PRACTICAL

ELECTRONICS

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MULTI CHANNEL RADIO CONTROL SYSTEM FOR Model Boat

Also in this issue

DRUMMER'S WHOOSH UNIT * CAMERA TRIGGER

MULTI CHANNEL RADIO CONTROL SYSTEM

FOR MODEL BOATS....

THE relatively simple transistorised multi-channel control system described here was designed specifically for controlling a 34in model diesel powered Vosper R.A.F. Crash Tender. Circuit and constructional details are given for the radio transmitter, receiver and control arrangements, including those for rudder and throttle actuator mechanisms. No special tools are required other than perhaps a power hand drill, although a multi-range meter is desirable and an oscilloscope is an advantage. The overall model with electronics will appeal to the do-it-yourself modeller who has a certain amount of electronics knowledge.

SINGLE OR MULTI-CHANNEL?

Undoubtedly the simplest control arrangement is "single-channel" operation in which only one item of information is transmitted at any one time. This can be quite effective, although special operating techniques may have to be evolved, particularly when high speed models are used, so that function selection is not unduly delayed.

In the case of model aircraft, the flying technique for single channel working differs completely from normal multi-channel practice. Therefore, it would seem to be a very natural progression to the more versatile "multi" techniques, which enable simultaneous movements of various controls to be made, particularly if the cost of such a system could be kept low.

AIRCRAFT OR BOAT?

The scope of "multi" aircraft control can be very rewarding, but the following points were the decisive factors in selecting a boat for using the control system described.

Cost of the installation

A boat or land vehicle control system need not be as complex as its aircraft counterpart, a four-channel system being usually quite adequate for controlling a boat, even at high speed. Surface vehicles are not seriously affected by equipment weight, size, or power consumption restrictions generally imposed by an aircraft of practical proportions.

This gives the home constructor much more scope to use materials and components which are readily available, rather than to have to purchase the relatively expensive, compact, and lightweight items generally required for aircraft control. There is no particular need to miniaturise the circuitry or actuators; with a boat of 34in overall length, lack of space is not a problem to be encountered here.

Loss or damage

In the experimental stages, particularly with home-built equipment in the hands of newcomers to model control, there is a very real risk of damage, or even a complete write-off, in the case of a powered aircraft, as a direct result of some form of loss of control.

Adequate operating facilities

Unless one joins a club it is difficult to find suitable large open spaces for aircraft flying without undue aerial hazards. It must be remembered that a powered aircraft in free flight at speed is potentially a dangerous projectile and serious personal injury has been known to occur to spectators. There are still plenty of smooth stretches of water to be found of quite sufficient size for putting a boat through its paces without risk of annoyance to anyone. Most marine diesels are equipped with silencers to reduce noise.

The effective working range of the transmitter/receiver combination described in this article is about a quarter of a mile. In practice, this was found to be more than adequate, because even at 200 yards distance it becomes difficult for the operator to ascertain the boat's position and attitude in the water.

BASIC ARRANGEMENT

The basic scope for control of a boat is probably less than that for an aircraft, and in order to justify the selection of a "multi" system, a high-speed planing hull was selected, capable of good manœuvrability at speed. Because of the low power/weight ratio achieved with electric propulsion, an ample size of diesel engine was chosen as the power unit. This was installed in an "Aerokits" R.A.F. Crash Tender available in kit form in plywood. The 34in model is used.

This boat is ideal for an installation of this type, the hull being conveniently divided, by bulkheads, into five compartments (see maker's plans). It is very wise if an internal combustion engine is used, to keep one compartment amidships reserved for the engine, fuel tank, and perhaps throttle gear, as these miniature engines tend to become dirty, exuding a mixture of soot and unburnt fuel—the penalty for throttling a diesel engine.

. . PART ONE

By E.J. PEPPER C.Eng. M.I.E.E.

The bow compartment (No. 1) (see maker's plans) is sealed off and filled with buoyancy material; No. 2 compartment (wheelhouse) is used as the main electronics area, as this is readily accessible but is well protected and well clear of any spray that might occur at speed. This compartment accommodates the radio receiver, preamplifier, and both control motion panels.

The receiving aerial plugs into a socket fixed to the deck adjacent to No. 2 compartment. No. 3 compartment is the engine room with throttle control and fuel tank. No. 4 houses the battery, relays, and the isolator switches. No. 5 compartment is occupied fully by the steering actuator and the actuator supply battery. It is probably a good idea to mark these compartments on the plans.

If polyurethane foam is inserted ahead of bulkhead B1, holes of about 1in square should be made in the bulkhead.

The second compartment houses the four perforated s.r.b.p. modules: the receiver (aft), the pre-amplifier (port side), rudder control (starboard side), and throttle control (forward). These four modules are easily recognised in the circuit diagram, each being indicated by a hatched line box (see Fig. 2). The complete circuitry in the boat is shown; the transmitter will be described later.

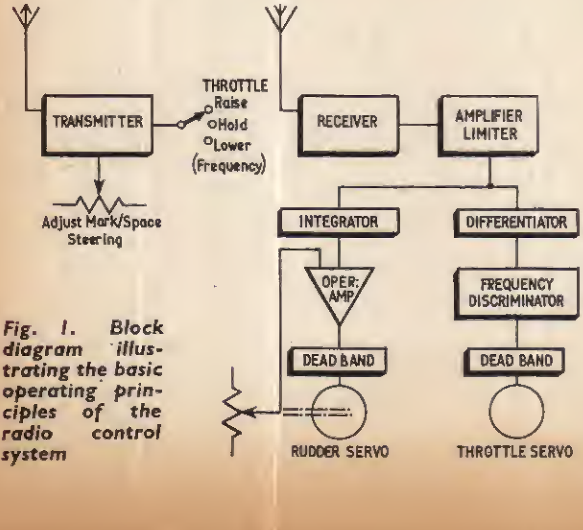


Fig. 1. Block diagram illustrating the basic operating principles of the radio control system

TWO BASIC SYSTEMS

There are two basic systems of control in general use, and there are also two main ways by which the control intelligence can be made to actuate the controlled member (see Fig. 1).

