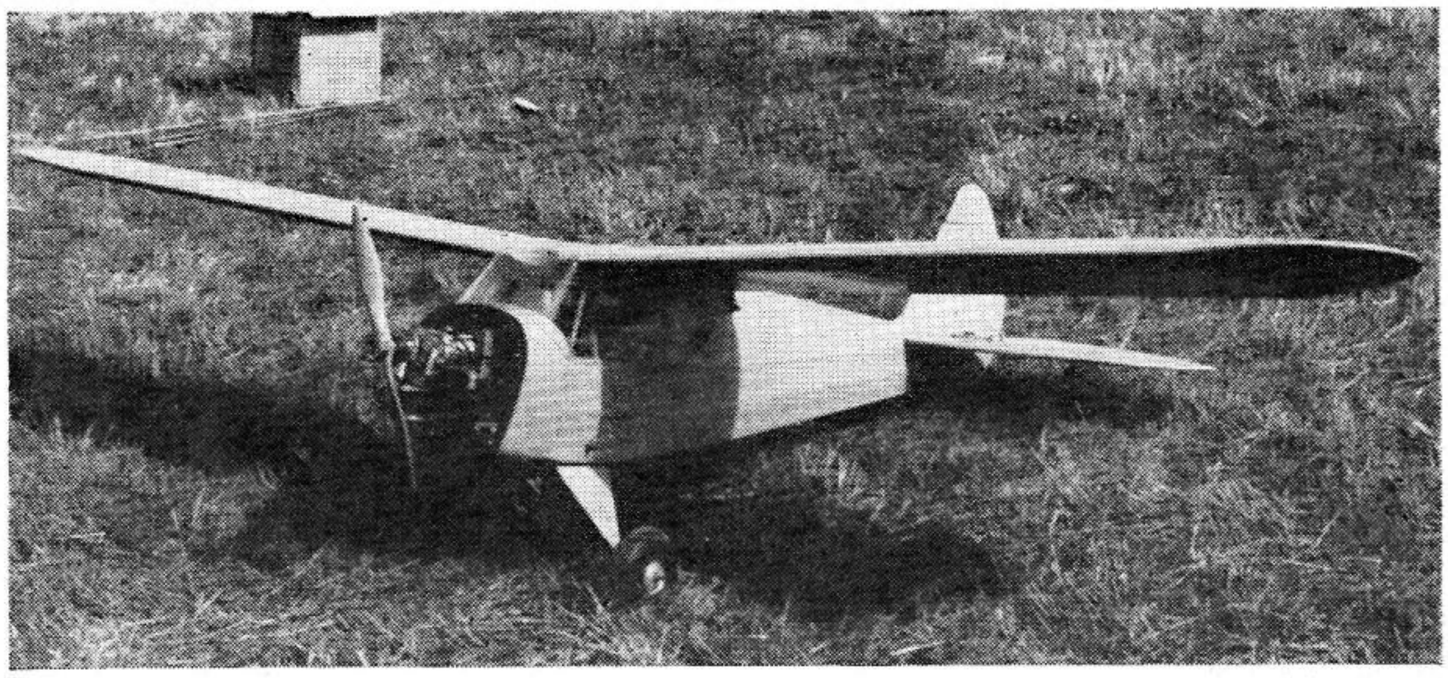
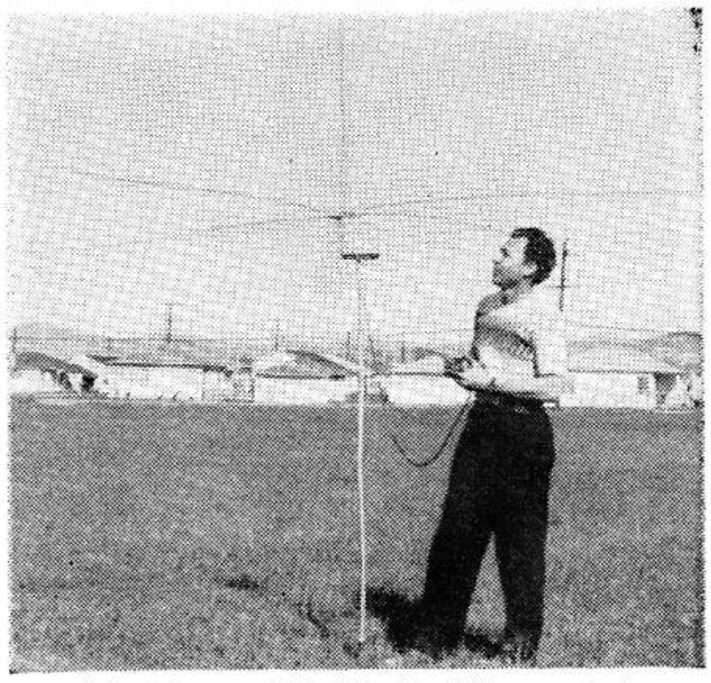
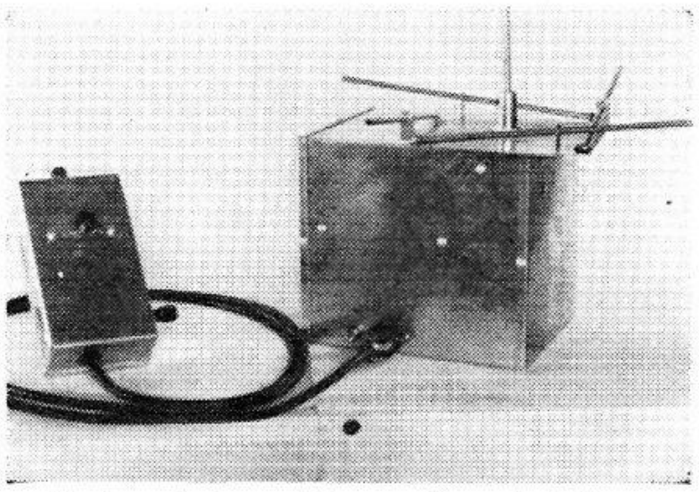


