electronics today INTERNATIONAL

MAY 1979

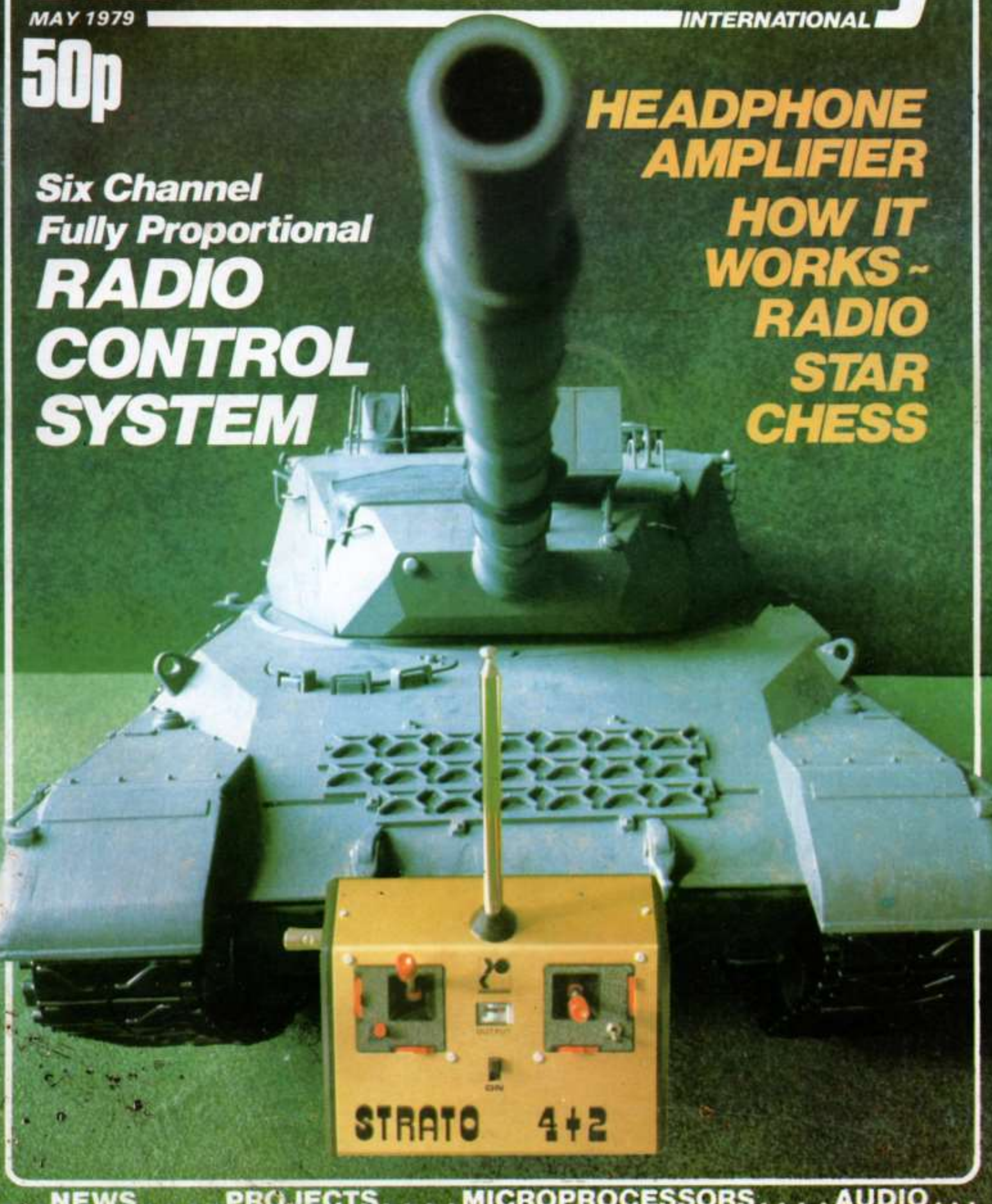
50p

Six Channel Fully Proportional RADIO CONTROL SYSTEM

HEADPHONE AMPLIFIER

HOW IT WORKS ~ RADIO

STAR CHESS



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RADIO CONTROL SYSTEM PART 1: TRANSMITTER

THERE WERE SEVERAL criteria we considered important in any radio control system before this project came up, and these have been perhaps the main reason for ETI keeping out of this field thus far.

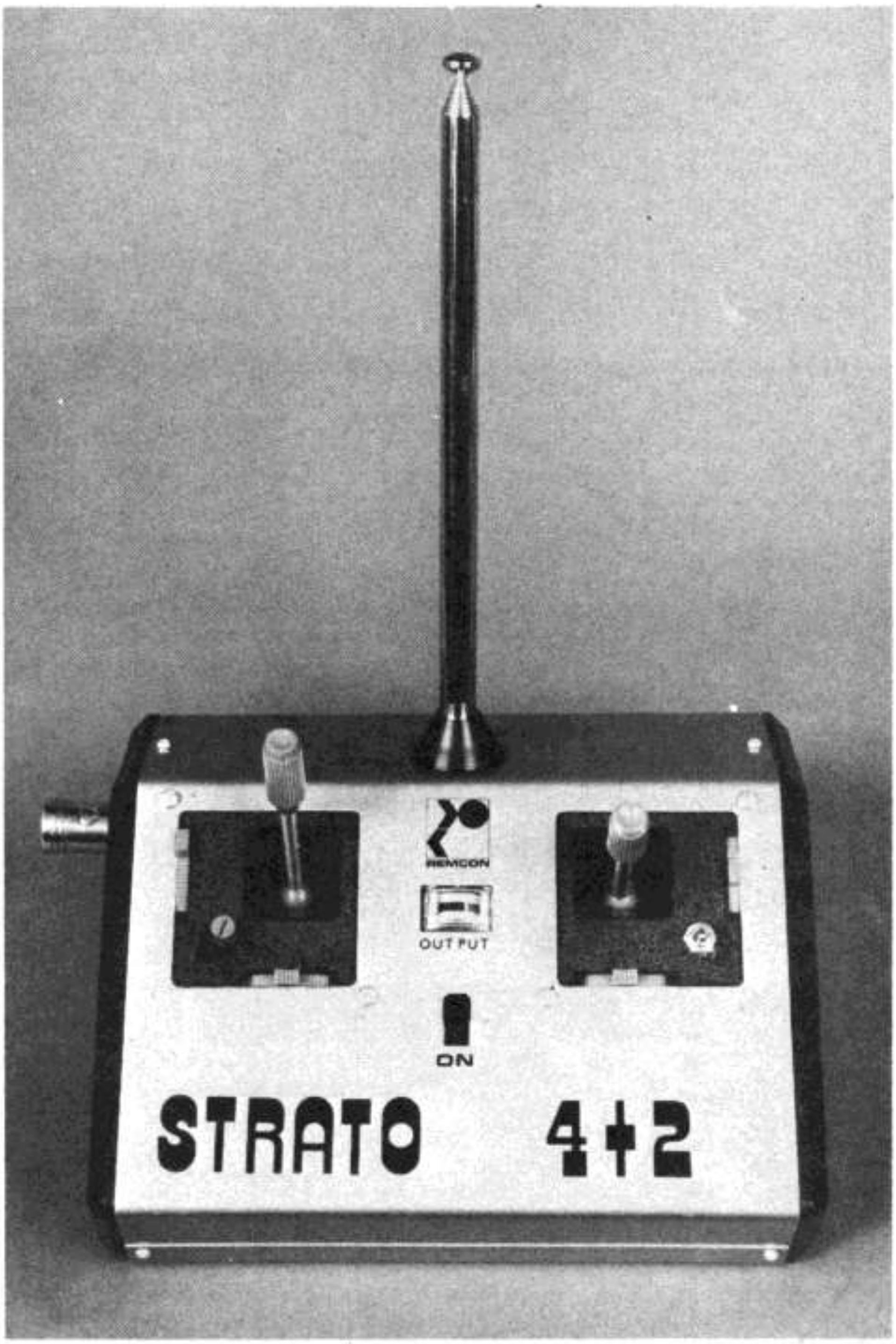
However Rencoms design, presented here, satisfys our requirements perfectly and fulfills a few we hadn't thought of. Firstly it is easily constructed and easy to set up — too many systems are marred by their requirements for expensive test gear in the alignment procedures. All that is needed here is a simple voltmeter.

Secondly the transmitter produces a 'clean' output which does not interfere with adjacent channels to any degree worth mentioning. This is an essential requirement since the receiver can handle 10kHz channel spacing, and interference would render this unusable. In any case this is now a legal requirement in many countries.

The charger for both transmitters and receiver can be built into the transmitter case itself, which any enthusiast will recognise as a decided convenience a five pin socket fitted to the case allows access to the charger circuit for this facility, and the same socket holds the transmitter crystal (normally encased within a DIN plug). This means channels can be changed quickly — or the set disabled — simply by removing the plug.

