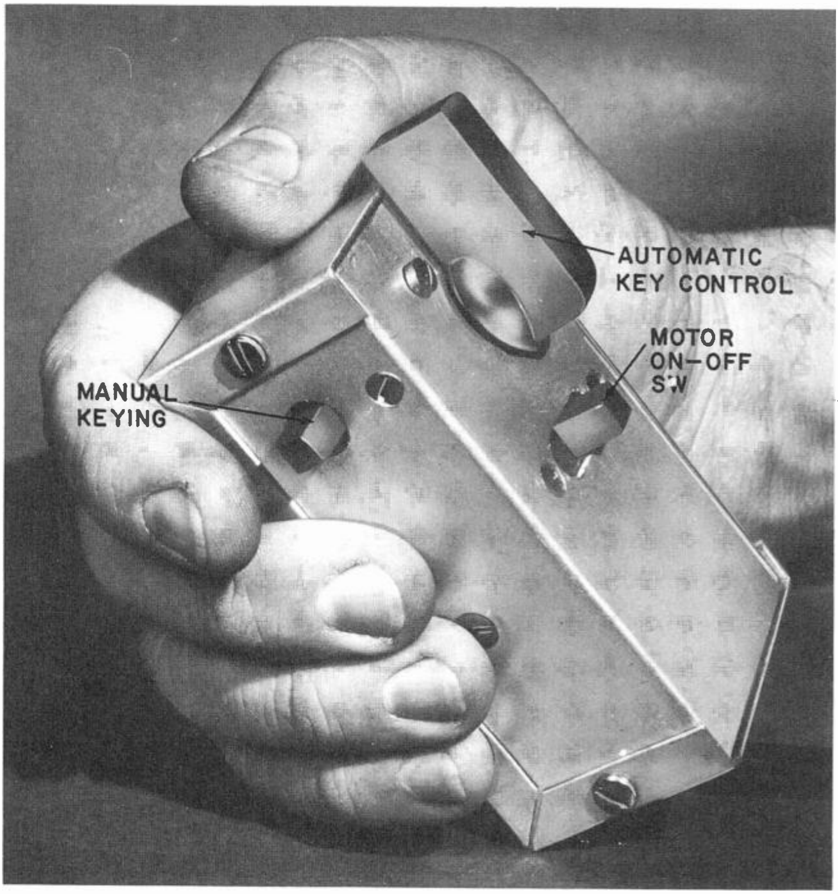


Fig. 804. *Beep box is motor driven, with power supplied through cable to transmitter. Transmitter A battery can be used, with low voltage motor.*

motor at the right that drives an insulated drum in the center. At the lower center is a pair of electrical contacts which key the transmitter; they are closed by small bolt heads set in the edge

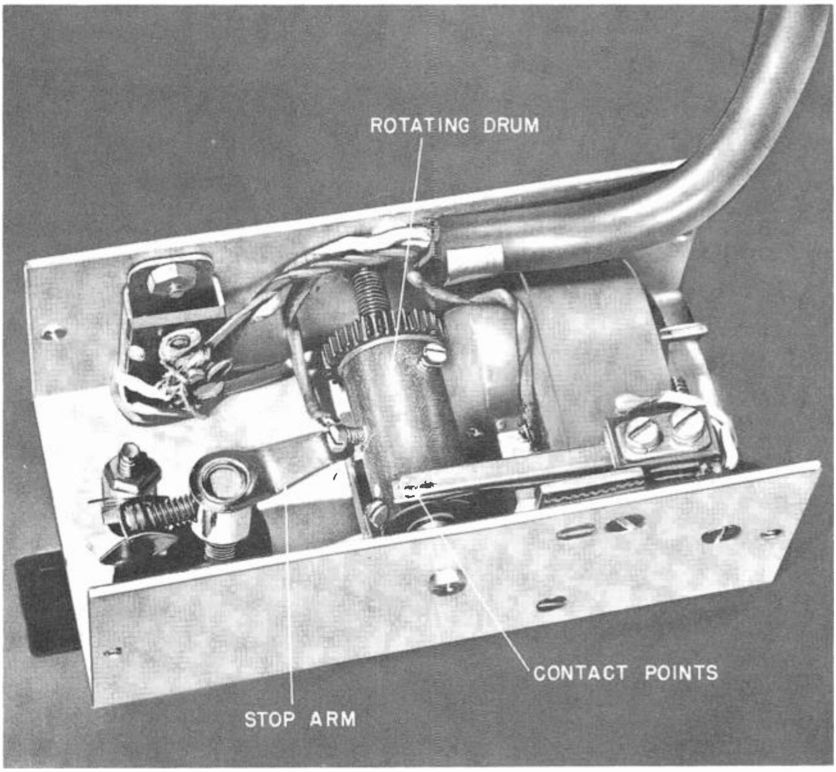


Fig. 805. Wilson motor at right has worm on shaft, drives drum through gear and slipping clutch. Keying contacts at lower right, operated by heads of screws in drum edge. Long set screw on stop lever held in center by two springs, to give positive neutral.

of the drum. The drum is "connected" to the driving gear through a slip clutch so that, when the stop arm at the left engages any of the stop screws, the drum is held from turning but the motor and gears continue to rotate. Stop screws and screws to close the contacts are inserted in the drum according to the type of escapement it is desired to operate.

The unit shown used HO model-train drive gears with a ratio of 32 to 1. The clutch disc is cut from an old leather glove. The coiled spring seen adjacent to the motor in the exploded view in Fig. 806 pushes the large bevel gear and leather clutch disc

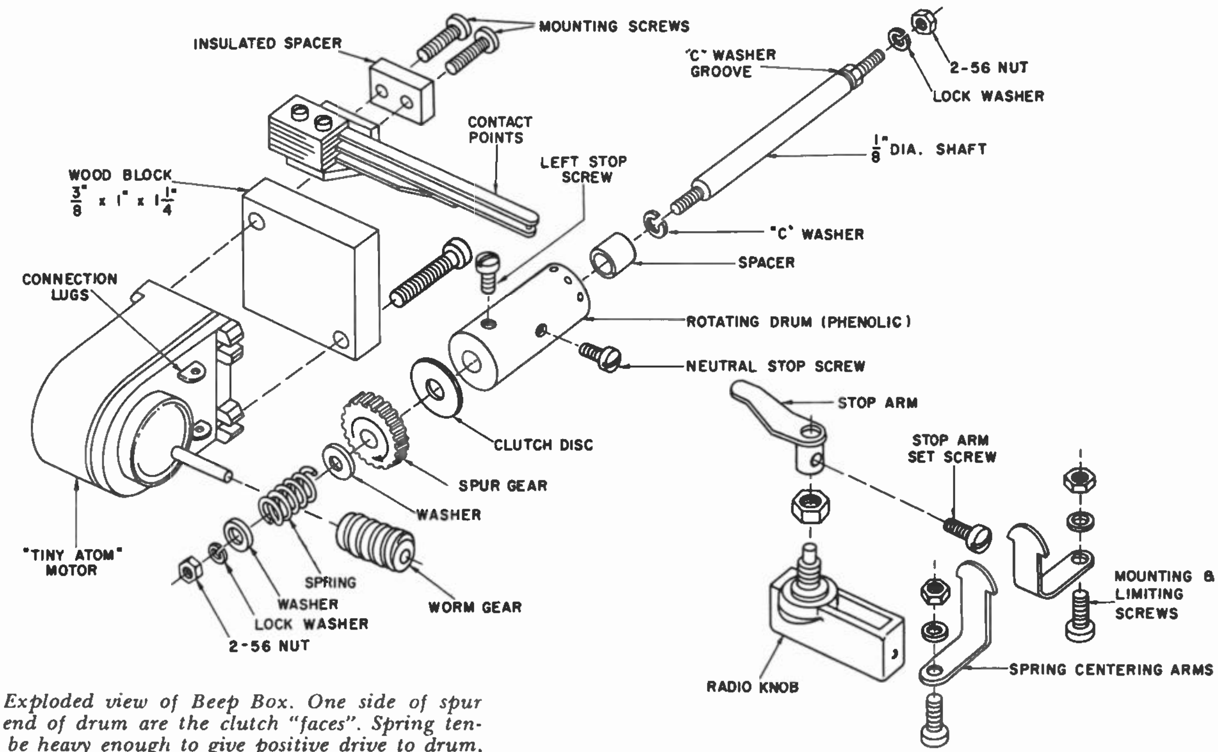


Fig. 806. *Exploded view of Beep Box. One side of spur gear and end of drum are the clutch "faces". Spring tension must be heavy enough to give positive drive to drum, but must allow motor to turn at good speed when drum is held stopped by stop arm.*

against the end of the drum. Be sure to bore the drum concentrically and get the rotating parts running smoothly. Fig. 807 gives the drum details. The only critical adjustment is spring tension, which must be strong enough to assure reliable drive of the drum at all times but not so strong that the motor tends to stall when the drum is held by a stop screw. An aluminum box 4 x 2⅛ x 1⅝ inches holds all the parts.

The motor speed and gear ratio must match the escapement you intend to use. The motor shown turns at about 4,500 rpm on 1½ volts but, due to slowdown of the motor when the drum is held stopped, the average drum speed is about 125 rpm. This gives very rapid escapement action. A pushbutton on the box Fig. 808 allows manual keying of the transmitter and also is used to get the beep box synchronized with the escapement.

Relay pulse sender

The beep box may be used with a compound escapement by altering the stop and contact screws. However, some fliers who

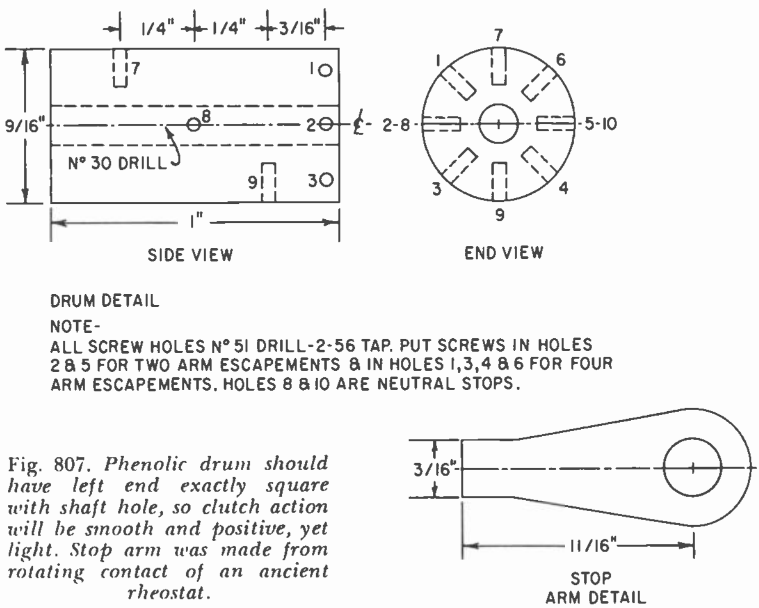


Fig. 807. *Phenolic drum should have left end exactly square with shaft hole, so clutch action will be smooth and positive, yet light. Stop arm was made from rotating contact of an ancient rheostat.*

prefer making electrical rather than mechanical gadgets are using the system shown in Fig. 809. A single relay is employed, while the actual control is a three-position lever switch which will give a single pulse (and hold) when moved one way, and two pulses (and hold) the other. Variable resistor R1 is adjusted to make the second pulse come at the proper interval so that the escapement catches correctly on the second arm. If motor control is desired – which calls for three pulses – the control lever is pushed rapidly to the right and then left; this transmits the required triple signal. Adjust the relay with large spacing between the contact points and with weak spring tension.

Quick-blip pulser

It takes a very rapid and short pulse to work the quick-blip system for engine control described in Chapter 3, and some modelers prefer a gadget to do the job for them rather than trying to remember to do it right each time themselves. The circuit

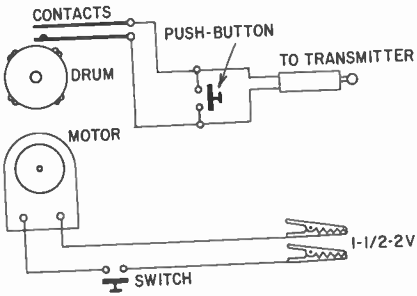
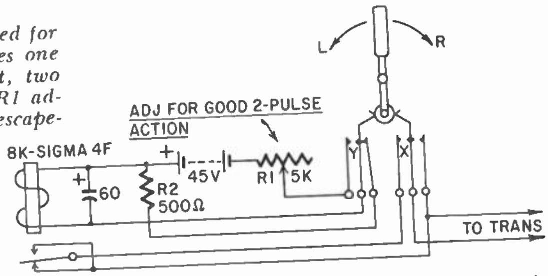


Fig. 808. *Beep box connections are very simple. Contacts key transmitter; push button used to get escapement in model in synchronism with beep box, can also be used for direct keying. Clips in motor circuit can go to transmitter A battery, or to glow engine starting battery. If either of these sources are used, motor should be low voltage type.*

in Fig. 810 will send a blip of any desired length when you push the microswitch. The pulse does not vary no matter how fast you punch the switch or how long you hold it operated. The relay can be a Sigma 4F. The 1000-ohm resistor is adjusted to give de-

Fig. 809. *This keyer designed for compound escapement gives one pulse and hold for right, two pulses and hold for left. R1 adjusts extra pulse to suit escapement in use.*



sired length of pulse. Other voltages, relay resistances and circuit values can be used, of course, but with a lower-resistance relay (and lower operating voltage) the electrolytic capacitor's value must be increased.

Simple relay proportional pulser

The circuit of Fig. 811-a is not a true *proportional* pulser as it does not allow variation between the proportions of on and off pulses, but it has uses in some control systems. The pulse length in the center position is adjusted by resistor R. The relay always operates at the rate set by R, regardless of the position of the switch lever. For true proportional operation, the circuit of Fig. 811-b is about as simple as you can get. Here the pulse length or proportion is varied by R, to which a control knob

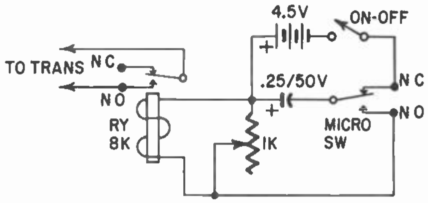
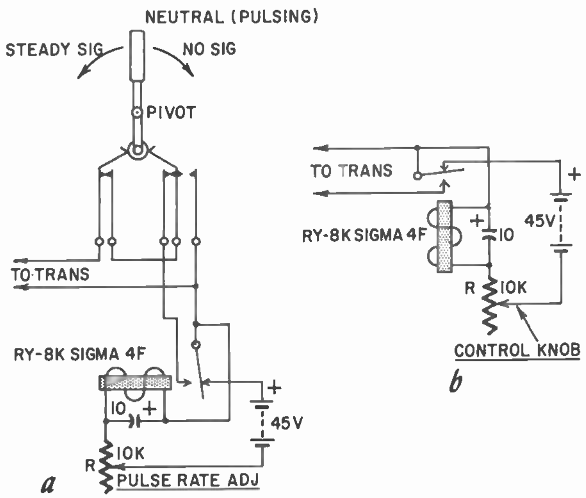


Fig. 810. *Quick blip operation takes single very short pulse; this circuit does the job, regardless of how you operate microswitch. Relay is operated by current in charged electrolytic, when switch is pushed to normally open (NO) contact. 1K resistor sets length of pulse.*

is attached. The pulse rate varies as R is manipulated, but in many simple control systems this makes no difference.

Twin-relay pulser

If, for a certain control system, you want a unit that has more



Figs. 811-a, -b. *At left (a) is simple pulser that gives neutral but no variation of pulse length. Lever switch allows no signal (lever to right), even on-off pulsing (lever centered) or solid on (lever to left). Very simple pulser (b) allows true pulse proportional action, but with considerable pulse rate variation over its range.*

independent pulse speed and pulse-length controls, try the system shown in Fig. 812. Here, there are two relays of the same type, RY1, being the *timing* relay which works continuously at the same speed (unless the setting of R1 is changed), while RY2 is the *keying* relay that actually operates the transmitter. Though there is a slight change in pulse rate as the pulse length is varied by R2, it is far less than in the circuit of Fig. 811-b. Since some

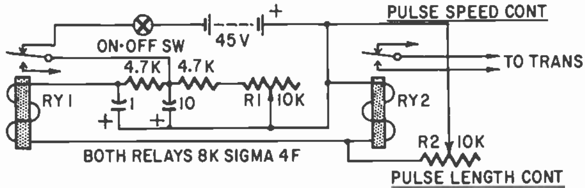


Fig. 812. *Use of two relays provides better isolation between pulse length and rate. This is a good use for Sigma 4F relays, not too popular in receivers these days, due to weight and size.*

control systems require that the pulse speed be changed abruptly – for example, to operate a motor-control escapement – a switch can be arranged to shunt R1 with a fixed resistor. This will give instantaneous pulse-speed change.

Knupple pulser

A very simple type of pulser is shown diagrammatically in Fig. 813. This design was said to have been worked out by the Germans during the last war and used for proportional rudder con-

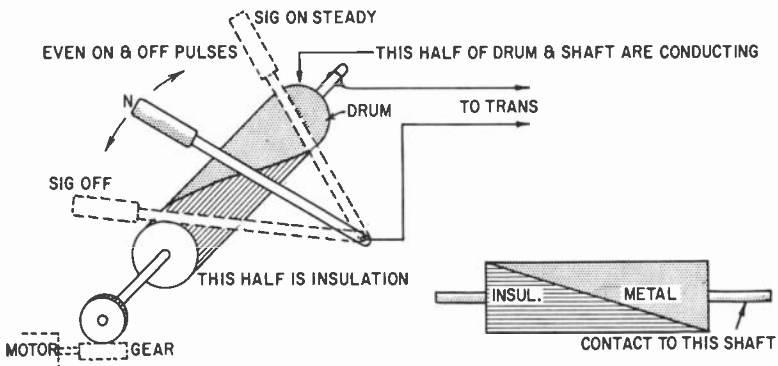


Fig. 813. *Lever sliding over face of Knupple provides pulse length variation. Electrical contact to conducting portion of drum may be made to shaft, as shown (shaft must be connected to drum surface) or you can provide an additional contact or "brush" at extreme right drum end.*

trol on glide bombs. The drum is made up of sections of insulation and conducting material, with the junction between them splitting the drum diagonally. If the drum is carefully made, the pulses will be absolutely uniform. Aside from the drum itself, the rest of the mechanism is fairly simple. Of course, for best results, both the metal portion of the drum and the section of the arm that makes contact with it should be of silver or at least heavily-plated. However, plain brass will do if the surfaces are cleaned occasionally; apply some substance such as Lubriplate to the surfaces.

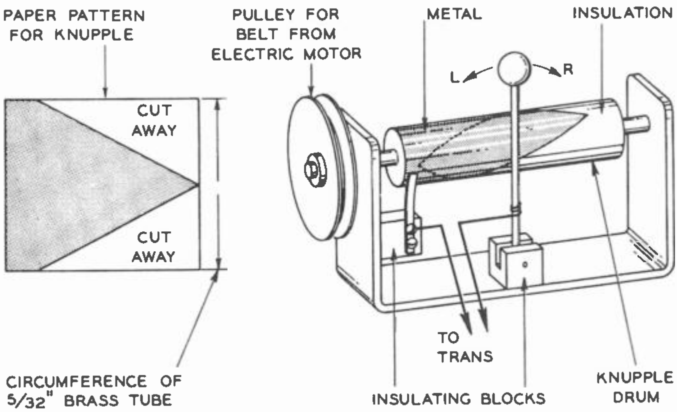


Fig. 814. *Drum conductor is cut following marks traced on it from paper pattern. Though 5/32" diameter is specified, larger diameter is easier to make, does not require such careful workmanship.*

This gadget is called a "Knupple" by its originators. The drum-speed considerations are the same as for the pulser of Fig. 814, and 200 rpm could be considered about average. Some receivers will not handle this speed, while if you go much slower, the rudder movement may become slow enough to allow the ship to wobble in flight as it responds partially to each rudder movement.

It might appear that the best way to make the Knupple would be to slice off sections of conducting and insulating material, mount them on a shaft and turn the surface smooth. Actually, this does *not* produce the best control action. Examination of a drum made in this manner will show that control action near the limits of right and left is not linear, and the rudder (or other control) will go to its extremes rather suddenly and with a very small stick movement. To make a Knupple that gives a more even action over the entire control range, start with a piece of brass tubing of the desired diameter (some very successful pulsers have been made using tubing as small as 5/32-inch diameter, but larger tubing will not require such careful workmanship) and wrap a piece of paper around it, trimming the paper until it encircles the tube exactly, without overlap. Then lay the paper out flat and mark it as in Fig. 814. Wrap this pattern around the tubing and mark carefully around the outline of the paper. Then cut away the unwanted part of the tubing. Now slide this piece inside a short section of the next larger tubing, *carefully* center a metal shaft in the assembly and pour in Fiberglas resin. When this hardens, cut off the outer form and smooth the Knupple surface.

Mount the part on suitable bearings and arrange a motor drive (this can be done with gears or pulleys and belts) and a contact arm, and your pulser is ready to go.

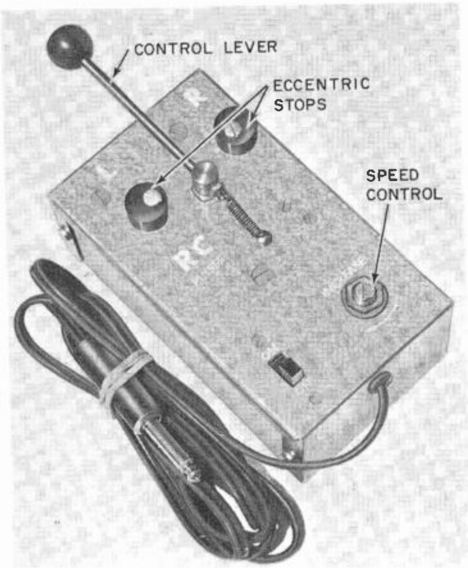


Fig. 815. *Quiet "mechanical" pulser holds necessary drive battery inside case. Stops may be set to give full on and off at lever extremes, or you can turn them to allow short pulses at each end of lever motion.*

Cam type pulsers

There is considerable argument among pulse enthusiasts as to whether the Knupple or cam types are the best. Without joining the argument, let's look at a simple cam type unit. The external appearance is shown in Fig. 815. The control lever with a plastic knob is at the top (good knobs for this use can be had from plastic deodorant bottles of the "roll-on" type); two eccentric stops can be set to vary the limits of stick movement. The on – off switch is at the lower left and the rheostat knob to control speed at the lower right.

These so-called mechanical pulsers have a reputation of being "coffee-grinders" and indeed, some of them do make as much noise in operation as such a device. To cut down on noise, the entire rotating mechanism of this pulser is mounted on a motor plate and insulated from the case with gum-rubber grommets (not the firmer black rubber type) and the type of cupped washers sold for this use (see Fig. 816). As a means of quieting, the motor

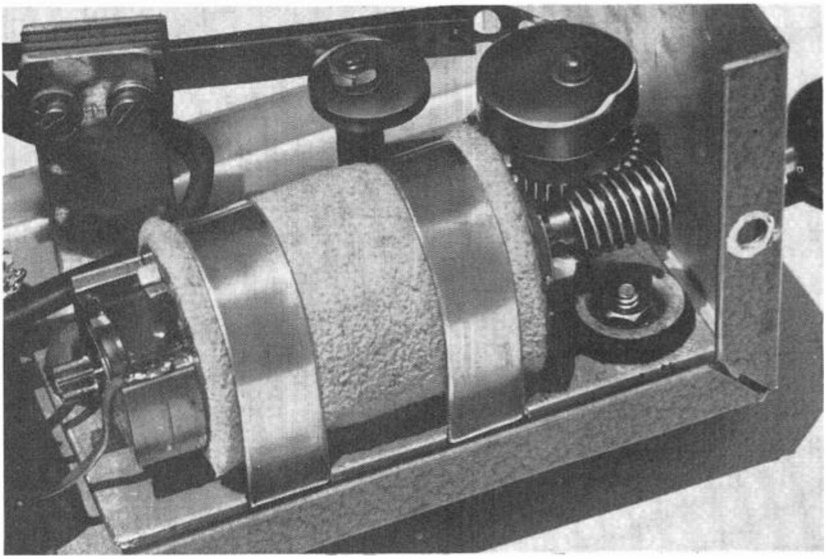


Fig. 816. *Motor is an Aristo-Rev #2, which operates at good speed on 1½ volts. Metal straps hold it to plate carrying cam mounting shaft. Motor is insulated from plate, and latter is further mechanically insulated from case, to keep noise down.*

itself is wrapped in foam rubber (Fig. 817) and an extra layer of the same material placed under it when it is fastened to the motor plate. As a result the noise level is quite low, though enough can be heard to assure the user that the pulser is still operating.

A material called Adhesive Foam sold at drugstores for foot care was used in this pulser. It is about ⅛ inch thick and has an adhesive layer on one side. Foam insoles can also be used; they have no adhesive but can be attached with rubber cement.

If you can get them in the desired ratio, model-train engine-drive gears are useful for this pulser. For the motor indicated, a gear ratio of about 10 to 1 or a little less is suggested; if the pulser runs too fast, the speed can be reduced with the rheostat.

The worm gear will probably have a hole in it much larger than the motor shaft, but this can be filled with short lengths of telescoping brass tubing. Solder all the tubes and the worm together (keep solder off the worm teeth).

The motor shaft was found to make a very snug fit in a hole drilled through the center of the worm and tube assembly with a No. 46 drill. A small setscrew can be added if desired.

A plain circular cam (details are given in Fig. 818) will work on such pulsers as this but does not give the best pulse action, especially near the ends of the stick movement. A heart-shaped cam (such as that in Fig. 816) is preferable; it can be laid out with a piece of slotted rod (to hold the inner end of the wire) and a sharp

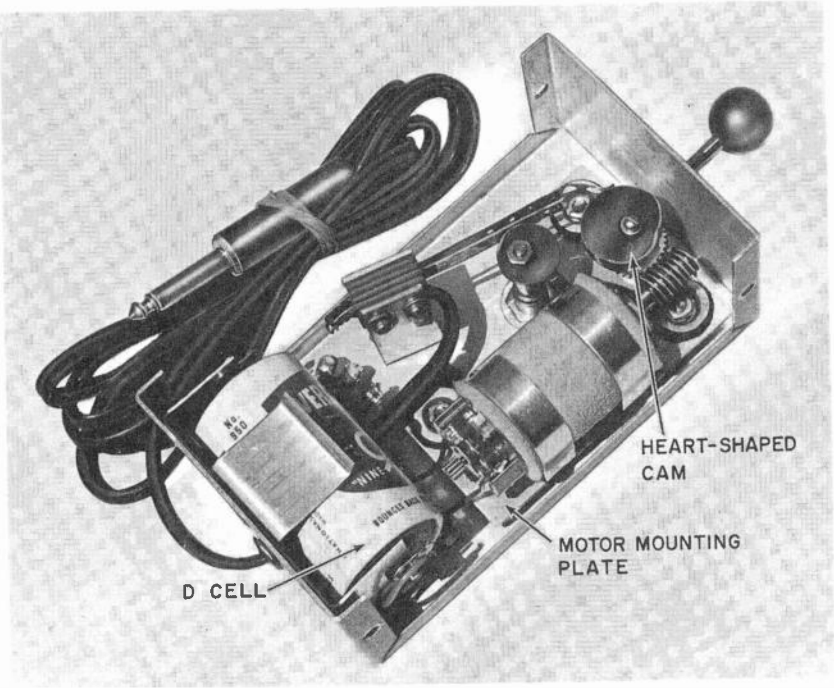
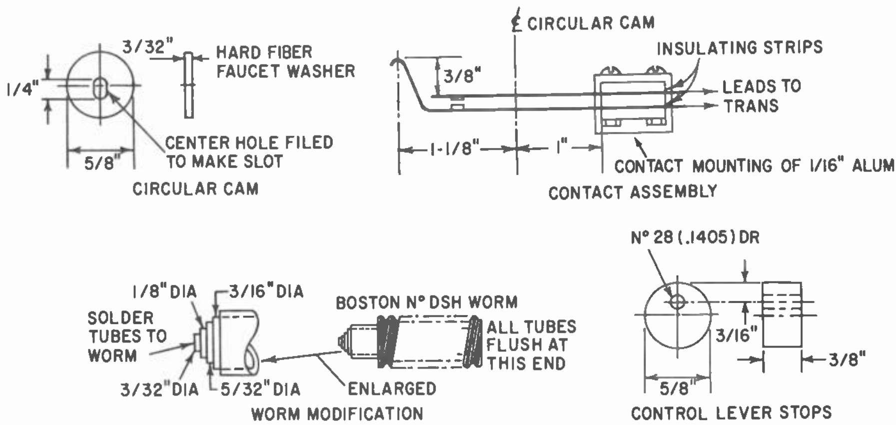


Fig. 817. *Over all view of pulser shows single D cell in aluminum holder at left, motor plate and heart-shaped cam at lower right, keying contacts angled to cam above. Circular cam is on end of control stick, varies position of one contact strip relative to the other which rides on motor-driven cam face.*

scriber (see Fig. 819). If you put the scriber point in a loop of wire and pull it round 180° (always keeping the scriber exactly vertical), the wire will wind around the center rod and reduce its effective length as you proceed. Do this on both sides of the cam and you will have scribed the proper heart shape.

The cam is assembled with the cam gear on 3/16-inch diameter tubing, the whole then turning on a 5/32" diameter rod. The hole for this shaft in the motor plate is made a bit oblong so that a good fit can be obtained between gear and worm — snug, but with just a bit of looseness so the gears won't bind.

Since it turns only a small fraction of a complete revolution, an offset disc is satisfactory as a cam on the control lever rod. The hole is made oblong so the amount of cam action can be adjusted as desired. A fiber faucet washer can be used for this.



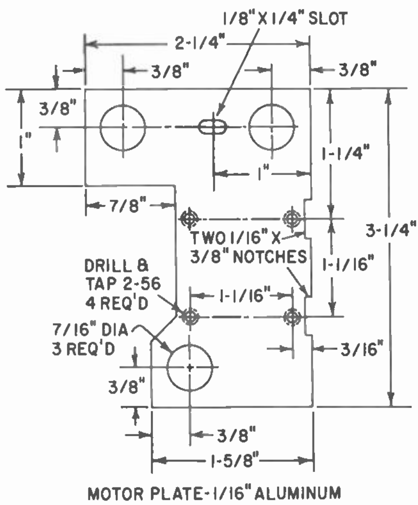
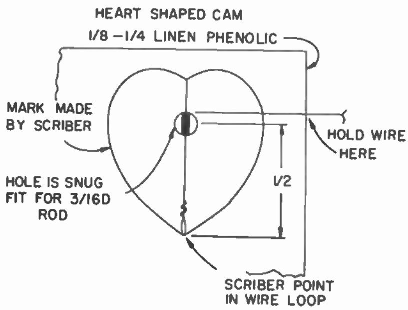


Fig. 818. *Components for pulser in Fig. 817. Hobby shops can supply suitable worm and gear from Wilson assortments, or use Boston worm indicated above, with Boston #D1118 mating gear. Control shaft was made from Bud #PB-532 panel bearing, and case was Bud #CU-2106. Latter measures ¼x 3 x 2⅛". Worm must be absolutely concentric on motor shaft.*

Assemble all parts carefully. The cup washers holding the grommets should not clamp them down too tightly — remember, you want as much shock-absorbing action from the grommets as possible, without allowing the motor plate to wobble sideways.

Commercial shaft and bushing assemblies can be had at radio suppliers, but have been found to have far too much "slop" in them for use as the control-lever shaft and bearing (looseness here would play havoc with your carefully controlled pulse lengths). Again, that invaluable hobby-shop telescoping tubing can be used to get a snug fit with these parts, which are assembled as in Fig. 820.

A pair of contacts from an old relay or leaf switch (or made from some flat springy material) complete the mechanism of the pulser. Those shown are of .010-inch spring bronze and have silver contacts. Be sure they are well insulated from the case.



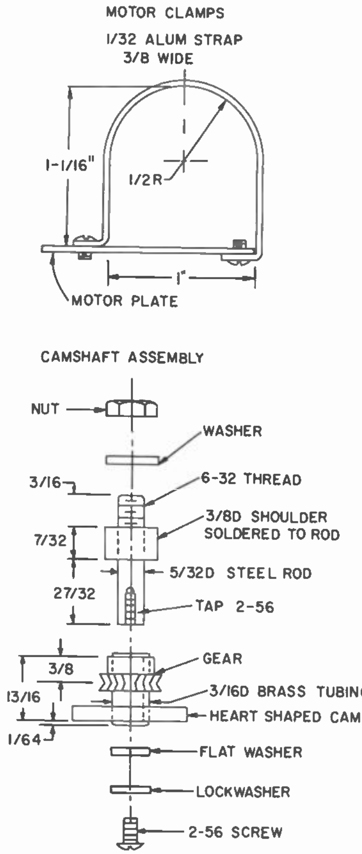


Fig. 819. *Heart shaped cam made as seen at left gives best results, but plain circular cam has been widely used too. Wire winds around 3/16" D rod as you scribe line, and continuously shortens. Cam bearing assembly must be made with care; try for lack of "slop", but bind-free rotation.*

For most rudder-only pulse systems, the contacts are adjusted so they just open at one extreme of stick movement and just close (no pulses sent out at either extreme) at the other. Due to a lag in receiver response, it is often desirable to "offset" the pulsing – that is, you will not have even on – off pulses with the stick centered. This can be done easily by bending the contact tip that rubs on the rotating cam.

Electronic pulsers

If there is some debate between advocates of various types of mechanical pulsers, there is even more among those who prefer mechanical types in general rather than the electronic pulsers. The latter had a name for being rather fussy, especially as to type of relay used, until the circuit shown in Fig. 821 was suggested. This pulser — a form of multivibrator — can be used with almost

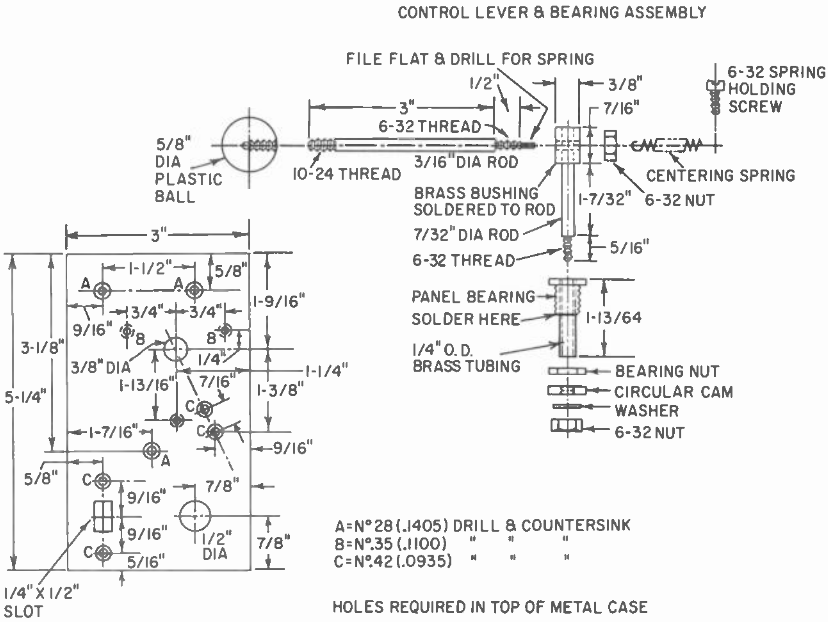


Fig. 820. Drawing (lower left) shows positioning and hole sizes in top of case. Exploded view (right) of control lever and bearing assembly.

any relay and has generally proved to be most reliable. It has been used in many forms but always with the basic multivibrator setup employing a pair of pentodes. As shown here, the pulse-length range is about 20% — 80%. A greater variation in pulse length can be had by reducing the two 330,000-ohm grid resistors, but they should not be smaller than about 100,000 ohms. The rate control will give a variation of about 2 – 8 cycles. To change this range, the .22 μf coupling capacitors can be changed (smaller to get higher frequency pulsing). The originator of this circuit, Dr. W. A. Good, suggested that only the very best potentiometers be used; the Allen-Bradley type J was specified (Ohmite type AB is practically indentical).

