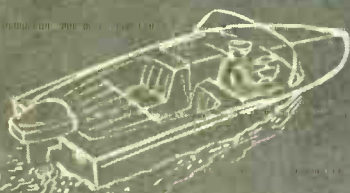
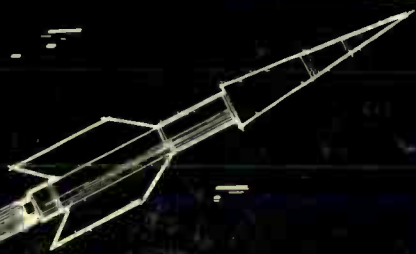


RADIO CONTROL MANUAL

EDWARD L. SAFFORD JR.



GERNSBACK LIBRARY BOOK No. 91

RADIO CONTROL MANUAL

EDWARD L. SAFFORD, JR.

Training Supervisor
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GERNSBACK LIBRARY, INC.

NEW YORK, N. Y. 10011

First Printing — May, 1961
Second Printing — May, 1962
Third Printing — March, 1964



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Library of Congress Catalog Card No. 61-8092

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introduction

WELCOME to the ranks of the radio-control enthusiasts! We offer this greeting to you if you are a beginner and want to learn all about this great hobby. We'll try to tell you everything, starting from scratch.

To you old-timers, the warmest of salutations and our sincere appreciation for your acceptance of our previous book *Model Radio-Control* (Gernsback Library book No. 74). We think we have something for you, too, in the later pages of this volume.

This is a new work based on a progressive radio-control system idea. This means that as each page is turned you not only advance your knowledge (if you are a beginner) but also advance your system until you finally arrive at the ultimate. Because of this approach, you will not find a multitude of transmitters and receivers described. The theme is just one single system which starts as a carrier-operated type and advances through all presently possible uses of tones, from single-channel through multi-channel simultaneous proportional control systems.

Another concept was incorporated. Although construction of the basic system is described, you can buy some, or all, units if you would rather buy than build, so those who want to operate and do not want to construct will also find the information they want. How to use single- and multi-channel equipment is covered in the systems described, but remember that the systems apply not only to planes but also to model cars and boats. In those items which some may want to construct, an effort has been made to use standard parts which are readily available. No tricky circuits, delicate adjustments or special, hard to come by components. Just a good, solid, reliable system that works!

May we here express our appreciation to Ace Radio Co., Babcock Models, Bonner Specialties, deBolt Engineering Co., Electronics Magazine, Flying Models Magazine and Heath Co. for their interest and help in furnishing material for this text. Our deep appreciation also to Majors W. H. Holcome, Jr., and 'Ollie' Strickland for letting us use their models.

Finally, the author wishes to express his gratitude to his son, Eddie, who spent countless hours with the camera, and to Mother and Dad, whose sage council and constant encouragement were largely responsible for bringing this effort to completion.

E. L. SAFFORD, JR.

electronics

Six channels are allocated by the Government for radio control. A channel means the same thing here that it does when you refer to your television set. Each channel is a frequency and these are, in megacycles:

26.995

27.045

27.095

27.145

27.195

27.255

The only importance of the numerical values given is that when we go to the hobby shop to purchase our crystal, we should ask for one of these frequencies. A second note of importance here is that there *are* six channels for radio control and you can operate a system on any one of them without taking any kind of examination.

Effective November 15, 1959, Section 19.71 of Part 19, Citizens' Radio Service, is amended to set forth the following requirements concerning home construction of radio-control transmitters which are built from "scratch"; that is, which are not built from kits which have the crystal circuit as a sealed unit.

"All transmitter adjustments or tests while radiating energy during or coincident with the construction, installation, servicing or maintenance of a radio station in this service (Class C or D . . . Class C is radio control) which may affect the proper operation of such station, shall be made by or under the immediate supervision and responsibility of a person holding a first or second class commercial radio operator's license, either radiotelephone or radiotelegraph, as may be appropriate for the type transmission employed (for tones, a telephone licensed operator . . . for carrier, only a telegraph licensed operator) and such person shall be responsible for the proper functioning of the station equipment at the conclusion of such adjustments or tests."

This means that you do not need a commercial license to operate your radio-control transmitter, but when it is built you must have it checked by a man who has a first or second class radiotelegraph or radiotelephone operator's license.

Components—tools—terms

Surprising as it may seem, electronic devices are composed of very few primary parts. The manner in which these few parts are connected determines what the particular device does. Let's examine some of these components, particularly the types that we are going to be concerned with, and learn the names and purposes of each. Refer to Fig. 101.

Starting at the left side we see four objects called *resistors*. Although they differ in physical size somewhat, they all have the same purpose.

A resistor is a device which opposes the flow of an electric current. It is described by its physical size, its wattage and by how much it will resist the current flow.

Let's examine the concept further. Suppose you took an automobile tire and rolled it down the street very fast. Now suppose you press your hand firmly against the tire tread. What happens? Your hand will get very hot. The harder you try to stop the tire, the hotter your hand gets. A resistor is like that.

If there is a large amount of current flowing in a circuit and you want to reduce it, you can insert "electrical friction" — a resistor. Just like distance, or weight, or volume, resistance is a quantity that can be measured, and its unit of measurement is known as the ohm.

Current can be controlled by using resistors of different values — the larger the resistance, the smaller the current. Conversely, you can increase current by removing or lowering the resistance, assuming, of course, that you make no other changes while doing this.

Heat is produced when current passes through a resistor. The heat-dissipating ability of a resistor, known as its wattage rating, depends on its size, its position in a receiver or transmitter (especially with relation to other heat-generating components) and the surrounding temperature.

Refer to the photograph again. The resistor at the left is rated at 10-watts. The second and third resistors are 1-watt size, the fourth is a 1/2 watt. We will be mostly concerned with the 1/2-watt resistor; later you will learn what other resistance values we will need and how to measure them.

The next most important component is the capacitor (you will sometimes find it referred to as a condenser). Several types are shown in Fig. 101.

A capacitor must also have some unit of designation to indicate its value and so it does. The unit is called the farad. This unit is much too large and not generally used, and the values we deal with are microfarads (μf) and micromicrofarads ($\mu\mu\text{f}$).

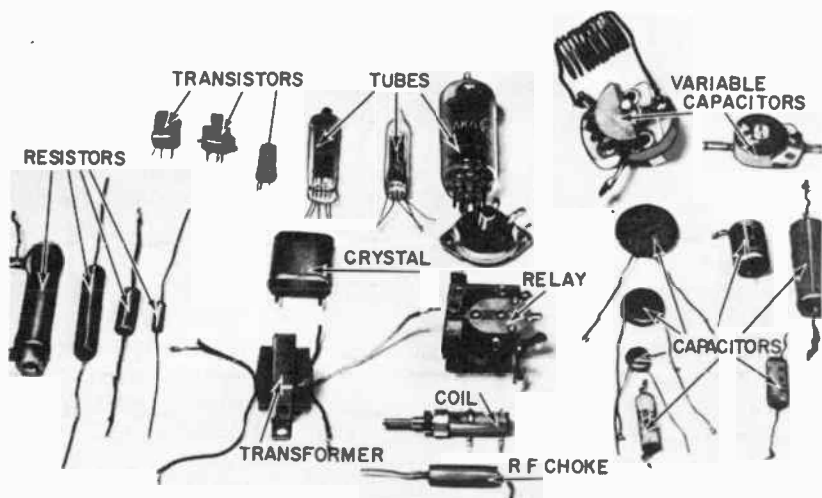


Fig. 101. Some of the primary components used in the construction of all electronic devices.

Essentially a farad is a unit which tells how much electricity the capacitor can store, for it is a storage device. A farad is a measure of capacity, as is a gallon. You can have a gallon jug or a microfarad capacitor. A micromicrofarad capacitor, using our previous analogy, is teaspoon-size compared to the gallon-jug size.

Like the resistor, the capacitor is designated by two values: its capacitance (in micro- or micromicrofarads) and its rating in volts.

The electrical force that causes a current to flow is measured in volts. Voltage is electrical pressure and so (in thinking of our capacitor) if the voltage rating of the capacitor is not large enough, the electrical pressure will be too great and the capacitor will break down. We will be interested in capacitors with voltage ratings from 100 to 450, and in sizes from $20 \mu\text{f}$ to $5 \mu\mu\text{f}$.

What does a capacitor do in a circuit? We say that it passes (allows to continue on its path in a circuit) the signal currents and prevents the battery currents from passing. Thinking about this for a few moments, you will see that by proper use of these devices, we can make the signals go wherever we want them to and also prevent them from going where we don't want them to go.

We are going to be working with two types of current: direct and alternating (or signal current). Direct currents are the type of flow that comes from batteries. Capacitors won't let these currents pass through. Alternating currents, though, are old friends to the capacitors and pass through them readily. The rate of current flow is expressed in amperes. This is a very large unit, so we will be primarily concerned with milliamperes (thousandths of an ampere).

Coils

Coils come in a tremendous number of sizes and shapes, but fundamentally they are all alike in that they consist of turns of wire. Sometimes the coils require some support for their turns and in these cases the coils are wound around an insulating material known as a coil form.

When a current of electricity is passed through it, the coil (also known as an inductor) becomes an electromagnet. Soft iron in the form of round slugs or in thin sheets (called laminations) increases the strength of the electromagnet. When used with a coil, the iron is known as a core. A coil that works without the help of iron is known as an air-core coil.

In a radio-control receiver, or transmitter, we use resistors, capacitors and coils to control the flow of current and to get the current to do various jobs for us. Resistors have no particular preference for direct or alternating current. Capacitors block the flow of direct current completely. For direct current a capacitor is very much like an open switch. For alternating current, both coils and capacitors have a certain amount of opposition, known as reactance, and measured in ohms.

Tubes and transistors

A radio-control system is a communications system. The signal, sent out by the transmitter on the ground and picked up by the receiver in the plane, is weak and must be strengthened or amplified. We are going to do this with the help of tubes and transistors. To operate, tubes and transistors need two kinds of voltage – direct and alternating. The alternating voltage is usually known as the signal voltage.

Both of these devices are peculiar in that they like to have the signal they are going to amplify presented to them in just the right manner and at just the right place. They will strengthen the signal and then pass it along but, to get the signal out of a tube or transistor we must know just where it is coming out and have the conditions just right for this exit. Refer to Fig. 101 and note the wire leads from the bases of the tubes and transistors. Each one of these has a particular designation. Let's examine tubes first.

The input to a tube is called the control grid and this may be any pin on the base of the tube, depending on the type of tube used. The output always comes from the plate of the tube (p).

A tube won't work unless we heat it with electric current by connecting a battery across the pins called filaments (or fil). This heating is what you see when you look at a tube and see it glow. Finally, there are two more pins or wires, one of which is called the cathode and the other the screen grid.

The cathode allows the electrical currents from the battery to get into the tube. The screen grid is used to apply more electrical pressure on those types which require this. Some tubes do not have a cathode

pin and, when you encounter this type just remember that the filament connection then performs the dual function of heating and presenting electrical currents inside the tube.

Electric currents (from the battery) are the life blood of tubes or transistors and so these must always be supplied. The battery which

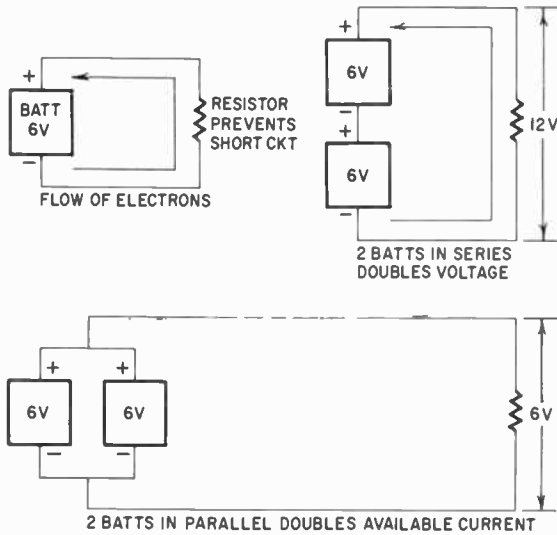


Fig. 102. Three simple circuits using batteries in series and in parallel.

furnishes this current is a B-battery. Since the battery is capable of more current than the tube needs and since tubes and transistors are fussy about being connected directly to this B-battery, we keep them happy by always using a resistor, a choke or a transformer between the tube or transistor pin and the battery. Tubes are very fussy also about which terminal of the battery their plate or screen grid is connected to. It must always be the *plus* (+) terminal. Their cathode or filament is always connected to the *minus* (—) or negative terminal.

The transistor is a much happier little fellow. Being warm-natured anyway, he doesn't want to be heated up and so we find no wires or pins labeled FIL associated with him. He does have a particular wire which serves as an input; this is labeled (b) for base. The wire which connects to the minus side of the B-battery for P-N-P-type transistors is called the collector (c), and the wire which connects to the plus side is called the emitter (e).

Because we will not be concerned with N-P-N type transistors, we will not go into their operation. Like the tube, however, the P-N-P transistor requires resistors, chokes or transformers connected between its collector pin and the negative side of the B-battery.

The other devices are the relay, an electrically-operated switch; the crystal, which is a sealed unit that keeps us on the right channel; a tube socket, for the larger type tubes; and a variable capacitor with a tuning coil (air core) attached.

Two types of variable capacitors are shown in Fig. 101. The variable capacitor, as the name suggests, is one whose capacitance (or farad) value can be changed. We will use both fixed and the variable types.

Batteries

We have already described one type of battery used in radio control, the B-battery, and we have mentioned another, the one that keeps the tubes hot. The latter is called an A-battery. The transmitter's A- and B-batteries are much larger than those used in the receiver.

Before leaving the subject of batteries, there is a very important concept that we must understand: the concept of a complete circuit (Fig. 102).

One way to visualize this is to imagine that at the negative (or minus) terminal of the battery are millions upon millions of electrons, which have no other desire in life but to get over to the positive terminal. Unfortunately for them, and fortunately for us, it is impossible for these electrons to go back through the battery from the minus to the plus side. So there they are, so near to home and yet unable to return.

Now if we attach a wire to the minus terminal of the battery, these electrons instantly go to the end and stop. Since they represent the flow of electric current, this means that there is an instantaneous flow for about $1/10,000,000,000$ second, and then none. Were we to connect the free end of the wire to the positive terminal of the battery, however, every electron in that battery (and remember there are billions of them), would rush to get through the wire to that positive side. You've seen what happens. A spark, several sparks, then heating and even fusing or melting of the wire. When a resistance or other device is placed in the circuit this flow will do useful work for us.

This is a circuit and we will always want to keep this thought in mind. No matter what we have those little electrons do for us, they must always be provided with a path, through resistors, coils, tubes or transistors; but there must be a path to the positive terminal from the negative terminal of *the same* battery, or electric current will not flow. If we were to connect the negative terminal of one battery to the positive terminal of another, these electrons *wouldn't* rush across the link. Not until we *complete* the circuit by again connecting the negative terminal of the second battery to the positive terminal of the first, and then the rush begins.

In a way this means that we must always have two wires to everything that we want electricity to go through. A wire for the electrons to arrive on and one for them to leave on. This is the concept of a circuit.

More about circuits

While we are thinking in terms of circuits, let's spend just a moment contemplating those hen scratches called circuits. We don't have to be able to understand them to build the radio-control system in this

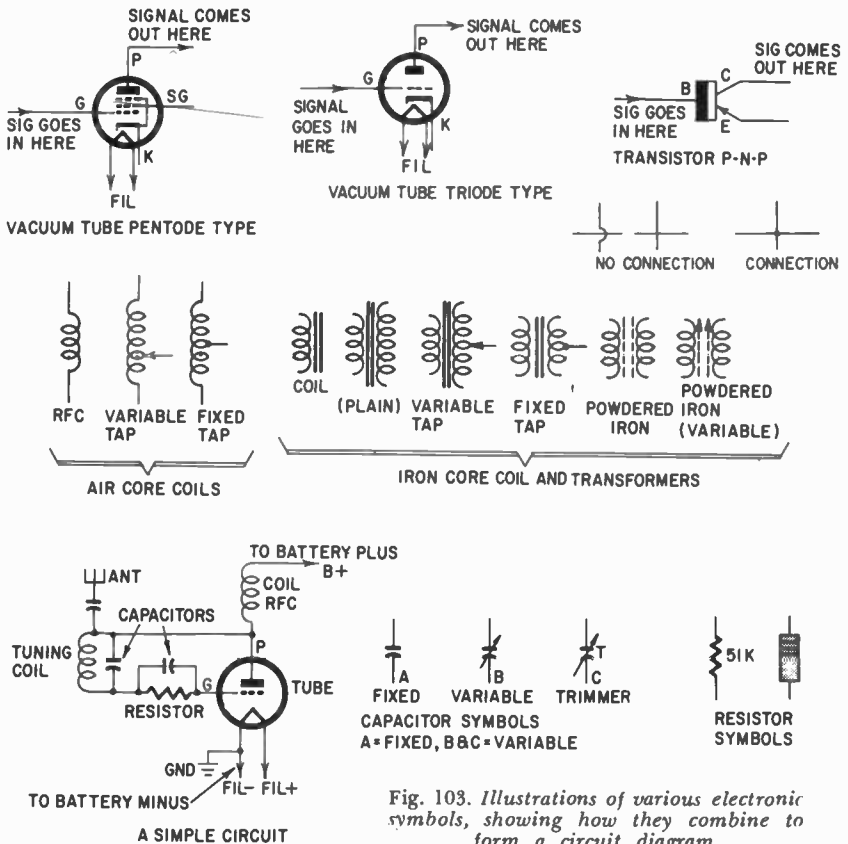


Fig. 103. Illustrations of various electronic symbols, showing how they combine to form a circuit diagram.

text, but just so we won't be completely at a loss when someone refers to a circuit diagram, let's examine what this means.

In a circuit diagram, a line represents a wire or other metallic connection like the metal chassis we are going to use to build our first transmitter on. Connected to this line will be resistors, represented by wiggly lines (and we now know what they do), coils, represented by smooth loop symbols, and tubes, represented by circles with more lines designating connections to plates, grids and filaments. There will be the bar with its three lines representing transistors and other symbols such as illustrated in Fig. 103.

To show that two wires cross but are not connected, we can use either of two ways: draw a little U at the intersection, or just let them cross.

A small dot is placed where two lines intersect to indicate when a connection is to be made, or has been made. (Modern style is to let the lines cross and use dots for connections).

Fig. 103 shows a small circuit diagram. Let's read it. The reading will sound somewhat like the old song, "The toe bone is connected to the foot bone, the foot bone is connected to the ankle bone . . ." etc.

The antenna is connected to the tuning coil, the tuning coil is connected to the fixed capacitor, the fixed capacitor and the coil are connected to the tube plate. The other end of the tuning coil is connected to the other end of the fixed capacitor, and this end of the tuning coil and the capacitor are connected to the resistor. The resistor has a capacitor across it, and the other end of this second capacitor and the resistor are connected to the tube grid. That's how we read a circuit diagram, and the connections are just what they mean.

Tools

Enough about fundamental electronics concepts.¹ It's time we rolled up our sleeves and began construction.

Most of the tools we will need are illustrated in Figure 104. Some of these may be familiar, with the exception perhaps of the soldering iron and the solder. Let's make a list, however, just so we can obtain any we don't have.

Screwdriver, 1/4-inch tip

Screwdriver, 1/8-inch tip

Needle-nose pliers

Wire-cutting pliers; diagonal cutters

Insulated alignment tools with 1/4-inch tip (get these from a radio parts store)

Assorted drills (1/16 to 1/4-inch) and an electric or hand drill

Soldering iron, 37-watt pencil type

Box of rosin-core solder

Pocket knife

Small file

Roll of 18-gauge flexible, insulated hookup wire

Carpenter's brace and a 3/4-inch metal drill bit

The first big step . . . soldering

Because more than 60% of the troubles encountered in constructing any type of radio-control or electronic equipment are caused by improper soldering or bad connections, let us learn how to do this before we go a step further. It is not difficult, it just takes practice — so let's practice.

The first step is to plug the iron into an outlet and allow it about

¹ A subject such as radio, even if on a basic level, requires a book of its own. The purpose of this book is radio control, with emphasis on mechanical details. The reader is urged to learn more about radio by consulting any of the numerous books available.

five minutes to heat. In the meantime, prepare two scraps of wire. Most wires have either a rubber, plastic or enamel coating for insulation,

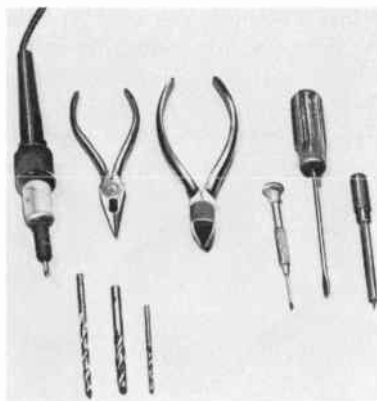


Fig. 104. *Most needed tools for radio-control construction.*

and we must remove this from the two ends to be soldered together. A knife will help, but be careful not to nick the wire so that it will break. All we want to do is to remove the insulation or scrape the enamel until the copper shows bright and clean.

The next step is to twist these two cleaned ends together physically to make a joint. This will apply to any part we use later on. Most have wire leads which must be cleaned and when they are connected to other parts, the joint must be strong mechanically.

Take your iron and touch the tip to the end of a 6-inch length of the solder. See how it runs and flows down over the tip. It's bright and silvery and smooth. Don't use too much, just enough to coat the tip of the iron. Wipe away the excess with a cloth.

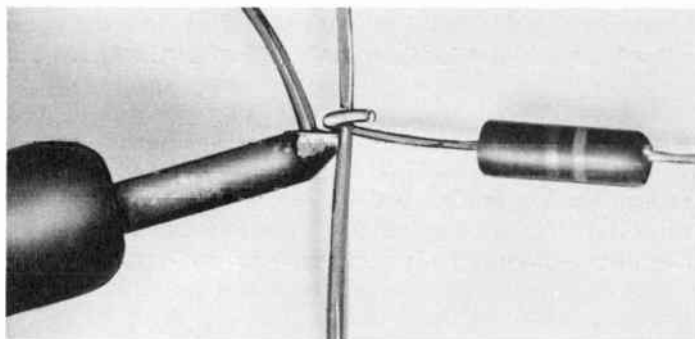


Fig. 105. *Correct way of making a good solder joint. The solder must be applied to the tip of the iron at the same time the iron tip is applied to the wires to be joined.*

Now apply the tinned tip of the iron to the cleaned wire joint and at the same time apply the solder to the iron tip so that the melted solder runs down onto the two wires (Fig. 105). This helps to heat the joint. In just a second, you will be able to apply the solder directly to the joint (keeping the soldering-iron tip against it), and the joint of the two wires will be hot enough to melt the solder.

Don't use too much solder, just enough to coat the joined wires smoothly and evenly. Remove the iron. Hold the wires absolutely

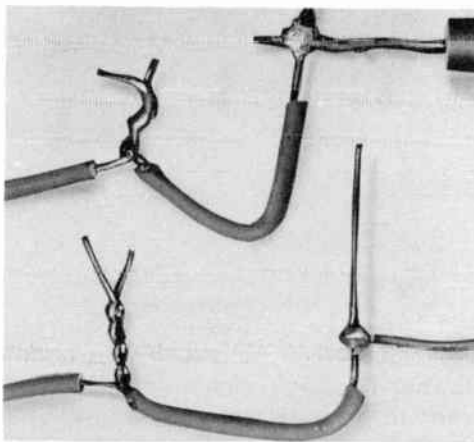


Fig. 106. *Examples of a good and a bad solder joint. The bad one, obviously, is at the top. Note how the solder is unevenly melted.*

still until the joint cools. Now examine the connection. Twist it. Is it stiff and hard and firm? Is the solder smooth and evenly melted? Is there just enough solder to cover the joint and no more? If your answer is yes, you have made a good soldered connection. Fig. 106 shows a good and a bad solder joint. Practice soldering until you get this step thoroughly mastered before going ahead.

The purpose of soldering is to make a perfect electrical connection. When you have a bad joint, you have added resistance in the circuit or else you have no circuit at all. Either means failure.

A final word. Always keep the tip of your iron bright and clean. As you use it, it will erode and pit and you will have to use your file to keep the tip squared up, as it was when new. A good system is to keep an old cloth around when using the iron and every now and then wipe the tip, cleaning off the corrosion and excess solder that somehow always accumulates and blackens the tip.

Now that we have learned something about radio parts and how to join them, our next step is to build a test set. With its help we can check components and circuits. We will be able to adjust our receiver and transmitter for peak performance before launching the radio-controlled model.

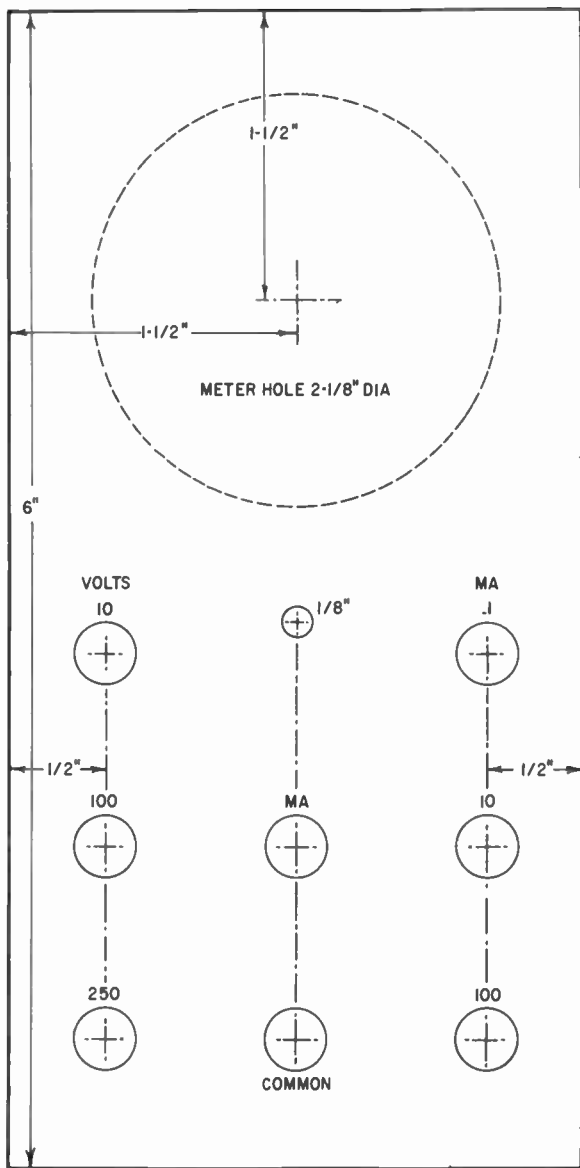
the basic test set

BEFORE starting on the construction of this basic test set, remember there are many fine small test instruments which you can buy and use. The primary requirement, if you buy, is to obtain an instrument which will measure: ohms (up to at least 1,000,000); volts, and this is dc volts (such as you have with batteries) in scales of 10, 100 and 250; and direct current in milliamperes in scales of 1, 10 and 100. Although the commercial scales available may not exactly correspond, get as close a similarity as possible.

For those who want to construct the instrument, here is a very economical one which will do all the measurements that we will need.

Mounting the parts

1. Drill the panel exactly as shown in the template of Fig. 201.
2. Insert the phono jacks up through the holes from the bottom side of the panel and turn them so that no metal part of one touches the metal part of another (Fig. 202).
3. With a pencil, mark the screw-hole locations, drill these and mount the phono jacks. Use small-size nuts on the ends of the screws so that the nuts do not touch the metal of any jack.
4. Mount the insulated one-terminal solder lugs on the inside screws of jacks X and Y (Fig. 203). Turn the lugs so that they are parallel to the bottom edge of the panel.
5. Fasten the resistors (make mechanically strong connections) to the jacks and terminals. A 4-inch length of insulated lead goes from the top center jack through the small hole above. Fig. 204 illustrates the wiring.
6. Solder all connections.
7. Turn the panel over and solder a phono plug on the end of the lead which you brought through the panel. Make sure that this lead



ALL JACK HOLES 5/16"

Fig. 201. Layout of the front panel. Screw holes for the jacks have been omitted.

is long enough to allow you to insert this plug into the lower right-hand jack.

8. Now mount the meter. This is a simple process since the meter is supplied with a mounting bracket. Do not fasten this too tightly or you may damage the plastic case. Connect the two leads to the meter (Fig. 204).

9. Obtain two 24-inch lengths of insulated flexible wire, and one red and one black alligator clip. Solder one on each end of the wire.

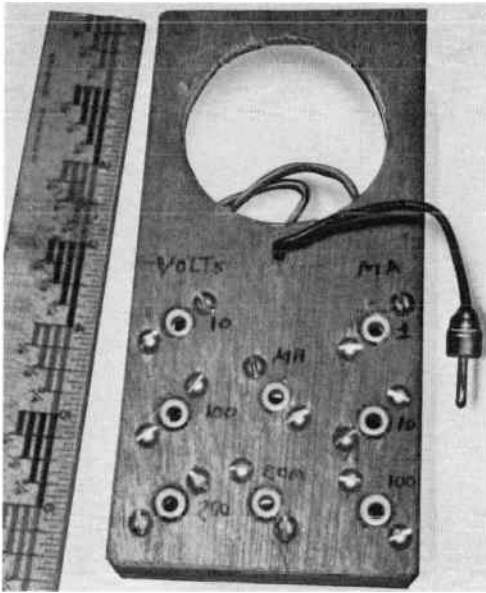


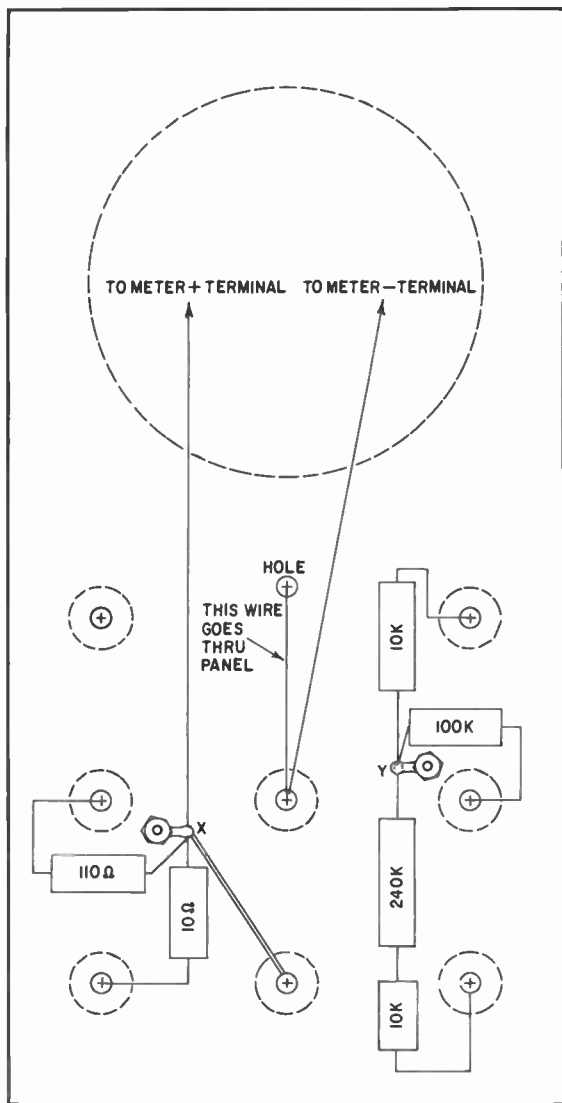
Fig. 202. Illustration shows phono jacks inserted in the tester panel.

Solder phono plugs on the other end of each wire. These will be the test leads.

10. Using red paint, place a mark just over the phono jack marked *COMMON*. The lead connected to this jack will always be connected to the plus side of a battery when voltages or currents are measured. It is always advisable to use the test lead with the red alligator clip in this jack.

Adjusting the meter

The small screw on the face of the meter is the zero-set screw. It can be turned a small amount in either direction and then will be limited by a mechanical stop built into the meter itself. The purpose of this screw is to allow you to adjust the meter pointer to zero. Try it. Don't force the screw if the pointer doesn't zero. Turn the screw in such a direction that the pointer comes closest to zero if it does not actually reach that point.



SOLDER LUGS LOCATED AT X & Y

Fig. 203. Pictorial diagram of the parts in the tester. The placement of the components is not critical. Use this diagram for wiring your connections. Make sure to check them against this pictorial when you have completed the tester. The 10K resistor will not be needed if the 240K resistor is close to the needed value of 250K. These resistors are available in 5%, 10% and 20% tolerances. The $\pm 5\%$ variation can properly give a measured value as high as 252K or as low as 228K. (1K = 1,000 ohms - 240K = 240,000 ohms.)

parts list for the basic test set

Resistors: 1-10-ohm; 1-110-ohm; 2-10,000-ohm; 1-100,000-ohm; 1-240,000-ohm. All resistors, 5%, 1 watt.

Clips: alligator, 1-red, 1-black.

Meter: 0-1 milliampere (Lofoyette Rodio, TM-60; TM-400; DC 0-1 D or equivalent).

Miscellaneous: 8—phono jacks; 3—phono plugs to fit the jacks; 2—insulated one-terminal solder lugs; 1—3" x 6" piece of 1/8- or 1/4-inch plywood, bakelite or pressed-board panel; solder; wire.

Now this highly useful meter is constructed like a magnetic compass and, in fact, acts like one. If you turn the test panel around, you can point it in such a direction that it will zero, while in some other direction it will not. This is not a particular disadvantage so don't let it worry you. Also, the meter is very sensitive to any magnetism that may be around it. Tools become magnetized and some of the

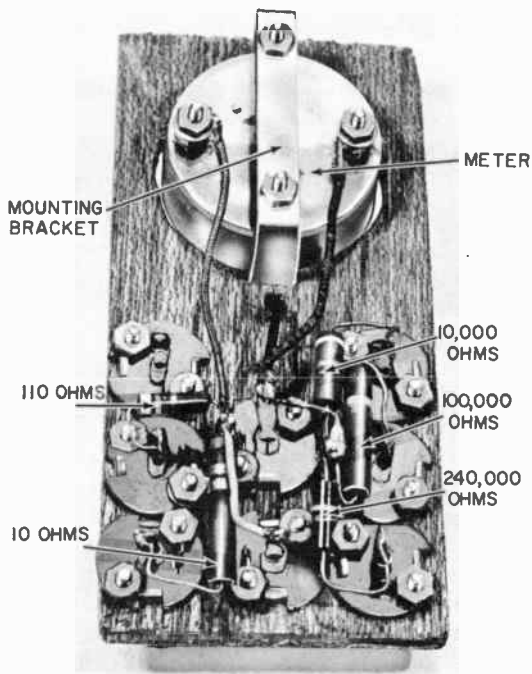


Fig. 204. Back view of tester panel, showing circuit wiring and meter connecting leads.

devices we are going to use later have built-in magnets. Keep the meter away from them. When measuring, always adjust the zero-set screw until the pointer reads zero. If you wish, mount your test set in a small metal box which will shield the meter. But whatever you do just make sure you have zero reading before taking measurements.

Learning to use the meter — measuring volts

Practice using the meter to become familiar with its operation. Obtain one flashlight battery. Now insert the red clip lead into the common jack. Insert the other lead into the 10-volt jack. Let the flexible lead on the test set just dangle in space as shown in Figure 205.

The positive terminal of any flashlight-type battery is the small center terminal. Connect the common lead to this terminal. Hold the other test lead to the base of the flashlight battery. The negative terminal of this battery is the base near the center. The meter pointer will now rise and indicate a reading of about 0.15. Our voltage rating will be this number multiplied by 10, or 1.5 volts, which is the voltage rating of a flashlight battery.

We will use this type of battery in our radio control system, hence it is important that we understand this voltage measurement. When such a battery reads less than 1 volt, its useful life, so far as we are concerned, is over. Note that we do not have much leeway in our reading, and this is why that initial zero set is so important. If our meter is not zeroed, we could have a reading of 1.5 when actually the battery might have only 1 volt of electrical pressure.

Some discrepancy may be noted between the reading you get and the voltage value of the battery. This is all right, since we are using a simple test meter. (Make a note of the reading obtained from a new battery of each type used. This will be handy in the future.) In general, all we want to know is that the voltage is in the vicinity of the marked value. In some cases all we will want to know is whether or not voltage exists at various points in our circuits.

Let's take the next step—measuring a higher voltage. Buy a 67.5-volt B-battery (Eveready No. 467 or equivalent in Burgess or RCA). It will eventually be used with the transmitter. Change the test lead from the 10 volt to the 100 volt jack. Again we connect the red alligator clip to the positive (+) terminal and the unmarked lead to the negative (–) terminal. The meter pointer should rise to between 0.6 and 0.8. To determine the voltage when using this scale, you must multiply the reading by 100. Our tolerance using this higher voltage battery will be much greater. You should measure approximately 70 volts.

The final jack for volts is used the same way, except that the scale reading must now be multiplied by 250. Try this scale on your 67.5-volt battery.

A word of caution! If your test leads are reversed, the meter will try to read down scale. Be careful or the meter can be damaged! Also, when you are going to measure a voltage and are not sure of the amount, always start with the highest (250) volt scale first. If the reading is small, then you can try the 100-volt scale. For under 10 volts, use the 10-volt scale.

Measurement of current (milliamperes)

In radio-control systems, the measurement of current is of primary importance. It is by current measurement that we adjust receivers and transmitters as well as many other devices. (*You cannot measure house current with this meter. It will be ruined if you try. Use it only as we show you in this text and you will have no trouble.*) For those

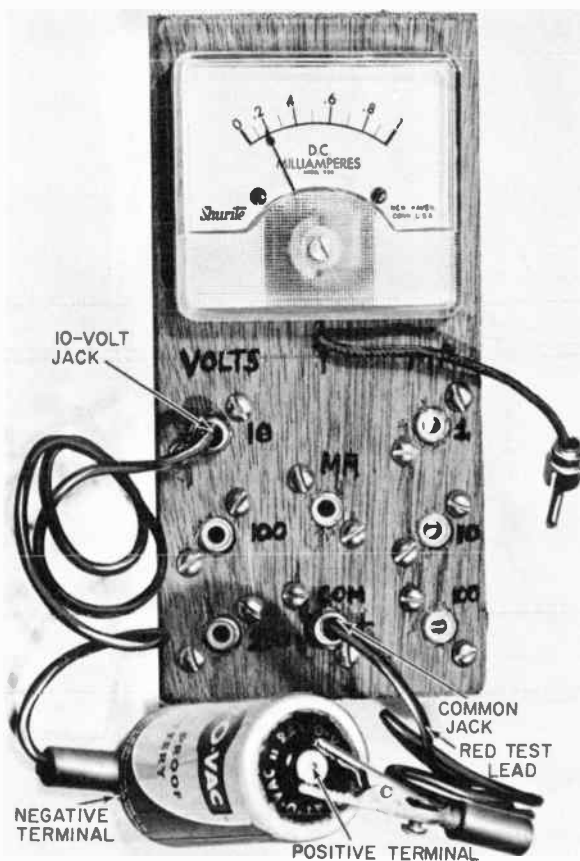


Fig. 205. Front view of the completed tester. A $1\frac{1}{2}$ -volt cell can be used to calibrate the meter.

of you who may have a slight knowledge of electronics, this is a dc-type meter only. It will not measure ac.

The first step is to remove the unmarked lead from the jack on the left-hand side of the panel and insert its plug into the center jack just above the one marked COMMON. This lead will remain here for all of our current measurements. The red test lead will be inserted in its COMMON jack, and it will not be changed.

The lead which we will change to make the various current measurements is the small one coming from just below the face of the meter. Note in Figure 206 how we plugged this lead into the 10-ma jack. Make this connection now.

We are going to use our flashlight battery again, but this time we

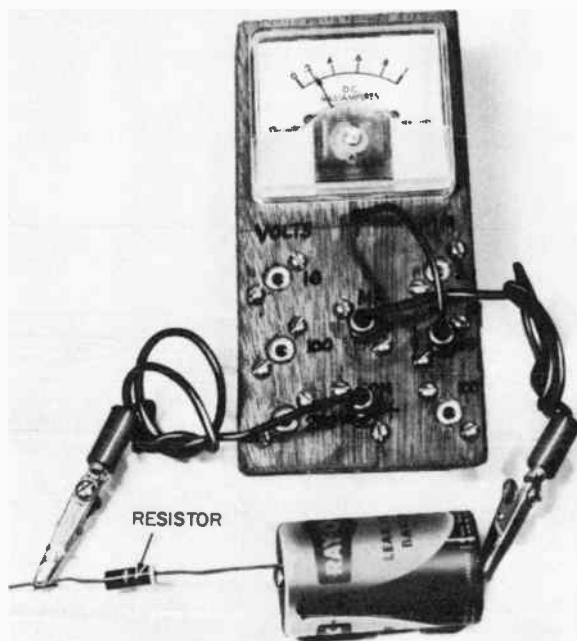


Fig. 206. Test lead used for making current measurements is plugged into the 10-ma jack, while the red lead plugs into the common jack. Remember to connect the unmarked test lead to the negative side of the battery; the other lead connects to a 300-ohm 1-watt resistor in series with the battery.

must use a resistor in series with the test lead. Connect one end of the test lead, as shown, to one end of a 680-ohm 1-watt resistor. Note now that the unmarked test lead is again connected to the minus (—) or negative terminal on the bottom of the battery. We now touch the free end of the resistor to the plus terminal of the battery, and note the meter reading. The meter pointer will rise to about 0.2 on the scale. Multiplying this by the scale factor of 10, we have a current of 2 milliamperes going through the resistor, the meter and back to the battery.

Basic electronic concepts

Several of the ideas we have discussed previously are now in use; the concept of a *circuit*, a path from the minus terminal of the battery through the meter, through the resistor and back to the plus side of that same battery. A *series connection*: That is, the battery is connected to the resistor, the resistor to the meter, and all three are in series. The concept of *current*: we are actually measuring the flow rate of electric current instead of the pressure indicated by volts. When we measure current, we must have our meter in series with the lead to the battery and we will still always want the plus terminal of the battery to connect to the COMMON lead of the test meter.

Thus, in every circuit we have three basic ideas. *Resistance* (electrical opposition to the flow of current); *voltage* (electrical pressure) and *current* (an electrical flow produced by the voltage.)

Measuring higher voltages

Try a measurement with a larger battery—your 67½ volt unit. Before starting to measure, change the meter plug from the 10-ma to



Fig. 207. The test meter can be used to measure resistance.

the 100 ma jack. The higher pressure will cause a higher flow rate (current). We want to have a higher flow rate, but not so great that it will damage the meter. We can limit the current flow with a 3,300 ohm 1-watt resistor. Connect the red lead of the meter to one end of the resistor; connect the unmarked lead to the minus terminal of the battery. Touch the free end of the 3,300-ohm resistor to the plus terminal. The meter pointer will read about 0.22 or about 22 milliamperes of current. Note that the reading is higher even though we have used a much larger *resistance*. The higher pressure (volts) of this battery forced a larger amount of current through the circuit.

Measuring small currents

We have not mentioned the 1-ma jack. This is used when there is very little current flowing. When using this jack, the flashlight battery and the 3,300-ohm resistor, the meter will read about 0.5 milliampere. This is a very sensitive scale and use it with caution, otherwise the meter can be damaged.

The general rules for current measurement are like those for voltage. When you are not sure of the amount of current, use the largest scale, 100 ma. If the reading is small, change to the 10 ma scale. If the reading is still smaller (less than 0.1 on the meter face), use the 1-ma scale. But make certain you always use the ma side of the meter with the leads in *series* with the battery.

Measurement of resistance (ohms)

We can now measure the two big factors in electronic circuits – voltage and current. There is just one more measurement we need to make our testing complete: this is a measurement of ohms. We want to know how much resistance is in a circuit, or in fact, if there is any. When we build a circuit, we want to know if we have provided a path for the electric currents – thus, we measure the *continuity* of the circuit. This is simply a measurement of the path to see how much resistance is in it, whether the path is complete, etc. We never have voltage applied (batteries connected to our equipment) when we measure ohms.

However, we do use a battery in this measurement. But this battery is connected to the meter in another way (Fig. 207). In this test we will need a 1-megohm (1 million-ohm) variable potentiometer. Just ask your radio dealer for a “1-meg pot.” A potentiometer is a variable resistor. With its help we can add more or less resistance to a circuit.

This new component has a shaft which can be turned and, it has three terminals. We connect one outside terminal to the plus side of the 67.5-volt battery. The negative side of this battery is connected to the unmarked test lead, which in turn is connected to the 10-volt jack. The meter plug lead may be inserted in the 1-ma jack or left free.

Connect the red test lead to the common jack, and connect another test lead to the center terminal of the potentiometer. Rotate the shaft as far as it will go in the direction of the terminal which is *not* connected to the battery. This puts maximum resistance in series with the test leads.

Now touch the ends of the two test leads together. Adjust the potentiometer shaft by rotating it until the meter hand reads exactly 1 (full scale). We are now ready to measure ohms and continuity.

What is continuity?

Current will flow in a circuit only if the circuit is continuous. Just as a rubber band is best if it is unbroken, so too will a circuit work if it is complete.

The source of current for a circuit can be a battery. This means that the current will move out of the battery along one wire, through the circuit, and then along another wire back to the battery again. When we check such a circuit for continuity, all we are doing is making certain that the circuit does represent a complete, closed path. An open circuit is one that is not complete.

Sometimes we want a circuit to be open. This happens every time we operate a light switch and turn off the lights. This happens when we key a transmitter. But we have trouble if a circuit is open when it shouldn't be.

A simple way to start checking continuity is to use a light bulb. Let's determine if there is a path through this bulb for electric currents. Connect one lead to the side of the bulb base and the other to the center of the base. Note that the meter hand reads full scale or 1. This means that there is a path.

Obtain three 1-watt resistors from your radio store. These we will use later on, anyway. These should be 1 each of 1,000, 51,000 and 200,000 ohms, 1/2-watt.

Connect the 1,000-ohm resistor between the test-lead tips. Note the meter reading. It is almost but not quite full scale. Try the 51,000-ohm unit. Note that the meter pointer is now farther from full scale. Finally, try the 200,000-ohm size. The pointer barely moves away from zero.

You can now see how we measure the resistance in a circuit. If the meter point deflects full or nearly full, we do have a path and this path has very little resistance. If the pointer does not deflect, this means either that there is no path or that the path has a very high resistance. We will have both situations with our equipment.

We now have added to our knowledge the fundamentals of testing so that we can adjust our radio-control equipment and insure that it is operating correctly. We will also be able to determine causes of troubles and possible equipment failure.

Commercial meters

A final word is about commercial meters. All meters operate exactly this way and the methods of test are the same. The only difference is that the jacks and plugs, or switching, for measuring voltage, current and resistance may be different. The meter scales will also be different but if you can use this little test meter, you can use any other, once you understand the mechanics of it.

the basic transmitter

WE are now ready to start construction of the first component of our radio-control system, the basic transmitter. There are several reasons why it is logical to start with this item. First, it is not too complicated to build, and we want more construction experience before we get to more complex projects. Second, the basic transmitter is easy to adjust, and it is also easy to determine when it is operating correctly. Much of the knowledge we have gained concerning our test meter can be used in adjusting this piece of equipment. Third, we will need to have a means of sending a signal when we work on our basic receiver, and what better item to do this than the transmitter itself.

Our transmitter can be operated on any of the five channels simply by getting a crystal for the channel of your choice. Which channel you choose won't affect the overall performance of either this unit or the receiver. The choice is strictly arbitrary and is left up to you.

If you would rather buy than build, remember that this particular transmitter is so designed that we can add to it as our system expands. However, any standard transmitter and receiver may be used in the single-channel systems to be described later on.

The circuit is a simple crystal oscillator which uses a capacitive feedback system for stability and power. The decision to use the 6-volt tube rather than battery types was based on the planned use of a vibrator power supply later on and the adaptability of this tube to operation from a 6-volt storage battery. In this first stage, however, dry-battery operation will be used.

The first step is to drill the chassis according to the template of Fig. 301. More holes are shown than we will use for this first transmitter; some will be used as we expand.

The second step is to mount the tube socket so that, as you look at it from the bottom (Fig. 302), pins 1 and 7 will be farthest from the front lip. You should have the tube socket on the left-hand side as you look down.

Next mount the crystal socket and after this, the two 2-lug terminal strips. One is mounted below the chassis and the other right on top of the chassis above it. Now mount the one-terminal solder lug, using the tube socket screw and nut nearest pins 1 and 7.

We are now ready to begin wiring and this is done in the following steps:

1. Connect a 10-inch length of flexible, insulated wire to pin 3.
2. Connect a 10-inch length of flexible, insulated wire to pin 4. (Twist these two wires together and run out to the left of the chassis as shown in Fig. 303). These wires will connect to our filament A battery. Either lead may connect to either terminal.

3. Using a small length of bare No. 20 gauge wire, connect pin 1 of the tube socket to the nearest crystal socket terminal. (Always make sure that bare wires do not touch other wires on the chassis.)

4. Place the 390,000-ohm resistor in position so that one lead connects to pin 1 of the tube socket and the other end connects to terminal B of the one-terminal solder lug (see Fig. 302).

Solder these connections in place. (Do not use too much solder when soldering to the tube socket pins, as the solder will run down and prevent the tube from seating in the socket. Make certain that you do have good soldered connections, however.)

5. Connect leads from the two 100 μf capacitors together and twist them right up to the capacitors themselves. Snip this joint so that it is about $\frac{1}{2}$ -inch long and solder it to the other crystal socket terminal.

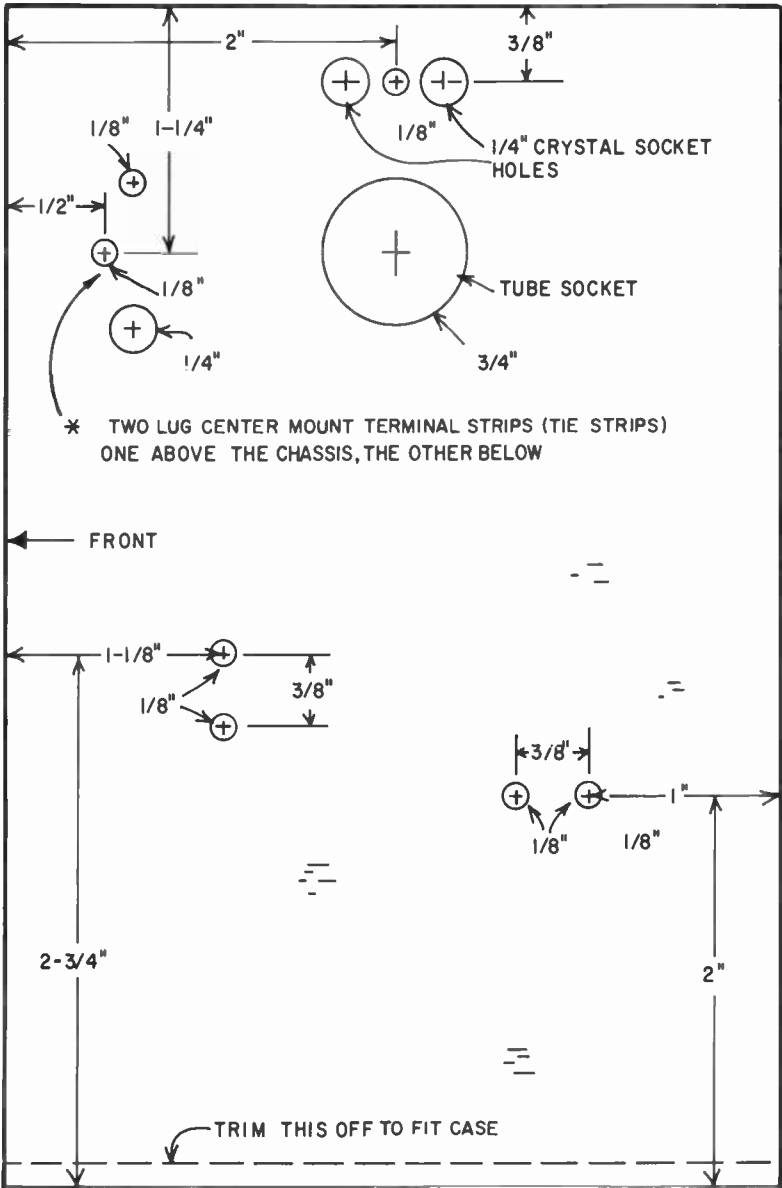
6. Position these capacitors so that the free lead of one goes to the left-hand terminal of the upper solder lug (Fig. 302) and the free lead of the second goes to terminal B of the one-terminal solder lug.