Progressive control

Progressive control is usually simplest, but less precise, being in principle an "open loop" arrangement of integration where the controlled member will move at more or less constant rate in the desired direction until it is checked.

Proportional control

This is a true "closed loop" servo position control.

The simplicity of the system to be described stems from the fact that it permits simultaneous transmission of one progressive system and one proportional system, the former being used to actuate the throttle, i.e. commands "close", "open", and "hold", the latter to steer the boat.

The rudder assumes the angular position corresponding to that set up on the steering "wheel" on the transmitter unit, regardless of the load conditions on the rudder. To achieve this it is necessary to feed back the rudder position to the controller by means of a potentiometer (VR2) ganged to the rudder shaft.

CONTROL PRINCIPLE

The two controls, rudder and throttle, may be operated individually or simultaneously, and the principle of operation may be readily understood from Fig. 3. The transmitted 27MHz carrier is 100 per cent modulated by a square wave of adjustable mark/space ratio to correspond to rudder control, and at three pre-selected fundamental frequencies to provide throttle control.

The appropriate frequency (110Hz, 600Hz, 400Hz), corresponding to "increase", "decrease", and "hold" throttle respectively, can be selected by a centre biased three-position key on the transmitter, without affecting the pre-set mark/space ratio. The mark/space ratio of the square wave is variable from 1 : 10 to 10 : 1 for

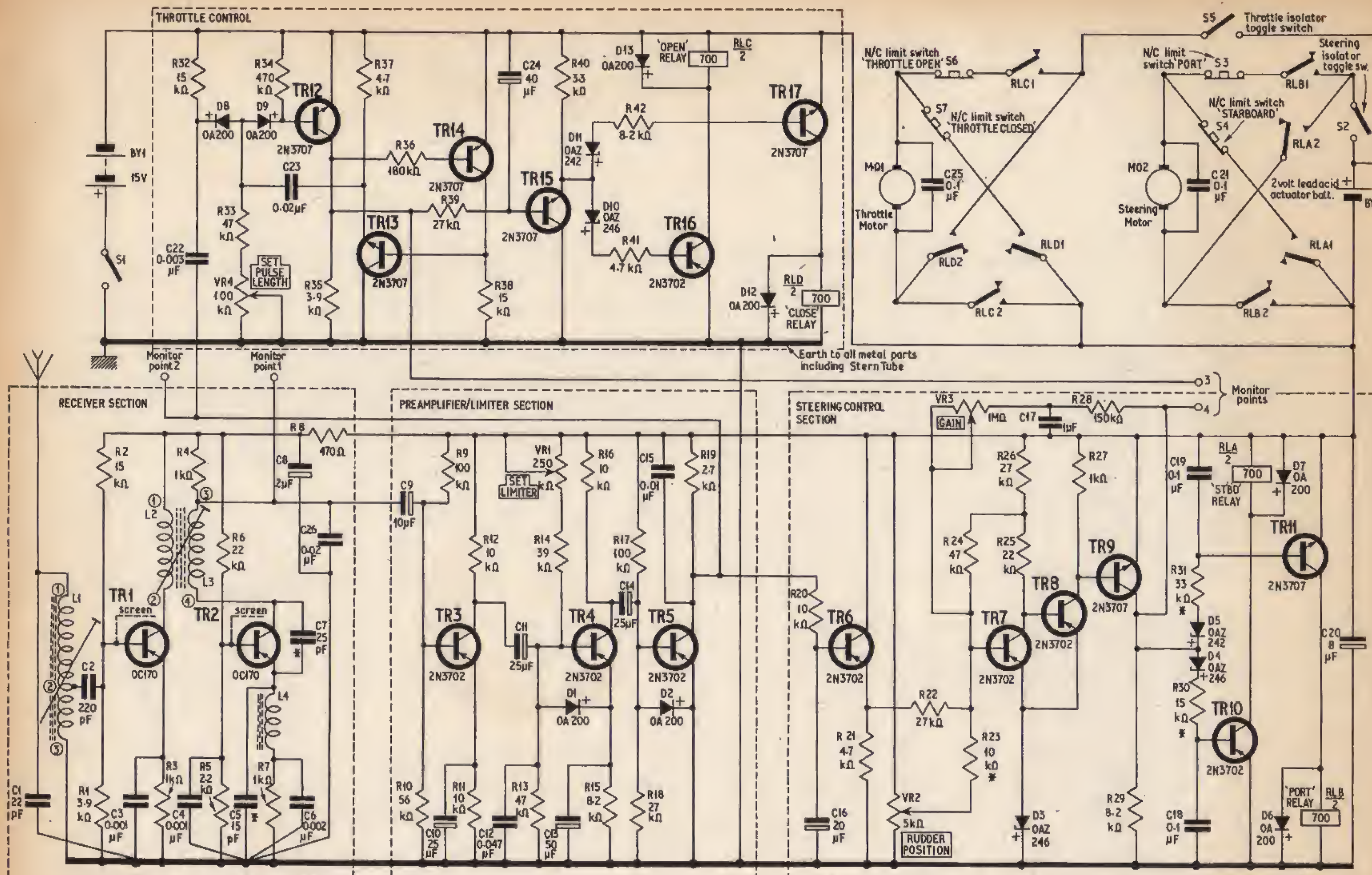
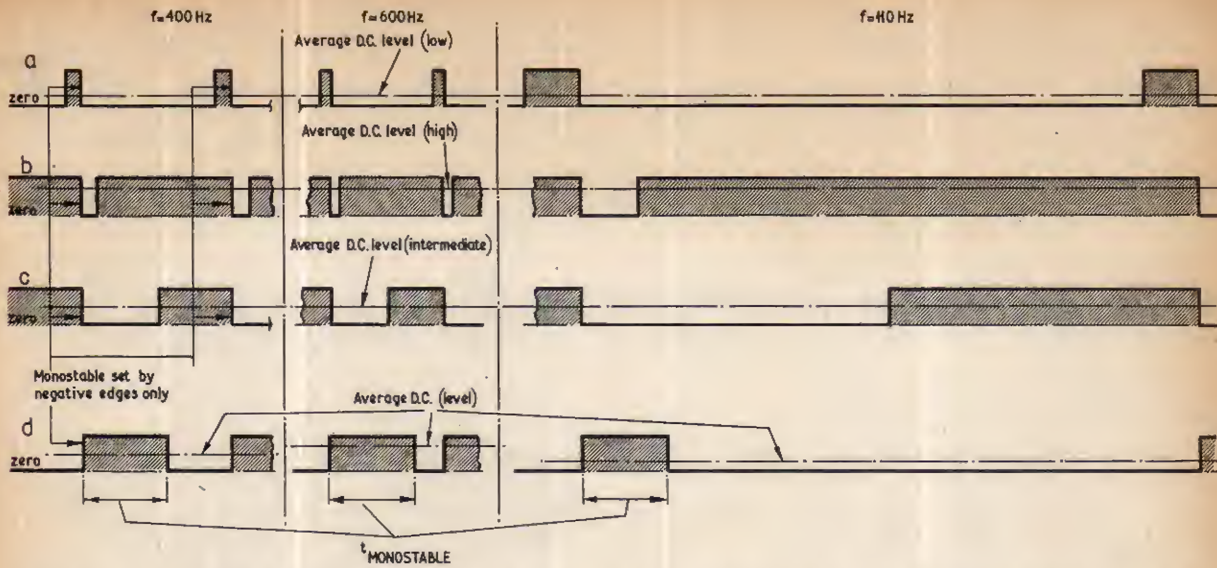


