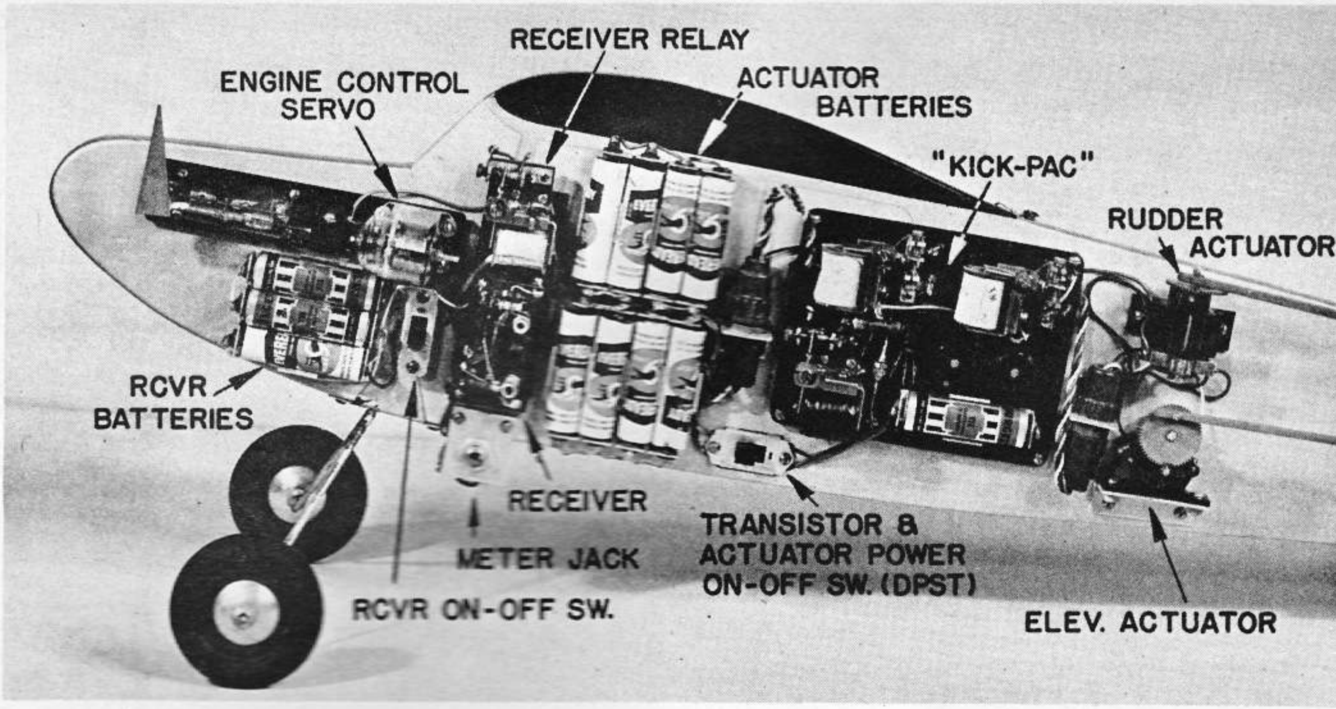


FOR THE RADIO CONTROL EXPERIMENTER.................. By JOHN WORTH

Multi-Pulse Control Systems

■ The pulse length control system, which uses variations in the ratio of signal on to off time in each pulse cycle to obtain a proportional rudder movement, is fairly well known to most R/C flyers. Though popular for rudder-only control, pulse systems have been limited in multi-control work by the difficulty of adding extra controls to the basic system. This has been true despite the knowledge that the use of pulse rate control, based on variations in the number of pulse cycles per second, is a logical means of obtaining additional controls. But methods of utilizing rate control have required much development and only recently have gotten off the bench and into regular flying use.

One of the biggest single developments in rate control was the introduction of the inductive kick principle as a simple and flexible method of separating pulse rate signals from the pulse length system. This principle fostered the addition of independent and simultaneous proportional elevator control to the already well-proved rudder control and details of this system were published in the April '55 issue of this magazine. But even on a simpler scale, the rate applications made practical by the inductive kick principle are numerous, including a method of removing another previous objection to pulse control; namely, full over rudder position on signal failure. Yet, a lot of attempts to use this kick principle have not been successful, due to a lack of know-how concerning the factors affecting an inductive kick and how component substitutions may be made. This report is intended to provide the working information needed, with application to several recent control system developments.