7. Connect one end of the 100- μh choke to terminal A of the lower solder lug. Connect the other end to the left-hand terminal of the upper terminal strip. (A terminal strip is also called a tie strip.)

8. Using a short length of bare No. 20 wire, connect pins 2, 5 and 6 of the tube socket and then run this lead from pin 5 to the right-hand terminal of the upper solder lug.

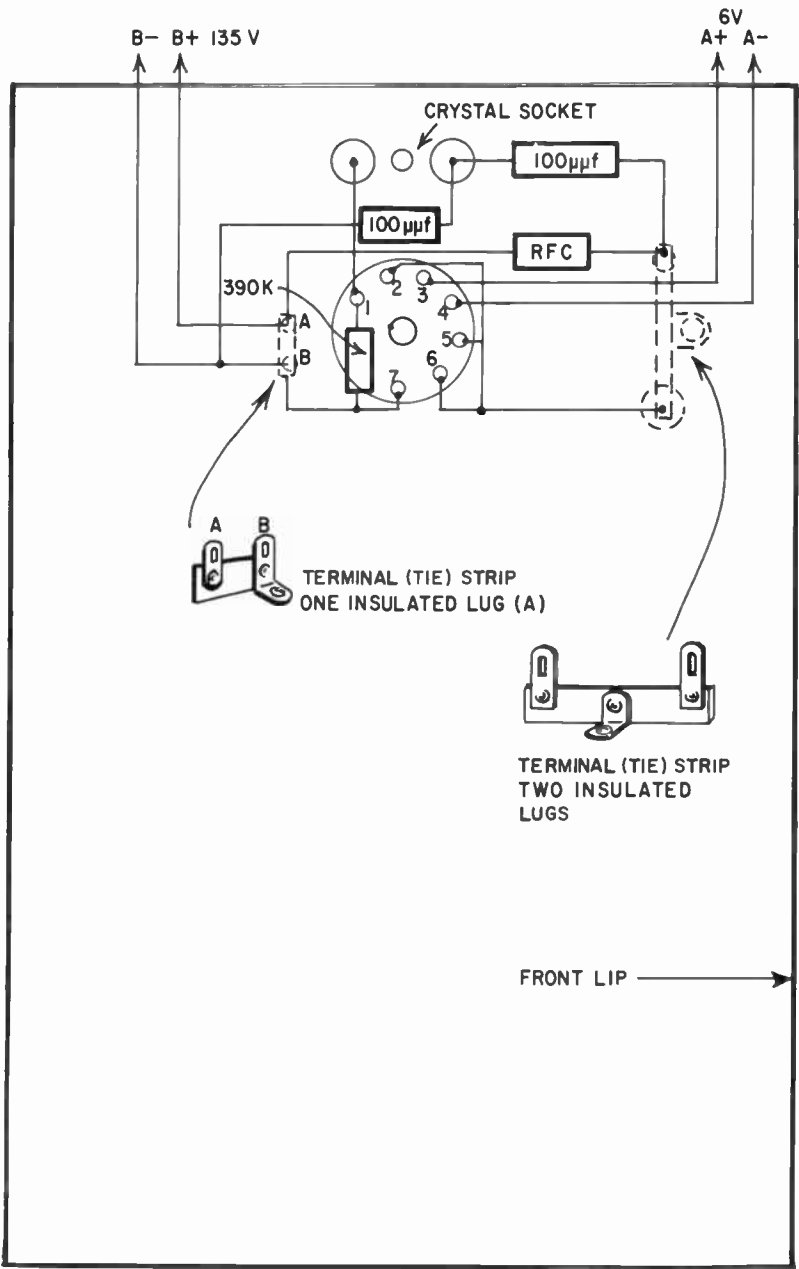
9. Take a 10-inch length of insulated wire. This wire should have plastic- or cloth-type insulation and it is desirable that it be red in color. This lead will connect to the plus (+) terminal of our B-battery and may be so marked. Solder this wire to terminal lug A.

10. Wind the tuning coil (L1) using No. 18 enamel insulated wire. Use a $\frac{5}{8}$ -inch diameter coil form (bobbin) and wind 12 turns. Bend the two end leads down, cut them 1 inch long and scrape off the enamel.



ACTUAL SIZE
CHASSIS DRILL TEMPLATE — TOP VIEW

Fig. 301. Chassis template for the basic transmitter.



BOTTOM VIEW

Fig. 302. Parts layout for the basic transmitter. The vacant space remaining will be used when we add more circuits to the transmitter.

11. Mount this coil onto the 2-terminal tie strip on top of the chassis. Let the two ends of the coil protrude through the solder lugs at least $\frac{1}{4}$ inch. See Fig. 305.

12. Mount the 5-20 μf variable tuning capacitor. Bend its leads so that they also fit through the eyes of the tie strip terminals. Solder all connections. Check to make sure that you have not accidentally used so much solder that one or the other terminal is now connected to the chassis through a blob of solder.

13. Connect the left terminal of the upper terminal strip, Fig. 303, to the left terminal of the strip in Fig. 305 with a short piece of insulated wire. Solder both connections.

14. Connect the right terminal of the upper strip, Fig. 303, to the right terminal of Fig. 305 with a short piece of bare wire. The wire will pass through the large hole in the chassis. It must *not* touch the chassis. Solder both connections.

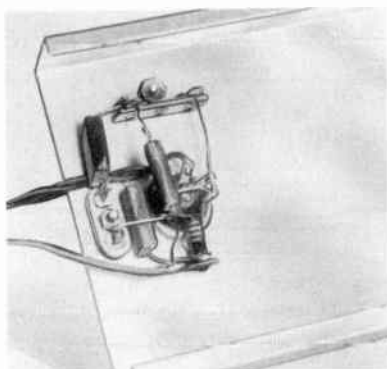


Fig. 303. *Illustration showing mounting of the crystal socket.*

15. Also check the solder lug located underneath. We want to avoid a blob solder connection to the chassis. (Terminal B is connected to the chassis through the screw going through its mounting lug).

16. Connect a short length of bare wire from pin 7 of the tube socket to terminal B under the chassis and then run a 10-inch length of another colored wire from terminal B out alongside the red lead. This connects to the B-minus terminal of the B-battery.

17. Recheck all connections to insure good solder joints. Fig. 304 is a pictorial of the transmitter. You can use this illustration to make sure you have all parts connected as they should be. Insert the tube and crystal and we are now ready to adjust and test our basic transmitter.

Testing and adjusting

Before testing our unit, we will need another item of test equipment

besides our test set. This is a small 6-volt pilot light (Mazda No. 47) connected to a two-turn loop, which we can make from a piece of insulated wire such as we used for the battery leads. The two turns should be 1-inch in diameter, close together. Solder the free ends of the wire to the base and side of the lamp. Now place this loop over the transmitter coil so the bulb is upright and the loop is around the right-hand end of the coil.

Now connect the unmarked lead of your test set to the red lead from the transmitter and connect the red marked lead of the test set

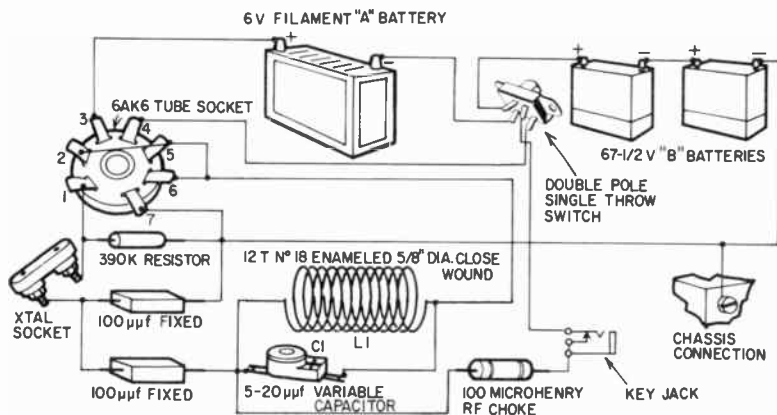


Fig. 304. Pictorial wiring diagram of the basic transmitter.

(common) to the plus side of a 135-volt battery. This voltage is obtained by connecting two 67½-volt batteries in series. Adjust your test meter to measure ma on the 10-ma scale.

Connect the two filament leads to the terminals of a 6-volt battery and the last lead from the transmitter (chassis or ground) to the minus side of the B-battery.

The meter pointer will rise as soon as the tube gets warm. Immediately insert the alignment tool end in the slot on the variable capacitor (C1) and start turning it slowly, watching both the meter and the pilot light. You will find a spot where the light glows. At the same time the pointer of the meter will drop back toward zero with a pronounced dip. Further rotation in either direction will cause the light to go out and the meter pointer to rise.

With the light glowing, turn your attention to the meter. Carefully turn the alignment tool, first in one direction and then the other, noting the meter reaction. You will find that as we turn in one direction, the hand dips down and then rises abruptly — kicks out — and the light goes out. As you rotate the capacitor in the other direction, the pointer rises but more gradually. This is the side we

want. We want to adjust the tuning capacitor so that the *meter hand is just off zero on the gradual-rise side.*

Now make a keying test by disconnecting the transmitter lead to the minus terminal of the battery and then touching it to the terminal rapidly several times. If you have the transmitter adjusted correctly, the pilot light will glow each time you do this. If you are too near the dip, the light may or may not glow. Readjust the tuning capacitor, if necessary, until the light glows with each tap of the wire on the negative battery terminal.

What to do in case of trouble

1. Examine the tube visually. You should see it glow inside. If it doesn't, recheck your filament connections and leads.
2. Check all connections to the B-batteries and to the test meter.
3. Check your pilot light with a continuity check by unsoldering one of the wires. Have the 6AK6 tube tested.
4. If there was no indication of a dip, then spread the turns of the coil (L1) apart, a little at first and then more until there is about

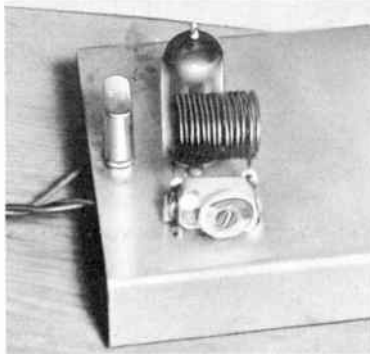


Fig. 305. Positioning of crystal on top of chassis. The coil and capacitor can be seen to the right of the crystal.

1/16-inch spacing between all turns. If there is still no dip, wind a new coil and add one or two turns. You may then have to spread these turns. (This measure is "just in case" advice. As designed, the coil and capacitor will produce the dip.)

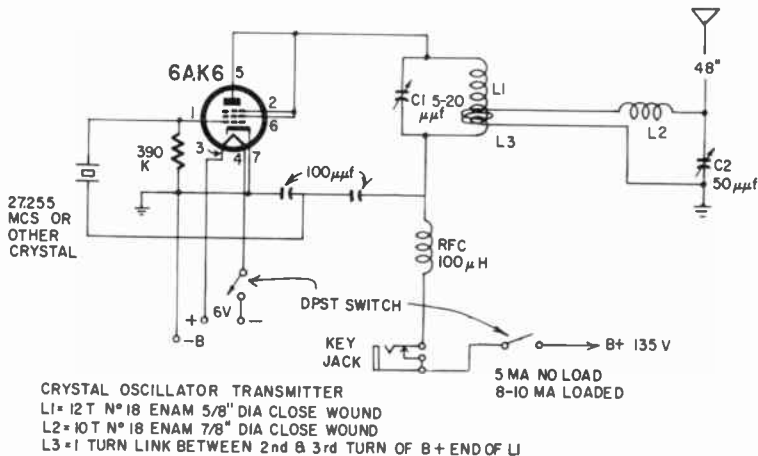
5. In case of no meter reading, with the tube glowing, and the wiring checked out with no blob solder chassis connections, then remove the test set leads from the battery and red transmitter lead. Connect the red transmitter lead directly to the plus terminal of the battery and connect the minus lead to its terminal. Adjust the test meter to measure volts (250). *Make sure that the meter phono plug is not left in the 10-ma jack.* Now connect the unmarked test lead to the chassis and touch the common (red) lead to either of the two-terminal solder lugs that the coil (L1) is connected to. The meter

should read about half-scale. If not, turn the chassis over after disconnecting all batteries, remove the 100- μ h choke and test it for continuity. If the choke is open, replace it. If battery is bad, replace it.

6. Try another crystal. The position of the crystal on the top of the chassis is shown in Fig. 305.

Connecting to antenna and keying

With the transmitter operating, you can connect it to an antenna so that it will send the signal out into space. Also, you must provide



parts for the crystal oscillator transmitter

Resistor: 1—390,000 ohms, $\frac{1}{2}$ watt.

Capacitors: 2—100 μ f mica; 1—5-20 μ f ceramic variable; 1—50 μ f air variable.

Miscellaneous: 1—crystal holder and 27.255-mc crystal; 1—6AK6; 1—7 pin tube socket;

1—100 μ h choke coil (rfc); 1—key jack; 1—dpst toggle switch; 1—6-volt filament "A" battery; 2—67 $\frac{1}{2}$ -volt "B" batteries; spool of No. 18 enameled wire; 3—soldering lugs; hardware; chassis; pilot light (Mazda No. 47); roll of pushback hookup wire; solder.

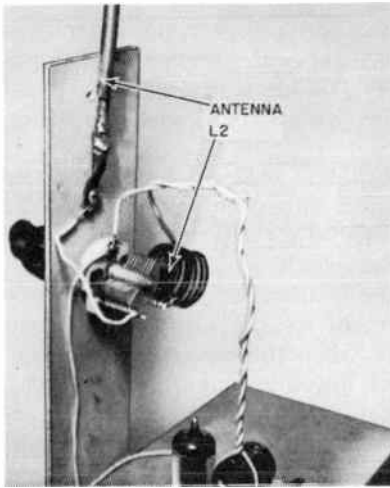
Fig. 306. Circuit of the crystal oscillator transmitter.

means of turning the transmitter on and off, and a method of keying so that we can send commands.

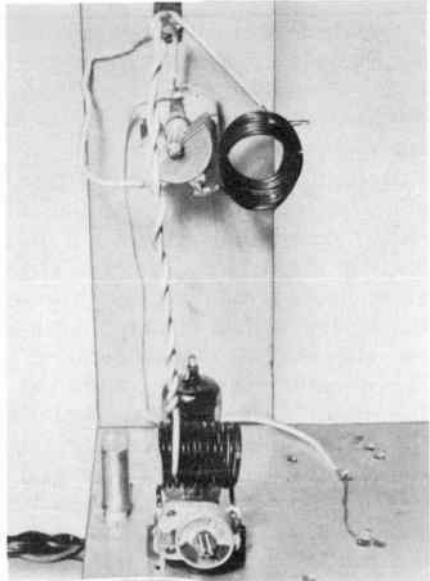
We must now obtain a 50- μ f air variable capacitor. It may have a screwdriver slot for adjustment or it may have a long shaft. But it must be an air-dielectric type which has plates you can see. If it has a shaft, cut a slot in it for alignment-tool adjustment.

Next, wind another coil (L2) using No. 18 enamel wire. (Coil winding data is given in Fig. 306.) We want a ten-turn coil whose diameter is $\frac{7}{8}$ -inch. Connect one end of this coil to the fixed plates of the capacitor and then mount the two on a small strip of plywood or pressed wood. (Fig. 307).

Take about a 14-inch length of flexible insulated wire such as used for the transmitter battery leads and make a one-turn loop (L3)



a



b

Fig. 307. (a) One end of a 10-turn coil is connected to the fixed plates of a 50- μ f variable capacitor. (b) The junction of these two components is joined to the antenna.

in the center. Twist the two ends together as shown in Fig. 307.

Now connect one end of the loop to the free end of the coil (L2) and connect the other end of the twisted line to the rotating plates of the capacitor. (A lug is provided on the capacitor for this purpose). Connect a second wire from this same rotary-plate lug to the chassis of the transmitter.

Make an antenna 48 inches long out of piano wire, aluminum tubing or a telescoping automobile antenna. Connect the antenna to the fixed plates of the air variable antenna capacitor. Turn the capacitor plates of C2 so that they are engaged about one-quarter of full mesh. The loop of twisted line is now inserted between the second and third turns of the transmitter coil, L1.

Next we turn our attention to the switch and key. Buy a double-pole single-throw toggle switch, and an earphone plug and jack. On the switch will be two lugs (as we look at it from the back) on each side. Connect a wire from the free end of the rf choke to one lug of the key jack. Connect a wire from the other jack lug to the bottom terminal of the switch (see Fig. 304) and a third lead about 6 inches long to the lug just above this. This last lead will now go to B-plus.

Our double-pole, single-throw switch is going to be used as an on-off switch for the A- and B-batteries. Fig. 304 shows how this is done. One section of the switch is inserted between the negative terminal of the A-battery and pin 4 of the tube. The other section of the switch is inserted between the plus terminal of the B-battery and the key jack.

Obtain a normally open pushbutton switch (this could even be a doorbell-type switch). If the contacts are exposed, mount it in a small box and connect two 3-foot lengths of flexible insulated wire to its terminals. Connect the other ends of these two wires to the keying plug. Insert the plug into the jack.

Reconnect the test set between the B-plus lead of the transmitter and the plus battery terminal. Connect the minus lead from the switch to the minus terminal of the B-battery. Connect the two filament leads to the filament battery. Turn the switch on if the tube doesn't glow. Replace the pilot light around the transmitter coil. Now depress the keying switch. It may take a moment for the tube to get warm but after it does, the light should glow when the button is depressed. If it doesn't, retune the transmitter coil, holding the key switch closed. It shouldn't glow brightly, but the glow should be discernible. Key the transmitter by depressing the button switch. The light should come on each time it is depressed.

The transmitter is now ready for operation, but we won't put it in a case yet. Let's learn a new term before we go on. When we depress the button switch and release it, we say we have sent a "pulse", meaning a pulse of energy. If we depress the button switch twice in rapid succession and release it, we say we have sent two pulses, etc.

This transmitter will now operate *any* commercial-type carrier-operated receiver. If you have a friend who has one, let him tune his receiver to your transmitter and try it out. We have not really adjusted the antenna using our meter and so the distance we may transmit will not be as great as it will be when we do this. But we will be able to transmit far enough for the immediate developments ahead.

Don't rush out to buy a cabinet for the transmitter just yet. We are going to make a few additions so the transmitter cabinet is a decision that can be postponed for a little while.

the basic receiver

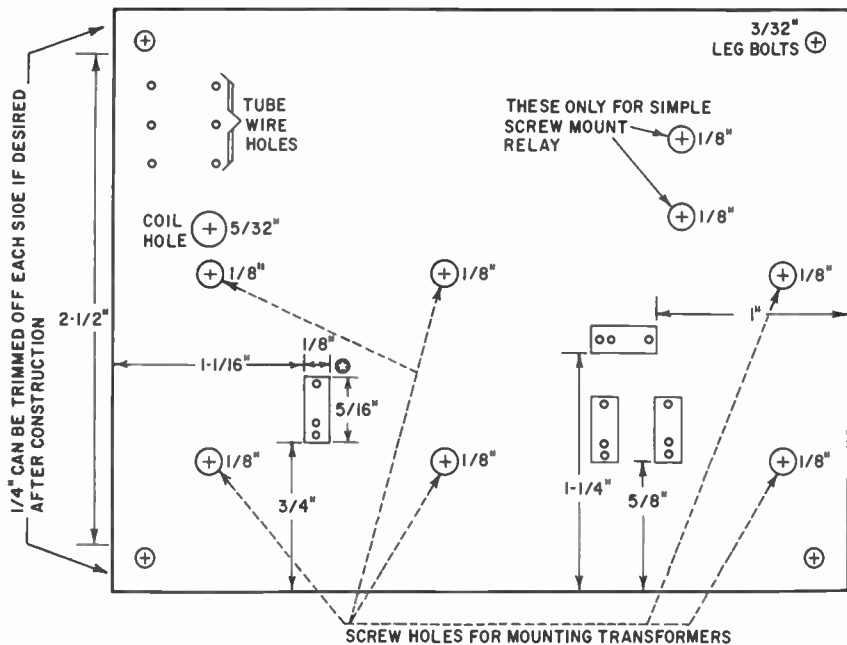
You have probably glanced ahead and are now shaking your head over the thought of constructing this “basic” receiver. *It's not as bad as it looks!* Actually, this receiver was designed so that you would have the least trouble getting it to operate correctly, and have a set that would give you long-range and reliable, trouble-free performance.

Also this receiver can be operated with our basic transmitter to start; then as we expand and enlarge our transmitter we will be able to expand and enlarge this receiver also, so that from a carrier-only type of operation we can change to tone and then to multi-channel operation for our final effort. The only big requirement in its construction is going to be your ability to make good soldered connections and to follow the steps in construction exactly. We will be soldering fine wires to much smaller sockets than we used in our transmitter. Remember to keep your soldering-iron tip clean and bright, and also we suggest you obtain a roll of multicore 60/40 No. 16 gauge radio solder. This solder is thin and has plenty of material in its internal construction to make soldering easy. Don't use any more solder on the joints than you actually need to make a good firm electrical connection.

How does it work?

This receiver in its first form consists of a standard superregenerative detector. Several tube types are applicable: the 1AG4, 6007, 5672 and the one we recommend as giving the best performance, the CK5676. This tube is connected directly to the antenna tuning coil and thus receives the radio signals first.

This type of detector is a peculiar little devil because, when it is not receiving signals, it hisses and sputters and generally makes quite



⊕ ALL TRANSISTOR SOCKETS HAVE SAME DIMENSIONS

⊕ INDICATES HOLE NUMBER ALONGSIDE IS DIAMETER

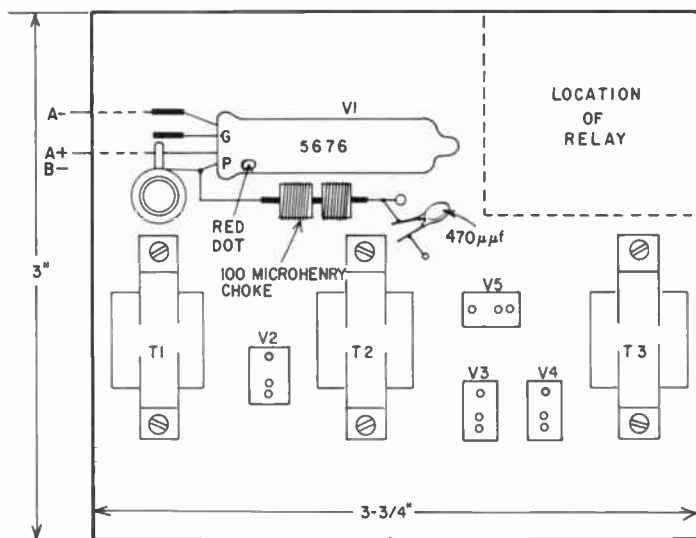


Fig. 401. Template for constructing the receiver base. (Template is not to size.)

a bit of noise. When a signal is sent to it, it quiets down and purrs softly, while it amplifies the signal and sends it along to the next part of the receiver.

We take advantage of its nasty temperament (without its knowing) by so designing the rest of the receiver that the little transistors following build up and increase the noisy hiss until it becomes a roar

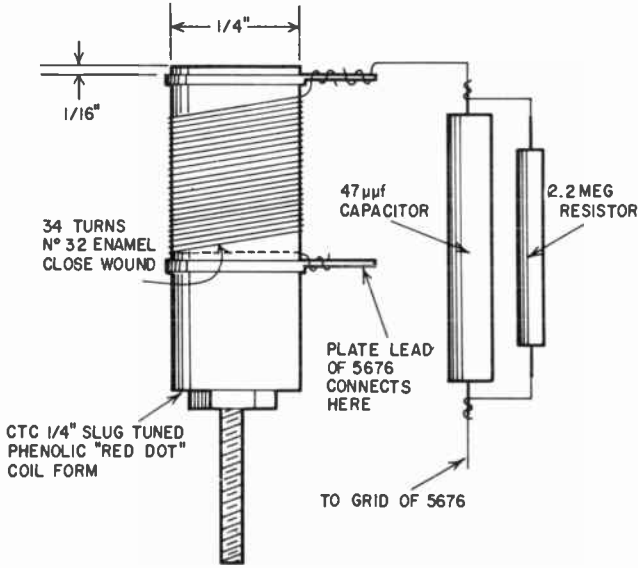


Fig. 402. Winding the coil. The winding begins at the open end on top.

— a roar so loud that it just simply paralyzes a little transistor, whose sole purpose is to operate a switch (called a relay).

Well, you can guess what happens. As long as this superregenerative detector does not have a signal sent to it, that last little transistor is paralyzed, and the switch it is supposed to operate (to turn on power to motors or steering devices) just doesn't close and nothing happens. When a signal is transmitted and the detector quiets down, the little transistor regains its faculties, does what it's supposed to do and closes the switch! Motors turn and we control our model.

So it isn't so complicated after all. All we have to do is connect the tuning coil to the tube, the resistors to the transistors and the relay to the transistors, etc.

Get a couple of pieces of cardboard 6 or 8 inches wide by 10 to 12 inches long and mark all of your component values on it by a number designating the part, allowing enough room to fasten on the units. When you make a purchase, fasten the part to the board according

to its number value. Then, as you start construction, you can identify each part easily, quickly and accurately.

Our first step is to construct the base according to the template of Fig. 401, Make the cut outs as indicated and drill all holes shown to the size indicated.

Now put the chassis aside momentarily and wind 34 turns of No. 32 enamel wire on the coil form. Start the coil so that the winding begins near the open end as indicated in Fig. 402. Scrape the ends of the wire and solder them to the two lugs provided with the form so that the winding is neat and tight.

The next step is to mount the coil on the perforated chassis board as shown in Fig. 403. Note that a solder lug has been placed under the nut on the bottom and faces inward. Using lengths of bare

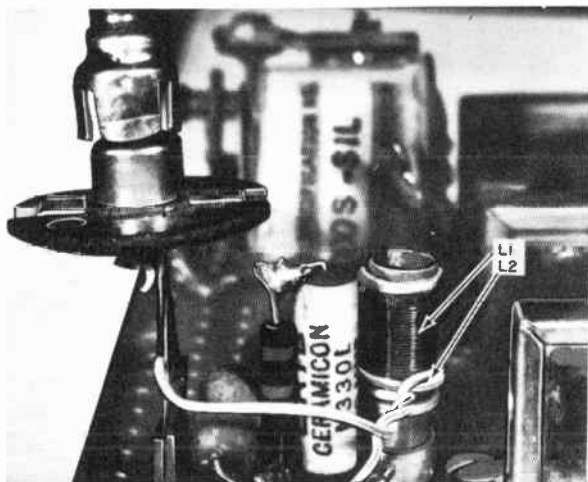


Fig. 403. The coil is mounted on the perforated chassis board. The unit at the left, standing on a little platform, is the antenna connector.

No. 20-gauge wire, put in the B-plus line (bottom of Fig. 404), the B-minus line (top of Fig. 404), and the tube connecting leads (top right of Fig. 404). Note that the tube connecting leads are bent up and through the perforations on the chassis base. Fig. 405 is a layout of the parts below the chassis.

The CK5676 does not require a tube socket. As shown in Fig. 406, three of the leads are soldered to the wires you had previously looped through the perforations in the chassis. The remaining lead is soldered to a terminal on coil L1.

Now mount the transistor sockets in the pegboard chassis and make certain that the No. 3 pin (as designated in Fig. 405) is nearest the center of the chassis. Most sockets have a small metal retaining ring

which holds the socket in place. It also helps to use a little glue around the edges.

Fig. 407 is a photo of the components—mounted, wired and soldered. Compare this picture with the drawing shown in Fig. 405.

Note the considerable usefulness of the pictorial. It will help you position the parts. You can also use the pictorial as a guide for connecting the parts if you are not too familiar with reading circuit diagrams.

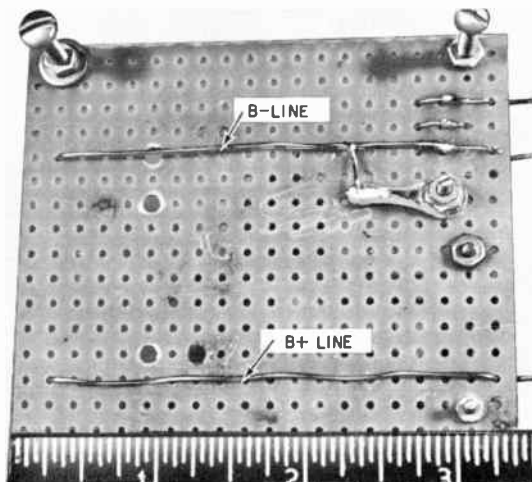


Fig. 404. The bare wire across the bottom of the base is the B-plus line; long wire across top is B-minus line; two short bare leads at top right are tube connecting leads.

We can now mount the three transformers. Place them so that the red and blue leads of each are on your left as you look at the chassis from the top. Run the leads down through the perforations. Twist the leads from each side of the transformer together and position them as shown in Fig. 408. This is a view looking down on the top of the chassis.

Place the 2.2-megohm resistor and the 47- μ f capacitor side by side so that their leads are parallel. Twist these leads on each end and then snip them off so that you have only $\frac{1}{2}$ inch left on each end. Solder the twisted wires and then bend them at right angles to the parts. Solder one end to the top lug of the coil form as shown in Fig. 402 and solder the bottom end to the center upright of the tube wires. The coil, resistor and capacitor should look like Fig. 403, except that your capacitor may not be the exact type that is illustrated in the photo.

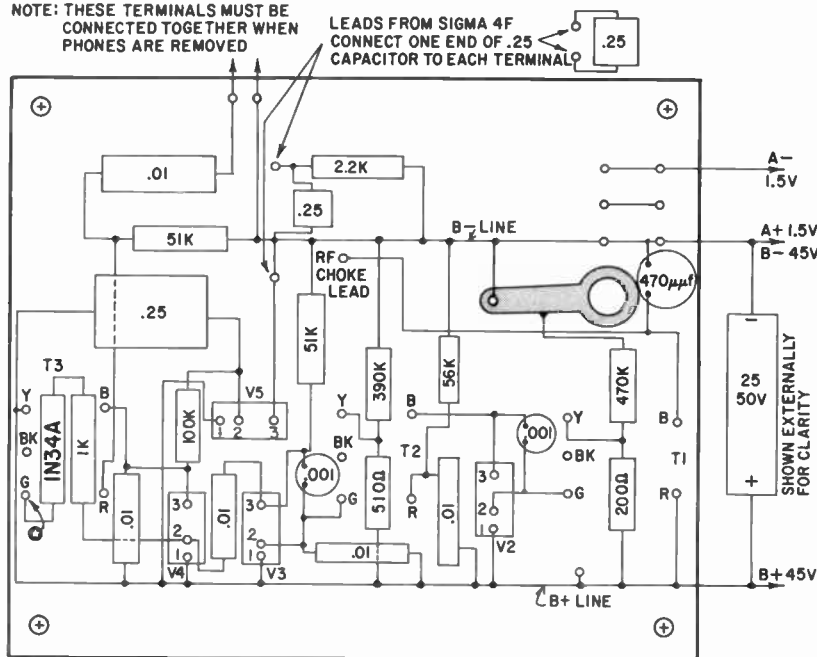
Now connect one end of the 100- μ h choke to the bottom lug of the

coil. Position it as shown in Fig. 406. The other end of the choke is bent to a right angle and run down through the nearest perforated hole in the chassis. Turn the chassis over and cut this lead off so that it extends only about $\frac{1}{8}$ inch below the chassis.

When bending the leads of components be careful to do it in such a way that you don't damage the parts. Do not hold the radio component in your hand and then bend the leads. Hold the lead with the flat portion of a pair of long-nose pliers. You will now be able to make a nice right-angle bend by pushing down on that part of the lead that extends away from the pliers.

NOTE: THESE TERMINALS MUST BE CONNECTED TOGETHER WHEN PHONES ARE REMOVED

LEADS FROM SIGMA 4F CONNECT ONE END OF .25 CAPACITOR TO EACH TERMINAL



COLOR CODE FOR TRANSFORMER LEADS

B- BLUE BK- BLACK
R- RED G- GREEN
Y- YELLOW

.01 CAPACITORS ARE ELECTROCAD R374
ALL RESISTORS ARE 1/2 WATT

⦿ COLOR BANDS
NEAREST LEAD CONNECTED
TO GREEN TRANSFORMER LEAD



Fig. 405. Parts layout of the components mounted beneath the perforated chassis board. The CK5676 (V1) is mounted above this board. V2 and V3 are 2N107 transistors. V4 and V5 are CK722 transistors. After you have completed the wiring, check it against this pictorial.

Connect one lead of one of the 470- μf capacitors to the end of the choke nearest the relay. This choke can be seen in Fig. 406 in the

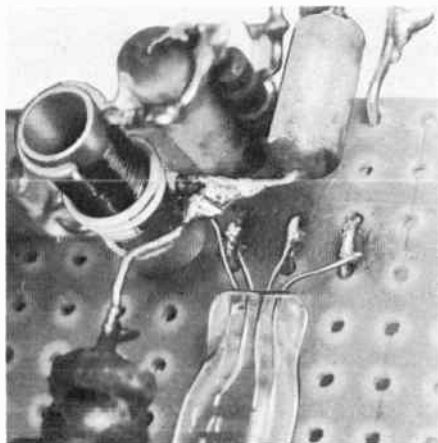


Fig. 406. Three CK5676 tube leads are shown soldered to the wires looped through perforated holes in chassis base (Fig. 404). The 100 μh choke coil is parallel to the perforated board and is shown to the left of the tube.

lower left-hand corner and the position of the 470- μf capacitor is shown in Fig. 401.

Push the second lead of this capacitor down through the base so that it comes out alongside the B-minus line. Solder this lead to the B-minus line. While the chassis is turned over, connect a short

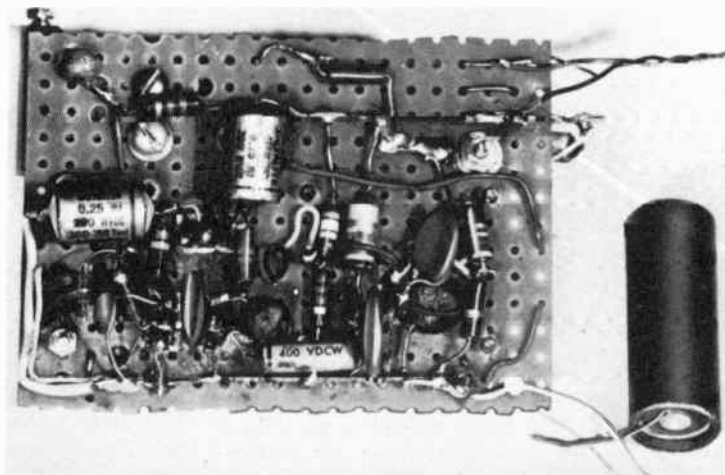


Fig. 407. Under-chassis view of the perforated board shows the components mounted and connected.

length of bare wire between the solder lug under the tuning-coil nut and the B-minus line (See Fig. 404).

Adjusting and mounting relays

Before mounting the relay, we will adjust it. We note from Fig. 409 that either of two types may be used: the Sigma 4-F, which we recom-

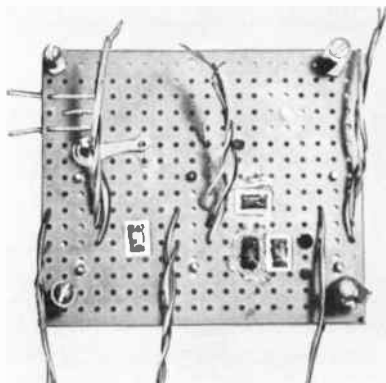


Fig. 408. Top view showing how twisted transformer leads are positioned on chassis.

mend if you are a beginner, or the smaller types such as Gem, Jewel, etc., which have a coil resistance of at least 5,000 ohms.

Let us spend a moment here discussing the two types of relays. The

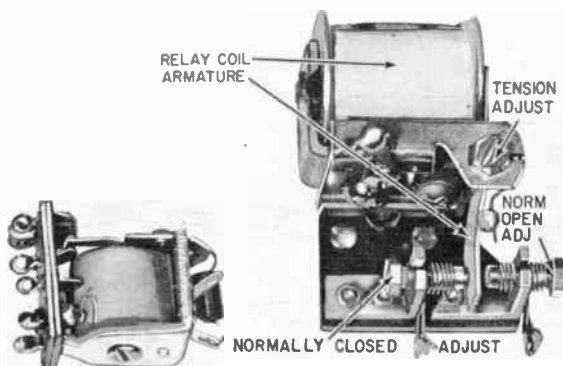


Fig. 409. Larger relay shown (Sigma 4-F) is easily adjusted and less subject to vibration than the smaller one.

Sigma 4-F is heavier and larger but it has three easily accessible points of adjustment. It also has a balanced armature, which means that it is less subject to vibration than those which have the moving armature pivoted at one end. The smaller types are lighter by far, but adjustments are difficult, and most of these have only one adjustment that

can be easily made. When adjusting a relay you will quickly learn that three adjustment points are desirable: You must *bend* the contact points. This could result in a damaged or inoperative relay unless you know exactly what you are doing.

In a relay, the "normally closed" adjustment controls the spacing of the armature from the pole piece which is the iron core of the coil. The "normally open" adjustment controls the spacing of the armature from the pole piece when the coil is energized. The spring tension adjusts the power it takes to cause the armature to move. All three must be adjusted correctly for reliable operation.

To adjust the relay, we will use our basic test set (Fig. 410). Note that we have inserted the leads so that we can measure current. We will use the 10-ma scale. We will also need a 50,000-ohm potentiometer and our 67.5-volt battery. The lead from the mA phono jack

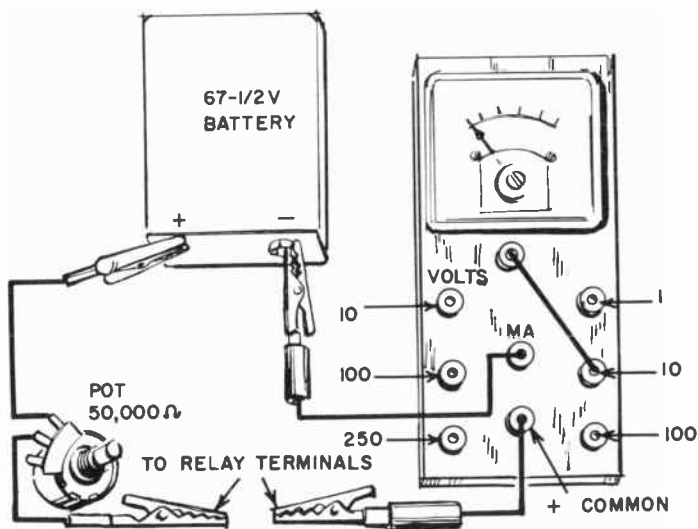


Fig. 410. Basic test set with leads inserted to measure current.

on the test meter connects directly to the minus terminal of the battery. The plus terminal of the battery is connected to one end-terminal of the potentiometer. The center terminal of the potentiometer will be connected to one relay wire or coil connection (through a test lead) and the other coil connection will be attached to the common terminal of the test meter. Make sure that the short lead of the meter is plugged into the 10-ma phono jack on the right side of the panel.

As you look at Fig. 410, and before you make all connections, the shaft of the potentiometer must be rotated *counterclockwise*, or in the direction of the unconnected terminal as far as it will go. We are now ready to make our adjustments.

Adjusting the Sigma 4-F relay

1. Disconnect the common lead from the test meter. Obtain a pack of book matches. Adjust the normally closed contact with a screwdriver until the cover can be slipped down between the armature and the pole piece of the magnet. This is a spacing of about 1/16 inch.

2. Now adjust the normally open contact until you can just slide a piece of typewriter paper between the contact itself and the armature.

3. Connect the test meter and battery to the relay as previously discussed. The meter pointer should hardly rise from zero. Slowly rotate the potentiometer shaft *counterclockwise*, watching the pointer. When the hand rises just above the 0.1 scale reading (or to about 1.3 ma), the armature should close toward the pole piece. If it does not, carefully adjust the spring tension by turning the screw on top of the armature frame in a direction such that the coil spring tends to unwind.

4. Now recheck this adjustment by backing off the potentiometer, letting the meter reading decrease and then slowly bringing it back up to just over the 0.1 reading. It may take several tries and adjustments but this is a very necessary procedure. Keep at it.

5. Now start from zero ma once more and very carefully rotate the potentiometer shaft *while you watch the relay armature*. Stop the rotation the instant the armature pulls in. Now very slowly rotate the potentiometer shaft *clockwise*, watching the armature. Stop the instant the armature opens. The reading on the meter should be just less than 0.1.

6. The final adjustment consists of rocking the potentiometer back and forth slowly while adjusting the spring tension and the normally open and normally closed contact spacing, until the armature closes *every time* the meter pointer is *halfway* between the 0.1 and 0.2 reading, and opens every time the pointer drops to 0.1 or just under 0.1 on the scale.

Adjusting the Gem or Jewel-type relay

These smaller relays do not have a screw-type adjustment for the two fixed contacts. The tension may be set by using a screwdriver to raise or lower the bottom end of the spring lug which is fastened to the frame. This lug must be bent up or down, or the spring itself may be lengthened or shortened as necessary. Most of these relays are factory-adjusted to open and close at just about the readings specified, so check before you begin making adjustments.

Our experimentation with the AR21 showed that the spring tension in the unenergized position of the armature was less than desirable and that the relay was then so subject to vibration that operation of the steering devices was erratic. Also, because of the type of pivot mounting used, the armature tended to stick under some conditions. Therefore, if this relay is used, make sure that it operates properly.

Check it just the way we did the Sigma before installing it on the receiver base.

If necessary, the drop out value of current can be increased to insure reliable operation. Drop out is the amount of current present when the armature just opens. A larger drop out current always results when a higher spring tension is used. The spacing of the contacts may then be adjusted to keep the pull in value of current close to the 0.15 or 1.5 ma value.

Take your time and be patient in adjusting your relay. This is a most important device and its operation determines the entire success of your control system. Make a note that later, after you have constructed control systems, if you are ever in doubt about erratic operation, recheck the pull in and dropout currents of the relay.

It is also wise to provide a dust cover for the relay to prevent dust or moisture from corroding the contacts and thus causing trouble. This cover may be a small plastic box. *Never file* relay contacts. Use a piece of paper and, holding the armature with your fingertip, run it back and forth several times between the armature and the contacts. (The direction of pressure on the armature should be such that it pushes the paper against the fixed contact). Or buy a tool called a relay burnisher to clean your contacts.

Testing the contacts

There is one more test we should make on the relay, and we can make this test even before the receiver is completed. This is a continuity check, to determine whether the relay is actually closing the control circuits. Recheck the method of setting up the test meter to measure continuity. After you have done this, connect one lead of the meter to the frame of the relay and the second lead to the normally open contact. There should be no reading. Now close the armature gently with your fingertip. The meter should read full scale. Release the armature.

Keeping one lead on the frame, move the second lead to the normally closed contact. The meter hand should rise full scale. Depressing the armature should break the circuit, and the meter hand should return to zero. Release the armature, and the meter hand should rise to full scale again.

Later on, after the receiver has been constructed, you can connect the test meter in exactly this same way and then, when it is connected across the normally open contacts and you transmit a signal, the meter should read full scale. This gives you a positive method of checking to determine whether the relay is actually performing as it should under operating conditions. Should you fail to get the reading required, clean and check the contacts first. Make certain that there is no dust or any other foreign particle between the points preventing completion of the circuit.

Mount the relay in the position shown in Fig. 411.

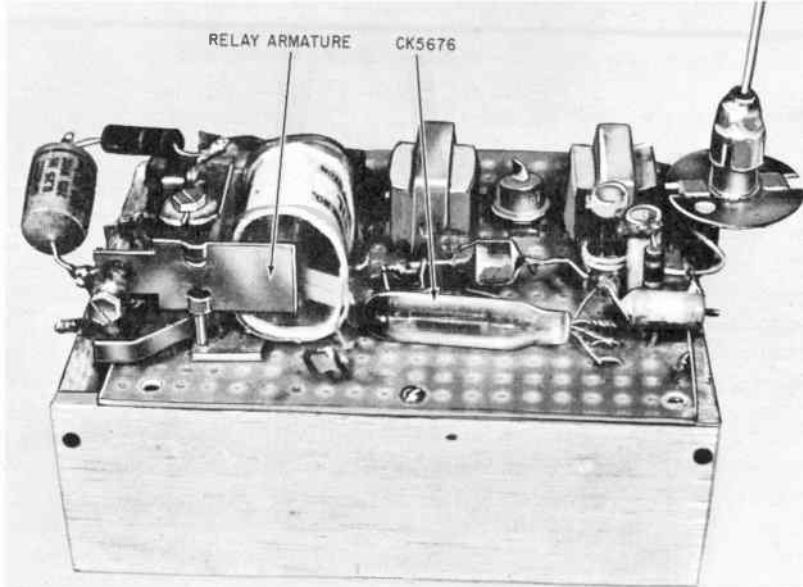


Fig. 411. Top view showing relay mounted on chassis. Note the positioning of CK5676 tube and transformers.

Receiver wiring

We will wire the receiver following a certain specific sequence of steps. A pictorial diagram is shown in Fig. 412. Refer again to Fig. 405 for the pin designations of the sockets. *Do not* have the transistors inserted while you make soldered connections to the sockets. These steps are the complete underside instructions, some of which you have already performed. They are repeated here for those who have skipped ahead.

1. Using bare wire, fasten in the B-plus line (Fig. 404).
2. Using bare wire, fasten in the B-minus line (Fig. 404). These two wires can be fastened to the chassis at the edge by running them up through the perforations and bending so that there is about a $\frac{1}{4}$ -inch anchor.
3. Connect a short piece of bare wire between the solder lug and the B-minus line. Connect the right-hand end of the B-minus line to the tube wire nearest the coil (Fig. 404).
4. Solder the blue lead of T1 to the end of the rf choke lead which protrudes through the chassis (Fig. 405). The transformer leads are designated as: Blue-B; Red-R; Green-G; Yellow-Y; and Black-Bk.
5. Solder the red lead to the B-plus line directly below.
6. Twist the 470,000- and 200-ohm resistors together and solder the joint. Cut it so that the joint is about $\frac{3}{16}$ -inch long and perpendicular to the two resistors.
7. Place in position and solder the free end of the 470,000-ohm resistor to the solder lug and the free end of the 220-ohm resistor to the B-plus line. (The solder lug is our ground point or terminal for our B-minus line.)

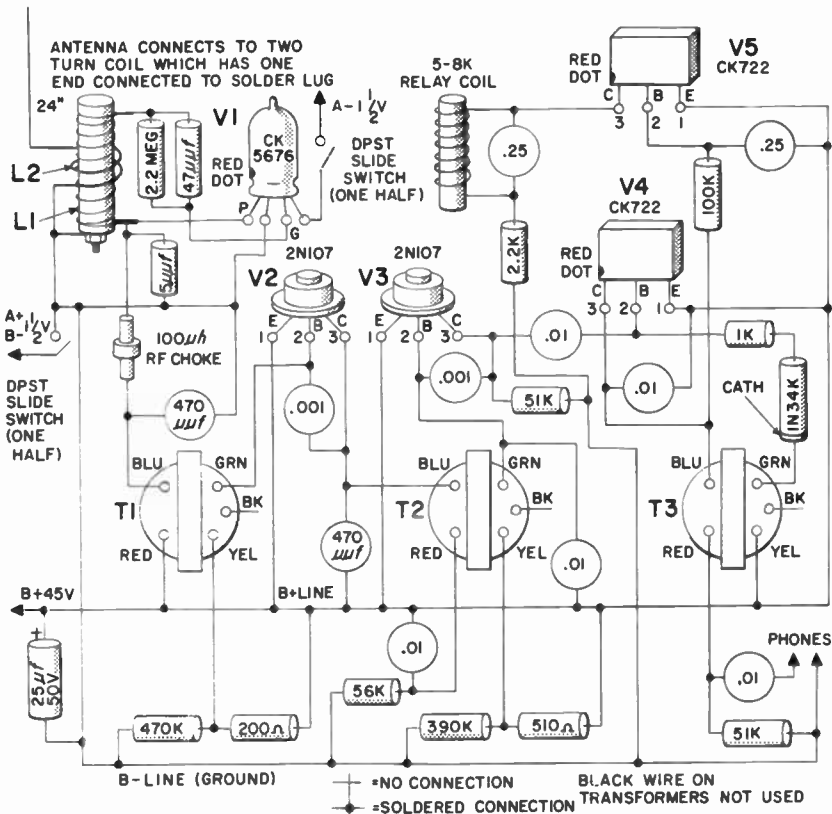


Fig. 412. Pictorial wiring diagram of the receiver.

8. Solder the yellow lead of T1 to the junction of the two resistors.
9. Solder the green lead of T1 to the middle (pin 2) of V2.
10. Clip the black lead of T1 to about $\frac{3}{4}$ -inch and fold it back out of the way. We will not use this lead.
11. Solder a short length of wire to pin 1 of V2. Solder the other end to the B-plus line.
12. Take a 470- μf ceramic capacitor and connect one lead to pin 3 of V2. Make this lead short. Solder the other lead to the B-plus line.
13. Twist together the leads of a 56,000-ohm resistor and a .01- μf capacitor.
14. Cut this twisted joint to a $\frac{1}{4}$ -inch length and solder. Place in position just to the left of V2 (Fig. 405).
15. Solder the free end of the capacitor to the B-plus line.
16. Solder the free end of the resistor to the B-minus line.
17. Solder the red lead of T2 to the junction.
18. Solder the blue lead of T2 to pin 3 of V2.

19. Solder a .001- μ f capacitor lead to pin 2 of V2.

20. Solder the other lead to pin 3 of V2.

21. Turn the chassis over and solder the tube leads to the tube wires. *Make certain* that the red dot on the tube is *nearest* the coil. The tube lead nearest the red dot is soldered to the bottom coil lug, the next lead is connected to the B-minus line, the third lead is connected to the 47- μ f capacitor and 2.2-megohm resistor, and the fourth lead is connected to the A-minus tube wire (Fig. 405).

22. Carefully adjust the coil slug so that it is down about $\frac{1}{8}$ -inch from the top.

23. Connect the leads from your earphone to the yellow and green leads of T2.

24. Connect a flashlight A-battery so that the positive terminal goes to the B-minus line and the minus terminal (the base) to the tube lead designated in Fig. 405.

25. Connect the plus terminal of a 45-volt battery to the B-plus line and the minus terminal to the B-minus line.

26. Insert a 2N107 transistor in the V2 socket, making certain that the transistor leads match the socket-hole spacing.

You should now hear a soft hiss in the earphone, indicating that the tube and the first transistor stage are operating correctly. If you do not, then follow this check procedure:

a. Recheck all connections. Make certain that you have removed the insulation from the leads of T2 where the earphones are connected.

b. Adjust your test meter to measure 100 volts. Connect the unmarked lead of the test meter to the B-minus line. Touch the common lead to either lug of the coil. The reading should be about half-scale. If it is not, disconnect the rf choke and measure its continuity. Check the red and blue connections of T1. We want a path from the B-plus line to the coil. Remember to disconnect the receiver batteries when making a continuity check.

c. Inspect the coil to make sure the leads of the winding are not broken; that they are soldered to the lugs.

d. Look for globs of solder making shorts across the transistor socket.

e. Make certain the transistor is properly inserted.

f. Make certain that the tube is good by removing it and checking for continuity between pins 2 and 4 (the filament leads) counting from the red-dot end.

g. Adjust your test meter to measure volts (10-volt scale) and connect the common lead to the B-plus line. Touch the unmarked lead to pin 3 of the transistor socket. The voltage here should be about 3 to 4 volts. If it is higher than 10 volts, then pin 1 is not connected to the B-plus line or the transistor is improperly inserted in the socket. If the reading is lower than this, do not worry so long as there is some indication of a reading.

h. Make certain that you have the 470,000-ohm resistor connected to the B-minus line and haven't reversed it and the 200-ohm resistor.

i. Finally, try another transistor or tube.