Fig. 2. Complete circuit diagram of the electronics in the boat. Each section is divided into shaded areas to show the individual panels



(a) Steering control waveforms Port Rudder (b) Steering control waveforms Starboard Rudder (c) Steering control waveforms Rudder Amidships (d) Corresponding Throttle control waveforms

f=400Hz 'HOLD' throttle (Intermediate D.C. level) f=600Hz 'CLOSE' throttle (High D.C. level) f=40Hz 'OPEN' throttle (Low D.C. level)

NOTES:
(1) The D.C. level of the Rudder waveforms does not change with frequency (2) The Throttle waveform is not affected by change of Rudder Mark/Space ratio

Fig. 3. Steering and throttle control waveforms

any selected frequency and is set by the steering wheel control on the transmitter, a ratio of 1 : 1 corresponding to "rudder straight".

After detection by the receiver, the square wave signals are converted to d.c. levels which in turn actuate relays. These control the d.c. motors which rotate, in the appropriate direction, the actuator lead screws.

The general description of the system will now be followed by a more detailed account of the various functional units. However, it is emphasised at this stage that general information on constructing the boat is excluded since it is outside the scope of this magazine. It is expected that the constructor will acquire the boat kit with instructions through a retailer.

A kit of accessories for this model is available through retailers from Keil Kraft. The electronics are not generally available in complete kit form; constructors will find that all electronic parts are obtainable through the usual retailers.

RADIO RECEIVER

It is an undisputed fact that, because of their selectivity performance, superheterodyne receivers are to be preferred to t.r.f. types; nevertheless super-regenerative receivers can give excellent results and are undeniably simple. If the constructor has no intention of becoming involved in active competition work, where a superhet could offer advantages, he would probably do well to compromise and go for a super-regenerative receiver, which is simple and inexpensive while offering adequate performance.

At the high transmission frequency used, it would have been very difficult to have achieved adequate r.f. amplification with a conventional tuned radio frequency (t.r.f.) receiver, whereas the super-regenerative receiver is capable of providing tremendous amplification, provided that faithful reproduction of the modulation signal is not an important criterion.

As we are dealing with "clipped" rectangular waveforms the effects of signal distortion are of little consequence.

The principle of the super-regenerative receiver is to employ large amounts of positive feedback, to increase the overall gain or sensitivity. This "regeneration", or "reaction" as it was once known, is arranged to render the circuit alternatively oscillatory and non-oscillatory at a fairly rapid rate.

In ordinary t.r.f. receivers, the amount of regeneration possible is limited by the tendency towards instability, leading to continuous oscillation or "howl". The super-regenerative receiver makes full use of this phenomenon, and sufficient positive feedback is applied to ensure that self-oscillation will definitely occur.

TR2 is the super-regenerative detector stage and regeneration is applied via C7 from collector to emitter from the tuning coil L3.

As self-oscillation is assured, the strong resulting a.c. level is rectified by the base/emitter junction of TR2 to provide a d.c. bias signal. This bias builds up progressively on C4 and C6 such that the gain of TR2 progressively reduces until the transistor cuts off, and oscillation ceases.

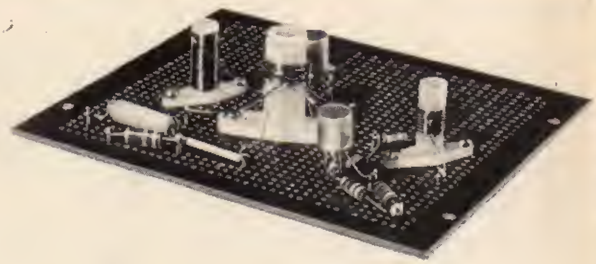
The charges on C4 and C6 immediately begin to leak away after cut-off occurs, and ultimately TR2 will again commence to conduct, the current and gain increasing until oscillation again ensues, when the

process repeats itself. The time constants C4–R5 and C6–R7 are selected such that the periodic bursts of oscillation (referred to as "squegging") occur at some low radio frequency, which is not particularly critical, and will be found to increase with the antenna signal strength, normally being between about 30–100kHz. This is well out of the signal modulation frequency range, and can be filtered out after detection.

It can be seen, therefore, that there is a substantial portion of time in each period of "squegging" when the gain of the receiver is exceptionally high, but when self-oscillation does not exist. The gain during this period is far higher than could be achieved, with stability, in any single stage "conventional" t.r.f. receiver.

RECEIVER CONSTRUCTIONAL DETAILS

COMPONENTS . . .



