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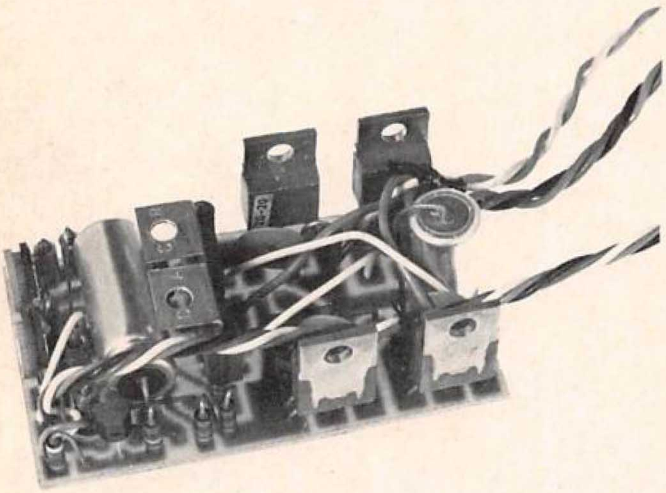
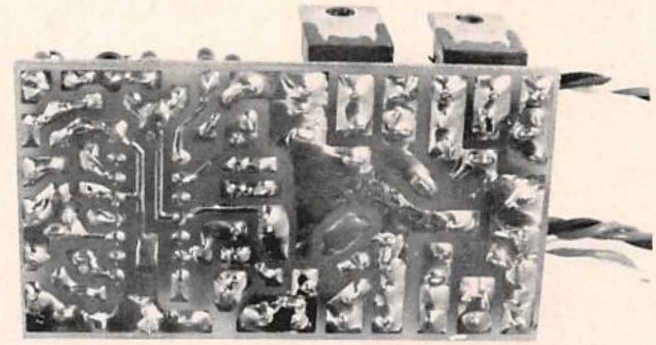
ELECTRONIC SPEED CONTROL

BY JAY W. EITELMAN





It all started back in December, 1975, while thumbing through my RCM where I found an electric car article. With electronics being one of my too many hobbies, I thought that building an electronic speed control would be an interesting and fairly easy project. Since then, I have suffered countless hot transistor burns, sleepless nights and generated several scrap boxes full of failures.

One of my major discoveries was a new and remarkably fast means of communication being telemodeler. Now the postman is suing me for a double hernia, and the phone company has charged me for replacing five miles of worn out phone lines and six sets of bells. The moral to this story is don't read RCM, and don't tinker with speed controls!

Being a newcomer to the sport of R/C, I thought that things with wings made the world turn. I was quite surprised to discover the world of scale boating, which suddenly appeared in my mail box and at my telephone. Meeting these fine modelers and their fascinating projects has been a very rewarding experience, and I guess that reading RCM isn't all bad.

From this experience, I have concluded that the major problem of the scale ship builders is the method, cost and reliability of the speed control which has also been indicated by several Radio Spectrum column comments. This article is intended to help those fellow soldering iron jockeys, and I don't recommend its construction or use unless you have a working knowledge of transistors and ohm laws, or at least have a friend who can help.

I have observed that the average modeler does not have a degree in electronics and, with this in mind, the so-called mechanical servo driven controllers are hard to beat since they are easily understood and repaired; there is relatively little loss and, excluding the servo, inexpensive.

The electronic controller, if home-built, can be inexpensive when compared to the servo that it eliminates; should operate relatively cool without requiring special cooling techniques; can provide instantaneous and a smooth response; and doesn't require any periodic maintenance or adjustments. On the other hand, it is more susceptible to destruction if mis-wired or mis-used and, due to its mysterical nature and quick response, it can be falsely accused of causing problems which can handicap its installation or field repair.

I have observed several installations using this controller and its similar predecessor. Some of these installations I would term a gross mis-use, and much to my surprise they are still working. My Chief Test Captain, Mr. Bob Schefke, accuses me of being too pessimistic and conservative in my recommendations and specifications. Since he has seen and used it with larger motors than recommended, I must conclude that this is an endorsement of its reliability but, Bob, I told you it wouldn't drive that starting motor even though it did operate for the full event.

CIRCUIT DESCRIPTION

The design objectives of this circuit was to provide both forward and reverse porportional speed control; to interface with either positive or negative pulse systems; to be compatible with motor voltage requirements of 6 to 12 volts; to provide in excess of 5 amps of motor current; and to consist of inexpensive and available components.