Tune In

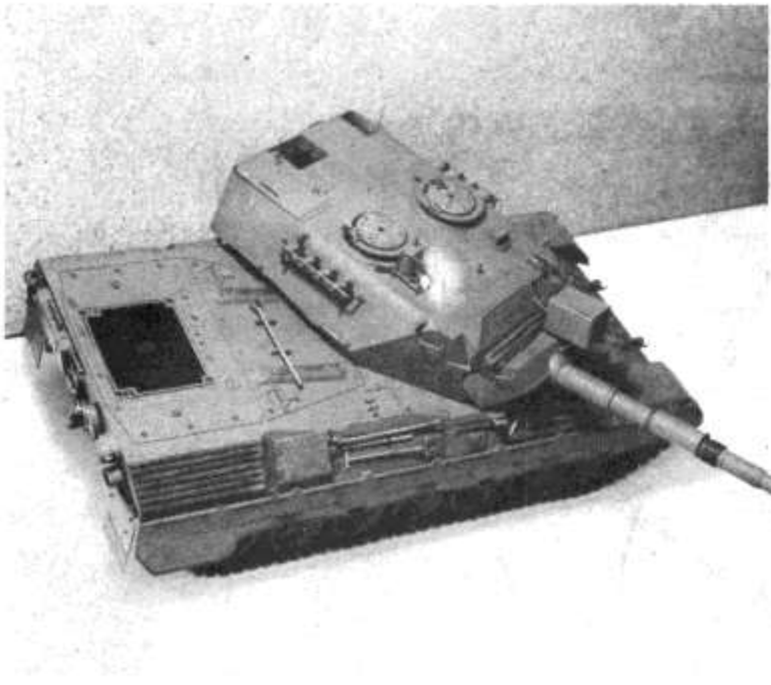
The Strato system can be built as either a four or six channel unit, and is suitable for any kind of model from airplane to boat. Choice of servo will be made according to the vehicle to be controlled. ▶



Publication of the system will be in two parts, transmitters first. Next month there will be full details of the receiver unit along with some hints on installing the radio control. There will also be a follow up article later designed to give some ideas of what can be achieved with a system of this versatility.

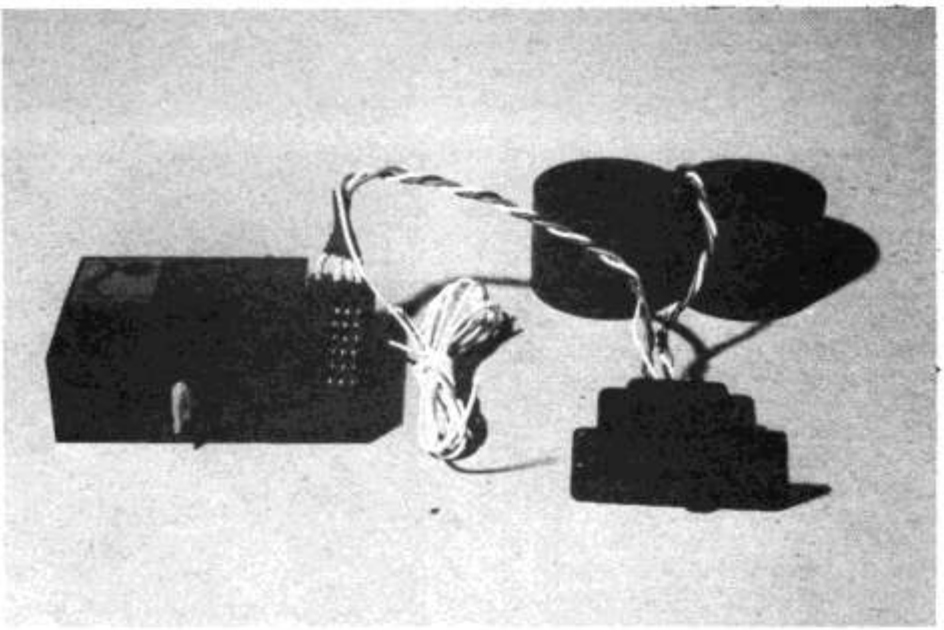
We chose an armoured vehicle as the example upon which to base our articles, as this is more general in principle than most and allows easier illustration. The model we used was the excellent Tamiya 1/16th Leopard kit. This gives a splendid model of the W. German tank with Tamiyas usual superb moulding detail and a drive system designed for radio control through an ingenious twin clutch system.

It is an expensive kit, but in our opinion is well worth it, and includes everything right down to the servo rods.



Above: the Tamiya tank upon which the system is based

Below: the receiver with its DEAC and charger switch



A Case For It

The transmitter case is designed for four channels to be controlled by joystick and two by either pot or simple switch. The latter could be useful for aircraft undercarriage and the like.

The angled aerial produces a radiation pattern that reduces the risk of an aircraft (in particular) getting itself into an area of low strength and thus passing beyond operator control.

The meter on the front panel is a form of field strength meter and is used initally for setting the only tuning control in the TX circuitry, and thereafter indicates RF output as a check upon performance.

Construction

Building the Tx should pose no problems to the average constructor, but when fitting the joystick and case, follow the photographs carefully otherwise it could cause unnecessary problems.

Assemble the PCB first, and check carefully the polarity of semiconductors etc. Fit the aerial and other sockets initially, then the passives and leave the transistors until last. Note the inductors are labelled.

The small PCB fits aback the meter and carries the components for the FSM.

Solder the output wires to the board at this stage as fitting the control pots later will be tricky else. Follow the installation drawings carefully and there should be no trouble. Check everything carefully though.

Power To The Aerial

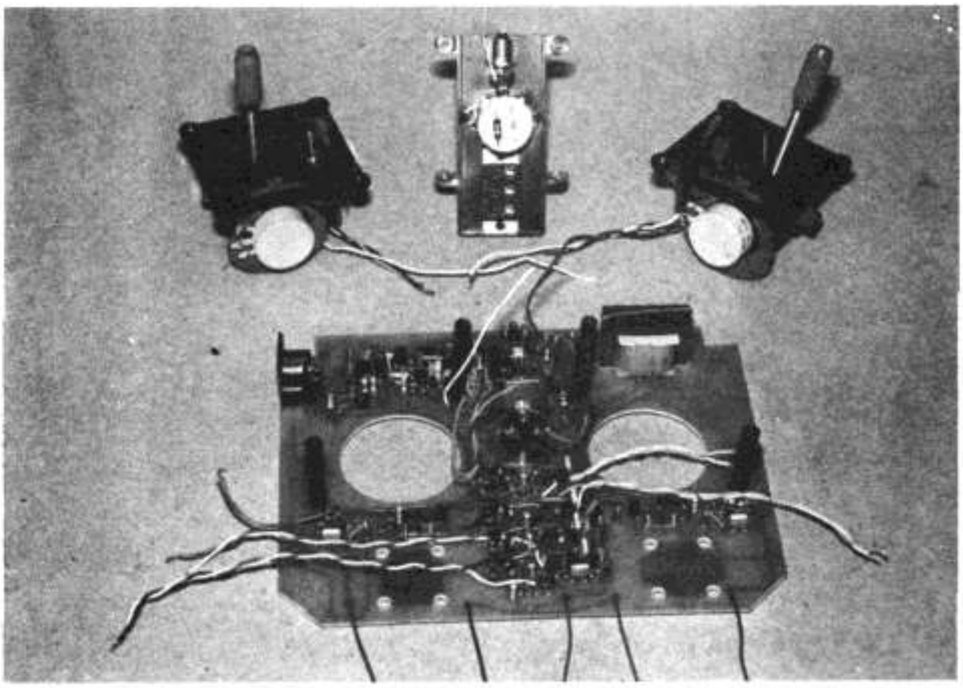
Once the board is complete and the sticks wired fit the rechargeable cells, screw in the aerial (telescoped) and plug in your crystal. Switch on.

The meter should show a reading. Rotate CI using a small insulated screwdriver or better yet a plastic control trimmer the reading will rise and fall as CI is rotated.

Extend the aerial fully and rotate CI to get a maximum meter reading. It helps during this operation to keep a finger on the —ve of the cells to provide an earth load.

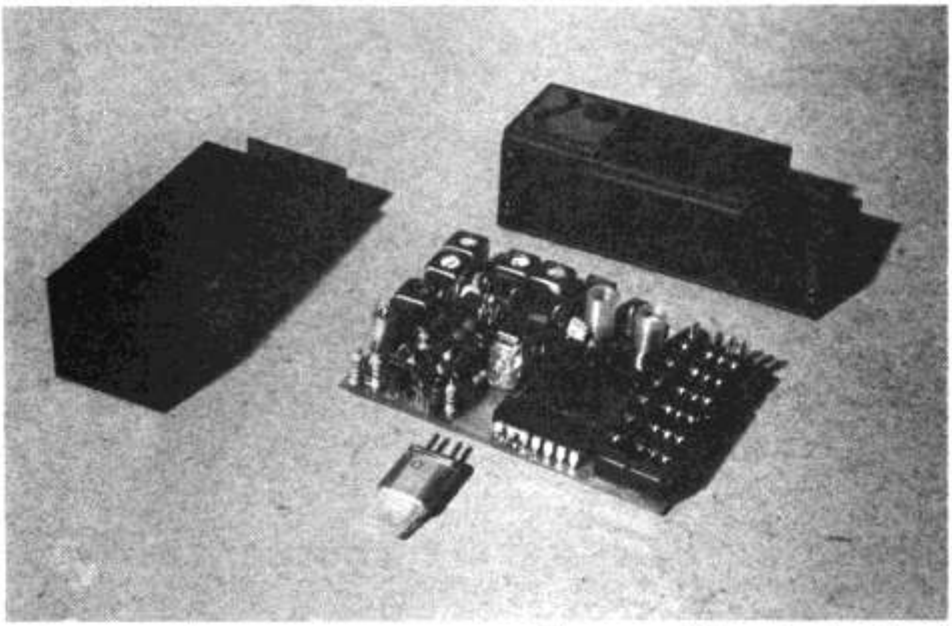
The reading should be about 80-90% of FSD so move the FSM aerial around slightly to obtain this.

