

Introducing **PULSE — PROPORTIONAL** single channel control



THE "GALLOPING GHOST" radio control system offers the modeller simultaneous proportional rudder and proportional elevator control. The name for the system came from the observer's natural response to the control action since the rudder and elevator surfaces flap continuously during operation. The system is intriguingly simple and amazingly inexpensive. Both ground and airborne components are merely additions to basic R/C equipment. Neither the simplicity nor the low cost of the system, however, seem to detract from its performance in the air.

Ground equipment requires a pulse box (see photographs of box) in place of the normal keying switch on any single channel transmitter. The box is able to provide variable mark-space pulse ratios according to stick lateral motion, and also provide variable pulse frequency according to stick fore and aft motion. Thus rudder control with this system, as with any rudder-only proportional system, is determined by the mark-space pulse method. The additional elevator control is a function of pulse rate.

The airborne portion of the "Galloping Ghost" is shown in the sketch. The reader undoubtedly recognises how the mark-space ratio (ratio of relay energised to relay de-energised time) determines effective rudder position. The important thing to note from the sketch is the effect that pulsing frequency has on amplitude of crank oscillation thereby conveying elevator intelligence. At a very slow pulse frequency (2 c.p.s.) the crank oscillates through maximum swing (about 270 degrees) dwelling on its limits to give effective up-elevator. The extreme opposite or fast pulse frequency (8 c.p.s.) dithers the motor crank through a small arc (about 10 degrees) giving down-elevator. Any proportion of pulse rate between these limits produces an appropriate elevator position.

Most difficult to overcome in understanding the "Galloping Ghost" are the mental blocks the

By Nathan H. Rambo III
A comprehensive survey of
pulse-proportional radio control
systems as contributed by
leading experts on the subject.

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**AERO
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RADIO CONTROL INFORMATION
BOOKLET RC 735 3/6d.

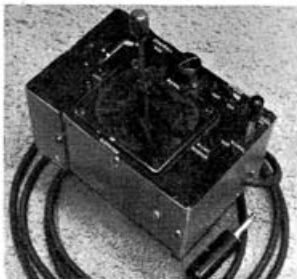
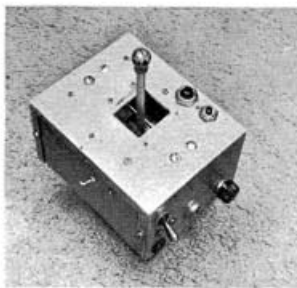
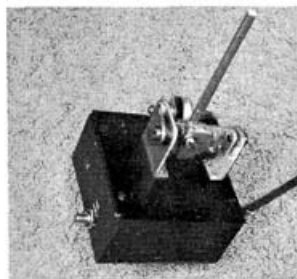
escapement and multi-reed modellers conjure before trying the system. Of particular example is the feeling that applied rudder will reflect up-elevator position. This is negligible except at very extreme limits of rudder control normally not used if rudder area is large. Furthermore, any other mentally contrived interactions due to crank geometry or fancy theory just don't show up when making a pylon turn, inverted flight, or a true spin . . . so relax.

Box Construction

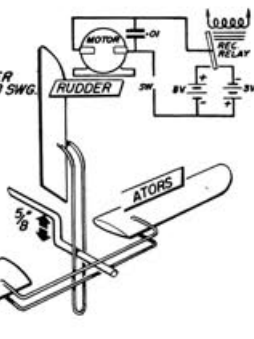
The heart of the G.G. system is the control box which varies the mark-space and pulse rate as discussed. Although any sloppy makeshift arrangement can be made to serve the purpose of the box, it is felt that a neat, self-contained electronic control box fabricated with extra care will reward the modeller with years of hard service on the flying field.

A double-pivoted yoke system must be made to facilitate rotation of the rudder and elevator potentiometers with one control stick. The control box mechanism photograph and sketch show a good approach in building this mechanism. Note that gears of about 4 : 1 ratio will give adequate potentiometer arc-of-rotation without excessive stick movement. Rather than present exacting and complex diagrams, the mechanism is left to the builder's discretion.

The electronic design is shown in diagram form with values for the 3V4 valves. The circuit should



Miniaturised box, top left, uses 1AG4 valves and deaf aid batteries. Bottom left is pulse box with external pot. and gear system, see drawing above. All these control boxes have been built by clubmates of the author and connect to the transmitter by means of extension cable as shown bottom right. Stick mechanics necessitate a somewhat large hole in the box lid and it is a good idea to make a flexible cover as in the one example



NEUTRAL RUDDER (50-50)
FULL UP ELEV. (2 CPS)



NEUTRAL RUDDER (50-50)
FULL DOWN ELEV. (8 CPS)



PARTIAL LEFT RUDDER (40-60)
PARTIAL UP ELEV. (8 CPS)

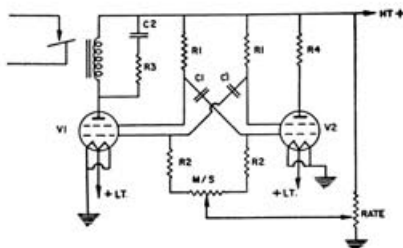


PARTIAL RIGHT RUDDER (60-40)
PARTIAL DOWN ELEV. (7 CPS)

CRANK
OSCILLATION
FOR
VARIOUS
CONTROL
POSSIBILITIES

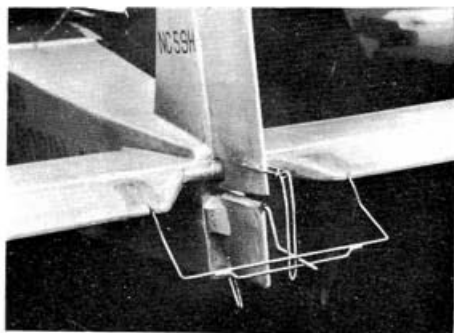
The "Galloping Ghost"

Component values for Circuit Diagram



- | | |
|-----------------------------|----------------------------|
| R1—15,000 ohms | Rudder Pot.—1 meg. linear |
| R2—100,000 ohms. | Elevator Pot. 100K linear. |
| R3—5,000 ohms | Valves—3V4's. |
| R4—Same resistance as relay | Relay—4K to 10K. |
| C1—35 mfd. | H/T—67½ volts. |
| C2—05 mfd. | L/T—1½ volts. |

It should be noted that with this type of circuit R2 should be greater than 1-R1 for the Mark/space ratio to be independent of rate and vice versa, i.e., sufficient time must be allowed for C1 to recharge via R1.



Typical rear end crank linkage

work unless wrong connections are made. First, adjust the relay by feel for positive operation. Connect an ohmmeter across the output points. Using the meter needle as a guide to rudder intelligence, check for neutral rudder (50 per cent. on—50 per cent. off) and hard-over rudders (about 20-80 and 80-20). In neither hard rudder stick position should pulsing stop because elevator intelligence is then lost. Also, pulse rate should be fairly constant as long as the stick is moved only left and right.

Now try moving the control stick back and forth with no side travel. The ohmmeter needle should not vary in mean position but pulse rate should vary between about 2 and 8 pulses per second. A stop watch and some mental counting will determine if the rate is right. If troubles with circuit symmetry are encountered, try switching valves. If pulse rates are too high, increase the sizes of the .35 MFD capacitors (or vice versa if too low).

Mount the electronics in any convenient box. Most people feel that a 4 x 5 x 6 steel or aluminium box is about nominal. Include a pulser on-off switch, a manual keying switch, and a six foot long cord with transmitter plug fitting.

Airborne Installation

The sketch of equipment in the airplane speaks for itself. Crank dimensions are not critical and may be adjusted in necessary after first flights. Slightly larger rudder area and throw than used on escape-models is suggested. Small chorded elevators (10 per cent. area) with about 20 degrees throw in each direction are also recommended. Note that the crank arm and torque rod are all one piece of 18 s.w.g. wire which replaces the upper shaft of the Mighty Midget motor and extends rearward and out the aft end of the fuselage. The centring rubber should be a light rubber band stretched tightly from a small radius. Be positive that all linkage fits loosely with lots of slop in the control yokes to avoid friction and binding (see photograph of model).

A few words should be said about the electric motor. The Mighty Midget motor and its stock

7 : 1 gear-reduction should not be replaced by any other. When installed, its brushes should be bonded or blocked in place so they cannot fall out. If mounted on a wood platform, and sponge suspended in the model, the plastic bearings of the motor will hold up much longer than if the motor is rigidly fastened to the airframe. Nominal voltage on the motor is three volts with battery supplies ranging from four pencils to four medium cells depending on model size.

As far as receiver and relay are concerned, reliability is of utmost importance. Also to be mentioned is that certain receivers do not take fast pulsing. Beware of any receiver using diode rectifiers in the relay stage, for these usually won't pulse rapidly. A single tube receiver is acceptable but the user should use as high a current change as permissible with the unit. If the receiver relay points are not spark suppressed, it is wise to add a 100 ohm resistor and a .005 MFD capacitor in series from each relay point to relay frame. The Lorenze type receiver with two soft valves or a soft valve and transistor is recommended for good reliability, also the "Aeromodeler Transistor Receiver".