The control was built around the new Signetics NE 544N servo integrated circuit which has been discussed in several previous Radio Spectrum columns and can be obtained from many Signetics distributors for about $3.00

The circuit operates on the slow speed switching principle in which the motor is turned on and off at the frame rate of the transmitter. The percentage of on-time is varied to produce a variable motor speed. A complimentary bridge output configuration is used to provide the bi-directional current which enables

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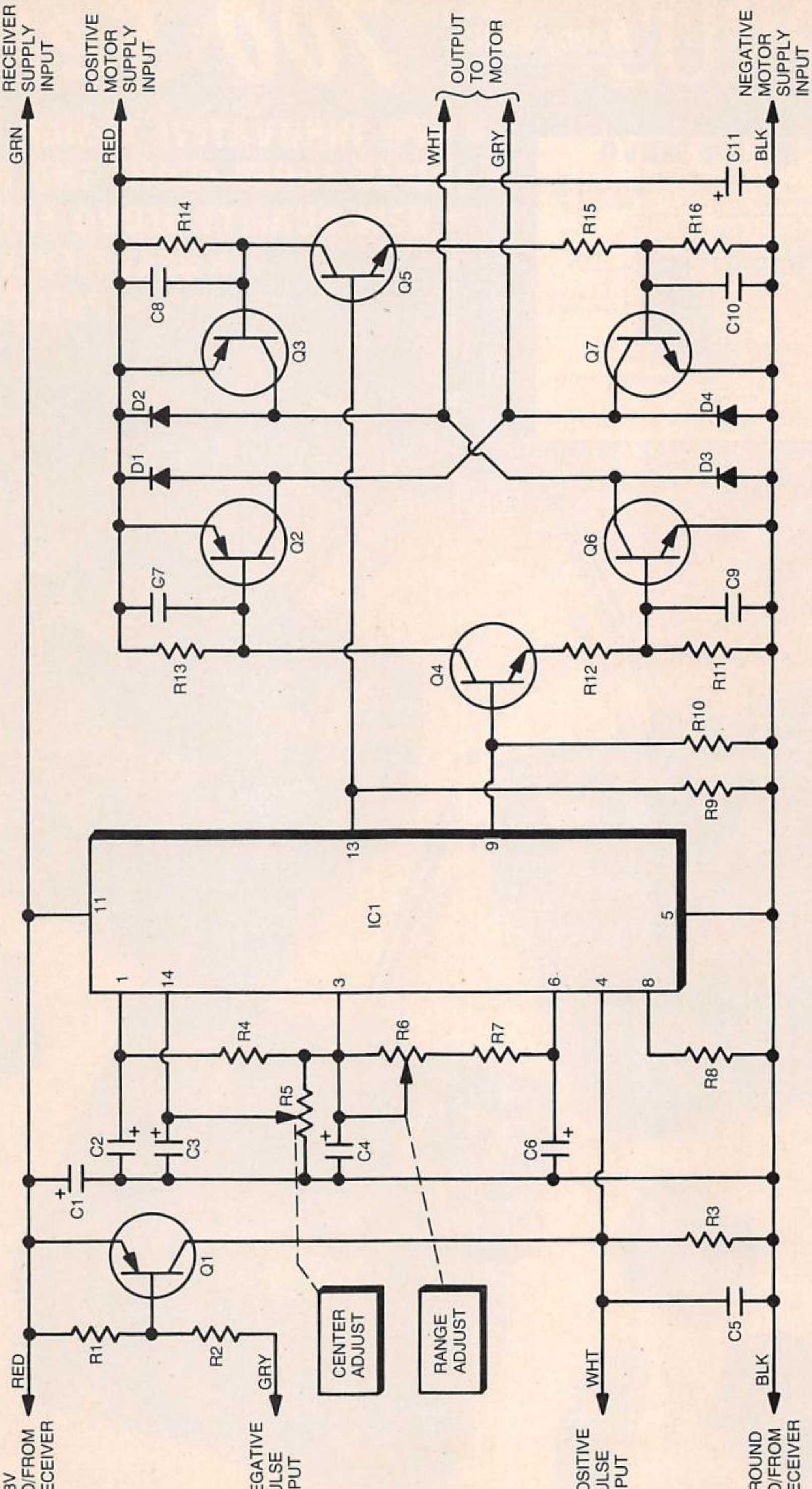
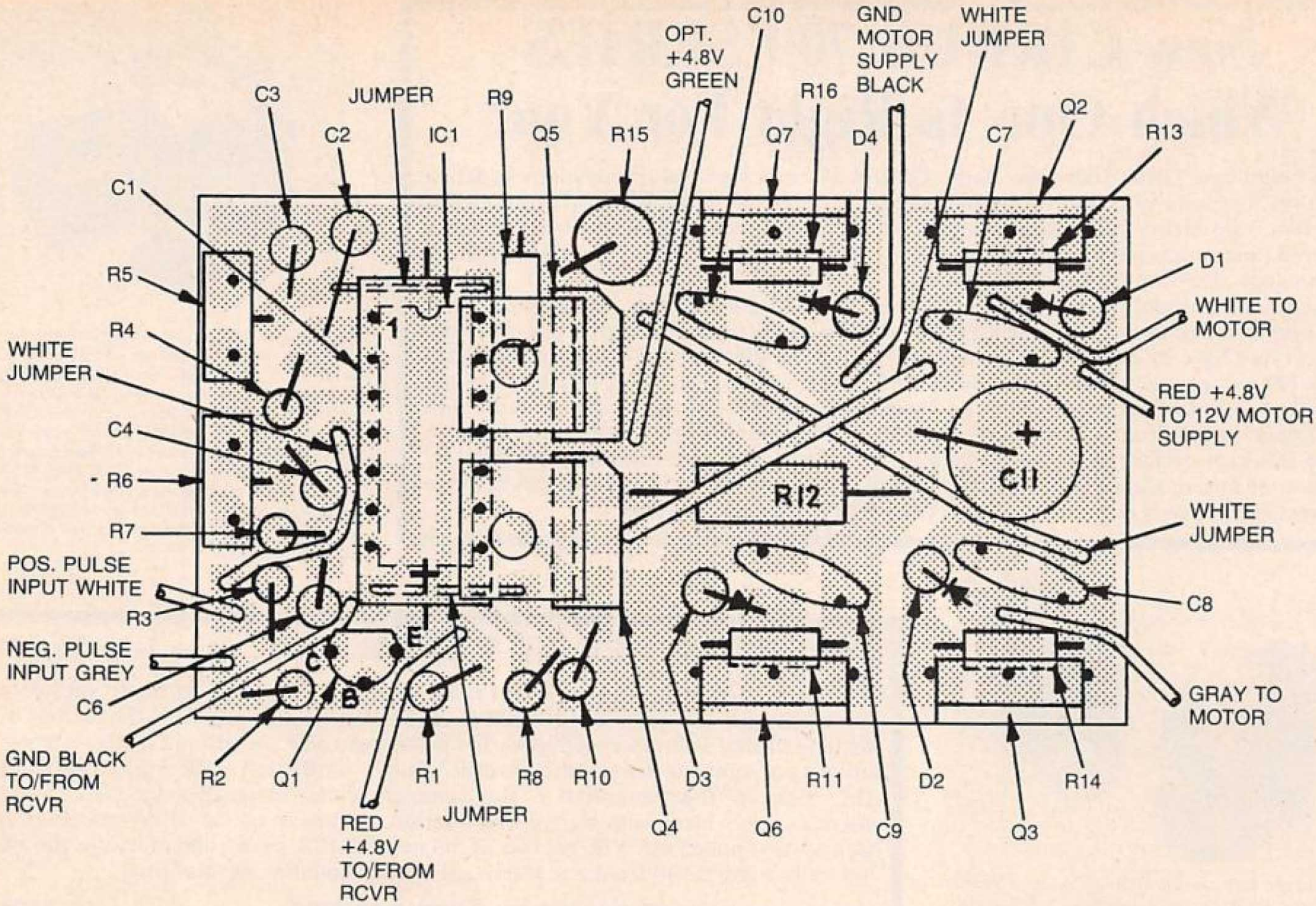
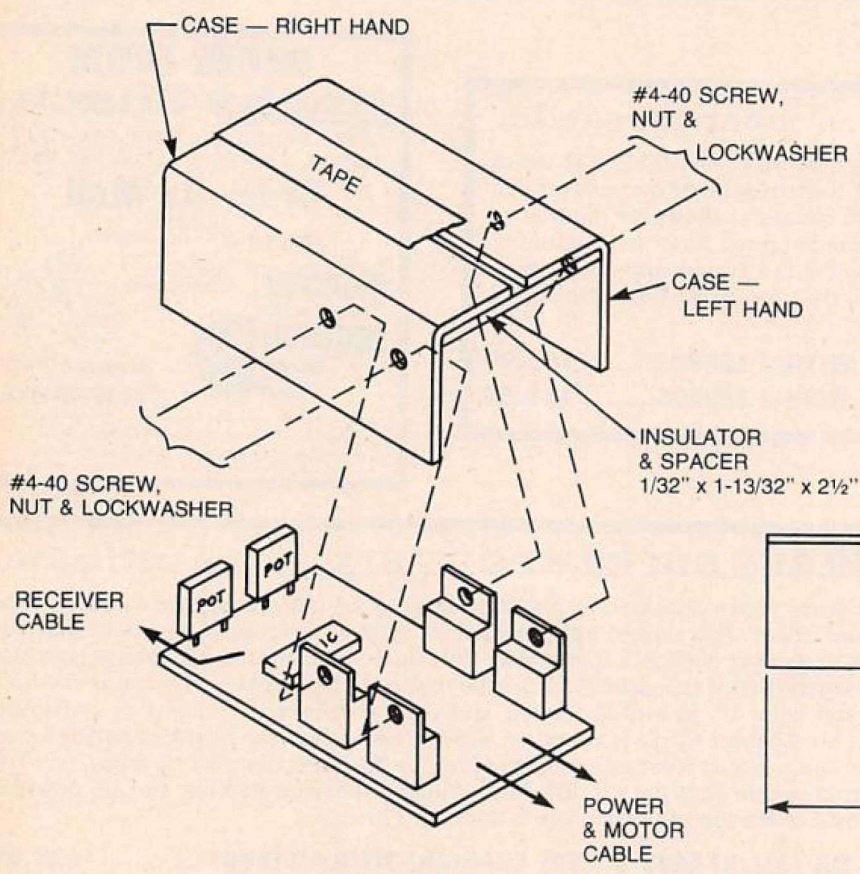


