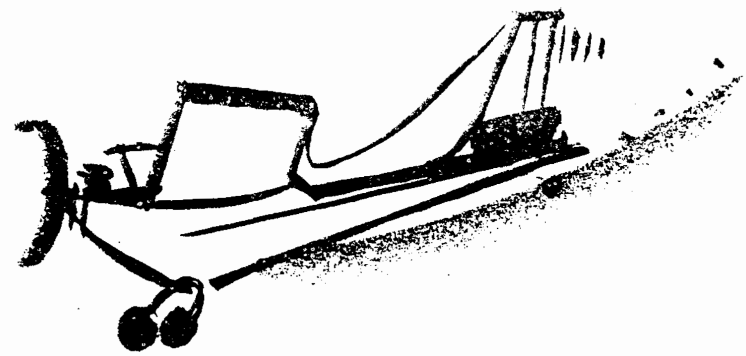
Proportional Control

THE SIMPLE APPROACH
BY USING PULSE

There is no doubt about it--this is the day of proportional control. It is in reality a dream come true. Since the early days of controlling remotely a model of a flying machine, modelers have wanted to do it as nearly like the real thing as possible.



For many years, however, this was not to be the case for most of them. In its initial stages, model flying was bang-bang stuff. You pushed the button, and the control surface in the plane went all the way over and it responded all the way. This was true whether it was single channel or multi channel flying with reeds, and whether there were 4, 6, 8, 10 or 12 reeds to command the servos at your finger tips with transmitter buttons.

Adept fliers learned to lean on the control push buttons just a bit, off; then on a bit more, off, then on a bit more--in effect they were getting only portions of what was built into the system, but the flying was more realistic. If you listened to a monitor when a contest pilot was going through the maneuvers you heard a succession of tones that could come only from a virtuoso of the push buttons---so elaborate was the finesse and fine degree of skill that was required to get the response desired.

Proportional control--or a system which gave the aircraft just the degree of surface response the modeller called for by moving a stick in the direction he wanted that control--has been attempted in a variety of ways and with some success. This was early pulse proportional. It did win contests, even some NATS. It had quite a following among the Sunday fliers, and those willing to tinker, but generally reeds came out best because the systems offered were compatible, had powerful servos, and required only a minimum of maintenance.

Then came analog proportional and the modeler's original concept of flying almost like the real thing, again began to whet appetites. Digital was something to be dreamed about, and some of top producers said it was still light years and many national debt limits away. However a form of digital emerged and while not in its purest sense true digital, it made a hit, and manufacturers have put in more or less the same reliability that the reed flyers had accomplished--and the age of proportional was "discovered" again. But--it is at a rather steep cost that separate the moneyed from the unmoneyed. It takes the bucks to go digital. Indications are that with advances in design, improvements in manufacturing techniques, and strides in electronics itself, prices will come down still more in the next few years.

There are many R/C fans, however, who can't and won't wait that long. Even if they would, they still could not afford the cost, because it still would be out of their reach. For them there is the third alternate in the proportional picture--pulse.

Of the three systems in proportional--analog, 'digital' and pulse--pulse is the least costly and while it does not have all of the advantages of the higher ticket outfits. In our opinion it can and does offer more people a greater degree of satisfaction per dollar spent.

We won't go into analog or 'digital' for the purposes of this discussion. We will detail the elementary phases of pulse proportional in, hopefully, an understandable form so you will know what this simple approach has to offer. Basic understanding is not only essential--it is absolutely vital to your success. For unless you do understand it and what it can and can not do, simple pulse proportional can also be disastrous from a flying, building and financial standpoint.

Let's get real elementary and start with the basics of Radio Control, beginning at the transmitter. The simplest we have in use today, when they are switched on, send out a continuous carrier wave on the frequency which has been tuned in by virtue of the crystal frequency of your transmitter. All transmitters are crystal controlled to comply with FCC regulations. When you push the button, you close another part of the circuit and this causes a tone signal to be sent out over the carrier wave. This tone signal, is received by the receiver in your plane. It has been tuned to match exactly the frequency of the carrier and in some cases the tone of the transmitter. When it receives the signal the battery in the receiving end sends voltage to an actuator which may be an escapement, a motorized servo, or a magnetic device, depending largely on your choice and purposes.