Flying

When the model and pulse box are finished the entire "Galloping Ghost" system should be checked out carefully before flying. With a shrewd eye and some good imagination, one may readily ascertain if the effective control position on the model duplicates the control stick attitude. In some cases, it may be necessary to restrict stick motion, if excessive mixing occurs in extreme control positions.

Once on the flying field, begin with test glides with the radio system operating and a pilot on the stick. Trim the model for normal glide with the stick in neutral. This trim should be accomplished by slight shim under wing or by weight shift but never with excessive decalage (wing-tail angular difference) since this makes elevator control ineffective. Now fire up the engine and make the first flight. Use your proportional stick to compensate for any minor trim problems on this flight, making changes later.

Piloting ability with any dual proportional control system increases with practice. The flyer will find that his general flight procedures are entirely different than when flying rudder-only ships. For instance, flight altitude rarely exceeds two hundred feet, and instead of an occasional tap of rudder control, the model is constantly guided by the pilot who never takes his eyes from the model.

The pylon turn is the first manoeuvre the pilot learns once past the first flight. Inverted flight, however, is probably the most spectacular and advanced manoeuvre performed with this system. The manoeuvre is entered from a half loop. It is important to enter the manoeuvre from a near-vertical dive so that air speed is still high at the top of the half loop where top elevator is applied by full down stick. Be sure to hold exactly neutral rudder here or the model will roll.

Ace R/C



4

The following hints from the Ace Radio Control Kit for "Simpl-Simul" are of great help for better model performance:-

Poor model trim, with accompanying low pulse rate, causes galloping of the model which prevents obtaining good performance. Most models of the conventional R/C type end up tail heavy - it takes deliberate effort to jam equipment forward and to hold construction weight behind the wing down to a minimum. The usual 'cure' for a tail heavy model is to reduce the angle between wing and tail incidences. Doing this usually requires going too far in this direction to get positive down elevator action. The result is an unstable hair raiser that requires holding much back stick just for level flight. Lowest pulse rate is likely to be 2 cycles per second or less to get sufficient up and the model usually gallops terribly.

It's rough to do in many cases, but the CG needs to be forward - from 20 to 30%. With forward CG, wing-tail angular difference increases and the overall result is a much more stable model - it flies level with neutral or even slightly down stick. With enough wing-tail angle, the model wants to zoom unless held down by forward stick. So, up elevator action is positive without going to excessively low rates. Recovery from all attitudes is immediate and sure - grey hair comes less easy.

Too much stability, however, requires too much actuator power and surface deflection to overcome. We need a balance between adequate stability and responsive control. We get stability by the forward CG and generous wing-tail angle. Some stability can safely be taken away by using smaller horizontal stabilizers and/or shorter tail moment arms. 18 to 25% stab area is good, as is a tail moment arm of $1\frac{1}{2}$ to 2 wing chord lengths. Smaller tail volume helps us to get that CG forward also.

Power is the key to real performance. If a .15 engine is plenty for a rudder only ship, up to .29 may be required for good S/S performance. A .19 may be adequate for a light ship, but it may take that .29 to make a heavy clunker perform. Better to have too much power available than not enough - if full power is too much, use the free flyer's trick of putting the prop on backwards to kill thrust. This lets the engine rev up for smoothness in manoeuvres; better than richening mixture which is harder to set exactly and consistently.

Remember to use opposite rudder first when correcting or coming out of a sharp turn. Up elevator seems more natural but only tightens the turn. Opposite rudder brings up the nose immediately, so be prepared to slap in some down elevator to come out smooth, fast and level. By flicking opposite rudder as needed, you can hold tight and spectacular low level vertical banks in continuous circles - use elevator only on the recovery to level flight. Here's to hot piloting success with "Simpl-Simul", - and of course, "Galloping Ghost"!

The pulse system requires a relay which will follow each generated pulse. Contact pressure is the key to good pulsing. Increased relay coil current will increase contact pressure, an important factor at high pulse rates and at extreme pulse widths. Another important point is the rigidity of the contact points. Any weakness here is asking for trouble. The relays deemed best in this category are the Sigmas (4F, 5F, and 26F), Gems and Price units. A balanced armature is not essential to proper operation of a pulse system. Relays using a non-balanced free-floating armature are taboo. The Gem and Price type relays, having a semi-floating armature, are acceptable.

In summing up the choice of relays for pulse work, especially in the receiver, the Sigma 4F, 5F, and 26F are tops, followed by the Gem and Price. How do you know if you have a good pulse receiver and relay? First of all, the transmitter must not block or swamp the receiver and the receiver must be capable of receiving the desired pulse rate. For those with a scope this check procedure will not present any trouble. With no scope available, check for a sharp clean click, with no fuzziness. With the transmitter pulser relay operating, the receiver relay should follow it and sound like it was connected directly in the same circuit. Simple pulse systems work reliably provided you use a little care and common sense.

MULTI-VIBRATOR CIRCUITS BY J. BLACKBURN

THE USE of the multi-vibrator circuit to obtain mark-space modulation of transmitters for proportional control systems is well known. This circuit is used, for instance, in the "Galloping Ghost" systems as described.

The system as generally used is not completely satisfactory, however, as it is usual to use a relay to switch the transmitter on and off. This is noisy and, strictly speaking, crude. In the circuit about to be described it will be shown how the relay can be dispensed with giving the following advantages:

- (1) The rate of pulsing does not necessarily have to be low enough for the average relay to be able to follow it.
- (2) It dispenses with a relay that the impecunious modeller probably feels could be better employed in a receiver.

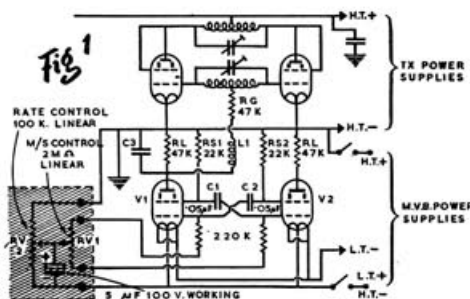
- (3) The transmitter is completely silent, which mystifies the uninitiated.

Circuit

The multi-vibrator circuit now becomes an integral part of the transmitter circuit. It will be seen in Fig. 1 that the earth line of the transmitter is the H.T. line of the multi-vibrator, which requires a separate battery pack. At the anodes of the multi-vibrator valves, square waves are generated; each valve cuts off and conducts in turn, causing the voltage at the anodes to rise and fall. The anode load RL for V1 is also the grid leak for the TX; when V1 is cut off, this valve is effectively removed; RL then acts only as the grid leak for the TX, and oscillations are produced. When V1 is conducting, however, a large voltage is developed across RL; this voltage is sufficient to cut off both TX valves, and the TX will stop oscillating. Thus our TX is switched on and off completely electronically.

The multi-vibrator valves are of the usual type, e.g., DL92, 3S4, DL96, etc. In practice about 1mA flows through an RL of 47K giving us by Ohm's Law about 50V, more than enough to cut off the valves.

The TX circuit shown is of the TATG type, with a single grid leak, and is the most suitable type of oscillator for this purpose. The circuit could be modified for use with the simpler type of cross-coupled oscillator, but the component values are much more critical (Fig. 2). RL should still be 47K. In all circuits a certain amount of fiddling with Rg may be necessary to keep the TX H.T. current at the right value. Rg may be as large as required but should not be less than 10K or it will cause excessive damping of the tuned circuit. In the case of the cross-coupled oscillator, the Cg's may have to be reduced in value—they can even be made by twisting two pieces of insulated wire together if necessary (this



should be done with the aerial connected). If the cross-coupled circuit will not work satisfactorily, the circuit could be modified as in Fig. 2a. This would most certainly work, but requires an extra valve, increasing the drain on the batteries. It would be better to change the TX to the TATG type, which is rather more efficient anyway.

L1 and C3 form a filter which stops the 27 Mc/s getting to the M.V.B. L1 is a normal 27 Mc/s R.F. choke, and on no account should it be omitted. Some experiment is possible with C3; it is not critical, but if large, the modulation square wave will be distorted. Try reducing it to 100pF.

The circuit could also be applied to the McQue TX. This is most simply done with the circuit shown in Fig. 3. The P/A valve only is modulated; RL and RB form a bleeder which gives a certain amount of bias even when the TX is oscillating; RB should be adjusted so that when the M.V.B. is switched off and the oscillator put out of action by removing the crystal, the current through the P/A valve is approximately 2Ma.