SCHEMATIC DIAGRAM

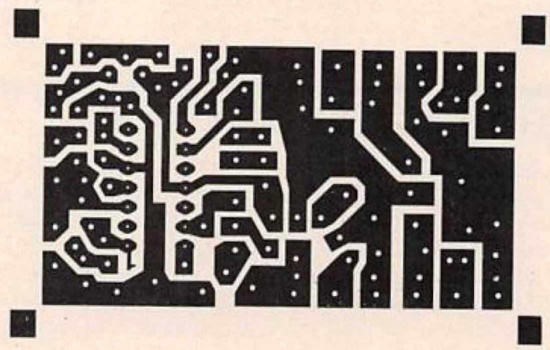
drawings continued on page 90



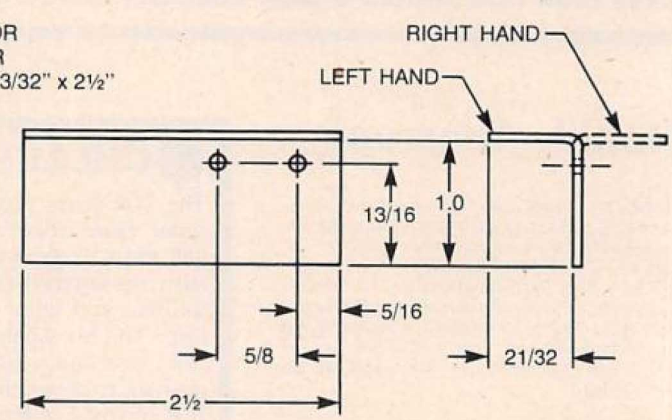
COMPONENT OVERLAY



CASE INSTALLATION



P/C BOARD — ACTUAL SIZE



CASE LAYOUT (NOT SHOWN FULL SIZE)