Assuming that you had no trouble, or that it was cured and you now have heard the hiss:

27. Disconnect the receiver batteries and the earphone.

28. Solder the green lead of T2 to the center (pin 2) of V3.

29. Join the 390,000- and 510-ohm resistors by twisting their leads. Solder the junction and clip to $\frac{1}{4}$ inch in length.

30. Place in position as shown (Fig. 405). Solder the free end of the 390,000-ohm resistor to the B-minus line.

31. Solder the free end of the 510-ohm resistor to the B-plus line.

32. Solder the yellow lead of T2 to the junction of the 510 ohm and 390,000 ohm resistors. Clip the black lead of T2 and fold to one side (we won't use this).

33. Connect a short length of wire to pin 1 of V3.

34. Connect the other end of this lead to the B-plus line.

35. Take a .01- μ f capacitor and connect one end to pin 3 of V3.

36. Connect its other end to pin 2 of V4.

37. Take a second .01- μ f capacitor and connect one end to pin 2 of V3.

38. Connect its other end to the B-plus line.

39. Take a .001- μ f capacitor and clip the leads to about $\frac{5}{8}$ -inch. Solder one lead to pin 3 of V3 and the other lead to pin 2.

40. Solder one end of a 51,000-ohm resistor to pin 3 of V3, and solder the other end to the B-minus line.

41. Connect one earphone lead to pin 2 of V4 and the other earphone lead to the B-plus line. Reconnect the batteries as before. Insert a 2N107 transistor in the V2 and V3 sockets. Again listen for the hiss. It should be equal in intensity or louder than the previous check. If you do not hear the hiss, check all new connections, following the same procedure as before. Measure the voltage between pin 3 of V3 and B-plus. It should be about 12 volts, so use the 100-volt scale of your test meter.

42. Disconnect the batteries and earphone.

43. Connect a short length of wire from pin 1 of V4 to the B-plus line. Solder each connection.

44. Solder the blue lead of T3 to pin 3 of V4.

45. Take the 100,000-ohm resistor and connect one end to pin 3 of V4 and the other end to pin 2 of V5.

46. Take another .01- μ f capacitor. Solder one of its leads to pin 3 of V4 and the other lead to the B-plus line.

47. Take a 1,000-ohm resistor, shorten its leads and solder one lead to pin 2 of V4.

48. Take the 1N34A diode and shorten the leads to about $\frac{3}{4}$ -inch. Solder the lead farthest from the color end to the free lead of the 1,000-

ohm resistor. Solder the other lead of the 1N34A to the green lead of T3. (Use care not to get the diode too hot).

49. Solder the yellow lead of T3 to the B-plus line.

50. Take a 51,000-ohm resistor and lay it alongside the B-minus line. Connect one lead to the B-minus line.

51. Connect the red lead of T3 to the other end of this 51,000-ohm resistor. Connect one lead from a .01- μ f capacitor to this same junction. The other lead will be our earphone connection for the finished receiver.

52. Connect a short length of insulated wire to the B-minus line. This is the other earphone connection.

53. Take a 0.25- μ f capacitor and solder one lead to pin 2 of V5 and the other lead to the B-plus line.

54. Clip the black lead of T3 and fold back out of the way.

55. Solder a lead to pin 3 of V5 and connect this to one relay winding.

56. Take the 2,200-ohm resistor and solder to the other relay winding lead.

57. Take a second 0.25- μ f capacitor and connect one lead to pin 3 of V5.

58. Solder its other lead to the junction of the second relay winding lead and the 2,200-ohm resistor.

59. Solder the free end of the 2,200-ohm resistor to the B-minus line.

60. Using a short length of wire, connect pin 1 of V5 to the B-plus line.

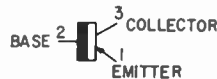
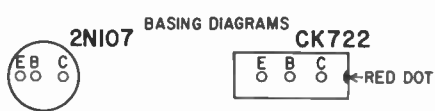
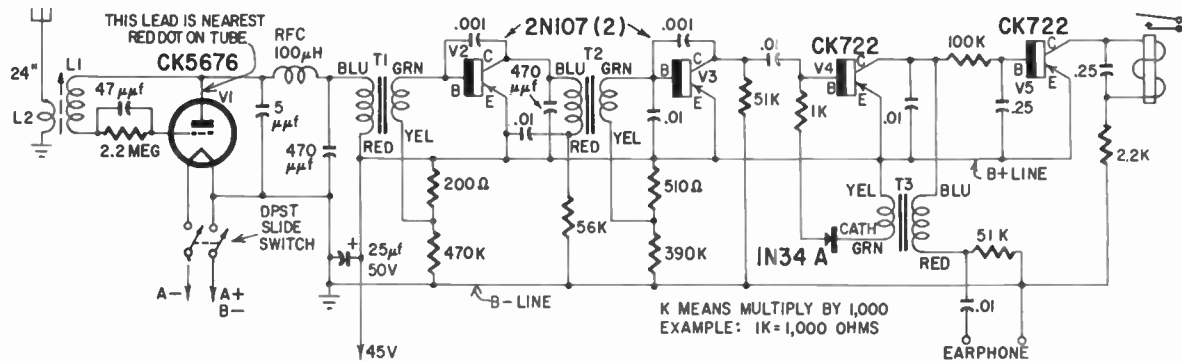
61. Connect the plus terminal of the 25- μ f 50-volt electrolytic capacitor to the B-plus line and its minus terminal to the B-minus line.

62. Recheck your wiring against Figs. 405 and 412 for accuracy and neatness. Check accuracy against Fig. 413 also.

63. Insert the CK722 transistors in their sockets. The wire leads of these transistors are not spaced like the 2N107's. The key is given in Fig. 413. Make certain that you get the leads into the right socket holes.

64. Reconnect the batteries as before and connect the earphones to the earphone leads. Again you should hear a hiss, equal to or louder than before. If you do not, use the same check procedure indicated earlier. The voltage from pin 3 of V4 to B-plus should be almost zero. The voltage from pin 3 of V5 to B-plus should be around 30.

The relay should not remain energized although it may click when the batteries are first connected. Should it remain energized, you have trouble. Touch your finger to one of the tuning-coil lugs. If the relay clicks, the trouble is in the wiring associated with the tube or those parts. If there is no reaction, check back over every step of test and construction and, if necessary, swap the CK722's around, or the 2N107's.



K MEANS MULTIPLY BY 1,000
EXAMPLE: 1K=1,000 OHMS

parts list for receiver

Resistors: 1—200 ohms; 1—510 ohms; 1—1,000 ohms; 1—2,200 ohms; 2—51,000 ohms; 1—56,000 ohms; 1—100,000 ohms; 1—390,000 ohms; 1—470,000 ohms; 1—2.2 megohms. All resistors ½ watt.

Copocitors: 1—5 μmf; 1—47 μmf; 2—470 μmf; 2—.001 μf ceramic; 5—.01 μf, ceramic or paper (Electrocod R374 or equivalent); 2—.25 μmf tubular; 1—25 μf, 50 volt electrolytic.

Transformers: 3—AR-96, AR-109, TR-98 (Argonne) or SSO-8 (UTC) 10K to 2K.

Transistors, tube ond diode: 1—CK5676; 2—2N107; 2—CK722; 1—1N34A.

Miscellaneous: 4—transistor sockets; 1—¼ inch CTC red dot phenolic slug-tuned coil form; 1—100 μh choke coil (rfc); 1—dpst slide switch; 1—rely (Sigmo 4F or Argonne AR21, or equivalent); eorphone; No. 32 enameled wire; No. 20 bore wire; pegboard chassis; soldering lugs; solder; hardware.

Fig. 413. Schematic wiring diagram of the receiver.

65. Wrap two turns of insulated wire (No. 28 gauge) around the tuning coil as shown in Fig. 403 and connect to a phono jack mounted on a solder lug. Bolt the lug to the chassis and connect a 24-inch length of piano wire to the phono plug for an antenna.

The construction is almost finished. Insert a $5\text{-}\mu\text{f}$ capacitor between the bottom lug of the tuning coil and the B-minus lead when the CK5676 tube is used. For other types, such as the 5672 and 1AG4, this may be omitted.

Testing and adjusting the receiver

We now assume that the receiver is connected to the batteries, that the relay is not energized and that the hiss is audible over the earphones. The antenna is connected. Now we turn our attention to the transmitter for a moment. (Either the transmitter for which we have given construction details or any other commercial transmitter operating on 27 mc may be used).

The transmitter is connected to its batteries and placed at least 10 feet from the receiver. Do not connect its antenna. Turn the transmitter on and, after it gets warm, depress the keying switch or button.

While the transmitter is on — transmitting — adjust the receiver tuning coil. To do this, listen in the earphone and at the same time screw the slug in the coil down so that it is about $\frac{1}{4}$ inch or so from the top. *Use wooden screwdriver for this if you insert the end into the coil.* (We made a small screwdriver from a small flat piece of hardwood that works very nicely). Never insert any kind of metal into the coil. If you adjust from the underside, you may use your fingers or a metallic screwdriver on the metal screw extension of the slug.

Keep adjusting the slug down and then up until you hear the hiss become very, very soft or even vanish completely. The relay may close at this time.

In this 'dead' position, the slug will be approximately in the center of the coil when the CK5676 and the $5\text{-}\mu\text{f}$ capacitor are used. It may be nearer the top when the other types are used.

Locate the extremes of the dead zone by first screwing the slug into the coil until the hiss just begins to return. Carefully turn the slug in the other direction so that it tends to come up out of the coil. Keep turning *through* the dead zone until the hiss again begins to return. Count the number of revolutions of the screwdriver necessary to do this. Now screw the slug back down into the coil exactly one-half the number of turns just counted. This tunes the receiver exactly in the center of the dead zone.

Remember this adjustment. We will want to do this again later when we connect the transmitter antenna and carry the receiver out away from the transmitter for a range test.

Now you should be able to key the transmitter by releasing and depressing the transmitter button switch. The receiver relay will close

each time the button is depressed and open when it is released.

That's all there is to it. You tune your receiver simply by turning on the transmitter and tuning for the middle of the no-hiss position of the slug.

Range testing the receiver

At this point, we will make our first range test of the receiver. Its purpose is to insure that the equipment will work over the distances we will want our model to operate.

Set the receiver and its batteries on a flat piece of cardboard or other nonmetallic plate so that it can be carried. Connect the antenna to the transmitter and, with the help of a friend to key the transmitter, walk away from the transmitter location. You may remove the earphone from the receiver and listen to the clicking of the relay. Keep walking. The relay should close firmly each time a signal is transmitted and release when the signal is off.

In a city area where there are buildings, water mains and light lines, you may find that, as you walk, there will be certain places where the relay either won't work or clicks erratically. If there are buildings or trees between you and the transmitter, it will also happen. If you have a direct line of sight back to the transmitter, however, you should be able to go out at least 200 yards with the receiver relay working properly. You might find that when you get out 100 yards, the relay

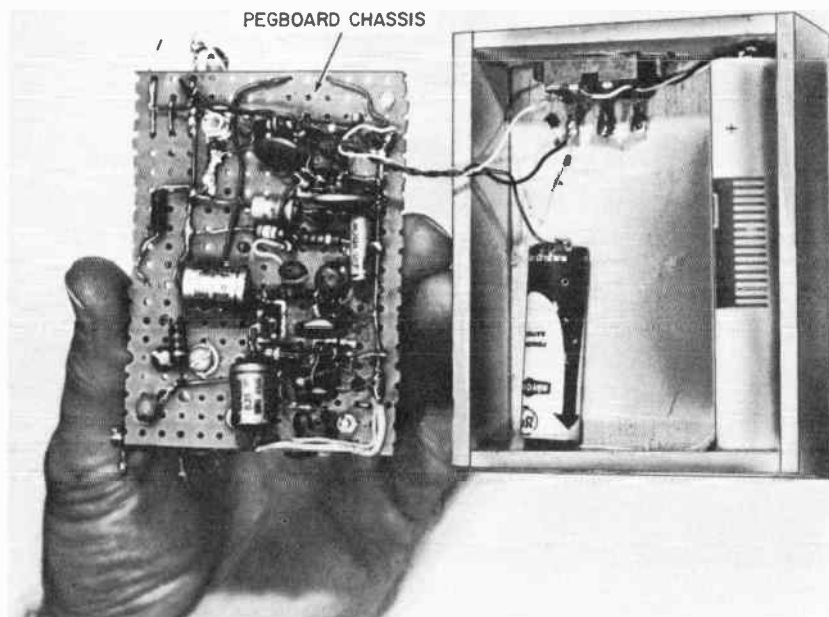


Fig. 414. Small box of balsa wood houses the receiver B-battery and flashlight A-batteries. Note dpst switch mounted in upper right-hand corner.

stops working. Right then you will want to retune as we did previously. Listen to the earphone and, if you hear the hiss, it means that the signal from the transmitter is not reaching you or that the tuning is not correct. The final tuning of the receiver should always be made some distance from the transmitter and with the transmitter antenna connected. Of course, the receiver antenna should be in place, also.

As your final step, purchase a double-pole single-throw switch. Disconnect the receiver batteries and then connect a 4-inch lead from the B-minus terminal of the receiver to the bottom lug on one side of this switch. Connect two more leads to the lug just above this and on the same side. One of these two leads will be connected to the B-minus terminal of the 45-volt B-battery and the other to the flashlight A-battery plus terminal.

Connect a lead from the A-minus wire of the receiver to the bottom lug of the other side of the switch and a lead from the lug just above this to the A-minus side of the flashlight battery.

Finally, you can make a small box of balsa wood as indicated in Fig. 414. The B-battery (if a hearing aid or small portable radio-type)

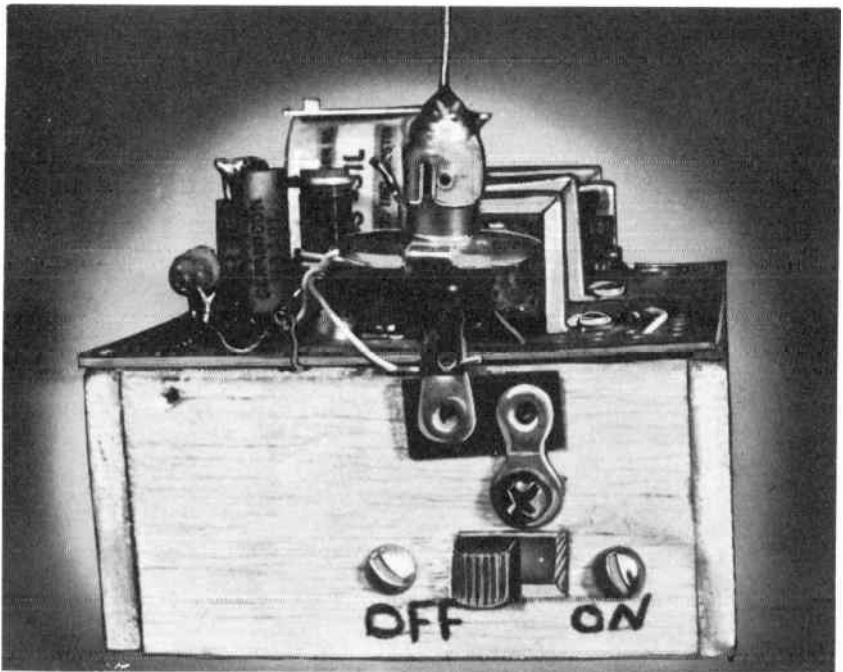


Fig. 415. The antenna mount is fastened to one side of the box supporting the pegboard chassis.

and the penlight cells (two are used, with their plus terminals connected together and their minus terminals connected together) may be fitted right into the box itself. The switch is located in the upper right-hand corner, and the antenna mount can then be screwed to the side of the box. (See Fig. 415.) We now have a complete unit ready for radio control operation.

Miscellaneous considerations of the receiver

When this receiver was operated with a 5672-type tube, it was found that, in addition to removing the 5- μmf capacitor, a 270- μmf capacitor across a 15,000-ohm resistor was necessary between the end of the rf choke connected to the blue lead of T1 and the B-plus line. Some 5672 or 1AG4 tubes may not require this.

The circuit is designed to operate with P-N-P CK722, 2N107 or 2N109 transistors. The first two are used because they are cheaper. If a CK722 is used in the V2 socket, it may be necessary to add a 2,200-ohm resistor in series with the 45-volt B plus line to reduce the voltage slightly.

With a 2N107 in V2 and CK722's in the rest of the sockets, the voltage readings in the receiver for signal-on and signal-off conditions using the basic test set adjusted for 100-volt scale are:

no transmitted signal			with transmitted signal		
pin 3 of V2 to B-plus		10 volts			10 volts
" " V3	" "	20 "			30 "
" " V4	" "	zero "			20 "
" " V5	" "	35 "			zero "

These readings may differ slightly if measured with a commercial meter; for example, a commercial 1,000-ohms-per-volt unit. With 40 volts applied between the B-plus and B-minus lines of the receiver, the following measurements resulted with a 2N107 in V2 and CK722's in the other sockets:

no transmitted signal			with transmitted signal		
pin 3 of V2 to B-plus		12 volts			12 volts
" " V3	" "	15 "			30 "
" " V4	" "	0 volt			38 "
" " V5	" "	35 "			0 "

When a 2N107 is used in V2 and V3 and CK722's in V4 and V5 (we found this best), the readings were found to be:

no transmitted signal			with transmitted signal		
pin 3 of V2 to B-plus		2 volts			5 volts
" " V3	" "	12 "			12 "
" " V4	" "	1.5 "			5 "
" " V5	" "	28 "			7.5 "

2N109's may be used but, the relay spring tension has to be increased slightly if a 2N109 is used in the V5 socket.

Now that we have the transmitter and receiver, let us practice coding.

Connect a small 6-volt light (like your loop light) *in series* with a 6-volt battery and then connect the two free leads to the frame of the relay and the normally open contact of the relay, so that, when you close the armature with the tip of your finger, the light glows. Turn your receiver and transmitter on and practice sending signals, flashing the light as you command. Try short flashes (pulses) and long ones.

If you have a small electric motor, connect it in the same manner to the relay, but now you must also connect a 10-ohm, $\frac{1}{2}$ -watt resistor in series with a 0.25- μ f capacitor. Connect the free lead of the resistor to the frame of the relay and the free lead of the capacitor to the normally open contact. This is a spark filter to prevent erratic operation of the receiver due to noise from the motor. Practice running and stopping the motor by command, for the next chapter deals with devices which use motors. Incidentally, keep the leads to the motor away from the receiver antenna and tuning coil. Make these leads short and keep them tightly twisted together.

servos

IN this chapter we will discuss one of the many types of devices which furnish mechanical motion with sufficient power to move our steering element. This element might be the wheels of a model car or the rudder of a model boat. It will also enable us to start and stop our drive motor on command. The actual steering elements of a model airplane will be covered later in a complete section devoted to that aspect of radio control. Since radio control of a model airplane is much more exacting than that of other models, it deserves special consideration. Going through the mechanics of actually radio-controlling a model car or boat will provide the experience necessary to insure success in the later, more complex and exacting field of airplanes. So let's consider the servo, a device used in every type of model.

In the previous chapter, you connected your receiver to a small motor and started and stopped it at will by either sending a command or not sending a command. To make this motor turn to any one of three given positions and stop, which is our requirement for steering, we have to add cams to it and we also have to learn something of a new method of sending commands by pulses.

Perhaps you are wondering about the name *servo*. In radio-control applications, this word is applied to any device which will produce mechanical motion on command and which has (generally) a small electric motor as a prime source of power.

Let's consider the problem at hand before we construct the device in order that we may understand what we want it to do and, thus, why it is built the way it is.

The first and most important control that we must have is steering. This means that we want to have at least three positions of the steering wheels or rudder and be able to send a particular command for each one. The three positions are, of course, left, right and neutral.

The second most important control is the ability to start and stop the model at will, which represents two more commands.

It's possible, however, to simplify our system. If we construct our servo so that, in the absence of signal, it will always return to neutral automatically, we have, as far as remembering the command goes, eliminated it. It is *sent* (in this case the absence of a signal represents a command) but we just don't have to worry about it at all. Whenever we release our button switch, the model goes straight.

For the left and right commands, we will use pulses. If we depress the keying switch and hold it down, the model will go, say, left. If we release the keying switch, the model goes straight. Now to make the

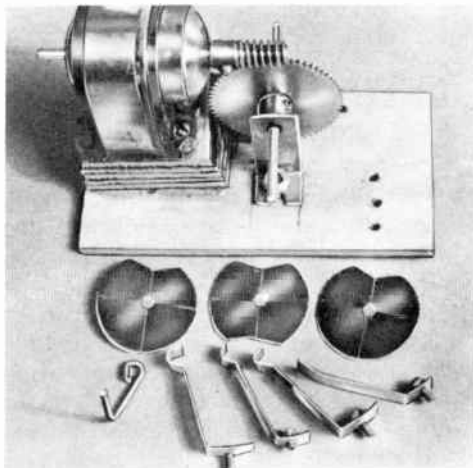


Fig. 501. Mounting of motor, worm gear and pinion gear is the first step in servo construction.

model go right, we press the keying switch, release it, then depress it again and hold it down. Try this code with your light connected to the relay of your receiver. One flash is left, a flash off and then a light on is right. The final command as we will use it is a modification of the first—a very quick press and release—a sort of 'blip.' This last command will stop our drive motor.

How do we *start* the drive motor? That command is just like a signal for left. A press and release at about the same speed as the command used for left, but not a 'blip.' It may seem confusing so let's build the unit now and, as we operate it, this section will all become much clearer.

The parts we will need are simply a small motor (the 3- to 6-volt-type found in any hobby shop), a worm gear and a pinion gear. These can generally be found at a shop selling model trains. Just make certain that the worm gear will fit the shaft of the motor as indicated in Fig. 501. We will also need a piece of light tin (in the model shown, a

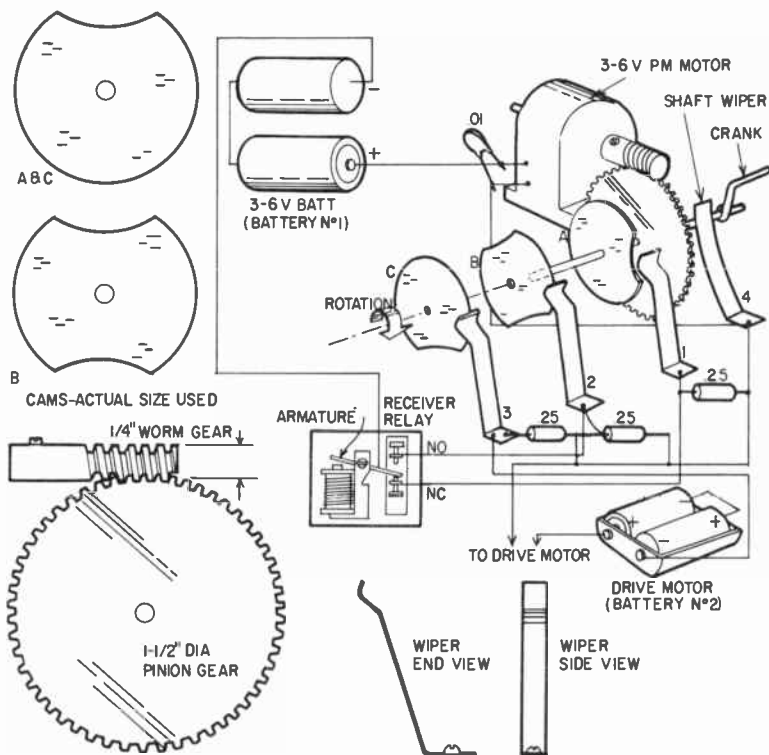


Fig. 502. Template for constructing the three cams and four contact fingers shown in Fig. 501.

coffee can furnished this material) and a small piece of $\frac{1}{8}$ -inch plywood for a base.

The first step is to mount the motor, worm gear and pinion gear as shown in Fig. 501. The two angle brackets holding the shaft of the pinion gear should be made of heavier material than the coffee-can tin — we do not want them to bend under operation. After mounting, make sure that the motor turns the gears easily and without binding. The spur gear is fastened tightly to its shaft. (Only one angle bracket is shown in Fig. 501 since the photo was taken during assembly.)

The next step is to construct the three cams and the contact fingers according to the template of Fig. 502 and, finally, mount them on the base and shaft as shown in Figs. 503 and 504. Note in Fig. 504 that the shaft wiper contact and the crank (which will actually move the steering element) are shown. In this figure you can also see the spacing between the cams. This spacing is not critical so long as the three cam wipers do not touch each other.

The cams must be positioned as shown in Fig. 502 and, as we discuss the wiring, we will refer to them as: A, the neutralizing cam; B, the left-right cam; and C, the drive-motor control cam.

The wiring is quite simple. One lead from the motor (on the right in Fig. 502) connects directly to the shaft wiper. To this same motor terminal we connect one side of a .01- μ f capacitor. The other motor terminal connects directly to the battery's plus terminal and the other lead from this capacitor. The battery to be used will depend on the size of the motor. Check your dealer or parts house for the battery you need.

The minus terminal of the battery connects directly to the frame lug of the receiver Sigma 4-F relay. The normally open contact of the

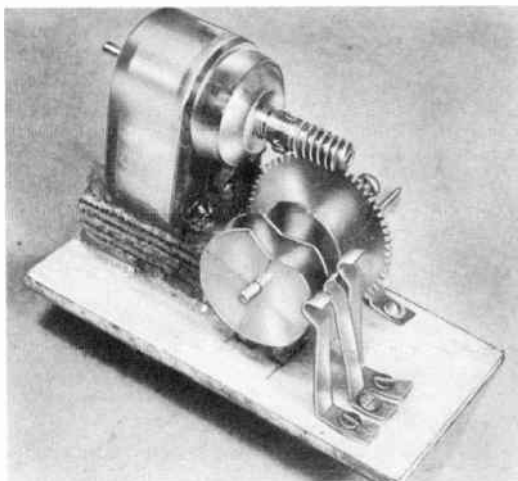


Fig. 503. Cams and contact fingers mounted on base and shaft.

relay connects to cam wiper 2, and the normally closed contact to cam wiper 1. (Note that each cam wiper has one lead from a .25- μ f capacitor connected to it, as well). The other lead from each of these capacitors is connected to shaft wiper 4. These capacitors prevent sparking, which can be picked up by the receiver and cause erratic operation.

From shaft wiper 4, a length of insulated wire is connected directly to one terminal of a drive motor. (The drive motor is the motor which causes a propeller or the real wheels of a car to turn. It makes the model move.) A second insulated lead is connected to cam wiper 3 and this goes to one side of the drive-motor battery as shown in Fig. 502. The other terminal of the drive motor battery is then connected to the second terminal (or lead) of the drive motor.

Now let's see how the basic servo operates. If the cams are correctly

positioned on the shaft (they are soldered to it so that they turn when the shaft turns) and the relay is not energized, the electrons will want to go from the minus terminal of the battery (s) to the plus terminal. So, starting at the minus terminal (battery No. 1) the electrons can go to the relay armature and through the normally closed (NC) contact of the armature to cam wiper 1. Since this is a battery, the electrons

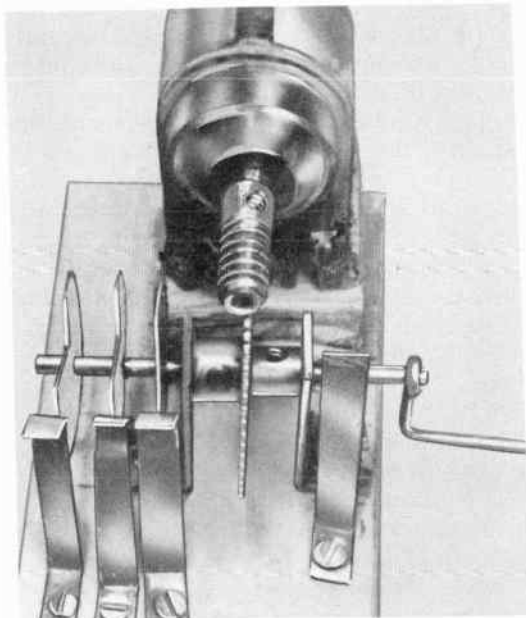


Fig. 504. Closeup of cams and contact fingers mounted on base shows spacing between cams. Note the little crank on the right side, used to move the steering element.

cannot go through the capacitor so they stop. The circuit is incomplete and nothing happens.

Now let's send that first command — press and hold. When we do this, the receiver relay armature moves from the NC to the NO contact. The electrons (or current of electricity) now can go from the NO contact to cam wiper 2 and, since it is resting against cam B, they will flow through this cam to the shaft, down the shaft to shaft wiper 4, down shaft wiper 4 to the second motor terminal, through the motor (motor No. 1) and back to the plus terminal of the battery.

The circuit is now complete, the motor turns and keeps turning until the indentation in cam B breaks the connection to cam wiper 2. To do this, the shaft has to rotate 90°. The little crank on the end, instead of being down, is now to the right and it will stay there as long as we hold the keying switch depressed.

Releasing the keying switch causes the relay armature to move back to the NC contact, but now, since the shaft has turned, the electrons can flow through cam wiper 1, cam A, the shaft, wiper 4 and the motor to cause the motor to run again. This time it runs until the cam A indentation breaks the circuit to cam wiper 1. The crank has turned a full 270° more and is now back to its original starting place. This will be the neutral steering position.

To turn the crank 270° from this neutral position and stop, giving us the 'right' steering position, we use the code given previously: press, release and press, and hold the keying switch closed. This has to be done with the right rhythm because this is what should happen: when we press the first time, the electrons flow through the relay (as previously described) wiper 2 and cam B. The motor starts turning. When the first indentation of cam B breaks the circuit to wiper 2, if our rhythm is correct, we will have released the keying switch so that the electron flow is transferred to cam A through wiper 1 to keep the motor going. Now as soon as the first indentation of cam B has passed wiper 2, we have again depressed the keying switch, once more transferring the electron flow to wiper 2 and so, as the second indentation breaks the circuit here, the motor will stop. The shaft will have rotated a full 270°, and the little crank will be to the right.

This will take a little practice and you may have to readjust the positions of the cams to have the motor stop with the crank in the positions specified. You may have to add a small drag or friction wire pressing against the motor shaft (as described in the next chapter) to prevent the motor from coasting past the broken circuit positions. You may also have to reduce the amount of battery voltage applied to the motor to prevent continuous rotation. These are adjustments best done by experimentation so we leave those details up to you.

Assuming now that you have the steering part working as it should, let's examine the motor start – stop action. This involves cam C. As shown in Fig. 502 cam wiper 3 rests against cam C. The electrons from the drive-motor battery (battery No. 2) can go through the wiper, the cam, down the shaft, out wiper 4 and the line to one side of the drive motor. They won't go anywhere else because they want to get back to their own battery. They go through the drive motor and back to the plus side of their battery (battery No. 2) and so the drive motor runs.

Now, if we send the 'blip' mentioned earlier, the *steering-motor* circuit is momentarily completed through wiper 2, but only momentarily – just long enough for the shaft to rotate a very small amount, causing the indentation of cam C to break the circuit to the drive motor. At this time, the receiver relay armature is back against the NC contact but the shaft of the motor didn't move far enough to close the circuit between cam A and cam wiper 1. What happens? The drive motor stops, the steering motor stops and the model stops.

To start the drive motor, use the code given previously: depress the keying switch for a longer time and release. The cam shaft will make

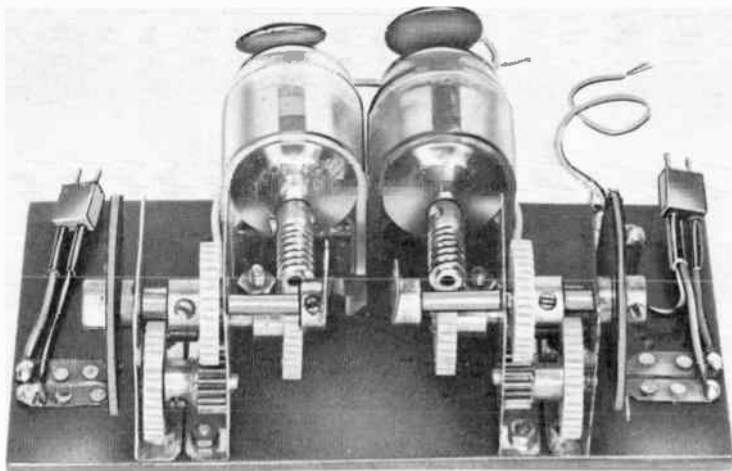


Fig. 505. Front view of dual-unit servo with elaborate pinion-gear train added.

a complete revolution, stopping when the circuit to cam A is broken but, at this stopped position, cam C does make contact to wiper 3 and the drive motor runs. Try it. Adjust the cam if necessary so that this does happen. It will again take a little practice to get the rhythm but, once you do, you have mastered the basic method of radio-controlling a model car or boat. We do not recommend this servo¹ for use in model aircraft.

Construction of a more elaborate servo

Our first servo was the simplest possible and, because of this, somewhat limited in power. We will construct a more elaborate single or dual type which has had application in a model aircraft for control of rudder and airplane motor speed.²

Figs. 505 and 506 show the front and rear views of the dual unit. Note that the basic worm gear is used but, in addition, a more elaborate pinion gear train has been added. While the method of breaking the circuit to the motors is similar to that of the simple servo, the method of making the cams is different. Instead of individual cams, this unit uses a single plate with cutouts positioned as shown in Fig. 507. This type of cam is referred to as a commutator. Note the capacitors for arc suppression mounted directly across the motor

¹ This type of servo is manufactured commercially by Babcock Co., if you would rather buy than build. The commercial unit, however, does not have the capacitors shown on the cam wipers. We will show how to use this servo in a car and boat in subsequent chapters.

² Courtesy of *Flying Models Magazine*.

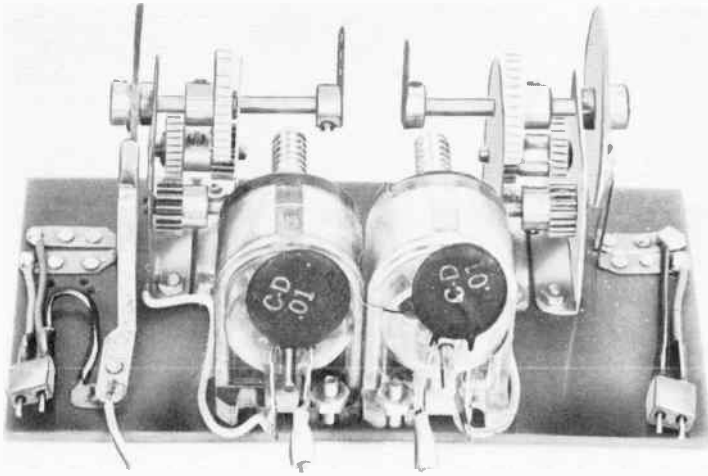
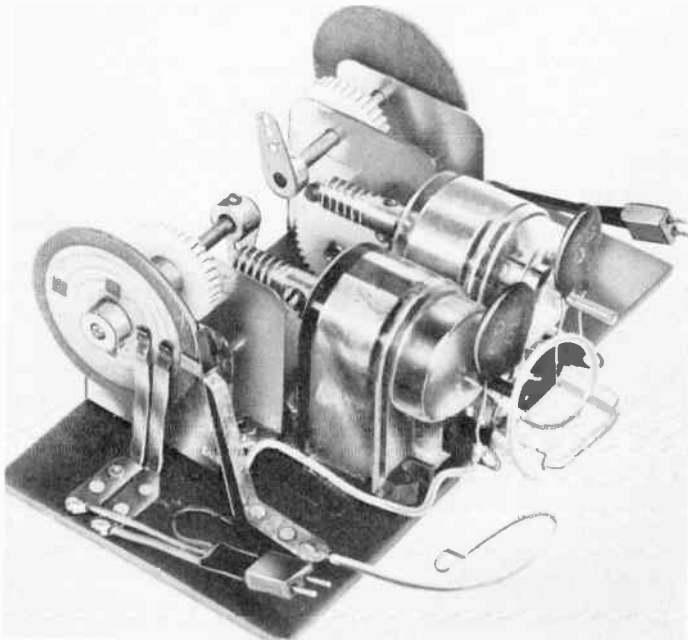


Fig. 506. Rear view of dual-unit servo, showing arc-suppression capacitors mounted directly across the motor terminals.

terminals in Fig. 506 and, in all three figures, the neat method of using small plugs to connect the unit into the battery and receiver

Fig. 507. Dual-unit servo uses a single-plate with cutouts instead of individual cams. Note the positioning of this type of cam, known as a commutator.



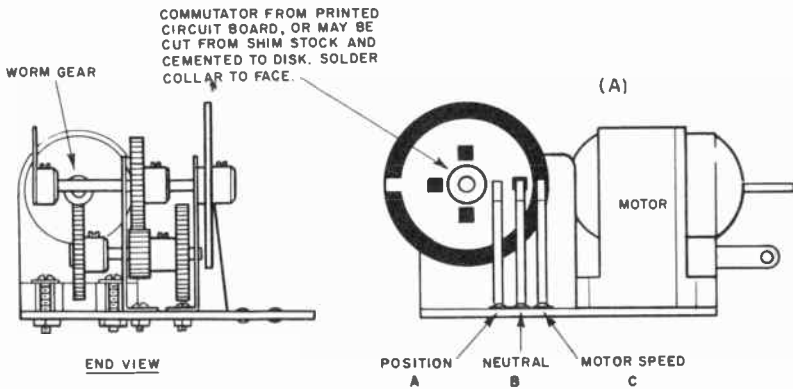
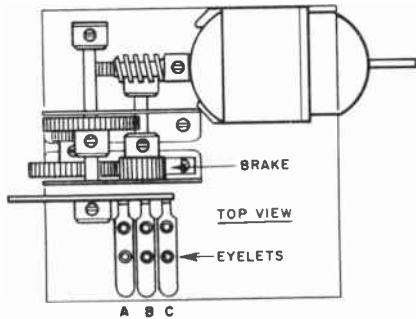
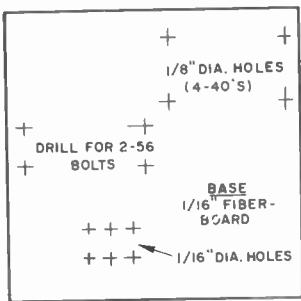
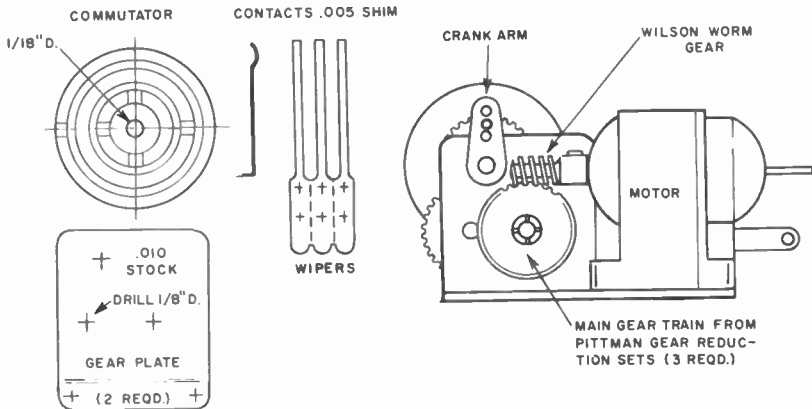


Fig. 508. Template (not to scale) and details of the dual type servo. The Pittman gear train is a reduction unit obtainable at most hobby shops. Check the gears through a complete revolution to make sure they do not bind at any point. (Flying Models Magazine)

circuitry. This is an excellent idea and should be used with all radio control components (receivers, etc.), so that each is readily removed for inspection, servicing, test or use in other models.

Refer to Fig. 508 for templates and details of mounting. The components are mounted on the 1/16-inch base plate as shown. The gears (a Pittman reduction unit available at most hobby shops) come with shafts which are easily cut to the proper length. Mount the gear

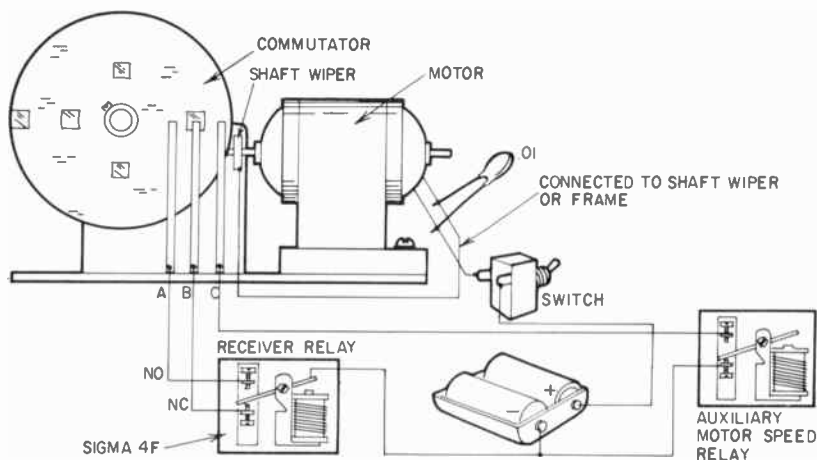


Fig. 509. Pictorial wiring diagram of dual type servo.

train first and make certain that all gears turn easily by hand. Now mount the motor, and again make certain that there is no binding. Connect a battery to the motor and run it, checking to see that all gears move freely and easily after being firmly anchored to the base plate.

To make the commutator, cut a metal disc from tin or brass stock and cement it firmly to the face of a fiberboard disc as shown in Fig. 507. We won't worry about the alignment at this time since we can adjust the little cranks (center of Fig. 507) after everything else has been constructed and adjusted. These cranks are made from tin and are drilled and soldered to small collars which may be screwed tightly to the shafts. The three holes in the cranks allow a variable amount of movement of the steering element. The hole farthest from the shaft will give the greatest amount.

The commutator is mounted by either soldering the metal disc to the shaft or soldering it to a collar and then tightening the screw to hold it fast against the shaft. The contact arm (or wipers) can be made by tracing the pattern of Fig. 508 onto a sheet of beryllium copper .005-inch thick. Bend these wipers and also the base mounting tab so that the arm leans down 30° from the vertical. Clamp these contacts in

place on the baseboard so that they connect to the commutator. Drill through their bases and the base plate simultaneously. Make certain that these wipers do not touch each others. Mount them with small screws and check the tension against the commutator disc. They should be firm and tight, making a good wiping contact.

If the wipers are mounted as a single unit, you can separate them by sawing through the mountings with a fine-toothed metal saw.

Here is how the command code works: One pulse and hold (depress and hold) — the shaft turns 90°. Release, and the shaft returns

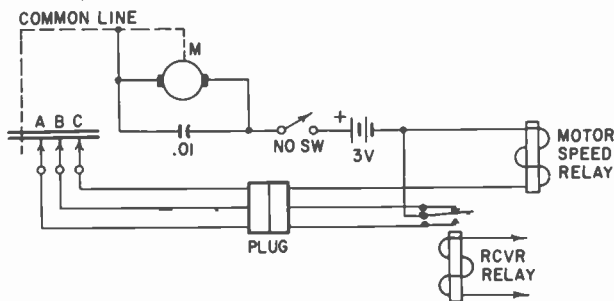


Fig. 510. Schematic wiring diagram of dual type servo.

to neutral. Two pulses and hold (with the correct rhythm) — the shaft moves to 180° and stops. Release, and it returns to neutral. Three pulses and hold — the shaft turns 270° and stops. Release, and it returns to neutral.

A small spur will be under motor-speed wiper C when the commutator has turned 180°. Refer to Fig. 507 and note that this little projection is closing the switch mounted just in line with the commutator. (The motor-speed wiper C can be mounted in line with the other wipers, as in Fig. 508 or to one side as in Figs. 506 and 507). Wiring diagrams are shown in Figs. 509 and 510. Fig. 509 is a pictorial while Fig. 510 is a schematic.

Either of two methods can be used: closing an auxiliary circuit when the code (press, release, press and hold) is transmitted or keeping this auxiliary circuit energized. The latter method might be used if a second motor with a large gear train controlled the drive-motor speed. However, you must realize that this auxiliary circuit would be energized each time the steering servo completes a cycle. There are ways to avoid this, and we will leave this contact in place, although we may not use it at present. Later on, when we talk about full and half-speeds and reversing the drive motor, we will show how such an auxiliary contact can be used, so that this auxiliary circuit will not operate unless we specifically command it.

Fig. 511 shows how a small brake may be made to ride on one of the pinion gears to prevent overtravel. It also shows the general sequence of operation related to the positions of the commutator cam.

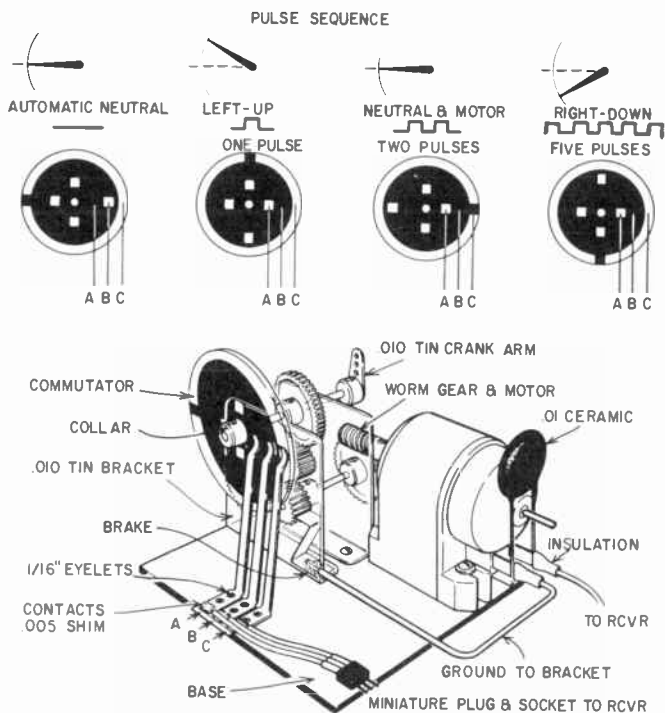


Fig. 511. General sequence of operation showing commutator cam in its various positions.

So much for servos. Many commercial types are available which operate in a similar manner; others require two "channels" from our receiver to obtain neutral and left-right steering. We will discuss these when we get to the multichannel stage of our radio control development.

radio control systems

A good model to test our radio control system in is a toy car. Not only is it economical (if we buy one at the five and dime store) but it is rugged, lots of fun and easy to adapt to radio control. Finally,



Fig. 601. Small model toy truck is quite suitable for radio-control system testing.

even though we may make mistakes in sending commands or have some part of the system fail or malfunction, we won't lose the model completely (as is often the case with aircraft).

A model truck is a good way for the beginner to start since the model can be controlled around the house and, if you so desire, you can expand the system later to do more than just start and stop and steer. So plan

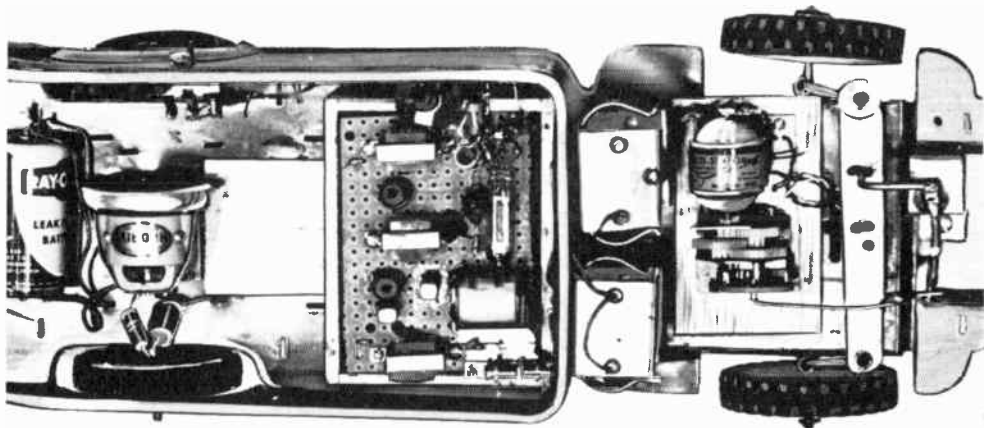


Fig. 602. *The drive motor is mounted over the rear axle.*

accordingly. We can later modify our system to include high and low forward speeds, reverse, and if our model is large enough, horns, doors that open or, if a truck, a body that will rise and, of course, lights. So if you want to become this elaborate with the model car, be sure you get one large enough to hold the additional equipment that will be needed.

In this first phase, we choose the smallest possible model, as shown in Fig. 601. The cab is removable by turning some twist lugs on the under side of the chassis. The body is large enough to contain the receiver, batteries and drive motor. A model of this kind is ideal since it allows easy access to the receiver for adjustments if necessary.

Installing the drive motor

As the first step, we will install a small Hi Drive motor mounted in the center of the after body directly over the rear axle. See Fig. 602. We obtained an enclosed gear train from a surplus timing motor and attached it to the motor with a metal band, as shown in Fig. 603. Any of the many kinds of gear trains available at hobby shops will do, so long as it produces enough power to make the model go. The rear axle was cut and soldered to the body (left side). A collar made of a small piece of brass tubing was soldered to the shaft of the gear train and to the other half of the rear axle (Fig. 604.) It is a one-wheel drive, and that is the way it should be.

To make certain that it will run and move the model after the drive

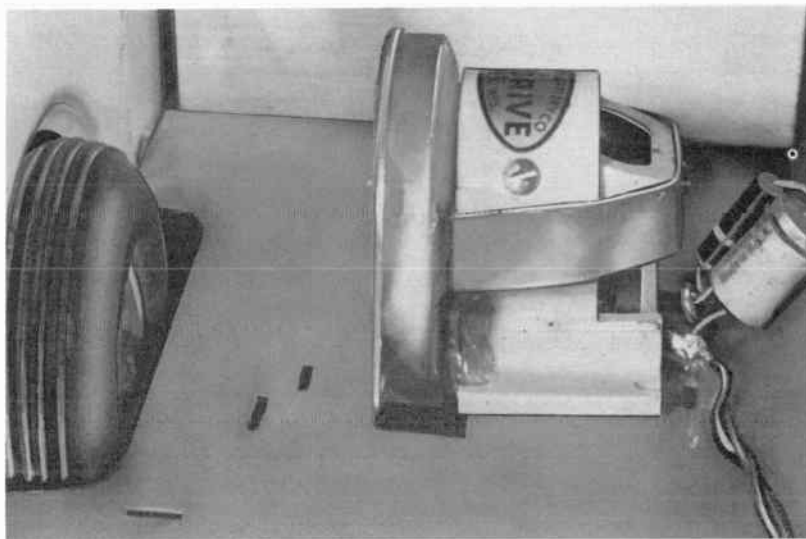


Fig. 603. Enclosed gear train is held to drive motor with a U-shaped metal band.

motor is installed, test it by connecting it to two flashlight batteries connected in series.

The next step is to remove the cab and in the space thus available, mount the steering mechanism. Two types of servos are shown for this model, the one we constructed and also a commercial one, the deBolt 2P2N. With the deBolt unit, only steering is possible and the drive motor must be started and stopped by hand, using a switch on the body.

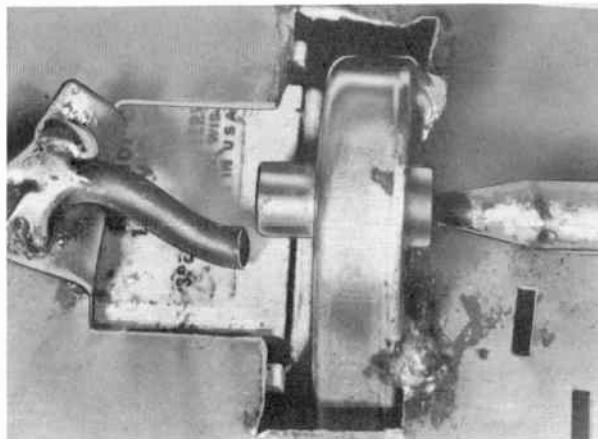


Fig. 604. One-wheel drive is had by soldering a brass tubing collar to the gear-train shaft and to the other half of the rear axle.