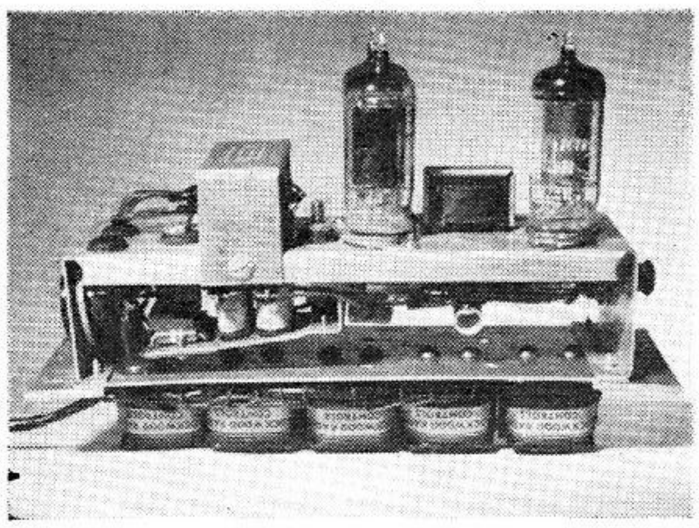
7′ Piper Cruiser, built by the author, has 3-channel tone control described herewith



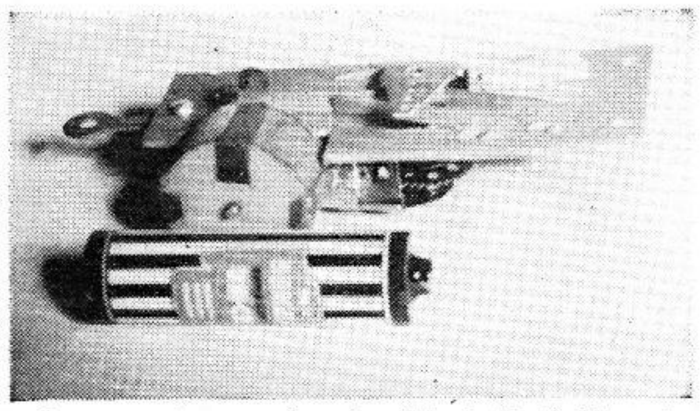
John Terry, of Oakland, at the controls



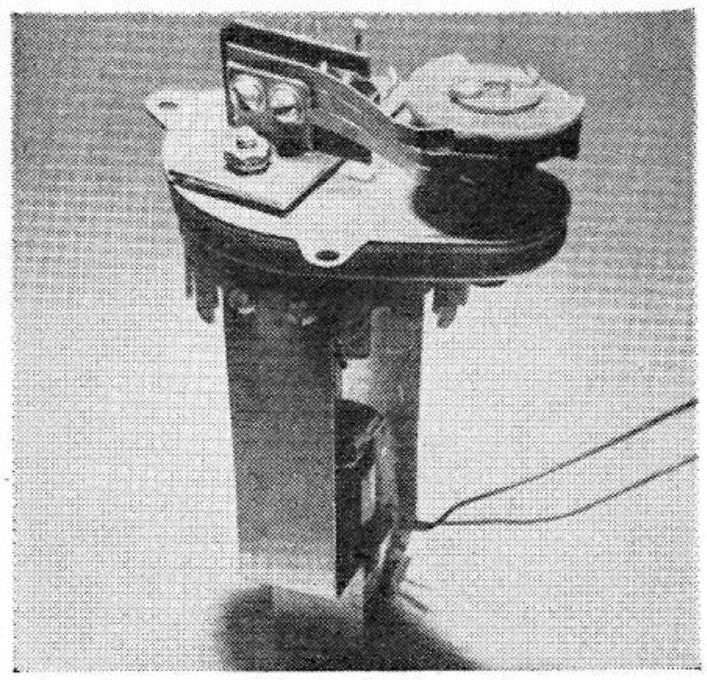
5-channel transmitter and control box. Stubs on case carry "ground-plane" rods



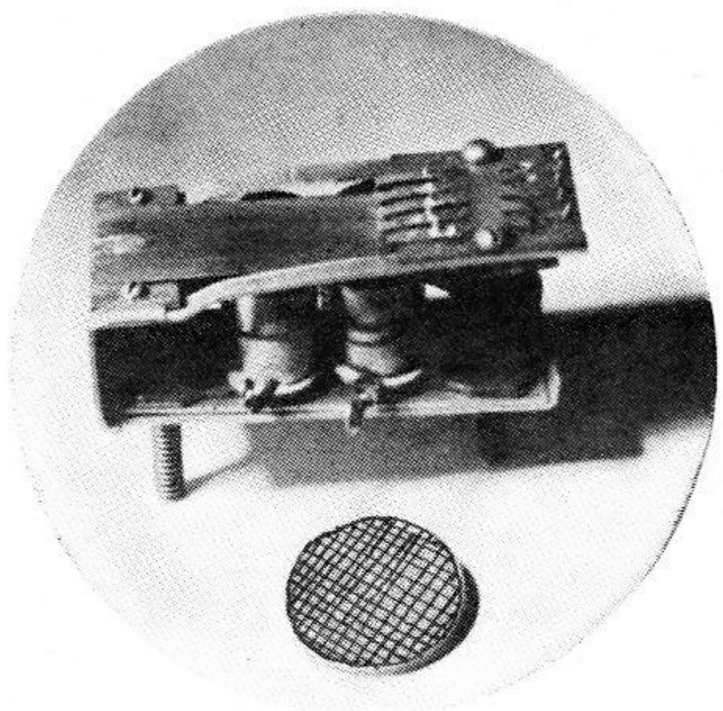
5-channel receiver with sensitive relays in line along the bottom



Servo motor equipped with both limit and neutral return switches; weight is 1½ oz.



Synchronator picks audio tones in sequence, enables 5 simultaneous operations, if desired



Heart of the system is this reed selector shown in comparison with 1-cent piece

Audio Tone R. C.

By E. L. ROCKWOOD

Adaptable to single or multi-surface control, the system described is a real advance

IN all the years that have passed since radio control was first introduced to the field of model airplanes, despite all the material published under the heading of "Radio Control," there has been actually little if any progress in the design of the factor which, in the first place, makes remote operation possible—the radio system itself. Certainly little has been published in the popular magazines which shows more than slight modifications of the one-tube idea, during the past ten years or so; at least, nothing that could be squeezed into a model plane. A search of the Patent Office discloses a similar condition.

Desiring a very reliable set of "radio ears" that would catch the slightest whisper of impulse from the controller's hand, yet would not let him down when most needed, the author has spent a number of years investigating various angles of the problem; the answer arrived at has crystallized for the present at least, in the form to be described here.

Early in the investigation it became desirable to use the principle of a carrier wave from the ground, using tone modulation; the major drawback to such equipment seemed in the direction of excessive weight. The army uses tone modulation in their 12′ ships employed as aircraft targets, but the equipment weighs much more than the total flying weight of a model plane. Tone selection is made by heavy tuned circuits, requiring in addition an extra tube per tone, to operate the relay putting into action the particular function selected. That means more battery to be carried, thus still more weight.