"Compact" pulser

An early effort at shrinking the Good pulser circuit is shown in

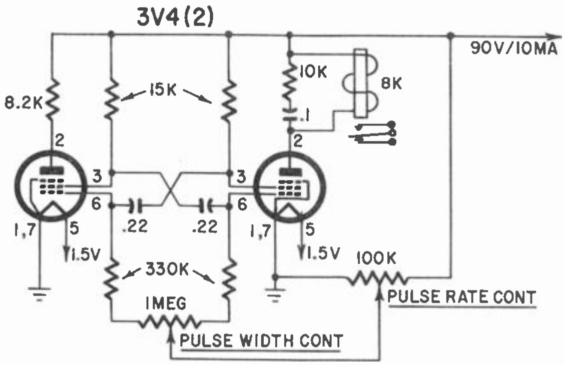


Fig. 821. *WAG multivibrator pulser uses pair of pentodes. If parts are carefully matched, there will be little interaction between pulse length and rate controls. Circuits of this type are susceptible to rf interference, through rf from transmitter getting to tube grid circuits. Careful shielding is necessary.*

Fig. 822. It was called the "compact" pulser, since the whole works, including A- and B-batteries and the highly reliable Sigma 4F re-

Fig. 822. *The "compact" pulser, so-called because all batteries are in 3 x 4 x 5" case. Large knob at case upper edge is rudder trim control.*

lay (Figs. 823 and 824) are all contained in a commercial aluminum box, 3 x 4 x 5 inches. Subminiature tubes and a few circuit modifications allowed somewhat lower drain on both A- and B-batteries. Extensive field use of this pulser has shown it to be extremely reliable, About the only modification suggested would be larger A-batteries, as penlight cells tend to lose their voltage

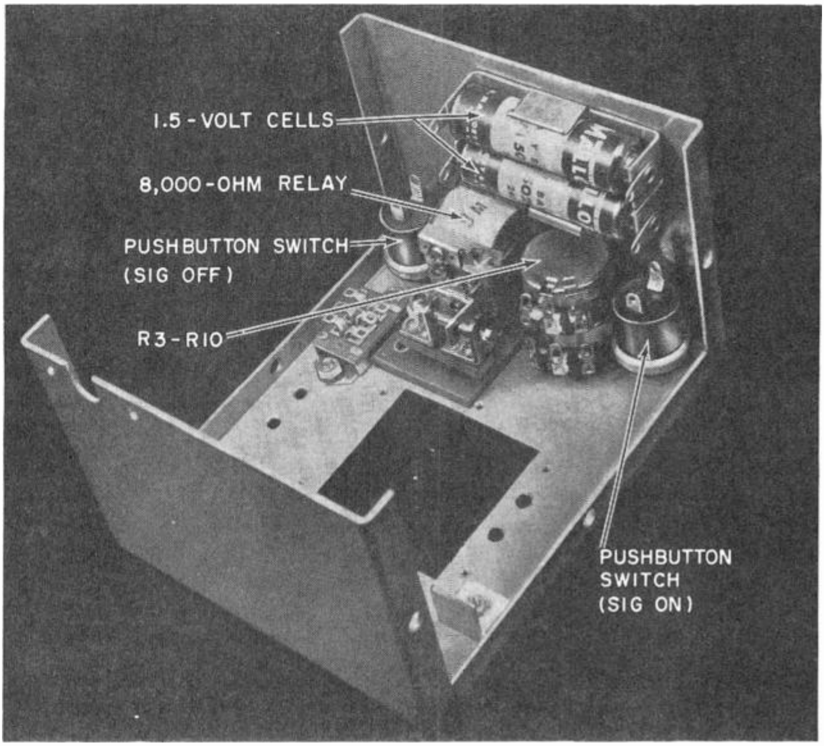


Fig. 823. *Photo of all parts in "compact" pulser case aside from those associated with control pots and circuit chassis. Note insulated base for Sigma 4F relay, necessary to isolate relay frame from pulser case.*

fairly fast under the current drain of 90 ma. However, use of heavy-duty penlight cells has helped a lot here. The B-battery has very long life, with average B-drain being about 4.5 ma.

The trickiest part of construction is making the control-stick assembly, which works the two potentiometers independently. Rather than use the more expensive AB potentiometers, low-cost commercial units were substituted and have been found very satisfactory. A type with a solid 1/4-inch shaft was selected for ease in attaching the gears. The big problem in using any of these potentiometers is the fact that the resistor shaft turns through about 200° while we want to limit control-stick movement to 90° or less. Gearing seems the logical solution. The smaller gear, which fits on the potentiometer shaft, must be large enough in diameter

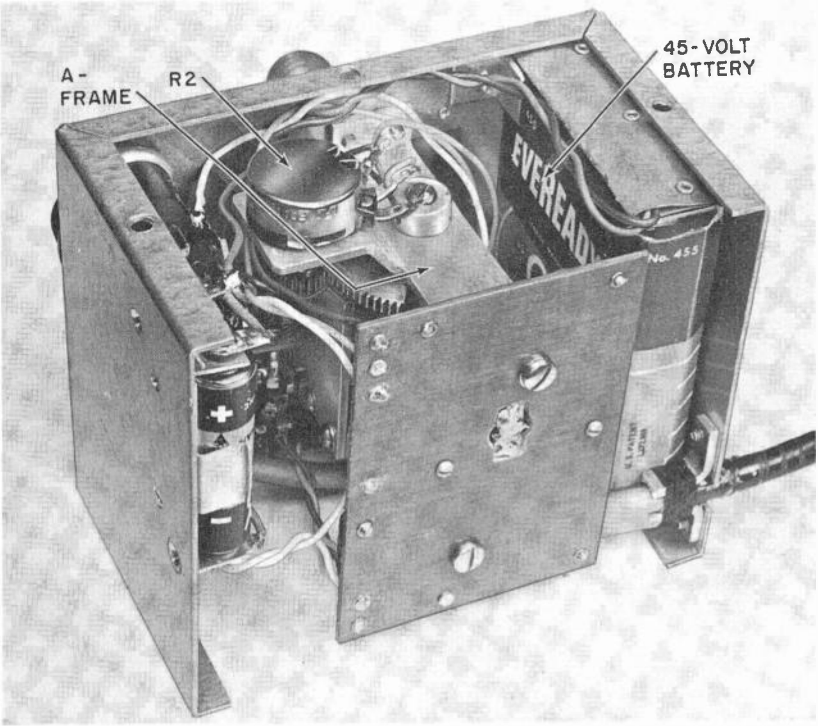


Fig. 824. "Compact" pulser ready to work. B-battery at right is held by cable passing around it, and by foam plastic cemented inside bottom cover. Note wires on R2 are soldered to ends of lugs, then passed through lug inner holes, to take strain off soldered joint.

to allow boring to the required ¼-inch. Gears A and B (Figs. 825 and 826) are cut down, since only a small portion of the teeth is required. The basic frame A is bent from a single strip, and includes an extended ear to hold the rate potentiometer R2. R1 is held in a center cradle made from two pieces of strip, B and C.

It is essential that all parts move smoothly and that the gears mesh evenly. Some users prefer not to have self-centering, but the pulser shown has a simple centering arrangement: it is just a single spring running from the lower end of the control stick and held by a pin on the underside of the hole. It serves to pull the stick back to neutral from any position (Fig. 827).

Though the original "compact" pulser was made just as shown and is still giving fine results, many modifications have been devised that allow simpler potentiometer operation, some of these being given later in this chapter.

Several handy innovations are included in this pulser. For one there is a rudder-trimming arrangement through use of

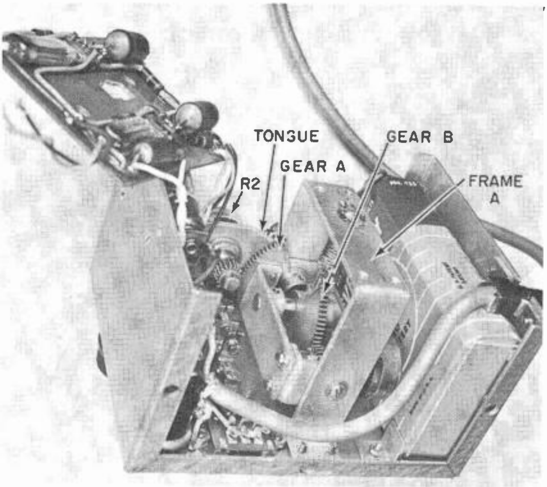


Fig. 825. *All wires to tube mount plate run to one edge, so plate may be unfastened and folded back for access to tubes and other circuit parts. Sockets are used for tubes; latter held to plate with a spot of Goo. It's wise to cement thin fiber to inside of case bottom to prevent shorts.*

variable resistors R3 and R10 (which together are actually a dual potentiometer) controlled by a small knob on top of the case. Also, switches S2 and S3 (Fig. 828) were installed, making it possible to get full-signal or no-signal from the transmitter at will (these extremes cannot be reached with the pulse-length potentiometer R1). R3 and R10 must be wired so that as the resistance of one is increased, the other decreases. Very flexible wire is used to connect to R1. The bare ends of the leads are first soldered to the innermost hole of each potentiometer lug, then threaded through the other hole to take the strain off the soldered joint and that portion of the wire which has no covering.

All circuit components except the relay, variable resistors, switches and batteries are mounted on a single linen phenolic plate (Fig. 829). The oblong hole near the center is to clear the centering spring and its pin. Be careful in selecting the electrical parts, especially C1 and C2, R5 and R6, and R9. Match these pairs of parts as closely as possible or the pulsing may be lopsided. Of course, there is a certain variation in tubes, too, which can give uneven pulsing. You can compensate for some of this by resetting the trim control (R3—R10), but variation in parts can also lead to interaction — that is, variation in pulse rate as the pulse-length potentiometer is varied, and vice versa. Most radio control suppliers can furnish matched parts for this pulser.

The Sigma 4F relay must be mounted on a piece of insulation.

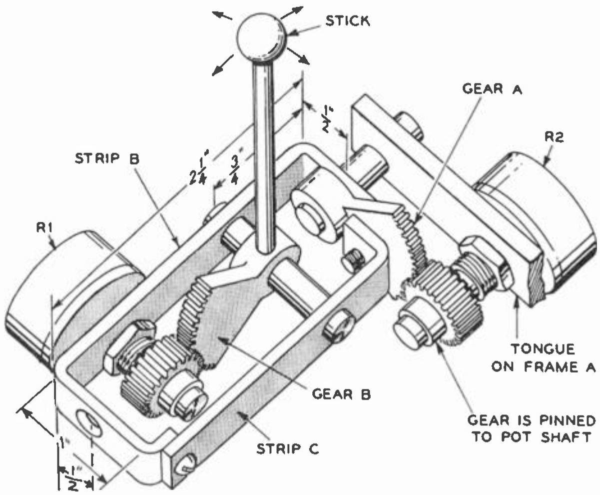


Fig. 826. *General dimensions of "cradle" which holds R1 and R2 in "compact pulser." Two pieces of aluminum strip are used, to make for easier assembly. Large gears are cut away to allow tighter layout. Hole at left side of cradle is for screw, seen at left of main frame in Fig. 827.*

The entire frame of the relay is hot because it is connected to the B-plus circuit of the transmitter. The relay is an 8,000-ohm-unit, but other types can be used — just change R4 to match the relay resistance. The relay adjustment is not at all fussy. The armature is set so that it can come quite close to (but not touch) the core when operated with a finger; the other contact is set to give a gap of 0.006 — 0.007 inch.

The most critical situation for relay operation is at the highest pulse rate with R1 set all the way to either side, so check operation carefully under these conditions, and adjust the spring tension to obtain reliable pulsing. Relay current is about 0 — 3 ma.

If your plane rudder moves the opposite way from the control stick, just transpose the connections to R3 and R10. Pulse-rate operation can be reversed by interchanging the leads to the outer terminals of R2.

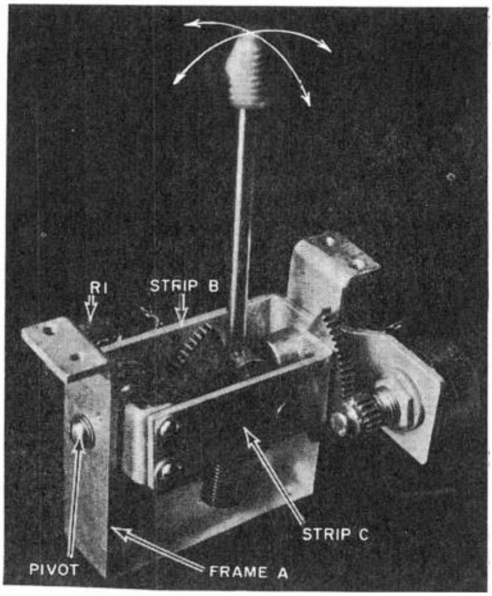


Fig. 827. *The complete potentiometer and control handle assembly of "compact" pulser. Single spring under lower end of vertical lever gives rough centering action to the entire assembly.*

The "compact" pulser produces a rate change of about 3 to 12 pulses per second. It's tough to count at the higher rate; one way is to get your foot tapping at the lowest rate, then as you advance

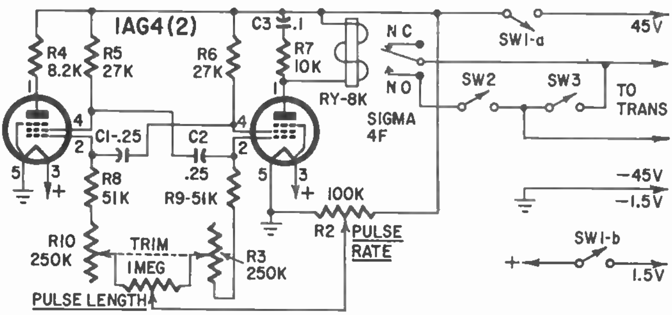


Fig. 828. *Compact pulser circuit. Note connections of R3 and R10; as one increases value, other decreases. Sub-min sockets used for tubes, cemented and fastened with single screw each. R1 and R2 in original were IRC type PQ-11-137 and PQ11-128; these have solid one-piece shafts. Two mercury cells have been used for A supply, or Eveready E91 cells recommended. Fixed resistors should be 5% units preferably, and C1 and C2 matched for capacity; latter are Aerovox type P82.*

the rate control you can hear the relay click twice as fast (for 6 pps in this case) and so on up the scale. Some users have found a rate-trim adjustment handy. This can be added by simply inserting a 250,000-ohm variable resistor in series with the connection between the movable contacts of R1 and R2.

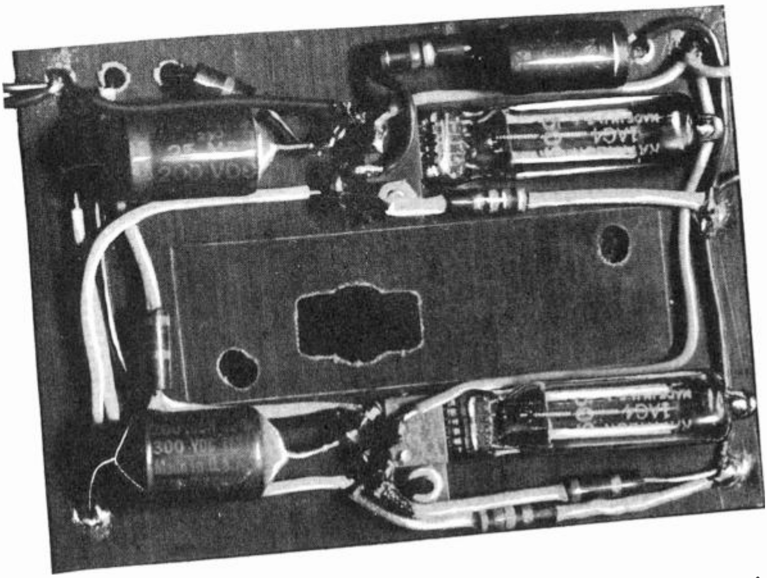


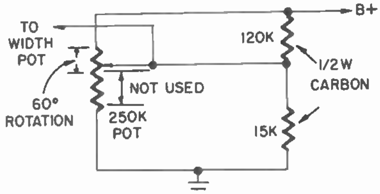
Fig. 829. *Several eyelets are used to hold ends of small parts on tube deck of "compact" pulser. Rectangle and odd-shaped hole in center of phenolic plate are for bottom of control "U" frame, and for centering spring.*

Troubleshooting electronic pulsers

Most pulsers of this type are multivibrators, so here are a few hints on obtaining the best operation. First, the pulsers are af oscillators but work at a much lower frequency. These circuits are quite likely to pick up rf and work incorrectly. The best test of this is to turn on the rf section of the transmitter *after* the multivibrator has been started pulsing and listen carefully for any change in pulse rate (easy to distinguish from the sound of relay operation. Often, pulsers work much better when used with their own A- and B-power supplies. Also, vibrator or dynamotor B-supplies are sometimes not as carefully filtered as they should be. This won't bother the transmitter too seriously (though the hum or hash on the carrier could interfere with proper receiver action), but is very likely to cause erratic multivibrator pulser operation, if the pulser gets its power from the transmitter. It is good practice to use a shielded cable to connect a remote unit like the "compact" pulser to the transmitter and to ground the shield to both cases.

Always match multivibrator pulser parts carefully. The pulse rate might change slightly as the control stick is moved to side

Fig. 830. *Circuit for limiting potentiometer action electrically. Overall resistance will be about 100K, but the total potentiometer arm movement needed to obtain this is only some 60 degrees.*



extremes, but this does little harm if the change is the same on both sides. If the rate changes radically as R1 (Fig. 828) is moved to extremes, make R8 and R9 larger; add enough resistance to both so that the rate change is not excessive.

If you find the pulse length to be different at one extreme

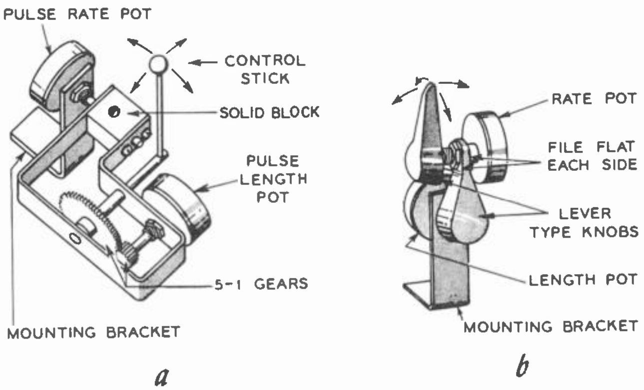
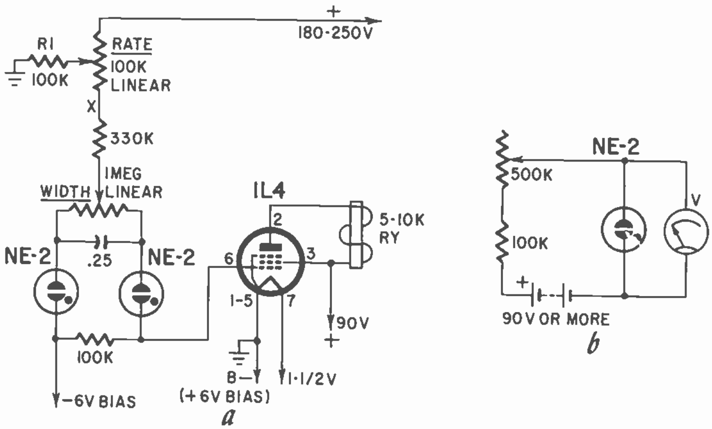


Fig. 831. *Two styles of potentiometer mounting. One at left (a) uses a geared and an ungeared pot for the two controls. Latter would have to be a 60-degree unit, this result obtained either electrically or otherwise. The other arrangement (b) has two potentiometers and two long lever-type knobs, in a simple control assembly.*

of R1 than the other, try interchanging the tubes or substituting others of the same type. Such imbalance can also be cured by changing the value of one of the screen grid resistors. Insert a variable resistor of perhaps 75,000 ohms in place of R5, and try different settings till you get the pulse length balanced; then replace the variable with a fixed resistor of the same value.

Simpler dual-potentiometer mountings

Many ingenious schemes have been used to mount the two potentiometers required for a rate – length variable multivibrator. The arrangement used in the "compact" pulser has proved ex-



Figs. 832-a, -b. *Two neon bulbs are the oscillator in pulser circuit at left, the af they produce being amplified by 1L4 tube, to modulate transmitter. Test circuit to pick matched neon bulbs shown at b.*

tremely satisfactory, but it is a bit tricky to build and the gears are not always easy to obtain. One of the neatest solutions to the problem is the use of restricted-range pots: some radio-control suppliers carry special potentiometers that give the entire resistance variation in only about 60 to 70 degrees of shaft movement. This makes possible a very simple mounting where one potentiometer acts as a pivot to support the other and the latter is controlled directly by the stick.

Lacking special potentiometers, other tricks can be used. Some modelers have painted out large portions of the carbon element with silver conducting paint. If this is done, a higher-resistance potentiometer than that specified in Fig. 828 must be used, so the active section will be the total resistance required. Another good trick is to rub a gold ring on the carbon element. This leaves a slight metal deposit to short the unwanted sections to the end connections.

It is possible to limit the rotation electrically (Fig. 830). Here, we end up with the desired 60° rotation of the shaft, to give a change equivalent to about that obtained from the 100,000-ohm potentiometer (R2) is the "compact" pulser.

Fig. 831 shows a few mechanical schemes that can be adapted as required. In Fig. 831-a, the rate potentiometer might be connected as in Fig. 828, while the one turned through the 5- to 1-gears would be used for pulse length. This arrangement would give full control of both pulse rate and length with perhaps 75° of stick movement sideways and fore and aft.

Fig. 831-b is an even simpler arrangement. The rate potentiometer is held on a piece of metal or plastic secured to the shaft of the pulse-length resistor which is fastened to the case. Some radio suppliers carry long lever-type knobs usable in such an assembly.

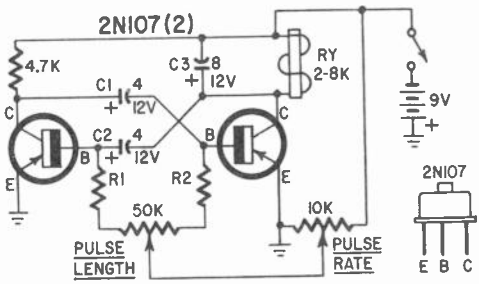
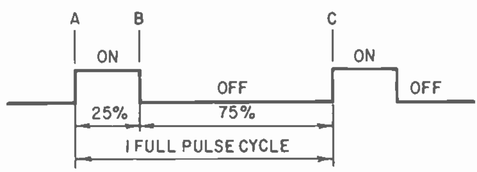


Fig. 833. *Simple transistor multivibrator pulser uses low cost transistors. Pulse rate adjustment not usable for such control systems as Kickin' Duck, as the rate and length controls have considerable interaction.*

Neon-tube pulser

Simple circuitry is a feature of this unit (Fig. 832-a) but it requires fairly high B-voltage. It is used in transmitters which have a dynamotor or vibrator power supply. The two tiny neon tubes

Fig. 834. *Graphical representation of a pulse, showing relative length of "on" and "off" periods for the entire pulse cycle.*



(NE-2) are the actual pulsers, the impulses being fed to the 1L4, which operates the relay. R1 should be such that the voltage at point X is no less than 90 volts over the entire range of the rate adjustment. Pulse-width variation can be caused by uneven firing of the NE-2 tubes. The best way to select them is to wire a test circuit as in Fig. 832-b and check the voltage at which the bulbs fire. Select two which light at the same voltage. Bias supply can be from the tiniest dry or mercury batteries and will last almost indefinitely.

Transistor pulser

Due to their compactness and low power requirements, transistor pulsers are quite popular. A suitable circuit is seen in Fig. 833. This is a form of multivibrator so, again, parts must be balanced carefully for good operation. As low-cost transistors vary quite a bit, several might have to be tried to get a fairly well-matched pair. R1 and R2 may be varied to even the pulsing; if you can't obtain matched transistors, values from 4,700 to 22,000 ohms are useful here. All three capacitors should be of the low-

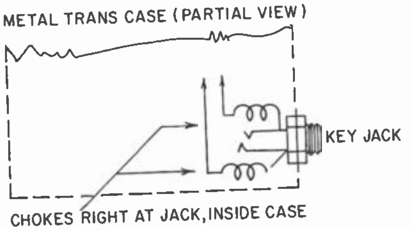


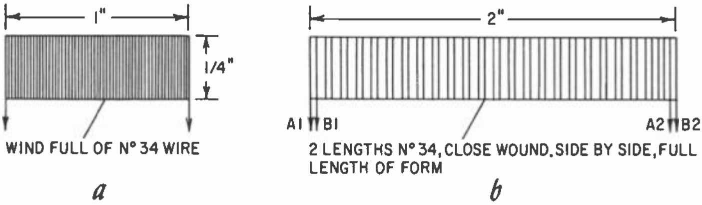
Fig. 835. *Mount rf chokes in keying leads right on key jack, for maximum effectiveness. These chokes prevent key lead from acting as an extension of the antenna. Since key leads generally carry low current, chokes may be quite small ones, similar to those used in receiver circuits. As a rough guide, for 27 mc chokes should be at least 20 μh, while half this will do for 50 mc transmitters.*

leakage type (tantalum construction preferred). B-battery voltages of 6 to 10 are suitable, depending upon sensitivity of the relay used. Possibly, a high-conductance diode such as a 1N91 or 1N56 would be as good or better than the electrolytic across the relay winding. Pulse-rate variation with the circuit shown was about 3 – 10 pulses per second and current drains 3 – 5 ma.

This circuit is not recommended for dual proportional purposes, since there is some interaction of the controls for rate and length. The former should be set to the desired pulse speed and left in that position. Good operation can be had with almost any pair of 2N107's if the builder is willing to spend a little time juggling values of R1, R2, C1 and C2. The object is to get on – off pulsing with the length potentiometer centered. Quite possibly, higher-grade transistors would not require so much experimentation.

Practical pulse rates

Some receivers will pulse much more rapidly than others, the lag in the poorer pulsers often being caused by certain component values associated with the tube that actuates the relay. One receiver with a circuit similar to that in Fig. 509, but with a V3 total grid leak of 44 megohms, was used regularly at a pulse rate of 400 pulses per minute, a rate high enough so that the rudder did very little flapping (an actuator was used). The faster the pulse rate, the more of the total range of pulsing you lose; with the receiver mentioned, it was found that at a pulse rate of 370 a minute, the receiver relay would not operate unless the pulses were *on* at least 25% of the time. To make this clear, refer to Fig. 834. One pulse cycle should be considered as the total time between A and C; this includes an on-signal period (A — B) and the off period (B — C). Thus, if the pulses were as in Fig. 834, the receiver mentioned would not respond at all. This has not been found too great a disadvantage in use, as the pulser and rudder linkage can be "offset" to compensate. However, it can produce difficulties for any dual-control circuit (such as the inductive kick) which depends upon pulse rate and length. On this same receiver, raising the pulse rate to 620 a minute increased the useless portion of the total pulse



Figs. 836-a, -b. *Some homemade chokes that have been used successfully to isolate keying leads. These should be placed right at key lead jack in transmitter case.*

length (when the relay would not operate) to about 40%, while lowering the rate to 225 cut this unusable area to only 18%. When the grid leak was cut from the original 44 megohms to only 10 megohms, the receiver would follow the pulses down to 15%, at the 370-ppm rate (but relay current change was not as good with the lower value of leak). Most of the receivers described in this book have been found suitable for rudder-only pulse operations.

Not only receiver circuitry but other elements in the radio control system can impede high-speed pulsing. For example, a sluggish crystal in a CW transmitter might be slow to start, though it would be satisfactory in other respects. Relays can also be responsible for poor pulse response, even though the associated receiver is good in this respect. Generally, the smaller relays with lighter armatures will react the fastest. It is very bad on *any* relay to allow the armature to come into physical contact with the polepiece. as sticking will occur. For best pulsing operation, the total armature movement should be kept as small as possible. Spring tension affects pulsing too, but an average balance must be reached here, as too heavy or too light tension will have adverse affects at opposite ends of the pulse-length range. Some modelers alter the spring tension of a working receiver to center the rudder of a model, but this is generally bad practice. It is much better to set the relay up as necessary to satisfy requirements of receiver current change and vibration in the model, and make compensation for uneven pulse response elsewhere in the system.

Key lead chokes

Though it is not exactly involved in the subject of keying the transmitter, the use of rf chokes in the key leads might be considered here. The reason these are needed is simply that the key leads act as part of the antenna system (when any sort of simple antenna such as the popular quarter-wave type is used) and moving the lead around – or even holding it in your hand changes the loading and in turn varies the transmitter output. Normally this does no harm, but if a non-MOPA transmitter is tuned too near the peak of output (that is, just below the point where the crystal drops suddenly out of oscillation), movement of the key lead is likely to put the transmitter off the air completely, with possible disastrous results to the model under control.

Fortunately, the remedy is very simple and has been used in a few commercial and homebuilt outfits. The solution consists of installing rf chokes in each of the key leads. Note that if a hand-held motor-driven pulse box is used, chokes must be in the wires that go to the motor too – in other words, everything in the keying system outside of the transmitter case must be isolated rf-wise. Suitable chokes are shown in Fig. 835. These might be satisfactory to carry motor current unless the motor is a very greedy one in which case larger wire will be nesessary. The chokes may be individual ones for each lead, or you can wind them all together on one form, as in Figs. 836-a, -b.

chapter NINE

batteries and power supplies

BATTERIES are our best source of cheap power in small packages, and the radio-control modeler would do well to get acquainted with the various types and to learn the advantages and disadvantages of each. By far, the most popular are the so-called dry cells (which really aren't dry at all — they must have considerable internal moisture to operate)! These can be had in a large variety of makes and sizes.

Because they are more widely distributed, the flashlight cells see the greatest use. In the lower voltages there are three main sizes; the AA, or penlight cell; the C, or intermediate; and the D, or large cell. All have the same nominal voltage — about 1.5 when new — but they vary widely in capacity, which is simply the length of time they will supply power of a given amount.

Recuperation is most important. A dry cell consists of electrodes of carbon, zinc, an active chemical and a depolarizer. The carbon and zinc are arranged differently according to make (most use a zinc case with a center carbon rod), but the zinc is always consumed by the active chemical to produce electricity. During this reaction, considerable hydrogen gas is produced and this collects on the carbon. If you draw too much current from the cell, the carbon becomes heavily coated and the cell loses its power to produce electricity. Usually, with a good rest, it will come back; the depolarizer combines with the hydrogen to do this job.

Always check dry cells under load. You can get small test meters that put a load on the cell. You can then read the resultant voltage. It does little good to check a dry cell with a high-resistance meter, since even weak cells will often register nearly 1½ volts with no load. An easy way to get a load is simply to turn on the receiver, transmitter or whatever other equipment the battery powers, and measure the voltage under the normal load. Since voltage drops under load according to the useful life left in the cell, you can get a rather fair idea of when to change your batteries. Many makers of commercial radio-control equipment specify the voltage you can allow A- or B-batteries to drop to before they must be replaced.

The general rule when selecting batteries is to use the largest size you can accommodate; it will invariably be found more economical. If, due to space limitations or some other reason you have to use smaller cells, you can prolong their life by connecting two or more in parallel. This is most useful with single flashlight cells. Though some users parallel small 22½ volt B-batteries it is probably not wise, however, to use B-batteries of higher voltage in parallel.

Mercury cells

Mercury cells and batteries are considered to be dry types, but have some of the characteristics of alkaline storage cells. They have a nominal voltage of about 1.35 when fresh, and hold this voltage much more steadily during discharge than do the carbon – zinc dry cells. Due to their somewhat higher cost and rather high weight, mercury cells have not seen very wide use in model work. They cannot be recharged or de-polarized, and the makers strongly warn against such practices. Now that all-transistor radio-control receivers are becoming more popular (with their requirements of 3- to 9-volt batteries or so) mercury batteries might be more widely employed. There is a wide variety of them in these lower voltages, and they are well-distributed due to use in the popular all-transistor pocket broadcast receivers. Many of these compact batteries have sturdy snap fasteners ideal for use in radio-control equipment. Commercial holders can also be obtained for various sizes of mercury cells and batteries.

Lead – acid storage cells

Storage cells of various types are more and more coming into use, particularly in view of the fact that planes carry more equipment and power drains are getting so high that dry cells are often not feasible. The most familiar storage cell or battery is the lead – acid type. These cells are also used to quite an extent in transmitters. Various sizes of such cells and batteries are sold as surplus at very low prices, as, for example, the 2-volt cell used in the transmitter at the beginning of Chapter 7. Many modelers use similar cells solely for glow-plug engine starting, where their large capacity assures plenty of current for the glow plug, despite the usual several-ampere drain.

Most of the surplus cells are sold "dry" – they have no acid solution in them. Cells in this condition will last for years, especially if the vent is sealed. They can usually be filled with standard auto-battery acid. Many of the larger cells have one or more colored plastic balls inside the case; these act as a constant check on the amount of charge in the cell. The usual arrangement is a green,

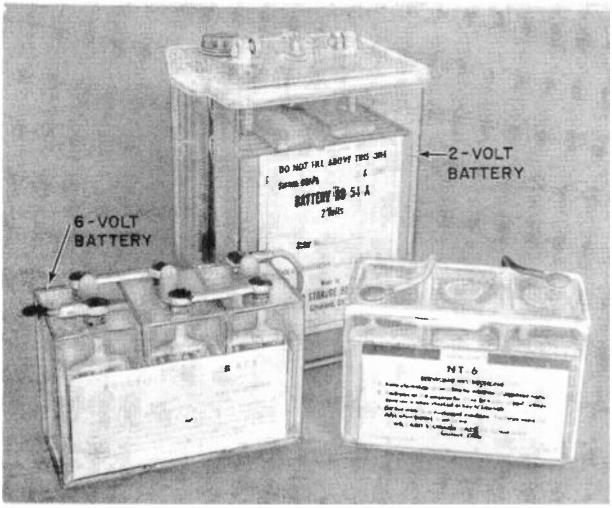


Fig. 901. *Several types of lead-acid units used in R/C. In background is BB-54A surplus 2 volt cell, widely used in transmitters, and for engine starting. 6 volt unit left foreground is Aristo #64, especially made for model uses. This and the surplus NT-6 at right are popular in smaller model boats for drive purposes.*

a white and a red ball. When the green drops, you have about 75% capacity remaining; the white drops at 50% and, when the red goes down, you still have 25% capacity left. *These figures are good only if the cells are filled with electrolyte of 1,280 specific gravity.* Some surplus cells are marked for use with lower specific-gravity fluid than this; a few for higher. Generally, the 1,280 value should be used in all cases. Lower-gravity electrolyte was often specified for cells intended for use in hot climates and the converse for cold climates.

Since lead – acid cells are relatively heavy, they are used very little in planes, though some of the smaller surplus types such as the NT-6 are popular for model boats and cars. In general, most users have not obtained very good results from the NT-6 (Fig. 901), a type which was intended mainly for one-shot use in military equipment. They have a short life and will not hold a charge very long. However, on the hobby market are quite a few small cells and batteries of recent manufacture that *are* intended for many recharges, and so are a much better buy. They can be had in various capacities, and in 2-, 4- and 6-volt types.

One other type of lead – acid cell should be mentioned. This is a tiny unit originally designed for pocket cigarette lighters. The cells have a translucent plastic case and weigh an ounce or so; hence, they should be very useful for application in planes. Unfor-

Fig. 902. *Plastic-cased alkaline cells include surplus nickel-cadmium 5 ah (ampere-hour) unit at left rear (popular in transmitters and for engine starting), the ABC (also known as CG or Gulton) VO-800 at right rear; left front is Yardney LR 1 Silvercel, and at right, the Sonotone 1 ah nickel-cadmium battery.*

tunately, these cells were not intended for recharging. The most popular type has a capacity of about 1/4 ampere-hour and, while it can be recharged several times, results are highly variable. They are generally not considered a good power source for radio-control work.