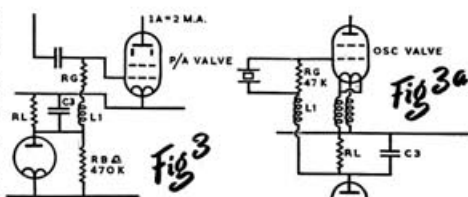
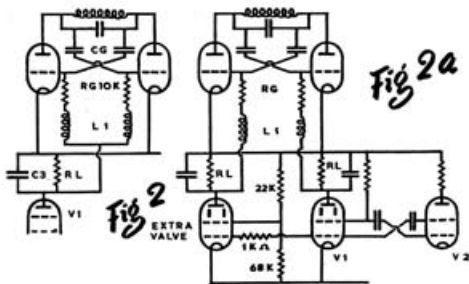
The writer has had some correspondence with Mr. McQue on this matter, and he suggests that this is not the best way to modulate the TX, since at very short range direct radiation from the oscillator causes a full mark to be transmitted. Mr. McQue is of the opinion that this is best overcome by modulating the oscillator as shown in Fig. 3a. In this case the bleeder RL and RB for bias on the P/A valve would still be used.

The writer feels, however, that it is better to modulate the P/A, as crystals do not react kindly to being switched on and off rapidly. It would be better to do that and mount the oscillator section in a metal screening can.

Layout

It is essential that the M.V.B. is mounted in the same box as the TX, as if it is mounted separately you would have 27 Mc/s travelling along about six feet of lead, which would be troublesome.

Since the M.V.B. has the normal earth-line as its H.T. line, care will have to be taken when wiring up. It is recommended that the unit be built on a paxolin sub-chassis. This can be very small; about 2 in. x 3 in. is big enough as there are very few components to be mounted on it. These may be soldered directly between the valve-pins provided that lengths of Systoflex are used to prevent any possibility of short circuits. Try and obtain matched C1 and C2 and RS1 and RS2. It would be advisable to fix a short tag-strip along one edge of the sub-chassis for external connections. A four-pin polarised socket should be fitted on one side of the TX case, to plug in the lead to the control box. A separate on/off switch for the M.V.B. will be required—in the H.T. line as well as in the L.T. line—since the pulse-rate potentiometer in the control box constitutes a bleeder across the H.T., which will become run down if the



user forgets to unplug the box.

The M.V.B. is very economical as regards battery consumption. In the original an Ever Ready B114 67½/1½V was used; this battery is quite compact being only 4 in. x 5 in. x 2 in.

Testing

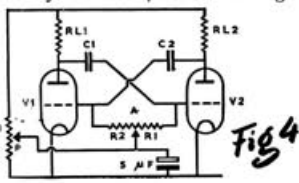
Switch on the M.V.B., and check that it is working by touching just one lead of a pair of head-phones to one of the anodes. A clicking noise should be heard. With the M.V.B. switched off, the TX should still have the same anode current as before; if not, alter Rg as explained earlier. With the M.V.B. on, altering RV1 should alter the average H.T. current of the transmitter from nearly zero to almost maximum. Altering RV2 should have negligible effect. If it is not satisfactory, remove V2 from the M.V.B. which should then stop oscillating. Enough bias should now be developed across RL to reduce the TX H.T. current to zero. If it isn't try increasing RL to 68K. If this doesn't work, increase the M.V.B. H.T. to 90V. If it still doesn't work properly, check the valves and all wiring.

Multi-Vibrators

Finally, some hints on multi-vibrator design. A simple circuit for mark-space control is shown in Fig. 4. V1 and V2 are alternately cut off and conducting; the length of time that V1 remains cut off, and therefore the width of square wave produced, is controlled by the produce C2R2; this is the time taken for C2 to discharge through R2, and increasing the size of either of these components will keep V1 cut off for a longer period of time. Similarly for V2; its time constant is C1R1. The time taken for one complete cycle is therefore the sum of these time constants. Moving the slider along the potentiometer A will increase one time constant and reduce the other; the mark-space ratio will be altered but the frequency will remain substantially constant. Raising the potential at P by moving the slider up the potentiometer B will make both C1 and C2 discharge more quickly. The pulse-rate will therefore rise without affecting the mark-space ratio; the 5μF condenser will help here (its working voltage must be at least equal to the H.T. supply to the M.V.B.).

The "squareness" of the square wave is governed by the time constants C1R1 and C2R2, which should be as small as possible. RL1 RL2 cannot be reduced too much or the valves will not amplify, so C1 and C2 must be kept small. To keep the frequency low enough for model use, R1 and R2 must be large. A 2 Meg potentiometer is the largest easily obtainable; this is about right. The potential at P has quite a large effect on the frequency.

The system works perfectly satisfactorily in practice.



Galloping Ghost

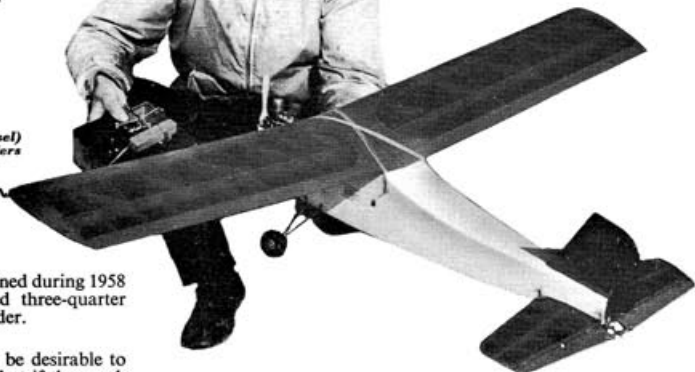
proportional radio control

by

CHARLES RIALI

Seen at right with prototype "Rattler" (Mills 1.3 diesel) which has intrigued many London Area modellers

Full Size plans
for RATTLER
RC 734 8/6d.
From Aeromodeller
Plans Service



These notes are based on experience gained during 1958 with the system installed in a modified three-quarter scale "Smog Hog" and in a 6-ft. span glider.

Considerations of the System

1. Fast pulse for UP elevator would be desirable to give more positive pull-out from a dive, but if the crank were arranged at the top to achieve this, rudder control would give a DOWN elevator tendency and this was thought to be undesirable, although it has apparently been done in America. The author has always used an arrangement with the crank at the bottom on fast pulse.

2. Apart from the control of rudder and elevator through the pulse system, in theory there is also the possibility of a steady signal or no signal for a short period causing the "Mighty Midget" to rotate in either direction. This would give two more channels of communication provided that the rotation can be made to produce a result in a very short time and the reactions of the model due to control movements are not too violent.

At first a simple mechanical device was made to operate an engine cut-out, but the effect on the flight path was found to be too violent and unintentional engine control was likely to occur during normal violent manoeuvres.

If control movements are reduced to obviate this, the system becomes much more critical and the attractive simplicity and wide tolerance to change in all the variables, such as battery voltage, is lost.

It was then decided to attempt engine control by other means, to fit stops at 270 deg. crank movement and to use an override switch on the control box giving FULL Signal/NO Signal for flying effects only.

Installation in the Model

Before the system is built into a model, it is strongly recommended that a mock-up be made with the same length of drive shaft and representative control surfaces. This can all be of odd balsa, etc., and mounted on a wooden plank. It allows relative positions of control

surfaces, hinge lines, etc., to be varied until an optimum arrangement is achieved.

In the "Rattler" installation, elevator and rudder hinge lines are in the same plane and the drive shaft centre line is $\frac{1}{8}$ in. above the centre line of the tailplane and elevator. This distance should be kept small.

The "Mighty Midget" servo is bolted to a piece of $\frac{1}{8}$ in. ply ($1\frac{1}{2}$ in. x $1\frac{1}{2}$ in.) with nuts Araldited below the ply. The ply is cemented to a block of plastic sponge approximately $1\frac{1}{2}$ in. x $1\frac{1}{2}$ in. x $1\frac{1}{2}$ in. high. (The plastic should be well pre-cemented.) This allows easy removal of the motor for brush and bearing inspection.

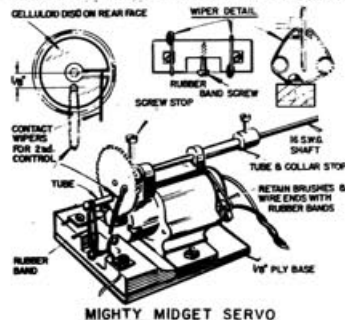
The plastic sponge is then cemented to the bottom of the fuselage in a similar manner. The motor can be packed up or angled as necessary to get good alignment between the two drive shaft bearings on the motor and the tail bearing and the sponge mounting will also assist in permitting self-alignment.

This arrangement is very satisfactory in flight, but quite uncrashworthy and to allow for this a very strong bulkhead is built across the fuselage at the height of the motor mounting and positioned about $\frac{1}{4}$ in. forward of the mounting and a piece of sponge is cemented to the bulkhead in the gap.

If the drive shaft is rather long a steady bearing can be arranged between the motor and the tail to damp out possible vibration and whip. For this purpose another piece of sponge is used 1 in. x 1 in. x $\frac{1}{4}$ in. thick and a hollow rivet or tube about $\frac{1}{8}$ in. internal diameter cemented in the centre. The sponge is then cemented to suitable supports across the fuselage. This complete arrangement allows very severe crash loads to be absorbed without much damage or mis-alignment occurring. The tail bearing should have good clearance, about $\frac{1}{16}$ in., and a hollow rivet inserted from the rear with the rivet head cemented to the stern has been found to be satisfactory.