At first it seemed that reducing the weight of the tone-selecting "filters," and working along the army lines would be the tack to take. This line of action afforded some relief. To those technically inclined, it may be pointed out that the higher in frequency the tones used, the lighter in weight can be the tuned circuits for their selection. There is, however, a limit to the modulation frequencies which may be used with super-regenerative receivers. It was desirable to stick to use of the latter for several reasons: the sensitivity that may be packed into small, light-weight equipment with low battery drain, the simplicity of the circuit, and the ability of such receivers to ignore interference from the spark ignition circuits of the gas engine. The technical limitation of these receivers is that detection of tones is limited to frequencies less than one-tenth of the "interruption-frequency" of the super-regenerative circuit. Since the latter is, in receivers suitable for this use, around 20,000 cycles per sec., the highest tone to be satisfactorily used is 2000 cycles. A "filter," or tone-selecting circuit, for that frequency is still too heavy, and too many tubes, moreover, must be used for the filter method of tone selection. While the tubes themselves add little weight, they must have batteries in order to function; there is the rub—the more tubes, the more weight that must be carried in the form of batteries.

The radio part of the set was finally boiled down to an arrangement using a maximum of three miniature tubes, operating from a 4-1/2 oz. B battery, with three or four pen-cells to light the fila-

ments. The set was so sensitive to tones that when used for voice communication, it would fill a room with sound from a portable transmitter using considerably less than 1 W of power, at a distance of several miles. In fact, at one time, loud-speaker volume was obtained from signals originating on the East Coast of the United States, with the receiver located here in California; the antenna used was short enough to be fitted from cabin-to-tail of a 6′ span model plane.

This was all very encouraging but it didn't constitute radio remote control. Actually, during development of the receiver itself, work was carried on to evolve a method of putting to use the excellent response of the receiver to operate relays from the tones which were so well received. Operation of relays from tones, by having the tones operate tuned reeds which would close low-current relay circuits, was the method finally selected. It is fundamentally not an entirely new idea, certainly, but one which has never been thoroughly exploited for the purpose. The principle is that a small length of steel has a certain speed at which it will naturally vibrate when secured at one end with the rest of it free. If acted upon by an electro-magnet near the free end, with the current through the coils of the magnet varying in strength at a speed corresponding to the "natural period" of the piece of steel or "reed," the latter will vibrate vigorously. If the current through the coils be varied at any other speed, the reed will hardly vibrate at all. The natural period of the reed is determined by its length, width and thickness, as well as the material of which it is made. Steel was chosen for its stiffness and its ability to be affected by a magnetic force.

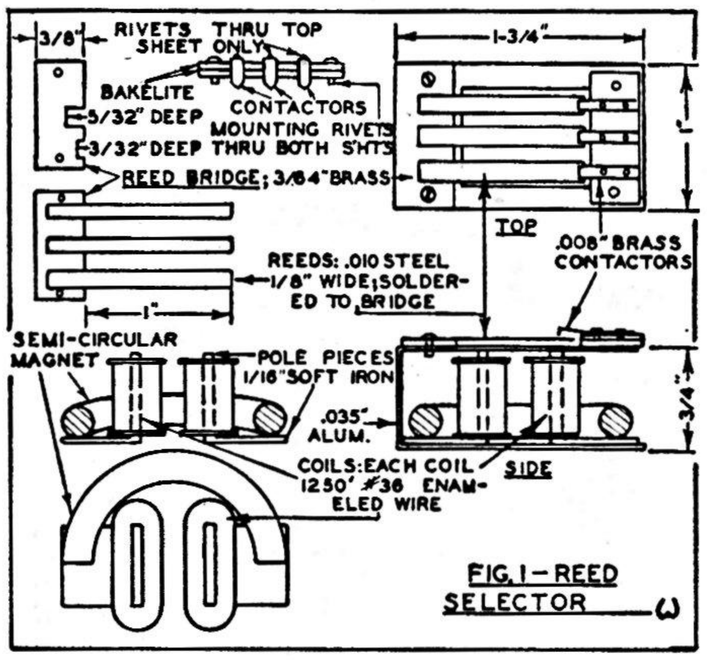
Fig. 1 shows the arrangement whereby a pair of coils connected to the receiver, like a loud-speaker, cause the reeds to vibrate from the receiver's output. The three reeds shown have different free lengths, being secured at one end to a "bridge." One certain tone, and only one, will cause one of the reeds to vibrate sufficiently to touch the contactor located above it. Each of the reeds may be caused to vibrate selectively at will, by sending into the receiver the tone which corresponds to its natural period. Vibration of the reed sufficient to cause it to touch its individual contactor will rapidly open and close a circuit through the reed and contactor, and may be made to hold a sensitive relay closed as long as the vibration continues. The vibrating contact, however, will cause a chatter of the relay, and its contacts will not close tightly. The arrangement of condenser and resistor shown in Fig. 2, called the "reed filter" smooths out the chatter, and the relay closes firmly whenever the reed hits its contactor during vibration.

