PROPO PRIMER

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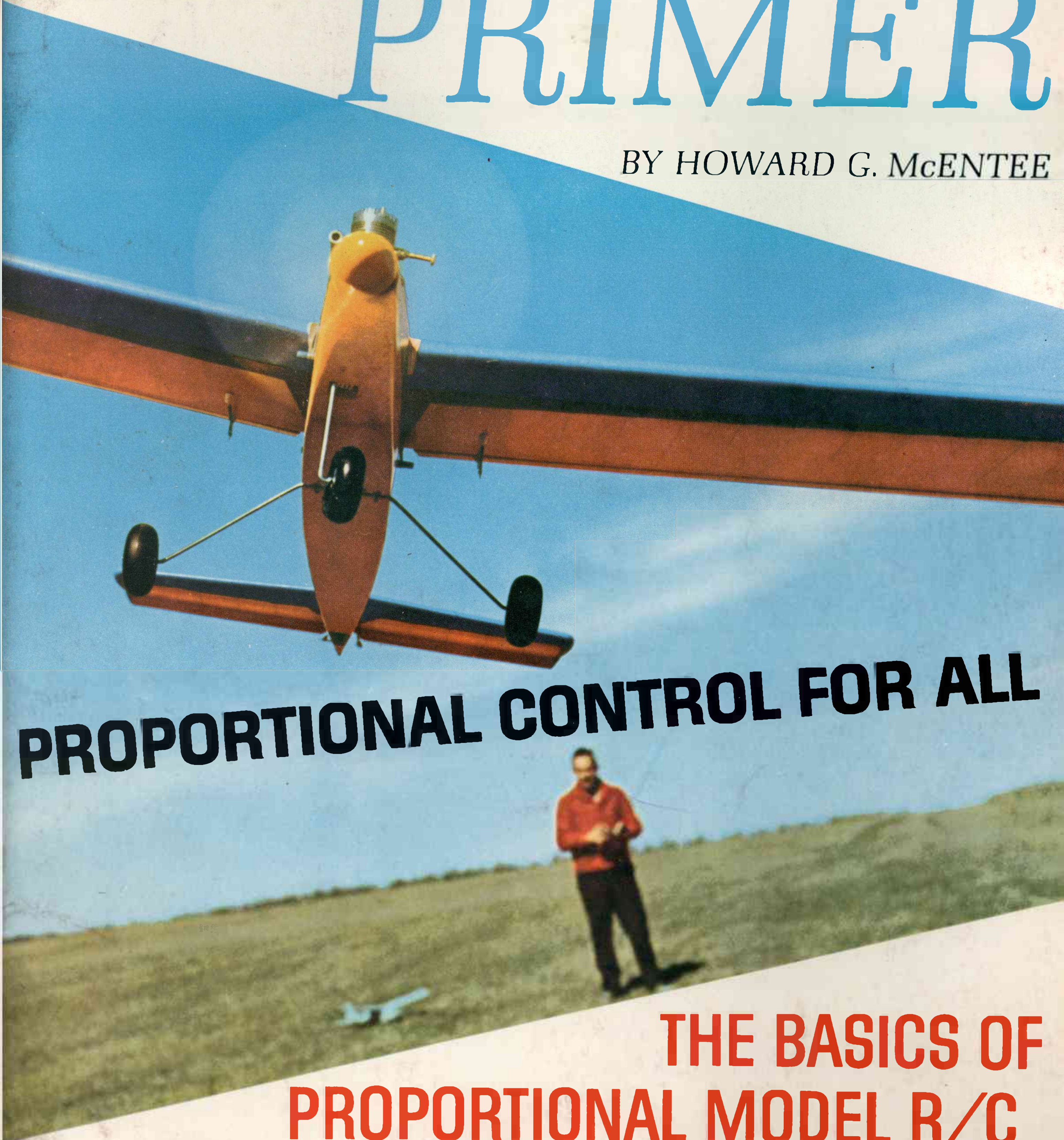
BY HOWARD G. McENTEE



PROPORTIONAL CONTROL FOR ALL

THE BASICS OF PROPORTIONAL MODEL R/C ...FROM SIMPLE TO COMPLEX

COVER PHOTO by A. L. Schmidt: Ken Seeling of Milwaukee, a member of the MARKS, uses a Kraft radio system to fly a Senior Falcon with an OS 49 engine.

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PREFACE

Proportional is a rapidly expanding form of radio control, and this volume is intended to give those with little or no knowledge of this specialty some idea of what it's all about. My earlier book R/C PRIMER was written to give those with scant knowledge of R/C, or even of model planes, an idea of what it is and how it works, to help in selecting equipment, to offer hints on installation, testing, and maintenance. So I also envision this new book. In order to devote maximum space to proportional, I have omitted much of the more general material pertaining to R/C — discussion of the radio frequency spectrum, licensing matters, competition requirements and rules, and so on. All these are covered in R/C PRIMER; hence I feel PROPO PRIMER should be considered a sequel and adjunct to my earlier work. A study of the two should give the newcomer to our hobby a good grounding in the field of model radio control, and considerable information on the fast-growing specialty of proportional operation.

You will find no "how to build" information here; no confusing circuit diagrams of complex equipment. I have included only a few circuits of the most elementary nature to show how some of the simplest apparatus is wired up, but many sketches to help explain how some of our equipment works and how to install it properly.

Thus, if you want to know the differences between analog and digital proportional, what Galloping Ghost is, whether you can operate a certain style of proportional actuator from a certain type of receiver, you can doubtless find the answer here. On the other hand, if you wish to know how to fill out the necessary R/C license forms, what controls are allowed in competition radio planes, or how to link up your engine throttle, you can obtain the necessary guidance in R/C PRIMER.

I strongly feel proportional control has expanded to such an amazing degree that a book devoted to its special needs and problems is very necessary today. Equally necessary, though, is a book covering the wider aspects of model radio control in general — and we already have such a book in R/C PRIMER. So study the two of them for a grounding in R/C fundamentals, and in the latest craze to sweep the field — proportional radio control!

Howard G. McEntee

1: WHAT IS PROPORTIONAL CONTROL?

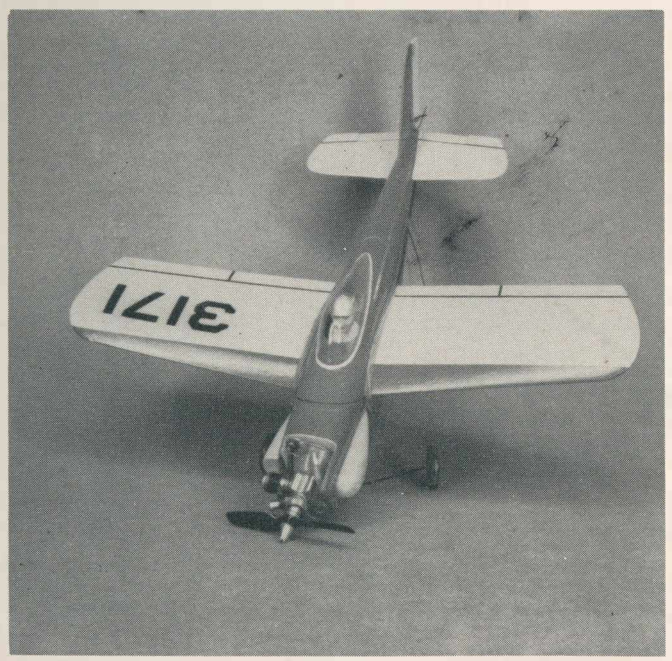
ONE can hear the query, "Why a book devoted entirely to proportional, when this is just one facet of the very wide field of radio control?" Good question! But the answer is simple. Proportional is rapidly becoming the predominant form of R/C, not only in multicontrol models, but in the simpler types right down to rudder-only. The modelbuilder is faced with a baffling array of systems, makes, equipment variations, and so on. Trying to sort this out, when one has a very meager knowledge of R/C in general, can be an almost impossible task, and might even convince the fledgling R/Cer that this field is just too much for him to try and tackle! It is the aim of this book to dispel the confusion, to show basic differences between control systems and components. A modeler who has read these chapters will very definitely *not* know all there is to know about proportional, but he will have a good basic foundation upon which to decide what's best for his needs — and his pocketbook.

The proportional "takeover" has astounded even those (like the writer) who have been advocating this form of R/C for years — often to the kidding from some of those who are now avid fliers (and in some cases, successful manufacturers) of proportional equipment themselves. Proportional flying is certainly not new. I can't tell you who started it, but it's known that the Germans steered glide bombs to their targets with simple proportional controls early in World War II. Also during that war, patents on proportional systems and servos were granted to that avid modelbuilder, flier, and manufacturer, the late Jim Walker. During the course of this book I will mention some of the pioneers of proportional control, but others who may have done much to develop it might be passed over simply because they have never come forward to receive their rightful share of whatever "glory" accrues to modeling pioneers.

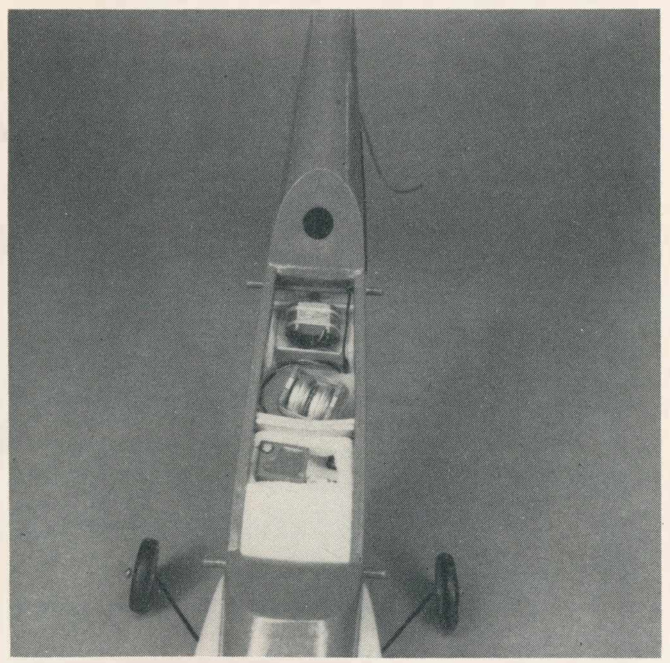
We hear the question, "Is proportional the system for the beginner in R/C?" Not too many years ago this would have had to take a very qualified, or even negative, answer; for, while proportional has been flown very successfully for years past by the expert modelers, there was so little equipment on the market that you simply had to make your own. Most of those taking up R/C just hadn't the knowledge nor the skill to do this, or to keep the equipment in good operating condition. Result: the escapement dominated the field of simple control systems, while reeds held sway in multicontrol. All this is now changed — we have plenty of good proportional R/C gear, accessories, components, complete systems, both simple and complex. So it comes down to the point of guiding the beginner in R/C to a proportional system that will fit his personal needs.

System comparisons

We'll go into more of the details of just how proportional control is obtained in later chapters, but to discuss comparisons with other systems we need to show what can be obtained from proportional. There is some debate as to where the term "proportional control" came from in the first place. I like to think of it in the sense that a control surface on your model — say, the rudder — will follow in exact proportion the movement of the control stick on your transmitter. If you allow the stick to remain in neutral (or center position), the rudder will hold neutral. Other control systems do this too, of course, as neutral is the basic starting point for all surface movement. *But* escapement or reed systems cannot provide an infinite number of positions to either side of neutral (though a very skilled



American Aircraft Modeler.
Tiny 12½"-span semiscale plane weighs 3 ounces; is powered by restricted Cox .01 engine and steered by propo rudder.

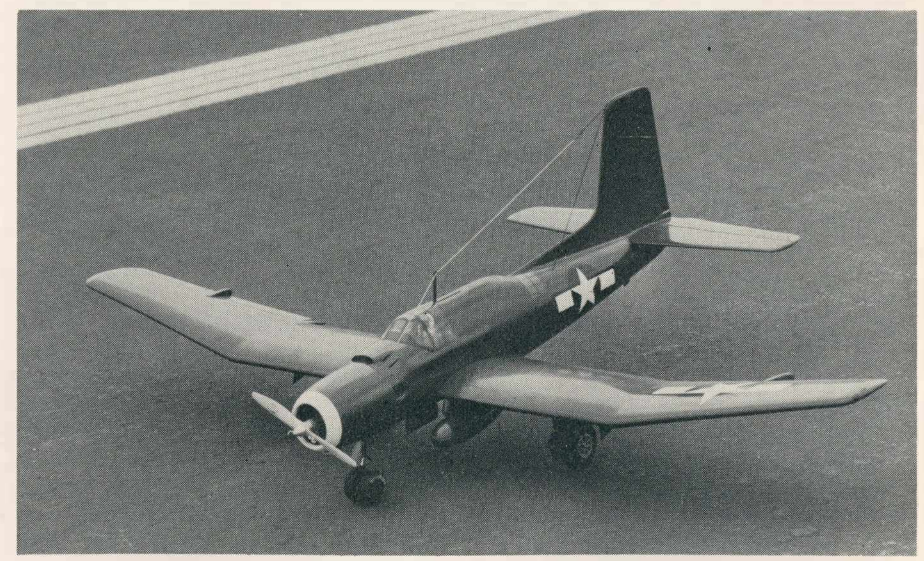


American Aircraft Modeler.
German .1-ounce receiver is almost lost in forward compartment; two 1½-volt cells in holder are next; actuator is at rear.

American Aircraft Modeler.
Claude McCullough adjusts his fine Scale Douglas XTB 2D-1 at AMA Nationals, above; Bud Atkinson (left) and Maxey Hester hold it aloft. Plane won 1965 event; has Merco .61 engine, Bonner propo. Front view below.

flier may make them appear to do so). Thus, if you move your proportional stick just a little to the right, the rudder also goes just a bit in the same direction. If you move the stick half left, the rudder follows immediately and holds there till you again move the stick. Rudder movement in a good proportional system follows stick movement exactly in degree and direction. A beginner finds it natural to move the stick in the direction he wants the model to turn, and though it is easy to overcontrol at first, it is very difficult to forget entirely what control you need to apply to turn the plane in a given direction.

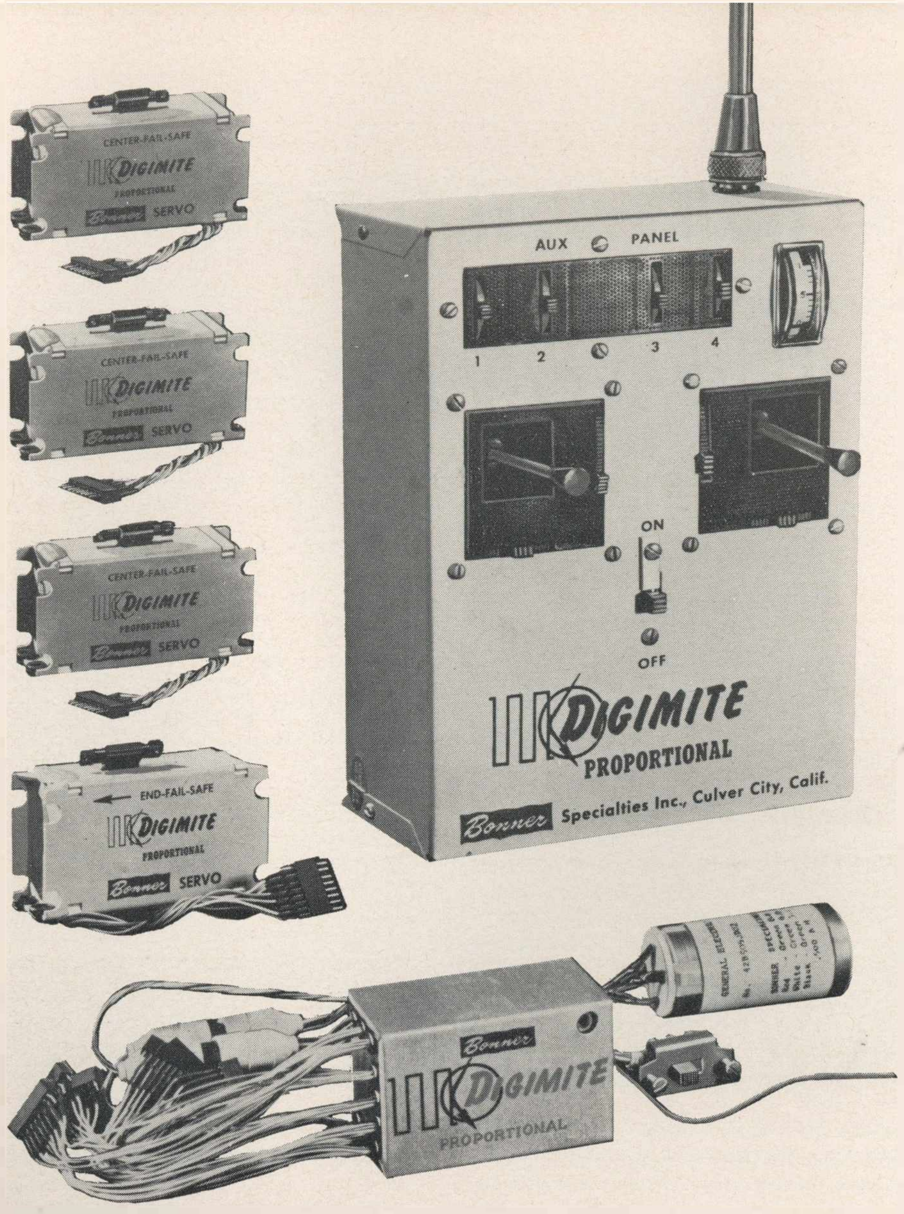
There is really no correlation at all between the number of punches you must give a button on the transmitter, and the turning direction you will get from an escapement plane. With some types of escapement you also have to remember which turn you gave last, since the next button punch will give an opposite turn. True, the art of escapement flying can be learned, but often only the hard way. By the time he has gone through several crashes due to forgetting how many times to punch the button, the novice R/Cer may likely decide he's had enough of



American Aircraft Modeler.

this so-called sport. (The required sequence is not so tough to remember when the plane is high in the air and flying along peacefully — but it's very easy to forget when the model is performing some wild gyration near the ground or some tall trees!)

Escapements are rather delicate units, prone to malfunction when subjected to engine vibration; they often "stick" in a turn position, or skip through such position. One must always remember to wind the rubber before it "runs down" — and con-



Bonner eight-control propo system (only four servos are shown here) was used in the McCullough plane on page 3; this system is favored for Scale R/C work due to the many extra channels that are available.

versely, try not to overwind it, which can be just as disastrous. Now, escapements are not passé by any means, and will doubtless be around for a long time. They do have such advantages as allowing overall system simplicity and low cost, light weight, low battery drain. However, I still contend that simple proportional systems offer much more precision of control for the better flier, much more ease of learning for the beginner.

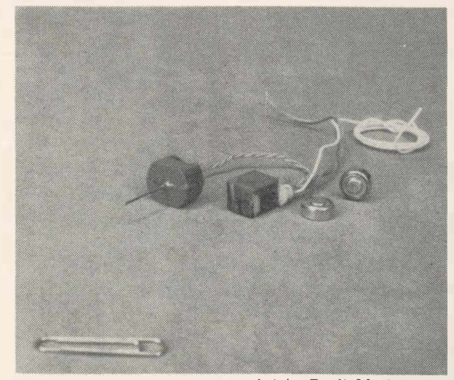
Some of the shortcomings of escapements are being overcome by the growing popularity of electric motor-driven servos that generally require the same button-pressing technique at the transmitter but are much more powerful and eliminate the troublesome rubber band. Such servos are still all-or-nothing control units, however; the control surface is either at center or full over to one side. They cannot in any way match the versatility of even the simplest rudder-only proportional.

When we enter the field of reed multicontrols, the picture becomes clouded by many more considerations. But reeds, too, are basically a neutral or full-over control system. Reeds reached their great peak of popularity in the multi field simply because they offered a relatively simple way (both technically and from a manufacturing standpoint) of adding more and more control functions to a model as the better fliers demanded them. The basic receiver for a 12-channel reed system is almost identical to that for 2 channels (2 channels being required to produce right and left rudder, for example). The main difference is in the number of reeds needed to accommodate the desired number of controls. As these controls increase, more reeds and servos are added. The early proportional systems did not allow this; single-control proportional gave satisfactory rudder action, and it wasn't too difficult to add one more control — elevator, for example. Beyond this, things got tough; and there just were not enough experimenters in the field to solve the problem quickly, nor enough manufacturers who would forsake the lucrative sale of reed equipment to try to work out the multi proportional difficulties.

In the hands of a very experienced flier, reed systems can be made to fly like proportional — smooth, no sudden jerks nor dips, gentle or sharp turns as desired. But this skill doesn't come easily; the thumbs of a good reed pilot are constantly in motion as he manipulates the many levers projecting from his transmitter. Such fliers are often said to have "nervous thumbs," and good, smooth reed flying has been called "nervous proportional"!

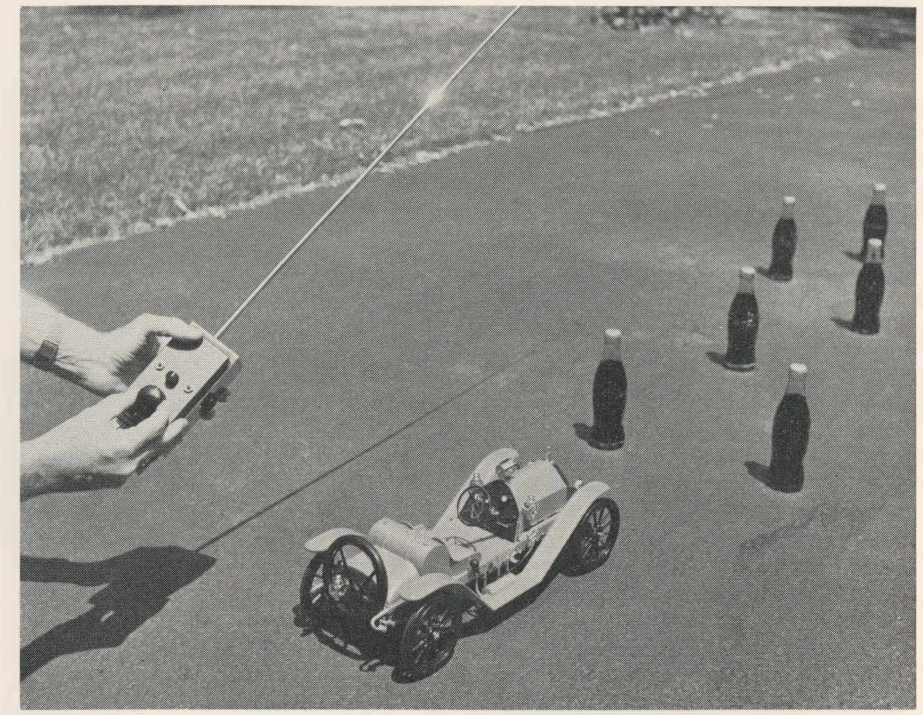
Multi reed systems are somewhat less expensive than proportional systems of like number of control functions; they are basically rather simple both electrically and mechanically, and the average flier can maintain them and even make repairs as needed. They are certainly highly reliable, fairly compact, not too greedy in power requirements. Why, then, the big takeover of multi proportional? Part of it is undoubtedly "glamour." Here is a "brand new" kind of control system reputed to be much better than reeds. But the real virtue of multi proportional is the same as in its simpler varieties — you get absolute smoothness in maneuvers, and even a very average pilot can do it long before he could learn the niceties of good "nervous proportional." Multi proportional also allows proportional throttle control, something you just don't have with reeds. It allows in-flight trim of *every* control surface (in many commercial systems), never available in reeds, since it would mean far too many servos to fit in a plane. It is thus far more versatile, and much closer to the kind of control a pilot can exercise over a full-size plane. No wonder, then, that the expert fliers today predominantly fly proportional, with reeds relegated to the status of a "low cost" multi system, more suited to the novice and sport flier than to the hotshot.

Multi proportional equipment decidedly isn't something you can tune up or repair in your cellar workshop. Trouble of any sort almost always means sending the entire outfit back to the manufacturer. This can be time-consuming and expensive, as such shipments are generally made by air express, often the full width of the country; and impatient model fliers hate to be "grounded." Several makers have set up repair facilities in



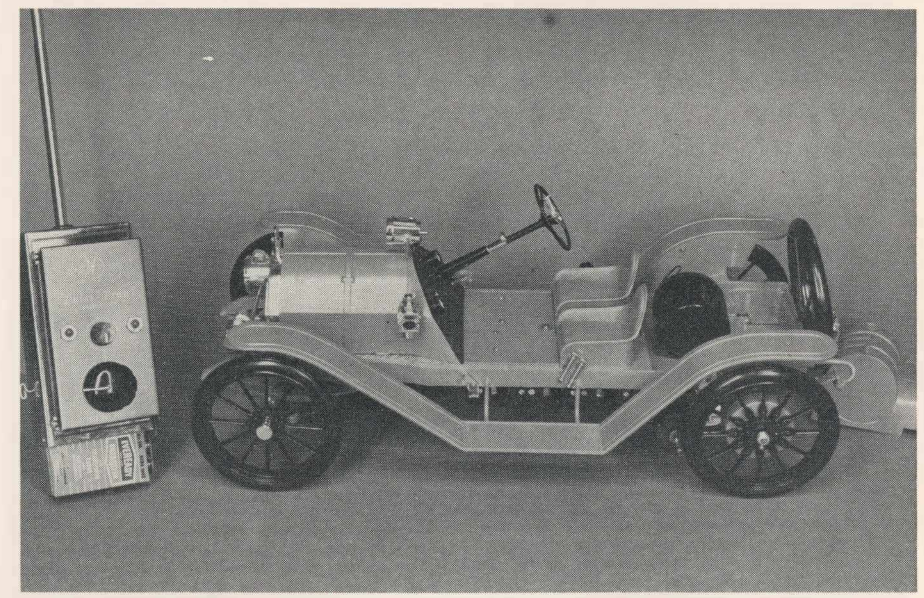
Aristo-Craft Miniatures.

German Bentert submin propo equipment used in plane on page 2 totals .6 ounce!



American Aircraft Modeler.

Model Mercer antique car is steered through a course marked by pop bottles; proportional steering allows precise control. Small hand-held transmitter has a Cannon pulser attached to the front; the large knob steers; the small one is for trim.



American Aircraft Modeler.

cities remote from their factories to cut down on the time and shipping expense of repairs. More will doubtless follow suit. Again, some manufacturers are much more prompt in making repairs and returning the outfit to the owner than others; the laggards in this respect are pretty well known to the model fraternity, and prospective purchasers might inquire among local fliers and hobby shops, if possible, before plunking down hard-earned cash for any particular make.

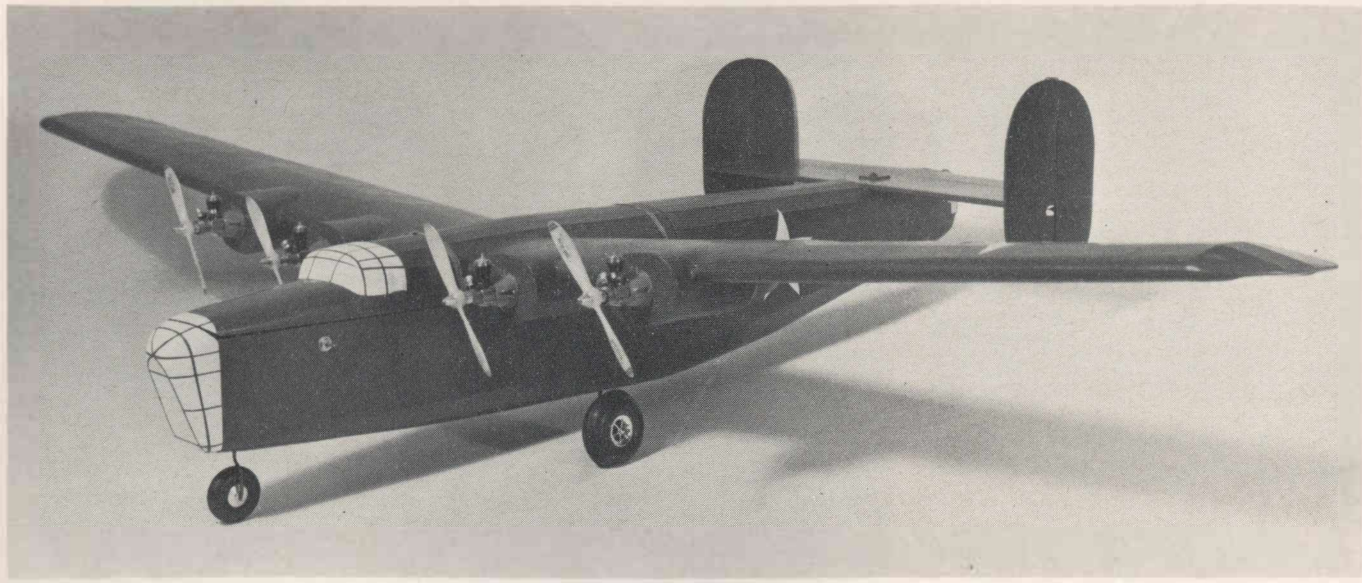
Relative power drains

With the advent of nickel-cadmium batteries, power drain is a much less vital matter than it was when all we had were flashlight cells and radio batteries to power our equipment. However, there is a considerable difference among various control systems, both simple and multi. Transmitter current drain isn't too important, and this drain doesn't vary anywhere near as much as does that in the model itself. A system that has a high average current drain requires larger, heavier, and generally more expensive batteries; the extra weight makes the plane fly faster and land harder.

In the simple control systems, for a given amount of twisting power at the rudder, the motorized escapement style of servo is probably the most economical; at neutral (and after reaching a control position) it draws no power at all, so if you don't continually punch the transmitter button, the average power drain in the model is very low. Escapements are in the same category, but often draw considerably more power than their motorized cousins. The simplest proportional systems require a constant current drain from the model batteries, and — while this can be fairly low — since it *is* constant, the average is definitely higher than for such on-or-off systems as escapements. This means the simpler proportional systems often take more power and require larger batteries than the more complex.

In the multi field, reeds are very economical, for here, again, if you don't signal a control, the servos require little power. Some of the simpler multi proportional systems utilize spring-centered servos (often called "wiggle type" proportional), as do the most elementary proportional systems (differences explained in later chapters), calling for a rather constant current drain and relatively large power supply. The more advanced multi proportional setups utilize "feedback" servos, a design that takes very little power unless it is actually moving from one position to another. The latter systems, therefore, can use battery packs of about the same size and weight as do the reed systems.

I have tried to simplify things as much as possible here, and many of the more subtle differences and comparisons between systems have been omitted; but the basic general differences noted, plus the more detailed descriptions that follow, should give the novice R/C modeler a good background upon which to base his equipment purchases.



American Aircraft Modeler

Semiscale Liberator by Frank Baker has four .02 engines, propo rudder. The 44-ounce plane has a wing span of 60″, is a fine flier.

2: SIMPLEST PROPORTIONAL SYSTEMS

PROPORTIONAL control systems can be extremely complicated, but they can also be amazingly simple. I'll cover the simplest in this chapter; we can get complicated later! Unlike escapement and reed systems, which send out a control tone only when you want to *move* that control, all proportional systems send a continuous stream of tones, or pulses, varying in many ways according to the needs of the system. Simple proportional generally entails a string of on and off tone pulses. Equal-length pulses produce neutral, or centered servo — and centered control surface; long pulses (or in some setups a solid on-tone) give one extreme, while short pulses (or no tone at all) give the other extreme. An infinite range of pulses, from full on to full off, therefore allows you to position the surface at any angle from neutral, and in either direction, that you require. A look at fig. 2-1 will show what the pulses look like in simple graphic form.

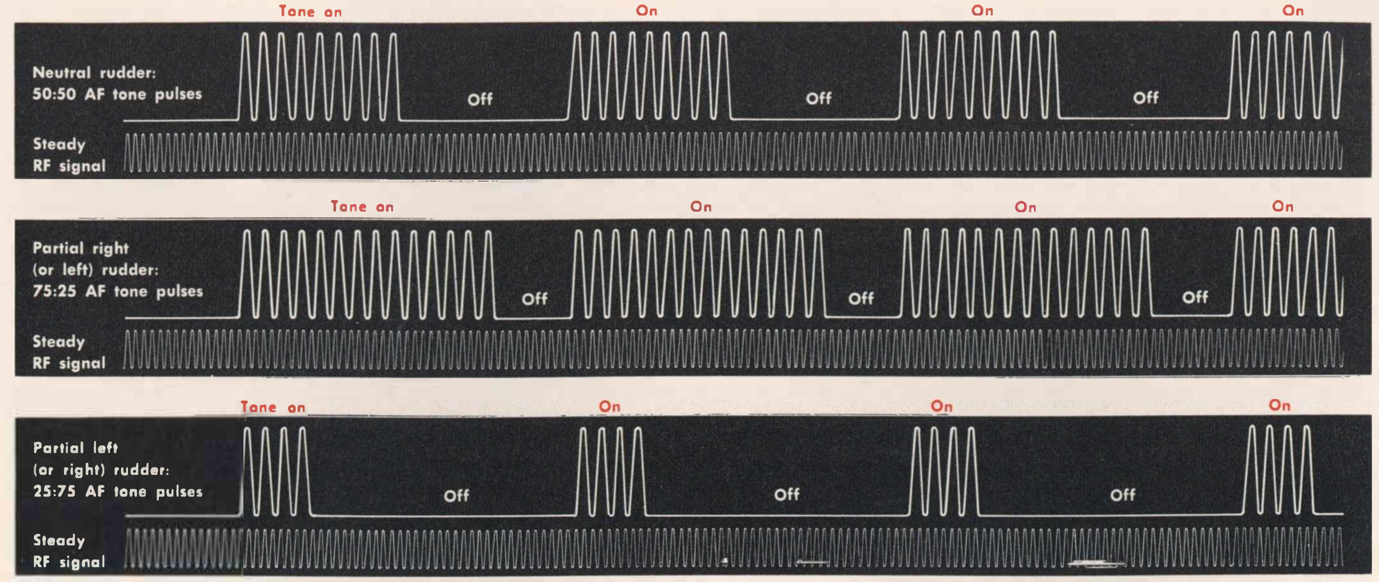
I must explain here that all of the simpler control systems send out a steady signal *at all times*; this is the so-called RF carrier, and is equivalent to what a broadcast-band station transmits all the time it's on the air, but when you hear no voices or music on the BC channel. In R/C it was not always this way, but by sending out a steady carrier or RF signal, then impressing on top of this the audio tone, we gain greatly in sensitivity; and even more important, we gain in reducing the effects of interference. When any R/C receiver — either superregen or superhet — is receiving a strong steady RF signal, it automatically greatly reduces its sensitivity. Thus an interfering signal has much less chance of disturbing it. Some of the more complex multi proportional systems do not actually use tone modulation, but the end result sounds much the same.

In fig. 2-1 we therefore show a steady signal with each line of pulses to represent the RF carrier (27, 50, 72 mc., whichever R/C spot you are transmitting on), and the actual pulses are indicated in pulse form above this RF signal (also known as CW—meaning Continuous Wave). It should be understood that the RF carrier is of relatively high frequency; on 27 megacycles there are actually 27 million signal variations (cycles) per second. Compare this to our household lighting current, which has only 60 cycles per second. Those 27 million cycles are far too high to hear, of course; the receiver interprets them as a solid signal tuned to its exact frequency, but these particular cycles or voltage variations do not constitute our control pulse signals — they just *convey* the pulses through space from the transmitting antenna to the receiver antenna.

Superimposed upon the 27-mc. carrier comes our tone; generally in R/C work this is in the range from about 300 to 1000 cycles, with a few much higher than this (4000 cycles or even more). These tones you can definitely hear — after they have been run through what is called a "detector" in the receiver. Superimposed upon this audible tone are our pulses, which are transmitted at a still lower number of cycles — in simple pulse systems from perhaps 3 to 20 pulses per second.

The vast difference in the number of cycles between the RF carrier, the audio modulation, and the control pulses keeps the three from interfering in any way with each other. This wide separation has been chosen for just that reason.

Now, getting back to our pulse pictures, note that the top line shows even on and off pulses (superimposed upon the pulses are vertical zigzags to indicate that each control pulse is made up of a number of tone pulses — actually many more than our artist can draw in the space). Directly beneath the control pulses we see the solid carrier line composed of far too many pulses to draw individually. Equal on and off gives us neutral control; or, let's say, the rudder is centered and the plane flies straight (provided it's balanced and trimmed correctly!). Going to the next line we find long on and short off pulses, which might be right rudder. (The system could just as well be set up to give left with long pulses.) Still farther down we come to a line of short pulses, which produce opposite rudder. Some simple pulse systems are set up to give full-on and full-off



2-1 Audio pulses for neutral, long, and short proportional signals. In each case there is always a steady RF signal.

modulation, which allows the maximum control movement (and power at the control surface) to steer the plane. This is quite possible and even desirable in planes which have only pulse rudder; if motor control is to be added, however, we cannot in some cases go full on and off for normal steering, for reasons to be explained later in this chapter.

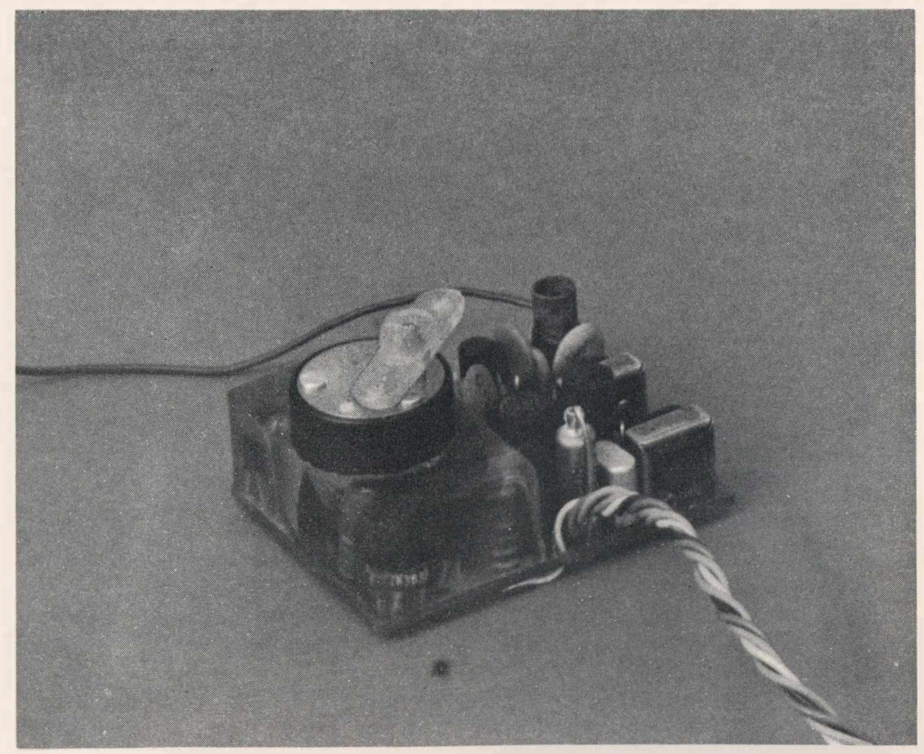
Note that under each line of pulses we always find the same solid line of RF carrier, and also that each pulse (and the solid on signal) is composed of the same-length *audio* pulses. The long pulses have more zigzags of audio because these pulses are of greater time length.

Rudder-only

The simplest form of proportional control allows us to move just the rudder of a model — but amazing things can be done with a rudder plane. A good flier with a responsive plane can accomplish perfect ROG (Rise Off Ground) takeoffs, loops, rolls, spins, and many combinations. He can also keep the plane from climbing too fast when heading into the wind, or even make it descend if desired. There have been some top R/C contest fliers who scorned more controls than rudder; they felt it's a bigger challenge to make a plane perform complex maneuvers with simply rudder (they all use motor control, too, which makes such a plane even more stuntable) than is the case when you have a "full house" system—rudder, elevator, ailerons, motor throttle — and possibly ground steering, brakes, and so on. Of course there must be some compromises in the stunt maneuvers of a rudder plane, but I mention these facts to show that you can do much more with a simple rudder plane than just gentle turns in the sky.

Because it does allow such a wide variety of control actions, single-control planes almost invariably have rudder. Some experimenters have tried using only ailerons (the two ailerons, one on each wing, are considered to be a "single" control, but good turn action in either direction has been demonstrated with only a single aileron), and this does allow smoother accomplishment of a few stunts, such as rolls. It simply is not as versatile, though, as just a rudder, and the necessary linkage is considerably more complex.

Installation of a rudder system in a model is very simple, and to make it even more so, hobby shops today stock "package systems" that include transmitter, receiver, servo, and all the small items needed for such installation. You can even purchase a finished and ready-to-fly model plane with such controls installed. The same thing is available in multicontrols — but at far higher cost, naturally. The widest variety of equipment is to be had individually, of course; and it is



Compact relayless superregen and motor-driven servo by Airtrol makes light and handy single-unit rudder installation for very small planes.

one of the intents of this book to reduce some of the bewilderment of a beginner in R/C who enters a well-stocked hobby shop and simply doesn't know what he should buy. If they will fit his particular needs, size of model, and pocketbook, I can recommend the package deals, as they include units that are completely compatible with each other. You cannot, of course, operate just any receiver with any transmitter, or with just any proportional actuator. The pulser in the transmitter has to match the receiver servo in a general way — even more so if you wish to include throttle control.