On the "Galloping Ghost" servo, a .001 mfd. capacitor is made up with each wire soldered into a loop and is placed across terminals. Several small rubber bands are used to hold brushes in place and to hold wires against motor body to keep vibration loads away from soldered ends. This allows inspection of brushes without unsoldering any connections and guards against vibration loosening brush holders. Control driving shaft is made

Left: The basic control unit is a converted Mighty Midget motor oscillating to drive the tail control shaft. Pin on gear wheel for centring is not to scale and should be approx. 5/32 in. from shaft axis and preferably bushed with tubing to prevent rubber band wear



from 16 s.w.g. piano wire (.064 in.) in place of $\frac{1}{16}$ in. "Mighty Midget" shaft and can be reduced in diameter slightly with emery paper to take the brass M.M. gear. A collar on the shaft prevents forward movement.

At the tail end, the shaft is just bent and not formed into a crank, but it will continue to be called a crank. Use of a true crank in this location is really a throw-back to the requirement for winding up an elastic driven escapement. A simple bent shaft is much better for the reasons that (a) it is so much easier to alter the degree of movement by altering the bend in the shaft; (b) if the bend is in line with the rudder hinge line the rudder movement each way will equal the degree of bend (about 25-30 deg.) and is easily judged; and (c) the crank will always pass at right angles through the rudder "loop" and therefore allow small clearances to be used to obviate backlash without the danger of binding even though the degree of rudder movement is altered. Likewise but to a slightly lesser degree for elevator.

Control surfaces should be made as light as possible; the less inertia the better. The rudder "loop" can be a simple U-bent-wire cemented to the rudder. The elevator "loop" can be the only connection between the two elevator halves, but should be easily removable, since spacer washers between "loop" and elevator can produce different elevator trim.

The elevator should be approximately neutral when the crank is 45 deg. from bottom dead centre. This is important and is the datum for the elevator movement.

The "Mighty Midget" is made in such a way that if the rubber band peg is fitted to the M.M. gear directly opposite to the screw hole in the boss and if a longer 8 BA steel screw is used, this screw will contact the motor casing each side after approximately 270 deg. movement.

PULSER UNIT

The pulser unit was made up in accordance with the amended circuit in August, 1957, AEROMODELLER. A 7,000-ohm Manning Carr relay is used and is arranged so switch on Tx when armature is released, sparking at the points is suppressed by 100 ohms and 0.5 mfd. (this teamed best when checking in the dark). The Pulser relay should be adjusted with the Tx switched on so that the relay points are actually switching the Tx.

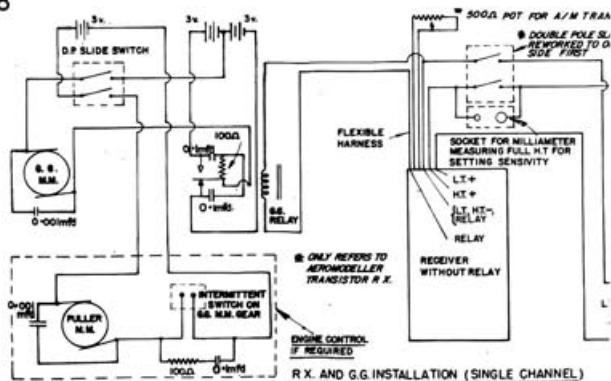
It is a good idea to arrange a meter socket in the H.T. + side of the circuit (the socket can have a separate switch, a 2-pin plug or can be across one side of a modified double pole slide switch). By plugging in a milliammeter with a variable resistance, about 10,000 ohms, in series, it is possible to reduce the H.T. current until the pulsing stops and this check gives an indication of the battery power "in hand" and relay adjustment.

Elevator and rudder potentiometers are driven by Meccano gears giving 3:1 ratio. The gearbox was made from odds and ends, but is basically a Meccano plate 5 holes x 3 holes on which is mounted the rudder pot, and gear drive. The plate is secured to a Meccano rod which pivots in a frame and drives a secondary shaft to operate the elevator pot.

Neither the rudder or elevator pots. are necessarily used fully. The rudder pot. drive is connected up to give neutral rudder with stick central and the elevator pot. drive is connected to give full up elevator at about $2\frac{1}{2}$ cycles per sec. with stick hard back. With stick forward the pulse rate should be fast enough (7-8 c.p.s.) to give little rudder movement. An even faster rate can be used to trigger off an engine control escapement.

Stops should be arranged on the control box to act on the stick and NOT on the pot. movement and should be very strong for an excited(!) operator.

Strong rubber bands or springs should be arranged to centre the stick. The operator cannot see the degree of control movement he is applying since he must watch the

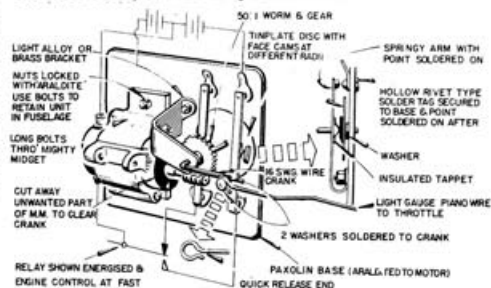


model to assess the result and the amount of control applied is entirely governed by the reaction of the model. Under different conditions of wind, engine power, etc., the results of control application will vary for a given stick movement and the purpose of the springs is (a) to approximately centre the stick if it is allowed to go free; and (b) to act as a "feed-back" of information to the operator so that he can tell by feel what he is, in fact, doing at any given movement.

The .35 microfarad capacitors will have to be made up with .25 and .1 in parallel. In practice the .25 alone will give a rate which is nearly slow enough and if some value near .1 is added and arranged to be permanently in circuit and a double-pole press switch is wired in to cut out the two .25, an extra fast pulse rate can be obtained by pressing the switch with the stick fully forward. This will give neutral rudder and full down elevator, but can be used for engine control as described later, when operated for only a very short time. The switch should be positioned for operation by the left hand so that the right hand does not have to leave the stick: this is most important.

An additional control has been added to the pulser unit in the form of a two-way spring centre switch to give FULL signal or NO signal. This is mounted beside the control stick and wired to give left rudder and full up elevator when pressed to the left and vice-versa. The effect on the model is violent and quite exciting and should only be tried out at a safe altitude.

As long as the rudder flaps symmetrically with the stick neutral and the rate is about 4 c.p.s., it does not really matter if the effects of stick movement are non-symmetrical or non-linear. The operator soon learns to move the stick correctly by the reactions of the model. Large rudder "flap" to one side naturally gives an up elevator effect, but this is by no means undesirable.



ENGINE CONTROL (using single channel radio)

SISTOR RX
DE SWITCH
TEN H.T.



The author being mechanically rather than electronically minded, engine control has been added to the G.G. system by the following rather tricky device, suitable for modellers with plenty of patience.

A celluloid disc about $\frac{1}{2}$ in. thick is cemented to the rear face of the *Mighty Midget* large gear. A slot about $\frac{1}{8}$ in. wide with bevelled edges is cut in the disc in a position to bring the slot horizontal when the centralizer peg (and the elevator, rudder crank) is positioned at the bottom.

A springy wire contact (silver wire was used) enters the slot and contacts the gear when the pulser motor is stationary at this position, but bounces across the slot when the motor is oscillating and thus only causes intermittent contact. This wire must be far enough toward the edge of the gear to clear the stop screw in the gear boss. A similar wire contact is permanently rubbing on the other side of the gear sufficiently far from the centre to miss the rubber band and peg. A 3-volt separate battery supply is switched by these contacts to a *Mighty Midget* motor actuator.

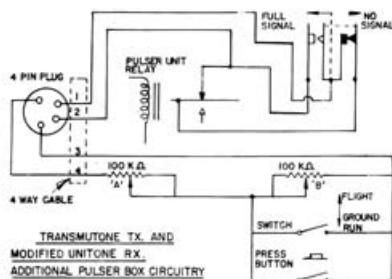
The engine control described above tended to be unreliable in operation and could not be used close to the ground because of the dive tendency. A system was required to give engine control *completely* independent of the flying controls and this has now been achieved by using a *UNITONE* receiver specially modified by Radio and Electronic Products to drive a reed unit as well as the normal relay. The reed unit is inside the set and the G.G. relay and engine control relay are mounted separately in the model.

The reed unit operates a slugged relay which switches an actuator for engine control. After various experiments, the author decided that the best way to arrange the engine control was as follows:

Pulser unit has a press-button switch which is held ON by the left hand forefinger (left hand must hold pulser box easily without use of forefinger!) to give suitable pulsed HIGH note to excite highest reed. Only highest reed is used.

Pulsed operation of reed unit energises a slugged relay by a separate 45 v. supply. Two B.122 to give a separate 45 v. supply are considered preferable to adding any load to the H.T.

On a steady tone the reed will switch about 7 m/A through the slugged relay, but when pulsing on a large



"space" to "mark" very little gets through and the relay should be set as low as possible—about 1N at 1.2 m/A and OUT at 0.7 m/A. Using 45 v. is rather "brute force", but it seems that this voltage will be able to fall a long way before relay fails to hold in. Relay held IN retains a motor-driven two-position actuator to give FAST engine speed.