Only a small current may be controlled by such a reed and contactor simple enough to be compact and light in weight for our purposes. It is necessary to use the current passed by this arrangement to open and close a sensitive relay such as is used in all radio controls, to actually work the motor or escapement circuits which will move the rudder or other control surface of the airplane. One relay is connected to each reed-contactor circuit, and each relay may therefore be individually selected at will by the tone which is sent out from the ground transmitter. Each tone will have the effect of controlling a separate control function of the plane. See Fig. 2.

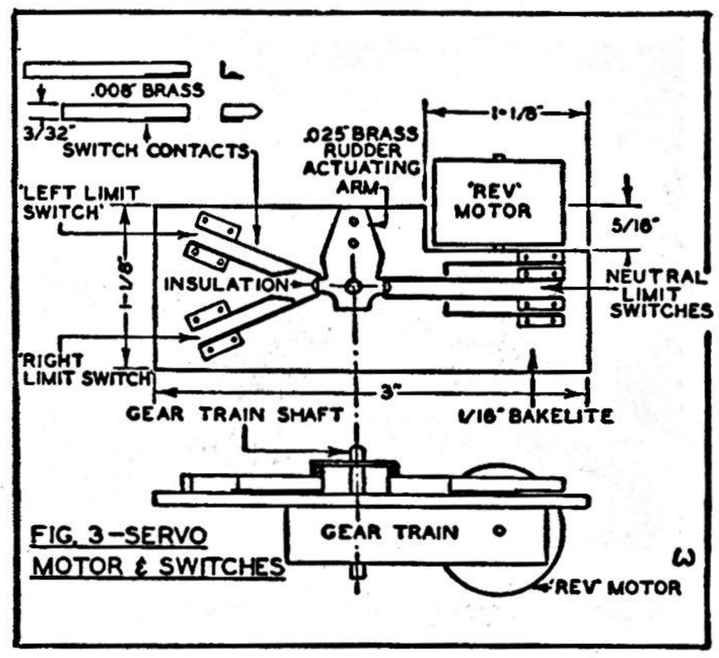
Fig. 2 shows the servo circuit used for rudder. When the "left relay" is pulled up by operation of the reed connected to it, a circuit is closed through the "left servo battery," causing the servo motor to rotate in a direction to move the rudder to the left. The motor speed is reduced through a gear-train with a ratio of about 300-to-one and an arm fastened to the shaft of the lowest-speed gear is connected to the rudder, as the operating rod is connected in U-control, from the bellcrank to the elevator. A satisfactorily light-weight motor for this purpose is the *Rev* motor, which is very light-weight and small and uses about the amount of current consumed by a flash-light bulb. A convenient gear-train, light in weight and inexpensive may be adapted from the works of a small spring-driven toy of which there are many to be found in toy and novelty stores. The spring is removed, and an operating arm attached to the end of that shaft. The wheels of the toy (an automobile, usually) are removed, and the *Rev* motor connected to that shaft. This may be done by a pulley and small rubber band drive or by substituting the shaft of the *Rev* motor for the wheel axle. The resulting actuator may be held down to a total weight of around 1-1/2 to 2 oz. including the motor.

When the motor has driven the control arm to the desired distance to the left, the limit switch stops the motor. As long

