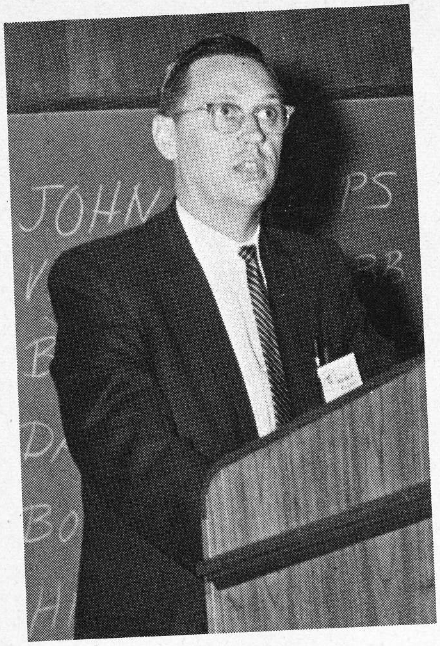
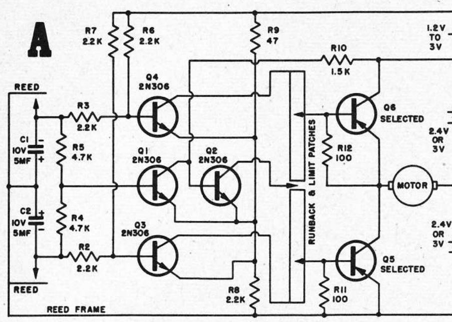
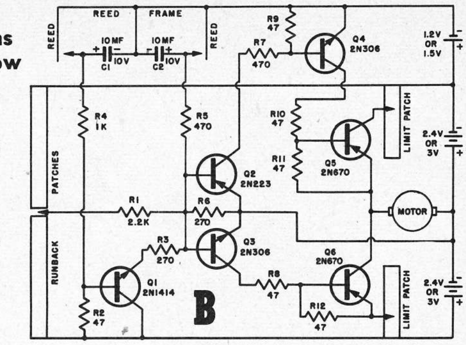
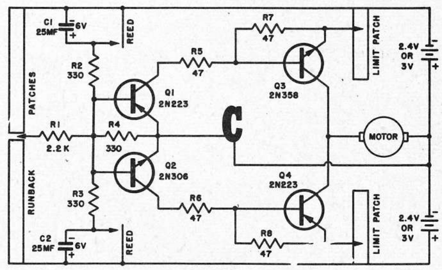
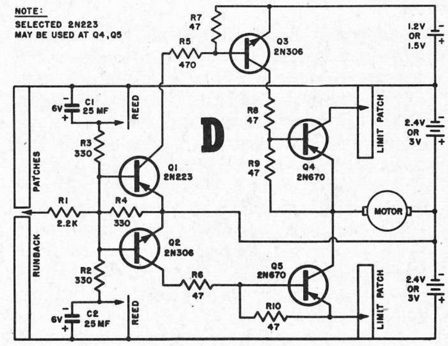


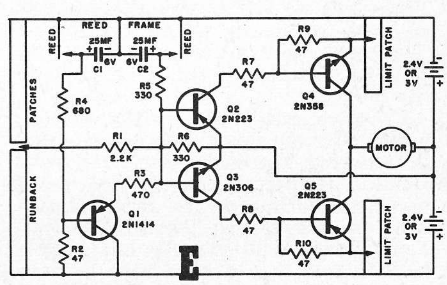
Bob Elliott, left, speaking before the 1961 DC/RC Symposium at Johns Hopkins Applied Physics Laboratories. Fig. A below is circuit for Bonner Transmite servo.











"RELAYLESS" Radio Control Circuits

by Robert Elliott

■ In the past few years, such modelers as Al Doig, Louis Scheel, Ken Oliver, and others, have presented systems which replaced the action of relays by transistor amplifiers. While all of these worked, they usually required a great deal of modification of existing equipment or some compromise in performance.

The circuits here represent the author's approach to relayless circuits for reed receivers. Some of this work has been in cooperation with Howard Bonner and is represented by the Transmite servo produced by Bonner Specialties.