Some receiver-servo combinations require separate batteries; with others you can use the same batteries for both. All these matters have been figured out in advance for a complete R/C package proportional system.

Types of actuators

What moves the rudder? Well, in proportional, the unit is generally termed either an actuator or a servo. Some years ago, "actuator" was used only for an electromagnetically operated steering device, as opposed to one that employed an electric motor. Now the terms are pretty generally scrambled, but in fact most control surface movers today are just lumped under the single term of "servo" — except, of course, for the escapement. So "servo" can mean almost anything that operates a control, whereas "actuator" generally refers specifically to a proportional servo, and even more specifically to a magnetic (not motor-driven) unit. The control movers in multi proportional systems, as in multi reed systems, are always called just servos.

Magnetic actuators are the simplest, and while they do not have as much power as motor-driven units, they do have special advantages of their own. They are suited for models from the very smallest up to those flying with engines of perhaps .19 size; there are exceptions, as always, and larger planes *have* been flown with magnetic units, but the higher power of motor-driven servos is generally required.

There are two main varieties of magnetic actuators, and you can buy examples of both in various sizes. One style, seen in fig. 2-2, is sometimes termed the "no-iron" actuator, or the Trammell type (recognizing R/Cer George Trammell, who popularized this variety). Actually, it does have iron in it in the form of a small permanent magnet, usually of rectangular shape; fastened to the shaft, it has a limited degree of rotation inside a plastic (or nonmagnetic metal) form upon which is wound one or more coils of wire. The actuator in fig. 2-3 has four terminals, since there are two windings, both ends of each being brought out separately. This allows several different forms of connection to the receiver and the necessary batteries.

Magnetic actuators can steer a model because of the attraction between the pivoted internal bar magnet and the magnetic field produced by current in the coils. The direction of output shaft movement is dependent upon "polarization" of the coil — that is, which end of it goes to battery minus and which to plus. Reversing connections reverses shaft rotation but doesn't change the force available to turn the rudder. Remember this if you hook up the equipment in your model and then find the rudder goes the opposite direction from the motion of the transmitter control stick.

The Trammell-style actuator normally has no centering action. By centering, I mean the tendency for the actuator to return to neutral — also neutralizing the rudder — when current is cut off. Actually, centering isn't vitally important, but it does tend to make the system a little more stable and to prevent drift off neutral while you are flying. Centering is very simple to apply to this sort of actuator; all you need is a tiny permanent bar magnet. Just hold it against the actuator case on the side opposite the shaft (see fig. 2-4) and you will note how the servo and rudder can be brought to center, or even be held a little to one side if you wish. Heavy centering is not desirable; put the magnet just close enough to reliably bring the rudder to neutral when it is deflected to either side. The magnet can be held at this spacing with a balsa strip, and can be taped permanently in place.

Magnetic centering of this sort is much more satisfactory than to force the linkage back to neutral with a spring or rubber band. First, it's much simpler and has no "moving" parts. Even more important, centering is the strongest exactly *at* center, and grows less as you get out toward extremes. This is just what we want, for at extremes the airflow over the rudder will tend to force it back toward neutral. Spring centering increases as you go to extremes, and thus robs power that could better be utilized for holding the rudder deflected against the heavy air pressure. Unfortunately, magnetic centering of this sort cannot be applied to motor-driven proportional servos very well; but, fortunately, such servos have enough power to overcome spring centering.

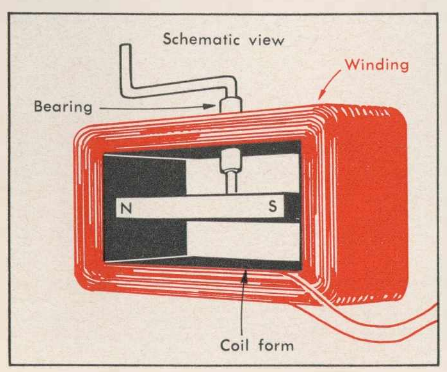
Polepiece actuators

For want of a better name, I'll call the other actuator design the "polepiece" style, for, in addition to a rotating magnet, there are also iron poles; and the coils are wound on an iron core clamped between extensions of these poles. Such actuators are considerably more efficient and powerful than the no-iron units, but they are also often heavier. They are in wide use, however, and both types can be had in hobby shops.

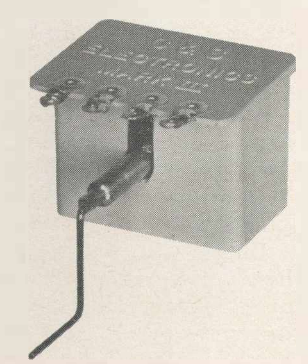
General construction of the Adams unit is seen in fig. 2-5. The rotor disk is magnetized across the face so that the north pole is on one edge and the south is on the opposite edge. Semicircular iron pieces carry magnetic flux from the windings to the disk. Though such actuators can be designed to have quite strong built-in magnetic centering, the Adams units have none, presumably to obtain more power at the rudder. Many fliers doubtless utilize them without any centering; if a rubber band or spring is used for the purpose, it should exert only *very* light tension.

For those who require more power, Adams makes a dual unit which has two disk magnets, seen in fig. 2-6. It weighs a bit more, but is also considerably more potent.

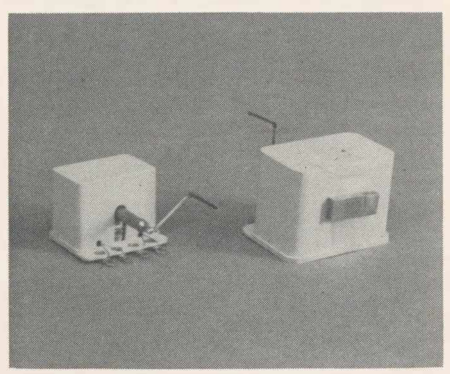
It's difficult to say just how large a plane magnetic actuators of the types described here will safely handle. It depends to a great extent upon engine size, what type of flying is to be accomplished (gentle sport flying, or wild stunting, for example), what weight of batteries you wish to carry. The more voltage applied to magnetic actuators — up to a certain point — the more power they will produce; also, the greater will be the current drain. Adams suggests the single-magnet actuator for up to .09-powered planes, the dual for .19 maximum. However, suggestions are packed with the unit to enable more power to be had by using higher voltage; see fig. 2-12. Another magnetic actuator maker, C & S Electronics, sets a general limit of .02 engine size for its Mk III "Septallette" and .049 for the larger Mk V. If these limits are too low for your needs, the only answer is to go to motor-driven servos, which will handle any size of plane you desire.



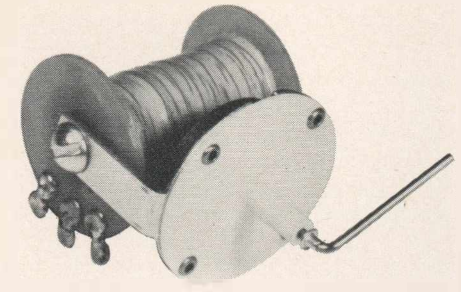
2-2 The so-called Trammell actuator has a magnet pivoted inside the winding.



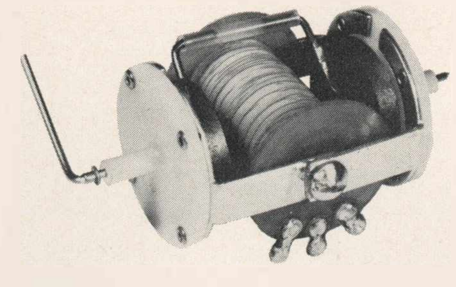
2-3 Cannon Septalette actuator is of the Trammell style.



2-4 Attaching a centering magnet to the case of a Cannon actuator is easy.



2-5 There is an even smaller size of this single-magnet Adams actuator.



2-6 Dual-magnet Adams is only slightly heavier, but has much greater power.

Pulse rate

Some modelers object to the wagging rudder of proportional planes with the simpler equipment. Actually, it's doubtful if the rudder flapping puts much drag on the model; the main thing is to have the pulse rate high enough that the *plane* cannot follow it. That is, even though the rudder is flapping very widely, the plane does not follow the individual flaps, but responds simply to the average position of the rudder to produce a smooth flight path straight ahead or in a turn of any desired radius. There is no particular advantage to very slow pulsing, and with it a plane certainly wobbles its way through the air. Conversely, very high rates are not required. Most planes will fly very smoothly with a pulse rate of from four to seven PPS (pulses per second). With a little practice, you can count at this rate; count the rudder cycles for a given period, such as 15 seconds; then divide to find the average pulse rate. (One cycle would be from neutral to one extreme, to the other extreme, then back to neutral — so just count the number of times you see the rudder hit one extreme.)

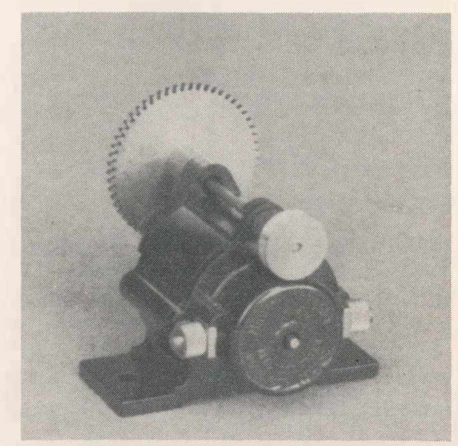
Magnetic actuators wiggle the rudder to a much greater extent than do motor-driven servos — possibly an esthetic point in favor of the latter, as some modelers just object on general principles to seeing the rudder wiggle. For their simplicity and light weight, however, these actuators are ideal for the proportional beginner. They have another advantage that is very real, also. Some receivers, and superhets as a class, are much more susceptible to the arcing at motor brushes which generates a form of electrical interference that can put a very sensitive receiver completely out of business. Since there are no brushes on actuators, there's no arcing, and no such interference. Actuators will work with almost any receiver that has the necessary output circuits to drive them. Such circuits are covered later in this chapter.

Motor-driven servos

Only the spring-centered types will be considered here. (Feedback servos are discussed in chapter 3.) These servos have the big advantage that you can multiply the torque by means of gearing. Direct drive from an electric motor shaft to a rudder is not very potent, though experimenters have used it. But if you load an electric motor heavily this way, its current drain goes sky-high. (Magnetic actuators draw the same current regardless of how you load them.) All we have to do is put a little reduction gearing on the motor and we are in business. How much reduction depends upon many factors: permissible current drain, how much rudder power is required, motor speed, servo response time. Very high gearing might give enough power to literally twist the rudder off, but you couldn't use the servo because rudder movement would be extremely sluggish. A compromise is thus called for: gearing must be designed to match the motor it incorporates. The venerable Mighty Midget (see fig. 2-7) comes with gearing of about 7:1 — the output shaft rotates once for every seven revolutions of the armature. This is fine for planes up to .09 or so, and will give good flying with reasonable current drain — and rudder response speed will be rapid. For larger or hotter planes more power is required. Countless planes have been flown with "double-geared" Mighty Midgets — an extra set of gears is added to those found on the motor. This extra gear pair is often the same as the original gears, giving a ratio of about 49:1.

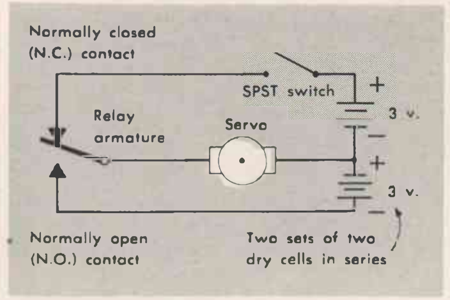
With much better motors now available, with and without gearing, the Mighty Midget is not as popular as when it was the mainstay of the home workshop servobuilder. For one thing, it was found that the MM case — a brittle plastic material — had a tendency to break in crashes, or even fairly rough landings. Modelers soon evolved ways to beef up the case so it would stand the rigors of R/C work, and you can now get an identical case molded in nylon — which would have been a godsend to many of us about 10 years ago!

Oddly enough, most of the motors used in servos today come from foreign countries. Overseas makers can produce high-grade motors in the rather small quantities needed for the servo market at a much more reasonable cost than they can be made here. Furthermore, there is a very wide variety available. Thus, the majority of servos made in the U. S. employ

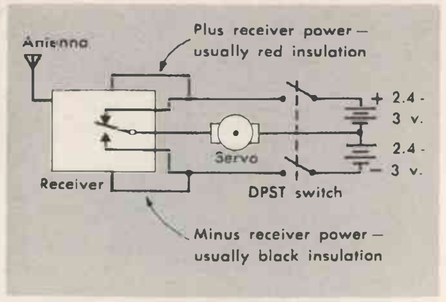


Aristo-Craft Miniatures.

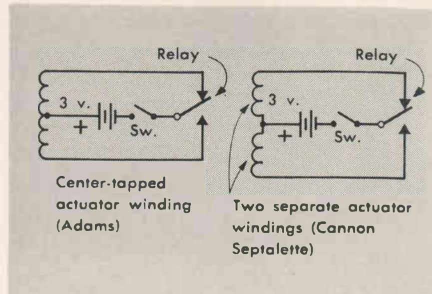
2-7 Mighty Midget motor has been popular, since it comes with 7:1 gearing.



2-8 Most simple motor-driven propo servos utilize this circuit.



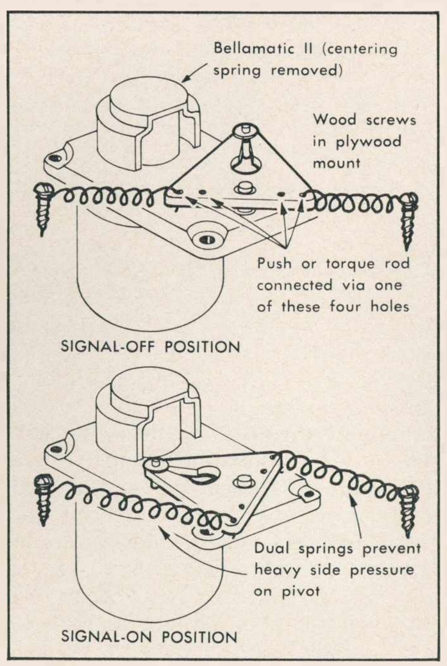
2-9 Here the receiver operates from both batteries that power the servo.



2-10 Slightly different wiring is used for Adams and Cannon actuators.

imported motors, mostly from Japan and Germany. Not many years ago our servos were based mainly on toy motors, but some of the motors used today are real precision units.

A motor-driven "simple" proportional servo (as oposed to the more complex feedback units used in multi systems) includes the motor with its gearing, sometimes a cam arrangement to an output arm, and almost invariably a centering arrangement. Due to the drag of most motors, it is desirable to attach the centering right at the armature shaft, if possible; this was usually the case with double-geared Mighty Midgets. Some forms of modern motors, especially certain German units, have so little inherent drag that it is quite satisfactory to apply centering right to the output shaft or arm. As noted for magnetic actuators, there is no need to have very heavy centering: it simply robs servo power. One very popular lightweight servo, the German Bellamatic II, comes with much heavier centering than we require for proportional. Actually, it was designed to be used much as are reed servos; it needed heavy centering to neutralize fast and reliably, and the German receiver it was made for provided only full deflection in either direction. Thus most proportional users modify this centering, and the Bellamatic II can be purchased modified expressly for proportional uses. (The Dee Bee Engineering version has been popular.)



2-11 Only a single battery is needed for a servo spring-loaded this way; a relayless receiver drove this setup.

Only a few years ago the proportional experimenter had to make his own servos — there was little marketed in the motor-driven variety. Today we have a good choice, with more coming all the time. There are also several servo kits, which will save you a little cash, and which are easy and fast to assemble.

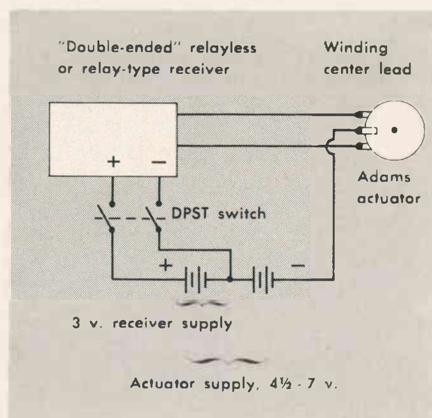
Wiring servos

While escapements require only a make and break action in the receiver, proportional servos are essentially double-action devices: you must reverse the current to drive them first one way, then the opposite. With a relay receiver this is simple, as all relays employed in R/C provide this capability. Such relays are referred to as SPDT, which means Single-Pole, Double-Throw. Fig. 2-8 shows such a relay connected to a motor-driven servo and a set of servo batteries. Note that we actually require *two* sets of cells, since the motor power must be reversed in potential to drive it in both directions. (Actually, a so-called double-pole, double-throw relay will do the job with a single set of servo batteries, but such relays are harder to adjust, they take more current, and they have not seen much use in R/C.) This is not too great a problem in some cases; certain receivers have been designed to operate on 4½ to 6 volts, and the same batteries can often be used to drive the servo, per fig. 2-9.

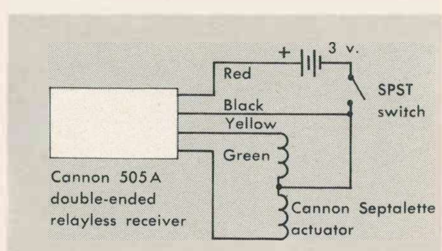
Magnetic actuators have an exclusive here, for some come with windings such that only a single battery is required. To reverse them you simply switch between the two windings. An SPDT relay will do the job nicely, as in fig. 2-10. The Adams actuators have a center-tapped winding, while the C & S Septallettes have two individual windings. Both circuits are shown.

Center-tapped motors have been made, but they are not very practical and are expensive. Fortunately, the space age has brought us semiconductors, with a few of which it is possible to achieve the effect of an SPDT relay, but with less weight, less cost, and most important of all, no moving parts. Thus, semiconductor servo switchers are bothered not at all by vibration.

Relayless receivers present a few problems for the proportional flier, since basically they give only the action of opening and closing a single circuit, not reversing it. This is fine for escapements, for which these re-



2-12 Added batteries can be applied to an Adams actuator in this manner.



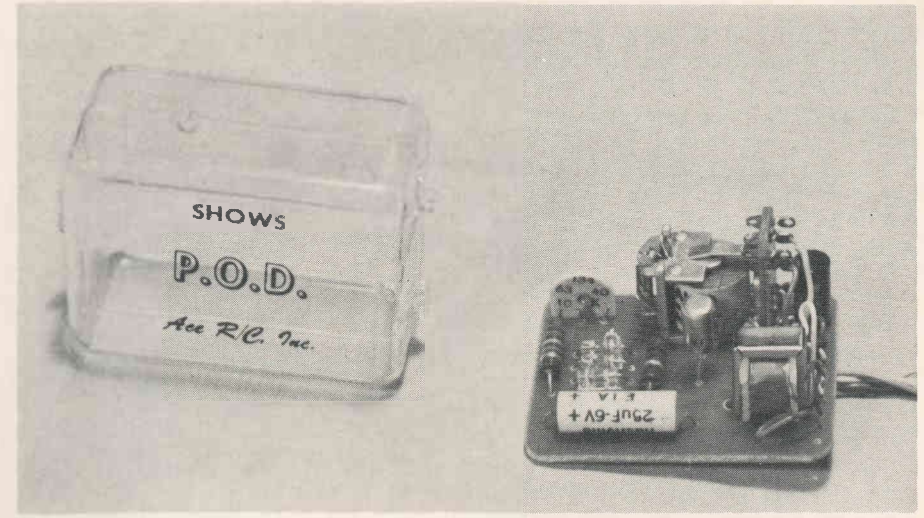
2-13 A single battery drives both actuator and double-ended Cannon receiver.

ceivers were originally designed. To use them for proportional, it is quite possible to wire them to either a magnetic actuator or a motor-driven servo which is spring-loaded to one extreme: the position of the unit when there is no input tone to the receiver. *With* such tone, the unit moves to the opposite position to give the other rudder extreme as in fig. 2-11. This sounds like a very unbalanced arrangement, and so it is; but a number of modelers have flown very successfully with such a scheme. Modified escapements or relays have been pressed into use as "single-ended" magnetic actuators, but they are pretty feeble — or if they have reasonable power, they *draw* a lot of power from the battery. Motor-driven servos are more satisfactory for such use. One would think the neutral would drift badly, but with properly working transmitter pulser and good receiver batteries, these systems have been surprisingly successful.

It wasn't long before single-ended relayless receivers were modified to produce double-ended operation by a little semiconductor magic. There are several such receivers on the market (see fig. 2-13). If you have only a single-ended receiver, there is still a simple out: purchase, or assemble from a low-cost kit, a "switcher" unit. This converts the receiver to double-ended action, somewhat as you would obtain with an SPDT relay. These switchers normally will handle only magnetic actuators with double (or center-tapped) windings; they will *not* drive an electric motor servo in both directions. The switchers are tiny units; they cost only a couple of dollars, so are a fine way to turn an "escapement receiver" into one that will handle a magnetic actuator. (For proportional use a receiver must be a good pulser: a matter covered in detail in chapter 6.)

It is possible to operate a relay from a single-ended relayless receiver: you simply hook the relay coil in place of the escapement coil. There are disadvantages, however. Such receivers are designed to feed a very low resistance coil (escapements for this use have a winding of around 8 to 12 ohms or so for the usual 3-volt receivers), and when working into a much higher resistance relay will be rather sluggish in pulsing. You can get low-resistance relays (on special order) which will pulse reasonably fast, but they take lots of power, to which you must add the power required by your actuator or servo. The best solution is thus to add a switcher to your single-ended relayless receiver, or to obtain one of the double-ended, or relay, variety.

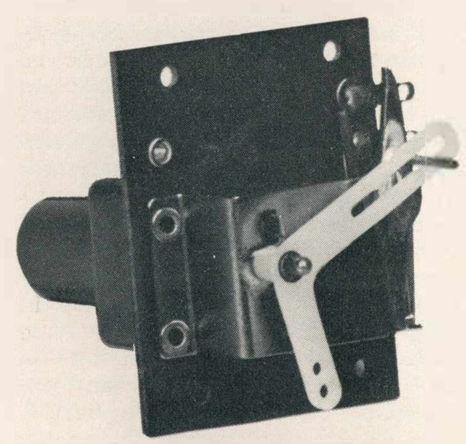
Several makes of proportional servos have been marketed with transistor amplifiers built in so they can be operated from a single-ended relayless receiver. More will doubtless come soon, as it makes possible utilization of this most popular style of receiver for the proportional operation that is growing so rapidly in acceptance.



2-14 The Shows pulse omission detector can be applied to many propo rudder installations to afford trimmable throttle action; relay allows versatility.

Adding engine speed control

After flying with wide-open engine for a while, the modeler soon feels the urge to slow that engine down so he can do touch-and-go's, make power-on landings, and such. A reliable engine control can be a pretty fair substitute for elevator — as witness the perfection of flying in the old AMA class 1 stunt category. It's quite easy to obtain trimmable motor control (or MC, as it is usually called). Trimmable means that you can open or close the throttle to any amount desired, but not proportionally. You push one button on the transmitter (or move a lever in one direction) for low speed, push another for high. The amount of speed change depends upon how long you depress either button. Proportional MC is standard on the more complex multi systems; the throttle moves in exact step with a lever or knob on the transmitter. Such operation is beyond the scope of the low-cost single-channel proportional systems, however.



Aristo-Craft Miniatures.

Aristo-Craft spring-driven escapement is light, needs no long rubber band; it is fine for working engine throttle.

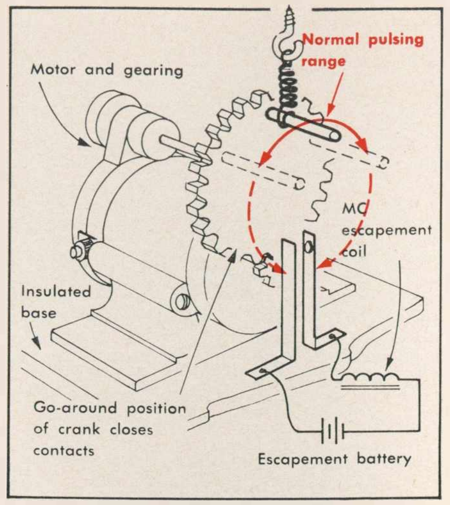
Most MC arrangements in our "simple" equipment category call for special receiver circuitry that will detect either a steady tone or no tone at all. Buttons on the transmitter allow you to turn the tone on or off. (Either action cuts out the rudder servo or actuator, and it's here we need good rudder centering to bring that surface to neutral as long as the MC buttons are in use.) In the plane, a so-called "pulse omission detector," or POD, interprets the full on or off tone and drives the MC servo in the desired direction, also cutting off power to the rudder servo. The POD (fig. 2-14) is a simple unit of several transistors; and, again, you can purchase them ready-made or in kit form. They are normally connected to the servo circuitry rather than into the receiver itself, and they can be either relay-type or relayless. Usually you can add the POD and MC servo to the equipment you are already using. An escapement can be used for moving the engine throttle, but here you will get only positionable throttle — not trimmable. Escapements can be set up to provide two or three set speeds: high, medium, and idle, for example. There are motor-driven MC servos that will do the same and have the advantage of eliminating the escapement rubber band. If you still prefer an escapement for MC, you can obtain a small, neat, spring-operated unit which operates just like a standard escapement, but instead of the usual long twisted rubber its power comes from a compact coil spring built right into the frame. It allows plenty of rotations for changing engine speed in several normal flights, but probably would not have sufficient for rudder purposes. Like the usual escapement you must remember to wind it, preferably after every two or three flights.

Fail-safe

Pulse omission detectors have a safety factor that some fliers find comforting. This comes about since you can rig up the circuitry so that no-tone provides low motor speed, which is the normal arrangement. Now supposing during normal flight a wire in the plane breaks loose, your model flies out of range, or the transmitter suddenly goes dead from any cause. Since the POD is getting no tone, it immediately cuts power to the rudder, which neutralizes. At the same time the engine throttle is moved to low speed. A flyaway is thus prevented. This "fail-safe" operation is not 100 percent foolproof, of course, since a few conditions could result in retaining the engine in high speed; this could occur, for instance, if the batteries driving the MC unit went dead during that flight. But you are at least "half-safe" from a flyaway!

Any POD that can operate a trimmable MC servo — that is, which can be made to drive such a servo in either direction — is capable of fail-safe protection whether you lose signal completely or whether you get some condition that sounds to the receiver like a solid tone. Certain types of interference can cause such effect, as can certain defects in transmitter, receiver, or component wiring. Such a full-time fail-safe is preferable, of course, to one that triggers only on *lack* of signal. All POD's *can* function if the transmitter goes off the air, but the receiver may prevent such action. Some receivers become very noisy when the transmitter is turned off, producing a loud and rough hissing sound which is like an audio tone to the POD and prevents it from operating. This is not really a receiver defect: just the nature of some designs. For reliable fail-safe when the transmitter is off, this matter should be checked.

While we are on the subject of fail-safe and possible flyaways, there is an aspect of simple proportional equipment that should be understood. As I have pointed out, this form of proportional is based upon sending alternate on and off tone pulses to the model, with steering based upon the length — or proportion — of on to off. Full on or full off in a plane with no POD circuit gives maximum rudder move-



2-15 "Go-around" servo normally moves only as far as dotted lines for rudder action: 180-degree turn triggers escapement.

ment one way or the other. Now, what happens to a proportional plane of this sort if the equipment fails for any reason? It spirals in — that's what! Depending upon where and what it hits, you could have a serious crash or possibly only a few scratches on the model. Offhand this sounds like a serious flaw in the system, and perhaps it is. But how many nonproportional planes have flown away with no control, never to be seen again? A modeler who has had this experience will doubtless prefer taking his chances on a possible crash nearby, where he can retrieve the pieces (with a good chance that he will have little damage in such contingency), than risking never seeing his model again. If you fly in wide-open flat country where a flyaway can be seen for miles and can be followed easily, this is not so important, nor even desirable. In wooded areas, or where there are large bodies of water nearby, it is certainly preferable to have the plane head groundward as soon as control is lost for any reason — even at the risk of a crash, serious or otherwise.

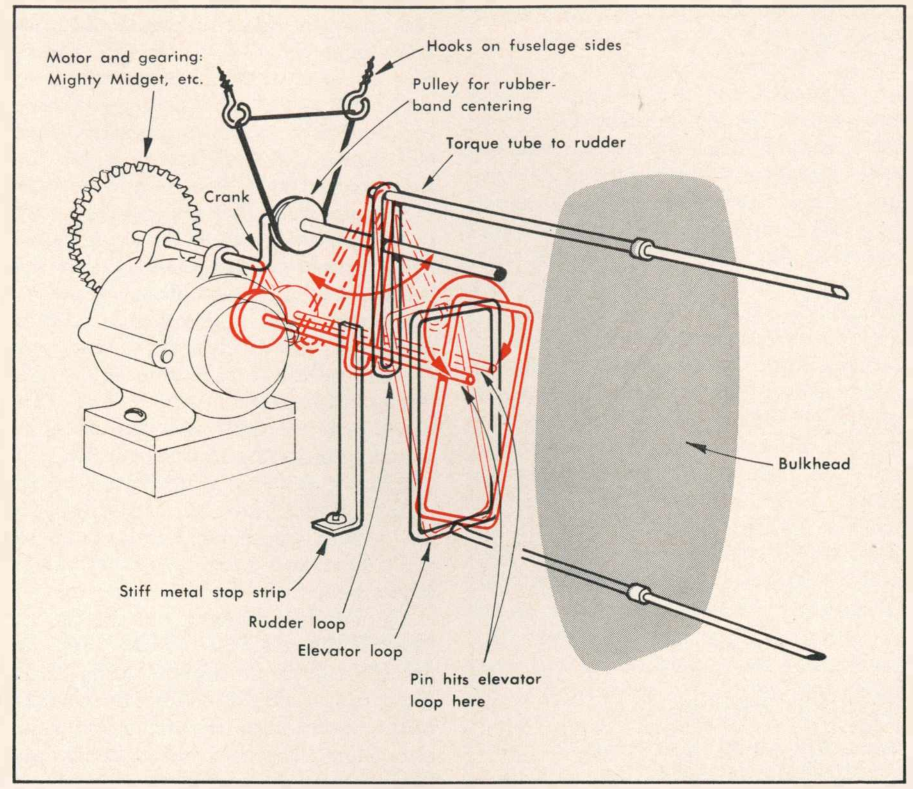
From the foregoing considerations you will have to decide whether you want to incorporate a fail-safe unit in your model if no throttle arrangement is installed. Most proportional fliers do not do so, but consider the fail-safe feature just a worthwhile bonus when they install engine control.

Because of their operating characteristics, all POD circuits have a slight lag in operation. While this may be only a small fraction of a second, it can cause quite a noticeable jerk in the path of your model. When you signal for an MC change, the rudder immediately jumps to full-control extreme on one side or the other because you are transmitting either full tone or no tone. Since the POD cannot be set up to operate instantaneously, the rudder holds this fully deflected position until the POD circuitry functions to operate its relay (if it has one). When the relay flips to fail-safe position it cuts power to the rudder, which can then neutralize, and also triggers the escapement or servo to move the throttle. The time elapsing between the instant you push the MC button and the instant the POD actuates its relay is often adjustable by means of a tiny variable resistor on the POD unit. It is desirable to have this time, or POD lag, as small as possible, since that full-over rudder will give your plane quite a noticeable twitch in the air before it is neutralized. The lag depends upon POD circuitry and also on the pulse rate. If you buy your POD, try to get one with a so-called "full-wave" (or bridge) rectifier. I won't go into specifics, but this variety can be set up for minimum lag. If your pulse rate is very low, say around 3 PPS or so, the POD must be set to match. It cannot be set for short time lag or it will trigger its relay between each two pulses! This is highly undesirable, of course.

Some POD circuits operate fairly rapidly — again depending upon the pulse rate — but release slowly. This is not too serious, but loss of control of a fast plane for even a fraction of a second, perhaps when you are maneuvering close to the ground, can seem like an eternity to the pilot! One of the advantages of the high-rate style of MC triggering system (described a little later) is that it can generally be set for a very short time lag, since it is not at all dependent upon minimum pulse rate. Such a system should operate your throttle almost instantly. It cannot be used for fail-safe, as noted previously.

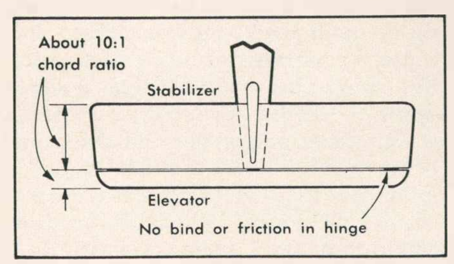
Go-around servos

A rather simple means has been used to some extent to provide engine speed control, often via an escapement linked to the throttle. It is more of a mechanical arrangement than the POD (which is triggered by electronic circuitry), and it is applied to the rudder servo, which must be of the electric motor variety. A servo so equipped is often termed a "go-around" unit; the reason for this can be seen from fig. 2-15, which shows the general idea. The gear ratio and centering of the servo must be such that during normal steering the servo arm never goes beyond the extremes indicated by broken lines. To ensure positive action, it is usual to limit the pulse proportions so that you never exceed about 70:30 or 30:70 percent (50:50 percent pulse proportion is neutral, while 100:0 and 0:100 percent would be the extremes on either side).



2-16 Go-around servo can trigger elevator up, down, or both. Crank arm moves rudder torque rod in normal manner, with about 30-degree rotation each side of neutral. With correct signal, crank turns fully to hit elevator loop.

Now suppose you switch on either full tone or no tone: the servo motor has enough power to drive the arm past the broken-line limits and around until it reaches the lower fixed contact, which closes the circuit to an escapement to shift engine speed. As soon as pulsing is resumed the arm snaps back into the normal steering range — the centering must be arranged carefully to ensure this. Since it takes only a momentary pulse to shift the escapement, and since the rudder is close to neutral when the servo is rotated far enough to close the contacts, the interruption in plane flight is very brief. (This system is good only for high and low engine speeds with most escapements, but with a little different switching it can also trigger a motor-driven throttle servo for either three-speed or full trimmable motor control.)



2-17 Narrow-chord elevator takes less power to move for system above.

High-rate detectors

Somewhat along the lines of the POD is the "high-rate" detector. This, however, is not affected by on or off pulsing nor by pulse length (and hence cannot function as a fail-safe), but upon a considerable increase in pulse rate. A button on the transmitter alters electrical values in the pulser circuit to increase pulse rate instantly by two, three, or more times. Circuits in the model interpret this change and trigger an MC escapement or servo. The big advantage of this system is that you do not lose rudder control when you signal for an engine change; in fact, you can change speed while holding a turn position. Generally it is not possible to get trimmable engine speed with a high-rate detector, but the circuitry can trigger either an escapement or a servo for step-by-step engine speed change.

Adding elevator action

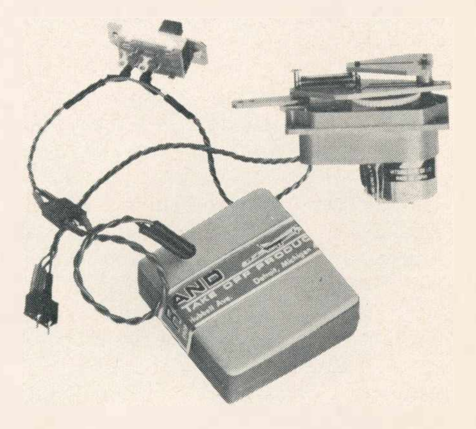
Only the simplest schemes will be covered here, with more complex arrangements saved for chapter 3. One of the easiest is the so-called "kick" elevator, in which the elevator can be made to go either up or down a set amount (not proportional). You can have both up and down if you wish, but just up is very handy and can be used to do loops, flare-outs just prior to touching down in a landing, and so on. The basis is the go-around arrangement mentioned earlier. You can use this principle either to trigger an escapement to move the elevator or to just let the go-around rudder servo move the elevator itself. Linkage for the latter is seen in fig. 2-16; if you prefer the escapement method, the circuit would be exactly the same as seen in fig. 2-15. Since a rudder servo that is doing double duty this way generally does not have an excess of power, you cannot move a big elevator, nor even a fair-sized one, far enough for violent stunting. Thus, it is usual to employ a long, narrow, strip-style elevator with suggested dimensions about as in fig. 2-17.

If you just want kickup (or kickdown, but not both), it is usual to have a fixed stop to hold the elevator from going to a down (or up) position, and a light spring to hold it against this stop. When you signal for kickup, you will normally want the rudder to go as close to neutral as possible. If it does, loops will come out true and the model will not "spiral off" due to unwanted rudder effect.

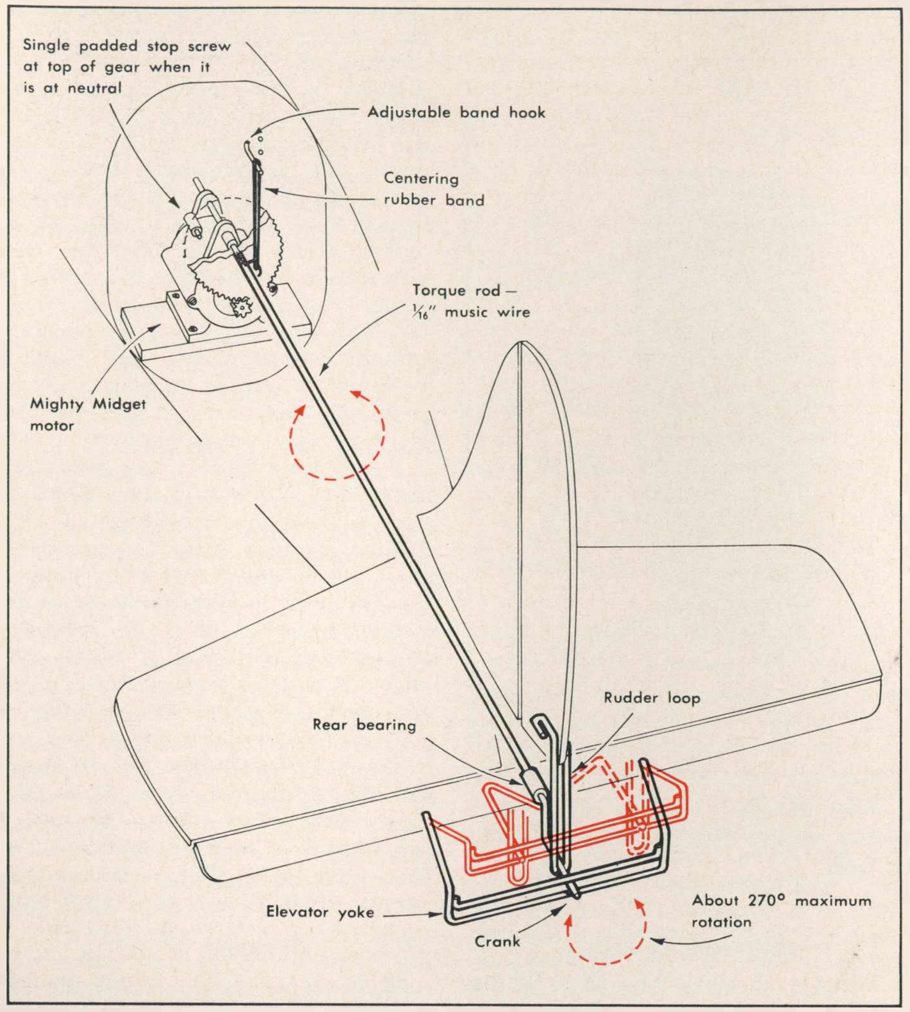
This go-around servo, for use either with MC or elevator, is purely a tinkerer's deal, since at the moment I don't know of a commercial servo of this type. The Mighty Midget has formed the basis of many such servos.

Galloping Ghost

Quite simple equipment can provide a good approach to true proportional rudder and elevator — and even tie in trimmable MC to boot! The control arrangement is variously known as Galloping Ghost, Simpl-Simul, or "the crank system." They all refer to about the same thing: a system where a single servo in the model handles both rudder and elevator, plus MC if desired. We thus have what is certainly the most control in a plane for the least weight, complexity, and cost — and rudder and elevator are fully proportional! Furthermore, several com-



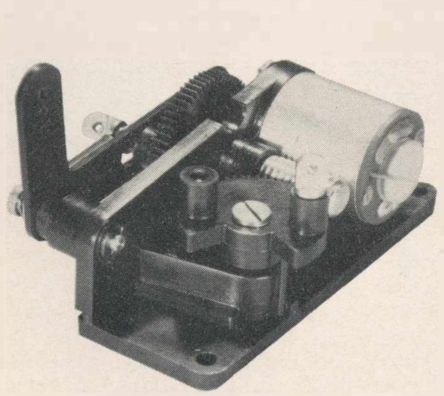
Rand GG-Pak includes a single servo that allows rudder, elevator, and throttle control, plus a nickel-cad battery pack.