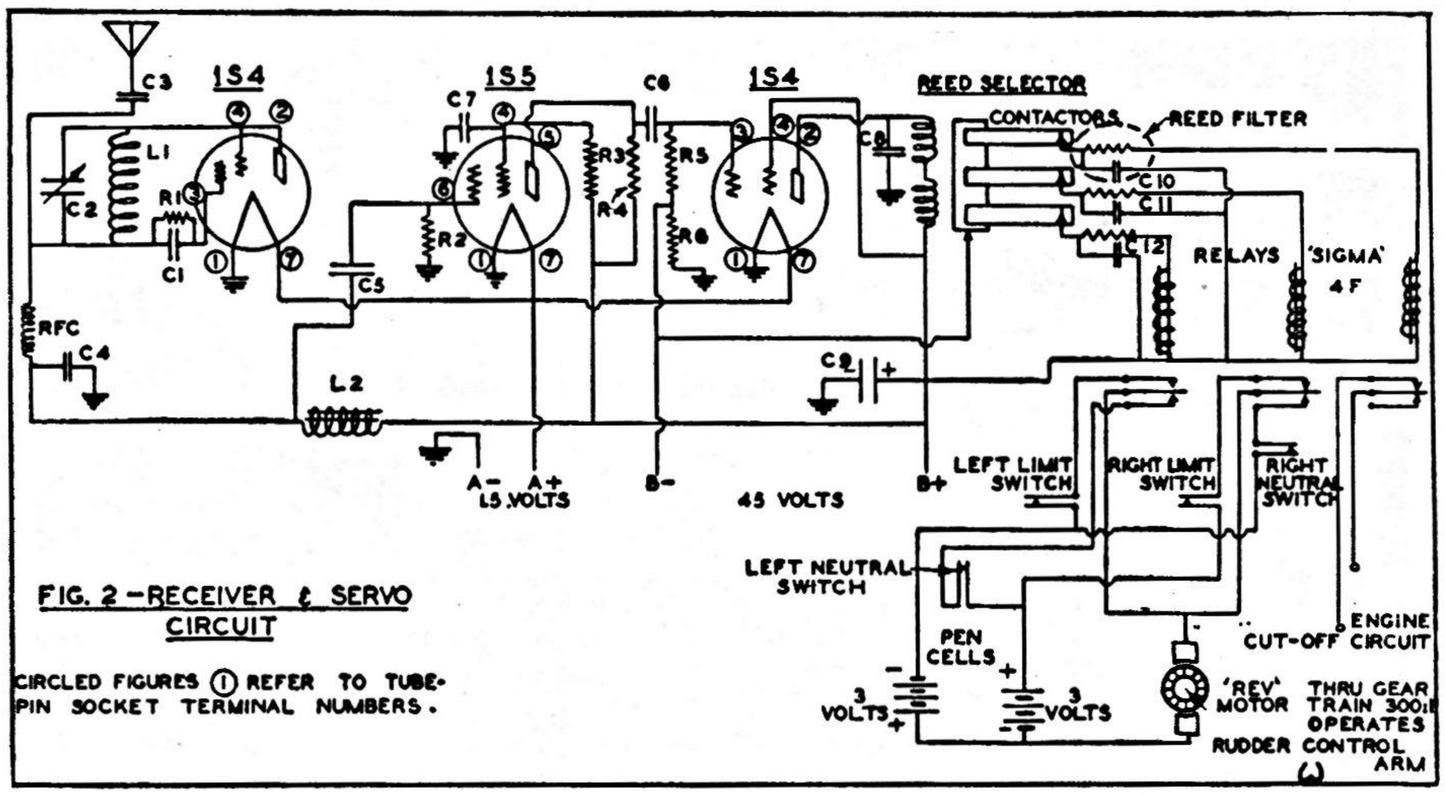
(*Turn to page* 54)



