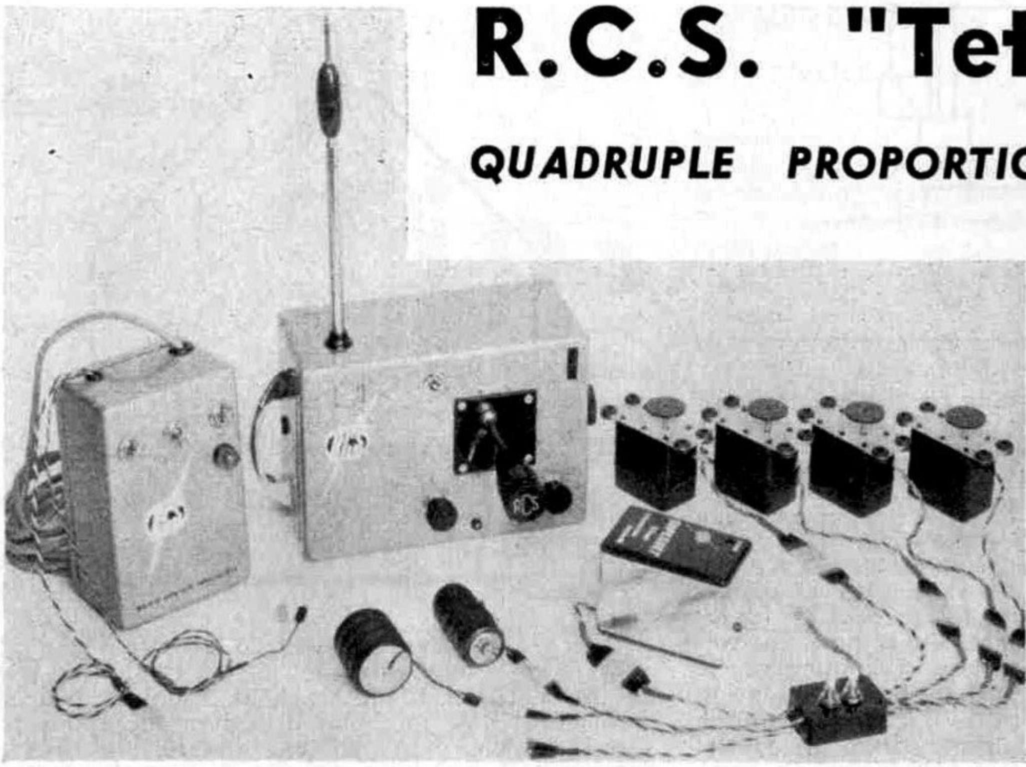
R.C.S. "Tetraplex"

QUADRUPLE PROPORTIONAL SYSTEM



FIRST OF A SERIES OF TECHNICAL DESCRIPTIONS OF PROPORTIONAL SYSTEMS

Peter Lovegrove, B.Sc., leader of the R.C.S. production team, describes the first British commercial quadruple simul proportional outfit . . .

THE R.C.S. Tetraplex is a time Multiplex-Frequency Modulator, Pulse Width and Rate (T.M. F.M. P.W.R.), system, providing four independent proportional channels. The design is a culmination of techniques investigated and developed over the past decade. Although complete originality is not claimed, the techniques employed are superior to those utilised in any other comparable equipment.

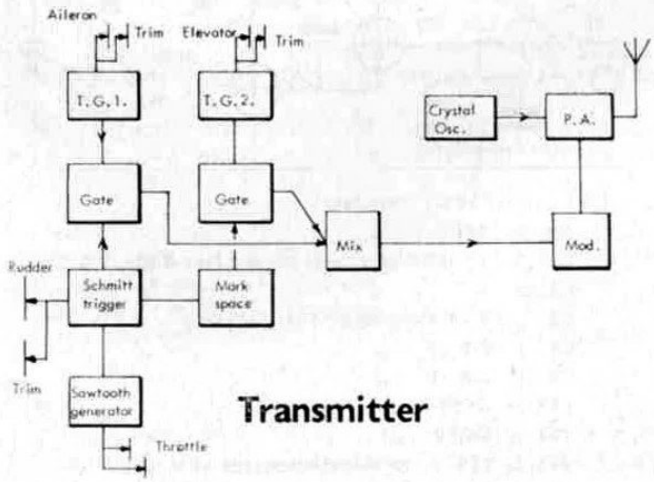
Principle of Operation

Two tones are transmitted on a time multiplex or time-sharing basis and comprise the subcarriers of an amplitude modulated, crystal controlled transmitter. To comply with international regulations, the frequencies chosen are contained within a bandwidth of 4 Kc/s and have centre frenquencies of 2.3 and 3.7 Kc/s respectively. Each frequency can be varied to ± 5 per cent about its centre frequency by the voltage emanating from its control potentiometer. The deviation produced can be measured by discriminators in the decoding section of the receiving equipment, resulting in a D.C. voltage proportional to the demanded control position. This voltage is fed into a voltage-operated closed loop servomechanism which takes up a position as demanded by the control potentiometer. This forms the basis of two of the proportional channels.