Escapement operation is easy to explain, and since it will provide a jumping off place, let's review it. When a tone signal is sent by the transmitter, the receiver circuit to the escapement is closed, sending voltage to the coil in the escapement. The magnetic force which is created pulls in the armature of the escapement, and lets the mechanism rotate to its first stop. This movement, by means of a link or linkages, causes the rudder to move. It will stay in this position as long as the key button on the transmitter is held on. When the tone signal from the transmitter is discontinued, the escapement circuit in the receiver is opened, voltage flow to the escapement coil is stopped, and the spring of the armature pulls it back to the open position, permitting the escapement to proceed to the next (generally neutral) position. The rudder follows exactly this movement of the escapement.

This bit of background helps lead into the explanation of pulse proportional. With the escapement method of control the plane is basically free flight when not receiving a signal from the transmitter. In RO or GG pulse proportional this is NEVER the case, because your model is never free flighting. It is continuously under control from the transmitter because in pulse proportional a tone is sent on and off in succession fast enough so that the actuating device in the plane is continously moving from one position to another. Your transmitter, and receiver, and actuating devices, are being constantly commanded by the tones sent.

To get into this on-off sequencing of the tone signal from a single channel transmitter forms the heart of pulse proportional from RO to GG and beyond.

At the transmitter, it has been found that it must be more than just turning on and off the signal with your thumb--although successful RO proportional flights have been made in this manner. But this is impractical because it is tiring and unprecise. So, either as an add-on unit or as an integral part of the transmitter itself, there is added an electronic thumb or key to turn the transmitter on and off electronically. Not too strangely this is called a pulser. This electronic button pusher establishes the length of time the transmitter sends out a tone in comparison to the length of time the tone is off. It also establishes the rapidity with which the on-off pulsing is completed. These last two sentences are worth reading again.

The relative length of time the signal is "on" compared to the length of time the signal is "off" is called PULSE WIDTH (PW). Our British cousins call it MARK SPACE and English publications will refer to it as such.

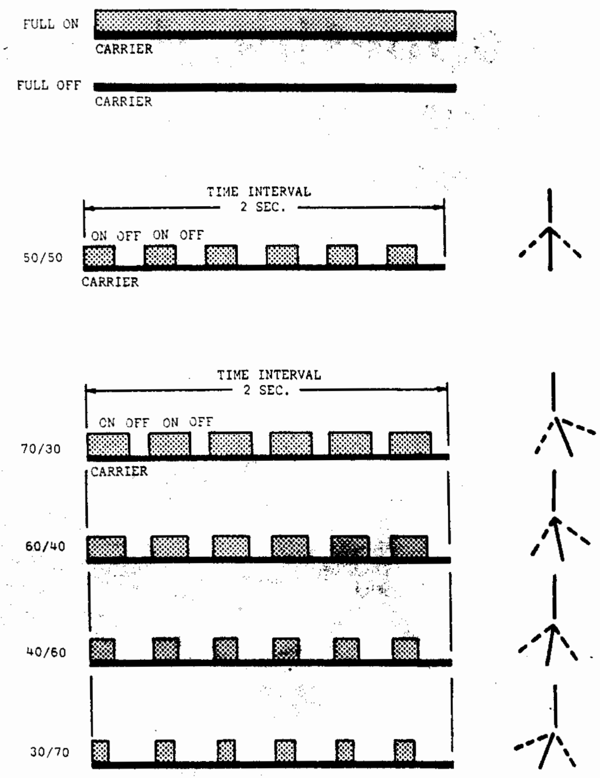
The rapidity with which the on-off sequence is completed is called PULSE RATE (PR).

In PULSE WIDTH you have the essence of rudder control, in the PULSE RATE you can expand into elevator for GG. Full on and full off, in addition to the pulsed series of signals, add yet another dimension.