Two of the most interesting features of lead – acid cells are the fairly high voltage they produce – about 2.2 when fully charged – and the fact that they will hold close to 2 volts even under heavy loads. Most storage cells have the latter characteristic, but the volages of the different types vary widely.

Alkaline storage cells

Almost the exact opposite in many ways of the lead – acid cell is the Silvercel (Fig. 902), an alkaline type. It is very light for its capacity (an LR-1 cell when new has about 1.8- to 2-ampere-hours capacity, weighs only 1 ounce) and has fairly high voltage. A fully charged cell will give about 20% of its charge at nearly 1.8 volts (depending upon load), then the voltage settles to 1.5 and holds there until discharge.

Like dry cells, Silvercels do not have a very long shelf life – they tend to discharge even when not in actual use.[1] Furthermore, they should not be stored fully charged for long periods. Silvercels are not tolerant of overcharge. If you must have the greatest possible capacity in the smallest package and lightest weight, Silvercels are the answer. However, balanced against this is the fact that they do not have a very long life, cannot generally be purchased except directly from the manufacturer and are quite expensive. The makers have another type called Silcad,[2] with characteristics midway between the Silvercel and the nickel-cadmium cells described below. So far, Silcads have not seen much use in

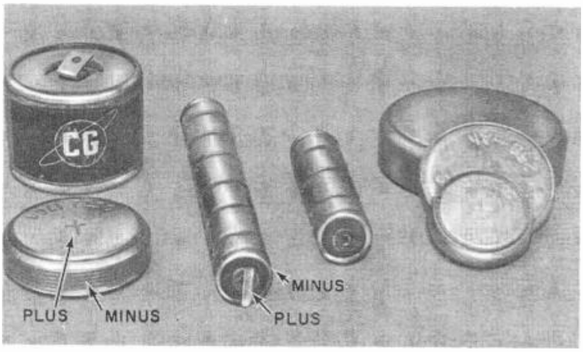


Fig. 903. *Sealed nickel-cadmium cells. Left foreground is VO-500, and behind it a "package" of two of same units in series. Left center, 900 mah (milliampere hour) cell marketed by Eveready and others, and alongside it, the similar 450 mah cell, same size as AA dry cell. Button cells at right run from 100 mah in front to 2 ah at rear.*

radio-control, but they are quite new and may become more popular.

Nickel-cadmium cells

Alkaline cells generally (not including Silvercels) have several

[1] Lead–acid cells have indefinite shelf life. They are kept dry until ready for use.
[2] Silcad has silver cadmium plates; Silvercel has silver zinc plates.

features that fit them especially for hobby uses – but they do have some undesirable features. The advantages win out, however, and one type of alkaline cell – generally called ni-cad for short – is gaining in popularity at a fast pace. The biggest advantages are fairly low first cost and long life. Also they can be stored charged or discharged with no damage, are of moderate weight and not too fussy as to charging. Some types, in fact, can be charged indefinitely at low rates without damage, so they are always full and ready for a day's flying when the modeler is set to go out.

Ni-cads[3] (a term stemming from the materials, nickel and cadmium, used in the plates) have an alkaline solution, but the latter does not enter into the actual chemical action during charge or discharge. The state of charge cannot be checked with a hydrometer. Users of alkaline cells, therefore, have to watch their charge and discharge times much more carefully since, like most storage cells, these "drop dead" rather suddenly when their charge is consumed. This is one of the greatest disadvantages of the type. The other is the low voltage – ni-cads run around 1.25 volts per cell.

Many sizes of ni-cads are now on the market, several lines being distributed widely in the hobby field. Fig. 903 shows a variety of metal-case ni-cads. They are available from tiny button cells of 100-ma capacity or so up to larger units of as many amperes as you are willing to pay for. Probably the most widely used are the button cells of 500 milliampere-hours and the penlight cell, which has about the same capacity but is exactly the size of a dry penlight cell and will fit in the same holders. Another very popular cell shown among others in Fig. 902 is the 800-milliampere-hour flat cell in a plastic case. In the same category is a 900-ma-hour cylindrical unit of the same diameter as a penlight cell but about twice as long. It is generally considered that ni-cads of 450 to 500 ma-hours will give ample power for simultaneous reed outfits up to 8 or 10 channels, providing at least 3 or 4 hours of service (including furnishing power for a dc converter which takes the place of a B-battery). For dual proportional outfits, which have a more or less constant drain from the rudder and elevator actuators, the 800- and 900-ma-hour ni-cads are preferred. For rudder-only outfits, smaller cells can be used.

Recently, quite large numbers of fairly small ni-cad cells have appeared on the surplus market. These are too large and heavy for model planes (they are ideal for boats and cars, however) but are

[3] The word ni-cad is often used to refer to all nickel-cadmium cells. Nicad is a trade name and is the property of Nicad Division, Gould-National Batteries, Inc.

increasingly in demand in radio-control transmitters, usually in conjunction with transistor dc converters. This use in transmitters is popular for the same reason the ni-cads are so widely employed at the receiving end of the system — fairly low cost (the surplus units are relatively *very* low in cost), long life, ability to stand continual low-rate charge indefinitely, and fairly constant voltage.

Battery holders

Some ni-cads are the same size as flashlight cells and can be carried in holders designed for the latter. There is a variety of such holders, not only for 1½-volt cells but also for various small sizes of B-batteries — one manufacturer has about 150 sizes in his line and more are constantly being added! When using all-metal holders many modelers wrap rubber bands tightly around the ends to make absolutely sure that there is good contact with the cell or battery ends, even under conditions of heavy vibration. The bands also help to prevent the cells from popping loose in bad landings. It is helpful to bend the vertical clips that grip the center of the cells so that a rubber band can be wrapped around the upper ends.

Plastic holders (Fig. 904) have a sliding lid, and the contacts are held against the cell ends by small coil springs so that they com-

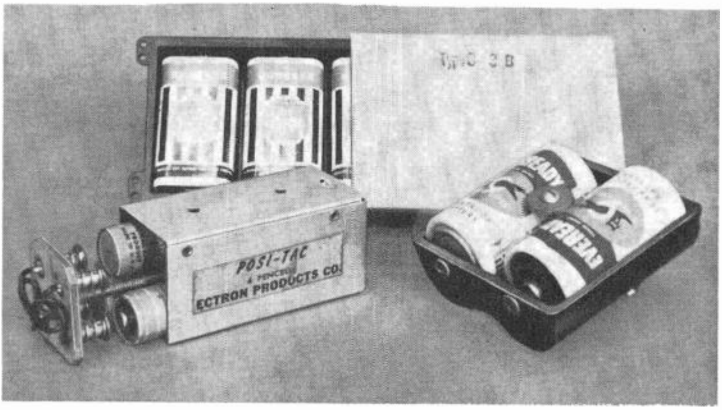


Fig. 904. *Metal holder with phenolic ends at left front is by Cobb Hobby, holds four AA cells (either dry type or equivalent size in nickel-cadmium). Hillcrest holder in rear is for three 22½ volt B batteries, can be had in other cell and battery complements. Holder at right by same maker carries larger cells.*

plete the circuit reliably no matter how carelessly you may put the cells in place. The flat-type holder is often used as a means of mounting a receiver. These holders come with contacts and internal compartments arranged for various numbers of penlight cells (either dry or ni-cad cells can be carried) and 22½-volt B-batteries of a single specific size.

A holder designed especially for button type ni-cads (Fig. 905) can easily be made at home. These cells are a little difficult to connect. While some modelers solder leads to each side, this is not recommended as there is too great a chance of ruining the plastic seal or doing other internal damage. Some ni-cads come with solder tabs welded on, which makes connections quite easy, of course. The holder shown is intended for those that don't have such tabs. It has the further advantage that the cells are held under

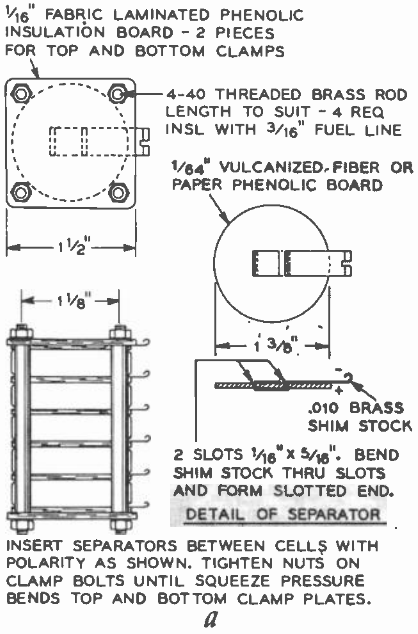


Fig. 905-a. *Austermann holder for button cells gives good contact, keeps them under desirable pressure. Metal tabs can provide connection to every cell, if desired. This is useful for checking individual cell voltage during charge and use, with rotary switch to shift meter from cell to cell.*

pressure on the flat sides – a condition encouraged by the cell makers. Under long charging, a fair amount of internal pressure builds up in these cells, enough to bulge the flat sides a bit. A holder which puts the cells under light pressure tends to keep the sides from bowing out excessively.

B-batteries

So far, little has been said about B-batteries. They can be had in a large variety, but generally, those used in planes are of one of three different sizes. Fig. 906 shows representative sizes of the

$22\frac{1}{2}$-volters of one manufacturer. The $22\frac{1}{2}$-volt battery is the most popular, used either singly to give $22\frac{1}{2}$ volts or in series to give 45, but some receivers require 30 volts. Three different 30-volt battery sizes correspond to those in Fig. 906. Holders can be had for one, two or three of most of these B-batteries.

Modelers who require the largest size of battery shown in Fig. 906 may find that these are not too easy to buy (the smaller sizes are easier to obtain as they are used in many of the older hearing aids). An economical way is to purchase a small $67\frac{1}{2}$-volt battery widely used in tube-type portable broadcast receivers. This battery (No. 457 in the Eveready line or No. K45 by Burgess) contains three stacks of cells the same size as the largest $22\frac{1}{2}$-volt battery

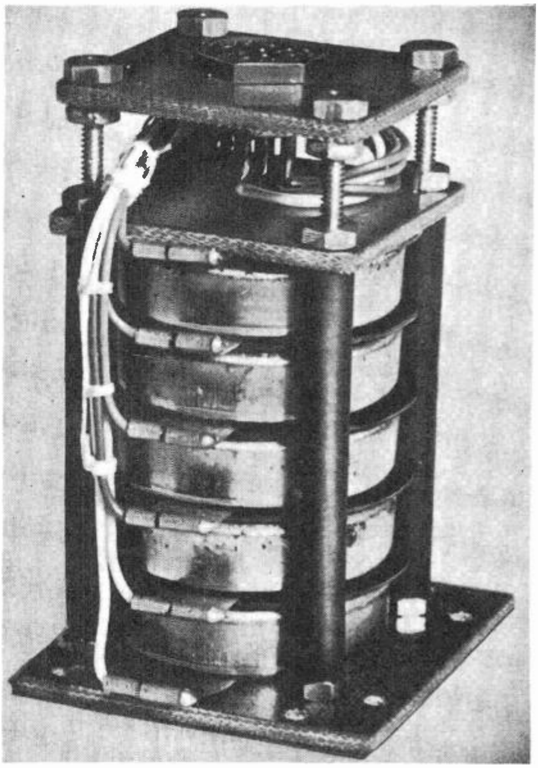


Fig. 905-b. *Photo of Austermann holder shows socket on top. This takes plug from voltage tester, charger, or from circuits in model. Any desired number of cells can be stacked in this manner.*

in Fig. 906. Buyers split the battery into three stacks and use them in pairs or singly for 45 or $22\frac{1}{2}$ volts as required. Connections can be soldered to the wires at the stack ends. Many fliers will not trust any connection to B-batteries (or even to the low-voltage cells) that is not soldered. Soldered connections make it more of a nuisance to change batteries but are certainly the most reliable as far as vibration goes.

Transmitter B-batteries are generally larger than those we have pictured, since more current is required at higher voltage. Most hand-held transmitters require two 67½-volt batteries for a total of 135 volts, while ground-type transmitters often use a larger size made principally in 45-volt blocks.

Battery charging

Storage cells must be charged periodically. Many of the ni-cads

Fig. 906. *The most widely-used sizes of 22½-volt B batteries. Unit at left employed only in smallest planes, center size probably most popular of all, that on right for use where current drain is heavier. 30-volt batteries in equivalent sizes have same cross-section but are proportionately longer.*

are designed for *continuous* low-rate charging. Chargers usually get their power from the 115-volt ac line, step it down to the voltage needed, and rectify it to dc. Most storage cells are sold with explicit instructions as to charging rate, time required, etc. Generally, it is safe to charge storage cells at about a tenth of their nominal capacity. Thus, a 900-milliampere-hour cell would safely take a 90-ma charging rate, while a 20-ampere-hour transmitter cell could be charged at 2 amperes. It always takes more power to charge a cell than you can expect to get out, since cells are not 100% efficient. The safest way to monitor charging is to measure the voltage of the cell while it is on charge at the specified number of hours at a certain rate and, even if you leave the cell on longer than you should, no harm will be done. Lead – acid and Silvercels, however, should *not* be overcharged.

Since you are forcing current *from* the charger *into* the cell, the charger voltage must always be higher than that of the cell. As a cell is charged, its internal voltage rises slowly and the charging rate drops (with most chargers of the simpler type used by modelers). This is, of course, a useful safety factor.

We have mentioned low-rate constant charging of ni-cads. This is generally accomplished by cutting the charging current to about one-hundredth of the ampere-hour capacity, at which rate the charger can be left on indefinitely. The cell will then always be ready to use at peak capacity. This low-rate continuous charging has been called trickle-charging, and has also been used with lead–acid batteries. Keep the current below the maker's specified maximum. When low or completely discharged, most types of storage cells can be fast-charged — using a current rate considerably higher than normal. Remember, though, that the cell can be damaged if this high rate is continued too long. Generally, if you can feel that the cell under charge is noticeably hotter than its surroundings, reduce the charging rate.

While dry cells cannot actually be recharged, it is possible to get considerably longer use from them by a form of "charging". What actually happens is that the current forced through the cell hastens the depolarization of the hydrogen gas formed within the cell when it is working normally. Both A- and B-batteries can be

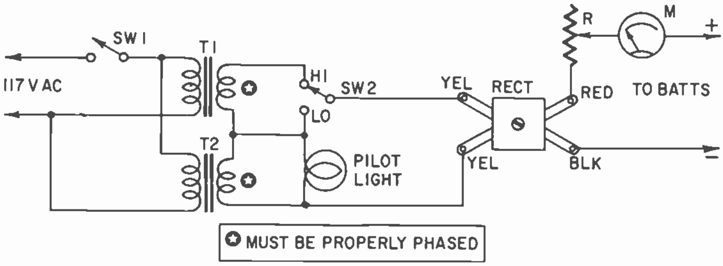


Fig. 907. *Two cheap 6.3 V filament transformers have primaries in parallel, secondaries in series. If you get no output voltage, reverse connections to one primary or secondary, to obtain proper phasing. Make quick check of this as improper phasing puts heavy load on transformers. Select R according to output voltage and current you require. M must suit current range. Parts specified good for about 500 ma and up to 10 volts output.*

pepped up this way. To get the most benefit from such an operation, you should not wait until the cell is too far run down; a short "charge" at frequent intervals is best. The charging current should be kept at about the same value as the current taken from the cell on discharge, and for an equivalent time. A circuit for a charger suitable for this use is shown in Fig. 907. This charger can also be used with small storage cells and batteries. Two inexpensive 6.3-

volt radio filament transformers supply the power (a 12-volt center-tapped transformer would do but is more costly) and the switch allows high or low voltage to be obtained. With center-tapped 6-volt transformers and a four-pole switch there is even more flexibility in output voltage.

Many chargers are on the market today, some quite elaborate, others relatively simple. One simple one intended for low-rate charging can be used on many sizes of low-voltage cells and batteries; it will also rejuvenate B-batteries. A representative circuit is seen in Fig. 908; note that there is no power transformer to isolate the low-voltage output from the line. You must be careful, therefore, not to contact any grounded metal object (radiator, BX cable, etc.) while touching one of the output leads.

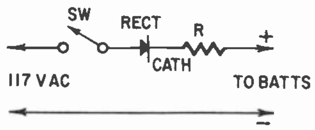


Fig. 908. *Simplest possible charger is not isolated from power line; keep away from "grounds" when connecting cells to it. With International Rectifier Corp. #1002A for rectifier and a 10 watt, 2000 ohm wirewound resistor at R, unit will charge most cells or batteries at about 20 ma, regardless of their voltage.*

Dc converters

These units are intended to change dc from one level to another; most of those used in model work *raise* the voltage. A motor – generator, or the more compact form — the dynamotor — is a type of dc converter. We sometimes use them for powering transmitters, especially where 6 or 12 volts is available from storage batteries. Generally very reliable, they do not have very high efficiency. Most dynamotors used in radio-control work are from war surplus; these units would be rather costly if purchased new.

Vibrator power supplies are also used in transmitters. Most of these are of the 2-volt type. They are quite reliable, more efficient than dynamotors and have the advantage that the 2-volt storage cell can also be used for glow-plug engine starting.

The highest efficiency in dc converters for radio control is achieved with transistors; some of these have efficiencies of 90% or more. Since we seldom have power to waste in radio-control installations, especially in the models themselves, this is a big consideration. Most receiver converters use two transistors connected in a push-pull low-frequency oscillator circuit (Fig. 909). Generally, a special type of transformer must be employed if maximum efficiency is to be obtained. Properly designed, such converters afford good regulation (they hold a fairly constant voltage regardless of the current taken from them), an important point with some types of receivers. Many converters have built-in overload protection and do not require a fuse. If they are loaded much higher than designed for, the output power drops to a very low value, as does the input current.

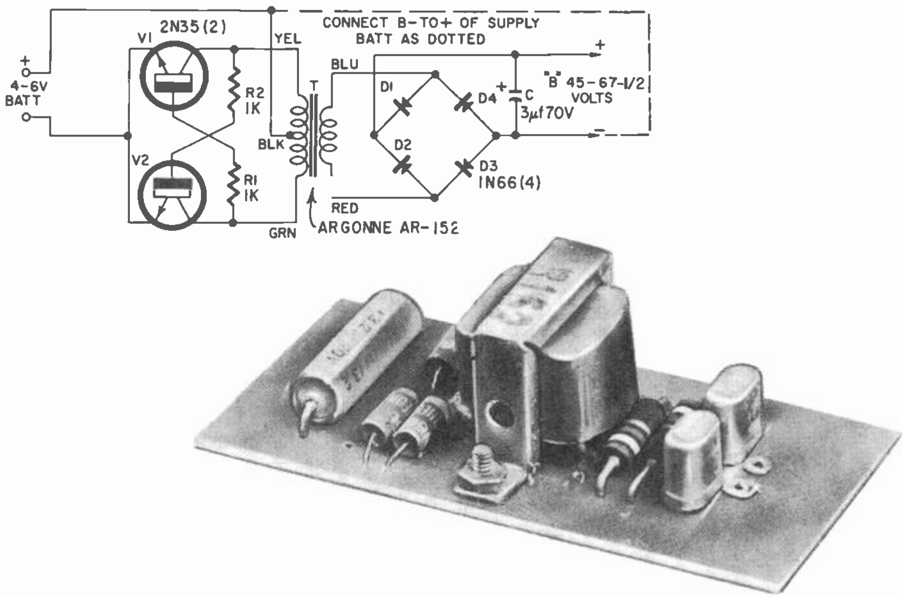


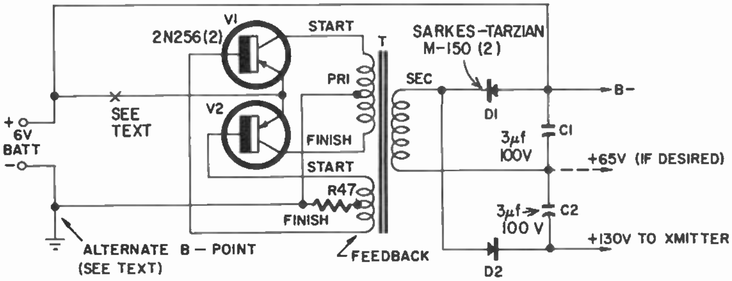
Fig. 909. *Receiver transistor converter. Commercial af transformer not too efficient but saves winding your own. Original was mounted on printed circuit plate.*

The transistors act as switches, turning the low voltage on and off at their normal rate of oscillation. This alternating current is stepped up in the transformer, rectified by several diodes and filtered. Because of the high frequency, very little filtering is required, a single capacitor normally being sufficient.

With receiver current drains rising all the time as more and more controls are added to models, transistor converters are becoming widely popular. Quite a few makes are now available, some of which are tiny indeed. They weigh far less than the B-batteries they replace. Of course, they must be supplied with power from low-voltage batteries, but the batteries used for the servo or actuator power are connected for this purpose. The added drain on such batteries is not too severe and, if they are of the rechargeable type, it makes a very practical setup.

Making your own dc converters

A receiver converter you can make from standard parts is seen in Fig. 909. To save time and trouble, a small af transformer is used for T (this is not as efficient as the special cup cores normally used in such converters, but saves winding time). The unit, assembled on an etched-circuit plate, will produce 67½ volts up to 5 ma with a 6-volt input. You can get 45 volts out with a 4-volt input. Battery drain either way will be about 100 ma. Resistors R1 and R2 are compromise values chosen to assure easy starting



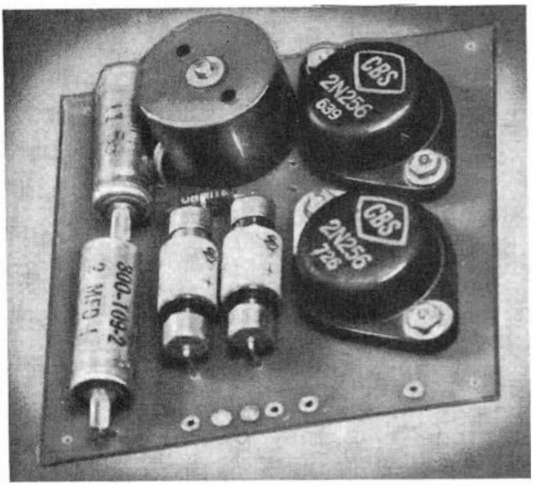


Fig. 910. *Special transformer core is Ferroxcube #398P360B1-3C2 (two are needed) and matching bobbin is #398F-410. Circuit shows 6 V battery in series with high voltage output, to get a little higher total. Though 2N256 transistors are shown, 2N255's are just as good and cheaper.*

and reasonably low current drain. The 2N35 transistors specified worked best; 2N229's and 2N107's worked fairly well but will not allow as much output current. The converter shown weighs 25 grams and makes an excellent power supply for such instruments as grid-dippers and the like, as well as for receiver purposes.

Note that the B-minus of the high-voltage part of the circuit is run back to the positive of the low-voltage supply. This simply adds the two voltages together to give a higher output, but, if you don't need this, B-minus can be connected to the negative of the low-voltage supply (which would normally be considered "ground" in the receiver circuit, and would also connect to one side of the filament cell).

To get good efficiency in the transmitter power supply, cup cores of special material are required. While 2N256 transistors are seen in the photo, Fig. 910, lower-cost 2N255's work as well and are recommended. Silicon rectifiers assure very high efficiency. With a 6-volt input, this converter will produce as much as 130 volts at 20 ma when fed with a small storage battery such as the NT-6. (Ni-cad cells can be used but, due to their lower voltage, you will need *five* of them in series). Even a 6-volt dry-cell lantern battery can be used for short periods, and will provide enough power to draw 15 ma from the converter. At full power output the input current drain is about 0.8 ampere.

The specified cores can be had with a matching bobbin, but it may be necessary to obtain these parts through a radio supply house, as the manufacturer normally sells only to dealers or manufacturers. The bobbin should be wound this way: The primary is 36 turns of No. 28 wire center-tapped; the secondary is 250 turns of No. 34; and the feedback winding is 8 turns of the same size and center-tapped. If heavy Formvar insulated wire is used, it will probably not be necessary to put added insulation between the secondary and the other two windings. Insulation should be used with regular enameled wire.

This converter, built on an etched plate (ordinary wiring will do just as well) 3 x 3 inches, is 7/8 inch high and weighs 4 oz. It operates at about 2,000 cycles. A low voltage tap can be taken from the center connection of C1 and C2 if desired. For most purposes, the converter can be keyed at point X, as it starts and stops quite rapidly. Keyed in this manner, there is no drain on the 6-volt battery when the key is open. For high speed and very accurate pulsing, as might be required for some proportional uses, keying should be done in the high-voltage side.

Buying, testing, storing

Since dry cells deteriorate even when not in use, make every effort to be sure they are as fresh as possible. Manufacturers used to put dates on their cells and batteries. Date codes are still seen but are sometimes arranged in a manner that is incomprehensible to the purchaser. Thus, the best idea is to buy dry cells where there is a large turnover.

Dry cells can be tested reliably only under load. Some test meters do apply a load, according to the voltage of the battery; others have a variable load switch that is rotated to pick the proper load for the voltage and capacity of the cell or battery. Small, low-cost battery test meters can be purchased that have two scale ranges, and that will test both single cells (on a scale ranging up to perhaps 2 volts) and B-batteries on a 0 – 50-volt scale. Due to the type of meter movement employed, a fair load is put on the cells and batteries under test. Such a meter is not infallible but with practice you can get a very good idea of battery quality.

Meters are also obtainable with ampere ranges of perhaps 0 – 35. Use these *only* on single dry cells and then only on the large sizes such as the D-cells and No. 6 dry cells (often used as a glow-plug engine starters).

One of the most useful checks of dry cells – either A or B – is simply to measure the voltage across them when they are operating your transmitter or receiver. In the case of B-batteries, depress the transmitter key to put full load on the battery. Test receivers with or without signal—whichever way produces the highest B-current drain.

Heat is one of the greatest enemies of any battery, dry or storage type, simply because it increases the internal chemical reactions. Heat will run dry cells down fast (even if they are not in actual use) and also causes a storage cell to self-discharge at a

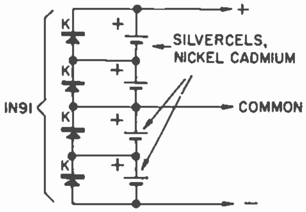


Fig. 911. *Diode safety arangement protects cells, still allows some control if one cell goes dead in flight. Diodes draw no current in normal use, are left across cells permanently.*

faster rate. Any cell or battery will last much longer if you keep it in a cool place. Placing them in the refrigerator is ideal – but don't put the batteries where they will be below freezing. About 40°F is a good temperature.

Battery voltage will be lower when a cell is cold, higher when it is hot. If you take dry batteries out of the refrigerator, you might have to warm them to room temperature before they will produce the power needed. Similarly, when dry cells are used in cold weather, they will have a fairly lower voltage than normal, nor can they supply as much current. It is quite possible that such units as the receiver or servos in your model will not even function. To overcome this handicap, you can use larger batteries than are normally needed or use more of the same size in parallel. Some modelers who fly in the northern states in winter have installed small chemical hand warmers in their models and transmitters;

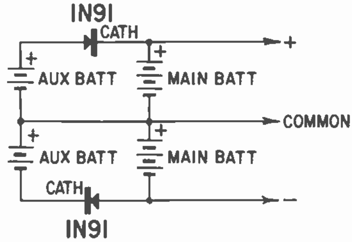


Fig. 912. *Circuit cuts in small auxiliary cells, if main battery drops voltage (as when one cell goes dead) in use. In normal condition, main battery must have higher voltage than auxiliaries.*

these produce quite an amount of heat for a considerable period and some are relatively small and light.

Storage cells suffer from cold or heat the same way as do dry cells, though perhaps not to such a degree. Nevertheless, their life can be prolonged by storage in cool places, and they should be kept from high heat as much as possible.

When storage cells are first purchased, coat the terminals with grease or petroleum jelly to prevent corrosion. It is difficult to prevent slight seepage of the acid or alkaline solutions. These corrosive fluids attack many metals, both on the cell and on holders and surroundings. The coating prevents rapid spread of the corrosion, and should be wiped off and renewed occasionally. Even the so-called "sealed" ni-cad cells often develop corrosion around the seal or the terminals. Silicone grease is very useful for coating terminals as it does not become very soft or liquid at the higher temperatures as do grease and petroleum jelly, and it sticks tenaciously to the cell surfaces.

Safety diodes in power supplies

It is difficult to determine the amount of charge in any of the very small storage cells — they hold a fairly constant voltage until they are almost fully discharged. Some modelers are very careful to record amount of use, amount of charge and so on. Others are careless, and the arrangement in Fig. 911 is especially useful for them. The idea is simply this: A high-conductance diode is connected across each cell in the servo supply in such a direction that it will pass little or no current. Should one of the cells suddenly expire during use, the diode across it will act as a bridge to pass along the current of the other cell in that pair. The servo would have only half voltage, of course, but this would probably be enough to land a plane without disaster. Since the diodes won't conduct under normal operation, they won't under charging either, so they can be left connected permanently.

This arrangement not only protects the plane but the cells as well; when one cell goes dead the other one in the pair tends to try to force current through the dead cell in the reverse direction — usually damaging to a storage cell. The diodes prevent this reverse current flow by acting as a fairly solid short across the dead cell, as far as this reverse current is concerned.

Another plane-saver idea is seen in Fig. 912. Diodes are used here, too, but in a different manner. The main cells on each side of the circuit could be the usual storage type, while the auxiliary cells would be penlights. Should one of the cells in the main supply go dead, the total voltage of that battery would drop drastically, and the associated diode would then cut in the auxiliary battery on that side to take over. The only precaution that must be observed here is that the two main batteries must have equal or higher voltage than the auxiliaries — otherwise, the latter would soon go dead trying to recharge the main cells.

chapter TEN

relays

WHILE relays may look tiny and rather insignificant, they are the heart of our receivers and play an important part in transmitter pulsers too. Not only do they have to be set correctly, they must be mounted properly (which usually means carefully mounting the entire receiver to which the relay is attached) and they must be given regular maintenance. They are important enough to devote an entire chapter to them!

Selection and adjustment

When you make your own receiver, there is a good chance that any given relay you purchase will not be set up correctly for the particular combination of maximum and minimum current your set requires. Some receivers require top quality relays, since they do not produce very high current or a great current change. Others can do with less sensitive types because of the husky current flow they afford. Present trends in receivers seem to favor the latter arrangement. Generally, the less sensitive relays are smaller and lighter. Power converters, transistors in the relay stage (which allow use of only 22½ volts or even much less) and the increasing popularity of multi-control equipment, make it mandatory to use the smallest and lightest relays — even though they may be less sensitive and take more current from the B-supply.

The subject of sensitivity is a rather vague one, but modelers look at it this way: If a given relay can be set to give very positive action with reasonable contact spacing, have high enough spring tension to make the relay fairly immune to engine vibration, and yet work on a very low current change (perhaps 0.75 ma or even less), it would be considered a "sensitive" type. In a broad sense, practically all the relays used in radio control are "sensitive" types, but most of them require much more than a 0.75-ma change (considering the widely popular 5,000-ohm style). Some of the smallest ones must have 2- or even 3-ma current change to be considered "solid". Typical examples of very sensitive types are the Sigma 4F and 5F (shown in Fig. 116) – the latter just about the best that can be purchased at a reasonable price. Both of these are considered too heavy for receiver use now, but are quite often put in electronic pulsers (where weight and size are no problem) and where their complete screw-adjustment facilities make them most

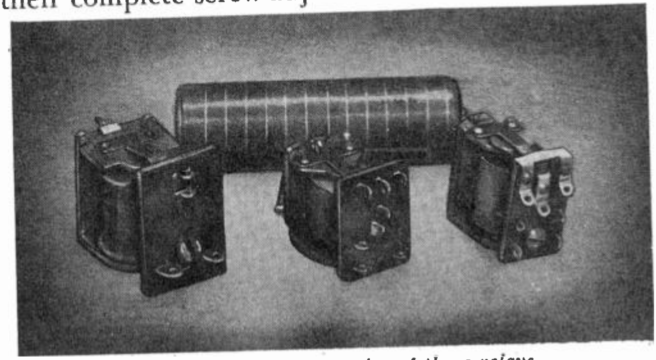


Fig. 1001. *The minute size of these relays by Lafayette, OS and Deans is emphasized by the AA penlight cell that is about 2 inches long.*

useful. Fig. 1001 shows some small relays – the Gem, RBM and Babcock types are in Fig. 1002.

The ability to adjust your relay (and know exactly what you are doing) is an absolute necessity if you expect to get the most out of your receiver and other control equipment. Some relays are

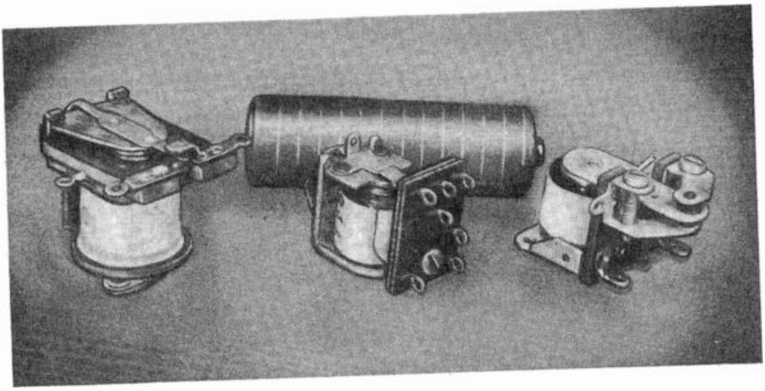


Fig. 1002. *Small relays in wide use today. Size AA pencell in background gives idea of sizes.*

rather easy to work on, since the necessary adjustments are made by turning screws; on most of our existing types, though, various parts have to be bent to change adjustment. The general process of adjustment is the same for all types, and you should follow a definite routine when doing it.

The electrical equipment for checking relays can consist simply of a small B-battery, a variable resistor and a meter. The battery can come from your transmitter or model, and the meter can be the one used to adjust your receiver. Fig. 1003 shows how the

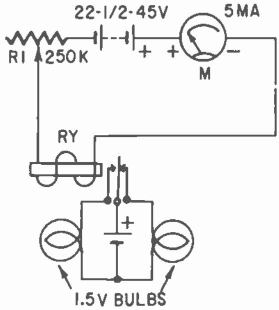


Fig. 1003. *Relay testing circuit. The lamp bulbs are not needed, but make it easier to tell when contacts actually move. This circuit is for high resistance relays, 1,500 ohms and up. For those used in low voltage receivers, you'll need lower battery voltage and resistor, higher range meter.*

parts are connected. For a deluxe job, you can add a flashlight cell and a couple of lamp bulbs to show exactly when the contacts make or break. Many modelers make up a relay tester using the circuit shown, either with its own meter or a jack to accept the receiver test meter. Flexible leads with small clips allow connection to the relay.

Incidentally, quick field or shop checks of receiver relay operation can be made simply with a variable resistor with clips on two terminals. Hook it up as in Fig. 1004; for tube circuits, clip onto the "ground" or filament side of the receiver circuit, and to the side of the relay away from the B-battery. The receiver test meter plugged into its normal jack shows current change and relay setting. Needless to say, *don't* try this system unless you are thoroughly familiar with your receiver and model wiring; also, always turn the variable resistor to maximum before clipping it on.

Core gap

The first thing to check is the core gap. Push the armature gently toward the core until the armature hits the normally open contact. Armature and core must *never* be allowed to touch physically, though they may be separated by only a few thousandths of an inch in some cases. Some relays have a rather flexible armature tip on which the moving contact is mounted. This is a good feature in some ways (the flexing as the contacts make and break provides a slight rubbing action that tends to keep the contact points clean), but does make it possible for the armature to slap tight onto the core. On such relays, cement a piece of thin paper

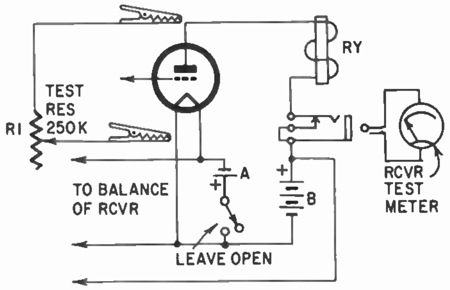


Fig. 1004. *If you are sure of connections in your receiver (so that you won't ruin the tube or other parts by inadvertent short) you can use resistor R1 as shown, employing receiver test meter, receiver battery to check the relay. Filament circuit should be left open.*

to the core end or give it several coats of model dope. Even with more solid armature contacts, the dope on the core is a wise precaution.

