MODEL CONTROL AMPLIFIERS

Last of a Short Series on Miniature R/C Designs

By D. Bollen

THE function of amplifiers in model radio control is to convert the low power signal from a receiver to a large d.c. current change, capable of energising a relatively insensitive relay or, in some cases, a motorised servo or escapement directly. This they must do without responding to spurious signals or background noise.

Although specifically intended for use with the receiver described in the November issue of PRACTICAL ELECTRONICS, the following units may be coupled with other receivers and with commercially manufactured equipment when additional controls are to be fitted.

AMPLIFIER "A"

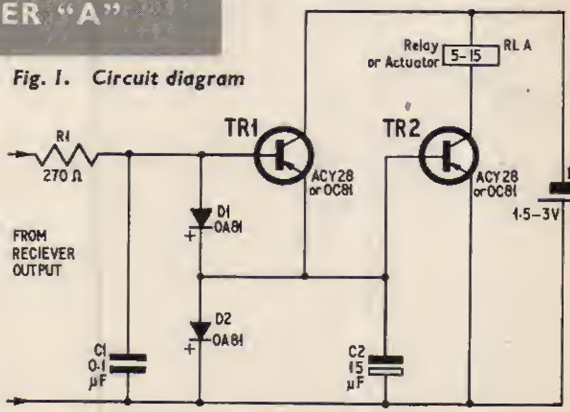
Fig. 1 shows the circuit diagram of a dual purpose amplifier designed to feed either a low resistance relay or an escapement. A photograph of this design is shown in the heading picture. It will be seen that only seven components are used and no transformer is required. An input of 50mV will cause a current change of 30mA, and the current gain is approximately 35dB.

The maximum current change is 250–300mA with the transistor specified for TR2. If small motors are to be driven by the amplifier TR2 should be replaced by a transistor of greater power handling capacity, such as OC81 or a power transistor.

With no signal on its base, TR1 remains cut off and so, therefore, does TR2, which passes a fraction of a milliamp leakage current. When an audio frequency signal is passed to TR1 base both transistors conduct—TR2 heavily—assisted by the action of diodes D1 and D2. The diodes, incidentally, also serve to stabilise the amplifier against the effects of temperature.

Inevitably the receiver will produce some noise, picked up on the base of TR1. This causes a slight bias to be applied to the amplifier, raising the stand-by consumption to approximately 6mA, well below the figure likely to cause relay chatter. This drain has a negligible effect on the life of the battery employed.

Fig. 1. Circuit diagram



BAND PASS FILTER

To reduce noise to a minimum, and to favour only the desired audio tone which activates the amplifier and relay, the overall response is tailored to give the curve shown in Fig. 2.

Capacitor C2, bypassing the emitter load of TR1, is of a small enough value to attenuate the lower audio frequencies, while still providing enough capacitance to smooth the raw d.c. pulsations resulting from a rectified a.c. signal. The input network, R1 and C1, filters out the high frequencies.

It will be seen that the peak response occurs in the region of 750 c/s and reasonable rejection of noise and interference may be expected. The low pass filter

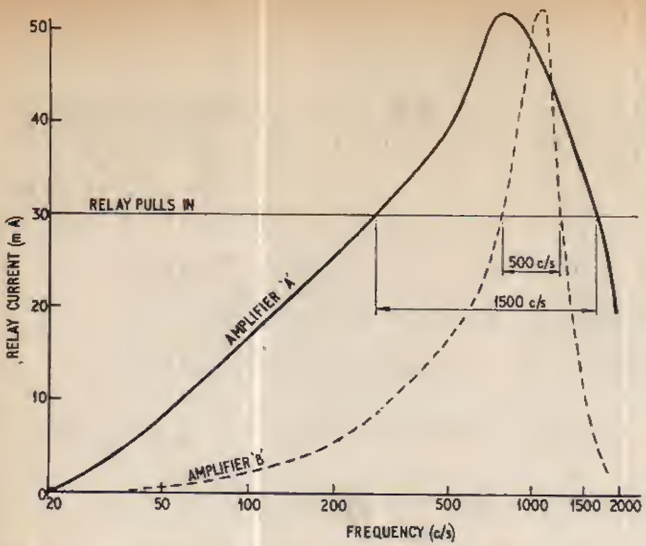


Fig. 2. Frequency response characteristic filtered to operate the relay over a narrow band

COMPONENTS . . .