In hopes of making the possibilities of pulse proportional as crystal clear as possible, let's break it down into several parts; Rudder Only and Rudder Only with Motor, then Galloping Ghost, and finally touch electronic decoding systems. Abbreviations which are quite common in Pulse Proportional will be used a lot. These are RO for Rudder Only, RM for Rudder and Motor, GG for Galloping Ghost, which also may be described sometimes as pulsed REM--Rudder Elevator and Motor.

OK--now what is simple RO pulse proportional and how does it come about?

On the receiving end now there is a bit of difference between the proportional actuating device and the escapement, but most of the basic principles still stand. However, now when you turn the receiver on, you also automatically turn on the circuit to the actuator, although no tone is being sent from the transmitter. The voltage going to the actuator makes it start to go in one direction--this applies if it's motor driven or magnetically operated. Then, when the transmitter sends a tone, the receiver shuts off the "no tone" signal circuit to the actuator and turns on a "tone on" circuit. This circuit reverses the direc-



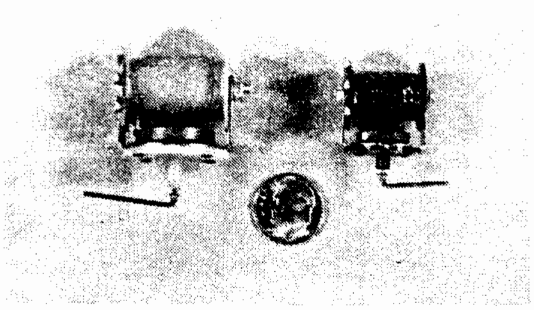
At the top the carrier with and without tone is shown. In the graphs below we take a 2 second interval and show how with the tone ON 50% of the time and OFF 50% of the time, the rudder position averages neutral although the rudder is going from side to side--but in equal amounts. The illustrations below depict variations of the tone ON to OFF ratio, as well as OFF to ON and the average rudder positions as interpreted by the aircraft. This is the variation of PULSE WIDTH that makes RO proportional possible.

tion of the current flowing through the actuator and makes it run or move in the opposite direction. This is because the actuator is a DC (Direct Current) device, and in effect the switching reverses the battery polarity, thus reversing directions.

This reversal of current to the actuator can be accomplished in several ways depending on receiver design. Most common, and for many years the only way, is by a relay where the opening and closing of the relay contacts does the trick. Today there are relayless receivers (double ended, or with switchers added) which have transistors to convert the on tone and the no tone into the reversal of the current.

Now let's look at what is happening. You are sending out tones of equal length ratio of on to off tone. The rudder during this time, because it is linked to the actuator responds to the signal and it is alternately going from left to right in direct response to the tones that the pulser "push button" puts out. As long as the ratio of width remains equal, (50% on -- 50% off), you will have the rudder constantly going from left to right equally. In effect, then, your airplane will read this as a neutral signal, because it is "averaging" the rudder positions. As long as they are equal you have, for flying purposes, a completely neutral rudder since the plane will respond JUST AS IF THERE WERE NO MOVEMENT OF THE RUDDER AT ALL.

The foregoing presumes that this is happening at a fast enough rate of say at least 3 to 4 pulses per second,



so that there is no time for the rudder to "catch" hold in the airstream.

At first the thought of the rudder waggling may disturb you, but it does not bother the airplane, so really there is no reason why it should bother you. As a matter of fact there are some fliers who take comfort in the fact that the waggle is there, since when it is they KNOW the system is performing. The rudder waggling also has helped to locate lost airplanes so it has side benefits as well.

Now let's see what happens to the signal when you begin to vary pulse width from the 50/50 ratio by moving the control stick. If the ON signal pulse is longer than the OFF time, the actuator will go further in direction caused by the ON signal circuit before the circuit is reversed with the OFF signal. This means the rudder will begin to dwell in the ON direction just a bit longer. This bit longer is enough, in a properly trimmed plane with the actuator set up correctly, for the airplane to begin to respond.

Now take the opposite condition, whereby the OFF signal is longer than the ON and you have the rudder moving in the opposite direction, because the signal dwell is longer in OFF.

What is happening is that the stick connected to your pulser pot can be moved in infinite steps which will vary this on-to-off, or off-to-on ratio (or Width). This gives you rudder position averages which vary to just that degree and therefore directly translate stick movement into recognizable effects in your plane.