The actual core gap depends upon differential, which we'll discuss in a moment. Generally speaking, if your receiver allows a rather wide current change, the core gap may be quite small. If the current change from on signal to off is rather small, the core gap should be larger.

Differential

All relays pull in (close contacts when current is applied) at a higher current than when they drop out (armature moves away from magnet when current is reduced). The difference between the two currents is called the differential. What value you want to try for depends on your receiver; a large current change in the receiver allows a large differential (and the relay will be considerably easier to set). If the receiver has a rather small current change — even though the average current may be quite high, you need a close or small differential.

Differential is dependent upon the spacing between the fixed contacts. It is easier to get a small differential when the gap between armature and core pole piece is fairly large.

Getting started

You have to start some place, so connect your test circuit and reduce the resistor (R1 in Figs. 1003 and 1004) until the armature suddenly snaps to the other position; note the current required. Then slowly increase the resistance until the relay snaps open, and again read the current. Let's say the relay pulled in (or closed) at 3 ma and dropped out (or opened) at 1 ma. If your receiver relay stage idled at zero or very close to it and the current rose to, say,

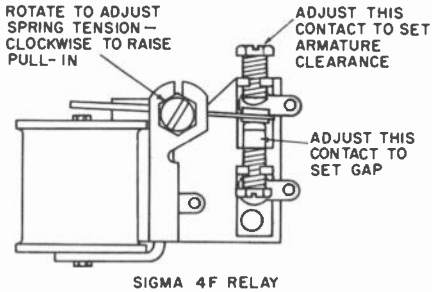


Fig. 1005. *Adjustments for a Sigma 4F relay.*

5 ma on signal (or vice versa), this relay setting might be considered quite adequate and you could stop right there. But maybe your receiver goes up only to 2.5 ma maximum and idles at 0.5. Some changes must be made. First, the 2-ma differential indicates that: the gap between contacts is too large; the pole-to-armature gap is too small; or both. If the pole-to-armature gap looks fairly good when you press the armature closed with your finger, try moving the normally closed (NC) contact — the one against which the armature rests with no current through the coil — closer to the normally open (or NO contact) and try again. Perhaps this change will bring you down to 2-ma pull-in current — the 1-ma dropout should remain exactly the same.

With that 0.5-ma receiver idling current, we should have a little higher dropout figure, so bend the NO contact closer to the NC one and try again. Maybe this brings the dropout up to 1.25 ma. Up to now, we haven't even mentioned spring tension. Provided it is not too far off, it's best to leave it alone at the beginning, since a change in tension will modify both pull-in and dropout figures, and each to a different degree. Reduce tension a bit now; a test might show that the pull-in has dropped to 1.75 ma, while the dropout might have been lowered to only 1.1 ma.

At this point, a bit of judgment must come into the picture. Depending upon the relay itself, you must decide whether the armature movement is reasonable. Many of the small relays used today will operate reliably with a contact gap of only a few thousandths of an inch. It should be large enough to see and to feel with your finger, of course. Next, consider the amount of spring tension. This is even harder to specify than contact gap, so one way to check — until you have adjusted and used relays enough to have a good working idea of what the tension must be for a given type — is simply to try the receiver in your model with the engine running. Run the engine over a range of speeds; almost always, there will be a point of rather heavy vibration somewhere in the engine speed range — and not necessarily at top speed.

When setting a relay, you have to take into consideration the factors mentioned here plus others, too. First, when you were setting it up, you probably kept the high and low currents pretty close to the pull-in and dropout points. But in actual use, the current will go quite a way *above* pull-in and *below* dropout. If you try the relay in your checker circuit using the actual maximum and minimum currents it will get in the set, you will generally find that it will pull in a tenth or two higher than you set it for and drop out another tenth or two lower. Keep this fact in mind when making your adjustments. Fig. 1005 shows the adjustment points of a Sigma 4F relay.

Always mark the side of the relay that goes to the battery in your receiver and connect it to the checker with the same battery polarity. A reverse in polarity will make quite a change in some relays.

Remember that receiver battery voltage drops as the batteries age; thus, the relay maximum current will also decrease. Make allowance for this in setting the relay. Most receivers give about the same current maximums and minimums regardless of whether they are getting a strong signal or a very weak one but, if yours is one which gives a lower current change with weak signal, this too must be accounted for in relay adjustment. Some sets get "hotter" or more sensitive as the batteries age; thus, you could find that your maximum relay current (in a receiver that gives maximum with signal) is decreasing but, due to more sensitive circuit conditions, the minimum might actually rise! It seems that everything that might happen is against the modeler! This is not strictly true, of course. But it does explain why the relay must be set to close at perhaps 2 ma and open at 1.25, when the actual receiver currents (with fresh batteries) could be 3.5 and 0.25 ma.

Practically all relay adjustments interact, so it is simply a matter of going over and over the settings until you get them all as you wish. Once this is accomplished, the adjustments will usually hold for long periods of time, barring crackup or other damage.

Relay resistance

For years the most popular relay has been the 5,000-ohm unit, a good value for use in tube circuits with 45 volts on the plates. With some output tubes, this combination might allow as much as 3 ma or more of relay current. When transistors came into radio control, the same resistance was used but the voltage (at least on the transistor stage) was dropped to no more than 22½ due to transistor limitations. With things working right, this voltage would produce about 4.4 ma, since transistors that are conducting fully act almost like a closed switch (unlike tubes which always have appreciable internal resistance). To save battery power, it is possible to go to higher-resistance relays in transistor receivers. The next step after 5,000 ohms is usually 7,500 with a transistor in the output stage. With 22½ volts you could get almost 3 ma with the higher resistance – enough for good relay operation, yet much lower B-drain. Even though the current is less, the 7,500-ohm relay might give as good results in terms of contact gap and spring tension, due to the use of more turns of wire on the coil.

Low-voltage receiver operation is also becoming more widespread, with increasing use of transistors. All-transistor receivers now operate on 3 to 9 volts and, of course, relay resistances must be much lower. For the 3-volt sets, relays of around 100 ohms are generally specified, and the current could run up to 30 ma or more.

Relay mounting

Relays are almost always shock-mounted in models. Some prefer to mount the relay by itself, as this generally means a smaller mass that must be protected from vibration. Some modelers maintain that relays should never be mounted with the axis of the armature pivot in the same line as the shaft of the engine. Since the latter is almost always fore and aft of the fuselage, this means you should mount your relay so that the armature pivots in *any other direction* but fore and aft. While we have never seen test figures on the matter, it does sound reasonable. In any case, if you have vibration trouble traceable to your relay, try mounting it so the armature moves in a different direction; such a change has brought welcome relief for some harried modelers!

Maintenance

Relay maintenance consists mainly of keeping the points clean. Arc suppression should *always* be used (refer to the end of this chapter) even though many present-day commercial receivers come without it. Even with such suppression, it is wise to give the contacts a gentle cleaning occasionally. About the best thing to use for this is a fairly hard-surfaced (but not glossy) white paper. Cut into strips about 1/4 x 2 inches, these can be slipped between the contacts of most relays without changing the adjustment. If the paper slides in easily, press the contacts together with your fingers until you feel a reasonable drag on the paper, then pull it the full length of the strip. You will often see a dark spot on the paper where it has rubbed off dirt and corrosion.

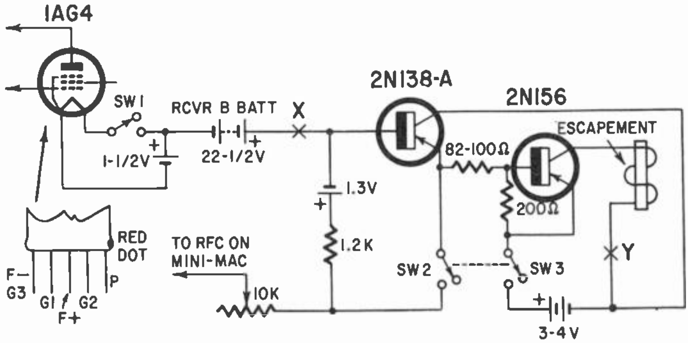


Fig. 1006. *Circuit for operating escapement without relay. This arrangement is intended for use with receiver that idles at high current with no signal. Output transistor may be smaller one, if escapement is high enough in resistance.*

Metal relay contact burnishers can be purchased, but they are too thick to go between the contacts of most small relays without opening them. Use them carefully! Even though they look quite smooth, they can remove a surprising amount of metal, especially the soft silver used in most contacts.

Because they break quite a bit of current, contacts of transmitter keying relays (or contacts in mechanical pulsers) get quite dirty and often build up little points on one side, with a corresponding hollow on the other. To smooth such contacts, it may be necessary to use an auto ignition-point file, but again we caution – take it easy. Those files were designed to cut hard tungsten alloy – our points are mostly soft silver! Incidentally, where you have the buildup on one contact and hollow on the other, you can reverse the action by simply reversing connections to the two contacts.

A few relays in use today have actual pivots of one sort or another to support the armature. These can be cleaned if you feel the relay action is sticky or sluggish, but *never put oil on them.*

Dust, specks of lint, even metal chips can get between relay contacts or the armature and core, and cause malfunction. It is for this reason that it is highly desirable to have your relays enclosed. This also prevents gummy fuel fumes from reaching them.

Relayless operation

Now that we have covered relays and all their little problems, let's see how we can go about eliminating relays entirely! Transistors make this quite possible, and many of the newest control

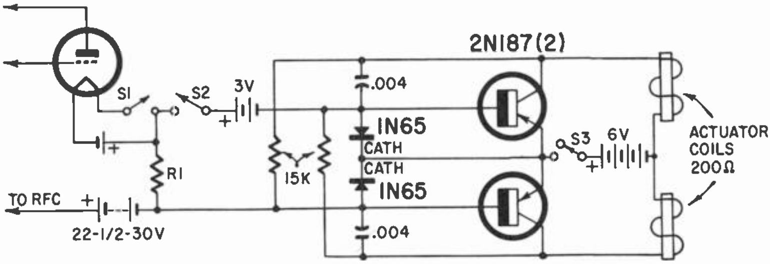


Fig. 1007. *Trammell circuit gives action of a spdt relay, to operate magnetic actuator, which has special high resistance coils. This can be used with receiver that idles high or low.*

systems have no relays in either transmitter or receiver. If you want to operate an escapement, Fig. 1006 shows a circuit that will do it. This was originally used with a receiver similar to that in Fig. 413, with a 1AG4 tube in the set. Later a type CK6148 (10-ma filament) was substituted with about the same results. The 1.3-volt cell is a tiny mercury type which gives long life at the drain of about 1.75 ma through it. The receiver A- and B-batteries are also shown in Fig. 1006. Due to variations in transistors, it might be necessary to use other than 1,200 ohms in series with the mercury cell. To check this, leave receiver switch SW1 open, connect a 1-ma meter across SW2 and put a variable resistor of about 2,000 ohms or more in place of the 1,200-ohm unit. Reduce the resistor until the meter shows 0.7 to 0.75 ma; measure the resistor value and substitute the nearest fixed value you can get. This resistor will not have to be changed unless the transistor is replaced.

To check the tripping point of the transistor stage, turn the receiver on, connect a 1-ma meter into the circuit at point X and vary the 10,000-ohm resistor. The escapement should operate when the meter indicates 0.7–0.75 ma and release when it shows 0.73–0.78 ma. The resistor is set to hold the receiver idling current (no signal) measured at point X at about 0.85 to 0.95 ma. With a signal, the receiver current drops to around 0.2–0.3 ma, and the escapement pulls in. If your escapement draws no more than 300 ma or so (check it at point Y), you can use the smaller and lower-cost 2N188A in place of the 2N156.

For use with same type of receiver, Fig. 1007 shows an arrangement that will give proportional operation of a magnetic actuator (the type shown in Fig. 211, for example, but with higher resistance coils) without the use of a relay. Receiver A- and B-batteries are connected as shown, and receiver plate current passes through resistor R1. Since it is necessary to have only about 1.3 ma through R1, the Mini-Mac could doubtless be operated on 30 volts or even less. The current drain on the 3-volt battery is very low and the tiniest penlight cells could be used here.

With 6 volts on the transistors and with 200-ohm actuator windings, about 28-ma current was obtained; with 7.5 volts, the current rose to 34 ma.

Another escapement circuit is seen in Fig. 1008. It was designed for use with a tone receiver and a frequency range of 1,000–5,000

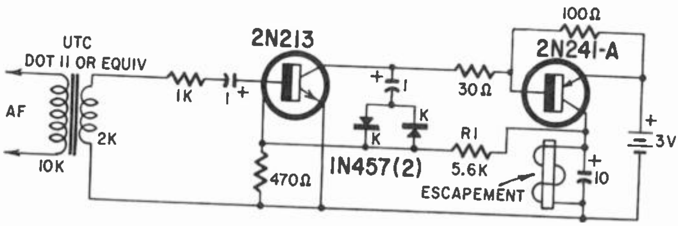


Fig. 1008. *For use either with tone or CW receivers (see text) this circuit acts as transistor switch to control escapement. For CW use, the transformer, two diodes and two electrolytics are not needed.*

cycles. The 2N241-A functions as a fast-acting switch and, though escapement current is considerably higher than its normal rating, the fact that this transistor switches from virtually nonconducting to full conduction so rapidly allows it to handle the higher current with little trouble.

The only fussy component is R1; it is suggested that a variable of about 20,000 ohms be inserted here temporarily and adjusted until the escapement drops out at about 75% of the ac input value needed to make it operate. For example, if it takes 1 volt of ac at the transformer input to operate the escapement, set the variable resistor so the escapement opens at about 0.75 volt ac, then solder in a fixed resistor of the same value. The circuit can also be operated by dc. It takes about 0.3 volt applied between the base and collector of the 2N213 to do this, and the transformer, both 1-μf capacitors and the two 1N457 diodes could be eliminated. With the circuit shown, the no-signal current through the escapement is about 50 μa, while with signal on and a 6-ohm escapement, the current is 470 ma.

Relay arc suppression

Since sensitive relays are used in most radio-control installations, we must consider means to protect the contacts from the sparking

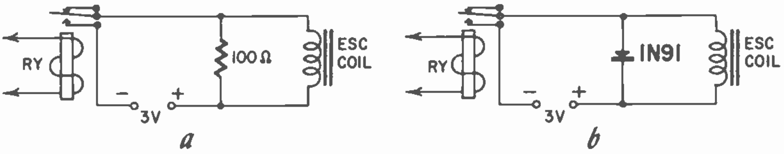


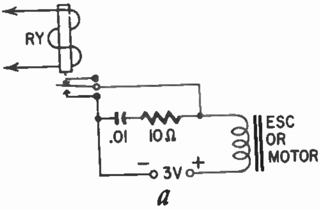
Fig. 1009. *Simplest arc suppressor is small carbon resistor across escapement (or actuator) coil, as at a. Even better is 1N91 diode (b).*

which occurs whenever contacts carrying current open. Some commercial receivers have relay arc suppression included in their circuitry, but many do not. Also, some commercial servos (but no escapements) have suppressors. Arcing occurs at contacts when they open and, if it is heavy, can result in relay failure; the contacts actually weld together (lightly, of course). The heavy arc causes great local heating and, when the contacts stick, they have to be opened manually.

Fortunately, arc suppression is quite simple. In escapements, probably the easiest way is to connect a small carbon resistor of about 10 times the escapement-coil resistance directly across the escapement coil (*not* across the relay contacts!). If you are in doubt, use a resistor of about 100 ohms; the ½-watt size is ample. This resistor will draw a small added amount of current, but not enough to reduce battery life to any extent. See Fig. 1009-a.

Fig. 1009-b shows a method of reducing the arc to practically zero that does *not* draw any measurable amount of additional current. Here, we connect a diode across the coil (again, not across the relay contacts). It must be connected so that it does not pass the dc from the escapement battery — the cathode of the diode should go to the positive side of the battery. The cathode is normally marked with a K, or sometimes with just a circle around the diode at the cathode end. Be *sure* to connect it this way; reversing it will probably ruin the diode and also run your battery down very rapidly.

The best diode for this purpose in the 1N91, available at many hobby shops and radio supply stores. Type 1N56 will also do reasonably well. The diode operates to suppress the "inductive kick" (described in Chapter 2) the culprit causing the contact arcing.



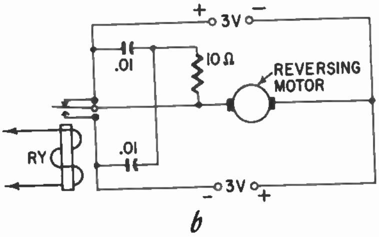


Fig. 1010. *Arc suppression at contacts of relay used in spst fashion is seen at a. When both relay contacts are used, you need extra capacitor (b).*

A third suppression method (Fig. 1010-a) is useful on both escapements and on electric motor devices. If both relay fixed contacts are utilized – as they are for many motor-driven devices –you can put a double suppressor on the relay as in Fig. 1010-b. The fixed-resistor method can also be used on motors, but the diode arrangement is usable only *if the motor is to be run in one direction.* If it is to be driven both ways (as is necessary in some of the control systems described in the next chapter), it is necessary to reverse the current flow, and the diode cannot be used.

chapter ELEVEN

installation of parts

CONTRARY to general belief, there is more to putting the various components of a radio-control system into a model than just stowing them in the most convenient spots. There are many factors to consider, depending upon what type of model we have, how it is powered, what sort of receiver and actuator are to be employed, and so on. Because they have limited space and because of the necessity for watching weight distribution, most of our remarks on location of parts will be directed to model airplanes.

Linkages

Let's start with the gadget that moves the rudder. Since this is an item of moderate weight, it can be put in the most convenient spot, considering that there has to be a link to the rudder itself, and wires running to the receiver and actuator battery. Let's say further that an escapement is to be used to move the rudder. This means we must have space to string out the rather lengthy rubber that turns it. If the escapement is located at the rear wall of the cabin, we will need a rod of some sort back to the rudder.

There are two main methods of moving the rudder – push rod and torque rod. These are shown in Figs. 1101 and 1102. If a torque rod is employed and made of a length of music wire, there is often so much twist in the wire that the rudder will not turn sufficiently when the plane is in flight, even though the escapement has plenty of power to move it. The wire just winds up a bit, but the slipstream of air keeps the rudder from turning as much as desired. Some builders overcome this by making the main portion of the torque rod from square balsa, with wire ends bound on to fit in the two end bearings. See Fig. 1103.

If a push rod is utilized, it is often necessary to put at least one extra guide between the two end supports, or the wire may tend to bow when the rudder is moved in the direction which puts the push rod in compression. The center bearing may be very loose, and in fact it should be, so that it adds very little to the overall friction of the system.

To use an escapement with a push rod, it is necessary to start the linkage with a bell crank since the escapement has to be mounted so that the rubber band may be run the length of the fuselage. When this arrangement is in use, you must take care to

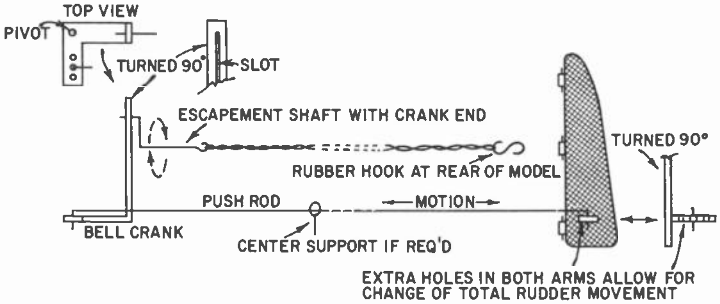


Fig. 1101. *To use most escapements with a push rod, some form of bell crank is required, since escapement shaft usually runs fore and aft in model. One make of escapement has a bell crank built in.*

have every moving part as free of friction as possible, since the motive power of the escapement (often just a single loop of 1/8-inch flat rubber) is not very strong. There is far less chance of excessive friction in the torque rod method of rudder drive.

Speaking of rubber, note that not all grades of a size – say 1/8-inch flat rubber – are the same; some may be thicker, others of a different formula, etc. Thus, while one batch of "1/8-inch flat" might work your controls satisfactorily, a supply of supposedly the same material purchased at a different shop might not have enough pep, even though it is still perfectly good rubber. As rubber grows old, it loses strength, often becoming somewhat brittle and takes on a granular or cracked appearance. Naturally, such rubber is to be avoided. When you locate a size and grade of rubber that does the job for you, it pays to purchase enough for future use. It can be kept for long periods if stored in a small tightly closed jar, in a dark, cool place. Dust the rubber well with talcum powder before storing it to keep the strands from sticking together.

Proportional actuators are linked to rudders and other control surfaces in the same manner as escapements, but here there is more leeway in mounting and placement since there is no need to consider the position of a rubber band. Both actuators and escapements have been mounted in the cabin of the plane and in the tail section, adjacent to the rudder. In the latter case, the effect of the lumped weight so far from the center of gravity must be considered, and this position is seldom used.

Rear mounting does simplify linkage problems. In this case, the rubber terminates in the cabin and is reached through one of the hatches. If the escapement is forward, the rear end of the rubber can be fastened to a plug that fits into the side of the fuselage. When the rubber is to be wound, the whole plug is

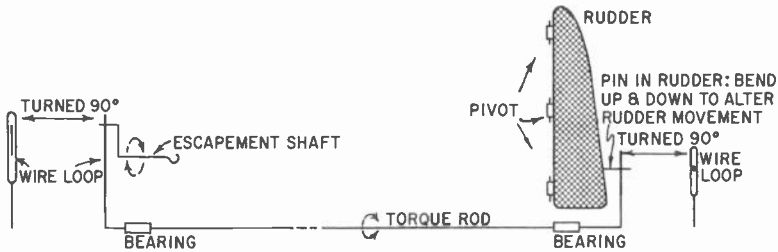


Fig. 1102. *Escapements are normally linked to surfaces with torque rods, as seen here. Wire loops at each end of rod mate with pins on escapement shaft and on rudder.*

pulled out and the loop of wire (the rearmost end of the rubber hook) is attached to the winder.

Incidentally, it is wise to unwind the escapement rubber after every flying session rather than to leave it wound tightly till the model is taken out again. Also, a bit of lubrication on the rubber will preserve it and allow you to put in more turns. Just rub in a little glycerin thoroughly, then wipe off the excess. When winding, stretch the rubber out to about twice its normal length. The rubber loop should be about a quarter again as long as the length between the two hooks that hold it; what we want here is not tension but torque.

Escapements or any other form of actuator should be firmly mounted on a strip of plywood. Some escapements are so constructed that if they are screwed tight against some rather yielding backing — such as balsa wood — they will be pulled out of shape enough to render them inoperative.

It is often handy to have a fine adjustment for making trim adjustments in controls. Simply bend a small V in the pushrod (Fig. 1104-a), which allows adjustments as needed. A screw adjustment as in Fig. 1104-b is a more sophisticated way to do the same job. Bicycle spokes can also be adapted to such use, but add a locknut as shown. Make torque-rod trim adjustments by simply bending one or the other of the vertical torque-rod members (Fig. 1102).

A neat way to make a detachable end for a push rod is seen in Fig. 1105. The keeper wire is much lighter than the main rod and merely serves to keep the latter from coming out of the hole

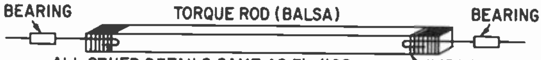


Fig. 1103. *Wooden torque rod (made of balsa, or a hard-wood dowel) is much stiffer than music wire, also affords desirable "insulation" in system, to reduce electrical noise troubles.*

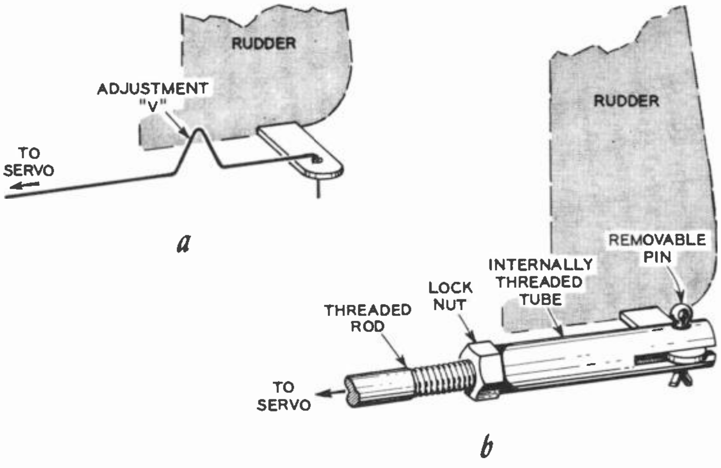
in the horn. It can be sprung aside when you want to detach the linkage.

Electrical noise

This problem was mentioned earlier and is due almost solely to control linkages and the escapements, actuators, etc., used to move the various controls. It is especially a problem when metal push or torque rods are used to connect the controls. The trouble comes about this way: Let's say an escapement is utilized to drive a rudder through a metal torque rod. The escapement is connected to the batteries and to the receiver, so it can be considered a part of the "ground system" of the latter. The long torque rod is connected to the escapement and thus acts as a further extension of the ground connection. The trouble comes in the fact that several slip joints are in the "circuit" between the escapement and torque rod. When an installation is brand-new, these joints may be clean enough to offer little resistance, and hence there may be no trouble with electrical noise. However, as the parts get older, they corrode a bit and naturally get dirty. Thus the joints offer variable resistance as the escapement moves or as the motor vibrates. This is when real trouble can be experienced. Note that even though there is no electrical connection between the escapement winding (which *is* connected to the receiver) and the metal parts and the linkage, the capacitance between escapement parts is often enough to cause the same effect as a direct connection.

There are actually several easy ways out of this dilemma. One is bonding the moving parts. Fig. 1106 shows points that should be bonded to offset electrical noise. While there is often a metal-to-metal contact between the rear end of the torque rod and the metal loop on the rudder, the loop is so short that it doesn't appreciably extend the length of the torque rod, so generally, no bonding is needed between these parts.

While it is often not so serious a source of noise, the linkage between an escapement and a motor throttle is also an occasional source of trouble. Bonding the linkage and the motor itself is often a help in a receiver bothered by this type of interference.



Figs. 1104-a, -b. *Small V in push rod (a) allows adjustments to be made. More precise adjustment (b) can be had with a threaded rod and tube. Latter can be made from a bicycle spoke.*

Bonding wires are effective but they must be arranged carefully to allow full movement of the bonded parts without any drag, and also so that the bonding wire can do its job well and yet last for a reasonable time. Needless to say, use the most flexible wire possible. It does not need to be heavy; fine multistrand is good for the job. It is usual to bond the escapement frame to the plane wiring. "Ground" is usually considered to be B-minus in planes using tube receivers. In transistor receivers ground can be connected to plus or minus of the battery – it varies from set to set. The torque-rod bond wire can also be attached to the escapement frame. Solder the wire carefully to the torque rod and wrap a few turns around it to take some of the strain of the constant twisting.

In place of bonding wires, some users prefer to insert insulation in the linkage "circuit" somewhere so that the long torque or push rod is isolated from the escapement or other control unit. One way is to use a nonmetallic rod (Fig. 1103). If you use a metal rod, insulated ends can be put in; Fig. 1107 shows one way to do this, using $\frac{1}{4}$-inch thin wall aluminum tubing for the main part of the

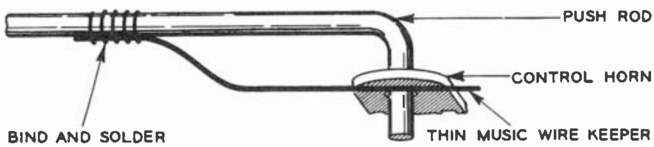


Fig. 1105. *To allow quick removal of push rods they can be fitted with "keeper" as seen here. Handy for quick change of surface movement, where control horn has several holes in it.*

rod. Bind music-wire ends to the dowel pieces. The gap between the wire ends and the tubing serves as electrical insulation (also the capacitance is very low at these points). Another point where insulation could be put into the linkage might be at the bell

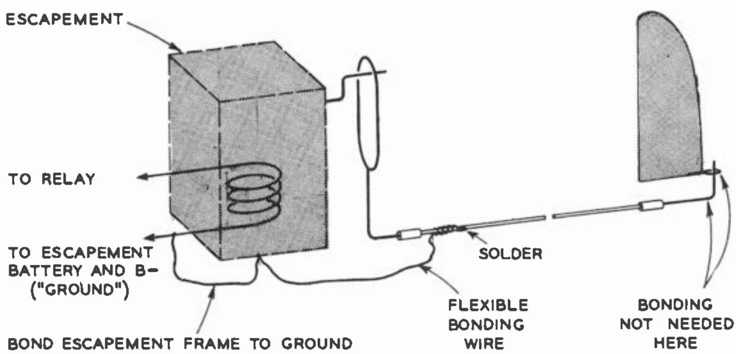


Fig. 1106. *All-metal control linkage should be bonded together as seen, including escapement metal frame. Wrap several loose turns of bonding wire around torque rod, to reduce load on soldered joint.*

crank (Fig. 1101); either the horizontal or vertical portion of the unit could be of a material such as linen phenolic.

If it can be done, the insulation method is to be preferred to bonding wires. Wires have a bad habit of breaking and then, of course, all bonding effect is lost.

Electrical noise can also be produced by small motors used for servos. Methods were presented in chapter 10 for overcoming relay-contact arcing but it is usually necessary to apply "hash filters" right at the motor itself to kill the interference at its source, before it can travel along the wiring. The easiest way is to hook a capacitor directly across the motor brushes with the shortest possible leads (Fig. 1108-a). Sometimes two capacitors help, with the center grounded to B-minus, as in Fig. 1108-b. In stubborn cases it might be necessary to use rf chokes as well. The size of

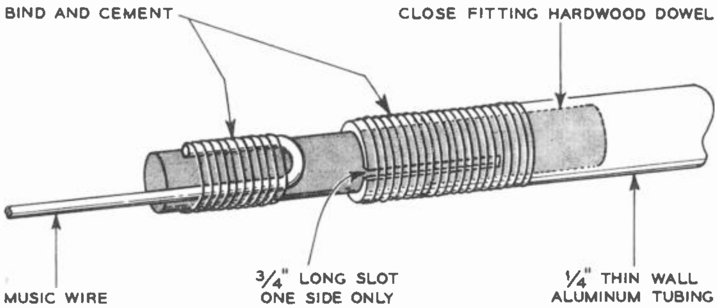


Fig. 1107. *Thin wall aluminum tubing is extremely resistant to twisting. Can be fitted with wooden dowel ends, wire fittings attached to latter. Single slot does not weaken tubing much; binding thread clamps it tight to dowel.*

the chokes depends upon the receiver frequency; for 27 mc, it is customary to use chokes of 20 – 25 μh. Such chokes should be of as low resistance as possible so they do not reduce motor power appreciably. If a motor has a metal case, this can be grounded.

In any installation, it is a wise precaution to keep the receiver antenna lead as far as possible from the low-voltage control-circuit

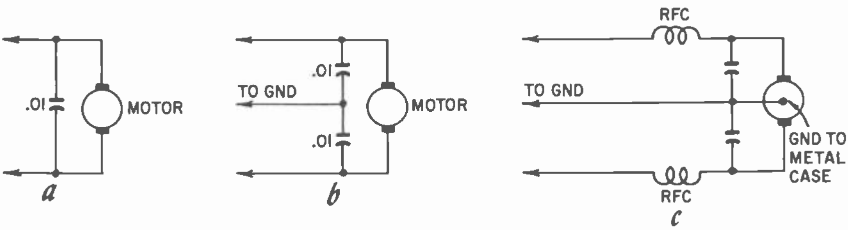


Fig. 1108. *Simplest motor noise suppressor (a) is single capacitor. In some cases, pair of capacitors (b) with center grounded is better. Bad cases have been cured with capacitors, rf chokes (c) grounded motor frame.*

wiring and especially from motors. There have been cases where a shielded antenna lead (with the outer shield grounded) helped relieve stubborn interference cases, but it is usually not necessary to go to such extremes.

Mounting batteries

Batteries, since they are a concentrated weight, should be located with great care. It is best to place them against the rear face of a sturdy bulkhead to prevent them from flying forward in case of a crash or hard landing. Because of their weight, batteries are normally mounted forward in the fuselage. It is best to place the receiver behind them, so that in case the batteries tear loose in a crash, they do not mangle the receiver. In any case,

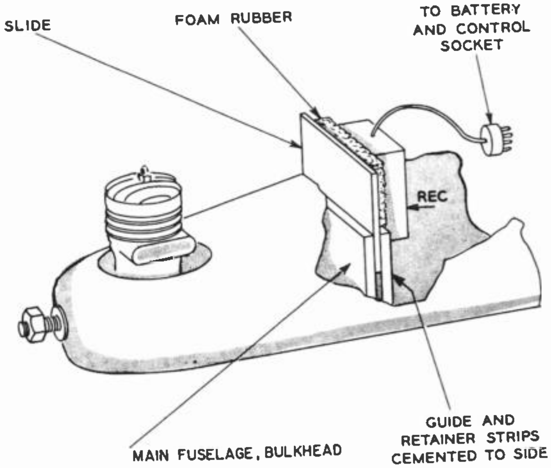


Fig. 1109. *Receiver, batteries or both can be mounted on wooden slide. If slide is directly back of a strong bulkhead, it may be of balsa. Some modelers mount entire radio installation on slides, for ease of removal.*

they must be fastened securely. The damage done by a flying battery must be seen to be believed!

The widely used flashlight cells can be fitted into one of several sorts of holders. (Refer to chapter 9.) Some open holders made of sheet aluminum have a reputation of doubtful contact due to corrosion; the contact points must be checked frequently and both the holder and the cell ends cleaned with fine sandpaper. Many fliers prefer to solder directly to the cells. Although this makes it much more of a problem to change cells, it clears a potential source of trouble through the poor friction contacts that are found in some holders. In soldering to cells, clean the ends carefully with fine sandpaper, then tin with a hot iron. Try to do the soldering just as quickly as possible so as to limit the heat applied to the cell.

Regardless of where you mount them, remember that batteries must be checked frequently and replaced fairly often, so make your installation practical from a convenience angle.

Mounting the receiver

It used to be the practice to suspend a receiver with rubber bands and, while this did isolate it from vibration, the receiver could take severe punishment in hard landings by bouncing around the cabin. Present practice is for a much more "solid"

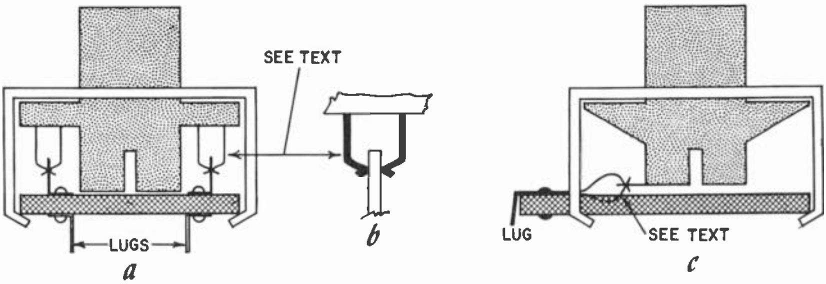


Fig. 1110. *Slide type switches come in many makes and styles, but best for R/C use are those which have knife edge contacts, as seen here. Edges slip between two spring contacts, assure good electrical circuit closure.*

mounting, with vibration absorbed by foam rubber. Since receivers (especially multicontrol types) are getting larger and heavier, these units are often mounted vertically on the rear of a bulkhead, in which position they can best absorb the shock of crashes and heavy landings. Receivers in plastic or metal cases are easy to mount: the case – or one cover of it – is attached to the foam-rubber pad with heavy-duty rubber cement. The pad can be cemented to the bulkhead.

A more flexible mounting arrangement is to utilize a slide mount. The idea is sketched in Fig. 1109. The entire receiver, foam rubber pad and slide can be removed from the cabin as a unit. This allows for easy inspection and adjustment. Position the controls so that the set can be tuned without removal, however.

This slide can be backed up against a bulkhead, in which case the slide can be lightweight plywood or even balsa. If there is no such backing, heavier plywood is required. Some builders also use the slide system to mount batteries in the model. They can be placed in their holders on the same slide that holds the receiver, if you wish.