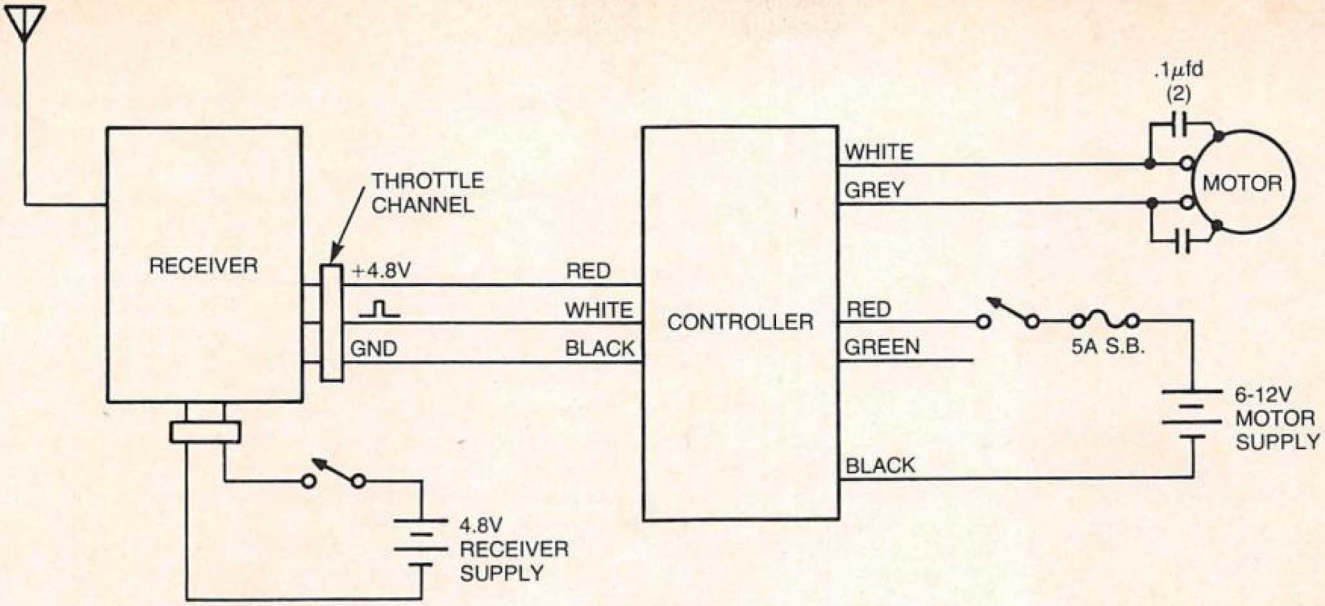


FIGURE 1

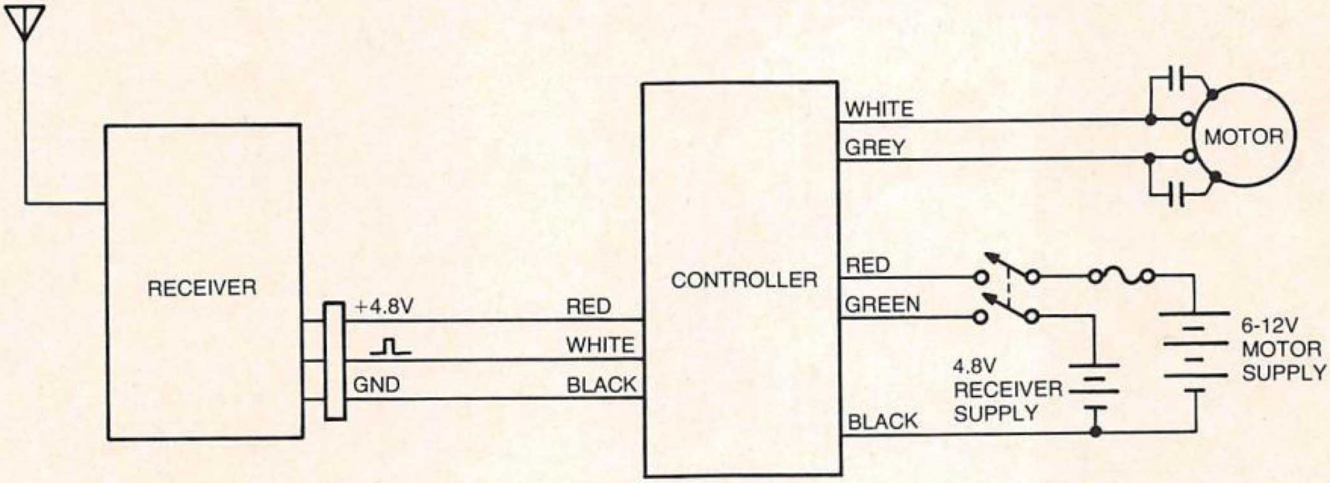


FIGURE 2

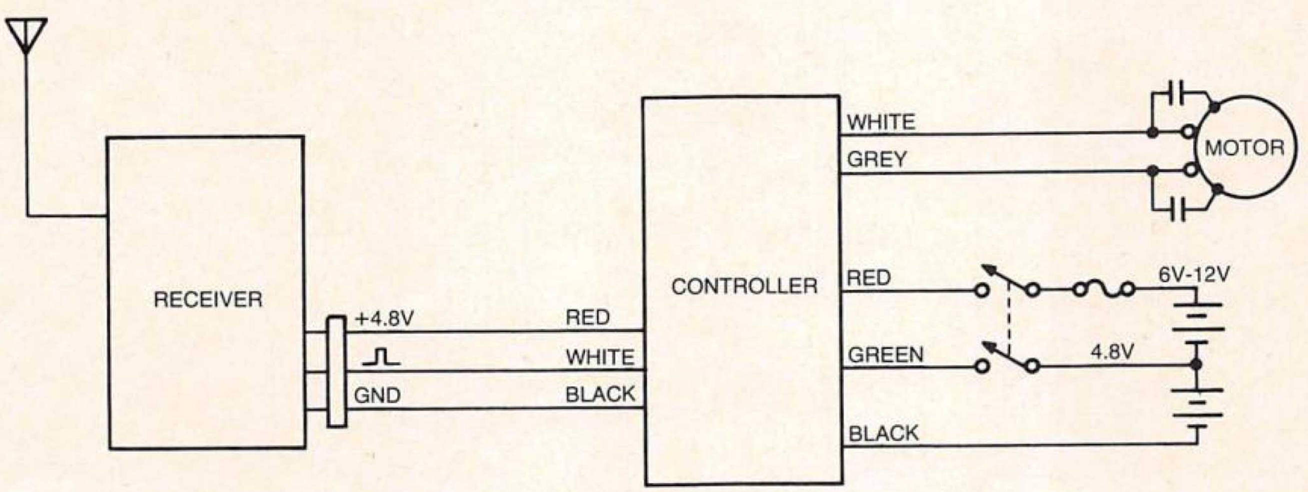


FIGURE 3

ELECTRONIC SPEED CONTROL

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both the forward and reverse directional control.

A constant current driver configuration is employed to provide interchangability between systems using different motor supply voltages. A pulse inverter stage is included for either positive or negative input pulse operation. This control was built primarily for the electric scale boat applications, which use the lower current motors, and where a slight voltage loss can be tolerated or compensated for by increasing the motor supply voltage. The relatively low output current capability and the voltage loss of the bridge output would be a serious disadvantage in an application where speed or power is a primary concern.

This control should not be used to drive motors which consume more than 5 amps when stalled and operated at the desired voltage.

SPECIFICATIONS

Receiver supply voltage: 4.8v nominal, 6.0v maximum.

Receiver supply current drain: 6ma to 50ma depending on throttle position.

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Motor supply voltage: 6.0v to 12.0vdc.
Motor supply current drain: 0 to 200ma in addition to motor consumption.
Maximum output current: Not less than 5 amps.
Voltage loss, typical: .5v with 2 amp load, 1.0v with 5 amp load.
Input pulse polarity: Positive or negative.
Size: 1½" x 2½" x 1⅛".

CIRCUIT THEORY

The operation of the Signetics' IC is basically the same as its typical servo application in which it compares the input pulse width to a reference pulse width and produces an error pulse. This error pulse is stretched producing an output with a variable duty cycle.

R1, R2, R3 and Q1 comprise a pulse inverter stage which will accept a negative pulse and provide the positive pulse required at pin 4 of IC 1. Since this PNP stage is normally biased off, it will not effect a positive signal at its collector and the control can be interchanged between positive and negative pulse systems without modification other than providing the correct input wiring. These components may be omitted for use with only positive pulse systems.

C5 is employed to reduce the susceptibility to radiated noise pulses which can be picked up by the input wiring. This effect is dependent on the specific application and installation, and proper motor noise suppression must be included for a complete cure.

The NE 544 will produce a regulated 2.0vdc output at pin 3, which is used for the external components.