Figure A, the Transmite servo circuit, and Fig. B were the only ones actually optimized. The others are to show the history of particular circuits. They may also be a stimulus to others working in this comparatively new field.

Relayless servo circuits for reed type receivers will be presented first, then some receiver conversions.

What advantages does relayless operation offer? Is there a savings in weight? How much more does it cost than the standard relay system? Experience has shown that the weight savings ranges from 4 ounces in an Orbit 8-channel outfit to about 8 in a Bramco 10-channel, with the added servo weight considered. While most weight reduction comes from the elimination of relays, some results from the smaller, simpler receiver case and maybe a smaller B battery. Ten-channel planes designed for relayless equipment weigh 5¼ to 5¾ pounds, as compared with 6¾ to 8 for Astro Hog planes equipped with 8-channel reed systems.

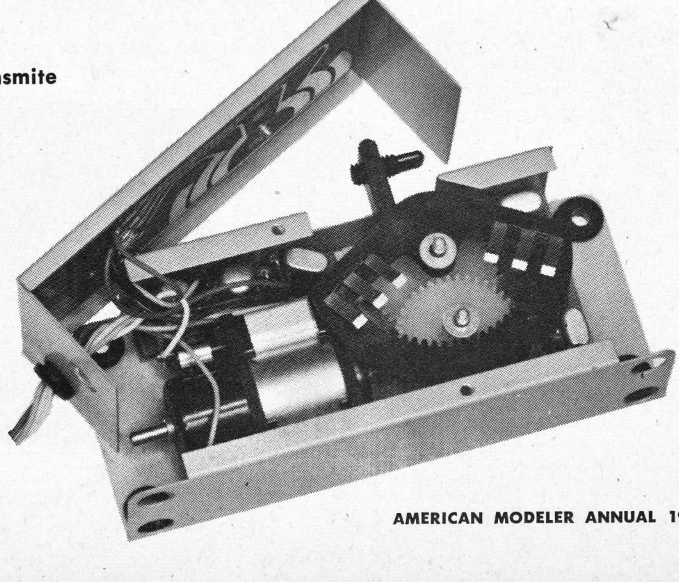
Your receiver is no longer the largest and heaviest piece of equipment. Batteries are the heaviest single item, the 5 servos form the greatest part of the total weight. With the relayless equipment distributed about the airframe in 3- to 5-ounce lumps, there is less equipment damage in a crash. No bent relay deck, no broken printed circuit board, no relays to readjust or replace. Relayless receivers and the servos with transistor amplifiers inside have proved remarkably rugged.

The price differential? Compare the manufacturers' prices of the older relay types with their relayless receivers. The receivers are far cheaper, the transmitters have remained at their former prices. The servos have increased in price due to the addition of several transistors and the associated resistors, capacitors and circuit board. Total cost of receiver, transmitter and servos together has not materially changed. One 10-channel relayless outfit selling for about $330 complete with servos costs only $10 more than a 10-channel relay outfit, an increase of but 3%. Another brand, specializing in superhets figures out just about even.

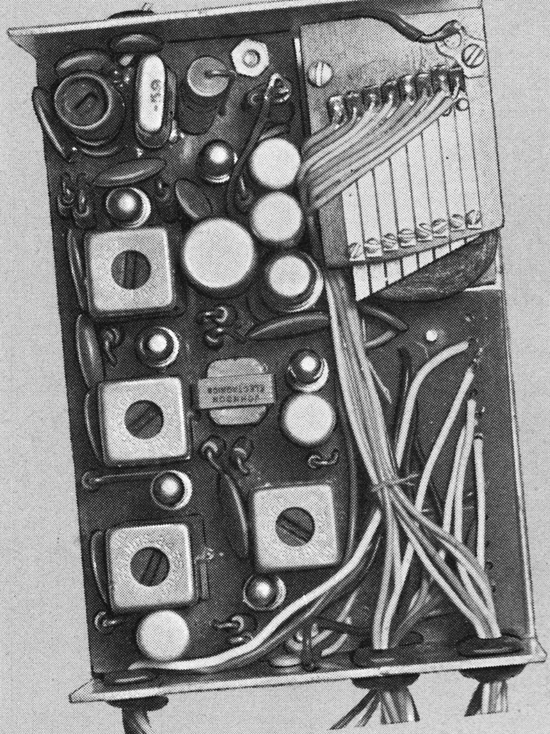
Increased reliability should be a bi-product of relayless systems. Enough flying was made with the Bonner Transmite servos during its first 10 months to prove that such a system is indeed highly reliable.