The switching period, Mark Space ratio, or duty cycle, of the two f.m. channels is now made continuously variable between the limits of 3:1 to 1:3, and the envelope waveform is detected from one of the f.m. discriminator channels, which, after limiting, is reproduced as a "square" wave, having a mark space identical to that of the switching circuit in the transmitter's control unit. This waveform is converted to a D.C. signal by a simple integrator circuit and is fed into its respective servomechanism, resulting in the third proportional control. The switching rate is also made variable between 20 and 45 c/s and this frequency is counted in the receiver by a linearised device, which produces a D.C. voltage proportional to rate. This forms the fourth channel. The design of the switching circuit in the transmitter is such that the mark space is absolutely independent of rate and vice versa. Similarly, the decoding circuits in the receiver are so designed that there is negligible cross-modulation between the two f.m. channels, the mark space detector and the rate counter.

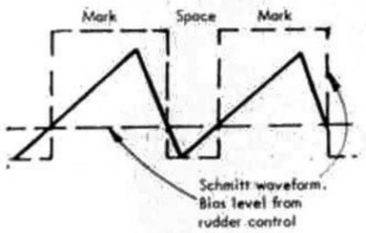
A. The Multiplex Switch

Although a simple multivibrator could have been used in this application, it was considered that its performance would be inadequate in equipment of this calibre. It has long been acknowledged that



Transmitter

the best method of producing a variable mark space waveform with a variable repetition rate is to use a sawtooth waveform in conjunction with a variably biassed trigger circuit to produce a "square wave", whenever the amplitude of the sawtooth exceeds the bias level. A transistorised circuit was therefore developed to fulfil this function. The principle is similar to the well known hard valve "Puckle" time base. The constant current characteristic of the transistor is put to use in producing a linear charge on a condenser. When a predetermined level has been reached a Flip-Flop circuit is activated, which discharges the capacitor almost to zero, the discharge period being very short compared to the linear charging period. At the end of the discharge period, the capacitor recommences to charge and the cycle is repeated. Since the charging current is the collector current of a transistor, it is proportional to the base current and hence the charging rate and thus the frequency of the sawtooth can be controlled by variation in the base current of the transistor. This variation is produced by the THROTTLE control. The variable square-wave generator is similar in principle to the Schmitt trigger, which changes state from ON to OFF whenever the input falls below the reference bias level and from OFF to ON when the input rises above the reference level. Sufficient regeneration is used in the circuit to ensure a rapid snap action, but at the same time the overall loop gain is such that there is negligible hysteresis in the circuit, i.e., there is no apparent change in mark space as the sawtooth rate is increased. The variable input bias level to the square-wave generator is controlled by the RUDDER potentiometer.



Schmitt Waveform

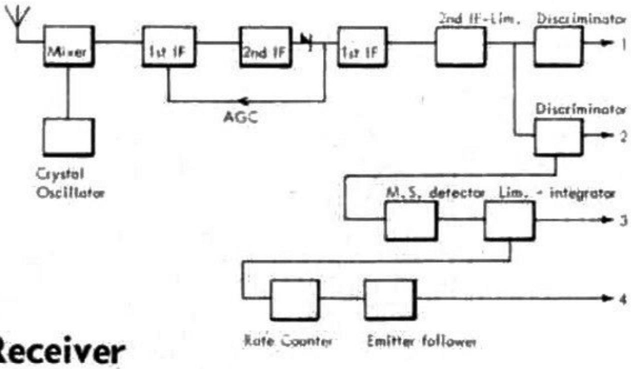
B. The Tone Generators

A characteristic peculiar to all f.m. systems is that any drift in the mean frequency of a subcarrier produces an error in the received quantity not equal to the value of the error, but to its ratio to the maximum deviation of this subcarrier, i.e., suppose the subcarrier mean frequency is 2 Kc/s and the control deviation is −100 c/s; if a drift of 10 per cent is considered acceptable, this represents 20 c/s, which is 1 per cent of the mean frequency. Therefore attention must be paid to the stability of the subcarrier oscillators.

In this equipment, rather specialised multi-vibrators have been employed as voltage controlled oscillators. The circuits contain certain elements which compensate for variations in transistor characteristics, and hence, change of frequency, due to variations in voltage and temperature.