Resistors

R1	3·9kΩ	R4	1kΩ	R6	22kΩ
R2	15kΩ	R5	2·2kΩ	R7	1kΩ
R3	1kΩ				

All 10%, $\frac{1}{4}$ watt carbon

Capacitors

C1	22pF ceramic	*C5	15pF ceramic
C2	220pF mica	C6	0·002μF mica
C3	0·001μF mica	*C7	25pF ceramic
C4	0·001μF mica	C8	2μF elect. 25V

C26 0·02μF polyester (additional squegging filter)

*C5 and C7 may be altered in value so that the dust core in L2/3 is about mid travel for optimum tuning

Transistors

TR1, TR2 OC170 *or* OC171 (2 off)

Coils

L1 12 turns 28 s.w.g. enam. wire close wound on Neosid $\frac{1}{4}$in polystyrene former with adjustable core. Tapping is taken 2 turns from the "earthy" end of the winding.

L2/3 $\frac{3}{8}$in Aladdin former with dust core. L3 wound first—9½ turns 28 s.w.g. enam. wire close wound. L2 2 turns 28 s.w.g. enam. wire wound on top of L3 at "TR1 collector" end

L4 R.F. choke, 38 s.w.g. enam. wire in single layer on $\frac{1}{4}$in Neosid former with dust core

Miscellaneous

Aerial, 14 in whip type made from 20 s.w.g. brass or nickel silver wire with wander or banana plug fitted to one end. Socket for aerial. Plain or perforated copper clad s.r.b.p. sheet (see Text) 4in × 4in. Pins for perforated board

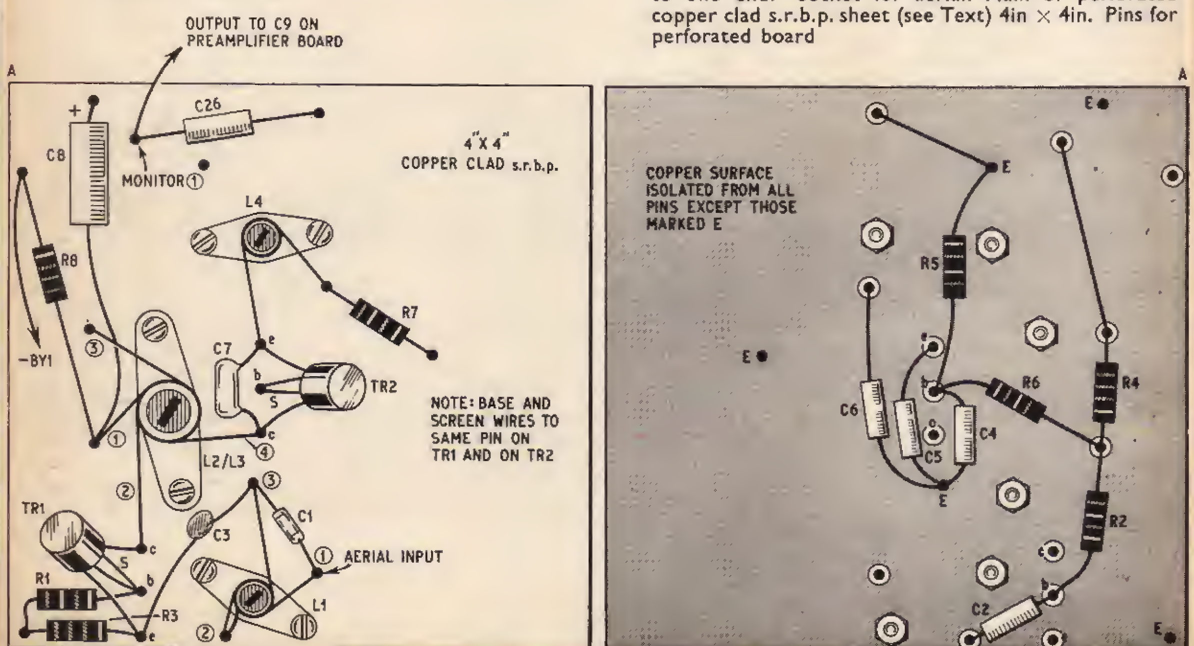


Fig. 4. Component layout and wiring of the receiver panel

Because of the fact that TR2 operates very close to its cut-off point, its characteristic is non-linear, and it is this non-linearity which provides the essential characteristic for detection of the modulation of the carrier. Therefore, TR2 performs the dual role of high gain r.f. amplifier and detector.

If no signal is being received, then self-oscillation is induced at a higher level of collector current, or gain, and hence any circuit noise is greatly amplified in the absence of a carrier. It is because of this inherent characteristic that the super-regenerative receiver is affectionately referred to by some as a "rush-box".

The selectivity of a super-regenerative receiver is inherently poor, and hence is prone to receive simultaneous transmissions, on neighbouring frequencies, from other model control operators in the vicinity. This undesirable feature is to some extent offset by the tendency of the circuit to "latch on" to the strongest signal present, and suppress any weaker signals received.