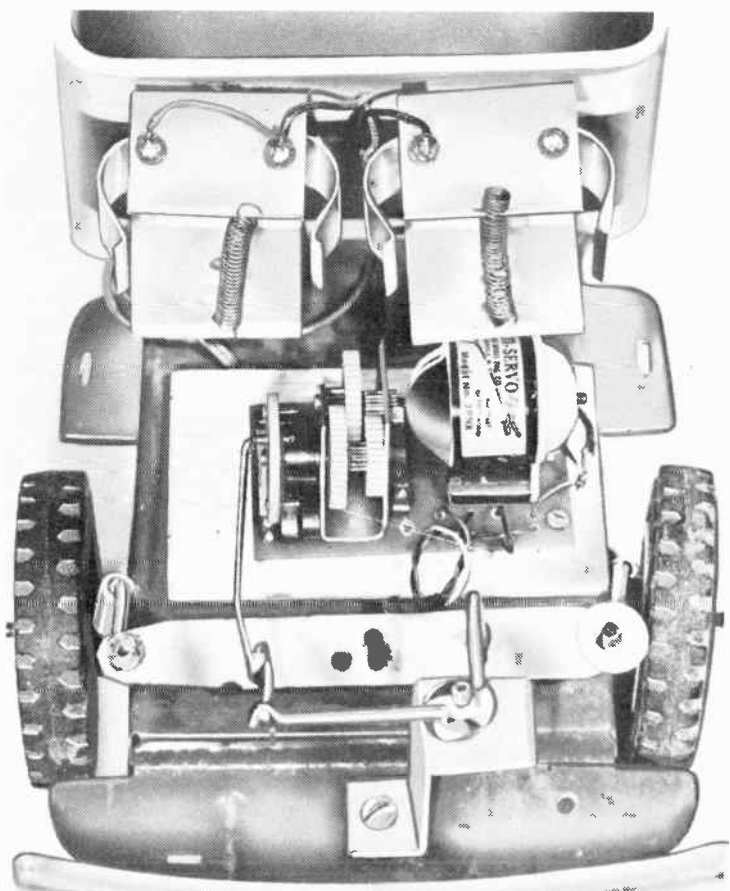


Fig. 605. One end of a small lever arm pivoted on the aluminum mounting bracket (bottom) connects to the crossbar slot and other end to the servo eyelet, causing the wheels to turn as the eyelet rotates.

Using our servo or its Babcock equivalent, we can start and stop the drive motor by commands, as well as steering.

Figs. 605 and 606 show the two types of servos and the method of mounting them just behind the front-wheel line. Note in Fig. 605 the small lever arm pivoted on an upright aluminum bracket. One end of this arm fits in a slot in the crossbar and the other end is attached by a short length of stiff piano wire to the eyelet of the deBolt servo. As the servo eyelet rotates, it pushes the wire back and forth. This in turn causes the part of the lever in the crossbar to move sideways, thus making the steering wheels turn left and right.

Fig. 606 shows a new method of connecting the crossbar to the servo. A small slotted bracket is bolted to the crossbar so that the crank

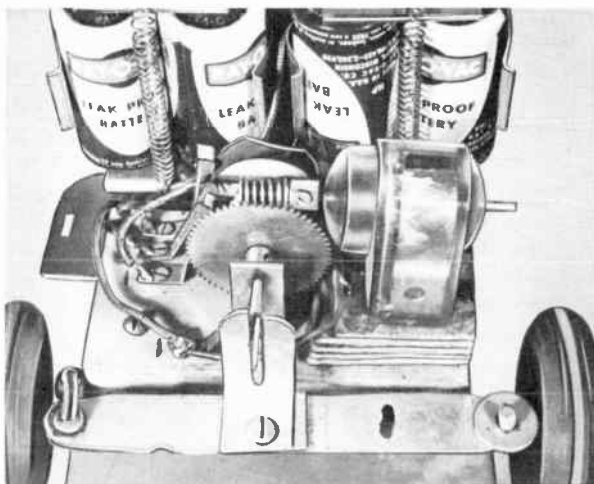


Fig. 606. Complete front-end installation with two sets of batteries. A small nut soldered under the section coming up through the crossbar prevents it from sliding off as the servo motor moves it.

rotates it to cause this same sideways movement. The flashlight batteries which operate the servo can be seen to the rear. These are mounted in insulated holders available at hobby shops. The insulation is necessary to prevent the batteries from being shorted by the metal body of the truck.

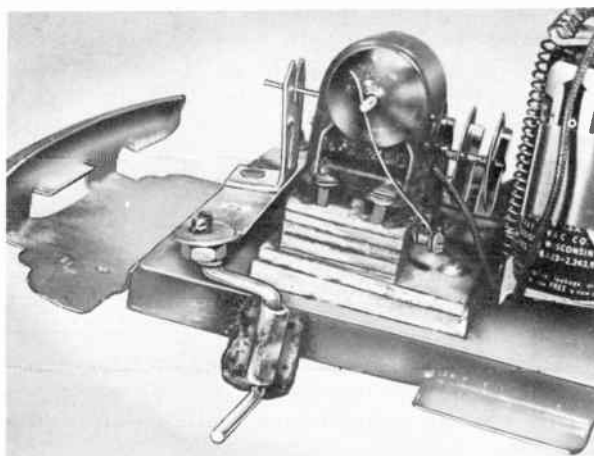


Fig. 607. Detail of the front axle. The small wire resting against the motor shaft and fastened to screw in base of motor keeps the servo from overtraveling or continuously rotating when full voltage is applied.

The front wheel axles

Look again at Figs. 605 and 606, paying particular attention to the front wheel axles. Fig. 605 shows how the piece of welding rod is bent after it comes up out of the small tube fastened to the side of the truck frame. The rod is bent toward the front and then vertically so that the crossbar will fit tightly down on both uprights. Just below the tube support, the rod is bent out from the side of the body to form the axle for the wheel. A small nut is soldered to the section passing up through the crossbar. This prevents the crossbar from sliding off as the servo motor moves it. Use aluminum as the crossbar metal so that solder won't stick to it.

Fig. 607 shows the complete details of the front axle and also another very important addition to our servo. Note the small wire resting against the motor shaft. This wire is fastened to a screw in the base of the motor mount. It exerts pressure on the motor shaft and keeps the servo from overtraveling or continuous rotation when using the full 3 volts from the flashlight cells. The drag pressure is adjusted by experimentation, bending the wire so that it gives the correct tension. Fig. 606 shows the complete front-end installation with two sets of flashlight batteries. One of these flashlight pairs, used in this model as the drive motor battery, is wired in series.

Be careful mounting the servo on a metal body of this type. If the screws holding the cam wipers project through the base, then you must use an additional piece of wood (such as 1/4-inch balsa) underneath to prevent the screws from shorting against the body.

We have already discussed and shown how to connect the servo to the receiver and the drive motor, so we won't elaborate on that here. In testing our model after the receiver was installed, we first operated the receiver relay by hand, touching the armature with our finger tip to send the required pulse code. We found that the wipers did not make firm contacts to the cams, but this was easily cured by increasing the wiper tension.

The servo has sufficient power to move the wheels, provided they are hard rubber or metal and if you operate the model on a smooth surface. If soft-rubber wheels are used, or operation on rough ground is contemplated, then increase the number of gears in the gear train, as we did in our constructed servo. The cam arrangement can still be exactly the same on the output shaft. If a greater gear reduction is used, the output shaft turns slower while providing more power. There will be less tendency for the output shaft to coast over the broken circuit positions. If you use a larger gear train, the drag brake can be eliminated.

One other important note: refer to Fig. 603 and inspect the filter across the motor terminals. This consists of a 10-ohm resistor and a .25- μ f capacitor in series. This filter is a must when the receiver is located close to the motor, and advisable in every case, no matter

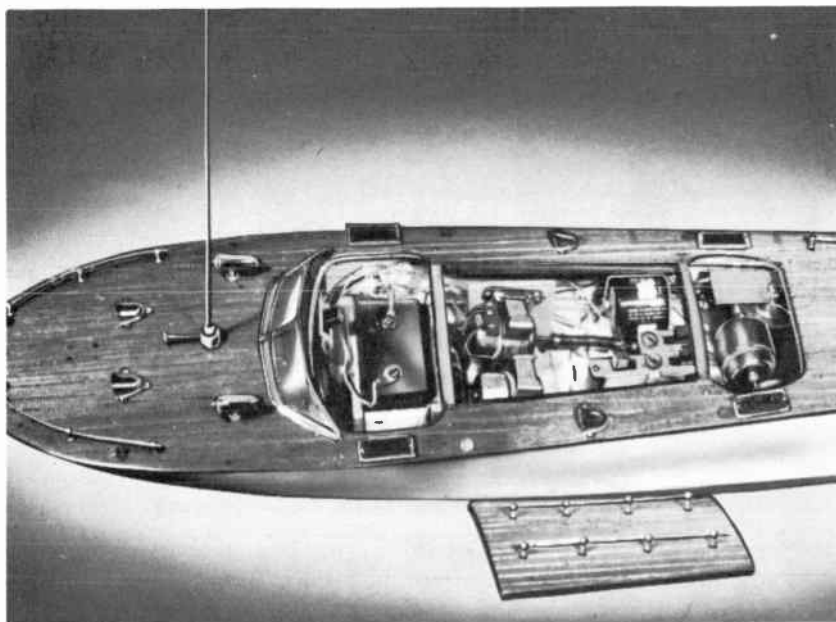


Fig. 608. Model boat houses the receiver, the batteries, Babcock servo and the drive motor easily, but in a compact manner.

where the receiver is located. Make certain that you do not run any circuit wires near the receiver antenna or coil. String them on the underside of the chassis.

Bathtub-size boat

If you would rather buy than build your radio control equipment, we offer this as a beginning project. The model is small enough (Figs. 608 and 609) so that you can actually control it around the bathtub or any small pool. The model, which can be obtained at hobby shops, requires only 3 or 4 feet of water.

Although two drive motors are used, only one is necessary. The primary battery is the 2-volt wet cell shown in the cockpit of Fig. 608. Since the greatest drain is on the drive-motor batteries, this wet cell is the answer — it has a long operating time and can be recharged. The flashlight batteries for the servo can be seen in Fig. 609. These have a long life and you will find that frequent replacement is not necessary.

One unusual feature of this installation is the method of moisture-proofing the receiver and its B-battery. The commercial receiver is encased in a small plastic box to make certain that the relay will not be restricted in its operation, and then the whole receiver and its battery

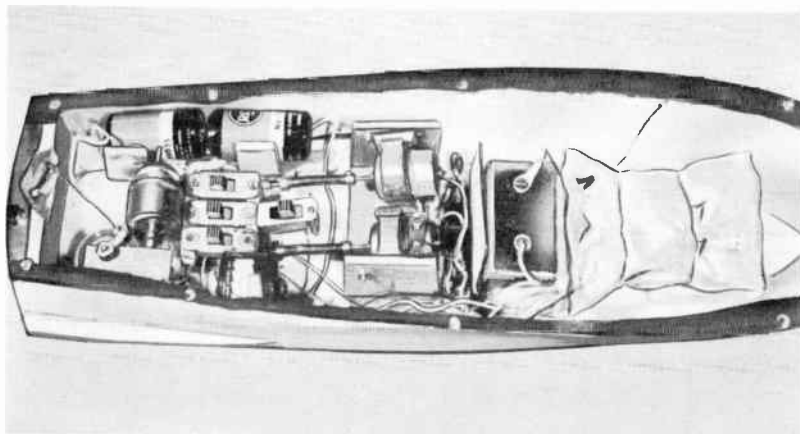


Fig. 609. Entire receiver and its battery are wrapped in moistureproof cellophane bag. The servo flashlight batteries are at the left.

are wrapped in a moistureproof cellophane bag, shown in Fig. 609. The antenna lead comes out between the folds.

The equipment necessary for this model includes a Babcock servo of the type previously discussed, a small commercial receiver, batteries and the drive motor. The transmitter discussed in Chapter 3 will operate any commercial carrier-operated receiver.

The wiring of the servo to the receiver relay is shown in Fig. 610. The only difference when you use two drive motors instead of one is that the battery terminals of the motors must be connected as if you had just one motor. If either propeller turns in the wrong direction, reverse the wires to its motor terminals.

The drive motors used (Japanese size No. 2, available at hobby shops) have excellent characteristics as far as power is concerned. They produce little arcing, which means no erratic receiver operation. As a precaution, however, .01- μ f capacitors were placed across each motor's terminals. Fig. 611 shows four switches. They control the following circuits: (a) receiver OFF-ON; (b) servo OFF-ON; (c) drive motors OFF-ON; (d) signal selector.

The signal selector is the one we are interested in here. It is a double-pole double-throw switch which reverses the leads to the receiver relay contacts as shown in Fig. 612. When the switch is in the OFF position, the servo will operate when we send a pulse or two pulses, as we discussed previously. In this case, the transmitter is ON only when we depress the keying switch.

In operation, if there is signal interference from some unknown source, to prevent the model from becoming uncontrollable or maneuvering erratically, the selector switch is moved to the ON position. (Of course, this must be done by hand prior to sailing the model, but the mode of operation can be selected by guess work or running the model

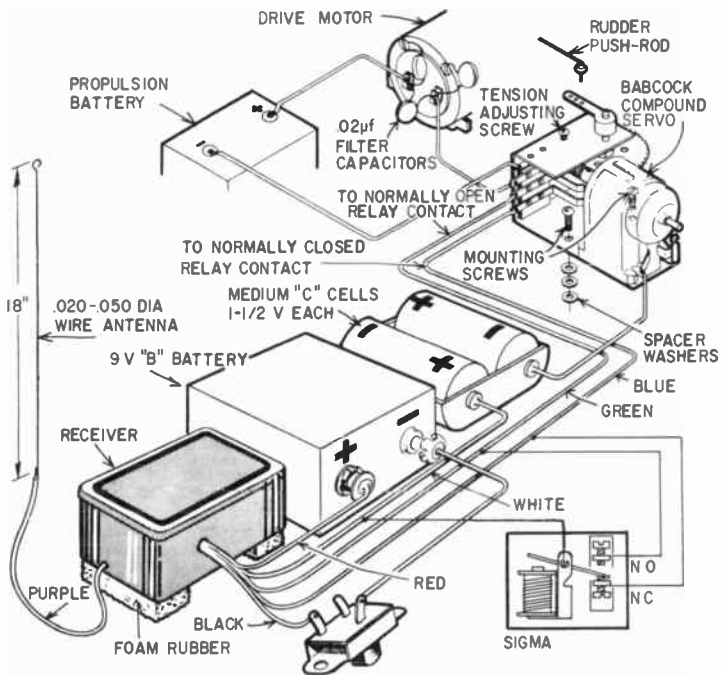


Fig. 610. Pictorial wiring diagram showing how to connect the servo, receiver, batteries and drive motor.

on the supporting stand in the contemplated sailing location long enough to find out if there is any interference).

When the switch is in the ON position, the two leads to the relay contacts are reversed. This means that the transmitter must be ON to have the servo neutralize. When we send a command under this system, we turn the transmitter OFF for the same length of time, or with the same rhythms that we used before in keying it ON. The servo operation will then be the same. (Note that you must now have a keying switch which *opens* the transmitter circuit when it is depressed instead of closing it as in the previous case.)

What effect has it? Simply this: if there is an interfering signal, although we may not be able to send a command, the model will go straight and will not maneuver erratically. We can test by holding our new keying switch closed and the moment we see the model respond, turn it around and head it back to home port. If the interference returns (and it is usually intermittent), the model will not change course.

Fig. 613 shows the details of the rudder linkage to the arm of the Babcock servo. All the wiring is run along one side of the model and bunched together to prevent internal interference. The only wires

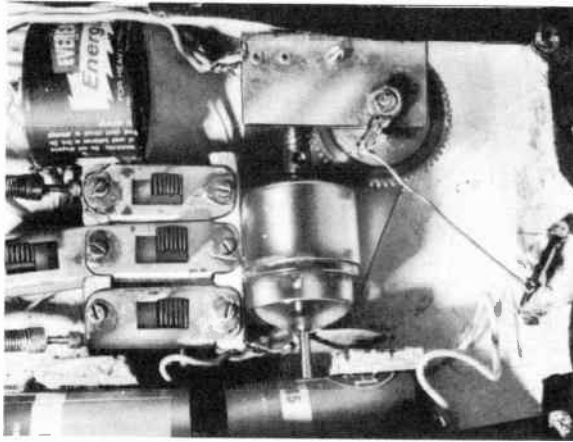


Fig. 611. Four switches seen at right are the three on-off switches for the receiver, servo and drive motor and the signal selector switch.

near the receiver are the leads, located next to the wet cell and the receiver antenna wire (which is way out by itself). This is an excellent example of an installation designed to give good results rather than trouble.

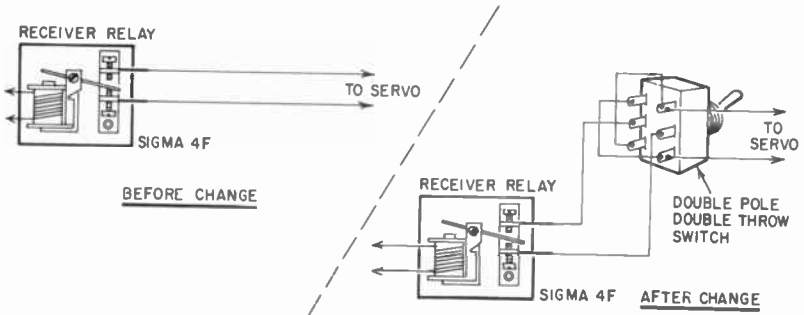


Fig. 612. Pictorial diagram shows how dpdt signal-selector switch reverses leads to receiver relay contacts.

Details of the circuit wiring

The wiring diagram (Fig. 610) shows how to connect the servo, the receiver, the batteries and the drive motor. Note the three filter capacitors connected across the drive-motor terminals.

This installation uses the Babcock Mark III receiver although any other single-channel type can be used. See Fig. 614. The wiring color code corresponds to the leads of the Mark III. With the transmitter not signaling, the current drawn from the battery is about 4 ma. When the transmitter signal is tuned in, the current rises to approximately 13 ma.

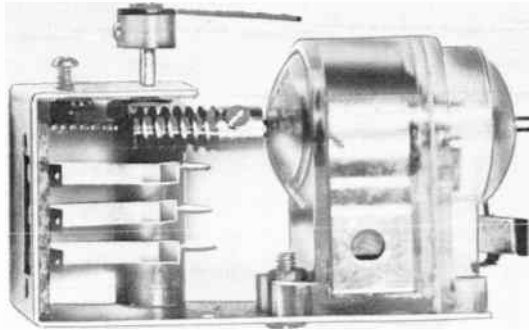


Fig. 613. Rudder linkage to the arm of Babcock servo. All wiring (not shown in the photo) is bunched together and run along one side of the servo to prevent interference.

Some precautions

In radio control (as in every other hobby) a certain amount of craftsmanship is necessary. But what do we mean by this? Craftsmanship is attention to detail and keeping in mind just what it is you are going to try to do.

We want to operate a model remotely. This means that your craftsmanship starts when you buy your model. Examine the wheels. Do they turn freely and easily? Will they turn as easily when the model is



Fig. 614. The Babcock Mark III receiver.

loaded? Can the wheels be removed if necessary? Can the model be changed easily should you need to do this? Is the model large enough to hold all the equipment? These are just a few of the questions you should have in mind.

Buying is just the beginning of your craftsmanship. It continues up to and through the testing period. It means that you must plan the receiver and servo installation carefully. The amount of traction power we have is limited and we are going to lose a good part of it in friction. The smoother and easier mechanical linkages operate, the greater our chance for better and easier control. The layouts we have given are suggested ones. Your own model may require some modification or change.

Finally, don't expect perfection immediately. You will find that minor alterations can improve performance and that best performance will be due to the sum of numerous small changes you will make, all based on your attention to detail, and all adding up to better radio control.

expanding the transmitter

WE start this chapter with the admission, "No, we have not yet discussed a model-airplane installation." Why? Because our control equipment is not reliable enough yet for this type of operation. We have been discussing very-short-range systems up to the present (with the exception of the commercial receiver) and, even if you have been able to operate your models over a quarter-mile distance with the equipment thus far specified, we will not consider using a model airplane until our system is such that we can expect 100% success.

Let us begin by increasing the range of our equipment. We will add a tube to our transmitter to increase its power and reliability in preparation for the better things to come.

Our first step will be to add a neutralized amplifier stage to our oscillator. This will not only increase the power but provide the circuit for 100% plate modulation when we use tones later on. The neutralization will require no adjustment. The added tube, a 6AK6 will be wired as a triode.

The method of mounting the parts and the construction specified follow a layout that provides maximum efficiency and minimum trouble. Even if you are experienced in radio-control, give serious consideration to this statement before layout changes are made. Let's do the addition in the following steps:

1. Cut a plywood board to size, as shown in Fig. 701.
2. Drill a $\frac{3}{4}$ -inch hole for the tube socket and a $\frac{1}{4}$ -inch hole for the tuning capacitor, and five $\frac{1}{8}$ -inch holes.
3. Fasten the three mounting lugs (L brackets) to the board.
4. Cut and bend a metal shield (Fig. 702). Tin or aluminum may be used but aluminum is recommended. It should be at least $\frac{1}{32}$ inch thick and quite stiff.

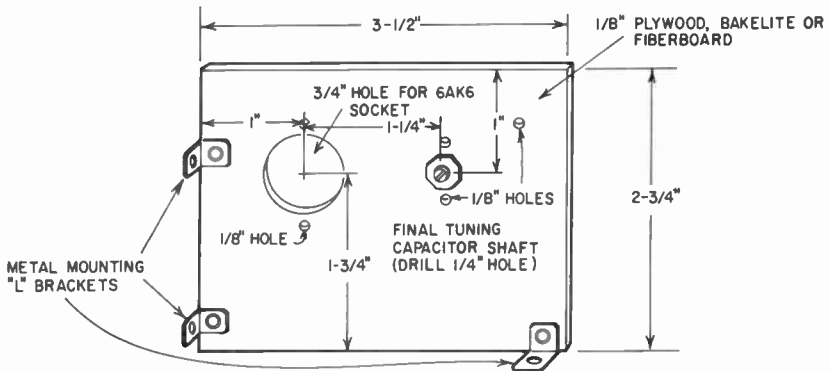


Fig. 701. Template for cutting insulated plywood board. (This template is not drawn to scale.)

5. Mount the plate to the shield. See Fig. 703.

6. Fasten the tube socket and variable capacitor (slot the shaft with a hacksaw, if necessary) to the insulated board. There should be three 1/8-inch holes in the chassis just below the tube socket. Drill these if necessary. (Also refer to Fig. 301 on page 31.)

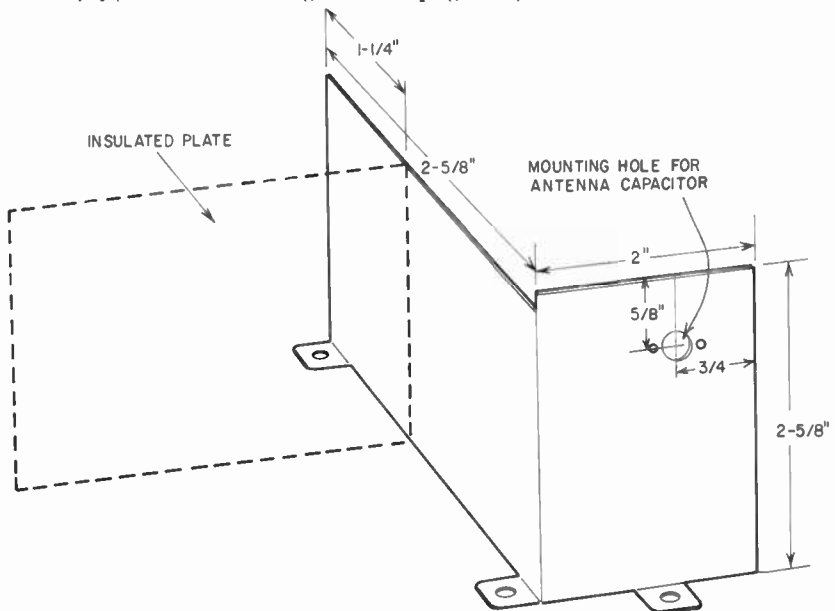


Fig. 702. The oscillator and the amplifier (now being added) will be separated by a metal shield. The insulated plate is the chassis for the amplifier. (This is a rear view.)

7. Wind a coil of 12 turns of No. 18 enameled wire (close-wound), 13/16-inch in diameter. This should make the coil 3/4-inch long.

8. Scrape the ends of the coil and solder to the capacitor lugs, one lead to the fixed plate lug and the other to the movable one. Make

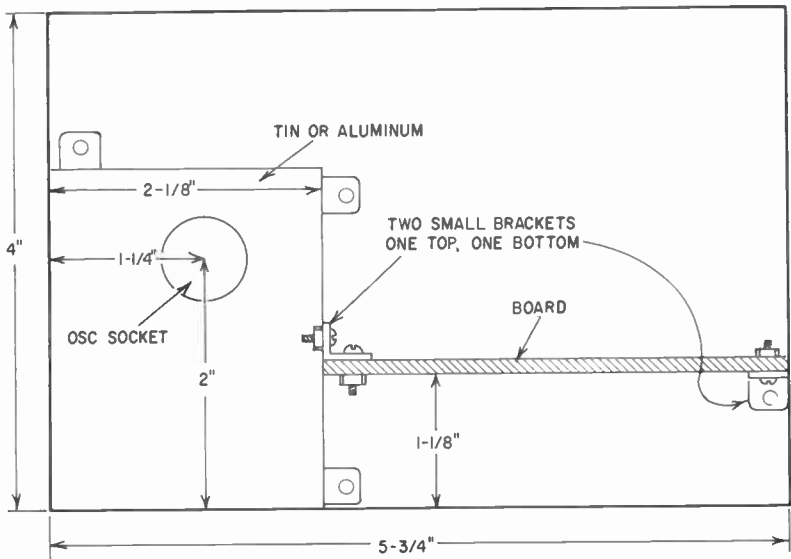


Fig. 703. The plywood board of Fig. 701 is fastened to the metal shield shown in Fig. 702.

certain that the coil is oriented as shown in Fig. 704. The coil winding is spaced about 1 inch from the capacitor plates.

9. Turn the chassis over and solder one end of a 6-inch length of insulated No. 18 hookup wire to pin 3 of the oscillator tube socket.

10. Solder one end of a second 6-inch length of insulated No. 18 hookup wire to pin 4 of the oscillator tube socket.

11. Twist these leads as shown in Fig. 705 and run them up through the holes just below the new tube socket (we will henceforth refer to this new socket as the *final* amplifier tube socket or V2.) Make sure the insulation is not scraped from the wires where they pass through the chassis. These wires will supply filament voltage to the amplifier tube.

12. Solder a 7-inch length of bare No. 18 gauge wire to terminal B of the solder lug nearest pins 1 and 7 of the crystal tube socket. This is the lug connected to the chassis by the mounting bolt. Bend this wire around the socket, keeping it next to the chassis, and then run it along with the twisted wires and up through the chassis.

13. Solder one lead of a .001- μ f capacitor to pin 3 of the oscillator tube socket and solder the other lead to the bare wire (see step 12).

14. Referring to Fig. 706, run the twisted leads up the left side of the final amplifier tube socket and solder the end of one lead to pin

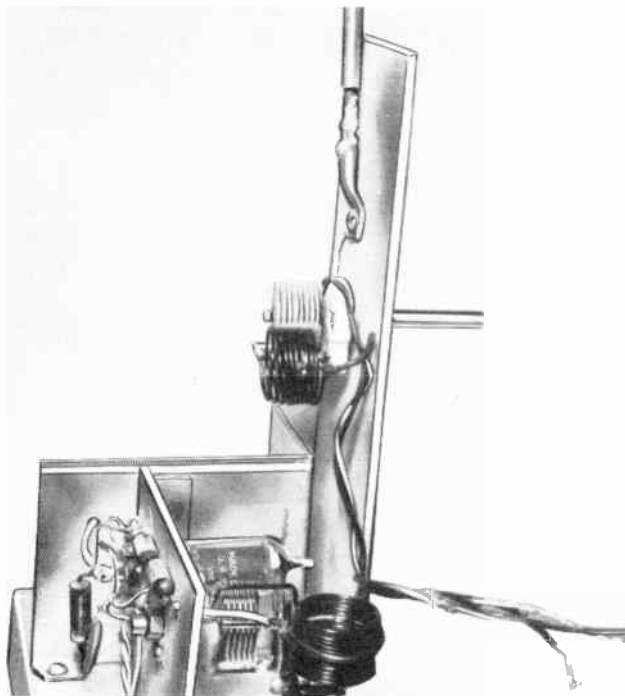


Fig. 704. One coil lead is soldered to the rotor of the variable capacitor and the other to the stator.

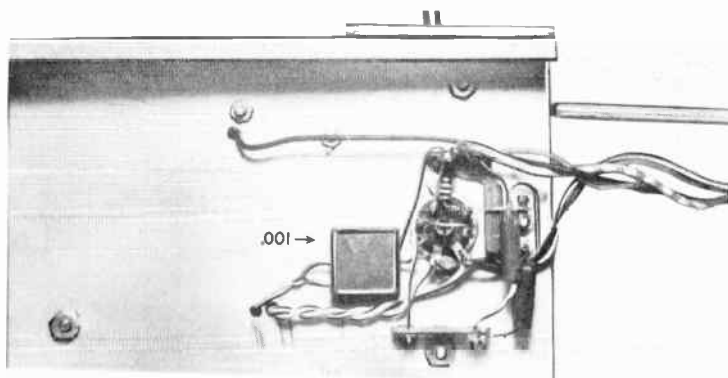


Fig. 705. Two twisted 6-inch lengths of insulated wire are run up through the chassis holes beneath the final amplifier tube socket (V2).

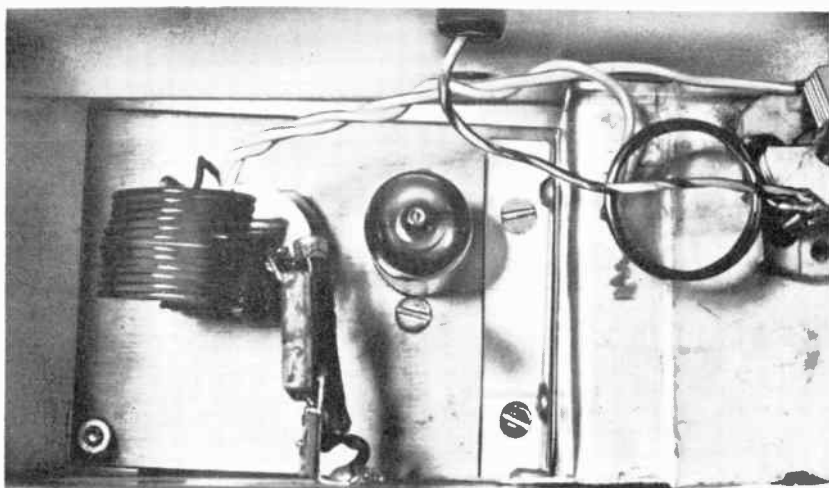
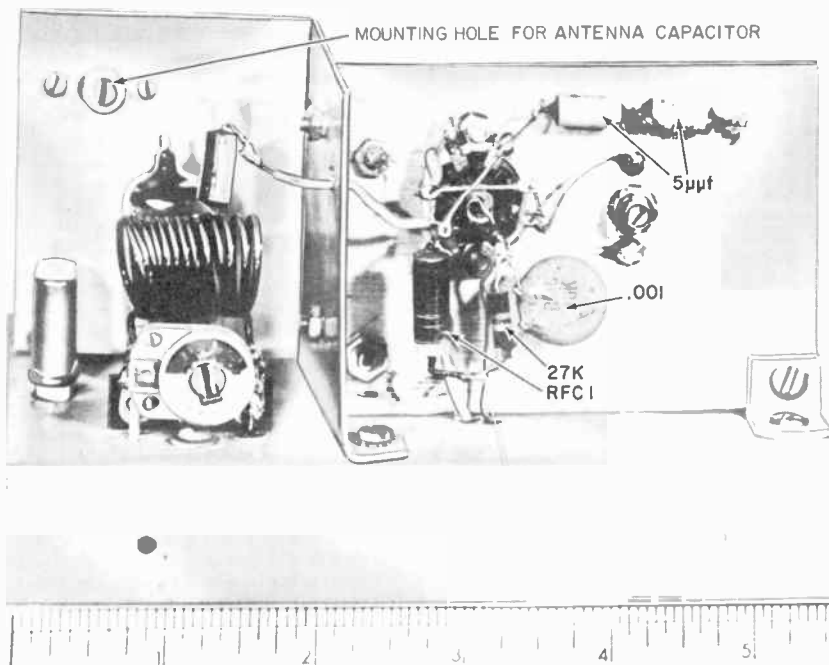


Fig. 706. The oscillator is the unit shown at the left. An under-chassis view of the amplifier is at the right (top photo). An above-chassis view of the amplifier is shown in the lower photo.

3 and the end of the other lead to pin 4 of V2. These are the filament pins of this tube. Run these leads close against the panel. (Construction details are given in Fig. 707.)

15. Solder the bare wire to pin 7 of V2, cutting off any excess wire so that the lead is short and direct.

16. Join the two 5- μf capacitor leads (C4 and C5) together and solder, then snip the joint off so it is about 1/4-inch long.

17. Solder the free end of one 5- μf capacitor (C5) to pin 1 of the final amplifier tube socket.

18. Drill a small hole through the panel for the free end of the second of the 5- μf capacitor (C4). This lead is soldered to the fixed-plate terminal of the 50- μf variable capacitor (C2). A small piece of insulated tubing is slipped over the wire on the rear of the panel.

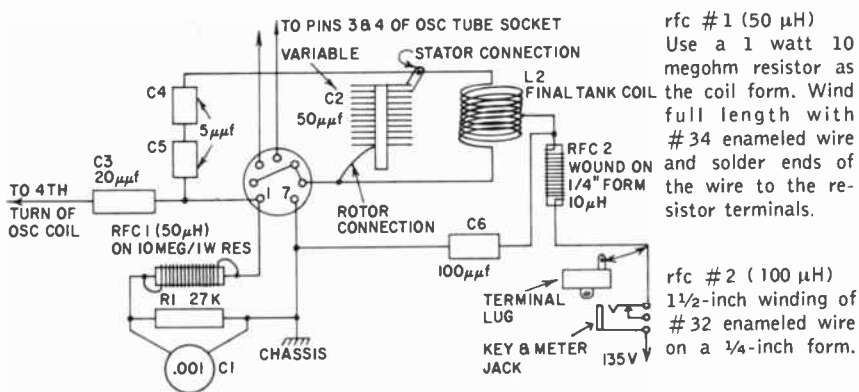


Fig. 707. Pictorial diagram of the amplifier.

19. Construct the two radio-frequency chokes RFC1 and RFC2. (Construction details are given in Fig. 707.)

20. Solder one end of a 3-inch length of insulated wire and one end of RFC1 to pin 1 of the final amplifier tube socket (V2.)

21. Solder the .001- μf capacitor (C1) to the leads of the 27,000-ohm resistor (R1) so that the two appear as in Fig. 706.

22. Solder the free end of RFC1 to one end of the capacitor-resistor combination (R1-C1). This joint should *not* touch the chassis or any other wiring.

23. Solder the other end of R1-C1 directly to pin 7 of V2.

24. Solder one end of a 3-inch length of bare No. 18 gauge wire to pins 2, 5 and 6 of V2.

25. Taking care that this lead does not touch any other and is not within 1/8-inch of any metal or any other lead, connect it to the rotating plate lug of the variable capacitor, C2. (On the capacitor we used, this connection could be made through the mounting screw.)

26. Take the 20- μf capacitor (C3) and snip one lead to a length of about 1/2-inch. Solder this lead to the top of the fourth turn of the oscillator coil. Be sure to scrape the insulation off the coil turn, and

do not use too much solder or the turns may be shorted. Pry the two adjacent turns apart so that you have at least a $1/32$ -inch air gap between them and the turn you solder to. (The tap is at the fourth turn from the end of the coil that is connected to the plate, pin 5, of V1.)

27. Run the insulated lead from pin 1 of V2 through the center of a $1/4$ -inch hole in the shield and solder the other end to the free lead of the $20\text{-}\mu\text{f}$ capacitor, C3. Keep this lead as short as possible.

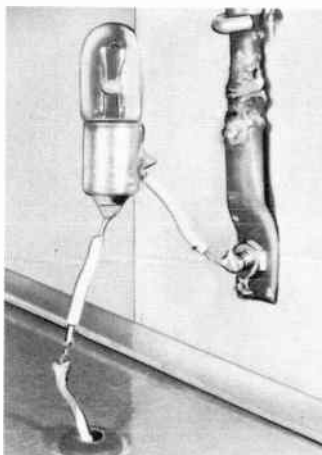


Fig. 708. One short lead from a No. 47 bulb connects to a screw-terminal base of a 4-foot antenna.

28. Referring to Fig. 707, mount one insulated terminal solder lug in the position shown.

29. Directly above the lug and a little to the left will be the final amplifier coil, L2. Determine the center turn (thru 6, counting from either end) and the two turns next to it. Separate the center turn from the others so that it is clear by at least $1/32$ -inch. Solder one end of RFC2 to this turn, using the same procedure as in step 26.

30. Solder the other end of RFC2 to the insulated lug of the terminal strip.

31. Take a $100\text{-}\mu\text{f}$ capacitor, C6, (disc or flat type) and solder one lead to the same spot on the coil as the connection of RFC2.

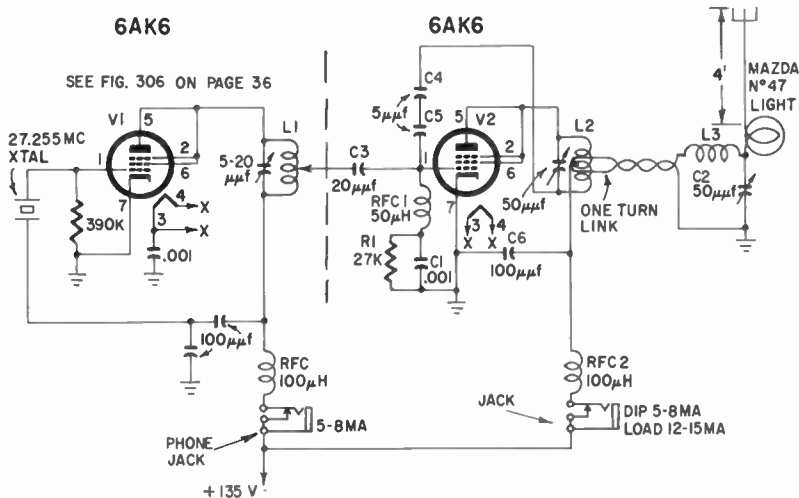
32. Solder the other lead to the grounded lug (connected to the chassis by the mounting screw) of the insulated terminal strip.

33. Take a 16-inch length of insulated flexible wire and solder one end to the same terminal lug that RFC2 is soldered to. Drill a hole through the chassis. Run this lead down through the hole, bend it and run it out to the side that the oscillator B-plus lead goes to. This is the B-plus lead for the final tube. It should be so marked.

34. Make an antenna coupling loop by wrapping one turn around

the exact center of the final coil of wire (Fig. 704) and connecting the two free ends to the antenna coil and capacitor (just as we did previously when we had only the oscillator tube working in our basic transmitter).

35. We can now solder one end of a short lead from a pilot light (Mazda No. 47) to the base of a 4-foot antenna (Fig. 708) and connect a short lead from the light to the same junction of the antenna coil



- L1-12 TURNS N°18 ENAM 5/8" DIA 1" LENGTH
TAPPED 3-1/2 TURNS FROM PLATE END
L2-13 TURNS N°18 ENAM 13/16" DIA CLOSE WOUND
3/4" LONG CENTER TAPPED
L3-5-1/2 TURNS N°18 ENAM 7/8" DIA CLOSE WOUND

parts list for the transmitter amplifier

Resistor: 1-27,000 ohms, 1/2 watt.

Capacitors: 2-5 μf; 1-20 μf; 1-.001 μf ceramic; 1-100 μf mica; 2-50 μf air variable.

Coils: 1-100 μh rf choke; L1, L2 and L3 -

see above.

Miscellaneous: 1-shorting-type phone jack (key and metering jack); 1-7-pin miniature tube socket; 1-6AK6; 1-Mazda No. 47 pilot light; soldering terminal; solder; No. 18 enameled wire.

Fig. 709. Our transmitter now consists of an oscillator followed by an amplifier.

and capacitor that we connected our antenna to previously. The two leads to the lights should not be over a couple of inches long.

36. Insert a second 6AK6 tube in the final socket and we are ready to adjust and test our new expanded transmitter.

The circuit schematic of Fig. 709 is included for those who would prefer to construct by using this kind of diagram. (Pictorials are an excellent first step toward learning how to read schematics.)

Testing and adjusting

For our initial testing and adjustments we chose to use the upright board for the antenna, antenna capacitor and coil (Fig. 702). The photograph (Fig. 704) does not show the antenna light men-

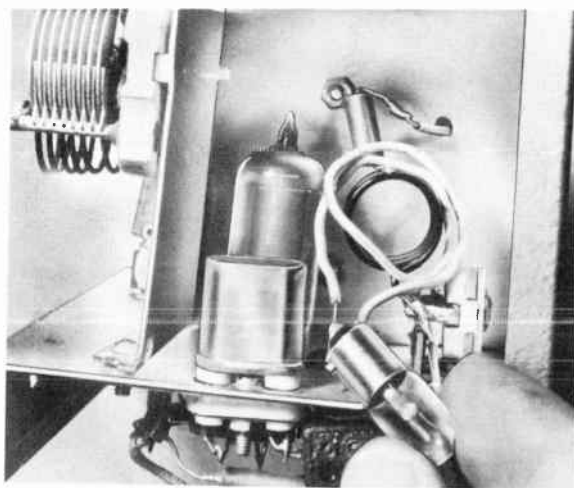


Fig. 710. Loop light placed over oscillator coil should glow as keying switch is depressed.

tioned in step 35. It would be connected in place of the wire you see going from the side of the capacitor up to the antenna. It is important that you have an antenna within a couple of inches of exactly 4 feet for these tests and adjustments.

Now the only new thing in connecting this transmitter to our batteries is that we have one additional lead which we must connect to the B-plus terminal. Other than that, the rest of the battery leads connect exactly as they did for the one-tube transmitter.

Step 1 is to leave this new B-plus lead disconnected. Connect the others as you did for the one-tube transmitter and be sure to have your test meter in the B-plus lead to the battery. Now tune the oscillator just as you did before, looking for that setting on the gradual dip side just a little higher than minimum. Place your loop light over the oscillator coil as shown in Fig. 710. It should glow when you depress the keying switch. Adjust the oscillator tuning capacitor until it does. Now hang the light over the coil so you can monitor this stage and be sure it's working, before we switch our test meter to the final B-plus lead.

Set the meter scale to read 100 ma. Connect the red (common) lead to the same B-plus terminal of the B-batteries that the oscillator B-plus is connected to. Now connect the other meter lead to the final B-plus lead. Insert your insulated tuning screwdriver in the final tuning

capacitor shaft slot. (If it doesn't have a slot, make one with a hack-saw). Depress the keying switch and immediately tune this capacitor for the *lowest* possible meter reading.

With the antenna capacitor's plates set to mesh about one-fourth of the way, the antenna pilot light should start to glow.

If you are unable to tune to a dip, check the pilot-light loop around the oscillator coil. Does it glow when the key is depressed? If it doesn't, then retune this stage till it does. You might also, just for the moment,

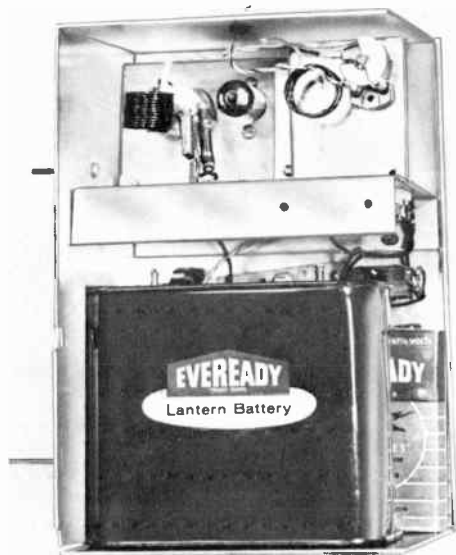


Fig. 711. Chassis shown mounted in a 6 x 9 x 5-inch cabinet.

remove the antenna by disconnecting the light lead to it. Open the antenna capacitor until the plates mesh the least amount. Now, making sure that the oscillator light is glowing (holding the keying switch closed), try tuning the final stage again. You'll find the dip if you tune slowly. You'll also find that when you remove the alignment tool, the reading will rise slightly. Tune a little higher than the dip, first on one side and then the other, until you find out which setting allows the meter hand to drop to a lower reading when the alignment tool is removed. That's the way we want it!

Now reconnect the antenna and tune the antenna capacitor for the brightest glow of the antenna light. The meter reading will rise as we do this, but we do not retune the final now. As long as the antenna light burns, we have power to the antenna and our transmitter works.

Fig. 711 shows the chassis mounted in a cabinet 6 x 9 x 5 inches. With this setup we have now mounted the antenna capacitor and coil to

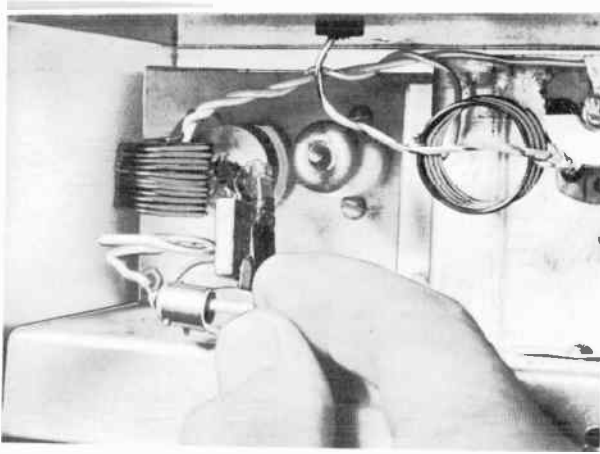


Fig. 712. *Checking transmitter operation with the pilot-light loop.*

the rear of the oscillator shield and run the antenna wire up through a rubber grommet in the cabinet top. Tuning is still done in the same way, and the procedures previously discussed can always be used.

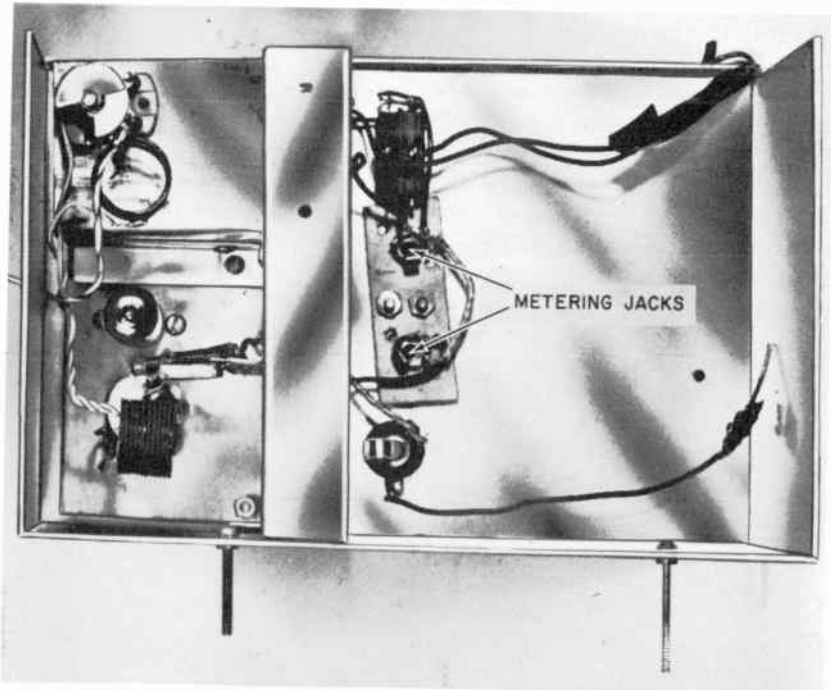


Fig. 713. *Positioning of the metering jacks.*

To see if the transmitter is operating when we do not have a meter, we can use our pilot-light loop as in Fig. 712. Make sure the antenna is disconnected. Using the light as indicated here, just tune the final for the brightest glow of the pilot light. (*Use care here! The voltage is high on the solder-lug terminal strip*).

With the chassis in the cabinet, there is plenty of room below for batteries (Fig. 711). We will also want to install the on – off switch and the keying and metering jacks, which are located just below the chassis. Figs 713 and 714 show how the keying and metering jacks (these are shorting type phone jacks) are positioned under the chassis.

The keying jack can be mounted directly on the metal panel. The two small shorting type phone jacks must be mounted on a strip of plywood, bakelite or fiberboard so that no metal part of the jack touches the metal of the cabinet. The wiring is straightforward. First, solder lugs 1 and 2 of each jack together. Solder the B-plus lead of the oscillator to the connecting wire between jack lugs 1 and 2. Solder the B-plus lead from the final stage to the connecting wire for the jack on the left.

The third lug of each may be connected by a short length of wire. This lead is extended to connect to one terminal of the switch. A longer length of wire is then soldered to the switch lug just above this or the center one, and this lead is the one that now goes to the B-plus battery terminal.

Obtain a phone plug that fits these metering jacks and solder two 8-inch lengths of insulated wire to its two terminals. Scrape the free ends and connect your meter to these ends. The common meter lead goes to the lead connected to the tip of the plug; the other meter lead goes to the shaft-terminal lead of the plug.

Connect the batteries, insert the plug into the oscillator jack, turn the switch on and watch the meter pointer as the tubes get warm. If the meter pointer starts to move downscale or in the wrong direction, turn off the power and reverse the connections to the meter leads. Use the meter to adjust the oscillator. Then, put the plug into the final jack and tune the final stage (the oscillator will keep working). When the final stage is tuned, remove the plug. The final stage will keep on working, so you won't need to have the meter always connected after the transmitter has been adjusted.

In the field, you will be able to use your antenna light to check that your transmitter is operating properly before you let go of the model.

A word about the batteries: the case we selected was large enough to accommodate two 67.5-volt Eveready No. 467 B-batteries and a 6-volt lantern battery (Fig. 711). If you desire, you may use a 6-volt motor-scooter wet cell. This is ideal. The wet cell is not only rechargeable but it has a very long charge life.

What to do in case of trouble

There are three common causes of trouble with transmitters of this type: weak batteries, incorrect tuning and open circuits. Of these, we are concerned with the first and last, since we have covered the tuning in some detail and you are now able to check this.

To determine whether the batteries are furnishing sufficient voltage, the most obvious inspection point is the antenna light or the loop light around one or both of the transmitter coils. Assuming that you started with fresh batteries, you have some idea how bright the light

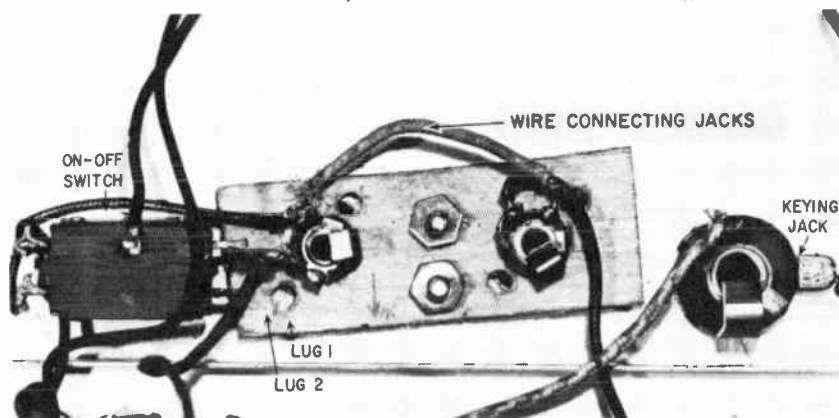


Fig. 714. The two metering jacks are connected by a wire. This wire is a temporary jumper only.

should be and thus as it dims, you will know the batteries are getting weaker.