The frequency controlling voltages are derived from the AILERON and ELEVATOR potentiometers. (It should be noted that all the controls in this equipment carry D.C. only, and are not involved as active elements in the circuit.)

The output waveforms from the subcarrier oscillators are fed into two gates operated by the Mark and Space respectively, and the gate outputs are



Receiver

commoned and the two subcarrier frequencies, now sampled sequentially, are fed into the modulator. This, in turn, switches the Power Amplifier of the crystal controlled transmitter.

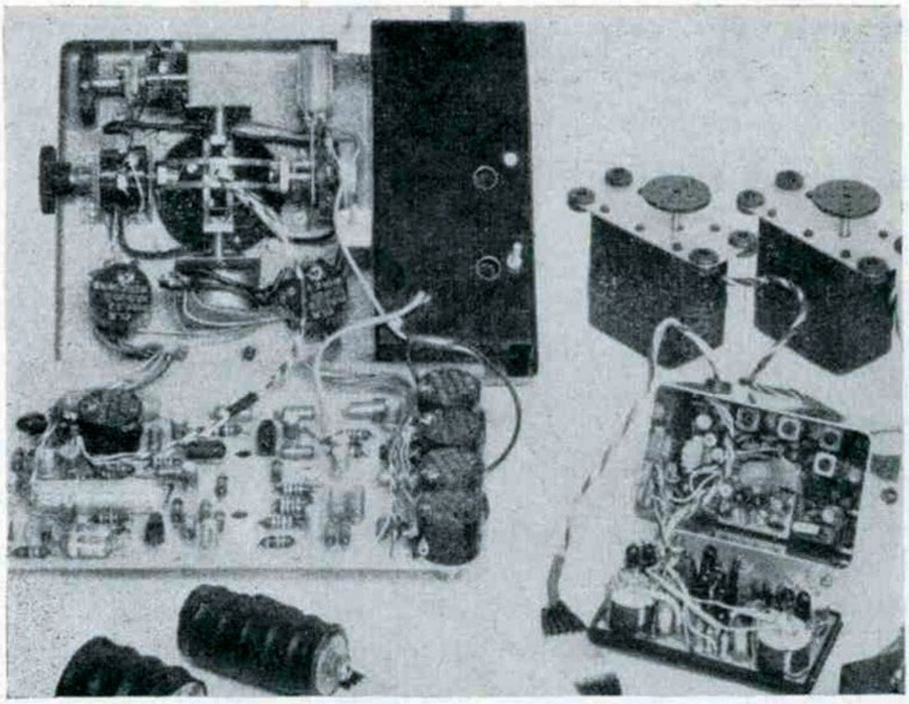
Silicon transistors and high stability resistors and capacitors are employed in the circuits, which would otherwise be affected by changes in temperature.

C. The Receiver

The receiver is a fairly conventional, crystal controlled superhet with automatic gain control fed back to the first I.F. A double-tuned I.F. transformer is used to prevent the de-tuning effect on the first I.F. stage by A.G.C. action. The diode detector is followed by two L.F. amplifier stages, the second stage acting as a limiter when the received signal level exceeds 2 microvolts, thus ensuring a relatively noise-free output over any anticipated range of control.

The output from the limiter is divided and fed into the two discriminator circuits. Each discriminator circuit consists of two tuned circuits, wound on high quality variable ferrox cores. The circuit design is similar to that of the Travis discriminator in that the tuned circuits are tuned above and below the mean subcarrier frequency. But, in addition, the filter outputs are fed via complementary P.N.P. – N.P.N. emitter followers into a common storage capacitor, the voltage across the capacitor being the difference between the amplitudes of the voltages in the two tuned circuits. Since the output resistance of the emitter followers is low, the capacitor charges rapidly when a signal is fed into the discriminator, but as the discharge period is long, when the emitter followers are turned off, there is virtually no discharge during the space period, and in this respect, the circuit behaves as a "box car" detector. It follows, therefore, that the D.C. output voltage from the discriminators should not vary as the mark space or repetition rate is varied. In practice the cross-modulation observed is negligible.