PREAMPLIFIER CONSTRUCTIONAL DETAILS

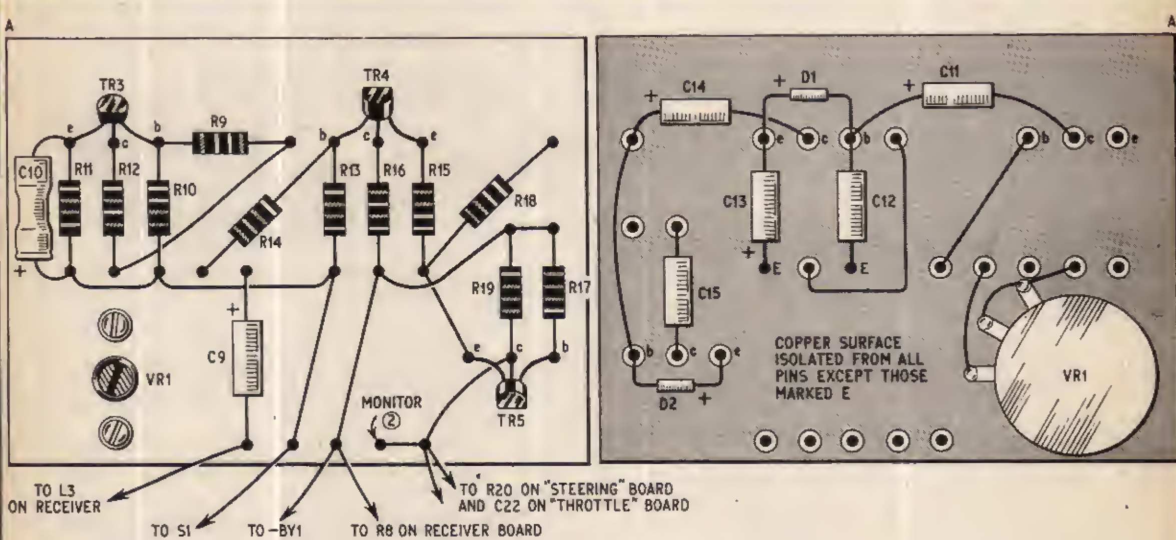
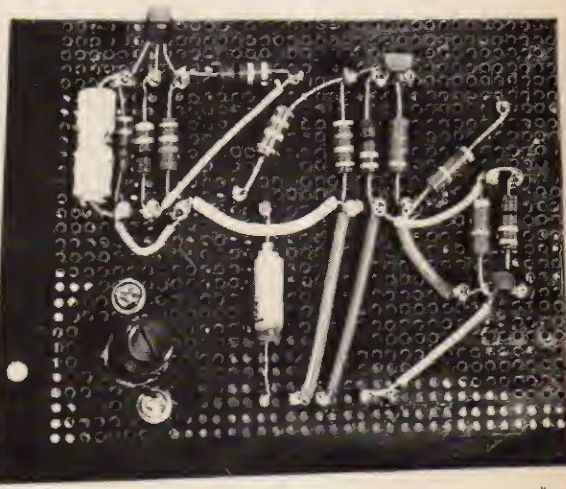


Fig. 5. Component layout and wiring of the preamplifier panel



COMPONENTS . . .

Resistors

R8 470Ω
R9 100kΩ
R10 56kΩ
R11 10kΩ
R12 10kΩ
R13 47kΩ
R14 39kΩ
R15 8·2kΩ
R16 10kΩ
R17 100kΩ
R18 27kΩ
R19 2·7kΩ
All 10%, ¼ watt carbon

Potentiometer

VR1 250kΩ carbon min. preset

Capacitors

C9 10μF elect. 12V
C10 25μF elect. 12V
C11 25μF elect. 12V
C12 0·047μF paper
C13 50μF elect. 6V
C14 25μF elect. 12V
C15 0·01μF paper

Transistors and Diodes

TR3, 4, 5 2N3702 *or* 2N3703 (3 off)
D1, 2 1S44 *or* 1S130 *or* OA200

Miscellaneous

Plain or perforated s.r.b.p. sheet (see text) 4in × 3in
Pins for perforated board

The "squegging" action of the receiver can cause unwanted r.f. radiation from a receiving antenna connected directly to the input. Indeed, the initial experiments, performed in an attic workshop, caused considerable interference to television receivers via aerials in the immediate vicinity. This was eliminated and a 6dB gain achieved by fitting an r.f. stage TR1.

This acts as a buffer between the "squegging" detector TR2 and the antenna, and is merely a class A amplifier biased by R1 and R2 in the base, and R3 and C3 in the emitter circuit, for stable operation. The output at the collector is loosely coupled by L2 to L3.

The effect of the antenna loading is reduced on the detector stage, thereby increasing its performance,

STEERING CONTROL CONSTRUCTIONAL DETAILS

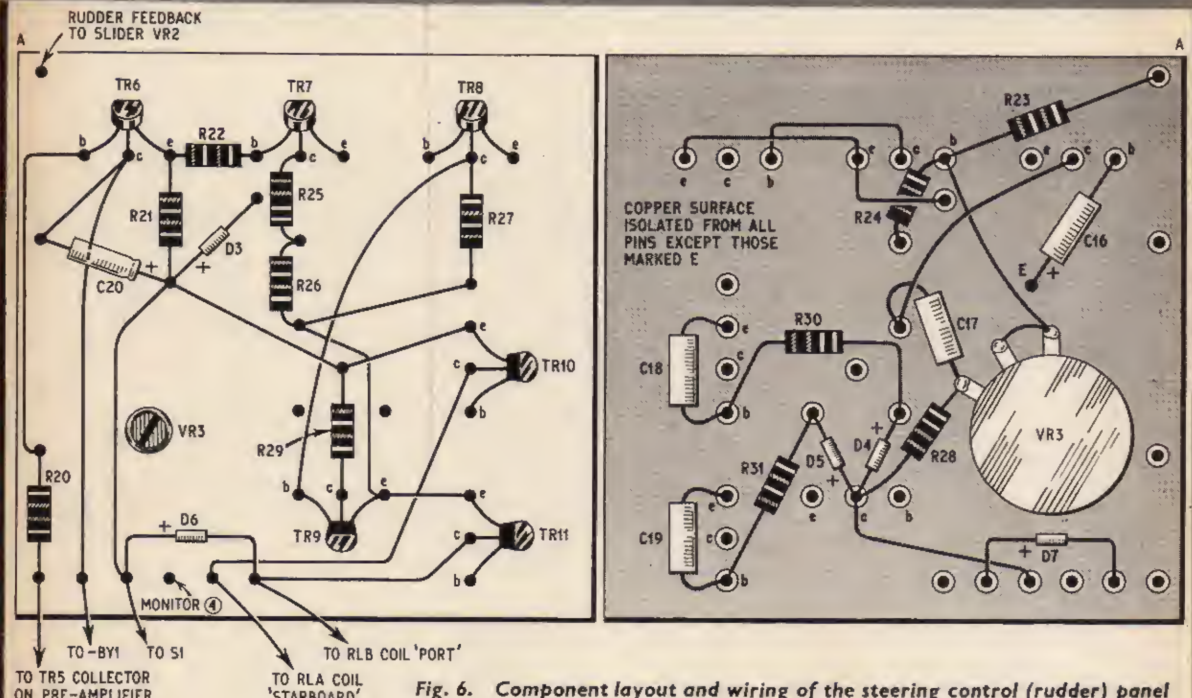
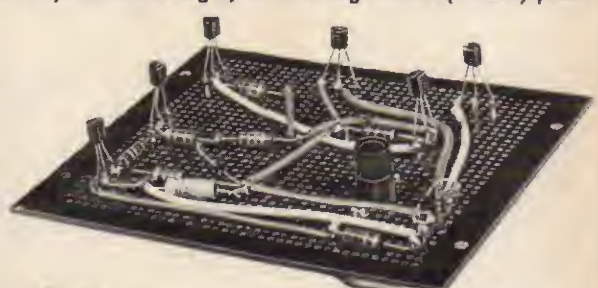


Fig. 6. Component layout and wiring of the steering control (rudder) panel

COMPONENTS . . .