The first circuit presented, Fig. C, is an adaptation of the circuit by Louis Scheel and Ken Oliver which reached the public in May 1960. The circuit was redesigned to more adequately power the Bonner Duramite servo. In all the circuits presented, the Bonner servo was used as the standard. It offers sufficient space for mounting an amplifier internally.

From my point of view disadvantages of Fig. C circuit are the requirement for a split, insulated reed bank and the lack of adequate PNP-NPN complimentary transistors for the output stage. I believe that the amplifier should be designed for stalled motor currents. This puts a great demand on the circuit to furnish up to 0.8-amp for full starting torque and also provide a safety factor for heavily loaded or stalled servos. NPN transistors that are inexpensive enough to use here do not have the current or thermal capacity required. The maximum current limit as published by the makers can be exceeded on some transistors provided the



Bonner Transmite with cover removed.



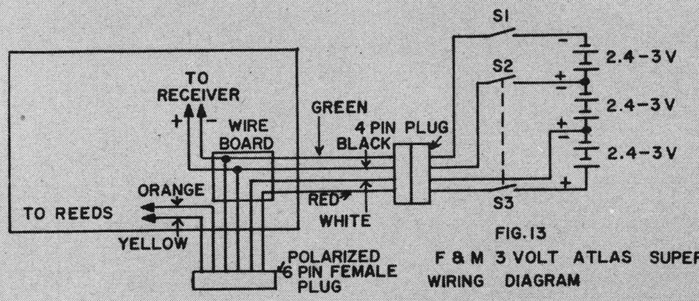


FIG. 13
F & M 3 VOLT ATLAS SUPERHET WIRING DIAGRAM

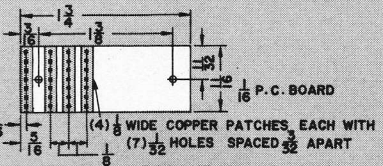
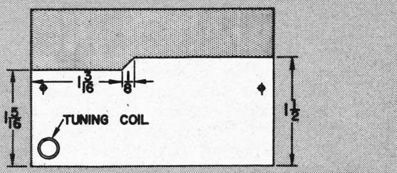


FIG. 11 F & M ATLAS WIRE BOARD



REMOVE CAPACITORS, RESISTORS, & TRANSISTORS AND CUT AWAY SHADED AREA
FIG. 6 F & M ATLAS

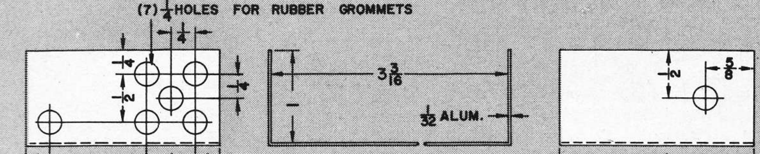


FIGURE 3
F&M ATLAS BASE DEV. = 5 1/4
USE OLD COVER

Photo Figure 18 (above) is F&M Atlas Conversion.