2-18 The original GG linkage was mostly on the tail of the plane — the so-called "birdcage." A Mighty Midget motor drove the tail surfaces via a single torque rod; it was centered by a rubber band running to a hook on the fuselage.

mercial servos are available today for those who don't wish to make their own.

Originated as far as I know in southern New Jersey by Don Brown and his buddies, it was taken up in a big way by the R/C modelers at NASA in Hampton, Virginia; and the gospel spread from there. In those days you made all parts yourself — and the proponents used to say that a



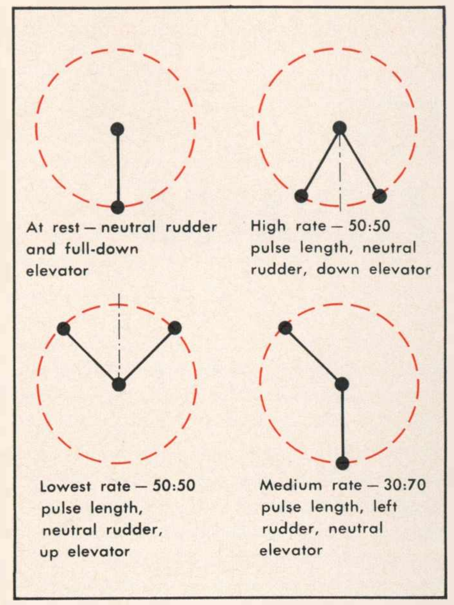
World Engines Ghost servo; rudder and elevator pushrods connect on left; throttle is driven from disk at right.

modeler wishing to start in GG (even an experienced flier) had to resign himself to at least three crashes before he could get his model adjusted reasonably well and be ready to really enjoy their variety of proportional. It certainly is not that way now. All parts can be had in hobby shops, including servos far advanced over those primitive homemade jobs.

One might wonder where the odd name "Galloping Ghost" originated unless one had seen the early GG planes, which did indeed gallop, especially under up elevator. The servos then employed required very low pulse rates: low enough that the plane itself could follow the movement of the control surfaces. GG requires variable pulse rate, with low rate normally being full up and high rate full down. It has been used in reverse, but this utilization of the pulse rate range is not common. With the lowest rate around 2 PPS, the plane tail traveled in a sort of corkscrew path — and it's a wonder even worse names were not applied to the system! John Worth (now AMA Executive Director) thought the name was undignified, and preferred to call it Simpl-Simul. While he and other early experimenters did try various means to combine MC with the system, most GG planes up until recent years had just proportional rudder and elevator — seldom MC. As we can see now, these pioneers started a simplified multicontrol proportional system that has come a long way. Some of the old equipment was pretty crude, and so were the results, though Brown won the Intermediate R/C title at the 1957 Philly Nats with a GG plane. The equipment, though still simple compared to any other form of multi proportional, is much improved; and the flying is still more so, for practically all "gallop" has been eliminated from the Ghost and such planes fly amazingly well.

The Mighty Midget was by far the most favored servo for GG, and the general setup is shown in fig. 2-18. Note that a single torque rod controls both rudder and elevator, and all linkage other than this rod is at the tail. The torque rod is generally of 1/16" music wire attached right to the MM countershaft. The tail end of the rod is bent into a crank (from which came the name "the crank system") engaged in wire links attached to rudder and elevator. With the crank downward — which is as near "neutral" as the system gets — the elevator is full down and the rudder is centered. Actually, neutral in this system is had with the crank rotating over a range of degrees such that the effective elevator position (averaged out between full up and full down) produces level flight; the rudder waggles back and forth, also averaging out for straight flight. In fig. 2-19 I have shown a few of the infinite possible control positions, but each system has to be set up individually, to suit servo motor, plane characteristics, balance, and other factors. Getting these factors all to cooperate usually *did* produce at least the three crashes that the pioneers predicted for the fliers who entered the then-mysterious field of Galloping Ghost.

Any GG system requires a reliable pulser capable of a fair range of pulse rate and length change, with minimum interaction between the two. Early electronic pulsers often left much to be desired, with interaction the worst fault. Mechanical pulsers (that is, driven by electric motors) were sometimes more reliable, but often produced such a clatter in operation that they were generally termed "Coffee Grinders." With the advent of transistors, very stable pulsers have been developed, and most in use now do not even utilize relays on the output. They are entirely silent.



2-19 Four of the countless combinations possible for rudder and elevator on the original GG control system.

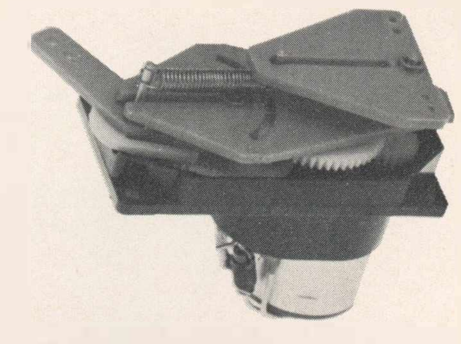
To suit various control systems, some pulsers now come equipped with adjustments allowing variation in pulse rate and other factors. GG operation requires generally about a 3:1 variation in pulse rate, and if equipped to give motor control, the pulser should have full-on and full-off buttons — or a lever switch to handle both jobs. Quite a variety of suitable pulsers and transmitters with pulsers built in are now marketed. The Rand LR-3 servo, fig. 2-20, works over a range of 4 to 12 PPS, and 70:30, 30:70 percent pulse length change.

Modern GG servos have another plus: the "birdcage" has been eliminated from the tail. Rudder and elevator are handled via two pushrods direct from the servo, making a much cleaner system and one less likely to get out of adjustment or trim. The commercial servos are designed to give the proper relative movement between the two surfaces, and it no longer takes many flights (and "at least three crashes") to get satisfactory flight from a plane.

These servos attain MC action via a form of go-around action. When you signal for a throttle change, the servo mechanism rotates continually; the control surfaces waggle violently over their full range, but since they go from one extreme to the other the net result is neutral control, while the throttle is being inched toward high or low, as you wish. The throttle can be left at any intermediate position, so is said to be fully trimmable.

GG has also been applied to aileron operation on the same plane with rudder and elevator — but this is a project for the experienced only. With all three controls waggling, such a plane is an awesome sight indeed. Aileron is simply tied in with rudder, and operates at all times in conjunction with rudder. This is generally termed CAR (Coupled Aileron-Rudder) and has been utilized most successfully with a little more advanced proportional systems, discussed in chapter 3.

Throttle may also be had with the various electronic means already covered (POD or high-rate detector) and a separate MC servo. However, now that you can obtain a variety of servos for GG use that have throttle facilities incorporated, there seems little use in complicating what can be a very simple system of obtaining RME



2-20 The Rand LR-3 servo drives the rudder and elevator pushrods from the right side, the throttle via the lever at left.

(Rudder, Elevator and Engine Control) all from a single servo in the model.

Due to its simplicity, GG does have some limitations. For example, there is often a certain amount of interaction between R and E. Experienced fliers learn to live with it, and to compensate for it, but the two controls cannot be said to be completely independent. Some planes, due to flying speed, balance, and such factors, do gallop under some control positions. The control surfaces do waggle over quite a wide range. Since a single servo is doing *all* the control work in the plane — which would be handled by three individual servos in more complex systems — GG is not applied to planes much larger than can be handled by a .19 engine; it is actually more suited to even smaller ones. But all in all, it *does* allow a great deal of proportional control with simple, lightweight and low-cost equipment: probably more so than any other control system ever developed.

American Aircraft Modeler.

3: SIMPLER SYSTEMS FOR INDEPENDENT RUDDER AND ELEVATOR

BEFORE I get into specifics, perhaps we had better settle the matter of how many "channels" a system has. Back in the days when R/C equipment was much simpler, a "single-channel" system was generally understood to provide just rudder, while "multichannel" was anything more complex than this. This held true for escapements, reeds, proportional, or any other form of operation. As reeds became more widely used, the "channel" concept became more firmly rooted, since the number of reeds in a receiver — and hence the number of different audio (or AF) tones a transmitter had to produce — led to a 10-reed outfit being termed 10-channel. But it takes 2 reeds to actuate 1 "control," so a 10-reed system really is a "5-control" system. Regardless of number of reeds, such a system takes only a single RF channel, or spot frequency.

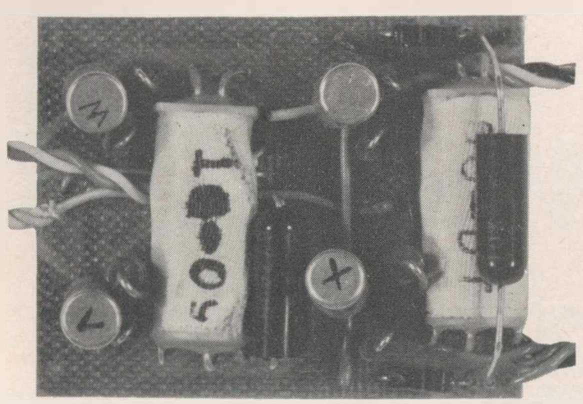
To compound confusion, the simplest rudder-only system also requires just a single RF channel. So it seems better to define our systems on the basis of control functions, or just on "controls." Every R/C system today operates via a single RF channel or spot frequency regardless of the number of controls it can actuate in the model. (A few experimental systems have used two RF frequencies to control a single model, but in this day of crowded flying fields and limited frequencies, such practice is now very much frowned upon.) The number of controls thus depends upon the number of tones transmitted on our single RF channel, or upon how that RF channel or these tones are varied, interrupted, or pulsed.

We will, throughout this book, stick to the concept of "controls" for the various functions we can operate in a model, and reserve the term "channel" strictly to the AF sense. Thus we have available six spot frequencies on the 27-mc. area of the Citizens Band, any one of which might operate a model with any number of controls from just one up to six or even more, depending on the number of audio tones or how they are pulsed or varied.

Single-channel multi proportional

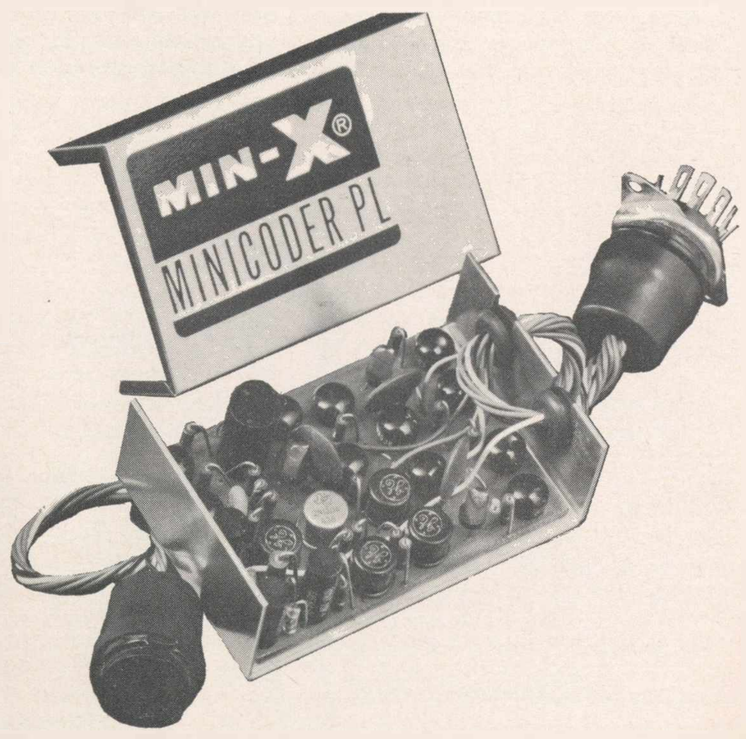
In chapter 2 we saw how a simple form of multicontrol proportional could be obtained via a single pulsed tone system to produce what is generally known as Galloping Ghost. As servos for such systems are refined, the result is more and more like the complex multicontrol proportional systems; "gallop" is all but eliminated, motor control can be had, and so on. GG still has very definite limitations. For one thing, you are asking a single mechanical gadget (the servo) to do an awful lot, and it just cannot handle large and high-powered planes. There is generally a certain amount of control interaction in GG systems, not serious but something you have to learn to live with. While GG systems have flown with ailerons added to the basic R and E, here again we are just further loading down that one lone servo. Can we not, then, modify this single pulsed tone proportional system to overcome some of these objections, yet retain much of the basic simplicity of the equipment? We can indeed, and the result can be highly satisfactory, and may be purchased in many commercial forms today.

The transmitter remains just about the same, though the pulser might be a little more refined to get the best from the more advanced equipment in the model. Thus, the transmitter



Ace R/C.

Simpro III decoder allows rudder, elevator, throttle control with two Rand (or equiv.) servos, relayless receiver.

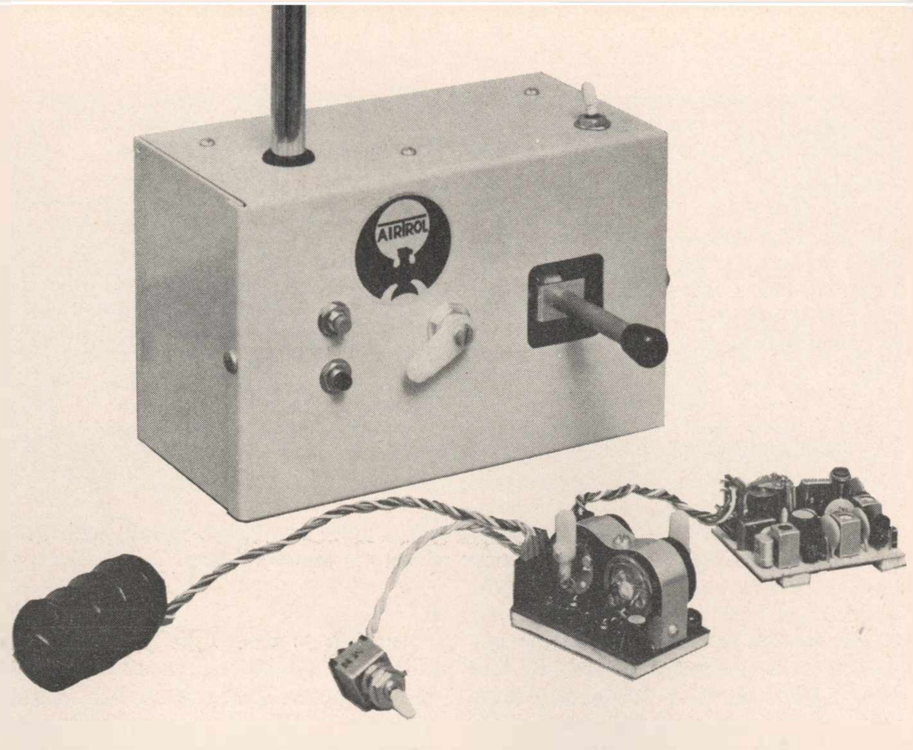


This decoder does the same job as that at left, but all servo drive is accomplished via transistors; no relays are utilized.

sends out a train of pulses which may simultaneously be varied in length as well as width. Pulse rate variation is generally employed for elevator; pulse width (or length, as it is often termed) gives rudder action. Engine control is had by on or off tone, again just as in GG systems.

When we get into the plane, though, the equipment becomes more complex, and more versatile. In place of the single servo found in most GG planes we have a separate servo for each control function. These servos can be just as potent as necessary to handle their jobs, and thus such systems can fly the largest and hottest planes. They can also provide force to turn a steerable nose or tail wheel, or to work mechanical brakes on the plane. We are thus approaching closer to the still more complex "full house" proportional systems, both in equipment and in results.

Again nomenclature becomes a little confusing here, for these systems have no clear-cut distinguishing name as is the case with Galloping Ghost. The term most generally applied to them is "Kickin' Duck," though this really should be reserved for a single specific system in this general category. They are also sometimes referred to as "Mickey Mouse" — but really this term belongs to an entirely different control arrangement (a method of obtaining rudder and elevator from escapements). For want of a better name, let's just refer to the systems in this chapter as "pulse rate-length," or "rate-length" for short.



Rudder and elevator are driven by individual servos in this Airtrol outfit that operates via changes in pulse rate and length. MC can be added too.

Rate detector

Also sometimes termed a "decoder," the rate detector makes use of the pulse rate variation of the incoming signal, but is not affected by pulse length alterations. Since such a detector must at all times *have* a pulse to detect, we cannot let the pulses go fully on or off, as is quite acceptable in pulse rudder systems (at least, in those that do not incorporate MC). Pulse length changes are generally maintained within the ranges of 80:20 and 20:80 percent.

Unlike some GG systems, there is no necessity to have the low end of the pulse rate range down at 2 or 3 PPS and thus there is never a possibility of a well-designed rate-length system causing a model plane to gallop. The lowest required pulse rate can be high enough so that the model cannot possibly waggle its whole fuselage in unison with the control surfaces. Low rate on such systems is generally at least 5 PPS, and high can be perhaps twice this, or in some cases three or four times higher.

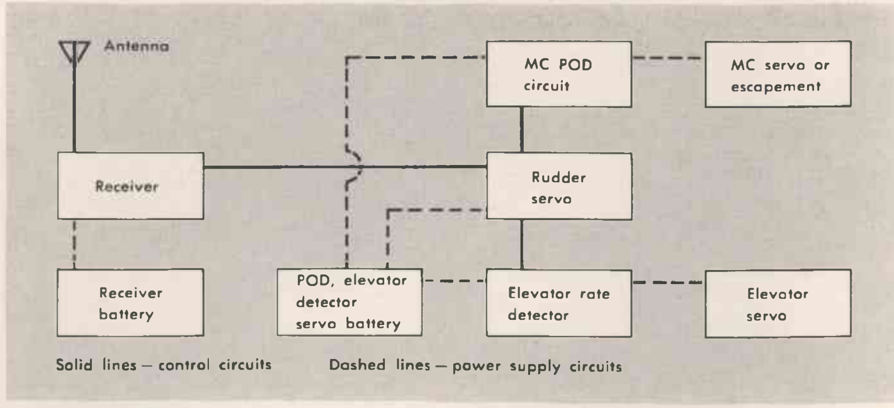
In many rate-length systems, the rate detector is not actually hooked directly to the receiver — though it could be — but gets its signals from the rudder servo and its battery system. The Kickin' Duck system (so named because it functions via an "inductive kick" produced as the rudder servo circuit is closed or opened) utilizes a tiny transformer connected across the rudder servo, the output of which feeds several diodes and a high-value capacitor, ending up in a transistor. The latter may drive a relay directly, or perhaps a relayless output circuit, either of which controls the elevator servo. Some rate detectors omit the transformer and simply couple to the rudder servo with an electrolytic capacitor. Connections in either case are made to the rudder servo (rather than into the receiver), since a fair amount of power is available and less amplification is needed to build the pulse up enough to operate the rate-sensing circuits.

It may be evident that while we employ an electronic rate detector or decoder in such systems, in a sense the Galloping Ghost servo is also a rate decoder, although it is electromechanical.

Developed and publicized just in time to slip notes on it in this book is a supersimple pulse rate-length system utilizing individual servos for each control, named "Simpro." The work of Dave Robelen, the rate decoder is so elementary that one wonders why no one thought of it before. Speaking as an experimenter who has done a lot of pulse rate system development and flying, I imagine it's probably because we experimenters just didn't believe such a simple arrangement could do a useful job. But it does, and many Simpro outfits are flying successfully. The entire rate decoder (or detector) consists only of a small 50-ohm relay in series with an electrolytic capacitor of about 95 mf. This combination is connected directly across the motor of the rudder servo (which is, of course, driven directly from the receiver) and gets its power from the servo batteries. The elevator servo motor is connected in the usual way to the 50-ohm relay contacts and is powered by the same servo supply. The receiver recommended for this system is the Controlaire SH-100 superhet, and the makers of this receiver offer a kit to convert it to Simpro uses. With this receiver and a pair of Controlaire Ghost servos, total system weight in the model is about 8 ounces — and by utilizing the go-around feature of these or similar GG servos you can have trimmable MC too. With a much lighter receiver and homemade servos, plus smaller batteries, it is possible to have proportional R and E with wiggle-free control surfaces for only a few ounces total weight!

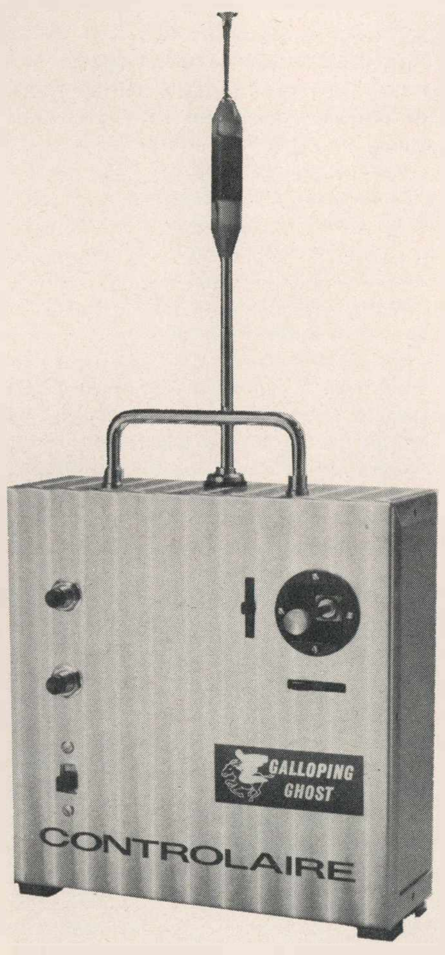
Rate-length systems normally require a POD for operating the engine throttle, and this detector is entirely separate from the rate detector although it is also triggered from the rudder servo. A high-rate detector cannot be employed for MC here (as it can in rudder-only pulse systems), for the high pulse rate would drive the rate detector and its associated elevator servo to one extreme.

It is accepted practice to arrange the system to provide up elevator for low rate, down elevator for high rate.



3-1 Block diagram illustrates the basic units in a pulse rate-length system, with POD for trimmable engine. Control and battery wiring are separated here.

It can be the reverse, and a few experimenters have preferred it that way. Also, there is no real reason why elevator has to be actuated by the pulse rate channel. Since the rate detector is a little "further down the chain" than the pulse length decoder (which is actually the rudder actuator itself in normal systems), it is in some ways not quite as "solid" in its servo operation as the rudder servo. I've



This transmitter by World Engines is usable for GG systems, also for those that operate by means of separate servos.

often felt it would be preferable to drive the elevator servo directly from the receiver, since in many planes elevator is a much more sensitive and touchy control than rudder. I've never tried it, though, nor heard of anyone else who has.

A block diagram of a pulse rate-length system with MC is seen in fig. 3-1. It is common practice to run all servos, plus the rate detector and POD, from a common set of batteries (usually two sets of two nickel-cad cells, connected as indicated). The receiver may or may not work from the same supply. If it is designed to operate from 4½ volts this is ideal, as it can be connected across the entire servo power supply. If not, it is best to run it from separate cells; a 3-volt receiver should never be run from one half of the servo supply, as every effort should be made to keep the two halves of this supply as nearly alike as possible in voltage and current drain. While a GG system can be run by penlight dry cells, the drains on rate-length batteries are much higher, and nickel-cad cells are the only practical solution.

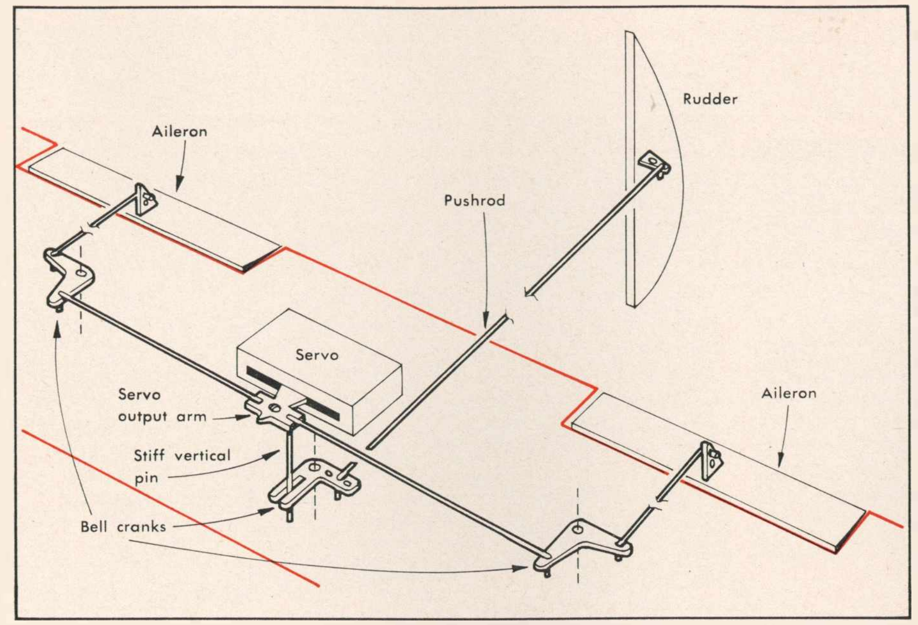
Adding ailerons

The simplest way to add ailerons is by means of CAR — that is, Coupled Aileron-Rudder. The coupling can be done either mechanically or electrically. A single servo may operate both rudder and ailerons — though the linkage for such a system is a little tricky — or you can employ one servo in the fuselage for rudder, another in the wings for ailerons. The two servos would then be connected in parallel (each lead from the aileron servo motor would be hooked to one lead from the rudder servo motor). The overall current drain when utilizing two servos this way need not be too much higher than with a single servo to drive both functions. The latter setup requires quite a potent servo, and the drag in the necessary linkage adds to the load on the motor — and results in higher current drain. Current drawn by an electric motor rises as it is loaded more heavily: that is, as it has more work to do. The servo motor that is driving both rudder and ailerons in a CAR system is indeed doing a lot of work!

While CAR certainly isn't as good as having rudder and ailerons available separately, it is a lot better than either alone. A plane with CAR will do much better turns than one with just rudder, for example, and can do very good "axial" rolls, given a good pilot and a plane designed and trimmed for best performance. On the other hand, a plane with just ailerons (no movable rudder) is very difficult, if not impossible, to spin, and cannot be made to do a good wingover. Also, lack of rudder is very noticeable during takeoffs, where the ailerons are of little use until the model is actually airborne and high enough so that it may be safely banked to turn it. Some fliers feel that if you have just two proportional channels, elevator and ailerons are the best way to utilize them. My experience has proven — to me at least — that elevator and CAR is far more versatile, and that the CAR does not "get in the way" nearly as much as might be expected.

For those who want to experiment, it is quite possible to cut out the ailerons (or rudder) for those maneuvers which are accomplished more easily without them (or it). This has been done by having a switch actuated when the throttle servo goes to medium or low engine speed, which then opens the circuit to the aileron servo. Individual rudder and aileron servos must be used, of course. The ailerons are thus cut out for anything other than high engine speed. Actually, I have not found this necessary. CAR produces smooth, coordinated turns, and it is very useful when you are coming in "dead stick" (with the engine dead); under this condition, there is no propeller blast on the rudder to facilitate turns, and flying speed is low, so the ailerons are not especially effective. The combination of both assures reliable turns during your landing approach, when sudden turns are often a vital necessity.

For "mechanical CAR" — that is, where you use only a single servo and link the control surfaces by mechanical means — there are several considerations you must keep in mind. First, the linkage must be as free as you can possibly make it to reduce load on the servo. This means good bearings for all components, no binding anywhere. Since the ailerons are generally conceded to be the principal control, in that they are important in more stunt maneuvers than is the



3-2 The aileron servo in this midwing setup is in the wing center; it drives the rudder via a vertical pin. Pin and fork coupling allows wing knock-off with least damage.

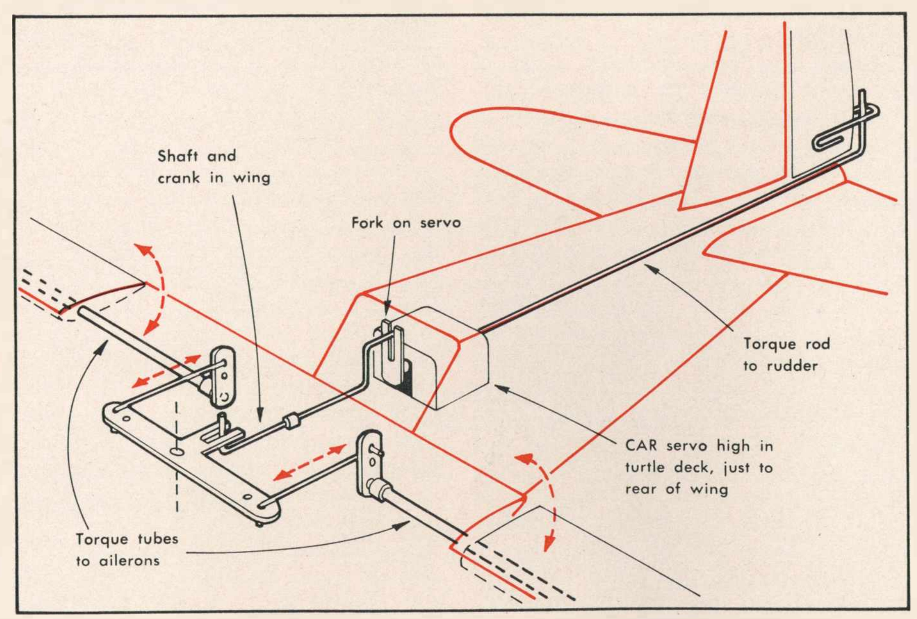
rudder, you will want plenty of movement for them, and only enough for the rudder to do a few maneuvers where it is dominant, such as spins and wingovers.

The linkage and the type of connection between R and A depends upon wing position, but it must be such that minimum damage is done to the system if the wing is knocked off. It is probably wise to drive the dominant controls (the ailerons) directly from the CAR servo, with the rudder linked in by torque or push-rods and a slip-joint to allow easy wing removal. A removable connector on a short cord must be used to carry power to the wing-mounted servo. One possible setup for a mid-winger is seen in fig. 3-2. I have used most successfully a fuselage-mounted CAR servo on a shoulder wing model, rigged up as in fig. 3-3. In this plane the servo is mounted in the turtle deck just behind the wing. Fuselage mounting has the advantage that the CAR servo can be permanently wired into the control circuits, without necessity for removing a connector every time the wing is removed.

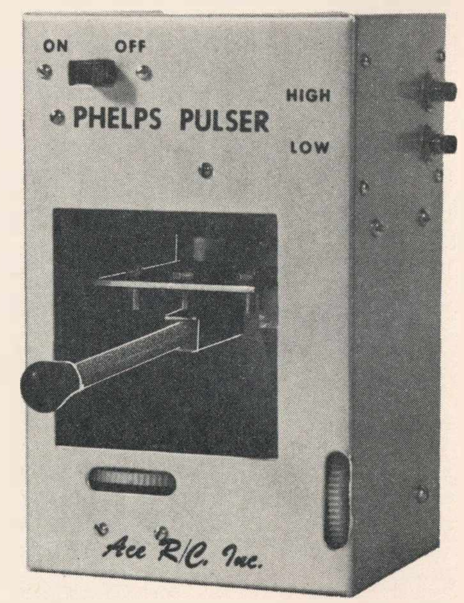
Pulser requirements

As noted previously, a transmitter or pulser that works satisfactorily with a GG system will often do OK for a pulse rate-length system, but for top results the more advanced (and complex) system dictates more stringent pulser requirements. Primarily, there should be *no interaction whatever* between the pulse rate and the pulse length functions over the entire range of both, and also with the stick "in the corners" (to produce, for example, maximum pulse length and maximum rate). It is under the latter conditions that some simpler pulsers fall short of the desired performance. The best transistorized pulsers today have three or more transistors, generally including what is termed a "unijunction" transistor. Properly designed and operated, such pulsers afford 100 per cent interaction-free operation. As with GG transmitters, there is generally a pair of buttons for on-off tone to trigger the MC servo, or a single two-way lever switch for the same purpose.

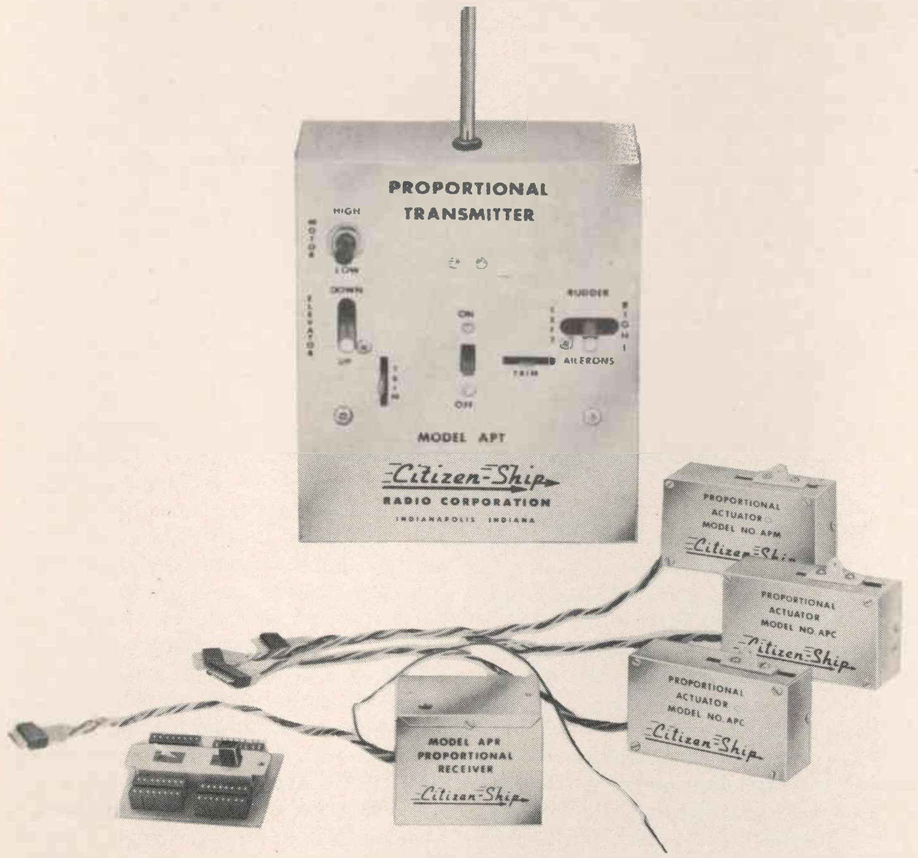
There should be a trim control for both pulse rate and length, to take care of slight drift that can occur in such systems or to purposely "untrim" the model for certain maneuvers. There is much variation in how much trim such a control affords. I feel it shouldn't be more than about 20 percent of the normal control surface movement; otherwise the trim control becomes too hard to set — and if you hit it accidentally while flying, the plane could be forced into a dangerous position. Ideally, trim controls should have no effect on the maximum control surface end positions, when the stick is at any maximum. Unfortunately many trim controls *do* vary the maximums, and you just have to live with the condition.



3-3 Another midwing or shoulder-wing arrangement puts the CAR servo in the fuselage turtle deck, back of the wing; again, knock-off provisions are important.



The Phelps pulser was one of the first that used a unijunction transistor; such circuitry is now widespread.



3-4 This analog system was an early entrant in the pulse rate-length commercial field. Two servos are fully proportional; the other is trimmable only.

Since it is possible to get more precise and independent control operation with rate-length systems than with GG (the latter are also rate-length systems, of course), more precise control stick centering is mandatory. The centering should preferably be such that you have a good solid feel of center in one direction when you want to move the stick only in the other. For example, with a well-trimmed plane you want only up elevator to do a loop; any small amount of sidewise stick motion you apply while you are giving up will very likely cause the model to twist out of the loop. If your control stick has the desired centering arrangement, you can move the stick fully up and down; yet you will immediately feel a side pressure if you inadvertently start feeding in a little pulse length change. Sticks centered by the so-called "scissors spring" arrangement (of which there are many variations) generally have a very good feel this way. The centering should not be *too* stiff or you will feel fatigue after a long flying session, but centering should be such that the stick returns to precise center when you let it go from any position.

Feedback servos

We will go into feedback servos in some detail in chapter 6, but suffice to say that it is the type used in all the more advanced multicontrol proportional systems. It offers considerably more power — at the expense of considerably more complexity — and draws appreciable power only when you are actually signaling for a control surface movement. Thus it takes much less average power than a spring-centered servo and the power supply can be considerably smaller and lighter.

Now, can this advanced style of servo be utilized in a pulse rate-length proportional system? Indeed it can; there have been, in fact, several such commercial systems, of which the Citizen-Ship Analog system (fig. 3-4) is a good current example. You can also install feedback servos in a system intended for driving the spring-center style. When this is done, however, it will mean some modification of the means used to trigger the pulse rate detector, since a feedback servo is not continuously moving and producing pulses of current needed by the rate detector (and also the POD). On a simple rate-length system, then, it might be best to retain the spring-centered servo for the rudder, which can then handle the pulse rate and pulse omission detectors as intended. But the output of the rate detector may be fed through a coupling circuit to the input of a feedback elevator servo. You will gain considerable power on the latter; yet overall system current drain will drop to quite an extent.

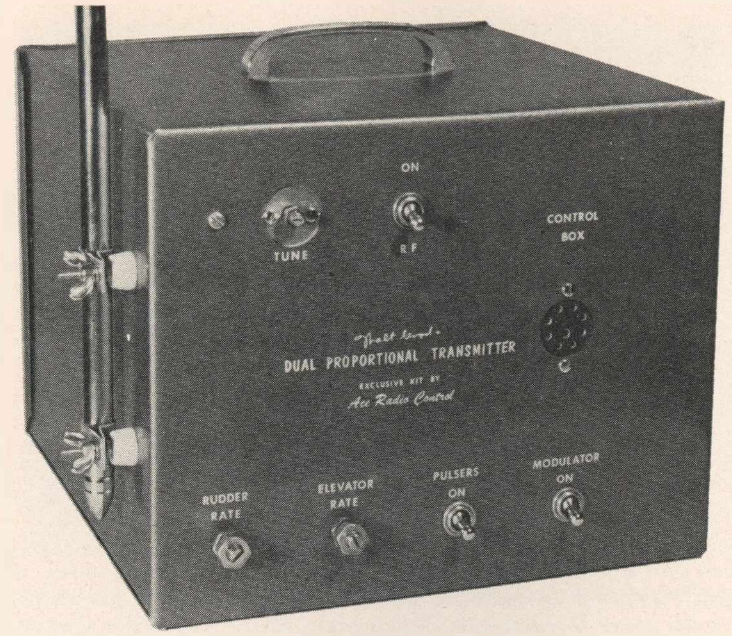
A third proportional control

Pulse rate-length systems are basically two-control arrangements, since there is not a great deal you can do — in a fairly simple manner at least — to gain a further proportional control from them. (Engine control on such systems is not proportional but trimmable, attained by full on or full off of the single audio tone.) One solution to this has been utilized in the B&D pulse system, which has been marketed in parts package form, but not finished and ready to fly. This is basically a pulse rate-length setup with the usual on-off tone for motor control, and it utilizes feedback servos. However, the designers were able to add a third *proportional* channel for ailerons by varying the audio modulation frequency. So far I do not know of any ready-to-use outfit based upon such a system, but parts packages are available for those who like to build their own equipment.

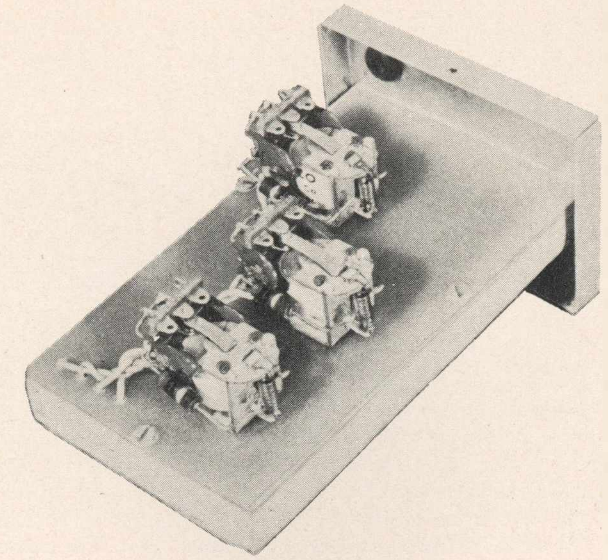
Rate-length future

While it is doubtful that any *brand-new* system will come along — that is, one which has not already been explored by R/C experimenters in the past — it is evident that more and more equipment is coming on the market for pulse rate-length uses. These are basically simple systems compared to the present-day multicontrol proportional rigs, and due to their simplicity (at least in the spring-centered servo styles) can be manufactured at fairly low cost. Thus they are ideal for the sport flier, who generally is not interested in the perfection of operation that is required for top-grade R/C competition performance.