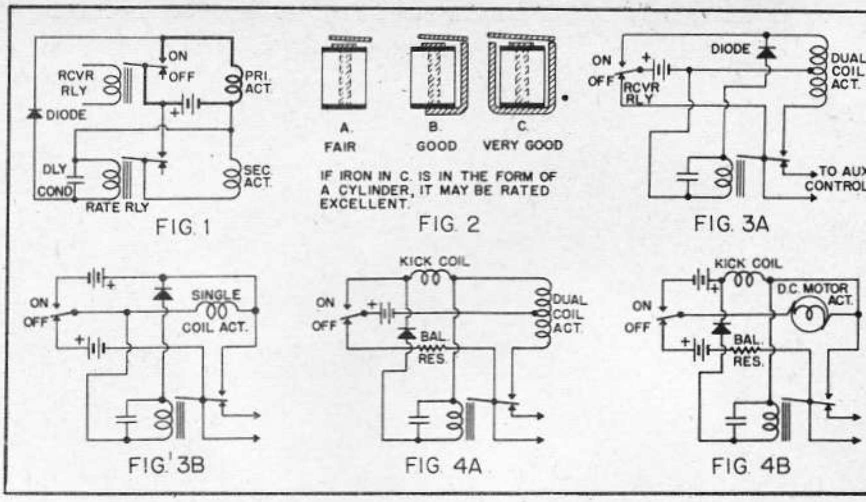
First, consider a conventional actuator hookup with a basic kick circuit added, as shown in Fig. 1. The light lines show the kick circuit, which consists of a diode, an auxiliary relay and an actuator —note that no extra batteries are required! With on signal, the receiver relay connects the battery to the primary actuator, but current does not also flow into the auxiliary circuit because of the diode which blocks the flow. With signal off, the receiver relay opens and disconnects the battery, causing the magnetic field which had built up around the primary actuator to collapse. As the magnetic energy in this field collapses across the actuator coil windings, it changes back to electrical energy and induces a high voltage current flow momentarily in the circuit.

The action is momentary because it occurs only during the field collapse and so appears as a very brief surge, or kick, of current. In a normal circuit, the kick current has nowhere to go except across the receiver relay contacts and is usually seen there as a spark, unless suppressed, but in this case the auxiliary circuit offers an easier path. As the kick current is of reversed polarity from the original flow, the diode no longer separates the two circuits and energy is provided to the auxiliary relay. Note that the time of this surge action is of fixed length and instantaneous, regardless of how long the primary coil might have been energized previously. During pulsing, the kicks produce bursts of energy which correspond only to the rate of pulsing and not to any pulse length variations.

The problem in this type of rate circuit is to get sufficient kick energy for reliable operation of the auxiliary, or rate, relay. It takes a combination of factors working together to produce a workable kick and the complete system must be considered rather than just individual components. There are many variables which determine how much kick energy can be obtained and used. *Primary circuit voltage* is the first factor —with more voltage, more kick is available. Where 3 volts may be sufficient, 6 or more will provide greater tolerance in component selection. *Kick coil resistance* is also important. In general, less kick is obtained with higher resistance. Between 5 and 30 ohms is favorable to a good kick and most commercial actuators are in this range. Actually, it is not so much the resistance that counts as it is the ampere turns value of the coil. This simply refers to the fact that the more current through the coil or the more turns or wire in the coil the greater will be the kick. Having more turns, however, means that more wire is used which results in less current due to increased resistance. Since these are opposing factors in coil design, it works out that the coil resistance is a good rough guide for estimating how effective a kick can be obtained, when comparing coils of similar design and construction.