Resistor
R1 270Ω 10%, 1/10 watt carbon

Capacitors
C1 0·1μF ceramic 10V
C2 15μF elect. 15V

Transistors
TR1 and TR2 ACY28 *or* OC81 (Mullard) (2 off)

Diodes
D1 and D2 16P10 (Radiospares) (2 off)

Relay
RLA 5 to 15Ω (see text)
Reed switch type RS/2 (Cockrobin Controls)

Battery
BY1 1·5V *or* 3V (one or two pen-light cells)

Miscellaneous
S.R.B.P. sheet 1in × 1in
P.V.C. wire

also effectively removes the quench component of the signal. In extreme cases of interference when, for example, an old electric motor is sited close to the receiver, R1 may be replaced by a variable resistor of up to 10 kilohms. This acts as a sensitivity control and should be preset to just below the point where interference triggers the relay.

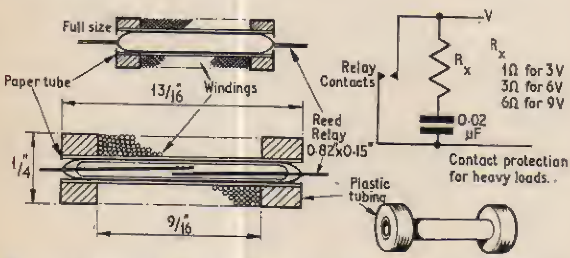


Fig. 3. Construction details of a suitable reed relay coil with suppression circuit for the contacts

DRY REED RELAY

The dry reed relay used in the original model deserves an individual mention, mainly by virtue of its simplicity and small size. Details are shown in Fig. 3. A gummed paper cylinder, fitted with plastic cheeks, acts as the bobbin on which is wound 600 turns of 40 s.w.g. enamelled wire, giving a d.c. resistance of 15 ohms. The pull-in sensitivity of the relay alone is under 20 milliwatts and the speed of operation better than 1 millisecond.

In circuit, TR2 dissipates some power giving a total of 40 milliwatts including the relay. The speed of response is limited by the decay time of C2 which works out to around 0·01 second.

The recommended long-life contact current, for the particular dry reed used, is 100mA. However, the reed is quite capable of handling heavier loads, such as small electric motors with a switch-on surge of 1 amp, in normal circumstances where the relay does not operate continuously at high repetition rates and where contact arc suppression is incorporated.