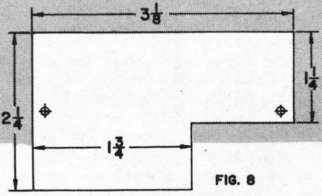


FIG. 8
F & M ATLAS INSULATING BOARD

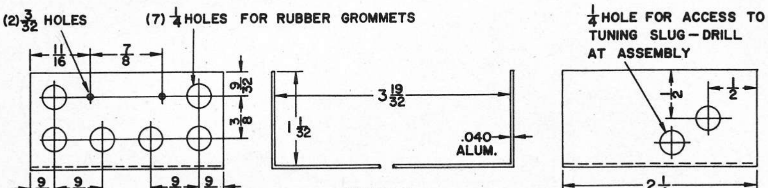
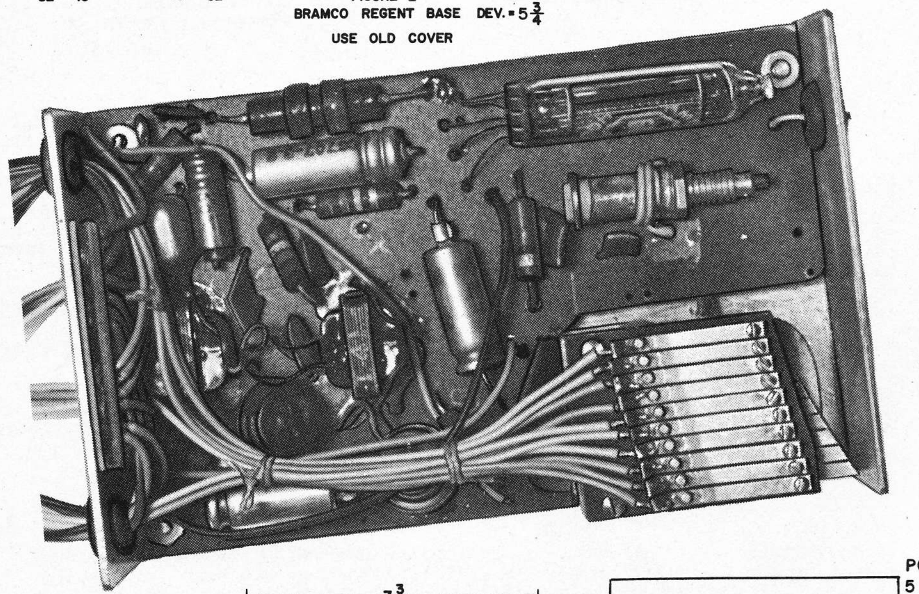
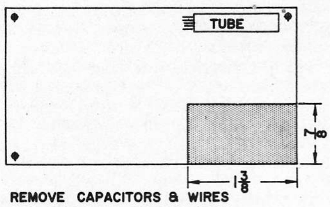


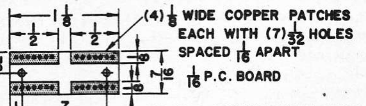
FIGURE 2
BRAMCO REGENT BASE DEV. = 5 3/4
USE OLD COVER

Photo Figure 19 (left, below) is Bramco Regent Conversion.





REMOVE CAPACITORS & WIRES AND CUT AWAY SHADED AREA
FIG. 5 BRAMCO REGENT



BRAMCO REGENT WIRE BOARD
FIG. 12

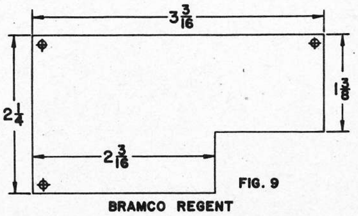


FIG. 9
BRAMCO REGENT INSULATING BOARD

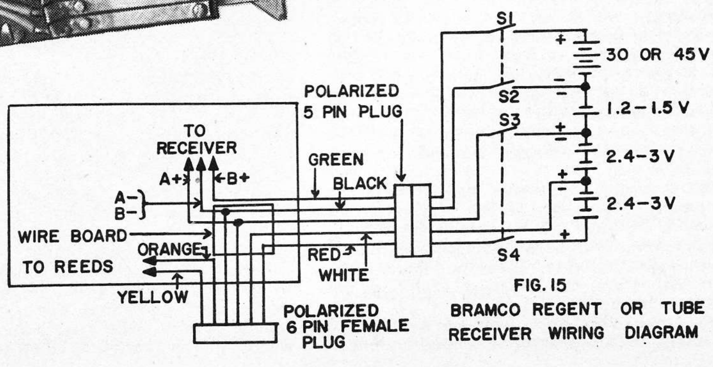


FIG. 15
BRAMCO REGENT OR TUBE TYPE RECEIVER WIRING DIAGRAM

thermal limit is not also exceeded. The PNP 2N223 is such a transistor but no suitable NPN can be found without exceeding the thermal rating at some temperature below the design limit of 140 degrees F.