Whenever the press switch is released, the Tx transmits a pulsed lower note and reed unit pulsed excitation ceases (this also happens if Tx should fail or if NO SIGNAL switch is operated). The relay falls OUT after about half-second delay and the engine control goes to SLOW.

When engine is at SLOW a quick press on the button will give a burst of power without the delay or holding the button produces FAST again.

A slide switch on Pulser Unit parallels the button for starting and ground running which must, of course, be carried out with the radio link in operation. Switch must be returned to FLIGHT before take-off and button held in.

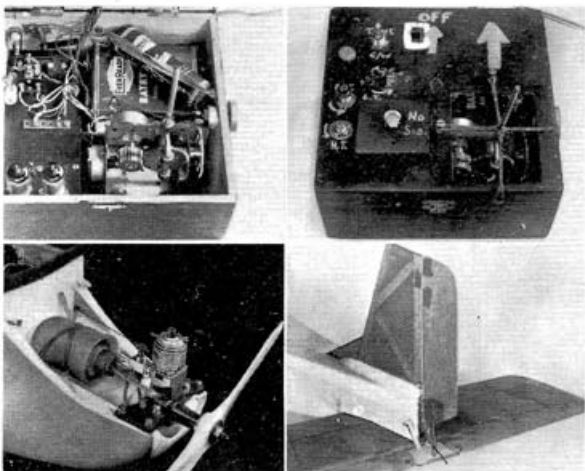
A characteristic of the Rx and this arrangement is that the pulsed tone on rudder selection by mark/space towards "space" (in the author's case RIGHT RUDDER) will fail to hold the engine control at FAST at long range before the G.G. flying controls fail.

A large change in tone between FAST and SLOW should be avoided since tone change affects G.G. pulsing. Also, always go to a lower tone for SLOW since the pulsing of the Rx causes unwanted "twitching" of the reed unit when away from the chosen note and this is much worse when above the chosen note.

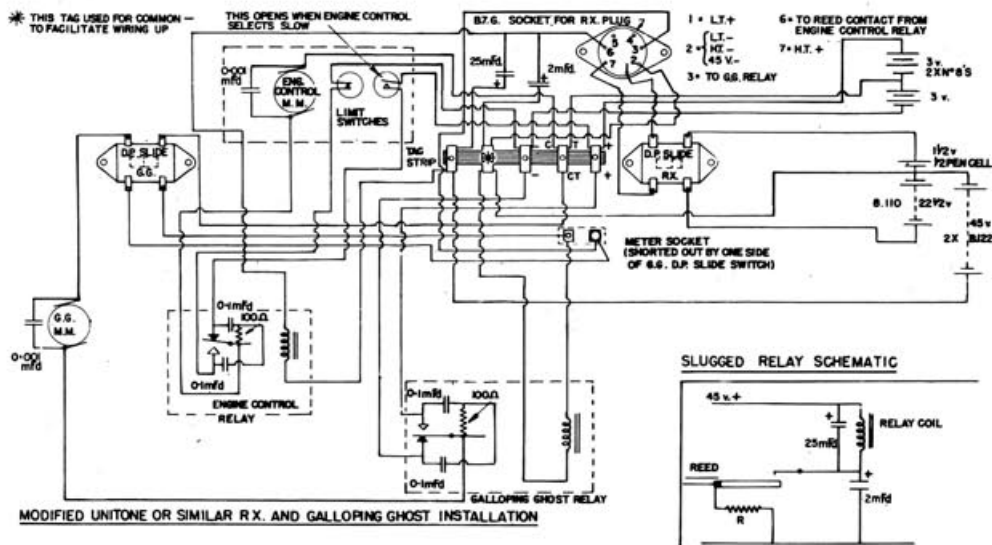
The motor-driven rotary actuator with limit switches for engine control is fed by the G.G. batteries and 3 v. feeding G.G. M.M. on "no signal" should drive engine control to FAST so that 3 v. supply driving engine control to SLOW under "no signal" conditions will only be feeding one M.M.

A twin battery feed to an engine control rotary actuator is recommended so that the ineffective crank angle simplifies adjustment and any unwanted effect from the reed unit just causes hunting on the limit switches rather than complete rotation of a step-selector type of actuator.

Many flight trials have shown this to be a most satisfactory method, it being "fail-safe" for both radio and human failings, since when disaster is imminent the human mind (the author's at any rate!) appears to be



Inside and outside of Charles Riall's control box shows general layout and his various switches, etc., which have been adapted to suit his two systems of engine speed control described in the article. The D.18 battery is used for bench test only. Flying demands a larger L.T. battery. Below left: Mills L.3 installed with polythene tank doubled back to adjust capacity. At lower right is the tail control system at neutral rudder with down elevator



Though complicated at first sight, above harness for model wiring is actually very simple to follow. Use of separate switches, tag strips and socket actually simplify installation.

much more capable of releasing a push button than of pushing one. As far as the author is concerned, this is known as the "PRESS ON" system.

The additional FULL signal/NO signal control has now been mounted at the top of the control stick itself. This gives much easier operation. A second similar model has been built with an E.D. 2-46 c.c. Racer and the G.G. system controls it well, but it is thought advisable to gain first experience of the system on a slower model.

In the Mills 1-3-powered model a P.100 relay is used for the G.G. system, but trouble has been experienced in the "Racer"-powered model which was thought to be due to vibration on the P.100. A Siemens high speed relay (3,400 ohms) type 96 is now being used and appears to be more satisfactory.

FLYING

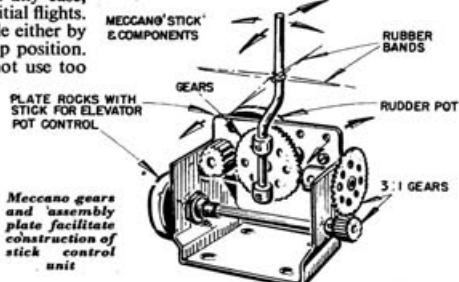
The model has C.G. position at about 35 per cent. and longitudinal dihedral about $3\frac{1}{2}$ deg. Rudder movement is about 25-30 deg. each way with crank at 90 deg. to B.D.C. Elevator movement is about 10 deg. down and 30 deg. up with Mighty Midget on the stops.

The system appears sensitive to elevator control but this may be partly due to the fact that change in pitch is harder to judge than change in direction. In any case, a more forward C.G. position is advised for initial flights.

Start with very little down elevator available either by suitable bending of the crank or elevator loop position. R/C glide tests are advised at first, but do not use too much elevator to try and keep the model airborne. On powered flights, if it is found that a lot of UP elevator is required to get the model airborne, do not take off or, if after a hand launch, end the flight as quickly as possible. When in this trim condition the model may appear to be

controlling reasonably well, but will then suddenly dive and fail to pull out since available UP elevator has already been used up. Correct by packing at front of tailplane to reduce the tailplane incidence.

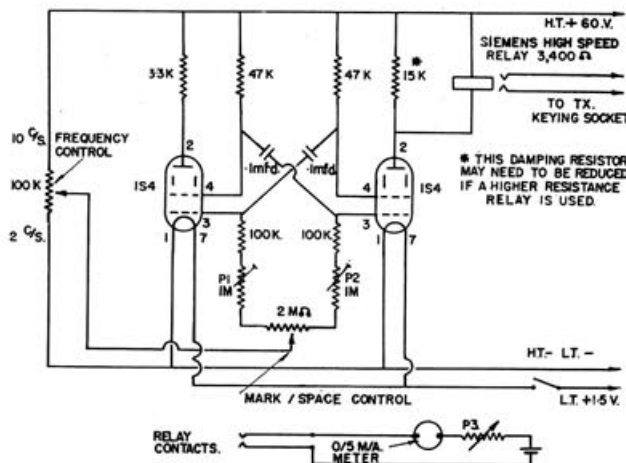
The G.G. model won't fly itself. Plenty of piloting experience is essential before advanced manoeuvres are attempted. Be content with accurately controlled flight at first and then loops, stall turns and spins—inverted flight may come later; and don't take your eyes off the model! The degree of control in normal flight compared with escapement models more than compensates for the additional complication and the model is really flown all the time. Operation of the FULL SIGNAL/NO SIGNAL switch can produce a barrel roll in certain conditions. Failure of any part of the system is, of course, almost certain to lead to a crash but the author is of the opinion that a model in pieces in the vicinity is no worse than a model in one piece (perhaps) in the next county! Vibration affecting the relay may give a dive tendency and this happened several times before the cause was realised and the relay rubber-mounted. Also it is very easy to become over-confident, and, pitch attitude being hard to judge, a stall at low altitude can cause the model to fall out of the sky, particularly with such a low-powered model.



McQUE PULSE BOX FOR RUDDER ONLY.