Resistors

R20	10kΩ	R24	47kΩ	R28	150kΩ
R21	4·7kΩ	R25	22kΩ	R29	8·2kΩ
R22	27kΩ	R26	27kΩ	*R30	15kΩ
*R23	10kΩ	R27	1kΩ	*R31	33kΩ

All 10%, ¼ watt carbon
* R23, R30, and R31 may require adjustment on test

Potentiometers
VR2 5kΩ linear carbon or wirewound min.
VR3 1MΩ carbon min. preset

Capacitors

C16	20μF elect. 16V	C19	0·1μF paper
C17	1μF tantalum or paper 12V	C20	8μF elect. 25V
C18	0·1μF paper	C21	0·1μF paper

Transistors and Diodes

TR6, 7, 8, 10	2N3702 *or* 2N3703 (4 off)
TR9, 11	2N3707 (2 off)
D3, 4	Z8·2 (Brush) *or* OAZ246 (Mullard) Zener diodes (2 off)
D5	Z5·6 *or* OAZ242 Zener diode
D6, 7	1S44, 1S130, *or* OA200 (2 off)

Relays
RLA, RLB 12V 700Ω type MH2 with two changeover sets of 1A contacts (Keyswitch)
or type 4190GD (S.T.C.) (2 off)
(Normal open pair of contacts used)

Switches
S2 Single pole toggle
S3, S4 } Part of Drive System, see Part 2

Miscellaneous
MO2 Motor 3V 6,000–7,000 rev/min (Ripmax Orbit type 505)
Plain or perforated s.r.b.p. sheet 4in × 4in. Pins for perforated board

whilst the antenna loading circuit itself is flatly tuned by L1–C1 prior to amplification by TR1.

The high frequency "squegging" component at TR2 output is filtered out by C26.

PRE-AMPLIFIER

Satisfactory operation of the controls depends entirely on the preservation of a good rectangular waveform after detection by the receiver. This is effected by the use of a high gain pre-amplifier (which is normally saturated), together with a degree of noise rejection filtering. Due to the saturated condition of the amplifier, it is quite stable, and the limiting action is effective in removing the inherent noise generated by the super-regenerative circuit.

The pre-amplifier comprises TR3–TR5 in a circuit which is optimised to clip and square the full range mark/space ratio for minimum signal strength conditions, and provides automatic d.c. restoration of the rectangular wave relative to the zero level for all signals.

Potentiometer VR1 is an optional preset control, which is fitted to the prototype, and can be adjusted to give optimum noise rejection at the limit of the working range of the transmitter. Some degree of noise rejection is provided by C12 and C15.

PROPORTIONAL RUDDER CONTROL

The resultant "clean" rectangular waveform appearing at TR5 collector contains an average d.c. component proportional to the mark/space ratio, but independent of the frequency. This component is extracted by the smoothing circuit R20 and C16 and buffered by emitter follower TR6, prior to being used as a "reference" voltage. This voltage is to be compared with a feedback reset voltage proportional to the actual rudder position as derived by VR2, which is driven mechanically by the rudder shaft, and is some fraction of the battery voltage.

The comparison is made at the input of the d.c. operational amplifier TR7, TR8, TR9, whose closed loop gain is controlled by VR3, the feedback potentiometer, to something around 15.

The quiescent state of the servo is that associated with an amplifier output of about half the battery voltage, when the input currents derived from the

IMPORTANT

Readers intending to construct this radio controlled model boat are advised that, before operating in the U.K., the appropriate "model control" licence must be obtained. This licence, which is allocated for model control only at 26·96 to 27·28MHz for a radiated power not exceeding 1·5 watts, can be obtained, upon payment of £1 (sterling), from the Radio Services Branch, G.P.O. Headquarters, St. Martins-le-Grand, London, E.C.1.

reference source and the feedback potentiometer are approximately equal. If, however, the reset voltage differs from that required to obtain this state by about 0·25 volt or so, the amplifier will drive hard to saturation or cut off depending on the polarity of the difference voltage.

A deadband circuit embodying Zener diodes D4 and D5 follows the amplifier, which inhibits operation of succeeding circuits until the "error" voltage exceeds about half that necessary to saturate the amplifier in either direction. This "error" voltage corresponds to about 5 degrees of arc of the steering control at the transmitter (270 degrees helm to helm) and is experienced as lost motion. The deadband, however, creates a definite quiescent state for the control, in which the rudder relays and actuator motor are not energised, and hence once the rudder "homes" to the selected position, current consumption falls to a very low level.