Fig. D circuit represents one developed by the author and demonstrated at the 1960 DC/RC Symposium at Washington, D. C. It features a PNP-PNP output stage and adequately drives both output transistors even under stalled conditions. This circuit still had the disadvantage of requiring split, insulated reeds. It is shown here to provide the history for a later circuit.

Fig. A circuit is the Transmite servo (printed with the permission of Bonner Specialties, Culver City, Calif.). Developed in the spring of 1960 by Howard Bonner and the author, many others gave valuable assistance in perfecting the circuit. It does not require split, insulated reeds and does provide adequate drive to the Duramite motor. The transistors are used within their thermal limits. Let us take a detailed look at it.

This Transmite servo circuit duplicates electronically almost exactly the functions found in reed relay type receivers. Transistors Q3 and Q5 perform a function much like the normally open contact of a relay. Transistors Q4 and Q6 form the normally open contacts of the second relay. Q1 and Q2 duplicate electronically the normally closed, return to neutral contacts on both relays.

When a reed vibrates, current is delivered through R2 or R3, transistor Q3 or Q4 is switched on, and—in turn—Q5 or Q6 is switched on, running the motor in one direction or the other depending on the polarity of the current in the motor. At the same time, some current from the vibrating reed is fed through R4 or R5 causing the Schmitt trigger cricuit, consisting of Q1, Q2, R9 and R10, to switch to a non-conducting state.

When the output arm is moved off center by the rotating motor, the collector of Q2 in the Schmitt trigger is connected to the base of the non-conducting output transistor Q5 or Q6. Since Q2 is switched off at this time, nothing happens in the output circuit. The motor will continue to move the output arm to its extreme position, where a limit switch opens in the base of the conducting transistor, and the motor stops. The servo will remain in this position until the reed stops vibrating, at which time, all the previously conducting transistors revert to a non-conducting state.

The Schmitt trigger now switches Q2 into conduction and since it is connected to the formerly non-conducting output transistor, causes the motor to run opposite to its former direction. When the neutral position is reached, the collector of Q2 is disconnected from the output transistor by the servo switching patches, and the motor stops.

Resistors R6, R7, R8, R11 and R12 form the temperature compensating networks to allow operation in excess of 140 degrees F.

Batteries required are those used in most receivers. The motor is powered from 2.5 or 3 volts. A bias supply (labelled 1.2V to 3V) is required to adequately drive the servo. This bias battery can be the usual 1.25 or 1.5 volt "A" battery found in tube receivers or can be the 3 volts required for powering low voltage receivers.

Fig. E is a further development of the circuit shown in Fig. C which removes the requirement for split, insulated reed banks but the lack of a suitable NPN transistor (for Q4) remains. This as well as all the circuits shown could be designed to operate with high voltage to the reeds similar to the 30 and 45 volt receivers but it is considered that this would not be in keeping with the trend toward low voltage transistorized receivers.

Fig. B circuit represents the ultimate development of the original Fig. D. This circuit as well as that of the Transmite servo, contains none of the disadvantages mentioned for the other circuits. These circuits can be used with converted receivers so let us get into that phase.

Reed receivers first became popular 10 years ago with 5 non-simultaneous channels.