The transmitter is now tuned. Presets PRI-6 are used to set the centres of servo operation and do not interfere with RF output at all.



Above: a denuded transmitter unit. The joysticks mount above the board.

Below: the receiver removed from its case. Note the crystal.



Fit the completed assembly to the case, lining up the aerial bush with the plastic grommet on the case top. For those not fitting the internal charger, cover the holes in the back of the case with some tape or card.

Charge

Remember that the cells used will take 14 hours to charge from flat, and the bulb will light quite brightly at first and then dim as charging progresses. To charge the Tx batteries alone fit the DIN plug with R32 across pins 1 and 2 and plug in the mains lead to the rear socket.

That same DIN socket is utilised many ways. Pins 4 and 5 are the connections for the Tx crystal. Pins 1 (+ve) and pin 2 (—ve) allow charging of both the Tx and Rx cells together. Pins 2 and 3 if strapped together can switch on the Tx so that when removed 'locks off' the unit. Makes unauthorised use a little difficult! Pins 2 (+ve) and pin 5 (—ve) connect an external charger to the Tx cells. 50mA maximum please.

Crystal Clear

By changing crystal you change channel, and the colour can be used ▶

BUYLINES

With a project of this type the metalwork is more important than for our usual endeavours. For the transmitter in particular, with the joysticks and aerial to be mounted, we cannot imagine anybody enjoying filing away for hours. In consequence we strongly recommend use of the hardware packs offered by the *designers, Remcon.* Our photographs and text employ these.

Ambit are marketing the components for this project, so between the two a complete kit is to be had. We estimate that, including four servos, the project will cost about £130 in total, which is approximately £60 less than a commercial set-up of approximately equal performance would cost.

The model we intend to base our installation on is the Tamiya Leopard A4 in 1/16th scale, which is designed for radio control. The kit is superb in all respects, both as a model and as a vehicle for radio control, and cannot be recommended highly enough. Beatties chain of stores stock the kit and it will cost around £90 including the gearbox/clutch/motor assembly for direction control.

Component details:
From Remcon.

Manual for system (worthwhile step-by-step constructional details) £2.75

£1.00 refundable against purchase of packs over £25

Transmitter hardware pack (everything except components and batteries):
4 channel £39.95
6 channel £45.00

All components available separately. SAE to Remcon for details.

Receiver hardware pack complete (six channels) £18.50

All components available separately.

From Ambit —

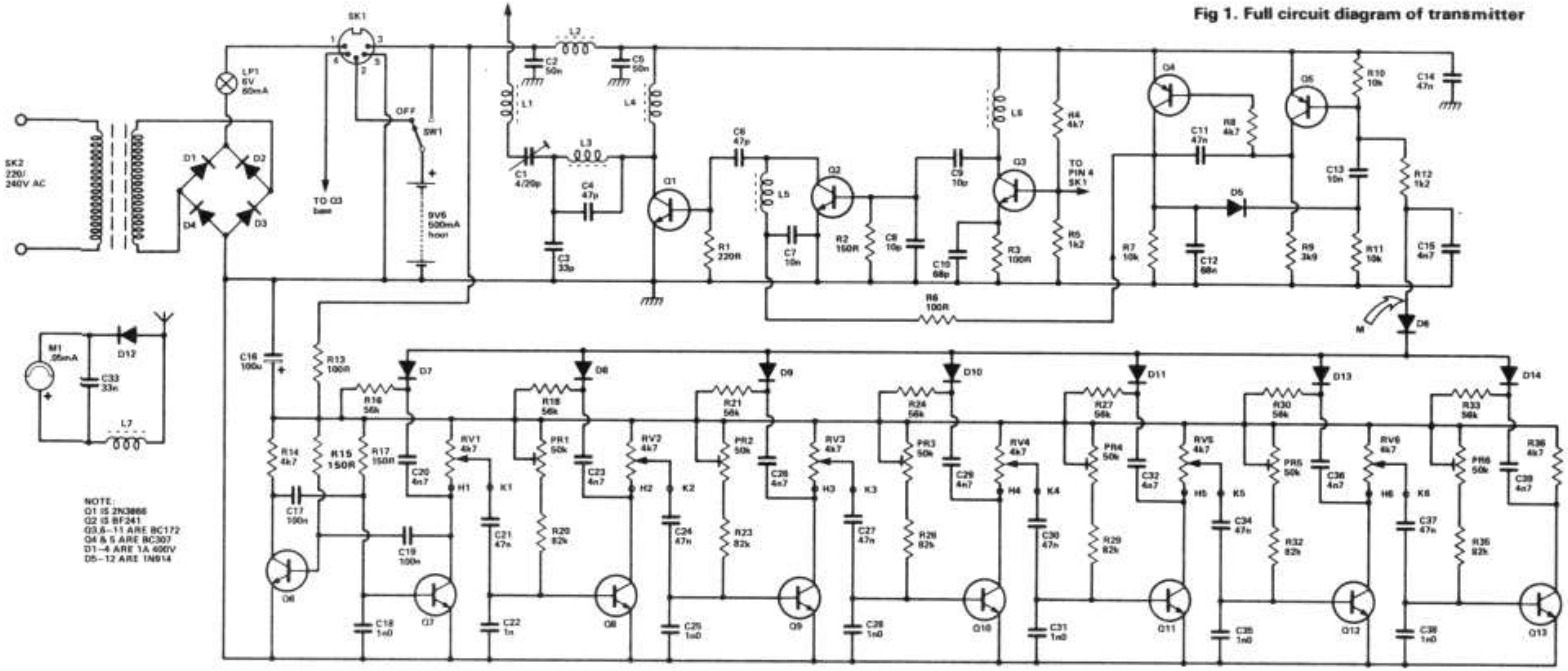
Transmitter components £10.95
Two PCB DIN plugs and charging resistors £1.60
Matched crystals (2) and DIN plug £4.00
Five-pin plug DIN (options) £0.75
Receiver components (complete) £8.95

All components available separately. Rechargeable batteries also available. SAE for details.

Any servo will operate with the Strato system. Next month we will give wiring details for the different types.

Addresses:
Ambit International, 2 Gresham Road, Brentwood, Essex.
Remcon Electronics, 1 Church Road, Bexleyheath, Kent.
Add 12½% VAT to all prices except manual.

Fig 1. Full circuit diagram of transmitter



HOW IT WORKS

This has been designed to meet the stringent requirements of continental post offices in respect of harmonic radiation and sidebands and has adequate power output to ensure out-of-sight range for model aircraft.

Referring to the transmitter circuit Q6, 7 R14-17, RV1, C16-19 comprise a conventional astable mutivibrator of unity M/S ratio, and period approximately 20mS. This is the system clock. If we look for a moment at Q8-11 it will be seen that these initially have their collectors close to the - ve rail potential due to their base bias. Now when the collector of Q7 goes to logic 0, the step change in voltage at the slider of channel 1 control potentiometer RV1, is passed via C21 to the base of Q8, cutting off its collector current. The collector of Q8 therefore goes to logic 1. The base potential of Q8 slowly rises on a time constant C21 (R19+R20) until the base/emitter diode again becomes forward biassed At this point the collector goes to logic 0 once again. When this happens, the -ve going stage voltage at the channel 2 control potentiometer RV2 cuts off Q9, followed by the same pattern of events as detailed for Q8. This sequence is followed by Q10 and Q11. Potentiometers RV1-4 are the operator controls, and R19, 22, 25, 28 permitsetting of the pulse width with the channel controls centred. These adjustments are carried out to set the mid-travel position of the servos.

The encoding process is completed by the C,R and diode network at the collectors of Q7-11. Taking as an example, C26, C21, D9, capacitor C26 is normally charged to a potential approximately that on C16, When Q9 is cut-off by the pulse from Q8, C26 discharges on a time constant C26 (R21+RV3), which is much less than the 1ms minimum duration of channel data. When Q9 is again turned on, D9 and D6 are forward biassed by the current through R12 turns on Q5 which is part of the monostable which modulates the buffer stage Q2. Before triggering, Q5 to cut-off, and Q4 therefore turned on by base bise current through R9, R6. When triggered by an encoder pulse via D6, Q5 conducts turns off Q4, which reverse biasses D5. C13 then charges through R11, maintaining Q5 in its turned on state for a period determined by C13, R11. Since this occurs when Q7-11 collector go to logic 0 then five absolutely identical pulses will be generated by Q4 and Q5 in every 20 mS frame of data.