Pulse width generally is variable for most rudder only pulse propo systems from 50-50% to 80-20, or 20-80. This is the variation of the ON to OFF and the OFF to ON. Some of the GG systems to be discussed later require a lesser degree of width and the pulser must be set so that you have a 70-30 to 30-70 width ratio.

So this takes care of the rudder only portion, but your simple width variations can be made to give you more by utilizing full off and full on signal. Your pulser under normal conditions is generally short of full on or off.

With a magnetic actuator, such as the Adams, you can go in for violent control movements since full ON and full OFF will give you full left and full right and can thus be reserved for violent maneuvers.

With the addition of a button that by a special circuit uses an extremely fast rate from the pulser, you can achieve motor. A Pulse Rate Detector in the receiver circuit detects this faster pulsed signal. This is hooked up to an escapement or servo which is linked to the engine to achieve throttle control. This response is sensed so quickly, you merely blip the fast pulse rate button and there is no noticeable effect to the flying of your plane, but the engine changes speed.

The foregoing has sketchily covered an electronic detection system; we will touch on this in greater detail later in a discussion of the electronic decoding device that are also used in simple pulse proportional control systems. They do add a bit of complexity, but also add some advantages. More on this later.

Motorized actuators of the Rand type HR2 take advantage of the on and off signal in another way. Full ON cycles the motor--and the rudder--completely around. They have built into them a gear which takes advantage of the cycle and this moves an arm. This arm is hooked to the engine so that you can get throttle control. Your ON signal is set so motor cycles through in the direction to give you high speed throttle, while the OFF signal gives the opposite. Consider the rudder is cycling through without pausing in either left or right, so the plane reads this as an average rudder position and therefore flies straight ahead. With full-on and full-off buttons and a motorized actuator, you can easily obtain motor control on RO planes with a minimum of effort.

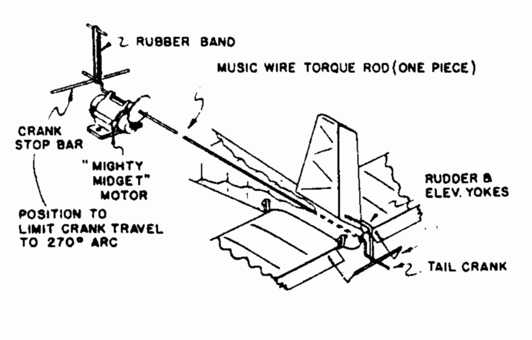
Up to now we have been concerned largely with Rudder Only operation plus the addition of throttle control by the added technique of full on and full off tone signals or high pulse rate. Our concern has been mostly with the variation of the Pulse Width. Let's move on a bit and see what more we can do with the simple pulse proportional by adding variation of the Pulse Rate.

This gets us into the area which is commonly referred to as Galloping Ghost--a nickname which has hung on from the early days. It comes from the flight path that models used to take. In the early days, the control system used to make the rudder flap slowly from right to left, with the elevator simultaneously flapping almost FULL up to FULL down. This caused the tail of the model to oscillate up and down as the model flew; it seemed to gallop and since the control was not visible it got the tag "Galloping Ghost".

It was also known as the Mickey Mouse system since it took quite a bit of tinkering. As it evolved and became simpler, it was also know as the Simpl-Simul due to the fact that it was relatively simple, and was capable of producing simultaneous rudder and elevator functions.

To trace the history of this R/C phase a bit, it appears that Bill Sydnor was one of the first to attempt this system in Pennsylvania around 1950. Development lagged for a lack of a satisfactory ground control unit. Although there were attempts at many mechanical pulsers (One by Don Baisden was published in Grid Leaks), it wasn't until Don Brown and Bill Gilkey in New Jersey really brought the system out from its rough stage by making a multivibrator type of electronic pulser and the use of the Mighty Midget motor for an actuator. Variations of this began to emerge in the Jersey area and proved quite successful.