The modern trend is to make all parts of the control system easily removable. This includes *everything* – receiver, servos, batteries — even wiring and switches. The various parts are connected with small plugs and sockets. A completely removable system of this sort makes trouble-shooting very easy, as you can place the whole works on your bench and connect it to operate just as it would in the plane — but with plenty of room to work on it.

One large plane-kit maker has popularized a form of box mounting in which all radio-control parts are in a single unit. Servos are included, and push rods to them terminate in ends as shown in Fig. 1105, so that the box may be removed as a unit. The box is a close fit in the central section of the fuselage and is made strong enough so that it serves to brace this area from twisting strains.

Switches

The various controls that must be reached from the outside of the plane in normal use, such as the battery switches and meter jack, should be mounted where they are most convenient for the owner. Switches are usually placed on the side of the plane and, if possible, should be on the side away from the exhaust of the engine. Any exhaust that gets into the meter-jack opening can make the installation inoperative due to dirtying of the contacts. The average installation requires two switches and a meter jack. The former should be placed where there is little chance that they will be accidentally flicked off as the plane is hand-launched.

There is a big difference between switches. The slide type is widely used today, due to its light weight and small size. However, some kinds of slide switches are very unreliable. If they are used, make sure that your switches are of the knife type. Fig. 1110 illustrates how these look in cross-section. The knife edges are self-cleaning and make very good contact.

Other types of slide switches that appear something like Fig. 1111 and have ball or rocking contacts have been found dangerous for model uses. Most toggle switches seem to work well, though they are a bit on the heavy side for small models. Some modelers use subminiature toggle switches. Although rather expensive, they seem to be very positive in action and, of course, are very tiny and light.

Wiring

Do all wiring in the model with flexible conductors; solid wire has a bad habit of breaking under heavy motor vibration, unless it is fastened for its full length. The wire can be quite thin. Flexible wire as small as No. 24 (or even thinner) can be used for receiver A- and B-connections. Double this wire so that there is no large voltage drop in the case of conductors that carry current to several servos. It is desirable to terminate the wires from a receiver in a plug that fits a socket in the model; this makes it simple to remove the receiver for repairs or adjustments without having to unsolder any wires. Use wires of various colors

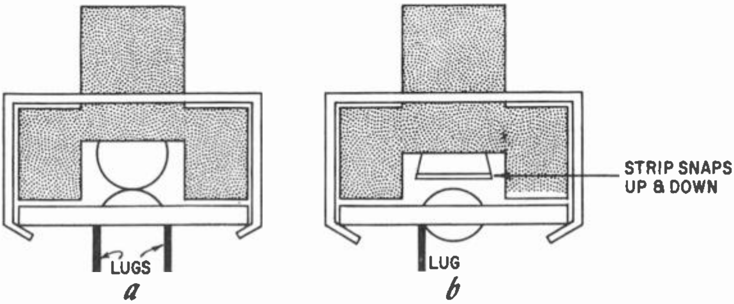


Fig. 1111. *Avoid slide switches with various types of ball contacts. They collect oil and dirt quickly, do not have desirable sliding action to clean it away.*

so that it will be easy to trace any particular circuit. Try to use the same colors in all your models. There is no special code for this except that B-plus is usually red, B-minus black and A-plus often yellow.

Wires from the receiver to the plug should be evenly twisted (some builders take the trouble to braid or weave the wire together) and bound together with a wrapping of tape every few inches. The same can be done with wiring that is left permanently in the model. Fasten such wiring at intervals with sticky tape or other means that will hold it in place but will allow it to be removed easily if necessary.

There is a material now available called Spectra-Strip. It consists of 10 strands of flexible wire, each with insulation of a different color (the colors run through the color spectrum, hence the name). All 10 insulated wires are lightly fastened together in the form of a flat tape, but they can easily be separated if desired. This wiring material makes possible a very neat installation in your model. It can also be used to advantage in transmitters; even to some extent in larger receivers.

Model planes are now being built with more thought to the factor of convenience in use. For example, many builders put a hatch on the bottom of the fuselage, and under it install all the batteries. This makes test and replacement an easy matter, and the wing doesn't even have to be removed to do it. As an aid to ease of use, some larger planes are even fitted with miniature milliameters that are always handy for measuring receiver current. Such meters are only about 1 inch in diameter and weigh about 0.7 oz. They afford continuous check of receiver operation right up until the moment the plane leaves the launcher's hand.

Though it is more a matter of plane design than of radio

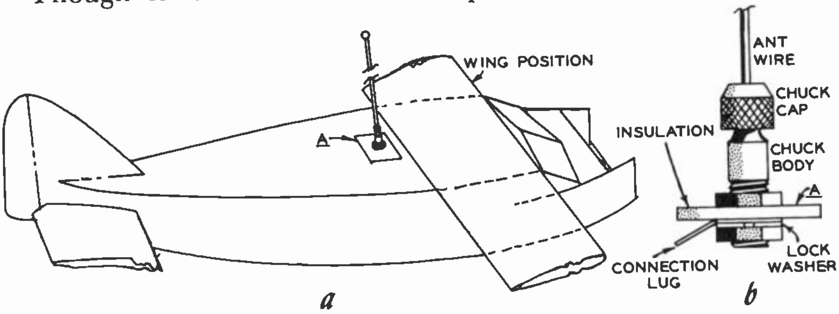


Fig. 1112. *Vertical antenna of stiff wire can be held in test prod chuck end; such ends come threaded for standard nuts. Chuck also makes neat and easily removable end.*

installation, be certain that the receiver controls and batteries are not mounted where they can be affected by fuel seepage from the tank or by oil from the engine exhaust. If it is necessary to run the engine with the cabin open or the wing removed to make vibration tests, be sure that the exhaust cannot get into the cabin or come in contact with any other parts of the electrical installation. Nothing will gum relay contacts and cause defective switch and escapement operation quicker than model-engine fuel, either fresh or out of the exhaust!

Antennas

It used to be thought that the receiver antenna in the model had to be of the same type as that at the transmitter. Thus, a vertical transmitter antenna would call for a vertical one on the model. Nowadays, almost all transmitter antennas are vertical; but model antennas are of all types, with the vertical probably in the minority. Actually, with a well-tuned and correctly-operating transmitter and receiver, the kind of antenna used for the latter makes little difference. In some receivers, length is fairly critical, as mentioned in Chapter 4. Some manufacturers specify a minimum or maximum antenna length, or both. Generally though, a couple of feet of wire will do the job. In the case of the receiver, the total antenna length should be measured right from the set itself, along the full wire to the end.

If a vertical antenna is used, it is ordinarily mounted to the

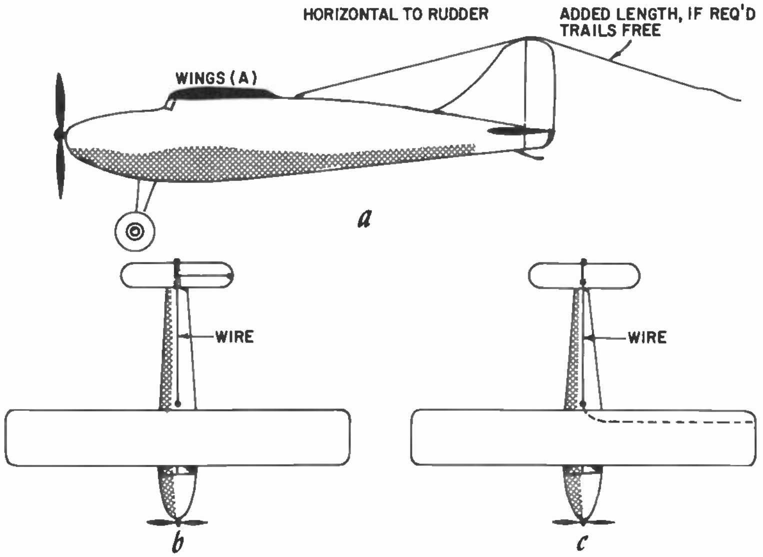


Fig. 1113. *Larger planes (a) can use wire running to tip of fin. If more antenna length needed (b) extend to tip. Small planes may require a wire to fin (c) and also to wing tipe, or to both tips.*

rear of the wing (Fig. 1112-a). In this case, the wire must be stiff enough to withstand the wind pressure (1/32-inch music wire or 1/16-inch aluminum rod are useful). A handy mount for a vertical antenna is seen in Fig. 1112-b. It consists of a small chuck taken from the end of the type of radio test prod intended to hold phono needles. These chucks will take a 1/16-inch diameter rod and hold tightly, but the antenna can be removed for transporting the model or storing it. Always bend the upper end of a vertical receiver antenna in a protective loop of about 1/4-inch in diameter. A metal or plastic bead can be attached there.

While it might be felt necessary to mount the chuck in Fig. 1112-b on insulating material, a piece of plywood will do well enough. Moisture absorption is no great problem as the outer surfaces of the model are always well doped.

Many builders run an insulated wire from the top of the fuselage (at the rear of the wing back) to the top of the fin (Fig.

1113-a). If more antenna length is desired, the wire can be continued to the stabilizer tip. A length of wire can be left to trail loose, but this can be troublesome in acrobatic planes. The loose wire has sometimes tangled in the control linkage and brought about disaster.

On very small planes, it is often a problem to get sufficient antenna length. It sometimes helps to run one length of wire to the tail and another fastened to it but stretched out along the tail surface (Fig. 1113-b) or the trailing edge (Fig. 1113-c).

Receiver antennas are seldom of the resonant type, although those on transmitters always are. Therefore, don't try to "tune" the receiver antenna to the operating frequency; to do so will make a superregenerative receiver useless.

Theoretically, vertical transmitting antennas put out the strongest signal at a fairly low angle toward the horizon in every direction, but there is a dead spot right overhead (Fig. 1114). In

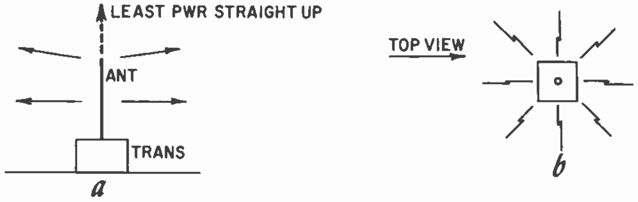


Fig. 1114. *Ground type transmitter with vertical antenna puts out strongest signal towards horizon, least directly overhead. Signal goes out in every direction, 360 degrees around antenna.*

use, the mounting of the antenna, the surroundings, the key lead held by the operator and many other factors all work to upset this theory, so we need not generally worry too much about the direction of signal propagation or dead spots.

One last word on antennas in the model: Remember that the other wiring in a plane acts as part of the antenna system. For this reason, a receiver that has been tuned and found to work perfectly on the bench might be very balky when installed in the model. You may find that the antenna coupling will have to be considerably different for you to get the receiver working as it did before installation. If you later change some equipment in the plane, such as using a metal push rod to the escapement in place of a wooden one, this again can alter receiver operation until you have compensated by changing antenna length or coupling to get things back to the way they were.

chapter TWELVE

adjustments and tests

WHETHER you have made your receiver or purchased it, the first thing you will want definitely to know is — does it work? Preliminary tests can be made with the receiver, batteries, escapement or servo mounted on your bench, and with temporary wiring. This will prove whether the equipment will work when it receives a signal from the transmitter you will use. Some receivers overload with a transmitter very close by, so take this fact into account. Also, if the test is made in your shop, most of the transmitter antenna will probably be removed. This reduces the output so it probably won't bother the receiver, but make sure the transmitter is tuned to operate properly with the shortened antenna. If everything seems all right, proceed to install the apparatus in your model.

Installation tests

First, double-check to be absolutely certain all wiring is correct. Then you can make a quick test to see if the control surfaces will work when you give the proper signal. Right here you should be alert for the first signs of trouble. The preliminary tests were probably made with just the escapement connected (if this is what you are using). But now you have the same escapement in the model and you should have all the linkage installed.

Make the first check with the escapement batteries removed (or open the switch in this circuit, if you have one). With a test meter plugged in, key the transmitter to see if the receiver relay current follows the keying. You will probably have to retune the receiver, readjust the sensitivity control if it has one, readjust any antenna coupling capacitor, etc. In other words, you must set things up to satisfy the receiver as it is mounted in the model. If it follows your keying exactly, then switch on the escapement or servo power and try again. If all is well, your controls should follow the transmitter keying consistently. Key the transmitter repeatedly — as much as a hundred times or more – and if you get even a single skip in control action, find out why. It might be the electrical noise we covered in Chapter 11, possibly an escapement with a binding linkage or one that needs a little adjustment, etc. But there is no sense going on until the controls are absolutely reliable at this point.

When you are satisfied, try a distance check. For this, get out in the open, set the transmitter up with full antenna and then start walking away with the model. Have an assistant at the transmitter who knows your hand signals perfectly – or the tests will end in

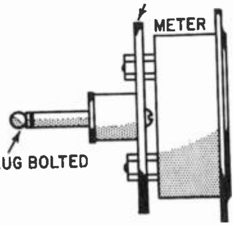


Fig. 1201. *Phone plug can be mounted directly on test meter, either with stiff wires or by means of phenolic plate, as seen here. Whole unit then slips into jack on model.*

utter confusion. You will find it useful to have the transmitter turned off as long as your assistant with the model faces away from from the transmitter. Some receivers require a check with no signal, after which the man with the model can turn toward the transmitter, as a signal to turn "on" and tap the key. This is most useful for CW transmitters. For tone outfits, you seldom need to check with the carrier off, so the transmitter can be turned on (but no tone transmitted) when the assistant with the model stops walking. When he turns toward the transmitter, key the tone on.

It is usual to hold an arm up, down, right or left, according to whichever way you want the controls keyed. When 500 or 1,000 feet away it is often difficult to see what the signals are calling for, so hold a hat or handkerchief in your hand to make sure your helper knows the score.

Always do your final tuning of a receiver from a good distance – at least 500 feet away. Closer to the transmitter, a receiver may tune very broadly. Once you tune at a distance, *don't* "touch it up" when you get back near the transmitter. But *do* make a test for overloading. If your receiver is affected this way, you can still work in close proximity by holding one hand on the transmitter antenna (if it is of the MOPA type, this will greatly lower the output, but generally will not cause detuning). Don't forget to let go of the antenna when the plane is a hundred feet or so away, after it is launched!

But *don't* launch it yet! Still to be made is one of the most important checks of all — a trial of the equipment with the engine running. Some careful builders run through several tankfuls of fuel to make absolutely sure the equipment isn't bothered by vibration. If you see signs of trouble at this point, try to isolate it. Plug in a meter, turn off the servo circuits and note if the receiver behaves, as shown by the meter reading. If it still acts up, you might

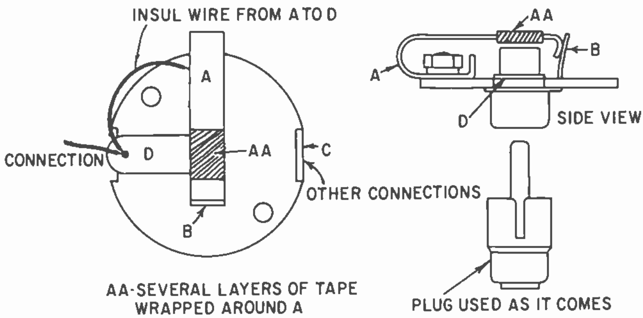


Fig. 1202. *So-called phono plugs and jacks widely used for R/C. Open circuit jacks available everywhere, closed circuit type not so widely distributed. If you can't locate one, make it from open circuit unit, like this.*

check for linkage noise, install bonding, etc. A relay that is bothered by vibration is harder to spot, as the trouble will not show up with the servo circuits open. And don't forget that the escapements themselves can be bothered by vibration; you can check this with the motor running and no power to the receiver.

An even tougher vibration test is to install the wing, then run the engine while the plane is held suspended by the wing tips or with the tips seated on thick pads of foam rubber. This scheme will sometimes show up vibration you can't notice with the plane resting on the ground, or when you hold it by the fuselage.

If all goes well up to this point, you are ready to try glide tests (if you have not already done this), and finally, powered flight.

Most of the tests mentioned have been for escapement or servo systems. Proportional actuators can't skip with vibration, of course, but you might find that the neutral is much different with the engine running than without, or that the neutral wanders from side to side. This can be caused by relay vibration or even mechanical vibration that directly affects the actuator or linkage. There should be no difference in rudder position with or without the engine running. Always check rudder (and other control action) with the engine running and just before the plane is launched. Note carefully that the controls can be moved to full extremes and that they center perfectly upon your command, before the plane is let go. This holds true for the simplest and the most complex controls.

Soldering

The building and operation of radio-control equipment makes essential a fair knowledge of soldering, plus a certain amount of skill. *All* joints and connections must be soldered for maximum reliability, unless they are made by screws or binding posts. Twisted, unsoldered leads are a sure source of grief. Use only rosin-core solder in any radio equipment; never use soldering flux or acid-core solder, for these substances are corrosive.

In making model receivers, which are usually small and rather delicate, a tiny pencil-type iron is a great help. Some of these have a socket arangement, so you can change the tip as desired. When making field adjustments and repairs, it is very handy to have a 6-volt or a 12-volt soldering iron which works from an auto storage battery.

Meters

The test leads to a meter used to check receiver operation in the field must be kept very short. In fact, they should be nonexistent for best results. This means that the meter should be attached right to the test plug itself, as shown in Fig. 1201. This is entirely practical.

If an ordinary radio phone plug and jack are used in the plane test circuit, the meter can be mounted on the plug with a couple of heavy wires or perhaps with a piece of bakelite to hold both meter and plug. A meter rigged this way is normally used for no other purpose, but is kept strictly for receiver testing.

Radio-control builders often use what are known as *phono* jacks and plugs for their test meter. If the former is small enough, it may be attached to the plug, but this is practical only for the tiny 1-inch meters, since these plugs and jacks are not as rugged as the radio plugs and jacks mentioned earlier.

Phono jacks are available in both open- and closed-circuit types. but the former are more widely known. With the open-circuit type, you must insert a shorting plug when the meter is removed. You can change one of the open-circuit jacks to closed-circuit operation (Fig. 1202.) This is much more convenient and removes the chance that the shorting plug will be forgotten or mislaid.

It is necessary to make another part, A, from good spring brass or bronze (taken from a discarded radio jack or leaf switch), which is attached to the jack base with a 2-56 machine screw. The end is bent to make good contact with the lug B that was intended for connection to the outer portion of the jack; the new connection

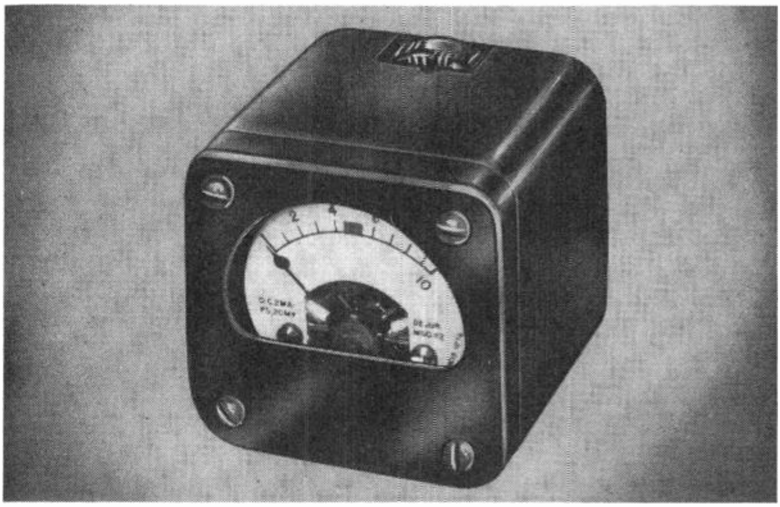


Fig. 1203. *This 1½" meter with phenolic case is light enough to support on a phono plug and jack. Knob at rear of case is tiny pot useful for checking relay adjustment in some types of receivers.*

to this part is made to one of the bent-over ends C that crimp the metal to the jack base.

The lug D for the center connection of the jack is bent outward to clear piece A. The latter must have insulation on it at point AA. You can cement on a piece of phenolic or just wrap it with tape. Properly made, a jack of this sort will prove absolutely reliable. Since part A makes a wiping contact on the lug B, it tends to keep the contacting areas clean and no maintenance is required.

The meter in Fig. 1203 has a phono plug attached right to the case by a soldered-on flat washer. This is a very convenient setup, since the meter can be tucked in a pocket when not in use.

Test phones

Many tone receivers must be checked with an earphone rather than a meter, which means that your test jack should be of the open-circuit type. It is possible to check some types of tone receivers with phones, using a jack connected in the high-voltage battery circuit. To do this, you must use a low-resistance earphone or a transformer with a low-resistance winding; putting any considerable amount of resistance in series with the B-circuit of most receivers will make them inactive. With sets that use 22½ to 45 volts, the circuit seen in Fig. 1204-a will usually work. Note that the low-resistance transformer winding is in series with the B-circuit; the earphone may be any high-impedance type, either magnetic or crystal.

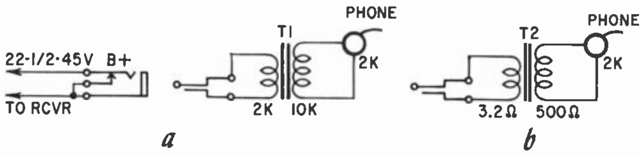


Fig. 1204. *For high voltage receiver, use a tiny transistor interstage transformer such as the Lafayette TR-98, with lower resistance winding in B-plus line. Low voltage receivers require output transformer, T2 being plate or collector to voice coil unit (Lafayette TR-99).*

For low-voltage all-transistor receivers, the circuit in Fig. 1204-b may do the job. This does not give much earphone volume but enough to be usable. Some receivers will not tolerate even a few ohms in the battery circuit without malfunction. If your set will, though, you can often use the same jack for earphone checking and for use with a milliameter.

Many tone receiver users carry hearing-aid type phones for field testing. But remember that such testing is often necessary with a motor running nearby (even the motor on your own plane), and it is useful to wire two such phones, either in series or parallel, so you can put one in each ear and shut out some of the external noise.

chapter THIRTEEN

test instruments

THE most elementary test instruments you can use are a low-range milliameter to check your receiver and a higher-range milliameter for the transmitter. While the receiver meter is a plug-in type, it is highly advisable to build the transmitter meter right into the case so it can serve as a constant check on operation. Some builders have operated without either of these essentials, of course, but it certainly isn't advisable. You just can't tell what's going on inside your equipment without meters to take its pulse.

Milliammeters and voltmeters

Aside from low-cost surplus units, the lowest-cost meters are the iron-vane type. They give good service if you consider their shortcomings, the main one of which is that they have a relatively high internal resistance, especially in the 3- or 5-ma range used for many receivers. This resistance is enough to throw some receivers off adjustment when the meter is plugged in or removed. Wire a resistor into the meter jack circuit as shown in Fig. 1301; the resistance is thus about the same with or without the meter in the circuit. The resistor's value should be as close to the meter resistance as you can get; a representative 3-ma iron-vane meter has about 4,000 ohms internal resistance. These meters usually have an accuracy of about 5%, and the needle tends to oscillate a lot more than with moving-coil meters. Iron-vane meters are better than none at all, however.

Moving-coil meters are generally more expensive. The accuracy of moving-coil meters is about 2%, and their low internal resistance means they can be connected to receivers without disturbing the circuit. For high voltage receiver uses, a 0 — 5-ma meter is suitable, while transmitters require meters of about 0 – 50-ma maximum scale. Tiny 1-inch diameter meters now available at reasonable cost are ideal to install permanently in your model;

this is not often done in planes, but model boat and car builders often use built-in meters.

Built-in transmitter rf meter

A plate-circuit milliameter is most useful in a transmitter but it will not, in all cases, tell you whether you are actually putting out a signal. Some transmitters, in fact, show almost exactly the

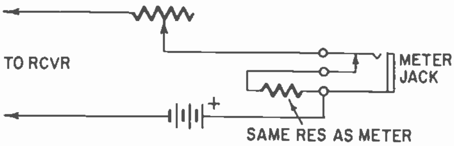


Fig. 1301. *With low cost "moving-iron" type meters, receiver test jack should have resistor that is cut into circuit when meter is not in use. In this way, receiver will operate same with or without meter in the circuit.*

same milliampere indication whether they are working normally or not at all.

Many commercial transmitters have a tiny pilot bulb as an rf indicator. Some connect the bulb to a single turn of wire placed near the plate coil; it lights if any rf is being produced. A No. 48 or 49 bulb is always used, as these are the lowest-drain types

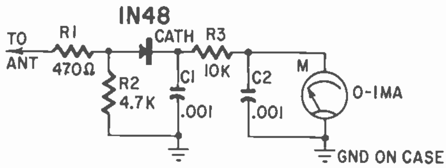


Fig. 1302. *Rf output meter can be built right into transmitter, using this circuit. Vary R1 to get ½ to ¾ scale reading with your particular transmitter. This unit takes very little power from antenna.*

commercially available. Such a bulb can also be placed in series with the antenna circuit to show when power is being produced. This arrangement is even more foolproof than with the bulb coupled to the plate coil. In the latter setup, the bulb will light even if power is not going into the antenna — in fact, there will be *more* light with the antenna disconnected (and the plate circuit tuned to resonance).

A circuit for an rf meter built right into the transmitter is shown in Fig. 1302, and a representative installation in Fig. 1303. The tiny 1-ma meter and the various small circuit parts were mounted on a four-lug strip attached to the rear of the meter plate. This arrangement takes virtually no power from the transmitter output, in contrast to the pilot bulbs which can take as much as 1/10 watt to light. Some hand-held transmitters don't put out much more rf than this! Tune the tranşmitter to show maximum meter indication with the arrangement in Fig. 1302, remembering, of course, that the crystal oscillator must be detuned slightly for stability. The circuit shown is for use on a transmitter with about

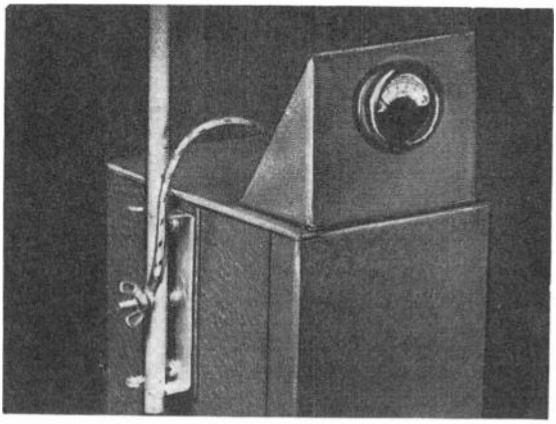


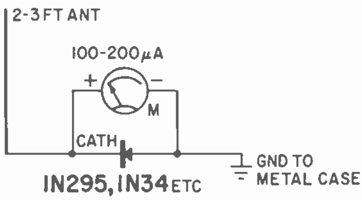
Fig. 1303. *Where room is not avaliable inside case, rf output meter can be mounted externally, as seen here. One side of circuit is grounded to case, the other attached to antenna itself.*

2-watts input. Resistor R1 can be changed to accommodate different powers and should be increased if the meter goes off scale.

Field-strength meters

These instruments are usually self-contained and have their own little antennas. They give a definite indication of transmitter output, and sensitive types can be used up to 50 feet or more from

Fig. 1304. *Simplest field-strength meter is just a diode and a meter, with short antenna. Not very sensitive, even with 100 μA meter.*



the transmitter antenna. A very simple field-strength meter is seen in Fig. 1304. Since it is an untuned type, it can be used on almost any frequency utilized for radio control. By the same token, it is not very sensitive; you have to use a fairly long antenna or put the meter antenna close to that of the transmitter to get a high-scale reading. Also, for good sensitivity you should use as low a range microammeter as you can afford; 100- and 200-μa meters are preferable and will do a good job. A 1-ma meter will work, but it would be necessary to hold the meter very close to lower-powered transmitters.

Much more sensitivity can be achieved with a tuned field-strength meter, which also can give a rough indication of transmitter frequency as well, so this type is recommended. With a

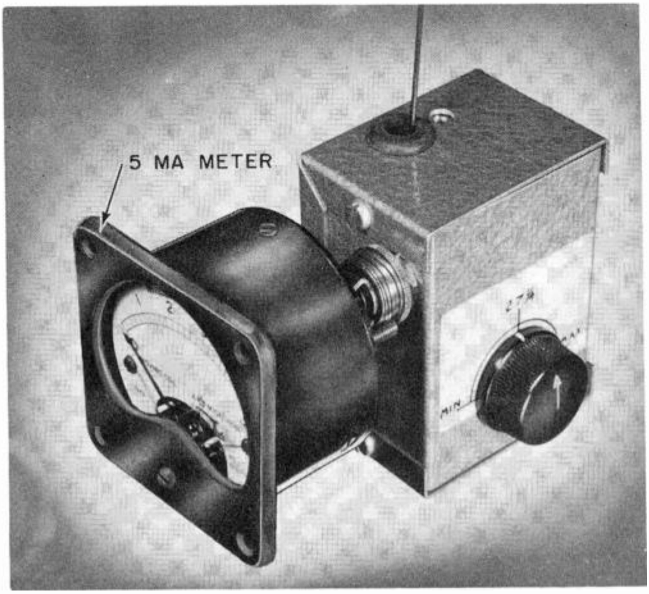


Fig. 1305. *Field-strength meter adapter makes use of usual 5 ma receiver test meter, has tuned circuit and transistor amplifier to boost sensitivity. Tiny case makes it handy for field uses.*

tuned circuit, even a 1-ma meter will give very satisfactory sensitivity. Since most modelers carry around a meter of about 5-ma range to check their receivers, it would be handy to have an adapter that would permit fairly sensitive field-strength checks to be made with the same meter. Fig. 1305 shows such an adapter which boosts meter sensitivity by a simple transistor circuit. The whole instrument is built into a tiny case measuring 2¾ x 2⅛ x 1⅝ inches. Most of the parts are mounted on a chassis of 1/16-inch linen phenolic (Fig. 1306). The transistor acts as a dc amplifier for the current produced by the crystal rectifier (Fig. 1307). Parts placement isn't fussy, and you can make a different arrangement, if you prefer.

Because of the low current drain, two tiny mercury cells were used as a power supply. No switch is needed since the battery circuit is open unless the meter is plugged into the adapter jack. Mercury cells have an extremely long shelf life (they do not

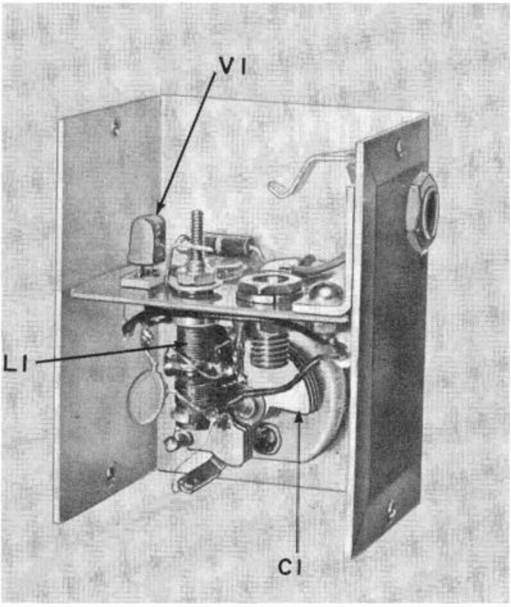


Fig. 1306. *Parts placement inside field-strength meter adapter is not fussy. Mercury cells can be seen just to rear of banana jack and L1 slug screw. No switch is needed; unit only draws current when meter is plugged in.*

deteriorate when not in actual use, as do dry cells) and are ideal for this purpose. However, a pair of subminiature penlight cells will do a fine job, too, and can be fitted into the same case. The mercury cells have solder tabs for making connections and are held in ½-inch diameter holes in the bakelite plate.

Almost any transistor will work in the unit; the high gain of more expensive types is not required. More sensitivity can be had with lower-milliampere-range meters.

Antenna length also governs sensitivity, but you will seldom need to use more than 2 feet. Since you can't see any indication unless the meter is plugged in, don't leave the adapter sitting near a transmitter with the antenna in place. A powerful signal could ruin the transistor and diode, and you would never know it.

A socket was used in the unit shown, but the transistor might as well be soldered in place. Take the usual care to prevent heat damage to both transistor and diode when you are soldering them.

Combination test meter

A combination test meter that incorporates several volt and milliampere ranges, as well as a built-in field-strength circuit is shown in Fig. 1308. It uses a 500-μa meter. The case and several other parts came from a surplus BC-366 jack box (of which there seems to be an inexhaustible supply). The rotary switch in the

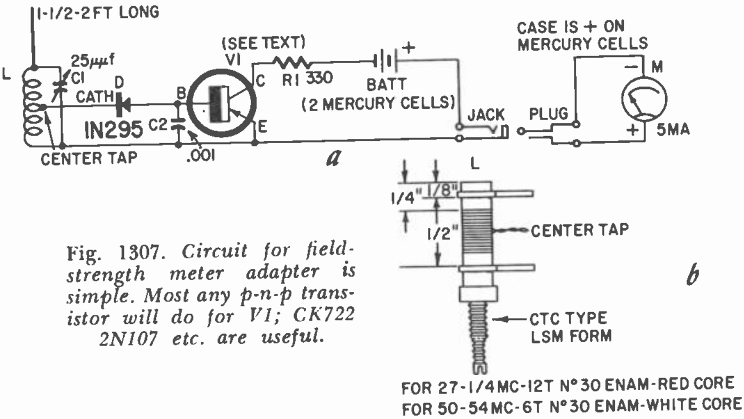


Fig. 1307. *Circuit for field-strength meter adapter is simple. Most any p-n-p transistor will do for V1; CK722 2N107 etc. are useful.*

BC-366 has enough positions for our use, but the lugs are arranged in a rather peculiar pattern so follow the circuit in Fig. 1309 most carefully. Also, remove the heavy detent spring that comes into play at one end of rotation and cut down the detent disc with a hand grinder, so that the last two positions may be located reliably.

R1 and R2 are the voltage range resistors and should be of the low-cost carbon-film precision type, unless you have facilities for selecting accurate values in the normal ½-watt carbon style. If other voltage ranges are desired, note that you can get what you want by making R1 and R2 2,000 ohms *for each volt* of full-scale meter reading. The voltmeter circuits do not apply much load to a dry battery under test. R5 and R6 can be provided to include such a load if desired, and you can further add SW2 (not built into the unit shown) to cut out these load resistors when desired.

Resistors R3 and R4 are the milliampere-range shunts. The values shown were approximately right for the particular meter used. Other makes of meters (or other internal resistances of the same sort of meter) will require different shunt values. These may

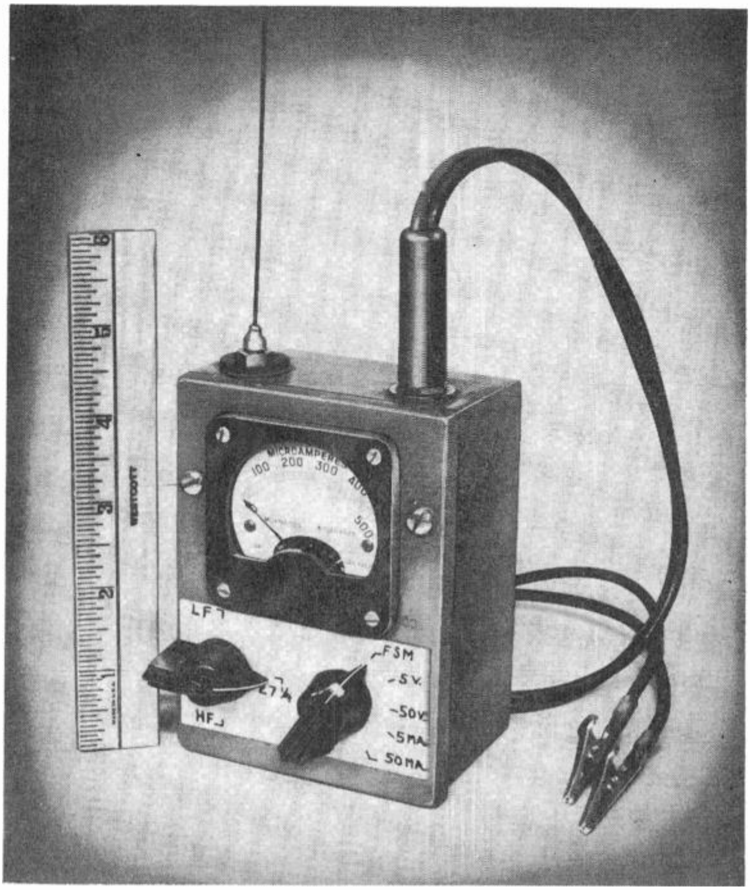


Fig. 1308. *Multirange test meter is made from surplus switch box (can be built from low cost new parts too, of course). Left-hand knob controls field-strength meter tuned circuit, right is for ranges. Plug and flexible leads are used only when utilizing volt or ma ranges of unit.*

be calibrated by the circuit shown in Fig. 1310. This requires a meter of known accuracy and the range you want the field-strength meter to cover. Resistance wire for the shunts can come from old wirewound resistors. Some modelers find control line wire, either fine single-strand or a wire or two from the stranded type, useful for this purpose. Fine copper wire will also serve. Always open the battery circuit before you shift the clip along the resistance wire, or the 500-μa meter may be damaged.