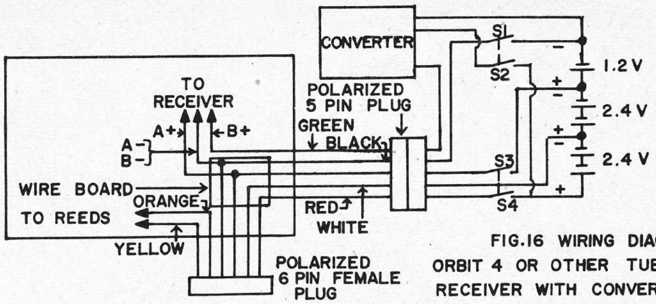


FIG. 16 WIRING DIAGRAM FOR ORBIT 4 OR OTHER TUBE TYPE RECEIVER WITH CONVERTER

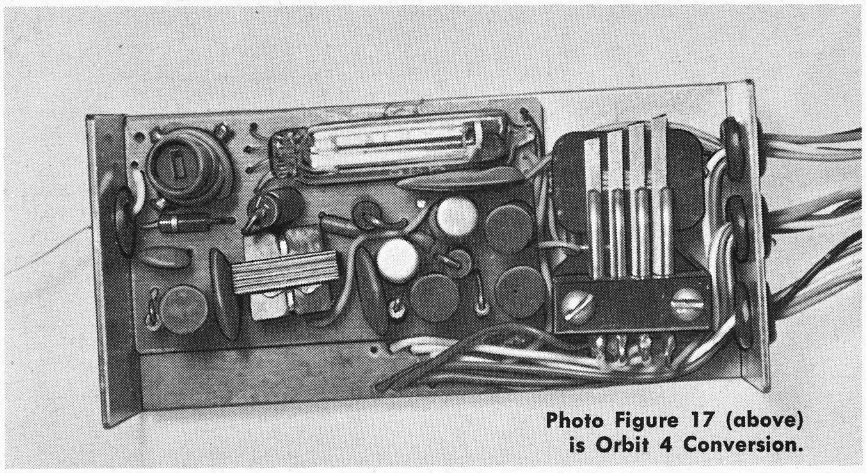


Photo Figure 17 (above) is Orbit 4 Conversion.

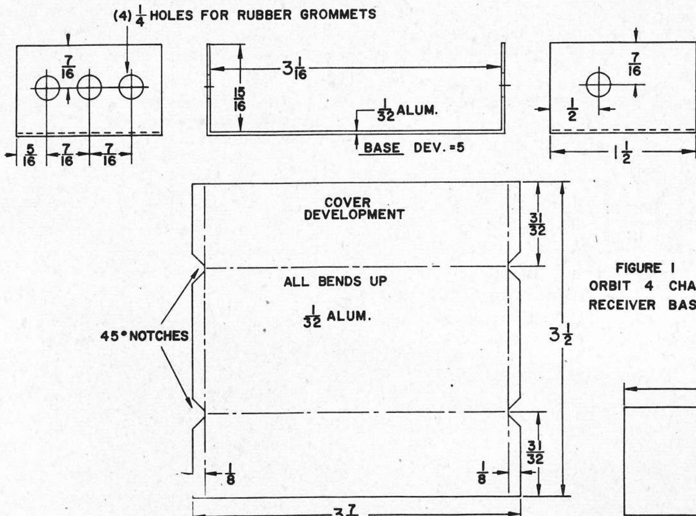


FIGURE 1 ORBIT 4 CHANNEL RECEIVER BASE & COVER

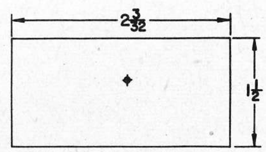
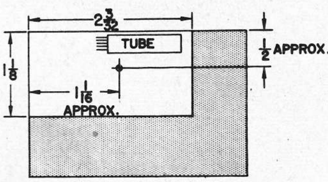


FIG. 7 ORBIT 4 INSULATING BOARD



REMOVE RELAYS & CAPACITORS AND CUT AWAY SHADED AREA

FIG. 4 ORBIT 4

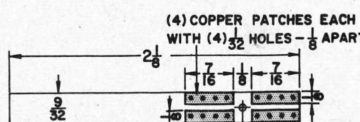


FIG. 10 ORBIT 4 WIRE BOARD

As the years passed, the channels increased from 5 to 6, then to 8 simultaneous. Now 10-channel simultaneous is the standard. Some 12-channel sets have been offered. 10 channels of "bang-bang" control seems to be about all most of us can handle.

With the advent of the relayless servo we must make a new appraisal of the number of channels. It is quite evident that 10-channel simultaneous equipment is only a few dollars more than 8. The extra cost is due to the added tone switching circuits in the transmitter and the extra servo. There would be no significant difference in the weight of the receivers. Likewise, 6 channels of non-simultaneous cost only a little more than 4 channels and again there is practically no difference in weight. It would seem then for "relayless" that 6 channels of non-simultaneous and 10 channels of simultaneous could be established as the standard.

The transistor amplifier mounted integrally with the servo offers the greatest benefits from the relayless concept . . .