Right, shows the circuit of McQue's proportional mark/space producer. It is the usual electronic type with a potentiometer to control the pulse speed. With this circuit the pulse speed does not vary much, so long as the 0.1 mfd and 47k are matched. This controller can be built in an "oxo" tin and run from an ex-gov. combined H.T. and L.T. battery. Although 1S4 valves are shown there is no reason why other similar valves such as 3S4, N18, etc., should not be used providing both valves in the circuit are identical. P1 and P2 are used to set the limits of the mark/space

Firstly, adjust P3 to give full scale deflection with relay contacts shorted. Then turn main mark/space control fully clockwise and adjust P2 for 80% average deflection. Now turn main mark/space control fully anticlockwise and adjust P1 for 20% average deflection and repeat process until no further adjustment is required. Limits should then be 80:20 and 20:80.



2 CONTROL PULSE FOR BOATS. A. C. Armstrong

The pulse box circuit (Fig. 5) gives the basic idea of the set-up. With both key switches in neutral (i.e. centred) the box gives out a 50/50 pulse. This is adjusted by potentiometer P3, which is provided with a knob on the face of the control box. Moving the key switch 1 to the left selects the extreme end of pot P3 and gives a 95/5 pulse, this ratio being adjusted by P1. Moving the switch to the right gives a 5/95 pulse from the other end of P3, the ratio adjustment being P2. This is much faster and easier than turning the knob of P3 from one extreme to the other, and reversion to 50/50 pulsing is, of course, automatic.

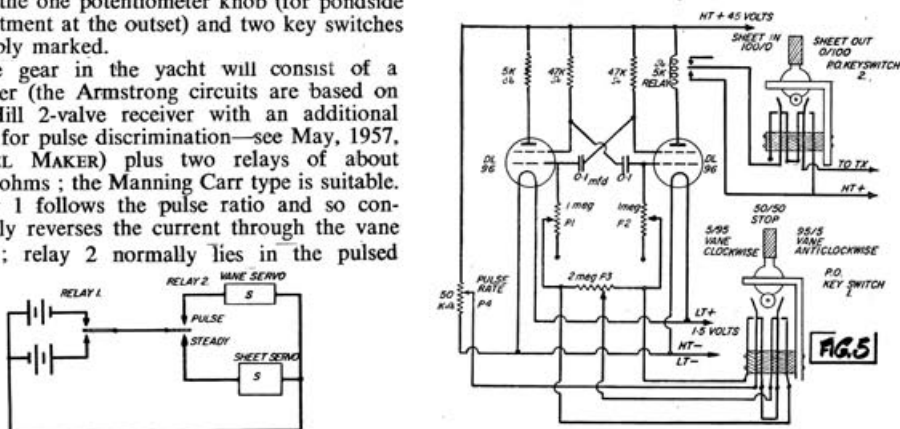
P.O. key switch 2 selects either full off or full on, the central position allowing pulses of whatever ratio key switch 1 decides.

The controller's mechanism, then, simply consists of a box attached to the transmitter with the one potentiometer knob (for pondside adjustment at the outset) and two key switches suitably marked.

The gear in the yacht will consist of a receiver (the Armstrong circuits are based on the Hill 2-valve receiver with an additional valve for pulse discrimination—see May, 1957, MODEL MAKER) plus two relays of about 5,000 ohms; the Manning Carr type is suitable. Relay 1 follows the pulse ratio and so continually reverses the current through the vane servo; relay 2 normally lies in the pulsed

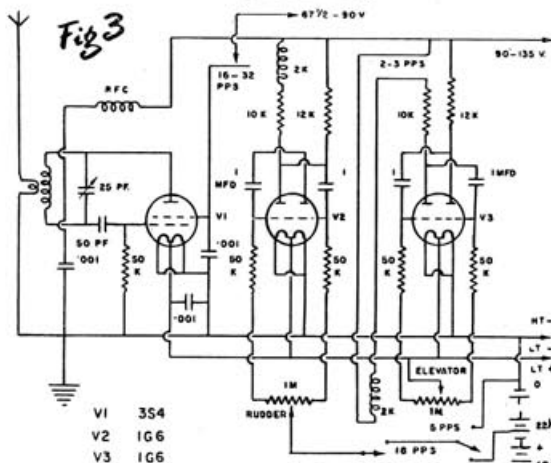
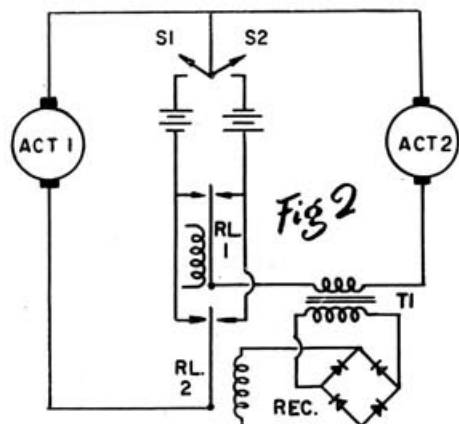
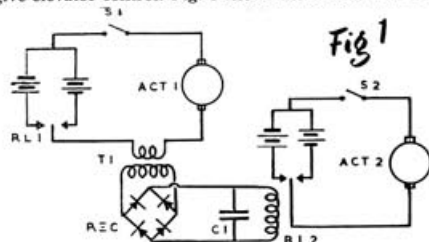
position, i.e. out. With a 50/50 pulse the vane servo will merely dither with the continual current reversal, but will not turn the vane. Any tendency to "creep" is killed by adjustment of the P3 potentiometer on the pulse box. Using key switch 1 will alter the ratio of current passing backwards and forwards in the vane servo, the servo rotating in the direction of the greater ratio. The vane can thus be moved to any position and held.

When key switch 2 is used a steady full or no signal results and relay 2 in the receiver pulls in, switching out the vane servo and switching in the sheet motor. Whichever side the switch is pressed, the sheet motor will move the sheet arm accordingly, and when the key is returned to neutral the sheet arm will stop in that position. It would possibly be necessary to provide stops for the extreme positions of the sheet arm to prevent the servo crank from completing a full revolution and thus creating the possibility of control reversal.



“Galloping Ghost” By Howard Boys

Lately the writer has been experimenting on a modified version of this system with good results. It might also be called a modified version of the "Galloping Ghost", since it does the same things with the same transmitter arrangement. The same pulsing is used with mark space to give proportional rudder, and pulse rate variation to give elevator control. Fig. 1 shows the circuit with RL1



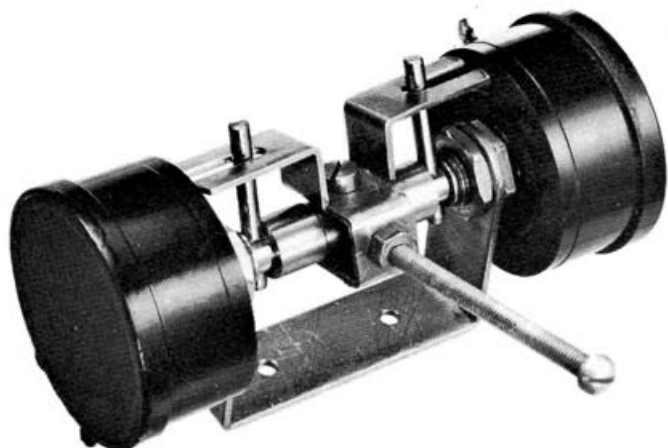
being the normal receiver relay, and Act. 1 the rudder actuator. This can be a magnetic type or a small motor. Every pulse through the actuator sends current through the low resistance winding of the transformer T1, this being a midget radio output transformer. The secondary pulse is rectified by a 5 milliamper meter rectifier REC, and gives a kick to relay 2. The condenser C1 may or may not be desired, 2 mfd. having been used in one case when using Mighty Midget motors which gave best results. The transformer was a standard midget type for use with battery valves such as 3S4, etc. This transformer was not satisfactory with the magnetic actuators favoured by the writer, probably due to the lower current flow, but the writer's motors are old and battered and no longer reliable. Due to the high initial starting current motors are specially suitable for this system. For us with magnetic actuators a government surplus transformer was found with a ratio of about 20 or 30 to 1 which gave good results, though it needed an increase in the actuator battery voltage. Both actuators can be worked from one pair of batteries as shown in Fig. 2. The switches S1 and S2 can be embraced by one double pole type.

To switch the transmitter a Fenner's Pike pulse box was modified. The variable resistance was mounted outside and a small lever added so that it could be varied easily by hand. This meant using one hand for rudder and the other for elevator, which was quite convenient with the switch on the transmitter box. One advantage of using a motor driven switch like this is that it can be heard, and a good impression of the output from the transmitter can therefore be gained.