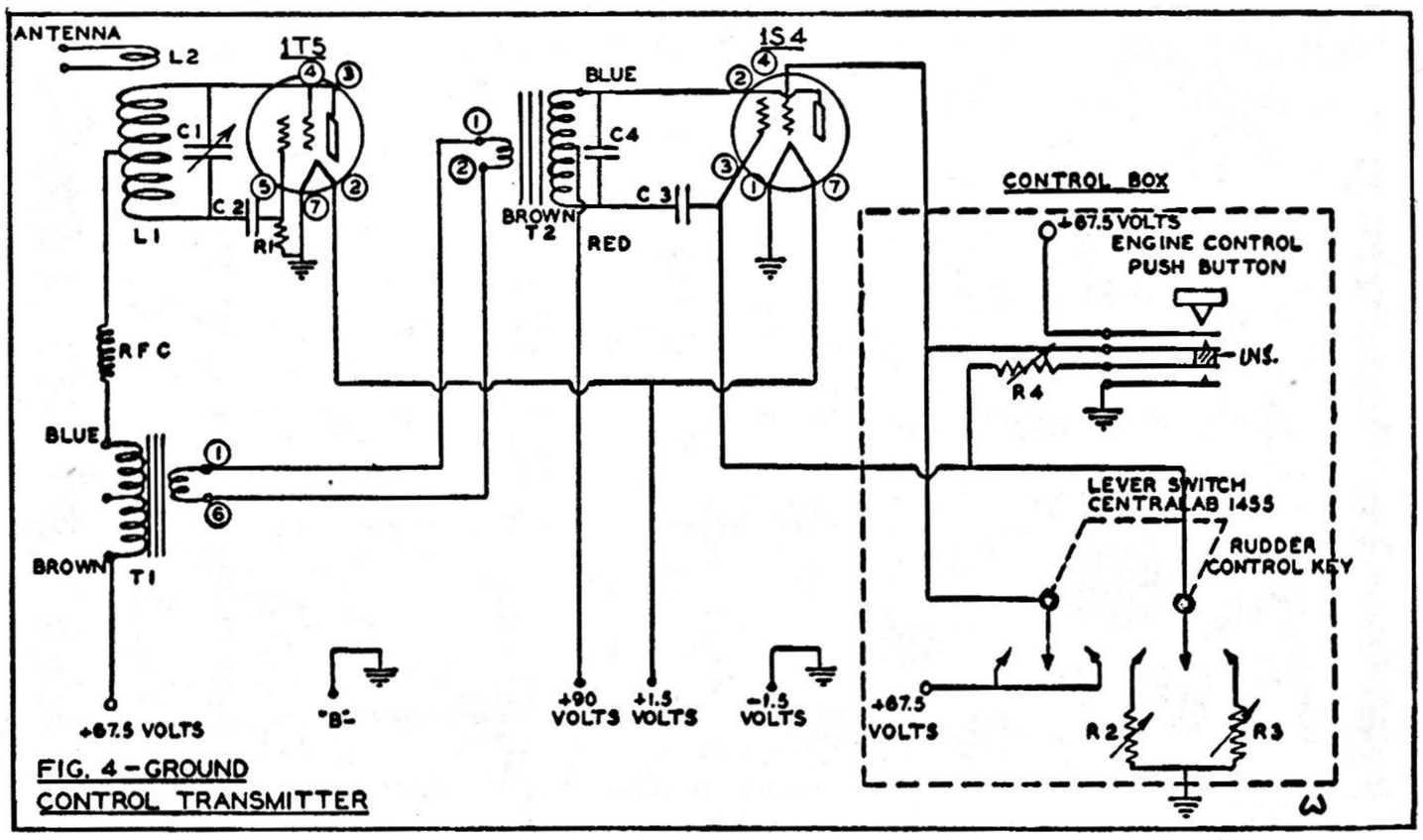
Three-channel reed selector. Notches in bridge produce different reed lengths



This servo unit has both neutral limit and right-left limit switches



Complete receiver diagram. A and B batteries for the receiver are not shown here



The transmitter is very simple. This circuit omits the *Synchronator*

Audio Tone R.C.

(*Continued from page* 15)

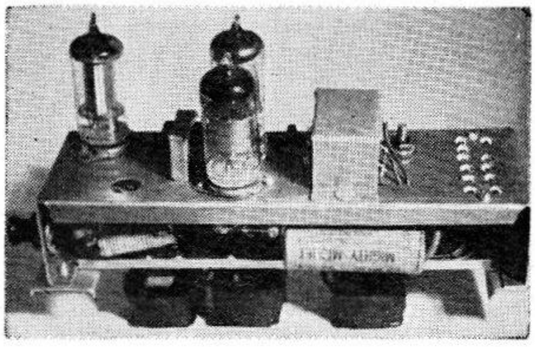
as the relay is held closed its signal contact will hold left rudder. When the tone is removed at the ground control, the reed stops vibrating, the relay drops to its back-contact, the opposite polarity battery is connected to the motor, which then runs back, moving the control arm to neutralize the rudder. When neutral is reached, the neutral limit switch opens the motor circuit and the rudder stops in neutral. Sounds complicated, but its operation is much more simple than the explanation. Of course, if another tone is sent from the ground, another relay operates and the rudder operates in the opposite direction in the same manner—but let's not go over *that* again!

The operation of this system is as follows: the transmitter or ground control is equipped to send out a modulated wave, which is similar to the signal sent out from broadcasting stations, but instead of containing voice or music, the wave contains only one particular pitch of tone at a time. The control equipment at the transmitter can select what pitch is desired, by means of switches in the operator's hand. Each tone will control a function of the airplane, and only that particular tone will do it. Thus, many forms of interference to the radio wave will have no bad effect on the plane's controls.

The fundamental idea employed for actuating the receiver may be applied to any of the various control systems which have been advanced in the form of "gadgets," and due to its ability to handle more than one control signal from the ground, will make possible the expansion of the utility of such arrangements. The improvement in the art offered by the equipment under discussion is in sensitivity and reliability. The receiver is so sensitive that it may be reliably operated by a transmitter only 5-1/2" x 6" x 6-1/2" in size, containing its own batteries, and to a distance of several miles if there are no intervening objects. This is fortunately the condition under which we operate when controlling model planes. Having more than one channel or selectable circuit makes possible the selection at will of the circuit desired, without going through a sequence of signals, and without having to operate controls one after the other in a certain order. For instance, right rudder may be repeated over and over with instant reaction, without proceeding through "right, neutral, left, neutral, right" and so on, every time it is desired to repeat a control. No matter what the last control was, any control may be executed at any time. All of these features have been brought out in a Patent Application now pending.

