Unlike some offerings this proportional pulser has proved its worth over an extended period of field testing by the author and numerous New Jersey R/C fans; so you can build it with assurance!

# Transistorized Encoder For Proportional Control 

BY CHARLES M. KENNEY



- This encoder is the conversion of a prime function single channel on-off radio signal into two independent simultaneous proportional channels. In recent years electromechanical and multivibrator type encoders have met with limited success but most have exhibited an interaction of channels, i.e., a change in one channel causing a change in the other.

Our transistorized encoder, based on an original circuit by R. W. Ketchledge, has no interaction between channels. Here you have a complete parts list for the construction of the encoder as well as its Theory of Operation, plus Adjustment and Alignment.

The encoder serves to tuurn the radio transmitter off and on with variable duty cycle and variable rate. The duty cycles is defined as the ratio of "on" time to total time period; the rate is defined as the number of on-off cycles per second. The way in which the duty cycle is used to control a model suurface is as follows.

The transmitter "signal off" position corresponds to full left rudder. The transmitter "signal on" position corresponds to full right rudder. Keying the transmitter alternately off and on so that the off time equals the on time produces neutral rudder. Although the rudder moves back and forth at the keying rate ( 3 to 12 cycles per second) it "dwells" for the same length of time on each side of neutral and has no net aerodynamic effect on the model. If, however, the off-on period is changed so that the transmitter is keyed more off than on, the rudder will dwell on the left side in proportion to the off time percentage and the model will turn left. In this manner, any degree of left or right turn may be obtained between neutral and full left or full right.


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By using a rate sensitive decoder in your model plane to convert rate information into elevator movement, proportional control of this surface is also possible. Fast rate ( 12 cps ) corresponds to down-elevator and slow rate ( 3 cps ) corresponds to up-elevator.
A block diagram of a proportional control system is shown. It may be seen that motor control is included in addition to elevator and rudder control. Motor control is obtained by use of another decoder. Two types of motor control are in general use, the fast rate detector, or the pulse omission detector. The encoder is capable of working either type by providing a fast train of pulses, or by keying the transmitter off for several cycles.

The encoder is constructed in a $3 \times 5 \times 7$-inch aluminum box and is connected to the transmitter by means of a two conductor 10 -foot cable. This length allows the operator to move about while controlling his model. A stick is used on the pulser, its movements corresponding to similar movements of the model: left, right, up, down, or any intermediate position. Rubber bands return the stick to the neutral position.

Although the encoder described was specifically designed for miniature airplanes, there is no reason why it cannot be adapted for control of model boats or cars as well.

Theory of Operation. The pulsing relay contacts of K2 provide the output of this encoder. The relay contacts are made and broken by transistor circuitry immediately preceding it. Three transistors provide for independent control of duty cycle and rate.

TR1, TR2, and K1 generate a constant amplitude


A, Down elev; B, Stick; C, Lt rud; D, Xmtr off; E, Xmtr on; F, Centering bands; G, Rt rud; H, Up elev; I, Fast rate; J, Upper rate; K, Lower rate; L, Duty cycle trim; M, Pwr on-off; N, Elev on-off; O, Xmtr plug.
sawtooth waveform of variable frequency. Because discharge of the $100-\mathrm{mfd}$ electrolytic capacitor (C1) must be rapid to produce a clean sawtooth, the low impedance of relay K1 is utilized. When SW2 is closed, C1 charges at a rate established by R1, R5, TR1, and R3. The voltage that appears across C 1 also appears across the coil of K1. When this voltage reaches approximately 1.5 V , the relay closes, C1 discharges, and the cycle repeats. Thus, appearing at the base of TR3 is a constant amplitude sawtooth whose rate may be varied. By adjusting R11, in the emitter circuit of TR3, the sawtooth amplitude level is set to cause 2 to close. If R11 is large, the sawtooth must become large before TR3


Control stick assembly: (A) R-12; (B) K-2; (C) Sw-3; (D) Sw-4; (E) Battery holders; (F) R-11; (G) Sw-5; (H) R-5; (I) Control stick assembly; (J) P.C. board; (K) R-3; (L) Sw-2; (M) R-1.