If the lights are dimmer, or if meter readings are lower than they were with fresh batteries, these batteries should be tested *under load*. This means that we must measure the voltage while the batteries are operating the transmitter.

Pull the batteries out of the case but keep the leads connected. Turn the transmitter on, remove the test meter (if it was attached to the metering plug) and adjust it to measure 100 volts. Now have someone depress the keying switch, or using a weight to keep it closed, measure the voltage across each B-battery's terminals. If the reading is less than 0.5 (50 volts), then your batteries are becoming weak. Watch them from now on. Replace when the voltage drops to 35 or when the antenna light just glows.

To check the A-battery, measure across its terminals, using the 10-volt scale of your test meter. When the voltage drops to 4.5, replace the battery. (Or charge it if a wet cell is used).

This method of testing under load should be used on all batteries in the radio control system. *Never assume that a battery is all right if you test it without having it operating in its circuit.*

If you use phone jacks in this transmitter, make sure that the finger contact of the jack makes a good connection to the extended metal strip (which is depressed when the plug is inserted) whenever the plug is removed. We had to bend those we used slightly to make certain that the connection was good. When this finger does not make contact, the transmitter *will* work with the meter plug inserted but *will not* operate when the plug is removed from the jack.

Final considerations

A few additional words now that we are ready to start operating again:

1. You may use an additional 67.5-volt battery in series with the previous two to have a still larger power output. The B-plus lead of the final tube is connected to the plus terminal of this third battery, while the oscillator B-plus is left at the junction of batteries 2 and 3. The jumper between the two jacks (Fig. 714) is removed from the oscillator jack and extended to become the final B-plus lead.

2. If, after you mount the chassis in the metal cabinet, the transmitter starts operating as soon as you turn it on and the keying switch has no effect, make certain that the lead from the minus terminal of the series B-battery is connected to the *insulated* phone-jack (keying jack) terminal and not the grounded one. Connect the *transmitter* B-minus lead to the grounded terminal. (When we say grounded, we mean that terminal which is connected to the case or chassis through some metallic strip).

3. Anytime that you make a change in the transmitter or receiver, retune the receiver to the transmitter and make a range test to get the tuning absolutely correct. Refer to the sections in which we have discussed the receiver to remind yourself of the details.

two forward speeds, reverse and steering

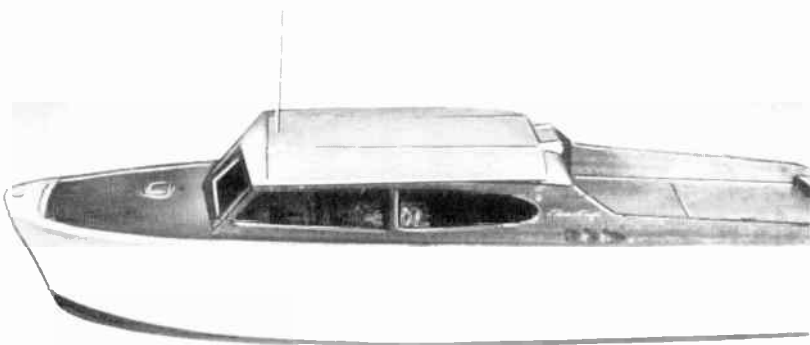
WE do not start all over again. We merely add to what we already have in our radio-control system to obtain more control over our drive motor. We want to be able to make our model go forward at either cruising speed or high speed and also to make it reverse on command (as well as to start and stop it).

We have lumped together two types of models – the car and boat – because they both have propelling motors and essentially the same steering requirements. The system we are going to discuss will be adaptable to either although we describe a model-boat installation. The model, however, is larger than the one shown previously because it must accommodate the additional equipment required. Figs. 801-a,-b show the relative size of the model and the general details of equipment installation.

Fig. 802 shows how to connect the servo to the rudder. (No connections to the basic servo are indicated since the area of primary interest is the mechanical linkage to the rudder.) Figs. 803-a,-b show the actual installation. Note in Fig. 803-b (on the far side of the stepper) how a radio knob has replaced the commercial cam. In Fig. 803-a, no wires are anywhere near the receiver antenna or coil, and the drive motor is a completely shielded type. (We do not recommend any motor with a plastic case if your installation has the receiver close to the drive motor.) In Fig. 803-b, note the sponge-rubber pad under the stepping relay; we will refer to it again.

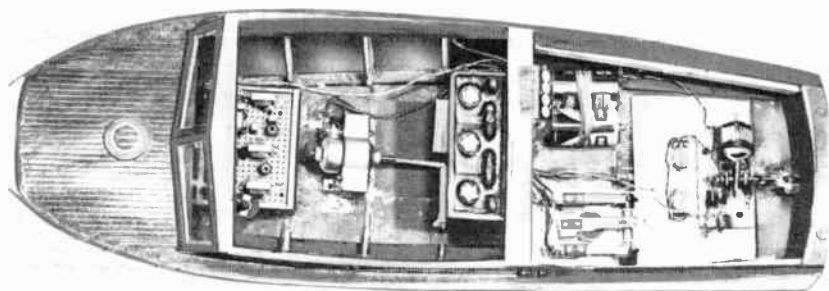
We must first modify our servo:

1. Remove the motor start – stop cam.
2. Make a new cam by cutting this down to the dimensions shown in Fig. 804. This illustration shows the wiring details of the motor-control circuit.



a

Fig. 801. (a) Larger-size model boat. (b) General details of equipment installation.



b

3. Solder the new cam in position. In both the Figs. 804 and 805 the servo is shown in the neutral position. Note that the cam is positioned just above the wiper so that, as the shaft rotates clockwise just a few degrees, it will make contact with the wiper and then break this contact as it continues to rotate. The motor batteries must be connected so that the motor will turn the shaft clockwise. Try connecting the plus battery terminal to one motor lug and the minus to the other. If the motor turns in the wrong direction, reverse these leads.

4. Mount the basic servo on a new base board (Fig. 806), leaving room for the two AR-21 relays.

5. Mount the two relays. The extra width of the base board (1/16-inch plywood) is to allow enough room to bolt or screw it to the model hull.

In Fig. 806, no capacitors are shown, although these are indicated in the wiring diagram (Fig. 804). They can be seen on the actual installation (Fig. 803-b).

The wiring diagram of Fig. 804 is self-explanatory, with the exception of the stepper relay and the 6-volt battery, which operates both the stepper and the drive motor of the model. Before we discuss these, however, let's spend a moment learning how the system operates.

We have added two relays and changed a cam. The whole purpose of doing this is to allow us to make the stepper relay change position

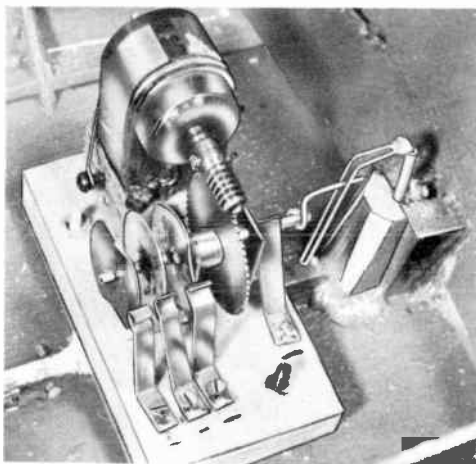


Fig. 802. Details of servo connection to rudder.

on command. When we send a signal which causes the receiver relay to close, it in turn closes the two auxiliary relays, instead of operating the servo motor directly, as it did previously. Each of the auxiliary relays has two contacts as well as the armature: each is just like the receiver relay. When the steering control relay (relay S in Fig. 804) operates, it controls the servo just as the receiver relay did earlier.

When the receiver relay is energized by command, it not only operates the steering control relay but also the motor control relay (M). The motor control relay has a wire connected to its normally closed contact and the wiper of cam 3. The armature of this relay is connected through the frame and lead X to one side of the stepping relay coil.

This means that if the motor control relay is energized when cam 3 makes contact with its wiper, the circuit from the minus side of the 6-volt battery to cam 3 through the cam shaft and through cam 3's wiper to the normally closed contact of this relay finds an open circuit, because the armature has pulled away from the NC (normally closed) contact. *Nothing happens.* (Of course, cam 3 will not make contact with its wiper unless the motor is turning the shaft).

Now if we make the motor turn by sending a short signal and then stop sending the signal, relay M will energize, *but will release before*

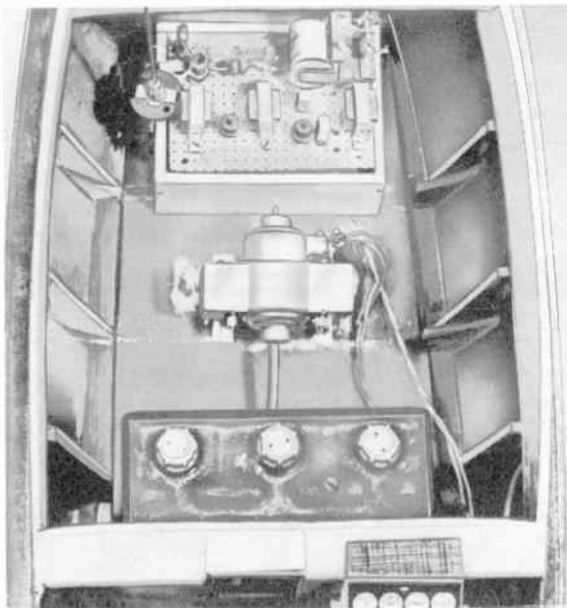
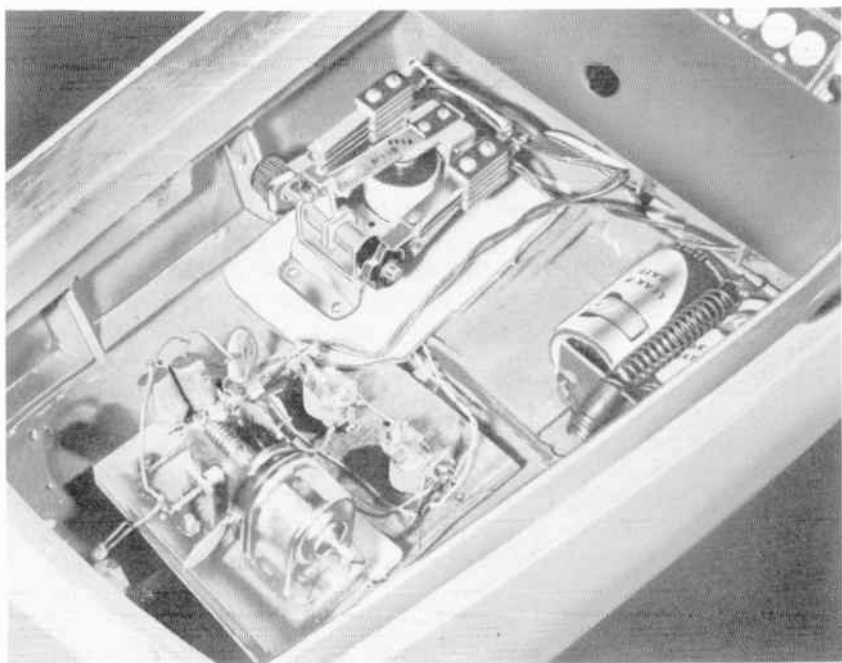


Fig. 803. (a) Drive motor (center) is a completely shielded unit. (b) Sponge-rubber pad under stepper relay reduces vibration.



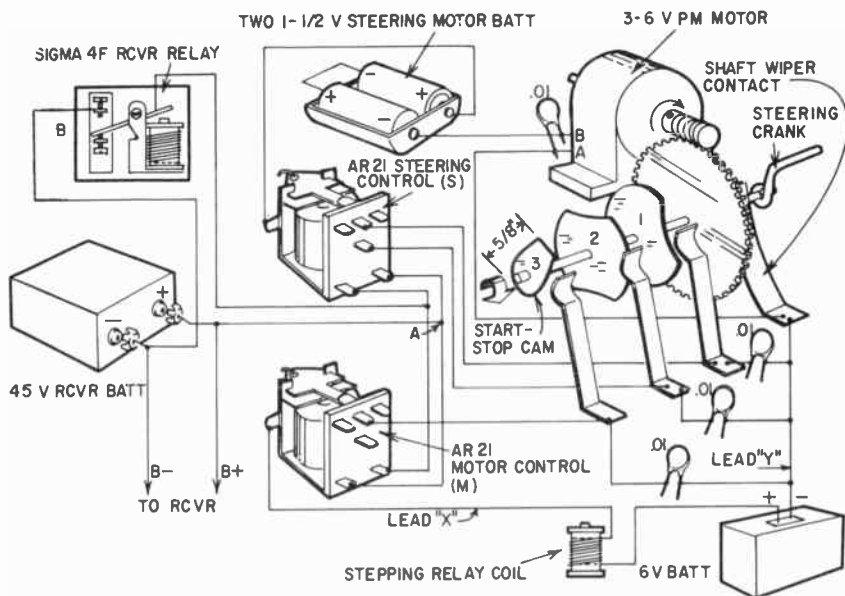
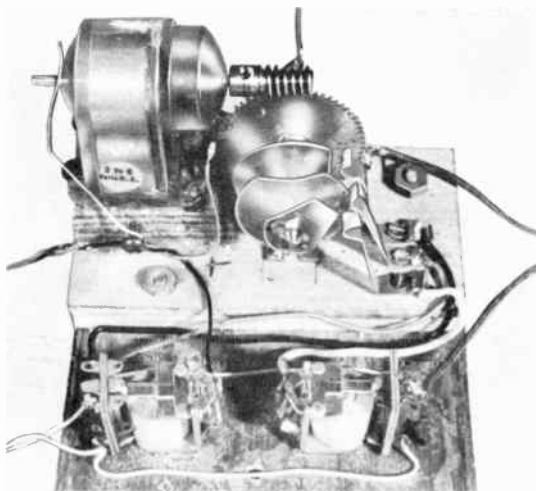


Fig. 804. Pictorial wiring diagram of motor-control circuit. Leads X and Y must be at least 12 inches long.

cam 3 makes contact with its wiper. Thus, when the cam makes this contact, the circuit is not broken by the relay (which is now de-energized) and causes current to flow through the stepper coil. This will be only a momentary circuit, for then the motor will drive the cam

Fig. 805. Servo shown in neutral position. Cam is positioned above wiper ready to contact wiper and break contact as shaft rotates.



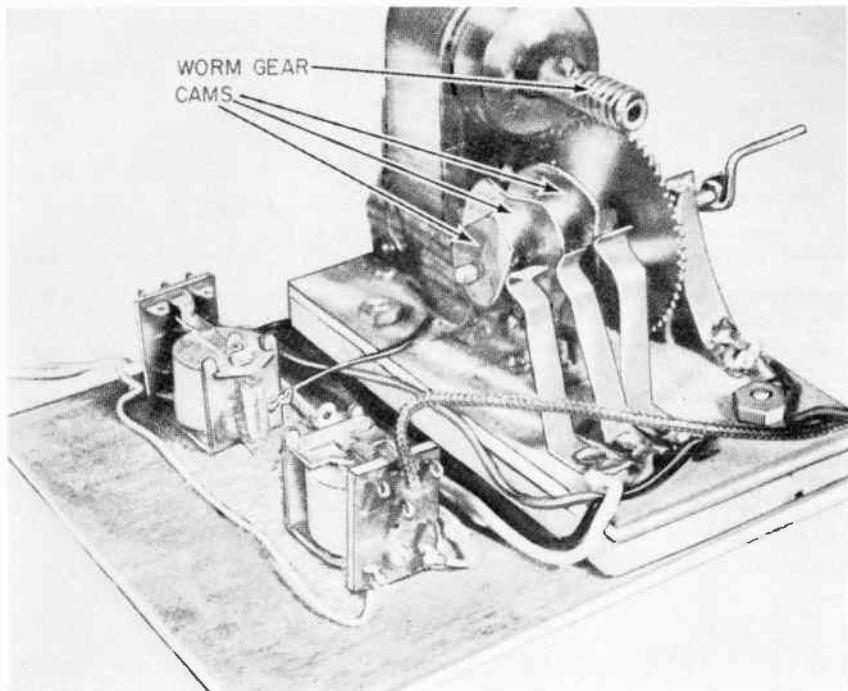


Fig. 806. Basic servo mounted on new base board. To the left are two AR-21 relays.

shaft around to neutral and will stop. This momentary impulse to the stepper relay coil will cause the model drive-motor to change.

Now complete the wiring. Be sure that the two leads, X and Y, (Fig. 804) which go from the servo to the battery and the stepping relay coil, are at least 12 inches long.

Note the use of the receiver B-battery in Fig. 804. This battery can still remain in the receiver case, but you will have to solder a lead to its plus terminal and a second lead to its minus terminal to connect to points A and B, if you use it to operate the AR-21 relays. You may use a second 45-volt battery to operate the AR-21's. If you do, connect it as shown and omit the leads to the receiver.

One final note: If you use the receiver battery alone, make certain that the *receiver relay frame* does not touch any of the wiring on the underside of the receiver. This can happen if you accidentally have a wire or part touching the relay mounting bolts.

In case you'd rather buy than build, the deBolt 3PNX servo is the solution. It has this momentary switch built in. Fig. 807 is a photo of this unit.

Stepping relay

Let's turn our attention to the AP11D stepping relay (Figs. 808 and 809). There are two identical composition cams on each end of the shaft. With your fingertip, push down on the armature of the relay

and note how this causes the shaft to step. It will take eight steps for the shaft to make one revolution.

As the shaft turns, the two cams cause the center leaf of the contact bank to rise and fall, both sides rising and dropping at the same time. We want to change this sequence and so we make the cam shown in Fig. 810 out of our radio knob.

A radio knob was used because its shaft is exactly $\frac{1}{4}$ -inch in diameter, and thus we can mount this new cam easily by merely removing the factory-built cam, sliding the knob on the shaft and tightening the knob setscrew.

Perhaps you couldn't obtain a knob that was exactly $\frac{3}{4}$ -inch in diameter all across its width. That's all right if its rim is $\frac{3}{4}$ -inch. We used a tapered knob and had no trouble.

File flats on the knob to match Fig. 810 exactly. Remove the factory-built cam by lifting the locking spring with the tip of a screwdriver. Pull the old cam off and push on the new one (Fig. 810 also shows the factory-supplied cam).

To set the cam in the correct position, we must determine what we want it to do. Now we must refer to Fig. 811. We want to position our new cam on the shaft so that, as the relay causes the shaft to step, the leaf springs make the following contacts: start with leaf A. It must make contact with 1 at the same moment leaf B makes contact with 3. Now push down on the relay armature and release. Leaf A should still make contact with 1 but leaf B should drop to make contact

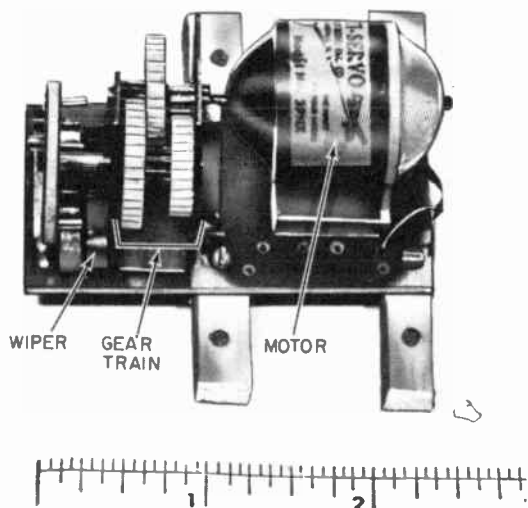


Fig. 807. The deBolt 3PNX servo with momentary switch built in.

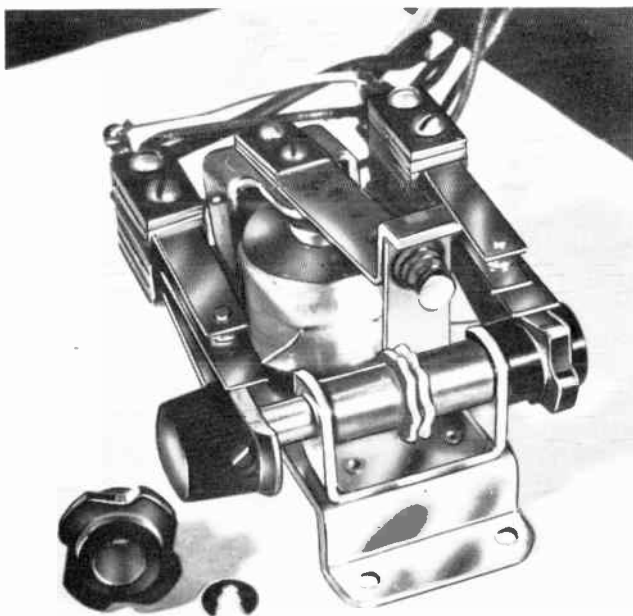


Fig. 808. AP11D stepping relay with knob cam on the left.

with 4. Depress the armature and release. Leaf A should drop to make contact with 2 while leaf B moves up to make contact with 3. Depress the armature again. Leaf A remains on contact 2 and leaf B drops to make contact with 4. This is a cycle.

If we depress the relay armature again, both leaves (A and B) should rise, making contact with 1 and 3 – which was our original starting

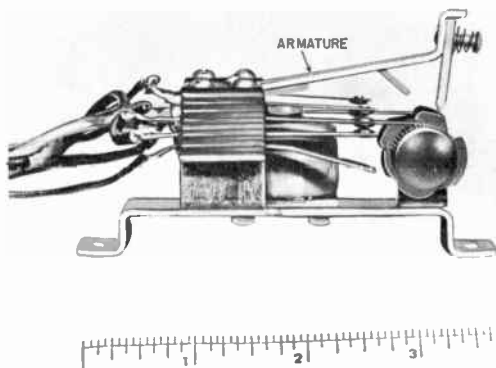


Fig. 809. AP11D, showing leaf construction. Pushing down on armature causes shaft to step.

position. If we continue depressing and releasing the armature, the cycle will repeat. We must position the new cam on the shaft so that it does exactly as we have specified. Lock the cam in place by tightening the set screw.

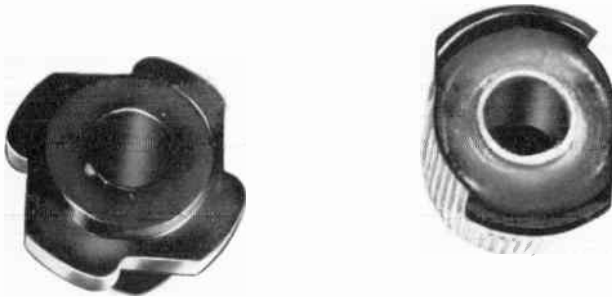


Fig. 810. New cam made from a 3/4-inch-diameter radio knob with a 1/4-inch-diameter shaft. Factory-made cam is shown at left.

That's about all there is to it, except to connect the stepper to the battery and the two leads from the servo. This is shown in Fig. 811, which also shows how to make the connections to the drive motor and the drive-motor wet-cell battery.

If you use dry batteries, say 1.5-volt types, instead of the wet cell, just connect them in series and make certain that you tap off at

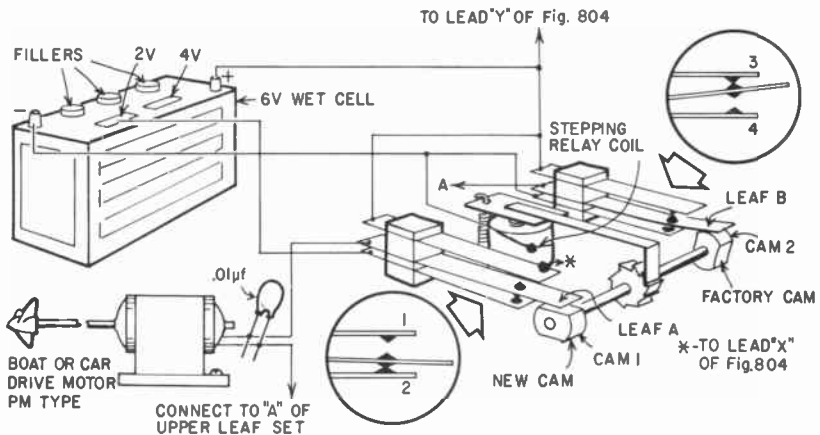


TABLE
8 STEPS PER CYCLE FOR 1 REVOLUTION

- 1+3 = OFF
- 1+4 = FORWARD HIGH SPEED
- 2+4 = FORWARD LOW SPEED
- 2+3 = REVERSE LOW SPEED

Fig. 811. Pictorial wiring diagram showing connections of stepper to battery and two leads from servo. Connections to drive motor and drive-motor battery are also shown.

the 4.5-volt connection, measured from the positive lead to the junction.

Testing the motor control stepper

A simple way to test the stepper is to use the circuit of Fig. 811 without connecting the two leads from the servo.

Study the table of Fig. 811. Using your fingertip, step the shaft around so that the leaves connect to contacts 1 and 3. The drive motor should not operate. This is the off position. Depress and release the armature. The motor should turn at high speed. If it turns in the wrong direction, then reverse the leads from the stepper to the drive-motor terminals. Step the shaft again. The motor speed will decrease. The amount of decrease can be controlled by changing the lead from the 4-volt tap on the battery to the 2-volt tap. Step the relay again; this time the motor should reverse at this same low speed. A final step causes the motor to stop again.

Now we are ready to reconnect the leads from the servo to the points indicated and, having made the connections to the receiver relay, we will test to make certain that this relay can control all the

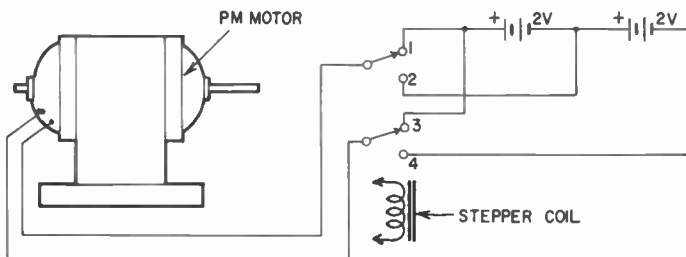


Fig. 812. Circuit diagram of motor-control system.

steering and speed operations. To do this, we do not turn the receiver on; we merely close the receiver relay with our fingertip, using this new command code: depress and release quickly (but not too quickly) and the motor control stepper should operate. The steering servo should also operate, the steering servo cam making one complete revolution and then stopping at neutral. Depress the receiver relay armature and hold it so that the armature touches the normally open contact; the servo should turn 90° and stop. The motor-control stepping relay *will not* operate. Release the receiver relay armature, and the servo moves the crank around to neutral and stops. *There is no stepper action.*

Depress the armature and hold it until the servo has had time to turn 90°, release and then depress again. The servo will now continue turning to the 270° position and will stop there. Release, and the servo returns to neutral. The stepper has not operated during this command sequence.

In other words, a short pulse and release causes the stepper to operate. A continuous signal causes the servo to move 90° and stop. This would be, say, turn left. A longer pulse, OFF and then a continuous signal will cause the servo to move through 270° and stop, giving right and no stepper action.

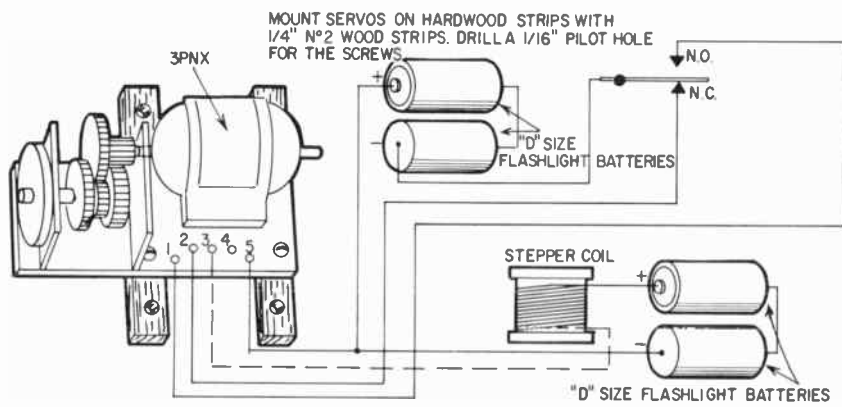


Fig. 813. Pictorial wiring diagram shows connection of deBolt servo to stepping relay and receiver relay.

Work this sequence over and over until you get the feel of the rhythm. Try sending a series of short pulses to put the drive motor through its various speeds. When you are able to see how you command the operations, turn your receiver ON and the transmitter ON and try sending the same kind of signals with your keying switch.

It may take a little practice before you get the hang of it. Remember, the worst that can happen is no change in motor speed. You always have the steering, just as with the model car.

In case of erratic operation, you may have to mount the stepper on a sponge-rubber pad. The armature of this relay bangs down so hard it may jar the small AR-21 relays and cause erratic operation. The cushion cures this. We also tightened the spring tension of the AR-21's by pushing the bottom lug as far down as it would go against the base board.

You may find that, due to increased transmitter power, the receiver tends to miss when it is too close to the transmitter. Either move the transmitter away 20 or 30 feet, or use only one 67.5 volt B-battery for B-plus when testing.

The circuit diagram of this motor control system is shown in Fig. 812.

Using a commercial servo

It is possible to buy a servo which will perform this type of operation. (deBolt 3PNX, shown in Fig. 807). The 3PNX has a built-in contact which can be closed by sending a third pulse and holding the

keying switch depressed. The code is: On, hold – left. On, release, on and hold – right. On, release, on, release, on and hold – stepper activated.

Fig. 813 shows how to wire this unit to the stepping relay and to the receiver relay. The terminal connections 1 through 5 are numbered on the underside of the baseboard.

This commercial servo uses printed circuit wiring, so be careful not to hold your soldering iron tip against the wiring too long. Make a good solder joint, but don't apply the soldering-iron tip to the joint any longer than absolutely necessary.

still more controls

THERE are still many things we can do to make radio control of our models more fun. How about front and backup lights and a horn for the car? A boat could use a searchlight and running lights, a horn and perhaps winches.

This chapter presents a real challenge because, not only do we want these additional functions, but we would also like to remove that fishtail that always occurs when we steer; i.e., the movement through left when we command right, and the movement through right when we go from left to neutral.

The pictorial shown in Fig. 901 is our basic servo expanded still further. Let's examine its features.

Identify the receiver relay (RY4) and the receiver 45-volt B-battery (or the auxiliary 45-volt B-battery). Note the steering control relay (RY1) and see that contacts Y and Z are not shown connected to the two cam wipers. This wiring was omitted for clarity — it should be made. Locate the motor control relay (RY2) and its stepper (ST1) and cam wiper (6). They are all the same as before.

Now the new features: a new wiper for cam 3, wiper No. 5. A new relay (RY3) and the new stepper coil, ST2. Note also that the crank end of the camshaft has been changed. There is a cam there now which will push against wipers A and B as it rotates. These two wipers make connection to spring segments 2 and 3 when cam 4 is at neutral (as shown). When the motor runs (turning the camshaft 90° clockwise), cam 4 will cause wiper B to break connection to spring segment 3, and to make connection to spring segment 4, instead.

At the 270° position, cam 4 pushes wiper A away from spring segment contact 2 and causes it to make a connection to spring segment 1.

Signal command sequence

The code for operation will be:

1. A blip signal will change the motor speed (as before).
2. Signal ON and HOLD will give left steering.
3. ON, RELEASE, ON and HOLD will give right steering.
4. ON, RELEASE, ON, RELEASE and a quick ON blip will cause the lights to turn on; blow a horn; or turn a winch. This last blip must be transmitted between the time the camshaft is at 270° and its return to the neutral position, however. It will take practice.

That's why this particular command sequence was chosen to operate such things as lights, horns, etc. If we miss or are unable to send the command correctly, no great damage is done. We still will always have our steering and motor control. Note how the most important things to be performed are always set up so that they are the easiest to command and so that the fewest mistakes can be made in sending the commands or decoding them.

This second stepper will cycle, of course, and at this stage of development we cannot turn on a light, say, without tooting the horn and momentarily activating the winch. This may limit what you will want to energize with this auxiliary device. It makes no difference if the horn toots and the back-up lights (or searchlight of a boat) turn on before the headlights or ship's running lights. Operating winches may be a problem. We leave that decision to you.

Since there is no change in the method of operation or command to the motor-control stepping relay, we won't go into that. Let's examine the new steering arrangement, however. The commands are the same, but now the rudder or steering wheels won't fishtail as we steer.

When we send ON and HOLD, the basic servo camshaft turns 90° clockwise. Cam 4 pushes wiper B over against contact 4. Now the current from the battery can flow through wiper B, through contact 4 and into the self-neutralizing servo. This causes the servo arm to go out from its neutral position, and, in turn, moves the rudder or steering wheels in the correct direction for a left turn.

When we release the keying switch and no signal is sent, the basic servo shaft turns cam 4 around to neutral and stops. The first thing that happens is that wiper B is now back against contact 3, which is connected to the yellow (or neutral lead) from the servo. Thus, the servo operated to pull the arm back to the neutral position. There was a momentary secondary effect: in passing wiper A, cam 4 caused it to close against contact 1. This caused a momentary current to the *right* (blue) connection of the servo. A problem? Absolutely not! The return from left to neutral has to be made in a *right* direction and so this merely hastens the return to neutral. There was no fishtail.

When we command *right*, cam 4 rotates around to the 270° position and stops. It made a momentary connection between wiper B and

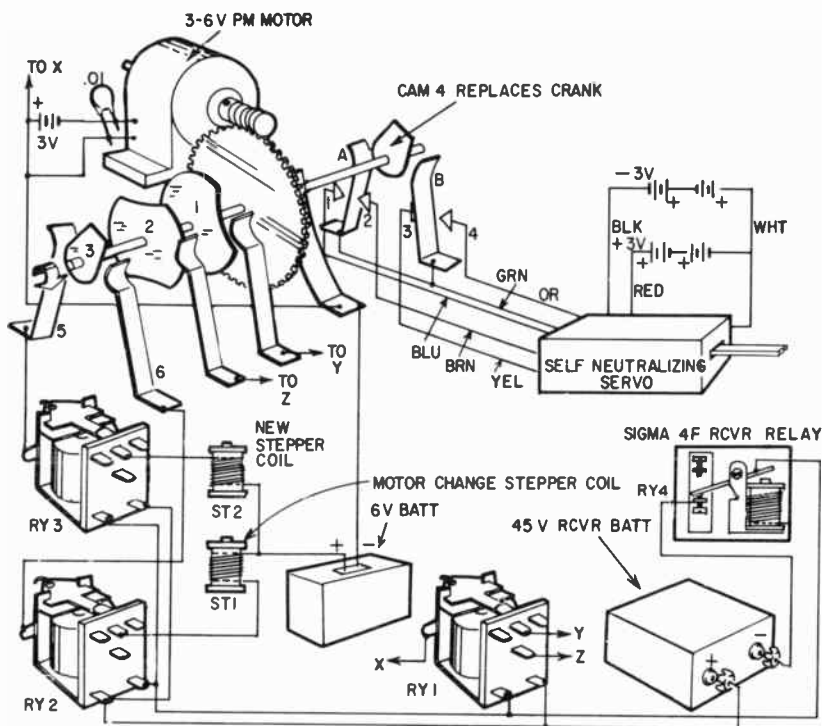


Fig. 901. Basic servo expanded further: a new wiper for cam 3, a new relay, RY3, and a new stepper coil, ST2.

contact 4 as it passed, but this was so fast that the steering element of the model hardly moved. Now, in the 270° position, wiper A is connected to contact 1, which is the *right* connection of the servo. The servo now draws its arm in from the neutral position and the model steers right, releasing our command, and the servo is self-neutralized as before.

In constructing this portion of the new control unit, just make sure that wipers A and B make connections in the manner just described. They must be mounted on a wood or fiberboard base.

So much for the steering, now for the auxiliary stepper.

As you send an ON command, watch the model and, just as it starts to turn, release the keying switch. Cam 3 will have passed wiper 6 *without* making contact. If you count mentally, 1, 2, 3, etc., as you watch the basic servo camshaft turn (as we previously operated it on the bench), you will know how far to count before cam 3 makes contact with wiper 5. Therefore, you can send a quick blip signal which will cause the armatures of all three relays to close.

Nothing will happen because of relays RY1 and RY2 closing (you

can verify this by checking the wiring); but when RY3 closes, it completes the circuit from the camshaft, through wiper 5, through the relay armature and through the *normally open* contact of RY3 to one side of the new stepper coil, ST2.

Since the minus side of the 6-volt battery is connected to the cam wiper shaft and the plus side of this battery is connected directly to the stepper coil, the circuit is complete and the stepper activates. As the stepper closes its various contacts, these can, in turn, be connected to the lights, horns, batteries, or other devices so they will operate.

There you have it — a system to challenge your knowledge and construction ability, to say nothing of your operating skill. Give it a whirl!

A more advanced coder

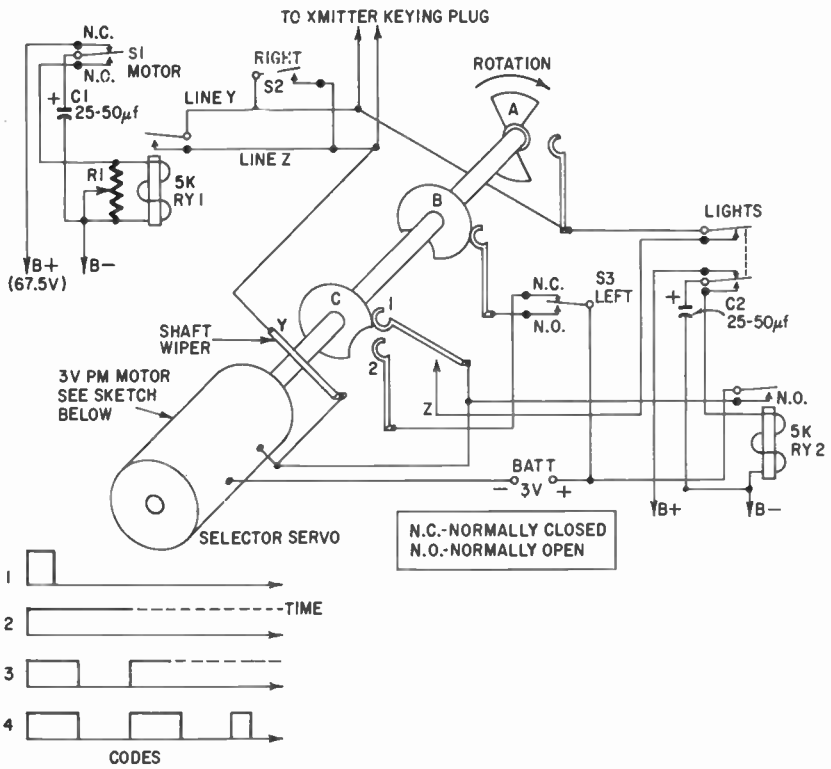
When we have a system which requires a rather complex code to obtain the various commands, it is advisable to build a coder to transmit the commands automatically whenever we push a button. In the coder to be described, the control box would contain four button switches: one for left, one for right, one for motor and one which would control the auxiliary functions, such as lights.

Because this coder is mechanized, it can be adjusted to send just the right code with just the right spacing of pulses every time for any particular command. As long as we can operate our model easily by just pushing buttons or levers or turning wheels, we don't care how complex the system gets to be. But, in the final analysis, the more complex the system is, the greater the possibility of trouble. Thus, the two concepts must be weighed against each other. One further thought along this line: in some cases, such as aircraft, it becomes *necessary* to effect control by means of a coder, since we just don't have time to think which code represents which command.

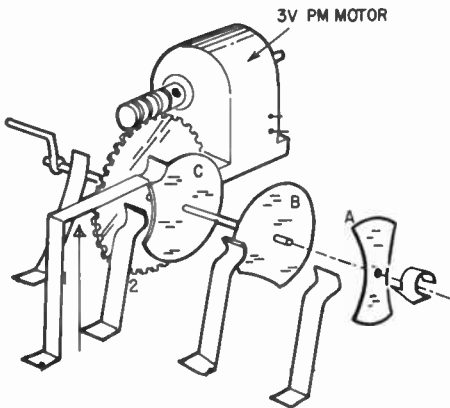
Coder operation

Here is how this coder works. RY1 (Fig. 902) has one end of its coil connected to the B— terminal of a 67½-volt B-battery. The other end is connected to the normally open contact of a pushbutton switch. The armature of the switch (which should be a leaf type), is wired to one side of a 25- or 50- μ f capacitor (C1). The other end of this capacitor is connected to the same side of the battery as the relay. (Be sure that the polarity of the capacitor is correct — positive end to the plus side of the battery). Because the other end of the battery (plus) is connected to the normally closed contact of the pushbutton switch, the capacitor charges and remains charged all the time.

When this switch (S1) is depressed, the capacitor will discharge through the relay winding (RY1), causing the relay to close for an instant. When the capacitor is fully discharged, the relay will release. The resistance (R1) across the relay can be varied to govern the



a



b

Fig. 902. Pictorial arrangement of the coder.

discharge time. What this does, when properly adjusted, is to send a signal just long enough to cause the selector servo to start turning and then to cut the signal off. Then, when the selector cam of the model servo makes contact with the wiper which operates the stepping relay, the receiver relay will be de-energized and the stepper will operate. Then, since the signal is off, the selector servo will continue rotating on back to zero and stop. This switch then provides a quick automatic blip.

To steer left, we hold the signal ON so the pushbutton switch (S3) is connected across the line to the transmitter. As long as it is held down, the signal will be transmitted, and the selector servo will move to the first steering position and remain there until the signal is removed. Similarly, to steer right, depress pushbutton switch S2.

To cause the selector to move to the second steering position requires an ON signal, an OFF and an ON signal. These must be fairly long; thus, we have to provide a device in the coder which will make the timing correct.

Note that the shaft wiper at Y connects to one of the transmitter keying leads while the wiper of cam A connects to the other. This means that as cam A rotates, the transmitter will be turned OFF-ON-OFF-ON-OFF as it rotates through one revolution.

Now see how wiper 2 of cam C connects to the normally closed contact of the pushbutton switch (S3) and the wiper of cam B connects to the normally open contact. The leaf of the switch connects to the plus side of the 3-volt battery.

Since one lead of the 3-volt motor connects directly to the minus side of this battery and the other lead connects to the shaft wiper, you can see that closing the left switch (S3) will cause the motor to turn. One further word about the motor and shaft: in actuality, there is a gear train between the motor and shaft just as in the basic servo.

When the left switch (S3) is closing its upper contact, the only way that power can be cut off from the motor is by having the shaft turn so that the indentation of cam C breaks the contact to wiper 2. This is the neutral position. Cam A does not touch its wiper and therefore the transmitter is not sending a signal.

To send a left command, we depress S3. Its leaf moves down to the lower contact. Now the circuit from the battery to the motor is complete through cam B and its wiper. The motor runs (clockwise) until the indentation in cam B breaks the circuit. The shaft will have turned 270°, the transmitter keying circuit will have been closed, opened and closed again and now remains closed. This is the code for left. Since the signal was transmitted mechanically by almost a duplicate of the model servo, the ON-OFF timing of the transmitted signal is precisely correct to obtain left without energizing any of the steppers. To adjust the speed of this coder servo to get the correct timing, the

battery voltage may be increased or decreased, or larger or smaller gear trains to the camshaft can be used.

Now for the final switch, which sends the command for lights, horn, etc. This switch (S4) must have two leaves and be of the double-pole double-throw type. The first point of interest is the upper leaf. It is connected directly to one of the transmitter keying leads. The lower contact of the upper leaf is connected to contact Z near the servo shaft. This contact and its mate, wiper 1, are so positioned that while wiper 1 rests on cam C, it does not make contact with Z. Once every revolution of the shaft however, the indented portion of the cam will pass under wiper 1, allowing this wiper to move down and close the circuit to Z. Note carefully that this condition will occur just before the indentation moves under wiper 2, which would be the shaft neutral position. In other words, contact Z meets wiper 1 at just about the 315° position of rotation.

Let's inspect the connection to wiper 1. It is connected to the camshaft wiper and also to the lower (NO) contact of RY2. The armature is connected to the plus side of the 3-volt battery.

Looking at the lower leaf of S4, note that it is connected in the same manner as the motor switch (S1) except that we have capacitor (C2) across its winding.

When we depress S4, the upper leaf touches the contact below it. The bottom leaf connects the charged capacitor to the relay winding (RY2). When the relay armature closes its normally open contact, the circuit is completed from the plus side of the battery directly to the motor lead attached to the shaft wiper. Since the other motor lead is connected to the minus side of the battery, the motor runs. If capacitor C2 is the correct size (this would have to be determined by experiment), it will have discharged through RY2 by the time the camshaft has turned halfway around. RY2 then opens, even though we are holding the switch closed. The motor keeps running because its circuit is now complete through cam C and wiper 2. As it rotates, however, the indentation of cam C passes under wiper 1 and it drops to make contact with Z. Since we are holding the leaf switch closed, this completes the circuit from the upper leaf of the switch through the lower contact, through Z, through wiper 1 to the shaft wiper, which is connected to the other transmitter keying lead. The transmitter sends a signal.

This signal is only momentary, however, because the shaft keeps moving until the indentation breaks the circuit to wiper 2. Then the whole circuit is neutralized. The timing has been such that not only have the signals ON-OFF-ON-OFF been sent by cam A and its wiper (which caused the decoder servo in the model to move to 270°) but at this last instant before they both neutralized, that last quick blip was sent (wiper 1 connected with Z).

Admittedly complex, once constructed and adjusted this coder will

allow you to forget the codes and to operate your model by pushing buttons for the command you wish to send. But remember, you cannot send two commands simultaneously.

Other coders

There are many other types of coders, some of which are quite ingenious. Coders can be simple or complex. An on-off switch or a telegraph key is probably the most elementary type. This doesn't mean that it isn't any good, just that we should realize its limitations. It has the very definite advantage that it is practically foolproof. Its big disadvantage is that it is difficult to control pulse timing with it.

The telephone dial is a much more complex coder. Through the years it has become mechanically refined to the point where we consider it completely dependable.

By now you probably realize that a coder is just about as important as any other item of radio control. Certainly, the amount of smooth and continuous control you wish to maintain can be no better than the sort of coder you construct.

increasing transmitter power

WE are now getting into larger models and approaching the time when we want to consider radio control of model aircraft. We want to make certain that, as the distance over which we control our model increases, we have a good strong signal to insure positive control. To do this, we want to change the primary power supply of our transmitter from batteries to a vibrator unit. This will give us not only more power by increasing the voltage to the transmitter, but also a side benefit; we can operate from rechargeable storage batteries such as our little 6-volt wet cell or directly from an automobile battery.

Just for a moment, let's talk about the effect of increasing the transmitted power and what we can expect from this operation. The range over which a signal is transmitted, assuming a given value of received signal, can be doubled only by increasing the transmitted power *four* times. This means that if you have a given distance of, say, 200 yards, for a transmitter output of $\frac{1}{4}$ watt, you will have to transmit four times as much power (1 watt) to increase the range to 400 yards (only twice the distance). Or, if you are now transmitting 1 watt (which is about the output of our transmitter), we must increase the power to 4 watts to expect twice the range. This, of course, assumes that we use the same antenna system, etc., and that nothing changes in operation but the transmitter power.

Thus, there really wouldn't be much use in increasing the transmitter power to say, 8 watts, if we had 4. To double the range again, we would have to go to 16 watts output. Under these conditions then, for radio control, having 4 or perhaps 5 watts output gives all the power we could possibly need for ranges up to 1, 2 or even 3 miles. Using a vibrator supply such as we are now going to discuss, our transmitted power output will be on this order.

The vibrator supply we have selected is manufactured commercially (Heathkit VP-1-6). It is more economical than purchasing the parts separately and it is designed as a unit for the utmost efficiency and smoothness of operation. It is also possible to obtain a companion unit (the VP-1-12) for 12-volt operation.

Fig. 1001 shows this unit and indicates its relative size. The single wire coming up from the corner of the base on the left-hand side is a modification that we have to make and which we will discuss in a

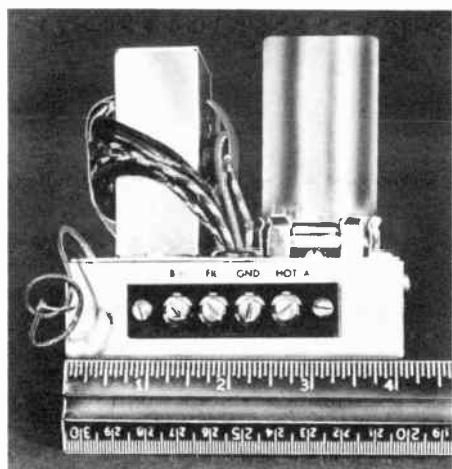


Fig. 1001. Relative size of the VP-1-6 vibrator power supply. Transmitter leads connect to fil and gnd terminals on chassis. (Heath Co.)

moment. Note that the terminal lugs are labeled B+, FIL, GND and HOT A. The leads from our 6-volt battery connect to GND and HOT A.

The leads from the transmitter (filament) connect to FIL and GND. The B-plus connection is obvious, and we will connect our B-minus lead from the transmitter keying jack to the single wire coming out of the base on the left.

The general pictorial wiring diagram is shown in Fig. 1002, and step-by-step construction details are furnished with the kit. Note the red-yellow lead of Fig. 1002. Instructions specify that this lead is to be soldered to terminal E-3 of the solder-lug strip between the sockets. *We don't want to make this connection.* Instead, look at the top left corner of the chassis in Fig. 1003. Here we have bolted a two-terminal solder lug to the chassis. The red-yellow lead connects to one insulated lug; our B-minus lead connects to this same lug and is run out through the hole in the corner. Run a short length of insulated wire between the second insulated lug and B-plus which is terminal E-1 of Fig. 1002. The 510,000-ohm 1-watt resistor is then soldered to the two insulated terminals allowing a discharge path

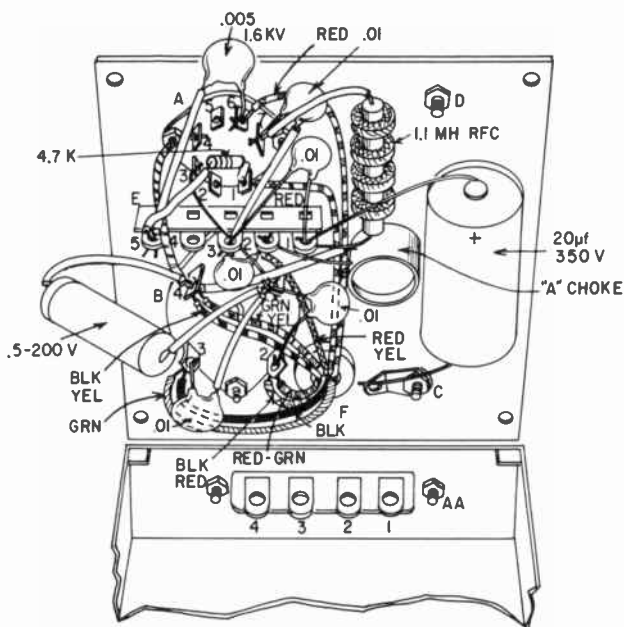


Fig. 1002. Pictorial wiring diagram of VP-1-6 vibrator supply.

for the large capacitor when the transmitting keying switch is not depressed.

We also make one other change: the kit has a 350-volt electrolytic capacitor included. Replace this with a 16- μ f 450-volt unit to have a larger safety factor.

Fig. 1004 shows how nicely this power supply fits into the base of our transmitter cabinet. The two leads which connect it to the wet-cell battery have been omitted in this photo. We suggest you connect some kind of heavy-duty switch between the HOT-A lead and the battery to enable you to turn the vibrator off when transmitter operation is not wanted.