Kick coil construction is probably the most important single factor to be considered. A magnetically efficient coil can produce an ample kick while retaining high resistance for lower battery drain— up to 50 ohms may be suitable if the coil is of excellent design and construction. An ideal coil would have an iron core and be enclosed in an iron cylinder with iron end plates—the more iron the better, and preferably in as complete a magnetic path as possible. The iron concentrates the magnetic field and produces a maximum energy kick. Fig. 2 shows several examples of coil construction and is in agreement with two ex-

Profile mockup of complete model R/C system featuring "Kick-Pac" unit which enables any receiver to provide simultaneous proportional pulse control of rudder and elevator, plus engine speed control.



amples of pulse actuators which provide a good kick: the commercial Adams unit and the Mactuator (Nov. '54 issue). On the other hand, some pulse actuators have very little iron and so offer poor inductive kick, even with large increases in primary voltage. Confusing the picture further is the fact that small D.C. motors, frequently converted for use as pulse actuators, also produce a poor kick despite having considerable iron because of different internal magnetic and electrical circuitry. However, means of obtaining satisfactory kick when using these actuators is described later.

Type of diode used has a big effect on the kick, as they vary considerably in the amount of internal resistance. The most common type, the 1N34 (equivalent to a CK705), is a cheap general purpose unit, having what can be considered as medium resistance, but a much better choice is a high conductivity type, such as the 1N56 or 1N91. These present very low resistance and so let as much of the kick get through as possible. A 1N64 (CK706) is also commonly available, but has even higher resistance than the 1N34 and is not a desirable type for kick circuits. It pays to use the highest conductivity type diode possible so that none of the kick is wasted. It is possible to use diodes in parallel to reduce the effective resistance through them, much as with two resistors in parallel, but this seems to be a limited gain and we find it better to use one 1N56 than two 1N34's.

Sensitivity of the rate relay also determines how much kick is necessary. In general, high resistance in a relay makes it more sensitive since the resistance comes from having more turns of wire which increases the power and enables the relay to work on very low currents. But there is a point of diminishing returns when too high a resistance in itself reduces the current so much that not enough is available for relay operation. The high limit of resistance depends upon the mechanical and magnetic construction of a particular relay. An 8000 ohm **Sigma 4F or 5F** can be adjusted to operate reliably on much lower currents than most other relays of the same resistance because of precise adjustment features and efficient magnetic design. These Sigmas, plus the newer type 26 Sigma which, though it does not have adjustable contacts, pulls in at very low currents, are preferred as rate relays in kick circuits. Other Sigma relays are available as surplus items in resistances varying from 2000 to 5000 ohms and they make even better rate relays since they have less resistance to dissipate the kick.

It is important to have enough kick current to work with and using a low resistance relay is one way of getting it, provided the relay is of excellent design so that it will operate reliably even though not as sensitive as higher resistance relays of the same type. In general, a rate relay may be anywhere from 1000 to 8000 ohms, but should be capable of being adjusted to operate reliably at 1 milliamp of current. To obtain more freedom of relay choice and less critical adjustment, a transistor arrangement that may be used to boost the kick is described later.

The manner of checking kick output in the non-transistor circuits is simple. Connect a 3 or 5 mil meter anywhere in series with the rate relay, then hold the receiver relay in the signal on position (kick coil energized)—no current should show on the meter. If current is indicated, reverse the battery polarity or the diode. Diode polarity is indicated by a painted or printed bar or band at one end of the body of the diode. This end is the cathode and should always be connected to the plus side of the circuit. When the hookup is such that no current is indicated on the meter while the primary circuit is energized, release or movement of the receiver relay armature to the signal off position should result in meter needle kick. The needle should kick up as the armature breaks contact and by repeating this step several times an average peak current value can be obtained. Actually, the peak is higher than the meter can show and will vary with different meters, but for all practical purposes the current shown will be the working value. A kick current reading of less than 1 ma. is generally too weak unless a very sensitive relay adjustment is used. Almost any kick circuit will produce about .5 ma., but a good circuit will produce more than 1 ma. and we consider this a minimum satisfactory value for reliable operation.