I can see further refinement in this field: better servos and so on; also reduction in size of equipment so it can be utilized in smaller models. As mentioned earlier in this chapter while discussing Simpro, it is possible to fit a pulse rate-length system into a plane that can carry just a few extra ounces of "payload." Such planes can fly on the smallest commercial engines, and can be operated in very small areas. U. S. experimenters have built super-regen receivers of only .1 ounce weight! A few custom-made imported regen receivers have been marketed here that weigh only .15 ounce. Indoor flying of rate-length system planes thus is quite feasible. Such systems are ideal to power small scale planes. In any case, the outlook for the purely sport flier in the pulse rate-length field seems bright indeed.



A commercial kit version of the pioneering TTPW dual-propo control system — the first such equipment ever marketed.



Ace kit matching WAG TTPW receiver. Five submin tubes were in center under relays; small parts were on bottom.

4: DUAL AND TRIPLE PROPORTIONAL

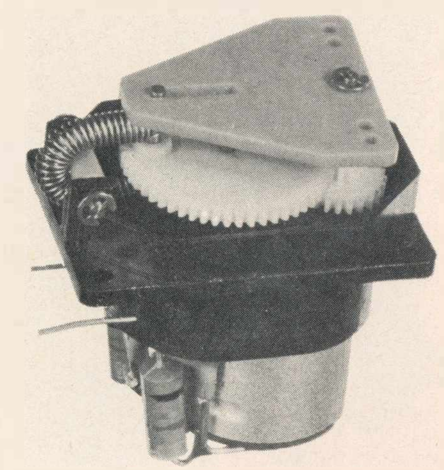
ACCORDING to our definitions at the beginning of chapter 3, dual-*channel* should signify continuous use of two AF tones upon a single RF frequency, and this book would not be complete without mention of two such systems that were really pioneers in multicontrol proportional, though they have been overshadowed now by more advanced systems. The real pioneer dual-channel proportional system was TTPW (which stands for Two-Tone, Pulse Width), developed by Dr. Walter Good and first flown around 1956. This was long before simpler systems (Galloping Ghost, Kickin' Duck, and such) had attained any general recognition, and the experience gained with TTPW by a number of talented experimenters led to a real understanding of the full advantages of multiproportional control, and to the further development of the field right up to the sophisticated systems we have available today.

Unfortunately, TTPW was never marketed in ready-to-fly form, though for a while you could buy parts kits for transmitter and receiver. Reeds were undergoing considerable refinement at the time TTPW came along, and had had quite a head start, so all commercial activity was with reeds. But meanwhile the experimenters continued development of TTPW, much of the work going into servos and methods of spring-centering them. Since TTPW was basically a two-control (plus trimmable MC) system and it did not look feasible to add another proportional control, it also forced experiment and development of CAR. The combination of TTPW-CAR did some remarkably good flying around the country, and a number of contests were won with such systems. It remained primarily, however, a tinkerer and homebuilder system, since it was not marketed commercially. Though overshadowed to a great extent by modern all-transistor systems with their light weight, small size, and low battery requirement, a few of the old TTPW systems are still flying, but some now do their control-surface moving via such modern lightweight servos as the Rand HR-1 (fig. 4-1).

Another early two-channel proportional system was Dual Marcytone. This functioned through pulsing of two AF tones that were separated in the receiver by sharply tuned filters. (Other Marcy systems utilized up to five such tones and filters, but operated servos in the manner of reeds — two tones to each control surface servo.) Again, the Dual Marcy pulse system was not marketed ready to use but only in kit form.

Both of these systems offered essentially interaction-free pulsing of two controls. The rate-length pulsers of the day were not as well developed then as now (they were tube pulsers, as were those used in most TTPW systems), and the performance of such systems was not quite in the class of the dual-channel outfits. The latter were flown in the "Multi" AMA competition category, while rate-length outfits flew in "Intermediate."

Other experimental proportional systems of the day operated on variable tones — one tone per channel



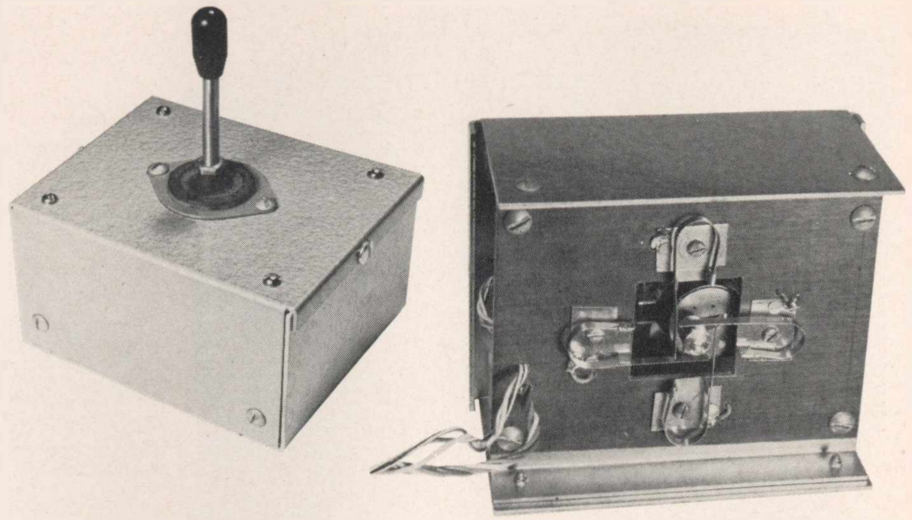
4-1 Rand HR-1 servo is modern U. S.-made pulse-type unit. Pushrod goes in holes at right; long spring is for centering.

would be varied in frequency over a small range. Depending upon the number of audio tones transmitted, these could be two or more control systems.

Pulsed reeds

The development of pulsed reeds is quite recent, having been brought about by the wide interest in proportional of all sorts and the large number of perfectly workable reed systems owned by modelers who don't feel they can afford the current multi proportional systems. In order to be most adaptable to the reed equipment now in use, most of the pulsed reed outfits utilize two tones (and thus two reeds) per control, pulsing them to allow a fair simulation of proportional servo action. Unfortunately, not many experimenters are working on such systems, probably feeling that such work would be useless in view of the great variety of multi proportional commercial lines now on the market. But there is a tremendous amount of reed equipment around the country in perfectly good condition, and it seems likely that the experimenter, or manufacturer, who brought out a successful "converter" which would change most such outfits to acceptable proportional operation could reap quite a harvest, if the price of conversion could be kept to a reasonable figure.

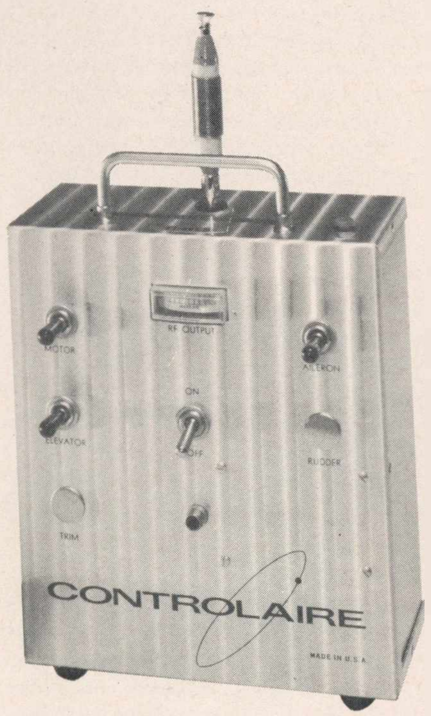
There are some fundamental reasons why pulsed reeds — at least conversions of present reed systems — will probably never equal true multi proportional in final results, but at least they would be fine for sport flying and would give many reed owners a try at proportional flying from which they might likely be encouraged to "step up" to a modern multi proportional system. Basically, reeds will not start and stop as rapidly as might be desired for the best proportional action. Several experimenters have spent long hours trying to pulse a *single* reed per control, but it is generally conceded that the best reed pulse operation comes from utilizing two reeds per control, just as in normal reed servo operation. As far as converting present reed systems to proportional, further limitations arise in the servos themselves. But even so, successful pulsed reed operation *has* been accomplished. Considerable information on the matter has been presented in model aviation publications. See fig. 4-2.



American Aircraft Modeler.

4-2 The pulsed reed system by Joe David was based upon this motor-driven pulser. A rubber "shock-mount" supported and centered the stick. A small geared motor on the lower end of the stick drove the disk cam, which could handle two plane controls.

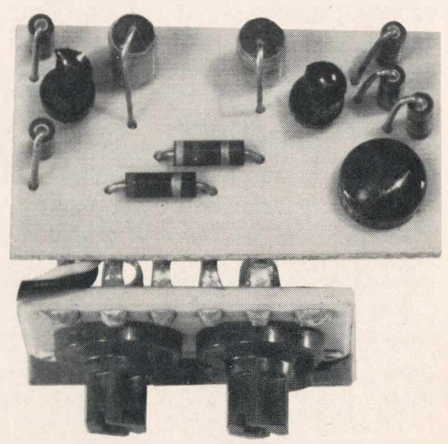
At least one manufacturer went partway toward pulsed reeds. The six-channel Controlaire reed transmitter at left has a built-in pulser; when a button is depressed, *all* output tones are pulsed on and off. This really doesn't provide proportional, as there are no means provided for altering the pulse length. However, with the pulser in operation, a servo in the model would hold an intermediate position, rather than going to an extreme. Thus, while by no means a substitute for proportional action, this arrangement proves that reeds *can* be pulsed. The maker still sells the pulser at right, and a six-channel receiver and transmitter, equipped with this pulser, for experimental purposes.



4-3 Reed pulser in this World Engines six-channel transmitter is operated by pushbutton at top right of case.

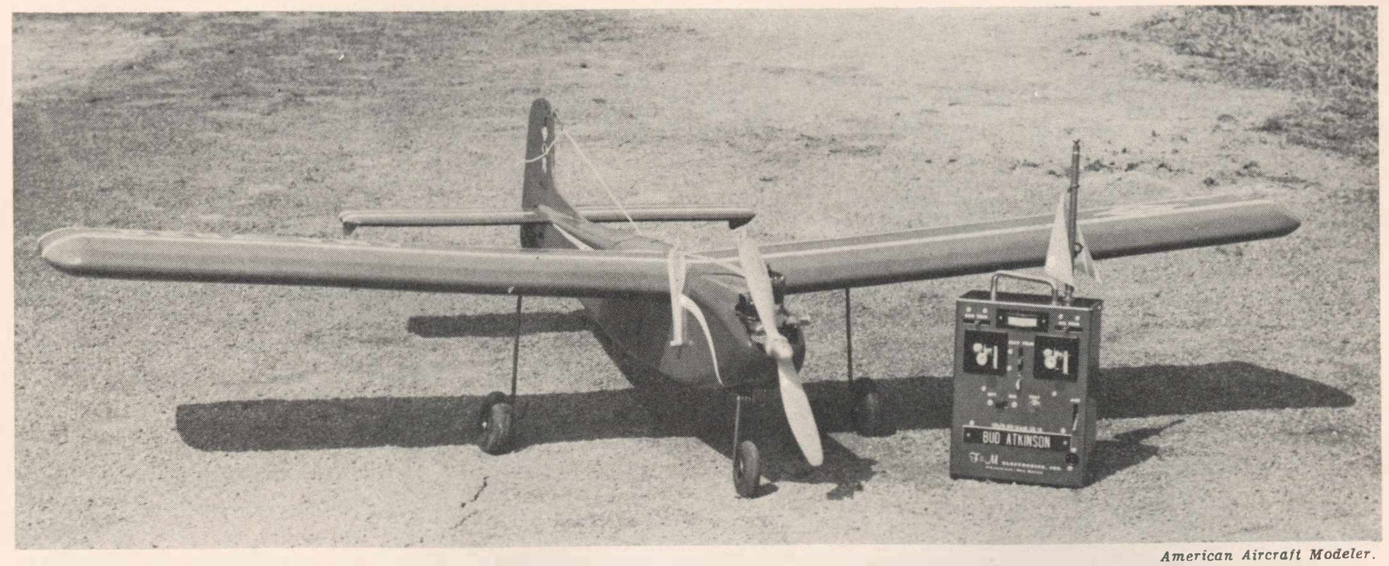
Three-plus-one systems

While not exactly comparable to the dual-control systems described earlier in this chapter, the three-control proportional systems now offered by several makers are ideal for sport flying, and can be used in such competition planes as class A and B, and Pylon. (Orbit calls its version 3-plus-1, fig. 4-4, for reasons following.) By eliminating one of the usual four proportional functions of their more exotic systems, the manufacturers have been able to reduce price to a considerable extent. The three controls might normally be utilized to provide proportional rudder, elevator, and motor control. By including our old friend CAR in the setup, ailerons can be handled in conjunction with rudder. Orbit suggests that the three main servos be linked to elevator, ailerons, and engine; a fourth servo is connected in parallel with that for ailerons (it takes care of rudder) but can be cut out of operation in all engine speeds except low. Other switching arrangements for utilization of CAR,



World Engines.

Controlaire reed pulser unit is a tiny job available only in kit form; knobs set the pulse rate and length.



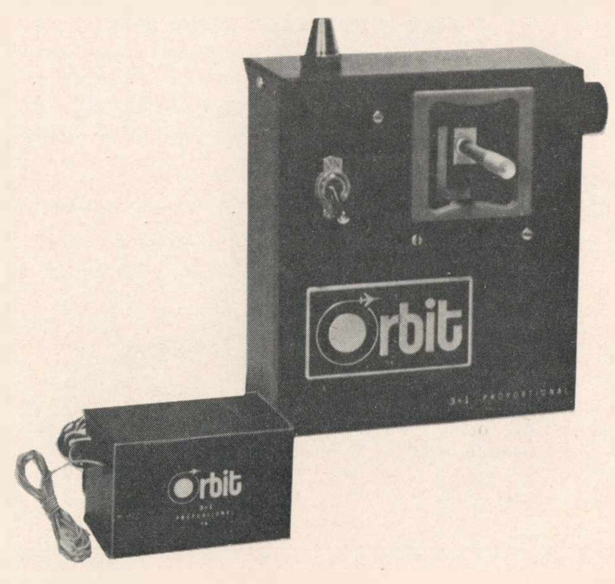
American Aircraft Modeler.

Bud Atkinson's Propo-Cat is a modification of his earlier Aristo-Cat: the latter was flown on reeds.

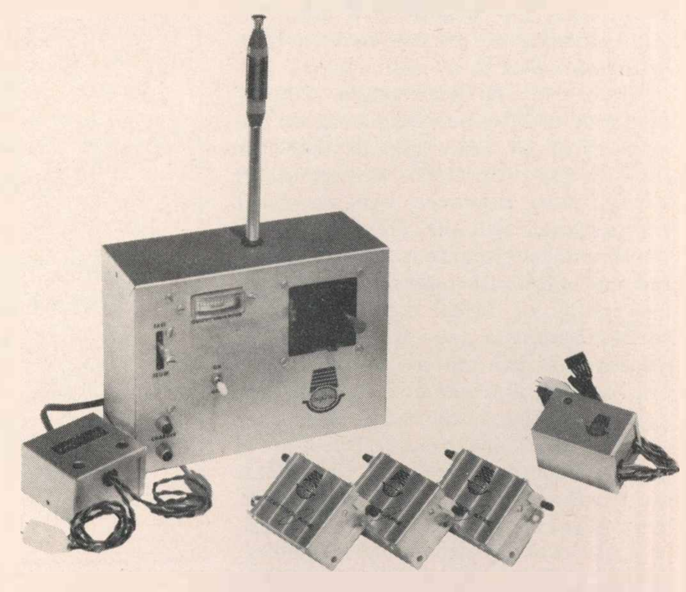
or cutting out one of the coupled controls, can be accomplished by simply varying the switching. Of course, if you do use electronic CAR with these three-control systems (which normally are supplied with just three servos), you must purchase a fourth servo. Even so, the three-control rigs (with or without the fourth servo) are considerably lower in cost than the full-house multi proportional systems, and so are ideal for the sport flier. In the case of the Orbit outfit, this junior version of the four-control analog apparatus has been made possible by simply lopping off one control; otherwise the three- and four-control systems are very similar. Present three-control transmitters are mostly packaged in smaller cases, and some can be had with either one or two control sticks.

I believe the Orbit 3+1 outfit depicted was the first on the market; it was an analog type, is no longer available. But several makers now offer similar outfits in digital proportional form. (See chapter 5 for a description of this more recent proportional technique.)

Bridging the gap between 3+1 systems and those that allow four fully proportional controls we have had such systems as the Quadruplex 21, now considered rather obsolete. However, it provided three fully proportional controls, plus trimmable MC. This system transmitted three pulsed tones, separated them in receiver tone filters, and used them to drive spring-centered servos. These servos were the Bellamatic II style mentioned earlier, but were modified with a special centering spring to provide true linear control action. (See fig. 7-2.) While this was a pulse system, the gear ratio in the servos was so high that the control surfaces could hardly be seen to wiggle. Motor control was had via a POD connected to the rudder servo; thus, even when the engine speed was being changed (and the rudder servo was in neutral) the other two controls were still fully workable. Some experimenters were able to apply true proportional MC to this system by varying the rate of the transmitter pulser (and hooking a pulse rate detector to the rudder channel, to drive a feedback servo for throttle variation). The 21 system was relatively simple compared to complex current proportional equipment, and was reliable and easy to service. At low second-hand prices today, these outfits still offer much for the experimenter.



4-4 Orbit 3+1 equipment started the trend to "less than full-house" true multi propo commercial systems.



Many copies of the Digitrio (three propo controls) system have been built from World Engines parts kits.

5: "FULL HOUSE" MULTI PROPORTIONAL

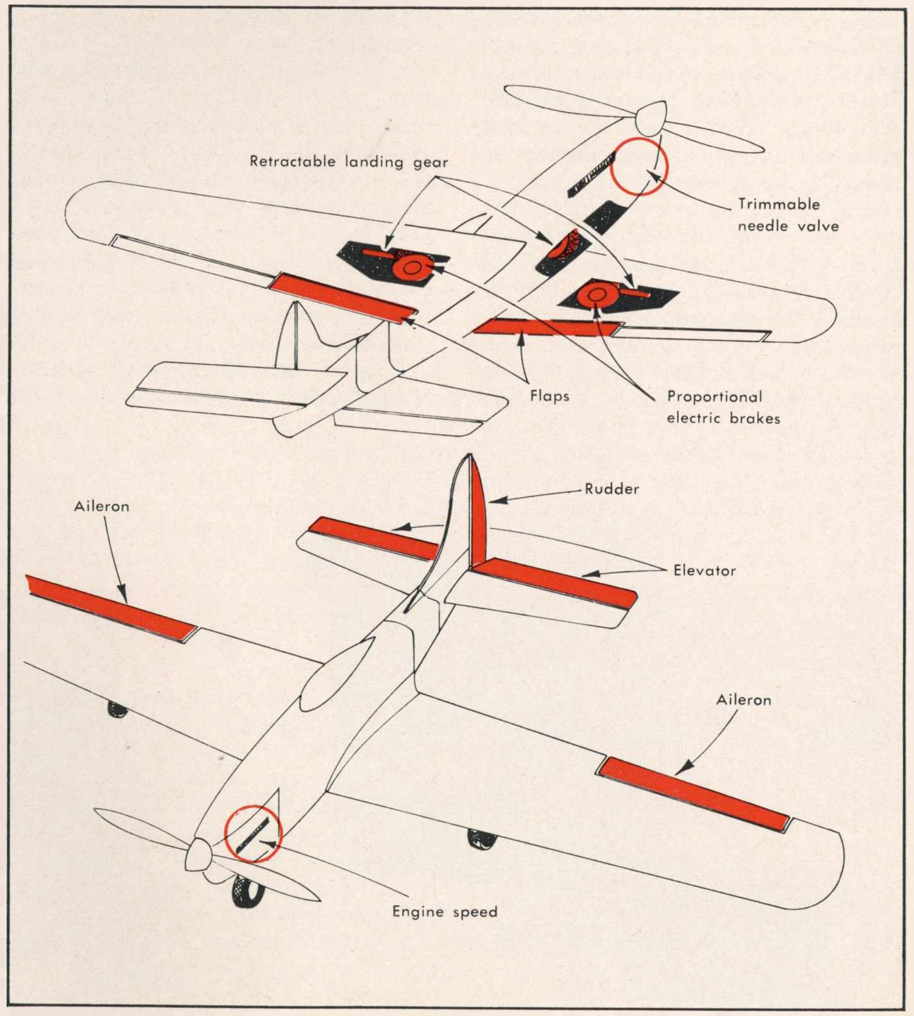
THE odd name "full-house multi proportional" comes from the fact that with such equipment you have *all* the controls to make a model plane do anything you wish it to, and some of the things our models will do often top their full-size stunt plane counterparts (though often this might be due to the fact that our models can do stunts that a full-size plane cannot do without breaking up). Generally speaking, "full house" means the plane has fully proportional and independent controls to handle rudder, elevator, ailerons, and engine throttle, per fig. 5-1A. Auxiliary controls (fig. 5-1B) such as brakes, steering via movable nose or tail wheel, flaps, retractable landing gear, or even trimmable throttle mixture are not strictly necessary, though practically all modern stunt planes have steering and brakes. The steering generally is handled via linkage to the rudder, while brakes are often turned on by a switch actuated when the pilot signals for down elevator. (On planes with two-wheel landing gear, brake action would come from full up-elevator.) Various combinations of switching can provide added control functions or combinations of same. For example, a few planes are equipped with brakes that can be actuated together in normal fashion, or individually, to aid in ground maneuvers. (See fig. 8-5.) This is most easily accomplished with electric brakes, which would, for this purpose, be on the rear wheels of a tricycle-gear plane or on the two main wheels of a two-wheel job.

Little use has been made of proportional brakes, probably because the equipment we have had in the past did not allow this to be accomplished easily. Now, however, with standard proportional systems offering up to eight control functions, such brakes become a definite possibility. In fact, one maker of digital apparatus has a special amplifier (see chapter 9) that allows this use in conjunction with one or two electric brakes. The resultant braking action is as precise as you get on a modern auto. It is a great help to contest fliers, as the AMA stunt rules call for quite a number of ground maneuvers where exact steering and braking capability are a real asset.

Despite all the foregoing comments on auxiliary controls, quite a number of present-day full-house systems allow only the basic four: rudder, elevator, ailerons, and MC. In most systems at least three of these are trimmable. (Engine-speed trim is not always offered.) As noted previously, steering and brakes are generally operated from rudder and elevator respectively. Possibly as outfits with more than the four basic controls become more widely used, builders will tend more to utilize the additional functions of their equipment for steering and brakes, two auxiliary controls that are today considered so vital.

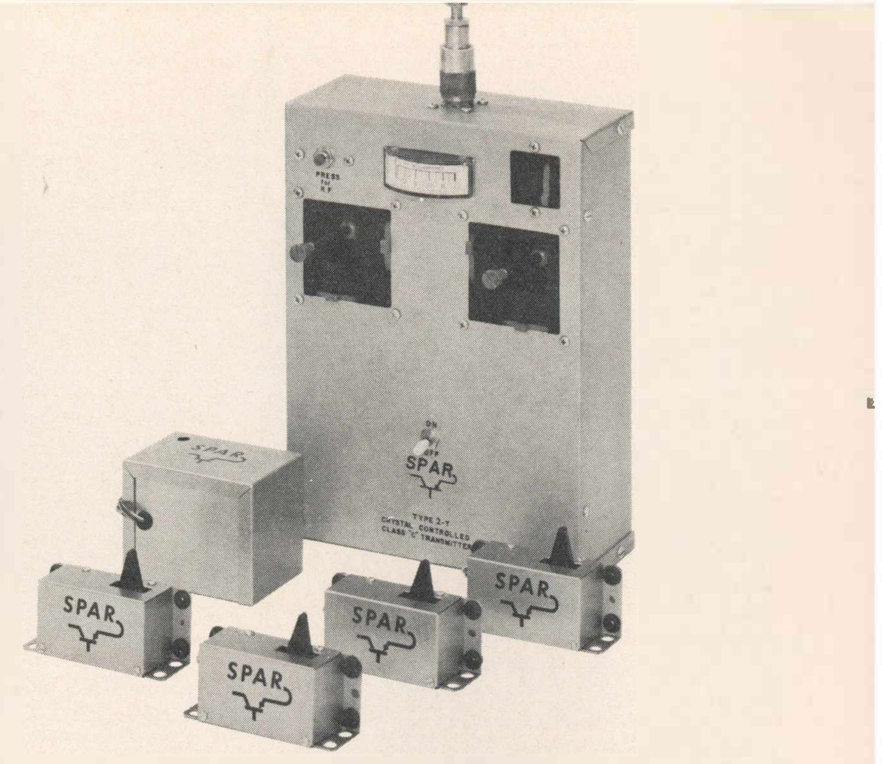
Moderate use has been made of retractable landing gear, and, in fact, you can purchase commercial components for this. There is no need for proportional action of such gear, of course; you want it either fully up or fully down. Most modelers trigger such gear from switches operated by the throttle linkage.

Some proportional systems allow a certain amount of extra control movement at one extreme of at least one control function. For example, let's say the engine throttle (fig. 5-2) requires a servo output disk rotation of 60 degrees to produce the full speed range from idle to wide open. This would be handled proportionally at the transmitter by a lever or knob. But by depressing a button, an extra 15 or 20 degrees of servo rotation in the low-speed direction could be had. The throttle linkage would be set up so that this extra movement could not move the rotating part of the throttle farther than the desired idling position, but the extra servo rotation could trigger a switch to shift a retractable landing gear, drop a parachute, move flaps, and so on. In some systems it is quite possible to modify the servo action at both ends in this manner, giving the possibility of further auxiliary control actions. One popular use is "overdrive" on the elevator servo; some planes are reluctant to go into a spin, but additional up-elevator will make them spin consistently. So the added servo movement on the up extreme does the job when the pilot presses a "spin button" on his transmitter. This is preferable to simply providing a wider range of elevator movement on the regular stick, which would make *all* elevator action much more touchy.



5-1 The lower sketch shows a plane with normal "full house" multi controls — rudder, elevator, ailerons, and throttle. The upper plane has added controls. Flaps are coming into more use these days.

All of the auxiliary controls we have mentioned have been accomplished with reed systems, of course; but multi proportional offers the extra channels to make them much easier to apply in the model. This fact has been a boon to builders of scale R/C planes, many of which, in order to duplicate the controls of the full-size planes they simulate, must be fitted with such controls as flaps, bomb drop, retractable landing gear, and even the ability to lay smoke screens, in addition to the basic four! When it is helpful to have true proportional action from these auxiliaries, as it is with flaps or brakes, then multi proportional has a real edge.



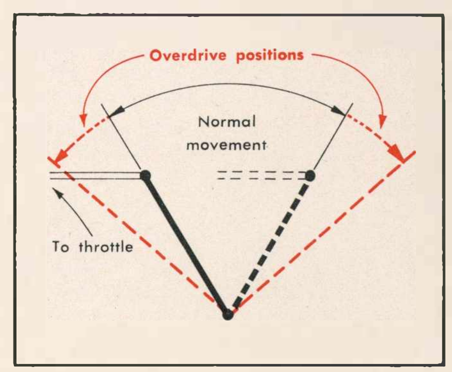
This Spar Electronics five-control outfit (not all servos are shown) is one of the last few full-house analog systems still being made today.

Analog proportional systems

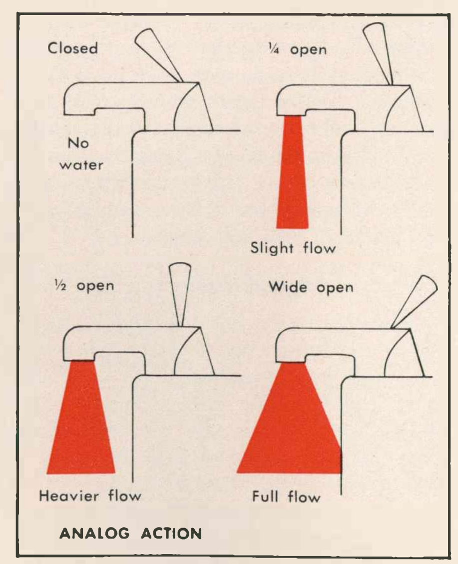
You will hear much discussion on the merits and drawbacks of "analog" systems as opposed to "digital." What are they, how do they differ, and which is preferable? Actually, the field of full-house multi proportional has pretty well narrowed down to 100% digital — though there are still many analog outfits in operation, and some users strongly prefer them. But for reasons shown in the table on page 29, digital is top dog in the field today. It is even getting a foothold in the field of simpler propo, such as rudder-only and GG, but analog still prevails here.

Since analog systems have been with us far longer than digital, let's start with this proportional category. The very simplest and most basic difference between the two types of systems is that analog operates via the smooth variation of some value at the transmitter — varying a pulse width or rate (or both) over a considerable range, or varying an audio tone over a considerable range. This sounds like just what we want for proportional action at the model controls, and it has, indeed, proved to be so. Digital systems, on the other hand, operate basically by simply sending an on-signal, or an off-signal. Suppose (fig. 5-3A) you turn the handle on a water faucet slowly from full off to full on; the water flow varies in an analog manner, increasing smoothly in volume as you move the handle. But if you yanked a lever-type faucet handle suddenly from off to full on, that is digital action (fig. 5-3B). Offhand it does not sound like an equivalent action in models could possibly produce the smooth variation of control that we desire and expect from proportional equipment; but it does, as we will see later in this chapter.

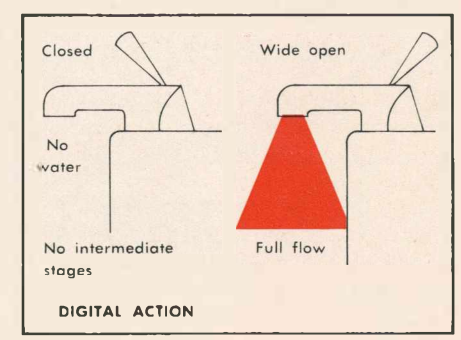
Concentrating on analog action for the present, per fig. 5-4, let's say that when a control lever on the transmitter is varied over its full range, the transmitter sends out an audio tone varying from 1000 to 2000 cycles. Neu-



5-2 Normal servo movement, and "overtravel" or "overdrive"; can operate throttle, plus switches for other functions.



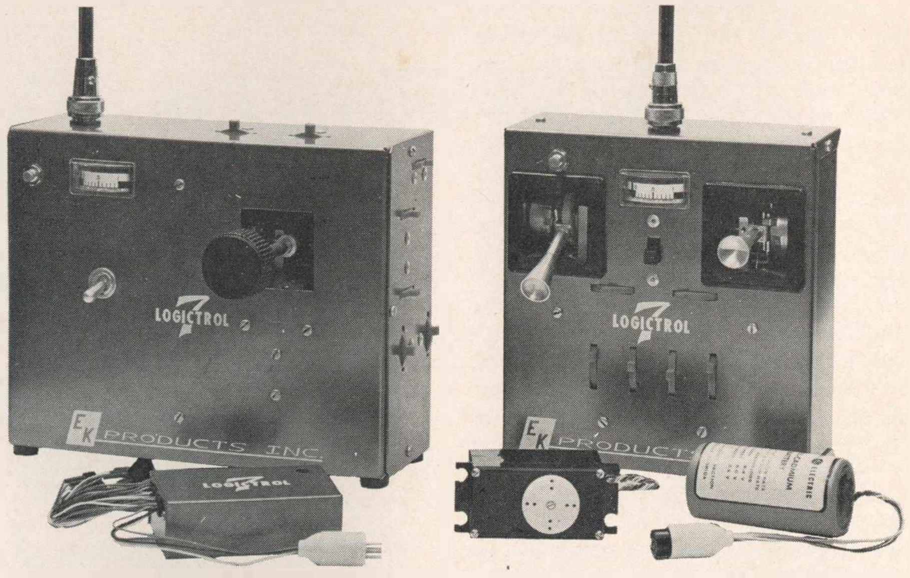
5-3A Analog propo action varies a tone or pulse gradually over an infinite range; only four steps are seen here.



5-3B Digital signals are either off or on full; however, receiver circuitry is such that proportional action occurs.

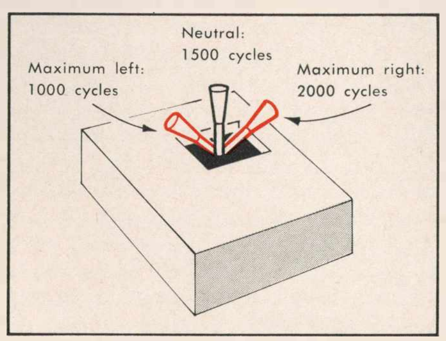
tral would then be 1500 cycles, or center-stick position. The varying tone would be picked up by the receiver, amplified and detected, and converted to a smoothly varying voltage. Let's say it might go from 1 volt plus, through zero (which would be neutral control position) and on to 1 volt minus. Transistors in the servo amplifier sense the change, and supply current to the motor in exact relation to the incoming servo voltage (which depends upon the exact audio tone sent to the receiver, and prior to that, on the exact position in which you place the control lever). The motor moves the control surface to the desired angular displacement (on the rudder, plus voltage might call for right, minus for left). As the servo moves in the desired direction, a sensing unit (usually a variable resistor driven by the servo output arm and a transistor amplifier) compares the voltage from batteries in the model to that applied to the servo input; when the voltages are equal, the servo stops, for zero voltage applied to the motor drive transistors means no voltage is going to the motor itself. This zero-voltage servo position, of course, is different from that for neutral to the extent of the control stick displacement at the transmitter. When you allow the stick to return to neutral, the servo follows right along, for you have upset the balance between the voltage input to the sensing amplifier (which depends upon transmitted tone pitch) and the voltage of the servo-driven variable resistor. Though it takes quite a time to describe, the control action is actually very rapid; some systems will drive their servos from one extreme to the other in a maximum of ½ second, and shorter movements are much more rapid, of course.

While we used the concept of a variable tone in the above description, the job can be done just as easily with variable pulse rate or length, or with audio pitch and pulse combinations. Our description covered just a single



Logictrol 7 transmitters: single-stick at left, dual-stick at right. Small levers on each transmitter are for trim and additional functions.

control, actuated by a single varying tone; but we want *at least* four proportional controls, and the difference in methods of obtaining them varies quite widely among the commercial systems. The Quadruplex CL5, for example, sends four simultaneous tones, varied exactly as we described by the control knobs and levers at the transmitter. All four variable tones are transmitted simultaneously, which means a tough separation job at the receiver, but special circuitry accomplishes this nicely. Other systems have sent four tones in sequence, each going out for one quarter of a set repetition cycle rate. The four tone filters in the receiver thus each get tones in their respective ranges from pulses for a quarter of each cycle. The circuitry "stretches" these pulses so that the voltage applied to the servo inputs is essentially steady. Some analog systems (Orbit analog and its forerunner, Space Control) vary tone frequency, and also pulse rate and length. Many variations in the way tones and pulses are combined have been tried; some have been retained, others dropped for various reasons — and we may still see others.

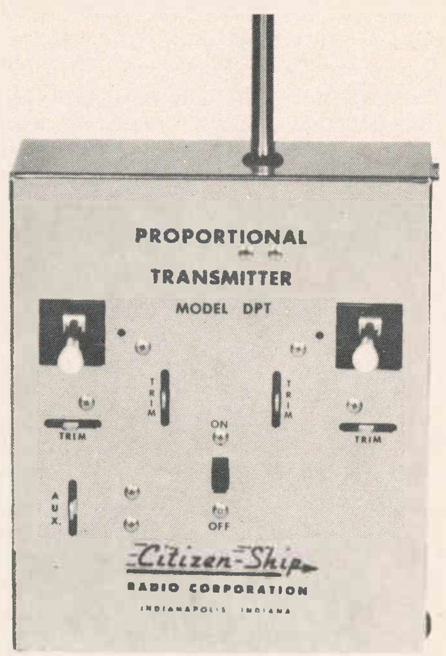


5-4 Analog control stick here varies the tone over a continuous range from 1000 to 2000 cycles; there are no "steps."

Digital systems

There actually have been few true digital systems in modelwork, but those we have presently do function to a considerable extent via digital techniques; hence the general class name. These systems employ quite a few of the techniques of digital computors; in many respects they function by circuits which are in either of two conditions: on or off. This affords considerable advantages as well as some problems, as we shall see later under Comparisons.

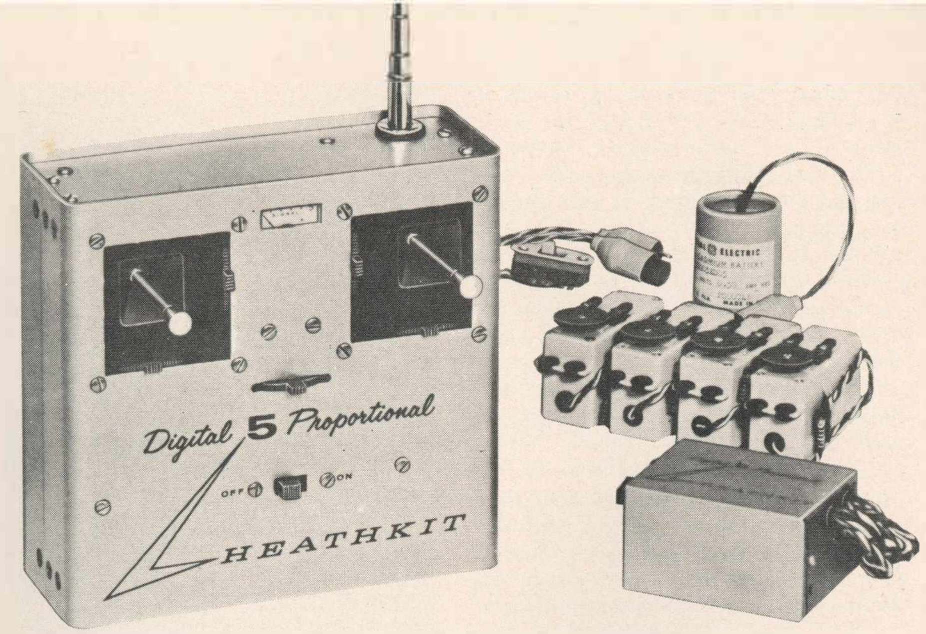
A digital system starts out with an "analog" control — a stick or knob — for you will remember that analog indicates a smooth variation, not just an on-off action. We move the transmitter controls in an analog manner, and we want the model controls to move in an exactly similar manner; but in between, these systems use on-off circuitry to do the job. Describing exactly *how* this is accomplished is beyond the scope of this book, but much information on it has been published in model magazines and other publications, such as the papers of the DC/RC Technical Symposiums



Five controls are handled by the two main sticks, and lever at lower left, on Citizen-Ship DPT-5 transmitter.

(some of which are available through the AMA Supply Service). Basically, a digital transmitter sends out a string of pulses: let's say five of them as in fig. 5-5. At the end of five pulses there is usually a space of no pulsing (set aside for synchronization — that is, making sure that the frames of pulses go out in the exact time intended), then five more pulses, repeated indefinitely. For our mythical digital system, let's imagine we are repeating the five-pulse sequence 100 times a second. There are quite a number of ways the individual pulses can be varied to operate our four basic controls. One way to give variable control action is to shift the position of each pulse from the position it occupies at neutral (as indicated by dotted lines for one pulse in fig. 5-5). In a properly designed system we can vary all four control pulses simultaneously and with absolutely no interaction among them.

The pulses can be sent from transmitter to receiver via an audio tone of any required frequency (in R/C work, the tone frequency range is generally from perhaps 300 to 4000 cycles per second), or we can simply turn the RF signal from the transmitter on and off to correspond to the pulses. In most present-day digital systems the latter technique is utilized, mainly because it decreases complexity and cost. As we saw in an early chapter, any R/C receiver is most resistant to interference when it is tuned to a strong nearby signal — hopefully to its matching R/C transmitter. For the same considerations of interference, practically all present-day R/C transmitters and receivers of the simpler varieties do function via a steady RF signal between them, with variations of one or more audio tones carrying the desired control signals. It would seem, therefore, that digital systems which do *not* use an audio modulation tone might be considered a step backward. This does in fact seem to be the case, and some of the early RF-only digital proportional systems were badly troubled by interference, both from other transmitters and that produced in the model itself from servo motor commutators, rubbing metal linkage parts, and the like. Some of these problems have been overcome by various means, but most digital manufacturers apparently feel that it is worth the risk of somewhat more sensitivity to interference (which can be offset to some extent by internal equipment modifications and improvements) rather than go to the more complex and expensive AF modulation principles of conveying their pulse information from transmitter to receiver. It will be noted in fig. 5-5 that the RF signal is on most of the

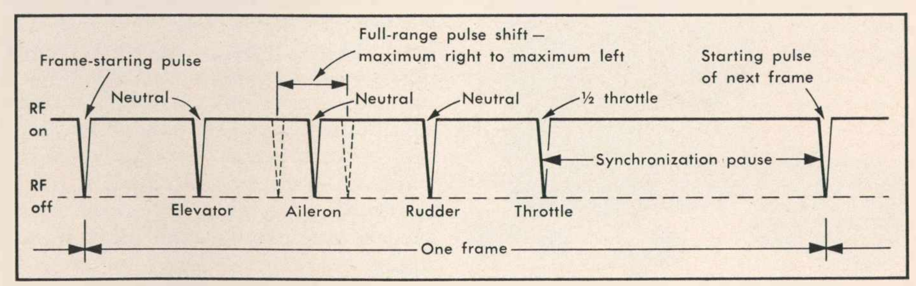


Heathkit Digital 5 outfit is unusual in that it can be had only in kit form. It can be assembled and put into operation without need for any test equipment whatsoever. Construction is not difficult, but is not for the rank beginner.

time, with the pulses coming in the form of no-signal. It is during these RF-off periods, of course, that the extraneous signals can bother the receiver; pulses coming in when you don't want any can cause control malfunctions.