One additional precaution: if you operate this transmitter from your automobile battery and you have the cabinet resting on the metal frame of the car, the GND terminal of the vibrator must be connected to the battery terminal which is connected to the automobile frame. If it isn't, you'll short the battery and have hot leads and sparks all over the place. Be sure to use at least two strands of No. 18-gauge insulated wire for *each* line to the car battery. Do not have these leads over 6 feet long. There will be plenty of electrons flowing through these wires, and we want them to get through.

The circuit schematic is shown in Fig. 1005 with the indicated changes.

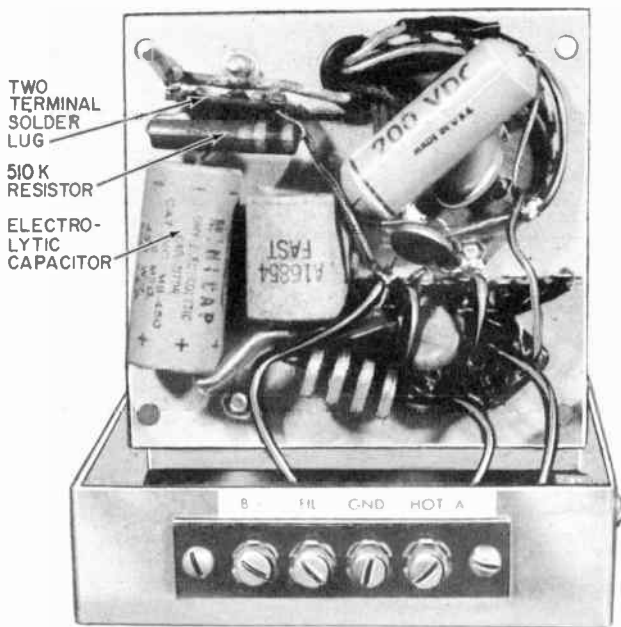


Fig. 1003. Red-yellow lead (Fig. 1002) and B-minus lead both connect to two-terminal solder lug at top left corner of chassis.

Testing the transmitter

The transmitter operates just as before. The meter readings will be slightly higher and the pilot light and antenna light will glow brighter, but the overall procedure of adjusting and operation is exactly the same.

Connect the crystal B-plus lead to a 10,000-ohm resistor and a lead from this resistor to the final B-plus lead. Now connect the final lead to the B-plus of the vibrator power supply. *Be careful! Those 260 to 300 volts can give you a nasty shock if you are careless!*

Tone operation

The transmitter as we have modified it will operate our receiver in any type model. We are, however, basing our operation on the transmission of a carrier signal only. It is the simplest method of making our receiver respond, and modelers everywhere have had very satisfying results using this method.

When we evaluate the advantages and disadvantages of carrier against tone operation, however, we come to the conclusion that tone does offer a little more reliability and security against interference. Look at it this way: if the receiver is operated by a carrier alone, it can also be operated by *any* carrier that it happens to receive, whether this be a commercial station, another R/C transmitter or even, in some cases, by another R/C receiver.

When we use tone, we transmit the carrier (the normal signal radiated by the transmitter) all the time and it does *not* operate the

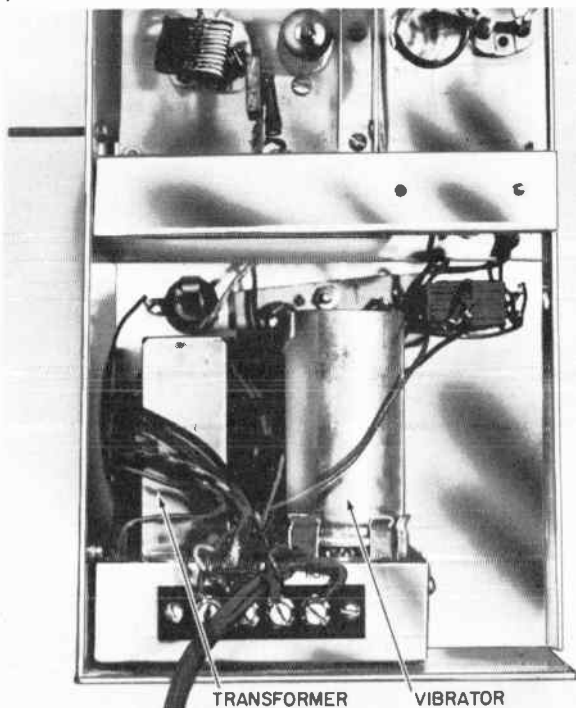


Fig. 1004. Power supply fitted into the transmitter cabinet base. The connecting leads from the power supply to the wet-cell battery are not shown.

receiver. We must also transmit a *tone* over our transmitter, and it is this tone which makes the receiver function. Now we have this difference in the two systems: if we use tone, we must have our carrier on all the time, so that if there is an interfering carrier signal, it has no effect on our receiver. Thus, our overall reliability of performance is improved.

We will not have to make any changes in our receiver to operate it with tone. Let's turn to the transmitter then and add our first type of tone modulator.

Mount the tube socket and transformer for the tone modulator on one end of the chassis as shown in Fig. 1006. Make certain that the leads from the transformer go down through the chassis near the tube socket.

Refer to Fig. 1007. Note how the phone jack is mounted first to a small wooden strip, which is then bolted to the chassis so that no metal part of the jack touches the chassis. Note also the location and

orientation of the two terminal solder lugs, which can be fastened under one of the transformer mounting bolts.

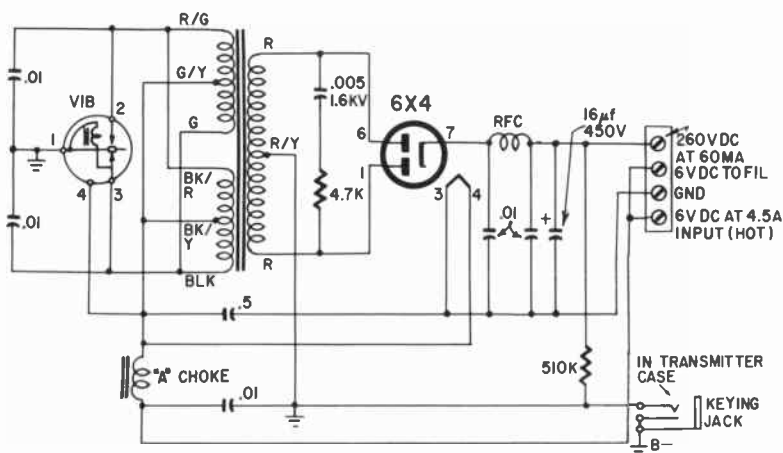


Fig. 1005. Circuit diagram of the modified power supply.

You can now make your wiring connections by following the pictorial diagram shown in Fig. 1008.

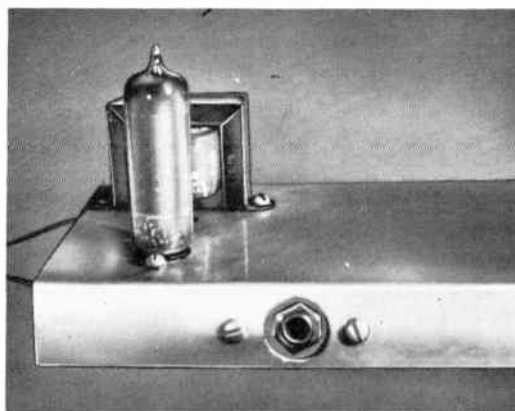


Fig. 1006. Mounting of tube socket and transformer.

1. Solder the blue lead from the transformer to pin 5 of the tube socket.
2. Solder the brown lead from the transformer to a lug of the two-terminal strip.
3. Solder one lead from the .01- μ f capacitor to this same terminal.
4. Solder the other lead of the .01- μ f capacitor to pin 1 of the tube socket.

5. Solder one lead of the 51,000-ohm resistor to pin 1 of the tube socket.
6. Solder the other lead of the 51,000-ohm resistor directly to the center lug of the terminal strip (this is the lug that is bolted to the chassis).

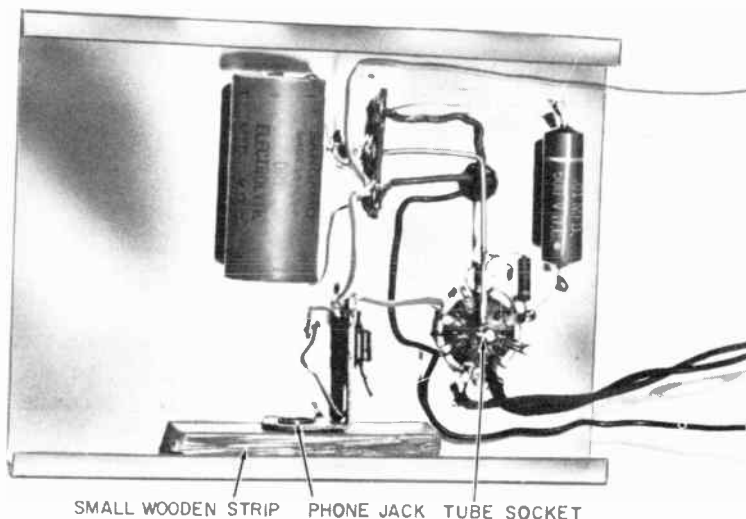


Fig. 1007. Underchassis view of Fig. 1006. The phone jack (arrow) is first mounted to a wooden strip to prevent shorting and is then bolted to the chassis.

7. Solder a short length of bare wire to pin 2 of the tube socket. Solder the other end to the center lug of the terminal strip. Run this wire down close to the chassis.
8. Take two pieces of insulated wire about 12 inches in length. Solder one end of one to pin 3 of the tube socket and one end of the other to pin 4. These are the filament leads.
9. Solder one end of a short length of insulated wire to pin 6 of the tube socket and the other end to one of the key jack lugs.
10. Solder another short length of insulated wire to the second key-jack lug and connect the opposite end to the free terminal of the two-terminal strip. Solder the red lead of the transformer to this terminal as well as the plus lead of the 16- μmf capacitor.
11. Solder the capacitor's minus lead to the center lug of the terminal strip.
12. Solder one end of a 12-inch length of insulated wire to pin 5 of the tube socket and mark this FINAL B+. This lead will connect to the final B+ lead of the transmitter.
13. Solder one end of a 12-inch length of insulated wire to the inner terminal of the terminal strip and mark this B+. This lead

connects to a 15-henry, 50-ma choke. The remaining choke lead then connects to the vibrator's B+ terminal.

14. Solder one end of a 12-inch length of insulated wire to the center lug of the terminal strip and mark this TRANSMITTER CHASSIS B-MINUS. This lead connects to the chassis of the transmitter.

15. Solder one lead of the 470- μ f capacitor to pin 1 of the tube socket.

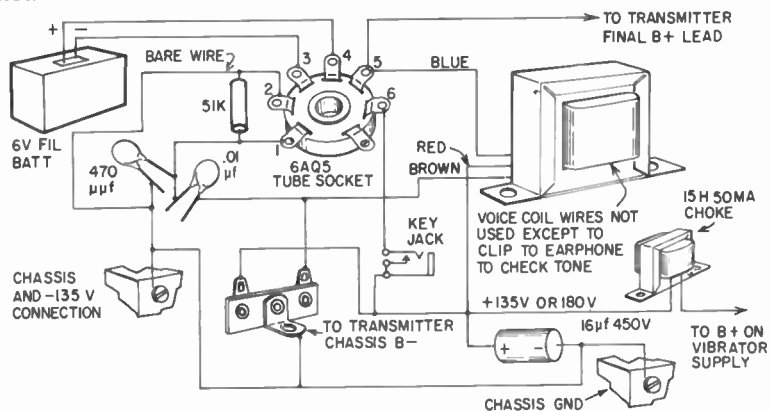


Fig. 1008. Pictorial diagram of the tone modulator.

16. Solder the capacitor's free lead to the center lug of the terminal strip.

17. Connect B-minus from the modulator chassis to the transmitter chassis.

18. Check all your connections against the pictorial and also against the schematic shown in Fig. 1009.

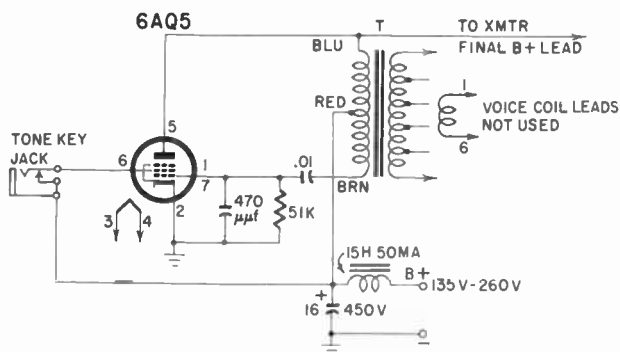
Testing the modulator

Insert the 6A Q5 tube into the socket. Connect the B-plus lead to the vibrator's B-plus (or you can use the plus terminal of two 67.5-volt Eveready 467 batteries connected in series). Connect the transmitter chassis lead of the modulator to the B-minus wire lead of the vibrator supply (or the minus terminal of the two 67.5-volt batteries). Connect the two filament leads to the two terminals of a 6-volt battery. Insert your keying plug into the keying jack *before connecting B-plus or turning the vibrator on. If your finger touches the metal part of the jack and the chassis at the same time, you'll get a nasty shock!*

Now connect your earphones to lug terminals 1 and 6 of transformer T. Turn the vibrator supply on or connect the B-plus battery lead. After allowing time for the tube to get warm, press your keying switch. You will hear a tone of about 1,000 cycles. You can key this tone by pushing and releasing your keying switch.

We will now need to get another keying switch. We want a *normally*

closed type which will cause the tone to be cut off when we depress the switch, rather than turn it on. If we make this change in keying switches, then we need make no change in our receiver relay wiring to the servos. If we do not make this change, then we will have to reverse the leads to the receiver relay's normally open and normally closed contacts.



parts list for the tone modulator

Resistor: 51,000 ohms, $\frac{1}{2}$ watt.

Capacitors: 1—470 $\mu\mu\text{f}$ ceramic; 1—.01 μf paper; 1—16 μf , 450 volt electrolytic.

Transformer: 1—audio output (Triad SX-51 or

equivalent).

Miscellaneous: 1—7-pin socket; 1—6AQ5; 1—shorting-type phone jack; 1—15H, 50 ma choke.

Fig. 1009. Schematic diagram of the tone modulator.

The normally closed keying switch is preferable. When we operate our system in this manner, we will be transmitting a carrier constantly and also a tone, unless we send a command. *The command will be the number of times the tone is cut off.* This means still more immunity from interference because, if there is any other signal on the air, tone or not, it can't cause the model to change course. Of course, if another tone is being transmitted on our frequency, we may not be able to command the model, but we can hold our keying switch closed and, when we see the model respond, we will know that we have control again. We then command it to return or do whatever else we may desire at that moment.

The way the receiver is designed, if the model should get beyond the range of our *tone*, the receiver will still respond to keying the carrier as it did previously. So now we have a double safety feature. To key the carrier, we merely change our keying plug from the modulator to the original keying jack in the transmitter. (Here, however, we must use a normally open keying switch). We will need to place a phone plug in the carrier keying jack (a phone jack with its ter-

minals wired together) to cause the carrier to be transmitted constantly. We will have to do this when we plan to operate with tone.

Connecting to the transmitter and adjusting

To connect the modulator to the transmitter, connect the lead from pin 5 of the tube socket to the final B-plus lead. The B-plus oscillator lead is connected to the vibrator B-plus directly through a 10,000-ohm resistor (omit if batteries are used). Connect the transmitter chassis lead to the modulator chassis. Connect one filament lead to FIL of the vibrator supply and the other to GND. B-minus of the vibrator connects to the B-minus transmitter lead just as before.

Turn the vibrator on and, after warming up the transmitter and modulator, key the tone off. The antenna light of the transmitter will get brighter. Release the key and the light dims. You may also use your loop, held close to the final coil of the transmitter, with the antenna disconnected. When the tone is off, the light will be bright; it dims when the tone is on. This is the condition that must prevail if we are to know that the transmitter is sending out the tone as it should.

Retune your receiver. Listen with your earphones for the tone, and tune for the loudest sound on a range test. Then, operate your receiver just as you did before.

Circuit notes

In case you wonder why we chose to key the screen circuit instead of the cathode circuit of the tone oscillator, it is because this prevents chirp and delay in tone generation. It may be necessary to connect a 10-15-hy 50-ma filter choke between the B-plus lead of the tone modulator and the B-plus terminal of the vibrator supply. Do this if you hear hum (listening to earphones connected to the receiver) when the tone is not being transmitted, or if the relay fails to follow your keying commands.

Practice using this system. Learn to adjust it and operate it on the bench and on range tests.

model aircraft

WE'VE been a long time getting around to model aircraft, but there was a reason. By this time, you have a good mastery of the concepts of radio control if you have experimented at all with the projects discussed earlier. You now know much more about your equipment. You have *checked it out*. You know how to test, adjust and check operation. We feel that you should know all this before going to aircraft since a mistake with this kind of model is expensive and disheartening.

To begin with, let's take up the matter of the model itself. There are two general schools of thought concerning radio-controlled model aircraft. The first believes that the models should be very solidly constructed so that even if it has a crackup no damage can result. This school prefers models which are generally large and heavy.

The second group believes that the models should be light, but strong. They rely for the most part, however, on the very lightness of the model to prevent bad damage due to possible crackups.

We are *in-betweeners*. Make it light and strong, but add the extra weight and strength in those areas most subject to damage and rough abuse. These areas are the landing gears, the nose sections and the leading edges of the lifting surfaces.

Many types of models designed for radio control are commercially available in kits. The one we like best — it operates properly at any altitude from sea level to 7,000 or 8,000 feet; it carries all the weight we may require; it has structural strength, performance and a nice appearance — the deBolt supercruiser. Of course, it is a large airplane and you may like a smaller one. One good way to learn more about the type giving the best performance in your town is to visit your local clubs and see what models are being used successfully. Note the

weight of the equipment they carry and also whether the original kits have been modified (90% will be!) to fit individual requirements or tastes.

Some good rules-of-thumb in selecting a model are: Weigh the equipment you plan to install in the model, including the batteries. Note how much this is in ounces. Look over the models, select one and note its weight in ounces (usually specified on the box). Add the two weights. Now determine the wing area (width times length) in inches, divide this by 144 to convert to square feet. Divide the total ounces by the number of square feet. If this figure is less than 14, the model will be suitable; if the figure is over 14, then don't try it if you are a beginner. Choose another model.

This figure of 14 means that the wing loading is 14 ounces per square foot of wing area. Now there is a difference, of course, depending on your location. A loading of 12 ounces is better if you live in high altitudes, say 7,000 feet, while you may be able to use 17 ounces at sea level.

Now for the motor size. This is recommended by the manufacturer of the model or kit, but we can also come up with a rule-of-thumb which works quite well: 1 cubic-inch displacement for each 200 ounces of model weight. Thus, for a 4-pound airplane (model plus equipment): $4 \times 16 = 64$ ounces and $64/200$ times 1 gives a .32 engine. You could use a so-called 29 or 35 motor.

The propellers should be large and of low pitch; lengths of 10, 11 or 12 inches are common. The pitch may vary from 3 to 5 inches. Pitch means how far the propeller would go per revolution if it were screwed into a solid substance.

We might, then, generally indicate the features we would want as:

1. Large enough cabin space to accommodate our equipment (Fig. 1101) and means of easy access to this equipment once installed.
2. A large enough wing so that the wing loading is 14 ounces per square foot of wing area (or very close to that figure).
3. Good dihedral (the V bend to the wing) and a high wing type — these contribute to the model's flight stability.
4. A good strong tail wheel high enough off the ground so that the tail surfaces won't be damaged on normal "one-wheel" landings.
5. A good strongly-constructed wing which will withstand warping and which can stand the strain of violent maneuvers. (We may not command these, but sometimes the model gets into them on its own!)
6. A good strong nose section which will be able to withstand "nose-over" landings.
7. A landing gear strong enough to withstand landings without damage to itself or the model.
8. Large enough wheels so that they won't "dig in" on ground takeoffs or landings.

Building the model

Follow the plans. Use silk or nylon for the covering. Use a good strong glue. The ultra-quick-drying kind usually results in a model which won't last. Use a glue which penetrates the wood before it dries, making a very strong bond. Ambroid is one recommended type.

Make absolutely certain there are no warps in the wing or tail structures before you cover them. Lay the wing on a flat board, holding one end up slightly, and see if it's warped. If necessary, break

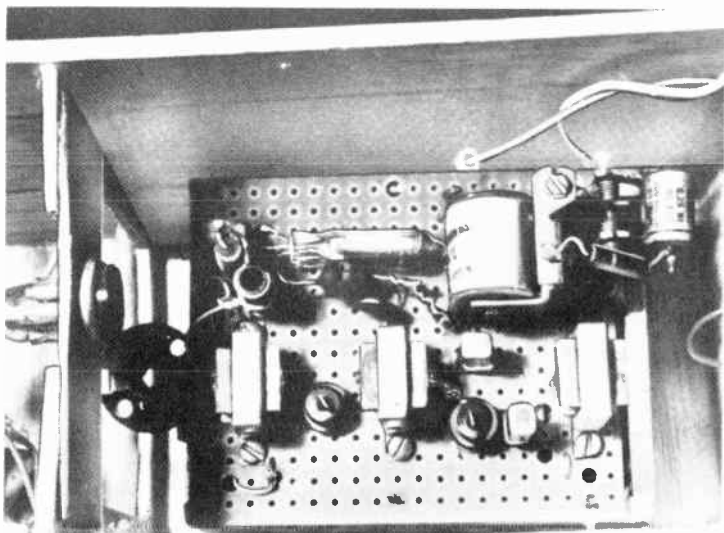


Fig. 1101. Cabin space should be large enough to accommodate equipment.

the glue joints and do it over, but don't try to fly a model with warped wings.

In covering, keep the grain of the cloth parallel to the leading edge of the wing. If you cross-grain, warping will result as the dope dries.

After constructing the wing, balance it. This is done by setting it on a straight edge running crosswise to its center and adding weights to the tips (if necessary) to get as perfect a static balance as possible.

These are just a few pointers on constructing your aircraft. It's best to visit your hobby shop and get acquainted. Building an airplane is an art and, if you are new at it, you'll be wise to get help.

The simplest control system

When the wing and tail surfaces and the fuselage are constructed, but not covered, you are now ready to install the radio-control equipment. We are going to start with a simple and reliable setup.

This undoubtedly is one of the most controversial subjects in the

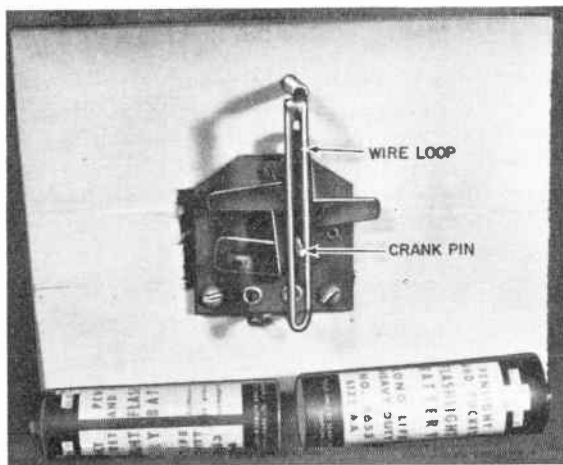


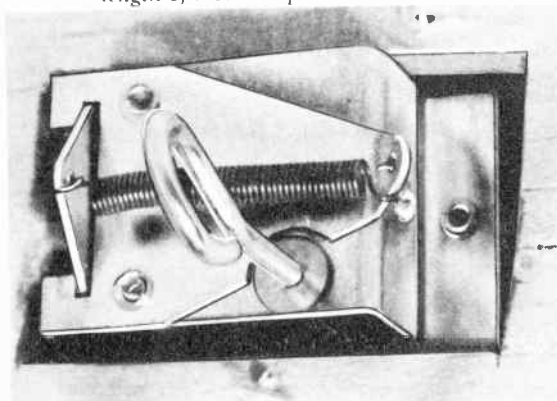
Fig. 1102. Front view of a four-arm two-neutral-position escapement. Note piano wire bent into a loop so that the escapement crank pin can ride up and down as the crank turns.

radio control field — what should the beginner use in the way of equipment, or what is the simplest and most reliable installation.

The simplest, lightest and most reliable device to cause the movement of airplane control surfaces is the escapement. There are several reasons why we say this. First, it is powered by a rubber band, which adds little weight to the model. Second, there are no motor contacts to cause arcing and possibly interference. Third, it has a positive neutral to which it will always return in the absence of electrical power. It can't stick in a position to cause a crash.

There are installations which use servos and later, we are going to

Fig. 1103. Rear view of four-arm two-neutral-position escapement. Notice the hook to support a 12-15-inch length of model airplane rubber band.



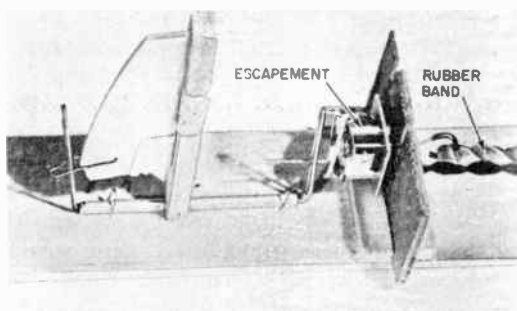


Fig. 1104. Escapement mounted on a flat board with rubber band and short linkage. Piano wire (far left) is bent vertically in exact line with bent loop at escapement end (providing linkage to crank).

show how to use them successfully. We do not mean to underrate these devices — they are fine after you have gained some experience in this field. But for the beginner, we say, use the escapement. Even when we go to servo control, we will indicate how your escapement can be used for control of other functions.

Let's learn something about the escapement. Examine Figs. 1102 and 1103, which show the front and rear views of a four-arm, two-neutral-position unit. Note in Fig. 1102 how a length of 1/16-inch diameter piano wire is bent into a loop so that the crank pin of the escapement can ride up and down as the crank turns. The wire loop is just wide enough to contain the crank without binding. Never make this any wider than necessary. Note also that the piano wire runs through a length of aluminum or brass tubing. This tubing is pushed far enough through the wood plate so that its end makes a bushing and prevents the piano-wire loop from binding against the four plastic arms.

At the bottom of Fig. 1102 are two terminals which connect to one end of the two penlight cells shown below. The other terminal of the escapement connects to the normally open terminal of the receiver relay. The other end of the penlight-cell supply (say, minus) connects to the relay frame terminal (the two cells are connected in series).

In Fig. 1103, you can see the hook that will support one end of a 12–15-inch length of 1/4-inch rubber, or which will hold one end of a loop of 1/8-inch rubber band. You can obtain these types and lengths of model-airplane rubber from your hobby shop. Also note the spring which always returns the little catch point to a position which will stop the rotation of the crank only in the neutral position.

The best way to get acquainted with this device is to mount it on

a flat board so that you can attach the rubber band and a short linkage and connect the whole unit to the receiver relay (Fig. 1104). The linkage is shown connected to the crank in a slightly different manner in order to make this illustration clear. Note that the far end of the piano wire (far left) is bent vertically, exactly in line with the bent loop at the escapement end.

Fig. 1105 shows how to connect the escapement. The escapement, the switch, the relay and the penlight cells are all wired in series. In this way, the escapement is operated with 3 rather than 1.5 volts. A tighter rubber-band winding can be used with this method.

Now that you have made the necessary connections and wound the rubber band (you can wind it only in one direction) till you have at least a single row of knots, turn on your transmitter and start sending signals. A press and hold gives left, release is neutral. Press and hold again is right, release is neutral. No matter what signal you send, release and the linkage goes to neutral — an important thing to remember if you panic during those first flights.

Now try to signal right: press, release and press and hold. Sooner or later you will find that the sequence changes due to the fact that you somehow get to the second neutral as a starting point. Remember this. If, when flying your model, you ever send a command for, say, left and the model starts right, immediately release and press and hold and you'll be back in control again. This is one reason why practice is recommended. Keep at it until you can send the correct command almost without thought. If you should get the wrong movement of the test linkage, you can correct it automatically. Some beginners have even had friends stand by and call out commands, and they practiced that way till they were almost perfect. Needless to say, their first and subsequent flights were also perfect.

There are other types of escapements (the compounds) but we'll get to those presently and you can start with one of them if you so desire.

Tips on escapements

For an efficiently operating escapement:

1. The frame should be rigid so that it won't deform under operation or installation.
2. There should be two bearings for the rotating shaft, whether it be one arm or six or a wheel or a cam. These bearings should be solid and non-binding and of a type which won't wear and become loose during a reasonable life.
3. The little catch point should engage at least 1/16-inch of the arm, and the bearing of this catch point on its frame should be secure enough so no binding can take place.
4. The catch fingers should be hard and rigid enough so that they won't bend or deform under operating conditions.

5. The end of the hook shaft, which has the pressure of the rubber band against it, should work against hard metal or plastic, or have a bearing which won't bind under the pressure.

You have now covered the fuselage with silk or nylon, and you have installed the linkages as well as the escapement. We can now begin preliminary tests and make initial adjustments, so that when we install our radio-control equipment and make that first flight (that's the one we sweat out!), the chances of success will far outweigh those of failure.

Since we have chosen a model capable of carrying a reasonable payload, if we glide-test it without the payload it should just about float through the air. We plan to do this and expect no damage, even if the first few glides are not perfect. However, the first step is to locate the center of balance.

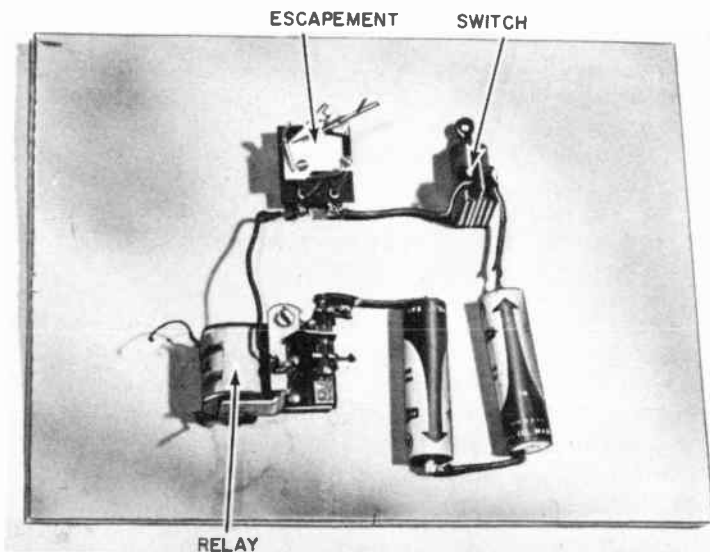


Fig. 1105. Escapement switch, relay and penlight cells are connected in series.

The wings and tail surfaces are fastened in place according to the plans furnished with the kit. The motor is mounted in place and then wrapped with a piece of cloth or plastic to keep out dirt. Do *not* put on the propeller. Now locate the center of balance. For this, you will have to ask a friend or member of the family to help. Each of you will take a wing tip. Hold the model with one finger and move it along the end of the wing until the body of the plane is horizontal. Make certain that the wing is not on crooked. You can check this by measuring with a string from the tip of the tail to the rear corner of each wing tip. The distance should be the same. The model should balance at about one-fourth to one-third of the wing width back from the front or leading edge. If it doesn't, add weight in the pay-

load compartment until it does. Mark this line of balance across the top of the fuselage with a pencil.

Now take a 12-inch length of good heavy twine. Tie one end to a hook set into the body exactly in the center of the width of the fuselage at the point where the leading edge of the wing crosses the fuselage. Make a second fastening just behind the wing, also in the center of the width of the fuselage. You will now be able to raise the model by this string and, using a hook placed just above the front-rear balance line, adjust its position until the model is level. Note the side balance. Does one wing tend to drop? If so, add weights to the high wing until the model is balanced on its longitudinal axis. The model is now ready for the test glide.

Pin the movable control surfaces so that they are exactly in line with the fixed portion. Select a day when there is as little wind as possible. Grasp the model just behind the balance point underneath the cabin. Hold it up just higher than your head. As you run forward, you'll feel it begin to lift in your hand. *Now, push it forward toward a point on the ground about 50 feet ahead and let it go.*

The airplane should glide down toward this point in a smooth flat glide. If it doesn't, this is what may happen: it may try to climb and then suddenly drop; it may veer sharply or gradually to the right or left; or it might even drop very sharply without a glide at all.

If it tends to rise and then drop, raise the rear edge of the wing and place about a 1/16-inch piece of balsa strip underneath this edge. Try it again. If it still "balloons," use another strip.

If it tends to drop sharply, raise the leading edge, using the same procedure. If it should veer somewhat sharply to either side, check the position of the wing to make certain it is on straight. Check the horizontal part of the tail assembly to make certain it is level and that one side is not raised higher than the other. If these are OK, then remove the pin holding the rudder in place. Repin it so that the rudder has an angle of about 10° from the fixed part, and is turned in the opposite direction the model turned. Test again and adjust the rudder until the model glides straight.

If you find this takes an excessive amount of rudder, say 30° or so, check the wing for warps and the vertical tail surface for misalignment with the center fuselage line. *Do not try to fly your model under power until you get a good straight glide.* The model may not float in the glide, but this is all right as long as the glide is straight and reasonably flat (on a flat glide, the model would go straight down the line from your eye to that point 50 feet ahead on the ground). *Never try to throw the model either up or straight ahead. Push it, and always toward that same point on the ground.*

There are two schools of thought on this phase of testing a model. One says "fly it, the control will take care of possible trouble." The other says "test glide it, there's enough to do to fly it without asking for trouble." We agree with this second point of view.

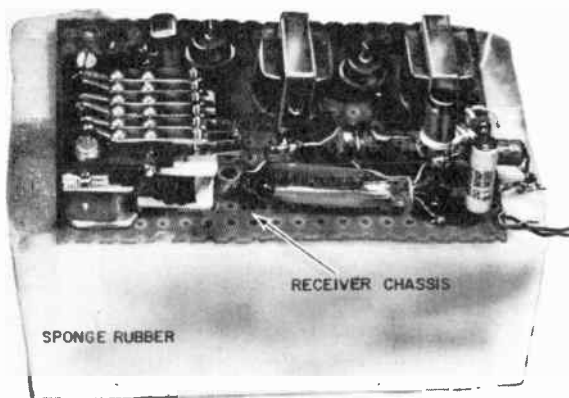


Fig. 1106. *Sponge-rubber cushion around receiver protects it from motor vibration and prevents damage to radio equipment.*

Even if the model is damaged in the test-gliding phase, that damage will always be slight compared to a full-powered crash.

Now that the model has been checked without the radio receiver

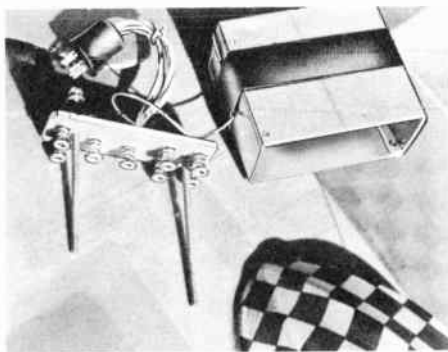


Fig. 1107. *Battery boxes are used to connect batteries to escapement and receiver. Note pressure spring contacts for making tight connections.*

and batteries, install these and maintain the same balance. Put heavy sponge-rubber cushion around the receiver. (See Fig. 1106). This not only prevents damage to the radio equipment, but also protects it from trouble due to motor vibration. A servo is used in this particular model for control of the rudder, a plug connection allowing easy removal for servicing. A servo, like the escapement, may be mounted directly to the fuselage. If you test-ride the model now, the glide will be steeper and faster due to the increased weight. This is all right

so long as it is straight. After you have completed the first test-glide phase, run the motor again and send signals to make certain that the equipment operates satisfactorily with the motor running. In case of vibration trouble, check all connections. If you have a bad solder joint, it will come apart during this phase of testing.

There are two methods of connecting the batteries to the escapement and the receiver: first, by soldering all wires, and second, by using battery boxes. If battery boxes are used (and they are recommended, since they make the replacement easy), the type shown in Fig. 1107 is recommended. Note the pressure spring connections. The batteries in this box will never have a connection jarred loose.

Now, we're ready to fly! Choose a low-pitched propeller (3-4-inch pitch) 10 to 12 inches in size (the kit will recommend one). Make certain that the motor has some "down thrust" . . . that is, the line of the motor shaft should run back to a point as high as the tail surface and about three inches to the right, as we look at the model from the nose. This offset to the right is called side thrust. Now rev up the motor, making sure it's running smoothly and steadily. Put the model on a smooth runway if possible and let it go, headed into the wind. It may take off right from the ground. Try this first if you can, using the philosophy that if it takes off, it will fly correctly.

If it doesn't take off, then launch it exactly as you did in the test-glide phase. Try to let it gain at least 75 feet of altitude before you send a signal, unless the model turns so sharply that you think it's going to dive in. Then, of course, send a corrective signal (remember all that practice)! Keep it circling around you until the motor fuel is exhausted (you will have put in only two minutes worth of fuel), then circle around and land into the wind.

For the receiver antenna, use a length of flexible insulated hookup wire running from the receiver to the tip of the tail. This will work fine.

multiple controls

WE are now ready to advance to the next step, still using our single-channel receiver. As a matter of fact, in this chapter we are going to advance two steps. First, we will add motor control so

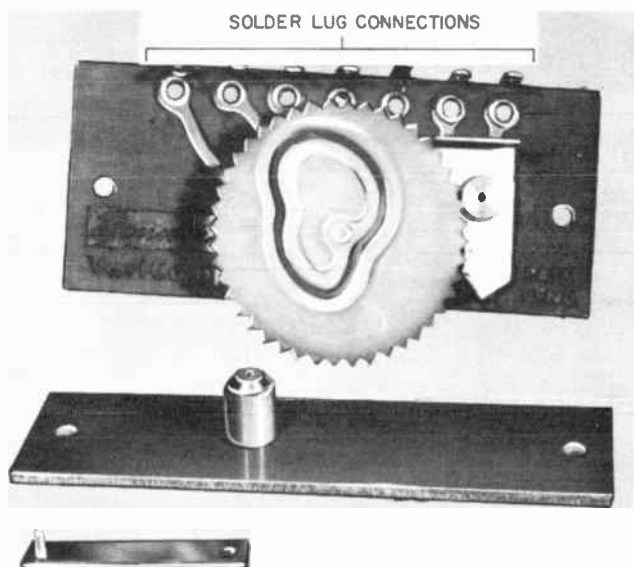


Fig. 1201. The Bonner Varicomp compound escapement comes in three pieces. Solder-lug connections on large piece at top energize other circuits and cause rudder movement.

that we can have full or cruising speed. Then, an elevator and aileron control for stunt flying and better control during windy flying conditions.

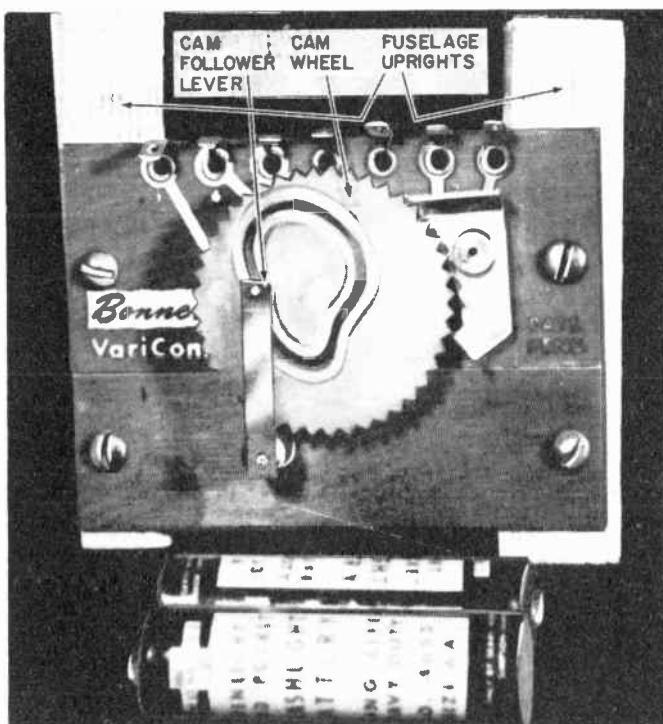


Fig. 1202. The cam-follower lever (bottom, Fig. 1201) is soldered to one end of a 1/16-inch length of piano wire which is then run through the mounting on the lower plate (center, Fig. 1201).

Again, it is necessary to purchase additional parts, and this time we chose a B compound escapement¹ which comes in three pieces as illustrated in Fig. 1201. Other types are available, but this one is most adaptable to the multiple control system we are working toward.

The compound escapement, in general, operates like the little four-arm escapement discussed previously except that only three commands are needed. We don't have to remember what the last signal was because each command, whenever transmitted, will always cause the same operation to be performed. The commands, sent using the transmitter keying switch, are: PRESS and HOLD — left; PRESS, RELEASE, PRESS, and HOLD — right; PRESS, RELEASE, PRESS, RELEASE, PRESS and HOLD — motor speed.

Through the various connections (the holder lugs at the top of the large section of Fig. 1201), we will be able to energize other circuits, as well as effect rudder movement (somewhat like our basic servo).

¹ Bonner Varicomp.

To assemble the Varicomp, first mount it on two of the fuselage uprights as shown in Fig. 1202. The little cam-follower lever is soldered to one end of a length of 1/16-inch piano wire. (Make sure this is a good strong joint, soldered only on the side facing you in the photograph). Then, the piano wire is run through the mounting provided on the lower plate, and the pin of the cam follower is placed into position in the cam wheel as shown. The cam-follower lever then replaces the loop used with the previous escapement. The wire can go through a tube to the rudder as before, or preferably, can be connected to a wooden rod which has the rudder moving wire fastened to its far end.

For the moment, leave the Varicomp and inspect Fig. 1203. Here, we have the motor control installation. The previous escapement, the two-neutral type, is now mounted in the engine section, and the rubber band powering it must be crosswise to the fuselage and thus

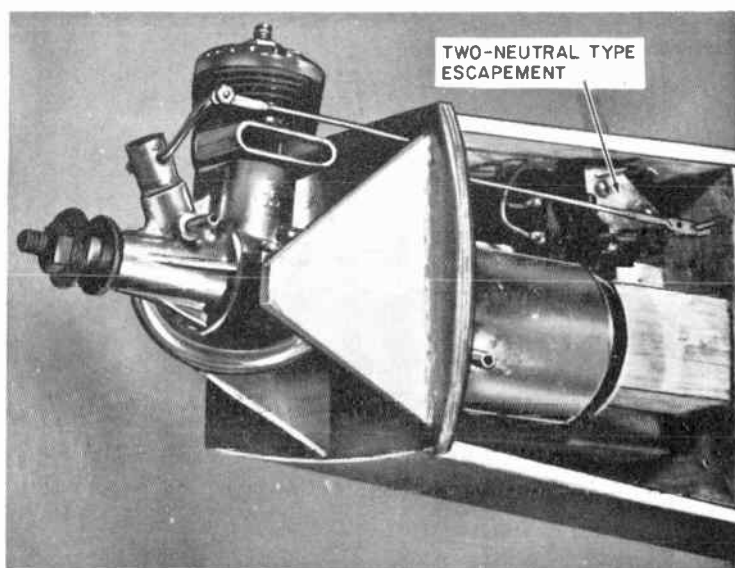


Fig. 1203. Motor control installation. Two-neutral type escapement is shown mounted in the engine section.

much shorter in length than before. This is all right. We change motor speed only a relatively few times during a flight and thus won't need as many turns.

Fig. 1204 shows the details of the linkage to the motor choke. The motor speed is varied by controlling the flow of air through the intake. A rich fuel mixture will cause the motor to "four-cycle" or run at reduced speed. Commercial throttles are available at hobby shops.

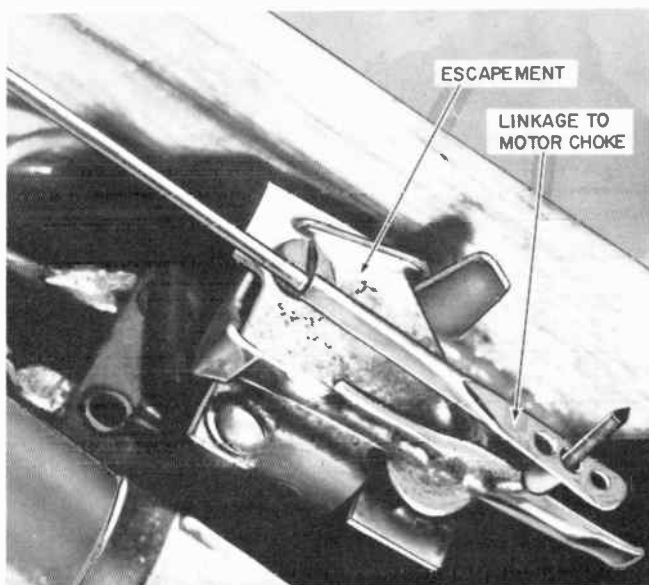


Fig. 1204. Details of escapement linkage to motor choke. The escapement is shown in neutral position.

The position of the escapement shown in Fig. 1204 is one of the neutrals. If we were to energize this escapement and then let the

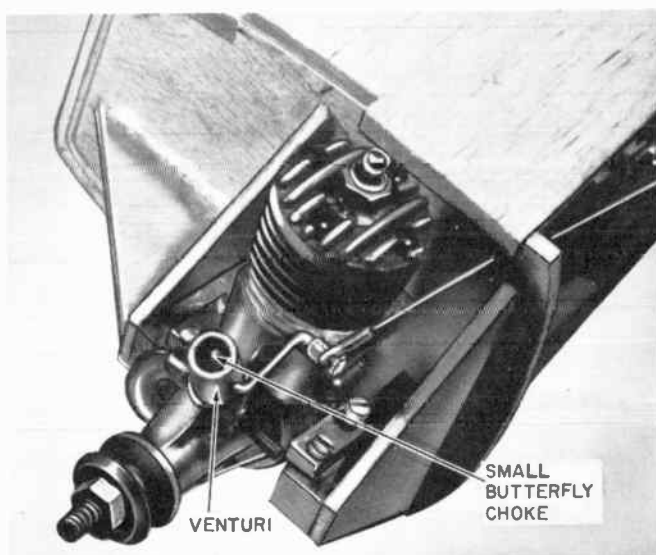
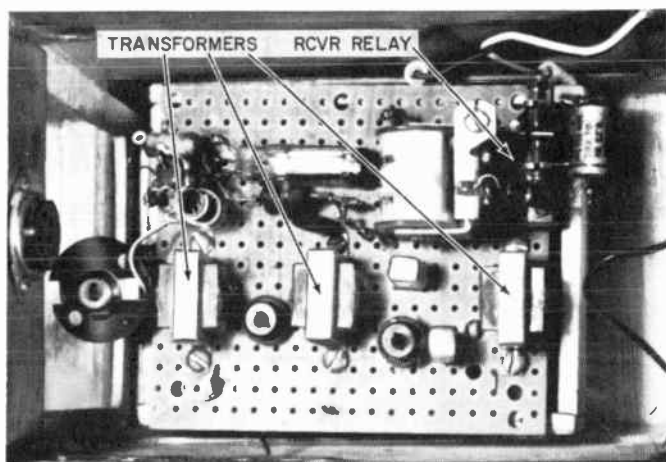


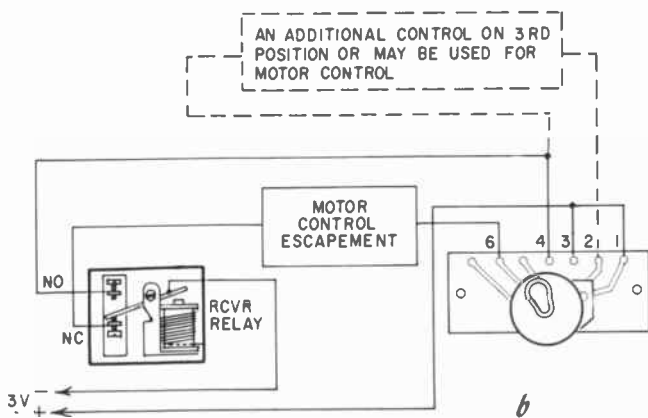
Fig. 1205. Small butterfly choke is seen in venturi of engine. A tin or brass disc is run through the venturi and bent into a crank.

crank go to the second neutral, the linkage would be moved forward because the crank moves 180° and stops.

In Fig. 1205 a small "butterfly" choke has been placed in the venturi of the engine. A small disc is cut out of tin or brass, soldered to a shaft running through the venturi and bent into a crank as shown. The soldering of the disc must be done down in the opening and takes patience and care. Don't let gobs of solder run down into the crank-



a



b

Fig. 1206. (a) Mounting of receiver relay and motor-control escapement. (b) Pictorial wiring diagram showing connections of Varicom to receiver relay and the motor-control escapement

case! If they do, take the motor apart and pull out the crankshaft to remove them.

The butterfly choke should not close the venturi opening completely. Provide a 1/16- to 1/8-inch opening when it is closed by drill-

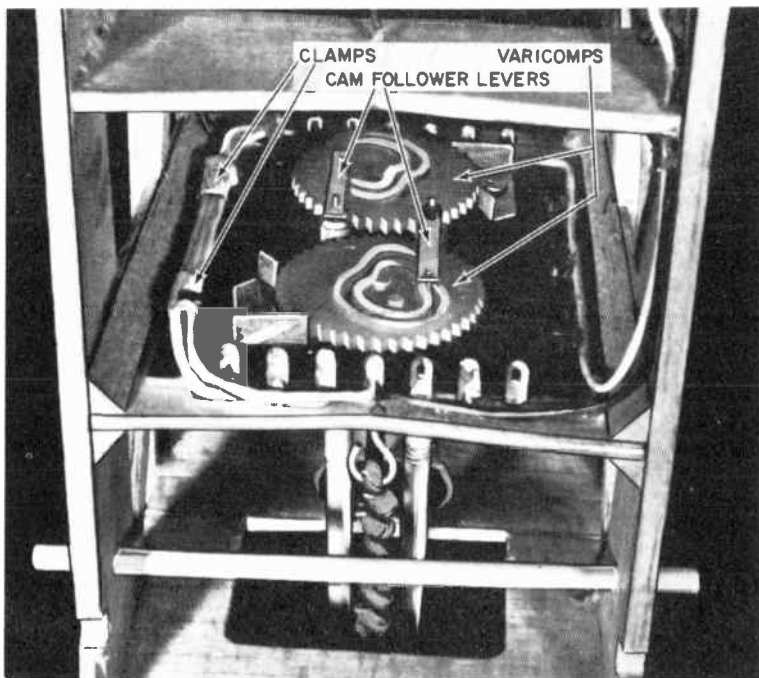


Fig. 1207. Wiring of Varicomps is held neatly in place by clamps fastened to mounting screws. Varicomps are mounted to rear of receiver compartment.

ing a small hole in the disc or preferably, by clipping a little off an edge. Before connecting the escapement, test the motor. Open the butterfly and run as usual. Close the butterfly by hand, using the little crank, and see if the engine slows down. Adjust it till it does.

Now complete the installation by connecting the linkage. Test again by connecting a battery directly to the escapement through a pair of 12- to 18-inch wires soldered to the escapement terminals and flashlight batteries. If you can throttle the motor and cause it to speed up by operating the escapement, this part is completed. If you have trouble, look for binding in the joints or where the linkage goes through any part of the fuselage wall (Fig. 1205).

All that remains is to connect the Varicomps to the receiver relay, the batteries and the motor control escapement. Fig. 1206-a,b shows the details. Now you will want to practice sending signals to the model while the motor is running. Memorize the new command codes until you can send them almost without thinking, and then go flying. No longer will the model climb up out of sight; now you can let it climb to any desired altitude and then throttle the motor and cruise.

You can perform these contest patterns easily. If the plane gets too low, speed up the engine and climb back to the height you desire.

Adding elevator and aileron control

To add aileron and elevator controls, we merely add a second Varicom escapement and a compound² to our system. The Varicomps are mounted just to the rear of the receiver compartment. The Babcock Mark II will be mounted right in the center of the wing.

Fig. 1207 shows how the wiring of the two Varicomps is neatly run around the sides and held in place there by small clamps fastened to the mounting screws. We certainly don't want any loose wire interfering with the cam action.