1) It achieves the lowest cost through volume production by the servo manufacturer.

2) It achieves the smallest and lightest installation by using space and mounting

means available in the servo.

3) The modular or building block approach is made possible, permitting the beginner to purchase the number of servos he desires and he can invest in additional servos as he becomes more proficient and ambitious.

4) Maintenance is simplified since a failure of a component does not put the whole outfit out of service.

5) There is less wiring to the servos and with the power points connected inside the receiver (shown later), the chances of a wire failure is reduced.

6) Conversion of existing servos is possible and is compatible with equipment commercially available.

7) The highest reliability is obtained through proper design of the transistor amplifier for use with a specific servo motor.

With the above in mind, the conversion of receivers to relayless will be described with the assumption that the amplifiers will be mounted integrally with the servo mechanism by conversion of present servos or purchase of new relayless servos.

Basically, conversion of receivers to relayless operation consists of removing the relay deck and mounting the rest on a new "U" shaped can. The old cover is usually retained. It may be necessary to move the reed bank from the upper deck to the base in some receivers. The receiver generally is reduced to $1/2$ the former height and weighs only 3.5 to 5 ounces. 8-channel relay sets can easily be converted to 10-channel relayless by replacing the reed bank.

The general instructions for converting to relayless are as follows:

1) Remove present circuit board from the receiver can and unsolder the reed bank from the circuit. Carefully tag the identity of the power and reed bank leads.

2) Cut away the unnecessary part of the circuit board. See instructions for specific receiver in Figures 4, 5, or 6.

3) Bend a new base as shown in Figures 1, 2, or 3. Drill holes as shown and install grommets.

4) Locate the circuit board and drill mounting holes. Consult specific photo Figures 17, 18, or 19.

5) Cut an insulating board as shown in Figures 7, 8, or 9.

6) Mount receiver on base with the insulating board between. Also mount the reed bank. Locate the mounting holes from the reed bank frame. The reed bank coil leads can now be re-connected.

7) Make a small printed circuit or machined connection board as shown for the specific receiver in Figures 10, 11, or 12.

8) Attach the reed bank leads according to the arrangement shown. (See photograph of the particular receiver for dressing of the wires.)

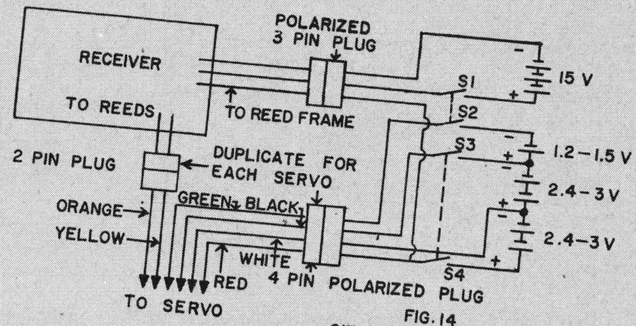


FIG. 14
CITIZENSHIP 15 VOLT SUPERHET
WIRING DIAGRAM

9) Attach the servo power leads to the circuit board. The use of the new small Bonner wire is recommended for all wiring. Note: there are four patches for the power points required for the Transmite servo. Wire each servo and power plug according to Figures 13, 14, or 15.

10) Bring out the power leads and reed leads for each servo through the $1/4$ inch grommets. See photograph of particular receiver for dressing of the leads.

11) Wire servo leads to polarized plugs. Note 6 pin plugs are required for the Bonner Transmite servo.

12) Wire receiver power leads to a polarized plug, preferably a type different from the servo plugs.

This completes the general conversion steps. The following notes apply to specific receiver conversions.

Orbit 4—Note the position of the printed circuit power point board at the bottom of the photograph figure 17. Note also the position of the reed bank.

F & M Atlas—The crystal socket adjacent to the tuning coil must be unsoldered from the eyelets and resoldered on the opposite side of the printed circuit board as shown in figure 18. Remove the crystal while relocating the socket.

Bramco Regent—Note in figure 19 the position of the printed circuit board for the power points on the lead end of the case with an insulating board beneath it.