The RF section is one of elegant simplicity, having only one adjustment, C1, Q3 is the crystal oscillator using 27 MHz 3rd overtone crystal base to -ve rail 27 MHz output is coupled to the base of buffer/modulator stage Q12 via C9. As we mentioned in the description of the encoder, Q4 is normally conducting, which means that collector voltage is applied to Q2 via R6 and L5. The amplified RF from Q2 collector passes to the power amplifier Q1 via C6. Impedance matching from Q1 collector to the power amplifier Q1 via C6. Impedance matching from Q1 collector to the aerial is effected by pre- coupler C3, L3 C4, and base loading by the adjustable network L1, C1. A simple RF meter circuit is included, comprising the meter, C33, L7, D12, it is used to peak the aerial matching adjustments during initial setting up. Thereafter it constantly indicates the carrier strength.

Before leaving the transmitter it is perhaps worth mentioning C2, L2, C5, C11, C14, C15, C18, C22, C25, C28, C31. They are all there to prevent R.F. from reaching unauthorised, and sensitive parts of the circuit!

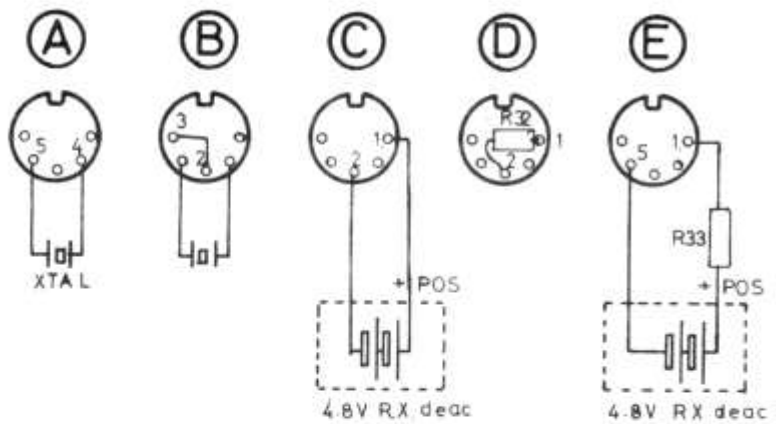
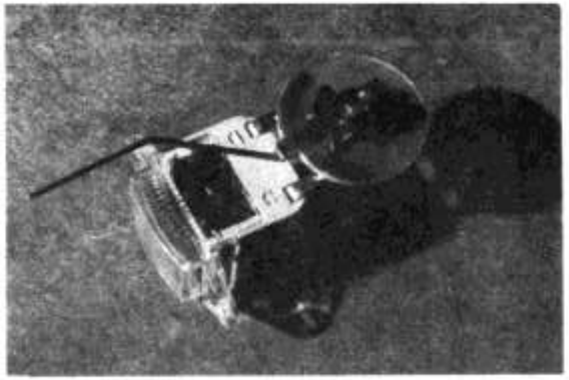
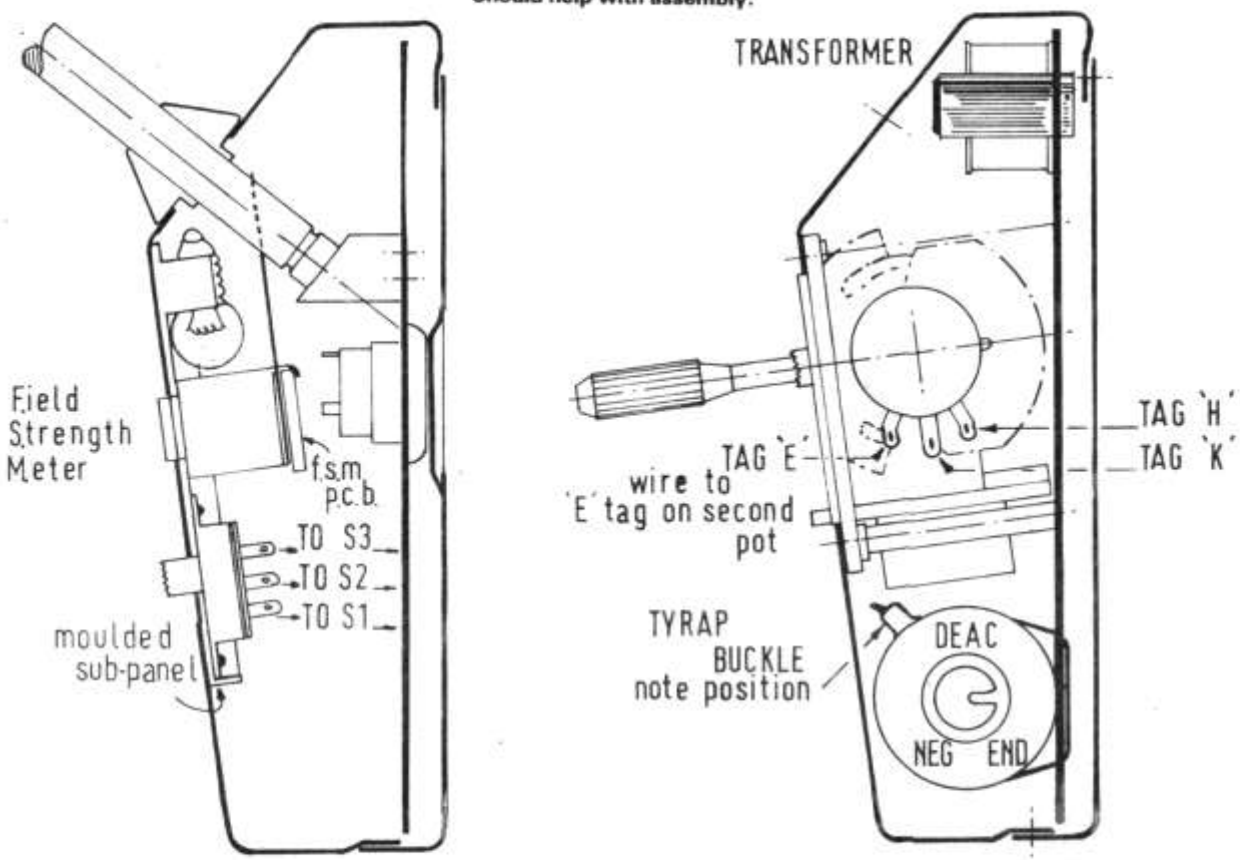


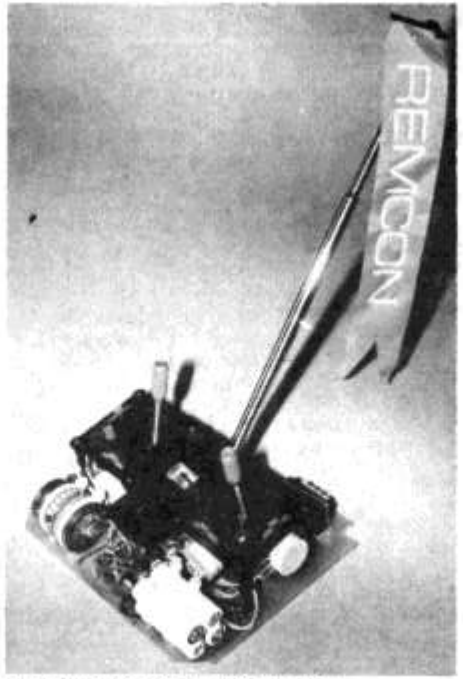
Fig 2. All the possible DIN plug configurations. See text for uses.



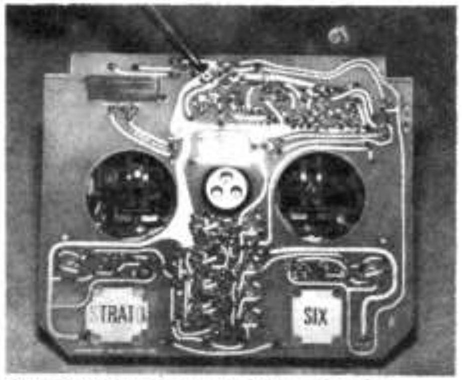
The field strength meter, with PCB ready for bending at the meter tabs.

Fig 3. Section through transmitter case. Should help with assembly.

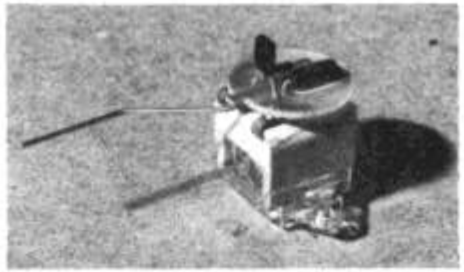




The complete Tx excluding case.



Copper side of PCB. Note earth bush.



The field strength meter with pCB bent over for fixing.