There is no mechanical connection between the two escapements shown in Fig. 1207. Each operates independently of the other. Before turning to the wiring diagram, see Fig. 1208, which shows a top view.

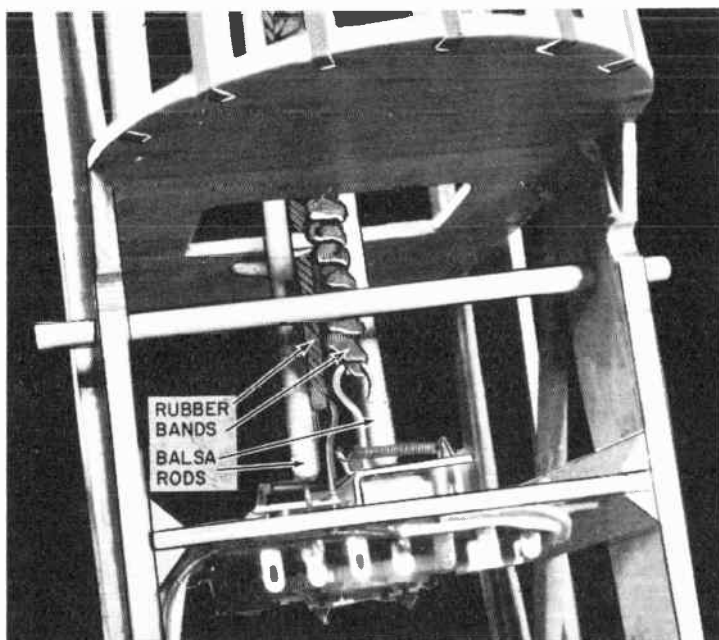


Fig. 1208. Top view of Varicomps. Rubber bands powering escapement are run to rear of fuselage. Wire linkage to rudder and elevator is replaced by hard-balsa rods.

Note how the rubber bands powering the escapement are run to the rear of the fuselage. One is brought out to a small hook on one side just ahead of the tail assembly, and the second on the other side. Wooden rods of hard balsa replace the wire linkage to the rudder and elevator. This eliminates the spring play of the wire, which would prevent good control if it was too long.

² Babcock Mark II.

The balsa rod is connected by clipping the wire about 2 inches from the escapement and bending a small right angle into the end. Run this through the balsa rod and bind wire tightly to it with thread (glue the thread winding). Do the same on the other end, since we want a wire connection to the rudder and elevator. Fig. 1209 shows how these wires are brought out through the end of the fuselage. Fig.



Fig. 1209. Wires connecting to rudder and elevator are brought out through the end of the fuselage.

1210 shows the horizontal stabilizer in place, and the elevator link resting almost against the edge of the elevator. The neutral position is shown.

When we use escapements to move a model airplane elevator, this control surface must be balanced aerodynamically so that the rubber bands can power it fast and accurately. If it is unbalanced, more power will be required to move it first to the up position and then to the down position. And we certainly want to return to neutral or even the up position if we have sent a down command for a dive!

Balancing is not difficult. Simply pivot the elevator about a third of the way back from the front edge (Fig. 1211.) This takes care of the aerodynamic balancing. You can then add a little weight to the leading edge so that it will balance when the model is not moving.

We could fly with just rudder, motor and elevator, so let's inspect

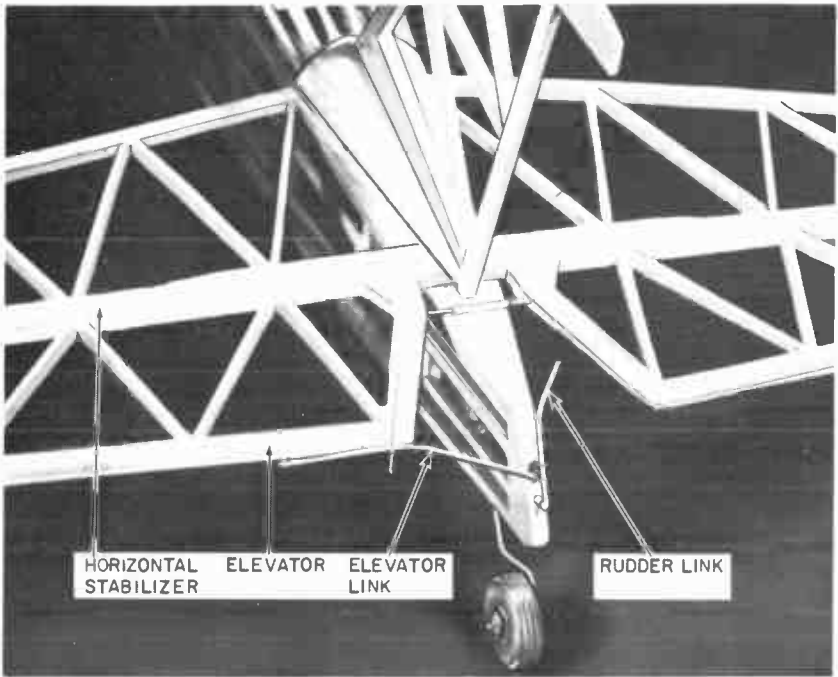
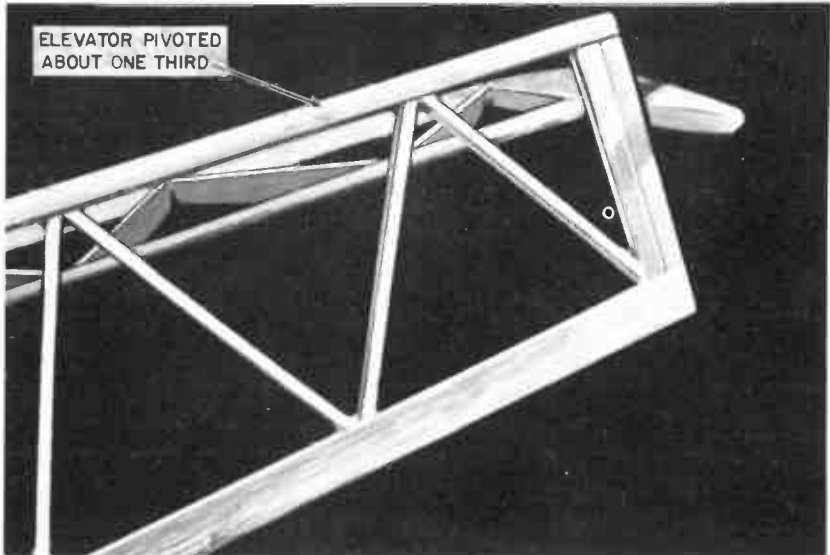


Fig. 1210. Illustration shows horizontal stabilizer in place and elevator link resting against edge of the elevator.

Fig. 1211. Aerodynamic balancing is accomplished by pivoting elevator about one-third back from front edge.



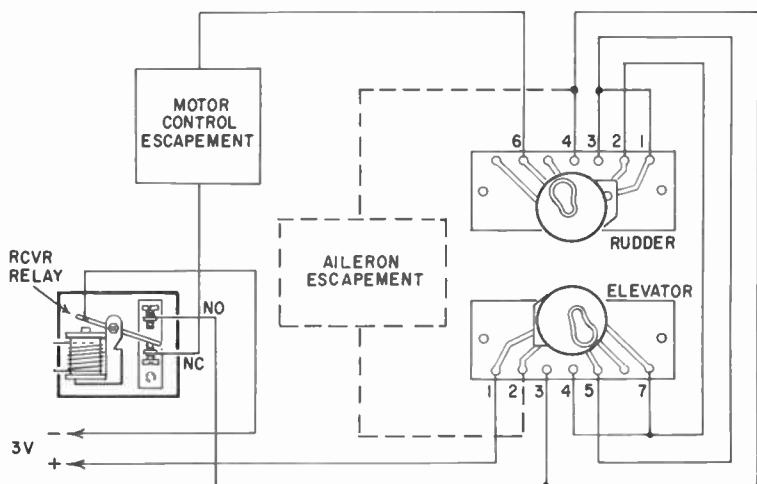


Fig. 1212. Pictorial wiring diagram showing interconnection of two Varicoms.

the diagram showing how the two Varicoms are connected together to allow us to do this. Fig. 1212 shows the interconnections that must be made between the terminals of the Varicoms, the leads to the motor control escapement, the receiver relay, the batteries and the aileron escapement (you can omit the aileron escapement connections, if desired).

How do we operate it? This is your command code now:

LEFT — press and hold

RIGHT — press, release, press and hold

UP — press, release, press, release, press and hold

DOWN — press, release, press, release, press, release, press and hold

MOTOR — quick blip

AILERON — press, release, press, release, press, release, press, release, press and hold.

Any time you desire, just release the keying switch and, no matter what you have the model doing, all controls will immediately return to neutral. You can fly it just as though you only had rudder by using just the first two commands, or rudder and up elevator using the first three, etc. You do *not* have to go through the whole sequence of commands each time.

The aileron

The reason for using an aileron is to permit the model to roll about its longitudinal axis on command. It's a pretty maneuver. We will be able to roll in only one direction with this system and thus we want our aileron to move to only one other position from neutral. It may be up or down, as you choose. The Mark II escapement was chosen because we desire just two positions: neutral, when no signal is received and down, when the escapement is energized. This escapement

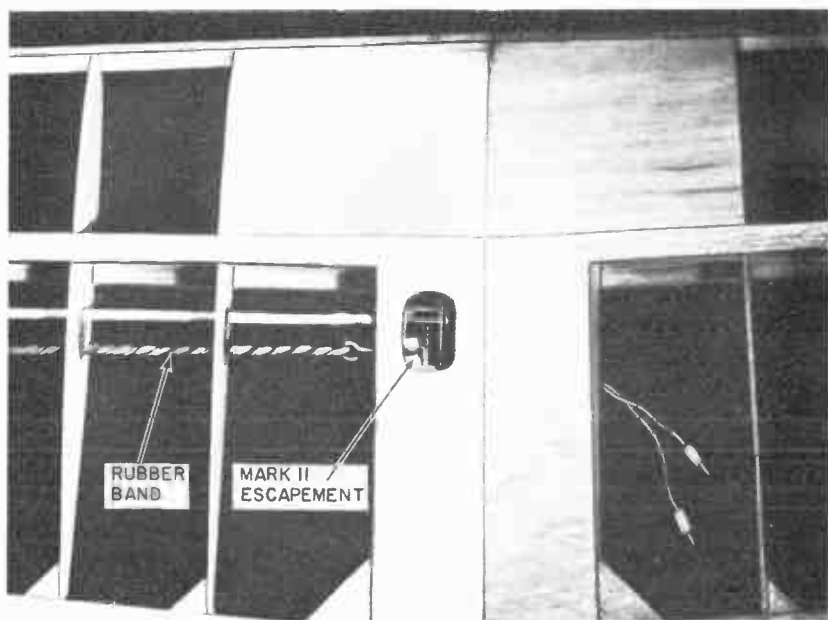


Fig. 1213. Two-position Mark II escapement mounted in center of wing.

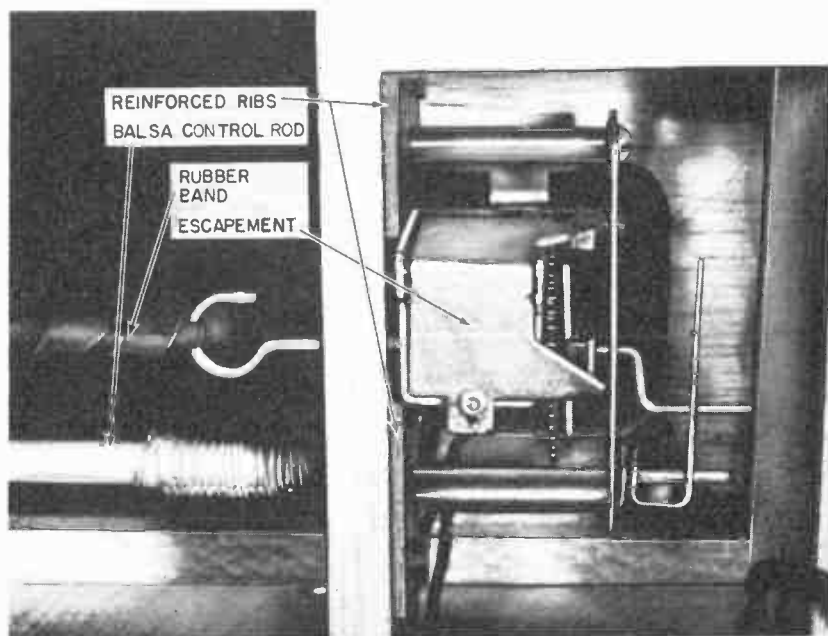


Fig. 1214. The Mark II is bolted to a reinforced rib and the rubber band is run out to the end.

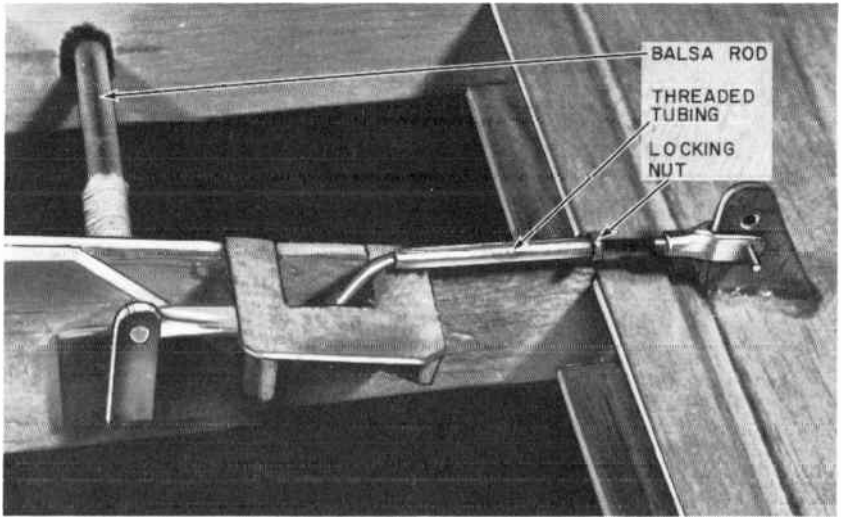


Fig. 1215. A small fiberboard bushing in the center of the aileron houses the balsa rod.

will give us both. Also the Mark II is small enough physically to mount in the center of the wing (Fig. 1213).

The installation is not difficult. The escapement may be bolted to a reinforced rib (Fig. 1214) and the rubber band run out to the end. The balsa control rod is again fastened to the piano wire soldered to the small metal lever as shown. Out along the wing, in the center of the aileron itself (Fig. 1215), the balsa rod is housed in a small fiberboard bushing. A small metal crank is attached to the end of the wooden rod by soldering it to a second piece of piano wire, and again fastening this to the balsa rod.

The wood U through which the linkage comes up to connect to the aileron horn is necessary to provide a place to glue the silk or nylon covering the wing. A small piece of threaded tubing with a locking nut allows adjustment of the aileron. Remove the pin through the linkage and horn and screw the end section in or out of the tube.

If we want to provide a means of replacing the aileron escapement rubber band, it will be necessary to plan for a small hatch opening in the wing on the underside. We leave the details of this to you.

One final word: You've perhaps already guessed that, even though we do have control over many functions of the model airplane, there must be something we haven't considered. We will get rudder movement, left and right, before we can get elevator up or down, and we will get rudder and elevator "waggle" before we get aileron. This doesn't affect the operation of the airplane at all in flight, so don't let it worry you. The action is so fast that the model doesn't respond except to the command we send and hold for a short length of time.

two-channel operation

PROBABLY the first question that comes to mind is, "Why do I need more than one channel?" The reason is that it will allow us to do still more things by means of radio commands and will enable us to try other control setups which are not adaptable to single-channel systems. With multichannel systems, we can use servos instead of escapements in our model airplanes, and our method of control can more nearly approximate "real" flying.

What we have to do is add a little to our transmitting system and make some changes in our receiver. It won't be difficult and, if we use care, we'll have no trouble. We are going to add to our transmitting system first by changing the tone modulator. We do this so that, when we make the changes in our receiver, we will have the transmitter to test it with. We will be able to test the transmitter with our earphones, our antenna light and the basic test meter.

We are going to construct a tone section capable of generating the two tones required for operation, 1,900 and 3,000 cycles and we will modify our present tone generator so that it will function as an amplifier to give us high-level *plate modulation*. This is a new term and concept so let's spend a moment on it. At the present time, with the one-tube tone modulator, we have what is called "plate modulation," meaning that we apply the tone power to the B-plus lead of the final transmitter stage. But we are getting reduced output because our antenna light *dims* when we send a tone. This means that the power being sent out is actually decreasing when the tone is sent.

What we want is a tone modulator which will cause the antenna light to brighten when we depress a tone keying switch. This would mean that power is being added to the transmitted wave to give us better range and reliability and a more foolproof system. If we want

to increase the transmitted power, we must necessarily supply the increase by means of the tone section. That is why our modulator is slightly more complex than others. The results, however, will justify the effort and expense.

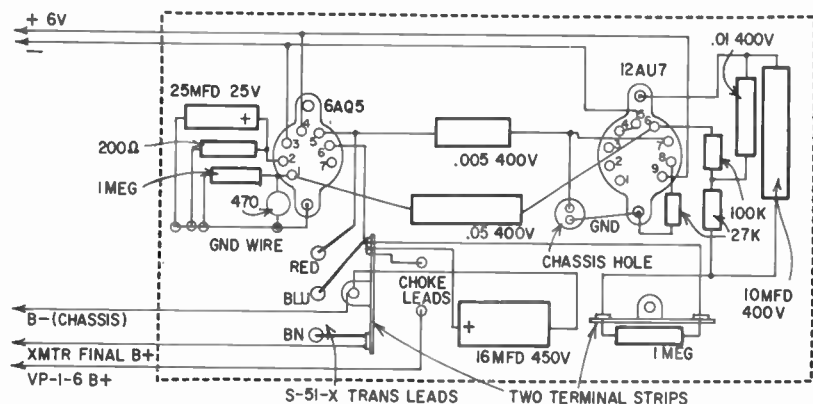


Fig. 1301. Bottom view of chassis showing location of parts in modified basic tone modulator.

Let's change our basic tone modulator (originally shown in Chapter 10, Fig. 1008 and Fig. 1009) as follows (See Figs. 1301 and 1302).

1. Swap the red and blue transformer leads. (Just interchange their connections.) Remove the extra wire from pin 5 of the 6AQ5 which went to final B-plus. The 470- μ f capacitor connected to pin 1 of the 6AQ5 should remain in place.

2. Remove the 51,000-ohm resistor and the .01- μ f capacitor from pin 1 of the 7-pin tube socket (6AQ5).

3. Solder a 1-megohm resistor lead to pin 1 and the other lead to the bare chassis ground wire.

4. Remove the short jumper between pin 2 and the ground wire. Replace it with a 200-ohm 1-watt resistor and connect one resistor lead to pin 2 and the other to the ground lead.

5. Connect the plus terminal of the 25- μ f electrolytic capacitor to pin 2 and the other to the ground wire.

6. Solder one lead of the .05- μ f capacitor to pin 1.

7. Solder a short lead directly from the B-plus terminal of the two-terminal strip to pin 6. Remove the leads from the keying jack and remove the jack itself from the chassis.

8. The brown wire from the transformer now is not connected to anything except the terminal strip. Solder a 12-inch length of insulated wire to this terminal and mark it "final B-plus." This is the lead which will now connect to the transmitter.

9. Drill a hole and mount a nine-pin tube socket (for a 12AU7) and its associated terminal strips as shown in Fig. 1303. Make certain that you orient the socket as indicated in Fig. 1301.

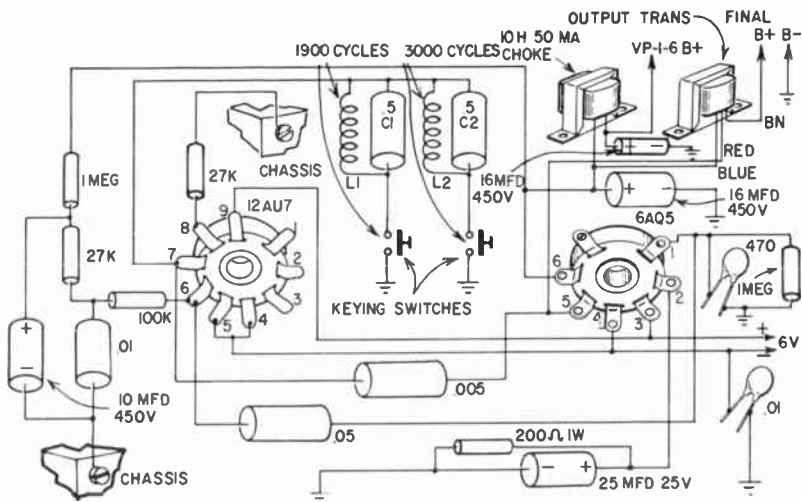


Fig. 1302. Pictorial wiring diagram showing changes in basic tone modulator.

10. Solder pins 4 and 5 of the 12AU7 together. Then solder a short length of insulated wire to pin 4.

11. Solder the other end of this wire to pin 3 of the seven-pin tube socket.

12. Solder the end of another short length of insulated wire to pin 9. Solder the free end to pin 4 of the seven-pin socket. Run

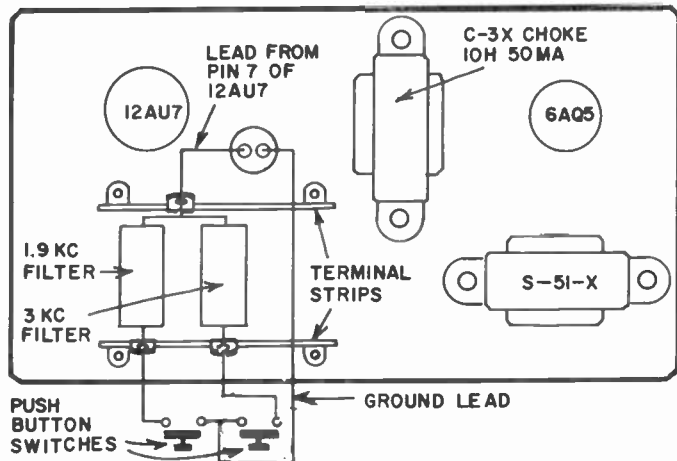


Fig. 1303. Positioning of the nine-pin tube socket for the 12AU7 and associated terminal strips.

these two leads along the corner formed by the front lip and top of the chassis.

13. Solder the free lead of the .05- μ f capacitor to pin 6 of the nine-pin socket.

14. Solder one end of the 100,000-ohm resistor to this same pin (6). Before soldering, clip the lead so that it is only about $\frac{1}{2}$ inch long.

15. Twist the free lead of the 100,000-ohm resistor with one lead of a 27,000-ohm resistor, solder the joint and clip it so that the twisted ends are about $\frac{1}{2}$ inch long.

16. Connect one lead of the .01- μ f capacitor to this joint and solder.

17. Solder the other lead to the base ring of the socket (chassis).

18. Solder a length of bare No. 18 wire from the base ring (chassis) to the center terminal of the same terminal strip to which the transformer blue and brown leads are connected.

19. Solder the free end of the 27,000-ohm resistor to the left-hand terminal of a two-terminal strip located just below the nine-pin socket.

20. Solder one lead of the second 1-megohm resistor to this same left-hand terminal and its other lead to the right-hand terminal.

21. Solder a short length of insulated wire to the right-hand terminal and run it across to the upper terminal of the two-terminal strip located below the seven-pin socket. The blue transformer lead is soldered to this same terminal.

22. Solder a 12-inch length of insulated wire to this blue-lead terminal and run it out to the right. Mark it VP-1-6 B-plus. This lead will connect to the vibrator supply B-plus through the filter we are going to construct.

23. Solder one lead of a second 27,000-ohm resistor to pin 8 of the nine-pin socket. Clip the lead to about $\frac{1}{2}$ inch before doing so.

24. Solder the free lead of this resistor to the base ring.

25. Solder the negative lead of the 10- μ f 450-volt electrolytic capacitor to the base ring.

26. Solder the plus lead to the junction of the 27,000-ohm and 1-megohm resistors at the left-hand terminal of the strip above the nine-pin socket.

27. Solder one lead of the .005- μ f capacitor to pin 7 of the nine-pin socket.

28. Solder the free lead of the .005- μ f capacitor to pin 5 of the seven-pin socket.

29. Solder about a 6-inch length of insulated wire to pin 7 of the nine-pin socket. Run this lead up through the chassis to the right of the socket. This connects to the common junction of the two filters.

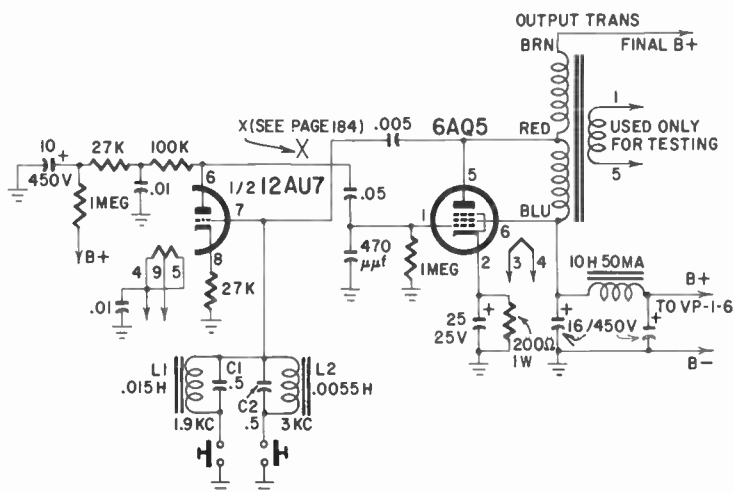
30. Solder a second 6-inch length of insulated wire to the base ring of the nine-pin socket and run it up through the chassis the same as in step 29. These two leads can go through the same chassis hole.

31. Now twist one lead of the 1,900-cycle filter with one lead of the 3,000-cycle filter and solder the two to one of the *insulated* terminals of the strip nearest the 12AU7 tube on top of the chassis.

32. Solder the lead from pin 7 to this junction.

33. Run the free leads of the filter through two of the insulated terminals of the strip at the front of the chassis. Solder these to the terminals.

34. Bring the insulated lead from the base ring out toward the



parts list for the two-tone oscillator-modulator

Resistors: 1—100K; 2—27K, 2—1 megohm; 1—200 ohms, 1 watt.

Capacitors: 2—16 μf , 450 volts, electrolytic; 1—25 μf , 25 volts, electrolytic; 1—10 μf , 450 volts, electrolytic; 2—.01 μf tubular; 1—.05 μf tubular; 1—.005 μf tubular; 1—470 μf disc ceramic.

Tone filters: L1, C1; L2, C2

Miscellaneous: 1—Triad S-51-X push-pull audio output transformer; 1—iron-core choke, 10H, 50 ma; 1—7-pin miniature tube socket; 1—9-pin miniature tube socket; 1—6A Q5; 1—12AU7; 2—normally-open push button switches (spst).

Fig. 1304. Circuit diagram of two-tone oscillator-modulator.

front of the chassis also. When you connect this lead from the ring to one of the free filter leads, one tone will be produced; connecting the lead to the other filter lead will produce the second tone. You can make these connections through keying switches by first connecting the base-ring lead to one terminal of each of two switches. Then, connect the lead from one filter to the other terminal of one switch and the lead from the second filter to the other terminal of the second switch.

After completing the wiring of the two-tone oscillator-modulator, check your work against the pictorial of Fig. 1301. The circuit diagram is shown in Fig. 1304. It is helpful to check your construction against the circuit diagram for a number of reasons. It is an excellent method of learning how to read and draw circuits, and, of course, it is a fine double check.

The type of filter we have specified should be used. It is available;

in fact, it is available in even more tones.¹ If you want more than two channels, simply add filters to the strips on top of the chassis, connecting the ends of the additional units to the common pin 7 lead and the free ends to additional keying switches.

Fig. 1305 shows how to determine the resonance of any parallel-tuned circuit, in case you don't want to build your own, but the filters must use a small coil and have a large capacitor.

Testing the modulator

To connect the modulator to the VP-1-6 vibrator supply, solder the lead marked VP-1-6 B-plus to one end of the 10-henry 50-ma choke. At this same junction, solder the plus lead of one of the 16- μ f 450-volt capacitors. Solder the free end of this capacitor to the lead connected to the modulator chassis, which earlier we marked B-minus (or ground). Connect the free end of the choke to the B-plus terminal of

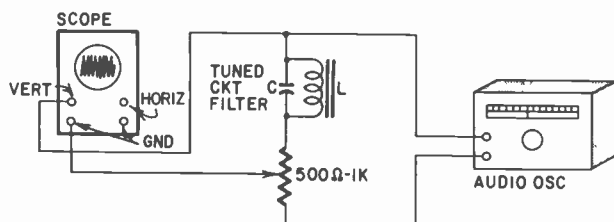


Fig. 1305. Circuit diagram for determining the resonance of any parallel-tuned circuit.

VP-1-6 and the plus lead of the second 16- μ f capacitor to this same vibrator terminal. Solder the minus lead of this capacitor to the B-minus or ground lead.

Connect the minus lead of the modulator to the minus wire of the vibrator supply. Connect the filament leads of the modulator to the FIL and GROUND leads of the vibrator supply. Connect the vibrator supply to a 6-volt car battery or to the motor scooter 6-volt wet cell mentioned previously.

Now connect your earphone across terminals 1 and 5 of the output transformer. Allow about 2 minutes for the tubes to warm up and then touch the wire from the ring of the 9-pin socket to one of the free filter leads (or depress one of the keying switches). You'll hear a loud and clear tone. Try the second. You'll hear another loud and clear (but different) tone. The modulator is now finished and ready to connect to the transmitter. In case of trouble, recheck the circuit wiring for mistakes, poor solder joints, or the wrong part put in at some step of the wiring.

Connecting to the transmitter

This is easy. Connect the lead we marked final B-plus to the B-plus lead (final) of the transmitter.

¹ Ace Radio Control, Higginsville, Mo.

Connect the oscillator B-plus lead to the B-plus of the VP-1-6 and also the modulator filaments to the FIL and GROUND leads of the VP-1-6. Connect the B-minus lead of the vibrator supply to the chassis of the transmitter. Now turn on the power and wait for the transmitter antenna light to glow. When you depress the keying switch now, the antenna light brightness will increase. Tune the antenna capacitor for the brightest glow when no key is depressed and the transmitter portion of our change is completed. Before changing the receiver, you can, if you desire, listen to the two tones by connecting your earphones to the receiver and having someone else key the two

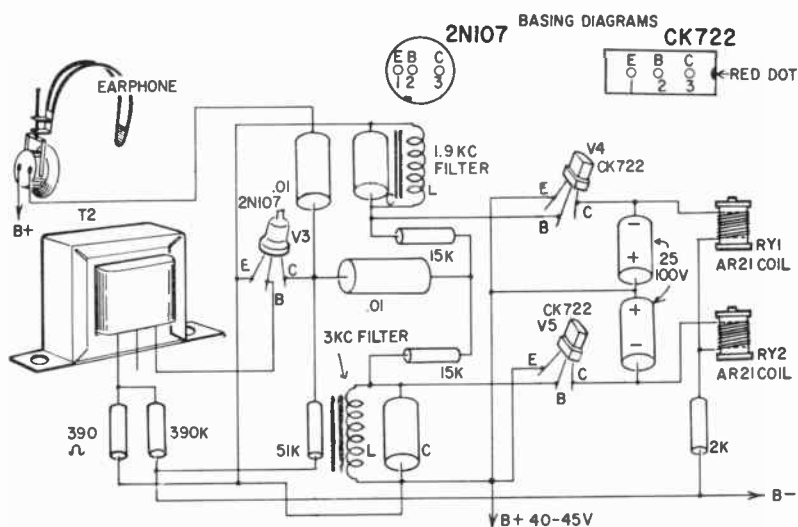


Fig. 1306. Pictorial wiring diagram showing modifications of receiver for two-channel tone operation.

transmitter tone switches. Note that the relay of the receiver energizes and, when the tones are received, it de-energizes. Note also that either tone operates the relay.

Our next step is to reconnect a portion of our receiver so that one tone will cause one relay to operate and the second tone a second relay, and then we will have our *two-channel* system completed.

Reconnecting the receiver for two-channel tone operation

Refer to Fig. 1306 for the pictorial wiring diagram, and modify the receiver as follows:

1. Remove transistors V4 and V5 from their sockets.
2. Unsolder all the connections to pins 2 and 3 of these two sockets.
3. Remove all parts with the exception of the .01- μ f capacitor connected to pin 3 of V3, the 51,000-ohm resistor connected to pin 3, and

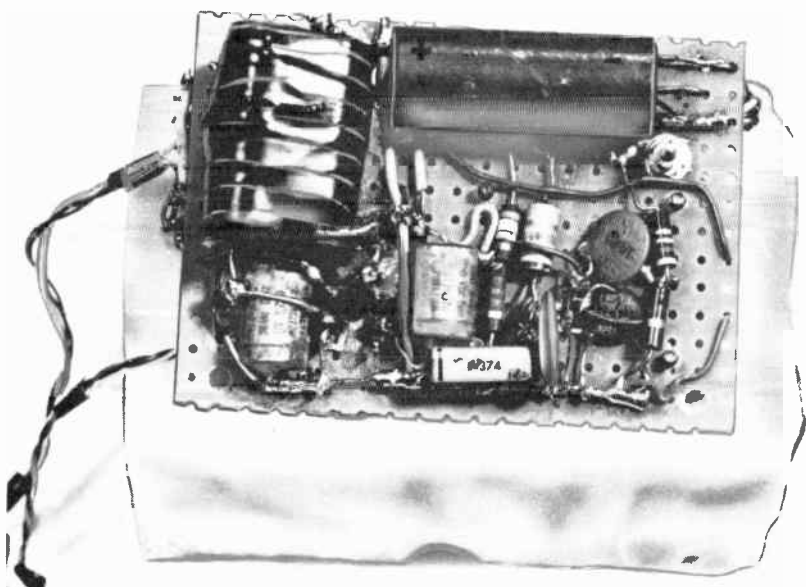


Fig. 1307. Filters for 1,900 and 3,000 cycles, mounted with a strap made from a piece of metal or wire.

the 2,000-ohm resistor connected from one lead of the relay to the B-minus line.

4. Remove transformer T3 and also remove the Sigma 4F relay.

5. Remove the .001- μ f capacitor from pins 2 and 3 of V3's socket.

6. Now we are going to use smaller relays, Argonne AR-21's, or Gem's or equivalent. You may use Sigma's if you desire but you will have to mount them on a separate chassis. If you use AR-21's, mount them on the receiver chassis.

7. Join the two nearest bottom terminals on the relay terminal panels and then solder a short length of insulated wire to one of these terminals. Run the wire through the chassis and solder its free end to the free end of the 2,000-ohm resistor connected to B-minus.

8. Run short lengths of wire from the other terminal of each relay panel. Solder the free end of one lead to pin 3 of V4 and the other lead to pin 3 of V5.

9. Obtain a .25- μ f capacitor and solder one lead to pin 3 of V4 and the other lead to the B-plus line.

10. Solder one lead of a second .25- μ f capacitor to pin 3 of V5 and the other lead to the B-plus line.

11. Obtain two more filters for 1,900 and 3,000 cycles, duplicates of those used in the transmitter modulator. Mount these as indicated in Fig. 1307 using a piece of metal or wire as a strap.

12. Connect one lead of one filter to one lead of the second, just

as you did in the modulator. When the filter sections are mounted in the chassis, these leads should be at the end shown in Fig. 1307.

13. Solder a short length of insulated wire to the junction of these two leads. Solder the other end of this wire to the B-plus line.

14. Solder one of the remaining filter leads to pin 2 of V4 and the other filter lead to pin 2 of V5.

15. Secure two 15,000-ohm $\frac{1}{2}$ -watt resistors. Solder one lead of one to pin 2 of V4 and one lead of the other to pin 2 of V5. (See Fig. 1308.)

16. Join the two free resistor leads and solder the junction to the free lead of the .01- μ f capacitor connected to pin 3 of V2.

17. Solder one lead of a .01- μ f capacitor to pin 3 of V2. Fasten its free lead to the chassis so that it does not touch any other wiring. This is an earphone connection.

Check your wiring

Once again we are going to ask you to check your wiring, either against the pictorial shown in Fig. 1306 or the circuit appearing in

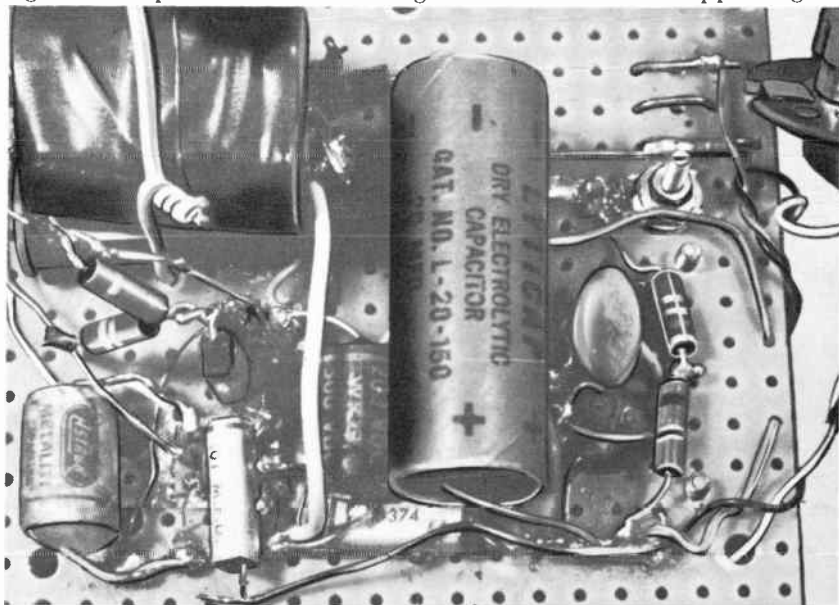


Fig. 1308. Component mounting is not critical. Compare the positioning here with that of Fig. 1307.

Fig. 1309 and preferably against both. After doing this, reinsert the two CK722 transistors in the two sockets, turn the receiver on and listen to the earphone. The earphone is connected to one lead of the .01- μ f capacitor (step 17), and to the B-plus line. You will now hear a loud hiss, almost a roar.

You will not have to adjust the relays unless you have drastically

changed the original spring tension. Turn on your transmitter and have someone depress a tone keying switch. Tune the receiver until the tone is maximum and one of the relays operates. Key the second tone switch and the second relay will close. Make a range test, always adjusting the receiver tuning for the loudest signal, and that's it. You now have a two-channel receiver.

The only possible troubles result from using other than the filters

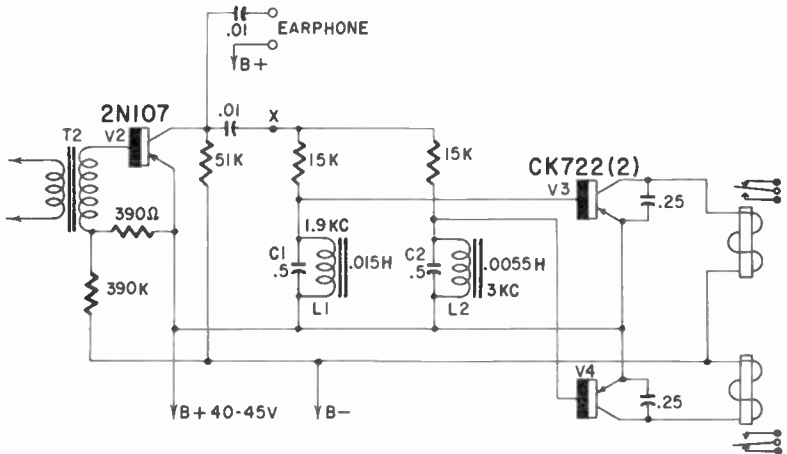


Fig. 1309. Circuit diagram showing receiver changes for two-channel tone operation.

specified or from solder running down into the transistor wire opening in the socket. In the second case, replace the socket. It may have a bad or improper connection, or possibly two bare wires touching.

Adding more channels

If you desire to add more channels of this type, simply add duplicates of the relay stages just described. If you use the same filter in

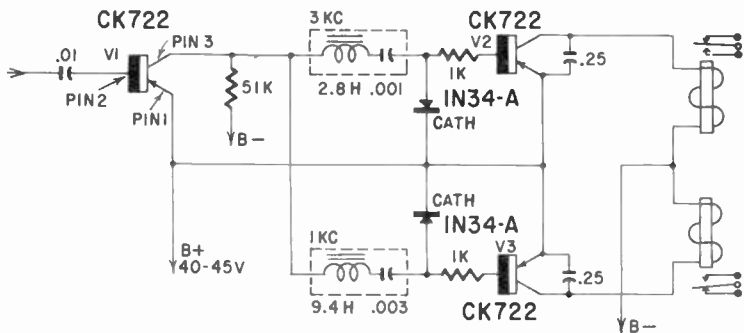


Fig. 1310. Circuit diagram shows bandpass filters in series arrangement.

the transmitter modulator as in the receiver, you will experience no trouble matching tones.

As far as the relay stage transistors are concerned, use CK722's, 2N109's or any standard p-n-p type. The current change through the relay is such that if you adjust the relays to close at 2 ma and open at 1 ma, you'll have no trouble. As set at the factory, most R-C relays close at about 1.6 ma and open at about 1 ma, so actually no change will be needed.

Alternate method of using band-pass filters

In the system just discussed, bandpass filters using low values of inductance and large values of capacitance were necessary. An alternate method will enable you to experiment with larger values of inductance and smaller values of capacitance, should you happen to have these on hand.²

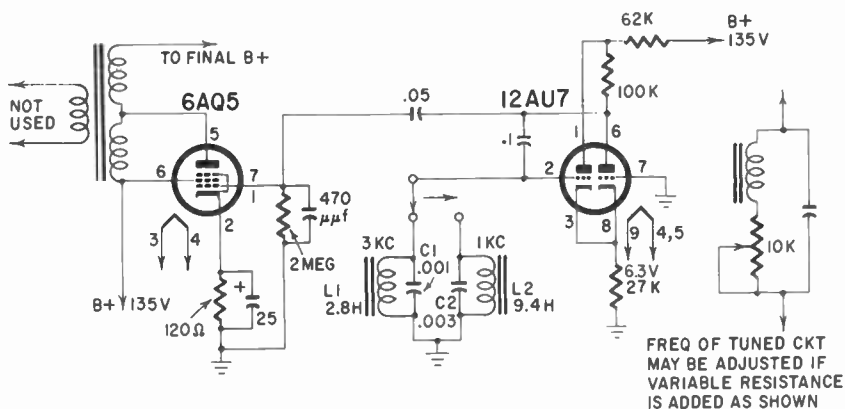


Fig. 1311. Circuit diagram of another type of tone modulator.

It is possible to use a choke and capacitor in a series arrangement as shown in Fig. 1310. In this case, the receiver circuit is not changed as much as previously. Note that the filter sections are connected directly to pin 3 of V3. The two tones required to operate this way are widely separated, a necessary requirement when using this system.

An alternate tone modulator is shown in Fig. 1311. This is an excellent tone generator, provided the coil is reasonably large. This circuit will generate any tone from the lowest to the highest simply by using the correct values for the filters.

Working with tone systems

By now you undoubtedly have a good idea of just what a tone system is. If you blindfolded yourself and listened to a man and a woman

² See also Gernsback Library's No. 74, "Model Radio Control," for additional data on determining the resonance of L-C circuits, and also for other information on radio control.

talking, you ordinarily wouldn't have much trouble deciding which was which. That is the general idea of what we are asking our receiver to do. We are going to transmit two different tones (not at the same time, of course) and our receiver is going to respond to a command, depending on which tone we use at the moment.

The tone filter in the receiver and in the transmitter must be as close to each other in frequency as possible. If your tone modulator uses a frequency of 1900 cycles, the receiver will not respond if its filter is set, say, for 2600 cycles. If you use manufactured filters, just make sure you use the same type for tone modulator and receiver. If you make your own, use identical capacitors and coils. The circuit of Fig. 1305 shows how you can check home-made filters with test equipment, but aside from requiring the equipment, it calls for experience in its use.

While we have shown two tones in operation, a radio-control system could use more. This adds to the complexity of the modulator and receiver. Although this isn't too serious at the transmitter end, it will add weight to your model, and it will use valuable space which you might want to reserve for some other function.

what to do with two channels

WE have already discussed the installation of our radio control equipment in small- and middle-sized boats, increasing the number of things we can do as we progressed. Why not consider a big boat, then, in the application of our two-channel system? By big boat, we mean one on the order of 3 to 4 feet long (Fig. 1401). This

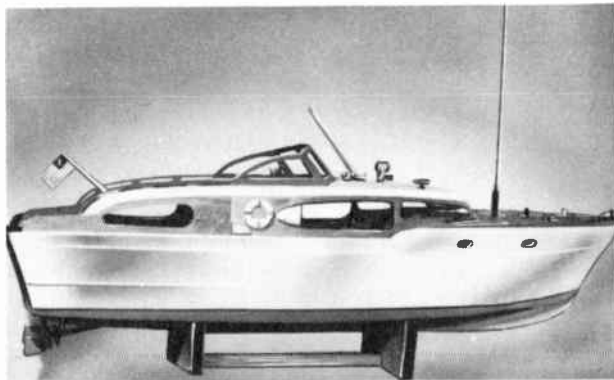


Fig. 1401. Large, elegant-looking model Chris-Craft provides all the space needed for most radio-control applications.

model Chris-Craft not only is a beauty, but also provides all the room necessary for the things we can now do by means of radio control.

We will use the same installation discussed previously, using our single channel for steering and motor control and our second channel to operate a stepping relay which will allow us to control 24 more circuits.

We can operate running lights, deck lights and searchlights. Assuming that these will take three signals to turn on and three to turn them

off, we will need 6 of our 24. Now let's operate a couple of winches which might control fishing lines, flags or anchors. These will require two circuits for on and two more for off. That makes ten. We might use a small rocket launcher or two and these would require two more circuits. We would load the rocket launchers prior to sailing from the dock, and fire them.

A small horn which we could operate at will would take one more circuit. If we lowered a lifeboat from each side, raising and lowering the two independent arms would take four more circuits. That makes a total of 17, and there are still seven left. Suppose we just leave these to you. By the time we have discussed the method of connecting some of the devices, you will be able to devise your own uses.

The stepping relay

The stepping relay¹ (shown in Fig. 1402) is the heart of our expan-



Fig. 1402. A 24-contact stepping relay is the heart of our expanded two-channel radio-control system.

sion and may be procured from hobby shops or some electronic parts stores. Although designed to operate on house current, it can be operated in our boat by two 67.5-volt batteries in series. Smaller batteries can be used but they should be at least 45 volts each. If you are fortunate enough to obtain a stepper that will operate on 6 volts, then you do not have to add these batteries but can operate it with, say the 6-volt wet-cell supply which powers your model drive motors. Whichever type you use, though, it's going to be necessary to connect them in the same manner, so let's look at that situation right after we inspect Fig. 1402 which shows the unit. Note the ring of contacts. You will connect directly to these and also to the small lug extending just below the center hole of the insulated panel. This is the *common* or frame connection. Keep this in mind.

This stepper has two relay coils, and each coil has an armature.

¹ Guardian MER 15

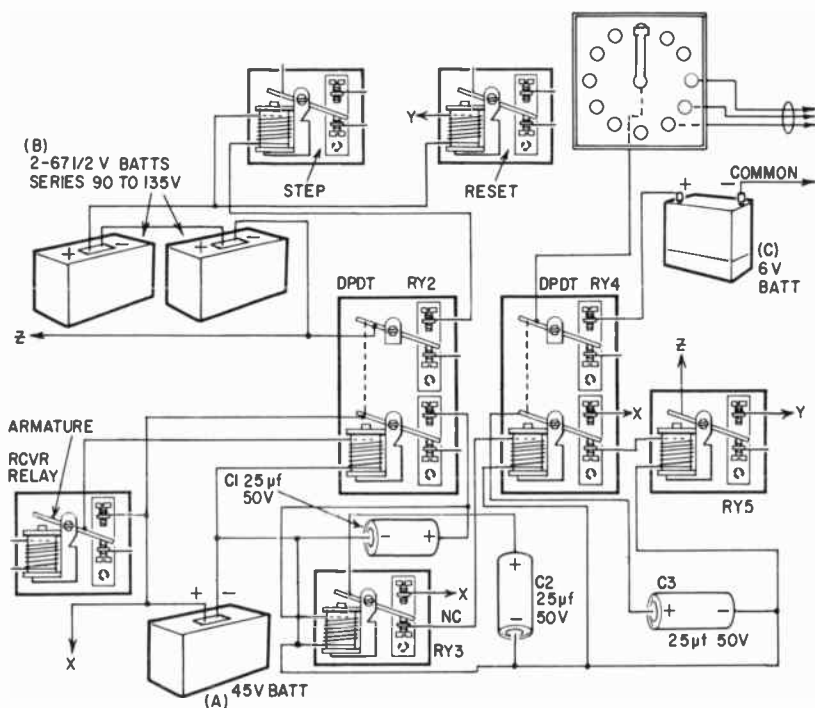


Fig. 1403. Pictorial diagram showing wiring of stepper and its associated relays.

One coil moves the wiper arm around the set of 24 contacts, and the second coil, when energized, makes the arm fly back to the original starting position.

We will make one connection to each contact spot for each thing we want to do, and complete the circuit by a common connection to the wiper through the common connection of the stepping device.

We want this stepper to operate this way: if we send one pulse via our new channel, we want the arm to move to the first contact. We want it to remain there until it energizes the circuit we have connected to this contact, and then we want the wiper to return automatically to the starting spot. In this way, if we send one pulse we cause one thing to happen; two pulses, something else; three pulses, another device operates or stops operating, etc.

The simplest method of sending these pulses is to use our keying switch. We can depress it and release it the required number of times and keep track by counting, or we might be able to obtain a telephone dial which will send the pulses automatically just as it does in telephone work. We will discuss this and other methods of sending the pulses later. Right now we just want to understand generally how we will transmit the signals.

Let's return to the stepper relay. For it to act the way we have just described, we need to have some auxiliary relays connected into this stepper circuit. We will need two dpdt plate-circuit relays². We will also need two spst³ relays. The final parts needed are three 25- μ f 50-volt electrolytic capacitors.

Method of operation

Refer now to Fig. 1403 to understand how the stepper and its associated relays will operate. When we send one pulse over our second channel, the receiver relay closes. In so doing it completes the circuit from the plus side of the 45-volt battery, through its contacts, through the coil of RY2 and back to the minus side of the battery. RY2 will close.

When this happens, one armature of RY2 (on the top) closes the circuit from the stepping relay coil to its 67.5-volt batteries; thus, this coil is energized. As its armature pulls down, it advances the wiping contact to the first of the 24 fixed contacts.

At the same time, RY2's second armature has closed the circuit from the plus side of the 45-volt battery to the first 25- μ f capacitor (C1). Since the other side of the capacitor is connected to the minus side of the battery, the capacitor charges during the period RY2 is closed. At the same time, this second armature has connected the winding of RY3 to the plus side of the battery and it also closes.

If no other pulses are transmitted, the receiver relay and RY2 de-energize, but RY3 is held closed momentarily because of the discharge of the capacitor through its windings. While RY3 is closed, it connects the plus terminal of the second capacitor (C2) to the B-plus terminal of the 45-volt battery and so this capacitor charges.

After a moment, when the capacitor C1 discharges, RY3 de-energizes. Since the lead from the capacitor is connected to its armature and the armature now touches the NC contact, the second capacitor (C2) can now discharge through the winding of RY4, energizing the relay.

The upper armature of RY4 is connected in series with the common lead from the stepper and the battery which energizes the motors, lights or still more relays. Thus, at the instant the circuit is closed the common line is energized for the length of time it takes the second capacitor (C2) to discharge.

The lower armature of RY4 is connected like the armature of RY3 and so, while RY4 is energizes, the third capacitor (C3) is being charged through its connection to the 45-volt B-plus terminal.