The tuned circuit is set up to cover the 27-mc radio-control

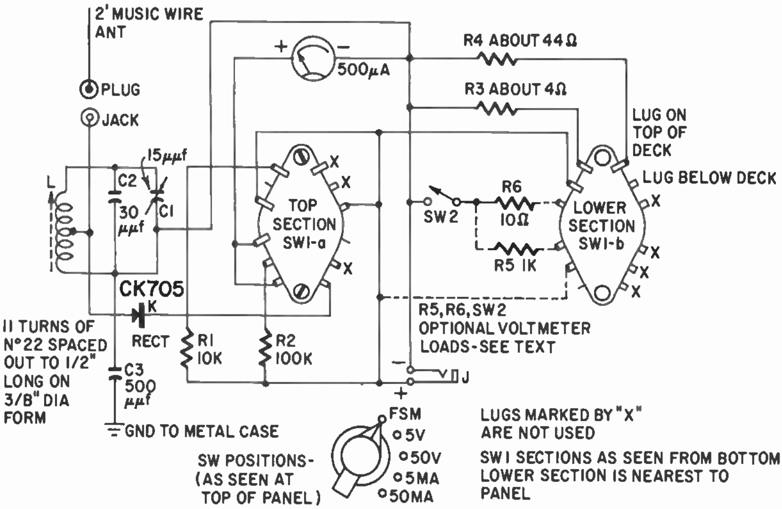


Fig. 1309. *R3 and R4 will depend upon meter used. Might differ widely from values indicated, which were correct for 500 μA surplus meter. R1 and R2 depend on voltage ranges desired and full scale current of meter. R5 and R6 are optional load resistors, for use in checking voltage of dry cells.*

frequencies and a little on either side. A 2-foot antenna is normally used with this instrument, and has been found to give a good scale reading when the field-strength meter is 10 feet away from a 5-watt transmitter.

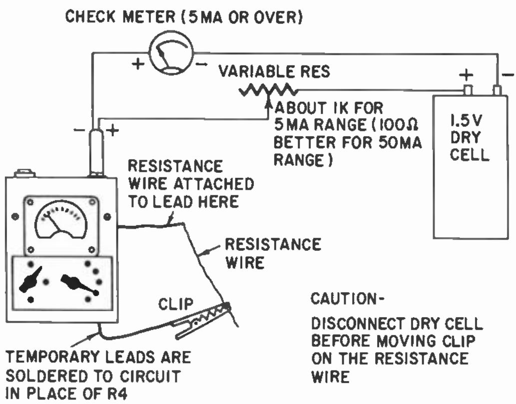


Fig. 1310. *Setup for selecting meter shunts R3 and R4. After correct length of resistance wire is determined, wind it on any sort of insulating form, and make sure no adjacent turns are touching. High value carbon resistors are handy. As forms pick 100,000-ohm resistors, or higher.*

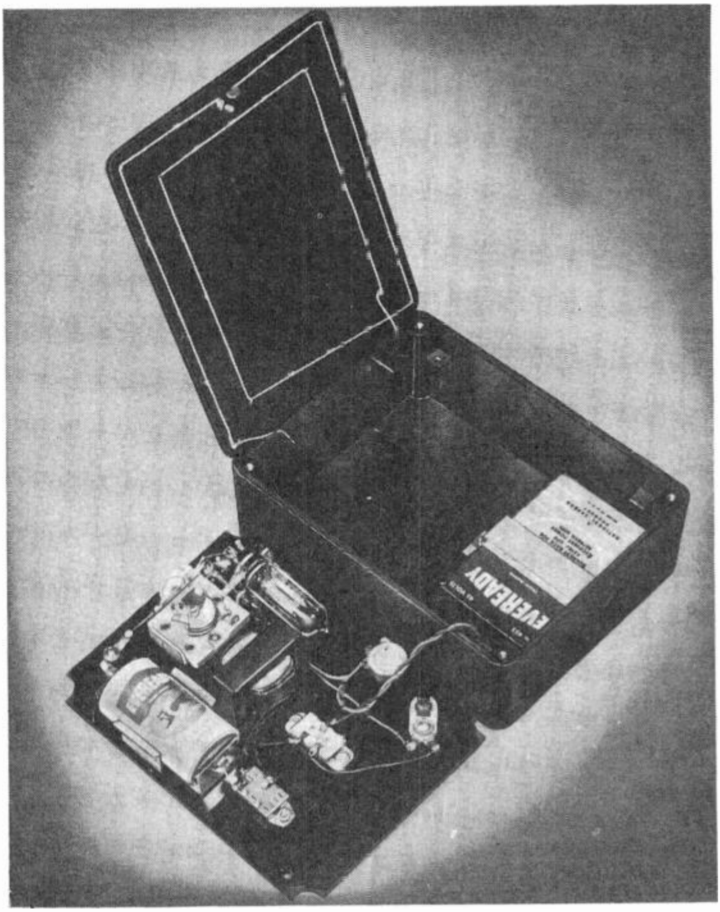


Fig. 1311. *Simple 27 mc direction finder with panel out of case. Due to size of case, subminiature parts are not required and over-all cost is low. B-battery gives very long life; A-battery will be as good, if recommended mercury cell is used. If not, the "alkaline energizer" type of dry cell is best.*

The reading of any field-strength meter will depend upon how far it is from the transmitter, whether it is held in the hand or placed on the ground, etc. For comparative readings, therefore, you should always use the meter in the same way (for example, hold it in one hand a given number of feet from the transmitter). Make your frequency checks in the same manner, though here the distance from the transmitter makes little difference.

Direction finding

Small direction finders have been used by a few modelers, and lost planes have actually been found with them. If the general vicinity where the plane disappeared is known and if the plane came down with receiver intact and still working, such direction finding work is feasible. The plane receiver acts as a very-low-power transmitter, and the direction finder loop antenna allows you to "home" on the lost plane. Of course, you must get there

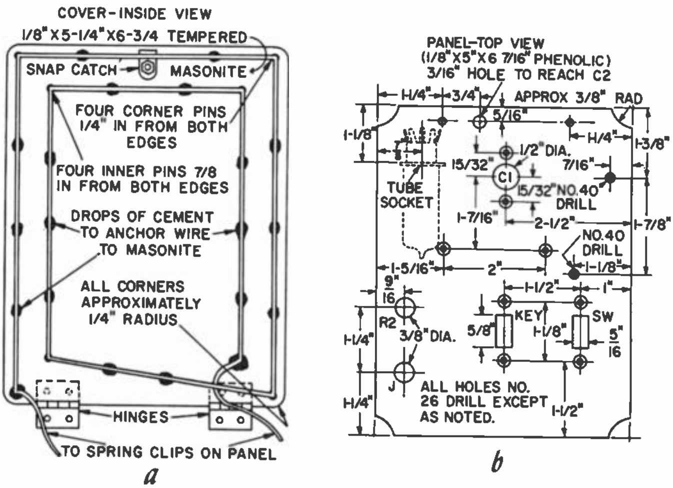


Fig. 1312. *Loop is simply two spaced turns of flexible hookup wire on cover. Phenolic panel that comes with case (Waldom #BP-139, to fit case #BC-140 or equivalents) is used as chassis, drilled as in b.*

before the plane's batteries give out! Actually, most owners of direction finders of the type shown here use them as monitors to see what signals are on the air, and to trace interference. For the latter purpose, the loop offers the same directional properties as it does when you are looking for a lost model.

The finder shown in Fig. 1311 is encased in a commercial phenolic box which comes with a matching panel. The panel, sunk into the box a bit, is held on four angle brackets and carries all the parts except the loop and B-battery. A cover made of Masonite hardboard is hinged to one end of the box and has a snap catch to hold it closed. The loop is attached as shown in Fig. 1312-a. Spring clips hold the loop ends which can be easily detached to remove the panel for battery replacement.

The single 3A5 tube (Fig. 1313) acts as superregenerative detector and single af amplifier. The circuit provides good headphone output. The tuned circuit covers the 27-mc radio-control frequencies with a fair amount of leeway on both sides. The loop antenna *must* be kept away from other circuit parts, and the cover should project straight away from the box (and be perpendicular to the ground) when the finder is in use.

Fig. 1312-b supplies drilling information for the panel. The tube socket is on an aluminum bracket, and the variable capacitor (C1) is held as far from the panel as possible, on ¾-inch metal bushings. A phenolic shaft extension runs from the cutoff capacitor shaft to the knob. This mounting is designed to reduce hand-capacitance effect as much as possible when tuning.

Potentiometer R2 was made variable (Fig. 1314) since it was found that adjustment of this resistor makes it possible to peak the squeal picked up from some types of receivers. When R2 is turned to minimum, the detector functions as a regular oscillator

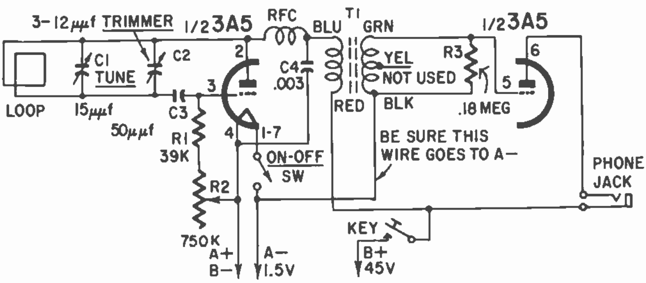


Fig. 1313. *Simple direction-finder circuit. C1 is mounted well below panel, and an insulated shaft extension (ICA #2110 or equivalent) used to carry knob. The A-cell is carried in Acme #11 holder. RFC is Miller #6152, T1 is Triad A31X or any low cost 3:1 audio transformer.*

(not superregenerative) and the finder may then be used as a low-power test transmitter. The most sensitive receiving condition is had with R2 set at the point where a loud hiss just starts in the phones. When using the direction finder as a transmitter, the af section of the 3A5 has no function and just draws current. The B-drain can be eliminated by pulling the phone plug from its jack.

The layout of parts is not critical except that C1 and the tube are mounted near the edge of the box so the loop leads may be kept short. The B-battery will have a very long life, as drain is low. With R2 at full resistance and without the phones plugged in, the B-drain is about 0.1 – 0.2 ma; turning R2 to zero resistance raises the drain to about 2 ma. The af section of the 3A5 also draws about 2 ma. The B-battery should give several hundred hours of service, but the single D-cell will last for only 10 hours or so. For longer A-battery life, consider installing a mercury cell, type RM42D, which should last for a hundred hours or so.

With a simple direction finder like this, the operator can tell along what line the lost plane is on, but it can be either in front or back of the loop. Note that the loop must be turned for *weakest* response from the signal you are trying to locate; this is because the weak signal — or null — is much sharper than the maximum signal, which is quite broad. As it is impossible to tell the "sense" of the signal location, it is necessary to take several fixes from

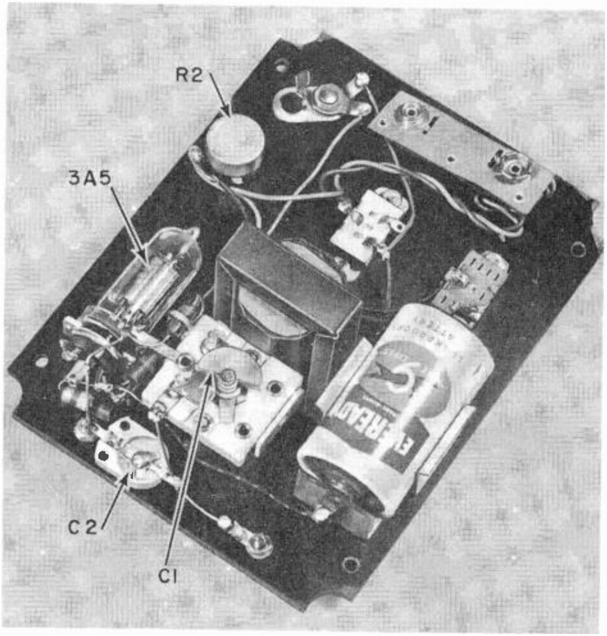


Fig. 1314. ***3A5 tube socket held on aluminum angle bracket. C1 is Bud #LC-1641, C2 is CRL #827B. Snap connector for B battery seen at upper right. Panel must be cut out at corners to slide down inside case.***

different positions (Fig. 1315). Imaginary lines from the center of the loop at each location will then converge on the target.

Direction finding of lost planes is made difficult by the fact that some radio-control receivers put out an extremely weak signal; others produce quite a strong output. Be sure, therefore, to check your own receiver before flying your model to see how it will work with the direction finder. Try it with R2 at different positions; a setting can usually be found that gives much louder squeaks and whistles than any other. Actually, most owners of such direction finders use the outfit much more often for checking interference than searching for lost planes. But it's a most handy gadget to own in any case!

An even more compact direction finder (Fig. 1316) is contained in a wooden case measuring only 5½ x 4 x 1⅝ inches. In this

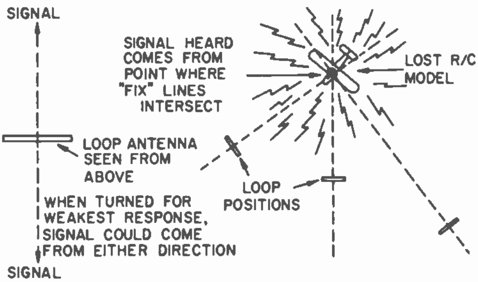


Fig. 1315. *Note that direction finder loop antenna is turned so signal is weakest, to get direction. Two or three "fixes" are needed to get actual location of the transmitter.*

one, too, the loop is attached to the case lid, which must be vertical when the instrument is in use. Subminiature parts and smaller batteries account for the difference in size, even though this unit has provisions to take in both the 27-mc frequencies and the 50-mc ham band. SW1 (Fig. 1317) on the cover takes care of this. Otherwise, the circuit is much the same as for the direction finder in Fig. 1313.

The B-battery compartment is large enough to hold a single 22½-volt battery of either the Eveready 412 or 420 size (or equivalent). To work at this low voltage, it was necessary to use a CK5676 high-frequency triode for V1 to get good operation on 50 mc. If a 45-volt B-supply is used, it is probable that many other subminiature tubes would work as well, even on 50 mc.

In the set shown, C1 is a split-stator type which was made by altering some of the plates of a commercial 25-μμf unit. This particular capacitor is no longer available, but it is possible to use a single-section unit of perhaps 10 or 15 μμf if it is mounted as far from the panel as possible and if an insulated shaft is used. R2 is a variable grid resistor used for the same reason as in the larger direction finder; when turned to zero resistance R1 acts as a transmitter grid leak for V1.

Tuning

To tune up, you will need a signal in the middle of the 50-mc band. With R2 at mid-resistance (you should hear a loud hiss in the phones) and C1 at mid-scale, set C2 to pick up the signal at about 52 mc. Then move bandswitch SW1 to 27 mc, again place C1 at midscale and turn C3 to bring in the 27-mc signals. Actual tuning ranges of the direction finder shown are about 49.5 – 54.5 mc on the high band and 26.9 — 29.2 on the low.

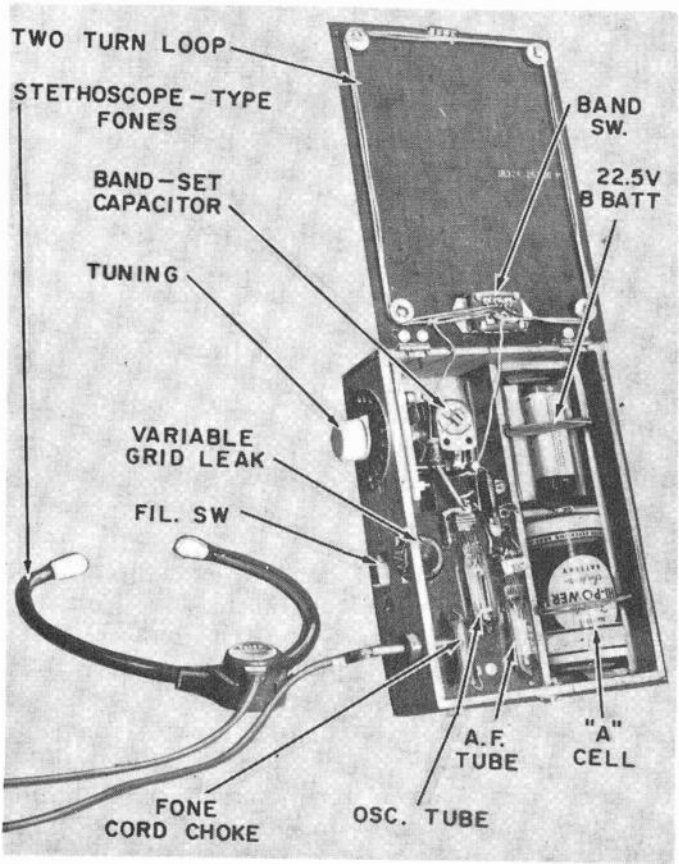


Fig. 1316. *This direction finder is more compact than that shown in Fig. 1311, but has switch to select either the 27- or 50-mc range. On the unit shown, there is no connection to rotor of double-section capacitor C1; "hand capacitance" effect is nil. Single section variable capacitor will work OK, used with insulated shaft extension.*

Many other subminiature tubes can be substituted for the CK533AX, but the CK5676 is the only one that will do the job as

V1 — if you want the direction finder to work on 50 mc with 22½ volts.

Transmitter output

It is often desirable to measure the actual power output of radio-control transmitters with fair accuracy, to check between different tubes, crystals, circuits, etc. One way to do this is shown in Fig. 1318. This illustrates a photometer (an ordinary photography light exposure meter will work as well) fitted with a holder for a small pilot lamp. To this is connected a series circuit including a 3 — 12-μμf ceramic trimmer and 4¾ turns of thin insulated hookup wire. The loop of wire is coupled to the plate coil of the transmitter output stage, and the trimmer is varied to load the transmitter to the desired input. (Loading can also be varied by moving the coupling coil either closer to or farther from the plate coil).

Select a lamp that will light brightly at the power produced by the transmitter. Table 13 – 1 shows the calibration for several sizes of pilot lamps. To vary the range a bit, layers of white paper were put under each bulb and a recalibration made. These same pieces of paper should always be used thereafter. Also, for most accurate

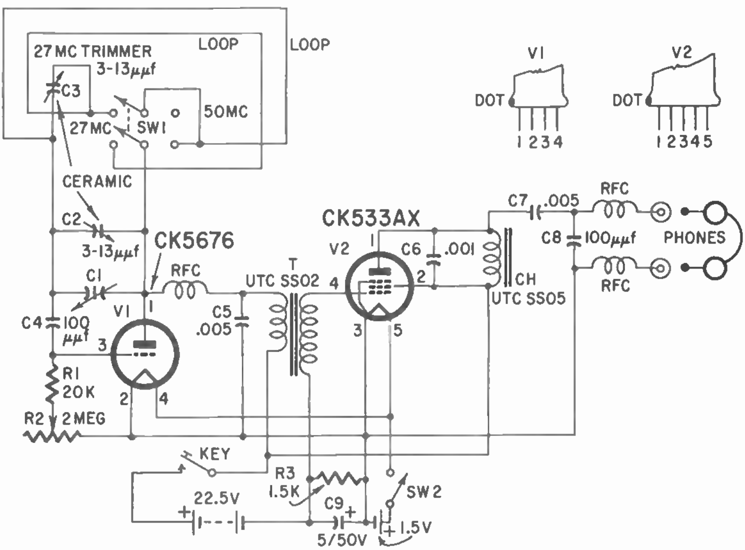


Fig. 1317. *Circuit diagram of the direction finder. The radio-frequency chokes are made of 135 turns of no. 34 enameled wire wound on a form, ¼" in diameter and 1" long. The antenna is a double loop (3½" x 5") of no. 22 double-cotton covered wire. The outer turn is used for 50 mc, both turns in series for the 27.255-mc spot.*

Table 13—1. Power Ranges of Various Bulbs

No. 47 bulb — without paper filter	0.36 — 1.16 watts
No. 44 " — " " "	0.43 — 1.27 "
No. 44 " — with one layer of paper	0.65 — 2.16 "
No. 53 " — " " " " "	1.15 — 2.7 "
No. 53 " — with two layers of paper	1.33 — 3.50 "

results, always use the same pilot lamps. They should be turned in their sockets so that the plane of the filament is parallel with the top of the photocell.

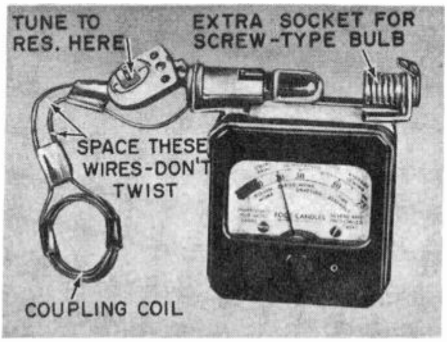


Fig. 1318. *Rf power output meter coil is coupled to transmitter plate inductance (remove antenna, push antenna coupling coil, if any, away). Coil and capacitor shown here must tune to output frequency. Cover is normally used over bulb to exclude light.*

Calibration

The output meter must be calibrated, and Fig. 1319 shows how this is done. A calibration made on dc is fairly accurate for use on

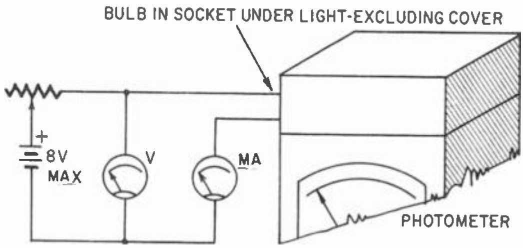


Fig. 1319. *Calibrating the rf power meter. The variable resistor depends upon bulb being used and input voltage; must have resistance enough to dim bulb considerably. V and ma meters also vary with bulb. Don't put higher than about 8 volts on 6-volt lamps.*

27 mc and still not too far out on 50 mc. Absolute accuracy is not needed in most cases, as it is a *comparison* that we want. The readings of the volmeter and milliammeter are multiplied to get the wattage figure, and a record of this made for whatever points you

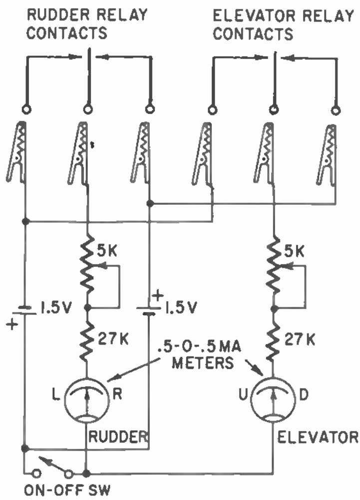


Fig. 1320. *Circuit of dual pulse tester. 5K resistors are used to set zero center meters at desired maximum scale reading. Resistor values would be different if meters of much different scale reading are employed. A single pulse tester is very useful, of course.*

wish to select on the meter scale. The bulbs should not be run at more than 8 volts. For very-low-power transmitters, you can run a calibration with No. 48 or 49 pilot lamps. To keep out external light, paint a small box dull black inside and always place it over the top of the meter and the bulb when the instrument is in use.

Pulse checker

For testing proportional pulsers and receivers, and even relays intended for this use, a means of checking the accuracy of pulsing is often needed. Suppose, for example, that you want a 50 – 50 on – off pulse for neutral; how can you be *sure* your pulser is producing exactly this? The ear is a rather poor judge, and an ohmmeter connected to the pulser isn't much better.

Most proportional work makes use of *both* contacts of a spdt relay, and a reliable check of operation requires that the pulse checker connect to both contacts too. Fig. 1320 shows one that does so. This circuit is actually a double unit and includes two complete pulse checkers, though both work from the same batteries. The pulse checker can be attached to the rudder and elevator relays of a dual proportional unit to check for interaction between the two. It is also sometimes helpful to connect one circuit to the pulser and the other to the receiver relay and to compare the two readings.

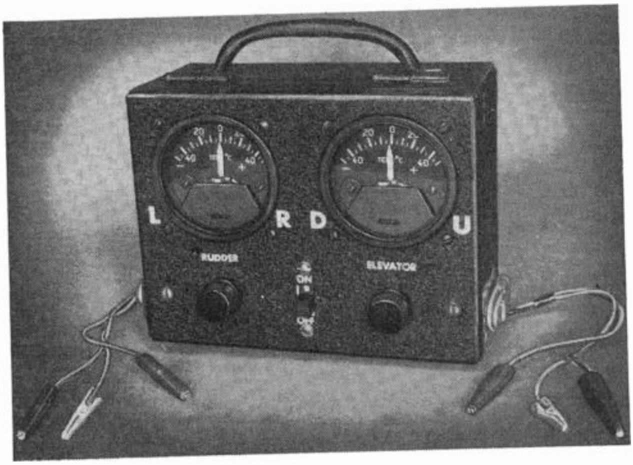


Fig. 1321. *This pulse tester used surplus meters, is mounted in surplus meter case. Actual scale reading is of no consequence, but it must be the same both sides of center.*

Meter type

Meters of any range can be used, but the lower-current-drain types make it possible to use the smallest batteries. The meters *must* be of the zero-center style, however. Fortunately, these are available at quite reasonable prices. The actual scale markings are of no consequence as long as they are the same on both sides of center.

The circuit shows a 5,000-ohm variable resistor for each meter, used to set maximum scale deflection as desired. The switch opens both meter circuits. A finished test meter using this circuit is shown in Fig. 1321. Flexible leads terminating in tiny spring clips make it easy to connect to relays or other units under test. Since the meter scales are fairly linear, it is simple to estimate at what position either side of center the needle must be in to indicate, say, a 25 – 75 pulse proportion or almost any other split. And, of course, a 50 – 50 pulse should move the meter needle evenly to both sides of center zero, regardless of pulse rate (at slower rates, the needle will swing farther to each side).

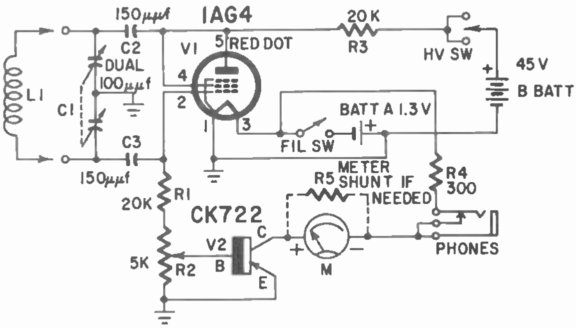


Fig. 1322. *Grid-dip oscillator used dual section 100 μμf midget tuning capacitor (C1) so that rotor could be grounded to eliminate hand capacity. Single section 50 μμf unit would be just as good, if used with insulated shaft; even this not really necessary, as fingers touch only edge of "dial". V2 gets power from tube A-battery.*

A grid-dip oscillator

One of the handiest instruments an electronic experimenter can possess is a grid-dip meter. Such units have been in wide use for years. Since radio-control equipment is strictly portable, it's a worth while project to make a fully portable dipper that is not tied to the power line.

The circuit is not complicated (Fig. 1322). The 1AG4 acts as an oscillator (non superregenerative) tuned by C1. Normally, a grid-dip oscillator has a sensitive meter in the grid-leak circuit, but due to the low power available we must work a bit differently. The grid circuit is connected to a transistor (V2) with the meter in the collector circuit. This makes it possible to get full-scale reading with only a tiny grid current. The reading can be set as desired by adjustment of R2. The A-cell provides power for the transistor and meter, the 45-volt B-battery being used only for the 1AG4. (Construction details for L1 are shown in Fig. 1323.)

How the grid-dip oscillator works

A grid-dipper works in a very simple way. If you bring coil L1 close to a circuit tuned to the same frequency, some power will be absorbed from the dipper and as a result the dipper's grid current will drop a bit. This change in grid current is a much more sensitive indication than the corresponding plate-current change. In the circuit shown, we make it even more sensitive with the help of a transistor amplifier. The dipper furnishes its own power and does

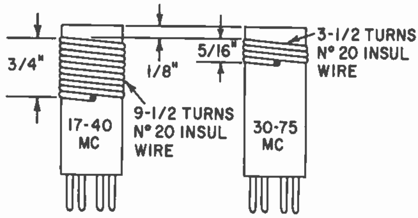


Fig. 1323. *Coils are wound on Amphenol #24-5H forms, held in #78-RS5T socket. Several socket pins are removed to reduce capacitance. Forms are polystyrene. Socket is mica-filled phenolic.*

not require that the coil you are checking be in a "live" circuit. In fact, you can test a tuned circuit that doesn't even have a tube – or just a coil all by itself if you wish! This means that you can check rf chokes for resonant frequency – an important point in many receivers.

The dipper is actually a miniature transmitter (Fig. 1324) and can be used to send signals to receivers for close-range testing. If you want a little more power output, attach a short antenna as in Fig. 1325-a. The tuned circuit you want to test may possibly be located in a rather inaccessible spot, as far as reaching it with dipper coil L1 goes. In this case, you can use a link, as in Fig. 1325-b. Crystals can be checked for frequency (Fig. 1325-c) but the indication will be *extremely* sharp, so tune slowly and carefully.

All parts are mounted in an aluminum case measuring 5¼ x 3 x 2⅛ inches. For most convenient use, the coil socket is mounted on one end of this case and tuning capacitor C1 as close as possible to it. The tube socket plus C2, C3, R1 and R3 are attached to a small bakelite plate that mounts right on the bottom of C1; thus, all rf "hot" components are kept in a compact group and isolated from other parts. The latter are mounted strictly for convenience, though the A-cell holder is attached to the case right under the coil socket. It will carry a single penlight cell, but the longer-life hearing-aid type should be used. For even better life, a Mallory RM502R mercury cell can be put in the same holder.

The tuning capacitor has two 100-μμf sections. A single section 50-μμf capacitor will work as well, especially with an insulated shaft coupling to reduce hand-capacitance as much as possible. The dial is a disc of white cardboard cemented to the top of the case, while the "knob" is a disc of 1/8-inch-thick clear acetate sheet attached to the stub capacitor shaft with a small screw. This setup makes it very easy to hold the dipper in one hand and tune with the thumb of the same hand. A more conventional knob and dial or a smaller vernier dial would work fine, of course.

The switch in the tube plate circuit has a center-off position; the lever will stay on if pushed one way, while the other way it springs back to off. This makes a handy "key" when testing receivers. With the high-voltage switch off but the filament turned on, the dipper can be used as a field-strength meter by turning R2 to maximum resistance and noting the meter reading as the instrument is tuned near a transmitter antenna. If a pair of magnetic phones are plugged into the jack, the presence of audio modulation can be checked, again with R2 at maximum.

So far, only two coils have been made covering the 27- and 50-mc bands plus a wide range on both sides. The biggest problem

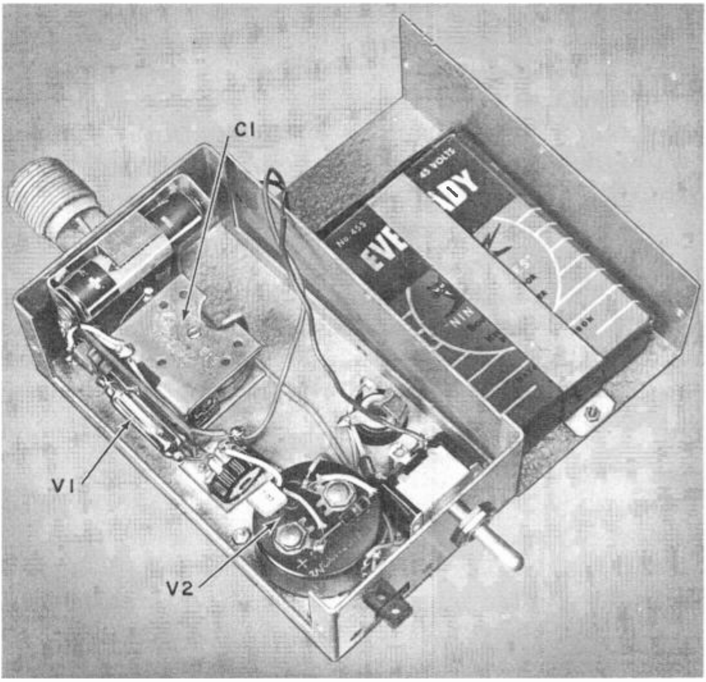


Fig. 1324. *Inside the grid-dip oscillator. C1 is fastened to the case. Plate with tube socket and small parts are attached to C1. R2 is CRL subminiature, held on bracket so edge of knob is outside case top. Case, Premier PMC-1006 or equivalent; 5¼ x 3 x 2⅛".*

with a unit like this is calibration. The job can be done using an rf generator, or any other source of variable-frequency rf. Actually, while it is handy to have, a full calibration is not really too essential. For radio-control purposes, what you want to know is

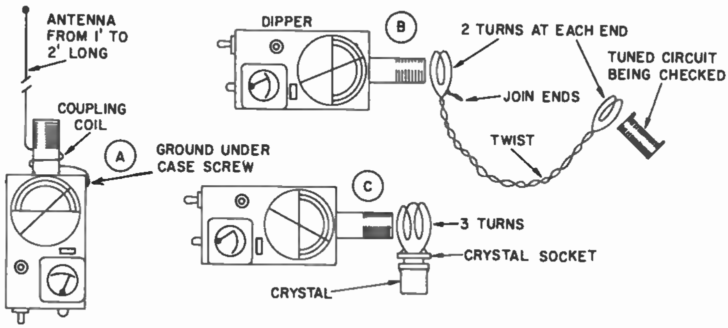


Fig. 1325. *Antenna can be used for added pickup (or greater rf output for receiver testing) with coupling coil as at a. Link may be utilized for coupling to inaccessible coil as in b. Very close coupling (c) may be needed with some crystals (note that this will make calibration inaccurate).*

how far you are *above or below* the desired radio control spot. These spots can be calibrated by radio control transmitters fitted with the desired crystals. The circuit will oscillate to perhaps 100 mc; for operation higher than this, a redesign of the tuned circuit would be needed, and perhaps the use of a tube better fitted for such frequencies. You can go much lower, of course, and coils all the way down into the broadcast band could be made and calibrated.

Because of the transistor amplifier, the meter does not have to be especially sensitive. The one shown is a 500-μa unit, and it was shunted by R5 to bring the full-scale range up to about 1.5 ma. Most any kind of p-n-p transistor will do, as a great amount of gain is not required.

Propeller balancer

While not an *electronic* test instrument as the others are in this chapter, the propeller balancer is something all radio-control model-plane builders should have. Many model-plane "props" are quite well balanced but some are far off. An unbalanced prop is one of the most likely causes of excessive vibration on a powered model. Because they provide longer life, nylon props are used on many glow-plug engines. Here again, some of the commercial props are rather badly out of balance and, with the relatively heavy nylon props, you can *really* have a vibration problem.

Prop balancing techniques

The classic way to balance props has been to run a shaft through the hole and set the shaft on two upturned razor blades. This works fine but be extremely careful. The blades quickly become dulled and they have to be absolutely level to do a good job.