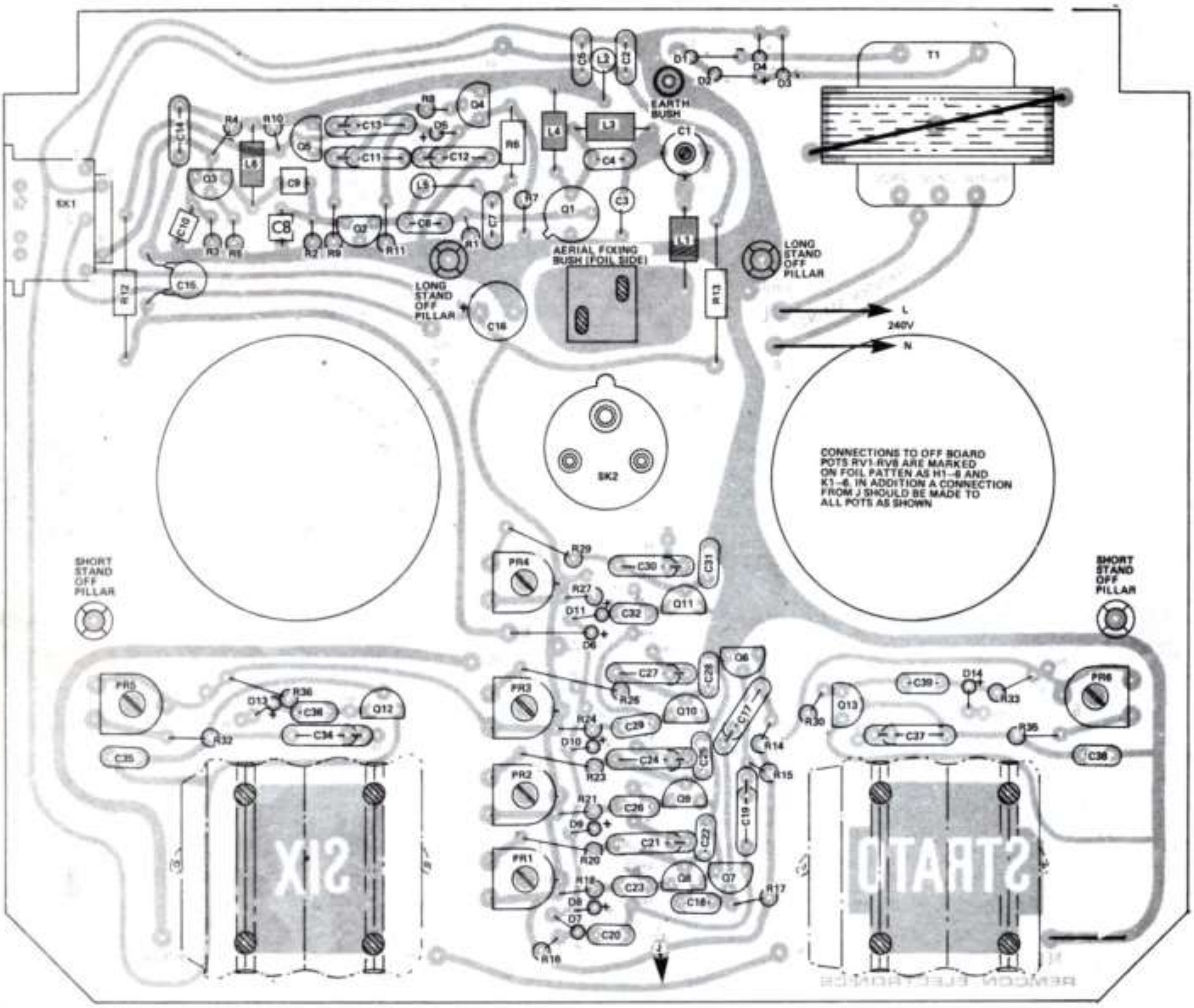


Fig 4. the main component overlay for the transmitter. Note that PR1-6 are 50k in value.

PARTS LIST

RESISTORS (all ¼W 5%)

R1	220R
R2,15,17	150R
R3,6,13	100R
R4,8,14,36	4k7
R5,12	1k2
R7,10,11	10k
R9	3k9
R18,21,24,27,30,33,16	56k
R20,23,26,29,32,35	82k

Note that R19,22,25,28,31,34 are annotated as PRI-6 to correspond to channel number

POTENTIOMETERS

RV1-RV6	4k7

CAPACITORS

C1	4-20p trimmer
C2,5	50n polystyrene
C3	33p polystyrene
C4,6	47p polystyrene
C7	10n polyester 5%
C8,9	10p polystyrene
C10	68p polystyrene
C11,14	47n ceramic
C12	68n polyester 5%
C13	10n ceramic
C15,20,23,26,29,32,36,39	4n7 ceramic
C16	100u electrolytic 25V
C17,19	100n polyester 5%
C18,22,25,28,31,35,38	1n0 ceramic
C21,24,27,30,34,37	47n ceramic
C33	33n ceramic

INDUCTORS

L1,2	4u7
L3	220n
L4	22u
L5	680n
L6	1u5
L7	10u

SEMICONDUCTORS

Q1	2N3866
Q2	BF241
Q3, 6-11	BC172
Q4,5	BC307
D1-D4	ITT 2002 or equivalent
D5-D12	1N914

MISCELLANEOUS (for charger version)
Mains skt, 6V 60mA bulb, 20V 1A secondary transformer, meter 200uA FSD, 5 pin DIN skt, metalwork (see Buylines), aerial — 1.4m long.

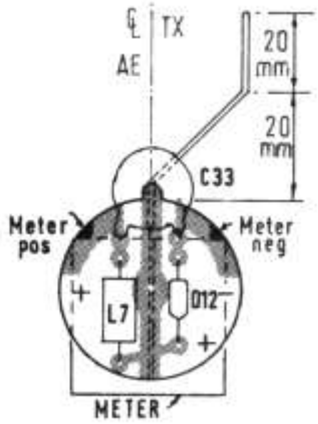
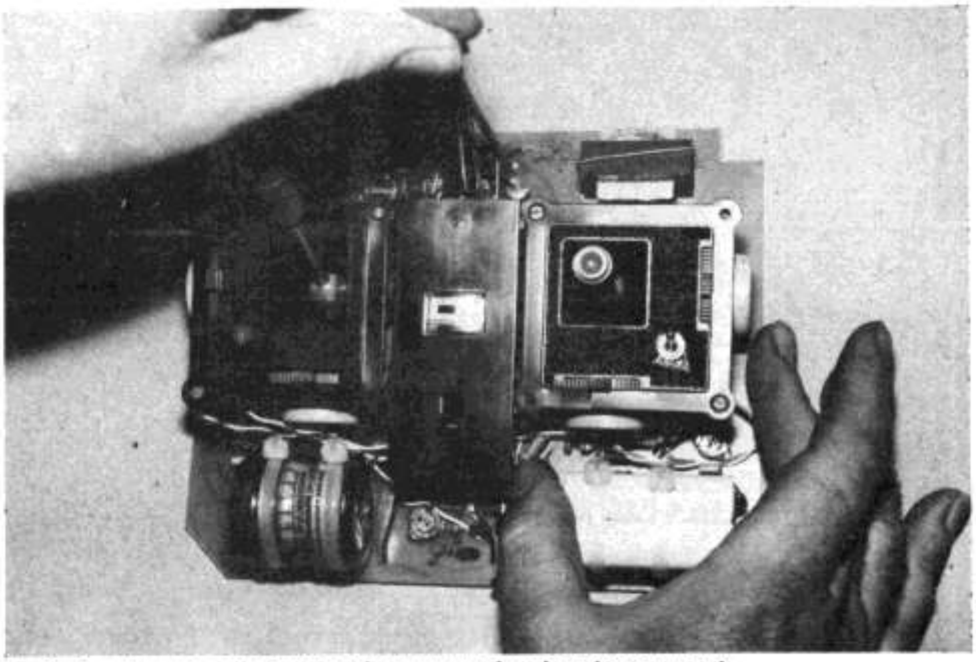
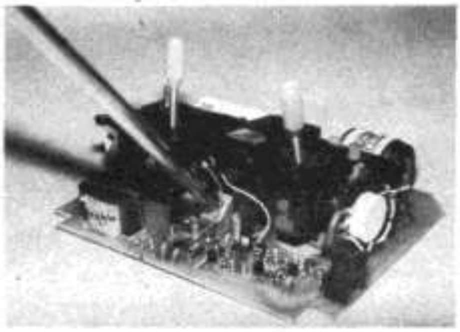


Fig 5. (Above) the overlay for the meter PCB. This mounts atop the meter itself



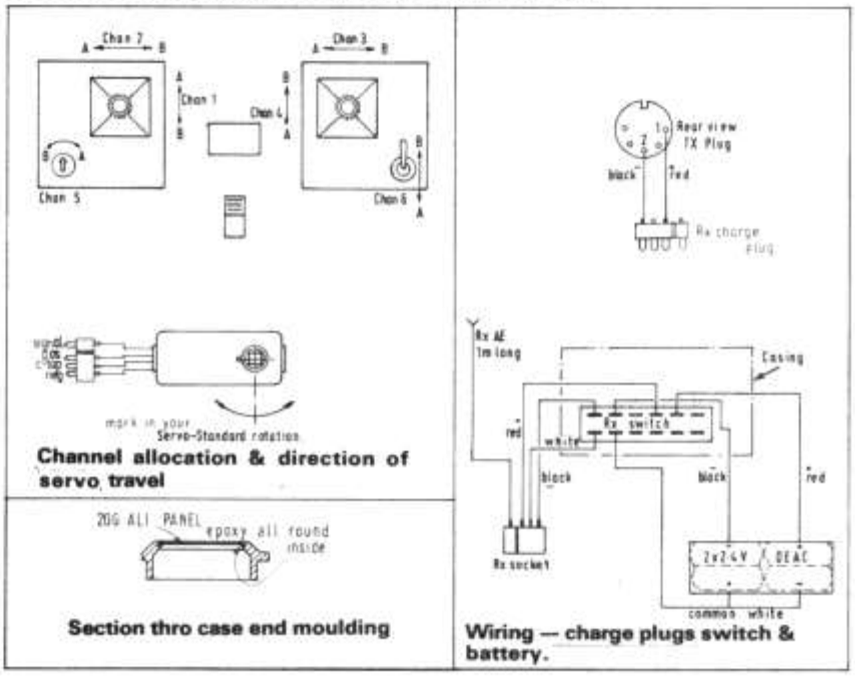
Tuning involves one adjustment only one note thumb on battery earth.