C1, C3, C4 and C11 are used as AC bypass capacitors for their respective DC signals. For those scrap box builders, these values are not critical.

The time constant of R4 and C2, in conjunction with the DC voltage returned to pin 14, determines the width of the internal reference one shot multivibrator, which is normally set to about 1.5 msec.

The time constant of R6 + R7 and C6 determines the amount of pulse stretching, which controls when full throttle is achieved relative to the width of the error pulse.

The value of C6 will establish the amount of dead band. This dead band, as related to a speed control, determines the amount of control stick movement required before minimum throttle is applied. The very tight dead band of the typical servo application would make it practically impossible to

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obtain a neutral setting. The specified value of C6 will provide about a 10% dead band relative to the total stick travel. For those who may wish to change this dead band, increasing C6 will increase the dead band, and R7 may need to be reduced to restore the range adjustment.

R8 determines the amount of minimum output pulse (throttle) that can be achieved. R8 was chosen to produce a very short pulse.

Pins 9 and 13 of the IC provide the forward and reverse output pulse. These outputs are floating when the control is in neutral, and R9 and R10 are employed to pull these outputs to ground.

Q4 and Q5 comprise the constant current drivers for their respective sides of the bridge output stage. The amount of drive current is established by the 3.9v output from IC 1 −9 or 13, and the value of R12 and R15. The D42C1 driver was chosen for its high free air power rating of 2.0w. This power limitation determines the maximum motor supply voltage and drive current.

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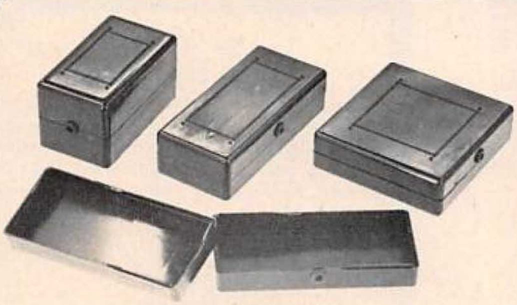
Nick Ziroli, noted scale modeler with his Heinkel 162, jet fighter.



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The D44H2 and D45H2 output devices were selected on the basis of their cost, high beta, and saturation characteristics. The actual circuit performance will depend on the pot luck parameters of the specific devices used. The several units that have been assembled indicate that a 5.0 amp output and a total saturation voltage loss of about 1.0v at 5 amps represents the minimum performance of this circuit.

For those experimenters who may wish to try some changes, I will mention that the circuit board was designed to accommodate the larger TIP35 and TIP36 transistors, and there is room for a separate heat sink for the two drivers. The three unused holes just happen to fit several of the 5v regulator IC's for back-powering the receiver. The maximum current, and minimum input voltage must be carefully considered to avoid receiver problems or destruction if a regulator is to be used.

ASSEMBLY HINTS

(1) C5 (which is not shown) will occupy the same holes as pins 4 and 5 of IC 1. Drill accordingly and install C5 and IC 1. Observe that pin 1 or the index of IC 1 is toward the top of the circuit board.

(2) Using two spare resistor leads, install the jumpers adjacent to the ends of IC 1.

(3) C1 is installed on top of IC 1 with its positive end toward the bottom of the board.

(4) C2, C3, C4 and C6 are installed with their positive end up and positioned as shown.

(5) If the control is to be used with only positive pulse systems, the components Q1, R1, R2 and R3 may be omitted. The jumper wire to IC 1-4 will be replaced with the white positive pulse input wire which will connect directly to IC 1-4.

(6) Install the receiver input wires as desired. The white wire may be omitted if the control is to be used in only negative pulse systems.

(7) When installing R12, position it about 1/8" above the circuit board.

(8) R15 may require sleeving to prevent a short to the collector tab of Q5.

(9) Complete the resistor, potentiometer, disc capacitor and jumper installation as shown.

(10) C11 is installed with its positive end down and positioned as shown. Check for case clearance.

(11) Install the four diodes, observing the polarity as shown.

(12) Bend the collector tabs of Q4 and Q5 as required to clear the case and C1. Note that the index (or emitter) is positioned toward the top of the circuit

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board and install these devices so that their collector tabs cannot short to each other or any other component.

(13) Install Q2, Q3, Q6 and Q7 so that their collector tabs face the outside edges of the circuit board. Solder only one lead of each device since they will probably require repositioning for true case alignment. Q2 and Q3 are the PNP's which will be the green pair.

(14) Install the three motor supply input wires and the two motor control wires. Use 22 gauge stranded or larger to avoid wiring losses.

(15) Install the case assembly by mounting to the four output transistors. The two case halves must not short to each other or any other component.

(16) Reposition the four outputs as required for case alignment and complete the soldering. Be sure to tin all exposed copper to prevent oxidation and increase the conductivity.

(17) Be sure to use lock washers for the final case installation.

INSTALLATION SUGGESTIONS

Figure 1 illustrates the standard speed control installation which uses two separate power supplies to power the receiver and motor. A positive pulse system is shown using the white receiver input wire to the control. The grey wire is either removed or disconnected. A negative input system would use the grey input wire and the white wire would remain disconnected. The optional 4.8v input is left unconnected and this green wire may be removed.