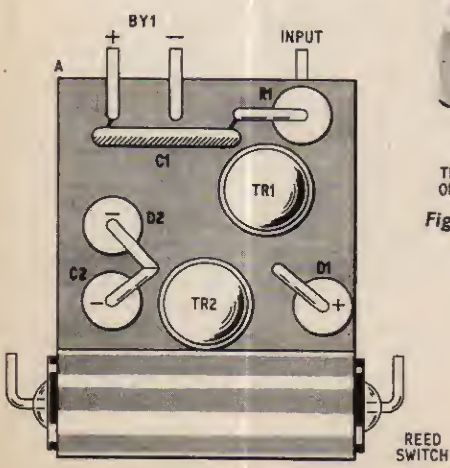


Fig. 4a. Component layout

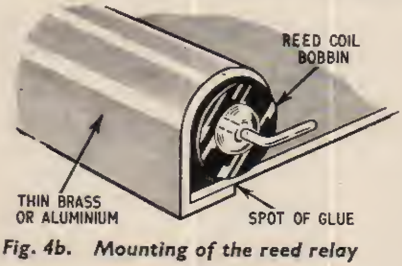


Fig. 4b. Mounting of the reed relay

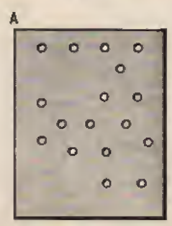


Fig. 4c. Full size drilling template

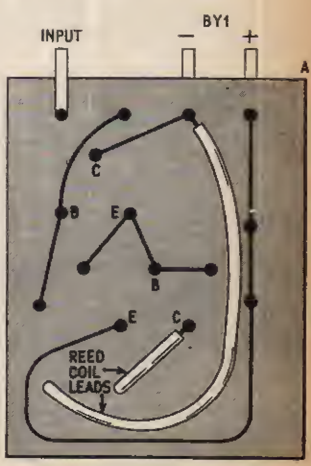


Fig. 4d. Underside wiring

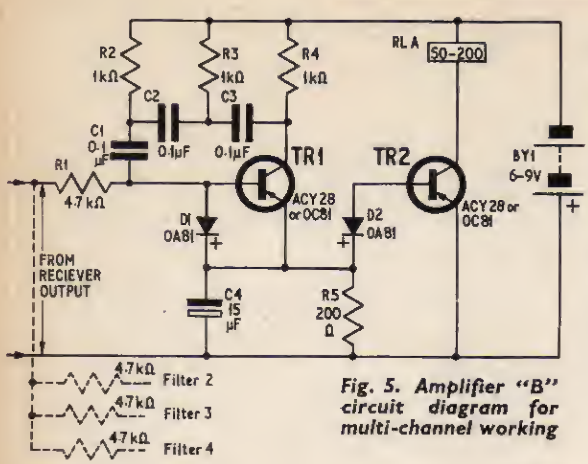


Fig. 5. Amplifier "B" circuit diagram for multi-channel working

COMPONENTS . . .

Resistors
R1 4·7kΩ R4 1kΩ
R2 1kΩ R5 200Ω
R3 1kΩ
All 10%, $\frac{1}{10}$ watt carbon

Capacitors
C1 0·1µF disc ceramic 20V (Radiospares)
C2 0·1µF disc ceramic 20V (Radiospares)
C3 0·1µF disc ceramic 20V (Radiospares)
C4 15µF elect. 15V

Transistors
TR1 and TR2 ACY28 or OC81 (Mullard) (2 off)

Diodes
D1 and D2 16P10 (Radiospares) (2 off)

Relay
RLA 50 to 200Ω (see text)

Battery
BY1 6 or 9V (type PP5 or PP3)

For multi-channel working the amplifier must discriminate between different tones, responding only to the one to which it is tuned. Neglecting for the moment reed operation rather large ferrite pot-core inductances are normally employed to resonate at the selected frequency.

As a separate amplifier is needed for each channel, obviously its individual size and complexity will be multiplied by the number of channels required. It is preferable to plan for a simple, basic unit on which to build if a reasonably compact ultimate assembly is to be achieved.

The circuit of Fig. 5 provides a useful and compact alternative to the inductive filter and, with a subminiature relay, can be built on a panel less than 1in square.

PHASE SHIFT

The phase shift network composed of R2, R3, R4, C1, C2, and C3, connected between collector and base of TR1, feeds back an in-phase signal at the resonant frequency, thus increasing gain. At other frequencies the feedback is out of phase, tending to reduce gain.

The rest of the circuit is similar to that in Amplifier "A" although, in this case, D2 (Fig. 1) is replaced by a resistor R5 (Fig. 5) and a diode D2 has been added in the base circuit of TR2.

The purpose of D2 may at first sight seem obscure, but it is, in fact, a useful one. At very low input voltages the d.c. resistance of this diode is high, around 10 kilohms in the forward direction, which reduces to about 200 ohms as the voltage increases.

When low level breakthrough occurs, as from an adjacent tone, the non-linearity of D2 assists in rejecting the unwanted signal and the overall effect is to sharpen the response of the circuit.

NARROW BANDWIDTH

Returning to Fig. 2, where the output of the amplifiers "A" and "B" are presented in similar low signal terms, with their relays set to operate at the same level as a datum for comparison, it shows that "B" has the much narrower bandwidth of 500c/s, resulting from selective feedback.