The top of the PCB slips under the flange at the top of the case.



The Rf end of the PCB.

Fig 6. (Below) Plug wiring for servos and channel line-up.



Channel allocation & direction of servo travel

Section thro case end moulding

Wiring — charge plugs switch & battery.

to identify operation easily. The standard system of coding is:—

Tx	Rx	Colour
26.995	26.54	Brown
27.045	26.59	Red
27.095	26.64	Orange
27.145	26.69	Yellow
27.195	26.74	Green
27.255	26.80	Blue

Conclusion

So that's about it for the transmitter, except to remind you that to run a radio control system you NEED A LICENCE. This costs £2.80 for five years and obtained from:—
The Home Office
Radio Regulatory Dept
Waterloo Bridge House
London
SE1 8UA.

Next month we will be giving full details of the receiver and installation of the system into a model. In the meanwhile for the fleet of soldering iron, or just plain impatient, Remcons manual contains full constructional details of the complete system and will be available shortly.

RADIO CONTROL SYSTEM

PART TWO: RECEIVER. In this concluding part of the article, we cover the receiver and its associated circuitry and give some ideas on installing the system into the model.

CONSTRUCTION OF THE receiver unit for our radio control system should pose most hobbyists no real problems, although the physical size is somewhat less than the average constructor might expect. The PCB itself is quite well packed, and for once IC sockets are a disadvantage as they both increase the weight and make casing tighter and more difficult to fit.

The reason for this drive to miniaturisation will be well understood by regular followers of the disciplines of radio control — aircraft need all the help they can ▶

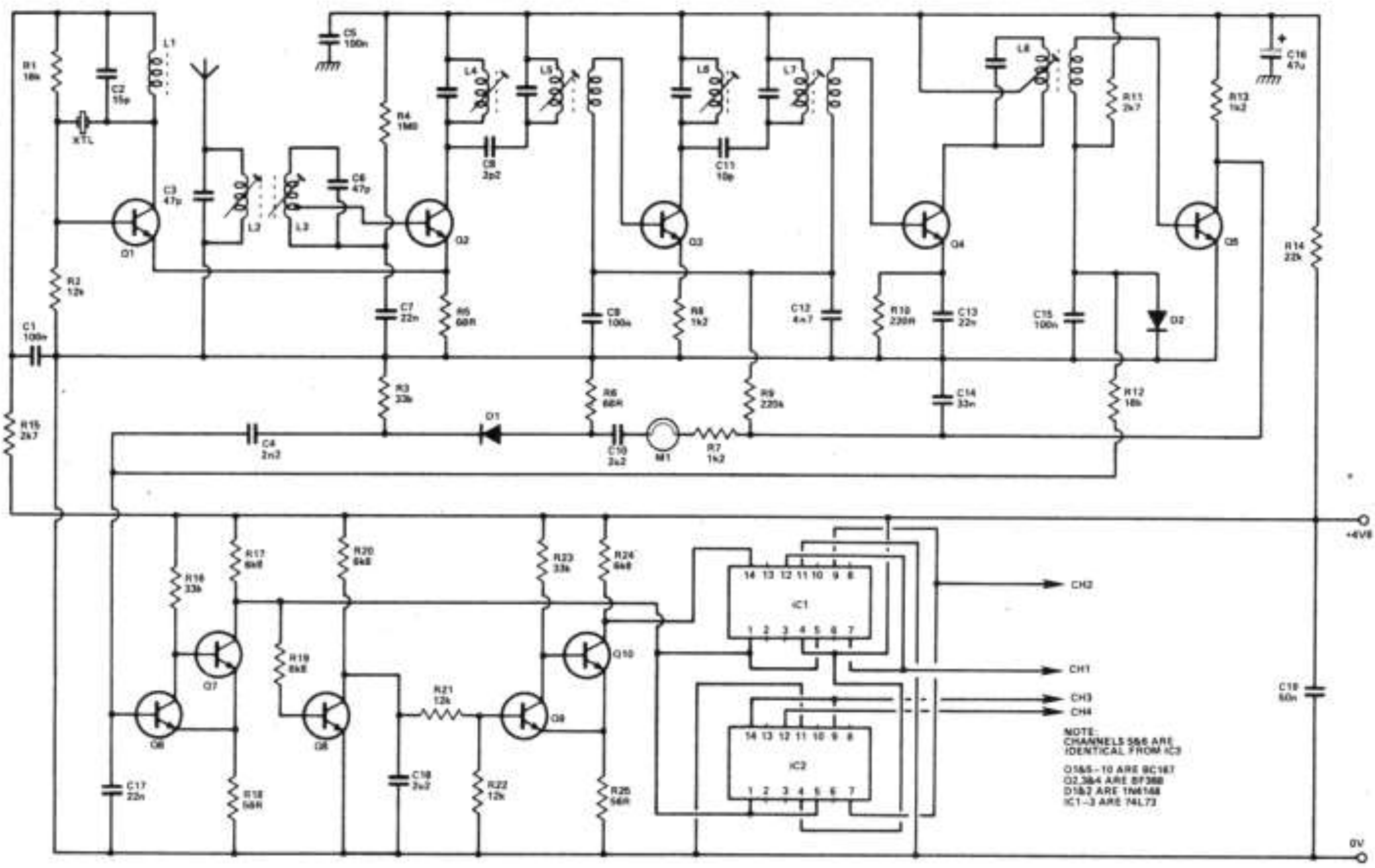


Fig 1 (Above) The full circuit diagram of the receiver unit. Note that power is best obtained from a rechargable cell. MI is a normally bridged test point.

HOW IT WORKS

The RF section is of single conversion superhet design, Q1 is a crystal controlled local oscillator, using a third overtone circuit, it has emitter injection to the mixer Q2. The aerial circuit has L2, C3 as a preselector which is inductively loose coupled to L3, C6 and provides a useful amount of image rejection. The base of Q2 is apped in near the earth end of L3 to provide impedence mathing.

A similar arrangement is used for the first LF stage, Q3. The second IF stage, Q4, uses a conventional single tuned transformer to couple it to the detector D2 and AGC amplifier Q5. D2 and R11 provide temperature compensated bias for the working point of Q5 and Q6. Amplified AGC is taken to the two IF stages from Q5 collector, via R9. The somewhat unusual IF amplifier, detector and AGC arrangement provides better than average selectivity at 455 kHz, together with a good AGC dynamic range. In addition to an AGC amplifier, Q5 has another role to play. It is also a pulse amplifier for the demodulated pulse train. After passing the test point m, the DC component of the pulse train is lost in C10, R6. The forward drop of D1 allows only signals in excess of about 0.6V to be passed to Schmitt trigger Q6, 7 and in so doing improve the receiver's noise rejection capabilities. Q6 is turned on by the incoming +ve going pulses, and the regenerative action of Q7 ensures that clean rectangular pulses appear at the junction of R17 and R19. The nicely reconstituted pulse train is now fed to a shift register comprising IC1, 2 (and 3 if fitted). The channel outputs of the latter sequentially go from logic 0 to 1 in response to the clocking action of the incoming pulses. Now the pulse train from the collector Q7 is passed via R19 to the base of Q8, the pulse omission detector. With no input pulses, this stage is cut off, allowing C18 to charge positively through R20. Under this condition Q9 conducts, cutting off Q10. When the pulse train is present at Q7 collector, C18 is discharged repetitively, maintaining a voltage across it which is lower than the threshold level for Q9. Then the collector of Q10 remains at logic 0. However, after the last pulse in the train there is a minimum pause of 8mS the reset time. This is long enough for C18 to charge to a potential which triggers Q9, Q10, causing a logic 1 to be produced at the collector of Q10. This effectively resets the shift register, ready for the next frame of data. Individual pulse outputs to the servos are taken from the shift register.

get. The Strato system is primarily a utility system, and as such must be suited to both vehicles and aero-models.

A Case For It

If you're building up the system using the kit, your coils have arrived ready wound on the PCB. For you more fortunate souls the next few paragraphs hold no interest. Pass on quickly, despairing of those who must tread the path of weird windings.

L2 and L3 are wound on 6mm x 15mm formers using 0.4mm wire. Wind L3 first, and mount the former on the PCB before you start. Insert one end of the wire into the pad at the junction of C7 and R4 and solder it there. The other end goes around the core approx. 2½ turns and is soldered to the pad at the base of Q2. The second winding on this core consists of approx. 6½ turns between the base of Q2 and the connection at C6.