After the circuit selected (the No. 1 pulse circuit, in this case) is energized and C2 discharges, the armature of RY4 moves to its de-energized position. It breaks the common line circuit of the stepper and, at the same time, through its upper armature contact, applies

² Radio Shack type LM-11 (03N012 10,000-ohm plate relay)

³ Lafayette Radio, Argonne type AR-21

the fully charged third capacitor (C3) to the windings of RY5. When this last relay is energized, it closes the circuit to the *reset* coil of the stepper, causing its stepping wiper to fly back to its starting position again. No circuits can be energized during the forward or reverse motion of the wiper since RY4 can only be energized after the pulse transmission stops. RY4 is de-energized during the flyback.

Thus, we have selective stepping. If we send five pulses, one after the other, the stepping relay wiper will move to the fifth position, energize that circuit and return to its starting position. Only the circuit we select by sending the proper number of pulses will be energized.

We can test the operation of the stepper (after wiring it as shown in Fig. 1403) by connecting a series of small battery-operated lights

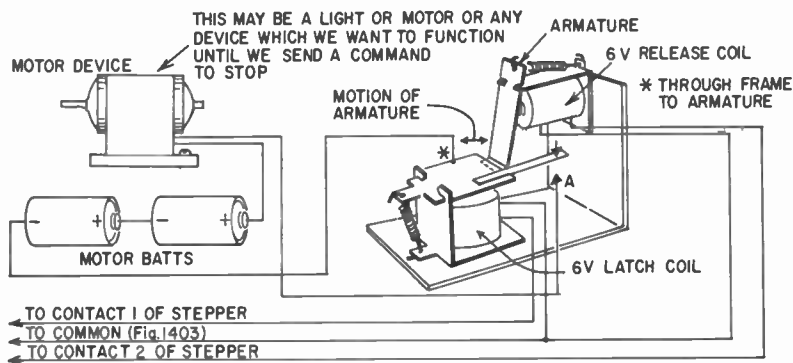


Fig. 1404. Pictorial diagram showing operation of a 6-volt latching relay.

to the contacts on the face of the stepper and by connecting the common lead of the lights to the common lead of the stepper. Send the pulses simply by closing the receiver relay with your fingertip. You will be able to step the wiper around, light any particular light momentarily and then have the wiper return to the zero or start position.

The auxiliary relay circuits

Although the stepper provides us with the selection, it will energize the desired circuit only for an instant. We will want to have this circuit energized until we send a command to cause it to de-energize. To do this we use latching relays.

Latch relays are of two types: electrical and mechanical. Fig. 1404 shows how these would be used. Note that we are going to connect the coil of the latch relay to the first stepper contact and the coil of the release relay to the second stepper contact. When we send one pulse, the armature of the latch relay drops down momentarily and, when it does, the armature of the release relay moves to the left, mechanically locking the latch relay. The contact on the latch armature (A) is closed, the circuit from the motor to its battery is completed and the motor runs.

When we send two pulses, the coil of the release relay is energized momentarily, causing its armature to pull to the right. This allows the armature of the latch relay to rise, opening the circuit to the motor, and the motor stops running.

An electrical latching system, also operating a motor, is shown in Fig. 1405. Two 6-volt relays are used, one dpdt and one spst. When one pulse is transmitted through stepper contact X, it causes the latch relay armature to pull down. This connects the motor to battery B. It also completes a circuit from the coil of the relay (point B), through the armature and normally closed contact (C) of the release relay, to the 6-volt battery. The latch relay is held closed by com-

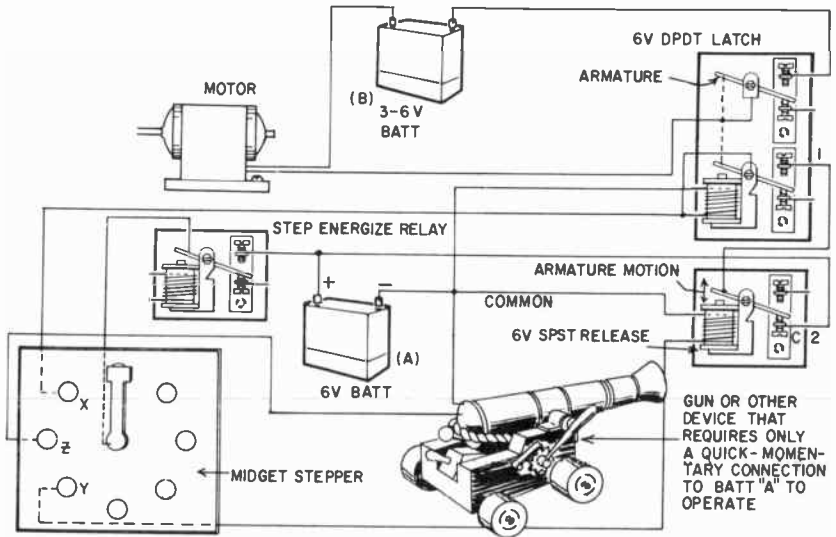


Fig. 1405. Another example of an electrical latching system operating a motor. One 6-volt dpdt and one 6-volt spst relay are used here. Gun or missile launcher is used in this system.

pleting the circuit from its coil, to the battery through its own contacts, and the contact of the release relay.

When three pulses are transmitted, the stepper arm energizes contact Y. This causes the release-relay armature to pull down, momentarily breaking the circuit to the coil of the latch relay and causing the motor to stop running as the latch relay de-energizes. The latch relay will not energize again until we send that one-pulse command to do so.

Fig. 1405 shows a gun or missile launcher which requires only a short impulse or "quick connection" to a battery to fire. We could operate this by sending a two-pulse command. You would have to

load this type of device and set it for firing before sailing the boat out from the dock; after firing, the gun would have to be brought back into port to be reloaded.

Using this same concept of running motors or firing guns, you could connect lights in place of the motors and these would remain on until turned off. Now that you understand the method, see what operations you can think up to be controlled. Your boat will be a knockout with all the things this last expansion allows you to do.

Just in case you think of more devices you would like to control than this system represents, consider the possibility of using another stepper system which would be driven from, say, the No. 1 pulse position of the first stepper. You would then add 24 more functions to the system for a grand total of 48! In case you experience difficulty in being able to transmit pulses fast enough, increase the size of the capacitors to 50 μf .

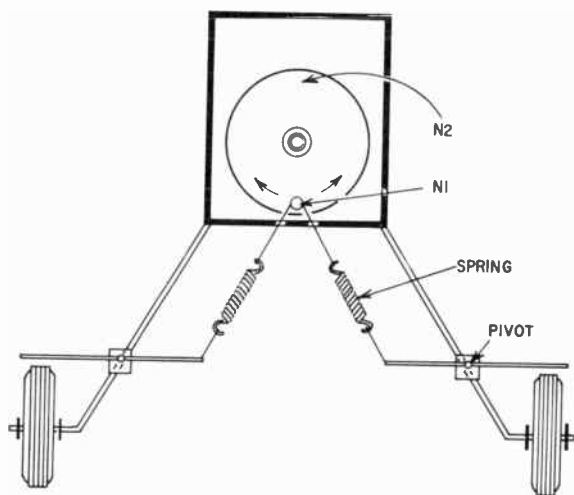


Fig. 1406. Example of two-neutral servo system. One neutral tightens the plane's brakes; the other loosens them.

Coders

Just a note on possible coders to use to transmit the pulse sequences automatically. Probably the best, and easiest to obtain, is a telephone dial. This will send a pulse train or sequence of 10 consecutive pulses. You'll have to dial two numbers above ten to get all the positions — zero and 1 for 11, zero and 2 for 12, etc.

Back to airplanes again

If we use our two-channel receiver with the same system of escapements discussed previously, we find that we have one extra channel

which could be used to operate, say, a small two-neutral escapement to drop bombs from a trapdoor. We could mechanize this by using a small rod (as we did for motor control), to hold the trapdoor shut when the escapement is in one neutral position and to draw the linkage back to let the door open in the second neutral.

Instead of operating the bomb door, this second channel could connect to a servo.⁴ This servo, like the escapement, has two neutral positions, but has much more power due to the motor and gears. If we mount small lever type brakes on the landing gear near each wheel (Fig. 1406) and run the linkages up to this servo, we could have a system in which the servo would tighten the brake in one neutral position, and in the second position, loosen it.

A third possible use of that second channel, with the previous system, would be to operate flaps in the wing. We would use the same type of servo as for the brakes, but this time arrange the linkage to the flaps so that one neutral position would be neutral flap position and the second neutral would give down flap. The flaps or brakes would remain in either of their two possible positions until we send a command to change.

This is important because we cannot send two signals simultaneously with the system we have thus far. For example, if we wanted to taxi out to the center of the runway, stop and rev up the motor prior to takeoff, we would need to send signals via channel 1 to control the motor speed. By having the brakes lock till we are ready to release them and by not requiring a signal to hold them locked, we could accomplish this maneuver.

The same concept applies to the flaps, since we might want to have down flaps while coming in for a landing and then would need to steer by using rudder on the approach. Again, once we have positioned the flaps, the channel 2 signal will not be used and thus we can steer, stopping the steering long enough to reposition the flaps back to neutral should it become necessary.

The ideal system would be one giving control of all three functions in addition to rudder, elevator, motor and aileron, but to do this we would need three additional channels instead of the one we have thus far incorporated. So that will be our next area of expansion. Before we approach this, however, let's consider a few more aspects of plane control which are adaptable to our two-channel system.

Proportional control

Proportional control means the ability to position the rudder or elevator just a little to one side or the other, or up or down a small amount as we require. You may have noticed that in the system thus far, the rudder goes fully to one side or the other and the elevator full up or full down when we send an appropriate command. In a way this is not bad; in fact, probably more modelers use this system

⁴ deBolt 2P2N

than any other. If you constructed the previously described system, you have been able to make gradual turns by blipping the rudder. But you may or may not have realized that the rudder always went to the extreme position and it was the *time* you kept it there that governed the sharpness of that turn.

For proportional control, we want a system in which we can move a "joystick" or lever a small amount, have the rudder move a small amount, and have the aircraft make a gentle turn. If we move the lever farther, of course, the turn is sharper as the rudder would move more.

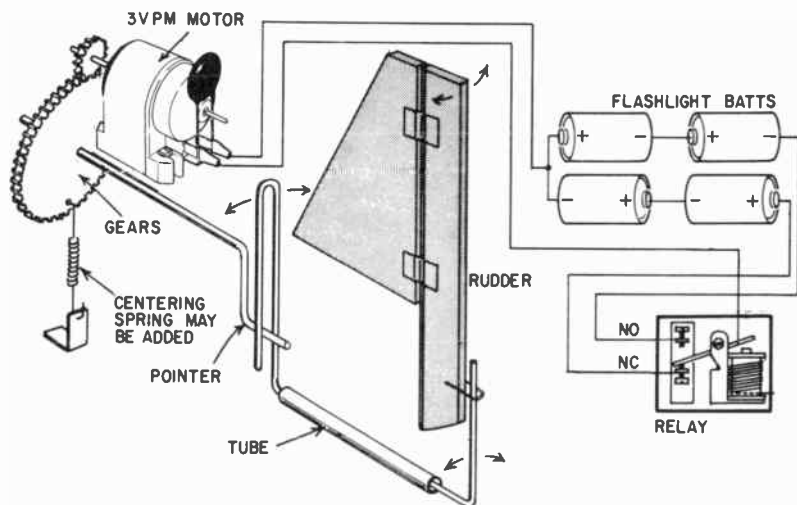


Fig. 1407. Pictorial diagram of a proportional control system showing connection of motor to receiver relay.

Currently, there are two methods of so positioning the rudder that this is possible—the so-called true proportional and pseudo-proportional systems.

Before we examine the pseudo-proportional system, let us discuss transmitting commands by *pulse widths*. Until now, we have achieved all our commands by *pulse sequences*. We have sent one, two, three, four pulses, etc., depending on the system and the command, and it was always *the number of pulses* transmitted that governed what command was performed. Now we are talking about how long we hold the keying switch down as we send a continuous stream of pulses over the airwaves.

Try an experiment. Connect a light to your receiver relay, which is one of the channels. Now take the keying switch and try sending signals for 1 minute so that the light is on for exactly 1 second and off for 1 second. This represents a *pulse width* or transmitted-signal.

The ON time is exactly equal to the *pulse spacing* or transmitted-signal OFF time. Learn to think in these terms of pulse widths and spacing. Pulse *width* is transmitter ON time; pulse *space* is transmitter OFF time.

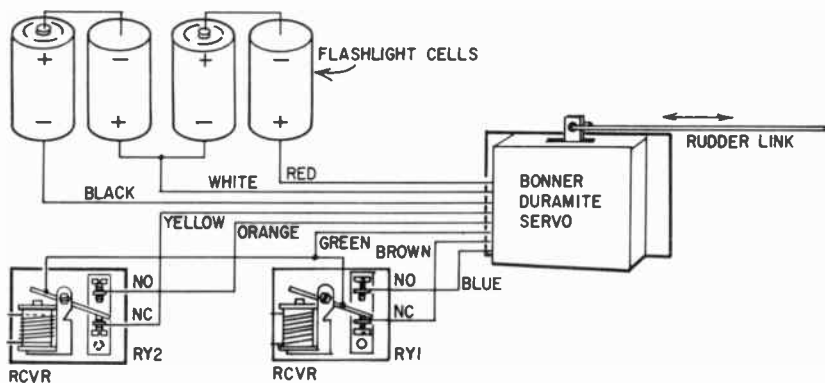


Fig. 1408. Pictorial wiring diagram showing connections of Bonner self-neutralizing servo to two relays.

Let's try another experiment. Take a small motor whose shaft is connected to a gear train through several gears. On the shaft of the last or output gear, attach a small pointer. Now connect the motor to the receiver relay as shown in Fig. 1407. Note that with the relay armature in one position the motor tends to run in one direction continuously. But take your transmitter keying switch and begin pulsing exactly as you did in the previous experiment. What happens? If the gear reduction is large enough, you will be able to stop the pointer and keep it from moving even though the motor runs first in one direction and then in the reverse direction.

Experiment a little further. If you make the ON signal time longer than the OFF time, the pointer begins to creep around in one direction, and the speed at which it creeps is directly related to the difference in ON-OFF times of the signal. Make the signal OFF time longer than the ON time and the pointer does exactly the same thing, but it now goes in the opposite direction.

This is the so-called pulse-width-pulse-spacing type of proportional control system. We have labeled it a pseudo-proportional system, because each time the receiver relay closes, it applies full power to the motor and it is only through the gear reduction that we are able to make the pointer behave at all.

This system is very common and can be used with single-channel receivers. However, there is always the danger of receiver or transmitter failure or going out of range, which would cause the rudder, say, to be deflected fully just as it would if you stopped your signal transmission altogether. In the model, a physical stop prevents the out-

put shaft of the gear train from going round and round as it does in our experimental setup.

With our two-channel receiver, we can actually fly our model with absolute proportional control (pseudo system) without this danger. Let us take our Bonner self-neutralizing servo and connect it to the

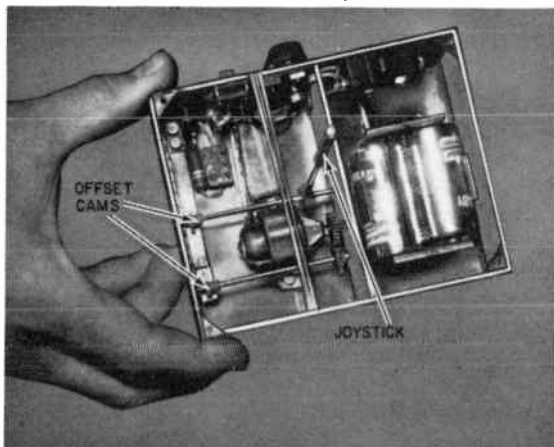


Fig. 1409. True proportional control system showing batteries and an auxiliary switch to energize either channel for testing or tuning before flying.

two relays as shown in Fig. 1408. When the relays are not energized, the servo is always neutralized. If we beep, or pulse one channel slowly, the rudder moves back and forth from neutral to one side.

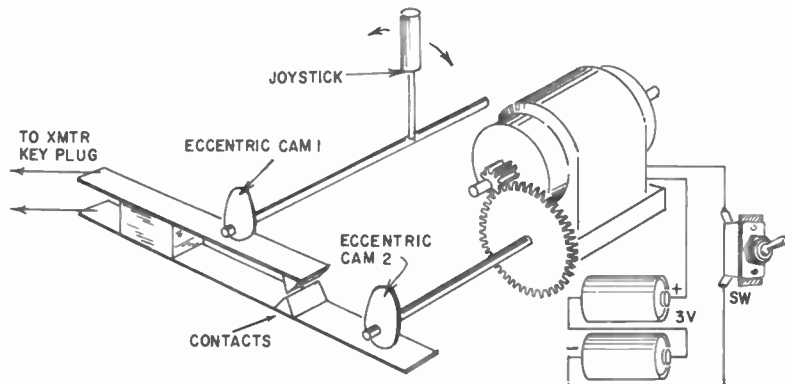


Fig. 1410. Pictorial diagram of proportional control system of Fig. 1409.

If the pulse width is narrow (short transmitter ON time) the rudder moves just a small amount. As we increase the beeping rate by making the ON time longer, the rudder moves farther, etc. Try it.

If we have the same type of control with the second channel, the rudder moves in the opposite direction in the same manner. Thus,

all we need to do is devise a coder which will send out this new type of command signal when we move a lever left or right, and we have our proportional system.

Admittedly, this system is costly because we are using more channels to do less. With two channels, we are controlling only the rudder! The reason why we do it is that we really do want this type of proportional control, but we want the other controls — elevator, motor and aileron also. This means then that we will want more channels from our transmitter through our receiver, and we will get to that. Right now, however, as a beginning, let's continue with the rudder-only operation to learn more about this system.

The pulser (this is what the ground coder is called when it sends out this type of command) may be a relatively simple device. It consists merely of a motor, a set of gears and two movable contacts set close to an eccentric cam mounted on the gear train output shaft. Fig. 1409 shows one example. It also shows the batteries and an auxiliary switch by means of which either channel could be energized for test purposes or receiver tuning prior to flying. Since by now you are able to read diagrams and understand how the connections are made, we will not elaborate further on the connections but refer you to Fig. 1410 for the constructional and wiring details and connection to the transmitting channels.

The proportional type of system has one very real advantage. This is its ability to maneuver smoothly and accurately and, as one good friend put it, "to fly as though you were steering a car or had a seat inside the model itself."

more than two channels

“EAST is East and West is West and never the twain shall meet.” This old saying might readily be applied to the methods used in the Eastern and Western parts of the United States to obtain more than two-channel operation. Eastern enthusiasts are supposed to favor

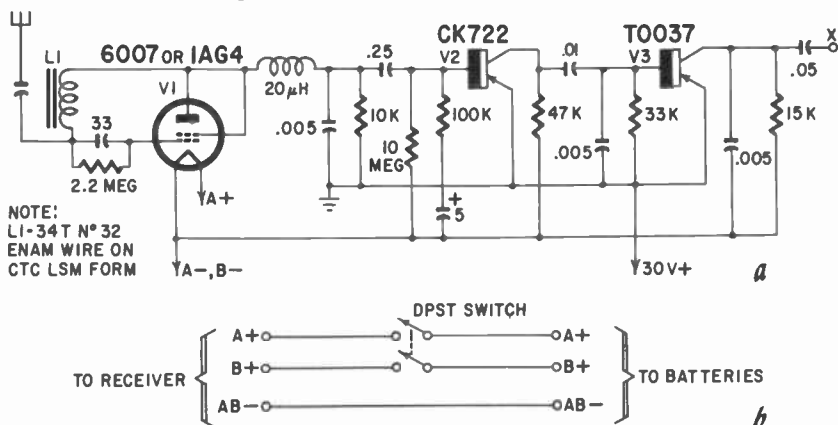


Fig. 1501. (a) Circuit diagram of combined tube and transistor receiver showing detector and audio amplifier stages. (b) Dpst on-off switch circuitry used with receiver and batteries.

filter-type tone decoders and proportional control, which we have already investigated; the West, reed-type decoders. Both require that tones be transmitted, and both can be multi-channel.

Fig. 1501 shows the detector and audio amplifier of a combined tube and transistor receiver. The output of the receiver can be fed into a 6-channel filter. A double-pole, single-throw on-off switch must be used with the receiver to prevent the transistors from putting a constant drain on the batteries. A single-pole switch in the common

lead (A-, B-minus) will not work since it will only turn off the filament current of V1 and will not isolate the transistors from the batteries.

The 6-channel filter is shown in Fig. 1502. The input to this filter

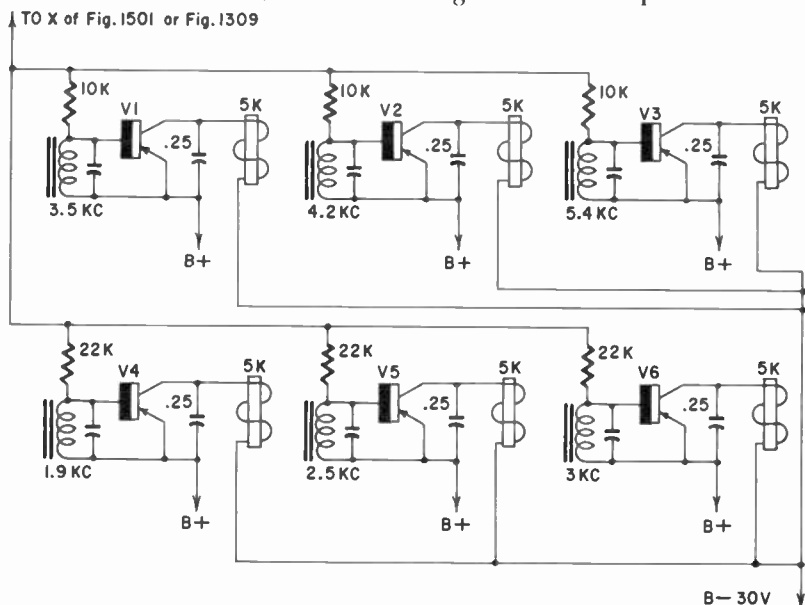


Fig. 1502. Circuit diagram of six-channel filter which is fed from the output of the receiver. Tone filters are available from Ace Radio Control.

is connected to point X in Fig. 1501. Alternatively, it could be connected to point X in Fig. 1309 (page 160). Some of the arguments in favor of the filters are that they are rugged, do not require maintenance or adjustment, and that the tones transmitted do not have to be so exact.

Fig. 1503 shows a tone-modulated transmitter. Two tubes are used. One of the 3A5's acts as an oscillator and amplifier (V1-a and V1-b) while the other tube (V2) is the modulator. The output tube (V1-b) is a frequency doubler. V2 is a multivibrator whose audio frequency is determined by the values of its grid resistors and capacitors. The tone is changed by adding resistors in parallel using keying switches.

Changing the modulator

Instead of building a new tone-modulated transmitter you could modify the simple modulator (previously shown in Figs. 1008 and 1009). The modulator we want now is identical except that we will incorporate six potentiometers into the grid circuit and connect the free ends of each one to one of the tone keying-button switches as shown in Fig. 1504. The final B-plus of the transmitter is connected to the modulator as indicated in this pictorial.

Now getting back to reed-type decoders, users point out they are lighter in weight and smaller in size and thus can accommodate more channels in a given weight-size layout. Also, since they are very sharply tuned, more channels are available within the range of tone

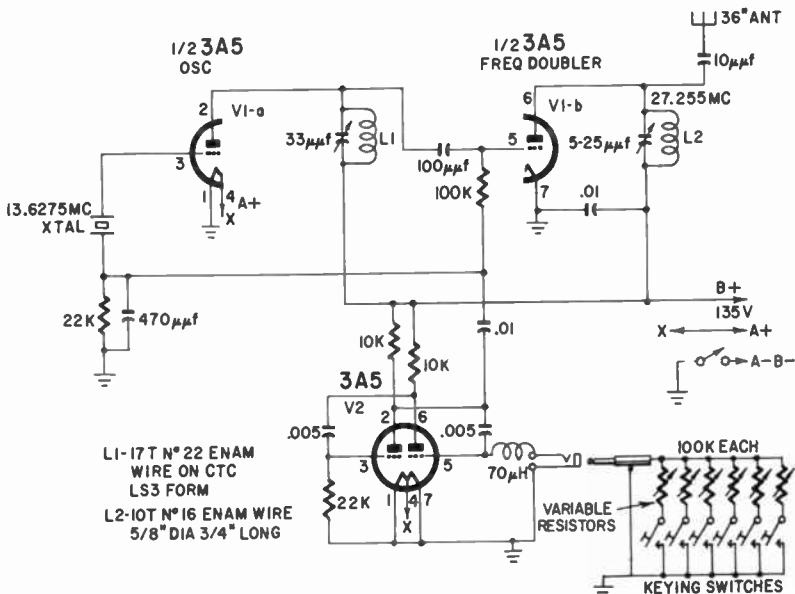


Fig. 1503. Circuit diagram of the tone modulated transmitter.

frequencies that can be used for radio control. For example, it is possible to have as many as 32 tone channels¹ through one receiver!

Fig. 1505 shows a typical six-channel reed decoder. Note that the reeds are the thin strips of spring steel suspended over the coil and that they are almost in contact with the little adjustment screws (contacts) above. The coil has but one winding and this is connected to the last transistor stage of a receiver, much like the output transformer is connected to the last tube of a conventional broadcast receiver. When a tone is transmitted which is exactly in pitch with one of the reeds (they act somewhat like tuning forks) and this tone is passed through the coil, it causes the reed to vibrate up and down. As its swing increases to a maximum, it will hit its contact every time it is in the up position. This, then, can cause a relay to close, and we can so arrange the connections to the relay that it will hold closed during the entire time the reed is vibrating.

When the tone stops and the reed no longer vibrates, the circuit to

¹ Such 32-channel reed units, weighing 10 grams, have been announced by Wurlitzer Co., Chicago, Ill.

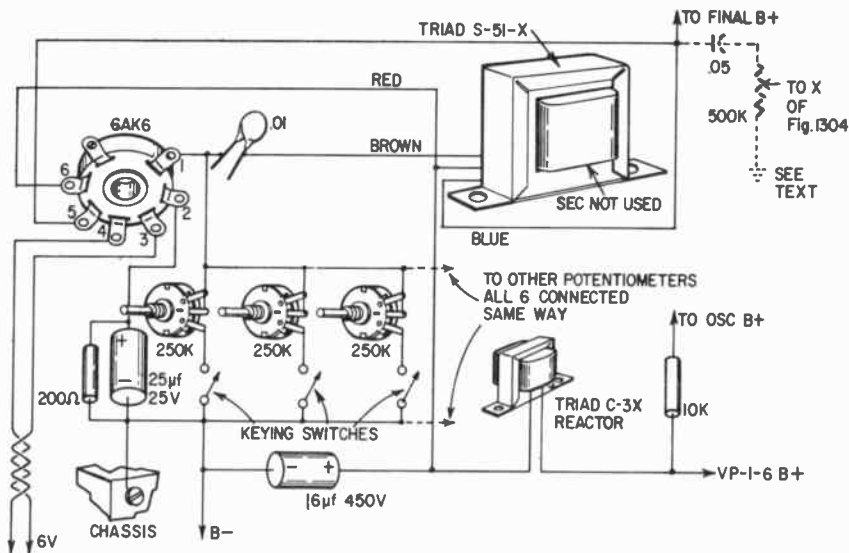


Fig. 1504. Pictorial wiring diagram of changed modulator incorporating six potentiometers in the grid circuit. This replaces the 12AU7 tone circuit of Fig. 1304 on page 155.

the relay is broken and the relay is de-energized. Thus, through this secondary relay's contacts we will be able to control our servo motors and our escapements. The important idea here is that the reed decoder merely enables us to close a control relay. The reed unit itself does not connect directly to our servos.

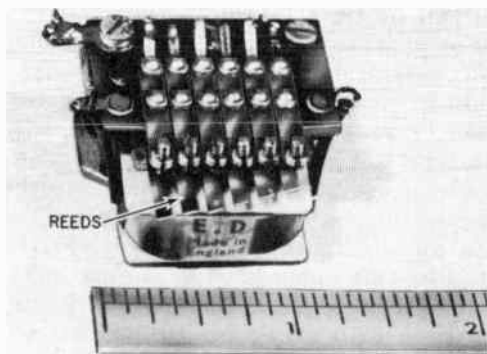


Fig. 1505. Typical six-channel reed decoder. The reeds are made of thin strips of spring steel.

The pitch at which the reed vibrates is controlled by the thickness of the steel and its length and width. If we were to make one of exactly the correct dimensions so that its natural vibrating frequency

was, say, 200 cycles, it would not respond to 220 or 180 cycles, for example. As a matter of fact, some reeds won't respond to frequencies or tones that are only 2 cycles off! So you see how exact our tone frequency must be. Harmonics (or overtones) of the reed frequency may cause a small vibration of a reed other than the one we want

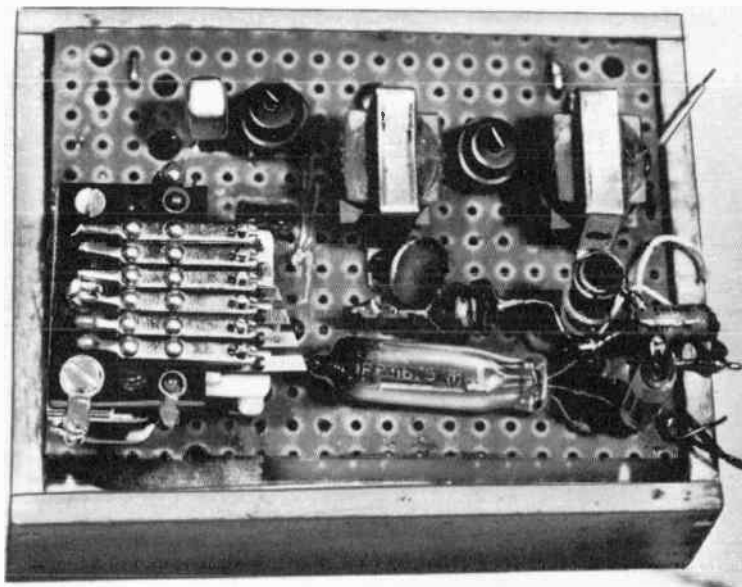


Fig. 1506. Illustration showing parts layout in modified receiver.

to activate, but this vibration is small in amplitude and, with proper adjustment of the fixed contacts, harmonics do not cause trouble.

Let's summarize this discussion about reeds and filters as methods of decoding tones: Both systems require relays. The filters require an additional transistor for each channel, as well as the coil and capacitor composing the filter. The reed system requires no extra transistors, but does need a resistance-capacitance filter for each reed contact. The reed unit does require care and maintenance. You must make sure that the contacts are clean and correctly adjusted, but it is small and light in weight. The filters require no maintenance, but are larger and heavier. The reed tones must be exact while some filter tones may vary as much as 10% of the correct value.

Let us adapt our system to a reed unit and investigate this type of control. The reed unit gives excellent results, and the range is as good as with filters. The adjustment of the tone frequencies is not too critical but, of course, has to be checked before and between flights.

Adding the decoder to the receiver

The changes to the receiver are simple and can be seen in the photo,

Fig. 1506. The modification of the basic receiver (Fig. 413, page 55) to use the reed decoder is shown in the pictorial, Fig. 1507.

1. First, remove the filters (if you have used them) and all connections to the socket of transistor V5. Remove this transistor.
2. Remove transistor V4 from its socket.
3. Solder the free end of the .01- μ f capacitor, (whose other end is connected to pin 3 of V3), to pin 2 of the V4 socket.
4. Solder one end of the 1-megohm $\frac{1}{2}$ -watt resistor to pin 2 of V4, and the other end to the B-minus line.
5. Remove the jumper from pin 1 of V4 and the B-plus line.
6. Solder a lead from one end of the coil of the reed unit to pin 3 of V4.

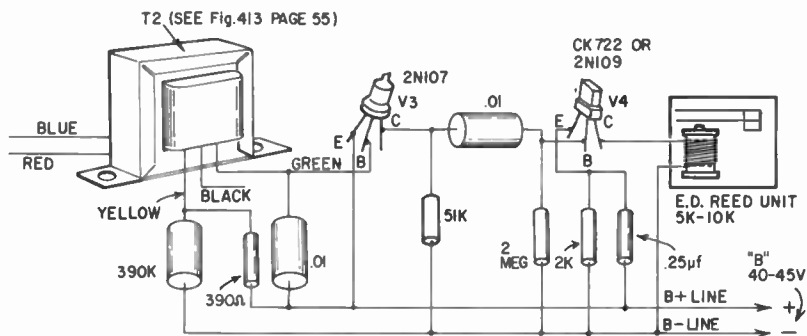


Fig. 1507. Pictorial wiring diagram of modified basic receiver using a reed decoder.

7. Solder the other end of the coil of the reed unit to the B-minus line.
8. Remove the lead to the relay from pin 3 of V5 and remove the two relays (if you have constructed the two-channel unit).

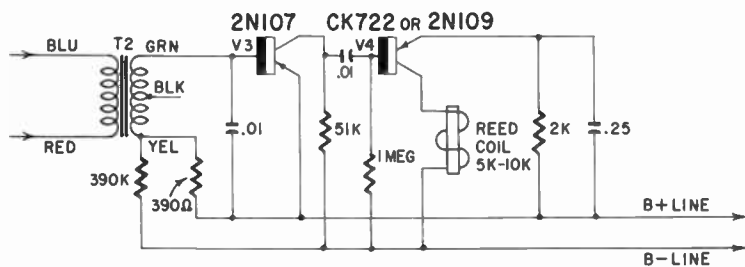


Fig. 1508. Circuit diagram of the modified receiver of Fig. 1507.

9. Make certain that a 0.25- μ f capacitor is connected from pin 1 of V4 to the B-plus line.

10. Solder one end of a 2,000-ohm $\frac{1}{2}$ -watt resistor to pin of 1 of V4 and the other end to the B-plus line.

After you have finished with the modification, check your work against the pictorial in Fig. 1507, and, as a further check and to learn more about circuit diagrams, compare your completed job with the circuit in Fig. 1508.

That's all there is to it, except for connecting the relays to the reed decoder. We suggest right here that you take a small, thin piece of paper and carefully place it between the reed and its fixed contacts. Next, cautiously and lightly lift up on the reed with your fingertip so that some pressure is applied to the paper and then pull the paper back and forth until you have cleaned the contact and the reed. In some cases, when these reed units are stored or, perhaps in their manufacture, particles or grease or spray film collect on the reed and contact; this *must* be removed.

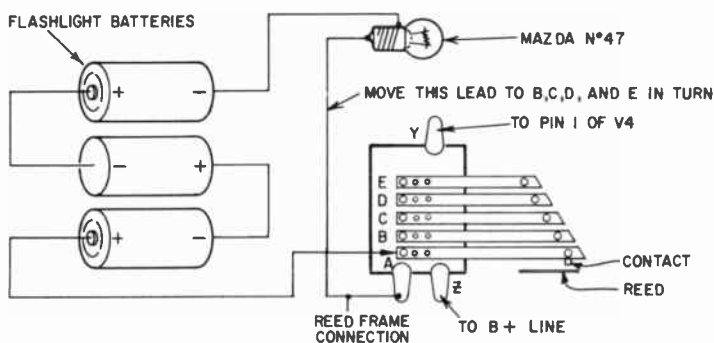


Fig. 1509. Pictorial wiring diagram showing connections for testing the reed decoder.

Testing the reed decoder

We found it advisable to test the reed unit in the following manner: Connect a Mazda No. 47 6-volt pilot light in series with a 4-6-volt battery. Connect one end of the light bulb to the common lug (Fig. 1509) of the reed unit. Now touch the free end of the battery to the first reed contact lug. Raise the reed with your finger till it makes contact with the fixed screw and the light goes on. If it doesn't, clean the contact and the reed at its point of contact until the light does operate. Do this for each fixed contact and reed and you will be certain that the reed will close the circuits as it is supposed to.

After you have done this, you can go one step further. Solder the free end of the light to one of the reed contact lugs and then turn the receiver on. Check to see if the receiver is working properly (after replacing transistors V3 and V4 in their sockets) by clipping the leads of your earphone across the reed coil (points Y, Z in Fig. 1509), one

lead to each side of the coil. A loud hiss, almost a roar, indicates the receiver is functioning properly.

Leave the receiver, removing the earphone, and go to the transmitter and turn it on. The transmitter is placed about 20 feet away and con-

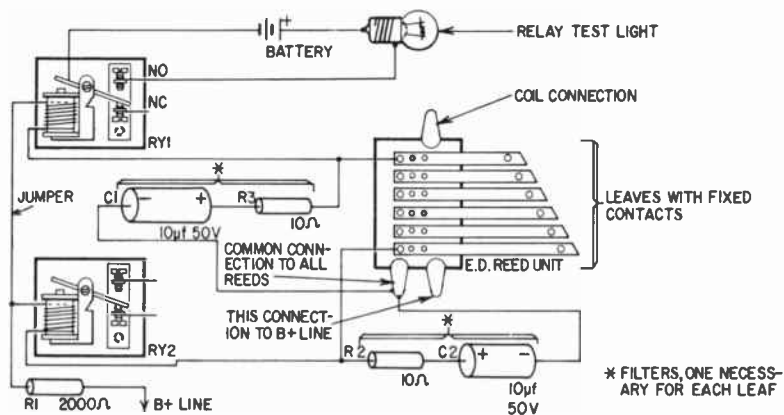


Fig. 1510. Pictorial wiring diagram showing relays connected to the reed unit.

ected to the antenna. After the antenna light glows, indicating that the transmitter is functioning properly, close the keying switch to one of the potentiometers and then slowly rotate it from its maximum toward its minimum value. Move it *very slowly*, until you come to a position where the light connected to the reed decoder glows. It probably will not burn brightly; but it will indicate. Adjust the potentiometer for the maximum brightness of this light. This will give you the correct setting for that particular reed. Adjust the other potentiometers for the other reeds in this same manner.

With the transmitter still sending out a tone, go to the receiver and listen. The reed vibration is plainly audible, although you cannot see it. Once you have completed this step, you know that the transmitter, the receiver and the reed unit are all functioning properly; thus you can turn everything off to add the control relays. Fig. 1510 shows how these are connected to the reed unit.

Connecting the relays to the reed unit

We used AR21 relays, but other equivalent types will work satisfactorily also. Following Fig. 1510 connect two of them to the reed decoder as follows:

1. Solder a lead from one relay-coil lug (RY2) to the longest reed contact-lug.
2. Solder a lead from the second relay-coil lug (RY1) to the shortest reed-contact lug.

3. Solder a jumper between the two remaining relay-coil lugs and continue this connection to one end of a 2,000-ohm resistor (R1).
4. Solder the other end of this resistor to the B-plus line.
5. Solder one end of a short length of wire to the same reed-coil lug that is connected to the B-minus line.
6. Solder the free end of this wire to the common reed lug.
7. Solder the minus end of the two electrolytic capacitors (C1 and

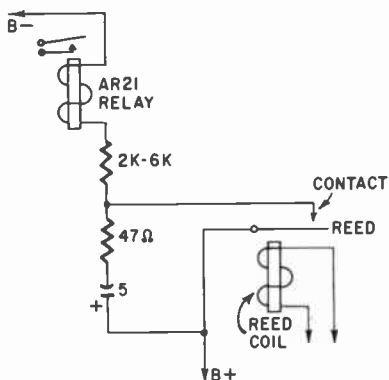


Fig. 1511. A resistor and capacitor are connected in series and are then wired across the reed and reed-contact points.

C2) together. Then solder this junction to the same reed-coil lug that is connected to the B-minus line.

8. Solder the plus lead of one electrolytic capacitor (C2) to one end of a 10-ohm resistor (R2). Solder the other end of this resistor to the same long reed contact that RY2 is connected to.

9. Solder the plus end of the C1 to one end of a 10-ohm resistor (R3). Solder the other end of the resistor to the short reed contact that the second relay is connected to.

10. The capacitors hold the relay closed when the reed, by vibrating, opens the circuit to the battery.

Fig. 1511 shows an alternate method of connecting a capacitor and resistors across the reed and reed-contact points. This method is equally common and may be used if the first method proves unsatisfactory.

Now you must test again. Connect the 6-volt light and its battery to the relay armature and normally open contact as shown in Fig. 1510. With the tip of your finger, close the reed to its fixed contact. If the relay does not operate, adjust its spring tension until it does. It should be adjusted so that every time you move the reed up to make contact, the relay closes. Be careful not to use too much pressure on the reed in this adjustment. Make certain that you do not get the relay tension so light that the armature fails to break the circuit when you release the reed.

When the relay tests out satisfactorily, you can again operate the

reed unit with the transmitter. Turn the receiver on, and send signals as before. This time, when you get the proper adjustment of the tone-control potentiometer, the relay will close, causing the light to burn *brightly*. There will be no flickering if the tone is adjusted correctly. This is the condition we want. Now key the tone circuit and the light will come on and go off as with previous types of receiver systems. It may react a little more slowly, but that is really not a problem, since we normally use reed decoder receivers to operate servos in the models.

Now test *each* reed with its own individual relay in the same manner and adjust each potentiometer. Mark the final settings of the potentiometers so you have a handy reference position to return to for adjustments in the field. The settings may vary slightly due to changes in the B-plus voltage of the transmitter, but they will not change much.

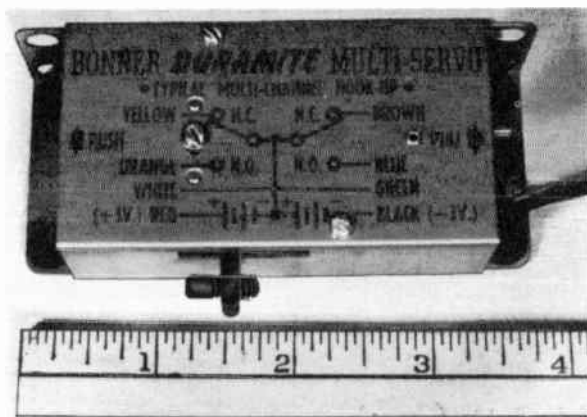
As always, testing is not finished until you have completed a range test. This is done in exactly the same manner as we described previously. Have another person send the commands as you walk away from the transmitter. Make sure the receiver is tuned exactly to the transmitter and that the tones are correct; then, operate the receiver at a distance.

A few final words: First, remember that the reed decoder depends on the vibration of the reed to effect operation. Make certain, when installing the equipment in a model — especially an airplane — that it is well cushioned against vibration from the engine. Engine vibration could cause the reeds to activate the control circuits if you are not careful. If you go into the field to operate, be sure to check the tone frequencies by sending commands before every flight. If the model does not respond to a particular signal, adjust that particular tone channel slightly (be careful and don't move the potentiometer too much) and you can often regain control while the model is in operation.

The percentage of modulation in the system described is low. Note that the transmitter antenna light does not increase in brightness in the positive manner it did with the filter system.

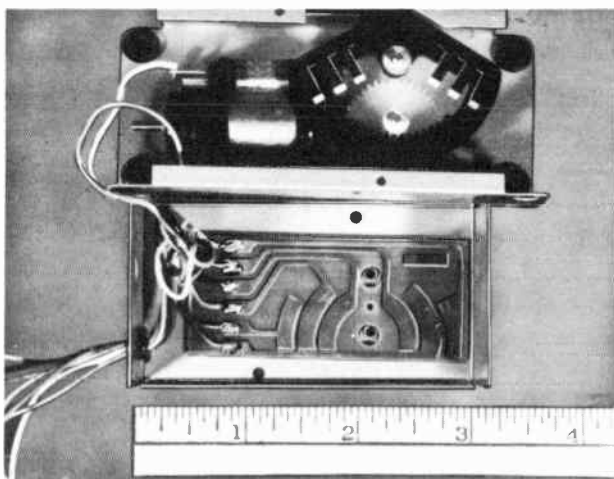
We can change the modulator slightly to accomplish this. Instead of connecting the tone oscillator solely to the final B plus as shown in Fig. 1504, note the dotted connection. If we connect this point through a .05- μ f capacitor and a 500,000-ohm potentiometer as shown, we can couple the output of this oscillator directly to the grid (point X) as shown in Fig. 1304. The .005- μ f capacitor must be removed.

Now we have added an amplifier to our oscillator and, with the variable 500,000-ohm potentiometer, we can adjust the power of the tone to the final stage of the transmitter. Do this and adjust the potentiometer controlling the gain till a *positive increase* in brightness of the antenna light is obtained when a tone is transmitted. The



a

Fig. 1512. (a) Top view of Bonner self-neutralizing servo. (b) Bottom view of Bonner self-neutralizing servo.



b

operation of the whole system will become much more reliable and the range of operation will be increased.

Note that the final B-plus lead is now connected to the second transformer in the same way as shown in Fig. 1304.

Using multi-channel equipment

Having built multi-channel operation into our receiver and transmitter, what do we do with it? Let's examine some of the systems used in model aircraft to see how these channels are used.

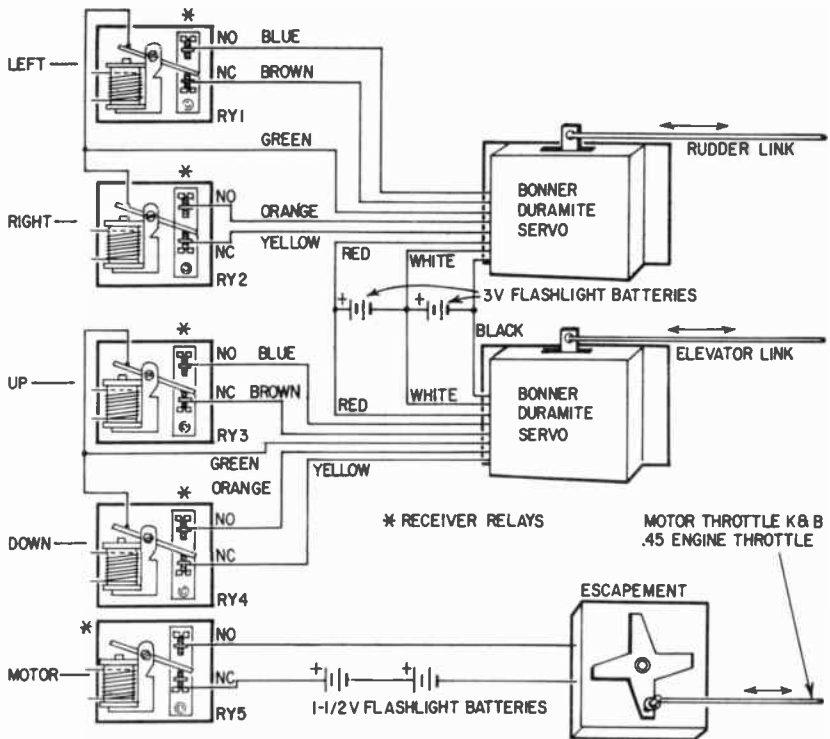


Fig. 1513. Pictorial wiring diagram showing multi-channel operational system for controlling aircraft, rudder, elevator and motor.

If we have at least five channels, we can control the rudder, elevator and motor of a model aircraft, using the self-neutralizing Bonner servo (Fig. 1512-a,b). If we connect the system as shown in Fig. 1513 the operation will be as follows:

Left is obtained by depressing a keying switch marked left. If it is held down, the model makes a sharp left turn and, if the rudder moves far enough, the model will go into a spiral dive. Release this button and the model straightens out. If you have held it long enough to spiral-dive the model, the airplane will often loop as it comes out of the dive.

If we keep the left switch, the model makes a gentle turn. Fast beeping produces a sharper turn; slow beeping a very slow gradual turn, so we have a type of proportional control.

To steer right, we change buttons. We do not have to remember any sequence, nor do we have to depend on elaborate decoders. We simply push the correct button for right. This also applies to up or down. We cannot send these commands simultaneously with this system, however.

Motor control becomes a simple matter of depressing the motor control switch, once for high, a second time for low, a third time for

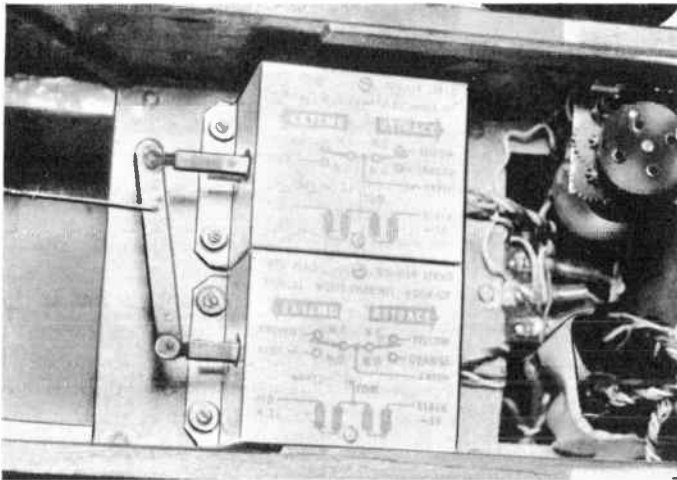
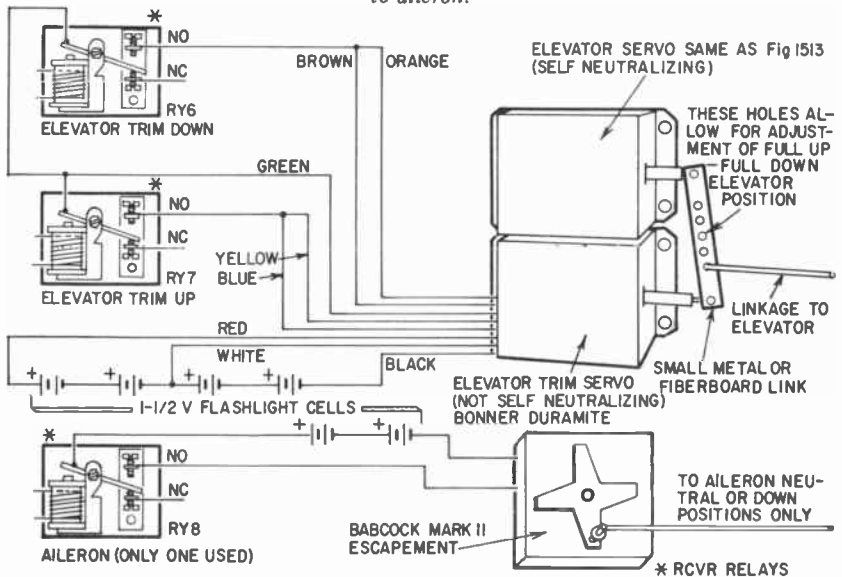


Fig. 1514. Two servos (one of which is self-neutralizing) control elevator trim in an eight-channel system.

high, etc. Of course, we can fly the model around until we get it high overhead and coming straight across the field and then dive it, using down elevator. Send up-elevator for the loop, down-elevator

Fig. 1515. Pictorial diagram showing wiring details of elevator servos and connections to aileron.



again when it reaches the top of the loop, and we will be flying inverted. It will take lots of experimentation before you have mastered all the things you can do with this type of system. The commands are sent faster, and there is much pleasure in flying the model like a "real one".

If we have eight channels (desired by most modelers now), we can control the *trim* of the elevator in addition to having full up and full down. This is accomplished by using two servos; one is a self-neutralizing type, the other is not (Fig. 1514). The linkage between the two makes it possible to trim the elevator for windy flying conditions, etc. The photograph shows an installation in which the servos are identical, but the self-neutralizing connection of one has been omitted. If this servo arm is moved in or out, it moves the linkage to the elevator a small amount because of the distance to the linkage pivot point. The shaft remains fixed after trim is obtained and, when we send commands for up or down, the servo shaft nearest the linkage pivot point moves in or out, moving the linkage a long distance for the large elevator deflection required. "No command" results in this servo returning to its self-neutralizing position, which is the trimmed position of the elevator. Fig. 1515 gives wiring details for this type system for the elevator servos and shows how to connect the aileron channel.

The eighth channel can be used to operate an escapement or servo for aileron control, while the seventh controls the motor. It doesn't take long to use up eight channels in aircraft control.

If two six-reed units are operated with their coils connected in series or parallel, you will leave more channels for brakes and flaps and bomb release. We won't investigate this possibility, leaving it to those of you who are experimentally inclined and want to continue on your own.

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