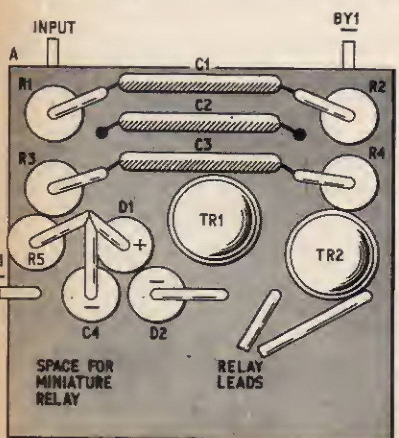
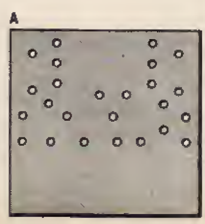
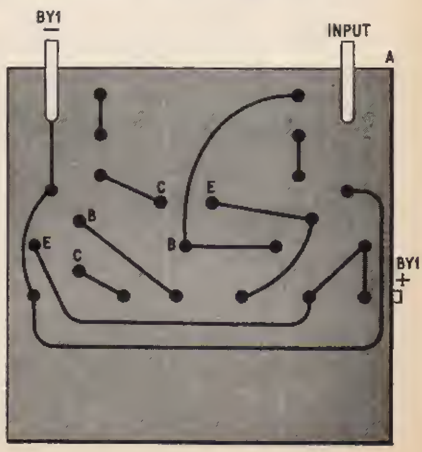


Fig. 6a (left). Component layout

Fig. 6b (below). Full size drilling template

Fig. 6c (right). Underside wiring





If amplifiers of ascending resonant frequencies are spaced at regular 1kc/s intervals, seven channels will be available up to 7kc/s, with 500c/s interval between tones. In practice it is better to make the spacing as wide as possible to prevent interaction at high signal levels, and five channels up to 7kc/s or higher would be a reasonable aim.

The tuned amplifiers may be cascaded, as indicated in the circuit diagram, each with its own feed resistor from the common source. To enhance the selectivity of the higher frequency filters, capacitors can be included in series with the 4·7 kilohm feed resistors.

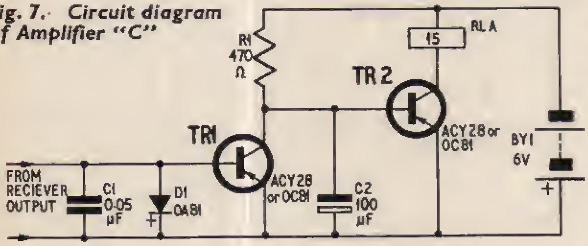
The capacitance value should be chosen to give a good current change without breakthrough from lower tones. Smaller values for C4 will also assist and should be found by experimentation.

The supply needs to be at least 6 volts to ensure sufficient regeneration from TR1, consequently a relay of 50 to 200 ohms d.c. resistance will be needed. It is possible that a dry-reed relay, wound with more turns, could be matched to the output, but a 120 ohm miniature multi-contact armature driven relay was finally employed with the prototype.

The circuit of Amplifier "B" is remarkably stable and free from any trace of self oscillation. The overall performance is largely determined by the current gain of TR1 and a minimum of 60 should be the aim. Stand-by consumption is only 0·5mA when connected to a working receiver and the total current change exceeds 50mA on signal.

AMPLIFIER "C"

Fig. 7. Circuit diagram of Amplifier "C"



Amplifier "C" adopts the principle formerly mentioned, responding to both modulated and unmodulated carrier. The circuit is given in Fig. 7.

With no signal the idling current may be set, by selection of C1, to a pre-arranged figure, say 50mA. This capacitor determines the noise bandwidth and hence the bias derived from noise. On receipt of a plain carrier the current rises to 100mA, and falls to 12mA when a tone is sent.

Tests should only be carried out while Amplifier "C" is coupled to its receiver, otherwise TR2 could be overloaded when there is no noise bias of TR1.

If a polarised relay is used, adjusted so that its armature is central at the idle current level, tone or plain carrier commands will select one of two contact positions. For example, plain carrier may represent right and tone represent left, while no signal at all would select neutral rudder providing fail-safe operation.

COMPONENTS . . .