In the mid-50's the S. E. Virginia R/C Group at Langley Field, Va., took hold of it, dubbed it "Galloping Ghost and within a year dozens of planes racked up thousands of flights. The group learned to trim the gallop out of the model, and to add auxiliary controls. The system used the same principle used today--the variation of Pulse Width and Pulse Rate. It used a simple motor actuator in the plane to decode the information for the rudder and elevator by means of a "bird cage" at the rear of the airplane. (See below.)



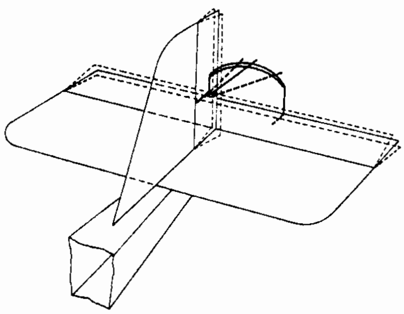
It was this "bird cage" that caused the most frustration. It required tinkering, experimenting and some degree of slop to work. The purists objected to the flapping of the surfaces--although, when adjusted correctly, the planes performed well because they couldn't care less about the flapping.

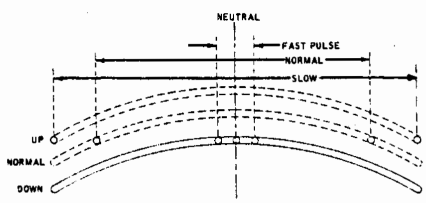
The GG system, Simpl Simul or whatever name was used spread through the country, but it had its limitations. Although the same principles used then, are in use today, the difference is that we now have actuators that do the decoding right in the device itself and translate the Pulse Width and Pulse Rate into push rod linkages to the rudder and the elevator. This allows for more precise installations and does away with the "bird cage" and its attendant adjustment problems. It does NOT entirely do away with the flapping of the surfaces, but it does tone them down to where even some of the purists no longer regard them with their former disdain. And many an old pro flyer is getting his feet wet with the system by teaching his son to fly using GG.

The actuator manufacturer has taken a lot of the guess work out of the GG simple pulse proportional system, and while they still are a compromise of sorts, they don't cost as much as full house propo or even equivalent reed outfits.

We thoroughly covered how and why Pulse Width does what it does to the rudder and why this can be used for RO pulse propo flying. We touched on the fact that the Pulse Rate must be fast enough so that it will not cause the plane to respond to the flapping rudder.

Now let's take a look at what can be made to happen with Pulse Rate in the way of elevator movement. Rudder action is independent of the Pulse Rate, so we need a way of translating this Pulse Rate into elevator movement.

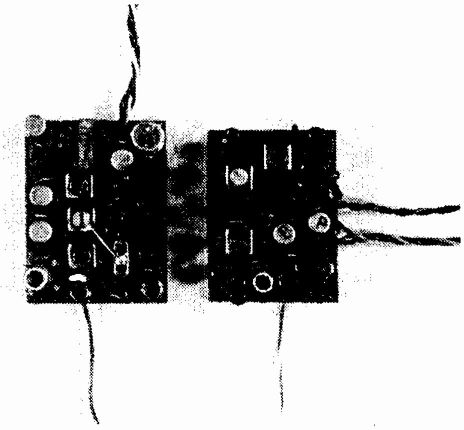




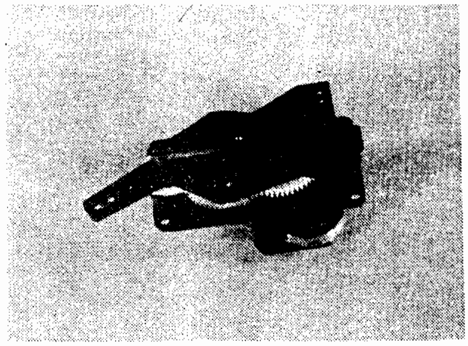
The above shows an ultra simple installation back at the elevator which will do just that. (Please note: This is used for illustration only--since with modern actuators this is accomplished in the actuator.) Assume we have a wire, sticking straight out from the rudder trailing edge, in line with the rudder. This passes through an arc slot made of wire and attached to the elevator as shown. This is somewhat similar to the earlier days of GG and while not used now, it does the job of explaining.