The balancer sketched in Fig. 1326 is simple to make and easy to use. It consists of two upright posts set firmly in a hardwood base, with center-punch marks made on the two filed-flat upper ends. The prop slides on a cross-rod tapered to a fine point at each end, and is just long enough to fit into the punch marks *without any binding.* A separate cross-rod is required for each prop hole size (or you can cut "steps" in a ¼-inch rod to take the smaller props). About the only place where fair accuracy is required is in making the pointed tips on the rods. The side posts will spring out far enough for you to slip the cross-rods into the punch marks.

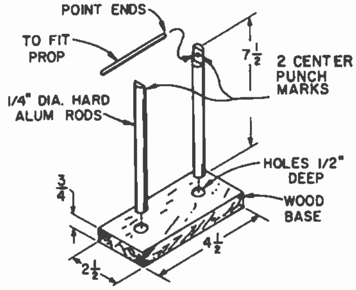


Fig. 1326. *This prop balancer is simple unit that works very well. Prop shafts should have slight end play in punch marks to make sure there is no binding. Aluminum welding rod will do for metal parts.*

This type of balancer has been found highly sensitive, enough so that it is an easy matter to balance nylon props as small as 4½ inches in diameter. It is not necessary to level the balancer to use it either. Hard aluminum for the side supports and hardened steel for the cross-rods would probably be desirable, but very satisfactory results have been obtained from such a balancer with all parts made from aluminum welding rod. The rods were pointed by spinning them in a lathe and holding various grades of files against the ends, finishing with very fine emery paper, then crocus cloth.

Conelrad monitor

While it is not exactly test equipment, FCC regulations now require that a Conelrad monitor receiver be in operation at all times where radio-control transmitters are in use. This provision is easily met by carrying any sort of portable broadcast receiver to the flying site, and leaving it on during radio control transmissions.

Conelrad spot frequencies

The Conelrad spot frequencies are 640 and 1240 kc but actually, if you listen to *any* broadcast station, you will be doing the job, since all such stations will immediately go off the air in the event of a national emergency that brings the Conelrad frequencies into use. Thus, as long as you can hear a broadcast station on your monitor on any other frequency than 640 and 1240 kc, you can feel assured it is all right to continue your transmissions. The tiny pocket all-transistor receivers are used by many radio-control groups for such monitoring.

chapter FOURTEEN

complete control systems

WE have covered all sorts of individual radio-control components, receivers, escapements, pulsers and so on, in previous chapters. But what about complete control systems? Several complete radio-control models might offer enough ideas to make their inclusion here worth while. Since most of the equipment we have detailed was slanted toward model aircraft, and we have already given complete data for a simple model-plane control system, let's see first what can be done with boats and vehicles.

Many radio-control experimenters are turning to boats as a most valuable test bed for radio-control equipment that might eventually be installed in a plane; boats do not "fly away" nor do they suffer disastrous vertical-dive crackups, as do planes with malfunctioning radio equipment. Thus, they offer the beginner as well as the more advanced hobbyist an invaluable means for learning how to handle equipment, make tests and adjustments, and yet not lose valuable apparatus if things go wrong.

Radio-controlled boat

A very elementary boat installation is illustrated in Fig. 1401. For simplicity and cleanliness, the boat is electrically propelled, the motor being an extremely economical type; the current drain is low enough so that the eight penlight cells connected in series-parallel, to give 6 volts, will afford reasonable life. If longer life is wanted, you can install cells made for hearing aid use. These cost a little more, but give improved service.

The boat is made from a kit, and is about 19 inches long. The equipment it carries weighs it down to a bit more than scale depth, and any heavier apparatus would make it sink still lower, destroying the scale illusion and making it harder to drive. For small boats of this sort, where the drive power is a real problem, an ideal solution is the use of ultra-light rechargeable storage cells, the lightest available being the Silvercels. Four such cells in the nominal 0.5 ampere-hour size would drive this boat for at least a half a dozen hours, and weigh lots less than flashlight cells. The first cost, of course, would be rather high, though.

The receiver

The receiver is the same one described in Chapter 4 (Fig. 413). The eight penlight cells that run the drive motor and the rudder

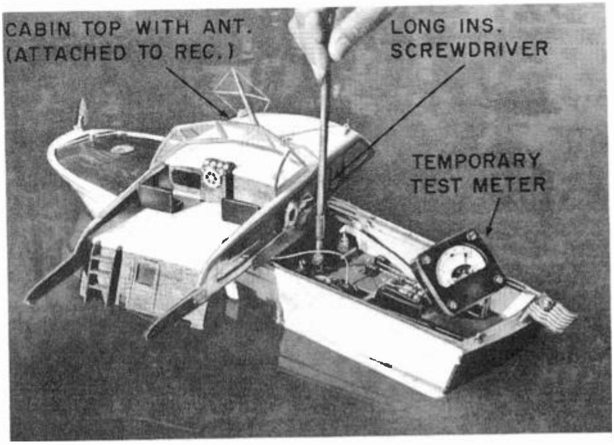


Fig. 1401. *Very simple control system was used in this Sterling B-3 model Chris-Craft cruiser. Single hard tube receiver being tuned here; antenna must be attached when this is done. Meter leads end in phono plug which fits closed circuit jack in model.*

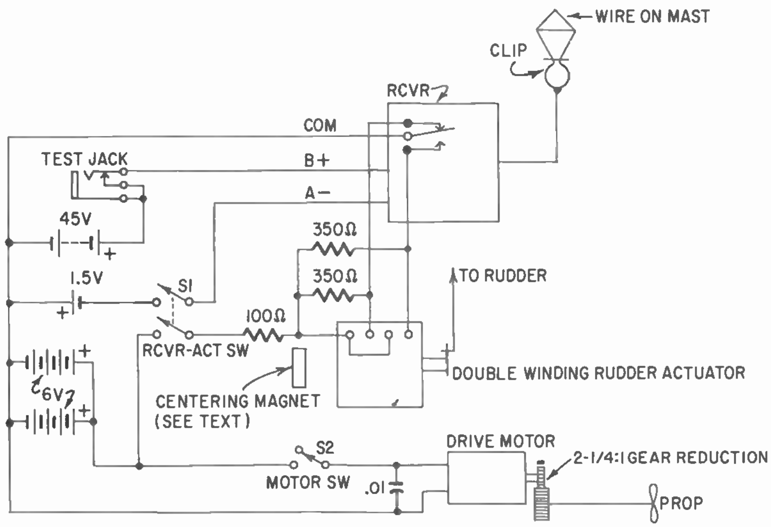
actuator are carried in two plastic holders, while the A- and B-batteries for the receiver go in aluminum holders that are attached to a strip of plywood and held down just in front of the motor. The receiver is held on sponge rubber with a rubber band over the top of it. Rubber mounting is not used because of vibration when the boat is in action, but rather to give a bit of protection when the craft is being transported to and from the pond.

There are only two control switches: one turns on the receiver and the actuator; the other controls the motor. These are S1 and S2 in Fig. 1402. A closed-circuit phono jack (marked test jack in the diagram, Fig. 1402) is provided for checking the receiver plate current.

For short-range work, it is sufficient to connect the antenna lead from the receiver right to the wire rigging on the stubby mast.

Longer range can be had if a vertical wire of 15 inches or so is installed.

The control system is what we have called "semi-proportional"; that is, the signal from the transmitter is pulsed continuously to give neutral for centering the rudder. To get left or right turns, the signal is cut off completely or sent out continuously. If a true



List of parts for radio-control boat

1 — Mini-Mac single hard-tube receiver; 1 — Southwestern R/C proportional actuator; 1— dpst slide switch; 1 — spst slide switch; 1 — Aristo-Rev #1 drive motor; 1 — Sterling nylon 1" dia. propeller; 1 — closed-circuit meter jack; 2 — Hillcrest 4-cell battery cases; 9 — Eveready 1015E hearing-aid style pencells; 2 — Eveready 412 22.5-volt batteries; 1 — Acme holder for B-batteries; 1 — Acme holder for A-batteries; 1 — 100-ohm resistor; 2 — 350-ohm resistors (all resistors, ½ watt); 1 — .01-μf ceramic capacitor.

Fig. 1402. *Though penlight cells (pencells) were used in original boat, rechargeable cells would be much more practical for drive and actuator power, and would reduce over-all weight. An all-transistor receiver to work on the same cells would further reduce weight, allow model to float higher in water.*

proportional pulser is used at the transmitter, the boat rudder can be operated proportionally, turning only as far from center as you wish. However, the control system shown is very fast and, if wide turns are desired, the steering level is just flipped on and off in the desired direction, the boat then making a fairly smooth wide turn.

The rudder is operated by an economical commercial make of actuator, but it was found possible to cut down the current drain still further with a 100-ohm series resistor. This is shown in the wiring diagram of the complete boat system, Fig. 1402. A tiny bar type permanent magnet is held to the deck of the boat near the actuator with adhesive tape; it serves to provide a definite neutral position for the rudder when the current is turned off. The particular style of actuator used doesn't have any centering action and, without this magnet, steering is a bit erratic. The rudder is of the balanced type; that is, about 25% of its area is

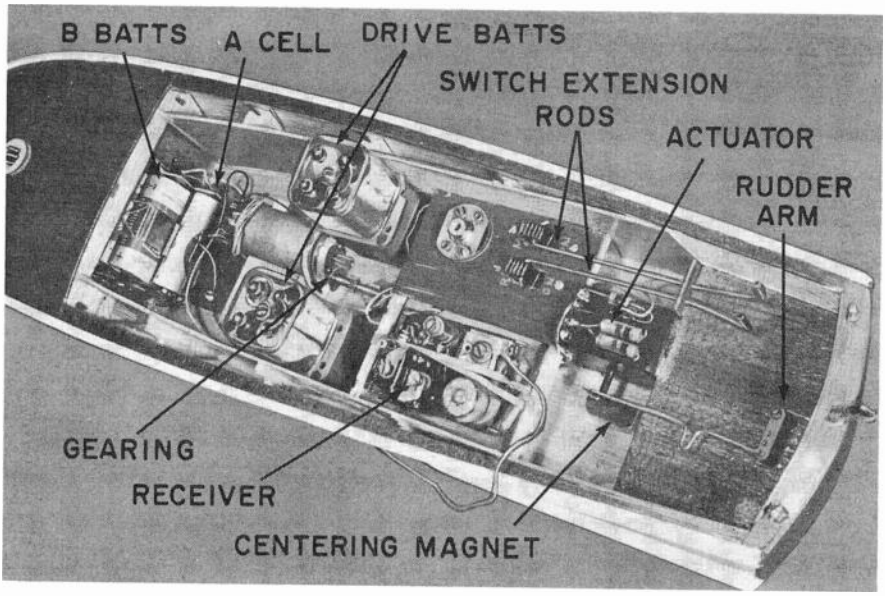


Fig. 1403. *Hull is pretty crowded with "machinery". The switches have wire extensions, allowing them to be operated without removing boat cabin. Batteries can be placed so that boat balances correctly on water.*

in front of the pivot line. Note carefully the *arc suppressors* across the actuator windings in Fig. 1402. They are merely 350-ohm ½-watt carbon resistors and have about 10 times the resistance of the actuator windings. They keep the relay contacts from sticking by greatly reducing the arc formed as the contacts open.

The boat does not travel at a high rate of speed, but at that it probably goes at more than scale speed. It can be guided in and around buoys and obstacles in its path with real precision, and the only thing missing is means to start and stop the motor by radio. Such equipment could easily be added, but this was intended to be an ultra simple job, so we have stuck to just steering. The transmitter normally used with it is the same one described later in this chapter for operation of the radio-control tractor, and will not be covered now. Even though the transmitter works at very low power, it will control the boat up to a hundred feet or so, and with careful tuning, lots more range can be had.

Tuning the receiver

To start, tune the receiver with the boat in the water. The cabin comes off for access to the equipment. When the set is being adjusted, the cabin top is set crosswise on the hull sides, so that the antenna is in about the same position it normally occupies, and a very small test meter is plugged into the test jack. The sensitivity adjustment of the receiver is set first, then the tuning can be touched up, with the transmitter on, and at least 100 feet away. The receiver can't be used in its most sensitive condition, due to interference created by the brushes on the motor commutator. The .01-μf capacitor across the brushes (Fig. 1402) helps

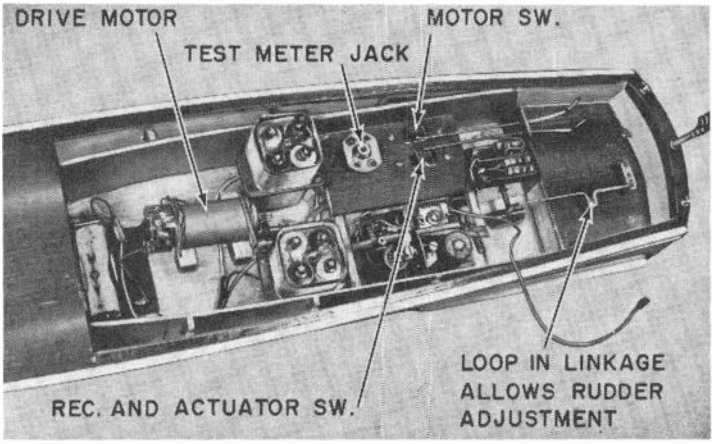


Fig. 1404. *Most wiring in the boat terminates under the panel carrying the two switches and the meter jack. A few sockets and plugs (for receiver, as an example) would make service work easier.*

reduce this. It probably would be even better to put a small metal can over the brush end of the motor, and ground this and the motor metal frame to B-minus. Interior views of the boat installation are shown in Fig. 1404.

Radio-controlled car

If you wish to conduct your radio-control experiments on dry land (and not above it), the little car shown in Fig. 1405 may give you some pleasure. Though the mechanism of the car itself is rather complex – at least if it is compared to the boat we have just described — the transmitter can be any at all, since just a plain pushbutton is needed, there being no pulsing requirements. The car was originally fitted with a box truck body, painted and lettered to represent a TV truck (Fig. 1406.) This body was made

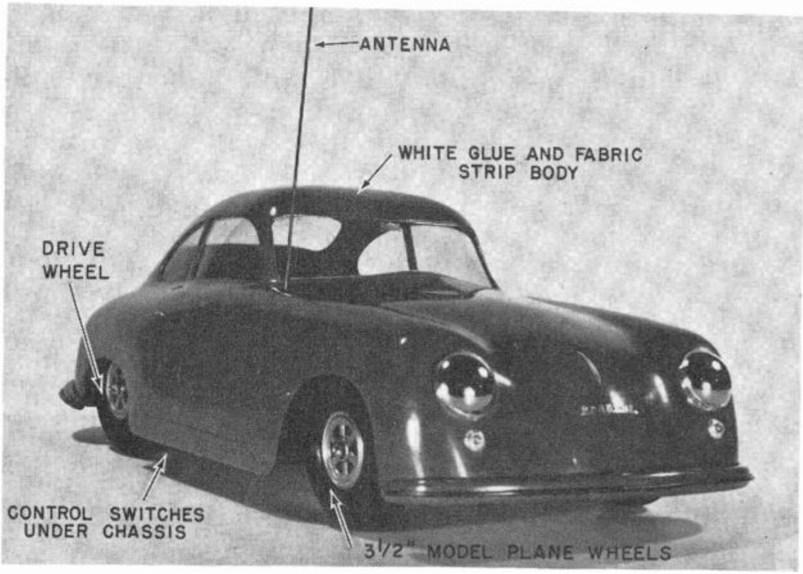


Fig. 1405. *White glue and fabric body is very tough and strong, but was very difficult to smooth down. Fiberglass cloth and resin might be better materials to use. Finished model did look very realistic, however.*

out of sheet balsa and was a good quicky to cover up the works on the chassis. To dress the project up more, a scale Porsche sports-car body was built (the chassis having been designed to accommodate this at the start). The Porsche body was built over a clay form by laying on strips of fabric soaked with white glue. After this was built up to the desired thickness, it was allowed to dry thoroughly, then removed from the form, and finished off with much sanding, followed by sealer and colored dope.

The chassis is a piece of 3/8-inch plywood, which makes an ideal base upon which to mount all the parts. Details of the running gear are shown in Figs. 1407 and 1408. The motor drives one rear wheel by friction, the rubber-tubing diameter being chosen to give the car the speed desired (better start off with small-diameter tubing, until you have mastered the trick of steering!). The motor is hinged from two brackets so that most of its weight is on the drive shaft; a piece of sponge rubber at the free end regulates the actual friction on the wheel.

The steering mechanism, shown in Figs. 1409 and 1410, is patterned after that found in large cars. Each wheel is held on a pivoted stub axle, and the two are linked together in such a manner that they track quite well whether going straight or turn-

Fig. 1406. *Quicky body for chassis in Fig. 1407 was just a balsa box, painted to represent TV mobile unit. Artistic finishing job made it look like the real thing. 1/8" thick sheet balsa used throughout.*

ing at any radius. The entire front-wheel assembly is moved from side to side by a geared-down electric motor. The motor may be stopped at any position, to allow the car to make constant large- or small-radius turns. Since the steering is too fast if the full 6 volts is put on the motor, an adjustable 10-ohm wirewound resistor is provided to slow it somewhat. This is shown in the top-view chassis layout, Fig. 1411. Limit switches are positioned so that they will open and cut off the current to the steering motor if a steering signal is held too long; however, the opposite steering signal will immediately start the wheels back toward center. You have to learn to anticipate a bit, since the motor coasts somewhat after the turn signal is stopped. After a good amount of practice, though, you can pilot your car almost as well as you might be able to drive a full-sized one.

The steering motor is of the PM type, and gets its power through a reversing switch operated by an ordinary two-position self-neutralizing escapement. The double-pole double-throw switch contacts are moved by a cam (Fig. 1412) fastened to the escapement shaft. The cam is sort of an egg-shape, so that in the two neutral escapement positions, the contacts are in mid-position and open. One *operate* position then drives the steering motor one way, the other moves it the opposite way. Since the escapement is a sequence device, you have to learn an entirely new

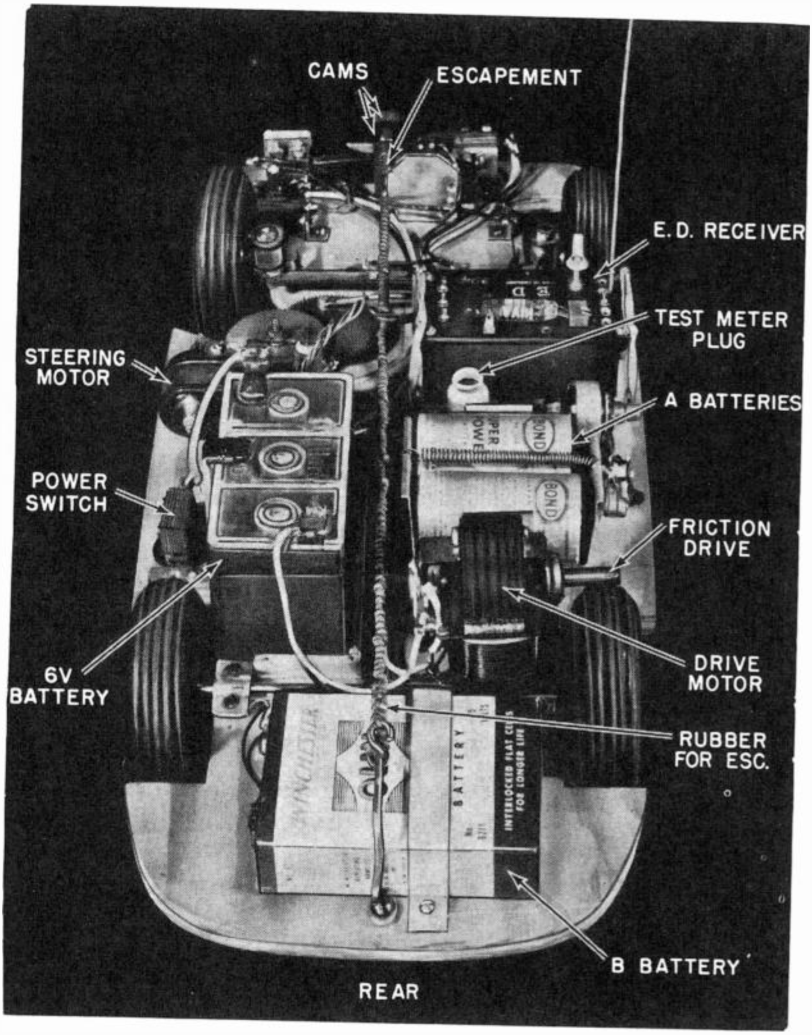


Fig. 1407. *NT-6 surplus battery powered the drive motor; Aristo #64 battery would do a better job, is same size. Note escapement rubber running full length of chassis. Drive was by heavy duty 6 volt PM motor. Boat drive motors are ideal for this purpose.*

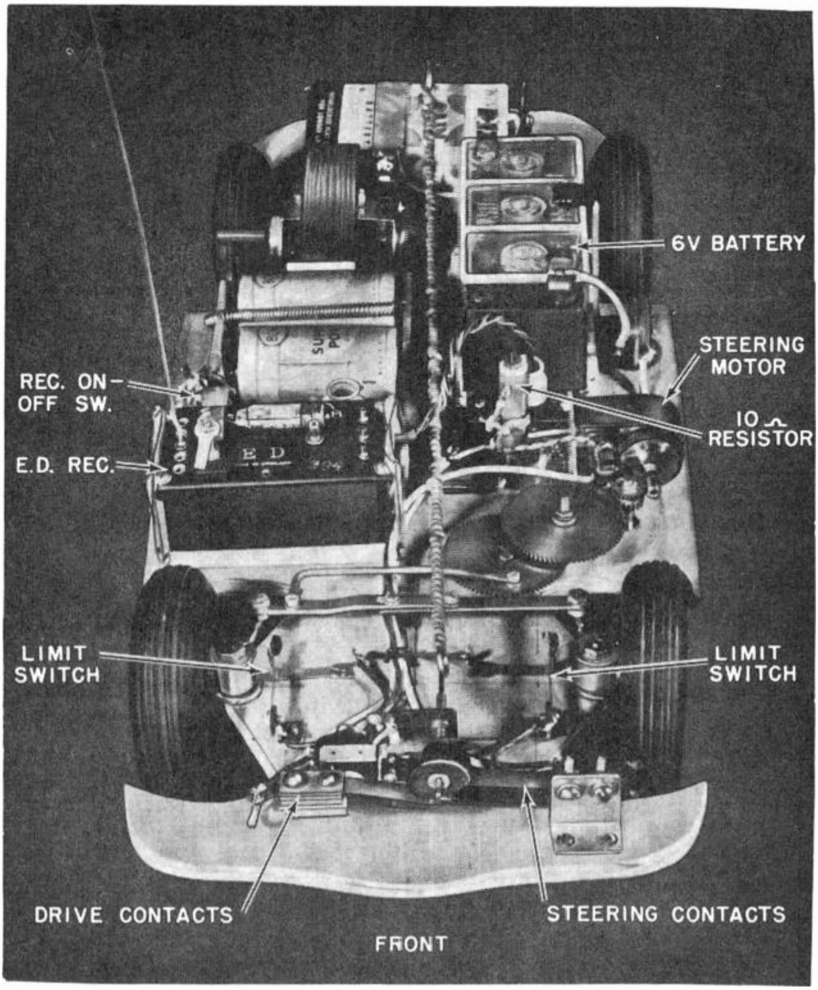


Fig. 1408. *Steering linkage, motor and reduction gearing seen here. Motor is a Wilson 3 volt unit; HO model train gears give initial reduction. ED receiver probably not now available; a tone receiver would be best substitute.*

manner of driving — you can't do it as you drive your own car!

The escapement also controls the driving motor through another cam which opens the circuit in one of the two neutral positions; the drive motor thus functions in the other neutral, and in both turn positions.

The entire radio installation in the car is a commercial job that came all wired and ready to use. It was put in just this way, with no changes whatever, except to add the cams to the escapement shaft. The receiver is held on a piece of sponge rubber by elastic bands; the two sockets (one for the test meter and one for the cable from the receiver) were raised above the chassis top by brass spacers and round-head wood screws. A small bracket holds the variable resistor, and the on – off switch goes through a

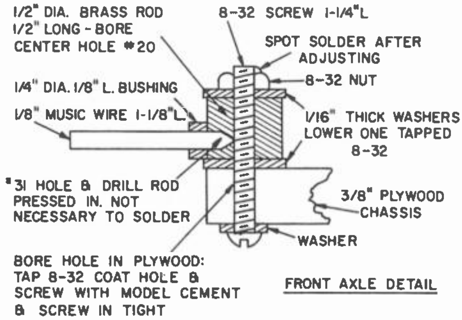


Fig. 1409. *Careful work on the steering assembly makes for smooth operation on the road! Tighten 8-32 nuts so steering "knuckles" turn with no bind, no wobble.*

hole in the chassis, with the knob under the edge of the chassis.

This equipment can be used with either a hard-tube or gas-tube receiver; we chose the latter, since gas-tubers are generally more tolerant to *electrical noise* made by opening and closing contacts, motor commutators and the like than are hard-tube receivers.

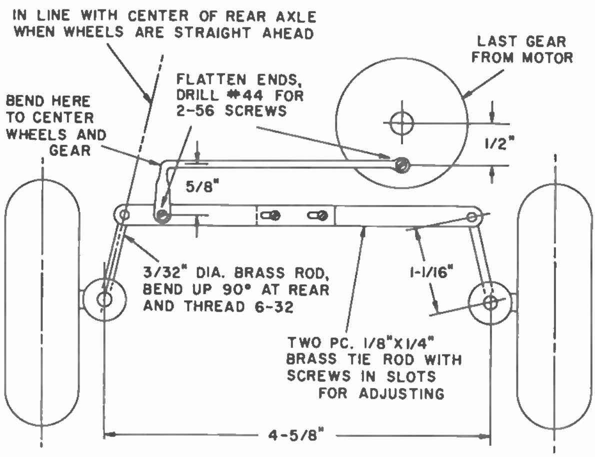


Fig. 1410. *Two-piece tie rod allows proper angular adjustment of the two front wheels so they will follow the necessary different radius curves on all turns.*

The receiver was unaffected by any of the contacts, and neither motor, rf filters or noise suppressors of any kind were needed. The chassis wiring diagram is shown in Fig. 1413.

The antenna is a 1-foot length of music wire attached to the

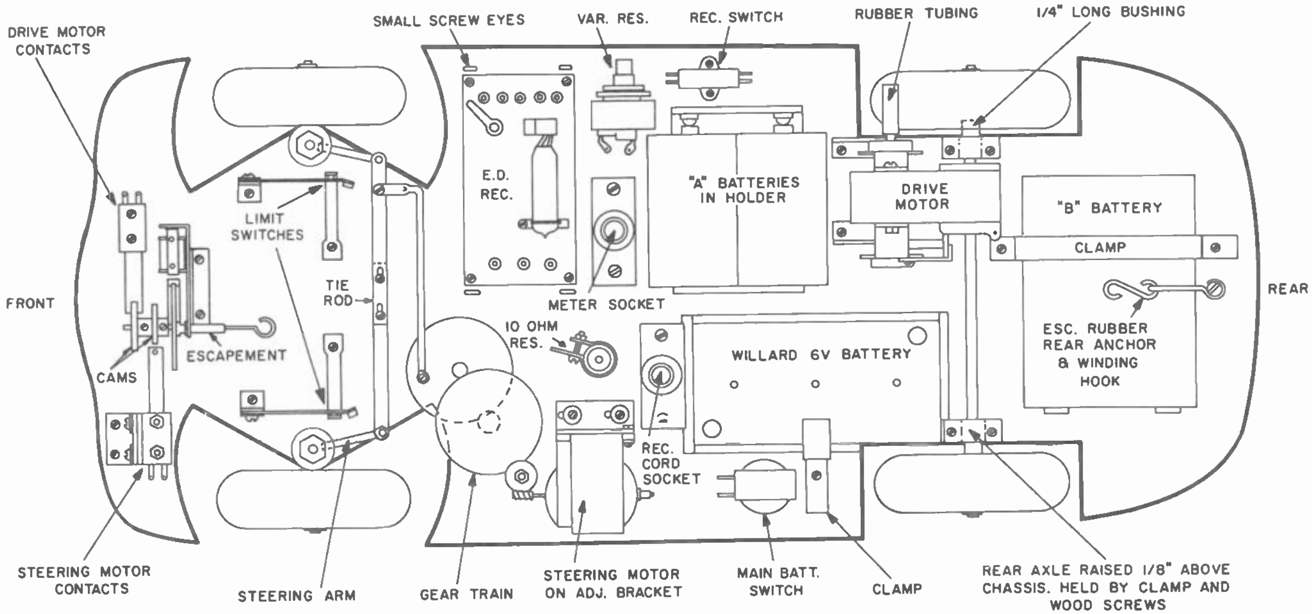


Fig. 1411. *Escapement controls both drive and steering motors. Though they were not available when this car was built, much simpler control of car could be had through use of such specialized units as Babcock Electric Compound servo or Cobb Hobby type BC servo. Both of these would give direct steering from built-in motor and gear train, and have contacts to control forward-off-reverse action of drive motor.*

body. The receiver has a variable antenna loading system that makes it possible to provide proper loading by shifting a tiny plug to any of five sockets.

In view of the initial difficulty in learning to operate the car, it might be worth while to install a compound escapement; then you would always have, say, left with one pulse and right with two. The third position on the compound escapement could be wired to a second escapement to control the drive motor. If this second escapement were fitted with dpdt contacts as is the one for the steering motor, you would be able to run the car forward or

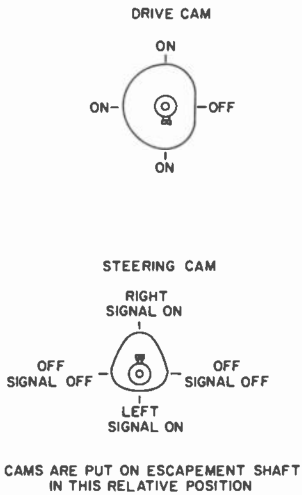


Fig. 1412. *These cams are for use with a 2-arm or self-neutralizing escapement, as used on original car. Different shaped cams would be required for other styles of escapements; a compound type would make for easier control, since it is not a sequence-operation unit.*

back and stop it at will. You could also use one of the neutrals of the second escapement to cut in a resistor, for slow-speed operation!

Any CW transmitter of the proper frequency and a plain push-button will be usable with this car. However, "driving" it would be a lot easier if the transmitter were fitted with a beep box to send the desired pulses automatically.

There is plenty of room on the car chassis for a good-sized B-battery. The A-supply is two large flashlight cells in parallel. The fairly high current drain of the drive motor is handled by an NT6 6-volt storage battery, which also runs the escapement and the steering motor. There is only a single switch for all these, since, if the escapement is stopped in the correct position, the drive and steering motors will be off when the receiver is turned on. Then, the first pulse you send starts things going.

The storage battery, available from most radio-control suppliers, must be charged at a rather low rate to prevent damage. Don't hook it up to a regular car-battery charger unless you use a series resistor to limit the current to about 500 ma. A diagram for a charger using an ordinary 7.5-volt filament transformer is shown in Fig. 1414.

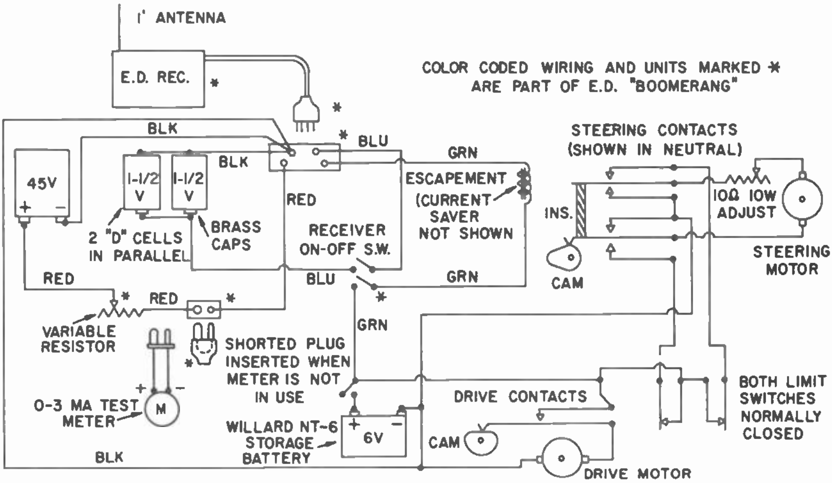


Fig. 1413. *Wiring is quite straightforward, can easily be modified to use other receivers, control units, etc. If latter are of type suggested under Fig. 1411, separate limit switches will not be required, as they are built in.*

Radio-controlled tractor

Another radio-controlled vehicle is shown in Fig. 1415. It is a caterpillar tractor, built up from a heavy-duty toy carried in most

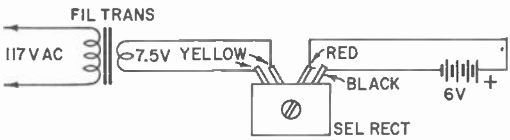


Fig. 1414. *NT-6 or Aristo #64 storage batteries may be charged with this setup. Rectifier can be International Rectifier Corp. type C1B. Charging rate should be no higher than ½ ampere.*

large toy stores. This is a rather ambitious project, if only because the tractor is rather small and everything has to be crammed in. The tractor can be made to start, stop, go forward or reverse, and can be steered in either direction instantly and without any sort of sequence — a lot of control to be crammed into such a small package and handled over a single radio channel.

Here again, commercial equipment was utilized. And for the same reason as in the radio-control car, a gas-tube receiver was fitted because it just isn't bothered by all those snapping relays and sparking motors. Just as insurance, a 100-μμf ceramic capacitor was connected across each motor (but they may not be really necessary).

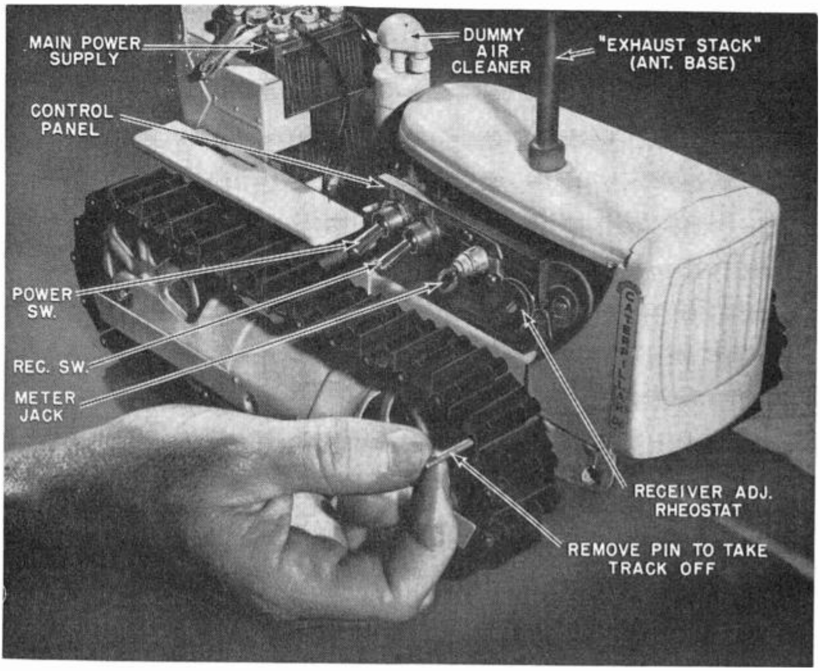


Fig. 1415. *Miniature caterpillar tractor steers just like the real thing. Made from a non-powered toy, considerable revision of wheels is required. Note set of Silvercels strapped in seat. "Track" is removed by pulling out special pin, as shown. Receiver and its batteries go under hood.*

A kit-type receiver was utilized, seen at the lower right in Fig. 1416. It had an XFG-1 tube, Kurman sensitive relay and a circuit quite like that in Fig. 403. A more up-to-date circuit might be employed by anyone duplicating this project; for example, the Gazistor receiver (Fig. 406) would be a good choice and could be fitted into the available space.

Unlike the car, steering a unit of this sort is somewhat of a problem, unless you want to do it as they do in the big Cats, by stopping one tread or the other. That's just what we do, and the little tractor slews around on the stopped tread in a most realistic fashion. It is lots of fun to run and, since you have full steering control whether it is going forward or back, it can be maneuvered into unbelievably tight places.