Next to L2. Glue on the former, and start with one end of the wire soldered to the connection at C3. Add on about 8½ turns which should take you to the other end of C3 and solder off there. Insert the slugs in both L2 and L3 and screw in until they just enter the windings.

Refer to the overlay throughout these machinations.

IF You Can

The IF transformers are colour coded, L4 is yellow (so is L6), L5 is white (so is L7) and L8 is black. Fit these to the PCB, but do not solder the centre pin of the group of three you will find on one side of the base. Make sure also that this rouge pin does not make contact with the board. If thine pin offends thee, cut it off.

L8, the black coil, is to be treated normally and all pins soldered.

The rest of the board should be assembled normally, but take the usual care with IC orientation and polarised components. Putting on the plugs and sockets should be easy — remember that the only plug fits at the bottom LH corner of the PCB, and the rest are sockets.

From this sole line of pins comes the aerial and goes the receiver power.

Xtal Clear

Changing the crystal changes the frequency of operation of the receiver, and so having the Xtal mounted in a socket makes for easy switching around. These sockets are, however, expensive, but worth it for their usefulness. Pin money well spent.

It is probably worth noting that most components fit the board vertically and that at this frequency there is no room for overlong leads. Keep them as short as possible and watch the soldering iron does not burn its bridges!

Fit all the resistors and capacitors, leaving L1 until all are nestled nicely with solder around their ends. The semiconductors too should be sat sitting there looking at you before L1 joins them. As sockets are not to be used watch the orientation of the semiconductors.

Play A Tune

Once you've checked the PCB and are satisfied it is correct, check that it fits the case and that no solder clogs up the runners. Now the receiver needs tuning. Make up a power lead, connecting the battery and (39") aerial to the only socket on the board.

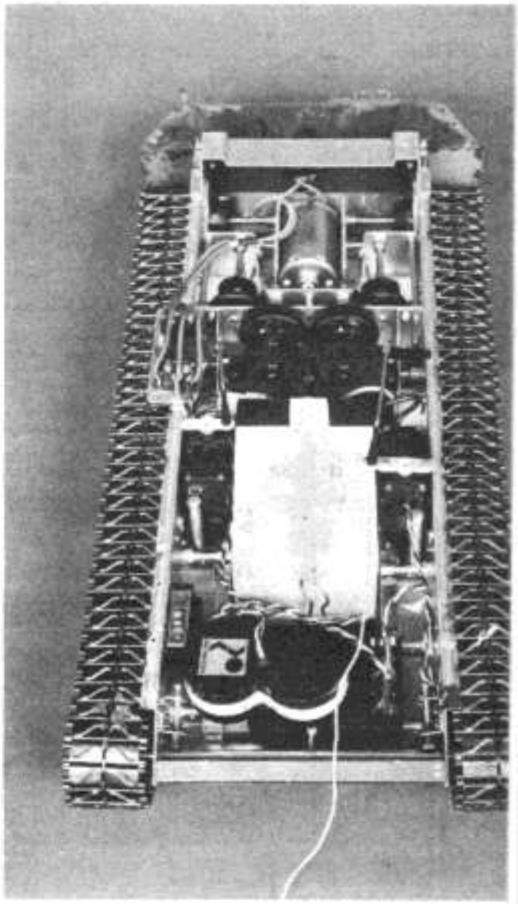
Connect a voltmeter with FSD around 5V between negative rail and the positive side of R7. The reading should be around 3V. Place the transmitter next to the receiver and switch it on. The meter should go down to about 1V. Remove the Tx aerial, and move it away until you get a reading of between 2V-2V5.

Core Wot A Job

Using a non-metallic tuning tool — even a piece of wood will do — screw in the core of L2 until you get a minimum reading on the meter. Go to L3—do not pass go or collect 200V — and tune that in to a minimum too. Work your way along all seven coils in this manner, tuning each in turn to get that minimum reading.

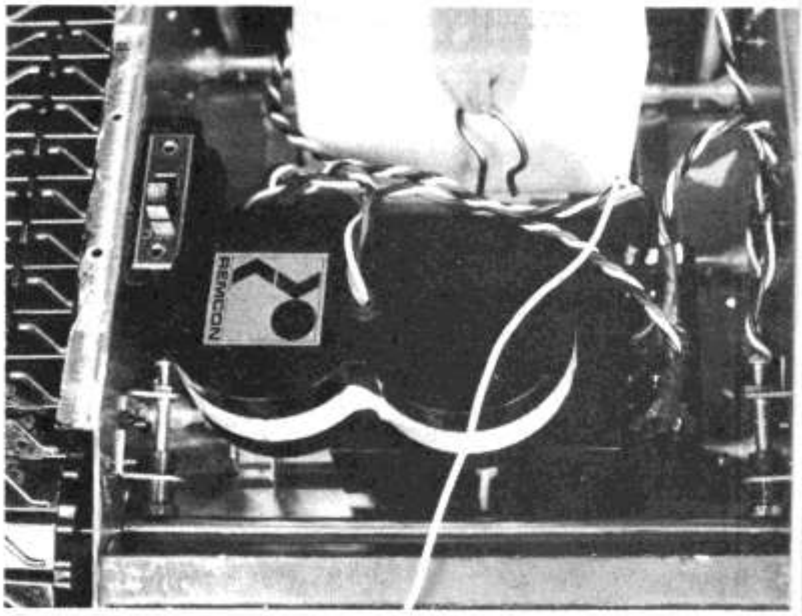
There may be some interaction so it is probably worth going through the whole thing a couple of times to make sure you've got it right. Once you're satisfied — that's it.

All this takes longer to read than it does to do, and the whole operation shouldn't take more than ten minutes. ▶



Above: The Tamiya Leopard laid bare to the world. The receiver is mounted right at the front and sits beneath the DEAC. Note the clutch steering mechanism about 2/3 down the chassis. The servo to operate this is on the right of the battery.

Below: The receiver mounting in more detail.



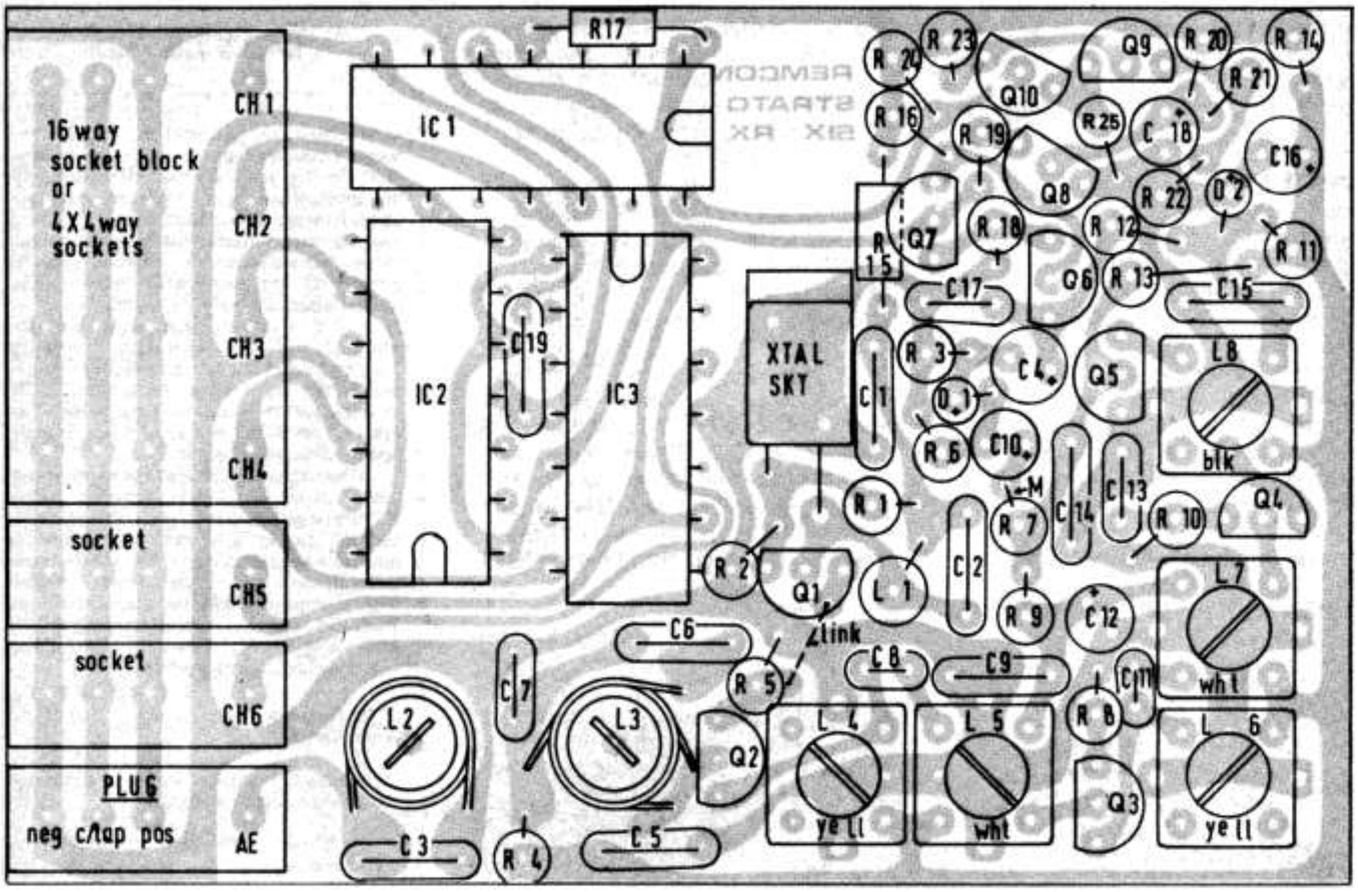


Fig 2. (Above) Component overlay for the radio control receiver board. In contrast to our usual style this is shown twice size to make construction easier. Since no sockets are employed take care with the ICs.