In looking into the means of getting enough kick energy, the fact remains that the action is so brief that it is not very useful since a more lasting action is required for most applications. This can be obtained by combining the energy from a number of kicks, using a condenser across the relay to store the energy and release it as called for by the circuit. The capacitance value of the condenser determines how long the relay holds in after the kick current stops. By selecting this value in accordance with the resistance of the rate relay a specific time delay action is accurately obtained, and this time element will determine the type of auxiliary control operation. If the rate control system requires a comparatively long delay period, higher capacitance is used. Short delays need

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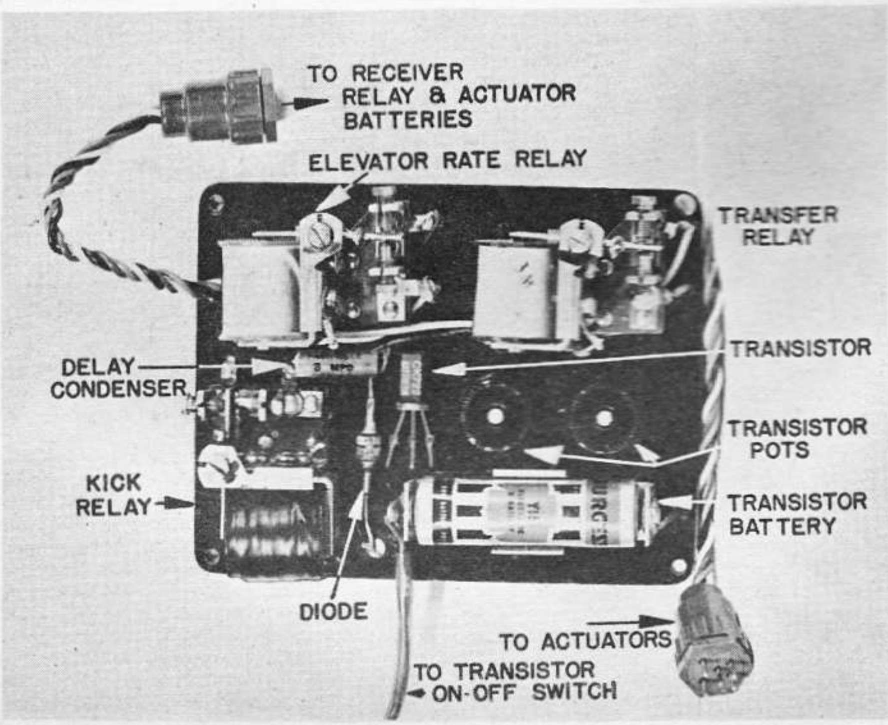

"Kick-Pac" panel converts any one-channel receiver to multi-control via transistor boosted pulse rate kickback circuit. Mounts flat on model floor or against bulkhead. 9 oz. with Sigmas, weight may be cut ½ with subminiature relays. Layout ideal for etched or conventional wiring.

Multi-Pulse Control Systems

(*Continued from page* 33)

less capacitance. A look into the workings of an actual circuit will indicate how the capacitance controls the action. For instance, consider a safety circuit for pulse length rudder systems, as shown in Fig. 3. This circuit permits normal pulsing control of the rudder, but prevents the rudder from going full over if pulsing stops.

The rate, or delay, relay pulls in during any pulsing and the condenser action keeps it pulled in between pulses so as to maintain a complete primary actuator circuit to the battery through the receiver relay. With signal failure, pulsing stops and the receiver relay disconnects the signal-on side of the actuator circuit, after which the delay relay drops out and disconnects the signal-off side. With no power, the rudder actuator then is centered in neutral by a light spring. The response of the delay relay is initially determined by its mechanical adjustment. The spring tension governs how much energy is required for pull-in, as does the clearance between the armature and the relay pole face. The tension and/or the clearance should first be reduced as low as possible so that pull-in of the armature at the lowest kick current is assured. Then the capacitance value is experimented with to determine the proper hold-in time. Somewhere between 10 and 50 mf., depending upon the delay relay resistance, is required for this type circuit. Starting with the high value, several successively lower values may be tried to obtain the best circuit response. Too low a capacitance will show up as a tendency for the relay to drop out intermittently during pulsing; too high a value will result in excessive lag before drop-out. Lag is more desirable and a slightly higher than necessary capacitance is not objectionable.