To continue following the pulses through the system, the position variation of each pulse is what conveys the required control surface information in our mythical system. Instead of being transformed to a variable plus or minus voltage for the servos, the servos actually receive their information in the *form* of pulses. Complex receiver circuitry separates the different pulses and channels each pulse to the correct servo. As required by digital techniques, the input to each servo is in the form of either no voltage or full-on voltage. This is passed through amplifiers to drive the motor, and the latter also receives either full drive power or none at all. It might seem that the servo would move in a series of jumps, and theoretically it does; but remember that we are supplying the pulses at the rate of 100 per second, so at the worst the motor would receive 100 very short jolts of full power each second. In some digital systems you can actually see the servo move in a series of tiny steps; in others, due to motor armature inertia and other factors, the motor pulse input is smoothed out to quite an extent. In any case, the "steps" the motor may make are spaced so closely that even tiny control stick movements are transmitted very accurately to the control surfaces of the model.

Like the feedback servos used in analog systems, digital servos also have a sensing arrangement to stop the servo when it has moved far enough to match the control stick displacement. There is a variable resistor linked to the servo output arm in the same manner, but each servo has a built-in oscillator which produces pulses matching the overall range that is presented to the servo input. The pulses developed by this internal oscillator are compared to those at the servo input and the servo moves until both are identical. The variable resis-



5-5 Simplified sketch of digital signal. Control pulses are evenly spaced when servos are at center. Sideways movement of one pulse varies one servo accordingly. All can move together if needed. Note longer "sync" pause.

tor makes this possible by changing the action of the servo internal oscillator.

The basic difference between analog and digital systems is the method of conveying information between control stick and servo. The analog systems function via a technique of continuously and smoothly varying a tone, pulse, or combination, and all of them use transmitters with tone modulation. Digital systems transmit basically on-off pulses (the engineers generally call them "spikes," which are extremely short relative to the pulses used in analog systems), and most of them do *not* use AF modulation, though when you listen to their transmitter signals on a monitor you do hear what sounds like audio tones.

Fail-safe or not?

Aside from the basic controversy of whether analog or digital systems are best, probably the second most controversial matter is that of fail-safe. It is present in some form in most analog systems, where it can be had without much added complexity, but to add it to digital equipment does increase complexity and cost. Because interference spikes can look like valid control information to a digital receiver, but can put the controls in completely unwanted positions, those systems that feature fail-safe also have what is termed "lockout." Lockout circuitry checks the incoming pulse trains, and if it sees any that are different than the normal incoming pulse trains from its own transmitter (and random interference *would* very likely make the pulse train look quite different), the lockout cuts all control pulses to the servos but holds the servos in the exact position they were when the garbled pulse trains were first detected. The usual hold period in the lockout mode is about ¼ second;

American Aircraft Modeler.

Hal deBolt with his Mark 5 Interceptor, a very successful competition design for full-house multi. It has been flown with and without retractable landing gear. Strip ailerons on wing run almost full length.

Robert Hall Studio.

F&M five-control propo transmitter and receiver. Sticks handle two controls each; added control is via lower left lever.

if normal pulse trains are not restored in that time, then fail-safe takes over, all servos return to neutral, and motor control goes to low speed. This situation continues until the interference ceases, when normal control is restored.

This sounds like a very desirable feature, and some manufacturers think enough of it to build lockout and fail-safe in their systems. Why the controversy, then? It stems from the type of planes operated by the top contest fliers today, all of which have multi proportional. The modern hot competition stunter is designed to have "neutral stability" — that is, it goes where it is pointed. Sport planes are generally designed so that they will right themselves to a normal flying position if they have sufficient altitude. The anti-fail-safe group claims it will do them no good, as their hot, fast planes will end up in the ground anyway, given lengthy interference; but if the interference were not too severe, they might have a fighting chance of landing their planes intact even though with somewhat erratic control. It is probably true that a modern hot stunter with fail-safe would very soon be headed straight down even if it had been in level flight when fail-safe cut in. Such a plane can build up frightening speed when headed earthward, even though the engine might be idling, or stopped entirely. Actually, some fast modern stunters have landed safely, or with minimum damage, while the receiver was in fail-safe. (It should be understood that fail-safe also operates if something goes wrong in either transmitter or receiver to disturb the normal flow of pulse trains to the lockout sampling circuits. Should a vital wire break loose, or some similar catastrophe occur, you would also get fail-safe, but the subsequent course of the model would be in the hands of the gods — and you couldn't alter matters with or without fail-safe.)

What this boils down to, then, is what type of model will you want to fly with your multi proportional? If it's a sport design with reasonable stability, fail-safe could very well prevent a flyaway in case of interference or other trouble. If it's to be a hot neutrally stable stunter, fail-safe *might* save the plane — or it could prevent you from fighting it down to a possibly rough landing but perhaps with minimum damage. Equipment without fail-safe will save you a little money and will also drop the parts count in the system appreciably, which could increase reliability a bit.

Recognizing the differences of opinion concerning fail-safe, one maker of digital equipment in recent years has offered its five-control outfit either with or without this feature; the outfits were identical otherwise, but systems without fail-safe cost some $40 less. So far this has been the only maker to offer such a choice.

Do I hear a voice asking, "Well, how can I *tell* if the plane I want to build is neutrally stable, or whether it will right itself from some unusual attitude?" The key is found mainly in "angles" — the angular difference between wing and stabilizer, and the dihedral angle. Wing-stabilizer angular difference is sometimes termed longitudinal dihedral; the most versatile stunters have zero longitudinal dihedral (or angular difference between wing and stabilizer). They also have very low — in some cases, *no* — dihedral in the wing (the angular difference between the two wing halves); an angle less than perhaps 4 degrees would be considered fairly low dihedral. With zero dihedral a plane will fly just as happily inverted as upright — which is one of the reasons for using low dihedral — but it will not right itself. You have to do the righting, and if you don't do it fairly quickly — Mother Earth, here she comes! Generally, high-wing (and "cabin") planes are most stable; shoulder or mid-wingers are less so, and low-wingers are least stable.

Analog-digital comparisons

It may be felt somewhat academic for us to dwell at such length on the comparisons between analog and digital apparatus. At this writing, analog full-house multi apparatus has gone out of production almost completely. However, there is still much fine analog apparatus available in the used equipment market. Such apparatus will give the sport flier fine service at a very reasonable cost; it could have other advantages for him too. As we have noted, analog multi systems are relatively easy to service, and an owner with a little electronic know-how and simple test apparatus could handle most troubles. Furthermore, as a class, analog equipment has been felt to be less bothered by interference — another plus for the sport flier.

With the analog field of simpler proportional systems being invaded by digital, the analog-digital comparisons again become of interest. So far, analog equipment strongly dominates this field, but digital may make further inroads. For concerns that manufacture only multi equipment of the digital style, this approach makes sense, as they can utilize circuitry in their one or two control systems that is very similar to what is in their full multi apparatus; servos, for example, can be the same for both. So table 5-1 could be of considerable interest to the beginner in R/C, even today.

Prices in the multi digital field are dropping to quite an extent as more and more concerns enter the field. It is fairly common knowledge in R/C circles that considerable discounts can be had on some lines, though perhaps not on others. Manufacturers come and go quite rapidly in this highly competitive field, and I would strongly urge the prospective purchaser to consider the reliability and reputation of the maker of any equipment he contemplates buying. It is often impossible to obtain service on "orphan" equipment — something to consider when you are making a $300 to $500 investment!

Table 5-1: Analog-digital system comparisons

Analog systems	Digital systems
Fairly simple in circuitry and construction; fewer parts means fewer soldered joints; should increase reliability	Very complex, many parts (growing use of commercial integrated circuits will cut individual part count, though)
Good rejection for interference from inside and outside the model	Much more susceptible to interference; metal-to-metal linkage joints can give trouble
More subject to temperature and battery voltage drift	Drift is generally not a problem
Factory tuning needed to match more than one receiver to a transmitter	In many makes, any receiver will operate with any transmitter of like make and frequency
Can be serviced by knowledgeable owner with fairly simple test equipment	If it goes sour — *send it back!*
Servos somewhat load-conscious; as plane moves faster, there is less control deflection for a given stick movement	Servos always driven at full power, so load is not as much a factor
Servo motors should preferably be of precision style (likely to be more expensive and delicate) to respond rapidly to low voltages they sometimes receive	Because of above, more rugged motors may be utilized
Servo moves smoothly, due to input filtering	Servo moves in tiny jumps; *starts* moving faster than analog servo
Tune-up can be time consuming, thus fairly costly	Tune-up is rapid, but testing takes much more costly equipment
Fail-safe fairly simple; lockout not required	Lockout and fail-safe add considerable complexity and cost
Extra controls not easy to add; five is about maximum	Quite easy to add extra channels; eight is tops now (Digimite), but more could be had if there is need

6: TRANSMITTERS AND RECEIVERS

THIS chapter will cover mostly the special requirements of transmitters and receivers used in proportional systems. Nowadays we can purchase a wide variety that are *designed* for such use, but it was not always this way. It is also possible to adapt some nonproportional units to proportional operation with fine results, but others are not very good for the purpose, and in some of them the necessary changes just would not be worth the trouble.

Simple pulse equipment

In this category we place rudder-only apparatus, and also RO with motor control. The basic transmitter requirement, of course, is that it have a pulser. There is not too much to say of those recent transmitters which have a built-in pulser and were designed right from the beginning for proportional operation. If you are new to R/C and have to purchase all your equipment, there are a few considerations to keep in mind when obtaining a transmitter. First, is your interest in R/C, or in model planes, just a passing fancy, or do you really want to dig into it? If the former, you can obtain low-cost transmitters fitted with a pulser of the most basic kind that will control a proportional rudder, and that's all. They will have a small stick or lever on the case front for steering; this is usually linked to a variable resistor to alter the transmitted pulse length.

I strongly feel that the lever should be spring-centered, though some fliers will not use such centering. With it, however, when a novice flier gets into trouble—if he has a reasonably stable plane and it's high enough in the air — he can just release the control stick entirely and it will snap back to neutral and the plane will usually quickly settle down to steady flight. With a noncentered stick, the harried pilot has to look down at the transmitter to see what control he is calling for (the experienced flier knows this instinctively by the feel of the stick), and in his flustered state he is likely to put the stick in anything but neutral. Most modern pulsers do have a spring-centered stick, but a few have a knob on the control resistor, and this presents some complications for the beginner, especially if the full pulse range requires that the knob be turned over the entire variable resistor rotation

Low-cost Airtrol transmitter for rudder-only operation has a pulser operated by the large lever.

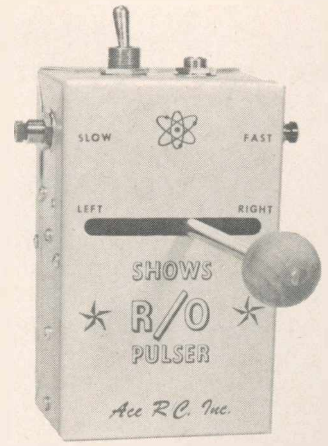
range (which averages about 270 degrees) for the full available pulse range. With a slow plane this is no problem, and with a slow-moving boat it is probably an advantage; but with a fairly fast plane you just do not have time to twist the knob through the wide range required for certain maneuvers.

Some fliers have adapted to this situation by putting two buttons on the pulser to give a steady audio tone output from the transmitter, which would produce full rudder in one direction, or no tone for full rudder the other way. The wide knob rotation is then put into use only to fly the plane through gentle turns and maneuvers; for violent stunting, the knob is left in center position and the plane is flown by the two buttons. It has always seemed to me that this sort of flying loses the prime advantage of proportional, which is simply that you can get a full range of rudder surface movement (or other control) from a single stick moved through perhaps 70 to 90 degrees total, *without* having to resort to added knobs or buttons to get the extremes you sometimes want, and get them fast enough.

All right — we have a pulser with a spring-centered lever (which moves some 40 degrees each side of center), and the pulser may have an on-signal and an off-signal button. You will recall from an early chapter that if you want to have rudder and motor control, the latter being operated from the widely popular POD, these two buttons are what make the throttle servo go to high or low speed. Let's say you have a perfectly good single-channel transmitter (under our adopted nomenclature this refers to one that produces a single RF output and can modulate same with a *single* AF tone) but without a built-in pulser. This is no real problem, for there are several add-on pulsers marketed (both in kit and completed form) that can be attached to the transmitter case. Some of them have built-in batteries; others can be hooked to the transmitter batteries, if they are of the correct voltage. Modern pulsers are all-transistor jobs operating on from 3 to 9 volts; many transistor transmitters work on 9 volts, too. However, tube transmitters (and there are still a few of these in use) generally have batteries of $1\frac{1}{2}$ volts and perhaps 135 volts, and so are not able to power the transistor pulser.

The front of the transmitter is the logical place to attach the pulser case, but if it has on-off switch, keying button and other items in awkward places, you can fasten the pulser to the side, or even to the back. Before drilling holes, though, make sure your proposed pulser location is going to be handy for flying the model. Needless to say, you will attach the pulser in the manner that best suits your "handedness." Some manufacturers, especially of the more complex pulse equipment transmitters, will make "left-handed" transmitters on special order at small extra cost.

The so-called unijunction pulser is the most popular today, especially where pulse rate and length variations are required. A block diagram of one of these appears in fig. 6-1. The actual pulses are produced by the oscillator transistor at the left; all the other transistors in the unit are concerned with shaping the resultant pulses to do the job required of them, and to build them up to whatever level is needed at the pulser output. If you



Ace R. C.

Shows Rudder-only pulser can be applied to most nonpulse transmitters. It has relay output for greater utility.

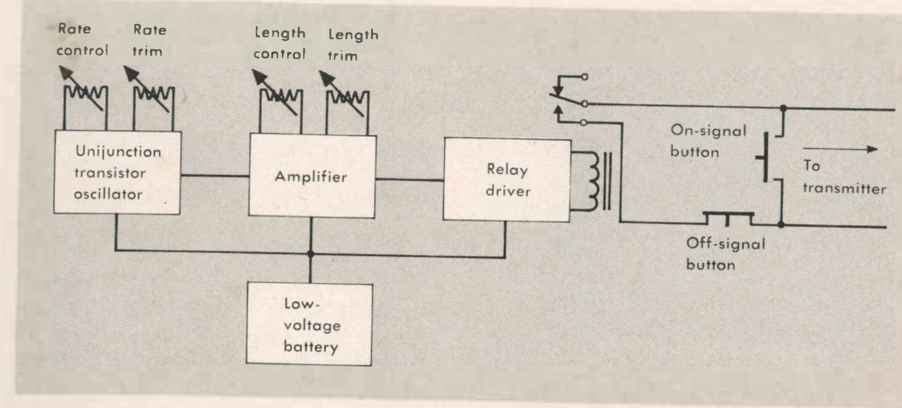
wish to add a pulser to an existing transmitter, the job is often easier if you obtain an add-on pulser ending in a relay, and most of them on the market do. The two connections from this relay are then simply wired across the existing keying button in the transmitter, per fig. 6-2.

To make the installation a little more versatile, so that you can add motor control when desired, you might want to add another pushbutton to the transmitter case front. (All simple transmitters come with a button that produces a steady tone, which is the one you connect your pulser leads across, per fig. 6-2.) This must be a no-tone button and can be added as in fig. 6-3. Note that the tone-on button will usually be what is termed a "normally open" unit; that is, the contacts are open until you depress the button, but for the tone-off button a "normally closed" button is required — the contacts are *closed* until you press the button.

I asked some time back if your interest in R/C and proportional is serious or not. The reason for this question is that if it *is*, you would be much better off to purchase a pulser, or a transmitter with pulser built in, that affords variation of *both* pulse length and rate, and with no interaction between the two. Such pulsers are a little more complex, and more expensive, and will do fine for just simple rudder-only pulse flying, but they also have the necessary added capabilities to allow your entry into Galloping Ghost or even more complex pulse rate-length systems. Pulsers which have a unijunction transistor generally are preferable for this, while pulsers with just two plain transistors will do nicely for rudder-only, and these are considerably lower in cost — and smaller.

There is one precaution to consider when adding a pulser to a nonpulse transmitter. It concerns the possibility of getting RF from the transmitter output circuits into the pulser itself. Normally if your pulser is attached to the outside of the transmitter case there will be no problem, even if it's driven from the transmitter battery; but if you mount it inside the transmitter, and especially if you have to take the pulser out of its own little case to do so, you could have a problem. When RF gets into the pulser circuits it can cause the pulsing to change in undesirable ways; the pulse rate might vary when the RF circuitry is turned on, for example. This was a serious problem when all we had were tube pulsers, but fortunately transistor pulsers are not as badly disturbed by a little stray RF. If your pulser has a relay, you can easily check by noting the pulsing speed with just the pulser turned on, then flipping on the transmitter switch. If there is no change in the relay sound, you have no problem. If there *is* much change you will have to try better shielding, using a separate external battery for the pulser, and similar measures to isolate its circuitry from the transmitter RF circuits. (It might not make any real difference in a rudder-only system, but could be serious in pulse rate-length work.)

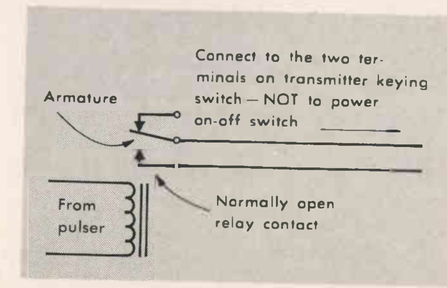
I have covered pulser requirements for various systems rather thoroughly in this and previous chapters, and just emphasize again that you should get a pulser, or a pulser-transmitter combination, that will suit *your* requirements. Check particularly the pulse rate and length ranges, MC buttons (or lever) if you will need them (or



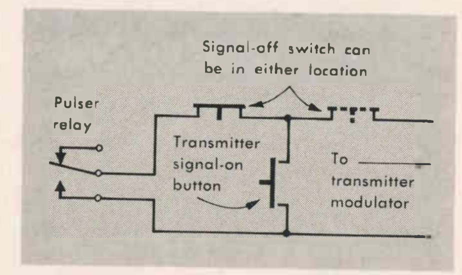
6-1 This block diagram gives a rough idea of how the components of a unijunction transistor pulser are connected; many have a relay on the output.

Cannon Electronics.

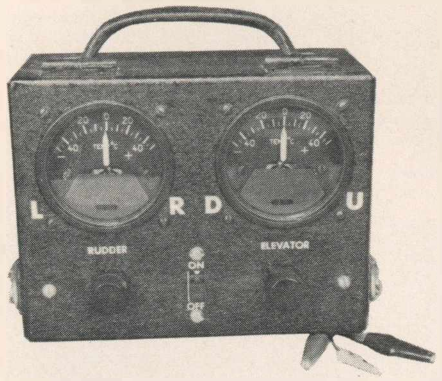
Compact Cannon pulser attached to front of single-channel nonpulse transmitter. A single nut holds the pulser in place.



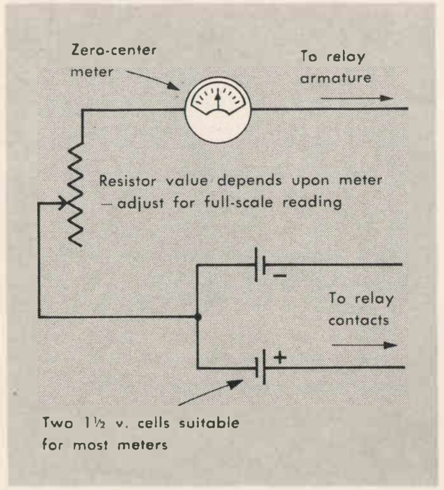
6-2 Two wires from the relay of an add-on pulser are hooked to the key button on a nonpulse transmitter for propo work.



6-3 Nonpulse transmitter has on-button. Off-button is easy to add.



Above dual pulse meter has two circuits as below; same batteries for both.



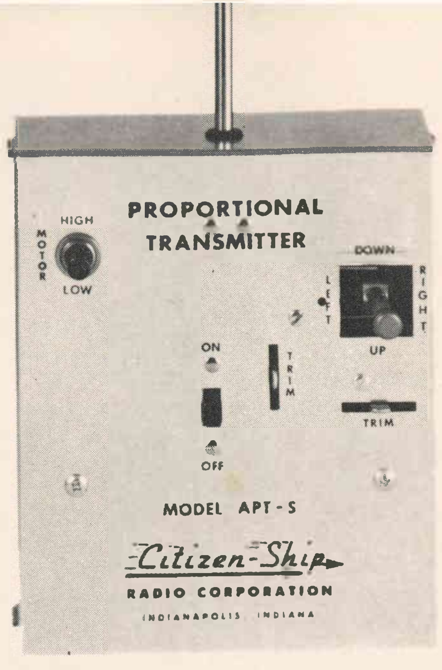
6-4 Zero-center meter of pulse tester is driven both ways, by a pair of cells, through SPDT relay contacts.

it), the presence of trim levers, or knobs, on pulse rate and length output. (Some such levers have a very wide range intentionally, more to adapt a given transmitter to various types of rate-length control systems than to allow small precise trim changes in a specific system.) If you wish to attach a pulser to a transmitter you already have, remember the job is much simpler if the pulser has relay output. Make sure it will fit on the transmitter conveniently. Some add-on pulsers have single-hole mounting with a hollow bushing through which pass the leads to key the transmitter, and also to obtain battery power if the pulser does not have its own batteries.

The serious pulse experimenter may wonder how to tell if a pulser is giving even on-off pulses, or if a receiver is sending the required form of pulses to its associated actuator. With a pulser ending in a relay (or receiver similarly equipped) you can soon learn to judge if the pulse length is near to 50:50 on-off. If you can listen to the transmitter output on a monitor, you can check the pulsing; relayless pulsers make no noise at all in operation. If your pulser has a relay on the output, though, there is a simple and precise way to check pulse length by use of a zero-center meter, as seen in the simple circuit of fig. 6-4. Such meters may be had from surplus electronics concerns at a cost of only a couple of dollars, and the scale is of no consequence as long as the divisions are even on both sides of the center zero. Most such meters will be of the milliammeter variety, and again, the current requirement for full-scale reading is not important as long as it is not over perhaps 100 ma. Meters of much higher current requirements can often be converted to low milliamp range, but such a job is a bit beyond the scope of this book. The meter is linked with a pair of small batteries and a variable resistor, and a set of tiny clips to connect it to the pulser relay. If the batteries are of equal voltage and you are getting true 50:50 output from the pulser, the meter should stay at zero (which is center-scale, remember) when the control stick is at center. (Check battery voltages beforehand by shorting each battery-clip line with the clip lead from the meter. The resistor should be set to provide full scale readings under these conditions.) As you move the stick to one side or the other, the meter needle will move in step. Though it makes no special difference, the needle might go in the opposite direction from the stick; if so, just reverse the two leads from the test-unit batteries to the two pulser relay *contacts*.

The same meter can be used to check the output of a relay-type receiver by connecting the clips to the receiver relay just as you did for the pulser relay. Testing relayless receivers is a bit trickier; you would use the same style of meter, but would need no batteries, since power would come from the actuator batteries. This would be feasible only if the meter were of a rather low-current type (say, less than 10 ma. for full scale). One might think the pulsing of the receiver could be judged well enough by the movement of the actuator arm, and normally this would be the case; but there might be some doubt as to the actuator's bearings, or internal sticking on one side. The test meter would soon show up such problems, or indicate the need to check into the switcher circuits, if any, or to go all the way back to the transmitter pulser.

Though it is not much of a factor anymore, it should be noted that relays themselves can generate lags that will make a pulse system operate poorly. Due to dirty or sticky contacts, incorrect spring tension or contact



The C-S analog transmitter on page 20 has dual sticks. But you can get it with a single stick, like this. It is also made to suit GG systems.

spacing, or to the fact that the relay armature can actually touch the top of the adjacent core piece, relay action (in either pulser or receiver) may become erratic. Some notes on relay setting are included in chapter 9, R/C PRIMER.

Perhaps I should mention here that in some rather rare cases the transmitter circuitry itself (rather than its pulser) has been known to distort pulse output. The AF oscillator (which acts as a modulator in many of the simpler transmitters) can be sluggish in starting each pulse, or possibly sluggish in stopping, which would naturally put out pulses different than desired. Such cases should be referred to the maker for cure.

One or two control sticks?

You can get a good argument on this matter at practically any model flying field today. Early proportional systems all had only a single control stick; TTPW, for example, could handle just two controls, rudder and elevator, via the stick; and no one thought of using a separate stick for each control. When ailerons were added to these systems by means of CAR, the sideways movement of the stick still handled "steering," while up and down movement still produced elevator action. When further refinement of the early systems allowed separate aileron control, some builders just added a separate lever for this control and kept rudder and elevator on the normal stick. One pair of experimenters (Doig and Bonner, on the Ulti four-control analog system) retained the single stick but added a rotating knob on the end which would allow rudder movement, while the side-to-side stick motion was transferred to aileron. A separate lever or knob allowed proportional engine speed action. When the first commercial four-control proportional outfit was marketed (Space Control) the same sort of single stick was featured, but many accomplished reed fliers found it difficult to shift over to the new proportional gear, and one of their biggest problems was in learning to operate three control surfaces from a single stick when they had always been used to having both thumbs in the act. Gradually the proportional makers saw the need for two sticks, and some marketed only this kind of equipment. Their refusal to build single-stick transmitters was doubtless based upon the more difficult and costly stick and pot mounting required. Now, many proportional transmitters are available with either single or dual stick.

Which is best? Like the fail-safe vs. no-fail-safe controversy, you can get a good argument either way. Generally, it seems that reed fliers adapt more easily to proportional transmitters with two sticks. Modelers getting into multi proportional who have flown simpler proportional systems such as GG or Kickin' Duck will very likely prefer a single control stick. Those with little previous R/C flying experience could probably adapt to either one or two sticks equally as well.

Actually, the controls on a two-stick proportional transmitter are normally not arranged like the ones on a multi reed job, where, through long refinement, it has become accepted practice to have the aileron and rudder levers on the right-hand edge of the transmitter case, and elevator and motor on the left (plus elevator trim, if it is included). General practice in two-stick proportional transmitters has been to put aileron and elevator (generally considered to be the most important — and most active) controls on the right stick, with rudder and motor on the left. Some manufacturers will alter this arrangement to whatever a buyer prefers on special order. On some multi proportional systems (such as the Min-X in fig. 6-5) you can put any control on either stick, in any combination you desire. This is accomplished simply by shifting servo plugs in the preferred order in a common connector block, thus producing quite a universal setup.

Even though they afford only two or three controls (and motor control might not be proportional), some makers of simpler systems also offer your choice of one or two sticks. To accommodate the oddballs among us (of which your author is one) a few manufacturers will even provide their transmitters with controls to suit left-handed fliers, as noted earlier.

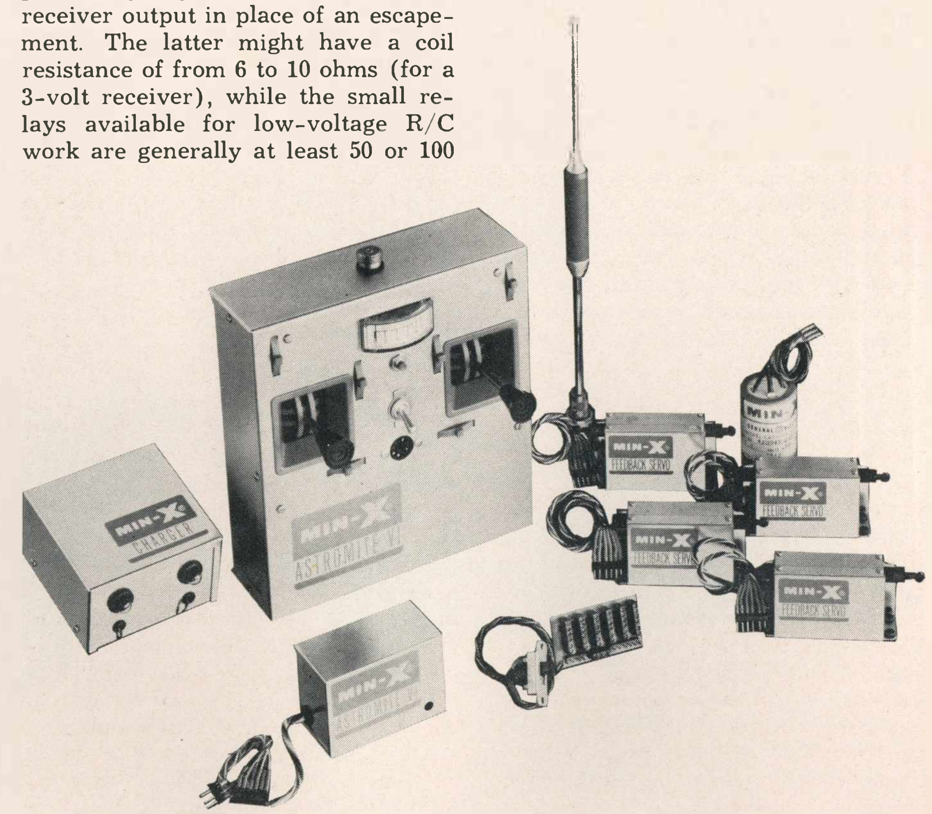
Adapting simple receivers

For general pulse uses, receivers with relay output are the most flexible. Also, they are most likely to be able to follow pulses accurately. Up to only a few years ago most single-channel receivers were designed for one specific use—to trigger an escapement — and some of them were pretty dismal pulsers. Most will do a fair job if the pulse rate is kept as low as possible, no higher than 3 or 4 PPS, and if you do not want to use them for pulse rate variation. For the latter, it is wise to choose a receiver made specifically for pulsework, which will also be fine for escapement or sequence-type motor-driven servos as well. With the huge upsurge of pulse interest in recent years, receiver manufacturers have become conscious of the special needs for pulse operation, and few receivers made today will not do well on the simpler kinds of pulse systems. One possible exception is the single-ended relayless receiver. This is definitely intended to trigger an escapement and to handle a fair amount of current in the output circuit, up to as much as ½ ampere or possibly even more. The components needed to assure this high current capacity can make the receiver a poor pulser if you just hook a relay to the receiver output in place of an escapement. The latter might have a coil resistance of from 6 to 10 ohms (for a 3-volt receiver), while the small relays available for low-voltage R/C work are generally at least 50 or 100 ohms. They will work on the relayless receiver but can be very sluggish in action. If you are interested in rudder-only at low pulse rates, most of them will do, but for higher rates, or pulse rate-length, the relay lag can cause trouble.

It's possible to speed up the pulse action of some of these receivers and still get enough output current to operate a relay reliably. This is usually accomplished by reducing the capacity of an electrolytic connected to the output transistor or the one before it— this unit will often be of 100 mf. or more and will be connected from collector or base to emitter of one of these transistors. Dropping the value of this capacitor to half, or even less, might reduce the maximum current in the relay a bit, but there will still be plenty to work reliably a 100-ohm relay, the size often used in 3-volt receivers.

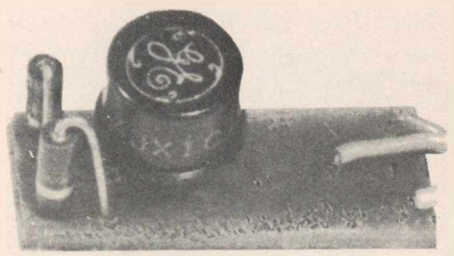
Some relay-type receivers will be found sluggish upon rapid pulsing, though, as noted, most modern transistor receivers will pulse sufficiently fast even for pulse rate work. In any case, almost any receiver you buy today will do well enough for plain rudder pulsing at moderate rates. It's only when you add a pulse rate circuit that receiver (and relay) pulsing characteristics become much more important.

As we have found, a "single-ended"

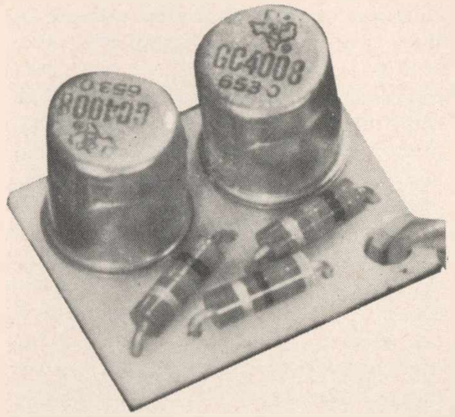


Min-X Radio.

6-5 The connector block in the center allows the user to plug in any servo for operation from any control lever in the transmitter. This is a six-control system.



Add-on switcher by Ace R/C converts single-ended receivers to operate double-coil (or C. T.) actuators.



World Engines.

6-6 Controlaire NND-1 switcher works servos from relay receiver, single battery.

receiver (most of which were designed to operate an escapement without need for a relay) will not control the most satisfactory style of actuator: it can handle only a single-coil style which is spring-loaded to one extreme. While fine flying can be done with such an arrangement, it really is not the best for the beginner in proportional, as it takes a bit of trimming and testing to get neutral set up just right. The best bet is a receiver *designed* for proportional operation, and a few manufacturers can supply them: the so-called "double-ended" receivers. These have no relay but do have an extra output transistor so connected that they will drive an actuator with double coils, such as the C&S or Adams units. Connections of such a unit are given in chapter 2. Also mentioned there is another solution. If you have only a single-ended receiver, obtain one of the "add-on switchers" which will effectively change a single-ended receiver to double-ended output.

There is only one angle you must keep in mind with either a double-ended receiver or a single-ended with the simplest form of switcher. They will *not* operate a motor-driven servo from two sets of cells. You must use a double-coil magnetic actuator with them, or one that has a center-tapped coil. It is quite possible to make a transistorized switcher to drive an electric motor in both directions from a single-ended relayless receiver and two sets of batteries. Circuits for such units have appeared in the model press.

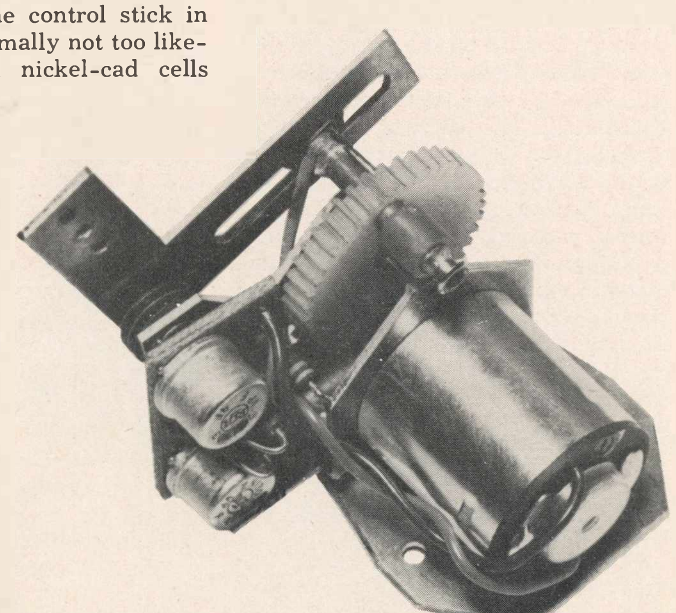
The tiny NND-1 switcher, fig. 6-6, offered by Controlaire, operates still differently. It is intended to afford better pulsing from a *relay-type* receiver, allowing operation of a motor-driven servo in both directions from a single set of cells. This has several advantages. You can use fewer cells in the plane (though you are making the single set of servo cells do double duty, so they will last less than half as long), thereby probably cutting total installation weight. When you are using two sets of cells for a proportional servo, it is possible for one set to run down before the other, and since this will make the servo weaker on one side, you get rudder drift: that is, the plane will no longer fly straight with the control stick in neutral. This is normally not too likely to occur when nickel-cad cells power your servo, but plain penlite cells are used for servo power in the majority of rudder-only planes.

Knowing that there are many more single-ended receivers in circulation than double-ended, a few servo makers have marketed motor-driven proportional servos with a transistor switcher built in. This allows operation of such servos from a single-ended receiver, thus cutting down weight in the model and saving space. At the low current drain of modern efficient motors, even a set of penlite cells will last several hours under such service, and will supply all the current required by the receiver, too.

Pulse rate-width

Most receivers will work reasonably well for just rudder pulsing (pulse length only), but when adapting a receiver to pulse rate work, the requirements are much more stringent. A receiver that will give reasonably good output on a pulse *length* change, and at a rate of perhaps 4 PPS, may distort the pulse rate output badly when sent pulses twice or three times as fast. Again, relay receivers are better in this respect, generally speaking, and some of the modern units retain pulse fidelity (both rate and length, or any combination of the two) up to 15 PPS or even more. If you are in any doubt as to a receiver you may have on hand, suspect the receiver first if your pulse rate and length output is distorted or nonsymmetrical, rather than the pulse decoder or servos. Some receiver manufacturers can give assurance that their products will pulse properly; in fact, such receivers are designed to use with the

Bellamatic II servo with modified centering mounted on same board with switcher, for use from relayless receiver. Formerly marketed by Airtrol; worth copying.



Tomoser Elect. & Mfg.

Tomoser GG servo has switcher (lower right) to operate from single-ended receiver. Handles rudder and elevator.

pulse rate decoders of the same manufacturer.

Some receivers fail the pulse rate test because of the internal lags mentioned in connection with pulse length work, but such lags are much more serious at higher pulse rates. Furthermore, the lag gets progressively greater as you increase the rate, which simply means that your pulse rate output will be hopelessly distorted. The worst conditions will be at the highest pulse rate when the control stick is held in such a manner as to give very long or very short length pulses. The receiver may "lock up" solid when the stick is only half-way off center toward longest or shortest pulse length. A model *can* be flown under such conditions, as long as you know what to expect, but such action will certainly prevent you from getting the most out of your system, or model.

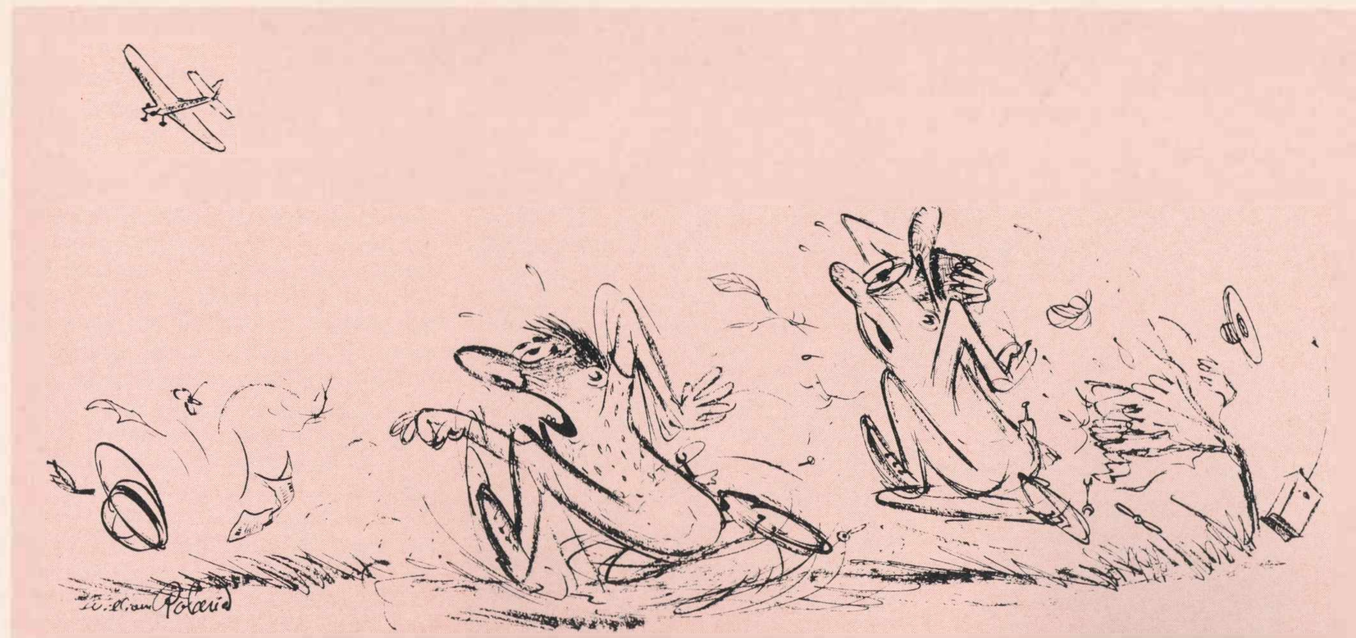
As mentioned previously, pulse rate decoders, and also POD's, are not really attached to the receiver circuitry itself but are generally connected to the servo circuit batteries. This may seem a small distinction, but the point is that such decoders are *add-on* units, not really a part of the receiver itself. Thus, given a receiver that is a good clean pulser, you can use any of several different rate decoders, or even try your own from circuits printed in the model press. The variety of commercial rate decoders is increasing; several may be had with POD as well, and in fact most are packaged this way. Again, such decoders may have relay or relayless output, and while the relay variety is probably more versatile, the relayless is less likely to be bothered by engine vibration. Both work fine, and both allow you to parallel a second servo across the rudder servo to enjoy the benefits of CAR flying.