Fit the board into its case and the receiver is now completed. However it's not all over yet. You still need to make up a charging lead to run from the Tx, if you're using the internal charger, or whatever source of power takes supplies the electrons. Last month's article gives the plug configurations to enable you to avoid two dimensional batteries.

Your Servo

We have not given details of home build servos because the commercial market makes the exercise a singularly uneconomic and unattractive one. There are a very large number of servos available, both kit and complete, IC and discrete, and most of these will work with our system perfectly well.

The words which, upon incantation inside a shrine of servo supply, will conjure forth a compatible unit are: 4V8 supply, positive going signal, pulse width swing 1-2mS (1.5mS centre) and commutation rate 50 Hz.

With our system a tolerance of 20% surrounds the ideal. In order to set up the drive accurately, it is best to buy at least one ready built (and set up to 1.5 mS centre) servo. This

PARTS LIST

RESISTORS ALL 5%	
R1, R12	18k
R2, R21, R22	12k
R3, R16, R23	33k
R4	1M0
R5, R6	68R
R7, R8, R13	1k2
Rg	220k
R10	220R
R11, R15	2k7
R14	22k
R17, R19, R20, R24	6k8
R18, R25	56R

CAPACITORS	
C1, C5, C9, C15	100n polyester
C2	15p ceramic
C3, C6	47p ceramic
C4	2n2 polyester
C7, C13, C17	22n polyester
C8	2p2 ceramic
C10, C18	2u2 polyester
C11	10p ceramic
C12	4n7 polyester
C14	33n polyester
C16	47u electrolytic

INDUCTORS
L1-8 IF coils (see text)

SEMICONDUCTORS	
Q1, 5-10	BC167
Q2-4	BF368
D1, D2	IN4148
ICI-3	74L73

MISCELLANEOUS
4 V 8 battery, case, PCB
Servos to suit application
Switch to fit model

can then be plugged in and used to set the output pulse widths of the transmitter, using the on board presets, to align with servo centre.

Having A Fit

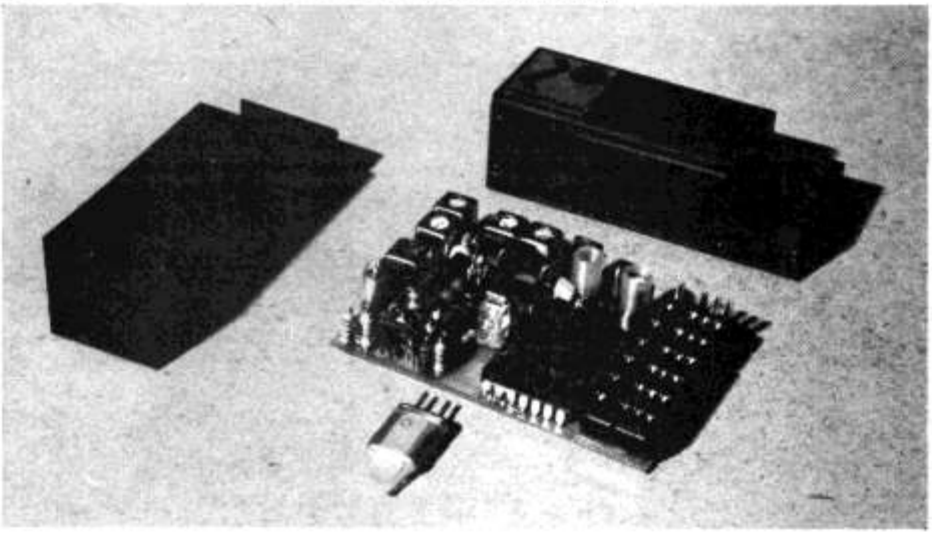
Installation of the system is totally dependent on where you intend to put it! If the unit is to spend its days running down pigeons in the smog above this green and pleasant land of ours, then your servos need to be smaller than average, and will generally cost more the smaller you want them.

For several reasons — probably all to do with delusions of being Gueridan reincarnate — our prototype went into a tank model—Tamiyas Leopard A4. Such a siting is probably atypical, but as you can see from the photographs it allows more flexibility of illustration. One thing did become clear after only a couple of runs though, the need for some kind of speed control.

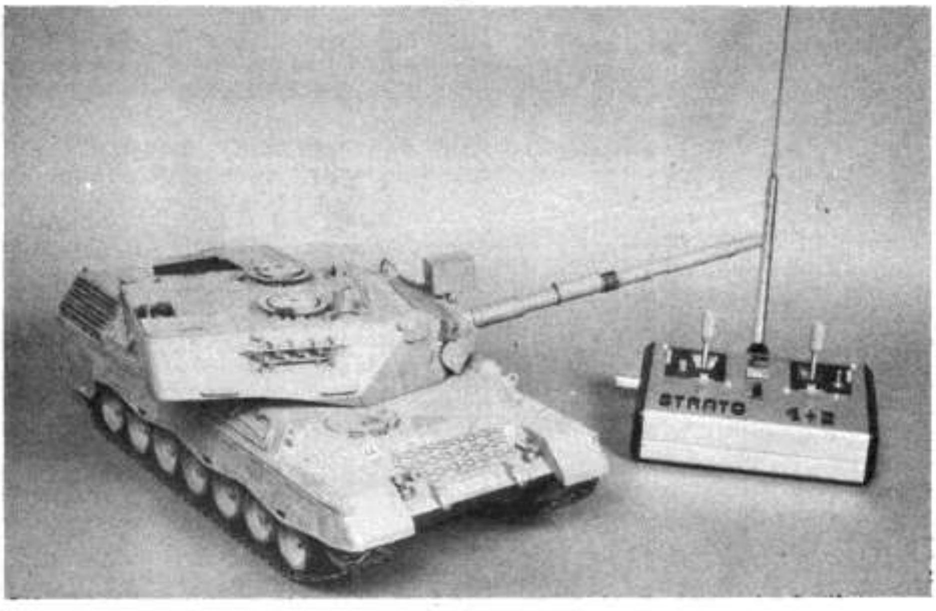
This kit is capable of about 3 MPH absolute (about 50 MPH scale) and just try driving a very heavy, metal-tracked stubborn mass around at flat-out walking speed sometime, when the only speeds available are fatal and off.

Our illustrious Project Editor has developed a 'pulse stretcher' electronic speed control which would seem to be applicable to any sort of Radio control vehicle and we'll be publishing this as a separate project next month as it is not part of the basic system presented here. ETI

Below: the receiver removed from its case. Note the crystal.



Below: all you gotta do now is find something to shoot at.



BUYLINES

With a project of this type the metalwork is more important than for our usual endeavours. For the transmitter in particular, with the joysticks and aerial to be mounted, we cannot imagine anybody enjoying filing away for hours. In consequence we strongly recommend use of the hardware packs offered by the designers, Remcon. Our photographs and text employ these.

Ambit are marketing the components for this project, so between the two a complete kit is to be had. We estimate that, including four servos, the project will cost about £130 in total, which is approximately £60 less than a commercial set-up of approximately equal performance would cost.

The model we decided to base our installation on is the Tamiya Leopard A4 in 1/16th scale, which is designed for radio control. The kit is superb in all respects, both as a model and as a vehicle for radio control, and cannot be recommended highly enough. Beatties chain of stores stock the kit and it will cost around £90 including the gearbox/clutch/motor assembly for direction control.

Component details:
From Remcon.

Manual for system (worthwhile step-by-step constructional details) £2.75

£1.00 refundable against purchase of packs over £25

Transmitter hardware pack (everything except components and batteries):
4 channel £39.95
6 channel £45.00

All components available separately. SAE to Remcon for details.

Receiver hardware pack complete (six channels) £18.50

All components available separately.

From Ambit —

Transmitter components £10.95
Two PCB DIN plugs and charging resistors £1.60
Matched crystals (2) and DIN plug £4.00
Five-pin plug DIN (options) £0.75
Receiver components (complete) £8.95

All components available separately. Rechargeable batteries also available. SAE for details.

After considering the market availability of servos, we found that World Engines of 97 Tudor Avenue, Watford, Herts. have at least a dozen types to offer in both kit and assembled form — mostly American.

Fleet Electronics of 47 Fleet Road, Fleet, Hants can offer a design perfectly suited to our system in both kit and built form. There are undoubtedly many many more. Prices run from about £10 to about £15-£20 depending upon whether you intend to assemble it yourself.