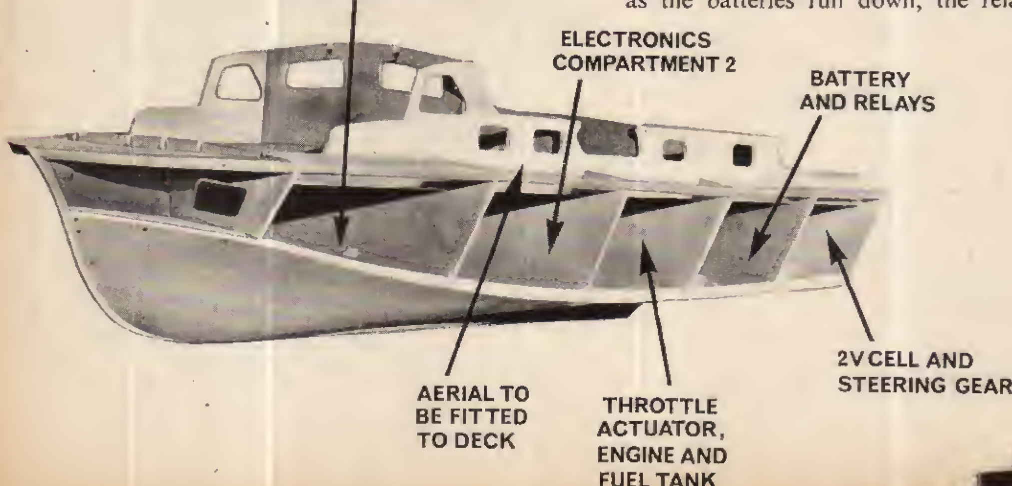
If a signal of more than 5 degrees helm is given then TR10 or TR11, as appropriate, conducts and the associated port or starboard relay is energised which in turn actuates the helm motor. When the rudder nears the selected equilibrium position, the amplifier "zeros" and the relay is released.

Limit switches are fitted at the extremes of lead screw travel which open the motor circuit for the direction selected, should hard helm be given.

The servo system is simply and effectively stabilised to one overshoot by the phase lead circuit in the feedback path (R28, C17).

Adjustment of the gain control VR3 will optimise the response, corresponding to minimum dead zone without any tendency to oscillate.

As the distance from the transmitter increases, some waveform degeneration is experienced which results in a slight "wander" of the rudder position. Similarly as the batteries run down, the relationship between



helm position and rudder position will be observed to change slightly. In practice these effects were not found to be severe enough to be embarrassing.

If desired, the effect of battery voltage deterioration affecting the rudder control can be easily compensated for by merely rotating the rudder potentiometer body, with respect to its fixing bracket, slightly, say every half hour or so during operation.

PROGRESSIVE THROTTLE CONTROL

The output of TR5 is differentiated by C22 and R32 and fed to the throttle control circuit TR12–TR17.

THROTTLE CONTROL CONSTRUCTIONAL DETAILS

COMPONENTS . . .

Resistors

R32 15kΩ	R35 3·9kΩ	R39 27kΩ	R42 8·2kΩ
R33 47kΩ	R36 180kΩ	R40 3·3kΩ	
R34 470kΩ	R37 4·7kΩ	R41 4·7kΩ	

All 10%, ¼ watt carbon

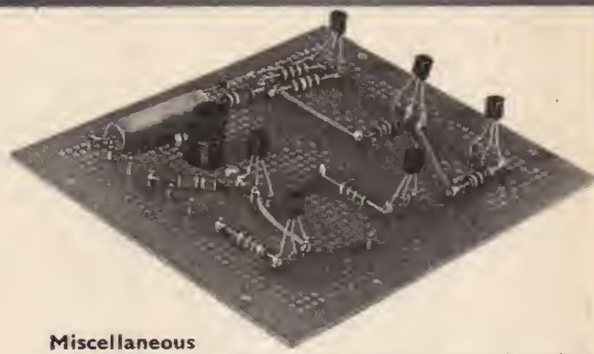
Potentiometer
VR4 100kΩ carbon min. preset

Capacitors
C22 0·003μF paper C24 40μF elect. 16V
C23 0·02μF paper C25 0·1μF paper

Switches
S5 Single pole toggle
S6, S7 } Part of Drive System, see Part 2

Transistors and Diodes
TR12, 13, 14, 15, 17 2N3707 (5 off)
TR16 2N3702 *or* 2N3703
D8, 9, 12, 13 1S44 *or* OA200 (4 off)
D10 Z8·2 *or* OAZ246 Zener
D11 Z5·6 *or* OAZ242 Zener

Relays
RLC, RLD 12V 700Ω type MH2 with two changeover sets of 1A contacts (Keyswitch) *or* type 419GD (S.T.C.) (2 off)
Normal open pair of contacts used



Miscellaneous
M01 Motor, miniature for throttle control with a short shaft (Keil Kraft)
Plain or perforated s.r.b.p. sheet 4in × 4in
Pins for perforated board

OTHER ITEMS FOR ELECTRONICS

Switch
S1 Single pole toggle

Batteries
BY1 15V made up from 12 nickel cadmium cells connected in series (Deac 1·25V, 225mAh)
BY2 2V 1·6Ah lead acid cell