Printed ckt board (above, below); A- \#30 drill; others- \# 60.

conducts enough current to close K2. Under these conditions, the duty cycle is low (more off than on). If R11 is small, the sawtooth will cause K2 to close early in the cycle, so that the duty cycle is large. Thus, duty cycle may be changed independently of rate. We show pictorially how this is accomplished. It may be seen when R11 is large, K2 closes only a short time and the duty cycle is small. If R11 is small, K2 closes early in the sawtooth cycle and remains closed until K1 discharges C1; thus the duty cycle is large.
By placing pots R5 and R11 on the control stick, their shafts may be varied as a function of stick position. This provides for duty cycle and rate changes as a function of control stick position, corresponding to a control surface position in the model. Thus, the model is flown by the ground controller as if he were sitting in the cockpit of the model.
R12 is a duty cycle fine control or "trim" pot, and allows for in-flight trim about the neutral duty cycle stick position (R11). R3 and R1 provide the same trim capability for the control stick rate pot, R5. Two pots, used to provide for independent upper and lower rate set, determine the rate extremes present at the rear and forward stick positions. In addition, the upper rate set pot, R3, allows for in-flight trim adjustments.

SW1 is used to switch on or off the control stick. This is an especially advantageous feature when one is first flying a model with elevators. The model can thus be flown on rudder control only until sufficient altitude is gained to try the elevators. It should be noted that the upper rate trim pot is independent of switch position so that, even with the rate pot switched off, the control stick in-flight trim is (Continued on page 112)

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still available.
SW3 and SW4 are in series and parallel respectively with the transmitter keying relay contacts. These momentary contact push-button type switches provide full-signal-off and full-signal-on positions for purposes of stunting or rapid maneuvers.
SW5 allows for a rapid train of pulses which may be employed for an auxiliary function such as motor control. This motor control rate is variable as determined primarily by R1.
A PJ055B plug connects the keying lead to the transmitter.

Construction begins with the printed circuit board. Using the layout, locate all holes with a center punch on the copper side of the copper clad laminate. Then paint the pattern on with a quick dry enamel or lacquer (see parts list). When the pattern is dry, place it in a ferric chloride solution for etching. Keep the solution in a nonmetallic container and maintain its temperature between $70^{\circ}$ and $110^{\circ} \mathrm{F}$ when etching. The normal etching time is 4 to 5 minutes with a fresh solution and frequent agitation.

When the board etching is complete, drill it as shown. Component placement and wiring is straight forward and not critical. Leave the five wires that connect the printed circuit board to the rest of the circuit about 15 inches long. After the board is complete, drill the minibox. Next, fabricate the control stick assembly with rate and duty cycle pots (R5 and R11) and the printed circuit board into the minibox by means of right angle brackets. Mount all other components as illustrated and sketched. Contact cement the battery holders to the inside wall of the minibox top.

Cut shaft on R11 to $3 / 4$ inch length and slotted. Cut all others $3 / 8$ inch long.

Your unit is now ready for wiring. Number 20 plastic jacketed wire is used throughout, except for those connections to the duty cycle pot (R11) on the control stick assembly. Use No. 24 wire there for flexibility, since the pot moves with the control stick. We have provided a practical wiring diagram. Wire SW3 so that actuating the push button opens the circuit. Wire SW4 and SW5 so that actuating the push button closed the circuit.

For soldering use a low wattage soldering iron ( 25 to 37 watt) and a good grade rosin core solder. Wrap joints and tie points at least once for mechanical strength before soldering. Wiring the encoder as shown will give more signal-on with right stick, more signal-off with left stick, slow rate with back stick, and fast rate with forward stick.

Adjustment and Alignment: Perform the following adjustments prior to turning on the encoder:
(1) Adjust relays K1 and K2; Pullin to 15 -milliamps plus or minus 1 -ma. (This is the setting of the relay "as is" in the Radio Sonde Modulator ML-310F/AMT-1.
(2) Adjust R1, Lower Rate Set, to the mid-travel position-approximately 125 -ohms.
(3) Adjust R3, Upper Rate Set, to the mid-travel position-approximately 500 -ohms.