When the rudder is in the center, the wire from the rudder passes through the arc of the slot at the uppermost point.

When the rudder is in full right or full left, the wire passes through the slotted arc at the extreme right



Receivers must be capable of accepting pulsing. Shown above are the SSH-P by Citizenship which is now modified for pulse use, and the Ace Commander DE superhet which is specifically designed for pulse and has dual output for use with an actuator of the Adams dual coil type. May also be used in single output systems--recommended for Dickerson See Saw Switcher for GG.



The Rand LR-3 provides mechanical decoding for rudder, elevator and positionable motor control.

or left ends, both of which are lowermost on the arc. And when this happens, since the wire moves horizontally as the rudder swings, the slotted arc must move up whenever the rudder moves away from neutral. This pulls the elevator up.

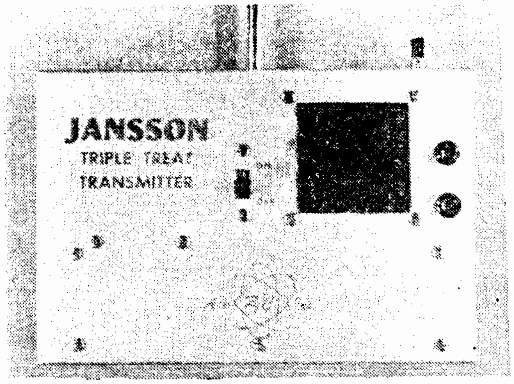
So now we have a condition where, with the rudder in the center, the elevator is full down: and with full right or left rudder, the elevator is full up. Just what we want in order to take advantage of Pulse Rate.

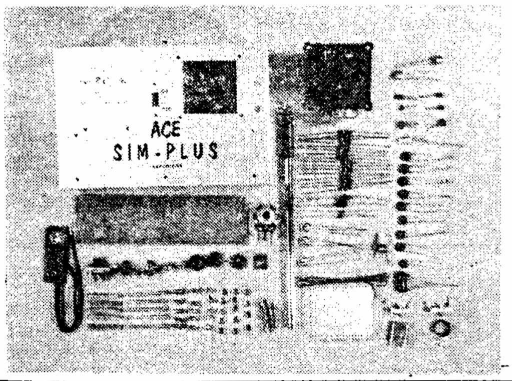
With a fast Pulse Rate, the actuator--and in turn the rudder - doesn't move very far in either direction. This keeps the wire near the top of the arc. So, with FAST pulse rate we get DOWN ELEVATOR.

With slow Pulse Rate, the rudder will oscillate from right to left, the wire will move from end to end in the slotted arc, and the elevator will flap all the way down. The average position of the elevator under this condition is an effective full up position. So, with SLOW Pulse Rate we get UP elevator.

With a Pulse Rate somewhere in between the fastest and the slowest, the rudder will oscillate part way to right and left, and the elevator will flap part way up and all the way down. Thus a middle Pulse Rate will yield a NEUTRAL elevator.

Add to that your 50-50% Pulse Width, and you have your averaged rudder and elevator positions--even though flapping--at neutral for both. Vary Pulse Width for rudder; vary Pulse Rate for elevator--or vary both and achieve both rudder and elevator average positions simultaneously.





Now take a look at the drawings we have of the Rand LR3 actuator (See Right.) This shows why this mechanically decodes the signal in the actuator instead of at the control surfaces. With the Rand LR3, squint your eyes a bit and let the crank that drives the rudder and elevator plates blur just a bit. Just focus your eyes generally and the blur effect looks like the drawings. When actually observing the Rand--or any of the other modern commercial GG actuators--the same principles apply. Also remember that the actuator is constantly commanding the rudder and elevator and that they MUST flap--if they don't there's something wrong. The flapping is part of the compromise.