Adequate noise suppression must be installed at the motor and the antenna and receiver wiring must be positioned away from the motor and its associated wiring. Using a single capacitor across the motor terminals is recommended by a few of the motor manufacturers, but has been inadequate in a few installations due to motor case radiation. The two capacitor arrangement with each capacitor connecting to the metal motor case has been sufficient in these problem installations.

Figure 2 illustrates using the controllers power input wiring to back-power the receiver through its servo output connections. This option will simplify the power switch and charging connector wiring if the receiver power could be included in the motor battery pack. In order to use this option, the receiver's 4.8v input must be wired straight through to each servo output. If the receiver's wiring is unknown, it should be visually traded or checked with an ohmmeter.

Figure 3 illustrates using a tapped motor supply to provide the 4.8v receiver power. This arrangement may result in problems due to voltage fluctuation created by the current drain of the motor. This problem is generally a shift in servo position caused by throttle position or motor loading. The extreme problem is erratic operations due to glitches in the receiver's decoder. These problems are determined by the design of the R/C system, amount of current consumed by the motor and the capacity of the batteries used. If the R/C system is a late design which uses a servo IC that provides internal regulation, the odds are that this arrangment can be used without any adverse effects.

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Featured on the January '78 cover of RCM was an outstanding Royal Super Cessna Skymaster built by Roy Gilbert of Covina, Calif. We inadvertently omitted the builders name of this beautiful aircraft in that issue — Sorry, Roy!

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This control has been used in several systems which use the same 4.8v to power the motor and receiver. As designed, this control will suffer about a 20% reduction in output current capability if the motor supply voltage equals the receiver supply voltage. For the experimenters, a resistor in series with base of each driver (Q4 and Q5) would eliminate this reduction.

In any installation, the motor supply power switch may be omitted since the control will not draw any current when the receiver is turned off. This method is only suggested for those installations where this switch would be difficult to include. A quick disconnect is strongly advised for possible malfunctions or for periods of storage. It has been experimentally proven that a 5 amp Slow Blow fuse would have prevented a fire caused by temporary and sloppy wiring.

The case of this control is electrically connected to the two motor drive wires. This control case must not be allowed to short to any other electrical components or wires and this definitely includes antennas.

ADJUSTMENTS & OPERATION

The initial control check-out and adjustment should be performed using the hook-up configuration of Figure 1. The phasing of the white and grey motor drive wires will determine the direction of motor rotation relative to the desired direction of control stick movement. For this reason, temporarily connect the motor until the desired phasing is established.

Again — be sure to insulate the control's case from any other component or wiring and apply power to the transmitter and receiver-control system.

Adjust the centering pot (R5) to obtain a neutral or zero throttle condition.

Apply about 3/4 forward control stick throttle and adjust the range control (R6) to achieve a setting where the motor just attains maximum rpm. This maximum throttle setting may be observed with a voltmeter across the motor or monitoring the voltage at pins 9 or 13 of the IC. It is not advisable to operate a stalled motor any longer than necessary. With this in mind, the range control may also be adjusted by applying 3/4 forward throttle into a stalled motor and adjusting R5 until the motor just stops humming.

If the direction of motor rotation is reversed, with respect to the desired direction of control stick movement, the two motor drive wires must be reversed, and the final motor connections can be completed.

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If the control is operating correctly and the motor does not consume more than 5 amps, the case temperature should remain relatively cool. If the case temperature becomes painful to touch, it means that the motor is requesting more current than the control can provide. This condition should be checked at both low and full throttle continued operation into a loaded motor. If the case temperature (at the transistors) sizzles water, it's time to turn everything off, find out what's wrong, and hope the outputs are still good.

TROUBLESHOOTING HINTS

The two case halves provide the interconnections between the collector tabs of the two pairs of output transistors. If the control is to be operated without the case, these collectors must be jumpered accordingly.

The motor supply voltage is not required to operate the integrated circuit stage. The operation of the IC can be monitored at pins 9 and 13, which are the servo motor outputs when this IC is used in a servo application. A small servo motor across pins 9 and 13 could also be used.

With 4.8v applied to pin 11, pin 3 should provide a regulated 2.0 to 2.2 volt output.

The voltage at pin 14 should agree with the setting of R5. The voltage at pins 9 and 13 should be variable from 0 to 3.9v corresponding to a neutral to full throttle setting. One output will respond to a forward command, and the other will respond to a reverse command.

The driver stage can be tested by measuring the base to emitter voltage of each output transistor. This voltage should be from 0 to .6vdc, depending on a zero to full throttle position, which may be either a forward or reverse command. If the voltage exceeds .6v, it indicates a faulty output device.

The output devices may be tested by removing the case halves and disconnecting the motor. A 12v auto tail lamp (borrowed from the family grocery cart) can be used to test each output device by connecting one lead to the collector tab. The other lead of the lamp will be connected to ground when testing the green pair (PNP's). When testing the red pair (NPN's) this remaining lead of the lamp will be connected to the positive motor supply voltage. For each test, the lamp should respond to either a forward or reverse transmitter command. If a 0 to 10A ammeter was used instead of a lamp, it would indicate the approximate

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maximum current capability of each device. If the ammeter is used, the test must be performed quickly since the transistors are operating out of saturation and maximum power is being developed in each device.