The scheme evolved by Harry Cuckson was a little more complicated on the transmitter side but seems likely to give better results. The full transmitter diagram is given in Fig. 3. V1 is a 354 or similar valve with switching by means of a relay in the H.T. supply to the screen grid. V2 and V3 are multi-vibrators to give the switching. Rudder and elevator controls are 1 megohm rheostats which vary the switching rates. The relays 2K are 2,000 ohms each. The actual pulsing requires a little explanation. The rudder control is a plain mark/space, of the type that is now fairly well known. The pulse rate of the mark/space is, however, changeable between 16 pulses per second, and 32 n.p.s. This is done by the

A CONTROL BOX FOR PROPORTIONAL RUDDER AND ELEVATOR

By T. IVES

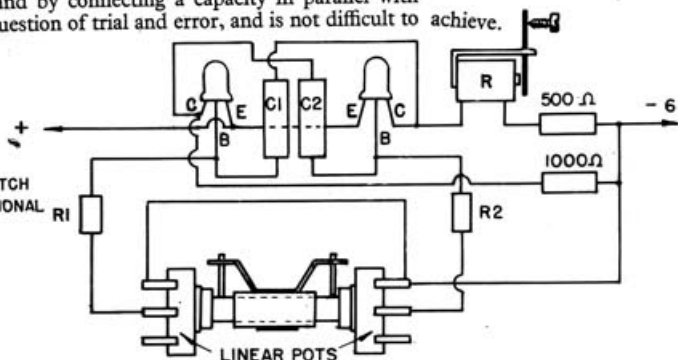
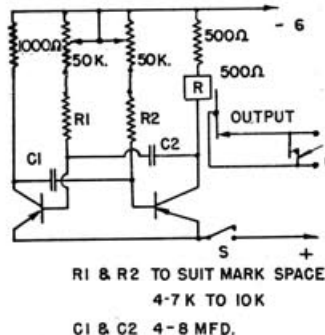


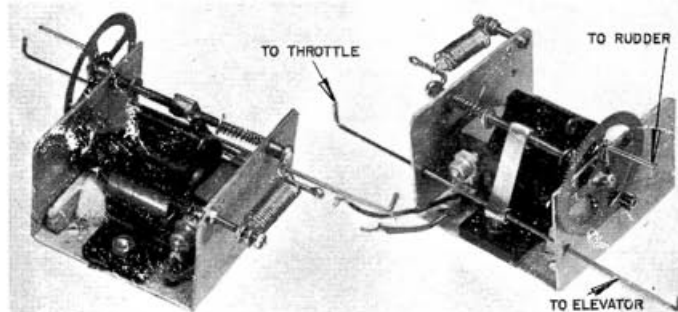
Differential linkage for potentiometers is shown on left. Note the centre sleeve made from brass tubing which is a sliding fit on the two pot. shafts (see diagram). The latter items are drilled to take the steel pins which are a drive fit. It is essential that the pins are a loose fit in the slots of the yoke which can be made from either $\frac{1}{16}$ th sheet brass or mild steel.

The system at first included the conventional arrangement in which one pot. varied the M-S ratio and the other the pulse rate, but trouble was experienced due to the change of M-S when the pulse rate was varied. As the coupling condensers were of the order of 4 to 8 mfd. the question of size became important. Also it was not easy to arrange control stick linkage without gears, which were considered cumbersome, and in the case of the M-S pot. without gears it was necessary to short out a large proportion of the resistance.

The present system makes use of a differential arrangement in which the M-S ratio is varied by moving the two pots. in opposite directions, and for P-R change moving them in the same direction. Due to the fact that both pots. move together a larger change of resistance is obtained for a given movement of the control lever. Also there is no need to use the whole of the track, and one end of each is left unconnected. Provided the transistors are allowed to bottom at all positions the M-S ratio should remain reasonably constant. This can be achieved by keeping the total resistance in the base circuit low enough, and depends on the transistor used. If the collector resistance (which will be about 1,000 ohms) is multiplied by the gain (beta) this should give the approximate limit of base resistance.

Adjustments can be made by loosening the nut of either pot. and rotating it a fraction; by soldering a parallel resistor across either pot.; by varying the resistance of either R1 or R2; and by connecting a capacity in parallel with either of those in circuit. It is a question of trial and error, and is not difficult to achieve.



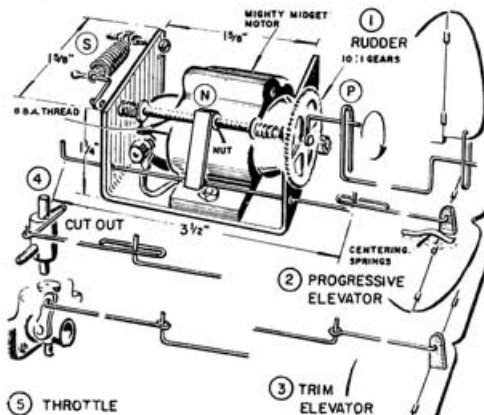


J. C. Hogg's Revmaker servo from front and rear three-quarter views shows how the layshaft is arranged for driving ancillary control for engine or elevators. Provision for seeking a neutral is suggested in sketch below

Two servos for pulse proportional

Multiplicity of servo application for the popular Mighty Midget motor is exemplified by two interesting uses which will be of interest to all radio experimenters. First, one for the mark/space pulse proportional enthusiasts . . .

THE TROUBLE with this flying business is that we are (praise be!) never satisfied, says J. C. Hogg of Parkstone, Dorset. As soon as we have a simple, reliable little receiver working a sturdy escapement rudder we begin to think wistfully about non-sequential systems. The escapement comes out, and in goes a proportional servo operating on mark/space. Ah! if only a spot of elevator control could be obtained—so in goes a "Galloping Ghost". Now, what about some engine control (that last flyaway was grim, especially the spiral-in as she went out of range). In no time at all we are thinking of multichannel audio and boxes of relays . . . But before you pull out that simple RX, try this "Revmaker". It is a servo which goes with any receiver and relay. It will give Proportional Rudder and Progressive Elevator and Engine Cut-out. Or, it will give Proportional Rudder and Progressive Throttle control. In either case when "out of range" the rudder goes neutral and the engine cuts out.

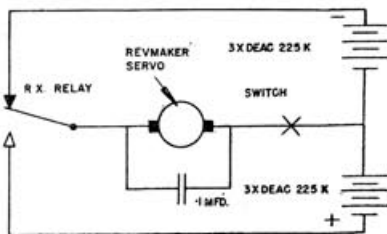


The circuit shows nothing new. The servo can be made from any reliable little motor and drives a threaded shaft via about a 10:1 gear. The pin "P" on the gear wheel operates the rudder via a suitable crank. This must be able to rotate completely (the rudder will waggle when this happens). A nut "N" on the screwed shaft provides the movement for the second function (elevators or throttle).

The first function (steering) operates in a conventional way, responding to mark/space. The gear wheel and crank move in accordance with the ratio, say full rudder left at 80 per cent. mark, rudder central at 50 per cent. and rudder full right at 20 per cent. *BUT* when a full mark is sent the gear will rotate causing the rudder merely to flap and the nut "N" to travel along the screwed shaft. A full space will rotate the gear in the opposite direction and bring the nut back. Short marks (or spaces) will of course "inch" the nut along quite steadily, thus providing a progressively controlled second function. Threads at the ends of the shaft are skimmed down to limit the travel of the nut and springs and washers fitted to help return it on to the shaft.

Four diagrammatic arrangements are sketched for linking up, but there are several other combinations including an additional control which can be obtained by fitting a snap lever or contact at the "mark" end of the screwed rod. It will be seen that a prolonged Space (=out of range) sends the nut up to the "Space" end and cuts the engine, leaving the rudder flapping, and the plane glides down without spiralling-in. Normally, however, with elevator control you centre the nut after cutting the engine and trim it for the glide-in.

Circuit for the Revmaker below with D.E.A.C. cells used to power the popular Mighty Midget



Constructional points

At the transmitter a normal Mark/Space keying device is required, either mechanical or electronic. A button for full Mark and one for full Space is also needed. The spring "S" should be quite light and should not be so strong as to pull the rudder to centre without the aid of the Mark/Space signal. It will pay to experiment with various springs to find the best suited to your motor and gear.

For over a year six small DEAC cells (Type 225 DK) have been used arranged in a block with a centre tap and these have proved ample for the servo. For L.T. another DEAC 225 DK is used. These, with the 22½ v. H.T. (for the AEROMODELLER Transistor Rx) make a compact battery pack. The batteries are fitted in a removable balsa box with a B7G socket which enables the DEACS to be re-charged without disturbing the connections. These batteries still take their charge (17 mA) well.

The main need (as for all R/C motors) is reliable self starting and low stall current. Five different motors have been tried and are satisfactory. The Mighty Midget can be readily adapted using its own gears, but the ratio is rather low for best results in the Revmaker, and a larger gear will improve its operation.

Some interesting flying has been had with the Revmaker and it behaves according to plan. The rudder is steady in action. It is interesting to see it snap back into its previous position after a second function waggle.

Transistors replace relay

Now for a transistor proportional rudder control devised by R. A. Bacon of Woking, whereby the relay is replaced by transistors.

This system was developed from the governor mechanism described by Doug Bolton in the April, 1953, issue. A two-transistor circuit gives a current gain of 400, and has proved to be very reliable. Although no temperature compensation is used, no signs of thermal runaway have occurred after quite a lot of use.