Fundamentally, a multi-channel system like this differs from the same number of channels of separate transmitters and receivers in that it is not practical to cause all of the various controls to operate simultaneously, unless a special arrangement is used. Sending a composite tone from the transmitter will operate the various reeds all right, but sending more than one tone at a time from the transmitter will reduce the loudness of each tone as it affects the receiver; the effective range of the equipment is thus reduced; more complicated modulating and mixing equipment is needed in the transmitter. Fig. 4 shows the simple transmitter and tone-generating circuit which is used. The key switch sets up conditions which determine what tone will be generated.

A more satisfactory way to accomplish simultaneous operation of controls if desired, is to equip the transmitter with what is called a *Synchronator,* which interrupts the tone controls from the control box and applies each tone to the transmitter in regular sequence, and in rapid succession, as they may be selected at the control box keys by the operator. This requires introduction of a slight time delay on each relay in the receiver to make it hold up solidly with the rapidly interrupted signal, and any or all of the relays may be operated at once, with full tone volume; thus full receiver sensitivity is had on each channel. The time delay introduced need not be enough to make it noticeable in controlling.



Three-channel receiver used in 6' *Buzzard Bombshell*. Size is 1⅞" x 5½"; weight 11¾ oz. Circuit is shown in Fig. 2.

A single-channel version of the receiver has been developed for the purpose of keeping weight down, as for use with such controls as the Owbridge-Rhodes *Rudevator.* Weighing about 6 oz., this receiver is less than 4" long and 2" wide, and operates with 4-1/2 oz. of "B" battery, with 3 to 4 pen cells for lighting the filaments. The tubes are good for about 1000 hr.; antenna adjustment of the receivers is not critical as to length, and there is no adjustment for sensitivity. All the receivers discussed will operate without attention or adjustment while the batteries hold out. As long as the signal received is above the minimum necessary to operate the receiver at all, the relays receive full current to operate them, no matter what the signal strength. The actual value of current available to operate the relays does not depend on the signal strength, and may be preadjusted to any value desired up to about 4 ma., by changing the value of the resistor in the reed filter shown in Fig. 2.

Considerable field experience has been rolled up, using both the single-channel and multi-channel systems; results have exceeded all expectations. Equipment given a slight touch-up of tuning adjustment at the beginning of a day has operated all day without further attention, and has at times been used for several days without readjustment. Control of a model has never been lost for even a moment due to any failure of a signal from the ground to reach the plane in the air, or even after landing again on the ground. At times a plane flying low, over the brow of a hill, has been controlled so as to make it reappear in sight. No more than 3 W. of power has ever been used in any transmitter, and less than 1 W. is normally used.

This equipment, the result of over ten years' development on the part of the author, is now available commercially and it is hoped will give an impetus to more wide-spread activity in the radio control field, which holds a great deal of enjoyment in store for all model plane fliers, whether interested merely in keeping a cherished model from getting away out of sight or in doing aerobatics and pylon-racing.

Circuit Values

Figure 2

L1—16 turns # 24 enam. wire on ¼" form (52 mc.)
L2—UTC type SO-5 subminiature audio choke
C1—.0001 mfd. Ceramicon
C2—3-30 mfd. trimmer
C3—5 micro-mfd. Ceramicon
C4—C5—.01 mfd. tubular
C6—.0005 mfd.
C7—.02 mfd. tubular
C8—.002 mfd.
C9—25 mfd.—30 volt electrolytic
C10—C11—C12—¼ mfd. paper
R1—1 Meg. ¼ watt
R2—5 Meg. ¼ watt
R3—3 Meg. ¼ watt
R4—1 Meg. ¼ watt
R5—2 Meg. ¼ watt
R6—1000 ohms ½ watt
Reed filter resistors—15,000 ohms
Relays—8,000 ohms

Figure 4

C1—20 mmfd. air trimmer condenser
C2—.0001 mfd. mica
C3—.01 tubular
C4—.03 tubular
T1—T2—Universal Output transformer—Merit A1300 or equivalent
R1—25,000 ohms ½ watt
R2—R3—R4—½ Megohm volume controls
L1—10 turns # 14 ½" I.D. spaced (for 52 mc.)
L2—1 turn # 14 ½" inside diameter
RFC—2.5 milhenry pie-wound universal choke