Resistor
R1 470Ω 10%, $\frac{1}{10}$ watt carbon

Capacitors
C1 0·05μF ceramic 30V
C2 100μF elect. 15V

Transistors
TR1 and TR2 ACY 28 *or* OC81 (Mullard) (2 off)

Diode
D1 16P10 (Radiospares)

Relay
RLA 15Ω (see text)
Reed switch type RS/2 (Cockrobin Controls)

Battery
BY1 6V (four pen-light cells)

If slowly pulsed with mark/space tone and constant carrier from the transmitter, a proportional control will result.

In the event of a fault, switching the transmitter off would automatically centralise the rudder. Similarly, this amplifier could be incorporated with existing equipment to perform a corrective function when the

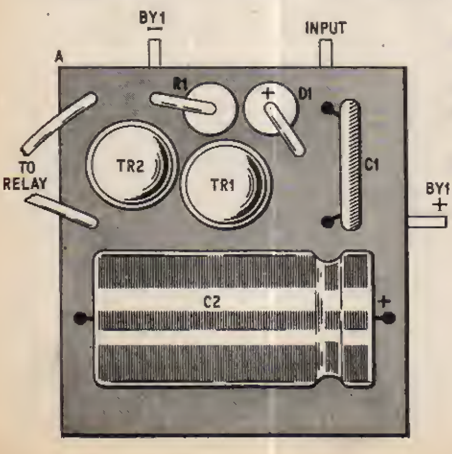
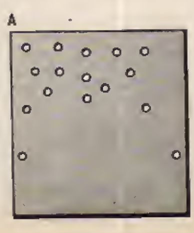
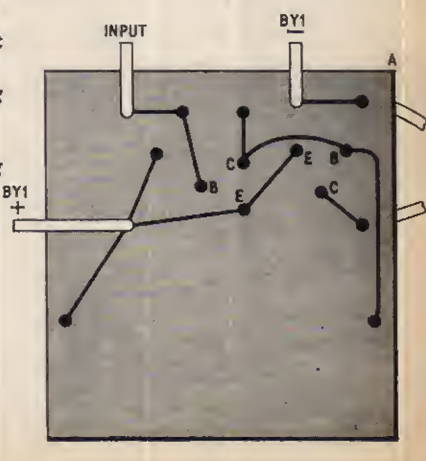


Fig. 8a (left). Component layout

Fig. 8b (below). Full size drilling template

Fig. 8c (right). Underside wiring





Amplifier "A" housed in a matchbox alongside the receiver described in Part 2

model goes beyond the range of control, triggered by the absence of carrier.

Although very simple, using few components, amplifier "C" needs careful setting up initially. Different receivers have different noise levels; the amplifier standing current can be expected to vary over quite a wide range before the right value for C1 is found.

If carrier only reception is wanted, the quiescent current may be set to a low level and the current rise resulting from a signal used to operate a relay in the normal way.

An inexplicable tendency to oscillate at a very low frequency (about 10c/s) was exhibited by the original amplifier but this in no way interfered with the correct working of the amplifier as the self-oscillation ceased with a signal, and did not interfere with the level of the standing current.

Relay details are the same as described under amplifier "A" for a 15 ohm type.

OTHER AMPLIFIERS

Considerable scope for experiment exists with the design of model control amplifiers, and the wide range of control gear now available renders each application novel in its requirements. Variants, of the amplifiers given here, may be found to suit alternative systems so no hard and fast rules of design exist.

One very promising field of investigation lies in the adoption of computer principles, the use of binary switches cascaded to give fast, positive selection of controls in sequence on one channel, with an automatic coder in the transmitter.

This could challenge the present superiority of multichannel systems as, theoretically, thousands of individual controls could be selected and set in operation within the space of a second.

Reed amplifiers have not been mentioned because they follow standard a.c. amplification principles. The reed occupies an intermediate stage in the chain of events following the receiver, needing either relays or additional amplifiers before the signal can be converted into mechanical motion. Amplifier "A" would make an ideal reed-follower if a slight bias of a fraction of a volt is switched on to the base of TR1 by the reed contacts. ★