The circuit consists of a direct coupled two stage amplifier, a half mA anode current change in the receiver results in a 200mA current change in the motor. Method of operation is as follows: the Rx standing current of 3.5 mA, say, sets up a voltage of 1.15 v. across R_1 . This is backed off by adjusting the 1 K preset potentiometer so current flowing through R_1 from the 4.5 v. supply in the opposite direction exactly neutralises this voltage. No current flows into the base

of the first transistor therefore and the standing current of the second is 350 mA, thus driving the motor at full speed and pulling on the control rod. When the Rx current drops on signal to say 3 mA, the voltage across R_1 due to this is 0.99 v. resulting in a voltage change of approximately $1.15 - 0.99 = 0.16$ v. thus causing a base current of 48 mA in the first transistor, this is amplified and the output current drops to 150 mA and the motor slows down.

The setting up procedure is simple in the extreme, after adjusting the Rx to give the maximum current drop in the normal way the pre-set potentiometer R_2 is adjusted from its mid position so that the motor is revolving slowly (but reliably) ON SIGNAL and the job is done. To get fully proportional control the transmitter must be pulsed with variable width pulses, of course, a 50/50 pulse giving a mean motor current of 250 mA.

The construction of the governor can be seen from the photograph and consists of four arms of 0.015 in. brass the holes in which are $\frac{1}{8}$ in. centres. The two weights consist of an 8 B.A. bolt, two nuts and two thick washers each and these give ample power to operate the rudder of a Junior 60 against rubber band tensioning.

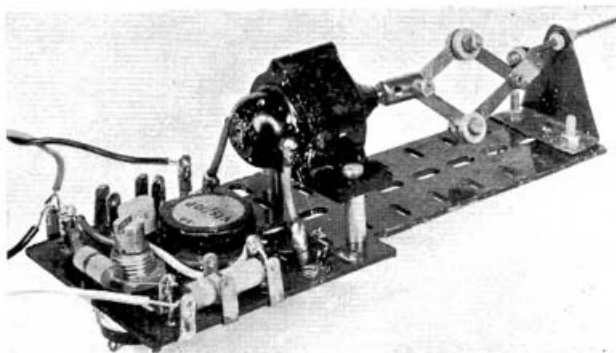
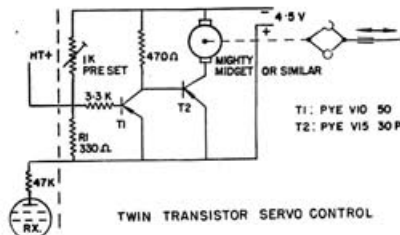
The receiver is an AEROMODELLER No. 1, but if a receiver that gives a rise on signal is being used the adjustment of the pre-set potentiometer R_2 should be made with the SIGNAL OFF, i.e., always with the Rx in the minimum current condition. The pre-set of 1 K gives sufficient range to cover anode current of 3.4 mA to 13 mA. As the anode current of the receiver was about 3.6 mA, this was suitable, but if the circuit is to be used with a receiver that takes less than 3.4 mA, a larger potentiometer should be used, say 2.5 K, which will give a range of 1.6 mA to 13 mA and should cover most requirements.

This booklet is one of many reprint services by AEROMODELLER Consult current Plans Handbook catalogue - price 2s. for full range

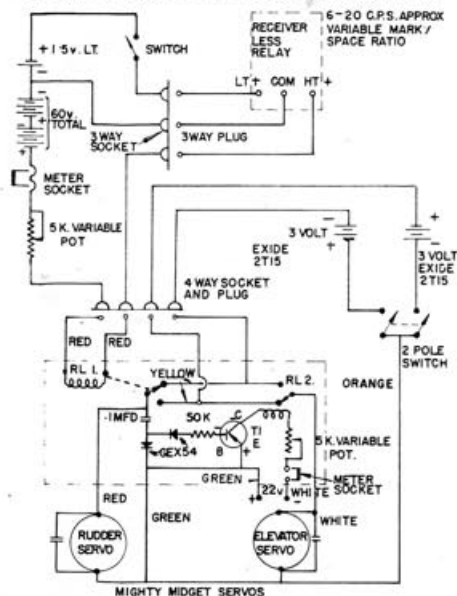
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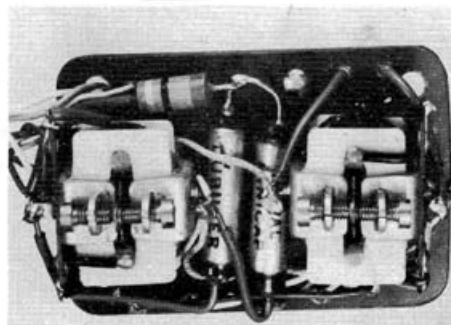
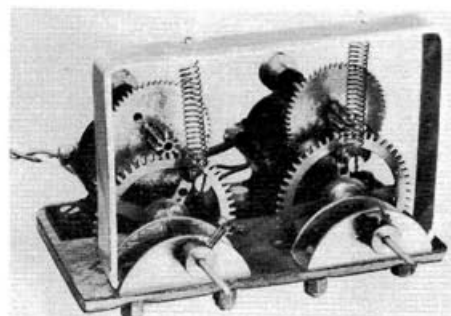
Circuit below as provided by Mr. Bacon for his Transistor servo unit employing flyball modified Mighty Midget as seen in the photograph. System replaces the relay, but tends to rely on too many variables and is an experiment worth noting for future development



CIRCUIT: SINGLE CHANNEL DUAL PROPORTIONAL



Photos show motor and relay units



Sinclair dual proportional

The dual proportional unit was installed in a fast flying 60 in. span model; it has been found completely reliable and the degree of rudder and elevator control is quite remarkable, response being immediate in all flight attitudes. The receiver and relay unit has functioned so reliably that it has not been found necessary to fit any fail to safe units, though this could be achieved by fitting cut-outs in any of the extreme limit positions on the servos. A standard ECC951A receiver (which has been used in about 7 radio models over the past few years) was stripped of its relay. Two E.D. Polarised relays and the rest of the components shown within the lower dotted area are mounted on a small paxolin chassis 2½ x 2 in., layout of components not being critical. Operation is via transmitter pulse box, a Mighty Midget motor driving a set of contacts and made to give a variable Mark Space (Rudder Control) motor speed via a 20 Ohm resistor (elevator control).

As can be seen, the rudder servo responds to M/S ratio via relay 1, but when the contacts of relay 1 change over, the pulses are fed via the .1 mfd. condenser and 50K fixed resistor to form a time constant circuit. Thus each time the rudder relay changes over, a pulse of a definite time is fed into the coil of relay 2 (elevator relay) and thus another independent M/S ratio is formed. The diodes used to prevent the wrong polarity on the transistor are GEX 54, but any similar type would be suitable also the transistor used in an (OC 71) but any suitable type could be used. The best method of finding the correct time constant circuit is to substitute a variable pot in place of the 50K fixed resistor and adjusting until an acceptable value is obtained.

The circuit shown does not operate from the back S.W.F. or either the relay or the rudder servo motor (the capacitor across the rudder servo motor would cancel such an S.W.F.). This pulse-rate discriminator is the well known diode-pump circuit and in this case is deriving its signal from the alternating voltages which are created by the successive connections of the contacts of Relay 1 to the 3-volt batteries, one of which gives a positive voltage with respect to earth, and the other a negative.

When the contact of Relay 1 moves to the lower position, the positive battery is connected and the polarity is such that the left-hand diode then conducts and the .1 mfd. capacitor becomes charged quickly (since the forward resistance of that diode should be small) to 3 volts with the lower plate negative with respect to the one connected to the relay arm. When the relay arm releases to the upper position, this capacitor is connected to the -3 volt battery which means that instantaneously the lower plate is now at -6 volts relative to earth (i.e. battery centre tap). The left hand diode blocks but the right hand diode is connected in the sense that it now conducts. While the relay contact remains in this position the capacitor discharges through the 50 K resistor and the base of the transistor, making the latter conductive so that Relay 2 is then operated. Relay 2 stays operate: until the capacitor has become discharged to the extent that the current flow through the second diode has become so low that the transistor will not pass enough current to maintain the relay. At some later time, the next pulse operates Relay 1 and the cycle begins again.

It will be seen from the above explanation that it is important that the time constant of the .1 mfd. capacitor and the 50 K resistor (together with the forward resistance of the second diode and the base emitter resistance of the transistor) be less than the minimum time for which Relay 1 may be held into a "mark" situation. If this is not complied with, then the rudder control signals will tend to alter elevator in addition. These time constants therefore should be carefully chosen for the range of pulse rate variations used by the pulse generator connected to the transmitter. It also shows how important it is to "re-tune" the circuit should Relay 2 or the transistor characteristic change, and users should be warned to check their circuits for susceptibility to temperature variations. Such variations do not always matter much in a proportional system since the operator makes unconscious corrections to the stick according to aeroplane behaviour, but if some of the circuit characteristics, such as that of the relay, are marginal, sudden changes could occur.

Neutral.