The delay relay operation must be checked not only to see that it pulls in and holds solidly during the lowest normal pulse rate, but also during that extreme in the pulse length cycle which has the longest off to on ratio. With this type circuit, pulse length signals for maximum rudder position do not go full on or off, since pulses must be continuously repeated to maintain the kick energy to the delay relay. In practice, the maximum control position is obtained by going almost full on or off, interrupting for only a bare fraction of a second during each cycle—just enough for the kick coil to release and provide the kick. With the pulse length signals at the maximum on extreme there is no question of having enough energy for the kick, but at the maximum off extreme the charging of the primary coil is limited by the very short on time in each cycle and the delay condenser must have enough capacitance to hold the relay in during this condition. Final adjustment of the delay relay is made by increasing the tension as much as possible to make it less sensitive to vibration and still have the response desired. Since fairly stable electronic or mechanical keying is used with pulse systems, the delay relay adjustment may be very precise.

This circuit may help to eliminate the fear of those who have not tried pulse control because of the fact that in the usual system the rudder fails in full over position. Actually, we find this a blessing as the pieces can be picked up and repaired, after a crash resulting from signal failure, whereas a flyaway usually means the loss of model and equipment. But for those who won't accept this, the safety circuit offers a simple fail-safe set-up. In addition, it may be used to provide another control: by connecting a suitable actuator circuit and battery to the other contact of the delay relay, an engine control or other mechanism may be operated. Any time this control is desired, the transmitter is simply shut off long enough to let the delay relay drop out, then pulsing is resumed to pull the relay in again and restore control to the rudder.

By selecting a lower capacitance value to provide a minimum delay, proportional elevator control may be provided in addition to proportional pulse rudder. The delay relay in this system is a true rate responsive relay since it is set up to follow each rate pulse that comes through from the primary circuit. With a pulse type actuator controlled by the rate relay so that the on relay position gives down elevator and off gives up elevator, the effective control position varies in accordance with the pulse rate, as follows: with the relay capacitance chosen for a delay time of only one tenth of a second, a pulse rate of 2 cps. (cycles per second) causes the elevator to be held down for only .2 of each second of pulsing, at 5 cps. the elevator spends .5 of each second in the down position for an effective neutral, at 10 cps. it stays down. The rates used in a particular system may differ but the general idea is that by using a very short delay interval and wide rate variation a variable control position results. The circuit in Fig. 1 is suitable for such a system if spring-loaded actuators are provided and the relay is adjusted to pull in and drop out during each pulse cycle. See the April '55 issue for more complete details.

We've mentioned the importance of proper primary coil construction for maximum kick energy and we've suggested that the rate system may be easily added to an existing pulse length control, even though many of the popular actuators used for such systems produce a very poor kick. For example, the Trammell type actuator (Jan. '54 issue) has no iron and so provides very little kick energy. The popular Southwestern commercial actuator is of the same type. Small D.C. motor type actuators, such as the Mighty Midget, are also poor kick producers. However, these actuators may be used through the employment of a separate kick coil. As shown in Fig. 4, this coil is wired in series with one side of the primary actuator circuit. Its resistance is not enough to take much power from the primary actuator, yet it is able in itself to produce all the kick needed. The balancing resistor serves to equalize the opposite side of the circuit to maintain even voltage to the primary actuator. Most of the R/C supply firms offer suitable coils for kick purposes. Control Research has subminiature coil forms which may be wound to suit. Full of #32 enameled wire, they average between 5 and 8 ohms, with #34 wire they average between 10 and 20 ohms. Gyro Electronics has larger ready-wound 14 ohm coils which are also excellent. In any case, the addition of iron frames, as shown in Fig. 2, will boost the kick obtained with these coils considerably.

Most low resistance relays also make excellent kick coils since they usually have good magnetic design and use a good grade of iron. To save weight, the relay may be stripped of everything but coil, iron frame and armature. It is important to secure the armature in the pulled-in position as a stronger kick is produced when the magnetic circuit of the coil assembly is closed. It is also practical to use the relay in its original form for other control circuits, retaining the advantage of the separate kick coil in that the use of any type actuator is possible since the kick is not taken from the actuator windings. We've had excellent results using a Sigma 4F relay rewound full of #28 enameled wire. Similarly, other smaller relays of the Neomatic or Price types make fine kick relays when rewound for low resistance. This is a good use for old relays with internally open or shorted coils.

So much for now. We'll let you digest that and continue the report in a subsequent issue.