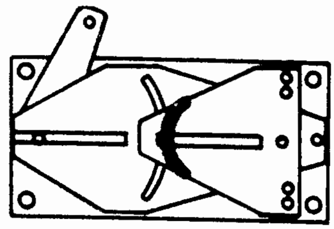
It will become apparent that, as Pulse Width is varied to get rudder action, there is a bit of interaction with elevator linkage which tends to give a little up elevator action at the same time. Normally, this is favorable, since most models tend to drop the nose in a turn. However, if the interaction is too pronounced, and nose tends to come up in a turn, you can apply any needed correction by increasing the Pulse Rate at the same time as you vary the Pulse Width. This simply means you put in a little down on the stick depending on the degree of left or right you push the stick.

With the Rand, Tomosor, Controlaire, Airtrol and others, if you give full on or full off to the GG actuator you have the same situation we discussed for the RO system. Except now BOTH rudder and elevator will cycle completely through so that your throttle for your engine can be advanced or retarded. Rudder and elevator go left and right-up and down; but fast enough so the airplane responds only slightly. Generally, a succession of quick blips give least disturbance.

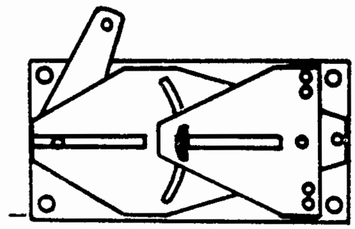
ELECTRONIC DECODING FOR RUDDER, ELEVATOR AND ENGINE

Up to now we have mostly been concerned with mechanically decoding the Pulse Width for rudder, and the Pulse Rate for elevator and full on and full off for throttle action.

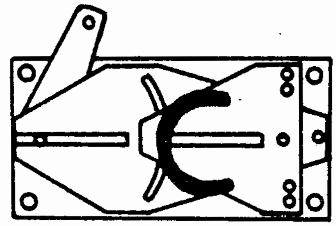
We can go a step further now and electronically decode the same information, feeding it to two or more actuators



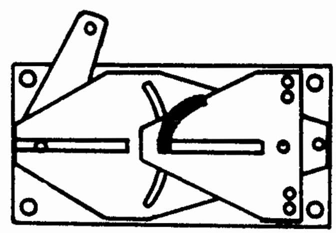
Here is the arc at neutral pulse width and rate for straight flight.



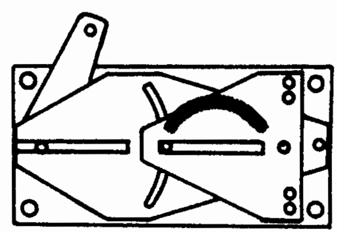
Full down is shown on this arc trace, no turn is had in this trace.



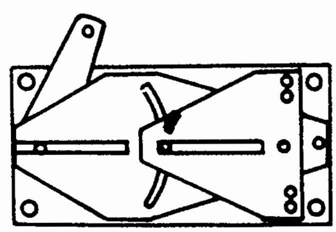
This is the view of the arc giving you full up. Again no side motion.



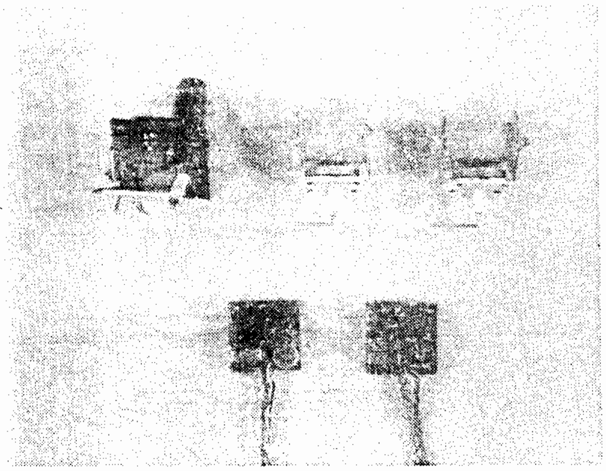
Here is a full turn arc. For opposite turn arc is on opposite side.



This arc depicts full up and a full turn. Opposite turn opposite side.



This is the view of the arc giving you a full down and turn.