This unit is being kitted by Davis Engineering Co., P.O. Box 1232, Kokomo, Indiana 46901, at a price of $37.50. For additional information on the availability of the kit, write to Davis Engineering Company. □

COMPONENT PARTS LIST

IC 1	Signetics NE 544
D1-D4	IN 4001
Q1	MPS A 70
Q2	D45H2
Q3	D45H2
Q4	D42C1
Q5	D42C1
Q6	D44H2
Q7	D44H2
R1	2.2K
R2	4.7K
R3	10K
R4	16K
R5	10K — Potentiometer
R6	10K — Potentiometer
R7	10K
R8	100Ω
R9	100Ω
R10	100Ω
R11	47Ω
R12	15Ω, 1/2w
R13	47Ω
R14	47Ω
R15	15Ω, 1/2w
R16	47Ω
C1	100μfd, 10v
C2	.1μfd, Tantalum
C3	.1μfd
C4	1.0μfd
C5	.001μfd Subminiature Disc.
C6	2.2μfd Tantalum
C7	.05μfd
C8	.05μfd
C9	.05μfd
C10	.05μfd
C11	100μfd, 16v

THE BIG CONTEST

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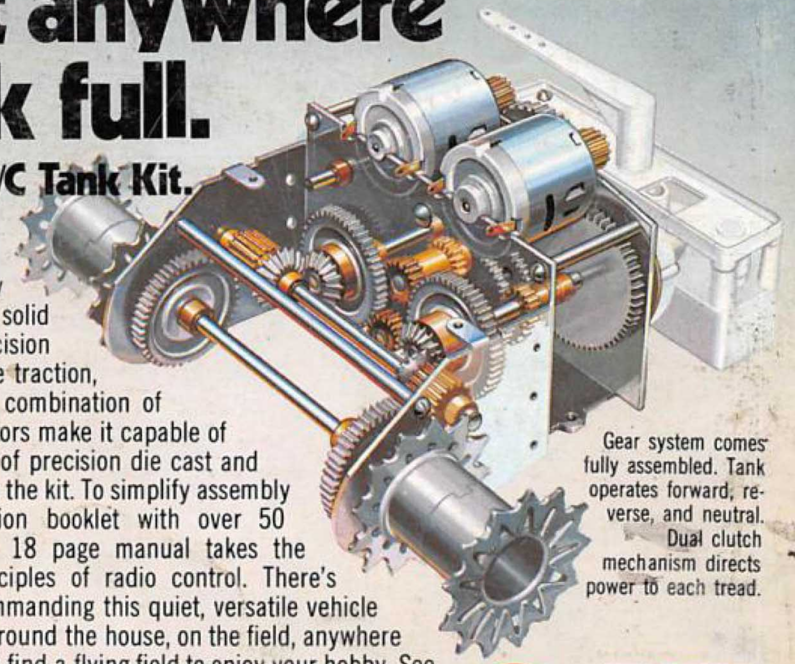
Then the big decision of what to cover it with arrives. Should it be MonoKote, Coverite or silk? Friends drop by, the phone keeps ringing, each advantage is carefully weighed, then the decision is

It'll run almost anywhere without a tank full.

MRC Tamiya Electric Powered R/C Tank Kit.



Gear system comes fully assembled. Tank operates forward, reverse, and neutral. Dual clutch mechanism directs power to each tread.

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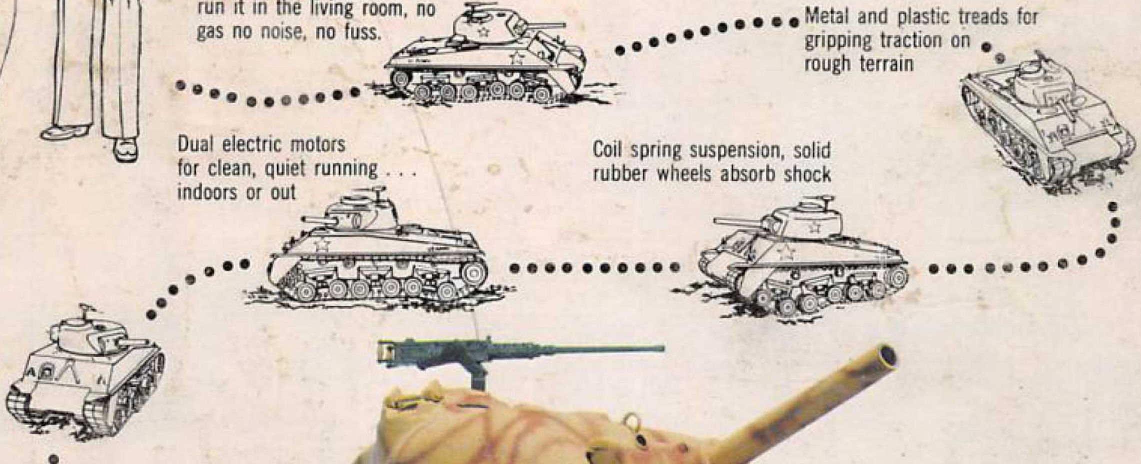

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