Components for mechanical actuators given next month

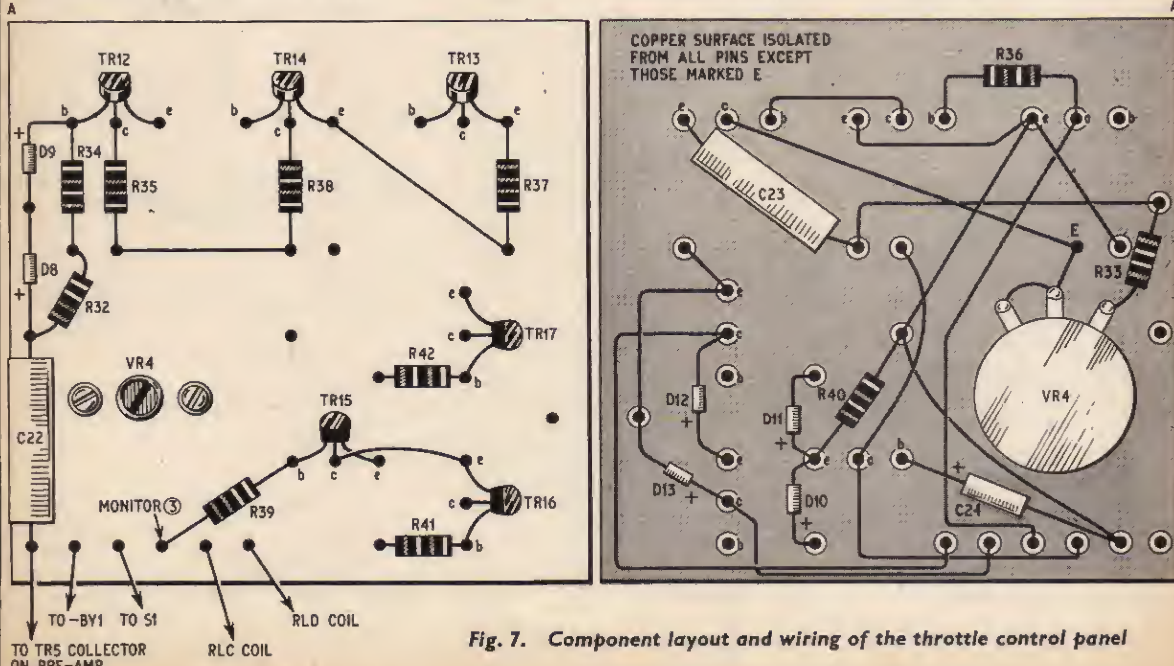


Fig. 7. Component layout and wiring of the throttle control panel

The negative-going edges are used to set a monostable multivibrator TR12, TR13 and TR14, whose quasi-stable pulse length is preset by VR4 such that it is approximately one half-period of the centre "hold" frequency, 400Hz, equal to 1·25ms.

The monostable output therefore comprises a 1 : 1 mark/space ratio for this condition, and has an average d.c. component after smoothing (R39, C24) of about half the battery voltage (7V). Neither Zener diode (D10, D11) conducts, thereby depriving TR16 and TR17 of drive; hence, neither throttle relay is energised.

It can be seen that as the monostable is only influenced by negative-going edges, and there is only one such pulse per cycle, the output d.c. level will be unchanged as the mark/space ratio of TR5 output varies over its full range.

If, however, the transmitted frequency is raised to 600Hz ("close throttle") the quasi-stable period of the monostable becomes nearly equal to one complete period of the signal frequency and TR12 is not conducting for a high percentage of time. The monostable output average d.c. component assumes a positive voltage, approaching that of the battery, and D11 conducts, operating the "throttle close" motion relay via TR17.

The throttle motor will continue to rotate until the frequency is restored to a lower level, or the limit switch on the lead screw is operated. If the frequency selected is 110Hz then TR12 remains in its stable state (conducting) for relatively long periods of time, with an average d.c. output voltage of about 1 volt to earth. This results in conduction of D10 and operation of the "throttle open" relay RLC via TR16.

The monostable is of a special design which permits rapid recharging of the timing capacitor C23 at the end of a quasi-stable period. This ensures that the monostable is ready to re-enter an accurate quasi-stable period with the minimum delay in the stable state (about 5 per cent), thus guaranteeing good separation between the "hold" and "throttle close" signals.

The "open throttle" discrimination is determined by the cut-off condition of TR15 (about 1·5 volts) as a result of TR16 base current. The "open throttle" frequency need only be low enough to create the cut-off condition, any further frequency reduction only results in unnecessary chatter of RLC.

The frequency allocations for throttle control functions are deliberately made to provide a fail-safe feature. It is obviously desirable that the throttle should be closed to minimum (tick-over) should the transmitter fail or the boat get out of range. Contrary to initial expectation, loss of signal does not produce the effect of frequency reduction to d.c. conditions, i.e. zero frequency.

The noise level of the super-regenerative circuit rises enormously if the carrier is removed, and becomes sufficient to trigger the monostable continuously, giving a high positive output from TR12. It is wise, therefore, to associate this condition with the "throttle close" command.

In a similar manner the random noise pattern generated under weak signal conditions results in an approximately "average" mark/space ratio of unity on the rudder control. As a result the rudder assumes a position roughly amidships. The slow speed straight-ahead attitude adopted by the vessel was very comforting during trials when the transmitter was deliberately switched off.

At this point it will be realised that, had the modulating frequency of the transmitter been made infinitely variable instead of being switched, which could be readily achieved by variation of the charging potentials of the transmitter multivibrator capacitor, the throttle control could have been an independently actuated simultaneous position control, in a manner similar to that used on the rudder. However, it was decided not to do this on the prototype both to preserve simplicity, and to explore the possibilities of both systems.

BOARD CONSTRUCTION

Perforated s.r.b.p. boards were used throughout for the electronic assemblies and layouts were not found to be critical although it is desirable to keep lead lengths as short as possible in the 27MHz portions.

The receiver panel is actually a peg-board manufactured from s.r.b.p. and copper laminate (unetched printed circuit material) the copper acting as an earth plate, being cut away round the plated pegs used for connections to components. This is easily done by countersinking the $\frac{1}{16}$in peg holes with a $\frac{3}{16}$in drill prior to insertion of the pegs.

The entire receiver section is mounted on an unetched s.r.b.p. card 4in × 4in fitted with isolated pegs, and soldering components straight down to the copper ground plane as required. The receiver layout is not particularly critical provided that lead lengths are kept to a minimum and the "earthy" end of certain capacitors are taken to a common point on the ground plane as shown.

So far as the other three assemblies are concerned, there is no special need for using copper clad board (as shown in the diagrams) and a plain type of s.r.b.p. board can be used here if preferred.

Full layout and wiring details for the boards are given in the illustrations (Figs. 4 to 7).

Next month : Actuator construction and installation of drive system and power supply.

POINTS ARISING

PRACTICAL TRANSISTOR CIRCUITS *(April 1968)*
The loudspeaker should be connected between C3+ and the −9V line in the complementary symmetry circuit; R6 should be connected between C3+ and TR2 base; C2 should be connected in parallel with R3.

SOUND EFFECTS : WIND AND RAIN *(April 1968)*
Capacitor numbering in the wiring diagram (Fig. 5) should be amended as follows: C1 to C7 should read C7 to C13 in sequence; likewise C8 to C13 should read C1 to C6. In the components list R1 to R7 inclusive should be 2·7kΩ.

FLUORESCENT CAMPING LIGHT *(March 1968)*
Modification for pre-heating the lamp electrodes was published in the May 1968 issue. It has been found that in this modified circuit (page 375) the capacitor C2 is no longer required and should be deleted. The lamp will then give maximum output when switch S1 is turned to position 3.