An emitter follower detector is connected to one of the filters in the high frequency discriminator and demodulates the modulation envelope contained therein. The resulting squarewave is amplified and limited, after which the waveform is filtered to produce a D.C. voltage proportional to the mark space. The limiter is biassed so that its output voltage is zero with respect to the "virtual earth" input of the servo, when either the signal is 50/50 mark space described f.m. channels. The limited squarewave is therefore, self-neutralising, should the transmitter fail or the aircraft inadvertently fly out of range. In this respect, it is similar in action to the previously described f.m. channels. The limited squarewaves is



Left : Inside story of Tx and Rx. The control stick unit is a real engineering job, seen centre left on Tx box. R.F. section on right is well screened. The back panel carries the coding system. Rx, lower right, open to show superhet with discriminators in lid. Below : Servo with output wheel removed the simple amplifier is shown separately with extra pot for setting damping.

fed into a linearised diode pump, which is designed to produce a similar range of voltage to that of the previously mentionel channels, as the pulse repetition frequency of the multiplex is varied, thus providing proportional control of throttle opening. On loss of signal, the output voltage will drive the servo beyond the tick-over position and stop the engine. It is therefore considered that the receiving equipment approaches the ideal fail-safe.

The Servos

These are second order closed-loop position servo mechanisms. Velocity feed-back is obtained by extracting the back e.m.f. of the motor to produce viseous damping. The damping factor is chosen to give optimum response.

The servos work on the constant input resistance "virtual earth" principle and thus can have several inputs. Under these conditions, the servos can operate as miniature analogue computors and can perform the functions of addition, subtraction, multiplication, division, integration and differentiation, of steady state or complex varying inputs.

Installation

Because they are completely prewired, the receiver, servos and their associated batteries are readily fitted into any type of model. It is not necessary to make the DEAC cells easily removable, as a charging point for coupling them to the mains charger has been incorporated in the wired harness.

The various plugs on the harness are identified as follows:

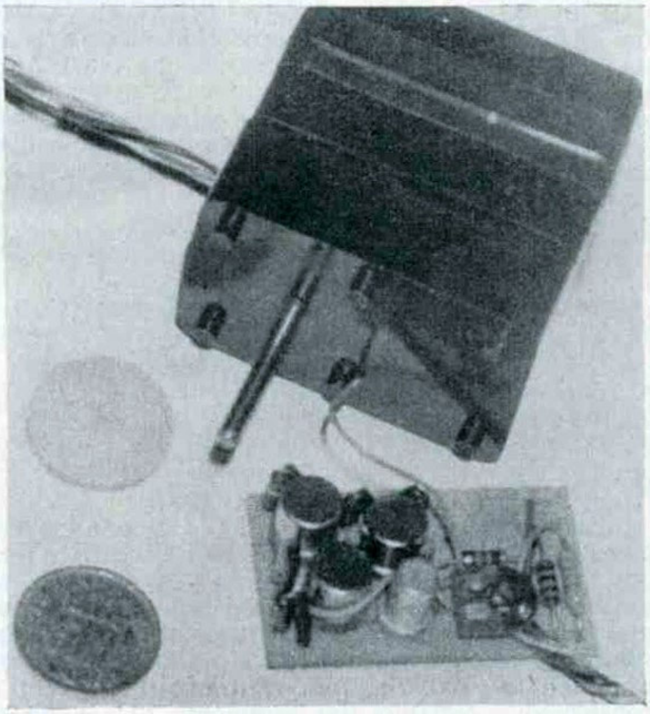
Receiver :
6-way with four polarising pins.

4.8 DEAC Cell :
3-way with two polarising pins, and brown, green and pink leads.

7.2 DEAC Cell
3-way with two polarising pins, and red, green and black leads.

Charging Plug
4-way with one polarising pin.

Throttle Servo :
6-way with one polarising pin, and leads coloured red, black, green, brown, pink and *orange*.



Rudder Servo :
6-way with one polarising pin, and leads coloured red, black, green, brown, pink and *white*.

Aileron Servo :
6-way with one polarising pin, and leads coloured red, black, green, brown, pink, and *yellow*.

Elevator Servo :
6-way with one polarising pin, and leads coloured red, black, green, brown, pink, and *blue*.

The servo supply DEACs are of 500 mA.hr. capacity and the receiver/discriminator ones are of 150 mA.hr. capacity.

The period of use of the equipment for each charging of the DEACs is dependent on the number of movements of the servos, since their supply DEAC is subjected to the heavier load. Minimum duration should, however, be 1½ hours. The receiver battery is capable of 4-6 times this duration, but has not been made smaller since weight ceases to decrease as fast as capacity at these smaller DEAC sizes.

The aerial should be installed well away from the servos and their wiring to avoid interference pick-up.

The receiver, being a relatively heavy mass, should be mounted so as to provide maximum protection in a heavy landing or crash. The best position is with the discriminator P.C. board facing forward. The superhet section will then be mounted with its components forward, but as these are considerably lighter than the High-Q filters, the likelihood of damage is less.