The pulse tester mentioned earlier is even more useful in testing the action of pulse rate decoders, and in fact the entire system, from transmitter pulser on. Pulse rate circuits really cannot be checked by ear; you need an instrument pointer to show up any discrepancies, which are much more likely to crop up in pulse rate circuits than in pulse length — and are tougher to trace down and cure.

Two- and three-channel systems

Unlike many single-channel proportional systems (single RF and single AF frequency) which gain their ability to handle rudder, elevator, engine control, and possibly ailerons (via CAR) by means of "outboard" units not actually a part of the receiver circuitry itself, the two- and more-"channel" receivers have this circuitry built right in. Even as far back as the TTPW and Dual Marcy rigs this was the case, and it is the same with the modern three plus one and other "junior full-house" outfits sold today. The *entire system* must be functioning, and there is not much the nonelectronic-type owner can do but send a malfunctioning unit back to the factory. Of course, before taking this drastic step, he should check such obvious matters as battery charge, sticking servo linkages, poor-connection plugs, and the like. Oh, yes, and take that last step when all hope is just about gone: *carefully read the instructions!*

The same is true of full-house proportional systems, of course, and possibly even more so in view of their complexity. Here, too, make sure the fault is not external to the transmitter or receiver, and possibly in the many cables, connectors and linkages inherent in such systems.



American Aircraft Modeler.

"Radio, SI! Control, NO!"

7: PROPORTIONAL SERVOS

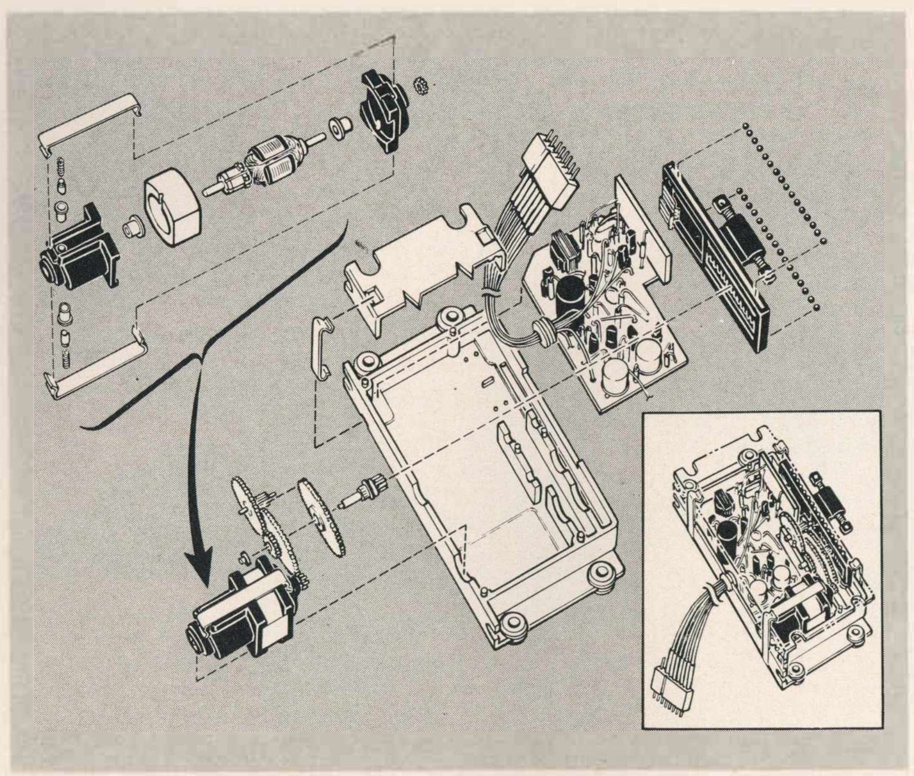
MUCH data on servos has already been given, principally in chapters 2 and 4: how they work, how to connect them, differences and similarities. Here we will go into more detail on some of the angles of servos that have not already been covered. Let's take first the matter of spring-centered motor-driven units. As indicated in chapter 2, such servos are held to center by some form of spring (or rubber-band) force. On some this is built right into the mechanism; on others it is external. The latter was usually the case with earlier home-made servos, and the majority were centered by rubber bands. Such bands stand up surprisingly well in this use, provided they are protected from sunlight and from engine exhaust residue. Some centering systems employed twisted bands, often linked to the motor armature via a small hook. Others simply stretched a band applied to the output gear or shaft, or often on the linkage torque rod itself. Metal springs are probably more long-lived than rubber bands, provided they are engineered properly so they won't soon break from fatigue or overbending.

As has been mentioned, servo centering of the spring variety helps to attain a reliable neutral; without it neutral is apt to vary or wander. Actually, it is generally no great disaster if a centering band or spring breaks during flight, provided the broken parts do not jam up the linkage or servo gearing. You will just suddenly find yourself a little busier with the control, in most cases. Actually, I have seen cases where the centering arrangement broke and the pilot never realized it till he had landed the model.

It takes power to continuously stretch a spring or band, and this power comes from your servo batteries. Furthermore, a servo has just so much torque to apply to the control linkage, and if some of it is soaked up in centering — and it always is — you have less left to move the surface against the slipstream of a flying model. It is for these reasons, among others, that the more sophisticated systems all employ feedback servos which have no spring centering whatever. The feedback servo takes little or no motor power when it is not actually displacing a control surface, whereas the spring-centered servo eats up quite a bit of power when it is just sitting at neutral awaiting a command. Recently a system of cutting this neutral power drain in half (or to an even greater extent) has been proposed by Dr. Walter Good; this can be applied to servos whose motors are driven by transistor amplifiers, but which are not of the feedback variety (as in the Quadruplex 21 system). It has been described in the model press and I won't go into it deeply here, except to note that it makes use of what are termed "triangular pulses," developed right in the amplifier, rather than the usual rectangular pulses. Since a good portion of the power taken by a proportional system with spring-centered servos is wasted in the centering, any method that allows this drain to be cut in half, while retaining the desirable attributes of such servos (which include simplicity, sensitive "feel," low cost), is worthy of much consideration.

Spring centering should never be excessive — just enough to bring the servo back near center when the control is displaced by hand. Some fliers feel even this much is unnecessary, noting that when a model is flying the airstream on the control surfaces tends to keep them centered and thus we need just a small amount of added mechanical centering to give the servo "something to work against."

Centering for a motor-driven servo should be applied to the motor armature itself, if possible. Most of the drag in such a servo comes from the armature in the form of brush friction, and also "magnetic drag" between the armature and its associated permanent magnet. If you apply your centering to the output of the servo, it has to overcome the friction of the servo gearing and bearings in addition to the drag of the armature itself. On homemade servos, therefore, the rule is to apply the centering right on the armature itself, if possible, and if this is too difficult, to the gear following the armature. There are some servo motors that have almost no armature drag whatever, due to special internal design and construction. The German Micro-Mo is one, and since it is very difficult to reach the motor shaft of this style, the centering can be applied very effectively to the output shaft. The Micro-Mo T-03 is widely used in proportional servos, both homemade and ready to use.

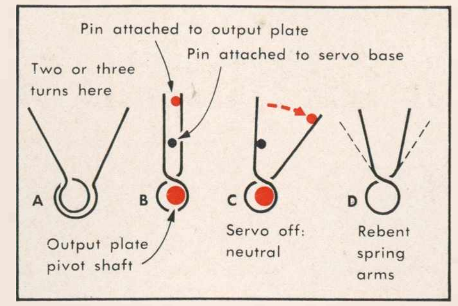


Bonner Specialties.

Exploded view of a Bonner digital servo. The concern makes its own motors, seen at upper left. For minimum friction, the output arm slides on 32 ball bearings.

The Bellamatic II is in the latter category, and is in wide use among fliers of the simpler proportional systems. As it comes, the centering is much too heavy for proportional uses, and experimenters have tried many ways to improve this. One is simply to remove the centering spring and bend it to eliminate most of the "pretension." This servo is centered by means of a "scissors spring" (a method used in other servos, also to center proportional control sticks) which works as in fig. 7-1. At A we see the spring before installation in the servo, formed so that the two arms spread quite far apart. Now when this spring is put in the servo, the arms are squeezed together and they exert considerable pressure on the fixed pin (7-1B). Thus it will take considerable power to move the servo to the position in fig. 7-1C. This pretension can be greatly reduced if you bend the spring arms to the form shown in Fig. 7-1D. Pretension of this sort is undesirable in a spring-centered proportional servo, since it makes the servo have a very "broad neutral": that is, you have to move your control stick quite a bit off center before the servo will leave neutral. Such tensioning is fine on a control stick, however, especially a stick that can move in two directions — as for ailerons and elevator. When a flier wants to apply only elevator, with no aileron at all, as in a loop, the scissors spring gives just the right feel for the job.

Some experimenters simply make a spring comparable to the one that comes on the Bellamatic II servo, but of lighter wire and with less pretension. Others use an entirely different form of centering spring. The Quadruplex modification utilizes a torsion spring of .050" music wire as seen in fig. 7-2, and this has proved very successful. The Bellamatic II has a built-in slip clutch to prevent damage to gears and other internal parts in a hard landing. When used in the larger and faster planes, the clutch must be tightened or it will slip just when you don't want it to, like when you are trying to pull out of a screaming power dive. The clutch can be tightened by forcing a C-shaped washer about .020" thick into the stack of clutch spring disks.



7-1 Scissors springs are used in servos and control sticks. Action is shown above, also how to modify a Bellamatic II spring.

Dee Bee Electronics.

7-2 Modified spring on Bellamatic II in older Quadruplex system. Right end is epoxied under base. Very smooth action.

Control-surface wiggle depends upon the type of servo and on the armature speed of the motor, and is most pronounced with magnetic actuators. Single-geared motor-driven servos cut the wiggle a bit — double-geared even more. Even with the latter, however, it is quite noticeable when the model is on the ground. But a servo like the Bellamatic II with its very-high-speed motor has a high gear ratio, and you have to actually put your hand on the surfaces to feel if they are pulsing. The Micro-Mo T-03 in the Bellamatic II has built-in gears of 60:1 ratio, and the output gearing raises the overall ratio to around 125:1.

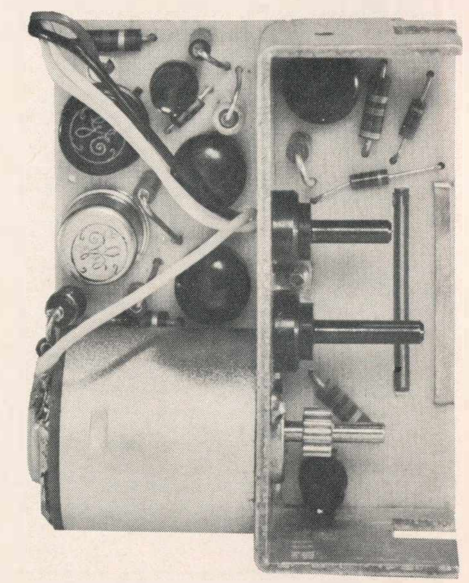
Most U. S. servos are now manufactured with Japanese motors, some of which are of very high quality and reasonable cost. These motors are not sold with integral gearing, so the servos using them look a bit complex but have proved very satisfactory. At this writing it is believed the only servos sold here that use made-in-U. S. A. motors are those of Bonner and Annco, both of which have motors designed especially for this R/C purpose.

Feedback servos

As compared to spring-centered units, feedback servos offer more power, less current drain (practically none in neutral, or when not actually moving from one position to another), no surface wiggle, very rapid centering — all worthwhile attributes — but they have some problems of their own. One of the greatest has been the feedback potentiometer itself, which, as we saw in a past chapter, is a most vital element. The wear on this pot can be quite rapid, and some fliers of feedback systems have routinely installed new pots (or replacement elements) after every 100 flights or so. Better materials for pot elements are now used, and eventually this problem will doubtless fade to the point of being forgotten.

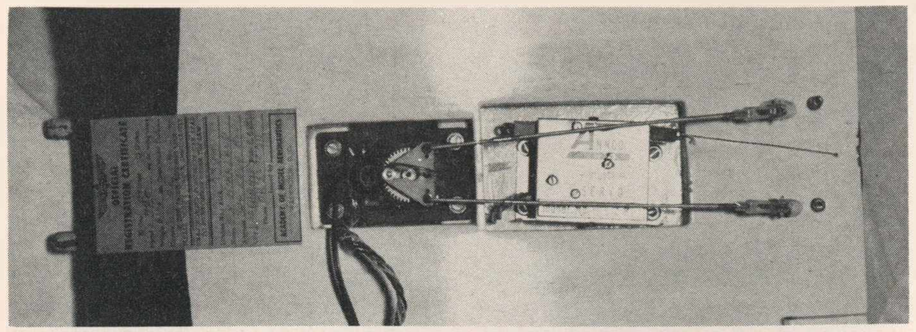
Whereas spring-centered servos are always "live" — that is, they are continuously wiggling, which keeps them always ready to answer a control command — most feedback servos are not; they are motionless and "dead" until they receive a command. For this reason, they have what is called "dead band": you have to displace the control stick a slight amount before they start to move. It is desirable to keep the dead band as small as possible, naturally. Some systems actually apply a small amount of pulsing input to feedback servos simply to keep them free and ready to move. Such a servo is often said to have a little "dither" when it is at rest. This takes a little servo power, of course, but not nearly as much as does a spring-centered servo.

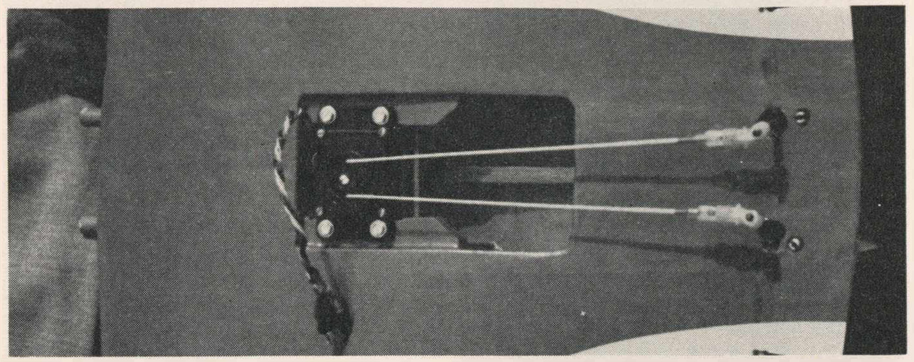
"Damping" and "overshoot" are also terms you will hear bandied about in learned discussions on servos. When a heavily damped servo is allowed to return from some displaced position back toward neutral, it will do so rather slowly, and may not get quite to neutral. One that overshoots will



World Engines.

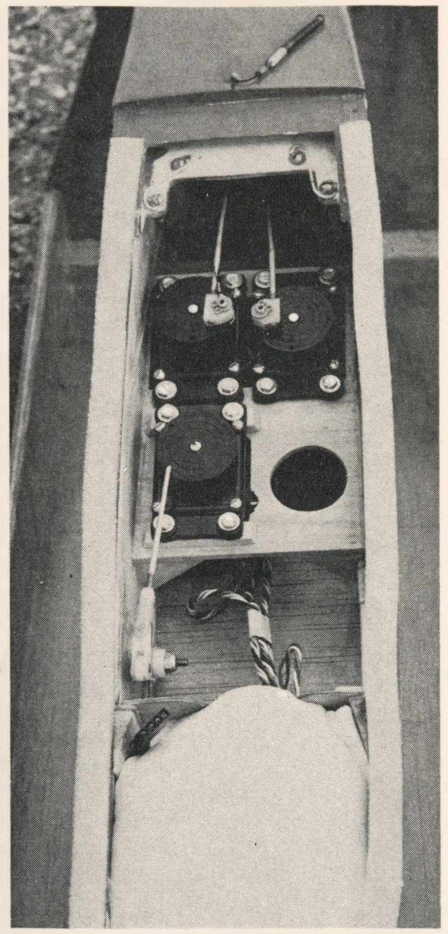
Inside view of Controlaire servo with gears removed. Linear feedback pot element is just to right of shorter gear shaft.





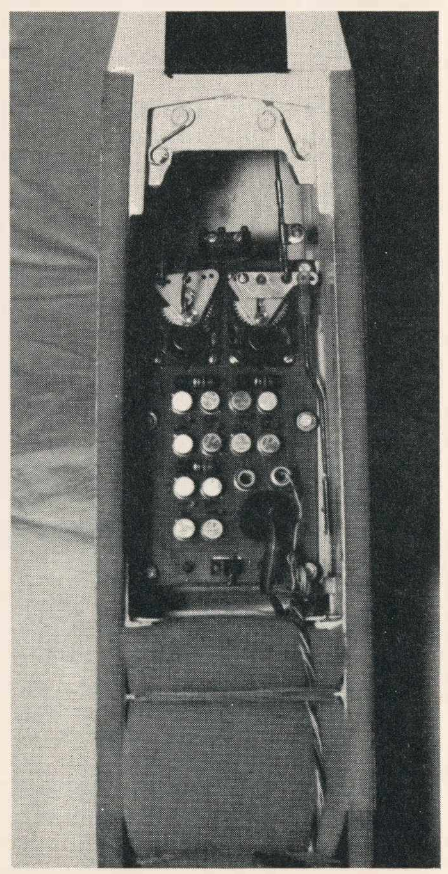
American Aircraft Modeler.

Top, aileron servo (left) and brake servo in Citron design by Jim Kirkland; plane had Quadruplex 21 controls. Brake servo was triggered by switch on down elevator and low throttle. Below, same plane by Ron Chidgey, but with Orbit feedback propo; brakes here are operated direct from elevator servo.



American Aircraft Modeler.

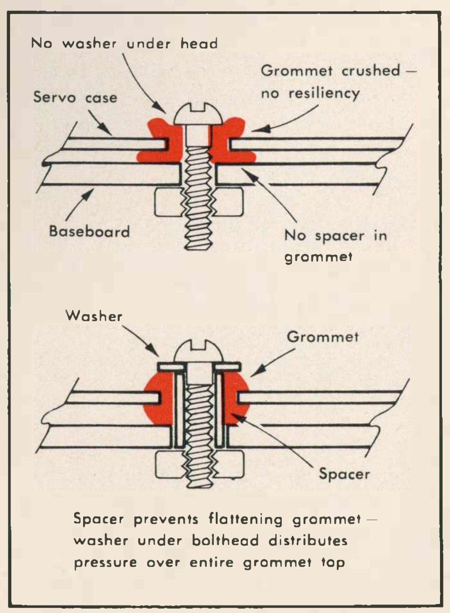
Top, underside fuselage view of Chidgey Citron; receiver is wrapped in foam at bottom. Kirkland plane below; "21" rudder and elevator servos are visible.



American Aircraft Modeler.

go back much faster, go a little beyond neutral, then reverse to reach the desired spot. A little overshoot and fairly low damping are found in most feedback servos today.

Centering accuracy is an important servo factor: if you allow your control stick to snap back to neutral, but the rudder servo does not go *quite* all the way, you will have a little turn remaining, and will have to apply opposite stick to overcome it. Thus, accuracy of centering is much to be desired.



7-3 Top, grommets are practically useless. Bottom, these grommets will really provide vibration isolation to servo.

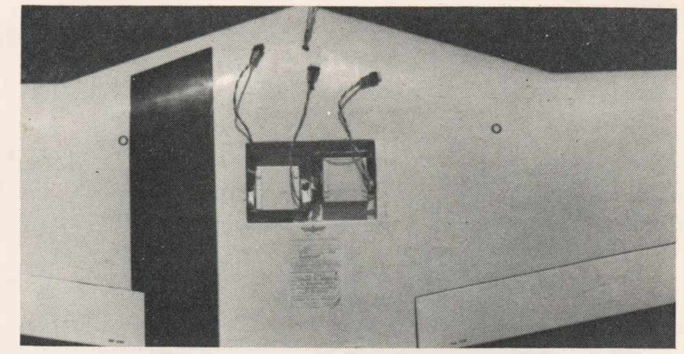
Centering speed is also often under discussion. Most servos will go from neutral to a control position very rapidly (how much so depends upon servo gearing, battery voltage, linkage drag, and such factors), but fliers of modern fast stunt planes want their servos, and attached control surfaces, to return as rapidly back to neutral, too. For slower "sports" planes, rapid servo response and exact centering are not so important, of course.

Servo mounting

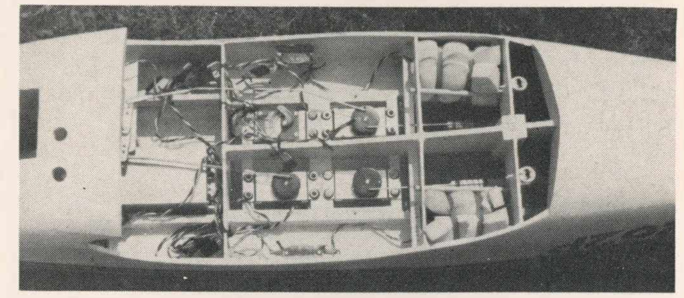
It used to be that a modeler would screw or cement his servos tightly into position, and that was that. But no more. With our larger and larger engines, vibration has become a real problem, and servos are among the prime sufferers. Much more pains are now taken in mounting them, and often they are shock-mounted. Quite a few commercial servos come with small rubber grommets in the mounting screw holes, and if the screws are used correctly, these grommets afford a fair measure of vibration protection. The screws must not be too tight (fig. 7-3A), nor too loose. Fig. 7-3B shows a good way to ensure that they are just right. A length of brass tubing from hobby-shop stock is cut to the exact length of the grommets, or possibly a tiny bit shorter. When installed as in the sketch, you can pull

American Aircraft Modeler.

Ralph Jackson holds Scale contest-winning Piper Comanche. Besides regular full-house propo controls, it has retractable landing gear, flaps, and lights. Right top pic shows aileron and flap servos in wing. Lower right, huge cabin area holds much equipment. One servo is a switcher to operate LG and lights; the other three are for rudder, elevator, and throttle.



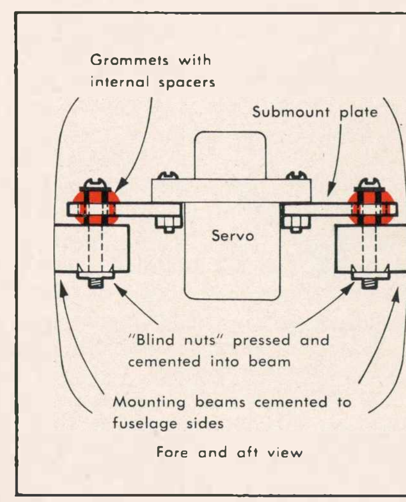
American Aircraft Modeler



American Aircraft Modeler.

the screws up very tight but the grommet is not too compressed and will serve its intended function as a shock absorber. The servos should not be really loose, of course, or they will move appreciably under heavy control surface loads; but if you clamp the screws down on the grommets without the inner metal tubing, you will lose practically all the shock-absorbing qualities that the manufacturer hoped to provide when he included the grommets with his servo.

Some servos are pretty rugged; others very definitely should be protected from shock and vibration. In the latter category we must include all those powered by the jewellike Micro-Mo motor. This motor is very potent and extremely efficient, but in many ways it is quite delicate and it definitely should not be banged around. The Bellamatic II servo using this motor has a built-in slip clutch to prevent shock of hard landing from doing any damage (when pushrods might suddenly be rammed forward against the servo gear train). Some feel the Bellamatic II should always be shock-mounted regardless of what plane it may be used in, and with what type and size of engine. I feel this is good insurance, too. A small submounting plate with grommets as shown in fig. 7-4A will do a good job; or cement a piece of ¼" thick foam rubber to the bottom, in turn cementing this to a mounting plate or the fuselage itself, as in fig. 7-4B.

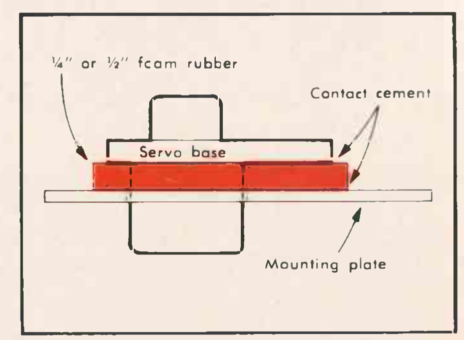


7-4A One good way to shock-mount Bellamatic II (or other) servos: cement blind nuts firmly — epoxy is best.

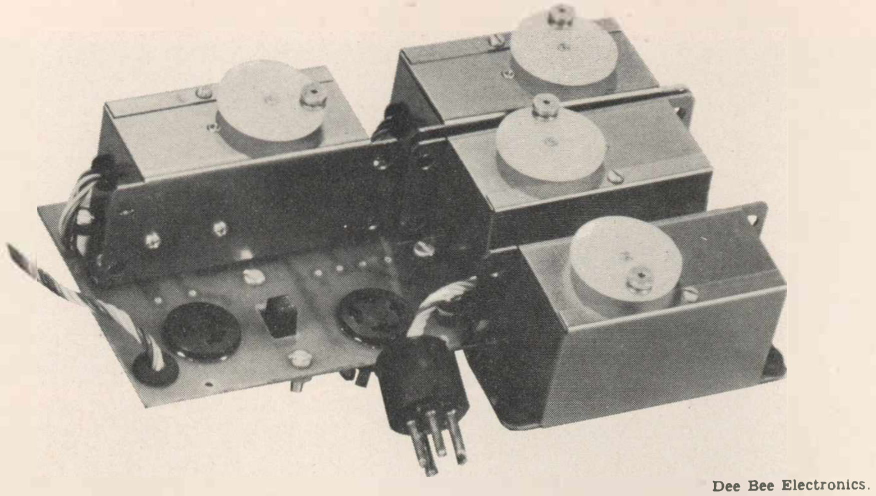
Vibration can have odd effects on servos. For one thing, it can shake the unit so much that the brushes do not have firm contact with the motor armature. This might allow the servo to run after a fashion, but it would not have normal power, and the arcing at the brushes would be greatly increased. Constant vibration beats up gear teeth and all the servo bearings, so a little time taken to isolate these vital units is certainly good insurance against future catastrophic failure (or in plain words — a crash).

Where you mount the various servos depends upon their function and on the space available in the model. Rudder and elevator servos are normally mounted as far back as possible in the space that is found under, or over, the wing. Servos can be mounted on the fuselage bottom or sides; some servos have holes in their cases for either side or bottom mounting. Motor control servos are often side-mounted so the linkage to the throttle will be as straight as possible. If your space allows, it is always considered wise to put the battery pack far forward, with the receiver behind it. This helps distribute weight better (probably a majority of model planes come out tail-heavy and thus require this forward weight), and, so placed, the battery pack cannot crush a receiver or servo in case of a crash.

Perhaps following the lead of multi reed planes, where the trend in recent years has been to fasten all servos to a "tray" which in turn is attached to hardwood rails cemented to the fuselage side, many proportional fliers used a similar unit mounting, at least for rudder, elevator and MC servos. All multi proportional outfits these days come with connectors on every cable, so you just have to plug things



7-4B Here the servo is insulated from the mounting plate with foam rubber. Clearance hole in plate for servo.



Three servos (CL-5 in this case) mounted on a "tray," with on-off switch, sockets for batteries, and aileron servo (latter at lower right).

together. Some manufacturers are now supplying connector blocks to make a neater job in the model, and on some of these the on-off switch is an integral part of the block unit. Modelers who are assembling a system from the individual parts would do well to follow these procedures, as a neat installation is much easier to check out and is much less likely to give trouble in the first place.

Antenna position is quite critical in some systems, to the extent that the entire antenna from receiver on out should be kept as far as possible from the servos, battery wiring, and in fact from *all* other wiring in the model. This is especially true for digital installation, but it is good practice in even the simplest R/C model. As noted previously, digital systems as a class are more interference-prone than those in the analog category. It was noted at the 1967 R/C World Championships in Corsica (where a good many entrants were flying commercial multi proportional) that the European fliers of such equipment favor running the antenna lead out of the fuselage *ahead* of the wing, rather than just behind it, and many used vertical whip antennas. The sole reason for this rather unhandy arrangement was to keep the antenna and its lead as far as possible from the servos and general system wiring.

Linkages

Quite a lot of information on linkages will be found in the R/C PRIMER and will not be repeated here. In the simpler proportional systems the torque rod is quite often seen, but more and more installations, even of the simpler types, are now based upon the pushrod. Even Galloping Ghost, which was inevitably operated via torque rod in its early days, has now shifted emphasis to pushrods, probably due to the growing crop of manufactured GG servos, most of which are designed for such linkage.

You may occasionally hear about "bonding linkages," which simply means connecting the metal joints together so that the entire linkage, from servo right back to the control surface (and forward to the engine throttle), is electrically the same as a single piece of wire. Why is this necessary when we are not running any power through the linkages? Actually, we *are*: metal servo linkages can act as part of the antenna system in a model. Even the electronic novice can see that an antenna composed of half a dozen short pieces of wire loosely twisted together might cause real trouble in a model, especially under vibration that would wiggle all those loose joints. Well, it works the same in metal linkages; and since some proportional systems are quite noise-conscious ("noise" here means the electrical effect of loose joints rubbing together, which can produce quite a clatter in a sensitive receiver), all such loose joints must be eliminated. Actually, *all* wiring attached to a receiver acts in a way as part of the overall antenna system, even though we normally refer to just one specific piece of wire as the "antenna." Antenna wires with loose joints strung out to the extremities of a model plane — the tail, nose, wing tips — would surely lead to immediate disaster. So will linkages with rattling metal-to-metal joints.

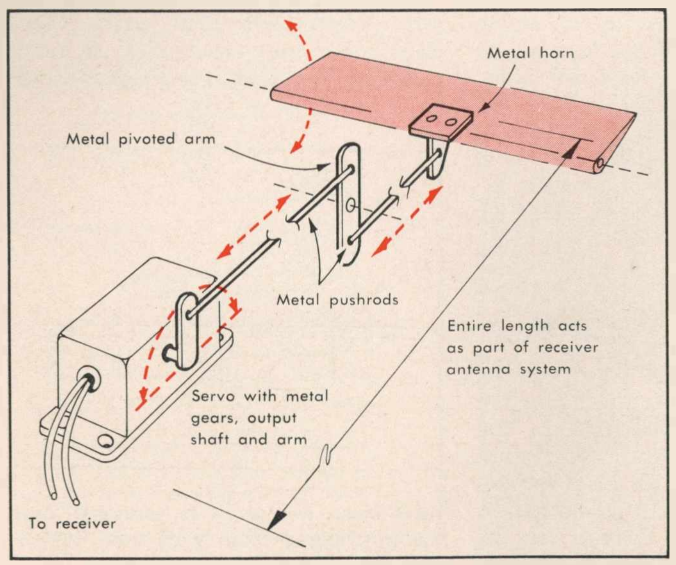
Such joints in the linkage might not give any trouble when an installation is brand-new; but with time, rust or corrosion sets in and the various metal joints become very poor conductors, and your equipment is bound to be affected. The obvious solution might be to run a "bonding wire" across every such joint. This will work fine, but it's a lot of trouble, and bonding wires can be broken by vibration or by continuous flexing. There is a much better solution: simply eliminate such joints! This isn't as difficult as it sounds. There are on the market today many well-made nonmetallic linkage components: control horns, clevises, bell cranks, and such. Some metal-to-metal joints in the linkage may do little harm, if they are not in the "wrong" places, or if the total length of metal is not too great; but look at fig. 7-5A for a horrible example of some that will. Here we have a metal "antenna" from servo right to the tail surface, complete with several joints. Now even though the metal rotor disk on the servo is not electrically connected to any part of the installation wiring, and very probably it may not be, the effect is still bad due to electrical capacity between the various metal parts of the servo. If we break the linkage metal parts up into smaller sections, a lot of grief can be eliminated. Fig. 7-5B shows one way. A few insulating parts serve to break up our false antenna — sufficiently so, probably, that the linkage will give no trouble when first installed or in the future.

Metal pushrods are in moderate use, but they do constitute a good portion of the total metal run to the tail. Just by substituting nonmetallic pushrods a lot of unwanted antenna potential is eliminated. Dowels, fiberglass arrow shafts, phenolic or nylon tubing are possible substitutes. Of course, the pushrod must be stiff enough so that it can truly *push* without excess bending to move the control surface against the high-speed slipstream. Probably the majority of motor-driven servos today have nylon gearing, or at least one or two nylon gears in the train. This is a further help in isolating the linkage from the rest of the system. Many servos now also have nonmetallic (usually nylon) output arms or disks for the same reason. A short metal link at one or both ends of the pushrod, as in fig. 7-5C, will do no harm at all. It is the long runs of metal starting from the servo itself that can be potential trouble.

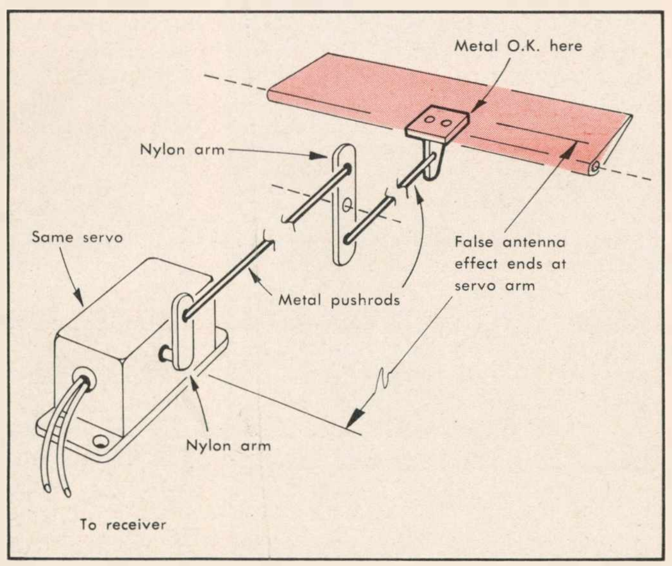
Aileron linkages should be broken up in the same manner. Use nylon bell cranks, and preferably a servo with a nylon connection to the pushrods in each wing, which are often of music wire.

Linkages to the engine throttle and to the steerable nose wheel, if you use one, should be handled the same way. Start them with a nonmetallic connection at the servo. Hobby shops stock flexible cable which runs in an insulating tube, ideal for MC and nosewheel linkages. You can also get such insulating tubing with the inner sliding member of heavy nylon, which should be ideal in stubborn cases of linkage noise.

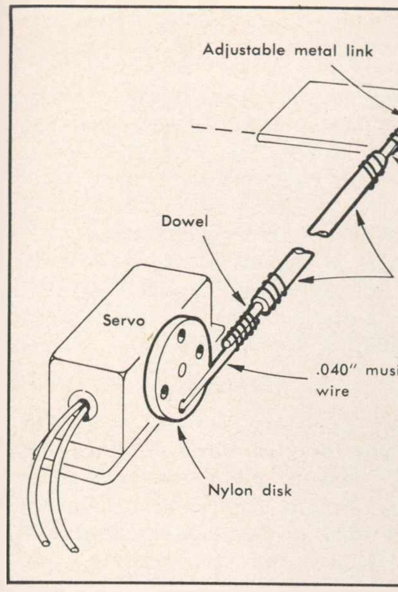
The advent of electric brakes is a boon to the modeler, as they assure smooth positive braking action without any fussy mechanical linkage to a servo; but, they can also bring interference trouble. It all stems from the fact that some modelers operate such brakes from the servo batteries (sometimes from the same batteries that run the receiver) and thus get into another form of the "unwanted antenna" situation. The brakes are always attached to a metal landing gear; generally the landing-gear metal itself is used as part of the brake circuit. The solution is simple: just operate the brakes from their own small batteries. A pair of penlight dry cells will give many weeks of opera-

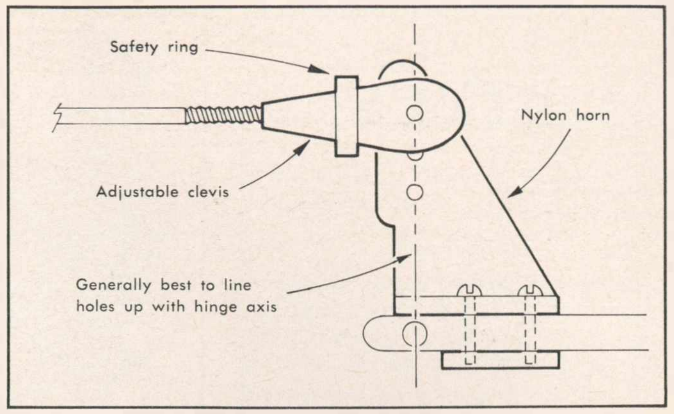


7-5A All-metal linkage from servo to surface can give serious trouble, even in nonpropo installations.



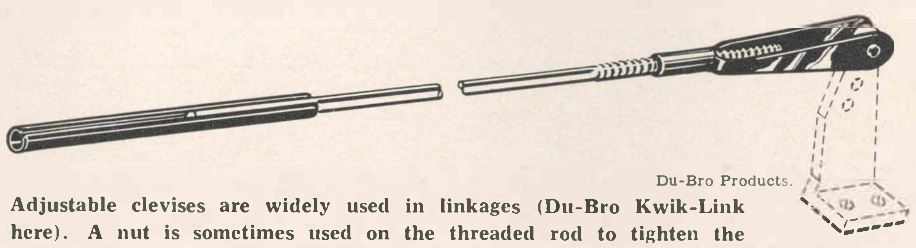
7-5B Break up linkage with insulating sections to prevent "noise" problems. Nylon horn is even better.



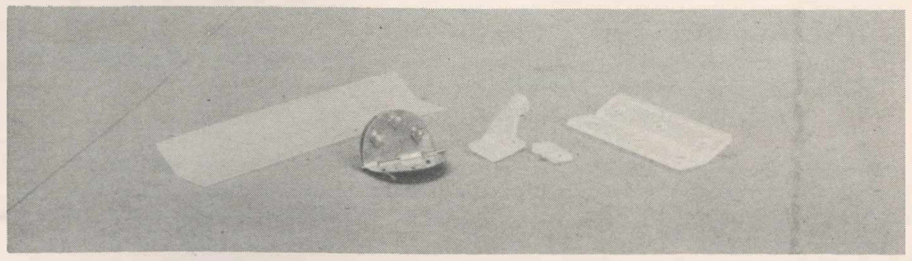


7-6 Safety ring on clevis prevents its popping loose under heavy vibration. It shouldn't be too tight, or it will bind.

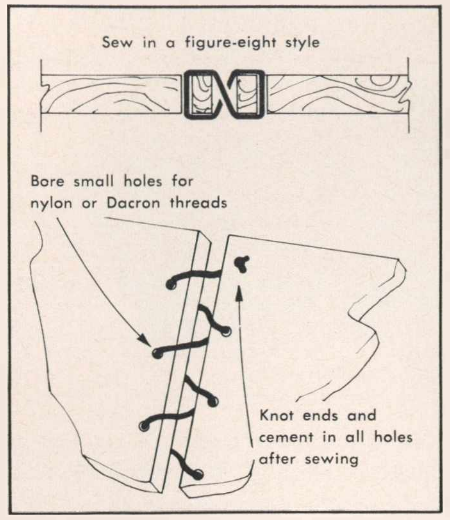
7-5C (left) Another safe linkage setup. There are no metal-to-metal moving joints anywhere in this one: thus, no noise.



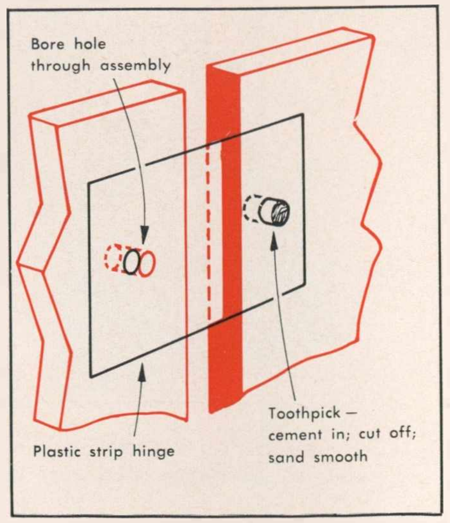
Adjustable clevises are widely used in linkages (Du-Bro Kwik-Link here). A nut is sometimes used on the threaded rod to tighten the clevis. Clevises are also available in nylon.