As purchased, the tractor had no drive mechanism, and the first task was to install the motive power. The front wheels turn freely, while each motor drives one rear wheel. See Fig. 1417. Tractors are supposed to move slowly, so we geared the drive about 800 to 1. A worm gear from an HO locomotive goes on the motor shaft, while the matching worm gear is attached to a small pinion. The worm and its gear have a 30 to 1 ratio, the next pair of gears are $4\frac{1}{2}$ to 1, while the final set are 6 to 1. Any combination that will give the desired overall 800 to 1 reduction will do.

It is necessary to fit better axles for the wheels, and small rollers

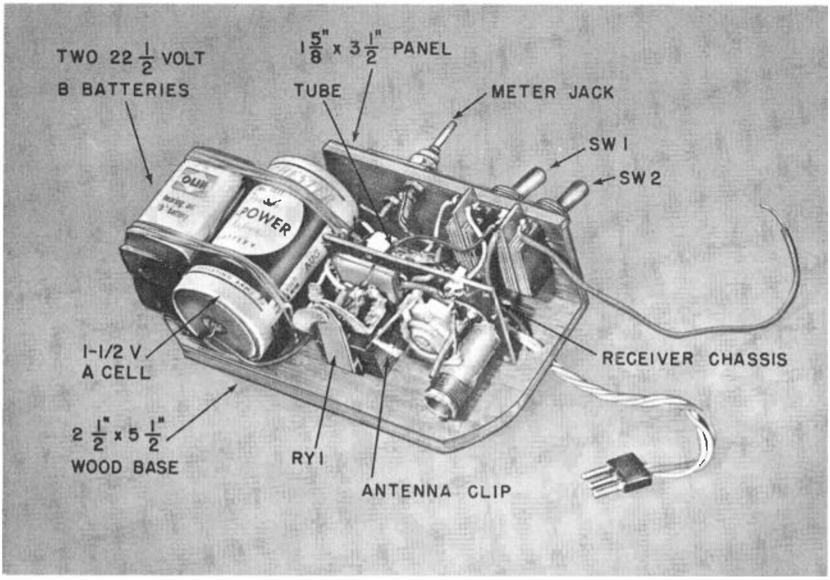


Fig. 1416. *Receiver is gas tube Super-Aerotrol, shown here on its mount, together with A- and B-supply. A tone receiver would be a good substitute; single hard-tubers and noise-operated CW receivers not so good for this sort of application, due to their sensitivity to "electrical noise".*

were installed in the bottom of each track frame, so the tractor can climb over books and other objects placed in its path without stalling. The two rear wheels have plywood centers added; these were split in half and forced in between the wheel sides, with a generous application of model cement. When dry, the wheels were chucked in a lathe, and the wood centers trued up and grooved to fit the rubber tires. The latter were attached with heavy-duty rubber cement and, after installation, the outer surfaces were

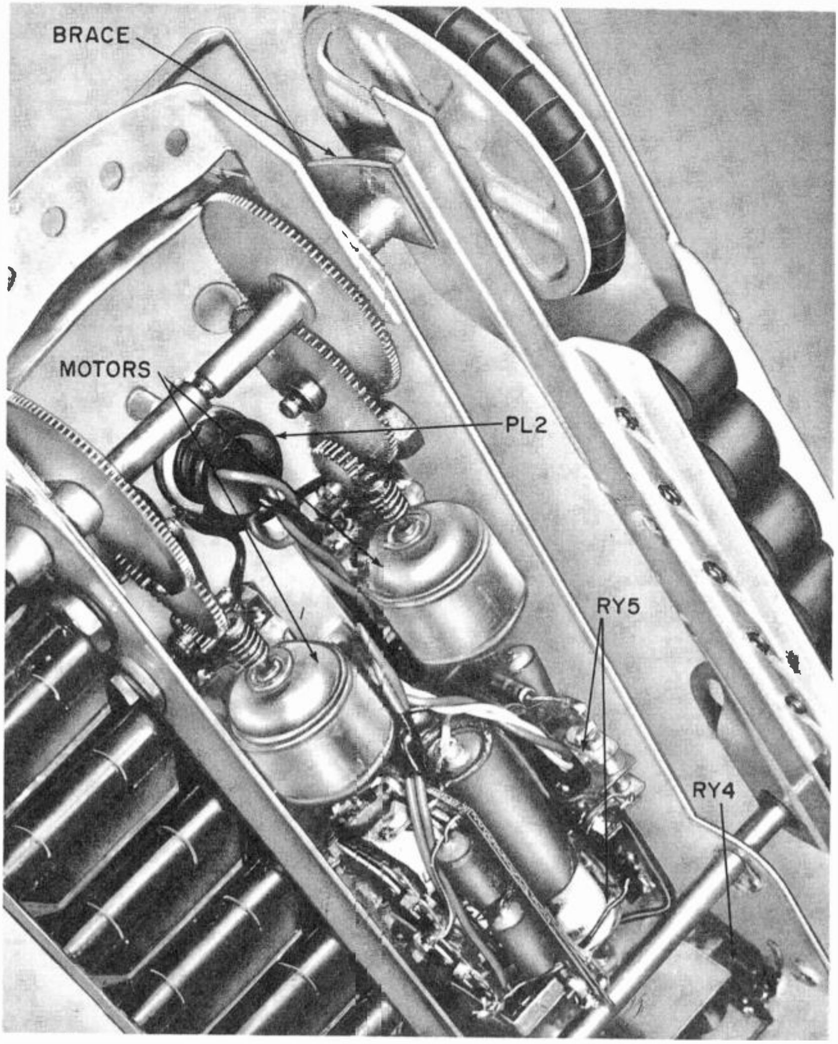


Fig. 1417. *Dual drive motors are Wilson units, with HO train worms press-fitted to shafts. Plastic rollers seen at upper right were added so that tractor could crawl over books and other obstacles. SO2 is fastened to frame, to rear of motors; PL2 from control chassis plugs into it.*

cut crosswise with a high-speed hand grinder. All this work on the rear wheels is for the purpose of assuring a good grip on the inside of the articulated plastic treads. If the wheels are found to slip in use, the front axle should be moved forward a bit more, to tighten the treads on the rear-wheel tires.

Tractor motors

The motors were found to be somewhat of a problem, since it is necessary to pick two that run at about the same speed. It is possible to insert a small resistance in series with one motor, if it is found to run faster than the other, but too much resistance will make the motor sluggish in starting. The holes in the HO model

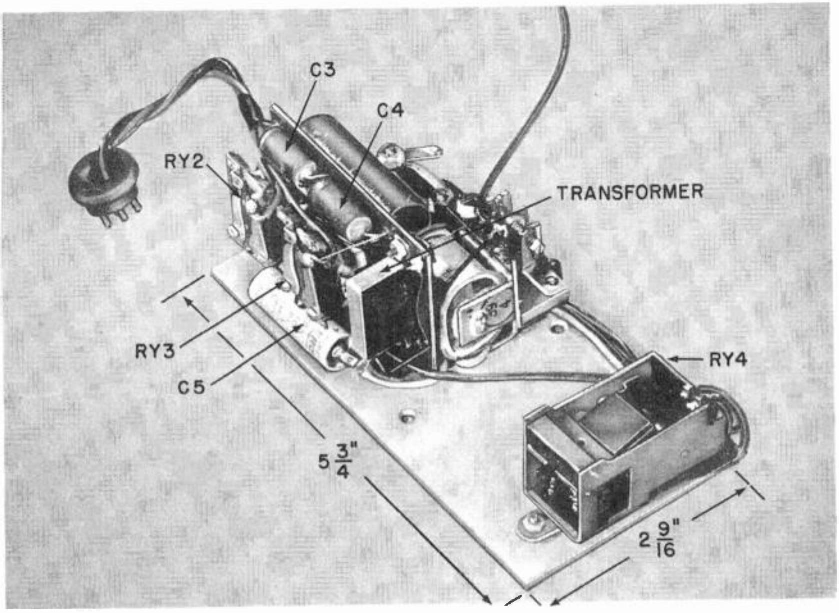


Fig. 1418. *Control chassis has large space between RY4 and other parts for two reasons. Front axle must go across here; also, magnetic field from RY4 disturbs RY5 if they are too close.*

train worms are a bit too small to slide on the motor shafts. Each motor was run on 3 volts, and a very fine file held so as to taper the outer end of the shaft slightly. Then the worm was slid on and given a slight tap to seat it firmly. Screws (2-56) hold the motors to the chassis and allow a bit of movement, so the gears can be meshed properly. In addition, the chassis side holes through which the axles of the intermediate gears pass are made somewhat oversize, again to allow adjustment. There should be a slight amount of play between the teeth of all gears, when final adjustments are finished, and the tracks must turn without any binding whatever.

The space beneath the hood which was occupied by a plastic copy of a diesel motor when we got the tractor is filled by the receiver and its batteries, as shown in Fig. 1417. In addition, there is an instrument panel holding two switches, a rheostat and a meter jack. The panel and base are cigar-box wood, and the batteries are held by rubber bands. The receiver is mounted with the phenolic base vertical, so that it can be tuned up when in the

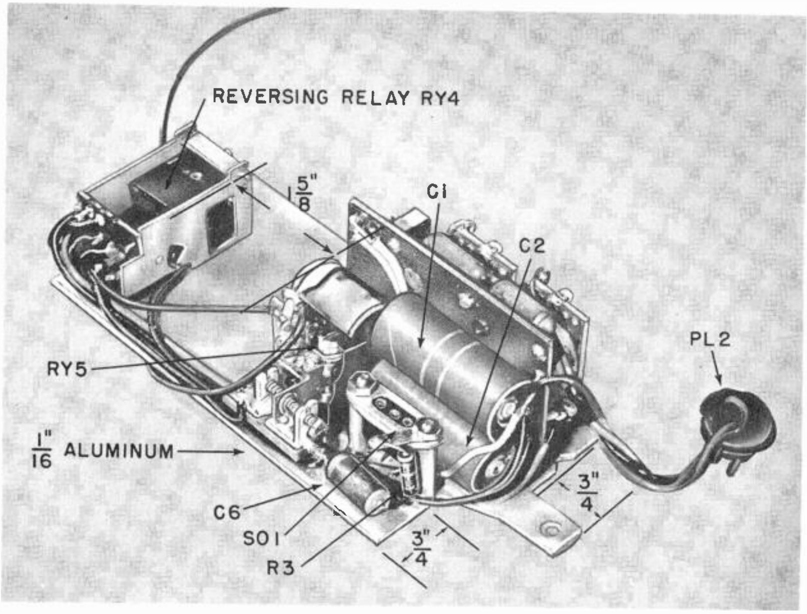
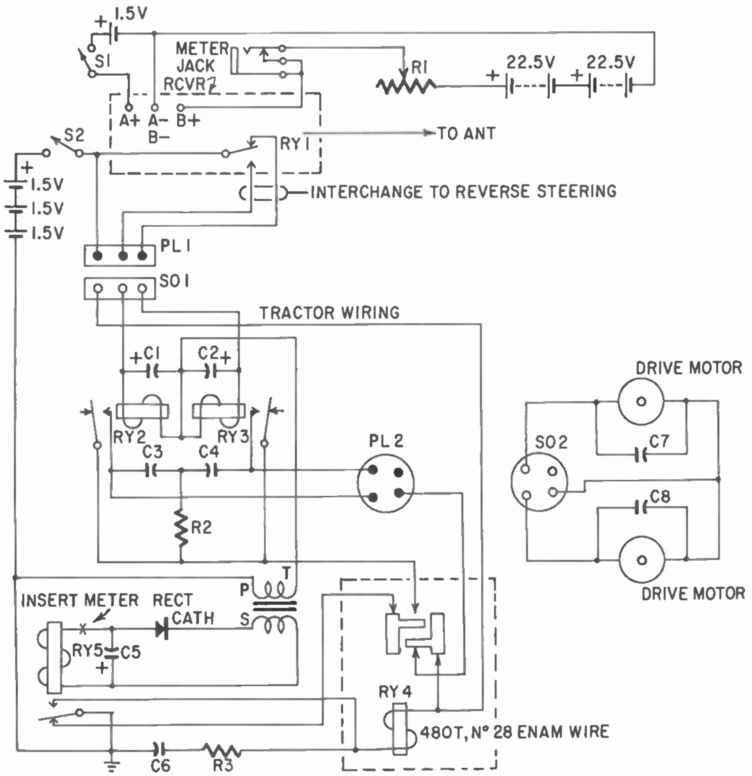


Fig. 1419. *Many of the small parts are attached to the vertical phenolic plate, which, in turn, is attached to aluminum control chassis. Socket for receiver plug is in foreground. Sigma 5F probably a better choice for RY5, though the 4F shown worked well.*

tractor. It takes a bit of juggling to get the receiver unit in and out when the batteries are in it, but it can be done once the trick is learned.

The antenna is a 14-inch length of music wire, held in a piece of black phenolic rod, turned to represent an exhaust stack. A tiny clip on the antenna lead of the receiver permits quick detachment of the antenna connection. There are three leads from the receiver to the control unit under the chassis, and they terminate in a tiny three-prong plug.

The control system is mounted on an aluminum plate, with many of the parts attached to a small bakelite panel. Note that reversing relay RY4 (Fig. 1418) is mounted as far from RY5 (Fig. 1419) as possible; this is necessary to prevent interaction.



List of parts for receiver and control unit

1 — Super-Aerotrol receiver kit with relay RY1; 1-XFG-1 tube; 1-half-wave rectifier, Raytheon CK705. Transformer—UTC type SO3.
Switches: S1 and S2 spst toggle.
Plugs and sockets: Miniature 3-prong plug and socket (PL1, SO1); miniature 4-prong plug and socket (PL2 and SO2).
Relays: Price midget 6-volt, 105-ohms (RY2, RY3); reversing switch (RY4); 8,000-ohm Sigma 4-F (RY5).
Capacitors: 250-μf 6-volt electrolytic (C1, C2); .1-μf midget, paper, (C3, C4, C6); 50-μf 12-volt electrolytic (C5); 100-μμf ceramic (C7, C8).
Resistors: 47-ohm ½-watt, carbon (R2, R3).
Batteries: 4-½-volt power battery; 3 Silvercel LR3 midget storage cells or D-size flashlight cells; 2—22½-volt hearing-aid B; 1—D-size flashlight cell.

Fig. 1420. *Three Silvercels or four nickel-cadmium cells make a good power supply for the tractor. C3, C4 and C6, plus R2 and R3 are arc suppressors. RY4 is an American Flyer HO train reversing switch rewound to work on the 4½-volt supply.*

It might be suggested at this point that a Sigma 5F relay be used instead of the 4F fitted to the tractor shown. The 5F would be easier to set for the rather small current change produced in this circuit, and it would probably be less affected by the magnetic field of RY4.

Operation of equipment

Before going further with a description of the construction, let's see how the equipment functions since it is quite different from anything covered in this book previously. For normal straight-ahead running, the receiver gets a series of rather slow pulses, and receiver relay RY1 therefore continuously opens and closes. Each of the contacts of RY1 (Fig. 1420) connects to an auxiliary relay (RY2 and RY3). Since there are large electrolytic capacitors (C1 and C2) connected across each of these windings, they stay closed as long as pulses above a certain rate are received. When

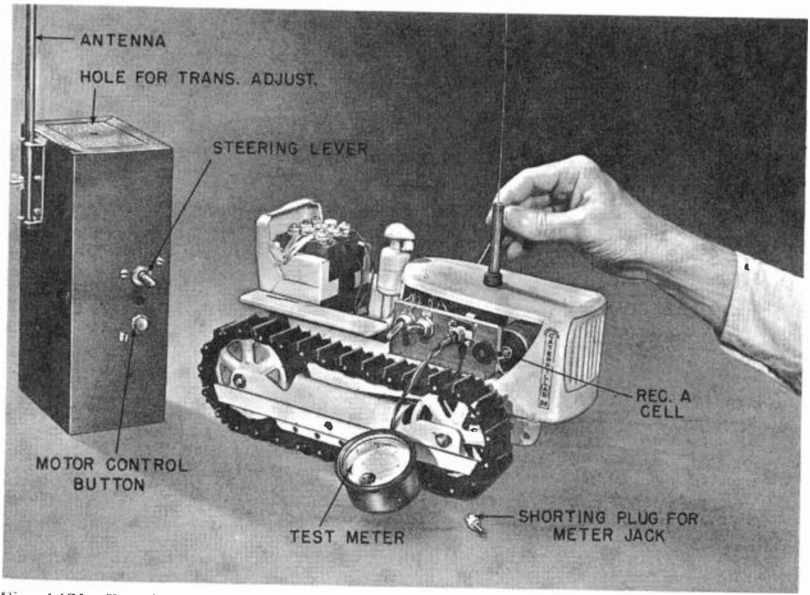
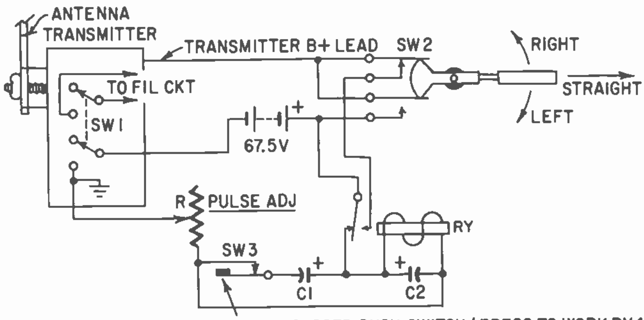


Fig. 1421. *Receiver is set up for proper operation with test meter plugged into panel jack. Music wire antenna projects from dummy exhaust stack, turned from phenolic rod. Object at rear of cowl is dummy air filter.*

both are closed, the two drive motors run steadily. Thus, each auxiliary relay governs the operation of one drive motor; when a solid signal comes in only one motor can run, while with no signal at all, the other motor runs.

The common return lead from relays RY2 and RY3 goes through the primary of transformer T, before getting back to the minus of the 4½-volt battery. Every time RY1 opens or closes, therefore, a pulse of dc goes through the primary of this transformer, where it is stepped up and put through a rectifier. The resultant dc goes to a very sensitive relay, RY5, which also has a capacitor, C5, across it to slow its action. Now, we don't want this relay to operate when the straight-running pulses are coming, so its spring tension is such that it will not pull in no matter whether pulses or solid signal come in, as long as those pulses are slow. To work RY5, we must send rapid pulses; RY2 and RY3 will close as we want with either slow or fast pulses, so fast pulsing affects only RY5. Normally, RY5 gets a current of about 0.5 ma, and the spring is set so that this will not pull it in. When pulses of about three times normal speed come in, RY5 gets about 1 ma of current and closes. This action sends current to RY4 (which is a model-train reversing switch) and the two drive motors are stopped or reversed.

RY4 must be rewound to work on our low voltage — 480 turns of No. 28 enameled wire allow it to work with a real kick on the



List of parts for transmitter and pulsing unit

1—Super-Aerotrol transmitter kit; 1—3A5 tube; 2—½-volt A-battery; 1—67½-volt B-battery; 1—8,000-ohm Sigma 4F relay; 1—dpst switch (SW1); 1—Switchcraft 3037 steering switch (SW2); 1—Switchcraft 103 normally closed pushbutton switch (SW3); 1—25,000-ohm potentiometer (R); 1—20-μf 150-volt electrolytic (C1); 1—5-μf 150-volt electrolytic (C2).

Fig. 1422. *Pulser circuit works on same 67½ volt battery that supplies transmitter. SW2 is main control switch; it allows even on-off pulsing in center position (shown here), cuts off transmitter signal in left, gives solid signal in right.*

4½-volt supply. RY5 is wired to cut the power to the two motors as soon as it is actuated, so there is no arcing whatever on the drum and brushes of RY4. The armature of the latter is held open by its own weight. The unit will not work correctly unless it is turned with the armature downward, a point to remember when you are first checking operation. It is a sequence device giving two off positions, a forward and a reverse.

To facilitate easy removal of the various parts, two sets of plugs and sockets were used. The motor leads connect through PL2 and SO2, while PL1 and SO1 make connections between the receiver and the control unit. The battery plus lead also goes through

PL1 to the control unit, while the negative lead from the latter connects directly to the battery.

Since it was expected that the tractor would be run for considerable periods of time, it was felt advisable to fit it with storage cells that could be recharged; the power for all circuits except the receiver comes from three type LR3 Silvercels (3 ampere hours each) connected in series. They are just the right size to fit into the space occupied by the seat, which was removed. They are held firmly by rubber bands so they will not drop out if the tractor is turned upside down. If you want a lower-cost power supply, you could use six or more size-D flashlight cells connected in series-parallel; even larger dry cells could be carried in a small trailer, which the tractor has plenty of power to pull.

The receiver relay is set to operate according to the type of receiver used, but careful adjustments are needed for RY2 and RY3. Reduce the armature spring tension until the armature will just snap open reliably when the coil is not energized. Bend the upper contact down so that there is a gap of .006 inch between the armature and lower contacts when the coil is not energized.

RY5 must work on very little current. Turn the normally open contact so that there is a gap of 0.010 inch between the armature and core when the former is held in by hand. Then set the other contact to give a spacing between contacts of 0.0025 inch with no current. Make the final adjustment of the tension spring after the equipment is set up for test.

To get the entire tractor ready to go, tune the receiver to the transmitter. Pull PL2 from its socket so the motors won't run and turn on the receiver and transmitter; with the latter pulsing steadily (neutral or straight-ahead position of the control lever) both RY2 and RY3 should hold steadily in the closed position. When the steering control lever is moved first one way and then the other, one relay should open first and then the other. (Fig. 1421.)

To check the stop and reverse circuits, connect a milliameter at point X (Fig. 1420) in series with the winding of RY5, and turn on the transmitter and receiver; you should get a reading of about 0.5 ma. If it is much less than this, try reversing the leads to the primary of T. Now push the forward-reverse button on the transmitter. The relay current should rise to 0.9 ma or more, causing RY5 to close and, in turn, operating RY4. If RY5 doesn't release as soon as the transmitter button is released, a quick flip of the

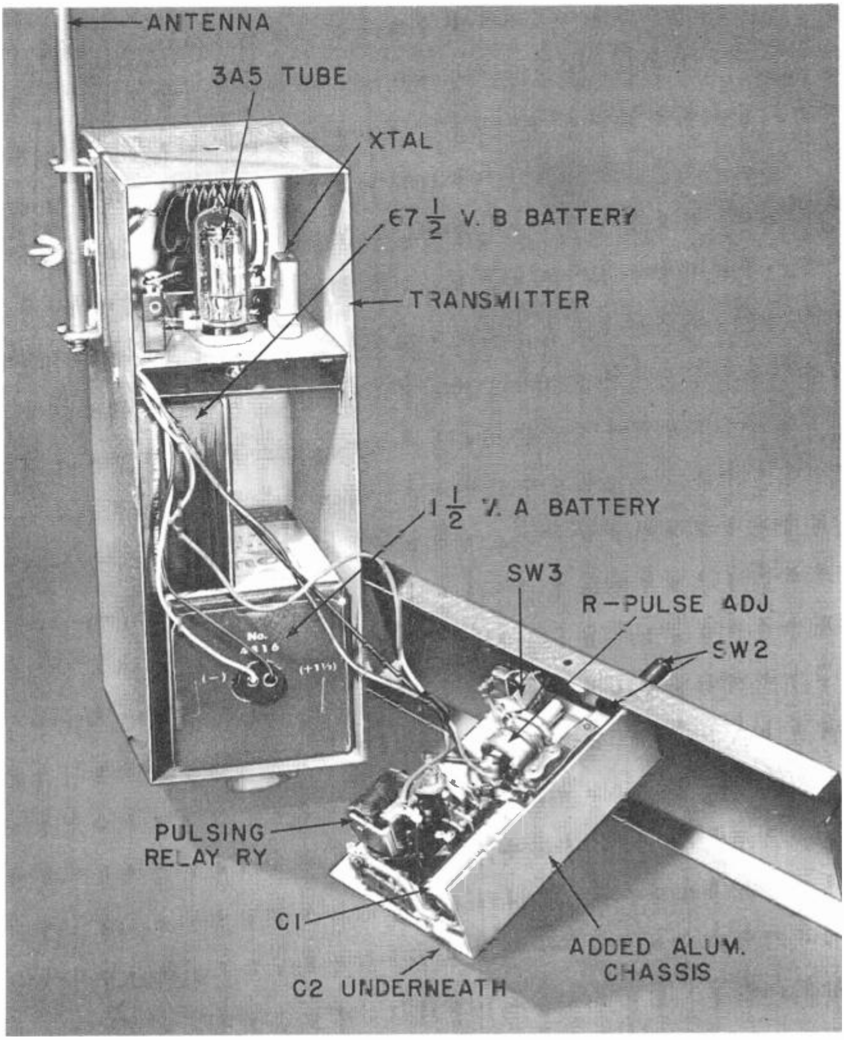


Fig. 1423. *Super-Aerotrol transmitter case normally held two B-batteries; only one is needed for short range operation with tractor. Pulser fits in empty space. Any CW transmitter would do as substitute for this transmitter; Aristrol MOPA is closest in size to that shown here, has same battery arrangement. Its stable circuit would work fine on 67½ volts.*

steering lever to either side will make it do so.

Transmitter and pulsing unit

The transmitter seen in the photo (Fig. 1421) was a companion to the kit receiver originally employed: this unit is no longer made but some may still be in dealer stocks. In any case, only very low power is required due to the short range. The transmitter was made to hold two 67½-volt batteries but only one was used. In place of the second 67½ volt battery a small aluminum chassis is bent up and attached to the cover. This chassis holds pulsing relay RY (Fig. 1422) plus C1, C2 and R. SW2 and SW3 are attached directly to the cover, while SW1 is a dpst unit that replaces the original on–off switch of the transmitter. Bend the contacts of SW2 so that when the lever is centered, *right* will close the lower contacts and give solid signal while *left* will open the upper pair, giving no signal.

Fig. 1424. *Author's wife holds shoulder wing "Kickin' Duck" plane. Though much overweight, it was good performer. All low-voltage requirements of the plane, including receiver filament supply, were handled by a single LR-1 Silvercel. This arrangement was used in effort to keep weight down.*

When SW3 is depressed, C1 is removed from the circuit and the relay pulses at a high rate. RY is adjusted the same as described for the pulser in Fig. 811-a; be sure this relay is mounted on a piece of insulation, since the entire frame is "hot." Potentiometer R serves to vary the pulses, best results being obtained when the pulses are roughly 50% on and off. R also changes the pulse speed, which is handy to get a close setting for operating receiver relay RY1.

This same transmitter was used to work the little boat described at the beginning of this chapter. As shown there, SW3 is not needed. When used with the boat, R is turned till the boat follows a straight path. It was found wise to reduce the value of C1 to 10 μf to speed up the pulse rate a bit. For the boat, SW3 and C2 could be omitted, with C1 connected directly across the relay winding. The transmitter is illustrated in Fig. 1423.

Simple dual proportional setup

Employing many of the pieces of equipment already described in this book, the shoulder-wing model plane seen in Fig. 1424 was flown for many months with simplified dual proportional control. The rudder was operated by an actuator (Fig. 211) and the receiver was a modified Tech Two (Fig. 503). The plane was flown with just rudder control for an extended period, then was fitted with an inductive-kick elevator arrangement. During most of the flying, the transmitter was the Mac 50 (Fig. 715), while the

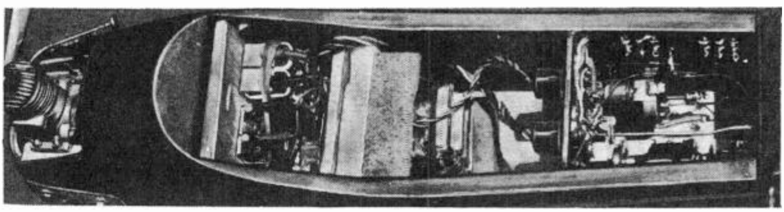


Fig. 1425. *Compartment at left holds all batteries on ply slide; single LR-1 and two 22½ volt batteries can be seen. Chassis of Fig. 1427 fits on fuselage bottom under batteries. Receiver is packed in foam rubber in center compartment; rudder and elevator moving units at right.*

pulser used with this transmitter was the "compact" (Fig. 822). The latter already had the necessary pulse-rate change circuits built into it, so the only addition needed to the whole system was an elevator rate circuit and the elevator servo itself.

The rate circuit was built on a separate small chassis with its own 22½-volt battery and foam-rubber shock pad. The complete unit fitted under the batteries in the forward fuselage compartment (left in Fig. 1425). The edge of the elevator servo can just be seen at the bottom right in this same view. To the rear of the motor is the rudder actuator; on the fuselage side are the two on – off switches. The center compartment holds the receiver, well protected in foam rubber.

The circuit of the control system is seen in Fig. 1426. Note that a single 1½-volt cell drives both rudder and elevator, and this cell is also used for the receiver filaments. An LR1 Silvercel was used and was found ample for several hours of flying, the average current drain on it being about 450 ma (these cells run close to 2-ampere hours capacity when new). The plane itself had a wing area of about 400 square inches and was flown with a Cameron .19 engine. Overweight to start with, the plane gained still more weight from repairs until finally, the wing loading was around 27 ounces per square foot – a rather ridiculous figure for a plane this small (it had a span of 56 inches). Even so, it could be put through many of the maneuvers accomplished by planes with much more complex controls, including nice inside loops, slow and snap rolls, true spins, frightening vertical dives and prolonged inverted flight.

Because it worked on the inductive-kick principle, the control system became known as the Kickin' Duck. It was set up so that at the lowest pulse rate (about 3 pps), the elevator gave solid "up"; it was also pretty solid "down" at the high rate of around 12 pps. There was a slight amount of interaction between rudder and elevator, but so little that it was never bothersome.

An examination of the circuit will show that the basic rudder arrangement is just the same as we have sketched in earlier chapters. The receiver relay drives the actuator right and left, and 1N91 diodes are connected across the coils for arc suppression. A new addition is the tiny transformer, T; this has a very low-resistance winding in series with one side of the actuator (which incidentally was fitted with magnetic centering, per Fig. 214). The transformer is a transistor-type output-to-speaker-voice-coil unit, (500 to 3.2 ohms impedance). The higher impedance winding is connected to the transistor input circuit. Each time the receiver relay opens and closes the lower actuator winding circuit a kick is produced in the transformer. The diode, D, allows those of only one polarity to charge capacitor C1, the rate at which the charge leaks off being governed by the setting of R1 (and the transistor input resistance). The circuit thus acts to "stretch" the very short kick pulses; at low pulse rates, RY1 is open continuously and the elevator gives solid "up." As the pulse rate is increased, the kick pulses come closer together and relay RY1 is held on the "down" contact longer and longer, until finally, at top pulse rate, you get full down elevator.

Essentially a very simple control system, there are some tricky points about it. First, even though there is a diode across the lower actuator coil, some of the inductive kick from this coil still gets into the rate circuit. Resistor R3 kills most of it. Although it takes a fair amount of current, it was felt to be worth while.

With the pulser stick centered, the elevator can be brought to center by adjusting R1. But when the stick is then pulled back to full up, it will probably be found that the elevator still flaps a bit. This is where R2 comes in; it should be reduced in value — and the elevator neutral is then reset with R1 each time — until the elevator just goes to solid up with the stick all the way back.

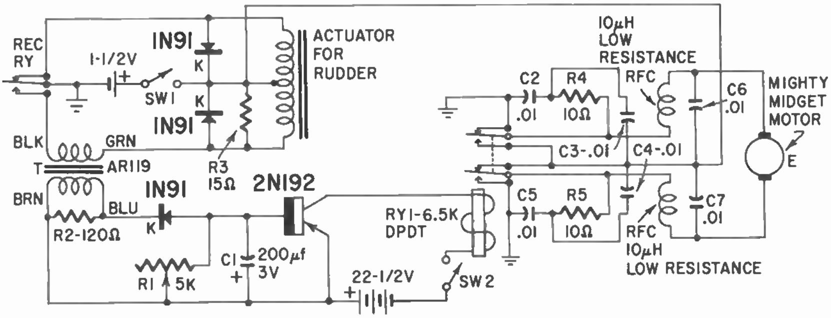


Fig. 1426. Complete circuitry (aside from receiver itself) used in simplified dual proportional plane. T is a Lafayette AR119; R1 is sub-miniature CRL type B16-113. Motor chokes might not be needed in some installations, depending on type of receiver used. Actuator is magnetic type rudder described in Chapter 2.

R2 could be a variable of about 500 ohms. A fixed resistor of about 120 ohms was used in the original installation.

To make it possible to use the equipment on a single cell, it was necessary to use a dpdt relay for the elevator motor, a Price unit of 6,500 ohms being fitted. This relay got a maximum current of about 3 ma from its 22½-volt battery and was set to operate at 1.7 ma and open at 1.4. It proved to be extremely reliable.

For any control circuit which depends upon pulse rate, it is necessary to have a receiver that can follow fast pulsing, and modifications were found necessary to the Tech Two to allow clean pulsing at the top 12-pps rate. The transistor version of this receiver is a much better pulser (Fig. 507), and this one is recommended for the Kickin' Duck and similar circuits.

In Fig. 1426, the two rf chokes and capacitors C6 and C7 are "hash filters" on the Mighty Midget elevator motor; C2, C3, C4 and C5, plus R4 and R5 are relay-contact arc suppressors. The M-M motor (Fig. 1427) was fitted with a second set of gears that brought its total gear reduction to about 18 to 1 (the original gears on this motor have a ratio of about 7 to 1) and the linkage used added another 2 to 1. A centering arrangement is a must and that shown in Fig. 222 is strongly recommended.

Though the system shown worked successfully on 1½ volts, it must be admitted that to get it to do so was a struggle; it needed great care to reduce voltage drops throughout the system. It would be much more practical to set things up for at least 2.4 volts (two nickel-cadmium cells in series). Transformer T was picked for one reason — because it has very low dc resistance in the primary — about 0.3 ohm. Note that this transformer should be connected exactly as illustrated in Fig. 1426, too; many other small transformers that were tried did not work as well.

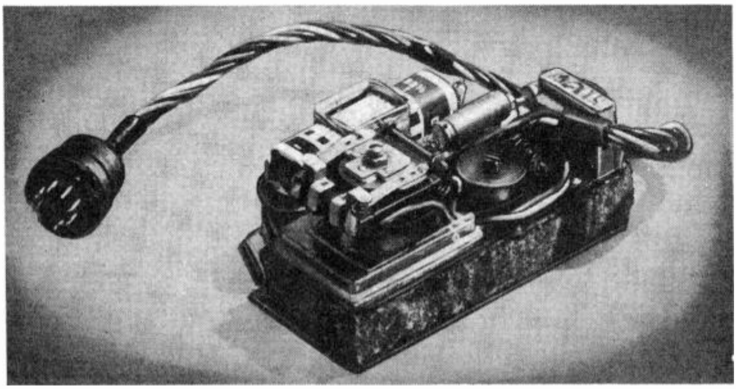


Fig. 1427. *Dpdt relay is at left in foreground, AR-119 at far right. 22½ volt power supply for transistor is in Acme holder at rear. Transistor is held in sub-miniature socket. Plastic dust cover goes over relay.*

When first trying out a system of this sort, it is wise to connect the pulser relay contacts into the rudder circuit in place of the receiver relay. Presumably, there will be no trouble in getting the rudder to work properly. If there is trouble with the elevator circuit, a pulse checker (Fig. 1322) connected to the elevator relay will show if the kick circuit is working as it should. After things are working suitably, the receiver then can be connected up, and the pulser transferred to its usual position, controlling the transmitter.

The four complete control systems shown in this chapter can be varied to make up an arrangement to suit your own purposes. And by addition of circuits shown in other parts of the book, you can assemble a bewildering array of control systems. It is the working out of complete control systems — and making them operate as you intended — that is the real fun of radio-control modeling!

INDEX

N

O

P

Q

R

Printed in the United States of America

Radio Control handbook

Radio control systems, equipment, gadgets etc., fully explained for those who have a modest knowledge of radio, little of R/C. Building data for many transmitters, receivers, and control units.

GERNSBACK LIBRARY, INC., 154 WEST 14TH ST., NEW YORK, N.Y. 10011