A thick pad of foam rubber or Hairlok should be placed between the receiver unit and the forward bulkhead, and light packing used to retain the unit in place, without actually clamping it into position. This is, in fact, much the same practice as with a normal reed receiver.

The servos may be mounted in any position but one simple way is to drop them through rectangular cut-outs in a ply plate, bolt them to it and then screw the plate to bearers set in the fuselage.

The aileron servo can be mounted by bolting it to a similar ply plate in the wing. If it projects below the wing, in a low-wing model, it can often be disguised and protected by a dummy intake or radiator.

Alternatively, the servo can be bolted to a ply web in the same plane as the spar web, or strapped down with an aluminium saddle to a ply bearer plate.

All linkages to servos should be made so as to avoid metal-to-metal joints; nylon control horns are recommended. The coupling to the engine throttle is particularly likely to produce electrical noise due to the excessive vibration, so treat this carefully.

IMPORTANT: All linkages, bell-cranks and couplings generally, should be as free as possible. It is not good enough to make installations which are as stiff as those which are acceptable for reed equipment. Although plenty of control power may be available, the response and centring will be noticeably affected by frictional loads, such as stiff hinges incur. Heavy pushrods also can introduce assymmetric loads under "G" forces.

It is possible that, with certain input conditions, a servo may show a slight tendency to low-amplitude oscillation. This will not be large enough to be visible on the control surface and is due to the servo-amplifier circuitry being adjusted to give the fastest possible response consistent with one or two overshoots. Heavier damping would obviate all tendency to oscillate but would give sluggish response and dead-beat approach to control position, which is plainly undesirable.

Operation

The transmitter is quite straight-forward. The following notes apply to the single stick version.

The elevator is controlled by fore and aft motion of the control stick. Elevator trim is accomplished via the small knob at the centre of the right-hand edge.

Aileron control is achieved by transverse motion of the control stick, and trim by rotation of the lower right knob on the transmitter face.

Rudder control is by rotation of the knurled knob on the top of the joystick, whilst trim is carried out by rotation of the lower left knob on the transmitter face.

The throttle control is the knurled wheel in the upper right corner of the transmitter face.

On switching on, the output R.F. power is indicated on the small meter and experience will show to what extent this can be allowed to drop before the transmitter DEACs must be charged. Since R.F. output falls with battery voltage, any separate monitoring of that voltage would be superfluous. *But note*: Since R.F. output is low with the aerial telescoped, there will be a higher reading shown on the meter. Similarly, if the case is not held, output is lower and the meter reading higher, than if the case is held by the operator, who then acts as an aerial counterpoise.

Since the modulation is continuously impressed upon the R.F. carrier, there will be little variation in the meter reading as the controls are moved.

Charger

This is suitable for use on 200/250v. c/s A.C. mains supplies. It provides three outputs, one fixed at 50 mA. for the transmitter DEAC, and two variable ones for the receiver and servo DEACs.

The switch on the right of the case is the on-off switch. The one in the centre controls the receiver (7.2v.) DEAC giving 22 mA. when switched down and 11 mA. when switched up. The left-hand switch controls the servo (4.8v.) DEAC giving 50 mA. when down and 25 mA. when up.

The unit is isolated from the mains by a transformer and is fitted with a fuse and indicator lamp.

Miscellaneous Notes

(1) It is advisable to make the linkage connections to the servos in such a way that the output discs can rotate 360 degrees if the equipment is switched on incorrectly or if a lead should become disconnected in a crash.

(2) The output discs on the servos are a force fit on the shafts. They can be moved round, if required, by gripping the shaft below the disc with a pair of thin-nosed pliers and turning the disc by hand.

It has not been found necessary, in the course of development flying, to lock the discs to the shafts, but if this is considered vital then a No. 60 drill hole should be made through the disc bush and steel shaft and a steel locking pin put through. Fairly soft wire would be quite satisfactory, for example about as stiff as that used in paper-clips.

(3) Always switch on the transmitter first, then the red receiver switch and finally the white servo switch. Switch off in the reverse order.

(4) It is recommended that, unless you have considerable experience in the flying of proportional control systems, you do all your initial flying in some form of stable aircraft. A high wing model, trimmed so as not to be neutrally stable, is probably best.

This suggestion is made because, although one may have very considerable skill with reed multi systems, the response and piloting requirements of proportional system are so different as to need basic acclimatisation on the part of the operator.

We hope to conduct a test report later. So far, having seen the equipment flown we can record the fact that it is smooth in action, adequately fast in response and accurate in positioning. The workmanship is excellent.

With any proportional outfit it is essential to fly the gear in order to evaluate its efficiency as a link between mind and model; so when a test is conducted it will be an elaborate one.