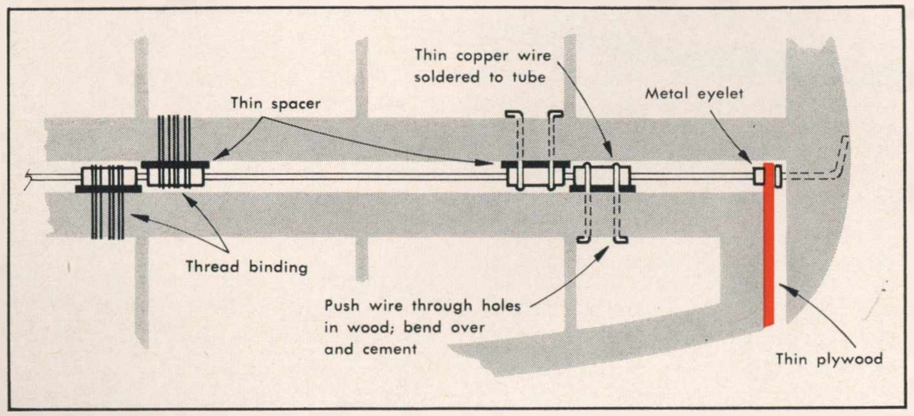
A great variety of control-surface hinges are available, in plastic and metal. Seen above (left to right) are deBolt, Tatone (metal), Williams, and Bonner units.



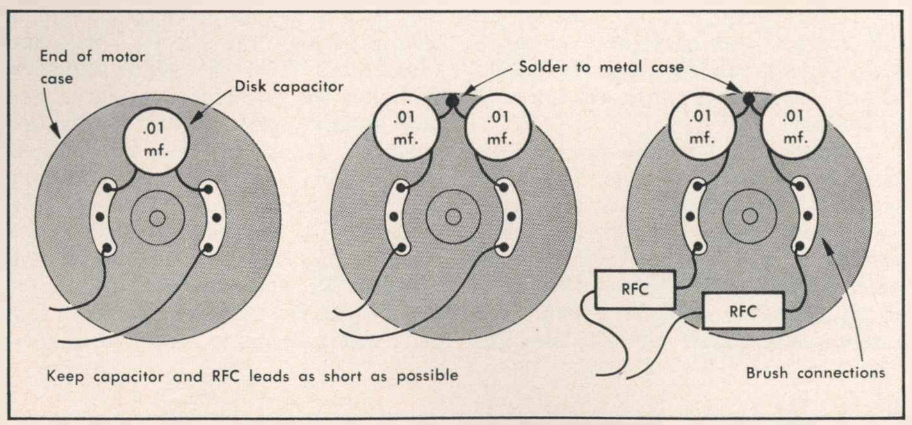
7-7 **Figure-8 hinges are "sewn" with tough cord AFTER surfaces are covered and finished. Nylon cord is good.**



7-8 **After slits are cut for sheet plastic hinges, cement toothpicks in place and trim them flush after the glue dries.**



7-9 **Properly lined up, wire-and-tube hinges are extremely free in action. Tubes can be bound with thread or held with wire U's. Surfaces are easily removable.**



7-10 **(left) Single capacitor on brushes. 7-11 (center) Two capacitors, one end of each grounded to case. 7-11 (right) Capacitors and RF chokes.**

tion, and the brake wiring can be completely isolated electrically from the rest of the control system.

Metallic or nylon clevises are very handy in control linkages to allow easy adjustments and as an aid to easy removal of the linkage from servos or control surfaces. It is always wise to "safety" such clevises with a ring cut from fuel tubing or with a tiny rubber band (some commercial clevises come with such a band) as in fig. 7-6. The safety ring should not put a lot of pressure on the two arms of the clevis, but should be just snug enough to prevent it from opening under heavy vibration.

Some servos which have a rotary output motion will turn more than 180 degrees when the transmitter is turned off before the receiver (and some will allow continuous rotation of the MC servo under such conditions). If yours is one of them, make sure your linkage will allow such servo rotation without binding up the linkage and stalling the servo motor.

Hinging

Control-surface hinges are now available in real variety; there are metal, plastic, cloth, or just plain "string" hinges. The latter are applied in the form of figure-8 stitching, and are surprisingly long-lasting and smooth in operation. Fig. 7-7 shows how it is done. Such hinges are generally applied *after* the control surfaces are covered and completely finished, to keep the dope or other finish from stiffening the thread.

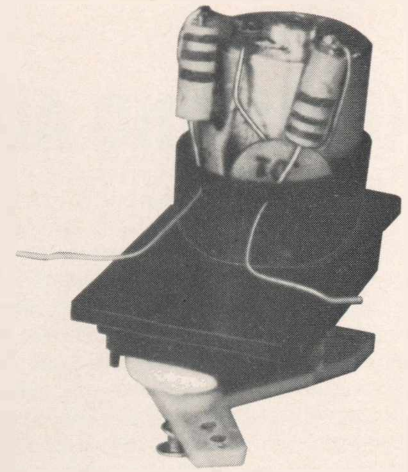
Plastic hinges come in two main forms: one comprises molded halves that you attach to the plane framework which operate as a hinge should, and the other variety is plain thin plastic strip which is cut to the desired lengths, then creased where desired (some of them are precreased), and installed. Due to the special plastics used, the crease won't tear as soon as you might expect. Some will continue to bend happily for months and never let go. When installing these strip hinges it's usual to cut a narrow slit in the framework, force cement into the slit, then push the strip end in. When the surface is hinged as desired, a round toothpick is forced through predrilled holes to lock the strip in place, as in fig. 7-8.

You can buy light and rugged metal hinges that work just like those on a door, or make your own with lengths of music wire and short pieces of hobby-shop brass tubing, per fig. 7-9. Needless to say, any hinges you use should be smooth and nonbinding; this is especially true when you are driving the controls with magnetic actuators, or where one servo operates several controls as in GG or CAR. For these it is probably best to forego the plastic strip style of hinge, which is generally a little stiffer in action, in favor of properly applied figure-8 or metal hinges, or those made in two separate halves of molded nylon.

Arc suppression

Any opening and closing metal contacts will generate a form of electrical interference due to the tiny sparks produced. The more power going through the contacts, the more interference. Since motor-driven servos do require a fair amount of power, the brushes produce considerable interference. (Magnetic servos, such as the Cannon and Adams, do not, of course.) More and more manufacturers are building at least minimum arc suppression into their servos in the form of a small capacitor across the motor brushes. If your servo does not have this capacitor, install it yourself as a preventive measure (fig. 7-10). A value of .01 mf. is generally sufficient, and the tiny disk ceramics of 100-v. rating or more are fine for the purpose. To be effective, the capacitor should have its leads cut as short as possible, and should be attached as closely to the brushes as possible. If the motor has a metal case, some feel that a better job is done by using two such capacitors, as in fig. 7-11, with one lead of each soldered or otherwise firmly attached to the metal case. Again, to be most effective the capacitor leads should be kept very short.

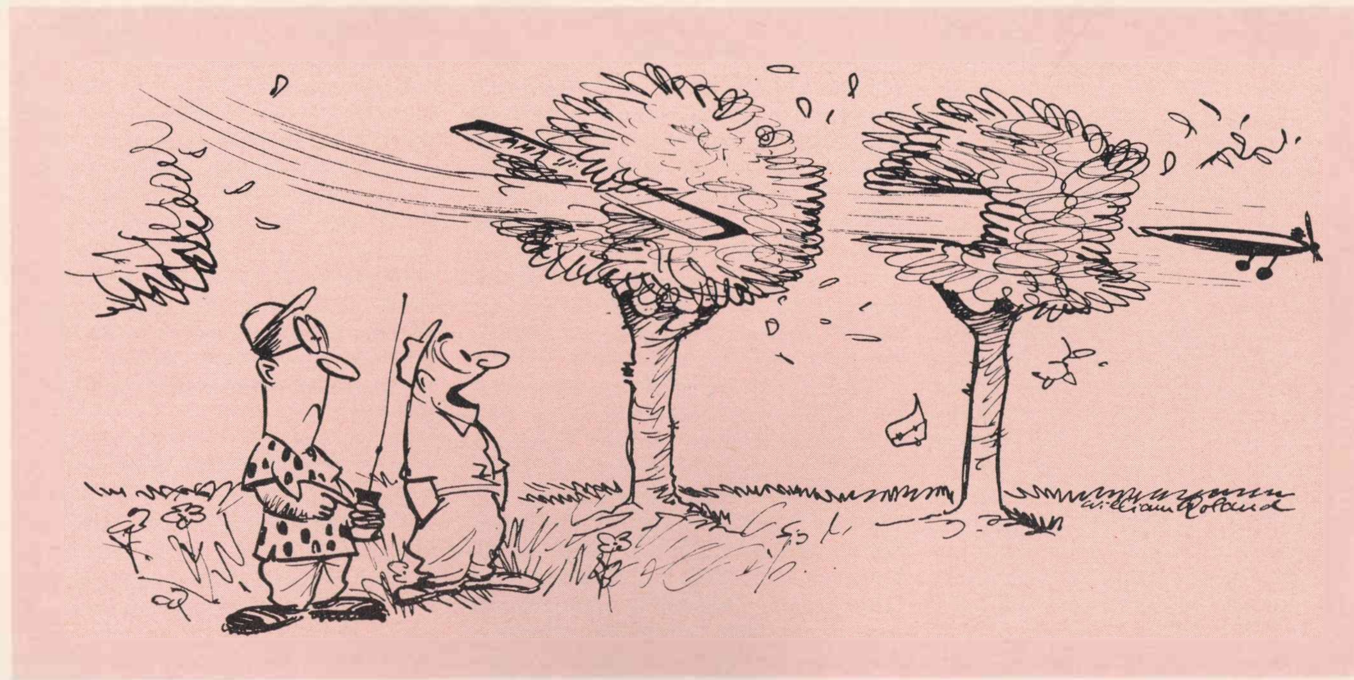
Some receivers are more affected by motor noise than others (and remember again that keeping the antenna away from servos, batteries, and other wiring helps here), and the .01-mf. capacitor measures described may not be good enough. Stubborn cases can sometimes be cured by the addition of RF chokes in the motor leads, as in fig. 7-12. At least one make of commercial servo (Rand Manufacturing Co.) comes fitted with both capacitors and RF chokes: fig. 7-13. Such chokes must have wire heavy enough not to drop the voltage to the motor appreciably, and of a value matched to the receiver frequency. Generally, 20-microhenry chokes are used for 27-mc. systems, and 10-uH chokes for 6-meter outfits. Sometimes different choke values are better — it is often a matter of custom-matching the chokes to the particular situation.



7-13 **The maker fits both dual capacitors and dual RF chokes to this Rand servo, to make sure motor noise from brushes is well suppressed.**

The future

I have covered some of the handling and problems of present-day proportional servos. Unfortunately, servos seem to be the weakest link in proportional and, indeed, in other R/C systems. Great strides have been made through the use of better motors, better gear trains, better mounting, and so on, but we still have a way to go. Most R/C prophets look for servo improvements as the prime development field in R/C. Some predict we may soon have servos of entirely different types than those now in use. All our servos, for example, operate on direct current or on pulses of same, but the pros (full-size plane designers, missile and rocket engineers) long ago dropped d.c. servos in favor of alternating-current drive, or of hydraulic setups. Maybe a few years hence we'll be worrying about keeping up the servo system oil pressure instead of plain old battery voltage!



American Aircraft Modeler.

"That's what I call penetration!"

8: ACCESSORIES AND AUXILIARIES

IT is probably hard to visualize a piece of wire as an "accessory" to an R/C installation — it's more of a necessity — but let's consider antennas briefly. Those for proportional systems are in most ways little different than for any other sort of control system, with one big exception. Some proportional receivers are very susceptible to electrical noise such as that generated at the brushes of servo motors. For this reason, and especially with digital multi rigs, it's essential to keep the entire antenna (and this includes the portion *inside* the plane, too) as far from servos and all servo and battery wiring as possible. On shoulder wing craft it is common to bring the antenna out the top of the fuselage just behind the wing and run it up to the top of the fin. It would be preferable to bring it out of the fuselage in front of the wing, but this would be very impractical due to need of wing removal. One way is to bring the antenna out the side of the body right at the receiver and run it to a stabilizer tip, which will carry it away from the wiring and servos.

On low-wingers you can bring the antenna out right above the receiver, with no problem of wing removal. Because just any old haphazard running of the antenna won't do on some receivers, manufacturers often give instructions for preferred installation. If you can possibly do so, follow their advice.

Some years ago vertical antennas on planes were quite common, but they fell into disfavor, probably mainly for esthetic reasons. Antennas from fuselage top to fin tip, or those entirely within the fuselage, became the accepted thing. Now vertical antennas may be due for a comeback, for two reasons. One is that they keep the sensitive signal pickup element about as far away from the servos and wiring as possible, and another is that they probably *are* more efficient, used in conjunction with the vertical antennas on our transmitters. Due to the need to convey an unbroken string of information from transmitter to receiver in all proportional systems, momentary loss of signal can range from noticeable, through annoying, and on to downright disastrous. In the days when escapements and reeds reigned practically supreme, such slight signal losses were seldom noticed (though longtime proportional fliers have always known them and accepted them as one of the facts of life). It's different now, and at long last some real investigation is being done on antennas, both transmitting and receiving, and on their placement, polarization (the direction the receiving antenna runs in comparison to that on the transmitter), and many other factors. It is too early to say what the results will be, but you can be sure makers of commercial equipment will adhere to the findings of the experimenters — so read and *heed* those instruction booklets that come with your equipment! As mentioned earlier, many European fliers of digital equipment (often of U. S. make) use a vertical antenna on their models, an antenna that projects up from the fuselage directly above the receiver. Such antennas would seem to be much more practical — at least for the more touchy multi proportional systems — than the horizontal antennas which are practically universal in this country.

Batteries

Probably the most important "accessories" in a proportional system are the batteries that power both the transmitter and the equipment in the model. Transmitter batteries are self-contained, of course, and the use of nickel-cad cells is very widespread. Even many of the Galloping Ghost and Kickin' Duck transmitters employ them. The simplest pulse transmitters — those intended solely for rudder — really do not need heavy-duty power supplies and get along very well with some of the huskier units intended for portable radio receivers. Most transmitters of this sort are designed for a 9-volt battery, and perhaps the most popular size is the Eveready no. 276, or equivalent in other makes. Depending upon current drain and how often the plane is flown, one of these units can give from a month up to a whole season of service.

Transmitters with built-in pulsers require only a single battery for all circuits, but if you add a pulser to an existing transmitter you may need separate pulser batteries. Most add-on pulsers have internal provision for holding the power supplies, and modern semiconductor pulsers generally require from 4½ volts up to 22½ volts. (The higher voltage is needed in some pulsers based upon unijunction transistor oscillators.) Tube pulsers, of which there are few, if any, still on the market (but you might find them in secondhand and trade-in stocks), need both filament and high-voltage batteries; the former are generally 1.5 volts, such as large flashlight batteries, and the latter are small B batteries of up to 90 volts. The B batteries are quite expensive, so consider this angle before you purchase such a pulser, even if you can get it at a "bargain" price. Pulser B batteries generally have a good life, however, as current drain is normally quite low.

When you get out of the rudder-only proportional class, even into such simple systems as Galloping Ghost and Kickin' Duck, it's wise to consider the advantages of a rechargeable power supply for your transmitter. The voltage of such a supply is much more uniform, which means your pulser will have a more uniform pulse-rate output. In simpler transistor pulsers, the pulse rate is generally more sensitive to dropping battery voltage than is pulse length.

Nickel-cads are the only thing to use in multicontrol proportional transmitters, and all are provided with the correct power supply, usually included in the retail price. Such supplies are fitted with the proper connectors, so you can't insert them incorrectly — which in a transistor transmitter could cause very expensive damage. In some makes, the guarantee is void unless you use the power supply recommended and furnished by the manufacturer.

Receiver power supplies

Here again, dry cells — usually of the penlight variety — are quite acceptable in small planes with simple control systems. They are adequate for Galloping Ghost planes, even with added throttle control, for such planes normally only have a single servo. For anything larger or more complex, nickel-cads are the best answer. A few receivers require 9 volts, and for these the smaller transistor broadcast-band receiver batteries are a good choice (Eveready no. 216 or equivalent). Receivers requiring from 3 to 6 volts can be powered nicely by penlight cells, either with firmly soldered connections to the cells, or carried in a commercial holder that provides positive contact.

Some receivers are sensitive enough that they do not work well on the same power supply that drives a motorized servo. (Such receivers will often operate well on a common power supply with a magnetic actuator, since the latter does not generate "brush noise," as do some motorized units.) Generally, the receiver instructions will clearly state whether or not you can use the same cells for receiver and servo.

Where there is more than one servo in the system, again we must turn to nickel-cads for reliable and economical results. Several servos, plus the receiver too, will drain penlight cells far too rapidly, and the next larger-size flashlight cells (the so-called C cells) are rather heavy for smaller planes; but penlight-sized nickel-cads (or disk-type cells of equivalent capacity) are not much heavier than dry penlight cells, and they will withstand the heavy drain with no complaint, and can be recharged many, many times. Even more important, they hold a fairly steady voltage during discharge.

It should be pointed out that in the "dry" cell category, the so-called "alkaline" types will give considerably longer service for a given drain and will withstand heavy drains much better than the common dry cells you can obtain in any drugstore. They do cost a bit more, but are well worth it. Even in the simplest control systems the batteries are a very small part of the total cost, and considering the vital part they play in the welfare of your model, it is certainly worthwhile to get the best. Although alkaline cells are better than the common type, again I must stress that the "best" can be only nickel-cads.

Relayless receivers of the double-ended variety are intended to work off the same batteries as the magnetic actuator they are designed to drive, and since these actuators do not draw a very heavy current, dry cells will give fairly good service. Even for such simple control systems, though, many modelers prefer to invest a little more and enjoy the many advantages of rechargeable cells.

Chargers

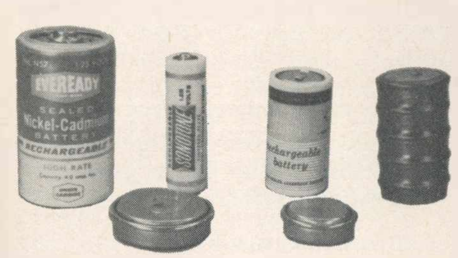
For those with nickel-cads, a charger is a vital necessity. There is a wide variety on the market, and about all that can be said here is to be sure you get one that will handle the size of cells you are using and will not overcharge them. Multi proportional systems almost always come with a charger matched exactly to the cells fitted in both transmitter and model, and they will recharge these cells completely overnight. (Charged at the maximum rate recommended by nickel-cad makers, you can put a full charge into a dead cell or set of cells in about 14 hours.) Some systems provide the charger as a small separate unit; others include it right in the transmitter. In the latter an outlet is fitted to the transmitter so that you can charge the plane batteries at the same time you are boosting those in the transmitter.

If you use a charger designed expressly for the batteries powering transmitter and receiver, there is no real need for meters or other indicators on the charger, as it will provide just the output required. Most chargers, though, have at least a pilot lamp which glows when power is going into the cells so you can be sure you *are* charging. Otherwise you might plug into a dead wall socket and restore no power at all to the cells even though they were hooked to the charger.

So-called "universal" chargers are handy, as with them you can put the proper amount of power into almost any of the popular sizes of nickel-cads and do so for just one cell or any number up to half a dozen in series. Some chargers have a meter and variable resistor to tell you what current is reaching the cells.

Another popular style has a calibrated variable resistor and a table printed on the front so that you can match the charging current and number of cells in the series. Fig. 8-1 shows a unit that will handle up to six cells in series and up to 200 ma. charging rate. It is practically universal in nickel-cad cells, regardless of size or make, that the recommended charging rate is one tenth of cell capacity (often stated as C/10); this holds true for a single cell or for any number in series. The more you have in series, of course, the higher the voltage output of the charger must be. Since the capacity and voltage of nickel-cad cells and batteries used in R/C varies rather widely, the more versatile chargers (which naturally cost more) often have high and low ranges as well as a dual-range meter and variable resistor to control exact current.

An odd characteristic has come to light in recent years concerning nickel-cadmium cells, and since it concerns use of such cells in the manner practiced by most R/C modelers, I feel it's important enough to mention here. It is simply that these cells develop a sort of "memory" of how much they are used between charges. Most modelers make sure never to use anywhere near the maximum ampere-hour capacity of their nickel-cads simply because to do so might bring a sudden failure during flight if one or more of the cells went dead. The average modeler probably does not make more than three to five flights at an ordinary flying session, and then he takes the equipment home and fully recharges the cells. The fact that the cells are thus actually overcharged is of little consequence. They are designed to accept such overcharge as long as the charging rate is kept under specified maximums.

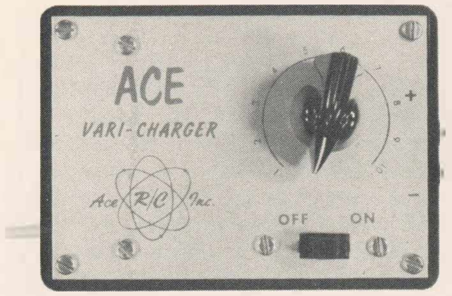


Popular nickel-cads. Left, 4-ah. D cell; next, 500-mah. AA; 1.2-ah. sub-C; 450-mah. disk; 225-mah. disk.

Pen or AA cells. Left, medium-duty carbon zinc type; the other three, more potent alkaline AA cells.

American Aircraft Modeler

Compact dual charger will put 400 ma. into transmitter battery, up to 100 ma. into receiver battery, simultaneously.



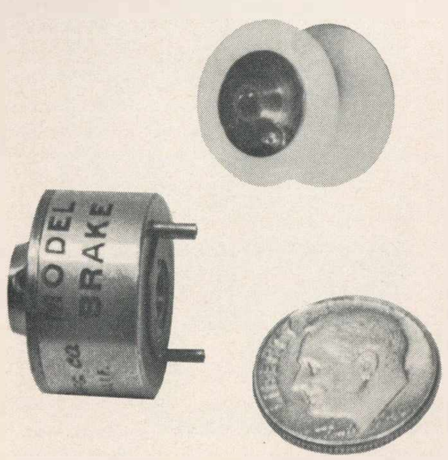
Ace R/C.

8-1 Charge rate is selected from separate table, set according to numbers around knob; no meter is required in most cases.

It is claimed, however, that if you habitually use only a part of the charge each flying session — say half the available cell capacity in both transmitter and model — your cells will come to accept this as their *maximum* capacity. If you then engage in a prolonged flying session, you might find your nickel-cads suddenly going dead long before their theoretical capacity has been reached. Actually, the cells are not damaged by such half-capacity use, and can be restored to full ampere-hour capability by several cycles of full discharge and recharge. For the average modeler, it is probably wise to put the cells through these deep-discharge cycles every couple of months during the flying season: then you can be reasonably sure your batteries will have that expected reserve capacity when you want it.

Brakes

Mechanical brakes have been in use for years. The simplest variety, often fitted to small planes with simple control systems, is the so-called "drag" brake. These are simply set to apply a continuous moderate friction on the wheels (normally to the two main wheels of a two-wheel-geared model, or the two rear wheels of a plane



Ace R/C.

8-2 Tiny WAG electric brake is small enough to fit entirely inside hub of wheel; hub accepts standard model tires.

equipped with tricycle landing gear), and cannot be controlled via radio. They are "on" all the time, but not heavily enough to prevent the plane from taxiing or taking off. They must have enough drag to bring the plane to a stop on a smooth runway when the engine is at idle speed (and preferably when it is headed downwind). This takes a fairly delicate adjustment, and R/C brakes are naturally much to be preferred.

Brakes on planes equipped with reed control systems have usually been mechanical, often driven by the elevator servo at one extreme or the other (generally full up on two-wheel-geared planes, or full down on trike jobs). Reed servos have ample power for this purpose, but some proportional servos do not. Such brakes are marginal with spring-centered servos, and of course are useless on planes with magnetic actuators. Most feedback servos can handle them.

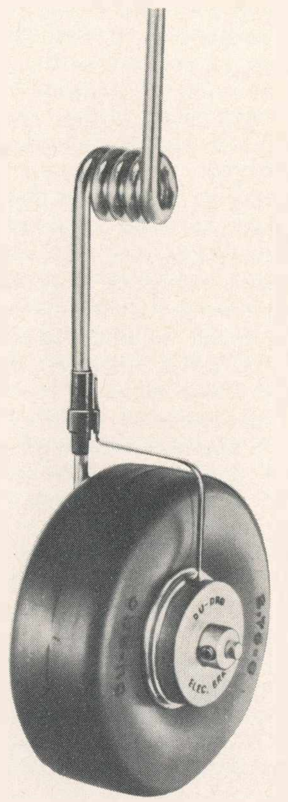
The advent of electric brakes has made it possible to fit this accessory to just about *any* proportional (or other) plane, regardless of size or type of servo. As a practical proposition, brakes are seldom used on planes with engines smaller than perhaps .15 cu. in., as they are really required only on competition planes to take advantage of the many points that can be picked up by well-executed ground maneuvers; and few competition planes these days have engines much smaller than .19 or even .29.

Electric brakes come in several sizes and types. Those in fig. 8-2 can be mounted on an axle alongside standard model wheels, and can be linked to them via the projecting pins. The inner portion of each brake is attached firmly to the axle with one or more setscrews, and when power is applied the outer portion of the brake drags on the inner due to magnetic attraction. The brake width plus that of the wheel hub requires a rather wide axle, so the makers now offer a hub inside which the brake fits, taking up only a tiny bit more axle space than the hub alone. Standard makes of model plane tires fit this hub. The brake in fig. 8-3 is only 7/16" thick, and while too large to fit inside the hub, it does not require a very lengthy axle.

Electric brakes are designed to operate on 2.5 to 4.5 volts, and are sometimes driven from the servo batteries. For more power you can apply higher voltage, but this increases the current drain, of course. The simplest system for energizing these brakes is via a switch which closes in full down elevator for trike-geared planes (full up for those with two-wheel landing gear). In normal flight or even in stunting, full elevator is not used often, or is not held for any length of time; thus the brakes are not energized to any extent except when you want them on the ground.

Proportional brakes should be an advantage — you can "drive" your plane on the ground just as you do a car! If you own a digital system that has a spare control channel, it's easy. Just fit the special amplifier shown in fig. 8-4. Designed for Logictrol apparatus, it can be had to match most any digital system, and it converts the pulse output of such systems to smooth analog braking action for one or more brake units.

Some experimenters have found it very helpful when doing ground maneuvers under gusty wind conditions to be able to lock each brake on the



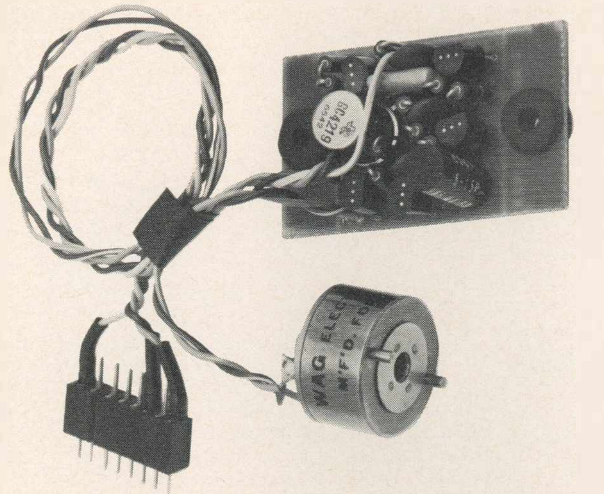
Du-Bro Products.

8-3 Du-Bro electric brake unit is placed alongside wheel hub; is held by setscrew, as is WAG.

rear wheels of a trike landging gear individually. This takes several microswitches, per fig. 8-5, but it enables positive ground handling under very adverse winds — just what's needed at many contests. The use of brakes in this manner, plus steerable nose wheel and matching rudder action, gives the most positive possible ground control.

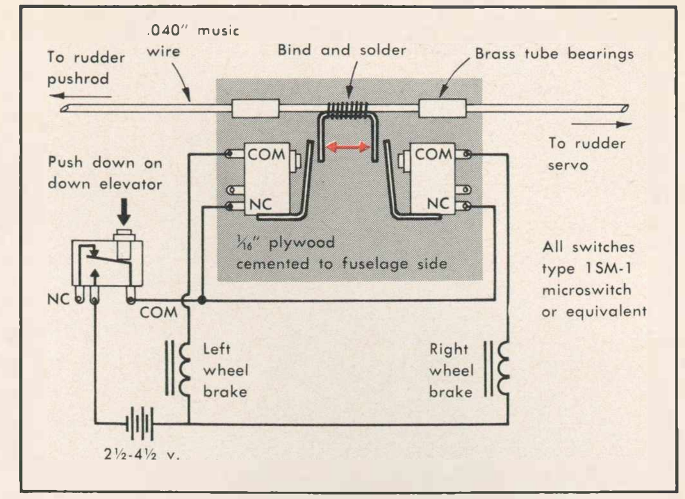
Other auxiliaries

Working flaps have been found useful by the few who have tried them. They can be operated at moderate angles, as is done on full-sized planes to



EK Products.

8-4 Logictrol amplifier converts one output from digital receiver to variable voltage to power electric brakes.



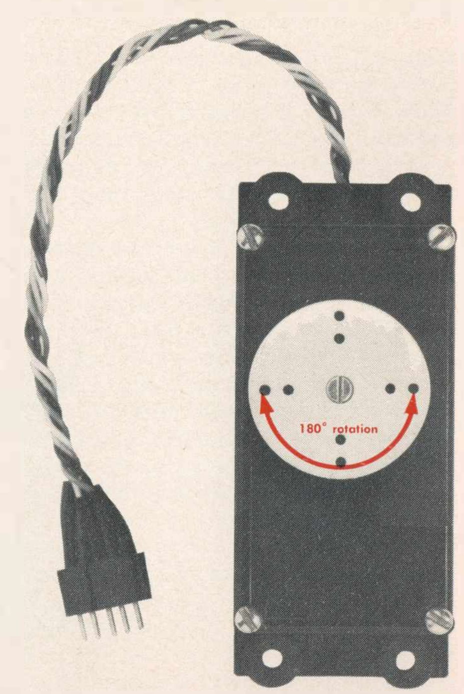
8-5 "Bulldozer" brake hookup by Kirkland is versatile; a single small switch unit (SACS) can replace three 1SM-1's.

give added lift for takeoff and lift plus drag for landing, or they can be dropped 90 degrees to the lower wing surface for pure drag to bring down planes that tend to "float" (those which have a long, flat glide) and are difficult to bring down to a spot landing, especially if the plane has to be brought in over trees or other obstructions. Most users of flaps arrange them to be either up or at some predetermined down angle, and thus have little need for proportional flap action. This could be had, however, if desired. Some planes have been fitted with "air brakes" — small flaps that pop out from the fuselage sides — again to reduce a floating tendency. These brakes can be quite small. Two flaps the size of ordinary calling cards have been found very effective for a normal-sized stunt plane of about 65" to 70" wing span. Again, there is little need for proportional action on such brakes, though if it were available the expert flier might find it useful.

Wing flaps take quite a large amount of power to operate and generally require servos with a high gear ratio. A servo made especially for such work is seen in fig. 8-6; this Logictrol unit produces 180-degree rotation of the output disk, which allows the linkage to be positively locked in both up and down positions.

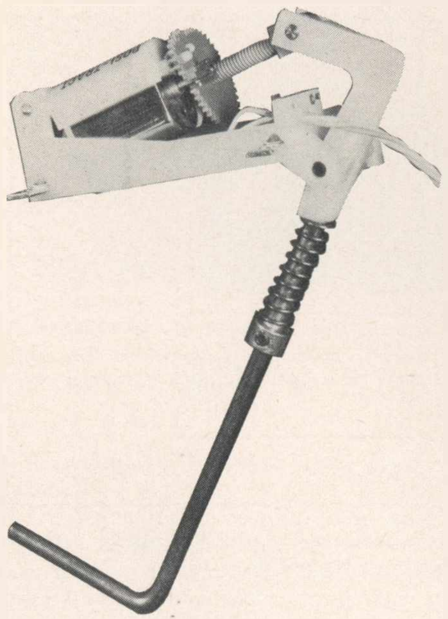
Retractable landing gear has been used in quite a number of model planes, and while there is no real advantage to this feature for stunt planes aside from the fact that the model with landing gear retracted is much "cleaner" and goes through maneuvers better, quite a number of points can be picked up in scale competition if the model has retractable landing gear just as does the big plane from which it is copied. Such gear can be used on two- or three-wheel landing gears, and those which have proved successful have been operated both by pneumatic and by electric means. Quite a few ingenious pneumatic outfits have been described in the model press, and now there are several commercial systems on the market. Generally they are operated from pressure taken from a fitting threaded into the engine crankcase (the pressure "stolen" from the engine is slight, and has no effect on engine operation). A simple pressure valve is generally linked to one of the servos — the throttle servo or its linkage is favored — so the gear can be operated when the throttle is moved to low speed. Some modelers install an "overtravel" arrangement such that the throttle servo has to be moved *farther* than for full low engine (the throttle itself has a fixed stop, but the servo can drive past this to actuate the valve). Generally, air pressure is required to *raise* the wheels of such systems and hold them raised. When pressure in the various wheel unit cylinders is vented, they descend by gravity, or are helped by springs. This gives a "fail-safe" system — if your engine stops while the plane is flying, the pressure leaks off and the wheels come down by themselves.

Electric retractable gear units have been marketed for some years. The first such unit available was that produced by Dmeco; it weighed about 3½ ounces per wheel unit, and the switching moved the wheels in sequence rather than all at once, due to the fairly heavy current drain. While some users operate such units from the servo batteries, others feel it is safer to install a separate power supply for this purpose alone. If this is done, the battery can be heavy enough that all wheels may be extended or retracted together, rather than in sequence. (With the latter arrangement, it is possible for the wheels to get out of sequence — say one wheel on a trike LG might go up while the other two were going down.) The Dmeco unit is presently being redesigned (you can still find some of them in secondhand stocks), but a somewhat similar electrically operated unit — though of much lighter weight, only 1.8 ounces per wheel — is depicted in fig. 8-7. This Posi-Tract has a motor built into each wheel unit, and can be had with a conversion adapting it to act as a steerable nose gear. You can also purchase retractable LG units without any actuator built in; they are designed to operate with any servo that will provide 180-degree rotation of



EK Products.

8-6 This Logictrol servo has greater than normal rotation for such purposes as operating retracting landing gear or flaps.



Wing Mfg.

8-7 Posi-Tract landing gear unit has built-in motor; is adaptable to main or trike nose gear uses.

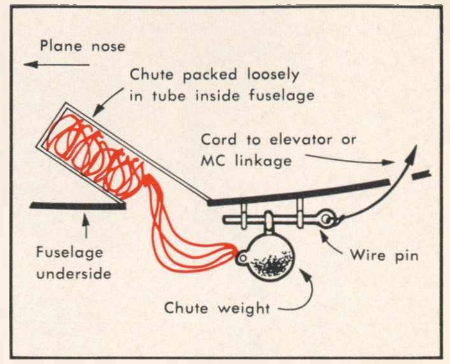
the output disk. (They might be adaptable to pneumatic cylinders too.)

Many fliers have expressed a wish for a special control to trim the engine needle valve while in flight. Often the engine will richen up or lean out too much during flight; with the former condition you lose considerable power (and fuel is used up more rapidly), while with the latter the engine can overheat and seize up. When such conditions occur, it's best to land the plane and readjust the fuel feed, of course; but if you are flying in competition, a premature landing will lose a flight for you. Most competition fliers just sweat it out, hoping the engine will keep running.

The advent of digital proportional systems with their many extra controls makes it quite possible to rig up a trimmable needle valve. So far there is no commercial equipment marketed to do this, and the few who have tried it have had to cobble up their own. It is quite possible to do, though, and very practical, and we now have the means to *do* something about those wrongly set needle valves!

Scale modelers can gain many extra points by fitting their copies of military planes with bomb drops, moving turrets, and such. On nonmilitary scale jobs you can rig up operable running lights, landing lights, cabin lights, and such. All these things have been done with nonproportional equipment, of course, but the extra channels available on digital proportional rigs make it that much simpler. Even if your system does not offer any spare controls, these auxiliaries can be operated from extremes of one of the normal controls — up elevator, for example (but you must remember not to signal for full up elevator until *after* your bomb is safely dropped!).

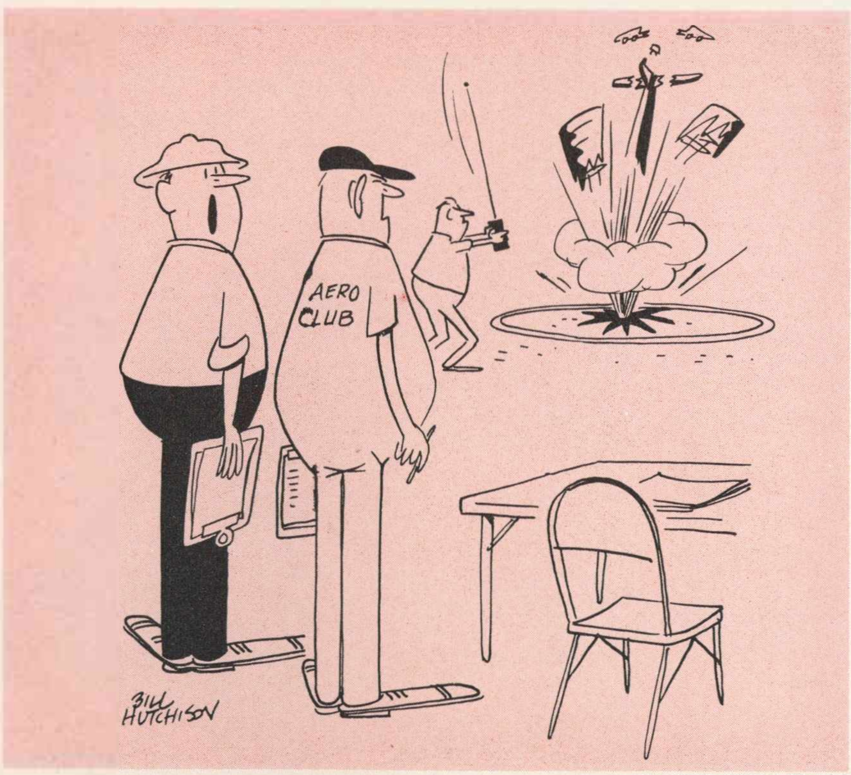
A feedback servo on a spare channel can be equipped with a rotary switch so that as you move the lever on the transmitter to marked spots,



8-8 A simple arrangement to drop a parachute, by maximum movement of one control servo in plane.

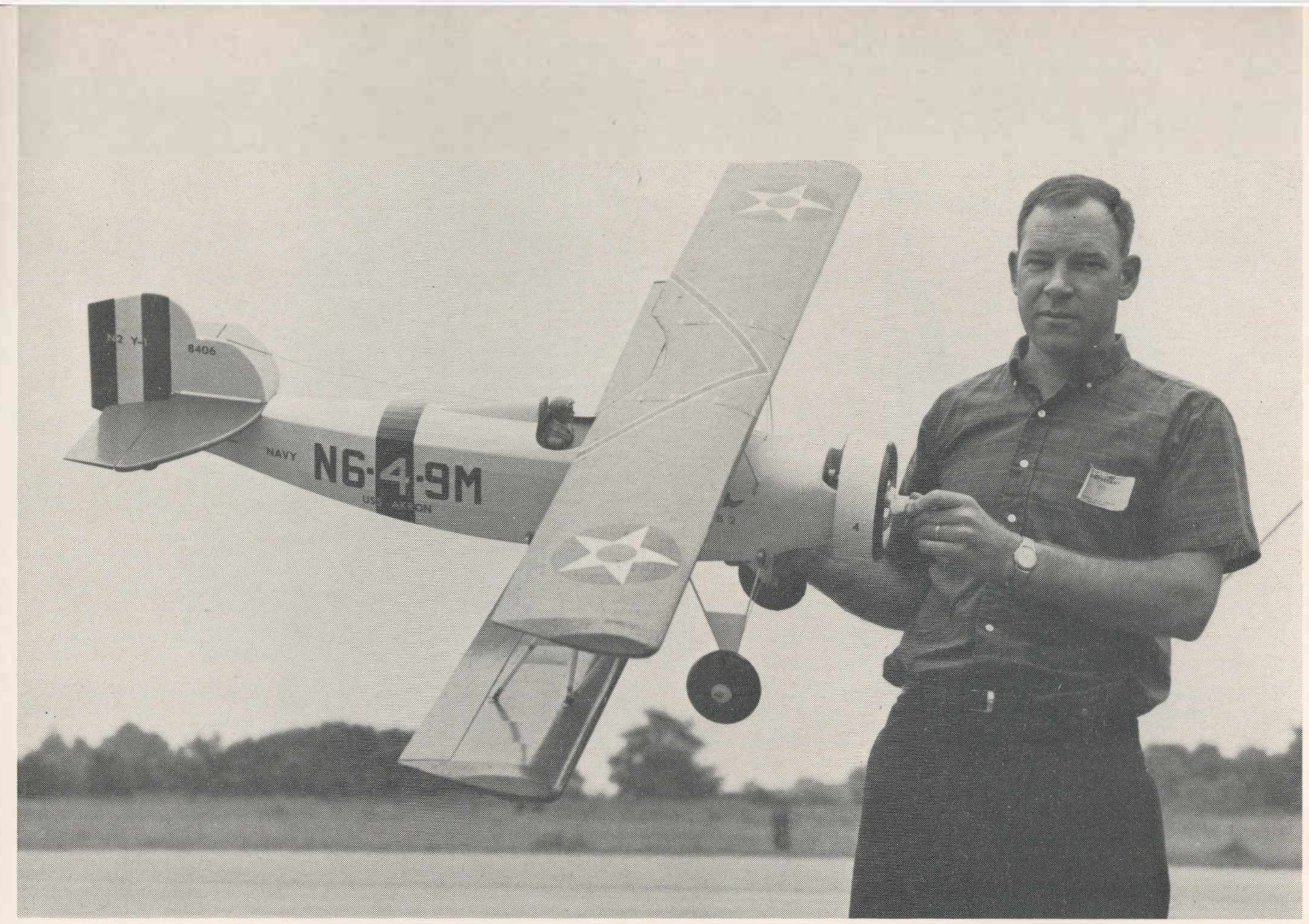
corresponding circuits are closed in the model. You could even arrange to fire a number of tiny rockets one by one by this means. Don't laugh — it's already been done!