Orbit 8 or 10—This receiver may be converted by following the instructions for the Bramco Regent. The removal of the printed circuit board occupied by the reed filter capacitors will provide space to mount the reed bank and a power point board similar to the one in figure 12. The new base is similar to figure 2 except it is made to fit the Orbit 8 or 10 cover. The power and servo cables may be brought out of the case similar to the pattern shown in figure 3.

Here are some suggestions for better installations. The alternate reed arrangement is recommended. The reed functions for a 10-channel reed bank should be as follows:

#1 (low reed) and #5 for motor
#2 and #4 for elevator
#3 and #6 for elevator trim
#7 and #9 for rudder
#8 and #10 (high reed) for aileron

The reeds for an 8-channel reed bank should be as follows:

#1 (low reed) and #3 for motor
#2 and #4 for elevator
#5 and #7 for rudder
#6 and #8 (high reed) for aileron

These recommendations do not mean that it is dangerous to fly with adajcent reeds or any arrangement other than that shown. Indeed, there are hundreds of relayless outfits flying successfully with other reed arrangements.

Some transmitters will permit the change to alternate reeds with only re-tuning of the tone adjustment pots. Others may permit the changing of only some of the channels. The most that is required to be changed is one half of the channels. On a ten-channel reed bank the tones for 2, 3, 5, 8, and 9 must be shifted and on an eight-channel reed bank the tones for 2, 3, 6, and 7 are shifted. Other functions may be substituted for those shown but they should be paired as listed. The actual shifting of the tones can be accomplished easily by either exchanging the wires to the switches or by exchanging the padding capacitors.

Figure 14 shows the wiring diagram and switches required to use the Transmite servo with the new Citizen-Ship 15 volt superhet receiver. The instructions given by the manufacturer should also be consulted for the method of converting the receiver and in particular the method of isolating the reed frame. The servo plus-3 volt lead is connected to the reed frame; see Figure 14.

Figure 20 is a photograph of the same Orbit 4-channel circuit used in the previous conversion except here it was converted to a 10-channel receiver $2\frac{1}{8}$ inches square and $\frac{7}{8}$ inch high. This receiver was not described here since it was not a true conversion—it required the use of a new transmitter.

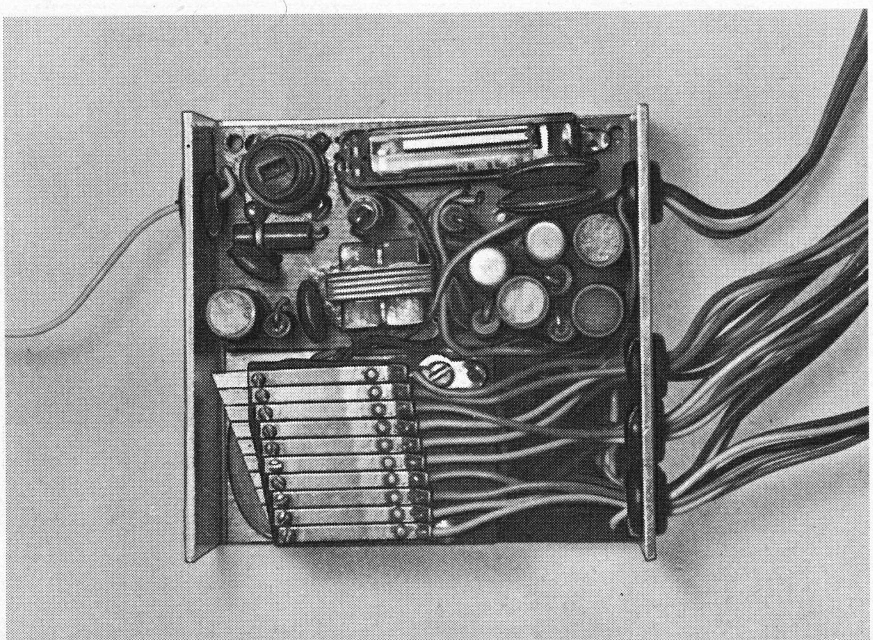


Photo Figure 20 (left): Originally an Orbit 4 relay receiver (as was set in Figure 17), this is now working as a 10-channel relayless rig.