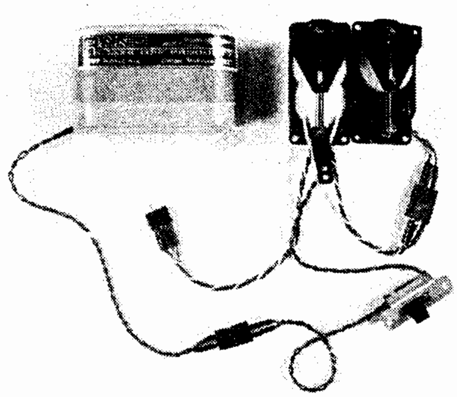
The Jaecks' system of electronic decoding consists of an elevator decoder and a high pulse rate detector. The decoding system feeds two Adams actuators, one for rudder and the other for elevator, while motor control may be had with a conventional escapement or a motorized control.

to achieve independent action electronically. Howard McEntee experimented with this quite successfully in the early 1950's. His Kicking Duck systems used relays as do Dave Robelen's Simpro systems described in the American Modeler magazines of 1966. A later development of the Simpro system by Ed Sweeney, called Simpro III, does away with relays entirely using fast following reed switches to trigger transistor driving circuitry. Rand does the entire thing electronically with their Dual Pak #6080.

Even in this advanced stage of the art, do not belittle the use of relays as used in Simpro systems. They are electro-mechanical devices. As such they are more easily understood than the purely electronic switching circuitry which is the ultimate. The simpler Simpro systems detailed in the January, February and March 1966 American Modeler magazines (Or in Ace reprint #33K22) have a lot going for them in that they offer the mostest for the leastest of any of the decoder systems.

In any decoder system you have several advantages. You still utilize the same transmitter with its electronic thumb, and its varying Pulse Width and Pulse Rate and full on and full off. You probably also can use exactly the same receiver with a possible few modifications. (We won't go into these, since they will vary). The major advantage you have with decoders is that your Pulse Rate for neutral and of course the corresponding Pulse Width for up and down can be doubled, tripled, or even quadrupled, depending on the decoder used. This does away with the flapping rudder and elevator, since the rates are usually so fast that only the barest quiver is evident in the rudder. With decoders still using the mechanical on and off for throttle signal you do have cycling through of the surfaces, but only when the engine control is commanded. Some higher priced units do away with even this, but here we get into more expensive and also more complex units. WITH DECODERS THERE IS LITTLE IF ANY INTERACTION BETWEEN RUDDER AND ELEVATOR as is the case with mechanical units.

The decoders must use two actuators. One is for the rudder-throttle, and the other is for elevator. This means you automatically have more power for control and can consider planes with engines of .45 or even .60 engine displacements. They do require batteries with heavier drain capabilities, but with the larger engines the added weight of an extra actuator and extra capacity batteries present no problem.



Shown above is the Rand Dual Pak. This is a decoder type system and provides an actuator for elevator and rudder. Motor is taken from the go-around on the rudder. Decoder systems offer less wiggle since a faster pulse rate is used--for the Rand about 13 to 16 pps; there is little if any interaction between controls; and since two actuators are used you have more power.

NOTE: Batteries have been referred to only briefly. Nickel Cadmium batteries in ANY pulse system are musts. If you attempt to use dry batteries, you might as well tear up the manufacturer's instructions--they won't count!

Another decoder system uses the Adams magnetic type actuators. With this system, when you electronically detect the pulse rate change with a Pulse Rate Decoder, which is all electronic. You couple this signal into yet another Adams type actuator for elevator control. This system is completely electronic and does not use any brush type of motor in the actuators and is therefore completely free of any "noise" which is generated and must be suppressed in motor driven devices. (We've already mentioned the fact that to achieve motor, you must use a pulser that can give you a very fast pulse rate with a touch of the button. A High Pulse Rate Detector translates this into a signal to move an escapement or other throttle device.)

There you have a rundown of simple pulse propo. Analog or digital it's not--but it offers you almost the same type of action in the airplane for about one-third to one-fourth the cost. This savings can make one overlook a lot of flapping rudder and elevator surfaces--especially when the airplane couldn't care less!

ACKNOWLEDGMENT

In compiling the data presented here, we gratefully acknowledge the use of material which has appeared in Grid Leaks, American Modeler, R/C Modeler and Model Airplane News.

Ace R/C Inc.

HIGGINSVILLE, MO 64037