A sure crowd-pleaser is a parachute drop. Again, this can be accomplished by using an extreme control movement. Fig. 8-8 shows one way; in full up elevator (for example) the cord pulls the pin from the rings, dropping the parachute weight loose and so pulling the chute from its container. Full low-speed position of the motor control servo can be used the same way. Normally you will climb at full power until you are ready to pop the chute, then throttle down to make sure the chute doesn't tangle with the tail surfaces. As you reach low speed the parachute is safely launched.



American Aircraft Modeler.

"Well, he gets full points for a perfect bull's-eye!"



American Aircraft Modeler.

Bill King proudly displays his contest-winning Scale Fleet biplane, which carries full-house propo controls.

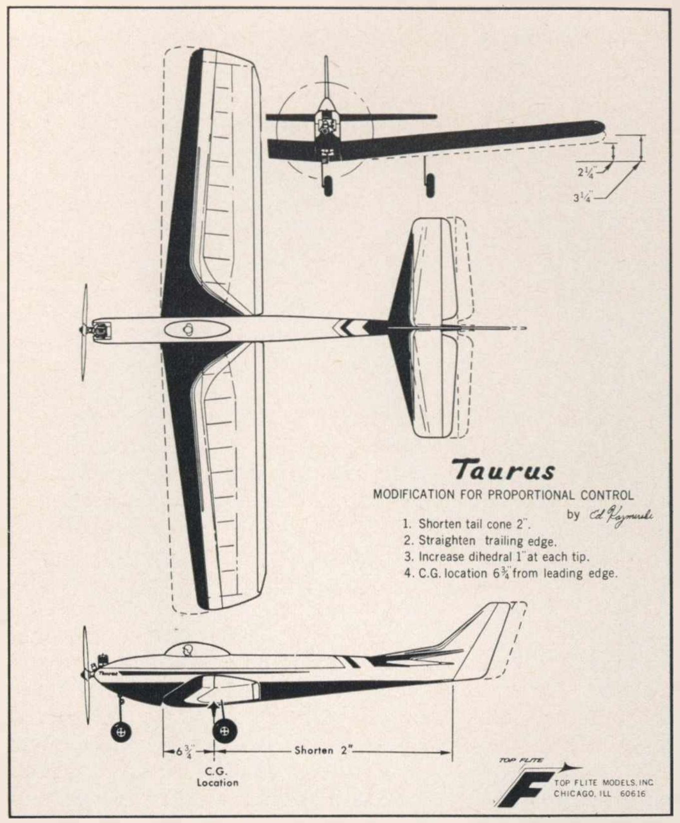
9: WHAT MODELS AND WHAT SYSTEMS?

THIS book is dedicated to the novice in proportional — not necessarily the novice in model plane flying, nor even in R/C. So we will be concerned mainly with what style of plane and equipment is best for the *proportional* beginner. If he is also new to model aviation, R/C, or to both, my advice would be to build a plane of conservative design and medium size (there are many good kits on the market that will do the job perfectly), perhaps for an engine of from .09 to .15. Start with rudder control and throttle, and really learn to fly that combination before going to anything more complex.

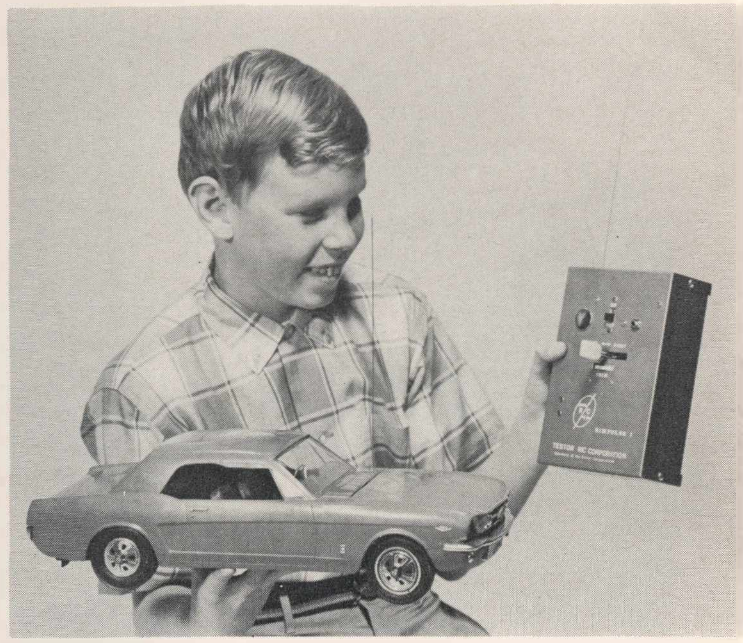
The modeler will probably want eventually to try his hand at elevator control, and certainly the cheapest and simplest way is with Galloping Ghost, but *don't* start out with a full Ghost installation. Elevators add a completely new dimension to flying, and if you are a beginner in R/C you will have enough problems just learning to fly rudder successfully. There are certain reflexes that just *must* become automatic before you can be said to have mastered rudder proportional flying. If you have to "think" which way the stick must be moved when the plane is in certain awkward positions, such as coming toward you (the rudder action must be reversed here), then you have not really learned to fly rudder yet! As noted before, if you can afford the modest extra expenditure, you might as well purchase a transmitter that offers full pulse rate and length action, and a full Galloping Ghost servo. Just be strong, though, and forget the elevator attachment to the latter until you are sure of your rudder-flying prowess.

Some modern Galloping Ghost servos are said to be husky enough to handle planes up to .35 engine size, but when these servos are used just for rudder (with or without MC) they can control a considerably larger plane than when they also have to handle the elevator chores as well. Actually, though, GG is really best suited for smaller planes, and will certainly afford only marginal action on those with engines as large as .35. The ideal size is probably .09 to .15 engine size, as previously suggested, and all commercial GG servos now available are intended for planes up to this size. Some servo makers give instructions for operating their units on higher voltage for more power, but in any case, follow the instructions carefully as to suggested pulse length and rate.

If you have purchased a good pulse rate-length transmitter, or a separate pulser to go with an existing nonproportional transmitter, you have one of the basic ingredients to go to the next higher step in proportional: a full pulse rate-length system with rate decoder in the model, and separate servos for each control function. If you have mastered Galloping Ghost in smaller planes, you will be fully qualified for this step and can confidently tackle a plane with engine in the .19 to .29 category. Actually, even larger and hotter planes can be handled by equipment in the Kickin' Duck category, and with spring-centered servos at that. Many hot stunt planes have



Top Flite Models.



9-2 (above) Attractive scale Mustang by Testor R/C is 16" long; allows propo steering, speed change, start-stop.

9-1 (left) Changes suggested by Ed Kazmirski for his Taurus design.

been flown with spring-centered servos (such as Bellamatic II's) and engines up to .60 displacement. However, as with GG, there is probably an optimum size for pulse rate-length systems with spring-centered servos, and I feel .19 to .35 is probably the best size range. Such systems can handle ailerons via CAR, but one can't expect a single CAR servo to handle the chores of rudder and elevator on *too* large and fast a plane, and do a top-rate job of it. Separate rudder and aileron servos electrically coupled will afford much more control response, and will allow more violent stunting.

Now how about full-house proportional — the works? Again I can only repeat that previous extensive experience in rudder-only, GG, and KD will be of the greatest help in a successful transition. If you have been flying KD systems, the changeover is the easiest, since servo installation, linkage, and trim problems are practically identical. More than one present-day top competition stunt flier has told me that earlier extensive experience in the simpler proportional systems was of inestimable help in making the change to full-house multi proportional, both in control-stick handling and in the pocketbook — the latter because he had already learned many pitfalls to avoid, probably through crashes experienced when flying the much-lower-cost equipment.

Of course there are always the fliers who start out in full-house proportional with no previous proportional experience, nor even any earlier model plane experience. I know a few who have fought this battle out and are top competition fliers today, but this is certainly the hard and expensive way, and most tyro R/Cers would not have the fortitude to stick it out — nor the cash to do so.

Differences in planes

In the smaller and simpler types, it can probably safely be said that almost any plane which is a successful escapement performer will do fine with proportional. I am not considering here the highly specialized planes which have evolved for competition flying, just the average kit plane of the proper size as outlined before. Almost the same can be said for planes intended to take equipment in the simpler reed categories — the four- and six-channel reed systems, for example. Many of these in the smaller sizes make fine GG planes, though on some the movable tail surfaces might have to be altered. GG elevators, for example, tend to be much more narrow than those intended for operation with separate servos, whether these servos be of the "motor-driven escapement" style, reed, or separate servo proportional. Balance may also have to be altered to get sufficient control action with the somewhat limited control surface power afforded by some GG servos. Basically, though, there are few differences between good noncompetition escapement and reed planes of modest size, and proportional planes of the same size.

Almost the same can be said for the larger reed planes, and here again I stress *noncompetition* designs. Actually, if you ask half a dozen top model fliers and designers what the design differences should be between multi reed and multi proportional planes, you are very likely to get half a dozen different answers, for at the present state of the R/C art, with proportional finally coming into its own, there do not seem to be too really outstanding differences in requirements between the two types of planes. This is especially true of sport planes, and those to be flown by any but the really dedicated competition pilots. It's undoubtedly true that the latter experts can detect little differences between the two widely different types of control systems in a given plane, but few of the rest of us can.

Most accomplished reed fliers take extreme pains to trim out their models and to keep them in exact trim, while many proportional fliers are considerably less painstaking. The reason is doubtless to be found in those little trim levers or knobs found on most multi proportional transmitters with which you can alter the in-flight trim of every control surface — and sometimes of the engine throttle as well. Reed systems normally have trim on only one surface — elevator. Thus, if you find your ailerons are not set quite right in flight, you have to make mechanical adjustments in the linkage to compensate. In a sense, of course, and even discounting the trim levers, proportional gives you the effect of *continuous* trim, since it is no great chore to hold the stick a little off neutral to cause the plane to fly as you wish. Unless you have gone to the extreme of a trim lever movement, this is seldom necessary. Continued flying with these levers far off-center is not advisable, of course; wind strength or other variables might change drastically during flight and you could "run out of trim" in trying to compensate.

Basically, reed planes are designed to "groove" more and to fly flat and level until disturbed by the controls. With the much more flexible control possibilities of proportional this is not so vital. As noted, however, the competition fliers do have strong ideas on what the differences should be between multi reed and multi proportional planes. As an example, one of the most widely copied reed planes was the Taurus, designed by Ed Kazmirski (kitted by Top Flite Models, Inc.). The design came into prominence at the 1962 AMA Nationals in Chicago when Ed won the multi event with his new design. It was designed for reeds, of course, as multi proportional was still somewhat of a novelty at that time (though the handwriting was on the wall as proportional took third, sixth, and several other high places among the vast group of reed fliers). When Ed tried proportional in this plane, his tests convinced him changes were needed, and the comparision is seen in fig. 9-1. Many of the original Taurus configurations have flown nicely with proportional, but for competition the modified job is doubtless preferable.

Model cars

Proportional is ideal for model car steering. You can actuate the front wheels with any of the small spring-centered servos, or just a small motor with the simplest gearing. GG servos work fine, using the drive that is normally employed for rudder to handle the wheels. With such a servo, the elevator output could be linked to a rheostat to give you variable engine speed, though the "gallop" could wear out the rheostat rather fast. The MC output could be linked to a switch for forward and reverse. There are lots of other combinations to be worked out with these versatile servos.

Actually, you can have lots of sport with the simplest cars fitted with just proportional steering. Exciting races are very practical. In fact, some R/C clubs located in climates where outdoor R/C operations are greatly curtailed during the winter have scheduled races at their meetings to keep the members active, and have had very good turnouts. Some of these "cars" have been very crude contraptions with just the minimum work on them needed to produce a unit that would move and could be steered. One eastern group, the Central Jersey RCC, coined the term "rolling breadboard" for these vehicles, many of which were little more than a board with wheels, plus drive and steering mechanisms.

The smaller sizes of cars can be steered very well with magnetic actuators, and in fact you can buy a ready-to-run car so equipped today at your hobby shop. (See a model Mustang by the Testor Corp. in fig. 9-2.) Some modelers and manufacturers feel that small R/C cars may be the next "craze" to follow slot-car racing, since they will allow true road and track races where the driver has just as much control of his vehicle as do the drivers of the full-sized cars.

Some highly versatile conversions have been made of such toys as model bulldozers and tanks. The latter have been made to aim and fire their guns, rotate turrets, and so on. In fact, one of the large R/C manufacturers (Bonner Specialties) produced some rather sophisticated model tanks for the armed services to be used in simulated war games, training future tank drivers and commanders on the needed tactics. These models were produced before proportional came into its own, however, and were controlled by multi reeds.

Model boats

As with planes and cars, boat control possibilities range from simple steering of the tiniest craft, right on up to "full house" operation of very complex craft. Cabin cruisers and open runabouts are very popular, probably because there are many fine kits on the market for them; but you can also get kits of ocean liners, PT boats, and battleships — even submarines, and some of the latter can be made to submerge and run under water, all via R/C. Proportional is not a necessity for any of these boats, but it does provide much more flexibility for such operations as steering and speed control. In the more complex multi systems, unused channels can be arranged so the servo drives multi-contact switches to perform such operations as turning on lights, blowing horns or sirens, dropping anchors, and so on. As with cars, there probably is not the need for four proportional controls in most model boats, and this means you can get most of the benefits of proportional for your boat (steering and drive-motor speed change) via the simpler systems. Here again the ingenious builder can adapt GG servos to perform just about all the actions required on a small craft, giving highly versatile action at very low cost.

When we get into the higher-speed boats, in larger sizes driven by glow and spark-ignition engines, real servo power is definitely needed; and the only answer here is feedback servos and the systems that go with them. The fast hydros still require only two controls — steering and engine throttle — but reliability is a must, as these craft travel at such speeds that they can be wrecked if the equipment fails and they roar into a rough bank or wall. The very expensive full-house systems are not needed, though, as good results have been obtained from such equipment as the Citizen-Ship type AP pulse rate-length system.

American Aircraft Modeler

Bob Robertory launches his cabin cruiser that has propo steering, forward and reverse electric drive. Pulser and other controls are in box on transmitter side.

10: TESTING, MAINTENANCE, TROUBLESHOOTING

WE shall not go into great detail here on these items, but will stress mainly those matters that pertain particularly to proportional systems. Considerable space is devoted to these subjects in the R/C PRIMER, to which this volume should be considered a rather specialized adjunct.

Preflight tests

If your batteries are all charged, or if you have fresh ones in both transmitter and model if they are not of the rechargeable variety, you are ready to try the last-minute tests before launching the model. First, are you *sure* the center of gravity is in the correct spot? If you have built a kit job, or from magazine plans, the proper CG location will have been specified and should be followed exactly. Most model planes tend to be a bit tail-heavy, and that's the worst kind! This means the CG is behind the ideal location, which makes the model fly in a mushy attitude with nose high, and in this stall attitude your rudder or ailerons can be very ineffective. Check CG position most carefully. The best way is to balance the model, per fig. 10-1, to see if the location is as called for.

Readers of this book who have designed and built their own model planes probably don't need the advice of this writer to tell them where the CG should be! For sport-type planes, which often have flat-bottomed airfoils, a good starting location is approximately 25 percent back from the wing leading edge. In any case, don't attempt flight until this elusive and mythical "point" is just about where specified, and rearrange equipment in the model to attain it if necessary. Often the batteries or receiver can be moved sufficiently to do the job. Adding weight to nose or tail should be considered a last resort, but even this is far better than trying to fly a plane that is out of balance. If weight must be used, try to get it just as far fore or aft as possible, as less weight will then be needed. A heavier engine could be used to correct tail-heaviness in some cases. Use of a nylon prop in place of a wood one, or the addition of a metal prop spinner, might help on small planes. If more weight than this is needed, small pieces of lead can be used. (Sheet lead about ⅛" thick is available in plumbing supply houses, and is very useful for our purposes.)

Nose-heaviness is less common, but easier to correct, since only a small weight at the end of the relatively long fuselage will restore balance. You can often do the job by applying several more coats of dope to the tail surfaces, in case the original dope job was a bit skimpy.

Now let's consider the radio equipment. Be sure your receiver is properly tuned to the transmitter. Even if this was checked with the equipment on your workbench, you must retune it in the model, as differences in wiring, parts location, and antenna placement will detune the receiver. With superregens, tuning is a most important process; with superhets it is less so, as all such receivers used in R/C are "tuned" by the crystal that is part of the oscillator circuit. Hets thus cannot really be out of tune (assuming the crystal matches that in the transmitter); however, the installation can cause a mismatch with the input circuit sufficient to reduce range considerably, even though the equipment might work fine close by or at moderate distance. So this tuning process should never be neglected for *either* superregens or superhets.

Range checks on the ground are an important part of preflight testing, and should preferably be accomplished by having an assistant hold the transmitter in normal flying position while you take your plane for a walk. Walk out far enough that the controls become erratic, showing that you are getting to the limit of ground range. This could be as much as 400 or 500 feet or more. When you get to the limit of solid reception, go a bit farther; then try retuning the receiver slug to restore proper reception. There is no need to use a tuning meter with modern equipment, and even an earphone, as supplied with some receivers, is not really needed. You can tell when reception is dropping out by listening to the servos in the model. Try to hold the plane so that the antenna is as far as possible from your body. You will doubtless find as you move the plane in various positions relative to the transmitter that reception will vary considerably. This is quite normal.

It is generally considered that the minimum reception range of a plane in the air is twice that on the ground, and it can be up to four or five times as far. To make preflight testing simpler and quicker, many manufacturers give you a range at which the equipment should work reliably with the transmitter antenna either collapsed or removed entirely. Such short-range tests are useful quickie measures, but an occasional test as outlined is valuable insurance toward trouble-free operation.

One point you should check most carefully, particularly in multi installations, is whether the controls move in the proper direction compared to control-stick movement on the transmitter. This sounds like such an elementary thing that no one could go wrong on it. But they do! Most experienced fliers — if they are honest enough to admit it — can relate some experience they have had (often with "fatal" results) when a carelessly installed servo or linkage was hooked up backwards. So check and double-check this matter on a new plane, or on one where you have changed the installation, servos, linkages, etc. Don't forget that such a simple matter as reversing the leads (or the battery polarity) on a motor-driven or magnetic servo will allow it to work perfectly — but in reverse!

With planes getting heavier and heavier, and faster and faster, glide tests are no longer feasible with most multi planes. Such tests are still useful for the smaller jobs, however. If you can glide a model from a reasonable height, and especially if it will land in soft grass or weeds, you get a fair idea of the glide balance and if the controls function properly (and in the right direction). Whether it is worth trying glide tests with a new plane is really a matter of experience, so try to get a seasoned R/C flier to help you here. In fact, such an expert can give invaluable help throughout your test period, calling upon his long experience to spot potential difficulties you might miss completely.

After you have made successful range checks, the next thing is to try the equipment with the engine running. You can begin with the plane simply held on the ground while the controls are given a good workout and the engine is run through its full speed range. Vibration troubles often show up at one particular engine speed—not necessarily wide open — when the equipment will work perfectly at all other speeds. If no faults show up with the plane held on the ground, have a couple of assistants hold it up in the air by the wing tips, or better yet, with the wing tips supported via rubber bands. This is about as close to actual flying as you can get.

If tests with engine running show vibration problems, make sure your propeller is balanced. Despite care used in manufacture, many props, both wood and nylon, are sadly out of balance when you buy them. A simple prop balance is a fine investment (see fig. 5-3, R/C PRIMER, for a very suitable unit). Most experienced fliers won't use *any* prop until they have personally checked the balance and made needed corrections. Because of their greater weight, nylon props can shake up a plane worse than the wooden variety when unbalanced, and unfortunately they are much harder to balance, too. With patience and a good balancer, almost any propeller can be brought into very good balance, including the three-bladed variety. Need for such balancing is not confined to the larger planes and engines. Even the maker of the tiniest engine available today (the Cox .01) strongly recommends balancing the 3"-long propellers used on this engine before running it.

When making operational checks at close range, keep watch for a condition known as "overloading" or "swamping." This normally happens only at very close range. Many fliers of the smaller planes like to hand-launch their model while holding the transmitter — tough to accomplish if the plane equipment goes haywire when near the transmitter. Overloading is generally a receiver problem, and there is not much you can do to cure it, aside from returning the equipment to the maker for a recheck. (Be sure to send the transmitter, too.) Sometimes the effect can be overcome, though, by partially collapsing the transmitter antenna (don't forget to fully extend it as soon as the plane gets 50 feet or so away), or better yet, try grasping the base of the antenna firmly with one hand. This detunes the transmitter output circuit and cuts power output very markedly, often eliminating the overloading. Resting the hand which grasps the antenna firmly against the case top or side will further reduce RF output.

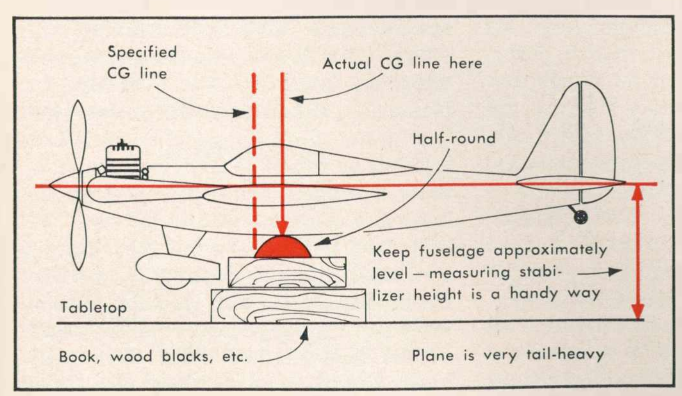
Flight tests

If you have an area where it can be done, flight tests should start with some "ground flying": that is, taxiing at low or moderate engine speed while you test flight controls, ground steering, engine response to throttle. If the model is too large and heavy for glide tests, or if you don't have a suitable site for them, taxi tests are the next best substitute. If your taxi area is extensive enough (as is often the case for those fortunate modelers who can operate from abandoned airports), you can run the engine fast enough for short straight flights, then try gentle turns and so on up to full-fledged flight. If at all possible, try to have an experienced flier do these first moving tests for you. He will know what to look for in control malfunctions that you might miss completely.

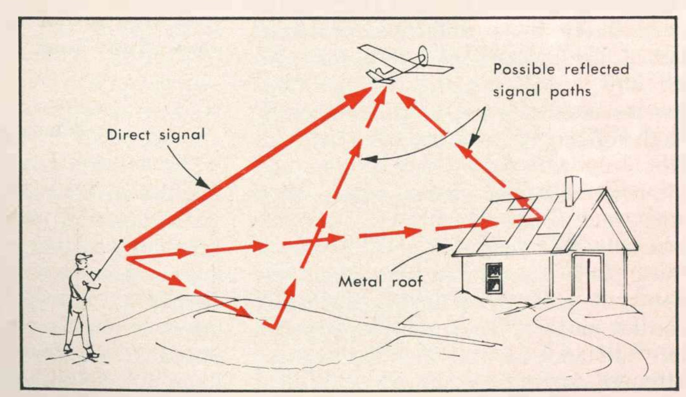
If you watch such an expert try out his own planes, you will find he runs through a few turns first, but before long he will very likely be doing violent stunts. Don't *you* be tempted to do likewise! Stick to gentle turns at reasonably high altitude. Then, even if you goof, you will have enough air space in which to recover level flight; and don't forget, most "sport" planes (but not many competition stunters) will recover to level flight from almost any attitude, given sufficient height above ground. That height is your best insurance, but don't get so high or far away that you cannot be sure whether the plane is going or coming. For those first trial flights, try to keep upwind; if there are any malfunctions or goofs on your part, the plane will drift downwind *toward* you, giving you much more time to get things under control again. It must be admitted that there are doubtless many R/C modelers who do not go through the long preflight and first-flight routine described. Quite possibly some of these same modelers might have been strictly R/C beginners, with their first plane, but the odds are heavily stacked against them. If you value the money you have put into your plane and equipment, and the many, many hours invested in the building job, play it coolly and carefully. You may not be as spectacular as the flashy showoff, but you will probably still be flying R/C successfully long after he has given up and gone to some other endeavor. Patience and caution really pay off here.

Bumps and glitches

When your plane is up for its first flight, watch for slight periods of signal loss. These are often termed "bumps" or "glitches," and have been with proportional fliers for many years — an accepted part of this form of flying. They are often not even noticeable with a slow rudder-only plane, but if you have engine speed control you might find the engine changing its speed when you have not signaled for such a change. If so, you have joined the fraternity. It was probably a glitch that was responsible. With faster planes, and with multi controls, you can often see a noticeable jerk in the flight path. It can happen with the best of equipment. Some glitches come from interference, either inside the plane (metal-to-metal linkage parts rubbing together, servo motor electrical noise, and such) or from without. The latter could be another flier



10-1 Checking the center of gravity of a completed plane. Landing gear must not touch supports. When balance is achieved, the center of gravity is directly above the point of support.



10-2 Signals can go from transmitter to plane by many different paths. Occasionally two of these signals may momentarily cancel each other, giving a short "glitch."

on the field testing his equipment, or it might be from Citizens Band phone stations or other interfering signals. Most surprising of all, perhaps, is that many of these glitches are not from in-plane sources nor from any external transmitters, but come about through odd momentary reflections of signals from your own transmitter. Most of us have seen television signals momentarily disrupted when a plane flies overhead, caused by so-called out-of-phase signals reaching the receiver antenna. One signal comes directly from TV transmitter to receiver antenna; another is bounced off the plane and reaches the receiver a tiny fraction of a moment later. The two signals can be just enough different in time to partly cancel each other, and the picture consequently twitches for a moment. So it is with R/C. The main signal goes directly from your hand-held transmitter to the plane antenna, fig. 10-2, but the secondary signal reaches the plane reflected from the ground, or perhaps from a nearby metal building, or from phone or light wires. By whatever path, if the two signals are out of phase (engineer language meaning they arrive at slightly different times), the continuous stream of signals upon which *all* proportional systems depend is disrupted for a moment. Depending upon the plane equipment, you might get a momentary twitch in the flight path, the engine speed might drop, or with some systems you might just hear a momentary change in engine speed.

The point here is that you must learn to accept a glitch now and then, and not always suspect interference or other trouble when one occurs. Again, an experienced flier will probably know the difference, or he'll know the possibility of having external interference in a given area, and he may likely know just about where he might be likely to have a reflection glitch.

If your digital system has lockout and fail-safe, and you just get an occasional engine speed change, it could very likely be a reflection problem; but if the system goes into fail-safe for any length of time, it's definitely *not* reflected nor out-of-phase signals, as the effects of these are very fleeting. Not only are they fleeting, you can often predict just about where they will occur. Some fliers have found, for example, that they will get a twitch of their plane quite often when they are doing the procedure turn in the AMA contest pattern. Here the plane is at a fair distance from the transmitter (though distance is not always a factor, as some reflective glitches occur quite close by), the transmitter antenna is probably pointing directly at the plane, thereby getting minimum *direct* signal transfer to the model, and the plane is making a complete circle, during some point in which its antenna will be in a minimum pickup position for direct radiated signal but possibly just right for a strong reflected signal from that metal barn roof on a neighboring farm.

High transmitter power output has not proved to be the complete cure for reflective glitch problems, though it does seem to help. What is needed is more study of antennas (both in the plane and on the transmitter), of signal propagation from the transmitter, and much more. Antenna design has been rather haphazard up to now, but with so much invested in equipment, and increased understanding that every time a model gives a twitch in the air it is not necessarily getting interference from another transmitter, some fairly comprehensive studies of R/C antennas are now going on. From them may come the knowledge that will practically banish the reflective, or out-of-phase, glitch from among our possible problems. We may also find out how to put a stronger and more consistent signal into the plane antenna to help negate stray signals from other transmitters.

Model Rectifier Corp.

10-3 MRC monitor needs no tuning, covers entire 27-mc. band.

Maintenance

We will not go deeply into this matter, but instead suggest the reading of such material in the R/C PRIMER, much of which is applicable to proportional equipment as well. One problem that is found only in proportional systems is feedback servo pot wear. As noted in chapter 7, most such servos have a variable resistor which moves — and thus wears — every time the servo output arm is moved. In some early systems it was accepted procedure to change the pots in all servos after 100, or even fewer, flights; but feedback pots are improving rapidly and generally last much longer now. Look in your instruction book for information on your particular system.

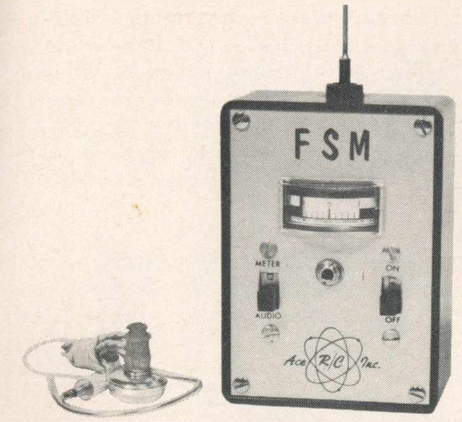
Servo pot wear is worst around neutral, since most servo motion is in that area; so if you find your servo neutrals wandering erratically, check those pots. Engine vibration must accentuate this wear, since supposedly the pot on your control stick is moved just as much as that in the plane servo, but control-stick pot wear has not been a problem in proportional systems. Be sure to shock-mount your servos if the maker suggests this.

Linkage and control-surface hinge wear should be watched, especially in those systems that use "wiggle-type" or spring-centered servos. Here it has been found that if the linkage is properly set up in the first place, rapid wear is very unlikely. Servo gears do wear, though, and in some cases so do motor brushes, and therefore these parts should be inspected at reasonable intervals. Most present-day linkages have few metal-to-metal contacts. Use of nylon or other long-wearing plastic linkage components not only has made it possible to eliminate the metal linkage joints which were a possible source of electrical noise, but at the same time has made it possible to get long wear at such joints without the need for lubrication. Just be sure that the metal portion of a metal-to-plastic linkage moving section is absolutely smooth and devoid of score marks and rough areas, which will rapidly cut into even the very best grade of bearing-type plastics.

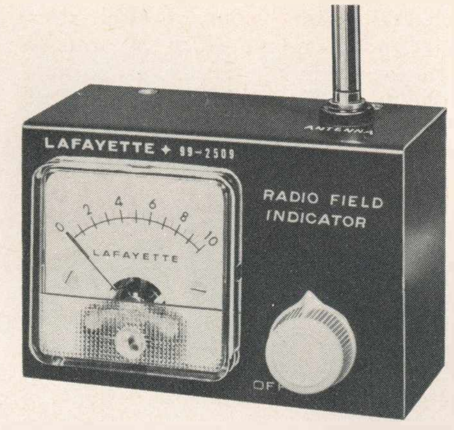
Relay contacts in proportional systems require the same care as those in other R/C equipment. Where contact arcing is a possibility, contacts should be equipped with suitable arc suppression, and if well done and protected from dust and exhaust fumes they should seldom require cleaning.

It has been found that certain types of servo motors have much less tendency to cause relay contact arcing than others. The best servos in this respect are those fitted with Micro-Mo motors. Generally, the heavier the current and the higher the voltage, the more arcing will be found at any electrical contacts, and this holds true for relay contacts and electric motor brushes.

It goes without saying that battery terminals must be kept clean, and also holder terminals, and that the holders must put strong pressure on *both* ends of the batteries or cells. Generally, most experienced R/Cers shy away from pressure contacts on *any* cells, as soldered connections are much more trouble-free. But unless it is carefully done, soldering to any sort of cell, be

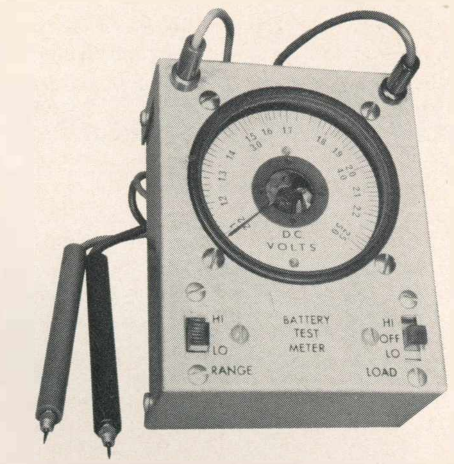


10-4 Ace R/C FSM checks transmitter output by meter, or by use of earphone and internal amplifier.



Lafayette Radio Elect.

Tiny Lafayette FSM is untuned, reads signal strength on meter. It has an earphone jack on rear of case.



American Aircraft Modeler.

Battery tester with surplus meter has very wide scale for precision.

it "dry" or rechargeable, can cause damage and shorten life. In the case of nickel-cads, be sure to get the style that has solder tabs on each terminal, to which it is easy and safe to make your soldered connections. Some modelers claim that such tabs are unsafe, as they can be pulled off. I feel they are quite reliable if care is taken never to put any tension on the lead from such a tab, and to fasten all such leads firmly so they cannot be affected by engine vibration or the effects of hard landings. A coat of silicone rubber over the tab and its soldered lead is double protection.

As mentioned earlier, aside from the most elementary checking to see if a lead is broken, or if there is some other easily visible defect, the average user of multi proportional equipment — and particularly the digital style — should very definitely keep his cotton-pickin' fingers and tools out of the innards! A competent radio man with good equipment can generally do most troubleshooting on analog proportional equipment, but if you don't have the necessary skill and equipment, don't take chances on doing more damage. Pack the stuff up and send it back to the factory. Trying to troubleshoot such expensive and complex apparatus is certainly not the way to start "learning all about radio."

Troubleshooting

This ties in to some extent with maintenance, of course. If your system is acting up, are you sure your transmitter is putting out a good signal? A monitor (fig. 10-3) will let you listen in, as such a unit is tunable to your transmitter frequency and is equipped either for headphone or loudspeaker listening. If you have a monitor, it's smart to check your transmitter when you first get it, when, hopefully, it is in perfect condition and emitting a good signal. Move the controls in various combinations to see how the signal changes. With many transmitters it will be most difficult to interpret what you hear, but if this is the case, probably the equipment is of such a complex variety that you should not be tinkering with it anyhow. On others, you can tell almost exactly what controls are being moved by listening to the transmitter output. If notes are made of control positions and sounds when the transmitter is new, you can check against them at future times when transmitter functioning may be suspect.

Some of the more sensitive monitors are also fine for checking on interfering signals. Others are good only for use right near a transmitter. Commercial monitors such as that in fig. 10-3 are not expensive and can easily be carried in tool kit or pocket.

Field-strength meters (fig. 10-4) are another form of monitor, but instead of phones or speaker output they have a meter which indicates how strong a signal the transmitter is putting out. Actually, this is a rather rough test, but if you use care always to check at the same distance from the transmitter antenna, with the transmitter held in the same position, etc., the meter indication can be very useful. Note that you should always hold the transmitter in your hands (the same way as you would normally fly), since the antenna systems of most transmitters on the market today depend upon this "hand capacity" to load the output circuit. Without such capacity, they will normally have very low output.

Control-surface drift in proportional systems can be from complex causes beyond the average owner to fathom, or it might stem from such a simple thing as the servo batteries being unevenly discharged. As explained in earlier chapters, many servo systems work on two equal-voltage sets of cells, usually a total of four nickel-cad cells with each pair giving about 2.5 volts. When the two sets of cells are even, the servo might be exactly neutral with the control stick centered, but if one set of cells drops to perhaps 2 volts you could have quite a severe unbalance, and the control stick would have to be held off-neutral to compensate — or the trim control, if any, would have to be moved well toward one limit. Barring possible leakage in the circuitry that would drain one pair of cells much more than the other, such an unbalance should make you suspicious of the cells themselves, as only a weak cell would normally drop this much provided you attend to your charging chores religiously.

Some feedback servos can be affected the same way, as they, too, depend upon even voltage from two pairs of cells to center properly. In some systems a second set of cells called the "reference voltage" will be found (these often power the receiver too), and these should also be checked for unevenness.

Proportional control interaction can come from so many causes that it would be impossible to cover them here. One could even be from such an apparently obscure cause as receiver RF mistuning. In simple pulse rate-length systems it could be a fault in the pulser, which would pin the trouble at the transmitter end of the system. If the pulser has a relay on the output, you could check its action by means of a pulse meter, as described in chapter 6. Again, if the receiver has relay output, you could check same with the pulse tester to see if the fault is before or after this point.

Lest you be discouraged by all these possible problems, let me say that with proportional control you will enjoy the finest type of R/C model flying possible. Just be prepared to accept the fact that *every* R/C system can have its bugs!

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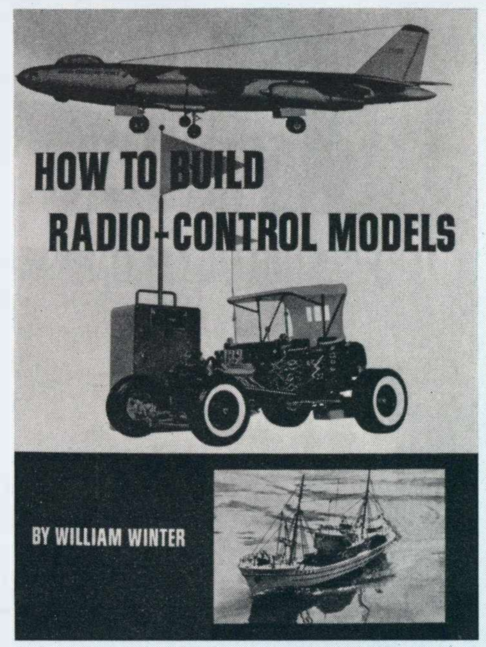

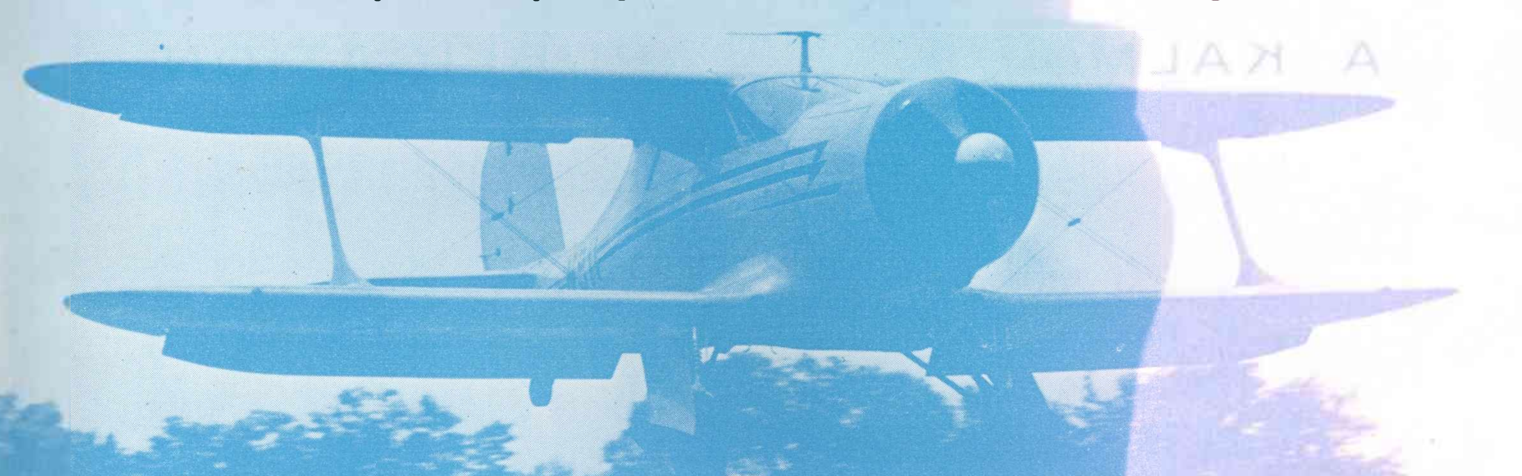

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