## TEST INDICATOR

(4) Adjust R12, Duty Cycle Trim, to the mid-travel position-approximately 50 ohms.
(5) Adjust R5 and R11 to the midtravel positions-approximately 500 and 250 -ohms, respectively.
(6) Place SW1 in the No. 1 position. Turn on the encoder.
(7) Place an ohmmeter across the output plug (PJ055B) and adjust R11 until the meter needle pulses at the mid-scale position. Lock R11 in this position with the control stick centered and remove the ohmmeter.
(8) Connect a 3 volt battery and flashlight lamp in series with the output plug so that the lamp flashes every time K2 closes.
(9) Adjust R3 so that the test lamp flashes about 90 times in 15 seconds. While counting, time the lamp flash with a stop watch or sweep second hand of your wristwatch.
(10) Next, adjust R5 so that, when SW1 is switched back and forth from Position 1 to 2, there is no rate change in the output relay, K2. The easiest way to determine this is by listening to the relay, and observing the flashing lamp. When this is accomplished, lock R5 by means of the set screws in the shaft collar. This is the neutral stick position for rate.
(11) Repeat Step 7 to make sure the duty cycle adjustment has not changed. If it has, readjust R11 and relock the pot shaft. Make sure the shafts of R5 and R11 are securely locked by the control stick assembly locking collars. The rate and duty cycle alignment is now complete.
(12) With the lamp and battery connected across the output plug and the encoder operating, push SW3. The light will go out and stay out until SW3 is released. Next, press SW4. The lamp will stay on continuously until SW4 is released.
(13) The encoder is now ready for use. See K2 waveforms for normal encoder operation. The waveforms for five stick positions are shown.
Parts List-Electrical: C1, Electrolytic Capacitor, $100-\mathrm{mf}$ at 10 V , Cornell Dubilier-"ultra small" electrolytic; CR1, Germanium point contact diode, 1N34A, CBS; K1, Relay 100 -ohm coil, Price* or Jaico Products Co., Chicago; K2, Relay, 100 -ohm coil, Price* or Jaico Products Co., Chicago; P1, Phone plug, switch craft. Must match transmitter jack, PJ055B; R1, Potentiometer, 250 -ohm, 2 -watt linear taper, Allen Bradley CU2511; R2-R6-R8, Resistor, 100 -ohm, $1 / 2$-watt, composition, $10 \%$ tolerance; R3-R5, Potentiometer, 1,000 -ohm, 2 -watt, linear taper, Allen Bradley CU1021; R4-R9, Resistor, 1,200 -ohm, $1 / 2$-watt, composition, $10 \%$ tolerance; R7, Resistor, 1 ohm, 2 -watt, composition, $10 \%$ tolerance; R10, Resistor, 1,000 -ohm, $1 / 2$ watt, composition, $10 \%$ tolerance; R11, Potentiometer, 500 -ohm, 2-watt, linear taper, Allen Bradley CU5011; R12, Potentiometer, 100 -ohm, 2-watt, linear taper, Allen Bradley CU1011; SW1, (Continued on page 114)

## Encoder

## (Continued from page 112)

Toggle switch, DPDT, Lafayette SW22; SW2, Toggle switch, SPST, Lafayette SW-21; SW3-SW4, Push button switch, DPDT, Mallory 1016; SW5, Push button switch, Lafayette SW-70; TR1, Germanium NPN Transistor. Sylvania 2N214; TR2-TR3, Germanium PNP Transistor, GE 2N188A; Battery, C-cell (4 required). Eveready 933.
Miscellaneous: Battery Holder, 2 required, Keystone 174; Minibox, 3 x $5 \times 7$, Bud CU2108A; PC Board, Copper laminate, 1 side, Lafayette MS511; Paint, KEM-enamel, or Testors Nitrate Colored Dope, hobby shop; Etchant, Ferric Chloride, $40^{\circ} \mathrm{Be}$, (mix $9-\mathrm{oz}$ ferric chloride with 1-pint water), chemical supply house; Knob, Lafayette KN-41 (3 required), Lafayette KN-60 (1 required); Wire, No. 20 plastic jacket hook-up, 3-ft assorted colors, No. 24 plastic jacket hook-up, $15^{\prime \prime}$ (2 pieces required).

Hardware: Potentiometer Mounting Bracket, right angle, Bud 549; Bracket, Right angle, $5 / 16 \times 13 / 32 \times 1 / 2$, Walsco Angle Bracket Type 3 (2 required) ; Machine Screws and Nuts, $6-32$ binding head, $34^{\prime \prime}$ ( 4 required), 6-32 binding head, $3 / 3^{\prime \prime}$ ( 4 required), $4-40$ binding head, $3 / /^{\prime \prime}$ ( 6 required),
(*Suitable Price relays are found in the RadioSonde Modulator ML-310F/ AMT-1 sold in stores handling surplus equipment, 1 relay per modulator.

